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Geospatial Techniques for Groundwater Potential and Water Quality Assessment: A Review

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Review Article

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ABSTRACT

In the 21st century, the water quality problem is one of the most severe issues that affected human health and social development. It is necessary to evaluate water quality for drinking purposes. Safe drinking water is one of the fundamental human rights nowadays. Groundwater is an essential source of freshwater. It is essential to develop and utilize groundwater resources in an area because groundwater resource is linked mainly with drinking purpose and different sectors. This paper has discussed the literature review in groundwater studies using Remote Sensing and GIS and other Multicriteria decision analysis techniques, groundwater recharge, quantitative assessment of groundwater, statistical modeling of groundwater fluctuation, and groundwater management, and groundwater quality. The literature review indicates that most of the techniques/logics/models/methods used in the past years for exploring the groundwater potential zone like Geospatial techniques, Analytic Hierarchy Process (AHP), Analytical Network Process (ANP), Fuzzy Logic techniques, Weighed Index Overlay Analysis (WIOA), etc. The Purity of water or drinking water quality can be identified by using some standard water quality testing parameters *viz*. Chemical, Physical, and Microbial. From the review of research papers, it is evident that a lot of research has been carried out in the above fields. This analysis could be used for the study area to assess the groundwater both quantitatively and qualitatively as it requires exploring the groundwater potential to overcome water scarcity or overexploitation in the study area.

INTRODUCTION

In India, almost a 60-65million people drink highly contaminated groundwater due to the scarcity of suitable potable water resources, especially in challenging water terrain. About 2.5 to 3 million people, mainly in Andra Pradesh, Jharkhand, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Naidu, and Uttar Pradesh are affected by high contamination of water resources [1]. Over the years, groundwater's rising importance based on an increasing need has led to unscientific exploitation of groundwater, creating a water hassle condition. This disturbing situation calls for a cost and time-effective technique for properly evaluating groundwater resources and management planning. A groundwater-developing program requires a large amount of data from various sources. Hence, recognition and quantization of these features are essential for generating a study area's groundwater potential model.

Role of remote sensing and GIS in potential groundwater zone

The remote sensing and Geographic Information System (GIS) tool play an essential role in water resource studies. Ancillary data, a Survey of India (SOI) topographical sheets, and collateral information among remote sensing data with necessary ground truth verifications help generate the baseline information for groundwater targeting. By using remote sensing data, identifying groundwater occurrence location is based on indirect analysis of straight observable terrain features like geological structures, geomorphology, and hydrologic characteristics. Lineaments also play a significant role in groundwater exploration in all types of terrain. Application of Geographic Information System and Remote Sensing can also be considered for multicriteria analysis in resource evaluation and hydrogeomorphological mapping for water resource management. The use of remote sensing and GIS tools to take out detailed drainage, slope, and geomorphic features in parts of the study area suggests appropriate methods for groundwater potential zone studies [2]. Water quality analysis results can be integrated into a GIS environment with their respective sources from which water samples are collected for analysis. RS and GIS techniques provide a synoptic view of extensive area coverage; we can query, analysis and display water polluted sources after integration of all data in the GIS environment.

The groundwater potential zones using remote sensing and GIS is an effective and useful tool for the study area and was generated by integrating various thematic maps *viz*., drainage, slope, lithology, soil, lineament, rainfall, and land-use using remote sensing and GIS techniques. Water quality parameters analysis for safe water availability of drinking water within the limit of WHO or BIOS defined standard of pH, TDS, Turbidity, Conductivity, Total Hardness, Fluoride, Chloride, Iron, Alkalinity, present/absence of Ecoli, etc. Multiple-Criteria Decision-Making analysis (MCDM) or (MCDA) is a sub-discipline of operations research that evaluates multiple conflicting criteria in decision making. In the AHP, each element in the hierarchy is considered independent of all the others the decision criteria are considered to be independent of one another. The alternatives are deemed to be independent of the decision criteria and each other. However, in many real-world cases, there is interdependence among the items and the alternatives. ANP does not require independence among elements so that it can be used as a useful tool in these cases. Both the AHP and ANP would provide valuable frameworks to use in making his decision.

