المياه الجوفية والينابيع الارتوازية في واحة فجيج، مساهمة في دراسة النظام المائي: الأطلس الكبير الشرقي

Groundwater and Artesian Springs in the Figuig Oasis, Contribution to the Hydro-System Study: Eastern High Atlas

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الملخص:

إن البيئة الطبيعية والسكان والتاريخ عناصر تتشابك لتنتج هوية أرضية تأخذ سمات مميزة ضمن حدود جغرافية محددة وطريقة حياة تحدد سلوك السكان وتفاعلاتهم مع الأرض. وفي هذه المقالة نحاول تحديد معالم البيئة الطبيعية والمناخية كمحدد ممتاز لتوجيه السكان في اقتصادهم، من خلال التذكير بالمقومات الطبيعية ودراسة مدى تأثيرها على المنطقة، عبر تحديد جوانب التكيف فيما يتعلق بهذه المكونات، وكذلك من خلال فهم التطورات التي شهدتها وتشهدها المنطقة سواء نحو الانفتاح أو الانعزال. وأيضًا في تخطيط برامج التنمية والتنمية الإقليمية والتخطيط المكاني.

الكلمات المفتاحية: فجيج، العيون الارتوازية، الجهة الشرقية، الخطارات.

Abstract:

The natural environment, the population and the history are elements that interweave to produce a land identity that takes on distinctive features, within specific geographical limits, and a way of life that determines the behavior of the population and its interactions with the land. In this article, we attempt to outline the contours of the natural and climatic environment as an excellent determinant in guiding populations in their economy, by recalling the natural components and studying the extent of their impact on the territory, identifying aspects of adaptation, focusing on these components, and understanding the changes that the territory has undergone and is still undergoing, whether towards openness or isolation. As well as, in the planning of development programs, territorial development and spatial planning.

Keywords: Figuig, artesian springs, Eastern, Khattaratts.

I-Introduction

A set of factors intervenes on the structure of the area and on the way in which the field is exploited and on the distribution of the population and activities. On this basis, the first elements seem to determine the future of this field, whether it is a productive field or an important productive field and attracts the population and activities, or a field that repels the population and investments. If the field is isolated, somewhat marginalized and unqualified, it is natural that it becomes an area of expulsion of the inhabitants and a destination for those who are punished. Therefore, the first question that arises is where is this field located? What are the characteristics of the place that it represents?

The oasis of Figuig is known for being a semi-desert area in addition to being a border area. In light of these preliminary data, which have created a kind of slow local dynamism experienced by the oasis of Figuig - the oasis, and on the other hand, to the phenomenon of external migration, which is considered the other character of this area.

In this article, we will address the natural features that characterize the oasis of Figuig, obtained from various sources, initially to study the relationship between the natural frameworks, especially those related to rainfall, soil and water resources, and the extent of their impact on the stability of the population and its distribution on the ground. As well as the role of these natural data in creating rapid local dynamism, and to what extent these natural data can be considered as a brake on the territorial development of the oasis of Figuig.

The Adopted Work Methodology:

The column methodology is one of the most important pillars on which the researcher stands in any article, as it forms its backbone. This is what prompted the necessity of adopting several methods, especially

the geographical, inductive and deductive methods, in addition to the tools of expression, with the aim of linking what is statistical and cartographic. The study of the annual and monthly climate data of the Figuig oasis enabled the tracking of rainfall changes during the period studied and specified in thirty years to extract the nature of the climate.

Presentation of the Oasis Town of Figuig.

1 General Data:

On the Algerian-Moroccan border, Figuig is located 236.12 Mile (380 km) east of Er-Rachidia and 233.63 Mile (376 km) south of Oujda, capital of the Oriental region. (Fig. 01). It is connected to Oujda by the national road 17, which crosses the city of Bouarfa, the last stop 100 kilometers before Figuig. On the borders of the Eastern High Atlas and the Saharan Atlas, Figuig forms, in Morocco, the northern limit of the climatic zone of the date palm.

The oasis town of Figuig is in a situation of geographical impasse given the political situation linked to the closing of the borders. The distance from the dynamic northern areas has a strong economic impact on the city, which has been accompanied by economic lethargy and intense depopulation. A situation, which has had a significant urban impact in view of the abandonment of the ksours, which are threatened with disappearance. (Fig. 02)

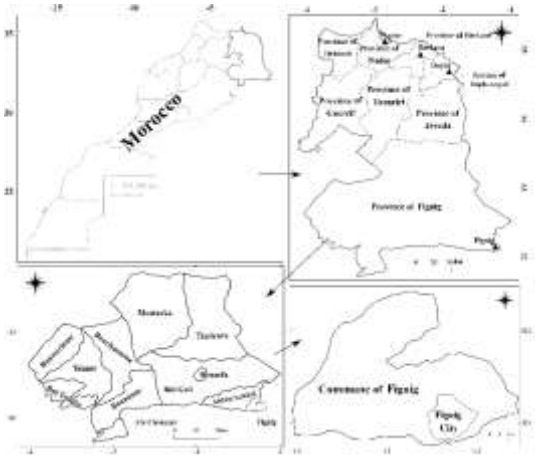

Figure -01: Administrative division map of the Orientale region .Source: Esri. Treatment: ArcGis 10.3/BOUABID, 2021.

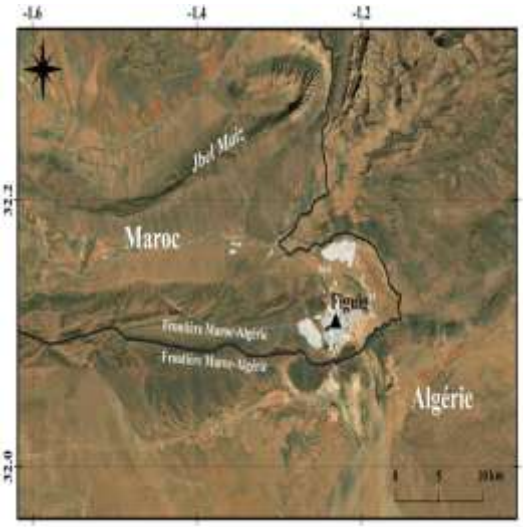

Figure: 02: the situation of the oasis town of Figuig. Source: https://earthexplorer.usgs.gov/ ArcGis 10.3/BOUABID treatment, 2021

1-2 Diversity Topographical in the Field of Study:

The geographical situation, as a general framework, is made up of basic elements that combine climate, water network and terrain aspect, and it can play a fundamental role in spatial transformations or be an obstacle to them.

1-2-1 Arc-shaped mountainous highlands; the dominant topographic unit in the study area:

The oasis of Figuig originality rests in a structural depression whose lower part is filled with siliciclastic deposits, that is, various rocky compounds, while the northern and western parts remain steep slopes as long as the slopes are connected to the mountain range by steep slopes. This depression remains surrounded by a series of peaks connected to each other belonging to the High Atlas chain, taking a longitudinal direction. The oasis of Figuig is located between 850 and 930 meters above sea level. In terms of land structure, it belongs to the eastern mountain range of the High Atlas. This explains the presence of many mountains and heights oriented longitudinally, which surrounds the oasis on all sides. Forming the north, where we find Mount Al-Amour, which is

the beginning of the Atlantic-Saharan chain [Figure 5]. Heading east to end at noon in eastern Tunisia. (Hassan & Abdullah, 2009: 37). Passing through Mount Cruz (1339 m) and its extension up to Jbel Al-Haymar in the northeast (1168 m). To the east, we find the hills [Zreikat] of Sidi Abdelkader (1000 m). On the southern side is a low-altitude mountain range, extending from west to the east: Jbel Melias (1,128 m). and Jbel Zenaga (1,051 m), which is separated from Jbel Tagla (1,117 m) by the Zenaga pass through which the road leading to the passes of Algeria (JANTY G., 2014: 23). The terrain of the Oasis of Figuig can be divided into distinct terrain units, where we find:

1-2-2 Plains:

It has the shape of a triangle with its base extending from south to northwest to east, and a summit formed by the two sides facing southwest to west. It is surrounded on all sides by mountains, which currently form the oasis of Figuig.

