Morphometric Analysis and Identification of Groundwater Potential Zones in Kodaikanal Watershed Using Remote sensing and GIS Technique

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ABSTRACT

Groundwater is important natural resource. Due to overexploitation, the groundwater get depleted day by day. Assessing the groundwater potential recharge zones is an important for the protection of water quality parameter and management of groundwater level. Morphometric analysis of the drainage basin play an important role to identify the climate, geomorphology, structural behaviour of the watershed area. This study was conducted to find the morphometric analysis and ground water potential zones in Kodaikanal Block, Dindigul, district, Tamil Nadu. Identification of Ground water potential zones and morphometric analysis has been find out by using Remote Sensing and GIS techniques. Thematic maps such as Base map, Geology, Geomorphology, Slope, LULC, stream order and drainage density map was prepared for the Study area. The weightage and ranking scores were assigned for each thematic map based on influencing of rate of water percolation. Finally by using GIS weightage overlay tools, to identify the quick assessment of ground water potential zones in the Kodaikanal area.

Keywords: *Drainage morphometry, groundwater potential zone, Remote sensing* and GIS.

INTRODUCTION

Groundwater is one of the most important natural resources, which is direct link with food security, agricultural need and increasing industrial requirement.(Rastogi 2007). It has been plays an immensely important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Todd and Mays 2005). Groundwater is a form of water occupying all the voids within a geological condition.High slope and steep slopes impart higher runoff, topographical depressions increase the infiltration. Area having high drainage density also increases surface runoff as compared to low drainage density area. Surface water bodies such as rivers, streams, ponds etc., act as a recharge zones (Murugesan B. et al., 2012).The Remote sensing and Geographic information system (GIS) tool plays important role in water resource studies. Analysis of RS and GIS along with survey of India (SOI) topographical sheets provide the baseline information to delineate the groundwater potential zones. (Aditya P. Nilawar 2015).

By using remote sensing and GIS tools extract the drainage, slope, and geological features of Kodaikanal area. Remote sensing and GIS techniques are proven effective tools in the delineation and morphometric studies of drainage basin. The drainage basin plays an important role in hydrological studies like assessment of groundwater potential and groundwater management.(Rastogi et al.,1976). The present study describes the morphometric analysis and identification groundwater potential zones in Kodaikanal watershed using RS and GIS techniques.

STUDY AREA

Kodaikanal lies in Dindigul District, Tamilnadu. It is also known as "Princess of Hill stations. It is one of the eighteen Biodiversity hotspots in the world. It has huge number of flora and fauna. They also remain as the watershed region of Vaigai, Manjalar and Amaravathi Rivers catering to southern districts of Tamilnadu. Kodaikanal is locaated between 77º14′26" and 77º45′28" E longitudes and 10º6′25" and 10º26′54" N latitudes

and Altitude of 2500 meters above sea level. In SOI toposheet, it forms part of 58 F/7, 8, 11 and 12 on 1:50,000 scale. The total geographical extent of the area is about 1039Km^2 with Population of 32,931 (2001Censes). The climate of the watershed is characterized by monsoon-influenced subtropical highland and humid climate. The temperatures are cool throughout the year due to the high elevation of the city. Relative humidity is high during retreating NE monsoon season (October to mid December). The mean temperature of Kodaikanal taluk is 15.93ºC with a mean summer temperature of 17.29ºC (June, July and August) and mean winter (December, January and February) temperature of 14.10ºC. The area receives rainfall from north east monsoon. The average annual rainfall is 1436.87mm. Fig.1 shows the study area map.

