Potential Areas For Groundwater Using Geographic Information Systems And Hierarchical Analysis Technology: Figuig Oasis as an example

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Abstract :

The excessive and unreasonable exploitation of groundwater has led to increasing pressure, with an increase in the demand for drinking water. In return, the need to know the available water potential has increased in order to better management resources in the future. And to prevent any problem that may be caused by a lack of groundwater, especially in a semi-arid area such as the oasis city of Figuig, which does not have surface water throughout the year to meet various purposes, and therefore residents in such areas must rely more on groundwater resources from For their survival.

On this basis, studies based on geographic information systems have gained great importance in exploring subterranean resources due to their processing and the rapid availability of data for further developments about the status of subterranean resources. Therefore, this study was conducted at the level of the oasis city of Figuig, with the aim of determining its available groundwater potential.

Keywords: figuig-groundwater- Hierarchical Analysis Technology-resources

1- **Introducing the studied field:**

1.1: Geographic data

On the Algerian-Moroccan border, Figuig is located 380 kilometers east of Errachidia and 376 kilometers south of the city of Oujda, the capital of the Oriental region. On National Road No. 17, which crosses the city of Bouarfa, its last stage is 100 kilometers before Figuig. It lies between the Eastern High Atlas and the Saharan Atlas. Figuig, in Morocco, forms the northern limit of the date palm climatic zone (figure 1)

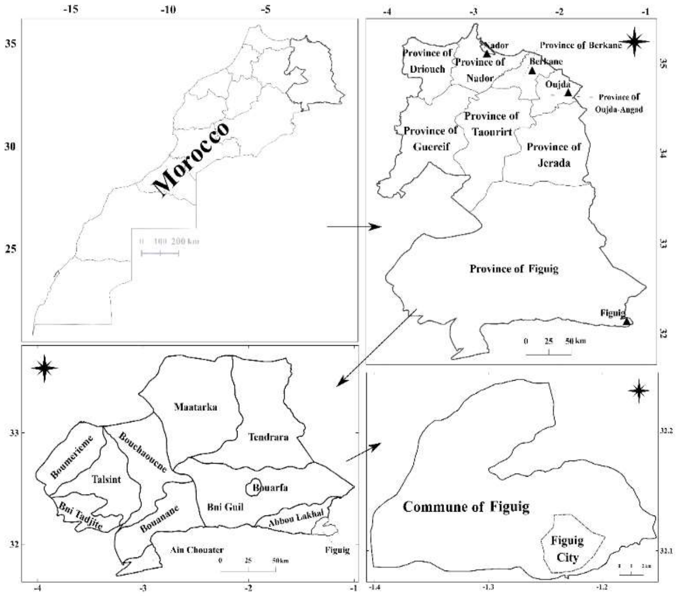

Figure 1 : Administrative division of the field of study.

Source: personal workArcGis10.1,2021

1-2 The Algerian-Moroccan borders

One of the elements that deeply distinguishes the Figuig oasis is the Moroccan-Algerian border. Which was established under the Lalla Maghnia Agreement on March 18, 1845. This borderline, which encircles the city of Figuig Oasis from the north and east, is in the form of a ring from the Zouzfana Valley, and to the south are the hills of the Milias and Zanaga mountains. This border path then separates the oasis town of Figuig, which is considered Moroccan, from Ksar Beni Ounif, located on the other side of the Zanaga mountain pass in Algeria. This part of it is in a geographical dilemma because of the political situation related to the closure of the borders, as well as the distance from the most important northern regions. This has a strong economic impact on the city, which was accompanied by an economic recession and a lot of population migration. A situation that had a major urban impact in light of the abandonment of palaces that are threatened with disappearance.

