International Journal for Modern Trends in Science and Technology
Volume: 03, Issue No: 08, August 2017
ISSN: 2455-3778
http://www.ijmtst.com

Geospatial Technology based Water Harvesting Models for Drought Prone Area

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To Cite this Article
Sunandana Reddy Machireddy, Venkata Rami Reddy Pesala, "Geospatial Technology based Water Harvesting Models for Drought Prone Area", *International Journal for Modern Trends in Science and Technology*, Vol. 03, Issue 08, August 2017, pp 216-224.

ABSTRACT

Water is one of the very important resources to human existence. None of the Earth's resources is equivalent and abundant like water. As the population has started growing and unregulated usage of surface water resources has been initiated in multiple fronts the available water is not able to cope up to human needs. So, the man has started searching and tapping the ground water resources using modern technologies like Hydro geological surveys, Geophysical surveys, Computer based numerical models, Remote Sensing and Geographical Information System etc. Those have started playing some dividend. So definite newer Avenues are to be created to replenish the extracted water from the underground reservoirs so that there exists equilibrium between the extraction and the replenishments. Such a Technique of pushing the water into the deeper part of the aquifer system is called artificial recharge. But such an artificial recharge cannot be done randomly and the same has to be done only in locations, which can quickly absorb the water as and when injected. Hence the present study has been taken up to identify suitable sites for artificial recharge in drought prone Pudukkottai district, TN. through Space and Spatial technology. In addition to the identification of suitable sites for artificial recharge, the site specific mechanisms have also been identified such as Sites for de-siltation of tanks, flooding and furrowing, percolation ponds, check dams, pitting, batteries of wells, enechelon dams, hydro fracturing etc. The geospatial technology is the excellent system in demarcating all the themes which are related to features of geology in the connection of showing solutions to artificial recharge, because of capacity to capture multispectral data and its temporal spatial data coverage and spatial technology achieved advent merits in the form of extracting, utilizing, managing and manipulation of vast data

KEYWORDS: *Artificial Recharge Zones, Geospatial Technology, Spatial Modelling, Suitable Sites*

I. INTRODUCTION

Need of providing resources like water facility to the community is challenging task to the countries or the nations due the drastic increase of population and their current needs in the present scenario. As we need to understand the required rate of water for the human needs like industry, domestic and other utilization, it is necessary to go through the balance of water budget including underground water resources globally. As fresh water is available in very limit percentage when compare to the sea salt water, it again need to do lot of investigations to utilize and replenish the groundwater [1]. Filling the gaps through groundwater replenishment in the form of recharge artificially, globally, investigations were carried out by different researchers and organizations to meet the demand.

Now a day, groundwater is enormously extracted to meets the current needs in the all the sectors related to water utility including domestic in the form of groundwater structures in the few decades which leads to different concerns related to groundwater quality and quantity in the form of groundwater depletion. It is also observed that due to the urbanization and infrastructure development in the form of surface construction, resulted in less rate of infiltration and low aquifer recharge system. Hence, it is challenging task to the policy makers and organizations to replenish the available natural resources by using various technologies to identify the gaps to refill. Remote sensing along with Geoinformatics is an excellent media to show the solutions to meet the demand by its specialty in spatial data and non-spatial data in the form of separate themes. It is also highlighted that usage [2], [3] of spatial data along with integration techniques of RS&GIS, it shows the analyzed results to identify the tasks through the input data. In current times, lot of results derived using applications of geospatial technology in groundwater through artificial recharge [4], [5]. As many areas of Tamil Nadu are facing lot of water crisis to meet the demand, it is required to suggest alternative measurements to improve the resources in the state. In this connection, a case study of Pudukkottai district of Tamil Nadu is selected to make use of resources through the geospatial technology [6].

