Identification of Groundwater Potential Zones on GIS based Multi-Criteria Technique

(A Case Study on Bhavani Watershed, Erode District ,Tamilnadu, Southern India)

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***Abstract* — Sustainable development and management of groundwater resources require application of scientific principles and modern techniques. It is believed that remote sensing and geographic information system (GIS) is an effective tool for integrated analysis of various parameters for exploration and management of groundwater. In this study an integrated approach is implemented using GIS based multi-criteria evaluation, to identify the potential zones for artificial recharge of groundwater. This study involves identification of various vital parameters that influence the mapping of potential zones and selection of suitable structures for recharge.Landsat-8 image was used to produce thematic maps such as geomorphology, geology, land use & land cover and lineaments. Slope and drainage networks were derived from ASTER DEM. Thematic layers such as soil, rainfall, groundwater fluctuation level and aquifer characteristics were also prepared and weighed by multi-criteria decision making technique. These thematic layers were used in the integrated model for identification of potential groundwater recharge zones in the Bhavani micro- watershed, Erode district of Tamil Nadu.**

Keywords— Landsat 8, ASTER DEM, GIS, Groundwater recharge, Bhavani watershed, India

I. INTRODUCTION

Groundwater is the water present in the zone of saturation below the ground. The zone of saturation is technically called aquifer. Aquifers are significantly porous and permeable to supply water to wells and springs. It acts as conduits for water transmission and as underground reservoirs for water storage. Practically, all groundwater originates as surface water. Water enters aquifers from the land surface or from surface water bodies through the vadose zone, and then it travels slowly within the aquifer for varying distances until it finally returns to the land surface by natural flow, plants, or humans The residence time of groundwater in the subsurface can vary from days to thousands of years (centuries or millennia) depending on the length of the flow path and the transmissivity of porous media.

The study of groundwater is essential because of its physical and chemical quality and it is a reliable source of water supply in both humid and arid/semi-arid regions of the world and during emergencies e.g., droughts, earthquakes, etc. as well as it sustains flow in rivers/streams and lakes during dry periods. Thus, groundwater is one of the most valuable natural resources of the earth, which supports human health, human livelihoods, socio-economic development, and ecological diversity.

The rapid and accelerated urbanization and industrialization has led to the decline of groundwater level and consequent stress on groundwater resource. With the continuous exploitation of such resource, at present, we are finding ourselves at the bottom limit of groundwater availability which is the indication of an upcoming disaster [1]. The drying up of streams and rivers not only results in the non-availability of water resource but also create many environmental problems such as crop failure, saline water intrusion in the coastal areas and general ecological degradation and regional drought [2].

In order to maintain the water table condition in balance and to restrict the surface runoff going waste, various methods for artificial groundwater recharge have been implemented in many parts of the world. The main goals of artificial recharge are changing the water quality, adding or maintaining underground water as an economic resource, preventing saltwater intrusion, and reducing or preventing of land subsidence. So artificial recharge is a mechanism to protect groundwater depletion in aquifers[3] [11].

In recent years, usage of satellite data for analysis and identification of potential areas for artificial recharge have become very common. Remote sensing technology with its wide range of data acquisition capability both spatial and temporal, have emerged as a useful tool for the generation of massive micro level information about various features responsible for the occurrence, movement, and recharge of ground water[6] [1]. For the utmost utilization of remotely sensed data, GIS is integrated with remote sensing. Under GIS environment, a series of activity i.e. construction of thematic layers, integration of layers and final output making, constitutes the whole mechanism of exploration and management of ground water resources. Several researchers have used Remote sensing and GIS techniques for the delineation of groundwater potential zones [4] [5] [7] [8] [9] [10] with successful results. The type and number of thematic layers used for assessing groundwater potential by remote sensing and GIS techniques vary considerably from one study to another and their selection is arbitrary. Multi-criteria decision making (MCDM) technique is used to weigh the criteria based on their influence on groundwater recharge[5].

