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Ksour of the SAHARA Desert as A Great Lesson of Sustainable Urban Design in Hot Desert Oases

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ABSTRACT

Despite the severity of the SAHARA Desert from many aspects, the man was able to confront it, and to build great human settlements distributed in different areas as the REG of Mzab Valley, the ERG of Righ Valley, Hoggar Mountains ... And many others points to human life.

*These Settlements called **SAHARAN Ksour**, which become today a valuable architectural and urban heritage. This paper presents a thorough study on SAHARAN Ksour from an environmental point of view, so we focused on its adaptation with the different environmental elements, and speaks about the most important components of architectural and urban design as:*

- *The internalization concept.*
- *Half-covered street system.*
- *Twisted street design.*
- *And the use of the palm grove as a climatic component of urban and architectural design.*

And how to deal with environmental variables such as warm winds (Sirocco), sandy spring wind, high temperature and the seriously low humidity, all these elements, components and relations are presented in this paper in many examples of Ksour situated in Algerian SAHARA.

This paper is a lesson between environmental components and SAHARA desert urban heritage, which we aim to give prominence to the ability of the past SAHARAN human settlements to challenge the desert at the time where present ones can't challenge it, all this to find a formula for the future SAHARA desert sustainable architectural and urban design.

Key Words: *Sustainable Urban Design, Ksour, a Ksar the SAHARA, Urban heritage, Desert urban design, Saharan architecture.*

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1. INTRODUCTION:

The *SAHARA* desert is considered as one of the largest and harshest deserts in the world along more than 1500 kilometers from north to south and 1,200 km from east to west, situated on 8.5 million km² are all barren except 200 thousand km² which are considered as urban areas which is nearly 3% of the global surface.

The difficulty of urbanizing the desert is due to several reasons as the vastness of its area, the harsh climate and water scarcity, but the cause of the human settlements diversity is mainly due to its different natures of the surface factor, which is changing from sweat sandy (*ERG*) to parchment flat salty soil (*REG*), rocky areas (*HAMADA*) and the arid mountains, as illustrated in (Fig.1). In

spite of these problems the man was able to live and create human settlements called Saharan Ksour become today's a very valuable urban heritage.

Figure 1: Different natures of the SAHARA surface from left to right (ERG, REG, HAMADA, and Mountains) [1]

2. SAHARAN KSOUR

The Saharan Ksour were distributed with intelligence, some of them came along trade routes crossing the desert as the ways of gold which connects African countries like Ghana, Mali and Sunray with the cities of the North (Fig.2), and other Ksour were distributed in areas where the water was available.

Due to all these reasons and factors the *SAHARA* was rich with several types of Ksour distributed in many areas called valleys as the *MIZAB* valley, the *ZIBAN*, the *SOUF*, the *RIGH*, and the *TOUAT* on the extreme west of *SAHARA*, ... etc. However, the difference was too simple on its urban level because the design was similar and characterized by:

• The Centralization concept where the usually center is a mosque or a Market.

• Its circular shape which is adapted and integrated with the hill where it is built on, and lots of Ksour are built on small hills.

• Urban tissue depends on a network of broken and zigzag lines due to natural, environmental and social causes.

• The Ksar is always situated in the heart of the palm grove or beside it to take the maximum of economic, social and environmental advantages of it.

• The use of local building materials in all construction processes.

• And other characteristics coming soon.

But in this paper, we do not care about its urban methods of design or their cause, we are interested about the relationship of this important urban and architectural heritage with the environment and how to deal with various environmental elements such as the high temperature, low humidity, sandy winds and dry winds (Sirocco) ... etc.

