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DELINEATION OF GROUNDWATER POTENTIAL ZONES IN LOWER PONNAIYAR RURAL WATERSHED, CUDDALORE DISTRICT, TAMILNADU, INDIA

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ABSTRACT

A systematic planning of groundwater development using modern techniques is essential for the proper sustainable groundwater resource management. The groundwater potential zones have been evaluated in Lower Ponnaiyar river basin , Cuddalore District, Tamilnadu, India using Remote Sensing and GIS techniques. The thematic maps considered in this study are geomorphology, soil, land use/land cover, slope, drainage density and lineament density, which are prepared from satellite imagery and conventional data. The groundwater potential map was prepared by assigning appropriate weightage to different thematic layers and finally all thematic layers integrated using overlay analysis of ARCGIS software to identify the groundwater recharge potential zones. Based on the weightage factors the map showing these groundwater potential zones categorized as poor, moderate, good and excellent is prepared. The results of this study suggested an efficient groundwater management plan for the study area so as to ensure sustainable management of groundwater resources.

KEYWORDS: Groundwater Potential, Remote Sensing and GIS, Thematic Maps

INTRODUCTION

In general, the occurrence and movement of groundwater, especially in fractured bedrock aquifers, in a given area is governed by factors such as topography, lithology, geology, geomorphology, slope, drainage pattern and climatic conditions. As a result, the groundwater potential varies from place to place, sometimes within a few meters and even within the same geological formation (Dar et al, 2010). In hard rock terrain availability of groundwater is limited and is essentially confined to fractured and weathered zones. There are several methods employed for delineating groundwater potential zones such as geological, hydrological, geophysical and remote sensing techniques. Integration of various thematic maps results in the generation of groundwater potential zone map. In recent times Remote Sensing and GIS techniques are proved to be cost effective and time-saving tool .

The integrated approach of Remote Sensing and GIS can provide the appropriate platform for convergent analysis of divergent database for decision making in not only mapping and planning of groundwater resources. but also the management of groundwater resources for its efficient and cost effective use of a region or state. This study is attempted to develop and applies integrated method for combining the information obtained by analysing multi-source remotely sensed data in a GIS environment for better understanding the groundwater resource for a watershed in Cuddalore and Villupuram district, Tamilnadu, India

STUDY AREA

The study area lies in between 79° 15’ 13” and 79° 48’ 28” E longitudes and 11° 50’ 18” to 11° 55’ 18” N latitudes with a total area of extent of 598 km^2 (Figure 1). It includes five taluks namely Tirukoilur, Ulundurpettai, Villupuram, Panruti and Cuddalore with a general elevation of 56 m above MSL sloping from West to East. The river is dry for the most part of the year. Water flows during the monsoon season when it is fed by the south-west monsoon in the catchment area and the northeast monsoon in Tamilnadu. However, this water flow raises the groundwater table throughout the river basin and feeds numerous reservoirs /tanks. The maximum rainfall recorded is 1851 mm (1996-97), while the minimum is 548 mm (1989-90). The maximum temperature may rise up to 40 °C and decreased during winter season up to 27 °C. The Index map of the study area is presented in Figure 1.

