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Evaluation of Groundwater Potential Mapping: A Review

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ABSTRACT: Water is an essential need for plant development. Subsurface water or groundwater is an essential source of water for farmers. Due to extensive overexploitation of the groundwater in agriculture, industrial and domestic purpose has resulted the depletion of quantity and quality of groundwater worldwide. Consequently, it is essential to replenish the groundwater and avoid its deterioration for sustainable agriculture development. Therefore, planning and management is critically needed in order to efficient utilization of groundwater resources. In hydrology and the development of water resources, the use of remote sensing and GIS is rapidly and significantly growing. Nowadays, with ease of availability of geographic, spectral, and temporal data over vast and inaccessible locations in a short period of time, remote sensing has become a very effective method for assessing, monitoring, and maintaining groundwater resources. The straight forward interpretation of satellite data provides immediate and useful baseline data on the variables that influence the occurrence and flow of groundwater, such as lithology/structural geology, geomorphology, soils, land use and land cover, slope, lineament, and geology. Groundwater is a critical and valuable resource for development. Consequently, groundwater evaluation and management are crucial. To fulfil the demand for freshwater, it has become essential to locate new groundwater potential zones at a low cost and to develop effective groundwater management and recharge strategies. Numerous assessments of ground water potential zones have been undertaken; thus, this study provides a concise summary of their results.

Keywords: Groundwater Potential Zones, Remote Sensing, GIS, Recharge Sites.

INTRODUCTION

Groundwater is a highly valuable natural resource on Earth. This resource is required for both human and animal consumption as well as the manufacture of industrial food. In India, shallow phreatic aquifers are accessed by the drilling of wells in order to recover groundwater. This technique stretches way back in time to extract the groundwater. In order to reach these shallow, unconfined, or anisotropic aquifers, which are often formed by weathered material, it is usually required to dig large-diameter wells. Despite an increasing demand for water, the supply of water in the basin is relatively steady. In India, the usage of groundwater has expanded dramatically during the last two to three decades, particularly for agricultural purposes (rivers, lakes, and artificial basins). This is mostly due to poor access to surface water sources in broad sections of the nation (rivers, lakes, and artificial basins). India's national water policy, originally stated in 1987 and subsequently revised in 2002, emphasized the role of water in defining the country's economic and social destiny. Using groundwater has the potential to ameliorate salinity and water logging issues, but it may also contribute to their worsening if an excessive quantity is drained at once. So the management of groundwater pollution and the preservation of natural resources, the rehab of the environmental ecosystem—are major focuses of policymakers and researchers, along with improving the standard of living in populated areas. Despite the fact that India receives a substantial quantity of annual precipitation, the country's groundwater situation is catastrophic due to an imbalance between recharging and groundwater extraction (Nema *et al.*, 2016). Geographic information systems, often known as GIS, are efficient computer-based technologies that play a crucial role in water resource management and pollution research. GIS represents a substantial technological leap in the area of overlay mapping techniques. It is at the cutting edge of water resource management technology since it stores, retrieves, and analyses a wide range of data types. The user is responsible for entering, managing, analyzing, and presenting geographic data using geographic information system (GIS) software. With the help of remote sensing and GIS techniques, a number of researchers have effectively mapped the potential of groundwater in recent years and done the spatial analysis using various thematic maps (Mishra *et al.*, 2010; Hutti and Nijagunappa 2011; Kumar and Kumar 2011; Sharma *et al.*, 2012; Patil *et al.*, 2013). (Mishra *et al.*, 2010; Hutti and Nijagunappa 2011; Kumar and

Kumar 2011; Sharma *et al*., 2012; Patil *et al.*, 2013). In addition to producing information from data on geographical and temporal patterns, it also helps to analyze the information in relation to the suitable site selection for recharging the aquifers with rainwater. So it is necessary to understand the spatial distribution of groundwater potential zoning so that planning can be done to enhance the quality of groundwater. Further, these aquifers are categorized and identified as promising zones for groundwater recharge. Various multi-criteria decision-making processes, including the analytical hierarchy process, frequency ratio, fuzzy-AHP, CART, and many more, may be used to delineate groundwater potential zones. The Analytical Hierarchy Process is also used by many researchers because of its user-friendliness and dependability.

