ISSN 2229-5518

Identification of potential recharge zone of the selected watershed using Remote Sensing and GIS

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Abstract— With the increasing use of groundwater for various activities the fast decline in groundwater takes place. In order to prevent the aquifer from fast depletion, the artificial recharge is resorted to. Keeping this in mind to avoid fast decline in groundwater levels in the hard rock regions of Tamil Nadu, a study has been undertaken to identify the favourable areas for artificial recharge and suggest suitable recharge structures to augment the aquifer system. The analysis was carried out in Kinathukadavu block of Coimbatore District, TamilNadu, India using Remote Sensing data and GIS techniques. Initially the source maps namely soil, landuse, geology, geomorphology, lineament and drainage were collected and the thematic layers were prepared. The above maps were prepared using IRS-1C LISS III satellite data and other collateral information collected from the field and digitized. Criterion tables were generated considering the importance of different themes and necessary ranks and weights were assigned to each theme. Using ARC/INFO GIS software, the above themes have been integrated and the areas suitable for artificial recharge have been identified. From the weighted overlay analysis, it was found that the entire watershed comes under the moderate potential recharge zone.Based on this finding the artificial recharge structures were to be identified and implemented to the augment recharge of groundwater.

Index Terms — Geology, Geomorphology, Hydrological soil group, Thematic layer, Weighted overlay

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1 INTRODUCTION

Groundwater is a dynamic and replenishable natural resource, but in hard rock terrains, availability of groundwater is of limited extent. Occurrence of groundwater in such hard rocks is essentially confined to fractured and weathered horizons. As it is the largest available source of fresh water lying beneath the ground it has become crucial not, only for targeting of ground water potential zones, but also monitoring & conservation of this important resource. Besides targeting of groundwater, to delineate the groundwater recharge zones is also an important factor for identifying artificial recharge structures (Saraf and Choudhury, 1997).

Remote sensing and GIS are playing a rapidly increasing role in the field of hydrology and water resources development. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface (Choudhury, 1999). One of the greatest advantages of using remote sensing data for groundwater investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Saraf, 1999).

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An integrated study covering the aspect of groundwater recharge is a crucial requirement of the present day (Choudhury, 1999).The present work is an attempt towards this direction. The study focuses on development of remote sensing and GIS based analysis and methodology in groundwater recharge studies in hard rock terrains. In order to demonstrate the integrated remote sensing and GIS based methodology has been taken.

2. RESEARCH METHODOLOGY

2.1 Location of the Study area

The selected area for study is **"Panapatti "** village part of Coimbatore district, Tamilnadu, India with the areal extent of 4.79 sq.km. The study area lies at 10^0 53′ to 10^0 54′N latitude and 77^0 5′ to 77^0 6′E latitude. (Fig 1).

2.2 Landuse/Land Cover

The study area consists of agricultural land, waste land, wasteland, water bodies and built-up lands. The landuse/land cover map was derived from IRS, LISS – IV

2.3 Soil

The hydrological soil group ′C′ with slow infiltration and moderate runoff potential and hydrological soil group ′A′ with high infiltration are found in the study area.

2.4 Geomorphology & Geology

The predominant geomorphological features are pediment, buried pediment deep, buried pediment shallow and valley floor. Hornblende Biorite Gneiss are the main geological features that are found in this block.

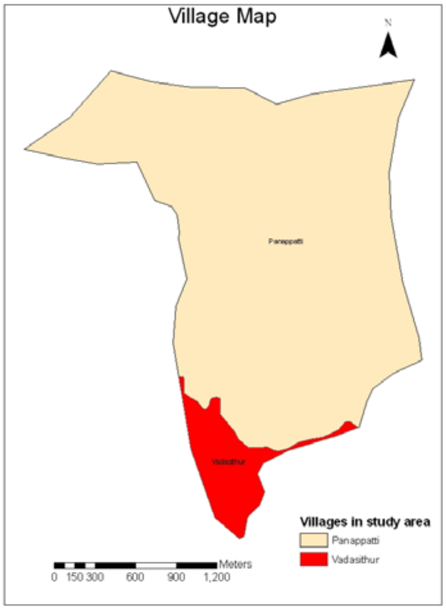

Fig. 1. Village map of study area

2.5 MATERIALS USED

2.5.1 Spatial data

The spatial data collected and used in the study are, Survey of India (SOI) Toposheet (1:50,000), Village map (1:50,000), Watershed map (1:50,000), Soil map (1:50,000), Geology, Geomorphology & Lineament map (1:50,000) and Landuse/ Land cover map (LISS IV – 2003).

2.5.2 Software used

ArcGIS 9.2 software acts as a tool for ground water potential study, which was used for integration, manipulation & analysis of data. Erdas Imagine 8.7 image processing software is also used in this study for sub-setting and mosaic purpose.

