International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF GROUND WATER POTENTIAL ZONE USING ARC GIS &REMOTE SENSING IN MADURAI DISTRICT

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Abstract - *Ground water is one of the major sources that contribute to the total annual supply. The explosive growth and uneven distribution of population, poor irrigation practices, rapid urbanization/industrialization, large-scale deforestation and improper land use practices creates depletion of ground water. The objective of this paper is to review techniques and methodologies applied for identifying groundwater potential zones using GIS and remote sensing. In order to evaluate the ground water potential zones, different thematic maps such as geology, slope, soil, drainage density map, Land use and Land cover and surface water bodies were prepared, using remotely-sensed data as well as topographical sheets and secondary data, collected from concern department .*

***Key Words**: Ground water, Remote sensing, potential zones, Madurai, slope, soil, Drainage …*

1. INTRODUCTION

Groundwater levels change for many reasons. Some changes are due to natural phenomena, and others are caused by man's activities. They are many different aquifers. Some are relatively shallow unconfined aquifers that are affected by surface activities. Others are much deeper confined aquifers that are well isolated from surface or shallow subsurface influences. Some aquifers consist of competent bedrock units; others are composed of unconsolidated sediments. Some aquifers are heavily used for water supply while others receive very little use. All of these factors can influence how water levels in the aquifers change over time.

1.1 Water Level

Water is the vital resource essential for the survival of mankind. Rainfall is the main source of water which is unevenly distributed spatially and temporally. Rapid increase in population, urbanization, agricultural expansion and industrialization leads to higher levels of human demand. As water demand increases, issues on water availability and demand become critical. This makes the management of water resources include assessing, managing and planning a complex task. It has become more critical in places where rainfall is very low and erratic. Even though India is blessed with a higher average annual rainfall of 1,170 mm as compared to the global average of 800 mm, it faces the problem of water scarcity in most part of the year . Groundwater balance deals with aspects of balancing various components of groundwater supply (recharge) and disposal (discharge) with storage changes in the groundwater reservoir.

In the last few decades, changes in land use and land cover, climatic conditions, population explosion, enhanced industrialization and urbanization has deteriorated the conditions. As a result, the effect of these changes on the water balance components is unknown. A serious problem recognized is that sufficient water is not available during the dry season. The water sector is very sensitive and is strongly influenced by the changes in climate and land use. Hence, it has the potential to impose additional pressures on water availability, water accessibility and water demand in the study area. Even in the absence of climatic change, present population trends and patterns of water use indicate that the basin will exceed the limits of the economically usable, land-based water resources before 2025.Therefore, the present study has been taken to delineate the groundwater potential zones and natural recharge in the study area. In which, input and output of water and changes in ground water storage are studied to draw up the water balance of the basin. Studies include determinations of various parameters concerned with the quantification of water resources such as precipitation, runoff, evapotranspiration and groundwater recharge.

1.2 Land Use/Land Cover (LULC)

Land use/land cover is two different terminologies which are often used interchangeably Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements whereas land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of land for economic activities. The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. The reliable and updated information on the LU/LC maps and their dynamics can help to provide base information for further decision making in watershed management activities.

Therefore, the LU/LC change is considered as an important measure to evaluate the impact of applied watershed management measures. Various studies have been undertaken to improve the accuracy of classification using different RS and/or GIS based ancillary data at various stages of classification. Hence, proper information on LU/LC is essential for implementing numerous developments, planning, and Land use schemes to fulfill up the increasing demands of basic human needs. In view of that, an attempt has been made to analyze the urban growth, monitoring the dynamics of LU/LC and also the path ways that impact urban ecosystem.

1.3 Objective

- To delineate the groundwater potential zones using relevant data (rainfall, topography, geology, soil, etc.)
- To develop a GIS model that can identify groundwater potential zones based on the thematic maps.
- To validate the results of this study with data from the field.

2. LITERATURE REVIEW

CHENG-HAW LEE et al., (2008) proposed that assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems. Further groundwater potential study was carried out in Taiwan with the help of remote sensing and the geographical information system (GIS) by integrating the five contributing factors: lithology, land cover/land use, lineaments, drainage, and slope. The weights of factors contributing to the groundwater recharge are derived using aerial photos, geology maps, a land use database, and field verification.

