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Provision of urban green spaces: A case study of Oujda City, Northeast Morocco

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ABSTRACT

The quality and quantity of urban green spaces have a direct or indirect impact on residents' living environment, providing environmental, social, psychological, and aesthetic benefits. However, these advantages can only be realized by all citizens if there is an adequate and equitable distribution of green infrastructure that meets the needs and expectations of users. In Morocco, the analysis of urban green spaces has primarily focused on quantitative aspects, offering only a partial understanding of the current situation. This study represents a pioneering effort at the national level, aiming to introduce a methodology for evaluating the provision of urban green spaces. The city of Oujda, situated in the Northeast region of Morocco, is used as a case study, employing various approaches that prominently consider accessibility and user satisfaction. This analysis incorporates three key approaches: firstly, a quantitative assessment utilizing ratios of urban green spaces per capita and per city area; secondly, a spatial and accessibility-focused investigation using maps and Geographic Information System (GIS) software; and thirdly, a qualitative examination based on a survey conducted among the city's residents. The results reveal a total green infrastructure of 1821 hectares, comprising 10 different types of green spaces and 132,457 meters of tree-lined streets, corresponding to ratios of 23% of the city's area and 37 m² per inhabitant. These figures surpass both national and international recommendations. However, the ratio of tree-lined streets per inhabitant remains relatively low compared to other European cities, at 0.27 linear meters per inhabitant. Notably, forests stand out as the most abundantly endowed green space type, with a ratio of 33 m² per inhabitant, surpassing national recommendations, while all other types fall below the recommended minimum. The distribution analysis of green spaces throughout the city reveals significant disparities between different districts. Employing the Normalized Difference Vegetation Index (NDVI) for cartographic analysis, it was observed that vegetation within the urban perimeter covers a total of 2,331 hectares, accounting for 29% of the city's area. Furthermore, the analysis of green space service areas shows coverage across 5,805 hectares, representing 72% of the city's area. Overlaying these analyses highlights the most underserved zones in terms of vegetation, encompassing an area of 1,232 hectares, or 15% of the city's area, with an estimated population of 71,667 inhabitants, or 15% of the city's population. The inequitable distribution of urban green spaces is further underscored by the qualitative analysis, wherein city residents report having to travel considerable distances beyond accessibility norms to access green zones. They assert that these spaces are inadequately equipped and fail to meet their quality requirements. The survey also reveals that their preferences lean towards larger, versatile green spaces that offer tranquility, proximity to nature, and a sense of calm.

Keywords: Urban green spaces, Accessibility, Service area, Inventory, NDVI, Morocco, Oujda.
Article type: Research Article.

INTRODUCTION

The quality and quantity of urban green spaces directly or indirectly influence an area's residents' living environment, providing environmental, social, psychological, and aesthetic benefits (Bennasser *et al.* 2020). While past analyses of urban green spaces primarily focused on quantitative and typological aspects, in recent years, notions related to equity and accessibility of these spaces have gained prominence. In September 2015, the United Nations General Assembly approved a set of new Sustainable Development Goals (SDGs), including a specific goal on public spaces (SDG 11.7), states that: "By 2030, providing universal access to safe, inclusive, and accessible green and public spaces, particularly for women, children, the elderly, and persons with disabilities" (Maria *et al.* 2016; Ch & Giuliani 2021). Though there is no uniform definition of green space supply and accessibility in scientific literature, most studies that evaluate the distance and/or quality of green spaces often considering the population that can benefit from these spaces, Biernacka & Kronenberg (2019), proposed three main levels of green space supply: availability, accessibility, and attractiveness (cited in Kolcs 2021). Availability refers to the existence of a green space at a certain distance as the crow flies. A simple method involves creating buffer zones around green spaces to determine the distance to surrounding residential areas. However, this method tends to overestimate physical accessibility despite its ease of calculation and comparability between countries (Kronenberg 2014; Kabisch *et al.* 2016; Biernacka & Kronenberg 2019; Biernacka *et al.* 2020; cited in Kolcs 2021). In contrast, accessibility is a more complex characteristic of green space provision. Approaches using cost-distance analyses, accounting for movement barriers and facilitators, as well as average travel speeds, offer a more realistic depiction of physical access (Wright Wendel *et al.* 2012; Park 2016; Biernacka & Kronenberg 2019; Biernacka *et al.* 2020; cited in Kolcs 2021). On the other hand, attractiveness focuses mainly on the quality of green spaces and describes their desirability among potential visitors. Another important aspect of estimating green space provision is determining the proportion of the population capable of reaching these green spaces within a given walking time (Zepp *et al.* 2020; cited in Kolcs 2021). Many studies combine availability or accessibility analyses with demographic data to estimate the number of residents who can reach green destinations within predetermined time intervals. Regarding green space provision, a purely quantitative approach must be complemented by a spatial one. Conventional statistical indicators, such as total area and number of parks and gardens, and ratios of green space area per capita or per city size, do not account for the exact location of parks and how citizens benefit from them (Oh & Jeong 2007; Chkird *et al.* 2024). Consequently, an urban area with a correct green space-to-city area ratio may still have certain inhabited neighborhoods lacking accessibility to these spaces (Poelman 2018). A relevant illustration is drawn from two European cities, Malmö (Sweden) and Brasov (Romania), with green coverage percentages of 8.1% and 40.8% respectively. In Malmö, 98% of the population finds a green space within a ten-minute walk, while in Brasov, despite a high proportion of green spaces, accessibility is less favorable, leaving over 40% of the population without green spaces within the same walking distance (Poelman 2018). In Morocco, the guide for developing green plans, considered a reference document in this field, mainly concentrates on quantitative standards, with occasional references to spatial approaches when discussing green space typologies and the maximum distances separating them from beneficiaries (Benabdeljalil & Boujmal 2008). This study represents a pioneering effort at the national level, aiming to initiate a methodology for evaluating urban green space provision (using Oujda City in Eastern Morocco as a case study) through various approaches that notably integrate the notions of accessibility and user satisfaction.

MATERIALS AND METHODS

Study Area

This study centers on the green spaces within Oujda city, the capital of the Oriental region in Morocco. Positioned in the northeastern part of the Kingdom of Morocco, in close proximity to the Algerian border and other cities in the Oriental region (Fig.1), this urban agglomeration is situated at 1°54'30" West longitude and 34°40'53" North latitude. Encompassing an area of 80.56 km² and accommodating a legal population of 494,032 inhabitants, as per the latest General Population and Housing Census of 2014 (RGPH), Oujda ranks among the most populous urban municipalities in the Oriental region. The city boundaries considered in this study are those defined by the approved urban planning in 2014.

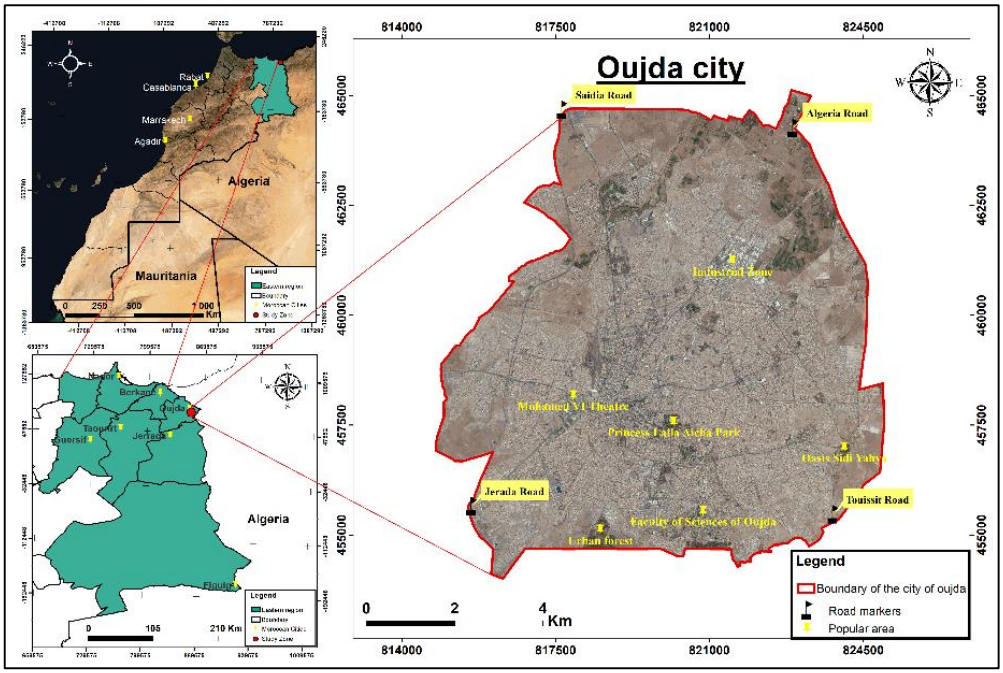


Fig. 1. Location map of the study area.

