

GROUNDWATER POTENTIAL MODELLING USING REMOTE SENSING AND GIS TECHNIQUES IN PATHRI RAO WATERSHED, HARIDWAR DISTRICT, INDIA ⁺

نمذجة جهد المياه الجوفية باستخدام التحسس النائي ونظم المعلومات الجغرافية للحد الفاصل باثري
راو في مقاطعة هردوار/ الهند

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Abstract:

Geographical Information System (GIS) and Remote Sensing techniques have been used to develop a methodology for evaluating the groundwater in the Pathri Rao Watershed, Haridwar District, India. Digital satellite data used to prepare thematic maps for the hydrogeomorphology, slope, drainage density and landuse of the area. All thematic maps have been integrated with GIS environments to identifying potential areas for delineate groundwater exploration. The result showed that most promising area for groundwater development is the southern part whereas the high area occupied by Siwalik rocks indicates very poor groundwater potential. The groundwater potential zones map generated through this methodology was verified with the yield data to ascertain the validity of the model developed in the study area by assigning suitable weights to the different attributes affecting on the groundwater potential. The verification showed that the groundwater potential zones demarcated through the model are in agreement with the bore well yield data. Thus, this study has clearly demonstrated the capabilities of remote sensing and GIS technique in delineation of different groundwater potential zones .

المستخلص:

تم استخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية لتطوير طريقه لتقييم المياه الجوفية في جابية باثري راو في مقاطعة هردوار في الهند. تم استخدام بيانات القمر الصناعي الهندي الجيل الثالث لتهيئة الخرائط الموضوعية الهيدروجيومورفولوجيه وخرائط الميل وكثافة التصريف واستخدام الاراضي. وقد وحدت جميع الخرائط الموضوعية مع بيئة نظم المعلومات الجغرافية لتحديد إمكانية تواجد المياه الجوفية في منطقة الدراسة لغرض التنقيب عنها. بينت النتائج ان اغلب المناطق التي يمكن ان تكون غنية بالمياه الجوفية هي الجزء الجنوبي لمنطقة الدراسة بينما المنطقة المرتفعة والمكونة من صخور السيوايك يقل احتمالية وجود المياه الجوفية فيها. ان خرائط مناطق المياه الجوفية المحتملة والمنتجة باستخدام هذه الطريقه تم معايرتها باستخدام البيانات المتوفرة للابار المحفورة في منطقة الدراسة وتبين انها تتوافق معها بشكل كبير وعليه فان هذه الدراسة تبين وبشكل واضح إمكانية استخدام تقنية الاستشعار عن بعد ونظم المعلومات الجغرافية في تخطيط وتحديد اماكن تواجد المياه الجوفية.

Introduction:

Groundwater constitutes an important source of water for various purposes like domestic needs, supply for industries and for agriculture etc. The conventional approaches for

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groundwater investigation are ground based surveys and exploratory drilling which are time consuming and uneconomical. Keeping this in view, the present study attempts to demarcate groundwater potential zones in Piedmont area using an integrated approach of remote sensing and GIS technique.

In modern computing, Geographic information system (GIS) has been successfully applied to groundwater mapping and assessment due to its ability to rapidly process large amount of data, present them as thematic maps, and carry out numerous analysis and interpretation [1].

Area of study:

The study area is located between 29° 50' 00" to 30° 11' 21" North and Longitude 77° 59' 19" to 78° 06' 21" East falling Pathri Rao watershed covering an area of approximately 58 square km² (Fig. 1).

Geologically the study area is comprised of Siwalik rocks and alluvial deposits. Towards north, the Siwalik sedimentary rocks are composed of indurated to compacted clastic sediments exposed in Haridwar district and represent a over 6000 m thick sequence, consisting of interbedded mudstones, sandstones, conglomerates and subordinate marls [2]. The area is both geologically and for groundwater exploration complicated area. In view of above, the above study area has been chosen to study through integrated techniques of remote sensing and GIS.

