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A review on groundwater potential zone

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Abstract
Ever increasing demands of water for portable, irrigation as well as industrial sectors have created water crisis worldwide. The surface water sources are generally precarious to get their supply during monsoon seasons while in non-monsoonal periods people have to largely depend on ground water resources for their domestic and agricultural needs. Now a days, surface water resources are becoming insufficient to fulfil the water demand because utility enhanced as compare to availability. Therefore a systematic planning of groundwater improvement using modern technique is essential for the proper management and utilization of this valuable resource. Therefore there is a need for demarcation of groundwater potential zones for securing the valuable natural resource. Remote sensing and GIS is recent technology which provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface for analysis of various studies, such as groundwater study, management etc. Geoinformatics have ability to generate information in spatial and temporal domain for hydrological investigations.

Keywords: Water resource, groundwater potential, remote sensing, geographical information system

1. Introduction

Groundwater development has immersed an important place in Indian economy because of its role in stabilizing agriculture and as a means for drought management. Over the years, particularly since the launching of Five Year Plans, there have been continued efforts in India for development of ground water resources to meet the increasing demands of water. In several parts of the country, groundwater development has already at critical stage, resulting in acute scarcity of the resource. Over-exploitation of the ground water resources results in declining ground water levels, shortage in water supply, intrusion of saline water in coastal areas and increased pumping lifts, necessitating deepening of ground water abstraction structures. It has serious implications on the environment and the socio-economic conditions. Ground water quality has also adversely affected the availability of fresh ground water in several areas.

Most groundwater potential traditional approaches are mainly based on geophysical method, geological method, hydrogeological method, ground-based survey and exploratory drilling which is very uneconomical, time-consuming and require large data sets. However, a Geoinformatics approach can provide the suitable platform for the analysis of large volumes of data and quite decision-making techniques for groundwater exploration and their management. There are so many techniques namely AHP, frequency ratio, random forest model and logistic regression model were adopted for delineating the groundwater potential zones (GWPZ). Analytic hierarchy process (AHP) based on remote sensing and GIS environment well chosen as a simple, effective reliable and cost effective technique. AHP is a multi-criteria decision making method which analyse different dataset into a pairwise matrix which is used to calculate geometric mean and normalized weight of parameters.

2. Demarcation of groundwater potential zones are assessed by recognising the assessment of Groundwater availability, Criteria weight for categorization of groundwater potential zones and their verification

To find water below the surface is very critical and there is no direct method for easy observation of groundwater. Only by studying the surface and geological parameters the presence or absence of ground water status can be identified indirectly (Raviraj *et al*. 2017) [13]. Groundwater is a mysterious natural resource and cannot be directly detected, therefore, availability and mapping of this resource can be a challenging task. Depiction of groundwater potential zones (GWPZ) is necessary for the optimal usage of available water resources to meet the needs of the communities (Etikala *et al*. 2019) [4]. For assessment of the locations of an aquifer stratigraphy analyses and test drilling are the traditional and effective techniques, but these processes are costlier and also time-consuming.

Using remotely-sensed data different thematic maps such as, lithology, landforms, lineaments and surface water bodies at a 1: 50000 scale, as well as drainage density and slope classes were prepared from Survey of India topographical sheets to demarcate the presence of groundwater (Krishnamurthy *et al*. 1996) [7]. In addition, a soil map at 1: 50000 scale covering the study area was generated from a 1: 250 000 scale soil map prepared by the Soil Survey and Land use Organization by regrouping the soil types based on their hydrological characteristics.

IRS LISS II multi band remote sensing data along with geological as well as geophysical resistivity sounding data in GIS environment is used for analysis of groundwater, mapping and preparing management strategies in Dhanbad district, Jharkhand, India (Srivastava 2000) [20].

Cunningham and Daniel (2001) [2] investigated availability and quality of groundwater in Orange County, North Carolina. A countywide inventory was conducted of 649 wells in nine hydrogeologic units in Orange County, North Carolina. It was assessed that two areas of the Country were more favourable for high-yield wells a west-southwest to east-northeast trending area in the northwestern part of the County, and a southwest to northeast trending area in the southwestern part of the County. Well yields in Orange Country showed little correlation with topographic or hydrogeologic setting.

