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Original Research Paper

Delineation of Groundwater Potential Zones in Vettikavala Block, South Kerala, India Using Geospatial Technology

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ABSTRACT

Geospatial technology was utilized in this study to specifically delineate groundwater potential zones. IRS-LISS III data in conjunction with Survey of India toposheet (1:50,000) and extensive field data were used for the preparation of various thematic maps. Various thematic maps have been prepared for geology, geomorphology, slope, relative relief, land use, drainage density, lineament density, transmissivity, storativity and water table fluctuation. Thematic maps have been integrated in GIS by assigning suitable rank and weightage to each parameter based on their respective significance. Integrated groundwater potential map is a genuine tool decidedly resourceful for sustainable groundwater development and management. The charisma of this innovative method is that, this model can be used in any other area to functionally demarcate groundwater potential zones, and hence will be of immense societal significance.

INTRODUCTION

Geographical information system (GIS) is a powerful set of tools for collection, storing, retrieving, transforming, displaying spatial data from the real world for a particular purpose. In recent years GIS has been considered as a powerful tool for multi criteria analysis in resource evaluation. Remote sensing together with GIS techniques is increasingly used in hydrogeology for groundwater modelling, delineation of potential zones, groundwater exploration and identification of artificial recharging sites. The study area faces acute water scarcity during summer; hence an assessment for groundwater resources is inevitable for planning groundwater availability for the future development. With this in view, an integration of data collected through remote sensing and field work has been integrated using GIS tool to delineate the groundwater potential zones in this block.

STUDY AREA

The study area covers the Vettikavala block of Kollam district, Kerala State with an area of 204 km^2 (Fig. 1). As per the CGWB categorization the block is declared as semi-critical. The area receives an average annual rainfall of 2500 mm. The area is having an undulating topography with hills, valleys and low lying plains. This is an agrarian block with more focus on agriculture. The study area is well drained by network of first and second order streams and shows sub dendrite type of drainage pattern. Kallada River is the major stream flowing across the study area.

MATERIALS AND METHODS

Remote sensing data, field data and GIS techniques were integrated to delineate groundwater potential zones. In the present study, Survey of India topographical maps of 58C/12, 58C/16 and 58D/13, on 1:50,000 scales, were used for doing comprehensive field work. For identifying the water level fluctuation in the study area, 82 locations were selected for water table monitoring. Observation wells were fixed at an interval of 1 km to ensure uniform spatial distribution. Aquifer parameters such as transmissivity and storativity were carried out by conducting pumping tests in selected locations. A lineament density map prepared from lineament map, geomorphology and land use map were set from the IRS-LISS data. A drainage map was prepared by digitizing the drainage in the study area and from this drainage density map was prepared. Slope map was generated from DEM and relative relief map is derived from digitized contour map. Spatial variation maps of all above parameters were prepared with the help of Arc GIS 9.3 software. Numerical weighted parameter rating (WPR) was used for accurate demarcation of groundwater potential zones.

Geology: Geology of the area is relatively homogeneous and underlined by precambrian crystalline rocks. Charnockites and khondalites occupy hill ranges, whereas migmatite complex cover a major portion with laterite cappings. The south western fringe is occupied by sandstone and clay. The intercalation of sand and silt is found in north and north eastern part. Nearly 90% of the area is capped by laterite with colour varying from reddish brown to yellowish. Another striking observation is that laterite sequence constitutes the major phreatic aquifer in the whole region. Groundwater extracted from these aquifers is the main source of water supply for agriculture and domestic purpose in this area.

Geomorphology: Many of the features suitable for locating groundwater can be inferred from geomorphology. In a drainage system, geomorphology contributes to a greater extent to the runoffs, storage potential of surface water bodies and also recharge to the groundwater (Thambi et al. 2006, Don Pool 1998). Many of these features are favourable for demarcating areas of recharge and discharge and thus useful to delineate groundwater potential zones and were deciphered by integrating the remote sensing data products (IRS P6-LISS III). Physiographically, the area falls under seven classes of land forms such as buried valleys, lower plateau, lower lateritic plateau, flood plain, water bodies, rock exposure and residual hills. It is found that lateritic lower plateau dominates the study area followed by buried valleys and lower lateritic plateau. A rock exposure is seen along the NW part, and residual hills described as an isolated hill occupying a small area along the NE part representing the runoff zones, where groundwater prospect is poor. Water bodies are seen along the extreme SW and NW part and are considered good for groundwater recharge (Chowdary et al. 2009). The valley fills present in the study area, act as discharge zones where the groundwater prospect is expected to be good.

