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Exploring Pattern of Green Spaces (GSs) and Their Impact on Climatic Change Mitigation and Adaptation Strategies: Evidence from a Saudi Arabian City

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Abstract: Green spaces (GSs) are significant, nature-based solutions to climate change and have immense potential to reduce vulnerability to heat waves while enhancing the resilience of urban areas in the light of climate change. However, in the Saudi context, the availability of GSs across cities and their perceived role in climate change mitigations and adaptation strategies remain unexplored. This study aimed to examine the per capita availability of GSs in the Jeddah megacity in Saudi Arabia, and their role in climate change mitigation and adaptation strategies. This study assessed the per capita availability of GS in Jeddah city using GIS techniques, and a questionnaire survey (online and an onsite) was conducted to assess the GSs users' perception of the role of GSs on climate change mitigation and adaptation strategies. Non-parametric tests were also used to find differences in roles based on socio-demographic attributes. The findings of the study revealed that: (i) the per capita availability of GS in Jeddah is relatively low in comparison to international organization recommendations (such as World Health Organization and European Union). As per the survey result, it was reported that GSs play crucial role for climate change mitigation such as temperature regulation, reduction in heat stress, enhancement outdoor thermal comfort, and the maintenance of air quality. More than 85% of the total respondents agreed with the very high importance of GSs for climate change mitigation. More than 80% of respondents in the city highly agreed with climate change adaptation strategies such as the enhancement of accessibility to GSs, ecosystem-based protection of GSs, and the improvement of per capita availability of GSs. The findings of the study will be very helpful to planners and policymakers in implementing nature-based solutions to reduce vulnerability to climate change in Jeddah city, and particularly other cities in a desert environment.

Keywords: green spaces; climate change; well-being; urban sustainability; vulnerability

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1. Introduction

Rapid rates of urbanization and climate change have emerged as serious challenges to urban areas [1,2]. The existing environment is being converted into semi-natural or artificial land surfaces, ultimately affecting energy flow, solar radiation, and atmospheric parameters [3,4]. Furthermore, the conversion of land surfaces, emissions from anthropogenic sources, and materials used in building result in the emergence of urban heat islands (UHI) [3,5–7]. The frequency of extreme climatic events, such as cold weather and heat waves, and the occurrence of UHI, are likely to increase due to global climate change [8,9]. In urban areas, air quality, energy, the health of the urban dwellers, and urban sustainability are profoundly affected by UHI [10–12].

In this context, effective management strategies need to be implemented to enhance the absorption of solar radiation, reduce heat storage, and use blue and green spaces to lessen the effects of UHI [1,13–15]. Green spaces can be treated as urban green infrastructure (UGI). UGI refers to the hybrid infrastructure of green spaces, such as urban forests, green roofs, green walls, and parks [16]. UGI plays a significant role in the enhancement of urban resilience and human well-being by providing ecosystem services (ES) [17–19]. UGI contributes to reducing temperatures, and many studies have established that the development of urban UGI is significant for climate change adaptation because these spaces are eco-friendly and cost-effective and are also acceptable from a political perspective [16–18]. According to McDonald et al. (2016) [19], urban green spaces (GSs) are relatively cost-effective compared to cool roofs in improving outdoor thermal conditions.

Several factors, such as the shape, size, density, complexity, and connectivity of GSs, profoundly influence their cooling effect [11,20,21]. According to Shih (2017) [22], spatial patterns and configurations influence the cooling effect of GSs. The cooling effect is not confined to the GS, but also benefits adjacent areas [15,23], although the cooling effect declines with increasing distance [17,24]. Average temperatures are reduced by 0.94 °C and 1.15 °C during the day and night, respectively, in the presence of GSs [25–27]. The literature shows that the cooling effect of GS is determined by the surrounding environment and its land use/land cover (LULC) pattern, as well as building materials, building height and density, and climatic conditions [15,26–31]. However, although previous studies have examined the cooling effect of GSs [11,23,32], they have not addressed the role of GS in climate change adaptation strategies, particularly in the Saudi context. The limitations of previous research affect the ability of planners and policymakers to make recommendations for land use planning and design to alleviate heat effects in urban environments [15,30,33]. In the Saudi context, most studies have been performed on patterns, types, and policies for open public green spaces [34–36]. Previously in Saudi Arabia, a number of research studies have been performed on the quantitative assessment of GS across cities including Jeddah, Riyadh and Dammam [34–36]. Apart from Saudi Arabia, many studies have been conducted across different cities, such as Chittagong in Bangladesh [37], Mandalay city in Myanmar [38], Berlin in Germany [39], and Shanghai in China [23,40]. Most of these studies mainly dealt with quantitative evaluations, spatial variation, and the impact on the well-being of people. However, the role of GS on climate change mitigation and adaptation strategies has remained unexplored in the Saudi context. It is well recognized that global vulnerabilities due to natural as well as human-made disasters have increased as a result of climate change [41]. Now, the basic question arises as how to reduce (mitigation strategies) and to cope (adaptation strategies) with the impact of climate change. Simply, "mitigation aims to avoid the unmanageable and adaptation aims to manage the unavoidable" [41]. Urban areas across the globe are experiencing serious challenges (such as floods, droughts, heat waves) due to climate change [5]. Thus, climate change in cities has put a significant question to spatial planners in the 21st century: how to adapt cities to climate change? [42]. Attention has grown towards the contribution of green spaces (GSs) in addressing the challenges. GSs were considered as one promising nature-based solution to the adverse effects of climate change in cities [43,44]. According to Davies et al. [45], GSs should be treated as a significant resource for climate change mitigation. GSs have been prioritized in terms of policy and governance in many scientific debates related to climate change mitigation and adaptation strategies [46]. The contributions and benefits of GSs to climate change mitigation and adaptation strategies have been widely studied [47,48]. However, very limited focus has been given to the role of GSs for climate change mitigation and adaptation strategies.