This study involves identification of various vital parameters that influence the mapping of potential zones and selection of suitable structures for recharge. Thematic layers such as geology, geomorphology, slope, land use/cover, lineament, drainage, soil, rainfall were considered. The importance of each factor on groundwater recharge is evaluated using AHP method and integrated using GIS to identify suitable zones for groundwater recharge.

II. STUDY AREA

This study is conducted in Bhavani micro watershed, which is located in Erode district Tamil Nadu. The micro watersheds are 4B2E3h, 4B2E3g, 4B2E3f, 4B2E3d, 4B2E3c, 4B2E3b, 4B2E3a. Due to over-exploitation of groundwater for the agricultural and industrial purpose, there is a steady decline of groundwater level in the study area. The micro watershed lies between 11°40’22” and 11°25’53” to the north, 77°10’27” and 77°28’51” to the east. The watershed covers an area of 465 sq.km.

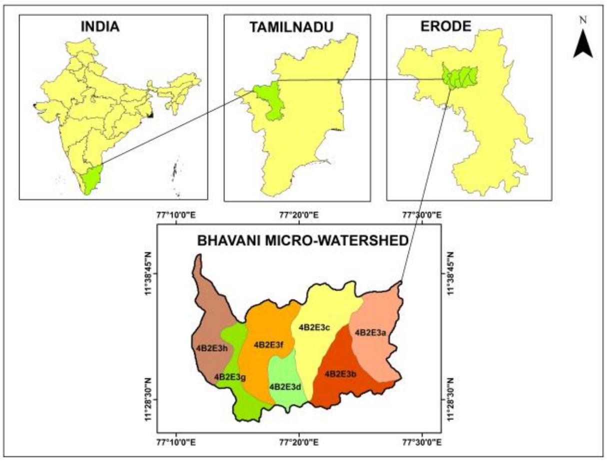

Fig.1 Location map of the study area

Annual average rainfall of erode district is 812mm. Bhavani is fed mostly by the South-West monsoon. This river runs for over hundred miles through Erode district traversing through Bhavani and Gobichettipalayam taluks. It feeds the Bhavanisagar reservoir which takes an easterly course flowing through Gobichettipalayam, Sathyamangalam and Bhavani taluks before it ultimately joins river Cauvery on the Salem borders. It has dry weather throughout except monsoon season. Agriculture is the dominant land use type in micro-watershed.

III. MATERIALS USED

For this study, existing hydro-geological and relevant data on soil, structural features, and climatic conditions of the study area were collected. The satellite image was used to get information on land use, geomorphology, and slope using ArcGIS 9.2 software.

Table 1: Data description

DATA	DESCRIPTION	MAPS
LANDSAT 8	30m resolution	Geo-morphology Lineament Land use / land cover
ASTER DEM	30m resolution	Slope Drainage
SOI Toposheet	1:50000	Base map Drainage
District resource map	1:50000	Geology, Soil
Rainfall	15yrs	Rainfall

IV. METHODOLOGY

The overall methodology of the present study includes data collection, fieldwork, and generation of thematic layers and integration of all the geological and hydrological parameters by weighted overlay analysis to identify suitable zones for artificial recharge of ground water. Landsat 8 image was used to prepare geomorphology, lineament, and land use/cover map. Geology map is prepared from district resource map. Drainage density and slope map is derived from ASTER DEM. Soil and rainfall are collected from respective departments and maps are prepared using ArcGIS 9.2. The thematic layers were converted into raster format and weightage for each thematic layer map is given. Thematic layers are integrated by weighted overlay analysis and the output map shows the potential zones for artificial recharge of groundwater.

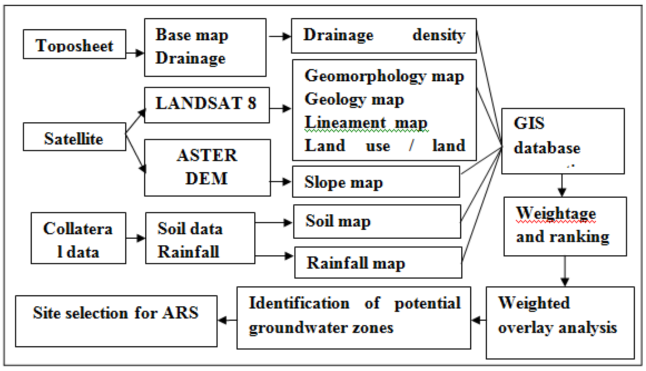

Fig.2 Methodology

V. RESULTS AND DISCUSSION

The thematic layers prepared are lineament density map, geomorphology, geology, slope, drainage density, rainfall map, soil map and land use/cover.

