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Assessing The Impact Of Green Structures On Health And Well-Being: The Construction Of A Decision-Making Tool For The Metropolis Of Annaba

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Abstract
This study examines the influence of green structures on the health and well-being of users in the city of Annaba, Algeria. A multidimensional grid of indicators is employed to assess three areas: the city center, the outskirts, and the suburban extension. The indicators analysed include accessibility, safety, biodiversity, aesthetics, and connectivity, with the objective of determining their influence on the quality of life and satisfaction of the inhabitants. The findings demonstrate that green structures in the city center are more effective in terms of connectivity, accessibility, and quality of infrastructure, which contributes to their high level of attractiveness. Conversely, green spaces in peripheral and suburban extension areas show deficiencies in connectivity and accessibility. However, they remain popular due to their role in fostering sociability and perceived safety by users. The study emphasises the need for a differentiated approach to enhance the governance of green structures in each area. Key recommendations include improving the connectivity of green spaces in the outskirts, reinforcing security measures, and creating community facilities to promote social attractiveness. Additionally, it is recommended to establish environmental education programmes to encourage active citizen participation. Ultimately, the implementation of continuous performance monitoring systems for green structures will allow local authorities to adapt their policies more efficiently and sustainably.

Keywords: Health, well-being, green structure, environmental performance, sustainability, indicator grid, Annaba.

Introduction

The expansion of urban areas frequently exceeds the limits initially planned, spreading out in an unplanned and disorderly fashion. This has a detrimental impact on natural environments and sites that are essential to the quality of life. This phenomenon, characterized by the anarchic sprawl of towns and cities, results in a notable decline, or even the complete disappearance, of green corridors in favor of grey corridors. This dynamic increases urban disorder, degrades hygiene conditions and weakens ecosystems by disrupting natural life cycles (Aguejdad, 2009 ; Dechaicha et Alkama,2020).
It is necessary to pay special attention to green structures, which are fundamental components of the urban environment, in order to ensure the viability of urban living environments. In the present era, urban environments have become increasingly mineralised, leading to accusations that they are contributing to the deterioration of public health and the ill-being of populations. This is occurring through the generation of psychological, aesthetic and ecological trauma (Thompson, 2018). Indeed, many cities in the world, including Zurich, Jinan in China, Sheffield (UK), and Copenhagen, have prioritized the density of green spaces in their public health policies[1].

The importance of green spaces for public health has been highlighted by many studies. In France, a 10% increase in green spaces around homes could result in significant savings on healthcare costs. For instance, a 10% increase in green space could save €56 million/ year on asthma treatments and €38 million/ year on hypertension treatments (observatories des villes vertes, 2016 ; Nowak & Crane, 2006). An urban environment conducive to well-being and health not only encourages the

[1]Urban projects: The benefits of greenery - Cité Verte. (2013),
https://www.citeverte.com/fileadmin/Citeverte_Ressources/PDF/LETTRE_CITE_VERTE_3.pdf

development of communities and individuals, but also their overall fulfilment (Hartig et al. , 2014). However, rapid urbanization, often carried out without consideration for environmental quality or sustainable development principles, undermines these goals (UN Habitat, 2016).

In light of the climate crisis, which is further exacerbated by the global rise in temperatures and the intensification of climatic hazards (Yamanoshita, 2019), it is imperative to rethink the relationship between the built environment, the living environment and human health. The concepts of health and well-being are inextricably linked and require particular attention in this context. The concept of well-being is an essential dimension of overall health, encompassing the mental, social and physical aspects of the individual (Forsé, 2014). The World Health Organization (WHO) does not consider health and well-being to be synonymous; rather, it emphasis's their essential interconnection in order for an individual to feel well (OMS , 2012). The term "well-being," whether physical or psychological, is defined as a state of satisfaction resulting from the fulfillment of the body's needs and peace of mind, albeit often transient[2]. The concept of health is defined as 'a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity'. This definition of well-being, which is considered in its entirety. This approach to health is outlined in the French National Health Authority's (HAS) report on the general principles of health for minors and young adults[3].

This concept, which is challenging to define or measure in a universal manner, is shaped by the social, political, economic, and geographical context, thus impacting all facets of daily life (Forsé, 2014). Other concepts, such as satisfaction of needs, fulfilment and comfort, are closely related to the concept of well-being (LaGuardia & Ryan, 2000). In order to gain an understanding of well-being, it is necessary to adopt a multidimensional approach that takes into account both individual capabilities and the living conditions that support these capabilities. This approach, which goes beyond the traditional measures of income or gross domestic product, assesses well-being in terms of the freedoms and opportunities available to individuals to lead a life they value .(Mokhtari, 2017)

The measurement of well-being is a comprehensive approach that integrates both objective indicators (health, education, income) and subjective indicators (satisfaction, perceived happiness) for a more nuanced assessment (Diener, 2000). Composite indices, such as the Human Development Index (HDI) proposed by the United Nations Development Program (UNDP), combine these indicators to provide a comprehensive overview of well-being (UNDP, 1990). The application of these methods necessitates an in-depth contextual analysis, which should involve a range of stakeholders in an iterative process of assessment and adaptation (Stiglitz et al. , 2009).

In the urban context, the presence of nature, particularly through green and blue spaces, is crucial to the well-being of city dwellers. Many studies show that these spaces improve mental health, strengthen social cohesion and encourage physical activity (Bell et al., 2008). Research by Bowler et al. (2010) shows that green spaces are major contributors to human health, while Lee and Maheswaran (2011) highlight the positive impact of blue spaces on people's emotional state.

The incorporation of green structures within urban and suburban environments is not merely an aesthetic or recreational endeavor; rather, it serves a pivotal role in the advancement of public health and social well-being. It is imperative that these elements be incorporated into urban planning if we are to develop more resilient and sustainable cities in the face of the environmental and social challenges that we currently face (Wolch et al., 2014; Tzoulas et al., 2007). Such spaces serve as tangible instruments for enhancing well-being, conferring a superior quality of life upon all urban dwellers.

In Algeria, it seems necessary, on the one hand, to develop tools for measuring the impacts and roles played by these green structures in Algerian cities; on the other hand, to maintain but also improve the direct factors responsible for well-being and the maintenance of public health, within the framework of the development of decision-making tools.

Annaba, Algeria's fourth largest city, is undergoing development that is at odds with the development or maintenance of its green structures (Noui et al., 2023), even though it is suffocating under the fumes from its factories. Even where town-planning tools are in place, buildings are hastily constructed, with no concern for harmony, comfort, hygiene or the quality of the environment. The result is a living environment that has deteriorated under the massive pressure of housing and equipment production and densification. It is strongly affected by the increase in pollution levels, health problems, ... etc. (Noui et al. , 2009).

How can green structures improve health and well-being in urban Annaba, particularly in the context of climate change? What tools can be used to measure the impact of green structures on health and well-being?

