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Original Research Paper

Groundwater Resource Assessment in Kushavathi Watershed, Chickballapur District, Karnataka, India

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ABSTRACT

In the present study, an attempt has been made to delineate the groundwater potential zones in the Kushavathi watershed, Chickballapur district, Karnataka. The study has been for targeting groundwater in hard rock terrain by adopting remote sensing and GIS techniques. Information on geomorphology and land use is generated using the remote sensing data. The hydrogeomorphic units like floodplains and valleys have good groundwater potential, and pediplains and pediments have moderate to poor groundwater potential. The structural hills, denudational hills and inselberg are indicated as runoff zones. The weathered and fractured zone constitute the aquifer system in the area.

INTRODUCTION

Groundwater availability is the amount of water that is available for use from an aquifer. When producing water from an aquifer, the water comes from three possible sources, i.e., recharge, storage, or cross-formational flow. Recharge is the amount of water that moves into aquifers, generally from rainfall, melting snow or rivers. When it rains, some of the rain runs off into streams, some evaporates back into the atmosphere, some percolates into the ground, eventually reaching and recharging aquifers.

Groundwater potential zones are governed by various geoenvironmental parameters such as drainage, texture, lineament and landuse (Sarkar et al. 2001). In addition geomorphology, geology, landuse, slopes and rainfall play an important role. Hence, it is necessary to prepare these thematic maps to assess the groundwater resource of an area. This paper deals with the delineation of groundwater potential zones in Kushavathi watershed using remote sensing and GIS techniques.

LOCATION AND EXTENT OF THE STUDY AREA

The study area, Kushavathi watershed, occupies the southeastern corner of Karnataka state (Fig. 1). The main stream of the watershed, Kushavathi flows in south to north direction. It occurs partially in Chickballapur, Gudibanda and Bagepalli taluks of Chickballapur district, Karnataka. Kushavathi watershed is located between latitudes N 13°31' to N 13°48' and longitude E 77°38' to E 77°47' and is covered in the toposheet No. 57G/09, 57G/10, 57G/13 and 57G/14 of SOI. The study area has an aerial extent of 166.08 km^2.

PHYSIOGRAPHY OF THE STUDY AREA

The study area is an undulating terrain with hills rising up to 1100 m and a lowest elevation of 730 m. Agriculture is the main occupation and groundwater is exploited to a maximum extent due to limited

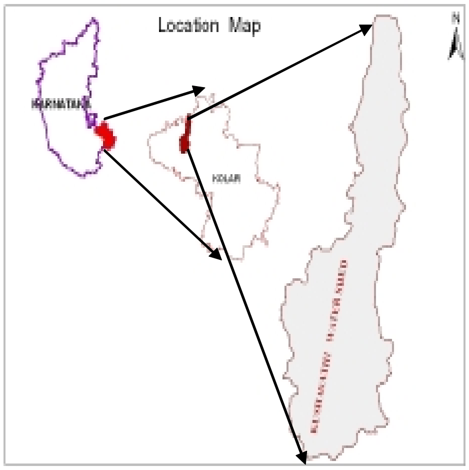

Fig. 1: Location map of the study area.

surface water resources. Tanks are the main source for irrigation and other sources of water are open wells and bore wells. The main stream draining the study area is Kushavathi river with small tributaries and runs from south to north. Drainage is mostly of dendritic pattern with more tanks in the N and N-E direction. The land adjoining the banks of the river course forms one of the most fertile lands, which is cultivated intensively for paddy and groundnut.

CLIMATE AND RAINFALL

The study area is a drought prone semi-arid region with mild summers and winters. The mean annual air temperature is 25°C. May is the hottest month with maximum temperature of up to 39°C. December is the coolest month with minimum temperature of 15.6°C. The normal average annual rainfall is about 760 mm. The study area receives major portion of its rainfall from the S-W monsoon. The soil moisture is likely to remain for about 150 days in a year, which allows one Kharif crop to be grown under rainfed conditions.

