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Assessment of groundwater potential in Tirukalukundram block of southern Chennai Metropolitan Area

K. Parameswari[1] · T. K. Padmini[1]

Abstract Groundwater is an important resource in all major urban centres. Continuous extraction leads to degradation and depletion in the water quality which can be protected by selecting proper groundwater recharging techniques. The present study aims to determine the groundwater potential by integrating the remote sensing and geographic information system which helps to identify the locations which are in critical stage and immediate steps can be taken to recharge the groundwater. Thirukalukundram block of Kanchipuram district in Tami Nadu, India, has been chosen as study area. To demarcate the groundwater potential zone, surface attributes such as geomorphology, land use/land cover, contour map, drainage density and sub-surface attributes such as lineaments and soil maps are created using satellite imageries, toposheet, soil and geomorphology data of the study area. The thematic maps prepared using geographic information system and weights have been assigned to the attributes by considering the influence on the storage capacity of groundwater. Four categories of groundwater potential zones such as below low, low, moderate and high have been classified. From the analysis, 5% along the coastal plain area covers high groundwater potential zone, 20% of the area towards north-west and south-west hold moderate groundwater potential. 60% of the total area hold low groundwater potential zone which are located towards south-west direction. 15% of the study area contains below low groundwater potential zone in parts of south-west direction. This study helps to identify the suitable locations for extraction and recharge of groundwater.

Keywords Geographic information system · Land use · Soil · Lineament · Slope · Drainage density

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1 Introduction

Urbanization and population growth has increased the demand for good quality water to meet the growing needs. Groundwater is a major source to supply the growing needs because of less contamination and wider distribution. The occurrence of groundwater mainly depends on the factors such as climate, geology, hydrology and ecology. The baseline information for groundwater can be analysed effectively using remote sensing data and topographical data along with ground truth data. In the present study, Thirukalukundram, in Chennai Metropolitan Area in Tamil Nadu, India, has been selected for evaluation of groundwater potential zones using remote sensing and geographic information system (GIS).

Minor et al. (1994) have attempted to present a unique methodology on groundwater exploration using the technique of remote sensing and GIS. The study developed interpretation strategies that integrate various data to characterize groundwater resources for locating a well point. GIS is a powerful tool, for integration and analysis of multi-thematic layers, in delineating groundwater potential (Saraf and Choudhury 1998; Chowdhury et al. 2009; Fashae et al. 2014). Krishnamurthy et al. (1996) exhibited the ability of remote sensing systems and GIS in outline of groundwater potential zones. Integrated studies using remote sensing and GIS approaches have been applied successfully used for delineation of groundwater potential zones by various researchers (Oh et al. 2011; Balakrishna et al. 2014; Venkateswaran et al. 2014; Sahebrao et al. 2014). Topical layers such as lithology, landforms, lineaments and surface water bodies were utilized. The soil data, drainage density and slope were also been used. For groundwater examination in hard shake zones, the groundwater possibility of the region was being assessed through coordination of diverse layers including hydro-geomorphology, lineament, incline, aquifer thickness and mud thickness [Lokesha et al. (2006); Raghuwanshi and Briz-Kishore (2008)]. The integrated hydro-geomorphology map was prepared to assess the groundwater resources revealed that the groundwater potential was moderate to poor in buried pediplains, denudational and residual hills and narrow gorges. The groundwater prospects are good in alluvial plains, valley fills and meandering channels. Senanayake et al. (2016) identify suitable sites for groundwater recharge using rainfall, lineament density, slope, drainage density, land use/land cover, lithology, geomorphology and soil type layers.

The estimation of groundwater potential using remote sensing, geographic information system, geoelectrical and multi-criteria decision technique proves good results when compared to observed yield data [Shah (2007); Al-Manmi and Rauf (2016)]. In this approach, the available hydrologic and hydro-geologic data were detached into two get-togethers, exogenous and endogenous. Arkoprovo et al. (2012) use satellite IRS-IC LISS III, Landsat TM computerized and SRTM information to prepare different topical maps, viz. geomorphological, land, slant, waste thickness, lineament thickness map. Prakash and Mishra (2013) concentrated on the depiction for groundwater change with the assistance of a remote sensing. IRS-LISS III information alongside with other information such as existing toposheet and field perception information has been used to concentrate data on the hydro-geomorphic peculiarities. Senthil Kumar et al. (2014) used remote sensing and geological data framework into one of the heading devices in the field of groundwater examination, which helps in surveying, checking and rationing groundwater assets. The objectives of the study are to prepare various thematic maps such as geomorphology map, land use map, contour map, drainage map, soil map and lineament map to identify

groundwater potential zone through integration of various thematic maps with GIS technique.

2 Study area

Thirukalukundram is a panchayat town of Kanchipuram district in Chennai Metropolitan Area, Tamil Nadu, India. The total study area spreads over 300 km^2, and population is 23,677 (2001), area covered in Indian toposheet No D44U2 in between latitude 12.6067° N and longitude 80.0625° E. Average rainfall recorded in this area is 700 mm, and the average summer temperature is 36.6 °C, whereas average winter temperature is 19.8 °C. The climate of the region varies between arid and semi-arid. Area consists of mainly alluvial plain, pediplain, coastal plain, deltaic plain and denudation hills. High relief areas occur in Thirukalukundram blocks. The terrain in major portion of the block is flat, with the slope varying between nearly level (0–1%) and gently sloping (2–3%) category. Very little pockets have slopes varying between moderately sloping (5–10%). As reported by central groundwater board (CGWB), kankery limestones, derived from igneous or sedimentary rocks by solution and re-deposition, exist around Thirukalukundram block. Granite, gneiss, charnockite, sandy clay and marine deposits are found in the study area. The water table ranges from 5 to 12.5 m. River Palar, a major river course, flows on the southern side of the study area. One of the major crops of Thirukalukundram is paddy. The other main crops are groundnut, sugarcane, cereals, millets and pulses (Fig. 1).

3 Materials and methods

Data such as satellite data, topographical maps, groundwater data and meteorological data have been collected from various organizations. The thematic maps were derived from the IRS-LISS III satellite data (2012). Toposheet procured from survey of India has been used. Geographic information system and image processing (arcGIS software) have been used for analysis and mapping of the individual layers. A topographical map was mainly used for cross-verification with the satellite data. In this study, ArcGIS software has been used to delineate different thematic maps such as geomorphology map, land use/land cover, contour map, drainage density map, lineament density map and soil map. Based on their groundwater potential, the attributes were assigned weights and overlayed in ArcGIS. From the overlayed map, village wise groundwater potential was identified and categorized into zones such as below low, low, moderate and high (Fig. 2).