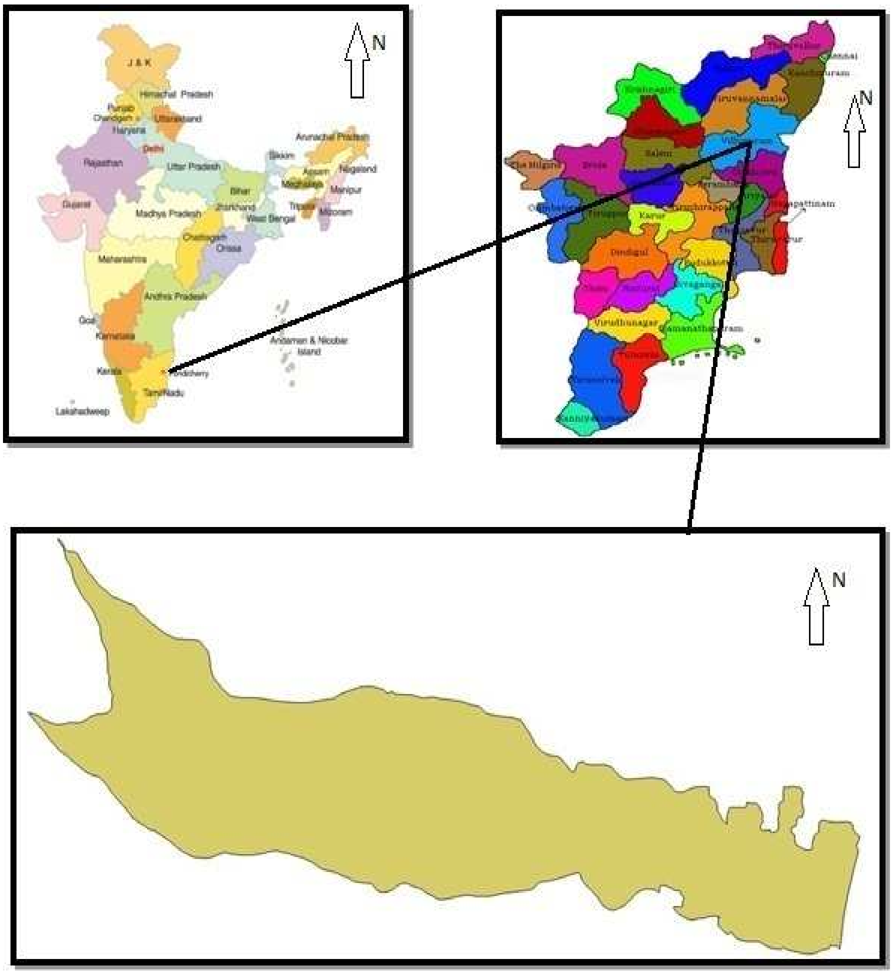

Figure 1: Index Map of the Study Area

Geology

The major lithology groups were noticed as Clay, Sand and silt, Sand/Clay admixture, Horne-blende Biotite gneiss and Gingee granite. The study area comprises mostly of sand and silt combination which is a good characteristic feature of groundwater. The other geological formations such as Clay, Sand/clay admixture, Horne blende Gneiss and Gingee granite occurred minimum which is moderate to poor characteristic feature of groundwater. Geology map of the study is presented in Figure 3.

