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Humanizing sustainable development through green spaces: a case study of Saudi cities

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This research examines the significance of green areas in urban communities in contributing to quality of life and fostering sustainable development for Saudi cities, specifically desert cities. The quantitative method was adopted relying on municipal records and population data, specifically for public green areas such as parks and gardens. The analysis was conducted with reference to the City Prosperity Index (CPI) to ascertain the role of green spaces in urban livability and sustainability. The results revealed enormous disparities in per capita green space provision across Saudi cities. While the Northern Borders region contributed 21.08^2 per capita, Jeddah contributed only 3.21^2 per capita. This observation stresses the immediate necessity to maximize urban greenery to augment quality of life and urban resilience. The results stress the vital importance of green spaces in advancing public health, supporting social cohesion, and promoting climate resilience. Moreover, the research highlights the importance of governmental programs, including the Saudi Green Initiative and the Humanization of Neighborhoods Initiative, that tend to solve these issues by promoting the use of drought tolerant plants and enhancing urban greening. The report ultimately presents key suggestions, including optimizing green space density, encouraging fair distribution, and raising people's appreciation of the environmental and social values of green infrastructure. These actions must be taken to foster sustainable urban development and enhance the overall well-being of urban residents.

KEYWORDS

humanization of urban spaces, sustainable development, Saudi cities, urban green infrastructure, environmental quality, quality of life

Introduction

Green spaces are essential in achieving urban sustainability, playing a significant role both socially and environmentally in cities. They offer various benefits, from encouraging physical activity to fostering social interaction and improving mental health. Research consistently shows that urban green areas enhance public health, extend life expectancy, and elevate the overall quality of life in city environments. This aligns with the many examples that highlight the importance of green spaces in promoting a healthy and active urban lifestyle (Addas, 2023b).

From an environmental perspective, green spaces address urban challenges such as the urban heat island effect and the intensity of heavy rainfall (Falchetta and Ahmed, 2023). They support biodiversity, improve air quality, and contribute to ecosystem revitalization, maintaining the balance of urban ecology. These spaces act as natural buffers, offering critical environmental management solutions and promoting environmental justice by providing

accessible spaces that support physical and mental well-being, thus contributing to more equitable health outcomes in cities.

However, in arid and semi-arid regions like Saudi Arabia, water scarcity complicates the maintenance of green spaces. Innovative methods, such as introducing drought-tolerant plants and advanced water management systems, are necessary to ensure that green spaces thrive without depleting water resources (Addas, 2023a). This resilience-focused approach aligns with regional green infrastructure strategies designed to prepare urban areas for future challenges and support long-term sustainability.

A study reveals that Saudi Arabia, particularly in cities like Riyadh, Jeddah, and Tabuk, is undergoing rapid urbanization, which has led to significant challenges in the availability of green spaces. Research indicates that many cities across the country have lower per capita green space compared to global trends, emphasizing the urgent need to expand urban greenery to improve quality of life and enhance resilience against environmental changes (Addas, 2022; Metwally and Ibrahim, 2022).

In response, Saudi Arabia has launched several strategic initiatives, such as the Saudi Green Initiative and the Humanization of Neighborhoods Initiative, aimed at enhancing green infrastructure, improving urban quality of life, and mitigating environmental impacts. These initiatives are essential for creating sustainable urban environments that promote ecological balance, social well-being, and long-term resilience in the face of climate change.

In conclusion, green spaces significantly strengthen the health and social fabric of urban populations and serve as indispensable tools for environmental management, fostering ecological balance and climate resilience. This is crucial for Saudi Arabia, as it addresses the growing environmental challenges of urbanization and ensures a healthy future for generations to come.

Problem

One of the most urgent environmental challenges facing the Kingdom of Saudi Arabia due to urbanization is soil degradation, leading to increased pollution, flood risks, and the urban heat island (UHI) effect from vegetation loss (Almulhim and Cobbinah, 2023). This ecological degradation has worsened the decline in essential oxygen production while carbon emissions and other pollutants have surged, negatively impacting public health (Abdulaziz and Alshahrani, 2022; MEWA, 2019). In cities with few trees, the UHI effect intensifies, raising urban temperatures and exacerbating extreme weather conditions.

