

Identification of Groundwater Recharge Potential Zones for a Watershed Using Remote Sensing and GIS

V.Keshavan¹, S.Ranjith², J.Sabarish³, J.Srinivasan⁴ and D.Sivasankar⁵

Assistant Professor, Department of Civil Engineering, Sethu Institute of Technology, Kariapatti, Tamil Nadu, India¹

U.G. Student, Department of Civil Engineering, Sethu Institute of Technology, Kariapatti, Tamil Nadu, India^{2,3,4,5}

ABSTRACT: Groundwater is considered as the preferred source of water for meeting domestic, industrial and agricultural requirements, due to its longer residence time in the ground, low level of contamination, wide distribution, and availability within the reach of the end user. Even the existing wells are getting dried-up due to depletion of ground water table as the natural recharge is not sufficient. Groundwater recharge is a basic pre-requisite for efficient groundwater resource development and management, which is particularly vital for India with widely prevalent semi-arid and arid climate. In case the natural recharge is not sufficient, it has to be met through artificial recharge. To provide scientifically, appropriate locations for constructing artificial recharge structures, each hydro-geomorphic unit will be evaluated for its recharge potential and suitably a map showing such groundwater recharge potential zones for appropriate recharge will be prepared. Using remote sensing and geographic information system (GIS) it is possible to take number of different thematic maps of the same area and overlay them on top of one another to form a new integrated layer. This study was aimed to identify the groundwater recharge potential zones, to be used for better and improved groundwater resources. The thematic layers considered in this study are, soil, land use and land cover, slope, hydrogeology which are prepared using satellite imagery and other conventional data. The thematic layers were first digitized from satellite imagery, supported by ancillary data such as toposheets and field investigation data, finally all thematic layers were integrated using ArcGIS software to identify the groundwater recharge potential zones for the study area and generate a map showing these groundwater recharge potential zones namely very poor, poor, moderate, good and very good on knowledge based weightage factors

KEYWORDS: Remote sensing, GIS, Weighted overlay, Thematic maps.

I. INTRODUCTION

Groundwater is one of the most valuable natural resources, which supports human health, economic development and ecological diversity. Because of its several inherent qualities it has become an immensely important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries. Groundwater is a form of water occupying all the voids within a geological stratum. Water bearing formations of the earth's crust act as conduits for transmission and as reservoirs for storing water. The groundwater occurrence in a geological formation and the scope for its exploitation primarily depends on the formation of porosity. High relief and steep slopes impart higher runoff, while topographical depressions increase infiltration. An area of high drainage density also increases surface runoff compared to a low drainage density area. Surface water bodies like rivers, ponds, etc., can act as recharge zones. Climatic changes also affect the hydrological cycle and directly influence the ground water. This alarming situation calls for a cost and time effective technique for proper evaluation of groundwater resources and management planning. Currently groundwater is gaining more attention due to drought problem, rural water supply, irrigation project and low cost of development it requires. Despite the extensive research and technological advancement, the study of groundwater has remained more risky, as there is no direct method to facilitate observation of water below the surface. The remote sensing and Geographic information system (GIS) tool can open new path in water resource studies. Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems.

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II. RELATED WORK

Balachandar D. et al. (2010) have used the remote sensing and GIS technique for generation of groundwater recharge zones map for the improvement and development of groundwater for the region.

Cheng-Haw Lee et al., (2008) proposed that assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems. Further groundwater potential study was carried out in Taiwan with the help of remote sensing and the geographical information system.

Deepesh Machiwal et al., (2010) proposed a standard methodology to delineate groundwater potential zones using integrated RS, GIS and multi-criteria decision making (MCDM) techniques. The methodology is demonstrated by a case study in Udaipur district of Rajasthan, western India. Initially, ten thematic layers have been considered. Weights of the thematic layers and their features then normalized by using AHP MCDM technique and eigenvector method. Finally, the selected thematic maps were integrated by weighted linear combination method in a GIS environment to generate a groundwater potential map.

Jobin Thomas et al., (2011) determined groundwater potential zone in tropical river basin (Kerala, India) using remote sensing and GIS techniques. The information on geology, geomorphology, lineaments, slope and land use/land cover was gathered GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential.

Shivaji Govind Patil et al., (2014) determined groundwater potential zone for a water shed in Pune district using remote sensing and GIS techniques. The information on geology, geomorphology, lineaments, slope and land use/land cover was gathered GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential.