This basin forms two parts, the first is high to the north and is bordered by a ledge [Fig. 3], overhanging the second lower part, which is separated by a cliff of average height of 30 meters, taking a steep vertical form.

Figure 3: picture of the cliff overlooking the lower part of the Bassin de Figuig. Source: personal shot, August 2022

The northern part: It is a plateau with a height of up to 900 meters, confined between the heights of Jbel Grouz and Jbel Al-Haymar, to the northwest, and Jbel Al-Arja and Zreikat Sidi Abdelkader, to the southwest. The latter two are considered an extension of the cliff dominating the southern plain, which includes most of the fractures at the origin of the eruption of the water sources.

The southern part: of the basin or so-called plain which extends to the south of the plateau, and is divided into two distinct parts: the plain of Baghdad to the east, and a higher part of the west. [Fig 4]

Figure 4: Picture general view of the eastern part of the Baghdad plain.

Source: personal take, August 2022.

In the middle of this group of land, both in its upper and lower part. Extends an ocean of important palm forests surrounding the Ksar. Six of which extend on the plateau on the line of the water sources near the cliff from west to east. While the seventh Ksar lies below them in the plain of Baghdad.[1]

[1]Baghdad Plain, not Baghdad in Iraq, and the meaning of the word Baghdad in Persian: [Bagh] meaning the enclosed garden, and [Papa] meaning given. The meaning of Baghdad is the gift of the garden or the gift of the garden.

Among the meanings of Baghdad also: the garden and the world, which is a metaphor for Paradise. And on the person of determination, generosity and progress.

1-3 Mountain groups:

The oasis of Figuig is surrounded by three groups of mountains, the northwestern group consisting of Mounts Al-Haimar and Kruz, then Mount Al-Arja and Zerikat Sidi Abdelkader on the northeastern side, and the third group to the south consisting of Mount Melias, Mount Zenaga, Tagit and Tamazhout [Fig 5].

The Northwestern Group: In this group, we find Mount Al-Kruz, considered one of the most important terrain units in the north. Which extends over a distance of 80 km in length and a distance between 3.27 and 3.10 Mile (5 and 6 km) in width, from northeast to southwest. In addition, its height reaches 1400 meters, and it characterized by steep slopes of the plateau.

The Northeast Group: This group includes Jbel al-Arja and Zreikat Sidi Abdelkader, and its height reaches 93370.1 inches (1,000 m) from northwest to southeast. Between them is the central basin of Oued Zouzfana, and it separates Jbel al- Kruz from Jbel al-Himar and Faj al-Bayda, which connects the oasis of Figuig with Oued Tsirfine and Difiliya (Mézian, 1988: 31).

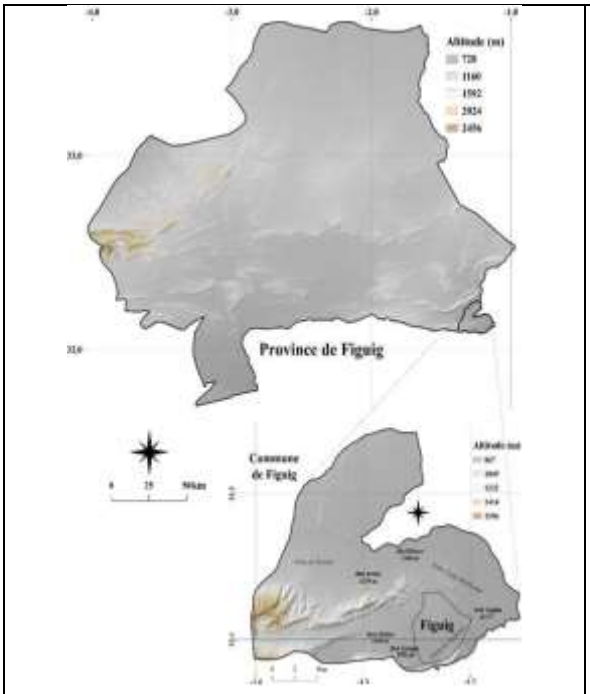

Figure 5: Map digital Elevation Model (DEM) the Oasis of Figuig
(Source: http://www.earthexplorer.usgs.gov. Own work, August 2024.

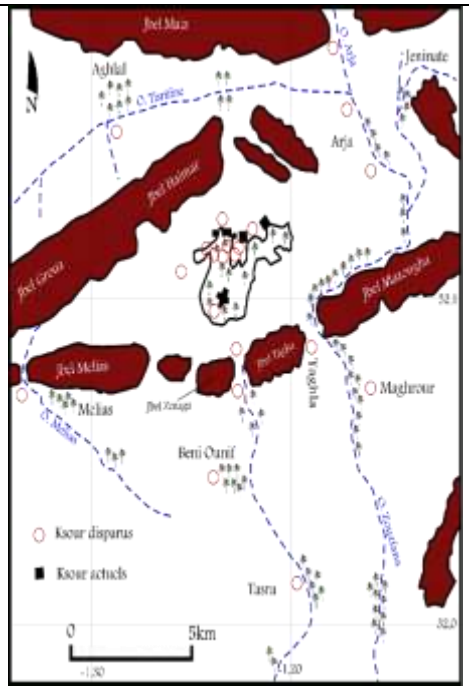

Figure 6: A simplified drawing of the Figuig oasis and surrounding land units
Source: Ahmed Meziane, 1988, adapted.

The southern group consists of a mountain belt surrounding the oasis of Figuig, to the south in the form of an arc divided into four units, with gaps between them caused by erosion or tectonic movements, which have led to the lowering of the folding axis of some of them. At the level of the plain and west, Mount Zenaga 1047 m, Mount Taghla 1115 m, and Mount Sidi Youssef 1062 m.

1-3-1 Zouzfana Valley:

It is believed that the Zouzfana Oued was born in ancient times from the active erosion of the Faj Taghla by a valley that came from the desert and which emptied the lake on the plain of Baghdad of its waters, thus connecting the Al-Halouf Oued to the north. The two are now one watercourse, so its upper part is called Al-Halouf Oued and its lower part is called Zouzfana Oued.

Jbel Al-Krouz and Jbel Beni Samir are considered the main source of the torrents that feed the only valley in the region, characterized by a continuous flow throughout the year at two main points, particularly during periods of major flooding:

The first point goes from Faj Taghla to the concave which separates Mount Zenaga from Mount Taghla, that is to say Faj Lakhnak or Oued Lakhnak, over a length of between 5 and 6 km of flow.

The second point is when he arrives at the oasis of Taghit, which is one of the oases of trout along a 15 km watercourse.

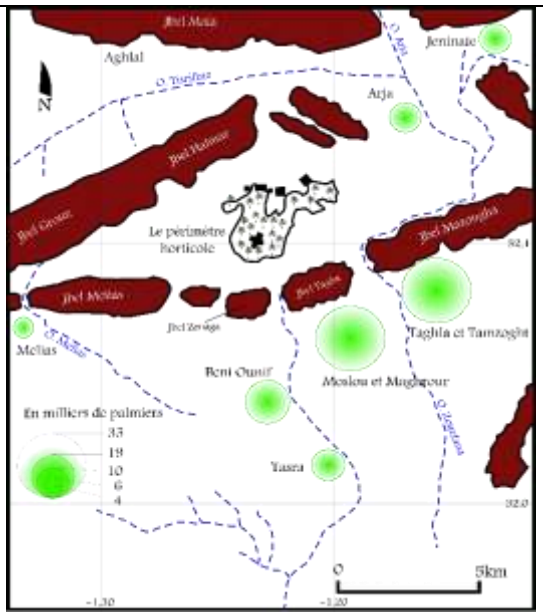

Figure 7: A simplified drawing of the agricultural areas exploited outside the residential areas of the ksours. Source: Omar Zayed, 1992, adapted.

