Analysis of Groundwater Potential Zone using ArcGIS

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***Abstract*: Changes in climate over the years Over-exploitation of groundwater have imposed immense pressure on the global groundwater resources. As demand of potable water increases, the need to evaluate the groundwater potential increases. The main aim of the project is to analyze the groundwater potential zone of the Kunnamangalam Panchayat, in Kozhikode district in the state of Kerala in India using the software ArcGIS. To achieve these seven layers of data of geology, geomorphology, land use land cover (LULC), drainage density, lineament density, soil and slope are prepared and using the analytical hierarchy process each of the layer is given a weightage importance and the layers and then superimposed in the software to get the groundwater potential zones.**

Index Terms: Groundwater potential zone, ArcGIS, Analytical hierarchy process.

I. INTRODUCTION

Groundwater is a reliable source of resource and it serves as a source of water for industrial, domestic and agricultural uses and other developmental initiatives. The growing demand of water for meeting human requirements and developments has imposed immense pressure on this limited freshwater resource. The traditional method used to identify, delineate and map the groundwater potential zones are mainly based on ground surveys, knowledge of pre dug wells and modern tools like magnetometers which are generally expensive and time consuming. This is where the ArcGIS software comes in, it is a software which helps to identify the groundwater potential zones of any region without having to go to the field, using satellite images and digital elevation models which are freely accessible online along with other required data such as geology and geomorphology which are also available online.

In our project, a combination of Analytical Hierarchy Process (AHP) and GIS techniques will be used for delineating the groundwater potential zones. The AHP is a tool for dealing with complex decision making in groundwater. This tool is useful for decreasing complex decisions to a series of pair-wise comparisons and then synthesizing the results. Moreover, the AHP tool is a suitable technique for evaluating the consistency of the result, consequently reducing the bias in the decision-making process. Considering all these, we examined the case of Kunnamangalam Panchayat in Kozhikode district in Kerala.

II. STUDY AREA

Kunnamangalam is a growing census town located about 14 km east of Kozhikode city on the Calicut-Bangalore National Highway. The geographical area is 27.23 km² and the geographical co-ordinates 11°18′23″N latitude and 75°52′44″E longitude. In Kunnamangalam, the dry season is partly cloudy, and it is hot and the wet season is overcast. Over the course of the year, the temperature varies from 73°F to 94°F and is rarely below 70°F or above 99°F. This region experiences extreme seasonal variation in monthly rainfall. The rainy period lasts for 9.2 months, from March 13 to December 20, with a sliding 31-day rainfall of at least 0.5 inches. The month with the most rain is June, with an average rainfall of 19.3 inches. The draughty period lasts for 2.8 months, from December 20 to March 13. The month with the least rain is January, with an average rainfall of 0.1 inches.

