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Identification Of Groundwater Recharge Potential Zones Using Rs, Gis & Ahp Technique

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Abstract : *The rapid growth of population and agricultural and industrial activities has caused an increase in demand of ground water. In fact, the over-pumping of this aquifer system has resulted in water-level declines during the past three decades. The explosive growth and uneven distribution of population, poor irrigation practices, rapid urbanization/industrialization, large-scale deforestation and improper land use practices have induced the depletion and pollution of both the surface and groundwater resources in India. In addition, recurrent drought further aggravates the problem of water even for drinking, especially in rural areas. The aim of this study is to identify favourable artificial recharge sites of this aquifer system based on the combined use of remotely sensed data, a geographic information system (GIS). The present study attempts to Identify the potential recharge zones and locations for artificial recharge structures in Upper Godavari Sub-basin. The input data for this analysis are different layers like geology, geomorphology, soil, rainfall, land use-land cover, soil lineament density and drainage density. The result depicted the groundwater potential zones into four categories, viz., good, moderate, low and poor That and can be used for better planning and management of groundwater resources. Various groundwater recharge Structures like boulder dams, check dams, percolation tanks, recharge pits etc., were suggested in appropriate locations of Upper Godavari sub basin according to the derived results.*

Keywords - *Groundwater recharge, Delineation, Remote Sensing, GIS, Analytical Hierarchical Process, Upper Godavari Sub-basin.*

I. INTRODUCTION

Climate change has a significant effect on earth systems which is evident through severe water scarcity in recent decades. Groundwater being the most proximate can heavily help in water shortage problems. Due to the rapid increase in population, industrialization and irrigation, the water demand increased, which severely influenced groundwater stress. Water Security is expected to be the biggest challenge in the 21st century. In the past decade, water demand increased due to human development activities and climate change, Therefore, identifying the potential zone of groundwater becomes an integral part of water resource management and planning. Conventional methods like geophysical exploration are expensive and time-consuming.

The study results that the integration of thematic maps prepared from conventional and remote sensing techniques using GIS gives more and accurate results. Remote Sensing is one of the major sources of surface feature information such as land use, landform and drainage density. These data can be easily input in GIS to identify the Groundwater zones. Data sets are going to be used to prepare 8 thematic layers of the slope, soil texture, drainage density, land use land cover (LULC), lithology, geomorphology, lineament density and rainfall. The analytical method of the AHP pairwise matrix will be used to evaluate the normalised weight of these thematic layers

Introduction to Analytical Hierarchical Process (AHP)

Analytical Hierarchical Process (AHP) is a multi-criteria decision-making method developed by Prof. Thomas L Satty in 1980. It is a strategy to get proportion scales from the paired difference. The information has been taken from actual measurements such as weights, price and difference. The information has been taken from actual measurements such as weights, price and subjective conclusions. In this study, a total of 8 parameters were used to delineate the groundwater potential zones such as drainage, density, geology, geomorphology, land use land cover, lineament, rainfall and scope. DEM data has been used to create aspect maps, scope maps and flow accumulation.

II. LITERATURE REVIEW

2.1 Potential Groundwater Recharge Sites Mapping in a Typical Basement Terrain: a GIS Methodology Approach, Oluwaseun Franklin Olabode, 2019

This study is in the area of Akoko with a progressively increasing population and infrastructural development, underlain by rocks typified of a basement terrain, was subjected to the search for potential groundwater recharge sites, to meet the challenge of water demand in the future. Groundwater recharge indicators such as lithology, topography, geomorphology, lineament density, soil, rainfall, drainage density, and land use/land cover were employed for this study. These indicators were then delineated, weighted, and classified on the basis of understanding of the local geology and hydrogeology of the study area. These indicators were integrated into a GIS environment to produce a potential groundwater recharge map for the Akoko area. Saaty introduced the AHP, which is relevant in multi criteria decision analysis for potential GWR site mapping. A weighted overlay analysis was employed which aggregated the 8 thematic layers by initial computation of rates and weights assigned to reflects their relative importance in relation GWR with the aid of Saaty's AHP as a tool. Five potential GWR sites were categorized from the generated potential recharge sites map. The results were validated with available borehole record data.

