Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
e-ISSN: 2395-3454
Vol. 18 | No. 1 | pp. 183-189 | 2019

Original Research Paper | Open Access

Identification of Artificial Recharges Structures Using Remote Sensing and GIS for Arid and Semi-arid Areas

R. Chandramohan*†, T.E. Kanchanabhan and N. Siva Vignesh*****
*Department of Civil Engineering, Vignan's Lara Institute of Technology and Science, Guntur-522213, India
**Department of Civil Engineering, Bharath University, Chennai-600073, India
***Department of Civil Engineering, Anna University, Chennai-600025, India
†Corresponding author: R. Chandramohan

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 15-05-2018
Accepted: 02-08-2018

Key Words:
Artificial recharge structure
Groundwater recharge
Remote sensing
GIS
Hydrology

ABSTRACT

Extensive and poorly regulated groundwater extraction to cater to agricultural, industrial, and domestic needs has severely depleted natural groundwater levels in arid and semi-arid areas. Suitable artificial recharge structures can serve as viable options for increasing groundwater levels in areas dependent on aquifers as their water source. Potential sites and suitable artificial recharge structures were suggested to recharge the groundwater level of the study area. The paper's aim is to facilitate an increase in aquifer recharge during non-rainfall days in the study area and contribute to sustainable groundwater conservation during periods of poor water availability by using remote sensing and GIS.

INTRODUCTION

Groundwater is essential for daily human sustenance. However, significant quantities of groundwater are being extracted in a poorly regulated manner for irrigation, domestic, and industrial needs (Chandramohan et al. 2017a). In India, especially in Tamil Nadu, farmers mainly depend on aquifers during non-monsoon periods. Natural recharge of the underground water basin is limited to 10 to 100 rainfall days in most arid or semi-arid areas. Moreover, most rainwater is lost through outflow during the monsoon periods. Artificial refilling techniques are frequently employed to transfer the surface water to underground water storage and aquifers during excess surface water availability. Artificial recharge structures can help conserve and store excess surface water for future use and can potentially improve the sustainable water yield in zones where aquifers have been depleted due to excessive extraction.

In light of high demand of water for urban and irrigation needs during the post-monsoon periods, technologies such as Remote Sensing (RS) and Geographical Information System (GIS) are frequently employed to identify spatial patterns in water demand and availability. These tools are very useful in identifying proper sites for artificial recharge structures. Also, artificial recharging in specific sites and replication techniques are based on local environmental and hydrological conditions (CGWB 2000).

Artificial groundwater recharge has usually been conducted in the following areas: Regions where groundwater levels shrink regularly, regions where several aquifers have already been desaturated, regions where the availability of groundwater is insufficient in the months of scarcity, and regions where salinity has increased. Some of the researchers have used Rain Water Harvesting (RWH) as an artificial recharge to reload underground water. However, much of the literature considers RWH as a part of the "aquarium managed recharge", which also includes artificial recharge, landfill, water activity, and sustainable underground storage (Gale et al. 2005).

Ramireddy et al. (2015), used thematic maps including slope, drainage, drainage density, and lineament density maps to identify sites for suitable artificial recharge structures such as desiltation of tanks, flooding and furrowing, percolation ponds, check dam, pitting and batteries of wells, en-echelon dam, and hydrofracturing to increase the groundwater level.

The researchers Anbazhagan (1994), Anbazhagan & Ramasamy (1993) and Missimer et al. (2012) have focussed on the application of remote sensing and GIS in the selection of artificial recharge zones. Combination of thematic layers (water level, rainfall, lineament, and others) is implemented by Samson & Elangovan (2015) to find suitable artificial recharge zones. Rokade et al. (2004) mentioned

