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Groundwater Prospects Mapping in Korapuzha River basin, Kerala, India - An Integrated Approach using Multicriteria Decision Making and GIS Techniques

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Abstract: Groundwater is a dynamic and replenishing natural resource. But in hard rock terrains, availability of groundwater is of limited extent. Occurrence of groundwater in such rock is essentially confined to fractured and weathered horizons. Poor knowledge about this resource, because of its hidden in nature and its occurrence in complex subsurface formations, has been and is still a big obstacle to the efficient management of this important resource. The present study aims in the identification and delineation of groundwater potential zones by combining remote sensing, geoinformatics and multiple decision making tool (AHP analysis) techniques in Korapuzha river basin which falls in Kozhikode districts of Kerala. Thematic layers of the factors which affecting groundwater potential such as Geology, Geomorphology, Soil, Slope, Drainage, Drainage density and Land use-Land cover classes were generated using primary and secondary spatial and non-spatial data as input in the ArcGIS environment. The features were assigned weightages accordingly to the magnitude of groundwater potential zones. The pair wise comparison matrix method, AHP (Analytical Hierarchical Process) was used to calculate the normalized weight of individual parameters. Further the normalized weighted layers were overlaid using spatial analyst tool in ArcGIS10 for the preparation of the final groundwater potential zone map. The final maps result reveals that, out of the 643 sq.km area of Korapuzha river basin, 146.95 (22.84%) sq.km area is identified as very good potential for groundwater prospecting zone. The high potential zone is underlain by gently sloping coastal alluvium having low drainage density. 237.46 Sq.km (36.91%) of the total area having good and 159.5 sq.km (24.8%) characterized with moderate potential for groundwater prospecting. Areas have been underlain by thick laterite and intervening valleys with gentle to moderate slope contributes good to moderate potential zone in the river basin. The poor groundwater potential zone is occupying 99.30 sq.km (15.43%) of the total area of the korapuzha river basin. Eastern region with steep terrain occupied with denudational hills, high drainage density, and thin soil cover results in poor groundwater yield.

Keywords: *Groundwater prospects, Analytical hierarchy process (AHP), Remote sensing and GIS, Korapuzha River*

1. Introduction

Water is one of the most important natural resource, 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. More than 1.5 billion people in the world are known to depend on the groundwater for their drinking water requirements.

Identification of groundwater occurrence is the important and complex task towards the management of groundwater resources. In order to overcome this tedious effort, the recent geospatial technologies like remote sensing and GIS could be used with relatively accurate results [1,2,3,4].GIS has the capability to integrate various thematic maps for delineating the potential artificial recharge zones. These thematic layers were assigned with a suitable weight based on their significance in storage and transmittance of surface water into the ground [5]. The application of geostatistical modelling on geospatial layers showed a positive result for demarcating the groundwater potential sites [6].AHP technique analyses the multiple datasets in a pair-wise comparison matrix, which is used to calculate the geometric mean and normalized weight of parameters [2]. In the present study, six parameters were used for the identification of prospects zone. These layers have been assigned appropriate weights using direct–indirect relationship among different layers and AHP analysis. The evaluation of the spatial parameters such as geological structure, geomorphic features and hydrological characteristics, among them geomorphology, slope and geology of the area have a great role to identify the groundwater prospects zone in the ArcGIS environment. Satellite remote sensing data has been widely used for the extraction of surface features, and the thematic layers integrated with GIS issued to identify of suitable areas for prospects zone along the inaccessible area [7].

Insufficient knowledge regarding the basics of groundwater is the primary reason why we have not been able to use groundwater resources to their full extent. Thus, there is a growing emphasis on groundwater management. Therefore, the current work deals with AHP coupled with remote sensing and GIS to identify the potential zone in Korapuzha river basin, Kerala.

1.1 Description of the Study Area

The study area is in Korapuzha river basin of Kozhikode district, Kerala. The river basin has an area extent of 643sq.km. And the area lies between north latitudes 11º32'45" and 11º15'1.2" and East longitudes 75º36'29" and 75º56'24"(Figure 1).It is on the southern part of the peninsular shield having a gently sloping terrain from the wyanad plateau. Rolling midlands intervene between the hills and the coast.

