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Delineation of Groundwater Potential Zones for Mavinahallikere Sub-Watershed of Kadur Taluk in Chikmagalur District, Karnataka State, Using Geospatial Technique

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Abstract

The present study shows the importance of remote sensing and geographical information system, which is found to be an effective tool for delineating groundwater potential zones of Mavinahallikere sub-watershed. Resource maps along with field investigation done to evaluate potential groundwater zones for the study area. The survey of India topographical map No. 57C/2 as the base and IRS LISS-IV satellite image (2015) used to prepare the thematic layers like drainage, lithology, geomorphology, lineaments, slope, land use/land cover and contours. The groundwater contour maps were prepared based on well details collected during fieldwork. Each unit of all thematic layers assigned with rank based on IMSD guideline and later integrated in the GIS platform to generate the groundwater potential map. The result shows that five distinct zones such as very poor, poor, moderate, good, and very good zones.

Keywords: Groundwater; Potential zones; Remote sensing; GIS

1. Introduction

Water resources are increasingly in demand in order to help agricultural and industrial development, to create incomes and wealth in rural areas, to reduce poverty among rural people, and to contribute to the sustainability of natural resources and the environment. Reliable and timely information on the available natural resources is very much essential to formulate a comprehensive land use plan for sustainable development. The land, water, minerals, and biomass resources are currently under tremendous pressure in the context of highly competing and often conflicting demands of an ever-expanding population. Consequently, over exploitation and mismanagement of resources are exerting detrimental impact on environment. In India, more than 75% of population depends on agriculture for their livelihood. Agriculture plays a vital role in our country's economy. In order to mitigate droughts, which occur frequently in several parts of the country especially in dry land areas the Ministry of Agriculture and co- operation, has launched an integrated watershed concept using easy, simple and affordable local technologies.

Groundwater is an important source for irrigated agriculture as it generally furnishes reliable and flexible inputs of water. To this extent, groundwater is instrumental in managing risk and optimizing food production in the rainfed areas. However, this reliance upon shallow aquifer systems for irrigation has turned to dependency. Depleting groundwater is a serious problem throughout Asia and more so in India as more than 22 million wells are operational in India supporting the economy.

Groundwater occurrence and its movement in an area totally depends on various aspects. Throughout the hydrological cycle, waters interact with different agents and go through various phases. This whole process takes place in an equilibrium manner, i.e. the total inflow is equal to the outflow in that system and the net change in total quantity is negligible or zero. Groundwater as a part of the hydrological system also needs attention, not only due to its contribution to the hydrological cycle but because it also plays a vital role in the existence of living beings. The quantity of groundwater in an area totally depends on various factors. The rate of infiltration, runoff, base flow, evaporation etc., mainly depends on the geology, geomorphology, slope, vegetation, various man made and natural structures, and soil type of the area. Even though these factors play a vital role in the groundwater or surface water quantity, the impact of each factor changes from area to area and is controlled by the distribution of them within the area of interest. Groundwater development program needs a large volume of multidisciplinary data from various sources. Its occurrence being a subsurface phenomenon, identity primarily based on remote sensing analysis, and some direct observable terrain capabilities like geology, geomorphology, and hydrologic characters can be analyzed using geospatial techniques for better demarcation of groundwater resources.

Satellite data provide quick and useful baseline information about various factors that are controlling directly or indirectly the prevalence and motion of groundwater. The factors such as geomorphology, soil types, land slope, land use/land cover, drainage patterns, lineaments, etc. [1–11].

2. Study Area

Mavinahallikere sub-watershed lie in Kadur taluk of Chikmagalur district occupies an area about 61 sqkm. The sub-watershed is located between latitude 13°36’18” to 13° 40’41” N and longitude 76° 0’39” to 76° 7’18” E, shown in the Figure 1. According to meteorological observation recorded an average annual rainfall of 646 mm and a temperature of 31°C. Winds are generally light in the study area, with some increase in force during the monsoon season. Winds are mostly, from directions between North-West and South-West during May to September and in the rest of the year, predominantly from the Southeast. The relative humidity is very high during the monsoon season, generally exceeding 90%. It is comparatively less during the rest of the year. The driest part of the year is from January to March, particularly in the afternoons. This forms a typical hard rock area having hydrogeological conditions less favorable for shallow groundwater reserve Migmatites and Granodiorte - tonalitic gneiss are the observed rock type.

