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The impact of the colonial architecture on the urban sustainability of Laghouat city in Algeria: ksar of Laghouat as a case

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Abstract

Among the risks that cities are exposed to, colonization emerges as a multifaceted concern representing historical and modern dimensions that can significantly impact a city's urban sustainability. This study explores the diverse implications of colonization on the urban sustainability with a focus on the Ksar of Laghouat in Laghouat city, Algeria. It examines the urban adaptation cycle and the imprint left by the colonial era on the fabric of the city. Utilizing the method of adaptive cycle approach and transfer entropy analysis, our goal is to quantify interaction on the historical and urban development of potential, connectedness, and resilience of Laghouat city. This study enhances the understanding of the Architectural heritage of Algeria and highlights dynamics between traditional and colonial architectural dimensions of Ksar of Laghouat. By assimilating the impact of colonization on the urban development of the city, we aim to improve the resilience and sustainability of Laghouat, through empowering its local community, and providing decision-makers with valuable sustainable strategies and adaptation mechanisms for future urban visions of the city.

Keywords Sustainability, Urban adaptation cycle, Resilience, Traditional fabric, Colonial architecture, Ksar of Laghouat, Algeria

Introduction

Sustainable development stands as a ubiquitous concept in modern societies, that promotes the wise use of resources—natural, human, or physical—in a way that is efficient and balanced in a range of areas, including the urban, environmental, human, economic and social way to ensure their continuity and sustainability without wasting the gains of future generations [1]. The concept of sustainability was first defined in 1987 by the Brundtland Report as "meeting current demands without sacrificing the capacity of future generations to address their own" [2]. It is a development that tries to adjust the use of natural resources for present and future generations, have four interdependent dimensions, which are: environmental; economic; social and cultural sustainability [2]. This concept extends its range to include all aspects of human life and its needs, including cities and urban environments, as one of the most important aspects of application of environmental dimensions, social, economic and even technology [1]. However, cities are also poised for various changes due to several drivers such as social and economic tensions and climate change, which will be unprecedented in both scope and speed [3].

In the context of architecture, environmental sustainability generally refers to the use of strategies that reduce the resource consumption and pollution emissions of buildings; in contrast, sociocultural and socioeconomic

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sustainability primarily relates to the preservation and conservation of the cultural landscape as well as the support of locally produced and used materials.

In relation to these requirements, the protection and understanding of vernacular architecture appear to be significant for all four dimensions of sustainable development [2]. For heritage and resilience, there are four themes that can be identified: economic, social, institutional, and infrastructure. Economic resilience is linked to the availability of financial and related resources. It is linked to the argument that heritage may provide employment opportunities and diversify income. Social resilience is linked to education, health, and social cohesiveness. It is linked to the argument that heritage may encourage community cohesion. Infrastructure resilience is related to different types of built environment, such as the quality of housing, roads, and access to services such as hospitals, schools, etc. It is linked to the argument that incorporating local/traditional disaster-related knowledge into the design and planning of the built environment may increase community capacities to protect from disaster. Institutional resilience is linked to the planning, implementation, and communication of disaster risk management. It is linked to the argument that heritage can be used to adapt institutional design to local needs [4].

In fact, resilience, which encompasses six characteristics—people, adaptability, transformability, sustainability, and systems thinking—denotes a system's ability to overcome obstacles or disturbances. Resilience research has historically been dominated by the ecological perspective, although there has been a noticeable incorporation of resilience principles within heritage conservation [5]. There is the theory of Panarchy, which is a framework of rules of nature that explains the dual and apparently contradictory properties of all complex systems, namely stability and change. It has been used to explain economic, environmental, and institutional systems and their interactions [6]. The Panarchy theory in ecology is organized by ecosystem properties, basic ecosystem dynamics and stages of the adaptive cycle (growth, conservation, release, and reorganization), characteristics of adaptive cycles, and the interconnections between adaptive cycles [6]. This theory describes three main dynamic characteristics of the adaptive cycle: potential, connectedness, and resilience.

Walker defines heritage resilience as "the ability of a system to withstand shocks while retaining essentially the same function, structure, feedback and thus identity" [3]. Approaches adhering to this interpretation have been formulated largely in terms of disaster risk management in the setting of historical sites and practices against future disasters (fires, floods, earthquakes, etc.). Research has therefore largely focused on developing different analyses and methodologies to identify vulnerabilities. Recent and ongoing military conflicts and colonizations have also shown that cultural heritage sites continue to be targets of destruction, highlighting the urgent need for recovery and resilience [7]. In this context, Colonization can be referred to as the enterprise aimed at the occupation then exploitation of one country by another. It can be also defined as "the control of a single power over a dependent region or people." It occurs when one nation subjugates another, oppressing and exploiting its population, often while imposing its language and cultural values on its people [8]. Research has therefore focused on the resilience and sustainability; which can be as a solution for the preservation of cultural heritage sites from the colonialization.

In Algeria, colonization was assimilated to the European population of the country: "It can generally be called colonization any work having as its object the increase in the number of Europeans, the extension of their cultures, or even the development of their civilization" [9]. The urban colonial policy in Algeria has brought about a radical transformation in the Algerian urban fabric, whose construction and architecture are derived from the Islamic Berber, Andalusian, and Ottoman styles, to be replaced by an alien urban style that derives its features from the European style, in which the Western aesthetic spirit is mixed with the colonial tendency. The destruction and vandalism carried out by the colonial authorities of the Algerian cities inherited from the Ottoman period is evidence of the colonial tendency that colonial France wanted to implement in Algeria [10].

The cities established by the colonial administration in Algeria since 1830 took one form which was the nature of assembly, as military engineering teams drew city plans on precise and specific rules and foundations. These plans respond to technical requirements such as the length of avenues, the width of streets, the distribution of facilities and the nature of civil and military buildings [10]. The general character that characterized the Algerian city during the colonial period is a reflection of the European style, which was prevalent in Europe during the nineteenth century AD and the colonial administration transferred and applied it to colonial Algeria. Among the principles that were adopted in planning colonial cities was the nature of grouping population units and bringing them closer together until they formed a regular urban cluster. Most colonial cities took the checkerboard shape, which consists of two main axes: a north–south axis and an east–west axis and at the intersection of these two axes is the central square, which includes many basic and necessary facilities [10].

In 1830, colonization was total in Algeria. The deconstruction of city centers and traditional fabrics, French political refusal of all that is traditional, and the superposition of the existing framework with the European one were the main strategies that the French colonization adopted. The first interventions in the city were of a military nature. Their objectives were multiple, and their motivations complex: First, the consolidation of defense and control by imposing order. Demonstrating the power of the colonizer by imposing his order. Second, many buildings are destroyed or diverted from their original destinations. The design of the spaces was in the image of France. The destruction of a large part of the city centers for the installation of the army and the first settlers. Finally, widening of roads. Creation of the parade ground. Consolidation of fortifications [11]. The urban planning developed by the French occupation relied on a policy of destruction and "Europeanizing," which responds to a policy based on the glorification of the power of the occupier, and demonstrating its superiority. This glorification appeared in geometric shapes and on street facades [12].

