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Identification Of Artificial Recharge Sites For Noyyal Watershed Using GIS And Fuzzy Logic

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Abstract

This paper intents to identify the artificial recharge sites in the noyyal watershed, TamilNadu using GIS and remote sensing. Due to revolution in industries and various anthropogenic sources in the past decades, groundwater has been polluted and depleted around the study area. Continuous failure of monsoon, increasing demand and over exploitation leads to depletion of ground-water level. This problem could be sorted out to certain extent by artificially recharging the potential aquifers. So the various thematic maps have been used for the identification of artificial recharge sites by integrating geology, geomorphology, slope, drainage and lineament of the study area. The results indicate the five different zones, namely poor, moderate, moderate to good, good and very good zone. Based on the weighted overlay analysis it was found that moderate to good category occupies 83.53% of the study area. In order to determine the most suitable locations for artificial groundwater recharge sites in a minimum period of time a model was created in fuzzy logic using matlab was created. It is suggested that, proper rainwater harvesting and artificial recharge methods and measures should be implemented in the moderate to good potential zones to overcome the water scarcity problem in the study area.

Key Words: Noyyal watershed, Weighted Overlay Analyses, GIS, Groundwater, Artificial Recharge Sites, Lineament Density, Drainage Density, Geology, Geomorphology, Land Use/Landcover.

Introduction

Water, one of the most essential materials in our day-to-day life is becoming scarce in rural as well as in urban areas mainly due to reduction in infiltration rate as a result of deforestation in rural areas and large scale paving of the surface in urban areas. In India, though a huge quantity of surface water is available, the topography and other factors limit the storage of this water (Elango and Mohan 1997). Where the surface water is scarce, the alternative source is groundwater assumes importance in the context of water supply. Due to over-exploitation of groundwater, the groundwater levels in many areas show a declining trend, which in turn tends to increase both the investment cost and the operational cost (Jothiprakash et al 2003). This problem could be sorted out to certain extent by artificially recharging the potential aquifers. Artificial groundwater recharge is becoming increasingly necessary as growing population require more water and as more stores is needed to save water in times of surplus for use in time of shortage. Artificial groundwater recharge and rainwater harvesting have emerged as two basic tools for the sustainable management of vital freshwater resources (both groundwater and surface water). Several studies have been carried out for the determination of areas most suitable for artificial recharge (Krishnamurthy and Srinivas, 1995; Krishnamurthy et al., 1996 and Saraf and Choudhury, 1998). An overview of artificial recharge is given by Bouwer (2002), who points out the major factors to be considered a varying number of thematic layers, such as geology, geomorphology, drainage density, slope, aquifer transmissivity, water table fluctuations or depth to groundwater level, lineament density, etc. A set of weights for the different themes and their individual features were decided based on personal judgments considering their relative importance from the artificial recharge view point. These thematic maps were then integrated in a GIS framework to identify suitable zones for artificial recharge. A few researchers have also attempted to select suitable sites for artificial recharge as well as to suggest salient recharge structures (Saraf and Choudhury 1998; Ravi Shankar and Mohan 2005). Furthermore, the use of remote sensing is indispensable due to requirement of updated data (Mahdavi et al. 2010)In this research, site selection for artificial recharge is considered in Noyyal watershed.

Study Area

The Noyyal watershed is one of the major tributaries of the river Cauvery, which originates from the hills of Vellingiri, also termed as southern Kailayam in Western ghats and flows towards the southwest of Coimbatore district in Tamil Nadu, and finally it ends in river Cauvery at Kodumudi in Karur district. During its course Noyyal watershed flows through Coimbatore, Tiruppur, Erode and Karur districts with its catchments in seven Taluks (Coimbatore, Tiruppur, Avinashi, Palladam, Dharapuram, Erode and Karur) (Environmetal cell Division, PWD,2001). It flows over a length of about 180 Kms covering an area of 3510 km^2. The boundary of the river Noyyal is between north latitude 10° 54’ 00” to 11° 19’ 03” and east longitude 76° 39’ 30” to 77° 55’ 25 ” which is shown in Fig. 1.

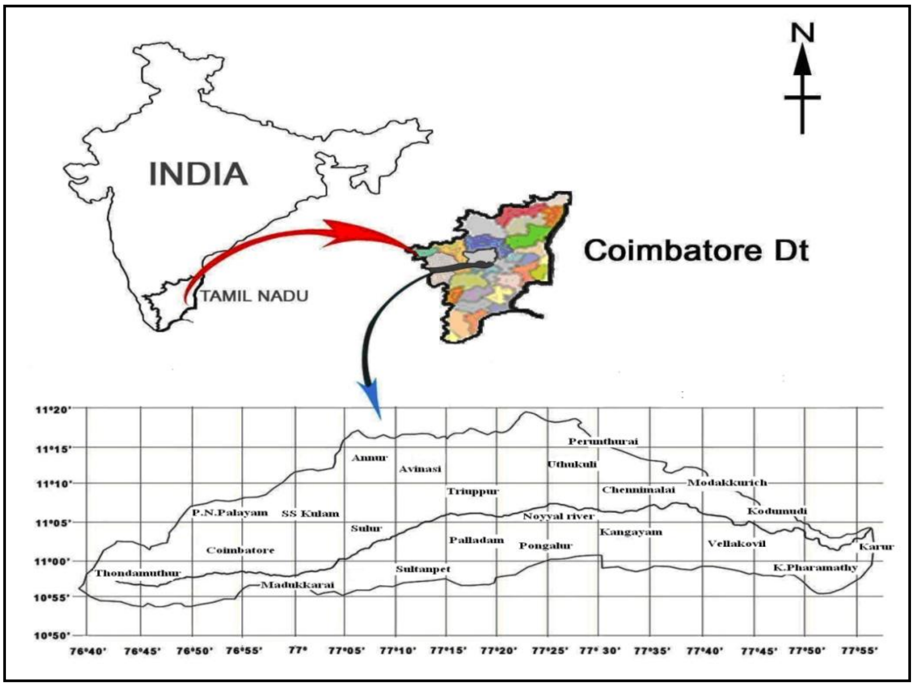

Figure 1 Key Plan Showing the Study Area Details

Watershed Noyyal was perennial with good flow till early seventies. In recent years, the scene has changed drastically and the river has become practically seasonal. River Noyyal receives copious water during northeast monsoon from September to November. The rest of the year it remains more or less dry. While the surface water resources in the area are inadequate to meet the local needs and the groundwater resources are also not properly explored. This problem can be alleviated to some extent by artificially recharging the potential aquifers. The type of soil that occur in river Noyyal are many and varied, ranging from shallow red non-calcareous soils to very deep grey calcareous ones. A standard reconnaissance soil survey of Coimbatore district reveals the occurrence of 14 different soil series and their associations in Noyyal watershed. These 14 series can be broadly classified into five categories: red soil, grey soil, alluvial soil, colluvial soil and forest soil (Soil Survey and Land Use Organization, 2002). The river Noyyal is covered by a wide range of high grade metamorphic rocks of peninsular gneissic complex. These rocks are extensively weathered and overlain by recent fills and alluvial at places. The major rock types existing in the watershed are basic rock, charnockite, complex gneiss, pink granite, pink granite and gneiss, unclassified gneiss and valley fill (Soil Survey and Land Use Organization, 2002)