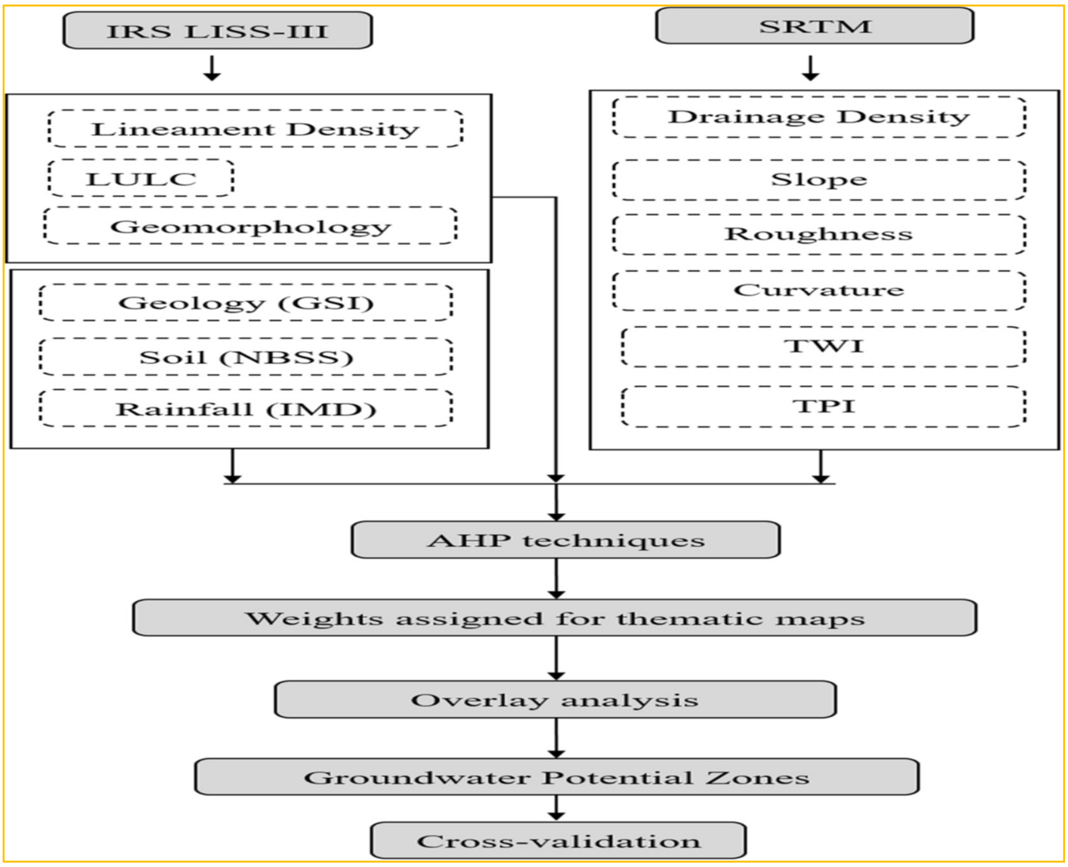

Figure 2: The methodology adopted for mapping
potential groundwater areas.

therefore residents in such areas must rely more on groundwater resources from For their survival.

2-Means and methods:

A set of thematic maps were produced using a combination of geographic information systems and hierarchical analytical process techniques in this study, and a set of thematic maps were produced: [geology - land use - linear density - rainfall - soil - slope - topographic moisture index Each thematic map has characteristics that indicate the possibility of the presence of groundwater, or that this possibility is weak given the quality of the characteristics. Among the well-known methods are remote sensing and information systems geography, as

A powerful tool that can be used to quickly assess natural resources and is considered cost-effective, for example, can be used effectively for groundwater exploration. In addition to the analytical hierarchy technique, AHP. It is, in turn, an effective tool in terms of making complex decisions in aspects related to groundwater

Table no1: Pairwise comparison of ten classes to study potential areas

Pairwise comparison										
Groundwater potential	Rain	Drainage density	Density of linear lines	Inclination	Height	Geology	Soil type	Ground cover	Topographic humidity index	Bending
Rainfall	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00	9,00	9,00
Drainage density	0,50	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00	8,00
Density of linear lines	0,33	0,50	1,00	2,00	3,00	4,00	5,00	6,00	7,00	7,00
Inclination	0,25	0,33	0,50	1,00	2,00	3,00	4,00	5,00	6,00	6,00
Height	0,20	0,25	0,33	0,50	1,00	2,00	3,00	4,00	5,00	5,00
Geology	0,17	0,20	0,25	0,33	0,50	1,00	2,00	3,00	4,00	4,00
Soil type	0,14	0,17	0,20	0,25	0,33	0,50	1,00	2,00	3,00	3,00
Ground cover	0,13	0,14	0,17	0,20	0,25	0,33	0,50	1,00	2,00	2,00
Topographic humidity index	0,11	0,13	0,14	0,17	0,20	0,25	0,33	0,50	1,00	1,00
Bending	0,11	0,13	0,14	0,17	0,20	0,25	0,33	0,50	1,00	1,00
the total	2,94	4,84	7,74	11,62	16,48	22,33	29,17	37,00	46,00	46,00

According to So, All subject classes were compared with each other in a pairwise comparison matrix (Table no 1). Subcategories of thematic strata were reclassified using the natural breaks classification method in the GIS platform to assign weight. Subcategories are assigned to each thematic layer rank on a scale from 0 to 9, according to their relative impact on groundwater development. The table shows6Designated rank and weights of thematic classes. To calculate next step.