DATA USED IN THE STUDY

Various data used in this study include satellite data, topographic sheets, geological map and field information (Table 1).

GEOLOGY OF THE STUDY AREA

The study area consists mainly of pink granulite and partly of gneisses. The composition of pink granulite in the area changes from tonalite to granodiorite. Gneiss is the second dominant rocks in the study area, seen along the north western and southern parts of the study area. Gneisses are the oldest, and by far the most widespread country rocks in India. They are medium to coarse grained and exhibit banding with leucocratic quarts + plagioclase + K-feldspar rich layers alternating with melanocratic biotite rich layers. The gneisses show light yellowish green colour on the FCC image mainly due to the presence of leucocratic minerals quarts, plagioclase and potash feldspar and due to weathering of gneisses. The area under banded biotite Gneiss is 48.21 sq. km and pink granulite is 117.87 sq. km.

Lithological map (Fig. 2) is derived from geological quadrangle map numbering 57G, published by Geological Society of India (GSI 1994) on 1:250,000 scale**.** The published maps are georeferenced

Table 1: List of various data used in the present study.

Types of Data	Details of Data		Sources of Data
Survey of India (SOI) topographic maps	57G/09, 57G/10, 57G/13 and 57G/14		Survey of India (SOI)
Geology map	Scale 1:2,50,000		Geological Survey of India
Remote sensing digital data sets of IRS 1C	Date 27-11-2006	Resolution 23.5 m	National Remote Sensing Agency (NRSA), Hyderabad

and the watershed is extracted using image processing software. Then the different classes of the themes are vectorised using GIS software.

Table 2: Slope % and its area.

Sl No	Slope	Area in sq. km
1	0-1%	41.98
2	1-3%	49.84
3	3-5%	27.92
4	10-15%	13.03
5	5-10%	8.83
6	15-35%	3.56
7	35 - 50%	20.91
8	Total	166.08

GEOMORPHOLOGY

The geomorphic character of a region has strong control on the groundwater regime. Satellite remote sensing has been found very useful in delineating geomorphic landforms because of its synoptic view, quick and inexpensive technique for getting information. On-screen visual interpretation of IRS 1C LISS III image data has been carried out to identify various landforms taking into consideration various image and terrain elements. GIS software was used to mark the polygons of various landforms (Fig. 3). The landforms, which are more important in the groundwater prospects, are classified into various broad categories and their distribution has been delineated from the remotely sensed data using standard image interpretation elements and characters. A brief description of landforms of the study area is as follows.

Denudational hills: These are the resistant hills resulting due to erosion and mainly act as runoff zone. Denudational hills are marked by sharp to blunt crest lines with rugged tops indicating that the surface run off at the upper reaches of the hills has caused rill erosion. The rugged topography of this region is due to the erosion of the denudational hills to the plain region, leaving the rock exposed. The groundwater potential is moderate to poor.

Pediment-Inselberg complex: It is isolated residual hillocks being remnants of weathering and denudation. Inselbergs are mostly barren, rocky and usually smooth and rounded small hills. From

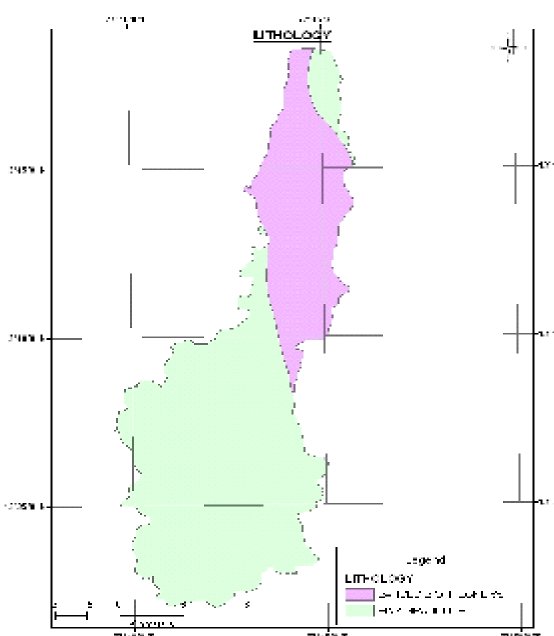

Fig 2: Lithology map.

