Identification of Artificial Ground Water Recharge Zone in Bagalkot District using RS and GIS

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ABSTRACT

Ground water is the main source for agriculture. With the increasing use of groundwater for various activities the fast decline in groundwater takes place. In order to prevent the aquifer from fast depletion, the artificial recharge of water is most important. Keeping this in mind to avoid fast decline in groundwater levels in Bagalkot - Karnataka, a study has been undertaken to identify the favourable areas for artificial recharge zones. The analysis was carried out using Remote Sensing data and GIS techniques. The various thematic maps such as Geomorphology, Geology, Soil, Slope, Drainage, Drainage density, Lineament density were used in the analysis. The above maps were prepared using satellite data and other collateral information collected from the field and digitized. Criterion tables were generated considering the importance of different themes and necessary ranks and weights were assigned to each theme. Using ARC GIS software, the above themes have been integrated and the areas suitable for artificial ground water recharge zones have been identified.

Keywords: Identification, Artificial, Ground water, GIS, RS, Zone, Bagalkot.

1. INTRODUCTION

1.1 General

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. The geological formation which are porous and have the ability to allow the flow through it they are called aquifer. Groundwater is a precious resource with limited availability. Groundwater plays an important role in sustaining India's economy, environment, and standard of living. It is not only the main source for water supply in urban areas for domestic uses, but also is the largest and most productive source of irrigation water. The relentless increases in population and the resulting spurt in the demand for water requirement, carefully planning and management of this limited water resources is urgently needed.

Groundwater resources development implies use of groundwater as a source of water supply, on a long-term basis, in an efficient and equitable manner sustaining its quality and environmental diversity. An understanding of the behaviour of a groundwater system and of its interaction with the environment is required to formulate a sustainable management plan. Mathematical models supported by field information play a key role in assessing the future behaviour of a system to stresses and to find effective operating conditions for sustainable development and management of groundwater resources.Ground water development in the country is 62%. The status of ground water development is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where the Stage of Ground Water Development is more than 100%, which implies that in the states the annual ground water consumption is more than annual ground water recharge. In the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh and UTs of Daman & Diu, and Pondicherry, the stage of ground water development is 70% and above.

The goal of most artificial recharge projects is to convey water to the saturated zone. Artificial recharge of aquifers is increasing day by day due to excessive demand of water by the ever-growing population and also because of the scarcity of good dam sites available for construction. Artificial recharge of aquifer is the process of adding water to an aquifer through human effort. The main purpose of artificial aquifer recharge is to store water for later use while improving upon the quality of water.

The term artificial recharge refers to transfer of surface water to the aquifer by human interference. The natural process of recharging the aquifers is accelerated through percolation of stored or flowing surface water, which otherwise does not percolate into the aquifers. Artificial recharge is also defined as the process by which groundwater is augmented at a rate exceeding that under natural condition of replenishment. Therefore, any man-made facility that adds water to an aquifer may be considered as artificial recharge. According to the Planning Commission, the average annual precipitation for India is 1170 mm. With a geographical area of 3.28 million km^2 the total input of water is taken as 4000 km^3 which is assumed to be a rounded-off. India receives annual precipitation of about 4000 km^3.Mousinram near Cherrapunji, which receives the highest annual rainfall in the world 11,690 mm. The ultimate irrigation potential of India has been estimated as 140Mha. Out of this, 76Mha would come from surface water and 64Mha from groundwater sources.

Water is one of the most essential requirements for existence of living beings. Surface water and ground water are two major sources of water. Due to huge population of Raipur district and higher use levels of water in urban areas, water supply agencies are unable to cope up demand from the surface alone sources like dams, reservoirs, rivers etc. In addition, they need to use the groundwater. This has led to digging of individual tube wells by house owners. Even water supply agencies have resorted to ground water sources by digging tube wells in order to augment the water supply. In rural areas also, government policies on subsidized power supply for agricultural pumps and piped water supply through bore wells are resulting into decline in ground water table. The solution to all these problems is to replenish the rain water harvesting may be technique of collection and storage of rain water at surface or in sub-surface aquifer before it is lost as surface run off.

Remote sensing and GIS are playing a rapidly increasing role in the field of hydrology and water resources development. The GIS technology provides suitable alternatives for efficient management of large and complex databases. Information from satellites is becoming more and more important for environmental research. Satellite images are increasingly used in ground water exploration because of their utility in identifying various ground features, which may serve as either direct or indirect indicators of presence of groundwater. The Geographic Information System (GIS) has emerged as a powerful tool in analysing and quantifying such multivariate aspects of groundwater occurrence. It is very helpful in delineation of groundwater prospect and deficit zones.

GIS techniques facilitate integration and analysis of large volumes of data, whereas field studies help to further validate results. Integrating all these approaches offers a better understanding of features controlling groundwater occurrence in hard rock aquifers. Geographic Information System has become one of the leading tools in the field of hydro-geological science, which helps in assessing, monitoring and conserving groundwater resources. It allows manipulation and analysis of individual layer of spatial data. It is used for analysing and modelling the interrelationship between the layers. GIS technique provides an advantage of having access to large coverage, even in inaccessible areas. It is a rapid and cost-effective tool in producing valuable data on geology, geomorphology, lineaments, slope, etc., that helps in deciphering groundwater potential zone. A systematic integration of these data with follow up of hydro geological investigation provides rapid and cost-effective delineation of groundwater potential zones. In order to implement artificial groundwater recharge, it is essential to delineate potential groundwater recharge zones.