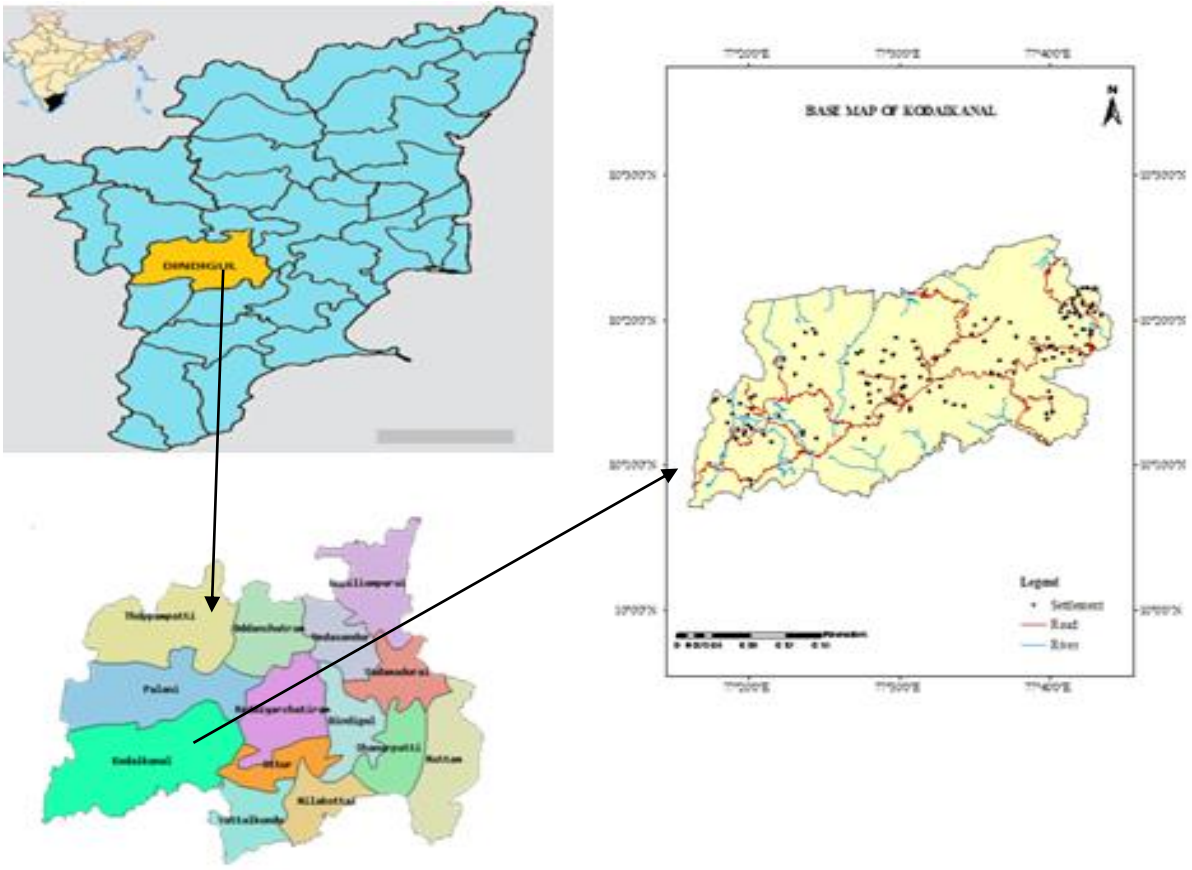

Fig.1 Location map of the study area.

METHODOLOGY

Methodology of the study area involved various thematic map preparation. The various thematic maps such as base map, slope map, drainage map, geology map, LULC map, geomorphology map etc, prepared by using ARC GIS 10 software. First step involved preparation of base map by using survey of India (SOI) Toposheet. In second step by using DEM (Digital elevation model) to prepare the slope map, stream order map, drainage map. By using stream order and drainage map is used analyse the morphometric studies of kodaikanal area. In third step by using IRS P6 LISS IV data is used to prepare the geology map, LULC map etc. All the thematic maps were prepared by using remote sensing and Gis technology (ARC GIS 10). In fourth step, ranking were assigned by each thematic map based on influencing of rate of water percolation. Finally, by using GIS weightage overlay tool to find out the groundwater potential zone in the study area.

