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Perceived and geographic access to urban green spaces in New York City during COVID-19

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ABSTRACT

In New York City (NYC), the early period of the COVID-19 pandemic in the spring of 2020 induced a significant shift in the use and accessibility of urban green spaces (UGS). To understand the impact of COVID-19 on the access to UGS, we conducted a spatial analysis of geographic access to UGS and perceived access based on data collected from a social survey deployed from May 13 to June 15, 2020. We examine geographical accessibility to UGS and how this compares to perceived accessibility, or the ease which residents feel they can access a UGS. We further explored the correlation between spatial access to UGS and fifteen social vulnerability variables including economic status, household composition, minority status, and housing type for different zip codes. The results show that geographical proximity variables can predict a number of the perceived access variables, particularly those related to COVID-19 measures. Although lower-income communities were found to have higher spatial access to UGS, many of the same communities, including people living in crowded and multi-unit buildings, on average only have access to smaller green spaces, suggesting an uneven distribution of larger quality parks. This observation is further confirmed by survey results. These findings have implications for policies surrounding the distribution of UGS and whether equitable access is provided to NYC residents, with implications for similar patterns that may exist in other cities.

1. Introduction

The COVID-19 pandemic significantly impacted cities worldwide, leading to social distancing measures and lockdowns to control the spread of the virus. These measures resulted in economic stress, grief, and isolation, particularly affecting urban areas. Urban green spaces (UGS), including parks, natural areas, and open spaces, play a crucial role in promoting physical and mental well-being among urban dwellers (Bratman et al., 2019, 2015; Hamer & Chida, 2008; Kaczynski & Henderson, 2007; Kahlmeier et al., 2014; Lee & Maheswaran, 2011; Li et al., 2018). They offer opportunities for recreation, exercise, and social interactions, all of which are essential for mitigating the detrimental effects of stressful events on health (Kondo, Fluehr, et al., 2018; Kondo, Jacoby, et al., 2018; Lee et al., 2015; Maas et al., 2006).

The pandemic's impact on physical and mental health, coupled with the growing understanding of UGS's importance, has led to an emergence of new research on the access, use, and benefits of these spaces during the epidemic (Ciupa and Suligowski, 2021; Felappi et al., 2020; Grzyb et al., 2021; Jato-Espino et al., 2022; Noszczyk et al., 2022; Ugolini et al., 2020).

Accessibility is a complex concept and presents challenges in both definition and measurement (Wang et al., 2013). The main areas of accessibility include real accessibility, geographic accessibility, and perceived accessibility. Real accessibility encompasses the ease with which individuals can access a particular location, considering factors such as land-use, transportation, time limitations, and individual capabilities and opportunities (Geurs and van Wee, 2004). Geographical accessibility quantitatively measures the physical accessibility of a specific site, considering variables like distance, transportation network, and spatial patterns (Anteneh et al., 2023; Deboosere and El-Geneidy, 2018). Perceived accessibility refers to the perceived potential ease of reaching a location (Pot et al., 2021), influenced by personal beliefs,

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attitudes, and past experiences that shape people's perceptions of the accessibility of specific locations.

Research on UGS access has highlighted factors like distance to parks and park size as critical influencers of access and use (Giles-Corti et al., 2005). Additionally, studies have raised concerns about the inequitable distribution of UGS in urban contexts, disproportionately affecting low-income and communities of color (Rigolon, 2016; Spotswood et al., 2021). Perceived accessibility, reflecting how easily people feel they can reach and use a UGS, has been found to be a crucial factor in determining park use intention and behavior (Wang, Brown, Liu, 2015). During the COVID-19 pandemic, the accessibility and use of UGS have been the subject of numerous studies across different regions (e.g., Ciupa and Suligowski, 2021; De Luca et al., 2021; Larcher et al., 2021; Noszczyk et al., 2022; Rousseau and Deschacht, 2020; Shoari et al., 2020; Venter et al., 2020; Spotswood et al., 2021). Many studies such as Maury-Mora et al. (2022) and Venter et al. (2020) have focused on COVID-19 related factors such as lockdown.

Generally, studies have shown increased UGS utilization during the peak of COVID-19 spread (Berdejo-Espinola et al., 2021; Lopez et al., 2021). Yet, few studies have explored perception UGS accessibility during early pandemic waves (e.g., Lopez et al., 2021). Exploring perceived and geographic access data offers valuable insights for urban planners and policymakers to enhance UGS design and urban development (Stessens et al., 2020). In this context, we investigate the perceived versus geographic UGS access relationship during the early waves of COVID-19, focusing on New York City (NYC), the initial U.S. pandemic epicenter. Analyzing UGS access disparities across different communities, race/ethnicity, and income levels is crucial, particularly considering COVID-19's disproportionate impact on various communities (Ortiz et al., 2022).

We hypothesized that people in areas with less geographic access to UGS would have lower perceived access and would be more likely to be concerned about a lack of UGS access during COVID-19 pandemic. Additionally, we hypothesized that those with access to smaller UGS would have more concerns about crowding and a lack of social distancing in parks. We further hypothesized that low-income and communities of color are more concerned about accessibility and use of UGS. We asked: 1) Do New Yorkers who perceive they have less access to parks geographically have less physical access (i.e. greater distance to parks or less nearby park area)? 2) How do perceived and geographic access to UGS vary across zip codes, race/ethnicity, and income levels? 3) Is geographic accessibility to UGS correlated with neighborhoods identified as either high, medium, or low locations of COVID-19 severity?

To answer these questions and to better understand how novel COVID-19 policies impacted the use, perceived importance, and perceived access to urban green spaces in NYC, the Urban Systems Lab at The New School (represented by the authors), in collaboration with The Nature Conservancy in New York, Building Healthy Communities NYC and NYS Health Foundation, launched a social survey between May 13 and June 15, 2020. The results of the survey show that many New Yorkers continued to use urban parks and open spaces during the pandemic and considered them to be more important for mental and physical health than before the pandemic began (Lopez et al., 2021). This pattern is mirrored in other studies outside the U.S. as well (e.g., Venter et al., 2020). We received 1145 responses that answered at least 70 % of survey questions, most of them are from 40 zip codes out of the 178 NYC zip codes. We followed the survey study with a spatial analysis to examine geographical accessibility of UGS and how that compares to perceived accessibility, captured by the survey, to improve the wider understanding of UGS access in NYC during the COVID-19 pandemic.