The consistency ratio (CR [Rapport from consistency]), is followed

He sees my watches[1]the consistency index, which ranges from 0 or less than 0.10, is acceptable for further analysis, but if the consistency value is =0, this means that there is an ideal level of consistency in the pairwise comparison.

λmax =105.95/10 = 10.66

$$CI = \frac{\lambda \max - N}{N - 1}$$

CI = (10.66 -10) / (10 -1) = 0.07Consistency index = 0.07

$$CR = \frac{CI}{RI}$$

Consistency Ratio = Consistency Index/Random Consistency Index =

[1] **Hierarchical analysis process (**In English, Analytic hierarchy process: A structural hierarchy process aimed at helping people deal with complex decisions.[1][2][3] Instead of inviting them to a "correct" decision, the hierarchical analysis process helps them to Make a decision"The most correct." This process, based onpsychologyHumanitarianand computational sciences, It was created and developed by the Iraqi-American scientist Thomas is a watchmakerinThe seventies of the last century. It has since been extensively studied and developed. It provides an integrated logical framework for an issue or issue by collecting and evaluating the elements of the issue, and then directing these elements towards the general goals in order to deal with them and provide alternative or related solutions. Furthermore, it is now used on a global scale when making multiple decisions in the fields of governance, work, industry, health and education. Access date: 06/05/2022https://ar.wikipedia.org/

Table N 2: Consistency ratio results

Degree of consistency													
Groundwater potential	Rainfall	Drainage density	Linear density	Inclination	Height	Geology	Soil type	Land cover/land use	Topographic humidity index	Bending	Total weight	Worker weight	Special value
Rainfall	0,33	0,45	0,45	0,40	0,33	0,26	0,21	0,18	0,17	0,17	2,94	0,33	8.95
Drainage density	0,16	0,22	0,30	0,30	0,26	0,22	0,18	0,16	0,15	0,15	2,10	0,22	9,39
Linear density	0,11	0,11	0,15	0,20	0,20	0,17	0,15	0,14	0,13	0,13	1,49	0,15	9,90
Inclination	0,08	0,07	0,08	0,10	0,13	0,13	0,12	0,11	0,11	0,11	1,05	0,10	10,52
Height	0,07	0,06	0,05	0,05	0,07	0,09	0,09	0,09	0,09	0,09	0,74	0,07	11,29
Geology	0,05	0,04	0,04	0,03	0,03	0,04	0,06	0,07	0,07	0,07	0,52	0,04	12,10
Soil type	0,05	0,04	0,03	0,02	0,02	0,02	0,03	0,05	0,06	0,06	0,37	0,03	12,49
Land cover/land use	0,04	0,03	0,03	0,02	0,02	0,01	0,01	0,02	0,04	0,04	0,26	0,02	11,56
Topographic humidity index	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0,01	0,02	0,02	0,19	0,02	9,87
Bending	0,04	0,03	0,02	0,02	0,01	0,01	0,01	0,01	0,02	0,02	0,19	0,02	9,87
private value [valeur propre]													10,66
consistency index [Indicator of consistency]													0,07
Random consistency index [Indice of consistency aléatoire													1,49
consistency ratio [Rapport from consistency]													0,05

0.07/1.49 =0.05 So the consistency ratio is:

The consistency ratio (CR[Rapport from consistency]), is followed. He sees my watches2the consistency index, which ranges from 0 or less than 0.10, is acceptable for further analysis, but if the consistency value is =0, this means that there is an ideal level of consistency in the pairwise comparison.