II. Study Area & Location

Pudukkottai district of Tamil Nadu is covering an area of nearly 4460 km2. The study area falls in the Survey of India topographic sheets 58J/6, 58J/7, 58J/8, 58J/10, 58J/11, 58J/12, 58J/14, 58J/15, 58J/16, 58N/2, 58N/3, 58N/4&8, 58/1&2, 58K/13. The Pudukkottai district of Tamil Nadu, lies at the south Eastern part of Indian Peninsular. It is bounded by Tiruchirappalli district in the North West, Tanjavur district in the Northeast, Ramananthpuram district in the Southeast and Sivagangai district in the Southwest. The Vellar and Koriyar rivers are the prominent rivers. The area is well connected by Roads and Railways from Tiruchirappalli, Tiruchirappalli is connected all major cities of south India by Roads, Railway and air via Chennai. Location map including base details are shown in the below figure (Fig .1).

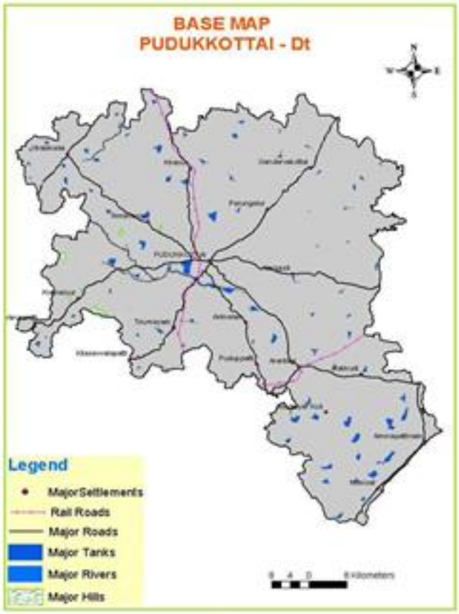


Fig.1. Base Map of the Study Area

The area experiences different climate depending on the altitudes. Summer, Rainy, winter seasons are prominent and experience from April to June, September to December, January to March respectively. The average mean rainfall of the district is 733 mm.Based on the nature of the rock types and the physiographic conditions, water resources of area are existing at different levels. The ground water occurs under water table conditions in the weathered and the fractured zones of the crystalline rocks in the study area [7]. The quality of water is good in major part of study area, in general and contains less than 482 ppm of dissolved solids and chloride content of about 100 ppm. Permeability is low to moderately high in laterite and laterite soils, high in granitic rock areas and low in migmatite complex. number of tanks has been identified in the study area. Vellar and Koriyar Rivers are flowing the study area. Sub surface geological data and also the geophysical data have been collected to understand the water resources scenario.

III. Methodology

The study depends on the data collected from both primary and secondary sources such as IRS 1C /1D geocoded data and survey of India topographic sheets on 1: 50000 scale. From the IRS 1C / 1D LISS III geocoded photographic products, four thematic maps have been prepared such as Structural trend line, Lineament and lineament density; geomorphology and Land use / Land cover maps [8]. From the survey of India topographic sheets three thematic maps have been prepared such as Drainage and drainage density maps, Slope map and Tank map. From the data collected from the public works department reports, two thematic maps have been prepared such as water level map and depth to bed rock map. From the geological survey of India reports, the geology map of the study area has been prepared. Limited field checks have been carried out for confirmation of details obtained from the Remote sensed data, GIS databases were generated for all [9], [10], [11]. From the GIS data bases water harvesting models have been prepared. Process of the methodology is depicted in the given figure (Fig.2) as flow chart.

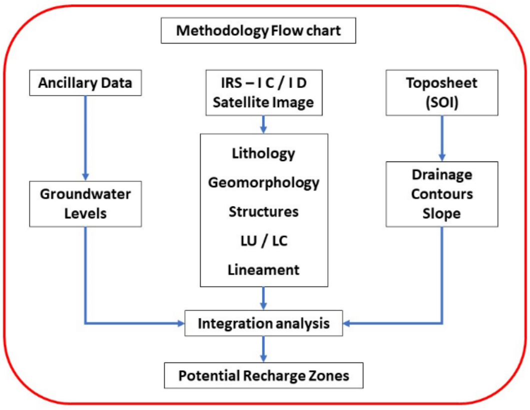


Fig.2. Methodology Flowchart

IV. Creation of Thematic Maps

The following thematic maps are playing vital role in the identifying and water resource feasibility areas and are also key elements in identifying the recharge structures using geospatial analysis methods [12]. Sub surface details can be effectively analyzed based on remnant features which are existing on the surface in the form of different themes. These themes can be integrated using spatial technology [12], [13]. The details of demarcated thematic maps are lithology, geomorphology, slope, secondary structures, lineaments, land use / land cover and drainage pattern.