Different types of urban green infrastructure offer a variety of benefits to urban dwellers. Studies found that small urban green spaces like pocket parks, street trees, flower beds, and green roofs, have the potential to provide recreational and experiential benefits (Balai Kerishnan and Maruthaveeran, 2021; Danford et al., 2018; Mesimaki et al., 2019; Peschardt et al., 2012). Liu and Wang (2021, p. 19) argued that pocket parks have advantages in improving accessibility to urban neighborhoods as they require small-sized land, which can be vacant lots or other forgotten and underused locations. However, a number of studies revealed that COVID-19 pandemic caused an increase in parks visitation which emerged the concern of the potential risk of green area crowding (Derks et al., 2020; Geneletti et al., 2022; Venter et al., 2020). An important consideration here is understanding how the potential benefits are influenced by the type and size of UGS. The National Parks and Recreation Association for instance has developed a set of guidelines for various urban park typologies which range from smaller neighborhood and community parks to linear parks where bike and running paths are typically located, to larger natural parks and sports and school parks which vary in terms of size. In a study conducted in Adelaide, South Australia (Brown et al., 2014) researchers found for instance that urban park benefits are related to the size of the park, noting increased physical activity among other benefits. They find the larger the park, the greater the overall benefits when controlling for a variety of mediating factors. Cohen et al. (2010) also reported a positive association between park size and park visits. A NYC-based study suggested that small UGS may lack enough space for physical activities and facilities for residents (Miyake et al., 2010) and this could be more of a concern during COVID-19. To define the pattern of uneven distribution of larger UGS among communities that differ in socioeconomic settings, we examined the correlation between spatial access to UGS and fifteen variables including economic status, household composition, minority status, and housing type for different zip codes. We also overlapped this analysis with the COVID-19 severity (the fraction of deaths to positive tests) for different zip codes that were adopted from McPhearson et al. (2020). This overlapping examination helps reveal the communities that are both significantly impacted by COVID-19 and lack sufficient UGS. We thus highlight neighborhoods in need of larger UGS for coping during times of crisis including potential vulnerability to future pandemics.

Our research approach aligns closely with Sustainable Development Goal 11 (SDG 11), which focuses on making cities and human settlements inclusive, safe, resilient, and sustainable. SDG 11 aims to ensure access to green and public spaces, enhance urban planning, and promote well-being for all residents, particularly in times of crises such as pandemics. Specifically, our study addresses the importance of UGS in promoting physical and mental well-being among urban dwellers, especially during the COVID-19 pandemic. UGS, including parks and open spaces, contribute to creating inclusive and sustainable cities by providing recreational opportunities, facilitating social interactions, and offering spaces for exercise and relaxation. By exploring the perceived and geographic accessibility of UGS during the pandemic, we shed light on the role of UGS in fostering resilience and mitigating the detrimental effects of stressful events on health. Furthermore, our research is in line with publications from UN-Habitat, which emphasize the significance of urban planning in the context of pandemics (UN-Habitat, 2021). The UN-Habitat has highlighted the need for cities to be well-prepared and resilient in the face of public health emergencies. Our study contributes to this discourse by providing valuable insights into the use and benefits of UGS during the COVID-19 pandemic in urban areas, with a specific focus on New York City. Understanding the interplay between UGS availability and access and COVID-19 severity can assist urban planners and policymakers in formulating strategies to enhance the resilience of cities in times of crisis.

2. Materials and methods

2.1. Study site

New York City is the largest city in the United States with ~8.4 million people according to the 2018 American Community Survey (U.S. Census Bureau, 2020) (Fig. 1). The New York City Department of Parks and Recreation (NYC Parks) are the stewards of 1700 parks, 1000

