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Research paper

A geo-spatial approach to perceive the groundwater regime of hard rock terrain- a case study from Morappur area, Dharmapuri district, South India

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ABSTRACT

The goal of the present study is to identify the groundwater regime of Morappur area at Dharmapuri district, India. The study area covers an area of 410 sqkm. The area belongs to a hard rock terrain where the primary porosity is feeble and the secondary porosity offered by fracture, joints and shear zones etc, contributes to the groundwater regime. The availability of surface water resources is sparse and hence the groundwater repositories are intensely utilized. In the current study area, the availability of groundwater is limited due to scanty rainfall and poor recharge. The entire study area underlain by hard crystalline rocks of Archaean age, Charnokite and Hornblende epidote gneiss are the main rock types encountered in the area. The over exploitation of these resources more than the adequate recharge has resulted to decrease in the groundwater level. In this context, it is very much important to identify and understand the groundwater regime of this area for the better groundwater monitoring and conservation of this precious resource. Remote Sensing and GIS are playing a vital role in the advancement of hydro-geological studies. The use of conventional methods alone has its own limitations in comprehending the groundwater regime of the area. The integrated study using remote sensing, field studies together with GIS has helped to understand the role of structural, lithological and geomorphic units in controlling the groundwater occurrence and movement in the present study area. Various thematic maps were prepared from the satellite images and they were integrated and incorporated in a GIS platform along with collateral information to study the groundwater regime of Morappur area. The outcome of this study clearly shows the importance of the geospatial studies in identifying the role of satellite imageries and geospatial techniques to understand the groundwater regime of a hard rock terrain.

1. Introduction

The concept of the groundwater environment and regime is mainly based on the combination of physical factors such as climate, topography and geology (PAEL, 1993). These factors and their components play a significant role in deciding the characters of the hydrogeological regime of an area. The present study area is a hard rock terrain with limited groundwater resource and the recharge is also poor due to the scanty rainfall and poor replenishment. The study of the groundwater regime of an area is important for groundwater monitoring and management. Agriculture is the primary occupation of the residents in this area. The irrational and intense use of precious groundwater is a threat to the agriculture occupation and for other indispensable needs in future. Due to the tremendous growth of human population, the natural resources suffer severe pressure to produce sufficient food and raw materials (Sitender, 2015). Hence, the study of the groundwater regime is significant in this area. The conventional methods alone will not be sufficient to carry out the current studies and also it will be time-consuming. The remote sensing and GIS techniques are widely used in hydro geological studies. But the geospatial approach will reduce the cost and time of the study. Many of the previous studies proved the importance and acceptance of the use of geospatial approaches in groundwater studies in hard rock terrain (Das et al., 2007; Vijith, 2007; Singh et al., 2013, Politi et al 2016) and most of the conventional field methods are typically site-specific (Kishel and Gerla, 2002). (see Fig. 1)

Groundwater accounts for about 30% of the earth's freshwater

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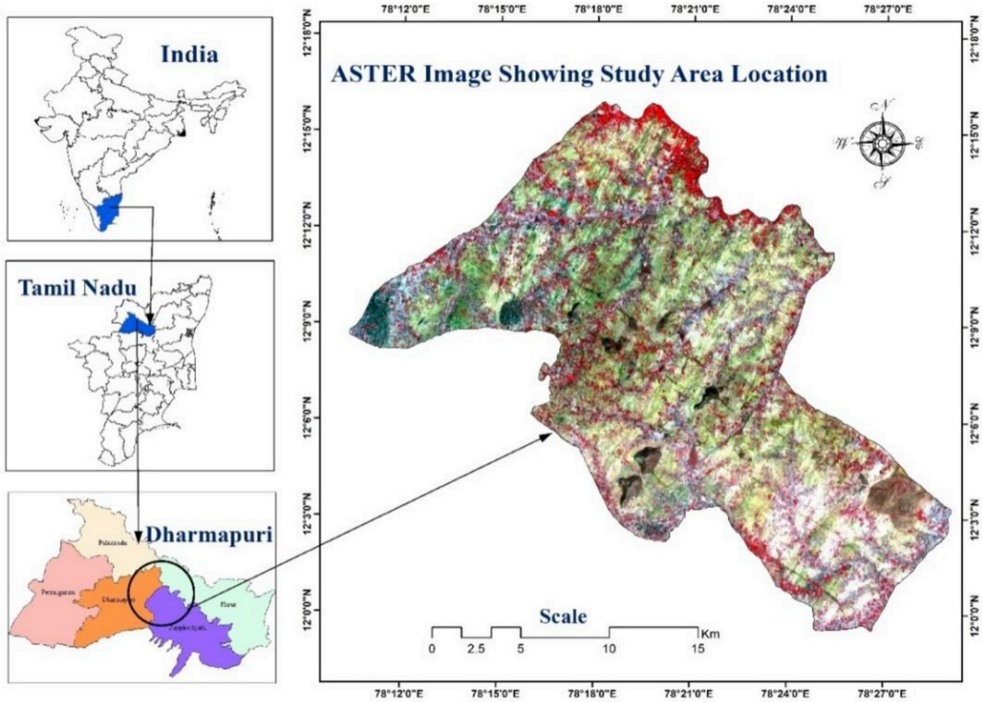

Fig. 1. Location map of study area.

(Shiklomanov, 1993). The over-exploitation of groundwater resources will lead to ecological problems such as fall off groundwater levels, water exhaustion, water pollution, deterioration of water quality and sea water intrusion (Yeh et al., 2014). The occurrence and movement of groundwater resource mainly depend on the aquifer characteristics of the region which is directly or indirectly influenced by geology, geological structures, lithology, geomorphology, soil texture, drainage patterns, lineament, land use/land cover, climate, extent of fractures, depth of weathering, topography, primary porosity, secondary porosity, slope, rate of precipitation and infiltration rate (Mukherjee, 1996; Jaiswal et al., 2003; Shekhar and Pandey, 2014; Selvam et al., 2015; Sathish and Elango 2016). The groundwater occurrence in the hard rock region is dominantly controlled by secondary porosity such as fault, fold, joints, etc. (Das, 2017), The distribution and migration of groundwater in hard rock terrains are variable and are dependent on the character, origin and size of secondary porosity either formed by weathering or tectonic activity. Irrelevant to the availability of secondary porosity and its dimension, the groundwater replenishment in the hard rock terrain takes place by rainfall as well. Geomorphic controls are also a deciding factor of the groundwater occurrence. Geological structures such as fault, fold, joints in shear zones have a major bearing on the groundwater aspects of any area (Elhag and Elzien, 2013; Mohamed, 2015), especially in hard rock terrain. This is due to lack of primary porosity in these rocks, except in the top most weathered horizon. Most of the parts of South India are characterized by crystalline and metamorphic rocks which are not rich in groundwater (Pullare, 2006). In such instance, they are the only secondary porosity which offered by joints, fractures and shear zones that contribute to the groundwater regime.

