Where Are Green Spaces Accessible? Exploring Green Open Spaces Access via Non-Motorized Transport and Analyzing Street Networks Around Green Spaces

Abstract

Inequality in green space and park distribution in Los Angeles is described in the academic literature and observed daily by its citizens. A green space network can support mental and physical health, mitigate climate change, and make the urban environment resilient to high-temperature periods. Better distribution of and access to green and natural areas can promote a more sustainable and equitable built environment. Green spaces and parks integrated into walking and bicycling networks pathways may play a vital role in maintaining public health and well-being. This paper explores the physical and social characteristics of green space clustering in Los Angeles. It asks: what are the characteristics of an urban street network that provides high access to green public spaces? What green open space patterns are most accessible by walking and bicycling? What policies and urban design approaches can expand the green spaces network? Based on open science principles, we use open data sources such as OpenStreetMap (OSM) and operationalize network, spatial, and clustering analyses. The descriptive statistics show that an increase in green space per capita does not necessarily contribute to green space accessibility. The street network analysis reveals that the density of walking and bicycling network are strongly related. However, green spaces tend to locate outside the highest-centrality parts of the case study neighborhoods, thereby underutilizing the street network for green space and parks access. In particular, low-income and historically disadvantaged communities are more isolated from green spaces and parks. However, large green spaces in high-income neighborhoods correlate with low walking and bicycling access. Policies addressing green space distribution and micro-mobility infrastructure should consider co-benefits of green space accessibility, green transportation infrastructure, and environmental equity.

Keywords: *green space, bicycling, walk accessibility, street networks*

Introduction

Green open spaces are essential for urbanized areas due to their positive effects on health, air quality, and well-being. People with everyday access to more green spaces are more likely to spend less on direct healthcare (Van Den Eeden et al., 2022). Green spaces can reduce crime risks (Ogletree, Larson, Powell, White, & Brownlee, 2022) and improve air quality (Diener & Mudu, 2021). Although according to the L.A. County Parks and Recreation Needs Assessment Plus, Los Angeles County has 38% (11.4% without Natural-Based Recreation Areas) green space, the accessibility and distribution of these green spaces are unequal because of the historical structural inequality in urban planning and design that prevented park construction in specific communities and in the inner city. Due to its car-oriented planning, Los Angeles County's green space allotment was neglected in the region's urban design and planning goals. For instance, according to the Los Angeles Recreation and Parks Department, in the City of Los Angeles, 15,000 acres of land is allocated to parks (Urban Forest, 2016) which is only 4.7% of the entire city area. Whereas there are at least 3.3 acres of parks for every thousand County residents (Final Report – Park Needs Assessment Plus, 2022), seven communities have neither parks nor walkable access to public green spaces.

This study identifies characteristics of neighborhoods that possess high accessibility to parks and green spaces (PGS) within Los Angeles County urbanized areas. Which street network patterns provide high walkable and bicycling accessibility to green spaces? What policies and urban design solutions might facilitate the expansion of the network of green spaces? The structure of the urban environment and the street network can significantly impact the feasibility of walking or cycling to PGS for routine utilization. Simultaneously, spatial characteristics may constrain the equitable distribution of PGS in urban settings. Socioeconomic factors can exert influence over access to PGS.

This analysis of the parks in urbanized Los Angeles County communities highlights limited correlations between economic and demographic characteristics of communities and both park acres density and walkable accessibility of PGS. Furthermore, higher park acres density does not necessarily correspond with high walkable access to PGS. The study of walking and bicycling infrastructure through the street network analysis of six case study neighborhoods suggests densely populated areas may have increased park accessibility but lower PGS density determined as acreage per thousand persons. The clustering analysis of neighborhoods based on economic, demographics, and PGS characteristics reveals groupings that can be utilized to further study walkability patterns in different urban neighborhoods and expand of best practices for comparable communities. The research offers an empirical perspective to facilitate policymakers and planners in sustainable urban development, cross-optimization of green space distribution and walking and cycling infrastructure.

