Contribution of Spatial Maps in Groundwater Potential Zone using Remote Sensing And Geographic Information System

ABSTRACT

Now a days, surface water resources are becoming insufficient to fulfil the water demand because utility enhanced as compare to availability. Therefore a systematic planning of groundwater improvement using modern technique is essential for the proper management and utilization of this valuable resource. Total annual supply will basically completed by major source that is groundwater. The objective of this paper is to identify the contribution of spatial map and their methodologies applied for acquiring groundwater potential zones of study area using remote sensing and GIS. The parameters that are used here for identifying their importance in controlling groundwater potential zones slope, drainage density, lineament density, geology, geomorphology, soil texture, land use land cover and rainfall. Vital importance of groundwater potential was to identification of appropriate locations for extraction of water. The remote sensing and GIS tool have a significant tool for land and water resource studies. The result demonstrated that integration of remote sensing and GIS tool with the detail information about the themes and their effect on the groundwater will assess the groundwater potential of study area.

Keywords: *Groundwater, Groundwater potential, Remote sensing, GIS, Slope, Drainage density, Lineament density, Geology, Geomorphology, Soil texture, Land use land cover and Rainfall*

1. INTRODUCTION

Groundwater is one of the most important natural resource of the earth which is required for drinking, irrigation, industrialization purpose and economic development. In order to make certain sensible use of groundwater its proper assessment and management is required. Availability of groundwater depends upon presence of rock types and their properties (i.e., porosity, permeability, transmissibility and storage capacity). Depletion of groundwater depends upon the development activities of the area, continuous failure of rainfall, increasing demand and overexploitation of ground water. These problems could be sorted out to some extent by artificial recharge to the aquifers by construction of small water harvesting and recharge structures across streams. The main objective of artificial recharge is to provide sustainability to ground water by restoring supplies to aquifers depleted due to excessive draft and to enhance recharge to the aquifers lacking adequate n b0atural recharge both in space and time.

About 30% of the earth’s freshwater accounts by groundwater, whereas surface water resources from lakes and rivers accounts for less than 0.3% (Shiklomanov,1993) .Demand for fresh water resources is constantly increasing day by day as a result of rapid industrialization and population growth. Therefore, groundwater extraction has become an integral part in many of the water management approaches.

Natural retrieval of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels and depletion of ground water resources. Therefore planning and management of groundwater potential zones are necessary for future wellness. The groundwater mapping is essential for the exploration of unexploited ground water potential zones with appropriate limitations.

In water resources studies remote sensing and GIS tools have opened new paths. Remote sensing and GIS provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface for analysis of various objectives such as groundwater study, management etc. (Choudhury *et al*., 2003). One of the greatest advantages of using geoinformatics for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very important for useful analysis, prediction and validation (Sarma and Saraf, 2002).

GIS integrates the information from several sources in such a way that it all has the same scale. Often, GIS must also manipulate the data because different maps have their different projections. A projection in the GIS is the method of transferring information from earth's surface to a flat piece of paper or computer screen. No projection can copy the reality of Earth's curved surface exactly. Different types of projections fulfil this task in several ways, but all result in some distortion. GIS takes data from maps that were made using different projections and combines them so all the information can be displayed using one common projection system. Geoinformatics technology have become a crucial tool in water studies due to their capability in developing spatio-temporal information and effectiveness in spatial data analysis and prediction.

2. MATERIALS AND METHODS

The geographical extent of the Tons sub-basin lies between 230 57' 53.98'' and 250 10' 09.15'' N latitude and 800 21' 35.03'' and 820 43' 25.41'' E longitudes. It basically covers five district of Madhya Pradesh such as Rewa, Satna, Eastern part of Panna and Northern part of Sidhi and Katni district. It is also bounded on north and east by Uttar Pradesh state. The geographical area of Tons basin is 12497 sq. km. The location map of study area is shown in following fig. 1.