The present work therefore focuses on establishing a tool which proposes a multidimensional approach, essentially grouping together dimensions such as the social, the psychological, the physical, the spatial, and so forth. This approach is scientifically valid insofar as the criteria relating to the two concepts (health and well-being) are all integrated into a single dashboard which is multidirectional in its reading and which is based on a sustainable development perspective.

The measurement exercise is applied primarily to three case studies: the city centre, the periphery and the extension of the city of Annaba. The results obtained will then be subjected to a critical analysis of the contributions and limitations of the effectiveness of the scoreboard, and more broadly, of the proposed approach.

[2] Medical Dictionary, https://www.dictionnaire-medical.fr/definitions/027-bien-etre.

[3] HAS,https://www.has-sante.fr/jcms/c_2835466/fr/presentation-generale-rbpp-sante-mineurs-jeunes-majeurs.

1.Methodology

The development of green structures in urban areas represents a pivotal aspect of sustainable urban development. Such structures offer a range of benefits, which can be classified into the following dimensions: social, aesthetic, psychological, ecological, economic and spatial (Manusset , 2012). In order to effectively assess these structures, it is essential to organize the aforementioned dimensions before establishing a grid of indicators. This is why a dimensional approach is of such significance. This is justified by:

- Global Understanding: The organization of the assessment into different dimensions permits the comprehensive capture of the multiple benefits of green structures, thereby ensuring a comprehensive assessment.
- Balance and relevance: A multidimensional approach guarantees that all essential aspects are taken into account, whether ecological, social or economic benefits, thus ensuring a balanced assessment.
- Facilitating Evaluation: The segmentation of benefits by dimension facilitates a more accurate evaluation, with each dimension having its own set of objectives.
- Strategic Planning: This enables the establishment of priorities for the enhancement of the green spaces that constitute this green structure, thereby facilitating the effective allocation of resources and the development of targeted policies.

The construction of the dashboard (Hadji, 2012; Hadji, 2013; Benzerara, 2019; Benzerara, 2022) is the pivotal step in this work, it is essentially made up of the dimensions and criteria relating to the two concepts mentioned above and mainly follows four steps: (1) overcoming conceptual divides, (2) the construction of a grid grouping statistical indicators, (3) the constitution of the specific indices (4) the assignment of a value (score) for each index.

1.1. Moving beyond the conceptual divides of health and well-being

The construction of indicators to assess well-being and health is based on a methodical process that progresses from the conceptualization of a framework to the development of measurable indices. The process commences with a conceptual analysis, which has already yielded a comprehensive and detailed conceptual model of well-being and health. This crucial stage enabled the delineation of the constituent dimensions of the concept, including physical, mental, economic, social, aesthetic, and ecological well-being. The definition of the dimensions (**Table 1.**) relating to these two concepts represents a crucial stage in the construction of the dashboard, as it enables the transition from an abstract state to a measurable one.

Table 1: Defining Dimensions

Specific themes	Main criteria	Dimensions
The quality of the green structure	Biodiversity	Ecological
	Air quality	
	La qualité de l'eau	
	Waste management	
Attractiveness	Accessibility	Spatial
	Connectivity	
	The quality of the layout	
	Physical security	
	Environmental diversity	Aesthetics
	Visuel quality	
	Production	Economique
	Assets and opportunities	
Well-being	Emotional well-being	Psychologica
	Stress reduction	
	Safety	
	Relaxation	
	Inclusion	Social
	Territorialité	

The dimensions and their objectives presented in the figure below have been developed from an approach based on an in-depth and diversified review of the scientific literature on green spaces and their contribution to urban well-being and sustainability.

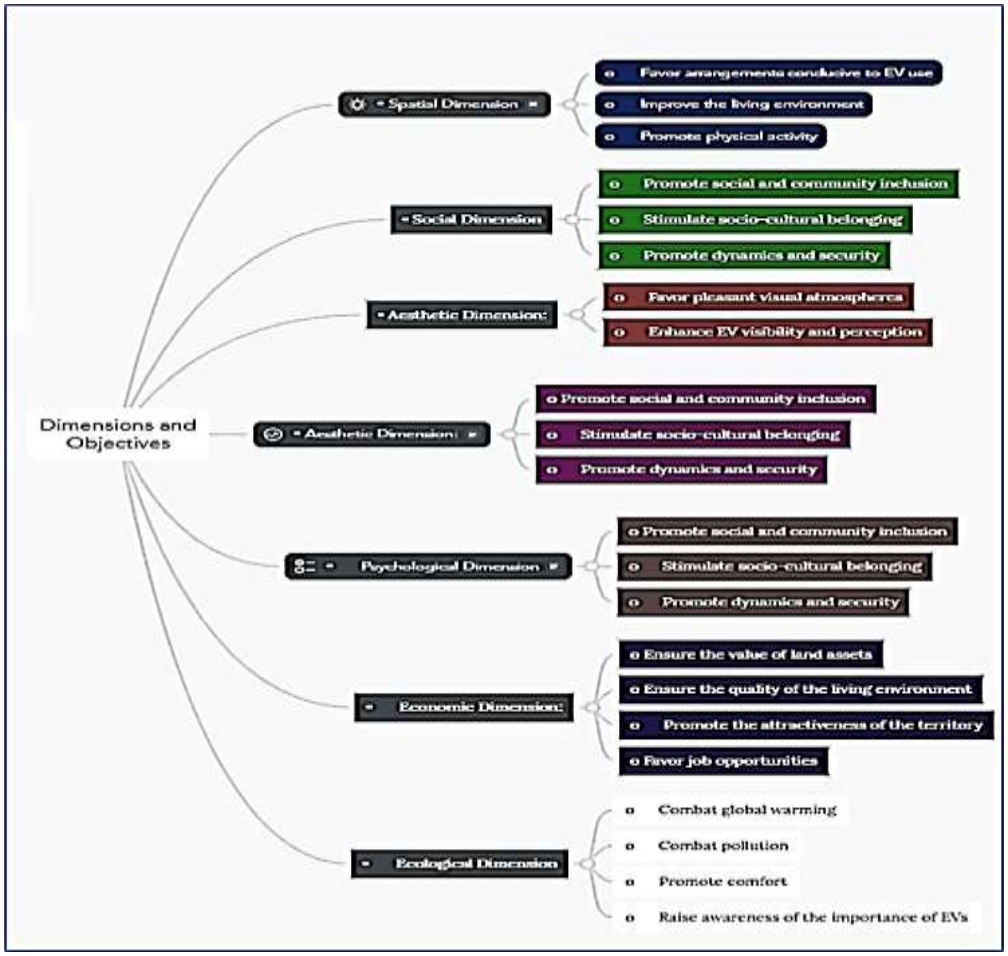

Figure 1. The six Defined Dimensions of the link between Green Structure and Well-being. (Author design 2024)

The spatial dimension emphasizes the significance of accessibility and integration of green spaces into the urban fabric, thereby promoting their regular use. Cohen et al. (2007) demonstrated that well-designed developments, connected to living spaces, encourage physical activity and enhance the quality of the living environment.