The Remote Sensing satellite data can provide information regarding numerous factors which directly and indirectly controlling the occurrence and movement of groundwater in the aquifer (Engman& Gurney, 1991; Meijerink, 1996; Jha et al., 2007; Machiwal et al., 2010). The GIS provides a quick and efficient platform for managing the large database and complex spatial data and non spatial data for the sustainable natural resource management (Machiwal et al., 2010; Stafford, 1991). The Remote Sensing data alone cannot be sufficient to provide the information of the groundwater regime of the area. However, the surface regime (topographical, hydrological, geological, landuse/landcover) which primarily governs the subsurface water conditions can be studied and mapped using remotely sensed image data. In the context of such remote sensing for groundwater exploration, the various surface features or indicators can be grouped into two categories viz. 1) first-order or direct indicators and 2) Second-order or indirect indicators. The first-order indicators are directly related to the groundwater regime (viz. recharge zones, soil moisture and vegetation). The second order indicators are those hydro geological parameters which regionally indicate the groundwater regime for e.g., rock/soil types, structures, rock fractures, landforms, drainage characteristics etc (Anbazhagan et al., 2005). Therefore, Remote Sensing plays a vital role and an efficient tool for regional and local groundwater exploration (Elbeih, 2015). The geospatial techniques can provide quick and cost-effective outputs with different spatial and temporal resolution. The conventional methods demand a lot of money and energy but the geospatial studies are quick and cost effective. Remote sensing studies have been used as a major geospatial tool to map the various thematic maps of the Morappur region. Geographical information system gives a platform for the integration of these thematic maps and other collateral data for this study.

In a drought-prone area such as Dharmapuri district, Tamilnadu State of South India has poor groundwater resources due to the excess use and poor recharge. This hard rock terrain is mostly fed by the secondary porosity offered by the faults, fractures, joints etc., in such a scenario, it is essential to have a detailed understanding of the structural, lithological and geomorphic detailsof the area, to have a better picture of the groundwater regime. The present study deals with mapping of structural, lithological and geomorphic elements of the drought-prone hard rock terrain in Dharmapuri district.

2. Study area and data

The study area (Fig. 1) lies between the latitude 11°59′32″ to 12°15′54″ North and longitude 78° 10′ 53″ to 78° 24′ 42″ East, covering an area of 410 sqkm in the Dharmapuri district of Tamil Nadu. The study area is an undulating terrain with elevations between 344 m in the East 470 m above mean sea level in the West. It is a drought prone semi-arid

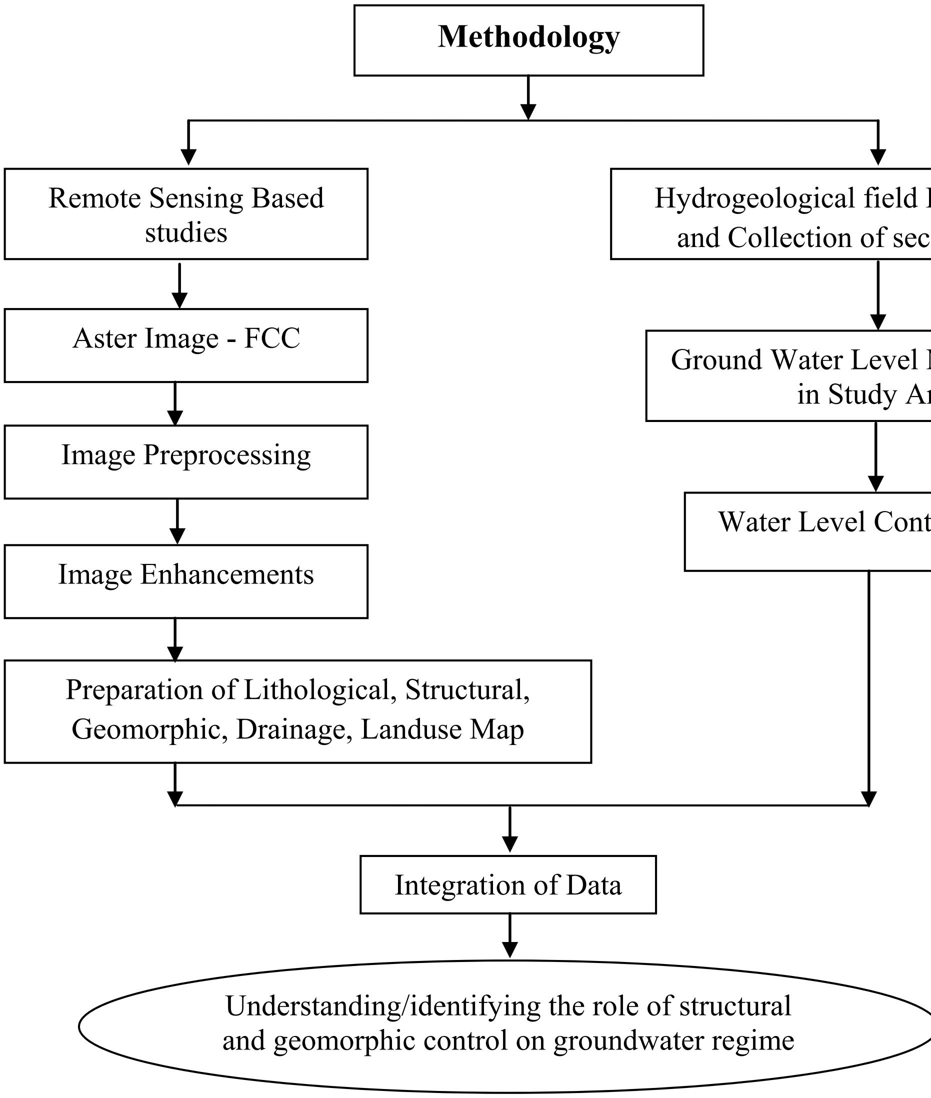

Fig. 2. Flowchart of methodology adopted.

region with hottest summer and cool winters. The area experiences good rainfall during the southwest monsoon (June–August) and northeast monsoon (October–December) seasons. Temperature of the area varies from 20 °C to 38 °C and attains the maximum in the summer seasons. The economy of the study area mainly depends on the agricultural activities. The main crop types are paddy, sugarcane, groundnut, and vegetables. The Ponnaiyar river and its tributaries play a major role in the drainage system of the study area. The entire Study area is underlain by hard crystalline rocks of Archaean age comprising of various rock types such as Gneiss, Charnockite, etc.

In the present study, various satellite data has been used for the preparation of various thematic maps. ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) is an imaging instrument flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS), which is collected on 15th Feb 2010. In this study ASTER-FCC (False Color Composite) has been used to generate various thematic maps. ASTER captures high spatial resolution data in 14 bands from the visible to the thermal infrared wave lengths and provides stereo viewing capability for digital elevation model creation. ASTER obtains high spatial resolution (15–90 m) images of the Earth in the visible near-infrared (VNIR), shortwave-infrared (SWIR) and thermal infrared (TIR) regions of the spectrum. The Landsat TM image was also used to prepare the landuse/landcover map. The ASTER DEM has employed for the comparison of topography with other DEMs. The SRTM DEM has also been utilized for the study. The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation models on a near-global scale from 56 °S to 60 °N to generate the most complete high-resolution digital topographic database of Earth to date. The digital elevation model of SRTM is also used in this study. SRTM consists of a specially modified radar system that flew onboard the Space Shuttle Endeavour during the 11-day STS-99 mission in February 2000. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). The survey of India toposheet of 1: 50,000 scales and Geology map of 1:250,000 scales were also used in the study. The secondary data such as water level information and well location details had been collected from CGWB. The field investigations have been carried out mapped the dykes and verified the well locations.

