

Groundwater Potential Distribution Mapping Using Multi-Influencing Factors in the Harir Basin, Erbil, NE Iraq

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Abstract

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Groundwater is a vital and safe source of water for sustaining life and is relied upon for a variety of uses. In the Harir Basin, some boreholes have failed due to low production capacity and permeability. Therefore, it has become necessary to track the spatial distribution of groundwater in a reliable and scientific way, for the sustainability of life in the Harir Basin. This project aims to prepare a map identifying groundwater potential zones in the Harir Basin using modern applied technologies. The project work included a Multi-Influence Factor analysis method based on a seven-list method, with some factors primary (such as Rainfall, Drainage Density, Lithology, and Slope) and others secondary (such as Land use and Land cover, Soil, and Elevations). Using geographic information systems, the final project map was generated and classified into five (very low to very high) categories, which covering of 9.144%, 27.023%, 29%, 25.943%, and 8.89%, respectively, according to groundwater potential. This work particularly in areas suffering from surface water stress, an applied scientific model that assists decision-makers in the informed management of water resources.

Keywords: Harir basin; Groundwater potential zone; Geographic information systems; Multi-influence factor; Drainage density

1. Introduction

Water is essential for all living organisms (Priyamvada and Awasthi, 2025). Groundwater is a vital, renewable, and reliable source for sustaining life (Odada, 2006), especially in the Harir Basin, where some boreholes have failed due to low production capacity and permeability. Consequently, tracking the spatial distribution of groundwater using accurate, scientifically sound methods is needed to ensure sustainability in the Harir Basin. In recently years, reliance on groundwater has been increased, as surface water resources are no longer sufficient for various uses (Basit and Ambreen, 2025). Thus, groundwater is considered a vital natural resource across all environments (Magesh et al., 2012).

Groundwater has greater value than surface water because it is less polluted (Akudo et al., 2010). Semi-arid, and arid regions are characterized by limited surface water availability due to climate change leading to rapid evaporation and evaporation rates (Ahmed et al., 2007). Such studies are crucial for addressing groundwater issues and ongoing challenges of rising water demand and climate change. These challenges necessitate the application of modern scientific techniques to identify groundwater potential resources and ensure water security in the Harir Basin. Advances in scientific research, satellite data, land use, and land cover information can be employed to detect groundwater potential zones using

robust scientific and applied methods. Assessing groundwater availability is vital for an investment perspective (Ali et al., 2023).

Currently, given global advances in the use of modern applications for groundwater exploration at lower cost, no study has used the MIF analysis method in the Harir Basin to identify GWPZ. Therefore, the groundwater potential of the basin was explored using an integrated approach combining geographic information systems and remote sensing via a multi-influence factor analysis. As a result, disruptions in surface water supplies that are supposed to supplement groundwater, have made daily water uses in the Harir Basin dependent on groundwater. Harir Basin relies heavily on groundwater, especially in the remote villages, due to its complex topography and the absence of a water distribution network infrastructure. The mapping of groundwater potential zones provides scientific support for water resource management. This project aims to prepare a map identifying the GWPZ in the Harir Basin using modern technologies.

The Harir Basin is located within the boundaries of Erbil Governorate, in the northeastern portion of Iraq. The Harir Basin covers an area between latitudes 4056041 and 4026730 and longitudes 454625 and 425346. The Harir Basin is approximately 350 km² and contains approximately 44 villages within its boundaries. The Harir Basin is bordered to the north by the Great Zab River, to the west by the Shaqlawa Basin, to the east by the Gali Ali Beg sub-basin, and to the south by the Zing Zinga sub-basin (Fig. 1).