Delineation of groundwater potential zone using geospatial techniques for Shimla city, Himachal Pradesh

The study's main objective was to identify and delineate potential groundwater zones by integrating GIS with multicriteria analysis and, hence, assessing the potential groundwater zones. Therefore in the present study area, multiple thematic layers have been prepared such as land use/land cover, slope, geology, drainage density, geomorphology, lineament density, rainfall, and soil to identify the groundwater potential zone by using remote sensing and GIS techniques. The slope map was prepared by using DEM (ASTER), and the drainage is used after updating from satellite imagery. All the thematic layers were assigned proper weightages through AHP techniques. By applying the above methodology, five areas with very low, low, moderate, good, and very good groundwater potential zones were extracted using the analytical hierarchy process technique. The result indicates a minor change in the groundwater potentiality in the study area using both the methods. Thus the above study has verified the capabilities of remote sensing data and a GIS technique for delineation of groundwater potential in challenging rocky terrain. The overall result shows a minor change in the groundwater potentiality using both the study area techniques.

Evaluation of fluoride contamination in groundwater sources in hard rock terrain in Garhwa district, Jharkhand

The safe and unsafe zone concerning fluoride contamination in the study was delineated using spatial interpolation in the GIS platform. The spatial distribution pattern of fluoride concentration varies from place to place, and most of the fluoride contaminated water sources are found in the northwestern parts of the area over the Untari and kharaundhi blocks and only some parts of Majhiaon and Ranka blocks were affected with higher fluoride contamination. The field survey involved groundwater sample collection from public wells, private wells, household hand pumps, general hand pumps, and water sources in the health centers and schools. The 4012 water samples were collected out of which 295 (7.4%) samples were tested in the laboratory for estimating the concentration of fluoride by using the SPADNS method and remaining were tested onsite itself by using the field test kit provided by UNICEF (Jal Tara kit). The fluoride was detected at elevated levels in the drinking water of Garhwa district. Very high fluoride concentrations (up to 5.92 mg/L) are found in the school and household hand pumps in Kharaundhi and Untari block. The water sources examined, water samples collected from the household hand pump had about 22.34% of samples with non-permissible fluoride concentration limits. Therefore, the remedial processes should be focused primarily on the household hand pump, which caters to the need of a large population. Organizations like UNICEF's efforts for demarcating safe and unsafe sources of potable water in the region would provide awareness to the masses towards the ill effects of using water with fluoride concentration beyond the permissible limit.

LITERATURE REVIEW

Land Use/Land cover change dynamics and river water quality assessment using geospatial technique: A case study of Harmu River, Ranchi (India)

Land use/land cover change dynamic and water quality assessment using the geospatial technique for Harmu river variability regarding various land use/ land cover maps (1992-2009) multi-temporal satellite datasets in a GIS environment. By using different water quality parameters like pH, Temperature, Electrical conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Ca^{++}, Mg^{++}, Total Hardness, Total solid (TS), Alkalinity Chloride, and Dissolve oxygen to the identification of pollution level among the river channel comparison the pollution level of Harmu river. The pollution level of the Harmu river is high at all sites due to the regular discharge of domestic sewage, disposal of automobile/ workshop waste, an increasing settlement near the river, and garbage which led to water not suitable for drinking and domestic purposes. The pH value of the Harmu river shows slightly acidic, which can be caused due to the regular discharge of domestic sewage and the disposal of automobile/workshop waste and is not suitable for health. The river's overall total hardness is much high due to mainly the discharge of washing clothes, animals, and domestic sewage. TDS values show that the water of the Harmu River is not suitable for drinking and domestic purposes. The calcium concentration in water is beyond the permissible limit. Chloride values are higher than their permissible limit. This study has verified that the geospatial technique provides an excellent tool for mapping and investigating land use changes/land cover changes. It was observed that the river/drainage channels were primarily encroached by built-up land and few of the drainage channels were extinct due to urban activities. This study has demonstrated that the geospatial technique provides a powerful tool for mapping and detecting land use/land cover changes.

Ground water quality and multivariate statistical methods

To study groundwater's physicochemical properties of the Kozhikode district, Kerala, India, by applying multivariate statistical methods on samples collected from various parts of the study area. The study covers an area of about 2344km2 located on the southwest coast of India. The focus of this study is to combined the PCA principal component analysis), MLR (multiple linear regressions), and SEM (structural equation modeling) techniques for analyzing water quality data. This study aims to develop an MLR (multiple linear regressions) model for predicting TDS in terms of different Physico-chemical parameters of groundwater of the study area. The combining (PCA) principal component analysis and Multiple Linear Regression (MLR), developed a regression model for predicting Total Dissolved Solids (TDS) in terms of calcium, magnesium, nitrate, sodium, chloride, potassium, bicarbonate and sulfate. Principal Component Analysis (PCA) was conducted, which helps visualize the data set when several variables are involved. A total of 38 water samples were collected from wells in different parts of the study area. First applied PCA to reduce the number of variables in the model, then developed an MLR model to predict TDS.