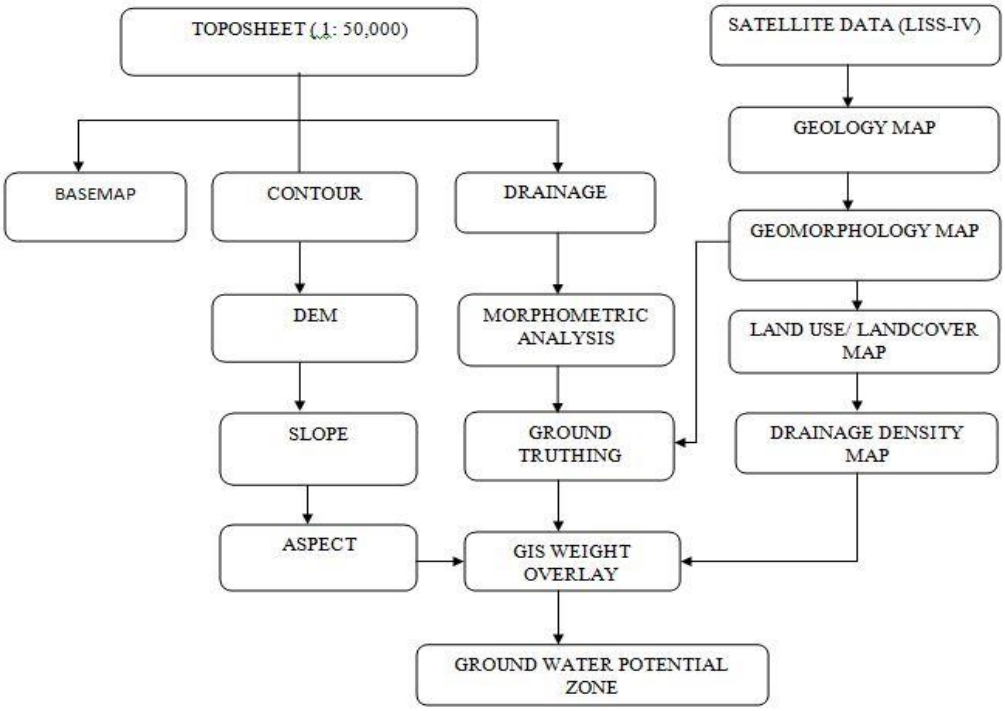

Fig.2 Methodology

	Morphometric parameter	Formula/ Definition
Linear	Stream order (U)	Stream order
	Stream Length (L_U)	Length of stream
	Meam (L_{sm})	L_{sm}=Lu/Nu, Lu=Mean stream length(km), Nu- Number of stream segment.
	Stream length ratio (R_L)	L_{sm}=Lu/Nu; ,Lu=Mean stream length (km), Nu=Number of stream segment.
	Bifurcation Ratio (R_b)	R_b = Nu / Nu+1 , Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order
Relief	Basin relief (B_h)	distance b/w the lowest and highest points of basin.
	Relief Ratio (R_h)	D_d*(H/1000)
	Ruggedness Number (R_n)	Rn=Bh×Dd, B_h= Basin relief, D_d=Drainage density
Areal	Area (Km^2)	A
	Perimeter (Km)	P
	Basin length(L_b) Km	L_b=1.312*$A^{0.568}$
	Drainage density (D_d)	D_d=L/A Where, L-Total length of stream, A- Area of basin.
	Form factor (R_f)	Rf=A/$(Lb)^2$ A=Area of basin, Lb=Basin length
	Elongation ratio (Re)	Re=√(Au/π)/ Lb Where, A=Area of basin, π=3.14, Lb=Basin length
	Length of overland floe(L_g)	L_g=1/D_d x2 where D_d =drainage density

Table1. Morphometric parameters of drainage basin.

RESULTS AND DISCUSSION

Morphometric analysis

The morphometric parameters such as stream length, drainage density, stream length, drainage density, form factor, circulatory ratio and roughness number are calculated by using formula suggested by strahler (1964).

Aspect map

Aspect means the direction at which side of mountain slope face. The direction of the aspect value 0º is true north, 90º is to the east. The aspect map plays an important parameter for morphometric studies.Fig.3 shows the aspect map.