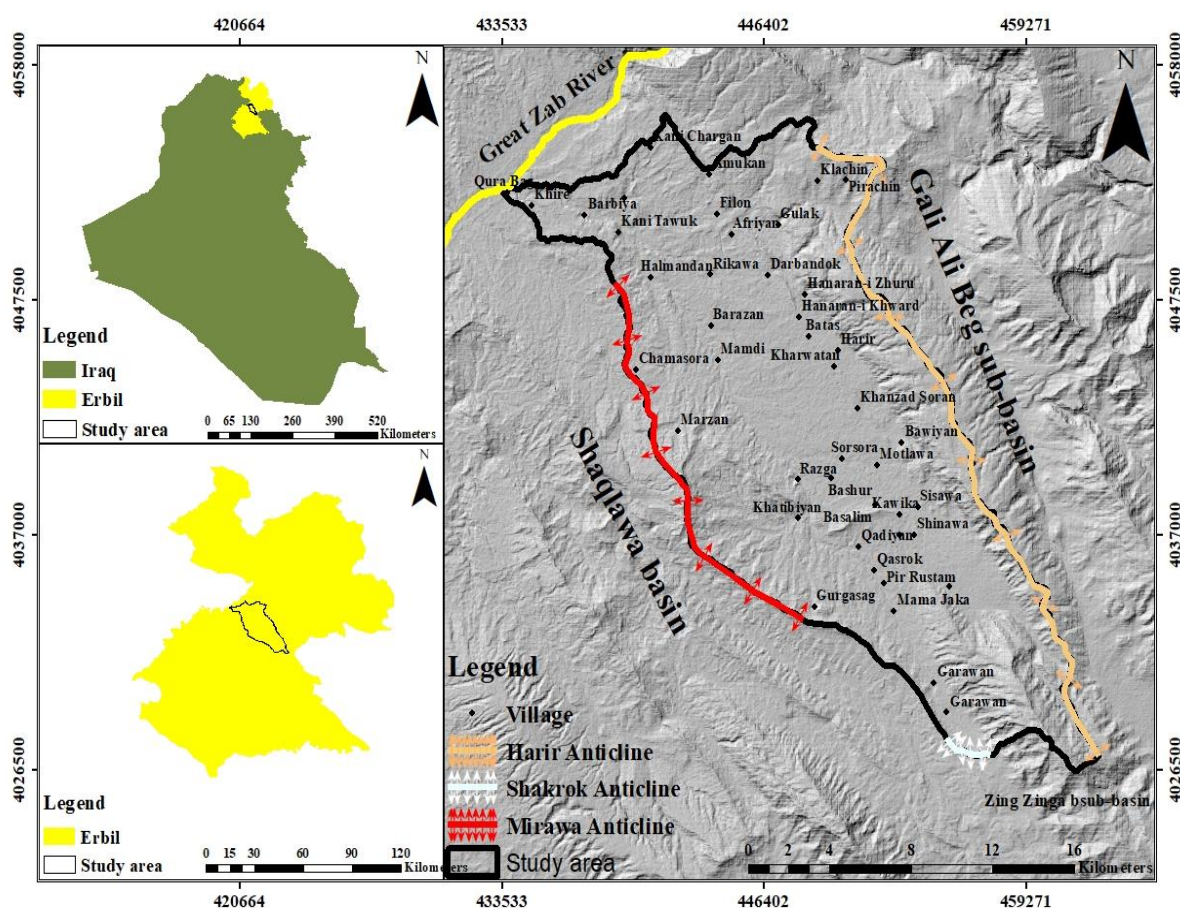


Fig. 1. Location map of the Harir Basin

According to tectonic studies, the Harir Basin is situated within the High Folded Zone (Jassim and Goff, 2006). Structurally, the Harir Basin is bordered by the East Harir Anticline to the east, the Mirawa Anticline to the west, and the Shakrok Anticline to the southwest (Surdashy and Aqrabi, 2001). The

Harir Basin contains 14 geological formations Bai-Hassan, Mukdadiyah, Injana, Fatha, Pila-Spi, Gercus, Khormala, Kolosh, Tanjero, Shiranish, Bekhme, Aqra, Qamchoga and Sarmord, which belong to the Tertiary and Cretaceous periods (Stevanovic and Marcovich, 2003) (Fig. 2).

