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MULTI-INFLUENCING FACTORS ASSESSMENT TO MAP THE GROUNDWATER POTENTIAL ZONES IN THE SOUTHERN DESERT OF IRAQ

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ABSTRACT

The reliability of deep aquifers makes groundwater a vital resource in semi-arid and arid regions. However, less precipitation and more droughts are predicted due to climate change. Iraq has been significantly affected by a prolonged drought, leading to a notable increase in groundwater use over the past decade. Consequently, utilizing groundwater has emerged as the most viable option for meeting water supply requirements. This study aims to construct a groundwater potential map (GPM) for the Dammam confined aquifer in Iraq's southern desert zone using integrated RS, GIS, and multi-criteria decision-making (MCDM) approaches, including the analytical hierarchy process (AHP) to facilitate groundwater management. A multiclass GPM is created by extracting relevant thematic layers based on factors that influence groundwater potential and integrating them into a normalized Pairwise comparison matrix using the AHP technique. The findings of this study demonstrate that the created GPM classifies the study area into five zones, including very good, good, moderate, poor, and very poor groundwater potential zones (GWPZs). The distribution of these zones as a percentage of the total area of 76732.71 Km2 is as follows: 15.91%, 39.02%, 33.01%, 6.49%, and 5.57%, respectively. The AHP method accurately delineates a groundwater potential map with 85.4% accuracy. Specifically, out of 349 well locations, 298 were correctly identified using this method. Such a study will significantly contribute to early planning of groundwater exploration by providing preliminary, reliable information on the optimal zone before drilling, especially in arid areas with limited groundwater information, to target appropriate drilling sites for groundwater wells.

KEYWORDS

Groundwater Potential Map (GPM), GIS, Analytical Hierarchy Process (AHP), Groundwater Depletion, multi-criteria decision-making (MCDM) approaches.

1. INTRODUCTION

Groundwater Potential Mapping (GPM) is a geospatial assessment approach using Geographic Information Systems (GIS) and multi-criteria analysis to identify areas within a watershed with high groundwater potential. It integrates multiple datasets, including geology, soil type, drainage density, topography, and climatic data, to support strategic planning and sustainable management of groundwater resources (Mostafa et al., 2025). Identifying suitable locations and aquifer thickness through drilling tests and stratigraphic analysis has been considered the most dependable and common method. However, this approach is also associated with high costs, time-consuming, and requires specialized labor (Shlash and Obead, 2023a). Additionally, random drilling without proper planning often leads to failure, and uncontrolled exploitation depletes groundwater potentiality (Ahmed and Sajjad, 2018; Ratnakumari et al., 2012; Prasad et al., 2008). Consequently, it is essential to conduct an updated assessment of groundwater resources using contemporary, effective methodologies to enhance management techniques and protect the sustainability of the aquifer system. Remote sensing (RS) and Geographic Information Systems (GIS)-based approaches are used to map groundwater vulnerability and assess risk. Satellite and remote sensing data are combined to identify factors influencing groundwater occurrence and flow, including geology, soils, land use, and drainage. Recently, integrated RS, GIS, and multi-criteria decision-making (MCDM) approaches have been used to identify groundwater potential zones, particularly in arid areas. According to Jha et al. (2010), accurately identifying groundwater potential zones can provide decision-makers with a practical framework for determining suitable groundwater strategies in areas with scarce water resources. Generally, identified three key groups of factors that influence groundwater accumulation: water sources, such as rainfall and distance from the channel network; possible infiltration pathways, such as geology, lineament density, distance from fractures, soil type, and land use; and opportunity, which refers to the amount of time available to infiltrate the water supply including elevation, slope steepness, and drainage density (Shlash and Obead, 2023b). Groundwater storage may be inferred indirectly from high-resolution satellite imagery. These satellites have the potential to provide substantial amounts of unprocessed data for resource inventory and mapping. To facilitate effective decision-making, the data must be appropriately processed to extract relevant information on indirect variables (Hussien et al., 2020). In several areas of natural resource management, environmental impact analysis, and regional planning, the AHP technique for multi-criteria decision-making (MCDM) has been successfully used by assessing the relatively significant factors, as evidenced by studies conducted by Jha et al. (2010), Ouma and Tateishi (2014), Rahaman et al. (2015), Mallick et al. (2019), Zghibi et al.