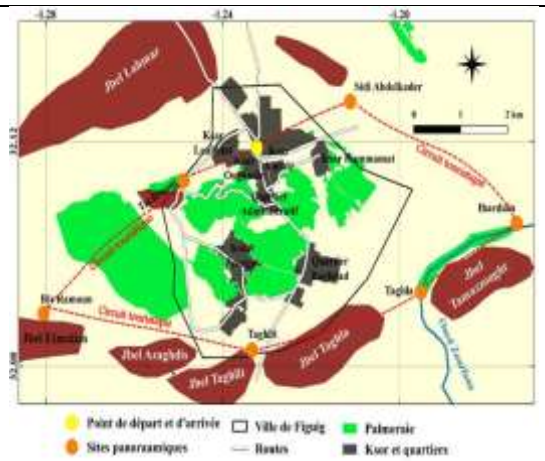

Figure 8: Location map of the oasis of Figuig and the surrounding highlands. Source (KASSOU, 2019) Adapted.

Considering that, the Zouzfana Oued is a desert. Wind erosion is active, which explains the presence of cairns and sandstone on its sides and along its entire length. The importance of this valley for the inhabitants of the oasis of Figuig lies in its agricultural exploitation outside the residential communities of the ksars. In the regions of Al-Arja, Mughrour and Tasra (Fig 7).

1-3-2 Plains represent narrow spaces:

To the east lies, a vast plain made up of the deposits of Oued Zouzfana[1]. Coming from the north of the oasis of Figuig, towards the east and the southeast. Where is the plain of Baghdad, Taghla and Sidi Youssef to the south and Zureikat Sidi Abed[2] Abdelkader (1000 m). Moreover, the Al-Arja plain to the north [Fig 7]. (Hassan and Abdallah, 2009) the abundance of sediments brought by the Zoufana valley [Fig 9].

These areas have become palm groves [Fig 10] as part of the new expansion, while the total area of the region is about (35 Km^2), and is distributed over the land for palm groves, comprising between (600 and 650 H) with an average altitude of about (880 m). This is called the cliff that separates the seven ksours from the Zenaga Ksar. These lands are assigned to palm cultivation, with a predominance of subsistence agriculture [vegetables] and fodder for animals.

[1] The Oued Zouzfana represents the most important watercourse of the oasis of Figuig. It takes its source in the north, where it bears the name of Oued El Hallouf, and enters the oasis in the east, forming at this level a natural and official border for the Moroccan-Algerian border.

[2] It should be noted here that the Arabic names of geographical places are: Zerigat, in reference to the color blue, which here designates the high plateaus where blue limestone rocks are found. As for the word Teniet (a small topographic depression in a line of hills). This toponym is linked to the arrival of nomadic Arabs from the 12th century: some groups settled in Figuig, but the majority continued nomadic pastoralism and settled in the surrounding area, notably the Beni Guil tribes...

Figure 9: Map shows the course of the Oued Zouzfana, where the Moroccan-Algerian border appears northwest of the oasis of Figuig.
(Source:http://www.earthexplorer.usgs.gov.

Figure 10: Photo of a palm grove in the Al-Arja region.
Source: Researcher Lens, dated August 20, 2022

1-4-3 degrees of decline:

Slope is a general characteristic of the terrain that gives us an idea of the severity of the slope of the Earth's surface, as well as tectonic movements. The slope of the surface through the [Fig 11] mainly affects surface runoff and the rate of leakage and absorption. It appears that the very low degree of slope is dominant, which varies between [0-3.9 degrees], and therefore, allows the possible formation of surface runoff which, in turn, infiltrates into the underground scrub depends on the presence of faults and the nature of the rocks. On the other hand, steeper slopes produce very low recharge of the undergrowth because the water discharged by precipitation flows rapidly downwards during precipitation, making infiltration and the recharge of the undergrowth difficult. When there is no slope, stagnant water forms, which will then be exposed to leaks depending on either the possibility of cracks or the formation of a network of water leaks, or to evaporate. The degree of slope can be classified into several categories, as we find very slight [the0-1.5 degrees, slight [1.6-3.9 degrees], moderate [3.6-8.9 degrees], steep [8.9-17 degrees] and severe [more than 17 degrees]. A high weight is assigned to slight slopes and a low weight to steep slopes.

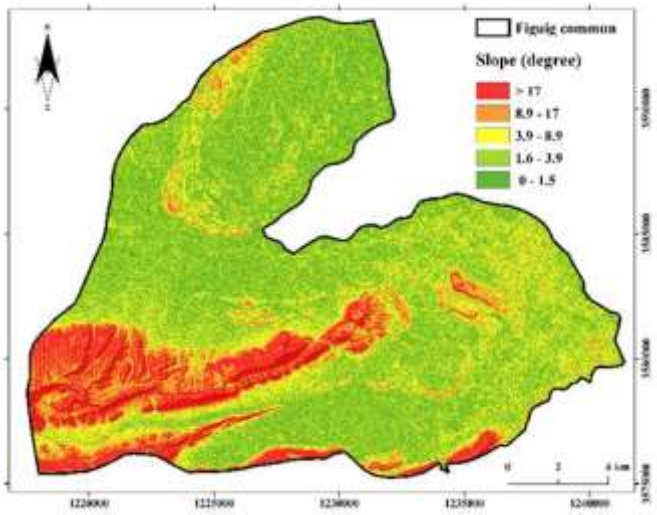

Figure 11: Regression degree map Source:
Own work ArcGis10.1, 2022

1-4-4 Curvature of slopes:

The curvature of the slopes helps to identify the nature of the lateral aspect 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 varies from more than 2.95 to less than 1.10. The high weight value was determined for the high slope value and vice versa, as shown in (Fig 12).

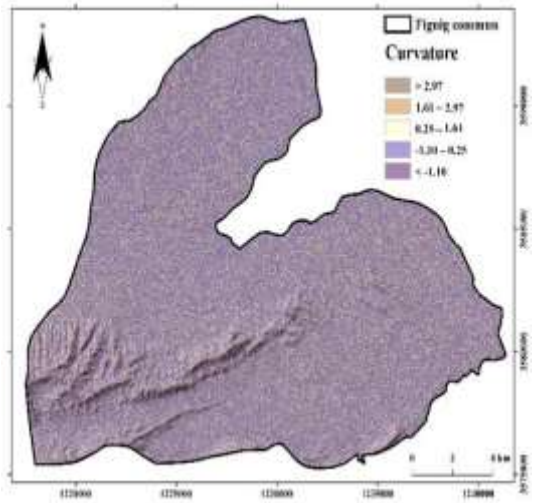

Figure 12: Slope curvature index map in the oasis city of Figuig.
Source: Own work ArcGis10.1, 2022.

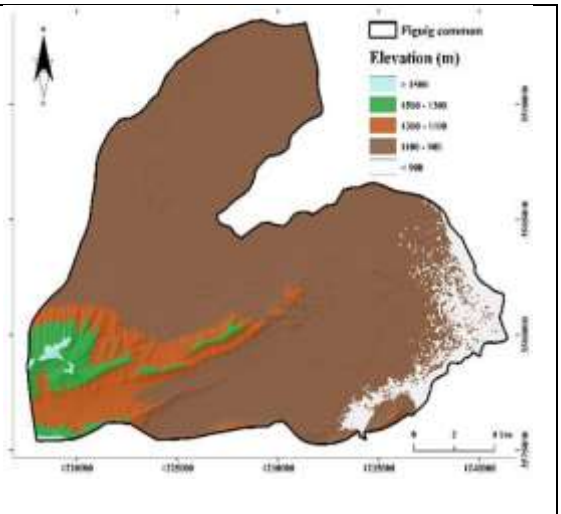

Figure 13: Elevation map of the oasis town of Figuig.
Source: Own work ArcGis10.1, 2022.