3. Methodology

The present study is an updation of a master project which has been carried out in the year 2010. In the current work all the maps and data were updated using the recently available satellite images and collateral data. The methodology adopted in this study includes two major components. First part includes a remote sensing-based studies and the later includes hydrogeological field investigations and collateral/secondary data collection. The combined study of field investigations along with remote sensing studies will give a better understanding of the groundwater regime of the area. The downloaded raw satellite images may contain variety of errors in the geometry and radiometry. The geometric correction, radiometric correction, calibration and noise removal have been carried out on the image. Image preprocessing should be completed before the post processing.

As the part of post processing image enhancement techniques like histogram equalization, contrast enhancement, principal component analysis, normalized difference vegetation index, spatial filtering etc., have been carried out on the satellite images. The image enhancement techniques were used to modify the brightness and contrast of the image to remove the blurriness and to filter out the noise. Enhancement technique intended to improve the visual quality of images. The satellite images after preprocessing are subjected to various enhancement methods for better interpretation. Certain manipulations can be performed on the digital image so as to have better visual presentation or for information extraction. From the enhanced images, various thematic maps were produced. The SRTM DEM is also used to understand the terrain information in detail. The height information from the DEM will give a better outline about the topography of the area. The various thematic information obtained from the image data using ENVI software were integrated to the GIS platform.

To verify the accuracy of the generated maps using satellite images and to add additional details in the maps and to collect data on groundwater parameters, extensive field works have been carried out in the study area. This field work included the following aspects:

- Traversing along and across the strike of formation in the study area
- Mapping, location and extent of the dykes in the study area
- Observing different strike of the formation
- Examining sample of the rocks and noting down the co-ordinates
- Examining/noting down the position of the well location, groundwater level and other detail in the entire study area
- Observing and noting down various geomorphic land use and land cover in the study area
- Photography of geological features in the study area

The role of remote sensing is not only confined to the preparation of thematic maps alone but also to study the detailed synthesis of geological, structural, geomorphic maps and their integrated study with the other baseline information to understand the groundwater regime of the area.

The methodology(Fig. 2) adopted in the study has been given in the following flowchart:

4. Results and discussion

The different thematic maps were prepared using the visual interpretation/analysis of satellite images along with the hydrogeological field investigations and available ancillary data for the study area. The various thematic maps derived from the integrated data set include Geology map, Geomorphology map, Structural map, Land use and Land cover map, Drainge and Drainage density map, Water level contour maps and the well location map. The geospatial techniques serve as an effective and efficient tool for the better understanding of the groundwater potential zones (Muralitharan and palanivel, 2015) of hard rock terrain.

4.1. The various thematic maps and inferences

4.1.1. Geology map

The entire study area is underlain by hard crystalline rocks of Archaean age comprising of various rock types such as Gneiss,

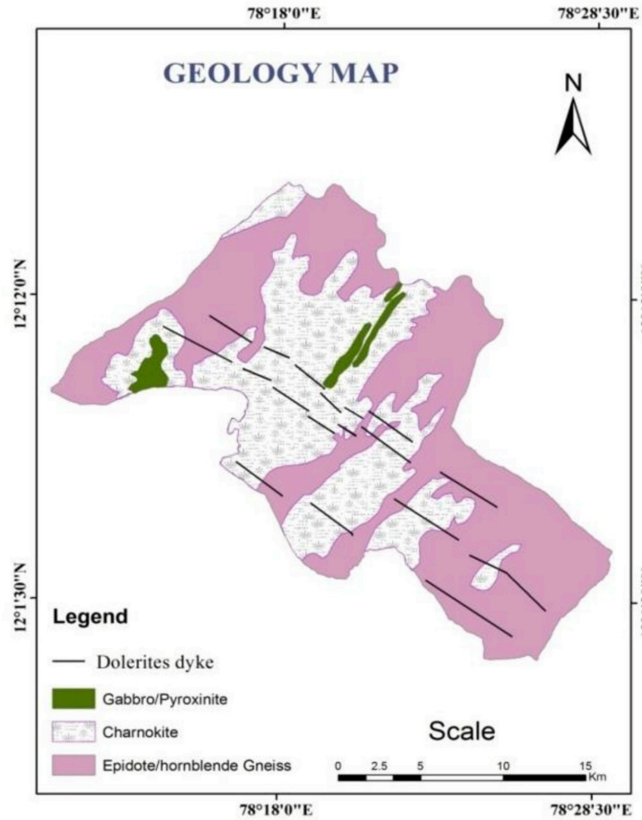

Fig. 3. Geology map.

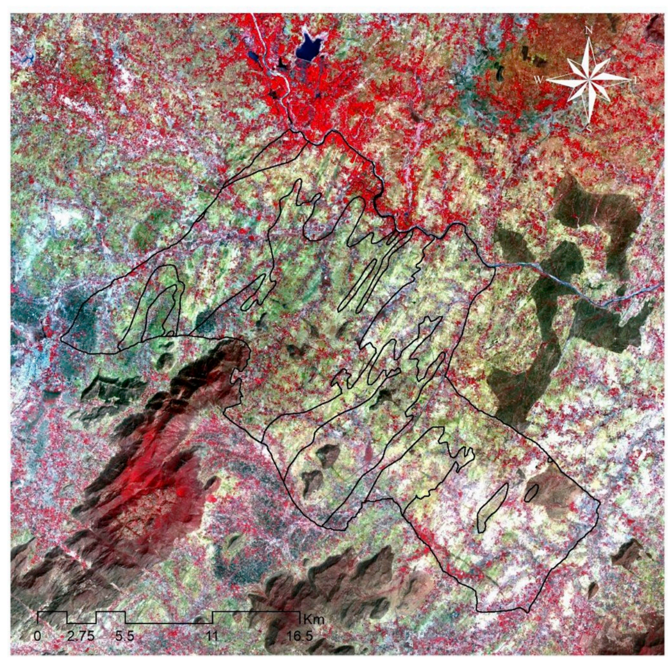

Fig. 4. Satellite image of study area - ASTER.

Charnockite, etc. The gneissic type of crystalline formation is found in the north and north-eastern part of the District. Dharmapuri, Harur, Gopinathampatti and Morappur areas are covered by epidote-hornblende gneiss. Kadathur and kambainallur areas covered by charnockite and gabbro-pyroxinite. Dolerite dyke varying from few feet to few miles in length and cuts across the country rock in this study area

