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RESEARCH ARTICLE

Application of Remote Sensing and GIS for Artificial Recharge Zone in Kodaikanal taluk, Tamil Nadu, India

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Abstract

Water has become a scarce resource all over the world. Water resources of Earth can be classified as surface water and ground water in which groundwater is the main source for the domestic purpose and agriculture. The aim and objectives of the work is preparation of various thematic data such as Drainage, Drainage density, Lineament, Lineament density, Geomorphology and Land use/Land cover using IRS P6 LISS IV satellite dataUsing Digital Image processing, the supervised, unsupervised Classification, band merging and filtering Techniques for updating the above all thematic maps.To identify the recharge favorable zone areas, the above-mentioned parameters were analyzed in a GIS by assigning appropriate ranks and weights. Integration analysis was carried with all the thematic maps. Weightages were assigned to prepare the artificial recharge zonation map.

INTRODUCTION

Artificial groundwater recharge is a basic tool for the sustainable management of vital freshwater resources (both groundwater and surface water). Replenishing the groundwater through artificial recharge has been carried out in various parts of the world for the last 6 decades (Babcock and Cussing 1942; Beeby-Thompson 1950; Buchen 1955; Todd 1959; Asano 1985). The concept of using modern techniques like remote sensing and geographical information systems (GIS) in groundwater management studies is comparatively new. As groundwater is dynamic and interdisciplinary in nature, an integrated approach of remote sensing (RS) and GIS technique is very useful in various groundwatermanagement studies. Remote sensing can provide diversedatasets over a large inaccessible area that can be efficientlyhandled and analyzed in a GIS framework. Over thelast 2 decades, RS and GIS have been widely used for thepreparation of different types of thematic layers and integratingthem for different purposes (Saraf and Choudhury1998; Jha and Peiffer 2006). Blending of these two technologieshas proved to be an efficient tool in groundwaterpotential zoning, and several studies have been conductedin this direction both in India and abroad (Krishnamurthy and Srinivas 1995; Krishnamurthy et al. 1996; Shahid et al.2000; Sener et al. 2005; Solomon and Quiel 2006). Acomprehensive review on the applications of RS and GISin groundwater development and management is presentedby Jha et al. (2007). The use of integrated RS and GIStechniques in artificial recharge studies, however, has been started very recently. A set of weights for the different themes and their individual features wasdecided based on personal judgments considering theirrelative importance from the artificial recharge viewpoint.These thematic maps were then integrated in a GISframework to identify suitable zones for artificial recharge.A few researchers have also attempted to select suitablesites for artificial recharge as well as to suggest salient recharge structures (Saraf and Choudhury 1998; RaviShankar and Mohan 2005). This review clearly indicatesthat the use of RS and GIS techniques for artificial rechargestudies is very limited and that, except for one study conductedin Iran (Ghayoumian et al. 2005), all the studieshave been conducted in India only. Furthermore, except for Saraf and Choudhury (1998), all the Indian studies havebeen conducted in the rocky terrains of south India.

Thus, such kinds of studies are completely lacking in easternIndia in general and West Bengal in particular. Therefore, there is a need to conduct more studies in these field indifferent hydrogeologic settings.

STUDY AREA

Study area (Fig. 1) is located in the Dindigul district of Kodaikanal hill, which is a mountainous terrain in the Western Ghats of Tamil Nadu with an area of 1039.46 km^2. It is geographically located between 77° 14' 26" and 77° 45' 28" E longitudes and 10° 6' 25" and 10° 26' 54" N latitudes. In the survey of India toposheet, it forms part of 58 F/7, 8, 11 & 12 on 1:50,000 scale. The climatic condition of the study area is characterized by humid conditions. Relative humidity is high during retreating NE monsoon season (October to mid-December). The mean temperature of Kodaikanal taluk is 15.93^0C with a mean summer (June, July and August) temperature of 17.29^0C and mean winter (December, January and February) temperature of 14.10^0C. The average annual rainfall is 1436.87mm. The study area is fully covered by hills. The plain area forms a small part. The hilly area is in the form of undulating terrain and slope towards south-southeast and east. The maximum elevation is 2517mts, located in the south west portion. The study area is rich in biodiversity and has variety of endemic Shola forests. The area is inhabited from prehistoric period and there are tribals still living in the ancient way. Labor intensive tea and coffee plantations and extensive vegetable cultivation mark the place.

