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DELINEATION OF GROUNDWATER POTENTIAL ZONES IN KOLAR DISTRICT USING REMOTE SENSING AND GIS TECHNOLOGY

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Abstract - *Water is elixir of life and all developmental activities enhance the demand of water, whether it is agriculture or industry. The water resources are available either as surface water or groundwater and the principal source for both the resources is precipitation. Growing water scarcity is being recognized as an important problem facing India. Groundwater is an important natural resource to meet the water requirements of our country. RS and GIS techniques are cost-effective and instantaneous process. Satellite pictures are widely being used for groundwater studies because of its ability to identify various ground features, which may serve as an indicator of groundwater. In this study, satellite images were used for preparing various thematic maps viz. geomorphology, lineament density, lithology, geology, slope, soil, land use/ land cover and drainage density. Ranks and weightages are allocated to each thematic map and their attributes based on their significance. Further overlay analysis of all maps was carried out which yielded various groundwater potential zones. The groundwater potential zones in Kolar district was divided into five different classes (i.e., Very Good, Good, Moderate, Low, Very Low) based on overall weightages.*

***Key Words*: Groundwater, Remote Sensing and GIS, Thematic Maps, Analytical Hierarchy Process, Weighted Overlay Analysis.**

1. INTRODUCTION

Water one of the most important natural resource occurring both as surface water and groundwater. It is vital for all life on the earth. Developments of our society are dependent on the availability and use of adequate water. This precious resource is sometimes scarce, sometimes abundant but unevenly distributed, both in space and time. Groundwater represents the second-most abundantly available freshwater resources and constitutes about 30% of fresh water resources of the globe *(subramanya,2008)*. More than 1.5 billion people in the world are known to depend on the groundwater for their drinking water requirements. The groundwater is derived from precipitation and recharge from surface water. It is the water that has infiltrated into the earth directly from precipitation, recharge from streams and other natural water bodies and artificial recharge due to action of man. Groundwater has been a popular resource of water in many tropical countries. Groundwater is easy to extract, and it remains well protected from the hazards of pollution that the surface water has to put up with. However, situations wherein we have encountered overexploitation of groundwater resources are not uncommon. Insufficient knowledge regarding the basics of groundwater is the primary reason why we have not been able to use groundwater resources to their full extent. Thus, there is a growing emphasis on groundwater management.

2. STUDY AREA

Kolar district lies between North latitude 12° 45’ 54” to 13° 35’ 47” and East Longitude 77° 50’ 29” to 78° 35’ 18”. It is bounded by Bangalore and Tumkur districts on the west, Chickballapur district on north-west, Anantapur district of Andhra Pradesh on the north, Chittoor district on the east and on the south by North Arcot and Dharmapuri districts of Tamil Nadu. The location of Kolar district in Karnataka is shown in Fig -1.

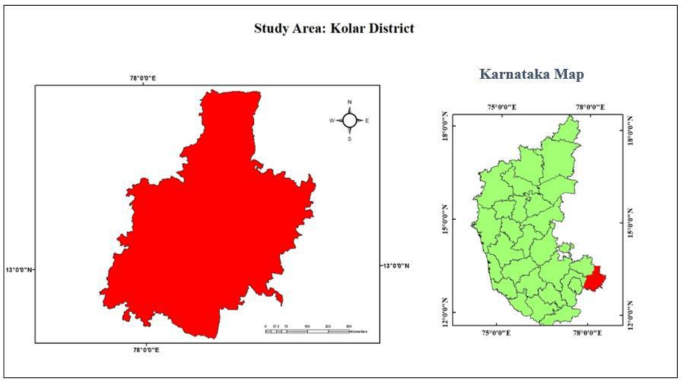

Fig -1: Location Map of the Study Area

3. MATERIALS AND METHOLOGY

The software used for the study was ArcGIS Desktop 10.7.1, downloaded from ESRI website and the data required to carry out the present study were collected from various sources. Cartosat-1, Digital Elevation Model (DEM) data was downloaded from the Bhuvan NRSC website, for developing drainage density and slope map of the study area. Lineament and geology map of the study area was downloaded in shapefile format from Bhukosh- Geological Survey of India website. Geomorphology, lithology, land use/ land cover and soil maps in shapefile format was collected from KSNDMC.