Using the digital elevation model, (Fig 13) the study area personalizes by the dominance of relative altitude, between [35433.1in and 43307.09 in, (900 and 1100 m). As well as relevant topographic factors such as slope degree and slope side, which contribute to the extent of potential groundwater availability. The high weight value was set to the low size value and vice versa.

2- Geological Structure of the Oasis of Figuig:

The Figuig Oasis is part of the Eastern Messita. Which personalized by a smaller area than the Western Messita. Which consists of three units: Moulouya Basin - the area of moraines and high plateaus that extend eastward into Moroccan territory, between the Hilly Atlas region. The Algerian Saharan Atlas and the Eastern High Atlas, which contains the ancient mountain range [of Tamalalt] [Fig 14]. Mountain barriers surround the Figuig Oasis to the south and north, forming an "enclave" bordered by Algeria on three sides. This enclave itself is composed of two geological formations: A plateau to the north and a plain to the south, separated by a cliff called the cliff. It is in fact a folded fissure extending along the plateau, increasing in height from east to west. Its height is about 30 meters at its highest point. [Fig 15] Limestone deposits surround its edge. It indicates the flow of hot springs during past geological eras.

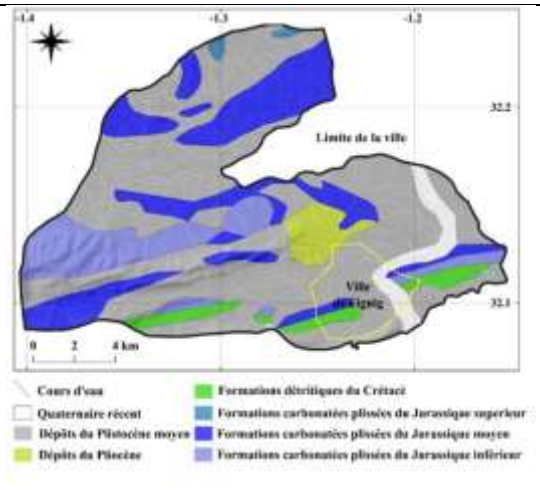

Figure 14: Geological structure map of the

Figure 15: A general view of the cliff,

province of Figuig, including the oasis of Figuig Source: Geological map 100000/1. (JILALI, 2014, p. 22) Adapted	the border between the upper plateau and the plain below. Source: personal take, dated August 2021.

Figure 16: Anomalous contact between the Sinemurian and the Bajocian of Jbel Mélias. Source: (JILALI, 2014, p. 22) Adapted.

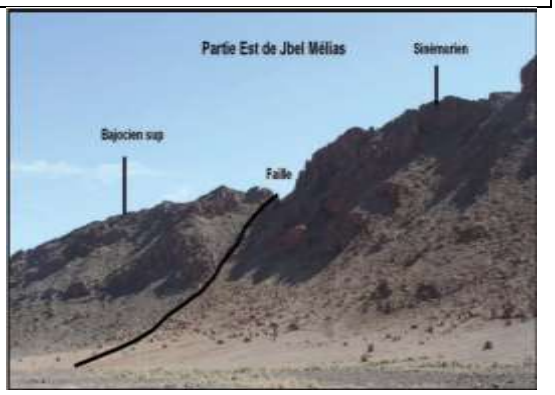

Figure 17: Triassic red clays and Sinemurian dolomitic limestones (JILALI, 2014, p. 22) Adapted.

The complete absence of manifestations of ancient life characterizes the geology of the region. Since it begins with the Triassic period (the red clay in the north and the blue limestone of Jbel Al-Kruz and Jbel Al-Haymar) (Al-Jilali, 2014), and ends with the Quaternary Era, so that the terrain units in their geological components belong to the second. (Fig. 16) distinguish the mountainous highlands of Jbel Al-Kruz and Jbel Al-Haymar.

Modern formations, limestone formations and hard sand formations are the most important geological aspects that dominate the structure of the oasis of Figuig, especially the modern formations of the Quaternary geological epoch, especially the Pliocene and Pliocene periods, where the Quaternary mainly occupies the oasis of Figuig. As for the plain that is composed of silt and limestone in addition to formations alternating with the Jurassic and Cretaceous to the south [Fig 18].

The geological structure is also characterized by the presence of a groundwater layer consisting of Quaternary alluvium [silt, sand, gravel].

The average depth of the water table does not exceed 1181.1 in (30 m). In addition, the salinity of the water is generally less than 2 grams per liter and can exceed this value, sometimes reaching 6 grams per liter. This condition explained by the fact that the substrate of these formations is located at the Triassic level. Layers of clayey gypsum (Hassan & Abdullah, 2009). This is the case of the palm groves of the south (MOHAMMI.A.).

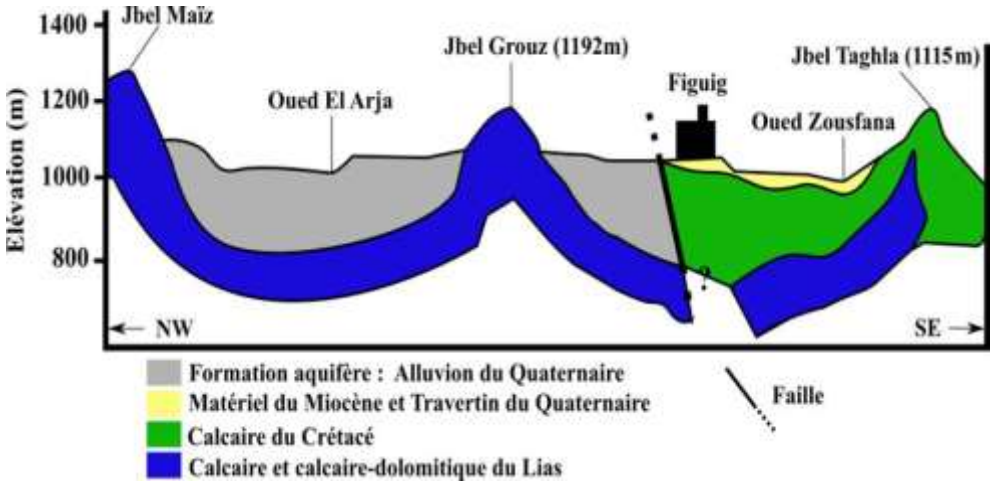

Figure 18: Geological section of the Figuig sector

Source: (JILALI, 2014, p. 25)ArcGis10.3©.BOUABID.2021 processing

3 -Desert Climate with Low Rainfall:

3-1- The Precipitation Has a Very Variable Spatial Distribution:

The climate of the oasis of Figuig is an arid Mediterranean climate. As is the case in the climatic division of the Mediterranean Sea (Emberger, 1939). As well as a dry mesophilic climate with desert influence, according to the classification of Thornwhaite, which has an overall drought index of -53.4 (Bencherifa, 1993). Where average rainfall does not exceed. The annual rainfall rate in dry areas is less than 150 mm per year, which requires the use of an irrigation system for agricultural activities. The annual rainfall rate is shown (Fig 19).