Slope map

Slope is also important parameter for morphometric and geomorphic studies. It is very helpful for various aspects of morphometric and groundwater studies. It also helps to identify the area at which erosion take place and sediment runoff. (J.S. John Wilson et al.2012).By using DEM data, the slope map is prepared using Arc GIS 10. The slope value of study area varies from 0-60º .The slope values of the study area have been classified in to five groups namely 0-5 º, 5 º- 10 º, 10 º-15 º, 15 º-30 º, and above 30º.These slopes mainly in the north-western, north-eastern and central parts of the study area. Steep slopes have high drainage density and high stream frequency and also facilitate high runoff and comparatively less infiltration and poor groundwater potential. In the nearly level slope area (0-1) allows low runoff and have good ground potential zone. Very steep slopes are mainly covered in the upper parts of study area. Fig.4 shows the slope map.

Relative relief

Relief is defined as the difference in elevation between lowest and the highest point of a basin. Its significant role in landforms development, drainage development, surface and subsurface water flow, permeability and erosional properties of the terrain can be understood. The relief of the study area is 2300m.the high relief value indicates high gravity of water flow, low permeable and high runoff condition.Fig.5 shows the relief map.

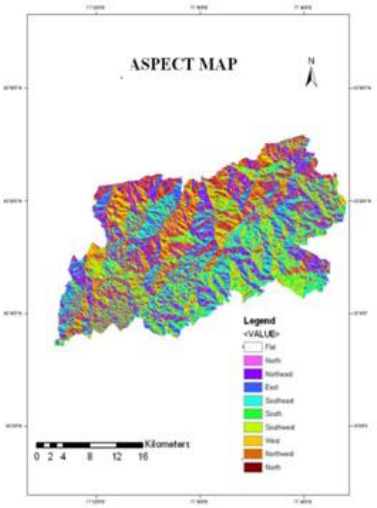

Fig.3 Aspect map

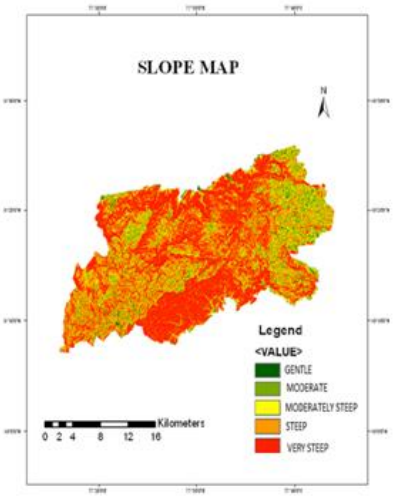

Fig.4 Slope map

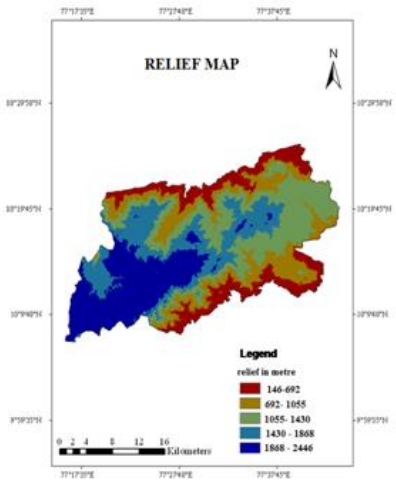

Fig.5 Relief map

Stream order (U)

In the present study, ranking of steams has been carried out based on the method proposed by Strahler (1964). The stream orders are classified up to fifth order in the Kodaikanal basin. Details of stream order of kodaikanal watershed are shown in table 2.Fig.6 shows the stream order map. of a given order and its next lower order. In

this study, R_L ranges from 0.44 to 0.53. (Table 2).the variation might be due to change in slope and topography.fig.6 shows the stream order map.