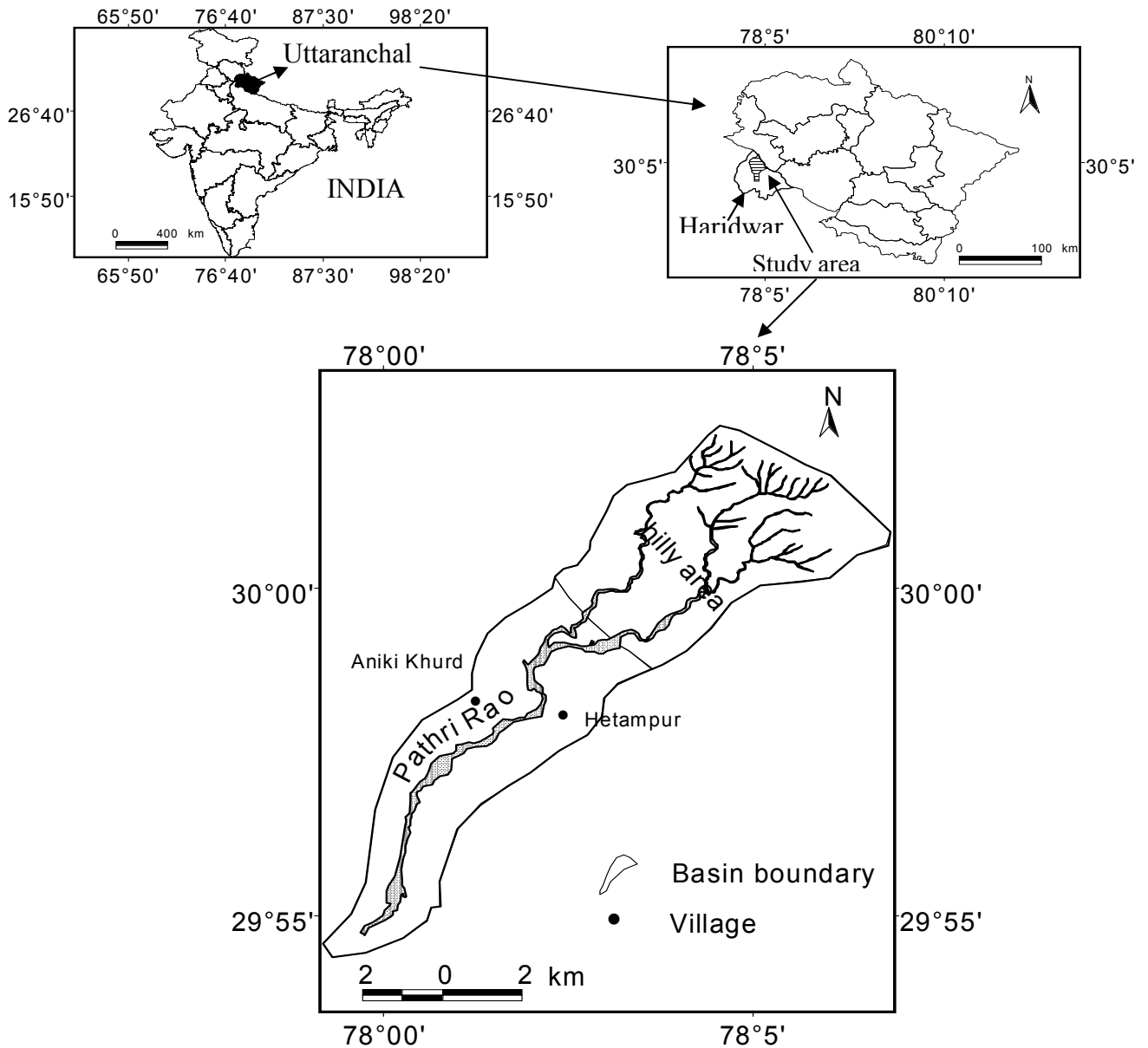


Fig.1: location map of the study area

Objective:

The main objective of the present study is to demonstrate the capabilities of using remote sensing and Geographical Information System (GIS) for demarcation of different ground water potential zones for a particular geohydrological setting.