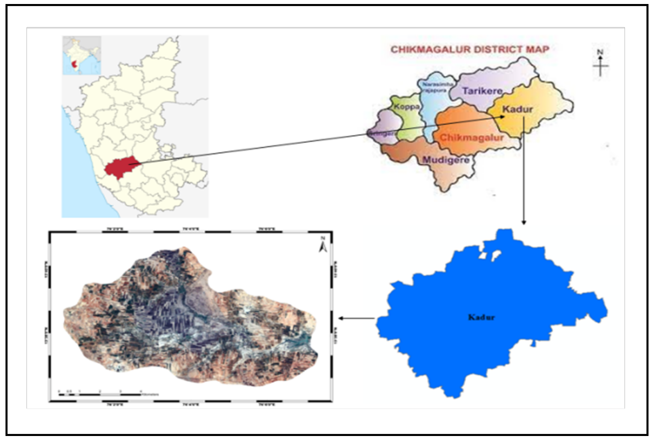

Fig. 1. Location Map of the Study area

3. Materials and Methodology

To prepare various thematic maps, we have used SOI topographic map No 57C/2 of 1:50,000 scale, and IRS LISS-IV 2015 image. The soil, lithology, etc. obtained from published literature, including research papers and reports. The FCC image interpreted to delineate various land use land cover patterns and geomorphic units based on the image characteristics. Thirty-five bore wells GPS points collected from the study area using GPS Garmin 60 with an accuracy of 3.5 meters, to identify the graticules to prepare the groundwater contour map. Each unit of thematic map assigned with ranking logically and integrated to generate the groundwater potential map generated in the GIS platform using Arc GIS10.3.

4. Results and Discussions

To demarcate the groundwater potential zones in Mavinahallikere sub-watershed, the various thematic layers like drainage, surface water bodies, land use and land cover, geomorphology, slope, lineament, soil, lithology, and groundwater contour maps are integrated using Arc GIS 10.3. The ranking has been given to various units of each thematic maps based on IMSD (1995)[12] guideline and their groundwater controlling factors.

Drainage and Surface Water Bodies

Mavinahallikere sub-watershed mainly exhibits sub-parallel drainage pattern, there is a good distribution and collection and run-off during the precipitation. According to the survey of India Topographic map, the study area comprises 15 tanks. Among these, the Mavinahallikere tank is the larger one, remaining are very small, which is shown in Figure 2.

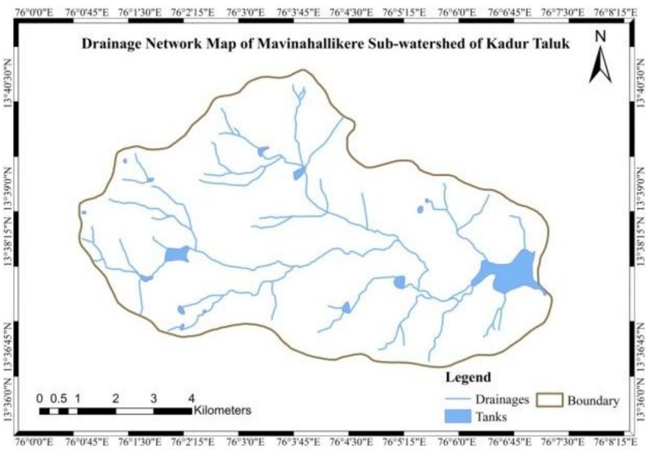

Fig. 2. Drainage Network map of the study area

Land Use/Land Cover Pattern

In the overall land use pattern of study area represents the agricultural land such as Kharif land, double-cropped land, current fallow land, agricultural plantations along settlements. Wastelands such as stony waste, gullied land, salt-affected land, and scrub land. The major area covered by agricultural plantation fallowed by current fallow land and then followed by Kharif land. The area statistics shown in Table 1, and various land use/land cover patterns are shown in Figure 3.