2.5.3. Methodology

The source maps like village, soil, landuse, geology, geomorphology & lineament and watershed maps were collected from Institute of Remote Sensing, Anna University, Chennai, Tamil Nadu. Toposheets were obtained from SOI, Guindy, Chenni, Tamil Nadu. The source maps were scanned & geo-referenced using ArcGIS 9.2 software.

2.5.4 Preparation of Thematic Layers

The thematic layers of soil, landuse, geology, geomorphology, & etc., were prepared using ArcGIS 9.2 Software.

2.5.5 Development of DEM

The toposheets (1:25,000) were collected from SOI, Guindy, Chennai, Tamil Nadu, India. The contour lines at 10 m interval were extracted from toposheets (200 to 1071). From the contour lines the DEM was developed using TIN tool in ArcGIS 9.2. From DEM the slope map (%) was derived.

2.5.6. Weighted overlay

In order to find out the effective recharge zones, the weighted overlay index (spatial anaysist tool from ArcGIS software) was applied according to the priority of thematic layers in the study area. Hence, the following weightage were assigned according to their influencing characters viz., soil=15, Geomorphology = 25, Land use = 10, Slope =15, Lineament = 15, Drainage=15, Geology=5. During the weighted overlay analysis, the rank was assigned in terms of 1, 2, 3 & 4 for each individual parameter of thematic layers to obtain the recharge zones in terms of good, moderate, poor & very poor zones. The assigned rank and weightage of thematic layers was presented in Table 1.

3. RESULT AND DISCUSSIONS

The remote sensing and GIS based method is found to be very useful in suitability and analysis for artificial recharge sites in the hard rock terrain The analysis of the thematic maps such as geology, geomorphology, soil, drainage, slope and land use maps were considered to be the best way of identifying the potential groundwater recharge zones in hard rock terrain using ArcGIS 9.2 platform.

3.1 Land use/Land cover

Infiltration and runoff are greatly depending on land use/land cover. It is well known that recharge is high in the cultivable land and irrigated land compared to the wasteland and settlements. Hence, this theme is considered as the one of the principle terrain parameters in the recharge site selection. The land use/land cover map was digitized from already existing land use/land cover map obtained from Institute of Remote Sensing, Anna University, Chennai. The IRS 1C LISS III satellite image was used to prepare land use/land cover map. It was then updated according to present condition. The classified map of land use/land cover of study area is presented in Fig. 2 and found that 89 percent of the area covers agricultural land and remaining are built up lands and waste lands.

3.2 Soil map

The infiltration of rainfall depends upon the type and thickness of soil present. Hence, soil is also considered as one of the principle terrain parameters in the groundwater recharge site selection process. Digitized soil map, obtained from Remote Sensing and GIS Centre, Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore, in 1:50,000 scale. This soil map was classified according different soil series (Fig. 3). There are seventeen soil series found in the study area. Statistic of different soil series is given in Table 2

Table.1.
Weightage of different parameters for Groundwater recharge zones

Sl. No.	Criteria	Classes	Rank	Weight age
1	Geomor mor-phology	Buried pediment deep, pediment, buried pediment shallow	1	25
		Residual hill, intermountain valley	2	
		Isenberg, pediment complex	3	
		Structural hill, Bozada zone	4	
2	Geology	Charnokite& Horn blend gneiss	3&4	5
3	Land use	Waterbody	1	10
		Forest,cultivable land, agricultural land	2	
		hill/barren rock/stone waste/sheet rock, mining/industrial waste/effluents, salt pan, salt affected land	3	
		Builtup land	4	
4	Hydrological soil group	A	1	15
		B	2	
		C	3	
		D	4	
5	Slope	0-20	1	15
		20-30	2	
		30-40	3	
		>40	4	
6	Lineament	present	1	15
		not present	0	
7	Drainage	First order	1	15
		Second order	2	
		Third order	3	
		Fourth order	4	

Table 2
Statistic of different soil series present in the study area

Sr. No.	Name of the soil series	Area in percentage
1.	Anamalai	16.4
2	Athipalayam	9.10
3	Dasarapatti	1.40
4	Ethinaickenpatti	13.10
5	Habitatio	0.3
6.	Kallivaalsu	6.9
7	Kanjampatti	1.6
8	Kattamaptti	1.1
9	Palathurai	7.8
10	Palvidithi	9.9
11	Pichanur	2.5
12	Pilamedu	7.5
13	Salaiyur	15.2
14	Sengalam	5.0
15	Varapatti	1.3
16	Miscellaneous	0.02

3.3 Geomorphology and Geology

The predominant geomorphologic features are found to be shallow weathered pedipalin (18.42 km^2), Moderately pediplain (2.6 km^2), and Pedimant (1.45 km^2) respectively (Fig.4). Geomorphology exercises a significant control over groundwater regime. The relief, slope, depth and type of weathered materials and the overall deposition of different land forms play an important role in defining the groundwater regime, more particularly in hard rock areas. The geomorphic units can be utilized for evaluation and management of groundwater resources.