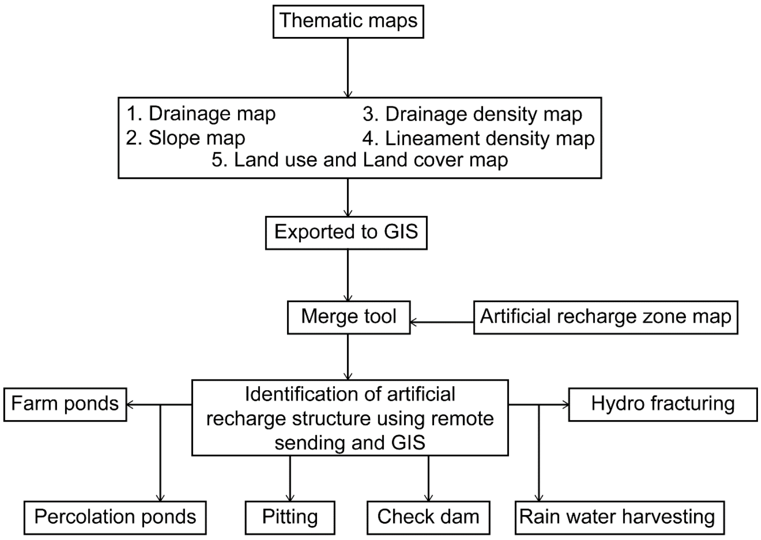

Fig. 1: Methodology for identification of artificial recharge structure using remote sensing and GIS.

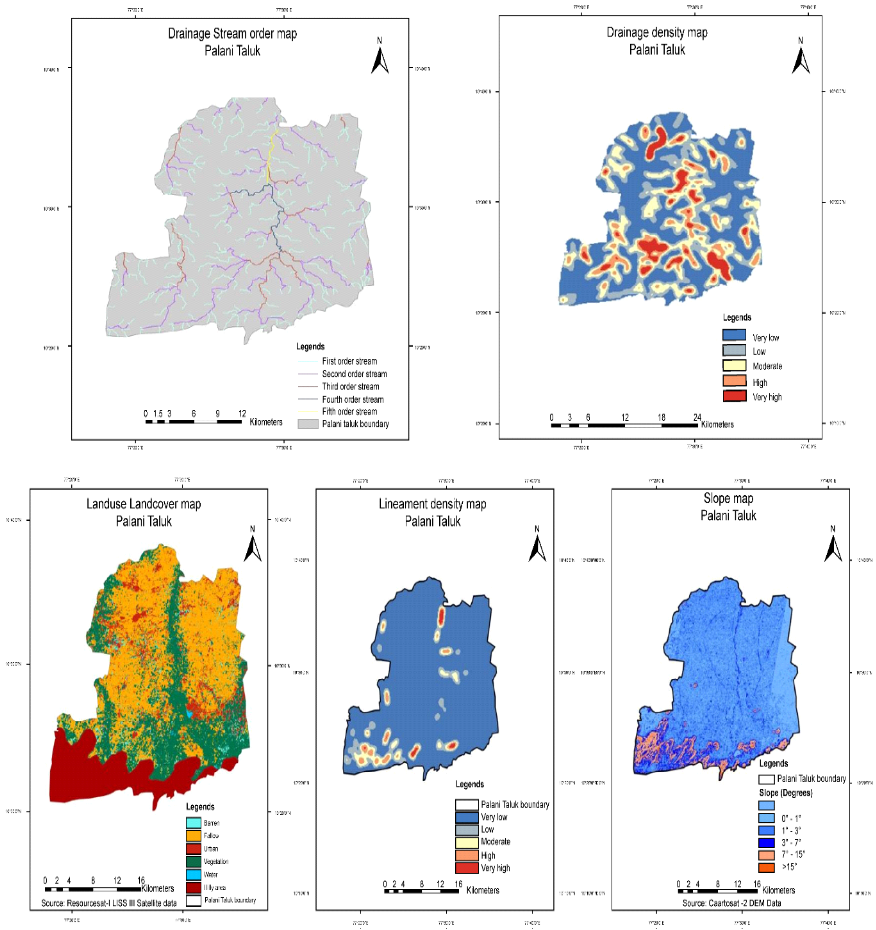

Fig. 2: Thematic maps used to identify artificial recharge structures (Source: Chandramohan et al. 2017b).