III. STUDY AREA

Madurai city has an area of 52 km², within an urban area now extending over as much as 130 km², it is located at show location on an interactive map 9°56'N 78°07'E / 9.93°N 78.12°E / 9.93; 78.12. It has an average elevation of 101 m above mean sea level. The climate is dry and hot, with rains during October-December. Temperatures during summer each a maximum of 40 and a minimum of 26.3 degrees Celsius. Winter temperatures range between 29.6 and 18 degree s Celsius. The average annual rainfall is about 85 cm as of the 2001 India census, the city of Madurai had a population of 928,869 within the municipal corporation limit the urban area 1,194,665.

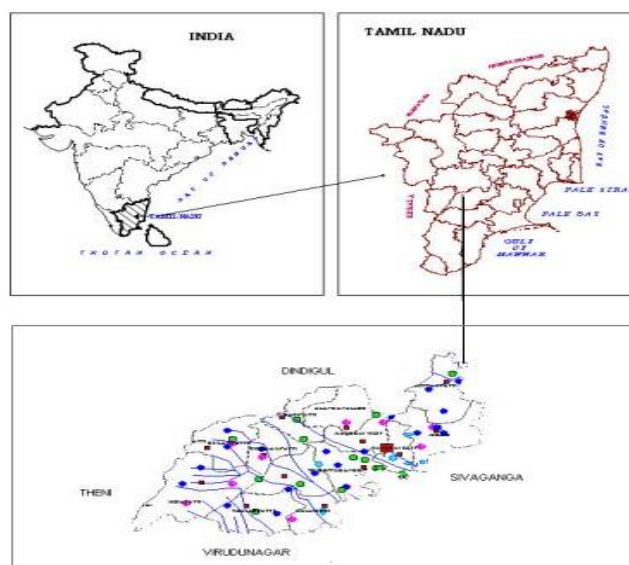


Figure 1 Location map of Madurai district

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IV. METHODOLOGY

First SOI toposheets are decoded with the help of known ground control points (GCPs) on it. These decoded toposheets are then mosaiced to create the boundary map of study area with relevant details, in the form of shape file using ArcGIS software. Clipping operation is carried out for obtaining required details for study area from the mosaic toposheets. Using map to image registration technique provided by the Geometric software, the IRS P6 LISSIII satellite image is geometrically rectified and registered with SOI toposheets on 1:50000 scale. The false colour composite (FCC) generated from red, green and blue spectral bands (1, 2 and 3). To enhance the satellite imagery linear, equalization and root enhancement techniques have been used for better interpretation of the geomorphologic, soil, structural and other information for preparation of thematic maps from it. For digitization, editing, and topology creation of various features Arc GIS software has been used. The most important work of assignment of rank and weightage to different features / themes and classes within theme was carried out and then integration of multi-thematic information is done to identify groundwater potential zones and to generate map for the same. The groundwater recharge potential zones map, thus generated through remote sensing and GIS technique, with 5 zones viz. 'very good', 'good', 'moderate', 'poor' and 'very poor' has been verified with field data to ascertain the validity of the study conducted.

Slope

Slope is one of the important terrain parameters which are explained by horizontal spacing of the contours. In general, in the vector form closely spaced contours represent steeper slopes and sparse contours exhibit gentle slope whereas in the elevation output raster every cell has a slope value. The slope values are calculated either in percentage or degrees in both vector and raster forms. Here 82% of the area is $< 5^{\circ}$ slope, 12 % of the area is between 5 to 10° slope while 6 % of the area is $> 10^{\circ}$ slope region.

Land Use & Land Cover

Land use/land cover mapping is one of the important applications of remote sensing. Land use plays a significant role in the development of groundwater resources. In the study area Crop land is mostly covered while dense Forest is covered at an area of 160 km^2 . In the Study area Fallow land is covered about 227 km^2 while Barren Rocky Land is covered at 68 km^2 while Settlement – 63 km^2 , Plantation - 309 km^2

Soil

Soil is an important factor for delineating the ground water potential zones. The soil type is predominantly clay loam, while red loam and black cotton types are widely prevalent in the outer fringes the study area.

Hydrogeology

Hydrogeology is an important factor for the application of remote sensing. It plays a significant role in the development of groundwater resources. In the study area about 86 % of the land is of aquifer while rest of them are on the hilly area i.e, about 14% of the study area.