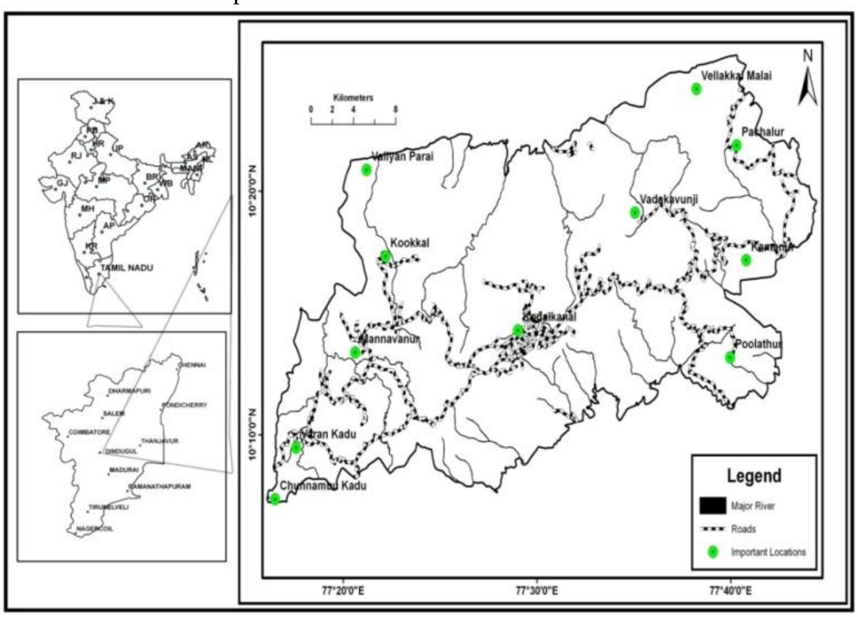

Figure: 1 Study Area

Methodology

In order to delineate artificial recharge zones in the study area, a multi-parametric dataset comprising satellite data and other conventional maps including Survey of India (SOI) toposheets were used. Eight thematic layers, viz., slope, geology, geomorphology, drainage, drainage density, lineament, lineament density and land use land cover, were considered for the delineation of artificial recharge zones. The geology layer was prepared from the Geological Survey of India (GSI), Government of Tamilnadu. To prepare the drainage density map of the studyarea, initially, the drainage network for the study area was digitized from the Survey of India toposheets at 1:50,000 scale. The land use/ land cover map prepared from the Indian Remote sensing Satellite IRS LISS IV MX data 2011. These thematic maps are in turn assigned ranks and weights to analyze in GIS domain. All the thematic layers were overlayed by using GIS to find out the final integrated output of artificial recharge zones (Fig.2).