Demarcation of groundwater potential using multi-criteria decision-making models (MCDM). Groundwater prospect zones for sustainable agriculture development were developed with the use of RS and GIS in order to efficiently pinpoint locations suitable for the extraction of potable water for rural regions in the geographical basin of Gohparu Block, Shahdol District, Madhya Pradesh, India. In the study conducted by Jaiswal *et al.* (2003), the groundwater potential zones of the Gorna subbasin were identified using remotely sensed data, and numerous themed maps at a scale of 1:50 000 were produced. The Indian Remote Sensing Satellite (IRS) Linear Imaging Self Scanning Sensor III (LISS III) and Panchromatic (PAN) sensors' 1:50 000 scale geocoded photographic and digitally enhanced products were used to create thematic maps of lithology, landforms, soils, land use/land cover, lineaments, and surface waterbodies. The Survey of India's 1:50 000 scale topographic maps were used to create thematic maps of drainage density and slope classes. All of the themed maps were scanned. Information on lithology, geological structures, landforms, land use/land cover, drainage networks, soil properties, and the slope of the earth's surface were collected from remotely sensed data and analyzed in an integrated GIS context to develop village-specific groundwater prospect zones. The addition of new and original data to the typical field data collected by remote sensing has the potential to revolutionize groundwater monitoring and management in the future. Despite the fact that such applications may offer new difficulties, rapidly evolving GIS technology is essential for the administration of enormous spatio-temporal data and for their effective interpretation, analysis, and presentation (Jha and Peiffer 2006). By including all pertinent data impacting the occurrence and flow of groundwater in the region, GIS was used to delineate groundwater potential zones in Krishnagiri District, Tamil Nadu. The procedure includes the collection of data, mapping of various themes, acquisition of satellite data from NRSA and image processing using ERDAS, the creation of a geo-database, and the development of a matrix for assigning weights to various factors; however, it is unknown how the ArcGIS ranking of the hydrogeological unit will respond based on the integration of all thematic layers. Calculating groundwater potential facilitates the comparative assessment of zones' groundwater potential. According to the results of the analysis, 0.18% of the total area lies within a zone with a very high water potential, 7.94% lies within a zone with a high water potential, 61.97% lies within a zone with a moderate water potential, 29.78% lies within a zone with a low water potential, and 0.13% lies within a zone with a very low water potential (Yeshodha *et al.,* 2010). Various thematic layers, such as lithology, landforms, lineaments, surface water bodies, drainage densities, and slope classes, were generated at a scale of 1:50,000 using geocoded photographic products from the IRS LISS-II to delineate groundwater potential zones. The 1:500,000 scale soil map of the study area was created by grouping soil types based on their general and hydrological characteristics from the 1:250,000 scale soil map (Krishnamurthy *et al.*, 1996). Efforts have also been made to identify possible groundwater recharge zones in the Nagpur Region (Vaidya *et al*., 2020). Using ArcGIS 10.3.1, thematic maps were made. The assessment of groundwater was based on 2011–2015 data on pre- and post-monsoon groundwater levels. Using remote sensing and GIS, the Deccan trap, Granite gneiss, Lametta group, and alluvial groundwater formations of the study region are identified. The complete groundwater recharge zones were classified into five categories, ranging from 'very good' to 'very poor,' and it was determined that the majority of the study area fell within the "moderate" category.