It is clear from the map that the geographical distribution of annual precipitation amounts personalizes by extreme variation throughout the territory of the eastern region [Fig. 19]. It is noteworthy that the areas with high precipitation are limited to the north and northwest. The arid and semi-arid regions that receive between 100 and 300 mm per year cover the southern regions, which include the province of Figuig. Alternatively, about (56,990 km ^{2}) of the area of the eastern slope, with the exception of some mountainous highlands whose height does not exceed (2,000 m).

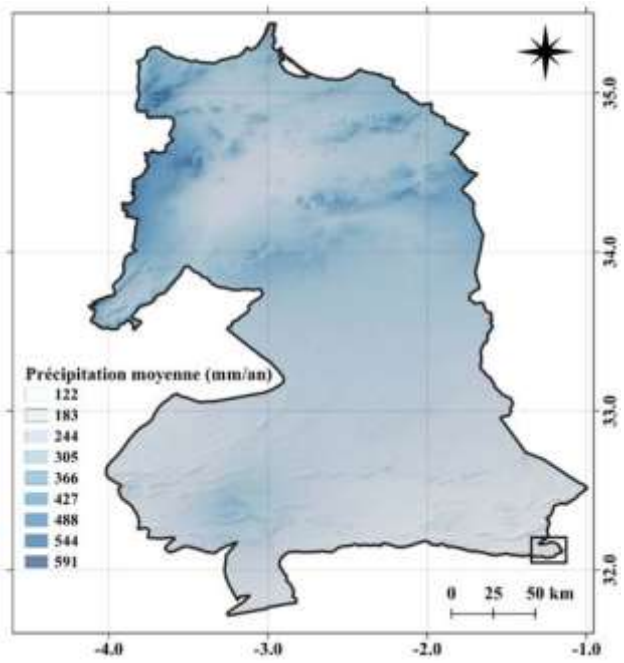

Figure 19: Map of average annual precipitation in the Eastern region, including the study area.
Source: http://power.larc.nasa.gov/data-access-viewer/;
Processing using the program [ArcGis10.3], personal work, 2022.

3-2 Future Precipitation Curve:

According to the report of the Intergovernmental Panel on Climate Change [Intergovernmental Panel on Climate Change, IPCC, 2007], the African continent is the most vulnerable continent to climate change, particularly in the tropics and in the tropics, because the amount of precipitation expected will decrease in most of the Mediterranean region and North Africa. As for Morocco, due to its climatic, ocean and geographical characteristics, Morocco is not immune to climate change

and its effects. Indeed, whether in terms of observed development conditions or future developments [2020/2040], rising temperatures, decreasing precipitation Cumulative precipitation, increase in severe drought episodes (JILALI, 2014). This decrease in cumulative precipitation will be of the order of 10% and 30% for the Oasis of Figuig [Fig 21] at the annual level (JILALI, 2014).

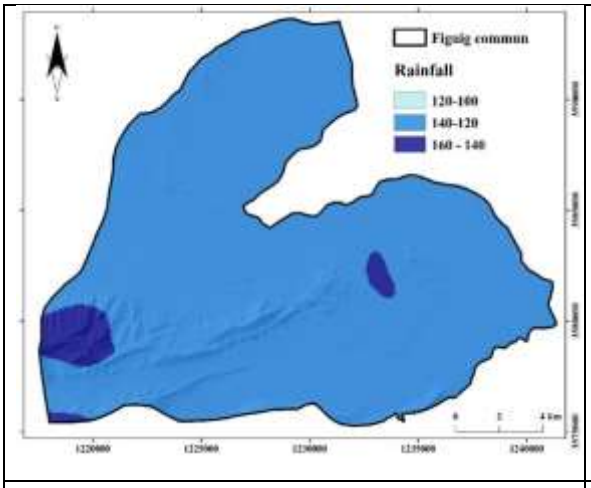

Figure 20: Volume of annual precipitation in the Municipality of Figuig 1981/2020.
Donation source: http://power.larc.nasa.gov/data-access-viewer.
Processing using the program [ArcGis10.3], personal work, August 2021.

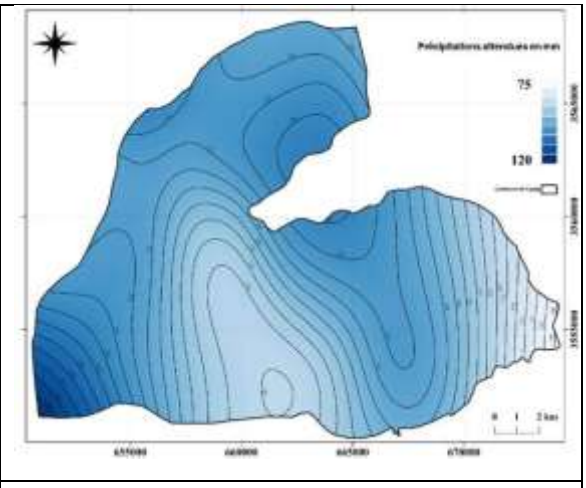

Figure 21: Expected precipitation in the Figuig oasis between 2020-2040.
Source Given: http://power.larc.nasa.gov/data-access-viewer Processing using the program [ArcGis10.3], own work, August 2021.

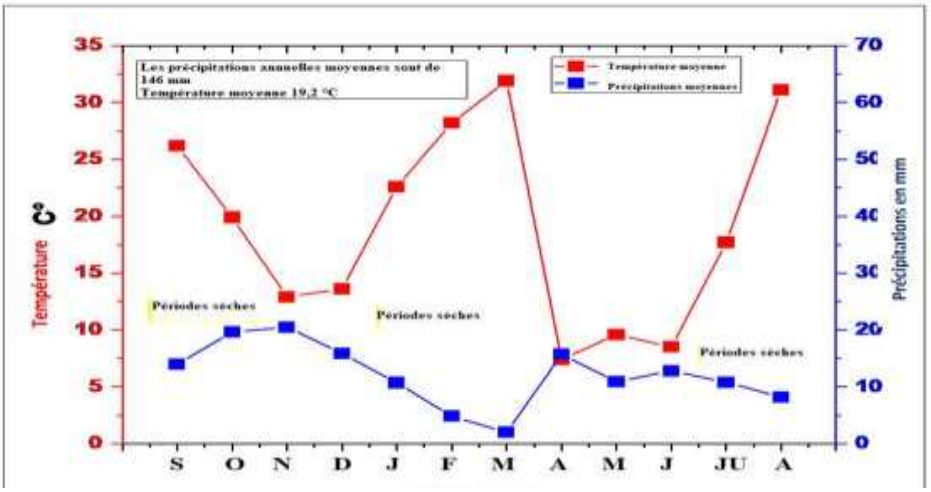

Figure 22: Average monthly precipitation and temperatures between [1981/2020].
Donation source: http://power.larc.nasa.gov/data-access-viewer/;
Processing using the program [OriginPro2021], own work, May 2022.

As for the precipitation associated with the Oasis of Figuig between [1981/2020] [40 years], the annual average is 146 mm [Fig 22] and this amount is unevenly distributed. The rainfall season generally extends from September to December, while July and August remain the driest months of the year.

The evolution of the average temperature 19.2C° and the average precipitation 146 mm shows that the months of July and August are the hottest and driest in general, while the months of January February March are the coldest months, but they are not the months with the highest temperatures.

4- Water Sources of the Figuig Oasis: Flow and Use Systems:

If Egypt is the gift of the Nile based on an aphorism of Herodotus [late 6th and early 5th century BC] (Hassan & Abdullah, 2009), we can say that the oasis of Figuig is the gift for the eyes located in the upper part of the oasis basin. The oasis of Figuig has a variety of groundwater and surface water resources that have contributed to the organization of the oasis area because most of the Ksar are concentrated on the plateau with the exception of the Ksar of Zenaga is located under the cliff called Azrou.

