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Assessment of groundwater potential zones using remote sensing and GIS techniques in Gomukhi River basin of Tamilnadu, India

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Abstract

The Gomukhi river basin of Tamilnadu is the region mainly depends on rain-fed agricultural system and partial areas under canal irrigation system, major cultivation crops are paddy and sugarcane. The western side of Kalrayan hills areas are mostly dry condition, drinking and agriculture activities are high depend on rainfall. Targeting groundwater potential areas in Gomukhi river basin is very much essential and it is necessary to improve the groundwater recharge artificially. The Groundwater potential zones were identified using various thematic layers such as geology, geomorphology, land use and land cover, slop of the ground, lineament, lineament density, drainage pattern and drainage density, texture of soil, and water level, all the thematic layers were assigned suitable for weights based on the Saaty's according their relative significance for the groundwater potential, and their features were normalized by using Analytic Hierarchy Process (AHP) and finally all thematic layers were integrated with Arc GIS 10.1 software, using map algorithm of weighted overlay techniques and delineate the groundwater potential zones map. The final zonation map was classified into three class and shows around 41.38 % of the basin areas falls under good, 29.65% areas are moderate and 28.98% areas are low groundwater potential zones. The village boundary map was super imposed over the zonation map to extract the village wise groundwater potential in the Gomukhi river basin and 8.55 % land area covered by the reserved forest. The groundwater potential zones map was finally validated with field check.

Keywords: Analytic Hierarchy process Methods, Village wise potential zone map, GIS, Remote sensing.

Introduction

The aquifers are typically made up of gravel, sand, sandstone or limestone. The water moves through these rocks because they have large connected spaces that make them permeable. The depth of the surface which has groundwater is found this is called the water table. The water table can be shallow as a foot below the ground or it can be a few hundred meters of deep. Heavy rains can cause the water table to rise and continuous extraction of groundwater can cause the level to fall[1]. The groundwater is an essential component of the environment and economy of the country. Its plays an important role in maintaining the fragile ecosystems. The proper management of both surface and groundwater resources through systematic inventory, conservation and proper planning is essential for economic and social development. The groundwater prospecting especially in the hard rock terrains requires thorough understanding of geology, geomorphology and lineaments of an area, which are directly or indirectly controlled by the terrain characteristics like weathering grade, fracture extent, permeability, slope, drainage pattern, landforms, land use/land cover and climate[2,3]. The groundwater is recognized as one of the most important and dependable sources of water supply in all climate region across the world[4]. There are many factors affecting the occurrence and movement of the groundwater, which includes topography, Lithology, geological structures, depth of weathering, extent of fractures, primary porosity, secondary porosity, slope, drainage patterns, landform, land use and land cover, climate[5]. The importance of water is felt in all sectors as the demand and needs of the population is growing. Increasing demands for fresh water in different sectors, especially for drinking and agricultural purposes so that, there is a need have to identify the groundwater potential zones[6-11]. The AHP methods proposed as a method of solving socio-economic decision making problems has been used to solve the wide range of problem[12] AHP is utilized when dimensions are independent. Saaty[13] provides a method for input judgement and measurement to drive ratio scale priorities for the distribution of influence between the different thematic layers[14]. The Geographical Information System can be used effectively for this purpose to combine different themes objectively and analyse those systematically for demarcating groundwater potential zones[15]. The remote sensing provides multi-spectral, multi-temporal and multi-sensor data of earth surface[16,17]. In the GIS analysis, weights are assigned to obtain the relative importance of one criterion over the other[18]. The several methods have been developed for this purpose, which are mainly classified as subjective and objective methods, in subjective weighting methods, the weights are derived according to the knowledge and preferential judgement of decision makers and on the other hand, mathematical models are used to derive weights in objective weighting methods.

In earlier studies of the delineation of groundwater potential zones, researchers have applied subjective weighting methods such as, weighted linear combination[19], Analytical Hierarch process[20], weighted aggregation methods[21], and weighted sum model[22], etc.

Study Area: Gomukhi river basin located in the eastern side of Vilupuram District, southern side of Salem district, western side of Dharmapuri district, northern western side of Tirvannamalai district and south eastern side is Cuddalore district. The area geographically falls between 11°31'40.7"N to 11°51'53.185"N and 78°36'44.894"E to 79°7'45.337"E. The areal extent of the river basin about 1122.67 sq.km and covers SOI toposheets 58I/9, 58I/10, 58I/13 and 58I/14 on 1:50,000 scale. The total population is around 4,52443 out of this 2,28385 male population and 2,24058 female population and population density is 403 for per sq.km in census of India in 2011 data. In the study area almost tropical deciduous forest and reserved forest area covered 130.97km². The maximum temperature is during the summer season is 38°C and minimum temperature during the winter season recorded is 22°C and also the basin gets around 75% of rainfall from the North-East monsoon during the winter months and its 25% rainfall receiving the South-West monsoon during the summer month. The average annual rainfall is around 1085. The maximum rainfall receive in the north-western region of the basin is 1260 mm and minimum rainfall receives around 792 mm in the western region of basin.

The Gomukhi river flowing from west to east direction and major catchment is in the north western side of the Kalrayan hills. The Kalrayan hills are the major range of hills situated in the Eastern Ghats of of Tamil Nadu. The study area falls in the Kalrayan hills is around 369.5Sq.km and highest elevation point observed in the nearby the area of Kallur village (1257MSL, 1298MSL) of north western region.

Materials and methods

Base map prepared from Survey of India (SOI) Topographic maps on 1:50,000 scale (Figure-1b), various Thematic maps like Land use/land cover, Soil, geology, geomorphology, slope, drainage, groundwater level and water quality was prepared from satellite data and collateral data. Maps like Lineament density and drainage density were derived using GIS spatial analyst module by interpolation method.

All the thematic layers were digitized on Arc-GIS platform. The stream orders were classified according to drainage order following[23]. The groundwater potential zones were obtained by integrating all the thematic layers by assigning suitable weightage to each parameters of individual thematic maps using Analytical Hierarchical process (AHP) methods using Raster calculator in Arc GIS. The finally village wise groundwater potential zones were identified (Figure-2).