These challenges are further aggravated by the scarcity of open and green spaces in many Saudi cities, particularly in fast-growing urban centers like Jeddah. While urban parks and green spaces are crucial for sustainable urban living, their use remains underdeveloped in the Kingdom. The uneven distribution of green spaces and inconsistent urban management strategies have contributed to environmental strain and worsened quality of life (Addas, 2022).

Studies have explored the complex relationships between economic growth, urbanization, and environmental degradation in Saudi Arabia. Rapid economic expansion has resulted in increased carbon dioxide emissions and the reduction of green cover in urban areas. While urbanization has boosted the economy, it has often overlooked its environmental costs (Alajlan and Alreshaidi, 2022). These challenges necessitate sustainable urban planning that prioritizes the development of

urban green spaces. In addition to providing essential ecosystem services, these spaces enhance the well-being and quality of life of urban residents (Kim and Kwon, 2021). Furthermore, improving urban green spaces supports broader environmental and social goals, such as reducing pollution, promoting biodiversity, and fostering healthier communities (Metwally and Ibrahim, 2022).

Goals

- Examine the impact of green spaces on quality of life and environmental sustainability in Saudi cities.
- Analyze the role of green spaces in addressing environmental challenges such as climate change and urban heat islands.
- Compare green spaces in Saudi municipalities with international standards to identify gaps in urban planning.

Understanding the relationships among green spaces, humanity, sustainability, and quality of life

The concept of sustainable development has gained prominence due to the growing recognition that social well-being and national development must be balanced with environmental sustainability. The environment should not be viewed as a limiting factor but as an integral component of development (Everard and Longhurst, 2018). This perspective has been supported by studies emphasizing the importance of integrating environmental considerations into development strategies to achieve long-term sustainability (Falchetta and Ahmed, 2023). Over time, it has become a comprehensive subject in global agreements and subsequently translated into local regulations and frameworks. Unfortunately, the process of translating this concept into regulations and tools has shifted the focus away from embracing minimum environmental and social standards. Instead, they are viewed as restrictions rather than opportunities for innovation and addressing human needs. Consequently, the ambitious aspect of sustainable development, particularly in addressing human needs, has often been compromised, transforming these ideals into rigid regulatory frameworks (Derkzen et al., 2017). This shift has limited the potential for innovation in addressing key human and environmental needs (Giannico et al., 2021).

Sustainable development goals (SDGs) reaffirm the importance of interconnected human needs and encourage the development of innovative products and processes to address these needs. To revive the neglected aspect of sustainable development—meeting human needs sustainably—we must create incentives for innovation and partnership. This shift requires moving beyond the traditional framework and adopting an "innovation framework" that does not impose constraints (Everard and Longhurst, 2018).

In alignment with global initiatives, UNESCO's vision is centered on humanizing cities to achieve socially and economically sustainable urban development. This approach emphasizes the need for urban areas to prioritize human well-being alongside environmental sustainability, fostering inclusive spaces that meet the needs of diverse populations (Busuttil, 1984).

Within the United Nations 2030 Agenda, public green spaces play a crucial role in promoting the sustainability of cities and the well-being of their citizens, especially by fostering connections between

humans and nature. In addition to the numerous benefits for human health and the environment, local and central authorities must ensure the provision of high-quality green public spaces to create healthier and more resilient cities. The World Health Organization recognizes access to such spaces as a fundamental right (Vidal et al., 2020). Numerous epidemiological studies have revealed the positive health effects of maintaining urban green spaces, including improvements in mental health, reductions in depression (Revich, 2023), better pregnancy outcomes, decreased rates of cardiovascular diseases and related deaths, obesity, and diabetes (Andersson et al., 2017). Overall, urban green areas contribute to a harmonious relationship between humans and the natural environment, enhancing the overall quality of life for residents.