(2020), Roy et al. (2020), and Morgan et al. (2022). These factors include lithological composition, drainage pattern, land use and cover, and climatic variables such as precipitation, temperature, and evapotranspiration. Also, geological features such as fractures and lineaments control the occurrence and availability of groundwater. As a result, this study employs a multi-criteria approach using Analytic Hierarchy Process (AHP), which is a decision-making methodology that uses a hierarchical structure to break down complex problems into smaller and more manageable components. It is widely used across various fields, including engineering and environmental management. In AHP, decision-makers evaluate the relative importance of criteria, alternatives, and sub-criteria in pairwise comparisons. The evaluations are then used to derive weights for each criterion or alternative, which are combined to obtain an overall score or ranking. AHP has been applied in many contexts, including land-use planning, environmental impact assessment, and resource allocation. It has been recognized as a valuable tool for supporting decision-making in complex and uncertain environments (Roy et al., 2020). Consequently, the study area was analyzed using field and satellite data, along with existing maps, to produce seven thematic maps of the influencing parameters. These parameters include hydrogeological aquifer unit types, transmissivity, lineament density, slope, soil type, land use and land cover, and drainage density. These maps were prepared using ArcGIS 10.7.1 software. These parameters were assigned weights using the AHP. Within each parameter, various classes (sub-criteria) were ranked based on their relative significance for groundwater potentiality.

2. STUDY AREA

The study area of about 76732.71 Km^2 is located in Najaf and Muthanna governorates in Iraq's southern desert zone, as shown in Fig. 1. The geographic coordinates for the study area are between longitudes 44° 19 '07.68" to 46° 33' 26.55" East and between latitudes 29° 06 '15.74" to 32° 19'55.97" North. The Southern Desert refers to the geographical area in southern Iraq. It is located west of the Euphrates River and the Shatt Al-Arab, extending into Saudi Arabia and Kuwait. The southern area of the Mesopotamian Zone covers the eastern and, to some extent, the northern areas. The remaining areas are attributed to the Salman zone of the stable shelf.

3. METHODOLOGY USED TO APPLY ANALYTIC HIERARCHY PROCESS

By applying this methodology to groundwater exploration, it is possible to identify and rank potential zones for developing groundwater resources. These steps were accomplished using the GIS software by assigning rank values to each class based on Saaty's 1-9 scale. This is done in accordance with their respective contributions to groundwater occurrence when compared to other factors. A high-weight parameter represents a layer with a significant influence on groundwater potential, whereas a low-weight parameter indicates a layer with little impact. Subsequently, construct a pairwise comparison matrix (PCM) to assign normalized weights to each class. Sub-classes are assigned weights by multiplying the normalized weight of each class by the rank of its corresponding sub-classes. Then overlay all the thematic maps using the Spatial Analyst Overlay tool in ArcGIS 10.7.1. Finally, the model was validated using actual field data of wells to calculate the overall accuracy. The methodology for delineating suitable sites for groundwater availability is presented in Fig. 2, which shows the integrated approaches used to produce the final map of groundwater potential zones for the study area.

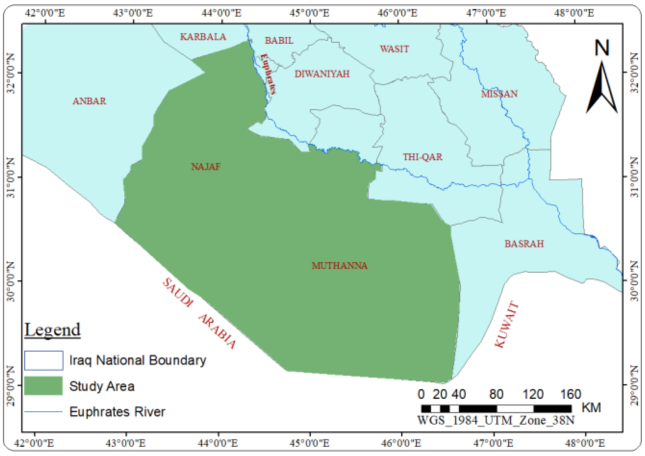

Fig. 1. Location of the study area.