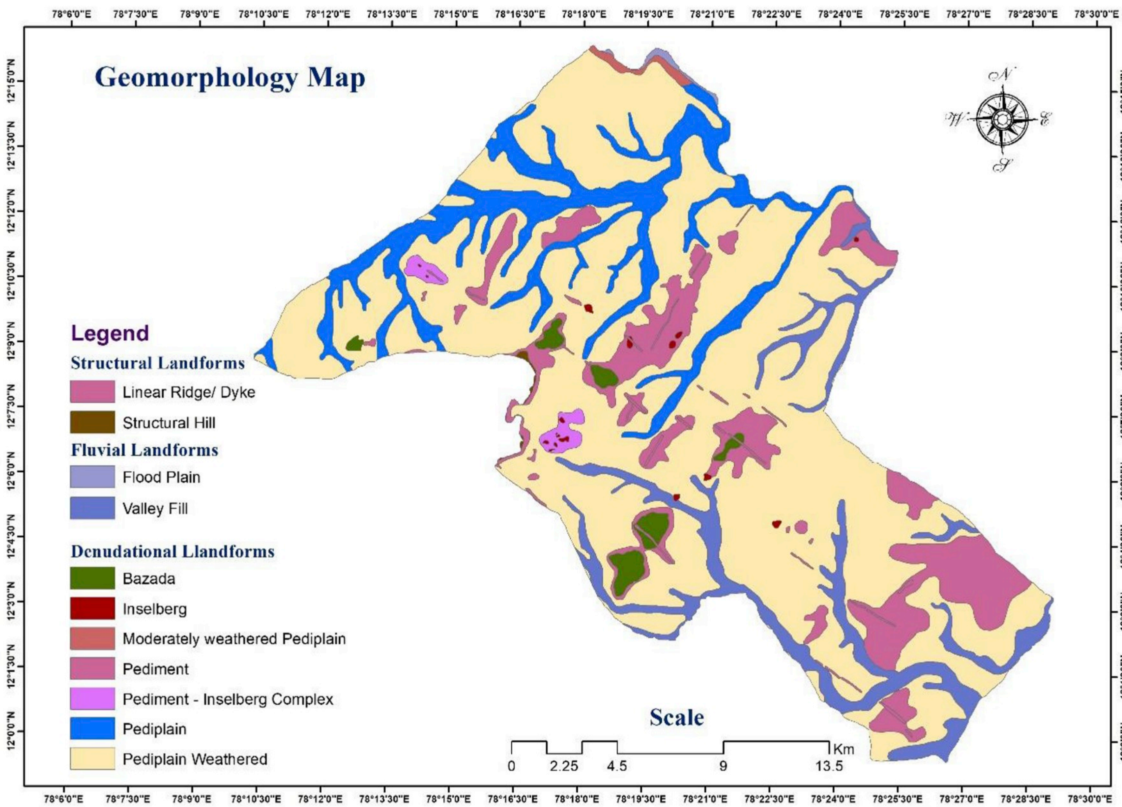

Fig. 5. Geomorphology map.

(see Fig. 3).

Geological map (Fig. 3) has prepared with help of published district resource map prepared by GSI on 1:250,000 scale, and has been updated using satellite data. The contact of the litho units can be accurately marked and extended using the tonal characteristic in satellite imagery with limited ground checking. The structures like dyke, faults and the extension can also be mapped from imagery because of the advantage of synoptic view. However, this data is reliable only if it is used in conjunction with ground truth and other information to get the best output for geological information. Accordingly, adequate ground truth verification was also done by carrying out field work. This study area consists of mainly charnockite and epidote/hornblende gneiss which have been intruded by dykes of varying composition. Epidote hornblende gneiss is the second dominant rocks in the study area. The gneiss which shows light yellowish green colour on the FCC image (Fig. 4) mainly consists of plagioclase and potash feldspar. Gneisses are the oldest country rock in India (see Fig. 5).

4.1.2. *Geomorphology map*

The science of geomorphology is the study of topographic forms/ geomorphic units/landforms Fig. 5. The geomorphic characters of a region have a very strong control on the groundwater regime of the area. The study area includes structural, denudational and fluvial landforms. The major geomorphic units seen in the study area are structural hills, bajada, moderate and shallow buried pediments, valley fills and tanks. Each geomorphic unit has varying effects on the groundwater regime.

Applications of the principle of geomorphology provide information, which will be of value in predicting the geometry of the aquifers. On the weathering and erosion, many geological formations develop land forms that are distinctive in respect of slope continuity of outcrops. The surface topographic features of bedrock can be sometimes extrapolated to reasonable depths to predict the thickness of alluvium or aeolian sands occurring as valley field deposits and by treating slope profile, those can be found. It is well known that hydrologic processes are influenced by geomorphometric properties like local slope angle and drainage density. From the groundwater point of view, the integration of geological, structural and hydrogeological data with hydrogeomorphological data is very much useful to understand the better information about groundwater regime with fruitful results. Satellite remote sensing has been found very useful in delineating geomorphic landform because of its synoptic view, quick and inexpensive techniques for getting information. Various enhancement techniques also helped to identify the different landforms.

4.1.2.1. Residual hills. These are isolated low relief and irregular outlines standing out predominantly and appear as isolated hills or continuous chains of hillocks due to differential erosion. Thus, more resistance formation of rocks stands as residue like hills usually marked with structures such as joints and fractures etc. These are poor for ground water prospecting due to steep gradient and the rain water is washed off immediately without much infiltration. On standard FCC image, it shows brownish tone due to exposed outcrops and varied reddish tone in some area due to partial growth of vegetation.

4.1.2.2. Pediments. Pediment is gently sloping area with erosional bedrocks situated between hills and plains consisting of a veneer of detritus and broad undulating rock floor. These units generally act as run off zones and as well as recharge zone whenever fracture and their intersection are present. The groundwater potential in pediments is poor except along with the fractures where limited quantity of ground water can be obtained for the domestic purpose.

4.1.2.3. Shallow buried pediments. Flat and smooth buried pediment with moderately thick (0–5 m) over burden. The groundwater potential in these geomorphic units is poor.

4.1.2.4. Moderately buried pediments. Flat and smooth buried pediment

Table 1
Score for attributes of various themes in the study area.

Geomorphic Units	Characteristics	No. of Wells	Hydrogeology	Ground Water Potential	Remarks
Structural Hills:	Valleys traversed by structural features	0	Run off zone.	Poor	SW of the study area
Linear Ridges/ Dykes	Composed of composite ridges	15	Run off zone. Little infiltration along secondary features.	Poor	Central part of the study area
Inselberg	Very deep cervical hill	0	Run off zone.	Poor	Very few
Bazada	Alluvial cones and fans, formed after composite slopes boundary	68	More infiltration Recharge zone composed of alluvial materials.	Very good	Bottom of the hills in WESTERN side
Pediments	It forms outcrops with or without soil cover	37	Run off zone. Little infiltration along secondary features.	Moderate	SE of the study area
Pediplain	Sloping area with erosional bedrocks	171	More infiltration	Very good	Major part of the study area
Pediplain-Weathered	Sloping area with erosional bedrock weathered	146	More infiltration	Very good	Major part of the study area
Flood Plain	It is a gentle plain adjacent to river and comprises of river alluviam	0	High infiltration Recharge mainly from river and other hydrogeological features	Very good	Adjacent to the Ponnaiyar river, hence no well
Valley fill	Low lying depressions	144	High infiltration	Very good	Adjacent to dykes.

Table 2
Relationship between the geomorphology and groundwater prospects in a hard rock terrain (Babar, 2005).

