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Original Research Article

Identification of ground water recharge potential zones by using remote sensing and geographic information system

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ABSTRACT

Background: The ground water is the most precious and important resource around the world and is decreasing day by day. In connection, there is a need to bound the potential groundwater zones. The geographical information system (GIS) and remote sensing techniques have become important tools to locate groundwater potential zones.
Methods: This research has been carried out to identify ground water potential zones in Nuthankal Mandal with help of GIS and remote sensing techniques. In order to evaluate the ground water potential zones, different thematic maps such as geology, slope, soil, drainage density map, land use and land cover and surface water bodies i.e., lakes and other using remotely-sensed data as well as toposheets and secondary data, collected from concern department. The prepared layers are further used for mapping and identification of ground water potential zones.
Results: In this study ground water potential zones are demarked with the help of composite maps, which are generated using GIS tools. The accurate information to obtain the parameters that can be considered for identifying the ground water potential zone such as geology, slope, drainage density and lineament density are generated using the satellite data and survey of India (SOI) Topo-sheets, the groundwater potential zones are classified into five categories like very poor, poor, moderate, good & very good. The use of suggested methodology is demonstrated for a selected study area in Nuthankal Mandal.
Conclusions: This groundwater potential information was also used for identification of suitable locations for extraction of water.

Keywords: GIS software (ArcMap 10.6), SOI Topo-sheets, Cartosat DEM data, Ground water data

INTRODUCTION

Ground water is the surface water that saturates the ground through a procedure called invasion. Creating populaces in rough territory regions have a fundamental need to discover new groundwater in that limit territories normally in general need unending surface water.[1] GIS is a fruitful instrument for gathering, putting away, changing, recovering, showing and investigating spatial Information from this current reality for explicit customer.[2] Ground water is an essential hotspot for businesses, networks and rural utilizations on the planet and as a result of its newness, manufactured blends, consistent temperature, cut down pollution coefficient and higher unfaltering quality measurement, considered as a basic wellspring of giving strong new water in urban and country regions.[3]

Groundwater is the biggest accessible wellspring of new water lying underneath the ground and comprises a significant hotspot for different purposes like household needs, flexibly for businesses and for horticulture and so on. Also, due to over abuse the accessibility of groundwater is decreasing steeply.

Other than focusing on groundwater possible zones, it has now gotten pivotal to target revive zones for counterfeit energize so as to safe watchman the future.[4]

Counterfeit energizing structures are one of the successful strategies for the administration of groundwater assets. Since the eighteenth century onwards, groundwater capacity structures like lakes, channels, and supplies have been utilized to store surface water all over India, however it is neither completely logical nor geographic area based. So as to evade these issues in distinguishing the groundwater revive zones, the ongoing geospatial advancements like remote sensing and GIS could be utilized with generally precise results.[5]

GIS strategies can be utilized for giving ground water quality zones to various utilizations, for example, water system, household needs. GIS can likewise be utilized to get ready layers of guides dependent on water quality and availability.[6]

Depending on the seasonal rainfall GWS recharge rate is changed from one spatial location to other and also over usage of ground water also make changes in recharge of ground water. The unbalanced recharge and usage of ground water cause depletion of groundwater from year to year.[7]

Remote sensing and geographical information system (RS-GIS) have become a leading tool for modeling and mapping of groundwater resources. An attempt has been made to delineate the groundwater potential zones of Puruliya district using the integrated RS-GISand AHP techniques. All the themes and their features have been assigned weights according to their relative importance and their normalized weights were calculated after the hierarchicalranking.[8]

Several methods are used for mapping of ground water zones. The parameters that are used for controlling groundwater zones are soil, drainage density, land use\land cover, geology, geomorphology, rainfall, slope, and contour. Groundwater mapping techniques are described and derived from satellite remote sensing and additional data sources. This technique includes both conventional methods and advanced methods. The thematic layers are used for mapping and identification of groundwater potential analysis. The importance of each thematic layer and its weight is discussed for the location groundwater potential zones using groundwater conditions. This groundwater potential information will be useful for effective identification of appropriate locations for extraction of water.[9]

The various thematic maps are boundary, drainage, digital elevation model (DEM), drainage density, slope, soil, lineaments, land use/land cover, rainfall maps. The DEM has been generated from the 20 m contour interval contour lines derived from SOI toposheets. The Slope map has been prepared from DEM. These maps have been overlaid in terms of weighed overlay method using Spatial Analysis tool in Arc GIS 9.3. During weighed overlay analysis, the ranking has been given for each individual parameter of each thematic map and weights were assigned according to their influence for soil (40%), land use/land cover (25%), drainage density (10%), rainfall (10%), lineaments (5%) and slope (10%). The resulting maps presents the ground water potential zones in terms of very good (3.91 km^2), good (22.27 km^2), fair (25.65 km^2), moderate (22.31 km^2) and poor zones (1.23 km^2).