3.1 Preparation of thematic maps

The thematic layers were prepared for surface and sub-surface attributes on the GIS platform. The study boundary was created in arcGIS. The different thematic maps were assigned weights based on the percentage of influence on groundwater potential is indicated in Table 1.
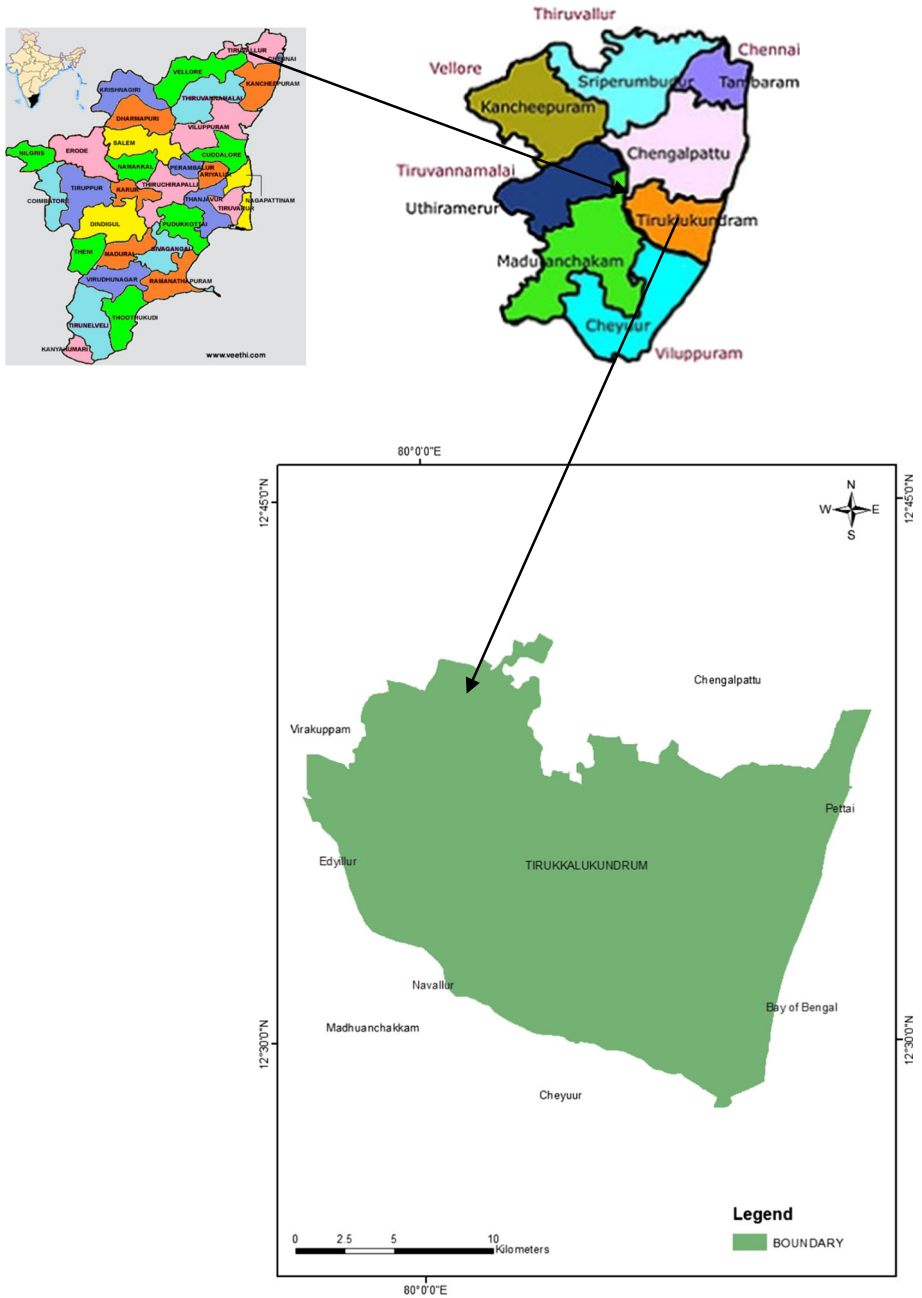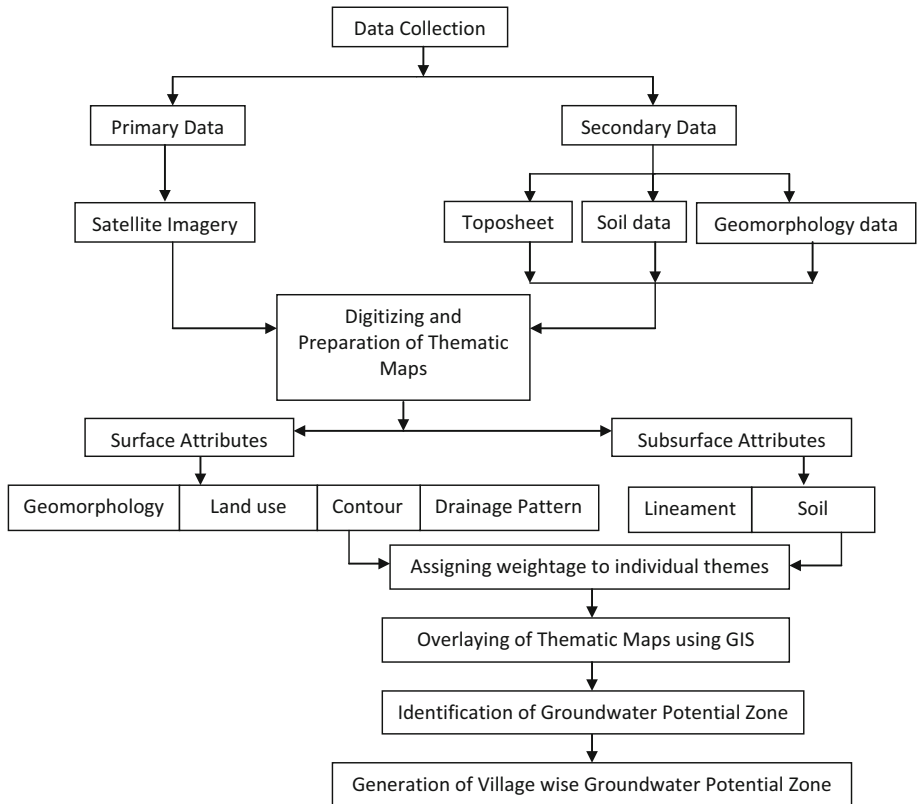
Fig. 1 Thirukalukundram block

Fig. 2 Methodology flow chart

4 Results and discussion

4.1 GIS analysis for groundwater potential zone

Various thematic maps were delineated using arcGIS software. The different thematic maps are shown below.

4.2 Geomorphology

Geomorphology is the reflection of various landforms and structural features of an area. The different geomorphology units were depicted from satellite information and are portrayed as shown in Fig. 3. It is considered to be extremely critical part in groundwater prospects, and subsequently the highest weight was assigned (Table 1). Different classes were distinguished in the study area such as alluvial plain, coastal plain, deltaic hill, denudation hill, flood plain, pediplain and structure hill. Deltaic hill has been assigned the lowest weight. Pediplain has been assigned the highest weight since it consists of chiefly bare rock but may have a covering layer of alluvium or gravel which acts as a highest groundwater recharge source in the study area (Ali et al. 2015). Highly deltaic hills and

Table 1 Weightage and % influence of different thematic layers

Sl. No	Theme	Percentage of Influence	Class	Rank
1	Geomorphology	30	Alluvial plain	4
			Coastal plain	2
			Deltaic hill	1
			Denudation hill	6
			Flood plain	3
			Pediplain	7
			Structure hill	5
2	Land use/land cover	25	Water bodies	7
			Evergreen forest	4
			Industrial	5
			Coastal	1
			Barren land	2
			Other waste land	3
			Crop land (Rabi + Kharif)	6
3	Lineament density	20	0.0000–0.5423	8
			0.5423–1.0840	7
			1.6270–2.1694	6
			2.1694–2.7117	5
4	Drainage density	15	0.0–1.8	4
			1.8–2.9	5
			2.9–3.9	6
			3.9–5	7
5	Contour	5	20–40	9
			40–60	8
			60–80	7
			80–120	6
6	Soil	5	Clayey	3
			Clayey skeletal	2
			Fine	4
			Fine loamy	6
			Loamy	5
			Sandy	7
			None	1

flood plain were given the lowest weight since it is having mainly runoff as compared with the moderately deltaic hills and coastal plain which is acting as recharge and runoff areas.