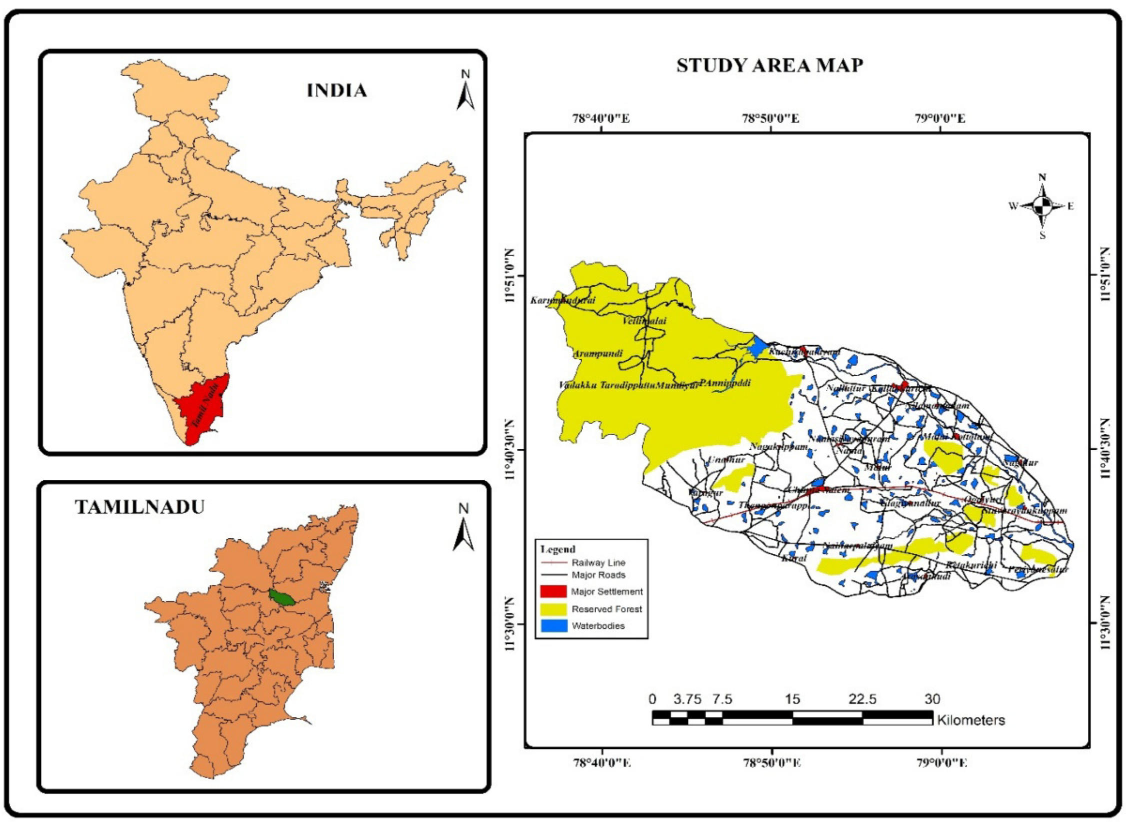

Figure-1a: Location Map.

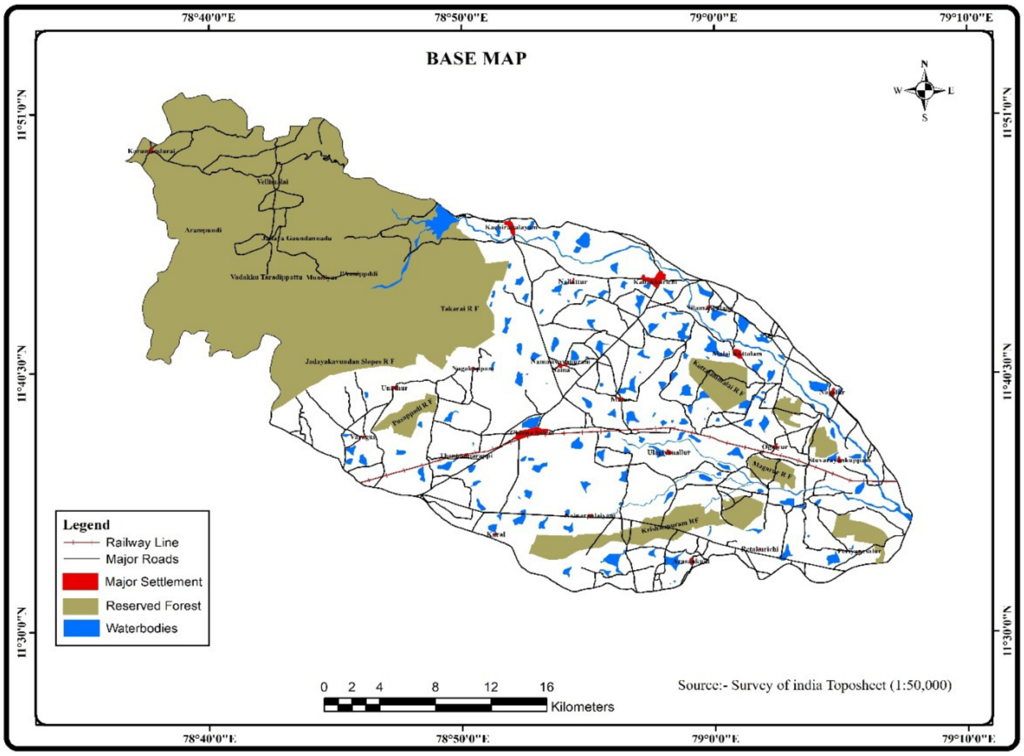

Figure-1b: Base Map.

