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DELINEATION OF GROUNDWATER POTENTIAL ZONE USING THE INTEGRATION OF GEOSPATIAL MODEL AND MULTI INFLUENCING FACTOR (MIF) DECISION MAKING TECHNIQUE: A REVIEW

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ABSTRACT

In this paper, an endeavour has been made to assess the potential groundwater areas by integrating the geospatial model with Multi Influencing Factor (MIF) technique. Groundwater potential areas are of prime importance in maintenance as well as conservation of available resources of water. Groundwater being the primary source of fresh water, is in great demand due to the increase in agricultural, industrial, population and domestic action. As a result, the groundwater table drops, causing water scarcity and resource deterioration. As a result, evaluating this irreplaceable resource is critical for the long-term sustainability of groundwater resources. In this paper, the prime focus is to find the groundwater potential zone using the MIF technique, which is a decision-making technique widely used in various sectors nowadays. It is a multi-criteria decision-making strategy in which the MIF technique assigns a defined rating and weight to raster layouts of all the subsurface water influencing characteristics. The prospective groundwater zones are then estimated statistically using graded thematic layers. Hence, the researchers and decision-making authorities can collaborate for some systematic exploration plan & the harvesting of zones done for future events. Protective & preservative measures can be taken by knowing potential groundwater zones to lower groundwater levels.

Keywords: Groundwater, MIF, Remote Sensing and GIS

INTRODUCTION

Groundwater is the water contained in the crevices of geological formations under the earth's crust and is a replenishable element of the water cycle. It is the largest available freshwater source in the world. Most of the people in India depend on groundwater for their basic needs. Rapid industrialization, increasing agricultural production, poor management and unplanned exploration of groundwater resources are the causes of the water crisis. The groundwater potential of a region depends on different facts & it varies from place to place according to its change. Groundwater prospective zones must be defined in order to develop artificial recharge programmes to counteract groundwater loss. Several different conventional methods have been using to provide statistics about the potential of groundwater in various locations with climatic and geographic conditions. Remote sensing (RS) and Geographic Information System (GIS) have emerged as efficient tools in evaluating and estimating potential groundwater zones. Groundwater Potential Index (GWPI) is a dimensionless quantification index method, designed to process groundwater potential scores for various places by amalgamating thematic maps (Pandey et al., 2010; Pandey et al., 2013; Singh and Pandey, 2014; Bhatt et al., 2017; Sharma and Kanga 2020). The core objective of the present study focused on the Ground Water Potential (GWP) zones by combining MIF with RS and GIS techniques.

Ahmed et al. (2021) integrated Multicriteria Decision-Making (MCDM) techniques like Analytical Hierarchy Process (AHP), Multi-influencing factor (MIF), and probabilistic model such as fraction ratio (FR) method with RS and GIS to delineate groundwater potential zones in Willochra Basin, South Australia. They attempted to develop a geographical model based on parameters like precipitation, lithology, drainage and lineament density, gradient, soil type, land cover, etc. to determine groundwater possibility in the area (Singh et al., 2017b; Kanga et al. 2020a, b). To produce prospective maps, GIS software was used to combine the characteristics and their given weights. The findings revealed that the southern portions of basin had a higher potential. FR model generated the most efficient map (84%) followed by MIF model (70%) and finally AHP approach (62%). The area under the curve technique was used to validate the final maps. Abijith et al. (2020) attempted the demarcation of groundwater prospects employing decision-making methods assaying the weights for controlling variables in Ponnaniyaru watershed, Tamil Nadu. The study of the possible subsurface zones was conducted via weighted linear overlays. The validation of results showed that the AHP has a relatively strong predictive precision of 75% and MIF has 71%. The reliability of the methods is determined by the classification standard, average ranks, and weights applied to the input variables, according to the researchers. MIF approach produced acceptable results but had a significant impact on the accuracy with 22% lower accuracy comparing AHP. Anbarasu et al. (2019) focused their study on identification of prospective areas in the Chinnar basin. Mainly, The Multi-influencing factor (MIF) method was combined with GIS and implemented to workout possible potential zones for groundwater. Toposheets and landsat images were utilised to draw up several thematic maps coupling weighted overlay approach for demarcating groundwater potential zones. In order to determine weights for all different layers, MIF procedure was utilised and rankings were allocated based on existing body of knowledge. The study indicated that gradient and geomorphology have a key influence in regulating groundwater attainability in more than 50% of the studied region. The variation of subsurface water levels caused by precipitation and geological strata was utilised to validate the prospective map. Etikala et al. (2019) assessed groundwater potential zones using eight influential thematic layers in hard rock area of Tirupati, Andhra Pradesh. Using the MIF approach, layers were created and allocated fixed ranking and weights based on their ability to store water (Bera et al., 2021; Tomar et al., 2021; Joy et al., 2021; Chandel et al., 2021; Kanga et al., 2021). The findings divided the research region into four zones with a maximum contribution of nearly 47% of total area from a moderate zone. This work provided reliable preliminary information on groundwater resources cost-effectively than conventional invasive methods. Fagbohun (2018) integrated the multi-influencing factor (MIF) technique with GIS for detection and mapping potential groundwater recharge zones in a hardrock geologic terrain, south-western Nigeria. Lineament, outflow, lithology, gradient, land cover, precipitation, and earth material were categorised and merged on the basis of weight calculated using the MIF approach. The combination of these criteria resulted in the creation of a prospective recharge zonation map that was divided into four categories. They established that portions of homogeneous migmatite-gneiss surrounding the severely fragmented quartzite had the highest recharging potential contributing nearly 15% of 2837 km^2 area. In Bengal's Birbhum region, Thapa et al. (2017) sought to bound potential aquifer spots. They converted eleven data layers including fault density into raster form and used MIF approach, in which factors were given scores and weights for statistic calculation. Validation was done and Groundwater potential index (GWPI) is obtained. Finally, zones were divided into four categories including extremely high. They discovered that the high potential zone comprises 35% of the research area and low & medium subsurface water potential zones cover 52.51% of 454500 hectares area. Using spatial information and traditional layouts in GIS environment, Das et al. (2017) delineated potential subsurface areas in Hingoli district, Maharashtra. The MIF approach was used to give ratings to eight parameters including soil type and precipitation patterns. Prospective zones for groundwater were classified as good, intermediate, low and extremely low. They observed that key sites were majorly in good zones due to alluvial soil accessibility in a large agricultural land having excellent penetration and all regions having structural hills were classified as low potential zones. Bhuvaneswaran et al. (2015) conducted study in the Cauvery basin to estimate potential subsurface water zones using GIS and MIF methods. Significantly thematic layers were set and each majorly and minorly effective factor was given an impact of x times and 0.5x times respectively. The relative scores were calculated using the total weightage of factors. The following algorithm is then used to determine the grade of each affecting factor and later integrated using weighted overlay analysis,