The inhabitants of the oasis of Figuig have created a particular and unique system of exploitation of these water resources through methods and techniques of filling, storage and distribution (Hassan & Abdullah, 2009). In addition to a set of customs that do not respond to the force of the law and that have not been able to solve certain problems related to water, or the so-called water war between the Ksar. In addition to the traditional exploitation of these resources, a set of modern techniques has emerged to manage them, based on automatic pumping and the organization into cooperatives and local associations. Which in turn have contributed to the expansion of the agricultural domain.

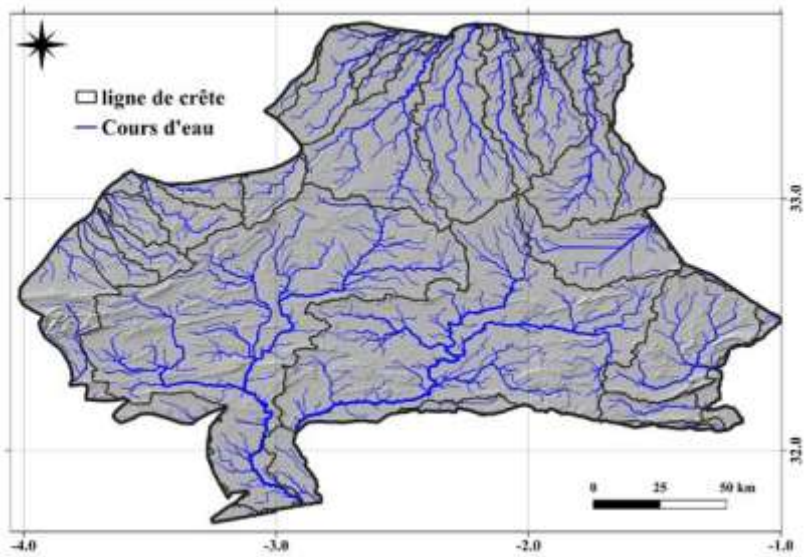

Figure 23: The water network and sandy basins in Figuig province Source: http://earthexplorer.usgs.gov. Processing in ArcGis 10.3, personal work, 2022.

4-1 Surface Water Resources:

Surface water resources consist of superficial or seasonal watercourses such as the Zouzfana, Aghlal and Tafilia rivers: These sources, represented by the Zouzfana valley located in the Arja area [Moroccan-Algerian border], although irregular and intermittent, are fed in places by springs, and in rainy periods, particularly during floods, by the Jbel Krouz and Jbel Beni Samir valleys. This situation explains the sometimes-sudden filling of these valleys, which use the waters of the Zouzfana valley for irrigation thanks to the construction of small dams.

The Zouzfana Oued is the most important watercourse in the oasis. It starts from the north, where it is called Oued Al Halouf, and enters the oasis towards the east, forming a natural and official limit of the Morocco-Algeria border at this point. From another point of view, the role it plays in the formation of sediments deposited by the impact of the dam formed by Mount Sidi Youssef and Mount Taghla, through which it passes to head towards Algeria and then disappear into the desert (MOHAMMI. A.)

Other Oueds of lesser importance than the Zouzfana Oued originate mainly in the mountains near the oasis, the most important of which is Al-Khanak Oued, with an area of 37 square kilometers, formed by the deposits of the polygenic glaciers located to the west of Ksar Zenaga. (MOHAMMI. A, 1996) currently, the course of this Oued deviates towards the southeast to pass into Algerian territory by the eastern end of the Jbel Mellias.

Then the Lakbir Oued and the Bouchlikhan Oued, which branches from the southern slope of Jbel Al Haimar and the easternmost part of the southern slope of Jbel Cruz, a small basin with an area of 32 km^2, whose landslide products constitute the main source of soil for the western part of the palm grove in the southern region.

4-2 Figuig Oasis, the Gift of the Sources:

Water is an important economic force and its control means the continuity and control of life. And, if Egypt according to the famous saying, the oasis of Figuig can be considered as the gift of its water sources, the inhabitants of the ksour of Figuig remain indebted for their life and existence and continue to the water sources, without which man could not live in these naturally arid areas. The water sources provided by the oasis of Figuig therefore remain of particular vital importance.

4-2-1 Groundwater Resources:

The oasis of Figuig has a significant water potential, despite current climatic constraints, in addition to the fact that most of the water sources located in the northern half have been exhausted due to strong, human and agricultural pressure, there are a number of water sources that have not been exploited for geopolitical reasons (border area).

On the other hand, in the southern part of the Figuig basin [Baghdad plain, south and southwest of Zenaga] [Fig. 24]. Today, the water table is

exploited thanks to the introduction of motor pumps, which have made it possible to meet the water needs for watering the palm groves by partly exploiting groundwater. Most of these sources, located directly underground, are used for the daily use of the inhabitants and for watering the palm groves.

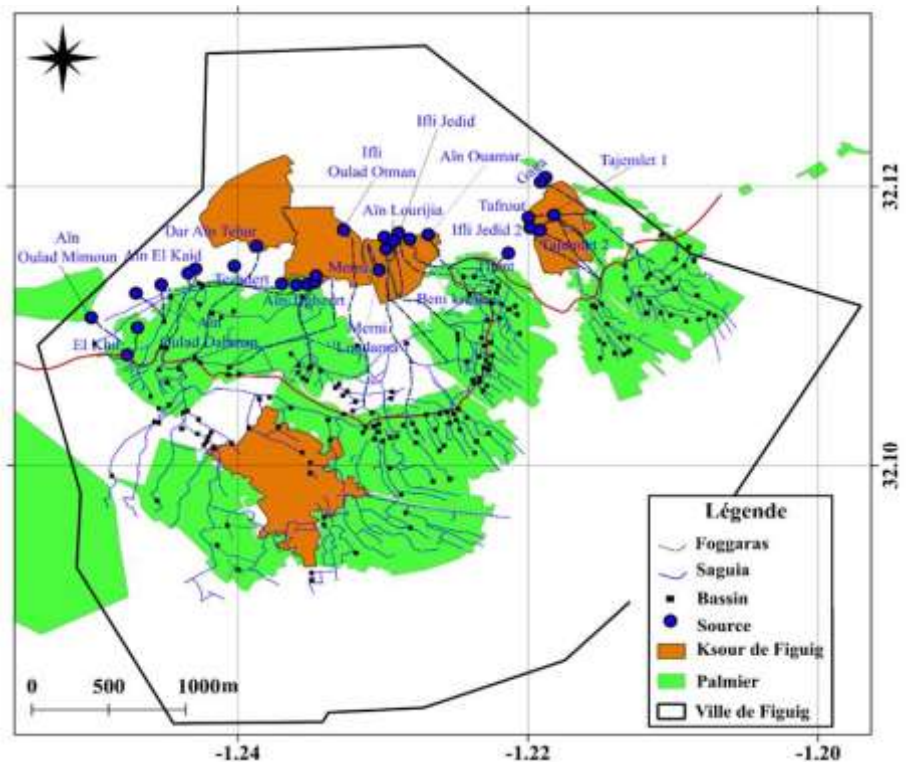

Figure 24: Distribution of hydraulic sources and Foggaras in the oasis of Figuig according to the ksours.

Source: BENCHERIFA and POPP., 1992; DPA, 2009 Processing under ArcGis 10.3, personal work, 2021.