Morph metric parameters along with physical aspects such as slope, lithology, elevation, land use/land cover etc. are used to identify suitable sites and structures for groundwater recharge, which are useful in water resources development plan. In the recent past several studies have been carried out based on GIS and remote sensing applications in delineating groundwater potential zones so as to formulate water resource development plan. Few researchers have used varying number of thematic layers, such as geology, geomorphology, drainage density, slope, aquifer transmissivity, water table fluctuations or depth to groundwater level, lineament density etc., for identification of artificial recharge sites. Since delineation of groundwater prospect zone and identification of artificial recharge sites is based on the combined role being played by various factors, it is necessary to use GIS. The present study is an attempt to identification of artificial recharge sites Bagalkot District of Karnataka, using satellite data and Geographic Information System. Therefore, the present study involves preparing the Plan for artificial groundwater recharge for Bagalkot districts with following specific objectives:

- To identify appropriate location for artificial recharge structures using Geospatial techniques.
- To develop ground water recharge plan for the study area.

- To validate recharge plan on the basis of ground truth data.

1.2 Groundwater Related Issues and Problems

Resource depletion due to over development, water-logging and soil salinity in canal command areas and geogenic and anthropogenic pollution of ground water are the main issues related to groundwater in the district. High groundwater development has taken place in Badami, (166.5%) Bagalkote(158.3%) and Hungund(119.7%) and in the non-command areas of Jamkhandi and Mudhol taluks. This has led to water scarcity in these areas, which adversely affects the domestic and agricultural sectors mainly during summer months.

Mining at localized areas for iron ores is being done in Kamatgi and Amingarh areas.Cement industries and extensive Limestone quarrying at Bagalkote and many other places are likely to affect the ground water availability and quality. Water – logging due to rise in water level is reported from the parts of Bilgi, Mudhol, Jamkhandi and Badami taluks falling in the Krishna, Ghataprabha and Malaprabha canal command areas. Though the exact area under water logging is not readily available, it is suspected that if not properly tackled, this may pose a threat in future resulting in loss of valuable arable land. Conjunctive use of surface and groundwater is a suitable management strategy in the command areas. The nitrate pollution of shallow aquifers is observed on a wide scale especially in canal command areas which is possibly due to extensive application of nitrogenous chemical fertilizers, shallow water level condition and due to other human interventions. Higher fluoride concentrations are observed in dug wells at places and are comparatively more in deeper aquifers as evidenced in bore well samples. The fluoride is geogenic and its concentration is likely to increase with over-development of groundwater. Though the district is industrially backward, existing cement, textile and engineering industries may cause groundwater pollution locally.

2. METHODOLOGY

Figure 1 shows the methodology of the study.

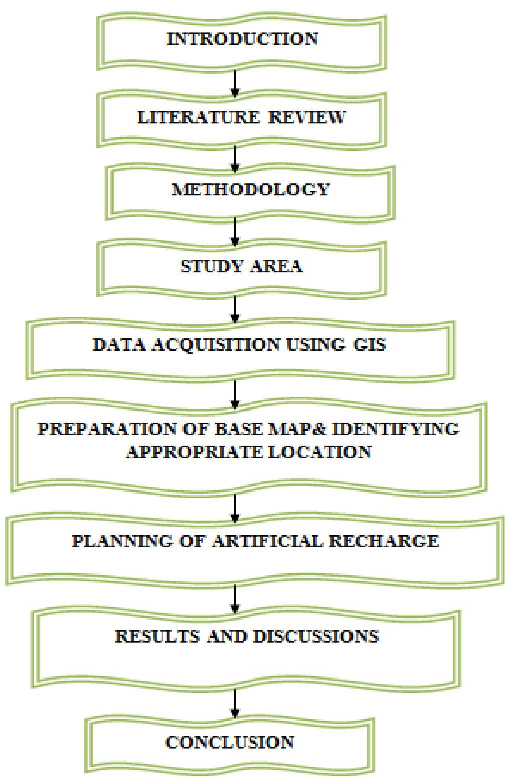

Figure 1 Methodology

3. STUDY AREA

3.1 General

The district of Bagalkot is situated entirely on the North Karnataka Plateau, which is part of the larger Deccan Plateau. Located in north-central Karnataka, Bagalkot is surrounded by Belgaum District to the west, Bijapur District and Gulbarga District to the north and northeast, Raichur District to the east and Koppal District, Gadag District and Dharwad District to the south-east, south and south-west respectively. It is positioned at 16°12′N 75°45′E and covers an area of 6593 km². Bagalkot district has seven taluks Bagalkot, Badami, Hunagunda, Mudhol, Jamkhandi, Bilgi, and Mahalingpur. The average elevation in this area reaches approximately 610 m. The climate is warm and dry throughout the year and rainfall is scarce. Bagalkot district receives the lowest rainfall annually in Karnataka. The average rainfall in the region is approximately 318 mm annually. The months of September and December account for about 52% of the total annual rainfall.