To create a map of the groundwater potential area in the oasis of the city of Figuig, All thematic classes are merged The ten With the weighted overlay analysis method in the GIS platform using Next equation

$$GWPZ = \sum_{i}^{n} (X_A \times Y_B)$$

Groundwater potential area:

x Represents the weight of thematic layers;

Y Subclass ranks represent the subject classes

CI	Indice de consistance		
λ max	Valeur propre (eigenvalue)		
N	Nombre de critère		
RI	Indice de consistance aléatoire		
CR	Rapport de consistance		
	$CI = \frac{\lambda \max - N}{N - 1}$		
		Standard	
	$CR = \frac{CI}{RI}$	If CR < 0,1	Poids Validé
		If CR > 0,1	Poids Non Validé

3- Results and discussion:

3-1 Geology:

The geological aspect plays a role in the occurrence and distribution of groundwater. The study area is characterized by a group of modern and limestone formations, which occupy most of the area. The formations remain solid sandy formations that form a strip extending from the southeast to the southwest. The groundwater consists of quaternary alluvium [silt, sand, gravel], which also characterizes the geological structure. The average depth of the groundwater level does not exceed 30 meters. The characteristics of the rock are taken into account when assigning weights. Sandstone and sand with silt and clay contents are given a high weight, while low limestone and hard sandstones are given a low weight.

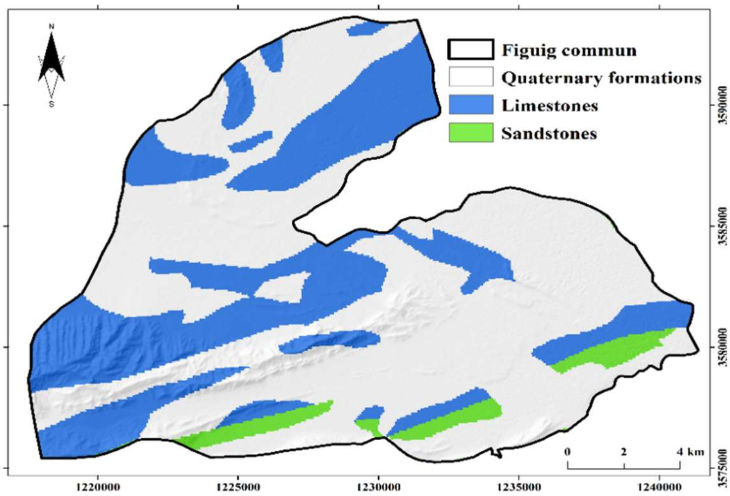

Figure 3: Geological map of the study area.

Source: personal workArcGis10.1,2021

3-2 Land use:

The land use map provides a set of information about groundwater indicators, as land use displays a set of categories that include agricultural land; forests; built-up areas and arid lands; and bodies of water. [Map No. 4]

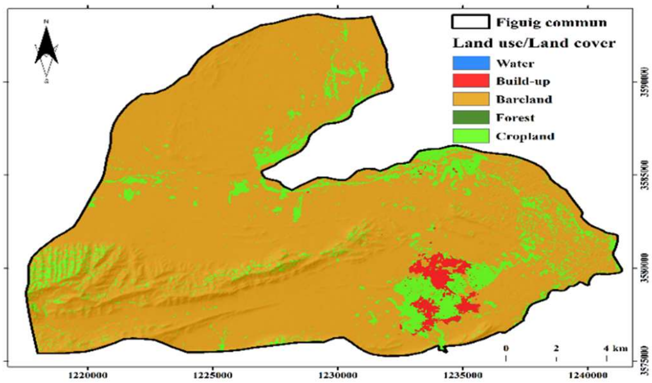

Figure 4: Land use or land cover

Source: personal workArcGis10.1,2021

Other classes mainly dominate vacant lands, and agricultural lands are represented in the form of palm groves and their extensions with patches of fallow land. It can be seen that the following is the case forests and agricultural lands contain a significantly higher percentage of water compared to built-up areas and barren lands. A high weighting is assigned to forests and agricultural lands, while a low weighting is assigned to built-up and barren lands.

3-3 linear density

The density of the lines enables the areas of cracks and fractures to be accurately determined. [Faults]

The increase in the percentage of porosity and permeability is shown in [Figure 4], which illustrates the linear density of faults that are most widespread in the studied area between 0-70 meters per km². This low density indicates that the process of leakage and absorption is weak. Additionally, there are other types of line density in the study area, namely very low (0-70 meters/km2), low (70-160 meters/km2) and medium (160-280 meters/km2). The latter can be observed as a longitudinal shape from the northeast. To the southwest, despite the presence of a permeable layer and the existence of faults, the process of absorption and leakage does occur. Additionally, high [280-450 metres/km2], very high [more than 450 metres/km2] densities are observed, indicating an increase in groundwater density as the distance along the faults lengthens. The weighting system assigns a high value to high-density categories and a low value to low-density ones...

