Assessing Spatial Equality of Urban Green Spaces (UGS) in Virginia Beach, Virginia using Geospatial Information Systems (GIS)

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Abstract

Urban green spaces (UGS) play a significant role in healthy living, improving physical, psychological, and social health. However, accessible UGS are not always equitably distributed across varied urban populations. In this study, UGS accessibility is explored using GIS to gain a deeper understanding of the spatial equity of UGS in Virginia Beach, VA. Specifically explored were: (1) the links between urbanization, land use, and population to public UGS ; (2) the accessibility of existing UGS using Euclidean and network buffers; and (3) recommendations of areas for future UGS implementation based off the needs of the community. The network and Euclidean buffer analysis of UGS access present stark differences in their results. The results of the Euclidean buffer analysis state that 92% of residents have accessible UGS, whereas the network buffer analysis concluded that only 63% of residents are within 800-meters of UGS. The results of these two measurements suggest that when using a more realistic approach to park accessibility, 75,396 citizens in Virginia Beach have limited access to UGS.

Keywords: Urban green space, Land use/cover, Urban, Remote Sensing, GIS, Virginia Beach, Virginia

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According to data compiled by the World Bank (2019) in 2018, 55 percent of the world's population lived in urban areas, a 25 percent increase from 1950. The United Nations (2018) projects that global urbanization is expected to increase to an average of 68 percent by 2050, numbering approximately 6.7 billion people. Urbanization has commonly been a positive force for economic growth and development, social transformation, and poverty reduction (Gu, 2019). On the other hand, the increase of inhabitants or densification in urban environments has exacerbated problems such as loss of urban green spaces (UGS) within cities and current policies governing green space management (Lin, Meyers, & Barnett, 2015).

Through various studies, the link between green space and positive effects on human health have become increasingly accepted (Bertram & Rehdanz, 2015; Bowler, Buyung-Ali, Knight, & Andrew, 2010; Kondo, Fluehr, McKeon, & Branas, 2018). The improved health benefits of green space are diverse, ranging from increased physical activity levels, reductions in cardiovascular disease increased birth weight, and improved mental health (Bowler, Buyung-Ali, Knight, & Andrew, 2010). The citizens of Virginia Beach (VA Beach) have access to more than 33,640 acres of parkland, ranging from beaches to a nationally recognized athletic complex, making Virginia Beach a popular city with both tourists and it's residents (The Trust for Public Land, 2011). As global urbanization impacts continue, it is crucial to ensure that the city of VA Beach maintains acceptable levels of UGS for its increasingly urban population.

Literature Review

Although there is a plethora of research outlining the benefits and necessity of UGS, many publications fail to set the parameters defining "green space." In the context of this research and in agreement with previous studies, UGS consists of formally designated areas such as parks and recreation venues, playgrounds and sports facilities, and informal green spaces such as nature trails, rivers, riparian buffers, beach/ocean fronts or green spaces surrounding historical sites (Taylor & Hochuli, 2017). Several authors, including those previously cited, have drawn a clear distinction between public and private space as challenging because the boundaries of these two spheres are continuously changing. Nonetheless, when it comes to the accessibility of the UGS, the distinct difference between the public and private spaces becomes a catalyst for debate. Importantly, the difference between the public and private may be drawn based on some criteria, such as access, management, ownership, appearance, as well as morphology (Threlfall et al., 2015). Concerning the landownership, the public UGS is owned by the government or state, whereas in the private UGS, the owner has a legal entity to it. Kabisch, Strohbach, Haase & Kronenberg (2016) suggested three categories linked to the public property: *stricter sensu public spaces*, special public spaces, and privately run public spaces.

The growing concern over the availability and access to UGS is primarily due to the positive effects of natural environments on the general human well-being within those urban regions (Aronson et al., 2017). A systematic analysis indicated that access to UGS close to the dwellings of pregnant women was positively linked to healthier birth weights, which is an essential indicator of health at the early stages of life (Cetin, 2015). Jennings, Larson & Yun (2016) demonstrated an inverse proportion between the distance city parks to the dwellings of pregnant women and an increased risk of preterm birth. On the other hand, UGS has its negative impacts: city parks are usually linked to the increased risk of accidents and injuries resulting from falls and drownings. Research in the United Kingdom shows that accidents and emergency hospital admissions rates were relatively higher in regions with several parks used as playgrounds (Fan, Xu, Yue, & Chen, 2017). Vegetation cover such as trees, shrubs, and grass can dampen the effects of the road traffic and industries, thus improving air quality in the urban residential dwelling, thereby offering considerable benefits to the public health (Bowler, Buyung-Ali, Knight, & Pullin, 2010).

The construction of impermeable surfaces in Urban environments replaces the natural permeable landscape creating a heat island (Bowler, Buyung-Ali, Knight, & Pullin, 2010). Heat linked to morbidity in urban areas is a major public concern within the World Health Organization, and the excessive exposure to sunlight/heat is associated with increased morbidity as well as mortality; this is especially true for elderly persons (Jennings, Larson & Yun, 2016). Research has shown that urban parks within towns/cities can offer a cooling effect of approximately 1^{o}C/ 33.8^{o} F. In cooler areas, vegetation offers shelter from the wind, which decreases the heating demand during colder seasons. Threlfall et al. (2015), investigated the role of vegetation and green space in decreasing the surface temperature in Phoenix, researchers noted that the vegetation cover does reduce income-linked to inequality as far as exposure to extreme heat condition is concerned. Green et al. (2016), noted that vegetation cover does reduce the levels of air pollutants, ultimately decreasing the amounts of atmospheric carbon dioxide. Research findings by Wang et al. (2015) reveal that a prominent factor of accessibility to UGS is proximity.

The standard spatial distribution of UGS is contested at best, with organizations having developed specific benchmarks and standards defining what constitutes “accessible UGS.” Green space accessibility is typically measured using two factors: travel distance and amount per resident. The standard distance generally used by cities in the United States is the guidance by the National Recreation and Parks Association (NRPA) and the Trust for Public Land (TPL): a walkable radius or *catchment area* of .5 miles/ten-minute walk, is the distance people are willing to travel to access a recreational area and ten acres/4four hectares per 1,000 residents (Harnik & Martin, 2012). A study by Richardson et al. (2010) used a radius of 1.3 km (1300 m) as the catchment areas of parks of at least 0.02 hectares. While these standards are used to identify the physical accessibility to UGS by walking/biking, there are many studies (Boone, Buckley, Grove, & Sister, 2009; Lin, Fuller, Bush, Gaston, & Shanahan, 2014; Wang et al., 2015) which argue that using the standard approach of park spatial distribution using universal walking distances poorly serves both parks and its residents.

