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Identification of groundwater potential zone through geospatial technology: a case of Kaliasot watershed area, Bhopal & Raisen district (M.P.), India

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Abstract
Kaliasot reservoir is under environmental stress due to siltation, human encroachment, and sewage input from various resources. Kaliasot Basin area in Bhopal and Raisen district has been identified as one of the problematic area under the semi critical category in terms of water crisis, encroachment and haphazard urbanisation. The study area is facing many problems like scanty rainfall, scarcity of water, increasing demand of water for irrigation, domestic & industrial purposes and deforestation. The research study employs an integrated approach by using GIS and Remote Sensing since groundwater conditions of the area are controlled by many parameters i.e. drainage, geology, geomorphology, lineaments, slope, land use and land cover. Various thematic layers have been generated and assigned weightages and ranks. These layers have been integrated in GIS software for generating Groundwater Potential Zone map of Kaliasot watershed. The area falls into five categories of groundwater potential zones i.e. excellent, good, moderate, poor and very Poor depending on the likelihood of availability of ground water. On the basis of this study it is found that only 13.44km^2 area is under Excellent and 110.97km^2 area is under good category of groundwater availability. An area of 59.75km^2 is found under moderate category whereas 7.97km^2 and 0.04km^2 area falls under poor and very poor category of availability of groundwater respectively.

Keywords: Groundwater potential zones, GIS, remote sensing, spatial data

Introduction

Water is one of the most widely distributed and most important resources of the mother earth. Water is most essential to life and is next to air in its importance. With the development of civilization and industrialization, our water demand has increased manifolds. The great variation, in rainfall in different parts of India and the gigantic differences in the physical features and geological formations in different parts of the country renders the problem of development of water resources.

In our country, more than 90% of the rural and 30% of the urban population depends for drinking water on groundwater resources (Reddy *et al*, 1996) [16]. The major cities and towns in India, are facing serious problems related to water table depletion and quality deterioration (Gautam *et al*, 2015; Kumar and Kumar, 2010; Verma *et al*, 2016) [4, 10, 17]. The decline in water table and the adverse impact of industrial, agricultural activities, urbanization and global climate change are increasing the pressure on existing groundwater resources. Therefore, groundwater development and management has become a priority in the field of water resource research. In present times, the RS & GIS is reliable, cost effective and time saving tool for water conservation and management.

Groundwater potential zone mapping can be easily done by employing Remote Sensing & Geographical Information System (RS & GIS) techniques. Various thematic maps like geology, geomorphology, drainage density, slope, land use/land cover etc. can easily generated. Many researchers (Chaudhary *et al*, 1996; Mishra et. al, 2010; Javed and Hussain, 2009; Narendra *et al*, 2013; Nandish Kumar *et al*, 2014) [3, 12, 9, 14, 13] have used this technique for groundwater potential zone mapping.

The different hydrogeological themes can be used to identify the groundwater potential zones of the present study area. Various thematic maps like geology, geomorphology, land use and land cover, slope, lineament density, drainage density of Kaliasot watershed have been generated. These thematic maps have been integrated by using GIS software to prepare groundwater potential zone map of the area.

Study Area

The (study area) Kaliasot River has originated at Bhadbhada spillway of upper Lake of Bhopal. It is situated in Huzur Tehsil of Bhopal district & Gairatganj of Raisen district Madhya Pradesh, (India) bounded by latitudes $23^0 6'$ to $23^0 13'$ and longitudes $77^0 23'$ to $77^0 35'$ (Fig. 1) covered in Survey of India (SoI) topo sheet no. 55 E/8 & 55 E/12. The total geographical area is 194 sq.km. The holy river Betwa forms the Southern boundary of the study area. Delhi-Bombay and Delhi-Chennai railway route and National Highway no. 12 passes through the area, which connect the area from other part of the country. It is bounded by Vidisha district on the north, Raisen District on the east and Sehore District on the Southwest. The watershed covering the part of Mandideep block of the Raisen district of Madhya Pradesh, which is highly industrialized and the water resources may be contaminated due to improper disposal of municipal, urban and industrial waste. Location map of the study area is given in Fig.1. The average annual rainfall is about 1009.29mm.

Materials and Methods

During the study, Survey of India (SOI) Toposheet No's 55 E/8 and 55 E/12 were Geo-referenced and processed in ArcGIS environment for the preparation of the major streams, roads, important settlements, drainage and drainage density map of the area. Geology and Geomorphology has been derived by processing of the GSI, District Resource Map (DRM) edition 2002, from which various rock units and landforms were extracted. National Bureau of Soil Survey and Land use Planning (NBSS & LUP) of Indian Council of Agricultural Research (ICAR, 1996) [15] map has been analyzed for the preparation of soil map of the area. Topography has been derived by processing of the Shuttle Radar Topography Mission (SRTM) satellite imagery. Land use/ land cover (LULC) mapping were carried out by processing of the LISS III imagery (2017 & 2018) supported by Google Earth visual image interpretation. Lineament mapping was carried by using LISS III imagery with resolution of 23.5 m. All the data sets were converted in to digital format from their source map. Further, all vector layer is converted into raster format for further analysis in GIS environment. All the thematic layers have been assigned ranks and weightages depending upon their influence factors on groundwater and overlay to evaluate suitable groundwater potential zone. The flow sheet of methodology adopted in the present study is given in Fig. 2