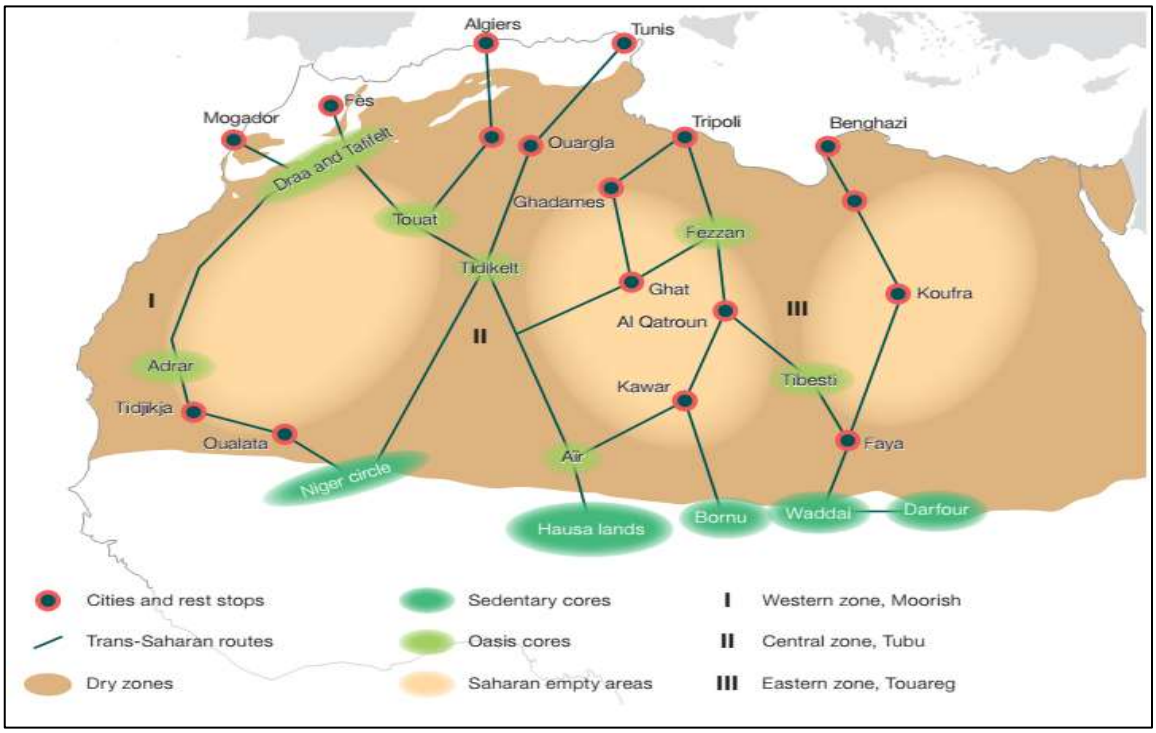

Figure 2: Map of trade routes crossing the SAHARA. [9]

3. CASE STUDY THE RIGH VALLEY

RIGH valley is not the name of a particular valley but the name of a geographic area, this name has launched soon and mentioned by the Sheikh Abdul Majeed bin habba, saying "*all historians talking about it call it RIGH valley or RIGH lands were Ibn Khaldun call it RIGHA land ...*" and *RIGH* is an amazigh word means a marsh. It is located in the northeast of the Algerian *SAHARA* (Fig.3) along 170 km from north to south between latitudes 32.54 ° and 34.9 ° north.

From a climatic point of view more than 06 months with a rate of temperature higher than 20 ° C and the amount of rainfall received is down to 100 mm per year although the coast is about 300 km from it, the valley is located on a huge Artesian Basin composed of aquifers one above the other and the closest one to the surface which allowed the creation of Ksour and oases in many centuries ago.

It is divided into three big groups of palm grove which are El Meghaier in the north, Jamaa in the center and Touggourt in the south, on more than 20,000 hectares with more than 4,000,000 Palm making it the largest oases in the *SAHARA* and the second largest one in the world. And contains 36 human settlements, including 26 old Ksour dating from 15 centuries ago, in addition to 10 new cities (Fig.4).