Access to UGS is a complex multidimensional paradigm with both physical and non-physical barriers (Wang et al., 2015). Socio-demographic features of visitors have a greater effect on the recreational responses/activities, and, to some extent, the size of the green spaces affects the levels and types of physical activities undertaken within the location. As larger UGS may provide more functions or activities (e.g., football or kite-flying), and if over half a mile away from a resident, may become a destination to travel other than a temporary or easily accessible location (Harnik & Simms, 2004). A larger area of UGS, in turn, may attract more planned exercises (Boone et al., 2009) when compared to the smaller pocket parks located in the city. Therefore, when evaluating the mismatched distributions, the consideration of the amount of UGS, and the type of activities available is essential. Environmental awareness and accounting for local community use of UGS is essential when planning UGS development (Wang et al., 2015).

A range of methodologies exists to correlate the amount of UGS and the population. Various studies use the census administration units, typically by calculating the percentage green space cover over the area. The more popular method to measure the social equity of UGS is by using a buffer around a census administration area, the use of a population centroid, or around individual residential units. There are also two approaches to creating buffers and measuring distances: using Euclidean (straight-line) and network distance. Euclidean uses a point-to-point approach, whereas network analysis provides a more realistic calculation of the amount of time needed to move from one location to another using established lines of transit (Browning & Lee, 2017).

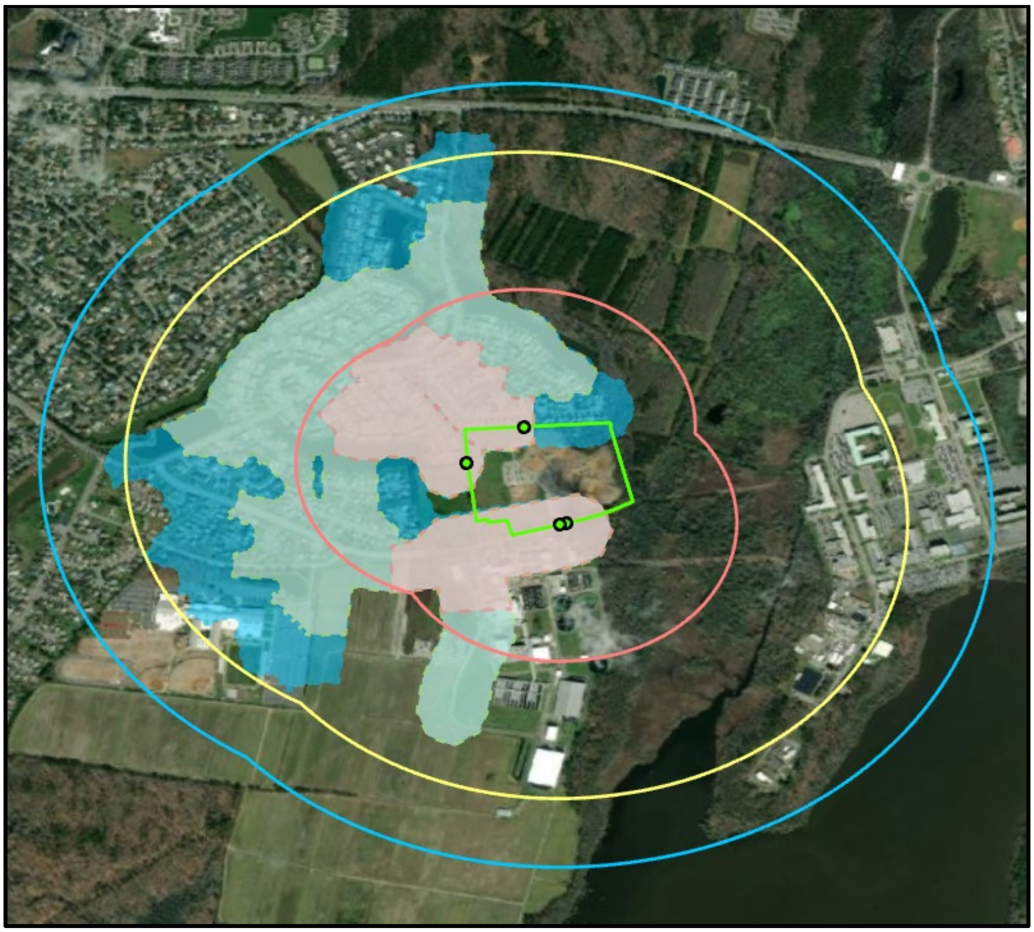

Figure 1. Overview of the type of buffers used in the study. The areas within network buffers (dashed lines) and straight-line buffers (solid lines) of access points for greenspace (green boundary points), shown as 400 (red), 800 (yellow), and 1000 meters (blue).

Past research employed GIS and the network analysis technique to examine how a variety of socioeconomic groups, ethnic societies, as well as, religious groups have access to UGS in Australia; their research indicates that access to UGS is uneven amongst the studied and observed groups (Kabisch, Qureshi, & Haase, 2015). As Browning & Lee's (2017) research demonstrates, a network analysis that utilizes a larger buffer area (within 1000-2000 meters) may enable urban planners, architects, and engineers to better understand the effects of environmental justice on the accessibility of UGS and to assist communities in achieving equitable access to the green spaces.

Goals and Objectives

Urban green spaces play a significant role regarding healthy living; the immensely positive health benefits resulting from access to and utilization of UGS to human beings are undisputable. Emerging from this review is a concept that stakeholders need to embrace: the advantages of UGS in maintaining or improving a populations' overall health outweigh any potential limitations. This study intends to analyze UGS accessibility using GIS to gain a deeper understanding of the effects of population rise on the existence of UGS. Considering the vital role UGS plays regarding healthy living, the findings of this research will benefit the general public, scientists, and urban planners in the VA Beach area. The specific objectives for the research are: (1) determine the current amount of UGS and assess if it is sufficient for current and future population growth, (2) evaluate UGS distribution equity and determine any socioeconomic correlations, and (3) provide recommendations for the optimal placement of future UGS.

Study Area, Materials, and Methodology

This study consisted of a four-step analytical process. The first step was examining land-use and its change over time. Determining the annual and total land-use change was done by calculating the change of each classification between the 2001 and 2016 30-meter NLCD. The second step of the analysis was used to evaluate the amount of UGS for current and future population projections. The third step evaluated the accessibility and access to UGS using Euclidean and network buffer analysis. The fourth step analyzed UGS distribution equity to determine any socioeconomic correlations using information derived from the census boundary data set. The results of the analysis provide the basis for recommendations of optimal locations for UGS growth and expansion.

