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Delineation of Groundwater productivity Zones with the integration of GIS and Remote Sensing methods, Bazian Basin, Sulaymaniyah, Kurdistan Region, Iraq

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Abstract

Groundwater is an essential source of fresh water in the semiarid areas and it contributes to the water supply for several purposes. Bazian basin has become an attractive area for the large companies to invest especially the cement and Iron factories. Hence there is an intensive withdrawal of groundwater. The objectives of this work are to categorize and delineation the productivity areas with the aid of remote sensing and geographic information system methodologies.

The Analytica hierarchy process AHP method is used for mapping of groundwater potential zones which the most broadly used Multiple criteria decision analysis (MCDA) models. Six thematic layers are introduced to the GIS platform which area soil, drainage density, land use\land cover, geology, geomorphology, slope. Based on the relative effect of controlling groundwater productivity the input layers were ranked. Each factor is classified into classes based on hydrogeological properties. The importance of each thematic layer and its weight is discussed for the location groundwater potential zones using groundwater conditions. The results revealed three productivity areas, low, moderate, and high and they cover 20.14%, 38.5%, and 41.4% of the total area respectively. Besides, the northeast and southwest parts of the basin characterized by low groundwater potential while the moderate zone of the potential area covers the central and some part of the west of the area of interest. The model is validated by testing the available discharge of 78 wells, and it showed that most of the high yield wells are located inside the high groundwater potential zone. The validation results are verified that the groundwater productivity areas recognized by the GIS (AHP) method are reliable and practical.

Keywords: Potential Zones. AHP.GIS. Groundwater. Bazian. Kurdistan

Introduction

Groundwater is a unique freshwater that intrigues all living organisms including humans, plants, and fauna. The two most components of water are particularly quality and quantity. Ground and surface water resources in the Bazian basin, undergo increasing pressure caused by the expanding population, and agricultural activities. Moreover, the industries in Sulaymaniyah district are concentrating in this area for the last years. The presence of various natural resources in the Bazian basin has brought many huge companies to put their plants in the area and as their activities need a large quantity of fresh water, hence groundwater is a crucial resource in the area.

Generally, the traditional methods for water resources study and development are time-consuming, costly and sometimes unsuccessful. With the coming of powerful computers, progress in geographical information system (GIS), groundwater flow simulation codes, and astonishing artificial intelligent methods such as an artificial neural network (ANNs) and fuzzy inference, effective and powerful techniques for water resources management have developed [1, 2]. The broadest method used for delineation of groundwater potential zones and environmental management is and Analytical Hierarchy Process (AHP) and multiple-criteria decision analysis (MCDA) models [3]. In this method, specialists can observe the relevant significance of thematic layers for evaluation of groundwater potential [4, 5]. [6] investigated the importance of the MCDA techniques in water resource management and proved that the AHP is popular and rising. [7] revealed that GIS analysis has immeasurable functionality for delineation groundwater recharge zone. From the mentioned literature it can be seen that the GIS and AHP techniques have been broadly used in groundwater potential evaluation [8].

Groundwater is more productive than surface water, although groundwater resources have not still completely used. The current study attempts to evaluate groundwater availability in the Bazian basin by selecting and delineating different potential areas using remote sensing and geographic information system (GIS) techniques. The porosity and permeability of geological units are controlled by the movement of groundwater. The surface hydrological characteristics perform an important role in groundwater replenishment. Steep slopes and high relief permit larger amounts of runoff, but the topographical depressions support enhancing infiltration. The area with higher drainage density has higher runoff while low drainage density area is vice versa [9]. Surface water bodies like rivers, ponds, etc. can serve as recharge zones improving the groundwater potential in the region. Hence, the description and quantization of these points are important in creating the groundwater potential design of a particular area [10, 11]. The GIS tool is considered the most powerful one, for analysis and combination of multi-thematic layers for delineating groundwater productivity zones [12, 13, 14, 15; 16, 17, 18]. The previous studies revealed that the combination of remote sensing and GIS methods improves groundwater investigation focusing on the target areas for manipulating complete hydrogeological and geophysical surveys on the ground [19]. Remote sensing is an excellent tool which can be used for getting the problems of groundwater study. In the past few years remote sensing and satellite data in recent years, satellite, remote sensing data has been widely applied in determining groundwater potential areas. Remote sensing data is considered reliable and timely;

besides it is cost-effective for the essential requirements of data in the GIS domain

Location of the study area

The study area is located about 25 km west of Sulaymaniyah City. Geographically, the area is bounded between the latitude N 35º 29′ 50″ and N 35º 42′ 45″ and the longitude E 44º 57′ 30″ and E 45º 16′ 25″. The basin occupied an area of about 242 km². Most of the study area considered as fertilizing agricultural plane occupying about 150 km^2. Fig (1).

The dominant climate in the study area is semi-arid conditions and the summer of Kurdistan is influenced by Mediterranean anti-cyclones and sub-tropical high-pressure belts moving from the west, south-west to north [20]. According to the long-term data obtained from Sulaymaniyah Meteorological Station, the minimum degree was 6 °C in January and the maximum average monthly temperature was 32.4 °C in August. The annual precipitation for the period of 1941-2019 over the area is 702 mm/year. The maximum average monthly pan evaporation of the area was 349 mm in August and the minimum was 49 mm in December.