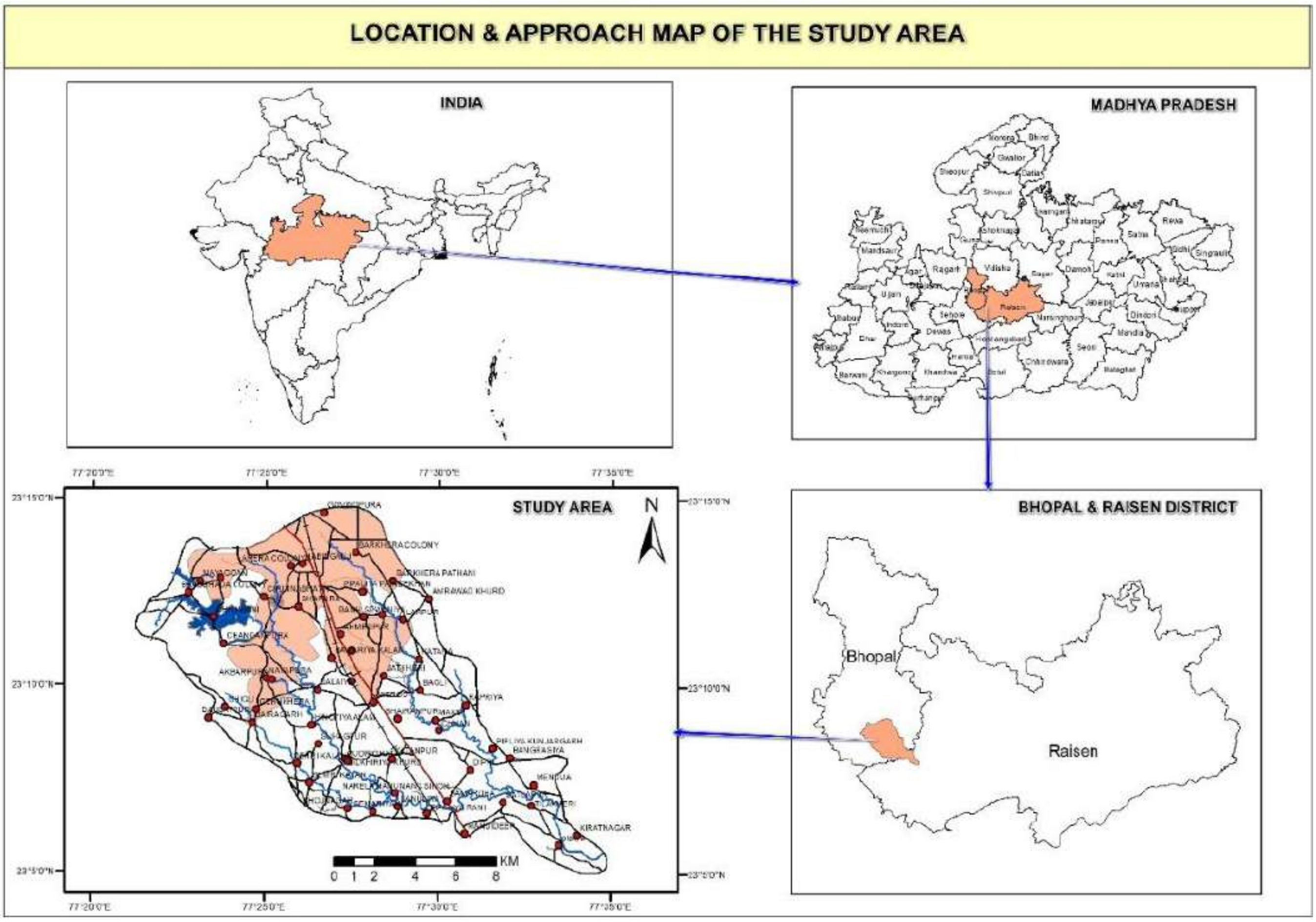


Fig 1: Location Map of Study Area

Results & Discussion

For present study, various permutation combination has been carried out during analysis and the results have been discussed. The results of whole study has been taken for identification of Groundwater Potential Zone Mapping is given below.

Geology

Geological mapping is used as basis for the study of groundwater condition in an area. Geology of the area has been extracted by processing of the Geological Survey of India, (GSI, 2002) [5] resource map supported by field observations. The various lithological units exposed in the area includes; Basalt which accounts ($156.23km^2$) of the total geographical area followed by Bhander Sandstone ($37.59km^2$) are exposed in the area (Fig. 3). The major portion of the area is covered by Bhander sandstone and basalt. Alluvium has occupied the central most part of the area with gentle slope and represents good groundwater formation zone. The highest rank of 5 is given to alluvium because of holding shallow aquifers and having good groundwater recharge potential. On the other hand low ratings of 1 and 3 were given to basalt and Bhander sandstone respectively, because of their impervious to nature. Sandstone has occupied the periphery hilly tract of area with steep slope supporting to less groundwater recharge. Basalt lava flows are exposed at foothills parts of the area, by virtue of their hydrological properties, it discourages to groundwater recharge.

Land use/Land cover (LU/LC)

Land use land cover map has been prepared from satellite data analysis in ArcGIS (Fig.4). In land use/land cover analysis, six major classes were identified in the area which includes Crop land, Fallow land, settlement, scrubland, barren land and water body. LU/LC has great influence on recharge of groundwater. Concrete impervious or built-up structures reduce infiltration of water, whereas good vegetation and water bodies enhance infiltration of water to aquifers. In this way, LU/LC plays a key role in groundwater recharging. Weightage and rating assigned to this parameter are given in Table 1. In the study, maximum rating of 5 was given to Crop Land and minimum rating of 1 has been given to settlement area.

Drainage Density

Drainage density map has been prepared and is presented in Fig. 5. Drainage and drainage density are major factors, which affect the ground water occurrence in the area. The surface water runoff is directly proportional to drainage density. If drainage density is higher, less will be the infiltration of water into the ground (Horton, 1945) [8]. High drainage density has been observed towards the northwest and southwest of the watershed along with Kaliasot River. Rating and weightage have been assigned to drainage density are given in Table 1. Based on drainage density, it is classified into five classes i.e. 0-1.6km^{-1}, 1.6-3.6km^{-1}, 3.6-5.8km^{-1}, 5.8-8.5km^{-1}, 8.5-15.9km^{-1}. Accordingly, these classes have been assigned very good, good, moderate, poor and very poor categories respectively.

