# Analysis of Urban Green Space Accessibility of London based on Space Syntax, and its Associations with Spatial Inequity of Different Social Groups

by

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**Abstract**

Urban green spaces have an important impact on the daily lives of urban residents. Good access to urban green spaces helps to improve ecosystems, enhance people's health, and promote social interaction. However, the current research has reflected spatial inequities in access to urban green spaces, especially in cities with diverse populations such as London. This research explores how access to urban green spaces in London can constitute spatial inequities for different social groups. The study measures the access to urban green spaces in five boroughs in London, including Islington, the City of London, Camden, Hackney, and Haringey, considering the four aspects of proximity, availability, quality, and centrality. Then combine it with census data on different social groups of age, ethnicity, and deprivation to construct spatial regression models for Islington. Through these models, the access to urban green space by different social groups in Islington can be explored. Based on these findings, it is possible to figure out the main associations and manifestations of spatial inequities different social groups face in terms of urban green space access in London. It is found that there are spatial inequities in urban green space access for different social groups, with inequities encountered by different social groups showing variations. The inequity among different age groups is reflected mainly in availability, ethnic groups mainly in proximity and centrality, and groups of different deprivation levels mainly in availability. The quantification of access to urban green space by different social groups can help planners design or improve a city more effectively and accurately according to the needs of different people and in different areas.

**Keywords**: Urban Green Space; Public Parks and Gardens; Access; Social Groups; Spatial Inequity

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# Chapter 1: Introduction

## 1.1. Research Background

Urban green spaces play a crucial role in urban residents' daily lives, distributing valuable ecosystem services and creating a spatial environment for social interaction. Extensive evidence demonstrates that living in an environment with easier access to more high-quality urban green spaces contributes to disease recovery and improves people's sense of well-being (Public Health England, 2020). Marginalised groups often face greater health issues due to socioeconomic disadvantages, while better access to urban green spaces can enable all social groups to have equal opportunities for health and social interaction in urban green spaces. This has a more obvious and substantial positive impact on the health and well-being of marginalised groups, which in turn enhances the living standard of the whole neighbourhood, promoting social equity and inclusiveness. With the development of society, people have begun to realise the significance of the equitable provision of urban green space. According to the European Environment Agency (EEA) (2022), all people should be within a 15-minute walk of urban green spaces (Stanners and Bourdeau, 1995). The Green Space Index (GSI) has been used by national and local governments, including Liverpool City Council and City of Edinburgh Council, to guide research and policy implementation about maintaining green spaces (Fields in Trust, 2020). It is developed to illustrate how local urban green spaces adequately serve the population, emphasising access within a 10-minute walk (Fields in Trust, 2020). More strictly, English Nature (2016) recommends that green space be ensured to people no more than 300m. In 2019, London was nominated as the world's first National Park City, and there are many strategies and policies proposed and complemented, such as Pocket Parks and the Big Green Fund, to improve urban green spaces in London, ensuring every people equitable access to green spaces (Mayor of London, 2023).

Over 6 million people in Great Britain are estimated to lack convenient walking access within a ten-minute radius from their homes to urban green spaces (Fields in Trust, 2023). Despite being recognised as a National Park city, London still needs to work on providing equitable access to urban green spaces. The GSI score for London falls below the minimum standard. Although numerous strategies and policies for green space enhancement are included in the London Plan, providing green spaces per person remains inadequate at 19 m2 per capita, leaving at least 150,000 people in London deprived of nearby green spaces (Fields in Trust, 2023). A report by Rambler (2020), an organisation interested in protecting spaces for walking, revealed significant inequity in access to urban green spaces in the UK, particularly among different ethnic and income groups, wherein certain groups enjoy relatively easier access while others face obstacles. Only half of the surveyed adults are within a five-minute walk of green spaces, and this figure diminishes further for people of Black, Asian or minority ethnic groups and those with lower income levels (Rambler, 2020). To improve the urban green spaces, it is crucial to ensure equitable access to green spaces for all social groups. Therefore, this research mainly focuses on Islington, a borough in London that has a relatively high population diversity, to investigate its urban green space access of different social groups, including age groups, ethnic groups, and groups with different deprivation levels.

However, achieving equitable access to urban green spaces is a multifaceted challenge that requires consideration of various factors, such as proximity, availability, quality, and centrality. To study the provision and access to urban green space, actual distance is used to represent the proximity, and the population served by the urban green space and the area of urban green space per capita to describe availability (Le Texier, Schiel, and Caruso, 2018). In addition, quality can reflect people's experience of using urban green space, which is also an important factor to consider when measuring the access to urban green spaces (Li, Huang, and Ma, 2021). Then centrality of urban green spaces is measured by the integration and choice value of the surrounding roads using space syntax to see their connectivity to the urban road network. By measuring access to urban green spaces to evaluate spatial equity, an equitable provision of facilities and services to people in space, the main associations between urban green space access and the spatial inequity of different social groups can be figured out. It consequently contributes to a more efficient urban green spaces improvement.

## 1.2. Research Aim and Research Questions

This research developed a space syntax-based approach using space syntax to evaluate the access to urban green spaces for assessing the access to urban green spaces in London and investigating the spatial equity issue of urban green spaces among different social groups. By analysing the access to urban green space alongside demographic and economic census data, this research explores the main associations of urban green space spatial inequity of different social groups. The research is structured around the following research questions:

<u>Main research questions:</u>

How does access to urban green space impact the spatial equity of different demographic/economic groups?

<u>Sub-research questions:</u>

1. How is the access to public parks and gardens in Islington for different demographic/economic groups?
    a. People of different age groups,
    b. People of different ethnic groups,
    c. People of different deprivation levels (represented by people with different number of deprivation dimensions).
2. What are the main associations of the spatial inequity of different demographic/economic groups in Islington?

## Chapter 2: Literature Review

This research explores the impact of accessibility to urban green spaces on the spatial equity experienced by various social groups. In this chapter, a comprehensive examination will be conducted to appraise the current body of research in three key areas: urban green spaces and the methods of access measurement, the concept of spatial equity, and the accessibility of urban green spaces for different social groups. Based on the above literature review, the research gap of the existing studies can be identified.

### 2.1. Spatial Equity

There is no agreed definition of spatial equity (Fasihi, and Parizadi, 2020). Generally, it is interpreted as an equitable provision of facilities and services to people in space (Tsou, Hung, and Chang, 2005). Spatial equity is closely linked to the degree of variation in the distribution of public resources within a spatial unit. The inequitable distribution of public resources is a key contributing factor to spatial inequity. Spatial equity does not simply refer to an even spatial distribution of all public resources. Still, it requires the equitable provision of services to all people and allocation based on the needs and preferences of people (Lucy, 1981). Consequently, spatial equity could be further divided into horizontal and vertical perspectives (Litman, 2002) (Table 1). The horizontal view of spatial equity aims to ensure an equitable distribution of goods and services among different demographic groups across a particular area. And vertical spatial equity falls into two sections, one section requires the resource distribution to correspond with the demand of different social groups and people with various income levels, and the other section is related to mobility needs and ability, prioritising disadvantaged social groups (Kelobonye, et al., 2019).

**Table 1**. Components of the spatial equity concept.

<table>
<tr><th colspan="3">Spatial equity</th></tr>
<tr><td>Horizontal</td><td colspan="2">The equitable distribution of goods and services, irrespective of people's location and socioeconomic status</td></tr>
<tr><td rowspan="2">Vertical</td><td rowspan="2">Equitable distribution of facilities over space in relation to the need or demand of people, reducing inequitable distribution of facilities by ensuring an unequal treatment with inequalities</td><td>Section one: correspond with the demand of different demographic groups and people with various income level</td></tr>
<tr><td>Section two: related to mobility need and ability, prioritising disadvantaged social groups such as children and elder people</td></tr>
</table>

Spatial equity is usually defined and assessed by accessibility, as varying levels of accessibility can help demonstrate the degree to which the spatial inequity has been achieved (Martens, Golub, and Robinson, 2012). In terms of horizontal spatial equity, it requires that accessibility of public facilities and services be equal for every person in a certain spatial unit. While from a vertical perspective, spatial accessibility should vary in accordance with the distinct needs and preferences of different social groups. When measuring spatial equity, it is crucial to consider not only spatial accessibility but also non-spatial factors of socioeconomic, demographic, and cultural features. These non-spatial factors provide insights into people's acceptability, affordability, and awareness to facilities and services, measuring spatial equity based on needs and demand, which helps achieve vertical spatial equity (Ashik, Mim, and Neema, 2020).

There has been increasing concern about spatial equity of urban green spaces. The unequal distribution has emerged as an environmental justice issue, giving rise to numerous problems regard with physical and mental health, such as cardiovascular diseases, type 2 diabetes, and depression (Wolch, Byrne, and Newell, 2014; World Health Organization, 2016). Initially, studies on the spatial equity of urban green spaces primarily focused on ensuring equal spatial distribution for all people, utilising metrics such as green space ratio, acreage, and per capita green space area for evaluation. With the improvement of geographic information system (GIS) technology, attention shifted to considering urban green spaces' distribution and sizes (Ma, 2020). However, these early approaches only addressed horizontal spatial equity, neglecting the quality of urban green spaces and their users. In recent years, increasing attention has been paid to the vertical aspect of spatial equity. The inequitable distribution of urban green spaces usually occurs among people of different socioeconomic or demographic backgrounds, usually characterised by income level, age, ethnicity, and so on (Wu and Kim, 2020). Therefore, the assessment of spatial equity in urban green spaces in this research integrates spatial and non-spatial factors, facilitating a comprehensive examination of the vertical perspective.

## 2.2. Urban Green Space and Measurement of Access to It

### Definition

Urban green space is considered an important component of "green infrastructure" (World Health Organization, 2017), which could provide public open spaces and services that benefit ecosystems and promote health and well-being for all people living in urban areas. It offers numerous ecosystem services to cities, including enhancing air quality, noise reduction, and effective rainwater management (Wolch et al., 2014). Urban green space is usually interpreted as all urban vegetation ranging from urban forest to other green spaces such as parks, green sports fields, natural vegetation, and street trees (Davies et al., 2008), which can be considered one of the urban green space definitions. However, many researches on access to urban green spaces, such as the work by Fasihi and Parizadi (2020) or Tannous, Major, and Furlan (2021), focus mainly on urban parks. According to Wu and Kim (2021), urban green space can also be defined as a park green space that offers recreational and leisure amenities to the public. This definition reflects the people-centred planning of urban green space. It emphasises its significant role in providing venues for diverse outdoor social activities to facilitate more social interaction (Taylor and Hochuli, 2017). Besides, as a form of public investment, park green spaces should strive to serve all urban residents equitably, with particular attention to children, older people, low-income people, and people from different ethnic backgrounds (Boone et al., 2009). So far, a consensus on the definition of urban green space has yet to be reached, and this research is closely related to the social dimension. Consequently, the latter definition of urban green space, focusing on the study of access to urban public parks and gardens categorised by the Ordnance Survey, is adopted for this research.

Measurement of Access to Urban Green Spaces

The definition of accessibility can be briefly summarized as the ease of accessing a destination from residential areas, determined by spatial distance, available modes of transportation, and associated time costs (Kelobonye, et al., 2019). Accessibility is a tool to determine the extent to which spatial equity has been achieved (Talen and Anselin, 1998). Hence, in research on urban parks' spatial equity, many methods have been developed to measure accessibility. Factors considered by different methods are distinct and can be categorised into three types: "container-based," "distance-based," and "gravity-based" (Zhang, Lu, and Holt, 2011) (Table 2). These three types correspond to proximity, availability, and the combination of proximity and availability for urban green space access in this research. Although the three types of methods all aim at measuring the accessibility of urban parks, the factors they assess reveal that they adopt different definitions of accessibility. Distance-based methods measure accessibility mainly by the proximity of urban parks to residential areas, for example, Talen’s minimum distance method (Talen and Anselin, 1998). While container-based methods and gravity-based methods, such as Talen’s container and coverage methods, focus more on the number and acreage of urban parks rather than using factors related to distance to evaluate accessibility, which seem more like a measurement of availability, reflecting population served by urban green space and urban green space available per capita.

**Table 2**. Different methods of measuring urban green space accessibility and their pros and cons.

| Method | Measurement objects | Pros | Cons |
|---|---|---|---|
| **Container-based** | number, acreage, and park access points within spatial units | Easy to access data | Consider mainly the supply and has the modifiable area unit problem |
| **Distance-based** | Service area, population within service area, and travel time | The utilization of widely adopted indicators enables convenient comparisons across different cities. | Consider mainly the demand, require higher level of QGIS analysis, and limited data access |
| **Gravity-based** | number of parks, the population within the spatial unit, and the distance between home and park entrances | Consider both demand and supply sides | Complex to analysis and limited data access |

*Availability*

Availability is the first level to demonstrate the provision of urban green spaces, reflecting the extent to which the urban green spaces are presented within a certain distance from home (Biernacka and Kronenberg, 2018). Based on the objects measured by the three types of methods of measuring urban green space accessibility, availability can be evaluated by the number of urban green spaces, service area, population within service area, total acreage, acreage per capita, and number of access points. In this research, availability is measured by two of the representative factors of these objects, including population within certain service areas and urban green space acreage per capita within certain service areas.

*Proximity*

Proximity in this research can be described as the actual distance to urban green spaces from home base on the road network. It implies the spatial distribution of urban green spaces in relative to population distribution, affecting the willingness of people to access urban green spaces. The measurement objects of the distance-based method to some extent help evaluate proximity, such as the service area and travel time. It assesses the accessibility of these spaces by considering the travel time required to reach them using various modes of transportation. To make the measure of proximity more direct, this research employs the shortest path distance from home to the nearest urban green space based on the road network to represent proximity.

*Quality*

There exists a limitation among these accessibility measurements that few of them consider urban park quality, while quality can be an important factor influencing accessibility (Schipperijn, Stigsdotter, Randrup, and Troelsen, 2010). Although there are many researches on urban park quality evaluation, using the Public Open Space Tool (POST) or developing it to a remote method (Taylor, et al., 2011), Systematic Pedestrian and Cycling Environmental Scan (SPACES) instrument (Pikora, et al., 2002), and so on, they rarely used as a part of accessibility measurement. POST is a tool that widely used in the research on the quality of urban green spaces, including on-site and remote modes. On-site POST requires a large amount of time and human resources to obtain more detailed and accurate information by in-person visiting and observing. Remote POST, on the other hand, eliminates the need for on-site visits and uses satellite imagery such as Google Earth to collect information about urban green spaces. In compared to the on-site mode, the remote POST saves time and human resources, but may fall short in terms of detailed and accurate information.

*Centrality*

Centrality is also a strong determinant of access to urban green spaces, demonstrating the location and connectivity of urban green space in the urban network. The pervasive centrality is a crucial concept of space syntax in terms of sustainable city (Hillier, Yang, and Turner, 2012). Hillier and Hanson (1984) propose the space syntax approach to explore the interrelationship between space and society. Unlike geographic accessibility measurements, the space syntax approach is rooted in network configuration and topology theory. It uses axial lines of the urban network and runs segment analysis to detect the relationship between local structures underlying the urban spatial pattern (Hillier, Yang, and Turner, 2012). According to the research conducted to evaluate the accessibility of urban parks using space syntax, it uses global and local integration and global choice to provide a very realistic urban functioning based on topological graph-based measurements (Tannous, Major, and Furlan, 2021). Integration is a measure of distance from any spatial element to all others in a built environment system, describing the extent of closeness between the initial space and all surrounding spaces (Hillier and Hanson, 1984). Choice is a through-movement measurement, it calculates the quantity of movements to pass through a road segment on all shortest paths connecting between all space elements within the built environment system (Hillier, Burdett, Peponis, and Penn, 1986). The normalise angular integration and choice (NAIN and NACH) can minimise the angular deviation from a straight line between origin and destination by excluding the total depth component from the calculation, resulting in a measure that mainly reflects pure choice, which is a better fit human's perception of distance (Hillier, Yang, and Turner, 2012). Therefore, in this research, it adopts the space syntax method to assess the centrality by NAIN and NACH value of the surrounding roads of urban green spaces. Through these, the likelihood of the place to be chosen as a destination and the degree to which to the surrounding roads to be used by people can be captured. Consequently, centrality to some extent implies whether the urban green spaces are located at a lively urban centre or a quiet area that is less urbanised. The specific measurement methodology will be further explained in the methodology section.

*Summary*

There are diverse methods for evaluating the accessibility of urban green spaces, but no single method can fully capture the complexities involved in assessing access to these spaces. When multiple indicators of different types of methods are employed, they can serve as a highly valuable tool for studying accessibility. Based on the various measurements and their limitations, to make the accessibility measurement more accurate, this research measures access to urban parks by considering four aspects: proximity, availability, quality, and centrality.

### 2.3. Access to Urban Green Space of Different Social Groups

Since the emergence of environmental justice, extensive evidence has documented the detrimental effects of spatial inequity suffered by ethnic minority people caused by the spatial inequity. Recent concerns about spatial equity have focused on the distribution of public facilities and services among different social groups, especially on the accessibility of parks (Rigolon, 2016). Spatial equity is an important topic in the research on urban green spaces, with increasing attention being paid to vertical social equity, which is regarded by different social groups (He, Wu, and Wang, 2020). According to relevant research in the United States and Europe, the inequity of access to urban green space for different social groups is present in many cities. It shows that people of lower socioeconomic class tend to live closer to low-quality environments (Mullin, Mitchell, Nawaz, and Waters, 2018). This pattern of spatial inequity has been observed in Germany and the Netherlands (European Environment Agency, 2022). However, this pattern of spatial inequities in urban green space between different social groups is not applied to each city, and the differences of urban green space accessibility among social groups are location-specific (European Environment Agency, 2022). Oslo, for instance, avoids these environmental and social equity issues with its comprehensive planning strategies and urban design, and there are no obvious differences in the distribution of urban green spaces among different social groups (Mouratidis, 2020).

Some literature that studies urban park accessibility from an ethnical perspective, particularly focusing on blacks, Latinos, and whites, has revealed a distinct pattern of spatial inequity that differs from income-based spatial inequity (Wolch, Byrne, and Newell, 2014; Rigolon, 2016). Regarding the spatial distribution of urban parks in the U.S., Black and Latino minorities sometimes live closer to parks than predominantly White communities (Wen et al., 2013; Johnson-Gaither, 2011). It could not reflect the degree to which the spatial equity of urban parks has been achieved among different ethnic groups. Spatial inequity also lies in the internal features of urban parks, such as size and quality, rather than their spatial distribution only. In many cities of the U.S., such as Baltimore and Los Angeles, although minority ethnic groups may have an advantage in spatial proximity to urban parks, the parks they have easier access to are usually fewer and smaller, resulting in increased overcrowding (Boone et al., 2009; Sister et al., 2010; Wolch et al., 2005). Research on the accessibility of green spaces in the UK also reflects marked differences between social groups. Over half of the people in Sheffield face inequitable access to green spaces, and these people tend to be those who may be considered most in need of green space, including people with low incomes, older people, and families with children (Barbosa et al., 2007). The urban green spaces in Leicester also reflect a considerable difference in distribution and pattern among social groups. The ethnic groups of 'white and black African' and 'other black' have less access to urban green spaces (Comber, Brunsdon, and Green, 2008).

There is a generic method to combine GIS-based network analyses with socioeconomic data to study different levels of access to urban green spaces of other social groups. Research focusing on investigating the accessibility of urban green areas for different ethnic and religious groups in Leicester, UK, proposed an approach that involves quantifying the size and spatial distribution of access to urban green spaces using GIS network analysis and census data to evaluate access patterns for various social groups (Comber, Brunsdon, and Green, 2008). It examines the urban area's street network and transportation infrastructure to assess urban green space accessibility. By considering factors such as road networks, public transportation routes, and pedestrian paths, travel distances and times from various locations within the city to urban green spaces can be calculated. To evaluate the accessibility of urban green spaces for each social group, it maps the demographic distribution across the city. It incorporates spatial analysis and overlays to measure the proximity of green spaces to residential areas predominantly inhabited by specific ethnic or religious groups. Another research in Shanghai investigates the urban green space accessibility and spatial equity of different social groups using a similar approach, mapping, and spatially clustering accessibility value of each census block (Xiao, Wang, Li, and Tang, 2017). However, the existing research methods do not pay much attention to people's preferred threshold distance for accessing urban parks. Yet, people rarely access parks that need a long travel journey (Xiao, Li, and Webster, 2016). In addition, these researches focus on figuring out the inequitable pattern of the spatial distribution of urban green spaces. Still, it is also important to understand the factors determining the spatial inequity of different social groups.

## 2.4. Research Gap

Despite the contributions made in measuring access to urban green spaces and their spatial equity, several research gaps still need further exploration. First, while various methods have been developed to measure accessibility, none of them capture spatial accessibility comprehensively. Most of the research focuses primarily on proximity and availability while often ignoring the quality of urban green spaces and people's preferred distance for access to urban green spaces. Moreover, although some recent research emphasises vertical spatial equity, there is still an insufficiency of a comprehensive understanding of the main associations and manifestations of spatial inequities of access to urban green space for different social groups. Moreover, few existing researches have investigated the associations between access to urban green spaces and different social groups in depth at a detailed borough scale, with most of the previous research studying all urban green spaces in a city. There is limited research on the urban green spaces in London boroughs. Therefore, this research focuses on analysing the borough of Islington in London.

## Chapter 3: Methodology

This chapter explains the methodology employed in this research to measure access to urban green spaces and investigate the main associations between it and spatial inequity of different social groups. To measure access to urban green spaces more accurately, it first evaluates proximity and availability on a larger scale across five boroughs, followed by the quality assessment of public parks and gardens in Islington. Subsequently, spatial regression models are established for Islington, exploring the correlations among these dependent variables and the independent variables of ethnicities, ages, and deprivation levels. The research employs the average distance of shortest paths to the nearest urban green spaces for proximity measurement, assesses availability via population and average acreage of urban green space per capita within the service area, and evaluates quality based on the average remote POST score and average integration and choice level of roads around urban green spaces. This analysis strives to reveal distinct main associations between access to urban green spaces and different social groups. The structure of the research methodology is demonstrated in Figure 1.

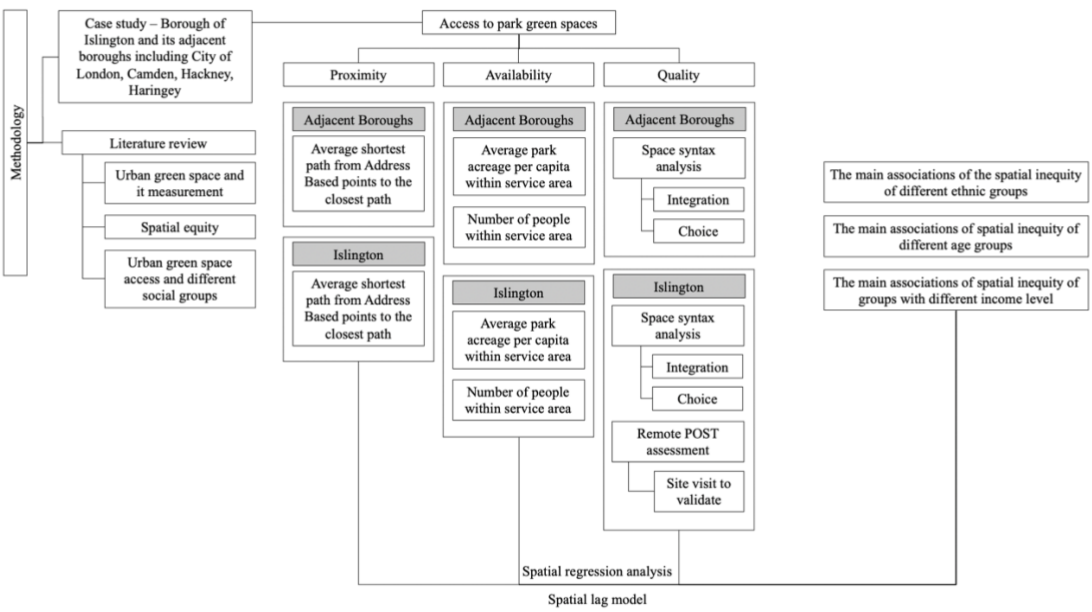


**Figure 1**. Structure of research methodology.

## 3.1. Site Selection

To study the access to urban green spaces of different social groups, this research selects five boroughs as its study sites, including Islington and its four adjacent boroughs of the City of London, Camden, Hackney, and Haringey (Figure 2). The Borough of Islington is a part of inner London, located in the north of London. It is the most densely populated and the third smallest borough in London, covering 15 km squared (Islington, 2021). One of Islington's strengths is its diverse population, consisting of people from various faiths, nationalities, and backgrounds. Less than half of the people in Islington are White British, while people of Black, Asian, and other ethnic groups comprise 32% in 2021 (Islington, 2021). Despite the diversity of Islington, it is also a place with an obvious gap between the rich and the poor compared with white children, children in Black, Asian, and other ethnic groups households in Islington are more likely to suffer deprivation (Office for National Statistics, 2020). In addition, urban green spaces account for merely 13% of the total area in Islington (Islington, 2019). Given certain groups' inherent disadvantages regarding living conditions and socioeconomic factors, it becomes vital for Islington, as a densely populated borough, to strive for more significant equity. To study the access to urban green space and its spatial equity of different social groups in Islington more accurately, this research also takes its four adjacent boroughs as the study sites to avoid issues such as the edge effect.