A. Lithology

The lithology map was prepared by using already existing geology and mineral map of Pudukkottai district (geological survey of India map) and it was counter checked by the intensive field check[14]. The study area exposes grey migmatite / hornblende – biotitic gneiss, Grey granulite garnet granulite, Pyroxene granulites, charnockite, calc –gneiss / calc granulites /crystalline limestone, laterite, pegmatite / quartzite veins, pink granite / granite gneiss, quartzite and fluvial, fluvio – marine, Aeolian, marine sediments which are shown in the below figure (Fig.3).

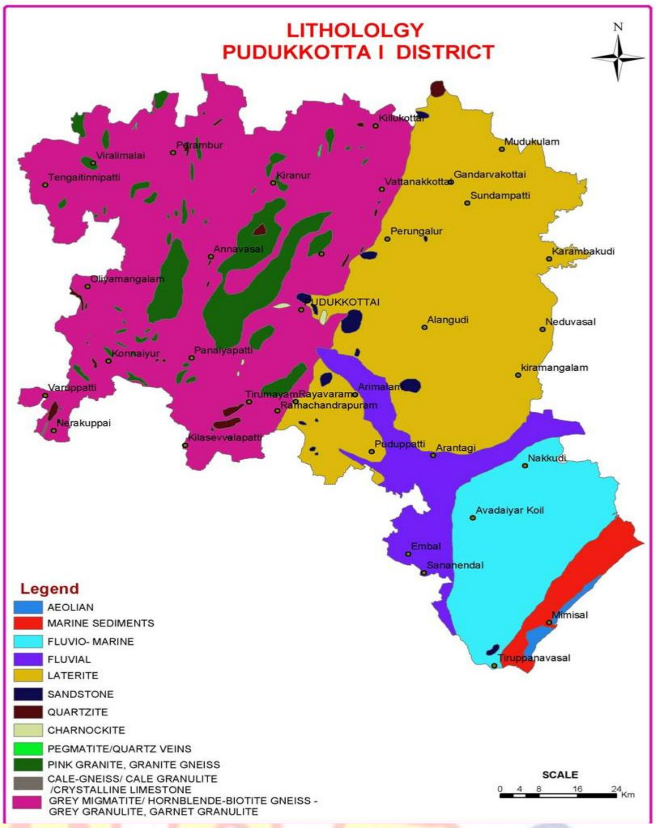


Fig.3. Lithology Map

B. Secondary Structures

The structural trends were seen in IRS 1C / 1D LISS – III FCC on 1:50,000 scale images as long and liner features in the area. These linear structures were observed in the form of soil tone, vegetation, relief and drainage linearity and curvy linearity. A detailed satellite image interpretation was made to bring out these structural trends.

C. Lineaments

Lineaments are the linear, rectilinear and curvilinear features of tectonic origin observed in satellite data. These lineaments normally show tonal, textural, soil tonal, relief, drainage and vegetative linearity and curved linearity in satellite data. All these linear features were interpreted from the satellite data and the lineament map was prepared for the study. The entire study area was girded into 4460 grids of 1 sq.km each. The lineament map was superimposed over the grid map and the total length of the lineaments was counted for each grid, plotted in the corresponding grid centres and contoured using Surfer software. These contours were designated as lineament density diagram [14]. After removing the anomalous values, the area falling in low, medium and high lineament density zones were demarcated and GIS image was generated in ARCGIS environment [15]. From the shape of the lineament density contours the linearity maxima axes were drawn along the crest of the contours of elliptical shapes with maximum value in the core and successive lesser and lesser values encircling them.

