

Evaluating Urban Green Space Accessibility and Per Capita Distribution in Erbil and Sulaimaniyah, Kurdistan Region of Iraq

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Abstract

Rapid urbanization has led to various environmental and human problems. Urban Green Space (UGS) is vital in this respect, as evidenced by scientific studies across different disciplines. In arid and semi-arid regions, where most cities have limited vegetation, the importance of UGS becomes even more critical. Yet, the issue of access to UGS is one of the crucial aspects of sustainable urban development and has received considerable attention in developed countries, but less is known about it in developing countries. This research investigates UGS in two major cities in the semi-arid region of Kurdistan-Iraq, Erbil and Sulaimaniyah, in an effort to improve equity and these cities' resilience to climate change.

The study employed remote sensing techniques to assess land cover since site visits were prohibitive due to private sites and lack of on-site data. Google Earth Engine (GEE) calculates the Normalized Difference Vegetation Index (NDVI) based on Sentinel2 and Landsat-8 adjusted to the Census for spatial population data. The goal is to identify equity in UGS access and provide insights for fostering equitable urban planning by assessing the Green Space ratio, Urban Green Space per capita, proximity using buffers 300m and 500m, and accessibility using network analysis 5, 10, and 15-minute walk.

The findings revealed significant inequality and a low sustainability rate, showing that 3% of each city is UGS. UGS per capita is near the minimum value recommended by WHO, 9m², in Erbil is 7 m², and 11 m² in Sulaimaniyah. For proximity, almost one-third of Erbil's and Sulaimaniyah's residents live within a 500-meter buffer of UGS bigger than 0.5 ha. For accessibility, only 17.8% of Erbil's and 11.6% of Sulaimaniyah's residents can access the same parks within a 5-minute walk (400m). Moreover, at the maximum 15-minute walk, 65.1% of the population in Erbil and 61.4% in Sulaimaniyah can reach the nearest one. This is much lower than the WHO accessibility standard, 0.5 ha. of UGS by a 5-minute walk, and the UK's Accessible Natural Greenspace Standards (ANGSt), which indicate access to 2 ha. parks within 300 m. distance.

The results suggest that the current issues are related to the planning and maintenance of the existing UGS, patterns, and road networks; by linking smaller parks through hilly forests, creeks, and main roads, walking interest can increase.

Introduction

Green Spaces (GS) are vital components of urban ecosystems, offering significant environmental, social, and economic benefits. Urbanization has increased continuously; currently, 55% of the world's population lives in urban areas, with projections estimating that this might reach 68%, raising urbanization to 64% in developing countries and 86% in developed countries by 2050 (United Nations 2025). In densely populated cities where residents often limit direct interaction with natural environments, Urban Green Space (UGS) acts as an alternative for nature exposure and recreation.

The multifaceted advantages of UGS have been well-documented, including their perception by humans, their role in promoting mental and physical well-being (Kabisch et al. 2016), mitigating urban heat island effects, enhancing ecological diversity, and reducing air and noise pollution levels (Kruize et al. 2019). UGS, or green infrastructure as some studies cited, is a creative approach to directly accomplish the goals of Sustainable Development Goal (SDG) 11 (Yamasaki and Takashi 2022), as accessible and safe green spaces are a sub-objective of the eleventh goal of the 2030 Agenda for Sustainable Development.

According to studies, improving access to UGS can increase equity in urban areas and improve "livability" (Li et al. 2021). Literature indicates various studies have dealt with the accessibility of UGS in developed countries such as Europe, North America, and Australia, and lately and similarly in East Asia; however, fewer in Africa (Farkas et al. 2023). To our knowledge, studies of UGS proximity and accessibility in the Middle East are very limited in this concern.

Establishing a single UGS standard for all counties is challenging due to the various environmental conditions and socioeconomic status. However, many counties and cities have set a goal to achieve sustainability based on UGS per capita, UGS proximity, and accessibility (Table 1). A wide range, from 9m² -50m² of UGS per person, is recommended as the minimum and ideal level by the World Health Organization (WHO) (Hassan et al. 2024). In the Kurdistan region of Iraq, Erbil city manager plans to have 15m² by 2030.

