ASSESSING GREEN SPACE FRAGMENTATION AND ACCESS IN CONSTANTINE (ALGERIA)

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Abstract: Urban green spaces are essential for biodiversity, ecosystem services, and human well-being in rapidly growing cities. This study examines how green spaces are spread out, fragmented, connected, and accessible in Constantine, a Mediterranean town with a historic center and expanding suburbs. Using GIS-based spatial analysis and resident surveys, green spaces were categorized into ecological cores (35%), linear and scattered elements (20%), and peripheral natural areas (45%). The analysis found 120 separate patches, low corridor density, and distances between patches of 500-800 m in central regions compared to 1.5 km in the outskirts. About 65% of residents can reach a green space within 10 minutes, but around 40% are unhappy with the quality, especially in peripheral neighborhoods. Fragmentation and limited connection reduce ecosystem services, and spatial inequalities limit social benefits. These results emphasize the need for integrated planning of urban green infrastructure, including protecting core areas, improving small and private patches, and creating ecological corridors to improve both environmental and social benefits. This study offers a transferable framework for designing sustainable urban green networks in Mediterranean and similar urban settings.

Keywords: Constantine; Urban green spaces; Fragmentation; Ecological connectivity; Accessibility; Ecosystem services.

1. Introduction

Mediterranean cities are facing increasing pressure on their urban ecosystems caused by rapid urbanization and soil sealing. These changes result in the fragmentation of green spaces and a gradual loss of ecological continuity, impacting both biodiversity and residents' quality of life (Benedict & McMahon, 2006; Forman, 2014; Kabisch *et al.,* 2016). In this context, the urban green network, defined as the interconnected system of green spaces including parks, gardens, urban forests, ravines, and ecological corridors, has become a key tool for sustainable urban planning. It helps regulate urban climate, conserve biodiversity, and enhance human well-being (Jim & Chen, 2008; Ahern, 2011).

Urban green networks are composed of complementary elements. Core green spaces, such as historic parks and gardens, constitute ecological hubs. Ecological corridors maintain connectivity and facilitate species movement.

Linear and scattered elements, including street trees and green roofs, complement the network, while peripheral natural areas, such as ravines, gorges, and riverbanks, play a crucial role in preserving habitats and urban biodiversity (Gill *et al.,* 2007; Aronson *et al.,* 2017).

Urban green networks serve multiple functions: ecological (thermal regulation, water infiltration, biodiversity maintenance), social (recreational spaces, health, and well-being), aesthetic and cultural (heritage and landscape valorization), and economic (tourism and property value enhancement)(Hansen &Pauleit, 2014; Lin *et al.,* 2015; Kondo *et al.,* 2018).

In Constantine, with its steep terrain, deep gorges, and dense urban development, the green network is currently fragmented and lacks sufficient connectivity. Parks, gardens, and ravines are often isolated, which restricts species movement, decreases ecosystem services, and limits residents' access. This fragmentation hampers urban heat island

40

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mitigation, climate resilience, and recreational use of green spaces (Gill *et al.,* 2007; Hansen &Pauleit, 2014; Lux, 2024).

Against this background, this study aims to evaluate the current state of the green network in Constantine and to identify ecological and social discontinuities associated with its fragmentation. The overall goal is to propose sustainable planning strategies to improve environmental connectivity, enhance the provision of ecosystem services, and ensure equitable access to green spaces. This analysis provides a vital foundation for guiding urban planning toward a more resilient, ecologically sound, and socially equitable city.

2. Methodology

This study was conducted in Constantine, Algeria, a Mediterranean city known for its steep terrain and dense urbanization, which contribute to the fragmentation of green spaces and disruptions in ecological continuity (Gill *et al.,* 2007; Hansen &Pauleit, 2014; Kabisch*et al.,* 2016). The main objective was to identify and map urban green spaces and the green network, evaluate their ecological and social connectivity, detect fragmented areas, and recommend sustainable planning strategies.

2.1. Data collection

2.1.1. Geospatial data

High-resolution satellite imagery (Sentinel-2) and orthophotographs (Google Earth Pro) were collected to identify urban green spaces, ecological corridors, and linear or scattered green elements. These data were combined and analyzed in ArcGIS to create thematic maps of the green network, classify green spaces, and compute fragmentation indices (McGarigal*et al.,* 2012; Lux, 2024).

