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Remote Sensing and GIS Based Groundwater Potential Zone Mapping in Ariyalur District, Tamil Nadu

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ABSTRACT

The groundwater is the most precious resources around the world and is shrinking day by day. In connection, there is a need for demarcation of potential ground-water zone. The geographical information system (GIS) and remote sensing techniques have become important tools to locate ground-water potential zones. This research has been carried out to identify groundwater potential zone in Ariyalur of south India with help of GIS and remote sensing techniques. To identify the groundwater potential zone used by different thematic layers of geology, geomorphology, drainage, drainage density, lineaments, lineaments density, soil, rainfall, and slope with inverse distance weightage (IDW) methods. From the overall result the potential zone of groundwater in the study area classified into five classes named as very good (13.34 %), good (51.52 %), moderate (31.48 %), poor (2.82 %) and very poor (0.82 %). This study suggested that, very good potential zone of groundwater occur in patches in northern and central parts of Jayamkondam and Palur regions in Ariyalur district. The result exhibited that inverse distance weightage method offers an effective tool for interpreting groundwater potential zones for suitable development and management of groundwater resources in different hydro-geological environments.

INTRODUCTION

There is a noticeable and increasing sense of urgency of good drinking water in connection with impending water extremity in India. Due to rapid industrialisation, modernisation, and population growth the scarcity and quality of the water supply in both rural and urban areas of India is affected. The production of aquifer and good quality of the water require high priority for quantitative assessment of groundwater (Hyun et al. 2011). However, in hydrological studies assessing of groundwater productivity has not been studied. In this connections geographical information system (GIS) and remote sensing techniques have great support in hydrogeological studies. GIS is considered as a most robust technique for managing spatial data and decision making in various field of geological, hydrological and environmental sciences (Brunner et al. 2004; Hyun et al. 2011; Chowdhury et al. 2009; Goodchild, 1993; Rahmati et al. 2014). This techniques is a rapid and cost effective tool in producing valuable data of various geological layers that helps in deciphering groundwater potential zone.

Remote sensing technique (RS) is one of the major source of information about the relationship of slope, land use, landforms and lineaments. This data can be entered as an attribute in GIS and over laid with other data (Jha et al. 2007; Hinton, 1996). Several researchers have used GIS and RS for the identification of potential zone of groundwater with the help of various thematic layers such as geology, geomorphology, drainage, drainage density, lineament, soil and lithology (Ganapuram et al. 2009; Hsin et al. 2016; Magesh et al. 2012; Nagarajan et al. 2009; Solomon and Quiel, 2006; Chowdhury et al. 2009; Prasad et al. 2008; Saha et al. 2010; Muralitharan et al. 2015; Pankaj Kumar et al. 2016). Now a days, satellite data are widely used to provide the base line data of groundwater potential zone (Tiwari and Rai, 1996; Harinarayana et al. 2000; Thomas et al. 1999; Chowdhury et al. 2010). This technique gives a comprehensive data about the ground surface observations (Leblanc et al. 2003; Murthy, 2000; Tweed et al. 2007).

Fresh water resources of India are unequally scattered. During monsoon season and diverse physiographic conditions give rise to unequal distribution of water. Over the years, population growth, urbanization and agricultural expansion have worsened the situation. The unscientific exploitation of groundwater is leading towards water shortage. Even now, some parts of the country are facing acute water crisis. Despite being a very important part of the nation's growth, water resource analysis has been fragmentary. So the main theme of this study is to delineate the potential zone of groundwater in Ariyalur district of southern part of India using integration of geographical information system and remote sensing.