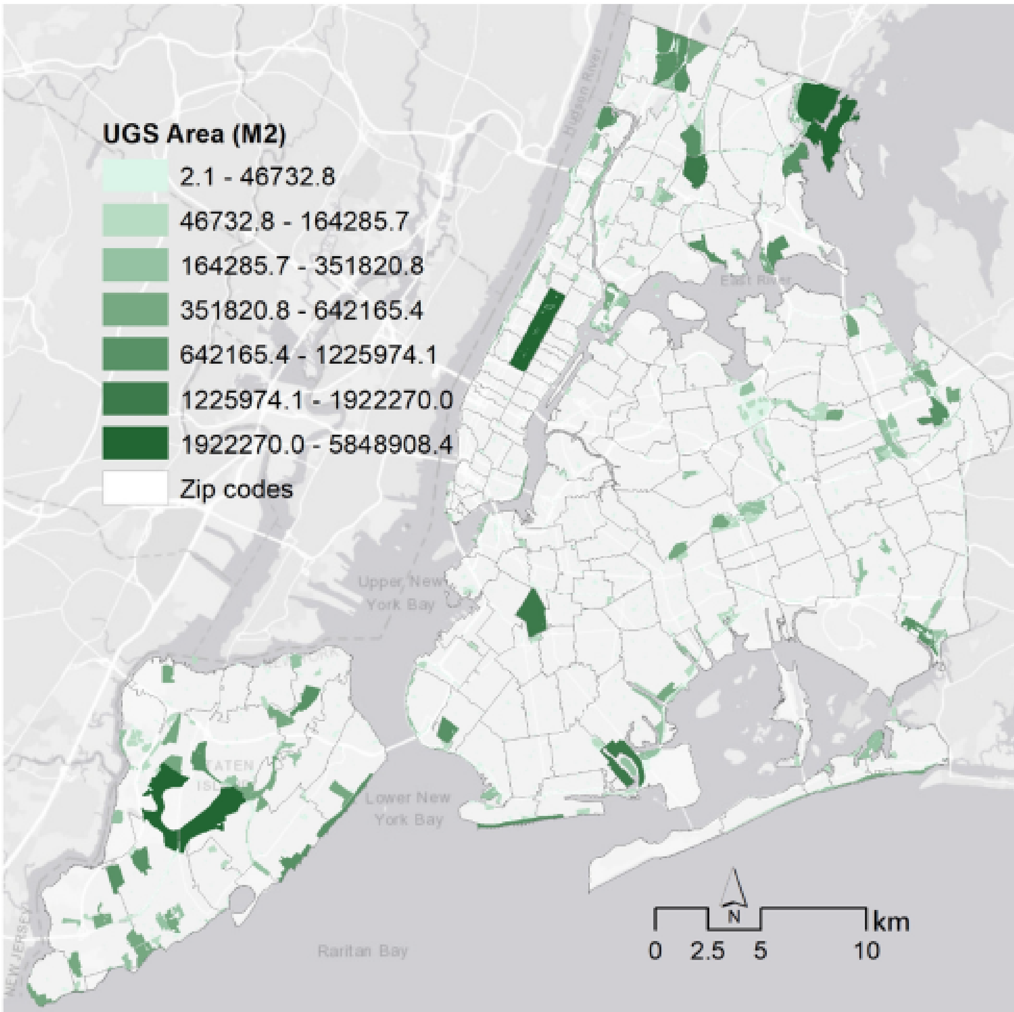

Fig. 1. The size and distribution of urban green spcaes in New York City. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

playgrounds, 650,000 street trees, and 2 million park trees. NYC also contains over 12,000 acres of natural areas including the Jamaica Bay Wildlife Refuge, and 520 miles of coastlines and 8 public beaches managed in part by the New York State Department of Parks and Historical Preservation, and the National Parks Service. There are approximately 12,600 acres of public or "passive" open space (1.5 acres per 1000 residents) such as plazas and esplanades within the city limits (Harnik 2016). In New York State, the first confirmed case of the SARS-CoV-2 coronavirus, COVID-19, emerged on March 1, 2020 and soon spread to NYC through community transmission. With nearly ~6 % of national confirmed cases and ~ 16 % of deaths, NYC has been described by scientists as the first U.S. epicenter or vanguard of the outbreak, prompting a shelter-in-place mandate (PAUSE) in addition to social distancing policies that include restricted access or temporary closure of public open spaces, parks, beaches, and other natural areas (Angel et al., 2020; New York State Department of Health and Mental Hygiene, 2020). New York City's "PAUSE" policy led to a large majority of residents being confined to their homes for most days, an interruption of worker commute, and induced a radical shift in the locations and demand for services including energy, transit, and green spaces.

2.2. Data

From May 13, 2020, to June 15, 2020 (the early months of the COVID-19 pandemic in New York City) an online survey was carried out among NYC residents. The survey aimed at understanding how people easily access UGS during the COVID-19 pandemic, how important people perceive urban green spaces to be for their physical health, and whether exposure to UGS is affecting people's mental health during this time. Lopez et al. (2021) provides a comprehensive description of survey methods and analysis of the survey sections, questions, and findings. The survey resulted in 1145 responses that answered at least 70 % of survey questions. Responders provided information about their zip code and we therefore aggregated the responses at the Zip code level. Out of the 178 NYC zip codes, only 40 zip codes had $\geq$8 survey responses and we used this as a minimum threshold for survey participation for inclusion in our spatial analysis (Fig. 2).

NYC green spaces and street centerlines were collected from the city's open data portal as the Open Space (Parks) layer and NYC Street Centerline layer made available by the city's Department of Information Technology & Telecommunications. We downloaded the updated layers as of July 22, 2020. The social vulnerability indicators were retrieved from the most updated 5-year estimates of the American Community Survey (ACS) - the US Census Bureau (2014–2018) at the zip code level and at the block group-level (finest available spatial unit). One of our aims is to identify the portion of residents who have access to UGS within a reasonable walking distance along roads. The ACS census data at the block group-level cannot provide a good estimate of the total population within walking distance from each UGS, particularly since the city has many large-sized blocks (NYC has an average of 60 parcels/