Study Area

Virginia Beach is located in the southeastern corner of Virginia at 36.78°N/76.03°W (Figure 2) and is the 43rd largest city in the United States, with approximately 454,846 residents over a land area of 718 km2 (World Population Review, 2019). The City of VA Beach contains more than 33,640 acres of parkland with multiple recreation centers, numerous public campgrounds, and a nationally recognized athletic complex (The Trust for Public Land, 2011). Virginia Beach is a popular destination for tourists and praised by its residents for its parks and recreation system. The study was focused in the northern portion of VA Beach (blue area in Figure 2) urban green space, as southern VA Beach is considered primarily rural.

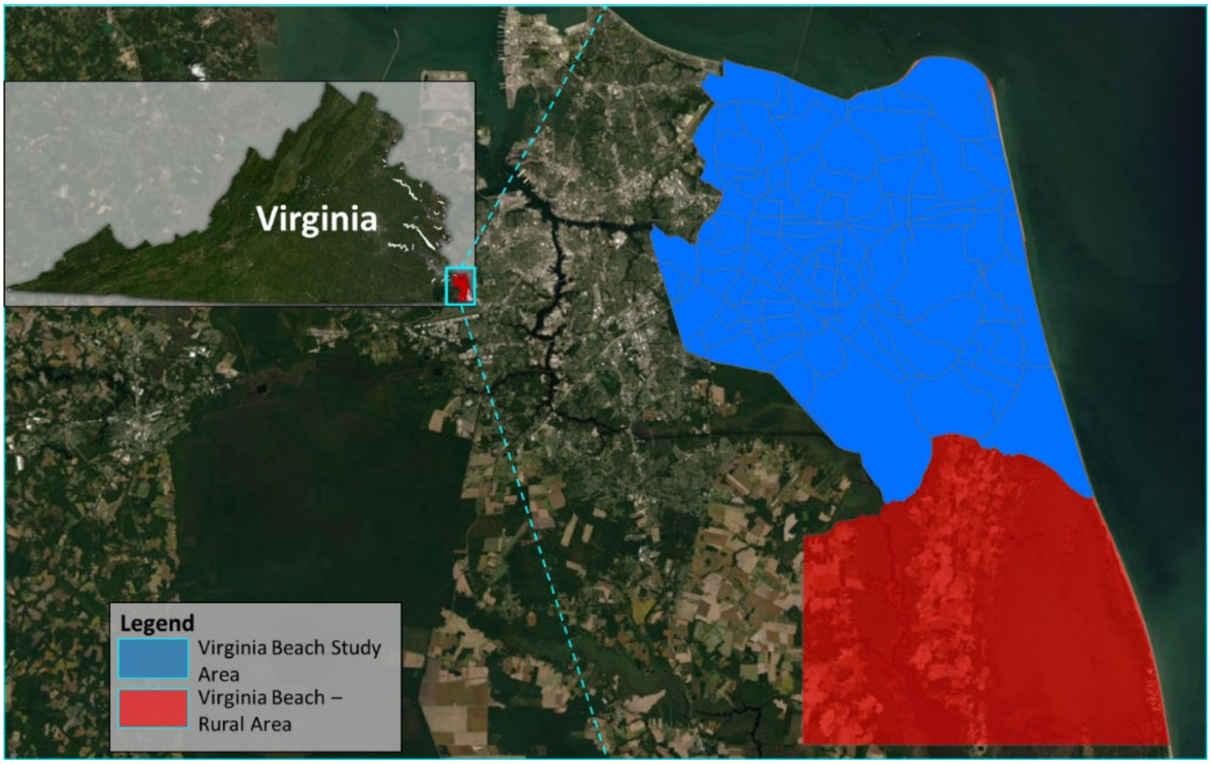

Figure 2. Overview of the study area in located in the state of Virginia (ESRI, 2019).

Data

All data sets used in this study were extracted from their original collection, using the study area as the mask. Environmental Systems Research Institute's (ESRI) ArcGIS Pro software was used to consolidate data and conduct the spatial analyses. Maps throughout this report were created using ArcGIS® software by Esri (ESRI, 2019). Summarized in Table 1 below are the datasets used for this study.

Table 1

Summary of data sources used in this study.

Data	Resolution	Year (year of last update)	Source
SF1/2/3 Census Block/Block Group	Census block group and tract	2000, 2010	US Census Bureau
American Community Survey (ACS)	Census block group and tract	2018	US Census Bureau
Parks and Recreation	City Wide	2019	City of Virginia Beach
Bikeways, Trails, Facility and Sidewalks Overview	City Wide	2019	City of Virginia Beach
Transportation Networks (Center line data)	State Wide	2019	Virginia Geographic Information Network
Virginia Address Points	State Wide	2019	Virginia Geographic Information Network
Virginia Statewide Land Cover Dataset (VSLCD)	1 Meter	2016	Virginia Geographic Information Network
National Land use/Land Cover (NLCD) – Land Cover	30 Meter	2001, 2016	United States Geological Survey

Units of Analysis

The first unit of analysis used in this study consisted of the census blocks (CB) and census block groups (CBGs) and census tracts (CT) containing population information. CB's are the smallest geographic area used to collect decennial census data typically defined by legal boundaries, roads, or water; BGs are a combination of census blocks located within an associated census tract and commonly used for presentation (U.S. Census Bureau, 2013). The second unit of analysis used was the Virginia address points to determine the location of residential and business locations within the study area. A map of the included BGs, showing the Virginia address data using color to delineate by census tract, is shown in Figure 3.