Methodology:

In order to demarcate the groundwater potential zones of study area different thematic maps on 1:50,000 scales were prepared from remote sensing data and topographic maps. The thematic map of hydrogeomorphology was prepared using IRS 1C LISS-III data by visual interpretation on 1:50,000 scale. Drainage map was prepared from Survey of India (SOI) toposheet & satellite data. Contour map and spot elevation map were prepared from SOI

toposheets. Land use map was prepared from SOI toposheet, satellite data and by real field check and slope map was prepared from digital elevation data. All primary input maps (hydrogeomorphology, contour & spot elevation, drainage and landuse map) were digitized using GIS (Arc View, version 3.1) software [3] to generate different thematic maps of the area. Finally thematic layers were converted into grid with related item weight and then integrated and analysed, using weighted aggregation method. The grids in the integrated layer were grouped into different ground water potential zones by a suitable logical reasoning and conditioning. The final ground water potential zone map thus generated was verified with the yield data to ascertain the validity of the model developed.

GIS bases data generation and analysis:

An integrated geographic database consisting of spatial and non-spatial data has been generated for the study area. The spatial data consists of thematic maps generated from topographic maps and remote sensing data while the non-spatial data comprises of attributes, primarily derived from ground checking during field survey and using available literature. These data have been stored in GIS environment. The Image processing software ERDAS [4] is used to enhance Indian Remote Sensing (IRS), LISS III image for interpretation of the hydrogeological features, which in turn are digitized using GIS (Arc View 3.1) software.

Generation of thematic maps:

Hydrogeomorphology

Based on hydrogeological characteristics, the area is classified into four geomorphic units. The geomorphic boundaries are digitized on the enhanced image through GIS and generated hydrogeomorphological map is shown in Fig. 2. *The Upper Piedmont* zone also known as Bhabhar, bordering the *Siwalik hill* comprise of unconsolidated coarse material. For groundwater point of view this belt provides an excellent hydrogeological setup for recharge and infiltration. *The Lower Piedmont* (also known as Tarai) is separated from the Upper Piedmont (Bhabhar) by the spring line along their junction. This zone is composed of coarse-grained sand and clays with gravel (boulders and pebbles).

Flood plains form the youngest geomorphic unit and include various landforms formed by fluvial action i.e. sandbars, channel bars, and meander scars. These are characterized by very gentle slope and consist of sub rounded to rounded fragments of sand, silt and clay

Topography:

Topographic information has been collected from (SOI) toposheet at scale 1:50,000 and a Triangulated Irregular Network (TIN) has been generated from elevation contours (20m interval) and spot elevations. Slope percent map has been generated from the TIN data for the area is shown in Fig. 3. Nearly 35 percent of the total area shows slope of (less than 1%). Whereas the steep slope (more than 6%) is found in the north and northeastern parts of the study area.

Fig. 3: Slope map of the area

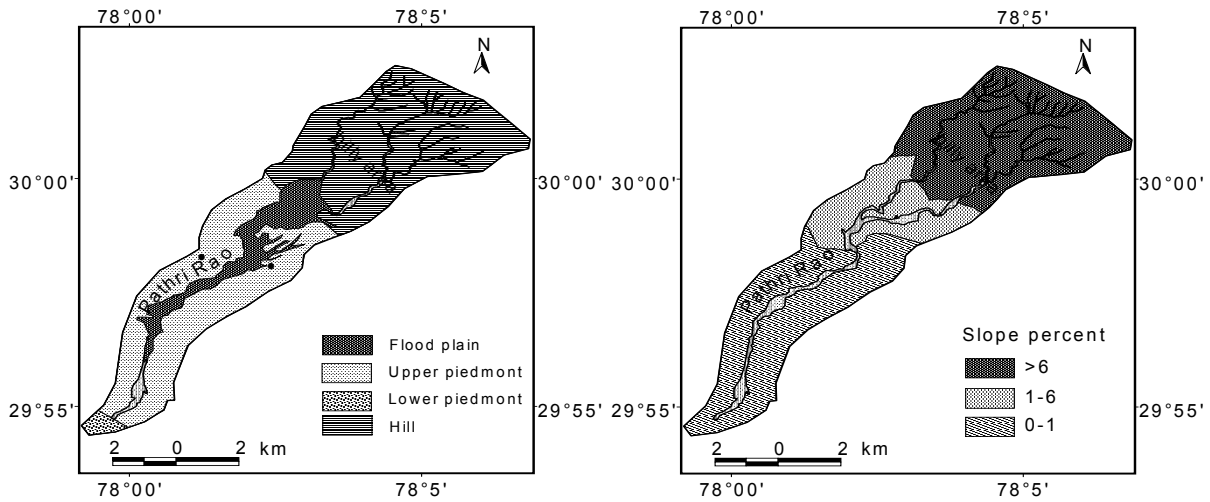


Fig. 2: Hydrogeomorphology map

Drainage:

A surface drainage map has been prepared from SOI toposheet and LISS III image at 1:50,000 scale as shown in Fig. 4. From the drainage map, the drainage density map of the study area has been prepared Fig.5. The area has maximum drainage density of 1.7 km/km² in the northern part of the study area and minimum of 0.9 km\ km² in the southern part of area.

