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Identification of groundwater recharge sites and suitable recharge structures for Thuraiyur taluk using Geospatial technology.

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This study is an attempt to identify the favorable zones for implementation of site-specific artificial recharge techniques for groundwater resources development. Various thematic layers such as base map, geology map, soil map and drainage map were prepared from toposheets and existing maps. Satellite data were used to prepare other layers such as geomorphology, landuse/ land cover, lineament. Water level, rainfall maps were prepared using collateral data. All these layers were integrated into GIS platform and get the artificial recharge zonation map and it was categorized into four different zones, namely 'most favorable 20%', 'moderately favorable 22%', 'favorable 34%' and 'least favorable 24% '.

[**Keywords:** Groundwater, Artificial recharge, Recharge Structures, Remote Sensing and GIS]

Introduction

Groundwater unlike surface water is obtainable in some quantity of the everywhere. Although it is replenish able, it is not inexhaustible. The depletion of groundwater levels in India has continued for at least a decade, when the farmers switched over from manual method of drawing water from wells to mechanical pumping for agricultural activities and Continuous failure of monsoons and unsystematic withdrawal of groundwater out of balance with input into groundwater aquifer systems have also added to the reduction of groundwater resources. Even though these resources are scarce, comprehensive surveys and especially artificial recharging of aquifers might help to overcome the problem to some extent[1].The integrate used remote sensing data and GIS technique, with the field of ground surveys, are well known as powerful techniques for groundwater mapping and exploration, particularly in the hard rock terrain. Over the last few decades, the international scientific community has shown great interested to this topic and, thus, many authors have used Remote sensing and GIS techniques for groundwater development[2-20]. Modern remote sensing techniques facilitate demarcation of suitable areas for groundwater replenishment by taking into account the diversity of factors that control groundwater recharge. Remote sensing has emerged as a useful tool for Recharge structures characterization, conservation, planning and management in recent times. Present study has attempted to identify the potential zones for groundwater exploration of artificial recharge using an integrated approach of GIS and remote sensing for a hard rock terrain in Thuraiyur taluk, Tamilnadu, India.

Materials and Methods

Thuraiyur taluk in Tiruchirappalli district, Tamil Nadu is one of the areas that suffer a severe water scarcity issue due to various reasons such as over-extraction, low infiltration rates, poor recharge practices and other issues. It is considered to be one of the most over-exploited zones of the state. It's bounded between the latitude of 11°0'0" to 11°20'0" North and 78°30'0" to 79°0'0" East (Figure1).

It is covered by the survey of India topographical sheets Nos. 58 I/7, I/8, I/11, I/12, and J/9 with the scale of 1: 50, 000.The taluk consists of two blocks namely Uppiliyapuram and Thuraiyur in which the former has 34 villages and the latter consists of 30 villages. Ayyar and Upparare the rivers flowing through the taluk. According to the 2011 census, Thuraiyur taluk has a population of 249,060 with a literacy level of 71.42%. The taluk has a tropical climate with the average rainfall of 790 mm with humidity ranging from 50 to 85%. The present study has been adopted the following methods (Figure 2). The survey of India toposheets 58 I/7, I/8, I/11, I/12 and J/9 has used to prepared base maps and the drainage maps. Hydrological soil group's map was prepared and J/9 has used to prepared base maps and the drainage maps. Hydrological soil group's map was prepared from International Soil Reference and Information Centre. Rainfall data obtained from Indian metrological department (IMD).That data has used to prepare rainfall distribution map for the theisson polygon calculation method. Lithology map was deriveded from district resource map. Waterlevel data were collected from Public Works Department (PWD), the kriging method in arc GIS were used to prepare pre and post monsoon water level maps.

The satellite images of Landsat-8, OLI/TIRS sensor data were used to prepare diferent thematic layers such as land-use/landcover, geomorphology and lineament. Drainage density and lineament density maps were prepared using the line density analysis tool in ArcGIS. Lineaments have been identified on images through visual interpretation by comparing spatial variation in tone, colour, texture, association, etc. All these thematic layers were converted into a raster format (30 m resolution) before they were added into GIS environment. Artificial recharge zones were obtained by overlaying all the thematic maps in the terms of weighted overlay analysis methods in ArcGIS 10.1.for using the spatial analysis tool.