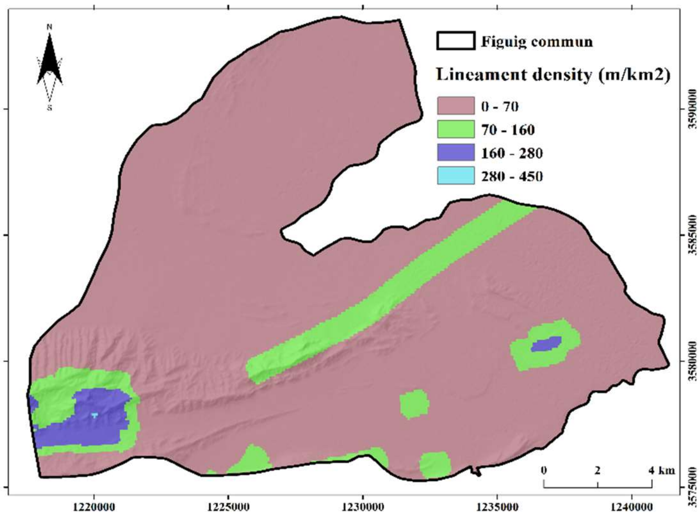

Figure 5: Linear density [faults]

Source: personal workArcGis10.1,2021

3- 4 Drainage or discharge density

The drainage network plays a role in the supply of groundwater. This is based on the nature of the rocks present in the area. A high drainage density means a low leakage rate and therefore does not allow groundwater to store and escape in the area. On the other hand, low drainage density represents a very high leakage rate and thus contributes more to the potential of groundwater, through the formation of surface streams and thus the leakage process takes place and absorption, with respect to the area of study, high.

Drainage density can be classified as the most widespread, i.e. more than [1900 m/km2], although there are other types of drainage network, for example: very low drainage network [0-350 m/km2], low [-760 m/km2], medium [660-1200 m/km2], high [1200-1900 m/km2], very high [more than 1900 m/km2]. 760 m/km2], medium [760-1200 m/km2], high [1200-1900 m/km2], very high [more than 1900 m/km2].As for the possible division of water underground.The high weight is assigned to the low area low density and weight for high density. [Figure 6].

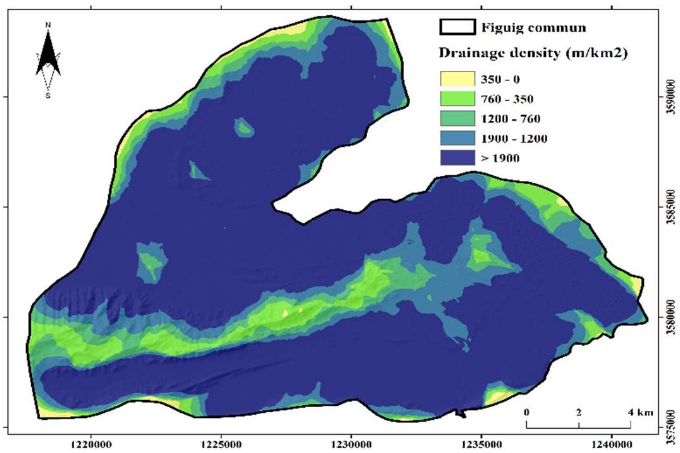

Figure 6: Drainage or discharge density.

Source: personal workArcGis10.1

3- 5 Degrees of decline:

Slope is a general terrain characteristic that gives us an idea of the severity of the Earth's surface slope and

tectonic movements. Surface runoff, infiltration rate and recharge are mainly influenced by the slope of the surface through [Figure 7 It appears that the very weak slope is dominant, ranging from [0-3.9 degrees], and thus allows the possibility of surface runoff to form, which in turn infiltrates into the subsurface vegetation, depending on the presence of faults and the nature of the rocks. Conversely, larger slopes have very poor understorey recharge. This is because the water from rainfall runs off quickly during rainfall and is therefore difficult to infiltrate and recharge the understorey. If there is no slope, the water will pond. It will then either leak out, depending on the possibility of cracks or the formation of a network of water leaks, or it will be exposed to evaporationThe degree of slope can be divided into several categories: very slight [0-1.5 degrees], slight [1.6-3.9 degrees], moderate [3.6-8.9 degrees], steep [8-17 degrees] and severe [more than 17 degrees]. A high weighting is given to a slight slope and a low weighting to a steep slope.

