DELINEATION OF GROUNDWATER POTENTIAL ZONES USING RS AND GIS TECHNIQUES: A CASE STUDY FOR EASTERN PART OF KRISHNAGIRI DISTRICT, TAMILNADU

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ABSTRACT

A systematic planning of groundwater development using modern techniques is essential for the proper utilization and management of this precious groundwater resource. Groundwater resources potential has been evaluated in eastern part of Krishnagiri district, Tamilnadu using Remote sensing(RS) and Geographic information system(GIS) techniques based on multi-criteria decision making approach (e.g. geomorphology, geology, soil, slope, aspect, drainage density land use/land cover, NDVI, rainfall). All these themes and their individual features are assigned weights and their corresponding normalized weights are obtained based on the Saaty's analytical hierarchy process (AHP) based on the potentiality of groundwater. The thematic layers are finally integrated using overlay analysis of ARCGIS-10 software to yield a groundwater prospective zone map of the study area. Thus, different groundwater potential zones are identified, namely 'Very good', 'good', 'moderate' and 'poor'. The results of this study could be used to formulate an efficient groundwater management plan for the study area so as to ensure sustainable utilization of scarce groundwater resources.

Keywords: RS, GIS, ARCGIS, Saaty's Analytical Hierarchy Process.

I INTRODUCTION

Water is the elixir of life, plays an important role in the wealth of nation particularly in a country like India, which is predominantly an agriculture dependent economy. While the surface water is inadequate to meet the demand for various purposes, groundwater is the only alternate resource which will serve the purpose [10]. The rate of groundwater flow is controlled by two properties of the rock: porosity and permeability. The main sources of groundwater recharge are precipitation and flow and of discharge include effluent seepage into the streams and lakes, springs, evaporation and pumping. It is estimated that approximately one third of the world's population use groundwater for drinking. Timely and reliable information on the occurrence and movement of groundwater is a prerequisite for meeting its increasing demand for drinking, domestic and industrial sector.

Being a subsurface feature, the detection of groundwater potential zones relies heavily on the controlling factors, namely geology, geomorphology, groundwater level, rainfall, drainage and its density, slope, NDVI, landuse/landcover and soil types of the area.

In the past, several researchers have used techniques of remote sensing & GIS for the delineation of groundwater potential zones [4]. The identification of ground water potential zones is helpful for the conservation and implementation of ground water management plans. Therefore, the present study has been made to demarcate the groundwater prospective zones of eastern part of Krishnagiri district by considering suitable thematic layers that have direct or indirect control over groundwater occurrence using Remote Sensing and GIS technology. The main objective of this study is to identify the groundwater potential zones in and around eastern parts of Krishnagiri district.

1.1 Study Area

The study area falls under eastern part of Krishnagiri district in Tamilnadu which is located between 12^0 15' 45" and 12^0 46' 20"N latitudes and 77^0 53' 20" and 78^0 38' E longitudes. The study area covers three taluks such as Krishnagiri, Pochampalli and Uthangarai. The study area is elevated from 300m to 1000m above the mean sea level (AMSL). One of the important rivers Ponnaiyar flows in this district. The bulk population is engaged in agriculture and related activities. The maximum amount of rainfall is received during the south-west monsoon season. The normal annual rainfall over the study area varies from 400 to about 900mm [3].