The Noyyal watershed is a major source for irrigation, drinking and other activities of the people who are living on both sides of the river and even for the people living beyond 3 kms from the river. The average rainfall in the watershed is about 700 mm. The river Noyyal flows from west to east and its maximum elevation is around 1600 m above mean sea level and the minimum elevation is 100m above mean sea level (Environmental cell Division, PWD,2001). It is also believed that water contains natural medicine which is good for health. The river Noyyal is a seasonal river which has good flow only for short period during the northeast and southwest monsoons. Occasionally flash floods occur when there is heavy rain in the catchment areas. Apart from these periods, there is only scanty flow in most part of the year. Floods are common during the rainy season due to the steep slopes in the upper part of the catchment (Sankaraaj et al 2002). Nearly 6,000 acres of cultivable land in Coimbatore district is irrigated by using river Noyyal (Environmental cell Division, PWD,2001). The groundwater recharge in river Noyyal is due to monsoon and non monsoon rains, seepage due to wet cultivation, seepage from water bodies such as tanks, anaicuts, canals and reservoirs. Water available for recharging the groundwater has become very low in some areas. Past records show that the depth of water levels in ayacut lands on an average varied between 3 to 20 m below ground level (bgl). In non- ayacut areas, depth of the well varies from 27 to 42 m bgl. Currently the water depth in non ayacut areas has reached even up to 165 m bgl (Environmental cell Division, PWD,2001). The groundwater table considerably goes down due to indiscriminately sinking deep bore wells and poor recharge due to scanty rain and the absence of many surface water bodies.

Methodology

In order to delineate artificial recharge zones in the study area, a multi-parametric dataset comprising satellite data and other conventional maps including SOI toposheets were used. The base map of the study area was created by using SOI toposheets bearing no 58A/12, 58A/16, 58B/9, 58B/13, 58E/3, 58E/4, 58E/7, 58E/8, 58E/12, 58E/16, 58F/1, 58F/5, 58F/9, 58F/13 in 1:50,000 scale. Land-use/landcover map was developed from the satellite images by using supervised classification according to National Remote Sensing Agency (NRSA) classification using Erdas imagine 8.4 software for the year 2010. The geomorphology, soil, geology and lineament density were prepared. After preparing all the thematic layers, different features/classes of the individual themes were identified, which were then assigned weights according to their relative importance towards groundwater recharge in the study area. By above mention methods seven thematic layers, viz., Geology, Lineament density, Land use /land cover, Geomorphology, Soil, Drainage density and Slope, were considered for the delineation of artificial recharge zones. Thematic layers for these parameters were prepared, classified, weighted and integrated by weighted overlay analysis. In order to determine the most suitable locations for artificial groundwater recharge sites in a minimum period of time a model was created using fuzzy logic.The methodology for identifying the artificial recharge is shown in Fig. 2

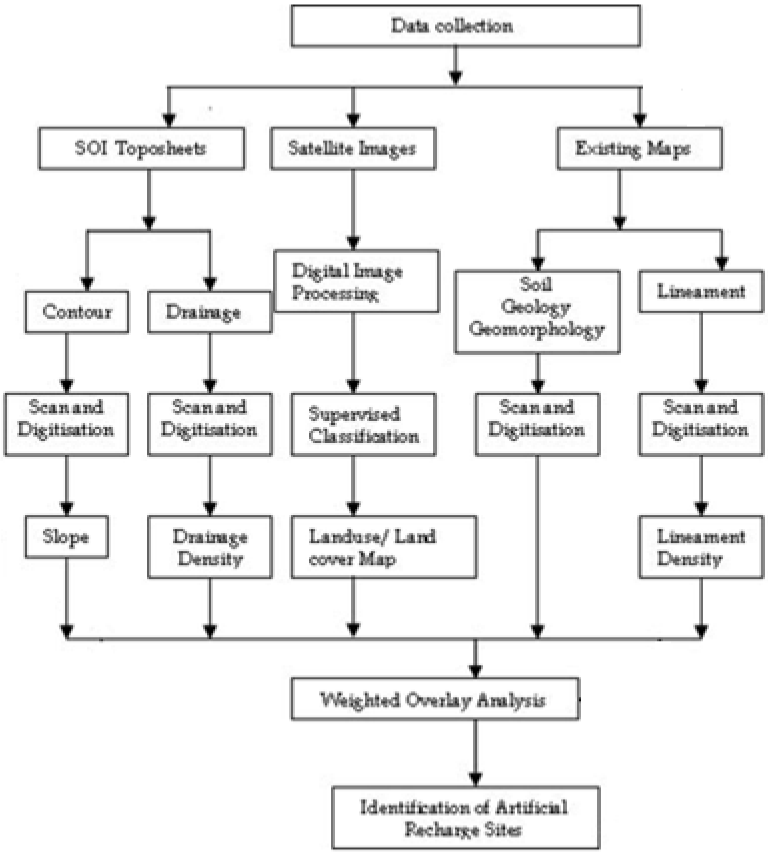

Figure 2 Methodology for Identifying the Artificial Recharge Site

Drainage

Drainage pattern reflects the characteristics of surface as well as subsurface formation. It is one of the most important indicators of hydrogeological features, because drainage pattern, texture and density are controlled in a fundamental way by the underlying lithology(Erhan Sener et.al 2005). The drainage density map was developed which was based on the entire drainage pattern and it is divided into square grids of 1 sq.km and the total lengths of all streams in each grid were calculated in order to determine the drainage density values in km/km^2 which is shown in Fig. 3. The study area is mostly covered with dendritic drainage pattern having a fine drainage density in the western part of the watershed, medium at the center and coarse drainage density is on the eastern side of the watershed. These values were regrouped to produce a drainage density map that was classified into five categories, i.e.,very good (2.2-1.43), good (1.43–1), moderate to good (1–0.6) , moderate(0.6-0.31) and poor(<0.31) in km/km^2.