RESEARCH SITE

Ariyalur (Fig. 1) is located in Tamil Nadu state of India with an area of 1,949 km^2. It is located between 78°40' and 79°30'E longitude and 10°54' and 11°30'N latitude. The main river is Kollidam and the branches of Marudaiyar, Ellar, Kallar, and Anaivari Odai. The climate is hot and dry with lowest temperature of 19.5°C and very hot in the months of May and June with temperature of 39.8°C. Rainfall occurs from November to December under the influence of north east monsoon, with an average precipitation of 825.6 mm. The major soil types are red soil, alluvium and black soil. The red soil is found in the hard rock terrains, black soil in the limestone regions and the alluvial soil in the sandstone regions. Geomorphologically, the district is divided into alluvial plains, burried pediments with low lands. Drainage pattern of the district normally radial and dendritic.

MATERIALS AND METHODS

Identification of groundwater potential zone is done by preparation

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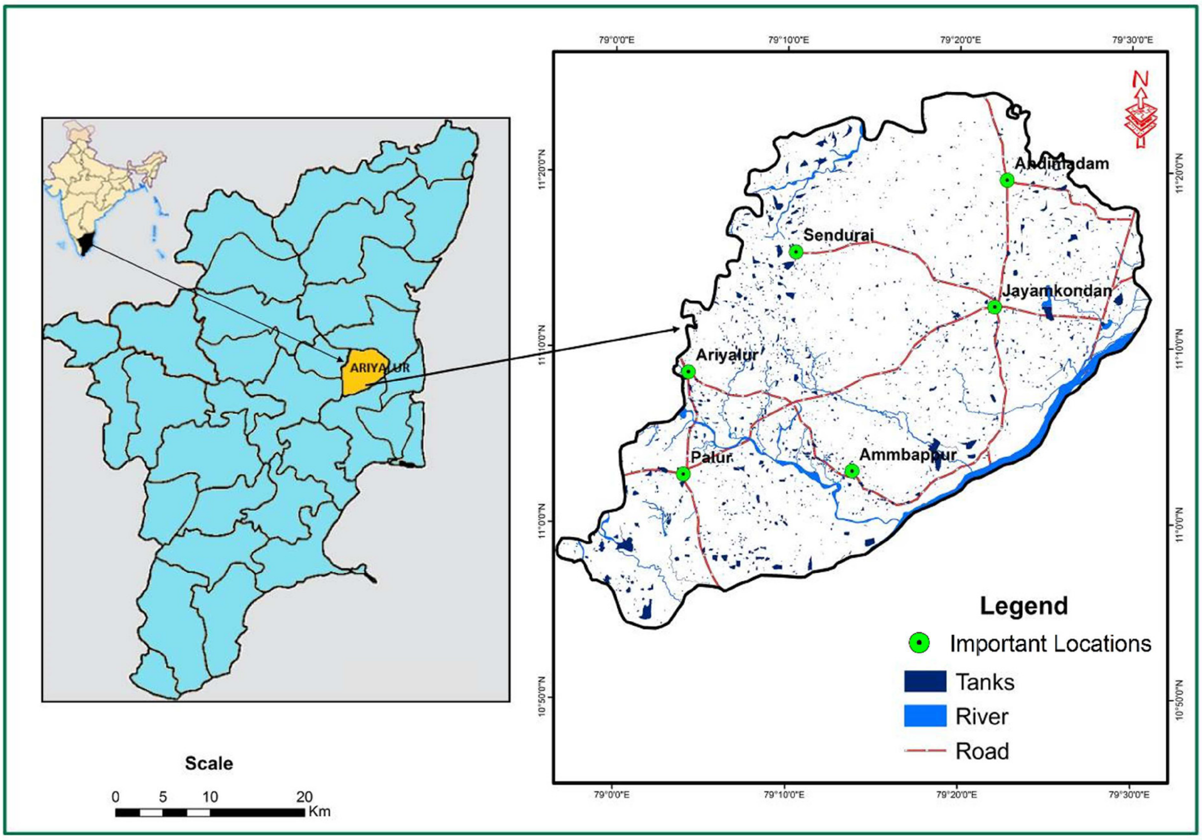