The first clear plan for European city expansion was seen in 1846. Not more than half a century had passed since the French occupation of Algeria until the shape of the European city began to take shape, which at first glance seemed to have been built at the expense of a major demolition of the rest of the walls, ancient ramps and many neighborhoods [12]. This period, 1870–1930 AD, is considered a period of creativity, innovation, and architectural colonialism due to the preparations for the celebrations of the centenary of the occupation of Algeria (1830–1930), where new architecture emerged as it represented a break with nineteenth-century architecture and the desire was to leave the imprint of the occupier all that done [12]. However, the valuable vernacular architecture heritage had been impacted by the French influence. After more than a century of French colonization, Algeria recovered its independence while inheriting an impressive colonial architectural legacy. Many of its valuable local heritage had been severely impacted or destroyed. The French presence on Algerian territory was not limited to the northern cities, but rather included the whole southern regions including the Sahara [13].

Several studies have been dedicated to the examination of this colonial architectural legacy in Algeria, however, the majority of them have focused only on colonial areas in the north of the country. There is still a lack of knowledge relating to the colonial impact in the southern regions which did not attract scientific interest comparable to the large northern coastal cities [13]. Therefore, the research targets this specific area and aims to explore the impact of the French colonization on the urban fabric of Laghouat city, a valuable vernacular heritage in the southern region of Algeria. The purpose of the study is to understand the urban adaptation cycle caused by the colonial system in the city of Laghouat and how these transformations have impacted the sustainability of the local urban fabric. Using the adaptive cycle approach, this study aims to trace the different stages of colonial influence on the city while highlighting how these transformational processes have impacted and reshaped the city's resilience, cultural identity, and urban tissue. To achieve this study, the following structure was adopted: The first chapter presents a broad analysis of the current literature and is followed by a comprehensive presentation of the case study "Zgag El-Hedjadj, Laghouat.". The methodology chapter then focuses on explaining the research methodology and analytical strategies used in this study. The following chapter thoroughly examines the applied adaptive cycle approach and its phases. After outlining the outcomes, this article ends with an insightful discussion and a comprehensive conclusion that summarizes the key point of this study.

Literature review: resilience and adaptive cycle in the complex socio-ecological systems

Walker et al. define resilience as "The ability of a system to absorb disturbances and reorganize itself while making changes in such a way that it retains essentially the same functions, structures and identity—in other words, to stay in the same area" [3]. Therefore, understanding the evolution of a system in relation to its resilience supposes looking at the model known as the adaptive cycle, according to which most dynamics Socio-Ecological Systems (SESs) would pass through four phases: Growth and exploitation phase (r), conservation phase (K), release phase (Ω) and reorganization phase (α) (Table 1) [14].

During the different phases of the adaptive cycle, resilience would start by decreasing and then increasing; the phases of growth (r), then conservation (K), are marked by a slow evolution and therefore easily predictive. They are sometimes followed by a chaotic phase of sudden change (Ω), which very quickly leads to a reorganization phase (α), slow or fast, when innovations transform the system. Resilience decreases as the system changes from state (r) to state (K), but it increases from phase (Ω) to phase (α), making the system less vulnerable [16].

Indeed, under "Panarchy", this adaptive cycle can be disrupted by cycles that affect subsystems, and at a higher level, the environment itself is assimilated into a system. The degree of resilience depends on the coupling of spatial scales and temporal rhythms. Multiple connections between the various phases of one level and those of another can potentially occur, but two of them are particularly significant with regard to sustainable development: the 'revolt' connection illustrates how rapid events

Table 1 Description of the four phases of the adaptive cycle, adapted from Gunderson and Holling [15]

Phase	Description
r (exploitation and growth)	- Innovators perceive unlimited opportunity—Bases for entrepreneurial and market competition are settled—External variability remains, favorable to entities more adapted to it (r-strategists)—Incremental exploitation of available resources and growth—Actors develop capacity for controlling external variability, hence reinforcing their own expansion—Future starts to be more predictable
K (consolidation and conservation)	- Growth rate slows down—Reduced opportunity and difficulties for new entrants—The future seems ever more certain and determined—Competitive edge shifts to those that control variability (K-strategists)—Increasing returns from efficiency(e.g., minimizing costs, streamlining operations)—Organizations become bureaucratized, rigid and internally focused (i.e., blind to external changes)
Ω (release)	- Extreme structural rigidity that may trigger sudden change, collapse and a "creative destruction" phase—Chaotic behavior, uncertainty rules govern—All of these create the source for reorganization and the systems begin to acquire a new identity
α (reorganization)	- System widely open to reorganization - Experimentation and initial establishment of actors, organizations and institutions, strongly subjected to evolutionary forces (i.e., competition, failure, survival) - Loss of resources (e.g., energy, information) is minimized, so that they become available in r phase(legacies) - Great uncertainty about options for the future and chance for unexpected forms of renewal

on a lower scale upset slow processes on a higher scale, while the 'memory, remember' connection reveals how the renewal of the cycle, which relies on inheritance (biological, institutional, economic), is organized by phase K (conservation) of the higher level. If the evolution of the system results from the behavior of the elements that compose it, its evolution itself has a directing action on its various elements. These mechanisms of scales interactions organize themselves in a feedback loop [16].

This resilience, which concerns all types of systems (physical, chemical, ecological, or human), presents four original characteristics. In the first, it designates, as in physics, the maximum disturbance that a system can undergo without changing state or leaving a basin of attraction. Second, it is also directly proportional to the self-organization of the system, with self-organizing systems being more resilient than systems with more hierarchical organization. Furthermore, resilience depends on the ability of a system to adapt, which is observed in human societies through learning and feedback [16].

Finally, it integrates and denies the opposition between nature and the social [16]. In cities as a living organism, there is a major distinction between resilience and adaptability, on the one hand, and transformability on the other. Resilience and adaptability have to do with the dynamics of a particular Socio-Ecological System, or a closely related set of Socio-Ecological Systems, while transformability refers to fundamentally altering the nature of a system [3].

Adaptability

The ability of actors, within a system to impact resilience, is known as adaptability. In Socio-Ecological Systems (SES), this represents people's ability to manage resilience. A characteristic feature of complex adaptive systems is self-organization without intent, and although the dynamics of SESs are dominated by individual human actors who do exhibit intent, the system as a whole does not [3]. However, as human behavior predominates in SESs, the social component—the individuals and groups in charge of managing the system—is primarily responsible for the system's adaptability. Their actions influence resilience, either intentionally or unintentionally. Their collective capacity to manage resilience, intentionally, determines whether they can successfully avoid crossing into an undesirable system regime, or succeed in crossing back into a desirable one [3].

Transformability

Transformational change includes the inclusion of new specific state variables, the removal of others, and an adjustment in the stability landscape's nature. It can be a cautious process, introduced by the actors involved, or it can be enforced on them due to changing conditions, either environmental or social and economic. Whether transformation is intentional or forced depends on the level of transformability in the SES concerned [17].

The capacity to develop a completely new system when circumstances such as those related to the environment, economy, society, or politics make the current one unsustainable. Transformability means defining and creating new stability landscapes by introducing new components and ways of making a living, thereby changing the state variables, and often the scale, that define the system [3].