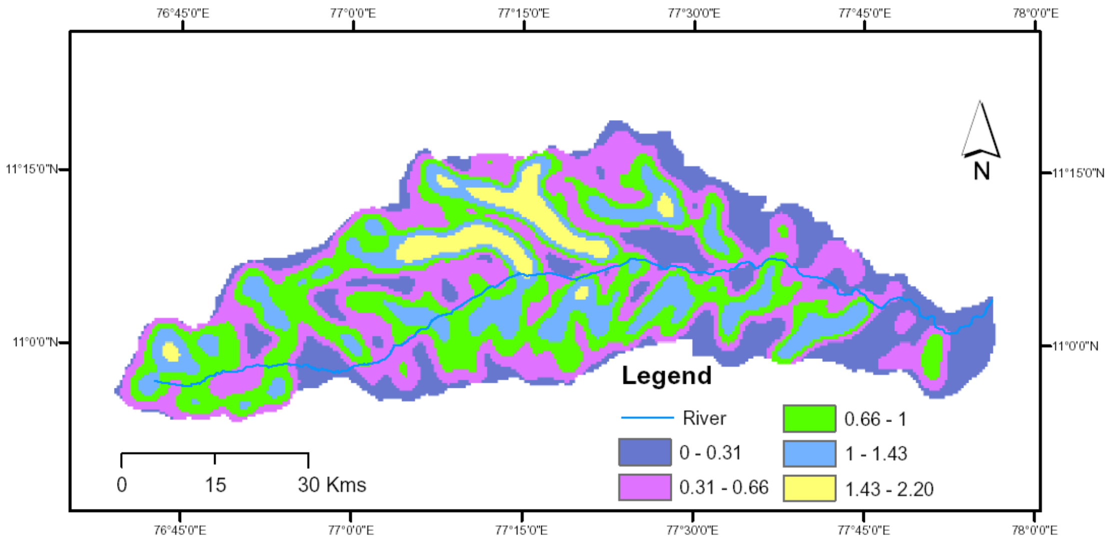

Figure 3 Drainage Density Map of the Study Area in km/km^2

Lineament

Lineaments provide pathways for groundwater movement and are hydrogeologically very important (Sankar et al 1996). In hard rock terrain lineaments and fractures act as master conduits in movement and storage of groundwater (Ramasamy, et.al. 2005, Subash Chandra, et.al., 2010). If lineament density is high then higher will be the rate of infiltration whereas low density leads to more runoff (Kumar, et al., 1999). There are 28 lineaments found in the study area which is shown in Fig.4. The length of the lineaments extended from few kilometers to several kilometers and the majority are oriented in northeast to southwest direction. The lineaments are predominant in Palladam and Sulur, trending in the directions of northwest to southeast and north to south. A few of them are oriented in eastwest and northwest to southeast direction also. On the basis of artificial recharge they were regrouped into five classes as very high(3.10 - 2.40), high(2.40-1.80), moderate (1.80 – 1.20), low (1.20 – 0.60) and very low (0.60 – 0.00) in km/km^2.

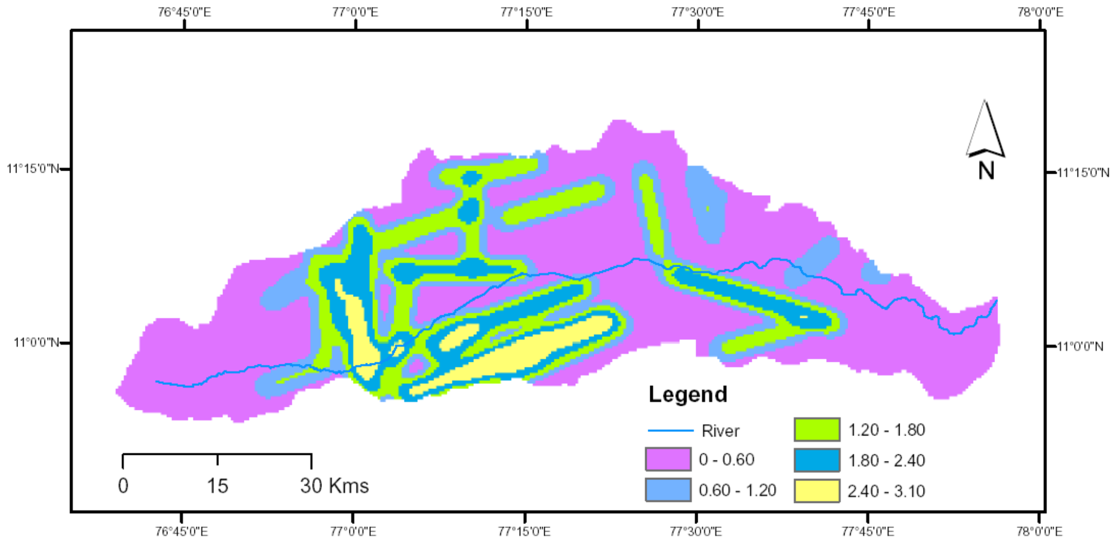

Figure 4. Lineament density Map of the Study Area in km/km^2

Soil

Soil characteristics of a terrain are the most important aspect, since it plays a major role in groundwater recharge and meets the basic needs for all the agricultural products. There are seven types of soil series in the study area based on the soil characteristics. They are alluvial soil, brown soil, black soil, colluvial and alluvial soil, red calcareous soil, red non calcareous soil and thin red soil which are shown in Fig. 5.

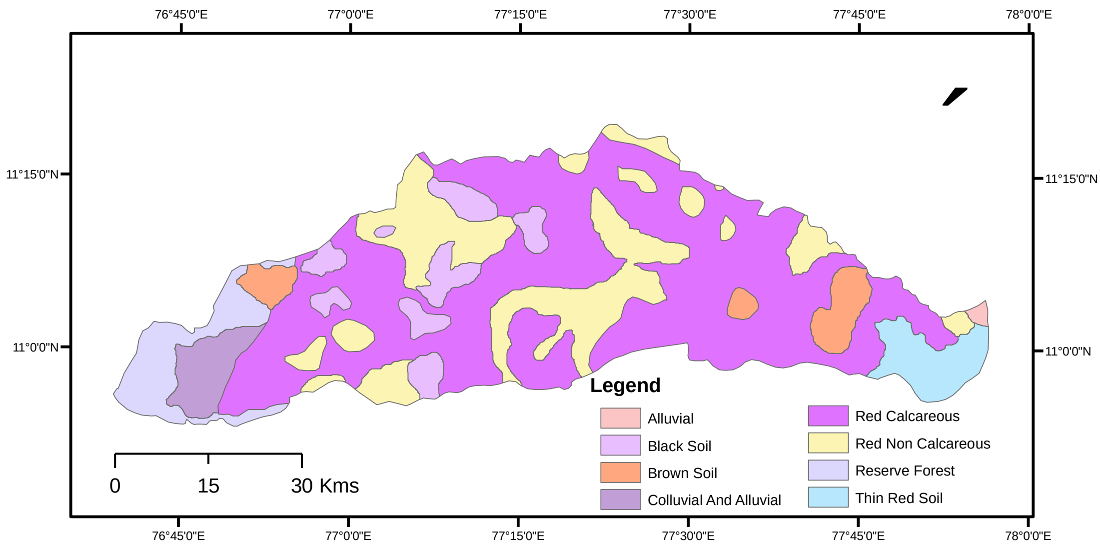

Figure 5 Soil Map of the Study Area

The entire watershed is mainly covered with red calcareous soil which is having medium to high infiltration rate. Alluvial soil is found in the western part of the basin which is having low to medium infiltration rate. A few patches of brown soil are observed on the western and eastern portion of the basin which is having a high infiltration rate. Black soil is found in western, southern and northern portion of the basin which is having low infiltration rate. Colluvial and alluvial soil is found only in Thondamuthur block on the western side of the watershed which is having low to medium infiltration rate. Red non calcareous soil is found in the center part of the basin. Thin red soil is found only in K. Paramathy block in eastern and southeastern side of the watershed which having high infiltration rate.