Study methodology

To analyze and assess the provision of green spaces in Oujda city, three principal approaches were employed: the quantitative approach, the spatial and accessibility-focused approach, and the qualitative approach.

Quantitative approach

Inventory of green spaces in Oujda City

To comprehensively evaluate the current state of the city's green assets, a thorough inventory of all public green areas within and immediately surrounding the urban area was undertaken. Conducting this inventory entailed surveys conducted with the administrators of urban and peri-urban green spaces, namely, the urban municipality's green spaces department in Oujda and the regional directorate of water, forests, and combating desertification in the Oriental region. Additionally, urban planning documents were consulted with the Oujda urban agency to enhance and refine these surveys, particularly concerning the delineation of the urban boundaries. Supplementary data were garnered from maps and field surveys to augment and clarify the gathered information. Design and Geographic Information System (GIS) software were utilized to discern the location, distribution, and size of the green entities. The collected data facilitated the construction of an initial synthesis presented in the form of tables and a map that aggregated all the characteristics of these green facilities. Excel spreadsheets and GIS software were employed for the purpose of collating, organizing, and analyzing all data pertinent to the identified green areas, such as area, type, location, etc.

Determination of green space ratios

Green space ratio is a widely utilized metric for assessing green space availability in urban areas (Le et al. 2018). Understanding the correlation between the urban population and the quantity of green spaces is of particular significance for evaluating their functionality and, naturally, for future planning of their provision (Haq, 2011). The per capita ratio is calculated using the following formula:

$$\mathbf{R_{(EV/H)} = S_{(EV)} / EP}$$

With: $\mathbf{R_{(EV/H)}}$ representing the ratio of green space per inhabitant; $\mathbf{S_{(EV)}}$ is the total green space area within a specified perimeter, and **EP** indicates the population count within the same perimeter. The calculation of green space area was based on the conducted inventory, while population data were sourced from the regional delegation of the high commission for planning. A second ratio, this time related to area, was investigated. It is expressed in square meters (m^2) of green space area within a designated perimeter per square meter (m^2) of the total area within

the same perimeter. The pertinent data were collected through the analysis of city maps. Furthermore, the ratio per unit area is determined by the following formula:

$$R_{(EV/V)} = S_{(EV)} / S_{(V)}$$

With: $R_{(EV/V)}$ representing the green space ratio in relation to the city's total area; $S_{(EV)}$ is the total green space area for a given perimeter, and $S_{(V)}$ is the total area of the city.
Both of these ratios were determined for the entire city and then calculated at the scale of each district.

Spatial and accessibility approach and determination of deficient zones

Analysis using the Normalized Difference Vegetation Index (NDVI)

When studying remote sensing information, the Normalized Difference Vegetation Index (NDVI) is commonly used to quantify the quantity and vigor of vegetation and to specifically identify deficient areas (Gao 1996). This analysis is based on the reflectance of the red ® and near-infrared (NIR) channels (La Télédétection & GéoBretagne: Méthodes, Produits & Exemples 2017). The index is calculated in the visible band using sensors aboard drones or high-resolution satellites such as Sentinel and Landsat. Its calculation expression is as follows:

NDVI = (PIR-R) / (PIR+R)

During this study, the vegetation index was computed using the Sentinel-2 image (captured over Oujda city on April 25, 2022). This satellite image was acquired during the spring season, which is conducive to highlighting the presence of green areas. This analysis enables us to approach the distribution of vegetated zones within the city, regardless of their status (public or private). Subsequently, the intersection of service areas with the vegetation index provides a more precise understanding of extremely deficient sectors. The deficiency in green space is perceived differently in residential areas compared to densely urbanized regions. Vegetation-deficient areas that lack access to public green spaces emerge as priority intervention zones for enhancing the residents' living conditions.

Analysis of Green Space Accessibility

While the per capita ratio indicator is widely accepted due to its ease of application, it is not considered efficient as it disregards the spatial distribution and accessibility of green spaces to users (Yao *et al.* 2014; De La Barrera *et al.* 2016). Consequently, for a comprehensive evaluation of green space provision, the study of accessibility and proximity is often integrated with it (Yao *et al.* 2014; De La Barrera *et al.* 2016). The consideration of green space service areas emerged concurrently with the formulation of green space policies in the early 1970s. Accessibility refers to the ease of reaching a green space from a place of residence or work, whereas proximity denotes the minimum distance required to access it. Various indicator tools can be utilized to quantify these two dimensions, such as walking time, the number of accessible green spaces, average area, or vegetation coverage rate. These indicators can be calculated at different spatial scales (neighborhood, municipality, urban agglomeration) and for different modes of transportation (on foot, by bicycle, by public transport) (Wright Wendel *et al.* 2012). In this study, the assessment of accessibility is based on defining the service areas of different green entities in the city. The depiction of a green space's service area is based on the observation that the space has a proximity attraction area, within which pedestrian visits are not significantly constrained by travel time. Hence, the utilization of a green space is contingent upon the constraint of distance; the farther the green space is from one's residence, the less likely an individual is to frequent it ((IAU 2009). Similarly, the attractiveness of a green space is also influenced by its size as well as the amenities it offers. Table 1 presents some recommendations regarding the accessibility of different types of green spaces in various countries. Given that Moroccan recommendations for green space accessibility are ambiguous, vague, and incomplete (Table 1; Bennasser *et al.* 2020), the Belgian recommendations (Table 1) were adopted for this study as they seem more appropriate for the Moroccan context. The service areas of different urban green spaces are delineated based on their endpoints, taking into account the recommendations from Table 1. Dwellings and populations located outside these service areas are considered to lack access to any green space. Graphical maps obtained from the Oujda urban agency and GIS software were employed to support this analysis.

Table 1. Recommendations for the accessibility of different types of green spaces in various countries (Bennasser *et al.* 2020).

Country	Green Space Area	Service Area	References
Morocco	450 m² (Small garden)	Between 300 and 750 m	Benabdeljalil & Boujmal 2008
	1 à 10 ha (Public garden)	<750 m	
	>10 ha (Public park)	Not specified	
France	<1 ha	100 metres	Barbarino-Saulnier 2005
	1 à 10 ha	500 metres	
	>10 ha	1 km	
South Korea	0,15 à 1 ha	250 m	Oh & Jeong, 2007 cited by Morar *et al*. 2014
	1 à 3 ha	500 m	
	3 à 10 ha	1 km	
	>10 ha	Not specified	
Belgium	<1 ha	150 m	Herzele & Wiedemann 2003 cited by Morar *et al.* 2014
	1 à 10 ha	400 m	
	10 à 30 ha	800 m	
	30 à 60 ha	1,6 km	
	60 à 300 ha	3,2 km	
	>300 ha	5 km	

Intersection of accessibility-NDVI and determination of deficient zones

To identify the most deficient areas in terms of green spaces which require urgent intervention, the data from the two selected approaches were overlaid. The resulting deficient zones are areas that are not served by any green space and do not support any vegetation whatsoever.

Qualitative approach

The qualitative approach to evaluating the provision of green spaces in Oujda City involved an online survey conducted among its residents. The objective was to comprehend the residents' perception of the green network provided to them, assess its attractiveness, identify practices, uses, and expectations, and characterize preferences. A questionnaire was developed for this purpose, primarily focusing on the identification of respondents, their usage patterns (frequency of visits, activities practiced, etc.), their perceptions of these green spaces, and desired improvements.

Sample size

The determination of a representative sample size for this survey was approached by referring to the formula below (François Daniel Giezendanner 2012) cited in (Aubin *et al*. 2021):

$$\mathbf{n = t^2 \times p \times (1\text{-}p) / m^2}$$

The present investigation adhered to a robust sampling methodology, with **(n)** representing the minimum sample size required to achieve statistically significant results for an event at a predetermined level of risk. Meanwhile, **(t)** denoted the confidence level, wherein the typical value for a 95% confidence level is 1.96. Furthermore, **(p)** signified the estimated proportion of the population manifesting the targeted characteristic, precisely set at 50% (Proportion p = 0.5). The margin of error **(m)**, typically fixed at 5%, was also accounted for in the sample size calculation. By adopting this rigorous formula, the sample size was ultimately determined to consist of 384 respondents. Notably, it is worth noting that the municipal population of Oujda city was approximated to be approximately 492,873 inhabitants, as evidenced in the most recent census data from 2014.