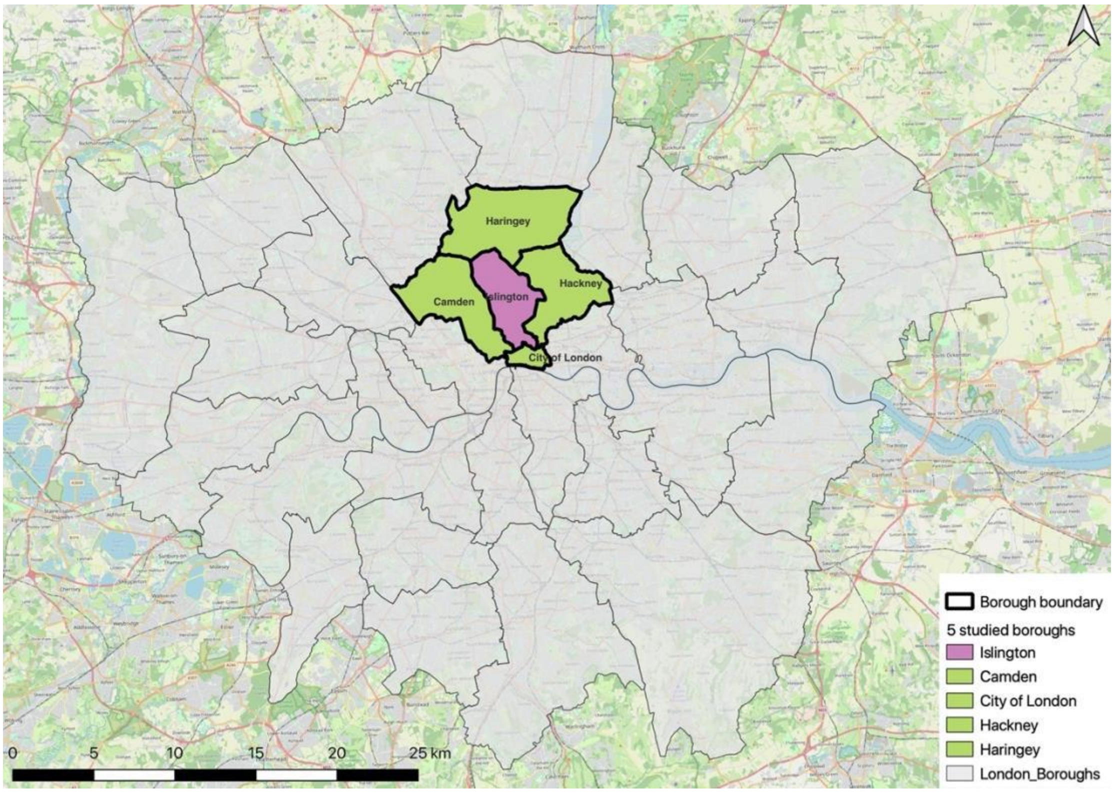


**Figure 2**. Location of the studied 5 boroughs with Islington in purple and its four adjacent boroughs in green.

## 3.2. Data Source and Data Selection

In this research, the urban green spaces to be analysed refer to all the public parks and gardens within the study sites defined by OS Open Greenspace data (2023) provided by Ordnance Survey, including access points. The axial map employed for space syntax analysis is extracted from the 2018 M25 London axial map by Space Syntax Limited. The network map for shortest paths and service area analysis is developed by combining OS Highways-Roads (2023) and OS Highways-Paths (2023), simplifying it using a Douglas Peucker simplification algorithm with a 7m parameter. Demographic and socioeconomic data about different social groups, including ethnic groups, deprivation, and ages, are derived from the 2021 census, with all census data available at the Output Area level of resolution, which is the highest available spatial resolution. According to the literature review section, the existing research on urban green space access of different ethnic groups usually focus on comparing white and black ethnic groups, while few explore the ethnic group of Asian Chinese. Hence, the data for ethnic groups focuses on the population and proportion of black African, Asian Chinese, and white British, based on people's culture, family background, identity or physical appearance (Office for National Statistics, 2023). People of different deprivation levels are represented by the households' data by deprivation dimensions, which consist of five categories ranging from not deprived in any dimensions to deprived in four dimensions. In this research, people of different ages are classified into four groups: toddlers and children aged 0 to 14 years, teenagers aged 15 to 18 years, adults aged 19 to 64 years, and older people aged 65 years and above. These census data are distributed equally among the address-based points to allow for more precise analyses in conjunction with OA-level data. However, due to restricted access to the Address Based data, this research employs an approach to alternate the data by removing all UPRNs from the OS Open UPRN data that match the OS POI data and keeping only those UPRNs that have no match. OS POI data describes any non-residential functions. Therefore, the result only contains residential UPRNs.

### 3.3. Data Analysis: Measurement of Access to Urban Green Spaces and Spatial Equity Analysis

Drawing upon the review and discussion of the existing research on the assessing approaches of access to urban green spaces in Chapter 2, this research formulates its own measurement framework by improving and combining the existing assessing approaches and introducing space syntax methods into it.

As mentioned in Chapter 2, this research measures access to urban green spaces from four perspectives: proximity, availability, quality, and centrality. However, only proximity and availability are considered for the larger-scale analysis of Islington and its four adjacent boroughs. The perspective of urban green space quality is considered in further detailed measurement of the access to Islington's public parks and gardens.

To assess the proximity, the research uses QGIS to perform a network analysis of the network map to calculate the shortest paths of each addressed-based point to its closest urban green space and aggregated to output area level, thus obtaining the average shortest path value of each area at the output area level. The availability of urban green spaces is assessed by measuring the population and the acreage of urban green spaces per capita for each area at the Output Area level within the service area. The service area of urban green spaces between 300m and 800m is obtained according to the shortest paths of the road and path network to reach the urban green spaces' access points. The distance selection of 300m is based on English Nature's (EN) suggestion that people should live within 300m of their nearest green space. The distance selection of 800m is because the maximum walk time of older people is about 10 minutes (Fatima, Moridpour, and Saghapour, 2022), and according to GSI, 800m can represent a 10-minute walking distance.

The quality of public parks and gardens is also considered when assessing the access to urban green spaces in Islington. The framework for the quality evaluation is based on the new remote Public Open Space Tool (POST) method (Appendix I) through Google Earth developed by Taylor et al. (2011). In-person observation are used to validate the data to make the remote POST method more accurate. Figure 3 illustrates the remote POST quality score for the urban green spaces within Islington, and Figure 4 presents a Google Earth view of two parks, with the left one scoring 0 and the right one scoring 64.9, as a reference sample for the remote POST scoring standard in this research.

This research applies the space syntax approach to capture the centrality of urban green spaces. Accessibility in space syntax usually refers to the easiness of reaching a place from another (Tannous, Major, and Furlan, 2021). This research measures the average NAIN and NACH of roads that access or define the edge of urban green spaces by setting a 20m buffer zone for each urban green space and calculating the average of NAIN and NACH of the roads within it. And then, the average NAIN and NACH of the roads surrounding the urban green spaces that each census tract can access can be calculated in QGIS. Through these, the traffic and pedestrian flow of the roads that surround the public parks or gardens can be reflected, which is also considered a part of urban green space quality (Abubakar and Aina, 2006).

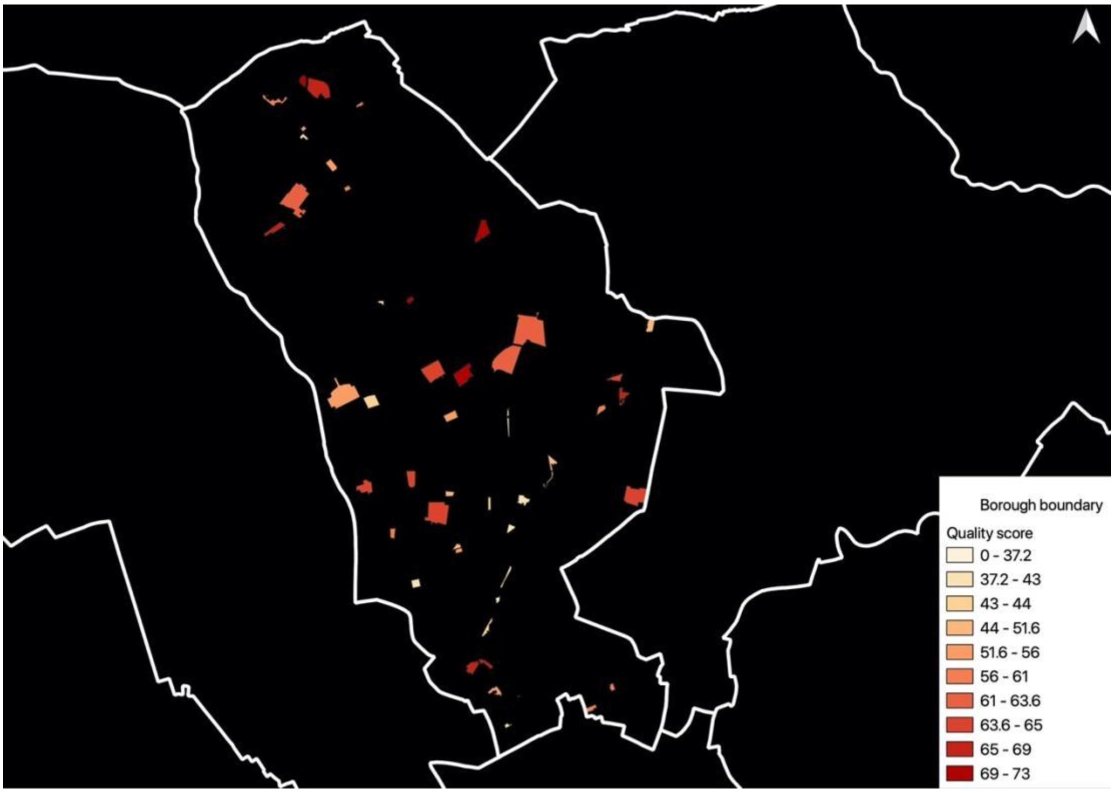


**Figure 3**. Remote POST quality score of public parks and gardens within Islington.

**Figure 4**. Google Earth view of two parks, with one (left) scored 0 and another (right) scored 64.9 at the new remote POST scoring standard. The urban green space on the left shows no walkable paths or facilities and lighting, while the right has walking paths shaded at good level, a football court, park benches, and a playground.

Because of the spatial autocorrelation of the studied variables, this research applies spatial regression models to identify the main associations between access to urban green spaces and the spatial inequity of different social groups. This research studies the spatial equity issue of different social groups' urban green spaces from three aspects: deprivation, ethnic groups, and ages. After measuring the access to urban green spaces as dependent variables, Moran's *I* (Moran, 1950), a spatial autocorrelation tool, is used to check whether there exists spatial autocorrelation in variables of proximity, availability, quality and demographic and economic census data. Moran's *I* is an important measure of spatial autocorrelation, which can determine the overall spatial autocorrelation of all variables in this research. The spatial autocorrelation reflects the degree to which the spatial attributes and their corresponding data values presenting spatial clustering (positive value of Moran's *I*) or dispersion (positive value of Moran's *I*). The larger the value of Moran's I, the more spatially clustered a variable is. Various variables exhibit the clear presents of spatial autocorrelation according to Moran's I

(Figure 5 as an example, Table 3), suggesting the necessity of using spatial regression models for this research to achieve a more accurate statistical analysis. The Lagrange multiplier (LM) test (Breusch and Pagan, 1980) is applied in the next step to help determine the most appropriate statistical model out of two, the spatial lag model and spatial error model, for each dependent variable (Appendix II). The model selection processes using LM test are illustrated in Figure 6. Besides, to eliminate errors introduced by data at the edges of the study site, this research statistically analyses only the data within the Borough of Islington.

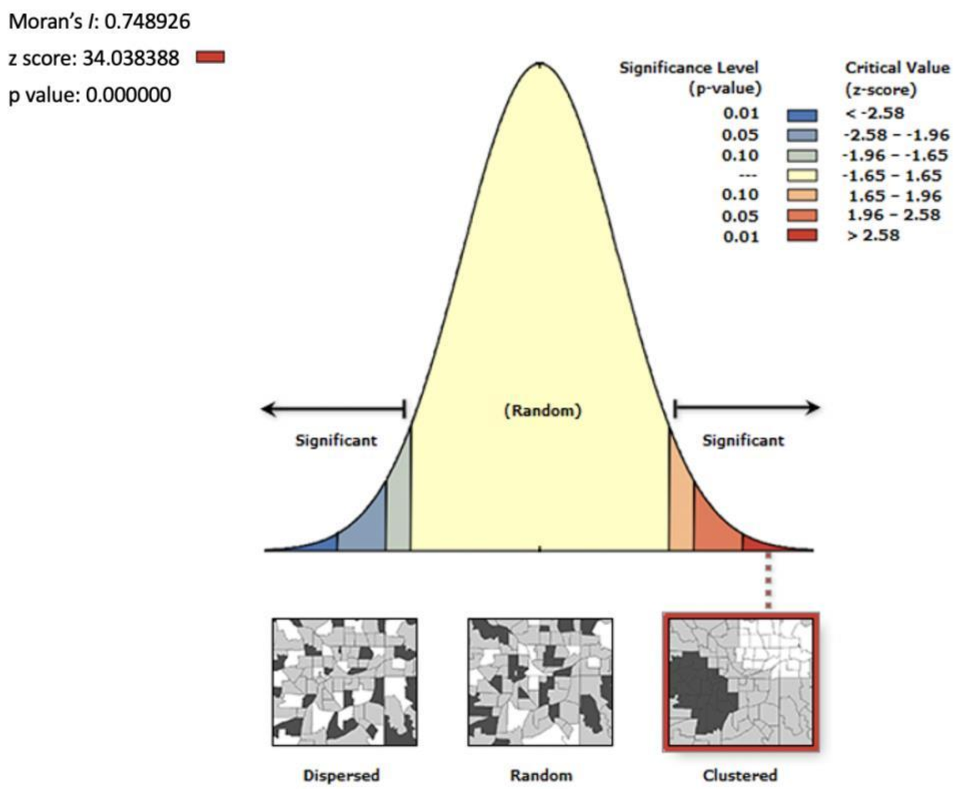


**Figure 5**. Moran's *I* report of the average distance of the shortest paths to the nearest public parks or gardens from home.

**Table 3**. Moran's I, z-score, and p value of all variables.

| | **Moran's *I*** | **z-score** | ***p* value** |
|---|---|---|---|
| Distance of shortest paths | 0.749 | 34.038 | 0.000 |
| Population_300m | 0.586 | 26.630 | 0.000 |
| Population_800m | 0.219 | 10.000 | 0.000 |
| Green acreage per capita_300m | 0.046 | 2.511 | 0.010 |
| Green acreage per capita_800m | 0.195 | 9.067 | 0.000 |
| Score | 0.910 | 41.345 | 0.000 |
| NAIN300 | 0.531 | 24.155 | 0.000 |
| NAIN800 | 0.869 | 39.529 | 0.000 |
| NAIN2400 | 0.956 | 43.422 | 0.000 |
| NACH300 | 0.566 | 25.739 | 0.000 |
| NACH800 | 0.805 | 36.622 | 0.000 |
| NACH2400 | 0.698 | 31.752 | 0.000 |
| Integration2400_max | 0.870 | 39.596 | 0.000 |
| Age 0-14 % | 0.145 | 6.667 | 0.000 |
| Age 15-19 % | 0.065 | 3.085 | 0.000 |
| Age 65+ % | 0.178 | 8.180 | 0.000 |
| White: British % | 0.431 | 19.614 | 0.000 |
| Black: African % | 0.242 | 11.112 | 0.000 |
| Asian: Chinese % | 0.220 | 10.197 | 0.000 |
| Population with 0 deprivation dimension % | 0.326 | 14.830 | 0.000 |
| Population with 4 deprivation dimension % | 0.027 | 1.327 | 0.180 |

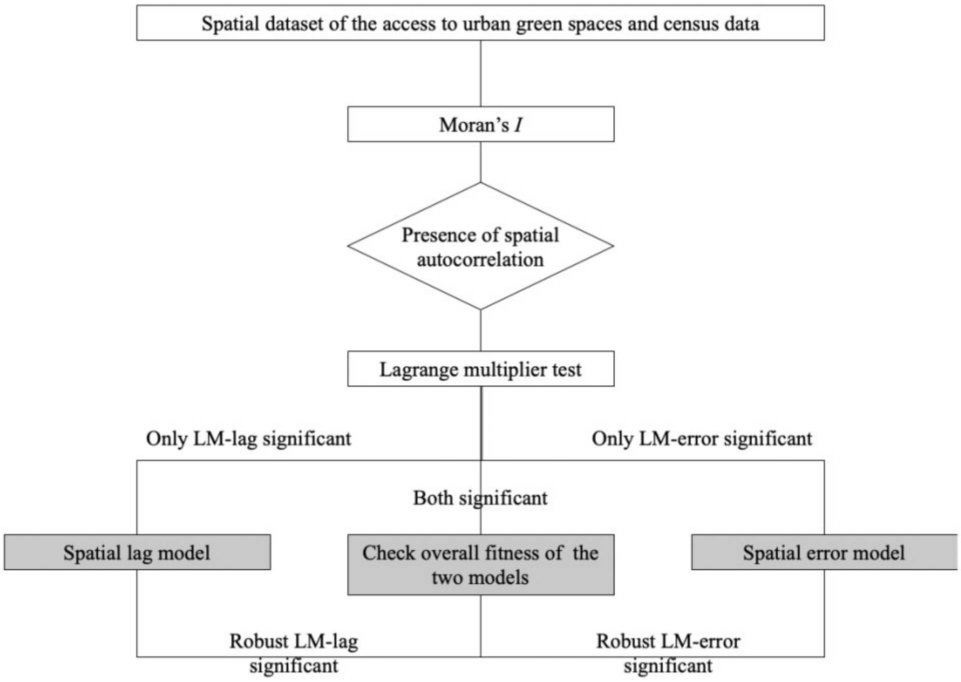


**Figure 6**. Spatial regression modelling framework.

Before conducting spatial regression analysis, this research checks the correlation between the independent variables for each type of social group, using the Pearson correlation matrix to test for the presence of multicollinearity (Table 4, 5, and 6). When the absolute value of the Pearson correlation coefficient is greater than or equal to 0.70, multicollinearity is considered to exist between the pair of variables, in which case only one of the variables is retained for regression analysis. Therefore, the spatial regression models in this research remove age group of 'age 20-64 %' and three groups with different deprivation levels, including population with 1, 2, and 3 deprivation dimensions %. The rest of the independent variables are retained.

**Table 4**. Pearson correlation matrix of variables in age groups.

| | Age 0-14 % | Age 15 to 19 % | Age 20-64 % | Age 65+ % |
|---|---|---|---|---|
| Age 0-14 % | 1.00 | 0.12** | -0.70** | -0.01 |
| Age 15 to 19 % | 0.12** | 1.00 | -0.48** | -0.13** |
| Age 20-64 % | -0.70** | -0.48** | 1.00 | -0.53** |
| Age 65+ % | -0.01 | -0.13** | -0.53** | 1.00 |

**Table 5**. Pearson correlation matrix of variables in ethnic groups.

| | White: British % | Black: African % | Asian: Chinese % |
|---|---|---|---|
| White: British % | 1.00 | -0.59** | -0.30** |
| Black: African % | -0.59** | 1.00 | -0.13** |
| Asian: Chinese % | -0.30** | -0.13** | 1.00 |

**Table 6**. Pearson correlation matrix of variables in groups with different deprivation levels.

| | Population with 0 deprivation dimension % | Population with 1 deprivation dimension % | Population with 2 deprivation dimensions % | Population with 3 deprivation dimensions % | Population with 4 deprivation dimensions % |
|---|---|---|---|---|---|
| Population with 0 deprivation dimension % | 1.00 | -0.74** | -0.89** | -0.73** | -0.26** |
| Population with 1 deprivation dimension % | -0.74** | 1.00 | 0.43** | 0.28** | 0.07* |
| Population with 2 deprivation dimensions % | -0.89** | 0.43** | 1.00 | 0.61** | 0.22** |
| Population with 3 deprivation dimensions % | -0.73** | 0.28** | 0.61** | 1.00 | 0.19** |
| Population with 4 deprivation dimensions % | -0.26** | 0.074* | 0.22** | 0.19** | 1.00 |

### 3.4. Limitations

This research exclusively concentrates on public parks and gardens as defined by the Ordnance Survey. Consequently, it could not reflect the associations between the access to other urban green spaces like private gardens and sports greens by the studied social groups and the spatial inequities. And the divisions of each social group, for instance, are limited to the three groups of white British, black African, and Asian Chinese, which fails to do a comprehensive analysis across the diverse social groups. Due to the presence of multicollinearity, some independent variables were removed from the spatial regression models in this research. However, in order to make the analytical results more rigorous, spatial regression analyses should also be performed on these removed independent variables. Furthermore, the results of spatial regression models cannot exclude the influence of natural or socioeconomic factors beyond the independent variables, such as discrepancies in the use of urban green spaces, recreational preferences, cultural practices, and educational levels. Besides, due to the limited time, only public parks and gardens within Islington were visited and scored using the remote POST. The spatial regression analysis is also restricted to Islington to prevent potential area edge errors. Therefore, the results of this study only partially reflect the relationship between different social groups in London and their access to urban green spaces, along with the spatial inequities they face. Another limitation arises from the use of the remote POST scoring method. Although this research uses site visits to validate the score and improve accuracy, some subjectivity may persist in scoring aspects like path shading and lighting, introducing potential errors into the analysis.

## Chapter 4: Results and Data Analysis

This chapter demonstrates the results of measuring access to public parks and gardens in the five boroughs and answer the first research question. It investigates their relationships with the spatial inequity of different social groups. Figures 7 to 18 visualise the census 2021 data of age groups, ethnic groups, and groups with different deprivation levels in the five boroughs.

The population proportions of people of different age groups are visualised in Figures 7 to 10. The population in the east and north of the study site skews towards a younger demographic, showing higher proportions in the toddler and child age groups and among teenagers. The adult population is mainly distributed in the central and the south of the site, while the proportion of older people is higher in the west and northwest compared to the rest of the site.