Background

Green Public Spaces in Los Angeles

There is a broad literature on green open spaces and their uneven distribution across communities in Los Angeles County. The historical scope of literature discusses the relations to public space in the U.S. and Los Angeles (Hayden, 1995; Ehrenfeucht & Loukaitou-Sideris, 2007). At the same time, the research regarding green public space across Los Angeles acknowledges the disparities in the allocation of parks and public spaces influencing socioeconomic and health conditions (Jiang & Yang, 2022). Douglas, Archer, & Alexander (2019) and (Kim, Cho, Wen, & Choi (2023) examine associations between asthma and public parks and open space in Los Angeles. These studies found that green recreational space contributes to respiratory disease healing. However, the vulnerable communities around highways benefit less from the open green spaces. Another set of literature speculates the importance of PGS for pedestrians and safety. Sun et al. (2021) highlight that it is essential to consider PGS from the pedestrians' perspective. Groenewegen, Berg, Vries, & Verheij (2006) analyze the effects of nature on feelings of safety; and walking behavior (Lu, Sarkar, & Xiao, 2018). High urban density might threaten to green spaces' insufficient spreading (Haaland & van den Bosh, 2015). Finding distinct spaces for expanding the PGS network is a challenge in Los Angeles County, pressured by urban design codes and regulations.

There are many European cities' case studies on green spaces in the compact, sustainable city model and street walkability (Bay & Lehmann, 2017). Clarke (2003) and Fenton (2003) observes continuous improvements in bicycling and walking condition in the U.S. The literature and research are mostly narrowed down to inequality, public health, and safety but do not highlight the feasible solutions or best case studies, particularly in the County of Los Angeles. The green open spaces studies are not linked to walking and cycling accessibility of green spaces. The current research is supposed to explore relationships between street patterns and PGS distribution to examine the accessibility of green spaces. Most green public spaces are within a car distance from vulnerable communities (Nesbitt, Meitner, Girling, Sheppard, & Lu, 2019). However, only 8.6% of occupied housing units have no vehicle available in Los Angeles County (ACS 5-year estimates data). Nevertheless, regularly visiting green spaces can alleviate stress and enhance well-being (Sung-Kwon, Sang-Woo, Hyun-Kil, & Yoo, 2019; Rogerson, et al., 2020).

Street Network and Access to Green Open Spaces

Effective use of green spaces ties to its routine utilization that rely on access to those spaces. The dense green network and PGS spreading can increase walking and cycling access. The literature about green spaces in Los Angeles tightens to describing the uneven distribution of public spaces and low access to them. Some research on walking activity and the configuration of green spaces in Greater London reveals that areas with smaller parks but high distribution have higher walking activity than areas with huge parks (Zhang, et al., 2020). The study on parks in Fuzhou City in China argues that higher street integration of streets leads to higher accessibility to parks in the context of overall unequal park distribution (Huang, Chiou, & Li, 2020). However, there is a lack of research providing a decent description of access to PGS from the urban structure of the cities in Los Angeles County

Methods

What characteristics do urban neighborhoods have with high green spaces density, and walking and cycling access to parks? Walking and cycling networks' density impact access to green spaces but the access may differ depending on the size and count of parks. The study aims to analyze the characteristics of different distribution patterns of parks and green open spaces in Los Angeles County neighborhoods. The study excludes natural areas, national forests, and regional parks as the research goal is to investigate green spaces in urbanized neighborhoods and explore the utilization capacity of PGS in populated areas.

Figure 1 visualizes all existing parks and green spaces and reveals the need for green space integration, connectivity, and accessibility. It suggests that parks are unevenly distributed, with high-income white communities having greater access to parks than low-income non-white communities. The high density of street networks and small-scale parks enhance walking and cycling accessibility to green spaces. However, the high density of green spaces might provide an illusion of living in a green area; large-scale parks tend to be located further from dense urban areas, making them less accessible for walking and cycling mobility. Therefore, high density or percentage of land dedicated to parks are insufficient parameters for investigating of PGS utilization and efficiency.