The result depicts the groundwater potential zones in the study area and found to be helpful in better planning and management of groundwater resources.[10]

Integration of remote sensing data and the GIS for the exploration of groundwater resources has become a breakthrough in the field of groundwater research, which assists in assessing, monitoring, and conserving groundwater resources. In the present paper, various groundwater potential zones for the assessment of groundwater availability in Then district have been delineated using remote sensing and GIS techniques. Survey of India toposheets and IRS-1C satellite imageries are used to prepare various thematic layers viz. lithology, slope, land-use, lineament, drainage, soil, and rainfall were transformed to raster data using feature to raster converter tool in ArcGIS. The raster maps of these factors are allocated a fixed score and weight computed from multi influencing factor (MIF) technique. Moreover, each weighted thematic layer is statistically computed to get the groundwater potential zones. The groundwater potential zones thus obtained were divided into four categories, viz., very poor, poor, good, and very good zones. The result depicts the groundwater potential zones in the study area and found to be helpful in better planning and management of groundwaterresources.[11]

Integration of remote sensing and GIS has become a breakthrough in the field of groundwater studies. The demand for water is increasing exponentially each year showing an increase in dependence on groundwater sources as surface water sources are no longer satisfying the demand. The present study attempts to identify the potential recharge zones and locations for artificial recharge structures in Amaravathy Basin, Tamil Nadu. Weighted overlay analysis tool in Arc GIS application is used to identify the areas. 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 Amaravathy Basin according to the derived results.[12]

The main objective of this study is to identify ground water potential zones in Noothankal Mandal by using RS-GIS tools.

Study area

Nuthankal Mandal (Figure 1) is located in the GPS coordinates of latitude: 17 °20’13.8’’N to 17°19'23.7"N and longitude: 79°41'35.2"E to79°42'06.6"E.

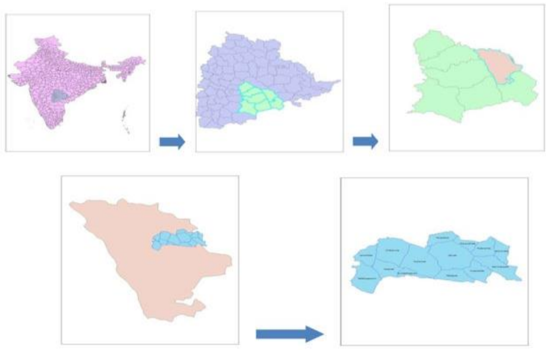

Figure 1: Study area.

METHODS

From Figure 2 to by interpolating the primary data (SOI toposheets and satellite imagery), collateral data obtained from the ground water department and by using GIS and remote sensing tools results to recommend sites for artificial recharge structures.

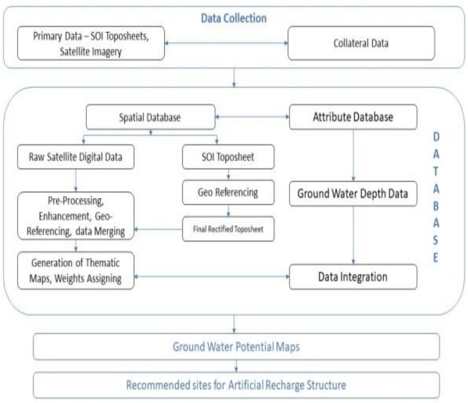

Figure 2: Methodology flow charts.

RESULTS

The study reveals that integration of five thematic maps such as drainage density, slope, geology, lineament density and land use/ land cover give first-hand information to local authorities and planners about the areas suitable for groundwater exploration. The given study area is classified into excellent, good, moderate, poor and very poor groundwater potential zones and indicated in Figure 8. Area having drainage density 0 to 1.2, slope 0º to 1º that means it is plain surface and cover with crop land is observed as excellent groundwater potential zone and covers an area 17.694 km^2, the area having slope 1º to 3º, drainage density 1.2 to 2.4 is observed as good ground water potential zone and covers an area of 25 km^2, the area having slope 3º to 5º, drainage density 2.4 to 3.6 observed as moderate ground water potential zone and covers area 35.388 km2, the area having slope 5º to 10º, drainage density 3.6 to 4.8 observed as poor ground water potential zone and covers area 24.7685 km^2 and the area having slope 10º to 15º, drainage density 4.8 to 6 observed as very poor groundwater potential zone and covers area 12.384 km^2. This ground water potential information will be useful for effective identification of suitable locations for extraction of water.

