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# Geospatial Technology Based Groundwater Potential Zone Mapping In Parts of Noyyal Basin, Tamil Nadu, India

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## ABSTRACT

Groundwater is considered as one of the most valuable hidden natural resources in the sub-surface. Generally, the rapid growth of population, urbanization and agricultural development leads to a major issue for progressively stresses of water in all over the world. Therefore, groundwater is gaining extensive attention to meet the demands. This study aims to delineate the groundwater potential zone (GWPZ) in parts of Noyyal basin, Tamil Nadu, India using remote sensing (RS) and geographical information system (GIS). Fissile hornblende-biotite gneiss, hornblende-biotite gneiss, fluvial (black cotton soil with gypsum), granite, charnockite, garnet sillimanite – graphite gneiss are the major rock types and amphibolite, fuchsite, sericite – quartzite, pyroxene granulite, patches of ultramafic rocks and calc – granulite and limestone are minor rock types in this region. Usually, the river flow is dependent both on northeast and southwest monsoons. The downstream portion of the river mostly in Coimbatore city is extensively polluted due to the direct discharge of domestic sewage and effluent from dyeing and bleaching industries. Consequently, groundwater close to the river turns into contaminated. Hence, proper management and planning of the aquifer in this region are mandatory. This planning includes preparation of groundwater prospective map to identify the groundwater potential of the study area using RS and GIS. Several thematic layers such as geology, geomorphology, drainage, drainage density, lineament, lineament density, slope, soil type, soil texture, soil depth and land use/land cover (LU/LC) were built in the GIS environment to generate the groundwater potential zonation map of the study area. Each individual thematic layer was given appropriate weight and ranking based on their contribution towards groundwater recharge and storage using spatial analyst tool in ArcGIS 10.2. In this manner, a final map i.e. groundwater potential zonation map (GWPZM) was produced by compiling all the required themes. The map indicates that the GWPZ of the study area can be classified into four categories such as very good (32 $km^2$ of the area), good (334 $km^2$ of the area), moderate (727 $km^2$ of the area) and poor (331 $km^2$ of the area). The region falling in very good groundwater potential category is auspicious for groundwater prospect. This study validates that RS and GIS provides a pathway to delineate the groundwater possible zones of the study area.

**Keywords:** Groundwater Potential Zone, Remote Sensing, ArcGIS, Noyyal basin

## I. INTRODUCTION

Groundwater is a concealed natural resource which is found beneath Earth's surface that fills all the pore spaces of soil and the fractures of rock formations. It is universally accepted as the largest freshwater resource available in the world. It is considered as one of the most important natural resources which support both human needs and economic development. The demand for water is increasing drastically in worldwide due to the rapid growth of population, urbanization, industrialization, and agriculture and also become a dependable source of water supplies in all climatic regions.

To find groundwater occurrence being in the subsurface is mostly done based on the presence of surface features like lineament, drainage, lithology, geomorphology, soil, slope and LU/LC. The occurrences of groundwater in hard rock terrains are mainly in the opening or weak zones such as fractures, joints, fissures and weathered rocks.

Integrated RS and GIS are extensively used for delineating the groundwater possible zones. Remote sensing is a powerful technique which is useful for mapping the earth surface in a large area within a short period of time with low cost. It provides significant information about earth surface connected to groundwater through various features like lineament, lithology, topography, LU/LC, soil and landforms which govern the subsurface water conditions. It plays an effective tool for targeting groundwater potential zone through the surface features even though it cannot notice groundwater directly. GIS offers an exceptional framework for competently handling large and complex spatial dataset. It is an important tool in the view of demarcating groundwater prospective zones and water resource management by integration and analysis of multi-thematic layers (Carver 1991; Saraf and Chaudhuray 1998; Nag 2005; Rokade et al. 2007; Ganapuram et al. 2009; Magesh et al. 2012; Selvam et al. 2012, 2014; Ghosh Prasanta Kumar et al. 2016).

The various thematic maps, namely, geology, geomorphology, drainage and drainage density, lineament and lineament density, slope, soil type, soil depth, land use/land cover were generated using RS and GIS and are compiled together to construct a prospective groundwater map. In the present study, the main objective is to identify Ground Water Potential Zones in parts of Noyyal basin using integrated RS and GIS techniques.