Urban green spaces, also referred to as UGSs, offer numerous advantages to urban inhabitants and constitute fundamental elements of urban landscapes. The investigation articulated in this manuscript delivers an exhaustive analysis of the roles and impacts of green spaces in diverse urban settings (Leite et al., 2023). The composition and volume of green space in Southeast Asia have undergone modifications as a result of swift urbanization. Affluent cities typically show a greater overall extent of green space, whereas more densely populated cities have a lower amount of green space *per capita*. This indicates that safeguarding ecological resources necessitates meticulous urban planning (Paudel and States, 2023). Comparable discoveries have been unveiled in Berlin, where the presence of urban green space has been correlated with heightened life contentment. Although numerous urban residents have less green space than the optimal quantity, an optimal level of green space conducive to well-being has been pinpointed (Barboza et al., 2021).

A study on health impact assessment conducted in Europe underscored the health advantages of green spaces and their contribution to establishing sustainable, habitable communities. Studies have proved that augmenting green space could avert a notable number of fatalities from natural causes (Derkzen et al., 2017). Green spaces are imperative for sustainable landscape advancement as they provide diverse functions, including recreational and ecological benefits, which are indispensable for urban sustainability (Giannico et al., 2021).

The outcomes of these investigations underscore the manifold benefits of urban green spaces, the obstacles to equitably distributing resources, and the intricate interrelations between green space and health repercussions at various levels. It is advised that urban planners and policymakers heed these findings when formulating urban environments that prioritize sustainable growth while emphasizing human well-being.

In essence, these studies indicate that green spaces are an essential aspect of humanity, which is a key component of quality of life. Quality of life stems from the interaction of three dimensions—social, economic, and environmental—all of which are necessary for sustainable development (Figure 1).

The relationship between green spaces and sustainability goals

The following is an understanding of the relationship between green areas and sustainable development goals: Goal 11: Make cities inclusive, safe, resilient, and sustainable.

FIGURE 1
The relationship between green spaces, humanity, sustainability, and quality of life.
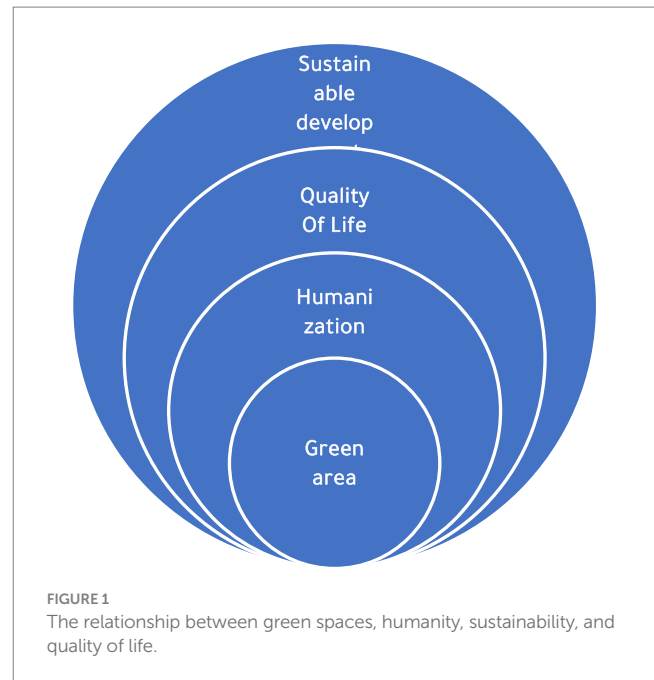
Green space offers an added advantage in improving the air quality of a city and reducing noise pollution, because it contributes to security and healthier living. Green spaces act as recreation facilities, allowing one to relax, and as a result, cities are more attractive to residents. Trees and green spaces are sponges, literally acting like sponges, soaking up rainwater that often leads to flooding.

Goal 13: Take urgent action to combat climate change and its impacts.

Green spaces serve the purpose of CO_2 absorption, which in turn helps handle the phenomenon of global warming. Green spaces are crucial to implementing the heating load issue because if there are fewer green spaces, the heating load will increase, and there will be significant consequences.

Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; and halt and reverse land degradation and biodiversity loss.

Green spaces contribute to preserving biodiversity in cities.

Green spaces provide places for education and scientific research.