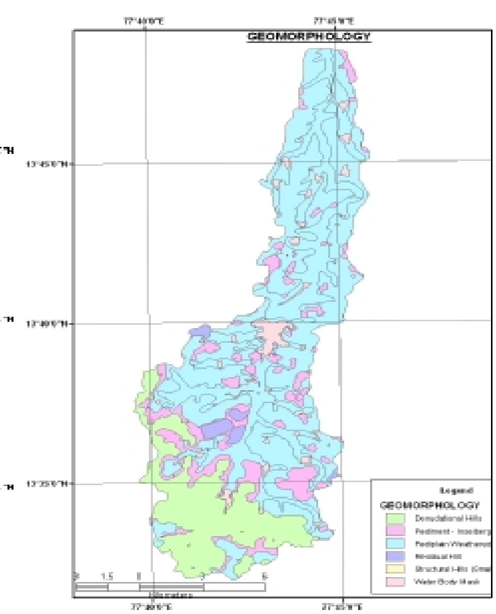

Fig 3: Geomorphology map.

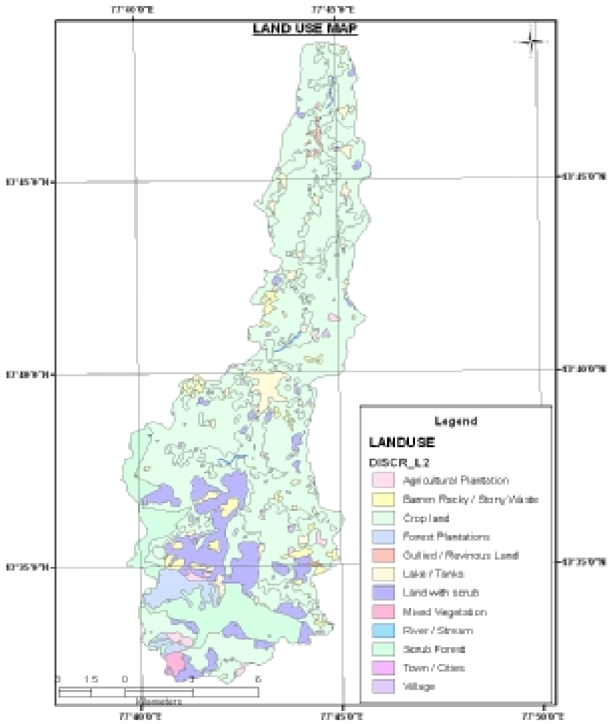

Fig. 4: Landuse map.

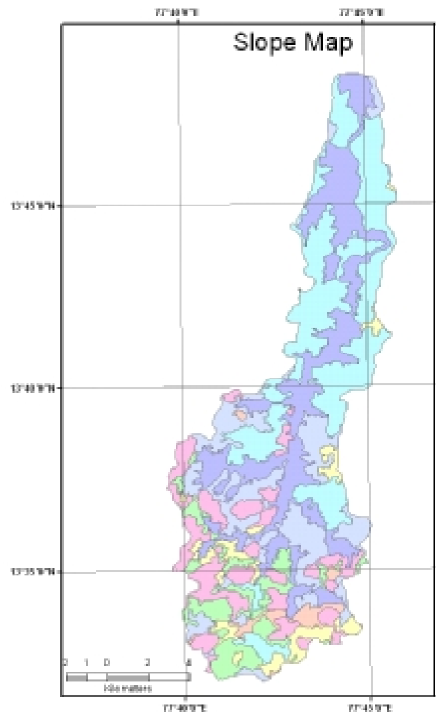

Fig. 5: Slope map.

groundwater point of view, these are all treated neither containing nor transmitting waters, i.e., aquifuge nature. Mostly act as run off zones.