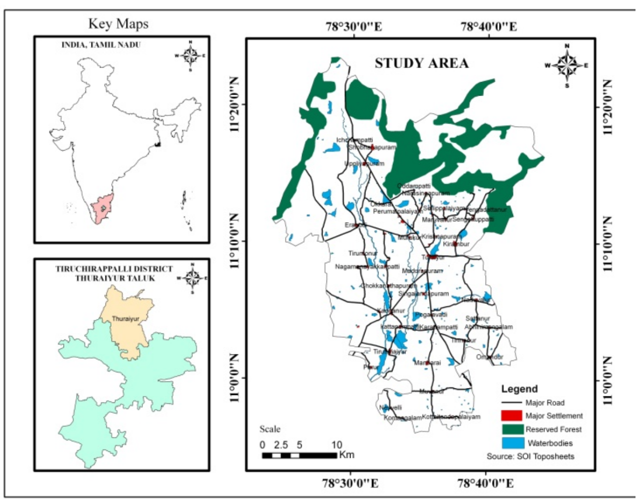

Fig. 1 — Study area location map

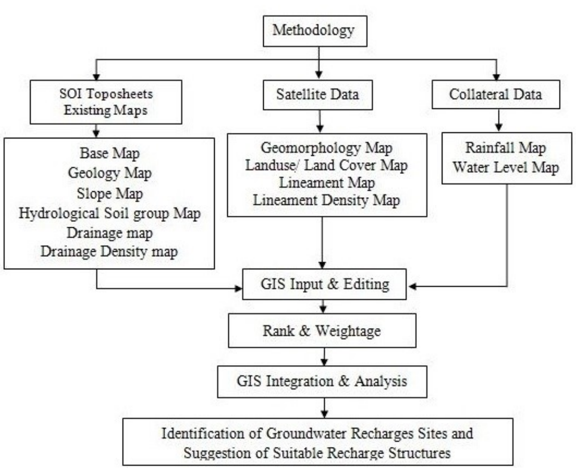

Fig. 2 — Methodology flowchart

Results and Discussion

Similar to the occurrence and movement of groundwater in an area the potential for artificial groundwater recharge is also contained by various factors, such as geomorphology, geology, soil type, slope, etc., based on the influence of each theme toartificial recharge. In addition to that, each class in a particular theme is also given a weightage based on their ability to store water.

In the present study, each theme is assigned a weightage on the basis of their significance of potentiality to artificial recharge. For example, Geomorphology and Land-use & Land cover play a prominent role in artificial recharge so it is given the maximum weightages. The different units in each theme are also given knowledge based ranking from 1 to 4, with 1 as most favorable and 4 as least favorable.The weightage of each theme and the ranks for different units in each theme are given in the (Table. 1)

Slope map has been prepared by using contours in the SOI toposheets. With the help of contour intervals slope has been classified into seven categories based on IMSD classification (Table. 2).The majority of the study area is covered by nearly level slope category and gently and moderately slope has been presented into NW, NE sides (Figure 3). This classification of the slope is used for the analysis to find out groundwater recharge sites in the study area.

The lithology is an important criterion which is to be considered while drawing the study area into favorable zones for artificial recharge as it has a mentionable impact on the infiltration and runoff of the precipitated water. The study area is underlain by crystalline rocks masses of Archean age, the major rock exposures are Ultra mafics, Pyroxene granulites, Migmatite (Figure 4). Around 62 % of the total area is covered with Charnockite.

Soil types and its texture are the preliminary role of infiltration and transmission of surface water into a sub surface of the aquifer system. The essentials of soil cover and subsoil conditions are important for prediction of surface runoff or recharge condition in an area based on infiltration rate, texture, depth, drainage condition and water transmission capacity. The hydrological soils groups is classified into A, B, C and D[21-23]. The study area having three different hydrological soil groups were presented (A, B & D).

The overall hydrological soil group 'D' occupies the major portion of the study area (Figure 5). Thus indicates that the Thuraiyur taluk has high runoff potential and low infiltration rates.

Table 1 — Rank and weightage for groundwater artificial recharge zonation in different parameters.