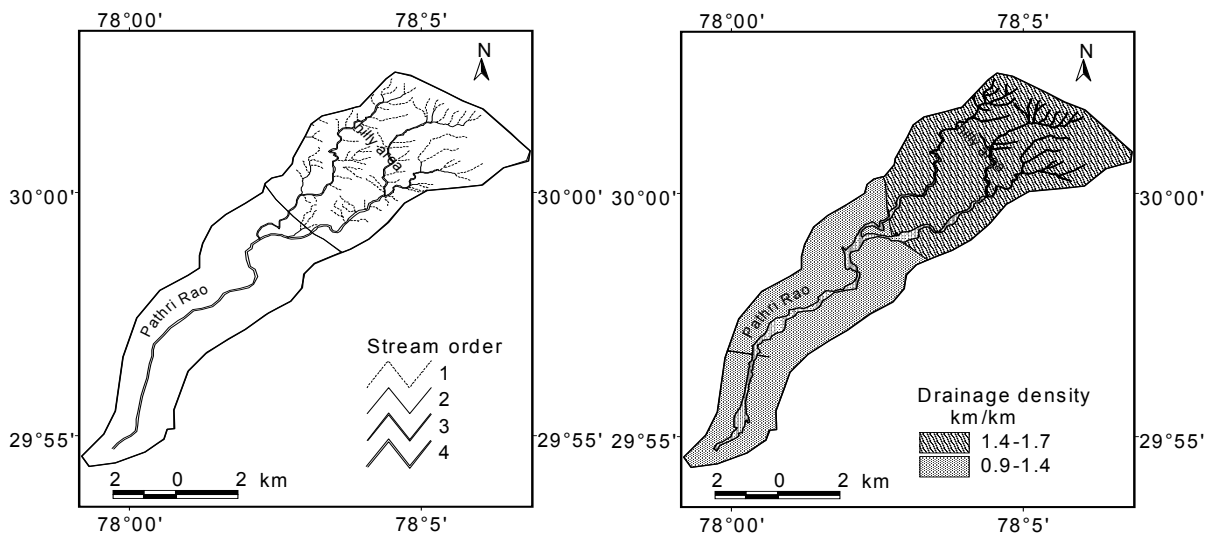


Fig. 4: Drainage pattern map

Fig.5: Drainage density map

Landuse:

IRS1-D-LISS-III digital data for November, 1998 was used for preparation of Landuse map of the study area. The image was classified using unsupervised classification in ERDAS Imagine software. Cultivated land, uncultivated and forest are the various landuse classes observed in the study area (Fig 6). In general, cultivated (agriculture) land indicates more permeable zone with high infiltration and low runoff.

Integration of Thematic Maps and Modeling Through GIS:

Hydrogeomorphological, slope, drainage density and landuse features play a vital role in controlling the occurrence and movement of groundwater. For quantitative analysis each theme may be assigned some weight which defines its influence on groundwater potential. For example, hydrogeomorphology plays a prominent role in groundwater potential [5], [6] and [7] than the slope and drainage density of the area, hence higher weightage is given to hydrogeomorphology. Whereas landuse has less influence over groundwater potential is assigned lesser weightage. The different units in each theme are assigned knowledge based hierarchy of ranking from 1 to 3 on the basis of their importance defining their potential. These ranking one, two, and three denotes poorly favorable, highly favorable and excellent zone respectively for groundwater potential. The final score of each unit of a theme is equal to the product of rank and weightage. The weightage and rank for different themes and classes used in this study are shown in table 1. The thematic maps are overlaid step by step to generate a composite map of the area. The groundwater potential for each zone has been defined on the basis of total score of various themes. Thus the entire area is qualitatively divided into three different groundwater potential zones namely excellent (greater than 10), very good (6-8), good (4-6) and poor to very poor (less than 4). These zones are shown in a thematic map in Fig. 7, which shows that the groundwater potential in the northern part of the study area (covering about 25 km² of the area) is very poor, due to very steep slopes and very high drainage densities which are resulting in low infiltration and high runoff. In the middle part, because of gentle slope and low drainage density, the groundwater potential is good (covering 11 km² of the area). In the southern part about 22 km² of area has very good and excellent groundwater potential due to gentle slope and very low drainage density.