This study assesses the perceptions of people towards the role of GSs on climate change mitigation and adaptation strategies. Spatial structures as well as entire urban regions are largely affected by climate change mitigation and adaptation strategies [49]. In addition to this, the users' behavior, motive, preferences, as well as attitudes are influenced by the perception of people towards the environment or landscape quality [50,51]. Thus, behaviors and attitudes of people to landscape quality affect GSs management and planning [52,53]. Positive attitudes and perceptions of landscape quality encourage physical activities and promote beneficial outcomes [54]. The perceived access to GSs can also promote recreational pursuits and mental health as well [55]. Apart from the objective assessment of the environmental, as well as landscape quality, self-reported perception of the user is crucial [56]. The perceived attitudes towards the GSs were proven to significantly influence the quality of life, mental stress, leisure activities, and psychological wellbeing of the people [57,58]. In spite of this, limited attention has been paid towards the perceived role and attitudes towards GSs in climate change mitigation and adaptation strategies. Particularly, perceived attitudes to the role of GSs remain unexplored in the Saudi context. Thus, to fill this research gaps, this study aimed to assess the perceived importance and attitudes to climate change mitigation and adaptation strategies in Jeddah city.

Saudi Arabia has a population of around 33 million (2018) and is vulnerable to climate change [59] due to its sensitive ecosystem, frequent occurrence of floods, and limited freshwater resources [60]. According to the Global Climate Risk Index [61], Saudi Arabia ranked 84th. In addition, Saudi Arabia has among the highest levels of energy consumption and CO_2 emissions per capita; energy consumption is three times higher than the global average, and CO_2 emissions are the 7th highest per capita. Between 2006 and 2015, energy consumption increased by about 58% (from 160 million tons to 260 million tons of oil) (British Petroleum (BP), 2017). The country uses domestic oil (about 40% of the total for Middle Eastern countries) and gas consumption (21% of the total for Middle Eastern countries) mainly for transportation, power generation, and industrial activities. According to Abubakar and Aina [62], resource demand in Saudi Arabia is three times greater than the capacity of the ecosystem.

Over the last few decades, Saudi cities have experienced rapid rates of urban expansion and population growth [63] (Figure 1), leading to extreme alteration of LULC [64]. Increased oil revenue has encouraged the government to implement various infrastructure development projects [40], with LULC changes resulting from urban expansion, industrial development, and agricultural expansion having an impact on ecosystems as well as biodiversity [65]. Thus, the rapid transformation of LULC has seriously impacted cities at a local level, through increases in temperature, the emergence of the UHI effect, and deterioration of thermal comfort levels across cities [66–70]. The impact of climate change, particularly on cities in a desert environment, is prominent due to rapid urban expansion. In the context of Saudi Arabia, most studies have been performed on the quantitative assessment of GS across the cities [23,39]. However, to the best of our knowledge, no study has been performed on the role of GSs for climate change mitigation and adaptation strategies on Saudi Arabian cities. These research gaps from previous studies inspired us to investigate the preferences for GS, the role of GS in climate change mitigation, and climate change adaptation strategies, as perceived by the respondent in Jeddah city. Thus, the findings will help city planners and policymakers to understand and implement nature-based solutions in climate change mitigation and adaptation strategies.

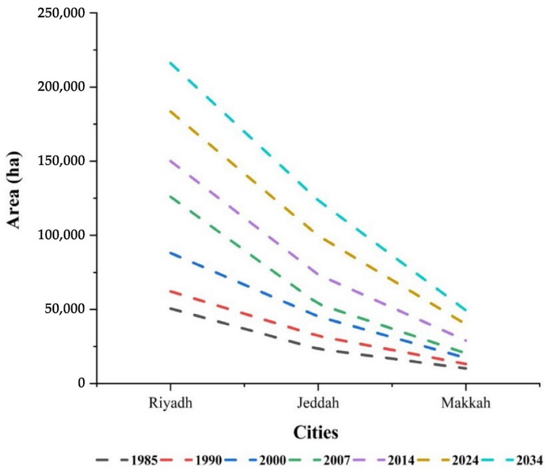

Figure 1. Urban growth pattern over Riyadh, Jeddah and Makkah from 1985 to 2034 (expected) (Alqurashi et al. 2016).

2. Materials and Methods

2.1. Study Area

The present study mainly focused on Jeddah city, in which the per capita availability of GS has been assessed as well as the people's perception on the role of GS on climate change. (Figure 2). Jeddah is one of the most populous cities in Saudi Arabia. Jeddah city was selected because (i) Jeddah is one of the most substantial cities in Saudi Arabia, and (ii) GS provision in this city is relatively low compared to other cities such as Riyadh and Dammam. The profile of Jeddah city has been presented in Table 1.