DEEPESHMACHIWAL et al., (2010) proposed a standard methodology to delineate groundwater potential zones using integrated RS, GIS and multi-criteria decision making (MCDM) techniques. The methodology is demonstrated by a case study in Udaipur district of Rajasthan, western India. Initially, ten thematic layers have been considered. Weights of the thematic layers and their features then normalized by using AHP (analytic hierarchy process) MCDM technique and eigenvector method. Finally, the selected thematic maps were integrated by weighted linear combination method in a GIS environment to generate a groundwater potential map.

JOBIN THOMAS et al., (2011) determined groundwater potential zone in tropical river basin (Kerala, India) using remote sensing and GIS techniques. The information on geology, geomorphology, lineaments, slope and land use/land cover was gathered from Landsat ETM + data and Survey of India (SOI) topo sheets of scale 1:50,000 in addition, GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential. The spatial variation of the potential indicates that groundwater occurrence is controlled by geology, structures, slope and landforms.

MURUGESAN et al., (2012) have carried out groundwater study in the Dindigul district of kodaikanal hill, which is a mountainous terrain in the Western Ghats of Tamilnadu. Ground water potential zones have been demarcated with the help of remote sensing and Geographical information (GIS) techniques. All thematic maps are generated using the resource sat (IRS P6 LISS IV MX) data and Inverse distance weight (IDW) model is used in GIS data to identify the groundwater potential of the study area. For the various geomorphic units, weight factors were assigned based on their capability to store groundwater.

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3. METHODOLOGY

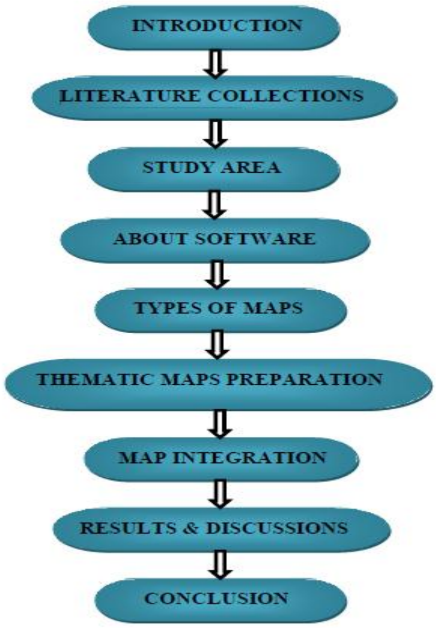

Fig -1: Methodology

Groundwater potential assessment is a dynamic one and not static. While assessing an area, the following factors can be considered such as Geology, Total Irrigated Area, Total Number of Wells used for Irrigation, Water Level Data for the past five years, Average Rainfall, Total Recharge, Irrigation methods adopted in the area, Cropping pattern details, Seepage factor, Specific yield, Geological conditions prevailing in that area, Recharge through Artificial recharge structures, etc.

4. STUDY AREA

Madurai is a district of Tamil Nadu located about 501 km away from the state capital, Chennai, on the Vaigai River. The district covers an area of 3,742 km2 and it bordered by Sirumalai and Nagamalai Hill to the North and West. Madurai district headquarters is located at Madurai city or metropolitan area. Madurai city is third largest among cities of Tamil Nadu with an area of 148 sq. km. Madurai Meenakshi temple is the main attraction of the district which located at the heart of Madurai Town. The temple attracts thousands of travelers in a day and the travelers are an important source of income for the city.

Fig -2: Study area map

According to census report India 2011, approximately 3,041,040 people reside in Madurai District. Among them male compromise 51% of population and rest are female. Madurai District economy mainly standing upon several small and large industries like rubber producing centers, automobiles component producing companies, Textile Industries, software companies and many more. You will also notice some large shops and malls around the city area. Some major of these are East Gate shops, East Masi Street shops and garments & textiles malls at South Masi Street.

The climatic characteristics of Madurai remain dry and hot for a long term. Three major type whether seasons are noticed in the district namely, summer, winter and monsoon. Summer season continue from April to mid-July when temperature levels vary from 26°C to 42°C. Winter season (December to February) of Madurai is stayed Pleasants when temperature levels vary 18°C to 28°C. It is the best season for tourism. Monsoon season of the district continue from September to November. Average annual rainfalls of Madurai are about 86 cm.

