EXPLORING THE SUSTAINABILITY ASPECTS OF BISKRA OASIS ECOSYSTEM: HERITAGE BASED PERSPECTIVE

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Abstract. An important ecosystem in the Algerian Sahara, the Biskra oasis is significant historically and culturally as an example of sustainable existence. However, it has suffered significant deterioration throughout time due to urban, socioeconomic, and environmental stresses. This study tracks the oasis's evolution and evaluates its sustainability aspects using a multidisciplinary methodology that combines historical analysis, literature evaluation, and cartography. The results show the palm grove's ecological richness, the economic resiliency derived from customs like phoeniculture and local trade, the social cohesion promoted by group projects like Twiza, and the microclimatic advantages of the urban-architectural composition. These insights highlight the oasis's potential as a paradigm for sustainable development in arid regions, emphasizing the need to preserve and adapt its traditional practices to contemporary challenges.

Key words: oasis changes, GIS, sustainable development, Biskra oasis.

1. Introduction

In the context of rapid urbanization, changes in urban space structure greatly affect the quality of human life and endanger environmental resilience (Maimaiti *et al*., 2021). This phenomenon is one of the most prominent indicators of the transformation of climate and natural landscapes (Fan *et al*., 2017). The accelerated and often unchecked

urbanization in developing nations presents critical sustainability challenges as urban areas keep growing in both size and population (Chaka *et al*., 2024).

According to a statistical report published by the United Nations in 2019, the worldwide rate of urbanization rose from 30% in 1950 to 55% in 2018 due to population growth, as well as it is projected to reach 68% by 2050 (Hadagha, 2022; Kuang *et al*., 2020).

The effects of urban expansion on living spaces have both positive and negative impacts, as it requires not only migration from villages to cities, but moreover, the shift from agricultural areas to other services. Most critically, it's about a complete change of integrated ecosystem services (Ejaro and Abubakar, 2013).

Today, built environments cover nearly 3% of the surface layer of the earth to satisfy the infrastructure needs (Almadini and Hassaballa, 2019). In other words, there will be an increase in requirements of the population in reference to the built environment in the coming years with the growth in its total. As countries make economic progress, people generally are further considering settling in built-up areas. This damages ecosystem conditions (Mahmood *et al*., 2020).

Given these trends, current studies have focused on the effect of rapid urbanization on the sustainability of ecosystem functions and services. A thorough understanding of how urbanization affects these services could help policymakers in making environmentally supportive decisions (Li *et al*., 2023; Deng *et al*., 2021; Nelson *et al*., 2009). With the degradation of ecosystem services, the oasis ecosystem has emerged as a critical topic in urban development in arid zones worldwide, where oases play a crucial role in social structures and biodiversity conservation (Houssni *et al*., 2023; Ge *et al.,* 2022; Fu *et al.,* 2018).

In North Africa, oasis ecosystems cover around 380,000 hectares (Schilling *et al.,* 2012). Oasis ecosystem services include date production, food, date by-products, and well-being benefits. Moreover, there are regulatory services that involve climatic, biological and air quality control (Houssni *et al*., 2023). Despite the significance of oasis ecosystem services, one of the major challenges facing these services is the rapid urbanization at the expense of oasis and agricultural land (Santoro *et al*., 2020) which leads up to the gradual decline and eventual disappearance of these vital ecosystems (Gong *et al*., 2025; Chen *et al.,* 2024).

In this regard, many methods and approaches are used to analyze the oasis ecosystem. One of the most prominent of these methods is Geographic Information Systems (GIS), which enables the visualization of the various transformations through remapping, integration and analysis of spatial data related to the oasis ecosystem (Hernández-Agüero *et al.,* 2025; Pundt *et al*., 2000).

GIS tools facilitate the conduction of projects focused on researching and analyzing aspects including the natural environment, the earth, atmosphere and subterranean layer. They assist the sustainable use of ecosystem resources and help in minimizing risks related to the natural environment. Geographic Information Systems support and improve sustainability planning processes, providing rapid and objective

analysis of environmental challenges and issues, as well as presenting information in a spatial and visual manner (González del Campo, 2012). Given their ability to analyze spatially the land-use patterns and environmental vulnerabilities, GIS tools are especially valuable in sensitive regions.

In this context, this is particularly true for the fragile oasis ecosystems of the Algerian desert, which are easily impacted by land-use changes due to the rapid urban expansion.

Algeria, home to numerous oases in North Africa, hosts the majority of these ecosystems in its desert regions. Oases, often perceived as islands within the vast Sahara, are undeniably vital to the Saharan region. They evoke the image of a green paradise within a constrained environment (Bouzaher and Alkama, 2013; Cote, 2012; Kouzmine, 2007).

In our research, we focus on Biskra's oasis station as we travel through this desert. It's defined by aridity and marked by distinct natural, climatic, economic, cultural, social, architectural, and urban characteristics. Moreover, this oasis is noted by its socio-spatial values, making it a unique ecosystem (Rais and Bouzaher, 2021).

Long ago, Biskra oasis, this natural and human masterpiece, gained great importance as a tourist destination for foreigners due to its picturesque character and unique atmosphere, characterized by its light and thermal qualities, which attracted many Americans and Europeans (Bouzaher and Alkama, 2017).

As well, this oasis ecosystem, characterized by its diverse physical and natural aspects, plays a vital role in enhancing the quality of life for Biskra's inhabitants. In particular, it served as the primary source of sustenance for the majority of them, due to its strategic position, with its central location on the connecting axis between the north and south of Algeria (Rais and Bouzaher, 2021; Bouzaher and Alkama, 2013; Cote, 2012).

Regrettably, in recent decades, Biskra's oasis ecosystem has been under threat and has even declined due to rapid urbanization. Numerous studies, such as those by Hadagha (2022), Berbache *et al*. (2022) Bouzaher and Alkama (2013) and Cote (2012) have shown that urban expansion is often a sign and an indicator of social, economic and political development. Nevertheless, it comes at the cost of oases, agricultural lands, orchards, forests, and the urban green spaces. This rapid urbanization, evident in the reducing number of palm groves, has led to a significant reduction in the number of trees and palm species in the oasis of Biskra, with their space gradually declining, potentially leading to their disappearance (Berbache *et al*., 2022).

Emphasizing Biskra's oasis ecosystem as a case study, this paper aims to determine the different causes of its decline and the key factors of its sustainability, suggesting solutions for its rehabilitation to ensure resilience against forthcoming and future challenges. It also seeks to explore its different dimensions and assess its sustainability by addressing the ensuing questions:

- What defines the sustainability characteristics of Biskra's traditional oasis ecosystem and what are the key factors driving its gradual transformation?

- Is Geographic Information Systems (GIS) required for analyzing ecosystem transformations in Biskra's oasis, and how can it help us to interpret the decline process?

To address these questions, the following hypotheses are proposed:

- (a) The sustainability attributes of the oasis ecosystem are multidimensional, encompassing social, cultural, spatial, and economic aspects; (b) Several causes are responsible for the degradation of this ecosystem, including socio-cultural, economic, and spatial factors.
- Using Geographic Information Systems (GIS) is crucial, assisting the creation of dynamic maps to visualize the development of Biskra's oasis over time. By mapping ecosystem transformations, GIS also helps us understand the decline process and identify required measures for sustainable rehabilitation.

2. Methods and materials

In order to investigate current GIS applications for analyzing land use and environmental changes over time, a state-of-the-art literature review was first conducted. This review incorporated case studies, peer-reviewed academic articles, and technical reports that demonstrated the use of GIS technologies for monitoring environmental transformations, evaluating sustainability indicators, and assessing landscape dynamics. Following this review, the selected case study was presented in detail to establish its geographical, environmental, and socio-urban characteristics. This step provided the necessary contextual framework for understanding the relevance of the subsequent analyses.

Subsequently, the materials and data sources employed in the research were introduced.

Finally, the adopted cartographic approach was explained, detailing the GIS-based techniques and analytical procedures applied to visualize land changes, map sustainability aspects, and evaluate spatial patterns over time.

2.1. State of art

Landscape dynamics and ecosystem changes are complicated processes caused by both anthropogenic and natural aspects. Indeed, anthropogenic activities have widely altered environments and landscapes all over the world, and additional transformations are expected going forward (Stephens *et al*., 2021).

Activities including agricultural, urbanization, and industrial development, together with the climate change impacts and natural processes (Mahmoud and Gan ,2018). In the view of Aziz *et al*. (2023) these activities can radically transform and damage the ecosystem stability, landscapes, water resources, minimize the agricultural land area, apply pressure on biodiversity also lead to environmental pollution.

