

## Article

# Role of Urban Greening Strategies for Environmental Sustainability—A Review and Assessment in the Context of Saudi Arabian Megacities

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**Abstract:** The review and assessment of urban greening patterns play a crucial role in sustainable urban planning and green spaces (GSs) management, helping to improve human well-being. In recent years, various methods and strategies were applied to examine the relationship between GSs and environmental sustainability, but so far, no studies on systematic review and empirical assessments were carried out in Saudi Arabian context. Thus, a comprehensive review and assessment of current GSs patterns and planning strategies are important for achieving urban environmental sustainability. This study aims to assess spatial pattern of GSs across the cities and a bibliographic review on the urban greening strategies in the Saudi context. These six urban strategies were further supported from empirical evidence on Saudi cities. Geographical information system (GIS) techniques and questionnaire surveys were performed for spatial mapping of GSs and the perceived role of GSs strategies of the respondent to environmental sustainability across cities. The findings showed that (i) highest PCGS was reported from Dammam (5.4 m<sup>2</sup>) followed by Riyadh (1.18 m<sup>2</sup>), and Jeddah (0.5 m<sup>2</sup>); (ii) most of the respondents use GSs for picnic (59%), mental well-being (53%), and physical activities (47%), respectively; (iii) GSs play a significant role for local climate regulation such as temperature control (78%) and UHI reduction (81%), and GSs provide thermal comfort (84%), respectively; and (iv) 40% respondents do not use GSs due to the lack of availability, accessibility, design, management, and safety of GSs. Thus, such findings of the study surely assist planners and policy makers to understand and implement the suggested GSs strategies to meet the satisfaction level of the respondents as well as to manage GSs at neighborhood and city level for urban environmental sustainability.

**Keywords:** urban greening; environmental sustainability; climate change; urban green space; accessibility



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## 1. Introduction

Green spaces (GSs) play a crucial role in mitigating climate change as well as climate management in cities. A number of studies were performed across the world to find out the role of GSs in climate change mitigation, and they documented the negative impact of climate change on the quality of life of urban dwellers and on ecosystem services (ESs) [1–3]. Various direct and indirect ESs are provided by GSs to city dwellers [4–6], regulating (climate regulation, carbon storage) and supporting (nutrient cycling) the urban environment. Thus, GSs play a significant role in climate change mitigation and therefore need to be integrated into urban design and decision-making frameworks to enhance urban resilience to climate change [2]. The application of innovative solutions and the development of new tools are essential for better urban planning and management over the rapidly growing cities. Climate change mitigation strategies, such as low energy consumption buildings, innovative urban structures, and enhancement of GSs have a crucial role to play in adaptation to climate change [7]. Enhancement of GS is considered to be significant to new visions of cities to achieve sustainability and resilience of the cities and

promote the well-being of the inhabitants. In the USA, GSs have been prioritized in decision making in New York, Washington D.C., Chicago, and Philadelphia [8]. In European cities, such as Milan, Mirandola (Modena), Catania, and Turin, GSs are an integral part of urban sustainability [9–11]. In Asian cities, GSs have been developed in Hong Kong, Beijing, and the Pukou District of Nanjing [12–14].

Thus, GSs provide valuable tools for reducing the adverse effect of climate change, enhancing the resilience of the urban environment, and improving urban sustainability [15–19]. GSs, in particular, provide socio-ecological and economic benefits, improve air quality [15,20], reduce noise pollution level, and support ESs (such as food, wood, and fuel provision) [20,21] and control of water pollution. GSs can also increase carbon storage capacity [22–24], reduce the urban heat island (UHI) effect [5,6,25,26], offer social benefits [6,27], enhance human health and well-being [28,29], and provide ecological benefits [30,31]. Thus, GSs have an immense impact on the overall sustainability of the urban environment. However, up to now, very limited focuses have been given to the quantitative assessment of GSs across the cities of Saudi Arabia [32]. Thus, from a review of the previous literature, some notable gaps were identified. Firstly, research studies performed in the Saudi context mainly concentrate only on quantitative assessment and a perceived valuation of GSs across cities [33,34]. Secondly, GSs have been assessed within a particular city, such as Jeddah [34], but no comparison has been made across cities for a better understanding of the role of GSs. Thirdly, in previous studies, the perceived statement of the respondents regarding the GSs strategies for urban environmental sustainability were not addressed in previous research studies. Fourthly, to the best of our knowledge, no studies have been performed on strategies for provisioning GSs in Saudi cities. Given these research gaps, this study quantitatively assesses GSs across three cities and the strategies for GSs for provisioning urban environmental sustainability across three cities in Saudi Arabia. The findings of the study will assist in the understanding of the spatial heterogeneity of GSs across the cities and identify how urban sustainability can be achieved through the implementation of effective strategies for urban landscape planning.

GSs have immense impact on the health and well-being of the people [35,36]. In previous studies, it was well documented that there was substantial impact of GSs on human health [37–40]. Apart from mental health (such as mental refreshment), GSs have a significant impact on physical health (such as walking, physical activities, and leisure) [33,34]. Considering the substantial impact on the well-being and human health, it has been prioritized in previous studies for the urban planning strategies and public health research [41–43]. Recently, a study was performed by the Addas and Maghrabi [33] on the social evaluation of public open space services at a very microscale, and the result of the study showed that the respondents of the King Abdulaziz University (KAU) were highly dependent on the services (such as educational value, walking, recreations, leisure, social cohesion, living area, etc.) provided by green public spaces (such as gardens). Therefore, it is essential to implement GSs provision for urban environmental sustainability and to enhance the quality of life of the people.

Recently, the rapid urban expansion has become of the significant threats to the management as well as restoration of GSs. The conversion of natural and semi-natural landscape into built-up areas has had an immense impact on the thermal behavior pattern in urban environment due to increase in anthropogenic heat emission, long-wave radiation, and storage of incoming solar radiation [44–48]. As a result, this UHI effect has emerged as one of the major challenges stemming from climate change [49,50]. The increasing trend of temperature in cities across the world has, in turn, had a major impact on human health and overall well-being of the urban population [51]. The United Nations [52] estimates that the global urban population is likely to increase from 50% in 2010 to 70% by 2050. The rapid increase in the population in urban areas will surely result in urban expansion and diversification of urban areas [53]. Sustainable urban development alongside rapid urban expansion is crucial for both resource-efficient systems and better urban infrastructure development to achieve higher quality of life for urban dwellers [53]. Urban areas provide

many conveniences due to their role in economic activities, commercial activities, and transportation, as well as linkages with rural areas and other cities. Thus, cities have a crucial role to play in promoting and enabling prosperity through rapid economic development [54]. Cities across the world have become the areas of production and consumption that radically affect the whole sphere of biophysical, social, and economic systems [55–57]. Cities cover only 2% of the area of the earth, but they consume more than 75% of energy and produce 70% of global CO<sub>2</sub> emissions. Thus, climate change has become a serious challenge to cities because of rapid urbanization [54]. Previous studies have shown that urban areas are adversely affected by climate change, and this effect is likely to worsen in the future [58–61]. The quality of life and urban infrastructure development, and indeed the entire urban system, are seriously threatened by climate change [54]. Therefore, effective management strategies for GSs are urgently required for betterment of urban environmental sustainability.

