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Application of geospatial techniques in delineation of groundwater potential zones of Vannathangarai Watershed of Noyyal River Basin, Tamil Nadu, India

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ABSTRACT

In ancient times, the venerable Greek philosopher, Thales Miletus is believed to have proclaimed that "the best of everything is water". Down the centuries, Leonardo da Vinci extolled water as the "driver of nature". It is difficult to conceive of any facet of human development that does not ensure a ready availability of water (Ghosh Roy, 2015). Water is the most abundant substance on Earth, the principal constituent of all living things, and a major force constantly shaping its surface (Chow, Maidment & Mays2010). Groundwater is widely distributed under the ground and is a replenishable resource, unlike other resources (Raghunath 2018).

The Vannathangarai watershed has been chosen for a pilot study for the present research using geospatial techniques.The fundamental goal of the study is to identify potential groundwater zones for the appraisal of groundwater availability in Vannathangarai watershed using geospatial tools. There is considerable change in the land use and cropping pattern in the study area over the last few years. Over dependence on groundwater for domestic, irrigation and industrial purposes in the area has led to the lowering of the water table and caused water scarcity. All these activities have made the water contaminated beyond permissible limits. In this scenario, it is high time to have a study on groundwater potential zones in the area. The identification of groundwater prospecting zones can be identified with the help of overlying different thematic layers like Geomorphology, Geology, Soil, LULC, Drainage density, with help of Remote Sensing and GIS techniques. The normalized weight of the individual themes and their different features were obtained through the Saaty's Analytical Hierarchy Process (Saaty, 1980). Each layers of the theme were given different ranks, depending on their significance in groundwater prospects. Based on all these parameters and weightages, the potential zones are identified. The identification of Potential zones in the area will help the planners for having a proper management in the area where ground water is at high risk.

Keywords:
Groundwater Potential Zones, Analytical Hierarchy Process, Sustainable Development, weighted Overlay method, lineament, drainage density

1. Introduction:

Water on Earth exists in a space called the hydrosphere. Water circulates in the hydrosphere through the maze of paths constituting the hydrologic cycle. Of the Earth's fresh water resources, about two-third is polar ice and most of the remainder is groundwater going down to a depth of 200 to 600m (Chow, Maidment & Mays2010). Ground water is the Earth's largest accessible store of freshwater and, excluding ice sheets and glaciers, has been estimated to account for 94% of all fresh water. Forty percent of groundwater is held within one km of the ground surface (Ward & Robinson 2011). In general, the term groundwater or sub surface water refers to the water that occurs below the surface of Earth. The

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main source of groundwater is infiltration. (Reddy 2011)

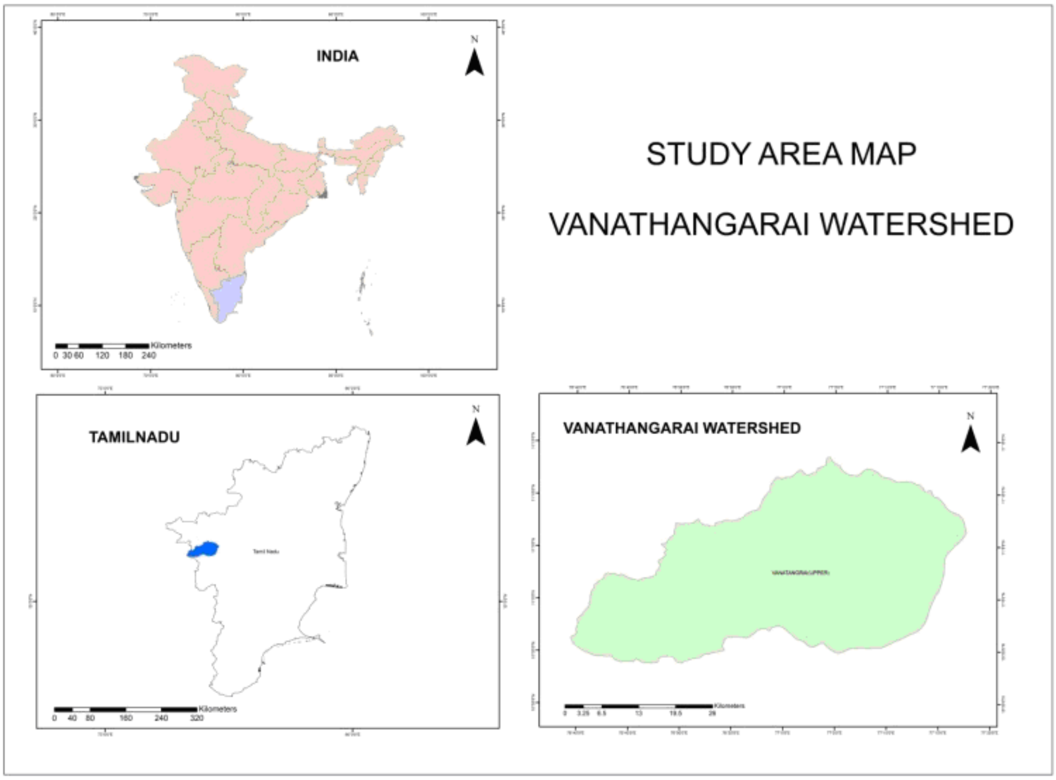
The amount of water on Earth is maintained by the process of hydrological cycle. Water from the land, reaches the atmosphere through evaporation. It reaches back to the Earth through condensation followed by precipitation. The water that reaches the Earth's surface either runs away to the sea as runoff or percolates into the ground through infiltration. This water which reaches the subsurface layers of the Earth is stored in different formation like aquifers. It is this water, which is exploited by us through open wells and tube wells.