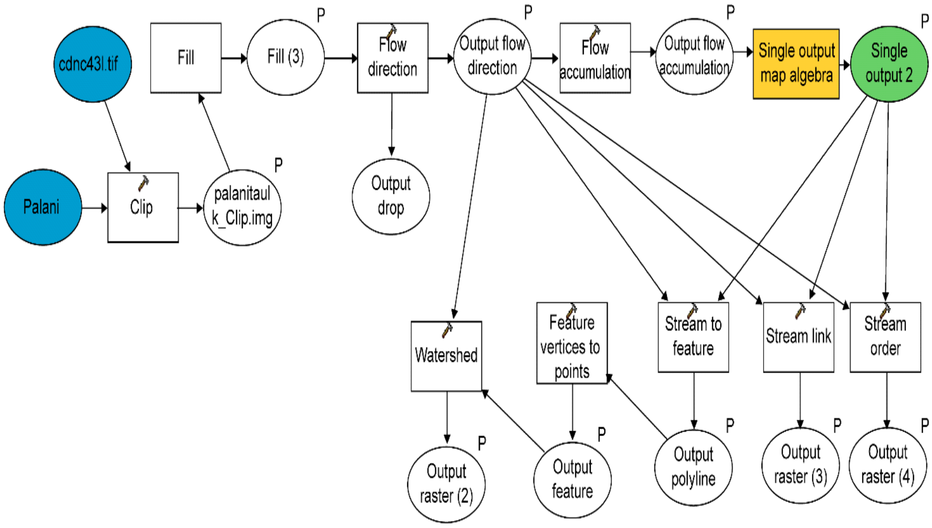

Fig: 3. Drainage catchment area delineation using GIS model.

Table 1: Thematic map combinations used to generate artificial recharge structures.

S.No	Artificial recharge structure	Thematic map combinations
1.	Check Dam	Drainage map (convergence points)
2.	Farm Ponds	Drainage map (first stream order)
3.	Percolation Ponds	Micro watershed and slope map
4.	Rain Water Harvesting	Land use land cover map
5.	Pitting	Drainage density map
6.	Hydro Fracturing	Lineament density and drainage density map
7.	Flooding and furrowing	Slope map (0° to 1°) and low drainage density map

that groundwater has become crucial and it becomes mandatory to identify potential groundwater zones and monitor and conserve this important resource.

Currently, groundwater level of the Palani Taluk in Dindigul District is very poor and artificial recharge structures are urgently required to address the rapidly depleting groundwater levels. This paper uses remote sensing and GIS to identify potential sites in the study area that will benefit from the implementation of artificial recharge structures. Further, a series of thematic maps and GIS tools are employed to suggest the type of artificial recharge structures best suited to the particular sub-regions.

MATERIALS AND METHODS

The study area included the Palani Taluk in Dindigul District in Tamil Nadu, India, which is expanded over an area of 766.83 km^2. The latitudes of the study area are between 10°20’2” N to 10°38’24” N and longitudes are between 77°18’6” to 77°35’41”. Topography includes mountains, which cover an area of 116.85 km^2 (Chandramohan et al. 2017a, 2017b). The principal source of groundwater is precipitation. The average rainfall during the 33 years (1980 - 2013) was 690 mm. The depth of groundwater varies between 4 m and 11.7 m in Palani Taluk.

Thematic maps combinations that were used to identify various artificial recharge structures are listed in Table 1. Sites that were appropriate for the implementation of artificial recharge structures were identified following the methodology described by Chandramohan et al. (2017b). The methodology employed for identifying artificial recharge structures using remote sensing and GIS is illustrated in Fig. 1.

Palani Taluk maps were primed from Dindigul TWAD (Tamil Nadu Water Supply and Drainage) Board and georeferenced by using Geological Survey of India Toposheet No. 58 F[10]. Thematic layers of drainage maps and slope maps were primed from Cartosat-I, DEM data.