Investigation progress

The survey procedure was meticulously executed, and the questionnaire was expertly crafted in both French and Arabic languages. It was subsequently disseminated through a strategic online platform, Google Forms, on June 23, 2021. Furthermore, the survey was extensively promoted across various social media platforms, including dedicated pages specifically tailored to Oujda city and Mohammed Premier University, as well as popular channels like Instagram, LinkedIn, and WhatsApp. Regarding data analysis, a rigorous approach was employed utilizing Excel and SPSS software. Specifically, the dataset was processed using Factorial Correspondence Analysis (FCA) through the powerful SPSS software tool. FCA, an essential statistical technique, seeks to explore

and comprehend relationships between categorical variables while striving to condense the dimensionality of the data as much as feasible. By effectively reducing the dimension space, this technique allows for the examination of the intricate interplay between two qualitative variables, particularly those deemed most discriminative. Moreover, it endeavors to identify composite factors that collectively capture the underlying structure within the data, all within a restricted number of dimensions. The primary objective of FCA is to yield a succinct yet meaningful summary of the data, thereby facilitating a comprehensive understanding of the patterns and associations inherent in the dataset (Baccini 2010).

RESULTS AND DISCUSSION

Results

Quantitative approach

Inventory of green spaces in Oujda City

The comprehensive inventory conducted as part of this study resulted in the identification of a total of 236 public green spaces, encompassing an area of 232 hectares within the urban perimeter of Oujda. Table 2 and Fig. 2 present the key findings of this inventory. Notably, the two forests located in the immediate vicinity of the city cover a substantial area of 1,653 hectares, of which only 64 hectares currently fall within the urban perimeter. However, considering their proximity and the fact that they have been developed as urban parks and are fully accessible to the city's residents, we propose incorporating the entire forest area, bringing the city's green assets to a total of 1,821 hectares. This vast green infrastructure can be classified into ten types of green spaces, with forests dominating in terms of area, followed by parks, green spaces along public roads, and sports fields, accounting for 90.71%, 2.75%, and 1.54%, respectively, of the city's total green capital. Furthermore, Oujda city boasts 114 tree-lined avenues, collectively spanning a length of 132,457 linear meters. Fig. 2. depicts the distribution of all the identified public green spaces in the city of Oujda.

Table 2. Area and ratio (%) of each identified type of green space in Oujda City.

Type	Number	Area (ha)	Report
Forests	2	1653* (64**)	90,71%*
Parks	4	50	2,75%
Large Gardens	7	16	0,88%
Squares	51	15	0,82%
Places	43	18	0,99%
Public nurseries	2	9	0,49%
Green spaces along public roads (Roundabouts & Refuges)	92	28	1,54%
Sports fields	32	28	1,54%
Riverbanks	3	4	0,22%
Total	236	1821	100%

Note: *All forests within the urban and peri-urbain perimeter; **The forest within the urban perimeter.

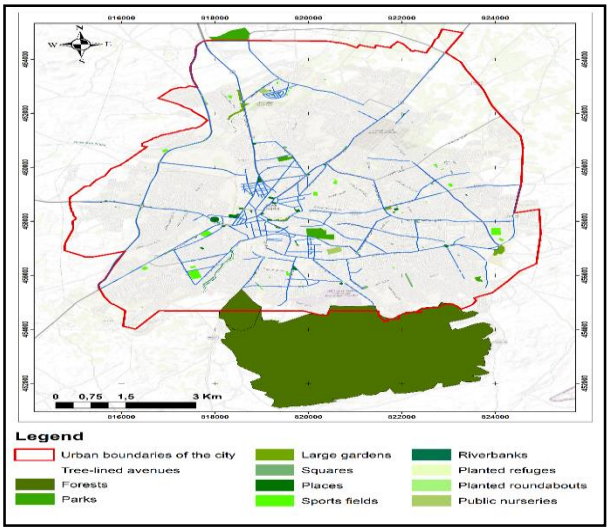


Fig. 2. Distribution of identified public green spaces in Oujda City.

Determination of Ratios

Table 3 presents the ratios of green spaces in Oujda City, expressed per capita and distributed among different types of green spaces. The analysis reveals that Oujda City provides 37 square meters of green space per inhabitant (considering the entire forested areas). Further examination of this ratio by green space type indicates that forests and parks exhibit the highest values, while other types, such as riverbanks, gardens, and squares, are relatively limited. This ratio, when compared to national recommendations (Benabdeljalil & Boujmal 2008), highlights certain disparities and deficiencies in the provision of green infrastructure in the city.

Table 3. Ratios (m²/inhab.) for different types of green spaces in Oujda City.

Type	Number	Area (ha)	Ratio (m²/inhab.)
Forests	2	1653*	33,45*
Parks	4	50	1,01
Large Gardens	7	16	0,32
Squares	51	15	0,30
Places	43	18	0,37
Public nurseries	2	9	0,18
Green spaces along public roads (Roundabouts & Refuges)	92	28	0,57
Sports fields	32	28	0,56
Riverbanks	3	4	0,08
Total	236	1821	36,85

Note: *All forests within the urban and peri-urbain perimeter.

At the district level, a significant spatial disparity is evident, favoring the southern and downtown areas (districts N°. 1, 11, and 15). Conversely, the western district (N°. 7), the former Medina (district N°. 4), and the eastern districts (N°. 8, 12, and 3) exhibit notably low ratios of 0.87 m²/inhab., 0.85 m²/inhab., and 0.81 m²/inhab., respectively, indicating considerable green infrastructure inadequacy (Fig. 3). Moreover, the overall green spaces, regardless of type, account for only 23% of the city's total area. Analyzing this ratio (green space area/total city area) also reveals pronounced spatial disparities (Fig.4). The southern and downtown districts concentrate the majority of these facilities, ranging from 6.03% to 2.72%, while the northern-eastern and western districts remain under-equipped, not exceeding 1.40%.

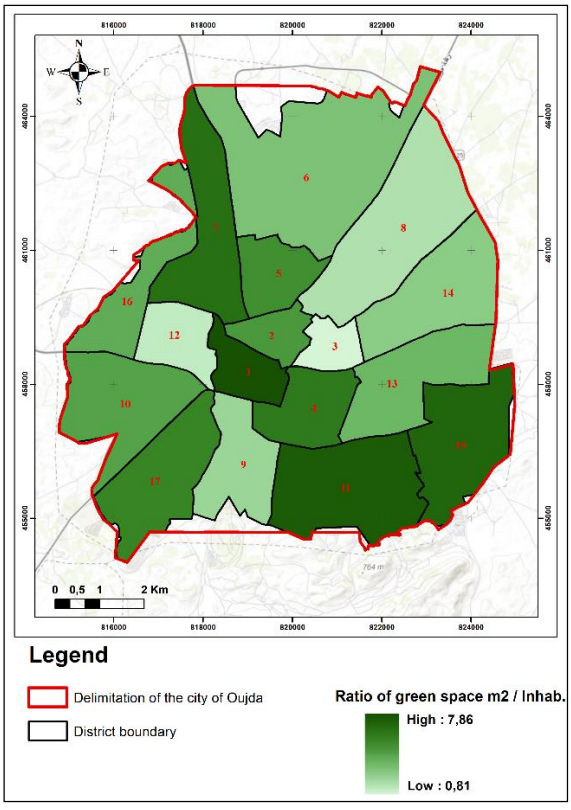


Fig. 3. Ratios of green space per inhabitant (m²/inhab.) for each district in Oujda.

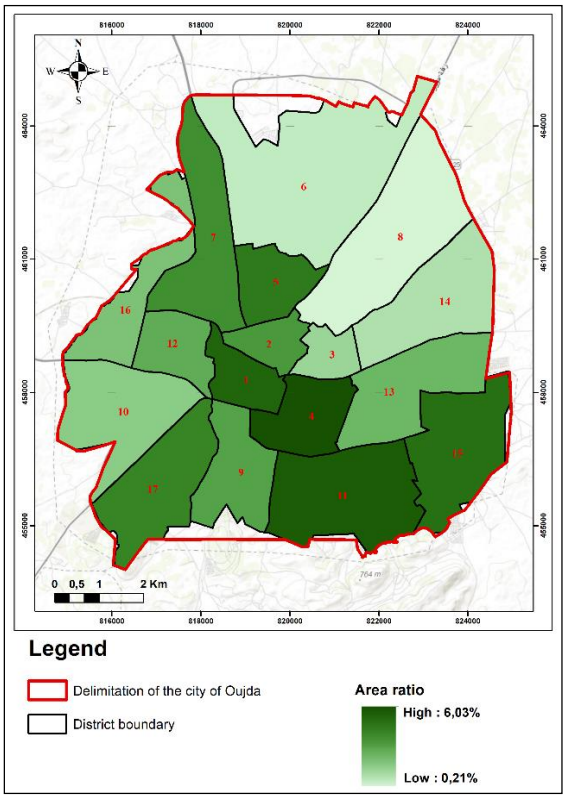


Fig.4. Ratios (%) of green space area to the city's total area for each district in Oujda.