4.1 Hydrogeology

The district is underlain predominantly by crystalline formations and alluvium is found along the courses of the river. Ground water occurs under phreatic conditions in weathered residuum and interconnected shallow fractures and under semi-confined to confined conditions in deeper fractures. The depth of weathering varies from 20-25 m bgl in Usilampatti, Sedapatti and Kottampatti area, while it varies from 30 to 40 m bgl in remaining parts of the district. The depth to water level in the district varies from 3.13 to 7.66 m bgl during pre-monsoon (May 2006) and 1.86 to 5.74 m bgl during post monsoon.

4.2 Geomorphology

The prominent geomorphic units in the district are structural and denudated land forms such as structural and denudation hills, residual wells, linear ridges, uplands and barried pediments.

4.3 Ground Water Quality

Ground water in phreatic aquifer in general is colorless, odourless and alkaline in nature. The specific electrical conductance of ground water in phreatic zone during May 2006 varied between 632 -6520 µs/cm at 25°C and in major part of the state it is less than 2200 µs/cm.

It is observed that ground water is suitable for drinking and domestic uses in respect of all constituents except TH and NO3. It is found to be excess of permissible limit in 34% of sample analysed in respect of TH and in about 66% in respect of NO3. The high incidence of TH can be attributed to gelogenic causes while NO3 excess may be due to either excess use of fertilisers or due to improper waste disposal.

In reference to irrigation suitability based on EC and Sodium Absorption Ratio (SAR), the ground water in phreatic zone may cause medium to very high salinity hazard and medium to high alkali hazard. Hence proper soil management practices are to be adopted when the ground water from phreatic aquifer is to be used for irrigation purposes. In case of deeper fractures, the ground water is suitable for domestic and irrigation purposes. However, the data of State Ground & Surface Water Resources Data Centres shows that ground water in Pulipatti, Chinnalatalai.

4.4 GROUND WATER SOURCES

The estimation of dynamic ground water resources (as on 31.3.2004) have shown that out of 13 blocks in the district, 3 blocks have been categorized as over exploited and 2 blocks as critical. Dug wells are most common ground water abstraction structure with depth range of 10 – 20 m bgl. The yield of dug wells may vary between 45-135 lpm and can sustain for 4-6 hrs of pumping.

4.5 PHYSICAL CHARACTERISTICS

Geography

Madurai is located at 9.93°N 78.12°E. It has an average elevation of 101 meters. The city of Madurai lies on the flat and fertile plain of the river Vaigai which runs in the northwest-southeast direction through the city dividing it almost into two equal halves. The Sirumalai and Nagamalai hills lie to the north and west of Madurai. The city has grown on the either side of the Vaigai river and lies at the low attitude and its about 100 M from mean sea level.

Geology

The land in and around Madurai is utilized largely for agricultural activity which is fostered by the Periyar Dam. Madurai lies southeast of the Eastern Ghats; the surrounding region occupies the plains of South India containing several mountain spurs. The soil type in central Madurai is predominantly clay loam, while red loam and black cotton types are widely prevalent in the outer fringes of the city. Paddy is the major crop, followed by pulses, millet, oil seed, cotton and sugarcane.

Drainage

Vaigai, a major ephemeral river originates in Western Ghats of Theni district flow in NW-SE direction, in the central part of the district. In addition, tributaries of Vaipar and Gundar drain in south-western part of the district, while the tributaries of Pambar drained in north eastern part. The general flow direction of the drainage is NW-SE.

Climate and Rainfall

Madurai is hot and dry for eight months of the year. Cold winds are experienced during December to March as in the neighboring Dindigul. The hottest months are from March to July. The city experiences a moderate climate from August to October, tempered by heavy rain and thundershowers, and cool and climate from November to February. Fog and dew are rare and occur only during the winter season

Being equidistant from mountain and sea, it experiences similar monsoon pattern with Northeast monsoon and Southwest monsoon, with the former providing more rain during October to December. The average annual rainfall for the Madurai district at large is about 85.76 cm. Temperatures during summer reach a maximum of 40 °C and a minimum of 26.3 °C, though temperature over 42 °C is not uncommon.