One major feature of groundwater is that, it is least affected by external pollutants. Such a valuable resource is being over exploited in many parts of the world today by the overwhelming population in such a way that in many parts of the world the water table has gone down considerably in the recent times. In such a situation, where there is no judicious or planned effort in the utilization of this resource, an attempt is made to study about the potential ground water areas of Vannathangarai water shed of River Noyyal basin, which is a sub basin of the major Kaveri river basin, using geospatial techniques.

Hydrological applications such as groundwater for resources assessment, planning, soil erosion and urban drainage system based on remotely sensed data derivative has gained popularity with the advent of raster and vector GIS environment (Burrough 1986, Brown 1995 and Lyon 2003). Groundwater prospecting and development require large amount of diverse data from various sources. Since groundwater occurance is a subsurface phenomenon, its prospecting is based on indirect analysis of some directly observable terrain features like geological, geomorphological, structural features and their hydrological characteristics(Senthil & Shankar 2014). A number of studies has been conducted in this field in many other parts of the world. Das et al (1997); Saraf & Choudhary (1998); Teeuw (1999); Goyal et al (1999); Murthy (2000); Bahuguna et al (2003); Lokesh et al (2005); Vijith (2007); Suja Rose & Krishnan (2009) etc has attempted to study about the potential groundwater zones with the help of remote sensing and GIS techniques.

2. Study Area

The study area of Vannathangarai watershed of the Noyyal river basin, which drains into river Kaveri,



Map 1: Study Area

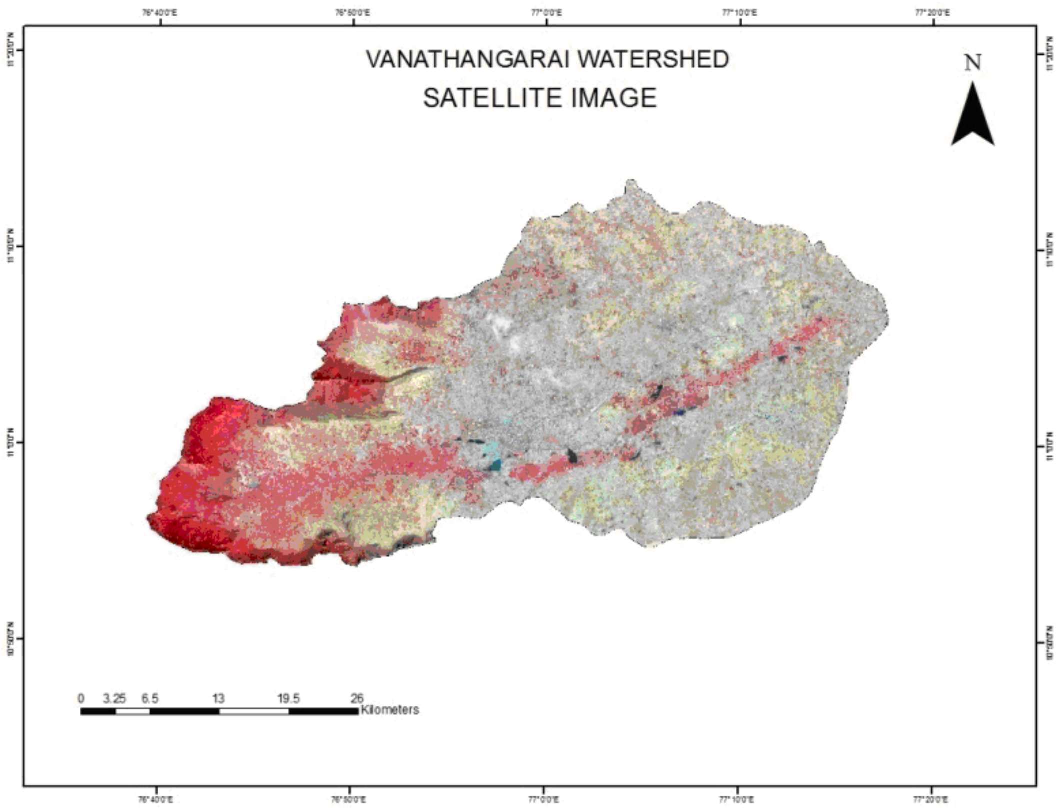
includes part of both Coimbatore and Tirupur districts of Tamilnadu. The Noyyal is a tributary of the Kaveri and originates in the Velliangiri Hills. The river travels through the cities of Coimbatore and Tiruppur and meets the Kaveri at Noyyal in Karur district. The "Noyyal" is a sacred river in Tamil history. It was originally known as Kanchi Nadi, and only later came to be known as Noyyal, which means "one who is free of illness."