Spatial and accessibility approach and determination of deficient zones

Analysis using NDVI

The values of the Normalized Difference Vegetation Index (NDVI) range from -1 to +1 in theory. Positive values generally indicate vegetation, with values typically ranging from 0.1 to 0.7, wherein higher values correspond to denser vegetation. Negative values represent other surfaces, such as clouds, snow, or water, which have stronger reflectance in the red channel than in the near-infrared channel. NDVI values close to 0 indicate bare soil. Overall, the green patches within the city's urban perimeter cover an area of 2,331 hectares, constituting 29% of the city's total area (Fig. 5). The north-eastern and south-eastern zones of the city appear to have the highest vegetative cover, primarily corresponding to agricultural plots located within the urban area and the city's private golf course. Sparse green patches are observed in the rest of the city, often corresponding to residential areas or significant public green spaces (parks, large gardens, riverbanks of the Isly River, and cemeteries). The dense neighborhoods in the west and surrounding the downtown areas show reflectances in red and orange, indicative of a complete absence of vegetation. These areas dominate this analysis. It is noteworthy that tree-lined avenues and planted refuges along boulevards significantly contribute to enhancing vegetation presence during this approach.

Analysis using Accessibility

The areas served by green spaces cover 5,805 hectares (within the urban perimeter), representing 72% of the city's total area, leaving 2,251 hectares or 28% of the city without accessible green infrastructure (Fig.6). Approximately 397,613 inhabitants, constituting 80% of the city's population, reside within these service areas, while the remaining 20% do not have any green space nearby.

Intersection of Accessibility-NDVI and Determination of Deficient Zones

The overlay of NDVI and accessibility maps reveals parts of the city suffering from a complete lack of greenery, encompassing public green spaces, private gardens, urban agricultural plots, and natural green areas. The results of this analysis identify deficient zones, totaling 1,232 hectares, representing 15% of the city's area. These areas should be prioritized in any green infrastructure expansion program to ensure equitable distribution (Fig. 7). The population residing in these highly deficient zones is estimated to be 71,667 inhabitants, constituting 15% of the urban population.

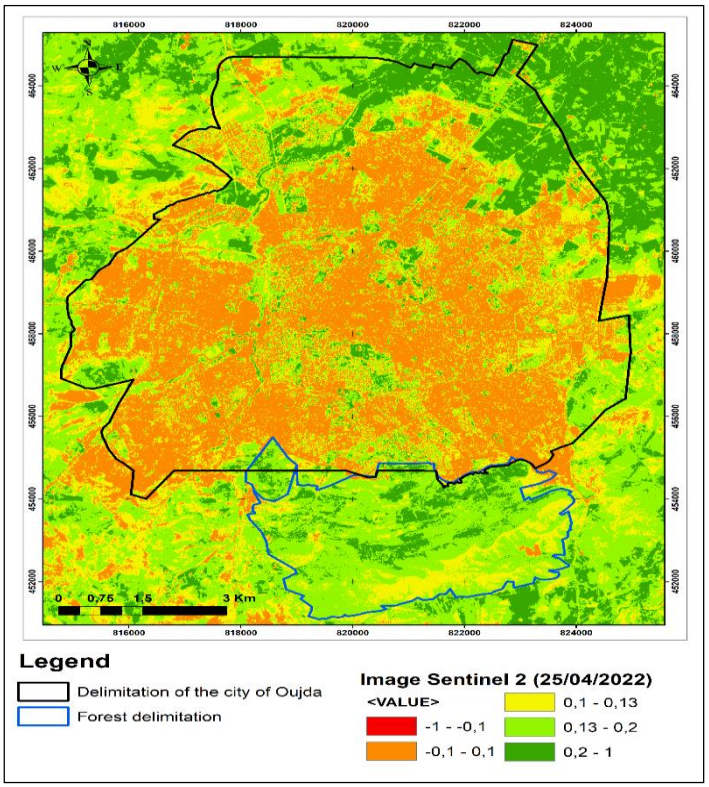


Fig. 5. Normalized Difference Vegetation Index (NDVI) map of Oujda City.

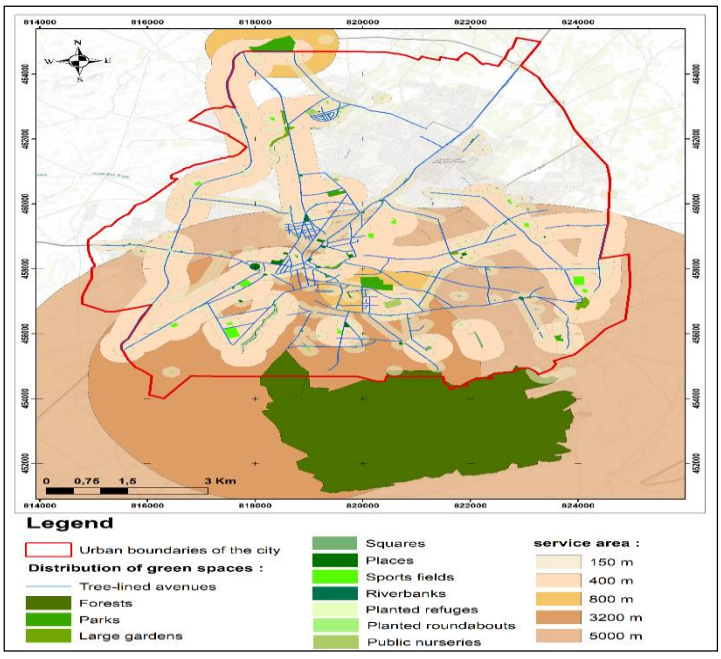


Fig. 6. Service area coverage of green spaces in Oujda City.

Qualitative Approach

Profile of Survey Respondents

A total of 400 responses were obtained from this survey. The average survey respondent can be characterized as follows: male (53.5%), aged between 18 and 39 years (35.3%), university-educated (94%), and employed (54%) (Figures 8 and 9). While the sex ratio aligns with the latest census data (HCP, 2014), the other characteristics can be logically attributed to the survey's methodology, favoring individuals who are educated, have internet access, and are familiar with social media.

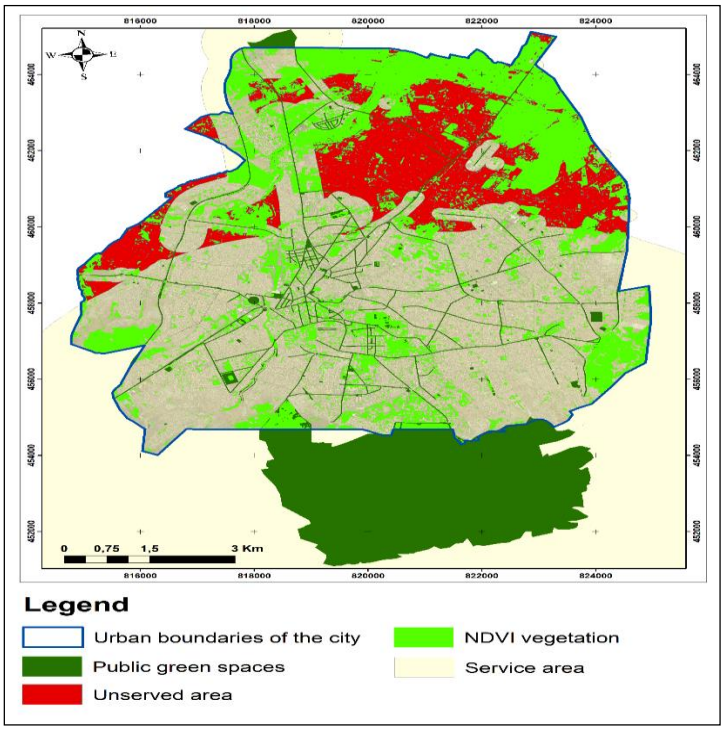


Fig. 7. Deficiency area coverage in the city of Oujda.