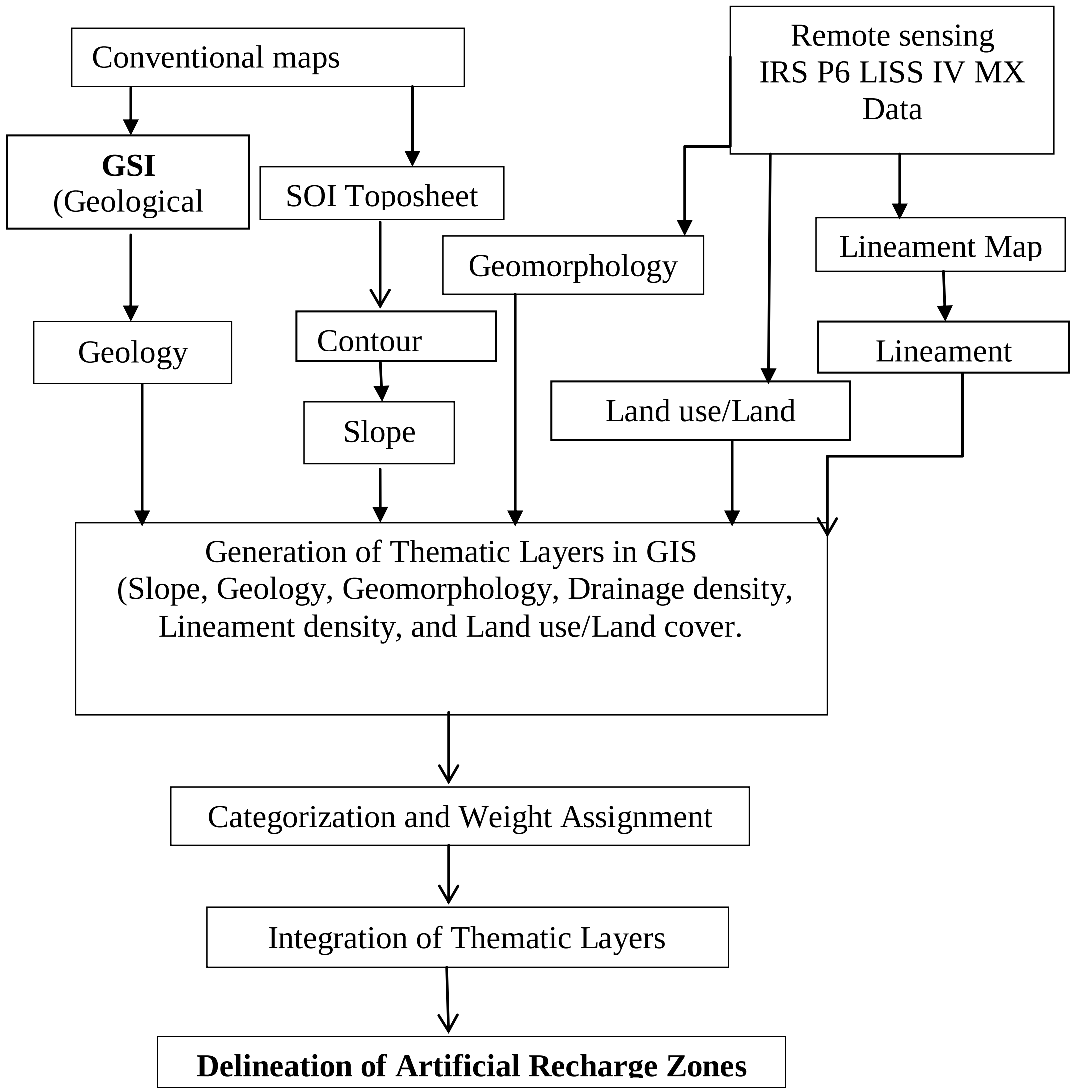

Figure: 2 Flow chart of the present study

Geology of the area

The geology map was prepared by using already existing geological data collected from the geological survey of India map (the resource map of Tamil Nadu) with the scale of 1:250000. The study area has the following rock types. They are charnockite, granitic gneiss, laterite and anorthosite (Fig.3). Among these rock types, the charnockite are found over large area in 837.90 km^2. The granitic gneisses cover less area in 195.58 km^2 and are observed in the southeastern portion. The other rock types namely anorthosite 3.59 km^2 and laterite 2.34 km^2 are distributed over very small areas and are observed in the northeastern portion of the study area

Charnockite as defined by Holland (1900) is a hypersthenes bearing granite; later on, hill and extended the scope of the term and gave it a "Series" status and included within the ultrabasic, basic and intermediate charnockite – an igneous series. The presently accepted version of charnockite in Indian geology is after Subramaniyan (1967), and it is commonly accepted that charnockites are metamorphic rocks, metamorphosed under granulite facies conditions.

Charnockite forms the bulk of the units of the study area. Charnockite is a mainly massive, greasy greenish in color and coarse granular rock consisting mainly of quartz, feldspar, and hypersthenes. The charnockite habitually occurs in terrains of high grade regional metamorphism dominated by rocks of the granulite facies. The origin of charnockite is a matter of controversy. The charnockite rocks occupy most of the total geographical area (nearly 80.61%).

The important mineral constituents present in granitic gneisses are quartz, feldspar, and mica. This rock type is distributed along the east and southeastern part of the study area. These formations occupy nearly 18.81% of total geographical area.

The Anorthosite is present in the north east portion of the study area. The Anorthosite is present over a very small area occupies nearly 0.35%.

Occurrence of sporadic pebbles and gravels of Laterite have been noted in Golf – links area, NW of Kodaikanal reservoir up to a depth of 0.3 m underline by the yellowish clay and lithomarge. At some places the Laterite is seen as bauxite. The laterite formation covers a very small area of nearly 0.23%.

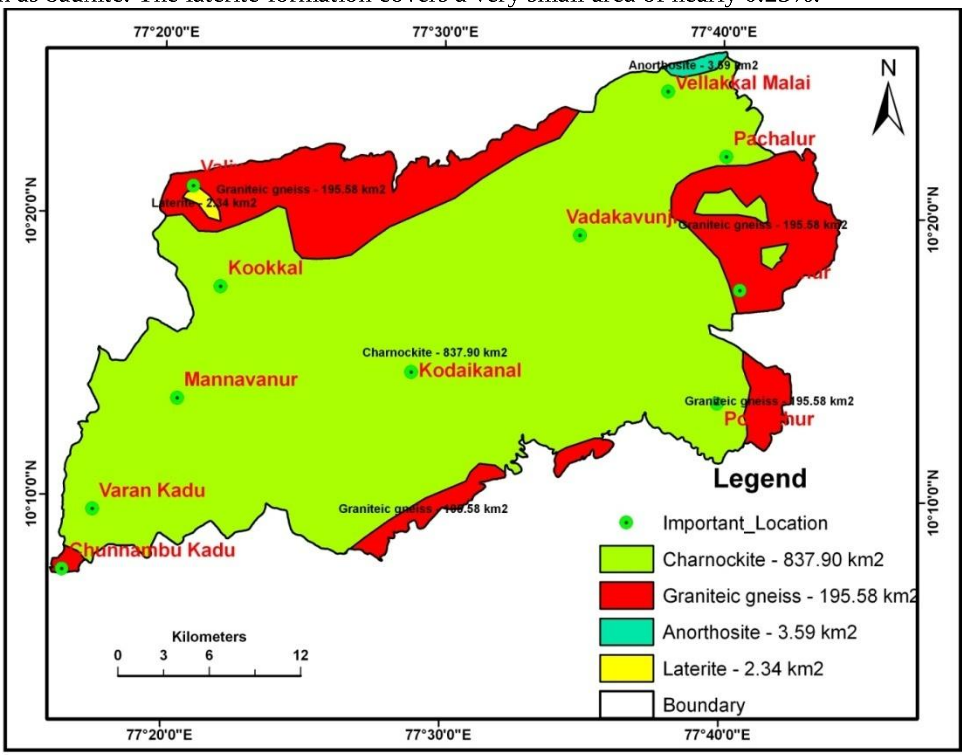

Figure : 3 Geological map of the area

Slope

The various slope classes and their spatial distribution map is shown in (Fig.4). In the study area slope varies from 0° to more than 30°. The entire slope map is divided into four categories as follows:

0 – 10° Degree : Gently Sloping

10 – 20° Degree: Moderately Sloping

20 – 25° Degree: Moderate Steep Sloping

25 – 30° Degree: Steep Sloping

>30° Degree: Very Steeply Sloping

The areas having 0 to 10% gently slope fall into the ‘very good’ category because of the nearly flat terrain and relatively high infiltration rate. The areas with 10 to 20% moderate slope are considered as ‘good’ for groundwater storage due to slightly undulating topography with some runoff. The areas having a slope of 20 to 25% cause relatively high runoff and low infiltration, and hence are categorized as ‘moderate steep sloping.’ The fourth (25–30%) and (>30%) categories are considered as ‘poor’ due to higher slope and runoff.