The social dimension emphasis's the part played by Green spaces in the cohesion of society. Peters et al. (2010) have demonstrated that they facilitate social inclusion by creating meeting places, thereby enhancing the safety and dynamics of neighborhood's. FRANKLIN, (2024)) also highlighted their ability to reduce social, spatial and environmental inequalities by developing new green spaces accessible to all..

The aesthetic dimension affects the way in which spaces are perceived by those who inhabit them. Chiesura (2004) demonstrated that the aesthetic appeal of green spaces has the effect of improving residents' moods and encouraging them to make these spaces their own. Furthermore, they enhance the appeal of a location for tourists, which in turn generates employment opportunities and income. The psychological dimension is associated with the positive impact of green spaces on mental well-being. The calming, stress-reducing and mood-enhancing effects of these environments have been documented by Ulrich et al. (1991) and Maas et al. (2006). They are therefore becoming an important element of the urban environment.

From an economic perspective, the impact of green spaces on attractiveness and local development is evident. Crompton (2001) has demonstrated that they enhance property values and stimulate the urban economy. Additionally, from an ecological standpoint, they play a crucial role in resisting global warming and management's decisions. Gill et al. (2007) have underscored their capacity to mitigate heat islands and preserve biodiversity, a notion also supported by Tzoulas et al. (2007).

1.2. The construction of a grid grouping statistical indicators

The construction of a grid grouping statistical indicators is based on the identification of a short list of indicators, selected according to their frequency of appearance in various sources. The reasoned choice of a concise list of indicators is part of an approach aimed at guaranteeing the effective measurability of the concepts under study. This approach enables the analysis to be concentrated on the most pertinent elements, thus ensuring the relevance and reliability of the resulting data. **(Table 2).** In order to ensure the reliability and relevance of the results obtained, it is essential that satisfaction scales and indicators take into account aspects such as the scale of measurement and temporality.

Table 2: Dimensions and Statistical Indicators for the Assessment of Well-being by green structures

Dimensions	Statistical indicators
Spatial	Access and degree of openness, Access for people with reduced mobility, Availability of parking, The modalities of soft traffic, The density of internal and external networks, The connections, Urban development: street furniture, Opportunities for physical activities, Maintenance and upkeep, Degree of closure and number of barriers, Night animation Street safety furniture,
Social	Participation in community events and activities, Specific programming for marginalized or disadvantaged people, Volunteering and collaborative projects, Forums and collaboration meetings, Conviviality and urbanity, Exchanges and meetings, Perception and sense of security, Crime and incident rates,
Aesthetic	Diversity of aesthetic elements, Cohesion and diversity, Consistency and relevance, The visual quality and panoramic views, Biodiversity, Decoration objects Visual and fonction Local materials Anthenticity Colar Urban design
Ecological	Richness and biodiversity, The freshness and purity of the air, Visibility, The clarity and transparency of the water, Connection and harmony, Waste management, Care and maintenance**,** Sustainability, Community outreach
Economic	Increased real estate value of properties located near green spaces, Attractiveness, Heritage value, Job creation, The positive economic impact of the events and activities organised, Management, The diversity of uses, Tourist attractiveness, Public-public, public-private, private-private partnership,
Psychological	Emotional well-being, Attendance rate, Satisfaction levels, Stress reduction, Usage rate, Feeling of attachment, Connectivity, Security, Comfort of use,

1.3.The constitution of particular indices

The objective of the present approach is to develop a matrix of specific indices that will facilitate a rigorous assessment of well-being and health in relation to urban green structures. This process is founded upon robust methodological principles, obtened from a comprehensive review of the scientific literature and an in-depth analysis of international best practices. A 16 indices were selected based on their empirical relevance and their capacity to keep the multiple dimensions of urban well-being, including social, ecological, aesthetic, and economic aspects **(see Table 3).** The selected indices create a multidimensional approach, encompassing a diverse array of factors, including stress reduction, air quality improvement, thermal regulation, and the accessibility and utilization of green spaces. Each index has been selected on the basis of its reliability, scientific validity, and capacity to provide quantifiable and comparable data in some urban contexts.

The indices thus create an indispensable analytical framework for researchers, urban planners, and political decision-makers, enabling the assessment of the efficacy of interventions in green spaces and the optimization of their long-term management.

Table 3: Synthetic Criteria and Specific Indices for the Evaluation of Green Spaces in the Green Structure of Annaba

Dimensions	Synthetic criteria	Specific indices
Spatiale	-accessibility -connectivity - use of space -Quality of the Physical Environment -security	-Connectivity and Accessibility Index (CAI) -Space Utilization and Quality Index (SUQI) -Safety Index (SI)
Social	-Social inclusion -Community cohesion - Diversity of users -Social interaction -Perceived safety	- Inclusion and Social Cohesion Index (ISCI) -Diversity and Social Interaction Index (DSII) - Perceived Safety Index (PSI)
Ecological	-Biodiversity -Air quality -Water quality -Waste management -Carbon footprint	- Biodiversity and Air Quality Index (BAQI) - Water Quality and Waste Management Index (WQWMI) - Carbon Footprint and Sustainability Index (CFSI)
Economic	-Value of real estate -Job opportunities -Tourism and Economic Impact -Investment and Development	- The Land Value and Employment Opportunities Index (LVEI) - The Tourism and Development Impact Index (TDII)
Esthétique	- Visual atmospheres -Amenities of green spaces -Landscape integration - Visual harmony	- The ambience and visual amenity index (AVAI) - The Landscape Integration and Visual Harmony Index (LIVHI)
Psychological	-Mental well-being Stress reduction -Connection with nature -The global satisfaction	- The Wellbeing and Stress Reduction Index (WBSRI) -The Nature Connection and Psychological Safety Index (NCPSI) - The Global Satisfaction Index (GSI)

1.3.1. index notation and values.

Once the indices have been defined, they must be measured in order to obtain the requisite scoring and index values. A quantitative and qualitative evaluation of the indices allows the identification of thresholds for the impact of the green structure on the health and well-being of users, employing a 5-level rating scale.

To conduct the assessments, each index is assigned a qualitative and quantitative unit of measurement, referenced to a nominal scale where the presence or absence of an indicator is equivalent to a value of 1 or 0, respectively. Consequently, the weight of each index is 01 (Talavera-Garcia, 2015 ; Erahimzadeh, 2016 ; Benzerara, 2019, 2022).The results of the calculation of the scores obtained for each case study are presented in the form of a radar chart, which contains all the indices. The scoring exercise is subjective, but necessarily based on simulation, measurement and calculation. Once the quoted value of the specific indices has been established, it must be compared with a reference value, which may take the form of ratios, norms, standards or examples. In this case, it is necessary to establish a multi-source reference from the various bibliographic searches, as this will serve as a guide to ensure the functionality of the proposed approach.