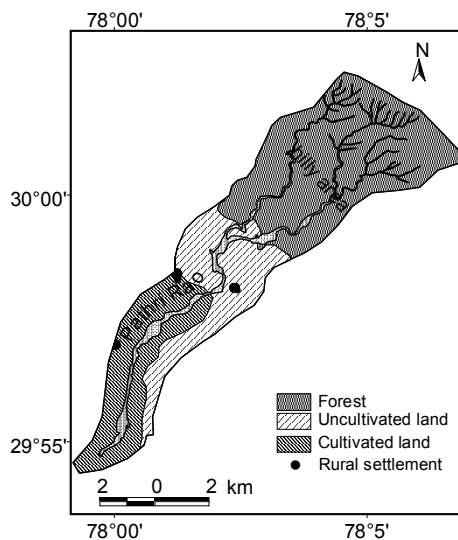


Fig.6: Landuse map of the study area

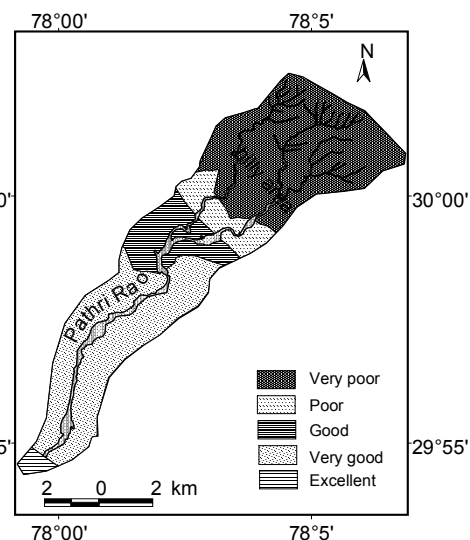


Fig.7: Groundwater potential map

Model Evaluation and Results:

The validity of the model developed was checked against the yield data collected from tube well division Roorkee. Yield data obtained from 10 tubewell locations spread over the different groundwater potential zones show that a zone very good potential is having good water yield ranging from 121-257 m³/h and a good having yield data ranging from 63-225 m³/h. It is also been observed from these data that the yields from locations close to gentle slope and low drainage density in the piedmont geomorphic unit are comparatively higher than that from other locations.

Table 1: Rank, weight and scores for attributes for various themes with respect to groundwater potential

<i>Parameters/ Attributes</i>	<i>Weight</i>	<i>Classes</i>	<i>Rank</i>	<i>Score</i>
Hydrogeomorphology	4	Lower piedmont	3	12
		Upper piedmont	2	8
		Hill	1	4
Slope	3	<1	3	9
		1-6	2	6
		2-6	1	3
		>6	1	6
Drainage density	2	0.9-1.4	2	4
		1.4-1.7	1	2
Landuse	1	Cultivated	2	2
		Uncultivated	1	1
		Forest	1	1

Conclusion:

In order to delineate the groundwater potential zones, different thematic layers viz: hydrogeomorphology, slope, drainage, drainage density and land use map are used to be integrated. This provides a broad idea about the groundwater prospect of the area. Presently groundwater potential zones have been demarcated by integration of above thematic layers, using a model developed through GIS technique. The groundwater potential zones map generated through this model was verified with the yield data to ascertain the validity of the model developed and found that it is in agreement with the bore wells yield data. This illustrates that the approach outlined has merits and can be successfully used elsewhere with appropriate modifications. The above study has demonstrated the capabilities of using remote sensing and Geographical Information System for demarcation of different ground water potential zones, especially in diverse geological setup. This gives more realistic groundwater potential map of an area which may be used for any groundwater development and management programme.

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