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Original Research Paper

Assessment Studies of Groundwater Recharge in Nagamangala Taluk, Mandya District, Karnataka Using Remote Sensing and GIS Techniques

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ABSTRACT

The groundwater recharge assessment studies in Nagamangala taluk in Mandya district were carried out based on geographical information system (GIS) and remote sensing techniques. In this connection satellite images (IRS-IA LISS+PAN+Wifs Image) and aerial plots were subjected to several treatment processes using software like ERDAS imagine and ESRI's Arc view. Thus, various thematic maps have been prepared for drainage density, lineaments, lithology and land cover/land use that allowed deciding their interactive effect. In the present study, the degree of effect was determined for each factor to assess the total groundwater recharge potentiality for two categories (moderate rate to low). The resultant map shows that 85% of the area has low and rest has moderate groundwater recharge potentiality. Finally, only 8.6% of the total average annual precipitated water (1685 mm) percolates into subsurface and ultimately contributes to recharge the groundwater.

INTRODUCTION

The remote sensing (RS) and geographic information system (GS) methods permit rapid and cost effective natural resource survey and management to accurately study the groundwater recharge potentiality that reflects hidden hydrogeologic characteristics and deals with intricate elements at the surface such as lineaments and drainage frequency and density, lithological character, land cover/ land use etc. It provides a better estimate and qualitative adjustment of the recharge potential. Groundwater occurrence being subsurface phenomenon, its identification and location is based on indirect analysis of some directly observed terrain features like geological and geomorphic features and their hydrologic characters. Satellite remote sensing provides opportunity units and lineament features following the integration with the help of GIS to demarcate the groundwater potential zones. The drainage number (frequency) has the strongest relationship with the recharge property (Chorowicz et al. 1992). Lineaments are closely related to groundwater occurrence and surface and subsurface lithological characteristics, and land cover/landuse play important role for recharge process of groundwater. So the aims of present study are to estimate qualitatively the recharge of water into the subsurface media using GIS and RS techniques and to produce a map showing different zones of recharge potential of the Nagamangala taluk, Mandya District covering an area of 1041 sq. km.

STUDY AREA

Nagamangala taluk forms a highly undulating terrain with considerable extent of barren rocky areas. The prominent hills of the taluk are Kottebetta, Halatibetta, Hodinakalbetta and Basavankalbetta.

The highest peak is 1093 m above m.s.l. Besides, there are a number of small hillocks with intervening minor valleys in which seasonal streams flow north eastern portion and the area is covered by coarse granites. Rainfall is meagre, basement hard rock depths are shallow and the human interference with nature being ever-increasing. There is unpredictable behaviour of the onset of monsoon and the average annual rainfall of the taluk is 567 mm. Nagamangala taluk comes under the semi-arid type with schist, granite and gneissic rocks occupying the area. It lies between longitude 76°35’-77°00’ E and latitudes 12°40’-13°05’ N. Based on the physiography, the entire taluk is in the southern maidan region (Fig. 1).

MATERIALS AND METHODS

For the study of groundwater resources development in an area different methodology have been applied for different factors in various steps that influence the recharge rates, based on RS along with the topographic and geological maps (1:50,000 scale) and previously collected data. The interpreted and resultant information was analysed in spatial data and each factor was studied independently, thus, four major categories were demarcated to arrive at qualitative recharge rates. Different methods described for different factors are as below.