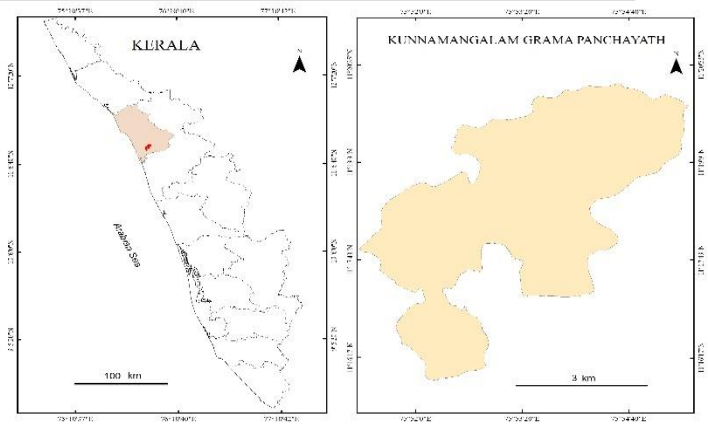


Fig1. Location map of study area- Kunnamangalam Panchayat

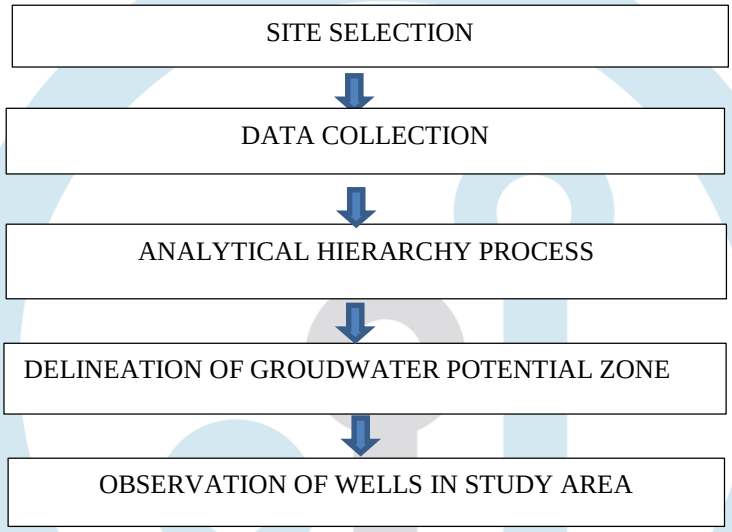
III. DATA COLLECTION

The project was attempted by considering seven different layers such as geology, geomorphology, drainage density, lineament density, land use land cover, soil and slope. These data were collected from different sources and are processed in the GIS

technology to create the data-base. The map of land use land cover, geomorphology and slope were obtained from National Remote Sensing Centre (NRSC). Drainage was extracted from SRTM and lineament was extracted from IRS LISS-III data. From the drainage and lineament, the density was prepared using the density in spatial analyst tool in GIS software. The map of geology and soil were collected and digitized from Geological Survey of India and National Bureau of Soil Survey, respectively.

IV. METHODOLOGY

Geospatial techniques were applied in our project to delineate the groundwater potential zones of the Kunnamangalam Panchayat using knowledge-based factor analysis of a total of seven layers of information of the area such as geology, geomorphology, land use land cover (LULC), drainage density, lineament density, soil and slope. Geographical Information Techniques were carried out using ArcGIS 10.4 software. Analytical hierarchy calculator was obtained to calculate the percentage importance or weights to each layer. Based on the various journals read the comparison values were given to each layer in the calculator. Then the calculator gives the output of importance of various layers. The georeferenced maps were assigned weights computed by the analytical hierarchy process.



Analytical Hierarchy Process

Analytical Hierarchical Process (AHP) is the most common and well-known GIS based method for delineating groundwater potential zones. This method helps integrating all seven thematic layers. A total of seven different thematic layers were considered for this study. These seven thematic layers are supposed to control factor of flow and storage of water in the area. The association of the influencing factors are weighted according to their reaction for groundwater occurrence and expert opinion. A parameter with a high weight represents a layer with high impact and a parameter with a low weight illustrates a small impact on groundwater potential. The weightages of each parameter were allocated according to Saaty's scale (1–9) of relative importance value. Further, the weights were allocated with consideration of the review of past studies and field experience. The Saaty's scale of relative importance value shows that, the value of 9 indicates extreme importance, 8 very very strong, 7 very extreme importance, 6 strong plus, 5 strong importance, 4 moderate plus, 3 moderate importance, 2 weak and 1 equal importance. As per the classification, weights are assigned to the seven thematic layers based on their importance and water holding capacity. To initiate groundwater potential zone map of Kunnamangalam Panchayat, all seven thematic layers were integrated with weighted overlay analysis method in GIS platform. We have given more percentage influence to geology and geomorphology as 25 and 20 respectively, land use land cover as 15, the least percentage influence is given to soil, slope, drainage density and lineament density as 10.