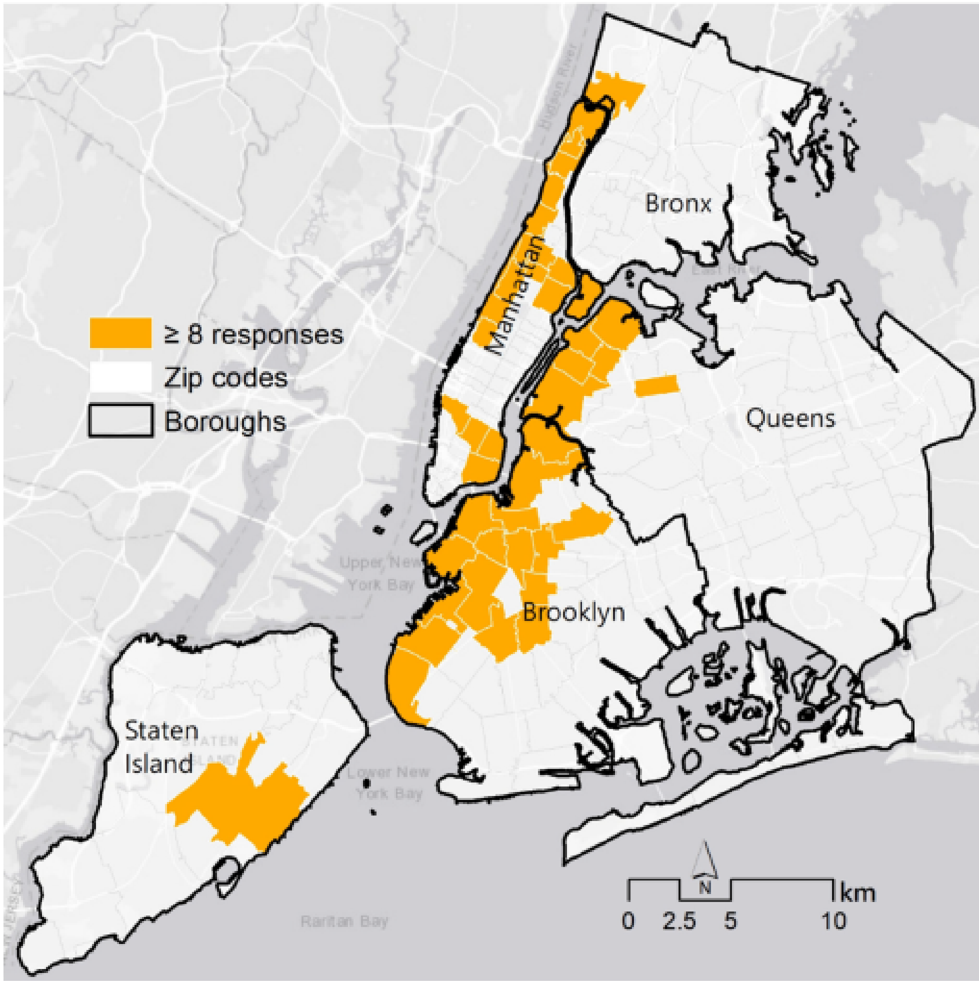

Fig. 2. Zip codes that had at least 8 survey responses.

lots per block). We applied the dasymetric mapping technique (Sleeter & Gould, 2007) to disaggregate the block-level census data (total population per block) to the parcel-level. This mapping technique uses an ancillary dataset representing possible population distribution such as various levels of residential density and the number of residential units per parcel. NYC parcels and attributes were retrieved from the land use field of the NYC tax lot dataset (MapPLUTO of 2018) that is downloaded from the city's open data portal and made available by the NYC Department of City Planning. MapPLUTO provides the total number of residential units per parcel and four residential classes: 1) single family, 2) multi-family elevator, 3) multi-family walk-up, and 4) mixed use residential and commercial. The dasymetric mapping tool included inputs from MapPLUTO and ACS block-level data to estimate the parcel-level total population that we then used to calculate the number of residents who have access to UGS.

2.3. Analysis

We used data from three principal sources: (1) surveys of UGS users, (2) spatial analysis of access to UGS, and (3) social vulnerability indicators of various zip codes. Among the 46 questions listed in our social survey (Lopez et al., 2021), the focus of this study is on three key questions and related answers (Table 1) related to people's concerns about UGS during COVID-19, the travel time to UGS, and the type of UGS they were able to most easily access. More than two-thirds of zip codes that had ≥8 responses have access to beach/water (Fig. 1), which may bias our analysis and therefore we consider the type of UGS in our analysis.

Researchers often define "service area" per UGS by placing a Euclidean buffer around each green space (e.g., Hamstead et al., 2018; Wendel et al., 2011). Unlike buffers that assume unimpeded movement in any direction, we define the service area per UGS as a maximum of 400 m that can be traveled along the road network as in Comber et al. (2008) and Stessens et al. (2017). The 400 m distance, roughly corresponding to 10 min' walk, are in line with previous studies (e.g., Hamstead et al., 2018; Miyake et al., 2010; Sturm & Cohen, 2014). We selected all parcels within 400 m walking distance from green spaces in New York City to examine the percentage of inhabitants that have geographical access to a green space (geographical access). This was also used to assess the average area of green space per capita (UGS per capita), Fig. 2.

2.3.1. Statistical analysis

Multiple linear regression (MLR) model was used to see if people's perceptions of UGS were related to their geographical access to UGS. In this study we examine the access to UGS and the area of UGS given that the size of UGS could be as important as the ease of access to UGS especially during pandemic times that require limiting crowding in open spaces. Therefore, we construct two MLR models predicting each survey response based on the two green space measures (geographical access and UGS per capita, Fig. 3). It is important to emphasize that the scope of this study is not to provide precise definitions for large and small green spaces in NYC. Instead, we adopt a comparative approach by describing urban green spaces as either larger or smaller based on the average green

Table 1
Survey responses (at the zip code level) for questions related to concerns about visiting UGS, access to different types of UGS, and travel time to UGS, used as variables in MLR. All variables represent proportions of respondents who selected the named response (0 to 1) except for travel times, which represent the mean of selected travel times in minutes.

Variable	Survey question/response	Proportion/ average	STD
Concerns about UGS	Currently, what concerns, if any, do you have with visiting parks or open space?		
Access	I do not have easy access	0.074	0.079
Crowded	Too crowded	0.589	0.152
Social Distancing	People are not practicing social distancing	0.602	0.134
Safety	It does not feel safe	0.118	0.081
Cleanliness	Not being maintained/kept cleans	0.106	0.092
Children area	Not child-friendly	0.030	0.047
Needs not met	Does not meet my needs	0.010	0.027
Type of UGS access	Currently, which outdoor locations do you feel you have safe and easy access to?		
Access Park	Public park	0.798	0.113
Access Natural	Natural area	0.227	0.149
Access Beach	Beach	0.117	0.129
Access NYCHA	NYCHA outdoor space	0.012	0.027
Access Plaza	Public plaza	0.152	0.111
Access Garden	Community garden	0.097	0.087
Access Open Street	Street opened for social distancing	0.313	0.196
Travel time to UGS	Currently, how long does it take you to travel to the park or open space that you visit most often?		
Travel Time	Average travel time by any means	6.768	4.047
Walk Time	Average travel time on foot	5.965	3.524

space available per inhabitant. The independent variables are the outcomes of the social survey questions shown above (see Table 1).

Fig. 3 shows that several zip codes have high geographical access but suffer from low UGS per capita rate and some zip codes show a contrary trend. This may indicate that while some zip codes enjoy a high number of "well" distributed UGS, these UGS are small. Fig. 4 illustrates indicators related to UGS and population distribution across the city's boroughs.

