# A Groundwater Potential in Thiruvarur District, Tamil Nadu using Geo-informatics

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## *Abstract*

*The global level climatic change combined with the demand for the freshwater in various part of the world, have resulted in increased dependence on groundwater. Groundwater utilised for numerous purposes like drinking, industrial and agricultural based activity, and rainfall failure which have put extreme pressure on water resource. In this study identification of groundwater potential is performed for Thiruvarur District using geospatial techniques. The key parameters in exploration of the potential spots are Geology, Geomorphology, Soil, Slope, Landuse / Land cover, Rainfall, Drainage and Lineament Density. The tools involved for decision making and picking-up appropriate regions are image processing for classification of land resources, Interpolation techniques, line density and Weighted Overlay. Weightage method was used to rank the features and its sub-classes. The result indicates the potentiality of the district which is classified into five types namely; Very Low (236.46 sq.km), Low (702.62 sq.km), Moderate (644.64 sq.km), High (368.77 sq.km) and Very High (272.19 sq.km). The results from the analysis sheds light on the geospatial tools to perform and identify groundwater potential zone, with faster result saving time, cost and management of groundwater resource.*

***Keywords:*** Groundwater Potential, Interpolation, Weighted Overlay, Geo-informatics.

## 1. Introduction

Groundwater is the vital source of water that fulfils human needs starting from drinking, agricultural needs and economic activities *(Waikar and Nilawar, 2014)*. Based on the groundwater statistics 80% is actively used to fulfil various needs and increase rate is predicted which can result in depletion of aquifers *(TNEIS)*. With increase in global warming, the effects can be severely which might result in droughts. India has population of 20% of the worlds, but still the water reserve is 4% compared to that of the world reserve *(Biswas, 2004).* In India the water shortage has arisen sharply due to over exploitation of water resource, because lack of proper monitoring and support infrastructure. Hence it's important to utilise the groundwater resource properly and bring-up mechanism to harvest the rainwater. The groundwater potential is vital assessment to identity the most suitable spots which will surely enhance water level. The occurrence of groundwater potential regions is depended on the natural structures or terrain factors like slope, geology and geomorphology *(Preeja et.al, 2011).* Groundwater potential is explored using the GIS and Remote Sensing through various parameters like Geology, Geomorphology, Soil, Slope, Landuse / Landcover, Rainfall, Drainage and Lineament Density.