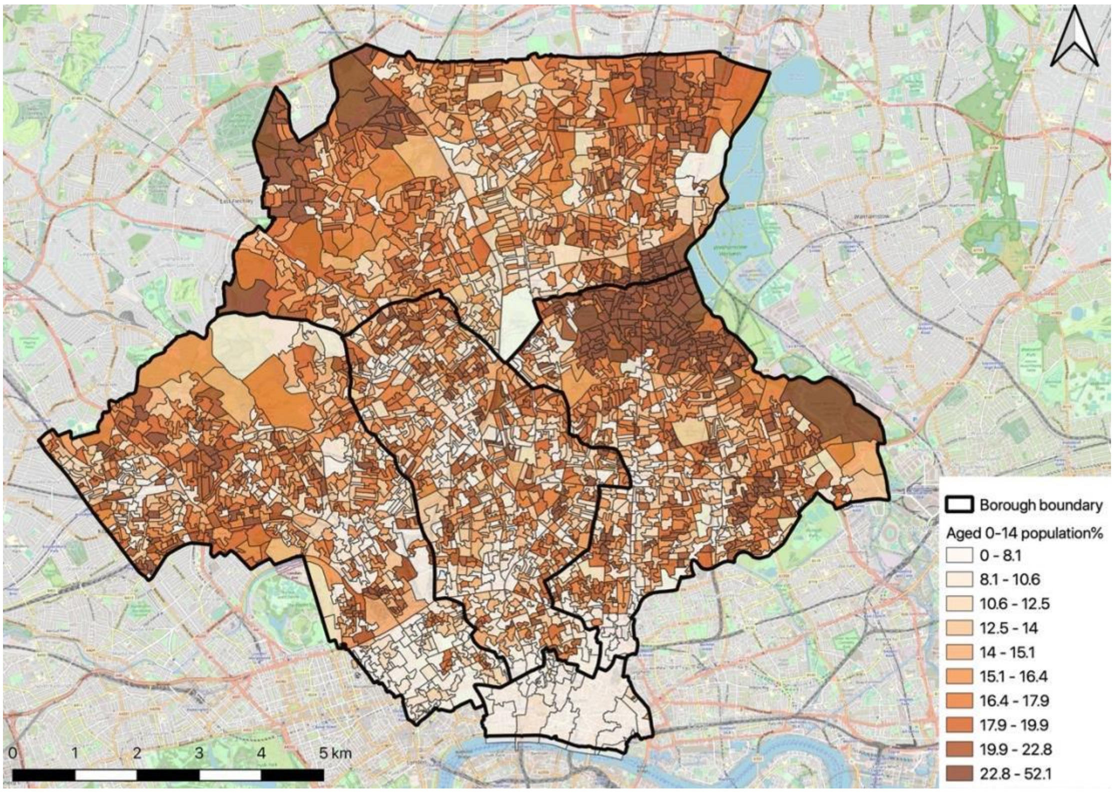


**Figure 7**. Population percentage of people from 0 to 14 years old.

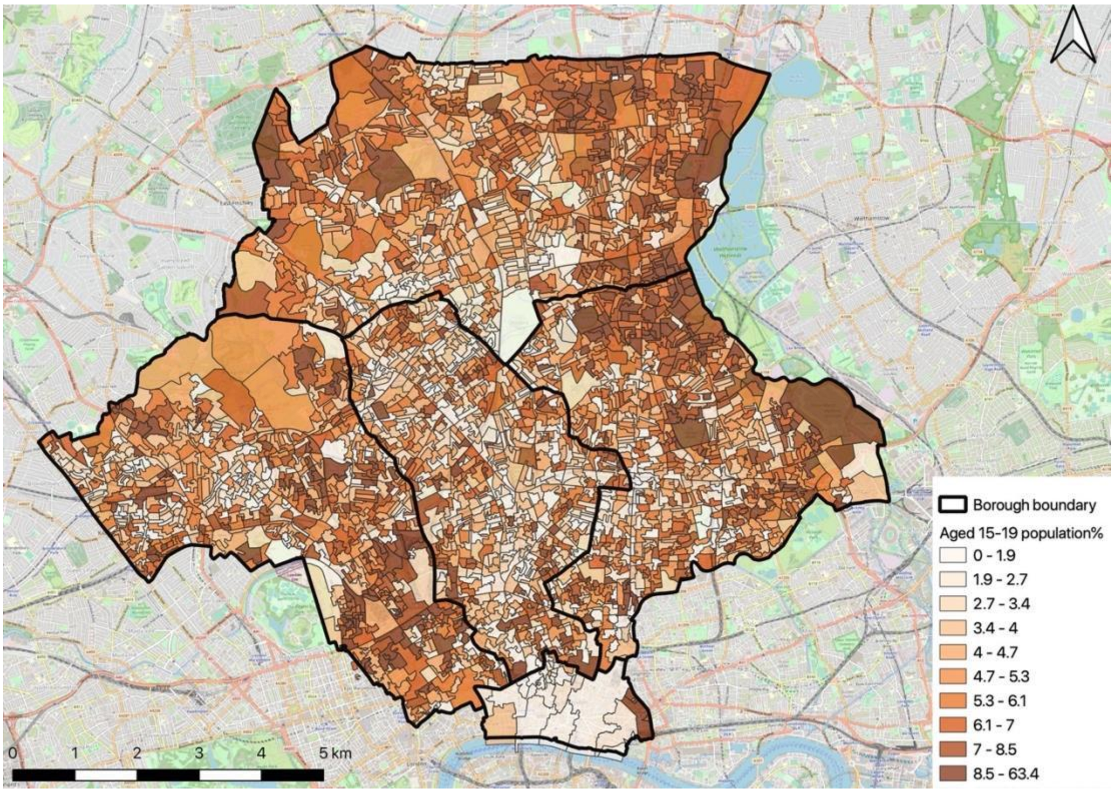


**Figure 8**. Population percentage of people from 15 to 19 years old.

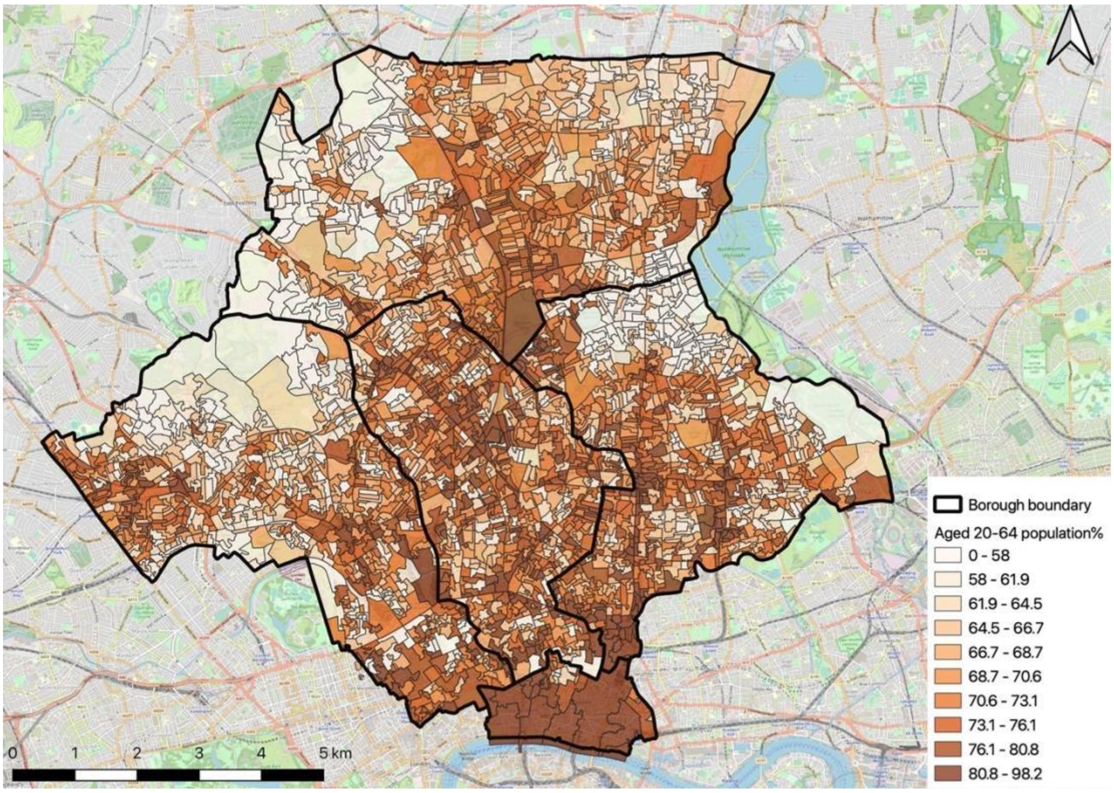


**Figure 9**. Population percentage of people from 20 to 64 years old.

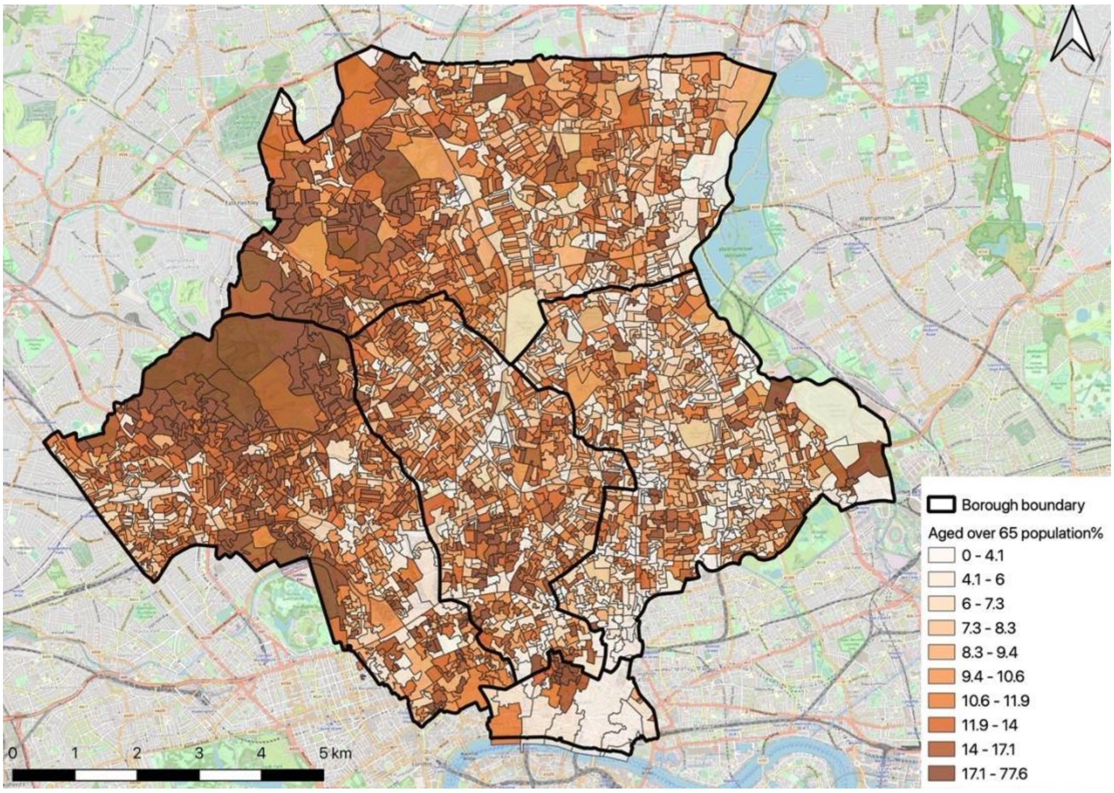


**Figure 10**. Population percentage of people over 65 years old.

Figure 11 to 13 visualise the population percentages of three ethnic groups. Most of the study site reflects a notable concentration of white British in the centre, west, and northwest. At the same time, the east and northeast display a higher proportion of black Africans. And as moving move southward, there is an increase in the proportion of Asian Chinese.

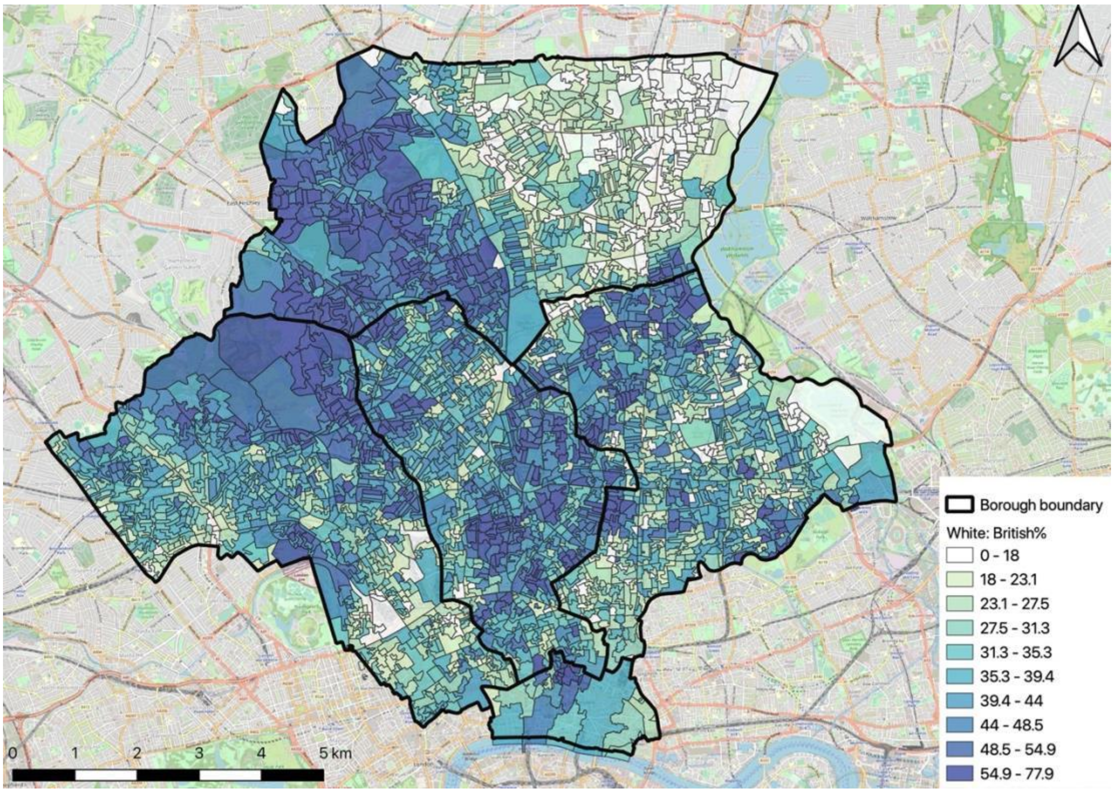


**Figure 11**. Population percentage of White: British.

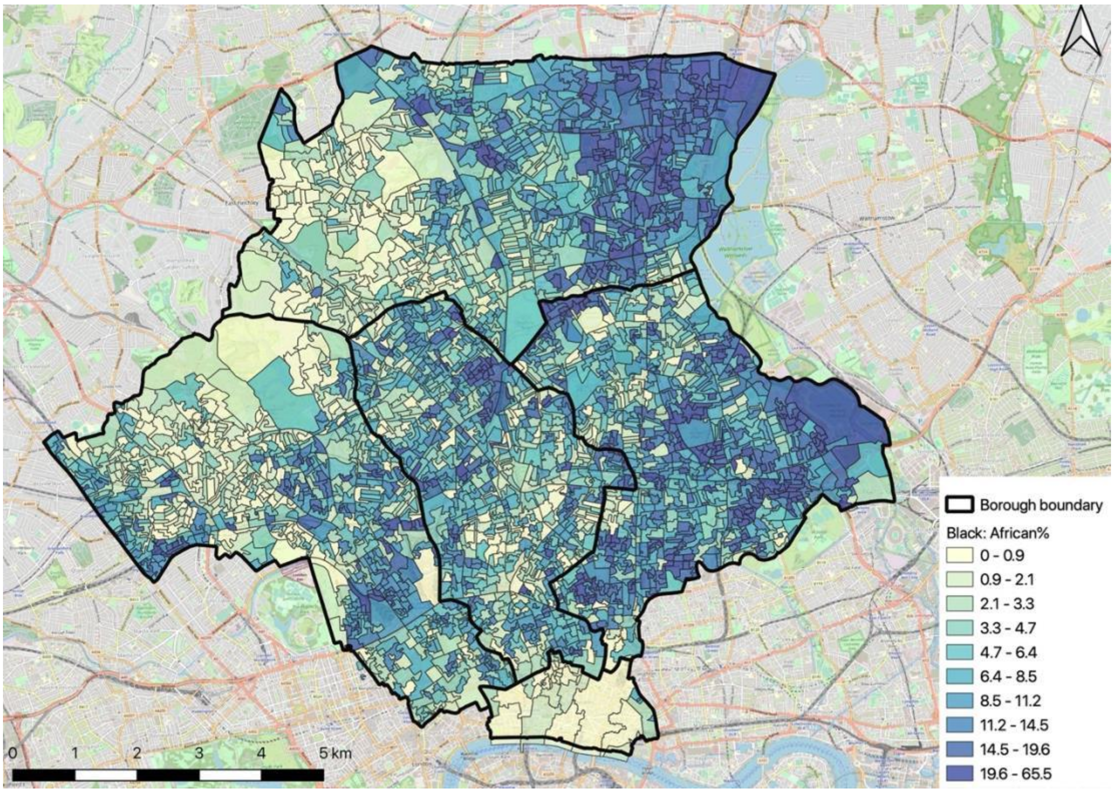


**Figure 12**. Population percentage of Black: African.

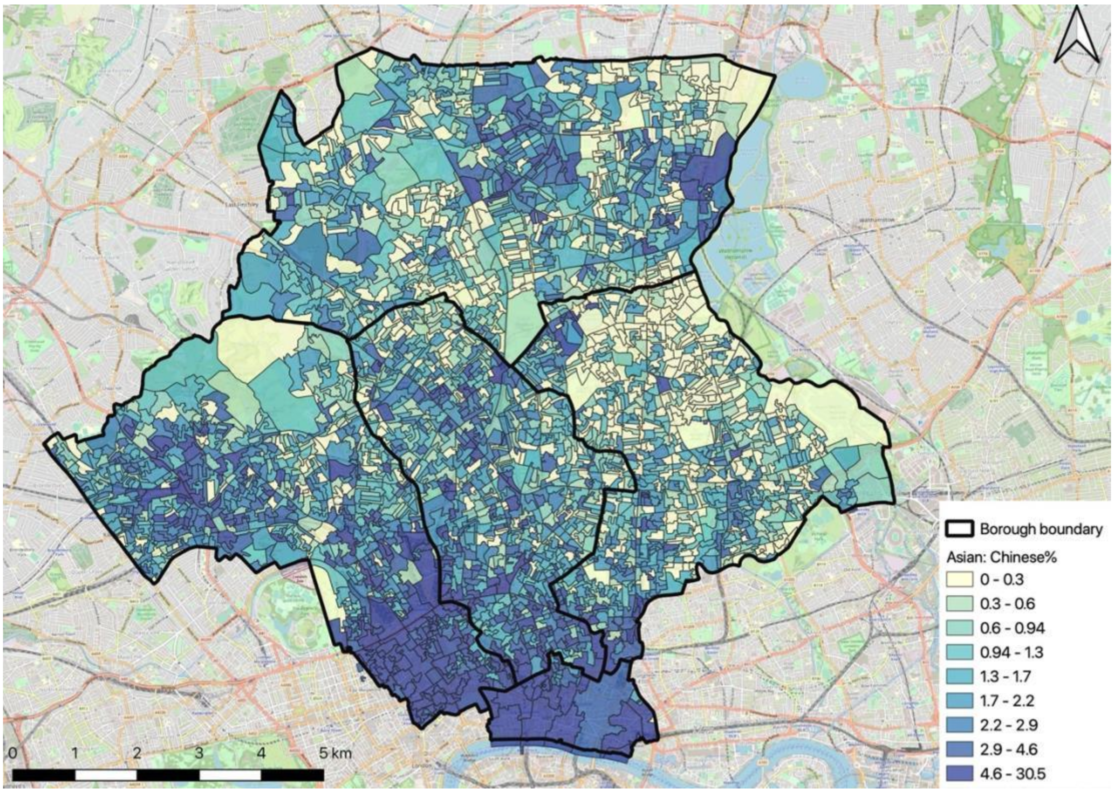


**Figure 13**. Population percentage of Asian: Chinese.

Figure 14 to 18 illustrate the population proportion of people with different number of deprivation dimensions. The study site's western, northwestern, southern, and southeastern parts are of low levels of deprivation, with a high proportion of residents in these areas deprived in 0 dimensions. While the east and the northeast demonstrate higher proportions of residents suffering from one to three deprivation dimensions, the proportion of residents with four deprivation dimensions is higher in the northeast of the site.