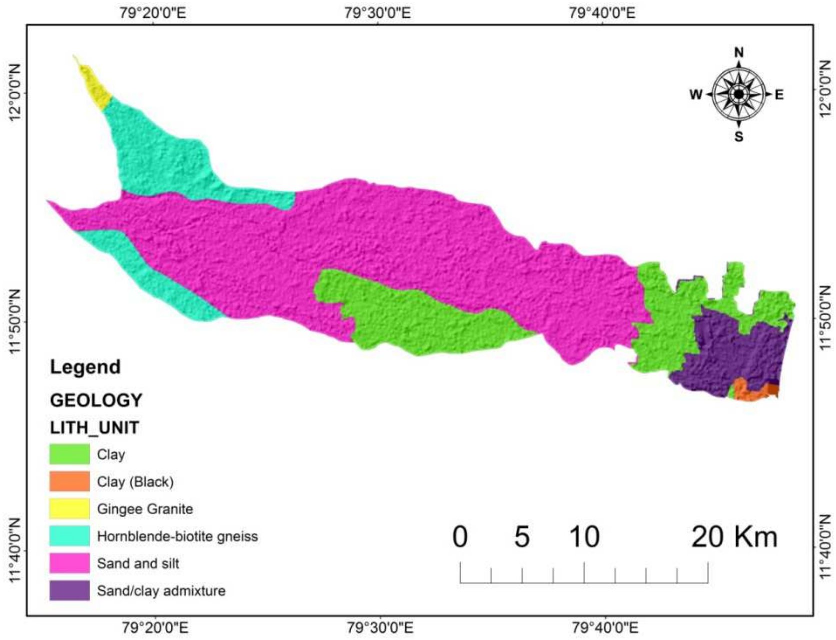

Figure 3: Geology Map of the Study Area

Geomorphology

Geomorphology exhibits various landforms and structural features. The geometric features of different landforms are created by the dynamic action of several geological processes such as temperature changes, freezing and thawing, chemical reactions, seismic shaking and moving of wind and water. Many of these features are favourable for the occurrence of groundwater and are classified in terms of groundwater potentiality. There are major geomorphic units were identified namely Pedi plain, Coastal plain, Floodplain, and alluvial plain are presented in Figure 4.

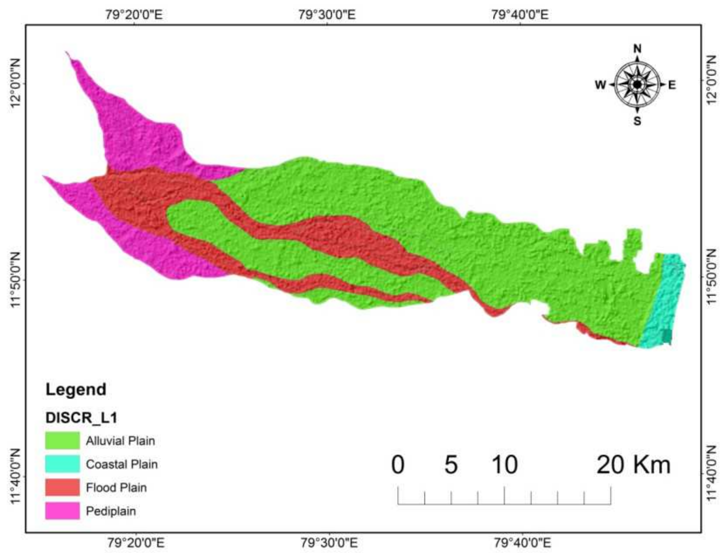

Figure 4: Geomorphology Map of the Study Area

Drainage Density

Drainage of an area is based on the topography, slope and the subsurface characteristics. Drainage density is calculated as the total length of all the streams and rivers in a basin divided by the total area of the drainage basin. The drainage density is inversely proportional to groundwater prospect. If the drainage density is high, runoff will be high, and infiltration of water into the subsurface will be affected. Hence lesser the drainage density, higher is the probability of recharge or potential groundwater zone. Drainage density (in terms of km/km^2) indicates the closeness of spacing of channels as well as the nature of the surface material. Drainage density has been calculated by Kernel density method in Arc GIS to understand the potential of the watershed to support the groundwater potential. The high drainage density area indicates low infiltration rate whereas the low-density areas indicate high infiltration rate as shown in Figure 5.