Coimbatore district occupies a major share of the region, while only marginal areas of Tirupur district is confined to this watershed. It is bounded by Palakkad district of Kerala to the West, Nilgiris district to the North, Tirupur to the North and East and parts of Coimbatore district to the South. This watershed is of paramount importance as the headwaters of the river Noyyal lies inside this. The western portion of the watershed embraces a small portion of the leeward side of the Western Ghats above the Palakkad gap.

This is the most thickly and densely populated area of the whole Noyyal river basin. The area is criss crossed by several transport networks including national highways, railway stations and air port. Another notable feature is the presence of major tanks like, Perur lake, Selvampathy lake, Kumaraswamy lake, Narasampathy lake, Selva Chintamani lake, Ukkadam Periyakulam, Valan Kulam, Kurichi tank. More of vegetation is seen along the western region of the watershed while traversing to the other regions, settlements can be seen more. (Map 1)

Materials and Methods

The present study is done with the help of thematic layers generated from both primary and secondary sources. Several thematical layers have been used for the identification of groundwater potential zones. Various thematic maps like geomorphology, geology, slope, lineament density, drainage density, land use / land cover, hydrogeology, soils and rocks & minerals were prepared. The Geomorphology details were extracted from Bhuvan Geo portal. The Geology details and lineaments were taken from GSI Bhukosh website. Slope and Drainage Density details were extracted from SRTM DEM data. The LULC details were extracted from LANDSAT 8 OLI of 15 March 2019. Soil details



Map 1: Satellite image of the study area

were collected from Soil & Land Use Survey of India.

Image processing was done in ERDAS IMAGINE 2015 using supervised classification. The maps were prepared in ArcGIS 10.1. The LULC classes were typified based on NRSC (National Remote Sensing Center) level 1 classification. The Kappa value is 0.85. Suitable weights were assigned to the seven themes and their individual features after understanding their hydrogeological importance in causing groundwater occurrence in the study area.

The normalized weights of the individual themes and their different features were obtained through the Saaty's analytical hierarchy process (Saaty, 1980). Each layers of the theme were given different ranking depending on their significance in groundwater prospect. The weights assigned to different features of the individual themes and the ranks of each units of particular theme are presented in Table 1.

Suitable ranking on a scale of 'six' are assigned to each class (factors) of a particular thematic layer on the basis of their significance with reference to their ground

Table 1. Ranks and Weight attributed to different thematic layers

Theme	Weightage	Features Identified	Source	Rank	Groundwater Potential
Geomorphology	32	Colluvial fan	Bhuvan Geo portal	1	Very poor
		Weathered hill top		2	Poor
		Inselberg		1	Very poor
		Moderately buried pediment		2	Poor
		Moderately buried pediplain		4	Good
		Pediment/ valley floor		1	Very poor
		Ridge type of structural hills		1	Very poor
		Shallow buried pediment		2	Poor
		Shallow weathered pediplain		3	Moderate
		Upper shallow bajada		5	Very good
		Shallow flood plain		6	Excellent
Geology	26	Carbonatites	GSI	2	Poor
		Feasible hornblende biotite gneiss		3	Moderate
		Granite		1	Very poor
		Granitoid gneiss		2	Poor
		Purple conglomerate		4	Good
		Sandstone and shale		5	Very good
		Quartz vein		3	Moderate
		Sand & silt		6	Excellent
		Shale with bands of limestone		6	Excellent
		Syenite / nepheline syenite		2	Poor
		Ultrabasic rocks		1	Very poor
Lineament density	8	High	GSI	6	Excellent
		Medium		5	Very good
		Low		3	Moderate
Drainage density	13	Very low	SRTM DEM	2	Poor
		Low		3	Moderate
		Moderate		4	Good
		High		5	Very good
		Very high		6	Excellent
Slope	5	Nearly level	SRTM DEM	6	Excellent
		Gentle		5	Very good
		Moderate		4	Good
		Moderately steep		3	Moderate
		Steep		2	Poor
		Very steep		1	Very poor

Theme	Weightage	Features Identified	Source	Rank	Groundwater Potential
Land use/ land cover	7	Forest	Landsat 8	5	Very good
		Water bodies		6	Excellent
		Waste land		1	Very poor
		Agricultural land		4	Good
		Settlement		2	Poor
Soil	9	Deep clayey soil	National Bureau of Soil Survey and Land Use Planning	1	Very poor
		Shallow red gravel loam		4	Good
		Shallow calcareous gravel loam		3	Moderate
		Medium deep red loam		5	Very good
		Shallow red gravel clay		2	Poor
		Deep calcareous clay		1	Very poor
		Medium deep red gravel loam		3	Moderate
		Deep to very deep red clay		1	Very poor
		Rocky lands		1	Very poor
		Very shallow red loam		6	Excellent

water potential. The first rank classes are considered as least favourable zones for ground water exploration and sixth rank is for most potential. So themes are classified based on their ground water potential as excellent, very good, good, moderate, poor and very poor. The final scores of each unit of the theme are equal to the product of the rank and weightage. This is calculated using 'raster calculator' and the entire study area was quantitatively divided in to six ground water potential zones and a map showing these zones were prepared using ARC-GIS 10.3.