Geology

Groundwater occurs in geological formations. The ability of the parent rock to store and transport groundwater is of great importance for its occurrence. Different rock types possess different abilities to store and transport water depending upon their texture, structure and mineral content. The major rock types existing in the watershed are basic rock, charnockite, complex gneiss, pink granite, pink granite and gneiss, unclassified gneiss and valley fill which is shown in Fig. 6.

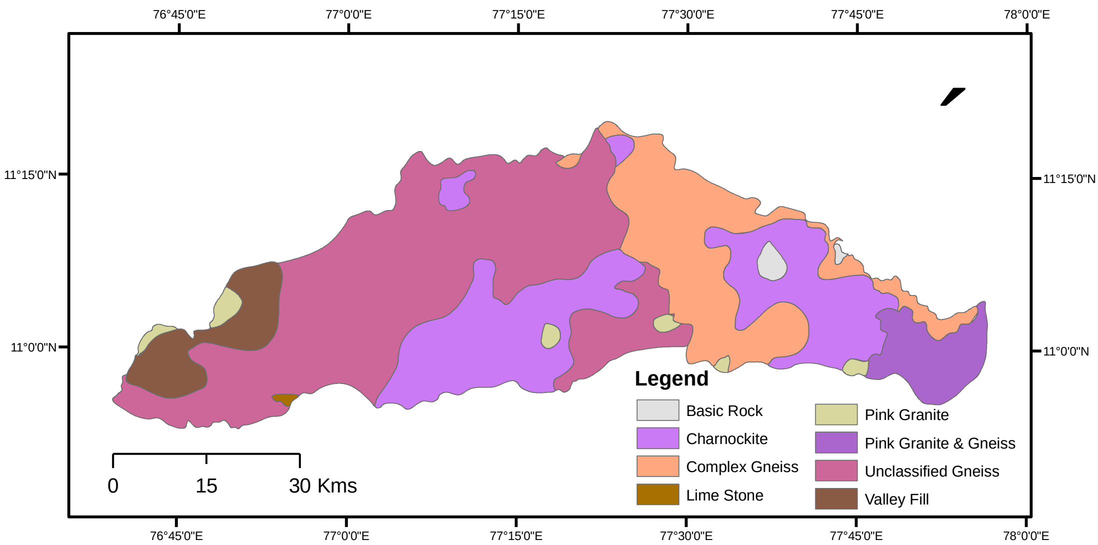

Figure 6 Geology Map of the Study Are

The river Noyyal is predominantly covered by unclassified gneiss which is maximum in the center part of the basin. Charnockite, is found in the south and southeast part of the study area. Basic rock is found in a few patches of Chennimalai and Modakurichi block in the eastern side of the study area. Formation of complex gneiss is mainly found in the downstream (eastern) side of the study area. Pink granite is found in few patches on south, southeast and western, southwestern side of the study area. Pink granite and gneiss is found only in K. Paramathy block in the eastern and southeastern side of the study area. Valley fill is found only at western part of the study area in Thondamuthur and PN Palayam block.

Geomorphology

Geomorphology reflects various landform and structural features. Many of these features are favourable for the occurrence of groundwater and are classified in terms of groundwater potentiality(Prasad et.al 2007). Geomorphology map helps to identify the various geomorphic units and groundwater occurrence in each unit. The various geomorphic units in the study area are structural hill, shallow pediment, duri crust, shallow buried pediment, denudational hills, deep pediment, valley fill, pediment, flood plain, composite slope and palaeo sand dune which is shown in Fig. 7.