In Saudi cities, Al-Maamary et al. [62] showed that the temperature increased by about 4 °C over just five decades, and coastal areas are more vulnerable to temperature increases; the temperature is likely to increase by 2–2.75 °C. The temperature rises to 52 °C during summer due to large-scale emissions from vehicles and anthropogenic sources in cities [63]. In 2000, per capita CO<sub>2</sub> emissions amounted to 14.3 million tons and reached 19.5 million tons in 2014 (an increase of 36% within just 14 years), with the highest contribution coming from the energy sector (about 90%) followed by industrial sectors (8%), and agriculture (2%) [26]. According to [59], there is an increasing trend of temperature ranging from 0.15 to 0.75 °C with an average increase of 0.40 °C in Saudi Arabia. The increase is likely to be 2.2–2.7 °C by 2040 in Saudi Arabia, which is much higher than the global projection [64]. Thus, it is clear that climate change is a significant issue for Saudi Arabia.

In Saudi Arabia, around half of the population lives in urban areas (in seven major cities) with an urbanization rate of about 84% [65]. There has been remarkable urban expansion and rapid growth in urban population over the last forty years due to the migration of people to cities. However, there has been a lack of infrastructure development and of sustainable strategies for urban planning. For example, Jeddah has grown beyond the capacity of its infrastructure. Other cities, including Riyadh and Dammam, have also experienced significant growth in the urban population over the last few decades [34,66]. In developed countries, the roles of GSs have been well documented due to their contribution to urban environmental sustainability and the well-being of urban dwellers. However, in comparison to rapid urban expansion, very little focus has been given to GSs in urban planning or to effective land-use planning [34].

Considering the research gaps of the previous research studies and limited focuses on the urban environmental sustainability across Saudi Arabian cities, this study mainly aims to fulfill two basic objectives: (a) to examine the spatial heterogeneity of GSs across cities and (b) to explore review and assessment of GSs strategies for urban environmental sustainability in the context of Saudi Arabian cities. To fulfill the first objective, PCGSs were measured across three cities. To attain the second objective of the study, six green spaces (GSs) strategies for provisioning urban sustainability were explained, and these strategies were supported from the three cities with empirical evidence.

## 2. Material and Method

### 2.1. Spatial Focus of the Study Cities

In this study, three cities from different geographical locations were selected (Figure 1) to examine the spatial pattern of UGS: Riyadh, Jeddah, and Dammam. Riyadh is the largest megacity of the three, with a population of 7.5 million. Riyadh is the capital city of Saudi Arabia and is located in the center of the country. Jeddah is located in the western part of the country on the eastern coast of the Red Sea, with an area of 1660 km<sup>2</sup>. The population of the city is about 4.2 million with a population density of 2672 persons/km<sup>2</sup>. Dammam is one of the largest cities in the country, with a population of 1.11 million. The population density of the city is 1440 persons/km<sup>2</sup>. The details of the cities are presented in Table 1.

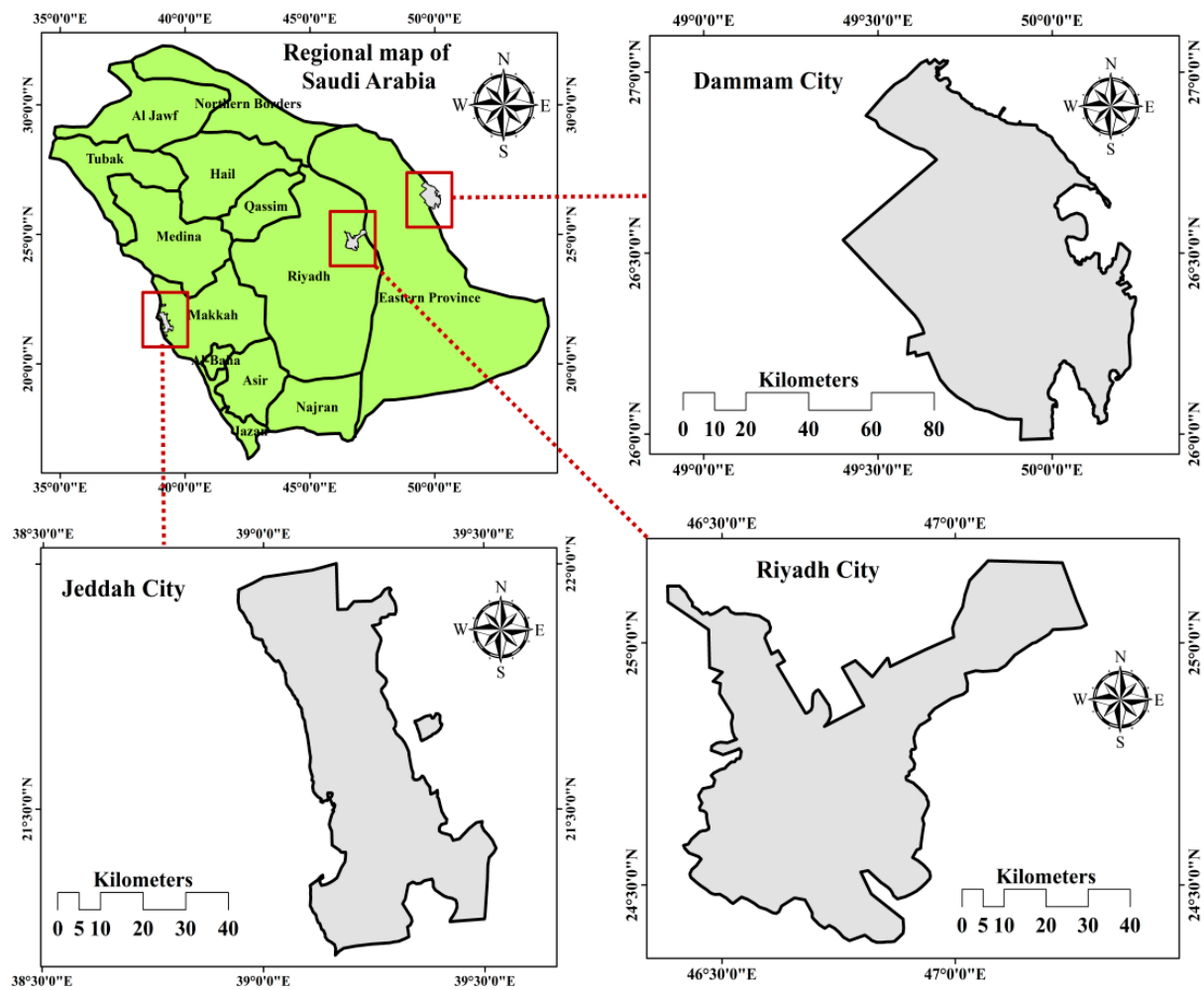


Figure 1. Location map of the study cities.