Figure 3: Situation of RIGH valley. [3]

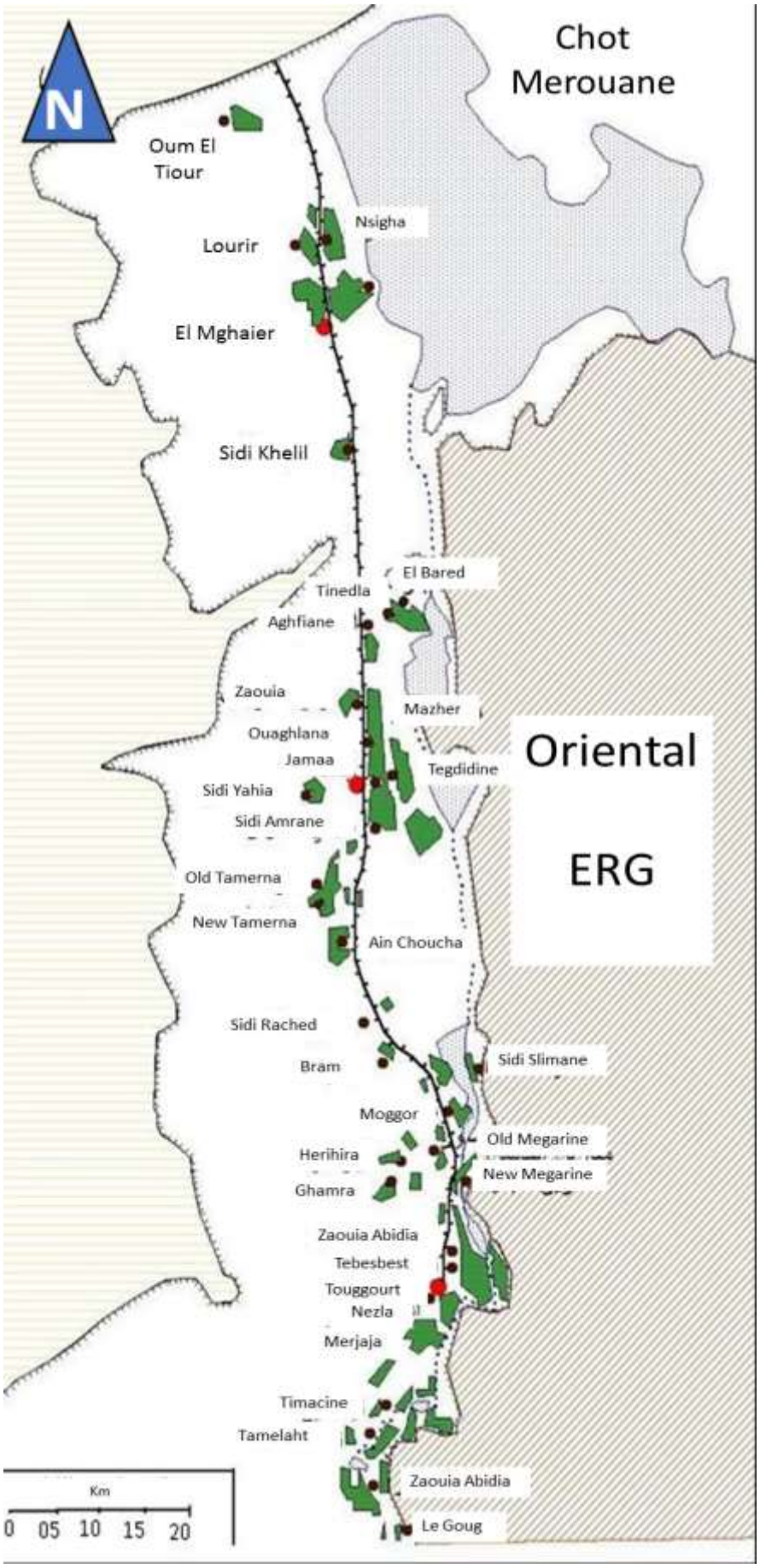

Figure 4: Ksour and cities of RIGH valley. [4]