DISCUSSION

General

The ground water potential map can be predicted by the investigation of different physical features i.e., geology, land use/land cover, soil, drainage density, confirms by utilizing merging proof idea, other than the collateral data acquired from State ground water department. The ground water potential map gives the accessible quantum of ground water. This map is portrayed into zones showing up great, moderate, poor and extremely helpless ground water likely regions. The precise good and moderate zones speak to zones with sufficient ground water assets, poor and very poor speak to zones where unnecessary with drawls may prompt ground water exhaustion. The penetration map is readied dependent on essential and auxiliary porosity of the geological conditions.

Drainage and drainage density map

Drainage network helps in delineation of watershed structures. Drainage density and type of drainage gives information related to runoff, infiltration and permeability.

The study area consists of dendritic drainage shown in Figure 3 (A), indicates homogenous rocks or soil. Drainage pattern reflects surface characteristics as well as subsurface formation and follows 4th order drainage pattern shown in Figure 3 (C). Measure of average length of stream channel for entire basin. The Strahler number or Horton-Strahler number of a mathematical tree is a numerical measure of its branching complexity. The Strahler stream order is used to define stream size based on a hierarchy of tributaries.

Low drainage density is more likely to occur in region and highly resistant of highly permeable soil material under dense vegetation and where relief/slope is low. High drainage density is the resultant of weak or impermeable subsurface material, vegetation and mountainous relief. Low drainage density leads to coarse soil texture while high drainage density leads to fine soil texture. The drainage density characterizes the runoff in an area or in other words, the quantity of relative rainwater that could have infiltrated. Hence the lesser the drainage density, the higher is the probability of recharge or groundwater potential zone. A drainage basin is a natural unit draining of water to a common point. The Nuthankal Mandal map consists of water bodies, rivers, perennial and ephemeral streams, tributaries, ponds. The study area is fourth order basin joining rivers, tributaries base topography depicted in Figure 3 (B).

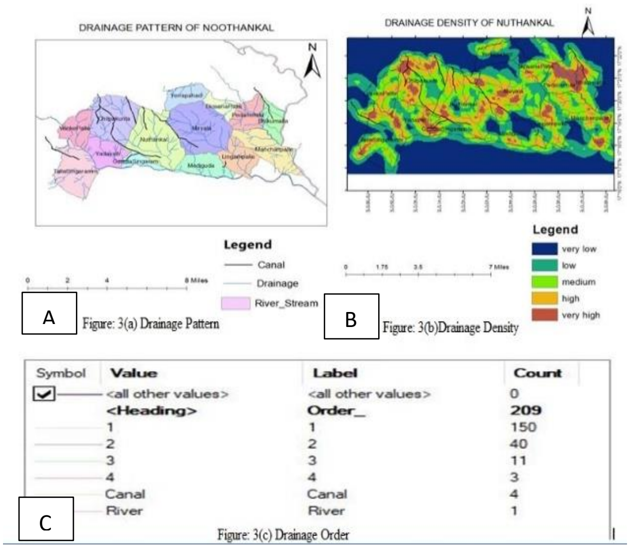

Figure 3: (A, B and C)

The entire drainage map is divided into five categories they are very low, low, medium, high and very high which means the land has very less drainage density, less drainage density, moderate drainage density, high drainage density & very high drainage density respectively. The drainage density of the Nuthankal Mandal is shown in Figure 3 (B) and the drainage density classification in terms of values as very less drainage density (0-1.2), less drainage density (1.2-1.4), moderate drainage density (1.4-3.6), high drainage density (3.6-4.8) and very high drainage density (4.8-6) in terms of km/km^2 are shown in Table 1.

Table 1: Drainage density category.

Class	Density (km^2)	Drainage density category
1	0-1.2	Very Low
2	1.2- 2.4	Low
3	2.4-3.6	Moderate
4	3.6-4.8	High
5	4.8-6	Very High

Soil distribution

Figure 4 (A) showing that the Nuthankal Mandal consists of (14) villages and soils have been divided into different groups namely Fine soils, calcareous soils, Loamy soils. Each soil has its own attributes. Ground water depends on the particular variables like soil vulnerability and porosity, etc. Clayey soils have more voids and less porosity i.e., lesser permeability. Loamy soils have good infiltration of water. The different types of soils available in that area are fine soils, calcareous soils, loamy soils. Very fine Calcareous soil covers 74% of the area, Loamy soil covers 18.9% of the area and Fine soil cover 7.1% of the area. The results are in loamy soil permeability is very high, fine soil permeability is medium to moderate. In very fine calcareous soils permeability is poor.