Table 1. Global Standards for Urban Green Space (UGS) Per Capita and Accessibility

No .	Country, Region, Organization	UGS Standards A) Percapita, B) Accessibility	Metric Type
1	World Health Organization (WHO)	A) Minimum: 9m ² per capita; Ideal: 50m ² per capita. B) Accessibility UGS within 15-minute walk, Accessibility to UGS within 500 m and 1,000 m	Population Share, Proximity
2	European Environment Agency (EEA)	A) No information B) Access to UGS within 900–1,000 m	Proximity or Green Space Catchment
3	U.S. Green Building Council (USGBC)	A) 11.25m ² per capita B) Accessibility to UGS with 10 minute walk (approximately 900- 1500)	Population Share, Proximity

4	Natural England, UK (ANGSt)	A) 1 ha of natural greenspace per 1,000 population B) No person should live more than 300m from 2ha. natural greenspace.	Population Share, Proximity, Area-Based Provision
5	Berlin (Germany)	A) No information B) Access to at least 0.5 ha. UGS within 500 m from home	Proximity, Area-Based Provision

3. Background and Literature Review

Urban green spaces have already been the subject of extensive research, mainly to support green space planning and management. Many relevant discussions overemphasize some types of green space and ignore others. This situation may refer to the fact that the current definitions and classifications seem not to have ended the debates on what an urban green space is. For instance, some researchers and planners describe it as a piece of land with a 'pervious surface' that includes trees, shrubs, grass, and soil; the main focus is on the land's character rather than individual elements (Dunnett 2002). Other defined as areas with a high rate of vegetation, are also open for public use and managed by the public. Moreover, UGS can be seen as any vegetation in an 'urban environment', from minor private gardens to large public parks (Kabisch et al. 2015). This paper used multiple definitions, where Green Space (GS) refers to vegetation within the city boundaries. Urban Green Space (UGS) follows a similar definition but only includes vegetation used for recreational and aesthetic purposes.

Even though UGS has been comprehensively analyzed globally, it remains understudied in the Middle East, particularly in Kurdistan-Iraq. In a study, UGS per capita analysis primarily focused on public parks and considered the total area of these parks (Hussein 2020). However, our study emphasizes UGS, including both public and private spaces, based on their spatial distribution. Other studies analyzing accessibility in Erbil focus on certain districts and active parks, using the center of the parks as the point of accessibility (Kemec and Hassan 2023). In contrast, we analyzed accessibility for the entire city, and to increase accuracy, we used the gates of the UGS or their boundaries if there were no fences. Several Vegetation indices are used to indicate vegetation, such as the Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Enhanced Vegetation Index (EVI) (Rebouch et al. 2023).

The current challenges facing Kurdistan cities are multifaced: climate change, such as increasing temperatures in summer and, in contrast, more floods in winter. Moreover, the fast growth of urbanization has led to pressure on land, and with rapid population growth, in Erbil 90% and in Sulaimaniyah reach 100% in the last 3 decades, land shortages have occurred. Due to migration from rural to urban areas and immigration from war and politically unstable surrounding regions, urban management has become even harder (Hassan 2023). These issues are linked by unclear policies for UGS development, a lack of standards, and implementation issues. The interest of decision-makers in urbanization as a symbol of development has led to the reduction of natural and semi-natural forests, and UGS per capita remains at a low level. Additionally, and importantly,

access to UGS is becoming even more challenging due to high temperatures from spring to the end of summer, compounded by a lack of public transport.

The study is unique due to its comparison of two cities within the same semi-autonomous region, each with 30 years of different development policies surrounded by 50 years of unstable political situations. The main goal of this study is to assess the equity of UGS by examining green space per capita, distribution, proximity, and accessibility. The study aims to determine the availability of UGS based on population density and service or catchment areas.

The Research Questions are;

- What does the analysis of the spatial distribution of urban green spaces in Erbil and Sulaimaniyah reveal in comparison to international per capita and accessibility standards?
- What are the Urban Green Space equity issues based on urban green space per capita, proximity, and accessibility?
- What are the suggestions for addressing the accessibility issue?

4. Method and Data

The study focused on two major cities in the semi-arid area of the Kurdistan Region of Iraq: Erbil, the region's capital, and Sulaimaniyah. We chose these cities due to their rapid urbanization and population growth, and city planners aim to meet sustainability goals and set a target of 15 m² of UGS per capita by 2030. With only five years remaining, it is worth evaluating progress.

Population data came from the LandScan-HD dataset, which has a 90-meter resolution. The data were adjusted to match census information to improve accuracy and reliability for urban-scale analysis. Vegetation data were from Sentinel-2 surface reflectance imagery processed in Google Earth Engine (GEE) and validated using high-resolution imagery from Google Earth Pro (Airbus, 0.5 – 1.5m resolution) and municipal data (Figure 1).

