Groundwater Potential Zones Identification Using Geographical Information System

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Abstract: The GIS has been found to be an effective tool for delineating the groundwater potential zones. The several studies have been carried out for identification of groundwater potential zones. Nishtha (2009) identified groundwater potential zones and results shows that the area having 'good' groundwater potential is about 152.6 km^2 which is about 44 per cent of the total study area. The southern and southwestern portion of the study area falls under moderate groundwater potential zone. It encompasses an area of 102 km^2 which is 29.5 per cent of the total area. Singhal et al. (2010) delineated aquifers in the piedmont zone of Himalayan foothill region in Pathri Rao watershed and results shows that the the stage of groundwater development in the watershed is 164 per cent indicating critical over-exploitation of groundwater. Preeja et al. (2011) identified groundwater potential zones in Ithikkara River Basin (IRB), Kerala and results shows that the groundwater occurrence is controlled by geology, structures, slope and landforms. Ndatuwong and Yadav (2014) identified the groundwater potential zones in Vindhyan basin of central India and results shows that the integrated map of the area shows different zones of groundwater prospects, viz. very high (0.77% of the area), high (35.57% of the area), moderate (54.53% of the area), while poor and very poor are made up of 9.13% of the area.

Key Words: Groundwater potential zones, GIS, Watershed

1. INTRODUCTION

The groundwater has become crucial worldwide not only for targeting groundwater potential zone, but also for monitoring and conserving this vital resource. To determine the position of groundwater, quality of groundwater ,physical characteristics and thickness of aquifers, etc. in any basin, test drilling and stratigraphy analysis are needed which are very costly, time consuming and require skilled manpower. Thus, a proper understanding of groundwater systems is conventionally obtained through expensive and time consuming methods/ investigations (Sander *et al.* 1996; Ansari et al., 2015).In contrast, the Remote sensing (RS) technology is useful for groundwater development and management as it provides the current basic information on geology, landforms, soils, land use/land cover, surface water bodies etc, quickly and repeatedly with relatively less cost and manpower than the conventional techniques (Engman and Gurney,1991; Jaisawal *et al*. 2003).The hydrogeologic interpretation of satellite data has been proved to be a valuable survey tool in areas of the world where little geologic and cartographic information exists or is not accurate as well as inaccessible regions of the world (Engman and Gurney,1991; Singh *et al.*, 2014). As remote sensors cannot detect groundwater directly, the presence of groundwater is inferred from different surface features derived from satellite imagery, which acts as indicators of groundwater (Todd, 1980; Jha and Peiffer, 2006). As a result, when combined with the relevant field data, the remote sensing data allow an interpolation between groundwater sampling points that helps in defining the subsurface structure better and more economically than by the surface method alone (Engman and Gurney,1991; Saxena et al., 2018).