Goal 13: Take urgent action to combat climate change and its impacts.

Green spaces have the potential to mitigate the effects of global warming by absorbing carbon dioxide. Green areas contribute to a decrease in the urban heat island effect.

Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; and halt and reverse land degradation and biodiversity loss.

Green areas help to maintain biodiversity in urban areas.

Green spaces offer venues for scientific research and teaching.

Research gap

Reimagining Public Spaces and Streets: Public spaces play a crucial role in fostering inclusivity, social cohesion, and overall

efficiency in urban areas. In the evaluation carried out in the year 2020 and based on data collected from 1,072 cities all over the world, the Global Street Space survey suggests that more than seven out of 10 cities allocate less than 20% of their total territories to open public spaces and streets. This falls significantly short of the desired objective of allocating 45–50 percent of urban land, with open public spaces accounting for 15–25 percent and streets and sidewalks accounting for 30–35 percent. According to statistics, green spaces such as parks and gardens occupy only 1.5 m^2 per resident as of 2020, being a bit more than four times as small as the areas dedicated to roads. Thus, a significant disparity appears in these numbers depending on the region, as cities in more developed areas generally allocate a greater amount of space for streets and open grounds than in those in poorer regions. Moreover, countries in developed regions also have higher percentages of the population enjoying convenient access to open public spaces (UN DESA, 2023).

Research on green spaces in urbanized cities in Saudi municipalities reveals several knowledge gaps that need to be addressed. The use of satellite images to study urban growth does not consider the integration of green spaces in urban landscapes (Addas and Maghrabi, 2021). Studies on sustainable urban planning in Taif Province have not assessed the effectiveness of urban green space development (Al-Hathloul and Mughal, 2004). The analysis of Saudi Arabia's urban growth management has not considered the inclusion of green spaces within growth boundaries. The evaluation of green spaces in Saudi Arabian megacities has not thoroughly examined the legal and socioeconomic aspects of their implementation and maintenance (Waheeb et al., 2023). Research on adopting green city concepts in Saudi Arabia does not provide a comprehensive analysis of the current green infrastructure or the necessary approaches for successful incorporation (Alyami, 2019). Further studies are required to explore the integration of green spaces into Saudi Arabian city planning, the socioeconomic and policy frameworks that facilitate or hinder their growth, and the strategies needed to overcome obstacles. This study aims to address the following questions: How much is one individual allocated as a municipal average for public space, and how does this compare to the global reference rates, which will indicate the gap that exists in the Saudi Arabian municipalities' needs to be bridged?

Providing the right response to this question would be instrumental to the creation of measures that support the widening of greenery in a manner that improves the wellbeing and quality of life for all residents.

Materials and methods

As such, this study aims to investigate the distribution of green spaces in Saudi Arabian municipalities via a quantitative approach to describe how previous findings and recommendations fit into the context. Green space data: Ministry of Municipal and Rural Affairs Population data: General Authority for Statistics. This method is identical to that followed by Addas (2022) in his recent work, which examined the deficiency in green spaces available in major cities, such as Jeddah, and how it influences inhabitants' quality of their lives. The study specifically concentrates on public green spaces such as urban parks, neighborhood parks, and public gardens—and omits private

green spaces to achieve a uniform evaluation of the common good from the ground level of greening. This classification followed the methodology from Kim and Kwon (2021) and stressed that diversity of green spaces is one of the preconditions for programmers not only to gain environmental benefits but also to promote social relatedness.

The total area of green spaces in each municipality was divided by the *respective population* to calculate *per capita green space availability*. To evaluate the adequacy of green space distribution, the study references the *City Prosperity Index (CPI)*, developed by *UN-Habitat*, which recommends a minimum of *15 m^2 per person as a benchmark for sustainable urban environments and improved quality of life* (UN Habitat, 2016). This benchmark serves as a *comparative reference* for assessing how Saudi municipalities align with internationally recognized urban sustainability targets.

The collected data were analyzed to identify *patterns in green space distribution* and examine variations across municipalities. The study aims to provide *insights into disparities in green space allocation*, supporting a deeper understanding of the relationship between urban planning strategies and green infrastructure development.