Adaptive cycle quantification

The works of Gunderson and Holling present a conceptual metaphor that defines the evolution of developing systems as a cycle of four phases. Each one is focusing on certain distinctive factors of change. Therefore, the

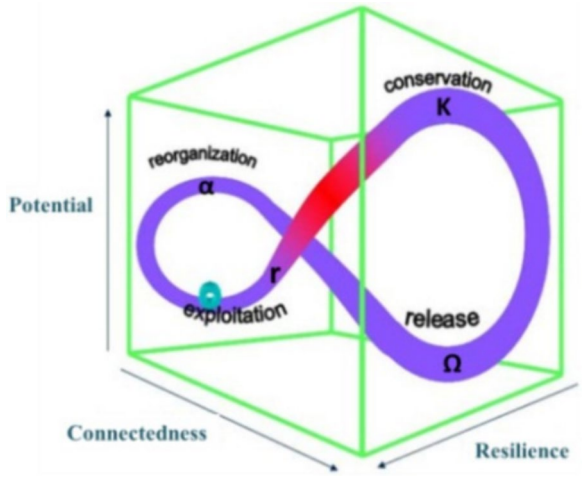

Fig. 1 Adaptive cycle in three dimensions [19]

adaptive cycle is inferred from the interactive dynamics between three essential variables which are: resilience, connectedness and potential. Together, these elements extend into a space in which the evolution of the system is depicted by the characteristic'lyingeight' figure (see Fig. 1) [18].

In order to have a profound scientific assessment, making the adaptation cycle quantitatively feasible is a necessity. This aims to provide a quantitative model of the system as a basis for quantifying potential, connectedness, and resilience, independent of the concrete instance of the system. Transfer entropy is also suggested to measure interaction. In order to examine the ability of the suggested process in analyzing factors of system development, it was decided to apply it to the historical and urban development of potential, connectedness, and resilience in Laghouat city.

Methods

The method used in this study is adopted from the works of Castell & Schrenk [18]. In general, this method can be applied to complex systems, which fits the specific case study 'Laghouat city'. The only requirement is that for a certain period of time and for each component of the system, there exists a time series of quantitative data reflecting the outcomes of the interactions [18].

The approach consists of two main steps: pairwise estimation of the transfer entropy between each agent is used to infer information transfer networks in the first step. In the second step, only the potential, connectedness and resilience are calculated using information transfer networks [18].

Step 1: estimation of networks of information transfer.
Let $\mathcal{V}$ be a collection of variables, quantifying the state of agents defining a system. Let $I = (i_1, \ldots, i_N)$ and $J = (j_1, \ldots, j_N)$ be two sets of samples of states for the components I and J, say. For example, I and J can be identified with abundances of two interacting species at time points $1, \ldots, N$. Transfer entropy from J to I is defined as [17].

$$T^t_{J\to I} = \sum_{n=t-w_t+1}^{t} p(i_{n+1}, i_n, j_n) \cdot \log\left(\frac{p(i_{n+1}|i_n, j_n)}{p(i_{n+1}|i_n)}\right)$$

Step 2: determining potential, connectedness, and resilience.
The definitions of potential and connectedness are based on Ulanowicz's notions of capacity and ascendency. Ulanowicz provides further information on the theoretical background of these measures [18].

It also provides the following notation:

$$T^{\text{out},t}_J = \sum_{I\in\mathcal{V}} T^t_{J\to I} \text{ and } T^{\text{in},t}_I = \sum_{J\in\mathcal{V}} T^t_{J\to I}$$

Define

$$P^t = -\sum_{(J,I)\in\mathcal{V}\times\mathcal{V}} T^t_{J\to I} \cdot \log\left(\frac{T^t_{J\to I}}{T^t}\right)$$

as the system's potential at time t

And

$$C^t = \sum_{(J,I)\in\mathcal{V}\times\mathcal{V}} T^t_{J\to I} \cdot \log\left(\frac{T^t_{J\to I} T^t}{T^{\text{out,t}}_J T^{\text{in,t}}_I}\right)$$

as its connectedness at time t

In order to define resilience, it needs to determine how vulnerable the system is to unexpected disturbances [18].

$$R^t = \min\left\{|\Re\sigma| : \sigma \in \text{Spec}(L_{\text{out}}) \cup \text{Spec}(L_{\text{in}}), \sigma \neq 0\right\}$$

Table 2 Summary of the definitions of the three systemic variables adapted from Castell & Schrenk [18]

Systemic variable	Definition
Potential	$P = -\sum_{(J,I)\in\mathcal{V}\times\mathcal{V}} T_{J\to I} \cdot \log\left(\frac{T_{J\to I}}{T}\right)$
Connectedness	$C = \sum_{(J,I)\in\mathcal{V}\times\mathcal{V}} T_{J\to I} \cdot \log\left(\frac{T_{J\to I} T}{T^{\text{out}}_J T^{\text{in}}_I}\right)$
Resilience	$R = \min\{\lvert\Re\sigma\rvert : \sigma \in \text{Spec}(L_{\text{out}}) \cup \text{Spec}(L_{\text{in}}), \sigma \neq 0\}$

The definitions of the three systemic variables are summarized in Table 2.

Following these 2 steps approach, provides an effective lens through which to see the complex interactions that occur inside a specific historical urban system like Laghouat city.

Case study: Laghouat city from pre-colonial to post-colonial

The location of Laghouat city

The research is based in the region of Laghouat. It is a city located at the center of Algeria, 400 km south of the capital and more than 750 m above sea level in the highlands. It is crossed by the chain of the Saharan Atlas with peaks that exceed 2000 m [20]. The Laghouat region is located in an arid to semi-arid area inside the steppe regions of Algeria. The total area within the administrative boundary is 25,052 km^2, with an estimated population of 581,771 inhabitants in 2013 [21].

The city of Laghouat is known for its old Ksar. A ksar, is a fortified village (Berber architecture) found in North Africa [22]. The old ksar of Laghouat was constructed in 1704 and classified as a national cultural heritage in 2007 (Fig. 2) [20]. This ksar is located in the east of the city of Laghouat and is considered as one of the specific achievements of traditional architecture (Figs. 3, 4 and 5) in the country. In fact, it represents the old nucleus of the city which consists of four districts: the district of El-Gharbia, the district of El-Safeh, The district of Zgag El-Hedjadj and the district of El-Zarbia El-Khadra [23].

Fig. 3 Old ksar of Laghouat [24]

Urban growth of Laghouat city

The study of the different steps of urban development in the city of Laghouat is presented with reference to