Land use: Land use is a unit of landscape that can be categorised by its stage of existence or management. The way in which a part of the landscape serves a functional purpose defines its land use. Land use of the area provides an important indication of the extent of groundwater requirement and utilization (Narendra et al. 2013). The natural features on the surface undergo continuous change. Depending on the rate or scale of changes it is classified into different types. The synoptic viewing through remote sensing has provided the multi spectral data, which has been utilized for classifying land use. This shows the different types of landforms such as agricultural plantations, mixed plantations, built-up lands, kharif crops, double crops, scrub lands, water bodies etc. From the point of view of land use, crop land with vegetation is an excellent site for groundwater exploration (Todd & Mays 2005) and majority of the study area (68%) is covered by mixed plantation, followed by rubber (17%). About 0.43% of the area is covered by water bodies and it is also favourable for groundwater recharge (Narendra et al. 2013, Chowdary et al. 2009).

Lineaments: A lineament is a regional scale, linear or curvi linear feature, pattern or change in pattern attributed to a geologic formation or structure and it reflects a subsurface phenomenon. In hard rock areas, lineament represents zones of joints or fractures resulting in high porosity and permeability and hence they are good indicators that show the groundwater movement. In a hard rock area, the major groundwater movement will be along the lineaments and are considered as groundwater potential areas and targeted for groundwater development. Lineament density map generated from the IRS-LISS III data, shows majority of the study area is devoid of lineaments and the prominent trend of lineament noted is towards NNW-SSE, however, other trend is also noted in the study area. The lineaments in the pediplain and valley fill areas are considered significant from the groundwater point of view (Adham et al. 2010). In the study area lineaments occurring along the rock exposure and high slope areas are less significant due to the better runoff in these areas.

Lineament density map was prepared from lineament map and the purpose was to calculate frequency of lineaments per unit area. Areas with high lineament density are good zones for groundwater targeting (Sander 2007). High values of lineament density are not noticed in the study area, predicting moderate groundwater potential.

Drainage density: A drainage map of an area gives an idea about the permeability of rocks and thus an indication of specific yield (Wisler & Brater 1959). Kallada River is the major river draining through the area. It is a 5^{th} order river and several tributaries cut across the area and join this river. A drainage map was prepared by digitizing the drainage in the study area and from this, drainage density map was prepared. Higher drainage density values in highlands could be attributed to steep slope of the valley, youth to early mature stage of the river, high amount of rainfall in the catchment area. While a low drainage density in low lands indicates late mature to old stage, low rainfall and moderate to gentle slopes and a subdued topography. It also indicates high permeability of the soil and lithology. Higher the drainage density, the greater will be the runoff and vice versa. Drainage density provides an indication of drainage efficiency of the basin. The drainage density map was generated from drainage network of the basin using GIS software. The drainage density contour of the study area has been generated based on the spatial analysis by dividing the area into grids of 1 km^2. Low drainage density dominates the study area and is followed by high drainage density in the north and north eastern part of the study area and it is considered as an unfavourable site for groundwater existence. Moderate drainage density has moderate potential and less/ no drainage density is high ground-water potential zone (Todd & Mays 2005). The drainage density in the area is found to be low, which is considered favourable for groundwater potential.

Ground slope: The slope has a dominant effect in contributing the received rainfall to the stream flow and groundwater. The slope conditions also control the depth of water table and distribution of vegetation pattern. The slope information plays an important role in finding suitable sites for recharging, (Gupta & Srivastava 2010) and it has a direct influence in the morphometry of the basin. Thus, the slope controlling runoff and infiltration rate, serves as an indicator of good groundwater prospect (Prasad et al. 2008). The slope model was generated from DEM of the study area and classified into different slope classes. The ground slope varies from 0 to 24° and majority of the area is characterized with moderate to steep slope. Low slope values are found along the western and south western part. Low slope in the study area are zones of high groundwater potential and high slopes are poor zones, since runoff is rapid.