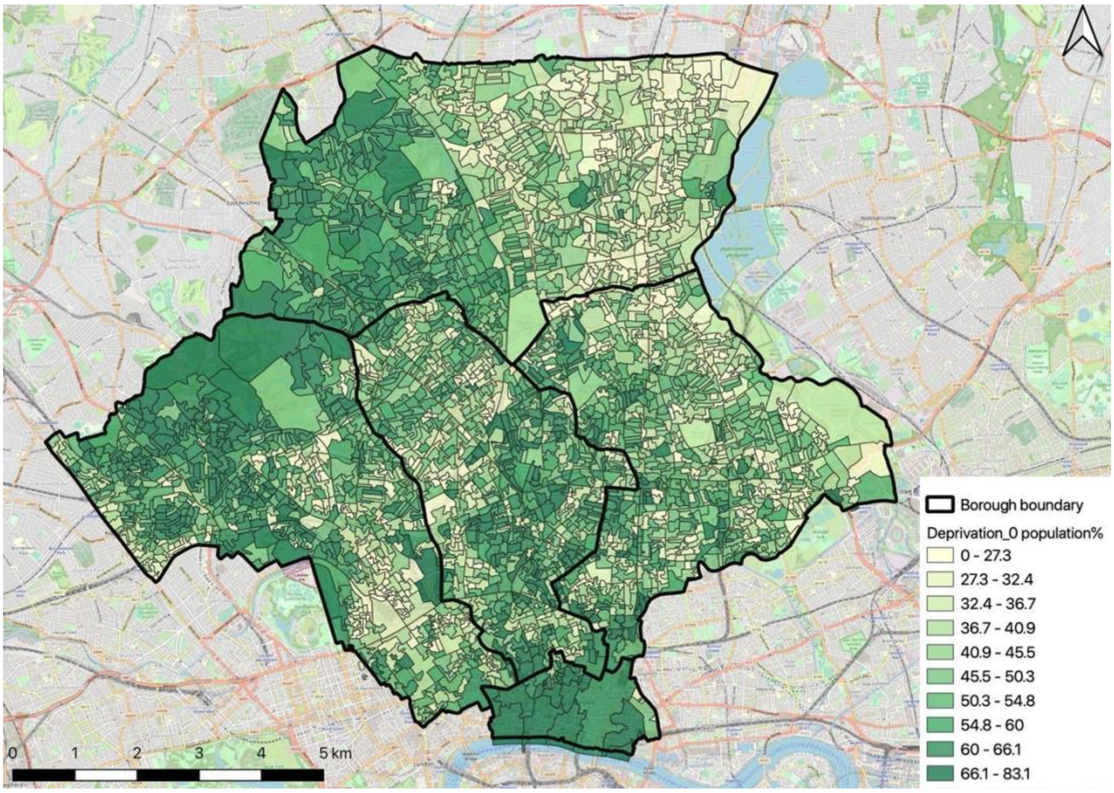


**Figure 14**. Population percentage of people deprived in 0 dimension.

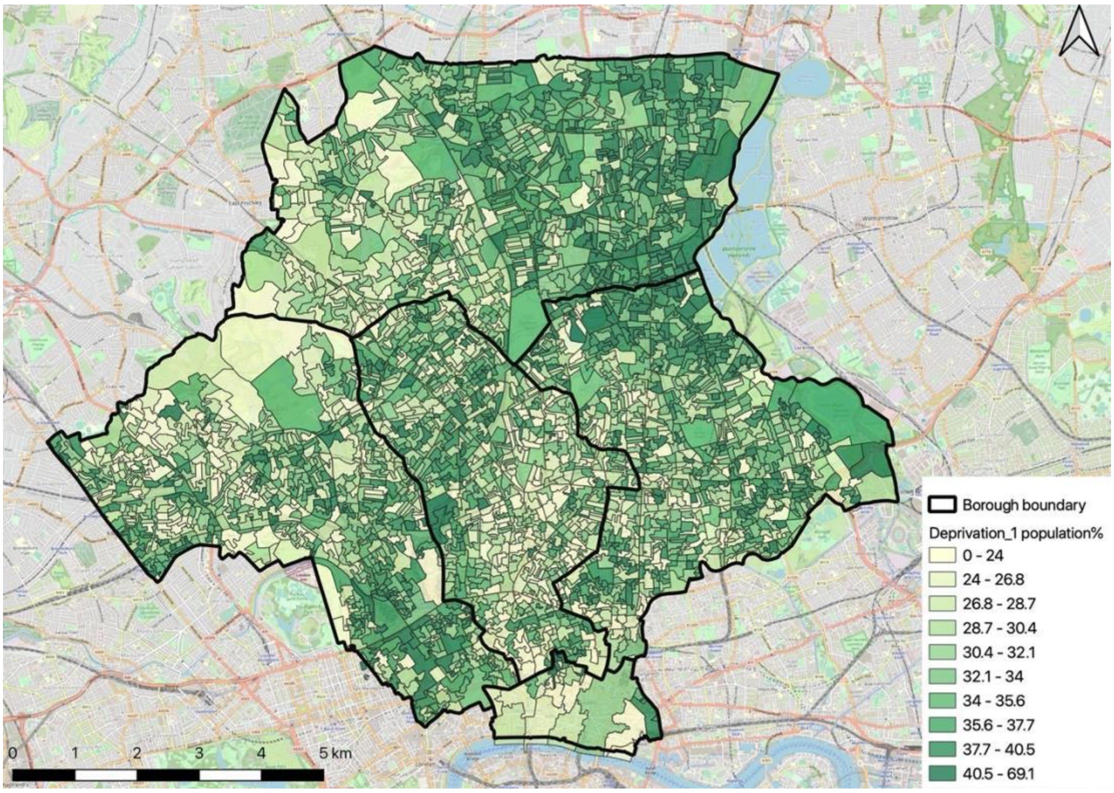


**Figure 15**. Population percentage of people deprived in 1 dimension.

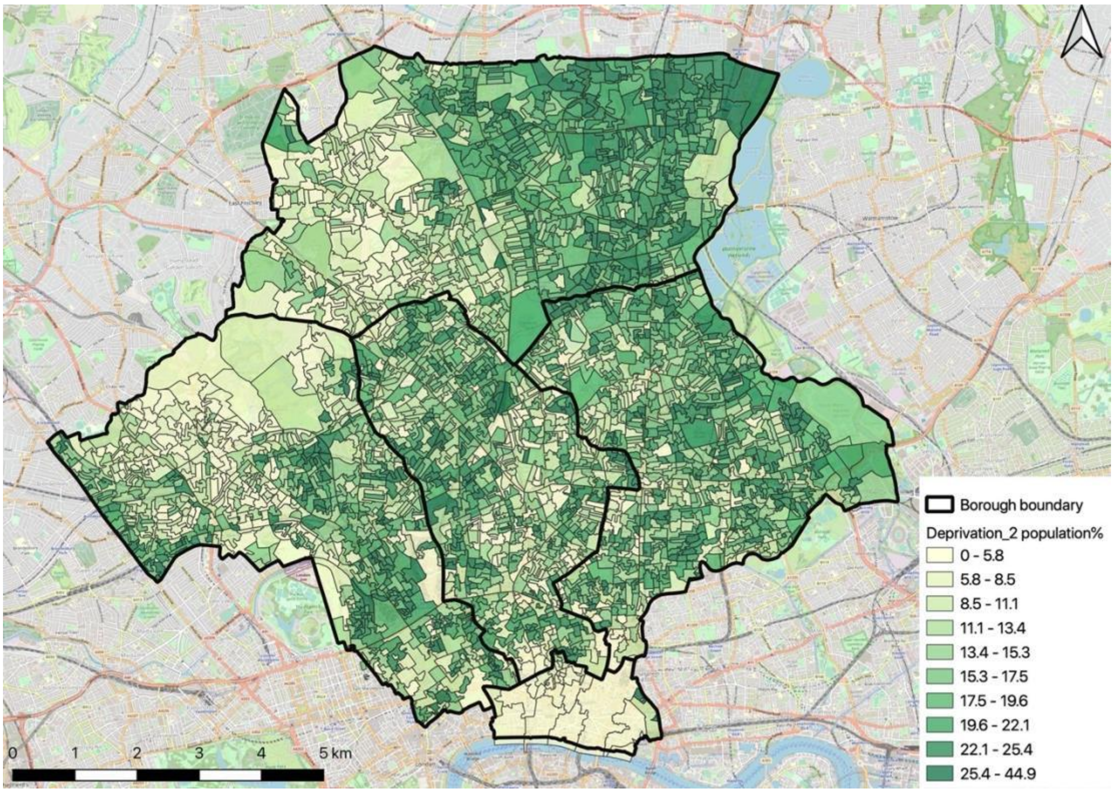


**Figure 16**. Population percentage of people deprived in 2 dimensions.

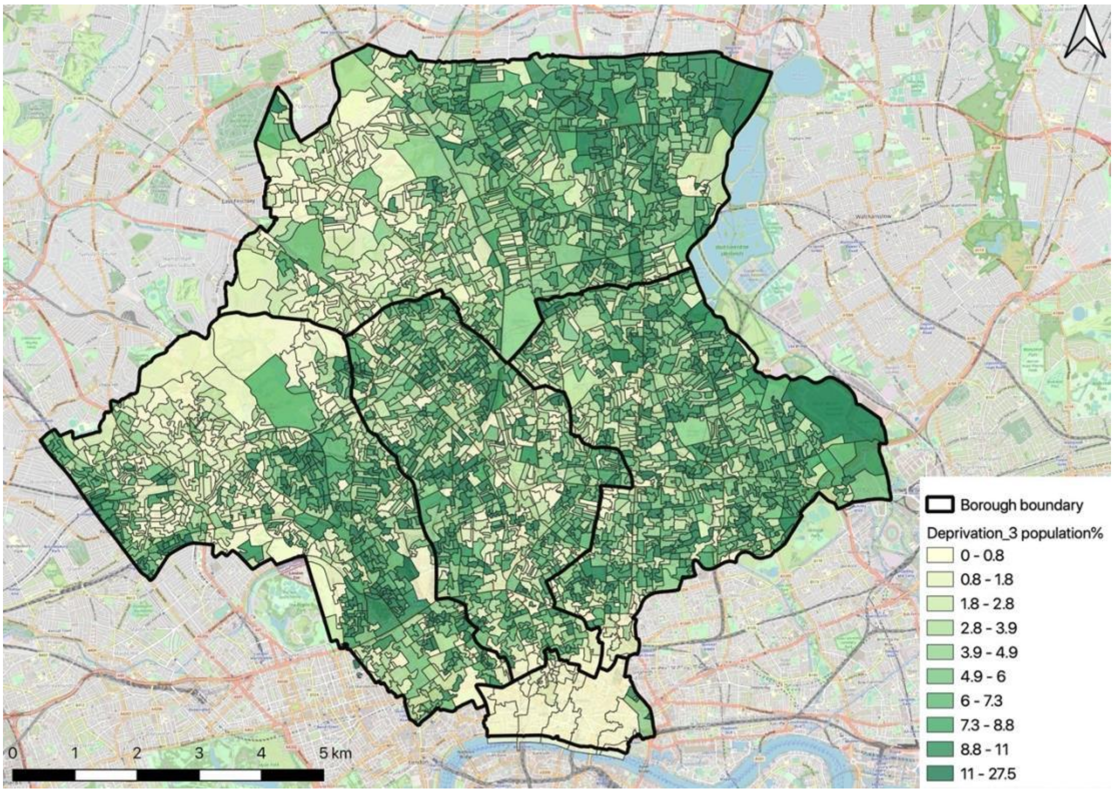


**Figure 17**. Population percentage of people deprived in 3 dimensions.

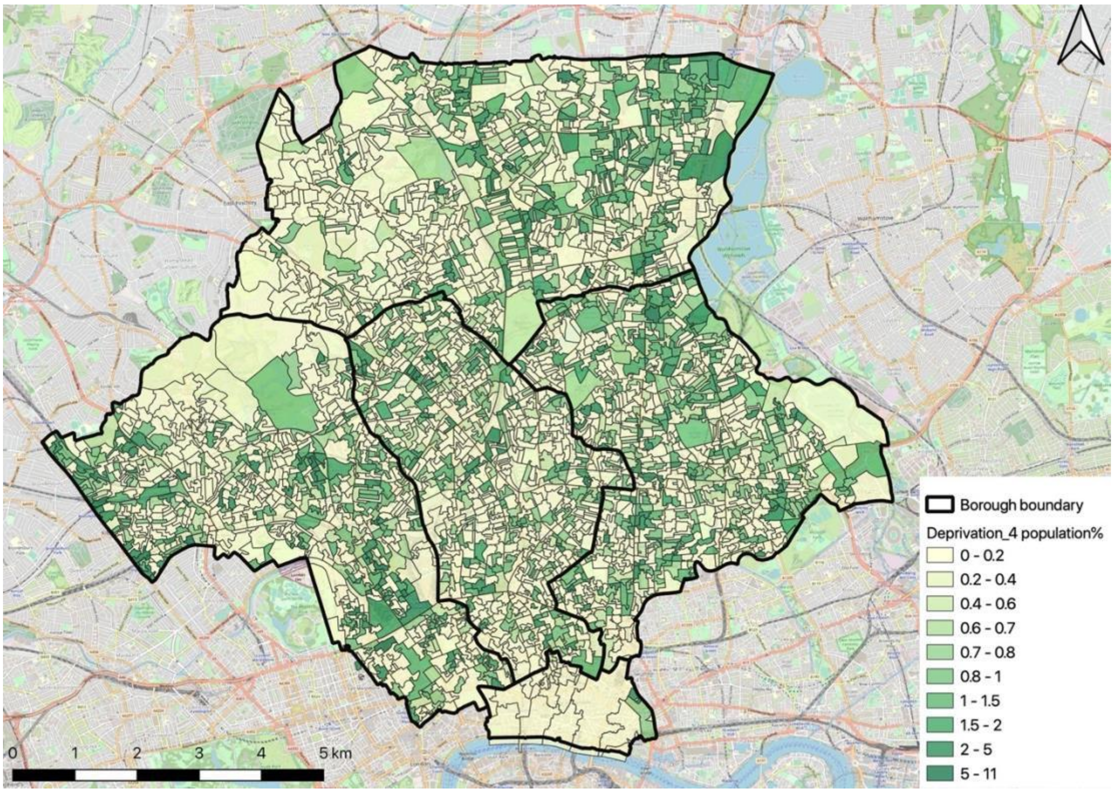


**Figure 18**. Population percentage of people deprived in 4 dimensions.

Table 7 presents the descriptive statistics for both dependent and independent variables in the spatial regression models developed for Islington. It includes information about the research variables' sample size, minimum, maximum, mean, and standard deviation. 12 spatial regression models are formulated, one for each dependent variable, to investigate the main associations between urban green space access and different social groups. All the spatial regression models take the maximum value of Integration_R2400 as the control variable to distinguish between more and less urban areas. By factoring in the degree of urban centrality, omitted variable bias can be mitigated, improving the accuracy of models.

**Table 7**. Descriptive statistics of all studied variables (the four variables of 'Aged 20-64 %, Population with 1, 2, 3,deprivation dimensions %' are not included in. the spatial regression models because of multicollinearity as mentioned in methodology section).

| Variable name | N | Minimum | Maximum | Mean | Std. dev. |
|---|---|---|---|---|---|
| **Dependent variable** | | | | | |
| Distance of shortest paths (m) | 729 | 36.901 | 569.084 | 236.464 | 124.376 |
| Population_300m | 729 | 0.000 | 250.800 | 59.598 | 58.730 |
| Population_800m | 729 | 28.050 | 340.000 | 118.341 | 42.671 |
| Green acreage per capita_300m ($m^2$) | 729 | 0.000 | 8849.482 | 178.214 | 486.036 |
| Green acreage per capita_800m ($m^2$) | 729 | 10.165 | 1404.590 | 180.745 | 123.321 |
| Quality score | 729 | 35.553 | 73.350 | 57.544 | 7.506 |
| NAIN300 | 729 | 0.000 | 1.769 | 0.920 | 0.582 |
| NAIN800 | 729 | 0.905 | 1.569 | 1.137 | 0.121 |
| NAIN2400 | 729 | 0.991 | 1.276 | 1.127 | 0.072 |
| NACH300 | 729 | 0.000 | 1.269 | 0.612 | 0.408 |
| NACH800 | 729 | 0.516 | 1.280 | 0.960 | 0.099 |
| NACH2400 | 729 | 0.873 | 0.981 | 0.925 | 0.017 |
| **Independent variable** | | | | | |
| Age 0-14 % | 729 | 0.000 | 40.200 | 14.156 | 5.531 |
| Aged 15 to 19 % | 729 | 0.000 | 39.100 | 4.624 | 4.088 |
| Aged 20-64 % | 729 | 39.900 | 98.100 | 71.514 | 8.543 |
| Age 65+ % | 729 | 0.000 | 43.500 | 9.691 | 5.113 |
| White: British % | 729 | 10.700 | 71.900 | 40.339 | 11.486 |
| Black: African % | 729 | 0.000 | 65.500 | 7.991 | 7.377 |
| Asian: Chinese % | 729 | 0.000 | 30.500 | 2.264 | 2.793 |
| Population with 0 deprivation dimension % | 729 | 18.400 | 82.200 | 48.036 | 13.919 |
| Population with 1 deprivation dimension % | 729 | 13.700 | 47.300 | 30.592 | 6.094 |
| Population with 2 deprivation dimensions % | 729 | 0.000 | 36.900 | 15.246 | 7.102 |
| Population with 3 deprivation dimensions % | 729 | 0.000 | 26.200 | 5.655 | 3.976 |
| Population with 4 deprivation dimensions % | 729 | 0.000 | 11.000 | 0.467 | 0.880 |
| **Control variable** | | | | | |
| Integration_R2400_max | 729 | 0.000 | 2211.200 | 831.704 | 381.036 |
| Valid N (listwise) | 729 | | | | |

## 4.1. The Proximity of Urban Green Spaces in Islington Accessed by Different Social Groups

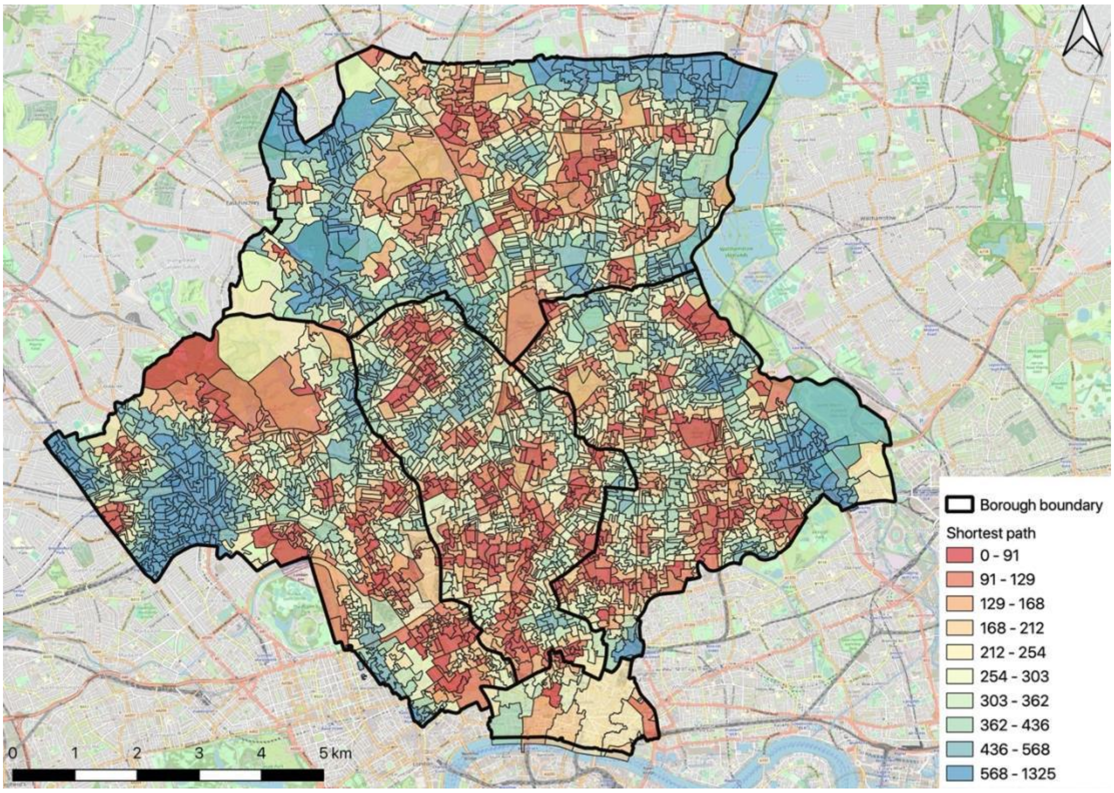


**Figure 19**. Average Distance of shortest paths to the nearest parks or gardens.

Figure 19 visualises the average distance of the shortest path to the nearest public parks or gardens from home. Table 8 shows the spatial regression results for the relationship between the average distance of the shortest paths to the nearest urban green spaces from home and all studied social groups. Based on the spatial regression results, it can be figured out that the percentage of people aged from 0 to 14 has a significant and negative correlation with the distance of the shortest paths. Concerning ethnic groups, a significant and positive correlation exists between the proportion of black Africans in an area and the average distance of the shortest paths. In contrast, no such correlation is found for the proportion of Asian Chinese or white British. It suggests that people in an area with a higher proportion of black Africans usually have a longer average shortest path distance from home to the nearest urban green spaces.

**Table 8**. Results of the spatial regression model for proximity (dependent variable = distance of shortest paths).

| | **Coefficient** |
|---|---|
| ***Independent variable*** | |
| *Age groups* | |
| Age 0-14 % | -0.933* (0.367) |
| Age 15-19 % | 0.018 (0.448) |
| Age 65+ % | -0.366 (0.427) |
| *Ethnic groups* | |
| White: British % | 0.430 (0.257) |
| Black: African % | 0.188* (0.346) |
| Asian: Chinese % | -0.805 (0.761) |
| *Groups with different deprivation levels* | |
| Population with 0 deprivation dimension % | -0.101 (0.178) |
| Population with 4 deprivation dimensions % | 1.297 (1.899) |
| ***Control variable*** | |
| Integration_R2400_max | 0.005 (0.005) |
| rho (spatial lag model) | 1.159** |