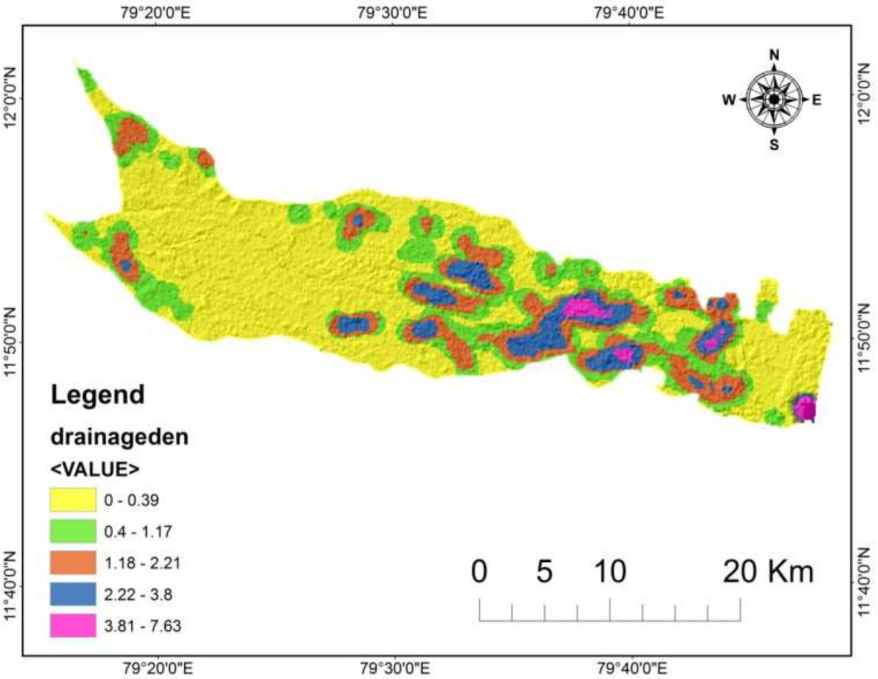

Figure 5: Drainage Density Map of the Study Area

Lineament Density

Lineament density map was prepared by using line density method. Lineaments are the appearance of linear features that are identified from remote sensing data. The predominant directions of lineaments are horizontal from west to east are shown in Figure 6. Directional analysis or lineament analysis has been carried out to depict the occurrence of lineament in the area. Although lineaments have been identified throughout the area, the lineaments density is high in the Alluvial plain, Floodplain which is considered significant from groundwater occurrence point of view. The presence of high drainage density, high-slope areas and the area occupied by clay units are less significant. In this situation, high runoff has been generated .

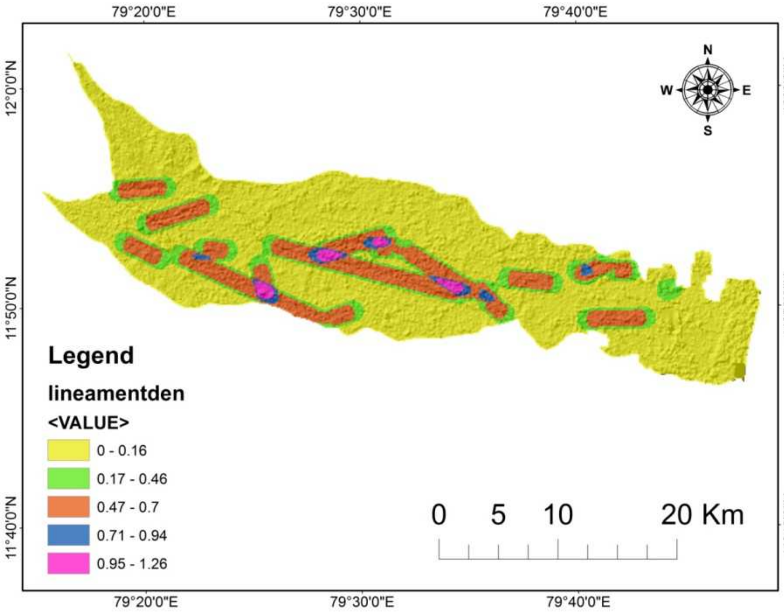

Figure 6: Lineament Density Map of the Study Area

Slope

The slope is one of the factors affecting the infiltration and runoff. The lower slope represents the high groundwater potential and higher slope represents the higher runoff i.e low groundwater potential. The slope map was prepared from SRTM DEM data. The study area has slope ranging from 0° –0.35° to more than 25°. Most of the study area occupies slope category of 0.35°–1° as depicted in Figure 7. Since, the slope is also a criterion for infiltration, most of the area has a gentle slope which is favourable for groundwater potential.