Fig. 1. Location of the research site of Ariyalur district, Tamilnadu state of India

of base mapusing Survey of India toposheet maps (58M/3, 58M/4, 58M/7, 58M/8) and digitized. For preparation of base map Arc map 9.3 was used with extensions of spatial analysis tools of IDW weightage method. Second, different thematic layers such as drainage, slope, geology, geomorphology, soil, rainfall, lineaments maps were prepared from various sources including state soil and land use survey department, Public Work Department (PWD), Tamil Nadu Water Supply and Drainage (TWAD) board- GIS division, satellite imageries (IRS-1C, LISS -III), and SRTM data with 1:50,000 scale Universal Transverse Mercator (UTM), WGS 84 datum, 44N zone. Third, each thematic layer classified into various types and denoted as classes (Table 1).

Each thematic layers were assigned rank of 1 to 3 based on their important relationship with groundwater resources. After that these allotted ranks were given by proper weightage values from 1 to 6, rendering their influence relative to other classes in the same thematic layer. Table 2 shows the different factors taken and assigning weightage with respect to groundwater potential. Then, pair-wise assessment matrix was achieved using ranked method to estimate normalized inverse distance weights (IDW) for each thematic layer and their features. To establish the potential zone of groundwater, all the thematic layers overlaid. The total weights of different polygons in the integrated layer were consequent from the following equation to attain groundwater potential index (Rao and Briz – Kishore 1991):

$$GWPI = ((GM_w)(GM_{wi}) + (GG_w)(GG_{wi}) + (DD_w)(DD_{wi}) + (LD_w)(LD_{wi}) + (RFw)(RF_{wi}) + (SL_w)(SL_{wi}) + (ST_w)(ST_{wi}))$$

Where, GWPI- groundwater potential index, GM-geomorphology, RF- rainfall, GG-geology, DD-drainage density, LD-Lineament density, SL- slope, ST-soil type, and the subscript "w" and "wi" refer to the normalized weights of layer and the normalized weights in each thematic layer, respectively. According to GWPI, the final groundwater potential zone map was classified as very good, good, medium, low and poor type. Detailed methodology flow chart is given in Fig. 2.

RESULTS AND DISCUSSION

Geology

Geological map (Fig. 3) of the present study was prepared with the help of Arc GIS software and numerous geological structures marked and mapped with suitable symbols. The lithologies are pink migmatite and graniotoid gneiss in southern part, sandstone and clay in northern part, sandstone with limestone clay in north western part, and fluvial, fluvial marine, aeolian and marine sediments in the centre, and northwestern boundary of the area. The individual geological layer separated and assigned by weightage on the basis of their water holding properties. Sandstone and clay, sandstone with limestone and clay are considered as potential water bearing formation and hence higher ranking was assigned. These type of rocks are found in maximum part of the study area and it is formed due to submergence of the sea in ancient times.

Geomorphology

Geomorphological map (Fig. 4) of the study area has been prepared by LISS-III satellite data by visual interpretation techniques. It is classified into four layers such as alluvial plain, flood plain, pediplain and upland. Major part of the study area is occupied by pediplain and followed by flood plain, upland and alluvial plain. Based on land forms and water holding capacity ranking is assigned in all the layers.

Soil

Soil (Fig. 5) is also one of the important component for the identification of groundwater potential zone (Pankaj et al. 2016). Six types of soil were identified and classified as very deep loamy soils,

Table 1. Factors taken and assigning weightage with relations to groundwater potential

Thematic map	Weightage Classes	Groundwater Potential
Geomorphology	Pediplain, Upland	Good
	Alluvial Plain, Flood Plain	Moderate
Geology	Sandstone with Clay and lst.	Good
	Fluvial, Fluvio- Marine, Aeolian and marine sediment	Moderate
	Pink migmatite, granitoid gneiss	Poor
Rainfall	High	Good
	Moderate	Moderate
	Low	Poor
Lineament and Lineament density	Low, medium and high	Groundwater movement
Drainage and drainage density	High	Unsuitable for groundwater potential
	Moderate	Moderately suitable for groundwater potential
	Low	Suitable for groundwater potential
Soil	Deep Calcareous Clay soils, Very deep Calcareous soils	Moderate
	Very Deep Calcareous Clay soil, Very deep Clay soils, Very deep Clayey Soils	Moderate to poor
	Very deep Loamy Soils	Good
	Low	High
Slope	Medium	Moderate
	High	Poor