## II. STUDY AREA

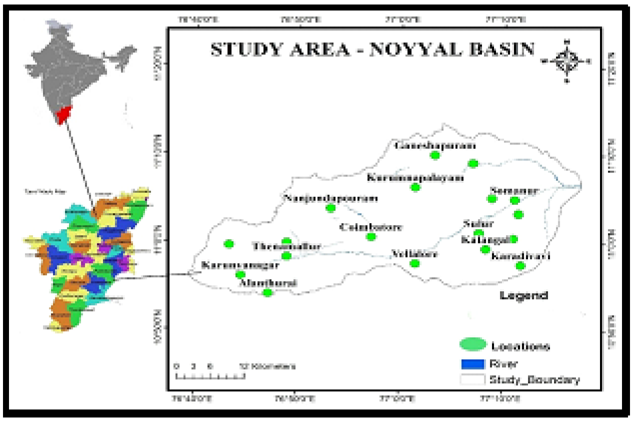


**Figure 1.** Location map of the study area

The Noyyal river is one of the most important tributaries of the river Cauvery. It originates from the Vellingiri hills in the Western Ghats in Tamil Nadu and flows through Coimbatore, Tiruppur, Erode and Karur districts, finally drains into the Cauvery river. The study area is a part of the Noyyal basin which lies between 10° 56′ 20.42″N to 11° 6′ 27.71″N latitude and 76° 39′ 20.98″E to 77° 17′ 36.45″E longitude, covering an area of 1519.11 $km^2$ (Figure 1). The river traverses for a distance of 71 km within the study boundary. It is located in the western part of the Coimbatore district in Tamil Nadu, India. The water flow in the river is seasonal and depends both on the northeast and south-west monsoons which has a good flow during these seasons. But, the area receives higher rainfall during the southwest monsoon only. Sporadically, flash floods occur when there is heavy rain in the catchment areas. Apart from these periods, there is an only scanty flow of water throughout the year. The study area obtains an average annual rainfall of 3000 mm. Direct discharge of effluent from dyeing and bleaching industries and untreated domestic sewage to the river consequences river pollution extensively, therefore, contaminating the groundwater adjacent to the river. The extensive sinking of deep bore wells and scanty rainfall in the region consequences in lowering the groundwater table.

## III. METHODOLOGY

Integrated RS and GIS techniques were used to delineate groundwater possible zones in the study area. Survey of India (SOI) topographic sheets bearing number 58A/12, 58A/16, 58B/9, 58B/13, 58E/4, 58E/8, and 58F/1 on 1: 50,000 scale were used to prepare the base map of the study area. All the toposheets were geo-referenced into Universal Transverse Mercator (UTM), World Geodetic System (WGS) 1984 using ArcGIS 10.2 software. Geology map was prepared from Geological Survey of India (GSI) map. Soil map was prepared by digitizing the geo-referenced soil map obtained from Soil Survey and Land Use Organization (Department of Agriculture, Tamil Nadu) and subsequently, it was updated with the help of satellite imagery. The other thematic maps viz., geomorphology, lineament and lineament density, LU/LC, slope, drainage and drainage density were generated from satellite imageries and further updated in GIS. Geomorphology, lineament and lineament density and LU/LC maps were generated from Landsat 8. Slope and drainage maps were generated from shuttle radar topography mission (SRTM) digital elevation model (DEM) data. Drainage density map was prepared using drainage layer and line density tool in ArcGIS software. To generate the final groundwater potentiality map of the study area, all the different thematic layers were integrated with weighted overlay in GIS. Weightage for each individual features of a theme was assigned during weighted overlay analyses which were mainly based on the impact towards groundwater movement and infiltration rate and each of the themes was given ranked based on suitability for groundwater occurrence. All the thematic layers were interrelated to one another which provide significant information regarding groundwater occurrence, therefore, helpful for the preparation of groundwater prospective map of the area. In GIS environment, each theme was overlapping to one another to identify the interconnecting polygon. In this manner, a new map was generated by integrating two thematic maps. Further, a composite map was overlaid on a third thematic map, and so on. In this process, the final composite map was generated. Thus, the groundwater prospective map was produced. Based on this map, the study area was categorized into four groundwater prospective zones namely very good, good, moderate and poor.