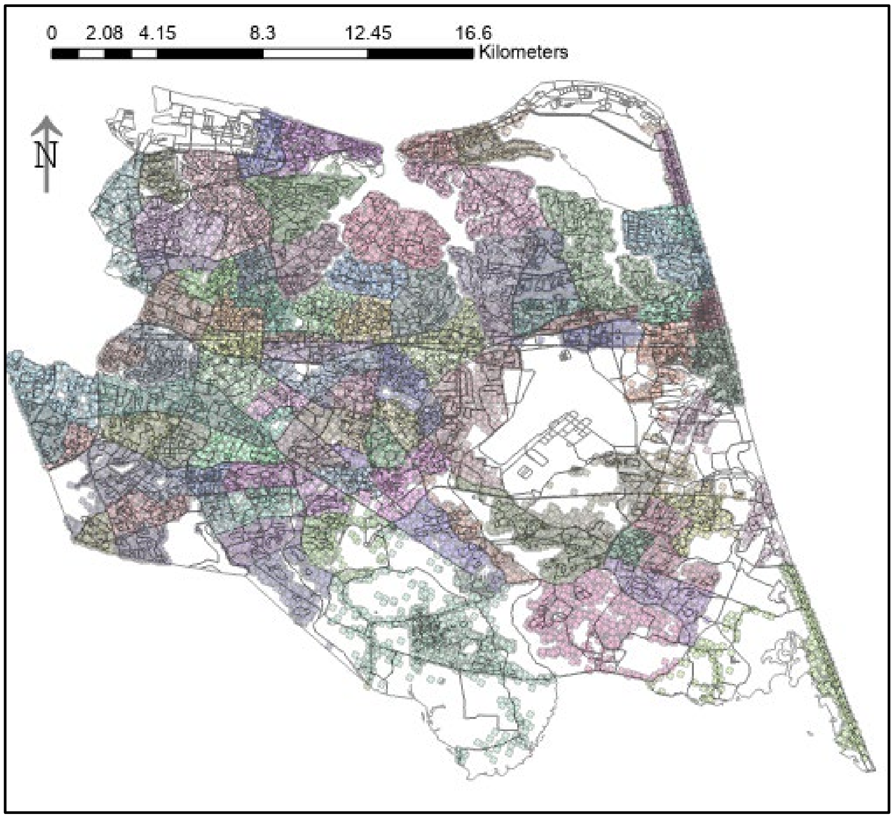

Figure 3. The census block groups (CBGs) of VA Beach within the urbanized study area, with the location of residents using color to delineate by census tract (ESRI, 2019).

Land Use Data

Figure 4. Illustration of the steps used to extract and determine land use data for this study.

Pre-Processing and Classification. Green space and land-use changes were measured using the 30-meter 2001 and 2016 National Land Cover Data (NLCD). While the 30-meter

NLCD serves as a useful component in general land cover modeling, the 30-meter resolution does not provide enough resolution. As depicted in Figure 5, the 1-meter resolution of the Virginia Statewide Landcover Dataset (VSLCD) provided an increased level of detail and accuracy for analysis.

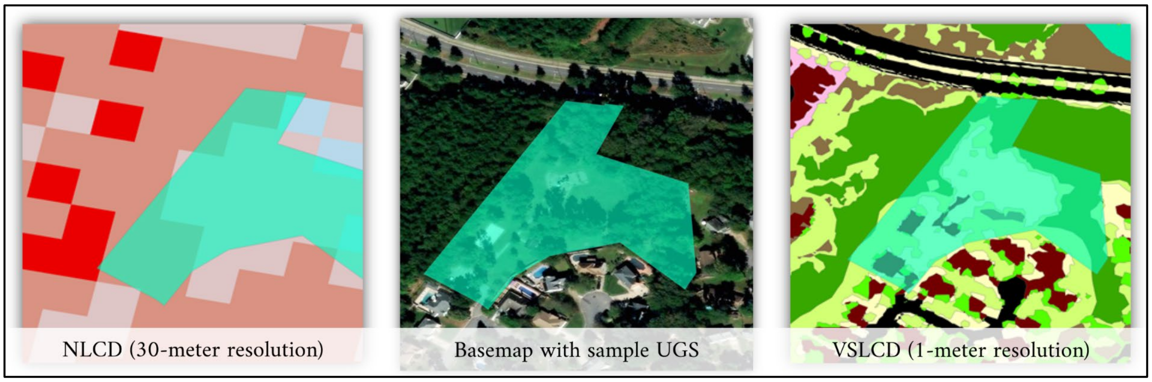

Figure 5. A comparison of the 30-meter 2016 National Land Cover Data (left) and the 1-meter Virginia Statewide Land Cover Dataset (right).

The 2016 VSLCD was used to determine the percentage and UGS density of UGS by census tract. Existing NLCD2001/2016 classes were reclassified into two classes: Developed and Green Space. The Developed class included the High, medium, low, open development areas, and the Green Space class included grass, shrub, pasture, grassland, wood/herbaceous wetland, and deciduous/evergreen forest areas delineated as described in Table 2 below (Scheibe & Ellsworth, 2016). The VSLCD reclassification for green space included forest, tree, shrub/scrub, turf, pasture, and the Developed class contained the impermeable surfaces.

Table 2

Land Use Change by Class Using 2001 NLCD Data.

2001 NLCD Study Area							
OBJECTID	gridcode	Class	SUM_SqMi				
1	11	Water	60.515277				
2	21	Developed Open Space	38.196744		Classification		
3	22	Developed Low Intensity	44.218003			Developed	Green Space
4	23	Developed Medium Intensity	16.950469				
5	24	Developed High Intensity	4.83729				
6	31	Barren Land	3.907496				1.007336
7	41	Deciduous Forest	1.007336				7.549276
8	42	Evergreen Forest	7.549276				2.929605
9	43	Mixed Forest	2.929605				0.724159
10	52	Shrub/Scrub	0.724159			38.196744	0.685299
11	71	Grassland/Herbaceous	0.685299			44.218003	0.806532
12	81	Pasture/Hay	0.806532			16.950469	60.538737
13	82	Cultivated Crops	43.69222			4.83729	20.394089
14	90	Woody Wetlands	60.538737		Total	104.202506	94.635033
15	95	Emergent Herbaceous Wetlands	20.394089		Percentag	42.28%	38.43%
		Total	306.952532				
		No Water	246.437255				

Table 3

Land Use Change by Class Using 2016 NLCD Data.