4.3 Land use/land cover

Figure 4 shows the land use/land cover map. The major parameter which influences the groundwater occurrence is the land cover and land use of the area. The effect of land use/cover is either by reducing runoff and facilitating infiltration or by trapping water on
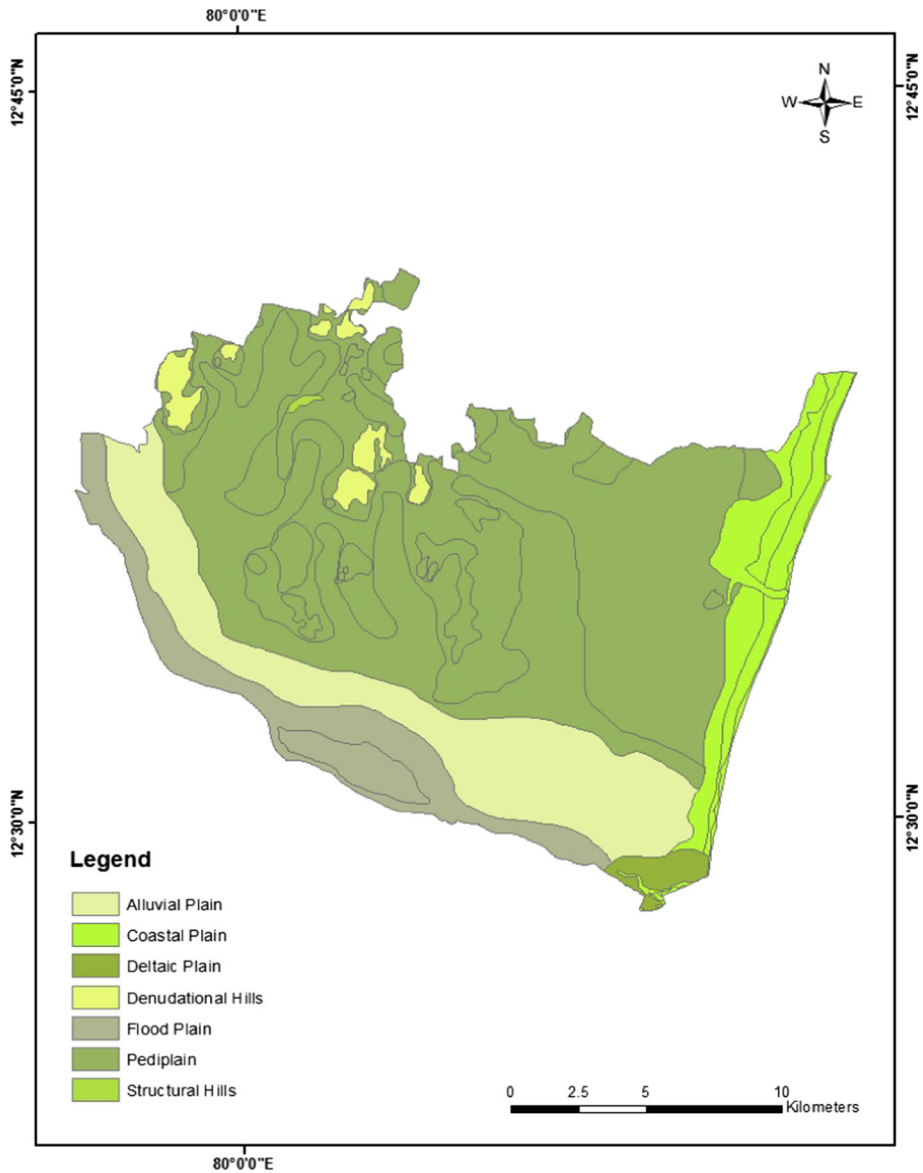
Fig. 3 Geomorphology map

their leaf (Al-Manmi and Rauf 2016). It determines the amount of precipitation recharging the water table. From the land use map, the different categories were grouped and the classes such as water bodies, evergreen forest, industrial, coastal, barren land, waste land and crop land are distinguished. Different land use/land cover classes were assigned weights based on their water requirement. The water bodies and salt pan were given the
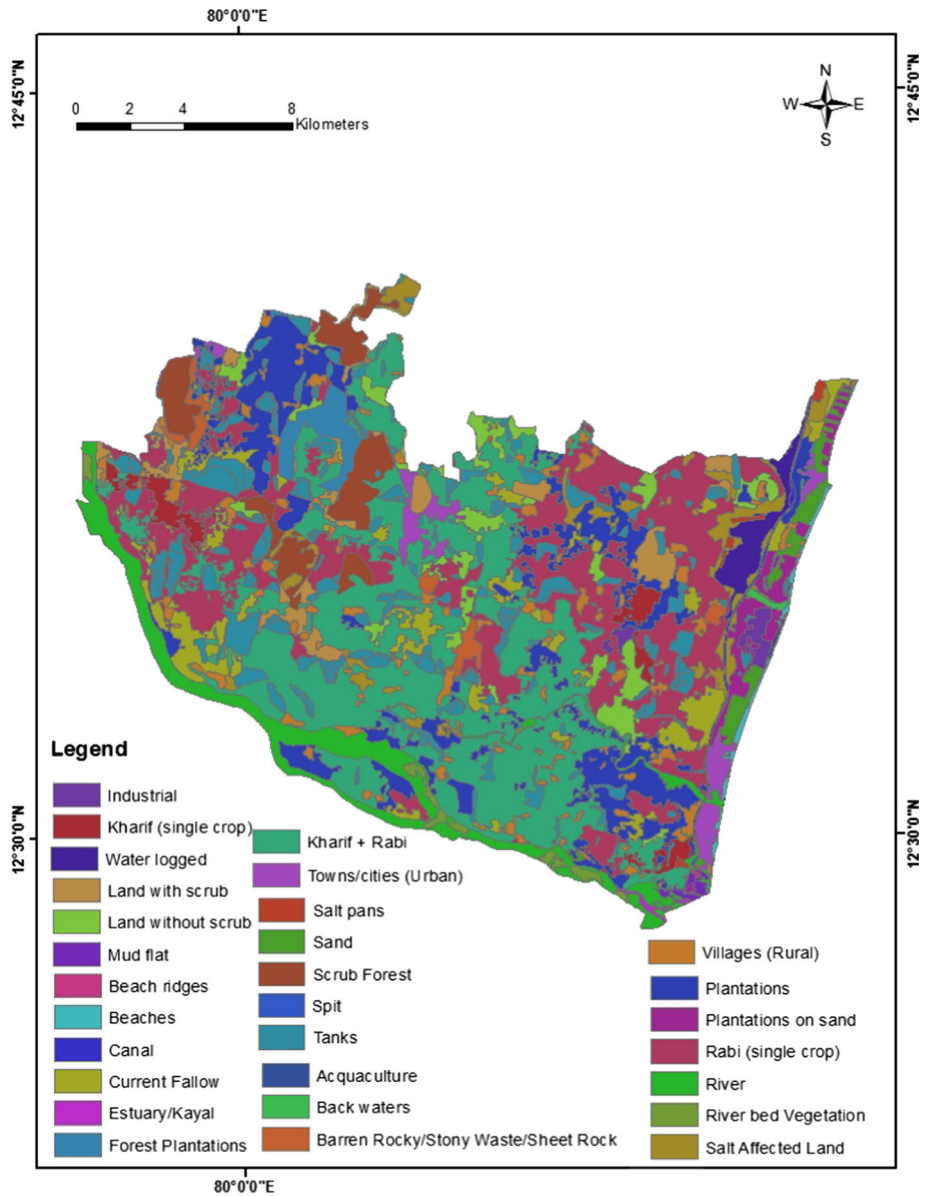
Fig. 4 Land use/land cover map