Figs. 3 and 4 indicate the disproportionate distribution of UGS across NYC. The average UGS in m^2 per capita is 18, 7, 7, 11, and 50 in Bronx, Brooklyn, Manhattan, Queens, and Staten Island respectively. Some boroughs enjoy a high portion of UGS number but share a low portion of the total UGS area such as Brooklyn and, to a lesser extent, Queens. Consequently, we conduct a bivariate analysis with the Spearman's rank correlation coefficient (Spearman, 1906) to examine the correlation between social vulnerability indicators and geographical access and UGS per capita.

In a previous study, we conducted a comparative analysis using the social vulnerability indicators originally selected by the Centers for Disease Control and Prevention (CDC) to develop its Social Vulnerability Index (McPhearson et al., 2020). These indicators are classified into four groups: economic status, housing composition and disability, minority status and language, and housing type and transportation. McPhearson et al. (2020) added three additional indicators to the ones defined by CDC to represent access to healthcare (percent population without health insurance), a measure of the economic stress induced by housing costs (percent population experiencing rent burden), and a coarse indicator of housing availability (percent vacant housing units). The authors found that immediate impacts of COVID-19 largely fall along lines of race and class. Indicators of poverty, race, disability, language isolation, rent burden, unemployment, lack of health insurance, and housing crowding all significantly drive spatial patterns in prevalence of COVID-19 testing, confirmed cases, death rates, and severity. Income has a consistent negative relationship with rates of death and disease severity. The largest differences in social vulnerability indicators are also driven by populations of people of color, poverty, housing crowding, and rates of disability. Building on this previous analysis, we correlate both geographic accessibility to UGS alongside locations identified as either high, medium, or low cluster areas of COVID-19 incidence and severity.

2.3.1.1. Data preprocessing. We quantified the degree of multicollinearity in independent variables (Table 1) with the variance inflation factor (VIF). We found a significant collinearity between travel time and walk time. We, therefore, excluded the travel time variable. The VIF

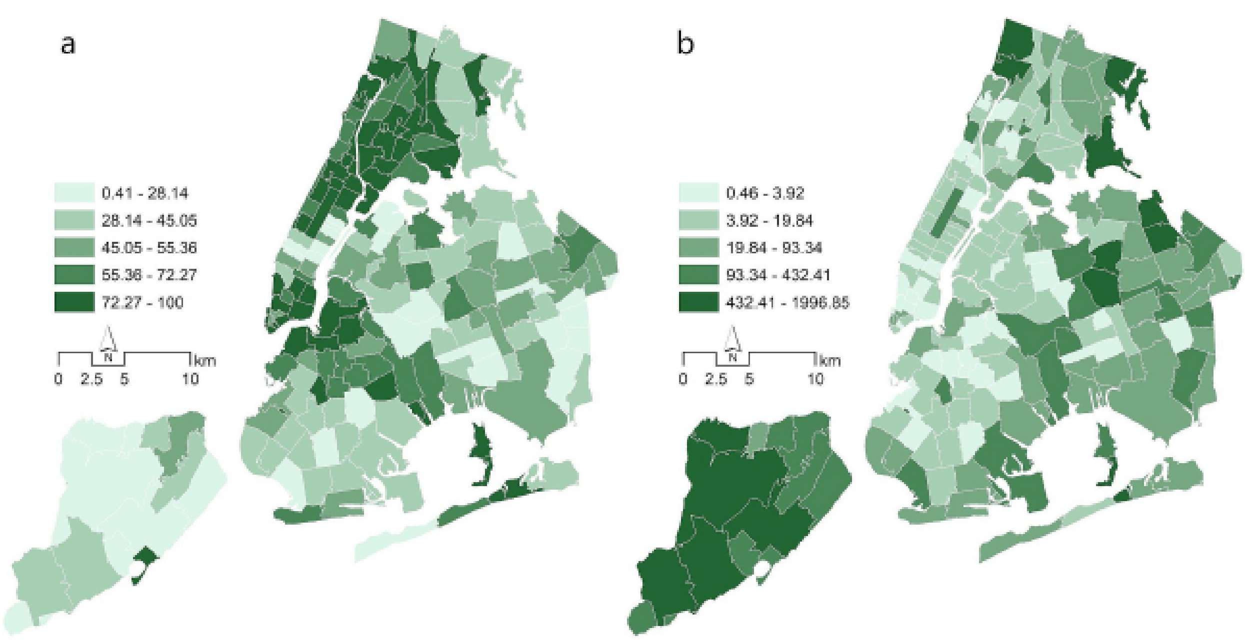

Fig. 3. (a) percentage of zip code residents within 400-m travel distance of UGS, and (b) average green space (m^2) per inhabitant (only those within 400 m travel distance of the UGS).

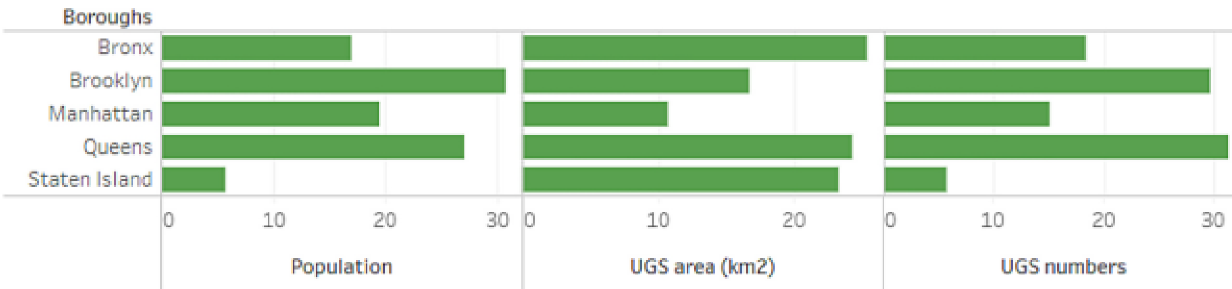

Fig. 4. The proportion of population per borough (left), area of UGS (middle), and proportion of UGSs per borough in percentage (right).

did not show collinearity between the rest of the variables with VIF values < 2.5 (Salmerón et al., 2018). Furthermore, we standardized all independent variables as they have been measured in different units.