Slope

The study area shows three categories of slopes, namely nearly level and very gentle, shown in Figure 4. The major area covered by nearly level category, and it covers an area about 28.257 sqkm, gentle slope category covers an area about 30.559sqkm, and very gentle slope category covers an area of about 1.318 sqkm. Slope plays a very important role in groundwater potentiality, usually high slopes are not good zone for the groundwater prospect, whereas gentle and plain land forms are good groundwater prospect zones.

Geomorphology

The relief, slope, extent of weathering, type of weathered material, and overall assemblage of different land forms play

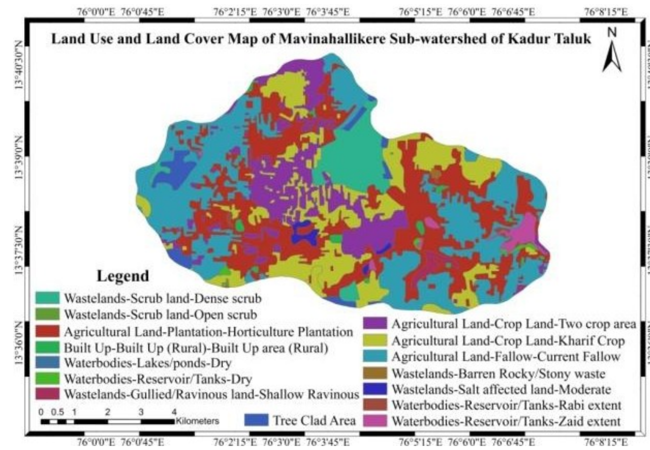

Fig. 3. Land Use and Land Cover map of the study area

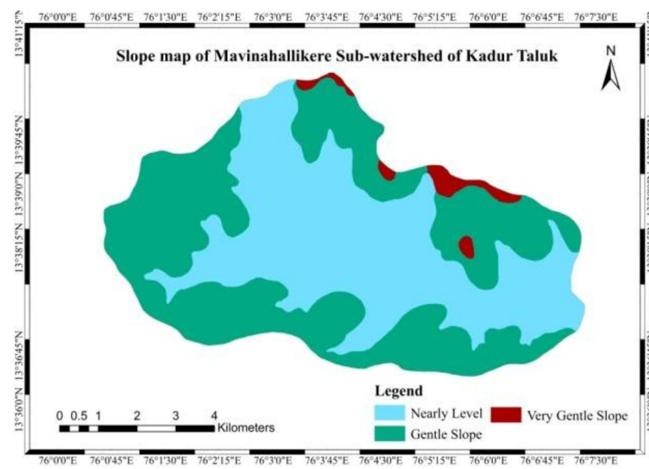

Fig. 4. Slope map of the study area

a crucial function in defining the groundwater regime, especially within the hard rocks. Geomorphology was assigned the highest weightage because it has a dominant role in the movement and storage of groundwater [13]. The study area represents various geomorphic units and are briefed below (Figure 5).

- **Pediment:** These zones are widely distributed along the boundary of the study area, and these areas are generally gently sloping land forms where there is scope for erosion, which covers an area about 5.531 sqkm.
- **Pediplain:** Pediplain are varying from nearly level to gentle slope land form, which consists of fairly a thick weathered zone and subdivided into two categories, namely Pediplain shallow weathered (PPS) and Pediplain moderate (ppm). The Pediplain weathered has a flat surface with a weathered zone that extended up to a depth of 10m. The moderately weathered Pediplain extended up to a depth of more than 10m.

