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Original Article

GEO-SYSTEM BASED AQUIFER DEVELOPMENT THROUGH ARTIFICIAL RECHARGE IN PUDUKKOTTAI DISTRICT, TAMIL NADU, INDIA.

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Abstract

Water has become a scarce resource all the World. Water resources of Earth can be classified as surface water and groundwater in which groundwater is the main source for the drinking, domestic and agriculture. The Pudukkottai district is one of the chronic drought prone areas in Tamil Nadu. But, at the same time, the district is pitted with over 5,400 tanks/water bodies widely distributed throughout in general and clustered more in Vellar delta in particular, as the interlobel depressions have provided basic depressions for the surface water to accumulate. However, these surface water bodies are heavily silted. In Pudukkottai district, there are three divergent aquifer systems, hard rock aquifer system in the western, sedimentary aquifer system constituted by the Tertiary Sandstone (Cuddalore Sandstone) in the central and quaternary aquifer system constituted by fluvial, fluvio-marine and marine systems in the eastern parts of the district. Though, a hierarchy of data is available with many agencies viz: monthly water level data for the past nearly three decades, borehole lithology, geophysical resistivity data, etc., not much of holistic and comprehensive studies have been done especially using the virtues available with Remote Sensing technology involving various Image Processing techniques and GIS using 3D visualization to understand the subsurface geology, aquifer parameters, etc. which could provide vital information for water management. So in the present study, these advanced tools were utilized deservingly to understand water resources for further effective planning. After generating the above buffered GIS layers, overlay functions were executed and the areas of coincidence of more than 3 to 5 variables were buffered out as suitable area for artificial recharge and most of the area fell under this category. The subsurface/groundwater is a very important resource having direct bearing over various developmental planning. The occurrence and the mobility of groundwater vary from aquifer system to aquifer system. In hard crystalline rocks, it is controlled predominantly by the fracture systems and their dynamics. In contrast, in layered sedimentary formations, the groundwater and its behaviour is controlled by primary porosity, type of layering, the rhythmicity of the layers, their compaction etc. and accordingly groundwater occurs in artesian/sub artesian/ confined/semi confined conditions etc. In Quaternary formations, again groundwater availability and the aquifer performance depends on primary porosity and the type/nature of layering. But, in the case of Quaternaries, the morphology and dimension of the layering will be very small when compared to the sedimentary formations, like Tertiary Sandstones and accordingly the groundwater behaviour will vary. Further, as it is a hidden resource, detailed understanding is essential before framing any developmental strategies for groundwater development. So, detailed Geomatics based studies were carried out in understanding the suitable technique in the particular artificial recharge zones.

Key Words: Geomatics, GIS, Artificial Recharge, Groundwater

1.0 INTRODUCTION

Water has become a scarce resource all the World. Water resources of Earth can be classified as surface water and groundwater. The total volume of groundwater is only 0.65% of the total water availability of the globe. Groundwater is the main source for the drinking, domestic and agriculture. Hence, the groundwater is the precious resources, in order to ensure a sensible use of groundwater the proper evaluation and management is required. The phenomenal population explosion and the resultant needs could not be satisfied with available surface water resources. Further, due to various anthropogenic activities, the surface water resources too substantially stand prone for pollution. Hence, the man has started mining the groundwater massively; such massive mining of groundwater has led to the drastic decline of water table the World over. Depletion induced quality deterioration, over pumping triggered salt water intrusion along the coastal aquifers, etc., has caused serious in adequacies in groundwater resources too. Hence, the Geoscientists, the World over, have started studying the anatomy, morphology, functions, performance etc. of the groundwater reservoirs.

1.1 Location of Study Area

The study area, Pudukkottai district, is located in the southeastern tip of Tamil Nadu state, India (Fig.1). The study area is bounded in the North and Northwest by Tiruchirappalli district, in the West, Southwest and South by Sivaganga district, in the Southeast by Bay of Bengal and in the East and Northeast by Thanjavur district. The study area (Pudukkottai district) is located in between North latitudes 9° 50’ 00” and 10° 40’ 00” and East longitudes 78° 25’ 00” and 79° 15’ 00”. The area falls in parts of the Survey of India topographic sheets viz: 58 J/6, 7, 8, 10, 11, 12, 14, 15, 16, 58 N/2, 3, 4, 8, 58K/13 and 58 O/1.

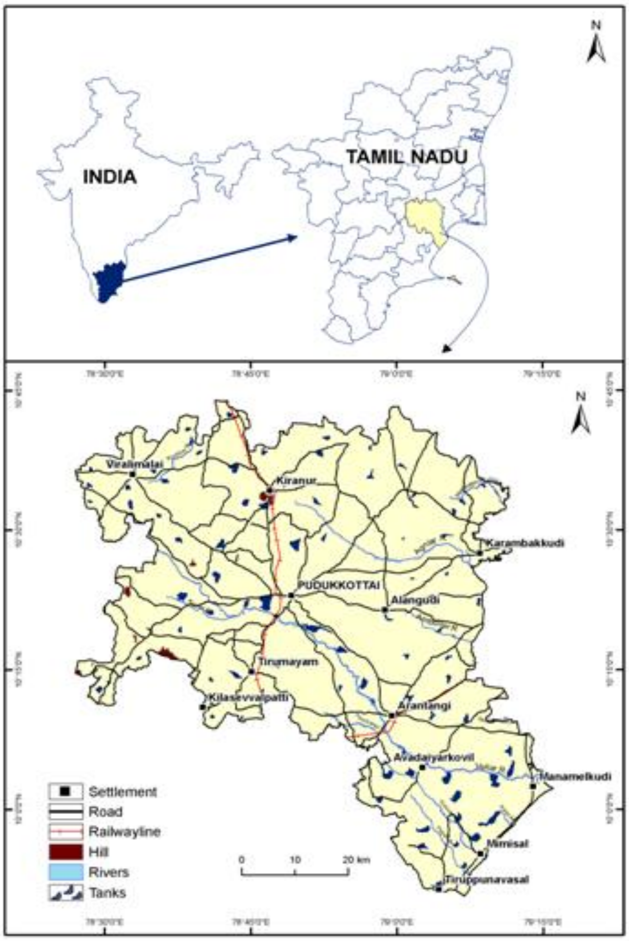


Fig.1 Location of Study Area

2.0 AIM AND OBJECTIVES

The aim and objectives of the present study is to preparation of different various thematic layers for Pudukkottai district of Tamil Nadu using the Remote Sensing and GIS techniques