The study site has 40.94 sq.km long sea shores. The Soil conditions are very good for cultivation of spices and coconut especially and normal for other crops except in the sea shore area due to the saline water intrusion. The population density of the District i.e., 1318 persons per sq.km is greater than the State average (860 persons per sq.km.)

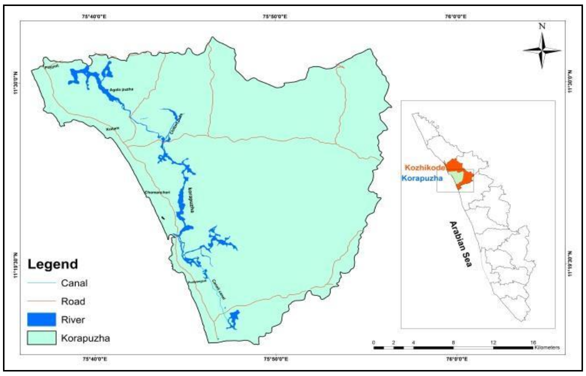

Figure 1.Location map of the study area

Groundwater Status of the Basin

As part of demarcating groundwater potential zone, present study intended to quantify dynamic ground water resources or annual replenishable ground water resources (recharge), annual ground water draft (utilization) and the percentage of utilization with respect to recharge (stage of development), which is expressed as a percentage of the net annual ground water availability for the Korapuzha river basin were carried out based on the Ground Water Resources Assessment Methodology, 1997[8].

Net groundwater recharge for the area is 88.65 MCM. Domestic withdrawal and withdrawal for irrigation is 62.039 and 0.037 respectively. The result shows that Net groundwater available for the river basin is 26.577 MCM and the gross groundwater draft is 62.076 MCM.As per the estimation, the Korapuzha river basin is in Semi-critical category. The stage of groundwater development , where the stage of ground water development is between 70% and 100%, point out the importance of sustainable management of the valuable groundwater resource in the study area.

1.2 Methodology and Data used

Survey of India (SOI) topographic sheet (1:50 000) was used to prepare base, drainage maps. Remotely sensed image data from IRS ID (LISS III) used to generate the geomorphology &land use/landcover map of the study area. The SOI topographic maps and satellite images have been geometrically corrected using ERDAS v9.1and ArcGIS v10.0software. Geology map of the basin was prepared using Geological Survey of India (GSI) in the scale of 1:2,50,000 whereas the soil map was prepared using the data from National Bureau of Soil Survey (NBSS) at1:2,50,000 scale. SOI toposheets were used to generate drainage and contour. Finally all data (geomorphology, slope, drainage density, geology, land use/ landcover, soil and their corresponding categories) were assigned with multi criteria decision making tool, AHP, according to their degree of prospect depending on the suitability to hold groundwater, integrated multi-thematic information and delineation of groundwater prospect map generated in ArcGIS environment [9, 10, 11].Table 1, shows the assigning weightages for the feature classes.

Table 1 *Assignment of weight for the feature classes of individual parameter and normalized weight calculation*

Sl. No	Parameters	Normalized weight (with AHP/ ANP using software)	Subclasses (map units)	Normalized weight (with AHP/ ANP using software)
1	Geomorphology	0.3935	Flood plain	0.0793
			Swale	0.0793
			Beach	0.0793
			Channel bar	0.0793
			Islands	0.0793
			Kayals	0.0793

			Natural levee	0.0793
			Residual hills	0.0138
			River channel	0.0793
			Denudational structural hills	0.0101
			Lower plateau	0.0138
			Valley	0.0793
			Younger mud / tidal flat	0.0793
			Young coastal plain	0.0793
			Rocky coast	0.0101
			Water body mask	0.0793
2	Geology	0.0836	charnockite	0.1578
			Composite gneiss and schist	0.0758
			Fluvial coastal sediment	0.7662
3	slope	0.3935	0 to 5	0.6769
			5 to 15	0.2052
			15 to 25	0.0588
			>25	0.0588
4	Soil	0.02285	Clay	0.0466
			Gravely clay	0.0791
			Gravely loam	0.2072
			Sandy	0.6669
5	Drainage density	0.0836	<0.75	0.6669
			0.75-1.50	0.2072
			1.50-2.25	0.0791
			>2.25	0.0466
6	Land use & Land cover classes	0.0228	Agricultural plantations	0.1111
			Waste land	0.0321
			Coconut dominant mixed crop	0.1111
			Commercial / residential area	0.0187
			Dense mixed forest	0.0321
			Double crop	0.1111
			marshy	0.1111
			Mixed built up	0.0187
			Mixed crop	0.0321
			Mixed trees	0.0321
			Water bodies	0.3892