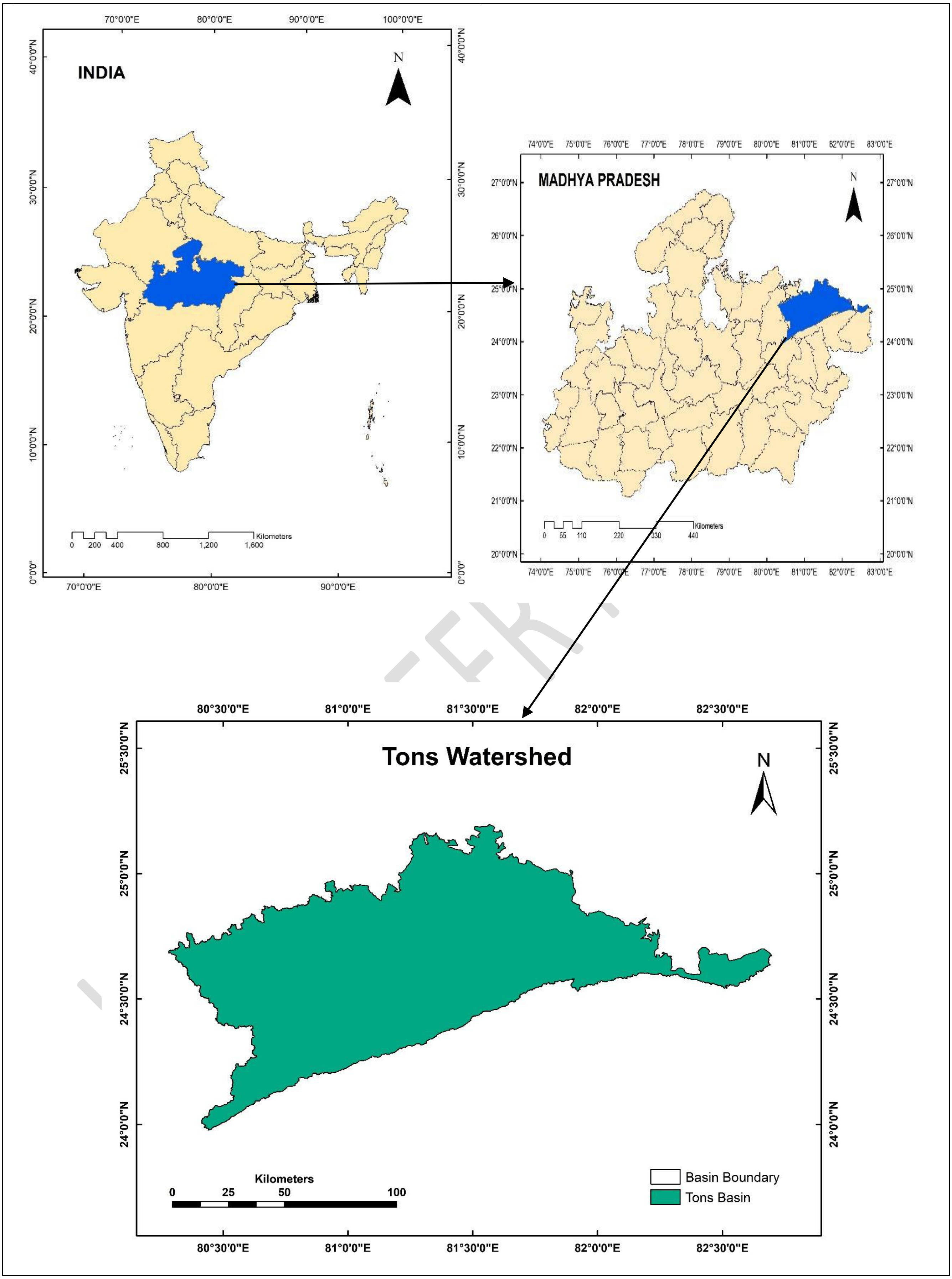


Figure 1. Location map of study area

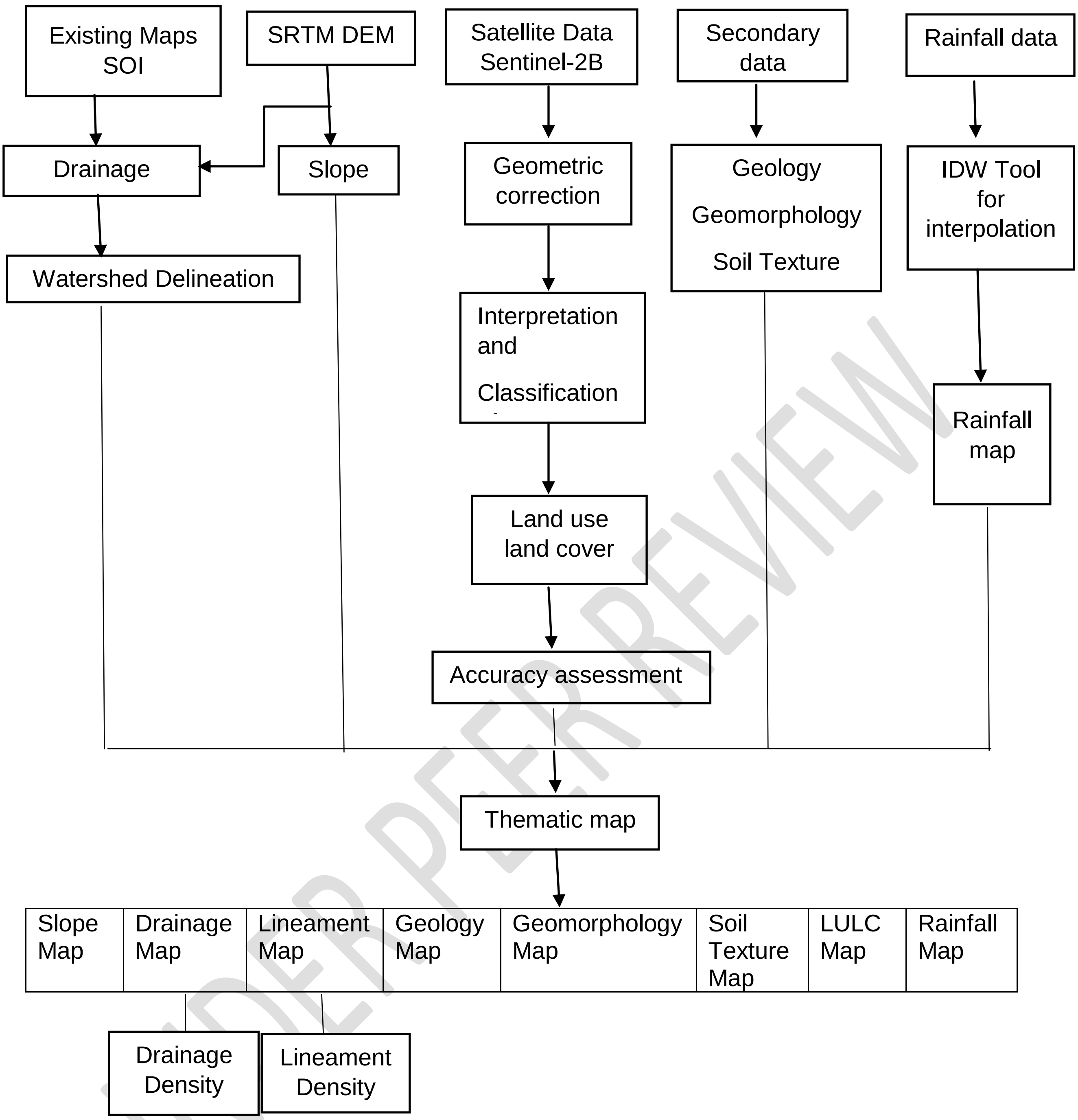


Figure 2. Flow chart of methodology of preparation of thematic maps

2.1 Data Product used in the study

Toposheet (1:50000) will be acquired from the Survey of India 'Nakshe' portal having URL: https://soinakshe.uk.gov.in. Shuttle Radar Topography Mission (SRTM) Digital elevation model (DEM) 30*30 m resolution data were used for delineation of watershed, slope, drainage and drainage density of the study area. Shuttle Radar Topography Mission (SRTM) DEM having a spatial resolution of 30 m will be acquired from the USGS Earth Explorer with URL: https://earthexplorer.usgs.gov . Sentinel 2B imagery with spatial resolution of 10 m will be downloaded from USGS Earth Explorer for preparation of land use land cover map. The map containing information about the geology, geomorphology and lineament of the study will be gathered from the website of 'Bhukosh' (*i.e.*Integrated Spatial Data Management Portal) with URL: https://bhukosh.gsi.gov.in/Bhukosh/Public. Soil map will be acquired from Soil Atlas of Madhya Pradesh generated by National Bureau of Soil Survey and Land Use Planning (NBSSLUP). Daily rainfall data in gridded format (0.25°×0.25°) will be procured from India Meteorological Department (IMD) having URL: https://www.imdpune.gov.in/Clim_Pred_LRF_New/ Grided_Data_Download.html.