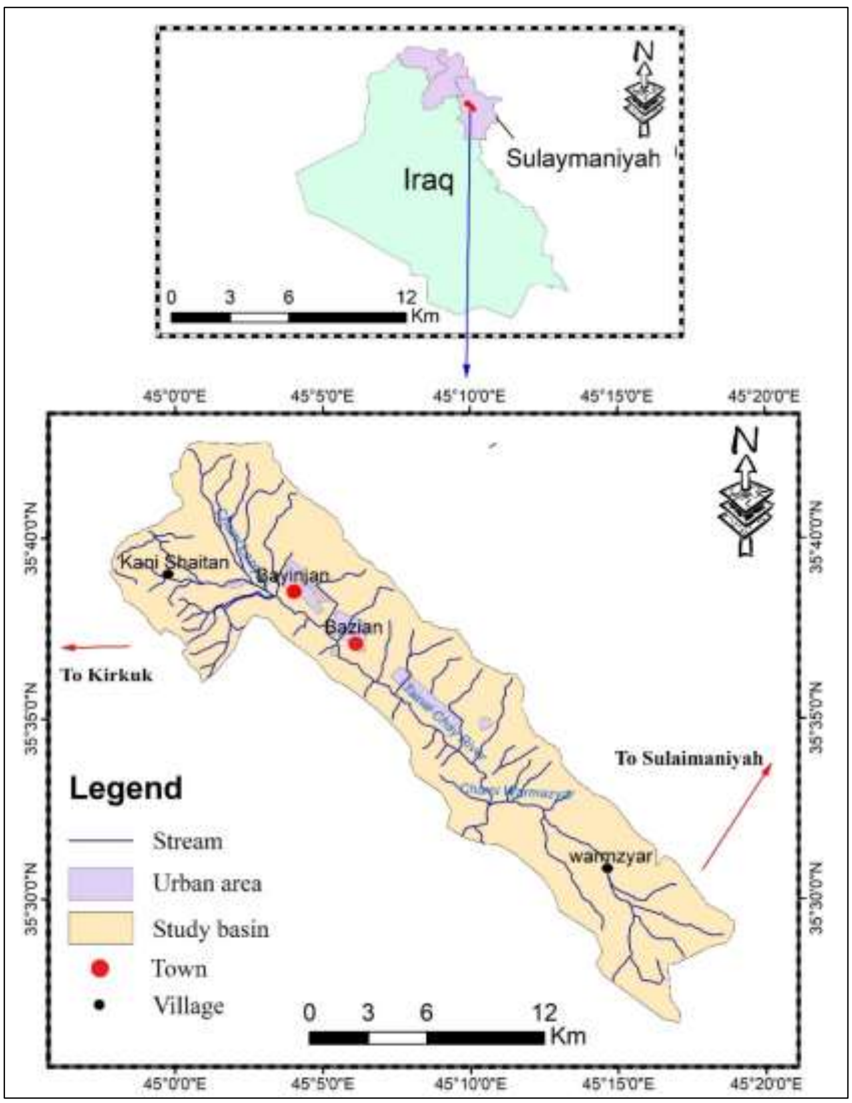

Figure 1- Location map of the study area

Geological and hydrogeological setting

The previous studies like [20, 21, 22] are used for the description of the geological setting of the study area, Fig.4 a. The oldest formation exposed in the area is Kolosh Formation, while the youngest one is recent deposits that belong to Holocene. Kolosh Formation (Paleocene-Eocene) is comprised of grey calcareous shale; sandy limestone, sandstone, and siltstone, its thickness is reached 600 m at the Bazian Oil Company well. Sinjar Formation is of Early Eocene, mainly comprised of massive yellowish-gray limestone, conglomeratic limestone, sandy limestone. According to [23], the thickness of this formation in the Bazizn b area is nearly 98 m, while [22] mentioned that the thickness varies between 50 m and 70 m. The Middle Eocene formation represented by Gercus Formation which comprised of consolidated red mudstones, gray sandstone with lenses of basal conglomerate bed at the top, showing unconformity with Pila Spi Formation, and green marl. Based on two geo-electrical sections carried out through the Hanjeera subbasin the thickness of this formation is about 80 m [2]. Pila Spi Formation (Middle-Upper Eocene) is comprised of well-bedded limestone, dolomitic and chalky limestone. The thickness of Pila Spi varies between 100-200 m [24], but according to [20] who drawn an isopach map the thickness ranges from 20 m to 130 m. Quaternary deposit which covers most of the catchment area is the youngest [25], it comprises deposits of river terraces, flood plains, alluvial fans, and slope deposits.The detail of the geological formations in the study area is presented in the Table.1

Table1-Lithostratigraphy of the exposed geological formations [22]

Period	Formation	Lithology & Description	Thickness (m)
Pleistocene and Holocene	Quaternary deposits	consist of river terraces, slope deposits, alluvial deposits and composed of mud, silt, sand, and gravel (It is mainly composed of pure clay inter-bedded with a variable thickness of coarse material such as gravel and sand.	150
Middle – Upper Eocene	Pila Spi	It consists of well bedded, highly fractured limestone, dolomitic limestone, dolomite and chalky limestone. The upper contact of the Pila Spi Formation with the Fat'ha (Lower Fars) Formation is unconformable.	80
Middle Eocene	Gercus	It consists of red clastic sequence of pinkish red to purple siltstone and claystone alternating with green marl, grey to reddish brown coarse-grained sandstone with conglomerate bed at the bottom of sandstone beds. The upper contact is unconformable with Pila Spi Formation.	80
Early Eocene	Sinjar	It is mainly composed of massive yellowish gray limestone, sandy limestone and conglomeratic limestone from algal reef and shoal nummulitic facies, The upper contact is unconformable with Gercus formation	98
Paleocene - Lower Eocene	Kolosh	its upper part exposed in the area consists of gray to dark gray calcareous shale alternating with siltstone and silty marlstone, greenish gray calcareous sandstone, pebbly sandstone and sandy limestone (rich in fossils). The lower contact is not exposed. The upper contact is gradational conformable contact with Sinjar Formation. Inter-fingering is the main characteristics of this formation with overlain Sinjar limestone.	600

The hydrogeology of the area characterized by existing two aquifer systems in the study area which are Quaternary intergranular aquifer, and Eocene karstic fissured aquifer (EKFA), [26], Fig. (2). The dominant aquifer in the study area is Quaternary intergranular aquifer which occupying a surface area of 133.9 km2 (% 55.3), the thickness of this aquifer varies from few meters to more than 100 m [22]. However, the geoelectrical survey conducted by [20] near Baynjan town obtained the thickness of this layer to be 150 m. Eocene karstic fissured aquifer is heterogeneous and anisotropic aquifers which are represented by Sinjar and Pila Spi formations covering approximately 40 % of the total area and it is identified as a very good aquifer [22]. The two aquifer systems usually distinguished by high transmissivity and highly fissured with many high-density fractures which can be distinguished from karstic aquifer lesser extent in their fracture. Each type of aquifer has its characteristics, which is studied to evaluate groundwater productivity.