highest weight over other land use features since it is a persistent recharge to groundwater and less weightage was assigned for coastal area and barren land as it has more runoff.

Evergreen forest was assigned higher weights than grassland as groundwater recharge is higher with intermediate tree densities. Scrubland is a land that is covered with small bushes and tree whereas current fallow land is a land which was periodically left idle.

4.4 Lineament map

Lineaments represent zones of fracturing and permeability which will augment the groundwater occurrence and movement (Lemacha 2008). Variations in size, shape and orientation of the lineaments are mainly influenced by the nature of deformation and geological behaviour of the rocks (Genzebu et al. 1994). Lineament characteristics (Fig. 5) mainly found along the S-W directions and a few along the W-N directions. Lineaments play a very important role in recharging groundwater in the hard terrains rock (Koch and Mather 1997). Groundwater potential is very much higher near lineament zone. The weights have been assigned based on lineament density.
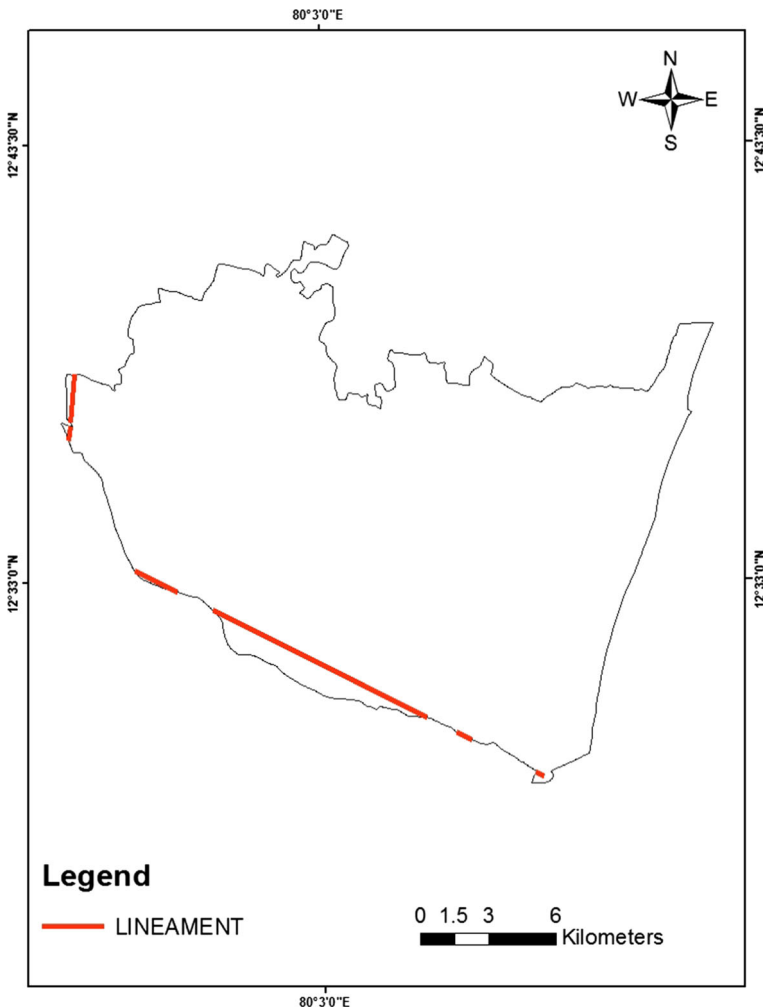

Fig. 5 Lineament map

4.5 Lineament density map

The lineament map was used for generating the lineament density, using the line density tool, as shown in Fig. 6. Polygons with higher values of lineament density will achieve greater recharge and hence better prospects for groundwater. Lineament density was divided into various intervals: 0–0.542, 0.5423–1.0840, 1.0840–1.6270, 2.1694–2.7117, and the weights were assigned. The most significant value of ranking was designated to highest lineament density interval.

4.6 Soil map

The presence of different types of soil influences groundwater occurrence at different rate. It is another major parameter which influences the rate of infiltration of the surface water. Soil group such as clayey, clayey skeletal, coarse, coarse loamy, fine, fine loamy, sandy, sandy soil has been ranked higher based on their groundwater expectations; the sandy soils are highly permeable, light-textured and well-drained soil with excellent rate of infiltration.
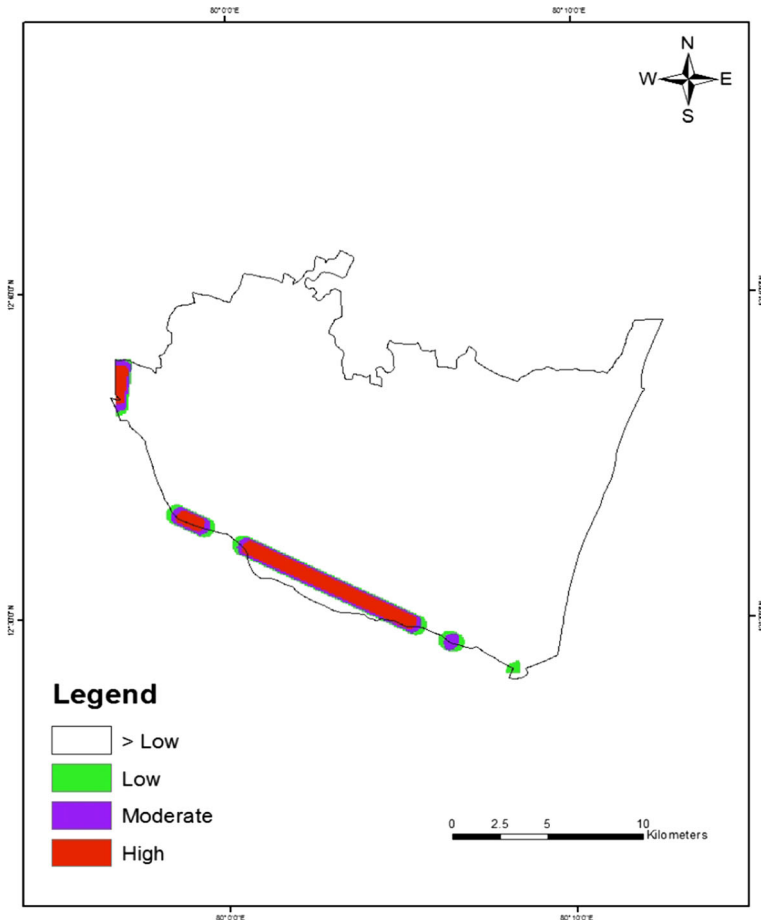

Fig. 6 Lineament density map

Coarse loamy soils are a moderately well drained and possess of fine loams. The moisture content of the fine loam soil is good because of its fine loamy texture. The green forest soil is rich in humus. It is found in the forest land of the study area (Fig. 7).