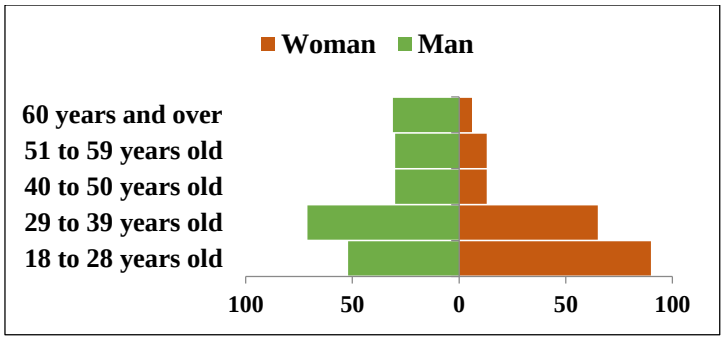


Fig. 8. Age pyramid of surveyed individuals in Oujda City.

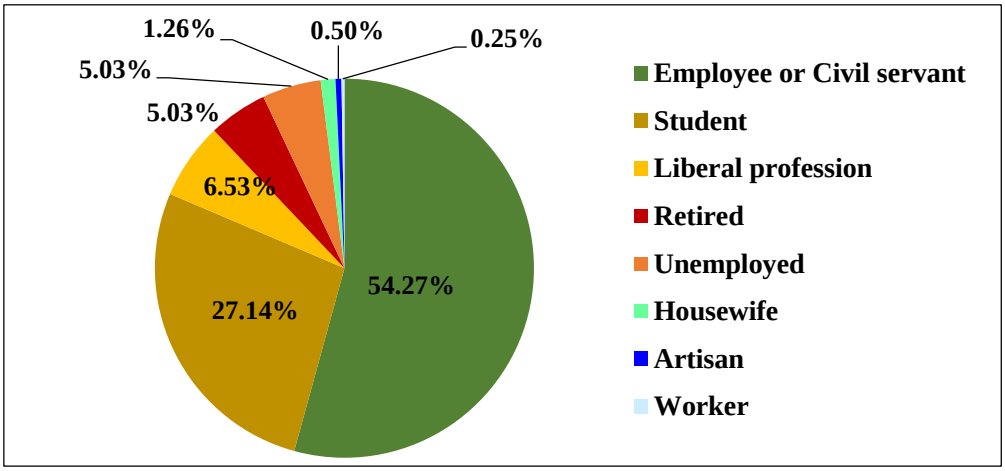


Fig. 9. Socio-professional profile of surveyed individuals in Oujda City.

Importance of Green Spaces: Practices, Perceptions, and User Preferences for Green Spaces

The survey revealed that the majority of respondents (96%) are aware of the importance of green spaces and their ecological and recreational roles for the population.

This interest in green spaces becomes even more apparent when 93% of respondents (Fig. 10) report visiting the city's green spaces, with 44% visiting very frequently (at least once a week; Fig. 11), and 60% visiting at least once a month for a duration of 1 to 2 hours (Fig. 12).

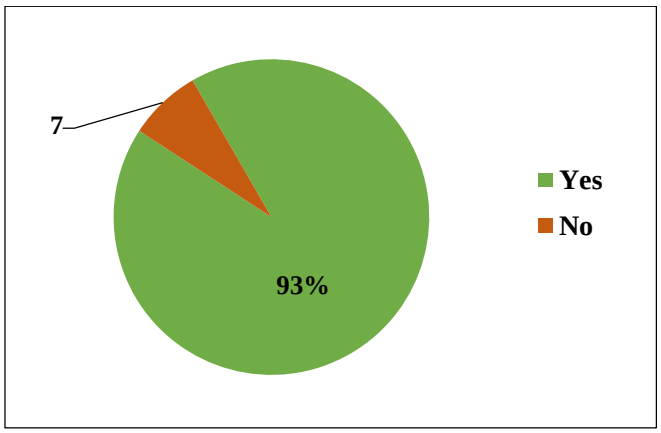


Fig. 10. Interest in visiting green spaces in Oujda City.

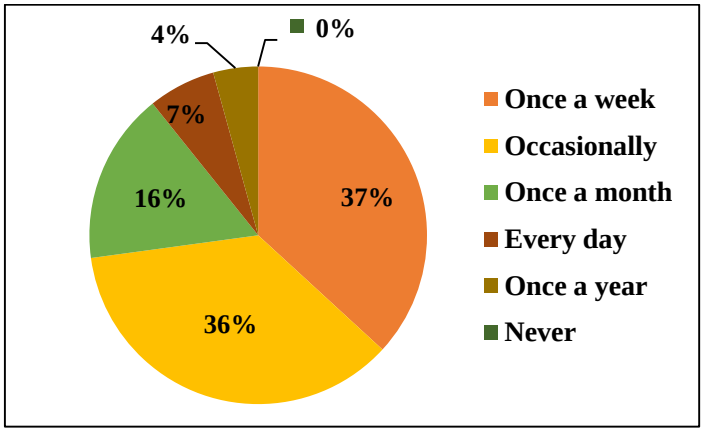


Fig.11. Frequency of visits to green spaces in the city.

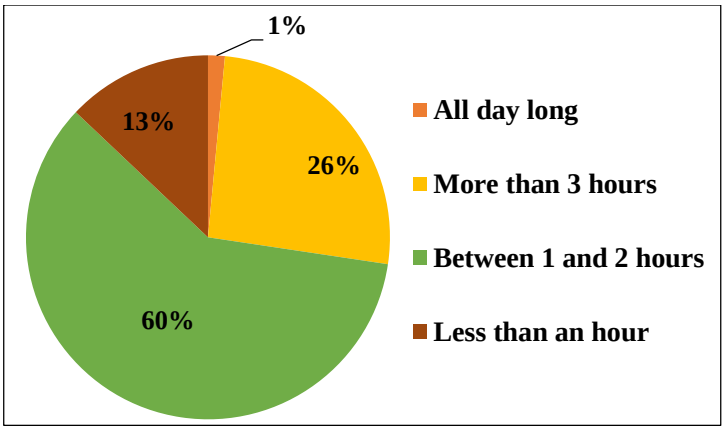


Fig.12. Duration of leisure time spent by the inhabitants of Oujda.

Appreciating this interest fully requires considering the city's green infrastructure. Indeed, 67% of respondents are located more than 500 meters away from the nearest green space, while 41% must travel over one kilometer to reach one. On the other hand, only 17% affirmed the presence of a green space nearby (within 250 meters) (Fig.13). Qualitatively, half of the respondents (50%) perceive the quality of the city's green spaces as poor to mediocre, while only a minority (17%) consider it somewhat good to excellent (Fig. 14). This observation is substantiated by their evaluation of the equipment and urban furniture in these green spaces. Specifically, 75% of respondents justified their assessment of green space quality based on the lack of maintenance and damaged

equipment that fails to meet visitors' needs and expectations (Fig. 15). Urban furniture in these green spaces is considered insufficient in quantity for 81% of respondents (Fig. 16) and of poor to average quality for 86% of them (Fig. 17).

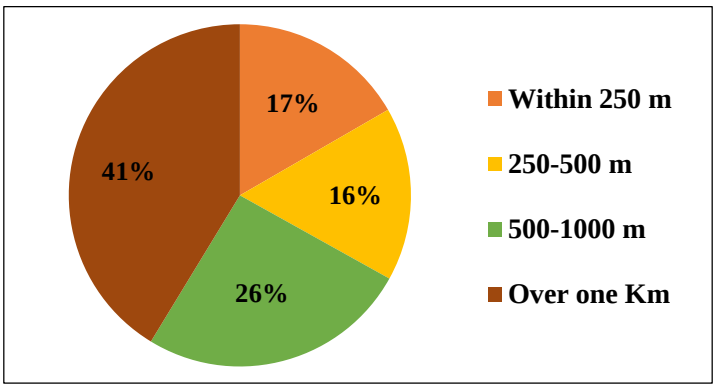


Fig. 13. Proximity to the nearest green space.

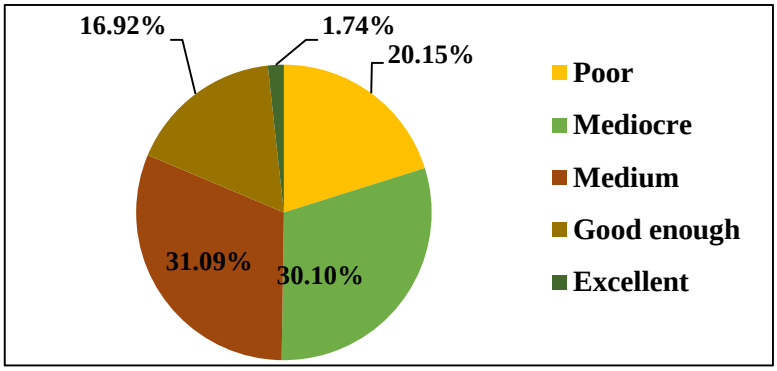


Fig. 14. Quality of green spaces in Oujda City.