1.4. Presentation of case studies

The case studies are presented in order to illustrate the distinctive characteristics of Annaba. These include its geostrategic position, its natural potential and its diverse infrastructure. The city's 80 km coastline on the Mediterranean Sea confers a degree of regional influence and opportunities for international openness. The city benefits from a diverse and multimodal infrastructure network, encompassing land, sea, and air infrastructures, traversed by many national and regional roads, including the RN44 and RN16. Additionally, the city is home to several significant industrial complexes, including the Asmidal

fertilizer complex in Seybouse and the El Hadjar steel industry. Furthermore, it is also home to two international university centers.

Since its designation as a development pole at the conclusion of the 1960s, Annaba has progressively established itself as a regional hub, transcending the designation of an agglomeration or metropolitan area. It is positioned as a future metropolis (SNAT 2030). The operational area is continuing to expand, encompassing the entire Annaba plain and creating a novel urban space. The urban dynamism of Annaba is not contingent on its local potential in the broad sense. The city's industrial base has facilitated its expansion into the surrounding area, resulting in the formation of a metropolitan area and the transformation of the region's former agricultural landscape.

The process of urbanization, marked by urban sprawl, has been disrupted or accelerated by the population explosion and the Ex urbanization of activities and functions. This led to significant changes in the organization, functioning and network of relationships between the city and the new spaces. These transformations have had significant impacts on the environment and its sustainability, breaking the resilience of the territory. There is an advance in urbanization (grey weft) and a decline and rupture in the green structure of the metropolis (to the detriment of the green weft). Noui et al. 2023)

The process of urbanisation, characterised by urban sprawl, has been disrupted or accelerated by the population explosion and the ex-urbanisation of activities and functions. This resulted in substantial alterations to the organisational structure, operational procedures and network of relationships between the city and the emerging urban areas. These transformations have had a considerable impact on the environment and its sustainability, eroding the resilience of the territory. The process of urbanisation is advancing (as evidenced by the growth of grey wefts), while the green structure of the metropolis is simultaneously declining and rupturing, with a corresponding detriment to the green wefts . (Noui et al., 2009)

1.4.1.Location

Annaba is located on the southern shore of the Mediterranean basin, 600 km from Algiers in the west of the Khalij El Morjane golf course. The geographical particularity of the future metropolis is the fact that it is in contrast between the mountains "a brutal relief" and a fairly flat and coastal plain. Like other coastal regions of Algeria, Annaba as a whole has Mediterranean-type traits with sub-humid and humid bioclimatic levels, i.e. a mild wet and dry wet season. It is the fourth largest city in Algeria after Algiers, Oran and Constantine. It is located in the extreme north-east of the country, 600 km from the capital Algiers, open to the Mediterranean coast for 80 km. It is located between the northern latitudes 36°36' and 37°05' and the eastern longitudes 07°17' and 07°49' and covers an area of 1439.20 km², or 0.06% of the national territory. Annaba is geographically bounded:

- To the north: by the Mediterranean Sea,
- To the south: by the wilaya of Guelma,
-To the east : by the wilaya d'El Taraf,
- To the west: by the wilaya of Skikda.

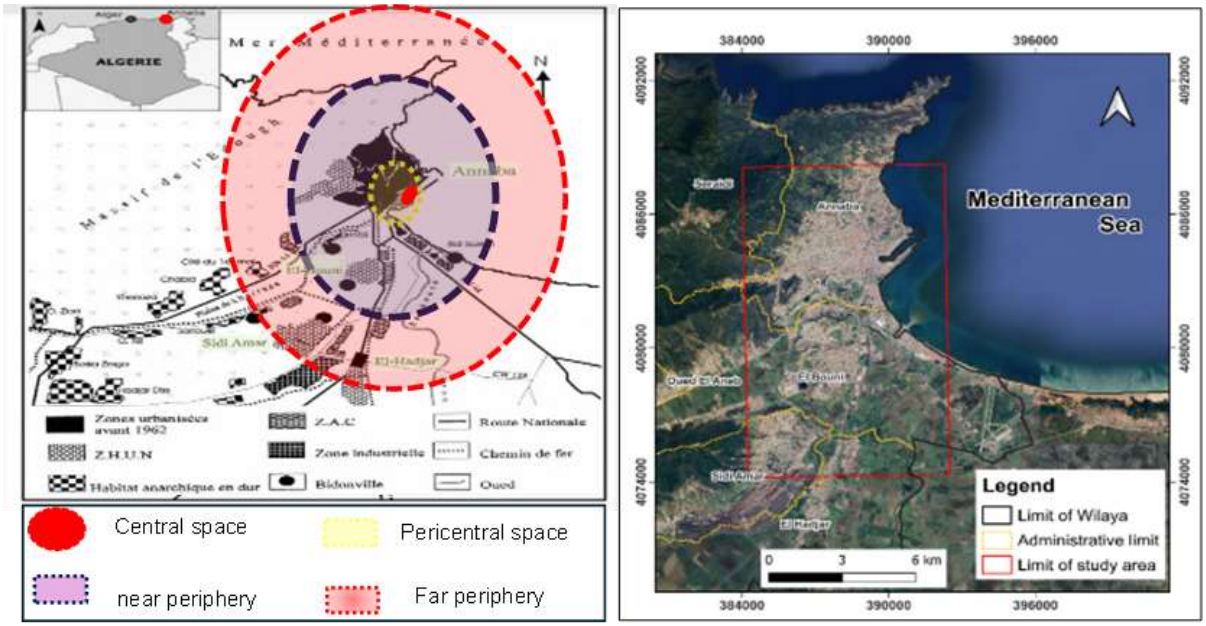

Figure. 2 Location of the study site at Annaba

2. Results and discussions

2.1. Evaluating the Performance of Green Structures: A Comparative Analysis Across three Urban Areas

The figure below, presented in the form of a radar chart, enables the visualization of the values of the various specific indices for each case study, categorized according to location (city center, periphery, extension). This graphical representation constitutes a valuable tool for the comparative and critical analysis of the performance of green structures. The graphic representation offers an immediate insight into the variations between the areas, thus facilitating the identification of disparities in terms of public health, user well-being and environmental sustainability.