Table 2. Thematic layers with classes assigned ranking and weightage

Layers	Classes	Assigned Ranking	Weightage
Geomorphology	Alluvial Plain	2	7
	Flood Plain	2	
	Pediplain	3	
	Upland	3	
Geology	Fluvial, Fluvio- Marine, Aeolian and marine sediment	2	6
	Pink migmatite, granitoid gneiss	1	
	Sand stone and Clay	3	
	Sand stone with Lime stone and clay	3	
Rainfall	Good rainfall	1	5
	Medium rainfall	2	
	Low rainfall	3	
Drainage density	< 1 (Extremely Low)	3	4
	1 to 2 (Low)	3	
	2 to 4 (Moderate)	2	
	4 - 6 (High)	1	
	> 6 (Very High)	1	
Lineament density	Low Lineament Density	1	3
	Moderate Lineament Density	2	
	High Lineament Density	3	
Slope	Gentle Slope	3	2
	Moderately sloping	3	
	Moderate steep sloping	2	
	Steep sloping	1	
	Very steeply sloping	1	
Soil	Deep Calcareous Clay soils	2	1
	Very Deep Calcareous Clay soils	1	
	Very deep Calcareous soils	2	
	Very deep Clay soils	1	
	Very deep Clayey Soils	1	
	Very deep Loamy Soils	3	

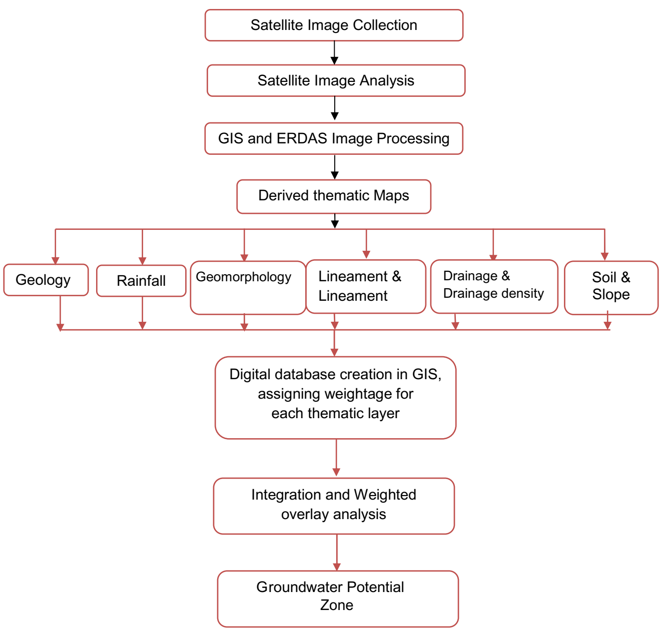

Fig.2. Detailed methodology flow chart of the proposed research.

very deep clayey soil, very deep clay soils, very deep calcareous clay soil, deep calcareous clay soil and deep calcareous soils. Each soil types are assigned weightage based on their characteristics related to the groundwater. According to infiltration rate and groundwater potential, loamy soil is considered as a very good potential with ranking of 3, these soils are in north eastern and south western part of the area. Very deep calcareous clay and deep calcareous clay soils are moderate to low potential (Imran et al. 2010) and ranking was assigned as 2; Very deep calcareous clay soils, very deep clay and clayey soil types have poor potential and was ranked as 1.