Results & Discussion

4.1. Geomorphology

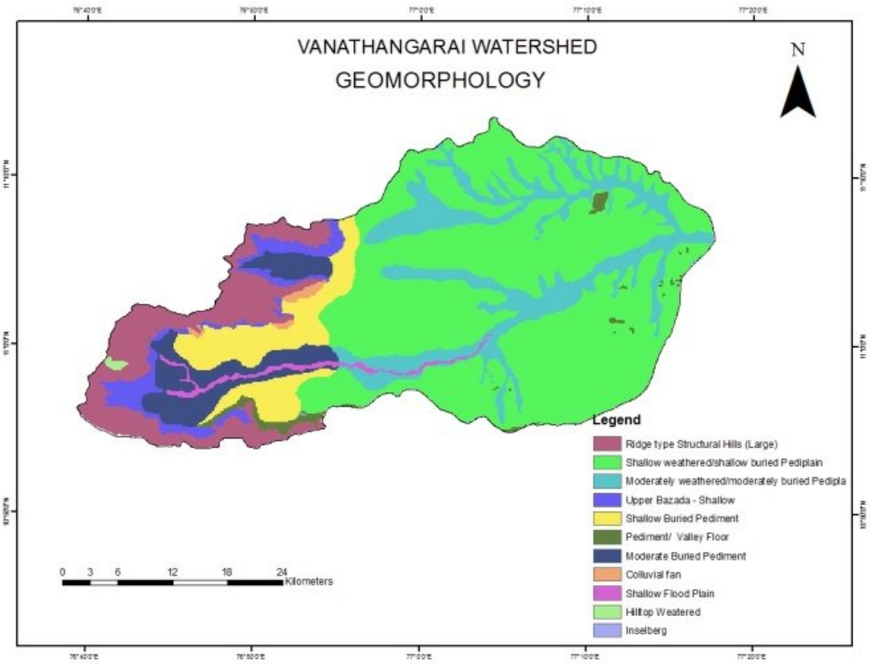
Geomorphology is that branch of Physical geography which studies about the spatial distribution and description of Earth's topographical features. Geomorphology is simply the science of landforms. According to Davis(1914), "landform is the function of the structure, process and stage". Hijulstorm (1935) defined geomorphology as the "science of land forms and land forming processes. A.L.Bloom (1935) defined geomorphology as the "systematic description and analysis of the landscape and the processes that change them. "

Analysis of the geomorphic characteristics of the study area shows that almost half of the area, comprising the northern and central part is coming under shallow weathered/ shallow buried pediplain. The major geomorphic features observed in this region are Colluvial fan, Weathered hill top, Inselberg, Moderately buried pediment, Moderately buried pediplain, Pediment/ valley floor, Ridge type of structural hills, Shallow buried pediment, Shallow weathered pediplain, Upper shallow bajada and Shallow flood plain. Colluvium is the soil and debris that accumulate at the base of a slope by mass wasting or sheet erosion. An inselberg or monadnock is an isolated rock hill, knob, ridge, or small mountain that rises abruptly from a gently sloping or virtually level surrounding plain. A pediment is a very gently sloping inclined bedrock surface. Pediplain is an extensive plain formed by the coalescence of pediments. Among the geomorphic features flood plain has the highest water potential where as inselberg, colluvial fan and pediment has the least potential. (Map 2)

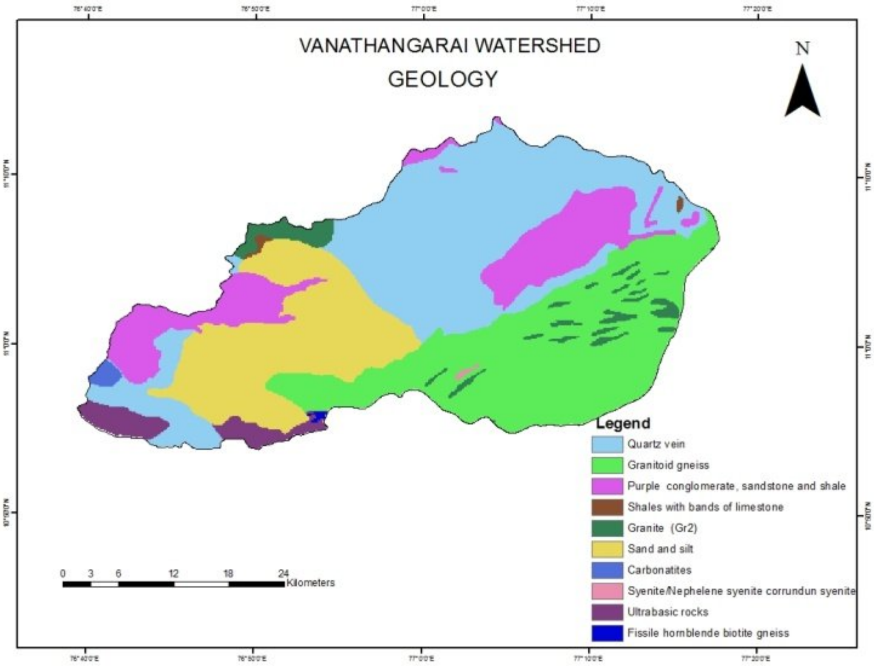
4.2. Geology

Geology deals with the physical structure and substance of the Earth, their history, and the processes which act on them. The major geological features seen in the region are Carbonatites, Feasible hornblende biotite gneiss , Granite, Granitoid gneiss, Purple conglomerate, Sandstone and shale, Quartz vein, Sand & silt, Shale with bands of limestone, Syenite / nepheline syenite, Ultrabasic rocks. Major part of the study area falls under quartz vein.

