Comparative Morphometric Analysis of Maghrebian Oasis Villages:
Case of the Ksar of Ouargla (Algeria) and the Medina of Gafsa (Tunisia)

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Abstract

The present research is a comparative study of the urban forms of Ouargla's ksar and Gafsa's medinal center, and an understanding of the systems that underlie them. The shapes produced by these Maghrebian oasis villages are expressed by a geometry that is difficult to grasp. They are complex and cannot be described in geometrically defined terms. To understand them, we adopt frequency analysis: a method that enables us to move from the perceptible to the intelligible. This numerical characterization, in this case morphometric, reveals explanatory models for the shapes produced. It provides objective explanations of the origins of the urban forms of the Ksar of Ouargla and the medina of Gafsa, elucidating the different logics underlying their genesis.

Keywords: *Frequency analysis, urban form, morphic stratum, energy descriptor*

Introduction

Urban heritage serves as the collective recollection of a city, and the broader environment it shapes reflects the characteristic panorama of a city during a specific historical era (Wang, 2012). Typically, when urban planners and managers contemplate the term "urban heritage," the immediate association is often with "monuments." However, this perception frequently overlooks historic residential zones and the central areas of cities, both of which equally embody urban heritage (Steinberg, 1996). Such elements are integral to a city's history and memory, and without them, the historical narrative would lack continuity (Wang, 2012).

Morphometrics is a branch of science that involves the quantitative analysis of the shape and size of biological structures. Although it is primarily used in fields such as biology, ecology, and paleontology, morphometric analysis has also found applications in architecture (Slice, 2007)

It is a numerical model for analyzing complex shapes that enables the study of their properties and numerical characteristics. Furthermore, it highlights new knowledge and constructs models to enhance the understanding of the morphology and functioning of urban tissues (Zeribi, 2021). Morphometrics has applications in a variety of fields, including systematics and taxonomy, ecology, developmental biology, forensic science, and biomedical research. It is also an important tool for studying the evolution of organisms and their responses to environmental changes (Carayon, 2018; Vuillien et al., 2017)

The process of morphometric measurement focuses on the mathematical representation of a shape rather than its observable form. Morphometrics creates a knowledge framework that distinguishes form from mythical thoughts, aesthetic traditions, and immediate spatial experiences.

In recent years, there have been significant developments in morphometrics, the study of biological shape analysis. Much of this progress stems from the emergence and acceptance of techniques for analyzing the precise coordinates of anatomical landmarks. Known as geometric morphometric (GM) methods, these approaches prioritize maintaining geometric data integrity throughout research endeavors. They offer efficient and statistically robust analyses, facilitating the correlation of abstract, multivariate findings with the physical characteristics of the specimens under study (Slice 2007).

In the context of architecture, morphometrics can be used to analyze and compare the shape and size of architectural elements or spatial configurations, with the aim of understanding design principles, identifying patterns, and informing design decisions. By quantifying and analyzing variations in architectural form and spatial relationships, morphometrics can provide insights into the underlying design principles and processes that govern architectural design.

In this method, the representation of shape occurs in the frequency realm. This means that the measurement of shape transitions from spatial data to frequency data. The frequency analysis involves breaking down the shape and mapping it onto the frequency domain, where each shape represents a "Morphic stratum" with its frequency axis formed by a combination of multiple layers. This concept is discussed by (Suissi, 2017).

In this article, we propose to characterize the forms produced by the past. We focus on two geographical entities at the gateway to the Sahara, witness to ancient civilizations, namely the ksar of Ouargla and the medina of Gafsa

The term "Ksar" derives from the Arabic word "Qasr," meaning castle or fortified village, which itself originates from the Latin term "Castrum," denoting a fort or stronghold. The ksar or village is an ancient fortified village with a very dense core. This term is given to the southern villages, while those in the north are called medina. The ancient village of Ouargla, located in southern Algeria and precisely northeast of the Algerian Sahara, is thus called 'Ksar Ouargla'. It is known as one of the oldest towns in the Sahara. (Gherraz et al, 2023).

Gafsa is a geographical entity in south-western Tunisia and witness to the Capsian civilization, the oldest on Tunisian territory. The town of Gafsa is known as the gateway to the desert". It is the anchor point between Libya and Algeria. "Described by some modern authors as the "gateway to the desert", Gafsa is the proud heiress of the ancient Capsa.

The aim is to question the forms produced by their ancient cores, evident in the organic layout and irregularly shaped alleyways that are difficult to grasp and cannot be simply described. The whole point is to objectively question, while at the same time making intelligible, the perceptible characteristics of these forms and the formal logics that can be analyzed and explained.

This article deploys the morphometric paradigm of quantification to identify the morphic logics informing the internal structure of these ancient Maghrebian cores and predicting their genesis. An experimental protocol for morphometric analysis, based on frequency decomposition, aims to gain knowledge and understanding of the structures underlying the genesis of these forms produced in the past. This tool identifies the morphic conformation logics of each tissue. Each

coded shape is translated into a signal with measurable energy. The frequency decomposition spreads the morphic information over the frequency bands. This breakdown into morphic strata provides information on the underlying structuring logics of the urban forms of Ouargla's ksar and the Gafsa's medina.

A further cross-examination is established based on a correlation between the numerical results and the entire set of extrinsic data. The provided results validate a logic in these determinative conformations within the spatial domain. They enrich and broaden the framework of observation and interpretation of analytical results through decrypting the genesis logic of these forms. This intrinsic morphological characterization thus becomes intelligible through activation and confrontation with historical, geographical, social, etc.

1-Methodology

1-1-*Study area:*

The chosen study corpus consists respectively of the ancient core of Ksar Ouargla and the intramural core of the Medina of Gafsa. We selected cadastral maps which provide a precise graphical representation of these urban fabrics. Urban forms are defined here by the map of Ksar Ouargla (Figure 1) and the map of the intramural area of Gafsa (Figure 2). They outline the overall configuration of the fabrics that constitute the basis for the analysis model. These maps are digitized using AutoCAD software. They result from verification of surveys and graphical documents, particularly through on-site visits and source cross-referencing. The digitized forms are processed using "Photoshop" and saved in "Tiff" format.

Fig. 1. Ksar of Ouargla

Fig. 2. Medina of Gafsa

1-2-Methods:

The application of the morphometric model requires a preliminary coding work of the material. This is defined by considering white as urban space and black as non-urban space (Figure 3 and Figure 4). This explicitly generates, without relying on intuition, the urban form of Ksar Ouargla and the Medina of Gafsa, which condition the analytical research.

Fig. 3. Coding of the urban form of Ouargla *Fig. 4. Coding of the urban form of Gafsa*

The shape figure is imported into the 'Morphique3' software, launched from the 'Matlab' interface (Figure 5 and Figure 6). We then proceed to calculate the representative frequencies of the shape in question. This operation provides three representative frequencies:

- Relative frequency: this is the range of low frequencies that provides topological morphic information.
- Useful frequency: this is the range of medium frequencies representing the transitional level between medium frequencies and high frequencies. This transitional domain adds more precision to the shape.
- Maximum frequency: this informs about the shape at the configurational level. The maximum frequency represents the shape as it is introduced.

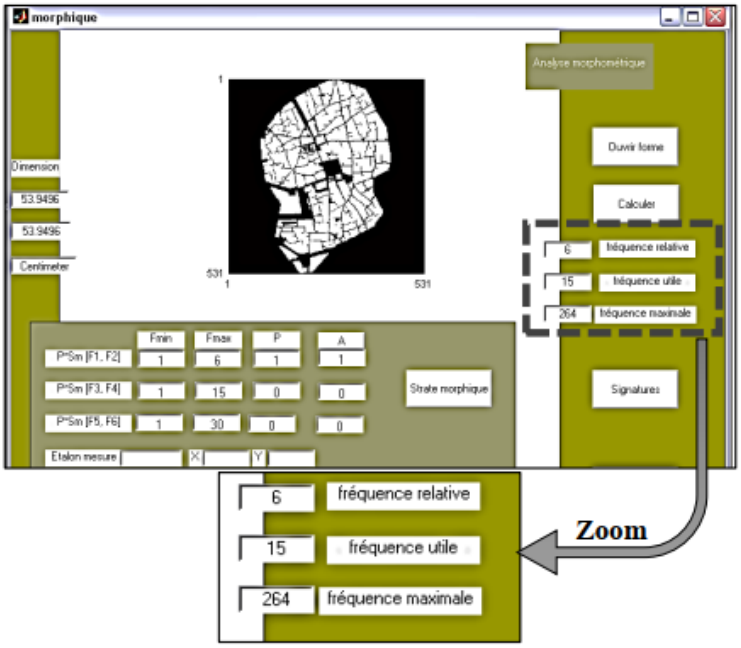


Fig. 5. Interface of 'Morphique 3' launched from the 'Matlab 6.5' interface and calculation of the three representative frequencies of the shape of Ksar of Ouargla.

