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Zoning of groundwater potential in Amaravathy river basin, south India, by integrating remote sensing and GIS

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In the present study, an integrated approach of remote sensing and GIS is used to delineate the groundwater potential regions of Amaravathy river basin, Tamil Nadu, India. The thematic maps were prepared for delineating ground water potential regions, with relevant data of the basin on geomorphology, geology, slope, density of lineament and drainage, soils and land use patterns. The weighted overlay technique in spatial analysis tool of Arc GIS 10.3 was used to obtain and discuss the groundwater potential zones. According to the influence and movement of ground water, all parameters of thematic map were assigned with a ranking. Thirty five percent of the basin area has good groundwater potential, 45 % of the basin area is with moderate groundwater potential and 20 % of the basin area bear low groundwater potential.

[Keywords: Amaravathy river basin, Groundwater potential, Remote sensing & GIS, Weighted overlay]

Introduction

Groundwater is considered to be most important source of water in India, for supporting human health, improving the quality of life, and for sustaining ecological diversity. Nearly 85 % of the rural population and 50 % of the urban population rely on groundwater resources for their domestic use. The agricultural requirements accounts for 60.0 % of the surface water resources, by way of irrigation, in the country[1].

Since surface water availability is inadequate and undependable, the increased rate of extraction of groundwater becomes necessary, and is increasing continuously with increasing human population. Among many factors, topography, lithology, lineament, weathering depth, land use patterns and slope characteristics are the most important ones controlling the groundwater movement. Identification of groundwater potential zone may be helpful to regulate the extraction rate, for obtaining the desired level of agricultural productivity.

Remote sensing and GIS techniques have been used earlier by number of researchers to trace the groundwater occurrence and to delineate the groundwater potential zones. Many pioneering investigations were carried out in certain areas in Northern India. For example, the potential zones of ground water in Dala-Renukoot area in Uttar Pradesh[2] was investigated, wherein various thematic maps were overlaid and classified into 5-catgories, namely, poor, moderate, good, very good and excellent. Similar studies were carried out in Dhanbad district of Bihar state[3]; and groundwater potential evaluation studies in Ken-Betwa basin in Uttar Pradesh and Madhya Pradesh[4]. Moreover Mondal *et al*.[5], have studied the groundwater prospects evaluation in Rishikesh area in the state of Uttarakhand in the Himalayan foot hills, besides the Ganga River, using high resolution satellite images. Studies were also conducted to investigate the groundwater availability in Narava basin and in Musi basin sub-basins of Krishna basin in Andhra Pradesh[1,6].

Groundwater movement in the northern Pennar river basin, in the state of Karnataka was evaluated by Vittala *et al*.[7] using data obtained from RS and GIS. Two more studies relating to evaluation of groundwater potential have been carried out from Tamil Nadu, namely, i) in Erode district, using Weighted Overlay technique[8], and ii) in Thirumanimuthar basin (covering Salem and Namakkal districts), and have identified groundwater potential zones[9].

While evaluating the ground water potential in any watershed area, the usual norms are to consider the various layers of thematic maps, in detail, namely, i) Geology, ii) Lineament density, iv) Drainage density, v) Geomorphology, vi) Slope vii) Land use and viii) Soil textures. The present study aims at characterizing groundwater enriched area in Amaravathy river basin.

Description of the study area

The Amaravathy basin, a sub-basin of Cauvery basin having an area of 7867 sq km[10] is chosen as the study area. The study area map is shown in Figure 1. The Amaravathy river is considered as one of the major rivers in Tamil Nadu. The basin originates from the valley near Munnar in Kerala state, in the Western Ghats. It flows towards a stretch of land between Aanaimalai Hills and Palani Hills, and enters Karur district, where its confluences with the river Cauvery. The Amaravathy river basin is located between latitudes 10°08´ to 11°01’ N and longitudes 77°06’ to 78°12´ E. The annual precipitation in the basin averages to 1029 mm. Land areas conforming to gentle slopes in topographical features are predominant in Amaravathy river basin. Kuthirai Aaru, Shanmugha Nadhi, Nallathangal Odai, Nanganji Aaru and Kodavan Aaru are the main tributaries of Amaravathy river. From left side of the river two small tributaries, namely, Uppaar Odai and Vattamalaikkarai Odai joins the river.