4. ELEMENTS OF URBAN DESIGN AND ENVIRONMENTAL VARIABLES

4.1. The palm grove as a major environmental component of urban design:

From an analytical point of view the ancient inhabitants didn't depend on the palm grove as an economic resource, but also as an important element of urban design, because a major percentage of Ksour built on the sides and edges of the palm Grove, while the larger part of it is located in the heart of the palm grove to take advantages of these several factors:

4.1.1. Protection from different winds

All the theories and measurements studying the phenomenon of wind between a desert and an oasis proved that the presence of the palm grove explains the existence of a high level of friction reverse the low irresistible level of the desert, and the palm grove moves the wind Level from the surface of the earth 00 m to a certain height. *Cionco [5]* proved that wind speed is different between a desert and over the palm grove.

- **Sandy winds:**

  Sandy winds are very strong and the most effective solution to stop it is by making a deviation in its direction by palm trees or windbreaks (Fig.5) to reduce its severity and its dust by the green palm infrastructure (trees and other plantings), that's why we usually find on the exterior side of a palm grove many rows of shorter palm and the longest ones are implanted in it to give the deflection direction of strong sandy winds without causing swirling air which may affect the palms (Fig.6) , usually we use a type of palm called " white degla" due to its force as a windbreak and in other cases we use a mud wall topped by a crown of palm leaves , but the most important point is the presence of trees and plantings under palms which crossed all the wind (Fig.5).

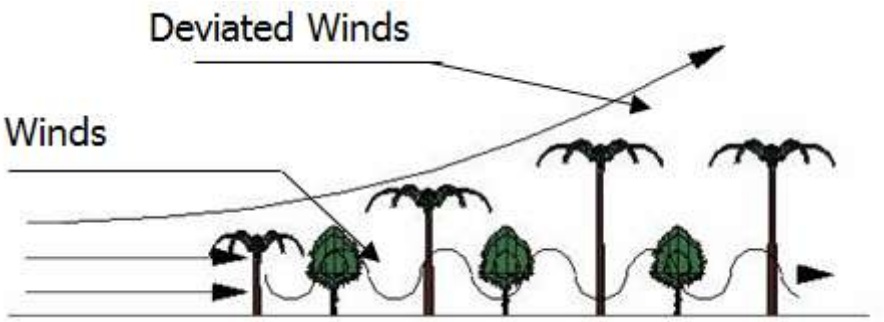

Figure 5: the repelling process of the sandy wind by the palm grove infrastructure. [5]

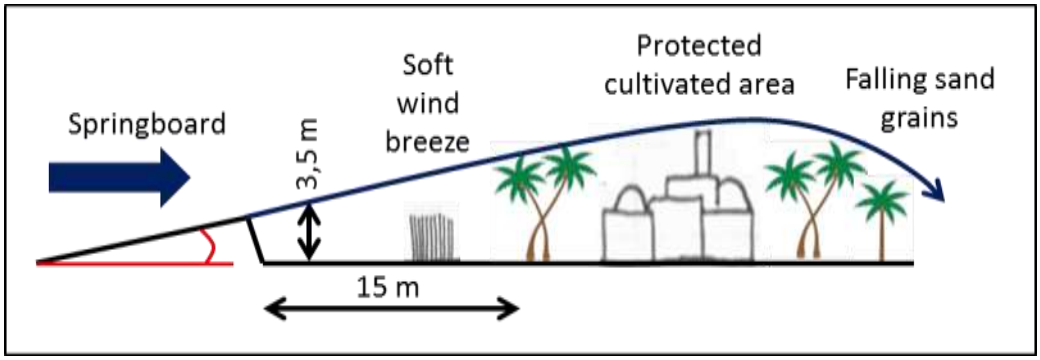

Figure 6: Type of a windbreak where sand is hopped by a wind jumper aided by the palms protection. [2]