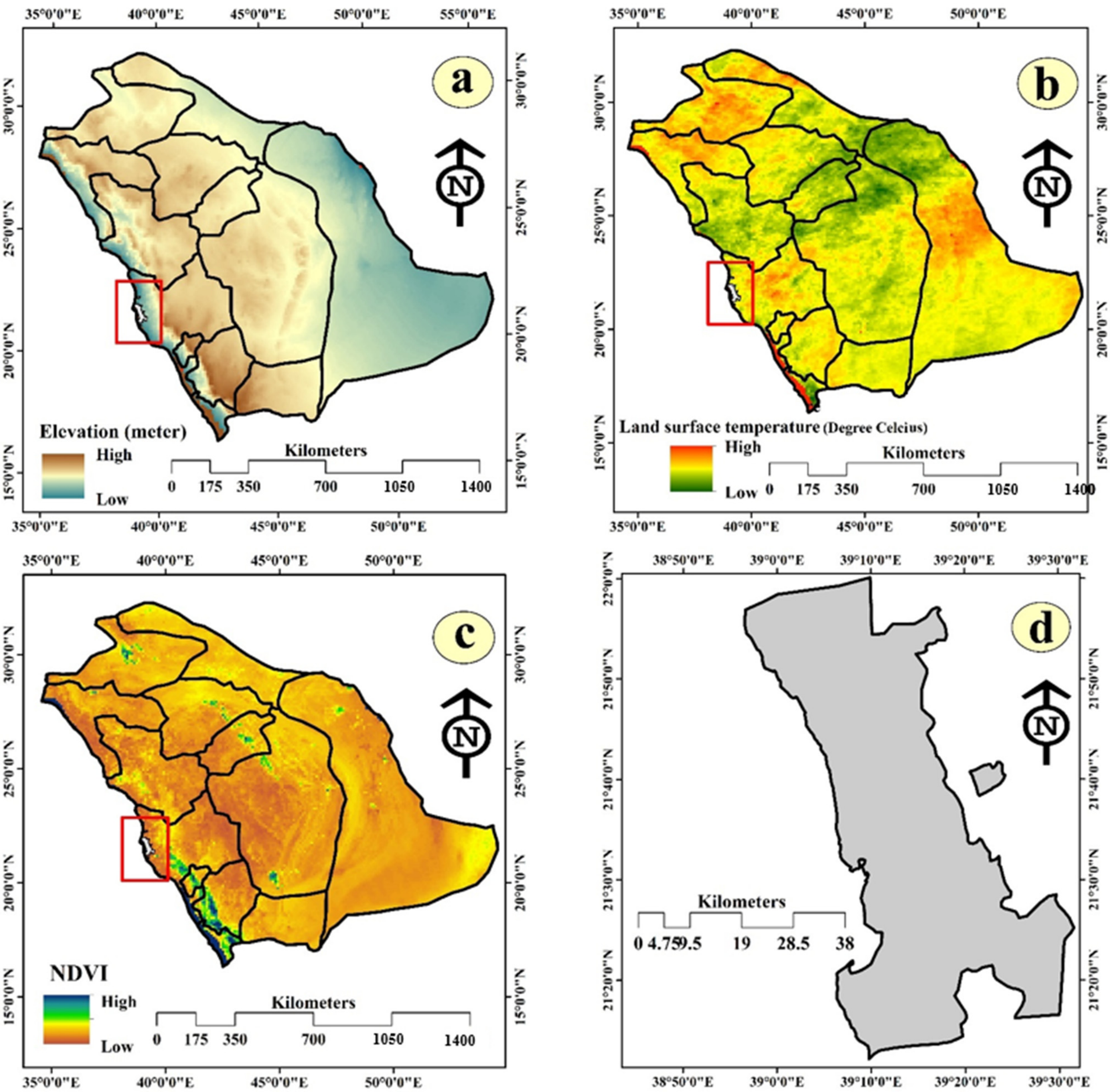

Figure 2. Location of Jeddah city within Saudi Arabia (**a**); elevation map; (**b**) land surface temperature map; (**c**) NDVI map and; (**d**) Jeddah city.

2.2. Methods

2.2.1. Data Collection and Questionnaire Survey

In this study, both an online and a direct field survey and semi-structured interviews were used to assess users' perception on climate change mitigation and adaptation strategies for the special visitors to Jeddah city. Questionnaires and semi-structured interviews were conducted to investigate preferences for GS, the role of GS in climate change mitigation, and climate change adaptation strategies, as perceived by the respondents. The questionnaire was divided into four major sections: (i) general information on the respondents (including socio-demographic attributes such as age, gender, and nationality). The responses from different genders (male and female), age groups (>20, 20 to 40 and >60) and nationalities (Saudi and Non-Saudi) were collected as perception regarding the climate change mitigation and adaptation strategies may vary; (ii) preferences for GS services as perceived by respondents (e.g., picnics, well-being, physical activities, family gathering); (iii) the importance of GS in climate change mitigation on a 5-point Likert scale (mitigation includes reduction in UHI effect, reduction in heat stress, reduction in local climate change) with questions such as "do you think GSs are important in reducing temperature?"; and (iv) perceptions of climate change adaptation attributes on a 5-point Likert scale, with questions such as "do you agree that accessibility of GSs need to be enhanced?". The terminologies used in the questionnaire were discussed with the respondents for better understanding of the objectives of the study.

Table 1. Profile of the Jeddah city.

Attributes	Information
Location	Western coast of the Red Sea
Physical environment	Desert and coastal
Area (km^2)	1600
Total population	
Population density (km^2)	5400
Growth rate	3.8
Climate type	Dry and hot desert climate
Average rainfall (mm)	45 mm
Temperature in winter	around 28
Temperature in summer	>40

In many previous studies, quantitative and qualitative techniques have been used for data collection [59,60]. The respondents were randomly selected from users of GSs in Jeddah. The survey was performed mainly in major parks and gardens, including Prince Majed Park, Alsalamh Garden, Alrawdah Garden, Alhamra Garden, Aljamaa Garden, and Alfalah Garden. The survey was performed during November 2019 and from January to June 2020. During November 2019, most of the survey was conducted through onsite interviews with the respondents; during 2020, we focused more on online surveys due to outbreak of COVID-19. In the case of online surveys, detailed instructions were provided with the questionnaire. All the questions were prepared in English and translated into Arabic for better understanding of the survey questions. Interactions with the respondents lasted at most for 20 min. The details of the respondents for onsite interviews are presented in Table 2.

Table 2. Socio-demographic profile of the respondents (%).

Dimension		Jeddah		
		Onsite Interview	Online Interview	Total Respondents
Gender	Male	75	66	585
	Female	25	34	
Type of resident	Saudi	94	93	
	Non-Saudi	6	7	
Age	20–40	51	48	
	40–60	33	33	
	>60	16	19	

For the online survey, a web-based questionnaire was prepared using Google Forms (Google LLC, Mountain View, CA, USA). The questionnaires were sent to respondents via email, WhatsApp, and other social media platforms with instructions. The details of the respondents to the online survey are presented in Table 2.

2.2.2. Evaluation of Data

A 5-point Likert scale was used to examine (a) the role of GS in climate mitigation, ranging from 1 (no importance) to 5 (very high importance), and (b) to assess perceptions related to the attributes of climate change adaptation strategies, ranging from 1 (highly disagree) to 5 (highly agree). The 5-point Likert scale values to assess the role GSs in climate change mitigations were assigned as 1 = no importance; 2 = low importance; 3 = fairly importance; 4 = high importance; and 5 = very high importance. On the other hand, understanding the agreement of the respondents related to the climate change adaptation attributes, the 5-point Likert scale values were assigned as 1 = disagree; 2 = slightly disagree; 3 = slightly agree; 4 = agree; and 5 = strongly agree. The relative importance of GS was computed by dividing the total score provided by the respondents by the number of respondents.