3.2 Physiography

The district of Bagalkot is situated entirely on the North Karnataka Plateau, which is part of the larger Deccan Plateau. Located in north-central Karnataka, Bagalkot is surrounded by Belgaum District to the west, Bijapur District and Gulbarga District to the north and northeast, Raichur District to the east and Koppal District, Gadag District and Dharwad District to the south-east, south and south-west respectively. It is positioned at 16°12′N 75°45′E and covers an area of 6593 km².

3.3 River System

Malaprabha River originates in the Sahyadri mountains at an altitude of 792.4 metres (2,600 ft) at Kanakumbi village 16 km (9.9 mi) west of Jamboti village, Khanapur taluka, Belgaum District, Karnataka.

The Ghataprabha river is an important right-bank tributary of the Krishna River and flows eastward for a distance of 283 kilometers before its confluence with the Krishna River at Almatti. The river basin is 8,829 square kilometres wide and stretches across Karnataka and Maharashtra states

The Krishna River originates in the western ghats near Mahabaleshwar at an elevation of about 1,300 metres, in the state of Maharashtra in central India. It is one of the longest rivers in India. The Krishna River is around 1,300 km in length.

3.4 Rainfall & Climate

The climate of the district is classified as tropical, semi-arid and hot which is mainly dry with very hot summer and cold winter except during south west monsoon season.

3.4.1 Rainfall

Rainfall in Bagalkot varies from 12mm to 670mm per month. The average annual rainfall in the district is 550 mm. The rainfall in the district increases generally from the South-west towards the north-east and varies from 435.5 mm. About 75% of the rainfall in the district is received during the period from June to September and as much as about 18% rainfall occurs during the period from July to September.

3.4.2 Climate

The climate of the area is sub-Tropical Monsoon climate. The climate of the area is characterized by general dryness except during the brief south-west monsoon season, a hot summer is a bracing winter. The year may be divided into four seasons. It comprises of the winter season (November to Feb) when temperatures range from 22 °C to about 16 °C, the hot season (April to June) when temperatures can reach 45 °C (113 °F), monsoon season (July to September) and post-monsoon (September to November). The climate is generally characterized by dry weather except the brief southwest monsoon season, hot summer and bracing winter.

3.5 Groundwater Scenario

3.5.1 Hydrogeology

The ovoid shaped Kaladgi and Badami Group of sedimentary basins is well marked lying mainly between Krishna, Malaprabha and Ghataprabha rivers, and an area of around 8,300 sq. kms. In the shallow aquifer (up to 50m) ground water occurs under unconfined/water table conditions, where as in deeper aquifer, semi-confined/confined conditions exist. The traditional dugwells tapping the shallow aquifer are not in use and most of them have been abandoned, however, this aquifer is being tapped by the hand pumps and shallow tube wells, which are widely used for domestic purposes. The permeable granular zones comprising fine to mediumgrained sand and occasionally coarse sand and gravel. Their lateral and vertical extent is limited. The borehole data reveals that clay group of formations dominate over the sand group in the district area. Ground water in the district occurs in the alluvium under water table and semi confined to confined conditions.

3.5.2 Water Level Behaviour

The depth to water level ranges from 12 to 450 m during pre-monsoon period and 22 to 50 m during post monsoon period. The seasonal fluctuation varies from 2.0 to 12.0 m in the area. The long-term water level trend indicates average fall of 0.50 m/year. The long-term water level trend is also showing little rise being 0.24 m/year around majauli, which is insignificant with respect to entire area.

3.5.3 Ground Water Flow

The elevation of the water table in the district varies from 430 m to 500 m above mean sea level. The highest elevation is in the South Easter part and the lowest in the North western part and reflects the topographic gradients. The hydraulic gradient in the northern western part is steep, whereas, in the south-western part, it is gentle. The overall flow of ground water is from northeast to south-west direction.

3.6 Land Use/Land Cover Mapping

The purpose of land use classification is to maximize the productivity and to conserve the land for prosperity; classification of land requires considerable time and expense. Therefore, there must be justification for classifying of land in to different categories. Land classification is not an end in itself but a means to obtain better land use. Land classification means dividing the land into different categories according to a single factor or a set of factors. Therefore, land classifications may be of many types depending upon the factors taken for classification. The land classification relates to climatic factors, soil characteristics, slope of the land, and degree of erosion, water supply, drainage and similar environmental conditions. The land use capabilities classification portrays the physical capabilities of land to produce over a long period of time under stated conditions of use and which can provide the operations with a basis for actual practice on scientific use of land.

3.7 Geology And Mineral Resources of Bagalkot

The ovoid shaped Kaladgi and Badami Group of sedimentary basins is well marked lying mainly between Krishna, Malaprabha and Ghataprabha rivers, and an area of around 8,300 sq. kms. It occupies in parts of Bagalkot, Bijapur, Belgaum, Dharwad, Raichur districts of northern Karnataka state, and some parts of eastern Maharashtra, at the Latitude 15°33’ to 16°31' N; and Longitude 74° 10' to 76° E [Fig. 4.1], as it is located almost centre part of the basin.