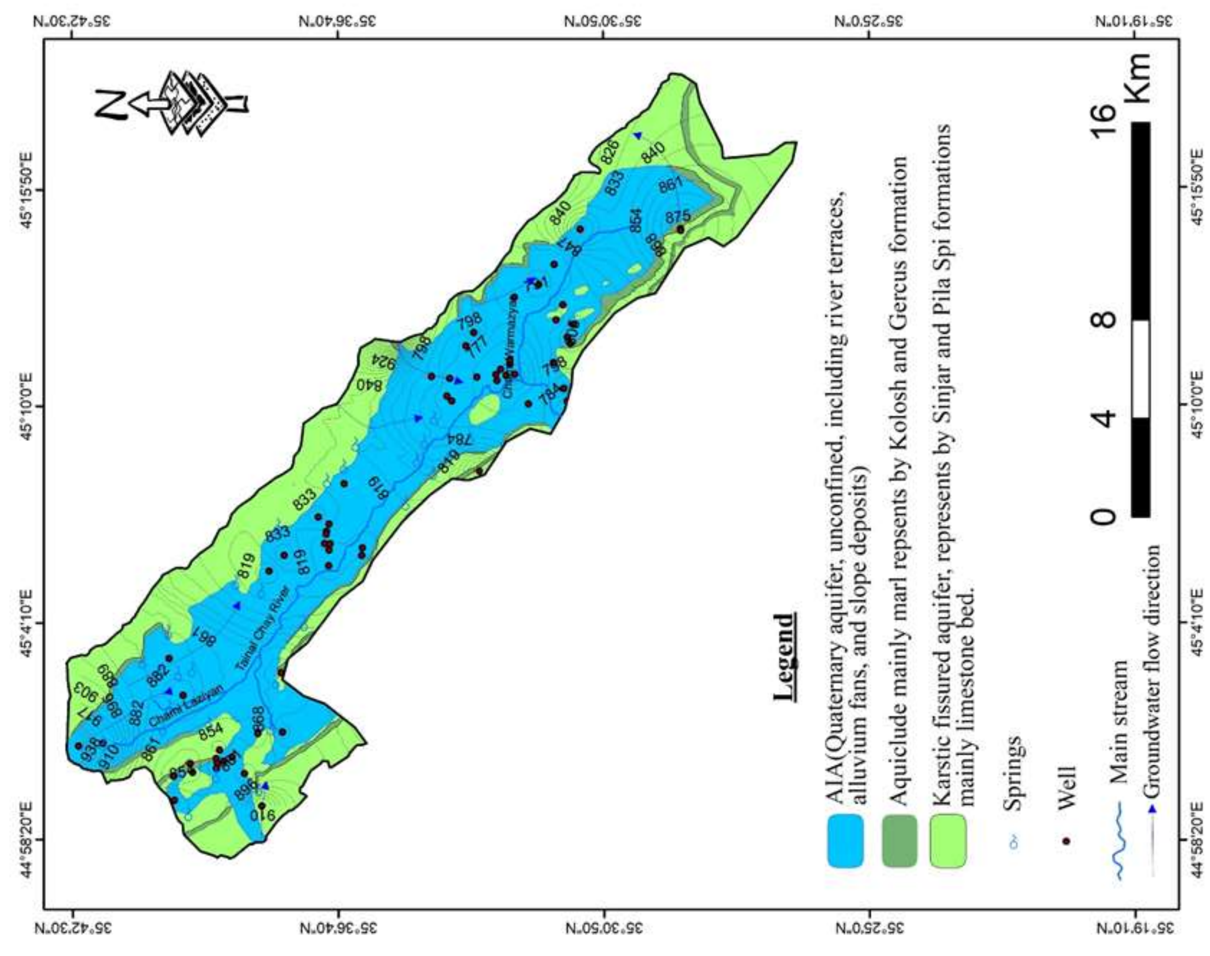

Figure 2- Hydrogeological map of the study area

Materials and methods

The method of the current study is utilized and covered by the evaluation of obtained field data and desk studies. The work procedures and steps are presented in (Fig.3). Desk studies include the review of the previous scale of maps, reviewing vertical electrical sounding (VES) which is carried by [20]. Continuous readings water table depth beginning on 3rd November 2018 through 10th May 2019 from tube wells and the obtained readings is used for drawing water table map.

To delineate groundwater potential areas many datasets have been used which are previous maps, Satellite data, the Landsat 8, Quick Bird on updating July 2018, and SRTM (DEM 15). The thematic maps of lineament density, drainage density, slope, and soil are prepared via ArcGIS 10.6. Besides; Landsat TM 30 m was used for preparing land use and land cover thematic layer of land use and land cover was prepared by using Landsat TM 30 m. The US Geological Survey (USGS) system is used for land use and land cover classification. The source geological map of Sulaymaniyah district on the scale of 1:250000 which provided by Geological Survey (GEOSURV) is used for preparing the geological map of the area. The soil type map is prepared depending on the FAO (2002) soil map of Iraq. For each input factor, a thematic map is prepared from different sources like geology map, records of water wells, and satellite. The ranking for the input layers is assigned depending on its relevant value in controlling groundwater potential [27, 28]. The thematic maps should be evaluated for their reflection of the relative importance, after that it is integrated into GIS with the aid of AHP with personal experience based on the expert's judgment. The AHP method is developed by [29] gives a manageable and simply understood the way of study to complex problems. The technique is considered as a multiple criteria decision-making that enables subjective as well as objective features to be viewed in the decision-making process ،30] .[32 ،31

Expert Choice 11 is used for weights calculated for each thematic map which is the results of the pair-wise correlation of each map based on their comparative importance to groundwater occurrence [33,34, 32]. The weighted of selected thematic maps lineament, geology, slope, soil, land use/land cover (LU/LC), and drainage density were obtained that show the importance of these maps in groundwater potentiality of the study area as shown in Table 1 and Fig.3. The highest value is assigned to the geology as it is the most important factor controlling groundwater potential area, while the drainage density layer has the lowest weight and the least importance .

The groundwater controlling features are converted into a raster format with the pixel size (30 × 30). All seven layers classified for raster for defining five classes of geology, four classes of drainage density, four classes of lineament density, four classes of the slope, six classes of LU/LC, and six classes of soil. Besides, the raster maps are reclassified to set a weight factor for each map. The reclassified maps overlay in terms of the weighted overlay method using a spatial analyst tool in ArcGIS 10.6. The weights of the different themes were assigned on a scale of 1 to 6 based on their impact on groundwater evolution. Expert Choice 11 software is used for assigning proper weights for the six themes and their individual features. The assigned weights for different themes are shown in Table (1). Eventually, the groundwater potential map is made in terms of high, moderate, and low. Moreover, the output is verified by carrying a field survey by selecting wells randomly in different locations .

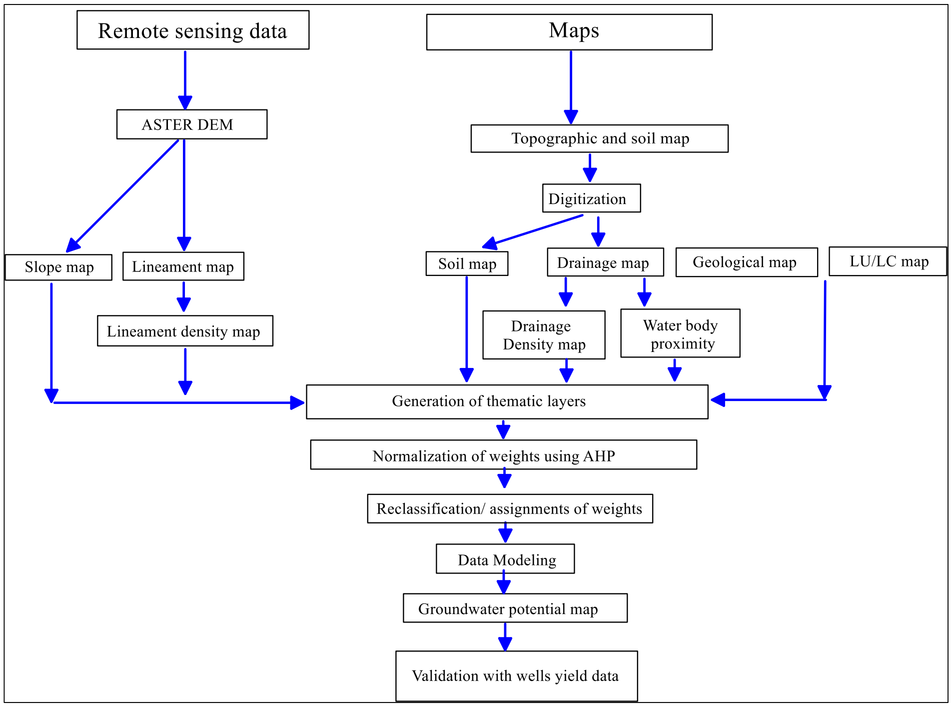

Figure 3- Flow chart showing groundwater potential mapping methodology

Groundwater potential factor maps

The selection factors and their value for identifying the groundwater potential zones depend on the available data in the area of interest. Based on the accessible data, six factors are used for generating the groundwater potential map [20, 22]. The weights of the factors were evaluated and scored based on the characteristics of the area. For groundwater potential zones and the score under various characteristics were evaluated based on the characteristics of the study area. These factors include geology, land use/cover, lineaments, drainage density, soil, and slope. Digitizing of geographic, hydrologic information, and basic database was performed by the GIS platform. Subsequently, the spatial analysis function was used to describe the groundwater potential zones of the study area. The six influenced input layers are prepared in order of their ranked importance in controlling groundwater potential, the prepared layers are listed below.

1. Geological map

The primary porosity and permeability of rocks are controlled by the nature of the geological succession of the area. Rocks with higher porosity have good groundwater storage, while higher permeability gives higher yields. The maximum rating value of 5 was assigned for the Quaternary deposit (Table 1 and Fig.4) due to its sympathetic characters for groundwater accumulation owing to their primary porosities and permeability, a geological map of the area was rearranged and presented in Fig. (5.A).

