A Study On Delineation Of Groundwater Potential Zones In Crystalline Terrain Using Remote Sensing And GIS Techniques

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***Abstract*: For assessing the groundwater potential in hard rock terrain using remote sensing and geographical information system (GIS) plays a an important role along with the terrain features like geological, gomorphological, structural aspects and hydrogeological nature. A groundwater potential assessment study conducted in the hard rock terrain of Mangalur Block (Tamil Nadu) for groundwater resource planning and management. Different thematic maps were prepared for the terrain features and the maps were converted into a grid (raster format) and superimposed by a weighted overlay method with the rank and weighted of the thematic maps. Groundwater potential zones assessment is referred with a hierarchy of ranking with increased orders from 1 to 4, based on the characteristics of potential zones, poor (rank 1), low (rank 2), moderate (rank 3), and high (rank 4). The high groundwater potential zones found in the north and northeast part, along the Vellar river stretch (in the southern part) areas are suitable for groundwater augmentation and irrigation development in the study area.**

***Keywords: Groundwater potential, Magalur Block, Remote sensing and GIS, thematic maps*.**

I. INTRODUCTION

Groundwater occurrence is a subsurface phenomenon. In the crystalline terrain, presence of groundwater is limited and its availability is essentially curbed to fractured and the thickness of weathered zones. Its assessment is based on indirect analysis of some directly observable terrain features like geology, geomorphology, architecture of rocks and the hydrological distinctiveness. Satellite remote sensing contributes a synoptic view, which is helpful in identification and delineation of various landforms, linear features, structural elements, and terrain characteristics. These are important indicators of groundwater potential. Remote sensing and GIS techniques are increasingly used in hydrogeomorphological mapping.

Hydrological applications such as groundwater resource assessment, planning, soil erosion and urban drainage system, using remotely sensed data have gained popularity with the advent of raster and vector GIS environment [4]-B[5]-[14].Geographic Information System and Remote Sensing applications have been used by numerous workers in the delineation of groundwater potential zones [33]-[9]-[11]-[19]-[24]-[6]-[23]-[1]-[25]-[32]-[8]-[30]-[15]-[12].

In recent years, the importance of coupling, remote sensing and GIS in groundwater potential assessment studies has been realised by many workers like [7]-[31]-[3]-[13]-[34]-[10]-[6]-[18]-[21]-[16].Identification of groundwater resources using remote sensing data is based on an indirect analysis of some directly observable terrain features like geology, geomorphology, slope, land use/land cover and hydrological characteristics. With the remarkable capabilities of the remotely sensed data and GIS techniques, numerous databases can be integrated to produce a conceptual model for delineation and evaluation of groundwater potential zones.

This study was undertaken to delineate both groundwater potential zones in the crystalline basement area for groundwater resource development and management using remote sensing techniques and the application of GIS technology.

II. STUDY AREA

The study area Mangalur Block has an areal extent of 472.26 Sq.Km. It is located between latitudes 11º 40’ 00” and 11º 20’ 00” North and longitudes 78º 55’00” and 79º 20’ 00” East. The area falls in the drought-prone and economically backward region of Tamil Nadu, India. The ephemeral VellarRiver flows through the southern part and forms the southern boundary of the study area. The drainage pattern is dendritic to sub-dendritic. Elevation of the area is 50 m above mean sea level. Due to shortage of surface and groundwater poor agricultural practices and no industrial development in the area. Part of Nangur Reserve forest falls in MangalurBlock.The study area map shown in Figure 1.

III. PHYSIOGRAPHIC CHARACTERISTICS

Geology

Geologically, the Block comprises mainly crystalline formations of Precambrian period. The rock types are charnockite, charnockite gneiss and migmatite gneiss. The charnockitic rocks are massive to foliated and the foliations usually trend in ENE – WSW direction with an average dip of 45º towards south. The charnockite thickness of the weathered zone varies from place to place in the study area. In the charnockite weathered zone, well-developed foliated fractures are noticed. The recent sedimentary formations (alluvial deposits) occur on the bed and banks of water courses (Vellar River and PeriyaOdai). The average annual rainfall is 1560 mm. NE monsoon is the main contributor. Hydrogeologically, the sedimentary formations consist enough groundwater potential than the crystalline hardrock formations.

