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OASIS LANDSCAPE: A VALUABLE URBAN SUSTAINABILITY SOLUTION IN ARID LANDS. CASE OF BISKRA, ALGERIA

Abstract: Over centuries, oases have been islands of survival and sources of human settlement. Nowadays, massive urbanization poses a direct threat to this ingenious ecosystem and generates intensely hot air. Under these conditions, achieving thermal comfort, especially in summer, constitutes a major challenge. The use of air conditioning has serious consequences on energy consumption and thus disrupts the elements of sustainability. This research aims to highlight the importance of landscape heritage by identifying and evaluating the contribution of oases to mitigating Ta (air temperature). Based on field measurements of Ta during the overheating period, a land use/land cover map was prepared, processed, and analyzed using ArcGIS software. The comparison between data recorded at stations located inside and outside the oasis showed the development of a cool island. The results demonstrate the beneficial role of vegetation density in thermal regulation, providing guidance for planning green cities in hot and dry climates.

Keywords: arid land, landscape management, oasis, planting density, cooling intensity

Introduction

Global strategies and policies aimed at achieving sustainable development emphasize reducing and rationalizing energy consumption, which significantly influences economic and environmental outcomes. Thermal comfort is a crucial aspect of liveable cities, and improvements in thermal conditions within urban areas enhance both quality of life and environmental preservation (Lai et al., 2020; Yang et al., 2022). However, new urban expansion exerts immense pressure on water resources, transforming areas once dominated by green cover and agricultural lands into fallow lands, roads, and buildings. This transformation has led to a rise

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in soil temperature due to reduced moisture, facilitating the emergence of the urban heat island (UHI) phenomenon. With global warming, summer heat waves will become more frequent and dangerous (Schar & Jendritzky, 2004; Kiarsi et al., 2023).

The Sahara Desert, occupying a significant portion of the Arab world, presents both a formidable challenge and a potential source of future prosperity. Despite scarce rainfall and high evaporation rates, communities have historically concentrated around oases, which play a pivotal role in ensuring food security and supporting tourism (Boudjellal & Bourbia, 2017; Pausata et al., 2020). The FAO (Food and Agriculture Organization of the United Nations) recognizes the oasis ecosystem as an innovative and creative global agricultural heritage system deserving of protection and encouragement (Koohafkan & Cruz, 2011).

In the 20th century, the relationship between humans and nature shifted, with oases viewed primarily as productive economic spaces. This shift contributed to the disappearance of cultural landscapes, the obliteration of the character and identity of desert cities, air pollution, and the loss of green landscapes. Additionally, earthen architecture was replaced with materials like concrete, brick, and paving (Boudjellal & Bourbia, 2017). This also led to the widespread use of air conditioners, distorting the aesthetics of houses. Many historical monuments have been devastated and abandoned in favour of modern construction, which is often adapted to the local climate. Achieving summer comfort in desert areas is challenging, and new materials and air conditioners do not provide adequate protection against solar radiation, especially in outdoor spaces.

In response to this harsh environment, many residents are forced to: (1) use air conditioners, (2) migrate to coastal cities, or (3) seek shelter in palm groves or their outskirts. This research seeks to answer the following main question: Can the neighbouring built area benefit from the positive effects of the oasis on the microclimate (e.g. air temperature, solar irradiance) and ecological conditions?

This study aims to explore the concept of sustainability by highlighting how landscapes are managed in desert areas. Numerous studies have demonstrated the role of trees in controlling air movement, humidity, and solar radiation across different climates, with their influence extending to nearby environments, however a few studies have examined this effect within desert environments (Oke, 1988 ; Spronken-Smith & Oke, 1998 ; Akbari et al., 2001 ; Chu et al., 2005; Andrade & Vieira, 2007; Chang et al., 2007; Potchter et al., 2008; Feyisa et al., 2014; Bao et al., 2016; Hao et al., 2016; Aram et al., 2019; Reis & Lopes, 2019; Li et al., 2020; Cheung et al., 2021; Sun et al., 2021; Wong et al., 2021; Das & Momin, 2022 ; Su et al., 2022). Also, our purpose of this research is to evaluate the intensity of OCI (oasis cool island) and to determine its spatial dynamics.

Materials and methods

Study area

The Sahara is one of the most fascinating deserts in the world, located in North Africa, its climate is constantly hot, where temperature can reach 58°C with very low humidity and rainfall is rare. The Sahara covers about 90% of Algeria's territory, and the agricultural sector depends heavily on the abundant groundwater. It is famous for the production of several varieties of dates, which has allowed the emergence of numerous oases known worldwide for the quality of their dates. In this context, our case study was conducted both inside and

outside the traditional oasis located 7 km east of the city of Biskra (Figure 1). Although some palm groves have begun to deteriorate and disappear, some families still live in their ancestral homes (Figure 3).