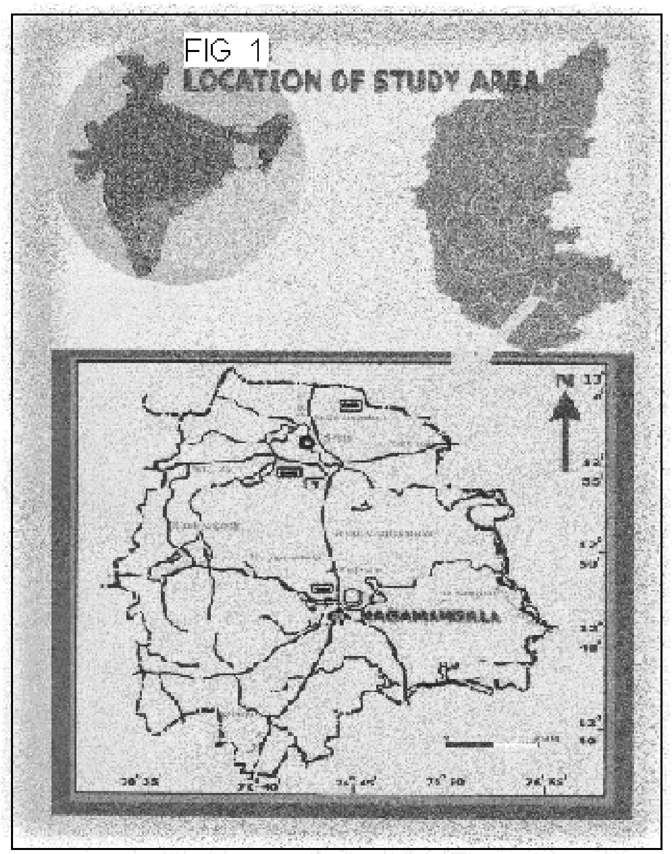

Fig. 1: Location of study area.

Drainage: The hydrogeomorphology in the hard rock terrain is highly influenced by the lithology and structures of the underlying formations, combination of field data, topographic maps, aerial photographs and metallic images are used for analysis of the drainage network and all algorithms use digital elevation models (DEMS) as basic data (Abdullah et al. 2002). Thus, a drainage map is prepared manually is order to calculate the drainage frequencies that involve more subjectivity, thus, the automated one (Jenson & Domingue 1988, Tribe 1991, Ichoku et al. 1996, Martinez-Casanovas & Stuvier 1998, Abdullah et al. 2002). For morphometric characteristics various parameters are computed according to laws of Horton (1945) and Strahler (1952), and for analysis of the drainage basin mainly topographic sheet and WiFs image have been used. The drainage system has been indexed as 1^{st} to IV^{th} orders, where the main channels of the rivers depressants the highest order. The drainage characteristics represent dendritic to sub-dendritic patterns, with minor sinuosity at places indicating homogeneous nature of surface bedrocks and lack of structural control. The stream order, stream number, bifurcation ratio and stream density are the linear properties of a drainage basin which have been analysed in the present study. Here, the higher 1^{st} order drainage density is related to surface topography, i.e., elevated and characterized by less infiltration due to clayey and semi to impermeable clay with excessive surface runoff (Fig. 2).

In the present study area, stream frequency values decrease with increasing stream order, which is an indicator of high slope and lack of facilities for the development of higher order streams due to

Fig. 2: Nagamangla Taluk (Drainage map).

Table 1: Lineament direction of the area.

Population	Direction	Lineaments	
Granitic schists and gneissic terrain	N-S	19	05
	NNE-SSW	21	40
	NNW-SSW	16	13
	NW-SE	26	14
	NE-SW	30	20
	E-W	17	09
	Total	129	101

bed lithology and tectonic condition (Melton 1958). Accordingly the counting of the tributaries followed the stream-order manner.

Lineaments: Study of lineaments has become an important part in analysing the structure and tectonic aspects of any area. Using 1 RS-1B imagery (Geooded subsene Satellite-1D:1RS-1B dated 26-01-1994), the lineament has been made and the holding major and minor lineaments were deciphered, which is aligning in different directions said to be composite and controlling a drainage pattern that helps in recharging the groundwater (Fig. 3).

Lithology: The geological map (1:50000 scale) is used as base map to bring out lithological distribution and with the application of remote sensing, additional information is obtained from satellite images (Lillesand 1989). Thus, visual tracing of many lithological patches and changes of lithological boundary are considered. With the help of GIS technique (especially Arc view program), the area is divided into grids and assigned the percolation values of the lithological units in the field of attribute based on percolation rates of soil type (Fig. 4).