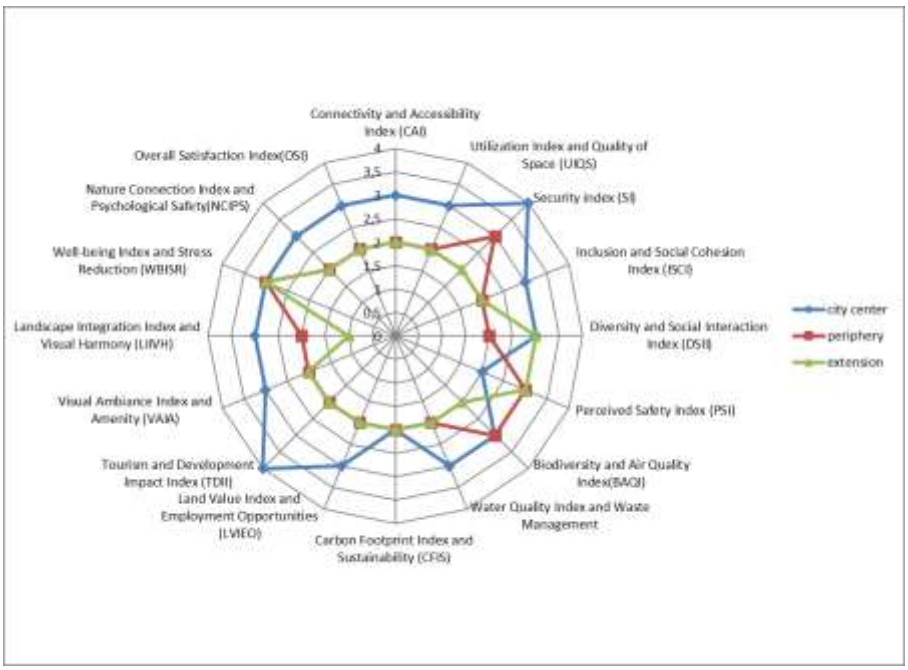

Figure. 3 The values of the well-being and health indices Via the green structure (source, authors, 2024)

The comparative analysis of the indices reveals significant differences between the urban areas under study. For instance, the relatively high values of the accessibility and connectivity indices in the city center reflect a superior integration of green structures into the dense urban fabric, with infrastructures that facilitate access to and utilization of green spaces. Conversely, the periphery and the extension exhibit lower indices in these areas, indicating a reduced accessibility of green spaces, potentially associated with a more pronounced urban sprawl and inadequate infrastructure connectivity.

The observed disparities in indices of social cohesion and diversity of social interactions are also noteworthy. The presence of green spaces in the downtown core appears to facilitate the needs of a diverse population, thereby promoting social inclusion. Conversely, the periphery appears to be experiencing a partial exclusion of certain communities, which suggests the necessity for the implementation of more inclusive urban planning policies in these regions.

A further crucial aspect of the analysis pertains to the role of cues pertaining to perceived and physical safety. The downtown area is associated with higher values, indicating that users perceive it as a safe environment within well-landscaped green spaces that are often subject to greater monitoring. In contrast, the periphery and extension exhibit comparatively lower safety ratings, which can be attributed to a dearth of security features or a negative perception of these spaces. This necessitates the implementation of targeted interventions to foster user confidence.

From an ecological standpoint, the index of biodiversity and management of natural resources is considerably higher in the extension and peri-urban areas, where green spaces benefit from a larger surface area and less anthropogenic pressure. Conversely, the city center, despite its endeavors to incorporate natural elements into urban design, encounters constraints due to high urban density and spatial constraints. This discrepancy underscores the necessity for strategic urban planning that incorporates ecological corridors and bolsters biodiversity in central areas.

Psychological indices, such as the well-being and stress reduction index, also reveal interesting trends. Green spaces in the city center appear to be ideal for relaxation, probably because of their accessibility and the quality of the facilities available to users. On the other hand, the outskirts, although offering a more natural setting, seem less suited to reducing stress, due to their often inadequate management or design that is less geared to users' needs.

From an economic standpoint, the index of land value and economic opportunities is demonstrably higher in the city center, where green spaces contribute to the desirability of property and local development. The periphery and extension benefit from more extensive green spaces, yet they fail to fully exploit their economic potential. This may be indicative of a lack of investment in these areas or an underutilization of the infrastructure.

2.2. User Perceptions and Spatial Dynamics of Green Structures

An analysis of the performance indices (**Figure 3.**) shows that several indices, in particular the ICA (Index of Connectivity and Accessibility), ISG (Index of General Satisfaction), IBRS (Index of Well-being and Stress Reduction), IAVA (Index of Visual Ambience and Pleasure), IVOE (Index of Land Value and Employment Opportunities), water quality and waste management, IBQA (Index of Biodiversity and Air Quality), ICNSP (Index of Connectivity to Nature and Psychological Safety), IIPH (Index of Integration and Visual Harmony), IDIS (Index of Diversity and Social Interaction), and the IBQA (Index of Biodiversity and Air Quality), ICNSP (Index of Connection to Nature and Psychological Safety), IIPH (Index of Landscape Integration and Visual Harmony), IDIS (Index of Diversity and Social Interaction), IICS (Index of Inclusion and Social Cohesion), IS (Safety Index) and IUQE (Index of Use and Quality of Space) for the city centre exceed the performance threshold of 3. This shows that the green structures located in the city centre exceed the performance threshold of 3. This shows that the green structures located in this area are performing very well, reflecting improved connectivity, better use of green spaces and a higher quality of life for users.

In the periphery, indices such as IBQA, IBRS, IIPH, IDIS and IS also show performances above the threshold of 3, indicating satisfactory results in terms of biodiversity, well-being, landscape integration and perceived safety in these areas, even if accessibility remains more restricted compared to the city center.

However, other indices are below this threshold, both in the city center and in the periphery and extension. For the city center, the ISP (Perceived Safety Index) and IECD (Carbon Footprint and Sustainability Index) indices are below expectations, suggesting that more efforts need to be made to improve users' perception of safety and reduce the ecological footprint of these spaces. On the periphery and extension side, several indices show insufficient performance, such as the ICA, ISG, ICNSP, IIPH, IAVA, IITD (Tourism and Development Impact Index), IVOE, IECD, as well as indices relating to water quality and waste management. These weaknesses reveal green infrastructures that are less well connected, less attractive and less adapted to the expectations of users, particularly in peripheral and extended areas. The observed differences in index values for each case study can be explained by two main factors:

-Typology of green spaces : The types of green spaces vary from one area to another, and the diversity of urban parks and gardens in downtown Annaba gives this area a greater richness in terms of biodiversity and accessibility. The city center also benefits from a long historical and administrative tradition that has favored the development of these green spaces over time.

-User perceptions: User perceptions make a strong contribution to the performance attributed to each area, as shown in **Figure 4.** Green spaces in the city center are generally perceived to be of a higher quality than those in the periphery and the extensions. This difference in perception is partly due to the better accessibility and diversity of development in the city center, as opposed to peripheral areas where green infrastructure appears to be less developed or less well perceived by residents.