3.1. Thematic Maps

The thematic maps of geomorphology, lineament density, lithology, geology, slope, soil, land use/ land cover and drainage density were prepared based on the attributes which are of greatest significance in groundwater prospect mapping and are discussed below.

Geomorphology

Geomorphology is the scientific study of nature, history of landforms on surface of Earth and other planets, and the processes of their creation." It is at the centre of understanding what earth materials are, how they interact, how they originated, and how far they extend and where similar conditions and materials are likely to occur. It focuses on the combinations of composition, stratigraphy, shape, and topography of the materials and the geologic processes that give rise to and modify them. The different geomorphology units were depicted from satellite information and are represented in Fig -2. Geomorphology contribute an extremely critical part in groundwater prospects (Horton 1945, Thornbury 1985) and subsequently given highest weight in groundwater mapping.

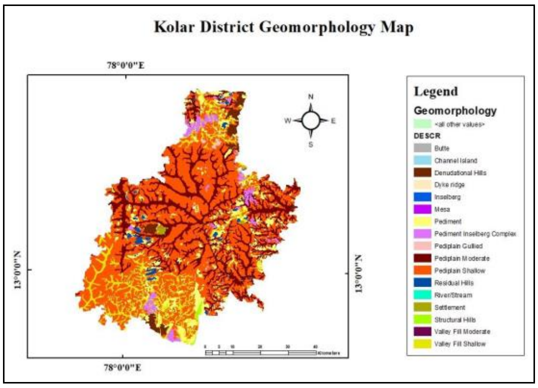

Fig -2: Geomorphology Map of Kolar

Lineament Density

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. Typically, a lineament will appear as a fault aligned valley, a series of fault or fold-aligned hills, a straight coastline or indeed a combination of these features. Lineament zones represent faults and fracture zones which are highly significant for mapping groundwater potential zones. Lineament density is defined as the total length of all the recorded lineaments divided by the area under consideration. The lineament density map of the study area is shown in Fig -3.

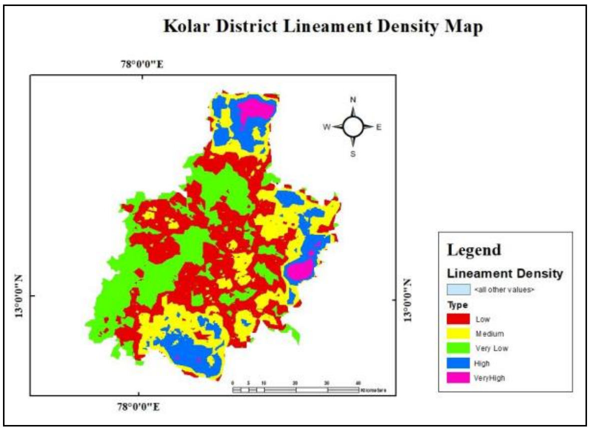

Fig -3: Lineament Density Map of Kolar

Lithology

Lithology is the branch of geology that studies rocks, their origin, formation, mineral composition and classification. The naming of a lithology is based on the rock type. The three major rock types are sedimentary, igneous, and metamorphic. Igneous rocks are formed directly from magma, which is a mixture of molten rock, dissolved gases, and solid crystals. Sedimentary rock is formed from mineral or organic particles that collect at the Earth's surface and become lithified. Metamorphic rock forms by recrystallization of existing solid rock under conditions of great heat or pressure. The different lithological units were depicted from satellite information and are represented in Fig -4.