2.1.2. Field inventory

Field surveys were carried out to verify satellite-derived data and record vegetation types, conservation status, accessibility, and land use. Georeferenced photographs of parks, gardens, ravines, and corridors were gathered to supplement GIS data, ensuring precise spatial representation (Jim & Chen, 2008).

2.1.3. Socio-economic and usage data

Structured questionnaires were administered to residents to gather information on green space usage, perceptions of quality, and ecosystem services. Additionally, municipal records, including urban plans, green space management reports, and corridor creation or restoration projects, were consulted to contextualize field observations and evaluate planning priorities (Wolch*et al.,* 2014; Kondo *et al.,* 2018).

2.2. Data analysis

2.2.1. Mapping and classification

Green spaces were categorized into five types: parks, gardens, ravines, linear features, and scattered elements (street trees, green roofs). Each space was also assigned to one of the following functional categories: ecological, social, recreational, aesthetic, or cultural(Hansen &Pauleit, 2014; Kabisch*et al.,* 2016).

2.2.2. Fragmentation and connectivity analysis

Fragmentation metrics were calculated, including the number of patches, average patch size, corridor density, and inter-core distances. Ecological connectivity was assessed using GIS-based connectivity models to identify isolated areas and ecological breaks (McGarigal*et al.,* 2012; Aronson *et al.,* 2017).

2.2.3. Socio-ecological analysis

Spatial data were combined with survey results to assess residents 'access to green spaces and the delivery of ecosystem services. This method allowed for the identification of priority areas

for sustainable planning and ecological restoration (Kabisch & Haase, 2014; Lux, 2024).

2.3. Software and tools

Geographic Information Systems (GIS) were used to integrate spatial layers, map green space distribution, and assess ecological connectivity, with all cartographic analyses performed in ArcGIS. Statistical analyses were conducted in R, which enabled the calculation of fragmentation indices, processing of survey datasets, and execution of the required statistical tests (R Core Team, 2023).

3. Results and discussion

Urban green spaces are crucial for supporting biodiversity, managing ecosystem services, and improving human well-being in cities experiencing rapid growth and development. Successful urban planning depends on understanding the spatial distribution, fragmentation, connectivity, and accessibility of these areas. In the Mediterranean city of Constantine, known for its dense historic center and expanding outskirts, we carried out a detailed assessment of urban green spaces. This study combined spatial classification, ecological connectivity measures, and residents' perceptions of accessibility to evaluate the environmental and social roles of the green network. The following sections describe the spatial patterns, fragmentation processes, accessibility issues, and the potential for ecosystem services in Constantine's green spaces, offering valuable insights to inform sustainable urban management and planning.

3.1. Classification and Distribution of Green Spaces

Spatial analysis of Constantine identified three main types of urban green spaces: ecological cores, linear and scattered elements, and peripheral natural areas (Fig. 1; Tab. 2). Ecological cores, including historic parks and gardens, make up 35% of the total green area and are concentrated in the city center. Linear and scattered elements, such as street trees and green roofs, account for 20% of the green space and are spread throughout the urban fabric. Peripheral natural areas, including ravines and gorges, comprise 45% and are mainly found on the city outskirts.
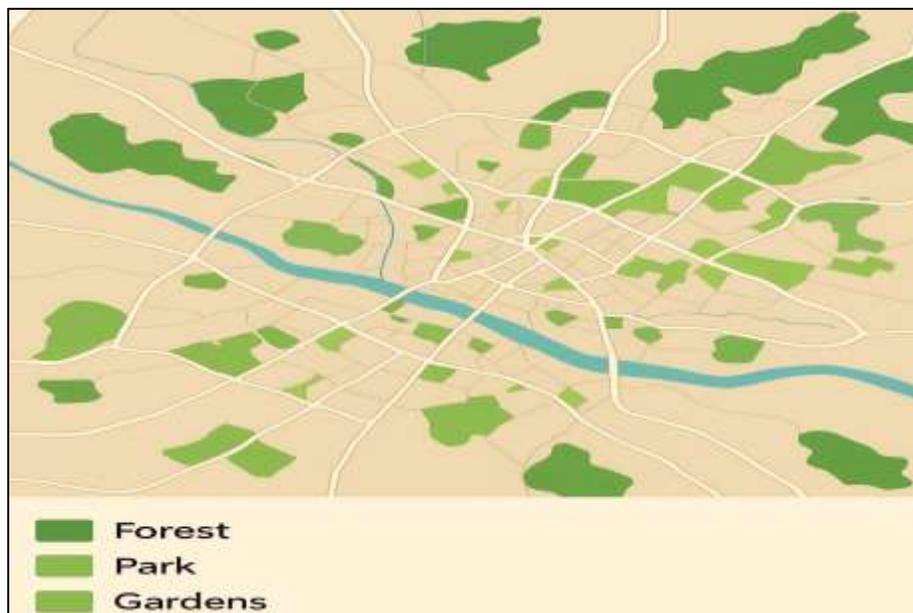