1. Preparation of various thematic layers such as Lithology, Drainage, Drainage density, Lineament, Lineament density, Geomorphology, Land use and Land cover using Satellite data.
2. Finally selection of suitable sites for Artificial Recharge zones

3.0 METHODOLOGY

Geo-systems play a vital role in artificial recharge of aquifer systems too. The difference between natural recharge and artificial recharge is that the natural recharge is a process in which the porous geo-systems where natural recharge is already going on are identified and motivated to accelerate the pace of recharge, whereas in artificial recharge even the inert geo-systems are activated to absorb water during rains. By duly interpreting the raw and digitally enhanced IRS-1D satellite images, Survey of India topographic sheets, collateral data, etc., various geo-system maps were Hydrological systems.

A large number of Scientists have carried out studies for selecting suitable site as well as for detecting site specific mechanisms for artificial recharge. Some of the significant studies are **Marelette (**1968), **Dvoracek** and **Peterson** (1970)**, Bhowmick (**1992)**, Ramasamy** and **Anbazhagan (**1994), **Boopathi** (1998), **Saraf** and **Choudhury** (1998) and **Ramasamy *et al.*** (2001b). Hence by duly considering the same, geo-systems based artificial recharge methodology was evolved as shown in flow chart Fig.2.

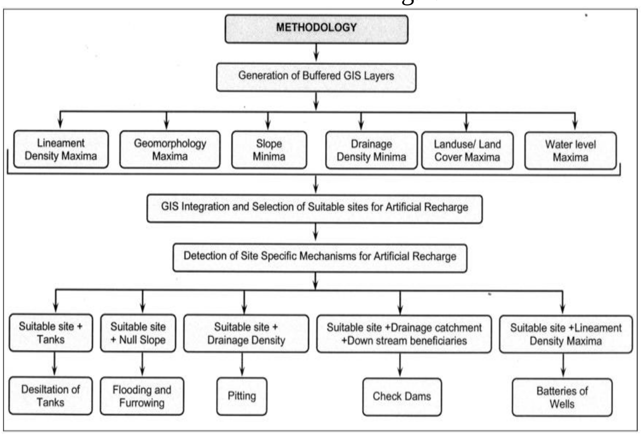
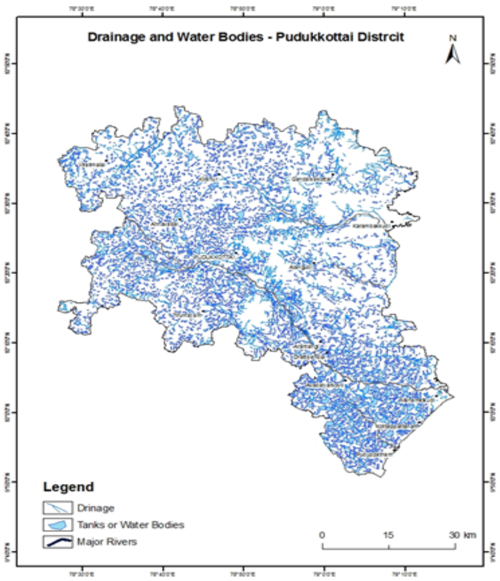


Fig.2 Methodology – Site Selection and Mechanism Detection for Artificial Recharge

4.0 SITE SELECTION FOR ARTIFICIAL RECHARGE

4.1 Drainage and Drainage Density Map

In the context of potential Quaternary geological records embedded in fluvial systems, the detailed drainage map was prepared for the study area using the Survey of India toposheets of 1976. These drainages were updated using IRS 1D FCC Satellite image of 2004. The drainages of the study area overall belong to three major drainage systems viz: Agniar, Ambullar and Vellar rivers, all of which are flowing towards easterly to south easterly and meet Bay of Bengal Fig.3. However, amongst these three rivers, the Vellar river seems to be the major river in the study area. While all these rivers are flowing south easterly, the river Koraiyar found in the northwestern part of the study area, near Viralimalai, flows towards northeasterly and meets the Cauvery river at Tiruchirappalli, which inturn meets Bay of Bengal far north east of the confluencing points of the above three rivers. Again, amongst the other rivers, the Vellar river has a network of distributaries and the major amongst them are Koluvan Ar and Papan Ar rivers.