Lineament Density

Lineaments are straight linear elements visible at the Earth's surface as a significant “lines of landscape” (Hobbs, 1904) [7]. In present study area lineaments are extracted from satellite image. Lineament mapping was carried by using LISS III imagery with resolution of 23.5m. Lineament density (km/km2) map has been prepared using the line density tool of ArcGIS spatial analysis tool. Lineament density is indirectly representing the groundwater recharge zone because the presence of linear structural features being favourable paths for good groundwater recharge and storage. Areas with dense lineaments are suitable for groundwater development. Lineament density map (Fig. 6) of the area has been prepared. Highest rank of 5 has been given to lineament class with lineament density >2 and low ranking of 1 is given to lineament class with lineament density between 0 to 1. Rating and weightage assigned to lineament density are given in Table 1.

Slope Analysis

In case of groundwater, the areas where the slope amount is low are capable of holding the rainwater and allow percolation into the ground, which can recharge the groundwater (Chaudhary and Kumar, 2018) [11]. Low or gentle slope areas allow water to accumulate for long time which enhances the groundwater recharge (Ahirwar *et al*, 2020) [1]. Slope of the area has been derived by processing the SRTM DEM data and is shown in Fig. 7. Slope in the area varies from 6 to >12%. Higher slope areas with slope > 12% & upto 29%are present at the northwest of the watershed, whereas low slope is seen in the middle & lower part of area. Rating and weightage to each slope class were assigned is given in Table 1. The highest rank of 5 was given to slope class 0-1%, whereas as the lowest rank of 1 is assigned to slope classes >12%.

Geomorphology

Geomorphology is the study of the form of the earth (landform), its description and genesis (Gupta, 2003). It is a branch of earth science, which has grown after the advent of aerial photographs and satellite data. Geomorphologic landscape features of the area have been derived by processing of the GSI map (GSI, 2002) [15]. Geomorphology map (Fig. 8) has been prepared by extraction of the each landscape feature present in the area using ArcGIS. Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. Geomorphology of an area depends upon the structural evolution of geological formation. Geomorphology reflects various landform and structural features. Many of the features are favourable for the occurrence of Groundwater and classified in terms of groundwater potentiality.