Focusing on the varied dynamics and changes within ecosystems and landscapes is crucial for successful management of sustainable resources (Musakwa and Wang, 2018). In this regard, recent innovations in Geographic Information Systems technologies offer vital opportunities for greater effective decision-making within these areas. Actually, GIS is considered to be a prime tool for detecting environmental changes, assessing landscape dynamics, and

supporting sustainable land management (Menasra and Bouzaher, 2021).

Additionally, GIS technology provides that, mapping and data analysis can support decision-making concerning threats and preservation strategies (Goodchild, 2011). In this way, various research has presented how GIS is able to support sustainability assessments at multiple scales, from general to detail levels (Ramos, 2019). For instance, in a study titled: *Sustaining Human Carrying Capacity; a tool for regional sustainability assessment*, the authors emphasize that GIS tools serve a vital role in guiding countries towards sustainability. GIS technologies must provide local managers to identify areas that most require initiatives to advance sustainability (Graymore *et al*., 2009).

Furthermore, another study mentioned that the integration of GIS with remote sensing can be useful for detecting urban expansion and assessing its impact on urban sustainability. This study highlights the importance of visualizing urban transformations over time through the evaluation of land use and land cover changes (Xiao *et al*., 2006).

Moreover, Geographic Information Systems support sustainability by analyzing environmental risks and damage. On the other hand, Joerin *et al*. (2001), found that the mapping of the land use plan for housing in a Switzerland town. Where, that can combine a set of complex conditions, integrating the perspectives of various decision-makers, and use GIS to assess the necessary parameters. In this way, predictive maps result as an effective tool for assessing potential risks and supporting sustainability projects.

The literature review shows a diversity of applications to assess the dynamic changes in oasis ecosystems. GIS technology can unravel complex issues such as urban expansion and land use change (Maimaiti *et al*., 2021; Ren *et al*., 2019; Liu *et al*., 2010), soil degradation (Abuzaid *et al*., 2021; Abdelrahman, 2023), climate change (Leal *et al*., 2024), water scarcity (Abdelhaleem *et al*., 2021) and biodiversity loss (Karmaoui *et al*., 2023; Liang and Liu, 2017).

Various research has been developed in China to explore the spatial and temporal changes of the oasis ecosystem. This research used GIS technology to approach the evolution of land use and land cover (Muyibul *et al*., 2018). Some of them use a combination of GIS and remote sensing techniques, to assess the environmental impacts of land-use change (Qi *et al*., 2007).

Furthermore, in the Middle East, many researchers have employed GIS technology. As an example, a study focuses on dynamic changes of oases-desert in northern Egypt, using geomorphological information mapping. This study explored that an understanding of the oasis change is crucial to the sustainable development of this region (Liu *et al*., 2024).

In another work, Almadini and Hassaballa (2019) quantified the spatio-temporal changes in land cover of oasis Al-Hassa in Saudi Arabia. Their study demonstrates that changes in oasis ecosystems are influenced by numerous factors such as environmental conditions, urban expansion, water scarcity, and social activities.

In the context of African countries, some researchers have integrated GIS to assess

climate change impacts on oases. For example, Leal *et al*. (2024) found that GIS was used to evaluate the vulnerability of oasis ecosystems to climate change in northern Africa by integrating spatial and environmental data, including temperature, precipitation, and water availability. The authors recorded that GIS tools are effective for predicting and visualizing the effects of climate change on ecosystems.

In another work, Karmaoui *et al*. (2023) applied GIS tools to monitor desertification, cultivated and urban areas, and changes in water surface in the oasis ecosystem of the pre-Saharan province of Errachidia in Morocco. In Algeria, the dynamics of oasis ecosystems have been the focus of several studies due to their strategic location, in the arid Saharan region, characterized by an extremely hot and dry climate.

In the study of Dechaicha *et al.* (2021) examined the state of uncontrolled urbanization in the Adrar Oasis and its consequences on landscape transformations. The results indicate that the use of GIS technology to monitor landscape dynamics is a crucial stage in the development of sustainable strategies for oasis management (Dechaicha and Alkama, 2020).

In spite of the important dynamics of oasis ecosystems of Biskra, only a few researchers have assessed these changes. For example, Berghout and Dridi (2022) integrated spatial analysis using GIS to evaluate the sensitivity to urbanization in Biskra city and its neighboring oases. Their research proposed a prospective approach to urban growth based on climatic and physical parameters.

In a related study, Dechaïcha and Alkama (2020) assessed the spatiotemporal urban sprawl of Biskra, the results indicated significant urban growth, accompanied by a progressive decline of the palm grove.

Berbache *et al*. (2022) applied GIS techniques to map and monitor the morphological and spatial transformations of the oasis ecosystem of Biskra.

In another work, Hadagha (2022) applied GIS tools to improve the oasis ecosystem. This study reported that using GIS aids in measuring the losses in terms of palm number in the oasis of Biskra.

2.2. Case study

The studied area occupies a wide extension of Biskra, the capital of Biskra Province, located in southeastern Algeria, covering 127.70 km², approximately 400 km from the capital Algiers (Fig. 1) (Farhi and Belhamra, 2012).

The climate of Biskra, consistent with that of the wider Saharan region, is marked by extreme aridity, minimal precipitation, frequent and intense sand-laden winds, and low atmospheric humidity, resulting in hyper-arid desert conditions (Hadagha, 2022). In summer, Biskra is considered one of the hottest places in the world, with temperatures approaching 50 °C. The summer nights are particularly harsh, as the city is located in the midst of a vast greenhouse-like environment, where the heat accumulated during the day does not dissipate during the night (Pizzaferri, 2011).

According to climatic data from 2017, the annual average minimum temperature was 23.07 °C. The thermal contrast is significant, with August registering 35.1

°C as the hottest month, while January dropped to 10.39 °C, the coldest month, reflecting the pronounced seasonal amplitude characteristic of arid desert climates (Hadagha, 2022).

Nestled at the southern edge of Roman Africa and shielded by the last foothills of the Aurès Mountains, the city serves as a gateway to the expansive Sahara (Pizzaferri, 2011). Its site resembles a basin framed by the Saharan Atlas to the north and the Zab range to the west, while two rivers, Oued Biskra to the east and Oued Z'mor to the west, traverse Biskra city (Sriti, 2013), Biskra lies at an average altitude of 87 meters, with a topography that tapers off from north to south.

This strategic location, at the threshold of the Great Sahara, has earned Biskra the title "The Gate of the Desert". Additionally, its rich palm groves, integral to the local ecosystem and economy, have given it the name "Queen of Zibans", derived from "*Zab*", meaning "palm oasis" in the southern Algerian dialect (Berbache *et al*., 2022). These extensive palm groves not only identify the region's ecosystem, furthermore, support the socioeconomic life of its inhabitants, and promote sustainable local development (Bouzaher and Alkama, 2012). The oasis forms the original city core of urban development in Biskra, also mentioned as Old Biskra. It is located in the southeastern district of the city and comprises seven districts: M'cid, Ras El Gueriah, Beb El Derb, Beb El Feth, Medjnich, Corra and Gueddecha. These zones present together the interaction between Biskra's urban transformations as well as its unique ecosystem (Hadagha, 2022; Bouzaher and Alkama, 2017).