## IV. RESULT AND DISCUSSION

### Geomorphology

Geomorphology is the study of the nature and genesis of its landforms shaped by physical, chemical and biological processes functioning at or near the earth surface. Geomorphology map was extracted from Landsat 8. Generally, the map provides an information about the presence of several geomorphological units existing on the earth surface and offers room for occurrences of groundwater in each unit (Pradhan 2009a, Thilgavathi et al. 2015). Geomorphology was given highest weight among the other thematic layers due to its unique role play in the movement and storage of groundwater at any place. The study area consists of various geomorphic units such as ridge type structural hills, moderately weathered buried pediplain, shallow weathered buried pediplain, pediment/ valley floor, colluvial fan, moderate buried pediment, shallow floodplain, upper bajada, hilltop weathered and shallow buried pediment (Figure 2). These geomorphological units are enormously supportive for delineating groundwater possible zones. Among the geographic units, moderately weathered buried pediplain (226.28 km$^2$) and shallow floodplain (17.65 km$^2$) are important units which allow widely for movement and storage of groundwater. Shallow weathered buried pediplain (799.79 km$^2$) covers the major portion of the study area. In the present study area, the presence of geomorphological features such as fissures, joints, porous zones in the geological formations plays a vital role in controlling the movement and storage of groundwater.

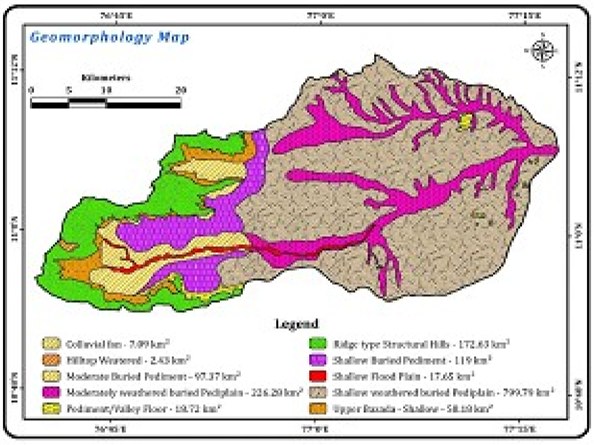


**Figure 2.**Geomorphology map

### Geology

Geology plays an important role in the occurrence of groundwater. The quality and movement of groundwater depend on both the physical and chemical properties of the rocks. The geology of the study area comprises mainly of fissile hornblende-biotite gneiss, hornblende-biotite gneiss, fluvial (black cotton soil with gypsum), granite, charnockite, garnet sillimanite – graphite gneiss and follow by minor rocks such as amphibolite, ultramafic rock, fuchsite, sericite – quartzite, pyroxene granulite, calc – granulite and limestone (Figure 3). Fissile hornblende-biotite gneiss (Peninsular gneiss – younger phase) of Bhavani Group is largely found in the central and northeastern part of the study area. Migmatite Complex of Hornblende – biotite gneiss occupies the south and southern regions whereas fuchsite, sericite – quartzite is seen in the southwestern portion. Fluvial (black cotton soil with gypsum) of Recent to Pleistocene Group is found in the west and southwestern regions. Granite of Alkali Complex occurs in the west, north and northeastern portions. Charnockite Group of rock like charnockite is found in northwestern and also found as patches in the east, south and southeastern side, and pyroxene granulite is seen in the southern part of the study area. Garnet sillimanite – graphite gneiss and calc – granulite and limestone of Khondalite Group occupy in the southwestern region. The Satyamangalam Group of amphibolite is found in the southwestern side and ultramafic rock is found as patches in the northwestern regions.

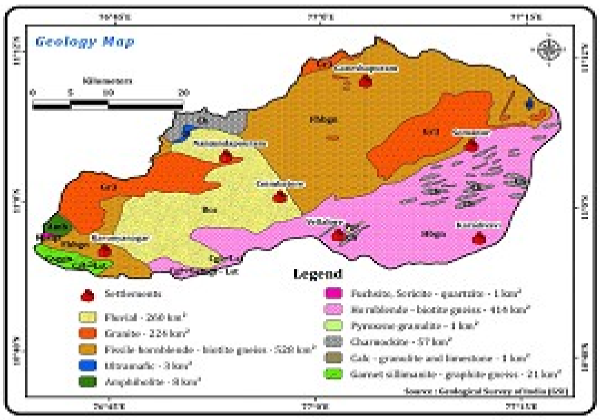


**Figure 3.** Geology map

### Drainage and Drainage Density

Drainage pattern determines the characteristics of both surface and sub-surface formations. The drainage network provides pathways for the movement and storage of groundwater. Areas with higher drainage density indicate high runoff while the lesser the drainage density, the lower the runoff and the higher the possibility of groundwater occurrences (Olutoyin et al.2013). Figure 4a reveals the drainage pattern of the study area is originated mainly from the western part of the study area where high hill slopes are situated. Generally, the type of drainage pattern is dendritic. Dense drainage pattern is mostly occupied in the western part of the region than the rest.