Land use/land cover

Land use/land cover plays an important role in the development of groundwater resources. It controls many hydro geological processes in the water cycle i.e., infiltration, evapo-transpiration, surface runoff etc. Land cover provides roughness to the surface, reduce discharge thereby increases the infiltration. In forest areas, infiltration will be more and runoff will be less whereas in urban areas rate of infiltration may low. From the land use point of view, Agricultural lands are an excellent site for groundwater potential. Built up land is given a low score because of the influenced revive of the groundwater system by hindering precipitation through the springs.

The Figure 4 (B) shows Nuthankal Mandal and it mostly consists of crop land followed by water bodies, built up land, waste land. Nuthankal Madal is consists mostly of forest land, moderately water body and built-up land, less waste land.

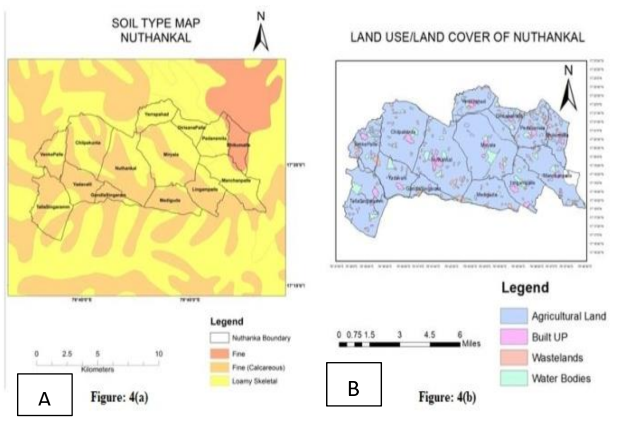

Figure 4: (A and B)

Slope characteristics

Slope is one of the important earth parameters which are explained by horizontal spacing of the contours. In general, the vector form closely, spaced contours represent steeper slopes and scanty contours exhibit gentle slope whereas in the elevation output raster every cell has a slope value. The Cartosat DEM data were used to derive the slope map, which is presented in terms of percentage using the 'slope' function in ArcGIS 10.6. It was then converted from slop to raster format and reclassified into different slope classes using re-classify option in the spatial analyst tool in ArcMap 10.6. Ranks were assigned for each class of the slope map. Here, the lower slope values indicate the flatter terrain (gentle slope) and higher slope values indicated to steeper slope of the terrain. In the elevation raster, slope is measured by the identification of maximum rate of change in value from each cell to neighboring cells. The slope values are calculated either in percentage or degrees in both vector and raster forms. The slope amount derived from digitized contours and spot heights have shown the average elevation with slope 0º to 10º in flat and mountainous areas respectively. Figure 5 shows the slope conditions.

In the almost level slant territory (0-1) degree, the surface overflow is moderate permitting more opportunity for water to permeate and consider great groundwater expected zone, whereas solid incline zone (10-15) degree, ease high spillover permitting less living arrangement time for water, thus similarly less invasion and helpless ground water potential. The entire slope map of study area is divided into five categories as in Table 2 and slope map is shown in Figure 5 as the nearly level surface (0-10), very gently sloping (1-3^0), gently sloping (3-5^0), moderately sloping (5-10^0) and strong sloping (10-15^0).

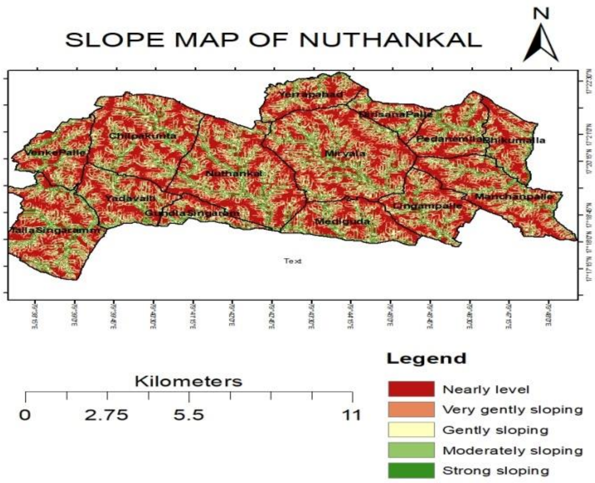

Figure 5: Slope maps of Nuthankal.

Table 2: Slope gradient categories.