Parameters	Feature Classes (Map units)	Rank	Weightage
Geomorphology	Bazada, Colluvial Fill, Deep Pediment	4	
	Moderate Pediment	3	
	Plateau, Rocky Pediment	2	20
	Structural Hill, Residual Hill, Linear ridge/Dyke, Hilltop Weathered	1	
Landuse / land Cover	Crop Land, Fallow Land,	4	
	Plantation, Land without Scrub	3	
	Land with Scrub, Scrub Forest	2	20
	Forest, Gullied land, Built-Up Land	1	
Hydrological Soil group	A	4	
	B	3	15
	D	1	
Lineament density	High	3	
	Medium	2	12
	Low	1	
Geology	Fissile HornblendeGneiss	4	
	Weathered Charnockites	3	
	Pink Migmatite	2	10
	Ultra Mafics, Pyroxene Granulites, Basic Dykes	1	
Slope	0-3%	3	
	3-5%	2	8
	5-10%	1	
Drainage density	Low	3	
	Medium	2	5
	High	1	
Rainfall	High	3	
	Medium	2	5
	Low	1	
Water level	Low	3	
	Medium	2	5
	High	1	

Porosity and permeability of the terrain has been identified through the drainage pattern. If the drainage density is not much of an area, then it can be derived that the rock type may be a porous and possess of high infiltration rate,on the other hand the high drainage density indicates the zone of impervious lithology[10&24]. In this study area have identified dendritic drainage pattern and it has classified into three categories low, medium and high drainage density it's shown in (Fig. 6).The high drainage density occurred in Kanappatti and Palamalai reserved forest region.

Lineament it's defined as large scale linear structural features such as fractures, deep seated faults, joints sets of drainage line and boundary of

Table 2 — IMSD slope classification

Sl. No	Slope category	Slope %
1	Nearly level	0 - 1
2	Very gently sloping	1 – 3
3	Gently sloping	3 – 5
4	Moderately sloping	5 – 10
5	Strongly sloping	10 – 15
6	Moderately steep to steep sloping	15 – 35
7	Very steep sloping	> 35

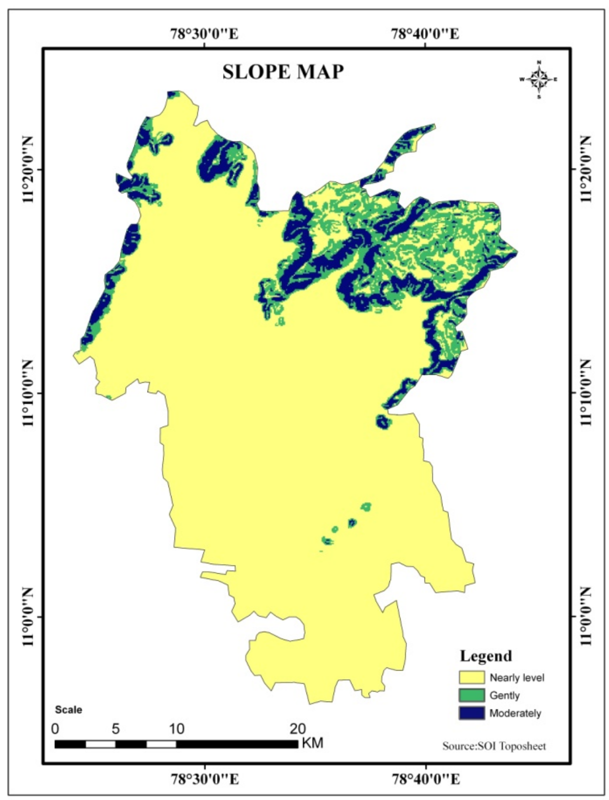

Fig. 3 — Slope map

different rock formation. It is hydrologically very important for providing the pathways of groundwater movement[25]. In addition, they reflect rock structures throughout which water can percolate and travel up to several kilometers were identified to suitable sites for artificial recharge[26]. Lineaments are very significant role in rocks formation it is a secondary porosity, permeability and intergranular characteristics together for influence groundwater movements. Two or more lineament point are intersected areas is considered as good groundwater recharge zones. In hard rock terrain, the lineament is acted as better conduits for groundwater movements with the blend of fractures and topographically low grounds can provide as the best aquifer horizons[27]. It's derived in four directions E-W, NE-SW, NW-SE and N-S (Fig. 7) throughout which water can percolate and travel up to several kilometers were identified to suitable sites for artificial recharge26. Lineaments are very significant role in rocks formation it's a secondary porosity, permeability and intergranular characteristics together for influence groundwater movements. Two or more lineament point are intersected areas is considered as good groundwater recharge zones. In hard rock terrain, the lineament is acted as better conduits for groundwater movements with the blend of fractures and topographically low grounds can also provide as the best aquifer horizons27. It's derived in four directions E-W, NE-SW, NW-SE and N-S (Fig.7). For analysis purposes lineament density has been prepared and categorized into three classes: low, medium, high (Figure 8). The higher density of lineament is very good favorable zones for ground water recharge than lesser one therefore weightage are assigned for higher density give more weightage and less weightage given to low lineament density. In the hard rock terrain geomorphologic land forms can play on important role because it's formed due to the relief, slope, extent of weathering, different types of weathered materials and overall assemblage of groundwater régime. Geomorphology was assigned highest weight because it has a Predominant role in the groundwater movement and storage of the study area[28]. Different types of landforms were identified in the area such as hilltop weathered, linear ridge/ dyke, structural hill, residual hill, pediment/valley floor, shallow buried pediment, moderate buried pediment, deep pediment, shallow buried pediplain, moderately buried pediplain it is shown in (Figure 9).