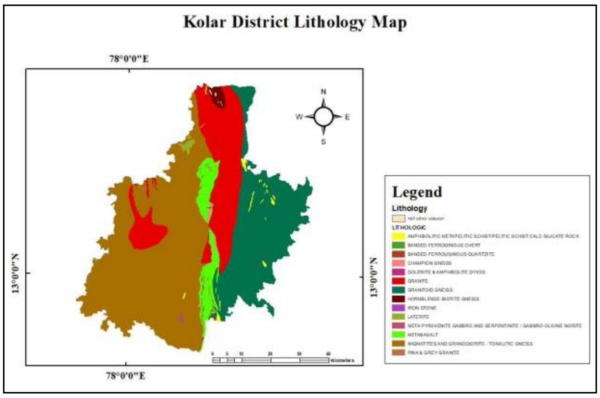

Fig -4: Lithology Map of Kolar

Geology

Geology is an Earth science concerned with the solid Earth, the rocks of which it is composed, and the processes by which they change over time. Geology can also include the study of the solid features of any terrestrial planet or natural satellite such as Mars or the Moon. The different geological units were depicted from satellite information and are represented in Fig -5.

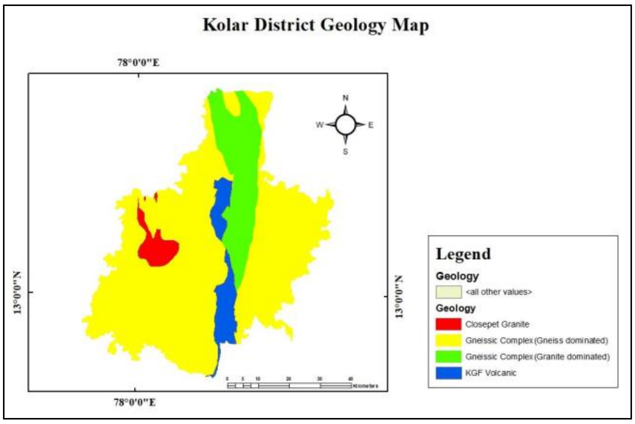

Fig -5: Geology Map of Kolar

Slope

Slope is a measure of change in elevation, it describes rise or fall of the land surface. Slope map was prepared from DEM. Slope range was differentiated into five groups, 0-1, 1-3, 3-5, 5-7 and >7 (indicated in degrees) as shown in Fig -6. Higher slope will produce more runoff with lesser infiltration and it will have a poor groundwater prospects contrasted with low slope region.

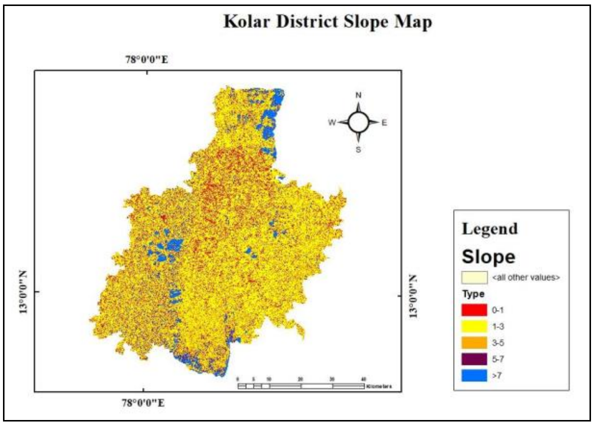

Fig -6: Slope Map of Kolar

Soil

Soil is the part of the earth's surface comprised of disintegrated rock and humus that provides the medium for plant growth. The process of soil formation is through the rock cycle together with the integration of soil microbial and chemical activities originating from living organisms. For instance, during the decomposition of dead plants and animals, nutrients are mixed up with the weathered and disintegrated rocks to form soil. Soil is considered as a natural resource because of its agricultural productivity benefits. Various soils have different mineral and organic compositions that establish their specific characteristics. The different soil types were depicted from satellite information and are represented in Fig -7.

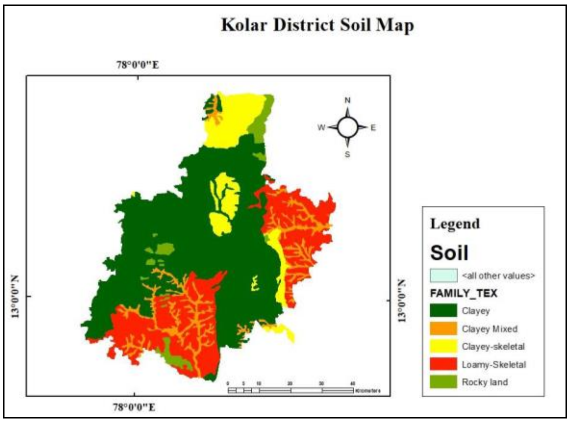

Fig -7: Soil Map of Kolar

Land Use/ Land Cover

Land use refers to the purpose the land serves, for example, recreation, wildlife habitat or agriculture, land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other. Land Use/ Land Cover (LULC) generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific time frame based on established scientific and statistical methods of analysis of appropriate source materials. LULC maps of an area provide information to help users to understand the current landscape. The different LULC were depicted from satellite information and are represented in Fig -8.