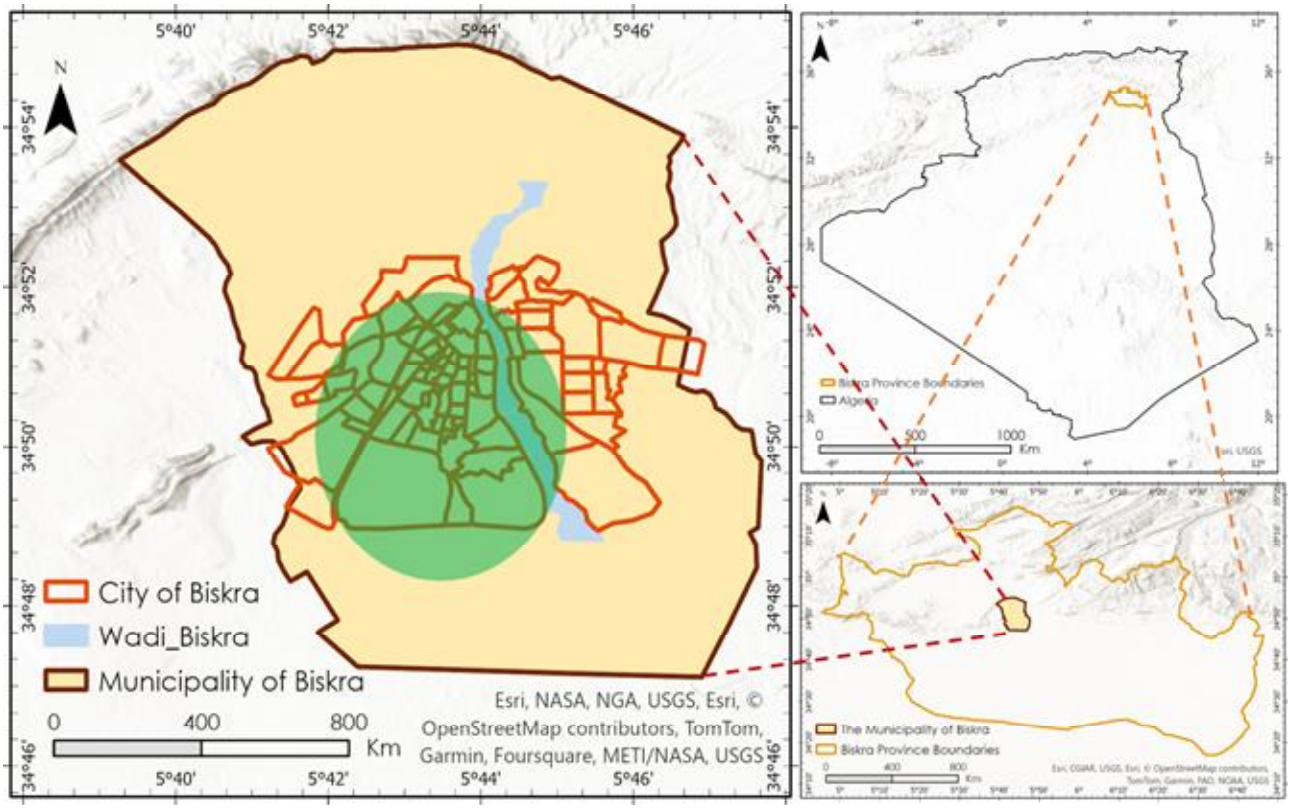

Fig. 1. Location map of Biskra's oasis. Source: Authors (2024).

2.3. Materials

Geographic information system (GIS) techniques, including QGIS, were utilized to examine the historical development of Biskra's oasis by producing detailed maps illustrating spatial and temporal changes in the oasis's landscape. These maps provided valuable insights regarding land-use changes, urban expansion, and evolving agricultural practices.

To support the GIS study, historical records, including archival documents, local records, and scientific research were used. This combined approach provided a comprehensive understanding of the key factors shaping the growth of the oasis ecosystem of Biskra city, enabling the identification of opportunities and challenges for the sustainable development of this area.

2.4. Cartography approach

To examine the historical evolution of the oasis ecosystem of Biskra city, this study relies primarily on archival materials, photos, and pertinent writings regarding its historical context, as there is no map showing the oasis in its original state. For this purpose, QGIS, an open-source Geographic Information System software, was utilized.

To map the oasis changes in land use, geographic data was gathered from historical maps (dated 1956, 1963, and 1966) and a Google Earth satellite image. These historical maps, available primarily in JPG and PNG formats, were imported into QGIS for analysis. Georeferencing was achieved using a French Army General Affairs map, which included coordinates that enabled alignment with other non-georeferenced historical maps (Hadagha, 2022).

A detailed georeferenced map was subsequently created by integrating data from historical sources, including Michelin (1956) and French Army maps (1963), alongside textual descriptions. In QGIS, vector layers were created to represent water canals, green areas, and built-up zones based on the analyzed historical maps. The resulting map depicts the layout of the oasis in 1956, during the French colonial era, utilizing a coordinate system tailored for the northern Sahara region (Zone 32). Building upon this 1956 map, it became feasible to produce supplementary maps that illustrate the dynamic transformation of the oasis over three pivotal periods:

Ottoman period: Highlighting the foundation and configuration of the ancient Biskra oasis.

Colonial period: Showcasing the emergence of a new district and a historical center (Sriti *et al.*, 2002).

Post-Independence period: Depicting the expansion of the city and the development of new urban forms dependent on the oasis ecosystem.

This multi-temporal cartographic approach provides a detailed understanding of the spatial and historical dynamics shaping the Biskra oasis. The methodological process described is summarized in the following schema (Fig. 2), which outlines the key steps taken to trace the historical transformation of the Biskra oasis.

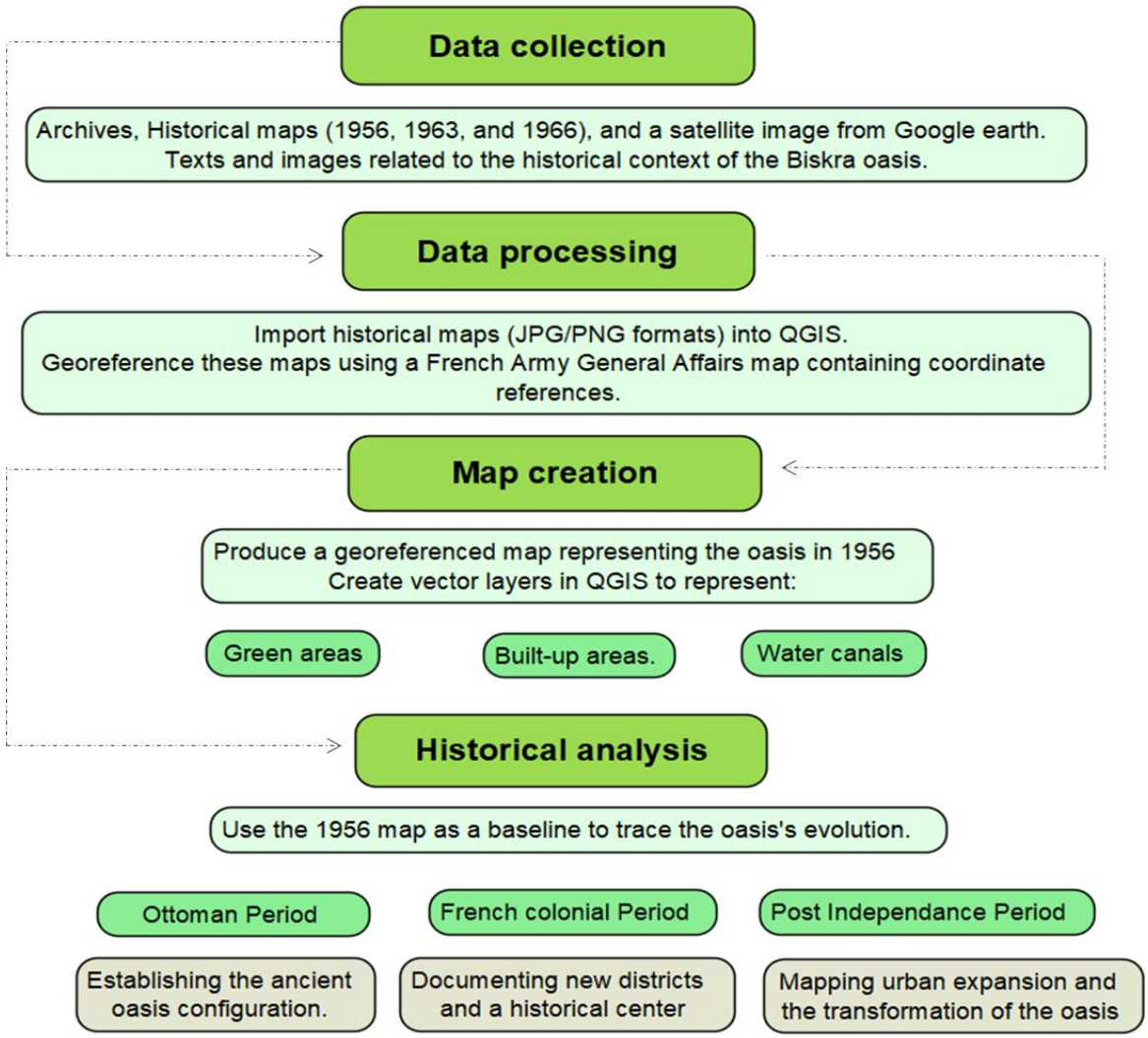

Fig. 2. Methodology process used to trace the oasis transformation. Source: Authors (2024).

3. Results and discussion

3.1. Biskra: From Roman Outpost to Oasis City – A Historical Urban Analysis

This text briefly traces the urban history of Biskra, drawing on various sources.

Roman period: According to Commander Seroka (1856), Biskra was an important Roman site, controlling water and the palm grove (Zerdoum, 1998a). Shaw (1980: 395) cited by Belguidoum and Boudinar (2015) mentions Roman ruins in the 18th century. Archaeological remains discovered in 1986 bear witness to this ancient presence (Pizzaferri, 2011).