## 2. Study Area

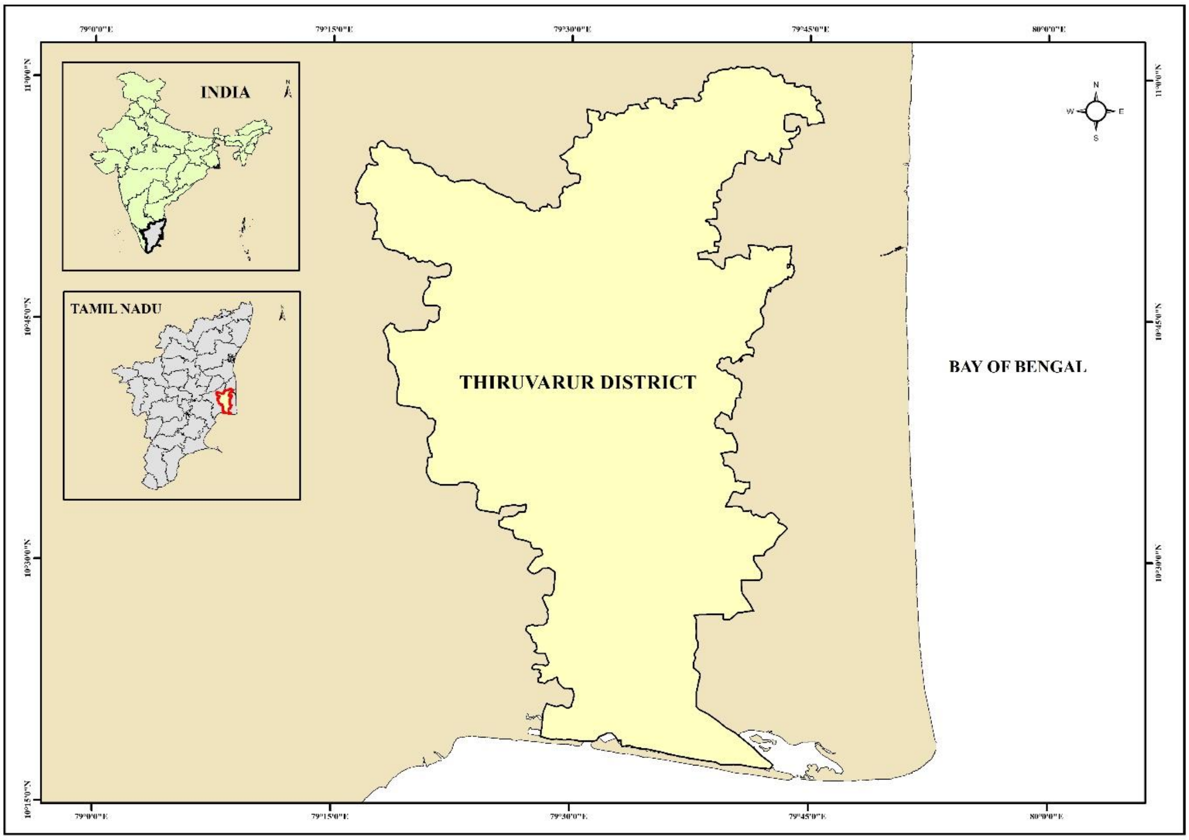



Fig. 01. Study Area

Thiruvarur (Fig. 01) is one of the 37 districts in Tamil Nadu, which is situated near the East coast of India, sharing the coast on south, situated between latitude of 10’0’20’00 to 11’00’7’00’ North and East of 79’0’15’00’ to 79’045’00’ longitude. It is bounded by Nagapattinam in east, Thanjavur in west, Cuddalore in north and Bay of Bengal on South. The district was the fragment of Thanjavur administration which was lately carved out in the year 1997 *(District Survey Report – Thiruvarur, 2018).* The administration division is mainly divided into revenue division which are Thiruvarur and Mannargudi and furtherly sub-divided into eight revenue taluk Thiruvarur, Nannilam, Kudavasal, Valangaiman, Needamangalam, Mannargudi, Thiruthuraipoondi and Koothanallur. It spans to cover 2097.97 sq.km area with 573 villages, with populations of 1,169,474 of which male population accounts for 5,80,784 and 5,88,694 is female *(Dhinagaran, 2008)*. District is drained by two tributaries of Carvery river which are Vettar and Vennar, well channelized canals supplying water throughout region. It learnt that Thiruvarur is irrigated mainly through canal systems and less dependent on well system. Annual average rainfall ranges from 1100 to 1260mm and the region is categorized under hot tropical climate which experience warmest condition during March to May month *(CCC&AR and TNSCCC, 2015).* Agriculture is the primary activity which is carried in most part of the district and have rich mineral deposits like Natural Gas and Crude Oil.

## 3. Material and Methods

The dataset procured for the analysis are Geology, Geomorphology, Soil, Rainfall, Lineament, Digital Elevation Model and Sentinel-2 which can be classified in two types which are Agency based and Satellite based. The agency based (Tab.01) comes under government data centres like Geological Survey of India (GSI) consists of Geology and Geomorphology, Soil Survey Department – Soil, Indian Meteorological Department (IMD) and finally the satellite based consists of United Stated Geological Survey (USGS) – Landsat-8 imagery and SRTM for DEM (Digital Elevation Model). The Landsat-8 Imagery was used to derive the Landuse / Landcover and Lineament of the Thiruvarur district. DEM utilized to prepare the slope and stream and finally producing the drainage density. The rainfall was interpolated using the available station with Inverse Distance Weighted Method. Lineament and Drainage density was produced using kernel line density using ArcMap. To delineate the groundwater potential zone weighted overlay was used and each parameter was weighted based on the influential level with maximum weight of 100. Furtherly, each parameters sub-classes were ranked from 1 to 5 (Very Low to Very High). Rank 1 – Very Low, rank 2 – Low, rank 3 – Moderate, rank 4 – High and rank 5 – Very High, these rank represents the groundwater potentiality. The weighted parameter is merged together to generate the groundwater potential zone for the chosen district and output classified into five group based on the groundwater potential region.