A. Geomorphology

Geomorphological mapping involved the identification and characterization of various landforms and structural features in the study area. The major geomorphological units found in the study area are flood plain, structurally dissected hill, alluvial plain, pediment, pediplain, denudational hill and colluvial deposits are shown in the Figure (Fig.3). Structurally dissected hill and denudational hill has eroding property so considered as less potential sites. Highest weightage is given to flood plain and alluvial plain due to its infiltrating capacity.

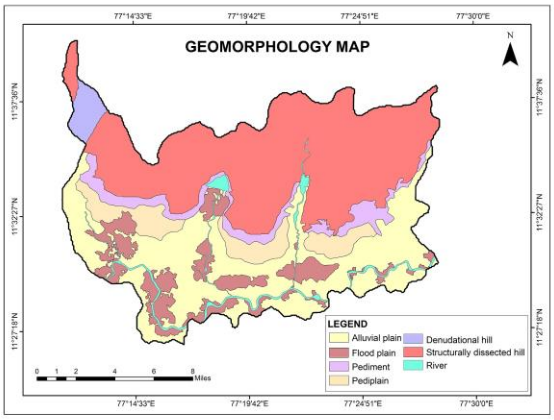

Fig.3 Geomorphology map

B. *Geology*

The major geological features in the study area are Amphibolite, Fissile horneblende biotite gneiss, Charnockite and Fuchsite quartzite are shown in the Figure (Fig.4). It influences the infiltration capacity of the ground surface. The weightage of these features based on their potential for artificial groundwater recharge are given by MCDM technique and overall weightage for the thematic layer is computed. Gneiss is considered as the most potential feature for artificial groundwater recharge due to its weathering property and very less importance is given for charnockite.

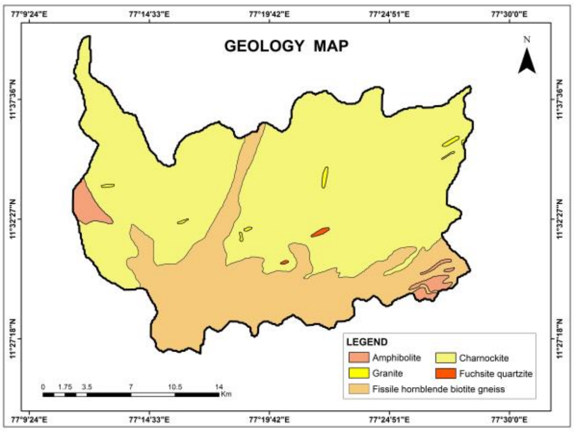

Fig.4 Geology map

C. *Lineameny density map*

The lineament is interpreted from Landsat 8 image is shown in the Figure (Fig.5) and lineament density map of the study area is shown in the Figure(Fig.6). The areas with higher lineament density are regarded as good for groundwater recharge since it act as pavement for water to infiltrate.