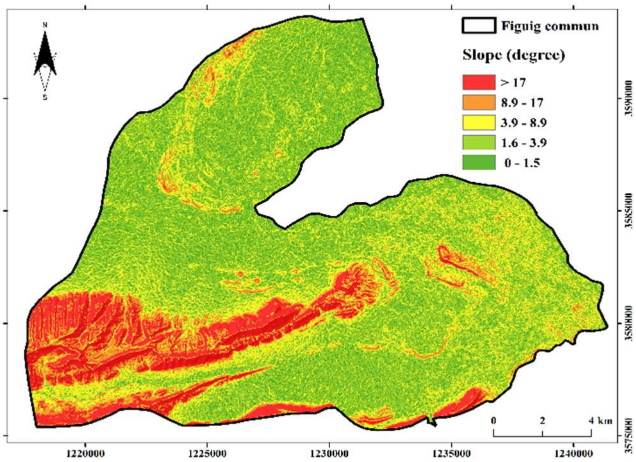

Figure 7: degrees of decline.

Source: personal workArcGis10.1

3 -6 Soil types:

Soil types play an important role for water that can percolate into underground formations and thus affect groundwater recharge. Soil texture and hydraulic properties are the main factors taken into account to estimate leakage rates. [Figure 8] shows the wide distribution of sandy soils, which allow water to percolate into the subsurface mattresses as they are permeable soils.

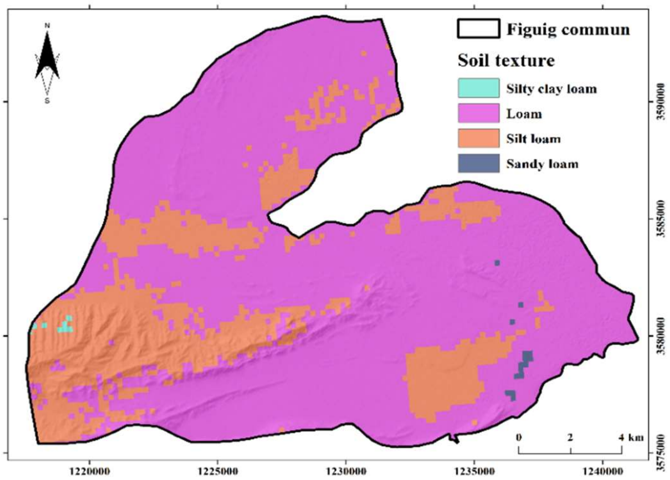

Figure 8: Soil texture.

Source: personal workArcGis10.1

3-7 Rainfall:

Precipitation is considered one of the main sources of water and the most influential element in groundwater in the studied area, based on the available data and Maximum and minimum values, precipitation were classified into three categories. The annual precipitation rate ranges between 120-140 mm annually, as it is the

dominant value in the study area, with the exception of some spots that are slightly above the annual average. As shown in [Figure 9].

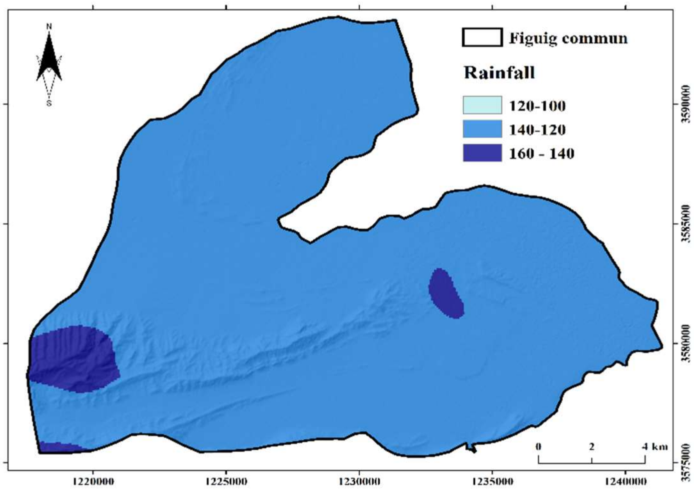

Figure 9: Rainfall.

Source: personal workArcGis10.1

The heavy precipitation in a short period of time that the Figuig urban oasis is exposed to can influence the formation of surface sewage compared to the occurrence of leakage at a low rate, which is the case in 2014. On the other hand, precipitation over a long period contributes to higher leakage rates

without the formation of surface sewage. Therefore, the percentage of heavy precipitation has a large weight and vice versa.