Hutti and Nijagunappa (2011) explored the groundwater potential zone in the Ghataprabha sub-basin of the Krishna River in Karnataka by including appropriate thematic layers that have a direct or indirect effect on the occurrence of groundwater. The basin was subdivided into twelve subbasins for the hydrological investigation. This study classified a digital image of IRS-1D LISS-III with a spatial resolution of 23.5 meters using the ERDAS IMAGINE-8.6 digital image processing software. As thematic layers, geology, geomorphology, soil, slope, recharge, surface water bodies, and drainage density were employed to characterize the groundwater potential zone in the study area. Using Autodesk MAP and MapInfo GIS software, all of these thematic layers were integrated to differentiate development zones. The thematic layers and their related features were assigned weights after establishing the relative significance of different themes in triggering groundwater occurrence on a scale from 1 to 9, and the normalized weights were obtained using Saaty's analytical hierarchy technique (Saaty, 1980). These layers were then merged into a GIS context using MapInfo software to identify groundwater potential zones in the study area. Using the variability of groundwater levels, the average annual exploitable groundwater reserves for each groundwater potential zone were also calculated. On the basis of groundwater conditions in the area, criteria for GIS analysis have been created, and adequate weighting must be supplied to each information layer according to its relative contribution to the desired outcome (Saraf and Choudhury 1997). Zhou and Li (2004) defined the uses of remote sensing in hydrological research and water resources management as follows: (i) using original remote sensing imagery directly to identify hydrologically significant spatial phenomena; (ii) using processed remote sensing data, such as precipitation, to force hydrological models; (iii) using multispectral data, such as vegetation (land cover) types and densities, to quantify surface parameters; (iv) direct calculation of evapotranspiration distribution in terms of spectral data of satellite remote sensing based on surface energy balance Remote sensing and GIS were used to generate five thematic layers for the investigation of groundwater potential: lithology, lineament density, topology, slope, and river density. Then, the two multi-criteria decision-making (MCDM) models, namely C5.0 and CART, were combined. The yields of 80 tube wells were used to categorise them into four categories. The decision tree algorithms were evaluated using 10-fold cross-validation and the kappa coefficient, with the average kappa coefficient for C5.0 being 90.45% and that for CART being 85.99%. Consequently, the outcome indicates that C5.0 is more accurate than CART. Duan *et al.* (2016); Nigam *et al.* (2020) demonstrated the delineation of groundwater potential zones, and thematic maps of different governing themes of groundwater potential zone such as geology, draining density, land use/ land cover, slope, and soil texture were created according to their relative significance. Multicriteria decision analysis was conducted using the Analytical Hierarchy Process (AHP) for the probable weighting of many governing themes. The resultant map defines the groundwater potential zone of the Tons basin into three categories: zones with excellent groundwater potential, zones with moderate groundwater potential, and zones with low groundwater potential. This classification facilitates the identification of groundwater prospective zones, the extraction and development of groundwater, and enhanced planning and management.