Drainage and Drainage Density

Drainage pattern of any terrain demonstrates that the features of ground as well as underground formations. This feature is identified by underlying lithology, and it provides significant indicator of percolation rate of water (Shaban et al. 2006). Drainage pattern (Fig. 6) is generally dendritic types, whereas drainage density (Fig.7) is the sum of all the streams order length per unit drainage area (km/km^2) and is a measure of proximity of channels (Horton, 1932). In the study area drainage density classified into five classes and it is varied from extremely low (<1) to very high (>6). Higher ranking was given to area of very low drainage density whereas lower

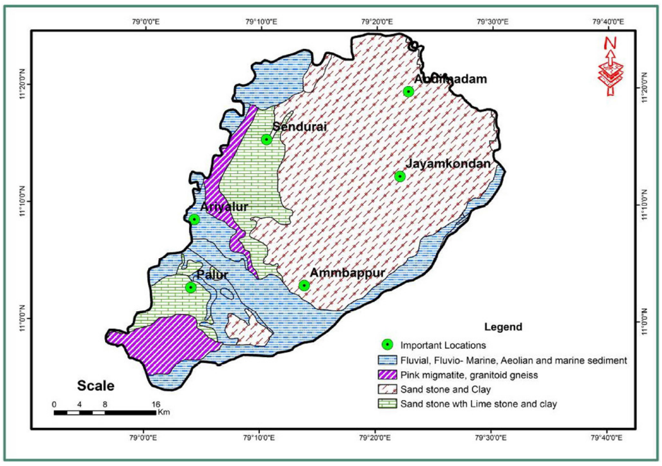

Fig.3. Geological classification of the research site.

