Mapping of Ground Water Potential Zones by Using ArcGIS

Chippy V P, Anjali S

Abstract— In our world one of the most important natural resource is water which is occurring both as surface water and groundwater. It is vital for all life on the earth. Developments of our society are dependent on the availability and use of water. The changing climate and global warming have effected the existing surface water.This study investigates the groundwater potential zones in kunnothuparamba, Kannur, Kerala by using ArcGIS 10.8. When we know about the groundwater very well then only we can use that resource. The parameters contributing groundwater recharge and sub-surface flow such as Drainage density, Geology, Land use/ Land cover, Lineament density, Rainfall and Slope are used in this study. The statistical analysis is done by using AHP method. Considering the influence of each parameter in the groundwater recharge, rank and weightage was given and potential groundwater areas were classified into very high, high, moderate, very poor and poor. The result map indicates the potentiality of groundwater availability in various parts of the study area. The ArcGIS based method is effectively performed for identification of groundwater potential zone and the information's can be used for planning the sustainable groundwater management.

Keywords— AHP, ArcGIS, Drainage density, Geology, Groundwater potential zones, Land use land cover, Lineament density, Rainfall, Slope.

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1 INTRODUCTION

One of the most important natural resource is water which is occurring both as surface water and groundwater. It is vital for all life on the earth. Developments of our society are dependent on the availability and use of adequate water. This precious resource is sometimes scarce, sometimes abundant but unevenly distributed, both in space and time. Groundwater represents the second-most abundantly available freshwater resources and constitutes about 30% of fresh water resources of the globe[10]. The groundwater is derived from precipitation and recharge from surface water. It is the water that has infiltrated into the earth directly from precipitation, recharge from streams and other natural water bodies and artificial recharge by man. Groundwater is easy to collect, and it remains well protected from pollution.

Over exploitation has depleted groundwater availability considerably and also led to land subsidence at some places. Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems[4]. Ground water serves as a source of water for domestic, industrial and agricultural uses and other developmental initiatives . In a semi-arid country like India, surface water is not available in the complete year for meeting different purposes and hence people in such areas have to depend more on groundwater resources for their survival[3].

As per one report , about 0.6 million people in India is

facing high to extremely high water stress due to inadequate availability of fresh water. Further, about three-fourth of the households in the country do not have access to portable water at their premises[6]. India will become a water stress zone by the year 2025 and a water scarce zone by the year 2050, according to a world bank report, if adequate measures are not taken[2]. So the identification of ground water potential zones and protective usage of that resource is also become important[3]. For that mapping is using by the help of ArcGIS software.

Several studies have been carried out on this aspect which reiterates the use of remote sensing and geographical information system (GIS) techniques for mapping groundwater potential zones in different parts of the world[9]. In this study, a combination of Analytical Hierarchy Process (AHP) and GIS techniques is used for the mapping of the groundwater potential zones. AHP is an effective tool for dealing with complex decision making in groundwater related fields which is introduced by Tomas Saaty in the year, 1980. This tool is useful for reducing complex decisions to a series of pair-wise comparisons and then synthesizing the results. The main objective of this study is to identify and map the groundwater potential zone of a panchayath in Kannur, Kerala.

2 STUDY AREA

The area chosen for this study is Kunnothuparamba. It is a Grama panchayath in Kannur district. Kannur is one of the coastal districts of Kerala. Kunnothuparamba is located in Puthoor village, Thalassery taluk, and it lies between North latitudes 11° 76' and East longitudes 75 ° 61'. Groundwater occurs under a phreatic condition in the weathered zone (Fig.1). People in this area is heavily dependent on groundwater resources for their domestic and agricultural requirements.