The analysis reveals considerable discrepancies in performance between the city centre, the periphery and the extension. It also emphasises the pivotal role of green space typology and user perceptions in determining the success or failure of urban green spaces. It is imperative that sustained efforts be made to enhance the accessibility and appeal of green spaces in the periphery and in extension, with due consideration given to local particulars and the expressed needs of users.

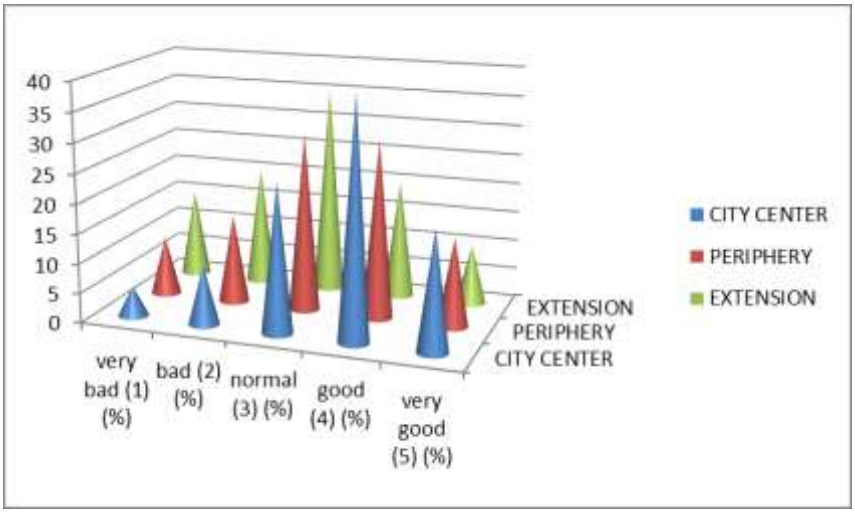

Figure 4. evaluation of green structures by users/case study **(source,** authors, 2024**)**

In order to gain a deeper insight into the underlying dynamics of green space performance in each study area, it is important to incorporate a subjective dimension into the concepts of 'health' and 'well-being'. This can be achieved by conducting sociological surveys of users (see appendices). This approach enables the analysis of users' perceptions of the services provided by green spaces and the establishment of correlations between objective performance indicators and users' perceived satisfaction.

The case of the city center

The results obtained for the city center **(Figure 5.)** indicate that this is a vibrant and highly frequented space, both in terms of the quantity and quality of time spent in green spaces. Figure 3 illustrates a high attendance rate, both for daily visits and for more infrequent visits. The data suggest that individuals engage with green spaces in the city center on a regular and

extended basis. This phenomenon can be attributed to the positive impact of green infrastructure on well-being and health, which in turn enhances the attractiveness of these locations.

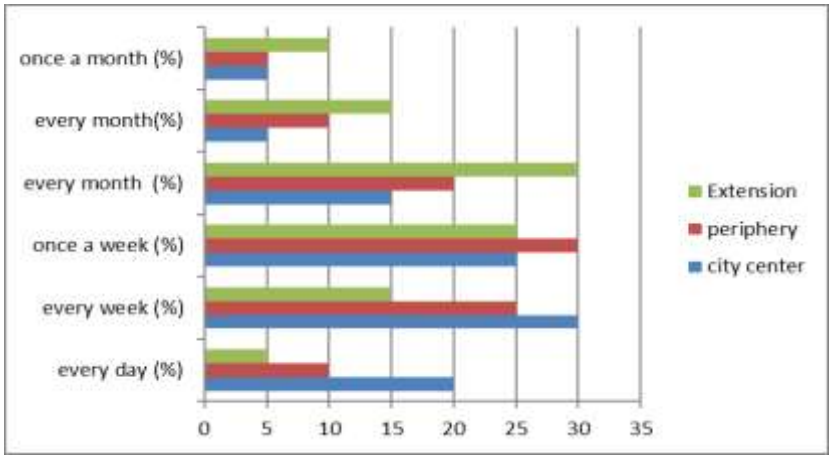

Figure 5. Frequency of visits to green spaces **(source,** authors, 2024**)**

Figure 6. corroborates this trend by underscoring user satisfaction above the performance threshold for a number of pivotal criteria, including accessibility, cleanliness, safety, aesthetics, layout, and upkeep and maintenance. The ratings for these indices exceed 3, indicating a high level of satisfaction with the green spaces in the city center. The appeal of these locations is not solely contingent upon their design and management; it is also contingent upon their ability to meet the needs of users in terms of quality of life and relaxation. These findings illustrate the necessity of maintaining these exemplary standards to guarantee the continued and satisfying uses of green spaces.

The indicators pertaining to aesthetics and safety exhibit a notably high level of satisfaction, surpassing the threshold of 3 (as illustrated by the red boxes in **Figure 6.**). This highlights the significance of visual and safety elements in the perception of green spaces as locations for relaxation and social interaction. Furthermore, the cleanliness and maintenance of the premises are also perceived as satisfactory, which contributes to the maintenance of a welcoming and pleasant atmosphere for regular visitors.

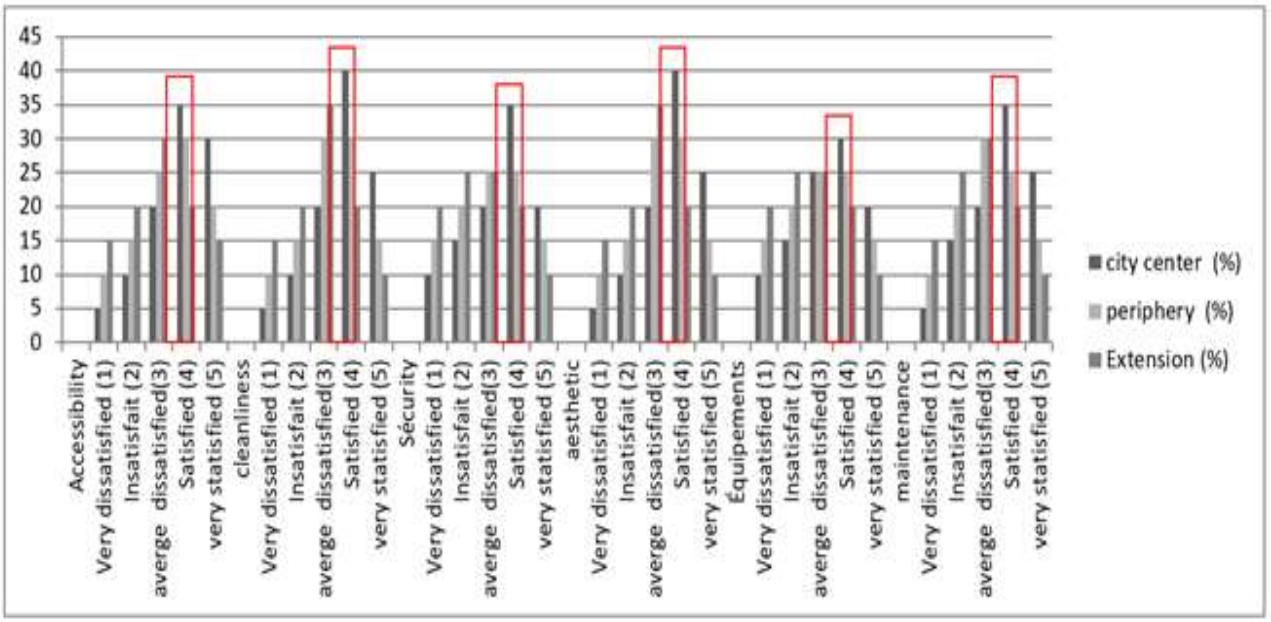

Figure 6. The values of the indicators attributed by the respondents/case studies **(source,** authors, 2024**)**