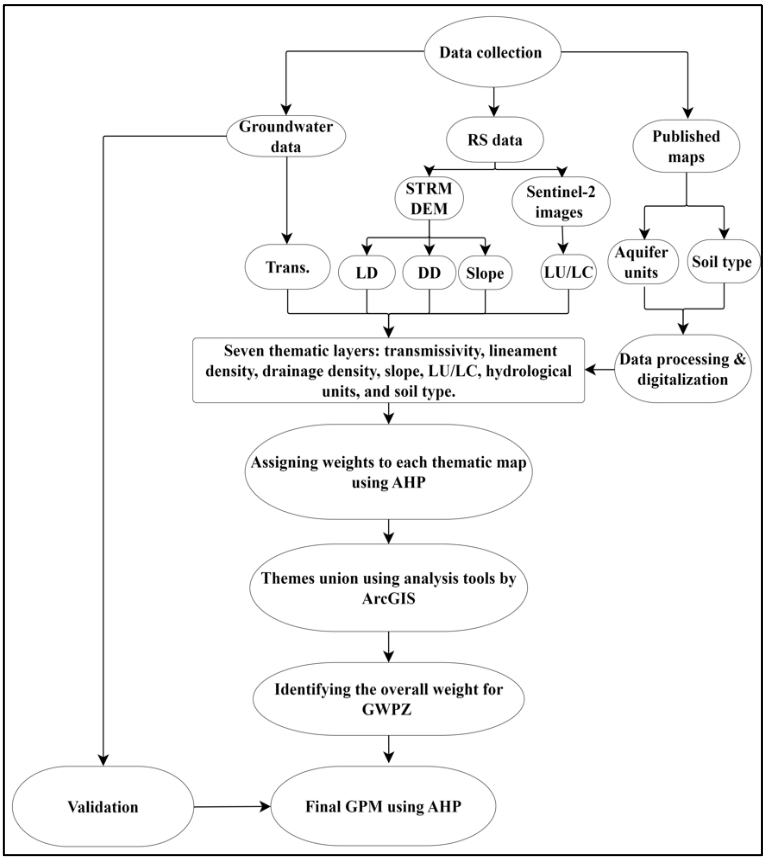

Fig. 2. Framework to delineate the groundwater potential zones.

Remote sensing data, such as SRTM DEM and Sentinel-2 images, were prepared for digital image processing along with geological and soil maps, in addition to the fieldwork data, to create the characteristic groundwater layers needed to generate the potential groundwater map. The study area's DEM was obtained with 30m accuracy and SRTM type. Furthermore, the Sentinel-2 images provide access to individual 10-meter-resolution scenes for all landmasses on the planet for each year from 2017 to 2021.

3.1. The Influence Criteria

The present study has taken into account seven thematic layers to identify the groundwater potential zones: hydrogeological aquifer unit types, transmissivity (T), lineament density (LD), slope (SLO), type of soils (SL), land use and land cover (LU/LC), and drainage density (DD). These factors significantly regulate groundwater availability.

3.1.1. Hydrogeological Aquifer Units

The study area comprises four distinct aquifer units, attributed to variations in geological formations. As illustrated in Fig. 3, the hydrogeological units' thematic map was produced by applying existing data and georeferencing Iraq's primary groundwater aquifers map, created by Jassim and Goff (2006).

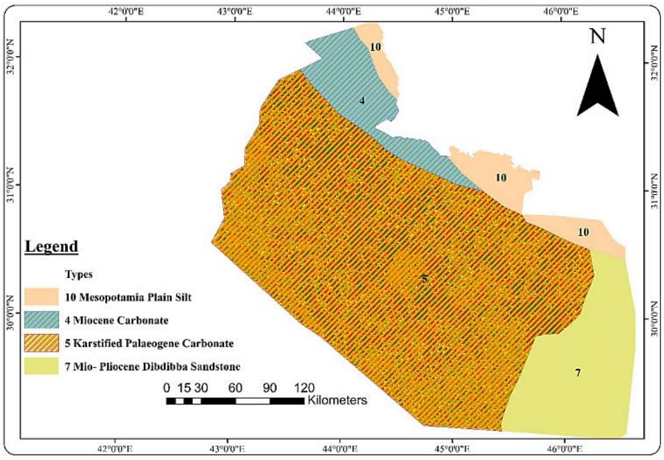

Fig. 3. Thematic map for the main hydrogeological units in the study area.

The ranking of hydrogeological units was positively correlated with the static water level. Specifically, units with higher static water levels were assigned the highest rank, while aquifer units with lower static water levels were assigned the lowest rank. The Karstified Palaeogene aquifer comprises the Tayarat and Dammam aquifers, which contain significant groundwater, indicating a high level of groundwater availability (Al-Jiburi, 2009). Furthermore, the Mio-Pliocene Sandstone, as illustrated by the Dibdiba aquifer, exhibits moderate groundwater availability. Conversely, the Miocene Carbonate, represented by the Euphrates and Zahra formations, exhibits low groundwater availability. The Mesopotamia Plain Silt is characterized by a notable scarcity of groundwater resources, leading to very limited availability.

3.1.2. Transmissivity of Aquifer Layers

The transmissivity of an aquifer layer is the rate of flow across a unit-width cross-section of the fully saturated thickness of the water-bearing layer under a unit hydraulic gradient (Tood, 2007). This parameter indicates the aquifer's ability to transmit water. The Kriging interpolation technique was applied to produce a thematic map of the spatial distribution of transmissivity in the study area, using available data. The study area was classified into five groups, as shown in Fig. 4.