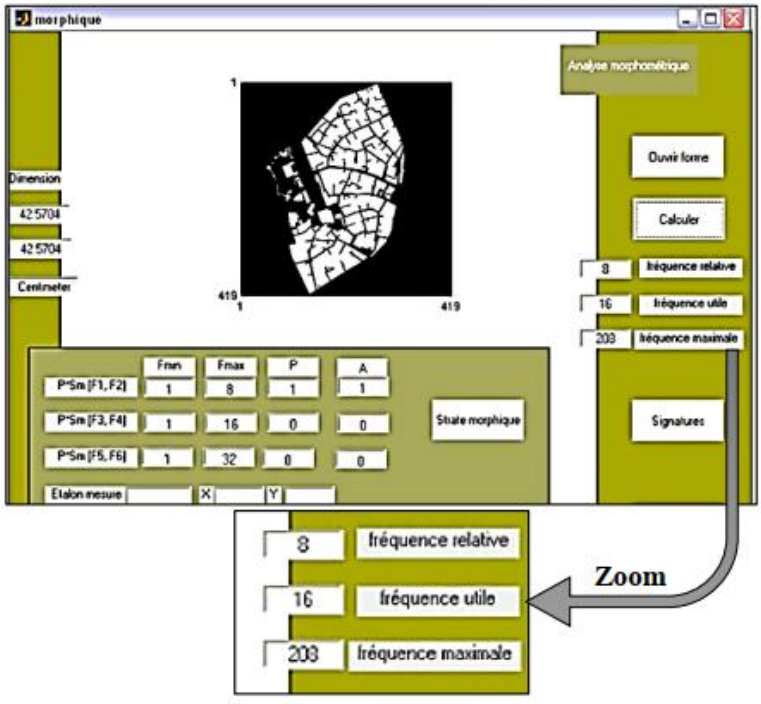


Fig. 6. Interface of 'Morphique 3' launched from the 'Matlab 6.5' interface and calculation of the three representative frequencies of the shape of Medina of Gafsa.

The numerical representation of each component, for the same frequency, generates an elementary morphic stratum, and the numerical representation of a component resulting from a set of frequencies is a morphic stratum. The frequency decomposition into successive morphic stratums informs about the urban form according to the chosen frequency. Ben Saci argues that: "*Frequency decomposition spreads morphic information, according to frequencies, into morphic stratums where each one is a frequency characterization of the form*" (Ben Saci, 2000). Each morphic stratum contains morphic information that increases the precision of the form according to the frequency band. The morphic stratums show the distribution of morphic information from low frequencies to high frequencies. This evolution allows us to infer a morpho-frequency progression of the urban fabric in question. Tables (1 and 2) illustrate the progression of morphic information according to frequency bands.

Table 1. Results of the frequency analysis of the urban form of Ksar Ouargla: Some morphic strata tested over the interval of 264 frequencies.

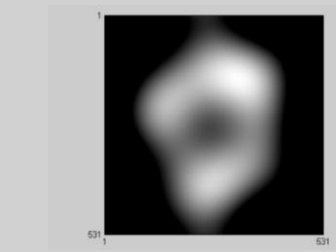
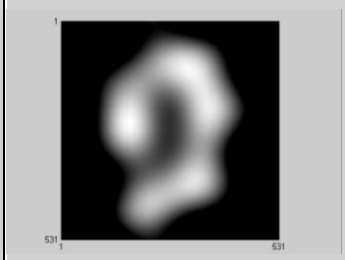
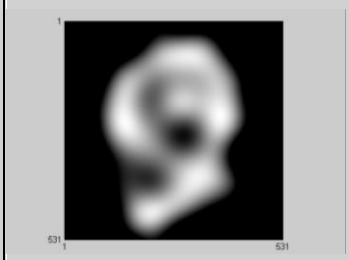
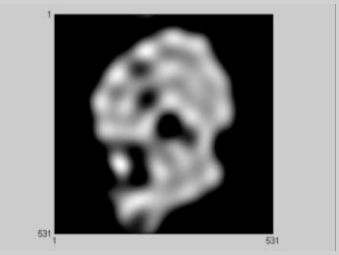
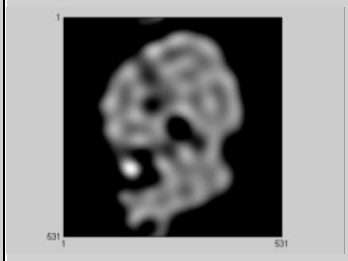
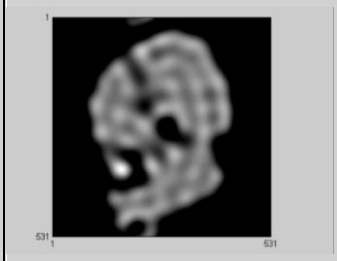
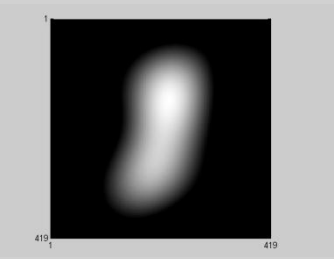
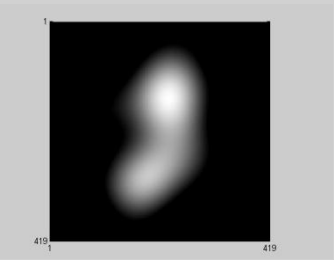
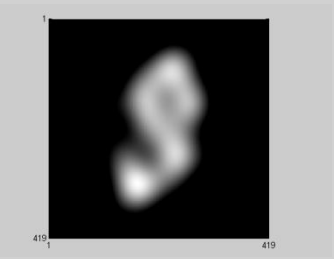
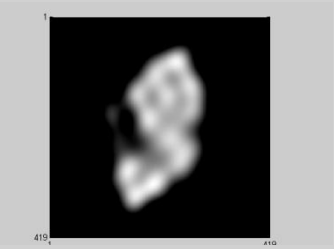
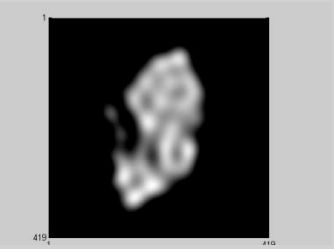
 Morphic stratum of the frequency band [1-2]	 Morphic stratum of the frequency band [1-3]	 Morphic stratum of the frequency band [1-4]
 Morphic stratum of the frequency band [1-8]	 Morphic stratum of the frequency band [1-9]	 Morphic stratum of the frequency band [1-10]

Table 2. Results of the frequency analysis of the urban form of Ksar Ouargla: Some morphic strata tested over the interval of 208 frequencies.

 Morphic stratum of the frequency band [1-2]	 Morphic stratum of the frequency band [1-3]	 Morphic stratum of the frequency band [1-4]
 Morphic stratum of the frequency band [1-6]	 Morphic stratum of the frequency band [1-8]	 Morphic stratum of the frequency band [1-10]

2- Results and interpretations

2-1-Frequency study of Ksar Ouargla

Frequency analysis in the sense of signal processing makes it possible to characterize urban forms. It provides access to an objective description of shapes and provides information on their structure. It accounts for spatial logics and describes spatial variation in the frequency domain. The result of this analysis provides a significant number of morphic strata: 264 for the case of Ksar Ouargla, it is therefore necessary to objectify the choice of significant strata. To do this, we use energy quantification of frequency bands. The energetic description thus consists of measuring the energy contribution of the frequency bands in order to define the quantity of information of each morphic stratum. Each band has a total energy which is the sum of the energies of the related frequencies. The frequency energy signature of the shape is an energy descriptor which characterizes the distribution of the energy of the shape according to significant successive morphic strata.

"*A quantification of the total energy distribution of the form along the morphic information calibration axis*. (Ben Saci, 2000). The frequency energy descriptor provides information on the information contribution of each morphic stratum. *Morgex'* software is used to calculate these descriptors. The abscissa axis corresponds to the frequency calibration axis. The ordinate axis shows the variation in morphic information. The result of the energy decomposition of ksar Ouargla shows that morphic information jumps are mainly displayed at the topological level. The most significant morphic strata variations are reflected by peaks in the descriptor and are inscribed in the following frequency intervals [1-3], [1-6], [1-8] and [1-11] (Figure 7).