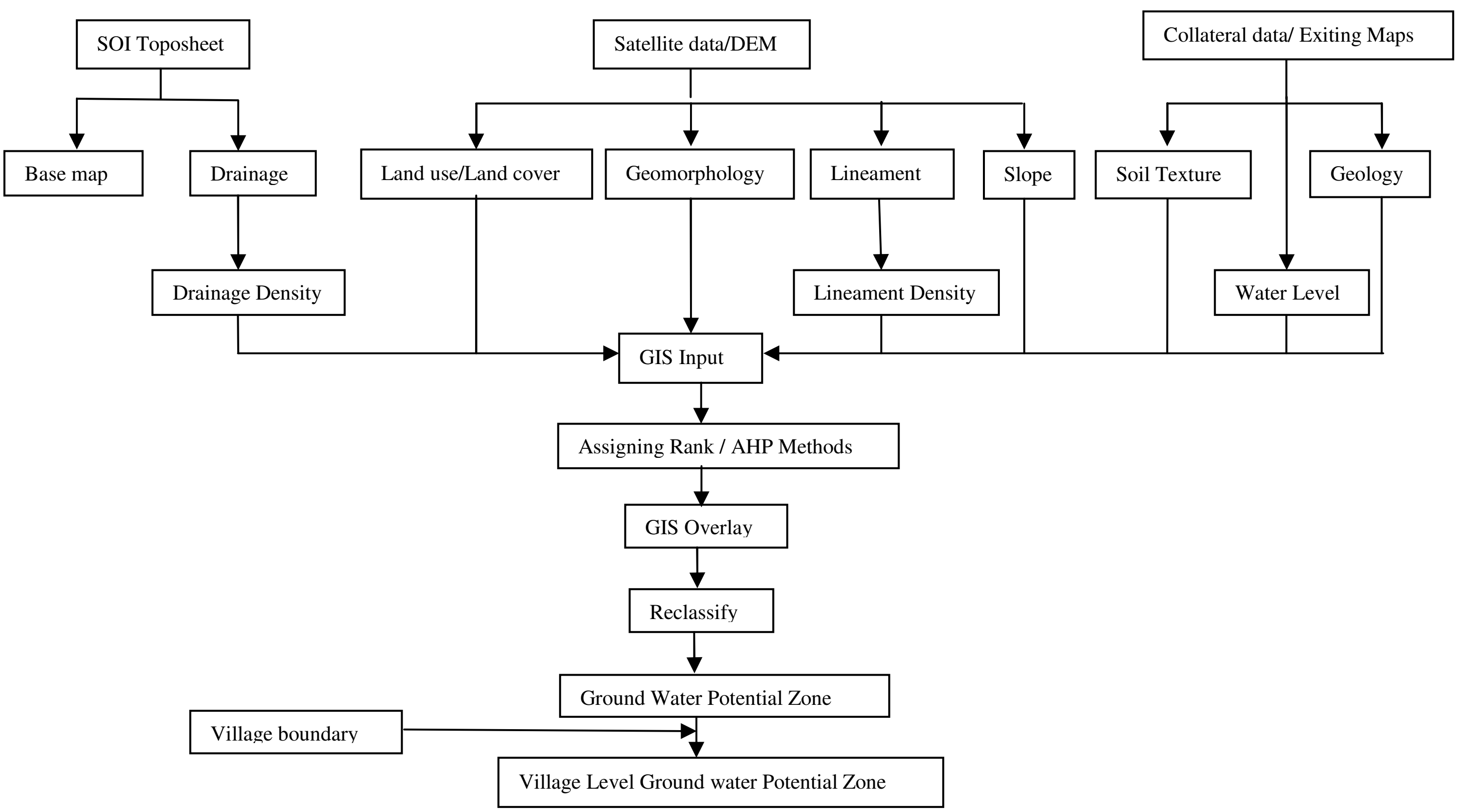

Figure-2: Methodology of study.

Result and discussion

Geology: They are three major rock types have been observed in the area, are hornblende biotite gneisses found in the eastern side of basin covered around 21.48%, Charnockitic rocks are found almost 68% of the basin and fissile hornblende biotite gneiss in west and south western region of the basin area covered 10.57% this rock formed to anorthosites of Archaean age. The study area of geology map shown in (Figure-3). The groundwater porosity is less is charnockite rock formation and also fissile Hornblende biotite gneiss rock formation good for groundwater porosity.

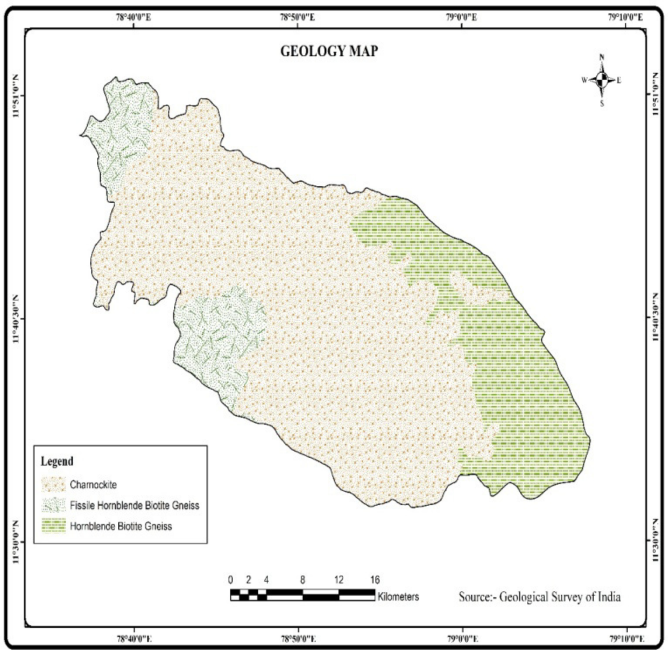

Figure-3: Geology Map.

Well inventory: Well inventory was conducted in the open well by observing the well cross sections and lithology of the various well, collected for groundwater level pre-monsoon. This information were observed the field verification. The groundwater level of Pre-Monsoon map shown in (Figure-4).

Geomorphology: The geomorphology of an area is one of the most important features in evaluating the groundwater potential and prospect[24]. The geomorphologic features of the study area identify the Lands at 7 ETM+ satellite image. The present study area number of erosional, transportation and depositional features in shown in (Figure-5).

The shallow buried pediment are described as nearly flat terrain with gentle slope this unit covered 516.3km² (45.99%) along with entre east basin of study area. The groundwater prospect of these areas is described as moderate and moderately buried pediment are found in the study area is along with the both side of river flowing area of western central and eastern central basins area covering about 172.58km² (15.37%) the ground water prospect of the unit is moderate to good. The valley fill are generally unconsolidated alluvial materials consisting of sand, silt, gravels and pebbles deposited along the floor of a stream valley[25] valley fill of features area covered 22.68km² (20.02%) found in north western side of Kalrayan hills along with valley of stream flow and down hills of Kalrayan nearby valley of the Kachirapalayam area this unit mainly covered by coarse sediment, very high agricultural activates with good vegetation cover. The groundwater potential of this unit is describe as very good.