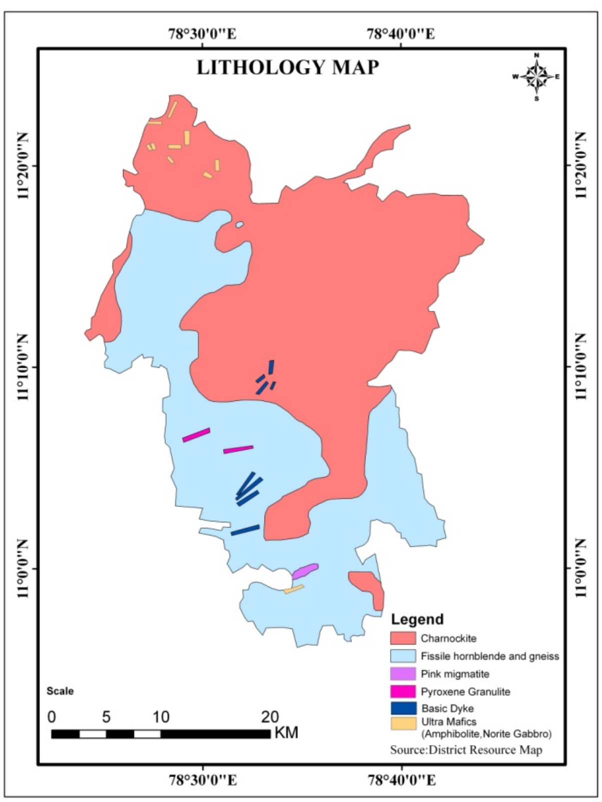

Fig. 4 — Lithology map

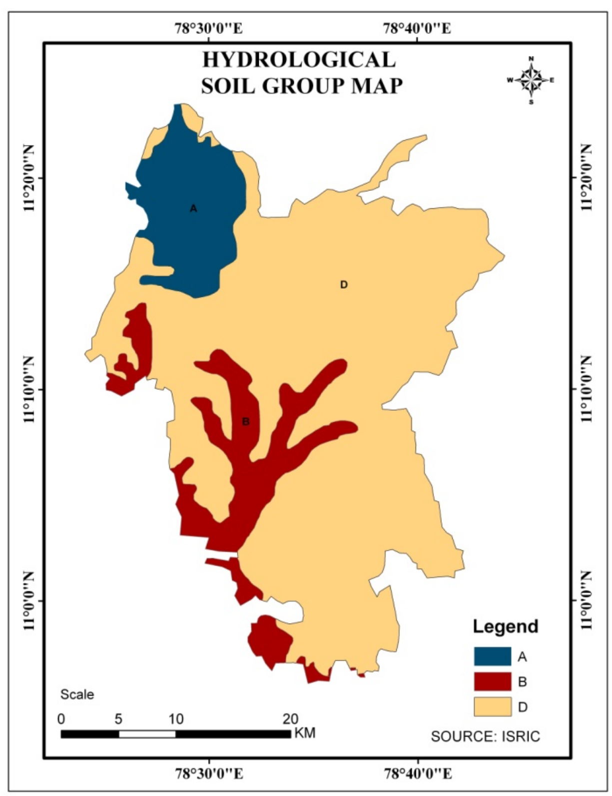

Fig. 5 — Hydrological soil group map

Structural hills are linear to arcuate hills it showing definite trend lineaments and they are associated with folding, faulting etc. it's occurred Archaean to lower Proterozoic period[29]. It's covered 154.95 sq.km study area. They generally refer to the hard rocks that are left behind after erosion that has occurred about 3.67sq.km of the area.