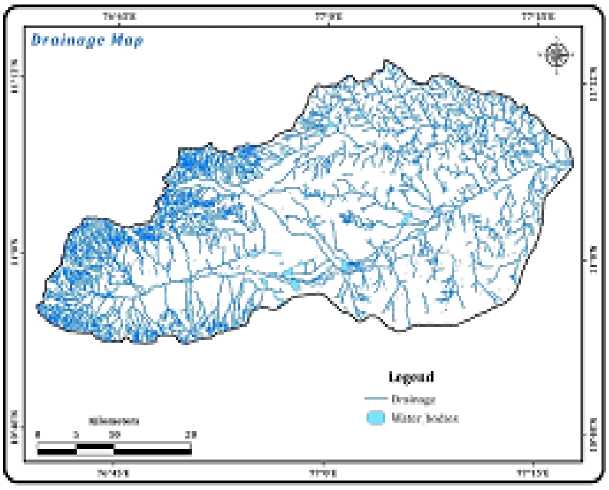


**Figure 4a**. Drainage map

According to Meijerink (2007), drainage density is a measurement of the total length of all the streams and rivers per unit area. It implies that permeability is associated with low drainage density. Drainage density of the study area is classified into five classes as shown in Figure The very high drainage density (> 4000 m/ km²) and high drainage density (3000 - 4000 m/ km²) covers 47.91 km² and 124.89 km² of the regions respectively. The region falls under these categories indicates low infiltration. The moderate drainage density (2000 – 3000 m/ km²) covered an area of 260.78 km² which suggests moderate infiltration and recharge rate. The major portion of the area (625.57 km²) is occupied by the low drainage density (1000 – 2000 m/ km²) followed by very low drainage density (1000 – 2000 m/ km²) covering an area of 459.96 km² (Figure 4b). These two categories are found in every direction except in some western part of the region. Generally, very high and high drainage densities govern the suitability for recharge and potential groundwater zone.

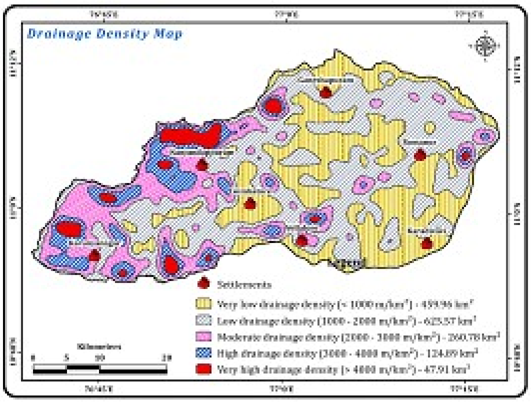


**Figure 4b.** Drainage Density map

## Slope

The slope is one of the significant factors which is interconnected to groundwater recharge. It controls the rate of infiltration and surface runoff. It gives an idea about the rate of groundwater recharge based on the slope angles. The area having steep slope causes less infiltration due to rapid surface runoff whereas, flat and gentle slope areas encourages less runoff thus allowing more time to percolate rainwater and promotes substantial groundwater recharge. Flat and gentle slopes are considered as good groundwater recharge. The slope of the study area was prepared from SRTM DEM, and was categorized based on the range of slope into five classes and is illustrated in Figure 5.

The area having <5⁰ slopes is classed as "very good" for groundwater recharge because of the flat terrain and relatively reduced runoff movement to downstream whereas slope value having >20⁰ represents high slope, classed as "very poor" for groundwater recharge. The map clearly shows that majority of the study area falls under <5⁰ category which indicates flat to a gentle slope and some in the western part is indicated as high slope which is mostly hilly region.