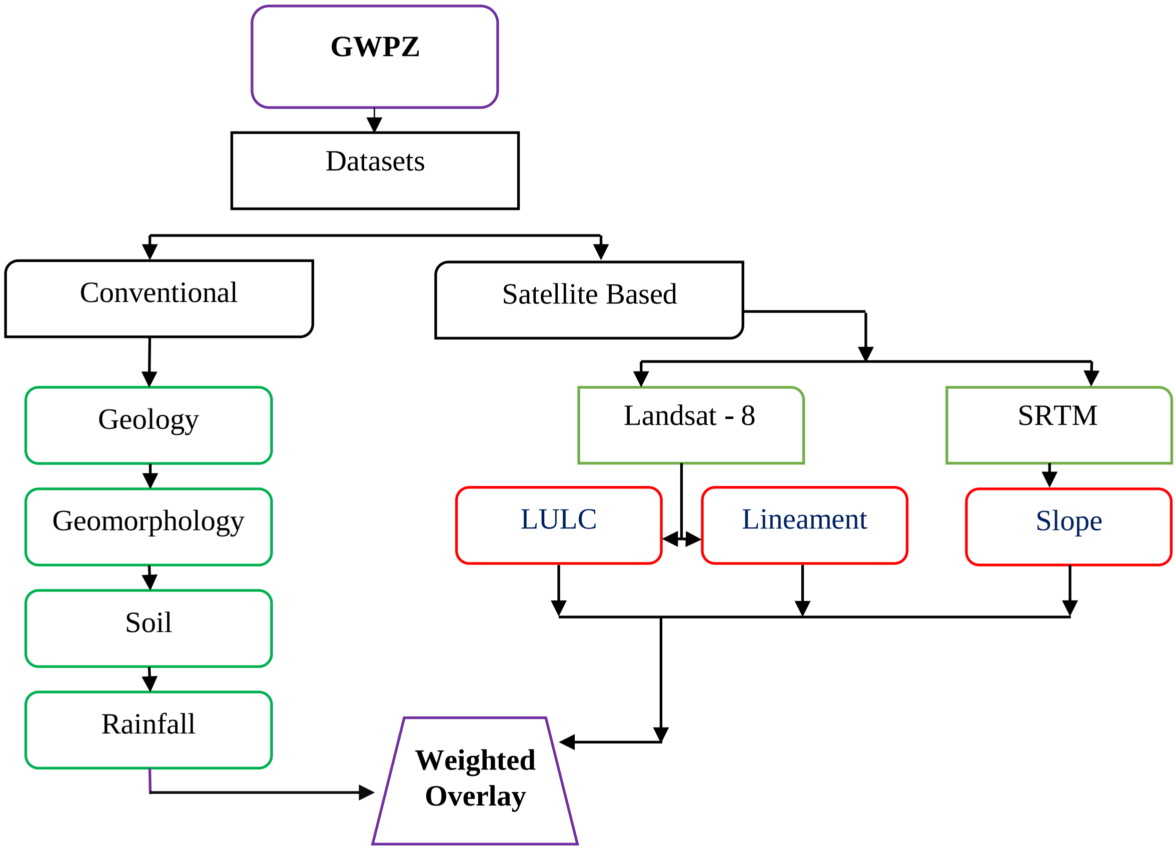
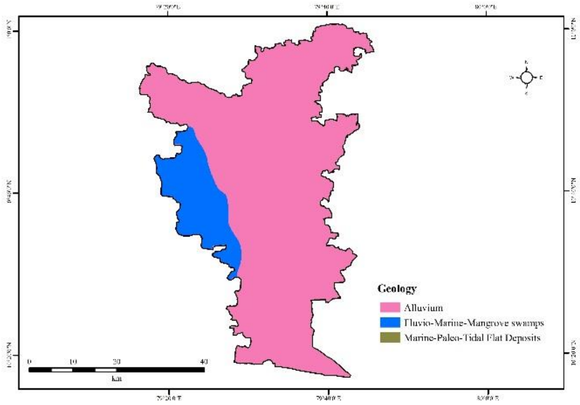