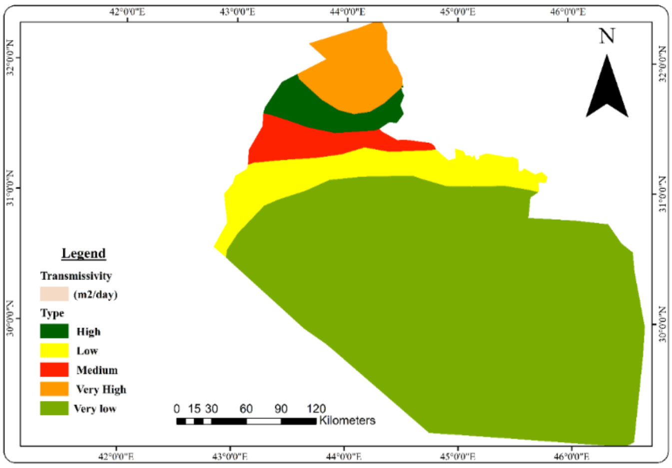

Fig. 4. Thematic map of transmissivity.

According to Luijendijk (2022), a significant correlation exists between transmissivity, groundwater flow, and drainage density: high transmissivity results in low drainage density, while low transmissivity results in high drainage density. This is attributed to the fact that areas with high drainage density experience limited infiltration, resulting in poor groundwater potential zones. As a result, the groundwater potentiality for transmissivity ranges from 9.474 to 12.089 m^2/day was classified as "very poor," 12.089 to 17.081 m^2/day as "poor," 17.081 to 24.332 m^2/day as "moderate," 24.332 to 32.414 m^2/day as "good," and 32.414 to 39.784 m^2/day as "very good."

3.1.3. Lineament Density (LD)

The lineament density (LD) is considered a crucial factor in determining groundwater availability and movement in the study area, as evidenced by the tectonic map of Iraq. Limestone and dolomite beds are part of the carbonate aquifers found in the Dammam Formation (Al-Jiburi and Al-Basrawi, 2009). Lineaments are identified by the presence of faults, fractures, and scattered karsts in the southern desert, which facilitate regional groundwater flow into the study area. The faults map was produced and modified from the Iraq tectonic map (GEOSURV, 1994), as illustrated in Fig. 5.

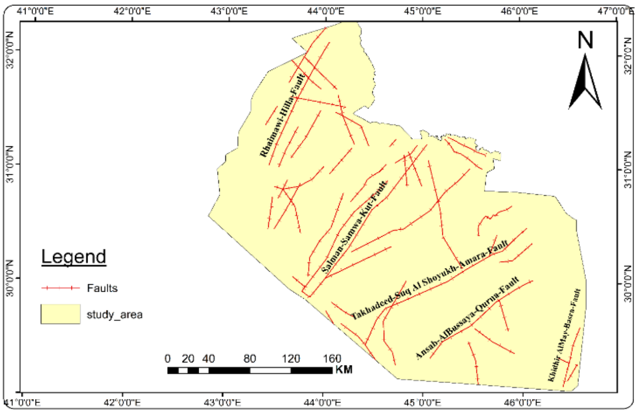

Fig. 5. Fault map for the study area

GIS software calculates the length of lineaments per unit area (lineament density) to generate the LD thematic map, showing where these features are concentrated. High lineament density areas often correspond to high groundwater potential zones, since these fractures denote secondary porosities that enhance water penetration and recharge of groundwater aquifers. Fig. 6 presents the classification of LD in the study area, segmented into five main categories.

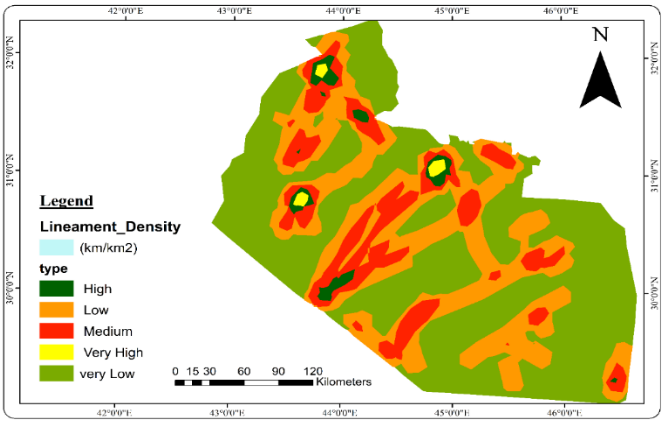

Fig. 6. Thematic map of lineament density.

Based on the findings presented in Fig. 6, it is evident that the areas exhibiting a high LD, ranging from 0.15 to 0.19 km/Km2, possess significant potential for groundwater resources. This is attributed to their favorable porosity and infiltration characteristics, which result in a higher ranking (very good) for these areas. The areas with a groundwater potential zone ranging from 0.11 to 0.15 km/ Km^2 of LD were identified as good groundwater potential. On the other hand, regions with groundwater potential in the range of 0.07 to 0.11 km/Km^2 were classified as moderate. However, the LD areas ranging from 0.04 to 0.07 km/Km^2 indicated poor groundwater potential zones. Areas characterized by low LD (0-0.04 km/Km^2) are deemed to have limited groundwater potential and are thus assigned lower rankings.