**Significant at 99% confidence level ($p$<0.01). *Significant at 95% confidence level ($p$<0.05).

## 4.2. The Availability of Urban Green Spaces in Islington Accessed by Different Social Groups

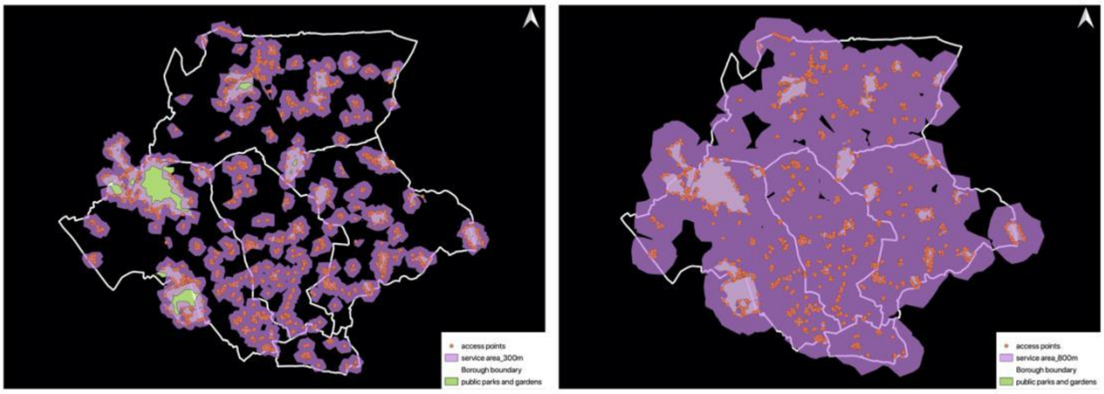


**Figure 20**. 300m (left) and 800m (right) service area from access points of public parks and gardens.

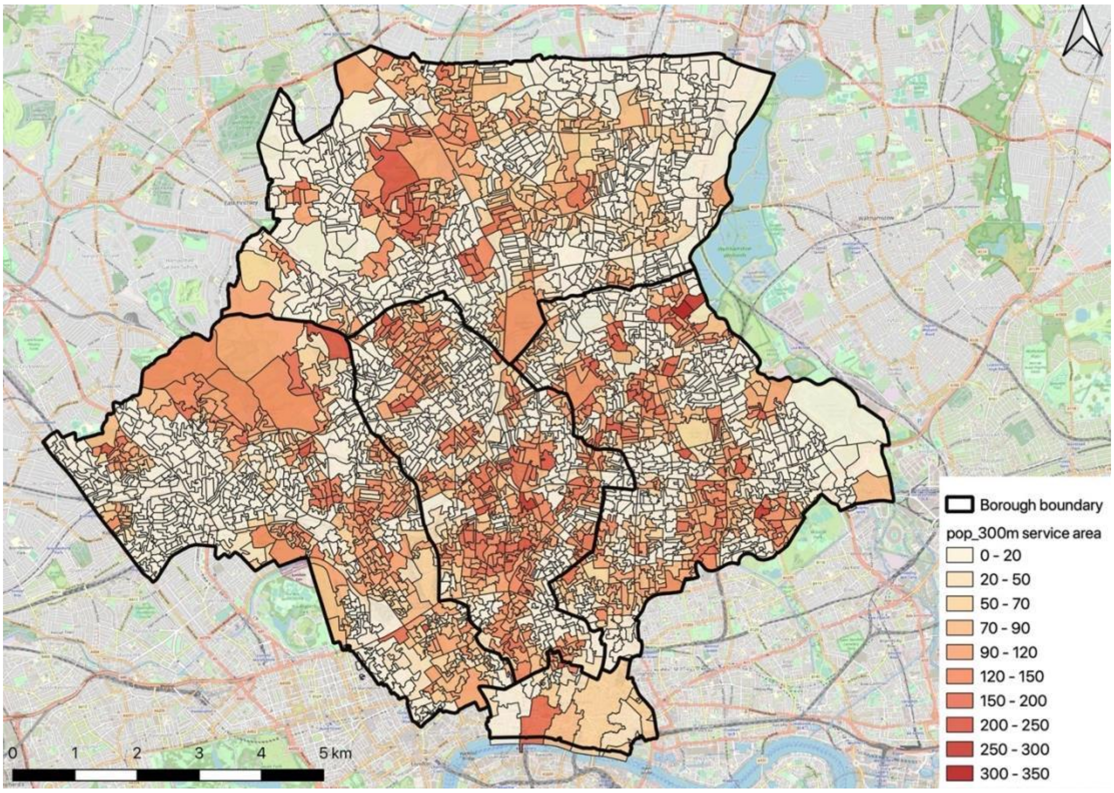


**Figure 21**. Population within 300m service area.

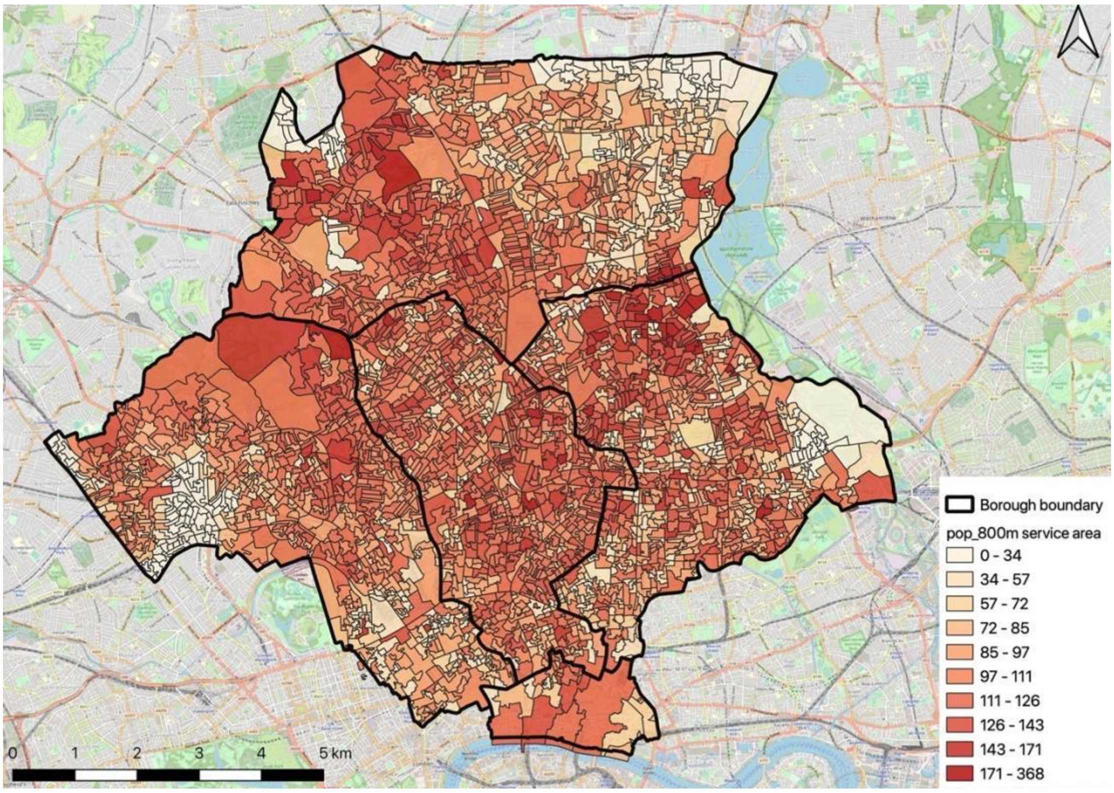

**Figure 22**. Population within 800m service area.

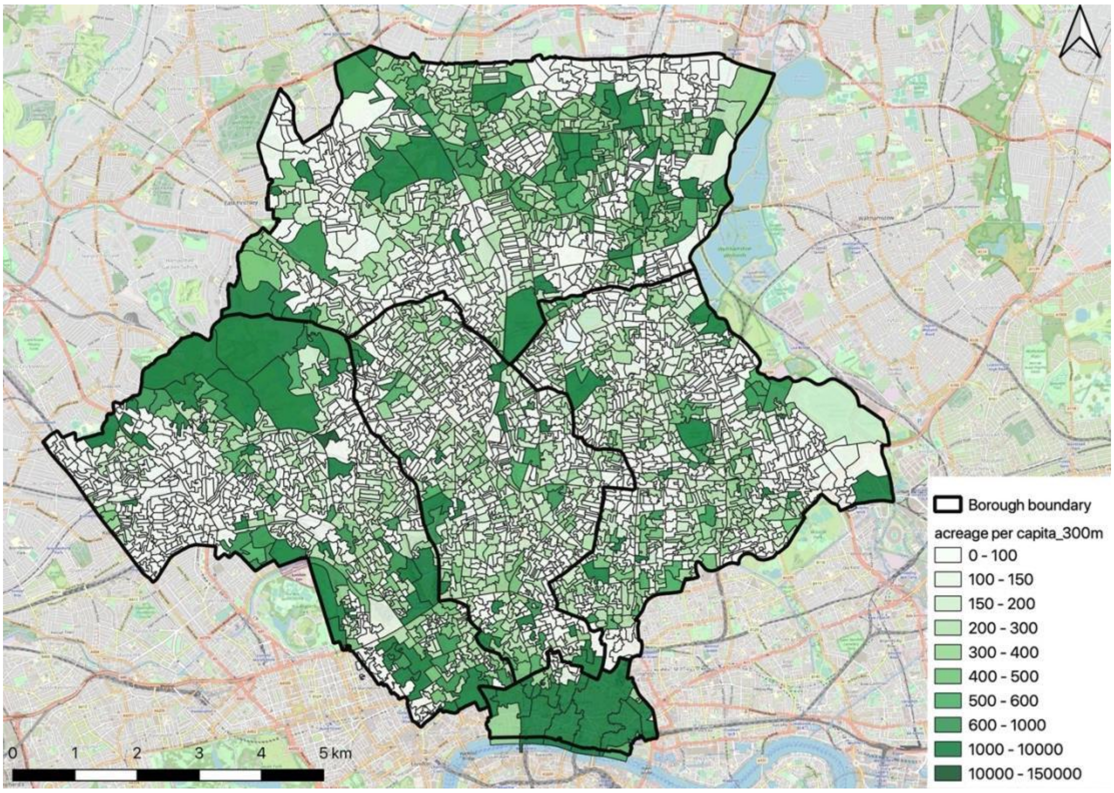

**Figure 23**. Acreage per capita within 300m service area.

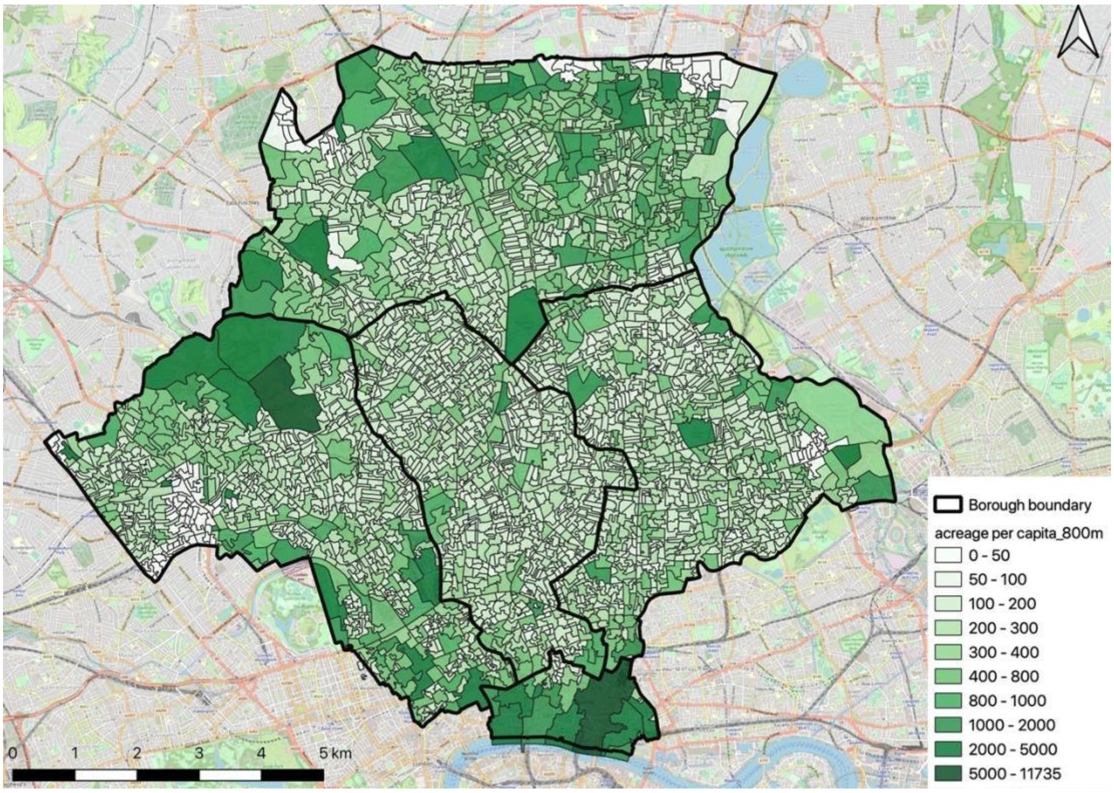


**Figure 24**. Acreage per capita within 800m service area.

Figure 20 shows the 300m and 800m service areas of urban green spaces of the studied five boroughs in this research. The results of the spatial regression model, with the availability of urban green spaces (Figure 21 to 24) as its dependent variables, are presented in Table 9. Among the four models for availability, only analytical results of the model with 'Acreage_800' as the dependent variable are affected by the control variable significantly. It indicates that after controlling the impact of all independent variables, the average urban green acreage per capita within an 800m service area will still increase as the maximum value of integration R2400 increases. The results reveal that the population within the 300m service area only shows a significant correlation with the proportions of people aged from 0 to 14 years old and white British. It implies that the area's population living within 300m service area increases as the proportion of toddlers and children or white British in this area increases. When the service area expands to 800m, the proportion of toddlers and children and the proportion of white British remain significant and positive correlation with this dependent variable. Besides, the results show that an area with higher proportions of people aged from 15-19 will have more people living within 800m service area of urban green spaces. When the proportion of people over 65 years old in an area increases, there is a high possibility that the population in this area that are within the 800m service area decreases. The proportion of people deprived in 0 and 4 dimensions have opposite but significant correlations with this dependent variable, with the one of 0 deprivation dimension being positively correlated and the one of 4 deprivation dimensions being negatively correlated.

At the scale of a 300m service area, in an area with a higher proportion of older people, the green space acreage per capita in this area is relatively higher. When extending the scale to an 800m service area, the spatial regression results show an increased number of independent variables significantly correlated with the dependent variable. The proportions of toddlers and children, teenagers, and older people in an area are all significantly correlated. The proportions of teenagers and older people present negative correlations, with a higher sensitivity to changes in the proportion of older people. Notably, the urban green space per capita in the area decreases with higher proportions of toddlers and children in an area. In addition, an area with a higher proportion of non-deprived people tends to have higher average urban green acreage per capita within 800m service area.

**Table 9**. Results of the spatial regression model for availability (dependent variable = population_300m, population_800m, green acreage per capita_300m, green acreage per capita_800m).

| | Coefficient (Standard error) | | | |
|---|---|---|---|---|
| | **Pop._300** | **Pop._800** | **Acreage_300** | **Acreage_800** |
| ***Independent variable*** | | | | |
| *Age groups* | | | | |
| Age 0-14 % | 0.619*<br>(0.298) | 0.093**<br>(0.024) | -0.094<br>(0.164) | -0.204**<br>(0.043) |
| Age 15-19 % | 0.670<br>(0.363) | 0.089**<br>(0.015) | 0.185<br>(0.104) | 0.090**<br>(0.026) |
| Age 65+ % | -0.509<br>(0.348) | -0.038*<br>(0.018) | 0.290*<br>(0.119) | 0.217**<br>(0.032) |
| *Ethnic groups* | | | | |
| White: British % | 0.926**<br>(0.209) | 0.906**<br>(0.047) | -0.074<br>(0.311) | -0.815<br>(0.084) |
| Black: African % | 0.056<br>(0.280) | 0.018<br>(0.014) | -0.016<br>(0.095) | -0.029<br>(0.024) |
| Asian: Chinese % | 1.745<br>(0.616) | -0.011<br>(0.012) | 0.122<br>(0.082) | 0.022<br>(0.022) |
| *Groups with different deprivation levels* | | | | |
| Population with 0 deprivation dimension % | -0.074<br>(0.144) | 0.131**<br>(0.047) | 0.444<br>(0.316) | 0.383**<br>(0.087) |
| Population with 4 deprivation dimensions % | 0.882<br>(1.538) | -0.147**<br>(0.028) | -0.237<br>(0.189) | 0.040<br>(0.048) |
| ***Control variable*** | | | | |
| Integration_R2400_max | -0.001<br>(0.004) | 0.006<br>(0.013) | 0.131<br>(0.089) | 0.253**<br>(0.026) |
| rho (spatial lag model) | 1.119** | | 0.944** | |
| lambda (spatial error model) | | 0.269** | | 0.603** |

**Significant at 99% confidence level ($p$<0.01). *Significant at 95% confidence level ($p$<0.05).

4.3. The Quality of Urban Green Spaces in Islington Accessed by Different Social Groups

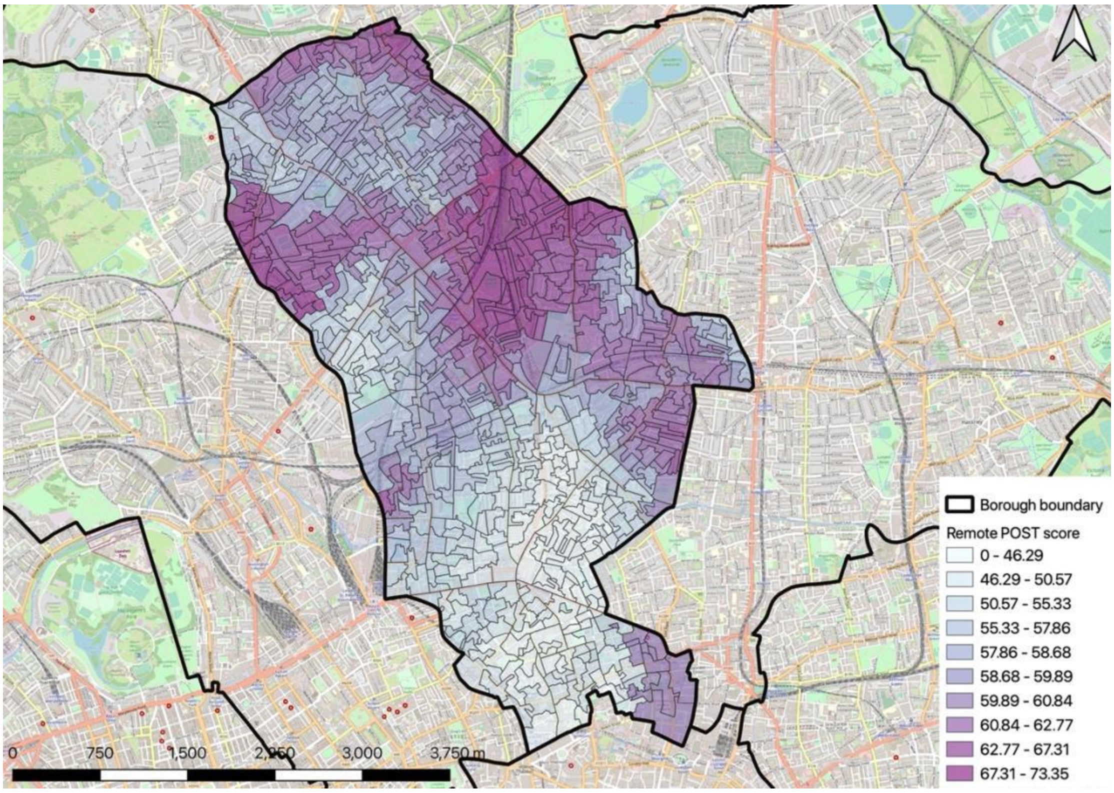


**Figure 25**. Average remote POST score of parks and gardens that can be accessed within 800m service area.

Table 10 presents the results of the spatial lag model used for the regression analysis of the average remote POST score (Figure 25). In this model, the control variable affects the dependent variable significantly and positively. Significant and positive correlations emerge between quality scores and the proportions of white British and non-deprived people. This implies that when the proportion of white British or non-deprived people in an area increases, this area tends to access urban green spaces with a higher average remote POST score, indicating better quality.

**Table 10**. Results of the spatial regression model for quality (dependent variable = quality score).

| | **Coefficient (Standard error)** |
|---|---|
| ***Independent variable*** | |
| *Age groups* | |
| Age 0-14 % | 0.015<br>(0.015) |
| Age 15-19 % | 0.020<br>(0.018) |
| Age 65+ % | -0.023<br>(0.017) |
| *Ethnic groups* | |
| White: British % | 0.017*<br>(0.010) |
| Black: African % | 0.001<br>(0.014) |
| Asian: Chinese % | 0.026<br>(0.031) |
| *Groups with different deprivation levels* | |
| Population with 0 deprivation dimension % | 0.001*<br>(0.009) |
| Population with 4 deprivation dimensions % | 0.082<br>(0.078) |
| ***Control variable*** | |
| Integration_R2400_max | 0.001*<br>(0.000) |
| rho (spatial lag model) | 1.042** |