And the results of the study sought to produce evidence-based instruments for decision-makers to support sustainable urban planning interventions. The results are consistent with the needs of the Saudi Green Initiative and Humanization of Neighborhoods Initiative (both part of Vision 2030) to develop green infrastructure and to enhance urban quality of life in general.

Study site

The Kingdom of Saudi Arabia is in the southwestern part of Asia (Figure 2). It shares borders with the Arabian Gulf, United Arab Emirates, and Qatar to the east; the Red Sea to the west; Kuwait, Iraq, and Jordan to the north; and Yemen and Oman to the south.

Area: The Kingdom of Saudi Arabia covers approximately four-fifths of the Arab Peninsula, with an area of approximately 2,000,000 km^2.

Administrative divisions: Saudi Arabia has 13 administrative provinces, or emirates, and 17 municipalities (General Authority for Statistics, 2018).

Population: As of 2024, the estimated population of Saudi Arabia is approximately 33,145,000 people. Riyadh is the capital and largest city in the center of the an-Nafud Desert in the eastern region of the Najd Plateau. Riyadh has a population of 7.6 million and is the most populous city in Saudi Arabia.

Criteria for evaluating green spaces

The United Nations City Prosperity Index and the World Health Organization Index have been selected for evaluation, and deficits and surpluses are identified as a basis for intervention by planners and policymakers.

City Prosperity Index

The topic of sustainability in urban areas is a multifaceted and expansive issue that not only involves the ecological but also economic and social aspects of urban settings. Conversely, the City Prosperity

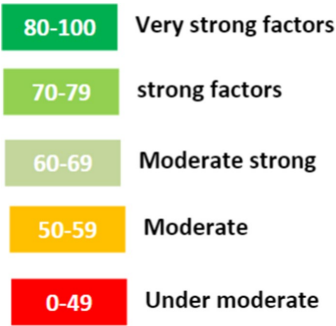FIGURE 2
The location of Saudia Arabia. Source: OpenStreetMap.

FIGURE 3
Scale of urban prosperity. Source: Data taken from United Nations City Prosperity Index (CPI), https://data.unhabitat.org/pages/city-prosperity-index. Figure created by the authors.

Index (CPI) has been developed as an assessment and monitoring tool in reference to this aspect of a city's growth. The CPI is a big multi-dimensional index that covers the key components of productivity, infrastructure, quality of life, equity, and social inclusion, along with environment, urban management, and housing laws. The CPI is a comprehensive guiding tool for urban development, pointing decision-makers in a sustainable direction (Wong, 2018; Jones et al., 2015; Altamirano-Avila and Martínez, 2021). The quality-of-life dimensions contain four subdimensions: health, education, safety, and public space. The indicators for public space are measured by two indicators: accessibility to open public areas and green areas *per capita*. For green area *per capita*, the benchmark has been set at 15 square meters per person (UN Habitat, 2016). Scale of urban prosperity, as shown in Figure 3.

The World Health Organization

The World Health Organization (WHO) has acknowledged the significance of green spaces in urban planning for fostering health and well-being at various life stages. The WHO has established a minimum requirement of 9 m^2 of urban green space (UGS) per person, which is not fulfilled in certain cities. This suggests a need for greater investment in urban greening initiatives (Prospects et al., 2012; Russo and Cirella, 2018).

Results and discussion

The study results are presented in Table 1, as well as Figure 4. These tables and figures analyze the green areas in the municipalities and compare them to the United Nations standard and the City Prosperity Index. The evaluation is as follows:

The data in this table illustrate the availability of green areas and the population in different municipalities in Saudi Arabia. It juxtaposes the current green area *per capita* with the minimum WHO threshold of 9 m^2 and a CPI benchmark of 15 m^2. Moreover, an evaluation of the magnitude of urban well-being is included.

Most municipalities do not reach the CPI benchmark, as evident from the negative figures in the final two columns. This implies a general insufficiency in green areas *per capita* among these municipalities.