Land form	Description	Groundwater prospects
Denudation hill	Resistant hills resulting due to erosion	Mainly act as runoff zone
Pediment	Gently undulating plain, dotted with outcrops with or without veneer of soil	Runoff and recharge zone
Buried pediment-Deep	Pediment covered with thick alluvial material (>20 m deep) or unconsolidated weathered rock	Good to moderate
Buried pediment-Moderate	Flat and smooth buried pediment with moderately thick (5–20 m) over burden	Moderate to poor
Buried pediment-Shallow	Flat and smooth surface of buried pediment with (0–5 m) shallow over burden	Acts as a runoff zone
Pediment and inselberg complex	Pediment dotted with isolated hills	Acts as a runoff zone
Bajada	Alluvial deposit of varying grain size deposited along with the foothill zone.	Forms highly productive shallow aquifers
Lineament	Fractures on the land surface or buried	Good

with moderately thick (5–20 m) over burden. The groundwater potential in these geomorphic units is moderate.

4.1.2.5. Bajada. These are alluvial deposits of varying grain size deposited along the foothill zones which forms highly productive shallow aquifers.

4.1.2.6. Valley fills. These are low lying depressions and negative land forms of varying size and shape occurring within the hills associated with stream course. These are unconsolidated alluvial and colluvial materials partly or wholly filled in the valleys by streams and rivers. The material in this surface consists of mainly weathered products of the surrounding rocks; mostly comprised with moderately thick gravels, pebbles, sand and silt. The prospect varies depending on the thickness of the fills. Valleys controlled by lineaments and fractures have good groundwater prospect and good potentials for agriculture also. Valley fills act as good groundwater potential zones and water table is shallow and they have very good groundwater prospects as they are being recharged by surrounding hills as well as by the river water. Deep bore wells are preferable in these zones for intensive agriculture. On standard FCC image, it exhibits reddish tone due to the presence of vegetation.

On screen visual interpretation of ASTER data has been carried out to identify various landforms taking into consideration of various image and terrain elements. The landform which are more important in the ground water prospects (Tables 1 and 2) are classified into various broad categories and their distribution has been delineated from the remotely sensed data using standard image interpretation elements and the characters.

4.1.3. *Structural map*

The structural map of the study area consists of lineaments, shear zone, faults and dykes. Remote sensing gives enormous facility in mapping the geological structures such as fold, faults, dykes and lineaments. The occurrence and movement of ground water in the hard rock are limited to weathered, jointed, fractured and sheared zones. Lineaments are defined as a large-scale linear feature, which expresses itself in terms of topography and an expression of the underlying structural features. Lineaments or linear fractures are commonly associated with displacements, deformations and prides pathways for groundwater movements. These are important where secondary permeability and porosity dominate. The lineaments intersection areas are considered as good groundwater potential zones. A fault is a fracture or zone of fractures between two blocks of rock. Faults may range in length from a few millimeters to thousands of kilometers. The South Indian shield comprises of Precambrian granite-greenstone Dharwar craton in the north bordered to the south by a mobile belt, the south Indian granulite terrain. Post Archaean mafic igneous activity is wide spread in the form of dyke intrusions in the shield. The dyke intrusions are quite spectacular in the immediate vicinity around the Cuddapah basin, the largest Palaeoproterozoic sedimentary basin in the Indian shield. Clusters of dyke intrusions are pervasive throughout the Dharwar craton up to the west coast and also in the granulite region of the south India. Beyond which, to the south, the dyke intrusions are predominant only in the west coast. The dykes are quite variable in lengths and thickness and mostly are fresh dolerites (grading into gabbro in the interiors where the dykes are thick).

The role of structural features at the study area is the WNW-ESE trending fractures that have been filled by fracture and the NNE-SSW trending fracture system. These structural elements have barring on the groundwater regime as follows.

The dyke filled fracture system acts as the defined barrier of the groundwater flow from northern region. This is clearly evident that the lesser number of wells in the area of south of the dyke system compared to large number of wells in the north of the dyke system.

The NNE-SSW trending fracture systems are potential sources of groundwater which are evidence by the presence of many wells along

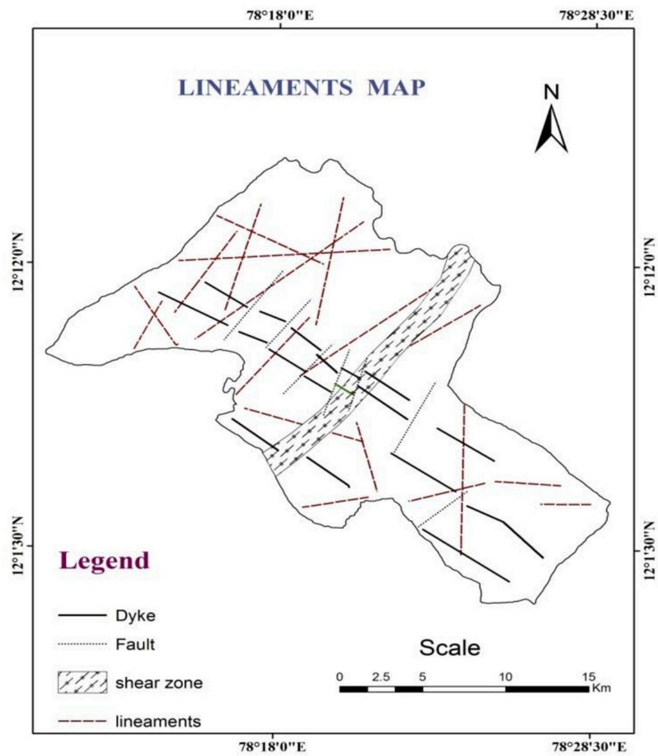

Fig. 6. Structural map.

with the fracture system (Fig. 6).

4.1.4. Landuse and land cover map

Landuse refers to man activities and various uses which are carried out on land. It describes how a parcel of land is used as agriculture, settlement or industry. Landcover refers to natural vegetation, water bodies, rocks/soils, artificial cover and other resulting due to land transformation. The term landuse/landcover is closely related and interchangeable per the purpose of which land is being used. They are commonly associated with different types of cover such as forest, agriculture, waste land or water bodies. Landuse/landcover exerts considerable influence on the various hydrological phenomenon's such as interception, infiltration, evaporation and surface flow. Applications of satellite remote sensing for land use surveys and mapping is gaining importance because of its ability to provide rapid and reliable data within a given time of framework. Realizing the relationship between landuse and hydro geomorphology is important for planning and management activities (Sajith, 2005).

The landuse/landcover map was prepared using satellite image in conjunction with SOI top maps on 1:50,000 scales. Visual interpretation of landsat TM FCC was used to delineate various landuse/landcover categories (Fig. 7). Landuse/landcover categorization is envisaged based on the classification scheme developed by National Remote Sensing Agency. The landuse/landcover characteristics were delineated based on the image characteristics like tone, texture, shape, association etc. During the interpretation wherever doubtful units are encountered the ground trouth survey was under taken to verify the same. Fig. 7 describes the landuse/landcover map of the study area. The characteristics of landuse/landcover classification are depicted in Table 3.

The landuse/landcover classes, identified in the study area are Built-up land, cropland, fallow land, land with scrub, land without scrub barren/sheet rock/stony waste area and tanks.

4.1.4.1. Built up land. It is defined as an area of human habitation developed due to non-agricultural use and that which has a cover of buildings, transport, communication, utilities in association with water, vegetation and vacant lands. Land used for human settlement in rural villages is comparatively less size than urban settlement.