Fig. 02. Flow Chart indicating the Methodology

Tab 01. Dataset used for Groundwater Potential Delineation

| Data Utilised | Data Source | Resolution |
|---|---|---|
| **Slope** | DEM – STRM (USGS) | 10 m |
| **Lineament** | Landsat -8 (USGS) | 30 m |
| **Geology** | GSI - Geological Survey of India | 30 m |
| **Drainage** | DEM - SRTM | 30 m |
| **Soil** | National Bureau of Soil Survey | 1:50,000 |
| **Geomorphology** | Geological Survey of India | 1:50,000 |
| **Landuse / Landcover** | Landsat -8 (USGS) | 30 m |
| **Rainfall** | IMD | - |

## 4. Result and Discussion



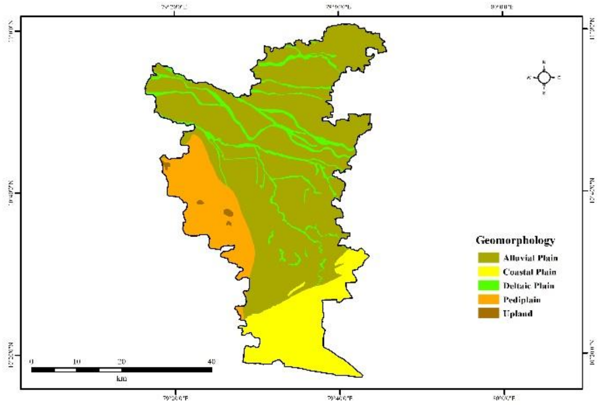




Fig.03. Geological Map Fig.04. Geomorphological Map

### 4.1 Geology

Based on the geological survey of India classification three types formation is found in Thiruvarur district (Fig.03) which are Alluvium, Fluvio-Marine-Mangrove swamps and Marine-Paleo-Tidal Flat deposits. The weightage and rank is based on the holding capacity of the features and the geographical coverage of each features is calculated. Based on the measurement Alluvium covers 2042.95 sq.km (86.05%), Fluvio-Marine-Mangrove swamps with 330.38 sq.km (13.92%) and Marine-Paleo-Tidal Flat deposits with 0.77 sq.km (0.03%).

### 4.2 Geomorphology

It is one of the determining factor in finding-out the trace of formation which are most suitable to store and rejuvenate of groundwater *(Gupta, 2003)*. There are five geomorphological (Fig.04) features available in the study area, namely; Alluvial Plain, Deltaic Plain, Coastal Plain, Pediplain and Upland. The weightage for the geomorphology is 15 out of 100, rank for the feature are Alluvial Plain – 5 (Very High), Deltaic Plain – 4 (High), Coastal Plain – 2 (Low), Pediplain – 3 (Moderate) and Upland – 2 (Low). Alluvial Plain covers 1491.84 (62.84%), Deltaic Plain with 179.86 sq.km (7.58%), Coastal Plain with 385.62 sq.km (16.24%), Pediplain and Upland with 308.47 sq.km (12.99%) & 8.31 sq.km (0.35%).