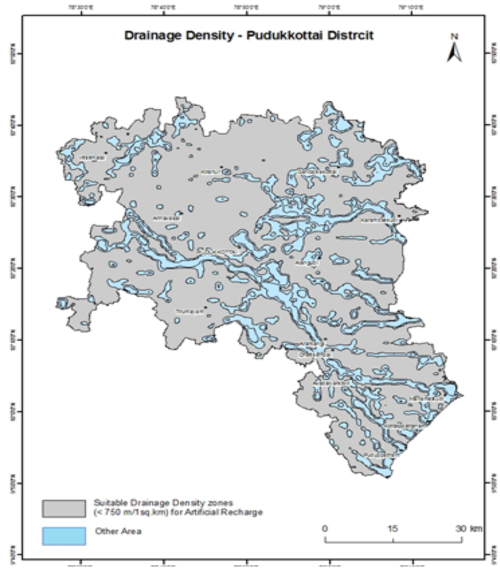


***Fig.3** Drainage Map* ***Fig.4** Drainage Density Map*

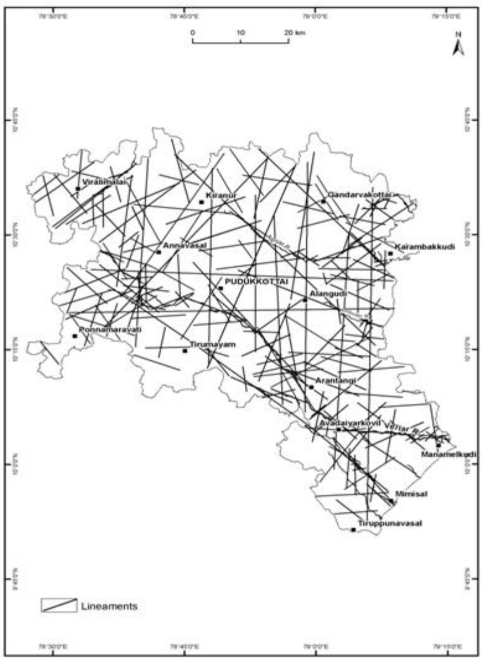
Similarly, the zones of more drainages in an area shows the impervious lithology which will obviously have maximum runoff. Whereas, the zones of less drainages indicate the porous lithology. So, the zones of less than mean drainage density (750 m/1.sq.km) were buffered out as suitable sites for the artificial recharge from drainage density point of view Fig.4.

4.2 Lineament and Lineament Density Map

The linear features of tectonic origin were interpreted for the study area using various raw and digitally processed Landsat TM data as briefed in the methodology section above. Besides various image processing techniques, the contrast stretched FCC, low pass gaussian filtered and edge enhanced data sets were found to be more useful for the interpretation of the lineaments, as these have expressed very clearly the drainage, tonal and textural linearities with more clarity. The topographic linearities were also interpreted using the Survey of India topographic sheets. Finally all the lineaments interpreted through the various above data sets were integrated and a detailed lineament map was prepared Fig. 5.

After preparing the lineament map for the entire study area, the lineaments were analysed for their linearity, extent, azimuthal frequencies, morphology, etc. The same has revealed that these lineaments predominantly fall in four azimuthal frequencies viz: N-S, NE-SW, NW-SE and E-W directions with genetical/tectonic conformities within the lineaments of each group.

The lineament density contours were analyzed and the lineament density varied from 200 m/4sq.km to 3200 m/4sq.km zones and hence the zones falling with more than 1600 m/4sq.km were buffered out and GIS layer was generated Fig.6 as suitable sites for artificial recharge as far as lineaments are concerned.



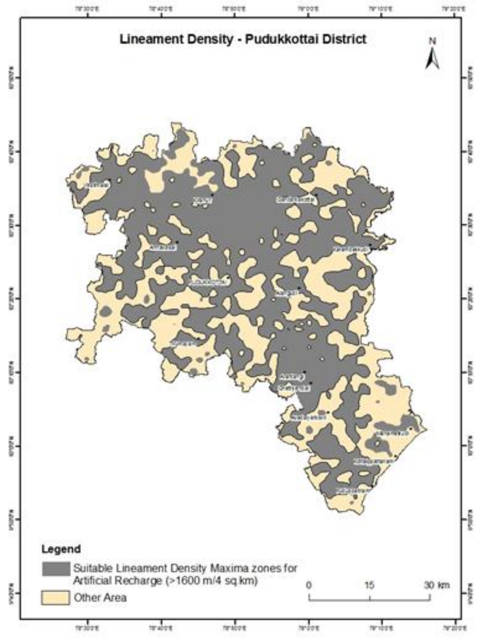


***Fig.5** Lineament Map* ***Fig.6** LineamentDensity Map*

4.3 Lithology

In the study, firstly all the existing data including the published maps of the Geological Survey of India (**Anon** 1972) were collected and collated. Keeping the same as the basic input, all the lithological details were updated interpreting the raw and the digitally processed Landsat TM data.

Whereas, the Proterozoics are membered mostly by Acid intrusives represented by Granite Gneisses & Pink Granite (Pudukkottai Granite) and Pegmatite and Quartz veins. The Grey Migmatite/Grey Granite/Garnet Granite mostly form rocky pediments with thin soil cover, whereas the Gneisses, especially the Hornblende – Biotite Gneiss forms vast plain in general, with thick cover of soil developed over it and hence supports prolific vegetation. In contrast, the Calc Gneiss/Calc Granulites/ Crystalline Limestone form tightly folded small patchy outcrops. On the contrary, the Charnockite forms mostly ground level outcrops as massive stocks and bosses. The Pink Granite and Granitic Gneisses are generally oriented in NNE-SSW direction. These Pink Granite/Granite Gneisses form potential building and ornamental stones in the area. While the Quartzites are found as sporadic outcrops in Arimalam and the adjacent areas, Pegmatite and Quartz veins show NNE-SSW trending low order ridges in Annavasal and Viralimalai areas.

The central part of the study area is occupied by the Tertiary formations, mostly the Sandstones, belonging to Mio-Pliocene period. This Mio-Pliocene Sandstone is widely referred to as Cuddalore Sandstone in India. This Sandstone is of course to fine grained, exhibits reddish brown colour and generally associated with ferruginous clays and thin beds of Limestones.

The contact between the central Mio-Pliocene Sandstone and the western Crystalline rocks are very sharp and regionally rectilinear, trending in NNE-SSW direction. All along such sharper contact between the western Crystallines and the central Tertiary Sandstone, gully erosion is significantly observed. The occurrence of Mio-Pliocene Sandstone at higher elevation and the extensive gullying along such contact zone indicates probable faulting along the Crystalline-Tertiary contact and the resultant rise of the central Tertiary Sandstone.