Table 1. Profile of the cities.

Name of the City	Designation of the City	Area (km <sup>2</sup> )	Population (million)	Population Density (km <sup>2</sup> )
Riyadh	Capital city	1798	7.506	4175
Jeddah	Major city	1660	4.276	2672
Dammam	Provincial city	810	1.116	1440

## 2.2. Methods

### 2.2.1. Methodology for Literature Screening

A large number of research studies related to urban greening strategies for urban environmental sustainability were reviewed. The research studies were reviewed from six perspectives. These were (i) enhancement the quality of GSs; (ii) standard approach of GSs; (iii) ecological landscape approach of GSs; (iv) improvement of GSs planning; (v) management of GSs through public participation; and (vi) greening strategies related to building and private properties, respectively. The details of the literature screening methods are presented in Figure 2. From the beginning of the study, GSs, sustainability, environmental sustainability, climate change, urban greenings, GSs management, greening strategies, ecological approach, and green spaces—these key words were searched. This research paper mainly encompassed those papers which were carried out from these six perspectives. Then, the results and findings of the papers were compared from the perspectives of Saudi Arabian context. The research studies performed from 2000 to 2020

were considered for the literature screening (Figure 2). These urban greening strategies were assessed from the survey result obtained from three cities. The strategies related to urban greening were selected in such a manner so that they can be applied as well as implemented on a city scale for better understanding the scenario of GSs across the cities, and the strategies can be very helpful to the planners and policy makers for future management of GSs across the cities in Saudi Arabia.

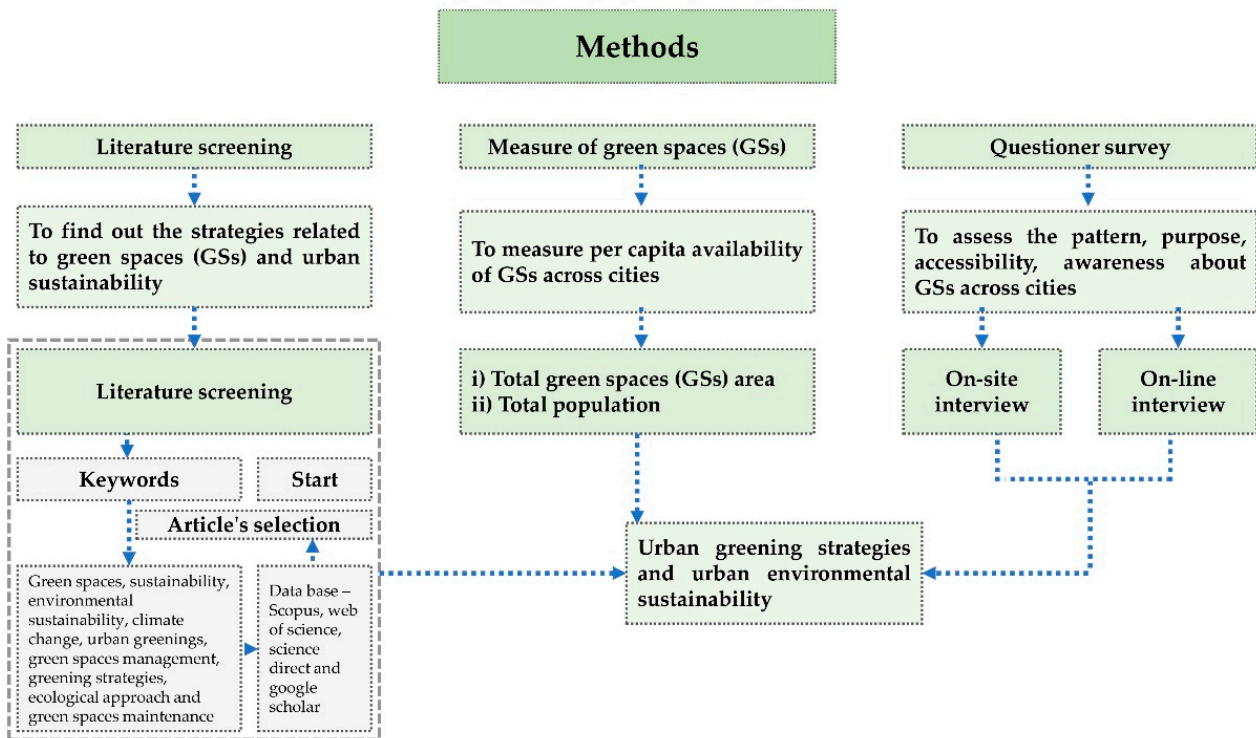


Figure 2. Methodological framework of the study.

### 2.2.2. Assessment of GSs Across Cities

The formulation of sustainable urban planning and effective land use planning are largely affected by the sustainable management as well as restoration of GSs particularly densely populated areas [67]. As per World Health Organization [68], GSs availability can be measured by PCGSs. In this study, the PCGSs were measured across three cities (namely Riyadh, Jeddah, and Dammam) to understand as well as to compare the PCGSs with global standard. Thus, the assessment of PCGSs surely helps to adopt effective strategies for urban sustainability. The PCGSs were measured with the help of following equation:

$$PCGSs = \frac{GSs_{total}}{POP_{total}}$$

where PCGSs is the per capita availability of GS;  $GSs_{total}$  is the total area of urban spaces; and  $POP_{total}$  is the total population of the city, respectively.

### 2.2.3. Sample Selection, Data Collection and Questionnaire Survey

In this study, semi-structure questionnaire was prepared for collection of data on GSs strategies for urban sustainability. The questionnaires were broadly divided into two sections: (i) general information of the respondents such as gender, age, educational qualification, and nationality; and (ii) in the second parts of the questionnaire, the questions were asked related to the GSs strategies for urban sustainability. There were six strategies related to (GSs that include three questions in each section (total 18 questions were asked). The details of the questionnaire were shown in (Appendix A (Table A1)). A

total of 1200 respondents were surveyed from three cities with maximum respondents from Jeddah ( $N = 520$ ) followed by Riyadh ( $N = 404$ ) and Dammam ( $N = 276$ ), respectively (Table 2). The direct interviews with the respondents were performed to collect data. The respondents were randomly selected from different GSs such as parks, gardens, and educational institution, respectively. The survey was performed during summer season in 2019 during June and July) due to better understanding of the role of GSs. All the strategies and questions were explained properly so that respondents could easily understand the strategies and questions. Then, the respondents were asked questions such as whether they were agreed with management of GSs strategies (such as design, maintenance, quality etc.,) (Do you think the GSs are properly managed?) (Strategies I). To understand the standard approach, the respondents were asked, "Are you satisfied with the availability of PCGSs in city?" before that, the PCGSs were presented to the respondents at city scale (Strategies II). The questions were prepared in English language, and after that, it was translated into Arabic for better understanding the objective of the study. The interactions with the respondents were continued up to 20 min. After June and July (2019), the survey was stopped, and an online survey was performed during June and July due to emergence of COVID-19 in 2020. The online questionnaire survey was conducted using Google Forms (Google LLC, Mountain view, CA, USA) from June to July 2020. The online survey was performed due to outbreak of COVID-19 in early year of 2020. Out of 1200 questionnaire survey, 35% (420) responses were collected through online mode. The detail instructions for online survey were given with questionnaires. We used the same questionnaire for direct interview and online survey. Similar questions were used for direct interview and online survey to maintain the consistency of the study result. For the both the cases, the objective of the study was clearly explained so that the respondents can understand the questions set for the study.