Table. 2 Results of Morphometric analysis of Kodaikanal basin

S.no	Parameters	Stream order				
		I	II	III	IV	V
1	Stream number(Nu)	1515	661	363	210	56
2	Stream length (LU) Km	872.68	391.78	196.50	108.65	25.60
3	Mean stream length(KM)(Lsm)	1.15	1.18	2.72	7.23	8.53
4	Stream length ratio(RL)	II/I 0.44	III/II 0.50	IV/III 0.55	V/IV 0.23	
5	Bifurcation ratio(Rb)		I/II 2.29	II/III 1.82	III/IV 1.72	IV/V 3.75
6	Mean bifurcation ratio (Rbm)	2.39				
7	Perimeter (P) (in km)	226.9				
8	Basin area(A) (Km^2)	1039				
9	Basin length(L_b) (Km)	67.83				
10	Basin relief (B_h) (m)	2300				
11	Relative relief (R_{hp})	1.01				
12	Elongation ratio(Re)	0.26				
13	Drainage density (D)	1.53				
14	Form factor (Rf)	0.22				
15	Length of overland f(L_g)	0.32				

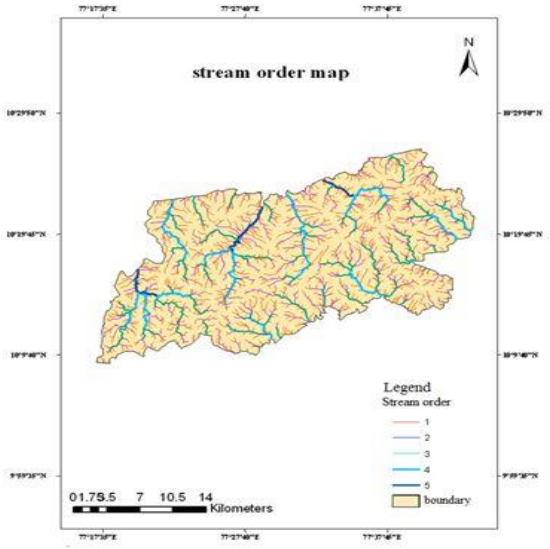

Fig.6 Stream order map

FACTOR INFLUENCING GROUNDWATER.

Geomorphology

In the study area the geomorphic units of the basin can be divided in to structural hill, dissected plateau, pediment, valley fill, structural valley. Among these valley fill, structural valley are good in groundwater

potential. Most of the valley fill, structural valley are found in south western part of Kodaikanal basin. The present study follows the classification of geomorphology by national remote sensing centre(NRSC).Most of the agriculture land in study area is constituted by pediplain and groundwater potential is good to moderate in this region. Depicted in Fig.8 shows the geomorphology map.

Geology

Geology is one of the major factor which plays an important role in the distribution of groundwater. The major rocks found in study area are Granite gneiss, Charnockite,Laterite, Anorthosite. The weightage were assigned based on the rock's influence in the groundwater. Fig.7 shows the geology map.

Land use/land cover (LU/LC)

Due to anthropogenic activities the land surface has been modified enormously in the recent years. The surface covered by vegetation like forests and agriculture traps and holds the water in 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 the study area's land surface. The LISS IV satellite image has been used for the study to find out the land use and land cover of study area. The supervised classification method has been used with level – I classification. The result of the study found the study area covered by six different classes such as agricultural land, forest, built-up, water body, waste land and others. The weight assigned based on water logging and runoff properties of LU/LC.fig.11 shows the LU/LC cover map.

Drainage map

The drainage network of the Kodaikanal basin is extracted from a series of geoprocessing tools in ARC GIS-10 (Fig. 9). The highest stream order in the kodaikanal basin was identified as fifth. To evaluate the drainage basin morphometry, various parameters like stream number, stream order, stream length, stream length ratio, bifurcation ratio, basin length, basin area, relief ratio, elongation ratio, drainage density, stream frequency, form factor and circulatory ratio, etc., have been analysed using the standard mathematical formulae given in Table 1. Drainage density and type of drainage gives information related to runoff, infiltration relief and permeability. Fig .9 shows the drainage map.

Drainage density map

Drainage density (in terms of Km/Km^2) indicates closeness of spacing of channel as well as the nature of surface material, thus providing a quantitative measure of average length of stream channel for whole basin.(N.S. Magesh et al, 2011). It has been observed from drainage density measurement made over a wide range of geologic and climatic type that a low drainage density is more likely to occur in region and highly resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. 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.fig .10 shows the drainage density map.