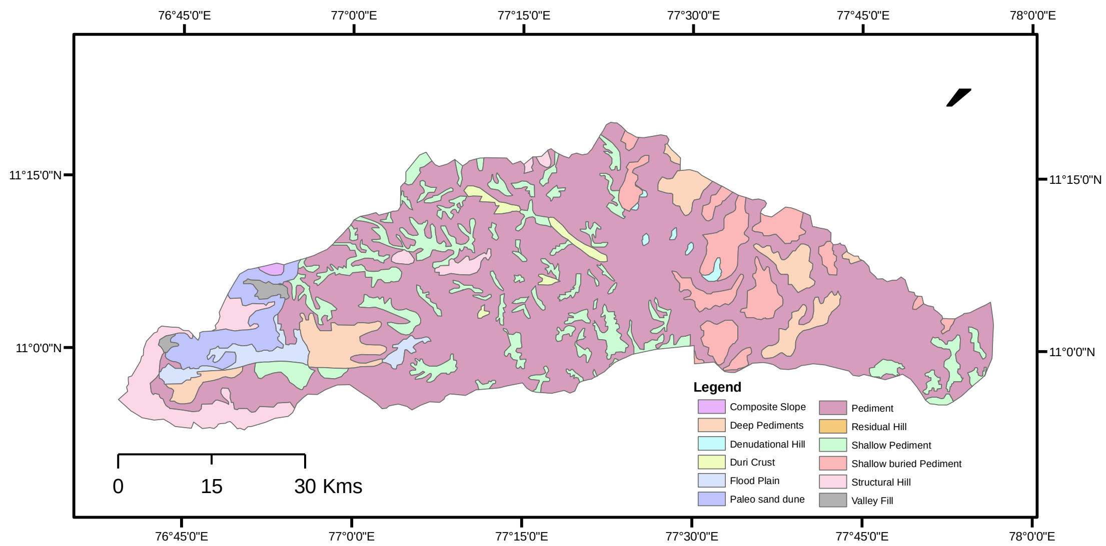

Figure 7 Geomorphology Map of the Study Area

Most of the area is covered by pediment, which makes artificial recharge to be poor due to runoff. The deep pediments are found adjoining the river courses and it is shallow, depressed low relief area with good drainage networks, deep weathering with shallow soil cover and fracturing. The infiltration of deep pediments is moderate to good since the storage is complemented by secondary fractures. The residual hill is found in the western part of the study area. The western side of the study area is bordered by structural hills of western ghat ranges and it comprises composite ridges and valleys traversed by structural features. The hydrological characteristic of structural hills is found to be poor due to runoff and low infiltration through secondary fractures. Valley fill is found in Thondamuthur and Sarkar Samakulam blocks and it is also found in the low lying valleys in the vicinity of hills. The hydrological characteristic of valley fill has a highly permeable and good infiltration condition, so the artificial recharge in that area is good. Denudational hill is found in few patches of Chennimalai and Uthukuli blocks in north and northeastern side of the basin. The artificial recharge for the Denudational hill is poor due to runoff. Duri crust is found in few patches in the northern side of Tiruppur, Palladam and Avinasi blocks in the study area and it is poor in artificial recharge due to runoff. Flood plain is found in the southwest, northeast, east, southeast of the study area and it has a gentle plain adjacent to the river and comprises of river alluvium, so it has a high infiltration and recharge mainly from river and has a good groundwater potential. Shallow pediment is an intermediate zone between pediments and deep pediments which is seen scattered in the center part and lower eastern part of the study area. The rate of infiltration and recharge is moderate which is mainly influenced by runoff. Palaeo sand dune is found in the western side of Thondamuthur and PN Palayam blocks of the study area. Composite slope is found in PN Palayam block of study area in the western side of the basin. It is formed by the weathered debris from structural hills.

Slope

Slope is also a crucial parameter for occurrence and recharging conditions of groundwater in a particular area.The slope is measured in degrees (Dawoud et al., 2005; Vittala et al., 2005; Solomon and Quiel, 2006). Generaly slope track is in the SW -NE direction of the study area. Steeper the slope, greater will be the runoff and thus, lesser is the groundwater recharge.Using contour information from the topographical map for estimation of slope in degrees. The various slope classes and their spatial distribution map is shown in Fig. 8. In the study area, slope varies from 0° to more than 81°. The entire slope map is divided into five categories as follows

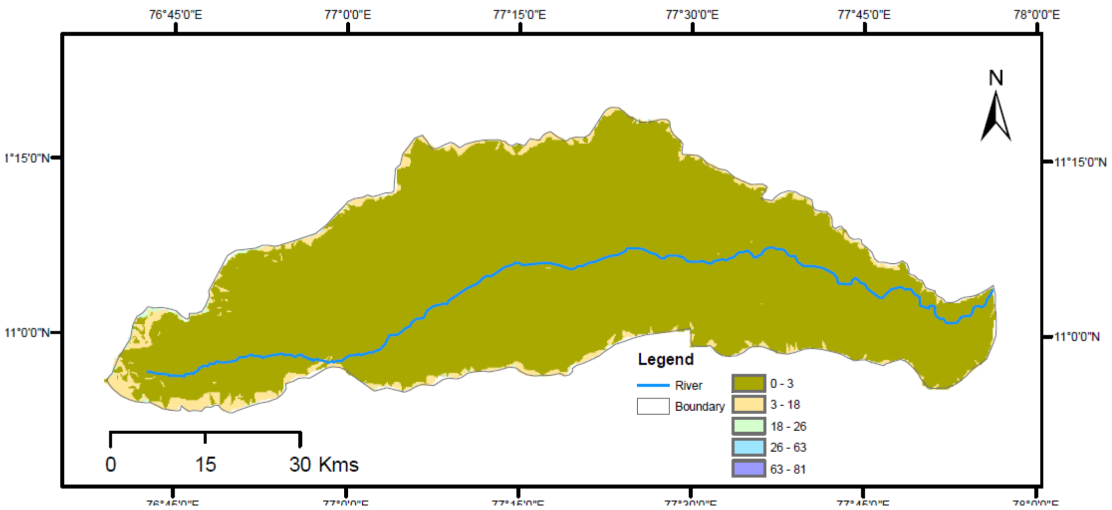

Figure 8- Slope Map of the Study Area

The five classes in the study area are nearly level to gentle slope (0 – 3°), moderate slope (3 – 18°), moderate to steep slope (18 – 26°), steep slope (26 – 63°) and very steep slope (63 – 81°). Major part of the study area falls under nearly level to gentle slope class (0 – 3°).

Land Use /Land Cover

Land is a prime natural resource and the mapping of land use/land cover is essential for planning and development of land and water resources (Srivastava et al 2006). Land use/land cover change detection mapping of the study area has been done by using software ERDAS Imagine 8.4 from IRS LISS III data. The classification system was based on the NRSA classification system using supervised classification.

The ten major levels of land use/land cover categories were interpreted in the imageries of the study area and it is shown in Fig. 9. They are built up land, fallow land, land with scrub, land without scrub, water bodies, agriculture land, dense forest, scrub forest, forest blank, open forest.

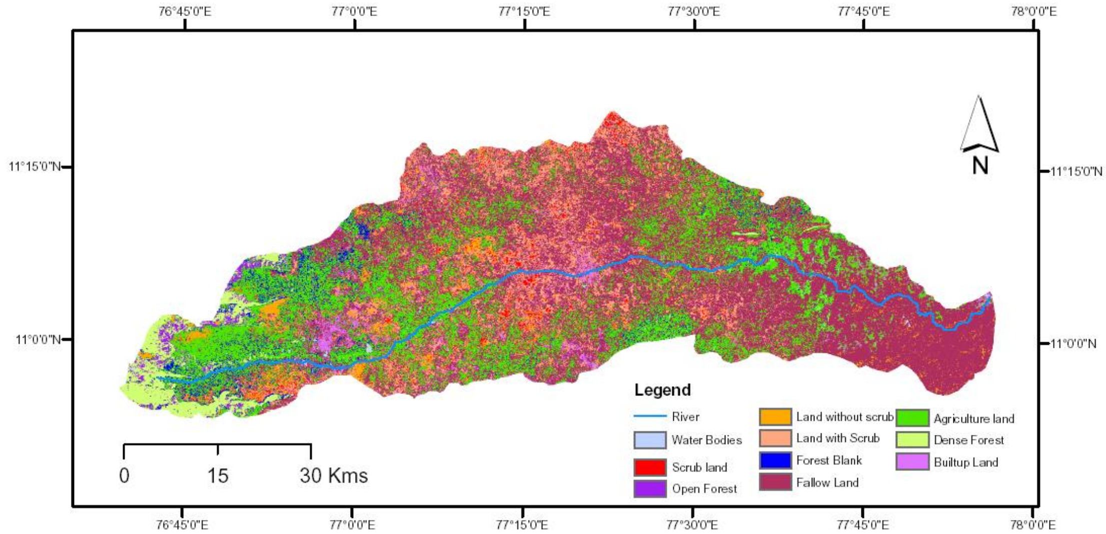

Figure 9 Land use Classification

Overview of the Fuzzy Logic System

Fuzzy Logic (FL) system provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy or missing input information. The FL model is empirically based, relying on an operator's experience rather than their technical understanding of the system. In the FL method, any reasonable number of inputs can be processed and numerous outputs will be generated. The fuzzy inference system can take either fuzzy inputs or crisp inputs, but the outputs it produces are almost always fuzzy sets. Sometimes it is necessary to have a crisp output, especially in a situation where a fuzzy inference system is used as a controller. Therefore, a method of defuzzification is needed to extract a crisp value that best represents a fuzzy set. A flow system in fuzzy logic shown in Figure 10.