The Precambrian epicontinental Kaladgi Basin represents a remarkable and significant geological unit displaying magnificent stratigraphic succession, lithologic assemblage, tectonic, structural and depositional features among the Precambrian rocks of Peninsular India. It covers the large area, as compared to the other Precambrian sedimentary formations of Karnataka namely the 'Bhima Group' and geologically it has long history

4. DATA ACQUISITION USING GIS

4.1 Materials And Methods

4.1.1 Research Methodology

Each of the thematic maps has been reclassified and assigned suitable weight age according to multi influencing factor. Groundwater potential recharge zones were identified by overlaying all the thematic maps in terms of weighted overlay methods using the spatial analysis tool in ArcGIS. The multiple parameter analysis for delineating groundwater recharge sites in the study area has been done by Multiple Influencing Factor (MIF) technique.

4.1.2 Data Collection

This study involves mapping of different features that influence groundwater recharge in different degrees. Hence thematic maps of Geomorphology, Geology, LULC, Soil, Slope, and Lineament of the study area were obtained from various sources for analysing and integrating to get the final result.

4.1.3 Preparation of Thematic Layers and Assigning of Ranks

The Cartosat DEM (30 m) data was obtained from Bhuvan (ISRO's geo-portal) and was used to develop drainage density map. Existing data of geology, geomorphology, soil, land use, and slope were converted from '.shp' format to raster format using polygon to raster tool and a cell size of 30 m was applied to all the maps during conversion. Then all the maps were projected to WGS 1984 Transverse Mercator. Lineament map was converted to lineament density (km/km-2) map using line density tool of spatial analysis tool. Each parameter is assigned weights from 1 to 4 scales as per the degree of contribution to the central theme.Table 1 shows the logic of assigning weightage.

Table:1Logic of assigning weightage

S. No	Rank	Logic Value
1.	1	High Contribution to Central Theme
2.	2	Moderate Contribution to Central Theme
3.	3	Low Contribution to Central Theme
4.	4	Least Contribution to Central Theme

4.1.4 Preparation of slope map

The Cartosat DEM data were used to derive the slope map, which is presented in terms of percentage using the 'slope' function in ArcGIS. It was then converted from .shp to raster format and reclassified into different slope classes using re-classify option in the spatial analyst tool. Ranks were assigned for each class of the slope map.

4.1.5 Preparation of Soil Map

Soil map of shape file format were converted to raster format using polygon to raster conversion tool. The eight major soil groups found in the study area was then reclassified in order to assign ranks to each class.

4.1.6 Preparation of Geomorphology Map

Geomorphologic map incorporates relationship of geomorphic units with their groundwater potential as interpreted from the landform characteristics as well as sub surface geology.

4.1.7 Preparation of Geology Map

It is well established fact that geological set-up of an area plays a vital role in the distribution and occurrence of groundwater. Geological classes were reclassified and assigned ranks.

4.1.8 Preparation of Land Use Map

Land use map of the study area was available in the Department of Remote Sensing and Geographical Information System (GIS), TNAU, Coimbatore in .shp format and it was converted to raster format and later reclassified using the conversion tool and reclassify tool in ArcGIS 10.1. Different land use classes were assigned different ranks based on their influence on groundwater recharge potential.

4.1.9 Preparation of Lineament Density Map

Lineaments are linear or curvilinear structures on the earth surface, which depict the weaker zone of bed rocks and the area is considered as secondary aquifer in hard rock regions. In hard rock terrains, lineaments represent areas and zones of faulting and fracturing resulting in increased secondary porosity and permeability and are good indicators of groundwater. The present study used lineament length density (LD, L-1), which represents the total length of lineaments in a unit area, as:

$$LD = \sum_{i=1}^{i=n} \frac{Li}{A(m^{-1})}$$

Where, Li= total length of lineaments (m) and A=area of study area (m^2).

Lineament map was converted to lineament density using the line density tool in spatial analysis tool. This was then classified into two classes *viz.*, lineament present and not present. Areas with lineament was assigned the maximum rank and without lineament with least.

4.1.10 Preparation of Drainage Density Map

The Cartosat DEM (30 m) data was obtained from Bhuvan (ISRO's geo-portal) and was mosaic and clipped to the study area. The clipped DEM was then filled, using the fill tool in spatial analysis tool to remove small imperfections in the data. To create a raster of flow direction from each cell to its steepest down slope neighbour flow direction tool was used. A raster of accumulated flow was next created using flow accumulation tool with flow direction as the input. Drainage map was then generated from Cartosat DEM using the raster calculator tool, which was then converted to vector and further the drainage density (km-2) map was obtained by the line density analysis tool.

4.1.11 Criteria Weightage Assignment

Weight is used to develop a set of relative weights for a group of factors in a multi-criteria evaluation. The multi influencing factors for groundwater potential zones namely geology, slope, land use/land cover, geomorphology, drainage, soil, and lineament were examined and assigned an appropriate weightage according to the multiple influencing factors (MIF) of that particular feature on the hydro geological environment of the study area. The effect of each major and minor factor is assigned a weightage of 1.0 and 0.5 respectively. The factors and their resulting weights can be used as input for the Weighted Overlay Analysis in ArcGIS environment for overlaying of thematic maps.