The third major lithological assemblages are the eastern Quaternary sedimentary formations. These Quaternary sediments have been formed by fluvial, fluvio-marine and marine and rarely by the aeolian processes. Amongst such various processes, the Vellar river which is the prominent drainage system in the area seems to have contributed more to the development of the eastern Quaternary sediments which comprise fluvial sediments of sand, silt and clay. The river Vellar has developed a wide delta which is occupied by hundreds of crescent shaped water bodies encircling the apex of the delta from Arantangi in the west to the coast in the east. These crescent shaped tanks/water bodies are nothing but the interlobal depressions in this major lobate delta. The prodelta region all along the coast from Manamelkudi in the north to Tiruppunavasal in the south is occupied by a narrow beach ridge complex of 1-2 km which also constitutes the eastern Quaternary sediments (Fig.7).

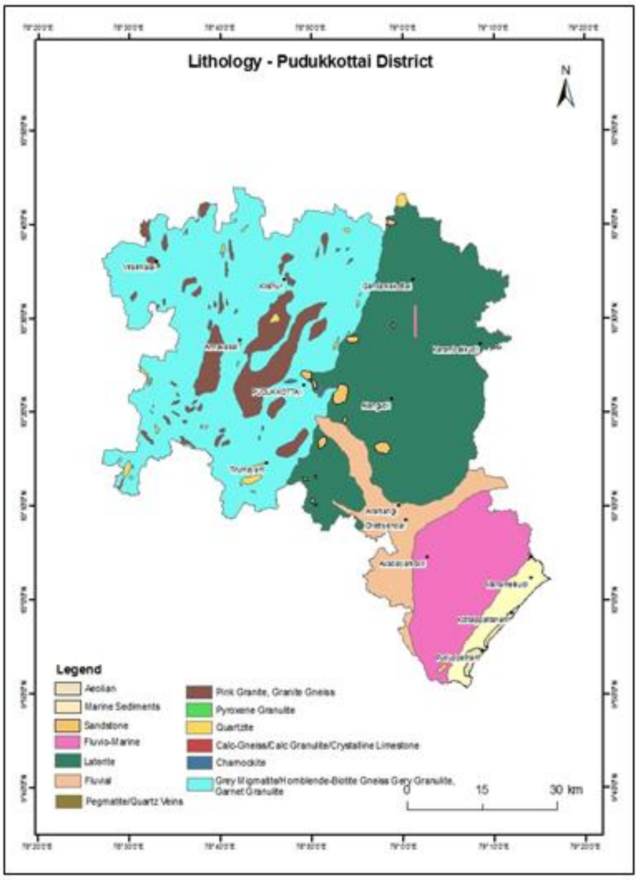


Fig. 7 *Lithology Map*

4.3.4 *Geomorphology*

As the area was made up of rocks of divergent age groups and parentage and further extensively drained by a number of streams / rivers and has a coast too, a variety of geomorphic features of tectonic, denudational, fluvial and coastal were seen in the area.

Hard rock formations located in the north western part of the study district had the high relief features such as denudo-structural hills, residual hills/inselbergs and linear ridges. In western half of study area, rocky pediments were exposed to a vast extent. The eastern half has predominantly displayed lateritic uplands & plains intervened by gulleys and floodplains. In the south eastern part, deltaic and coastal land forms such as, inter lobal depressions, deltaic lobes / deltaic plains, swales, mud flats, beach ridges, creeks and protruding deltas were found (Fig.8).

Similarly, the geomorphology map was prepared analyzed and the lateritic plains/uplands, pediplains, pediments, beach ridges, lobes, meander scars, floodplains, etc. were buffered out as suitable sites for artificial recharge Fig.9.

4.3.5 Landuse / Land Cover

The landuse / land cover map (up to level-II) was prepared by interpreting the IRS 1D satellite images based on the NRSA classification. The same was verified with ground truth surveys and corrected landuse / land cover map was prepared and digital GIS image was generated in ArcGIS (Fig. 10). The major landuse types found in the area were: Settlements, Agricultural lands, Reserved Forests and Mining areas. As far as the land cover categories, waste lands, drainages, rivers and water bodies were found to be the major ones.

Similarly, the landuse/land cover was analyzed and the zones of tanks, rivers, cropland, semi ever green forest, land with scrub, land without scrub and gullied / ravenous land were buffered out as favourable zones for artificial recharge Fig.11.