4.7 Drainage map

Drainage of the study area helps to understand the lithological and structural control of landform evolution. Agricultural activities depend on natural rivers, wells, rain-fed structure, minor irrigation, seasonal rivers, etc. The study area is covered by undulating hilly tract intersected by gorges and passes. Besides one canal, one perennial river is running in the region. Presently, the important source of supply of water is basically water tanks (Fig. 8).
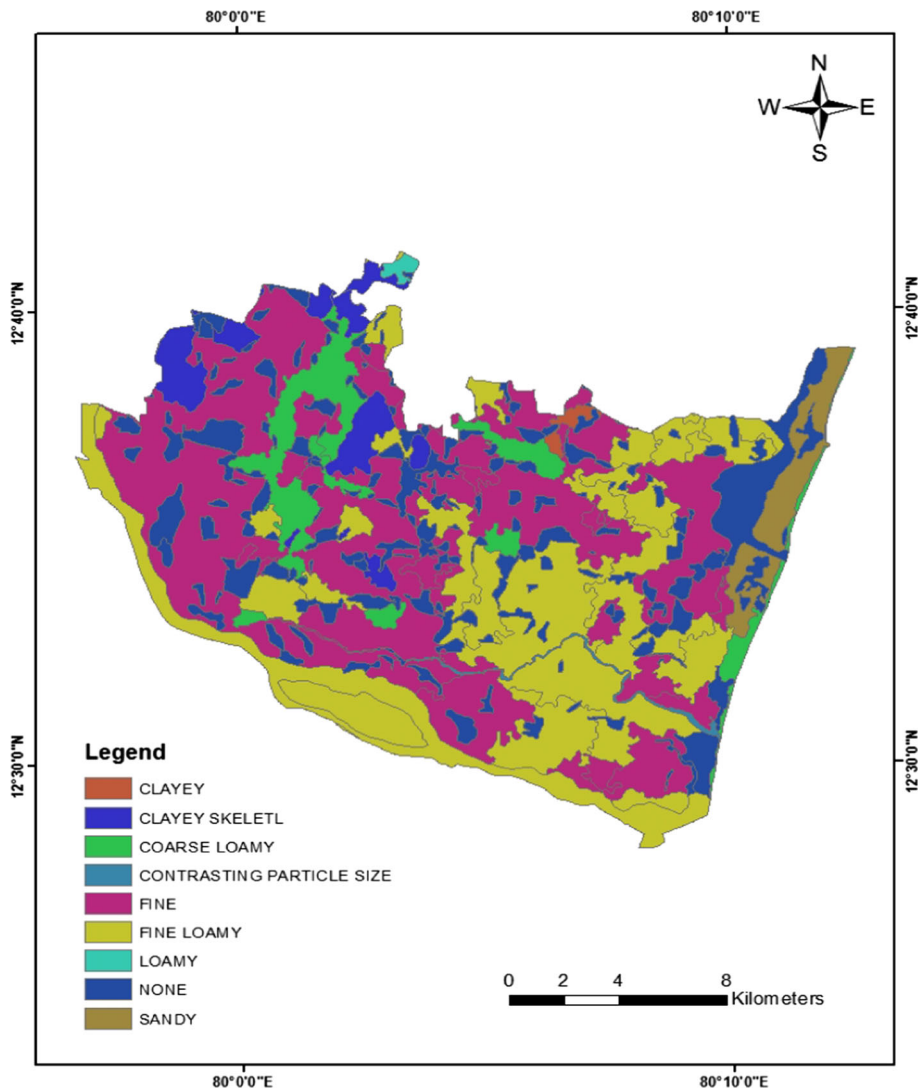

Fig. 7 Soil map

4.8 Drainage density

Drainage density influences the rock permeability and infiltration capacity which in turn influence the recharge capacity (Lemacha 2008). Low drainage density is related to higher recharge and higher groundwater potential. As connectivity between the low-lying areas (tanks) is less, there may be many non-system tanks exist in the study area.
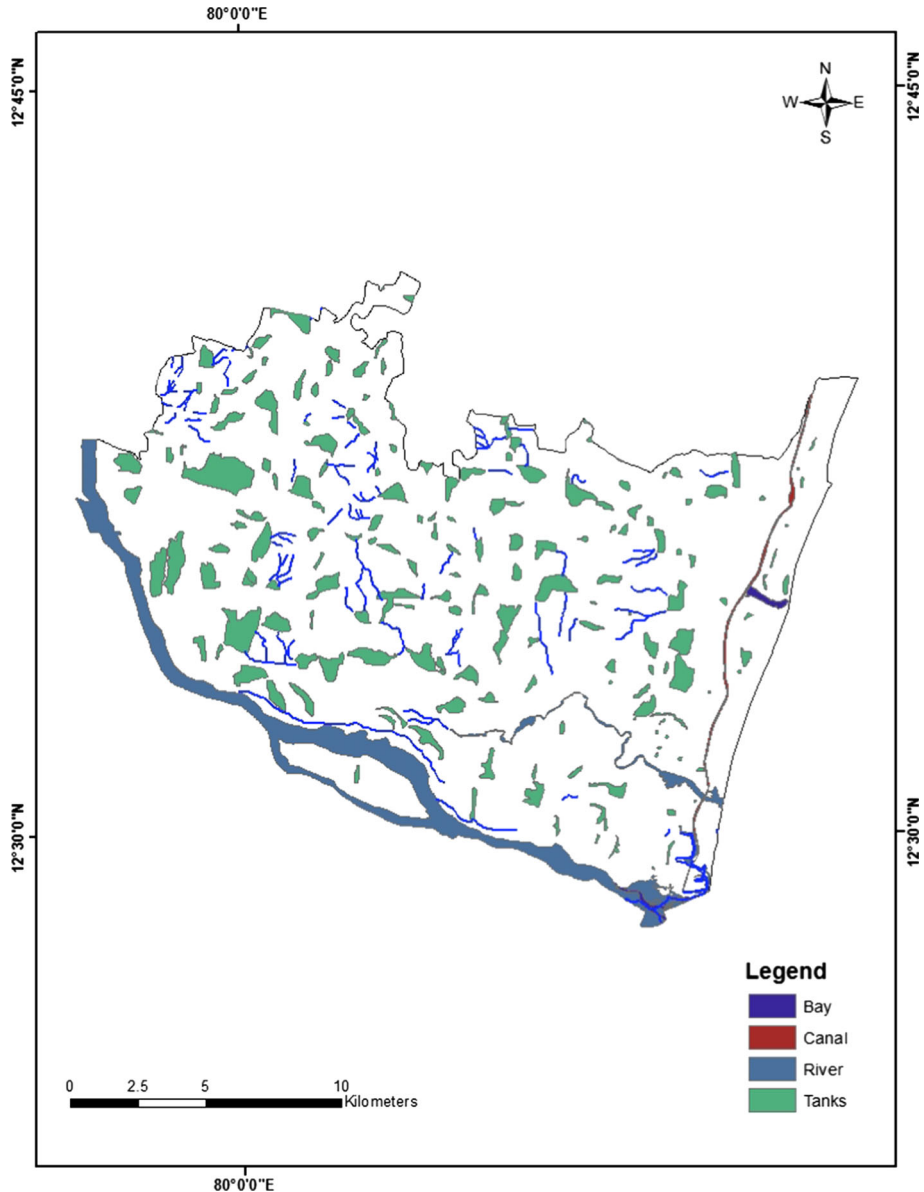