The geology features that are found in the entire study area are Biotile (Fig 5)

3.4 Drainage Distribution Pattern

The drainage network tanks were digitized and converted into whole single thematic map. In this region the drainage distribution pattern were identified as 1^{st}, 2^{nd}, 3^{rd} order streams. (Fig 6)

3.5 Digital Elevation model (DEM) and Slope (%)

The digital representation of the topography is called a Digital Elevation Model. The DEM was prepared by spatial Interpolation of the digitized contour lines using Triangulated Irregular Network (TIN) tool in ArcGIS.

ISSN 2229-5518

The contour map (10 m contour interval) was obtained with the contours range of 370 m to 440m (shown in Fig. 7). From the interpolation of contour lines the DEM was obtained as depicted .The highest elevation shows the terrain of the study area. From the DEM, the slope (%) was derived with the range of 0-5%

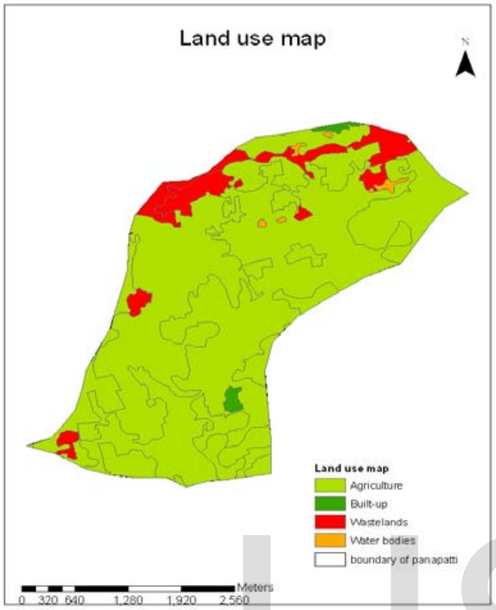

Fig.2. Land use map of study area

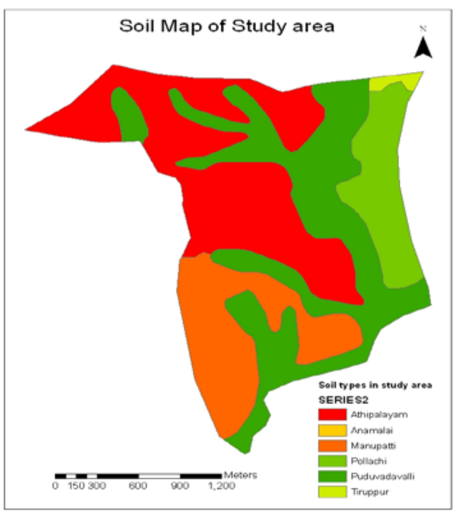

Fig.3. Soil map of study area

3.6 Weighted Index Overlay Analysis

Weighted Overlaying Analysis is done by combining the data from the multiple data categories and performing analytical, statistical measurement and other operations on the GIS based data sets to transform these data into suitable information for a given application. During the process of overlay, the thematic maps and their attributes were intercepted and a new thematic map with attributes was obtained.

Fig.4.Geomorphology map

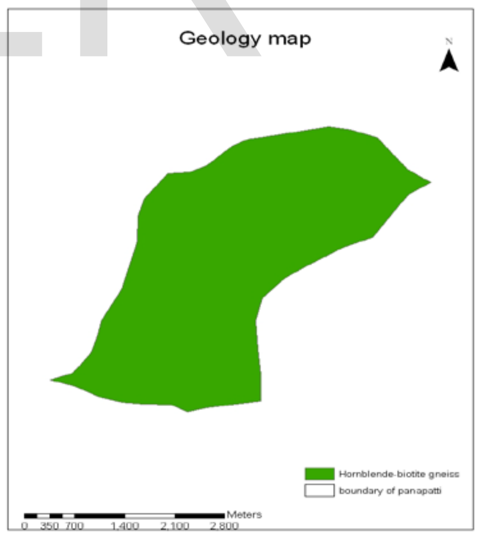

Fig.5.Geology map

This method is a simple and straightforward method for combined analysis of multi class map. In Weighted Overlay Method, the ranks and weights have been assigned to various classes of different themes like geology, geomorphology, land use pattern, soil type, slope and drainage according to its priority and importance to support the groundwater recharge. The weightages of each criterion was finalized on the basis of the ranges of the maximum and minimum values within each theme.