The residual hills is composed of massive rock formation and residual hills are the end products of the process of Pediment which reduces the original mountain masses into a series of scattered knolls standing on the Pedi plains[26] the shape of the residual hills controlled by spacing of joints and fractures. The western side of basin found small 4 hill lock presented area covered 5.28km² (0.47%) this unit groundwater point of view poor and it has an unfractured rock material founded. The structural hills are the linear or arcuate hills exhibiting definite trend lines and are dominated by charnockite rock formation the study area covered about 310.96km² (27.70%) entire basin of western side of Kalrayan hills mostly this area high elevation and high run-off zones.

The slope of the hill range is strong to very steep slope founded the groundwater potential is poor but some places we can saw moderately. The pediments are isolated hillocks being remants of weathering materials is called inselberge this unit is mostly barren rocky, smooth and rounded small hills. This unit found in the basin is east, north and central places. The area covered in 27.29km² (1.75%) the groundwater point of view is mostly in run-off zones. The flood plain is youngest and new alluvial landforms formed by the river action this unit good for permeable zones of artificial recharge structures this unit found in eastern basin of study area and covered 19.65km² (1.75%) the groundwater point of view good.

The Bajada zones of study are covered 34.76 km² (3.10%) along with the foot hills of Kalrayanes found in western side of the basin and small part covered Pusappadi reserved forest area. This unit is of detrital materials of various lithological and grain size deposited in stream and also alluvial origin places. This zone groundwater potential is good. The river founded west side to east side flowing the area covered about 13.16 km² (1.17%). The weightage assigned Valley fill, Bajada, Moderate buried pediment given high priority, Shallow buried pediment given moderate priority and structural hills, residual hills, Inselberg, River low priority.

Land use and land cover: The land use and land cover features is important controlling action of surface run-off. The land use/Land cover studies provide important indicators of the extent of groundwater requirement and groundwater utilization as well being an important indicator in the site selection of site for the groundwater potential zone. This map prepared from the

Google earth image-2016 and classify the NRSC classification eleven broad classes of land use/land cover were identified and demarcated are shown in the land use/land cover map of the study area (Figure-6). The different land use/land cover classes were classified and weightage assigned, crop land, fallow land, plantation, water bodies, land with scrub are good groundwater potential hence given highest priority. While forest, barren rocky, settlement and land with scrub are have low groundwater potential.

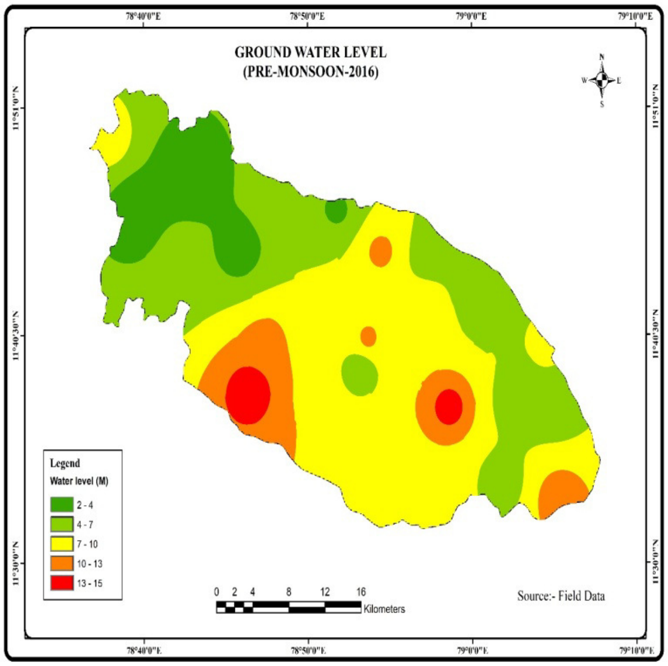

Figure-4: Ground Water level (Pre-Monsoon) Map.

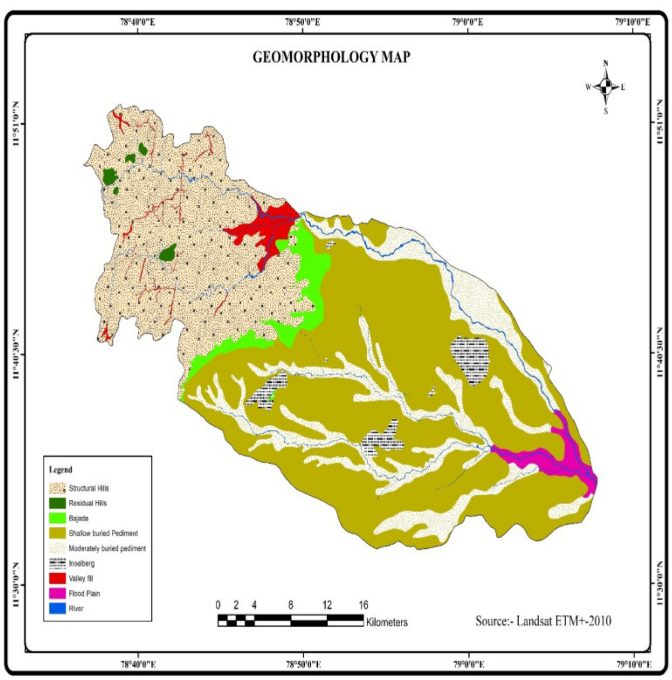

Figure-5: Geomorphology Map.