- **Dry winds:**

  Dry winds are usually with slower speed and force, in this case palms don't effect on it directly but its role is to protect the trees and plantings infrastructure which will process the wind moisturizing and temperature reduction (Fig.7). Because putting a wet area in a dry one can completely alter the humidity levels, this hypothesis was the subject of *Itier* and *Perier* studies [5], who treated temperature and humidity of the winds before entering and after leaving the Oasis, with a fixed wind speed, their results will prove later by *Rider & All [5]*. Whereas in houses the role of palms is changed because we are not talking about vast areas of palms but speaking about a single Palm or a couple, in this case we use

special types of palms which are young and don't exceed a certain height, in order to don't loss shade beneath palms. In some regions of the world they use palms near *al malkaf* to clean air and tempered it before entering the house.

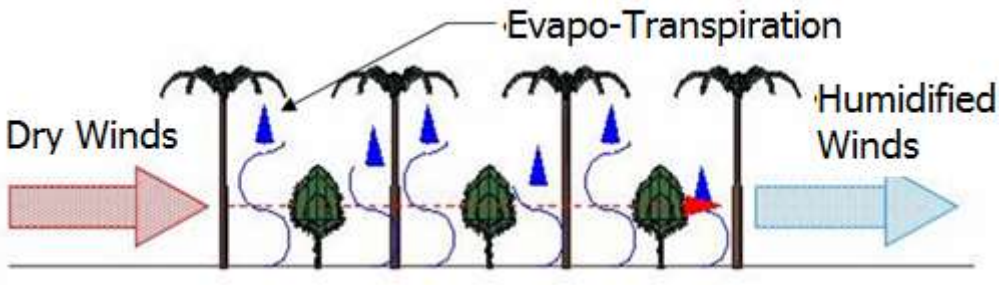

Figure 7: The process of moisturizing dry winds by the oasis effect phenomenon. [5]

4.1.2. Dealing with the heat and humidity

Many kinds of trees can produce significant quantities of water, which raises the humidity and lower the temperature, which is the result of evapotranspiration process. *SAHARAN* plants and trees in general and especially palms lose small amounts of water to keep it to themselves, so the high humidity measured in the Ksour and oases is not caused by palms itself, but by the protected green: trees, plants and the moist soil, here we must talk about a relation between dry winds level and the green area because a significant impact on the temperature and air humidity demand a vast green space, this last must be proportional with the Ksar size. Because one Palm can be enough to moisten the courtyard of a house and at the same time its influence cannot be felt at an urban open space (Fig.8), this hypothesis proves by results obtained through the computing program ***Oases Effect Calculator*** which is designed and programed specially for these Ksour *[5]*. The temperature inside the Ksar is less than 2C° to 6C° according to the season and the month while Relative humidity can reach the limits of +18% compared to their counterparts in the heart of the desert.

Also in summer days where there is no air movement, the built space is heated faster than the neighboring palm grove creating a low-pressure area which pulls the cool air from the palm grove. It is the forest breeze phenomenon.

Figure 8: Ksar of Touggourt in 1890, a photo representing the extent friction of the Ksar with the palm grove to take maximum of available protection. [6]

4.2. Expansion Unit

The limitation of the Ksour size from small to medium is due to several reasons, possibly social and economic but the most important is the environmental cause because of:

• Lack of spaces valid for the construction of Ksour because they were built on hills and plateaus.

• Inability to achieve the environmental protection of Ksour if they exceed a certain size.