4.1.12 Data Integration Analysis in GIS Environment

The thematic maps were used as input in the weighted overlay analysis, during the analysis, the weights were assigned to the thematic layers in the weighted overlay table and each of the classes was ranked accordingly. After assigning weight, the integration of all layers was carried out applying weighted overlay analysis in a GIS environment. The output map of the weighted overlay analysis gives the groundwater prospect map of the study area.

5. PREPARATION OF BASE MAP AND IDENTIFYING APPROPRIATE LOCATION

5.1 Drainage And Drainage Density Map

A drainage system thatdevelops on a regional surface iscontrolled by the slope of the surface and the types and attitudes of the underlying rocks. Drainage patterns, which are easily visible on space photographs and images, reflect tovarying degrees the lithology and structure of a region. Drainage patterns in an area depended mainly on the type distribution and attitude of the surface rocks, arrangements of zones or lines of weakness, etc. No natural resource survey is complete without an analysis of the drainage characteristics of the area. The study areas are observed in dendrite, sub-dendrite and rectangular type of drainage. Figure 2 shows the drainage pattern map for study area.

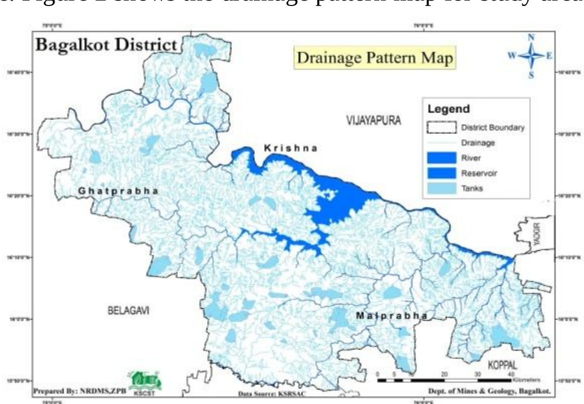

Figure 2 Drainage pattern map for Study area

Fgure 3 shows the Drainage density map.

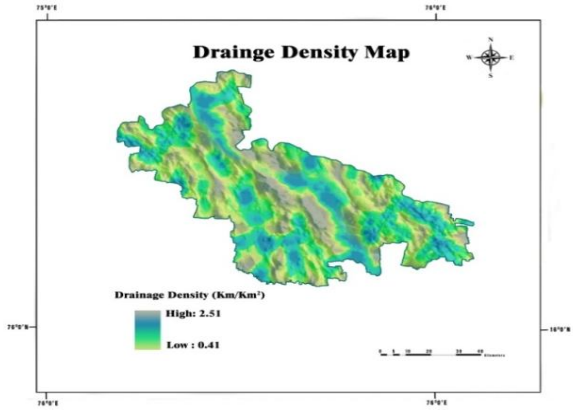

Figure 3 Drainage density map

The drainage map was prepared from the satellite images with inputs from the topographical map. A drainage map was digitized on 1:50,000 scales. The drainage Density map was prepared in Arc MAP and shown in fig 6.2, which was finally classified into different classes varying from very low to very high density. The zones of high drainage density will have poor groundwater prospects and gradually the zones of lower and lower drainage density zones will have better groundwater prospects.

A digital elevation model (DEM) is a 3D CG representation of a terrain's surface – commonly of a planet (e.g. Earth), moon, or asteroid – created from a terrain's elevation data. A "global DEM" refers to a Discrete Global Grid. Figure 4 shows the digital elevation model.

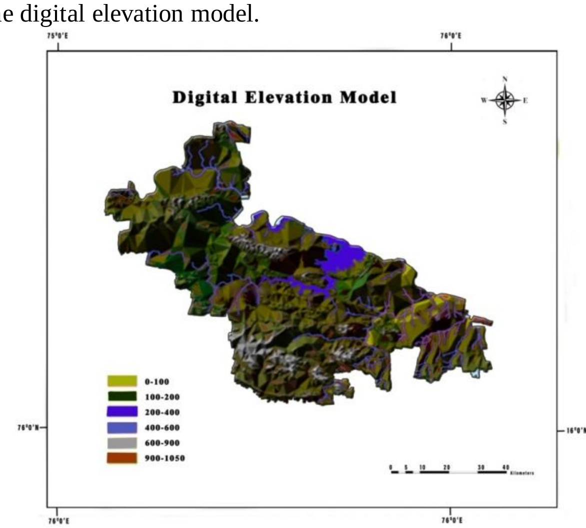

Figure 4 Digital elevation model

Figure 5 shows the slope map.