2016 NLCD Study Area							
OBJECTID	gridcode	Class	SUM_SqMi				
1	11	Water	60.626734				
2	21	Developed Open Space	37.417196		Classification		
3	22	Developed Low Intensity	45.71158			Developed	Green Space
4	23	Developed Medium Intensity	21.094972				
5	24	Developed High Intensity	6.17069				
6	31	Barren Land	3.746457				0.742292
7	41	Deciduous Forest	0.742292				7.308457
8	42	Evergreen Forest	7.308457				2.866391
9	43	Mixed Forest	2.866391				0.591701
10	52	Shrub/Scrub	0.591701			37.417196	0.489609
11	71	Grassland/Herbaceous	0.489609			45.71158	0.492246
12	81	Pasture/Hay	0.492246			21.094972	60.458185
13	82	Cultivated Crops	40.523841			6.17069	18.710494
14	90	Woody Wetlands	60.458185		Total	110.394438	91.659375
15	95	Emergent Herbaceous Wetlands	18.710494		Percentag	44.82%	37.21%
		Total	306.950845				
		No Water	246.324111				

UGS Data

The study area identified within VA Beach has 370 parks totaling 17.65 Sq. Mi. constituting 10.67% of the total land cover. Spatial data on various land use types, including public green space from 2019, was provided by the VA Beach Geospatial Information Systems (GIS) department. Only the official city and state owned public UGS show in Table 4 below were used in this analysis. The parks and recreation information from the city had incorrect park locations that did not encompass the correct area. Shapefile errors were corrected by deleting the erroneous information and using up-to-date imagery to confirm current park areas.

Table 4

Shapefile Combination Structure of City Green Space Data.

Official Public Green Space	Private/Limited Green Space
Community Parks (CP)	Special Use Areas (SU)
Metro Parks (MP)	a) Athletic Centers (SUAC)
Neighborhood Parks (NP)	b) Golf Courses (SUGC)
Signature Park (SP)	c) Recreational Centers (SURC)
General Open Space (GOS)	d) Water Areas (SUWA)
Natural Resource Areas (NRA)	
Open Space Preservation Area (OSPA)	
Linear Parks / Linkages (LINK)	

Methodology and Analysis

UGS and Population Change

When assessing the adequacy of UGS for the current and future population estimates, it is necessary to determine how the population has changed and where these changes have occurred. Population distribution in VA Beach was created using data from Census 2000/2010 and the 2018 American Community Survey (ACS). The population density was identified (population per square mile) per census tract by dividing the population total by the area for 2000, 2010, and 2018. The steps of this process included: finding the population change over time (see Table 5).; identifying the percentage of land use changes as it relates to the change in population growth (see Table 5), comparing the land use and population change to determine any correlation, and then calculate the approximate UGS per person by year.

Table 5

City of Virginia Beach – Population Change (Study Area)

	2000	*2010*	*2018(ACS)*
Total Population	420,735	433,265	445,249
Total Land Area (sq. mi.)	165.32	165.32	165.32
Population Density (sq. mi.)	2,546	2,620	2,693
Population Change	-	2.9%	2.76%

The total amount of land-use change, calculated as percent and square mile change per year, was used to determine which classes had the most change from 2001-2016, is shown below in Figure 6. The loss of classes included in UGS might suggest a high vulnerability to urban sprawl.

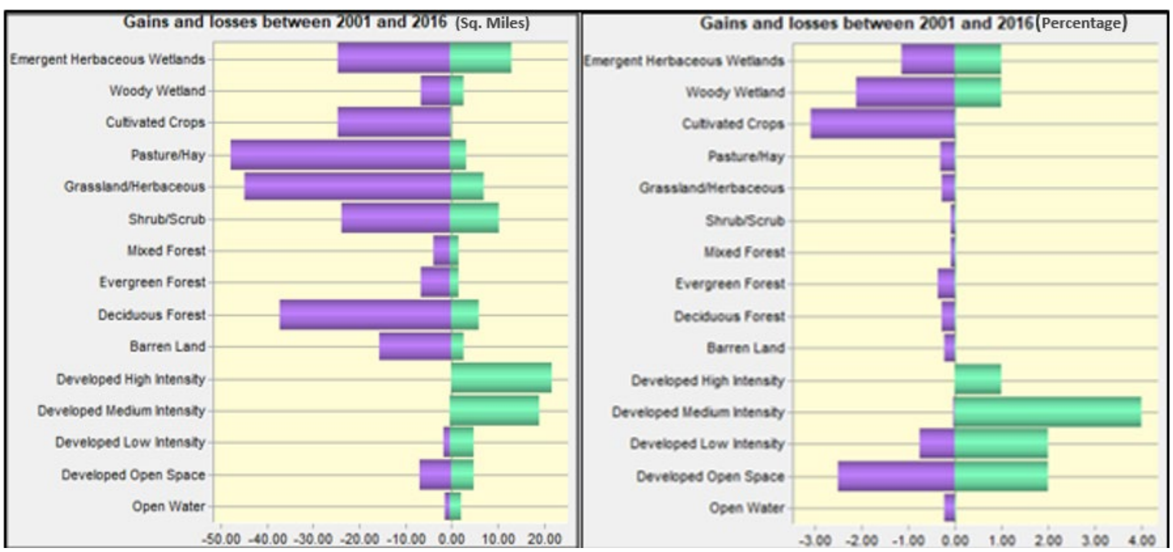

Figure 6. Square miles (left) and the percentage (right) of the total gains and losses of land use by class from the 2016-NLCD dataset using the TerrSet software suite.

UGS Accessibility

Common techniques used to study accessibility include Euclidean and network analysis. Most cities measure access to city utilities using Euclidean buffers, which is a point to point approach. In contrast, network analysis provides a more realistic representation of the amount of time needed to move from one location to another using lines of transit. The buffer areas measuring accessibility to UGS were 400 meters, the NRPA recommended distance of 800 meters, and 1000 meters based on the findings of Browning and Lee (2017). The address points within the different buffer distances were extracted to determine the number of residents and their access to UGS by census tract. There is no official standard or recommended catchment area associated with city parks. Thiessen polygons were created to define city park service area, or catchment area, to determine the city parks that serve most of the VA Beach population by systematically partitioning the geographical region. Centroids were created for each existing UGS location, and the create Thiessen polygons tool was used on the generated centroids. The UGS and demographic layers were merged and used to determine the amount of population, UGS, and density estimates per catchment area and census tract.

Euclidean Buffers. Euclidean buffers of 400, 800, and 1000-meters were created using the Buffer tool, shown below in Figure 7. The Address point data and Euclidean buffer data were spatially joined to summarize the number of address points within the respective distance to city green space.

Figure 7. Euclidean buffers of 400, 800, and 1000-meters buffers around city park features in VA Beach.

Network Buffers. Network buffers of 400, 800, and 1000-meters were using the *Network Analyst* extension in ArcGIS Pro. Random points were created using the Create Random Points tool for each official green space; polygons from the city data file were used to generate the point data. The Service Area tool was used to determined accessible areas at 400, 800, and 1000-meters, show below in Figure 8. A spatial select used to identify the address data points within the specified distance of each UGS.

Figure 8. Network buffers of 400, 800, and 1000-meter buffers around city park features in VA Beach.