Relative relief: The relative relief represents the difference in local relief at a place. It is very useful because of its direct relation with the slope of the area to provide a better index of erosion along with the stage of geomorphic development. It is found that the western portion and lower reaches of the eastern part falls in low relative relief <40 class, whereas majority of the area exhibits a relative relief ranging from 40-100m. A very high value of relative relief greater than 100m is found at the north eastern portion.

Water level fluctuation: Water level fluctuation in the observation wells, in an area between two successive periods, will indicate the net changes in the groundwater regime during the period in response to the recharge and discharge components and is important for the planning of sustainable groundwater development. Karanth (1987) also suggested that for the estimation of storativity in any aquifer, water level fluctuation data are essential. The water table fluctuation has been analysed using the observation wells data collected during four seasons. The water table fluctuation of each well was found out by subtracting the shallowest depth of water table from the deepest depth of water table. Rainfall plays an important role in the fluctuation of water levels. The magnitude of water level fluctuation depends on many factors, of them topography and climate are much momentous. The fluctuation ranges from 0.1m to 9.21m with a mean of 1.874m. Highest fluctuation is noticed along the central part, where slope value is highest, indicating wells piercing in to the crystallines and lowest fluctuation is observed in the well piercing laterite. A decline in water table represents groundwater abstraction in excess of increment, while a rise represents groundwater increment in excess of abstraction (Karanth 1987). Major portion of the study area shows fluctuation between 2 and 4m.

Transmissivity: Transmissivity is defined as the rate of flow under a unit hydraulic gradient through a cross section of unit width over the whole saturated thickness of the aquifer. Hence, it is the product of the hydraulic conductivity and saturated thickness of the aquifer. In the present study, transmissivity values range from $39m^2/d$ (Valakom) to $117m^2/d$ (Mylom). The highest values were obtained in the north and north eastern part, where sand content is high. Majority of the area posses a transmissivity value less than 70 and is noticed in the north, north east, south and south western part covered by Archean crystallines which possess low transmissivity compared to Tertiary.

Storativity: Storativity is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface. It is a dimensionless property and is dissimilar for confined and unconfined aquifers. In the case of unconfined aquifer, water table is considered as the height of hydraulic head. Thus, a change in hydraulic head results in either increasing or decreasing saturation of the aquifer, which in turn results change in the volume of water in the aquifer. For unconfined aquifers, the storage coefficient is the same as specific yield and it ranges from 0.05 to 0.30 (Reghunath 1987). The storage coefficient value ranges from 0.02 to 0.30 in the study area. Majority of the area falls in the range of 0.25-0.3 and lowest value of <0.25 is noticed at the N and NE part, where transmissivity and TFR are highest.

RESULTS AND DISCUSSION

Data amalgamation was done using the geo spatial tool (GIS) by integrating various thematic maps. The parameters which have got decisive influence are considered for demarcating groundwater potential zones. The selected parameters are geology, geomorphology, land use, drainage density, lineament density, slope, relative relief, transmissivity, storativity and water level fluctuation. In order to integrate all these data, an appropriate factor is needed. A numerical weighted parameter rating approach and weighted index overlay method was used to delineate groundwater potential zones. Various thematic maps are classified into different classes and rank was assigned to each subclass. On the basis of weightage assigned, an index value is derived and brought into the 'Raster calculator' function of spatial ana-

Table 1: Weighted parameters for groundwater potential zone.

No	Parameter	Class	Rank	Weightage	Index
1	Lineament density	<0.5	1	12	12
		0.5-1	2		24
		1-1.5	3		36
		>1.5	4		48
2	Storativity	<0.1	1	12	12
		0.1-0.15	2		24
		0.15-0.2	3		36
		>0.2	4		48
3	Transmissivity	<50	1	12	12
		50-70	2		24
		70-90	3		36
		>90	4		48
4	Water table fluctuation	<2	4	10	40
		2-4	3		30
		4-6	2		20
		>6	1		10
5	Slope	<5	4	7	28
		5-10	3		21
		10-15	2		14
		>15	1		7
6	Relative relief	<40	4	7	28
		40-80	3		21
		80-120	2		14
		>120	1		7
7	Drainage density	<2	4	8	32
		2-3	3		24
		3-4	2		16
		>4	1		8
8	Land use	Agriculture mixed plantation	4	10	40
		Water body	3		30
		Open scrub	2		20
		Builtup	1		10
9	Geology	Sandstone with clay	4	10	40
		Sand and silt	3		30
		Migmatite	2		20
		Khondalite	2		20
		Charnokite	1		10
10	Geomorphology	Valley	4	12	48
		Flood plain	3		36
		Lower plateau	2		24
		Residual hill and rocks	1		12