3-8 Topographic Humidity Index:

Knowing the topographic moisture index helps to know and understand the influence of the terrain units on the potential groundwater flow from the source in the direction of flow. The topographic moisture index for the study area varies from 2.95 to 9.94. The values have been classified into five categories such as less than 2.95, between 2.95- 5.28, 5.28 - 7.61, 7.61 - 9.94 and more than 9.94. The higher the humidity index, the higher the probability of the presence of water, on this basis we can say that high weights [more than 9.94] Specific to the topographic humidity index high and vice versa.. [Figure 10]

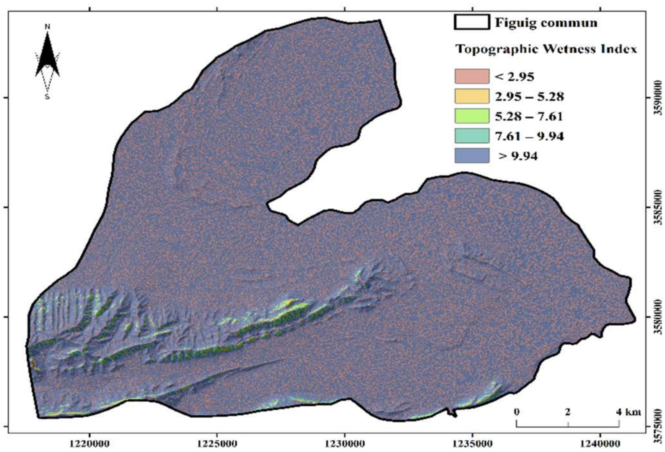

Figure 10 : Slope curvature index in the oasis city of Figuig.

Source: personal workArcGis10.1

3- 9Curvature of slopes:

The curvature of the slopes makes it possible to identify the nature of the lateral appearance of the surface, as it can be convex or concave, so that water tends to accumulate in either a convex or concave shape. The curvature of the slopes in the study area ranges between more than 2.95 and less than 1.10. The high weight value was determined for the high slope value and vice versa, as shown in [Figure 11]

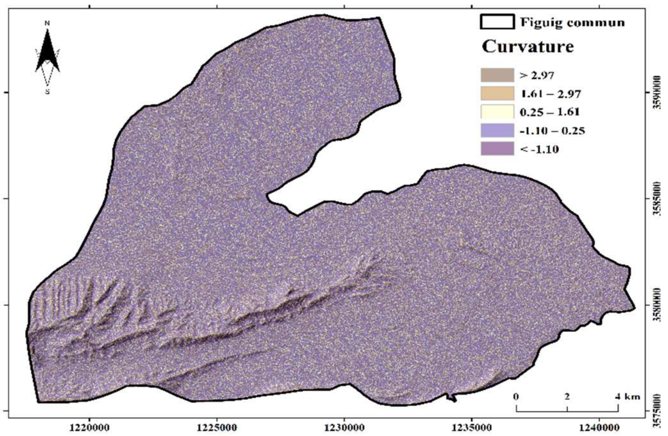

Figure 11: Topographic humidity index.

Source: personal workArcGis10.1

3-10 Elevations :

The digital elevation model distinguishes the study area, as it is characterized by the dominance of relative altitude, between [900-1100 meters]. Altitude, in addition to relevant topographic factors such as slope and aspect, contributes to the extent to which groundwater is likely to be available. The high weight value was determined by the low altitude value and vice versa, as shown in [Figure 12].

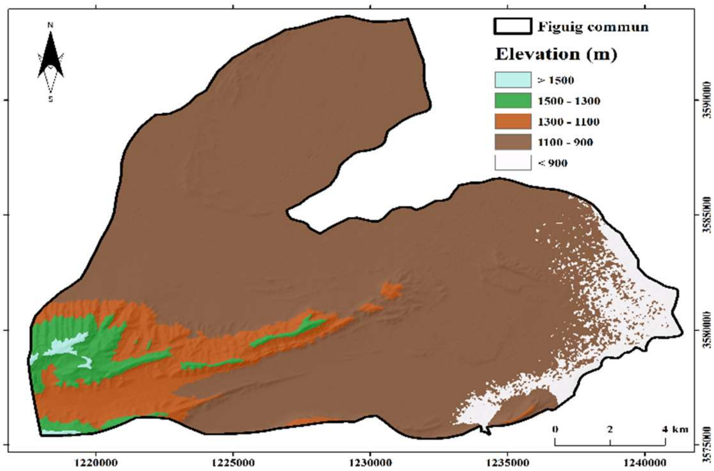

Figure 12: Elevations in the oasis city of Figuig.