Data

The research utilizes open-source spatial data extracted from the GIS Hub and OpenStreetMap sources. Each community's parks and green spaces data was obtained from the County of Los Angeles Enterprise GIS of L.A. County Park Needs Assessment – Demographics (PNA). In 2016, the Los Angeles County Department of Parks and Recreation conducted the Park Needs Assessment (PNA) of the county parks and green spaces. The used data set combines the PNA data about parks and green spaces (PGS), demographics data from 2020, health indicators from CalEnviroScreen of 2018, and sport and recreation trends. Due to the research goal to examine park distribution in urbanized areas, the data subset was created. The subset excludes nine communities (the highest park acres per thousand persons) identified as outliers by park acres density due to location near huge park areas but with low populated.

Park acres density account for acres of parks and green spaces per thousand persons in the community; the variable excludes regional open spaces, nature preserves, and State and National Forest land. Walking and cycling accessibility are comprehensive features that different methods can examine. In this research, the walkable accessibility variable is defined by PNA as the percentage of the population living within a half-mile walkable distance of a park. Median household income is identified as the average thousand dollars annual income in the community. Variables of the percentage of race include Hispanic or Latino, White, Black, and Asian. Other race/ethnicity variables were excluded due to the low proportion across the entire study area.

The data for street network analysis was obtained through the OSMnx package that sourced data from the OSM. The parameters of interest are street density per square kilometer and intersection density per square kilometer for walking and cycling street networks. The average access to the number of parks was calculated through the OSMnx for walking accessibility. Park count density was evaluated as the number of parks per square kilometer in a community.

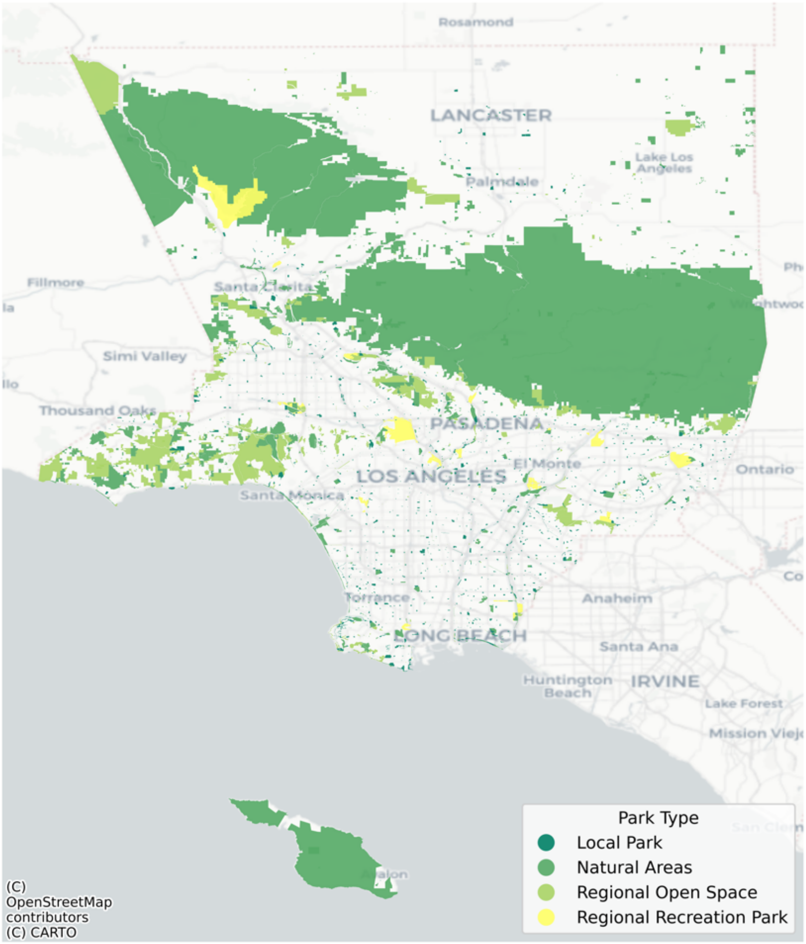

Figure 1. Los Angeles County's existing park and green spaces network/infrastructure.