D. Geomorphology

Geomorphology, the sculpture of Earth is an important parameter in any ground water investigation study. Since hydrological parameters are greatly controlled by morphology, it is one of the integral part of Hydro geomorphological studies [15]. The preparation of hydro geomorphological map is an impartment task of an exploration hydrogeologist. Each and every landform has their own physical characters and hence these land forms express distinct morphometric expression of their own in the satellite images. Landforms are the important surficial indicators to select the suitable sites for artificial recharge. So in the present, study an attempt was made to prepare detailed geomorphologic map on 1: 50,000 scale using IRS 1C / 1D LISS – III geocoded data. Photo recognition elements like tone, texture, shape, size, associated features etc., have been utilized in delineating the different landforms present in the study area, such as residual hills, Linear ridges, Inselbergs, Lower plateau (lateritic), Pediment, Buried Pedi plain deep, Buried Pedi plain medium, Buried Pedi plain shallow, Alluvial plain older, Alluvial plain younger, Deltaic plain upper, Deltaic plain lower, Paleao beach ridge (old coastal plain), Beach ridge (young coastal plain) Creek beach water, Swale, Salt flat, Mud flat were identified in the present study area that can be find in the figure(Fig.4).

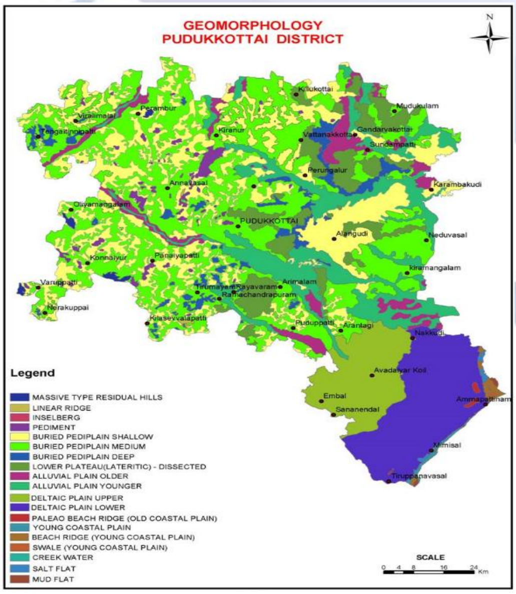


Fig.4. Geomorphology Map

E. Land Use / Land Cover

Land use refers to “Man’s activities and various uses which carried on land”. Land cover refers to “Natural vegetation, water bodies, rock / soil, artificial cover and other resulted due to land transformation. Standard Land use / Land cover classification developed by NRSA (National Remote Sensing Agency) and NRIS (National (Natural) resource information system has been followed.In the present study Land use / Land cover map has been prepared on 1:50,000 scale using IRS 1C / 1D LISS – III geocoded data. Land use map was prepared from satellite data using the photo interpretation elements and comparing with topographic sheets, it was further confirmed by limited field check [3]. The following are the different Land use / Land cover classes of the study area. These are Towns / Cities, Villages, Tanks, River, Cropland, Fallow land, Plantation, Land with Scrub, Land without Scrub, Barren rocky / stony waste, Gullied / Ravenous land, Mining area, Open forest, Semi evergreen forest, Sandy area, Mud flat, Saltpans and Aquaculture land etc. are clearly shown in figure (Fig .5).