Geomorphology and lineaments

The geomorphic features in the study area are duricrust, pediment, shallow pediment, buried pediment, flood plain and pediments covered by reserved forest (Figure 2). In the study area duricrust occurs as scattered patches. Pediments are surrounded by Nangur Forest. The shallow pediments are covered by black cotton soil derived mainly from charnockites. Most of the study area is covered by shallow pediments. Most of the lineaments run in NE–SW direction, and the remaining trend in NW–SE direction.

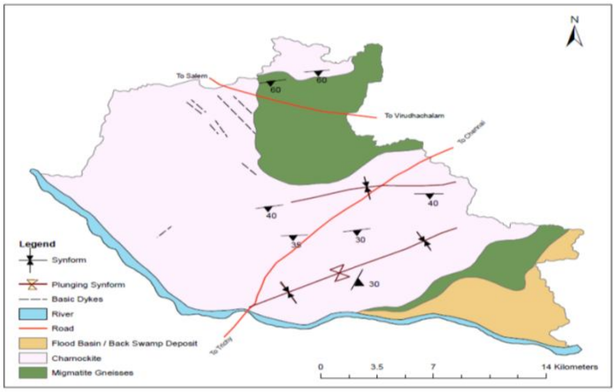

Figure 1. Geology map of the study area.

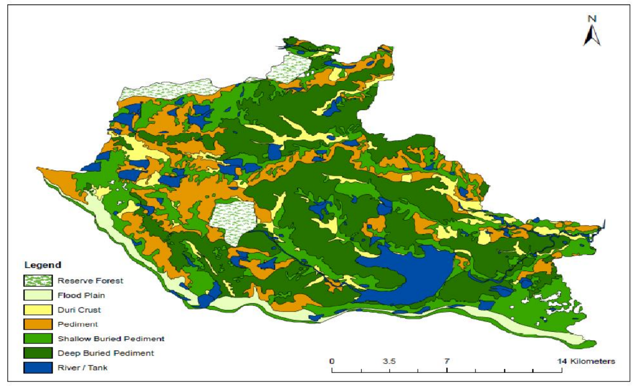

Figure 2. Geomorphology map of the study area.

Land Use/Land Cover

The study area shows the barren lands, cropland, dry crops, (BCS), duricrust, and river / tank / pond (Figure 3). A major portion of the terrain is barren land type. Crop lands are along the sides of Vellar river. Due to the flow of Vellar river and PeriyaOdai, the region is fertile and gives rise to crop lands. Surface water bodies like lakes, rivers, tanks, are also less in this area.

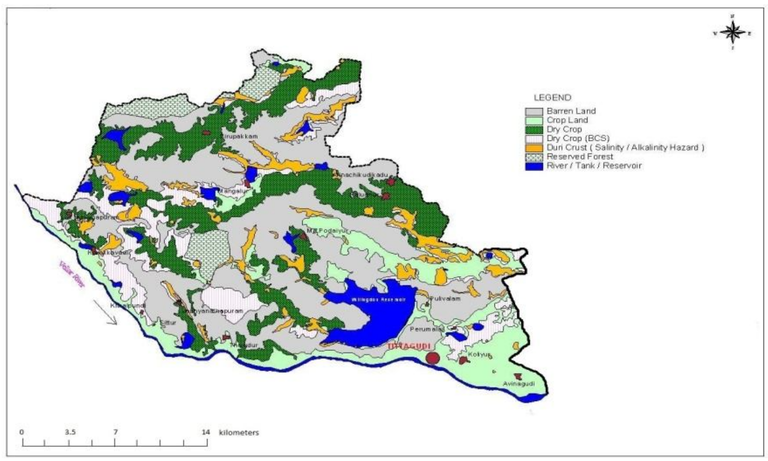

Figure 3. Land use pattern of the study area.

Soils

The study area soil patterns have been studied in detail and classified into the subgroup level according to the [27]. The soils of the study area are generally dark brown to grayish brown. The crops cultivated are paddy, sugarcane, cotton, chillies, coriander, and millets under rain-fed conditions.