Materials and Methods

The index map of Amaravathy river basin was prepared based on IRS 1C LISS III satellite data, merged with SOI topographic maps, on a 1:25,000 scale. Thematic layers of land use, geomorphology, geology and lineament were prepared. Slope is derived from the SRTM of USGS (DEM). Stream length (km) and area of the watershed (km^2) is calculated by using watershed delineator tool in Arc-SWAT 2012 Model. The study area was delineated into 45 sub-watersheds. The soil map was collected from Tamil Nadu Agricultural University, Coimbatore. The vector format thematic layers were converted in to a raster format (30 m resolution) in order to work with GIS. Spatial analysis tool of ArcGIS 10.3 was used to delineate groundwater potential zones by Weighted Overlay method. The overlay analysis would allow a linear combination of weights of each thematic map, with the individual capacity value, in respect of groundwater potential[11]. During Weighted Overlay analysis, all the thematic maps were overlaid. All thematic maps were ranked, and then weights were given as shown Table 1.

Results and Discussion

In the overlay method, the following parameters were considered as input, as detailed below:

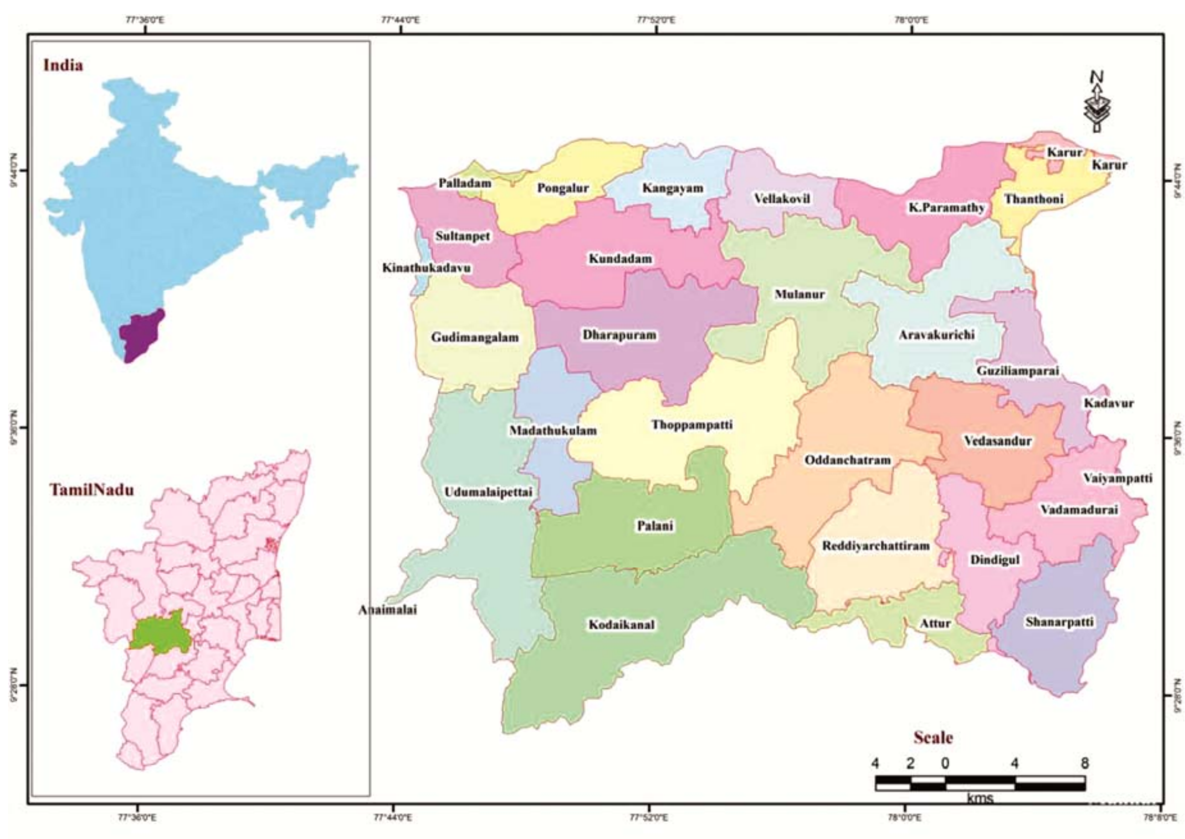

Fig. 1 — Study area location map

Table 1 — Rank and Weightage of different parameters for groundwater potential zone