Winter temperatures range between 29.6 °C and 18 °C. A study based on the data available with the Indian Meteorological Department on Madurai over a period of 62 years indicate rising trend in atmospheric temperature over Madurai city, attributed to urbanization, growth of vehicles and industrial activity. The maximum temperature of 42 °C for the decade of 2001- 2010 was recorded in 2004 and in 2010.

5. ABOUT SOFTWARE

5.1 Geographical Information System (GIS)

The expansion of GIS is Geographic Information System which consists of three words, viz. Geographic, Information and System. Here the word 'Geographic' deals with spatial objects or features which can be referenced or related to a specific location on the earth surface. The object may be physical / natural or may be cultural / man made. Likewise, the word 'Information' deals with the large volume of data about a particular object on the earth surface. The data includes a set of qualitative and quantitative aspects which the real-world objects acquire. The term 'System' is used to represent systems approach where the complex environment (consists of a large number, of objects / features on the earth surface and their complex characteristics) is broken down into their component parts for easy understanding and handling, but is considered to form an integrated whole for managing and decision making.

6. TYPES OF MAPS

6.1 Materials and Methods

Research Methodology

Each of the thematic maps has been reclassified and assigned suitable weight age according to multi influencing factor. The water level and land use/land cover (LULC) were identified by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS 10.2. The multiple parameter analysis for delineating groundwater recharge sites in the study area has been done by Multiple Influencing Factor (MIF) technique.

Data collection

This study involves mapping of different features that influence rainfall runoff in different degrees. Hence thematic maps of Density, Geomorphology, Geology, LULC, Soil, Slope, and Lineament of the study area were obtained from various sources for analyzing and integrating to get the final result.

6.2 Preparation of thematic layers and assigning of ranks

The SRTM DEM (30 m) data was obtained from ISRO's geo-portal used to develop drainage density map. Existing data of geology, geomorphology, soil, land use, and slope were converted from '.shp' format to raster format using polygon to raster tool and a cell size of 30 m was applied to all the maps during conversion. Lineament map was converted to lineament density (km/km-2) map using line density tool of spatial analysis tool. Each parameter is assigned weights from 1 to 4 scales as per the degree of contribution to the central theme.

7. ANALYSIS RESULT

7.1 Slope

The slope map shows that slopes of more than 10 degrees are found in close to the escarpments in the southern part Madurai district. The map as the histogram shows that the relationship between landslides and slope angle which indicate most of the landslides were observed in the range between 0 to more than 15 degrees and dominate in all the micro watersheds. In the study area less than 5% which covered 80% of the area and5 - 10° forms 10% of the area, more than 10° cover 10% of the area. It is observed that most of the landslides occurred within 10° and it is evident that above 10° slopes are restricted to landslides, since the area predominant with barren rocks are exposed.

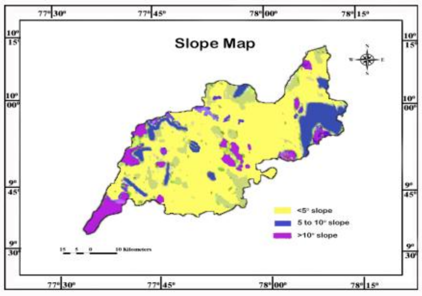

Fig -3: Slope Map

7.2 Drainage Density

The drainage density map of the study area shows that the maximum drainage density in the study area is 2.5 km/km2. The higher drainage density occurred in SE part of the area followed by NE. The drainage density categorized in to 5 classes namely very low, low, moderate, high and very high. The very low drainage density covers 70% of the area with less than 1.0 km/km2 ,low drainage density covers 8% of the area with 1.0to 1.5 km/km2,moderate drainage density covers the area 12% with 1.5to 2.0 km/km2, high drainage density covers 5% of the area with 2.0to 2.5 km/km2and very high drainage density covers 5% the area with more than 2.5 km/km2.