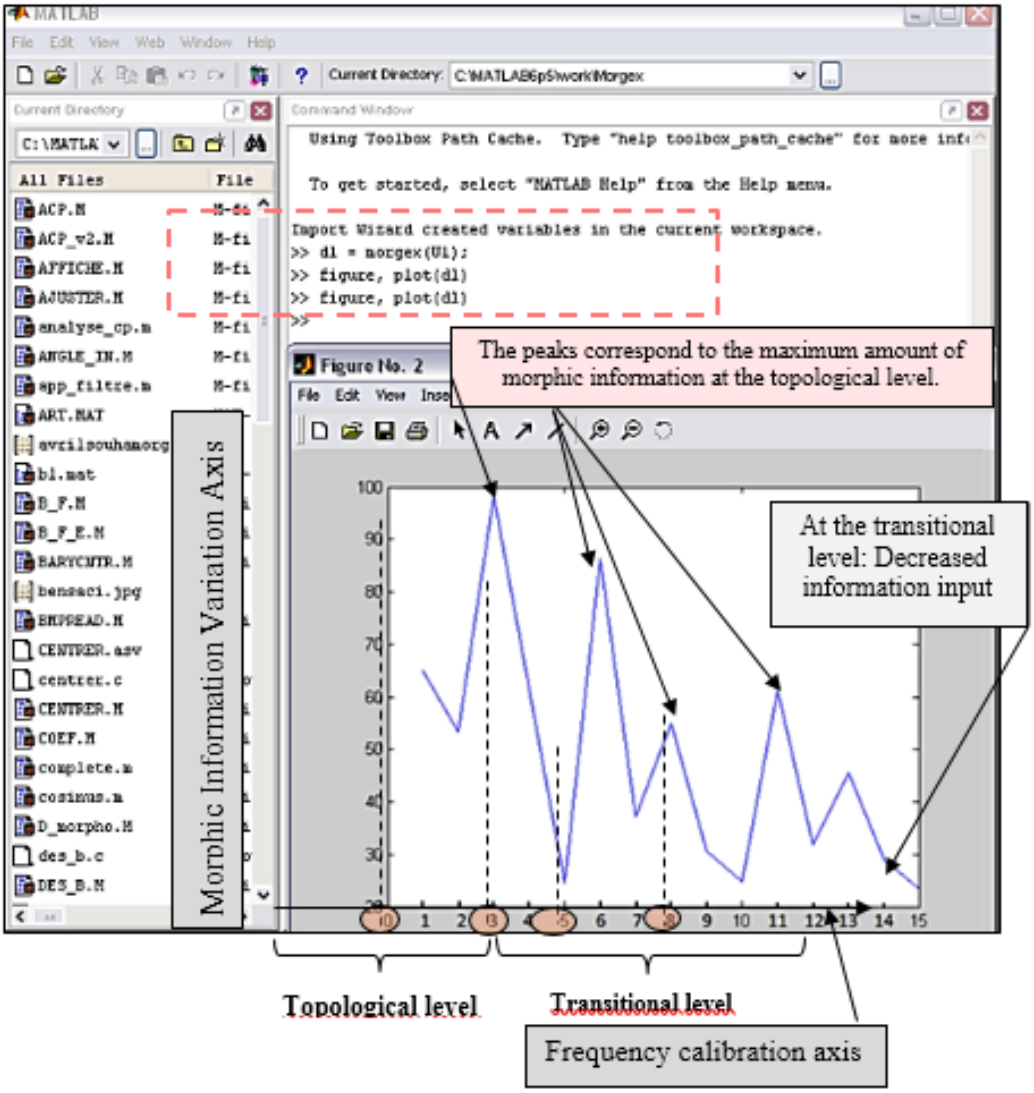
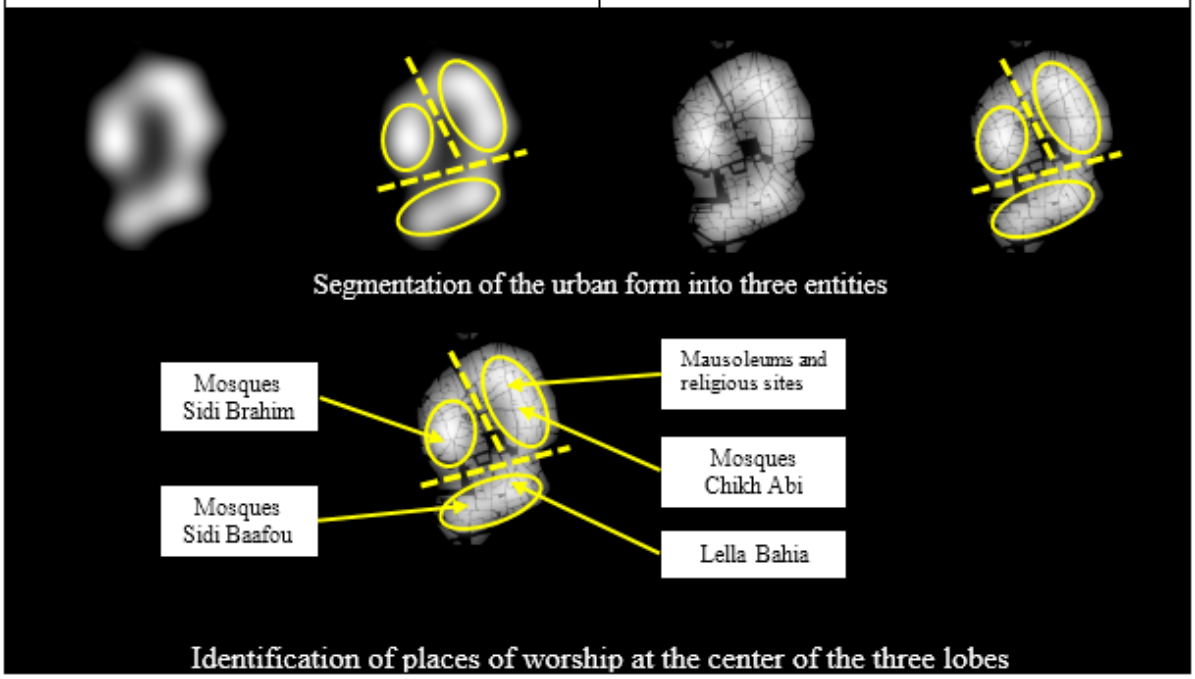


Fig.7. Display of the energy descriptor of the urban form of ksar Ouargla on 'Morgex', launched from the 'Matlab' software interface.

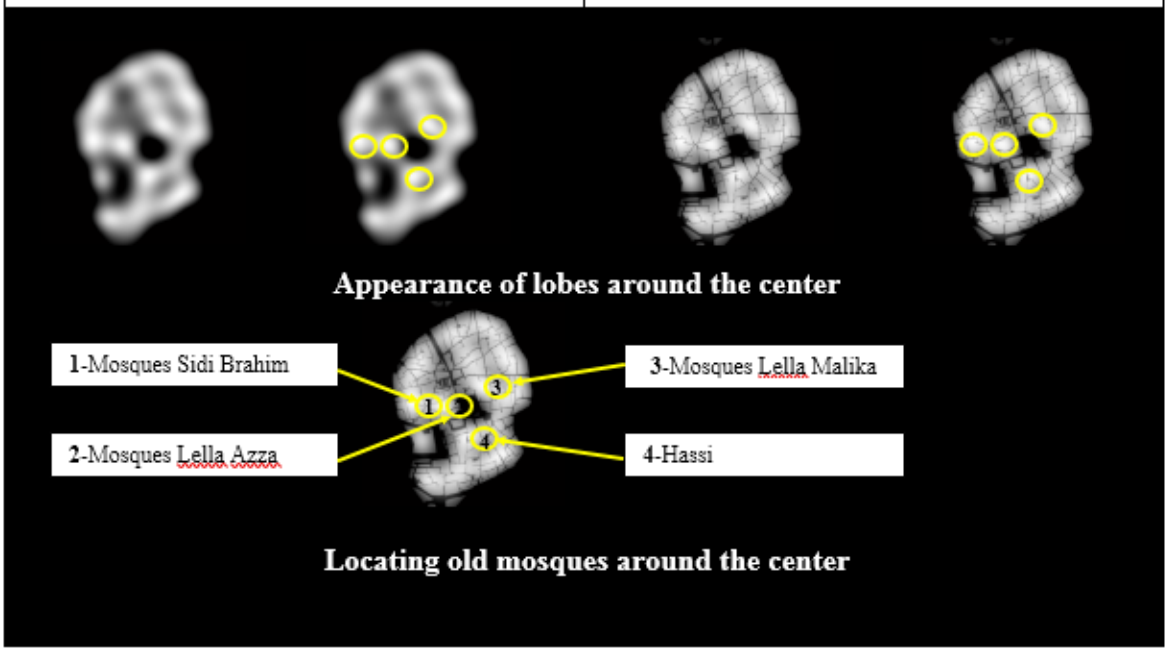
In what follows, we examine the manifestation of morphic information according to frequency calibration at the topological level. To clarify this frequency analysis, we superimpose the morphic strata obtained with the map of ksar Ouargla. This helps us to localize the urban components that appear in the first frequency bands of the topological level. The morphic stratum corresponding to frequency band [1-3] shows the appearance of three lobes structuring the urban form (Table 3). Superimposing the morphic stratum on the plan of Ksar Ouargla, we see that these lobes correspond to the districts that define Ksar Ouargla: Beni Brahim, Beni Ouaguin and Beni Sissin. This appearance confirms the hypothesis of the tripartite decomposition of the urban form of Ksar Ouargla, which is structured into three districts. What's more, this first frequency band highlights the centrality of each entity. The Beni Brahim district asserts a morphic manifestation in the center, that of the Sidi Brahim mosque. The second Beni Ouaguin district features mausoleums and mosques. The third is home to the Sidi Baafou and Lellah Bahia mosques (Table 3).