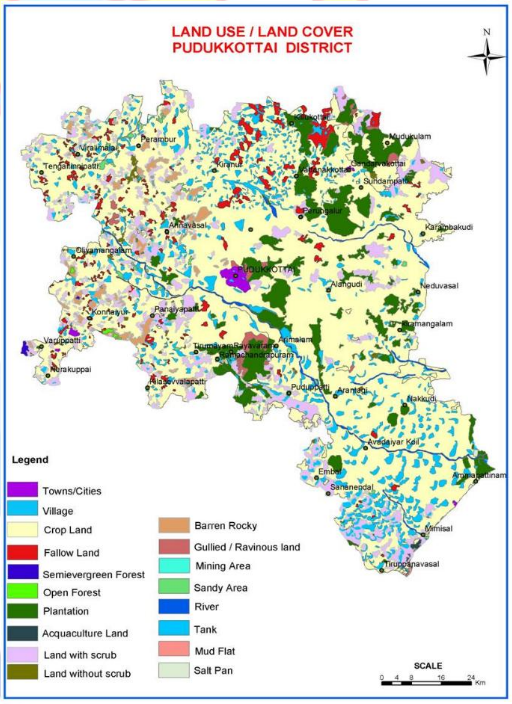


Fig.5. LU / LC Map

F. Slope Morphometry

Slope is yet another important parameter in artificial recharge investigations. If the slope is high then there is no time given to the water to percolate downwards, instead surface runoff will be more. If the same water need percolated downwards means, the slope should be negligible or very less. Survey of India toposheets have been used for the preparation of slope map. The contours were firstly transferred onto tracing sheet. Such contours were having an interval of 20mts on 1: 50,000 scale, then by measuring the distance between two contours, the slope was demarcated in to several categories as per given percentage. Nearly level plain – 0-1%, Very gently sloping -1-3%, Gently sloping -3-5%, Moderately sloping -5-10%, Strongly sloping -10-15%, Moderately steep to steep sloping –15-35%, Very steep sloping ->35%.In the study area major portion coming under 0 – 1 % of slope which indicates that the area is a plain country. Find the detailed map in the given figure(Fig .6).

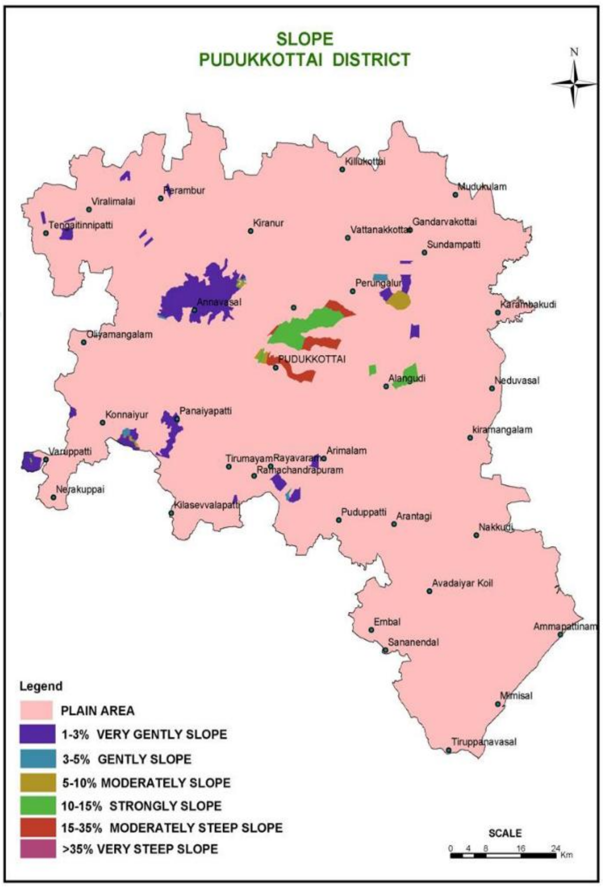


Fig.6. Slope Map

G. Drainage / Water Bodies:

Drainage refers to the area or catchment area whose rainfall being drained into the rivers. Drainage network helps in the delineation of water shed and for suggesting various water harvesting structures. The amount of water reaching a stream system depends upon the morphometry of the basin, total precipitation, losses due to evapotranspiration and absorption by soil and vegetation. The drainage basin morphometry throws light on the lithological and structural controls of the basin; relative runoff, recharge, erosion aspects and stage of development of basin itself. Water bodies show light blue to dark tone in satellite data. River stream and tanks have been identified and interpreted from toposheets and then compared with satellite data for minor corrections. The entire study area was girded into 4460 grids of 1 sq.km each [3], [16]. The drainage map was superimposed over the grid map and the total length of the drainage was counted for each grid plotted in the corresponding grid center and contoured using Surfer software. These contours were designated as drainage density diagram. After removing the anomalous values, the area falling in low, medium and high were demarcated and GIS image was generated in ARC GIS environment. Map is shown in the given figure (Fig.7).