The lineament map and land use and land cover map were generated using Resourcesat-I, LISS III Image. The the-

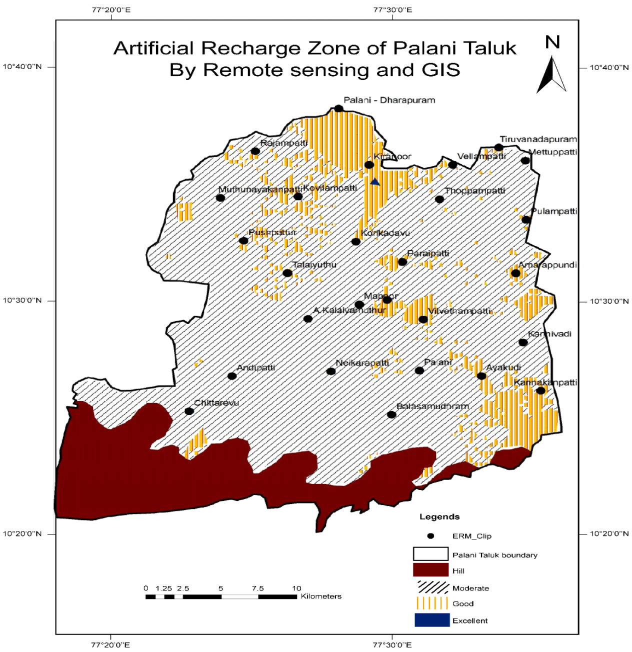

Fig. 4: Artificial recharge zone map of Palani taluk (Chandramohan et al. 2017b).

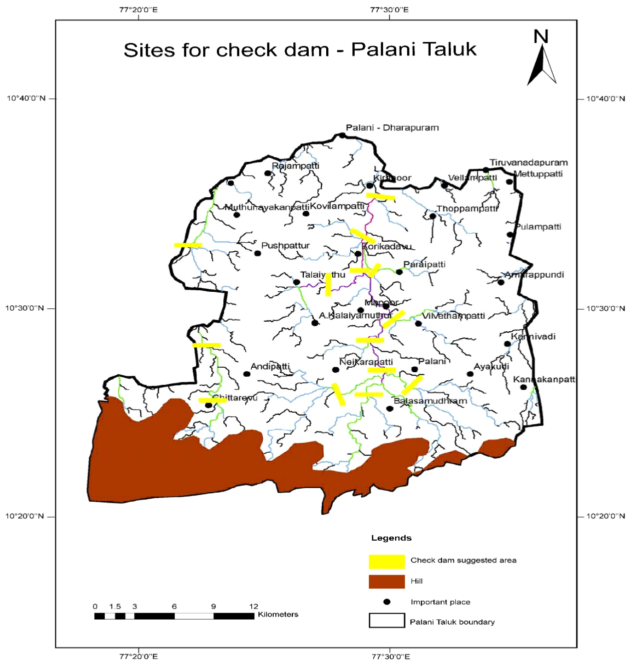

Fig. 5: Potential sites for check dams.

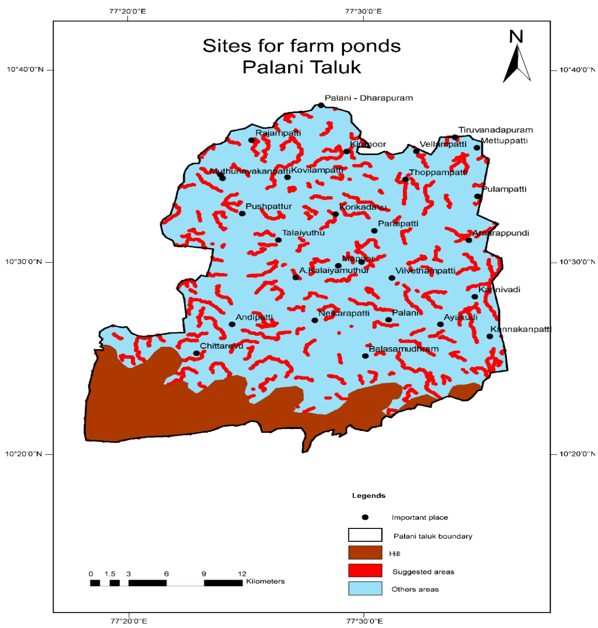

Fig. 6: Potential sites for farm ponds.