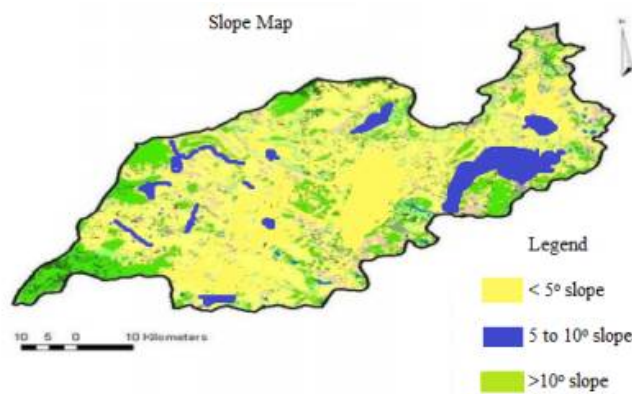


Figure 2 Slope map of madurai district

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Figure 3 Land use and Land cover map of Madurai district



Figure 4 Soil map of Madurai district



Figure 5 Hydrogeology map of Madurai district

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V. RESULTS AND DISCUSSIONS

This study analyzed the hydrologic and geographic attributes of the watershed in study area and identified 4 major factors influencing groundwater recharge potential, viz. Slope (%), hydrogeology, soil, land use land cover,. Each factor was examined was assigned an appropriate weight. Each recharge potential factor may influence the groundwater recharge process to a different degree. Overlay analysis is carried out, using weighted overlay analysis tool provided in the ArcGIS software, to integrate various thematic maps viz. hydrogeology map, soil map, slope (%) map, land use land cover map, which are being very informative and plays important role in the study for groundwater recharge potential zones of study area. The various thematic maps were assigned with different weightages of numerical value to derive groundwater recharge potential zones. On the basis of weightage assigned to these maps and bringing them into the function of spatial analyst for integration of these thematic maps, a map indicating groundwater recharge potential zones is obtained. This map has been categorized into 5 zones viz. 'very good', 'good', 'moderate', 'poor' and 'very poor' from groundwater recharge potential point of view. For more realistic evaluation, field investigations were made with data of dug wells, which satisfy the above analysis.

Table 1 Rank and Weightage of the Parameters

Parameter	CLASS	RANK	WEIGHTAGE
Slope	<50	1	25
	5-10 ⁰	2	
	>10 ⁰	3	
Soil	A	1	25
	C	2	
	D	3	
Land use & Land Cover	Agricultural plantation, croplands	1	25
	Degraded forest, upland with or without scrub, fallow harvested land	2	
	Built up land, hill, rock, salt affected land, mining	3	
Hydrogeology	Aquifer	1	25
	Hilly area	2	

Table 2 Ground Water Recharge Zone of the study area

GROUND WATER RECHARGE ZONE	% AREA
Very Good	22.8
Good	15.2
Moderate	48
Poor	9
Very Poor	5

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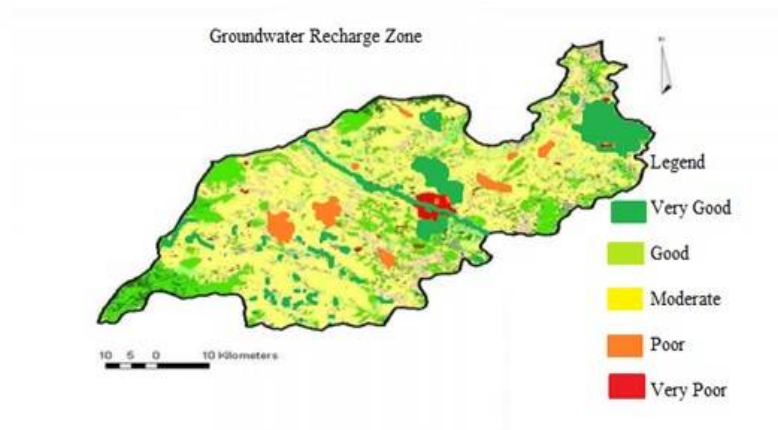


Figure 6 Ground water recharge map of Madurai district

VI. CONCLUSION

The results indicate that the most effective groundwater recharge potential zone is located on east-north part of the study area. Overall result demonstrates that the use of remote sensing and GIS technique provides powerful tool to study groundwater resources and design a suitable exploration plan for recharge of groundwater in study area. From this study it is observed that remote sensing and GIS technique can be used effectively to delineate groundwater recharge potential zones map. These results can be used for various purposes like identification of location of structures for artificial recharge, locations of new tube wells and efficient groundwater management for betterment of the society.

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