Pediplain weathered/buried: These are characterized by the presence of relatively thicker weathered material. Most of the area under this unit is agriculture land. Depending upon the thickness of the weathered zone, the groundwater potential is moderate to good and important for construction of dug well and dug-cum-bore well.

Residual hills: These are isolated low relief and irregular outlines standing out predominately and appear as isolated hills or continuous chains of hillocks due to differential erosion. Thus, more resistant formation of rocks stand as residue like hills usually marked with structures such as joints, fractures, etc. These are poor for groundwater prospecting due to steep gradient and the rainwater is washed off immediately without much infiltration (Tiwari & Rai 1996). On standard FCC image, it shows brownish tone due to exposed outcrops, and varied reddish tone in some area due to partial growth of vegetation.

Structural hills: Structural hills are linear to arcuate hills exhibiting definite trends composed of varying lithology. The structural trend of the hill ranges is in a north-west to south-east direction. The tectonic features are the result of structural deformation aided by superficial processes. Slope angles are very steep along the fault scarps. Generally groundwater potential is very poor in structural hills owing to their poor permeability where surface runoff is greater and only limited groundwater potential is expected along the faults, joints and fractures present in the structural hill ranges.

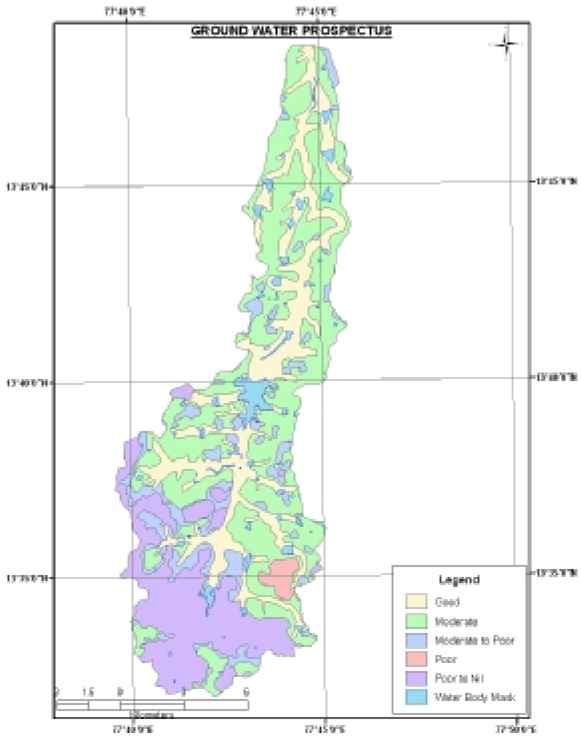

Fig. 6: Groundwater potential map.

LANDUSE/LANDCOVER

Landuse refers to human activities and various uses, which are carried out on land. It describes how a piece of land is used. Landcover refers to natural vegetation, water bodies, rocks/soils, artificial cover and other features resulting due to land transformation. The term landuse/landcover is closely related and interchangeable. Application of satellite remote sensing for landuse surveys and mapping is gaining importance largely because of its ability to provide rapid and reliable data within a given time of framework. The landuse map of Kushavathi watershed has been prepared to use an input to identify potential groundwater source.

The landuse/landcover map (Fig. 4) was prepared using satellite images in conjunction with Survey of India topographic maps on 1:50,000 scale. Visual interpretation of IRS 1C, FCC was used to delineate various landuse/landcover categories. Landuse/landcover categorization is envisaged based on the classification scheme developed by National Remote Sensing Agency (NRSA 1995). The landuse/landcover characteristics were identified based on the image characteristics like tone, texture, shape, association, etc. During the interpretation, wherever doubtful units are encountered, ground truth survey was undertaken to verify the same.

Classification: The landuse/landcover classes identified in the study area were built-up land, cropland, fallow land, plantation, forest, gullied/ravenous land, land with scrub, land without scrub, barren/sheet rock/stony waste area and tanks.