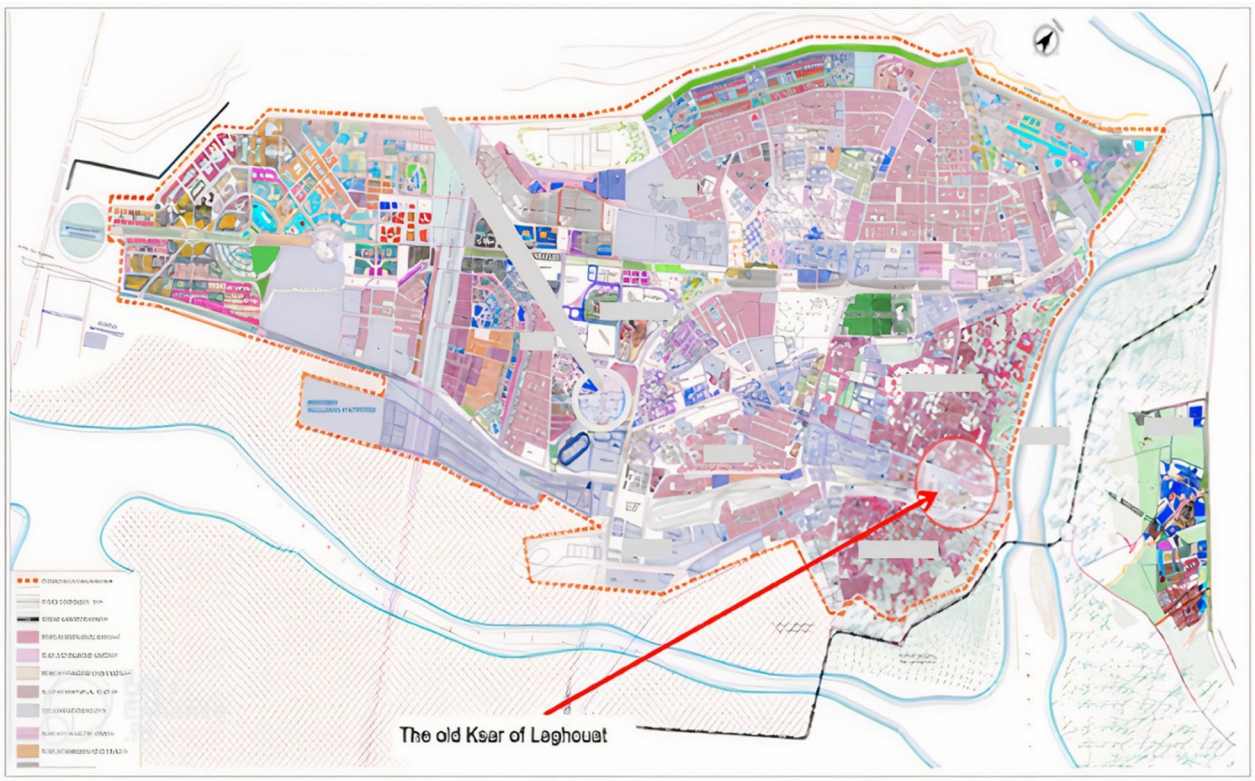

Fig. 2 Location of old ksar of Laghouat [24]

Fig. 4 Old ksar of Laghouat [22]

Fig. 5 Current state of the ksar of Laghouat. Source: Authors

periods that have marked the history of the city: the Pre-colonial period (before 1852), the Colonial period (1852—1962), and the Postcolonial period (after 1962) [25].

Pre-colonial period (before 1852)

Before 1708, in Laghouat, two rival clans lived inside the fortified area; Ouled Serghin and Ouled Ahlaf which shared the two districts of the city. Each of them aspired to impose himself on the other. The M'zi valley's irrigation water was a point of contention for these tribes as they fought for supremacy. The two rival clans lived in half of the city, which was divided in two by a wall. Each urban district is distinguished from the others by its market and its mosque (Table 3) [26]. The following Table 3 illustrates in detail the urban factors that affected Laghouat city during the pre-colonial period.

At that time, the urban configuration of ksar of Laghouat was characterized by an organic form. Inside this tissue, there are different types of streets for various categories of users: First, "Charaa", which is the principal street with a width between 4 and 3 m. This type of street is used by all the people. Second, there is "Zgag"; which is the secondary street with a width between 2.5 and1.5 m (Fig. 6). This type of street is used only by the inhabitant of the same street. Finally, there are "Droubs": which are the tertiary streets, with a width not more than 1 m. This type of street is used only by the inhabitants of the same family [30].

Moreover, each urban plot is formed by a group of houses that are pressed against each other, having only a courtyard or "El-Haouch" opens to the sky as illustrated in Fig. 4. The houses were built to accommodate many homes. That is why the houses consist of several rooms organized around a central courtyard called "El-Haouch" [30]. In fact, houses appear as a cube or a hollow parallelepiped. There is only one entrance in these houses, which is a chicane entrance "sqifa" (it means a closed and covered space). This space is directly accessible from a blind alley or a secondary street to preserve the privacy of the house, while the sqifa materializes the transition from public space to private space. The guest room "Bit Eddiaf" is an independent room from

Table 3 The urban factors affecting the pre-colonial period, adapted from Othmani-Marabout [26], Benarfa [25], Si Amer [27], Guidoum and Zerdazi [28] and Hamlaoui [29]

Social	Economic	Urban organization
The mosque functioned as the single organized political body and the cornerstone institution of the society. This customary arrangement brought together village and district chiefs under the leadership of a "Sheikh," who exercised last say and made crucial choices	The economic system depended on the production of oasis crops such pomegranates, figs, vines, and mostly palm trees. The economy depended heavily on handicrafts, particularly the weaving of carpets known as Haik, Burnous and Zarbia, with women being important participants in the wool spinning and weaving industries. By the 1830s, a small trade had developed, involving copper and metalwork made mostly by Jewish craftsmen, with Laghouat becoming known as a hub for the manufacture of jewelry and copper	Urban planning was carefully planned with security in mind, featuring well-defined thoroughfares and restricted access points. Markets were located close to city gates and served as a hub for trade between settled and nomadic populations. The only business buildings in the city were tailors, shops, and cafes along busy Zgag el Hadjadj street The houses were built with low entranceways and internal courtyards, mostly made of adobe bricks. Vast groves of palm trees surrounded the city center, which was essential for food. The plan of the city at that time reveals that Laghouat was therefore originally, constituted by a network of strangled passages where care was taken to multiply the angles and break the lines. It is the result of an interwoven network of alleys, corridors and blind alleys Beyond defenses, the lush gardens were essential food supplies for a large number of residents, enhancing the resiliency and standard of living of the city

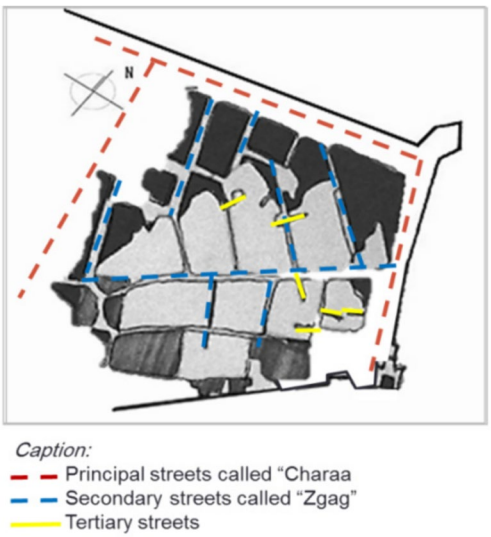

Fig. 6 Ksar of Laghouat (Zgag El-Hedjadj) during the pre-colonial period, adapted from Kerroum, 2013 [31]

the family space, the other rooms are grouped around the courtyard "El-Haouch" (Fig. 7) [22].

In reality, the courtyard, or "El-Haouch", serves as the center of the house, providing a micro-climate for the house surrounded by various other spaces, whether on one or more sides. In some cases, there is a gallery, which is called "Tahja", around these rooms and it could be on one or more sides. The facades of the traditional houses in Laghouat are predominantly blind, with a complete absence of windows on the outside. However, there are some simple decorative elements in the architecture of the traditional house, which may be inside or outside the house [33].

Colonial period (1852—1962)

In 4 December 1852 the French troops came to seize the city. After two months, the concern to turn the city into ruin began to be felt. Through Marshal Randon's decision; to make the city of Laghouat a political and economic center and promote its development into a stately and beautiful city. To answer Marshal Randon's instructions, an administrative reorganization was initiated. In 1853 by ministerial decision Laghouat was proclaimed a town composed of many Ksours and in 1869 it was transformed into a mixed commune. It marked the start of a new era. The most important thing during the colonial period (1852–1962) was the military town planning and restoration of the city besides the creation of a new urban space of the new colonial city (Table 4).