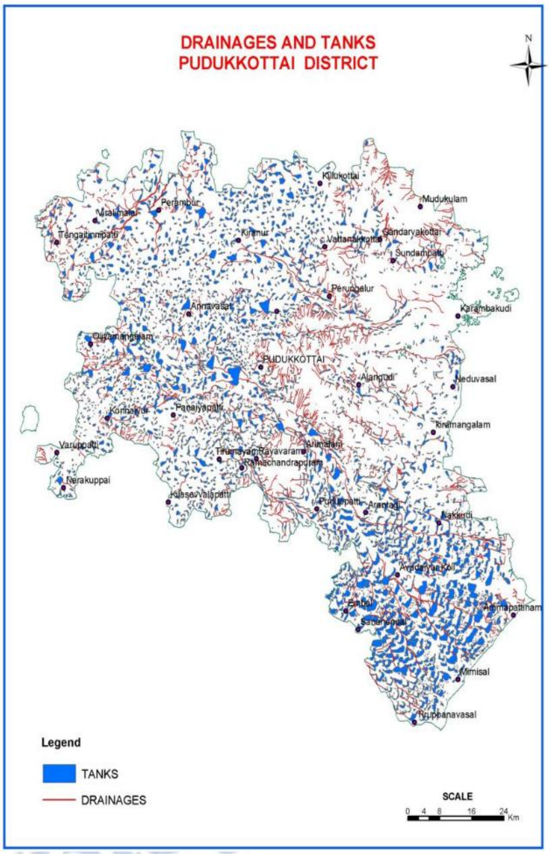


Fig.7. Drainage Map

H. Water levels

Water level of an area speaks about the availability of ground water from the surface and generally follows the topography and altitudes. Shallow water level indicates that the area had already saturated or bestowed with water whereas deeper water level indicates the poor ground water conditions. For the preparation of water level map, data has been collected from Public works department for 59 wells and 360 months. The 360 months of average annual water level data has been calculated for each location and fed into SURFER software for contouring. These contours were classified in to three zones as deep, medium, shallow. From these the ARCMAP based GIS database was generated showing the above deep, medium, shallow zones. Details depicted in below figure (Fig.8).

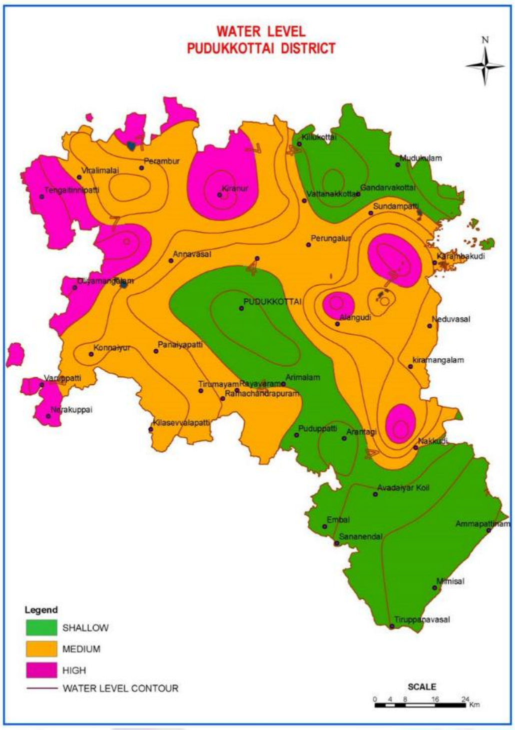


Fig.8. Groundwater Levels Map

Detailed databases were generated on the sub surface Geology, from the data collected from Public works department on such resistivity. In the study area, geophysical resistivity surveys were conducted by PWD – Ground water in 117 locations in hard rock area and 58 locations in Soft rock area. The same data was used for the analysis of the Sub surface geology.From the analysis we can get the data on Depth to Bedrock, (hard rock area) and Thickness of taped aquifer (soft rock area) for each point for the entire study area. These locations with their Depth to Bedrock, (hard rock area) and Thickness of taped aquifer (soft rock area) values are fed into the SURFER software for contouring [17]. These contours were classified in to three zones as deep, medium, shallow. From these the GIS database was generated showing the above deep, medium, shallow zones.