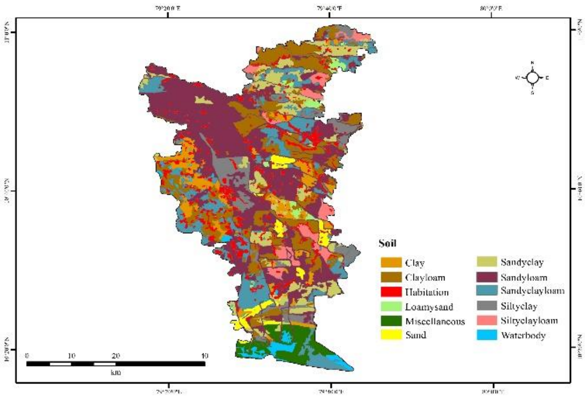



Fig.05. Soil Map

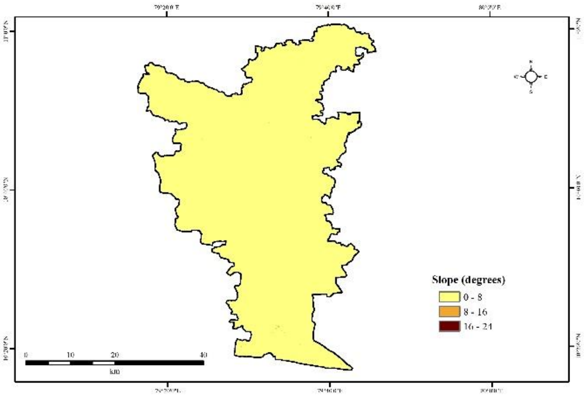



Fig.06. Slop Map

### 4.3 Soil

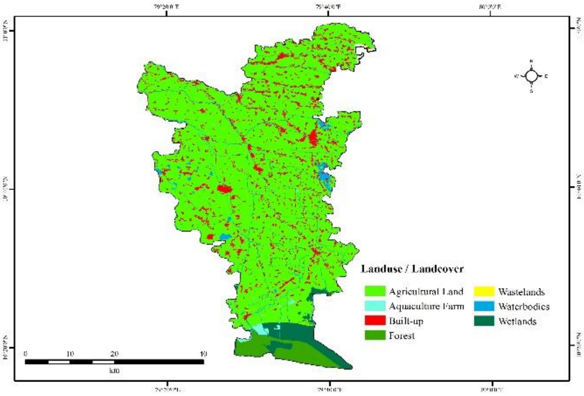
Soil is the top most layer of the earth surface which is vital factor supporting life, it helps in storing of minerals, nutrients, water which are beneficial in development of life *(Magesh et.al 2012)*. The major types of soil (Fig.05) available in the study are Sandy Loam, Clay Loam, Silt Clay, Silty clay loam, Sandy clay loam, Sandy clay, Habitation, Clay, Loamy sand, Sand, Waterbodies, Miscellaneous. Spatial extent of each soil was calculated which are Sandy Loam with 792.75 sq.km (33.39%), Clay Loam with 377.86 sq.km (15.92%), Silty Clay covers 132.18 sq.km (5.57%), Silty clay loam occupies 75.06 sq.km (3.16%), Sandy clay loam with 293.62 sq.km (12.37%), Sandy clay with 193.28 sq.km (8.14%), Habitation 164.9 sq.km (6.95%), Clay 142.42 sq.km (6%), Loamy sand with 27.89 sq.km (1.17%), Sand with 51.38 sq.km (2.16%), Waterbodies and Miscellaneous with 40.72 sq.km (1.72%) & 82 sq.km (3.45%).

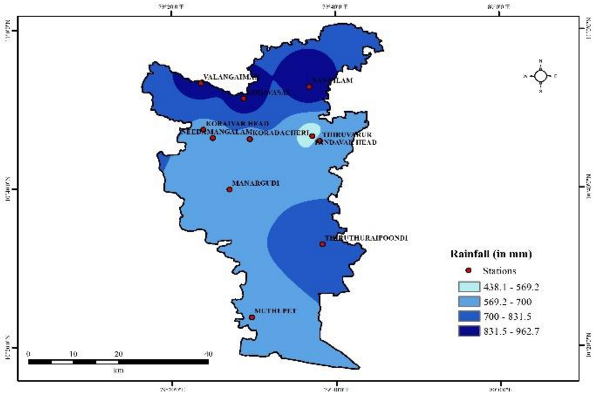
### 4.4 Slope

Slope map (Fig.06) is prepared using Digital Elevation Model (DEM) procured United States Geological Survey (USGS). DEM was the base data; ArcGIS tools were used to generate slope in degrees using the elevation data. Slope is useful to identify the water accumulation spots and in estimating the slope gradient to hold water or towards excessive runoff. Equal Interval method was used to generate the classes which are 0 to 8$^o$, 8 to 16$^o$ and 16 to 24$^o$. The area for each interval was calculated, 0 to 8$^o$ (Very High – Potential) with 2273.12 sq.km (99.96%), 8 to 16$^o$ (Moderate – Potential) covers 0.81 sq.km (0.04%) and 16 to 24$^o$ (Low Potential) with 0.0149 sq.km.