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3 MATERIALS AND METHODOLOGY

In the present study, the groundwater zone mapping is carried out by integrating multi thematic maps using GIS techniques. Landsat 8 image, Survey of India (SOI) toposheet no C43D9, maps from USGS were used for preparation of thematic maps.
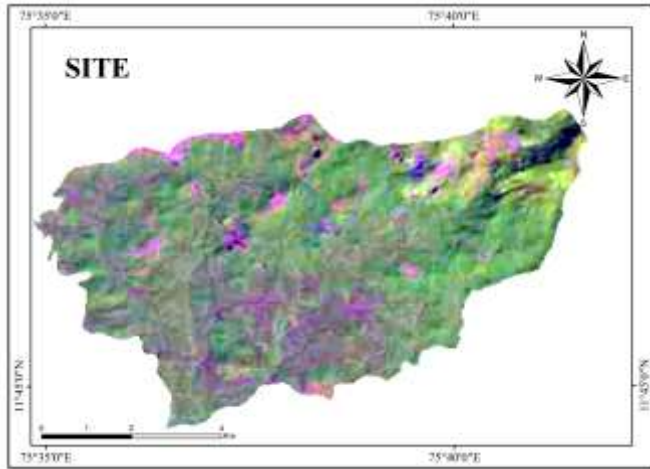

Fig. 1 Site map

All data are projected to Geographic Coordinate System-World Geodetic System 1984 (GCS WGS) Universal Transverse Mercator (UTM) zone 43 North for the easy handling in a GIS environment[1]. SOI toposheets are used as reference maps for the preparation of thematic maps. Analytical Hierarchical Process (AHP) is the most common and well known GIS based method for identifying groundwater potential zones.

TABLE 1
ASSIGNED WEIGHT OF PARAMETER

No	Parameter	Assigned weightage
1	Land use/ land cover	7
2	Geology	6
3	Lineament density	6
4	Slope	5
5	Drainage density	5
6	Rainfall	4

This method helps integrating all thematic layers for final result. Weight is assigned on the basis of Saaty's scale, according to parameters characteristics and interrelationships with groundwater and expert opinion. Table 1 shows the assigned weight of each parameter. Then created a pair wise comparison matrix (Table 2). A parameter with a high weight illustrates a layer with high impact and a parameter with a low weight illustrates a small impact on groundwater potential[3]. For calculating the consistency ratio (CR), the following equation should be used

$$CI=((\lambda-n)/((n-1))) \qquad (1)$$

Consistency Ratio is defined as

$$CR=CI/RCI \qquad (2)$$

Where RCI=Random consistency Index value, whose values were obtained from the Saaty's standard[8] (Table 3).

TABLE 2
PAIR WISE COMPARISON MATRIX

	LULC	Geology	Lineament density	Drainage density	Slope	Rainfall	Geometric mean	weight
LULC	7/7	7/6	7/6	7/5	7/5	7/4	1.31	0.212
Geology	6/7	6/6	6/6	6/5	6/5	6/4	1.13	0.181
L.D	6/7	6/6	6/6	6/5	6/5	6/4	1.13	0.181
D.D	5/7	5/6	5/6	5/5	5/5	5/4	0.94	0.152
Slope	5/7	5/6	5/6	5/5	5/5	5/4	0.94	0.152
Rainfall	4/7	4/6	4/6	4/5	4/5	4/4	0.75	0.122
Total							6.2	1

Saaty[8] has opined that CR of 0.10 or less is acceptable to continue the analysis. If the consistency value is greater than 0.10, then there is a need to revise the judgment to locate causes of inconsistency and correct it accordingly. If the CR value is 0; it means that there is a perfect level of consistency in the pair - wise comparison. Te threshold value is not exceeding above 0.1, which means the judgments matrix is reasonably consistent[9].In this study

$$CI = (6.2 - 6)/(6 - 1)$$
$$CI = 0.04$$

Then,

$$CR = (0.04)/(1.24)$$
$$CR = 0.032$$

So it is acceptable to continue the analysis. The parameter classes of thematic layers were re - classified for assigning weight. The sub - classes of each thematic layer rank was allocated on a scale of 1 to 5, according to their relative influence on the groundwater. The calculated weight is multiplied by 100. Then rank will be given to each parameter. Then ground water potential zone value is calculated by using the equation given below,

GWPI = (DDw × DDr) + (Gw × Gr) + (LCw × LCr) + (LDw × LDr) + (Rw × Rr) + (TGw × TGr)

Where, GWPI is groundwater potential index; DD, drainage density; G, geology; LC, land use/land cover; LD, lineament density; R, rainfall; SL, slope; r, feature rank within a layer; and w, layer weight calculated using AHP method[1].