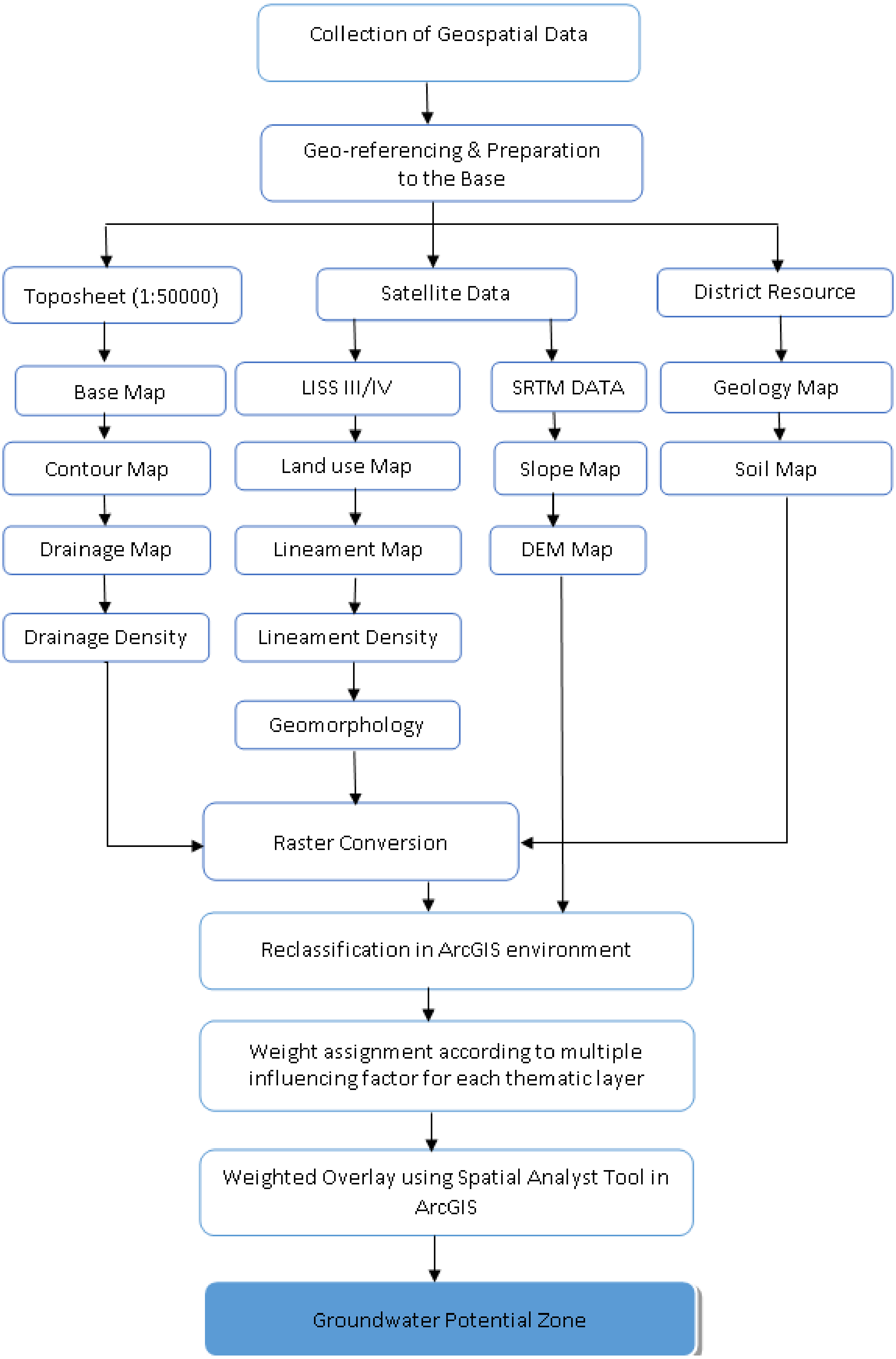
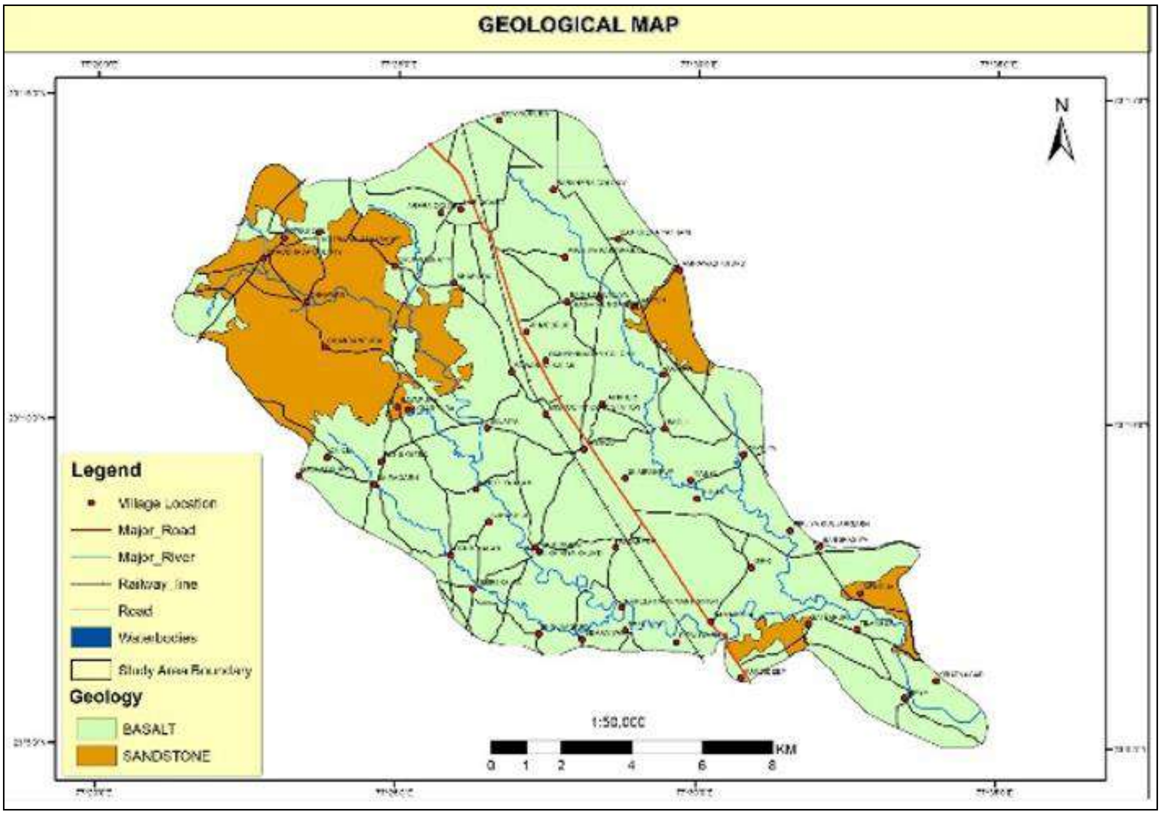


Fig 2: Flow sheet of Methodology followed in the present study

The geomorphic units of the basin can be divided into Pediplain ($111.02 km^2$), Pediment ($70.17 km^2$), Valley ($0.28 km^2$), water bodies ($2.02 km^2$), Residual hill ($3.44 km^2$) and Denudational hill (8. 09km^2). Among these pediplain are good in groundwater potential. The present study follows the classification of geomorphology by National Remote Sensing Centre (NRSC), based on ground truth verification, the geomorphology of the study area has been classified into five categories with their areal extend as depicted in Fig.8.