3.1.4. Slope (SLO)

The present study involved creating a slope map using a surface spatial analyst tool. Specifically, a slope tool was utilized to analyze the SRTM DEM dataset. The reclassification technique was applied to the slope map to determine the weights and rankings for groundwater availability as established by Roy et al. (2020). The study area was divided into five categories based on its variability. The resulting reclassified slope map is shown in Fig. 7.

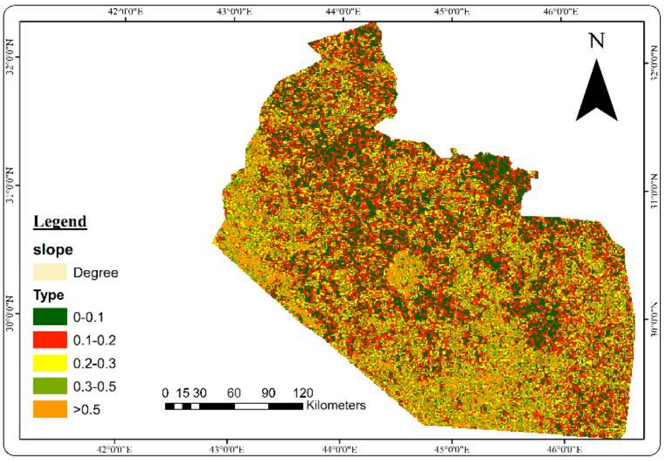

Fig. 7. Thematic map of study area slope.

As presented in Fig. 7, the areas with slope interval (0-0.1)° are considered (very good) due to flat topography and moderately decreased movement of runoff downstream, and increase the amount of infiltrated water, thus elevating the groundwater potentiality. The slope of (0.1-0.3)° classified as good to moderate, which is considered advantageous for groundwater recharge. Finally, the slope (0.3-0.5)° (steep slope) and greater than 0.5° (very steep slope) were regarded as (poor) to (very poor) groundwater potentiality, respectively, because the steep and very steep slopes were awarded low weights since they favour high amounts of runoff and do not give enough time for surface runoff to infiltrate. On the other hand, low-slope zones are suitable locations for water accumulation and infiltration.

3.1.5. Soil Type (SL)

Groundwater recharge is influenced by various soil properties, including porosity, structure, adhesion, and consistency. These factors affect the soil's ability to absorb and retain water, which in turn determines the rate at which groundwater is recharged (Lentswe and Molwalefhe, 2020). The gravel and sandy soils exhibit a high degree of infiltration, resulting in a greater influence. In contrast, clay and clay loam soils demonstrate the lowest degree of infiltration and, consequently, impose the lowest influence (Zghibi et al., 2020). This study employed soil texture data derived from the digital soil map, acquired in ESRI shapefile format from the official website of the Food and Agriculture Organization (FAO) of the United Nations. The map assigns a unique numerical value to each soil type by referencing the user soil file, as shown in Fig. 8.

The dominant soil textures in the study area are shown in Fig. 8, which indicates that loam, loamy sand, sandy loam, sandy, and clayey loam were the prevailing soil textures. Since the infiltration rate depends on soil grain size, coarse-textured soils (e.g., sand, loamy sand, and sandy loams) have a greater infiltration rate and, thus, a high groundwater potential. In contrast, medium-textured soils (loams and silt loams) have moderate to poor groundwater potential. On the other hand, fine-textured soils such as clay loams, silty–clay loams, and clays have the lowest infiltration rate and (very poor) groundwater potentiality.

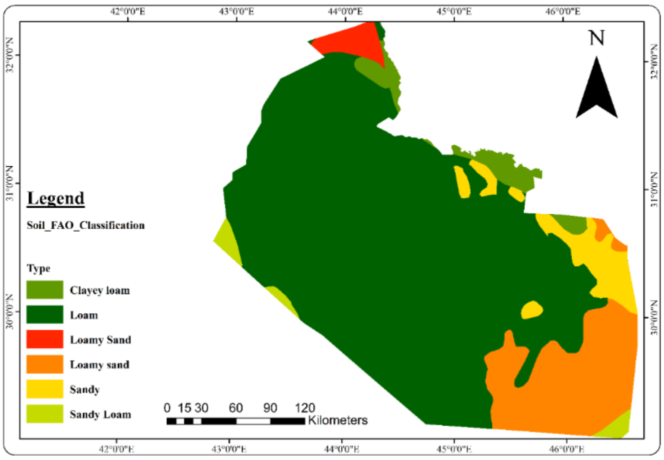

Fig. 8. Thematic map for the soil classification in the study area.