Built-up land: It is defined as an area of human habitation developed due to nonagricultural use and that which has a cover of buildings, transport, communication, utilities in association with water, vegetation and vacant lands. Land used for human settlement in rural villages is comparatively of lesser size than urban settlement. The area under this category is 1.05 sq. km, i.e., 0.63% of the total study area.

Agricultural land: It is defined as the land primarily used for farming and for production of food, fibre and other commercial and horticultural crops. It includes land under crops (irrigated and unirrigated), fallow and plantations.

Crop lands: It includes those lands with standing crops as on the date of satellite imagery. The crops may be either Kharif or Rabi or both. The area under crops has been identified and mapped. The area under this category is 146.32 sq. km, i.e., 88.1 % of the total study area.

Forest: It is an area (within the notified forest boundary) baring an association predominantly of trees and other vegetation types capable of producing timer and other forest produce. Satellite data have been used for mapping different forest types and density classes with reliable accuracy through visual as well as digital techniques. Forests exert influence on climate and water regime and also provide shelter for wildlife and livestock. The area under this category is 0.26 sq. km, i.e., 0.15 % of the total study area.

Gullied/ravenous land: Gullies are narrow and deep channels developed as a result of wearing away of soils by running water. Gullies develop from rills, which are tiny channels a few centimetres deep formed by the impact of rainfall and wearing action of runoff generated from them. In the study area, these gullied lands are found in eroded plains along the streams. On FCC it shows light yellow to bluish green depending on the surface moisture and depth of erosion with varying size. These geomorphic units have poor groundwater yield. These gullies and ravines contribute to soil erosion and land degradation. The area under this category is 0.06 sq. km, i.e., 0.03 % of the total study area.

Land with scrub: Scrublands are seen along the ridges and valley complex, linear ridges and deep slope area. Most of these areas are identified by the presence of thorny scrub and herb species; many hillocks of steep and dumbbell shaped are associated with poor vegetal cover. As a consequence, severe soil erosion frequently occurs during rainy season. As a result most of the hilltops become barren rocky. The area under this category is 4.4 sq. km, i.e., 2.65 % of the total study area.

Barren rock/stony waste: These are the lands characterized by exposed massive rocks, sheet rocks, stony pavements or land with excessive surface accumulation of stones that render them unsuitable for production of any green biomass. Such lands are easily discriminated from other categories of wastelands because of their characteristic spectral response. On FCC it shows greenish blue to yellow to brownish in tone with varying size associated with steep isolated hillocks, hill slopes and eroded plains. The area under this category is 23.7 sq. km, i.e., 5.9 % of the total study area.

SLOPE

Slope plays a key role in groundwater occurrence as infiltration is inversely related to slope. Slope is one of the major controlling factors in the development and formation of different landforms. The NE, NW, western, southern and SW parts of the area show maximum relief (between 710 and 1080 m m.s.l.), while the eastern and northeastern parts show minimum relief with elevation values ranging from 530 to 700 m m.s.l. The area is plain in the central and northeastern parts, whereas the topography is undulating in the remaining parts.

Nearly level (0-1%), very gentle (1-3%; low-lying areas) and gentle sloping areas (3-5%) are better than the much steeper hilly areas (5-10, 10-15, 15-35 and >35%) from the groundwater point of view.

GIS ANALYSIS

The role of GIS has added new dimensions in the field of groundwater resources mapping and management. It helps to integrate the remotely sensed derived data, data from the SOI topographical maps and other ancillary data to have more precise and correct information about various factors that are controlling the groundwater resources assessment and management.

In order to achieve the aim, groundwater potential zones, groundwater occurrence parameter such as geology, geomorphology, landuse/landcover, slope, map derived through remotely sensed data/ conventional method have been analysed using GIS.

METHODOLOGY

GIS enables user specific management and integration of multi-thematic data. In recent years extensive use of integrated approach for extracting groundwater potential prospect zones in hard rock terrain using GIS and remote sensing technique are many in recent literature (Krishnamurthy et al. 1996). The various thematic maps generated are geological map, geomorphology map, landuse/landcover map and slope map.