Assigning rank and weight

The ground water potential zones are obtained by overlaying all the thematic maps in terms of weighted overlay method using spatial analysis tool in ArcGIS 10.1. During the weighted overlay analysis, the ranks have been given for each individual parameters. The weights and rank have been considering the works carried out by researchers such as (Krishnamurthy et al 1996, Saraf & Chowdhary 1998). All the thematic maps are converted in to raster format and superimposed by weighted overlay method. For assigning the weight, the geomorphology, drainage density and land use/Land cover were assigning higher weight, whereas slope, geology were assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the GIS layer on geomorphology, slope and drainage density were analysed and ranks are assigned to their sub variable (Butler et al., 2002, Asadi et al., 2007, yammani, 2007).

The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the the lowest potential feature. The landforms such as structural valley and valley fill are given highest rank value and lower value assigned for structural hill. As for as slope is concerned, the highest rank value is assigned for gentle slope and low value is assigned to higher slope. The higher rank factors are assigned to low drainage density because the low drainage density factor favours more filtration than surface runoff. Lower value followed by higher drainage density. The geology such as Charnockite are given to highest rank and lower value is assigned to Anorthosite. In LULC high rank is assigned to agricultural land and low value is assigned to built up- land. The overall analysis is tabulated.

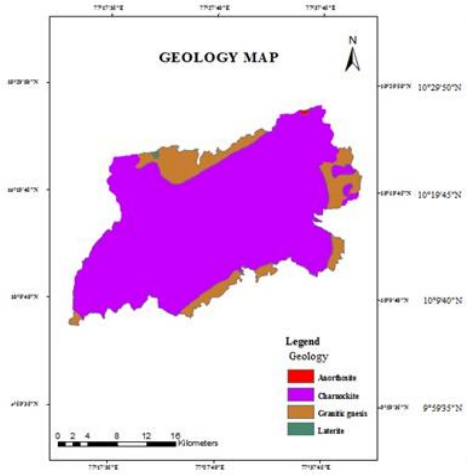

Figure.7 Geology map

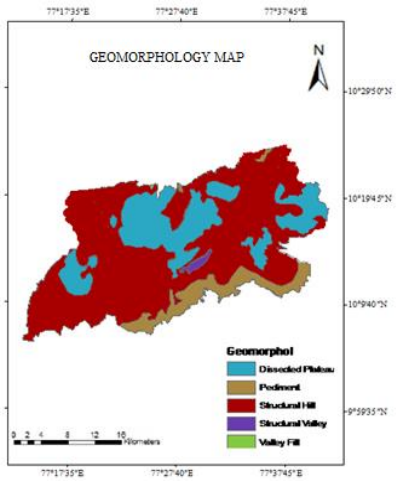

Figure.8 Geomorphology map

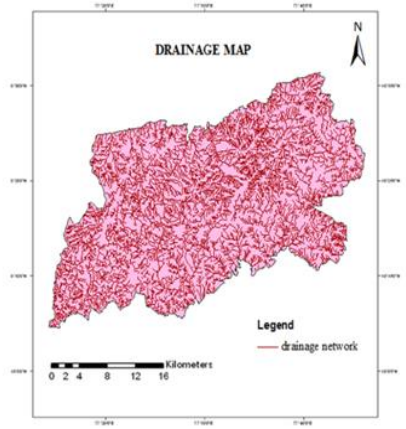

Figure.9 Drainage map

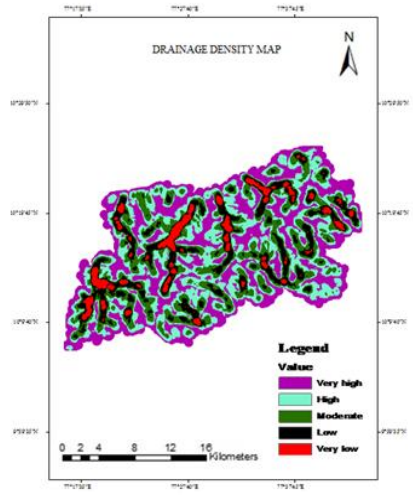

Figure.10 Drainage density map

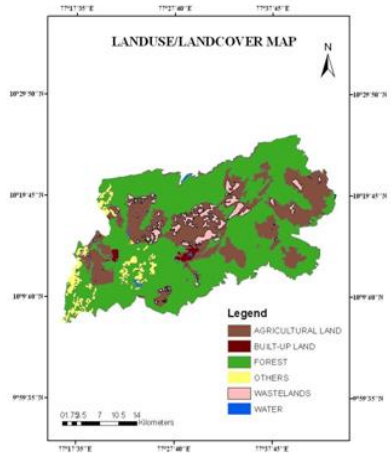

Figure.11 Landuse/ land cover map

Thematic layers	classes	Weight (%)	Rank
Geomorphology	Structural hill	20	1