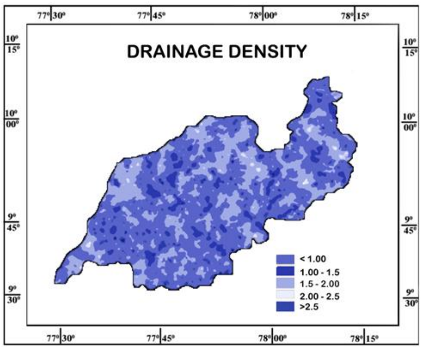

Fig -4: Drainage Density

7.3 Distance from drainage

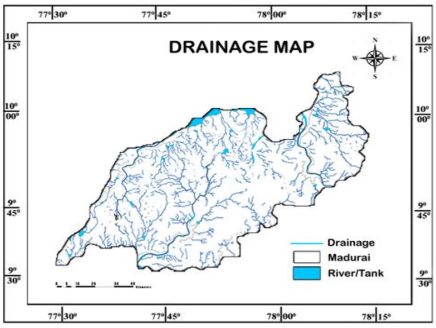

Fig -5: Drainage Map

7.4 Lineament density

The lineament density map of the study area grouped into five classes viz., very low, low, moderate, high and very high among these classes, areas with very low lineament density forms 53% of the area with 32% of landslides followed by low lineament density forms 25% of the area with 11% landslides, moderate lineament density forms 8% of the area with 27% landslides, high lineament density which forms 9% of the area with 26% of landslides and very high lineament density which is 5% of the area with 4% of landslides .

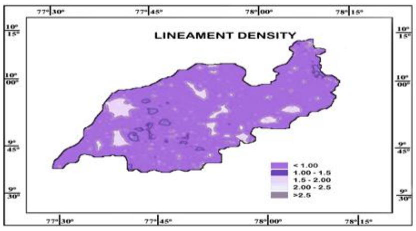

Fig -6: Lineament Density Map

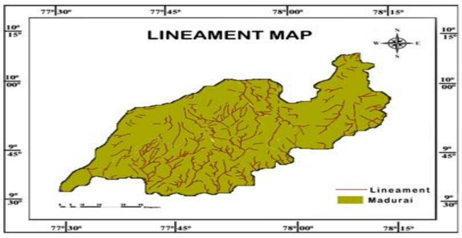

Fig -7: Lineament Map

7.5 Geomorphology

Geomorphologic factors plays vital role which induces the landslide in the study area. The study area is divided into four geomorphic units such as deflection slope, highly dissected plateau, moderately dissected plateau and valley fills by (Seshagiri et al., 1983). Highly dissected land form is the dominant class followed by, moderately dissected, deflection slope and valley fill.

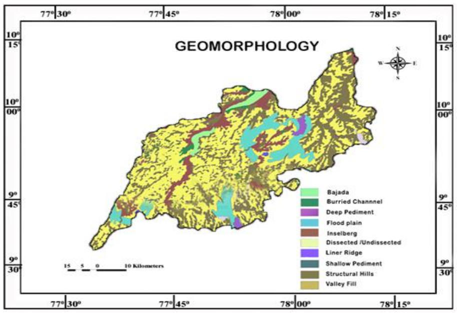

Fig -8: Geomorphology

7.6 Soil Type

The map of the study area shows that soil has classified in to nine variables namely clay, clay loam, habitation, loam, loamy sand, rocky outcrop, sandy clay, sandy clay loam and sandy loam. The most dominant class loamy sand which covers 18% of the area with 45% landslides followed by sandy clay loam forms 16% of the area with 17% landslides, sandy clay covers 17% of the area with 16% landslides, rock out crop covers 10% with 15% landslides, habitation covers 10% of the area with 4% landslides, sandy loam forms 9% of the area with 3% landslides, loam covers 8% of the area with 1% landslides and clay and clay loam covers the area 6% and 5% respectively and not recorded any landslides .

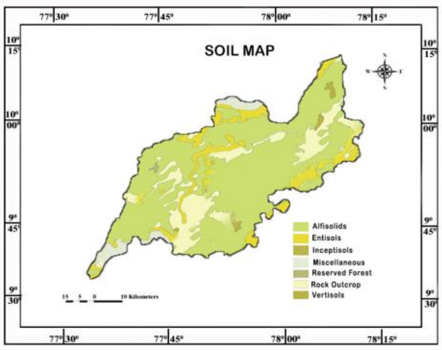

Fig -9: Geomorphology

7.7 Land use and land cover

The land use and land cover of the study area classified into eight categories viz.,barren rocky land, crop land, dense forest, fallow land, land with and without scrub, plantations, settlement and water bodies. Of these various classes, barren rocky land forms 5% of the area, crop land covers 70% of the area, dense forest covers 10% of the area, fallow land covers 5% of the area. Settlement covers 5% of the area. Though cultivation of vegetables involves regular disturbance to the lands due to ploughing and irrigation, landslides are less frequent as they are established in areas with gentle slopes by adopting contour cultivation.