We test all possible subsets of the set of potential candidate independent variables (32,767 subsets) using a full stepwise method for each dependent variable to exclude irrelevant variables that would decrease the precision of the estimated coefficients. Table 2 lists the independent variables that are introduced in the final MLR model which are selected according to Bayesian information criterion (BIC) and adjusted R^2 (Raffalovich et al., 2008).

3. Results

3.1. Perceptions and geographical access to UGS

Table 3 summarizes the MLR outcomes. Positive predictors of geographical access that are statistically significant at P-level > 0.05 are concerns with practicing social distancing, concerns with meeting overall needs, easy access to public parks, and easy access to community gardens. Easy access to natural areas is a negative predictor. Positive predictors of UGS per capita that are statistically significant at P-level > 0.05 are having easy access to public parks, beaches, and open streets. The fact that most zip codes, which have a group of ≥8 responses, have access to beach or waterfronts (Fig. 1), resulted in a strong positive relationship between UGS per capita and perceived access to beach or waterfronts. The positive relationship between UGS per capita and easy access to both public parks and beach or waterfronts generally indicate that most responders in the focal zip codes (Fig. 1) have access to large-sized UGS. This is further confirmed with the negative relationship between walking time and area of UGS per capita. Interestingly, an increase in the available UGS per capita shows a remarkable decrease in the concerns survey respondents indicated for "too much crowding".

Table 2
Independent variables included in the final two MLR models predicting each survey response based on the two green space measures (geographical access and UGS per capita.

Variable	Y variable (geographical access)	Y variable (UGS per capita)
Access	–	–
Crowded	Included	Included
Social Distancing	Included	–
Safety	–	–
Cleanliness	–	–
Children area	Included	–
Needs not met	Included	–
Access Park	Included	Included
Access Natural	Included	–
Access Beach	–	Included
Access NYCHA	Included	–
Access Plaza	–	–
Access Garden	Included	Included
Access Open Street	–	Included
Walk Time	–	Included

Table 3
Regression results for the two MLR models predicting each survey response based on the two green space measures (geographical access and UGS per capita).

Variable	Y variable (Geographical access)	Y variable (UGS per capita)
Crowded	−0.268	−0.492***
Social Distancing	0.438**	–
Children area	−0.247	–
Meet needs	0.365*	–
Access Park	0.287*	0.313**
Access Natural	−0.323*	–
Access Beach	–	0.694***
Access NYCHA	0.166	–
Access Garden	0.475***	0.125
Access Open Street	–	0.255*
Walk Time	–	−0.239**
	R2: 0.56, adjusted R2: 0.47	R2: 0.77, adjusted R2: 0.72

Signif. codes: 0.001 '***' 0.01 '**' 0.05 '*'.

The outcome of the MLR analysis highlights the importance of having large-sized UGS, especially during disease outbreaks to encourage greater use of these spaces.

3.2. Social vulnerability and access to UGS

Table 4 lists Spearman's correlation coefficients between social vulnerability indicators and geographical access, UGS per capita, and

Table 4
Spearman's correlation between social vulnerability indicators and geographical access, UGS per capita, and average UGS area per zip code.

	Variable	Geographical access	UGS per capita	Average UGS area per zip code
Economic status	Below Poverty	0.439***	−0.183*	−0.148*
	Unemployment	0.278***	−0.014	−0.019
	Median Income	−0.341***	0.047	0.057
	Health Insurance	0.007	−0.089	−0.101
	Rent burden	0.087	0.015	−0.046
Household composition and disability	Above 65	−0.281***	0.270***	0.237***
	Below 17	0.091	0.228**	0.120
	Disability	0.140	0.289***	0.251***
Minority status	People of Color	0.190**	0.016	−0.046
	Language Isolation	0.134	−0.012	−0.038
Housing type	Multi-Unit	0.537***	−0.430***	−0.284***
	Mobile Homes	−0.230**	0.115	0.193**
	Crowded households	0.184*	−0.180*	−0.186*
	Group Quarters	0.335***	−0.083	−0.124
	Vacant Housing	−0.096	−0.249***	−0.291***

Signif. codes: 0.001 '***' 0.01 '**' 0.05 '*'.

the average UGS area (size) per zip code. Our analysis indicates that lower-income communities, characterized by higher rates of population below poverty and unemployment, as well as lower median income, exhibit higher access to UGS. However, zip codes with a higher prevalence of population below the poverty line lack sufficient UGS area per capita and have access to smaller UGS. This discrepancy is likely because low-income individuals often reside in multi-unit buildings and densely populated residential units due to financial constraints preventing them from affording single-family homes. The noteworthy positive correlation between geographical access and negative correlation between UGS per capita with multi-unit buildings and crowded households further supports this observation. Additionally, Spearman's correlation between multi-unit buildings, crowded residential units, and the average UGS area per zip code reveals that individuals living in such housing conditions have access to smaller UGS spaces.

Elderly residents, expressed by people above 65 in Table 4, tend to live in neighborhoods with a low access rate to UGS and large UGS. USG per capita and average UGS area per zip code shows positive association with household composition and disability variables. According to the results of our survey and recent analysis, people of color have sufficient access to green spaces. Strikingly, there is no association between UGS per capita and minority status. Vacant Housing has no association with geographical access to UGS and has a notable negative association with UGS per capita meaning that these housing units can be found in areas with small green spaces.

4. Discussion

This study delved into the perception and geographic accessibility of UGS among NYC residents during the first COVID-19 wave. While our research's scope is UGS accessibility during the pandemic, considering additional factors like lockdowns, quarantines, and extended park closure times would contribute to a more comprehensive understanding of the pandemic's distinct effects on UGS accessibility and usage. Exploring this avenue remains a future research direction stemming from the current study's findings.