Any relative flat surface of bedrock (exposed or veneered with alluvial soil or gravel) that occurs at the base of a mountain or as a plain, which has no associated mountain. The general angle of a pediment's slope is 0.5° to 7° and it is found mainly at the base of hills in arid regions where rainfall is spasmodic and intense for brief periods of time. 23% area covered in pediment; there are three different types of pediments observed in the study area:

I) Shallow buried pediment 10.82 sq.km, II) moderately buried pediment 34.83sq.km and III) deep pediment has occurred 20.10 sq.km of the area.

Buried pediplain have been seen hill food of the study area that hasshallow buried pediplain 483.89 sq.km, moderately buried pediplain 145.52 sq.km. These regions exhibit smooth surfaces, possessing 0–8m thick weathered material covered with black soil. The groundwater prospects are poor to moderate, but moderate yields are expected along fractures/lineaments.

The landuse land cover of the study have been attempted in order to identify and map that various types of land use/land cover classes. The major propotion of the landuse is buildup land, crop land, fallow land, plantation, forest, scrub forest, land with scrub, land without scrub, attempted in order to identify and map that various types of land use/land cover classes (Figure10). To note that agricultural land and forest land allows more water to infiltrate than barren land[30]. In agriculture land water will be stored for agriculture practices thus acts as better recharge zones and hence a rank of 4 is assigned, likewise rank of 3 to the plantation, 2 for land with scrub, 1 for Forest built upland given and classified into four categories (Table-1).Around 43% of the total area is under cultivation and fallow land, 32% of the area have been forest and land with scrub land, remaining 25% respectively.

Rainfall is the another important parameter of artificial recharge consideration. In this study area had considered mean annual rainfall during the year of 2000 to 2013 using Theisson polygon calculation method (Fig.11).Particularly in the year of 2000 has