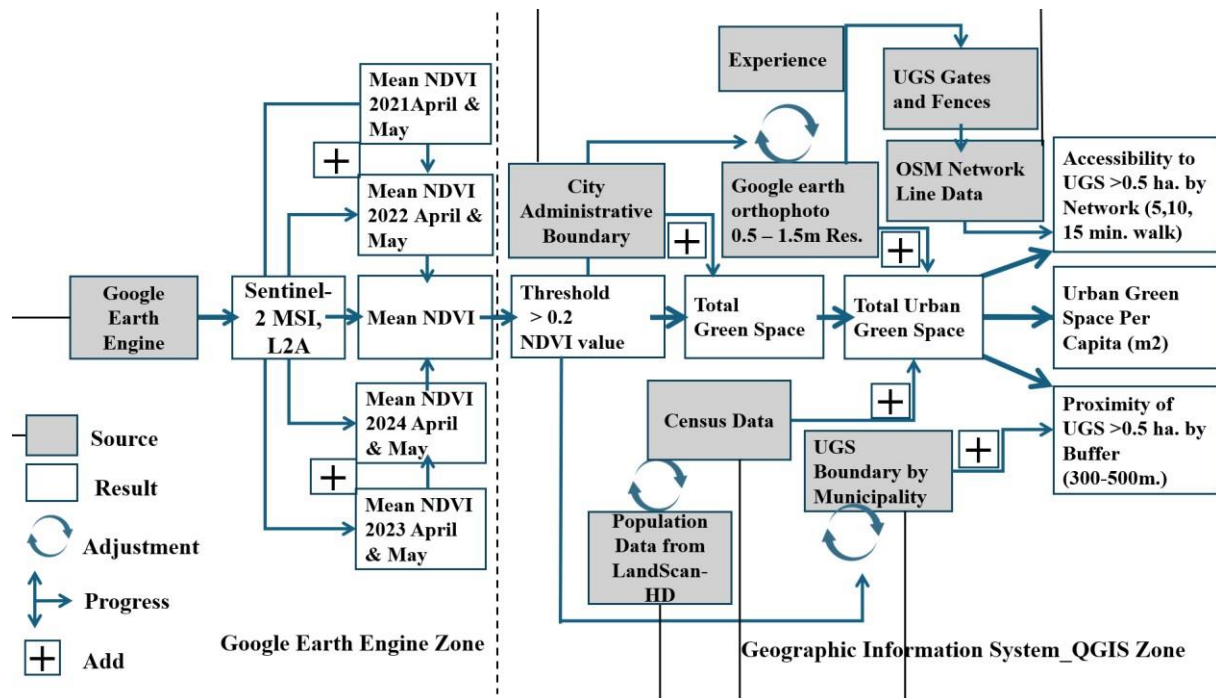


Figure 1. Analytical Framework for UGS Assessment.

NDVI threshold of > 0.2 defines the GS and UGS values, which were the base for UGS per capita. For proximity, UGS with municipal data boundaries served as the base layer to classify UGS areas > 0.1 ha into four different categories based on size: Neighborhood Park (0.5 – 5 hectares), Community Park (5 – 10 hectares), District Park (10 – 50 hectares), and City Park (> 50 hectares). Proximity analysis used buffer zones 300m and 500m from the UGS boundary. Accessibility analysis used OSM Line data as the road network for 5, 10, and 15-minute walks, equivalent to distances of 400m, 800m, and 1200m, respectively, calculated using the QNEAT3 algorithm in QGIS, gates and boundaries of not fenced UGS used as a target to reach.

5. Results

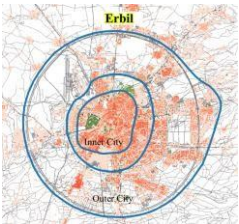
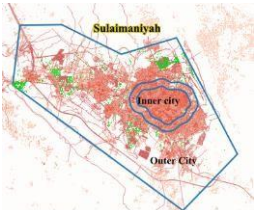
The results show the total green space in Erbil, representing 17% of the city's total area, as 70.8

km². In Sulaimaniyah, the green space was substantially larger, covering 48% of the city's territory by 216 km². However, it is crucial to highlight that these results contain all vegetation types, such as open land with seasonal vegetation and agricultural lands, which do not necessarily qualify as urban green spaces.

When focusing on urban green space as specifically designed for recreational purposes, in Erbil, the UGS only represents almost 3% (11km²) of the city area; similarly, in Sulaimaniyah, it covers nearly 3% (12 km²) of the city area (Table 2). In Erbil, the UGS per capita is 7 m², whereas in

Sulaimaniyah, it is 11 m² . Both cities are near the World Health Organization's minimum target of 9 m² per capita.

Table 2. Equity in UGS Per Capita and Lack of UGS in the City Parts.