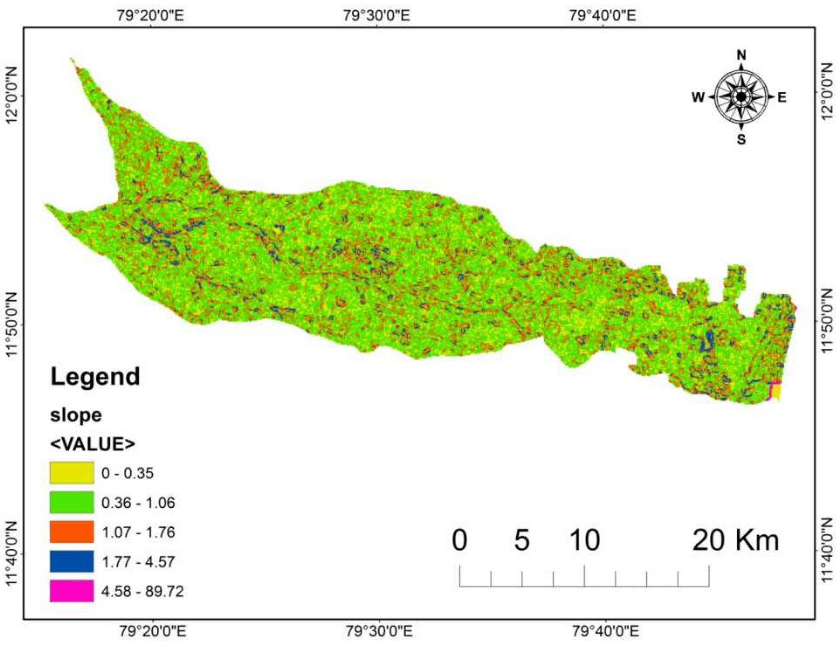

Figure 7: Slope Map of the Study Area

Land Use/ Land Cover

The availability of groundwater quantitatively is determined by the land use in an area. Fig 8 showed the land use / land cover pattern of the study area, which comprises of agricultural land (cropland, fallow land and plantation), water bodies (stream and tank), wasteland (land with or without scrub, stony waste and sheet rock area) , built-up land and wetland are identified from LISS III imagery. Irrigation is mainly (70 %) dependent on groundwater (CGWB 2007). The cropping pattern depends on the climatic conditions and availability of water sources. Paddy, castor, cotton, grams, guava, and groundnut are the major crops grown in this area. The majority of the livelihood is from agriculture and its allied activities.