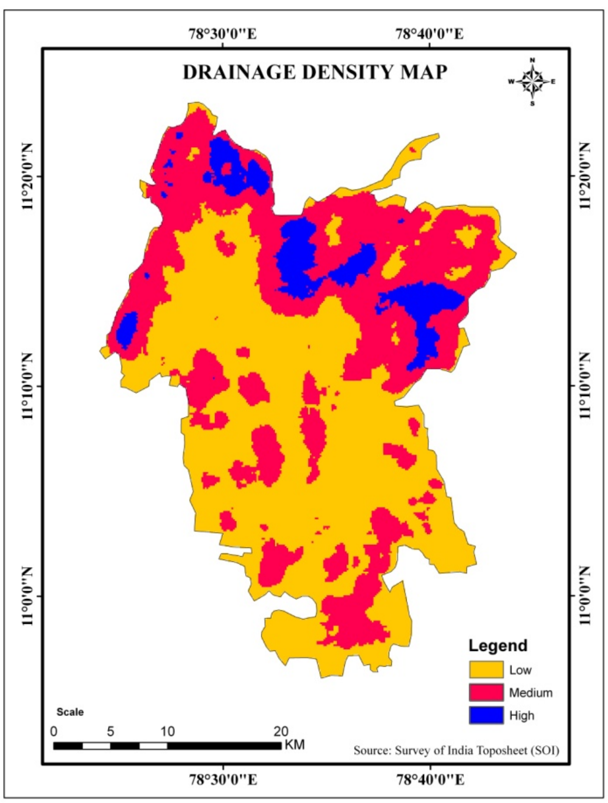

Fig. 6 — Drainage density map

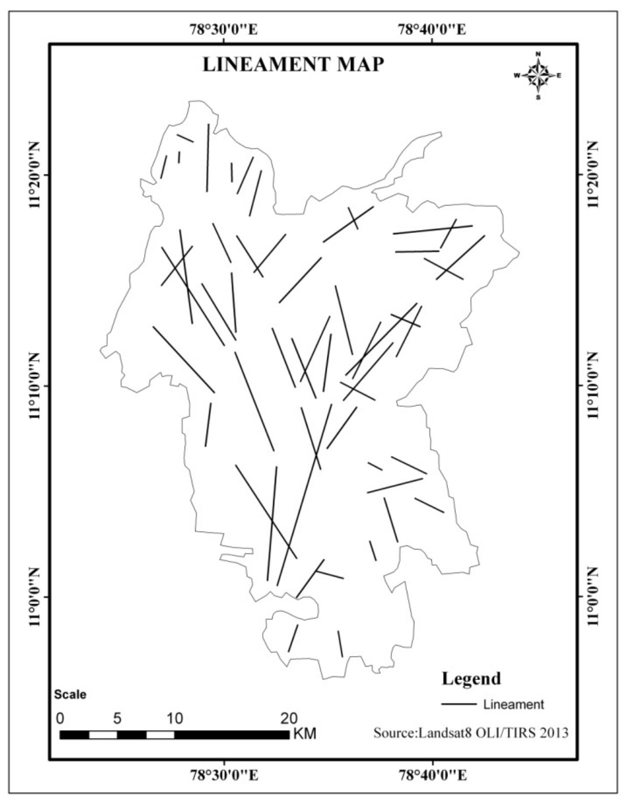

Fig. 7 — Lineament map

received maximum rainfall about 779mm it was occured in the hilly region and minimum annual rainfall 430mm was recevied in the central part of the study area The post and pre-monsoon water level fluctuation range from 3.5 m to 24 m(Figure 12) and 6.3 m to 31.9 m (Figure 13). The average pre and post-monsoon water level were 14.08 m and 10.36m.The maximum fluctuation in the water table as observed in the regions of Okkarai and Kurikkarankulam in the central and southern part of the study area.

After assigning the weightages of each theme is on overlaid by using the Arc GIS and gets the favorable zones for artificial recharge area delineated (Fig.14).

