Identification of groundwater recharge potential zones in a study region of South Kerala

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Abstract: Groundwater is considered as a precious natural resource which serves as the main source of agriculture and domestic purposes. Kerala state is blessed with around 3000mm rainfall annually because of two prominent monsoon. But the available water is insufficient to meet the demand of people. Increase in population and water demand cause threat to overall water balance. Groundwater resource must be managed well to overcome these problems. Ground water recharging is a major requirement for sustainable utilization of water resources. It also becomes highly relevant to assess the water recharge zones and to preserve water quality. This study proposes identification of suitable water recharge sites in Karamana river basin, Thiruvananthapuram, Kerala. Karamana river supplies majority of drinking water in Thiruvananthapuram district. Since its quality is deteriorating day by day, appropriate locations for recharging groundwater is identified using GIS technique. Various thematic maps like soil, slope, drainage, geomorphology and land utilization that affect the groundwater recharge is integrated and weighted overlay analysis is adopted to find the groundwater recharge potential map. Weights are assigned using Analytical Hierarchy Process (AHP) by constructing a pairwise comparison matrix. The result depicts the groundwater recharge potential zones which is divided into very high, high, moderate, low and very low potential areas.

1. Introduction

Ground water is an inevitable resource for the existence of life. Kerala state is blessed with two prominent monsoon with an average rainfall around 3000mm. Due to many reasons like urbanization, population growth, higher agricultural and domestic requirement, groundwater availability is depleting. When the rate of groundwater pumping exceeds the rate of recharging, it lowers the quantity as well as the quality of water in aquifer. Karamana river basin is a highly populated region in South Kerala facing water shortage. To find the solution to various problems like drought and water scarcity, investigation of groundwater potential and recharge zone is of prime importance. This condition can be solved by constructing some structures which artificially collect and recharges the water into the aquifer by infiltration. Various recharging structures can be constructed depending on the slope, soil type, land cover, geomorphological features etc. of the region. Various methods like test drilling, stratigraphic analysis are existing but need high cost, time and labour power. But nowadays remote sensing and geographical information system (GIS) can be used to locate ground points for artificial recharging and to prepare recharging potential map [1, 2, 3, 4]. They offer data availability accurately within a short time. The objective of the study is to prepare a groundwater potential zonation map for the Karamana
river basin in South Kerala which can further be used to suggest suitable recharge structures for augmenting the ground water potential for this area.

2. Study area

Karamana river basin is a thickly populated region in South Kerala. Karamana river, with two reservoirs, helps in the drinking water distribution in Thiruvananthapuram district and adjoining Panchayats. Water quality is deteriorating in these thickly populated areas due to urbanization. Hence it is necessary to adopt proper water management methods to maintain water quality.

Karamana river basin is located between north latitudes 8˚ 05’ and 8˚ 45’ and east longitudes 76˚ 45’ and 77˚ 15’. It has a total surface area of 676 km². Among all the west flowing rivers of Kerala, Karamana river ranks 15th and 17th with regards to river catchment and stream length. The river originate from Chemmunjimottai, a peak in Western Ghat mountains at an altitude of 1717 m above mean sea level. It falls within the small mountainous river category. The river flows about 68 km before joining the Lakshadweep Sea near Thiruvallam. The river wholly drains through Thiruvananthapuram district. The river flows 66 km westwards and merges with the Arabian sea at Panathura near Kovalam. The river get its name from Karamana, a suburb of Thiruvananthapuram city, through which it flows. The area receives an average rainfall of 3000mm [5].

3. Methodology

The groundwater potential zone was identified by integrating various satellite derived maps in GIS platform. For the present study, thematic layers like geomorphology, soil, drainage density, slope, lineament density and land use and land cover (LULC) were generated. DEM was downloaded and slope map was generated in ArcGIS. Geomorphology shape file was obtained from Bhukosh website and it was then converted to raster in ArcGIS. LULC map was prepared in ERDAS imagine software. Soil map was collected from soil grid site. These maps were georeferenced, digitized, and reclassified and then analysed using weighted overlay method in ArcGIS. Weights for each thematic layer were assigned by AHP method. Output of the weighted overlay provided the groundwater recharge potential map. The flowchart showing the complete methodology is depicted in figure 1.

3.1. Data source

Base map of study region was prepared with the help of Digital Elevation Model data (DEM) downloaded from Bhuvan which is shown in figure 2. DEM is a computer graphics representation of elevation data to represent terrain. Bhuvan is the national geoportal developed and hosted by ISRO comprising of geospatial data, services and tools for analysis. It provides visualization services and earth observation data to users [6].

3.2. Preparation of thematic maps

Thematic map portrays the geographical pattern of a subject matter or theme in a geographical area. Slope map, soil map, geomorphology map, lineament density map, drainage density map and land use map were used for deriving aquifer recharge potential zonation map.
4. Results and discussion

All the thematic layers were prepared as detailed in following sections prior to subjecting them to weighted overlay analysis.