Among the urban factors that marked the structure of the ksar of Laghouat during this period, it can find social factors, economic besides several other factors. The following Table 5 illustrates in details these factors that remarkably affected the colonial period:

In 1852, during the French occupation, the ''Zgag El-Hedjadj" district experienced restructuring, rehabilitation, and extension interventions (Fig. 8). these interventions are summarized by the following actions: [22]

- Widening and straightening of the streets.
- The creation and development of places, in the center of the colonial city along with beautiful constructions characterized by openings to the outside and the ground floor arranged with arcades, regrouping military and administrative building.
- Fortification of the city by ramparts, towers, and forts.

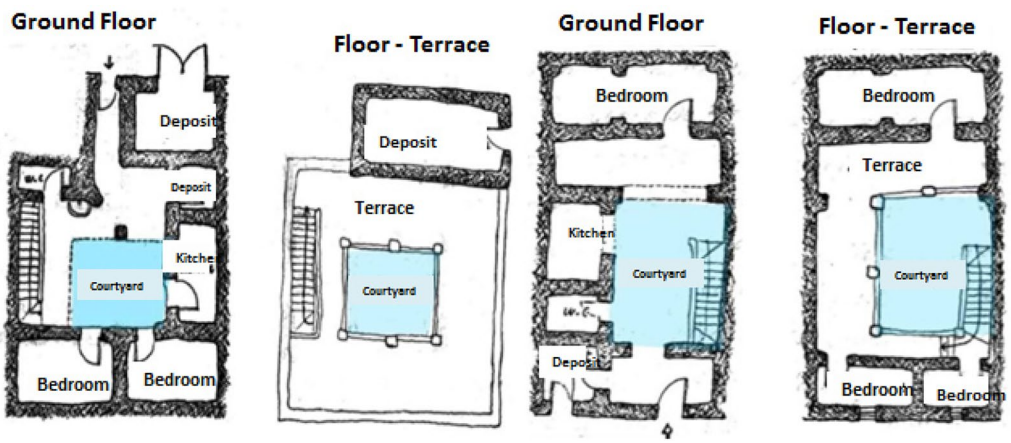

Fig. 7 Typical houses [32]

Table 4 The steps of the colonial city planning, adapted from Othmani-Marabout [26], Benarfa [25], Si Amer [27], Guidoum and Zerdazi [28] and Hamlaoui [29]

Military town planning and restoration of the city	The urban space of the new city
When Commander Du Barail took over as commander following Pelissier, he had the difficult assignment of restoring Laghouat's destroyed rampart As part of this initiative, two strong forts were established: Fort Bouscaren and Fort Maurand to the east. Additionally, a new bastion was constructed Laghouat became a major urban center in 1855 due to the carefully designed city plan, which was overseen by Commander Marguerite. Similar to an urban planner, Marguerite created a plan with straight roads slicing through the walled enclosure and breaking up the intricate web of the old system. With the addition of crossing streets and the improvement of public spaces, this design allowed for quick mobility The transformation of the city took place in accordance with a new paradigm, spreading widely to the North and South. Administrative infrastructure was established to emphasize its changing identity	Oriented in the North-East to South-West direction shown in Captain Du Barail's plan, the emerging city expanded rapidly Modernized areas and new facilities had to be installed, while outdated plots inside the old Ksar had to be demolished in order to integrate new districts with the existing urban core. Executive centers gathered around decorated squares, which were enhanced by the construction of new buildings Building the new city was a cooperative project that united disparate populations The main thoroughfares' expansion across the city defined the city's changing layout The new appropriation of urban space had marginalized the old Ksar of Laghouat, in effect the construction of the church as well as the buildings of the French administration compared to the poverty of the vestiges of the Muslim community

- The construction of some buildings like (church, school, hotel and hospital …).

Furthermore, during the colonial period, the orthogonal grid of the alleys resulted in rectangular plots measuring 35 by 65 m within the urban fabric of the district. Some modifications were made to the plots, including straightening along the street and adding additional elements on the side, such as balconies. Also, the interior structure of the plots was also condensed during this period, but the structure inside of the houses has been preserved to conserve the identity of the fabric. However, the urban facades were made up with openings; to reinforce the idea of the colonial power's existence [30]. The construction of houses follows the same style as the old town fabric, incorporating arcades with a specific horizontal symmetry. The rectangular-shaped plot is designed to align with the main street, introducing the concept of the courtyard, or El-Haouch, which is one of the defining features of the city of Laghouat. The colonial house is characterized by a simple arrangement of spaces that revolves around a corridor along which the rooms are aligned in a double straightening pattern to form the covered section of the house. This is followed by a courtyard situated at one of its corners. The main entrance door directly established access to the public space, which was the street. The facade's general homogeneity was enhanced by its flawless symmetry and simplicity, which produced a balanced and aesthetically beautiful exterior (Fig. 9) [30].

Postcolonial period (after 1962)

Like the majority of Algerian cities, Laghouat has undergone significant changes since the independence of the country, which have profoundly altered its physiognomy. This transformation resulted from the industrialization of the country and the exploitation of its natural resources. Laghouat experienced urban growth due to the increase in population driven by the phenomenon of rural exodus. This expansion of the city occurred in two phases: the first phase, given the existence of valley of M'zi on the eastern limit of the city center and the presence of the barracks, the city has expanded in the south-west part. However, during the second phase, the city has developed in a north-west direction. During this postcolonial period (after 1962), social and economic factors were among the major dynamics that shaped the Ksar of Laghouat structure. The following Table 6 presents in detail these factors and the main sectors that have been influenced by them.

Moreover, in 1962, after the independence, Laghouat city residents occupied vacant housing left by the colonial heritage, leading the town to develop in the same direction as the extension of the colonial city (in the west). The new urban housing was characterized by the copying of the morphological structure of the colonial one, the straightening and widening of the streets, and the abolition of the blind alley (Fig. 10) [26].

However, the post-colonial house appears to be similar to the colonial house. The evolution of lifestyles under the massive influence of the colonial model is evident through: first, the disappearance of architectural spaces in vernacular housing, like: Sqifa; the covered entry or chicane, Tahja; the covered and open enclosure gallery on one or more and Hojra; storage room.

Second, the modification of architectural elements in colonial housing, like: the courtyard or "El-Haouch", the guest room or "Bit Eddiaf" and the kitchen. Third,

Table 5 The urban factors affecting the colonial period, adapted from Othmani-Marabout [26], Benarfa [25], Si Amer [27], Guidoum and Zerdazi [28] and Hamlaoui [29]

Social	Economic	Urban organization
In the middle of the XIXth century, the region of Laghouat comprised at most a third of the population of 1950, that is to say 12000 to 15000 populations approximately In 1848 the number of houses increased as the population grew. 63 houses were built in the South Oasis and 90 in the North Oasis This increase shows the start of densification of the two palm groves which have been maintained for a long time	Compared to the advancements made after the French takeover in 1852, Laghouat's economic situation was basic until 1830. The period, marked by authentic urban vibrancy, progressively became more stable starting in 1961 It also witnessed the discovery of hydrocarbons between 1954 and 1962, which was a momentous event that greatly aided Laghouat's economic progress The original social structure of the community has been altered by economic transformations, which are closely linked to the new political structure that established Laghouat as the wilaya capital from 1902 to 1954. When sequestration ended in January 1855, Laghouat's people were able to reclaim their land and invest in land cultivation and varied agriculture, which marked the beginning of the town's economic development In order to improve irrigation systems, Du Barail approved the building of a dam in the M'zi valley in 1853. This allowed the M'zi valley's waters to revive the Oasis, which was on the verge of collapse The construction of these dams marked the beginning of a phase of national economic unification, strong population expansion, and rising living standards The spread of handicrafts, especially weaving, which saw a boom around 1956, was another indicator of this economic improvement, helped along by the opening of a public school in 1912	During the French colonial period, industry emerged as a crucial accelerator for the evolution of urban dynamics. Furthermore, Laghouat's trading scene was highlighted by the increasing number of new commercial businesses, which were evident in the dense concentration of retailers lining the city's avenues and thoroughfares As a matter of fact, the commerce structure functioned as a prominent gauge of the metropolitan spatial arrangement separating the Muslim and European communities