Class	Degree (^{0})	Slope category
1	0-1	Nearly level
2	1-3	Very gently sloping
3	3-5	Gently sloping
4	5-10	Moderate sloping
5	10-15	Strong sloping

Ground water data of Dirsenapally village from 2011 to 2019: Dirsenapally is one of the villages in Nuthankal Mandal. Groundwater data collected from the year between 2011 to 2019 i.e.,9 years. The graph shows that in the month of May, June and July the Ground water level is more compared to other months. May to July are the rainy seasons in Nuthankal Mandal. So that the ground water table is high in those months that means seepage of water is more in those months due to rainfall. Figure 6 (A) shows the water table levels in every month from 2011 to 2019.

Ground water data of Maddirala village from 2011 to 2019: Maddirala is one of the Village in Nuthankal Mandal. Ground water data collected from the year between 2011 to 2019 i.e., 9 years. The graph shows that in the month of May, June and July the ground water level is more compared to other months. May to July are the rainy seasons in Nuthankal Mandal. So that the ground water table is high in those months that means seepage of water is more in those months due to rainfall. Figure 6 (B) shows the water table levels in every month from 2011 to 2019.

Ground water data of Nuthankal Village from 2011 to 2019: Nuthankal is one of the villages in Nuthankal Mandal. Ground water data collected from the year between 2011 to 2019 i.e.,9years. The graph shows that in the month of May, June and July the Ground water level is more compared to other months. May to July are the rainy seasons in Nuthankal Mandal.

So that the ground water table is high in those months that means seepage of water is more in those months due to rainfall. Figure 6 (C) shows the water table levels in every month from 2011 to 2019.

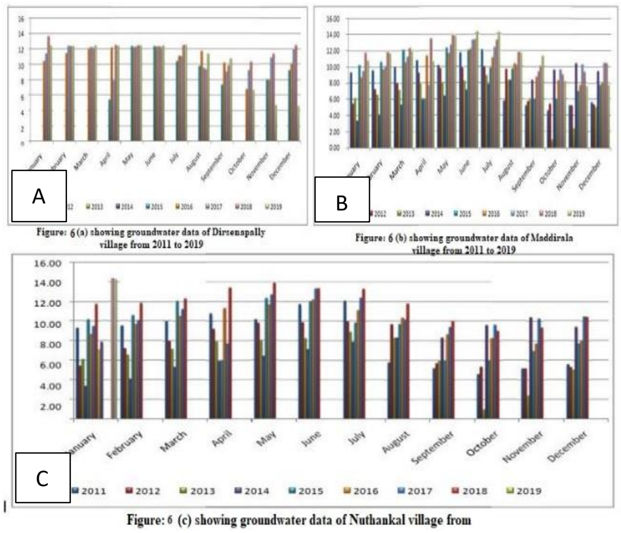

Figure 6: (A, B and C)

Ground water potential zones: Ground water potential zones in Nuthankal Mandal are classified as very good, good, moderate, low and very low as shown in Figure 7 and 14.72% area is in very good condition, 25% area is in good condition, 29.41% area is moderate condition, 20.58% area is poor condition, 10.29% area is very poor condition for groundwater storage as shown in Table 3.

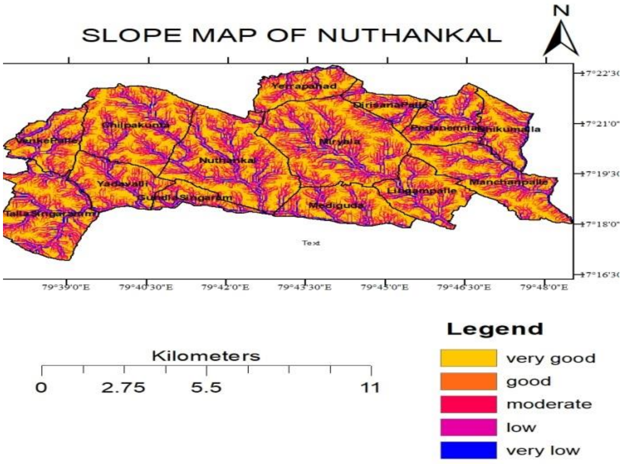

Figure 7: Ground water potential zones of Nuthankal

Table 3: Groundwater potential zones of study area.

Potential zones	Area (km^2)	Area (%)
Very good	17.694	14.72
Good	30.078	25
Moderate	35.388	29.41
Poor	24.7685	20.58
Very poor	12.384	10.29

CONCLUSION

In all the methods of artificial recharge structures the better and suitable process for Nuthankalm Mandal is to construct percolation tanks and recharge shaft wherever there is low ground water potential. In built-up areas it is better to recharge of dug wells through roof top by the process of rain water harvesting. Further, it is felt that the present methodology can be used as a guideline for further research.

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