IV. METHODOLOGY

There are two approaches for performing overlay analysis, one is feature overlay (overlaying points, lines, or polygons) and the other is raster overlay. Some kind of overlay analysis lends to one or the other of these approaches. Overlay analysis used to find locations meeting certain criteria to give the best raster overlay (although can do it with feature data). Indeed, this also depends on whether our data are previously stored as a feature or raster. It may be worthwhile to convert the data from one format to the other to perform the analysis. The principal elements in the feature overlay are the input, overlay and the output layers. The overlay behavior splits the features in the input layer where they have overlapped by the features in the overlay layer. Contemporary areas are shaped where the polygons intersect. The line containing input layer, the lines are split wherever polygons traverse the area.The created features are saved in the input layer, without changing the original input layer. The attributes of features in the overlay layer are assigned to the suitable new features in the output layer, beside with the original attributes from the input layer.

The overlay toolset contains tools to overlay multiple feature classes so as to combine, erase, modify, or to update spatial features in a new feature class. New information is created when overlaying one set of features with another. There are six types of overlay operations; all involve joining two existing sets of features into a single set of features to identify the spatial relationship between the input features.

Overlay analysis plays a key role in most of the GIS applications, so as to integrate information from different sources. The overlay process, whether performed in raster or vector representation, provides access to all the attribute values that occur in one location. There are many overlay methods such as dominance rule (exclusive screening and exclusive ranking), voting tabulation, weighted ranking and factor combination.

Manual integration consumes time and redrafting establishes additional errors while handling enormous data. Hence integration through the computer is preferred and is applied in this study using Arcview GIS software (Ver. 9.3). Polygons are built and IDs are assigned along with attributes. This strategy is adopted to identify freshwater zones in order to explore and meet the needs of the domestic water supply sector.

Spatial data

ArcView GIS software has been used to digitize the thematic maps prepared from different sources. The attribute information related to physiographic characteristics such as geology, geomorphology, soil, land use/land cover, drainage and lineament maps has been used in the analysis. The integrated potential zone modeling of groundwater adopted in this study is furnished in the form of flow chart (Figure 4).