Review of literature

Ganapuram *et al.* (2009) used Remote Sensing data and Geographic Information System to locate potential zones for groundwater in the Musi basin. Various maps (i.e., base, hydrogeomorphological, geological, structural, drainage, slope, land use/land cover and groundwater prospect zones) were prepared using the remote sensing data along with the existing maps (Pudake et al., 2013; Singh et al., 2017; Sharma et al., 2019). The groundwater availability of the basin is qualitatively classified into different classes (i.e., very good, good, moderate, poor and nil) based on its hydrogeomorphological conditions. The land use/land cover map was prepared for the Kharif season using a digital classification technique with the limited ground truth for mapping irrigated areas in the Musi basin. The alluvial plain in filled valley, flood plain and deeply buried pediplain were successfully delineated and shown as the prospective zones of groundwater. Nishtha (2009) used Geographical Information System (GIS) to integrate multiparametric data to generate several thematic maps, delineate groundwater potential zones and identify sites of Artificial Recharge in the Ahar River Basin, Rajasthan, India (Patel, 2012; Nagpal et al., 2012; Mishra et al., 2018). The area having 'good' groundwater potential is about 152.6 km^2 which is about 44 per cent of the total study area. The southern and southwestern portion of the study area falls under moderate groundwater potential zone. It encompasses an area of 102 km^2 which is 29.5 per cent of the total area. However, the groundwater potential along the boundaries of the study area is poor. It covers an area of 93.3 km^2, which is 26.8 per cent of the total area. The thematic layers used in this study to determine artificial recharge zones are Transmissivity, Recharge, Groundwater level (post-monsoon), Topographic elevation, Soil and Slope. These layers were combined using Boolean Logic analysis to delineate zones of suitability for artificial recharge structures (Srivastava et al., 2014; Ansari et al., 2016). The area suitable for artificial recharge is 44.6 km^2, which is 12.7 per cent of the total study area. Saha *et al.* (2009) demarcated groundwater potential zones of the Gangetic Alluvial Plain covering 2,228 km^2 in the state of Bihar. The area is mainly agrarian and experiencing intensive groundwater draft to the tune of 0.12 million cubic metre per square kilometres per year from the Quaternary marginal alluvial deposits, unconformably overlain northerly sloping Precambrian bedrock. Multiparametric data on groundwater comprising water level, hydraulic gradient (pre- and post-monsoon), aquifer thickness, permeability, suitability of groundwater for drinking and irrigation and groundwater resources vs. draft were spatially analysed and integrated on a Geographical Information System platform to generate thematic layers. By integrating these layers, three zones were delineated based on groundwater development potential. It is inferred that about 48 per cent of the area covering northern part has high development potential, while medium and low development potential category covers 41 per cent of the area. Further increase in groundwater extraction is not recommended for an area of 173 km^2, affected by over-exploitation. Dar *et al.* (2010) studied the groundwater conditions in Mamundiyar basin, Tamilnadu through remote sensing, evaluation of digital elevation models (DEM), Geographic Information Systems (GIS) and fieldwork techniques. Several digital image processing techniques, including standard color composites, intensity-hue-saturation (IHS) transformation and decorrelation stretch (DS) were applied to map rock types. Remote sensing data were interpreted to produce lithological and lineament maps. DEM was used for lineament and geomorphologic mapping. All thematic layers were integrated and analyzed in a GIS. The overall results demonstrate that the use of remote sensing and GIS provide potentially powerful tools to study groundwater resources and design a suitable exploration plan.

Singhal *et al.* (2010) delineated aquifers in the piedmont zone of Himalayan foothill region in Pathri Rao watershed, district Haridwar, Uttarakhand, India by using integrated hydrogeologic and geophysical techniques. The geophysical techniques included vertical resistivity soundings, two-dimensional resistivity image profiling and electromagnetic surveys. Nuclear isotope studies have been carried out to estimate groundwater recharge and its relative age. An assessment of groundwater availability and stage of groundwater development has also been made from the available and generated field data. On the basis of the study, it was found that the rate of recharge into the aquifers is of the order of 19 per cent and the stage of groundwater development in the watershed is 164 per cent indicating critical over-exploitation of groundwater (Gupta et al., 2014; Jnawali et al., 2016). Based on the findings, possibilities of artificial recharge of groundwater have been looked into in the study area for augmentation of groundwater resources by proposing a few check dams at the suitable sites in the upstream areas of the watershed. Machiwal *et al.* (2011) delineated groundwater potential zones using integrated RS, GIS and multi-criteria decision making (MCDM) techniques for Udaipur district of Rajasthan, western India. Initially, ten thematic layers, viz., topographic elevation, land slope, geomorphology, geology, soil, pre- and post-monsoon groundwater depths, annual net recharge, annual rainfall, and proximity to surface water bodies were considered in the study. The area falling in the 'good' zone was about 2,113 km^2 (17 per cent of the total study area), which encompasses major portions of Sarada, Salumber, Girwa, Dhariawad, and Mavli blocks of the study area. The northeast and southwest portions along with some scattered patches was fall in the 'moderate' zone, which encompasses an area of 3,710 km^2 (about 29 per cent of the total area). The 'poor' zone was dominant in the study area which covers an area of 4,599 km^2 (36 per cent of the total area). The western portion and parts of eastern and southeast portions of the study area were characterized as 'very poor' groundwater potential, and this zone covers an area of 2,273 km^2 (18 per cent of the total area). Preeja *et al.* (2011) identified groundwater potential zones in Ithikkara River Basin (IRB), Kerala, India. The information on geology, geomorphology, lineaments, slope and land use/land cover was gathered from Landsat ETM + data and Survey of India (SOI) toposheets of scale 1:50,000 in addition, GIS platform was used for the integration of various themes. The composite map generated was further classified according to the spatial variation of the groundwater potential (Singh et al., 2015; Arora et al., 2019). Four categories of groundwater potential zones namely poor, moderate, good and very good were identified and delineated. The hydrogeomorphological units like valley fills and alluvial plain and are potential zones for groundwater exploration and development and valley fills associated with lineaments is highly promising area for groundwater extraction. The spatial variation of the potential indicates that groundwater occurrence is controlled by geology, structures, slope and landforms.