Name of the layer	Weightage	Rank
Geomorphology	25	
Pediplain weathered buried		4
Flood Plain		6
Pediment Inselberg complex		2
Structural Hills		1
Residual Hills		1
Denudational Hills		1
Pediment buried		4
Water body mask		5
Bazada		3
Slope	20	
0 -5 %		5
5 - 10%		3
10 - 15%		2
15 - 35%		1
35 - 50 %		1
Geology	15	
Hornblende biotite gneiss		4
Sand and Silt		5
Charnockite		2
Granite		1
Garnet sillimanit gneiss		3
Lineament	10	
Poor		2
Moderate		3
Good		4
High		5
Land use	10	
Current fallow		3
Waterbodies		5
Agriculture Plantation		5
Agriculture Crop Land		5
Built up Rural		1
Built up Urban		1
Man Made Grass land		3
Open scrub		2
Industrial area		5
Forest		4
Soil	10	
Good		4
Poor		2
Average		2
Extremely Poor		1
Excellent		5
Drainage Density	10	
High		5
Moderate		3
Low		1

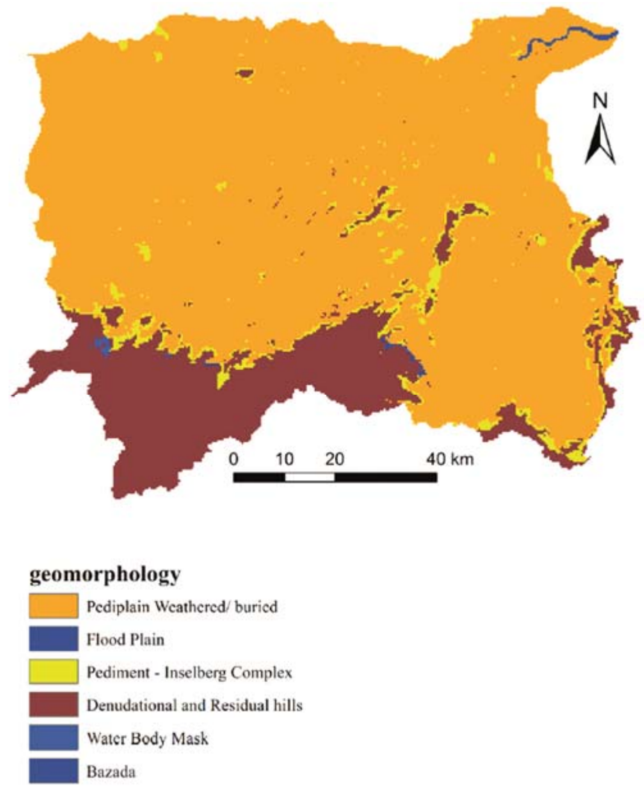

Fig. 2 — Geomorphology map

Geomorphology

The geomorphological features in the area were categorized into nine units (a) Pediplain weathered/ buried, (b) Flood plain, (c) Pediment-Inselberg complex, (d) Structural hills, (e) Residual hill, (f) Denudational hills, (g) Pediment buried, (h) Water body mask, and (j) Bajada. The geomorphology of the study area is predominated by a Pediplain weathered category, covering an area of 77.95 % as shown in Figure 2. The areas of low relief constituting Buried pediments can be considered as the most favorable zones for groundwater potential[12]. A continuous process of pigmentation is the major cause for pediplain formation. Granite and Charnockite which forms part of pediplain were found in small percentage of area in the region. This formation has resulted due to intensive weathering of rock materials, under semi-arid climatic conditions, representing the final stage of the cyclic erosion[13,14]. Pediment inselberg complex are those dotted with granites and gneisses, which cannot be separated and mapped, as the individual units. Three percent of the basin area is covered with Pediment inselberg complex. Also, Bajada are presently found in areas very close to the foothills. Generally, it is occupying an area of 0.01 % of the study area. Structural hills and Denudational hills are formed predominantly by linear ridge (corresponding to 16.78 % in the study area).