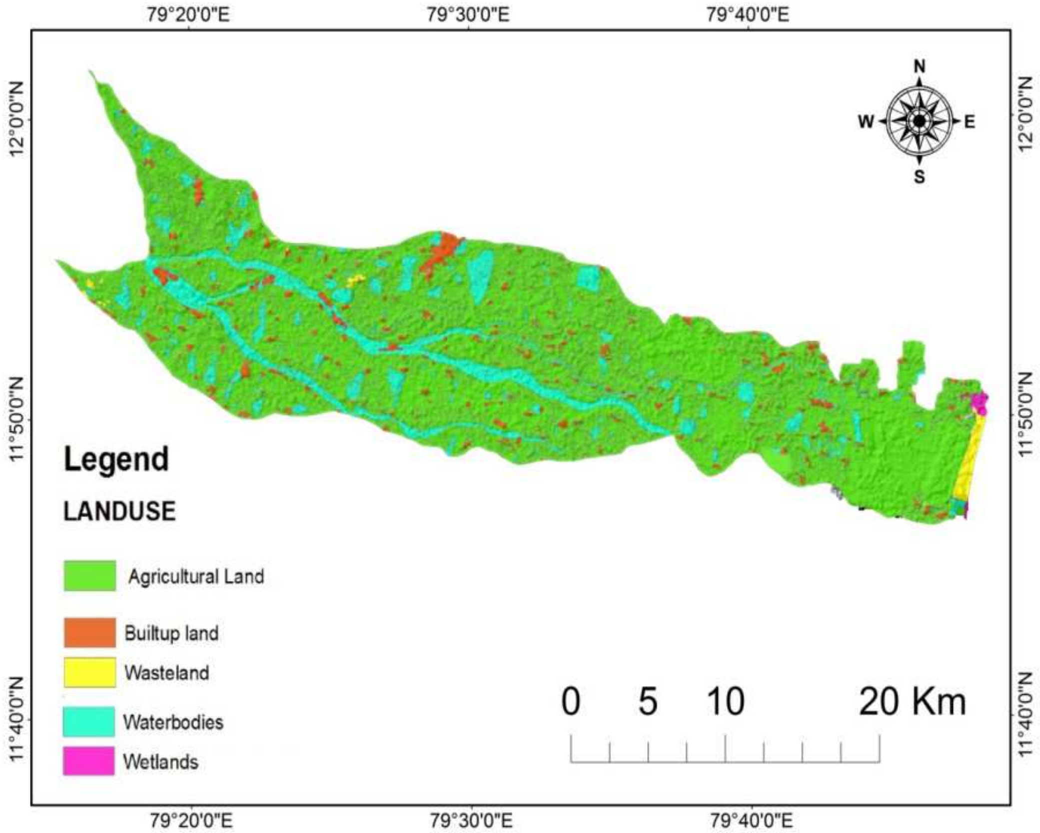

Figure 8: Land Use/ Land Cover Map of the Study Area

Soil

Climate, geology and soil play a significant role in groundwater recharge and runoff. The water carrying capacity of an area depends upon the soil types and their permeability. The initial infiltration and transmission of surface water into an aquifer system is a function of soil type and its texture. Four types of soils are found in the study area, viz. Alfisols, Entisols, Inceptisols, and vertisols (Figure 9). The delineation was based on differential manifestations on the imagery in the form of colour, tone, texture and association. Field checks in the identified soil units were conducted and confirmed.

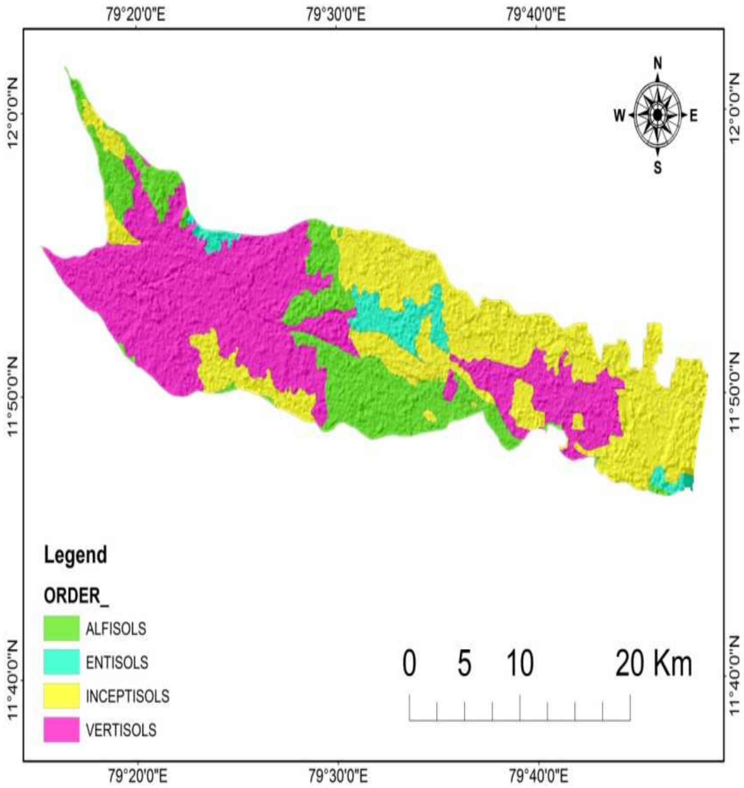

Figure 9: Soil Map of the Study Area

MATERIALS AND METHOD

GIS techniques were employed in this study to delineate the groundwater potential of Lower Ponnaiyar watershed based on time and cost effectiveness. Identification of suitable sites for groundwater recharge was conducted through a knowledge-based factor analysis, using lineament density, slope, drainage density, land use/land cover, lithology, geomorphology and soil type layers in GIS environment.