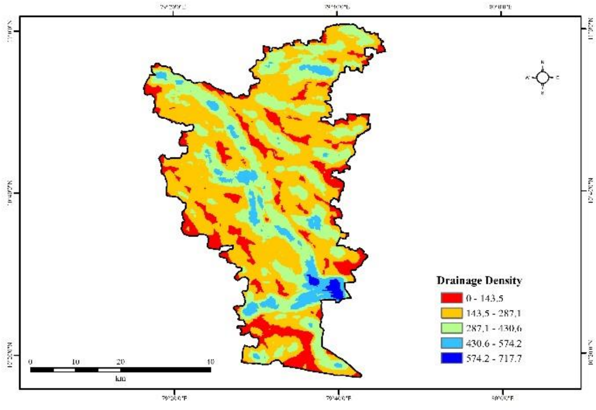
### 4.5 Landuse / Landcover (LULC)

LULC was processed using Landsat-8 (OLI) collected from United States Geological Survey with resolution of 30 m. The image was processed to eliminate the induced noise and atmospheric impurities. LULC map (Fig. 07) was prepared using supervised image classification, the sample sets were trained to the computers and cross checked with google earth for identification of features in the land surface, furtherly the image was processed to generate seven classifications. The major classes defined for Landuse / Landcover are Agriculture Land, Built-up, Wetlands, Aquaculture, Forest, Waterbodies and Waste land. The spatial extent was identified using area calculation, Agriculture Land occupied 1876.56 sq.km (79.03%), Built-up with 233.85 sq.km (9.85%), Wetlands covers 85.12 sq.km (3.58%), Aquaculture with 11.51 sq.km (0.48%), Forest with 85.27 sq.km (3.59%), Waterbodies cover 81.71 sq.km (3.44%) and Waste land covers 0.36 sq.km (0.02%). Agriculture is the largest occupation in Thiruvarur district.




data, using interpolation method for identification of unknown with known. Inverse Distance Weighted (IDW) method was incorporated to distribute the rainfall data for the study area. The identified rainfall (Fig. 08) for the districted was classified into four groups based on the rainfall intensity like 438.1 to 569. 2 mm with 22.8 sq.km (0.93%), 569.2 to 700 mm with 1322.43 sq.km (55.70%), 700 to 831.5 mm with 780.82 sq.km (32.89%) and 831.5 mm to 962.7mm covers 248.91 sq.km (10.48%). Rainfall is important parameter in discovering groundwater potential region.



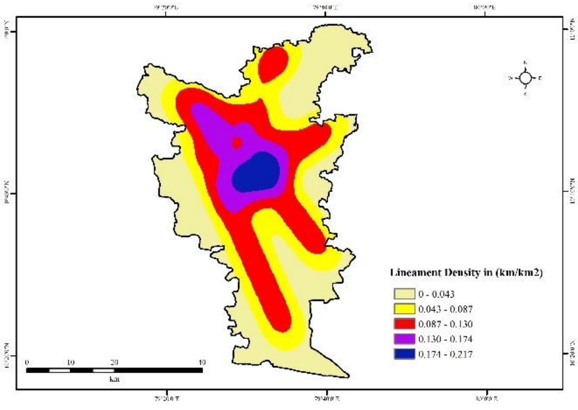




Fig.09. LULC Fig.10. Rainfall

### 4.7 Drainage Density

Drainage Density (Fig. 09) was generated using the DEM data which of 30 m resolution, it had been processed to fill the omitted during SRTM mission. The drainage density was calculated using stream data which was created through accessing the flow direction and accumulation and finally stream order was obtained using strahler method. The drainage density was performed using tool kernel density in ArcMap. Furtherly, the drainage density was classed into 5 based on its density which are 0 - 143.5 with 330.19 sq.km (13.91%), 143.5 - 287.1 with 1202.9 sq.km (50.67%), 287.1 - 430.6 with 682.82 sq.km (28.76%), 430.6 - 574.2 with 140.49 sq.km (5.92%) and 574.2 - 717.7 with 17.67 sq.km (0.74%). The higher density of drainage has excellent groundwater potential zone.

### 4.8 Lineament Density

Lineaments are fault or fracture which helps in water storage and recharge naturally, hence it is good source for storage and trapping of water. The lineaments (Fig. 10) were generated though the Landsat-8 satellite data procured from USGS. The lineament was converted into lineament density using the tool kernel density and had furtherly classified based on the density which are 0 - 0.043 km/km2 with 893.33 (37.62%), 0.043 - 0.087 km/km2 with 596.38 sq.km (25.12%), 0.087 - 0.130 km/km2 with 578.33 sq.km (24.36%), 0.130 - 0.174 km/km2 covers 220.24 sq.km (9.28%) and 0.174 - 0.217 km/km2 with 86.04 sq.km (3.62%).