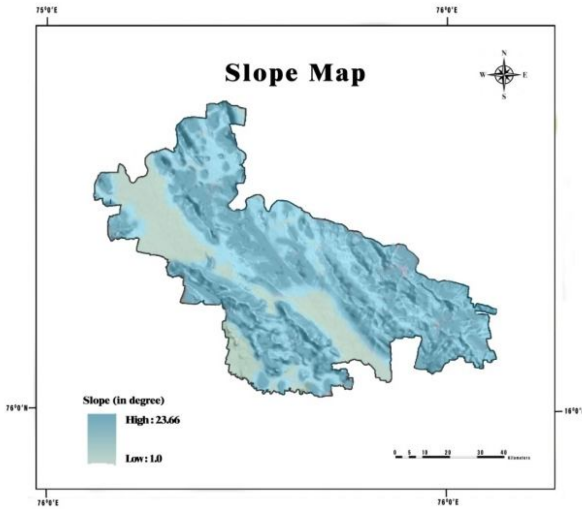

Figure 5 Slope map

5.2 Slope

The precipitous terrain causes rapid runoff and does not store water easily. Slope of any terrain is one of the factors allowing the infiltration of groundwater into subsurface or in other words groundwater recharge. In the gentle slope area, the surface runoff is slow allowing more time for rainwater to percolate, whereas, steep slope area facilitates high runoff allowing less residence time for rainwater to percolate and hence comparatively less infiltration. The slope map of the study area is derived from SRTM DEM 30 m and slope of the study area is classified into nine classes.Slope is the measure of steepness or the degree of inclination of a feature relative to the horizontal plane.The above slope map shows the slop of the study area ranges in between 1 to 23.66 degree.

5.3 Geomorphology Map

The major part of the study area composed of crystalline rock. Groundwater mainly occurs in the colluviums cover and especially secondary pore spaces created by the jointing, fracturing, fissuring and weakening of rocks. Groundwater potentiality is very promising in alluvial areas. Geomorphological the study area has special credential owing to the occurrence of multiple landforms. Based on the photo recognition techniques study area geomorphology map has prepared on 1:50000 scale using Landsat satellite data. The following geomorphic features such as structural hill, erosion plateau, shallow pediment, medium pediment, deep pediment, bazada, delta, upland, flood plain and inter local.Geomorphologic mapping is regarded as a fundamental technique of the discipline producing valuable base data for geomorphological and environmental research and practice. Geomorphological maps can be considered graphical inventories of a landscape depicting landforms and surface as well as subsurface materials.

5.4 Geology Map

The geology map was prepared by using already existing geological data collected from the geological survey of India map (the resource map ofKarnataka) with the scale of 1:50,0000. The most of the area is occupied by Charnockite and calcareous sand. Figure 6 shows the geology map.

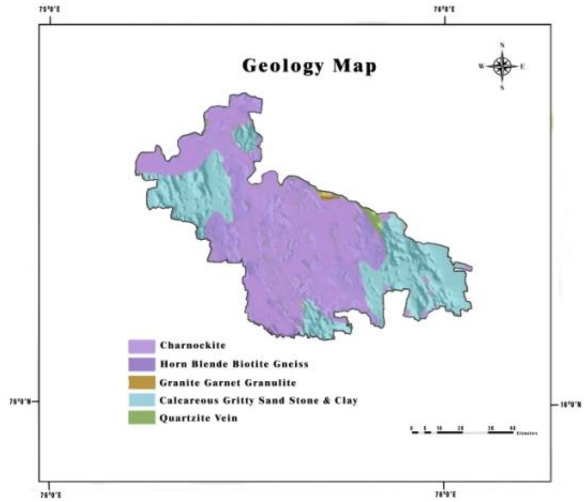

Figure 6 Geology map

Figure 7 shows the soil map.

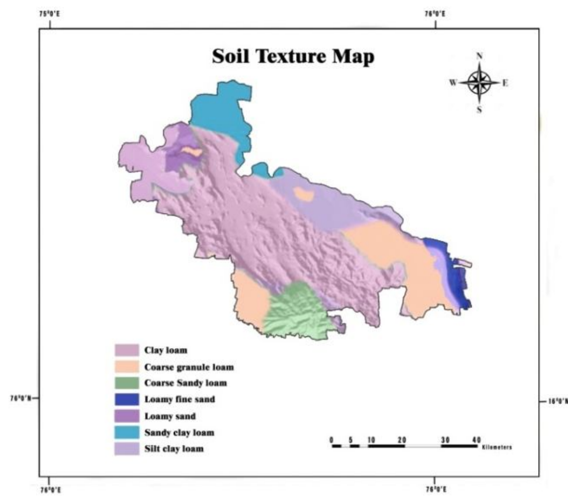

Figure 7 Soil map

5.5 Soil Order

The most general level of classification in the USDA system of Soil Taxonomy is the Soil Order. All of the soils in the world can be assigned to one of just 12 orders. Soil orders are frequently defined by a single dominant characteristic affecting soils in that location, e.g., the prevalent vegetation (Alfisols, Mollisols), the type of parent material (Andisols, Vertisols), or the climate variables such as lack of precipitation (Aridisols) or the presence of permafrost (Gelisols). Also significant in several soil orders is the amount of physical and chemical weathering present (Oxisols, Ultisols), and/or the relative amount of Soil Profile Development that has taken place (Entisols).This will examine each of these 7 soil orders in turn: Clay loam, coarse granule loam, Coarse sandy loam, Loamy fine sand, Loamy sand, Sandy clay loam and silt clay loam. Soil map is a map i.e., a geographical representation showing diversity of soil types represent in fig 6.6. It is typically the end result of a soil survey inventory, i.e., soil survey.