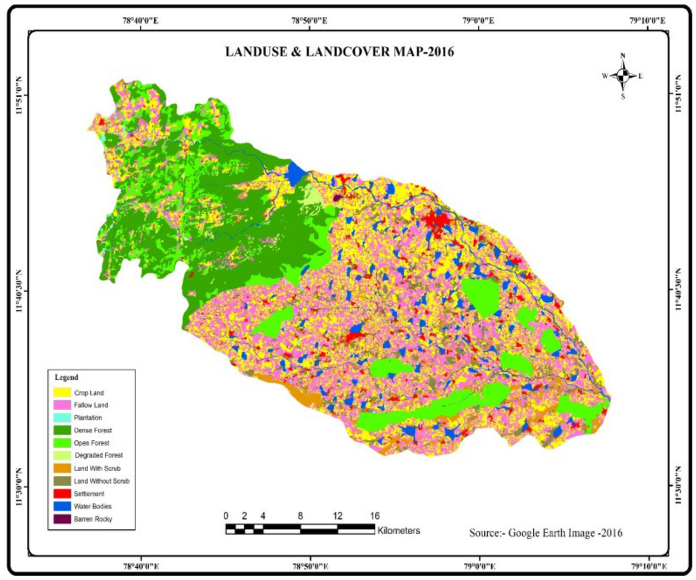

Figure-6: Land use/Land cover Map.

Lineament: The lineament is the linear features of the topography of the Sub-surface of the earth like fracture, faulting, Joining, hill range, ridges, displacement and straight and right angle of the setting at the stream courses[27]. The lineament map prepared satellite data in Landsat-7ETM+. The lineament map of the study area shown in Figure-7, the intersection of lineament is considered as groundwater potential zones. The lineament density is one of the important thematic layer prepared from lineament which are critically used in groundwater studied related to hard rock terrain[28]. Based on the concentration and length of lineaments a lineament density map was prepared shown in (Figure-8). The lineament density map categories by three class low, moderate, and high and high density lineament are favourable for groundwater potential than less density lineament therefore weightages are assigned more for high density lineament and less for low density lineament.

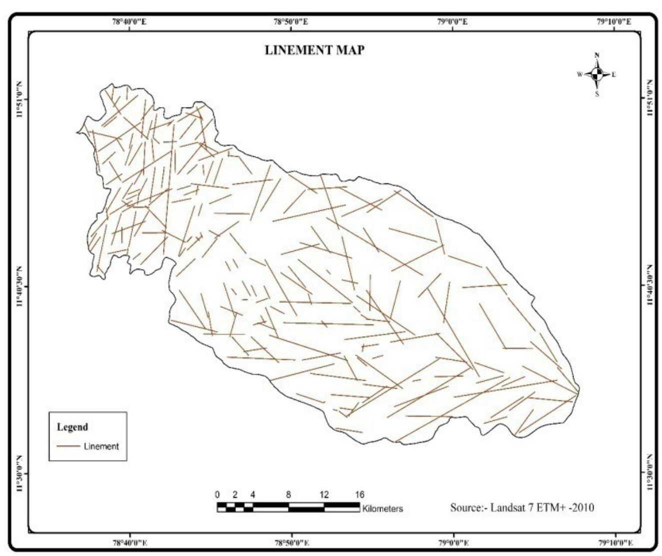

Figure-7: Lineament Map.

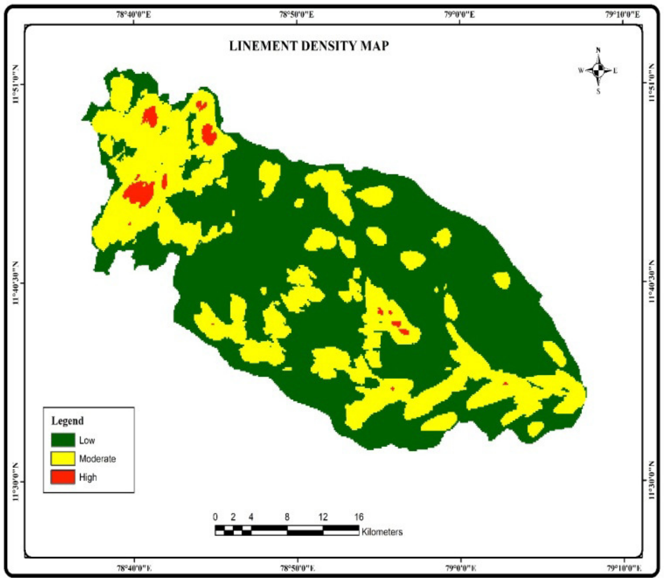

Figure-8: Lineament Density Map.

Drainage: The present study area highest steam order found is 7th order following the number of first order stream is1997, second order is 465, third order is 131, fourth order is 23, fifth order is 6, and sixth order is 2 observed. They drainage map of the study area shown in (Figure-9). Based this drainage map I will prepare drainage density map. The drainage density map reveals the density value range from $2.010km_2^2$ to $10.05km^2$. These classified into three major categories I.e. $<3.35km^2$ Low, $3.35km^2$ - $6.70km^2$ moderate and $> 6.70km^2$ for the analysis purpose the drainage density map shown in (Figure-10). The assigned the more weightages to low drainage density regions whereas low weightages assigned to high drainage density considering groundwater recharge point of view.

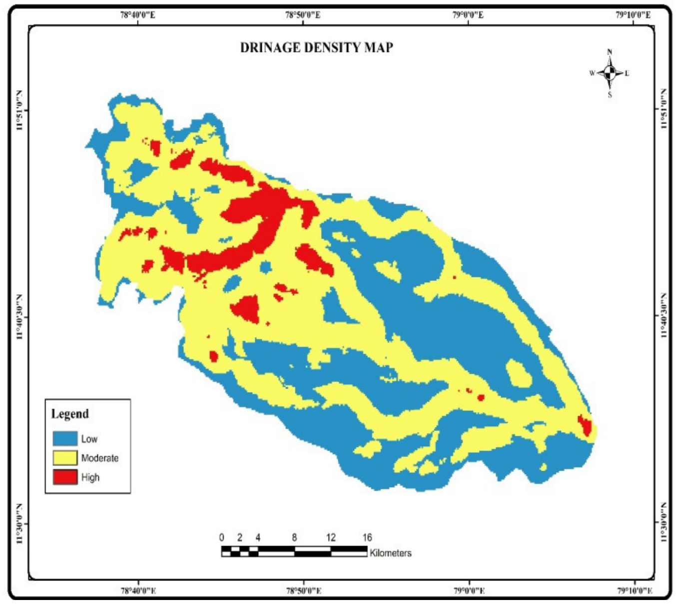

Figure-10: Drainage Density Map.