UGS Distribution and Socioeconomic Correlations

Regression models were developed using tools in ArcGIS Pro to test the relationships between residential/population density and percentage of UGS. The land use data with city green space data, and the census demographic data were combined into a single layer. Demographic features, including population changes, income-level, housing costs, age, and ethnicity, were extracted by census boundary for analysis. The "before" (2001) and "after" (2016) land use data and demographic data were then analyzed to determine patterns of disproportionate spatial equity of UGS. Using the Zonal Statistics tool, the distribution of land use was calculated per census tract.

Results

Population and Land Use Change

The urbanization of VA Beach and population growth (Average annual population growth is 3.99%) is increasing, while available urban green space is decreasing (Average annual decrease of green space is -3.4%), as shown below in Table 6.

Table 6.

City of Virginia Beach – Green Space Change (NLCD)

	2000	*2010*	*2018*	*2020*
Total Population	420,735	433,265	445,249	460,610
Total Land Area (sq. mi.)	165.32	165.32	165.32	165.32
Total Area UGS (sq. mi.)	66.59	42.45	31.67	29.65
UGS Density (sq. mi.)	.40	.25	.19	.14
Approximate UGS per person (sq. meters)	409	254	184	167
UGS Change	-	-36.25%	-25.4%	-6.37%

Based on information collected on the trend of the relationship between population growth and changes in population density, it is possible to predict the future change of UGS in VA Beach. To do so, we can use the time series data on changes in the size of land under urban green space and the data on population and population change to carry out regression and determine the quantitative relationship between the area under UGS and the population and land size. Assuming a linear relationship between the area under UGS and the population and land size, the equation $Y = b + cX$, where Y = Urban green space area and X = population of the people in VA Beach. The following are the regression results for the data.

Table 7

Regression results of the change of UGS in VA Beach.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.90721482							
R Square	0.82303874							
Adjusted R Square	0.7345581							
Standard Error	8.73688107							
Observations	4							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	710.0434185	710.0434	9.301908	0.092785177			
Residual	2	152.6661815	76.33309					
Total	3	862.7096						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	440.32658	130.4827291	3.374597	0.077714	-121.0952903	1001.748	-121.095	1001.748
X Variable 1	-0.000904	0.000296409	-3.0499	0.092785	-0.002179365	0.000371	-0.00218	0.000371

From the above regression results in Table 7, the linear regression equation can be rewritten as:

$$Y = 440.32 - 0.823X$$

This means that after every two years, the UGS in Virginia is reduced by 440.32 square miles regardless of whether there is a change in population or not. Moreover, for every unit change in population in the area, there is a 0.823 square miles reduction in urban green space. The line graph below shows the trend in how the urban green area changes with changes in population density.

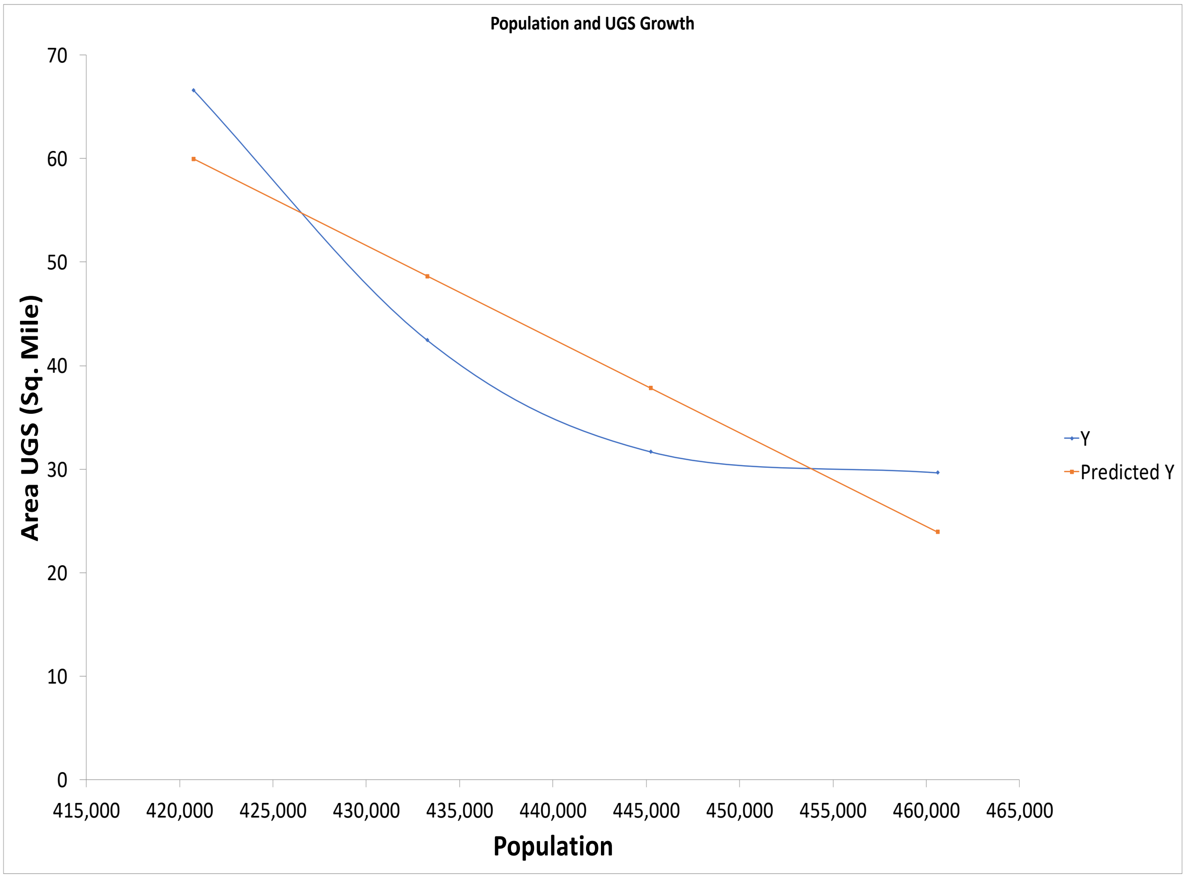

Figure 9. VA Beach UGS changes with changes in population density.

By substituting the population on the equation, Y = 440.32 - 0.823X, one can easily forecast the UGS in VA Beach in the future years. The amount of urban sprawl and population has increased, while the UGS of VA Beach has steadily declined from 2000 to 2018. Measuring land use data, current city UGS, and population change the negative correlation between population growth, and UGS is apparent (Figure 9).