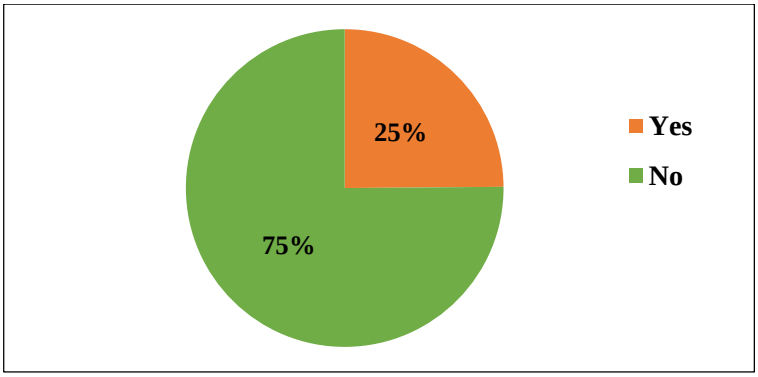


Fig. 15. Suitability of green space amenities to visitors' needs.

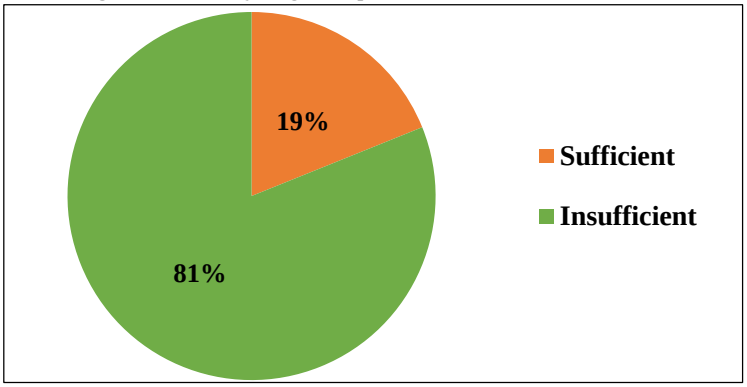


Fig. 16. Quantity of urban furniture in green spaces.

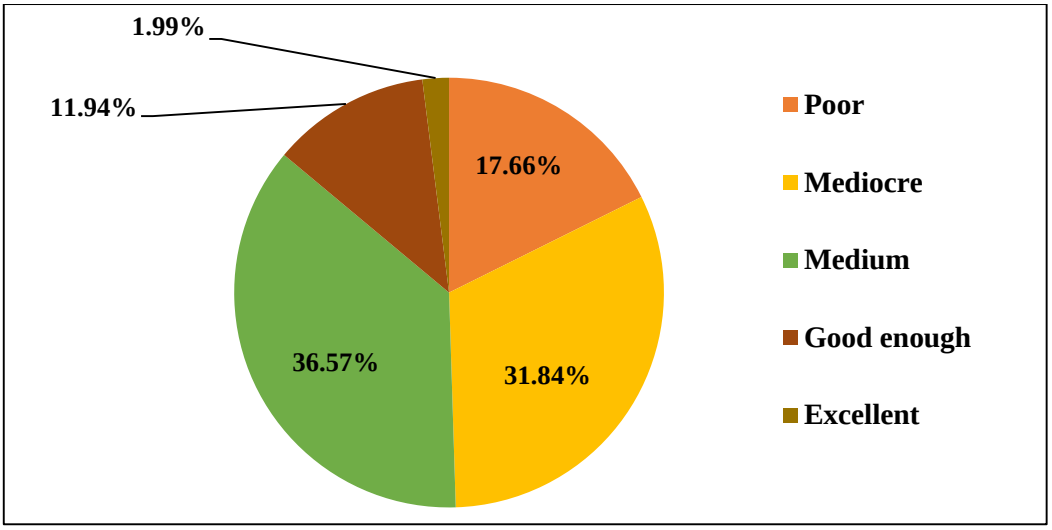


Fig. 17. Quality of urban furniture in the green spaces of Oujda.

The survey results also indicate that respondents' preferences for types of green spaces lean towards multipurpose parks (247 responses), peri-urban forests (208 responses), and to a lesser extent, neighborhood gardens (188 responses) and sports parks (171 responses). However, places (45 responses) do not seem to capture the respondents' interest (Fig. 18). These responses are corroborated by preferences and visitation among the green spaces constituting the city's green infrastructure (Fig.19). The large, versatile parks stand out as the most favored, with the top three parks in the city, Park Lalla Aicha (25%), Park Sidi Maafa (22%), and the new ecological park (21%), accounting for 68% of preferences, followed by significant gardens (Garden Oasis of Sidi Yahya 13%, Lalla Meryem Museum Garden 5%, and Al Qods Garden 6%) (Fig. 19).

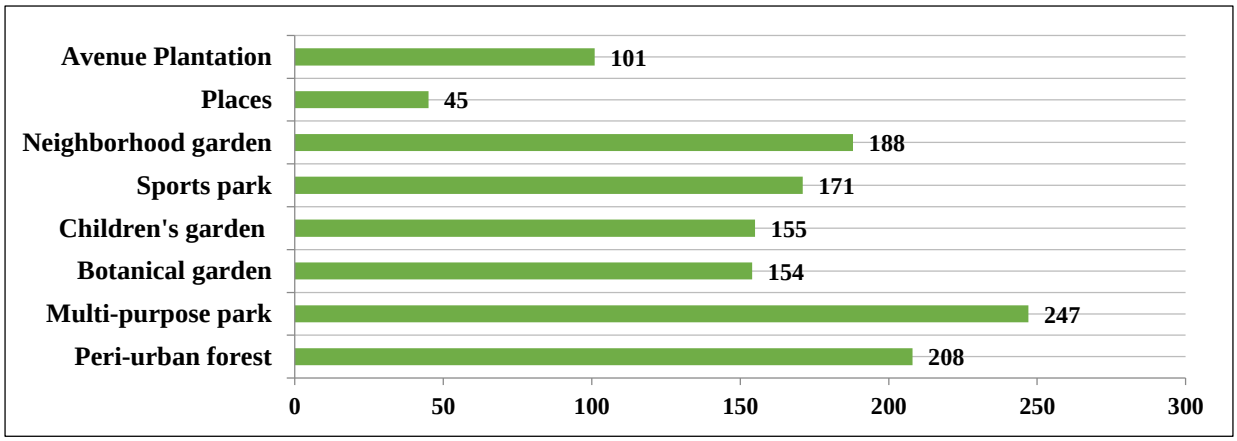


Fig. 18. Preferred type of garden by the inhabitants of Oujda.

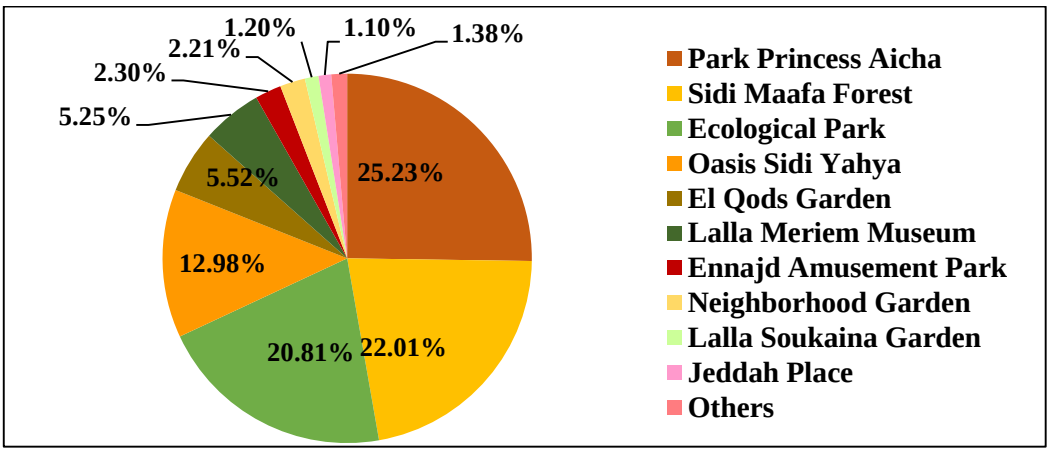


Fig. 19. Most frequented or preferred green spaces in Oujda City.

These preferences also align with the desired effects in a green space. Specifically, the calming and tranquil effects, as well as the proximity to nature, are the most sought-after in green spaces, with 329 and 298 responses, respectively (Fig. 20). The effects of beautification, entertainment, and freedom rank second, with 128, 125, and 112 responses, respectively.