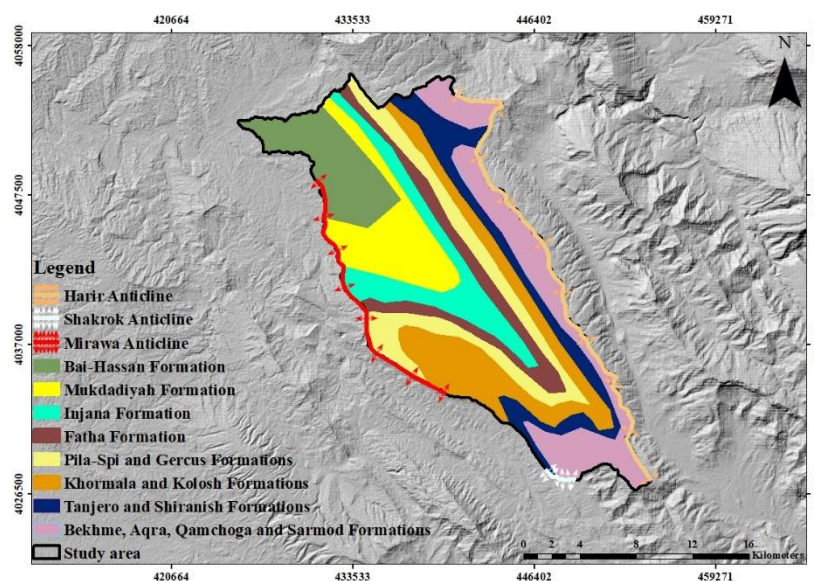


Fig. 2. Geological map of the Harir Basin

2. Materials and Methods

The study included using the MIF approach to prepare a map of GWPZ. In general, the method involved selecting and creating objective layers for the factors controlling groundwater and assigning weights to these factors. And in addition, performing a weighted analysis of the objective layers to determine the best areas suitable for groundwater. The MIF method is characterized by its sensitivity to all factors, its classification into primary and secondary criteria, and the assignment of a weight to each criterion. The project work included (MIF) method based on seven criteria, some of which are primary (P) such as Rainfall (R), Drainage Density (DD), Lithology (L) and Slope (SL) and others are secondary (S) such as (Land Ues and Land Cover (LULC), Soil (SO) and Elevations (E). In addition, the effect of each criterion on the other is determined, whether primary or secondary (Table 1).

Table 1. Effect of each criterion on the other

Factors	Major and Minor effect	Effect of the influencing factor
R	P	SL, DD, SO,LULC
LULC	S	R., SL
DD	P	R, L, SL
L	P	R, DD, SO
SO	S	R, L
SL	P	DD,LULC
E	S	R

The value is 1 for the primary criterion and 0.5 for the secondary criterion using the following equation (Magesh et al., 2012):

$$W = \frac{P + S}{\sum(P + S)} * 100 \quad (1)$$

The final weight for each factor in Table 2.

Table 2. Relative rates and the final weights for each criterion

Factors	Value	P	S	P+S	Weights
R	1	P=SL1, DD1	S=SO, LULC (0.5+0.5)	3	20%
LULC	0.5	P=R1, SL 1	S=0	2	13.3%
DD	1	P=R1, SL1, L1	S=0	3	20%
L	1	P=R1, DD1	SO0.5	2.5	16.7%
SO	0.5	P=R1, L1	S=0	2	13.3%
SL	1	P=DD1	LULC0.5	1.5	10%
E	0.5	P=R1	S=0	1	6.75
				Total= 15	Total=100

The data sources for GWPZ are listed in Table 3.

Table 3. The data sources used of GWPZ

Criteria	References
DEM	U.S. Geological Survey website https://earthexplorer.usgs.gov
Rainfall	NASA Power https://power.larc.nasa.gov/data-access-viewer period 2001–2024
Drainage Density	DEM (12.5 m) resolution
Lithology	Stevanovic and Marcovich, 2003
Slope	DEM (12.5 m) resolution
LULC	Environmental Systems Research Institute (ESRI), year 2025
Soil	Harmonized world soil database, FAO
Elevations	DEM (12.5 m) resolution

The categories within each criterion are classified from the least GWPZ represented by a value 1 to the most GWPZ represented by a value 5. Using GIS, the final project map was generated and classified into five categories according to groundwater potential, as shown in Table 4

Table 4. Categories groundwater potential map

Rating	Categories
<1-1	Very low
1-2	Low
2-3	Moderate
3-4	High
4-5	Very high

3. Results and Discussion

3.1. Rainfall (mm/y)

The main source of groundwater recharge through infiltration is rainfall (Andualemm and Demeke, 2019). The study area receives an average annual rainfall of 508 mm. Rainfall distribution along with the slope flat affects plays a crucial role in enhancing groundwater recharge rates, suggesting the presence of GWPZ. The zones that experience the highest rainfall are those that are most suitable for GWPZ, and vice versa (Fig. 3).