The case of the downtown area illustrates that the maintenance and accessibility of green spaces, associed with the implementation of quality infrastructure, have a considerable influence on user satisfaction. Effective management of these spaces has been shown to increase their visitation, while contributing to improved quality of life and well-being for residents and visitors. These results underline the need to invest sustainably in the maintenance and enhancement of green spaces, thus ensuring their sustainability and attractiveness.

The results indicate a clear preference among users for green structures located in the city center, despite a relatively low Perceived Safety Index (PSI) (**Figure 3.** 1). This suggests that, although security is generally a key factor in the attractiveness of urban spaces, it becomes secondary to other dimensions perceived as more influential in this specific context. Indeed, the

indirect impact of perceived insecurity on the duration of visits is evident (**Figure 7**.). However, users continue to use the green spaces in the downtown area in large numbers, staying there for a relatively long period of time, often more than 2 hours, despite safety concerns.

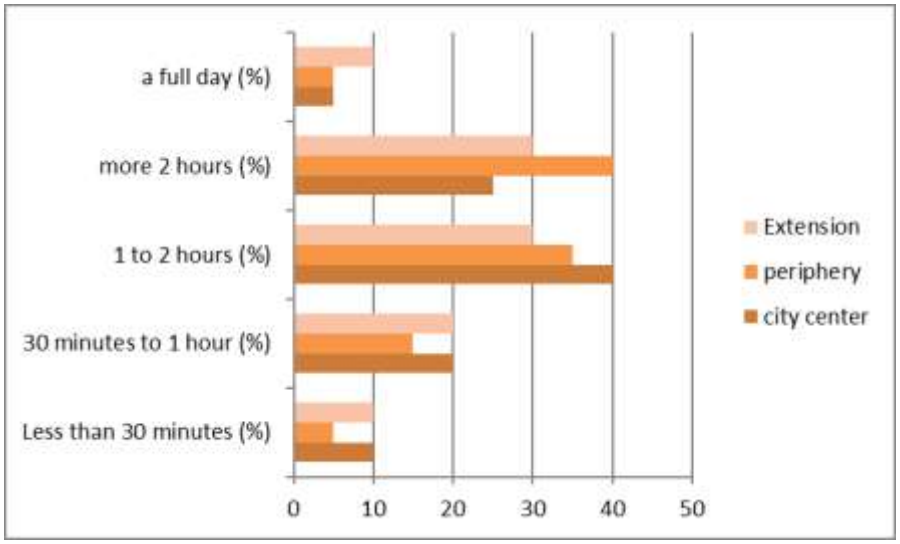

Figure 7. Visit durations/case studies **(source,** authors, 2024**)**

Figure 7. shows a distribution of visit durations according to the case studies, where the city center is distinguished by a large number of users staying for more than two hours. This shows that the perception of other dimensions (accessibility, aesthetics, maintenance, etc.) takes precedence over safety in the criteria for the use of these green spaces.

The Case of the Periphery and Extension

In contrast to the city center, the values of the majority of indices in peripheral and extension areas remain below the performance threshold (**Figure 3.**). However, these areas show an encouraging weekly attendance rate, both in quantity (number of users) and quality (duration of visits), as illustrated in **Figure 7.**

In this context, the indices traditionally considered as drivers of attractiveness (such as accessibility and the quality of infrastructure) become optional for users of these areas. Indeed, in the periphery and the extension, it is the safety index that plays a major role in the sustainable use of green spaces, particularly for extended visit durations of 2 hours or more. In this context, the concept of security is more subjective than material. A strong attachment to the place in question serves to reinforce a sense of territoriality, which is largely determined by the length of time that users have resided there.

Despite the relative weakness of green infrastructure compared to the city center, these spaces in peripheral and extension areas continue to play an important role in creating social links. **Figure 8.** shows that sociability is one of the main reasons for frequenting these green structures. These spaces thus become privileged places for meeting and social interaction, which partially compensates for the lack of certain environmental or aesthetic characteristics. Thus, for these areas, the dimensions studied in this work are not the main drivers of the attractiveness of green spaces, unlike in the city center where the quality of the infrastructure and aesthetics take precedence. Here, it is mainly the social needs of users that justify their use of green spaces, thus reinforcing the role of these places as spaces for socialization within local communities.

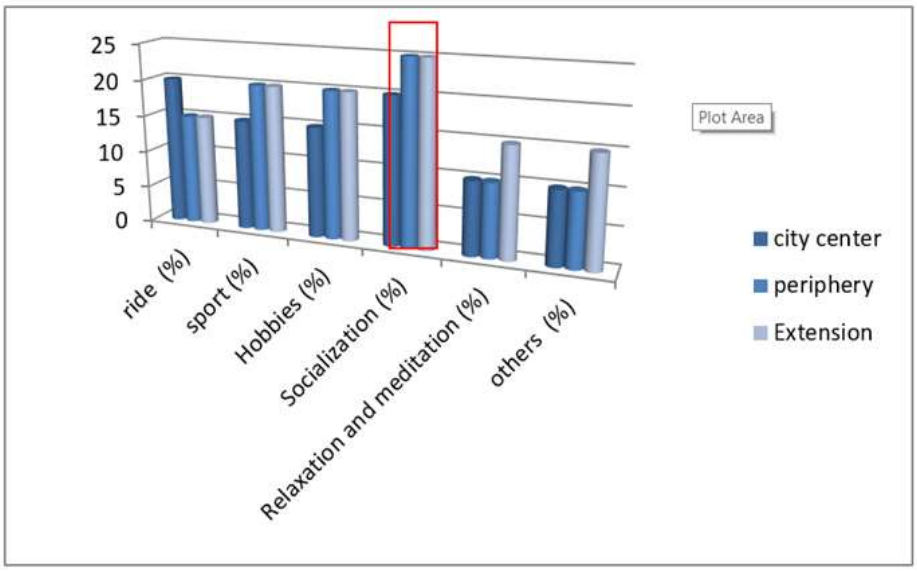

Figure 8. Reasons for attendance **(source,** authors, 2024**)**

Conclusion

In conclusion, the assessment of the impact of green structures on the health and well-being of users' needs a multidimensional approach, which should employ a variety of tools, including indicator tables, sociological surveys and quantitative and qualitative analyses. This type of assessment offers a more comprehensive understanding of the impact of green structures on the living environment of urban residents, taking into account the physical, psychological, social and ecological dimensions. Although the evaluation of green structures remains partially subjective, the proposed method introduces a greater degree of methodological rigour through the cross-referencing of different analytical scales and the assurance of proximity between the results obtained and the reality.