4-3 Water Use and Irrigation Systems in the Figuig Oasis:

The cataracts[1] are covered, the oasis of Figuig has been used by man since ancient times, as it represents a unique architecture that tells us an important strategy for the organization and distribution of water, the

[1]Al-Khatara has several names depending on the region, as it is called [Al-Khatara] in Tafilalet, Figuig, and the oases of southern Morocco, [Al-Foggaras] in Algeria, [Al-Kreija] in Tunisia, [Al-Qanat] in Iran, [Roman Canal] in Jordan and Syria, [Al-Ghariz] in Afghanistan and Pakistan, and [Kanir Ding] in China (Jamal, Hassan, 2020: 122).

most vital element in desert areas. Water and its property rights are exploited through a large number of khatarrate, numbering 32 khatars. Some of which have been somewhat neglected or overexploited, as is the case of the khatarrate Tzadarte. Which look at the most important in terms of their casting and in terms of the history of disputes. Over them, notably between the Ksar of Loudaghir and Zenaga; to what goes beyond what it is [Roger Groumd] to note that the conflict over water appeared in the 14th century AD, when the conflict between Kasr Zenaga and Kasr Loudaghir and Beni Abd Al-Jabbar took place in Ayoun Tzadart, which is of particular importance. As for the conflict between Ksar Hammam Al-Foukani and Hamam Tahtani, it was the source of Tajamalt, and this conflict only ended in the last years of the 20th century.

Due to the extent of the land, it irrigates, and the number of shares of the landowners, it was found more than 300 years ago, with 1,920. The Kharroubba Spread over four channels, the flow of the spring has dropped to 20 liters per second, compared to 88 liters per second in 1987, due to uncontrolled and increasing exploitation. In 2006, the number of pumps reached 300.

These pits were dug and built at different times, based on the human. Need for more water to irrigate the orchards. He spent decades of hard and continuous work digging and preparing them, relying all on muscular effort and with limited primitive means. With an axe and a palm leaf basket to carry the earth to the surface. This process takes place through gaps in the semi-dark tunnel, which varies in depth between [6-10] meters and a width between [0.5-1.5 meters].

The Tzadart spring is one of the largest springs in the Figuig oasis, and its excavations date back more than 300 years. Around it, several disputes and wars broke out between the inhabitants of Figuig, including the year 1768 between the Ksar of Zenaga and the Ksar of Oulad Jaber.

This spring gives thought to one of the most important springs on the plateau, and without it, the oasis would not have survived. This spring is located in the orchards of the Ksar Awlad Jaber, exactly next to their mosque, of which only traces remain. This arch, which is still erected for this day. According to some well-known oral stories, Boudiaf Hako, who was grazing sheep in this region [Fa Oulad Jaber], found this eye then the good value, Sidi Hajj Mohamed Abou El Fadl, would have served him for the benefit of all residents from Figuig at the end of the 9^{th} century of the Hegira and the beginning of the 10^{th} century.

The region has been the scene of bloody civil wars, as evidenced by the many towers surrounding it, particularly between the inhabitants of Ksar Zenaga and those of Ksar Ludagir, the last of which dates back to 1903, when the management and distribution of water was committed to Ksar Zenaga. There are several interpretations of the name "Tza which means sufficient and: "dirt which means abundant and fruitful".

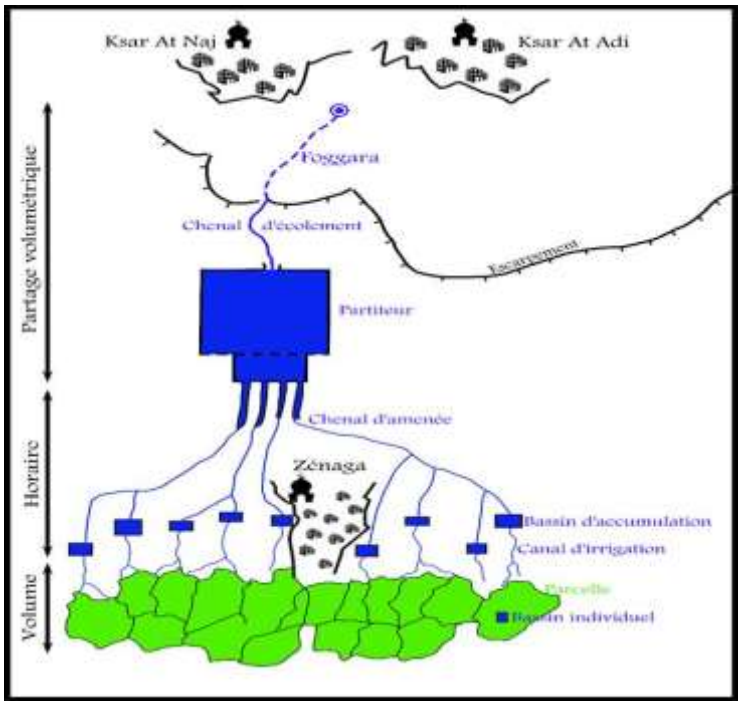

Figure 25: Shows Ain Tzadart in terms of water sharing in terms of volume and its relationship with time.

Source: Omar Zayed, 1992, adapted.

In its other meaning, the Igoudas are watering cans used to distribute water according to the quotas allocated to each faction or family. The flow of water in each hopper is 16 kharroubas[1] Every 12 hours, which is equivalent to 32 kharroubas in 24 hours. As for the idea of the Ikoudass, it came to reduce the conflicts known in the past between peoples, as well as regulate irrigation and control the flow of Ain Tzadart, because this flow has experienced a notable decrease in recent decades. During which years of drought and climate change have followed [Fig: 26].

Figure 26: Hydraulic networks connected to the collection basin for watering the orchards, Ikoudass – Tzadart.

Source: Researcher's Lens, August 19, 2022.

Figure 27: shows the flow rate, which is a tool for measuring water distribution.

Source: (Alahamo, 2019).

4-3-1 Al-Bahbouha [Bahbouha of the Ksar of Loudaghir]:

The oasis of Figuig personalizes by the presence of a group of barks whose meaning and significance are taken from the Hadith, as mentioned in the Hadith of Khuzayma: "The bark is perceptible and the modesty of modesty is revealed". Ibn Al-Athir said: "There is a hadith: Whoever wants to remain in the splendor of Paradise let him stick to the

[1] The kharrouba is the share of water that the farmer benefits from with the authorization of the Seraifi [the person responsible for water management in the oasis of Figuig], and this water is designated by Ain Tzadart, and the measure used in this is called [Tigret]. The price of the kharrouba currently reaches 40 thousand dirhams, and the rent of the kharrouba is linked to the yield, and this from October to May 350 dirhams. Then from May to October, 350 dirhams, and the total is 700 per year.

congregation. It is said that the house is the center of the house, and it is said that it is the center of the house and the place" (Haddadi, 2018).

Al-Zamakhshari said: "You are becoming arrogant in this matter: expand on it, because of the hoarseness of the house while it is in the midst of it". Ibn Faris said: "The origin of joy is in the midst of the house, and in the midst of the camp of the people...". Al-Farra' said: "It is said: We are in the courtyard of the house (with the emphasis on the "ha" in the courtyard), and it is the widest of them, so it is said that such and such delights in glory, that is, he is spacious in" (Haddadi, 2018).

According to the linguistic connotations and meanings, the people of Figuig called this place Al-Babouha because of the establishment of the faith in its bottom, its width and the abundance of water, as well as its power and solution. The water of Bahbouha personalizes by its sweetness and taste, it is used for drinking and treating kidney failure, and its flow varies according to climatic influences.

4-4 The Inherited System of Irrigation Water Distribution in the Oasis of Figuig:

The organization and distribution of water in Figuig are the most complex of its kind, since its study requires knowledge of all the historical stages in which the owner families organize them from the casting, the forms of distribution, the methods of digging and construction of the water network exploited the water sources. In the oasis of Figuig, the distribution of water is a more precise system for the distribution of irrigation water was introduced in North Africa, since it is based on the measurement of time instead of volume, as in Algeria, which was called Moufqouda and in the oases of Bani Abbas called: (Tsiria) [Fig 27].

Paul Pascon discovered in the Tazerwalt region a chronometric system of water distribution similar to a water clock, called a water clock.