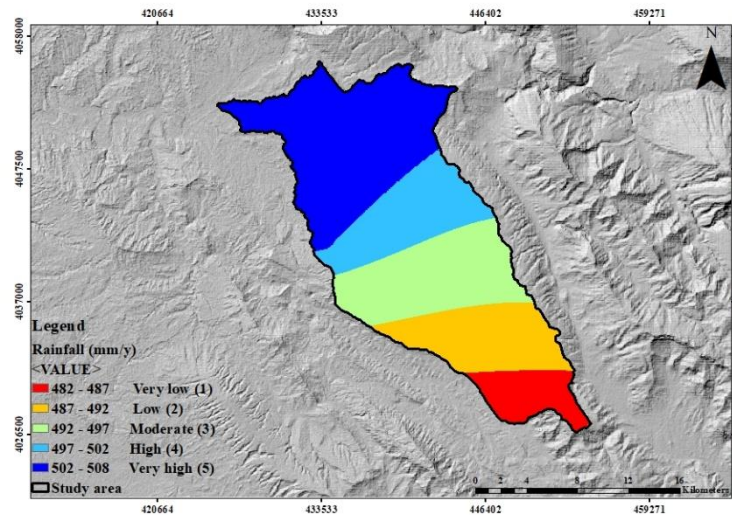


Fig. 3. Rainfall and rating value of the Harir Basin

3.2. Land Use and Land Cover

Aquifer recharge is affected by the nature of land use and land cover. Permeability is reduced due to buildings that prevent water from seeping into the aquifer, unlike agricultural and bare land areas, where permeability increases due to soil pores (Etikala et al., 2019). The Harir Basin covers water, trees, grass, crops, bare, shrub land and built-up areas. The rating value represents water (5), bare land (4), built-up (1), trees, grass, crops, and scrubby land (3) (Fig. 4).

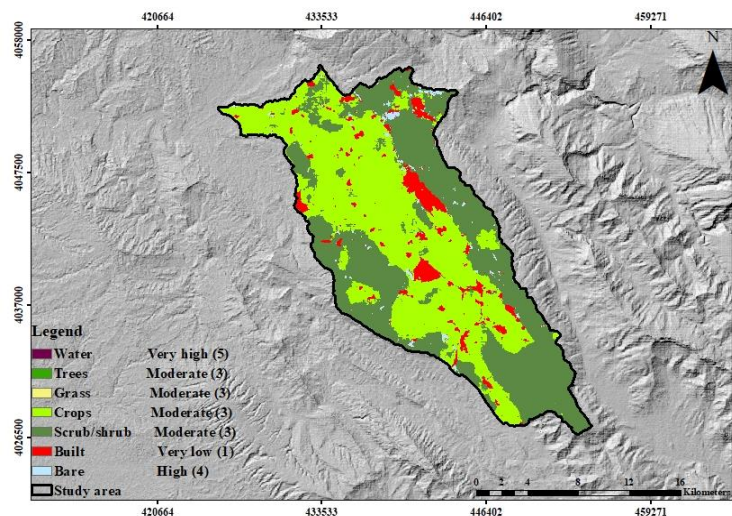


Fig. 4. LULC and rating value of the Harir Basin

3.3. Drainage Density (Km/Km²)

One of the factors that affects the recharge of the aquifer is drainage density (Dinesh Kumar et al., 2007). The rapid drainage density reduces permeability, so that rainfall does not infiltrate well into the aquifer. In general, rates with low drainage density feed the aquifer and vice versa (Ali and Salih, 2022). A drainage density map was prepared for five zones. The zones with the lowest drainage density were considered to be most suitable for groundwater potential (Fig. 5).