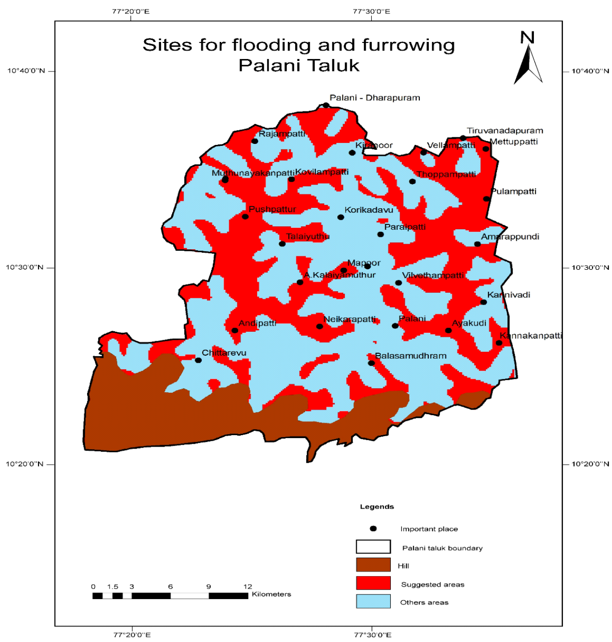

Fig. 7: Potential sites for flooding and furrowing.

matic maps (Fig. 2) and artificial recharge zone map (Fig. 4) were exported to GIS for further analysis using the merge tool.

The artificial recharge map (Fig. 4) generated by the study, revealed that the study area comprised of moderate to excellent artificial recharge regions. Most of the area in the Palani taluk falls under moderate artificial recharge zones, (Chandramohan et al. 2017b). Few regions on the northern

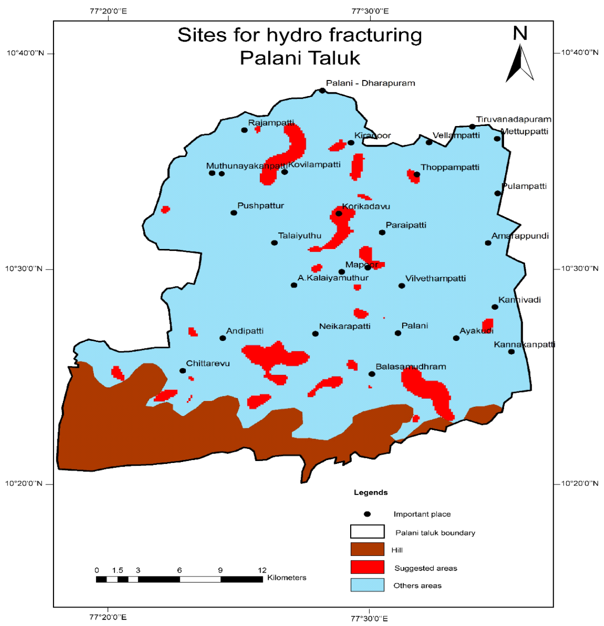

Fig. 8: Potential sites for hydro-fracturing.