Analysis

First, to observe the composition of PGS distribution at the Los Angeles County level, we calculated descriptive statistics of variables of interest of the PNA subset. We calculated their correlation coefficients to study the relationship between park acres density and population density. The linear regressions of walkable accessibility on median household income and park acres density were conducted. Then, the correlation coefficient of variables of interest was observed to characterize the walkable accessibility correlation coefficient on socioeconomic variables.

Second, to measure potential walking and cycling patterns in the vicinity of community parks, the street network analysis for each mobility mode was conducted for the six chosen neighborhoods. We chose six communities (Koreatown, L.A. Central City, San Pedro – Port of Los Angeles, Culver City, Hollywood North, and Hollywood South) with various spatial and socioeconomic characteristics comprising population density, park acres density, and walkable access. Then, we conducted the street network analysis to explore street density and walking and cycling access to PGS, counting the number of accessible parks in each node and park count density. The practical application of the street network analysis is to provide recommendations for future PGS locations that facilitate high utilization. In addition, the network analysis highlights the impact of the street network on access to PGS that may entail improvements of street design and cycling infrastructure that purpose to intensify walking and cycling activity.

Third, we conducted hierarchical clustering to identify the natural grouping of initial urban communities included in the study. Walking access was modeled as the outcome variable. The park area, park acres density, population density, median household income, and race percentages were taken as the scaled input features variables in four dimensionalities of principal components. The method pursues to impact future practical implications of sharing best practices inside the clustered communities.

Results

Descriptive Statistics and Regressions

The descriptive statistics summarized in Table 1 reveal the distribution of green spaces based on the acre area of PGS available for a community's population. The average and median park acres density is 3.49 and 1.37, respectively. However, the maximum park acres density is 44.41, and the minimum is 0.0, indicating the presence of outliers even after considering only urban communities. The correlation coefficient between park acres density and population density is -0.28, and the p-value is 0.00. Figure 2 visualizes the negative correlation of these variables. Meanwhile, walkable access is normally distributed. The mean and median values are 47% and 46%.

The correlation coefficients between median household income and race with walkable access are small. Walkable access is lower correlated with median household income -0.178 (p-value=0.017). Race valuables point low correlations between -0.168 and 0.142. Park acres density correlation coefficient with walkable access is 0.008, and the p-value is 0.921. Figure 3 shows regression plots of walkable access and median household income, and park acres density.

Table 1. Descriptive statistics of all variables of urban communities

Variable	Mean	SD	Min	Max	Median
Park land (acres)	182.12	409.27	0.0	4322.68	70.95
Park acres density (acres per 1000)	3.49	6.59	0.0	44.41	1.37
Walkable access (% population in ½ mi)	47.0	24.04	0.0	100.0	46.02
Population density (per acre)	13.35	10.02	0.02	60.43	12.04
Median household income (000)	82.56	36.63	33.36	200.0	76.26
Hispanic or Latino population (%)	45.2	28.08	5.22	97.77	39.21
White population (%)	29.7	24.9	0.57	84.12	24.62
Black population (%)	6.92	10.93	0.15	77.74	3.21
Asian population (%)	15.11	15.45	0.15	67.86	10.52