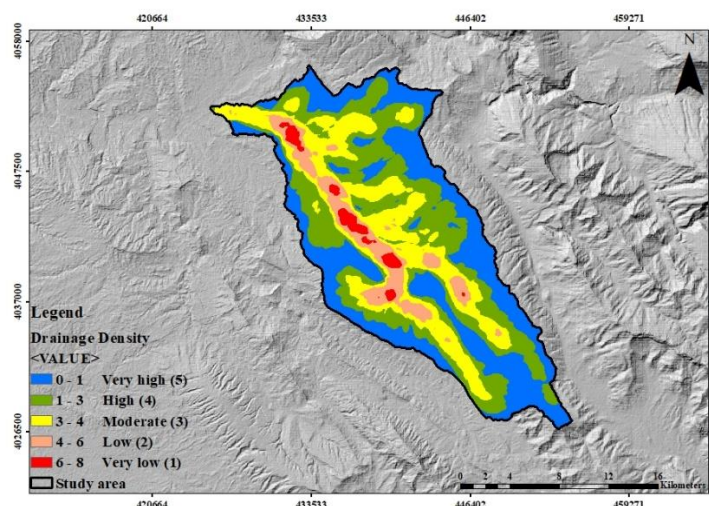


Fig. 5. Drainage Density and rating value of the Harir Basin

3.4. Lithology

The geological characteristics of any area control groundwater accumulation through the porosity and permeability of its lithology. The study area covers diverse geological formations including Bai-Hassan, Mukdadiyah, Injana, Fatha, Pila-Spi, Gercus, Khormala, Kolosh, Tanjero, Shiranish, Bekhme, Aqra, Qamchoga, and Sarmrod. Bai-Hassan Formation consists of conglomerates, claystone, and sandstones. Mukdadiyah Formation is composed of siltstone, sandstone, pebbly sandstone, and claystone. Injana Formation consists of clay, siltstone, and claystone.

The Fatha Formation includes gypsum, limestone, claystone, siltstone, and marl. Pila-Spi and Gercus formations consist of limestone, siltstone, red sandstone, and claystone. Khormala and Kolosh formations consist black claystone, sandstone, and siltstone. Tanjero and Shiranish formations include sandstone, siltstone, claystone, conglomerate, limestone, and marl. Bekhme, Aqra, Qamchoga and Sarmrod formations are composed of dolomitic limestone, limestone, clay, marl, and shale. The rating values are of Bai-Hassan Formation (5), Mukdadiyah Formation (4), Injana, Tanjero, and Shiranish Formations (2), Fatha, Pila-Spi, Gercus, Khormala and Kolosh Formations (3) and Bekhme, Aqra, Qamchoga and Sarmrod Formations (1) (Fig. 6).

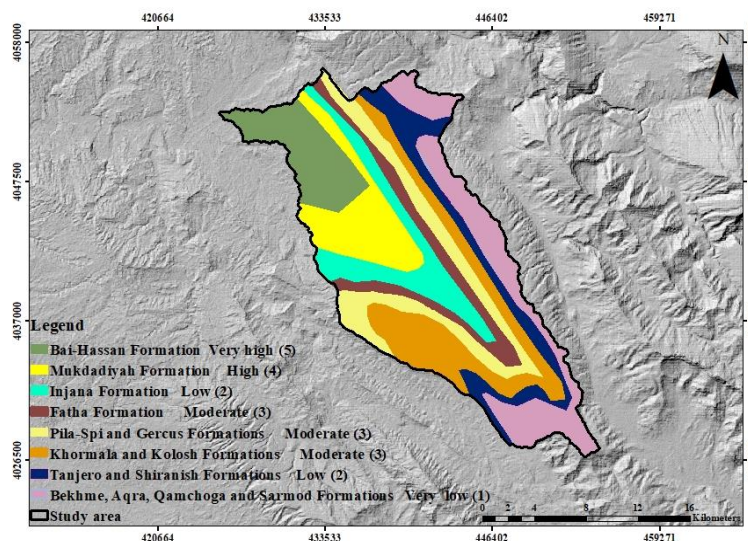


Fig. 6. Lithology and rating value of the Harir Basin

3.5. Soil

Soil is one of the factors affecting the recharge of the aquifer. Therefore, surface water seeps into the aquifer through the soil (Anbazhagan et al., 2005). Sand, sandy loam, and loam are better for infiltration than clay soils. Sand is characterized by high filtration. The Harir Basin contains four soil types: sand, sand loam, clay, and loam. The rating values were of sand soil (5), sand loam (3), loam (3), and clay (2). The clay soil occupies most of the Harir basin. The sand, sandy loam and loam are soil texture covers parts of the eastern, northeastern, southeastern, western and northwestern zone of the basin, respectively (Fig. 7).

