7th Intercontinental Geoinformation Days

igd.mersin.edu.tr

Delineation of groundwater potential zone and mapping using GIS/Remote Sensing techniques and Analytic Hierarchy Process (AHP) for District Bhimber, Pakistan

Muhammad Shahid Usman*[1], Ghani Rahman[1], Saira Munawar[1]

[1]*University of Gujrat, Faculty of Science, Department of Geography, Gujrat, Pakistan*

Keywords
Groundwater Potential Zones
Analytical Hierarchy Process
Multi-Criteria Decision Analysis
GIS
Bhimber

Abstract

Groundwater plays a critical role in the sustainability of both ecosystems and human activities. This study presents an integrated methodology that combines the Analytic Hierarchy Process (AHP), Multi-Criteria Decision Analysis (MCDA), Geographic Information Systems (GIS), and Remote Sensing (RS) techniques. The main objective is to precisely delineate groundwater potential zones in the Bhimber district, leading to the creation of a comprehensive guide map for optimized groundwater exploration and utilization. This approach aims to promote sustainable resource management and overall development. The methodology involves data collection from diverse sources, including the Shuttle Radar Topography Mission (SRTM) for digital elevation models and remote sensing satellite images for thematic layers like geology, rainfall, slope, soil, drainage density, land use, and lineament density. Integration is facilitated through multicriteria evaluation. Using weighted overlay analysis and AHP-guided weight assignment, potential groundwater zones are systematically identified and mapped. The resulting groundwater potential map is categorized into four classes: Poor, Fair, Good, and Excellent. The findings reveal distinct patterns of groundwater potential in the district. The eastern region stands out with an excellent groundwater potential covering 26 square kilometres, attributed to substantial rainfall and the presence of water bodies. The mid-eastern and western sectors exhibit good potential (512 sq km), influenced by water bodies and consistent rainfall. Elevated terrains correspond to fair potential (779 sq km), while the upper north-east part indicates a Poor potential (24 sq km). This integrated approach enhances informed decision making, boosts resilience, and spurs socioeconomic development. Furthermore, the study contributes to scientific insights on groundwater dynamics, laying the groundwork for future research. The study underscores the effectiveness of GIS, RS and AHP in addressing complex groundwater management challenges, offering valuable information for global water resource management efforts.

1. Introduction

Groundwater stands as a vital natural resource, vital for sustaining human societies and ecosystems across the globe. Its significance lies not only in supporting agriculture, industry, and potable water supply, but also in its role as a lifeline during periods of drought, ensuring socioeconomic stability (Castillo et al. 2022). Particularly in regions where surface water availability is limited or uncertain, groundwater assumes even greater importance. However, effective extraction and management necessitate a thorough understanding of its distribution, potential, and recovery dynamics (Faheem et al. 2023). Nestled in the picturesque landscapes of Azad Kashmir, Pakistan, the Bhimber district stands as an emblematic region where groundwater assumes paramount importance. Characterized by diverse topography and geological formations, the district encounters challenges pertaining to water resource management and sustainable development. Addressing these challenges effectively hinges upon the delineation and mapping of potential groundwater areas. Such delineation empowers informed decision-making and prudent utilization of this finite resource. Traditionally, geological, hydrogeological, geophysical, and photo geological techniques have been employed to identify groundwater potential zones (Ikirri et al. 2023). In recent times, however, the integration of various conventional methods with satellite imagery and

* **Corresponding Author**

*(shahidusmaninfo@gmail.com)

Cite this study

Usman, M. S., Rahman, G., & Munawar, S. (2023). Delineation of Groundwater Potential Zone and Mapping using GIS/Remote Sensing Techniques and Analytic Hierarchy Process (AHP) for district Bhimber, Pakistan. Intercontinental Geoinformation Days (IGD), 7, 164-167, Peshawar, Pakistan

remote sensing (RS) techniques, along with geographical information system (GIS) technology, has gained prominence due to the advent of powerful, high-speed computers. The fusion of GIS and RS tools offers a robust approach for evaluating diverse natural aspects and is particularly effective in delineating groundwater potential zones (Zabihi, M., 2019). A growing body of research suggests that multi-criteria decision-making (MCDM) offers an effective mechanism for water resource management, enhancing decision quality through structure, transparency, and accuracy (Razandi et al. 2015). Notably, the initial structuring of a decision problem, encompassing criteria and decision options, holds paramount importance in the MCDM process. The successful application of AHP in numerous water resource management studies, integrating MCDA with RS and GIS techniques, underscores its utility.