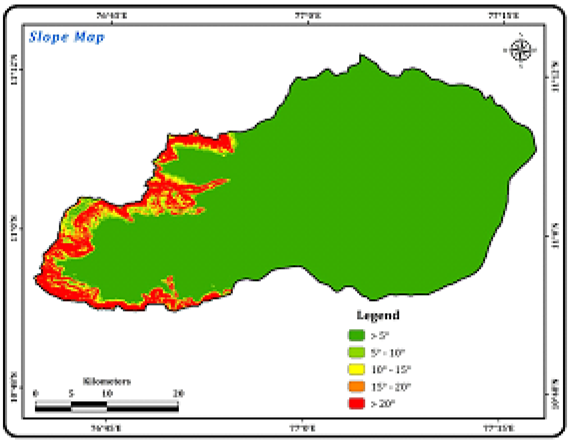


**Figure 5.** Slope map

## Lineaments and Lineament Density

The lineaments are linear features on the Earth's surface that reflects the underlying geological structures such as faults, fracture zones, shear zones and igneous intrusions like dykes. They are categorized as secondary porosity and permeability and are good indicators of groundwater. They are visible on satellite images as tonal differences compared to other terrain features. Hydrogeologically, these are considered as the weaker zones of bedrocks in the earth's crust, formed due to the earth movement; the connection between the lineaments provide room for movement and storage of groundwater (Rao and Jugran 2003, Thilagavathi et al.

2015). Groundwater recharge can be targeted in the region having major lineaments than joints because of their greater widths, greater lengths and acting as channels and better interconnections with other fractures (Edet et al. 1998; Fathy Abdalla 2012).

The lineament map was extracted from Landsat 8. Figure 6a shows that majority of lineaments in the study area were obtained in NW-SE, NE-SW directions. The lineament density map was generated based on the presence of the linear feature in the study area using GIS. The area having very high and high lineament densities are considered as very good groundwater potential zones. Figure 6b reveals that the lineament density of the study area comprises of five categories. The very high lineament density (>10000 m/ km²) is found in the central part of the area covering a very small area of 8.70 km² compared to the others. The region having high lineament density (8000-10000 m/ km²) is found in the central, north, south and eastern part of an area of 61.58 km². Majority of the area comes under very low lineament density

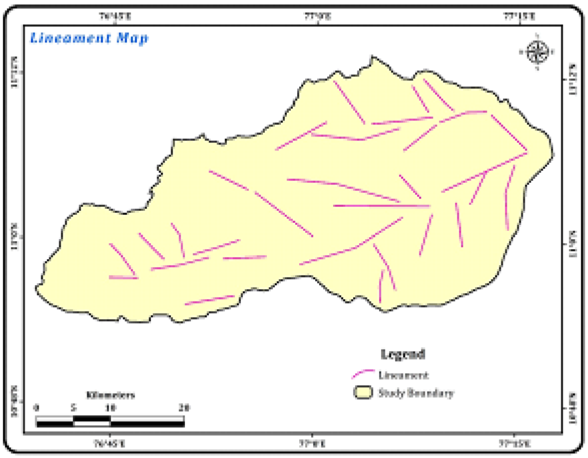


**Figure 6a.** Lineament map

category (< 2000 m/ km²) scattering throughout the directions for an area of 1116.06 km².

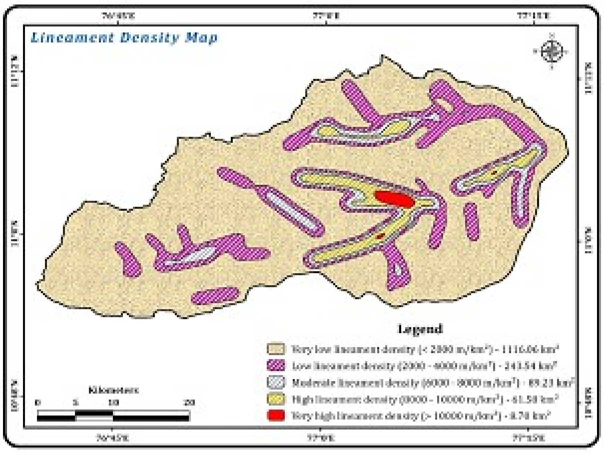


**Figure 6b.** Lineament Density map

## Soil type

Soil plays an important role in indicating the groundwater quality and quantity based on the soil type. Depending on the soil types, it also gives an information about the groundwater holding capacity and infiltration rate. Based on the characteristics and different types of soil present in the study area, it is classified into six main categories such as alfisols, entisols, inceptisols, vertisols, reserved forest and rock outcrop, as shown in Figure 7. The majority of the study area is dominated by alfisols, covering an area of 651.63 km², spreading throughout the entire region. Entisols are mostly found in the eastern and some in the north, northeastern and southeastern part of the study area i.e., 293.06 km². Inceptisols type is seen in the south, east, southeastern and northeastern part. It covers an area of 166.85 km². Patches of rock outcrop (2.67 km²) are found in the eastern part of the region. The place where the soil is associated with rock outcrops may have controlled infiltration to underneath ensuing in poor groundwater prospectus of the area.