Land Cover/Land Use: Based on satellite images and principal zones of similar recharge responses, only two zones of land cover/land used are delineated in the study area. The visual discrimination of colour and resolution is established depending on optical differentiation of satellite images of merged Landsat and IRS-1, and thus several polygons are obtained. Within each zone, different units are plotted, but all have relatively the same degree of effect on the recharge potential rate (Shaban et al.

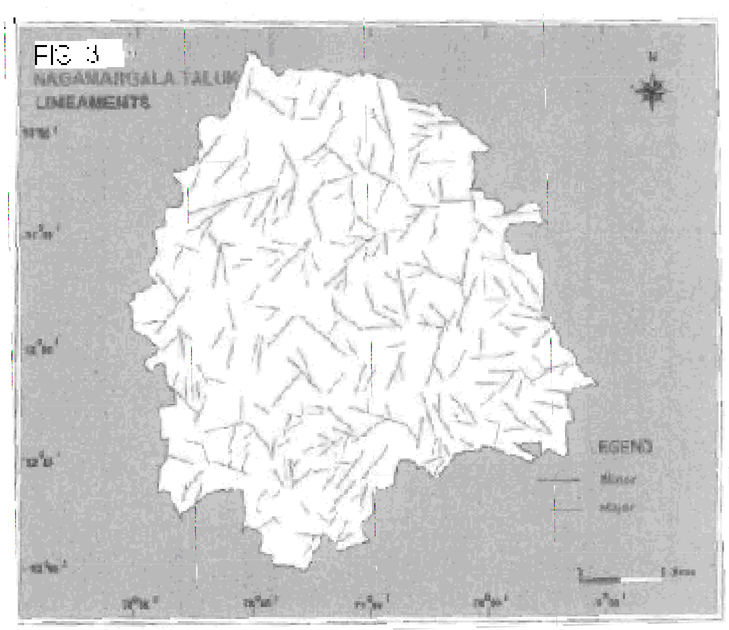

Fig. 3: Nagamangla Taluk (Lineaments).

2003). The selection of various units in specific zones lead to a supervised classification on the used image, thus, a land cover/land use map is produced for different water recharge zones (Fig. 5).

RESULTS AND DISCUSSION

In the present study, a synoptic classification based on factors like the lineaments, lithology, drainage and land cover/land use of different categories has been done which has different levels of effect, and is expressed in numerical value ranges depending on the resultant domains, which provide specific information about the recharge or infiltration of water. Based on average drainage frequency value, a three-fold numerical classification is established where segments per 25 km^2 are counted (Ichoku 1996). In selected domain, three class ranges are established where each factor influences mainly the recharging process. The high lineaments frequency indicates very high recharge potential, while that of low frequency does not indicate very low recharge potential, the average frequency values ranging from 1.0 to 0.25 per 25 km^2. The lithology domains work from high to very low, depending upon the type of sediments like sand, silt and clay. Similarly, the land cover/land used map is analysed based on human settlement and vegetation cover containing different values of water percolation, the values ranging from medium to moderate-low. Based on relative rates of each influencing factor, recharge potentiality of the study area is categorized (Table 2). Now to obtain a comprehensive evaluation of each factor on recharge potentiality (Kumar 1991, 1986, Shaban et al. 2001), the rates and weights are integrated, and thus, the total weighting assessment, after rounding off values is obtained (Table 3). The final map is derived by summation of the factor and the weight coefficient of the factor (Fig. 6).

Fig. 6 shows calculation process to get the exact value of the cell by weighting approach and obtained for each factor are considered as layers and overlaying of each layer with its own weight in a GIS system, resulted in different polygons of special characteristics with respect to the overall recharge potential for the area. After considering rate assessment, the ESRI's Arc View software was