Consequently, this study employs an integration of AHP-coupled MCDA, GIS, and RS techniques, merging hydrogeological, geomorphological, and climatic data. The primary objective is to delineate groundwater potential zones within the District Bhimber, culminating in the creation of a guide map for groundwater exploration and exploitation. This endeavor aims to ensure optimal and sustainable development and management of this vital resource.

2. Data and Methods

2.1. Study Region Description

This research focuses on Bhimber District, a region of vital geographical and strategic importance within Pakistan-administered Azad Kashmir. Covering around 1516 km² (Figure 1), Bhimber District is the southernmost among Azad Kashmir's ten districts. The administrative center is Bhimber town, a bustling hub of local governance and activities. Bordered by Kotli District to the north, Rajouri and Jammu Districts to the east (in Indian-administered Jammu and Kashmir), Pakistan's.

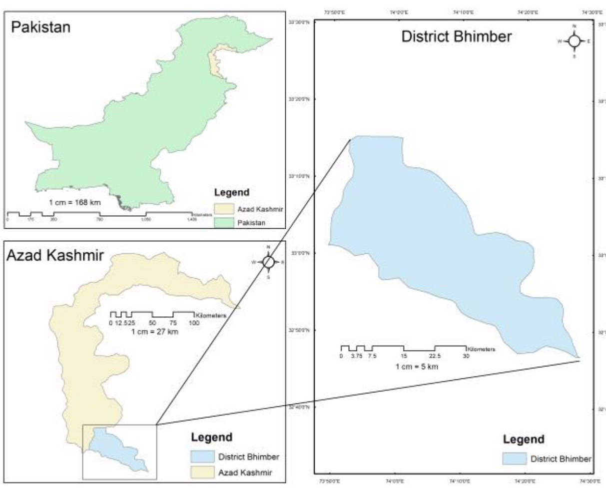

Figure 1. Study area map

2.2. Data

1. THE DIGITAL SOIL MAP FAO/UNESCO, 1995
2. U.S. Department of the Interior Geological Survey
3. CRU TS Version 4.05
4. Remote sensing Dataset

2.3. Methodology

In this study, various types of data were used to delineate groundwater possible areas in the study area. A digital elevation model (DEM) with a 30 m resolution was obtained from Shuttle Radar Topography Mission (SRTM) to derive a slope and drainage density map using the ArcGIS tool. Remote sensing satellite images and the corresponding data have been carried out for the preparation of thematic layers viz., geology, rainfall, slope, soil, drainage density, land use land cover, and lineament density of the study area. All thematic layers were integrated with Multicriteria evaluation technique. The potential zones of groundwater were obtained by overlaying all thematic layers based on weighted overlay method. Weighted overlay index analysis was carried out to give rank for each parameter of each thematic layer. The weight was given for each thematic layer depending on the Analytic hierarchy process (AHP) technique.