TABLE 3
SAATY'S STANDARD

Order of matrix									
N	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

The groundwater zones are delineated into five different classes according to the highest value gained as excellent groundwater potential zone and lowest gained value as poor groundwater potential zone[6]. Geospatial techniques were applied in this paper to delineate the groundwater potential zones of the kunnothuparamba by using knowledge-based factor analysis of a total of 6 layers of information of the area such as geology, land use/land cover (LULC), drainage density, lineament density, rainfall, slope. Geographical Infor-

mation Techniques were carried out using ArcGIS 10.8 software.

3.1 Geology

Regional geological features, like permeability and porosity of various rocks, regulates groundwater occurrence and movement, and types of rocks significantly influence the availability and recharge of groundwater.
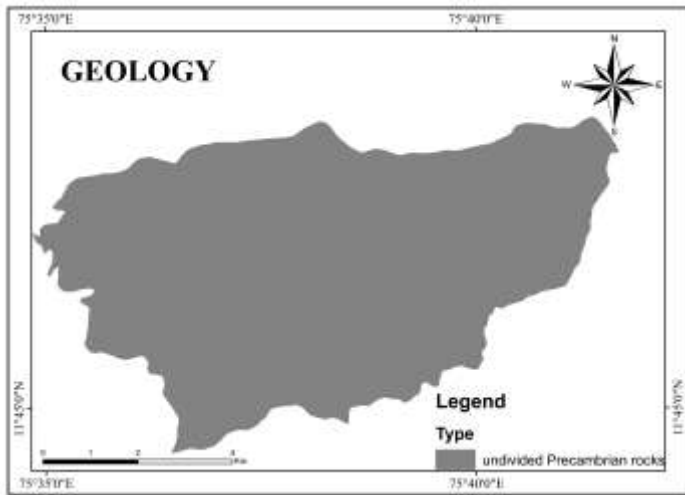

Fig. 2 Geology map

The data for geology map is collected from USGS geology map site. Here only undivided Precambrian rocks are present so rank is given as 1(Fig. 2.).

3.2 Lineament Density

Lineaments shows faults and fractures in subsurface regions, inducing the existence of groundwater as canals and reservoirs. Fig. 3 shows the map of lineament density. Usually the presence of lineament shows permeable zones.
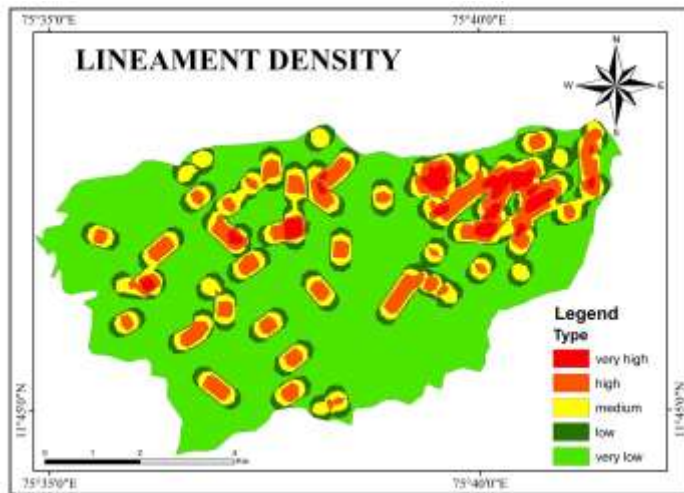

Fig. 3 Lineament density

The lineament density was computed from the density analysis tool in ArcGIS 10.8. here the lineament is classified into 5 groups that is very high, high, medium, low and very low. Based on these classification and effect rank is given to the layer. For very high value highest rank 5 is given and for very low 1 is given. In permeable zone the presence of water

will be high.