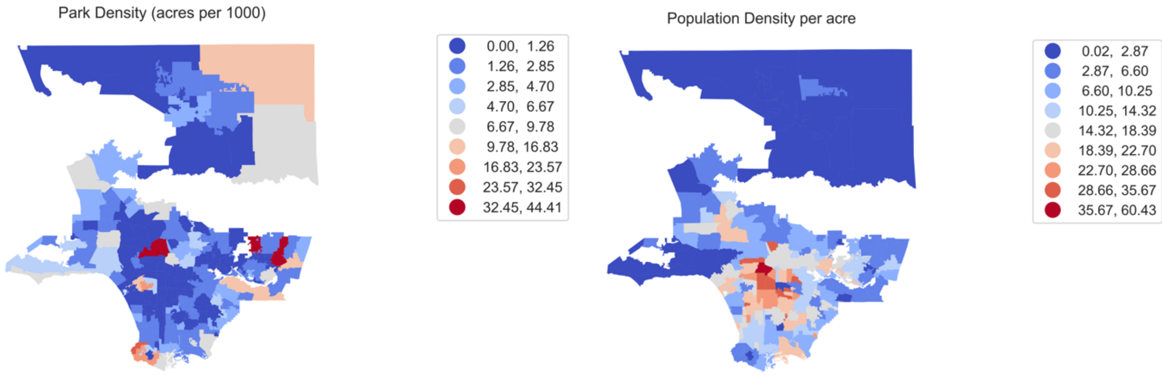

Figure 2. Park acres density and population density visualizations of urban communities

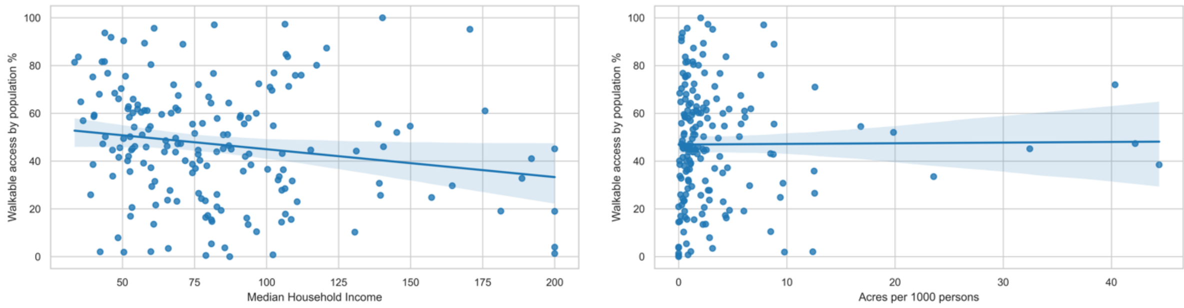

Figure 3. Regression plots of walkable access and median household income and walkable access and park acres density

Street Network Analysis

The street network analysis presents six case study communities with various spatial, social, economic, and park features. Table 2 shows values of PNA data of these communities and variables of interest extracted from OSMnx street network analysis. Figure 4 visualizes nodes' proximity to parks in the fifteen minutes threshold of walking and cycling networks.

The park acres density is the lowest in Koreatown and Downtown. However, the latter has the highest walkable accessibility of 91.83% and a park count density of 5.86 parks per square kilometer. The average number of parks within fifteen minutes of walking distance is 2.7 and 2.1 in Downtown and Koreatown, which is the highest value among case studies. The Hollywood – North has the highest park acres density (42.19) and the lowest park count density (0.52), with walkable access for 47.33% of the population. However, the Hollywood – South has higher walkable access (70.39%) and the average number of parks within walking distance (1.8), and park count density (1.53) by low park acres density of 0.26. San Pedro and Culver City have corresponding values of park acres density of 8.81 and 12.59, respectively. Walkable access is higher than 70%, and the average park number within walkable distance of 1.7 and 1.8.

The street networks composition the highest walk street density of 31,873 and bike street density of 19,867 are in Downtown, followed by Culver City with a walk street density of 29,220 and bike street density of 22,318. The lowest street density is observed in San Pedro and Hollywood – North communities.