That's why Saharan Ksour forms were from small to a medium size and has the ability for future expansion as a copy. The most important examples are:

- The case of the five Ksour of *Mzab* valley which are distributed linearly along the valley and palm grove where every Ksar have its own gate and wall.
- The two Ksour of *Tamerna* in *Righ* Valley (Fig.9): old *Tamerna* and new *Tamerna* where the old one moved from the first hill to another nearby as a twin with the presence of a third hill which can be the subject of the construction of another Ksar, but other factors that led the population to abandon the Ksour to a new urban nucleus

Figure 9: An aerial view of the old Tamerna at the top and the new one at the middle showing the transition from the first hill to another, (at the bottom is a third hill) it is the expansion unit system. [7]

4.3. Twisted street system:

The twisted street system (Fig.10) was used specifically for the conditions of the site and topographic exploitation but it made other social and environmental benefits, where a study made in 2006 by the author using Flovent system, prove that in the Ksour of new Tamerna, Nezla, Ouaghlana and Sidi Yahia, the twisted streets play an important role in reversing the wind and reducing the severity by dealing with its viscosity as mentioned by *Cionco [5]* has been Talked about. Also, the results obtained confirm that in many streets the air speed don't exceed 3 m/s which is ideal for reaching outdoor thermal comfort.

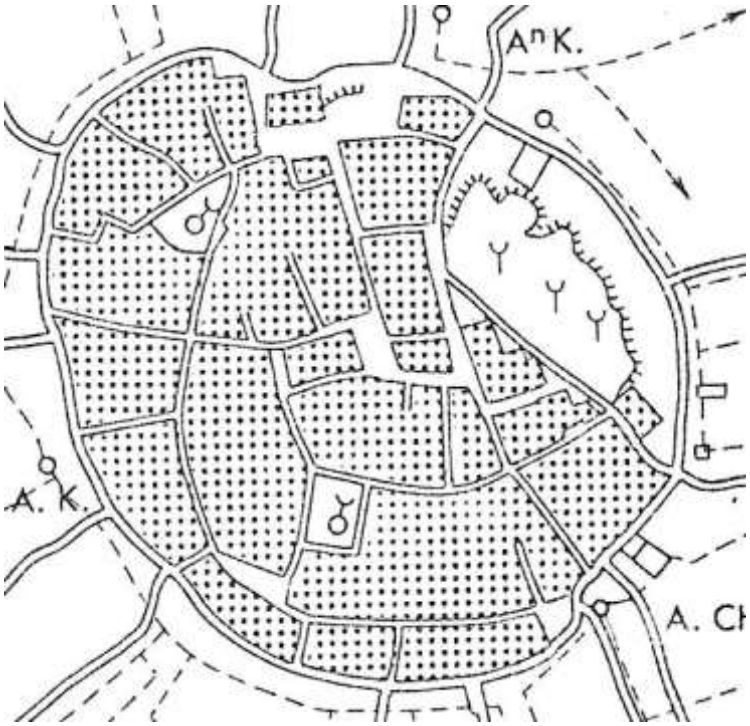

Figure 10: new Tamerna plan, showing the complexity degree of twisted streets, which reflects its ability to break down the various winds. [8]

4.4. System of half covered streets:

Half covered street System is a wonderful creativity contributed by the narrow streets (Fig.11) where the upper floor is used between two adjacent houses and the ground floor is considered a part of the street and a furnished urban space. Environmentally the half-covered streets create a kind of air pressure differences, which drives the air from the high-pressure area in a shaded space toward a low-pressure area in a sunny space, this is called scientifically the artificial breeze, which plays an important role in the ventilation and cooling urban open spaces in summer days.

Figure 11: a picture of New Tamerna street in 1820 (on the right) and in the Ksar of Timasin in 1870 (on the left). The pictures show that the streets have sunny parts and shaded parts creating an artificial breeze in summer. [6]

4.5. Concept of internalization:

The internalization concept in urban design (Fig.12) means reducing outdoor spaces and turn them into indoor of houses, that's why we find in the Ksour a lack of urban open space which are few and very small and this is called the Urban compactness. This last plays an important environmental role by reducing the energy gain in the hot summer days as mentioned by *Mahoney [5]*, while the compactness plays the role of stocking exchanged heat between the houses at cold winter days as mentioned in *Givoni* chart *[5]*.