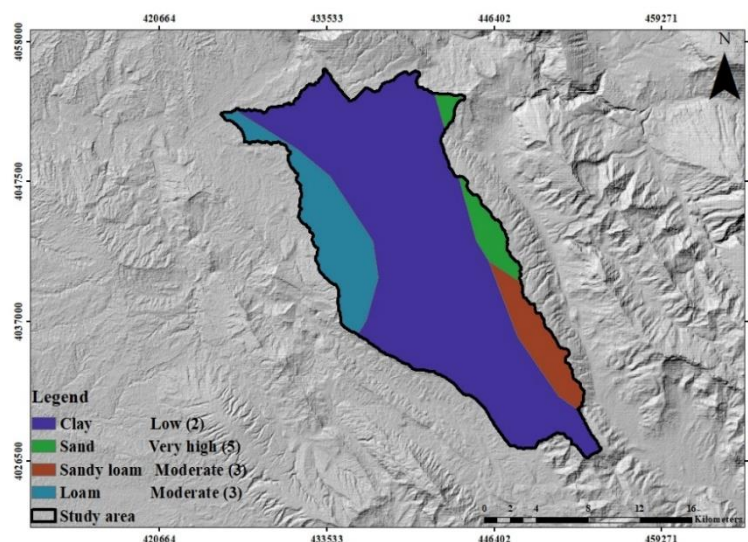


Fig. 7. Soil and rating value of the Harir Basin

3.6. Slope

Slopes are one of the factors that influence hydrogeological studies. So, increased erosion and feeble recharge of the aquifer are considered reasons for the rise in the degree of slope (Burrough, 1986). Therefore, gentle slopes indicate their ability to recharge the aquifer, unlike steeper slopes (Chaudhary and Kumar, 2018). A slope map was prepared for five zones. The zones with the lowest slope degree were considered to be most suitable for groundwater potential (Fig. 8).

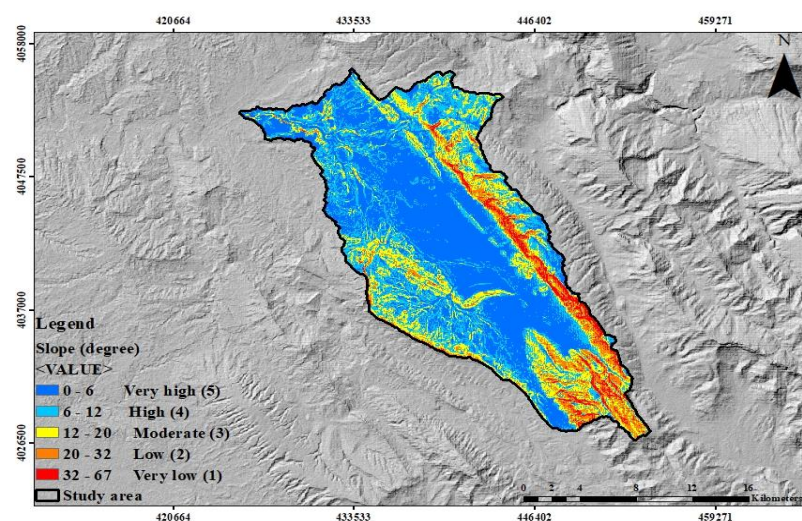


Fig. 8. Slope and rating value of the Harir Basin

3.7. Elevation

After deriving elevations from the SRTM DEM-12.5 m using GIS spatial analysis tools. It was observed that elevations range between 361 and 1819 m above sea level in the Harir Basin. The zones with the highest elevation were considered the least suitable for GWPZ (Fig. 9).

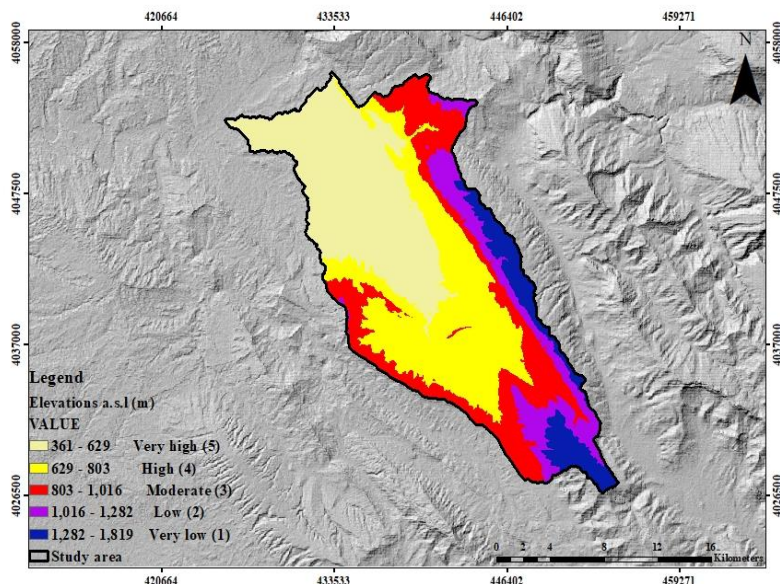


Fig. 9. Elevation and rating value of the Harir Basin

3.8. Groundwater Potential Map

The GWPZ for the Harir Basin was prepared through the integration of various thematic layers, such as rainfall, drainage density, land use, lithology, slope, soil, and elevations, using GIS techniques. The demarcation of the GWP for the Harir Basin was made by the weights of the interpreted maps, based on multiple influencing factors. The GWPZ for the Harir Basin can be divided into five categories, very low to very high (Fig. 10), demonstrating that the very high GWPZ is concentrated in the east, north, and northeastern region of the Harir Basin due to the good distribution of rainfall, low slope degree, and land cover with suitable infiltration ability. In addition to the good distribution of lithology. The very high, high, moderate, low, and very low areas cover 31.1, 90.8, 101.5, 94.6, and 32 km², respectively.