Figure 1. Map of Constantine showing the three types of green spaces.

Table 2. Classification, area, and connectivity of green spaces in Constantine.

Green Space Type	Area (%)	Number of	Average Size	Connectivity	Accessibility	Notes
Ecological Cores	35	40	2.1	Medium	Good	Concentrated in the city center, peripheral isolation
Linear/Point Elements	20	50	0.5	Low	Medium	Street trees, green roofs, scattered
Peripheral Natural Areas	45	30	3.5	Low	Low	Ravines and gorges have high ecological value

This typology aligns with patterns of Mediterranean cities, where historic city centers retain densely managed green spaces, while outer urban zones host ecologically diverse but structurally less organized habitats(Kabisch*et al.,* 2016; Lin *et al.,* 2015; Lux, 2024). The spatial isolation of central ecological cores can hinder habitat connectivity, restricting species movement and ecological interactions (Gómez-Baggethun*et al.,* 2013; Aronson *et al.,* 2017).

Recent research also emphasizes the significance of "green fragments" in dense urban areas, where even small patches, such as street trees and green roofs, play a meaningful role in the overall functioning of the green network (Lux, 2024).

3.2. Fragmentation and Ecological Connectivity

Analysis identified 120 separate green patches with an average size of 1.2 ha (Fig. 2). Ecological corridor density is low, especially in dense urban areas, with average distances between patches of 500-800 m in the city center and 1.5 km in outer zones. This fragmentation likely limits species dispersal, decreases genetic exchange, and weakens urban ecosystem resilience (Tzoulas*et al.,* 2007; McKinney, 2008; Lux, 2024). Central ecological cores, although concentrated, are spatially isolated, while peripheral natural areas, despite their larger size, remain poorly connected to the urban green network.

Figure 2. Fragmentation and spatial connectivity of green patches in Constantine,

emphasizing patch size, distribution, and

Recent studies highlight the importance of including private semi-natural areas, like gardens, in connectivity assessments, as these small patches can significantly improve habitat networks in fragmented urban areas (Jamil *et al.,* 2024).

Combining structural and functional connectivity metrics offers a more thorough assessment of urban green networks. Improving connectivity through corridors or links between private and public green spaces could boost biodiversity, support species dispersal, and strengthen ecosystem services like urban cooling

distances between patches.

recreation, and aesthetic value. Similar fragmentation patterns seen in other Mediterranean cities indicate that targeted management actions are crucial to maximize both ecological and social benefits (Lin *et al.,* 2015; Kabisch*et al.,* 2016).

To complement the spatial analysis, Figure 3 and Table 3 present the fragmentation and connectivity metrics numerically. These metrics offer further insights into patch size distribution, inter-patch distances, and corridor density, which are essential for urban planning and biodiversity management.

Figure 3. Fragmentation and connectivity metrics of green patches in Constantine, showing the number of patches, average patch size, distances between patches, and corridor density.

Table 3. Fragmentation and connectivity metrics in Constantine.