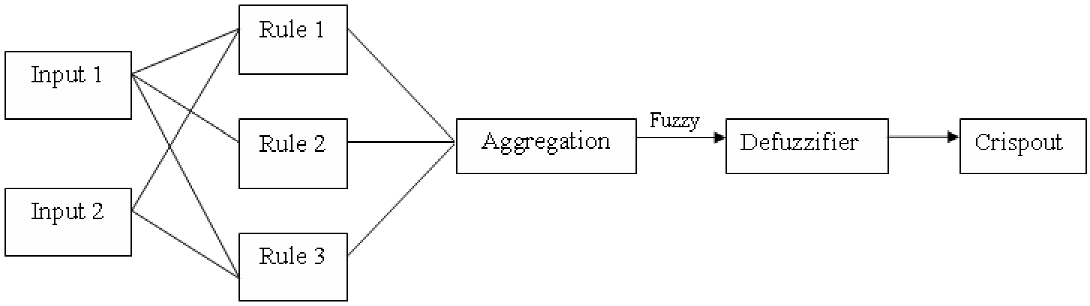

Figure 10 Flow System in Fuzzy Logic

Fuzzy Logic Model for Identifying Artificial Recharge Sites

Fuzzy logic provides a different way to solve a problem. The fuzzy logic system handles about numerical data and linguistic knowledge simultaneously. That is variable whose values are not number but words or sentences in a natural or artificial language.

The increasing complexity of the nature in the study area is due to the discharge of untreated industrial effluents in the river basin makes the human based decision an approximate one based on the available data. Generally, a perfect decision making system is required to find the suitability of a particular location for artificial recharge. Fuzzy is an easy and convenient way to relate the input parameter to the output parameter. A fuzzy logic gives a straight forward answer for a question such as yes or no which is a Boolean logic. So a fuzzy based model was created for the study area to locate the suitability for artificial recharge.

In this model Multiple Input/ Single Output (MISO) approach was used. The input was selected based on the parameters influence on artificial recharge site selection. Multiple rules were framed based on 7 input parameters.

The process involved in the fuzzy model is of five steps:

- Fuzzification of the input variables
- Application of the fuzzy operator (AND or OR) in the antecedent
- Implication from the antecedent to the consequent
- Aggregation of the consequents across the rules
- Defuzzification

The input factors of the model will be lithology, lineament density, land use/land cover, geomorphology, soil, drainage density, slope, rainfall and water level of a particular location. Based on the input parameters and the model will suggest the suitability of artificial recharge sites for that particular location. The model consists of four modules. In the first module the input parameters were soil and geology. In the second module the input parameters were geomorphology and lineament density. In the third module the input parameters were drainage density and slope. In the fourth module the input parameters were land use/land cover, annual rainfall and groundwater level and Figure 11 shows the input parameter of the model.

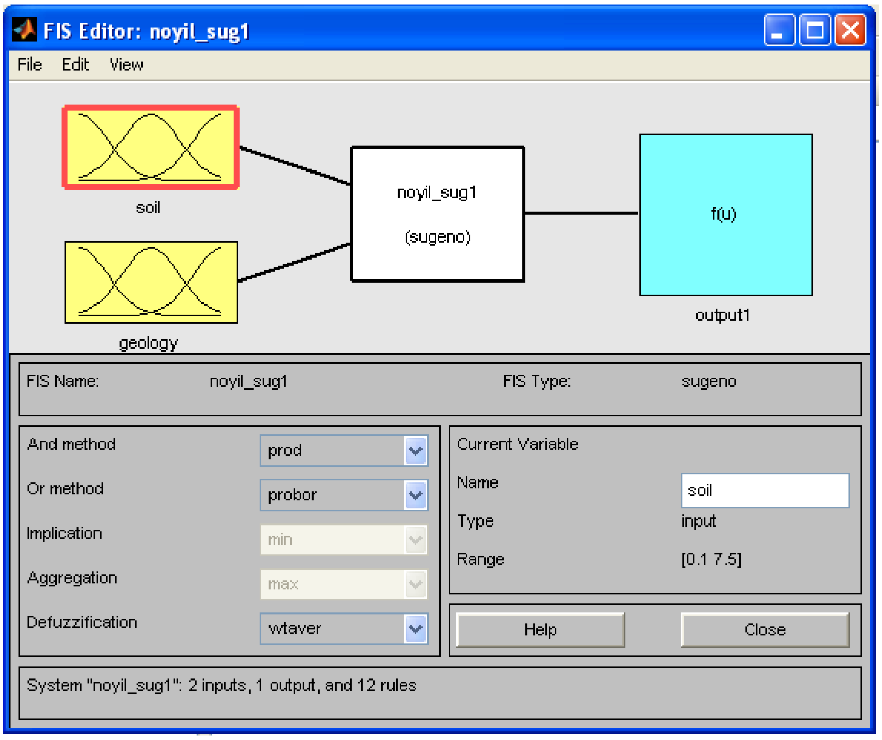

Figure 11 Input for Matlab

Interrelationships Between the Factors of the artificial recharge zones
The occurrence and movement of groundwater in an area are controlled by various factors. The influence of all factors need not be the same in the area. Therefore, each parameter is assigned a weightage depending on its influence on the movement and storage of groundwater. In order to estimate the weights of the involved factors, the effect of these factors on each other must must be calculated. The weightage for the major relationship between two thematic layers was assigned as 1 and the weightage for the minor relationship between two thematic layers was assigned as 0.5. Finally the total weight of each factor was the representing weight of the recharge potential. The weightage for artificial recharge is given in Table 1.

Table 1 Weight Influence for Identifying Artificial Recharge Sites

S.No	Factors	Weightage
1	Geology	4.0
2	Lineament density	3.0
3.	Land use /land cover	3.5
4	Geomorphology	5.0
5	Soil	3.0
6	Drainage density	3.5
7	Slope	3.0

The Normalised Weights were assisigned to various thematic layers using Analytic Hierarchy Process which include geology, geomorphology, lineament density, land use/land cover, soil, drainage density and slope provides certain clue for the occurrence of groundwater. The pairwise comparison for the seven layers were given based on the comparison between the layers and their relative importance towards groundwater prospects and a 7×7 matrix was formed. Based on the comparison matrix the following steps were carried out to calculate the normalized weight. In step 1 each thematic layer of the column were divided by their corresponding sum of the row to form the relative weight matrix. In step 2 the geometric mean was obtained by averaging across the rows and normalized weight was obtained by dividing each geometric mean thematic map with sum of geometric mean is shown in Table 2.