Quartz veins are found in association with all rock types: massive rocks, banded rocks, and micaschists. Almost the full eastern portion of the watershed is covered by Granitoid gneiss. *Granitoid gneiss* is a variety of gneiss that exhibits many of the properties characteristic of granite. Among all these features granite and ultra basic rock has the lowest potential where as sand, silt, limestone and shale has the highest potential. (Map 3)



Map 2: Geomorphology
Source: Bhuvan Geo Portal



Map 3: Geology
Source: GSI Bhukosh Portal

4.3. Lineament Density

Lineaments are very important from the groundwater point of view as they control the movement and storage of groundwater. (Biswajit & Sunilkumar, 2016). A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. Lineaments are structurally controlled linear or curvilinear features, which are identified from the satellite imagery by their relatively linear alignments. These features express the surface topography of the underlying structural features.

Lineaments represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. These factors are hydro-geologically very important as they are the path ways for groundwater movement. Lineament density of an area can indirectly reveal the groundwater potential, since the presence of lineaments usually denotes a permeable zone. Areas with high lineament density are good for groundwater potential zones (Haridas et al., 1998). The groundwater prospects were high in the area coming under high lineament density and lower in low lineament density area. (Map 4).

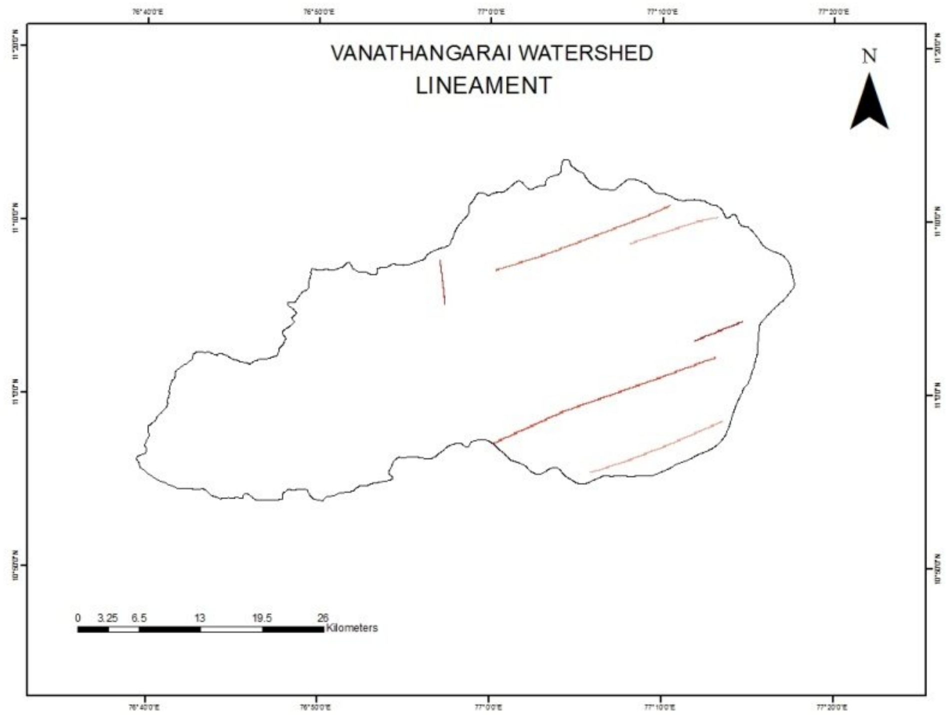
4.4. Drainage Density

Drainage density (D_d), expressed as a ratio of the total channel length of streams of all orders in a basin to the basin area, was introduced as an important morphometric parameter by Horton (1932). D_d is an important indicator of the linear scale of landform elements in fluvial topography. It indicates the closeness of spacing of channels, providing a quantitative measure of the average length of stream channel for the basin.

High drainage density is the result of weak or impermeable subsurface material, sparse vegetation and high relief. High drainage density gives rise to a fine drainage texture, while low drainage density results in a coarse texture (Strahler, 1964). In the study area, drainage density is observed to be higher along the stream, which suggested a higher groundwater potential and it was less in its peripheral areas indicating a low potential zone.(Map 5).