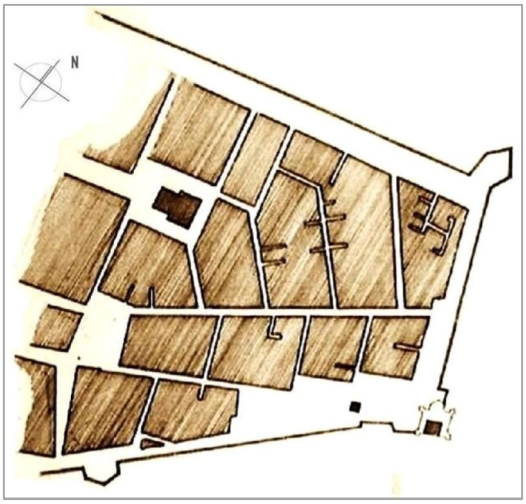

Fig. 8 Ksar of Laghouat (Zgag El-Hedjadj) during the colonial period [22]

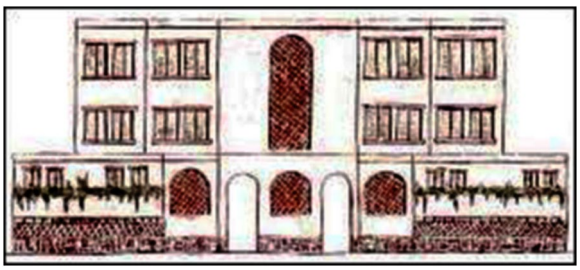

Fig. 9 Colonial house "main facade" [30]

the introduction of new architectural elements in post-colonial housing, like: corridor, hall, balcony, loggia and facade openings.

In general, the post-colonial housing is characterized by limited restructuring operations involving modest additions. Some owners carry out elevations that are easily identifiable by the construction process, where concrete, cement, or brick are used with openings at the outside [26].

Adaptive cycle quantification of historical and urban development of Laghouat city

After a comprehensive study and analysis of the urban growth of the city of Laghouat from 1852 to 1962 and from 1962 to the present, through 3 periods; the pre-colonial, the colonial and the post-colonial periods. it has been found that these periods align remarkably with the basic sequence of change in the adaptive cycle theory. This sequence involves a growth phase (r), followed by a conservation phase (k), prior to a release (Ω) event, that leads to the reorganization phase (α). Therefore, in the following analysis, it has focused on examining the historical and urban development, including economic factors, as well as the social and urban organization aspects of Laghouat city, highlighting the adaptive cycle in each period.

Adaptive cycle of the pre-colonial period

For the pre-colonial period, the city has undergone two phases: the growth (r) and conservation phases (k). The growth phase (r) is interestingly prolonged due to the establishment of ksar of Laghouat and all the favorable spatial, social, and economic factors that contributed to the structure of the city. On the other hand, it has been found that the conservation phase (k) is also extensive, marked by the continuity of the same conditions as the growth phase and slow and incremental changes.

The social aspect during the pre-colonial period was embodied by the indigenous population of the town of Laghouat through the creation of Ksar Laghouat and the building of Laghouat city.

The city in the pre-colonial period has undergone two phases; the growth (r) and conservation phase (k) and there are no release (Ω) and reorganization (α) phases.

The following Table 7 summarizes these two phases of the adaptive cycle during this period.

Adaptive cycle of the colonial period

The colonial period was an extended and complex phase. It took 110 years, spanning from 1852 to 1962. The city underwent four distinct phases: release (Ω), reorganization (α), growth (r) and conservation (k) phases. The release phase (Ω) was marked by the destruction and the new planning of the city. Followed by the reorganization phase (α), which was characterized by the beginning of the economic development of Laghouat (by re-appropriation of land). Surprisingly, during the growth phase (r), significant economic factors contributed to the development of the city such as the creation of a public school of handicrafts and the discovery of hydrocarbons in the area. The last phase in this period is the conservation phase (k). This phase was mainly characterized by the urban dynamic stabilization of the city.

During this colonial period, the French colonists and their settlement in Laghouat city represented the social aspect of this era. They have initiated the creation of a new urban plan of Laghouat and the beginning of a new era through the transformation of Laghouat into a mixed community.

The city in this period has undergone four phases; release (Ω), reorganization (α), growth (r) and

Table 6 The urban factors affecting the postcolonial period, adapted from Othmani-Marabout [26], Benarfa [25], Si Amer [27], Guidoum and Zerdazi [28] and Hamlaoui [29]

Social	Economic	Urban organization
The displacement and departure of nomadic communities towards the urban centers was ascribed to the population's movement patterns. Laghouat's urban population grew from 16,100 to 28,500 people between 1954 and 1961 On the other hand, the population of nomads reversed themselves, likely falling from 28,295 to 15,500 throughout that time This decline was mostly caused by the war's devastation and upheaval of the agricultural terrain. According to the 1966 population census, there had been an approximate growth rate of 24,231 inhabitants, with 77% of total people living in urban areas	Despite, low contribution to other economic domains, the agricultural sector experienced a downturn in spite of coordinated efforts and developmental initiatives delineated in subsequent plans intended to promote agricultural progress and limit urban encroachment on arable land. The tertiary sector industry currently dominates the city's economy and has been steadily becoming more important as the new town has grown, supported by the introduction of new services and facilities Beginning in 1988, Algeria, including Laghouat, undertook a period of political, social, and economic reforms that were codified in the 1989 constitution and approved by referendum. This marked the beginning of the country's transition from a state-monopolized economy to one that is driven by the market economy	In 1977, an important part of the population was employed in the construction, civil engineering and industrial sectors combined, with 26.1% working in industry and 22.6% in construction and civil engineering The three-year plan (1966–1970), which recognized industrialization as the essential base of Algeria's economic policy, was closely linked to this combined rate of 48.7% Notably, 17.26% of the population was working in civil engineering and construction, indicating a higher percentage due to extensive housing projects in Laghouat city