Mogaji *et al*. (2011) [9] demonstrated the application and importance of Remote Sensing and Geographic Information System (GIS) techniques for effectual groundwater resource exploration and management. LANDSAT 7 ETM+ imagery, ASTER digital elevations models (DEMs) and geological maps were used for mapping and analyses of lineaments in the Basement Complex region of Ondo State, Nigeria. Digital image processing techniques involving linear / edge enhancements and directional filtering were applied on the image to improve the edges of the linear features using ENVI 4.7. The improved image, normalized difference vegetation index (NDVI) image and hill shaded relief image (processed ASTER DEM) were visually interpreted through GIS overlay procedure for lineaments extraction through on-screen digitizing using ArcGIS 9.3. The extracted lineaments were statistically examined to direct their lengths, densities and intersections. Final results obtained were used to generate lineament density, lineament intersection map and rose diagram. The lineament / fracture result indicated that the area has countless long and short fractures whose structural trends are mainly in the north-south and east-west directions. Around the central, north-eastern part and south-western parts of the study area the cross-cutting lineaments are relatively high and relatively low in the other areas. The zones of high lineament intersection density are indicated the feasible zones for groundwater prospecting in the command area.

Multi-criteria decision making analysis provide effective decision that satisfy all the relevant criteria at various level. There are several methods for the multi criteria analysis technique. Analytical hierarchy process is one of the type of multi criteria decision analysis proposed by Saaty, 1980 is very popular and has been applied in wide variety of areas including planning, selecting a best alternative, resource allocation and resolving conflict.

One of two major components of quantitative multicriteria evaluation methods strongly affecting the evaluation results for the criteria weight determination. Weights is social and economic problem are decided on the basis of the economic development of the state and its regions, the commercial activity and strategic potential of enterprises, the effectiveness of particular investment projects etc. For determination of the significant weight of criteria by experts, several theoretical and the practical methodology were used. Pairwise comparison matrix of criteria and Analytic Hierarchy Process (AHP) used for decision analysis. Application of AHP technique to more complicated cases are considered and some algorithms are offered (Podvezko 2009) [11].

Demarcation of groundwater potential zones in Kattakulathur block, Tamil Nadu were obtained by weighted overlay methods using the spatial analysis tool in ArcGIS 9.2. In the weighted overlay analysis, the ranking has been given for each individual parameter of each thematic map and weights were assigned according to the influence such as soil – 25%, geomorphology – 25%, land use/land cover – 25%, slope – 15%, lineament – 5% and drainage / streams – 5% and it useful to find out the potential zones in terms of good, moderate and poor zones with the area of 49.70 km2, 261.61 km2 and 46.04 km2 respectively (Nagarajan and Singh 2009) [10].

Integrated RS, GIS and multi-criteria decision making (MCDM) techniques were used to demarcate groundwater potential zones. A case study in Udaipur district of Rajasthan, western India. Ten thematic layers had been considered for analysis purpose. Weightage of the thematic layers and their features were then normalized by using AHP (analytic hierarchy process) MCDM technique and also by eigen vector method. Finally, to generate a groundwater potential map, the selected thematic map were integrated by weighted linear combination method in a GIS environment (Machiwal *et al*. 2011) [8].

To assess the groundwater potential zone, there are several methodology such as geological, hydro-geological, geophysical and remote sensing techniques (Yeh *et al*. 2016) [22]. Several factors affect the occurrence and movement of groundwater including climate, topography, geological structure, depth of weathering, extent of fractures, slope, drainage patterns, landforms and land use/land cover characteristics etc. (Yeh *et al*. 2016; Raviraj *et al*. 2017; Senthilkumar *et al*. 2019) [22, 13, 16].

Geoinformatics plays a vital role in developing water and land resource management plan due to their capability in evolving spatio-temporal data and efficiency in spatial data analysis and prediction (Bhunia *et al*. 2012; Hutti and Nijagunappa 2011) [1, 5]. Geoinformatics detect presence of groundwater using different surface features derived from satellite imagery viz., geology, landforms, soil, land use and surface water bodies, which are indicators of groundwater existence (Bhunia *et al*. 2012; Jha and Peifer 2006) [1, 6].

Remote Sensing and geographical information system (GIS) are helpful to demarcate groundwater potential zones in hard rock terrain. The remotely sensed data at the scale of 1:50,000 and topographical information from available maps were used for the preparation of ground water prospective map by integrating geology, geomorphology, slope, drainage-density and lineaments map of the command area. Later the data on yield of aquifer, as observed from existing bore wells in the area, are used to verify the final groundwater potential map. The final result shows the favorable prospective zones in the study area and could be helpful in better planning and management of groundwater resources especially in hard rock terrains (Prasad *et al*. 2008) [12].

Groundwater prospect zones were delineated artificial recharge sites were using Indian remote sensing satellite (IRS) 1D PAN geocoded data on 1:12,500 scale and Survey of India (SOI) topographical sheets. Four-artificial recharge sites were assessed out of which the moderate and poor categories occupied more than 42% area and these were mainly plateau, ridges and buried pediment shallow. The most suitable artificial recharge sites occupied less area about 19% and mainly confined to buried pediplain and river terraces. The residual hill and linear ridge with steep slope covering about 39% areas that was not suitable for artificial recharge sites. This crucial information could be used effectively for identification of suitable location for groundwater potential and artificial recharged sites. Result shows that the good inter relationship was found among the geological units, hydro morphological units and lineament density. The field data further helped in quantifying various lithological and hydro-morphological units with reference to their potential for groundwater occurrence (Sarup *et al*. 2011) [14].