3.3 Land use land cover (LULC)

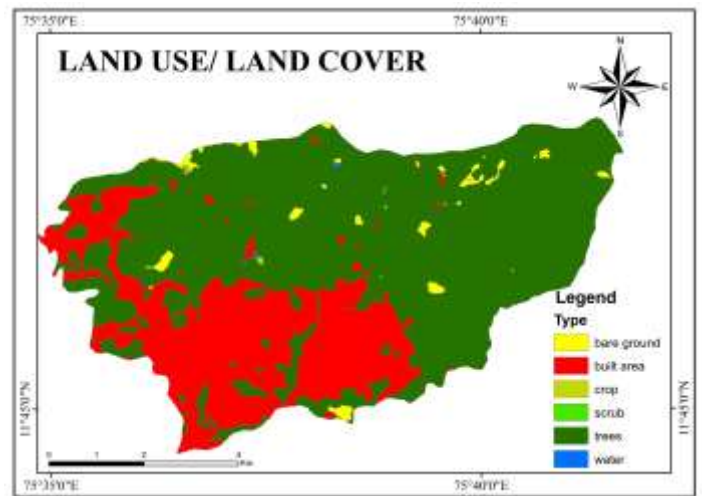Land use/ land cover map gives the idea about the coverage of land by different matters.

Fig. 4 Land use land cover map

The data for this map preparation is downloaded from Esri land cover maps. In these map there are different type of classification like water, trees, flooded vegetation etc.
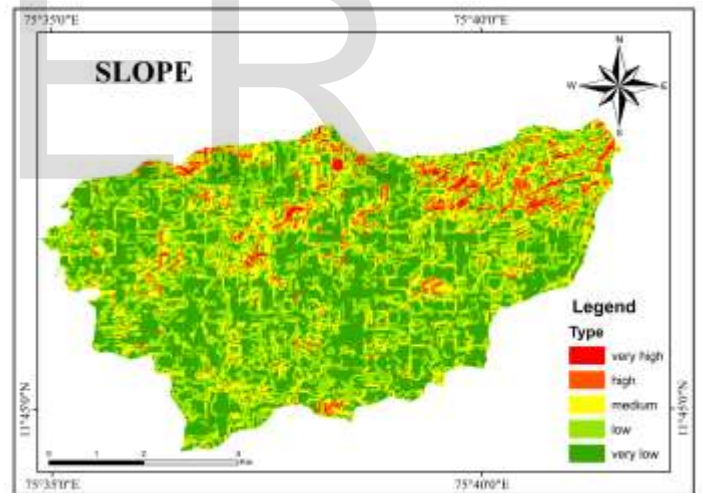

Fig. 5 Slope map

my study area is classified into 6 based on the different matters they are water, trees, crope, built area, scrub, bare ground(Fig. 4.). Land use type gives the necessary information on infiltration, soil moisture, groundwater, surface water, etc. then rank is given to the map based on the matters that is for water and trees rank is 5, crope 4, scrub 3, bare ground 2 and for built area 1. Large area is covered with trees in my location so there is a chance of increase in ground water.