Table-I: Categorization of Factors Influencing Groundwater Potential Zone

FACTOR	ASSIGNED WEIGHT	DOMAIN OF EFFECT	RANK
Geology	25	Charnockite rock	3
		Basic rocks	3
Geomorphology	20	Plateau	5
		Pediplain	6
		Water body	9
Land use and Land cover	15	Built up	2
		Waste land	2
		Agriculture	5
		Wetland	7
		Water bodies	9
Drainage density	10	Low	6

		Medium	4
		High	3
Lineament density	10	Low	4
		Medium	6
		High	9
Soil	10	Clay	6
		Gravelly clay	8
Slope	10	0-5%	8
		5-15%	6
		15-35%	3
		35% & above	2

V. RESULTS AND ANALYSIS

Geology

Geologic setting plays a vital role in the occurrence and distribution of groundwater in any terrain. The published geological map of the Geological Survey of India was used for delineating different geological units of the study area. Majority area of study area occur basic rocks, figure shows sky blue in colour and occurrence of charnockite is also noticed in the area which shows dark in colour.

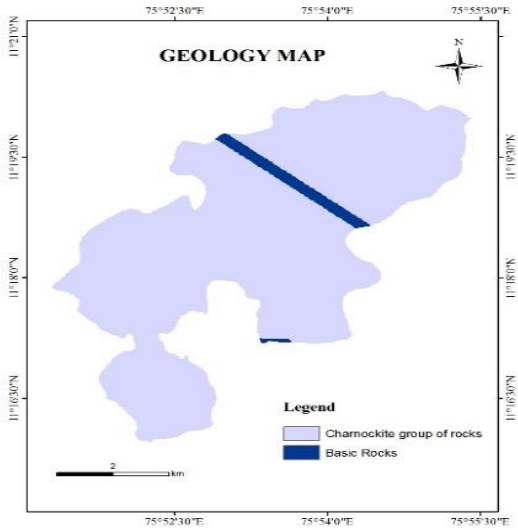


Fig 2. Geology Map of Study Area

Geomorphology

Geomorphology represents the landform and topography of an area, and is one of the main factors used for the delineation of groundwater potential zones. It gives detail information about the distribution of various landform features as well as processes like temperature changes, geochemical reactions, movement of water, freezing and thawing. The geomorphologic features in the study area were plateau, water body and pediplain. The main geomorphic feature of the study area is the plateau. The high weight is assigned for water bodies and low weight for plateau and pediplain.

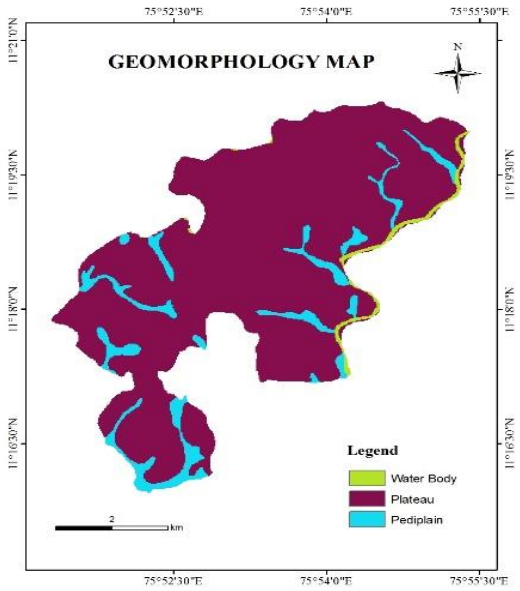


Fig 3. Geomorphology Map of Study Area

Land Use Land Cover

Land use Land cover gives the essential information on infiltration, soil moisture, groundwater, surface water etc, in addition to providing indication on groundwater requirements. The Kunnamangalam Panchayat exhibits a spectrum of land use categories which include agriculture land, built up land, wet land, waste land and water bodies. The high weight is assigned for water bodies, wet land and agriculture land and the low weight is assigned for the built-up land and waste land.