The application of this multidimensional approach allows for the formulation of recommendations for the development of green spaces and the identification of aspects that require improvement. Indeed, this evaluation highlights the specific factors that increase the attractiveness of green spaces, particularly in urban centers, where aspects such as accessibility, aesthetics and integration into the urban fabric are responsible for high user satisfaction.

It is also important to acknowledge that other factors are of significant importance, particularly in peripheral and extension areas, where the perception of safety and sociability appear to be key motivators for the utilization of green spaces. These spaces, despite occasionally exhibiting deficiencies in terms of equipment or connectivity when compared to those in the city center, are perceived by residents as privileged locations for social interaction and the establishment of community connections. Therefore, in these areas, the social dimension of green spaces becomes a more influential performance criterion than purely physical or environmental criteria.

This evaluation process enabled the identification of the key levers influencing the attractiveness of green spaces in the different urban areas under study. The results demonstrate that in urban centers, the quality of infrastructure and biodiversity are significant factors in enhancing user well-being. Conversely, in peripheral and extension areas, subjective factors such as security and social interaction assume greater importance. These findings emphasize the necessity for a differentiated approach in the design and management of green spaces, aligning their development with the specific needs and expectations of local communities.

In addition, this study shows that ecological corridors and nature-based solutions need to be integrated into urban planning to enhance ecological connectivity and promote long-term environmental sustainability. Adaptive management of green spaces, taking into account social and ecological dynamics, is essential to ensure their resilience in the face of current challenges such as climate change, urban growth and anthropogenic pressure.

Finally, this evaluation process highlights the need for participatory governance in the management of green spaces, directly involving users in the decision-making process. The integration of users' perceptions and expectations into development policies will make it possible to better respond to the specific challenges of each area, while strengthening citizens' ownership and attachment to these spaces. This participatory process is essential to maximize the ecological, social and economic benefits of urban green spaces, while ensuring their sustainability and adaptability to future developments.

Implications and limitations of the study

This study contributes to the existing literature by providing a multidimensional assessment of green structures in urban areas and their impact on the well-being of users. Using a framework based on several indices (accessibility, safety, biodiversity, etc.), the study helps to better understand the relationship between the quality of green spaces and public health.

As for the results obtained, they make it possible to better guide political and urban development decisions. Cities can use this methodology to target specific improvements in areas where green structures are deemed insufficient (such as the periphery and extension), or to strengthen existing assets in areas such as the city center. The use of detailed indicators allows for more detailed management of green spaces.

The study also highlights the significant disparities between urban areas (city center, periphery and extension), thus highlighting the need to adapt planning policies to the socio-spatial particularities of each area. For example, the city center offers better integrated green infrastructure, while peri-urban spaces and extensions require specific interventions in terms of safety and attractiveness.

On the other hand, the results also show that indices such as connectivity, perceived safety, and the quality of facilities directly influence the well-being of users. Areas with good green infrastructure improve the quality of life of city dwellers, reduce stress and provide spaces for socialization and relaxation.

For the limitations of this study, one of the major limitations lies in the subjectivity of the data collected by sociological surveys. Users' perceptions may be influenced by temporary factors, such as the state of play on the day of the survey, or by individual personal experiences. These factors can bias the evaluation of green spaces.

The study focuses on a limited number of case studies (city center, periphery, extension), and although this allows for an in-depth comparative analysis, the generalization of the results to other urban contexts remains limited. It would be necessary to replicate this study in other cities to verify whether the observed trends are generalizable nationally or internationally. While it uses a rigorous set of indicators to assess green structures, some important aspects may not be captured by these indicators. For example, dimensions such as the long-term impact of green spaces on users' mental health, or more precise data on the evolution of urban biodiversity, are difficult to measure in this context. In addition, the results reflect a situation at a given point in time. The assessment of the impact of green spaces on the well-being of users could evolve over time with changes in the layout, maintenance of spaces, or demographic changes.

Perspectives and recommendations

The Perspectives is as follows:

a. **Longitudinal studies**: An interesting perspective to deepen the results would be to conduct longitudinal studies to monitor the evolution of user perception and the performance of green structures over time. This would allow for long-term trends and a better understanding of the impact of infrastructure improvements or degradations.

b. **Broadening the geographic scope** : It would be relevant to extend the scope of this study to other cities, especially those with different urban dynamics (secondary cities, rural areas, metropolises). This would allow for an assessment of whether the trends observed in this study are similar in other geographic and socio-economic contexts.

c. **Development of an interdisciplinary approach** : To better assess the impact of green structures on well-being, it would be relevant to adopt an interdisciplinary approach combining urban planning, ecology, environmental psychology and public health. By integrating experts from these different fields, the analyses could be more complete, offering a global vision of the benefits of green spaces for the population.

It is recommended that:

a. The findings of the study indicate that green spaces situated on the outskirts and in extensions are characterized by a deficiency in connectivity and accessibility. It is recommended that multimodal transport networks (encompassing cycling, walking and public transit) be developed in order to enhance accessibility to these spaces, while simultaneously establishing ecological corridors that facilitate connectivity between green areas.
b. The perception of safety is a pivotal element influencing the utilization and accessibility of green spaces. It is crucial to reinforce security protocols, including lighting, surveillance, and the presence of security personnel, in peripheral and extended green spaces to foster a sense of safety and encourage regular usage.
c. It is essential to priorities the social appeal of green spaces. The extent to which green spaces on the outskirts are used is contingent upon the degree of sociability that they afford. To reinforce this aspect, it is advised that additional community facilities be established within these locations, such as playgrounds, sports fields, meeting spaces, and community gardens. This will serve to reinforce social interactions and enhance the appeal of these locations.
d. It is recommended that education and awareness programs be developed. In order to enhance citizen participation in the conservation and utilization of green infrastructure, the implementation of educational programs may prove beneficial. Such initiatives might include biodiversity workshops, ecological awareness activities, and community events designed to foster collective ownership of green spaces.
e. It is imperative to implement a continuous monitoring system to assess the performance of green spaces. This system should utilize the indicators outlined in this study to evaluate the effectiveness of green space development and management strategies. Such monitoring will facilitate the adaptation of green space development and management policies in accordance with the evolving requirements of users and environmental challenges.

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