Metric	Value	Notes
Number of green patches	120	Discrete vegetation units mapped by SIG
Average patch area	1.2 ha	Range: 0.3–5.6 ha
Mean inter-patch distance (center)	500-800 m	Dense urban areas
Mean inter-patch distance (periphery)	1.5 km	Less urbanized zones
Corridor density	Low	Limited connectivity between patches

3.3. Accessibility and Residents' Perception

Survey results show that 65% of residents can reach a green space within a 10-minute walk (Fig. 4). However, 40% expressed dissatisfaction with the quality of the spaces, citing inadequate maintenance, limited facilities, and low landscape diversity. Neighborhoods on the outskirts showed lower accessibility and safety concerns, especially at night.

This spatial inequity aligns with global observations in urban environments: proximity alone does not ensure accessibility or usability, and populations on the periphery often face lower-quality green spaces (Wolch*et al.,* 2014; Sun *et al.,* 2022; Skillington & Kirsch, 2024; dos Santos Facundes *et al.,* 2024).

Enhancing both the quantity and quality of green spaces, including infrastructure, maintenance, and safety, is crucial to foster equity and public well-being (Kabisch & Haase, 2014; Lin *et al.,* 2015; Huang *et al.,* 2023).
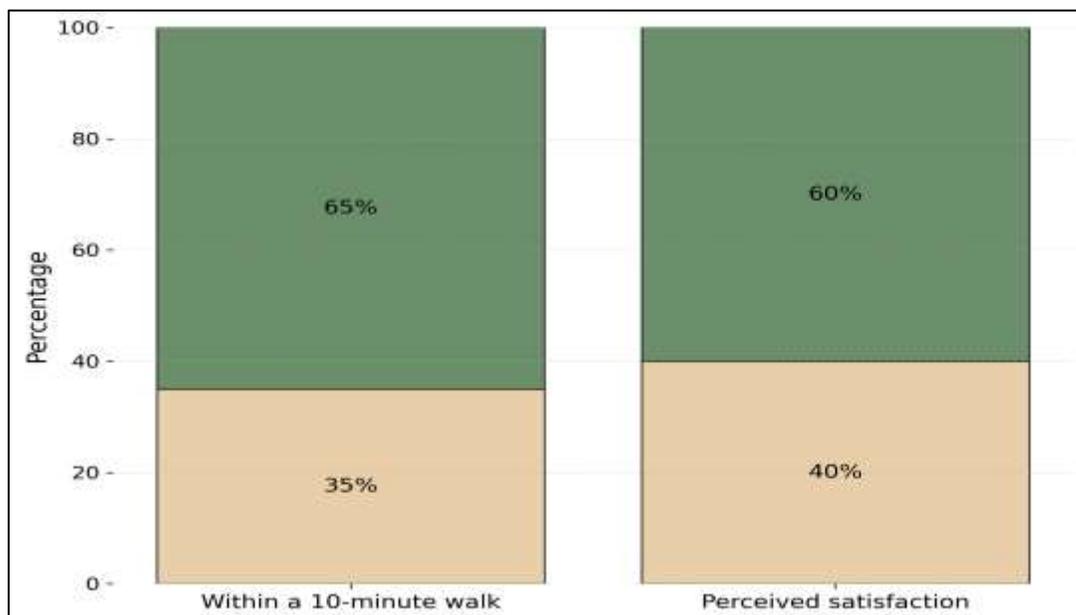

Figure 4. Accessibility of green spaces in Constantine based on survey responses and walking time limits.

3.4. Ecosystem Services and Ecological Connectivity

Central ecological cores provide local cooling, recreational benefits, and other ecosystem services, but their isolation limits their citywide impact (Fig. 5). Discontinuous corridors hamper species movement, and peripheral natural areas, though ecologically valuable, remain largely inaccessible (Jim & Chen, 2008; Bolund &Hunhammar, 1999). Fragmentation and low connectivity diminish the green network's ability to provide ecosystem and social services.