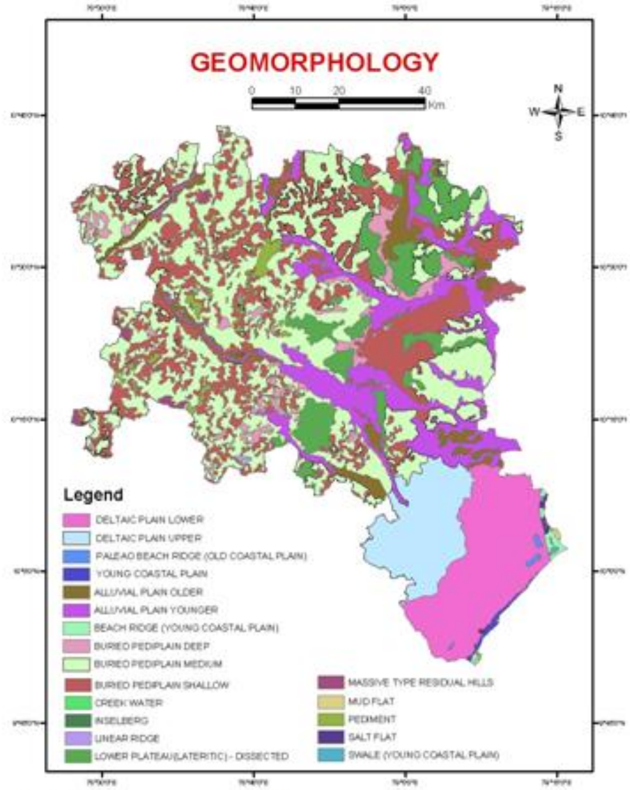


Fig. 8 *Geomorphology Map*

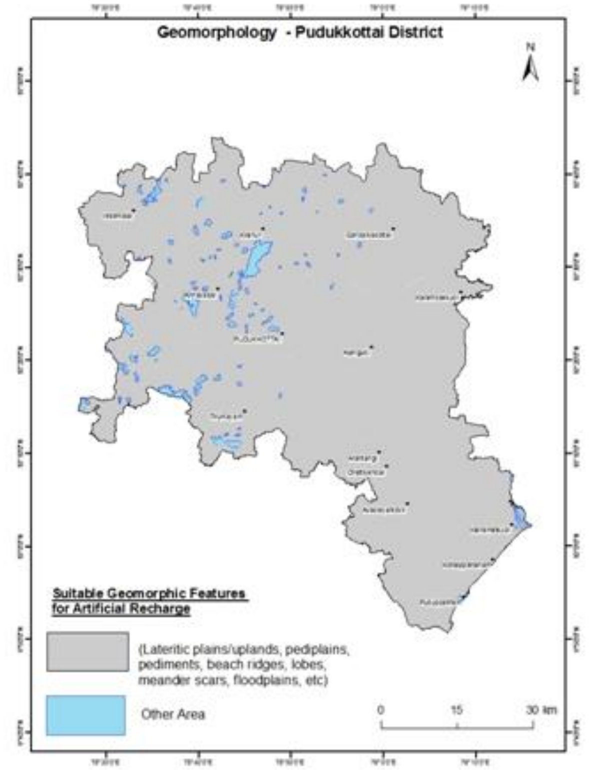


Fig.9 *Suitable Geomorphic features for Artificial Recharge*

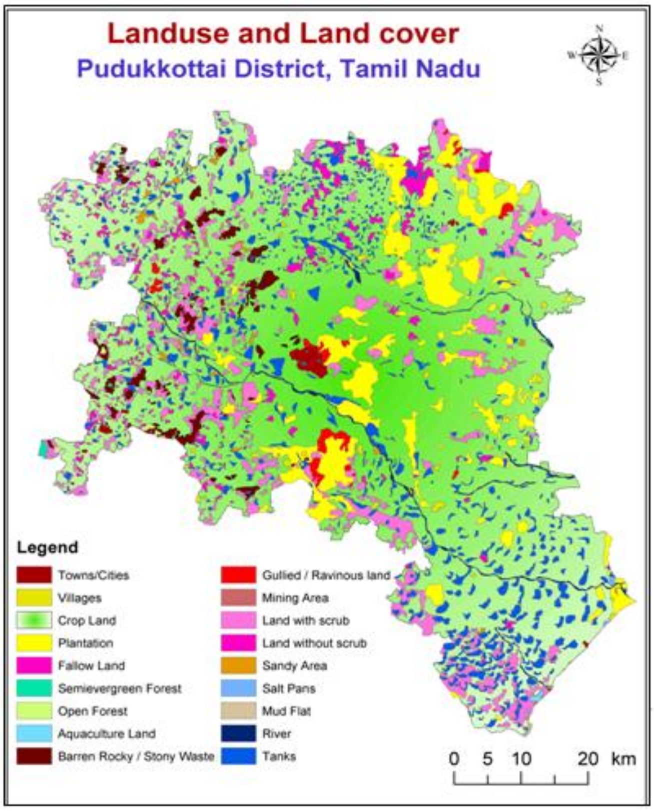


Fig. 10 *Landuse / Land Cover*

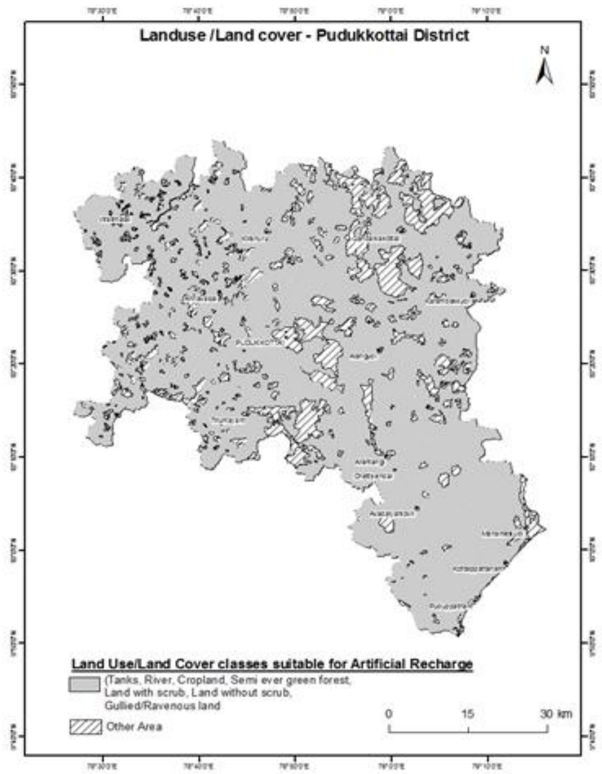


Fig. 11 *Suitable Landuse land cover features for Artificial Recharge*

4.3.6 Slope

The slope of the area varied from 1 % to greater than 35% and hence the areas where the slope is less than 3% were buffered out as suitable sites for artificial recharge Fig.12.