Groundwater potential zone map has been prepared based on index overlay method using hierarchical weights (Jothiprakash et al. 2003). Depending upon the perceived importance of their role in occurrence and movement of groundwater, weights have been assigned for individual themes; in turn different units in each theme are assigned knowledge based hierarchy of ranking from 1 to 4 on the basis of their significance with reference to their groundwater potential. In this ranking 1 denotes poor, 2 moderate, 3 good and 4 very good groundwater potential, to get final scores.

Table 3: Rank, weights and scores for attributes of various themes.

Geology		
Geology (Weightage-10)	Rank	Score
Banded Biotite Gneiss	1	10
Pink Granulite	2	20
Geomorphology		
Geomorphology (Weightage-60)	Rank	Score
Denudational hill	1	60
Pediment-Inselberg complex	2	120
Pediment-Weathered buried	3	180
Residual hill	1	60
Structural hills	1	60
Water body	4	240
Landuse		
Landuse (Weightage-25)	Rank	Score
Built upland (Towns, Villages)	1	25
Agriculture-crop land	4	100
Mixed Vegetation	3	75
Agriculture -plantation	3	75
Water body (Tanks, Streams, Lakes)	4	100
Scrub Forest	2	50
Land with scrub	2	50
Forest-Plantation	2	50
Gullied/ravinous	1	25
Barren rock	1	25
Slope		
Slope (Weightage-20)	Rank	Score
0-1%	7	140
1-3%	6	120
3-5%	5	100
5-10%	4	80
10-15%	3	60
15-35%	2	40
35-50%	1	20

INTEGRATION OF THEMATIC LAYERS AND GIS MODELLING

All thematic layers derived from satellite and collateral data are integrated in GIS environment. The occurrence and movement of groundwater in an area is controlled by various factors and influence of all factors need not be same in the area. Therefore, each parameter is assigned weights depending on their influence on groundwater. The different units in each theme are assigned knowledge-based hierarchy of ranking from 1 to 4 on the basis of their significance with reference to their groundwater potential. The final score of each units of the theme is equal to the product of the rank and weights.

OVERLAY

All the themes are overlaid using union in Arc View to generate composite map. Two thematic maps were overlaid at a time to generate a composite map. By this method a new map showing two thematic maps is obtained. Over this composite map a third map is overlaid and so on to get the final composite map. Each polygon in the final composite map is associated with a particular set of information of all thematic layers. The evaluation of groundwater prospect of each polygon in the output is based on the added values of scores of various themes. Theoretically, the minimum total weight of 175 and maximum weight of 820 should have been obtained. But practically a minimum of 175 and maximum of 790 is obtained. This shows the non-overlap of some of higher weights polygons with one another in the integrated layer.

DISSOLVE

The total scores obtained by integration have been classified into four categories to facilitate the delineation of very good, good, moderate and poor groundwater potential zones. The maximum score is 790 and minimum is 175. Mean of the resultant map is 492 and the standard deviation is 114. Very good prospect zone is assigned a value of 606 and above, which is the addition of standard deviation and mean. Similarly good has given a value of 492, moderate as 378 to 492 and poor as less than 378. After assigning the value, the resultant map is dissolved to get the final zonation map.

DISCUSSION

Groundwater potential maps aim at providing a clear picture regarding the groundwater condition of an area. Probable groundwater potential zones are delineated based upon multi criteria by evaluation by using geology, geomorphology, landuse/landcover and slope themes, which are directly or indirectly influencing the groundwater potential and depending upon their importance to groundwater augmentation (Fig. 6). The map shows that the river courses, valley fills and moderate pediments associated with prominent lineaments and high frequency of lineament intersection are classified into very good to good prospect zones. While the residual hills and shallow buried pediments, which are not intersected by lineaments, are demarcated under poor prospect zones. Majority of the part of the very good potential zones fall exactly on valleys and lineament zones. Good prospect zones are noticed adjacent to the rivers.

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