Table 1. The thematic maps used for the study and their area statistics

LU/LC	Area in sq. Kms	Slope	Area in sq. Kms	Geomorphic Unit	Area in sq.kms	Soil Type	Area in sq.kms	Lithology	Area in sq.kms	GW contour (ft)	Area in Sq.km	Ground Water Potential	Area in Sq.km
Agricultural Kharif Crop	10.55	Nearly Level	28.257	Pediment	5.531	Clayey Skeletal	24.388			20-47.29	0.343	Very Poor	3.21
Agricultural Double Crop Area	7.58	Gentle Slope	30.559	Pediplain Moderate	3.410	Fine Clay	9.463			47.29-64.88	11.744	Poor	3.80
Agricultural Current Fallow	16.65	Very Gentle Slope	1.318	Pediplain Shallow	49.672	Fine Loamy	17.145	Migmatites and Granodiorite - Tonalitic Gneiss	60.15	64.88-76.21	7.1829	Moderate	25.36
Agricultural Plantation	17.27			Waterbodies	1.675	Habitation Mask	0.560			76.21-83.51	6.028	Good	14.98
Built Up (Rural)	0.49					Loamy Skeletal	7.109			83.51-94.84	5.435	Very Good	12.85
Tree Clad Area (Grooves)	1.52					Water Body Mask	1.466			94.84-112.43	8.634		
Wastelands-Stony Waste	0.07									112.43-139.73	7.589		
Wastelands-Gullied	0.45									139.73-182.10	4.991		
Wastelands-Salt Affected Land	0.44									182.10-247.88	4.48		
Wastelands-Dense Scrub	3.79									247.88-350	3.549		
Wastelands-Open Scrub	0.03												
Waterbodies	1.29												

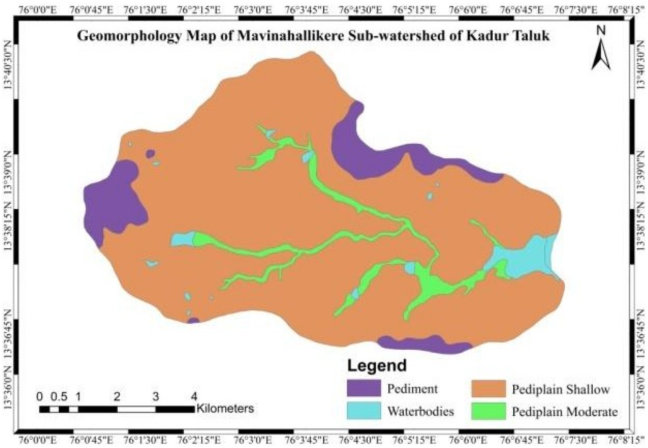

Fig. 5. Geomorphology map of the study area

Lineaments

Lineaments are linear features that are surface expressions of underlying structural features like faults or joints in hard rock area, considered as potential groundwater zones. Lineament generally been used as an indicative tool for locating potential groundwater zones. The drainage pattern in general and tributaries, in particular, are controlled by the geological structures in the area, as revealed by the perfect linearity of the second and third-order streams, which are considered as lineaments extracted as drainage lineaments which are shown in Figure 6.

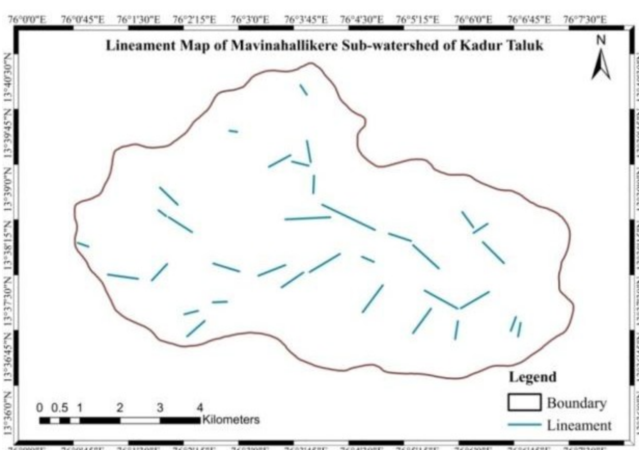

Fig. 6. Lineament map of the study area

Lithology

The lithology map of the study area reveals that only one type of rock represented in the form of Migmatite & Granodiorite-tonalitic gneiss shown in Figure 7. It exhibits very poor to the poor potential for groundwater occurrence because of low and inherent porosity and permeability in the study area. From the hydrogeological perspective, their weathering has produced vast structures of soil cover, facilitates sub-surface percolation and infiltration.