3.1.6. Land Use/ Land Cover (LU/LC)

LU/LC can significantly affect the potential groundwater zones in a confined aquifer. These aquifers are recharged by water that seeps in from surrounding areas, typically at higher elevations. When land use changes occur in the recharge areas of a confined aquifer, the amount of water that enters the aquifer can be affected. The LU/LC map was produced utilizing European Space Agency ESA Sentinel-2 imagery with a spatial resolution of 10 meters. The relevant data for the study area were obtained from a GeoTIFF file, a type of raster data. The data were processed using the raster processing tools in ArcMap 10.7.1 to clip the relevant raster data. Converting the raster-generated map to a polygon is a crucial step, and tools are used to convert it from raster to polygon format. This is due to the fact that the map assigns a unique numerical value to each LULC class, which can be identified by referring to the class definitions, as illustrated in Fig. 9.

Based on the LU/LC thematic map shown in Fig. 9, the study area has been divided into six classes: water, herbaceous wetland, herbaceous vegetation, cropland, built-up areas, and bare areas or sparse vegetation; each class has a weighted value representing its priority for groundwater accumulation. Runoff is often lower, and infiltration is higher, in agricultural and forested areas than in settlement and bare areas, where infiltration rates typically decrease. As a result, settlement and the bare regions are given a low rank, whereas agricultural land and the areas covered by vegetation are given a high rank.

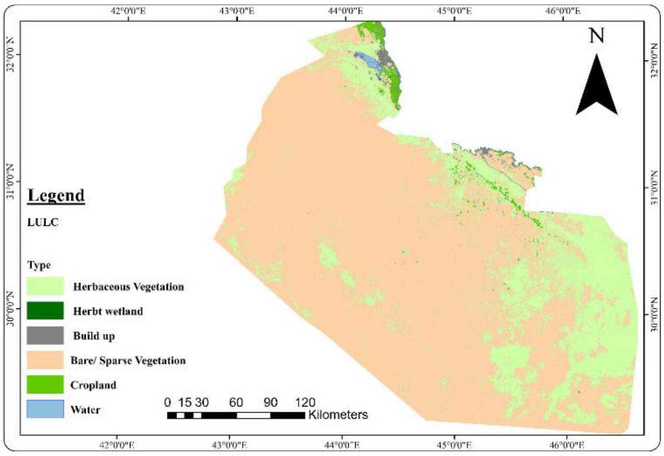

Fig. 9. Thematic map of the study area Land Use and Land Cover.

3.1.7. Drainage Density (DD)

The drainage density indirectly influences groundwater availability through its connection with infiltration capacity and permeability; higher drainage density reduces infiltration, thereby increasing runoff, and higher runoff indicates lower groundwater potential. Furthermore, observations across different geologic and climatic zones show that low drainage density is more likely in flat areas with highly permeable subsoils and dense vegetation. High drainage density develops in areas with mountainous terrain, few plants, and impermeable subsurface (Lentswe and Molwalefhe, 2020). As a result, Poor groundwater potential zones (GWPZs) occur in areas with limited infiltration and high drainage density. Hence, a high rank is assigned to the low-drainage-density area. The drainage density thematic map for the study area was produced from a SRTM DEM with a 30-meter resolution using hydrology tools in the spatial analysis tools of ArcGIS 10.7.1, as shown in Fig. 10.

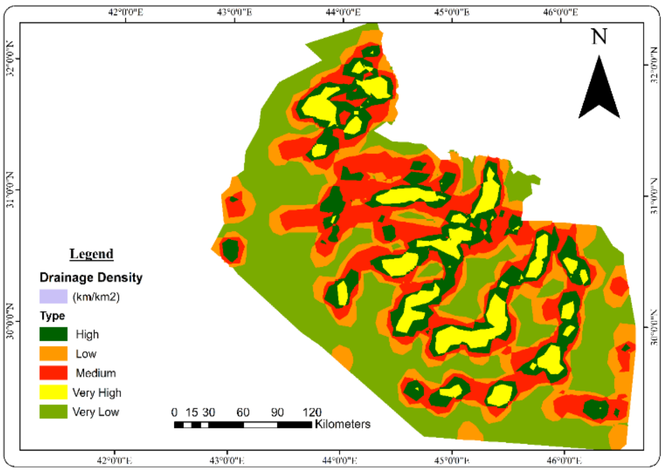

Fig. 10. Thematic map of drainage density.

As shown in Fig. 10, the area under study was categorized into five classes, each assigned a specific weight and assessed for its potential to yield groundwater. The assessment of groundwater potential for each class was conducted by considering its respective range of values. The findings indicate that higher drainage density reduces infiltration, thereby increasing runoff. Consequently, higher runoff values indicate a lower potential for groundwater availability. In light of this, the classes with higher drainage density values were assigned the lowest rank, while those with lower values were given a higher rank for groundwater availability, which were as follows: very poor (10.12 - 17.21) km/Km^2, poor (7.35 - 10.12) km/Km^2, moderate (4.66 -7.35) km/Km^2, good (1.75 - 4.66) km/Km^2, and very good (0 - 1.75) km/Km^2.