METHODOLOGY

Software's such as ArcGIS® 9.3, Erdas Imagine 2014 and also open source software GOOGLE EARTH in true sense were used for preparation of different spatial maps. ArcGIS® 9.3 software was used for creating map, compiling the geographic information, analyzing mapped information, and discover and share the information. This software provided an infrastructure for creating maps and collect geographic information throughout an organization, across a community, and openly on the Web.

ERDAS Imagine 2014 software was used for image processing that allows users to process both geospatial and other imagery as well as vector data. ERDAS can also handle hyper spectral imagery from various sensors. This software is integrated within other GIS and remote sensing applications and the storage format for the imagery can be read and process in many other applications (*.img files).

To prepare base map of study area mosaiced SOI toposheets were used. Outlet point of the basin chosen by using contour and drainage line available on the topographic map. Outlet point of study area were selected and verified with the help of topography map. Using the GIS based software ArcGIS® 9.3 (Slope tool in the spatial analysist tool), the slope map of the study area is generated. With the help of the soil information of the basin and referring the soil map by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Government of India. Soils are classified as per the soil conservation service soil classification system. This information was then transferred onto the base map for preparation of soil map of study area. Sentinel 2B imagery with spatial resolution of 10 m will be used for preparation of LULC. SRTM DEM 30*30 m resolution data were used for preparation of slope and drainage density of the study area. Geology, geomorphology and lineament information of the study area will be gathered from the website of 'Bhukosh'. Rainfall map was prepared by using daily rainfall data in gridded format (0.25°×0.25°) were procured from India Meteorological Department (IMD).

3. RESULTS AND DISCUSSION

Eight different thematic maps and their interpretation discussed regarding groundwater potential of Tons basin which covering five district of Madhya Pradesh viz. Rewa, Satna, Katni, Panna and Sidhi.

3.1 Slope

Topographic data information plays the vital role for the determination of elevation of groundwater table (Sener et al., 2005). For the identification of Groundwater potential zones, the slope angle was considered as an important input as it has considerable influence in the study area (Neelakandan et al 2012). The slope of study area has been calculated in percentage based on SRTM data. The slope map was derived from a SRTM data of the study area. Fig. 3 shows the slope map of Tons basin. The slope of the Tons basin were varied between 0 to 84 %. As we know that infiltration and surface water runoff basically depends on the slope. Slope is a vital factor for assessment of groundwater potential zone. Water tends to store in lower topographical region rather than higher topographical region. If there is higher the elevation lesser will be groundwater potential as well as groundwater recharge and vice versa. Hence it is a suitable indicator of groundwater prospectus suitability. Slope category of Tons basin classified in table 1 below.

Table 1 Slope category of Tons Basin

S. No.	Slope category	Slope percentage
1	Very low	0-12
2	Low	13-23
3	Moderate	24-33
4	High	34-49
5	Very high	50-84

3.2 Drainage Density map

Drainage map was prepared by using DEM data acquired form the USGS Earth Explores by using ArcGIS® 9.3 Software. Drainage pattern reflects the characteristic of surface as well as subsurface formation. Drainage density (in terms of km/km2) indicates closeness of spacing of channels as well as the nature of surface material. More the drainage density, higher would be runoff. Thus, the drainage density characterizes the runoff in the area or in other words, the quantum of relative rainwater that could have infiltrated. Hence lesser the drainage density, higher is the probability of recharge or potential groundwater zone.

In the present study, since the drainage density can indirectly indicate the groundwater potential of the area due to its relation to surface runoff and permeability, it was considered as one of the indicators of groundwater occurrence. Drainage density measurements have been made for the Tons basin. Accordingly classes have been assigned ‘very low’ ‘low’ ‘moderate’ ‘high’ and ‘very high’ categories. Fig. 4 shows the drainage map of the Tons basin.

3.3 Lineament Density map

Lineaments are structurally controlled linear or curvilinear feature. It can be identified from the satellite imagery by their relatively alignments (Nampak et al 2014, Nag and Kunda 2016). Lineaments represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. These factors are hydro-geologically very important as they provide 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). Lineaments density map of study area has been prepared using krigging interpolation technique of ArcGIS® 9.3 software. The lineament density map of the study area is shown in Fig. 5 and it revealed that the lineament density in the study area range from 0-19 Km/Km^2

3.4 Geology map

Geology map was prepared by using data procured from the Bhuvan at scale of 1:250000. Geology of the study area was comprised of mainly Rewa GP, Kaimur GP, Bhander GP, Semi GP and Malwa GP. The Semi GP is the oldest group of the Vindhyan SGP. Vindhyans Comprise of sand stone, shale and limestone. Sand Stone and Shale are hard and compact forming poor aquifers, Limestone has secondary permeability. Deccan Traps comprises weathered, fractured, jointed and vesicular units of Basalts form moderate to good aquifers, this type of units form the most important aquifers in the region. Geology map of the Tons basin is shown on fig. 6.

3.5 Soil Texture map

Soils are the resultant product of weathering of parent rocks caused by difference in temperature and hydration effect, (Kumar et al. 2017). Type of soil play an important role on the amount of water that can be resist in the subsurface formation and hence influences the groundwater potential zoning and groundwater recharging. Rate of infiltration of water will be mainly affected by the different type of soil texture and rate of hydraulic conductivity (HC). Fig. 7 depict the soil texture map of tons basin. The detail of soil texture categories identified in the basin as per the scheme of National Bureau of Soil Survey (NBSS) and Land Use Planning (LUP).