Nevertheless, the degree of inadequacy varies, with certain municipalities closer to meeting the criteria than others. The Northern Borders Municipality boasts the highest green space *per capita* (21.08 m^2), surpassing both benchmarks, indicating robust elements contributing to urban prosperity linked to its ample green areas.

In contrast, the Jeddah Municipality displays the lowest green space *per capita* (3.21 m^2), suggesting a moderate role in enhancing urban prosperity through its generous green spaces.

Najran Municipality barely satisfies the WHO standard but falls short of the CPI benchmark, implying a moderate impact on urban prosperity stemming from its abundant green spaces. Most municipalities in Saudi Arabia meet the minimum standard for green space per capita set by the World Health.

TABLE 1 Assessment of green area distribution in Saudi Arabian municipalities 2022.

Municipality	Green area	The need for the CPI benchmark (15 m²)	CPI benchmark 15 m²	Green area per capita	Population	Scale of urban prosperity	
Jeddah Municipality	12,058,198	−11.7859	15	3.214062	3,751,700	21.43%	Under moderate
Al-Ahsa Municipality	3,627,305	−11.7152	15	3.284808	1,104,267	21.90%	
Makkah Municipality	10,716,711	−11.2476	15	3.752415	2,855,950	25.02%	
Riyadh Municipality	37,041,229	−10.6887	15	4.311256	8,591,748	28.74%	
Eastern Province Municipality	23,220,719	−8.46628	15	6.533722	3,553,980	43.56%	
Al-Hafar Batin Municipality	3,161,402	−8.2305	15	6.769496	467,007	45.13%	
Asir Municipality	13,851,366	−8.1574	15	6.842597	2,024,285	45.62%	
Najran Municipality	5,557,909	−5.6164	15	9.383605	592,300	62.56%	Moderate
Jizan Municipality	14,619,155	−4.59489	15	10.40511	1,404,997	69.37%	
Taif Municipality	16,552,071	−3.2926	15	11.7074	1,413,813	78.05%	Strong factors
Madinah Municipality	25,204,428	−3.21112	15	11.78888	2,137,983	78.59%	
Al-Jawf Municipality	7,322,529	−2.71021	15	12.28979	595,822	81.93%	Very strong factors
Hail Municipality	9,482,310	−2.29604	15	12.70396	746,406	84.69%	
Tabuk Municipality	11,497,247	−2.02395	15	12.97605	886,036	86.51%	
Qassim Municipality	21,616,943	1.178179	15	16.17818	1,336,179	107.85%	
Al-Baha Municipality	6,271,534	3.49061	15	18.49061	339,174	123.27%	
Northern Borders Municipality	7,877,825	6.087554	15	21.08755	373,577	140.58%	

Source: Cols. 1, 2 from the Ministry of Municipal and Rural Affairs. Cols. 3, 5, 7 from the authors. Col. 4 from CPI. Col. 6 from the General Authority for Statistics.

Organization (WHO). However, some municipalities fall below this standard of 9² per person. The graph illustrates the current average per capita standard. The x-axis represents the different municipalities, while the y-axis indicates the amount of green area per person. Jizan Municipality has the highest average, with 7.2² of green space per capita. Conversely, Hail Municipality has the lowest average, with only 0.4² of green space per person.

In sum, this graph shows large differences in green per capita among municipalities in Saudi Arabia. From the data itself, it shows that Jizan Municipality has the highest average green space per capita at 17.61/cap while Riyadh and Tabuk municipalities are tied at 0.18/cap. These results are consistent with a study conducted by Addas (2022), indicating the scarcity in green spaces in large cities like Jeddah, and another by Metwally and Ibrahim (2022), listing similar obstacles for Riyadh. Nearly all Saudi municipalities are below the World Health Organization (WHO) minimum standard of 9² per person, highlighting the urgent need to increase green space provision to meet these benchmarks and exceed basic standards that can enhance quality of life.