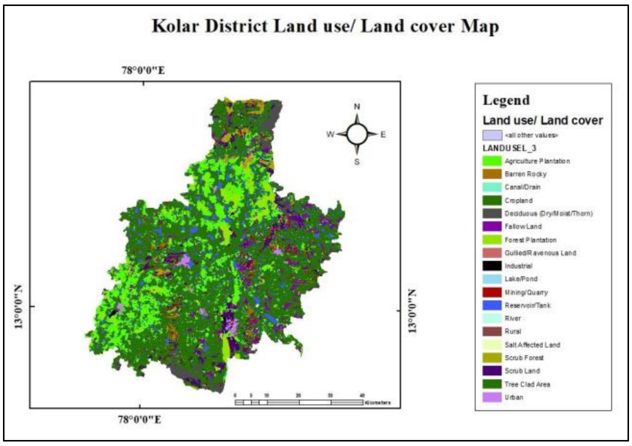

Fig -8: Land Use/ Land Cover Map of Kolar

Drainage Density

Drainage systems, also known as river systems, are the patterns formed by the streams, rivers, and lakes in a particular drainage basin. They are governed by the topography of the land, whether a particular region is dominated by hard or soft rocks, and the gradient of the land. Drainage density is defined as channel length per unit watershed area and it describes the spacing and distribution of the drainage ways in a catchment. The drainage density map of the study area is shown in Fig -9.

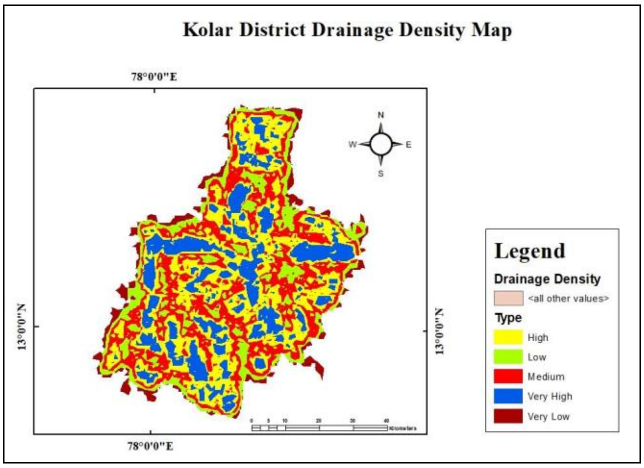

Fig -9: Drainage Density Map of Kolar

3.2. Analytical Hierarchy Process

This process involves studying of thematic maps and assigning numbers based on their priority in groundwater prospect mapping, 8 indicates highest priority and 1 indicates the lowest. Then weightages of each map are calculated. Further the attributes/ factors (sub categories) of each map is tabulated under each map title for assigning ranks and calculating overall weightages, rank 5 is of highest importance for potential zones whereas 1 is of least importance. The following tables show ranks and weightages assigned to each thematic map and their attributes contributing to the occurrence of groundwater.