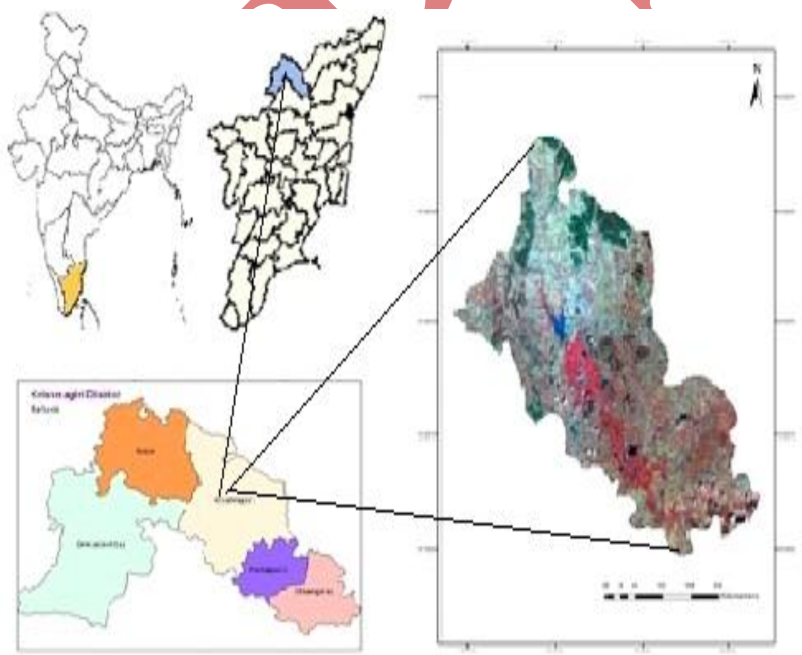

Figure 1: Map Showing the Study Area Extracted From Satellite Image.

II METHODOLOGY

The present study is adopting a GIS and Remote sensing based methodology, both spatial and attribute data of the various thematic layers, available in the form of maps and published report were collected from the various sources. Boundary, drainage, contour and road were extracted from the Survey of India Toposheets; geology is derived from the GSI map. The software used for this study includes ERDAS IMAGINE 9.1 & ARCGIS 10. The details of the Primary & Secondary data used for this study are mentioned in the following table 1& 2.

Source: NRSC, Hyderabad.

Satellite	Path/Row	Acquisition Date	Spatial Resolution
IRS-P6 LISS-IV(5.3m)	101/65, 101/64.	14/01/2014	70 sq.km

Table 1: Details of Satellite data used

Source: SOI, Chennai.

Toposheet No	Scale	Year of survey	Interval
57L/2, 57L/3, 57L/6, 57L/8, 57L/11, 57L/12, 57H/10, 57H/11, 57H/12, 57H/14, 57H/15.	1:50,000	2007	20m

Table 2: Details of Toposheet used

Existing maps	Scale	Source
Geology	1:2,50,000	Geological survey of India. (GSI)
Geomorphology	1:5,00,000	Geological survey of india.(GSI)

Table 3: Details of Secondary data used

The methodology for this study is summarized in the following Flowchart (Figure 2).The collected toposheets of study area were scanned, registered and mosaicked, subsetted using Erdas Imagine 9.1 software. Satellite data were collected and mosaicked. Contours from Toposheets were digitized from and digital elevation model (DEM) for the study area was obtained. Thematic layers are geology, slope, aspect, NDVI, drainage and its density, soil, geomorphology, landuse/landcover are developed for the study area. The weightage of each theme and individual features and its corresponding normalized weights were derived based on saaty’s AHP technique.

The maximum value is given to the feature with highest groundwater potentiality and the minimum being to the lowest potential feature. i.e., depending on its suitability to hold groundwater.