Table 3. Interpretation of frequency information in stratum [1-3].

Morphic stratum [1-3] and corresponding morphic hierarchy.	Morphic stratum [1-3] superimposed on the urban form of ksar Ouargla.
	

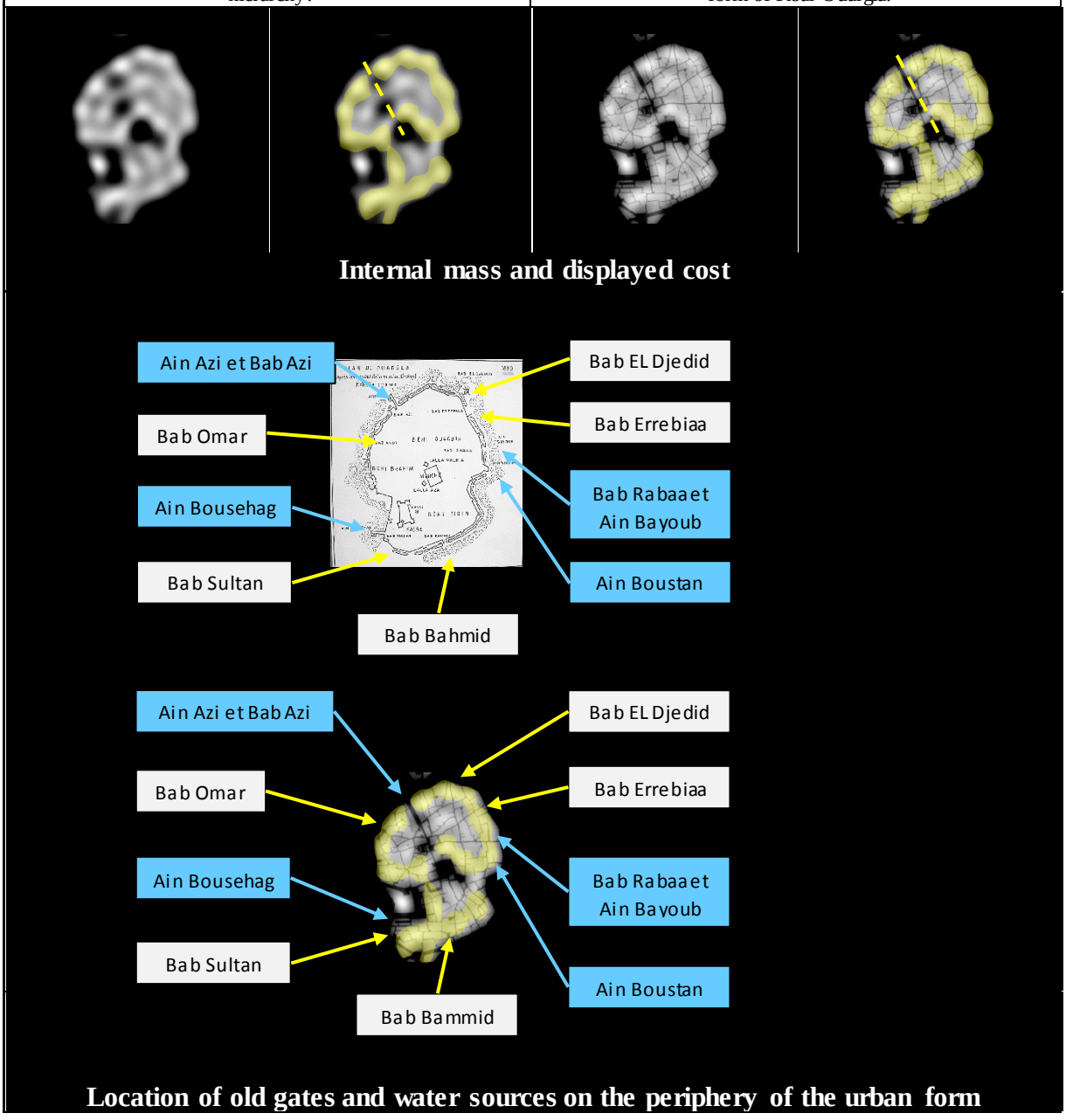
The frequency band [1-6] shows lobes appearing around the central void. These are the Sidi Brahim, Lellah Azza, Lellah Malika and Hassi mosques. The study of this morphic manifestation shows the importance of the religious component in the ancient core of Ouargla, which is of paramount importance (Table 4).

Table 4. Interpretation of frequency information in stratum [1-6].

Morphic stratum [1-6] and corresponding morphic hierarchy.	Morphic stratum [1-6] superimposed on the urban form of ksar Ouargla.
	

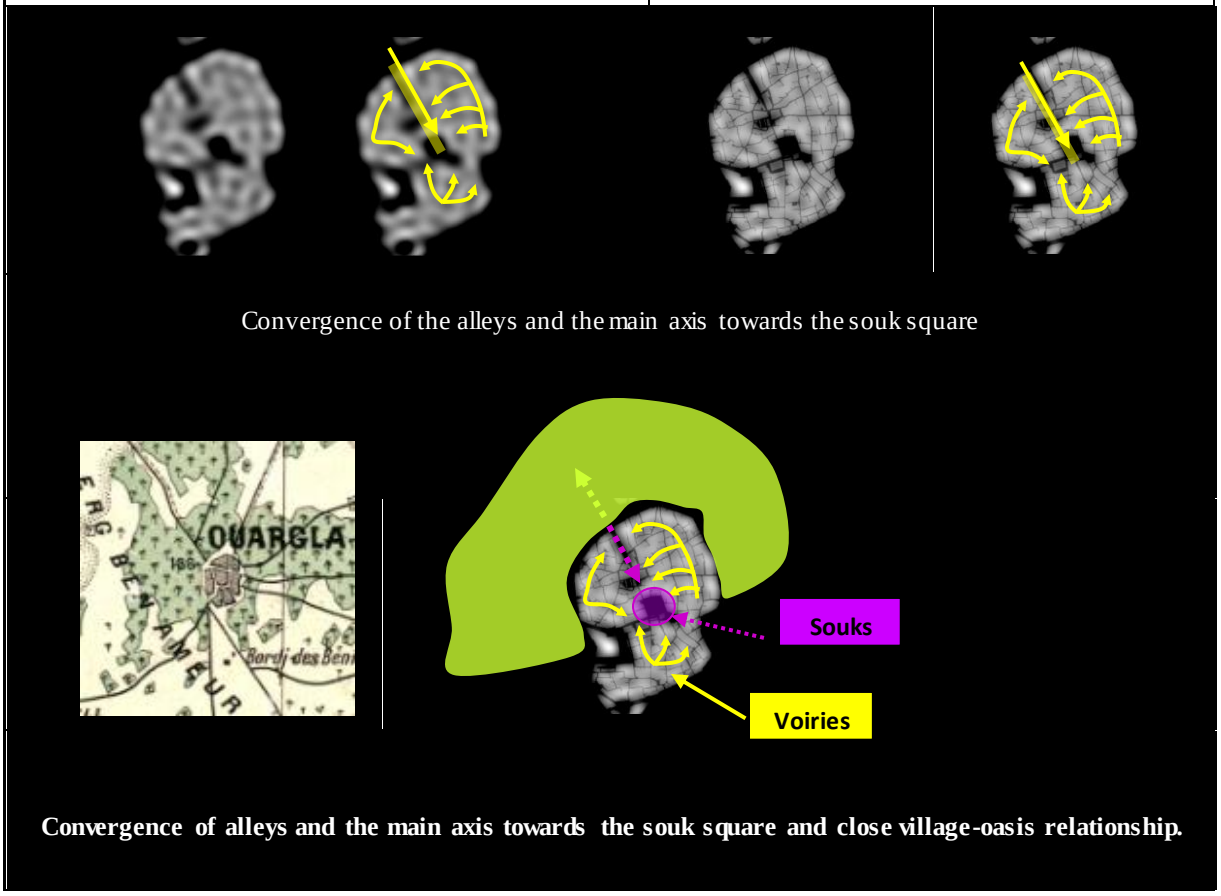
A small change in morphic strata provides a considerable contribution to morphic information. Starting from the frequency interval [1-8], we see a structuring axis running from a solid mass to a central void. This internal mass is surrounded by a contour that defines the periphery of the urban form of ksar Ouargla. Superimposing the morphic stratum on the actual plan of ksar Ouargla, we note the presence of ancient gates and water sources on the periphery of Ouargla's urban form. On the one hand, this shows the introversion of this ancient core. Indeed, the intramural part is protected by a wall defined by six gates allowing access to the extramural space. On the other hand, the presence of springs around the inner mass highlights the importance of the hydraulic component in relation to this ancient core (Table 5).