The structural hills characterized by hard rock which acts as a runoff zone bear poor groundwater potential.

The major part of Kodaikkanal and Palani hills occupy structural hills[15]. Flood plain is a flat or nearly flat land adjacent to a stream or river which experience flooding during periods of high discharge. This kind of pattern prevails in about 0.018 % of the Amaravathy river basin. The groundwater potential in flood plains is very good to good. The pediment complex occupies 0.08 % of the study area which is classified as moderate groundwater potential zone.

Slope

The slope of the basin varies from 0.0° to 50.0°. Water retention is intimately related to the slope of the basin. Slope with 0.0° to 5.0° areas corresponds to nearly 81.0 percent of the basin area, being categorized as gentle slope which are termed to be excellent category for groundwater recharge[16]. The category of 5.0° to 10.0° area forms about 1.0 percent of the basin area which indicates moderate potential zone, as identified. High slope > 35.0° is confined to the hilly area corresponding to 10.0 percent of the basin area where ground potential is poor, as presented in Figure 3.

Geology

Amaravathy river basin area consists of four geology units which include Migamatite complex, Alluvium fluvial, Charnockite group, and Khondalite groups, as shown in Figure 4. The principal stratigraphical units within the Amaravathy river basin are Archean and Quaternary rocks. It can be seen that the basin comprises of Hornblende Biotite gneiss (73.0 %), Charnockite (21.0 %), Sand and silt (3.0 %), Garnet silliminate gneiss (2.0 %), and Granite (1.0 %). The thickness of weathered zone is more predominant in hornblende biotite gneisses due its susceptibility to weathering. In these rocks, porosity in the weathered mantle, as well as in the foliation planes, are well developed. They constitute the main receptacles for ground water occurrence[17]. Throughout the Amaravathy river basin, it is found that sand and silt formations are prominent. Hornblende Biotite gneiss formations (consisting of medium to coarse grained, whitish to greyish, highly fissile with alternate biotite of felsic and mafic minerals) are found in the present study area, as reported in the documents of the Central Groundwater Board[18].

Intense cultivation practices are found in the region. These are good ground water prospective areas. Hornblende biotite gneiss formations are considered as the areas where groundwater potential is moderate. Charnockite also form the oldest group and found in the hilly areas. The entire Kodaikanal and Palani hills comprise these formations. These types of rocks are found in residual and denudation hills where the groundwater potential is poor, but the surface runoff could be greater.

Lineament density

Four different structures are noted in the Amaravathy river basin, namely i) Fault is