$(R+S)*100/\Sigma\,(R+S)$

where R is the primary connection between two parameters and S is the minor interdependence between two parameters. Each reclassified parameter received an equal share of the relevant score. They established that good subsurface water potential was owing to degraded pediplains and agricultural areas with strong infiltration capacity. Gradual grade, clayey soil and farm land with adequate infiltration contributed to moderate water potential. Arkoprovo et al. (2013) reported a research, where they used spatial data and applied several affecting parameters to categorise potential aquifers in coastal section of Orissa. Initially, the data of effecting parameters like lithology, slope, geomorphology, lineament density, drainage density and land use were derived from the spatial geo-database. The weightage and fixed score is assigned to each thematic layer afterwards normalized aggregation method is applied in GIS for computing groundwater potential index. They elucidated four types of potential phreatic water zones based on remote sensing and GIS technique. The results displayed excellent recharge potential close to the shoreline, while the majority of the land had a good potential. Poor recharge potential was primarily restricted to steep slopes and populated areas. This research and the accuracy of the derived groundwater potential prediction map, it can be concluded that the applied methodology, together with the used indices, is a useful background for the quick assessment of groundwater potential areas. Magesh et al. (2012) carried out the research work focused on the identification of subsurface water recharge areas in Theni district, Tamil Nadu. They mainly used the weighted overlay approach in seven multi influencing parameters, viz. lithology, slope, lineament, soil type, land use, drainage density and rainfall, and considered the effect of each implemented to workout possible potential zones for groundwater. The ranking was given by allocating a fixed value and rate of each parameter and categorised in very poor, poor, good and very good zones. They discovered that the high potential zone was confined to the upper regions of the research area due to the high moisture gripping ability of the land having alluvial soil.

Factors affecting groundwater:

The availability and productivity of groundwater in any aquifer depends upon numerous factors. For any study area, the influencing parameters considered totally depends on the availability of the data. The topographic, climatic, hydrogeological factors alongwith soil types, lineament density, geology, geomorphology and drainage density can be considered as influencing parameters. These influencing parameters give a strong dependable set of data base effective groundwater potential prediction of the study area in GIS framework.

Hydrogeological factors:

The depths to water level and aquifer thickness are the factors that influence the availability of groundwater in any study area. The depth to water level signifies the hydraulic gradient of any point which can be accessed from the India Water Resources Information System, is a valuable parameter in locating an area with significant potential subsurface water. The most significant hydrogeological elements for identifying groundwater quality is aquifer thickness and type. The data can be accessed Central Groundwater Board of India.

Drainage density is significantly important for the groundwater prospect in an area. The drainage system of an area is determined by the natural and structure formation in the area, the streamline and rainfall absorption capacity of soils, vegetation type, and infiltration rate and slope angle. A high drainage density causes lower infiltration and improved surface runoff.