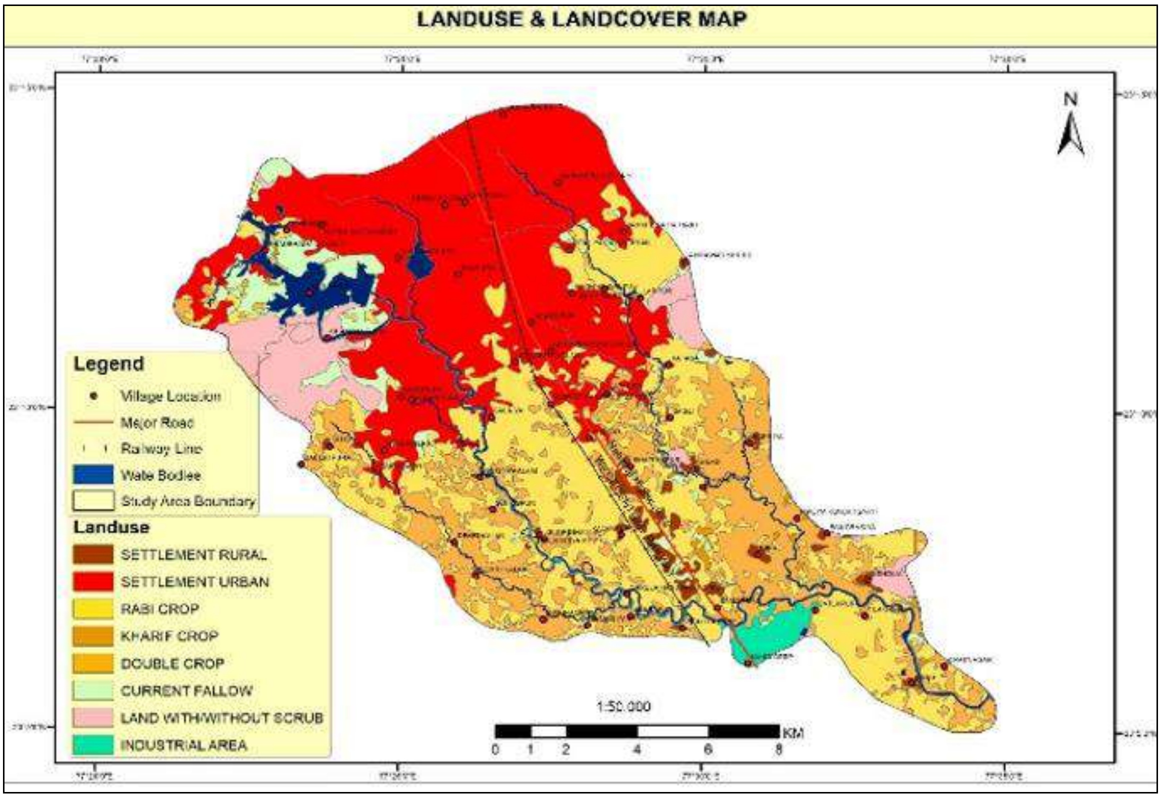


Fig 4: Land use /Land cover Map

Assigning Rank and Weights

One of the classic problems in decision theory or multi-parameter analysis is the determination of the relative importance (weights) of each parameter with respect to each other. This is a problem, which requires human judgment supplemented by mathematical tools. As not all parameters can be weighted equal for the suitability assessment, it is essential that a weighted method needs to be employed where the relative importance of the parameters defines the weights. Class wise rank and weight value were assigned for different thematic maps. All the thematic maps are converted into raster format and superimposed by weighted overlay method. For assigning the weight, the slope and geomorphology were assigned higher weight, whereas the lineament density and drainage density were assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the GIS layer on lineament density, geomorphology, and slope and drainage density were analysed carefully and ranks are assigned to their sub variable (Asadi *et al*, 2007, Yammani, 2007) [2, 18].

The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. The landforms such as moderately dissected plateau are given lower rank and highest value is assigned for pediplain. As far as slope is concerned, the highest rank value is assigned for gentle slope and low rank value is assigned to higher slope. The higher rank factors are assigned to low drainage density because the low drainage density factor favours more infiltration than surface runoff. Lower value followed by higher drainage density. Among the various lineament density classes the very high lineament density category is assigned higher rank value as this category has greater chance for groundwater infiltration. Lower value is assigned for very low lineament density. In LULC high rank is assigned to crop land and low value is assigned to barren land. The overall analysis is tabulated in Table 1.

Finally, all the parameters are superimposed by weighted overlay in order to get final integration of all the parameters influencing groundwater movement and occurrence in the region. The output thus generated as a final weighted map, which is further classified into five classes (Table 2).

Table 1: Rank & weight for different parameter of groundwater potential zone

Parameter	Classes	Groundwater prospect	Rank	Weight (%)
Geomorphology	Pediplain	Very good	5	30
	Pediment	Good	4	
	Valley	Good	4	
	Residual hill	Poor	1	
	Denudational hill	Very poor	1	
Slope	Nearly level (0-3%)	Very good	5	20
	Very gentle Slope (3-5%)	Good	4	
	Gentle slope (5-8%)	Moderate	3	
	Moderately slope (8-15%)	Poor	2	
	Strong slop (>15%)	Very poor	1	
Lineament Density (Km/Km^2)	0.0-0.30	Very good	1	15
	0.30-0.91	Good	2	
	0.91-1.66	Moderate	3	
	1.66-2.64	Poor	4	
	2.64-4.56	Very poor	5	
Drainage Density (Km/Km^2)	0.0-1.6	Very good	5	15
	1.6-3.6	Good	4	
	3.6-5.8	Moderate	3	
	5.8-8.5	Poor	2	
	8.5-15.9	Very poor	1	
Land use /Land Cover	Crop Land	Very good	5	15
	Waterbody	Good	4	
	Fallow Land	Moderate	3	
	Scrub Land	Moderate	2	
	Settlement	Poor	1	
	Barren Land	Very poor	1	
Geology	Basalt	Moderate	3	5
	Sandstone	Poor	1	

Table 2: Groundwater potential zone of study area

S.No.	Potential Zones	Area (Km^2)	Area (%)
1	Excellent	13.44	6.72
2	Good	110.97	58.30
3	Moderate	59.75	31.18
4	Poor	7.97	3.76
5	Very poor	0.04	0.014