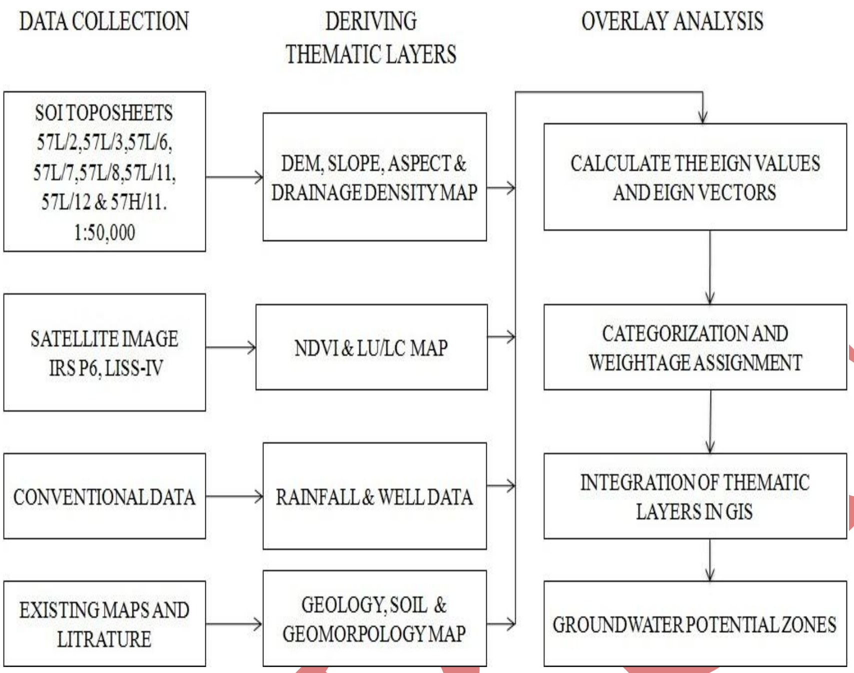

Figure 2: Flowchart showing methodology for this study.

The procedure of weighted linear combination dominates in raster based GIS software systems. After assigning the weightage and scores to the themes and features, all the themes were converted to raster format using ‘Spatial analyst’, extension of ArcGIS software. These thematic layers were finally integrated using overlay analysis and groundwater prospective zones of the study area were demarcated.

III WEIGHT ASSIGNMENT AND MODELING

The relative importance values are determined with Saaty’s 1-9 scale, where a score of 1 represents equal importance between the two themes, and a score of 9 indicates the extreme importance of one theme compared to the other one [8]. ANP is an extension of AHP for decision making in which a problem is divided into various parameters, arranging them in a hierarchical structure, making judgments on the relative importance of pairs of elements and synthesizing the results [9].The AHP captures the idea of uncertainty in judgments through the Principal Eigenvalue and the consistency index [10]. Saaty gave a measure of consistency, called Consistency Index (CI) as deviation or degree of consistency using the following equation (1):

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (1)$$

Where λ_{max} the largest eigenvalue of the pair wise comparison matrix and n is the number of classes or features. Consistency Ratio (CR) is a measure of consistency of pair wise comparison matrix and is given by equation (2):

$$CR = \frac{CI}{RI} \qquad (2)$$

Where RI is the Ratio Index. The weights of the different themes were assigned qualitatively on a scale of 1 to 9 based on their influence on the groundwater existence.Different features of each theme were assigned weights on a scale of 1 to 9 according to their relative influence on groundwater development. Based on this scale, qualitative evaluation of different features of theme was performed with: poor (1-2);moderate-poor (2-4);good-moderate (4-6);good (6-8); excellent (8-9)(Table 6)[4].Then, pair-wise comparison matrix was constructed using saaty's AHP and normalized weights were calculated (Table 5).

Theme	Weight
Geomorphology	9
Geology	8
Soil	7
Slope	4
Rainfall	9
Lu/Lc	4
Drainage Density	6
NDVI	1

Table 4: Qualitative weightage of different themes.

Theme	GM	GG	DD	SOIL	SLOPE	RF	LU/LC	NDVI	Geometric Mean	Normalized Weight
GM	1	9/7	9/8	9/6	9/4	9/8	9/3	9	1.868	0.1956
GG	7/9	1	7/8	7/6	7/4	7/8	7/3	7	1.4529	0.1522
DD	8/9	8/7	1	8/6	8/4	1	8/3	8	1.6605	0.1739
SOIL	6/9	6/7	6/8	1	6/4	6/8	6/3	6	1.2454	0.1304
SLOPE	4/9	4/7	4/8	4/6	1	4/8	4/3	4	0.8302	0.087
RF	8/9	8/7	1	8/6	8/4	1	8/3	8	1.6605	0.1739
LU/LC	3/9	3/7	3/8	3/6	3/4	3/8	1	3	0.6227	0.0652
NDVI	1/9	1/7	1/8	1/6	1/4	1/8	1/3	1	0.2076	0.0217
Column Total =									9.5478	1.0000