Thematic maps were prepared for geology; geomorphology, drainage density, soil, slope, land use/land cover and groundwater level are discussed as follows.

1.3 Thematic Layers Geology

The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. Charnockite and composite gneiss - schist are the most widespread rock types, occupies an area of 264.6 sq. km, 269.15 sq.km respectively (Figure 2). Fluvial coastal sediments considered as the sources of groundwater covers an extent of 125.45 sq. km. Charnockite Group of rocks makes up the high hills and steep slopes flanking the undulating terrain in the eastern and western part of the basin. Charnockite is mainly intermediate type consisting essentially of hypersthene, diopside, secondary hornblende, biotite, sodic plagioclase and waxy quartz. In some areas it occurs as thin bands and well-foliated and is often veined by pegmatite along the foliation planes. Pyroxene granulite of Charnockite Group occurs as small lenses and enclaves within the gneisses and charnockite. It is amelanocratic, fine- grained rock with granulitic texture.

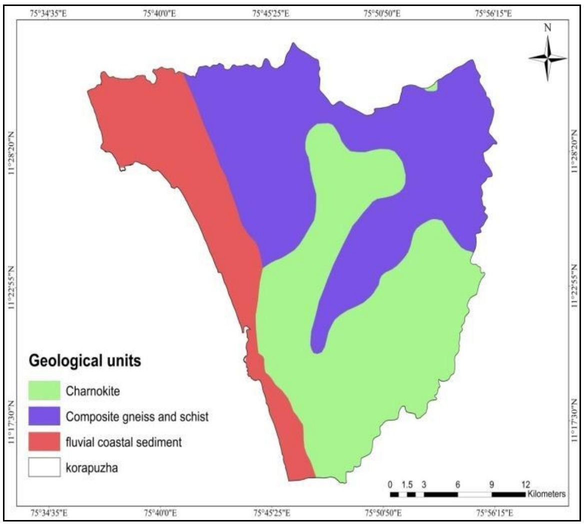

Figure 2.*Geology map of the study area*

Geomorphology

The different geomorphology units were depicted from satellite information and are portrayed underneath and introduced in Figure3.Linking of geomorphological parameters with hydrological characteristics of an area provides a simple way to understand the groundwater behaviour. Out of the total area of river basin 404.68 sq.km is lower plateau (lateritic), dominant geomorphological unit in the area having 61.35 % of the total area. In the study area 94.23 sq.km is valley, the high groundwater potential zo ne covering (14.28%) of the total area. The remaining geomorphologic features in the river basin includes is young coastal plain (63.97 sq. km i.e. 9.7%), denudational hills (44.7 sq.km (6.7%), residual hills (12.7 sq.km (1.9%), 9.5 sq.km flood plain (1.4%), 9.01 sq.km swale (young coastal plain) (1.36%) and 1.09 sq.km beach (0.15%). The coastal plain is very narrow 5 -10 km wide, gently sloping with a maximum height of about 10 m in the east. It comprises depositional landforms of marine, fluvial and fluvio-marine origin. There is a well-developed beach all along the coast with the sea cliff and rocky beaches near Quilandi, Kappad, and Elattur. Also the area having an undulating topography with numerous narrow ridges, moderately sloping hills, intervening valleys, flat and domal hills and broad valley floors all alternating with laterite capped hummocks and narrow alluvial strips. There is also steep to very steep hill ranges.