City	Part	Area KM ²	Green space KM ² (%)	UGS KM ² (%)	UGS per Capita (m ²)	WHO Standard (m ²)	Differe. (m ²)
	Inner (inside 100m ring road)				8		
	Transitional (between 100 -120m ring road)				10		
	Outer (120m ring road to city boundary)				5		
	Total	431	16	11.7	7	9	-2
	Inner (inside 60mRing road)				5		
	Transitional (1 km buffer around 60m ring road)				13		
	Outer (After tranzitinal Part)				14		
	Total	451	48	12.3	11	9	2

The analysis of proximity to UGS highlights significant disparities in service. In Erbil, only 30.9% (502,241) of the population live within a 500-meter distance from four UGS types. The value is 16.4% within 300m, indicating that most of Erbil's population lacks convenient access to urban green spaces (Table 3).

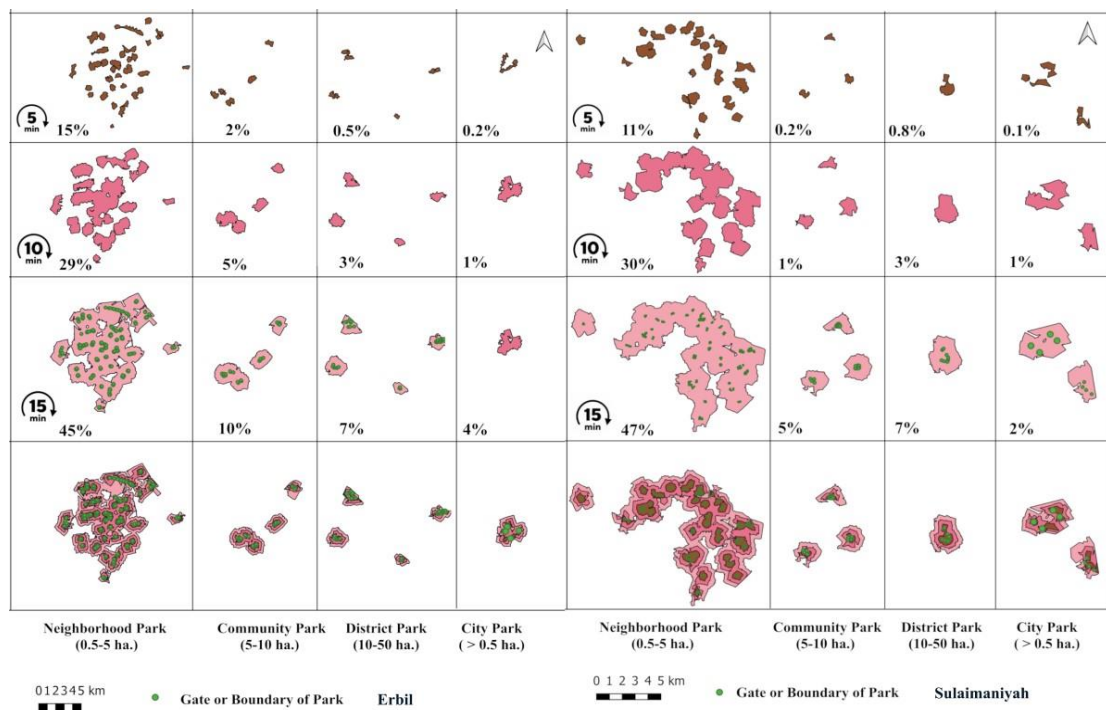
The analysis also reveals that for those with access to UGS, over 90% are limited to smaller parks, such as Neighborhood and Community Parks, which have less capacity and fewer amenities. Opportunities to access larger parks, such as District Parks and City Parks, remain scarce, further underscoring the unequal distribution of green spaces across Erbil. In Sulaimaniyah, a total of 30.6% (345,652) live within the 500 m service area of UGS. In a 300m distance, only 15.8% of residents live within the buffer. Although more people live within the buffers in Erbil than in Sulaimaniyah, the same percentage is based on the city population.

These values are much lower than standards. WHO recommends accessibility to 0.5-1 ha. parks by 300m, and according to the UK Accessible Natural Greenspace Standards (ANGSt), people need to have access to 2ha. parks by at least 300 m.