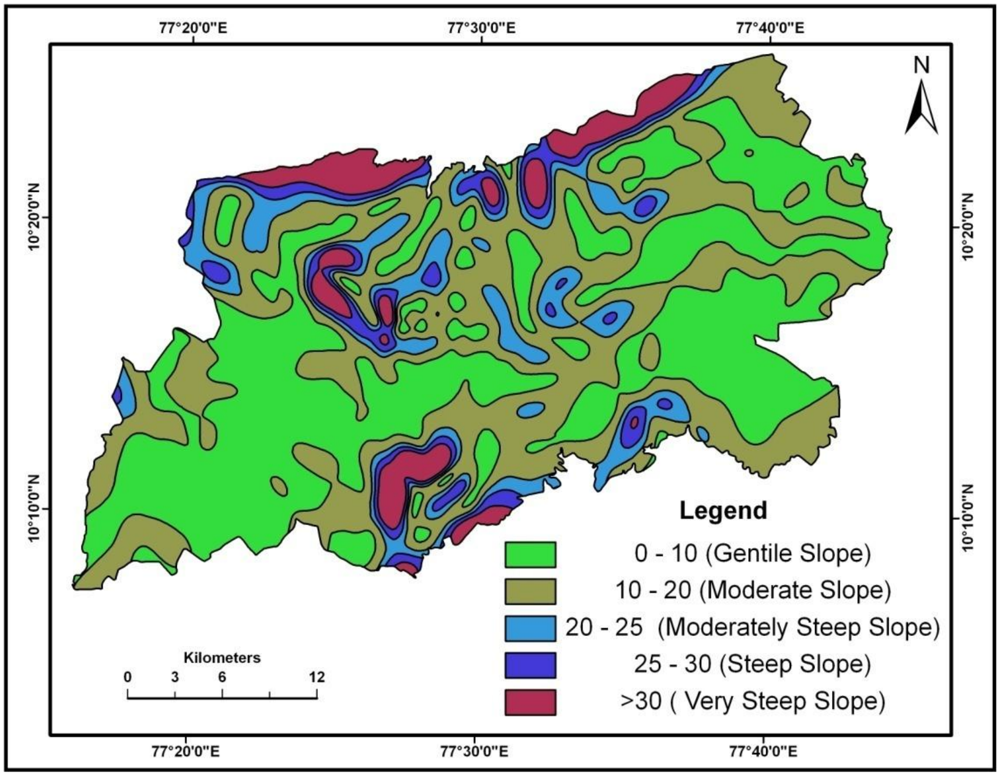

Figure : 4 Slope Map of the study Area.

Drainage density map

Drainage density is considered to be one of the important parameters for assessing the groundwater potential in an area Prasad et al., 2008. Since drainage density is a useful index for understanding the nature of the surface material and their permeability and infiltration characteristics. Drainage density has been used in conjunction with other parameters such as slope, geomorphology, rock types and lineament density, etc. for identifying the ground water potential zones Saha et al., 2010. Hence, for the present study, the drainage density has also been considered along with other parameters for identifying the ground water potential zones.

The simplest way to calculate drainage density on a regional scale is to divide the study area into grid squares of one sq.km each measure the total stream length in each grid and to group the derived data in drainage density categories (Savindra Singh, 2000). The methodology stated above has been used to obtain drainage density map of the study area.

The distribution of various density classes in the study area is shown in (Fig.5). From the figure, it is evident that the areas of very low density (<1000 m) are mostly on find to the plateau portion of the hill. Large patches of very low drainage density category found in Kodaikanal village. The small patches found in north eastern part Mannavanur, Poondi villages and south western part of Periyur, Vellagavi villages. Areas where drainage density is low (1000 to 2000 m), is found almost in all the portion of study area. Areas with moderate drainage density (2000 to 3000 m) occupy substantial area in the plateau portion of the hills as well as in the outer slopes. Most of the northern part of the upper plateau portion, which includes almost the entire Vilpatti, Vadagounchi, and central part of Poombarai, Poondi and Pannaikadu, is found to have moderate drainage density. Areas with the high drainage density (3000 to 4000 m) are found mostly in the slopes, especially in the southern (Vilpatti village), eastern (Kookkal village) and some other small patches found in Vadakavunji, Mannavanur and Poolathur villages.