**Significant at 99% confidence level ($p$<0.01). *Significant at 95% confidence level ($p$<0.05).

## 4.4. The Centrality of Urban Green Spaces in Islington Accessed by Different Social Groups

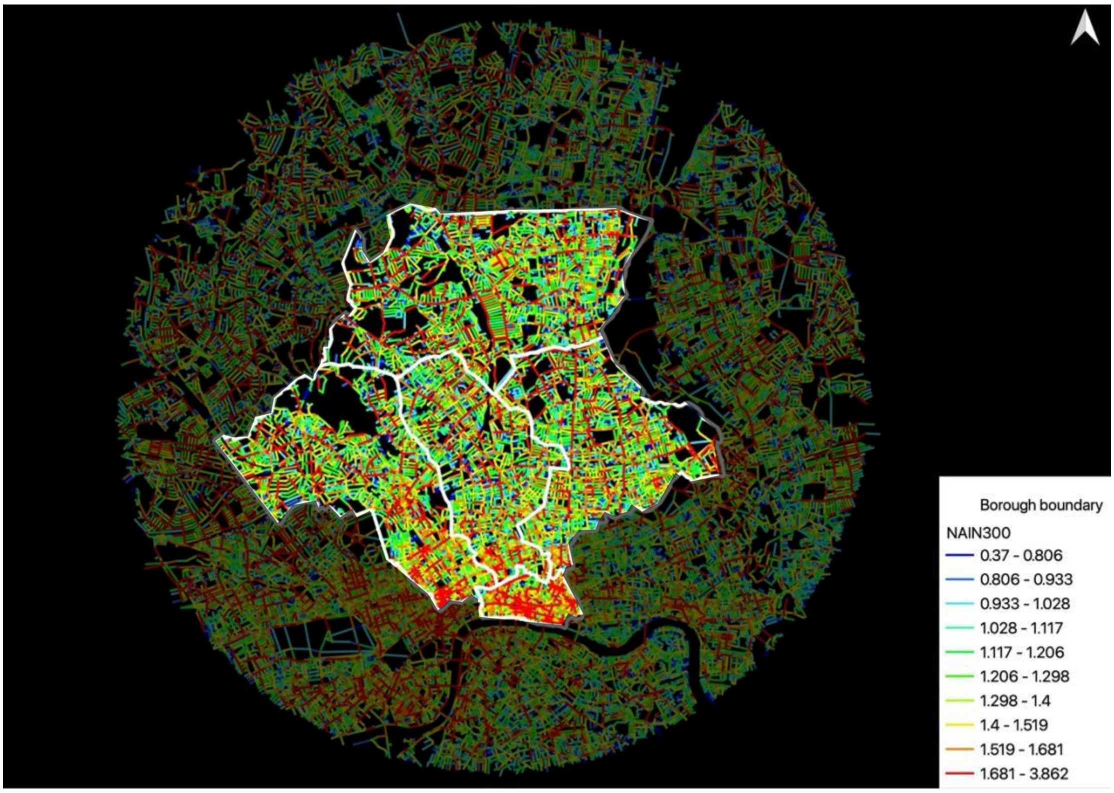


**Figure 26**. NAIN300 of the five boroughs.

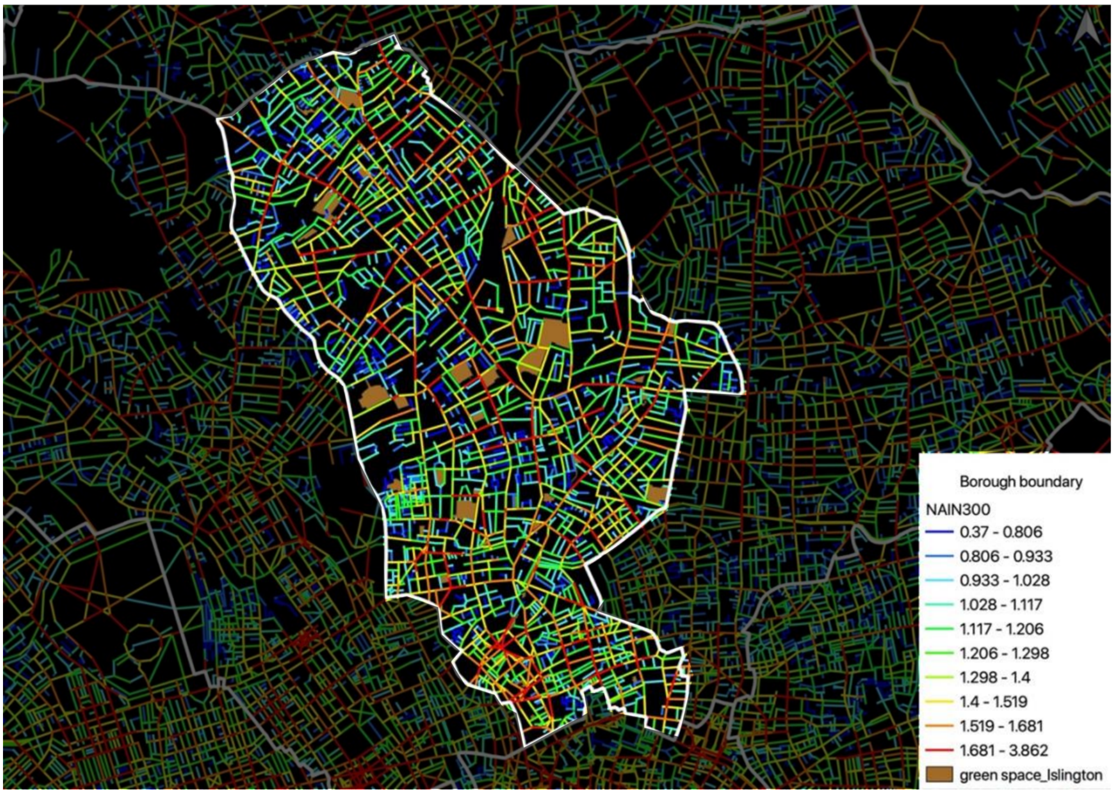


**Figure 27**. NAIN300 of the Borough of Islington.

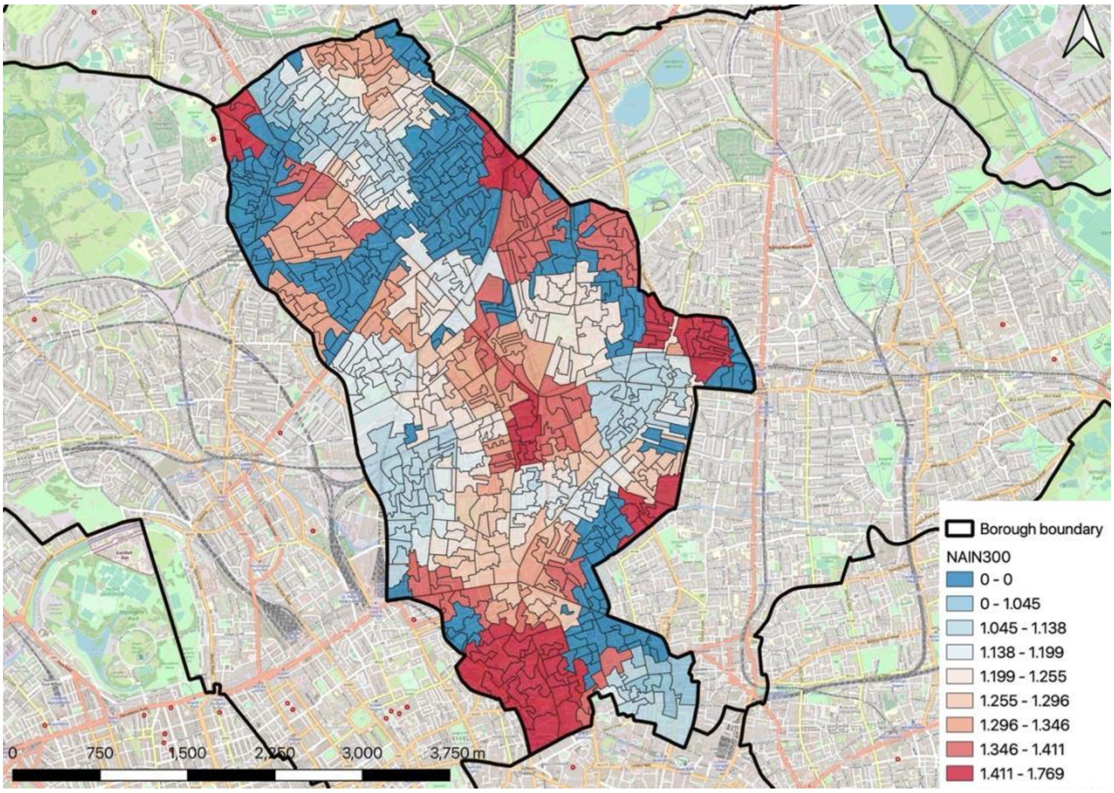


**Figure 28**. Average NAIN300 of the surrounding roads of urban green spaces in Islington that can be accessed.

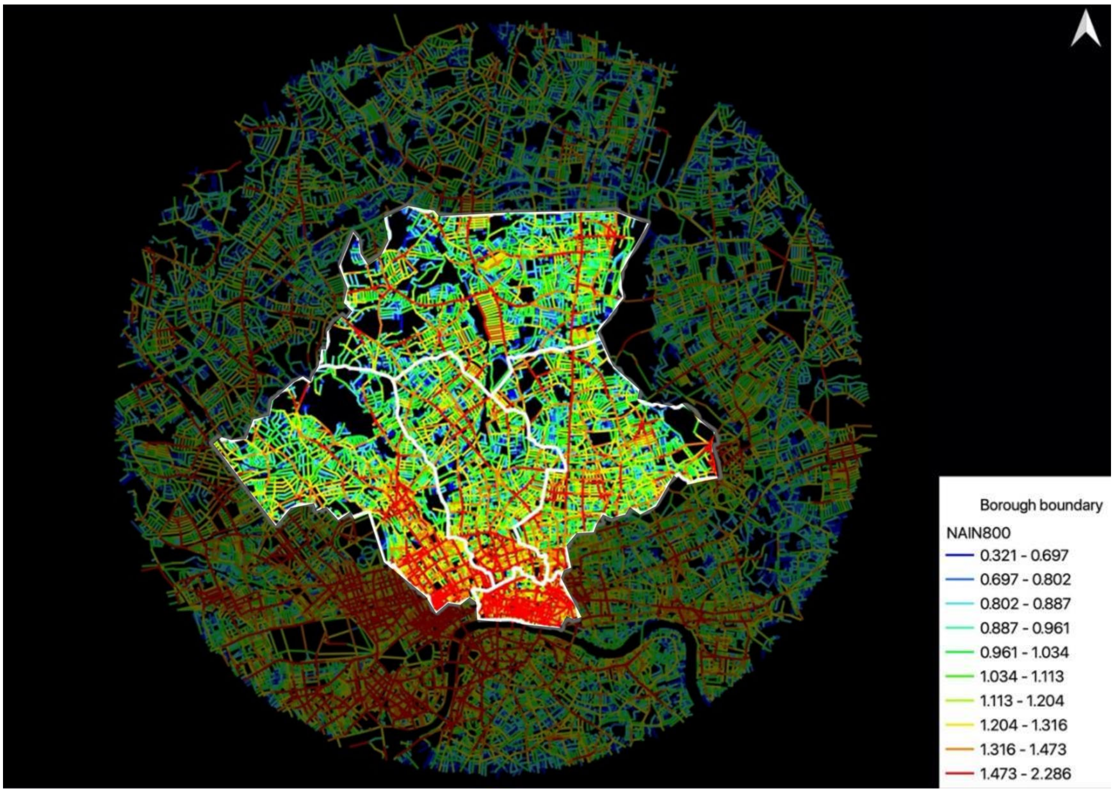


**Figure 29**. NAIN800 of the five boroughs.

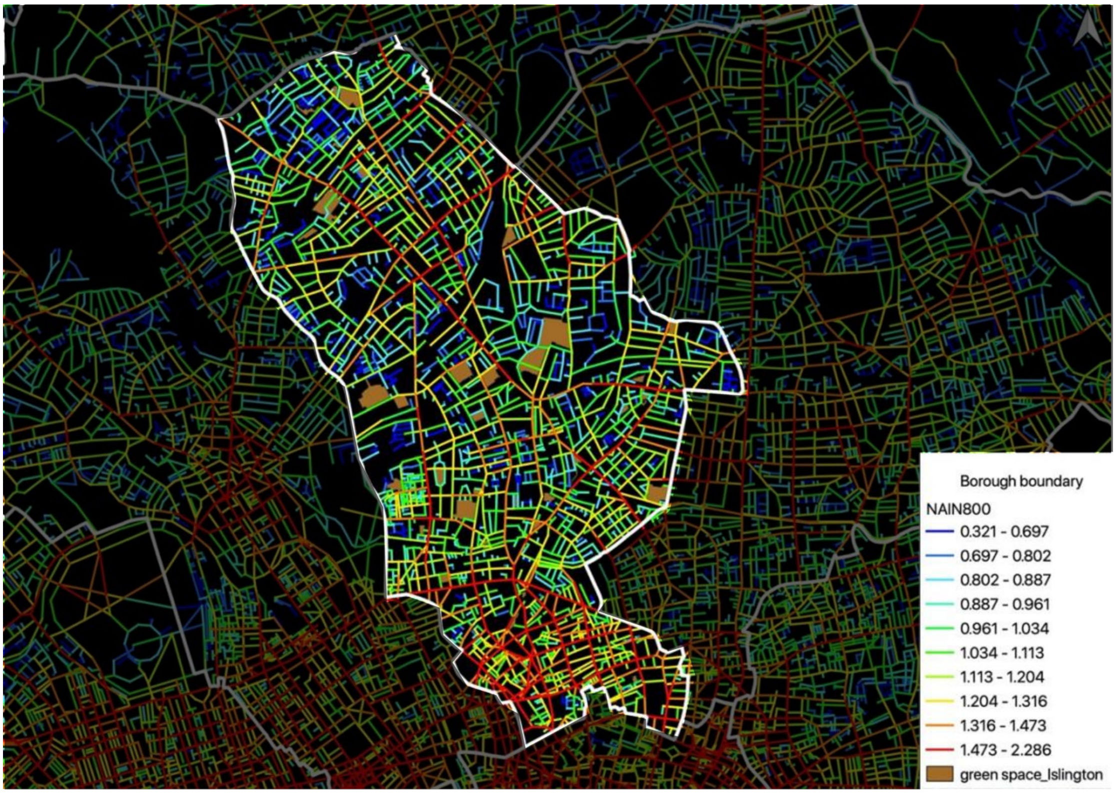


**Figure 30**. NAIN800 of the Borough of Islington.

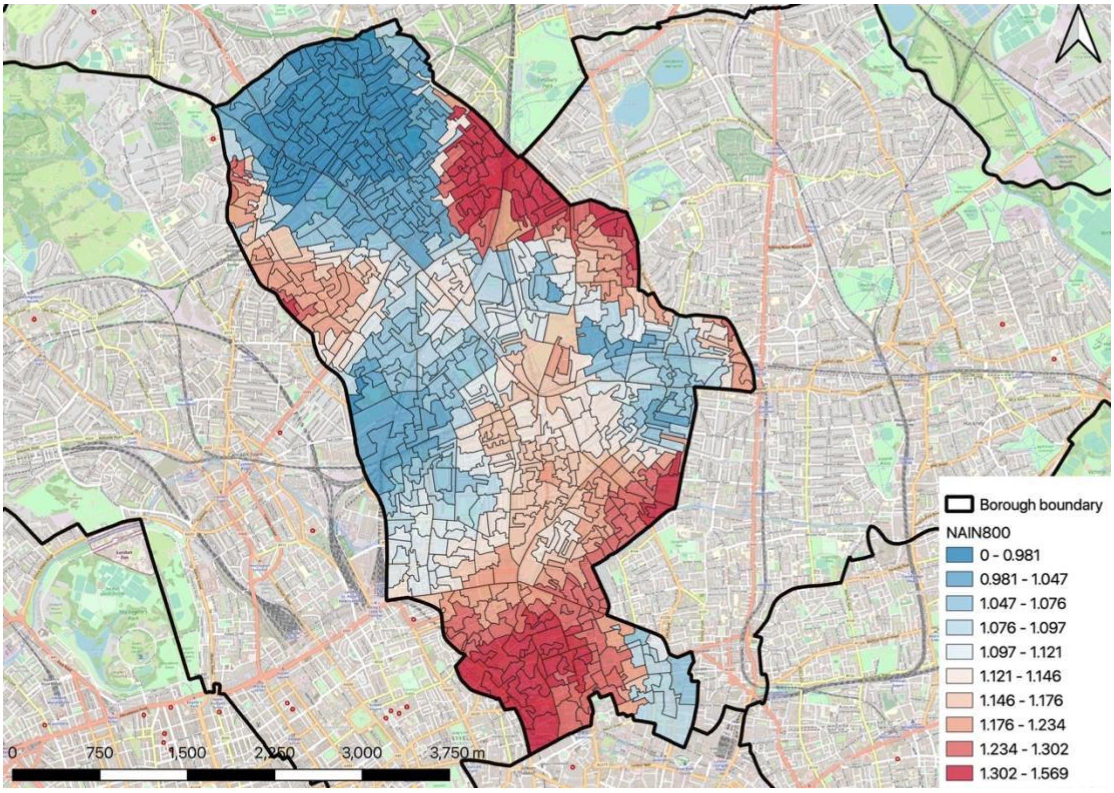


**Figure 31**. Average NAIN800 of the surrounding roads of urban green spaces in Islington that can be accessed.

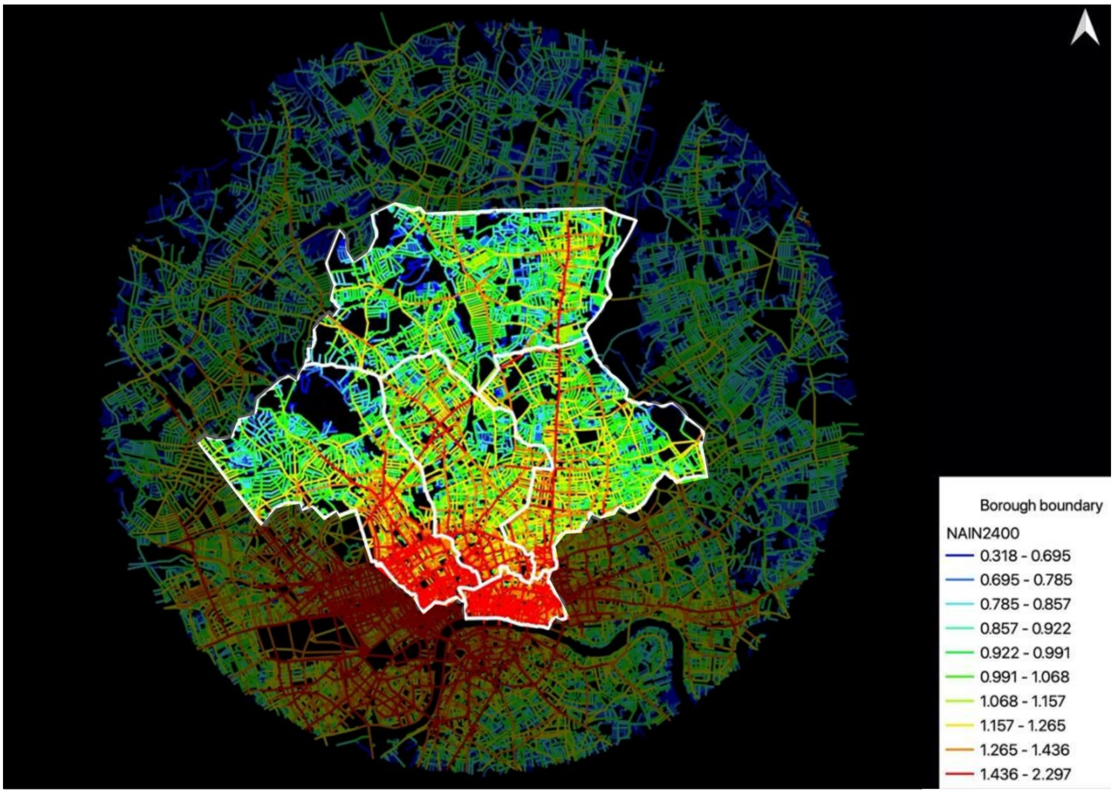


**Figure 32**. NAIN2400 of the five boroughs.

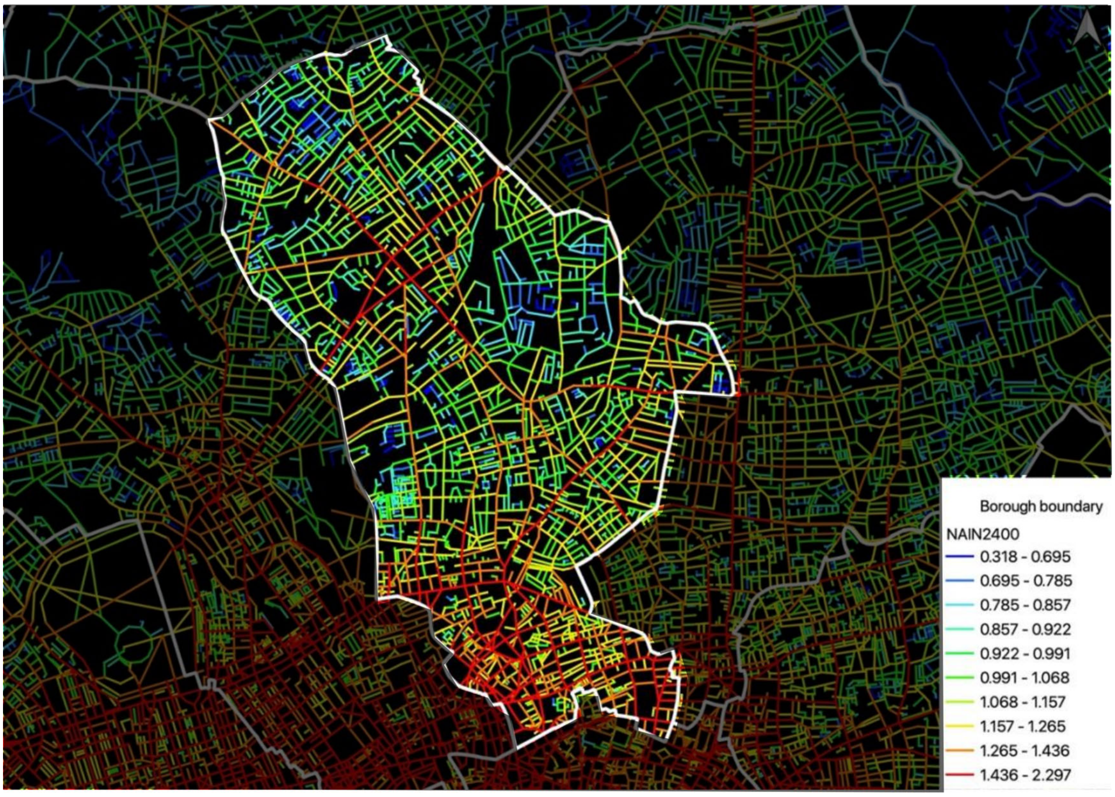


**Figure 33**. NAIN2400 of the Borough of Islington.

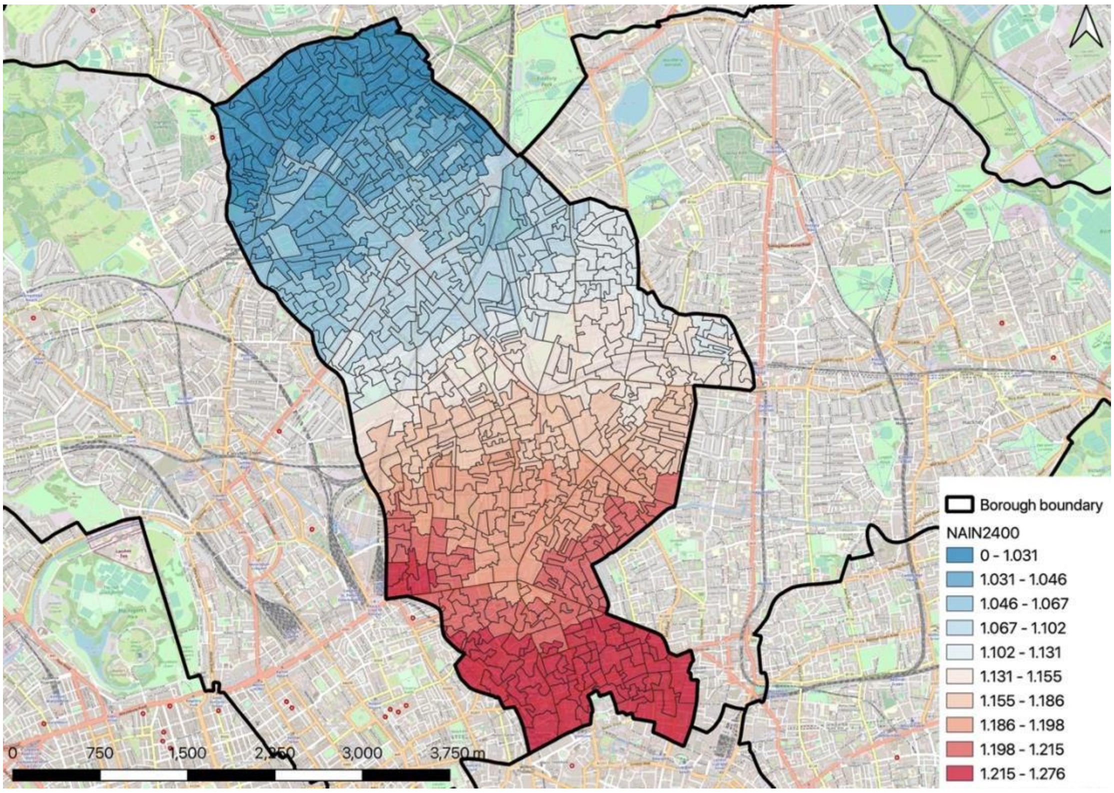


**Figure 34**. Average NAIN2400 of the surrounding roads of urban green spaces in Islington that can be accessed.

Table 11 provides the results of spatial regression models for the average normalised angular integration at different scales of 300m, 800m, and 2400m (NAIN300, NAIN800, NAIN2400) of surrounding roads of urban green spaces that can be accessed. The segment model analysis of NAIN for the study site and the dependent variables for these three spatial regression models are visualised in Figures 26 to 34. The higher the NAIN of the surrounding roads, the more likely the surrounding area of the urban green space to be a destination for people. This may imply a higher centrality with higher pedestrian and traffic flows at a certain scale. At the scale of 300m, the proportion of non-deprived people in an area is significantly and positively correlated with NAIN300, which suggests that an area with a higher percentage of people with 0 deprivation dimension tends to have urban green spaces that are more integrated at the 300m scale. Then, enlarging to the neighbourhood scale of 800m, the NAIN800 manifests a significant and negative correlation with the percentage of Asian Chinese in an area. An area with a higher proportion of Asian Chinese is usually associated with access to urban green spaces that are less integrated at the 800m neighbourhood scale. From the perspective of a 2400m urban scale, NAIN2400 is correlated with the proportions of black African and people deprived in 4 dimensions negatively and significantly, indicating lower urban-scale centrality of the urban green spaces accessed by the area with a higher proportion of black African or people with 4 deprivation dimensions.

**Table 11**. Results of the spatial regression model for centrality (dependent variable = NAIN300, NAIN800, NAIN2400).

| | Coefficient (Standard error) | | |
|---|---|---|---|
| | **NAIN300** | **NAIN800** | **NAIN2400** |
| ***Independent variable*** | | | |
| *Age groups* | | | |
| Age 0-14 % | -0.007<br>(0.009) | 0.001<br>(0.003) | 0.001<br>(0.000) |
| Age 15-19 % | 0.002<br>(0.006) | 0.001<br>(0.002) | 0.001<br>(0.000) |
| Age 65+ % | 0.010<br>(0.006) | 0.003<br>(0.002) | 0.002<br>(0.001) |
| *Ethnic groups* | | | |
| White: British % | 0.008<br>(0.017) | -0.011<br>(0.005) | 0.001<br>(0.000) |
| Black: African % | 0.005<br>(0.005) | -0.002<br>(0.002) | -0.001**<br>(0.000) |
| Asian: Chinese % | 0.004<br>(0.004) | -0.003*<br>(0.001) | 0.001<br>(0.001) |
| *Groups with different deprivation levels* | | | |
| Population with 0 deprivation dimension % | 0.014*<br>(0.017) | 0.002<br>(0.005) | 0.001<br>(0.000) |
| Population with 4 deprivation dimensions % | -0.017<br>(0.010) | 0.003<br>(0.003) | -0.001*<br>(0.001) |
| rho (spatial lag model) | 1.027** | 1.047** | 1.003** |