Table 5. Interpretation of stratum frequency information [1-8].

Morphic stratum [1-8] and corresponding morphic hierarchy.	Superposition of morphic Stratum [1-8] with the urban form of Ksar Ouargla.
	

The closer we get to the configurational level, the more detailed the morphic strata become. Stratum [1-11] reveals a morphic hierarchy of pathways. Their structure converges on an axial void that leads back to the souks, and therefore to the commercial functions. This explains the radiating structure of the fabric. This internal axis crosses the fabric to the center of the souks. It links the extramural part of the oasis to the souks (Table 6). Hence the oasis-urban connection of ksar Ouargla. This result shows the importance of the agricultural component. Indeed, the cultivated area provides a source of work for the village's inhabitants and ensures the needs of local consumption.

Table 6. Interpretation of the frequency information of the stratum [1-11].

Morphic stratum [1-11] and corresponding morphic hierarchy.	Superposition of morphic Stratum [1-11] with the urban form of Ksar Ouargla.
	

Convergence of alleys and the main axis towards the souk square and close village-oasis relationship.

2-2- Frequency analysis of the medina of Gafsa:

The frequency analysis of the Gafsa medina highlights two remarkable values: the *relative frequency equal to 8* at the topological level and the *useful frequency equal to 16*. The evolution of morphic strata in these two topological and transitional intervals allows us to infer a morpho-frequential progression of the fabric. As in the case of ksar ouargla, we use energy quantification of the frequency bands to select the most significant strata, providing information on the intrinsic structure of the fabric (Figure 8).

"*The energetic description consists in measuring the energetic contribution of the frequency bands in order to define the quantity of information of each elementary morphic layer"* (Ben Sassi et Zaabar, 2008; Zaabar, 2005). The result of the energetic decomposition of Gafsa's urban form shows that morphic information jumps are mainly displayed at the topological and transitional levels. The most significant morphic strata are therefore inscribed in these two frequency intervals. This is reflected in the peaks at descriptor level (Figure 8).

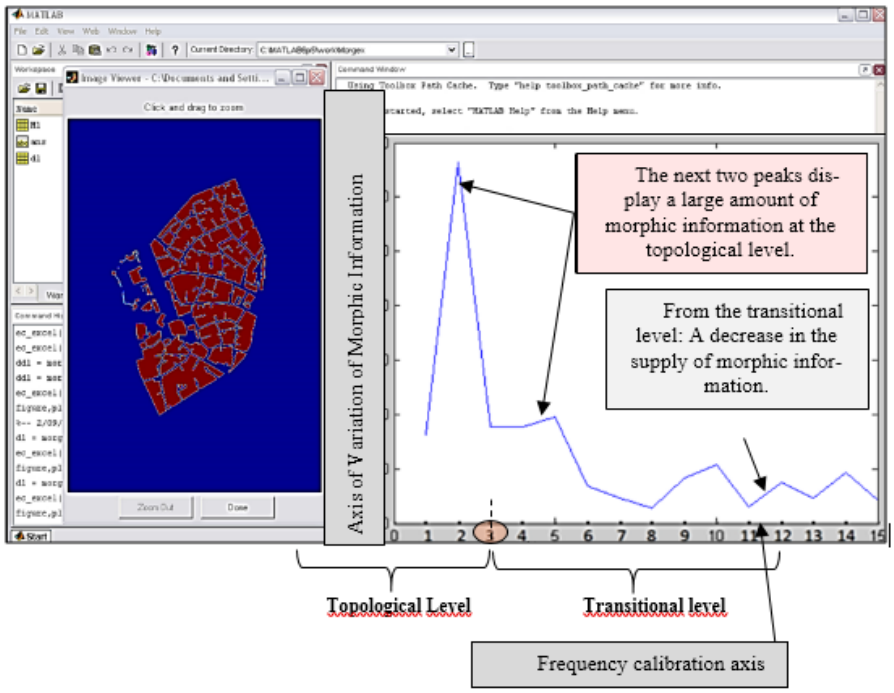
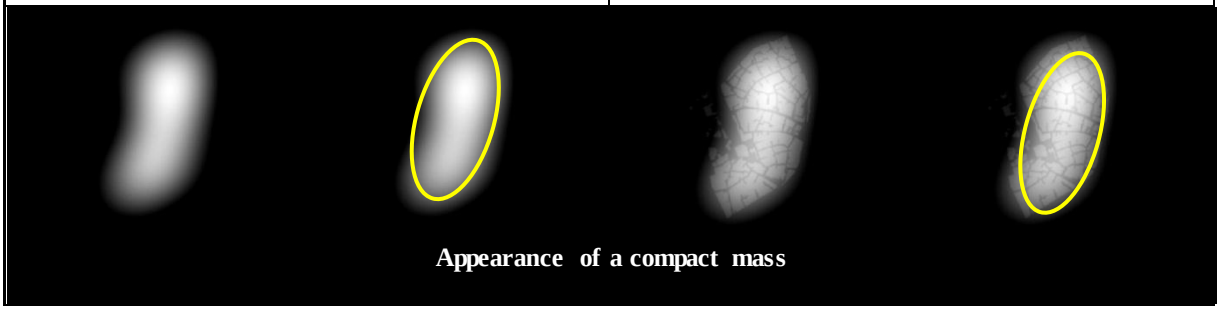


Fig.8. Calculation of the energy descriptor of the urban form of Gafsa

This first frequency band, in which the first morphic manifestation of the shape appears, provides the greatest amount of morphic information. This is justified by the appearance of an energy peak in the descriptor. The consequent morphic stratum is a basic component that reveals an embryo of the initial shape, highlighting a compact mass. *(*Table 7).

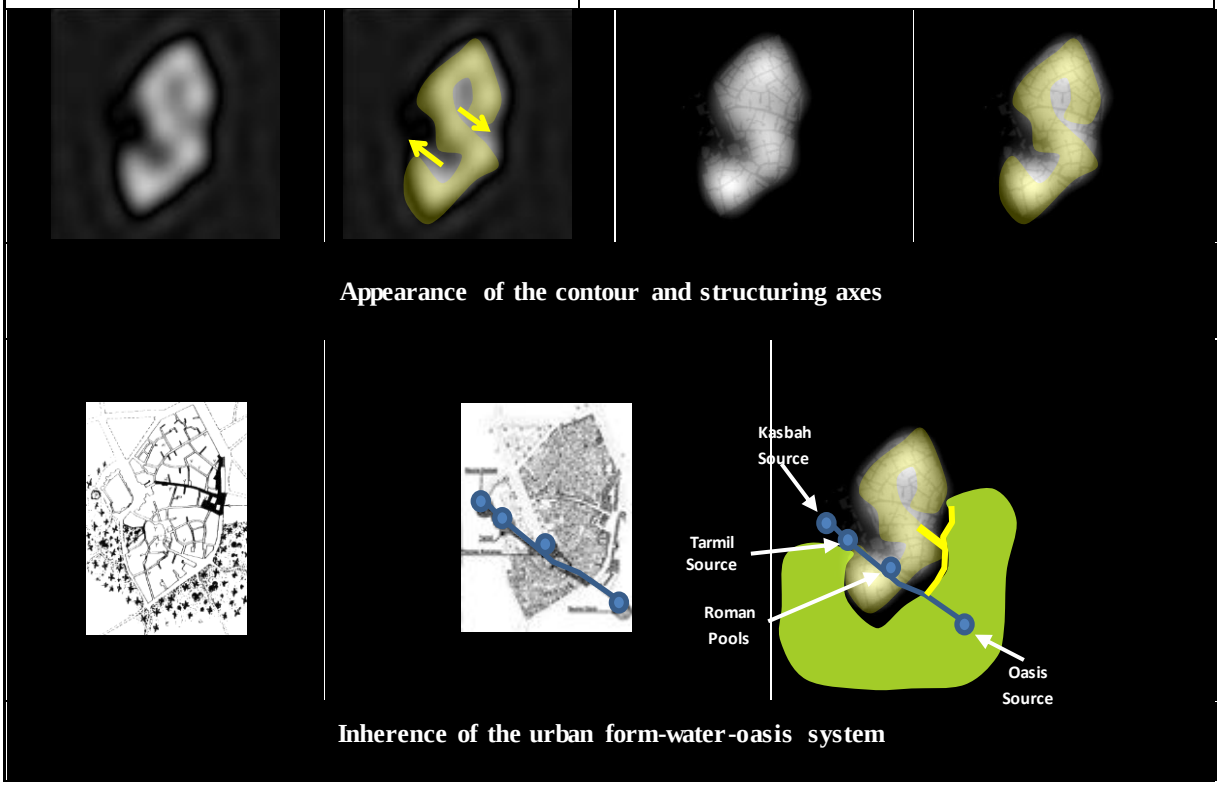
Table 7. Interpretation of the frequency information of the stratum [1-2].