3.6 Geomorphology map

Evaluation of surface and ground water resources vitally influences by the geomorphic features. The following geomorphological features such as active flood plain, active quarry, anthropogenic terrain, highly dissected structural hills and valleys, low dissected denudational hills and valleys, low dissected structural hills and valleys, low dissected structural lower plateau, moderately dissected denudational hills and valleys, moderately dissected denudational lower plateau, moderately dissected structural hills and valleys, moderately dissected structural lower plateau, older alluvial plain, pediment Pedi plain complex and piedmont slope are identified from the study area. Active valley fill, and buried pediment is good sources of groundwater whereas structural hills, pediment zone and gullied land are poor recharge zones (Subagunasekar et al.2012). Different features of geomorphology are shown in fig. 8.

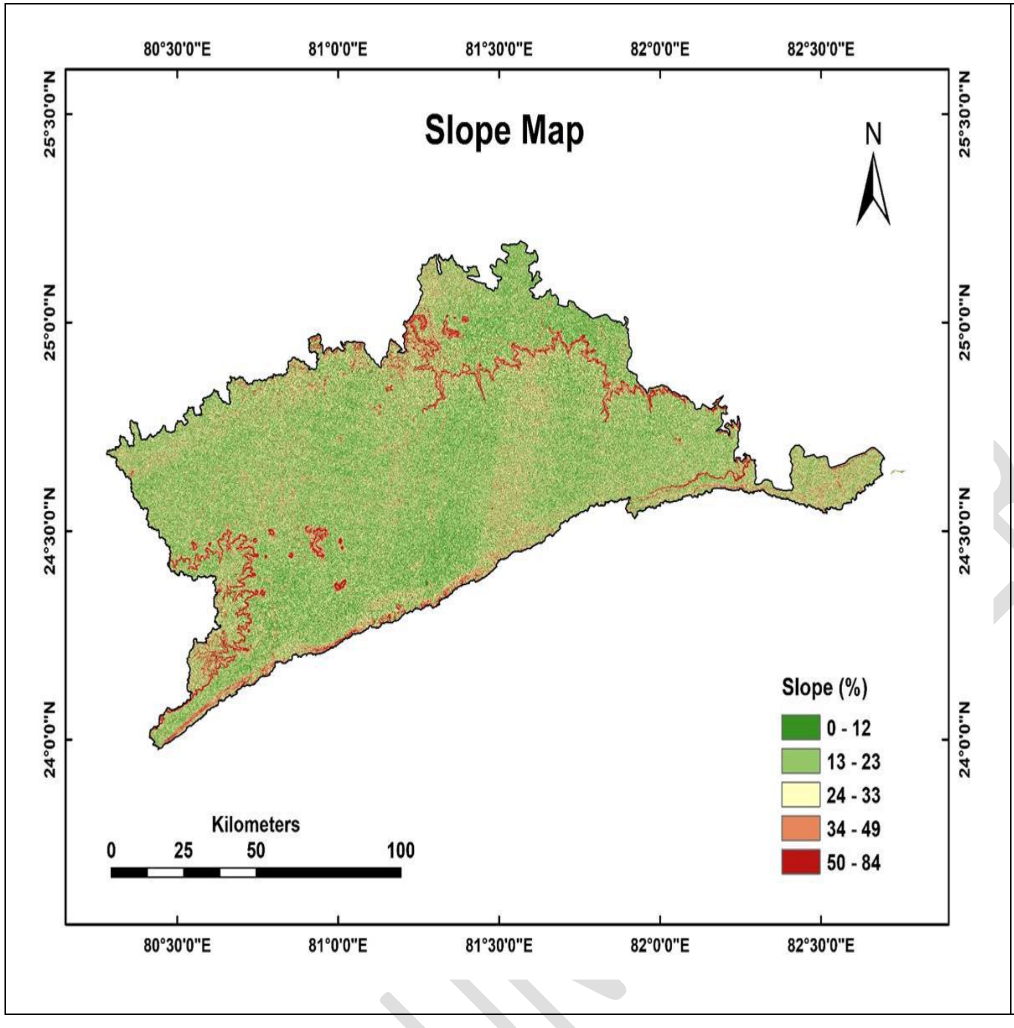
3.7 Land Use Land Cover map

Land use refers to man's activities in land, various uses which are carried out on land, whereas land cover denotes the natural vegetation, water bodies, rock/soil, artificial cover, and others resulted due to land transformation. The remote sensing data records the information essentially on land surface from which the information on land use has to be inferred. Identified land use/land cover features from the satellite imageries of the study area are water bodies, Agricultural land, Forest (Open forest, dense forest, evergreen forest), Open land, Barren land/wasteland (land with scrub and land without scrub), builtup land or habitation (Private or unplanned land).

The sentinel 2B satellite image has been used to find out the land use and land cover of study area. The unsupervised classification method has been used with level of classification. The result of land use land cover of the study area to be covered by six different categories such as water bodies, built up land, barren/waste land, forest, open land and agricultural land. Result of analysis is mentioned in table 2 which depict that most of the portion of study area 5513.10 km2 comes under agricultural land. Cultivated land are basically very inconvenient that results in poor groundwater potential. Basically forest region covers 1863.67 km2 of study area, which may have good potential and recharge capacity of groundwater. In the same manner water bodies covers basically 658.89 km2 which is very indicator of groundwater potential zones and groundwater recharge capacity. Groundwater potential is very poor in the habitation areas because it may be cover by private and unplanned holding; which accounts for 328.37 km2 of study area. Most of the habitation or urban settlement covering in city area of Satna and Rewa district. Fig. 9 shows the land use land cover map of Tons basin.