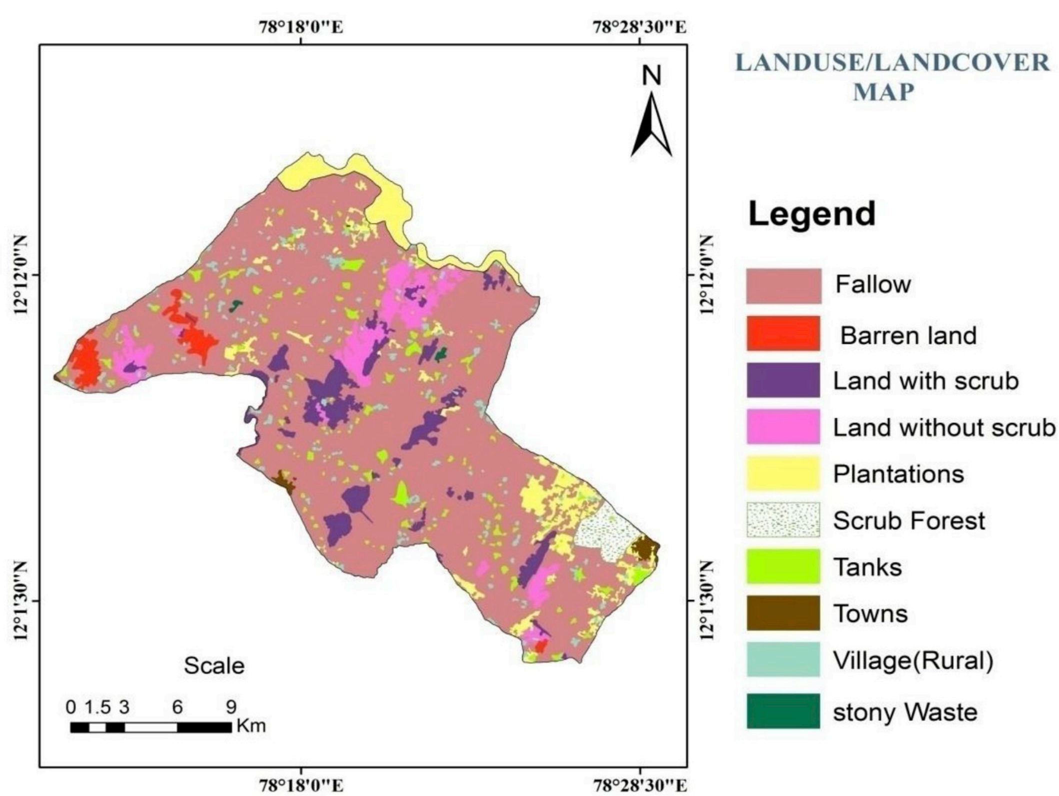

Fig. 7. Landuse/landcover map.

Table 3
Image characteristics of landuse/landcover category of the study.

Landuse/ landcover Category	Tone/ Colour	Size	Shape	Texture	Pattern
Built-up land	Dark bluish green	Small to big	Irregular	Coarse	Clustered to scattered
Crop land	Bright red to red	Varying in size	Regular to irregular	Medium to smooth	Contiguous to non contiguous
Fallow land	Yellow to greenish blue	Small to big	Regular to irregular	Medium to smooth	Contiguous to non contiguous
Plantation	Dark red to red	Small to large	Regular to irregular	Coarse to medium	Dispersed contiguous
Forest	Dark red	Varying in size	Irregular discontinuous	Smooth to medium	Contiguous to non contiguous
Scrub forest	Light red to brown	Varying in size	Irregular discontinuous	Coarse to mottled	Contiguous to non contiguous
Gullied land	Light yellow to light green	Varying in size	Regular broken	Very coarse to coarse	Dentritic to sub-dentritic
Land with scrub	Light yellow to brown to greenish blue	Varying in size	Irregular discontinuous	Coarse to mottled	Contiguous dispersed
Land without scrub	Light yellow to brown	Varying in size	Irregular discontinuous	Coarse to mottled	Dispersed contiguous
Stony waster	Greenish blue to brownish	Varying in size	Irregular discontinuous	Coarse to medium	Linear to contiguous, dispersed
Water bodies	Light blue to dark blue	Small medium large	Irregular discontinuous	Smooth to mottled	Non-contiguous dispersed

4.1.4.2. Agricultural land. It is defined as the land primarily used for farming and for production of food, fiber and other commercial and horticultural crops. It includes crops fallow lands and plantations.

4.1.4.3. Croplands. It includes those lands with standing crops as on the date of satellite imagery. The area under crops have been identified and mapped.

4.1.4.4. Fallow land. It is described as agricultural land which is taken for cultivation but is temporarily allowed to rest, uncropped for one more season but less than one year. At the time of the imagery taken of both seasons these lands are seen particularly devoid of crops. On the FCC, fallow land shows yellow to greenish blue tone, irregular shape with varying size associated with crop land or harvested agriculture field.

4.1.4.5. Forest. It is an area baring an association predominantly of tree and other vegetation types, capable of producing timer and other forest produce. Satellite data has been used for mapping different forest types and density classes with reliable accuracy through visual as well as digital techniques. Forest exerts influence on climate and water regime and also provides shelter for wildlife and livestock.

4.1.4.6. Land with scrub. Scrublands are seen along with the ridge and valley complex, linear ridges and deep slope areas. Most of these areas are identified by the presence of thorny scrub and herb species; many hillocks of steep and dumbbell shaped are associated with poor vegetal cover. As a consequence, severe soil erosion frequently occurs during rainy seasons, resulting most of the hilltops become barren/rocky.

4.1.4.7. Land without scrub. Land under these classes is generally prone to degradation/deterioration. It is confined to the higher topography like uplands or high ground etc., and excludes hills and mountain terrains. On FCC, it shows light yellow to brown to greenish blue, varying in size associated with gentle relief and moderate slope in plain and surrounded by agriculture lands.