Table 2 Pair-Wise Comparsion Matrix for the Seven Themes and Calculation of Normalised Weights by the Analytic Hierarchy Process

Theme	Theme							Geometric Mean	Normalised weight
	GG	LD	LU/LC	GM	Soil	DD	Slope		
GG	4/4	4/3	4/3.5	4/5	4/3	4/3.5	4/3	1.16	0.16
LD	3/4	3/3	3/3.5	3/5	3/3	3/3.5	¾	0.87	0.12
LU /LC	3.5/4	3.5/3	3.5/3.5	3.5/5	3.5/3	3.5/3.5	3.5/4	1.01	0.14
GM	5/4	5/3	5/3.5	5/5	5/3	5/3.5	5/4	1.44	0.20
Soil	3/4	3/3	3/3.5	3/5	3/3	3/3.5	¾	0.87	0.12
DD	3.5/4	3.5/3	3.5/3.5	3.5/5	3.5/3	3.5/3.5	3.5/4	1.01	0.14
Slope	3/4	3/3	3/3.5	3/5	3/3	3/3.5	¾	0.87	0.12
								7.22	1.00

In the present study, each parameter was assigned a rank which was depending on its influence on the storage and movement of groundwater. The parameter has been categorized into five zones from the artificial recharge point of view. The different parameters in each factor were assigned knowledge which was based on relative importance of artificial recharge from 1 to 5 on the basis of their significance with reference to their influence on identification of artificial recharge zones. In this ranking 1 denotes poor favourable zone, 2 denotes moderate favourable zone, 3 denotes moderate to good zone, 4 denotes good zone and 5 denotes very good zone for identification of artificial recharge zones and artificial recharge sites. The normalized weight for each parameter in each factor was assigned depending upon the geometric mean of each factor. The rank and normalized weight for artificial recharge using GIS and fuzzy logic is given in Tables 3.

Table 3 Rank of Parameters for Identifying Artificial Recharge Sites

S. No	Factors	Parameters	Rank	Normalized Weight
1	Soil	Alluvial Soil	5	0.22
		Colluvial & Alluvial	5	0.22
		Brown Soil	2	0.09
		Red Calcareous	4	0.17
		Black Soil	1	0.04
		Red Non Calcareous	2	0.09
		Thin red Soil	4	0.17
2	Geology	Unclassified Gneiss	4	0.16
		Lime Stone	4	0.16
		Charnokite	2	0.08
		Pink Granite	1	0.04
		Pink Granite & Gneiss	4	0.16
		Basic Rock	5	0.20
		Complex Gneiss	1	0.04
		Valley Fill	4	0.16
3	Geomorphology	Paleo sand dune	5	0.20
		Shallow pediment	2	0.08
		Duri crust	1	0.04
		Shallow buried pediment	2	0.08
		Residual hill	1	0.04
		Denudational hills	1	0.04
		Deep pediment	4	0.16
		Valley fill	4	0.16
		Pediment	1	0.04
		Flood plain	5	0.12
		Composite slope	1	0.04
4	Lineament Density km/km^2	0 - 0.60	1	0.07
		0.60 - 1.20	2	0.13
		1.20 - 1.80	3	0.20
		1.80 - 2.40	4	0.27
		2.40 - 3.10	5	0.33
5	Drainage Density km/km^2	0 – 0.31	5	0.33
		0.31 – 0.66	4	0.27
		0.66 – 1.0	3	0.20
		1.0 – 1.432	2	0.13
		1.43 – 2.20	1	0.04
6	Slope Gradient in degree	0 – 1	4	0.27
		1 -3	5	0.33
		3 -7	3	0.20
		7 -15	2	0.13
		>15	1	0.04

7	Land use /Land cover	Crop land	4	0.17
		Fallow land	4	0.17
		Scrub forest	3	0.13
		Built up land	NA	-
		Water bodies	NA	-
		Land with scrub	3	0.13
		Land without scrub	4	0.17
		Forest blank	1	0.04

Framing of Rules

The rules were framed to identify the artificial recharge sites in the study area by using four modules. In first module there are four classes(less, moderate, good and very good) in soil and four classes (less, moderate, good and very good) in geology. So total of sixteen rules were framed in rule editor. In second module there are four classes (less, moderate, moderate to good and good) in geomorphology and five classes (less, moderate, moderate to good, good and very good) in lineament density. So total of twenty rules were framed in rule editor. In third module there are five classes (less, moderate, moderate to good, good and very good) in drainage density and five classes (less, moderate, moderate to good, good and very good) in slope. So total of twenty five rules were framed in rule editor. In fourth module there are three classes (less, moderate to good and good) in land use/land cover, five classes (less, moderate, moderate to good, good and very good) in water level and five classes (less, moderate, moderate to good, good and very good) in rainfall. So total of seventy five rules were framed in rule editor. All the four modules were integrated by using simulink, which is a powerful tool to solve systems of different rules and Figure 12 shows the rules of the model.

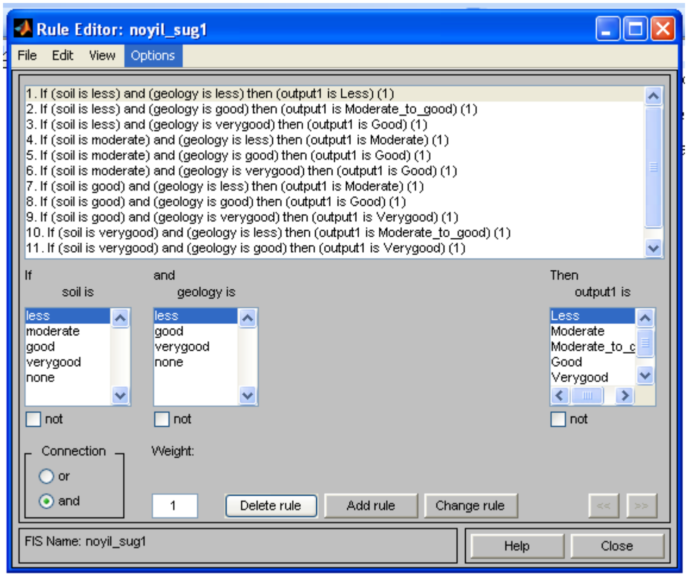

Figure 12 Rules for the Site Selection using Matlab – Fuzzy

Results and Discussion

The artificial recharge sites were identified by integrating available maps like geology, geomorphology, slope, drainage density, lineament densityl and land use/land cover map by using weighted overlay analysis.