3.4 Slope

Slope is a significant factor in identifying groundwater potential zones. When slope is high it results in high runoff. Level surface allows water to flow very slowly and provide adequate time to infiltrate into the soil. Large area in my location flat and very small area is steeper(Fig.5). It is also classi-

fied into 5 classes like very low to very high. In the case of slope highest rank is given to the lowest slope ie 5 and for highest slope rank 1 is given.
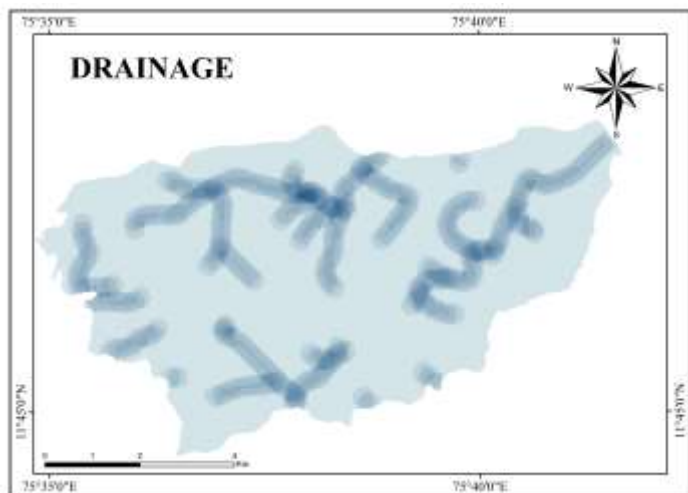

Fig. 6 Drainage

The slope map is created by taking DEM and using slope tool of ArcGIS 10.8.

3.5 Drainage density

For measuring drainage density different tools are available in ArcGIS 10.8. and it is utilized for the process. It is an indirect factor of surface runoff and groundwater infiltration.
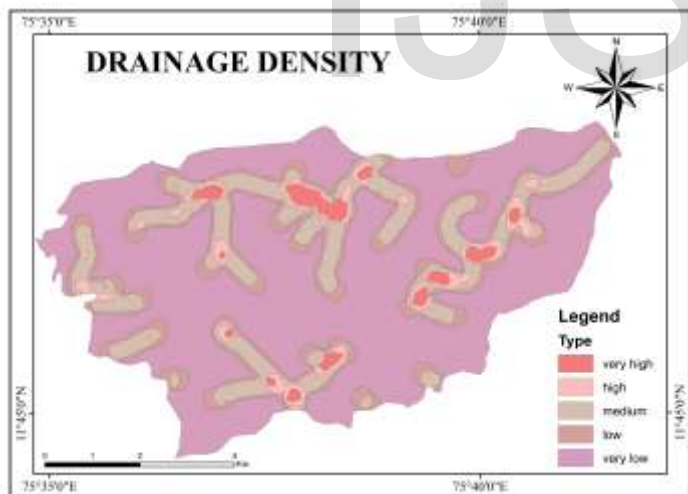

Fig. 7 Drainage density map

Fig. 6 is the drainage system in the region. The regions were classified as very low, low, moderate, high and very high drainage density zones(Fig. 7). Line density tool was used at the end to generate and drainage density map. In the case of drainage density high rank is given to the very low classification that is 5 and 1 for very high value of drainage density.

3.6 Rainfall

Rainfall is the parameter which effects the ground water because when water comes in the form of rainfall it will be infilters and combines with ground water. The data for rainfall map is collected then the data were added to ArcMap 10.8 for

interpolation. Then rainfall map was generated(Fig. 8) using inverse distance weighted (IDW) tool[5].
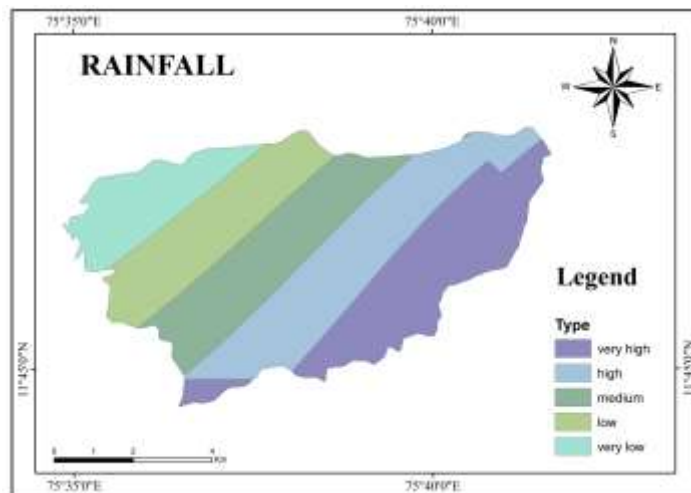

Fig. 8 Rainfall

The results of rainfall data of the study area is classified into five rainfall zones like very low, low, medium, high, and very high. The rank 5 is given to the highest amount of rainfall and rank 1 for lowest rainfall.