Table -1: Thematic Map Weightage

Factors	GeoM	LinemD	Litho	Geology	Slope	Soil	LULC	DrainD	Weight
Geomorphology	8	7	6	5	4	3	2	1	0.37
Lineament Density	8/2	7/2	6/2	5/2	4/2	3/2	2/2	1/2	0.18
Lithology	8/3	7/3	6/3	5/3	4/3	3/3	2/3	1/3	0.12
Geology	8/4	7/4	6/4	5/4	4/4	3/4	2/4	1/4	0.093
Slope	8/5	7/5	6/5	5/5	4/5	3/5	2/5	1/5	0.075
Soil	8/6	7/6	6/6	5/6	4/6	3/6	2/6	1/6	0.062
Land Use/ Land Cover	8/7	7/7	6/7	5/7	4/7	3/7	2/7	1/7	0.054
Drainage Density	8/8	7/8	6/8	5/8	4/8	3/8	2/8	1/8	0.046
Weight									1

Factors	Weightage	Rank	Overall weightage
Geomorphology			
Butte	37	2	74
Channel		5	185
Denudational Hills		1	37
Dyke ridge		5	185
Inselberg		3	111
Mesa		2	74
Pediment		1	37
Pediment Inselberg Complex		4	148
Pediplain Gullied		5	165
Pediplain Moderate		3	111
Pediplain Shallow		3	111
Residual Hills		1	37
River/Stream		5	185
Settlement		1	37
Structural Hills		1	37
Valley Fill Moderate		5	185
Valley Fill Shallow		4	148

Factors	Weightage	Rank	Overall weightage
Lineament Density			
Very High	18	5	90
High		4	72
Medium		3	54
Low		2	36
Very Low		1	18

Factors	Weightage	Rank	Overall weightage
Lithology			
Amphibolitic Metapelitic Schist/Pelitic Schist, Calc-Silicate Rock	12	5	60
Banded Ferruginous Chert		1	12
Banded Ferruginous Quartzite		4	48
Champion Gneiss		5	60
Dolerite & Amphibolite Dykes		4	48
Granite		2	24
Granitoid Gneiss		2	24
Hornblende-Biotite Gneiss		5	60
Iron Stone		3	36
Laterite		5	60
Meta-Pyr0xenite Gabbro And Serpentinite / Gabbro-Olivine Norite		3	36
Metabasalt		5	60
Migmatites And Granodiorite - Tonalitic Gneiss		1	12
Pink & Grey Granite		4	48

Factors	Weightage	Rank	Overall weightage
Geology			
985,Closepet Granite, Archaean-Paleoproterozoic	9.3	3	27.9
987,Peninsular Gneissic Complex-Ii (Gneiss Dominated),Archaean-Palaeoproterozoic		1	9.3
987,Peninsular Gneissic Complex-Ii (Granite Dominated),Archaean-Palaeoproterozoic		2	18.6
994,Kolar Gold Field Volcanics Fm.(Dharwar Sgp.),Archaean		5	46.5

Factors	Weightage	Rank	Overall weightage
Slope			
0-1	7.5	5	37.5
1-3		4	30
3-5		3	22.5
5-7		2	15
>7		1	7.5

Factors	Weightage	Rank	Overall weightage
Soil			
Clayey	6.2	2	12.4
Clayey-skeletal		3	18.6
Clayey Mixed		4	24.8
Loamy-Skeletal		5	31
Rocky land		1	6.2

Factors	Weightage	Rank	Overall weightage
Land use & land cover			
Agriculture Plantation	5.4	3	16.2
Barren Rocky		1	5.4
Canal/Drain		4	21.6
Cropland		3	16.2
Deciduous (Dry/Moist/Thorn)		3	16.2
Fallow Land		3	16.2
Forest Plantation		3	16.2
Gullied/Ravenous Land		4	21.6
Industrial		1	5.4
Lake/Pond		5	27
Mining/Quarry		2	10.8
Reservoir/Tank		5	27
River		5	27
Rural		4	21.6
Salt Affected Land		2	10.8
Scrub Forest		3	16.2
Scrub Land		1	5.4
Tree Clad Area		3	16.2
Urban		1	5.4

Factors	Weightage	Rank	Overall weightage
Drainage density			
Very High	4.6	1	4.6
High		2	9.2
Medium		3	13.8
Low		4	18.4
Very Low		5	23

After calculation of overall weightages of all the categories of thematic maps, the weightages are integrated to the attribute table of each thematic map across the factors.