Fig. 1. The study area location map: Shows the oasis in relation to the city of Biskra (Source: Google Earth, 2024)



The oasis selected for this study is characterised by an irregular shape and a tortuous perimeter (Figure 2), made up of several plots of land, each planted according to the needs of its owner, with a total area of about 195 hectares, a flat ground with a slight slope towards the south, and an average canopy height of about 10 metres.

In order to verify the OCI phenomena due to the presence of vegetation, the current research followed a quantitative approach. Data of T_a were collected through field measurements, which carried out during the summer period, specifically in the week of July 2024, the hottest month of the year. Due to the homogeneous climatic conditions in the desert, this period was characterised by warm weather and clear, sunny skies. Methods of data collection and processing are shown below:

Classification and mapping vegetation cover

The spatial framework of the study area was defined based on the plant cover, which includes the traditional residential core “Ksar” (Figure 3) and the areas along the road connecting the oasis with the new urban area (Figure 4). The preparation of the land use/land cover map constitutes a crucial step for this research, where it, was created after inventorying and classifying all existing palm groves, based on satellite imagery obtained from Google Earth and in-situ observations, using GPS and ArcGIS software. In Figure 4, the vegetation cover was divided into three classes according to the planting density parameter (number of palm trees per hectare), as shown in Table 1.

Table 1. Structural characteristics of the oasis according to the planting density index

Vegetation class	Properties	Illustration
High density	<ol style="list-style-type: none"> Density=400tree/ hectare; planting distance less than 5 m Small footprint; Often heterogeneous cultivation Vegetation is organized on three levels: <ul style="list-style-type: none"> - First layer, made up of Date palm - Middle layer includes fruit trees (Oranges, Fig,...) - Third layer of low plants (Grass, Grain,...) 	
Medium density	<ol style="list-style-type: none"> Density = 200 tree / hectare; planting distance range from 7-8 m Characterized by a large area, regular and homogeneous cultivation (Date palm + Grass) 	
Low density	<ol style="list-style-type: none"> Density = 100 tree / hectare; planting distance spaced more than 10 m. Large area, regular and homogeneous cultivation (Date palm + Grass) 	

Source: Author's, 2024

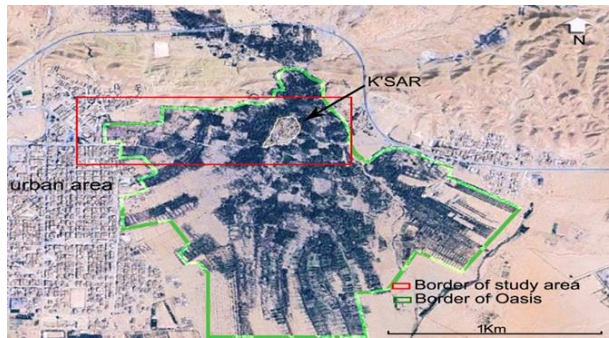


Fig. 2. Morphology and oasis components: Shows the main axes of vegetation cover and the location of the traditional residential core “Ksar” (Source: Google Earth, 2024)



Fig. 3. Traditional residential core “Ksar” (Source: Author's, 2024)

Data acquisition

Measurements were conducted using a high-precision Testo 925 portable instrument, with Ta measured at a height of 1.5 meters, during the most critical period (12:00 pm -14:00 pm), this period of time was characterized by intense solar radiation. These measurements covered all parts of the oasis, including the adjacent urban area, all Ta data were recorded according to the geographical coordinates of each station (Figure 4).

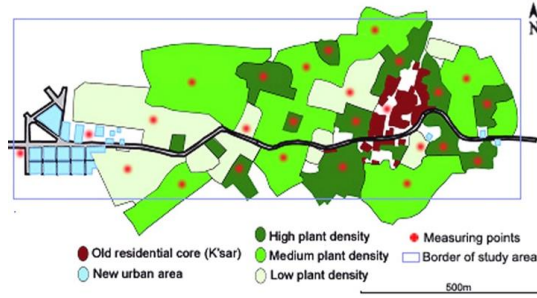


Fig. 4. Land use/land cover map of study area with measuring stations (Source: Author's, 2024)

Data processing and analysis

After recording Ta data for all the stations within the palm grove and the adjacent urban environment, we retained only the data taken at 14:00 pm, as they had the highest values. These data were entered into the land use/land cover (LU/LC) map of the study area, and using the spatial interpolation IDW tool of ArcGIS software, we obtained a spatial distribution map of Ta, which we overlaid on the Google Earth image of the study area (Figure 5).