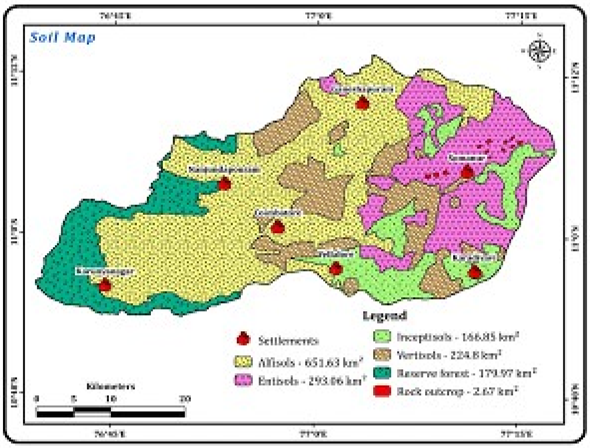


**Figure 7.** Soil Type map

### Soil Texture

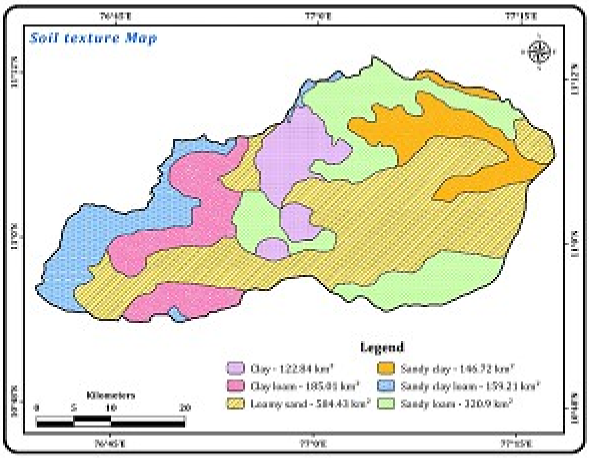


**Figure 8.** Soil Texture map

The soil textures found in the study area into six categories viz., clay, clay loam, loamy sand, sandy clay, sandy clay loam and sandy loam (Figure 8). Based on the water holding capacity, sandy loam is considered as very good for groundwater occurrence followed by sandy clay loam and sandy clay which are considered as moderately better than the rest soil textures. The soil texture of the region is dominated by loamy sand covering an area of 584.43 km$^2$.

### Soil depth

The amount of groundwater storage capacity is relatively depended upon the depth of the soil and their porosity. On this basis, the study area is classified into six categories, namely, shallow, moderately shallow, deep, very deep and rock land. Based on the Figure 9, maximum of the study area falls under very depth covering an area of 794.66 km$^2$. Shallow depths are located at the eastern and central parts of the area. The class depth is found in the northern and central region of the area. Moderately shallow is mainly found in the northern and southeastern part. Rock land area lies in the upstream (western) region of the study area.

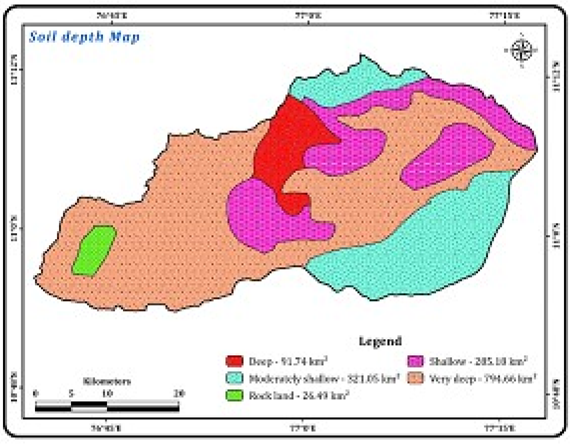


**Figure 9.** Soil Depth map

### Land use and land cover

Land use denotes the human activities and various uses which are carried out on land such as agriculture, settlements or industry, whereas land cover includes natural vegetation, water bodies, rock/soil, artificial cover, and others resulted due to land transformation that is present on the earth surface (Balachandar et al. 2010). The land use/land cover is characterized by a mixture of forest covers, agriculture activities, settlement, water bodies etc. Remote sensing and GIS technique offer consistent information for land use/land cover mapping (Selvam et al. 2012, Selvam et at. 2015, Deepa et al. 2016). There are totally eight different types of land use/land cover was delineated in the study area as shown in (Figure 10). The figure shows that the large area belongs to the cropland (642.51 km$^2$) followed by plantations indicating that the area is having moderate to good potential for the groundwater which is mostly distributed close to the waterbodies (e.g., lakes and rivers). The Hill and forest land (206.57 km$^2$) are occupied in the extreme most western part of the study area boundary. An area of 27.36 $km^2$ is covered by waterbodies which represent high potential for the occurrences of underneath groundwater.