3.3. Weighted Overlay Analysis

This process involves a union of all the 8 thematic map layers assigned with weightages in ArcGIS by using union tool, which creates the geometric union of any number of feature classes and feature layers as shown in Figure. For this process to work, all input feature classes or feature layers must be polygons. The output feature contains the combined polygons and attributes of all coverages. The input layers in the present study are thematic maps of geomorphology, geology, lithology, lineament density, drainage density, soil, slope and land use land cover. The output layer thus created is the "Groundwater Potential Zone Map". After the successful completion of Union process, the output layer will be added to the map layout and is further discussed in the results section.

4. RESULTS

The output of weighted overlay analysis of the thematic maps is the result of the present study, i.e. "Groundwater Potential Zone Map". The overall weightages are classified into 5 groups and categorized as "Groundwater Potential Category -Very Good, Good, Moderate, Low and Very Low" based on overall weightage as shown in Table -2. Groundwater potential map of the study area is thus delineated by highlighting groundwater potential category as shown in Fig -10.

Table -2: Classification of Overall Weightages

Overall Weightage	Groundwater Potential Category
7.5 - 75	Very Low
75.1 - 148	Low
148.1 - 200	Moderate
200.1 - 260	Good
260.1 – 371.4	Very Good

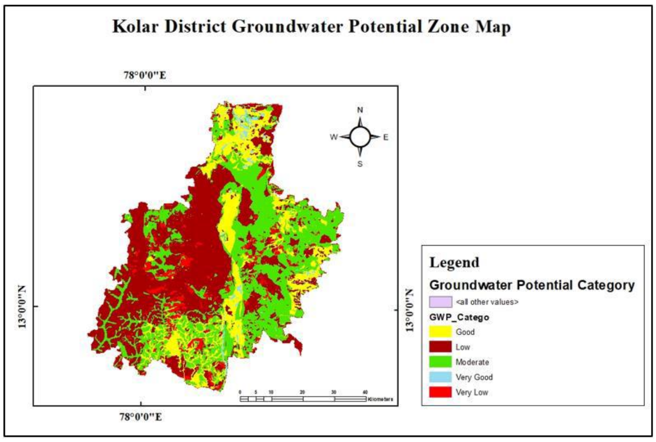

Fig -10: Groundwater Potential Map of Kolar District

Kolar district covers a total area of 4010 km^2 as calculated from the output attribute table of the present study and the distribution of area under each category is, Very Good - 64 km^2, Good - 660 km^2, Moderate – 1416 km^2, Low - 1624 km^2, Very Low - 244 km^2.

It can be concluded that area under very good, good, moderate, low and very low groundwater potential category is 1.6%, 16.5%, 35.5%, 40.5% and 6.1% of the total area respectively. This indicates that scarcely 18% of the Kolar district constitutes fairly good groundwater prospects and around 45% of the district has low groundwater prospects.

5. CONCLUSIONS

The use of Remote Sensing data on GIS platform proved to be successful in studying and analyzing the various factors and their attributes which are of great significance in groundwater prospect mapping. The data required were collected from various web sources and Karnataka State Natural Disaster Monitoring Centre and thematic maps of all the factors were prepared using ArcGIS 10.7.1 software. Various tools in the ArcGIS platform were useful in the present study for creating stream network, drainage characteristics, drainage density, slope characteristics, lineament density and other thematic maps such as land use landcover, lithology, geology, soil and geomorphology maps. Thematic maps were weighted based on their importance and priority in groundwater mapping, also the attributes of individual maps were studied and assigned weights. Further overall weightage was calculated and integrated into the maps for carrying out weighted overlay analysis using union tool in ArcGIS software. The overlay analysis of all 8 thematic maps resulted in a union map which indicated the groundwater potential category in the study area based on weightages, the highest weightage represents greatest groundwater potential. The weightages were reclassified into 5 classes or zones – Very Good, Good, Moderate, Poor and Very Poor. The low potential zone indicates the least favorable area for groundwater prospect; whereas very good zone indicates the most favorable area for groundwater prospect. This study carried out using remote sensed data is reliable and has emerged as an effective tool for systematic survey, analysis and better management of groundwater because it includes the ability to collect information over large spatial areas, areas inaccessible by human intervention, to characterize natural features or physical objects on the ground, also it can be collected, processed and analyzed expeditiously.

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