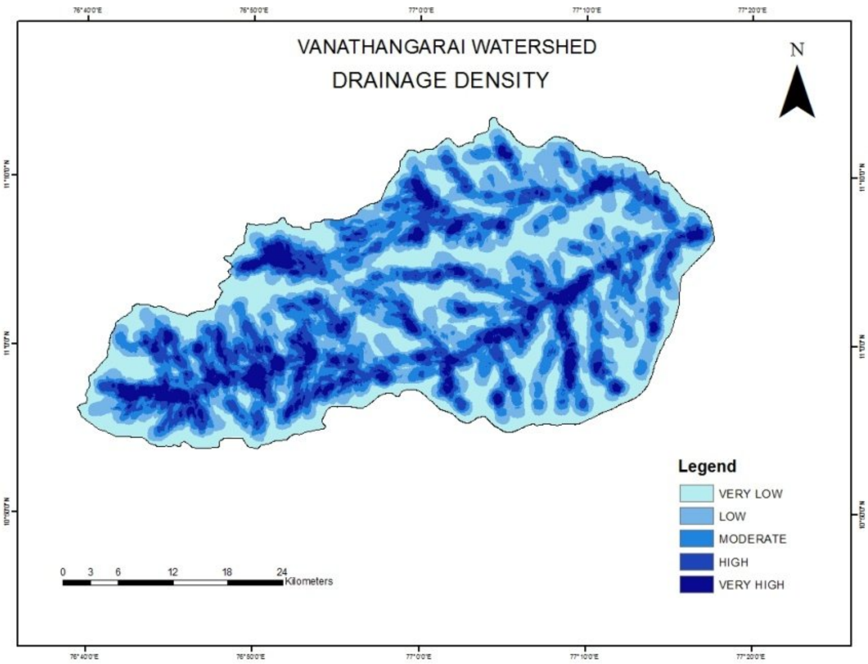
4.5. Slope

Slope is a measure of change in elevation. Slope can be defined as the angle, inclination, steepness, or gradient

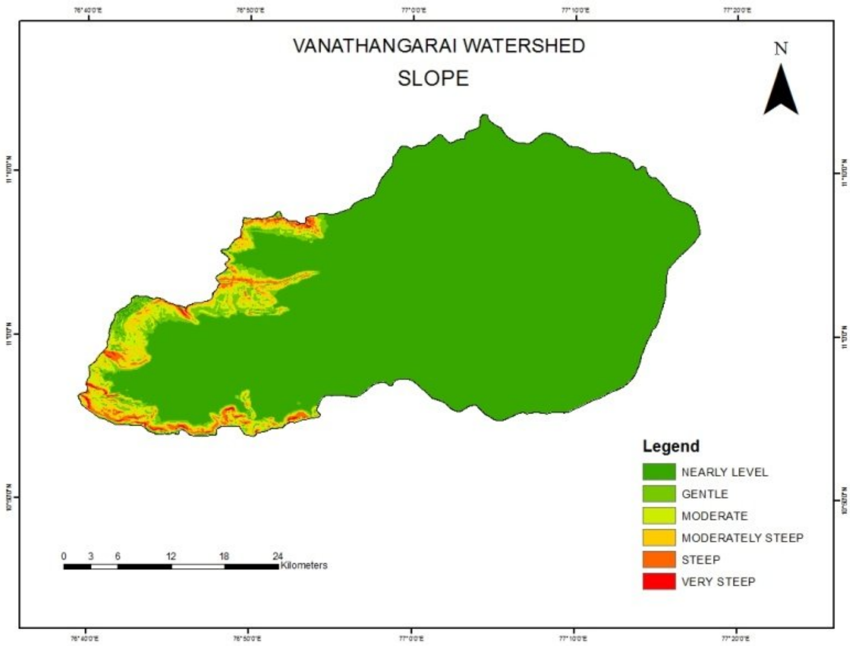


Map 4: Lineament

Source: GSI Bhukosh Portal



Map 5: Drainage density
Source: SRTM DEM



Map 6: Slope
Source: SRTM DEM

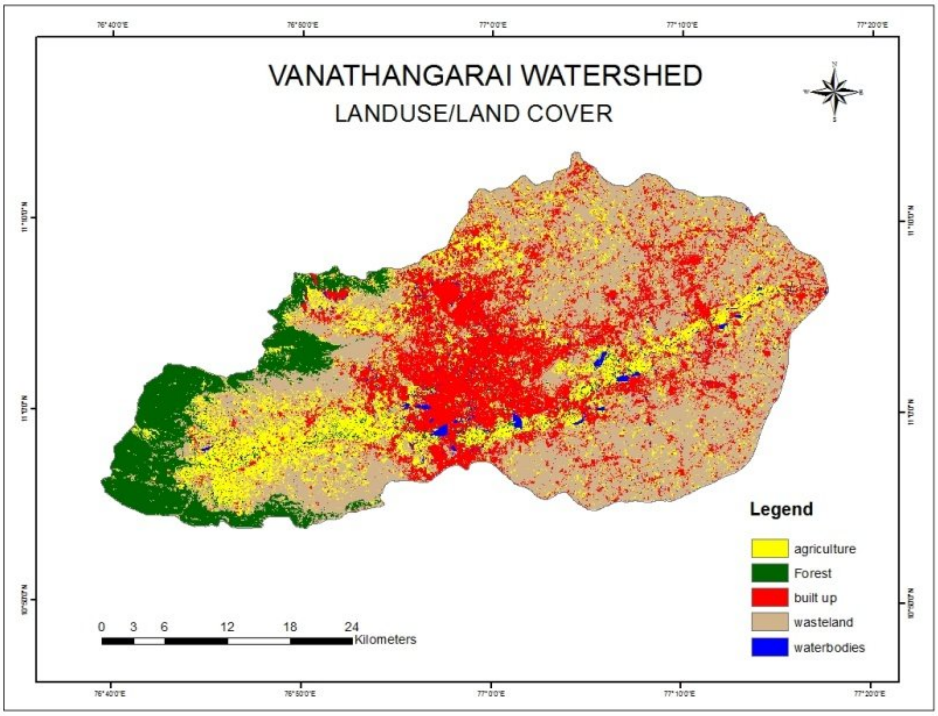
of a straight line. Slope often is used to describe the steepness of the ground's surface. Slope can be measured as the rise (the increase in elevation in some unit of measure) over the run (the horizontal distance measured in the same units as the rise). The relationship between the slope and the ground water potential is inverse, i.e an area with a steeper slope is poor in potential while an area having a level land is good in potential. In the present study area, a lion share of the region falls under gently sloping terrain whereas along the western fringes some areas have low to medium slope. (Map 6).