Fig. 8 Drainage map

The surface water stored in these non-system tanks increases the groundwater storage. Drainage density value was grouped into four groups: 0.0–1.8, 1.8–2.9, 2.9–3.9 and 3.9–5. A low drainage density region causes higher infiltration, and it yields better groundwater potential zones as correlated to a high drainage density region. The higher weight was given to the low drainage density regions and a lower weight to the high drainage density areas (Fig. 9).
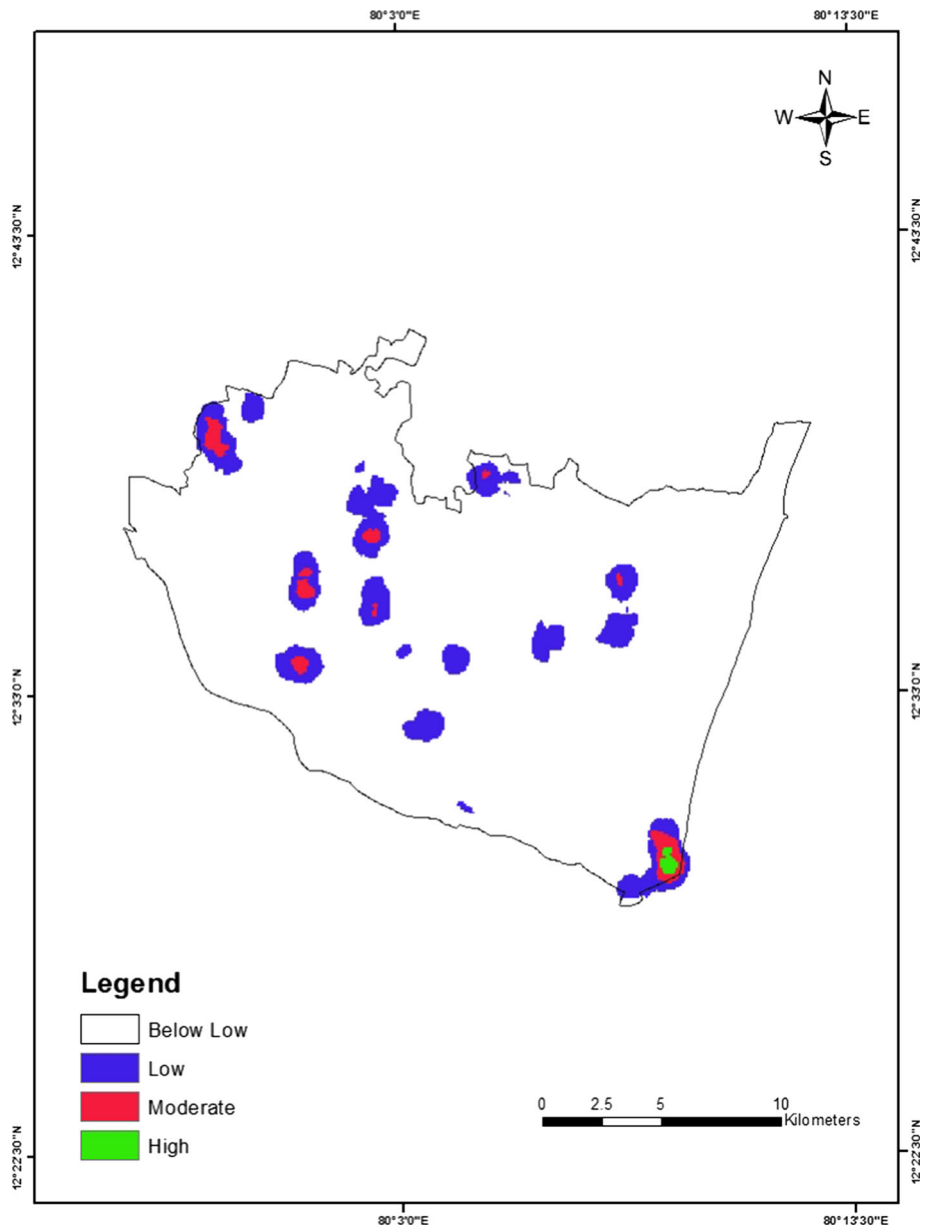