4 RESULT AND DISCUSSION

For mapping groundwater prospect zones individual thematic maps are prepared from the satellite data, toposheet and available secondary data. A weightage is given to different thematic maps. Then these thematic map is classified into different subclasses, and each is assigned a rank according to the interrelationships between the occurrences of groundwater. By using different journals and study the rank is given for each parameter sub classification.
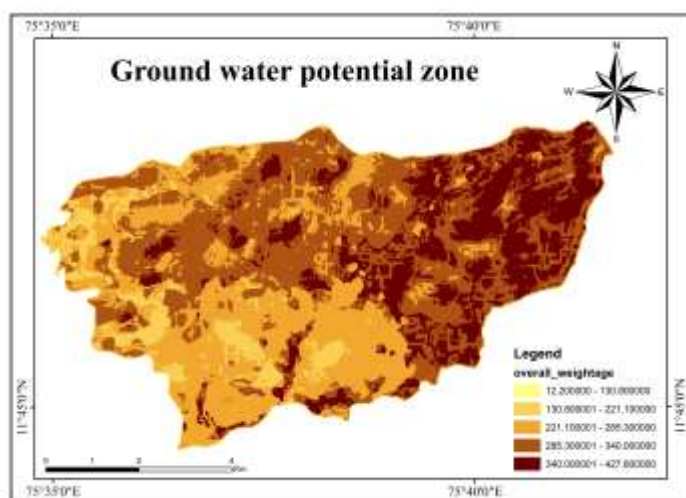

Fig. 9 Ground water potential zone map

After assigning weights to the individual class in each theme, the whole thematic layer is integrated into a single layer in ArcGIS software. Rainfall is irregular in these area and the area is not well irrigated from canals or channel irrigation. Hence, the farmer is forced to drill wells for the crop irrigation

and domestic water purpose.

There is some surface water bodies some of them use that for agricultural purposes only. Otherwise the water from the well is used largely. The ground water potential zone mapping is a time and cost reduced process for the identification of ground water potential zones[7]. The present groundwater potential zone map(Fig. 9) gives best site for the groundwater exploration.For trees, crops and other parts like vegetation is taken by giving high rank in LULC. Because the water penetrates to the ground through the roots of trees and plants. Then steep slope allows the rainwater to runoff, and flat region permits the rainwater to infiltrate to the soil. High rank is given to nearly level and gently slope area, and steep slope area is given poor rank. Lineament density is another important factor in groundwater resource.

Groundwater is stored in the joint and fractures of rock. The geology is another factor which effects the ground water, but in this region whole land is classified into single category. Drainage density also effects the ground water potential zone but the impact is negative or inverse. When the drainage is present the ground water will be less on that area. Groundwater zone map is useful for locating the drilled well and dug well for the irrigation and domestic water consumption purpose.

4 CONCLUSION

Groundwater potential map is prepared from freely available satellite images. It reduces the traditional field survey and consumes less power and time. The present result provides the preliminary information on the groundwater resources of the area. The groundwater level changes through the seasons. The present groundwater resource will be further enhanced by adopting the water harvesting structures and deepening on the existing lakes and tanks. The measure has to initiate to reduce the surface runoff and increase the infiltration and surface water bodies. Thus created groundwater potential zone map is useful for dug well for the irrigation and domestic water consumption purpose. By the development of the irrigation facility there is a chance to enhance the agricultural productivity in the region.

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