2.2.3. Measurement of Per Capita Availability of GS Across Cities

Exploring the per capita availability of GS is crucial to sustainable urban planning [5]. According to the World Health Organization [61], per capita GS is a significant metric in examining GS availability across cities. Other international organizations also suggest per capita availability of GS, such as the Public Health Bureau (USA), the European Union, and the United Nations (UN). In this study, a comparison of three cities was performed against international standards to find discrepancies in the per capita availability of GS (Table 3). GSs inside the urban growth boundary (UGB) were considered across the cities. Information on all GSs (particularly parks and gardens) was extracted using GIS. The GSs across the cities were prepared with the help of satellite images, Google Earth Pro, and Open Street Maps. The following equation was used to compute the average availability of GS across cities:

$$\mathrm{PCGS} = \mathrm{GSt}/\mathrm{Pt}$$

where PCGS is the per capita GS, GSt is the total area of GS within the city boundary, and Pt is the total population of the city.

Table 3. Per capita availability of GS in Jeddah.

Organization	Standard Per Capita GSs (m^2)	Jeddah Per Capita GSs (m^2)
United Nations	30	0.5
World Health Organization	9	
Public Health Bureau (USA)	18	
European Union	26	

2.2.4. Statistical Analysis

The Kruskal–Wallis test (K-S test) was performed [71] to examine differences in the assessments of the role of GS in climate change mitigation based on age, gender, and nationality. In addition, a Mann–Whitney U test was used to examine significant differences in perceptions between males and females and Saudi and non-Saudi residents. The quantitative data collected through the questionnaire were analyzed using SPSS 22.0 (Armonk, New York, NY, USA).

3. Results

3.1. Per Capita Availability of Green Spaces (GSs) in Jeddah

As per the results of the study, it was observed that per capita green space (PCGS) was 0.5 m^2. In Jeddah, there is a total of 2.05 km^2 of GS over more than 430 locations, meaning that there is one green space for every 8946 inhabitants in the city. In Jeddah, there was much less per capita green space (PCGS) in comparison to internal standards. Jeddah would need 31 million m^2 and 100 million m^2 GSs to meet the international standards of the European Union and World Health Organization (WHO) (Table 3). It is important to note that PCGS availability was also much less in comparison to the other cities in Saudi Arabia. The spatial distributions of GSs on Jeddah are shown in Figures 3 and 4.

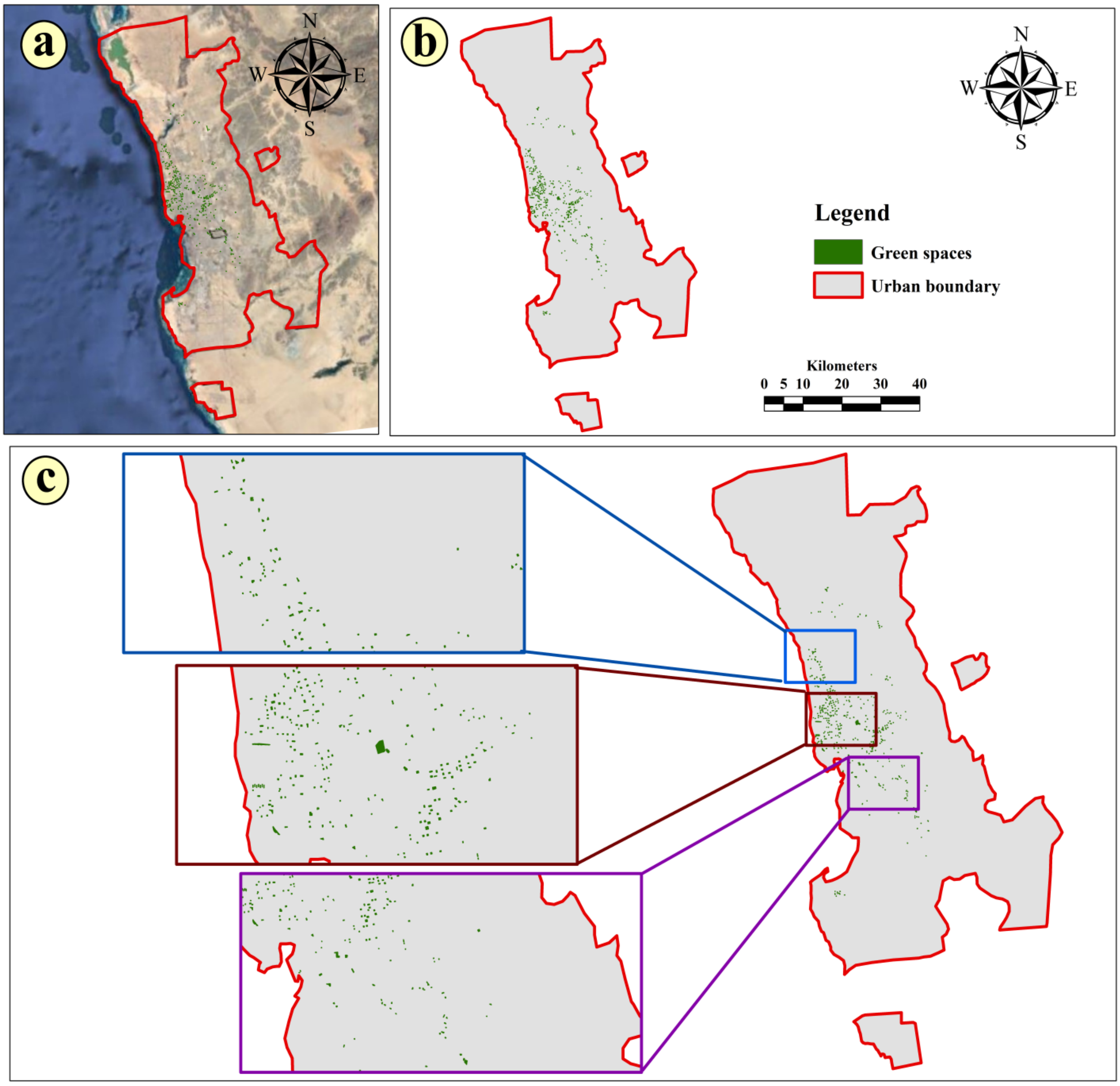

Figure 3. Spatial distributions of GSs in Jeddah City (**a**); Jeddah satellite image with the GSs; (**b**) GSs distribution in Jeddah in regard to the city urban growth boundary and; (**c**) detailed view to the GSs in the city.