III. METHODOLOGY

1. 3.1 Data sets used and preparation of thematic layers

Eight thematic layers of lithology, geomorphology, slope, LULC, lineament density, rainfall, and drainage density are chosen which had a major effect and more reliable of controlling the groundwater potential of an area. ArcGIS software will be used. The relationship between these eight parameters and their impact on delineating potential groundwater recharge zone is shown in Figure 3.1. Depending on the strength of a parameter and its respective classes relationship is weighted. A parameter with a higher weight value has a greater impact, and a parameter with a lower weight value has a smaller impact on possible groundwater zones.

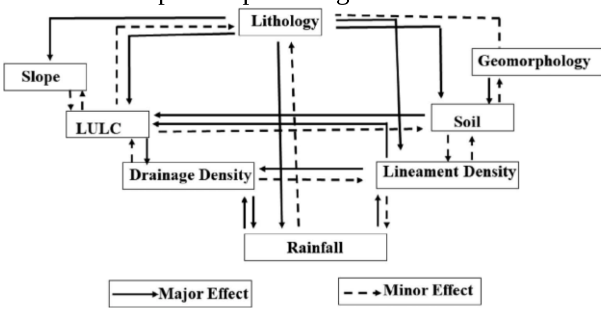

Fig. 1 Interrelationship between the multi influencing parameters controlling the groundwater potential zone

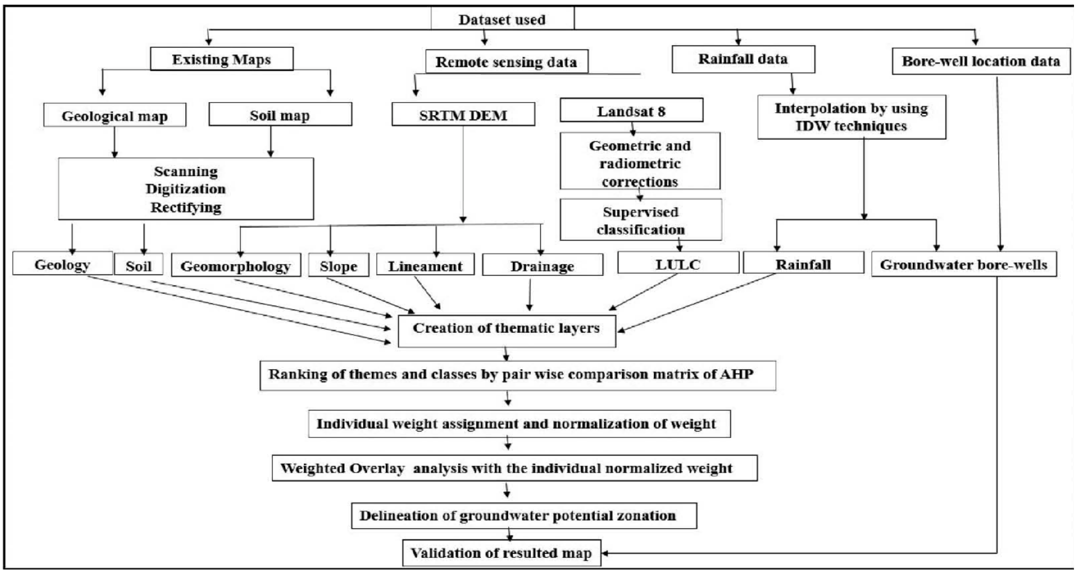

Fig 2 Flow-chart methodology adapted for the present work

2. 3.2 Preparation of thematic layers and assigning of ranks

1. 3.2.1 Preparation of slope map

The Cartosat DEM data were used to derive the slope map, which is presented in terms of percentage using the 'slope' function in ArcGIS. It was then converted from .shp to raster format and reclassified into different slope classes using the re-classify option in the spatial analyst tool. Ranks were assigned for each class of the slope map.

2. 3.2.2 Preparation of soil map

Soil map of shapefile format was converted to raster format using polygon to raster conversion tool. The eight major soil groups found in the study area was then reclassified to assign ranks to each class.

3. 3.2.3 Preparation of geomorphology map

The geomorphological map incorporates the relationship of geomorphic units with their groundwater potential as interpreted from the landform characteristics as well as subsurface geology.1

4. 3.2.4 Preparation of geology map

It is well fact that the geological setup of an area plays a vital role in the distribution and occurrence of groundwater [5]. Geological classes were reclassified and assigned ranks.

5. 3.2.5 Preparation of land use map

The land use map of the study area was available in the Department of Remote Sensing and Geographical Information System (GIS), TNAU, Coimbatore in .shp format and it was converted to raster format and later reclassified using the conversion tool and reclassify tool in ArcGIS 10.1. Different land use classes were assigned different ranks based on their influence on groundwater recharge potential.