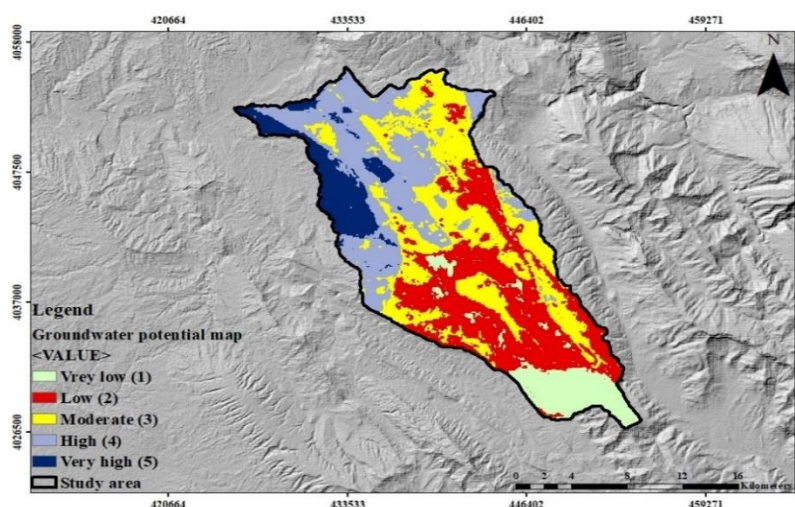


Fig. 10. Groundwater potential map of the Harir Basin

4. Validation

The groundwater potential map for the Harir Basin shows a high degree of agreement with previous studies of the same region. The resistivity values of saturated rocks such as sandstone, were between 70 and 300 ohm.m , indicating moderate resistivity (Ghaib, 2003; Ghaib and Aziz, 2003). In addition to the good porosity values of the geological formations representing the Tertiary rocks (Al-Shaikh et al., 1975). Their values are considered ideal for GWPZ in the north and northwestern part, which represents the very high GWPZ of the Harir Basin.

5. Conclusions

The study of groundwater recharge requires a scientific understanding of how to manage groundwater use systematically. This work presents a systematic study to identify GWPZ based on modern applications. This project used RS and GIS in addition to MIF to identify GWPZ in the Harir Basin. In general, the Harir Basin was classified into five zones: very low - low covering approximately 9.144% and 27.023% respectively; moderate covering 29% and high-very high, covering 25.943% and 8.89%, respectively. The current work proves its importance in identifying GWPZ through the use of thematic maps and modern technologies. This study and its results are considered to have scientific value in sustainable groundwater exploration

Author Contributions

The author presented an advanced applied approach using scientific standards that contributed to the completion of this work. In addition to writing the research paper and preparing the maps.

Declaration of Competing Interest

I affirm that I have no personal or financial interest in completing this study other than contributing to the advancement of knowledge and its applications to serve scientific and societal research.

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Data Availability

All data generated during this study are included in this published article and/or its supplementary materials.

References

- Ahmed, S., Maréchal, J.C., Ledoux, E., De Marsily, G. 2007. Groundwater Flow Modelling in Hard-rock Terrain in Semi-arid Areas: Experience from India. In: Wheeler H., Sorooshian, S., Sharma, K.D. (eds.). Hydrological Modelling in Arid and Semi-Arid Areas. International Hydrology Series. Cambridge University Press. <https://doi.org/10.1017/CBO9780511535734.012>
- Akudo, E.O., Ozulu, G.U., Osogbue, L.C., 2010. Quality assessment of groundwater in selected waste dumpsite areas in Warri, Nigeria. Environmental Research Journal, 4(4), 281-285. <https://doi.org/10.3923/erj.2010.281.285>
- Ali, M.A., Salih, S.A., 2022. Hydrogeological conditions and mathematical model of the area surrounding Hatra Suggested dam, Northwest Iraq. In IOP Conference Series: Earth and Environmental Science, 1080 (1), 012007. <https://doi.org/10.1088/1755-1315/1080/1/012007>