	Dissected plateau		3
	Pediment		2
	Valley fill		3
	Structural valley		3
Slope	Gentle(0-5°)	15	5
	Moderate(5-10°)		4
	Moderately steep (10-15°)		3
	Steep(15-30°)		2
	Very steep(>30°)		1
Geology	Granite Genesis	10	2
	Charnockite		3
	Laterite		1

	Anorthosite		1
Land use/land cover	Agricultural land Built up-land Forest Wastelands Water Others	30	5 1 4 1 2 3
Drainage density (km/km^2)	Very low Low Medium High Very high	25	5 4 3 2 1

Table 2.Rank and weight for different parameter of groundwater potential zone.

S.no	Potential zones	Area(%)
1	Very low	7.00
2	Low	9.13
3	Medium	47.67
4	High	27.20
5	Very high	8.98

Table.3 Groundwater potential zones of study area.

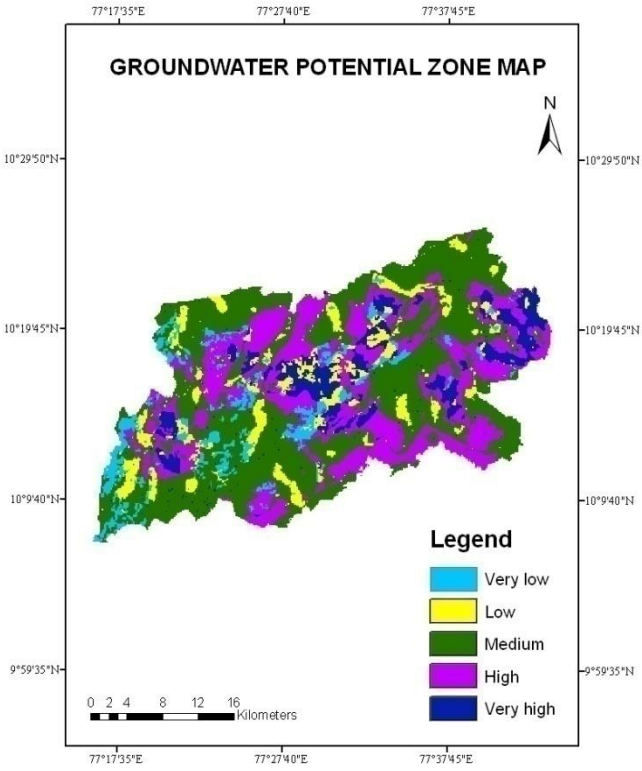

Figure.12 Groundwater potential zone map

CONCLUSION.

Geographical information system and remote sensing has proved to be powerful and cost effective method for determining groundwater potential in parts of Kodaikanal block. The study reveals that integration of five thematic maps such as geology, geomorphology, slope drainage density and land use/land cover gives first hand information to local authorities and planners about the areas suitable for groundwater exploration. This groundwater potential information will be useful for effective identification of suitable locations for extraction

of water. According to the groundwater potential zone map, Kodaikanal basin is categorized into five different zones, namely 'low', 'very low', 'moderate', 'high' and 'very high'. The results of the present study can serve as guidelines for planning future artificial recharge projects in the study area in order to ensure sustainable groundwater utilization.Further, the morphometric parameters evolved here will be the immense utility in river basin evaluation, flood management, watershed prioritization for soil and water conservation and natural resources management at micro level. The geoprocessing techniques employed in this study will assist the administrator in planning and decision making in basin development and management studies.

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