4. RESULTS AND DISCUSSION

4.1. Assignment and Normalization of Weights for Thematic Layers

The creation of GWPZs was accomplished through the utilization of the overlay technique within the ArcGIS software. This approach incorporated seven thematic layers and their corresponding percentage impacts on groundwater availability. The overlay toolset comprises tools that facilitate superimposing multiple feature classes to merge (union), erase, modify, or update spatial features, thereby generating a new feature class. Spatial relationships between input features can be identified by overlaying one set of features with another, creating new information. The present study employed the union geoprocessing tools of the overlay toolset to perform a geometric union of the input features. The resulting feature class will contain all features and their corresponding attributes. To apply the union option, the feature layers must have polygonal geometry. Prior to the overlay process, a score ranging from 1 to 5 was assigned to each factor that affected groundwater potentiality based on its relative importance when compared to other factors through pairwise comparison matrix (PCM) where a score of 1 indicates the equal influence of parameters and a score of 5 indicates the extreme importance of a parameter on groundwater recharge compared to the other factors, based on the Analytic Hierarchy Process (AHP) and Saaty scores each thematic layer was transformed into a single rank ranging from 1 to 5, which corresponds to very poor, poor, moderate, good, and very good, respectively, in terms of their potential for groundwater storage as presented in Table 1.

Table 1. Normalized pairwise comparison matrix (seven layers) developed for AHP-based groundwater potential zoning for the Dammam aquifer in the study area.

Influence Factors	Aquifer-Units	T	LD	SLO	SL	LU/LC	DD	Normalized Weight
Hydrogeological Aquifer Units	7	6	5	4	3	2	1	0.38567
Transmissivity (T) m^2/day	7/2	6/2	5/2	4/2	3/2	2/2	1/2	0.19284
Lineament Density (LD) km/Km^2	7/3	6/3	5/3	4/3	3/3	2/3	1/3	0.12856
Slope (SLO) (Degree)	7/4	6/4	5/4	4/4	3/4	2/4	1/4	0.09642
Soil (SL)	7/5	6/5	5/5	4/5	3/5	2/5	1/5	0.07713
Land use Land cover (LU/LC)	7/6	6/6	5/6	4/6	3/6	2/6	1/6	0.06428
Drainage Density (DD)	7/7	6/7	5/7	4/7	3/7	2/7	1/7	0.05510

The weight assignment ranks were assigned to sub-variables (subclasses) to determine the overall percentage weight. This was achieved by multiplying each parameter's normalized weight by its rank within each subclass. The resulting values were used to generate the groundwater potential zone map shown in Table 2.

Table 2. Weights assigned for groundwater control parameters of the Dammam aquifer

Classes	Normalize weight %	Rank	Potential index	Overall weight
Hydrogeological Aquifer Units				
Karstified Palaeogene		4	good	154.268
Mio-Pliocene Sandstone	38.567	3	moderate	115.702
Miocene Carbonate		2	poor	77.135
Mesopotamia Plain Silt		1	very poor	38.567
Transmissivity (T) (m^2/day)				
9.474-12.089		1	very poor	19.284
12.089-17.081		2	poor	38.567
17.081-24.332	19.284	3	moderate	57.851
24.332-32.414		4	good	77.135
32.414-39.784		5	very good	96.419
Lineament Density (LD) (km/$\mathbf{Km^2}$)				
0-0.022		1	very poor	12.856
0.022-0.054		2	poor	25.712
0.054-0.079	12.856	3	moderate	38.567
0.079-0.114		4	good	51.423
0.114-0.185		5	very good	64.279
Slope (SLO) (Degree)				
0-0.1		5	very good	48.209
0.1-0.2		4	good	38.567
0.2-0.3	9.642	3	moderate	28.926
0.3-0.5		2	poor	19.284
>0.5		1	very poor	9.642
Soil (SL) Classification				
Loam		2	poor	15.427
Loamy Sand		3	moderate	23.139
Sandy Loam	7.713	4	good	30.852
Sandy		5	very good	38.567
Clayey loam		1	very poor	7.713
Land use Land cover (LU/LC)				
Water		5	very good	32.140
Herbst wetland		5	very good	32.140
Herbaceous Vegetation		4	good	25.712
Cropland	6.428	3	moderate	19.284
Bare/ Sparse Vegetation		2	poor	٦12.85
Build up		1	Very poor	6.428
Drainage Density (DD) (km/$\mathbf{Km^2}$)				
0-1.754		5	very good	27.548
1.754-4.656		4	good	22.039
4.656-7.354	5.510	3	moderate	16.529
7.354-10.121		2	poor	11.019
10.121-17.205		1	very poor	5.510

4.2. Generation of Groundwater Potential Map

The study area was classified into five zones of groundwater availability using results from integrated Geographical Information Systems (GIS) and the Analytical Hierarchy Process (AHP) techniques. The overlay option in ArcGIS's spatial analysis tool was used to activate the union option. The seven layers were used as input to generate a new shapefile containing each of the seven weights in the attribute table. Subsequently, combine all seven weights to yield the final GPM within a ranking range of 1 to 5. The spatial distribution of groundwater potential zone (GWPZ) classes and their areal percentages are shown in Fig. 11.