5.6 Lineament

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. Fracture zones, shear zones and igneous intrusions such as dykes can also be expressed as geomorphic lineaments. Figure 8 shows the Lineament density map of our study area.

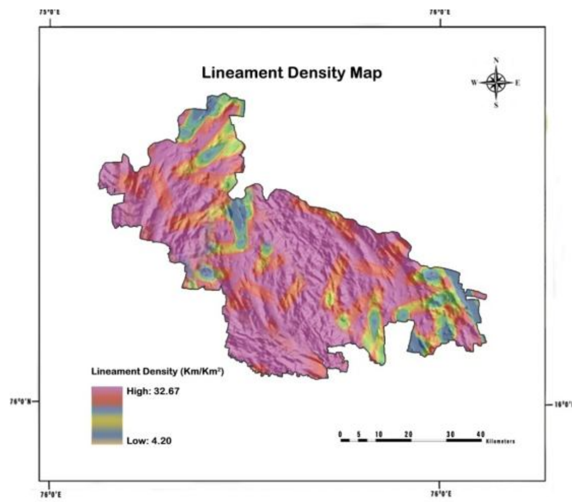

Figure 8 Lineament Density Map of Our Study Area

Lineaments are often apparent in geological or topographic maps and can appear obvious on aerial or satellite photographs. There are for example, several instances within Great Britain. In Scotland the Great Glen Fault and Highland Boundary Fault give rise to lineaments as does the Malvern Line in western England and the Neath Disturbance in South Wales.The term 'megalineament' has been used to describe such features on a continental scale. Lineaments have also been identified on other planets and their moons. Their origins may be radically different from those of terrestrial lineaments due to the differing tectonic processes involved. Table 2 shows the Base Map – datas.

Table 2: Base map – datas

Sl.No.	Parameter	Class	Rank	Weight
1	Drainage density (km/sq.km)	0-0.50 0.50 – 1.0 1.0 – 1.50 1.50 - 2.0 2.0 – 2.51	5 4 3 2 1	20
2	Slope (Degree)	<2° 2-5° 5-12° 12-25° >25°	4 3 3 2 1	25
3	Geomorphology	Shallow Pediment Deep Pediment Structural Hills Moderate Pediment Valley Fill Dissected/Undissected Pediplain Residual Hills Bajada Linear Ridge Burried Channel Inselberg Flood plain	2 5 1 4 4 3 4 1 3 4 1 2 3	10
4	Geology	Charnockite Calcareous gritty sand stone Horn blende biotite gneiss Granite garnet granulite Quartzite vein	5 4 2 2 1	10
5	Soil order	Clay loam Coarse granule loam Coarse sandy loam, Loamy fine sand, Loamy sand, Sandy clay loam silt clay loam.	3 4 5 2 1 3 1	15
6	Lineament Density (km/sq.km)	0- 6.5 6.5 – 13.0 13.0 – 19.5 19.5–26.0 26.0 – 32.50	1 2 3 4 5	20

6. RESULTS & DISCUSSIONS

6.1 Groundwater Management Strategy

Bagalkote district is basically agriculture-dominated district where it is the main occupation of the rural population, which constitutes 71 % of the total population (2001 census). As per the data available (Hassan District at a glance-2005-06), total irrigated area constitutes 45 % of the net sown area. The contributions of surface water, in irrigated agriculture through major and medium irrigation projects, tanks and lift irrigation schemes is 55 %. It is apparent that groundwater is playing equally vital role in agriculture sector apart from being the main source of drinking water in major part of the district. The non-command parts of the five out of six taluks (ie except Bilgi taluk) are showing high groundwater development and are falling in Over-Exploited category. Hence, judicious use of ground water and its sustainable management is all the more important. Water-economy irrigation practices like drip and sprinkler irrigation methods should be popularized. Efforts should be oriented towards conservation and augmentation of groundwater. In canal command areas conjunctive use approach can be adopted. In deeper ground water areas of the district and groundwater over development areas, artificial recharge measures like percolation tanks and check dams are to be implemented to augment the groundwater resource. Point recharge structures would help in recharging deeper depleted fractures and fissures so as to have a sustainable yield from bore wells. Technical management of groundwater should be kept in mind while extending institutional finance to farmers and awareness should be created in different user communities. Participatory approach in groundwater management especially in canal command areas is essential.