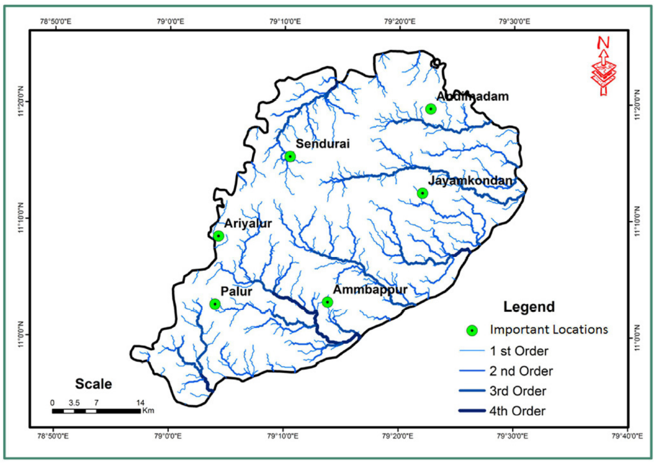

Fig.6. Drainage patterns of the research site

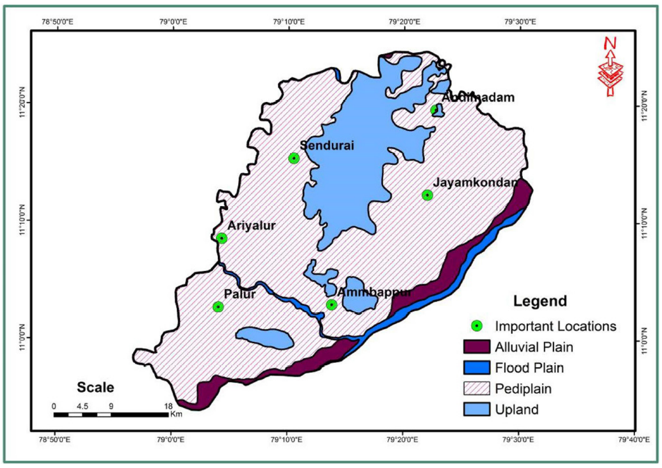

Fig.4. Geomorphological classification of the research site

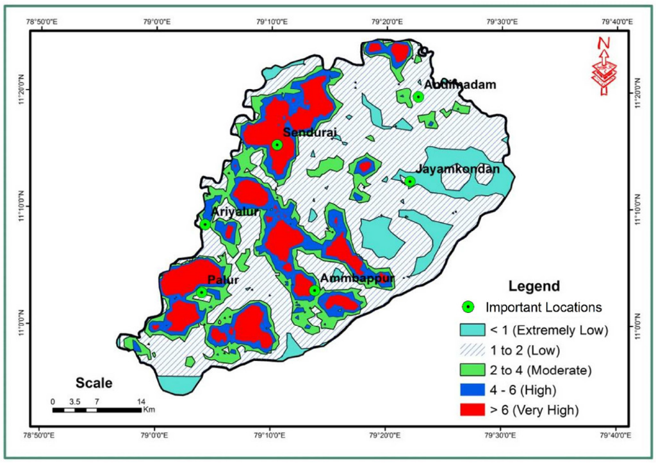

Fig.7. Drainage density classification of the research site

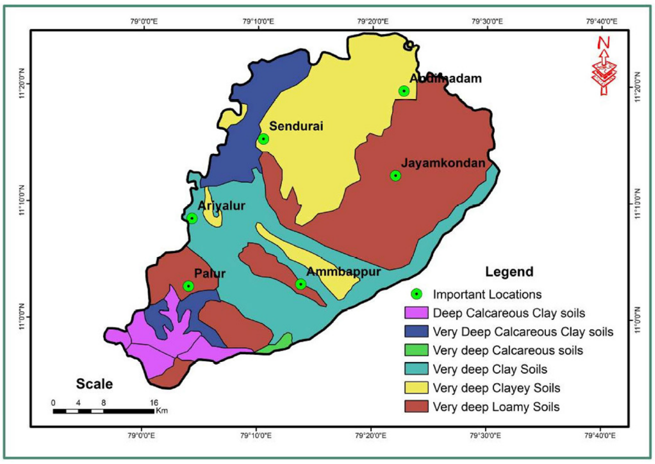

Fig.5. Soil classification of the research site

ranking was given to area of very high drainage density. The middle, western and southern part of the area showed higher drainage density and lower drainage density in northern part of the study area.

Lineaments and Lineaments Density

The presence of lineaments (Fig. 8) generally indicates a permeable zone and high lineament density (Fig. 9) shows good potential of groundwater (Prasanta et al. 2016; Haridas et al. 1998; Magesh et al. 2012). Lineament density is classified as high followed by medium and low categories. High lineament density are in the north, east, and southern part of the study area with a high ranking of 3.

Slope

Based on degree of slope the area is classified as gentle, moderate deeply, moderate, steep and very steep sloping (Fig 10). Gentle slopes are considered as good potential and highest ranking 3 was assigned. In case of steep and very steep slope having high surface runoff, are considered as having poor groundwater potential with lowest ranking 1 was assigned.