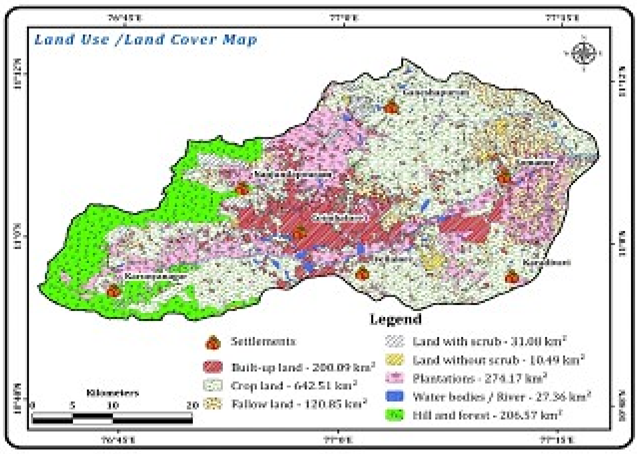


**Figure 10.** Land use/ land cover map

**Weighted overlay analysis**

The reason behind for usefulness of weighted overlay analysis is being able to make spatial complexity to simplicity in suitability analysis and site selection are mainly based on general measurement of dissimilar and diverse impacts (Girvan et al. 2003; Kuria et al. 2011, Malay et al. 2016). To delineate groundwater potential zone, all the thematic layers were given suitable weight using the procedures of weighted overlay in Spatial Analyst Tools of ArcGIS 10.2. Weightage and ranking for each individual feature of the thematic layers were assigned based on their impacts towards the groundwater recharge as shown in Table 1. All the thematic vector layers were reformed into raster format and overlaid in Arc/Info. The parameter which has high weight value represents significant influences in the groundwater potentiality. Among the thematic layers, geomorphology was assigned highest weight due to the significant role play for groundwater occurrence. To get a final output map of groundwater potential zone, each individual factors of the thematic layers were superimposed to one another.

**Table 1.** Weight and ranking for different thematic layers used for delineation of groundwater potential zones

| Theme | Feature/class | Rank | Weightages |
|---|---|---|---|
| Geology | Amphibolite | 1 | 10 |
| | Calc – granulite and limestone | 3 | |
| | Charnockite | 1 | |
| | Fissile hornblende-biotite gneiss | 2 | |
| | Fluvial | 5 | |
| | Fuchsite, sericite – quartzite | 3 | |
| | Garnet sillimanite – graphite gneiss | 5 | |
| | Granite | 2 | |
| | Hornblende – biotite gneiss | 5 | |
| | Pyroxene granulite | 2 | |
| | Ultramafic | 1 | |
| Geomorphology | Ridge type structural hills | 1 | 25 |
| | Moderately weathered buried pediplain | 5 | |
| | Shallow weathered buried pediplain | 3 | |
| | Pediment/ Valley floor | 4 | |
| | Colluvial fan | 2 | |
| | Moderate buried pediment | 2 | |
| | Shallow floodplain | 5 | |
| | Upper Bazada | 1 | |