4.6. Land use / land cover

The term land cover narrates to the type of characteristic present on the surface of the Earth where as land use refers to the human activity relating with specific piece of land (Lillesand & Kiefer, 1979). Land use/ land cover mapping is one of the significant applications of remote sensing as it plays a considerable role in the development of groundwater resources (Waikar & Nilawar, 2014). The major land uses noticed in the area are Forest, Water bodies, Waste land, Agricultural land, Settlement . Forest is seen only along the western region, along the hilly tracts. In almost all other regions, waste land and settlements dominate. Almost the entire eastern, northern and central portion is characterised by preponderance of waste land and settlements. Agricultural areas are seen scattered throughout the region with a maximum towards western half. Forest and agricultural lands indicate a higher groundwater potential while waste land and settlements show a poor potential. (Map 7).

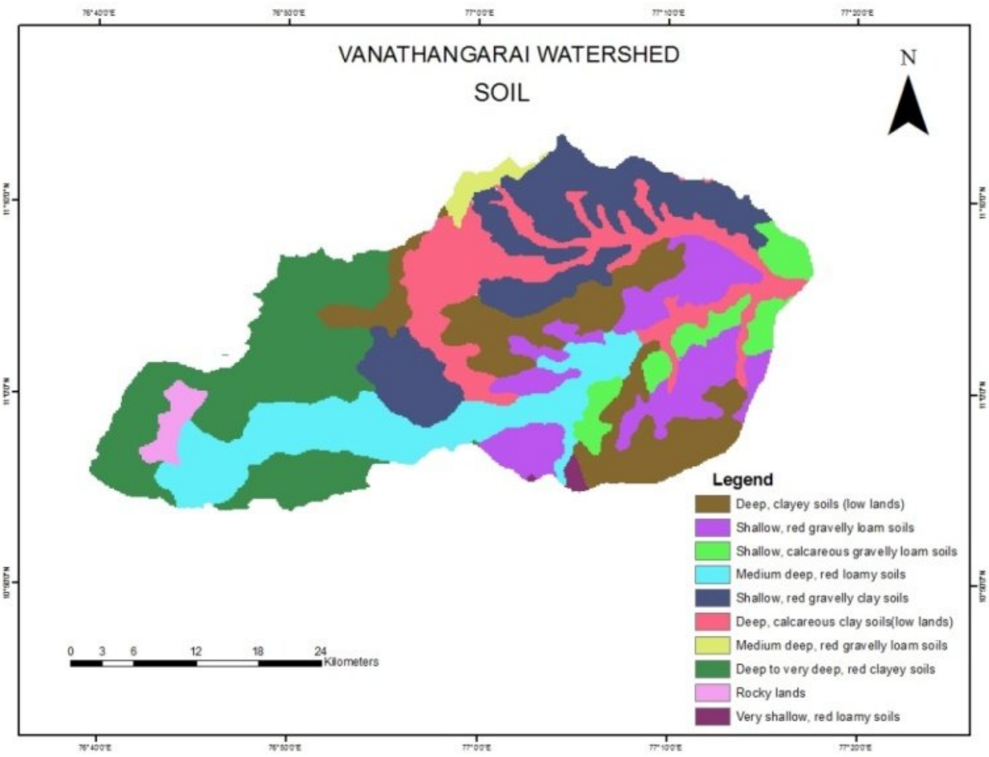
4.7 Soil

Soil is the upper layer of Earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. According to USDA, soil is the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants. Soil is one of the natural resources, which is an important parameter to delineate potential groundwater zones and it plays a vital role in groundwater recharge and encounters the basic requirements of all agricultural production (Radhakrishnan & Ramamoorthy, 2014).