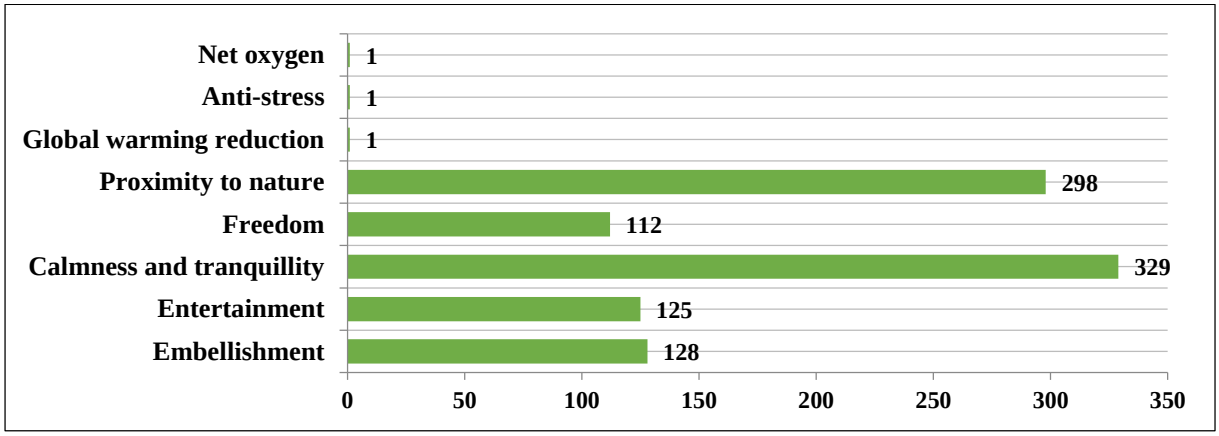


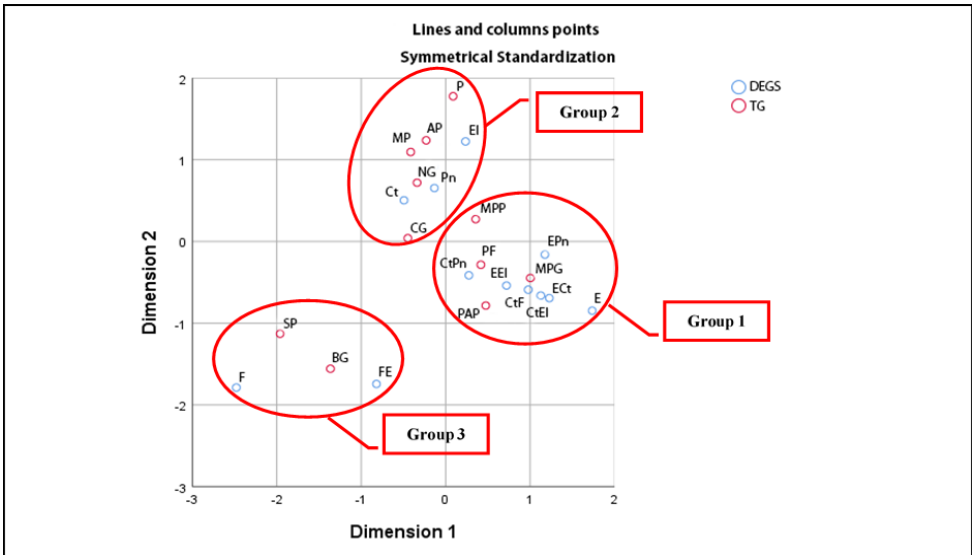
Fig. 20. Desired effect in a green space.

FCA analysis results

The Factorial Correspondence Analysis allowed the distinction of three groups (Fig;21):

- The first group encompasses green spaces of the types Peri-urban Forest (PF) and Multi-purpose Park (MP). The most sought-after effects related to these green spaces are Proximity to Nature (Pn), Tranquility, Calmness (Ct), and Entertainment (E; Group 1).
- The second group comprises several other types of green spaces, such as Neighborhood Garden (NG), Children's Garden (CG), Avenue Plantation (AP), and Places (P), with the most sought-after effects being Proximity to Nature (Pn) and Embellishment (El; Group 2).
- The third group gathers Sports Parks (SP) and Botanical Gardens (BG) as types of green spaces sought after for Freedom (F) and Entertainment (E; Group 3).

These findings are consistent with those obtained from the survey, where multi-purpose parks and peri-urban forests emerged as the most appreciated green spaces by a significant portion of respondents (Group 1). Similarly, the most sought-after effects in these green spaces are proximity to nature, less noise, and a calmer environment. However, the results of Groups 2 and 3 indicate that the perception of green spaces for a considerable part of the city's population is associated with various attributes such as Freedom, Embellishment, and Entertainment.



DAGS: Desired Effect in a Green Space
TG: Preferred Type of Garden

Fig. 21. Illustration of projections of observations related to green spaces in Oujda.

DISCUSSION

The city of Oujda boasts 1821 hectares of green spaces, including peri-urban forests, covering 10 types of green spaces: forests, parks, places, large gardens, squares, public nurseries, riverbanks, sports fields, green spaces along public roads (roundabouts and refuges), and tree alignments. Forests and parks account for the majority of this green infrastructure, with respective contributions of 90.71% and 2.75%. Internationally, the ratio per inhabitant is the most commonly used and recommended index to assess the supply of urban green spaces in a city. In this regard, UNHabitat (2009) recommends a minimum of 9 m² of open green space per inhabitant, with an ideal suggested value of 60 m² per inhabitant (Prance et al. 2014). The proposed ratio for urban green spaces in France is 10 m² per inhabitant. The proposed objective for green spaces intended for weekend activities, including urban forests, periurban woods, and forest regions, is 25 m² per inhabitant (*Ministre délégué auprès du premier ministre, chargé de la protection de la nature et de l'environnement* 1973). In Morocco, according to the green space planning guide, this ratio has been divided into three variants to adapt to the diversification of Moroccan urban contexts: a minimum threshold of 10 m²/inhab. for high-density urban fabric, a medium threshold of 15 m²/inhab. for medium-density urban fabric, and an optimal threshold of 25 m² for low-density urban fabric (Benabdeljalil & Boujmal 2008). The city of Oujda, with its 1821 hectares, provides a ratio of 37 m² per inhabitant, considering all types of green spaces, for the 494,032 inhabitants recorded in 2014 (HCP, 2014). This exceeds the recommended optimal value of 25 m² per inhabitant. Tables 4 and 5 provide a comparison of the city of Oujda with other European and Moroccan cities. It is evident from these tables that this offering allows the city to compete with pioneering cities in this regard.

Table 4. European cities with a green space ratio below 26 m² per inhabitant (Morar *et al.* 2014).

City	Population	Ratio (m²/inhab.)
Buenos Aires	2.891.082	1,90
Tokyo	13.222.760	3,00
Istanbul	13.483.052	5,00
Barcelona	1.621.537	5,60
Malaga	568.305	7,79
Santiago (Chile)	6.026.797	10,00
Sarajevo	321.000	11,00
Toronto	2.615.060	12,60
Salzburg	148.521	13,44
Madrid	3.284.110	14,00
Turin	905.352	19,44
Birmingham	992.400	20,00
New York	8.244.910	23,10

Table 5. Moroccan cities with a green space ratio below 37 m² per inhabitant.

City	Ratio (m²/inhab.)	Reference
Rabat	36,2	(Bennani 2019)
Marrakech	7,7	(Bulletin Trimestriel de l'INRA Marrakech 2007)

The analysis of this ratio (m²/inhab.) by type of green space shows that forests and parks have the highest values. While these ratios may be satisfactory for forests, they fall far short of the minimum requirements for all other types, as shown in Table 6.

Table 6. Ratios (m²/inhab.) for different types of green spaces in Oujda compared to the thresholds recommended by the Green Plans Guide (Benabdeljalil & Boujmal 2008).

	Number of inhabitants			
	Threshold: 100 to 200.000 inhabitants and more			City of Oujda 494.032 inhab. (HCP, 2014)
Threshold by type of green space	Minimal	Medium	Optimal	
Parks, garden, squares	3,6	5,4	9	1,63
Residential green spaces	1,2	1,8	3	-
Green spaces along public roads	0,4	0,6	1	0,57
Sport and leisure grounds	1,2	1,8	3	0,56
Green spaces in public buildings	1,6	2,4	4	-
Parks or Forests	2	3	5	33,45
Total Threshold	10	15	25	**36,21**

The 1821 hectares of green spaces represent 23% of the city's total area. In comparison, in European cities, this participation ranges from less than 7.5% to more than 33.5% (Poelman 2018). Fig.22 below illustrates the relationship between these two ratios for several major cities worldwide.