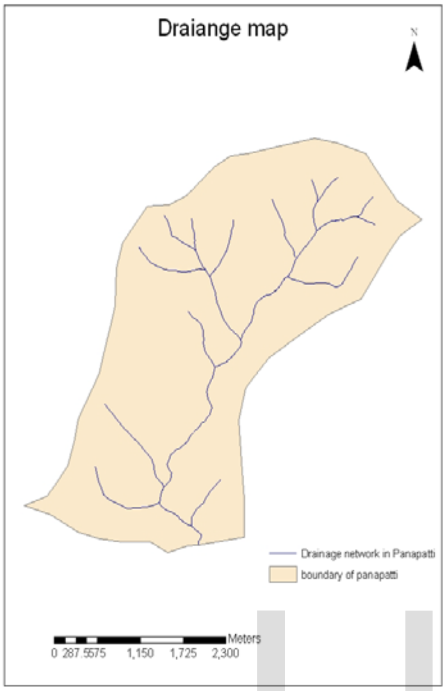

Fig 6 .Drainage map of study area

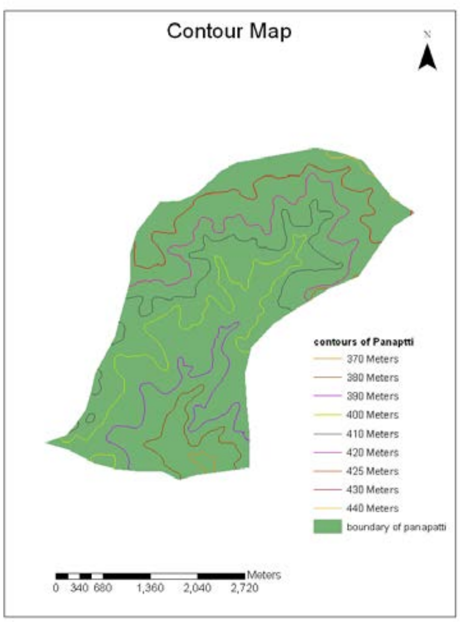

Fig 7. Contour map of study area

3.7 Ground water recharge zones

After these weighted overlay analysis the groundwater recharge zones were obtained (Fig.8) in terms of classified zones like good, moderate and poor depending on the potential influencing parameters of ranks and weightages of each thematic layer. From the recharge zone map it was found that the entire area comes under the moderate zone for recharging. The result supports the prevalence of hard rock terrain, which is covering maximum areal extent of 90% of the study area. Based on this finding the artificial recharge structures were to be identified and implemented to the augment recharge of groundwater.

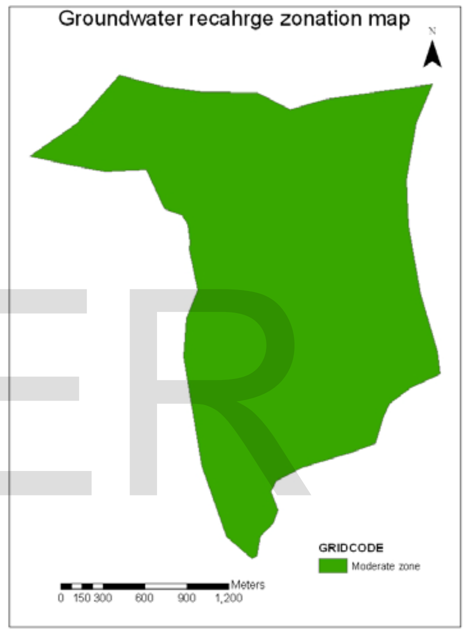

Fig 8. Recharge zonation map by weighted overlay analysis

4. SUMMARY AND CONCLUSION

Groundwater is a precious resource of finite extent. With the increasing demands for water due to increasing population, urbanization and agricultural expansion, groundwater resources are gaining much attention, particularly in the region of hard rock terrain. Groundwater development programmes need a large volume of data from various sources, time consuming and costly. The integrated remote sensing and geographic information system (GIS) techniques has provided an appropriate platform for convergent analysis of multidisciplinary data and decision making for artificial recharge of groundwater. The following conclusions are drawn from the above study:

In order to identify the potential recharge zones, various maps were obtained from different sources and integrated them into GIS environment for analysis. Thematic maps such as geology, geomorphology, land use/land cover, soil and slope map were prepared using Remote Sensing and GIS. Detail characteristics of each theme were studied in accordance with their response to artificial recharge process. After detail study and criteria, ranking and weightage applied for suitable site selection for artificial recharge process, weighted overlay analysis was carried out. Maximum weightage i.e. importance, given to theme, which is most favorable for groundwater recharge process and low weightage given to theme, which is less favorable for groundwater recharge process. For present study, importance were given in the order of geomorphology > geology > land use/ land cove >Hydrological soil group > slope > lineament > drainage. From the recharge zone map it was found that the entire area belongs to moderate zone of recharge.

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