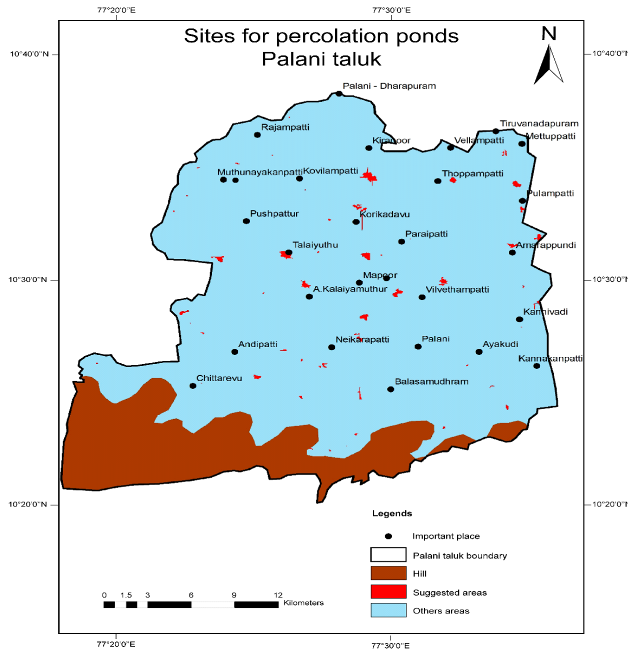

Fig. 9: Potential sites for percolation ponds.

and south-eastern parts can be categorized as good artificial recharge zones. A small area in the northern side exhibits excellent artificial recharge zone. Nearly, 71.37% of the total area is represented by moderate artificial zones; excellent artificial recharge zones account for only 0.04% of the total area, and good artificial recharge zones account for 13.29% of the total area.

RESULTS AND DISCUSSION

Check dams: The drainage map was prepared from Cartosat-I DEM image utilizing remote sensing and GIS software. The drainage convergence point areas in the drainage map were sorted using GIS software and integrated with artificial recharge zones (Fig. 4), which were categorized as good, moderate, or excellent. The check dam areas suggested for the Palani taluk are shown in Fig. 5. Most of the areas suitable for check dams are important drainage regions. The major drainage regions in the Palani taluk hilly area are situated in the southern part and flow towards the Thiruppur district located on the north side of the taluk. This drainage is a major sub-basin of the Amarathi River, which later joins the Cauvery River.

Farm ponds: Farm ponds suggestions for the area were also identified from the drainage map. The existing drainage map was demarcated based on the stream orders using the GIS model. First to fifth order drainage can be observed in the Palani taluk, as shown in Fig. 2. First stream order drainages need to be selected for farm pond sites. GIS tools were used to the selected first-order drainage maps from the other stream order drainage maps and were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. Farm pond suggestions were located throughout the Palani taluk, as indicated in Fig. 6. Rajanpatti, Kiranoor, Thoppampatti, Vellampatti, and A. Kaliyamuthur locations were the most suitable for farm ponds artificial structures.

Flooding and furrowing: Lineament density and slope maps were required to identify areas suitable for flooding and furrowing artificial recharge methods. Low drainage density areas were selected and integrated with flat surface areas (0° to 1° slope) to generate areas suitable for flooding and furrowing; these were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. Areas suggested for flooding and furrowing are shown in Fig. 7. Most of the prominent locations in the Palani taluk were suitable for flooding and furrowing artificial structures. The important locations included Ayakudi, Kannivadi, Kannakanpatti, Palani, Amarapundi, Pulaampatti, Mettupatti, Tiruvanadapuram, Vellampatti, Kovillampatti, Muthunayakanpatti, Pushpathur, Talaiyuthu, Andipatti, A. Kalaiyamuthur, Mapoor, Neikarapatti, and Balasamudhram.