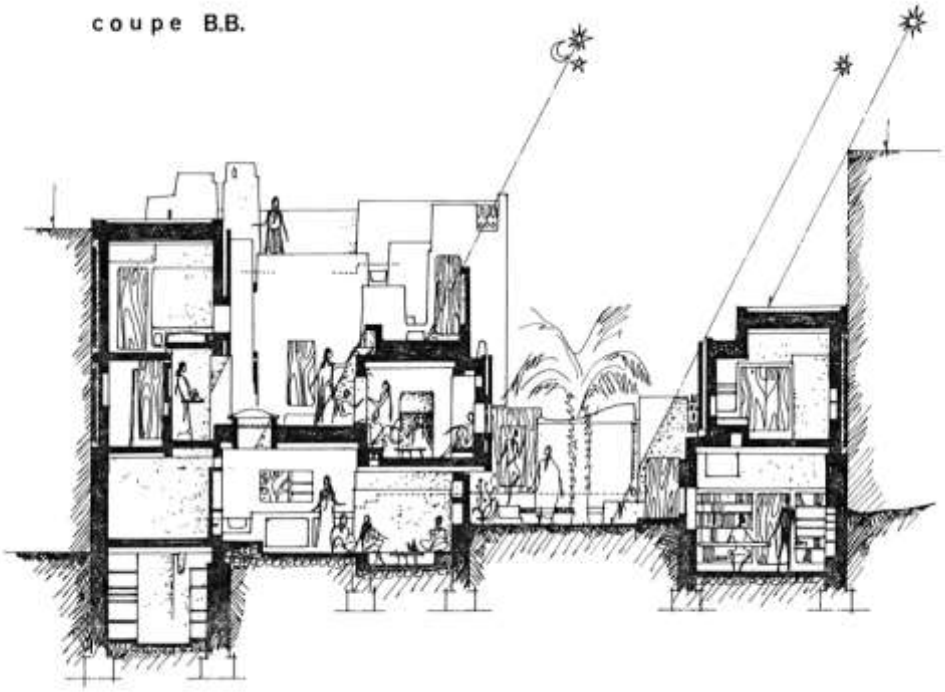

Figure 12: a section of house in Touggourt shows urban compactness and internalization concept by using patios and indoor courtyards. [5]

5. CONCLUSION AND RECOMMENDATIONS

Perhaps the first lesson that we conclude from this research that the Saharan Ksour abandoned today are considered as a very valuable urban heritage especially from an environmental point of view, and older people have given us many lessons that we have explained in this paper, despite the lack of resources available to them. After the results obtained through this research where the ability of the Ksar and the oasis to cope the Saharan harsh climate we present the following recommendations:

• attempt to renovate the old Ksour located in the heart of the palm grove as the Ksar of *Ouaghlana*, *Sidi Yahia*, old *Tamerna* and ancient *Jamaa*, which are demolished manually, especially they are equipped with water and electricity lines.

• starting a deep study of psychological and social behavior of Saharan habitants on the reasons for abandoning the Ksour and return to it greedily with the movement of agricultural support underlined by the Algerian Ministry of Agriculture, and a research on the look of current Saharans people about the possibility of accepting to live in Ksour like his grandfathers. As a famous question asked by a German researcher: "*What is left in the depths of the Saharan people from the ancient system?"*

• sensitize the Saharan people and habitants of oases and Ksour to the importance of the palm grove economically, socially and in particular environmentally, by a Saharan environmental education at all levels to maintain this wealth of palms and develop it.

• Reducing the rapid and chaotic expansion of small human settlements in order to don't fall into forms resembling to *Jamaa* city or *Touggourt*, where their climate is approaching to desert.

• verification and approving the results obtained in this research by taking measurements for a certain period estimated by four to ten years' experience with expansion to include other Ksour of *SAHARA* to reach more accurate and realistic results, which can help us in the design of the future Saharan cities.

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