Table 2 Land use land cover of study area

S. No.	**Classes**	**Area covered(km2)**
1.	Water Bodies	654.89
2.	Agricultural Land	5513.10
3.	Forest	1863.67
4.	Open land	2951.51
5.	Barren land/Waste land	1169.91
6.	Builtup land	328.379



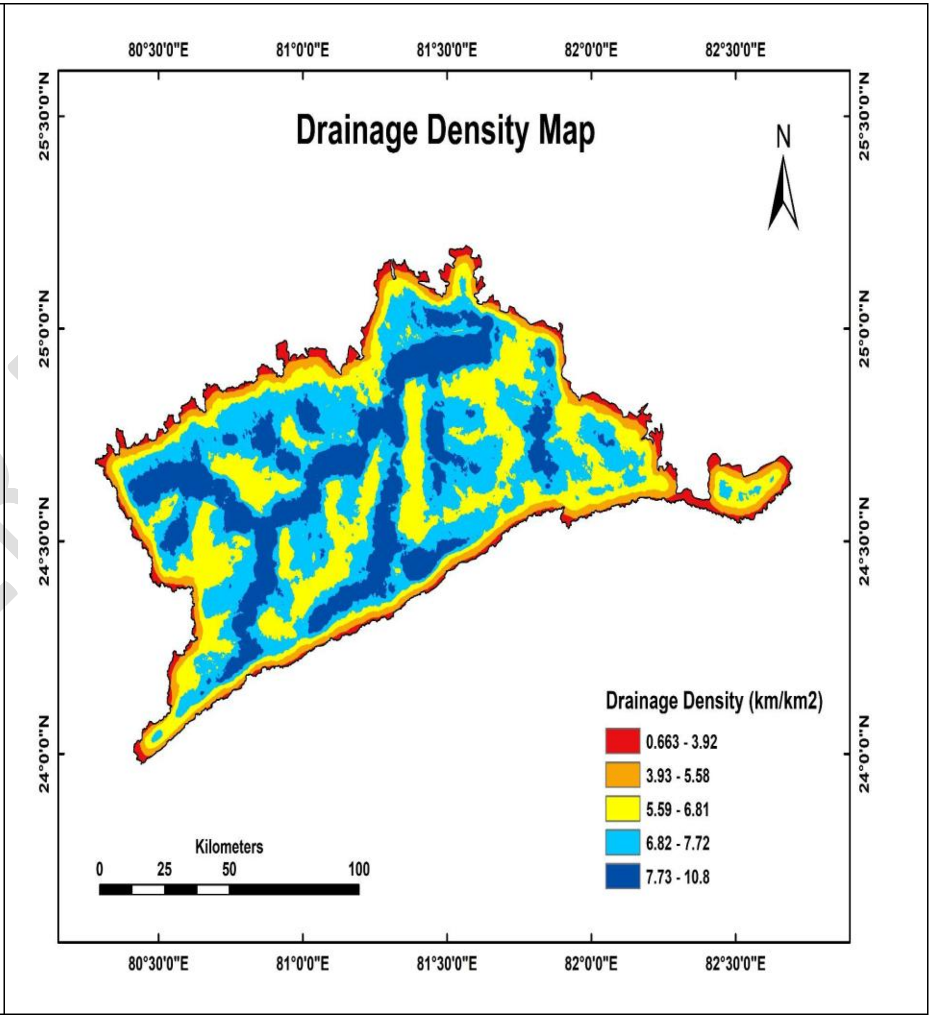


Figure 3. Slope map of study area

Figure 4. Drainage Density map of study area

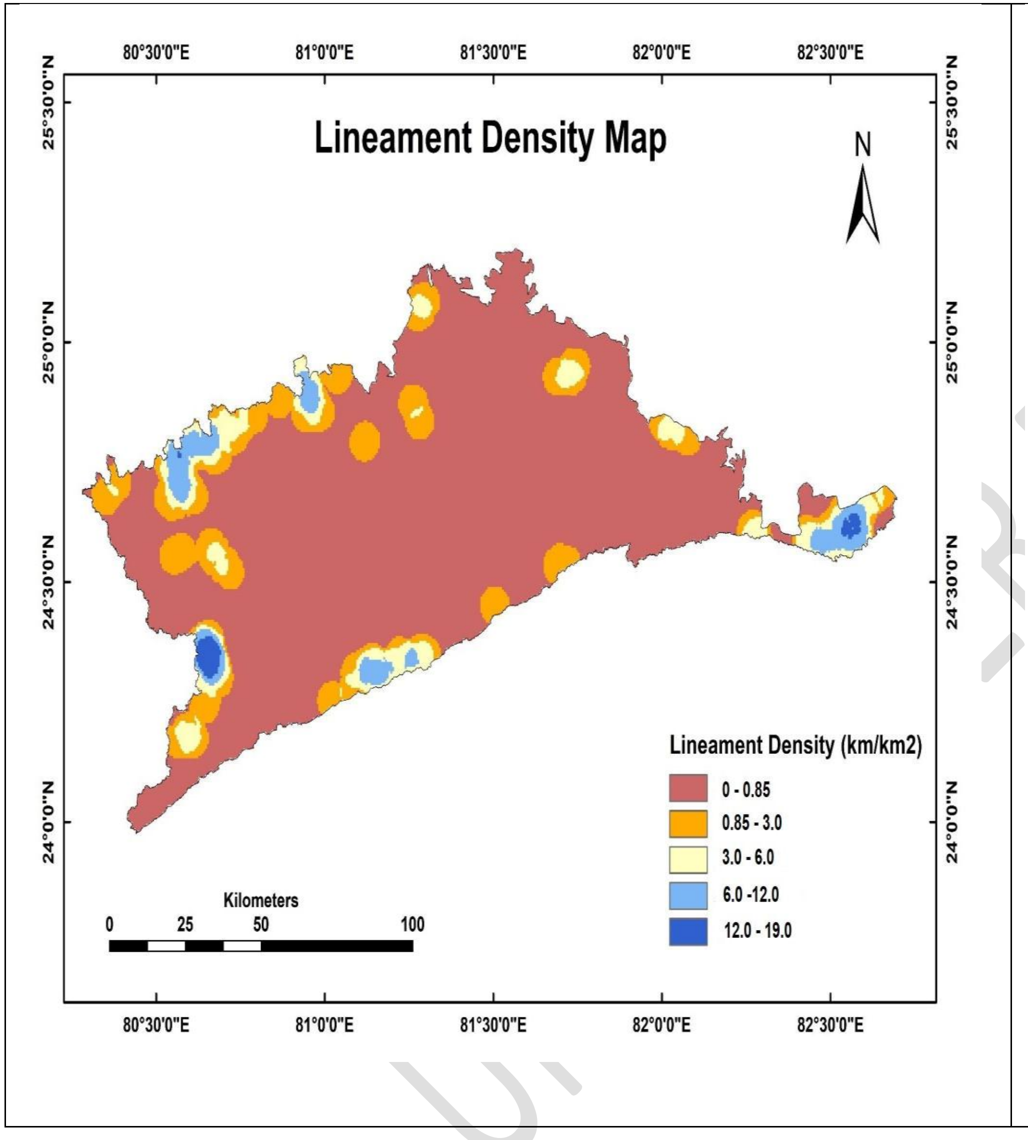


Figure 5. Lineament density of study area

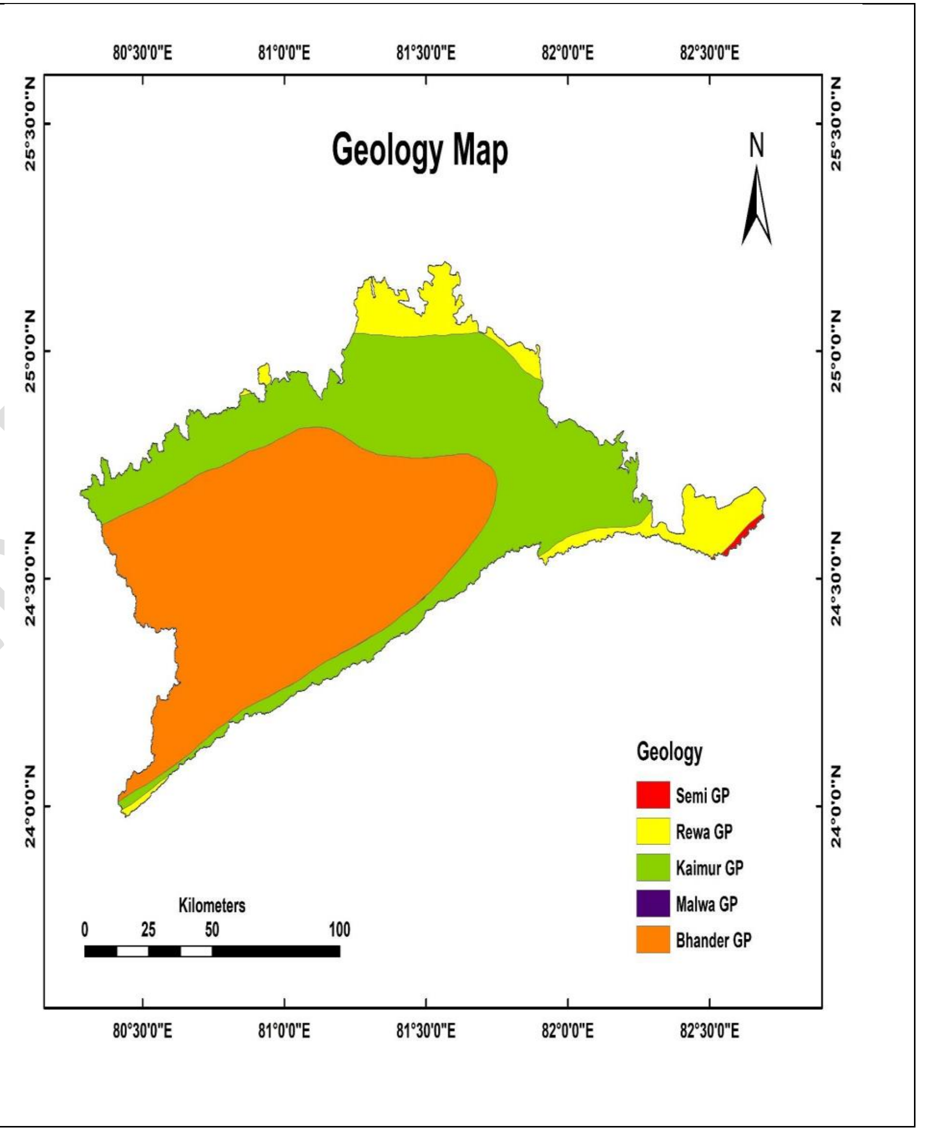


Figure 6. Geology map of study area