Hydrofracturing: Lineament density and drainage density maps were used to identify areas suitable for hydrofracturing. High drainage density regions were filtered from the drainage map; very high lineament density maps were filtered from the lineament density map in the GIS environment and

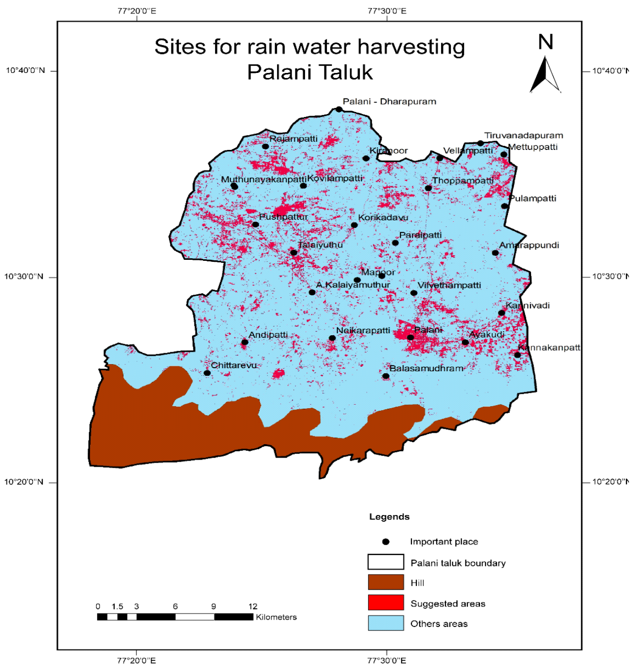

Fig. 10: Potential sites for rainwater harvesting.

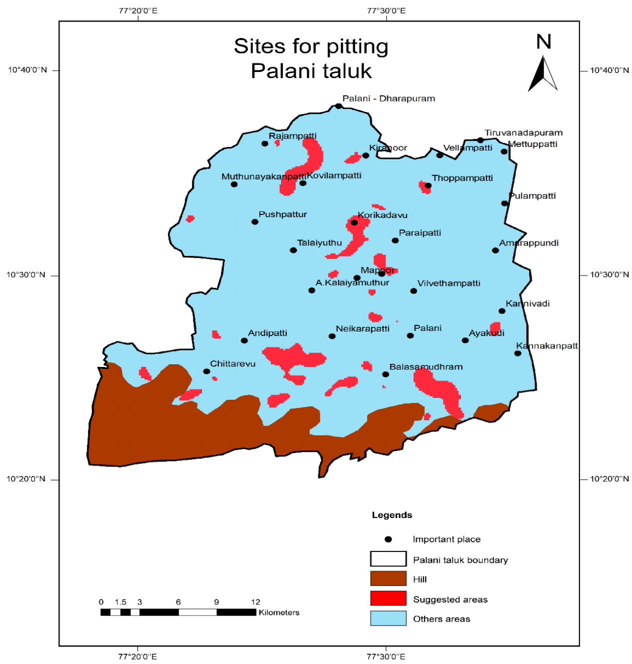

Fig. 11: Potential sites for pitting.

were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. The very high drainage density maps were incorporated into very high lineament density maps using the GIS integrated tool to identify areas suitable for hydrofracturing in the study region, as shown in Fig. 8. Korikadavu and Thoppampatti locations in Palani taluk were well-suited for hydrofracturing artificial structures.

Percolation ponds: Area suggestions for percolation ponds were primed from slope maps and drainage catchment area maps. Drainage catchment area map prepared using the GIS model is shown in Fig. 3. Percolation pond areas should have a shallow slope region and micro drainage catchment. Suggested areas for percolation ponds were generated from micro drainage catchment areas that were selected from the drainage catchment map using GIS and were superimposed with shallow slope regions of the study area. Selected areas were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. The results are illustrated in Fig. 9. Talaiyuthu was the most suitable location for the percolation pond artificial structure.

Rainwater harvesting: Suggested areas for rainwater harvesting were selected from land use and land cover maps of the study area. Land use and land cover map were primed from Resourcesat-I, LISS III satellite imagery. Classification tool of the remote sensing software was used to categorize the satellite images into various land use and land cover types, which were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. Areas suggested for rainwater harvesting are shown in Fig. 10. Palani, Ayakudi, Kannivadi, Kanakkanpatti, Talaiyuthu, Pushpathur, and Thoppampatti regions are well-suited for rainwater harvesting artificial structures.