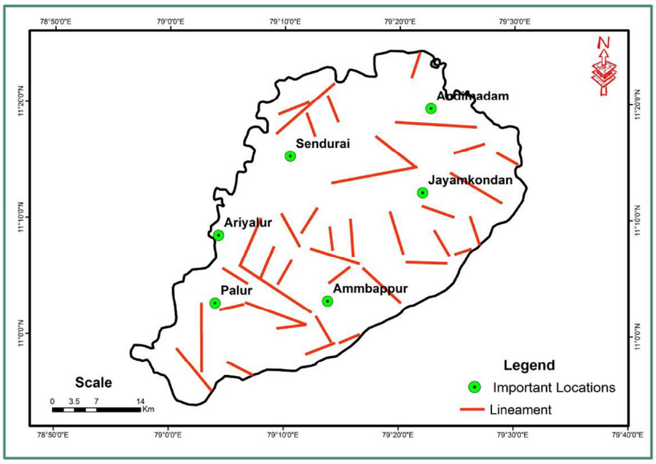

Fig.8. Lineament classification of the research site

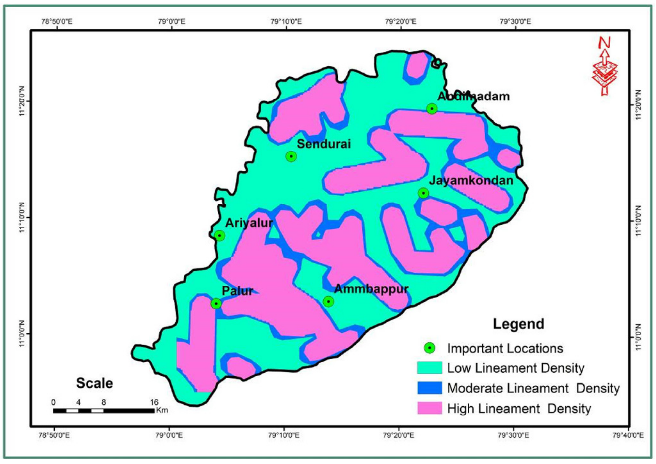

Fig.9. Lineament density classification of the research site

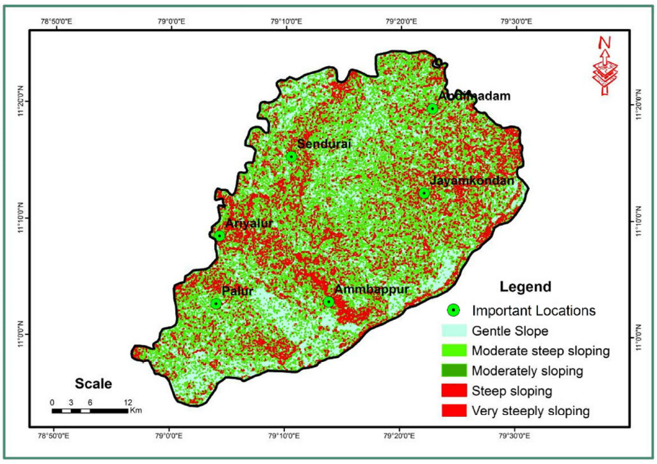

Fig.10. Slope classification of the research site

Rainfall

The rainfall map of this study was prepared using the data obtained from the Indian Meteorological Department (IMD) and Public Work Department (PWD), Chennai. The data was then transferred into GIS environment and spatial interpolation method IDW was used to obtain the rainfall map. Fig. 11 illustrates the rainfall map of the study area. The area of Ariyalur, Suthamalli, and Thirumanur have received high rainfall, moderate rainfall occurred in Sendurai and part of Jayamkondam, and low rainfall in Ponneri gauge station. Distribution of rainfall along with slope gradient easily affects the infiltration rate of runoff water hence increases the possibility of groundwater potential zones (Magesh et al. 2012).

Demarcation of Potential Groundwater Zone

The groundwater potential zone map was prepared by overlaying of cumulative weight assigned to all the thematic layers (geology, geomorphology, drainage, drainage density, lineaments, lineaments density, soil and slope) using the weighted overlay techniques in spatial

Table 3 Groundwater potential zone classification

S. No	Classification	Total area	Area percentage (%)
1	Very good groundwater potential zone	254.54 km^2	13.34
2	Good groundwater potential zone	982.64 km^2	51.52
3	Moderate Groundwater potential zone	600.37 km^2	31.48
4	Low groundwater potential zone	53.85 km^2	2.82
5	Poor groundwater potential zone	15.72 km^2	0.82