Based on Fig. 13, Artificial recharge is found under good category (occupies 6.12% of the study area) in the few patches of the south western side and western side of the study area. The suitable soil (red calcareous), geomorhological (flood plain and deep pediment) features, soil (valley fill and unclassified gneiss)features and fallow land, which are present in the portion of the study area,provides favorable condition for groundwater recharge, there by making the area suitable for artificial recharge. The predominant portion of the study area covers moderate to good category (occupies 83.52% of the study area) due to the presence of geomorphology (pediments and gneiss), soil (red calcareous and thin red soil) and with high lineament density. The artificial recharge is found under the moderate category (occupies 10.36% of the study area) in western, south eastern and north eastern side of the study area due to the presence of soil (red calcareous, black soil, colluvial and alluvial soil), geomorphology (shallow buried pediment, shallow pediment, pediment) and geological features (charnockite, complex and unclassified gneiss).

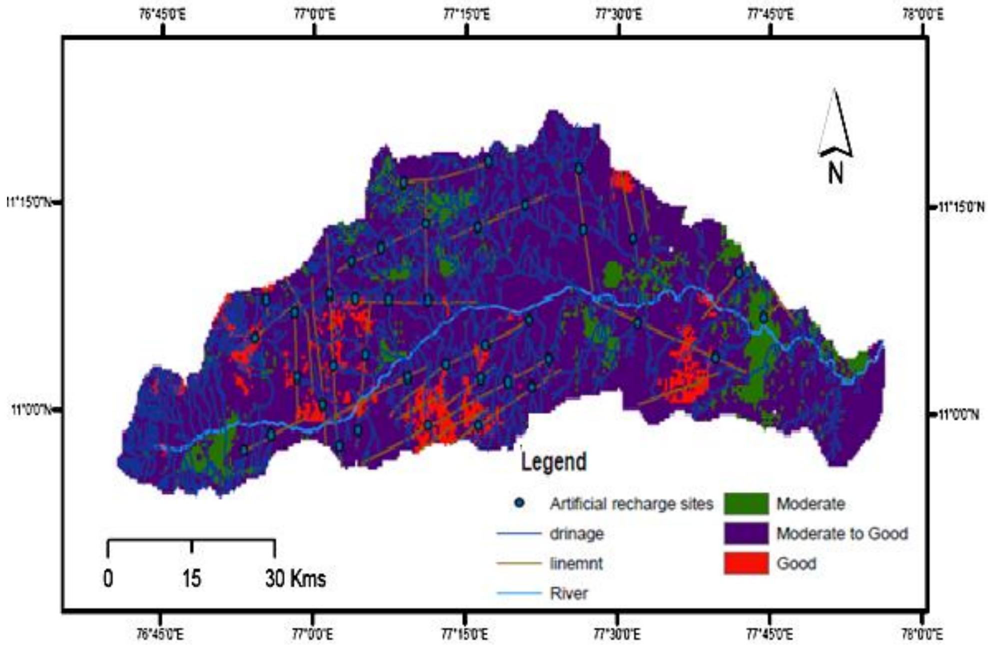

Fig. 13 Artificial Recharge Sites Map

Suitable artificial recharge sites

In the present study, map generated by superimposing the drainage map and lineament map helped to locate the favorable sites for the artificial recharge which is shown in fig. 13. Based on Fig. 13, 39 artificial recharge sites were identified, of which 4 sites fall in the 'good' recharge zone, 2 sites fall in the 'moderately suitable' recharge zone and 33 sites fall in the ‘moderate to good suitable’ recharge zone. As far as the artificial recharge structures are concerned, mainly check dams and perculation ponds are recommended at the identified sites for artificial recharge in the study area. These structures are small-scale structures that can be built across lower order streams in order to enhance infiltration into the subsurface formations.

The model can be run by assigning the weighted rank of each parameter of the different factors of a particular location which is shown in Table 4. Based on the parameters in a particular location the inputs are given as numerical values. The output will also be a numeric value and Figure 14 shows the model of the fuzzy to identify the artificial recharge sites of a particular location.

Table 4 Output Values for Artificial Recharge Sites

S.No	Range	Result
1.	25 - 45	Less
2	46 - 66	Moderate
3	67 - 87	Moderate to good
4.	88 - 108	Good
5.	109 - 126	Very good

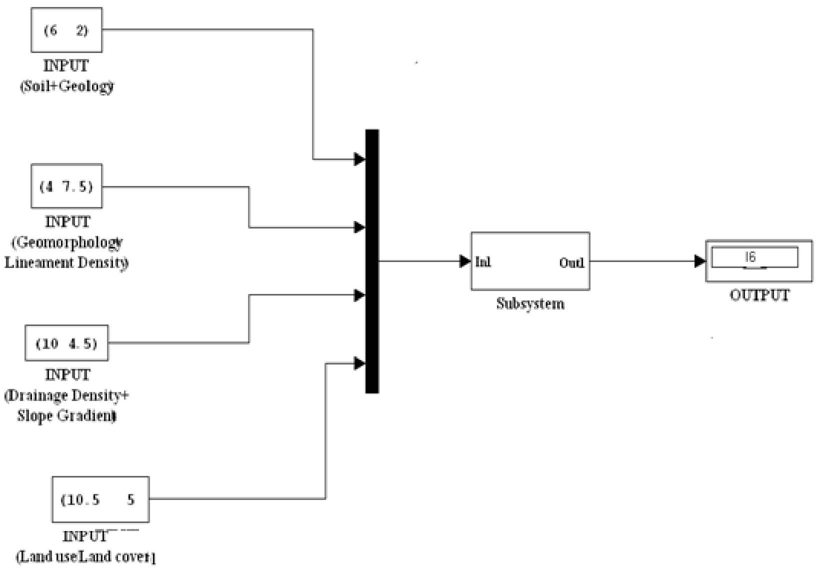

Figure 14 Simulink Block Diagram for the Fuzzy Model

The output of the defuzzification rules gives a single output value which depends upon the weighted rating of various parameters in different factors. The value was compared with values in Table 4. Based on the comparison it can able to identify the category of a particular location towards artificial recharge.

It can be concluded whether the particular location is suitable for artificial recharge site based on the ranges shown for the output values of the model in Table 9.2.

Conclusion

Noyyal watershed located in the western part of Tamil Nadu, India, has been suffering from growing water shortages for the past few years. The over-exploitation of groundwater has resulted in groundwater lowering in different parts of the study area, thereby aggravating the water problem. There is an urgent need to augment the groundwater resource in the area by suitable artificial recharge techniques. 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. 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. According to the recharge zone map,Noyyal watershed is divided into five different zones, namely poor, moderate, moderate to good, good and very good zone. Based on the weighted overlay analysis for artificial recharge and it was found that moderate to good category occupies 83.53% of the study area. It is suggested that, proper rainwater harvesting and artificial recharge methods like recharge structures like farm ponds,recharge pits, recharge wells etc and measures should be implemented in the moderate to good potential zones to overcome the water scarcity problem in the study area and it will help in proper utilization of water resources and to overcome the shortage of water faced by this region.

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