V. Spatial Modelling and Water Harvesting

The terrain conditions play an important role in controlling the recharge, different terrain parameters such as lineament density, slope, drainage, drainage density, depth to bed rock, thickness of taped aquifer and water level data were thematically integrated and suitable areas were identified accordingly. Scientifically selecting the suitable sites for artificial recharge, one has to identify suitable site-specific mechanisms also, in order to obtain full efficiency from such recharge structures, such as Sites for desiltation of tanks, flooding and furrowing, percolations ponds, check dams, pitting, batteries of wells, en-echelon dams and hydrofracturing etc. [18]. The study area has been divided in to two parts, as hard rock area and Soft rock area on the basis of lithology, accordingly water harvesting models have been prepared.

A. Site selection

For selection of suitable sites for artificial recharge, the study is divided into hard rock area and soft rock area based on major geological features. In hard rock terrain, the zones of porous lithology, lineament density maxima, pervious geomorphic units, zones of less than 3° slope, drainage density maxima zones, Land cover like scrubland, cropland, fallow land, depth to bed rock maxima zones etc. were buffered out from different maps and added using add function in ARCGIS. This output was overlay with zones of deeper water level and where ever polygons of intersection were there those areas were identified as better area for recharge which are shown in figure (Fig.9).

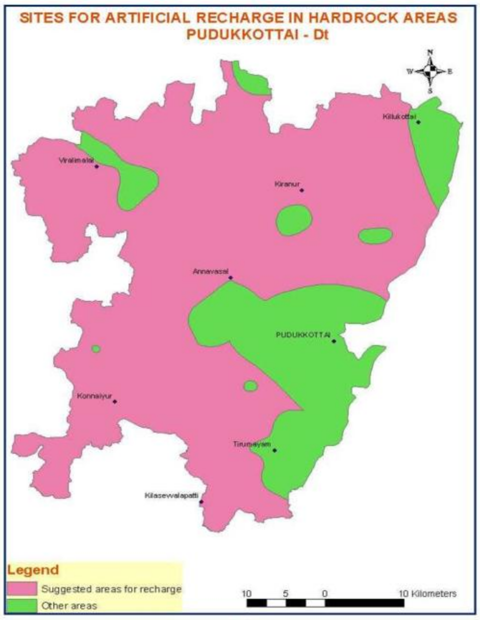
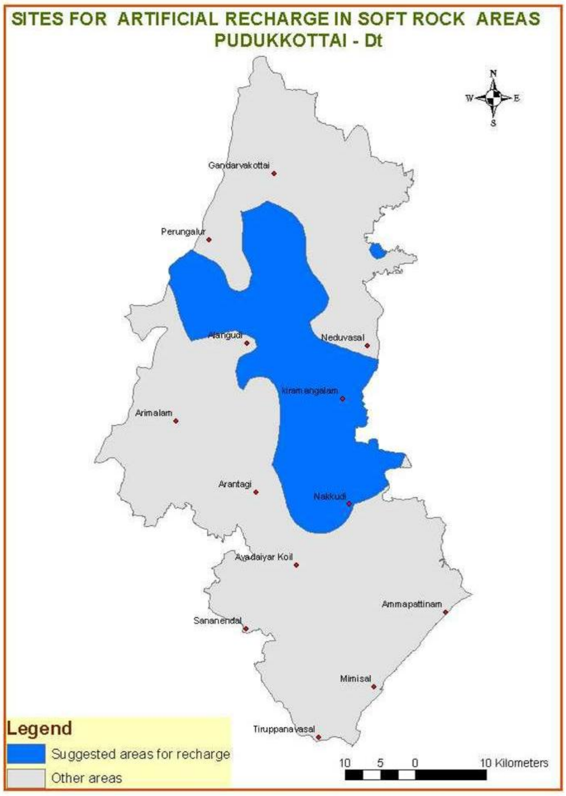


Fig.9. Sites for ARS in Hard rock

For selecting suitable sites for artificial recharge in soft rock areas, subsurface and water level data are to be studied in detail and taken into account. Evaluate the thickness of taped aquifer, prepare contour map and buffer out maxim zones as the areas for recharge, such map bearing thickness of taped aquifer maxima zones was superposed over GIS image showing deeper water level zones and wherever such deeper water levels were found within the thickness of taped aquifer maxima zones. The same was taken as suitable areas for artificial recharge, which are shown in below figure (Fig.10).