Source: personal workArcGis10.1,2021

4- Discussion :

As for the final map, in which various thematic maps were compiled, the study area can be classified into five potential groundwater areas, such as:: Strong, a task, Medium, Weak, Very weak. Areas with potential are located Strong and Important Mostly groundwater in the northeastern part towards the interior areas bordering the Moroccan-Algerian border, and from the southwest to the southeast for the southern part of the study area. The potential areas are medium and weak in the areas surrounding the highlands from east to west, then in the easternmost areas bordering Morocco and Algeria.

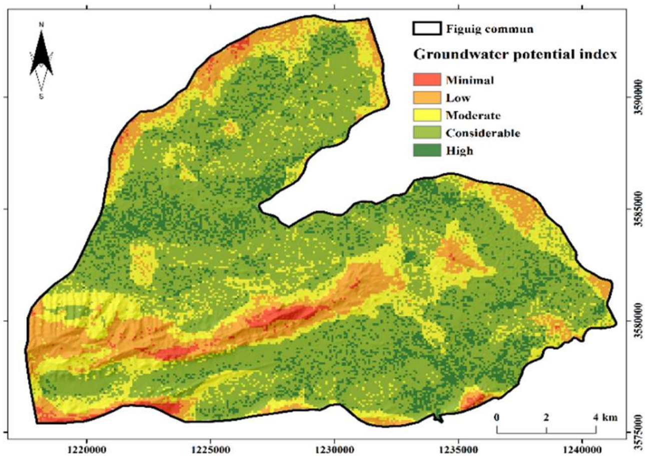

Figure 13: potential areas of groundwater in the oasis of Figuig.

Source: personal workArcGis10.1,2021

The groundwater potential area is widespread Strong and important; the catchment area covers 59% of the study area. Areas of high and low groundwater potential cover 11% and 29% respectively. Areas of very high and very low groundwater potential are included in the study and together cover less than 1% of the area. The map of groundwater potential areas has been validated [Figure 13].using groundwater flow information and groundwater horizons for the study area. Map of the groundwater potential area.

5- Conclusion

The present study provides insights to decision makers for proper planning and management of groundwater for urban and agricultural purposes. As most of the study area is covered with agricultural land, this study will help in improving the irrigation facilities and developing the agricultural productivity of the area.

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Internet source :

01- https://earthexplorer.usgs.gov.
02- http://power.larc.nasa.gov/data-access-viewer.

Table 3: Factors responsible for groundwater potential and their weights

factors	the weight	Consistency ratio	Sphere of influence	the weight	Consistency ratio
Rainfall [annual in mm]	0,33	0,05	> 160	0,49	0,02
			160 - 140	0,23	
			140-120	0,15	
			120-100	0,10	
			< 100	0,03	
Drainage density [meter/km2]	0,22		> 1900	0,48	0,06
			1200 - 1900	0,26	
			760 - 1200	0,15	
			350 - 760	0,08	
			0 - 350	0,03	
Linear density [m/km2]	0,15		> 450	0,43	0,03
			280 - 450	0,28	
			160- 280	0,18	
			70 - 160	0,08	
			0 - 70	0,04	
Inclination [degree]	0,10		0 - 1,5	0,50	0,05
			1,6 - 3,8	0,26	
			3.9 - 8.8	0,13	
			8,9 - 17	0,07	
			> 17	0,03	
Height [meters]	0,07		< 900	0,50	0,05
			900 - 1100	0,26	
			1100 - 1300	0,13	
			1300 - 1500	0,07	
			> 1500	0,03	
Geology	0,04		Quaternary formations	0,72	0,00
			Limestones	0,19	
			Sandstones	0,10	
Soil type	0,03		Sandy loam	0,52	0,05
			Silt loam	0,35	
			Loam	0,09	
			Silty clay loam	0,04	
Land use/land cover	0,02		Agriculture	0,45	0,06
			Forest	0,27	
			Bareland	0,18	
			Build-up	0,07	
			Water	0,03	
Topographic humidity index	0,02		> 9.94	0,42	0,02
			7.61 – 9.94	0,26	
			5.28 – 7.61	0,16	
			2.95 – 5.28	0,10	
			< 2.95	0,06	
Bending	0,02		< -1.10	0,42	0,02
			-1.10–0.25	0,26	
			0.25 – 1.61	0,16	
			1.61 - 2.97	0,10	
			> 2.97	0,06	

Source: Study results, EXCEL, ArcGIS, 2022