This study also explored the correlations between access to UGS and UGS per capita, and indicators of social vulnerability. Using measures of the geographic distribution of UGS, and survey responses concerning ease of access and concerns with social distancing, the study results indicate that concerns over practicing social distancing, ease of access to parks and open spaces, and meeting overall needs including quality of UGS amenities are positively related to geographical access. However, our survey and findings also suggest that both physical and socio-personal factors influence perceived accessibility to parks and open spaces in NYC, particularly during the COVID-19 pandemic (Lopez et al., 2021). In some cases, usership declined in part because of perceived safety risks, inability to socially distance, and the amenities or services a UGS provides (Lopez et al., 2021). Our analysis revealed that UGS size is a critical factor as is the travel distance, in understanding the characteristics and influencing factors of visitation and use which is in line with Wang, Brown, Liu (2015), Paul and Nagendra (2017), Basu and Nagendra (2021). Thus, from a city planning perspective, it is important not to assume that geographic access and proximity to UGS is the most reliable predictor of park and open space use, or transfer of benefits during times of crisis.

Our results confirmed that areas of the city with greater availability of UGS area per capita had less concerns with overcrowding of UGS. UGS size, in addition to the spatial distribution of UGS, was also related to survey responses about ease of access, use, and Coronavirus safety. This highlights the importance of having large-sized UGS, especially during disease outbreaks to encourage greater use of these spaces (See Table 3, crowded variable). This also suggests large UGS play a greater role in benefit transfer for recreational use, mental and physical health, and social cohesion. These results align with studies that examined the influence of park size on perceived accessibility and found similar conclusions (e.g., Stessens et al., 2020).

The results of a spatial analysis in NYC showed that larger UGS are unevenly distributed across the five boroughs. The findings of this study agree with the work of Miyake et al. (2010) and Rigolon (2016) who found that poorer people have access to fewer acres of UGS. Our study suggests relatively better UGS access, albeit to smaller areas, in lower-income communities. However, it's important to note that this trend might not hold true universally and could vary across different cities and regions (e.g, Astell-Burt et al., 2014). Our results also highlight a discrepancy in perceived access for city dwellers living in multi-unit buildings, which the city defines as privately-owned rental properties with five or more units. Despite having sufficient geographic access to UGS, according to the 10-min walk radius determined by our spatial analysis, our results find the UGS near many of these dwellings are not sufficient in terms of size. U.S. Census data from the 2018 American Community Survey confirms that residents who live in multi-unit buildings are more likely to be people of color and lower income. This trend suggests that the environmental justice implications related to park accessibility may have less to do with geographic access and proximity to UGS than perceived accessibility related to the parks size and park quality including park amenities and other socio-cultural factors, and perceptions of ease of access. Fig. 5 illustrates groups of zip codes that have low UGS per capita and low geographical access (low-low), low UGS per capita and high geographical access (low-high), high UGS per capita and low geographical access (high-low), and high UGS per capita and high (high-high) geographical access according to the quantile classification method. Only 11 zip codes out of 178 are classified as high-high, mostly in the Bronx and Queens. More importantly, there are 18 zip codes where residents have limited access to insufficient areas of green spaces (low-low). In addition to those 18 zip codes, there are 24 zip codes that have high access to insufficient green spaces. This should be a major concern for policymakers and city planners. Our results indicated that an insufficient area of UGS increases concerns with overcrowding and may restrain residents from visiting UGS. Local government and not-for-profit organizations are, therefore, recommended to invest more funds to purchase vacant lands for parks in zip codes that lack sufficient areas of UGS.

The relationship between UGS availability, and COVID-19 severity (deaths/positive cases) is also a key consideration. In Fig. 5 we illustrate the overlap and relationship between areas identified in this study as having higher access to higher per capita UGS and the COVID-19 severity rate according to McPhearson et al. (2020). McPhearson et al. (2020) identified areas of high and low COVID-19 severity during the first wave of COVID-19 outbreak (April 1, 2020, through May 19, 2020) in NYC. Fig. 5 shows the 22 zip codes classified as low UGS per capita and high COVID-19 severity rate. These areas are located predominantly in the NYC boroughs of Brooklyn, the Bronx, and Manhattan. The neighborhoods in Brooklyn that correspond to classifications are Crown Heights, Prospect Lefferts Gardens, East Flatbush, Bedford Stuyvesant, Bushwick, and Brownsville. According to the U.S. Census and NYC Community Health Profiles (2018), these neighborhoods are primarily working class and low-income people of color (POC) communities that have been impacted by disinvestment in social services, have lower rates of access to healthcare, and have a higher percentage of health outcomes such as obesity, diabetes and hypertension as compared to the city as a whole. Similarly, the neighborhoods in the Bronx including Claremont Village, Highbridge, Mott Haven, and Hunts Point have a similar demographic composition, predominantly POC communities with higher rates of social vulnerability. The neighborhoods in Manhattan such as East and Central Harlem, and Washington Heights are positioned similarly as well (deviations: Lower East Side, Stuyvesant Town, Lincoln Square, Carnegie Hill). This pattern in part shows how overlapping COVID-19 vulnerabilities interact with availability and usage of urban green spaces for physical and mental health during COVID-19 shelter-in-place policies.