Table2- Rank and weights of factors in AHP method

Theme	Class/Feature	Layer's weight	Assigned rank	Weight% (Feature normalized)
Geology	Quaternary	35	5	37.9
	Pila Spi		4	36.9
	Sinjar		3	15
	Gercus		1	5.1
	Kolosh		1	5.1
Lineament density	0-0.59	28	1	5
	0.6-1.2		2	15
	1.3-1.8		3	30
	1.9-2.4		4	50
Slope (degree)	0-7.6	14.9	4	50
	7.7-18		3	30
	19-53		2	15
	54-88		1	5
Soil	Loam and sandy loam	7.8	4	50
	silty loam		3	30
	clay loam		2	10
	Thin or absent soil cover		1	10
LU/LC	Water	8.8	7	50
	Forest		6	15
	Grassland		4	8
	Cropland		4	8
	Shrubland		3	8
	Bareland		3	8
	Impervious surface		1	3
Drainage density	0-0.26	5.5	4	50
	0.27-0.74		3	30
	0.75-1.3		2	10
	1.4-2.7		1	10

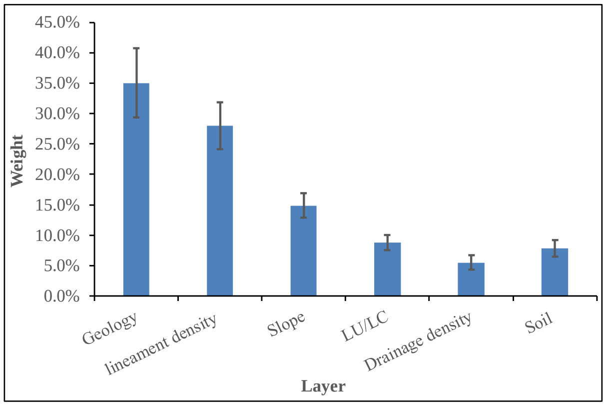

Figure 4- Layer's weights in AHP method

2. Lineament density map

Remote sensing is successfully used for fracture systems recognition. Despite, the real fracture systems are remarked as linear features on satellite images; consequently, these features are distinguished as "lineaments". Normally, a lineament is defined as any visible geomorphic linear feature that can be associated with geological structures, reputably fractures or lithologic contacts fault, fracture, joint, topographical line, and water conduit [35, 36, 37]. The higher density of lineaments means high permeability and porosity in rocks and vice versa and therefore it enhanced groundwater occurrence and movement [38, 27, 37].

The detectable linear feature from satellite images has various orientations and sizes. The produced lineaments map is shown in (Fig.5B). This map displays only the spatial distribution and dimensions of linear features; the density (i.e., concentration) cannot be directly figured out. For harmonizing the spatial distribution of lineaments, a number of steps are applied similar to those done by many researchers [39, 14]. A specific frame (5 km × 5 km) is put for classification of the area and then the number of lineaments in any frame was counted. The lineament density map is classified into four classes. Each class designates a variety of lineament density, which describes the number of lineaments per unit area (25 km^2) as presented in table 1 and Fig. 5B.

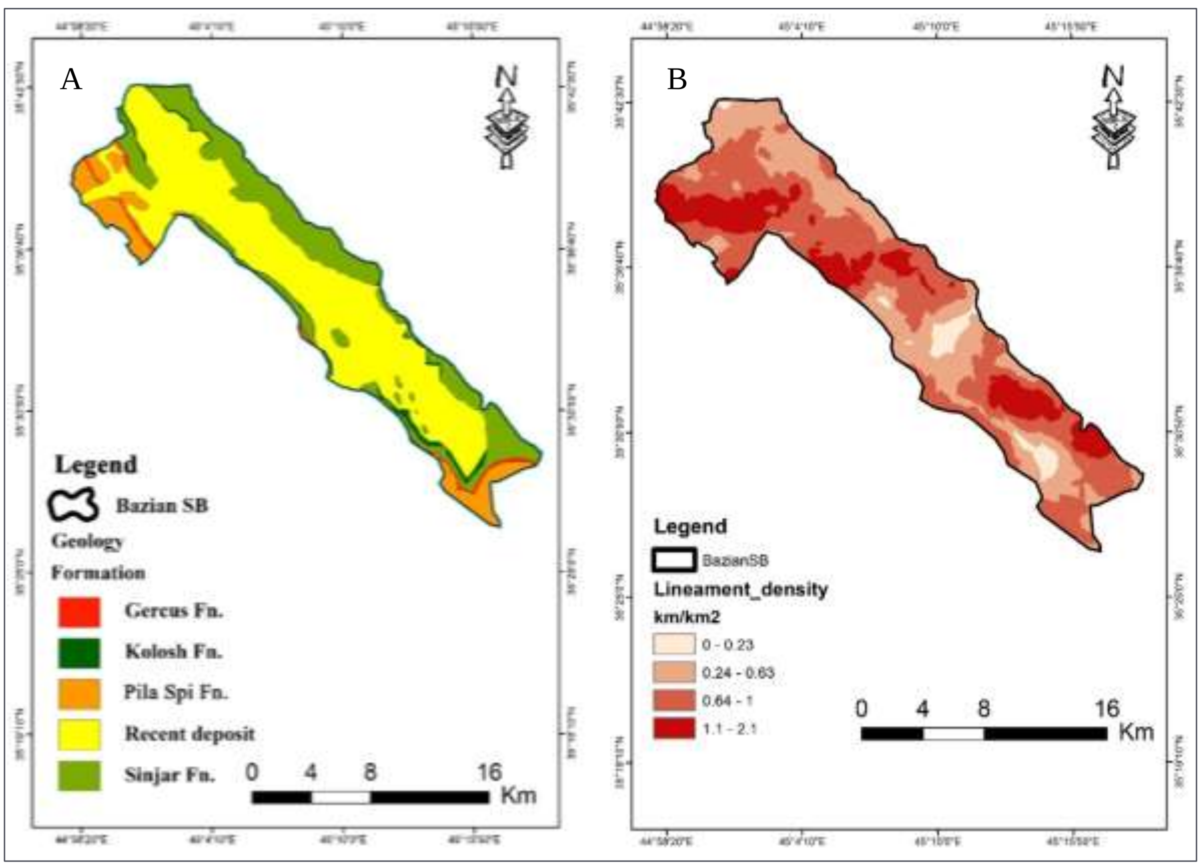

Figure 5- A. Geology B. Lineaments density maps of the area

3. Slope map

This factor is very important for increasing groundwater study and reduction of vertical percolation, and hence increasing recharge rate, especially in the flat areas and should be included in the controlling factors of groundwater potential mapping. However, many previous studies neglected this factor like [14, 15]. The slope gradient directly affects the infiltration of rainfall. Higher slopes allow a smaller recharge because the water flows quickly down a steep slope during rainfall, so it does not have enough time to infiltrate the surface and recharge the saturated zone [40]. A digital elevation model (DEM 15m) is used for slope map generation, and four slope classes were discriminated from the output map (Fig. 6 A). The classification was adapted from the SOTER (SOils and TERain) model [41], where the maximum slope that influences terrain is 60%. Table 2 shows the slope classification and the descriptions according to the SOTER model. The slope of the study area is classified into four classes as presented in table 1 and Fig.6 A.