lyst tool for integration (Table 1). A simple arithmetical model has been adopted to integrate various thematic maps. The final map represents four zones with diverse groundwater potential (Fig. 2). The result indicates that the stream courses, buried valleys in association with or without lineaments come under potential to highly potential zones and along the steep slopes hill underlain by compact lithology and high drainage density are categorized under moderate to non potential zones. Majority of the area falls in potential to moderate potential zones and only 4% was found to be non potential. Bar diagram in the map clearly depict percentage-wise distribution in various zones. Integration of thematic map led to the demarcation of groundwater potential zone which defines the potentiality for future groundwater development in the Vettikavala Block.

CONCLUSION

The study has been carried out utilizing remote sensing and GIS techniques in deciphering the groundwater potential zones in a lateritic terrain underlined by crystalline. The integrated groundwater potential map is generated on the basis of weightage assigned to the features based on their priority in terms of groundwater potential. The study reveals that 57% of the area falls in potential zones and those areas do not require any kind of groundwater development

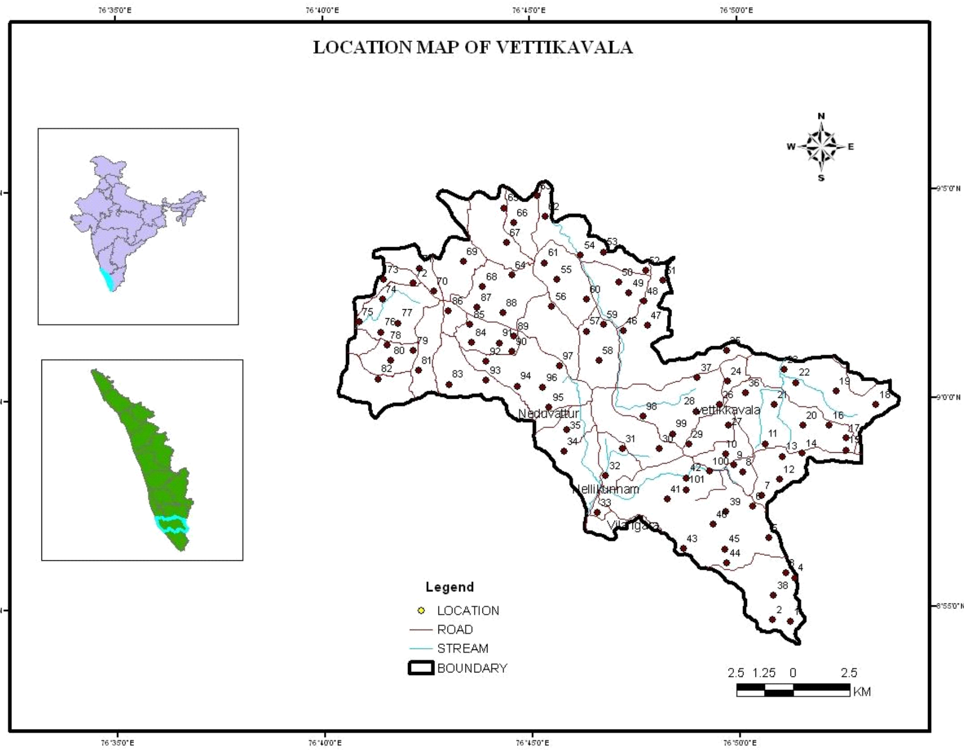

Fig. 1: Location map of Vettikavala.