The results of this study have implications for parks managers and

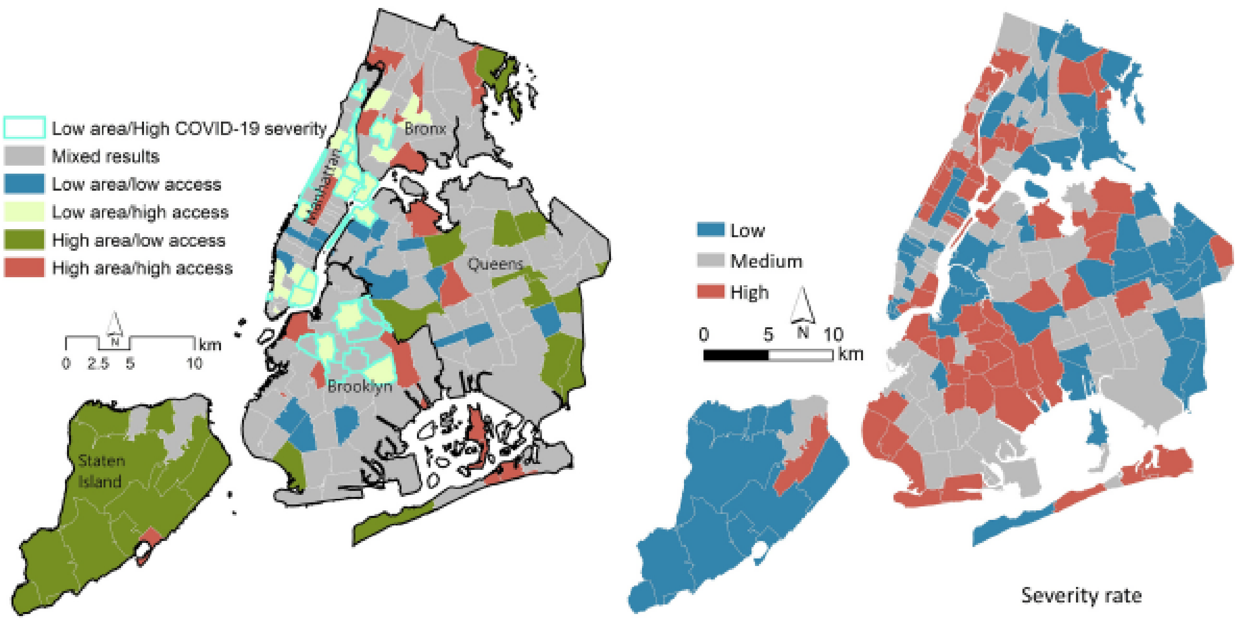

Fig. 5. (Left) Urban Green Spaces (UGS) clusters: Zip codes with low UGS per capita (low area) and high COVID-19 severity rates that adopted from McPhearson et al. (2020), and Zip codes with consistent groupings as low-low, low-high, high-low, and high-high for UGS per capita and geographical access to UGS respectively according to the quantile classification method. (Right) COVID-19 severity rate according to the quantile classification method, source McPhearson et al. (2020). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

organizers, to address uneven distribution and perception of access to UGS, particularly for socially vulnerable and at-risk populations who may benefit from the diverse values of UGS. Investments in future UGS should consider the need for adequate space, park quality, and the diverse values of current and future users which should inform the amenities provided to communities. However, it is also important to consider that investing in larger UGS without other investments to counter long standing environmental injustices could trigger environmental gentrification which often results in the displacement of low-income residents (Jo Black and Richards, 2020). In addition, simply investing more capital or placing more value on existing large UGS may not be sufficient to satisfy need, pointing to the critical role additional UGS can play ensure improved geographic and perceived access for those people who may benefit most, especially during extreme events. As such, we highlight the importance of distinguishing between geographic and perceived access to urban green spaces, particularly during times of crisis. This will become increasingly important as extreme weather events continue to impact communities across the New York region, and the cascading and interdependent impacts of the current health and economic crisis.

Although New York City was used as a case study in this study, other studies which show patterns of decreased access to quality UGS by low income and minority urban residents demonstrate the importance of the implications of our findings for cities elsewhere. Worldwide, there was worry about crowding and the practice of social distancing while UGS during pandemics. Additionally, uneven distribution and access to UGS is a problem in many cities UGS around the globe (e.g., Kabisch and Haase, 2014; Kaur et al., 2021; Wu and Kim, 2020; Zhang et al., 2020). Thus, further comparative study examining perceived and geographic access in other cities globally, especially given the importance of use of USG during pandemics could be useful to guide urban prioritizations of UGS investments in cities seeking to improve the health and wellbeing of urban inhabitants.

5. Conclusion

The primary objective of this study was to explore the perceptions and geographic accessibility of urban green spaces (UGS) among NYC residents during the early period of the COVID-19 pandemic. Specifically, our study delved into the correlations between UGS access, UGS per capita, and indicators of social vulnerability. By analyzing the geographic distribution of UGS and survey responses related to ease of access and concerns about social distancing, we found that concerns regarding social distancing, ease of access to parks and open spaces, and meeting overall needs, including quality of UGS amenities, were positively related to geographic access.

Our analysis emphasized that UGS size played a critical role in influencing visitation, use, and safety perceptions during times of crisis, particularly due to the need for social distancing. This aligns with previous studies (e.g., Wang, Brown, Liu, 2015; Wang, Brown, Zhong, Liu, & Mateo-Babiano, 2015) and highlights the importance of considering factors beyond geographic access in predicting UGS access and use patterns.

Our findings reveal that certain concerns related to COVID-19, such as crowding, social distancing, and travel time to UGS, can indeed be inferred by geographical proximity variables. Importantly, the relationship between UGS size and users' ability to practice social distancing is a significant takeaway, echoing the importance of large UGS spaces during public health crises. The findings of this study highlighted uneven UGS distribution across NYC's boroughs, particularly in relation to areas impacted by COVID-19 severity. We found that neighborhoods with higher social vulnerability indicators tended to have less access to sufficient UGS areas.

While our research focused on NYC, the implications of our findings extend to cities worldwide. Uneven UGS distribution and access during pandemics are challenges faced by many urban areas globally. Therefore, comparative studies exploring perceived and geographic UGS access in other cities, especially during pandemics, could provide valuable insights for urban planning strategies that prioritize the health and well-being of urban populations.

Lastly, our study contributes to the understanding of the complexities surrounding UGS accessibility during a crisis. By highlighting the interplay between geographic proximity, perceived accessibility, UGS size, and social vulnerability, we provide a foundation for more informed urban planning and policy decisions aimed at creating resilient and equitable UGS for all.

CRediT authorship contribution statement

Ahmed Mustafa: Conceptualization, Methodology, Formal analysis, ` Writing- Original draft preparation, Writing-Reviewing and Editing. Christopher Kennedy: Methodology, Writing- Original draft preparation, Writing-Reviewing and Editing. Bianca Lopez: Methodology, Formal analysis, Writing- Reviewing and Editing. Timon McPhearson: Supervision, Conceptualization, Writing- Reviewing and Editing. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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