- Ali, M.A., Salih, S.A., Hussain, A.I., 2023. Groundwater situation before production and after production stoppage in Al-Mishraq Sulfur field-1, northern Iraq. *Iraqi Journal of Science*, 64,(10), 5095-5107. <https://doi.org/10.24996/ij.s.2023.64.10.18>
- Al-Shaikh, Z.D., Salih, H.A., Abdo, H.F., 1975. Contribution to the geology of Shaqlawa-Harir area. *Iraqi Journal Geological Society*, Special issue, 55-67.
- Anbazhagan, S., Ramasamy, S.M., Das Gupta, S., 2005. Remote sensing and GIS for artificial recharge study, runoff estimation and planning in Ayyar basin, Tamil Nadu, India. *Environmental Geology*, 48(2), 158-170. <https://doi.org/10.1007/s00254-005-1284-4>
- Andualemm, T.G., Demeke, G.G., 2019. Groundwater potential assessment using GIS and remote sensing: A case study of Guna tana landscape, upper Blue Nile Basin, Ethiopia. *Journal of Hydrology: Regional Studies*, 24, 100610. <https://doi.org/10.1016/j.ejrh.2019.100610>
- Basit, A., Ambreen, R., 2025. Identification of groundwater potential zones using MIF, GIS and RS techniques in Killa Saifullah District, Pakistan. *The Critical Review of Social Sciences Studies*, 3(1), 275-290. <https://doi.org/10.59075/rxc2gt79>
- Burrough, P.A., 1986. *Principles of Geographical. Information Systems for Land Resource Assessment*. Clarendon Press, Oxford.
- Chaudhary, B.S., Kumar, S., 2018. Identification of groundwater potential zones using remote sensing and GIS of KJ Watershed, India. *Journal of the Geological Society of India*, 91(6), 717-721. <https://doi.org/10.1007/s12594-018-0929-3>
- Dinesh Kumar, P.K., Gopinath, G., Seralathan, P., 2007. Application of remote sensing and GIS for the demarcation of groundwater potential zones of a river basin in Kerala, southwest coast of India. *International Journal of Remote Sensing*, 28(24), 5583-5601. <https://doi.org/10.1080/01431160601086050>
- Etikala, B., Golla, V., Li, P., Renati, S., 2019. Deciphering groundwater potential zones using MIF technique and GIS: A study from Tirupati area, Chittoor District, Andhra Pradesh, India. *HydroResearch*, 1, 1-7. <https://doi.org/10.1016/j.hydres.2019.04.001>
- Ghaib, F.A., 2003. Geophysical survey for groundwater in some selected basins of Erbil Governorate. Internal report, FAO representation in Iraq, Erbil Sub-office.
- Ghaib, F.A., Aziz, B.K., 2003. A combination of electrical and gravity measurements for groundwater prospection in parts of Erbil City. *The Journal of the University of Duhok*, 6(1), 105-11.
- Jassim, S.Z., Goff, J.C., 2006. *Geology of Iraq*. 1st Edition, Published by Dolin, Prague and Moravian Museum, Brno, Printed in the Czech Republic.
- Magesh, N.S., Chandrasekar, N., Soundranayagam, J.P., 2012. Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. *Geoscience Frontiers*, 3(2), 189-196. <https://doi.org/10.1016/j.gsf.2011.10.007>
- National Aeronautics and Space Administration (NASA) Power, Prediction Of Worldwide Energy Resource. <https://power.larc.nasa.gov/data-access-viewer>
- Odada, E., 2006. Freshwater resources of Africa: major issues and priorities. *Global Water News*, (3).
- Priyamvada, M., Awasthi, M.K., 2025. Geospatial based assessment of groundwater potential zones using MIF technique in a watershed of Malwa region, Madhya Pradesh, India. *Research Square*. <https://doi.org/10.21203/rs.3.rs-5750566/v1>
- Stevanovic, Z., Markovic, M., 2003. *Hydrogeology of Northern Iraq*, Climate, Hydrology, Geomorphology and Geology. Spec. Edition FAO/UN, 1-122.
- Surdashy, A., Aqrabi, A., 2001. *Geology of Harir and Shqlawa areas*. Internal Report, FAO (GWU) (Northern Iraq Office).