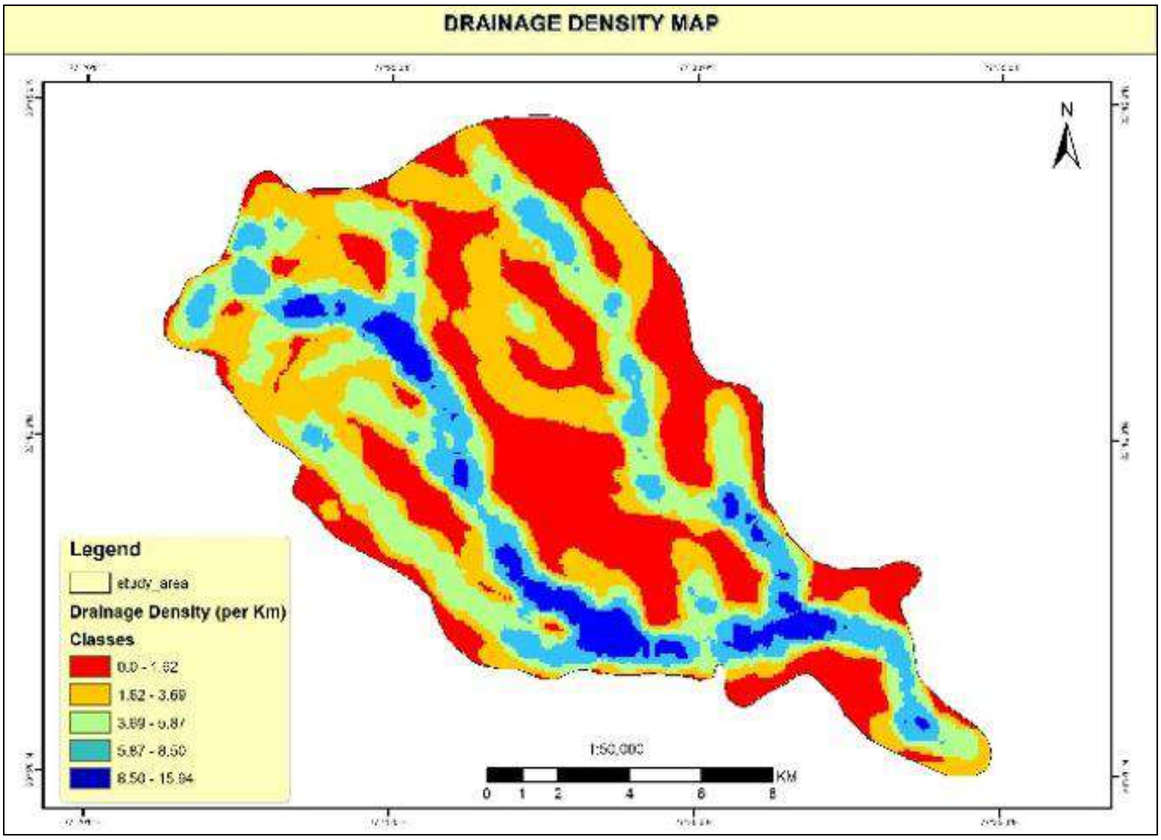


Fig 5: Drainage density Map

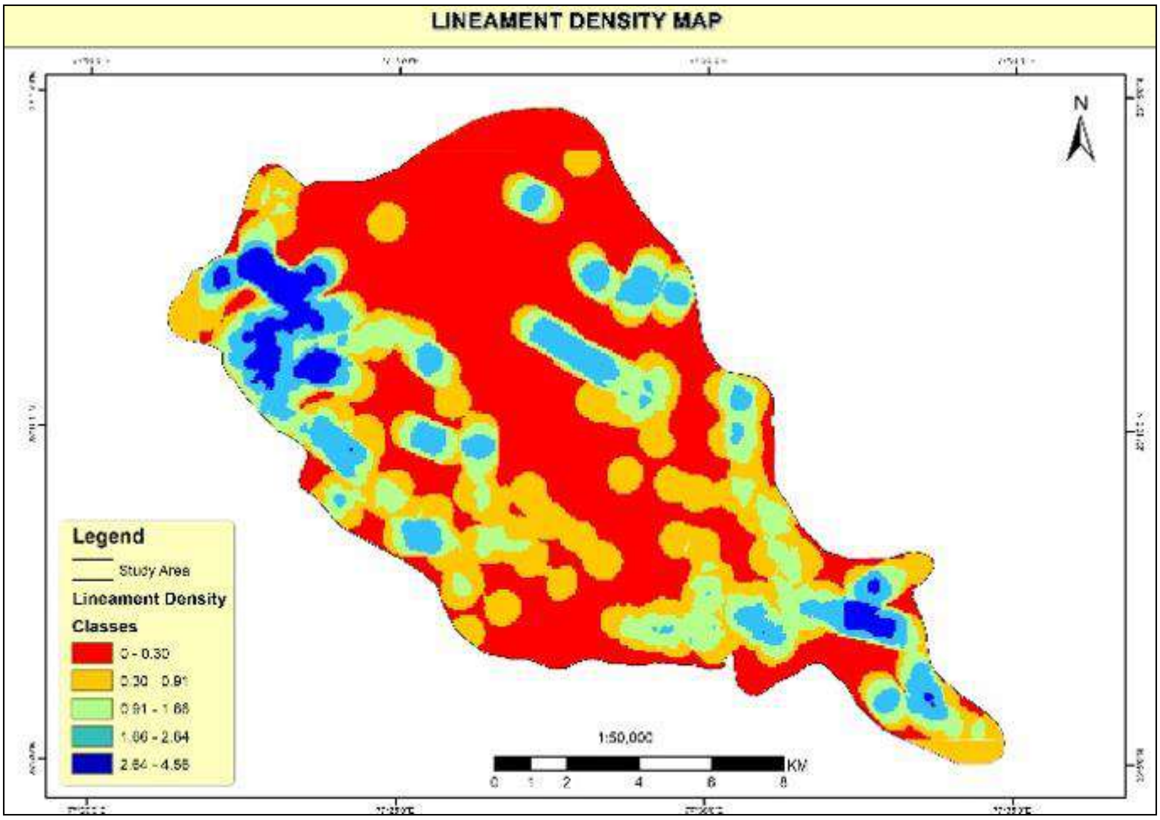


Fig 6: Lineament Density Map

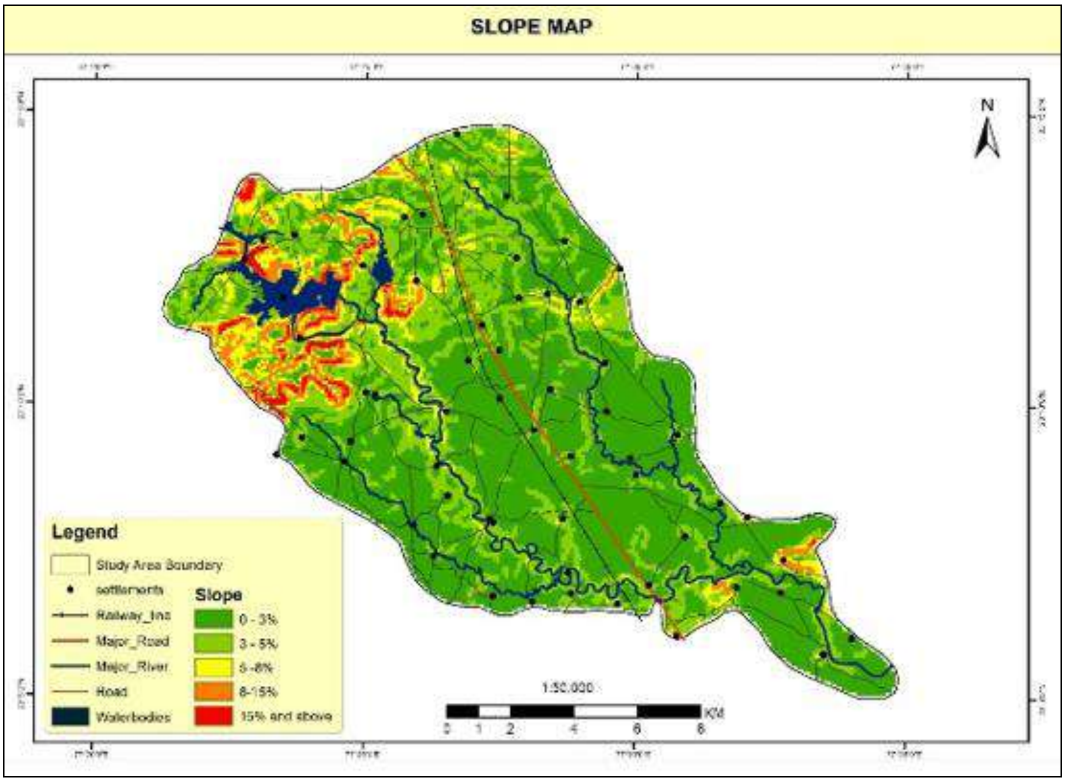


Fig 7: Slope Map

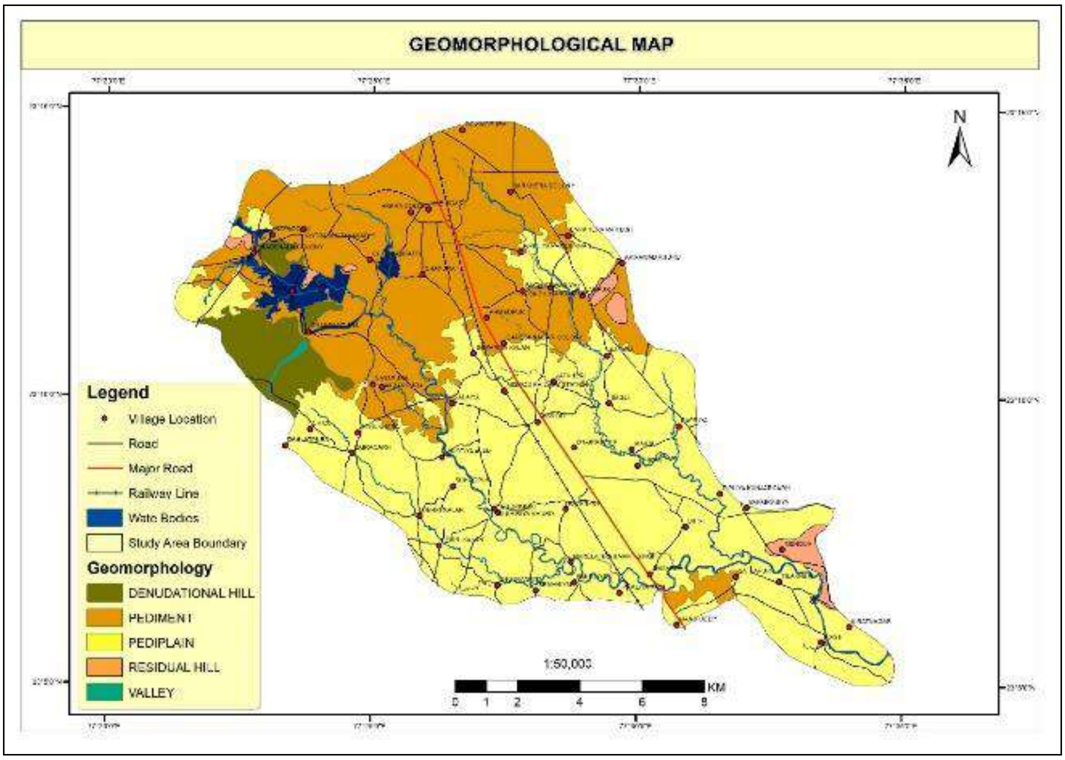


Fig 8: Geomorphology Map

Groundwater Potential Zone Map

Groundwater potential map (Fig. 9) of Kaliasot watershed was prepared integrating various thematic maps such as geology, geomorphology, slope, landuse-landcover, and lineament in GIS environment. The whole study area is divided into five categories for Groundwater potential development i.e.

i) Excellent
ii) Very good to good
iii) Good to moderate
iv) Moderate to poor
v) Poor.