Morphic stratum [1-2] and corresponding morphic hierarchy	Superposition of Morphic Stratum [1-2] with the urban form of Gafsa.
	

Low frequency variation indicates considerable morphic information. Morphic stratum [1,6] displays both an internal mass and the outline of Gafsa's urban form; an S-shaped structure. Superimposing morphic stratum [1,6] with the plan of the urban form highlights this S-shaped

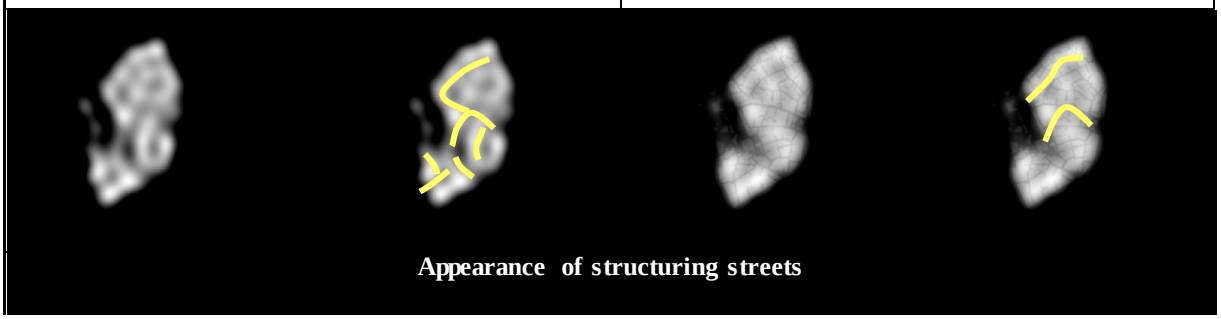
structure. On the one hand, the *suqs* that run along the border between the oasis and the medina constitute a major staging post and exchange point which, thanks to the caravan trade, is closely linked to other staging posts: Gabès, Kairouan to the north and Tébessa to the west. On the other hand, an axis integrating water sources was established by gravity. Water plays a structuring role in both urban and plant spaces. It forms a cohesive system between the urban form and the oasis. Its presence is at the origin of the genesis of the town of Gafsa around the water source in the southern part of the medina. It has justified the presence of man in the region for thousands of years. It flows freely, ending its journey in the oasis below, on the outskirts of the town, and is an indispensable factor in the prosperity of the Gafsa medina. These important locations meet the requirements of a human settlement linked not only to water, but also to agriculture and commerce (Table 8).

Table 8. Interpretation of the frequency information of the stratum [1-6].

Morphic stratum [1-6] and corresponding morphic hierarchy	Superposition of Morphic Stratum [1-6] with the urban form of Gafsa.
	

At the transitional level, the morphic stratum [1,10] provides a more detailed reading of the inner shape of the fabric. It highlights the division of the fabric according to the main services. Overlaying the morphic stratum with the urban form plan corroborates this morphic manifestation of the alleyways. The frequency analysis thus reveals the structuring urban services *(Table 9)*. It also illustrates three main entities of the Gafsa medina; this division cannot be arbitrary.

Table 9. Interpretation of the frequency information of the stratum [1-10].

Morphic stratum [1-10] and corresponding morphic hierarchy	Superposition of Morphic Stratum [1-10] with the urban form of Gafsa.
	

From this frequency band [1,15], we note a segmentation of the urban form into three sectors separated by the main roads. These articulate the masses of adjacent sectors. Frequency analysis thus enables us to understand this organization. Comparing this morphological characterization with concrete aspects of Gafsa's urban form shows that the strategy of appropriating intramural space is inscribed in morphic information. Previous studies (in history) have defined two sectors, North and South, for Gafsa's urban fabric. Our exploration shows that there are instead three sectors: the first, to the south, is home to the Roman swimming pools. The second, adjoining, is home to the Jewish quarter known as the *hara*. And the third, to the north of the Gafsa medina (Table 10).

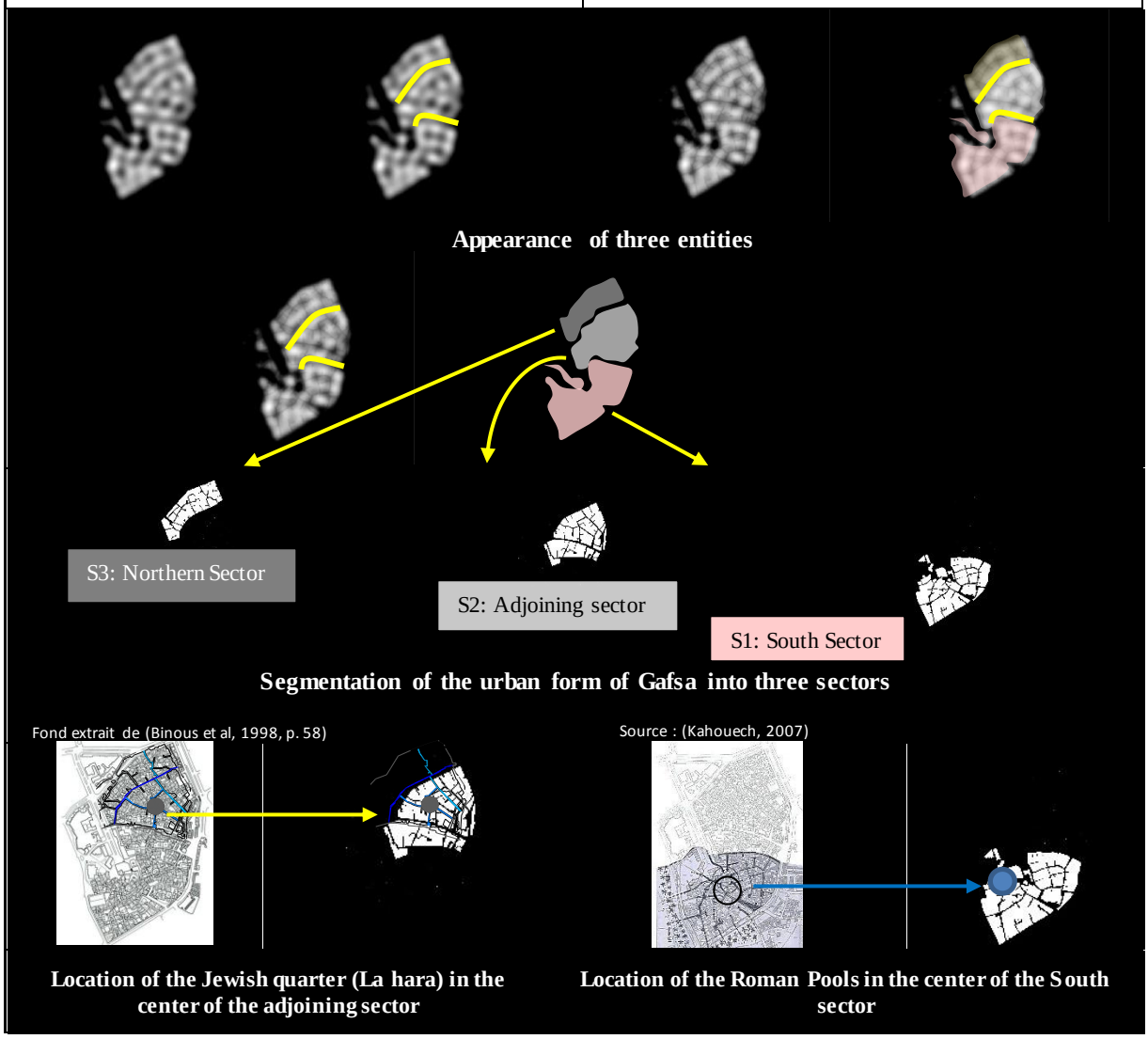
3- Discussion

Understanding the morphic manifestation of the urban forms of Ouargla and Gafsa is necessary in order to assimilate the genesis of these forms in space and time. This contribution could not be studied separately from that of previous studies. And this in order to understand the evolution of these forms produced in the past. The results of the frequency study of these fabrics support the work of previous research. Indeed, the results of morphic strata can be seen in the historical, geographical and functional reading of these urban forms. To validate the morphic abstraction, a confrontation with the extrinsic components of these urban spaces is initiated. Confrontation of the results with the functional, geographical or historical environments shows that the forms produced reflect formal logics that can be explained. The interest of such an approach is inherent in the form, and informs its genesis. A review of descriptive reading approaches and modalities is thus fruitful, providing information on these forms and their development. We can affirm that the morphology of these ancient nuclei, their modes of production and the models that regulate their urban production constitute an intelligible morphic expression. This numerical characterization, particularly in morphometric terms, highlights explanatory models for these forms. It provides objective explanations of the origins of the urban form of ksar Ouargla and the medina of Gafsa, elucidating the different logics underlying their genesis.