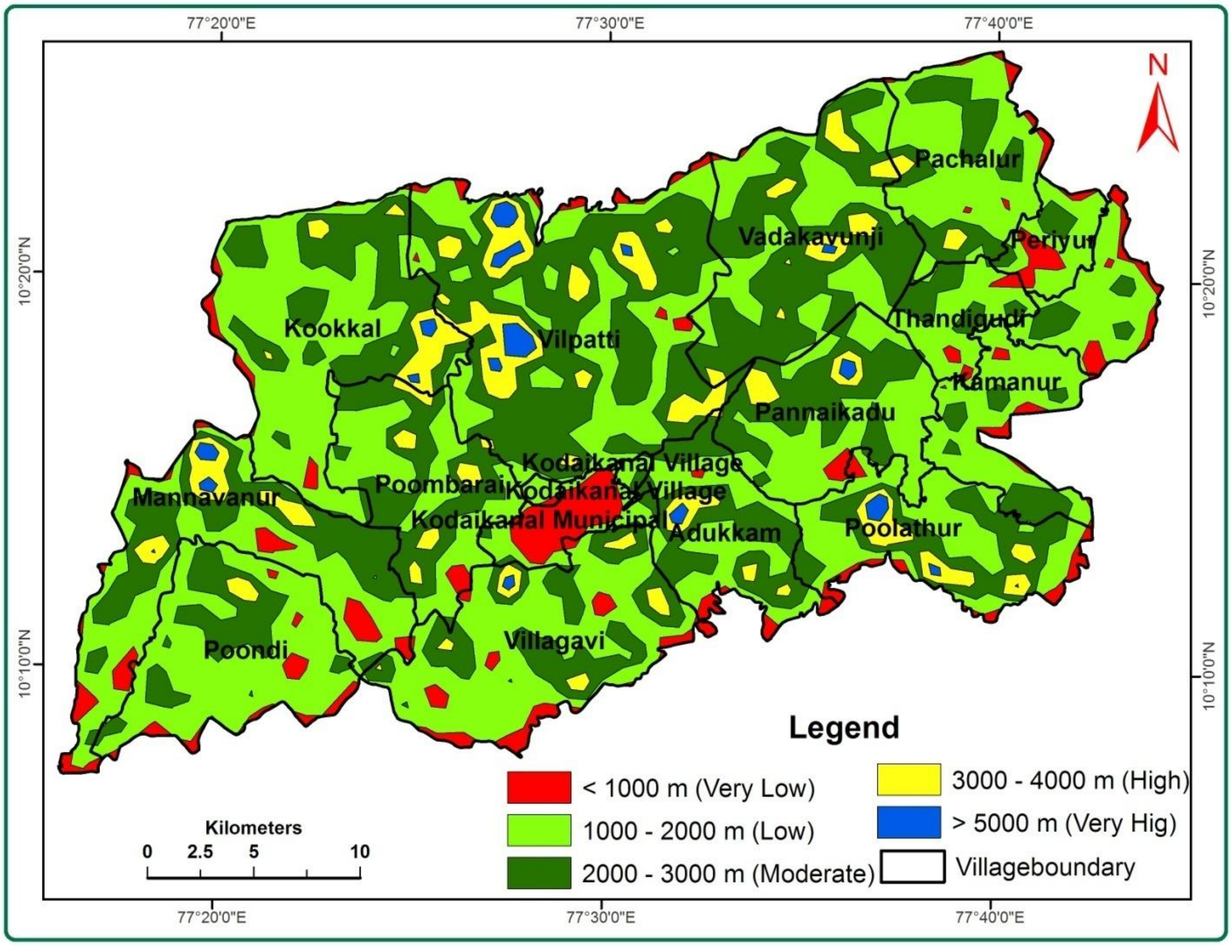

Figure :5 Drainage Density of the area

Lineament density

Lineaments are manifestation of linear features which is developed by the tectonic activity that reflects a general surface expression of underground fractures (Pradhan et al.2006; Pradhan and Yousef 2010). It is long and linear geological structure (fault and/or joint) that may be represented on satellite images as a straight course of streams, vegetation alignment, or topographic features such as aligned ridges. In hard rock terrain the storage and movement of groundwater is controlled by the secondary porosity i.e., presence of lineaments and fractures. Lineament study of the area from remotely sensed data provides important information on sub-surface fractures that may control the movement and storage of the groundwater. Subsurface permeability is a function of fracture density of rocks (Pradeep, 1998). Hence the identification of lineaments in the hard rock terrain from the satellite data possesses more importance. Most of the lineaments are identified with the anomalies associated with features like straight drainage course, vegetation pattern, topography etc. The study area is crisscrossed by major and minor lineaments. They vary in length from .few meters to kilometers in dimension. General trend shown by the lineaments present in the study area are NNE - SSW and NE - SW.

The study of lineament density may help to identify the weathered zones in an area, which is very essential in the studies relating to groundwater exploration, soil erosion, landslides etc. Subsurface permeability is a function of fracture density of rocks Münch and Conrad, 2007; Vijith, 2007. The lineament density map of present study area was prepared by interpretation of satellite data.

The lineament map, which was prepared on 1: 50,000 scale was overlayed by a 2cm grid sheet. The total length of the lineament in each grid was noted down and the process was repeated for all the grids covering the study area. By carefully examining the values obtained, the data were grouped into four classes as low (lineament density less than 1000 m / sq. km, moderate (1000-1500 m / sq. km.), high (1500-2000 m / sq. km.) and very high (>2000 m / sq. km.). Isolines were drawn for these values and thus the lineament density map was prepared and it is shown in (Fig. 6).