Consistency Ratio: 0.0001

Table 5:Pair-wise Comparison Matrix of different thematic layers

Theme	Influence on groundwater occurrence	Class	Rank	Groundwater Prospect
Geomorphology	Climate and geomorphological characteristics of an area affect its response to a considerable extent. Linking of geomorphological parameters with hydrological characteristics of an area provides a simple way to understand the groundwater behavior.	1)Flood plains 2)Pediplains 3)Pediments 4)Denudational hills	4 3 2 1	Very Good Good Moderate Poor
Geology	The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability.	1)Charnockite 2)Dunite 3)Epidote-homblende gneiss 4)Granitre 5)Granitoid-gneiss 6)Homblende-biotic gneiss 7)Pink Migmatite 8)Pyroxene Granulite	8 5 3 1 2 5 4 7	Very good Moderate Moderate-poor Very poor Poor Good Moderate Good
Soil	Soil characteristics invariably control penetration of surface water into an aquifer system and they are directly related to rates of infiltration, percolation and permeability.	1)Red soil 2)Black soils 3)Clay soils 4)Brown soils 5)Silt	4 2 1 3 5	Good Moderate Poor Moderate Good
Slope	Slope is one of the factor controlling infiltration of groundwater into subsurface; hence an indicator for the suitability for groundwater prospect. A high sloping region causes more runoff and less infiltration and thus has poor groundwater prospects compared to the low slope region.	1)0-5% 2)5-15% 3)15-30% 4)30-45% 5)>45%	5 4 3 2 1	Very Good Good Moderate Poor Very Poor
Drainage Density	Drainage pattern reflects the major characteristic of surface as well as subsurface formation. More the drainage density, higher would be runoff.	1) 0-1 km 2)1-3 km 3)3-5 km 4)5-6 km	4 3 2 1	Very Good Good Moderate Poor

Landuse / Landcover	Landuse/landcover is one of the important parameter for the geo-hydrological study because the land use pattern of any terrain is a reflection of the complex physical processes acting upon the surface of the earth.	1)Deep Water 2)Dense populated area 3)Dense vegetation 4)Reservoir 5)Fallow land 6)Hilly area 7)Low populated area 8)Rock area	8 6 5 7 1 3 4 2	Very Good Moderate Good Very good Very poor Moderate Moderate-Good Poor
NDVI	Healthy vegetation indicates good groundwater prospective zone and vice versa.	1)Healthy vegetation 2)Moderate vegetation 3)Weak vegetation	1 2 3	Good Moderate Poor
Rainfall Recharge	Water reaching the water table is known as the recharge from rainfall to the aquifer. The water table of an area is mainly controlled by variations in groundwater recharge, discharge and rainfall.	1)0-440 mm per year 2)440-540 mm per year 3)540-640 mm per year 4)640-740 mm per year 5)>740 mm per year	5 4 3 2 1	Very Poor Poor Moderate- Good Good Very Good

Table 6: Rank and groundwater prospect for the individual features of the different themes

To differentiate ground water prospective zones, all the thematic layers after assigning weights are integrated (overlaid) step by step using overlay analysis of ArcGIS extension.The total weights of different features in the integrated layer were derived from the following equation to obtain groundwater potential index [7], as depicted in equation 3.

$$GWPI=((GGw)(GGwi)+(GMw)(GMwi)+(RFw)(RFwi)+(DDw)(DDwi)+(Sw)(Swi)+(SLw)(SLwi)+(NDVIw)(NDVIwi)+(Lu/Lcw)(Lu/Lcwi)) \qquad (3)$$

GWPI=Groundwater potential index of the study area, GG=geology, S=soil, GM= geomorphology, DD= Drainage Density, RF=Rainfall, SL=slope, Lu/Lc=Landuse/Landcover, and the subscripts 'w' and 'wi' refer to the normalized weight of a theme and the normalized weight of the individual features of each theme, respectively.