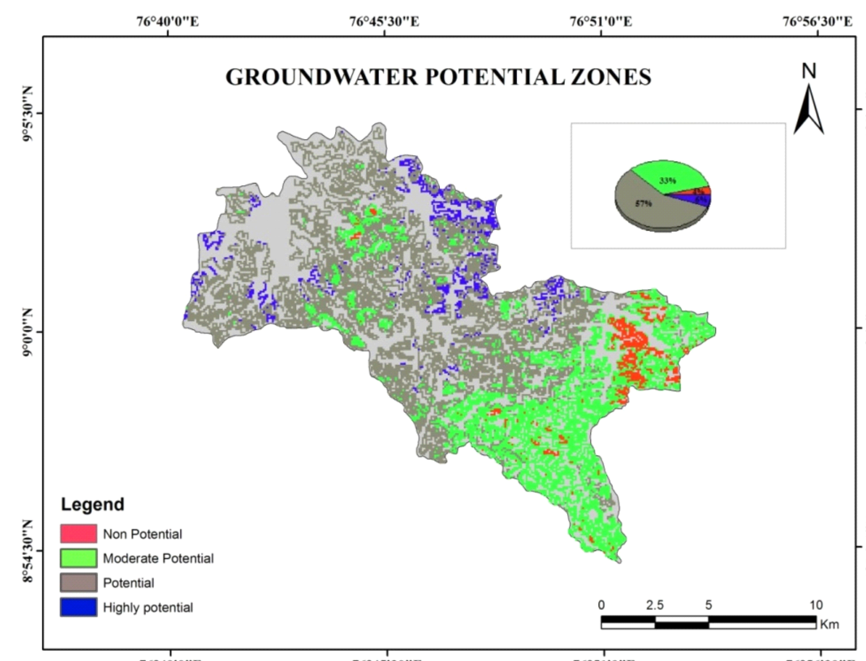

Fig. 2: Groundwater potential zone map.

and the rest 47% needs an efficient recharge program for improving its potentiality. Thus, the integrated groundwater potential map could be useful for a sustainable groundwater development and management. The attractiveness of this model is that the same approach can be used in any area to demarcate groundwater potential zones and this will be of great socioeconomic importance.

REFERENCES

Adham, M.I., Jahan, C.S., Mazumder, Q.H., Hossain, M.M.A. and Haque, A.M. 2010. Study on groundwater recharge potentiality of Barind tract, Rajshahi district, Bangladesh using GIS and remote sensing technique. Jour. Geol. Soc. India, 75: 432-438.

Chowdhury, A., Jha, M.K., Chowdary, V.M. and Mal, B.C. 2009. Integrated remote sensing and GIS based approach for assessing groundwater potential in West Medinipur district, West Bengal, India. Int. Jour. Remote Sensing, 30: 231-250.

Don Pool 1998. Assessment of Natural Recharge, Groundwater Storage and Aquifer Storage Properties in the Lower Canada Del Oro Basin, Pima Country, Arizona, Project Number AZ153, USGS.

Gupta, M. and Srivastava, P.K. 2010. Integrating GIS and remote sensing for identification of groundwater potential zones in the hilly terrain of Pavagarh, Gujarat, India. Water Int., 35: 233-245.

Karant, K.R. 1987. Groundwater Assessment, Development and Management. Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Narendra, K., Rao, N.K. and Latha, S.P. 2013. Integrating remote sensing and GIS for identification of groundwater prospective zones in the Narava Basin, Visakhapatnam Region, Andhra Pradesh. Journal of the Geological Society of India, 81: 248-260.

Prasad, R.K., Mondal, N.C. and Singh, V.S. 2008. Evaluation of groundwater resource potential using GIS in Kurmapalli watershed of Andhra Pradesh. Journal of the Geological Society of India, 75: 661-669.

Reghunath. H.M. 1987. Groundwater. Wiley Eastern Limited., New Delhi.

Sander, P. 2007. Lineaments in groundwater exploration: A review of applications and limitations. Hydrogeol. Jour. Remote Sensing., 21: 1919-1924.

Thampi, D.S., Shaji, E and Tamta, S.R. 2006. Changes in the groundwater development in Kerala over the last 15 years. Seminar on Role of Groundwater in National Economy, All India Central Groundwater Board Officers' Association, Bangalore.

Todd, D.K and Mays, L.W. 2005. Groundwater Hydrology. 3rd ed., Hoboken: John Wiley & Sons.

Wisler, C.O. and Brater, B.F. 1959. Hydrology. New York: Willey.