Map 7: Land use

Source: LANDSAT 8 OLI



Map 8: Soil

Source: Soil and Land Use Survey of India

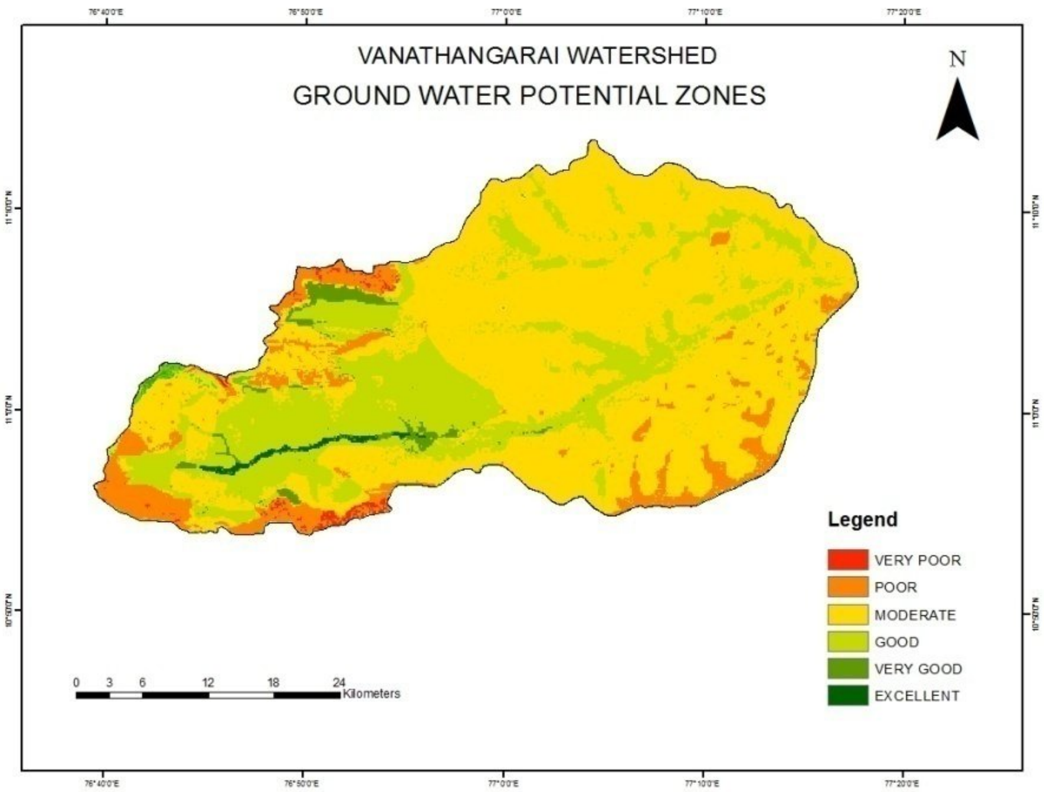
Soil features invariably control penetration of surface water into groundwater system and they are directly related to the rates of infiltration, percolation and permeability and those affects the water holding and infiltrating capacity of a soil(Sedhuraman et al., 2014). The major soil types seen in the study area are deep clayey soil, shallow red gravel loam, shallow calcareous gravel loam, medium deep red loam, shallow red gravel clay, deep calcareous clay, medium deep red gravel loam, deep to very deep red clay, rocky lands andvery shallow red loam. The soil types which support good groundwater potential are medium deep red loam and very shallow red loam, where as deep clayey soil, deep calcareous clay and rocky lands are very poor in potential. (Map 8).

4.8. Groundwater Potential Zones

All the above said thematical layers were examined in detail. The normalized weights of the individual themes and their different features were obtained through the Saaty's analytical hierarchy process (Saaty, 1980). Each layers of the theme were given different ranking depending on their significance in groundwater prospect. Accordingly the weightage assigned to each theme is Geomorphology (32), Geology(26), Drainage Density(13), Soil (9), Lineament density (8), LU/LC(7) and Slope(5). Consequently Geomorphology is the major determinant of groundwater Potentiality followed by Geology, Drainage Density, Soil, Lineament density , LU/LC and Slope.

The final output indicates that a most of the study area comes under the category of moderate potential. Almost the full of northern and eastern portion comes under this category. The potential is excellent immediately along the river course and gradually changes to very good and good moving progressively away from the water source. Along the western fringes, where the terrain is rocky, the potential appears to be poor or very poor. (Map 9).

The above result is verified with the databases from different sources like District groundwater brochure for Coimbatore district (2008) which is published by Central GroundWater Board, Coimbatore District Agricultural Plan(2008) prepared by Centre for Agricultural and Rural Development Studies(CARDS), Tamil Nadu Agricultural University and Groundwater profile of Coimbatore district (2014-15) published by Public Works Department, Tamil Nadu. All these reports have classified the Coimbatore district into various zones on the basis of groundwater usage as over exploited, critical and semi critical. All these reports justify the findings of the study. All the area coming under very poor groundwater potential is classified under over exploited category. Those areas having poor groundwater potential is notified as critical and those with moderate potential as semi critical.



Map 9: Groundwater Potential Zone

5. Conclusion

The remote sensing and the geographical information system is an efficacious instrument for the management of water resources, especially groundwater. It is an effective tool in integrating and spatially analyzing the various thematic layers like geomorphology, geology, soil, drainage density, lineament density, land use / land cover, slope etc. The output map which shows the groundwater potential of the study area, classifies the region into 6 major zones namely excellent, very good, good, moderate, poor and very poor.

This analysis is an important method to delineate the groundwater potential zones and this will be of immense help to initiate sustainable developmental activities. In areas of poor groundwater potential, strict control measures should be adopted so as to protect the limited resource. In such areas, artificial recharge measures should be adopted. This study is an example of how geo spatial techniques can be used in a pragmatic way to enable sustainable use of resources.

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