Figure 4 presents the per capita availability of GSs in Jeddah city. As per the figure, it can be observed that the average shortfall was 82.20 km^2 in Jeddah.

3.2. *Preferences for GS Services as Perceived by Respondents*

The respondents were significantly dependent on major services provided by the G in their daily lives. Most of the respondents used GS for picnics (23.93%) followed by mental well-being (23.63%), physical activities (18.95%), family gatherings (16.02%), escape from everyday life (15.2%), and no particular reason (2%) (Figure 5). A migrant interviewee commented that, "Green spaces have become the destination for a picnic all the time, we just love to use these GSs, and every time we have a relative visiting, we bring them in these green spaces". A total of 245 respondents from Jeddah reported that GSs are used for physical activities. One respondent said that "I like to exercise near the sea as it is good for my physical health". During interactions, most of the respondents reported words to the effect that walking and exercise in parks and gardens are "good for my physical and mental health" and "help me a lot in escaping from my everyday routine." Thus, the result shows that the services provided by GS are crucial to people in the cities.

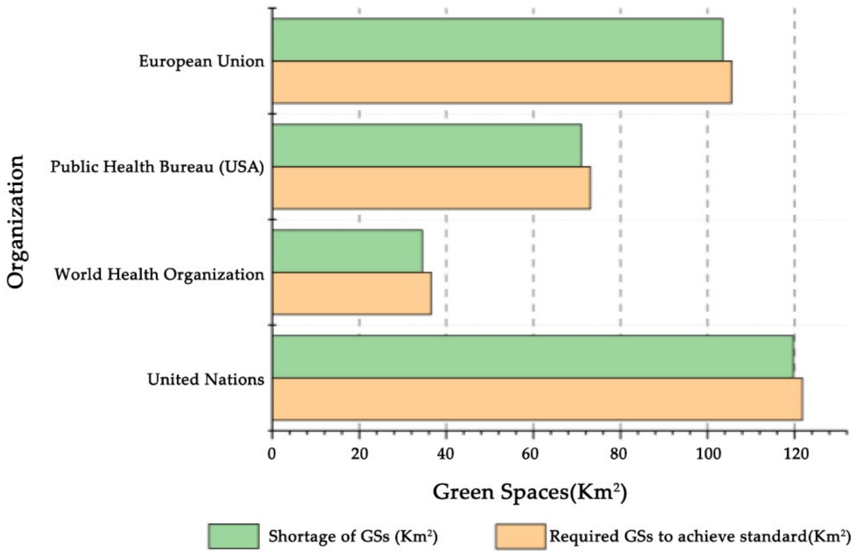

Figure 4. Shortage and required GSs (km^2) in Jeddah City.

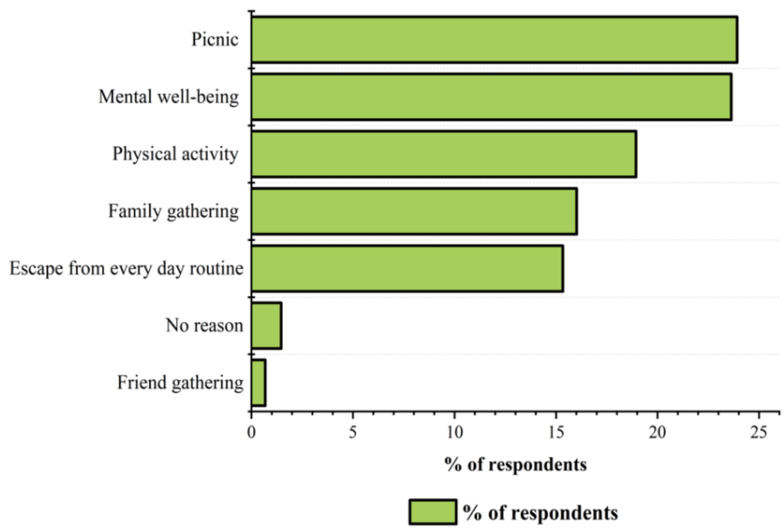

Figure 5. Preference of green spaces (GSs) by the respondents.

3.3. Respondents' Perception of the Role of GS in Climate Change Mitigation

A perception-based field survey was performed to understand the role of GS in climate change mitigation strategies in Jeddah. It was found that 85% of the respondents believed that GSs play a crucial role in climate change mitigation strategies, such as temperature regulation, maintenance of air quality, reduction in UHI effects, and enhancement of thermal comfort. The highest percentage of responses with very 'high importance' was for the mitigation of the local urban climate (92%) followed by the maintenance of air quality (91%), lower air temperature (89%), and reduction in UHI effect (88%) (Figure 6). Thus, the overall importance of GS for climate change mitigation strategies as perceived by the respondents was very high, clearly indicating that GSs have a significant impact on climate change mitigation strategies.