**Table 2.** Socio-demographic profile of the sampled respondents.

Dimension	Category	Riyadh ( $N = 404$ )	Jeddah ( $N = 520$ )	Dammam ( $N = 276$ )
Gender	Male	220	360	120
	Female	184	160	156
Educational qualification	High school	68	106	92
	Bachelor	189	195	126
	Master	64	146	29
	PhD	29	31	16
	Illiterate	54	42	13
Age group	<20	56	88	61
	21–40	203	251	144
	40–60	120	122	45
	>60	25	59	26
Nationality	Saudi	380	506	261
	Non Saudi	24	14	15

### 3. Results and Discussion

#### 3.1. Per Capita Scenario of GSs in Saudi Cities

In Saudi Arabia, there is a considerable shortfall in the per capita availability of GSs in cities in comparison to international standards. A study was carried out across three cities in Saudi Arabia (Riyadh, Jeddah, and Dammam) (Table 1) to examine per capita availability of GSs; the highest per capita availability of GS was reported for Dammam ( $5.4 \text{ m}^2$ ), followed by Riyadh ( $1.18 \text{ m}^2$ ), and Jeddah ( $0.5 \text{ m}^2$ ) [34]. However, to meet the World Health Organization (WHO) standard, Dammam would need to add 40% to its  $5.52 \text{ km}^2$  of parks and gardens, Riyadh 87 to its  $6.16 \text{ km}^2$ , and Jeddah city more than 90% to its  $2.05 \text{ km}^2$ . Thus, there were notable shortfalls in the per capita availability of GSs in all three cities; the shortfalls are even greater against European Union, Public Health Bureau (USA), and United Nations (UN) standards. The importance of GSs for

climate change adaptation in Saudi Arabia remains unexplored though climate change is prominent in Saudi Arabia as the annual average temperature has increased by 0.75% [26] and is projected to increase by 2.2–2.7 °C by 2050 with the global average increasing by 1.5–2.0 °C [54]. The spatial distribution of GS is shown in Figures 3–5. In these figures, dark green indicates a relatively high density of GSs, and a light green color indicates a relatively low density of GSs across the cities.

## Jeddah

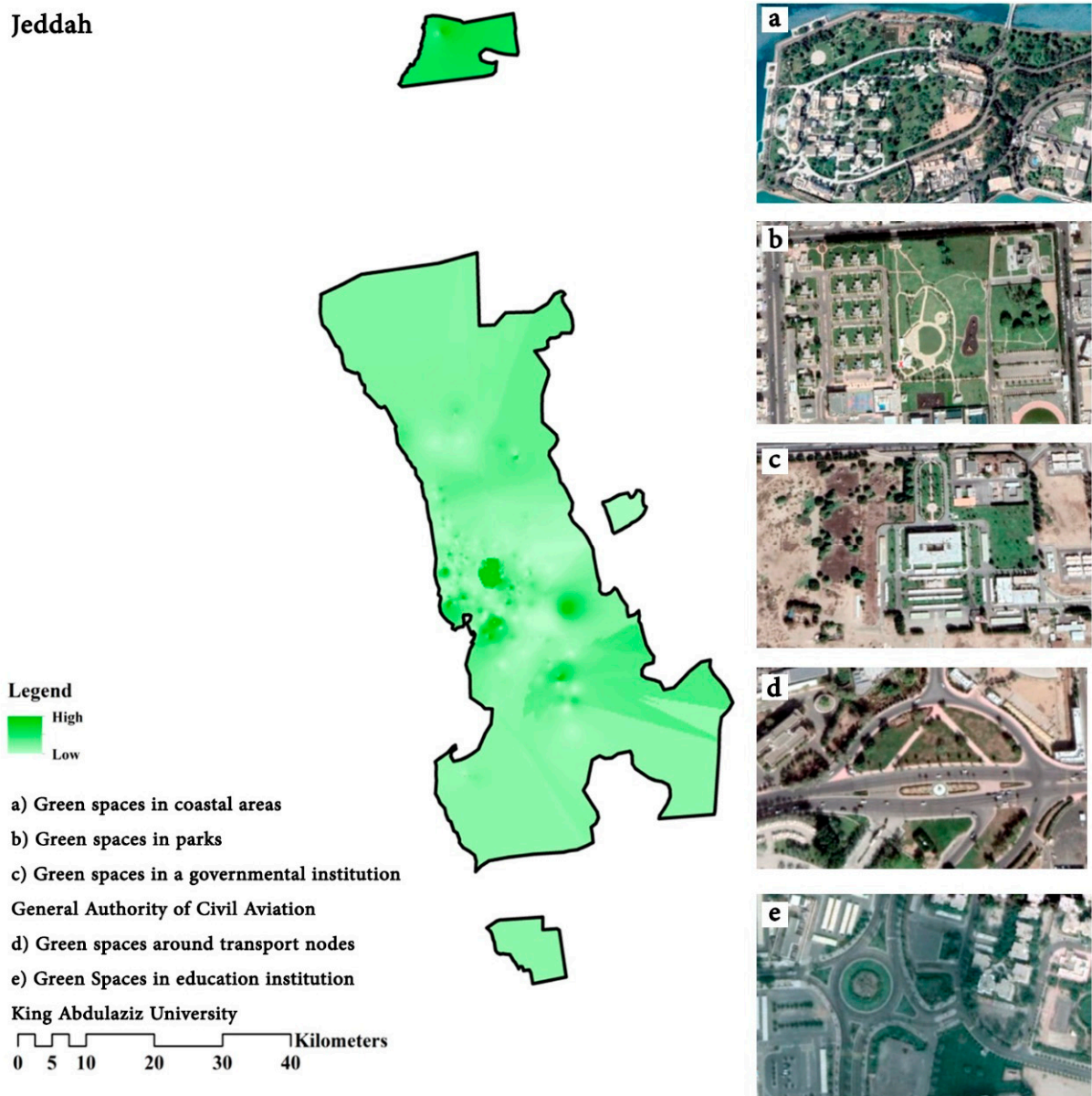
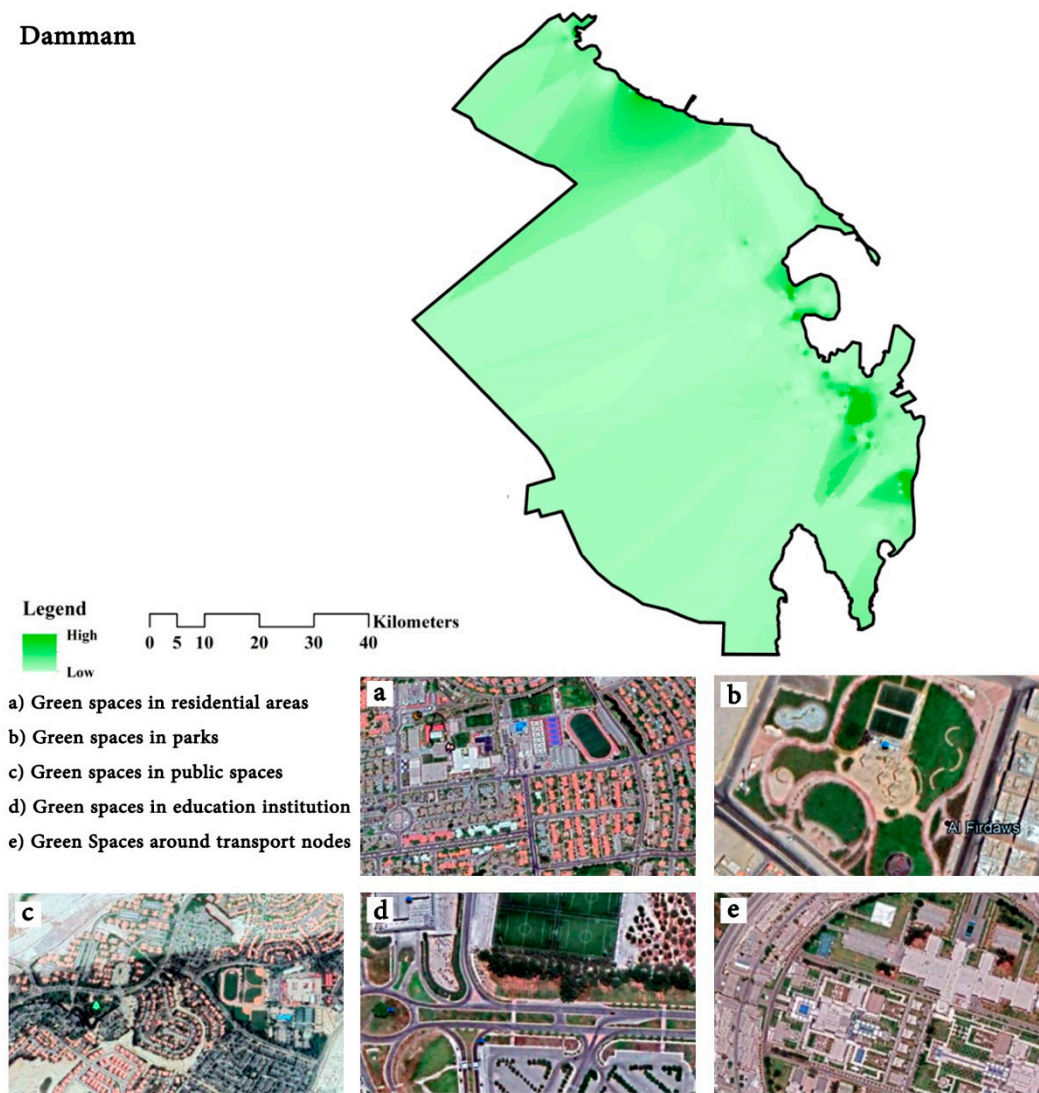