Bera and Bandyopadhyay (2012) delineated groundwater potential zones in Dulung watershed using RS and GIS techniques in West Bangal, India**.** In the present study, an integrated remote Sensing and GIS based methodology is developed and tested for the evaluation of the groundwater resources of Dulung watershed, Paschim Medinipur District, West Bengal and a small part of the adjoining Jharkhand state. IRS 1D LISS-III satellite data of 4th February, 2008 along with other data sets, existing maps and field observation data have been utilized to extract information on the hydrogeomorphic features of the study area. The ground water potential zones have been derived for the entire Dulangnala watershed and it has been divided into mainly four categories namely very low, low, medium and high recharge potential zone. Bhatnagar and Goyal (2012) delineated groundwater potential zones in Katni river basin using multi-criteria analysis technique. In this research a sub watershed of Katni river basin, Madhya Pradesh has been selected for study. Study area is facing shortage of water for domestic, irrigation and industrial activities. Because of the inadequate surface water resources the demand for ground water resources is increasing every year (Baranwal and Pateriya, 2016). To meet this growing demand for ground water, it is essential to identify the ground water potential areas through scientific approach. It is in this context the remote sensing and GIS technique has been applied to demarcate the ground water potential zones in the study area. IRS-1C LISS-III satellite image and SOI toposheets together with field traverses have been used as the data source. Lithology, drainage density, lineaments, geomorphology and slope map were prepared and emphasized for delineation of ground water potential zones. A multi-criteria analysis following probability weighted approach has been applied for overlay analysis that allows a linear combination of weights of each thematic map with individual capability value. The study area has been classified in to seven ground water potential zones varies from excellent to poor. Bagyaraj *et al.* (2013) demarcated groundwater potential zones with the help of remote sensing and Geographic Information System (GIS) techniques. The study area is composed rocks of Archaean age and charnockite dominated over others. The parameters considered for identifying the groundwater potential zone of geology slope, drainage density, geomorphic units and lineament density were generated using the resource sat (IRS P6 LISS IV MX) data and survey of India (SOI) toposheets of scale 1:50000 and integrated them with an inverse distance weighted (IDW) model based on GIS data to identify the groundwater potential of the study area. Suitable weightage factors were assigned for each category of these parameters. For the various geomorphic units, weightage factors were assigned based on their capability to store ground-water. This procedure was repeated for all the other layers and resultant layers were reclassified. The reclassified layers were then combined to demarcate zones as very good, good, moderate, low, and poor. This groundwater potentiality information could be used for effective identification of suitable locations for extraction of potable water for rural populations. Raju and Babu (2013) used remote sensing data for identification of groundwater potential zones in and around Kadapa area, Andhrapradesh, India. The present study was under taken to identify the groundwater potential zones by using IRS - P6 LISS III FCC (False Colour Composite).Satellite imageries used to demarcate the different hydrogeomorphological units, the major and minor trends of lineaments and various types of the geological units along with different structural fold patterns. To integrate with geomorphologic maps, geological units, finally groundwater potential zones were prepared. Floodplains and intermontane valleys are the most favorable zones for groundwater targeting.