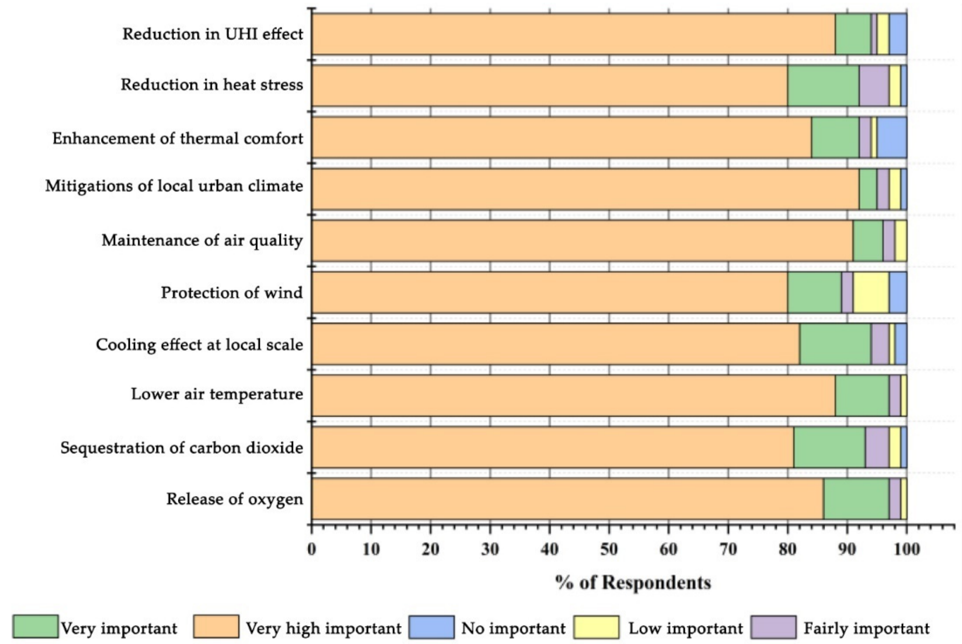

Figure 6. Role of GSs for climate regulation.

There were significant differences in perceptions of the role of GS in the city, depending on age, gender, and nationality, as shown by K-S tests. With the Mann–Whitney test (applied for bi-group analysis), there were significant differences in the perceived role of GS between males and females and Saudi and non-Saudi residents (Table 4).

Table 4. Perceived importance of GS based on age, gender, and nationality.

Services	Gender				Age Range					Nationality			
	M	F	Mean	SD	20–40	41–60	>60	Mean	SD	Non-Saudi	Saudi	Mean	SD
Release of oxygen	4.61	5.00	4.81	0.28	4.85	4.93	4.85	4.88	0.04	4.61	4.85	3.63	0.17
Sequestration of carbon dioxide	3.60	4.73	4.17	0.80	3.82	3.92	4.45	4.06	0.27	4.35	4.86	3.52	0.36
Lower air temperature	3.86	5.00	4.43	0.81	4.61	5.00	4.91	4.84	0.08	4.82	4.96	3.41	0.10
Shading	3.12	4.45	3.79	0.94	3.41	4.66	3.69.	4.04	0.44	2.42	4.63	3.24	1.56
Protection of wind	3.32	3.88	3.60	0.40	2.93	3.81	4.68	3.81	0.50	2.83	4.82	3.20	1.41
Maintenance of air quality	4.55	4.86	4.71	0.22	4.44	4.53	3.92	4.30	0.31	3.72	3.98	3.10	0.18
Mitigations of local urban climate	4.53	5.00	4.77	0.33	4.41	4.52	4.95	4.63	0.22	4.54	4.74	2.97	0.14
Enhancement of thermal comfort	4.21	4.55	4.38	0.24	3.91	4.22	4.63	4.25	0.23	2.98	4.69	2.59	1.21
Reduction in heat stress	4.12	4.86	4.49	0.52	3.42	3.36	4.91	3.90	0.79	3.35	4.19	2.24	0.59
Reduction in UHI	4.63	4.88	4.76	0.18	3.53	3.31	4.44	3.76	0.57	3.64	4.48	1.63	0.59
Mann–Whitney test	0.005					-				0.008			
K-S test	0.004					0.063				0.007			

ANOVA and K-S tests were performed at a 0.10 level of significance. Mann–Whitney test was performed at a 0.05 level of significance.

3.4. Perceptions of Respondents on the Attributes Related to Climate Change Adaptation Strategies

In this section, an attempt is made to understand adaptation strategies to climate change by looking at the role of GS in Jeddah city. The respondents were asked to state their level of agreement with the use of various adaptation strategies based on GS for climate change mitigation. Most (84%) of the respondents strongly agreed with the adaptation strategies related to climate change put forward (ten adaptation strategies were considered). The respondents were aware of the attributes and management strategies for coping with climate change. The highest percentages were 88% and 92%, where respondents agreed with the improvement of per capita availability and accessibility of GS across cities. The results reported that there were substantial shortfalls in per capita availability of GS across cities in comparison to global standards. The per capita availability of GS was lowest in Jeddah among the three selected cities. Thus, accessibility to GS is not only necessary to meet the needs of the city dwellers, but also to cope with climate change (Figure 7). Furthermore, 88% of respondents agreed that GS must be properly managed to cope with climate change. The results clearly indicate that the respondents were not satisfied with management strategies for GS. The adverse impact of climate hazards can be reduced through the effective management and restoration of GS (81%).