6. 3.2.6 Preparation of lineament density map

Lineaments are linear or curvilinear structures on the earth surface, which depict the weaker zone of bedrocks and the area is considered as a secondary aquifer in hard-rock regions. In hard rock terrains, lineaments represent areas and zones of faulting and fracturing resulting in increased secondary porosity and permeability and are good indicators of groundwater [6]. The present study used lineament length density (LD, L-1), which represents the total length of lineaments in a unit area, as:

$$LD = \sum_{i=1}^{i=n} \frac{Li}{A(m^{-1})}$$

where Li= total length of lineaments (m) & A=Area of the study region (m^2).

Lineament map was converted to lineament density using the line density tool in the spatial analysis tool. This was then classified into two classes viz., lineament present and not present. Areas with lineament were assigned the maximum rank and without lineament with least.

7. 3.2.7 Preparation of drainage density map

The Cartosat DEM (30 m) data was obtained from Bhuvan (ISRO's geo-portal) and was mosaic and clipped to the study area. The clipped DEM was then filled, using the fill tool in spatial analysis tool to remove small imperfections in the data. To create a raster of flow direction from each cell to its steepest downslope neighbour flow direction tool was used. A raster of accumulated flow was next created using a flow accumulation tool with flow direction as the input. The drainage map was then generated from Cartosat DEM using the raster calculator tool, which was then converted to vector and further the drainage density (km-2) map was obtained by the line density analysis tool.

3.3 Derivation of normalized weights of thematic layers by AHP method

A common approach for deriving weights for different factors is to draw a schematic sketch of the interrelationships of the different factors. The stronger the influence of one factor on other factors the larger its relative importance which leads to a larger weight (Magesh, Chandrasekar, & Soundranayagam, 2012; Prasad, Mondal, Banerjee, Nandakumar, & Singh, 2008; Shaban, Khawlie, & Abdallah, 2006; Thapa et al., 2017; Yeh et al., 2009; Yeh et al., 2016). AHP method is very helpful for multi-parameter assessment (Saaty, 1980). The relative significance for every individual layer is resolved with Saaty's 1–9 scale Table 4.1, in which a score of 1 represents equal importance between the two parameters, and a score of 9 shows the outrageous significance of one parameter contrasted with the other one (Saaty, 1980). Saaty's scale has been used to define the themes with their scale of rank and priority which helps to organize the criteria in hierarchical order through a pair-wise comparison matrix.

1/9	1/7	1/5	1/3	1	3	5	7	9	
Extreme	Very strong	Strong	Moderate	Equally	Moderate	Strong	Very strong	Extreme	
	Less important			Equal		More Important			
Note: 1/8, 1/6, 1/4, 1/2, 2, 4, 6, 8 can also be used if a greater number of classes exist.									
N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.21	1.24	1.32	1.41	1.45

The basis for groundwater prospective mapping technique is that the weight allocation of the various thematic layers and their corresponding classes are determined by the competence of the author ability so that each factor that controls the potential groundwater in an area has assigned appropriate ranks and weights (Das et al., 2017; Yeh et al., 2014). In the present work, several existing pieces of literature have been carefully evaluated before assigning ranks and weights to gain an adequate understanding of the ranking of variables under distinct environmental circumstances and in distinct regions. The AHP picks up the likelihood of uncertainty in assessments through the principal Eigenvalue and the index of consistency (Saaty, 2008). The Consistency index (CI), as a measure of Consistency, is derived from the following equation.

$$CI = \frac{\lambda max - 1}{n - 1}$$

where λmax is the significant eigenvalue of the pairwise comparison matrix, and n is the number of classes. To regulate the assessment of consistency analysis and scale, Consistency ratio (CR) defined as the measure of consistency between pairwise comparison matrices (Saaty, 1980) is calculated.

$$CR = \frac{CI}{RI}$$

Matrix		Geomorphology 1	Slope 2	Geology 3	Lineament Density 4	LULC 5	Rainfall 6	Soil 7	Drainage Density 8	Normalized Principal Eigen Vector
Geomorphology	1	1	2	3	4	5	6	7	8	33.13%
Slope	2	1/2	1	2	3	4	5	6	7	23.07%
Geology	3	1/3	1/2	1	2	3	4	5	6	15.72%
Lineament Density	4	1/4	1/3	1/2	1	2	3	4	5	10.59%