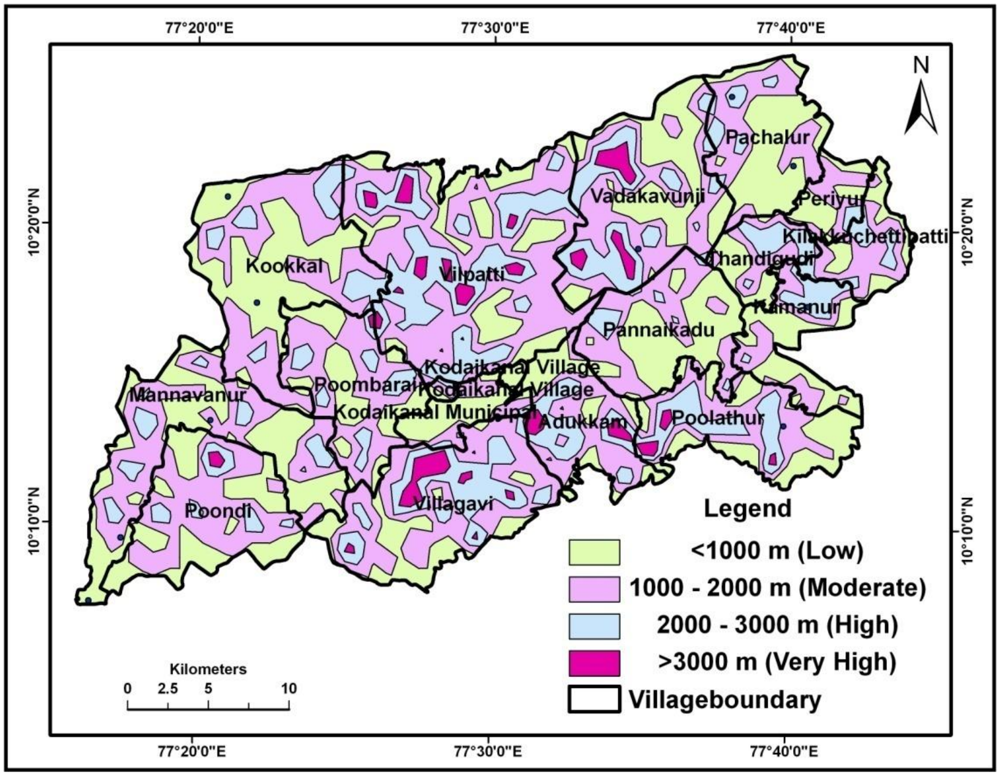

Figure : 6 Lineament Density of the area

Geomorphology

Geomorphology deals with the general configuration of the earth surface. It consists of description and measurement of the morphological features like mountains, rivers, elucidate the processes involved in their development and eventually construct the history of their evolution. Major geomorphologic units found in the study area dissected plateau, structural hill, structural valley, valley fill and pediment. Dissected hills are resulted from the end product of peniplaination which reduces the original mountains into a series of scattered knolls standing on the pediplains (Thornbury, 1990). These units are considered as poor potential zones, as they have unfractured rock material, low infiltration and behave largely as runoff zone. Structural hills are the linear or acute hills exhibiting definite trend lines and mostly act as runoff zones. Linear ridges are characterized by massive structure and high resistance to erosion. They also act as runoff zone and have poor potential for groundwater. Piedmont plain has low relief and surface water remains for considerable time before meeting major rivers. It provides good scope for infiltration and recharge of groundwater. Consequently they pose good potential for groundwater occurrence. The more vegetation cover was found in valley fill areas. From the ranking awarded above it may be seen that the geomorphological unit dissected plateaus, structural valley and valley fill are important factors to find groundwater potential zone. (Fig.7)

Land use / Land cover

Remote sensing data and techniques provide reliable, accurate baseline information for Landuse mapping and play vital role in determining land use pattern and changes therein on different cutoff dates. The major land use pattern of the study area includes agriculture land, forest area, plantations, built-up land, harvested land and waste land etc. Agriculture land has been identified by the light medium red tone, fine/medium texture varying in size, often rectangular in shape. The forest and plantation gives light reddish brown tone with white patches and fine to medium texture with irregular shape and varying size. Although, these areas have good ground water recharge potential, these have been purposefully categorized as poor, keeping in mind that these areas are generally restricted and are not permitted for any ground water exploitation activity. (Fig.8)