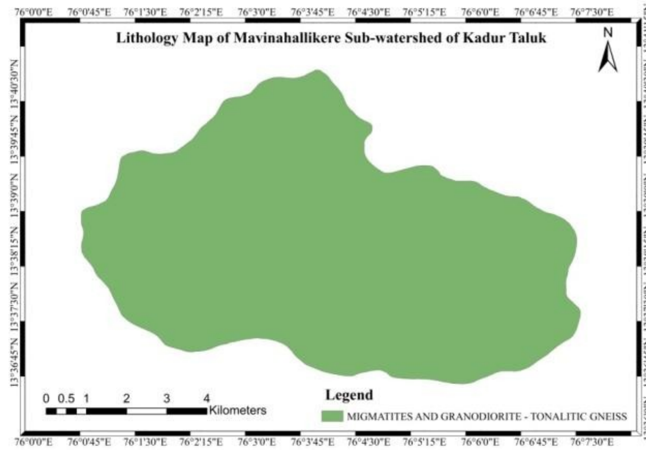

Fig. 7. Lithology map of the study area

Ground Water Contour

The groundwater contour map was prepared based on the bore well data collected during the field investigation. Thirty-five bore wells data used to generate groundwater contour map in GIS platform for Mavinahallikere sub watershed and exhibits the depth of the water table ranges from 20 ft to 350 ft with west to east flow direction (Figure 8).

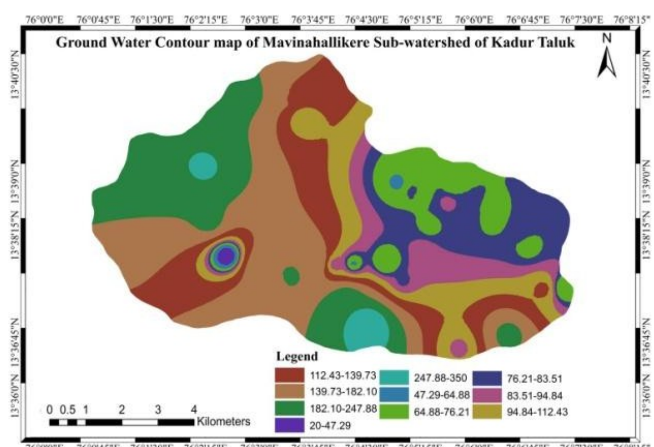

Fig. 8. Ground Water Contour map of the study area

Soil

There are four main soil types n clayey skeletal, fine clay, fine loamy, and loamy skeletal are encountered in the study area. Out of which Clayey skeletal covers an area of 24.388 sq

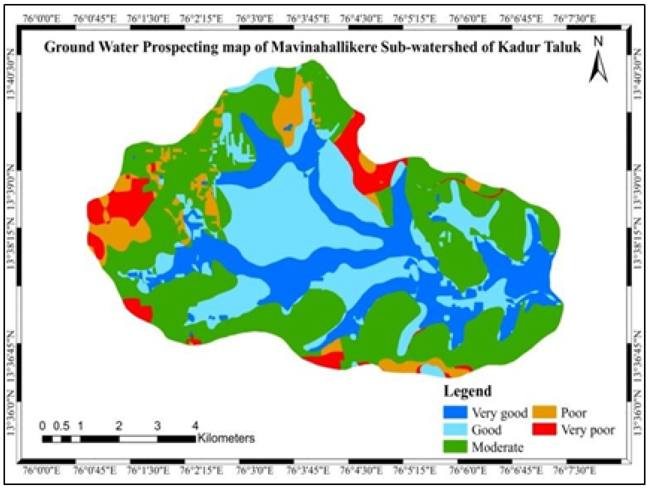

Fig. 10. Groundwater Prospecting map of the study area

km, fine clay covers an area about 9.463 sq km, fine loamy is covered an area about 17.145 sq km, and the settlement covers an area about 0.560 sq km and water bodies about 1.466 sq km. The soil types categorized by giving weightage according to their influence on groundwater occurrence shown in Figure 9.