Table 2- SOTER Slope classification system [41]

Slope (%)	Description	Potentiality for groundwater storage
<2	Flat	Very high
2–8	Undulating	High
8–15	Rolling	Moderate
15–30	Moderately steep	Low
>30	Steep	Very low

4. Soil map

The variety of soil influences groundwater and can show the existence of groundwater. The soil of the study area classified into four according to the soil map of (FAO, 2001), Table 1 and Fig.6 B. The general categories of soil types into various groups as used in the calculation of available water capacity of the root zone and implied in [42] of soil texture and vegetation combination, fine sand, fine sandy loam, silt loam, and clay loam are considered

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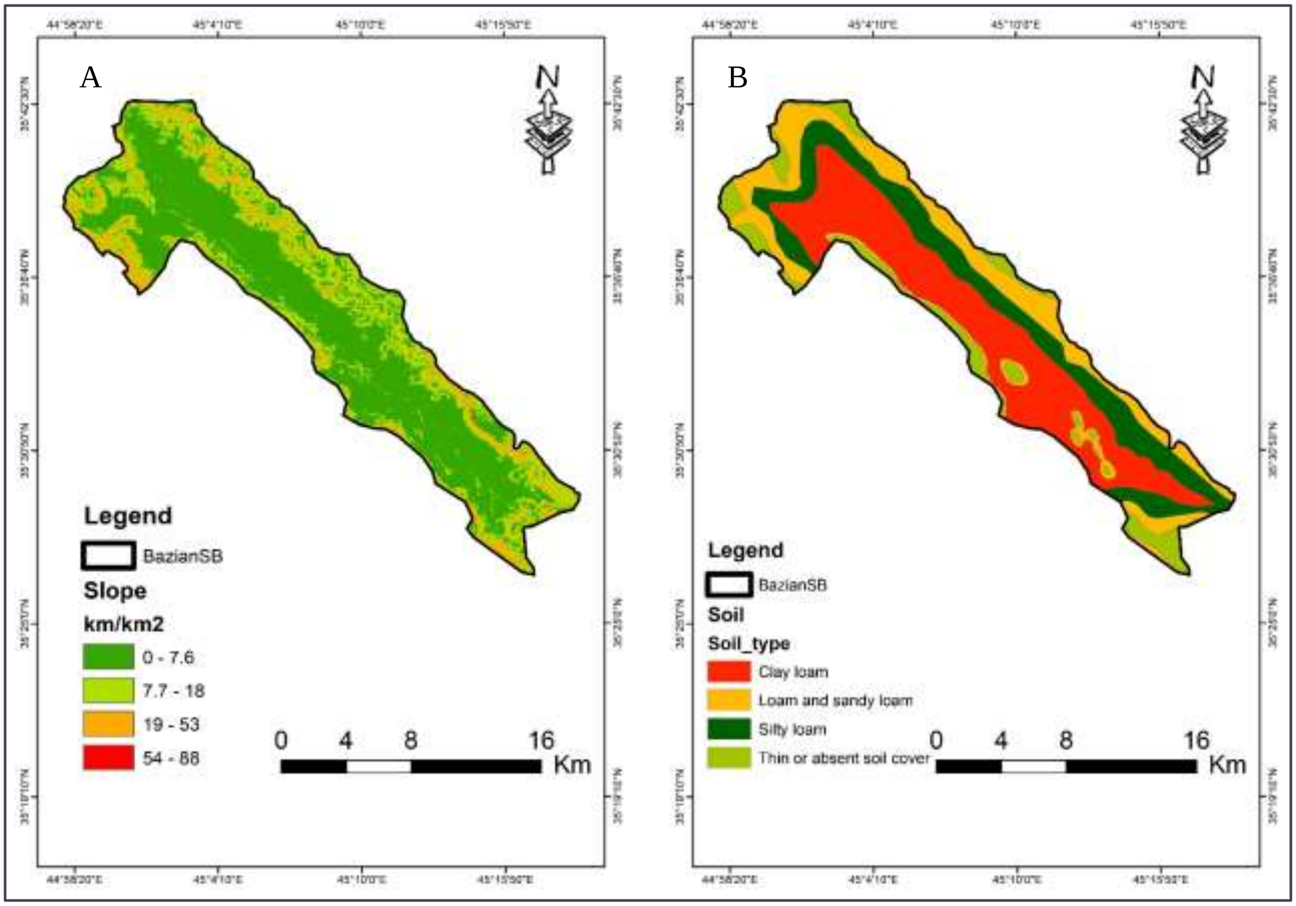


Figure 6- A. Slop B. Soil maps of the area

5. Land use and land cover map

The LU/LC factor has an impact on the occurrence of groundwater, it minimizes runoff, and increasing infiltration water and ultimately the recharge rate will increase. It determines the volume of rainfall that percolates to the groundwater, for example in the urban area when it covered by dense vegetation the interception rainfall over the ground is available for groundwater recharge .[27]

The lu/lc map is prepared from landsat-8 images by radiance calibration and atmospheric correction. For this analysis, envi 5.1 software implemented, later some points were added as training samples, and supervised classification was conducted by the maximum likelihood method [28]. Hence, the study area classified into seven classes including cropland, forest, grassland, shrubland, water, impervious surface, and bare fig.7 a. Each of the class has a weighted value with representing priority effect on groundwater accumulation, table 1**.**

6. Drainage density map

Drainage density is an indicator of the infiltration, permeability, and recharge capacity of rock units. [27]. Lower drainage density indicates more groundwater recharge and higher potential area and vice versa. The drainage density was calculated from the alos palsar dem data by using spatial analyst extension inside arcmap version 10.6. The study area classified into four class and each class has given a weighted value which shows in table 1 and fig.7 b. Commonly, the value is ranged from less than 0.1 km/km^2 to 2.7 km/km^2.