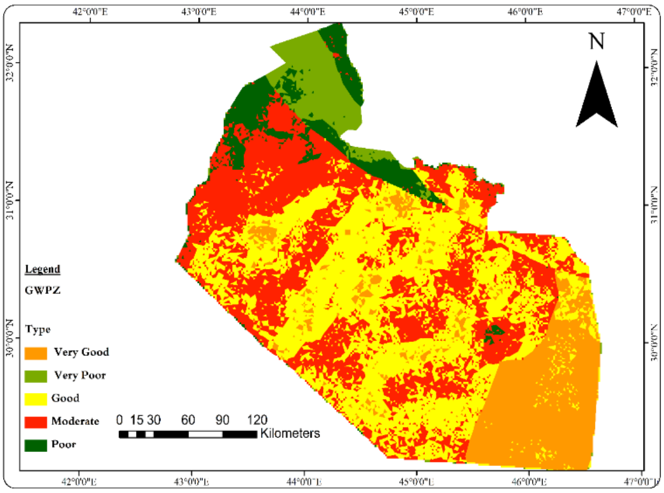

Fig. 11. Groundwater potential zones (GWPs) of the study area.

According to the results presented in Fig. 11, the classifications of groundwater potential zones (GWPZ), along with their respective percentages and total areas for each class in the study area, are detailed in Table 3.

Table 3. Groundwater potential zones of the study area.

Rank	Class attribution	Percentage Area	Area (km^2)
5	v.good	15.91	12208.51
4	Good	39.02	29942.26
3	Moderate	33.01	25326.31
2	Poor	6.49	4982.02
1	v.poor	5.57	4273.61

4.3. Verification of Groundwater Potential Zones

To assess groundwater potential, 349 wells were used as indicators of groundwater availability. The verification process involved analyzing yield data from the wells within the study area. The depths of the wells ranged from 75 to 346 meters, while their yield ranged from 0.002 to 0.02 $\mathrm{m^3/s}$. The well yield data were used to confirm the accuracy of the groundwater potential zones. The data of the wells in the study area were categorized into five categories (very poor) for pumping rates equal to or below 0.003 m^3/s, (poor) for pumping rates between 0.004 and 0.006 m^3/s, (moderate) for pumping rates between 0.007 and 0.009 m^3/s, (good) for pumping rate between 0.01 and 0.014 m^3/s and (very good) for pumping rates above 0.014

m^3/s. The number of wells with very poor, poor, moderate, good, and very good yields are (73, 32, 78, 138, and 28), with the proportion to the total wells (349) being (20.9, 9.2, 22.3, 39.5, and 8.0), respectively. A comparison was performed between the groundwater yields for each well and the corresponding groundwater potential zones to calculate the overall accuracy expressed as follows (Roy et al., 2020):

$$\text{Overall accuracy} = \frac{\text{No. of correct observation well location}}{\sum No.\text{ of observation well location}}$$

Thus, the total number of correctly observed wells' locations is 298. Therefore, the overall accuracy is calculated to be (85.4 %).

5. CONCLUSION

Groundwater availability in the Dammam confined aquifer within the study area was significantly influenced by the hydrological aquifer unit, transmissivity, lineament density, slope, soil type, land use and land cover, and drainage density. The normalized weights for these factors were determined using a pairwise comparison matrix (PCM) by integrating Geographical Information Systems (GIS) and the Analytical Hierarchy Process (AHP) techniques, which were found to be 38.567%, 19.284%, 12.856%, 9.642%, 7.713%, 6.428%, and 5.510%, respectively. The developed groundwater potential map (GPM) classifies the Dammam confined aquifer of the study area into five zones, including very good, good, moderate, poor, and very poor GWPZs. The distribution of these zones in terms of percentage to the total area of 76732.71 Km^2 is as follows:15.91%, 39.02%, 33.01%, 6.49%, and 5.57%, respectively. The AHP method accurately delineates a groundwater potential map with 85.4% accuracy. Specifically, out of 349 well locations, 298 were correctly identified using this method. The maps of groundwater potential zones have several critical applications, including groundwater management and planning such maps can be used to identify areas with high potential for groundwater availability, which can be used to guide decisions related to groundwater management and planning as well as to guide groundwater exploration activities, such as the siting of new groundwater wells, by identifying areas with high potential for groundwater availability.

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