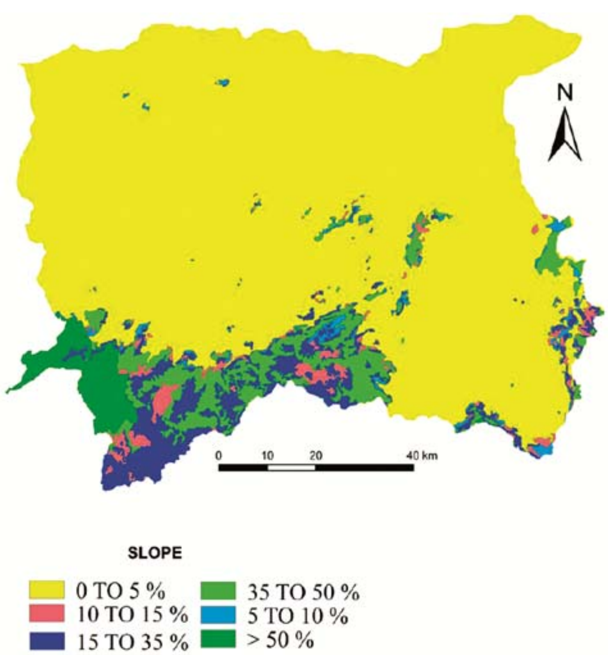

Fig. 3 — Slope map

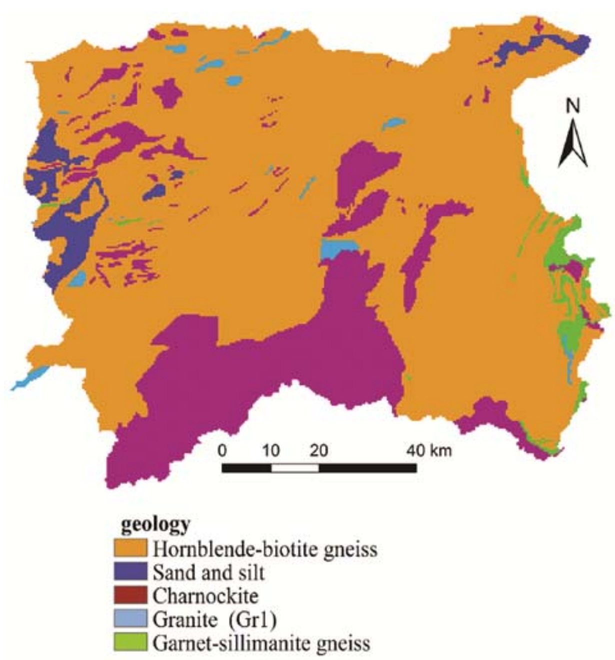

Fig. 4 — Geology map

categorized as good groundwater potential zone, ii) Fracture and lineaments belongs to be medium category of groundwater potential zone in the basin, iii) Inferred lineament in the range of moderate to poor category, and iv) Ridge crest is observed as poor to nil category in the basin, as presented in Figure 5.

Land use

The cropland is the dominant land use pattern, occupying about 53.0 % of Amaravathy river basin. It is followed by plantation (16.0 %), current fallow (8.0 %), forest (7.0 %), land without scrub (6.0 %), scrub forest (5.0 %), built-up area (2.0 %) and water bodies (2.0 %), as classified in the study area. Croplands are an excellent site for ground water potential. The fallow lands are categorized as moderate. About 80.0 % of the basin corresponding to the categories of covered forest, plantation, crop land and water bodies are found to be favorable for groundwater potential, as shown in Figure 6.

Soil

The soil is a major factor considered to delineate groundwater potential zones, as presented in Figure 7. The soil textures are shown in the following percentage: i) sandy loam (28.0 %), ii) sandy clay loam (24.0 %), iii) clay (14.0 %), iv) clayey loam (12.0 %) v) sandy clay (11.0 %) and vi) loamy sand (7.0 %).

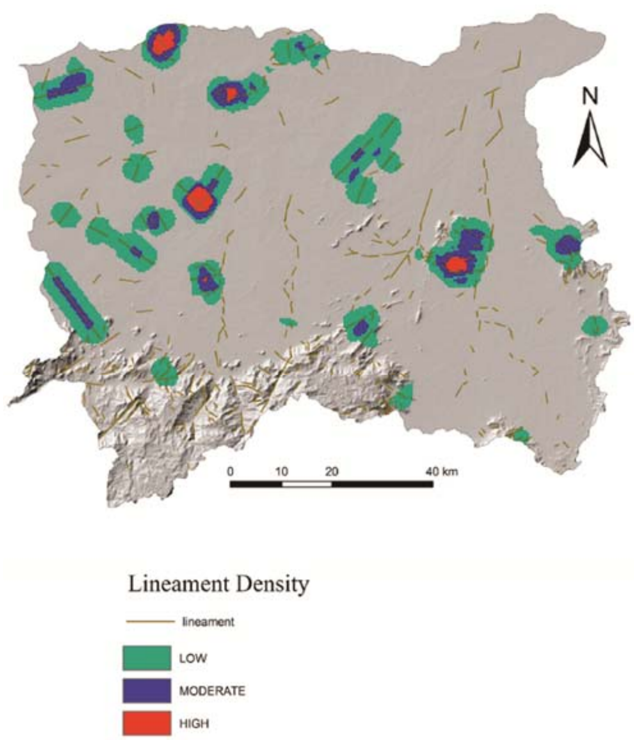

Fig. 5 — Lineament density map

Drainage density

The drainage pattern in Amaravathy river basin is dendritic as evaluated. It is calculated using the sub watershed wise stream length (km) divided by area of watershed (km^2). Generally, the drainage is found predominantly more in the hilly region, which indicates