**Significant at 99% confidence level ($p$<0.01). *Significant at 95% confidence level ($p$<0.05).

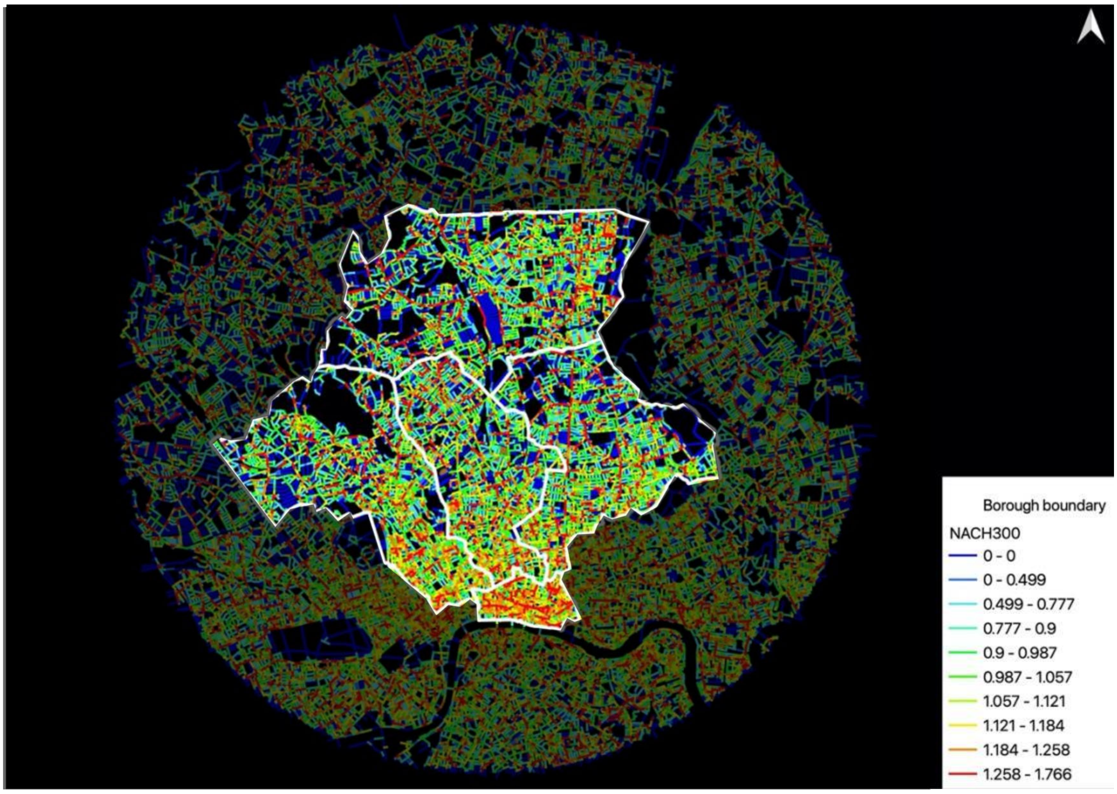


**Figure 35**. NACH300 of the five boroughs.

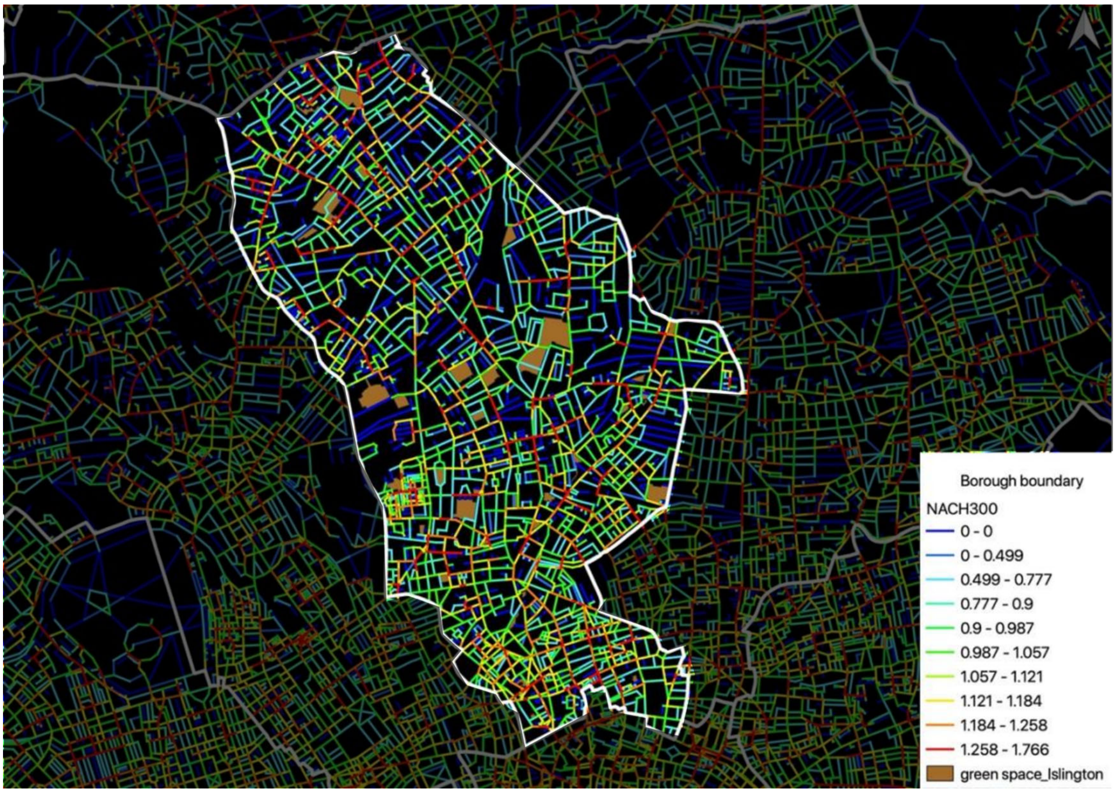


**Figure 36**. NACH300 of the Borough of Islington.

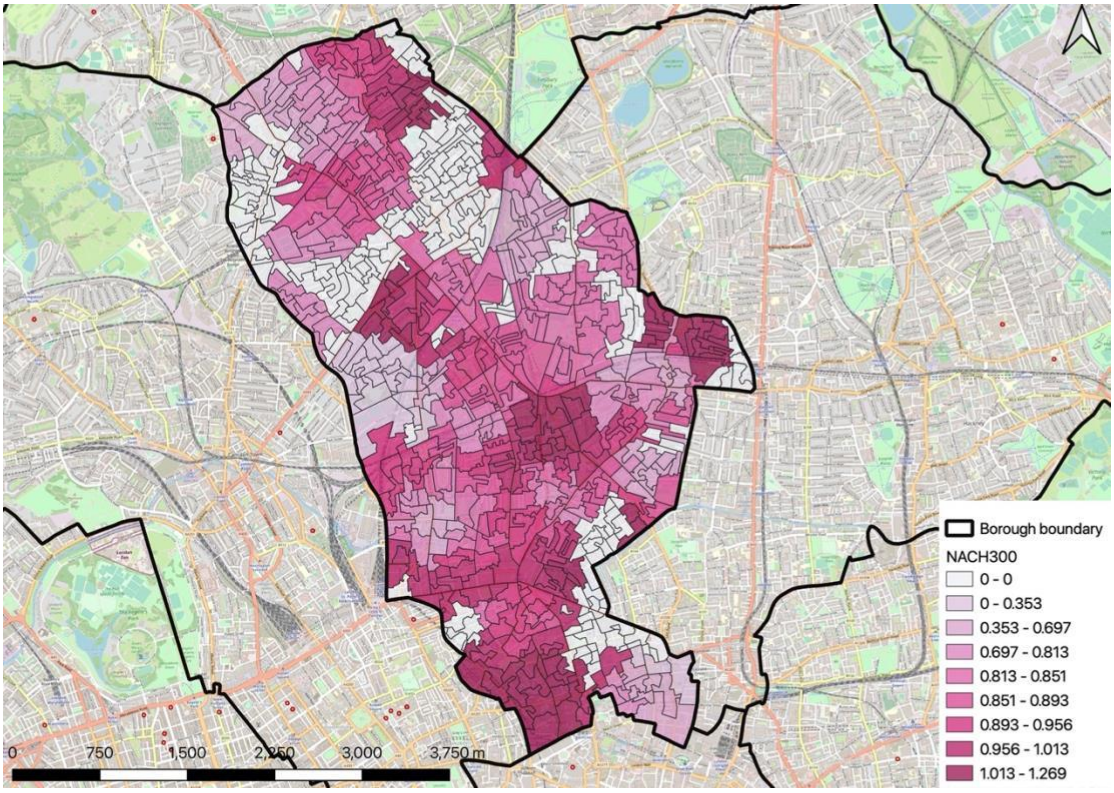


**Figure 37**. Average NACH300 of the surrounding roads of urban green spaces in Islington that can be accessed.

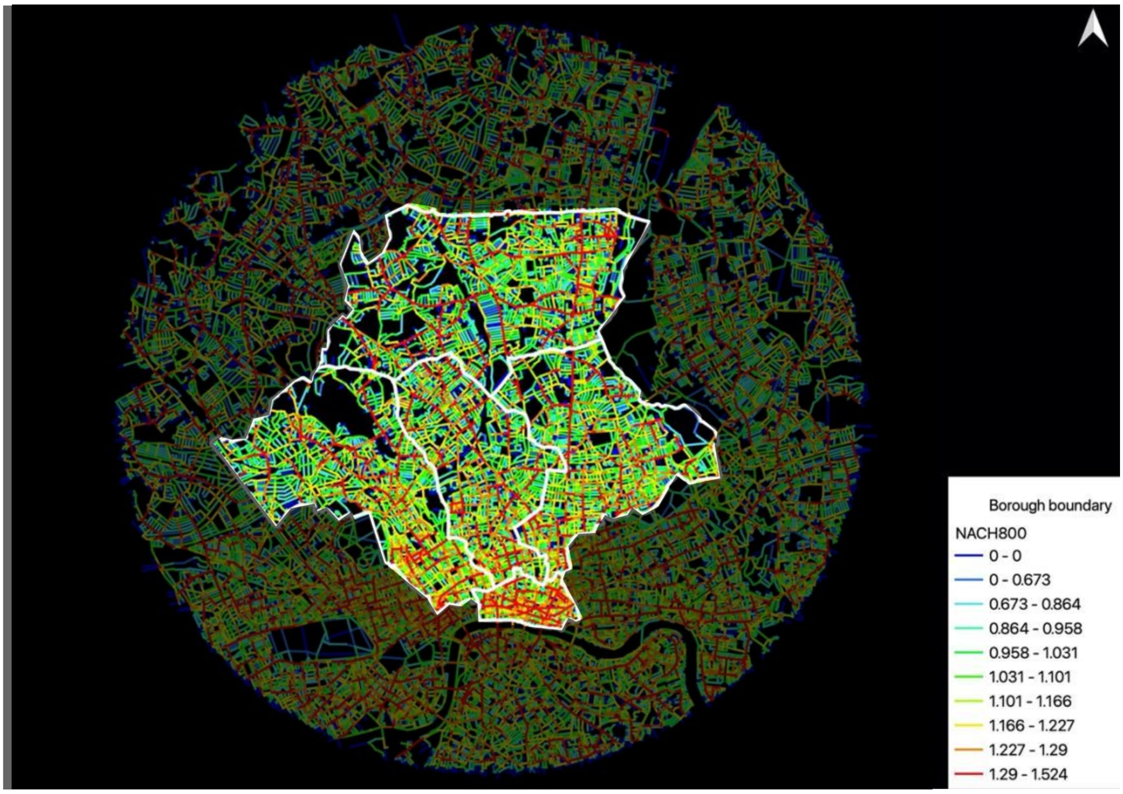


**Figure 38**. NACH800 of the five boroughs.

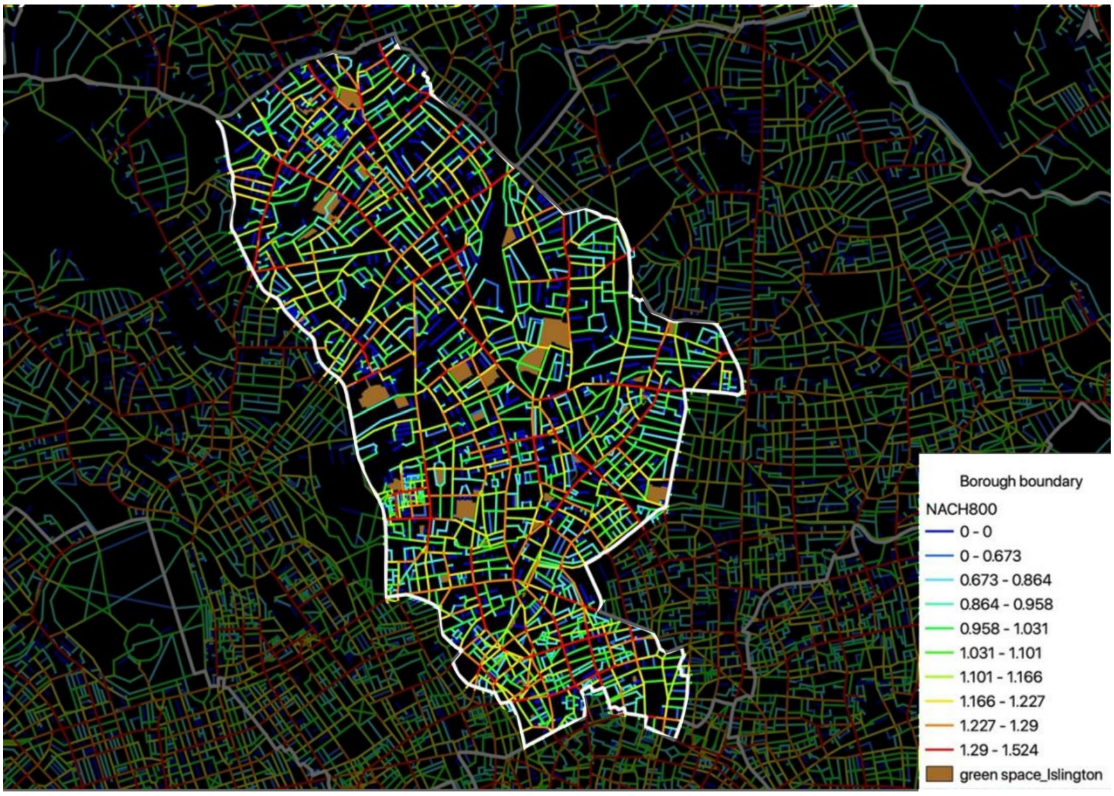

**Figure 39**. NACH800 of the Borough of Islington.

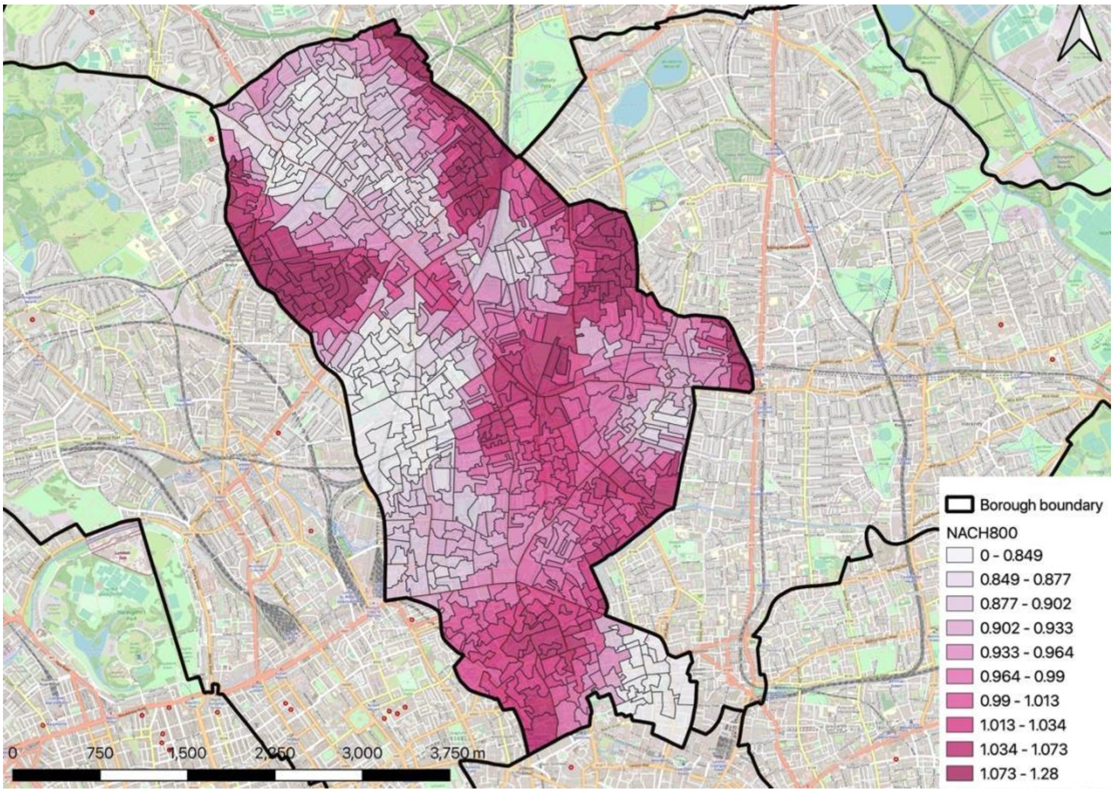

**Figure 40**. Average NACH800 of the surrounding roads of urban green spaces in Islington that can be accessed.

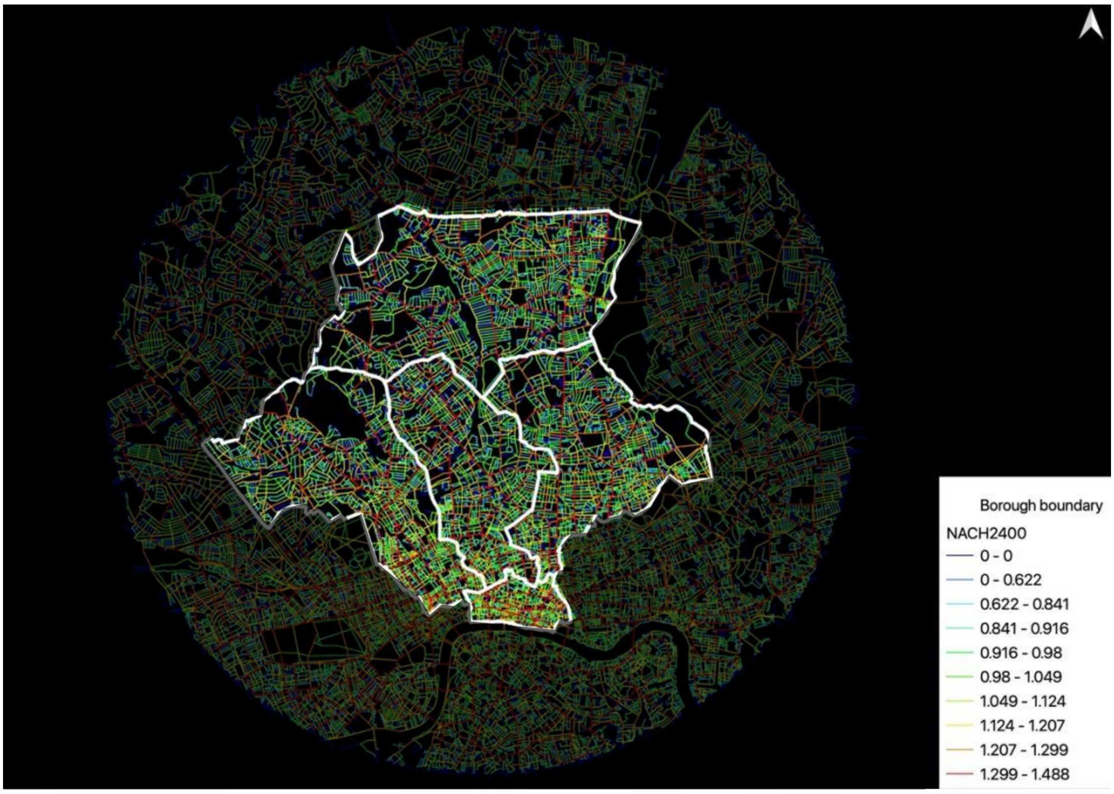


**Figure 41**. NACH2400 of the five boroughs.

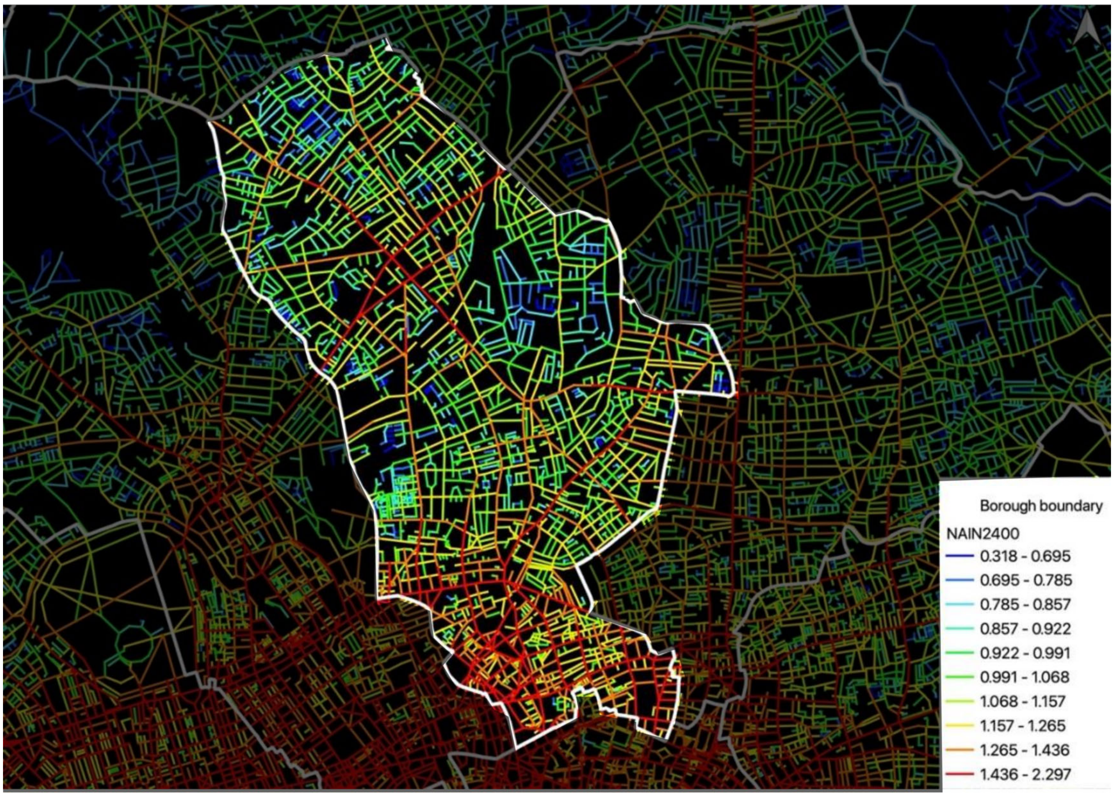


**Figure 42**. NACH2400 of the Borough of Islington.

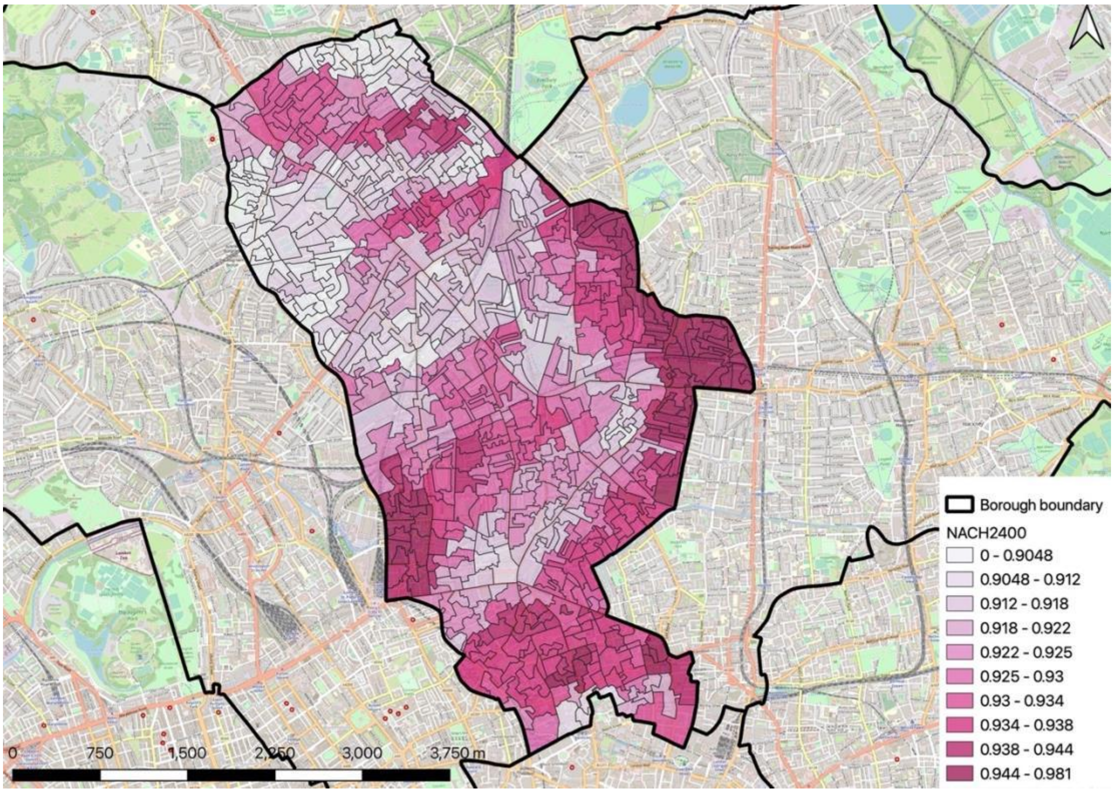

**Figure 43**. Average NACH2400 of the surrounding roads of urban green spaces in Islington that can be accessed.

The normalised angular choice value (NACH) demonstrates the likelihood for people to choose to use the surrounding roads of the urban green space. A higher value of NACH means there may be more pedestrian or vehicular flow around the urban green spaces at a certain scale. The results of the three spatial regression models with NACH at different scales of 300m, 800m, and 2400m (Figure 35 to 43) as dependent variables are shown in Table 12. Only the model for dependent variables of NACH2400 is significantly affected by the control variables. It is suggested that in the neighbourhood scale of 300m and 800m, the average NACH of the surrounding roads of urban green spaces that can be accessed has a significant and negative correlation with the proportion of black Africans. Areas with a higher percentage of black Africans are likelier to have a lower average NACH300 and NACH800 of roads around their accessible urban green spaces. Upon extending to an urban scale of 2400m, an increase in NACH2400 is usually associated with an increase in the proportions of teenagers in an area. Besides, the percentage of non-deprived people is also significantly and positively correlated with access to urban green spaces with a higher average

NACH2400 of their surrounding roads.

**Table 12**. Results of the spatial regression model for centrality (dependent variable = NACH300, NACH800, NACH2400).

| | Coefficient | | |
|---|---|---|---|
| | **NACH300** | **NACH800** | **NACH2400** |
| ***Independent variable*** | | | |
| *Age groups* | | | |
| Age 0-14 % | -0.001<br>(0.002) | 0.003<br>(0.003) | 0.001<br>(0.002) |
| Age 15-19 % | 0.001<br>(0.003) | 0.004<br>(0.003) | 0.002**<br>(0.001) |
| Age 65+ % | 0.001<br>(0.002) | 0.001<br>(0.003) | -0.001<br>(0.001) |
| *Ethnic groups* | | | |
| White: British % | 0.001<br>(0.001) | 0.001<br>(0.002) | -0.001<br>(0.003) |
| Black: African % | -0.001*<br>(0.002) | -0.006*<br>(0.002) | 0.001<br>(0.001) |
| Asian: Chinese % | 0.006<br>(0.004) | 0.002<br>(0.005) | 0.001<br>(0.001) |
| *Groups with different deprivation levels* | | | |
| Population with 0 deprivation dimension % | -0.001<br>(0.001) | 0.002<br>(0.001) | 0.011**<br>(0.003) |
| Population with 4 deprivation dimensions % | -0.008<br>(0.011) | 0.016<br>(0.013) | -0.001<br>(0.002) |
| ***Control variable*** | | | |
| Integration_R2400_max | 0.001<br>(0.001) | 0.000<br>(0.001) | 0.004**<br>(0.001) |
| rho (spatial lag model) | 1.034** | 1.080** | 1.059** |

**Significant at 99% confidence level ($p$<0.01). *Significant at 95% confidence level ($p$<0.05).

## Chapter 5: Discussion

Based on the four-dimension measurement, the access to urban green spaces in Islington of different social groups (Figure 44) and their correlations are analysed in Chapter 4. These findings reveal the existing conditions of proximity, availability, quality, and centrality of urban green spaces in this area, reflecting differences across different social groups. Consequently, it helps get a glimpse of the spatial inequity in accessing urban green spaces in London for social groups categorised by age, ethnicity, and deprivation levels. Therefore, the second research question could be answered in this section.

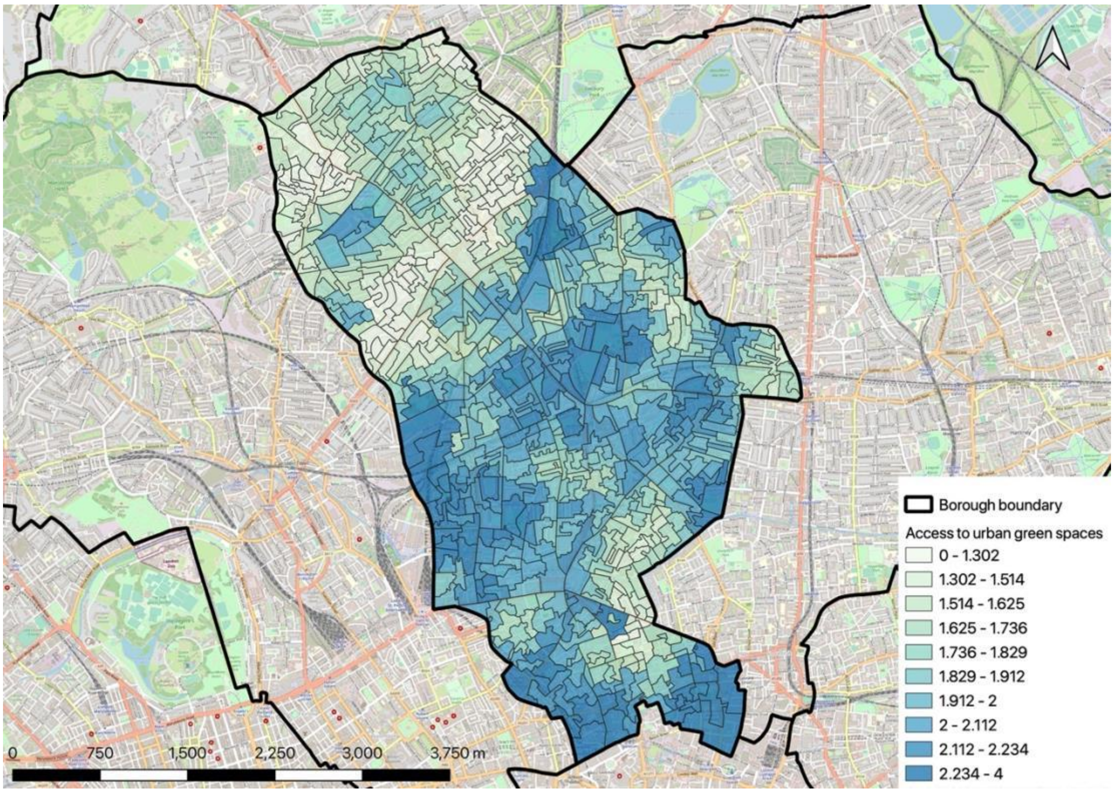


**Figure 44**. A visualisation of the four-dimension measurement results of access to urban green spaces in Islington.

### 5.1. Spatial Inequity of the Access to Urban Green Spaces for Different Age Groups

There exists spatial inequity among different age groups regarding access to urban green spaces. According to the findings, the groups of toddler child and older people encounters relatively insufficient availability of urban green spaces.

People living in an area with a higher percentage of toddlers and children tend to live closer to the nearest urban green space, demonstrating good proximity. An area with a higher proportion of toddlers and children aged from 0 to 14 usually has more people living within the 300m and 800m service areas. However, this age group has a negative correlation with the average acreage of urban green space within an 800 m service area. Although toddlers and children are more likely to live within the urban green space service area, their access to urban green space per capita decreases as this age group increases in an area. This implies a dearth of available urban green spaces per capita for the group aged from 0 to 14 years old. This is to some extent, in line with the prior study in China proposing a negative correlation between the percentage of children and the number of accessible park areas (Wu and Kim, 2020).