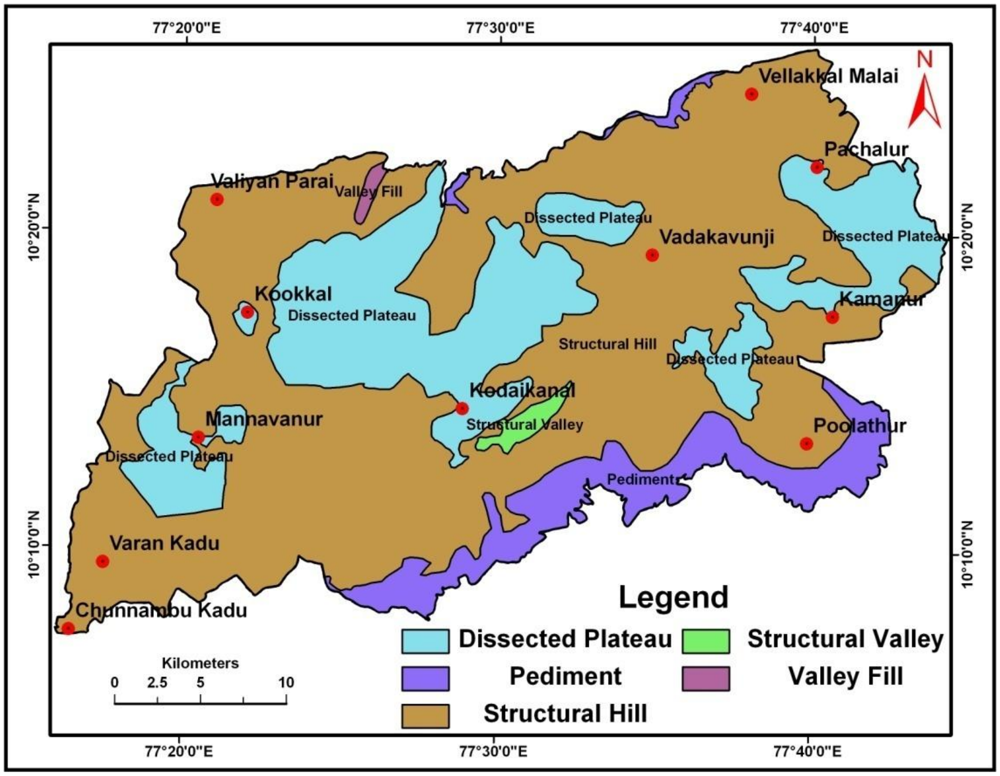

Figure : 7 Geomorphology of the Area

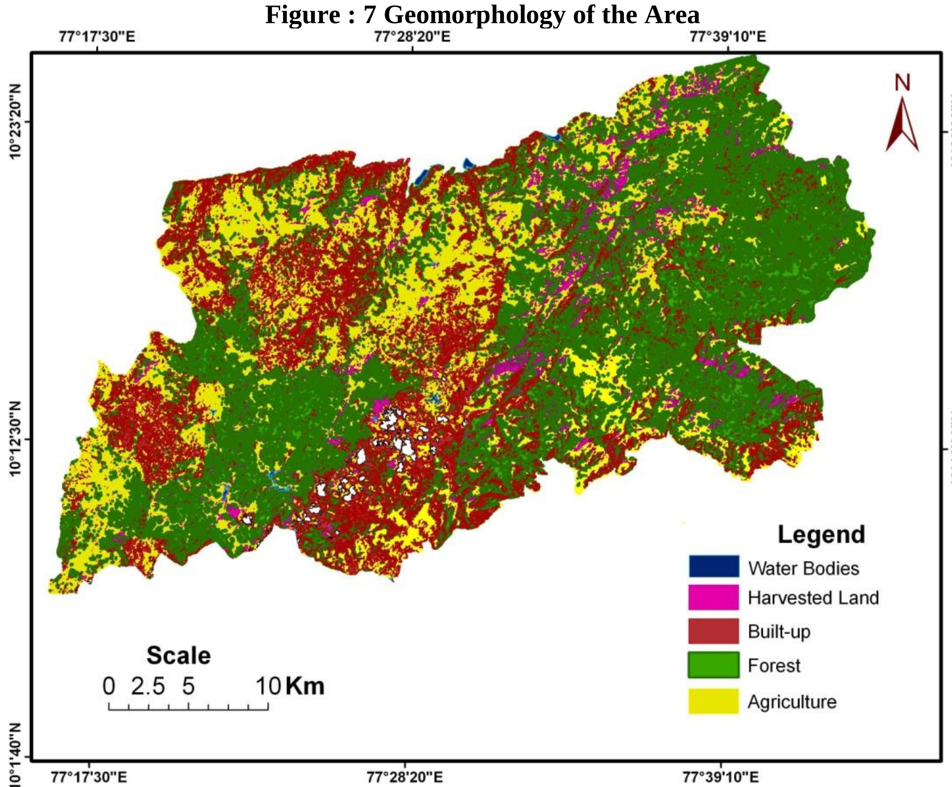

Figure : 8 Land use/Land cover Map of the area

Assigning rank and weightages

Different ranks and weightages were assigned to relevant different geo-system parameters. Depending on the relative importance in groundwater exploration, the themes were assigned specific weights as indicated for assigning the Ranks the Slope and geomorphology were assigned higher ranks, whereas the lineament density and drainage density were assigned lower ranks. After assigning ranks (maximum weightages) to the different geo-system parameters, individual weightages were given for sub variables of the above main four geo-system parameters (Table 1). Similarly, varies weightages were assigned to the individual sub variable of each geo-system parameter. In this process, the GIS layers on lineament density, geomorphology, and slope and drainage density were analyzed carefully and weightages were assigned to each of their sub variables (Butler et al 2002, Skubon, 2005, Asadi et al 2007, Yammani 2007). GIS layers of four geo-system parameters holding final weightages of each parameter also added and finally the study area is divided into different ground water recharge zones based on the added weightages.

The thematic maps are geology, lineament density, geomorphology and slope, drainage density and land us/ land cover layers were integrated over the GIS platform. The landforms such as structural valley, valley fills were given the highest weightage factors followed by plateau plains. Lower values were assigned for moderately sloping lands and for other geomorphic classes like structural hill, and pediments, which hardly have any chances for groundwater storage are assigned the least values. As far as slope is concerned the highest weightage value was assigned for the gentle slope category; low weightage values were assigned for moderate slope classes followed by moderately steep slope classes. Least values were assigned for steep slopes and very steep slopes. The various drainage density classes, higher weightages factor were assigned to very low drainage density category. The very low drainage density factors favor more infiltration than surface runoff. This category was given higher values. Followed by low drainage density classes are given lower values followed by moderate density classes and least values were assigned for higher drainage density. Among the various lineament density classes, very high lineament density category was assigned higher values as this category has greater has chance for groundwater infiltration. Lower values were assigned for higher lineament density classes and still low values were assigned for moderate density class and the least value was assigned for low drainage density class (Skidmore et al 1997, Jaiswal et al 2003, Tjandra et al 2003 and Pius et al 2011).