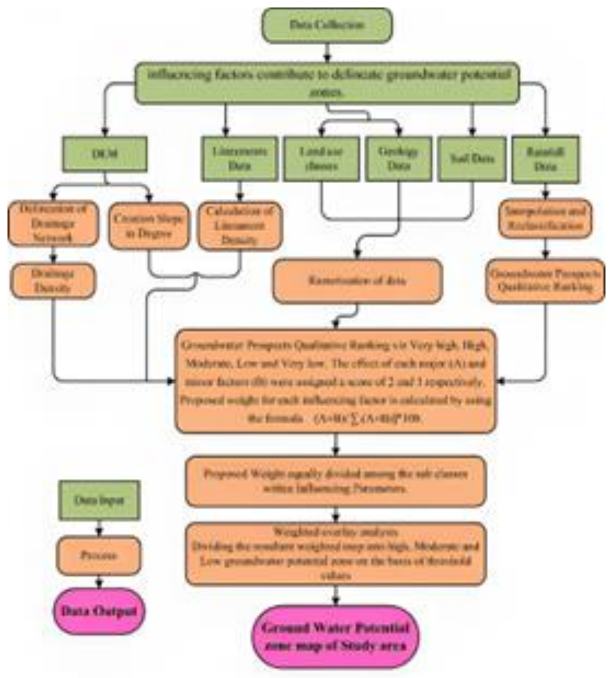

Figure 2. AHP

2.3.1. Multi-criteria decision-making (MCDM)

MCDM methods provide a structured framework to evaluate and compare different alternatives based on multiple criteria, helping decision-makers make more informed and rational choices. These methods aim to find a compromise or optimal solution that best aligns with the decision-maker's prefer.

2.3.2. Preparation of Thematic Layers

In this subsection, we detail the methodology employed for the creation, processing, and integration of the seven thematic layers—geology, rainfall, slope, soil, drainage density, land use land cover, and lineament density. These layers collectively form the foundational dataset for our multi-criteria decision-making analysis.

Infiltration rates, surface runoff, and overall groundwater availability. By integrating this map into our analysis, we enhance the precision of our understanding of how land use impacts groundwater dynamics within the Bhimber district.

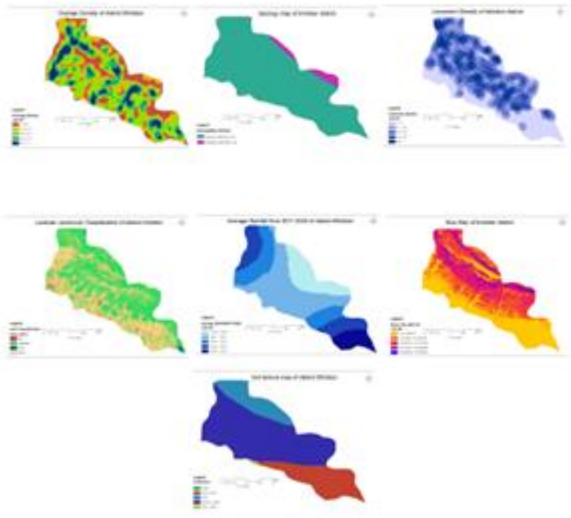

Figure 3. Thematic layers

2.3.3. The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology that helps individuals and groups make complex decisions by breaking them down into smaller, more manageable components. AHP was developed by Thomas L. Saaty in the 1970s and has since been widely applied in various fields, including business, engineering, environmental management, and resource allocation. The Analytic Hierarchy Process (AHP) acts as a methodological framework that facilitates the synthesis of various thematic layers and factors into a cohesive groundwater potential assessment. By providing a structured and transparent approach to assigning weights, AHP empowers you to derive more reliable and robust conclusions regarding the distribution of groundwater potential within the Bhimber district.

Matrix		Rainfall 1	Geology 2	Slope 3	Drainage density 4	LULC 5	Lineament density 6	Soil 7	8	9	10	normalized principal Eigenvector
Rainfall	1	1	3	3	5	5	5	7	-	-	-	38.14%
Geology	2	1/3	1	3	3	5	5	5	-	-	-	24.54%
Slope	3	1/3	1/3	1	1	3	3	5	-	-	-	13.11%
Drainage density	4	1/5	1/3	1	1	1	2	3	-	-	-	8.93%
LULC	5	1/5	1/5	1/3	1	1	1	3	-	-	-	6.61%
Lineament density	6	1/5	1/5	1/3	1/2	1	1	1	-	-	-	5.00%
Soil	7	1/7	1/5	1/5	1/3	1/3	1	1	-	-	-	3.66%
	8	-	-	-	-	-	-	-	1	-	-	0.00%
	9	-	-	-	-	-	-	-	-	1	-	0.00%
	10	-	-	-	-	-	-	-	-	-	1	0.00%

Figure 4. AHP

2.3.4. Overlay analysis

The relative weights derived from the Analytic Hierarchy Process (AHP) were applied to each thematic map, resulting in a cumulative weight for each respective thematic map. The weight value corresponding to the highest or lowest weight was assigned based on field conditions. Furthermore, the normalized and assigned weights for the distinctive features of various thematic layers were summarized, and the consistency ratio for each thematic map was computed and assigned.