LULC	5	1/5	1/4	1/3	1/2	1	2	3	4	7.09%
Rainfall	6	1/6	1/5	1/4	1/3	1/2	1	2	3	4.77%
Soil	7	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3.27%
Drainage Density	8	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2.36%

Table 1 Pair-wise comparison matrix for all themes (parameters) & Normalized Principal Eigen Vector

Sr. No.	Criteria	Comment	Weights	+/-
1	Geomorphology		33.1%	10.2%
2	Slope		23.1%	6.0%
3	Geology		15.7%	3.9%
4	Lineament Density		10.6%	2.7%
5	LULC		7.1%	1.9%
6	Rainfall		4.8%	1.3%
7	Soil		3.3%	0.9%
8	Drainage Density		2.4%	0.9%

Table 2 Weights for different criteria based on Eigen Vector Method

λmax: 8.288, n: 8, MRE: 28.4%, CR: 0.029, α: 0.1

3.4 Data integration analysis in GIS environment

The thematic maps were used as input in the weighted overlay analysis, during the analysis, the weights were assigned to the thematic layers in the weighted overlay table and each of the classes was ranked accordingly. After assigning weight, the integration of all layers was carried out by applying weighted overlay analysis in a GIS environment (ArcMap 10.3). The output map of the weighted overlay analysis gives the groundwater prospect map of the study area.

3.4.1.Overlay weighted analysis and delineation of groundwater potential zonation

Initially, reclassification of the individual layers (criteria) and assignment of ranks is done keeping in mind the impact of parameters and their respective classes in controlling the potential groundwater recharge over an area. However, in a groundwater zonation, the aim of creating several classes and their weights is to demonstrate the best possible variants. Each parameter and its respective classes are allocated the ranks and weights based on their comparative potential contribution (Table 4).

This is achieved based on the experience of a researcher and their insights on current literature, location, and the other characteristic variables (LULC, rainfall, Soil texture, Geology, Geomorphology, etc.) of the area. The below equation is a raster calculation of all of these parameters incorporated into ArcGIS software and followed by the resulting map.

$$GWPZ = (LTW * LTWI) + (GMW * GMWI) + (SLW * SLWI) + (SW * SWI) + (LDW * LDWI) + (DDW * DDWI) + (RFW * RFWI)$$

where GWPZ shows the potential areas of groundwater. LT, GM, SL, S, LD, LU, DD, RF are the lithology, geomorphology, slope, soil, lineament density, Land use, drainage density, and rainfall, respectively. The weight of a layer and the weight of a particular class of layer is represented by W and WI, which were combined on a pixel basis according to Equation

3.5 Validation of delineated potential groundwater recharge zone

The resulting map of the potential groundwater recharge zone was validated using existing pumping bore well data. The pumping bore well data was prepared and overlaid over the potential groundwater recharge map of the study area. To determine the accuracy of the potential groundwater recharge zone map, the Receiver Operating Characteristic Curve (ROC) and Area Under the Curve (AUC) were used. (Naghibi et al., 2016; Naghibi, Pourghasemi, Pourtaghi, & Rezaei, 2015a; Ozdemir & Altural, 2013; Pourghasemi et al., 2012a). In the ROC method, the area under the ROC curve value ranges from 0.5 to 1.0. It is used to evaluate the accuracy of the model (Nandi & Shakoor, 2009). If the model does not predict the occurrence of the groundwater zone the AUC becomes equal to 0.5.

IV. CONCLUSION

To reduce the problem of scarcity of water resources, there is need to map favorable groundwater recharge sites in upper Godavari sub-basin. After studying the past research works there is need of preparation of eight parameters (lithology, geomorphology, slope, LULC, lineament density, rainfall, and drainage density) were assigned with different weights and rates by the use of Satty's analytical hierarchy process (AHP) in order to produce a potential groundwater recharge map. In next phase of this study,

REFERENCES

[1] J. A. Sandoval and C. L. Tiburan, "Identification of potential artificial groundwater recharge sites in Mount Makiling Forest Reserve, Philippines using GIS and Analytical Hierarchy Process," *Appl. Geogr.*, vol. 105, no. January, pp. 73–85, 2019, doi: 10.1016/j.apgeog.2019.01.010.