Arab period (from 680): Real urbanization began with the arrival of the Arabs. El Bekri (1913: 111) cited by Belguidoum and Boudinar (2015), describes Biskra in the 11th century as a fortified city with mosques, baths and wells.

Ottoman period (17th century): The Turks built a fortified castle. Shaw (1980) cited by the same authors, mentions mud-brick walls.

This city no longer exists, only the mausoleum of Sidi Zerzour remains. The medieval city described by Ibn Khaldoun has disappeared. The Turkish city, built in a fort south of the city, was abandoned in 1670 following a plague epidemic and regenerated into seven villages: Medjniche, Bab El Feth, BabDarb, M'Cid, Ras El Gueria,

Korra, Gueddecha (Farhi and Hadagha, 2018).

Causes of the abandonment of old Biskra: Zerdoum (2003) mentions floods and earthquakes in 1660. Other sources speak of plague epidemics, notably that of 1683 (1000 deaths). The abandonment is probably due to a combination of these factors.

Before 1650: Biskra was a compact urban core of 12 hectares (Zerdoum, 1998a). The construction of a fort by the Turks (on the remains of the old city) marks the beginning of a new core, also abandoned later (Fig. 3). The analysis of urban evolution will therefore focus on the Ottoman period up to the present day.

3.2. Urban growth and the transformation of the city's form, from the origins of old Biskra to the development of the contemporary city

3.2.1. The Ottoman Era: The Founding of Old Biskra

Today's old Biskra, located in the southern part of the city within the palm grove, was founded during the Ottoman era more than 300 years ago.

According to Zerdoum (1998b), the occupation of the Ziban region by the Turks followed the destruction of the city of Biskra by an earthquake accompanied by torrential rains during the winter of 1660. The same author states that the earthquake and heavy winter rains of 1660 were the two factors responsible for the destruction of ancient Biskra.

The city of Biskra also experienced multiple outbreaks of a deadly plague, leading its inhabitants to abandon the inhabited areas and seek refuge in the outskirts. They dismantled their houses to reuse the materials for constructing new dwellings.

As a result, the ancient city disappeared, and seven villages emerged around it, eventually merging under the name of Biskra (Fig. 4).

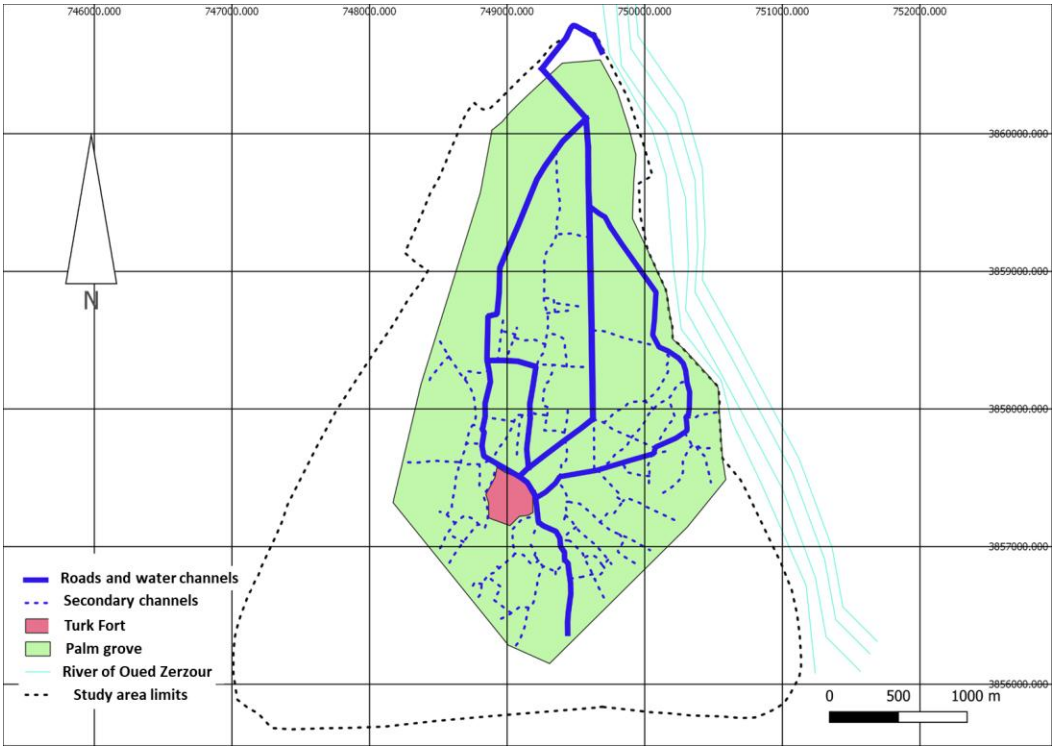

Fig. 3. The oasis map during the middles ages before the earthquake. Source: Hadagha (2019).

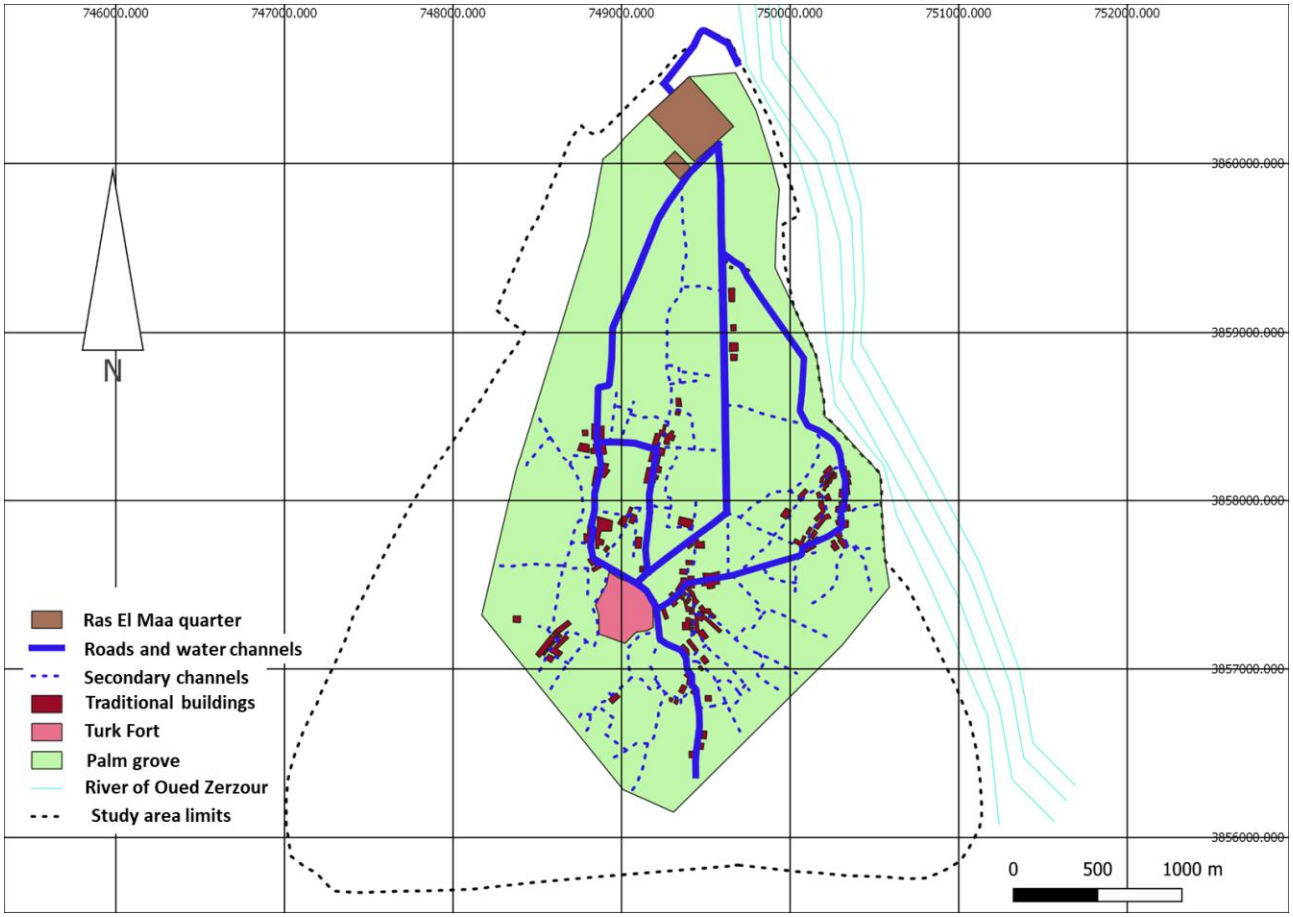

Fig. 4. Biskra oasis map of the seven villages. Source: Hadagha (2019).