Fig. 9 Drainage density map

4.9 Contour

Slope map was generated from DEM data. Generally, flat terrain is observed except the upper part, which is a hilly terrain with a steep slope varying from 50 to 60%. Slope range was
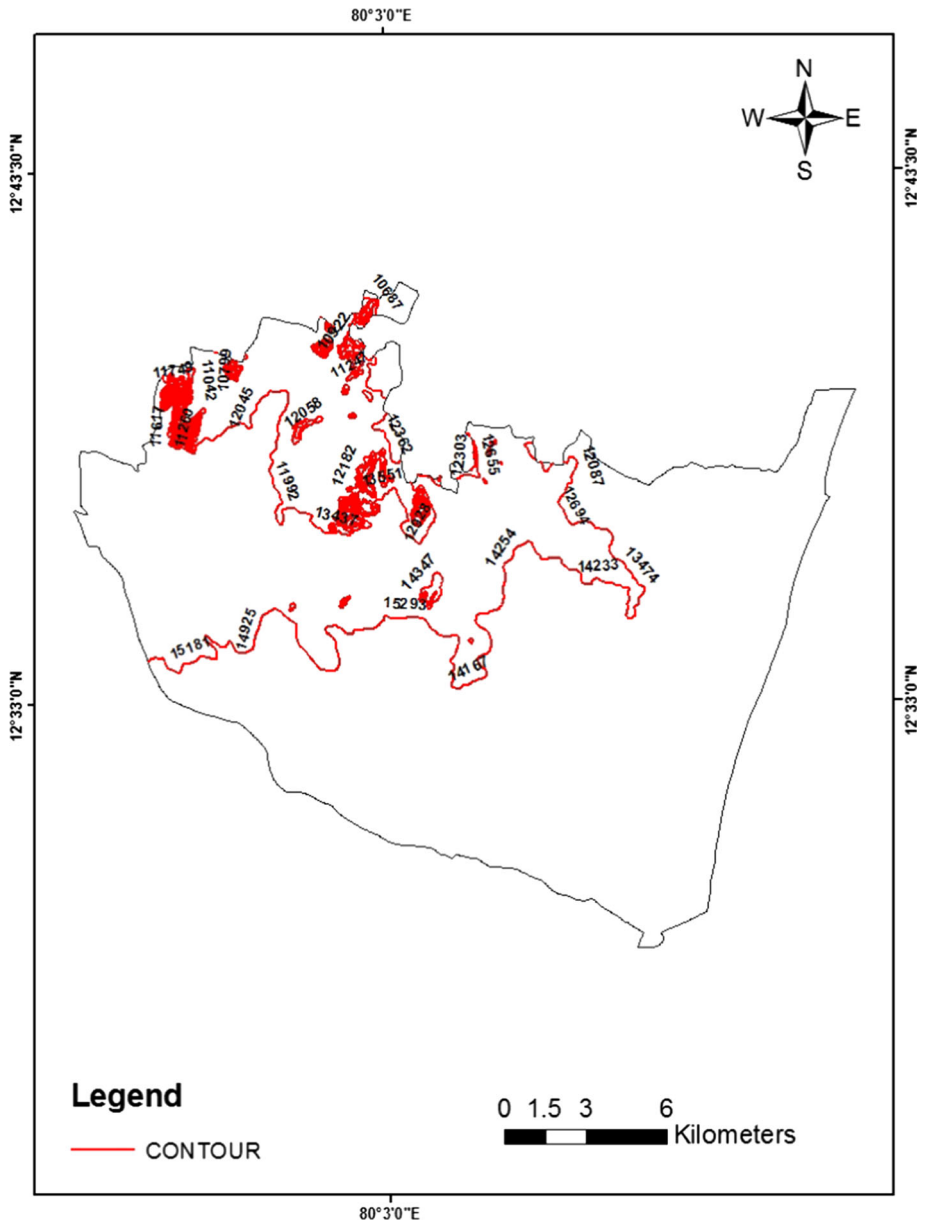

Fig. 10 Contour map

Table 2 Integrated weight range for various groundwater potential zones

Groundwater category	Lower and upper weight table
Below low	0.0–4.0
Low	4.0–6.0
Moderate	6.0–7.0
High	7.0–8.0

differentiated into four groups (20–40, 40–60, 60–80 and 80–120). Steep slope will produce more runoff with lesser infiltration, and it will have a poor groundwater prospects, whereas gentle or flat terrain will have comparatively good groundwater recharge. The higher weights have been assigned to gentle slope and lesser weights to higher slope (Fig. 10).

4.10 Integration of thematic layers for modelling using GIS: weightage index overlay model

Depending upon the groundwater potentiality, each class of the six thematic layers (geomorphology, slope, drainage density, lineament density, soil, land use) is placed into one of the following groups, viz. high, moderate, low and below low. Suitable weights on a scale of '0–8' have been given to each class of a particular thematic layer based on their contribution towards groundwater potential. All the thematic maps have been integrated, and groundwater potential map is prepared. From the analysis, 5% of Voy-alur, Meiyur and Kalpakkam villages located towards the coastal plain area covers high groundwater potential zone. 20% of the area hold moderate groundwater potential zone which includes villages such as Edayathur, Edaiyur and Keelanedu towards north-west and south-west, and 60% of the total area contains low groundwater potential zone in the villages such as Thathalur, Puliyur and Navallur which are located towards south-west direction. 15% of the study area contains below low groundwater potential zone which includes villages Nallur, Poonjeri and Vallipuram towards north and parts of south-west direction (Table 2; Fig. 11).

5 Conclusion

In the present study, groundwater potential zones have been delineated using remote sensing data on GIS platform in Thirukalukundram block of Kanchipuram district, Tamil Nadu, India. The study focussed on mapping various landform units and lineaments. The study area comprises of charnockite gneiss type which is generally massive and does not store or transmit considerable quantity of water except if any fractures are found in it. Geomorphological maps reveal that there are several landforms such as alluvial plain, coastal plain, deltaic hill, denudation hill, flood plain, pediplain and structure hill. Among these landform areas, moderate groundwater potential zones are found near coastal and alluvial plains. The salt pan and river course land use can hold the surface water by which good groundwater potential zones can be found. Lineaments are another indicator of the groundwater potential also found along the river course. As most of the study area has
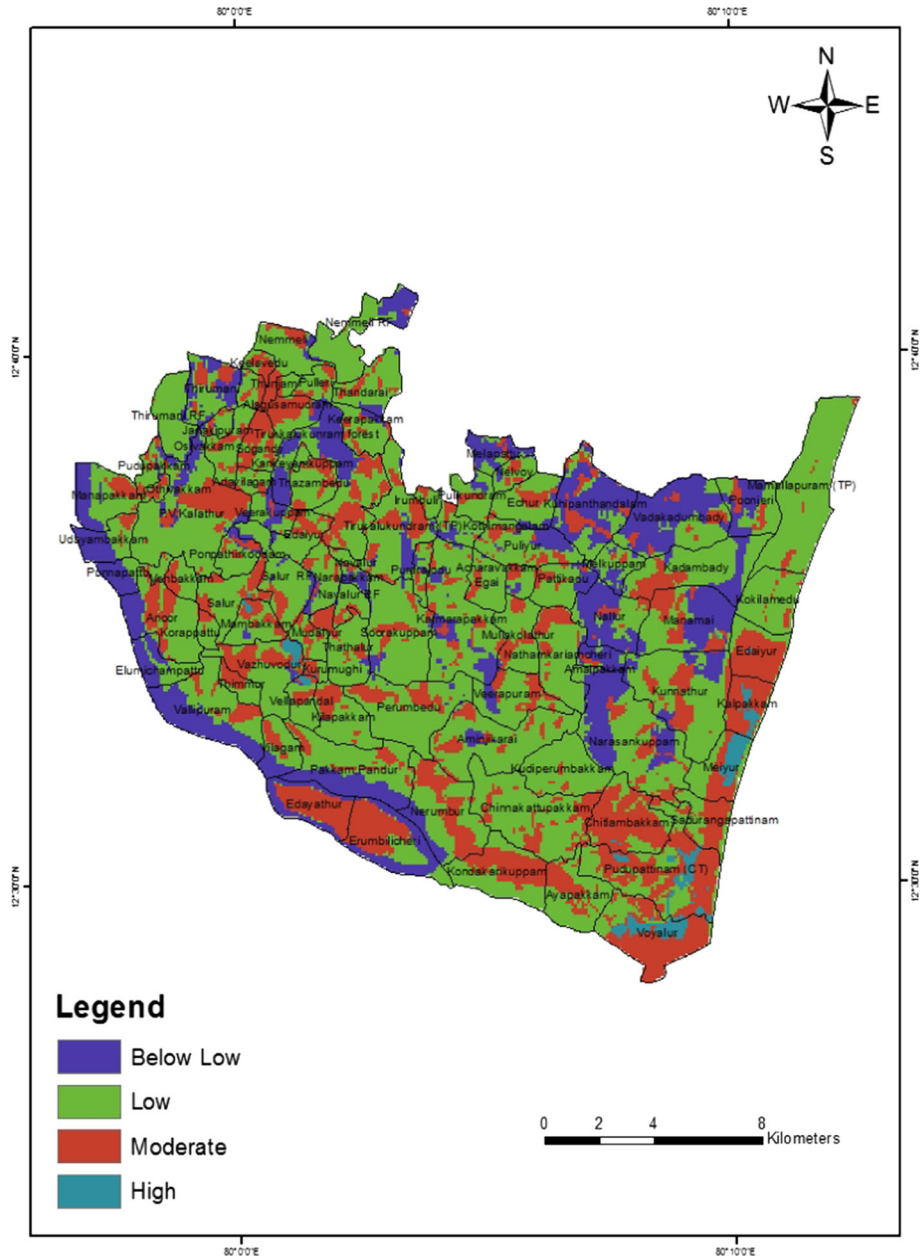
Fig. 11 Groundwater potential map of the study area