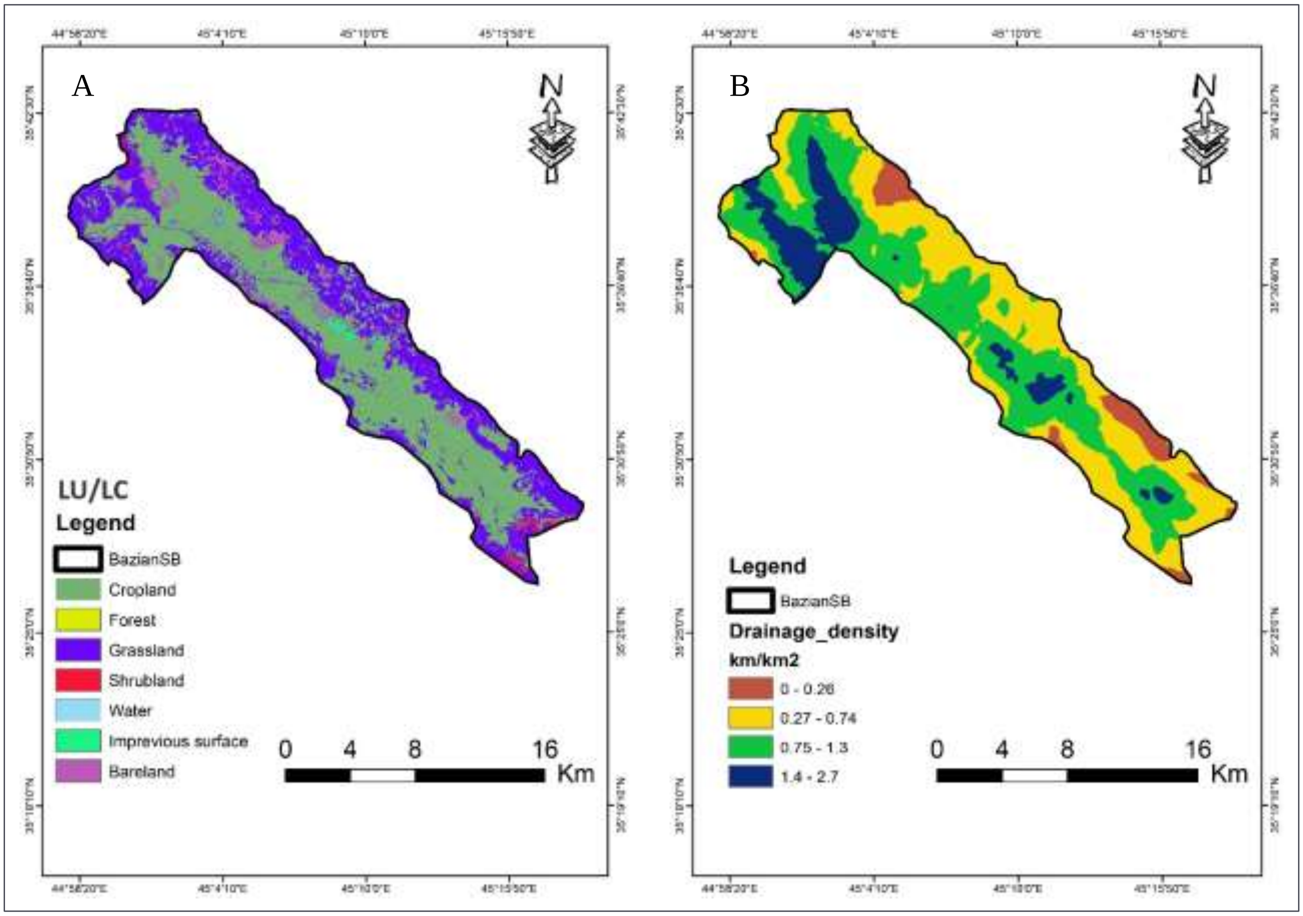


FIGURE 7- A. LAND USE AND LAND COVER B. DRAINAGE DENSITY MAPS OF THE AREA

RESULTS AND DISCUSSION

ASSIGNING WEIGHTS USING AHP

The ahp performs in expert choice ec 2000™ software. This software is an effective application that empowers teams to prioritize objectives and assess choices and accomplish alignment, buy-in, and confidence around significant organizational decisions [43]. Pair-wise comparison was calculated for all 6 layers (geology, lineament density, slope, soil, lu/lc, and drainage density), and the reclassified map of them produced based on the weights computed of the selected maps. The weights were assigned according to the relative importance of them, table 3. After introducing weights for the thematic maps and their attributes, and the data sets were combined in gis using equation (1), a model built in the arcgis modelbuilder engine, figure (8). The final groundwater potential map, figure (8), for the study area, is produced by linear weighted combination using equation (1).

$$GWPI = \sum_{j=1}^{m} \sum_{i=1}^{n} (wj * xi)\ldots\ldots\ldots (1)$$

Where gwpi is groundwater potential index, xi is the normalized weight of the *i*th class/feature of the theme, wj is the normalized weight of the *j*th theme, m is the total number of themes, and *n* is the total number of classes in a theme.

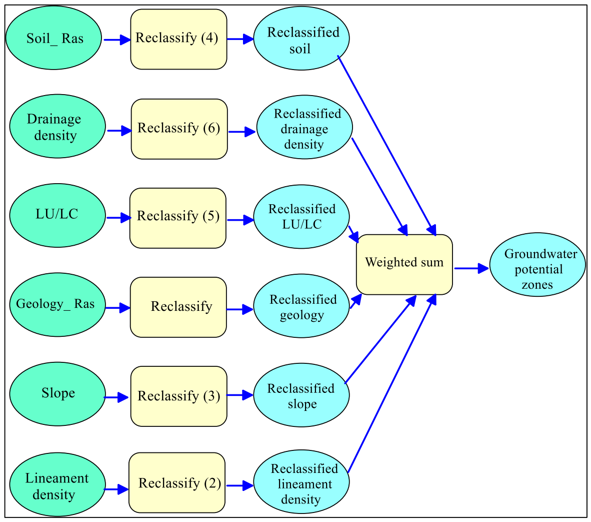


FIGURE 8- groundwater potential model of the study area

Based on the calculation of pair-wise comparison for the input layers, the generated maps were reclassified depending on the weights computed, fig 9, 10, and 11. All weights for the input layers of the study area is presented in tables (1).the consistency ratios are determined for the assigned weights for thematic maps and their attributes and it found to be less than10 % and through implying that the assigned weights are consistent [44].

TABLE 3- PAIR-WISE COMPARISON OF MAPS AND NORMALIZED WEIGHTS

THEMES	GEOLOG	LINEAM	SLOPE	LU/LC	DRAINA	SOIL
GEOLOGY	1	1	3	4	7	4
LINEAMENT		1	2	3	5	3
SLOPE			1	2	3	2
LU/LC				1	2	1
DRAINAGE					1	1
SOIL						1