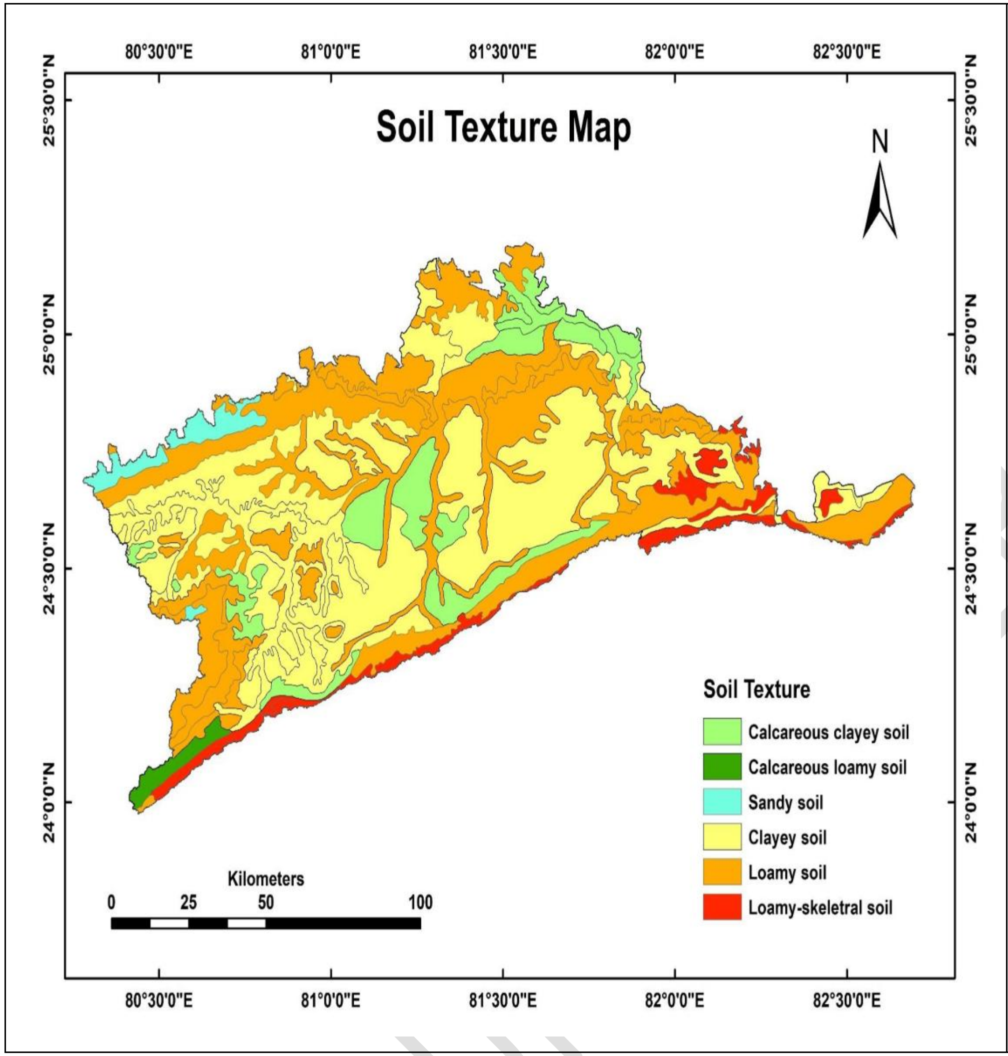


Figure 7. Soil texture map of study area

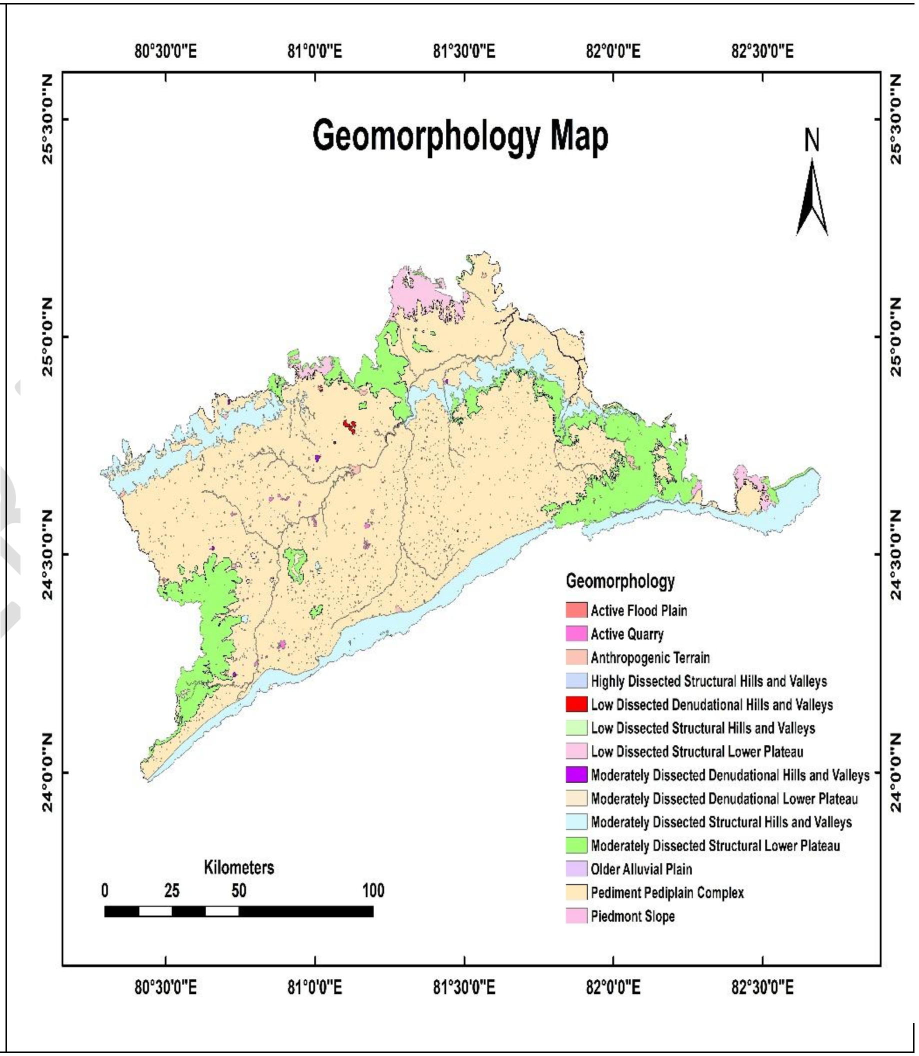


Figure 8. Geomorphology map of study area

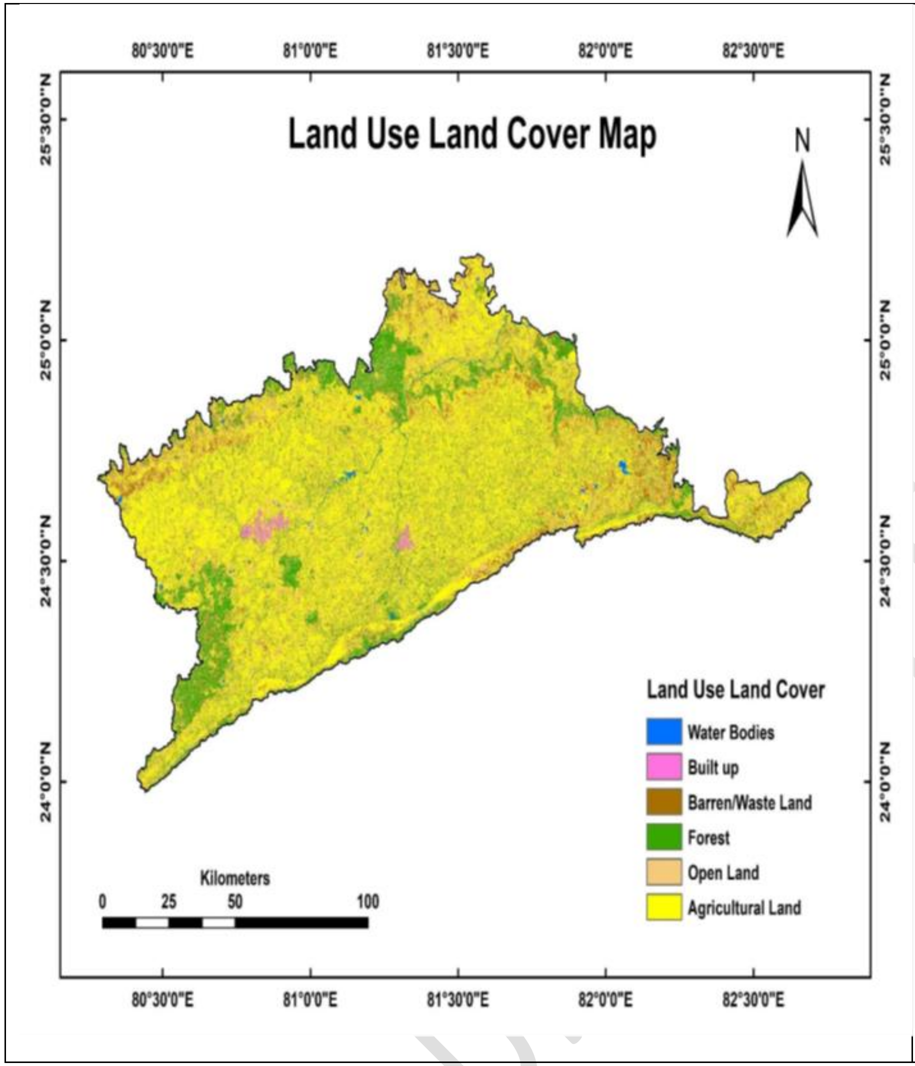


Figure 9. Land use land cover map of study area

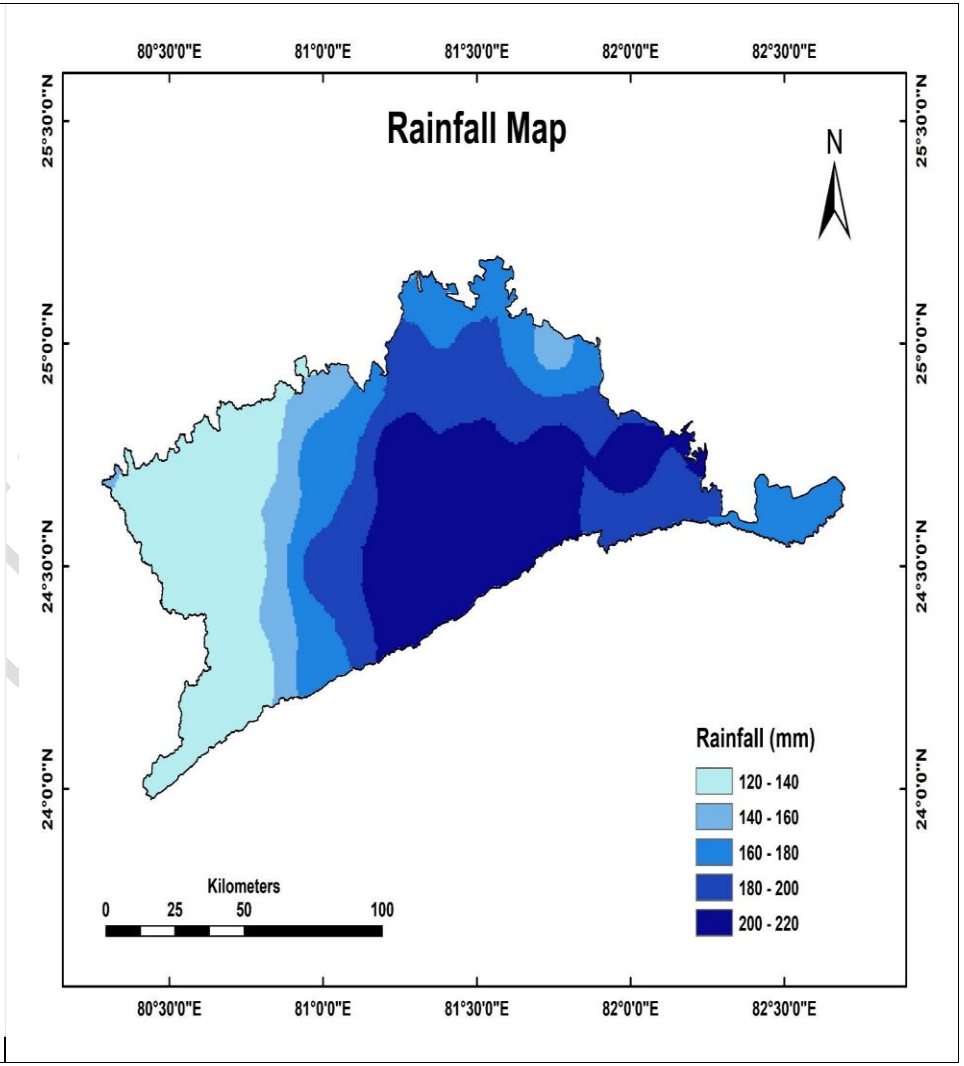


Figure 10. Rainfall map of study area

3.8 Rainfall map

Rainfall is the major and important water source in the hydrological cycle and here it's a most dominant influencing factor for the groundwater in the study area. The annual rainfall data is taken from the Indian Meteorological Department (IMD) for annual rainfall measurement. For the present study, the rainfall data of 2019 have been considered for the study. In the study annual rainfall ranges from 120 to 220 mm respectively (Fig. 10). Inverse distance weighing (IDW) interpolation method were used to prepare spatial distribution map of rainfall which inbuilt in ArcGIS@9.3 tool.

4. CONCLUSION

Remote sensing and GIS provide the information which are not accessible and difficult to analyse. For procuring the information regarding any objects, area or phenomenon without having any physical contact and also access information of inaccessible areas, remote sensing is there to provide it whereas it is very effective and time saving. Whereas, GIS is a tool used for mapping and analysing feature and event carrying in the earth. Groundwater potential zone vitally used for the development and proper utilisation of the groundwater in the needed areas.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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