Slope Analysis

Slope is the principal factor of the superficial water flow since it determines the gravity effect on the water movement, hence an indicator for the suitability for groundwater prospect. Based on the percentage of slope the entire Study area is classified into four-categories, shown in figure 4. The area with 0 to 5 % slope falls in the "very good" category for groundwater storage due to the nearly flat to gentle terrain, slow of surface runoff allowing more time for rainwater to percolate and relatively high infiltration rate.

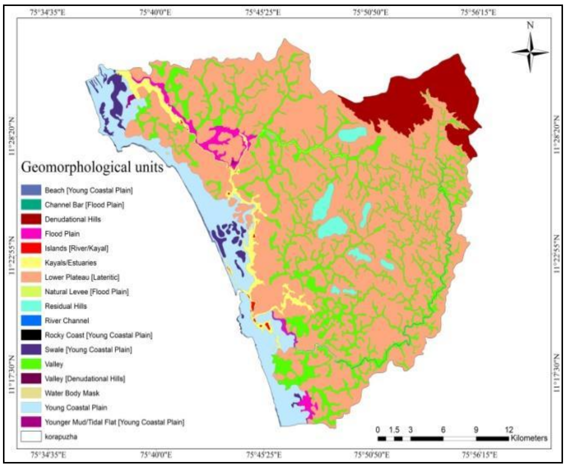

Figure 3.*Geomorphology of the study area*

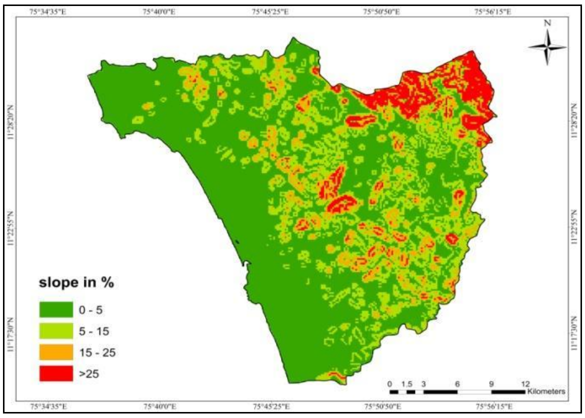

Figure 4.*Slope map of the study area*

These flat terrains have 394.3 sq km of the total study area (59.8%). The area with 5-15% slope is considered as "good" for groundwater storage. It covers an area of 168.2sq.km of the total area (25.5%). A steep slope is followed by a gentle slope promote an appreciable groundwater infiltration. 15-25% slope is considered as moderate for groundwater storage due to slightly undulating topography with some run-off covering 54.5 sq.km of the total area (8.27%). The fourth (> 25) category, a high sloping region causes more runoff and less infiltration and thus has poor groundwater prospects.42.3 sq.km of the area (6.4%) comes under this steep slope.

Land Use / Landcover Classification

Land use/landcover is one of the important parameter for the geo-hydrological study because the land use pattern of any terrain is a reflection of the complex physical processes acting upon the surface of the earth. Also it provides important indications of the extent of groundwater requirement and utilization. The land use/land cover map of the entire korapuzha river basin was generated and the derived statistical data using image processing software shown in figure 5. From the point of view of land use, crop land with vegetation is an excellent site for groundwater exploration. The area with water bodies is good for groundwater recharge and fallow land is poor for it. Out of the total area 421.73 sq.km is coconut dominant mixed crop. That is it's the dominant land use class in the area covering 63.94 % of the total area. The other major Land use classes shown in figure 5.

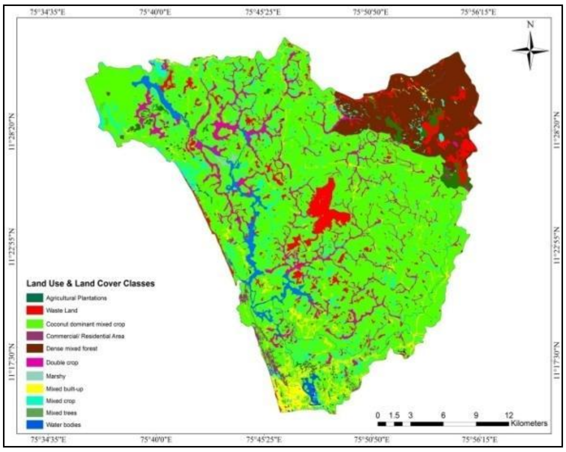

Figure 5.*Landuse/Landcover classes of the study area*

Soil Texture

Soil characteristics invariably control penetration of surface water into an aquifer system and they are directly related to rates of infiltration, percolation and permeability. The major soil types in the study area (figure 6) are clay, gravelly clay, gravelly loam and sandy. Gravelly clay (83% of the study area) is the dominant soil type in the study area. And the sandy soil (0.03%) is the least dominant soil type in the study area. The Sandy soils are very highly permeable, light textured and well drained, and rate of infiltration is excellent.