To achieve this, extrinsic data are temporarily set aside in order to access purely intrinsic knowledge. This intrinsic morphological characterization becomes intelligible through activation and confrontation with historical, geographical and social knowledge. At the end of all the descriptions approached by the readings, ksar Ouargla and the medina of Gafsa constitute an urban production that responds to contexts: historical, geographical, social and cultural.

Table 10: Interpretation of the frequency information of the stratum [1-15].

Morphic stratum [1-15] and corresponding morphic hierarchy	Superposition of Morphic Stratum [1-15] with the urban form of Gafsa.



- **On a geographical, historical and socio-cultural level, how is the urban form of** Ksar Ouargla manifested?

Ksar Ouargla enjoys a strategic geographical position. It is surrounded by one of the largest oases in the Algerian Sahara, located in the lower Oued Miya valley on a significant water table (Chaouche Bencharif, 2007). This particular situation is the reason why the town and its agriculture have flourished. The oasis was a staging post for caravan trade and a market for the region's nomadic tribes. For centuries, Ouargla enjoyed prosperity based on trade with Sudan, to which it exported dates and grains (Bensaad, 2013). Ouargla's importance in trans-Saharan trade has been demonstrated by the frequency study of morphic strata at the transitional level (see stratum [1-11]). The latter explains the appropriation of space by the region's inhabitants, who voluntarily settled around the oasis and hydraulic springs to stock up on water and food. This appropriation of space respects the plant mass and makes the oasis the only resource for

life. On the basis of all the descriptions given in the readings and the results of the frequency analysis, the components of this Ksourian system are complementary (Figure 9).

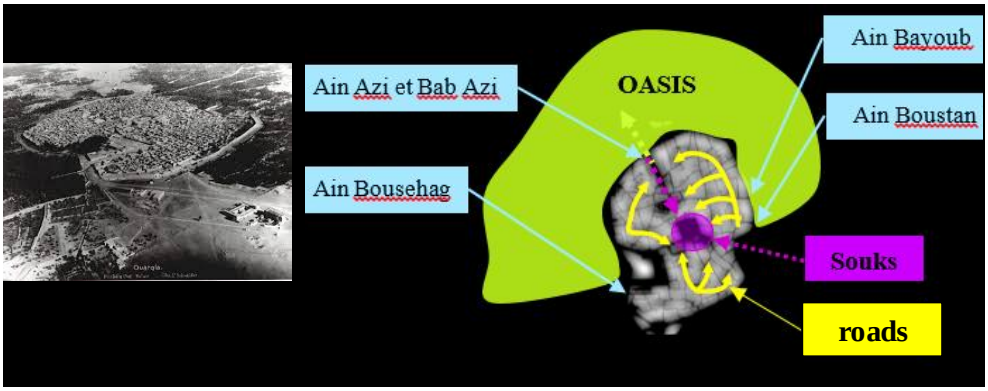


Fig.9. *Inherence of the water-oasis-Ksar Ouargla system*

Frequency analysis provides the experimental basis for our investigation into the form of ksar Ouargla, in order to identify the underlying logic behind the structuring of the urban space within the city walls.

The morphometric method applied provides an identification of the logic behind the genesis of the urban fabric in question. It validates the hypotheses put forward concerning the form produced, the meaning and substance of the heritage, and highlights the morphic hierarchy of the axes that make up this fabric. It shows how Ouargla is structured into three sub-neighborhoods: the Beni Brahim neighborhood, the Beni Ouagguin neighborhood and the Beni Sissin neighborhood (Figure 10). The Beni Brahim living in the northern district are Berbers, while the Beni Ouagguin and Beni Sissin in the eastern and southern districts are "Syrian ibâdites" (Blanchet, 1900).

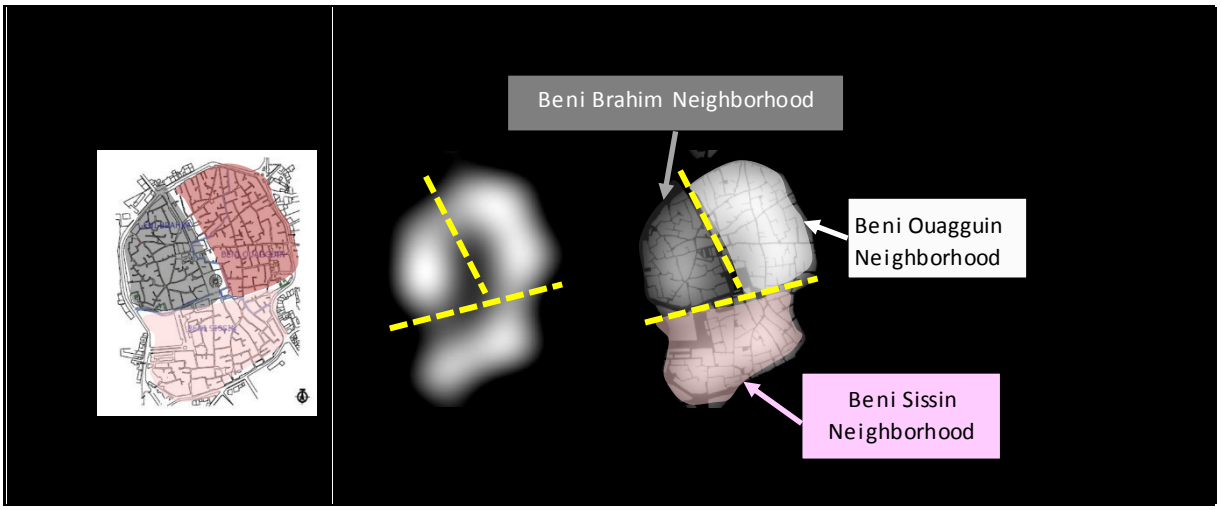


Fig.10. Breakdown of the urban form of Ouargla into three districts.

Ouargla's ancient core is undoubtedly linked to physical (topography, spatial setting), professional (local workforce) and socio-cultural factors. The urban evolution of the village towards the south is driven by the increase in the number of inhabitants, and therefore by new needs. Consequently, southward expansion (Beni Ouagguin and Beni Sissin) further corroborates the close relationship between man and his oasis, by respecting the limits of the

oasis and favoring southward expansion. The interconnectedness of the medina-oasis-water relationship can be seen in the morphology of the fabric.

- **Geographically, historically and socio-culturally, how does Gafsa's urban form manifest itself?**

The Gafsa medina is perceived as a self-structuring architecture. It refers to an interference between intrinsic characteristics and extrinsic contents. The latter are dictated by the properties of the environment, and dictate the specific features of this medina in relation to its internal properties and to what already exists. Here, digital morphometric investigation highlights the explanatory models of this urban form. The urban model, driven by water and food supply and settlement needs, generates a rather particular morphology based on the primacy of the immediate geographical factor. A system of correspondence links the presence of water and the oasis as a cultivated space (known for its biological diversity, its impressive number of palm trees, its three-storey crops) to the organization of the medina's form. These main components are prominent in the genesis of this medina (Figure 11). This explains the close and intimate relationship between water/medina/oasis/. The latter has been the source of the city's flourishing and prosperity for several millennia. The oasis is home to numerous natural springs, some of which lie in the deep aquifer. Irrigation is provided exclusively by gravity-fed water from these natural springs. Water sources are an essential passageway and a determining factor in the formation and progress of human settlements. Labor is available, skilled and free (family).