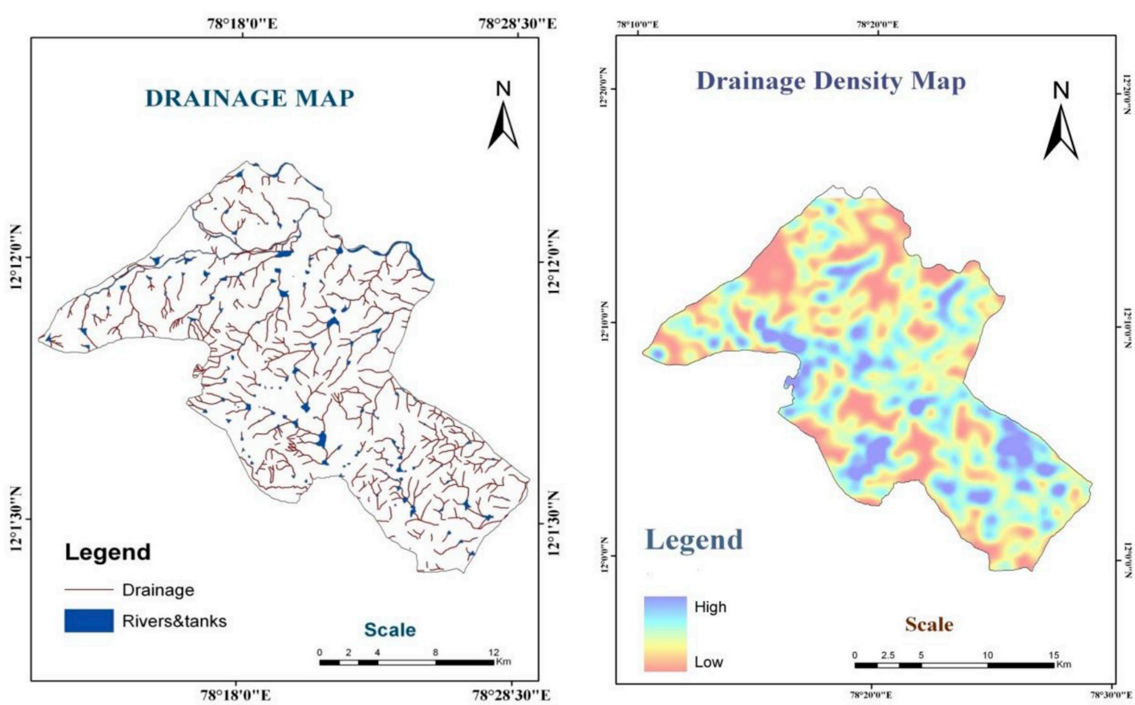

Fig. 8. Drainage map and Drainage density map.

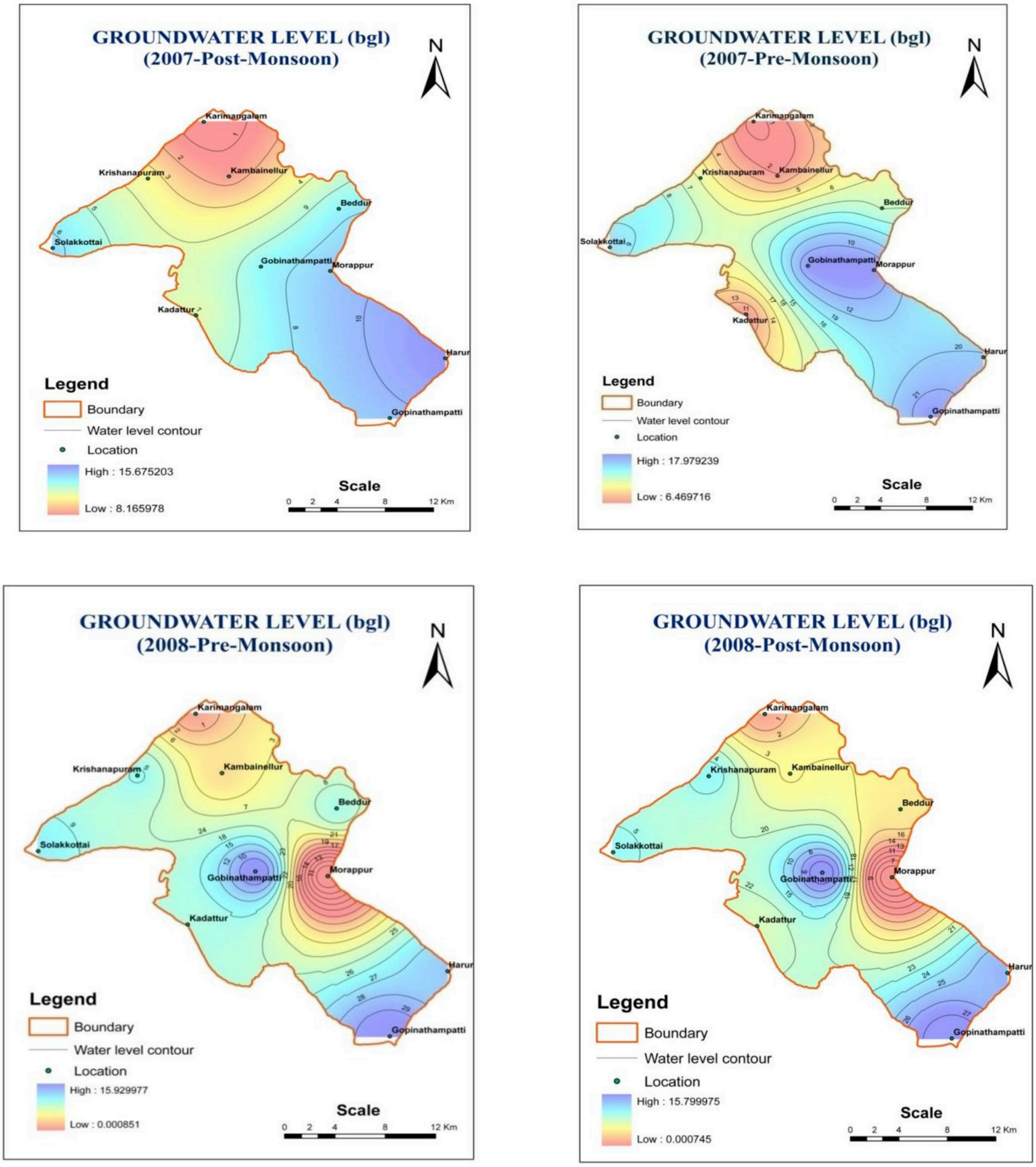

Fig. 9. Water level contour map of pre-post monsoon −2007 to 2008.

4.1.4.8. Barren rock/stony waste. These are the lands characterized by exposed massive rocks, sheet rocks, stony pavements or land with excessive surface accumulation of stones that render them unsuitable for production of any green biomass. Such lands are easily discriminated from other categories of wastelands because of their characteristic spectral responds. On FCC it shows greenish blue to yellow to brownish in tone with varying size association with steep isolated hillocks hill slopes and eroded plains.

4.1.5. Drainage and drainage density map

The drainage system of the study area belongs to the Ponnaiyar River basin and its tributaries. From the study, it is seen that the drainage is mostly of dentritic and sub dentritic pattern. The spatial arrangement of streams giving rise to a particular design is called as drainage pattern. The drainage pattern reflects original slope, structures like folds, faults, joints and wrapping. In the study area, dentritic, sub-dentritic and trellis type of drainage patterns are observed. In dentritic drainage pattern, the network of tributaries of various orders and magnitudes joints the master stream and resembles like the branches of a tree. The development of dentritic drainage is associated with the areas of homogenous lithology and gently sloping to almost horizontal or flat topographical surface having extremely low relief. Sub-dentritic patterns differ from the dentritic only in the lack of perfection of development of streams. Dentritic and sub-dentritic patterns are governed by regional slope, homogenous lithology and relief (Babar and Kaplay, 1999). Trellis drainage pattern tends to develop where there is strong structural control upon streams exist because of geology. In such situations, channels align themselves parallel to structures in the bedrock with minor tributaries coming at right angles. Fig. 8 deals with the drainage and drainage density map of the study area.