## 5. Groundwater Potential Region

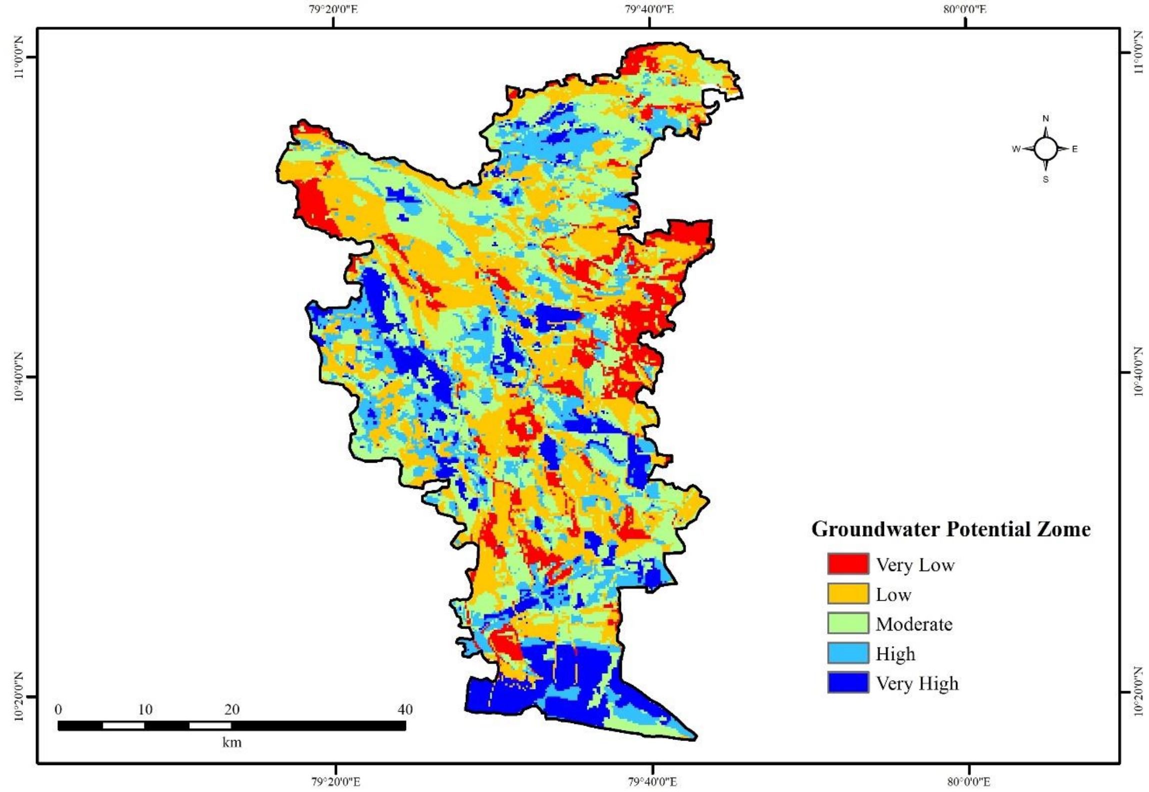



Fig. 11. Groundwater Potential Region

Tab 02. Weightage for Each Parameter

| Parameter | Sub-Class | Potential | Weightage | Rank |
|---|---|---|---|---|
| **Geology** | Alluvium | Very High | **20** | 5 |
| | Fluvio-Marine-Mangrove swamps | High | | 4 |
| | Marine-Paleo-Tidal Flat Deposits | Low | | 2 |
| **Soil** | Sandy Loam | Moderate | **10** | 3 |
| | Clay Loam | Moderate | | 3 |
| | Silty clay | Very Low | | 1 |
| | Silty clay loam | Very Low | | 1 |
| | Sandy clay loam | Moderate | | 3 |
| | Sandy clay | Low | | 2 |
| | Habitation | Very Low | | 1 |
| | Clay | Very High | | 5 |
| | Loamy sand | Moderate | | 3 |
| | Waterbody | Very High | | 5 |
| | Sand | High | | 4 |
| | Miscellaneous | Low | | 2 |
| **Geomorphology** | Alluvial Plain | Very High | **10** | 5 |
| | Deltaic Plain | High | | 4 |
| | Coastal Plain | Low | | 2 |
| | Pediplain | Moderate | | 3 |
| | Upland | Low | | 2 |
| **Landuse / Landcover** | Agricultural Land | Moderate | **5** | 3 |
| | Built-up | Very Low | | 1 |
| | Aquaculture | Very Low | | 1 |
| | Wetlands | Very High | | 5 |
| | Waterbodies | Very High | | 5 |
| | Forest | High | | 4 |
| | Wastelands | Moderate | | 3 |
| **Slope** | 0– 8° | Very High | **5** | 5 |
| | 8- 16 ° | Moderate | | 3 |
| | 16 - 24 ° | Low | | 2 |
| **Drainage Density** | 0 - 143.5 | Very Low | **15** | 1 |
| | 143.5 - 287.1 | Low | | 2 |
| | 287.1 - 430.6 | Medium | | 3 |
| | 430.6 - 574.2 | High | | 4 |
| | 574.2 - 717.7 | Very High | | 5 |
| | 0 - 0.043 km/km2 | Very Low | | 1 |
| | 0.043 - 0.087 km/km2 | Low | | 2 |

| | | | | |
|---|---|---|---|---|
| **Lineament Density** | 0.087 - 0.130 km/km2 | Medium | **15** | 3 |
| | 0.130 - 0.174 km/km2 | High | | 4 |
| | 0.174 - 0.217 km/km2 | Very High | | 5 |
| **Rainfall** | 438.1 - 569.2mm | Very Low | **20** | 1 |
| | 569.2 – 700 mm | Low | | 2 |
| | 700 - 831.5 mm | Medium | | 3 |
| | 831.5 - 962.7mm | High | | 4 |

Tab 03. Zone-wise calculation of GWPZ

| Ground Water Potential Zone (GWPZ) | Area (km$^2$) | Percentage (%) |
|---|---|---|
| **Very Low** | 246.462 | 10.38% |
| **Low** | 772.623 | 32.54% |
| **Moderate** | 690.64 | 29.08% |