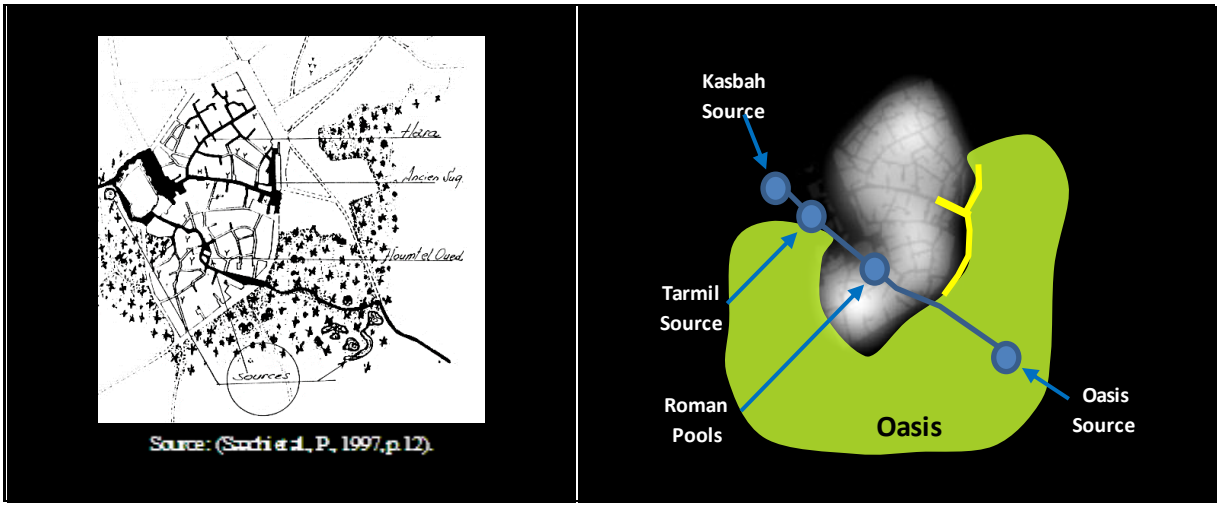


Fig.11. Inherence of the Gafsa water-oasis-medina system.

Morphometric analysis provides an intelligible understanding. It provides information on urban morphology. The entities identified by the frequency study are justified by the urban organization of the Gafsa medina. Indeed, the conformation of the fabric highlights the morphic hierarchy of the medina's main streets and sectors (see morphic stratum [1-15]). Comparing this morphological characterization with the concrete aspects of Gafsa's urban form shows that the strategy of appropriating intramural space is inscribed in morphic information. Previous historical studies have defined two sectors of Gafsa's urban fabric: North and South. Our exploration shows that there are rather three sectors.) the first, to the south, is home to the Roman swimming pools) the second, adjoining, is home to the Jewish quarter known as the

hara.) and the third, to the north of the Gafsa medina. The shape of these sectors is generated by the urban void (that of the roads), which structures and defines the full. Morpho-frequency decomposition enables us to construct the notion of morphic appearance of the sectors of Gafsa's urban form, based on the frequency order of morphic manifestation of these urban solids (Figure 12). It provides an objective and explicit understanding of the morphic conformation logics of the Gafsa medina and its intrinsic structuring. This method of analysis provides an objective characterization of complex shapes.

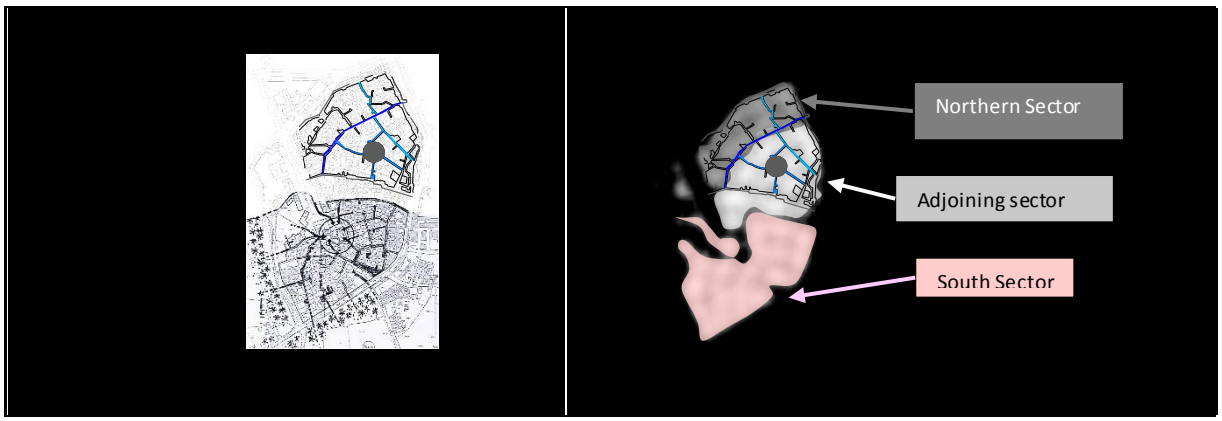


Fig.12. Breakdown of the urban form of Gafsa into three sectors.

Conclusion

In this work, we show how morphometry opens up new perspectives for understanding the form of traditional urban fabrics. This article enriches the debate on the process of urban form production. The tools we have used, such as frequency analysis and energetic description, confirm the postulate of the existence of a certain organization in the constitution of the urban form of ksar Ouargla and the medina of Gafsa. The study of the form of these Maghrebian oasis villages shows that it is not devoid of meaning, but rather bears the strata of development of these ancient nuclei, dependent on urban development and social situation. To this end, we focus on the relationship between urban form and mathematics in order to provide objective knowledge. We believe that form has a morphic identity. It can be mathematized using digital tools. Urban form is intelligible, and depends on an underlying organization. This article deploys the morphometric paradigm of quantification to identify the morphic logics that inform the internal structure of these fabrics and predict their genesis.

Our work argues in favor of the specific features of Ouargla and Gafsa, their historic oases, and their preservation. It presents an understanding of these ancient cores and their development. This cognitive contribution, based on frequency analysis of the fabric, is justified by the urban structure of these fabrics, which is subdivided into three sectors. In the case of Ouargla, the districts of Beni Brahim, Beni Ouagguin and Beni Sissin are home to a large number of the village's most emblematic monuments, which played a key role in its genesis. It's in these districts that we find the essence of Ouargla's architectural and urban heritage and all its authenticity.

medina of Gafsa: The southern sector *(Guebli Gafsa*) features a radioconcentric structure converging on a center housing the Roman swimming pools. The adjoining sector incorporates the long Rue *Kilani Metoui*, formerly known as the wool souk *(souk etto'ma*). To this day, this

sector retains a commercial and artisanal vocation that runs along Rue *Kilani Métoui*, the street and eastern boundary of the fabric. The northern sector, home to the Jewish quarter *(la Hara*) in the northern part of the medina. The intrinsic experimental results show that the complex system of shapes produced is not the result of chance, but the product of a decisive process of genesis.

Through frequency analysis, we are able to verify the intelligibility of the Ksourian and medinal structure and highlight the interactions that characterize the relationship between these forms and their geographical, historical, social and functional environments. Indeed, geographical and physical data (relief, location, water resources) have a major influence on the evolution of these nuclei, which dominate their oases. The relief of the land corroborates the extension of the sectors, which is gravitational towards the south in the case of Ouargla and towards the north in the case of Gafsa.

The presence of abundant water resources gushing up from within the fabrics is one of the attributes in the production of these towns and in the durability of their oases. "It *can certainly be said that the driving force behind these two areas, without which neither the town nor the oasis would have had any reason to exist, is undoubtedly water" (*Barbero et all, 1995). The development of ksar Ouargla and the medina of Gafsa took place at the edge of the oasis, to protect the plant mass representing the cultivated zone. The genesis of these forms is therefore dependent on the presence of water, which dates back over three thousand years.

Comparison of the results of the frequency analysis with the socio-economic environment reveals a correlation between the shapes and components of the souks. In fact, it's a place of commercial exchange, where the weekly market takes place and where the facilities associated with the oasis' various plantations are located. Hence, the cohesion of the oasis, representing cultivated space, with built space generates a place of exchange and a source of work for its inhabitants. *"Commerce, on the urban scale, not only occupies a specific space, but also covers a social function of some importance"* (Barbero et all, 1995). Water is also an imminent factor for both Ouargla (the springs are located on the outskirts of the city) and Gafsa (the main spring is located in the center of the southern district). In this respect, it is the main source of these nuclei and the reason for their foundations. It plays a key role in supplying the inhabitants and the oasis, linking the towns to their oases. We also note that these urban forms are closely related to their historical environments. Indeed, frequency analysis shows that the spatial organization of these fabrics presents a logic with regard to their appearance and distribution in the city. This logic manifests itself in a hierarchy of neighborhood spatial appearance.

The research work carried out in this article, based on the morphometric paradigm of measured urban form, provides convincing results and informative knowledge on the properties of the forms produced in Ouargla and Gafsa. It allows us to explain the specificities of the regions on the basis of cross-referencing the results of this knowledge, expected from operative frequency urban morphometry, with external environments in order to reciprocally generate understandings of the morphic logics of these fabrics. In the end, these Ksourian and Medinal forms are endowed with a morphological identity inherent in the forms they produce. They are endowed with an intrinsic formal identity engrammed in the conformation of their fabrics. These Maghrebian oasis villages have creatively exploited their wealth to produce original architecture and urban planning made from readily available local resources.

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