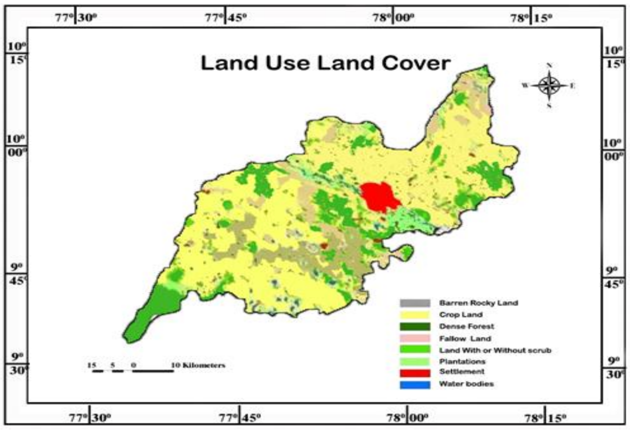

Fig -10: Land Use Land Cover

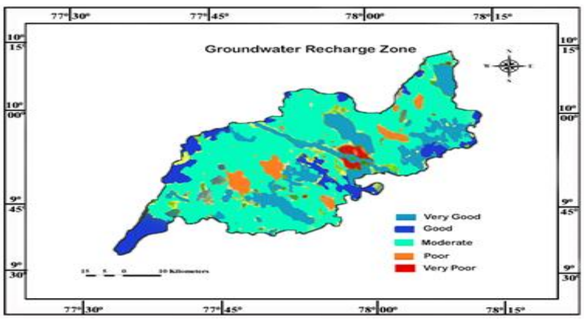

Fig -11: Ground water recharge zone

Sl. No.	Parameter	Class	Rank	Weight
1	Drainage density (km/sq.km)	0-0.42	5	20
		0.42-0.81	4	
		0.81-1.34	3	
		1.34-2.20	2	
		2.20-3.76	1	
2	Slope (Degree)	<2°	4	25
		2-5°	3	
		5-12°	3	
		12-25°	2	
		>25°	1	
3	Geomorphology	Shallow Pediment	2	10
		Deep Pediment	5	
		Structural Hills	1	
		Moderate Pediment	4	
		Valley Fill	4	
		Dissected/Undissected	3	
		Pedi plain	4	
		Residual Hills	1	
		Bajada	3	
		Linear Ridge	4	
		Buried Channel	1	
		Inselberg	2	
		Flood plain	3	
5	Soil order	Ent sols	3	15
		Inceptisols	4	
		Alfisols	5	
		Miscellaneous	2	
		Rock Outcrop	1	
		Vertisols	3	
		Reserved forest	1	
6	Lineament Density (km/sq.km)	0-0.12	1	20
		0.12-0.30	2	
		0.30-0.47	3	
		0.47-0.67	4	
		0.67-1.31	5	

Table -1: Land Use Land Cover

8. CONCLUSION

Geographic information systems are useful tools for groundwater resources management by storing and manipulating the vast array of data that may be available in various formats. In order to demarcate artificial recharge zones, a methodology using the overlay analysis method in a GIS-based multi-criteria analysis was used to map groundwater recharge zone in the madurai district, tamilnadu for the purpose of improving groundwater resource. The thematic layer linked to hydrological, drainage, aquifer thickness, slope and land use/land cover map were prepared, classified, weighted and integrated in a georeferenced project using GIS utilities. The produced map shows the groundwater recharge area which is of great importance in planning artificial groundwater recharge using surface water as a integrative and participative aspect of water management. Where the occurrence of groundwater is more restricted with increasing of water conflicts.The results show that about 10% of the area was very good for recharging purposes, while 10% of the area was good for groundwater recharging. Remaining 65% of the area was moderate for recharging of ground water. Finally, groundwater management requires that the study area are suitable artificial recharge structures in tirumangalam with surrounding area & alanganallur , vellalur & pazhamuthircholai areas and check dam methods were most favourable for recharge in the investigation area.

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