| **High** | 379.778 | 15.99% |
| **Very High** | 285.190 | 12.01% |
| | **2374.693** | **100 %** |

The groundwater potential region required the following parameters to find the storing or trapping spots, which are Geology, Geomorphology, Soil, Slope, Landuse / Landcover, Rainfall, Drainage and Lineament Density. The weightage was assigned to the individual features with overall weight of 100, Geology - 20, Geomorphology - 10, Soil -10, Slope - 5, Landuse / Landcover - 5, Rainfall - 20, Drainage - 15 and Lineament Density – 15. Furtherly each sub-class of parameter was ranked into five classes based its potentiality indicating (Tab.02) Rank – 1 with Very Low, Rank – 2 with Low, Rank – 3 with Moderate, Rank – 4 with High and Rank – 5 with Very High. The weighted Overlay tool was used to merge the data based on weightage and the output groundwater potential region (Fig. 11) was classified into five groups with respect to potentiality, which are Very Low, Low, Moderate, High and Very High. The spatial extent was assessed (Tab. 02) which indicates Very Low occupies 246.462 sq.km (10.37%), Low with 772.623 sq.km (32.52%), Moderate with 690.64 sq.km (29.07%), High with 379.778 sq.km (15.99%) and Very High covers 286.19 sq.km (12.05%).

## 6. Conclusion

Results from the analysis highlights that Thiruvarur district 28% of land have the high capability to be suitable for groundwater potential region, geographically the regions are situated in the south, western and central part & new northeaster portion of the district. Methods and techniques should be adopted to facilitate the potentially of region, because the groundwater can also be recharged in moderate potential region and it occupies 29% of the entire district which be greatly put into use. Through the proper recharge method, the groundwater can be increased in Thiruvarur District. Combination of local people and internal government can bring in change to improve infrastructure of water and sustain during the dry season or scarcity. From the study, it's clear that involvement of geospatial techniques can provide faster solution, helps to detect the new possibilities and achieve sustainable development.

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