Data Used

- Survey of India (SOI) Toposheet (No.58M/8, 9, 10, 13 and 14) - 1972
- Landsat TM – LISS III images - 2013
- SRTM DEM (90 m resolution) – 2016

Software Used

- ERDAS Imagine
- Arc GIS 10.1

Methodology

The base map of the study area was prepared based on Survey of India (SOI) Toposheets (1972). The slope map was prepared from SRTM DEM data (http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp) in Arc GIS 10.1 Spatial analyst module. The drainage density and lineament Density maps were prepared using the line density tool in Arc GIS.

The main task in this stage was to carry out analysis and interpretation of satellite data, in order to produce thematic maps, such as geology, geomorphology, land use/land cover and Soil. Initially, all the images were rectified using the SOI Toposheets. This was followed by processing the digital images using the various processing techniques, viz., enhancement, filtering, classification and other GIS processes. It was validated through ground truthing. The main job was to bring all the appropriate data and other collateral data together into a GIS database. All the available spatial data was assembled in the digital format and properly registered to make sure the spatial component overlaps perfectly. Digitizing of all the maps and collateral data, followed by transformation and conversion from raster to vector, interpolation and other GIS processes were undertaken. Finally to arrive the Groundwater Prospective map , all the thematic layers were overlaid using weightage overlay module in Arc GIS 10.1.

RESULTS AND DISCUSSIONS

Integration of the Remote Sensing and GIS techniques has proven to be an efficient tool in groundwater studies (Arivalagan, 2014). This study analysed hydrologic and geographic attributes of the study area and identified seven major factors influencing groundwater recharge potential, viz. geomorphology, geology, slope, soil, land use/land cover, lineament density and drainage density. Each factor was examined and assigned appropriate rank and weight. Based on the groundwater potentiality, all thematic layers were quantitatively placed together and categorized into very good, good, moderate and poor.

Overlay Analysis

Overlay analysis is a multi-criteria analysis wherein analysis can be carried out with complex things for finding out the certain theme with the help of assignment of rank to the individual class of feature and then assigning weightage to the individual feature considering its influence over theme (**Shivaji Govind Patil, 2014**) and is presented in Table 1. All the thematic maps were converted into raster format and superimposed by weighted overlay method, which consists of rank and weightage wise thematic maps and integration of them through GIS. Integration of thematic maps for carrying out multi-criteria or overlay analysis in GIS environment was done using Arc GIS software.

Table 1: Rank And Weightages of Each Layer for Groundwater Prospective Zone

Theme	Weightage	Class	Rank	Groundwater Prospect
Geomorphology	21	Coastal Plain	1	Poor
		Pediplain	2	Moderate
		Alluvial Plain	3	Good
		Flood Plain	4	Very Good
Geology	14	Clay/ Sand/clay admixture	1	Poor
		Hornblende -Biotite gneiss	2	Moderate
		Gingee granite	3	Good
		Sand and silt	4	Very Good
Soil	10	Alfisols	1	Poor
		Vertisols	2	Moderate
		Inceptisols	3	Good
		Entisols	4	Very Good
Landuse	12	Wasteland/ Built-up land	1	Poor
		Wetland	2	Moderate
		Waterbodies	3	Good
		Agricultural land	4	Very Good
Slope	15	> 4.8	1	Poor
		1.4 - 4.8	2	Moderate