GWPI is a dimensionless quantity that helps in indexing probable groundwater potential zones in the area. The range of GWPI values were divided into four equal classes and the GWPI of different features falling under different range were grouped into one class [2].Thus, the entire study area was qualitatively divided into four groundwater potential zones and a map showing these zones was prepared using ArcGIS software.

IV RESULTS & DISCUSSION

Integration of the remote sensing (RS) and Geographic Information technique (GIS) technologies has proven to be an efficient tool in groundwater studies. Depending on the groundwater potentiality, each class of the main eight thematic layers (geomorphology, geology, slope, drainage density, NDVI, Landuse/Landcover, rainfall, soil) are qualitatively placed into one of the following categories viz., i. Very good, ii. Good, iii. Moderate, iv. Poor. Considering their behavior with respect to groundwater control, the different classes are given suitable values, according to their importance relative to other classes.The good groundwater prospective zones are along the pediplains, flood plains and weathered zones. The major portion of the study area falls under moderate prospective zones..

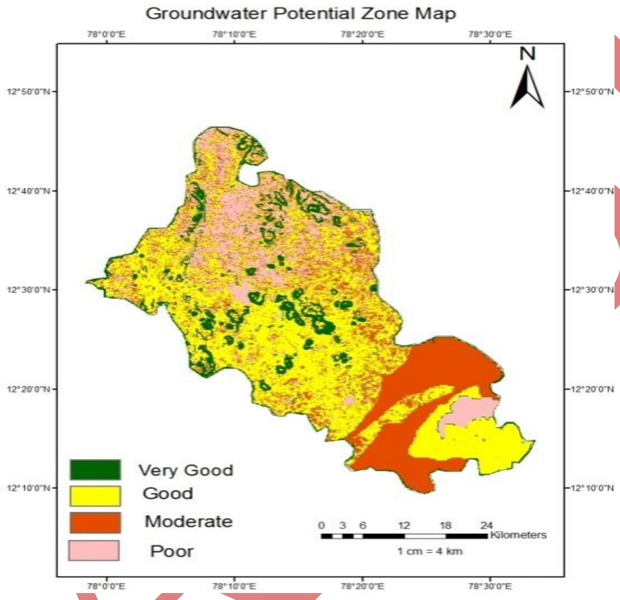

Fig 3: Groundwater Potential Zone Map

The poor prospective zones fall under denudational hills & the region where more withdrawal of water takes place for agricultural and industrial purposes. Thus, the total amount of average annually exploitable ground water reserve is more for the moderate zone compared to the good zone, which is attributable to the larger area under the moderate zone.

Therefore, these groundwater reserves can be considered as sustainable yields of the respective zones, which can be safely utilized to meet the water demands of different sectors in the study area. The occurrence and movement of groundwater depend upon the formation of rocks present in study area. It also depends upon the topography, geomorphology & hydro-geological properties of the water-bearing materials. Thus, the predicted groundwater potential map shown in figure 3**.**

V CONCLUSION

In this research, Weighted Index Overlay Analysis (WIOA) approach for easy assessment of groundwater potential is adopted for GIS integration of thematic layers developed from base maps. Adopted thematic layers gave fairly accurate about groundwater occurrence from geomorphological, topographical and structural features. Generated result from WIOA by employing AHP method for weight calculation qualitatively categorized the Area of Interest (AOI) as different zones based on groundwater potential. Hence this methodology of integrated remote sensing and GIS approach using Analytic Hierarchy Process (AHP) technique is a promising method for groundwater exploration.

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