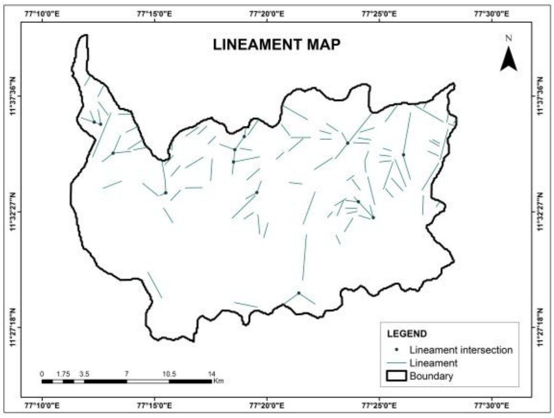

Fig.5 Lineament map

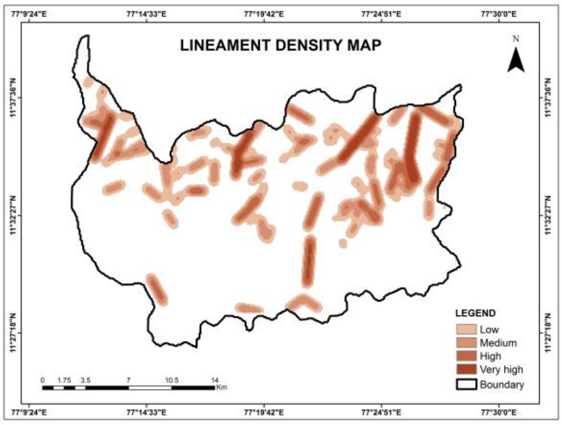

Fig.6 Lineament density map

D. *Land use/land cover*

Land use/land cover plays an important role in the

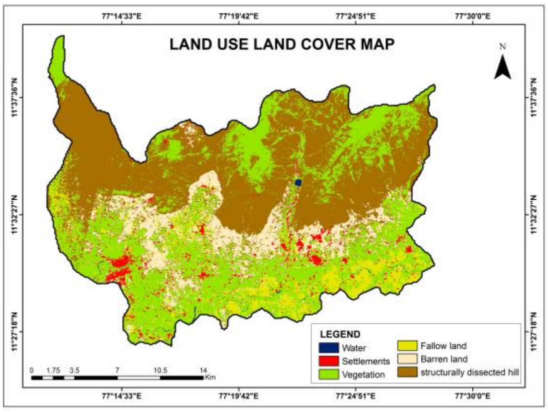

Fig.7 Land use/land cover map

occurrence and development of groundwater. The land use of the study area is classified into six classes: vegetation , barren land, fallow land, structurally dissected hill, settlements and water body are shown in the Figure (Fig.7). Classification of land use for weighted analysis is decided based on the land-use type, area coverage and properties to infiltrate water, and their characteristics to hold water on the ground surface. The land use which comes under vegetation and temporary fallow land has high potential for groundwater recharge since the infiltration capacity is high and the land use which comes under settlements and barren land has very low potential for groundwater recharge since its infiltration capacity is low.

E. Drainage density map

The drainage density of the study area is classified into five classes: very low, low, moderate, high and very high. The drainage and reclassified drainage density map is shown in the Figure(Fig.8) and (Fig.9). The suitability of groundwater potential zones is indirectly related to drainage density because of its relationship with surface runoff and permeability. The higher the drainage density the lesser the infiltration of water to the subsurface, which in turn leads to higher runoff and vice versa.