To overcome these challenges, Saudi Arabia launched several environmental initiatives, such as the Saudi Green Initiative and the Humanization of Neighborhoods Initiative, which aim to improve surroundings and increase green space in cities.
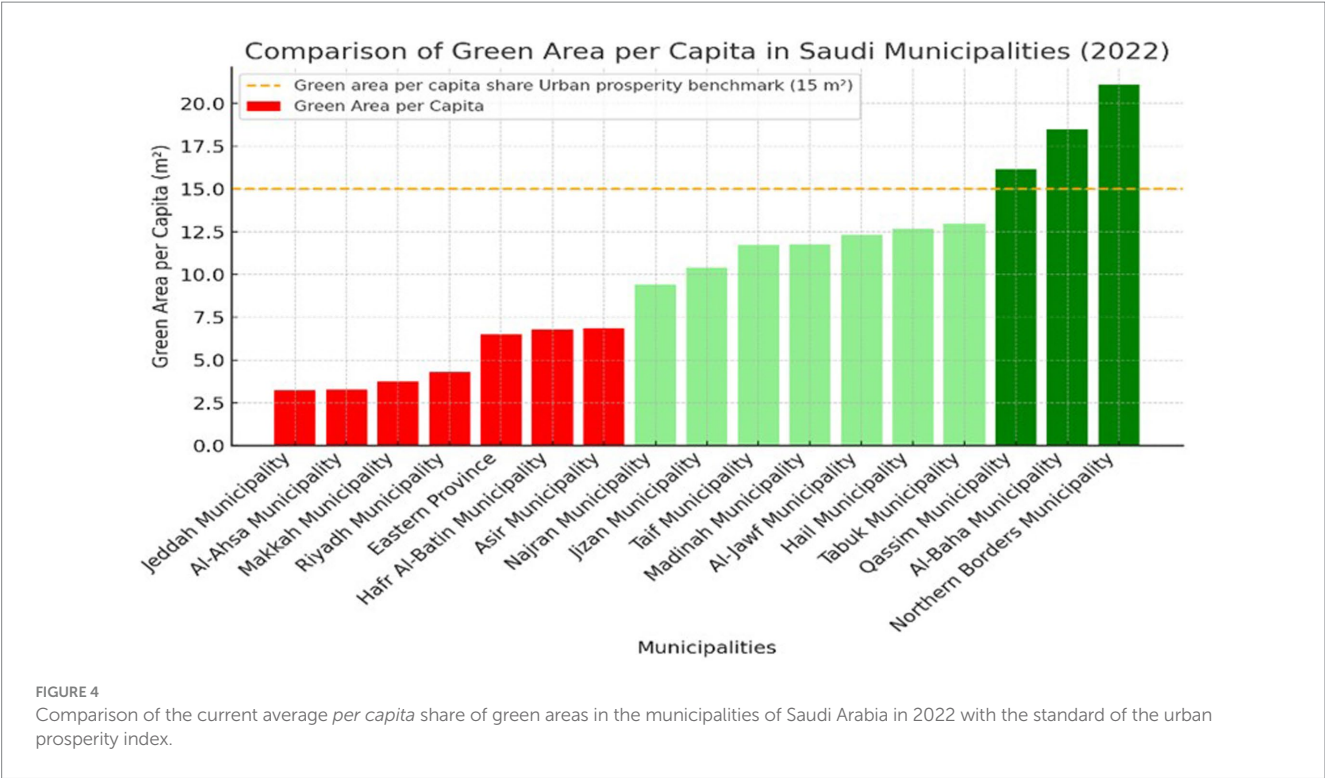
The Humanization of Neighborhoods Initiative, part of the Quality of Life (QoL) program in Riyadh, will be expanded to other urban centers nationwide. The initiative primarily focuses on improving public areas for pedestrians, a step

toward the goals of Saudi Vision 2030. Its mission is to transform streets from automobile-centric spaces into more livable, social, and active environments, encouraging physical activity and social interaction. Ultimately, this helps improve residents' quality of life by creating more pedestrian-friendly urban spaces (Mostafa, 2021; Ministry of Municipal and Rural Affairs, 2023).

Another major policy launched in early 2021 is the Saudi Green Initiative, which aims to plant 10 billion trees across the Kingdom and restore 160 million ha of degraded land. This initiative is built on three main pillars: increasing forest cover, reducing carbon emissions, and conserving trees on land and water bodies. By collaborating with various community sectors, this initiative seeks to restore essential environmental processes, improve air quality, reduce dust and sandstorms, and achieve sustainability goals (SGI, 2024).