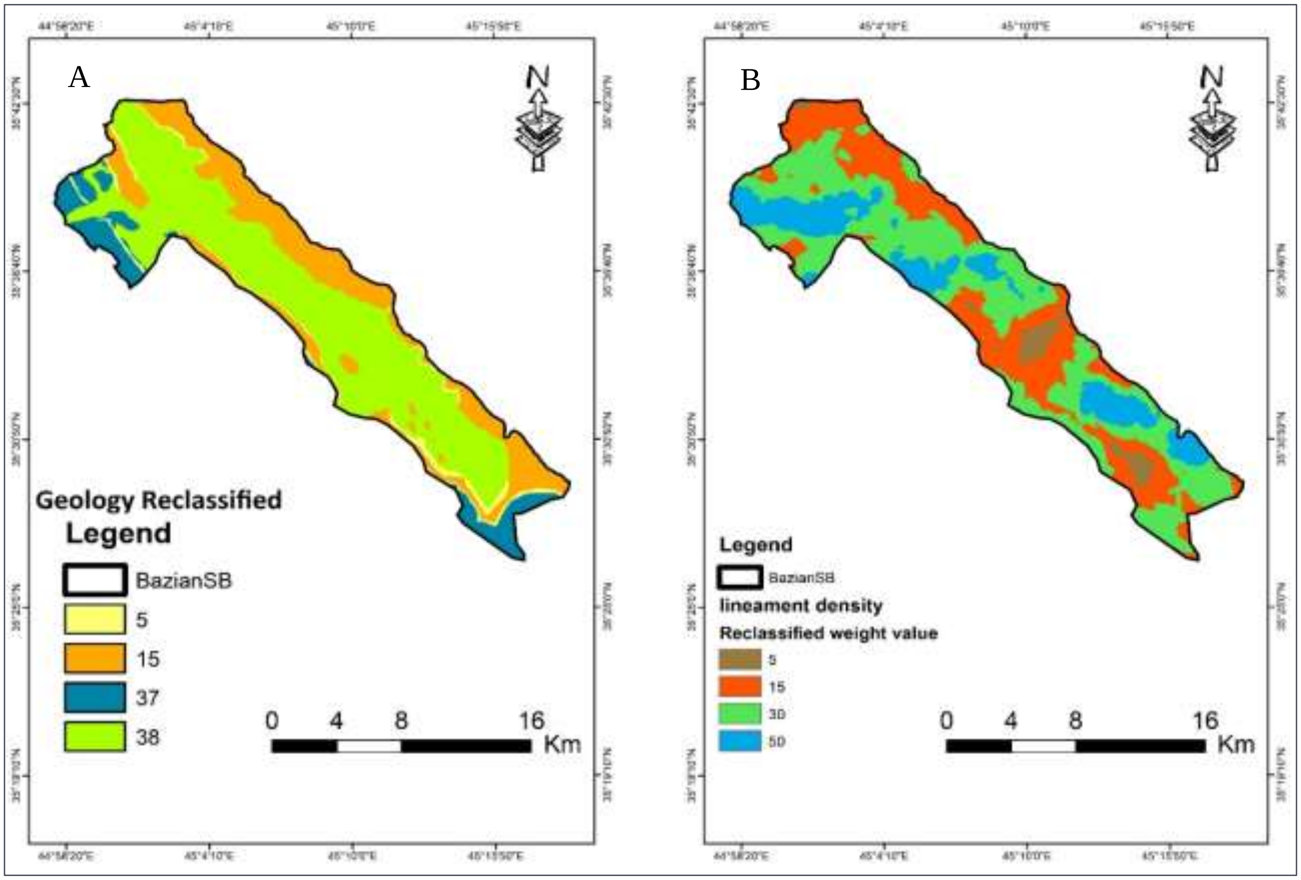
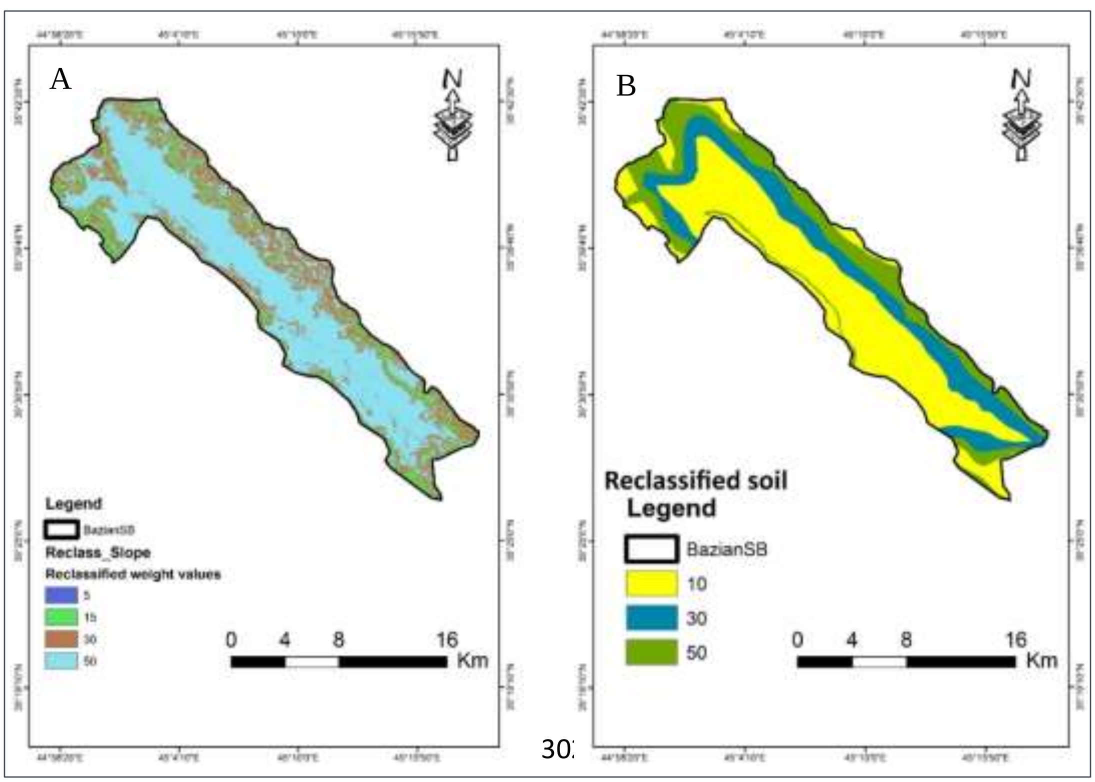


FIGURE 9- RECLASSIFIED MAP OF THEMATIC LAYERS A. GEOLOGY B. LINEAMENTS



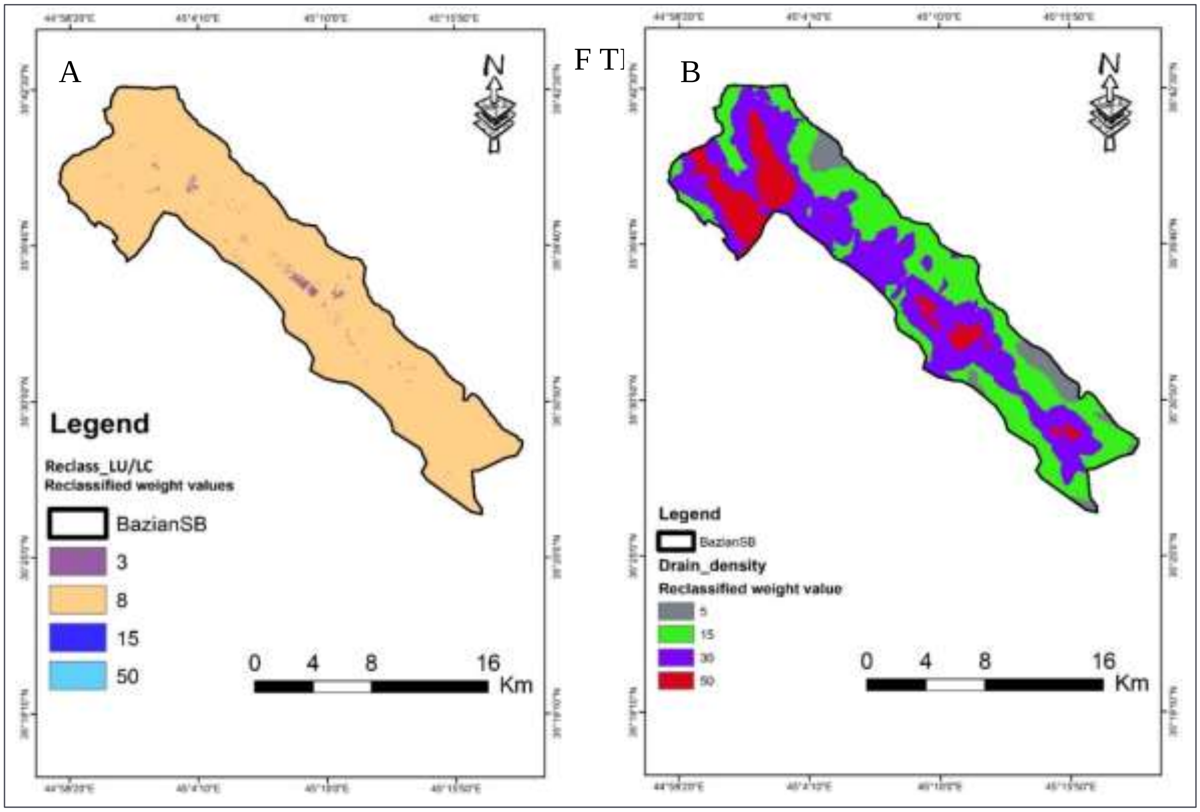


Figure 11- Reclassified map of thematic layers A. LU/LC B. Drainage Density

Groundwater potential map

The final map of potential zones was generated using the GIS-based AHP and grid procedures (Fig.12). According to the AHP method, three zones are identified depending on GWP values, which are: poor, moderate, and good classes. It is obvious that the good potential zones are found at the central and west parts of the basin which represents by Quaternary aquifer and covers 41.4% of the total area. Moreover, the northeast and southwest parts of the basin characterized by low groundwater potential and cover 20.14% of the study area due to the steep slope, denser drainage, and low permeability of rocks. The moderate zone of the potential area covers 38.5% of the area of interest.