Figure 3. Spatial distributions of GSs in Jeddah.



**Figure 4.** Spatial distributions of GSs in Dammam.

Thus, from PCGSs across the cities, it was clear that there was substantial variation of per capita availability of GSs across the cities of Saudi Arabia.

### 3.2. Strategies for Provisioning GSs for Urban Sustainability in the Context of Saudi Cities

As the aim of this study to present GSs provision strategies to achieve urban sustainability in Saudi cities, Figure 6 represents the proposed strategies and their details as follow:

#### 3.2.1. Improving the Quality of GSs

As per the result of the study, it was found that there is very limited access to GSs in Saudi cities. It was reported that about 54% of the respondents stated that GSs were available with a walkable distance (5 min or 300 m), with the highest-percentage respondents from Dammam (74%) followed by Jeddah (55%) and Riyadh (53%), respectively. About 40% of the respondents did not use GSs due to the lack of accessibility and issues related to the maintenance, design, and quality of the GSs. Most of the respondents use GSs for picnics (59%), mental well-being (53%), and physical activities (47%), respectively. From the interviews, 57% of respondents reported that they had access to nearby GSs. In the Al Salam Park in Riyadh, 25% of the respondents used GSs for physical activities on regular basis, and about 40% of respondents used parks for picnic and family gatherings. Among all the cities, the highest percentage of respondents in Jeddah (about 75% of the



total respondents) used parks followed by Dammam (69%) and Jeddah (51%), respectively. Respondents attached considerable importance to green spaces but noted poor accessibility of the GSs. More than 85% of the total respondents across the cities stated that GSs need to be improved and managed properly for their well-being. Thus, it was clear that substantial improvement is required to enhance the quality of GS across the cities in Saudi Arabia.

Preservation and restoration of GSs through GS management strategies have been suggested in previous studies [69–78]. Vaughn et al. [77,78] noted that effective planning strategies can assist in carbon sequestration (91%) and carbon storage (82%). Enhancing the quality of GS is also crucial from the perspective of recreation and biodiversity [79] and is particularly important when there is limited scope to extend the GS footprint in cities [80]. Ecological principles can be applied to GS planning, such as introducing species with a more natural composition [73]. The quality of GS can be enhanced through innovative greening ideas, such as green roofs, street sites, and green walls [81,82]. GS can also be managed through redevelopment planning strategies (such as saving or transplanting trees) to maintain the various direct and indirect functions of GSs [73,83–85]. Empty spaces without vegetation, such as narrow transport nodes, can be made green [86]. Apart from the quantity of GS, their spatial distribution and placement within the city are also significant [87].