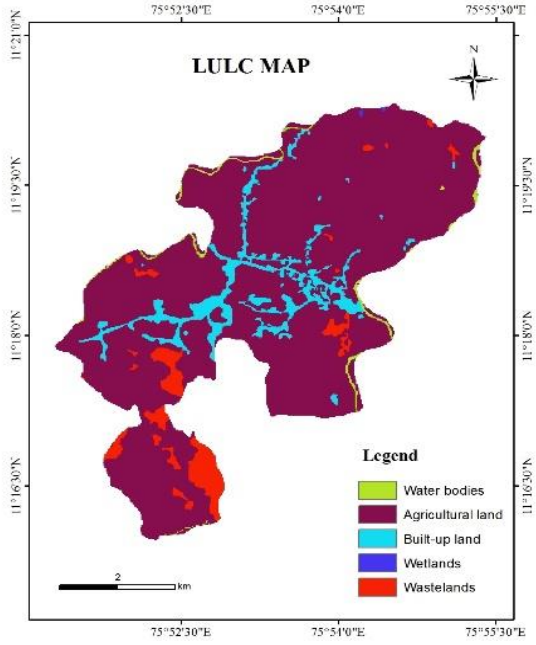


Fig 4. Land Use Land Cover Map of Study Area

Drainage Density

Drainage density plays a very crucial role in groundwater availability and contamination. The drainage network depends on lithology and also it provides an important index of infiltration rate. Drainage density is an inverse function of permeability. Therefore, it is a dominant parameter in the delineation of the groundwater potential zone. High drainage density illustrates less infiltration and hence do not favour much on the groundwater potential of the area. Low drainage density represents high infiltration and hence impart more to the groundwater potential. The regions were classified as low (0- 3.71 km/km^2), medium (3.71- 7.43 km/km^2) and high (7.43- 11.14 km/km^2) drainage density zones. The low weight is assigned for high density and the high weight is assigned for low density.

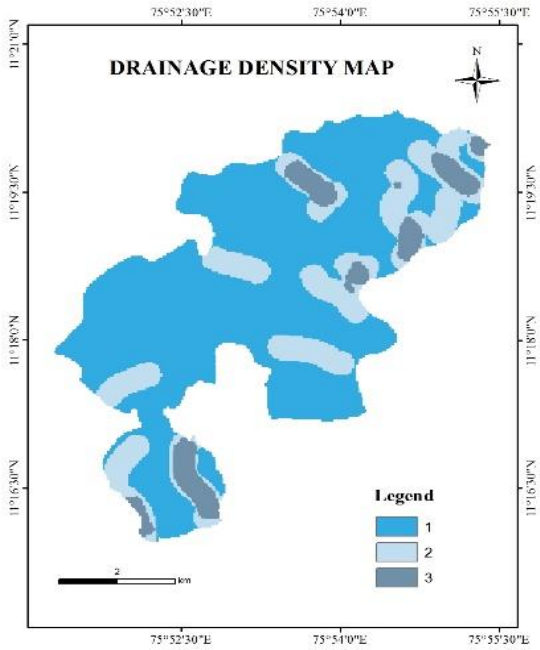


Fig 5. Drainage Density Map of Study Area

Lineament Density

Lineaments are structurally controlled linear or curvilinear features and it represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. The lineament density map was prepared using line density in GIS software. By carefully examining the values obtained, the data were reclassified into three categories - Low (0- 2.39 km/ km^2), Medium (2.39-4.78 km/km^2) and High (4.78- 7.18 km/km^2). The weightages are given for lineament density based on proximity of lineaments. It is disclosed that the intensity of groundwater potential decreases with increasing distance from the lineaments. For the ground water potential zonation, high weight is assigned for high density and low weight for low density classes.