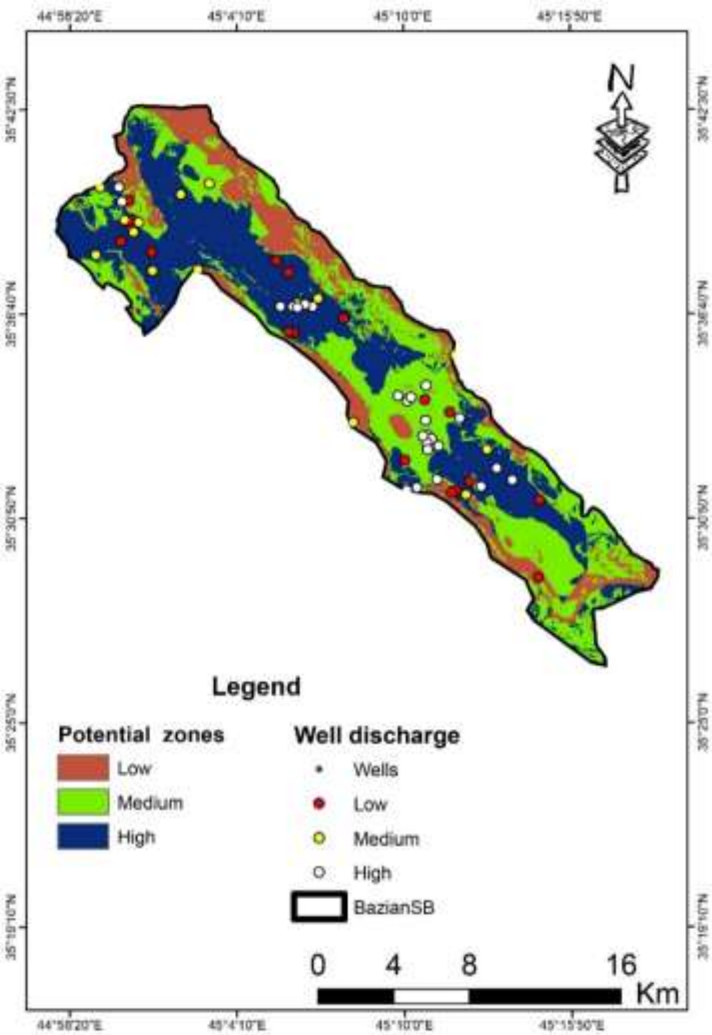


Figure 12- Groundwater potential map and distribution of extraction wells of the study area

Model validation and verification

The validation process for any model is required and is considered the basic method, the model is assumed to be scientifically useless without validation. The validation is done by comparing the drilled well yield data of the study area and the potential map obtained by the AHP method to the receiver operating characteristic (ROC) analysis [45, 46].

The discharge data from 78 wells were evaluated which have been drilled in the study area. The data were classified into three classes, good (>3.5 l/s), moderate (1.5–3.5 l/s), and poor yield (<1.5 l/s). The 46.8 % of wells are of good yield, 17 % of wells are of moderate yield, and 36.4% of wells with poor yield.

Despite this, there are few wells in a high groundwater potential zone characterized by poor yield due to the Quaternary clay barrier. Thus, the frequency of existence of good yielding wells decreases from high groundwater potential zone to low groundwater potential zone in agreement with the GIS evaluation of the groundwater potential of the study area.

As can be noted, some wells in the low groundwater potential zone have a good yield due to the presence of these wells near lineament. Based on these findings, it can be understood that the groundwater potential zones recognized by GIS and AHP techniques are reliable and representative. The model generated would help as a guide for designing a suitable groundwater exploration plan in the future and thereby help efficient planning of scarce groundwater in the study area.

The features of high to low groundwater potential zones are compatible with the GIS-based potential zones. Figure 7 shows the groundwater potential area verification; it is obvious that the model gives a guideline for designing a proper groundwater exploration program in the future [30].

The spatial distribution of the different groundwater potential zones shows patterns of geology, slope, lineaments, soil, LU/LC, and drainage. The high potential area is located along with Quaternary sediments with very high lineament density, depositional pediment, and low slope [30]. The medium potential area is associated with increases the lineament density, slope, and landform. The low potential zone is located mainly along structural ridges and monoclonal ridge and, to some extent, along less dense lineaments with high to a very high slope degree.

Conclusion

The GIS-based AHP method was used to delineate the groundwater productivity zone for the area of interest.

The weighted index overlay model has been found very useful in the mapping of groundwater prospective zones. The analysis and output of this method reveal three distinct zones representing high, moderate, and low groundwater potential zones. The final potential map is verified using the yield of 78 drilled wells in the area. Based on verification, it can be concluded that the groundwater potential zones identified by GIS and AHP techniques are reliable and representative. The Bazian area is covered mostly by a moderate zone while a small part is covered with the low zone from the south and from the west. Considerable areas of the center of the basin are covered by high zone, this is due to existing a very large unexpected thickness of recent sediments in the area, it ranges between 52-165 m. The largest thickness of this sediment appears at the center of the basin.

The output of this study showed that the AHP method is a successful approach for groundwater potential mapping. Onward, the resulting map can be helpful for planners in water resource management and overall evaluation of groundwater investigation development for prospective planning.

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رسم أنطقه وفرة المياه الجوفية باستخدام تقنيات نظم المعلومات الجغرافية والاستشعار عن بعد، حوض بازيان، السليمانية، اقليم كردستان، العراق

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الخلاصه:

تعتبر المياه الجوفية هي مصدر أساسي للمياه العذبة في المناطق شبه جافة وتساهم في توفير المياه لعدة أغراض. أصبح حوض بازيان منطقة جذابة للشركات الكبيرة للاستثمار خاصة مصانع الأسمنت والحديد. وبالتالي هناك سحب مكثف للمياه الجوفية. يهدف البحث الى رسم وتصنيف الانطقة الانتاجية بمساعدة الاستشعار عن بعد ومنهجيات نظام المعلومات الجغرافية.

تم استخدام طريقة AHP لرسم خرائط مناطق وفرة المياه الجوفية والتي تستخدم نماذج تحليل قرار المعايير المتعددة (MCDA) الأكثر استخدامًا على نطاق واسع. تم ادخال ست طبقات مواضيعية لبرنامج نظم المعلومات الجغرافية وهي مساحة التربة وكثافة الصرف واستخدام الأرض / الغطاء الأرضي والجيولوجيا والجيومورفولوجيا والمنحدر . تم تصنيف طبقات وفقًا لتأثيرها في التحكم في وفرة المياه الجوفية. تم تصنيف كل عامل في فئات على أساس الخصائص الهيدروجيولوجية. وتناقش أهمية كل طبقة موضوعية ووزنها لمواقع مناطق وفرة المياه الجوفية باستخدام ظروف المياه الجوفية.

كشفت النتائج عن ثلاثة انطقة إنتاجية، منخفضة، معتدلة، وعالية تغطي 20.14٪، 38.5٪، 41.4٪ من إجمالي المساحة على التوالي. علاوة على ذلك، تتميز الأجزاء الشمالية الشرقية والجنوبية الغربية من الحوض بإمكانيات منخفضة للمياه الجوفية بينما تغطي المنطقة المعتدلة مركز الحوض وبعض الاجزاء الغربية من منطقة .

تم التحقق من صحة النموذج من خلال اختبار التصريف المتاح لـ 78 بئرًا، وأظهر أن معظم الآبار عالية الإنتاجية تقع داخل النطاق العالي لوفرة المياه الجوفية. تؤكد صحة النتائج هذه أن مناطق إنتاجية المياه الجوفية المستنبطة بواسطة طريقة GIS (AHP)هي نتائج موثوقة وعملية.