For evaluating the potential zones for groundwater occurrence using a variety of contemporary techniques and tools, such as remote sensing, GIS, electric resistivity, and MCDM, which were used by Jhariya *et al.* (2021) to prepare thematic maps including geology, geomorphology, precipitation, lineament, and land use. Land cover, drainage density, soil type, and slope were each assigned a weight according to their influence on groundwater potential. Normalized concern with relative contribution is applied to this study topic using the AHP method. These methodologies have resulted in the classification of groundwater potential zones into five zones: low, moderate, medium-high, high, and very high potential. Using well yield data as a test, the ROC methodology achieved an accuracy of 80% and an area under the ROC curve of 0.857% at a significance level of less than 0.001, confirming the efficacy of the proposed method in the identification of the groundwater potential zone. Teja and Singh (2019) evaluated the Mangalagiri Mandal groundwater potential zones in Guntur district. Geology, geomorphology, soil slope, drainage density map, and surface body maps were developed at a scale of 1:500,000. Numerous departments, remotely sensed data, and topographical maps provided the data. Assume that various weights correspond to thematic layers. The land use, land cover, and slope maps were given the highest weight (25%) on the list, while the geology maps were given the least (10%). The weighted thematic layers were layered in ArcGIS. The groundwater potential was categorised as good, moderately poor, poor, and severely poor. The results reveal that the middle and upper classes dominate the Mangalagiri Mandal area. This study on the potential of groundwater will benefit groundwater conditions. Using geospatial methods, Poddar *et al*. (2020) analyzed artificial groundwater recharge proposals in Hamirpur, Himachal Pradesh. Utilizing remote sensing and GIS, seven factors affecting groundwater recharge, including slope, drainage density, lineament density, land use/land cover, geology, geomorphology, and soil texture, are input into GIS software. To generate thematic maps, numerous agencies and organizations prepare base maps for all of these influencing factors. Using the multi-influencing factor technique, each component is ranked and weighted depending on its ability to impact the rate of groundwater recharge after the formation of thematic layers. For every factor and factor-related metric, we provide weights and ranks. Individual weights are applied to each component, with 1 being given to each significant effect and 0.5 being assigned to each moderate influence. 73% of the areas have a moderate recharge potential, 18% have a high potential, and 9% have a low potential. Due to their ability to evolve spatio-temporal data, remote sensing and GIS play an important role in the development of land resource management planning. Geoinformatics is also useful for spatial data processing and forecasting (Bhunia *et al*., 2012; Hutti and Nijagunappa 2011; Nema *et al.,* 2019). The parameters considered to identify the groundwater potential zone of geology, slope, drainage density, geomorphic units and lineament density were generated using resource sat (IRS P6 LISS IV MX) data and survey of India (SOI) toposheet of scale 1:500,000 and integrated into an inverse distance weighted (IDW) model based on GIS data in order to determine the groundwater potential of the Kodikanal Taluka of South India. The findings are more accurate when groundwater potential zones are identified, and thematic maps created by geoinformatics platforms are included. The study found that the slope area varies from 0º to 10º and that the denudational slope, comprising 39.17% of the area, is an appropriate zone for groundwater inquiry and development. The suggested multi-parametric method using remote sensing and GIS is holistic in nature and will decrease the time and cost necessary to identify groundwater-potential zones and specific places for recharging in hard rock terrain (Bagyaraj *et al.,* 2012). The recharge sites for groundwater are evaluated using both conventional and non-traditional data, taking into account several factors such as lineament, geology, geomorphology, soil, and slope, and then the groundwater potential map is generated by superimposing these thematic layers. This map is separated into five different water potential zones: very excellent, excellent, decent, moderate, and bad. Using the well yield data, the validation is done. The groundwater fluctuation technique is used to validate all other approaches. The validation technique included pre- and post-monsoon data, and the result reveals minimal change, with the exception of few alluvial zones (Singh and Singh 2009). Developing water resources based on the integrated use of surface and subsurface water resources necessitates an appropriate strategy. The combination of remote sensing and GIS may provide an appropriate platform for the study of data sets. The examination of remote sensing data in combination with conventional data and ground truth information helps the identification of geological structures, geomorphology, structural patterns, and recharge conditions. In Pulivendula-Sanivaripalli, Andhra Pradesh's Kadapa district, the potential of groundwater resources has been evaluated. The topic maps have been constructed and weights assigned. In the area, there are zones with great potential, moderate potential, low potential, and no potential. The district of Birbhum's groundwater potential zone has been identified by Sunitha *et al.* (2016). Several thematic layers, such as geology, geomorphology, soil type, elevation, lineament and fault density, slope, drainage density, land use/land cover, soil texture, and precipitation, are digitized and converted into raster data in an ArcGIS 10.3 environment, using thematic layers as input parameters. Using the multi-influencing factor (MIF) technique, rankings and weights are statistically established for each component. Using yield data from multiple bore wells in the watershed area, the delayed outcomes of groundwater potential zones were assessed. Finally, prospective groundwater zones are classified as low, medium, high, or extremely high. Observations suggest that 18.41% and 34.45%, respectively, of the study area are within the zones of 'low' and 'medium' groundwater potential. 35.23 percent of the study area falls into the 'high' category for groundwater potential, while 11.9% falls into the 'very high' category. The model-generated groundwater potential zones are then validated using reported potential yield data from a number of wells within the study area. For the watershed region, the success rate curve indicates an accuracy of 83.03 and 78%, respectively. This research will help academics, decision-makers, and planners plan and manage groundwater in the watershed area more effectively (Thapa *et al*., 2017).