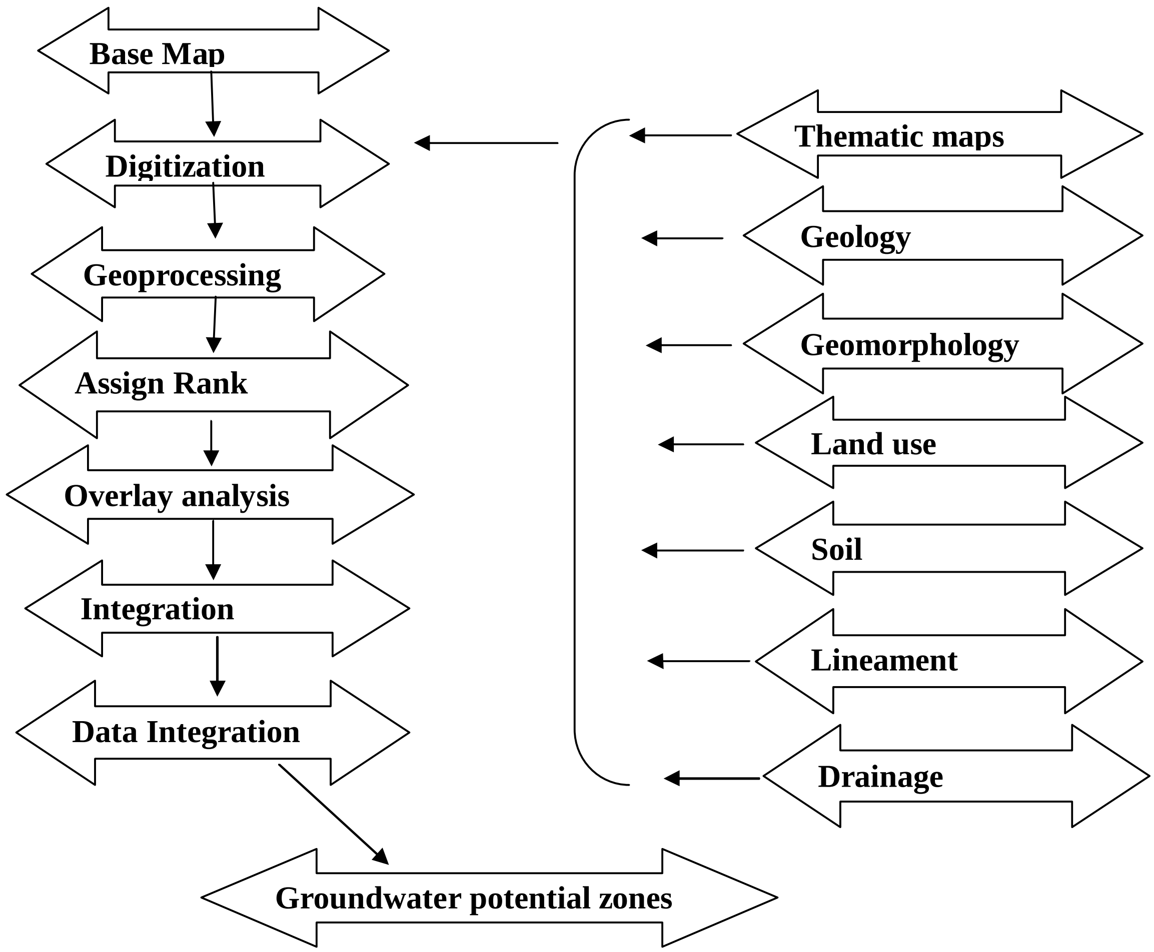

Figure 4.Flow Chart of methodology used in the study.

V. INTEGRATION OF THEMATIC MAPS THROUGH GIS

The integration of various thematic maps describing favourable groundwater zones was brought out as a single groundwater potential zone map with the application of GIS by [20]. In the present study, spatial data analysis has been made using GIS technique. Table analysis, classification, polygon classification and weightages classification have been carried out. Spatial dimensions of the geological / geomorphological features have been taken into account. These have been reclassified and assigned suitable weightages following the methods used by [11]-[28]-[2]-[26]. The ranks and groundwater potentiality are present in Table 1. The occurrence and movement of groundwater in an area is controlled by various factors. The influence of all factors will not be the same in an area. Therefore, each parameter is assigned weightages depending on its influence on the movement and storage of groundwater. For instance, the area being underlain by sedimentary rocks, the lithological control is less effective compared to the topographical control. Therefore, higher weightages are assigned to geomorphology and geology. In addition to the influence of land-use and drainage density in the area is comparatively less, lower weightages are given to these themes.

After assigning the weightages to the themes and features, all the themes have been converted to raster format using 'Spatial analyst', extension of Arc/GIS software. Spatial analyst extension of Arc GIS 9.3 has been used for converting the features to raster and also for final analysis. In this method, the total weights of the final integrated map have been derived as a sum or product of the weights assigned to the different layers according to their suitability. Further, different units of each theme have been assigned knowledge-based hierarchy of ranking in increasing order from 1 to 4, based on their significance with reference to groundwater potential, where 1 denotes poor potential and 4 denotes high potential of groundwater. The technical guidelines prescribed by National Remote Sensing Agency [17] have been made use for the preparation of various thematic maps and final integrated groundwater potential zone map.

Table 1 Ranks for various parameters for Groundwater potentiality

Thematic layers	Classes	Rank	Groundwater potentiality
Geomorphology	Duri Crust	1	Poor
	Pediment	1	Poor
	Shallow Pediment	2	Low
	Buried Pediment	2	Low
	Flood Plain	4	High
	River/Tank/Reservoir	4	High
	Reserved Forest	3	Moderate
Geology	Charnockite	2	Low
	Migmatite Gneiss	3	Moderate
Land use	Barren Land	3	Moderate
	Crop Land	4	High
	Dry Crop	2	Low
	Dry Crop(BCS)	2	Low
	Salinity	1	Poor
Soil	Typic Chromustert	3	Moderate
	Paralithic Ustochrept	3	Moderate