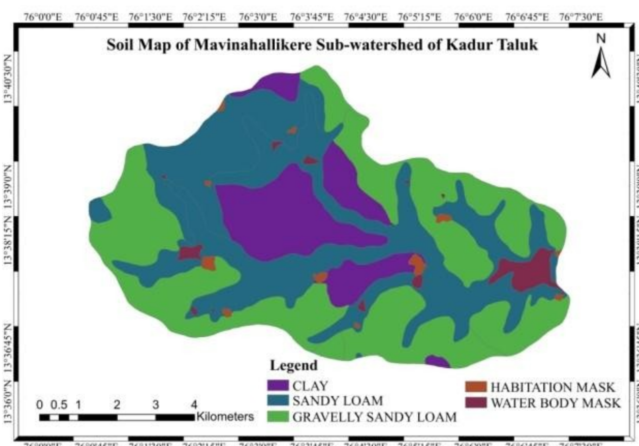

Fig. 9. Soil map of the study area

Ground Water Potential Zones

To generate groundwater potential zones for the study area using all thematic maps and each thematic map assigned with ranking and integrated. The results show that five distinct categories namely, very poor, poor, moderate, good, and very good zones have been delineated in the GIS platform. The groundwater prospect map of the Mavinahallikere sub-watershed area reveals that the groundwater potentiality varied with respect to variation in the morphology, slope, porosity, and permeability of lithology, geological structures, and current land use and land cover pattern. Very good groundwater potential zone covers an area about12.85 sq km, good groundwater potential zone covers an area about 14.98 sq km, moderate groundwater potential zone covers an area about 25.36 sq km, poor groundwater potentiality covers an area about 3.80 sq km and very poor groundwater potential zone represents run-off zone, which covers about 3.21 sq km shown in the Figure 10. The criteria adopted for the preparation of the groundwater prospect map shown in Table 2.

5. Conclusions

Geospatial techniques for groundwater potential mapping are a quick and inexpensive way of getting facts on groundwater incidence, which aids in selecting promising areas for further improvement in groundwater resources. IRS-LISS-IV data interpretation provided information pertaining to hydrological conditions of various features like lithology, geomorphology, slope, soil. Presently land use/ land cover pattern is beneficial in understanding the nature and water potentiality. Each thematic maps assigned with ranking and integrated to generate the study area's groundwater potential map. The results show that five distinct, very poor, poor, moderate, good, and very good zones have been delineated.

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Table 2. Criteria adopted for the preparation of ground water prospect map

LU/LC	Slope (%)	Soil	Geomorphology	GW- Contour	Altitude	Lithology	Weightage Rank
Water bodies Wasteland - Salt affected area Agricultural land - Kharif Agricultural land - Two crop area Agricultural land - Fallow land Agricultural land - PlantationBuilt up(Rural) Wasteland - Dense scrub	0-1	Fine Fine- Loamy	Water bodies (Valley) PPM PPS	20-47.29 47.29-64.88 76.21-83.51	700-720	-do-	”Very Good (5)”
Water bodies - Zaid extentWasteland- Salt affected areaWasteland - Dense scrub Agricultural land - Kharif Agricultural land - Current fallow Agricultural land - Plantation Built up (Rural)	0-1 1-3	Fine- Loamy Loamy-Skeletal	PPM PPS	76.21-83.51 83.51-94.84 94.84-112.4	720-740	-do-	” Good (4)”
Water bodies –Dry Agricultural land-Kharif Agricultural land-Two crop areaAgricultural land-Current fallow Agricultural land-Horti- Plantation Built up (Rural)Tree Clad Area Wasteland — Dense scrubWasteland - Open scrubWasteland - Ravinous land	0-1 1-3	Clayey-Skeletal Fine- Loamy Loamy-Skeletal	Pediment PPM PPS	83.51-94.84 94.84-112.4	740-760 760-780	-do-	” Moderate (3)”
Agricultural land-Kharif Agricultural land - Current fallow Tree Clad Area Wasteland - Dense scrubBuilt up (Rural) Wasteland-Stony waste Barren	1-3	Clayey-Skeletal Loamy-Skeletal	Pediment PPS	94.84-112.43 112.43-139.73 139.73-182.	780-800	-do-	”Poor (2)”
Agricultural land - Current fallowTree Clad Area Wasteland-Stony waste Barren rocky Wasteland - Dense scrub Wasteland - Open scrub	1-3	Clayey-Skeletal	Pediment PPS	247.88-350	780-800	-do-	“Very Poor (1)”

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