Soil Texture: The Soil texture or type unit is very important factor of controlling groundwater porosity because of the water holding capacity of any area depends up a unity and permeability. The Soil texture map of the study area is shown in (Figure-11). The soil in the study area reveals eight main categories is namely Clay 25.83%, Sandy clay loam 42.33%, Sandy loam 16.01%, Loam 1.86%, Sandy clay 6.51%, Sand 0.07%, Clay loam 2.10%, and Loamy sand 5.27%. The weightage of soil has been assigned on the basis of their infiltration rate, sand, loamy sand, sandy, loam and sandy clay loam these soil has been high infiltration rate, hence given higher priority, while thy clay, sandy clay, clay loam has least infiltration rate hence assigned low priority.

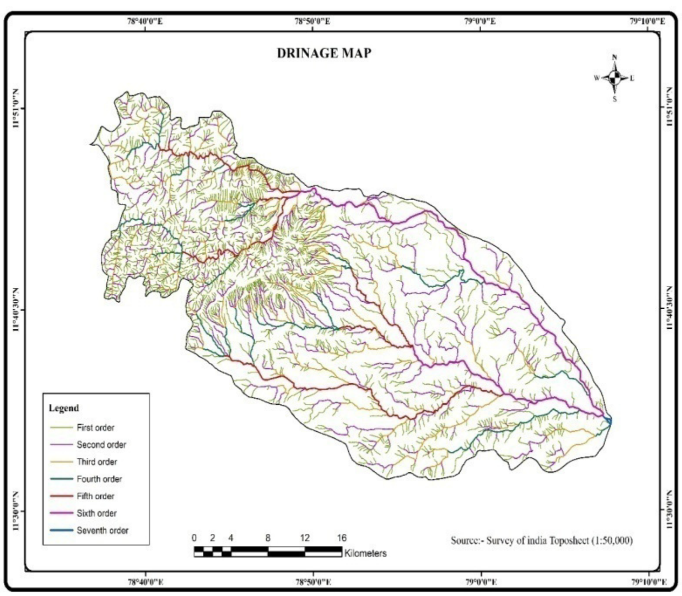

Figure-9: Drainage Map.

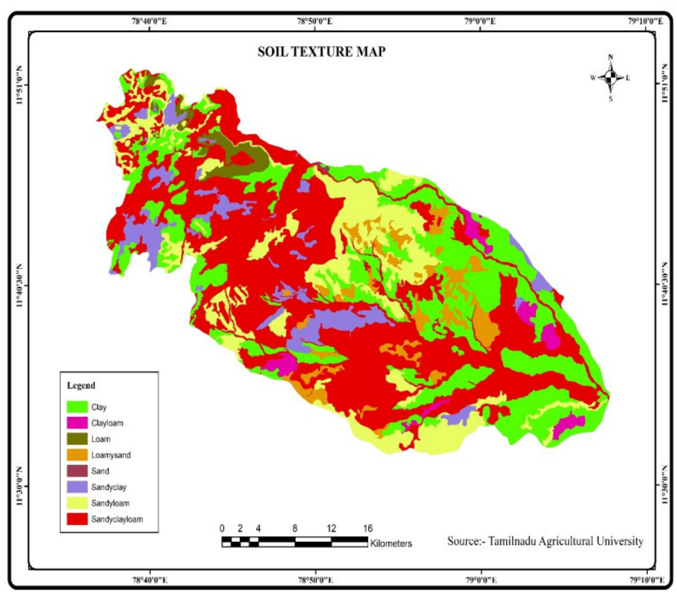

Figure-11: Soil Texture Map.

Slope: The overall topography is western region of basin very steep to strong slope found and east region of study area found in gentle slope.

The slope map of study area classify the five major categories according to the IMSD guidelines of NRSC[29] in Nearly level < 3%, gentle slope 3-5%, moderate slope 5-10%, strong slope 10-15% and very steep slope > 15%, slope map shown in (Figure-12) the more weightages is assigned to nearly level slope and gentle slope because of an area provides more time to infiltrate the rainwater to aquifer zone and strong slope and above given less priority that is high slope allows lesser time resulting low infiltration to underlying groundwater reservoir.

Assigning weightage based on AHP Method: Groundwater potential mapping require the analysis of different thematic layers such as geomorphology, geology, drainage density, land use and land cover, lineament density, soil texture, per-monsoon water level, and slope were considered. Each theme has a different importance in the context of determining the susceptible zones.

Hence, each thematic layer is assigned a weight based on the influence on infiltration characteristics using AHP method. The following table shows the assigned weight for each thematic layer based on Saaty's scale shown in Table-1. Based on this each thematic layer features given pair-wise comparison matrix Table-2. The calculated thematic layers and given priority wise relative weightage of various thematic layers and their corresponding class shown in Table-3.

Groundwater potential zoning: This all the thematic layers were converted into grid and superimposed by weighted overlay methods. This weighted overlay analysis based groundwater potential zones map prepared in terms of good, moderate and low zones classified following as area covered were is 464.33km², 332.72km² and 325.2km² respectively the ground water potential zones map of study area shown in Figure-13.

This output of groundwater potential zone layers overlaid the village boundary and we can identify village wise potential map of the study area shown in Figure-14. This also classify three category is good zones villages have 71 and area covered 29.20%, Moderate zones villages 33 and area covered 29.46%, 33 villages low zone area covered 32.79% and 8.55% land covered by the reserved forest. The groundwater potential zones map was finally validation with field verification.

Table-1: Assigning weightage to each thematic layer.

Thematic layers	Weightage
Geology	7
Geomorphology	8
Soil Texture	8
LU/LC	4
Slope	7
Drainage Density	6
Lineament Density	6
Pre-Monsoon water level	4

Table-2: Pair-wise Comparison Matrix.