## Riyadh

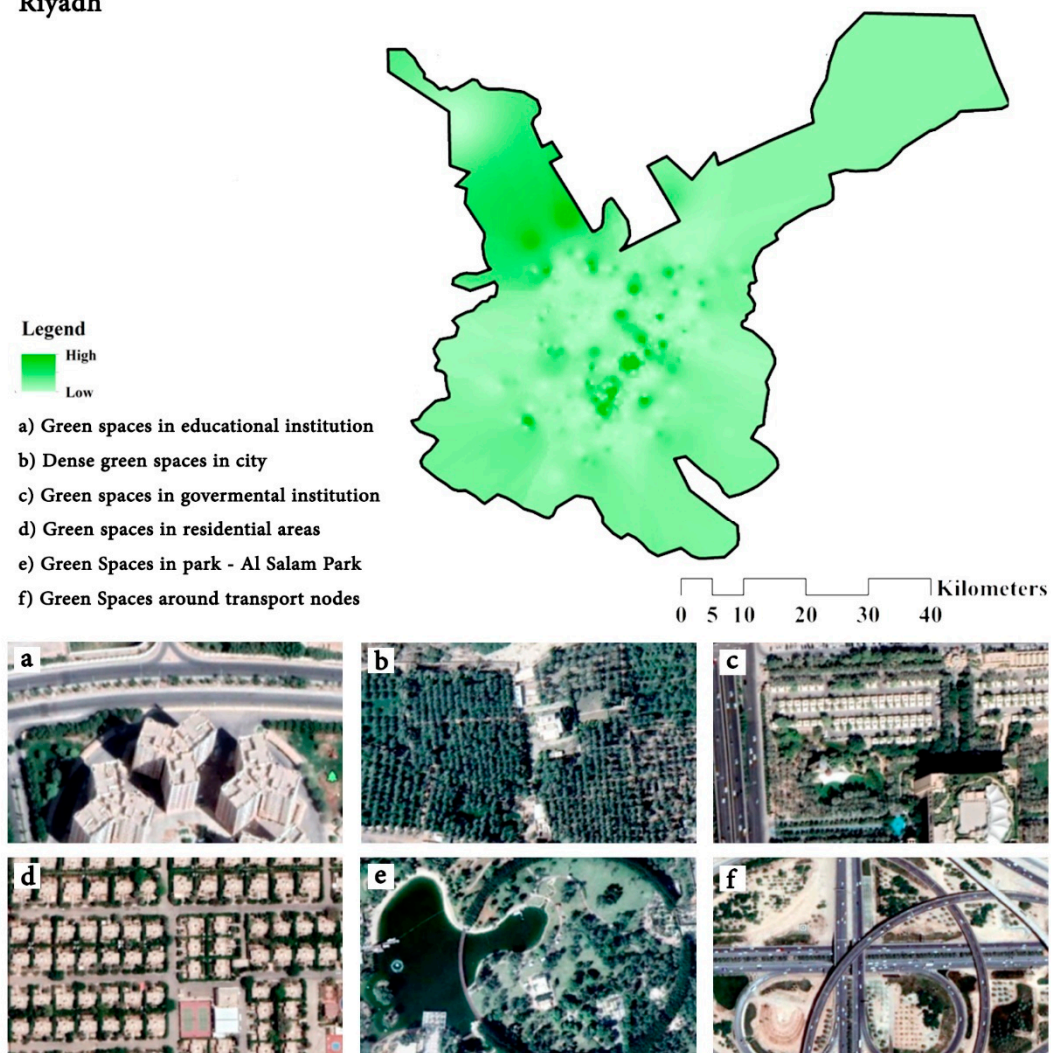


Figure 5. Spatial distributions of GSs in Riyadh.

Strategies for green spaces provision	Saving and enhancement of high quality GSs
	Application of GSs standard
	Involvement of public participation
	Greening strategies related to buildings and private properties
	Improvement of GSs planning process
	Application of landscape ecological approach

**Figure 6.** Proposed GSs management strategies for urban sustainability in Saudi cities.

### 3.2.2. Application of Standard Approaches

As per the result of the study, it was observed that there are substantial shortfalls in the per capita availability of GSs across the cities. The average per capita availability of GS was 2.36 m<sup>2</sup>, with the highest per capita availability in Dammam (5.4 m<sup>2</sup>) followed by Riyadh (1.18 m<sup>2</sup>) and Jeddah (0.5 m<sup>2</sup>), respectively. Per capita availability of GS was much less in comparison to WHO (9 m<sup>2</sup>), United Nations (30 m<sup>2</sup>), and European Union (26 m<sup>2</sup>), respectively. As per the survey result, it was reported that the people were not satisfied with the availability of GSs across cities. Particularly in Jeddah, about 90% respondents reported that PCGSs must be improved at a city as well as neighborhood level. As per the survey result, it was observed that highest percentage of respondents (51%) in Jeddah do not use GSs at neighborhood level followed by in Dammam (31%) and Riyadh (26%), respectively. Therefore, increase per capita availability of GSs is not only necessary just to reach standard but rather for the enhancement quality of life of the urban dwellers.

Adopting the standard per capita availability of GS is a common strategy to use when seeking to ensure adequate availability to city dwellers. However, according to Byrne et al. [80], the application of standards is difficult because quantitative measures alone do not improve the provision of GS international organizations, such as the WHO, provide their own standards for the per capita area of GS, but availability and accessibility are much more important than the area of GS [88]. In many previous studies, accessibility to GSs has been given higher priority for planning in cities [87,89].

### 3.2.3. Ecological Landscape Approaches

Being a desert country, there is a lack of ecologically sound landscape in Saudi Arabia (except desert ecosystems). Therefore, it is necessary to implement GS planning strategies at the city as well as at the neighborhood level (such as greening a specific area). Greening strategies, such as corridors of trees, can also be implemented along roads across the cities. Ecological approaches need to be integrated into urban landscape planning strategies at the city level, as well as neighborhood level. As per the survey, it was observed that people agreed that GSs play a significant role for local climate regulation such as temperature control (78%), UHI reduction (81%), and GSs provide thermal comfort (84%), respectively. The survey results also revealed the fact that more than 85% of the total respondents reported that the GSs must be managed as they were crucial for climate regulation and well-being of the people. Thus, these ecological landscapes were closely linked with daily well-being of the people. Therefore, ecosystem-based GSs must be managed effectively as per the respondents.

GSs can be managed sustainably through the application of ecological landscape approaches. In many previous studies, ecological landscape approaches have been given priority in urban planning and decision-making frameworks [76,90–94]. The principle of ecological landscape planning is to optimize the geometry of GSs, such as enhance connectivity as well as the network [93,95]. Ecological landscape approaches are necessary tools for effective planning of ecologically sound GS [76] and provide the foundation for urban landscape planning and GS planning [76,77]. Applying ecological landscape planning principles enables the achievement of sustainable landscape development through focusing on the three fundamental structural components, namely corridors, patches, and matrices [78]. Ecological landscape approaches are crucial for the maintenance of key ecosystems and biodiversity [96]. Ecological sustainability can be achieved through the comprehensive management and restoration of GS to achieve better urban ecological landscape planning [96].