Finally, applied SEM to validate the MLR developed model further, using the variety of fit indices associated with the SEM. Finally, the validity of the three regression models studied was tested using SEM, which revealed almost the same regression model for predicting TDS. This study showed that statistically, calcium is the most significant component of TDS in the study area.

DISCUSSION

Application of geoinformatics for the delineation of groundwater prospects zones: A case study for Melattur Grama Panchayat in Kerala

The groundwater prospect zones for 26 Grama Panchayats, including Melattur Grama Panchayat, with RS and GIS application for KRWSA (Kerala Rural Water Supply and Sanitation Agency) for the successful implementation of rural water supply schemes. Groundwater prospect zones were delineated through the integration of the reclassified map layers of geomorphology, geology, slope percent, drainage buffer, land use/land cover and soil texture using the weighted overlay analysis in Arc-GIS, various satellite images have been used in this study for the delineation of land-use/ land cover and geomorphology of the study area. DEM was generated through 20m contour lines and used to originate the slope. Appropriate weights were assigned to each of the map layers based on their groundwater prospects [3]. The overlay analysis of the spatial map of the water column's pre-monsoon thickness in wells on the groundwater prospect map shows a positive correlation. The study results have been verified with field data. The work shows that the groundwater prospect 'very good/excellent' is confined to only 2.49% of the study area, falls in valleys close to the higher-order perennial streams. A significant portion of the study area falls in the category followed by 'good'. Groundwater prospect map of Melattur Gram Panchayat will be served as a base for further exploration using geophysical methods to locate potential well sites for the implementation of a rural water supply scheme.

Delineation of groundwater potential zone: An AHP/ANP approach

In the present study, groundwater potential zone are delineated using Geographical Information System (GIS), remote sensing, and Multicriteria Decision Making (MCDM) techniques in Unnao district, Uttar Pradesh. The Analytical Hierarchy Process (AHP) is used as a particular case, and the analytical network process (ANP) is a method that makes it possible for one to deal systematically. The AHP and ANP are used to determine the weights of various themes and their classes for identifying the groundwater potential zone. In this study, Remote Sensing, GIS, and MCDM techniques have been successfully used and demonstrated to evaluate potential groundwater zone. A three-step methodology was employed to develop thematic layers, deriving the weights using ANP/AHP and overlay analysis to find the potential groundwater zone. Remotely sensed satellite image data and digitization of existing maps using GIS were used for the preparation of thematic layers. In this study area, some groundwater potential zone categories have been delineated based on remote sensing, GIS, and AHP/ANP techniques, and the following steps are used to evaluate potential groundwater zone. The first is to develop of all thematic layers. The second is to use deriving the weights using AHP/ANP. Third is to overlay Analysis for Groundwater potential to get groundwater prospect map [4]. It has been concluded that about 153.39 km^2 area has very good groundwater potential, which is only 3.37% of the total study area. However, the area with very low groundwater potential is about 850 km^2, approximately 19.63% of the study area. The site has good, moderate, and low groundwater potential, about 540.25, 1135.5, and 1868.6 km^2. The groundwater potential zone map was finally verified using the useful yield data of 37 pumping wells, and the result was found satisfactory.

Assessment of groundwater potential based on multicriteria decision making model and decision tree algorithms

A study on the assessment of groundwater potential in the south-western part of Ritu County, Ali city, surrounded by Kailash Mountain in the south and Karakoram Mountain in the north based on multicriteria decision-making model and decision tree algorithms. In the present study, Remote Sensing and GIS were utilized to generate five thematic layers, lineament density, topology, slope, topology, and river density considered as factors influencing the groundwater potential. The multicriteria 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 based on the yield. To test the precision of the decision tree algorithms, the10-fold cross-validation and kappa coefficient were adopted and the average kappa coefficient for C5.0 and CART was 90.45% and 85.09%, respectively. After applying the decision tree to the whole study area, four classes of groundwater potential zones were demarcated. According to the classification result, the four grades of groundwater potential zones, very good, good, moderate, and poor, with the

C5.0 algorithm, while occupying the percentages of 4.68%, 10.09%, 26.10%, and 59.13%, respectively, with CART algorithm. Therefore, we can conclude that the C5.0 algorithm is more appropriate than CART for the groundwater potential zone prediction.