Table 3. UGS Catchment Areas in Erbil and Sulaymaniyah Using 300, 500m Buffer

Proximity Analysis	People with Neighborhood Park (0.5-5 ha.)	People with Community Park (5-10 ha.)	People with District Park (10-50 ha.)	People with City Park (> 50 ha.)	Total Population with Access to UGS (> 0.5 ha.)
Erbil 500m. Buffer	(25.3%) 411,256	(3.8%) 62,461	(2.7%) 43,045	(1.7%) 27,194	(30.9%) 502,241
Sulaimaniyah 500m Buffer	(26.2%) 295,418	(2.6%) 28,830	(3.7%) 41,691	(1.5%) 17,329	(30.6%) 345,652
Erbil 300m. Buffer	(13.2%) 214,077	(1.9%) 30,471	(1.1%) 17,577	(0.7%) 11,971	(16.4%) 266,395
Sulaimaniyah 300m. Buffer	(13.4%) 151,535	(1.0%) 10,920	(1.4%) 16,090	(0.6%) 7,028	(15.8%) 178,566

The result of accessibility in Erbil and Sulaimaniyah highlights significant differences in the defined walking distances. In Erbil, 65.1% of the population has access to all types of UGS within a 15-minute (1200m) walk; however, 37.7% at 10 minutes (800m) and 17.8% at 5 minutes (400m). In Sulaimaniyah, 61.4% of the population is within 15 minutes reach UGS, while 34.9% at 10 minutes and 11.6% at 5 minutes reach the same UGS (Figure 2.)

**Figure 2. Percentage of UGS Accessibility by 5, 10, and 15-Minute Walking Intervals**

Neighborhood Parks in the four types of UGS provide the highest accessibility in both cities, serving 44.8% of the population in Erbil and 47.7% in Sulaimaniyah within 15 minutes. In contrast, larger parks (Community, District, City) serve significantly fewer people due to their limited number and more considerable travel distances. District Parks and City Parks contribute minimally to accessibility, reaching less than 10% of the population within the maximum walking distance. Most of the population in both cities cannot easily access UGS, particularly within shorter travel times.

Discussion and Conclusion

The annual precipitation in the region is moderate, ranging from 500 to 1,000 mm, which is generally adequate for vegetation growth. However, the UGS per capita remains low compared to global standards. Optimization can be done for UGS in both cities based on size, land use change, enhancement, and gentrification. In size, for example, Neighborhood Parks, which currently have the highest accessibility rates in both cities, can be further enhanced by connecting several of them. For instance, developing green corridors could create a larger green network, enhance biodiversity, and increase interest in walking. In Erbil, the main ring roads, and in Sulaimaniyah, the hilly areas with forests and creeks present significant development opportunities.

Other opportunities to enhance existing parks. Nearly one-quarter of municipality-classified lands designated for parks remain undeveloped. In Erbil, this percentage is even higher due to the rapid rate of urbanization. In the case of District parks and City parks, limited access arises due to their current locations. For example, Hawari Shar, as a City Park in Sulaimaniyah, is one of the main factors in raising UGS per capita in the 2010s; however, it serves very little regarding accessibility by walking. Similarly, despite that, Sami Abdul-Rahman Park, a City Park in Erbil located in the inner city, still has limited accessibility because fences surround it. These issues can be addressed by enhancing pedestrian networks and opening additional gates toward nearby residential areas.

In some cases, the new development demonstrates a significant step forward, particularly by enhancing land use by converting brownfields into parks. For instance, in southwest Sulaimaniyah, a former meat industry site was transformed into a new urban green space called Mawlana Park (Gulan media 2021). This transformation has reduced air pollution and unpleasant odors and introduced an area with over 200,000 flowers, shrubs, trees, and expansive lawns.

Additionally, this development influenced gentrification, as the new park created opportunities for further urban improvement. For example, a major shopping mall known as Family Mall was created nearby, revitalizing the area. Previously, the surrounding residential zones were impoverished, but the transformation has significantly improved the overall appeal and value of the district. Our study results also indicate that this park is located in an ideal spot, as there were previously few parks in the area. However, the findings emphasize that accessibility remains an issue due to a poorly connected pedestrian network and a limited number of open gates.

To conclude, urban green spaces (UGS) have been widely studied and assessed by researchers, planners, and stakeholders; based on their definitions, the efforts to develop urban areas, in some cases, had positive impacts on UGS, while in others, negative effects have been observed. Climate change, rapid urbanization, and political instability have significantly influenced city formation and

development in the Kurdistan region, and UGS is no exception. The availability of UGS per capita in the cities is close to the lowest recommendations set by the WHO, and almost half of the city management plans for 2030. Moreover, proximity and accessibility to UGS, as a means of sustainability, remain low. More than half of the cities have no access to UGS. However, there are opportunities for improvement, such as creating greenways or green belts that connect smaller parks to encourage residents to walk. This study is limited to accessibility by walking; other means of accessibility are subject to further research.

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