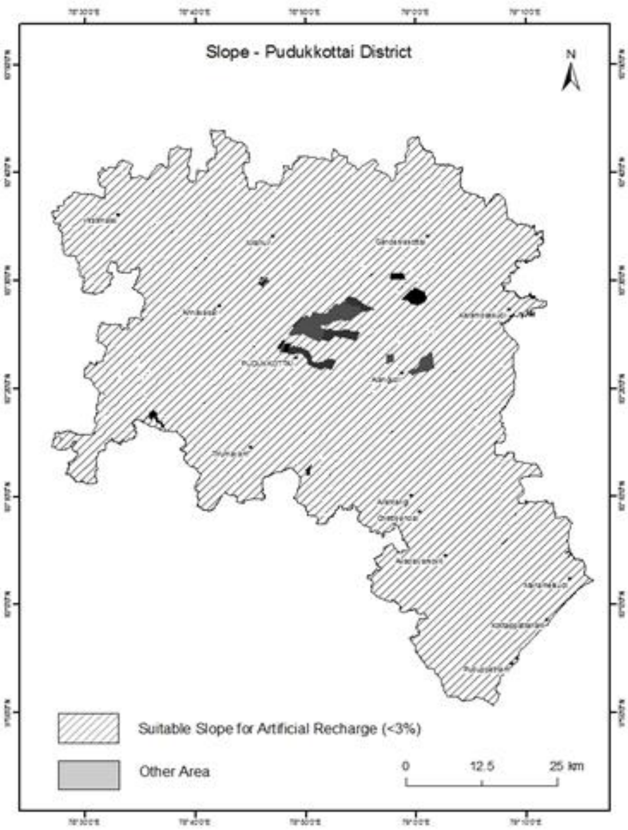


Fig. 12 *Slope*

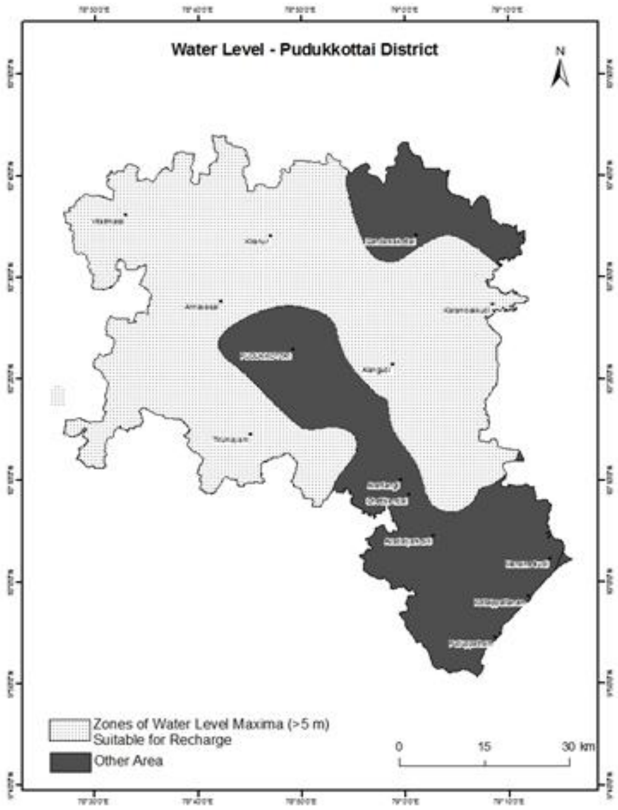


Fig. 13 *Water Level*

4.3.7 Water Level

With the help of monthly water level data, pre-monsoon and post monsoon water levels were worked out and thus by differencing them, the groundwater recharge and discharge areas were identified. From this GIS image, the areas of groundwater discharge for the past several years were separated out and named as depleted aquifers.

The water level contour map was analyzed and the water level in the area varied from 1m to 10m and hence the zones falling in more than mean 5m (> 5m) were buffered out as suitable sites for artificial recharge Fig.13 as deeper the water level better will be the recharge.

4.3.8 GIS Integration and Site Selection

After generating the above six buffered GIS layers, overlay functions were executed and the areas of coincidence of more than 3 to 5 variables were buffered out as suitable area for artificial recharge Fig.14 and most of the area fell under this category

5.0 DETECTION OF SITE SPECIFIC MECHANISMS FOR ARTIFICIAL RECHARGE

Subsequent to the selection of suitable site for the artificial recharge (Fig.14), various site specific mechanisms were identified. For example, the desiltation of existing tanks, flooding and furrowing, pitting, check dams and the batteries of wells, etc. will have to be executed depending upon the terrain/geo-system conditions. This was done, by integrating the GIS layer showing the suitable areas for artificial recharge with various GIS layers of the geo-systems as detailed below.

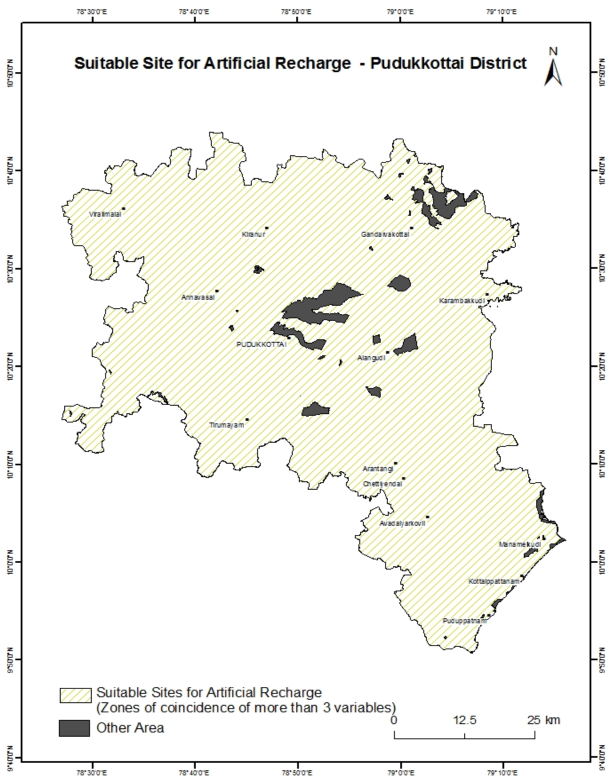


Fig. 14 *Suitable site for Artificial Recharge zone*

5.1 Sites Suitable for Desiltation of Existing Tanks

Wherever the tanks are found in the areas were selected for artificial recharge Fig.14 and suggested for the desiltation technique, so that, they can act as surface water bodies as well as rechargeable reservoirs. To do the same, GIS layer showing silted tanks was overlayed with GIS layer showing the zones selected recharge and the tanks located within such zones were buffered out for desiltation technique Fig.15.