According to Pirnat al. [95], corridors of trees can be prioritized along roads for connectivity of fragmented landscapes. The green plot ratio (GPR) was proposed by Ong [97] for GSs planning as a measure of ecological indicators. GPR refers to the green area per unit of ground area. These ecological indicators are considered to be very effective for the greening of urban landscapes and architectures and may be integrated with urban design, urban landscape planning, and sustainable land-use planning. In Beijing (China), ecological planning was developed by Li et al. [89] that can be implemented at different spatial scales, namely regional level (such as an entire country), city level (such as urban areas or suburban and peri-urban areas), and neighborhood level (such as specific areas within landscapes). According to Frischenbruder and Pellegrino [98], GSs within the urban environment have a significant contribution to enhancing the quality of life of urban dwellers.

#### 3.2.4. Improvement and Enhancement of GS Planning

From the survey result, it was reported that there were the lack of effective design, maintenance, and quality of GSs across the cities. More than 40% of respondents reported that they were not satisfied with the services provided by the GSs due to poor infrastructural facilities. Therefore, effective GSs planning strategies are urgently required to meet respondents' expectations and to improve urban landscape planning. More than 80% respondents of the cities agreed that the city must have more greenery to enhance availability and accessibility to GSs. The survey also revealed that only 16% respondents in Jeddah, 34% respondents in Dammam, and 29% use nearby GSs. It clearly denotes the fact that there is a lack of issues related to accessibility, design, and quality of GSs at neighborhood level. Therefore, GSs need to be improved to enhance the accessibility to the GSs at neighborhood level. In Saudi Arabia, several strategies have been adopted by the Ministry of Municipal and Rural Affairs (MoMRA) to improve GS across cities. As per MoMRA's guidelines, GSs, particularly gardens and parks, must be an integral part of urban landscape planning. MoMRA has made a huge investment in GS and plays a significant role in providing finance for projects. To achieve the standard per capita availability of GSs proposed according to the WHO (9 m<sup>2</sup> per capita) and the UN, the government needs to invest between 20 and 74 billion USD. The private sector needs to be involved to support and implement GSs planning in Saudi cities. In addition, the Vision 2030 National Transformation Program has been implemented to enhance the quality of life and make Saudi cities more livable. In Saudi Arabia, the Green Building Project (part of Vision 2030) was implemented to support the eco-sustainable development of Saudi cities.

In previous research, effective restoration and management were given priority in planning processes due to the many constraints and extreme shortages of the per capita availability of GSs across cities [99,100]. In many cities in the world, effective strategies have had significant impacts on the enhancement of GSs, such as in Kunming in China [101]. Many times, the lack of a strong database is one of the major limitations to the successful implementation of GSs planning across cities. Therefore, good databases are essential for

effective planning and the management of existing GSs within cities [101,102]. GS can also be managed through a proper understanding of the importance of services provided by GSs for the well-being of urban dwellers [103]. The improvement and enhancement of GS through effective planning processes is necessary due to their multiple functions such as ESs and significant role in human health (physical and mental) and well-being [104,105]. An ESs-based approach must be given priority in green planning strategies in cities, but previous studies have given only limited focuses to ecosystem services-based GS management [94].

### 3.2.5. Public Participation in GS Management

From the interactions with respondents, it was evident that GSs have an important part to play in their daily routine, through physical activities, mental refreshment, picnics, etc. However, there was a lack of understanding of the role of GSs in their lives. Some 42% of respondents were not aware of the role of GSs in air quality regulation, reduction of heat islands, and noise pollution reduction. According to the respondents across the cities, GSs can be managed more effectively through the public participation in GSs management. Therefore, building an understanding of the role of GSs among the public is necessary to manage and restore GSs.

Recently, a study was performed by Addas et al. [34] that showed a lack of understanding of the role of GSs. Involvement of stakeholders and public participation are considered to be significant aspects of effective GSs management [83]. However, the implementation of planning strategies is not enough to enhance the quality of the GSs within cities. Public participation and awareness of the importance of GS are also necessary for their effective management.

### 3.2.6. Greening Strategies Related to Buildings and Private Properties

In Saudi Arabia, there is limited implementation of innovative planning strategies, such as green roofs and vertical green infrastructures. Therefore, planners and policymakers must think of alternative spaces for urban greening to enhance the availability and accessibility to GSs across cities. Table 3 presents some alternative GSs that can be promoted across cities. As per the survey result, it was reported that the GSs must be promoted at households' level (such as small patches of greenery on roof and open spaces). About 86% of the total respondents of the survey agreed with the implementation of innovative techniques as greening strategies with highest percentage of respondents from Jeddah (91%), Dammam (84%), and Riyadh (82%), respectively. The survey results showed that respondents agreed to the urban greening strategies of building and private properties (more than 80% of respondents agreed). However, the interactions of respondents highlighted that there were effective planning strategies and spaces for greening of buildings and private properties.

**Table 3.** Proposed places for GSs planning in Saudi cities.

UGS	Proposed Places	Area Coverage
Street verges	Roadsides, trees, footpaths	About 100 m <sup>2</sup>
Structural	Walls, roofs, buildings, fences	Small (<100 m <sup>2</sup> )
Brown fields	Landfill, industrial parks	>1 ha
Gaps	Empty spaces between walls or fences	Small (<100 m <sup>2</sup> )
Microsites	Plantation in cracks or holes	Very small (<1 m <sup>2</sup> )
Power lines	Vegetation corridors under power lines	Medium to large (>1 ha)

In many cities across the world, there is a very limited scope for GS planning due to insufficient space, and therefore other urban greening strategies, such as green roofs and vertical green infrastructure (such as green facades), are implemented [93,96]. Different functions, including amenity provision [93], biodiversity conservation [87], cooling effect [86], and food production [106] can be supported. According to Tan et al. [87],

sky gardens can be significant assets in improving urban greenery and the well-being of people. Sky gardens are very small in size and cannot provide significant services like other open green spaces [86]. However, they can be developed to enhance the functions of green spaces [91,92]. In many studies in developed nations in Asia and Europe, GSs planning strategies have been a significant priority, such as in Hong Kong [69], Beijing [13], Copenhagen [106], Pukou District in Nanjing [107], and Berlin [108].

There are several example of GSs management strategies such as street edge cover, GSs between buildings, GSs along rail lines, GSs in industrial areas, GSs inside educational and governmental insulation spaces. In Saudi cities it will be recommended to adopted similar strategies to enhance and improve the GSs which will have positive impact on the urban environmental sustainability.

Saudi Arabia is characterized by desert climate. Therefore, innovative green infrastructures (GIs) such as rain gardens, porous pavement, green roofs, and green streets (see Glossary) can be applied in arid and hot climatic regions. Xeriscape landscaping can also be one of the significant urban greening strategies. Various types of cactus and succulent plants (such as moss rose, hen-and-chicks, autumn joy, etc.) can be planted for urban greenings.