		0.7 -1.4	3	Good
		< 0.7	4	Very Good
Drainage Density	12	> 4.5	1	Poor
		3 – 4.5	2	Moderate
		0.15 – 3	3	Good
		< 0.15	4	Very Good
Lineament Density	16	< 0.50	1	Poor
		0.50 - 0.75	2	Moderate
		0.75 - 1	3	Good
		> 1	4	Very Good

Groundwater Prospective Map

Preparation of groundwater prospective zonation map is seen as a prerequisite for creating and planning any agricultural and industrial development in this area. The prospect map describing the groundwater occurrence in the study area were identified and presented in Figure 10. From this study Groundwater potential zones were categorized into four types viz. poor (2%), moderate (57%), good (40%) and very good (1%). The best suitable areas were identified in Thiruvennainallur and Kandamangalam Blocks of the study area because of the presence of alluvial plain and floodplain with minimum slope. The map indicated that maximum plain areas were identified as moderate prospective zones, while steep sloping and high drainage density are classified as poor prospective areas like coastal areas and some places of north-west parts of the study area.

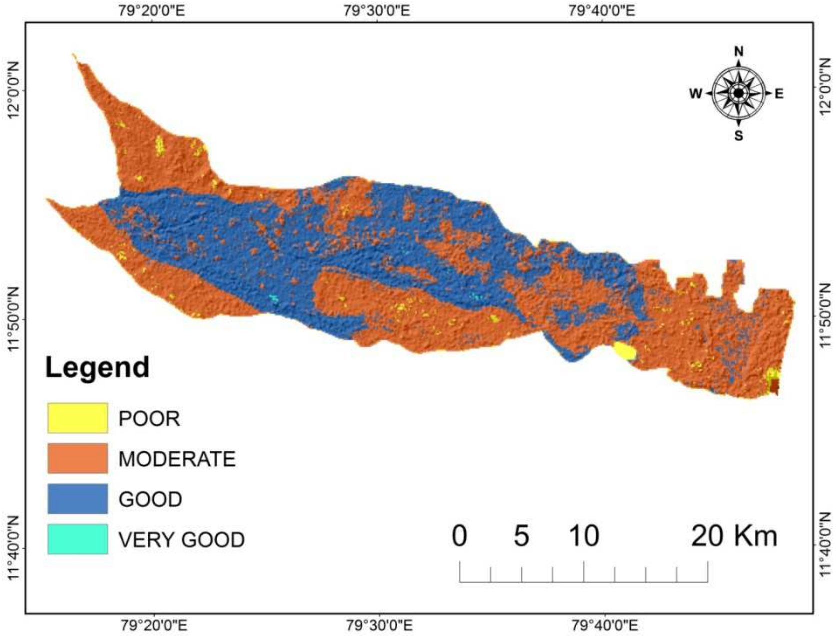

Figure 10: Groundwater Prospective Zones Map

CONCLUSIONS

Mapping and prospecting the zones will help to plan for sustainable groundwater management. Favourable areas for groundwater occurrence and storage were identified based on slope, drainage density, land use, geology, lineament density and geomorphological features of this area. The groundwater potential zones were categorized as Moderate (57%) , Good (40%), Excellent (1%) and Poor (2%). Then it has been verified by field observation of groundwater level data which proved to be comparable. Around 97 % of the area falls into the high and moderate artificial recharge potential zones. Agriculture is the backbone in this study area which is located in the rural drop and the demand for groundwater resources is also high. Hence artificial recharge structures can be implanted in the study area in order to improve the replenishment of the groundwater resources. Percolation pits, recharge basin, recharge wells, ridges and furrows, check dams, gully control/ stonewall structures, contour bunding, trenching and land flooding are some of the artificial recharging methods which can be employed in such endeavour (CGWB, 2007). The identified favourable groundwater potential zones from this study will serve as a management tool to various organisations and decision makers in planning for groundwater resources exploration and development in these areas.

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