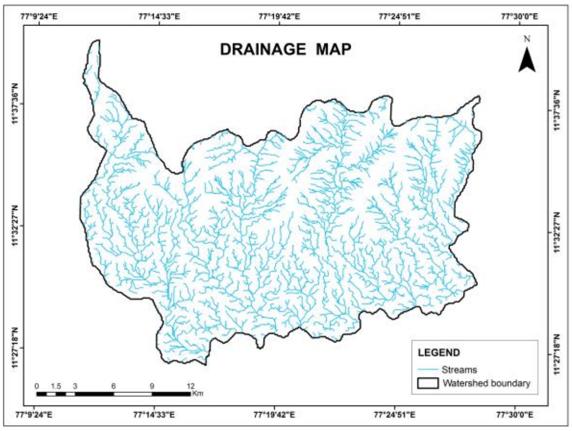

Fig.8 Drainage map

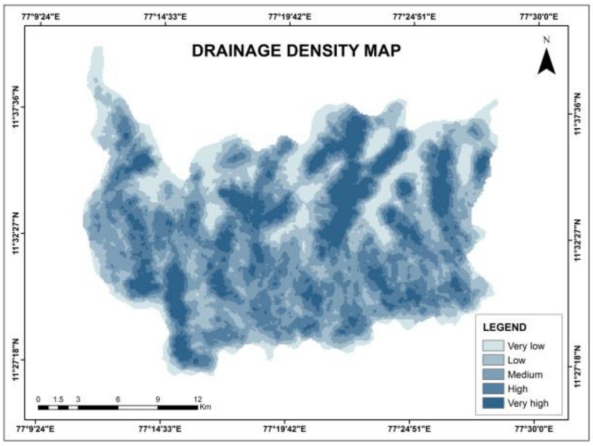

Fig.9 Drainage density map

F. Slope

The study area was divided into four classes based on the range of slope. The areas having 0–10˚ slope are categorized as ‘very good’ because of the flat terrain and relatively reduced runoff movement to downstream. The areas having slope of more than 45˚ are considered as ‘very poor’ due to the higher slope, which causes higher runoff. The slope map of the study area is shown in the Figure (Fig.10).

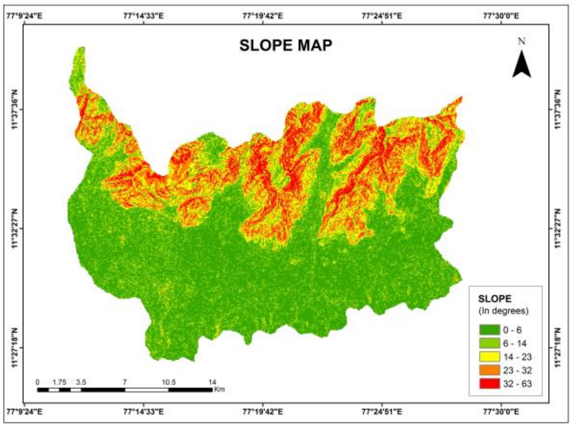

Fig.10 Slope map

G. Soil

The study area has three types of soil texture. They are sandy-clay, clay-loam and sandy -clay loam. The sandy clay has high infiltration capacity due to high sand content and considered as most potential zone. The least importance is given to clay loam textured soil because of its low infiltration capacity due to high content of clay. The soil map of the study area is shown in the Figure (Fig.11).

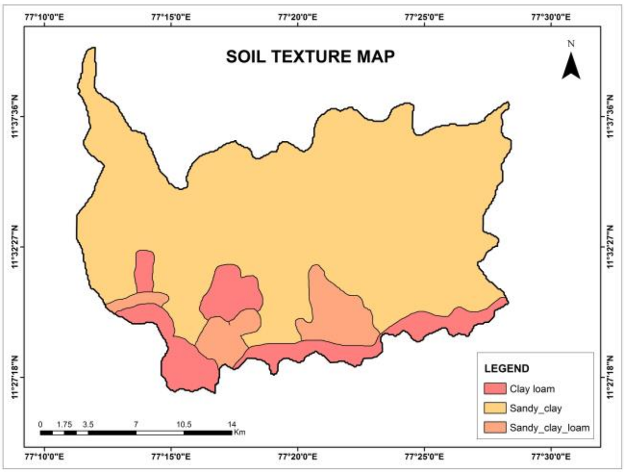

Fig.11 Soil map

H. Rainfall map

Rainfall plays important role in mapping groundwater potential zones because it is the primary source for groundwater. The rainfall data for 15 years(2000 to 2015) was collected and using thiessen polygon the rainfall station which influence the study area was identified. The area was divided into five zones as very low, low , moderate, high and very high. The annual average rainfall of the area is 800mm. Rainfall map of the study area is shown in the figure (Fig.12).

I. Overlay analysis

Based upon the influence of each criteria on groundwater recharge, weightage was given to each thematic layer. Drainage density, lineament density, slope , land use/land