4.1.6. Water level contour map

The understanding of spatial and seasonal changes in the groundwater level is significant in the understanding of groundwater regime of

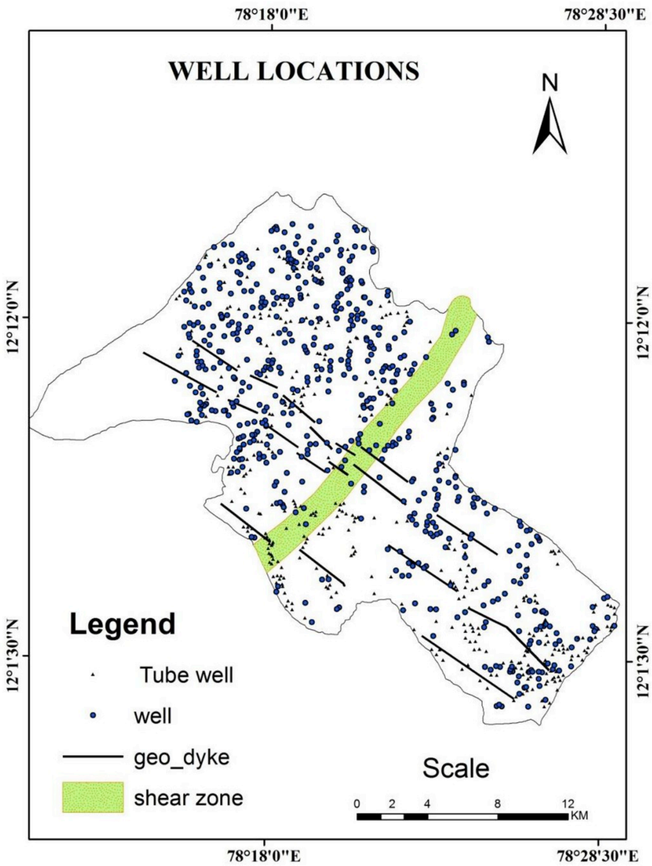

Fig. 10. Water well location map.

the study area. Field investigations have been carried out to measure the groundwater level in the pre and post monsoon seasons. The spatial variation of the measured groundwater level below ground surface for 2007 and 2008 has been given by the following Fig. 9.

4.1.7. The well location map

The groundwater is the main source of water and the presence of surface water is scanty. The agriculture sector depended mainly on the groundwater resource. A total of 780 number of wells (both tube wells and dug wells) are available in the study area. From the well location map it is observed that, around 450 wells were present at the northern side of the dykes, above 220 wells are existing at the southern side of the dykes and about 110 wells are observed between the dykes, the well location map has given in the Fig. 10.

4.2. Inferences

This study aims at mapping of geological, geomorphic units, structural unit's landuse and landcover and relates them with the groundwater resources of part of Morappur region of Dharmapuri district, South India. The study of Remote Sensing evaluated the groundwater regime of the Morappur area and identified the various factors which are influencing the groundwater in this hard rock terrain of Dharmapuri district of Tamil Nadu. It is essential to relate the lithology/geology of the terrain and the groundwater regime. Charnockite and hornblende epidote gneiss are the main rock types encountered in this area. The dykes traversing the entire study area along WNW-ESE direction are the other litho units that control the groundwater regime. To support the above fact, it can be observed that there are above 450 wells north of the dykes, above 220 wells south of the dykes and 110 wells between the dykes. Thus, it is observed that there are less than 50% of the number of wells in the area of south of the dykes, compared to the area of north of the dykes. Since there is no sedimentary litho unit in the study area, it may be concluded that the structural, geomorphic and Lithological aspects play a major role in groundwater regime of the area.

From the Table-1 it is evident that the fluvial geomorphic units are the most promising groundwater regions followed by denudational landforms (Bajada, deep pediments, peniplain). These units are followed by structural landforms (structural hills, linear ridges). The above inference is a result of analyzing the number of wells present in each landforms. It should be noted that the absence of wells in the NNE part of the study area doesn't indicate poor groundwater condition, but only suggests that the agriculture fields and villagers derive the water requirement from the Ponnaiyar river and not from the subsurface.

In general, the area can be divided into three units with regard to its groundwater occurrence. They are.

1. In northern and north-eastern flood plain dominated groundwater regime.
2. Pedimentous, low to moderate potential regime.
3. The moderate to high potential regime in the valley fills and Bajada regions.

The correlation of groundwater table at various seasons confirming the groundwater table is shallow during the period of post monsoon. Due to nonuniformity in the number of wells used for the preparation of spatial groundwater map, the minor variations also noticed in the spatial variation in the groundwater table among various seasons. Overall, the groundwater flow system is controlled by structural features that are clearly evident by spatial variation of groundwater table irrespective of various season. Two sets of fractures are present in the study area which are WNW-ESE trending fracture systems, filled by dykes and the NNE-SSW trending fracture system which induces water permeability. However, the dykes filled fracture system act as definite barrier of the groundwater flow from northern region. This is due to the presence of deeper groundwater table towards south west part of the fracture system occupied by dykes. The geometry of dykes represents that the dykes are comparatively younger than the period of shear zone occurrence. The comparison of groundwater table across the shear zone also representing the barrier effect of dykes in the groundwater control. The wells located towards western part of the shear zone represent deeper groundwater table than the depth of groundwater table towards Eastern part of the shear zone. The shallow groundwater table at the northern part is also evident by the presence of lineaments. The lineaments are trending in radial direction at northern part with high number of intersections. Towards south and south western part of the study area, two set of lineaments are noticed with minimal number of intersections. Hence the shallow occurrence of groundwater table in the north and north eastern part of the study area is dominantly controlled by the presence of dyke. Towards south and south eastern part of the study area, the NNE-SSW trending fracture systems are potential sources of groundwater which are evident by the presence of many wells along with the fracture system.

5. Conclusion

The present study evaluated the use of remote sensing integrated with field investigations along with collateral data to study the various factors influencing the groundwater regime in the hard rock terrain of Morappur area. The study area 'Morappur' is a typical hard rock terrain and sedimentary litho units are absent, hence it is difficult to identify the potential groundwater resources. Agriculture is the primary occupation and groundwater is exploited to a maximum extent due to limited surface water resources. Wells (both tube and dug wells) and Tanks are the main sources for irrigation. Unscientific ways of exploiting the groundwater may cause degradation of the valuable land, lowering of groundwater table and also financial loss to the farmers. Hence a scientific study has to be conducted to understand the groundwater regime of the area. A good understanding of the relationship between lithological, structural and geomorphic parameters and the groundwater regime has been achieved in the present study. The geology of the study area mainly consists of charnockite and epidote/hornblende gneiss. Instead of primary porosity, porosity is offered by secondary porosity. The drainage pattern is mainly dendritic to sub dendritic in nature. The drainage system belongs to the Ponnaiyar river basin and its tributaries. The observed geomorphic units in the study area are structural hills, Bajada, moderate and shallow buried pediments, valley fills and tanks. Each hydro geomorphic units have its own contribution in the hydrogeological regime of the area. Tables 1 and 2 details the role and distribution each geomorphic unit. The NNE-SSW trending fracture systems is the potential source of water. The number of wells in the North of dyke is more than the south. Overall, it is observed that the geomorphic units have major bearing on the groundwater regime while the structural elements that are, the dyke system controls the groundwater flow in the region and not the groundwater abundance. The significant LULC classes present in the study area are; built up land, crop land, fallow land, land with scrub, and land without scrub.

The observation made in the field and information obtained from remote sensing images was employed and the analysis was made to derive meaningful inference about the relationship among groundwater regime, geomorphology and structural elements of the study area. This study proves the role of remote sensing in groundwater studies is not only confined to the preparation of Hydro geomorphic map alone but also detailed synthesis of the structural details of the area which will give depth information about the groundwater regime.

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