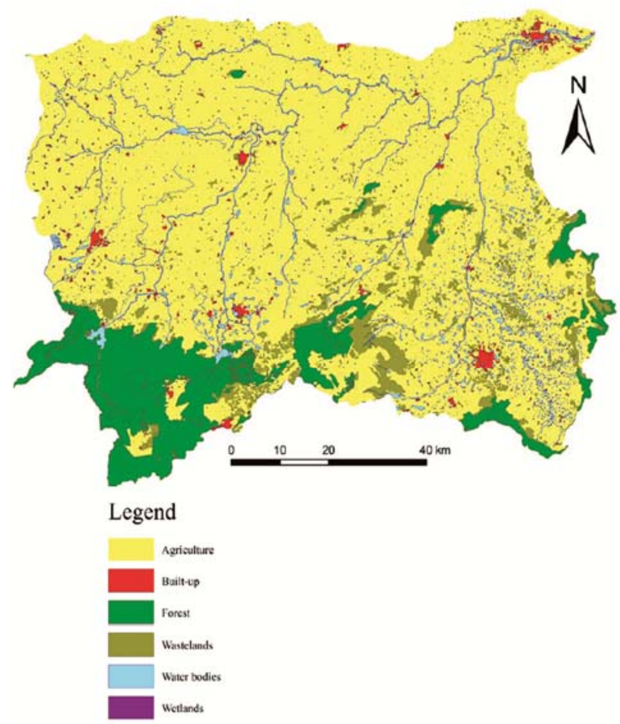

Fig. 6 — Landuse map

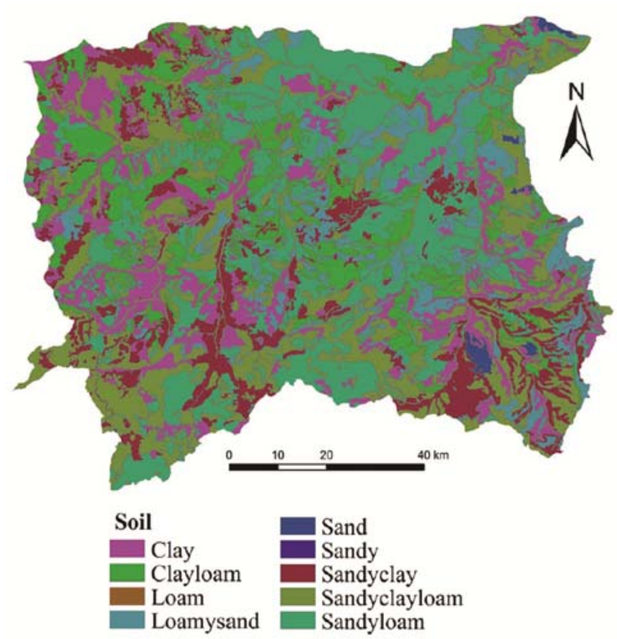

Fig. 7 — Soil texture map

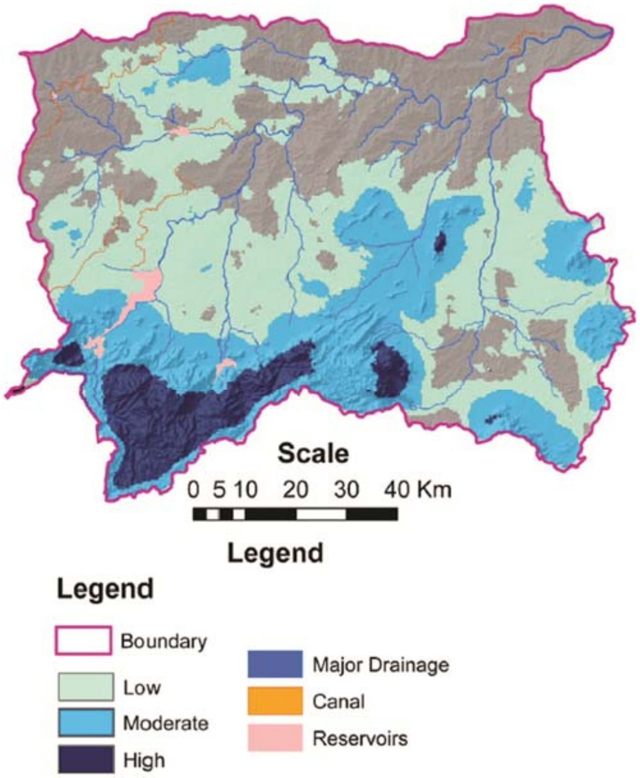

Fig. 8 — Drainage density map

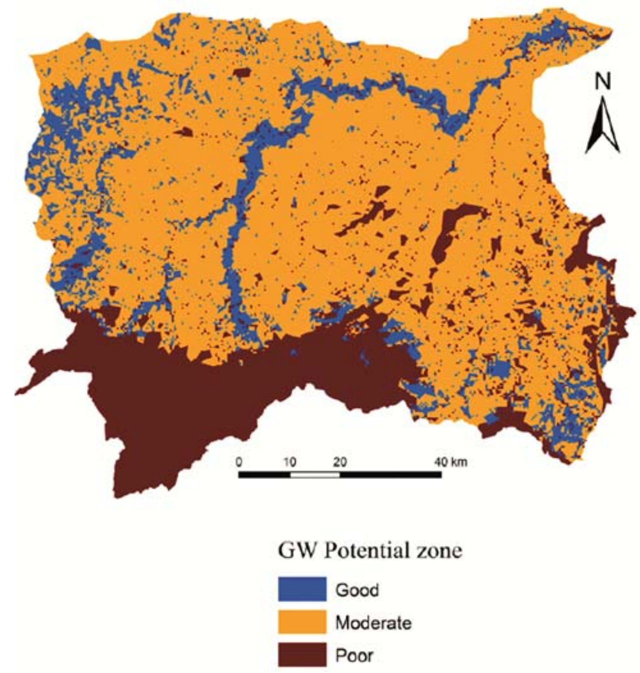

Fig. 9 — Zone of groundwater potential in Amaravathy river basin by integrating remote sensing and GIS techniques

a poor groundwater potential zone. Eight sub-watersheds which contribute 3 % of the entire area are not appropriate for groundwater development, due to its high drainage density which ranges from 0.41 to 20 km/km^2. Three watersheds are under low density (0.06 to 0.20 km/km^2). About 8.0 percent area of the basin is permitting more recharge to the ground water. Thirty-four watersheds are having moderate drainage density (0.20 to 0.40 km/km^2). About 92.0 percent area of the Amaravathy river basin corresponds to a good groundwater recharge potential, as presented in Figure 8.

The groundwater potential map was prepared by overlaying thematic maps of geology, lineament density, land use, drainage density, geomorphology, soil and slope. In this method, the total weights of the polygons that are created were derived as a sum /product of the weight that has been assigned to various layers. Referring to Figure 9, the groundwater potential zone map is generated by using the spatial analyst tool in ArcGIS 10.3, which was classified into three categories of area as good (35 % of the basin area), moderate (45 % of the basin area) and low (20 % of the basin area). The results indicates that the stream with, flood plains and areas consisting of sand and silt, with associated lineaments, are considered as high groundwater potential zones. The results are in agreement with the findings of Subramani[19] which carried out similar studies in Thamirabarani river basin, especially with reference to flood plain areas, buried pediments, and structural hills.

Conclusion

An integrated approach using RS and GIS data for delineating groundwater potential zones in Amaravathy river basin indicates that the maximum area corresponds to the moderate groundwater potential zone (45 %); whereas the 35 % of the area has good groundwater potential. The results obtained and presented in the present study can serve as a basis for evaluating any newly proposed groundwater development scheme, for achieving a sustainable water resource management pattern.

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Conflict of Interest

Authors should declare no competing of conflict of interest.

Author Contributions

PT and NKA devised the idea; PT carried out all technical details and prepared the map and performed GIS analysis. NKA contributed to the verification of the analysis methods and the results. PT wrote the manuscript in consultation with NKA. Both authors contributed to shape the work by discussing the results and contributed to the final manuscript.

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