Topographic factors:

The elevation, slope angle and aspect can reflect the availability of groundwater as higher the elevation and slope, lower the availability of groundwater. The digital elevation model (DEM) can be used to get the elevation, slope and aspect.

Climatic factors:

The annual precipitation is considered as most important climatic factor which is influencing the water level of any study area. The higher the rainfall, the higher will be the groundwater potential. India Meteorological Department (IMD) data can be used to get the database of the annual rainfall.

Geology, geomorphology, soil types and lithology:

The geology, geomorphology and soil types are influencing parameters to the groundwater prospect. Various sub-type of geology, geomorphology and soil types are having the different capacity to retain the water. Lithology plays an essential role in both the porosity and permeability of aquifer materials. Lineament is directly related to the availability and movement of groundwater beneath the surface.

All the factors cumulatively help to access the availability of groundwater in any study area.

Multi-Influencing Factor (MIF):

Multi-Influencing Factor (MIF) is an elementary technique to execute MCDM based on existing knowledge of the relative importance of different factors. This method is extensively used to delineate groundwater potential regions and sustainable watershed management in all parts of the world. MIF method combined with spatial database helps in effectively reducing time, manpower and cost, leading to rapid prioritisation for long-term water resource administration.

MIF is considered as one of the best approaches for the assessment of Groundwater potential and depends on user evaluation for weightage of the factors and this dependency can directly affect the final results (Kanga et al., 2017a, b; Rather et al., 2018; Hassanin et al., 2020; Kanga et al., 2021). It consists of the following steps:

Step 1: Selection of spatial scale: Initially, The study area for which the groundwater assessment should be done is selected. It can be carried out at different spatial scales, i.e., micro scale (village or household level) or macro scale (district or state level).

Step 2: Identification & selection of Influencing Parameters (IP) : The second step is to identify the impacting characteristics engaged in the demarcation of aquifer potentiality based on theoretical framework. Commonly used parameters include geology, soil, lineaments, aspect, gradient, drainage density, precipitation, land use/land cover, and elevation.

Step 3: Quantification and measurement of influencing parameters: Third phase involves awarding a rating to designated factors sub-groups and standardisation. An appropriate rating is provided when each factors subclasses are examined for their efficacy in subsurface water recharging. The impact of IPs with awarded rates is depicted in a table. Aquifer recharge subgroups with a strong impact (R) are given a value of 1, whereas subgroups with a weak effect (S) are given a value of 0.5. The subgroups that aren't useful are given zero value. The following algorithm is then used to determine the grade of each affecting factor and later integrated using weighted overlay analysis,

$(R+S)*100/\Sigma (R+S)$

where R is the primary connection between two parameters and S is the minor interdependence between two parameters. After that, weights are awarded to specified parameter subgroups. Each factors weight is evenly split and a score is allocated to each subgroup. Each factors subgroups and score are then represented as tables or charts. Data, in quantifiable units are required for estimating groundwater potential index. Groundwater potential index (GWPI) is calculated by formula given below.

$$GWPI = \sum_{j=1}^{m} \sum_{i=1}^{n} (Wj * Wi)$$

where, Wi and Wj are the normalised weights of the i^{th} and j^{th} classes of thematic layers, m represents the count of the total thematic layer and n represents the count of whole classes in each thematic layer.

Step 4: Rasterization and reclassification of influencing parameters: With the aid of GIS program, the fourth stage entails rasterizing and reclassifying factors levels as well as the derived score.

Step 5: Assessment of groundwater potential zones: The groundwater potential map (GPM) of the research region is generated by combining all thematic levels of impacting elements using ArcGIS in this step. The result of the significant primary impacting element and the subgroup score of each impacting element yields the resulting GPM.

Step 6: Representation of groundwater potential zones, spatial maps of influencing parameters, charts of interrelationship between parameters and tables of weight and rank: Finally, the obtained groundwater potential index value can be represented with the help of tables, charts and maps.

CONCLUSION

The integration of the remote sensing and GIS with decision making MIF technique comes out as a powerful tool to access the availability of groundwater in any study area. In MIF technique, unlike expert based methods weightage and ranking is given based on the interrelationship between factors which is liable to give more accurate assessment for the availability of the groundwater prospect. Studies have also shown the excellent efficiency of MIF technique in delineating ground water potential zones. Influencing parameters play a crucial role as outcome is highly dependent on these factors. This approach may be used in appropriate sites across a broad region having craggy terrain. Various groundwater recharge structures like boulder dams, check dams, percolation tanks, recharge pits etc., can be suggested in appropriate locations according to the derived results. The use of geoinformatics is of utmost for reducing time, manpower and cost, leading to rapid prioritisation for long-term water resource management.

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