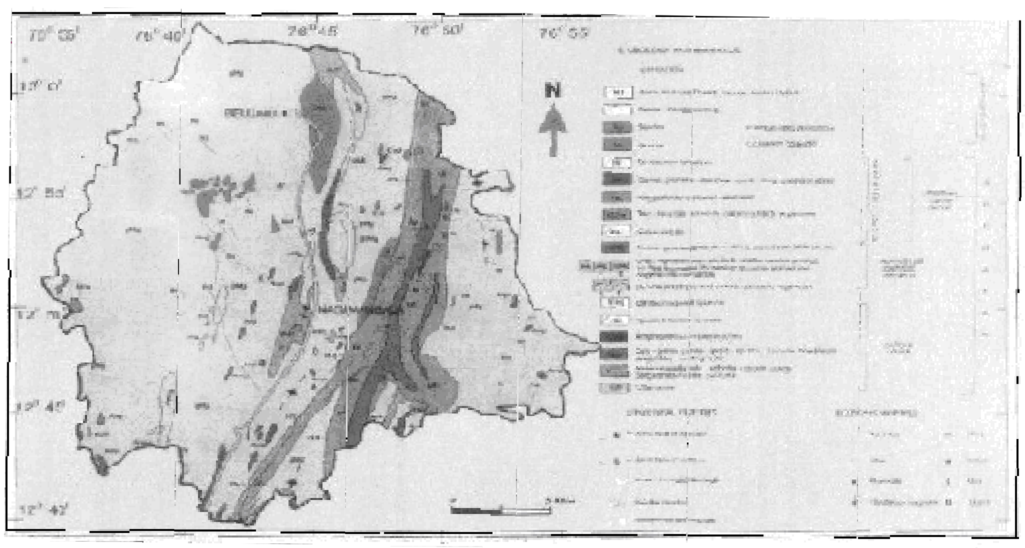

Fig. 4: Geology of Nagamangala taluk.

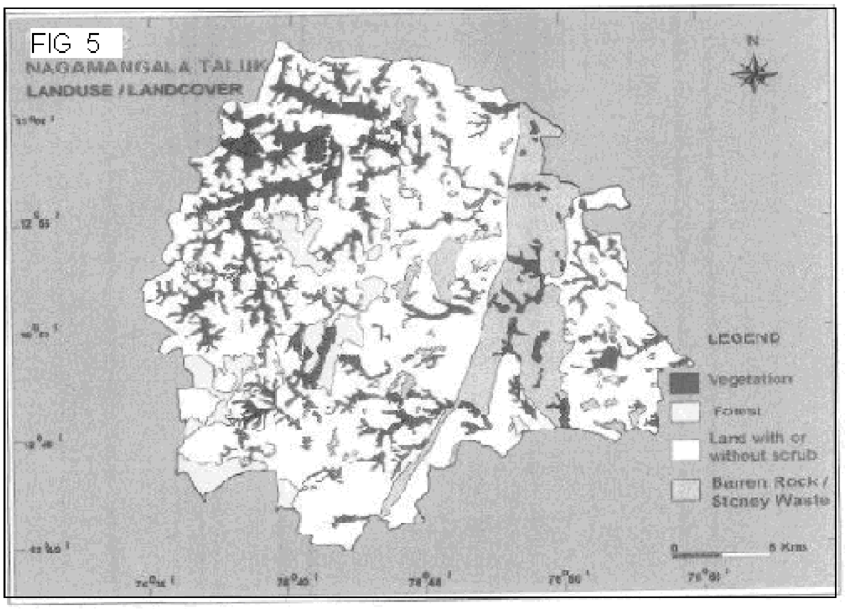

Fig. 5: Nagamangla Taluk (Land use/Land cover).