6.1.1 Groundwater Development

Thedevelopment is less in the taluks having surface water facility for irrigation. Hence, ahigher development of more than 100% is witnessed in Bagalkote, Badami and Hungund taluks. Further development in the over-exploited areas of the above-mentioned taluks should be restricted. In Jamkhandi and Mudhol taluks furtherdevelopment of groundwater should be done with all cautions. As groundwater level, ingeneral, is declining, deepening of dug wells, conversion of dug wells into dug-cum borewells is needed. The shallow zone of ground water can be developed for irrigationthrough dug wells in topographic low areas and dug-cum-borewells in valley slope areashaving comparatively deeper water levels. Optimum depth of dug well is 10-12 m havinga diameter of 6-7m. The optimum depth of dug-cum borewell is 15-20 m having adiameter of 6-7 m in dug part and 100 mm in lower borewell part to a depth of100 m. Aminimum spacing of 75 to 100m between dugwells is recommended. The recommended optimum discharge of dugwells is 3 – 4 lps for the prevailing croppingpattern for a pumping of 4 to5 hrs and 3-5 H.P. pump is needed. The recommendedcommand of each well is 1.2 hectare. Borewells are possible in all topographicconditions and pinpointing of site, depth, yield prospects etc, should be ascertained bysuitable investigations. The minimum distance of 150 m between two borewells isnecessary to avoid mutual interference.

6.2 Groundwater Conservation and Artificial Recharge

Fast, unchecked andindiscriminate withdrawal of groundwater through different abstraction structures hasresulted in the decline of ground water level. Hence, arrest of further decline of waterlevel and ground water resource augmentation is essential. Conservation andaugmentation can be achieved by adopting water efficient irrigation practices, suitablecropping pattern and constructing appropriate artificial recharge structures.Rain Water Harvesting would be a remedy in areas where there is ground waterquality problem due to high nitrate, chloride and fluoride concentrations and water leveldecline.

Selection of a particular type of RWH structure is area specific. By studying the nature of geological formations, slope of the land, depth of weathering, depth to waterlevel and availability of land and water source for these artificial recharge structures,different types of artificial structures are recommended and shown in the map. Thenorthern part of the district constituting a gently undulating to plain land is suitable for construction of Percolation tanks, Nalla bunds and point recharge structures like recharging through existing bore wells / dug wells and recharge pits. The moderate to high sloping, undulating terrain in the southern part of the district covering is suitable for artificial recharge structures like gully plugs, gabian structures, cement plugs, nalabunds, contour bunds and contour trenches. As mentioned earlier, the selection of a suitable artificial recharge structure is site specific and hence, scientific studies should be conducted while selecting the site for a specific type of structure. However, artificialrecharge structures are recommended in such areas considering the long-term waterlevel trends.

Artificial recharge (also known as aquifer re-injection) is the process of injecting (or recharging) water into the ground in a controlled way, by means of special recharge wells.It augments the natural movement of surface water into underground formations by some artificial methods. Hence, groundwater cannot suffice the requirement for agriculture or drinking water. Thus, additional recharge by artificial methods becomes necessary to meet the water deficit. The artificial recharge zone map shown in figure 9.

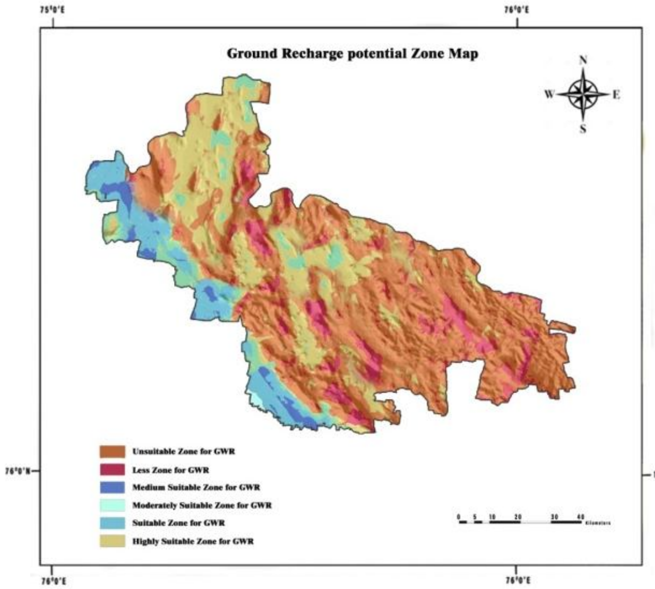

Figure 9 Ground water recharge zone map

The present study successfully demonstrated an integrated remote sensing and GIS technique to suggest the suitable zone for future artificial recharge zones in the Bagalkot District, Karnataka was integrated successfully by using the above explained base maps.

7.CONCLUSION

Geographic information systems are useful tools for groundwater resources management by storing and manipulating the vast array of data that may be available invarious formats. In order to demarcate artificial recharge zones, a methodology using the overlayanalysis method in a GIS-based multi-criteria analysis was used to map groundwater recharge zone in thebagalkot district, Karnataka for the purpose of improving groundwater resource. The thematic layer linked to hydrological, drainage, aquifer thickness, slope and land use/land cover map were prepared, classified, weighted and integrated in a georeferenced project using GIS utilities. The produced map shows thegroundwater recharge area which is of great importance in planning artificial groundwater recharge using surface water as a integrative and participative aspect of water management. Where the occurrence of groundwater is more restricted with increasing of water conflicts. The results show that about 30% of the area was suitable for recharging purposes, while 30% of the area was highly suitable for groundwater recharging.Remaining 40% of the area was not suitable for recharging of ground water. Finally, groundwater management requires that the study area are suitable artificial recharge structures in jamkhandi&bilgi areasand check dam methods were most favourable for recharge in the investigation area.

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