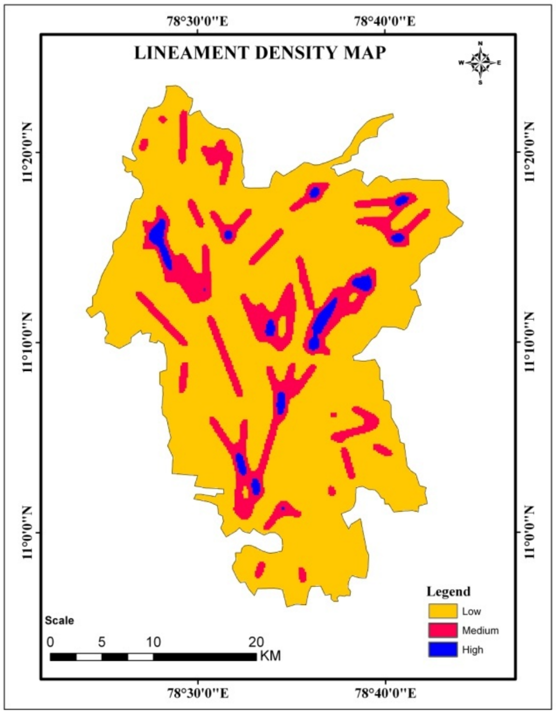

Fig. 8 — Lineament density map

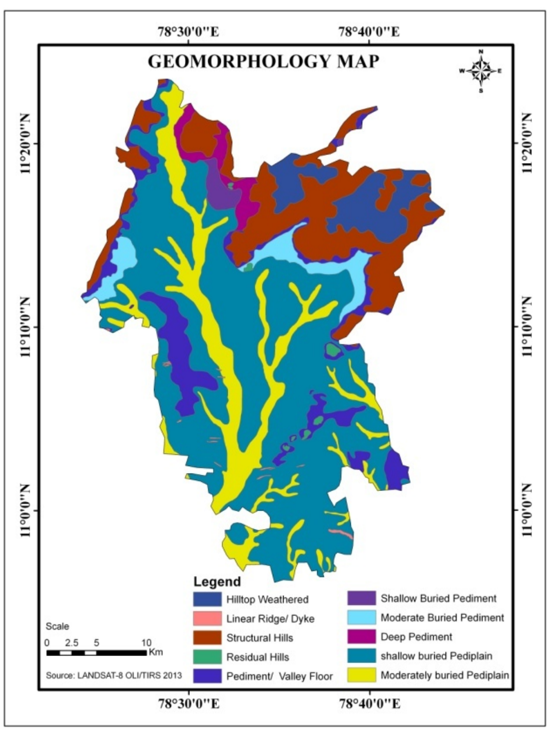

Fig. 9 — Geomorphology map

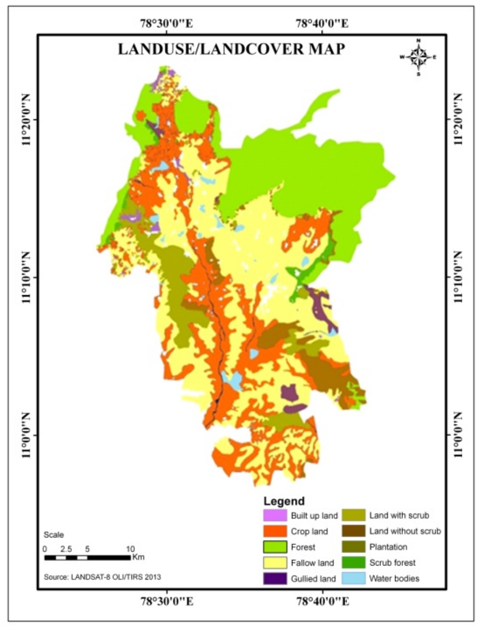

Fig. 10 — Landuse landcover map

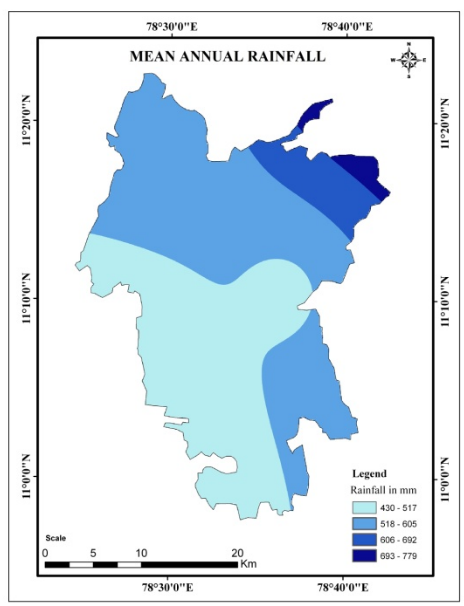

Fig. 11 — Rainfall map

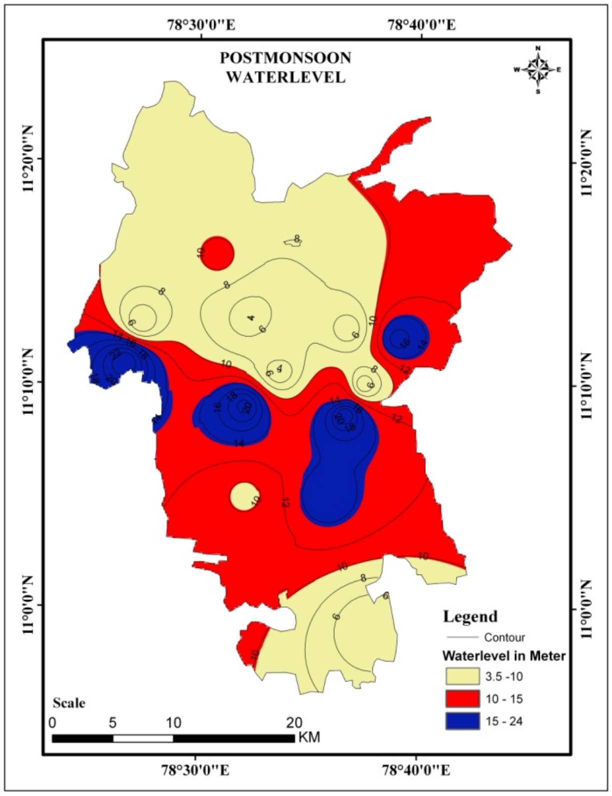

Fig. 12 — Post monsoon water level map

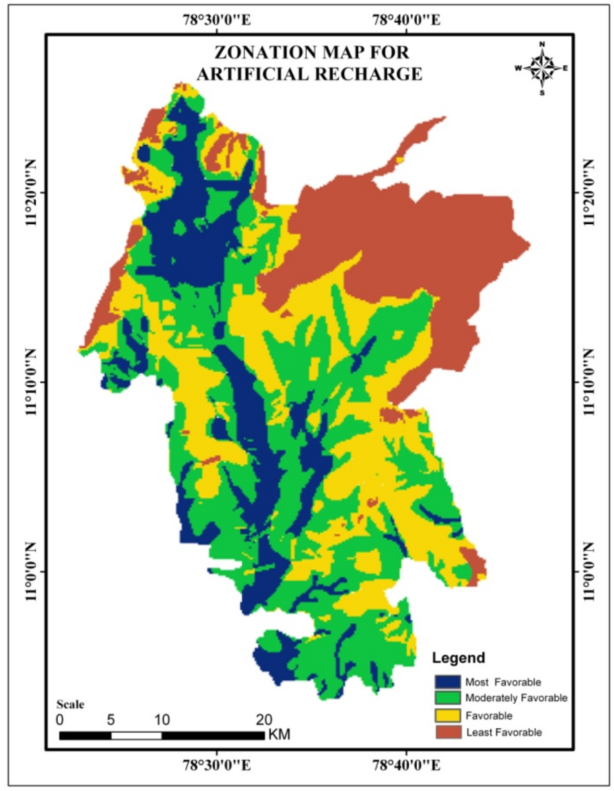

Fig. 14 — Artificial recharge zonation map

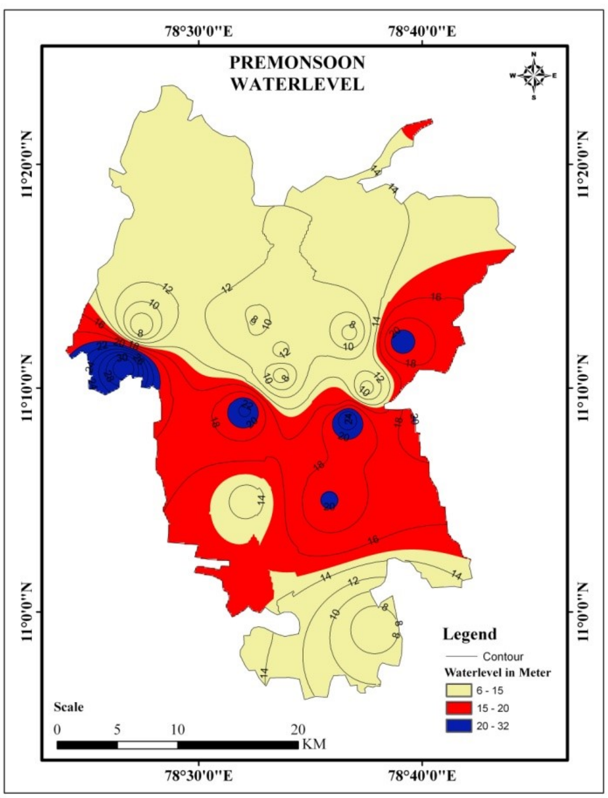

Fig. 13 — Pre monsoon water level map

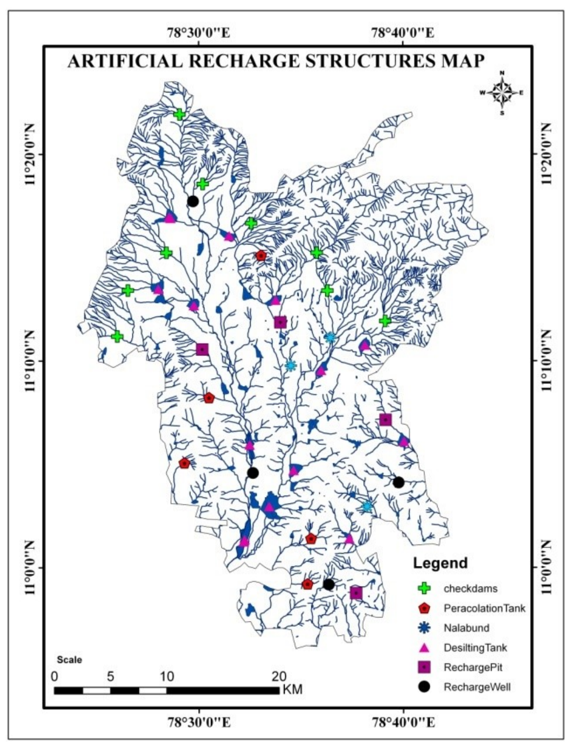

Fig. 15 — Artificial recharge structures map

Conclusion

Integrated all the thematic layers by using a GIS based model and get the zonation map. Thuraiyur talukis categorized into four different zones, namely ‘most favorable 20%’, ‘moderately favorable 22%’, ‘favorable 34%’ and ‘least favorable 24% ’. Drainage network map was superimposed above the artificial recharge zones map and taking into concern terrain conditions for construction of artificial recharge structures were suggested accordingly such as percolation tanks, check dams, nala band, recharge wells, de-silting of tanks and recharge pits (Figure15). Areas suggested for the construction of check dams on area having 1st to 4th order streams along the foot hill zones and 0-5% slops covered area in Koppamapuri, Alagpuri, Balaknishnampatti, Tenparainadu and Sengattupatti. Percolation tank suggested area having 1st to 3rd order streams located in the plain area and weathered zone / loose material / fractureswere occurred in Veramachanpatti, Valaiyeduppu and Manaparrai villages. The nalabund are recommended on the 1st to 4th order streams along the plains area in Venkatesapuram. Recharge pits are recommented in Eragudi, Kottathur and Kattukulam villages.

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