The integration of the seven distinct thematic maps was executed using GIS software, specifically ArcMap 10.3. This integration aimed to generate a groundwater potential map (GPM) for the study area, representing an aggregated measure of overall groundwater influence.

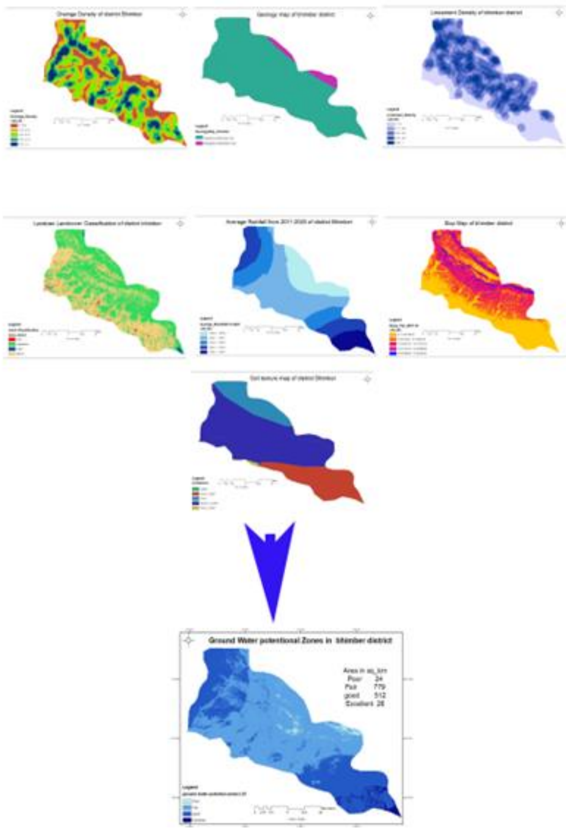

Figure 5. GPM

3. Results & Discussion

After applying all the methodologies, including the weighted overlay analysis of the seven thematic layers, the resulting groundwater potential map was classified into four distinct classes: Poor, Fair, Good, and Excellent. A careful examination of the generated map reveals notable patterns within the Bhimber district, particularly in its eastern region.

The eastern part of Bhimber district demonstrates an Excellent groundwater potential, covering an approximate area of 26 square kilometers. This classification can be attributed to the favorable combination of substantial rainfall and the presence of water bodies within this area. Moving towards the mid-eastern and western regions of the district, a Good groundwater potential is evident, encompassing a total area of approximately 512 square kilometers. This favorable classification is influenced by the proximity of water bodies on both the eastern and western sides. To the south-west, the district is bordered by a river, accommodating the Mangla Dam, while an intricate network of channels is present on the eastern side. Both of these areas receive consistent and substantial rainfall. The elevated terrain, extending over an area of 779 square kilometers, is characterized by a Fair groundwater potential. This encompasses a significant portion of the central district, emphasizing the balanced nature of groundwater potential in these regions. Conversely, the upper north-eastern segment, spanning an area of 24 square kilometers, exhibits a Poor groundwater potential classification.

Despite the relatively limited potential in this specific area, the broader evaluation suggests a diversified distribution of groundwater potential classes across the Bhimber district.