The expansion took a linear form along the paths of the irrigation canals (seguias) (Zkiri, 2015). The inhabitants settled within the palm grove in compact, organized clusters following the routes of the seguias that irrigated the gardens, after leaving the ancient city (Sriti, 2013).

3.2.2. The Colonial Period: The Birth of the Modern City and the Introduction of a New Life style

Under the influence of the colonists, a new metropolis with an orthogonal grid form arose to the north of the city. After renovating and occupying the Turkish fort, the French soldiers built Fort Saint Germain, a barracks next to the colonial city (Zkiri, 2015).

In order to establish authority and supremacy over the oasis lands, the colonial urban space was extremely geometric, following a checkerboard grid pattern outside the palm grove (the seven settlements), close to Fort Saint Germain in the northern section of the city (Sriti, 2013).

At the center of this new organization, a marketplace was established and acted as the only gathering place for the local and European communities (Zkiri, 2015).

The same writers claim that the colonial checkerboard grid was made up of a number of square blocks facing Fort Saint Germain, with a public garden—now known as the July 5th Garden—separating the fort from the blocks (Fig. 5). To encourage trade and tourism, a railway, a train station, and a collection of hotels were established in the Biskra

region, making it a Great oasis. The urge to build a new metropolis with contemporary urbanization methods and architectural styles that emphasized the colonists' superiority was another aspect of this era.

After that, the city started to become known as a large oasis that was both scenic and touristic, drawing visitors from Europe (Zkiri, 2015). Four blocks of collective housing (HLM-style buildings) had been built by the conclusion of this era (Sriti, 2013).

3.2.3. The Post-Independence Period: From Oasis City to Saharan City

The city of Biskra saw a notable phenomenon of disorderly urban expansion following the colonists' departure.

The native people controlled the colonial grid, which was extended along the railway line as slums and saw the rise of unauthorized buildings inside the palm grove.

Due to a lack of development management frameworks and urban planning tools, many residences were constructed illegally within the palm grove, despite the oasis city continued agricultural output (Farhi and Hadagha, 2018).

However, it is important to note that the traditional housing stock was influenced by the flooding caused by the 1969 floods (Zkiri, 2015).

By the end of this first decade, arcades were introduced on the ground floor of buildings along Avenue Zaatcha and Boulevard El Emir Abdelkader (Sriti, 2013).

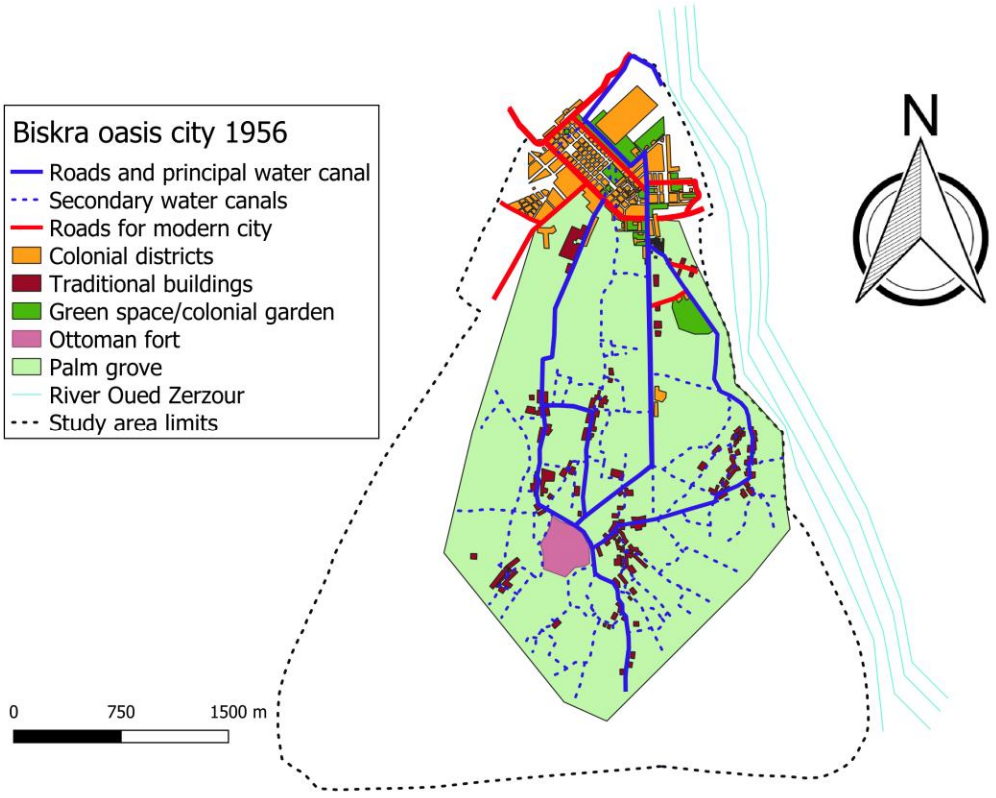

Fig. 5. Map of Biskra during the French Colonization (1956). Source: Hadagha (2019).

Due to migration and the establishment of an industrial zone, Biskra had a more rapid period of urbanization after obtaining Wilaya status in 1974 (Zkiri, 2015).

The emergence of the contemporary Saharan city was shaped by the 1980s collective housing programs in the East and West ZHUN and many other factors such as the 1984 urban master plan ill-adapted to the Saharan context, the spread of informal construction, the deterioration of traditional housing, and the progressive decline of the palm groves (Farhi and Hadagha, 2018).

The Saharan city maintained almost the same housing design principles around the courtyard, preserving the concept of privacy within the layout and the degree of openness in the façade, but without the palm grove (Sriti, 2013).

The urban street took a new form: a dual carriageway with a central median lined with decorative trees. Arcades continued to appear, creating shaded spaces, making the city a bioclimatic urban model (Farhi and Hadagha, 2018).

The same authors argue that Biskra's urban character has been defined by a structural contradiction between its Saharan environmental context and the northern-oriented urbanization models imposed upon it.

Biskra has implemented an urban development and planning master plan (PDAU) and implemented land management reforms since 1990.

It has expanded through the distribution of land in the East and West, especially for housing, and has profited from a number of POS (land-use plans) studies (Fig. 6).

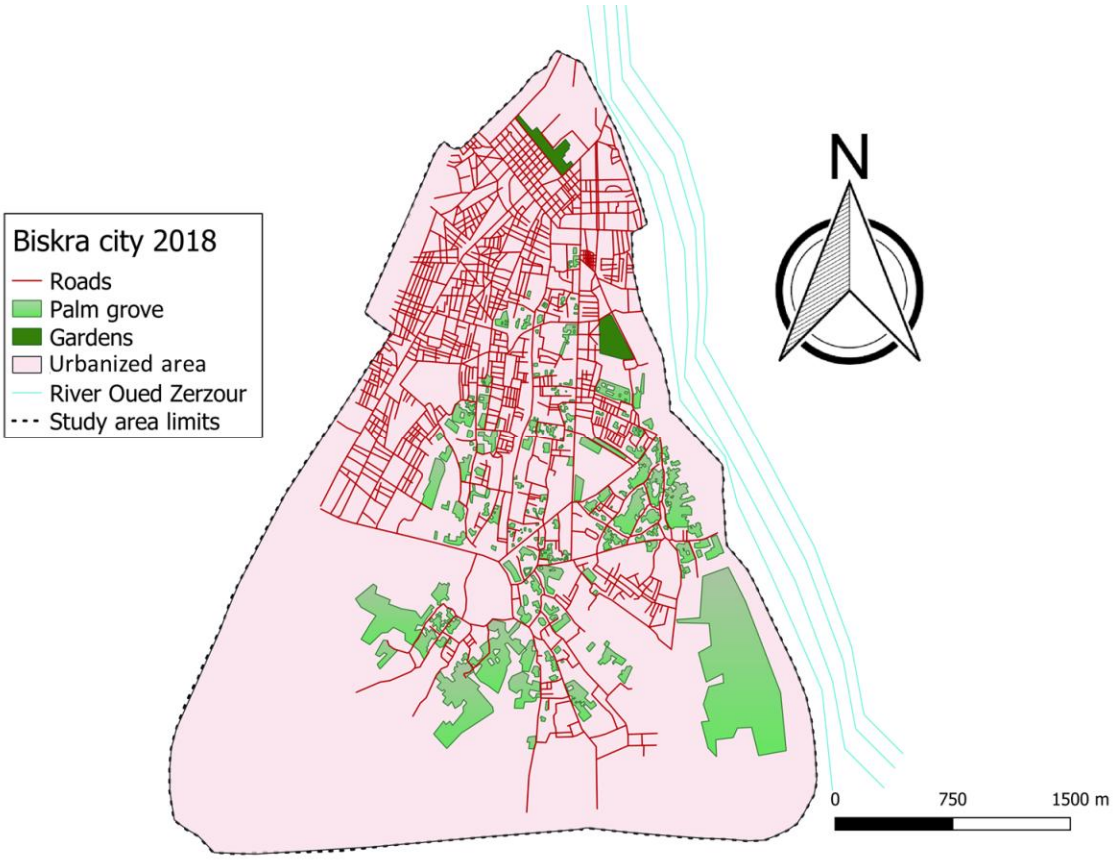

Fig. 6. Map of Biskra during the Contemporary Period. Source: Hadagha (2019).