Hierarchical Clustering Analysis

Figure 5 shows hierarchical clustering analyses of walkable access outcomes based on park area, park acres density, population density, median household income, and race in four principal components and cutting the dendrogram at six clusters. Hollywood – North stands alone; Koreatown, Hollywood – South, and Downtown correspond to one cluster, and San Pedro and Culver City are in one group. The six clusters groups community counts: 3; 1; 84; 63; 21; 7.

Table 2. Six case study areas analyzed characteristics

Variable	**Koreatown**	**Downtown (Los Angeles Central City)**	**San Pedro – Port of Los Angeles**	**Culver City**	**Hollywood – North**	**Hollywood – South**
Park acres density (acres per 1000)	0.11	0.26	8.81	12.59	42.19	0.26
Walkable access (% population in ½ mi)	38.57	91.83	88.96	71.0	47.33	70.39
Population density (per acre)	57.44	25.33	9.89	12.04	7.99	32.84
Median household income (000)	39.759	45.987	70.935	101.186	70.164	49.524
Hispanic or Latino population (%)	52.66	29.1	49.16	25.22	18.99	47.72
White population (%)	5.6	22.42	35.29	43.62	61.65	33.93
Black population (%)	3.79	18.27	5.65	8.78	4.43	3.36
Asian population (%)	36.31	26.32	5.76	16.58	10.56	12.19
Walk street density (length per sq. km.)	25,057.91	31,873.00	12927.19	29,220.03	12,941.12	23,916.02
Bike street density (length per sq. km.)	18,931.44	19,867.31	12,010.38	22,318.31	10,125.33	19,800.06
Walk intersection density (count per sq. km.)	249.59	382.74	98.21	355.21	76.09	224.60
Bike intersection density (count per sq. km.)	153.38	154.2	89.54	204.99	57.03	169.66
Average access to parks within 15 min. walk (count)	2.1	2.7	1.7	1.8	1.0	1.8
Park count density (park count per sq. km.)	1.49	5.86	1.39	2.65	0.52	1.53