These policies reflect Saudi Arabia's commitment to addressing environmental challenges and improving urban quality of life. However, success depends on ensuring equitable distribution of green spaces and access for all residents. By learning from global cities like Dubai and Abu Dhabi, which have adopted innovative methods such as wastewater recycling and planting drought-resistant trees, Saudi cities stand a better chance of revitalizing their urban environments and achieving sustainability.

Saudi cities can promote urban progress and citizen well-being under Saudi Vision 2030 by adopting sustainable urban planning interventions and expanding green spaces.

FIGURE 4
Comparison of the current average *per capita* share of green areas in the municipalities of Saudi Arabia in 2022 with the standard of the urban prosperity index.

Environmental initiatives impact

The Green Saudi Initiative and the Humanization of Neighborhoods Initiative are pivotal in Saudi Arabia's efforts to tackle environmental challenges. These strategies effectively address issues such as carbon emissions and land degradation, while emphasizing the welfare of the population and the creation of more resilient communities. With their ambitious goals and inclusive methodologies, these initiatives offer a hopeful perspective for a sustainable future in Saudi Arabia.

Limitations

It is crucial to acknowledge that the data provided is as of 2022 and may not fully represent the current situation. Additionally, the table and graph presented lack details regarding the quality or distribution of green spaces within individual municipalities.

Recommendations

To overcome these challenges, it is advisable to enhance the understanding of the benefits associated with green areas and foster community support. Improving metrics and disseminating information can aid in assessing the current state and shaping future developmental strategies. Increasing green spaces, including parks, gardens, and green pathways, is of utmost importance. Ensuring an equitable distribution of well-maintained green spaces

across urban areas will make them more accessible and appealing to all inhabitants.

Conclusion

Strengthening and expanding green spaces in Saudi Arabian municipalities plays an essential role in improving the health and lives of these communities. Understanding how green space networks contribute to sustainability and quality of life is key to grasping the concept of sustainable development. Just as green spaces are closely linked with human happiness, so too is the natural environment deeply integrated into the social, economic, and ecological fabric. Access to green spaces supports both physical and mental health, fosters social bonds, and preserves community culture, while also benefiting the economy. It is imperative that humans manage and protect these environments to ensure that all individuals have equitable access to green spaces in ways that meet their needs. Moreover, economic activities must be shaped with environmental considerations in mind to prevent further degradation. Ultimately, green spaces must be preserved for future generations, as they impact on human well-being and sustainability in numerous ways, offering experiences that enrich life and contribute to both social and environmental sustainability.

Enhancing green density

To further improve urban environments in Saudi cities, this study suggests increasing green density through the creation of

more forested zones, particularly in public spaces such as urban parks and neighborhood parks. Choosing the right tree species and vegetation is crucial to ensuring sustainability in arid and semi-arid urban ecosystems. Native species like Acacia and *Phoenix dactylifera* (date palm) are well-adapted to the local environment, while introduced species like Prosopis can also contribute to urban greening efforts. By focusing on increasing green spaces and selecting drought-tolerant species, Saudi cities can enhance biodiversity, improve air quality, and strengthen the resilience of their ecosystems.

Role of green spaces in combating climate change

Green spaces play a critical role in mitigating climate change, especially in arid environments, by absorbing carbon dioxide and reducing the urban heat island effect. The careful selection of drought-resistant plants will help maintain these vital ecological functions while contributing to biodiversity and climate resilience.

Assessment of green spaces in Saudi Arabia

Comparing the provision of green spaces in Saudi Arabian municipalities with international benchmarks underscores the need for substantial improvements. While aligning with globally recognized sustainability targets is essential, striving for even higher standards remains a priority. By enhancing the quality and equitable distribution of green spaces, Saudi cities can foster healthier urban environments, elevate overall well-being, and contribute to long-term urban prosperity.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

AM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. The authors used Generative AI tools such as Consensus.app, Typeset.io, and OpenAI.io for reference searching and language refinement purposes.

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