Excellent

The excellent groundwater potentials areas in the watershed are intersection points of lineaments and valley fills marked on the map especially in Basalt area, where slope is nearly level to gentle. These are contributing to form good aquifer zones. This is also realized by well inventory and field observation at villages Bhairanpur and Dipri where artesian condition of some of the wells has been noticed. The area is characterized by presence of loose and unconsolidated material.

Very Good to Good
This zone is specially considered for buried pediments of Basalt having gentle slope and double crop area. Wells observed in this unit are having less water table fluctuation. The area is characterized by vesicular and basalt with considerable depth of weathering.

Good to Moderate
This zone is found mainly in the northern to central portion of the watershed, covered by weathered vesicular basalt filled with secondary fillings having gentle slope. Geomorphologically the area is marked as buried pediment, which is almost flat with little undulations and maximum cultivation.

Moderate to Poor
This zone is mainly confined to areas having moderate slopes and minor lineaments, which are playing major role to develop the semi confined conditions, sandstones are coming under this category and water is moderately available only along lineaments.

Poor to Very Poor
North western boundary of watershed is emerged as poor zone for groundwater potential. Denudational hills and structural hills of Vindhyan's sandstone come under poor potential. All these hills are covered by open forest and scanty scrubs.

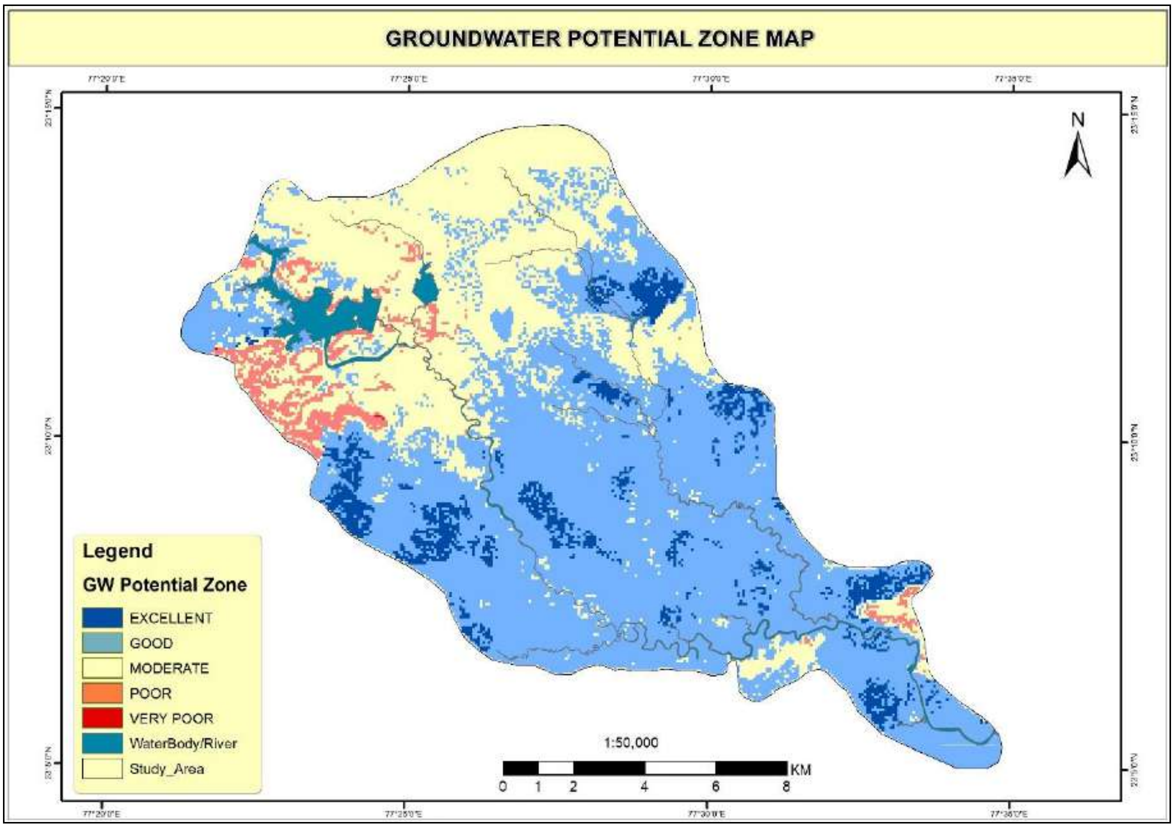


Fig 9: Groundwater Potential Zone Map

Conclusion
Based on satellite imagery six thematic maps such as drainage density, slope, geology, geomorphology, lineament density and land use/land cover have been prepared and interpreted in GIS environment and the weightage has been assigned to each thematic map on the basis of characteristics of groundwater potentiality. Further, these maps are integrated to give final product of groundwater potential map of the study area. Based on these five classes of groundwater occurrences have been evaluated. The given study area is classified in to

1. Excellent, comprising total area of (13.44km^2)
2. Good, comprising total area of (110.97km^2)
3. Moderate, comprising total area of (59.75km^2)
4. Poor, comprising total area of (7.97km^2)
5. Very poor, comprising total area of (0.04Km^2)

Groundwater potential zones and indicated in Fig.8. The area belonging to Good potential zone category comprising of maximum area of the order of 110.97km^2 followed by Moderate & Excellent potential zone have been suggested for groundwater exploration potential in the area of present study.

The final output of groundwater prospects map for Kaliasot watershed will be helpful in utilizing the land according to its capability and fulfilling the demand of water. The recommended treatments in the project are purely on scientific and technical basis that can be attempted in future for similar studies.

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