	Paralithic Ustorthent	3	Moderate
	Typic Haplustalf	3	Moderate
	Typic Ustochrept	4	High
	Vertic Haplustalf	3	Moderate
	Paralithic Haplustalf	2	Low
	Paralithic Rodustalf	2	Low
	Udic Rhodustalfs	3	Moderate
	Typic Ustifluent	3	Moderate
Lineament	Present	3	Moderate
	Absent	1	Low

VI. GROUNDWATER PROSPECTS MAP

The combined Remote Sensing and Geographic Information System (GIS) approach is very constructive because this integrates various geospatial information, especially for groundwater potential zone mapping. The study paying attention on the effectiveness of Remote Sensing and GIS in identification and delineation of groundwater potential zones of the study area. All the thematic maps have been converted into a grid (raster format) and superimposed by weighted overlay method (rank and weightage-wise thematic maps). From the analysis, the groundwater potential zones with high, moderate, low and poor prospects covering the whole study area have been demarcated and are shown in Figure 5. The output groundwater potential map reveals that the high potential zones occur in North, Northeast part (sedimentary area), along Vellarriver, and in the Southwest part as small patches. Moderate and low potential zones spread in all parts of the study area. Poor potential zone occurs in central, Northeast, South and Southwest parts as small to linear patches. From the overall analysis, it is found that moderate and low potential zones are common and they occupy a more areal extent in the study area. The high groundwater potential zones found in the north and northeast part, along the Vellar river stretch (in the southern part) areas are suitable for groundwater augmentation and irrigation development in the study area.

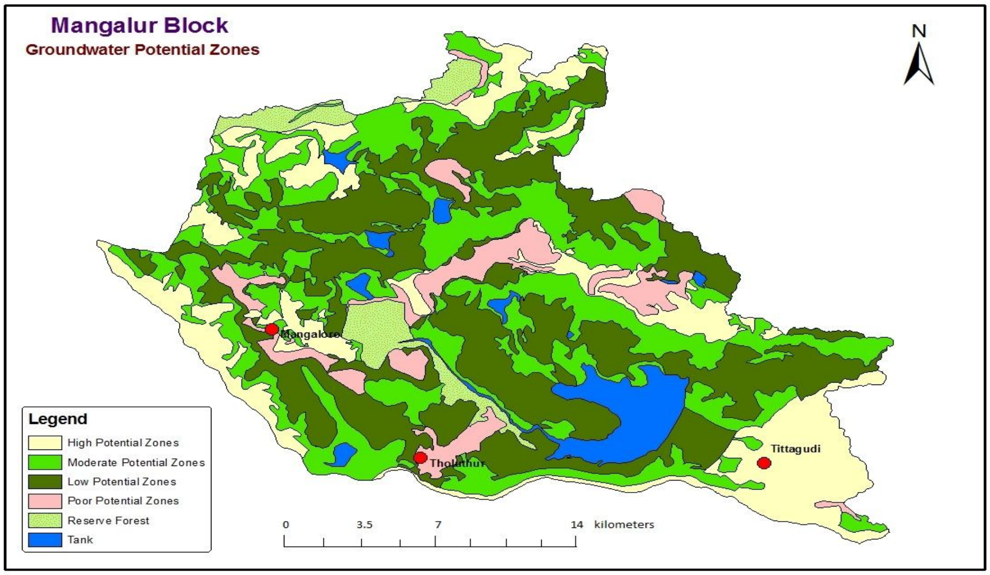

Figure 5 Groundwater potential zonation map of the study area.

CONCLUSION

- Groundwater potential zones have been assessed and demarcated by an overlay analysis of different thematic layers viz., geology, geomorphology, lineament, land use and soils using GIS software. The Groundwater potential zonation map has been prepared. The zones have been categorized into high, medium, low and poor groundwater potential.
- The groundwater potential map reveals that the high potential zones are in the North, Northeastern (sedimentary area) parts, along Vellarriver, near Mangalur and Southwestern parts as small patches.
- Moderate and low potential zones occur equally spread over the study area. These zones occupy the entire study area. Poor potential zone occurs in the Central, Northeastern, South and Southwestern parts as a small to linear patches.
- From the overall analysis, moderate and low potential zones are common and they occupy more areal extent of the study area.

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