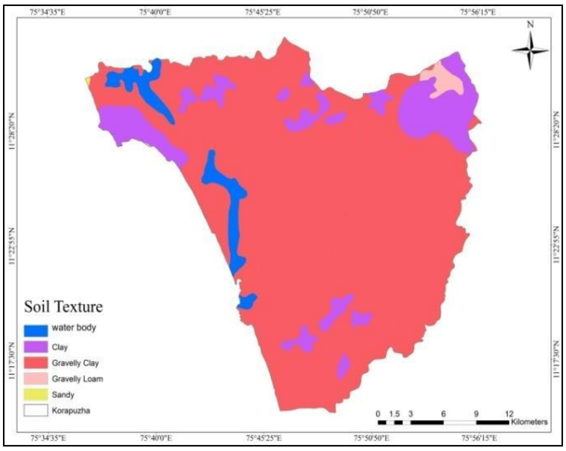

Figure 6.*Soil texture of the study area*

Drainage map and Drainage density

Drainage of the study area is one of the practical approaches to know the lithological and structural control of land form evolution. Korapuzha river basin is a sixth order stream (Figure 7).

In the present study, since the drainage density, shown in figure 8, can indirectly indicate the groundwater potential of an area due to its relation to surface run-off and permeability, it was considered as one of the indicators of groundwater occurrence. Development of stream segments is affected by slope and local relief and these may produce difference in drainage density from place to place. More the drainage density, higher would be run-off.

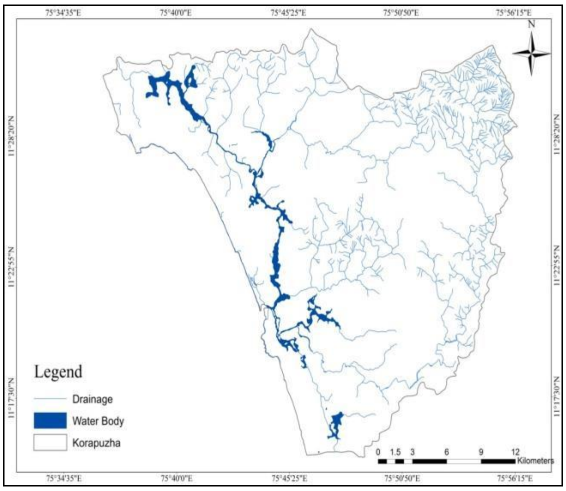

Figure 7.*Drainage pattern of the study area*

Based on the drainage density of the basins, it can be grouped into four classes: (i) 0–0.75 km; (ii) 0.75–1.5 km; and (iii) 1.5–2.25 km ;(iv) >2.25. Accordingly, these classes have been assigned very good, good, moderate and poor categories, respectively. Most of the study area (70%) has a drainage density of 0.75 – 1.5 km.