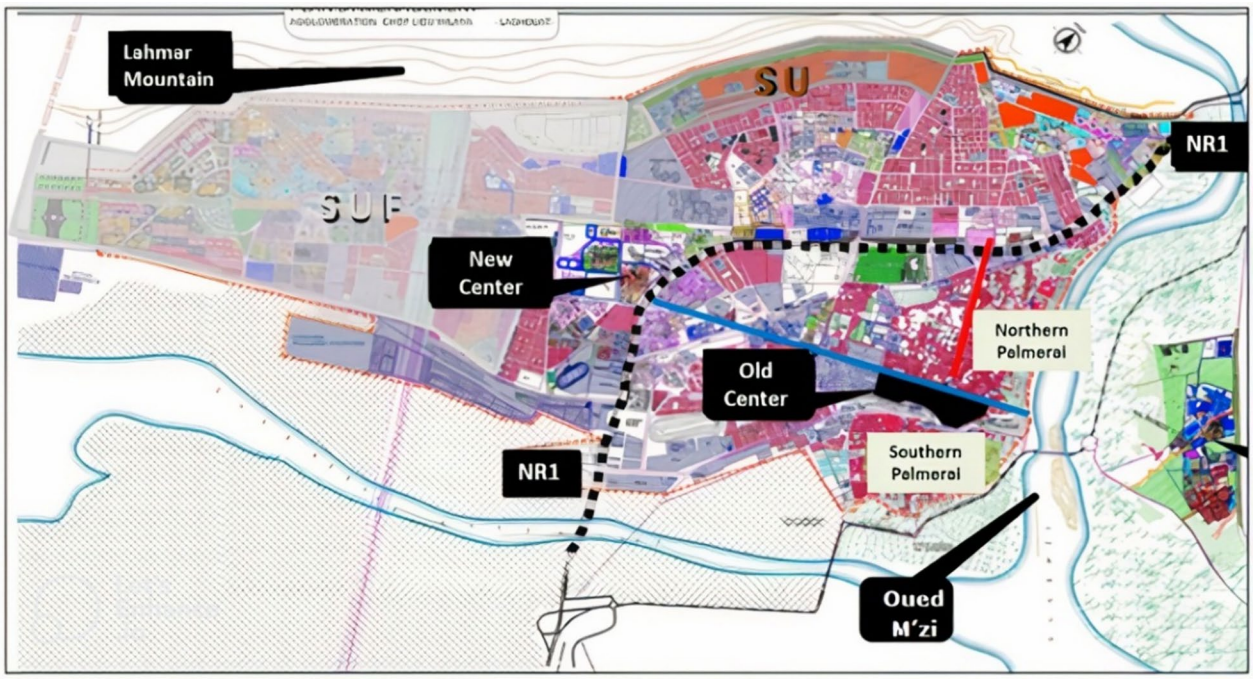

Fig. 10 Plan of development and urban planning of Laghouat [34]

Table 7 The adaptive cycle (historical and urban development) during the pre-colonial period

Pre-colonial period (Before 1852)	
Phase	**Adaptive cycle**
Growth (r)	Before 1708—the creation of ksar of Laghouat
Conservation (k)	In 1830—The development of the economic system

Source: Author

conservation (k) phases. The following Table 8 summarizes these phases of the adaptive cycle during this period.

Adaptive cycle of the post-colonial period

During the post-colonial period, Laghouat city has experienced a single phase, specifically the conservation phase (k). This phase has proven to be extensive, like the previous period. It demonstrated the continuity of the conservation phase's dynamics observed during the colonial period. Characterized by some accumulation, and a slow and incremental change. The postcolonial conservation phase has contributed to the city's current development and stability.

The social element during the post-colonial period was represented by the local population of the town of Laghouat. After the departure of the French colonists from Laghouat city, the local population of the town of Laghouat started making changes in the city and initiated conservation works, giving back to the city its stability. The conservation phase (k) is referred to all the historical and urban developments of Laghouat city; after independence the local population conserved the historical and urban development of Laghouat city. This phase was characterized by a specific element which is the expansive development of Laghouat city; due to the increase in local population caused by the phenomenon of rural exodus.

The city in the post-colonial period has undergone one phase; specifically, the conservation phase (k) and there is no release (Ω), reorganization (α) and growth (r) phases. Table 9 summarizes the adaptive cycle of the city during this specific period.

Discussion

During this research, and in order to demonstrate the ability of the proposed method in analyzing drivers of system development, it focused on the analysis of the adaptive cycle of the city through studying the historical

Table 8 The adaptive cycle (historical and urban development) of the colonial period

Colonial period (1852—1962)	
Phase	**Adaptive cycle**
Release (Ω)	In 1852 the French troops came to seize the city
Release (Ω)	In 1855 the new plan of the city of Laghouat by the Commander Marguerite
Reorganization (α)	In 1855 the beginning of the economic development of Laghouat, by reappropriation of land
Reorganization (α)	In 1869 the start of a new era by the transformation of Laghouat into a mixed commune
Growth (r)	In 1912 the creation of a public school of handicrafts
Growth (r)	The discovery of hydrocarbons in 1954 and 1962
Conservation (k)	The period which was characterized by a real urban dynamic tended to stabilize, from 1961

Source: Author

Table 9 The adaptive cycle (historical and urban development) of the postcolonial period

Postcolonial period (After 1962)	
Phase	**Adaptive cycle**
Conservation(k)	The development of Laghouat city due to the increase in local population with the phenomenon of rural exodus

Source: Author

and urban development of potential, connectedness, and resilience of Laghouat city. Therefore, as illustrated in Fig. 11 the adaptive cycle of Laghouat city underwent remarkable transformations during the three periods of its historical and urban development.

The examination of the case study, the historical and urban development of Laghouat city, reveals the expected interplay between potential, connectedness, and resilience in the temporal and physical evolution of the city. In a broader context, this analysis supports the concept of the adaptive cycle, enabling us to detect the predictable cyclic patterns of potential, connectedness, and resilience within a complex urban system such as Laghouat. This is visually represented in Fig. 12, which illustrates the cyclical nature of these critical elements across the studied temporal periods. Concurrently, the case study reaffirms the conceptual character of the adaptive cycle. As anticipated, the four phases (release (Ω), reorganization (α), growth (r), and conservation (k)) do not always occur in the ideal way as described in the metaphor. Surprisingly, the duration of the phases results rather from the interaction of environmental dynamics with the internal evolution of the system.

In conclusion, the comprehensive examination of Laghouat city as a case study validates the capacity of the approach and the effectiveness of its application. This process is indeed capable of analyzing systems independently of their specific realization and widely applicable without any inherent explanation, such as ecosystem or economic theory. Thus, the integration of the analytical approach with appropriate simulation toolsets can further enhance its utility, providing a powerful framework for understanding sustainability and guiding system management that may also improve the scalability of this approach for future work.

Conclusion

The urban adaptation cycle of Laghouat city has been and continues to be rapid, encompassing changes in the urban, demographic, economic, and social fields. The social structure of Laghouat community underwent significant changes due to the urban adaptation cycle and