Correlation study and regression analysis of water quality assessment of Nagpur cisty

In the present study by using a statistical method, water quality is determined based on Physico-chemical analysis like pH, Electrical Conductivity, Turbidity, Chloride, Sulphate, Total Alkalinity and Dissolved Oxygen. Total Alkalinity and Dissolved Oxygen, Total Dissolved Solids, Total Hardness, Calcium, etc. Groundwater samples collected from four different fields namely: Khaparkheda Water Supply, Koradi Gram Panchayat, Koradi Devi Mandir, Bokara. Groundwater potential zones prepared using various thematic layers *viz*. geology, slope, land-use, lineament, drainage, soil, and rainfall. The thematic layers and their features were assigned suitable weights on the Saaty's scale according to their relative significance for groundwater occurrence. The water testing was done in the water quality lab, Nagpur. After analyzing the drinking water quality in the study area, water used for drinking purposes should be colorless, odorless, and free from slight turbidity and excess salts. The taste of the water is slightly brackish at some of the locations. This technique has been proven as a very useful tool for monitoring drinking water and has good accuracy. This study can be concluded that the two important physicochemical parameters are used for drinking water quality i.e. dissolved oxygen and electrical conductivity because they are correlated with most of the water quality parameters. This study has revealed that all the physicochemical parameters of drinking water in Nagpur city are correlated in some of the other ways. The study could be more enhanced by studying groundwater quality movement shortly.

Combining AHP with GIS for assessment of irrigation water quality in Cumra irrigation district (Konya), Central Anatolia, Turkey

In the present study, the analytic hierarchy process (AHP) is combined with Geographical Information Systems (GIS) to assess the irrigation water quality in the aquifers of the Cumra Irrigation District (CID). 49 water samples were selected randomly to obtain a homogeneous distribution within the study area during September of 2012 were collected from all accessible and operational wells. The determination of irrigation water quality is very important for the region because it is one of Konya and Central Anatolia's most important agricultural areas. The criteria maps were prepared in a GIS environment using obtained numerical values, and then a final suitability map was created that combined all criteria. The combination of AHP and GIS for the assessment of irrigation water quality is thought to be feasible and sustainable to plan an irrigation program using groundwater. According to the obtained results, the irrigation water quality in CID was classified into three groups: high, moderate, and low suitability, with rates of 61.92, 19.20, and 18.87 %, respectively. It is believed that this information will be relevant to the government's decision-making in agricultural and environmental planning.

Water quality analysis of few villages from Gadhinglaj Tehsil, (MS) India

The Gadhinglaj tehsil is dependent on various water sources for drinking purposes so it is necessary to evaluate the water quality and to check either it is fit for utilization or not. Hence, the present investigation was undertaken. There are several drinking water sources like small and large water bodies and a vital river Hiranyakeshi, which is the lifeline of the Tehsil, Dug wells, and bore wells [5]. The samples of 27 villages were collected in September 2013. Samples were collected in an ice-packed plastic container. The fecal coliforms in the models were enumerated using the Membrane filtration technique with Mac Conkey's agar in sterile Petri plates. Physical-chemistry of all water samples discovered that the water is suitable for drinking and domestic purposes, while a major presence of fecal coliform may raise concern on the safety of its utilization. A significant number of fecal coliforms were found in all the samples and it was considerably higher than the WHO limit for drinking water. All samples may raise concerns about safety. So the overall results of the study are that the Physico-chemistry of all water samples revealed that the water is suitable for drinking and domestic purposes while a significant presence of fecal coliform may raise concern on the safety of its consumption.

CONCLUSION

In the review survey, multiple thematic layers have been prepared, such as land use/ land cover, slope, geology, drainage, geomorphology, lineament, rainfall, soil, etc., to identify the groundwater potential zone by using remote sensing and GIS techniques. The Remote Sensing and GIS technologies approach to explore

groundwater monitoring and management for the future by providing a new strategy and unique method to which will help for proper management and development of the poor groundwater potentiality areas. So, it is clearly showing that there is a lot of researches attempted for exploring the Groundwater Potential Zones. Those analyses will be very useful for effective identification and to explore the groundwater potential zone as well as drinking water quality in our study area which will be very helpful in planning for safe drinking water aspects for the society.

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