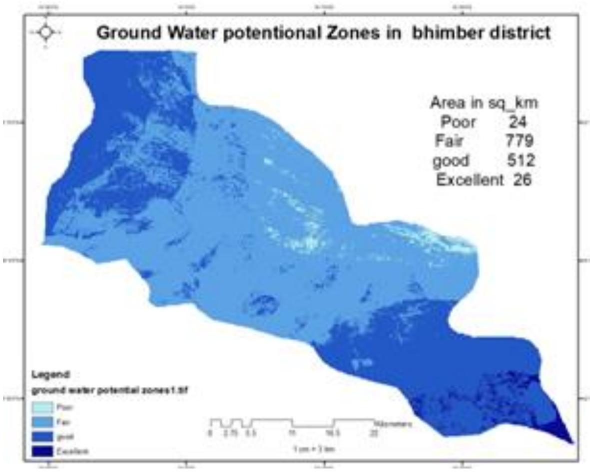

Figure 6. Groundwater potential

In summation, the integrated approach of weighted overlay analysis showcases the intricate relationship between various factors influencing groundwater potential within the Bhimber district. This comprehensive analysis provides essential insights for sustainable water resource management and informed decision-making in the region.

4. Conclusion

In conclusion, this research employs a comprehensive methodology integrating GIS, remote sensing techniques, and the Analytic Hierarchy Process (AHP) to delineate groundwater potential zones in the Bhimber district, Pakistan. The study not only addresses the critical role groundwater plays in sustaining ecosystems and human activities but also offers a practical guide for optimized groundwater exploration and utilization. Through a meticulous analysis of diverse thematic layers, including geology, rainfall, slope, soil, drainage density, land use, and lineament density, the study identifies distinct groundwater potential zones categorized as Poor, Fair, Good, and Excellent.

The findings showcase the effectiveness of the integrated approach, revealing intriguing patterns within the district. The eastern region stands out with an Excellent groundwater potential, attributed to substantial rainfall and the presence of water bodies. The mid-eastern and western sectors exhibit Good potential, influenced by water bodies and consistent rainfall. Elevated terrains correspond to Fair potential, while the upper north-east part indicates a Poor potential. These insights provide valuable information for informed decision-making, sustainable resource management, and overall socioeconomic development.

Acknowledgement

We acknowledged the support of the Departmet of Geography, University of Gujrat for providing us the opportunity and Lab to complete this research work.

Reference

Faheem, H., Khattak, Z., Islam, F., Ali, R., Khan, R., Khan, I., & Tag Eldin, E. (2023). Groundwater potential zone mapping using geographic information systems and multi-influencing factors: A case study of the Kohat District, Khyber Pakhtunkhwa. Frontiers in Earth Science, 11, 1097484.

Ikirri, M., Boutaleb, S., Ibraheem, I. M., Abioui, M., Echogdali, F. Z., Abdelrahman, K., ... & Faik, F. (2023). Delineation of Groundwater Potential Area using an AHP, Remote Sensing, and GIS Techniques in the Ifni Basin, Western Anti-Atlas, Morocco. Water, 15(7), 1436. https://doi.org/10.3390/w15071436

Razandi, Y., Pourghasemi, H. R., Neisani, N. S., & Rahmati, O. (2015). Application of analytical hierarchy process, frequency ratio, and certainty factor models for groundwater potential mapping using GIS. Earth Science Informatics, 8, 867-883. https://doi.org/10.1007/s12145-015-0220-8

Springer, A., Lopez, T., Owor, M., Frappart, F., & Stieglitz, T. (2023). The role of space-based observations for groundwater resource monitoring over Africa. Surveys in Geophysics, 44(1), 123-172. https://doi.org/10.1007/s10712-022-09759-4

Uc Castillo, J. L., Martínez Cruz, D. A., Ramos Leal, J. A., Tuxpan Vargas, J., Rodríguez Tapia, S. A., & Marín Celestino, A. E. (2022). Delineation of groundwater potential zones (GWPZs) in a semi-arid basin through remote sensing, GIS, and AHP approaches. Water, 14(13), 2138. https://doi.org/10.3390/w14132138

Zabihi, M., Pourghasemi, H. R., Motevalli, A., & Zakeri, M. A. (2019). Gully erosion modeling using GIS-based data mining techniques in Northern Iran: a comparison between boosted regression tree and multivariate adaptive regression spline. Natural hazards GIS-based spatial modeling using data mining techniques, 1-26. https://doi.org/10.1007/978-3-319-73383-8_1