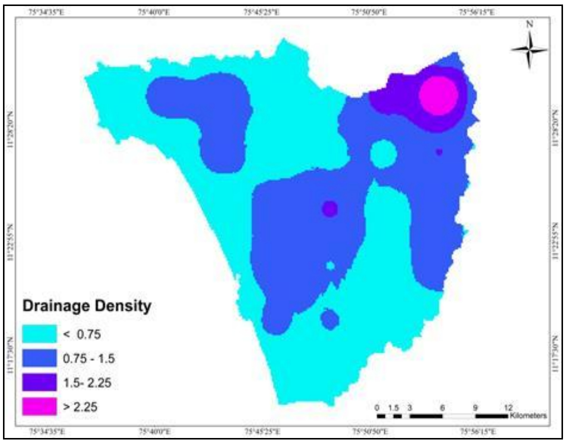

Figure 8.*Drainage density of the study area*

1.4 Result and Discussion

Delineation of groundwater potential zones

Groundwater potential zone is generated by overlay analysis of thematic layers prepared that is geology geomorphology, and land use and land cover classes, drainage-drainage density, soil texture and slope. Groundwater potential zone, shown in Figure 9, is classified into poor, moderate, good and very good zones. In this study area 99.30 sq.km is poor in groundwater potential (15.43%). 159.5 sq.km of the study area is moderate in groundwater potential covering 24.8% of the total area. The major portion of Korapuzha river basin is good in groundwater prospective zone, covering 237.45 sq.km of the whole area (36.91%). 146.94 sq.km of the area is very good in ground water prospecting (22.84%).

Depending on the groundwater potentiality, each class of the main six thematic layers (geomorphology, geology, slope, drainage density, Land use/Landcover, soil) are qualitatively placed into one of the following categories viz., i. Very good, ii. Good, iii. Moderate, iv Poor.

The major portion of the study area falls under good prospective zones underlined with gentle to moderate slope with lateritic lower plateau, intervening valleys charnockite rock structure and moderate to good drainage density. The high potential valleys, having a yield of up to 30 lps and the above features responsible for good prospects zone for groundwater occurrence. Gently sloping Young coastal plain, fluvial coastal sediments zone contribute very good prospects zone of the Korapuzha river basin. In figure 9,26%of very good zone marked as buffered zone, i.e. the area within 1 km from the coast, declared as area with saline intrusion. Water quality in this area is poor and therefore recommended as unsuitable for drinking. Eastern region of the basin with steep slope, denudational hills, thin soil cover and high drainage density together contributes poor potential for groundwater.

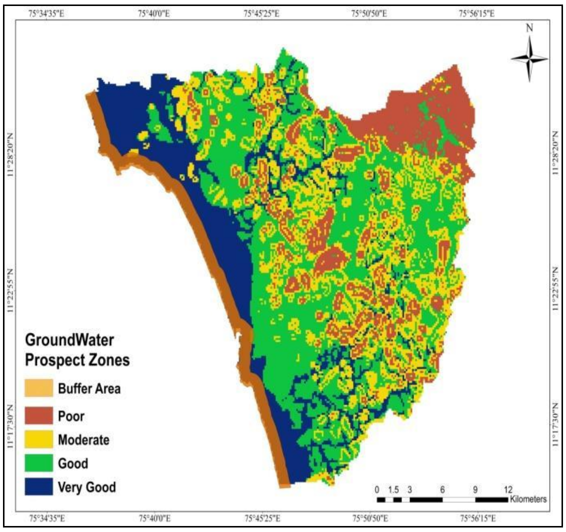

Figure 9.*Groundwater potential zones map of the Korapuzha River Basin.*

1.5 Conclusions

The present work ensured the application of integrated geospatial technology and AHP as a better tool for the identification of groundwater potential zone in Korapuzha river basin. The present study demarcates the potential zones for groundwater by analysing the influencing factors. The result reveals that, out of the 643 sq.km area of Korapuzha river basin, 146.95 (22.84%) sq.km area is identified as very good potential for groundwater prospecting zone. The high potential zone is underlain by gently sloping coastal alluvium having low drainage density. 237.46 Sq.km (36.91%) of the total area having good and 159.5 sq.km (24.8%) characterized with moderate potential for groundwater prospecting. These areas have been underlain by thick laterite and intervening valleys with gentle to moderate slope contributes good to moderate potential zone in the river basin. Depth to water in these lateritic terrains varies from 5-20 mbgl therefore suitable for open wells. And highly potential valleys, the yield of which go up to 30 lps and bore wells are feasible along fracture planes. The very good potential zone occurred in the coastal alluvium supporting the aquifers with yield up to 50 lps and the depth to water is 0.5-3 mbgl, suitable for open dug wells. From the recent trend, it is clear that the rate of population growth therefore the chances of exploitation of groundwater increasing in the river basin, indicates the significance of the identification and management of groundwater resources in the river basin.

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