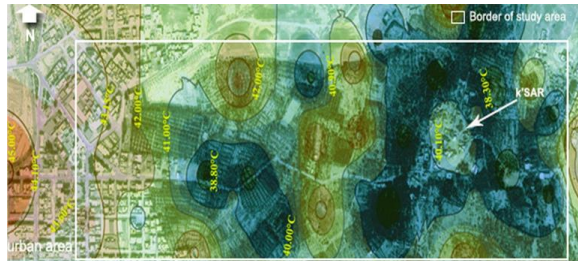


Fig. 5. Spatial distribution of air temperature at 14 :00 pm (Source: Author's, 2024)

Calculation of the cooling intensity index

The cool island index was calculated as the difference between the average value of Ta recorded in both the vegetation cover and the built environments (Oke, 1988; Spronken-Smith & Oke 1998; Potchter et al., 2008; Boudjellal & Bourbia, 2017; Aram et al. 2019; Li et al. 2020), as shown below:

$$OCI = \Delta T_a = T_{a_o} - T_{a_U} \quad (1)$$

Where:

T_{a_o} = Air temperature recorded inside vegetation cover,

T_{a_U} = Air temperature recorded in the urban area

Results and discussion

Research conducted over the past twenty years has shown that the cooling effect of plants depends on several criteria, including the type of trees, the size and shape of the green space, and various levels, from public squares and city streets to entire neighbourhoods (Boudjellal & Bourbia, 2017). Most studies applied to gardens as dense green spaces that decrease air temperature in urban environments have demonstrated a relationship between the intensity of the cooling index and the size of the garden, indicating that even small green spaces have a cooling effect (Chu et al., 2005; Potchter et al., 2008; Bao et al., 2016; Aram et al., 2019; Li et al., 2020; Sun et

al., 2021; Das & Momin, 2022). The oasis effect phenomenon develops where there is a source of moisture, and plants cool the environment through evaporative cooling and shading (Oke, 1988; Spronken-Smith & Oke, 1998; Potchter et al., 2008, Hao et al., 2016).

Throughout the experiment, areas with dense vegetation cover (high planting density) exhibited lower Ta values, generating the oasis effect and contributing to reduced Ta in neighboring spaces. These results confirm the potential of vegetation to cool spaces, aligning with numerous studies (Upmanis et al., 1998; Akbari et al., 2001; Andrade & Vieira, 2007; Chang et al., 2007; Feyisa et al., 2014; Aram et al., 2019; Reis & Lopes, 2019; Li et al., 2020; Cheung et al., 2021; Wong et al., 2021; Su et al., 2022). In particular, the following section will present the detailed, spatial distribution of Ta in the chosen sample (Figure 5).

The dense palm grove exhibited low Ta values ranging from 38 to 39 °C, followed by medium-density palm trees with values ranging from 40 to 41 °C. Sparse cover or areas with dead palm trees recorded higher values (43-44 °C), which are very similar to those recorded outdoors. The traditional agglomeration “Ksar”, located in the middle of the oasis, also benefits from a significant reduction in average temperature (41-42 °C). In contrast, high Ta values (>45 °C) were recorded outside the oasis, particularly in the new urban fabric, and these values decrease as they approach the edge of the oasis (Figure 5). The motorized road that crosses the oasis shows low Ta values within the oasis, which begin to rise as we move deeper into the new urban area.

After superimposing the Ta data recorded at 14 :00 pm with the map of the study area, we determined that from the western edge of the oasis toward the urban area, the distance of cooling effects provided by the oasis is about 100 meters.

Conclusion

In the harsh climatic conditions of the desert region, achieving a high quality of life has become increasingly challenging, and to adapt to these conditions, people have ingeniously created oases within confined environments, adding aesthetically pleasing scenes to the sandy landscape.

The old land management is a testament to human ingenuity and a deep connection to the nature, despite the extreme climate, the oasis system has played a crucial role in creating a pleasant thermal environment, characterized by decreased air temperature and widespread shade. Over time, this landscape has evolved into a tourist destination and an economic resource for the local population.

The landscape heritage, constitutes an island of prosperity that encourages and promotes sustainable development. The microclimate generated by the oasis suggests an alternative strategy for cooling outdoor spaces, which can mitigate heat intensity and reduce cooling loads within built environments. This decrease in air temperature, resulting from the presence of dense vegetation, will automatically lead to a reduction in the use of air conditioning. This, in turn, effectively contributes to saving energy and preserving the environment from gases emitted by air conditioners, thus enhancing the concept of sustainable development.

This research shows that within the traditional oasis, dense tree planting results in lower temperatures, generating the highest value of the cooling intensity index, estimated at -7.2 °C. In contrast, areas with low plant density have higher temperatures, similar to those recorded in arid and urban domains, and thus generate the lowest value for cooling intensity. Our results confirm that planting density is the main factor in cooling, indicating that a low degree of canopy

openness provides ample shade and prevents direct evaporation of water, making it the most efficient process for cooling the local climate. Accordingly, greening strategies and cooling processes in desert cities should primarily focus on shading, which can be achieved through parameters such as vegetation cover density and plant diversity.

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Conflicts of Interest: The authors declare no conflict of interest.

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