3.3. Biskra's Oasis Ecosystem in Its Various Aspects: Key Factors of Its Sustainability

3.3.1. Spatial Dynamics of the Biskra Oasis: Urban and Architectural Adaptations

3.3.1.1. A Unique Urban Form

The traditional villages of Medjniche, Bab El Feth, Bab Darb, M'Cid, Ras El Gueria, Korra, and Gueddacha comprise the Biskra oasis ecosystem, which is the subject of our study.

Small, fortified groups of traditional homes distinguish these villages, which make up Old Biskra, the city's old center, and an expansive palm grove. Every community has a public plaza, mosque, watercourse, and, occasionally, private gardens (Zerdoum, 1998b).

The arrangement of the irrigation canals (seguias) inside the palm grove shapes the dwelling distribution and contributes to the city's basic urban character (Sriti, 2013).

Ancient cities in arid or semi-arid locations do not have this feature, which makes Biskra oasis unique. Using local materials and vernacular techniques, it reflects a spatial structure based on an urbanization paradigm (Bouzaher and Alkama, 2012; Addad and Zerouala, 2002).

As such, this organization linked agricultural activity (date palm cultivation, fruit trees, and market gardening) with the built environment, designed on Earth, which served, in addition to its primary function, as a storage space and for production. The palm grove and the irrigation system formed a cohesive whole that could not be separated (Zkiri, 2015).

Due to climate reasons, the historic cores of the south are defined by an architectural concept that emphasizes housing compactness. Biskra's experience is very different, though. Since the structures are situated inside a palm grove, where the effects of sunshine are much diminished, compactness is not strictly followed. A particular urban structure and house typology that is unique to Biskra in both morphology and space has been created by the geographic location in conjunction with structural features (seguia, palm grove) and climatic conditions (Addad and Zerouala, 2002).

The streets and alleys of the oasis are marked by a range of distinctive features, all of which contribute to a sense of "calm and serenity". These characteristics are typically linked to the lush greenery that offers consistent, soothing shade throughout the area, the use of earth as a building material that restricts traffic flow, the meticulously paved streets that evoke a comforting rural atmosphere, and the narrow pathways that encourage closer social interaction among residents, among other factors (Farhi and Hadagha, 2018).

3.3.1.2. The architectural aspect of the study area, a bioclimatic housing model with a specific socio-cultural dimension

The traditional oasis house seems to be almost an identical replica of the Saharan dwellings found throughout the desert (Farhi and Hadagha, 2018).

The traditional house in Biskra is of a rural character, with its garden constituting a major part of its exterior space. Accordingly, the house symbolizes social and economic solidarity based on a common geographic basis (Addad and Zerouala, 2002).

Zerdoum (1998a) claims that the Ziban people's traditional home is made of toub, or clay stone, and has a single wooden door as the primary entrance. A private entry vestibule (sguifa) in the inside leads to a guest room that is separate from the rest of the home. The central courtyard, which is solely lit by a tiny aperture in the ceiling known as Rawzana, is reached straight from a corridor (Mazouz, 2005). "*The process of producing the housing unit generally follows a simplistic pattern,"* Drummond (1981) said.

The initial phase is constructing a multipurpose area next to two tiny open spaces, one of which will be used as an animal stable and the other as an access road (a zigzag entrance to block direct view into the house). Every activity—cooking, eating, sleeping, and resting—takes place in the same room. A second room was added to relieve the first of some functions because of the household's increased size and subsequent space requirements (Farhi and Hadagha, 2018).

This is the second stage of the living space's development. The courtyard, which will be used for all purposes pertaining to cooking, animal husbandry, and household tasks, is what defines the third step (Farhi and Hadagha, 2018; Hadagha *et al.,* 2017).

The traditional house is generally organized around three key areas: the Skiffa, a transitional space that serves as the entrance to the home (Fig. 7). This area is crucial for maintaining privacy and acting as a barrier that blocks the view into the house, a characteristic of a reserved and conservative society. The central courtyard, or *West eddar* in Algerian Arabic, functions as the heart of the home, with all other rooms, including the bedrooms, kitchen, storage, and WC, positioned around it (Barkat *et al.,* 2021). This space not only helps regulate the indoor climate but also serves as a communal area where family members can gather to relax. Additionally, the garden, a green space used for growing food and products for sale, mirrors the lifestyle of traditional economic communities (Hadagha and Farhi, 2018; Hadagha *et al.,* 2017; Sriti and Tabet-Aoul, 2004; Addad and Zerouala, 2002).

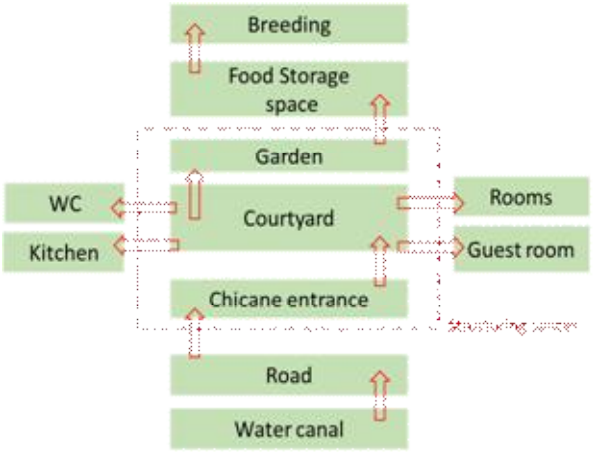

Fig. 7. Diagram showing the distribution of spaces in a traditional house. Source: authors (2024).

3.3.2. The economic aspect of the study area: a model of green and sustainable economy

The everyday activities of the Bsakra (Biskra residents) in the old city revolved around food, plants, domesticating animals, water, and materials like sand, gravel, and clay that came from the Oueds' flooding, according to Zerdoum (1998a).

Because the palm grove's economic resources—such as dates, wheat, barley, and olives—were limited, the Bsakra established an external trade centered on the export of rock salt made in El Outaya. According to Addad and Zerouala (2002: 120): "*It is a human endeavor based on a self-sufficient economy that has withstood time*

and the harsh conditions of the desert environment."

Date palm agriculture is the main practice in the oasis ecosystem, which operates as a socioeconomic and cultural organization. Agriculture, especially the production of date palms, is the main source of income for the majority of families in the oasis. All the oasis inhabitants congregate around the palm grove to strategize, hire, trade agricultural goods, and talk about the oasis's and their children's futures, among other things. Over time, social bonds are formed, reinforced, and maintained (Farhi and Hadagha, 2018).

In addition to producing dates, the oasis of Biskra acts as a free marketplace for the exchange of other commodities (Bouzaher and Alkama, 2012).

Palm farming, which continues to be the principal resource for agricultural activities in the Saharan environment, is the foundation of the traditional oasis economy. Date palms shield fruit trees and other plants with spacing of 3, 5, 7, and 10 meters in the traditional palm grove, which serves as an example of multi-layered farming (Bouzaher and Alkama, 2013).

The agricultural products from the palm grove are essential for the oasis community's subsistence (Sriti, 2013). "*The Bsakra, the people of Biskra, relied on their economic heritage, which included a palm grove, olive trees, fields of wheat or barley, vegetable gardens, a chicken coop, a sheepfold, and a donkey stable. Their agro-pastoral activities were very similar to those of the Ziban, a group of oases, and the Bsakra also traded rock salt from a mountain near the village of El-Outaya, 30 kilometers north of Biskra*" (Zerdoum, 2003).

3.3.3. The ecological dimension of the study area, a very rich biodiversity in the Sahara

The unique urban layout of old Biskra offers ecological advantages that help create a comfortable microclimate. The streets offer shade, while the seguias (irrigation channels) aid in cooling the air within the city (Addad and Zerouala, 2002).

With its tiered agriculture, the palm grove is a hotspot for biodiversity (Fig. 8), supporting a wide range of plants and animals that have helped the oasis ecosystem function properly and ensured the survival of its residents (Hadagha *et al*., 2018).