#### 4. Conclusions

This study mainly focuses on the assessment of the quantitative analysis of GSs across three major cities (Riyadh, Jeddah, and Dammam) in Saudi Arabia and strategies for provisioning GSs across these cities to improve urban sustainability and urban landscape planning. The quantitative analysis and the perception regarding the strategies related to the GSs provision were assessed through GIS and questionnaire survey, respectively. From the findings of the study, it was well recognized that: (i) there were substantial shortfalls in per capita availability of GSs in all three cities. The highest shortfall was reported in Jeddah; (ii) about 46% of respondents had no access to GSs. Thus, urban planners and policymakers should focus on the enhancement of availability as well as accessibility to GS; (iii) there is a lack of proper design and management of GS in the cities. Therefore, the quality of the green spaces must be improved to enhance the accessibility of urban dwellers to GS; (iv) there is a lack of understanding about the contribution of GSs; public involvement with GSs planning must be improved across the cities in Saudi Arabia; and (v) innovative techniques need to be integrated with decision-making frameworks for more effective urban greening planning. Thus, from the overall analysis, it was documented that there was substantial lack of strategies related to the GSs across the cities of Saudi Arabia. As per the survey result, it was reported that the respondents were (more than 80%) not satisfied with the present management strategies implemented by the governments. According to most of the respondents, the GSs need to be managed properly as there was limited accessibility, lack of awareness about the importance of GSs among the people. As per the survey, it was reported that (i) GSs need to be improved; (ii) per capita availability of GSs needs to be enhanced; (iii) ecological landscapes need to be managed properly particularly parks and gardens at neighborhood level; and (iv) there were lack of design, safety, water features, and maintenance of GSs. Therefore, the findings of the study will be very helpful to understand the perceived expectation of the city dwellers based on policies, and planning can be implemented to meet the need of the city dwellers. Thus, from the findings of the study, it can be suggested that Ministry of Rural and Urban Affairs (MoMRA) and local government must focus on the spatial distribution of GSs at a city as well as neighborhood scale. Effective focuses need to be paid on the planning and design of GSs, walkability, and accessibility and introduction of new GSs particularly at city scale. From the survey, it was the GSs at city scales that were more desirable as compared to the neighborhood scale to the respondents. Therefore, the city planners and policy makers must focus on the practical implementations of GSs. In Saudi Arabian cities, there were very few central parks across the cities in Saudi Arabia. In Riyadh, initiatives were adopted, and new large projects at city scale were introduced such as Green Riyadh project, King

Salman Park Project, Riyadh Art Project, and Sports Boulevard Project, respectively. Such projects can also be implemented in other cities of Saudi Arabia. Apart from this, a GSs management and restoration body can be formed by the MoMRA to manage as well as restore GSs across cities.

Although this has immense scope for understanding and implementing the strategies for provisioning GSs across cities of Saudi Arabia, it has some limitations. First, this study mainly deals with the assessment of per capita availability of GSs using recent data (2020). No temporal assessment of GSs was performed across the cities. Second, the survey for the study was started in October 2019 but was stopped due to the outbreak of COVID-19. A very limited survey was performed across cities. Despite these limitations, this study will assist urban planners and policy makers in understanding and implementing effective strategies for urban landscape planning through the management and restoration of GS and improved urban greening across the cities in Saudi Arabia. Future researchers may consider how to implement innovative tools, such as green roofs and vertical greening strategies across cities to aid urban sustainability and improve urban landscape planning. Local governments should consider urban greening strategies in their decision-making frameworks. Future research should consider the spatial–temporal mapping of GSs' better landscape planning

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## Glossary

**Green spaces (GSs)**—Green spaces (GSs) are the spaces covered with greenery such as trees, shrubs, parks, and community gardens, which are accessible to all Ecosystem services (ESs)—The direct and indirect services provided by ecosystems are known as ecosystem services. Ecosystem services are broadly classified into four categories: regulating, supporting, provisioning, and cultural ecosystem services, respectively. **Urban heat island (UHI)**—The urban areas are relatively warmer than the surrounding rural areas. This phenomenon known as UHI. UHI can be two types: surface urban heat island (SUHI) and atmospheric urban heat island (AUHI), respectively. **Perceived valuation**—The perceived importance of the services provided by green spaces (GSs) to the stakeholders or subjective valuation of green spaces. **Carbon sequestration**—Carbon sequestration is a process of storing and capturing carbon dioxide to reduce the carbon dioxide from the atmosphere. Green spaces (GSs) can be developed as one of the significant nature-based solution of carbon sequestration. **Green roofs**—Green roof is an innovative technique dealing with the greening of roof (partially or completely). This is one of the significant nature-based solutions of climate change, and these innovative techniques are widely applied in developed countries (such as Germany, France, Spain, etc.). **Green walls**—Green wall is also one of the significant nature-based solutions to climate change. **Rain garden**—These are vegetated areas retained water from rooftops and sidewall. **Porous pavement**—This reduces the surface run off and triggers infiltration process. **Green streets**—These can be developed at neighborhood scale for urban greening. **Ecological landscapes**—The landscapes that are related to ecology and provides benefits to the human for their well-being. Ministry

of Municipal and Rural Affairs (MoMRA)—MoMRA is the organization of the central government of Saudi Arabia. This ministry is responsible for urban planning across the Saudi cities. Green infrastructures—Green infrastructures are the green spaces focusing on the principal of protecting as well as enhancing the nature and green spaces.

## Appendix A

**Table A1.** Questionnaire used in this study for urban greening assessment.

Strategies	Questions	Response	
		Yes	No
<b>Strategy I</b>	<b>Improving the quality of GSs</b>		
Question 1	Do you think GSs need to be improved?		
Question 2	Do you think GSs are properly managed?		
Question 3	Do you think GSs need to be improved for wellbeing?		
<b>Strategy II</b>	<b>Standard approaches</b>		
Question 1	Are you satisfied with availability of PCGSs?		
Question 2	Do you think availability of PCGSs must be improved?		
Question 3	Do you think availability of PCGSs must be improved for urban sustainability?		
<b>Strategy III</b>	<b>Ecological landscape (ELs) approaches</b>		
Question 1	Do you think GSs patches must be managed?		
Question 2	Do you think GSs are crucial for climate regulation (such as temperature regulation, urban heat island reduction, etc.?)		
Question 3	Do you think ELs are linked with your daily life?		
<b>Strategy IV</b>	<b>Improvement and enhancement of GSs planning</b>		
Question 1	Do you think there is limited accessibility to GSs?		
Question 2	Do you think there is limited availability at GSs on the city and neighborhood level?		
Question 3	Do you think city need to become more greenery?		
<b>Strategy VI</b>	<b>Public participation is GSs management</b>		
Question 1	Do you think people must participate in GSs management?		
Question 2	Do you think people need to become aware of GSs importance		
Question 3	Do you think people of the city conscious of GSs management?		
<b>Strategy VII</b>	<b>Greening strategies related to buildings and private properties</b>		
Question 1	Would you like to make your house with GSs?		
Question 2	Do you have enough spaces for landscaping at your house?		
Question 3	Do you think GSs must promote at household level?		

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