UGS Accessibility

As expected, the network and Euclidean buffer analysis of UGS access present stark differences in their results. The results of the 800-meter (acceptable distance) Euclidean buffer analysis, seen in Figure 10, state that 92% of residents have accessible green space. The network buffer analysis of UGS accessibility, seen in Figure 11, concludes that only 63% of residents are within 800-meters of UGS. The results of these two measurements suggest that when using a more realistic approach to park accessibility, 75,396 citizens in Virginia Beach have limited access to UGS.

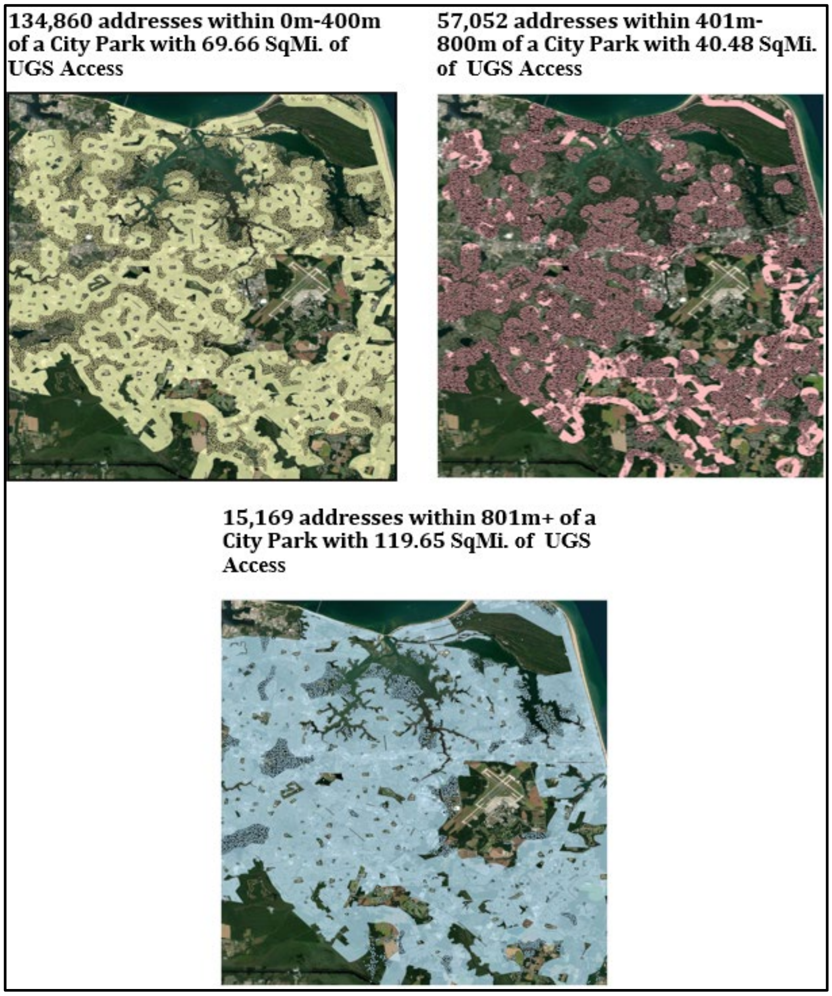

Figure 10. Euclidean buffer analysis illustrating the number of address points and their UGS access in Virginia Beach, VA.

Figure 11. Network buffer analysis illustrating the number of address points and their UGS access in Virginia Beach, VA.

UGS Distribution Equity

While the resulting data does indicate that a considerable amount of minority populations have limited access to UGS in Virginia Beach, as shown in Figure 12 below. With the analysis results from the currently available information, there is no conclusive evidence of unequal UGS distribution based on a single variable alone. Conflicting findings compared to the previous research are likely to be a result of the type of UGS included in the study, and the methodologies applied. For example, in our assessment of UGS accessibility, the results would likely have differed if the analyses included privately owned UGS. However, the analysis was deliberately focused on publicly available UGS to assesses only the accessibility to all residents. Publicly available urban green infrastructure offers the opportunity to provide needs-based provision to more deprived residents, who will disproportionately benefit from it (Apparicio et al., 2012).

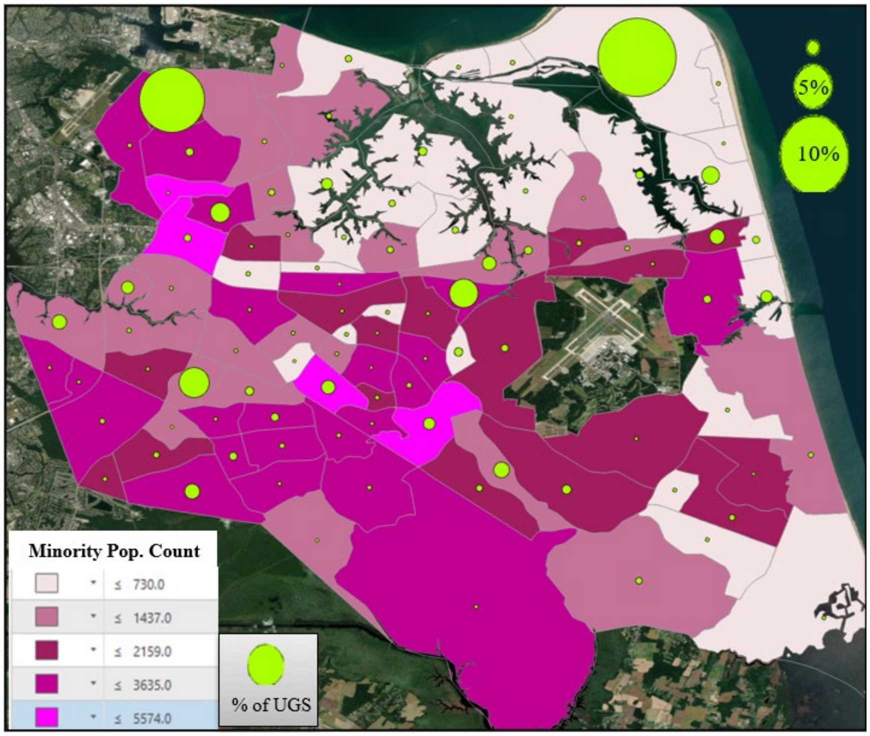

Figure 12. Visual representation of the census tracts with a majority-minority population and the percent of UGS of the associated census tract.