Pitting: The drainage density map generated using GIS density tool was used to locate suitable sites for pitting in the study area. Areas with very high drainage density were identified and were integrated with artificial recharge zones (Fig. 4) categorized as good, moderate, or excellent. Suggested areas for pitting in Palani are shown in Fig. 11. Most of the pitting areas fall in the southern part of the Palani taluk, which is near the hilly regions. Korikadavu and Thoppampatti locations were suitable for pitting artificial structures.

CONCLUSIONS

In this study, de-saturated aquifers and locations that could potentially benefit from artificial recharge techniques were assessed in the Palani taluk in Tamil Nadu, India. Suitable sites for implementing artificial recharge structures were identified using land use and land cover maps, slope, lineament density, drainage, drainage density, and micro-drainage catchment area maps of the study area. Artificial recharge zones that were identified as good, moderate, or excellent were merged with various thematic layers using GIS software and one or more appropriate artificial structures for a particular location were identified. Construction of artificial recharge sites will improve groundwater level and quality in and around the artificial recharge structure area. Temporal and seasonal variation in water demand can be monitored and appropriate recharge structures can be implemented to minimize water scarcity for irrigation and urban uses during non-rainfall periods. Thus, the artificial recharge structure maps generated using GIS in this study can be used for the construction of suitable recharge structures that will increase the groundwater level and groundwater quality and offer a long-term solution for seasonal water scarcity in the region.

REFERENCES

Anbazhagan, S. 1994. Remote sensing based integrated terrain analysis for artificial recharge in Ayyar Basin, central Tamil Nadu, India. PhD thesis. School of Earth Sciences, Bharathidasn University, Tiruchirapalli.

Anbazhagan, S. and Ramasamy, S.M. 1993. The role of remote sensing in the geomorphic analysis for water harvesting structures. Proceedings of the National Seminar on Water Harvesting, June 25-26 at Dept. Of Civil Engg., Regional Engineering College, Tiruchirapalli.

Centre Ground Water Board (CGWB). 2000. Guide on Artificial Recharge to Ground Water. The Government of India - Ministry of Water Resource.

Chandramohan, R., Kanchanabhan, T.E., Siva Vignesh, N. and Krishnamorthy, R. 2017a. Groundwater fluctuation in Palani Taluk, Dindigul district, Tamilnadu, India. International Journal of Civil Engineering and Technology, 8(7): 1041-1049.

Chandramohan, R., Kanchanabhan, T.E., Siva Vignesh, N. and Krishnamorthy, R. 2017b. Remote sensing and GIS based approach for delineation of artificial recharge sites in Palani Taluk, Dindigul District, Tamilnadu, India. International Journal of Civil Engineering and Technology, 8(8): 698-706.

Gale, I. and Dillon, P. 2006. Strategies for managed aquifer recharge (MAR) in semi-arid areas. United Nations Environment Programme, Division of Technology, Industry and Economics, UNESCO IHP.

Missimer, T.M., Drewes, J.E., Amy, G., Maliva, R.G. and Kel, S. 2012. Restoration of Wadi aquifers by artificial recharge with treated waste water. Groundwater, 50(4): 514-527.

Ramireddy, P.V., Padma, G.V. and Reddy, N.B. 2015. Identification of groundwater recharge zones and artificial recharge structures for part of Tamilnadu, India - a geospatial approach. International Journal of Engineering Sciences & Research Technology, 4(7): 999-1009.

Samson, S. and Elangovan, K. 2015. Delineation of groundwater recharge potential zone in Namakkal district, Tamilnadu, India, using remote sensing and GIS. Journal of the Indian Society of Remote Sensing, 43(4): 769-778.

Rokade, V.M., Kundal, P. and Joshi, A.K. 2004. Water resources development action plan for Sasti watershed, Chadrapur district, Maharashtra using remote sensing and geographic information system. Journal of the Indian Society of Remote Sensing, 32(4): 359-368.