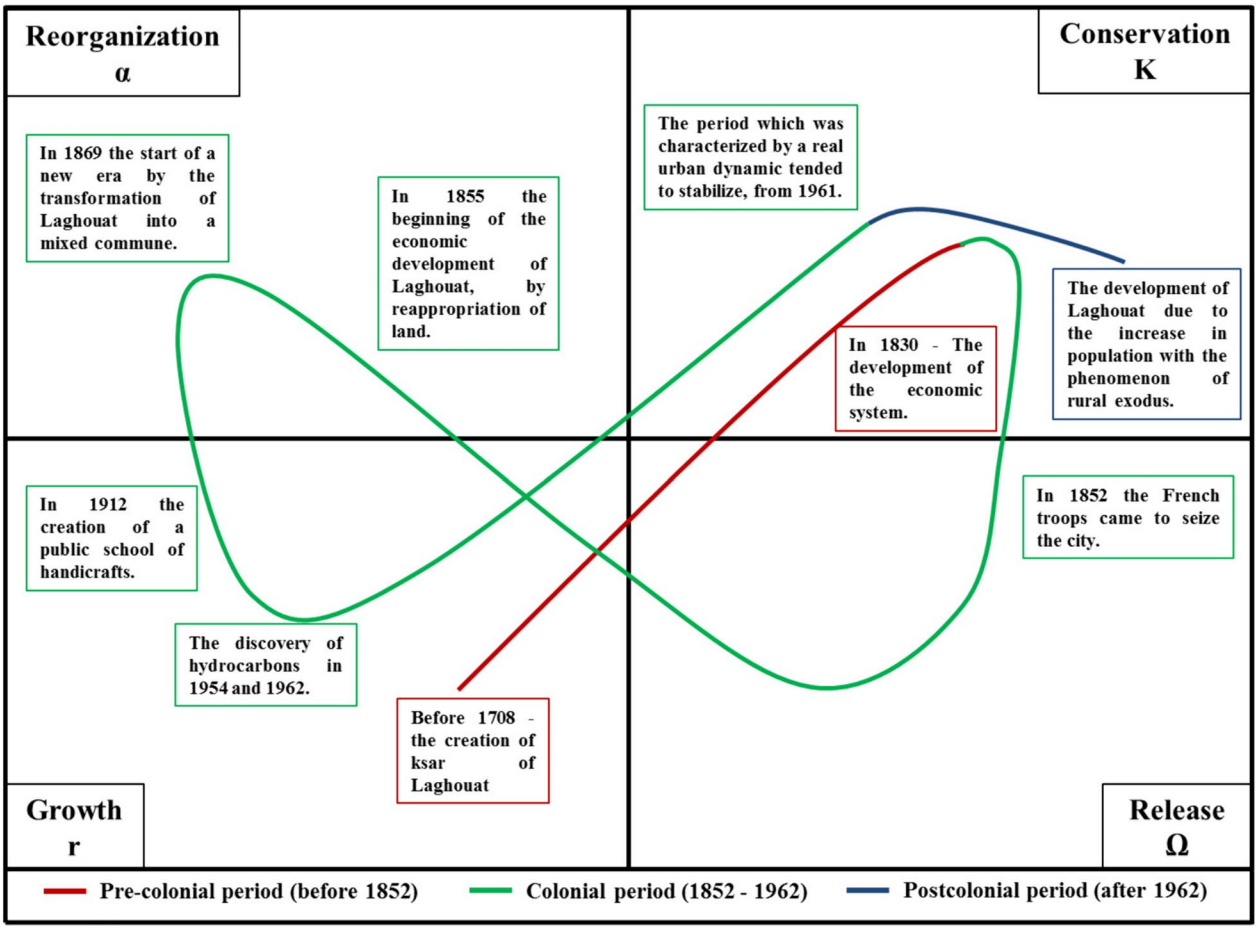

Fig. 11 The adaptive cycle (historical and urban development) of Laghouat city. Source: Authors

expansion that occurred during and after the colonization. Residents of Laghouat have remarkably integrated themselves with the evolving tissue. In the urban context, the city as a whole has undergone substantial changes by a large percentage, which highlights the impact of colonial architecture and planning on Laghouat city. The management of the urban adaptation cycle and development of the city represents a major challenge in the future decades.

The results of this study indicate that the urban adaptation cycle of Laghouat city, described as a major risk to the city, is likely to disrupt the identity and functioning of the city. The mechanisms of the city's resilience to this diffuse risk can then be observed in the short term, through the analysis of the impacts of the new urbanization of the city in the longer term using the adaptive cycle model, which was originally developed for Socio-Ecological Systems. In fact, the concept of resilience also makes it possible to provide a common frame of reference and therefore seems to have the capacity to better integrate and articulate the various urban policies, in order to adapt and transform urban systems such as the case study. In addition, resilience advocates for empowerment at local and individual levels, which can sometimes lead to show those who fail to rebuild or adapt against what would be implied by urban trajectories of sustainable development requiring more solidarity and more equity and responsibility towards future generations.

The approach had been applied only to Laghouat city, however, this work may open future research perspectives for application in different cities with similar backgrounds, thus, providing a deeper understanding of this specific type of architecture and assisting urban planners and decision-makers to develop more effective urban visions for the future.

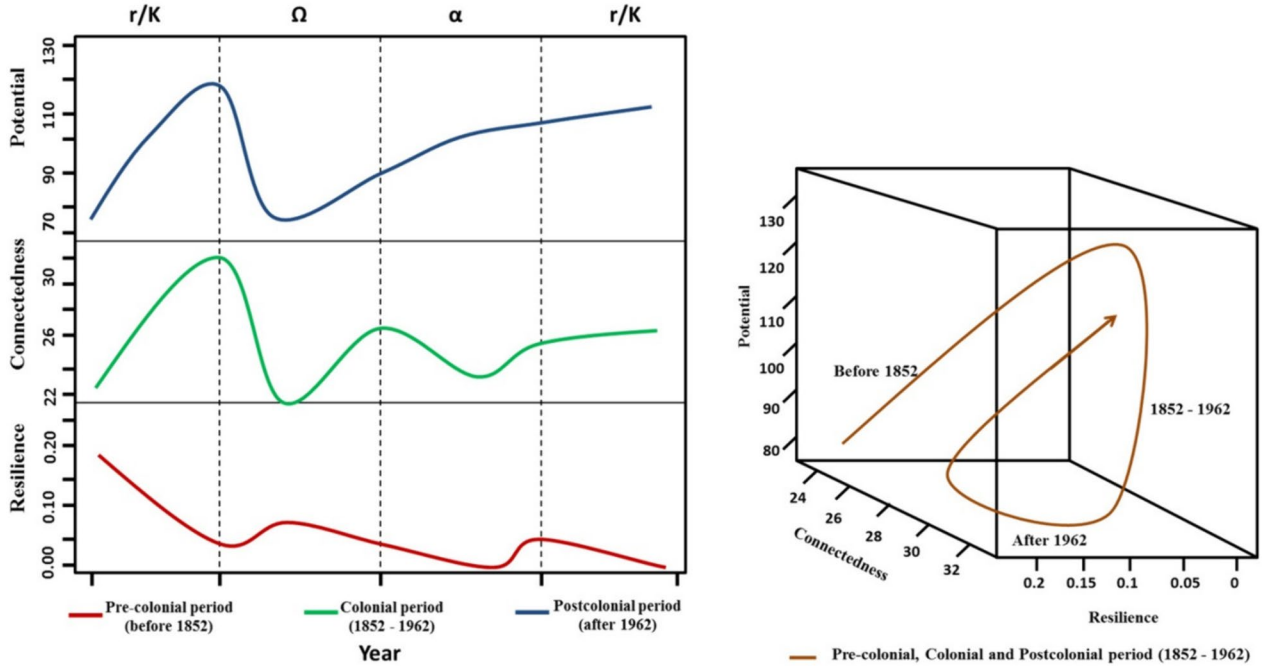

Fig. 12 Information theoretical analysis of Laghouat city during the pre-colonial, colonial and post- colonial periode. Historical and urban development of potential, connectedness, and resilience of Laghouat city. Source: Authors

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Author contributions
FIM: Formal analysis, Software, Investigation, Conceptualization, Writing the original draft, Project administration, Supervision and Coordination, Reviewing, Editing, Validation, and proofreading. SD: Reviewing and Editing. RB: Reviewing and Editing, proof reading and validation. TVA: Reviewing and Editing, proof reading and validation. All authors read and approved the final manuscript.

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