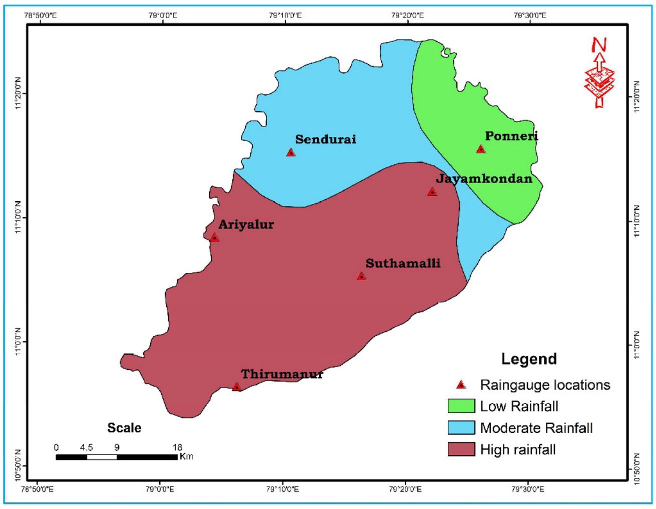

Fig. 11. Rainfall classification of the research site

analysis tool of IDW method. In the process of weighted overlay analysis each thematic layer has been assigned by ranking and weightage based on their water holding capacity. Higher and lower weightages were given to higher and low potential of groundwater, respectively. After assigning ranking and weightage of each layer were added and sum grouped into potential zone of groundwater. All the layers were converted into raster format and overlaid. Based on weighted overlay analysis the study area classified into five classes (Table 3): very good (13.34%), good (51.52%), moderate (31.48%), poor (2.82%) and very poor (0.82%). Result reveals that the majority of the area classified as good potential zone with total area of 982.64 km^2 followed by moderate (600.37 km^2), very good (254.54 km^2), low (53.85 km^2) and poor (15.72 km^2) potential zone. Very good potential zone of groundwater occurred in patches of northern and central parts of Jayamkondam, Andimadam and Palur areas due to sand stone with loamy soils having the high infiltration of groundwater. Moreover, the results of this study can be enhanced by increasing the precision and spatial resolution of the data. Potential zone of groundwater map shown Fig 12.

CONCLUSIONS

The present study focused a probabilistic approach that used both GIS and RS satellite imageries to find the potential groundwater zones in Ariyalur district. To locate the potential zone of groundwater was used by various thematic layers like geology, geomorphology, lineaments, lineaments density, drainage, drainage density, soil and

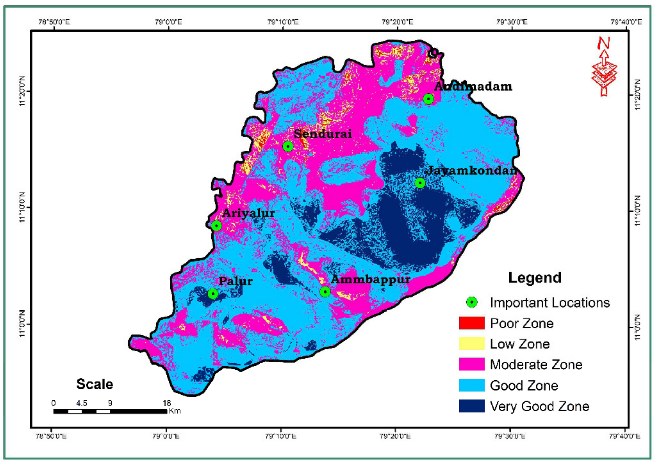

Fig. 12. Final groundwater potential zones classification of Ariyalur district, Tamilnadu state of India

slope maps were prepared from satellite data using GIS and ERDAS software and these thematic maps are integrated and overlaid in GIS to locate the potential groundwater zone of the area. Based on the integrated weighted overlaid thematic maps designate the groundwater potential zone of the Ariyalur district classified into five classes as very good (13.34 %), good (51.52 %), moderate (31.48 %), poor (2..827 %) and very poor (0.82 %). This GIS and RS techniques indicated that, very good potential zone of groundwater occurred in patches of northern and central parts of Jayamkondam, and Palur. While good potential zone of groundwater occurred in north, south, and north western part of the study area. This study is very useful to public and government sector to know the potential zone of groundwater sustainable management and utilization of this district.

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