Matrix	Geology	Geomorphology	Soil Texture	LU/LC	Slope	Drainage Density	Lineament Density	Pre-Monsoon-2016 groundwater level
Geology	1	7/8	7/8	7/4	1	7/6	7/6	7/4
Geomorphology	8/7	1	1	8/4	8/7	8/6	8/6	8/4
Soil Texture	8/7	1	1	8/4	8/7	8/6	8/6	8/4
LU/LC	4/7	4/8	4/8	1	4/7	4/6	4/6	1
Slope	1	7/8	7/8	7/4	1	7/6	7/6	7/4
Drainage Density	6/7	6/8	6/8	6/4	6/7	1	1	6/4
Lineament Density	6/7	6/8	6/8	6/4	6/7	1	1	6/4
Pre-Monsoon-2016 groundwater level	4/7	4/8	4/8	1	4/7	4/6	4/6	1

Summation of the normalised values will give 1. (i.e.) 0.13+0.15+0.15+0.07+0.13+0.11+0.11+0.07+0.09= 1.

Table-3: Relative weight of various thematic layers and their corresponding class through AHP methods.

Factor	Feature Class	Weightage
Geology	Charnockite	0.28
	Hornblende Biotite Gneiss	0.39
	Fissile Hornblende Biotite Gneiss	0.33
Geomorphology	Structural hills	0.04
	Residual hills	0.04
	Bajada	0.15
	Shallow buried pediment	0.13
	Moderately buried pediment	0.15
	Inselberg	0.04
	Valley Fill	0.17
	Flood plain	0.17
	River	0.06
Soil Texture	Clay	0.07
	Sand clay loam	0.10
	Sandy loam	0.17
	Loam	0.12
	Sandy clay	0.07
	Sand	0.17
	Clay loam	0.07
	Loamy sand	0.17
Slope	<3%	0.27
	3-5	0.23
	3-10	0.18
	10-15	0.14
	>15%	0.09

Factor	Feature Class	Weightage
Land use/ Land cover	Crop land	0.14
	Fallow land	0.10
	Plantation	0.14
	Dense forest	0.07
	Open forest	0.07
	Degraded forest	0.07
	Land with scrub	0.14
	Land without scrub	0.07
	Barren rocky	0.03
	Water bodies	0.14
	Settlement	0.03
Drainage density	High	0.06
	Moderate	0.18
	Low	0.35
Lineament density	High	0.033
	Moderate	0.022
	Low	0.06
Groundwater level (Pre-monsoon-2016)	2-4	0.3
	4-7	0.3
	7-10	0.2
	10-13	0.1
	13-15	0.1

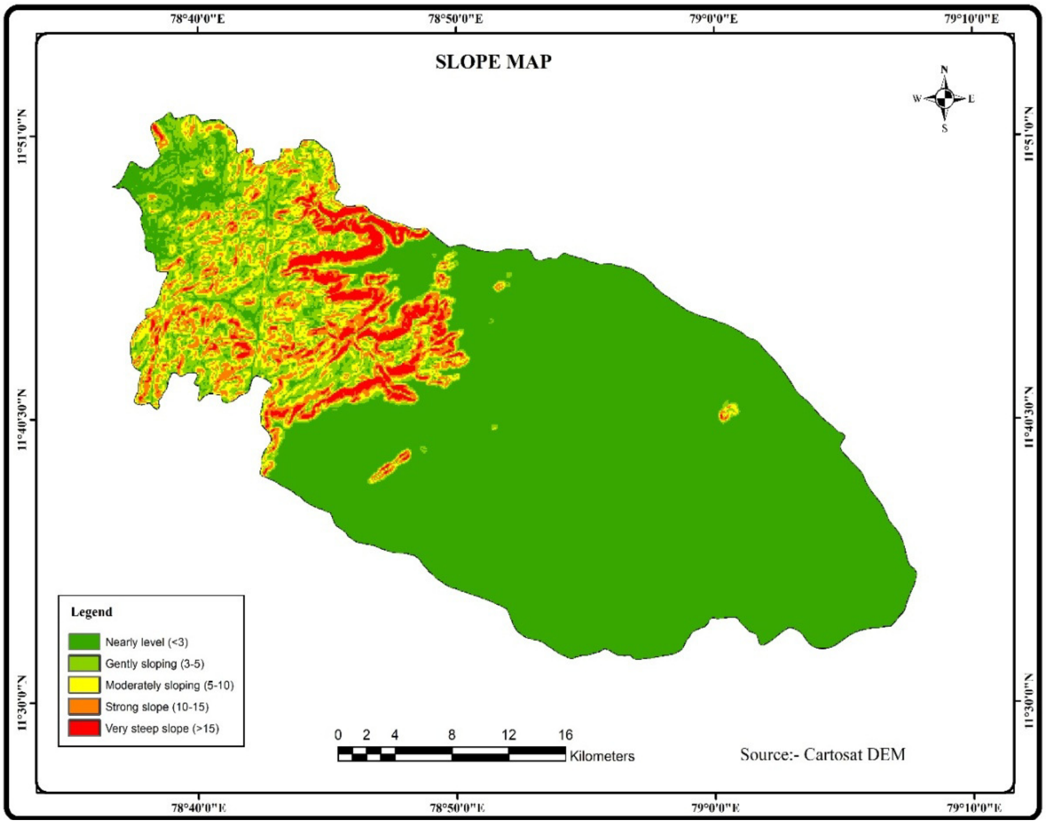

Figure-12: Slope Map.