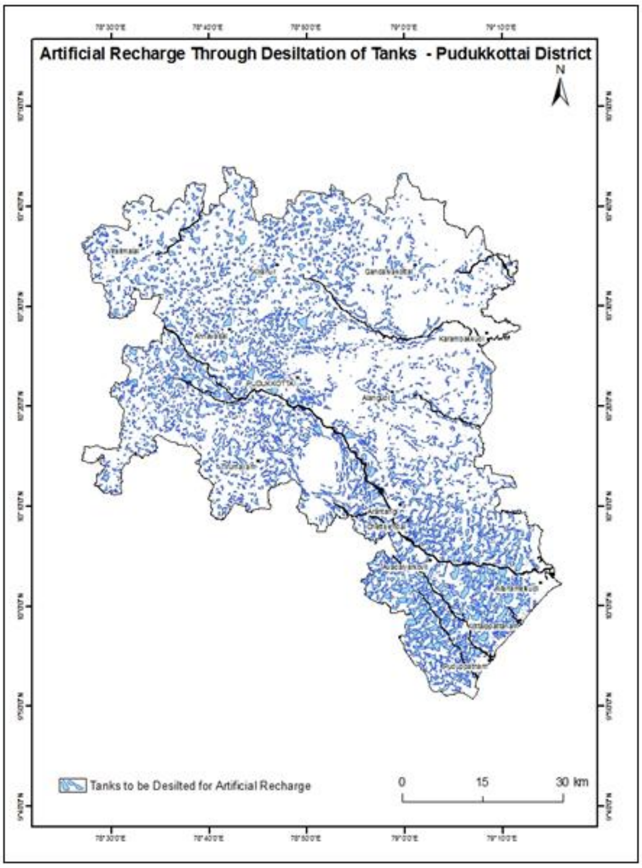


Fig. 15 Artificial Recharge through Desiltation of Tanks

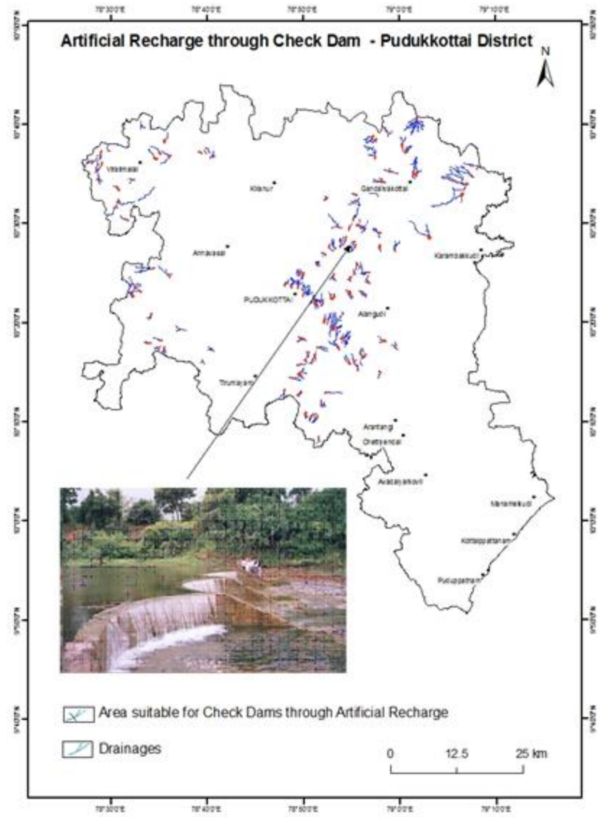


Fig. 16 Artificial Recharge through Check Dam

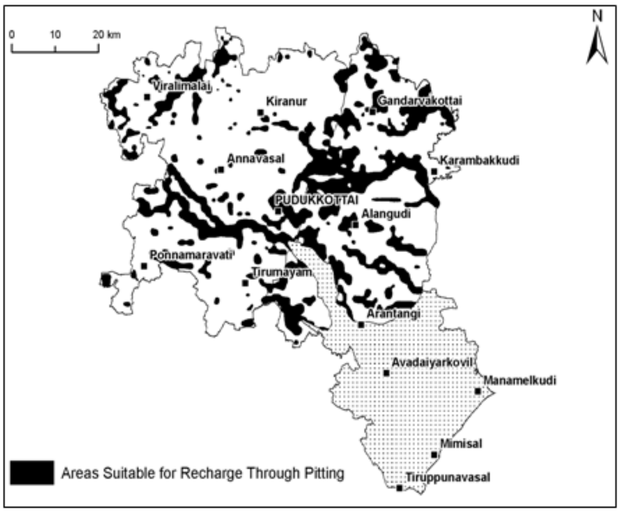


Fig. 17 Artificial Recharge through Pitting

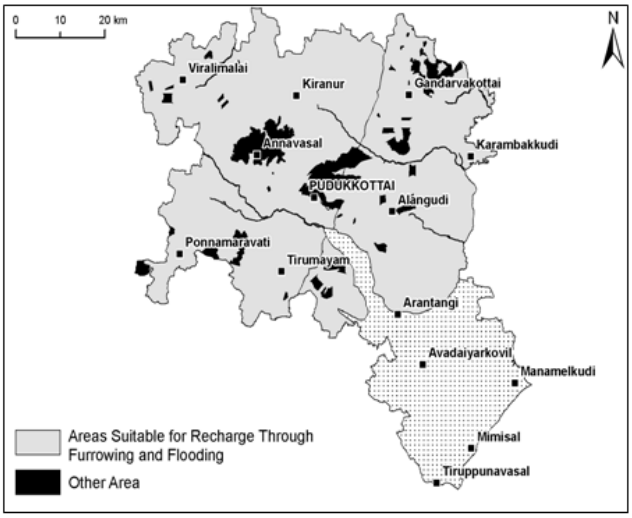


Fig. 18 Artificial Recharge through flooding and furrowing

5.2 Sites Suitable for Check Damming

For selecting suitable sites for check dams, within such positive zones of recharge (Fig.14), the criteria like drainage convergence and the locations of settlements down below were considered and only those drainages, satisfying these conditions were filtered out and GIS layer was generated. This GIS layer was superposed over the sites selected for artificial recharge and the areas of coincidence of both were recommended for check damming Fig.16.

5.3 Sites Suitable for Pitting

In certain areas, the subsurface formations will be porous, but the surface media will be clayey and in such zones if the impervious (clay) caps are removed by pitting, then the underlying porous formations will be exposed and the geo-systems will absorb the flood/rain water easily. So, to identify such sites suitable for pitting, the GIS layer

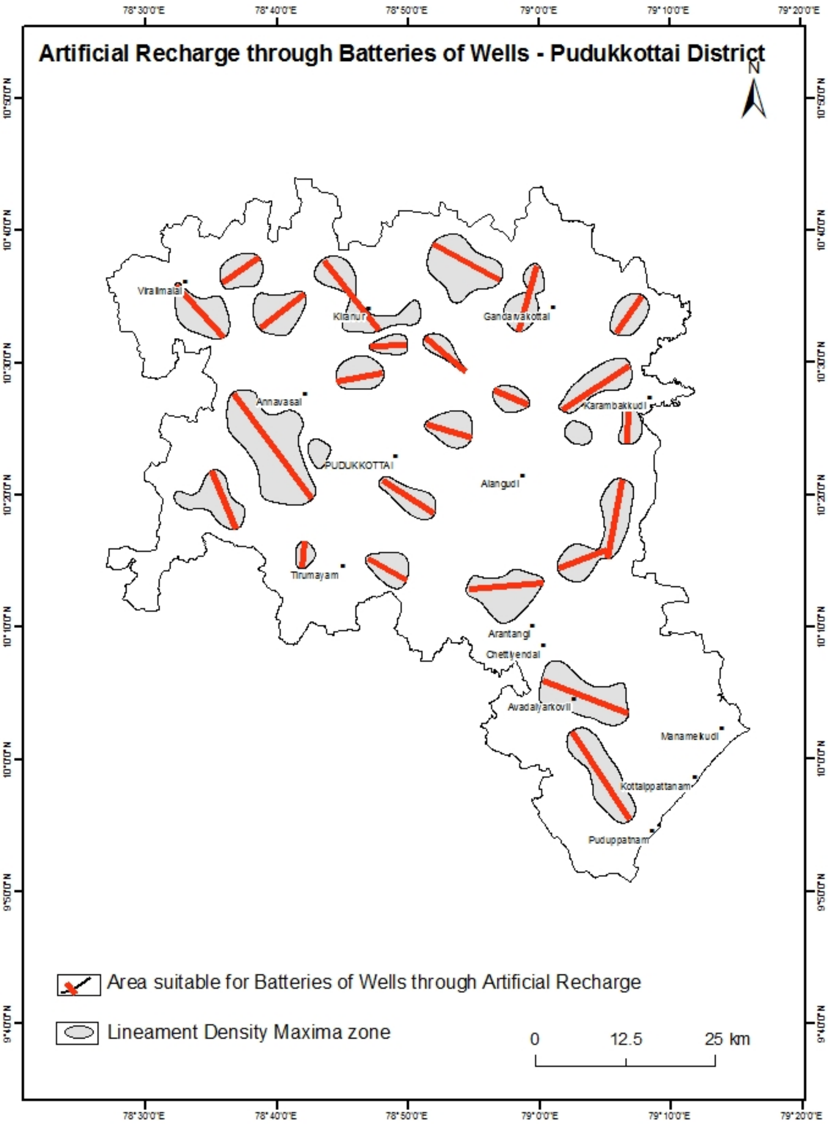


Fig. 19 *Artificial Recharge through Batteries of wells*

showing site suitable for artificial recharge (Fig.14) was superposed over the drainage density maxima zone and the zones of coincidence were buffered out and recommended for pitting Fig.17.

5.4 Sites Suitable for Flooding and Furrowing

The sites selected for flooding and furrowing should have null slope, especially less than 3% slope (<3%). So, the GIS layer showing the areas of <3% slope (Fig.14) was superposed over the GIS layer having sites selected for artificial recharge and the areas of intersection of both were identified for the adoption of flooding and furrowing technique Fig.18 for artificial recharge.

5.5 Sites Suitable for Batteries of Wells

Wherever the fracture/lineament density is more within the sites selected for artificial recharge (Fig.14), those will be the good areas for putting batteries of wells. So to do the same, the GIS layer having lineament density maxima zones was superposed over the GIS layer showing suitable sites for artificial recharge and the areas of coincidence were recommended for the batteries of wells Fig.19.

6.0 RESULTS AND CONCLUSION

Thus, in the present study, through this unique GIS integration, various mechanisms were also brought out according to the available geo-systems parameters.

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