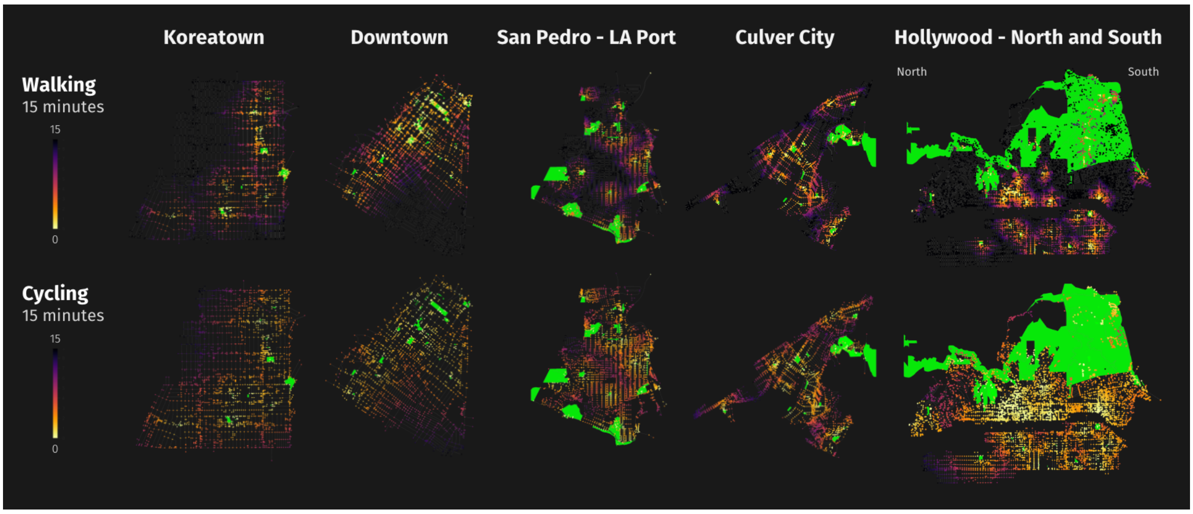

Figure 4. Street network analysis of six case study areas

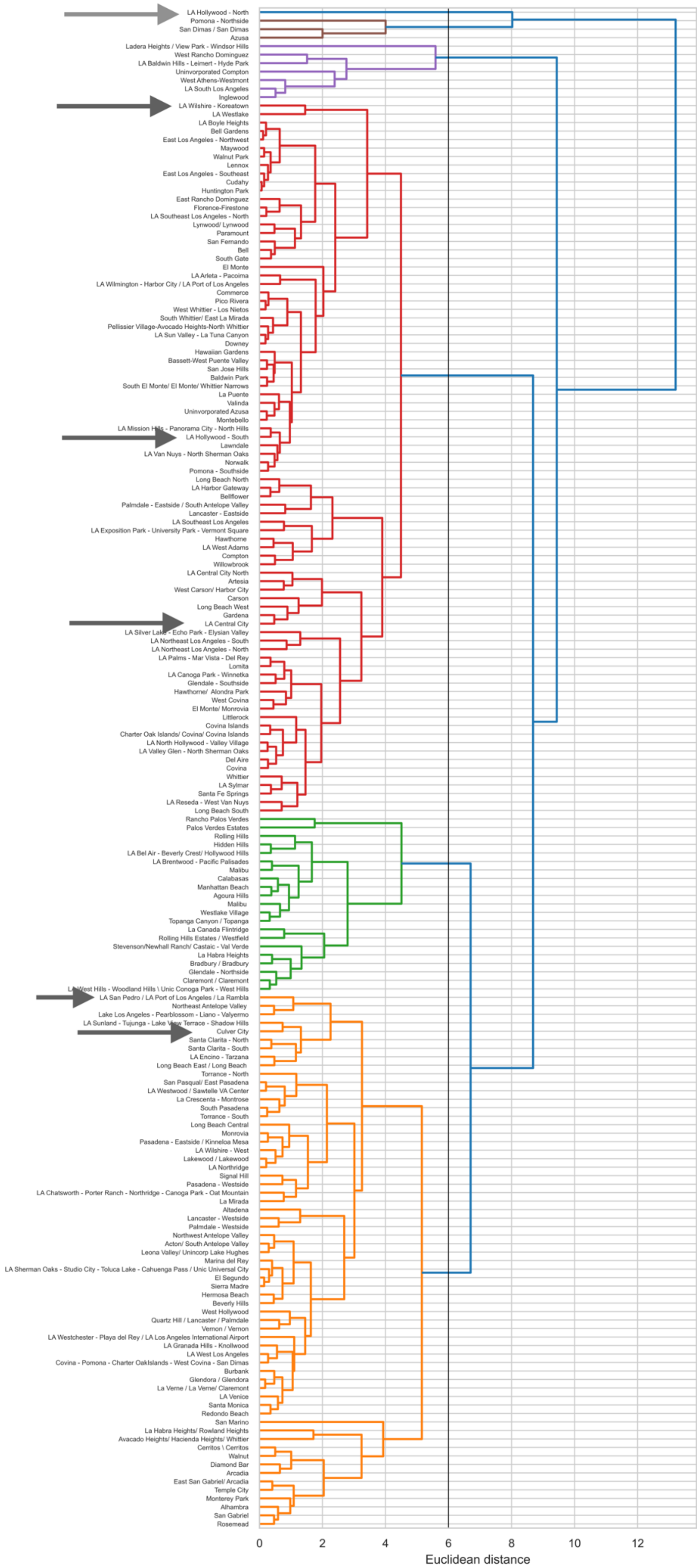

Figure 5. Dendrogram from clustering analysis

Discussion

Green spaces are a scarce but essential resource in cities making them a valuable community feature. The study examines the patterns of PGS distribution for walking and cycling access purposes. The walkable access to PGS is independent of the community income level. In addition, race characteristics may not significantly impact walkable access to parks. However, the study reveals that communities with higher street network density have access to more parks and a higher percentage of the population within walkable distance of a park. Thus, spatial characteristics of the urban environment impact PGS distribution regardless of socioeconomic parameters.