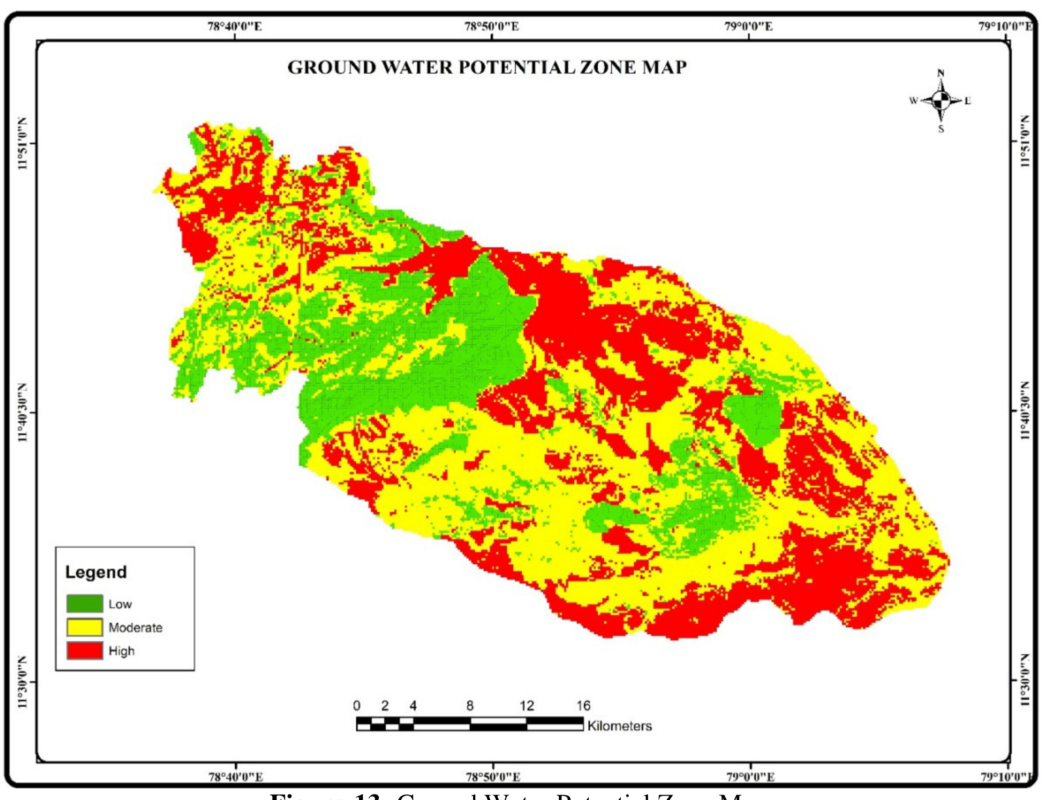

Figure-13: Ground Water Potential Zone Map.

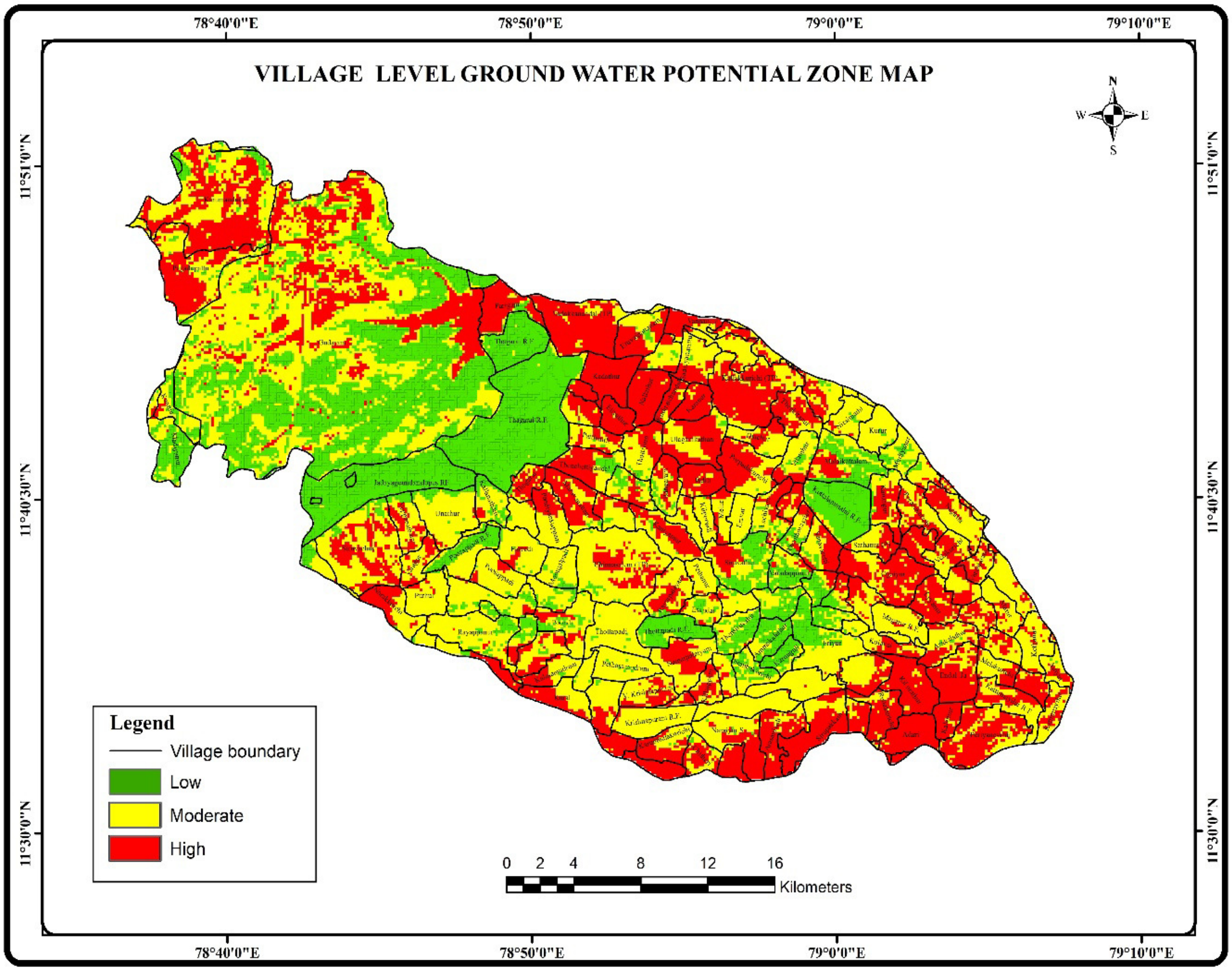

Figure-14: Village Level Ground Water Potential Zone Map.

Conclusion

In this study has more advance of GIS and remote sensing data in identifying favourable zones for groundwater potential zones this technology very much use full for larger area and also have time consumption is less .The groundwater potential is mainly controlled by lithological type, lineament, landforms, soil texture and drainage density as revealed from GIS analysis. The preparation of mapping is useful for the planning and implementation are scientific basis.

Thus the village wise groundwater potential map of Gomukhi river basin very helpful for the district and block level planning and also establishments of suitable location of groundwater recharge structure.

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