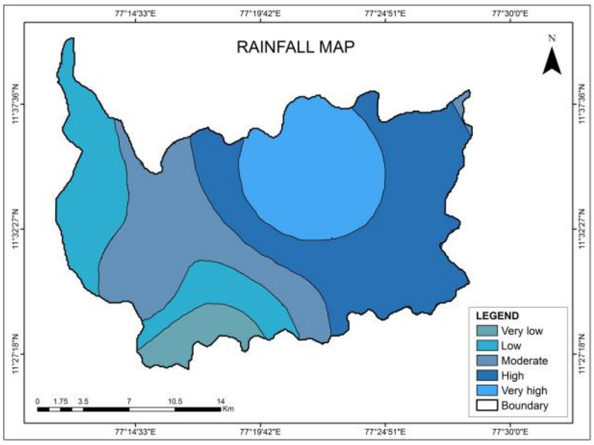

Fig.12 Rainfall map

cover, geology, geomorphology, soil and rainfall maps were generated and assigned suitable weights as shown in Table 2. Weighted overlay analysis was done to produce the groundwater potential zone map using ArcGIS 9.2.

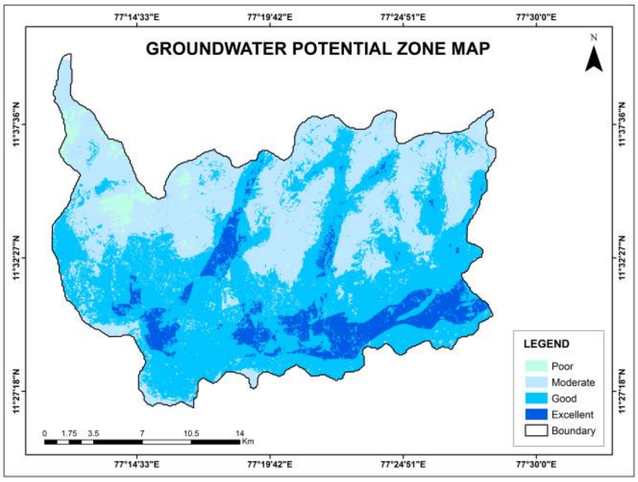

Fig.13 Groundwater potential zone map

J. *Groundwater potential zone*

On the basis of the weighting of the individual feature of the thematic layers, the groundwater potential zone was estimated. The groundwater potential zone was classified into poor , moderate, good and excellent zones. This map can be used to identify the suitable sites for implements of artificial recharge structure to augment the groundwater. As shown in the Fig.13, the alluvial plain in the south of Bhavani watershed were explored as high potential zone for groundwater recharge. The total areal extent of high potential zone covers about 156.25sq.km. The hilly terrain located in the northern part of the study area has moderate groundwater potential due to the presence of bamboo plantation. The terrain with denudational hill north eastern part of the study area has poor potential for groundwater recharge due to its eroding property and steep slopes.

Table.2 Weightage and Ranking

S.No	Criteria	Sub-criteria	Ranks	Weightage (%)
1	Geomorphology	Structurally dissected hill	5	14
		Denudational hill	5	
		Flood plain	1	
		Alluvial plain	2	
		Pediment	4	
		Pediplain	3	
2	Geology	Fuchsite quartzite	2	15
		Fissile hornblende biotite gneiss	1	
		Amphibolite	3	
		Charnockite	5	
		Granite	4	
3	Land use/land cover	Water	4	12
		Settlement	5	
		Vegetation	1	
		Fallow land	2	
		Barren land	3	
		Structurally dissected hill	5	
4	Lineament density	Very low	5	9
		Low	4	
		Medium	3	
		High	2	
		Very high	1	
5	Slope (degrees)	0-6	1	12
		6-14	2	
		14-23	3	
		23-32	4	
		32-63	5	
6	Drainage density	Very low	1	7
		Low	2	
		Medium	3	
		High	4	
		Very high	5	
7	Soil	Sandy clay	1	14
		Clay loam	3	
		Sandy clay loam	2	
8	Rainfall	Very low	5	17
		Low	4	
		Medium	3	
		High	2	
		Very high	1	

VI. CONCLUSION

The application of geospatial technology, remote sensing and MCDM technique is demonstrated as one of the tool for the identification potential zones for groundwater recharge. The present study identifies the potential zone by considering and analyzing different parameter based on their influence on groundwater recharge. This groundwater potential map can be used by government authorities to identify suitable sites for the implementation of artificial recharge structures such as check dams, percolation tank etc. to augment the groundwater.

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