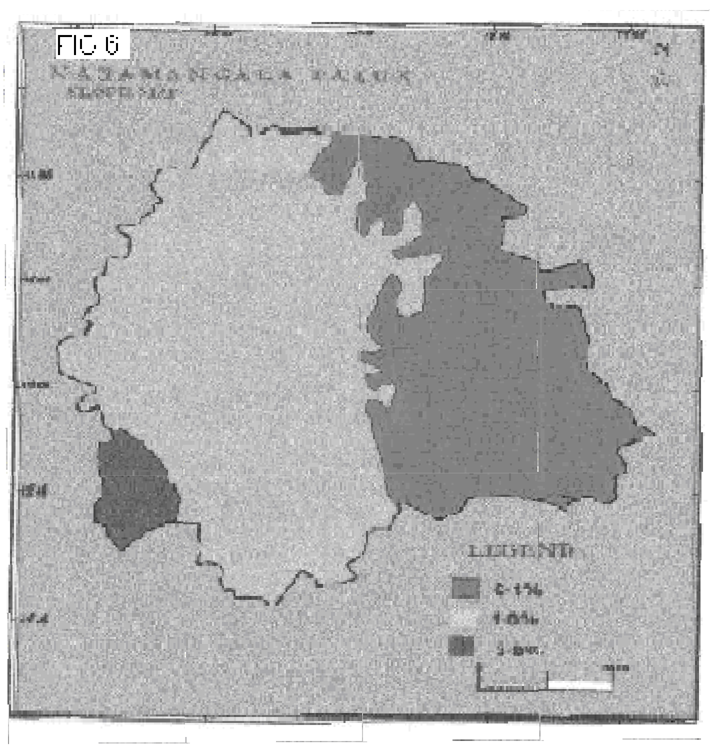

Fig. 5: Nagamangla Taluk (Slope map).

Table 2: Categorisation of factors affecting recharge potentials in the study area.

Factor	Descriptive level	Proposed weight of effect	Domain of effect
Drainage	High-moderate	6.5	4.43-6.15 (per 25 km^2)
	Moderate	5.0	2.72-4.43
	Low	2.0	1.0-2.72
Lineament	Moderate-low	3.5	0.778-1.0 (per 25 km^2)
	Low	2.0	0.556-0.778
	Very low	1.0	0-0.556
Lithology	High	8.0	4mm/day (Percolation rate)
	Moderate	5.0	3 mm/day (Percolation rate)
	Low	2.0	2mm/day (Percolation rate)
Land cover	Moderate	5.0	Sparse vegetation
/land use	Moderate-low	3.5	Human settlement

Table 3: Weight evaluation of factors influencing recharge potential capacity.

Factor	Descriptive scale	Weight (a) (1-10)	Rate (b) (1-3)	Weighted rating (a × b)	Total Σ(a × b)	Factors on recharge potential capacity (%)
Drainage	High-moderate	6.5	1.5	10	21	22
	Moderate	5.0	1.5	8		
	Low	2.0	1.5	3		
Lineament	Moderate-low	3.5	2.0	7	13	13
	Low	2.0	2.0	4		
	Very low	1.0	2.0	2		
Lithology	High	8.0	3.0	24	45	47
	Moderate	5.0	3.0	15		
	Low	2.0	3.0	6		
Land cover/	Moderate	5.0	2.0	10	17	18
land use	Moderate-low	3.5	2.0	7		
				Grand Total weight	96	100

Table 4: Recharge potential categories and their quantitative estimation.

Recharge potential category	Estimates according to FAO (1967)	Average (%)	Aerial extent (km^2)
Very high	40-50%	47.50	0.00
High	30-35%	32.50	0.00
Moderate	10-20%	15.00	113.34
Low	5-10%	7.50	631.71
Very low	<5%	2.50	0.00

used to manipulate the data, through superimposing different layers of recharge potential. Accordingly, the recharge potential categories and their qualitative estimation in the study area have been calculated (Table 4).

CONCLUSION

The present study provides an approach for qualitative assessment of groundwater recharge potential with the help of remote sensing and GIS in southeastern part of the Nagamangala taluk. An integrated groundwater potential map has been prepared and categorized on the basis of weightages assigned to different features such as lithology, lineaments, drainage frequency, density, and land cover/land use, which reveals the information of about 85% has low recharge potentiality and that of rest 15% has moderate recharge potentiality and only 8.6% of the total precipitated water (1136.19×10^6 m^3/year) is infiltrating downward to recharge the groundwater reservoirs, while the rest is lost either as evapotranspiration or surface runoffs, and the recharge potential categories and their qualitative estimation reveal optimistic values of recharge potential and finally it may be concluded that recharge potential map provides first hand information on groundwater recharge useful for planning of groundwater exploration. So it is recommended that such study should be applied to the whole of district on micro-level with instrumental verification to get more precise information about surface signature that governs the groundwater recharge potentiality.

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