4.1. Slope map

Slope map shows the slope of the surface of an area. In regions of steep slope, infiltration rate will be less and it reduces the ground water recharge potential. In regions of low slope, there will be less runoff and infiltration rate increases thus increasing the ground water recharge potential. Slope map was prepared from the Cartosat DEM -1 using spatial analyst tool in ArcGIS. The study area was divided into 5 classes, which is shown in figure 3.
4.2. Drainage density map

Drainage map shows the streams, lakes, rivers etc in a river basin. Drainage density helps us to identify the water penetration characteristics of river basin. Drainage map was developed from Cartosat DEM. The Cartosat DEM data was downloaded from Bhuvan and was clipped to the study region. It was prepared in ArcGIS 10.2.2. Drainage density map was produced from the drainage map using line density tool and is shown in figure 4.
4.3. Geomorphology map

Geomorphological mapping identifies the characteristics of different landforms. It is highly important since it provides information about various geomorphological elements and their capability in groundwater recharging. It was downloaded from www.bhukosh.gsi.gov.in. The study region mainly consists of pediment Pedi plain complex. The geomorphology map of Karamana river basin is shown in figure 5.

![Geomorphology map](image)

Figure 5. Geomorphology map

4.4. Soil map

Soil map specifies the type of soil and their properties of the region. Various types of soil will have various infiltration capacities. So their importance on groundwater recharge is evaluated on the basis of their infiltration capacity. Higher the infiltration capacity, higher is its recharging potential. Coarse grained soil is more permeable and hence they have high infiltration capacity. Soil map is obtained from the soil grid site which is shown in figure 6.

![Soil map](image)

Figure 6: Soil map
4.5. Land use land cover map

Land use map shows the various land utilization properties and land resources in a specific region. Our study region was divided into five land use categories based on land use. The study region mainly consists of vegetation. Forest region is seen mainly at the origin of the river and built up area is mainly located in the coastal region. Landsat 8 image was downloaded from www.earthexplorer.usgs.gov. The images were stacked, mosaicked and clipped and supervised classification was done to prepare the LULC map which is shown in figure 7.

![Land use land cover map](image)

Figure 7. Land use land cover map

4.6. Lineament density map

Lineaments show the linear features on the earth like faults and shears. They provide the pathways of groundwater movement and hence it is hydro geologically important. Lineaments are mostly seen in the midlands and highlands and seen less towards the coastal region. The places with high lineament density will have high groundwater recharge potential. The hill shade map was prepared for different combinations of azimuth and altitude using ‘hill shade tool’ and lineament map was prepared by digitization. And then lineament density map was prepared using line density tool. The generated map is shown in figure 8.

![Lineament density map](image)

4.7. Reclassification

Reclassification is the method of providing set of new values to the raster dataset. It is done using the reclassify tool from Arctool box in ArcGIS. The maps were reclassified into 5 classes; very high, high, moderate, low and very low potential. The ranks are provided from 1 to 5, and 1 corresponds to very high and 5 corresponds to very low recharge potential.
4.8. Assigning weights to each layer

The weights are assigned to each of the layer by using Analytical Hierarchy Process. It is a technique in which weights are computed by creating a pair wise comparison matrix and the matrix are filled based on the relative importance of the parameters. The elements influencing the result are arranged in a structural hierarchy and they are given in rows and column to form the comparison matrix [7]. The comparison values are given at a scale of 1 to 9 based on Saaty’s scale [8] as shown in table 1.

The AHP was done using a software, Super Decisions V3.2. The result of Analytical Hierarchy Process shows the weight of each of the layer. The pair wise comparison matrix along with the resultant weight is given in table 2. The consistency of AHP was checked and the consistency ratio obtained was 0.018 < 0.1. Hence it satisfies the consistency criteria.

4.9. Weighted overlay analysis

Weighted overlay analysis is the method of providing a common set of values to raster layers. All the reclassified maps are assigned weights that are computed by AHP [9]. These are given as the input and the weighted overlay analysis is conducted in ArcGIS 10.2. It is done using the overlay tool in the Arctool box. The ranks and weights assigned to various categories are shown in the table 3.

The study analyzed the hydro-geomorphic characteristics of the Karamana river basin. Six important factors that influence the groundwater recharge of the area were selected. All the thematic layers namely soil, slope, drainage density, lineament density, geomorphology and land use maps were prepared. The weights were computed and ranks were given for the weighted overlay analysis. The resultant map shows the ground water recharge potential map of Karamana river basin and it is shown in figure 9. It is classified into five sections that vary from very high to very low recharge potential areas. In the groundwater recharge potential map, the value 1 indicates very high, 2 indicates high, 3 indicates medium, 4 indicates low and 5 indicates very low recharge potential zones. The very high region is most suitable for groundwater recharge while low and very low region is not suitable. Majority of the study area falls belongs to high category. The downstream portion of the basin is more suitable since

![Figure 8. Lineament density map](image-url)
they fall under very high to high category. The upstream portion falls under low recharge potential region and hence it is unsuitable.