Recent studies confirm that connectivity, patch naturalness, and structural complexity strongly influence biodiversity outcomes and ecosystem service delivery (UrbanEcosystems, 2023; 2024 bird-biodiversity study; Transdisciplinary approaches, 2024). A mixed strategy that preserves core areas, enhances small fragments, and improves corridor connectivity is recommended to maximize both biodiversity conservation and urban well-being(Gómez-Baggethun*et al.,* 2013; Aronson *et al.,* 2017; Lux, 2024).
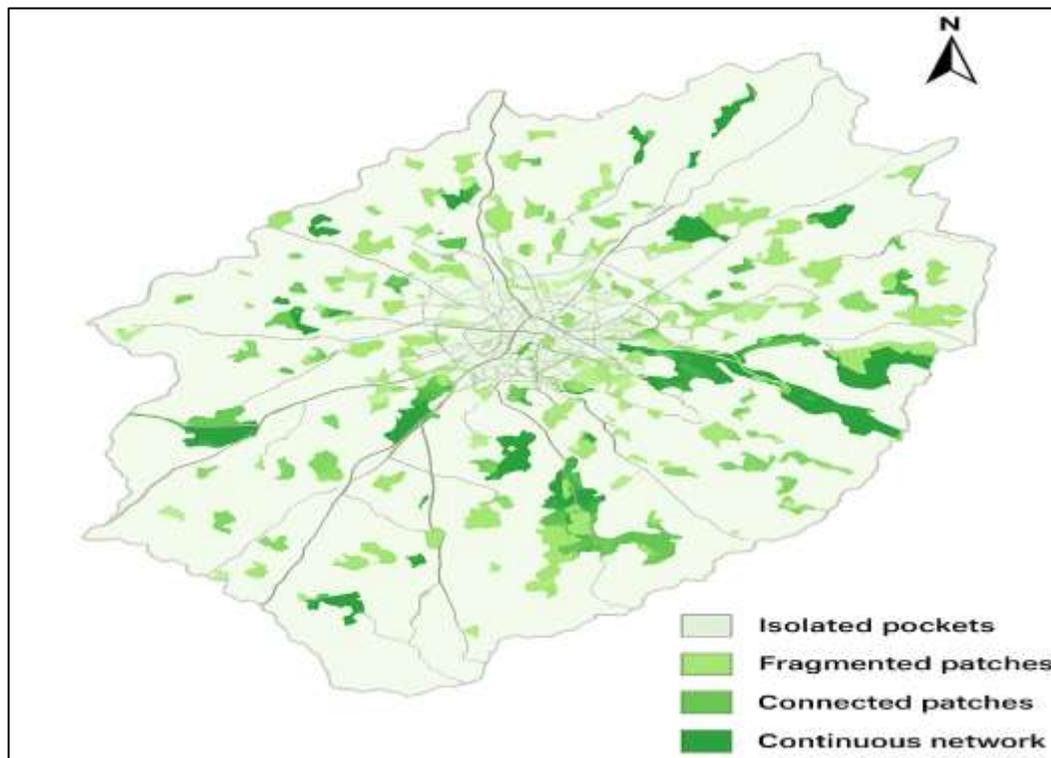

Figure 5. Ecosystem services and ecological connectivity of urban green spaces in Constantine.

4. Conclusion

This study provides a comprehensive assessment of urban green spaces in Constantine by integrating spatial classification, ecological connectivity, fragmentation metrics, and residents' perceptions of accessibility. The results reveal a heterogeneous green network composed of densely managed ecological cores concentrated in the historic center, linear and scattered elements dispersed across the urban fabric, and ecologically valuable natural areas on the outskirts that remain largely inaccessible. Elevated fragmentation, weak corridor connectivity, and inequitable access-particularly in peripheral districts-limit both biodiversity conservation and the provision of ecosystem services.

These findings underscore the need for strategic,equity-oriented urban planning that safeguards large core green areas while enhancing smaller patches and linear features, including private and semi-natural spaces. Strengthening ecological connectivity through corridors and stepping-stone habitats, along with improvements in quality, safety, and usability, would maximize ecological functions and social benefits.

Overall, this work demonstrates that sustainable urban green infrastructure requires a multidimensional approach that balances ecological integrity with equitable social access, thereby contributing to more resilient and livable Mediterranean cities. The methods and insights presented here offer a transferable framework for evaluating and designing green space networks in other rapidly urbanizing regions

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