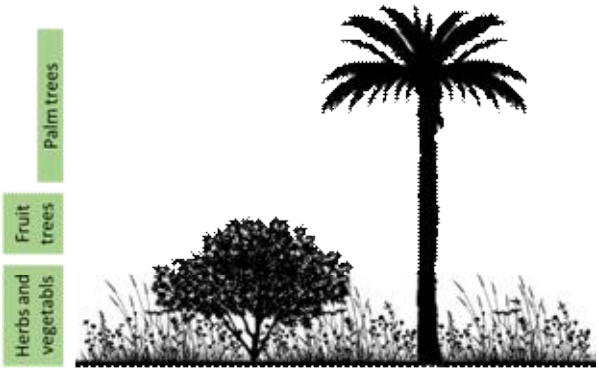

Fig. 8. Composition diagram of a palm grove vegetation module. Source: Authors (2024).

In addition to its economic significance for the residents of the oasis, this type of cultivation raises awareness of its ecological and social benefits, including the creation of a microclimate that supports other crops, family work, and neighborly solidarity during harvesting, gatherings, and celebrations in the palm groves (Farhi and Hadagha, 2018).

Belguidoum and Boudinar (2015) cited a Muslim author who visited Biskra in the eleventh century, El Bekri wrote: "*This*

great city has many date palms, olive trees, and fruit trees of various species." The surrounding area is covered in gardens, creating a six-mile hedge.

The palm tree served ecological functions by producing fences from its leaves and houses from its wood. Its trunks served as lintels, beams, pillars, and boards. Everything was recycled and turned into commonplace items, from the trunk's base to the palm fronds' tips (Bouzaher and Alkama, 2012).

3.3.4. The social aspect of the study area, reflecting the sustainable lifestyle of the oasis community

The date palm, which is essential to preserving social harmony among the inhabitants of the Ziban oases, is the lifeblood of the oasis community. It aids in the preservation of customs and knowledge that guarantee the prudent and sustainable use of natural resources, including water in irrigation methods and cultivar selection (Bouzaher and Alkama, 2012).

Religious holidays, mandatory social cooperation, and "*Twiza*," a custom that promoted social cohesiveness through group public gatherings, were all examples of social activities that characterized the Biskri way of life. Men and women enjoyed social life, and labor was divided equitably, effectively, and flexibly. Despite working from home, women were essential to the economy, especially in the palm groves where they harvested cereals, dates, and olives (Zerdoum, 1998b).

The oasis community's social life is founded on equality and features the distinctive images of communal life, which are characterized by a variety of solidarity-based behaviors.

The building of traditional homes, for example, is a group endeavor known as "*Twiza*," in which all locals band together to assist a needy person by allocating and dividing work to give the family a respectable roof in accordance with rural housing requirements. Social gatherings (like weddings, celebrations, or funerals) are another example of solidarity, where the whole community pitches in to help the bereaved family by gathering the required supplies and helping out with different chores.

A final example of solidarity relates to education and instruction, where members of the oasis community with religious or scientific knowledge volunteer as teachers to combat ignorance in traditional schools such as Medersas and Quranic schools (Farhi and Hadagha, 2018).

According to Zerdoum (1998a), the new Biskra of the 17th century was characterized by a just and rigorous water management system that revealed aspects of local governance. A brigade for monitoring watercourses and ensuring fair irrigation water distribution based on the agricultural and human significance of each area was housed in a fort called Borj_Tork, which was constructed in Ras El Ma, in the northern portion of the oasis, to handle irrigation difficulties. Each unit of the newly created Lokza system was equal to ten cm, or the width of a Biskri's closed hand. In the Grand Jardin Public of July 5, 1962, the primary water distributor was situated (Fig. 9). It had a 2.4-meter-wide canal that split into three smaller seguias, each measuring 40 cm in width for the M'Cid neighborhood, 80 cm in width for the Bab Derb neighborhood, and 120 cm in width for the three neighborhoods of Ras El Gueria, Medjnich, and Gueddecha (Annak, 2023).

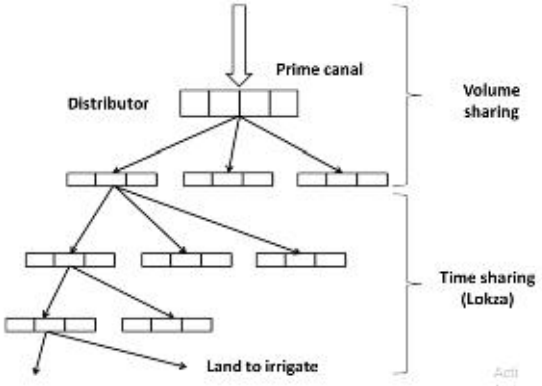

Fig. 9. Water management system in the oasis of Biskra city. Source: Hadagha (2022).

The social component and day-to-day activities and life of the oasis society were influenced by these systems of government and solidarity. Figure 10 illustrates the schematic representation of the sustainability dimensions of the Biskra Oasis, highlighting the interrelations between its environmental, social, and economic aspects.

3.4. Assessing the current state of the oasis ecosystem and examining the dynamics of its transformations

Over the course of six decades, the city of Biskra has seen numerous changes because of its steady and notable population expansion (from 1956 to 2018). Biskra had rapid and unplanned urban growth following the demographic boom brought on by post-independence changes in the economic system, with a significant increase in built-up areas at the expense of the palm grove (Hadagha, 2022) as shown in the Table 1.

"*Since 1962, the city of Biskra has undergone relentless transformations, particularly an uncontrolled rural exodus, bringing changes in mindsets, living standards, and lifestyles*" (Zkiri, 2015: 18).

Table 1. Dynamic of built up and green areas in the entire oasis (1956-2018).

1956		2018	
Built up area (m²)	Green area (m²)	Built up area (m²)	Green area (m²)
130322.44	2355932	1008680	1077150

The decline in household size, which went from 7.6 people per housing in 1998 to 6.9 people per home in 2008, is one significant development. The overall number of dwelling units in Biskra increased significantly in tandem with this (Hadagha, 2022) as shown in the Tables 2 and 3.

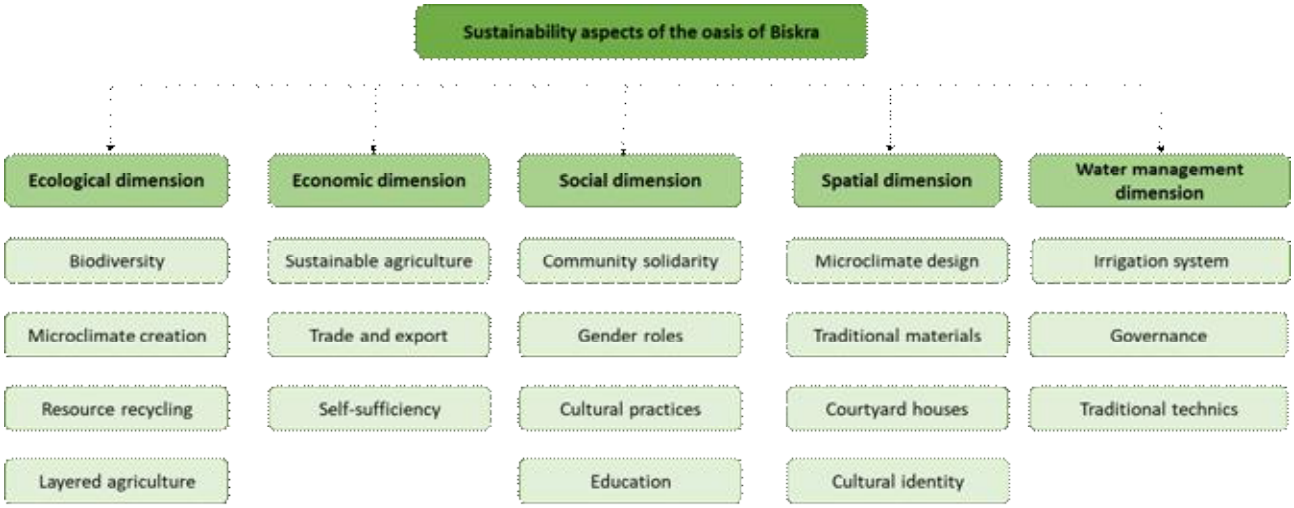

Fig. 10. Diagram of sustainaility aspects of Biskra Oasis. Source: Authors (2024).

Table 2. The housing situation in the region of Biskra (1998-2008).

Year	1998	2008
Housing occupancy rate	7.6	6.9
Housing number	100.357	105 292
Households number	90445	114666

Table 3. The housing situation in the city of Biskra (1998-2008).