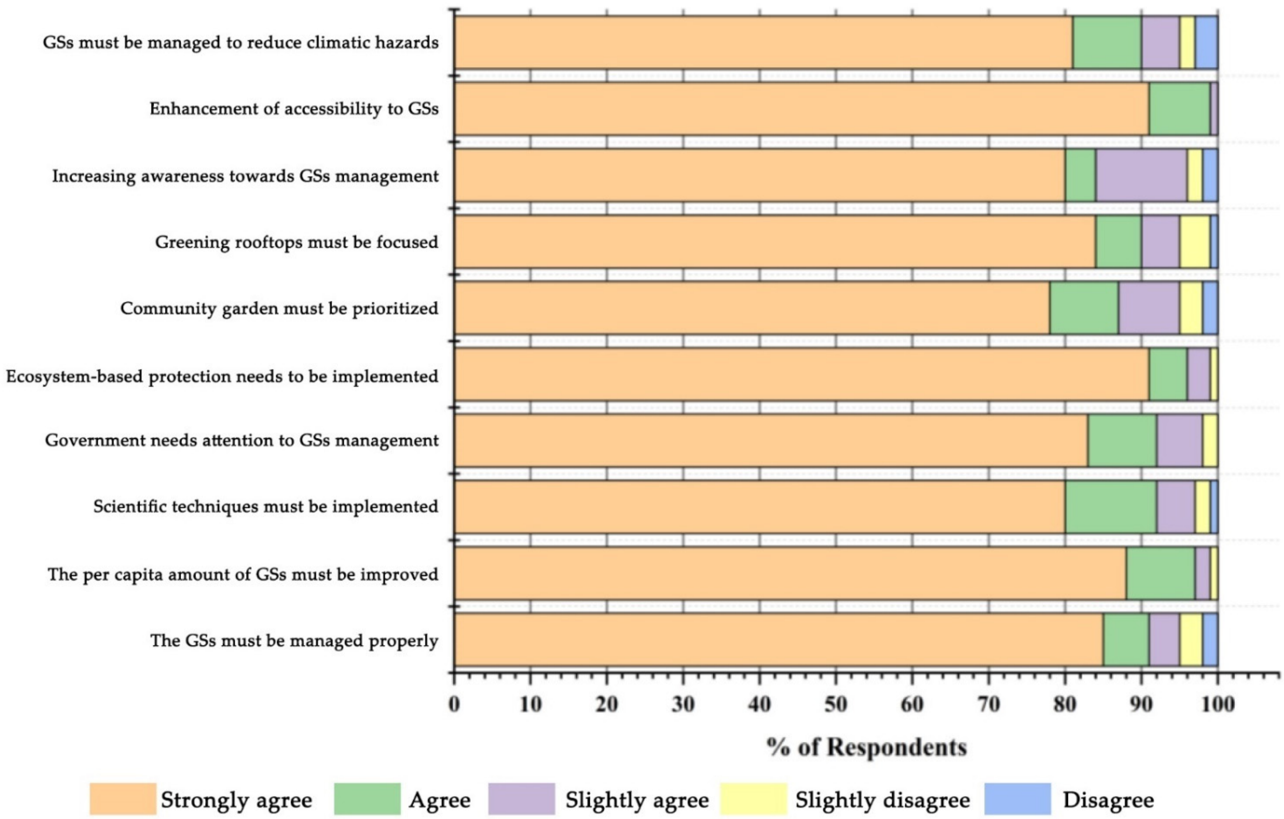

Figure 7. Level of agreement on attributes related to climate change adaptation.

4. Discussion

4.1. Impact of GS on Well-Being and Climate Change Mitigation Strategies

The study showed that most of the respondents in Jeddah use GS for picnics (23.93%), followed by mental well-being (23.63%), physical activities (18.95%), and family gatherings (16.02%). Respondents closely related to the services provided by GS for their well-being. Thus, various aspects of well-being are affected by the services provided by GS. Previous research has shown that there is a strong nexus between services provided by GS and residents' well-being [72–75]. Apart from people's well-being, GSs also play a significant role in climate mitigation [39,76]. This study showed that GS can contribute to climate change mitigation strategies such as the maintenance of air quality, local climate regulation, controlling of temperature, maintenance of UHI, and reduction in heat stress. These findings are similar to previous studies [75–77]. However, although GSs have an impact on well-being and climate change mitigation strategies, most respondents reported that there is a lack of effective management to enhance the quality of the GS. GS must be managed properly with the application of innovative scientific techniques, enhancement of per capita availability, prioritization of community gardens, and improved awareness of GS management among users. Previous studies have shown that GS can be managed through the application of innovative techniques (such as rooftop greening or vertical green walls), public participation and awareness, and effective management strategies [78]. Thus, restoration and management of GS are not only important to cope with climate change, but also to sustaining the well-being of city dwellers (Figure 8).

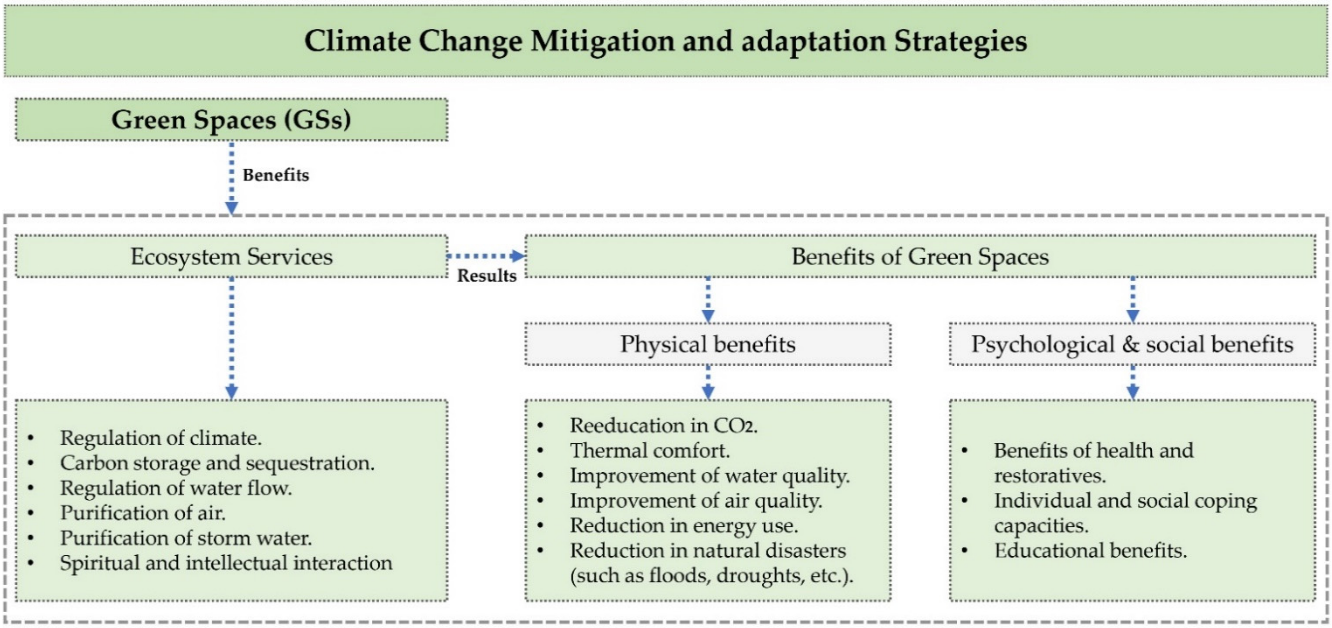

Figure 8. Benefit of GSs within climate change mitigations and adaptations the framework.