The age groups of teenagers aged from 15 to 19 years old usually get more benefits from easy access to urban green spaces. As with the age groups of toddlers and child and older people, the teenager group is more likely to live within an 800m service area of urban green spaces. Besides, the acreage of urban green space per capita within the 800m service area is higher in the area with a greater proportion of teenager, indicating better availability per capita. In addition, the urban green spaces accessed by teenagers often have relatively higher NACH2400, which is usually aligned with higher pedestrian and traffic flows around the urban green spaces. It reflects the teenagers' favourable access to urban green spaces that have higher centrality at the urban scale. The bustling surrounding roads can facilitate unexpected social encounters, contributing to the social interactions in the city. However, this is not necessarily an absolute advantage, as it may also raise some potential safety concerns for teenagers within service area such as traffic accidents.

Older people constitute another demographic group that suffers from insufficient availability. The previous study posited a positive correlation between a higher percentage of older people and increased park acreage (Wu and Kim, 2020). The findings in this research partially support it, as people in an area with a higher proportion of older people tend to have more acreage per capita within both 300m and 800m service areas. However, deviating from previous findings, a higher proportion of older people is aligned with a decrease in the population within the 800m service area of urban green spaces, which suggests that the likelihood of older people living within the 800m service area may be relatively lower.

## 5.2. Spatial Inequity of the Access to Urban Green Spaces for Different Ethnic Groups

In terms of the ethnic perspective, the findings demonstrate an obvious spatial inequity, reflected mainly in the better availability and quality for white British and the lack of proximity of urban green spaces for black Africans. An area may have more population covered by 300m and 800m service areas of urban green spaces as the percentage of white British increases. However, previous research in Leicester, UK, suggests that white and black Africans have 7.5% less access to urban green spaces within 2 km of a 20 ha site than British, with other blacks experiencing 28.4% less (Comber, Brunsdon, and Green, 2008). Drawing parallels between these findings and the findings in this research reveals a high likelihood of spatial inequity between ethnic groups regarding availability. Besides, an area with a higher proportion of white British tends to have urban green spaces with a higher remote POST score, highlighting white British is better than other ethnic minority groups in terms of urban green space quality.

The negative correlations shown between NAIN2400, NACH300, and NACH800 and the proportion of black Africans mean that black Africans are more likely to access to urban green spaces with relatively lower centrality. In other words, black Africans suffer from the disadvantage in obtaining urban green spaces situated at better-connected and prosperous segments of the urban network at both neighbourhood scale and urban scale. The negative correlation between NAIN800 and the proportion of

Asian Chinese also shows a similar inequity of urban green space centrality at neighbourhood scale.

The most intuitive spatial inequity is reflected in the low urban green space proximity of black Africans. When an area has a higher percentage of black Africans, the average distance of the shortest paths from home to the nearest urban green spaces for residents of that area is longer, reflecting the severe inequities in urban green space proximity suffered by this ethnic group.

## 5.3. Spatial Inequity of the Access to Urban Green Spaces for Groups with Different Deprivation Levels

A previous study conducted in Chicago on urban green space accessibility found that accessibility for low-income people is about half that of non-low-income people (Liu, Kwan, and Kan, 2021). These findings tie well with this research that there are spatial inequities in availability, quality, and centrality of urban green space between groups of non-deprived people and most deprived people. The urban green spaces accessed by an area with a high proportion of people deprived in 0 dimension this area tend to be with higher quality, indicating that other deprived people may experience a disadvantage in terms of quality. Besides, there is a higher likelihood for this area to have more population and higher average acreage per capita within the 800m service area of urban green spaces. However, for the proportion of people deprived in 4 deprivation dimensions, the most-deprived people, an area with higher of it tends to have less population living within 800m service area of urban green spaces. This reflects the spatial inequity of urban green space availability for people with different numbers of deprivation dimensions.

This research also presents a spatial inequity of urban green space centrality in groups of different deprivation levels, with the non-deprived group better than the most-deprived group. The positive correlation between NAIN300 and the proportion of non-deprived people implies that the urban green spaces accessed by non-deprived people are often at locations that are better integrated into the road network at a small neighbourhood scale, having higher possibility to be destinations for people. It is also correlated with NACH2400 positively, which also shows the relatively higher centrality of urban space accessed by non-deprived people. In contrast, the negative correlation between NAIN2400 and the people with 4 deprivation dimensions indicates that the urban green spaces accessed by deprived people are less connected to the urban network and may be less likely to become destinations for people travelling at the urban scale.

## Chapter 6: Conclusion

The dissertation begins with an overall presentation of the access to urban green space of different social groups in Islington and its four adjacent boroughs, including the City of London, Camden, Hackney, and Haringey. Drawing upon previous relevant researches, this research defines access to urban green spaces as the combination of four dimensions: proximity, availability, quality, and centrality. This research uses the average shortest path distance from home to the nearest urban green space to represent proximity, availability refers to an area's population and acreage of urban green space per capita within a 300m and 800m service area, quality includes the remote POST score and the average value of integration and choice at the scales of 300m, 800m, and 2400m of the surrounding roads of urban green spaces that the area can access. To explore the correlation between the access to urban green spaces and the different social groups studied in this research, as well as to illuminate its main associations with the spatial inequities faced by different social groups, twelve spatial regression models have been developed for each of the twelve factors that were used to measure the access to urban green spaces, with social groups of age, ethnicity, and number of deprivation dimensions as independent variables.

The results of the research show that there are spatial inequities in the access to urban green spaces by different social groups, and the inequities faced by different social groups have different associations with access to urban green spaces. Regarding different age groups, toddlers, children, and older people are the two disadvantaged groups. The spatial inequity of access to urban green spaces suffered by the two groups is mainly demonstrated regarding availability. From the perspective of ethnic groups, black Africans are the group that faces spatial inequity, mainly in proximity and centrality. Asian Chinese sometimes also face a disadvantage in centrality. The advantages of white British in terms of availability and quality, to some extent, could also imply other ethnic minority groups' spatial inequity in access to urban green spaces. Differences in availability are the main manifestation of the spatial inequities faced by groups with different deprivation levels, potentially extending to less evident differences in proximity and centrality. This research highlights that access to urban green space is a complex phenomenon and that a single factor, such as proximity, may not consider other factors like availability, quality, and centrality. Hence the four dimensions together capture a more comprehensive view. Also, the studied social groups in this research appear to experience spatial inequity in access to urban green spaces quite differently, as pointed out before, showing that looking only at one of these dimensions is insufficient.

This research fills a gap in the local scale research on urban green space that few studies have quantified access to urban green spaces and its spatial distribution for different social groups. This research develops a four-dimensional measurement of access to urban green spaces (Figure 44) and applies a quantitative method consisting of QGIS network analysis, space syntax, and census data. It provides a research framework as well as an analytical model for quantifying access to urban green spaces and analysing its spatial inequity of different social groups. Moreover, the spatial inequities in access to urban green spaces among different social groups obtained through quantitative analysis enable urban planners to identify the needs of different social groups and the specific areas that need to be improved in a more objective way. The next step for this research is to gain a more comprehensive understanding of the spatial distribution of access to urban green spaces among different social groups by extending the scope of urban green spaces to include all types of open spaces with green coverage in London, such as private gardens and sports greens, and considering a wider range of social groups. The scoring tool for urban green space quality could also be improved to reduce the influence of subjective factors. Future research is needed to investigate the actual access to urban green spaces of different social groups and analyse them with data analysis to enhance the credibility of the research. Nevertheless, a more in-depth investigation is required to discuss access to urban green spaces and their spatial inequity for different social groups in conjunction with other social factors, such as cultural practices and differences in perceptions of urban green space usage.

## References


Abubakar, I., & Aina, A. (2006). GIS and Space Syntax: An analysis of accessibility to urban green areas in Doha district of Dammam metropolitan area. *Saudi Arabia*, pp. 1-8.

Ashik, F. R., Mim, S. A., & Neema, M. N. (2020). Towards vertical spatial equity of urban facilities: An integration of spatial and aspatial accessibility. Journal of Urban Management, 9(1), pp. 77-92.

Barbosa, O., Tratalos, J. A., Armsworth, P. R., Davies, R. G., Fuller, R. A., Johnson, P., & Gaston, K. J. (2007). Who benefits from access to green space? A case study from Sheffield, UK. *Landscape and Urban planning*, 83(2-3), pp. 187-195.

Biernacka, M., & Kronenberg, J. (2018). Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. Urban forestry & urban greening, 36, pp. 22-33.

Boone, C. G., Buckley, G. L., Grove, J. M., & Sister, C. (2009). Parks and people: An environmental justice inquiry in Baltimore, Maryland. *Annals of the association of American geographers*, 99(4), pp. 767-787.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The review of economic studies*, 47(1), pp. 239-253.

Comber, A., Brunsdon, C., & Green, E. (2008). Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and urban planning*, 86(1), pp. 103-114.

Davies, R. G., Barbosa, O., Fuller, R. A., Tratalos, J., Burke, N., Lewis, D., ... & Gaston, K. J. (2008). City-wide relationships between green spaces, urban land use and topography. *Urban Ecosystems*, 11, pp. 269-287.

European Environment Agency. (2022). Who benefits from nature in cities? Social inequalities in access to urban green and blue spaces across Europe. [online] Available from: https://www.eea.europa.eu/publications/who-benefits-from-nature-in (Accessed 17th June 2023).

Fasihi, H., & Parizadi, T. (2020). Analysis of spatial equity and access to urban parks in Ilam, Iran. *Journal of environmental management*, 260, 110122.

Fatima, K., Moridpour, S., & Saghapour, T. (2022). Measuring Neighbourhood Walking Access for Older Adults. *Sustainability*, 14(20), 13366.

Fields in Trust. (2020). CHAMPION: The ten-minute walk and why it's important. [online] Available from: https://www.fieldsintrust.org/News/the-ten-minute-walk-and-why-its-important (Accessed 10th July 2023).

Fields in Trust. (2023). CHAMPION: Green Space Index. [online] Available from: https://www.fieldsintrust.org/green-space-index (Accessed 10th July 2023).

He, S., Wu, Y., & Wang, L. (2020). Characterizing horizontal and vertical perspectives of spatial equity for various urban green spaces: a case study of Wuhan, China. *Frontiers in Public Health*, 8, 10.

Hillier, B. and Hanson, J. (1984) "Introduction," in *The Social Logic of Space*. Cambridge: Cambridge University Press, pp. 1–25.

Hillier, B., Burdett, R., Peponis, J., & Penn, A. (1986). Creating life: or, does architecture determine anything?. Architecture & Comportement/Architecture & Behaviour, 3(3), pp. 233-250.

Hillier, W. R. G., Yang, T., & Turner, A. (2012). Normalising least angle choice in Depthmap-and how it opens up new perspectives on the global and local analysis of city space. Journal of Space syntax, 3(2), pp. 155-193.

Islington. (2019). Islington Council Biodiversity Action Plan 2020 to 2025. [online] Available from: https://www.islington.gov.uk/~/media/sharepoint-lists/public-records/communications/publicity/publicconsultation/20192020/20200326islingtonbiodiversityactionplan2020to2025web1.pdf (Accessed 12nd July 2023).

Islington. (2021). State of Equalities in Islington Annual Report 2021. [online] Available from: https://www.islington.gov.uk/-/media/sharepoint-lists/public-records/communications/information/adviceandinformation/20202021/20210311stateofequalities2021.pdf?la=en&hash=ADFF42B574549E55955F36777E0D5AF584649841 (Accessed 12nd July 2023).

Johnson-Gaither, C. (2011). Latino park access: examining environmental equity in a "new destination" county in the south. *Journal of Park and Recreation Administration*, 29(4), pp. 37-52.

Kelobonye, K., McCarney, G., Xia, J. C., Swapan, M. S. H., Mao, F., & Zhou, H. (2019). Relative accessibility analysis for key land uses: A spatial equity perspective. *Journal of Transport Geography*, 75, pp. 82-93.

Le Texier, M., Schiel, K., & Caruso, G. (2018). The provision of urban green space and its accessibility: Spatial data effects in Brussels. *PloS one*, 13(10), e0204684. [online] Available from: https://doi.org/10.1371/journal.pone.0204684 (Accessed 17th August 2023).

Li, X., Huang, Y., & Ma, X. (2021). Evaluation of the accessible urban public green space at the community-scale with the consideration of temporal accessibility and quality. *Ecological Indicators*, 131, 108231.

Litman, T. (2002). Evaluating transportation equity. *World Transport Policy & Practice*, 8(2), pp. 50-65.

Liu, D., Kwan, M. P., & Kan, Z. (2021). Analysis of urban green space accessibility and distribution inequity in the City of Chicago. *Urban Forestry & Urban Greening*, 59, 127029.

Lucy, W. (1981). Equity and planning for local services. *Journal of the American Planning Association*, 47(4), pp. 447-457.

Ma, F. (2020). Spatial equity analysis of urban green space based on spatial design network analysis (sDNA): A case study of central Jinan, China. *Sustainable cities and society*, 60, 102256.

Martens, K., Golub, A., & Robinson, G. (2012). A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. *Transportation research part A: policy and practice*, 46(4), pp. 684-695.

Mayor of London. (2023). Parks and green spaces. [online] Available from: https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/parks-green-spaces-and-biodiversity/parks-and-green-spaces (Accessed 9th July 2023).

Moran, P. A. (1950). Notes on continuous stochastic phenomena. *Biometrika*, 37(1/2), pp. 17-23.

Mouratidis, K. (2020). Neighborhood characteristics, neighborhood satisfaction, and well-being: The links with neighborhood deprivation. *Land use policy*, 99, 104886.

Mullin, K., Mitchell, G., Nawaz, N. R., & Waters, R. D. (2018). Natural capital and the poor in England: Towards an environmental justice analysis of ecosystem services in a high income country. *Landscape and Urban Planning*, 176, pp. 10-21.

Office for National Statistics. (2020). Child poverty and education outcomes by ethnicity. [online] Available from: https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/compendium/economicreview/february2020/childpovertyandeducationoutcomesbyethnicity (Accessed 12nd July 2023).

Office for National Statistics. (2023). Ethnic group variable: Census 2021. [online] Available from: https://www.ons.gov.uk/census/census2021dictionary/variablesbytopic/ethnicgroupnationalidentitylanguageandreligionvariablescensus2021/ethnicgroup#:~:text=Type%3A%20Derived%20variable-,Definition,including%20write%2Din%20response%20options. (Accessed 18th August 2023).

Pikora, T. J., Bull, F. C., Jamrozik, K., Knuiman, M., Giles-Corti, B., & Donovan, R. J. (2002). Developing a reliable audit instrument to measure the physical environment for physical activity. *American journal of preventive medicine*, 23(3), pp. 187-194.

Public Health England. (2020). Improving access to greenspace: A new review for 2020. [online] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904439/Improving_access_to_greenspace_2020_review.pdf (Accessed 9th July 2023).

Rambler. (2020). The grass isn't greener for everyone: Why access to green space matters. [online] Available from: https://cdn.ramblers.org.uk/media/files/ramblers-access-nature-11_0.pdf (Accessed 10th July 2023).

Rigolon, A. (2016). A complex landscape of inequity in access to urban parks: A literature review. *Landscape and Urban Planning*, 153, pp. 160-169.

Schipperijn, J., Stigsdotter, U. K., Randrup, T. B., & Troelsen, J. (2010). Influences on the use of urban green space–A case study in Odense, Denmark. *Urban forestry & urban greening*, 9(1), pp. 25-32.

Sister, C., Wolch, J., & Wilson, J. (2010). Got green? Addressing environmental justice in park provision. *GeoJournal*, 75, pp. 229-248.

Talen, E., & Anselin, L. (1998). Assessing spatial equity: an evaluation of measures of accessibility to public playgrounds. *Environment and planning A*, 30(4), pp. 595-613.

Tannous, H. O., Major, M. D., & Furlan, R. (2021). Accessibility of green spaces in a metropolitan network using space syntax to objectively evaluate the spatial locations of parks and promenades in Doha, State of Qatar. *Urban Forestry & Urban Greening*, 58, 126892.

Taylor, B. T., Fernando, P., Bauman, A. E., Williamson, A., Craig, J. C., & Redman, S. (2011). Measuring the quality of public open space using Google Earth. *American journal of preventive medicine*, 40(2), pp. 105-112.

Taylor, L., & Hochuli, D. F. (2017). Defining greenspace: Multiple uses across multiple disciplines. *Landscape and urban planning*, 158, pp. 25-38.

Tsou, K. W., Hung, Y. T., & Chang, Y. L. (2005). An accessibility-based integrated measure of relative spatial equity in urban public facilities. *Cities*, 22(6), pp. 424-435.

Wen, M., Zhang, X., Harris, C. D., Holt, J. B., & Croft, J. B. (2013). Spatial disparities in the distribution of parks and green spaces in the USA. *Annals of Behavioral Medicine*, 45(suppl_1), S18-S27.

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough'.

*Landscape and urban planning*, 125, pp. 234-244.

Wolch, J., Wilson, J. P., & Fehrenbach, J. (2005). Parks and park funding in Los Angeles: An equity-mapping analysis. *Urban geography*, 26(1), pp. 4-35.

World Health Organization. (2016). Urban green spaces and health: A review of evidence. *World Health Organization: Copenhagen, Denmark*. [online] Available from: https://www.semanticscholar.org/paper/Urban-green-spaces-and-health.-A-review-of-evidence/82cb19489b82d0e136555d60d0f3b210558bfa7c (Accessed 4th July 2023).

World Health Organization. Regional Office for Europe. (2017). *Urban green spaces: a brief for action*. World Health Organization. Regional Office for Europe. [online] Available from: https://apps.who.int/iris/handle/10665/344116 (Accessed 15th June, 2023).

Wu, L., & Kim, S. K. (2020). How Are Green Spaces Distributed among Different Social Groups in Urban China? A National Level Study. *Forests*, 11(12), 1317.

Wu, L., & Kim, S. K. (2021). Exploring the equality of accessing urban green spaces: A comparative study of 341 Chinese cities. *Ecological Indicators*, 121, 107080

Xiao, Y., Li, Z., & Webster, C. (2016). Estimating the mediating effect of privately-supplied green space on the relationship between urban public green space and property value: Evidence from Shanghai, China. *Land Use Policy*, 54, pp. 439-447.

Zhang, X., Lu, H., & Holt, J. B. (2011). Modeling spatial accessibility to parks: a national study. *International journal of health geographics*, 10(1), pp. 1-14.

## Appendix II. Remote POST Tool Scoring Criteria

**Table 1**. New remote POST scoring standard (Source: Taylor et al., 2011).

| **Quality Evaluation Method (new remote POST)** | |
|---|---|
| **Attribute** | **Weight (%)** |
| **Shade along paths** | |
| Very good | 21.05 |
| Good | 16.84 |
| Medium | 12.63 |
| Poor | 8.42 |
| Very poor | 4.21 |
| No paths | 0 |
| **Walking paths present** | 17.31 |
| **Sporting facilities present** | 16.56 |
| **Adjacent ocean or river** | 16.31 |
| **Water feature present** | 10.34 |
| **Quiet surrounding roads (minor road only)** | 9.96 |
| **Lighting present** | |
| Along some paths | 8.47 |
| In some areas | 6.35 |
| In barbeque/play areas only | 4.23 |
| No lighting | 0 |

## Appendix II. Lagrange multiplier test

**Table 2**. Lagrange multiplier test with distance of shortest paths as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 32.541 | 1 | 0.000 |
| Lagrange multiplier | 1026.766 | 1 | 0.000 |
| Robust Lagrange multiplier | 0.217 | 1 | 0.642 |
| Spatial lag: | | | |
| Lagrange multiplier | 1063.41 | 1 | 0.000 |
| Robust Lagrange multiplier | 36.861 | 1 | **0.000** |

**Table 3**. Lagrange multiplier test with population within 300m service area as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 27.643 | 1 | 0.000 |
| Lagrange multiplier | 729.627 | 1 | 0.000 |
| Robust Lagrange multiplier | 11.513 | 1 | **0.001** |
| Spatial lag: | | | |
| Lagrange multiplier | 745.931 | 1 | 0.000 |
| Robust Lagrange multiplier | 27.817 | 1 | **0.000** |

**Table 4**. Lagrange multiplier test with population within 800m service area as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 29.484 | 1 | 0.000 |
| Lagrange multiplier | 844.38 | 1 | 0.000 |
| Robust Lagrange multiplier | 2.113 | 1 | 0.146 |
| Spatial lag: | | | |
| Lagrange multiplier | 881.848 | 1 | 0.000 |
| Robust Lagrange multiplier | 39.582 | 1 | **0.000** |

**Table 5**. Lagrange multiplier test with green acreage per capita within 300m service area as dependent variable.

| **Test** | **Statistic** | **d*f*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 22.047 | 1 | 0.000 |
| Lagrange multiplier | 470.478 | 1 | 0.000 |
| Robust Lagrange multiplier | 1.519 | 1 | 0.218 |
| Spatial lag: | | | |
| Lagrange multiplier | 487.986 | 1 | 0.000 |
| Robust Lagrange multiplier | 19.026 | 1 | **0.000** |

**Table 6**. Lagrange multiplier test with green acreage per capita within 800m service area as dependent variable.

| **Test** | **Statistic** | **d*f*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 6.838 | 1 | 0.000 |
| Lagrange multiplier | 43.848 | 1 | 0.000 |
| Robust Lagrange multiplier | 42.946 | 1 | **0.000** |
| Spatial lag: | | | |
| Lagrange multiplier | 17.223 | 1 | 0.000 |
| Robust Lagrange multiplier | 16.32 | 1 | **0.000** |

**Table 7**. Lagrange multiplier test with average remote POST score as dependent variable.

| **Test** | **Statistic** | **d*f*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 35.347 | 1 | 0.000 |
| Lagrange multiplier | 1212.540 | 1 | 0.000 |
| Robust Lagrange multiplier | 25.344 | 1 | **0.000** |
| Spatial lag: | | | |
| Lagrange multiplier | 1267.240 | 1 | 0.000 |
| Robust Lagrange multiplier | 80.044 | 1 | **0.000** |

**Table 8**. Lagrange multiplier test with NAIN300 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 23.718 | 1 | 0.000 |
| Lagrange multiplier | 546.697 | 1 | 0.000 |
| Robust Lagrange multiplier | 0.325 | 1 | 0.569 |
| Spatial lag: | | | |
| Lagrange multiplier | 574.612 | 1 | 0.000 |
| Robust Lagrange multiplier | 28.24 | 1 | **0.000** |

**Table 9**. Lagrange multiplier test with NAIN800 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 37.895 | 1 | 0.000 |
| Lagrange multiplier | 1401.829 | 1 | 0.000 |
| Robust Lagrange multiplier | 5.618 | 1 | **0.018** |
| Spatial lag: | | | |
| Lagrange multiplier | 1478.753 | 1 | 0.000 |
| Robust Lagrange multiplier | 82.541 | 1 | 0.089 |

**Table 10**. Lagrange multiplier test with NAIN2400 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 38.518 | 1 | 0.000 |
| Lagrange multiplier | 1448.441 | 1 | 0.000 |
| Robust Lagrange multiplier | 1.016 | 1 | 0.314 |
| Spatial lag: | | | |
| Lagrange multiplier | 1672.082 | 1 | 0.000 |
| Robust Lagrange multiplier | 224.657 | 1 | **0.000** |

**Table 11**. Lagrange multiplier test with NACH300 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 24.528 | 1 | 0.000 |
| Lagrange multiplier | 581.215 | 1 | 0.000 |
| Robust Lagrange multiplier | 0.190 | 1 | 0.663 |
| Spatial lag: | | | |
| Lagrange multiplier | 602.916 | 1 | 0.000 |
| Robust Lagrange multiplier | 21.892 | 1 | **0.000** |

**Table 12**. Lagrange multiplier test with NACH800 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 36.198 | 1 | 0.000 |
| Lagrange multiplier | 1280.596 | 1 | 0.000 |
| Robust Lagrange multiplier | 2.034 | 1 | 0.154 |
| Spatial lag: | | | |
| Lagrange multiplier | 1331.169 | 1 | 0.000 |
| Robust Lagrange multiplier | 52.607 | 1 | **0.000** |

**Table 13**. Lagrange multiplier test with NACH2400 as dependent variable.

| **Test** | **Statistic** | ***df*** | ***p*-value** |
|---|---|---|---|
| Spatial error: | | | |
| Moran's I | 5.700 | 1 | 0.000 |
| Lagrange multiplier | 181.067 | 1 | 0.000 |
| Robust Lagrange multiplier | 1.588 | 1 | 0.208 |
| Spatial lag: | | | |
| Lagrange multiplier | 952.117 | 1 | 0.000 |
| Robust Lagrange multiplier | 772.638 | 1 | **0.000** |