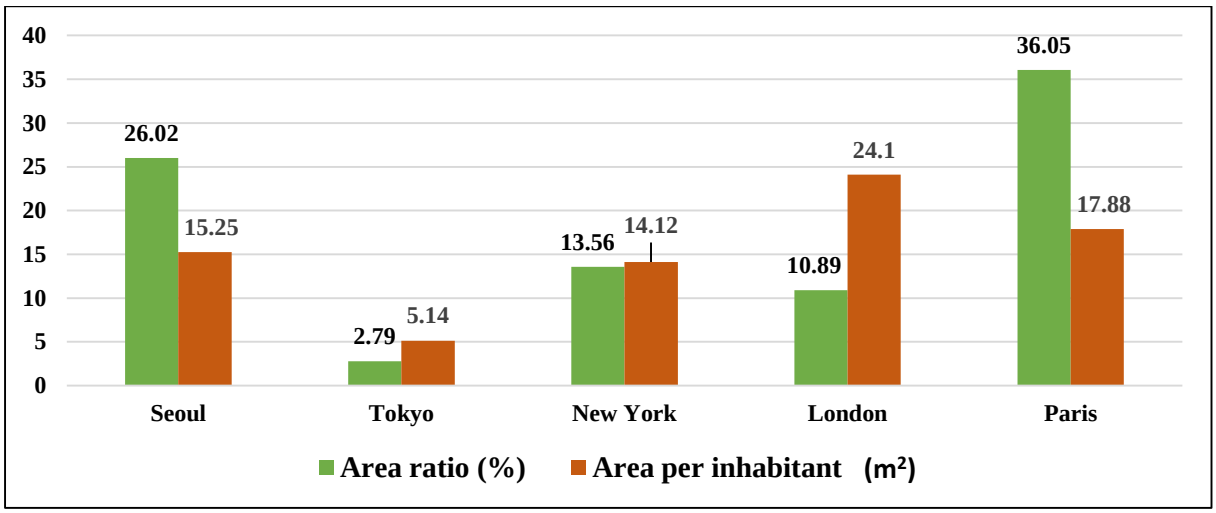


Fig. 22. Analysis of statistical measures of urban parks in important cities worldwide (Oh & Jeong 2007).

Additionally, the city of Oujda has 114 tree alignments totaling 132,457 linear meters, resulting in a ratio of 0.27 linear meters per inhabitant. This tree cover was more substantial in 2013, with over 212,000 linear meters of plantations and a ratio of 0.46 linear meters per inhabitant (Kouddane 2013). This decline is attributed to the removal of Olea europea trees by the urban municipality of Oujda due to severe allergic reactions caused by the pollen of these trees. In comparison, Agadir and Paris offer 1.30 and 1.50 linear meters per inhabitant, respectively (Kouddane *et al.* 2003). Apart from public green spaces, other green areas within cities are essential to consider. While not always accessible to residents, they still provide numerous ecological and health benefits. These areas include private gardens, natural areas, and agricultural fields or other fallow lands located within the urban perimeters. Their delimitation using remote sensing remains the most appropriate approach. The examination of vegetation in the urban area of the city using NDVI revealed a covered area of 2,331 hectares, constituting 29% of the city's total area. The northern and southeastern zones of the city appear to have the most extensive vegetation cover, while the dense neighborhoods in the west and around the downtown areas are the most deprived. The analysis of the map of green space service areas (Figure 6) identified a total of 5,805 hectares covered by the service area of at least one green space. This represents 72% of the city's total area, leaving 28% of the city without access to this green infrastructure. The northern and southern zones seem to be the most favored in this respect, while the western and central areas are the most deprived. This indicates a clear inequality in the distribution of these facilities, despite a substantial green capital (23% of the city is covered by green spaces, providing 37 m² per inhabitant). It demonstrates that while a minimum level of green space surface share is a prerequisite for ensuring decent proximity, a significant surface share does not guarantee adequate distribution throughout a city's territory. Urban green spaces must also be evenly distributed to fulfill relevant functions for the urban population. Studies by Poelman (2018), conducted on almost all European cities, showed a very weak correlation between these two indicators (surface ratio of green spaces on one side and accessibility on the other) ($r^2 = 0.09$), indicating that the proximity indicator adds information beyond the simple green surface share. For comparison, in the absence of a national study on the accessibility of green spaces, the city of Seoul (South Korea) has a coverage rate of 80% for green space service areas (Oh & Jeong 2007). Considering the population residing in areas without access to a green space, a total of 96,419 inhabitants (20% of the total population) are affected. The comparison made as part of the extensive study by Poelman (2018) shows that in nearly a quarter of the European cities studied, less than 2% of the population lacks accessible green spaces within walking distance. Some of the remarkable cities in this group include Madrid, Vienna, Turin, Stockholm, Prague, and Glasgow. In contrast, in about 10% of cities, this percentage is over 20% (e.g., in several cities in Romania and Italy). This additional indicator of green space supply provides important additional analysis. For instance, in Malmö, only 8.1% of the territory is covered by green spaces. However, more than 98% of the population has accessible green spaces within

a short walking distance (within 10 minutes). On the other hand, Brasov (Romania) also has a very high share of green spaces (40.8%), but this does not necessarily translate into good accessibility. Over 40% of the population lacks nearby green spaces that can be easily accessed (Poelman 2018). The deficiency in green space is not perceived in the same way in residential areas compared to dense urban fabric. Overlaying the vegetation cover map with green space accessibility areas highlights the extremely deprived sectors. These areas correspond to parts of the city lacking vegetation and without access to public green spaces. These zones emerge as priority areas for improving the quality of life for residents and achieving greater social equity. These deprived areas in the city of Oujda cover 1,236 hectares, representing 15% of the entire city's surface. The population corresponding to these highly deprived areas is estimated at 71,667 inhabitants, accounting for 15% of the urban population.

The analysis of the 400 responses obtained from the survey conducted revealed a general trend that can be summarized as follows: The city's residents are well aware of the role and importance of green spaces, which they regularly visit, even if they have to travel distances beyond accessibility norms. This interest is noteworthy, considering their low appreciation for the green infrastructure available to them, which they describe as insufficient, under-equipped, and not meeting their expectations. Their preferences lean towards large, multipurpose green spaces, such as periurban forests and multipurpose parks, where they seek tranquility, calmness, and proximity to nature. These practices and preferences seem to contrast with those identified in a study conducted in Greater Lyon (France) (Boutefeu 2011). According to that survey, 53% of respondents reported visiting squares 1 to 2 times per month (31% of responses). Parks experienced more significant visits (86% of respondents). 52% of square visitors traveled less than 500 meters to access them. 50 to 62.7% considered the number of available green spaces insufficient. Proximity squares ranked first among green space preferences for all age groups, followed by well-maintained urban parks. Natural parks ranked third in preferences (Boutefeu 2011).

CONCLUSION

The city of Oujda boasts a rich and green infrastructure, spanning over an extensive area of 1821 hectares and comprising 10 diverse types of green spaces, alongside 132,457 linear meters of tree alignments. A quantitative analysis of this green infrastructure reveals significant ratios of 37 m² per inhabitant and 23% of the city's total area, signifying a capital that surpasses both national and international recommendations. However, in comparison to other European cities, the ratio of 0.27 linear meters of tree alignments per inhabitant remains relatively low. Notably, forests stand out as the most well-represented green spaces, exhibiting a ratio of 33 m² per inhabitant, which greatly exceeds national recommendations, while all other types of green spaces fall below the suggested thresholds. A spatial distribution analysis of this infrastructure highlights a pronounced disparity among the various districts of the city, accentuating areas that are severely underserved in terms of green spaces. This disparity is further corroborated when examining the distribution of vegetation cover across the city and analyzing the service areas of different green spaces, ultimately affecting the overall accessibility of this infrastructure. By amalgamating the results of these two analyses, it becomes evident that the most underserved areas encompass 1,232 hectares, corresponding to 15% of the city's total area and affecting a population of 71,667 individuals (15% of the city's population). The survey results pertaining to the practices and expectations of the population further validate these identified trends and analyses. A majority of residents must traverse considerable distances before accessing green spaces (500 meters for 67% of respondents), and they perceive these green spaces as inadequately equipped, failing to meet their expectations. The preferences expressed by the residents depict a strong inclination towards expansive, versatile green spaces that exude tranquility, calmness, and a sense of natural ambiance.

The insights derived from this analysis, if effectively integrated, hold the potential to establish a comprehensive policy governing the development of green spaces. Such a policy necessitates urgent attention to the identified deficiencies and catering to the most underserved areas, in alignment with the objectives of sustainable development advocated by international organizations.

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