4.2. Role of GS in Urban Planning for Climate Change

GSs provide several climatic services that play a significant part in climate change adaptation and mitigation [5,39,76,77]. Studies have shown that GS provide multiple services, such as the maintenance of air quality, UHI reduction, and shading.

In previous research, the relationship between the city and climate change has been internationally recognized and the negative impact on quality of life and ecosystems has been highlighted [75,76]. Cities must have strategies with provisions and laws related to climate change to ensure the well-being of city dwellers. Thus, responding to climate change requires the application of innovative solutions and the implementation of effective urban management planning and policies [77–80]. This study showed that there is a significant shortfall in per capita availability of GS across the cities. Thus, the government must focus on the restoration and management of GS and enhance accessibility to GS. In Saudi Arabia, the Ministry of Municipal and Rural Affairs (MoMRA) has implemented several effective regulations and guidelines related to urban planning, GS projects, and the provision of GS across cities. GSs (particularly gardens and parks) must be considered in decision-making. Previously, only limited focus was given to GS across Saudi cities, but the Vision 2030 National Transformation Program (NTP) paid particular attention to the availability and accessibility to public open spaces, including GS, in Saudi cities [35,36]. In addition, the NTP set important goals, including (i) making Saudi cities more livable, and (ii) improving the involvement of the community in decision-making [34–36]. The Saudi

Government has invested a huge amount of money to support the project and to meet international standards and enhance the accessibility to GS across the cities. Thus, from the analysis, it can be seen that the government (MoMRA) and municipalities must focus on GS creation, restoration, and management to improve urban sustainability and enhance the well-being of city dwellers. On a city scale, Riyadh has implemented many initiatives, such as the King Salman Park Project, Sports Boulevard Project, Green Riyadh Project, and Riyadh Art Project to enhance the accessibility of GS and promote environmental sustainability. In the last few decades, GSs have been prioritized in policymaking across the world to deliver social and environmental benefits and to cope with climate change. In many cities, GSs have been considered as significant tools to help manage climate change, and experimental projects have been implemented as climate adaptation strategies [42]. From Europe to Asia, GS projects have been implemented as adaptation strategies in response to climate change; for example, in Catania [81], Copenhagen [82], Pukou District in Nanjing [83], Beijing [84], and Berlin [85]. Previous literature shows that GSs in an urban environment play a crucial role in adapting to climate change using low-cost mitigation strategies. Several models have been developed to evaluate ecosystem services provided by GS. Several GS projects and practices, such as the use of trees, lawns, green roofs, and green walls have emerged as efficient tools for reducing the UHI effect and air pollution, and regulating greenhouse gases, such as CO_2 and MH_4 [10,73,86].

Thus, from the analysis, it can be seen that climate change has emerged as a great challenge to cities, particularity in desert areas such as in Saudi Arabia; dealing with climate change is one of the most serious challenges for urban environmental sustainability. These challenges appear to be due to a lack of green and blue spaces (such as trees, vegetation cover, water bodies) in desert areas. Despite the natural barriers, the government must implement more effective measures to increase GS coverage to cope with climate change. Planners and policymakers must also focus on the implementation of green roofs (for example, as in Germany) and vertical forests (for example, Milan in Italy). Policymakers and urban planners must focus on the effective implementations of urban green space management as well as restoration. Local authorities must help people to appreciate the role of GSs and their contribution to well-being. Public participation must be encouraged for the better management of GS across cities in Saudi Arabia.

4.3. Limitations and Future Directions of the Research

To the best of our knowledge, few studies have been performed to assess GS in respect to climate change in the Saudi context. Thus, this study has immense potential to help understand the spatial distribution of GS in Jeddah city and the role of GS in climate change mitigation and adaptation strategies. Despite this novelty, this study has some limitations. Firstly, only limited data from the field survey were extracted during the COVID-19 pandemic and lockdown, therefore there was very little direct interaction with respondents. Thus, there is scope for future researchers to perform a similar study with a larger sample from the cities. Secondly, the field survey to understand the role of GS in climate change mitigation and adaptation strategies was carried out only in Jeddah. In the future, researchers may consider many cities to gain a better understanding of the distribution regarding the role of GS in climate change mitigation and adaptation strategies. Thus, there are many opportunities for future researchers to study patterns of GS using various advanced machine learning tools and techniques. Thirdly, the survey was performed during the winter season, so future researchers must focus on assessments of the role of GS during the summer season to improve understanding.

5. Conclusions

This study explored the per capita availability of GSs and the role of GSs in climate change mitigation and adaptation strategies in Jeddah city in Saudi Arabia. GIS techniques and a questionnaire were used to identify GSs in Jeddah city to examine the role of GS in climate change adaptation strategies and mitigation. It was observed that the per capita availability of GS in Jeddah was (0.50 m^2). The per capita availability of GS was compared with per capita standards proposed by the WHO, UN, European Union, and Public Health Bureau (USA). From the comparison, it could be seen that there were substantial shortfalls in the per capita availability of GS in Jeddah. For example, the UN and WHO standard per capita GS recommendations are set at 30 m^2 and 9 m^2, respectively, but the figures were 0.50 m^2 in Jeddah. Thus, there are huge shortfalls in the per capita availability of GS across Saudi Arabia in general, with the highest shortfalls in Jeddah (as compared to the WHO standard). Therefore, the availability and accessibility to GS in Jeddah city must be enhanced, not only to meet global standards, but also to aid urban environmental sustainability. The respondents in the cities were highly dependent on the various services provided by GSs, which also play a crucial role in climate change mitigation. However, there was a lack of effective planning and strategies for improving the services provided by GS. Therefore, city planners and policymakers must focus on land use planning and the implementation of ecosystem-based urban landscape planning.

The present study on the pattern of GS and the role of GS in climate change mitigation will open a new door for future researchers to understand the role of GS in climate change mitigation and adaptation strategies, based on which effective measures can be implemented. In most developing countries, the availability and accessibility of GS are poor, and climate change impacts at the city scale are very prominent, with issues such as increases in land surface temperatures, the emergence of UHI, heat stress, and an adverse outdoor thermal environment. Thus, the findings of this study may also be helpful for other hot and humid cities for better implementation of climate change-related strategies.

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