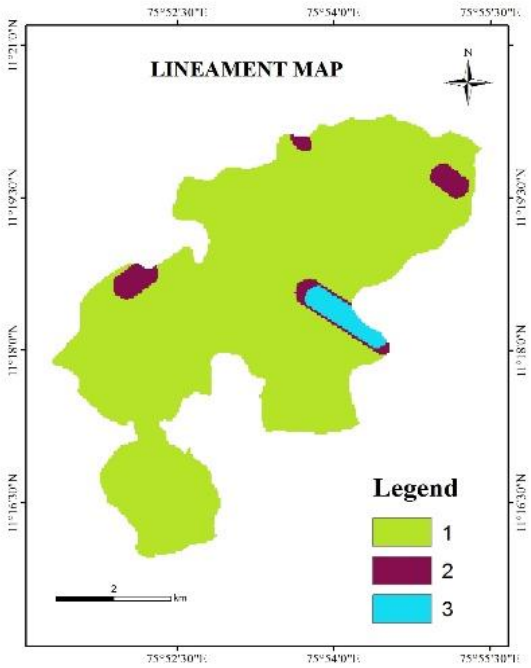


Fig 6. Lineament Density Map of Study Area

Soil

Soil types play an important role on the amount of water that can infiltrate into the subsurface formations and hence influence groundwater recharge. The soil texture and hydraulic characteristics are the main factors considered for estimation of rate of infiltration. Fig-7 depicts the soil map of the Kunnamangalam Panchayat. Soil types include gravelly clay and clay. The high weight is assigned for gravelly clay and the low weight is assigned for clay.

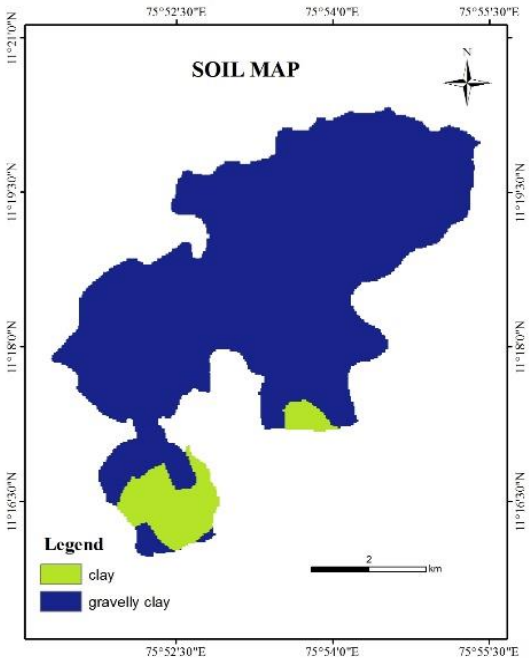


Fig 7. Soil Map of Study Area

Slope

The slope is a significant terrain characteristic which express the steepness of the ground surface. Slope gives necessary information on the nature of the geologic and geodynamic processes operating at regional scale. Surface runoff and rate of infiltration are influenced essentially by slope of the surface. Larger inclination produces smaller recharge because the water received from precipitation flows rapidly down a steep slope during rainfall. Therefore, it does not have enough residence time to infiltrate and recharge the saturated zone. Fig-8 depicts the slope map of the Kunnamangalam Panchayat. The slope values were reclassified and categorized into four classes such as flat (0- 5%), gentle (5- 15%), medium (15- 35%) and steep (35% & above). The high weight is assigned for gentle and flat slopes and the low weight is assigned for steep slope.

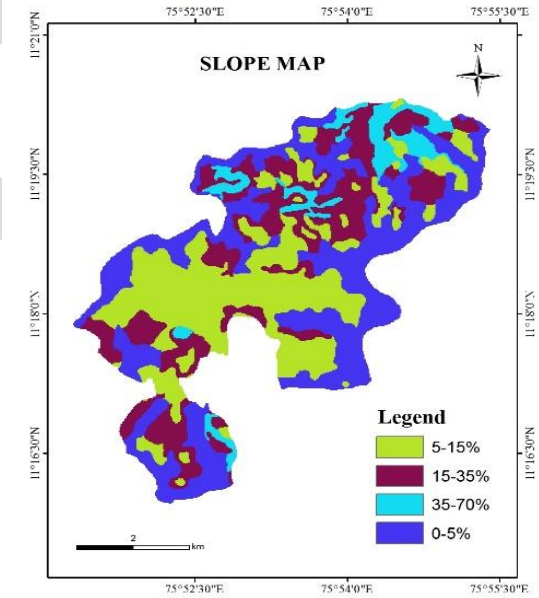


Fig 8. Slope Map of Study Area

Groundwater Potential Zone

Groundwater is a replenishable resource, but due to several criteria such as increased population, urbanization, and industrialization and various kinds of anthropogenic activities and skewed developments, recharge of this precious life sustaining resource has been reduced significantly. A better understanding of the groundwater potential is more important for planning and sustainable development of an area. Such information is essential for the design and implementation of structures for corrective