The most common techniques for modelling and mapping nowadays are remote sensing and GIS. The groundwater potential zones of the Puruliya district in West Bengal, India, were identified by Das *et al.* (2019 using integrated RS-GIS techniques. Each theme layer has a certain weighting. The normalized weights were determined using the analytical hierarchy approach (AHP). Groundwater potential maps were generated using a weighted overlay approach in ArcGIS 10.1 and ERDAS Imagine 2014 after integrating all theme layers. There are zones across the area that have a high, moderate, and low potential for groundwater. It was determined that 60.92% of the investigated area is located in moderate groundwater potential zones, while 22.55% is located in high groundwater potential zones. The results are verified using the water fluctuation approach, and ten of the fourteen (71.43%) validation sites match the expected yield class. To increase the wells' long-term viability and stop the trend of declining groundwater levels, a geoinformatics technique was used to locate places for artificial groundwater recharge. To create and overlay the theme layers, the 8 layers of geology, geomorphology, soil, slope land usage, pre- and post-monsoon water level, weathering depth, and water bodies/drainage were employed. Information on groundwater levels was acquired from 248 deep wells. Extremely high, high, moderate, and extremely poor were the classifications given to the potential groundwater zones. In the very high to high viable zone is around 45 percent of the research area. An additional 198 million m^3 of water resources will be produced annually by several masonry check dams, nala bunds, recharge shafts, and percolation ponds. Senthikumar *et al*. (2019); Senapati and Das (2022) evaluated the West Bengali district of Cooch Behar's groundwater potential zone. Groundwater potential zones are developed using theme layers, a comparative assessment of several contributing aspects, and the Analytical Hierarchy Process. The groundwater potential is rated in different categories, such as extremely poor, poor, moderate, excellent, and outstanding, after overlaying the weighted perimeters. While AHP exposes 8% of extremely poor GPZ and 20% of excellent GPZ, MIF reveals 9% of very poor GWPZ and 13% of outstanding GWPZ. Finally, groundwater fluctuation information derived from the Receiver Operating Characteristic curve has been used to verify the maps (ROC). The MIF methodology has an Area Under Curve (AUC) score of 76.5%, but the accuracy of the AHP method is 88.9%. Both methods of GPZ evaluation and monitoring have proven to be precise and reasonable. The remote sensing and GIS study was carried out by Dileshwari *et al.* (2021) in the area of Kotani watershed of Chattisghar, India. Thematic maps were prepared and processed in Arc-GIS software. It was found that 23.47% of the area is under medium potential zone when scaled from very high to bad recharge zones. In critical areas, the recharge sites are suggested as storage tanks, percolation tanks, check dams etc.

Finding groundwater potential zones in crystalline rock terrain necessitates the application of scientific knowledge from remote sensing and GIS. A study evaluates the GWPZ in the Mandavi River basin using remote sensing, geographic information systems, and multi-influencing factor techniques by Raju *et al.* (2019). Different thematic maps such as drainage density, lineament density, geology, soil, geomorphology, slope, rainfall, groundwater levels, and LULC are produced using IRS-R2 LISS IV satellite imagery, a survey of India's toposheet, and other data sets from different sources. The thematic layers were changed to raster format in Arc GIS 10.4. Raster maps have been given statistically generated weights and ratings using multi-influencing approaches. The results were rated as "very poor," "poor," "good," "very poor," and "good." Compared to 7%, 21%, and 35% for "very poor," "poor," and "good," respectively, 36% of the study area is classified as "very good". An overall accuracy of 72.8% and a Kappa value of 0.63 were found using observatory wells to corroborate the results. Scientists will benefit from the groundwater potential zone map in controlling and improving the Mandavi River basin's groundwater supply. The study simulates the potential for groundwater recharge in the Aravalli landscape's hard-rock sections using remote sensing and GIS. The groundwater fluctuation approach is used for quantitative groundwater replenishment. Bhuiyan *et al*. (2009) studied the identification of the groundwater potential zones in the Ganjam district of Orissa, India. SRTM, Lands at TM digital, and IRS-IC LISS III satellite data were used to create a variety of themed maps. There were five classifications assigned to the groundwater potential map, from excellent to bad. Additionally, most of the study area is located in areas with "good" and "moderate" groundwater potential (Biswas *et al.*, 2012).

CONCLUSION

Understanding groundwater resources is essential for the recharge and management of groundwater. This document provides an updated summary of groundwater potential approaches based on a comprehensive literature assessment. Various researchers' findings indicate that the identification of groundwater potential zones necessitates the construction of distinct thematic layers. Obtaining acceptable potential zones using Remote Sensing and GIS requires a thorough evaluation of the weightage. Among all strategies for overlay, the Analytical Hierarchy Process (AHP) methodology provides the highest degree of precision.

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