Inequality of green spaces distribution, to some extent, affects all communities regardless of socioeconomic characteristics, as the study shows a low correlation coefficient between walkable access to green spaces and median household income and race variables. Whereas the park count density of green spaces relies on the street network density, the park acres density blind the possible utilization of PGS. The cycling and walking street networks are related to each other. Culver City has distinct walkable access, park acres density due to high street density. This community is a prominent example of spatially equal distribution of parks. While possessing the low acres of park per person, Downtown has a high park count density and walkable access to them for most of its population. Therefore, planners can utilize this potential and improve PGS density increasing the number of parks per individual to achieve high accessibility and the desired minimum of 3.3 acres per thousand persons. The negative correlation coefficient of park acres density and population density is higher in the inner city like the City of Los Angeles (see Figure 2). Thus, researchers and planners should investigate such communities that lack parks in the places where they might have been most efficient.

Citizens should be able to utilize urban green spaces regularly and have equitable access to them regardless of vehicle ownership. As this research shows for six case study communities, the more sophisticated investigation of green space distribution provides planners with an understanding of access to PGS. The inter-topic research in urban planning, such as bicycling networks and green spaces, can highlight the co-benefits of different urban infrastructures and support the holistic approach of planning practice. Green streets can be a part of the PGS network and enhance green space distribution in dense urban areas (Rodriguez-Valencia & Ortiz-Ramirez, 2021; Stoia, Niţă, Popa, & Iojă, 2022). As walking and cycling street network patterns are strongly related and affect access to PGS, the strategic integration of bicycling infrastructure may increase cycling and walking access to PGS. Large-scale PGS tend to locate in the outskirts, decreasing walkable and cycling access to them. Therefore, planners and urban designers should expand the green space network while increasing small-scale park density. The Los Angeles County Department of Parks and Recreation may apply best practices from the same clustering communities identified in the hierarchical clustering analysis.

The study of the spatial characteristics of communities with limit by three factors. First, access to PGS might be defined differently and spatially weighted. Walkable accessibility can be defined as an index encompassing the number of parks in the walkable distance and park size. Further classification of green space patterns and adaptation of the green space index is needed. Second, study deliverables of the spatial distribution of parks and green spaces based on observation of six communities. The holistic research of the entire Los Angeles County is needed. Third, the cycling street network relies on bike pathways with protected and dedicated bike lanes rather than network extracted from OSM. That means the network characteristics reveal only potential bike street network density. Therefore, further research should examine actual walking and cycling pathways and include layer of existing and developing bicycling infrastructure.

Conclusion

The study contributes to observing parks and open green space distribution in the highly populated urban communities of Los Angeles County from the walking and cycling accessibility. Communities of Los Angeles County form a patchwork of various social, economic, and spatial compositions. Walking and cycling access to parks may depend on the spatial characteristics of urban communities, such as street networks. The study of accessibility and green space network can conceptualize patterns of urban design that provide regular access to parks and green space.

The methodology of descriptive PGS distribution analysis in conjunction with the street network highlights the possibility of reciprocal benefits for enhancing the effective use of green spaces in urban communities by advancing street quality and cycling infrastructure. The evidence points out that walkable access to PGS is controlled by street network density rather than the socioeconomic parameters of communities. However, clustering analysis reveals patterns of community grouping by social and economic characteristics with corresponding walkable access to parks measured in the percentage of the population living within a half-mile distance of a park. The analysis highlights that efficient planning of parks and green spaces in urban areas should be associated with analyzing accessibility and distribution. Therefore, the planning and design of green spaces encompassing walking and cycling infrastructure networks are more likely to optimize the regular access of PGS and increase the effective use of green spaces in the city.

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