IRS P6 LISS III satellite data was used for mapping of groundwater potential zones in Mewat district. The groundwater potential zones were identified based on pediment, valley fill, palaeochannel, alluvial plain, aeolian plain, structural hill, linear ridge and denudational hill. Result indicated that groundwater prospects of alluvial plain is good to very good, aeolian plain moderate to good, palaeochannels very good to excellent, valley fill moderate to good, pediment moderate and in structural hill, denudational hill and linear ridge, the groundwater prospects is poor. Groundwater potential zones mapping in the district are highly useful for selecting well sites at suitable location which reduces the time, money and man-power for searching the sites for groundwater exploration (Singh *et al*. 2014) [19].

Assessment of the groundwater recharge potential zones was carried out by using geographical information system (GIS), influence factor and RS techniques in Ottapidaram taluk in Tuticorin district. Survey of India toposheets and Indian Remote Sensing-1C satellite imageries were used to prepare various thematic layers viz. lithology, slope, land use, lineament, drainage, soil, and rainfall. Thematic layers were then transformed into raster format data using the feature to raster converter tool in ArcGIS 9.3 software. Criteria weightage were assigned to the respective thematic layers and overlaid in GIS platform for the demarcation of potential groundwater zones of the study area. Zones were categorized as high, moderate and low potential zones (Selvam *et al*. 2015) [15].

Groundwater plays a vital role in global climate change and also satisfying human needs. Remote sensing and geographic information system were utilized to generate thematic layers such as lithology, lineament density, topology, slope, and river density considered as factors influencing the groundwater potential. Multi criteria decision model (MCDM) was integrated with C5.0 and CART, respectively, to generate the decision tree with 80 surveyed tube wells divided into four classes on the basis of the yield. To test the precision of the decision tree algorithms, the 10-fold cross validation and kappa coefficient were adopted. After applying the decision tree to the whole command area, four classes of groundwater potential zones were demarcated as very good, good, moderate and poor respectively. C5.0 algorithm was found more appropriate than CART for the groundwater potential zone prediction (Duan *et al*. 2016) [3]

Spatial layers are integrated and examined by using a model developed with logical conditions in the geographical information system (GIS). To ascertain the validity of the model developed, the ground water potential zones map generated through this model was validated with the collected yield data. The validation indicated that the ground water potential zones examined through the model are in agreement with the bore well yield data collected in the field. Since result indicated that the approach was built with logical conditions and reasoning, this approach can be successfully used elsewhere with appropriate modifications. (Krishnamurthy *et al*. 1996) [7]

Groundwater potential zones in hard rock terrain with the merged approach of Remote Sensing and geographical information system (GIS) were used. After finding the groundwater potential zones, about 438 wells were monitored for the validation of the prospect zones and also the yield of these wells were also estimated. These yield data were superimposed on the groundwater potential map and then number of wells with different yield ranges was categorized for different zones of potential map. Frequency distribution of various yields in different zones had been estimated. Occurrence of number of wells with yield range in the zones which were indicated as ‘‘good’’ as well as ‘‘very good’’ in comparison to the occurrence of wells with these yields in other zones. Another exceptional feature was that as one moves from ‘‘good’’ to ‘‘poor’’ zone the number of occurrence of these better yielding wells decreased showing that possibility of getting better yield decreased. Hence, the most favourable zones for high yielding groundwater were concluded as ‘‘good’’ and ‘‘very good’’ zones derived from the application of GIS in the study area (Prasad *et al*. 2008) [12].

Groundwater potential zones were assessed by using the satellite data by the incorporation of several factors such as geology, geomorphology, lineament and slope and then with the help of these factors command area were classified as excellent to poor ground water potential zones. Assessment of groundwater potential zone data with the bore well yield data were used for the verification purpose. Pre- and post-monsoon data of groundwater fluctuation were used for the validation purpose and their validation results do not show any notable change except at some regions in alluvial area (Singh *et al.* 2009) [18].

Generated groundwater potential zones are validated with reported potential yield data of various wells in the command area. Success and prediction rate curve reveals an accuracy achievement of command area significantly. The outcome of the research work will help the local authorities, researchers, decision makers and planners in formulating better planning and management of groundwater resources in the command area in future perspectives (Thapa *et al.* 2017) [21].

3. Conclusion

This paper has provided an information regarding the importance of groundwater, several techniques and overview of groundwater potential methods based on the various review of the more recent literature undertaken in this field. Information about groundwater potential mapping is very typical task in a practical ways but conjunctive use of remote sensing and GIS provide a practical way to assess multiple number of data to demarcate those areas which are more favorable for groundwater development.

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