Against the background of the potential health effects of public green space, unequal socioeconomic distribution of UGS can amplify health inequalities within cities. Show in Figure 13 is the distribution of variable importance for several of the demographic variables used in the analysis. The data suggests the median household income has a higher relation to the distribution of UGS than the ethno-racial variables.

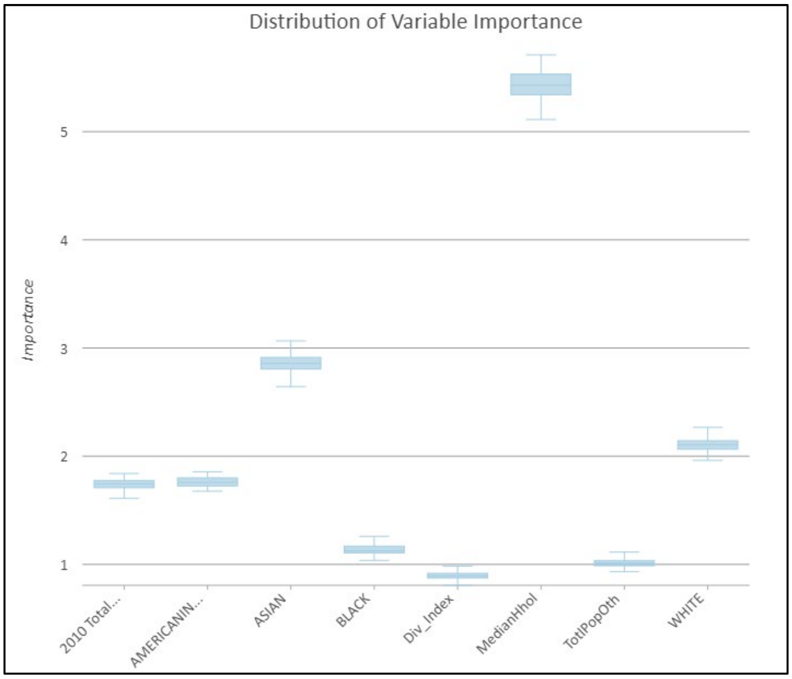

Figure 13. The distribution of importance for the variables of analysis.

Recommendation of Optimal Locations for UGS Growth and Expansion

Optimal UGS placement locations were identified using the results of the previous calculations and ESRI's *Location-Allocation* tool to determine locations to provide the most significant number of disadvantaged resident's adequate access to UGS. The *Location-Allocation* tool was used to determine the areas that would serve the most substantial portion of the population in need of UGS. The *Facilities* are the top five locations in need of UGS (determined using the results of previous analysis). The *Demand Points* were derived from the centroids of the Thiessen Polygons with the spatially joined count of address points that are 800 meters or more from the city green space layer.

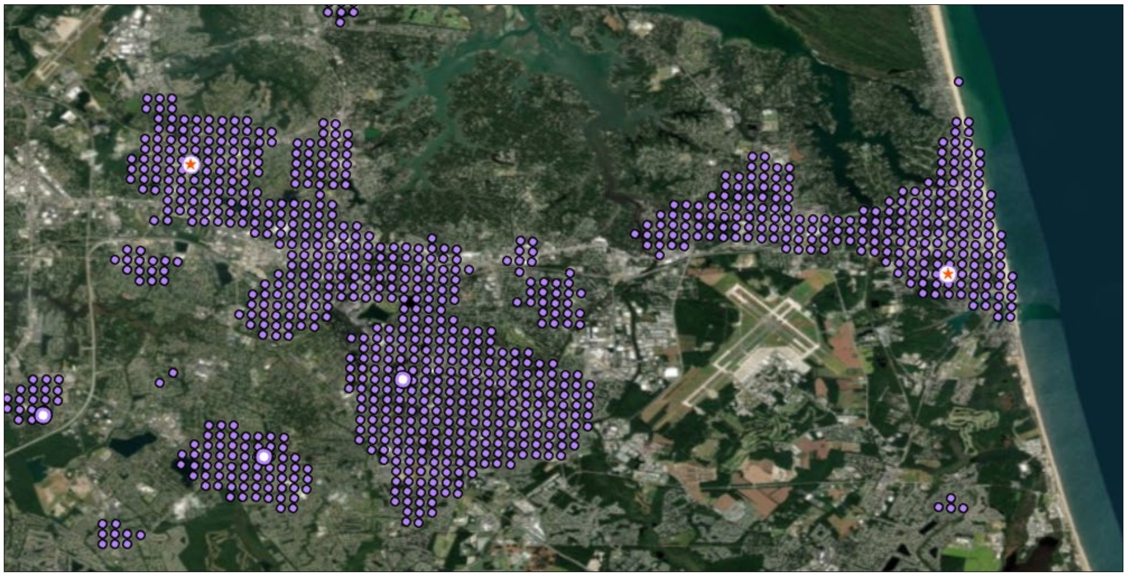

Figure 14. Optimal UGS locations determined using the *Location-Allocation* tool.

Limitations, Future Work, and Conclusion

There were various limitations noted in this study that must be mentioned. The study concentrated on the overall public green space availability offered by the city and did not include private green space in the analysis. Additionally, there was no data available on the quality and characteristics of public UGS, which differ by communities, and have a substantial influence on their usefulness to the local public (Harnik & Simms, 2004).

Optimal location selection for green space needs to account for physical proximity and local community needs when planning for future UGS development. The analysis of UGS could be improved upon with the addition of community surveys. Incorporating crowdsourced activity data can show the use of parks and supplemental travel data to improve park catchment areas. This data is seldom available for large areas, although the advances in smartphone GPS tracking show promise in this area. Crowdsourced information is applicable for analyzing of UGS use, which would record which parks individuals experience or travel nearby regularly in their daily travel to provide better insight to park use and minimize assumptions. As noted above, the spatial distribution of green space tends to be linked more towards economic status rather than race or nationality. An analysis of Hedonic pricing trends of real estate would add another layer of pattern analysis to determine the impact of UGS distribution.

Conclusion

There is still much to study to fully understand and quantify how varying forms and characteristics of UGS affect the accessibility of residents, especially by their socioeconomic and ethno-racial groups. A significant effort on the national scale would be required to understand UGS equity issues, requiring a reliable multi-indicator approach with supplemental information with higher quality information than what is available through census data. Understanding the data behind the spatial distribution of UGS is crucial to providing equitable access to UGS. Understanding these distributions can help policymakers to avoid counterproductive processes such as gentrification or ineffective placement of park facilities. However, doing so remains a challenging task for such a multidimensional issue.

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