Year	1998	2008
Housing occupancy rate	7.5	6.4
Average household size	27509	91 618
Housing number	27509	91 618
Households number	24.519	31878

However, colonial exposure to Western lifestyles brought about profound changes and resulted in the adoption of a modern and comfortable concept that was at odds with the true traditional life style. By changing building materials, reframing its relationship with outside areas, and embracing new aesthetic ideals, the oasis society tried to adapt its homes to this new vision (Sriti and Tabet-Aoul, 2004).

Because of this transformation, the number of traditional houses declined significantly in comparison to contemporary ones, as evidenced in the Table 4.

Table 4. Number of inhabited dwellings according to the type of construction in the city of Biskra 2008.

Type of cons-truction	Residen-tial building	Indivi-dual house	Traditio-nal house	Others	Total
Number	6553	23639	317	463	30972
%	21.2	76	01.02	1.49	100

The patio, which had been essential for natural air conditioning, was dropped from the architecture of oasis houses at the same time that the materials used for building changed. This shift resulted in a greater need for air conditioners and higher summertime energy usage (Latreche and Sriti, 2018).

Development has been placed at the urban level to address modern societal demands, like the supply of gas and electrical networks (Hadagha, 2022). The construction of national-scale industrial units and energy-related facilities like ENICAB and SONELGAZ coincided with the expansion of Biskra's industrial zone (Farhi, 2002). Because of this development, there were more people working in the industrial sector and fewer people working in agriculture (Djennane, 1990), as evidence in the Tables 5 and 6.

Table 5. Evolution of the active population rate by sector of activity in Biskra (1977-2013)

Year	Agriculture	Building	Industry	Services
1977	30.66	12.77	20.99	30
2000	3	15	12	70
2013	1	12	55	32

Table 6. Rate of the active population in agriculture in oasis districts.

El M'cid	Ras El Gueriah	Guedacha+ Hai El Feth
6%	Negligible	10.44

This change had an impact on the oasis society's everyday ecological practices in addition to its economic activity. Changes in food production and consumption patterns coincided with the abandonment of traditional waste management techniques, both home and oasis-specific as shown in the Table 7 (Hadagha, 2022).

Table 7. Quantity of urban waste produced between 2008 and 2013.

Year	Waste (kg/person/ day)	Waste (tons/day)	Waste (tons)year)
2008	0.77	225.88	82447,63
2013	0.83	274.09	100044,13

The loss of seguias, the disregard for palm groves, and the artificialization of roadways are further indicators of a breakdown in the link with nature (Annak, 2023; Hadagha, 2022; Bensaad, 2005). As demonstrated in Figures 11, 12 and 13, this transformation becomes particularly evident. All of these elements have affected both the standard of the traditional oasis lifestyle and the way the oasis ecosystem functions.

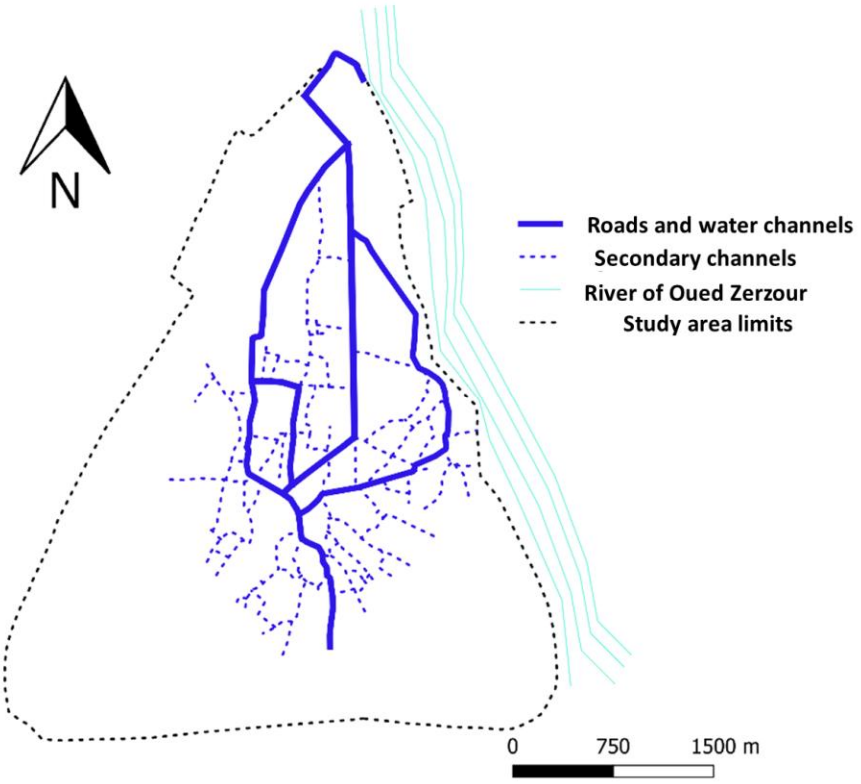

Fig. 11. Irrigation canals of Biskra Oasis. Source: Hadagha (2019).

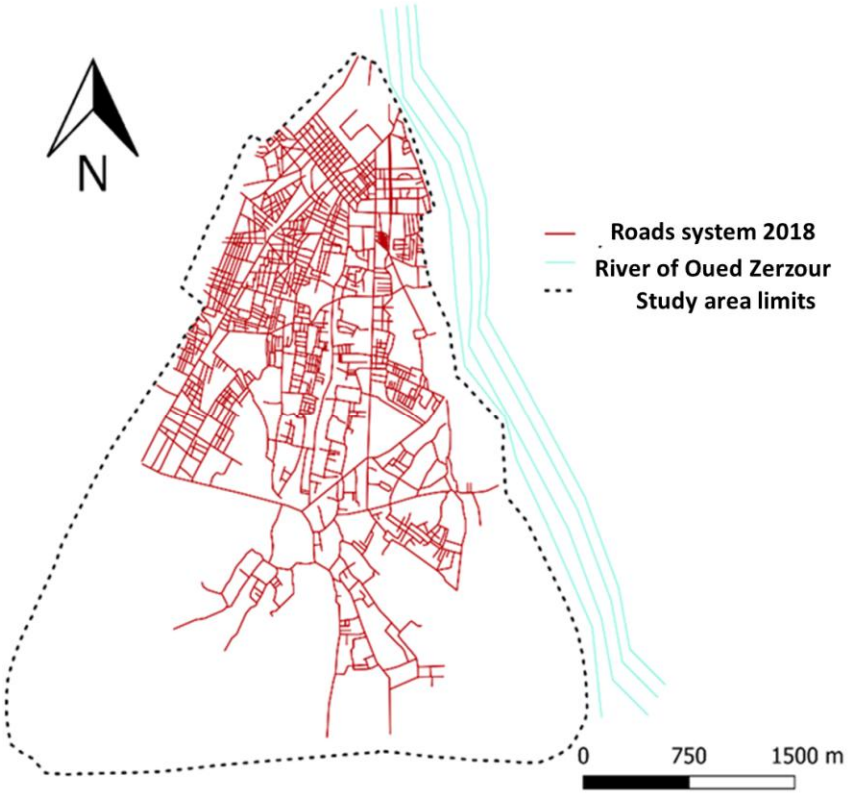

Fig. 12. Roads map by 2018. Source: Hadagha (2019).

Fig. 13. The oasis from the past to the present. Source: Hadagha (2022).

4. Conclusion

The use of Qgis enables us to understand the transformation process of Biskra's oasis ecosystem over time. The ongoing changes within this environment are evident in the disappearance of irrigation channels (seguias), the degrading of the palm grove, and the increasing artificiality of the ecosystem.

This study highlights the influence of economic, social, and spatial factors on the oasis ecosystem of Biskra city. Key drivers of change include evolving lifestyles, uncontrolled urban and population growth, economic development, and technological progress.

The interaction of these factors threatens the sustainability of the oasis ecosystem and negatively affects the quality of life for local inhabitants. Therefore, it is imperative to develop a comprehensive rehabilitation strategy that tackles the identified challenges across economic, sociocultural, and spatial dimensions.

From a theoretical perspective, this research contributes to broader debates on sustainable urbanism and oasis conservation by showing how GIS-based approaches can be mobilized to trace the socio-ecological trajectories of fragile environments. The methodological framework applied here not only highlights the drivers of unsustainability in Biskra, but also provides transferable insights for analyzing similar processes in other oasis contexts, whether in North Africa, the Middle East, or other arid regions facing comparable pressures.

Future research should therefore explore comparative analyses between oases, testing the adaptability of the framework developed here across different geographic and cultural contexts. Such comparative perspectives would strengthen the theoretical understanding of oasis transformations and contribute to the development of more generalizable strategies for the sustainable management of vulnerable ecosystems.

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