Pandian and Kumanan (2013) conducted study on Geomatics approach to demarcate groundwater potential zones using remote sensing and GIS techniques in part of Trichy and Karur district, Tamilnadu, India. The study is attempted to identify the groundwater potential zones using remote sensing and GIS techniques. This study helped to delineate the potentiality as moderate potential, and some part have been classified as high potential zones, low and very low potential zones and only few areas have been classified as very high groundwater potential zones. Ndatuwong and Yadav (2014) identified the groundwater potential zones in Vindhyan basin of central India. The present study has been carried out to evaluate the potential zones for groundwater targeting using an integrated remote sensing data, Survey of India (SOI) topographical sheets and field verification. Four features (geomorphologic units, slope, drainage density and lineaments density) that influence groundwater occurrence were extracted and integrated to evaluate the hydrogeomorphological characteristics of the study area and demarcate the groundwater potential zones. Thematic maps of the extracted features were prepared and integrated through geography information system (GIS) environment. The groundwater potential map was prepared by overlaying the thematic layers. Weightage percentages were assigned to the different parameters according to their relative importance to groundwater potentiality. The integrated map of the area shows different zones of groundwater prospects, viz. very high (0.77% of the area), high (35.57% of the area), moderate (54.53% of the area), while poor and very poor are made up of 9.13% of the area. Patil and Mohite (2014) identified the groundwater recharge potential zones for a watershed in Maharashtra, India using RS and GIS. This study was aimed to identify the groundwater recharge potential zones, to be used for better and improved groundwater resources. The thematic layers considered in this study are eomorphology, soil, land use land cover, slope (%), drainage density and lineament density, which are prepared using satellite imagery and other conventional data. The thematic layers were first digitized from satellite imagery, supported by ancillary data such as toposheets and field investigation data, finally all thematic layers were integrated using Arc GIS software to identify the groundwater recharge potential zones for the study area and generate a map showing these groundwater recharge potential zones namely ‘poorly suitable’, ‘moderately suitable’ and ‘most suitable’ on knowledge based weightage factors. The most effective groundwater recharge potential zone is located on east-north part of the study area. In this region, the alluvium soil, burried pediplain and agricultural land have high infiltration ability. Also the concentration of drainage also indicates the ability of stream flow to recharge the groundwater system (Balakumar et al., 2008; Chaudhary and Singh, 2012). Waikar and Nilawar (2014) identified the groundwater potential zones using remote sensing and GIS technique. In this study groundwater potential zones are demarked with the help of remote sensing and Geographic Information System (GIS) techniques. In this study a standard methodology is proposed to determine groundwater potential using integration of RS & GIS technique. The composite map is generated using GIS tools. The accurate information to obtain the parameters that can be considered for identifying the groundwater potential zone such as geology, slope, drainage density, geomorphic units and lineament density are generated using the satellite data and survey of India (SOI) toposheets of scale 1:50000. It is then integrated with weighted overlay in Arc GIS. Suitable ranks are assigned for each category of these parameters. For the various geomorphic units, weight factors are decided based on their capability to store groundwater. This procedure is repeated for all the other layers and resultant layers are reclassified. The groundwater potential zones are classified into five categories like very poor, poor, moderate, good & excellent. The use of suggested methodology is demonstrated for a selected study area in Parbhani district of Maharashtra. This groundwater potential information will be useful for effective identification of suitable locations for extraction of water.

2. CONCLUSION

On the basis of results obtained from the different studies it is concluded that the remote sensing and geographical information systems provides the useful techniques for the identification of groundwater potential zones.

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