The slope map was added with landforms units of geomorphology. The resultant layer was stored as a separate layer and reclassified according to the values of each cell. This procedure was repeated for all the other layers and resultant layers were reclassified. The reclassified layers were then combined to demarcate zones showing very good zone, good zone, moderate zone, low and poor zone. The output of such procedure is shown in Table.3. The study area is covered by 16 villages within Kodaikanal Taluk and the high groundwater potential zone falls in Kodaikanal, Vilpatti, Periyur, Kallar RF, Karungal Dhonimedu Block and Adukkam Block, Iruttrkanal Block, Pambar Block is considered as I priority zone, UmayarBlock, Palani upper shoal R.F, Marudanadar block and Vannilai block is considered as II priority zone, Kudirayar Block, Pumbaraipatti Block and Oliyanuttuodai block as III priority zone. The groundwater recharge zone is shown in (Fig.10).

Table.1. Assigned and normalized weights for the individual features of the themes for artificial recharge zoning

Parametric classes	Rank	Weightages
Geology		
Charnockite	4	1
Granitic gneiss	4	1
Anorthosite	4	3
Laterite	4	3
Geomorphology units		
Dissected Plateau	7	2
Pediment	7	2
Structural Hill	7	1
Structural valley	7	3
Valley fill	7	3
Drainage density		
Very low	3	3
Low	3	2

Moderate	3	2
High	3	1
Very High	3	1
Lineament density		
Low	3	1
Moderate	3	1
High	3	2
Very High	3	3
Slope		
0 – 10 (Gentile Slope)	5	3
10 – 20 (Moderate Slope)	5	2
20 – 25 (Moderate Steep Slope)	5	1
25 – 30 (Steep Slope)	5	1
>30 (Very Steep Slope)	5	1
Land use/ Land cover		
Forest	4	2
Agriculture	4	3
Waste Land	4	1
Built-up	4	1
Harvested Land	4	2
Water bodies	4	3

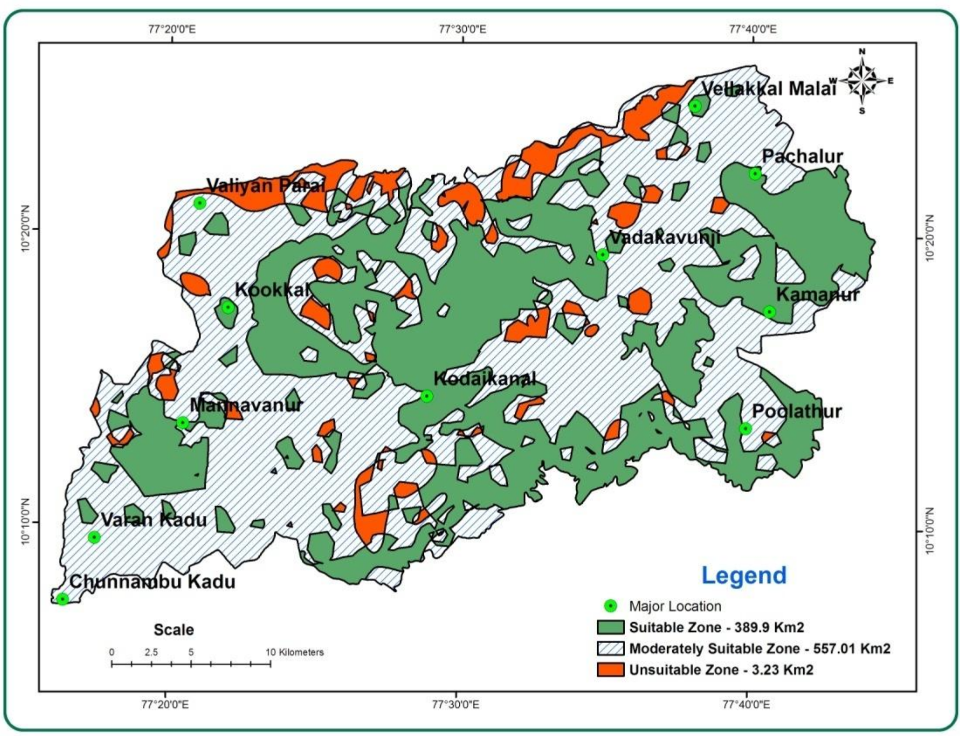

Figure : 10 Artificial Recharge zone Map.

Conclusions

The present study was to understand the groundwater recharge zone in Kodikanal and pictorially represent it using GIS. In order to delineate the groundwater Recharge zones, different thematic layers viz: geomorphology, slope, drainage, drainage density and land use map are used to be integrated. This provides a broad idea about the groundwater prospect of the area. Presently groundwater Recharge zones have been demarcated by integration of above thematic layers, using a model developed through GIS technique. The above study has demonstrated the capabilities of using remote sensing and Geographical Information System for demarcation of different artificial recharge zones of groundwater. This gives more realistic.

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