| | | | |
|---|---|---|---|
| | Hilltop Weathered | 1 | |
| | Shallow Buried Pediment | 3 | |
| Drainage density | Very low drainage density (<1000 m/km$^2$) | 5 | 10 |
| | Low drainage density (1000-2000 m/km$^2$) | 4 | |
| | Moderate density (2000-3000 m/km$^2$) | 3 | |
| | High density (3000-4000 m/km$^2$) | 2 | |
| | Very high density (>4000 m/km$^2$) | 1 | |
| Lineament density | Very low (<2000 m/km$^2$) | 1 | 20 |
| | Low (2000-4000 m/km$^2$) | 2 | |
| | Moderate (4000-6000 m/km$^2$) | 3 | |
| | High (6000-8000 m/km$^2$) | 4 | |
| | Very high (8000-10000 m/km$^2$) | 5 | |
| Soil | Alfisols | 5 | 5 |
| | Entisols | 4 | |
| | Inceptisols | 3 | |
| | Vertisols | 2 | |
| | Reserved forest | 1 | |
| | Rock outcrops | 1 | |
| Soil texture | Clay | 1 | 5 |
| | Clay loam | 2 | |
| | Loamy sand | 3 | |
| | Sandy clay | 4 | |
| | Sandy clay loam | 4 | |
| | Sandy loam | 5 | |
| Soil depth | Shallow | 2 | 5 |
| | Moderately shallow | 3 | |
| | Deep | 4 | |
| | Very deep | 5 | |
| | Rock land | 1 | |
| Slope | <5$^0$ | 5 | 10 |
| | 5$^0$-10$^0$ | 4 | |
| | 10$^0$-15$^0$ | 3 | |
| | 15$^0$-20$^0$ | 2 | |
| | >20$^0$ | 1 | |
| LU/LC | Built - up land | 2 | 10 |
| | Cropland | 4 | |
| | Fallow land | 3 | |
| | Land with scrub | 2 | |
| | Land without scrub | 2 | |
| | Plantations | 4 | |
| | Water bodies/River | 5 | |
| | Hill and forest | 1 | |

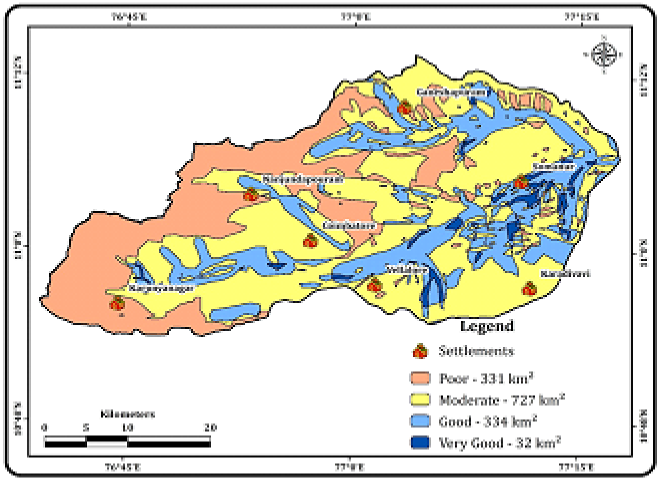


**Figure 11.** Groundwater potential zone map

**Groundwater potential zone**

Figure 11 illustrated the groundwater potential zone map of the study area was classified into four zones – very good, good, moderate and poor. The maximum study area falls under moderate potential zone which covers 727 km$^2$ area, spreading all over the entire study area and found largely in the flat terrain. Good potential zone (334 km$^2$) and very good potential zone (32 km$^2$) were mainly found close to the waterbodies (lakes, rivers, etc) where major cultivation is practiced and also covered by fallow land. Poor potential zone (331 km$^2$) was found in the hilly terrain of upstream region and granitic terrain in the downstream region, indicating high runoff and less infiltration.

## V. CONCLUSION

Integrated use of RS and GIS techniques proved to be a powerful tool for demarcating different groundwater prospective zones in the study area. Various thematic maps (i.e., geology, geomorphology, drainage and drainage density, lineament and lineament density, soil map, soil texture, soil texture and LU/LC) were produced from the geospatial environment which plays a significant role in storing and transmit groundwater. All the maps are integrated with weighted to generate a final map, GWPZM. Based on the GWPZM, the study area was divided into four zones, viz., very good, good, moderate and poor. The present study shows that 32 km$^2$ out of the total study area are identified as "very good groundwater potential zones". The reason for favorable of groundwater occurrence in this region is due to the factors like the occurrence of highly weathered, low gentle slope resulting in slow surface runoff which means slow infiltration rate of the region. It also shows that an appreciable amount of groundwater occurrence is highly possible due to very low drainage density and adjacent to the stream channels. The region having higher lineament length density is very good for groundwater potential since lineaments are described as a permeable zone. Geospatial technologies evidence the major role being taken to explore and delineate groundwater recourses in any areas to a large extent with low cost, short time and low labor. The map obtained by this method provides information about subsurface water condition of the area. The study suggested that the GWPZM generated will serve as useful guidelines for planners, engineers and decision makers providing quick decision- making in the management of groundwater resources, site selection for GW exploration and exploitation.

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