**Table 1.** Saaty’s scale of relative importance

| Scale                          | Numerical Ranking | Reciprocal |
|-------------------------------|-------------------|------------|
| Extremely preferred           | 9                 | 1/9        |
| Very strong to extremely      | 8                 | 1/8        |
| Very strongly preferred       | 7                 | 1/7        |
| Strongly to very strongly     | 6                 | 1/6        |
| Strongly preferred            | 5                 | 1/5        |
| Moderately to strongly        | 4                 | 1/4        |
| Moderately preferred          | 3                 | 1/3        |
| Equally to moderately         | 2                 | 1/2        |
| Equally preferred             | 1                 | 1          |

**Table 2.** Pairwise comparison matrix

|                 | Land use | Geomorphology | Lineament Density | Drainage Density | Soil | Slope | WEIGHT |
|-----------------|----------|---------------|-------------------|------------------|------|-------|--------|
| Land use        | 1        | 2             | 3                 | 3                | 4    | 5     | 36     |
| Geomorphology   | 1/2      | 1             | 2                 | 2                | 3    | 4     | 23     |
| Lineament Density | 1/3    | 1/2           | 1                 | 2                | 2    | 3     | 16     |
| Drainage Density | 1/3     | 1/2           | 1/2               | 1                | 2    | 3     | 12     |
| Soil            | 1/4      | 1/3           | 1/2               | 1/2              | 1    | 2     | 8      |
| Slope           | 1/5      | 1/4           | 1/3               | 1/3              | 1/2  | 1     | 5      |
| Parameter                      | Rank | Weight |
|-------------------------------|------|--------|
| Land use land cover           |      |        |
| Bareland                      | 2    | 36     |
| Forest                        | 4    |        |
| Waterbody                     | 3    |        |
| Built up area                 | 3    |        |
| Vegetation                    | 1    |        |
| Soil                          |      |        |
| Clay                          | 4    | 8      |
| Gravelly clay                 | 2    |        |
| Loam                          | 3    |        |
| Sandy                         | 1    |        |
| Waterbody                     | 5    |        |
| Geomorphology                 |      |        |
| Flood plain                   | 1    | 23     |
| Coastal plain                 | 1    |        |
| Moderately dissected          | 3    |        |
| hills and valleys             |      |        |
| Pediment pediplain complex    | 2    |        |
| Waterbodies-river             | 2    |        |
| Highly dissected hills and valleys | 4 |        |
| Quarry and mine dump          | 5    |        |
| Dams and reservoirs           | 2    |        |
| Waterbodies -other            | 2    |        |
| Lineament density             |      |        |
| 0-0.29                        | 5    | 16     |
| 0.3-0.57                      | 4    |        |
| 0.58-0.86                     | 3    |        |
| 0.87-1.1                      | 2    |        |
| 1.2-1.5                       | 1    |        |
| Drainage density              |      |        |
| 0-100                         | 1    | 12     |
| 110-200                       | 2    |        |
| 210-290                       | 3    |        |
| 300-380                       | 4    |        |
| 390-620                       | 5    |        |
| Slope                         |      |        |
| 0-4.4                         | 1    | 5      |
| 4.5-11                        | 2    |        |
| 12-18                         | 3    |        |
| 19-31                         | 4    |        |
| 32-560                        | 5    |        |
5. Conclusion

This study suggests the suitable ground water potential zones for the Karamana river basin. The six thematic layers namely soil, slope, drainage density, lineament density, geomorphology and land use maps were prepared using the ArcGIS software and were then assigned the computed weights and ranks for the weighted overlay analysis. The groundwater recharge map generated by the study shows five classes of recharge potential zones with values 1-very high, 2-high, 3-medium, 4-low, 5-very low. The results depicts the most effective groundwater recharging can be done at very high region. The lower slope gradients and the drainage density in these regions indicate the ability of stream flow to recharge the ground water system. These regions are heavily composed of gravelly clay soil and vegetation cover, which induces high infiltration ability. Also the geomorphological category of these regions come under pediment Pedi plain complex. The eastern region of the Karamana basin is poor for ground water recharging, due to its highly sloping topography. These regions are composed of loamy soil and forest cover with highly dissected hills and valleys. The artificially recharging structures could be constructed in the recharge potential zones which will improve groundwater level in the study region. This study uses ArcGIS software which was found to be a useful tool in combining different information to find suitable regions for ground water recharging.

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