These examples indicate a similar level of civilization in the oasis societies of North Africa.

The irrigation system of the oasis of Figuig is based on a unit of time called in Berber Tkhirbet, which is equivalent to 45 minutes of the time needed for the water to infiltrate the container called "Tghirt", which is the water-measuring device, and this container has the shape of a hemisphere that fits inside the oasis. About a liter and a half of water with a very small hole at the bottom, which is placed empty above a water surface that can accommodate a small tank built with stones and lime, so that the water gradually infiltrates the copper container until it is full and the tank sinks into it, which makes it possible to record a complete la Kharrouba (Maziane, 1988: 140).

The distribution of irrigation water is ensured by a man chosen by the Ksar community, called [Asrafi-A water maker], who is honest and knows perfectly this complex network as well as the process of purchase, sale and exchange to which the kharrouba is subjected. In exchange for these services, he is allowed to benefit from a full share during the year, which is extracted from the collective property of water.

There is no law that determines the price of carob water, although the time scale for the flow of carob does not differ from one Khattaras to another. In fact, before the adoption of the copper machine, the distribution of water in the oasis of Figuig was subject to two cycles, a diurnal cycle from sunrise to sunset and a night cycle thereafter. This process required the distribution of orchards into multiple and specific groups that benefit from the water from the lines either during the day or at night, and the next day the water is transported in other directions to irrigate a second group, but this system requires a longer waiting time. However, with the expansion of the agricultural area dependent on irrigation, the characteristics of conflicts began to appear on the horizon,

where the beneficiaries of water due to the different length of day and night, and the seasons. Then the flow of the Khattaras in turn varies from summer to winter and from one Khattaras to another. Therefore, the alternative was to look for a continental measurement tool that is not subject, to the change of time or seasons to determine the share of water of each individual or family.

4-4-1 Traditional Distribution and Operating System:

The Oasis of Figuig personalize by a particularly detailed water distribution system, the most elaborate of which is made up of underground passages that drain and transport water from the subsoil to the surface, towards the gardens for irrigation and other uses associated with the inhabitants [Fig 28]. The aquifer system of the Oasis of Figuig is made up of aquifers and springs. Groundwater represents a renewable resource with a total volume of approximately 13 million m^3/year throughout the basin, which extends over an area of 2778 km^2 [Fig 28].

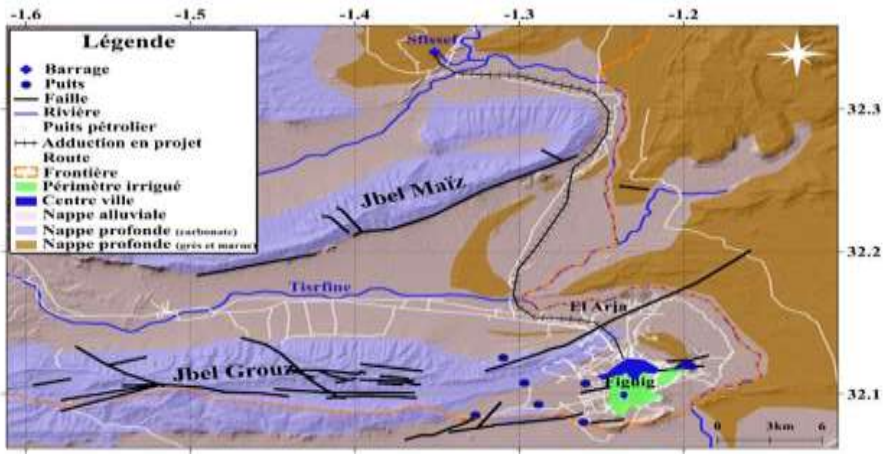

Figure 28: Underground water beds discovered in Figuig Province, including the Figuig Oasis.

Source: http://earthexplorer.usgs.gov.

Processing under ArcGis 10.3, personal work, 2022.

The shares of running water amount to 4.4 million m3 in the Figuig aquifer, 3.6 million m3 in the Tasrifin-Arja aquifer, which is an extension of the Figuig oasis, and 11.5 million m^3 for the deep aquifers of the basin

(Marzouk, 1996). The groundwater from the springs is drained and transported by underground galleries [Image 82-83] dug directly into the rock, called "khatarat", which are considered the original water sources in the creation of the Figuig oasis, since even the site of the current palaces was not only built along the water sources, but was considered part of their property.

The Khattaras are made up of:

- A drainage part located upstream, below the water table level.
- An annex located downstream, allowing water to flow towards the ground surface thanks to the slope.

This basin serves to collect water to facilitate control and regulate the flow for irrigation and storage [Fig. 29].

- The roof of the gallery is perforated at variable intervals with manholes for ventilation.

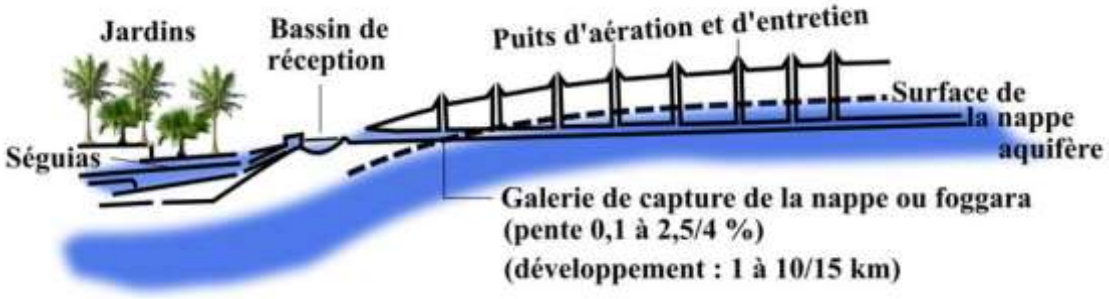

Figure 29: La Foggara. Diagram of operating principle and evolution. Source: (BOUSETTA, 2013, p. 66) Processed with ArcGis 10.3, adapted from 2021.

Figure 31: Interior of the Foggaras gallery associated with the Tajmlet 1 source at Qasr al-Hammam al-Fawqani. Source: The Researcher's Lens, August 20, 2022.

Figure 30: Aguadier/ Asrafai, measuring the water level during watering. Source:(BOUSETTA, 2013).

On the roof and in the gardens, the water transported by these galleries flows into channels called "the seguias". The water can be used in real time as it flows through the galleries to irrigate cultivated or uncultivated land, and this is one of the main assets of the irrigation system of the oasis of Figuig. Because it is transported and pushed into storage basins (receiver) that allow delayed watering cultivated areas with a more flexible subsequent distribution of water.

The khatarrate technology adopted in the Figuig oasis to save water is the result of a process of evolution and growth in which many human efforts have been accumulated over centuries. The general structure of the traditional irrigation system was improved by using cement [Image 85] to build channels and dams to prevent water leakage and protect it from evaporation [Fig 31].

The allocation of water for irrigation depends on the person called Al-Sarafi, the cashier of [Asrafai] [Fig 30], who knows perfectly the size of [Al-Kharouba] each family. After being collected in the receiver, the water is distributed among the beneficiaries according to their quotas, which are

strictly organized in terms of respecting the scheduled time and date so that each beneficiary receives their share of water in accordance with their rights.

Conclusion:

As a conclusion, the oasis of Figuig has been designated as "the gift of springs", similar to a saying quoted by Herodotus from his Greek ancestors, who recognize Egypt as "the gift of the Nile". Through this saying, we see a kind of congruence with what the inhabitants of Figuig have created in terms of a system of hooks to ensure the delivery of water to farms and gardens. This highlights the ingenuity of the people of the oasis on one hand. On the other, reflects the intangible human heritage of the inhabitants of Figuig.

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