measures to improve the groundwater recharge processes. The parameters considered here are geology, geomorphology, LULC, lineament density, drainage density, soil and slope. These thematic layers were created in GIS background and the appropriated ranks and weights determined by the AHP method were assigned to them for the overlay process. According to the importance of each layer, weight was given to respective layers in weighted overlay analysis tool in the software to obtain groundwater potential zones. The result obtained were categorized into three classes- low, medium and high, the aerial spread of these categories are 4.42 km^2, 21.68 km^2 and 0.84 km^2 respectively. The total area of study is 26.94 km^2.

The Groundwater Potential Zones delineated are cross - validated with the results of the observation well data. A total of 7 observation wells are located in the area and all these wells were analyzed for the purpose. It is found that, the wells located in the low groundwater potential zones have low water yielding capacity. However, the wells located in moderate groundwater potential zones have moderate water yielding capacity and the wells located in high groundwater potential zones have high water yielding capacity while comparing with others. By the observation of well the obtained results have a better correlation with actual field data.

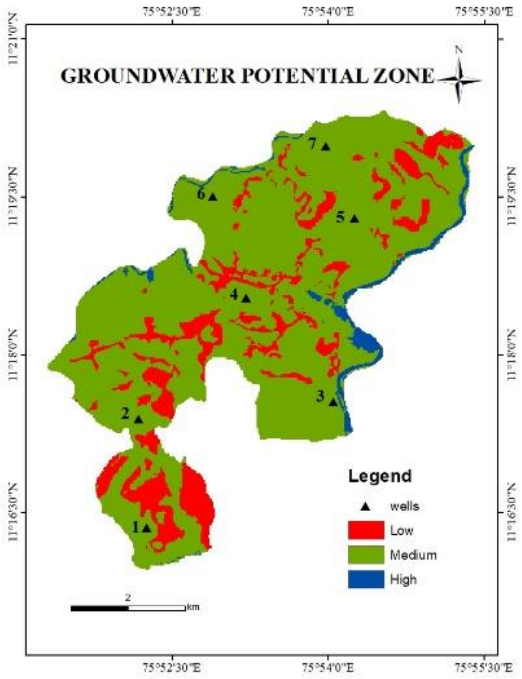


Fig 9. Groundwater Potential Zone of Study Area

VI. Conclusion

The present study is an attempt to delineate the groundwater potential zones using a combination of AHP and GIS techniques in study area, Kunnamangalam Panchayat, which is located in east of Kozhikode city on the Calicut-Bangalore National Highway. A total of 7 thematic layers such as Geology, Geomorphology, LULC, Soil, Lineament Density, Drainage Density, Slope were used in this study to delineate the groundwater potential zones. According to the final output map, the study area could be classified into three distinct ground water potential zones such as high, moderate and low. Moderate groundwater potential zone spreads over the catchment area and covers 80.4% of the study area. High and low groundwater potential zones cover an area of 3.1% and 16.4% respectively. From this study, it can be concluded that the GIS and AHP based techniques of delineation of Groundwater Potential Zones adopted herein is a useful method that can be used for the identification of ground water prospect area, evaluation of its sustainability, evaluation of its quality, identification of locations for site-specific recharge structures, development of wells, construction of recharge structures etc.

Table-II: Area of Groundwater Potential Zone

Sl. No	Category	Area (in km)	Area (in %)
1	Low	4.42	16.4
2	Medium	21.68	80.4
3	High	0.84	3.1
		26.94	**100**

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