VI. Mechanisms for Recharge

A. Desiltations tanks:

Existing tanks were extracted and superimposed over final output which is showing suitable sites for recharge structures. and wherever such already available tanks fell in such selected zones they have been recommended for desiltation.

B. Flooding and furrowing:

For the furrowing and flooding, the best suitable area are the areas which are having low drainage density and plain slope. For identifying such sites, the GIS image showing sites for artificial recharge was overlaid with GIS image having the plain slope and low drainage density and wherever all the three have coincided these areas were recommended for artificial recharge through flooding and furrowing.

C. Percolations ponds:

For the percolation ponds, the area must have shallow slopes and the micro drainage catchments. Hence at the first stage, such zones were buffered out having the above terrain conditions. This map, was superposed over the priority area map wherever those were coincided, those areas have been recommended for percolation ponds.

D. Check dam and Pit

The drainage map was prepared for the study area using topographic sheets. The same was analyzed for drainage convergence, meeting points, only those drainages satisfying these conditions were filtered out and GIS image was generated. This image was superposed over the site selected for artificial recharge and the areas of coincidence were recommended for check dams. The drainage density map was prepared for the study area. From the drainage density map, maxima areas were identified and GIS image was generated. Such an image having drainage density maxima was overlaid over the image showing suitable sites for artificial recharge, wherever such drainage density maxima were found within these positive areas of recharge were recommended for pitting.

E. En-echelon dam and hydro fracturing

By scanning the survey of India topographic sheets broad and straight drainages were identified in the study area and GIS image was generated accordingly. Then this GIS image was superposed over the GIS image showing sites suitable for artificial recharge and wherever such broad and straight drainages were found within such selected sites for artificial recharge, these were recommended for En –echelon dams.With the positive areas selected for artificial recharge, the zones of coincidence of lineament density maxima and drainage density maxima were recommended for hydrofracturing.

VII. Conclusions

Latest technologies like Geospatial technology is effectively used in identifying the recharge structures by means of integration and modelling of RS & GIS for the research project.

Various latest genetic applications and models were derived to find and fit the artificial recharge sitesand to suggest suitable site mechanism.

Pudukkottai District of TNhas selected in order to get at these techniques for better results. Flooding and furrowing, Pitting, Percolation pond, Desiltation of Tanks, check dams, En-echelon dams and Hydrofracturing are key solutions to implement on the ground by means of identifying the suitable sites for artificial recharge through different thematic maps, which haveprepared.

The different thematic maps which were prepared using IRS satellite image and toposheets were Lineaments, Drainage, Slope, etc., Images of Remote Sensing and data from toposheets and other processing techniques of GIS are utilized for the extraction of thematic layers. For site selection in the hard rock areas the databases generated on various geological variables and water level deep were used. These two databases were added, by using union function of ARCGIS. And wherever these two parameters coincided, those areas were identified as suitable sites for artificial recharge. For site selection in the soft rock areas the databases generated on thickness of taped aquifer maxima and water level deep were used. These two databases were added, by using union function of integration of ARCGIS and wherever these two Parameters coincided, that areas were identified as suitable sites for artificial Recharge. After duly identifying the sites for artificial recharge, depending on the terrain condition site-specific mechanisms were identified. Such as Sites for Desiltation of Tanks, Flooding and furrowing, Percolation ponds, check dams, Pitting, Batteries of wells, En-echelon dams and Hydrofracturing. Hence geospatial technologies are playing vital role in the extraction of features related to surface and sub-surface by means of integration of spatial analysis methods especially in the natural resource management like water resource management systems.

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