[2] D. Souissi, M. H. Msaddek, L. Zouhri, I. Chenini, M. El May, and M. Dlala, "Mapping groundwater recharge potential zones in arid region using GIS and Landsat approaches, southeast Tunisia," *Hydrol. Sci. J.*, vol. 63, no. 2, pp. 251–268, 2018, doi: 10.1080/02626667.2017.1414383.

[3] R. K. Jaiswal, S. Mukherjee, J. Krishnamurthy, and R. Saxena, "Role of remote sensing and GIS techniques for generation of groundwater prospect zones towards rural development - An approach," *Int. J. Remote Sens.*, vol. 24, no. 5, pp. 993–1008, 2003, doi: 10.1080/01431160210144543.

[4] T. Dar, N. Rai, and A. Bhat, "Delineation of potential groundwater recharge zones using analytical hierarchy process (AHP)," *Geol. Ecol. Landscapes*, vol. 00, no. 00, pp. 1–16, 2020, doi: 10.1080/24749508.2020.1726562.

[5] D. Abijith, S. Saravanan, L. Singh, J. J. Jennifer, T. Saranya, and K. S. S. Parthasarathy, "GIS-based multi-criteria analysis for identification of potential groundwater recharge zones - a case study from Ponnaniyaru watershed, Tamil Nadu, India," *HydroResearch*, vol. 3, pp. 1–14, 2020, doi: 10.1016/j.hydres.2020.02.002.

[6] G. B. Lentswe and L. Molwalefhe, "Delineation of potential groundwater recharge zones using analytic hierarchy process-guided GIS in the semi-arid Motloutse watershed, eastern Botswana," *J. Hydrol. Reg. Stud.*, vol. 28, no. October 2019, p. 100674, 2020, doi: 10.1016/j.ejrh.2020.100674.

[7] Z. H. Mseli, W. J. Mwegoha, and S. Gaduputi, "Identification of potential groundwater recharge zones at Makutupora basin, Dodoma Tanzania," *Geol. Ecol. Landscapes*, vol. 00, no. 00, pp. 1–14, 2021, doi: 10.1080/24749508.2021.1952763.

A. M. Al-Abadi, H. B. Ghalib, and J. A. Al-Mohammdawi, "Delineation of Groundwater Recharge Zones in Ali Al-Gharbi District, Southern Iraq Using Multi-criteria Decision-making Model and GIS," *J. Geovisualization Spat. Anal.*, vol. 4, no. 1, 2020, doi: 10.1007/s41651-020-00054-7.

[8] M. Senthilkumar, D. Gnanasundar, and R. Arumugam, "Identifying groundwater recharge zones using remote sensing & GIS techniques in Amaravathi aquifer system, Tamil Nadu, South India," *Sustain. Environ. Res.*, vol. 1, no. 1, pp. 1–9, 2019, doi: 10.1186/s42834-019-0014-7.

[9] B. J. Fagbohun, "Integrating GIS and multi-influencing factor technique for delineation of potential groundwater recharge zones in parts of Ilesha schist belt, southwestern Nigeria," *Environ. Earth Sci.*, vol. 77, no. 3, 2018, doi: 10.1007/s12665-018-7229-5.

[10] S. Saidi, S. Hosni, H. Mannai, F. Jelassi, S. Bouri, and B. Anselme, "GIS-based multi-criteria analysis and vulnerability method for the potential groundwater recharge delineation, case study of Manouba phreatic aquifer, NE Tunisia," *Environ. Earth Sci.*, vol. 76, no. 15, 2017, doi: 10.1007/s12665-017-6840-1.

[11] K. R. Mussa, I. C. Mjemah, and R. L. Machunda, "Open-source software application for hydrogeological delineation of potential groundwater recharge zones in the singida semi-arid, fractured aquifer, central Tanzania," *Hydrology*, vol. 7, no. 2, 2020, doi: 10.3390/HYDROLOGY7020028.

[12] R. A, N. Kuruppath, and B. Kannan, "Identification of Potential Groundwater Recharge Zones Using Remote Sensing and Geographical Information System in Amaravathy Basin," *J. Remote Sens. GIS*, vol. 06, no. 04, 2017, doi: 10.4172/2469-4134.1000213.

[13] O. F. Olabode, "Potential Groundwater Recharge Sites Mapping in a Typical Basement Terrain: a GIS Methodology Approach," *J. Geovisualization Spat. Anal.*, vol. 3, no. 1, 2019, doi: 10.1007/s41651-019-0028-z.

[14] M. Brunneli, *Introduction to the Analytic Hierarchy Process*. 2015.