gentle slope, non-system tanks are found in many places due to which there may be the variation in the groundwater potential. The thematic maps for the groundwater prospecting zones of the study area are generated by using remote sensing data, toposheet and geo-morphology map in arcGIS software and integrated. The integration of all the thematic maps result in four groundwater potential zones—below low, low, moderate, high—and

the weighted range for various groundwater potential zones was categorized as high zone (7.10–8.00), moderate (6.1–7.0), low (5.1–6.0) and below low (0.0–4.0). The below low zone was indicating the least favourable area for groundwater prospect, whereas high indicates the most favourable area for groundwater prospect. From the analysis, it can be concluded that Thirukalukundram block is found to be utilizing groundwater which exceeds the recharge rate as the groundwater potential is found to be low in major parts of the study area.

References

Ali, H. Y., Prijub, C. P., & Prasad, N. B. N. (2015). Delineation of groundwater potential zones in deep midland aquifers along Bharathapuzha river basin, Kerala using geophysical methods. *Aquatic Procedia, 4,* 1039–1046.

Al-Manmi, D. A. M., & Rauf, L. F. (2016). Groundwater potential mapping using remote sensing and GIS-based, in Halabja City, Kurdistan, Iraq. *Arabian Journal of Geosciences, 9,* 357. doi:10.1007/s12517-016-2385.

Arkoprovo, B., Adarsa, J., & Shashi Prakash, S. (2012). Delineation of groundwater potential zones using satellite remote sensing and geographic information system techniques: A case study from Ganjam district, Orissa, India. *Research Journal of Recent Sciences, 1*(9), 59–66.

Balakrishna, S., Maury, S. B., & Narashimulu, G. (2014). Groundwater in fractured aquifer of Ophiolite formation, Port Blair, South Andaman Islands using electrical resistivity tomography (ERT) and vertical electrical sounding (VES). *Journal of Geological Society of India, 83,* 393–402.

Chowdhury, A., Jha, M. K., Chowdary, V. M., & Mal, B. C. (2009). Integrated remote sensing and GIS-based approach for assessing groundwater potential in West Medinipur district, West Bengal, India. *International Journal of Remote Sensing, 30*(1), 231–250.

Fashae, O. A., Tijani, M. N., Talabi, A. O., & Adedeji, O. I. (2014). Delineation of groundwater potential zones in the crystalline basement terrain of SW-Nigeria: An integrated GIS and remote sensing approach. *Applied Water Science, 4*(1), 19–38.

Genzebu, W., Hassen, N., & Yemane, T. (1994). Geology of the Agere Mariam area (NB37-10). *Ethiopian Institute of Geological Surveys Addis Ababa, 8,* 1–112.

Koch, M., & Mather, P. M. (1997). Lineament mapping for groundwater resource assessment: comparison of digital synthetic aperture radar (SAR) imagery and stereoscopic large format camera (LFC) photographs in the Red Sea Hills, Sudan. *International Journal of Remote Sensing, 18,* 1465–1482.

Krishnamurthy, J., Venkatesa, K. N., Jayaraman, V., & Manivel, M. (1996). An approach to demarcate ground water potential zones through remote sensing and a geographical information system. *International Journal of Remote Sensing, 7*(10), 1867–1884.

Lemacha, G. (2008). *Groundwater potential for upper Tumet catchment, Merge and Komosha woredas, Benishangul-Gumuz region.* Guide for GIS developers, Water Aid Ethiopia and Ripple.

Lokesha, N., Gopalkrishna, G. S., Gowda, H. H., & Gupta, A. K. (2006). Delineation of groundwater potential zones in a hard rock terrain in Mysore district, Karnataka using IRS data and GIS techniques. *Journal of the Indian Society of Remote Sensing, 33*(3), 405–412.

Minor, T. B., Carter, J. A., Chesley, M. M., Knowles, R. B., & Gustafsson, P. (1994). *The use of GIS and remote sensing in groundwater exploration for developing countries* (No. USATEC-R-236). Beloir, VA: Army Topographic Engineering Center Fort.

Oh, H. J., Kim, Y. S., Choi, J. K., Park, E., & Lee, S. (2011). GIS mapping of regional probabilistic groundwater potential in the area of Pohang City, Korea. *Journal of Hydrology, 399,* 158–172.

Prakash, S. R., & Mishra, D. (2013). Identification of groundwater prospective zones by using remote sensing and geoelectrical methods in and around Saidnagar area, Dakor block, Jalaun district, U.P. *Journal of the Indian society Remote sensing, 21*(4), 217–227.

Raghuwanshi, B. V., & Briz-Kishore, B. H. (2008). A methodology for locating potential aquifers in a typical semi-arid region in India using resistivity and hydrogeologic parameters. *Geoexploration, 27,* 55–64.

Sahebrao, S., Satishkumar, V., Amarender, B., & Sethurama, S. (2014). Combined ground-penetrating radar (GPR) and electrical resistivity applications exploring groundwater potential zones in granite terrain. *Arabian Journal of Geosciences, 7,* 3109–3117.

Saraf, A. K., & Choudhury, P. R. (1998). Integrated remote sensing and GIS for ground water exploration and identification of artificial recharges sites. *International Journal of Remote Sensing, 19*(10), 1825–1841.

Senanayake, I. P., Dissanayake, D. M. D. O. K., Mayadunna, B. B., & Weerasekera, W. L. (2016). An approach to delineate groundwater recharge potential sites in Ambalantota, Sri Lanka using GIS techniques. *Geoscience Frontiers, 7,* 115–124.

Senthil Kumar, G. R., & Shankar, K. (2014). Assessment of groundwater potential zones using GIS. *Frontiers in Geosciences, 2*(1), 1–10.

Shah, T. (2007). The groundwater economy of South Asia: An assessment of size, significance and socio-ecological impacts. In M. Giordano & K. G. Villholth (Eds.), *The agricultural groundwater revolution: Opportunities and threats to development. Comprehensive assessment of water management in agriculture series 3* (pp. 7–36). Wallingford: CABI.

Venkateswaran, S., Vijay Prabhu, M., & Karuppannan, S. (2014). Delineation of groundwater potential zones using geophysical and GIS techniques in the Sarabanga Sub Basin, Cauvery River, Tamil Nadu, India. *International Journal for Current Research and Academic Review, 2,* 58–75.