

Title

Regional Disparities in Access to Urban Parks in Osaka City, Japan: Spatial Analysis
Using Socioeconomic Proxy Indicators

Concise and informative title

Park Equity in Osaka: A Socioeconomic Spatial Analysis

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Abstract

Urban parks improve the quality of the living environment by forming open spaces where people can engage in static and dynamic activities. However, access to urban parks may be uneven and associated with socioeconomic disparities. Because urban parks allow different activities depending on their size, studying their access by size is necessary. This study examined effective socioeconomic status (SES) proxy indicators and the spatial association between SES proxy indicators and access to urban parks by size in Osaka City, Japan. The results revealed that the average percentage of professional and managerial workers, years of schooling, and roadside land price may be effective SES proxy indicators in Osaka City. The relationship between the three SES proxy indicators and access to urban parks varied according to park size. The northern area of the city center was found to have higher values of the SES proxy indicators and better access to large urban parks. On the other hand, the western area of the city, except for the northwest area along the Yodogawa River, had lower values of the SES proxy indicators and had poorer access to large urban parks but better access to small and medium urban parks. In particular, the southeastern part of the city, except for the farthest southeast, had lower values in the SES proxy indicators and poorer access to all sizes of urban parks, indicating the need for a prioritized supply.

Keywords

Park accessibility, park equity, socioeconomic index, city planning, landscape planning

1. Introduction

Urban parks are essential as green spaces in cities. They improve the quality of the living environment by forming open spaces where people can engage in static and dynamic activities. Many studies have been conducted on urban green spaces' physical and mental health-promoting effects on residents. For example, older people living within 1 km of green spaces exercise 20% more frequently (Hanibuchi *et al.* 2011). Urban green spaces positively impact the life satisfaction and mental health of neighborhood residents (Aoshima *et al.* 2017). “Health Japan 21 (the second phase)” was applied by the Ministry of Health, Labour and Welfare in 2013; it prioritizes the reduction of health disparities (Ministry of Health, Labour and Welfare 2012). In this context, a quantitative increase in the area and number of urban parks is expected (Mitchell and Popham 2008).

In Japan, urban parks under the Ministry of Land, Infrastructure, Transport and Tourism are classified into different types according to their size and purpose. Smaller parks are classified as City Block Parks (*Gaiku Koen*), Neighborhood Parks (*Kinrin Koen*), and Community Parks (*Chiku Koen*), whereas relatively large parks are classified as Comprehensive Parks (*Sogo Koen*), Sports Parks (*Undo Koen*), Regional Parks (*Koiki Koen*), and others. Before the 2003 revision of the enforcement ordinance of the Urban Parks Act (*Toshi Koen Ho*), specific numerical values for attraction distance and site area were stipulated for each park type to ensure the systematic securing of urban parks (Ministry of Land, Infrastructure, Transport and Tourism 2018). Although numerical values of attraction distances are less common today, ensuring that each type of urban park is evenly distributed and that all residents can use them under similar conditions remains essential.

However, previous studies have indicated that access to green spaces, including urban parks, is uneven and is associated with social and economic disparities, such as differences in occupation and income (Wüstemann *et al.* 2017; Yasumoto *et al.* 2014). In Germany, a household earning more than 5,000 EUR had about 11,000 m² more urban green space within a 500 m buffer around their residence than a household earning less than 1,300 EUR (Wüstemann *et al.* 2017). In Yokohama City, the area and number of parks based on the census 1 km grid analysis were strongly positively correlated with the proportion of professional and managerial workers (Yasumoto *et al.* 2014). Between 1988 and 2005, 125 urban parks were established in areas with a high proportion of these workers, whereas 59 urban parks were established in areas with a low proportion (Yasumoto *et al.* 2014). Although the mechanisms underlying social and economic disparities in access to urban parks have not been fully clarified, the following possible reasons have been suggested in previous studies: First, more affluent or socially advantaged communities may have the political influence to attract amenities such as parks (Boone *et al.* 2009). Second, even in areas where property prices are relatively high, the affluent may move to areas with better environments, such as parks (Boone *et al.* 2009; Jones *et al.* 2009).

Various indicators, such as household income, educational background, number of unemployed persons, and race, have been used as socioeconomic status (SES) proxy indicators in studies on social inequality overseas (Klompmaker *et al.* 2023). In Japan, due to the limited availability of official statistics, occupations, educational backgrounds, and homeownership percentages, which can be obtained from census data, are often used (Uesugi and Yasumoto 2018). However, examining the effectiveness of SES proxy

indicators remains necessary as the context in which socioeconomic disparities emerge depends on the cultural and socioeconomic characteristics of the study area.

Because social disparity is a problem of inequality among individuals, increasing the resolution of regional units is important (Sato *et al.* 2007). Studies on access to urban parks have been actively conducted outside Japan, and many use census blocks as reliable data (Estabrooks *et al.* 2003; Wen *et al.* 2013). In Japan, few studies have been conducted on the access to urban parks using the smallest spatial unit of the census. Furthermore, even in a study of access to urban parks using the smallest spatial unit of the census (Yasumoto *et al.* 2021), the spatial association between SES proxy indicators and access to urban parks has not been examined. As it is pointed out that the establishment of parks by the government in deprived areas with limited parks can be the most effective measure of the inequity of objective park accessibility (Yasumoto *et al.* 2014), we need to identify such areas by spatial analysis. Additionally, while some studies have addressed access to urban parks, many have ignored the park size (McConnachie and Shackleton 2010; Lachowycz and Jones 2014). Park size is an important parameter to consider as urban parks will allow different activities depending on their size, and thus, differently impact their users. Therefore, this study examined effective SES proxy indicators and clarified the spatial association between SES proxy indicators and access to urban parks according to park size using the smallest census unit. Osaka City, where the social disparity is significant, was used as a case study.

2. Methods

2-1 Study area

Osaka City was selected as the target city. It has the second largest population (estimated at 2,753,149 inhabitants as of June 1, 2022) and the highest population density (12,208 inhabitants per square kilometer as of October 1, 2021) among the 20 government-ordinance-designated cities in Japan (Osaka City 2022). Osaka City has a large social disparity between areas. There are areas in the inner city where a large number of low-income residents reside (Toyoda 2012). Among the 24 wards, Fukushima Ward has the smallest public assistance proportion (0.99%), while Nishinari Ward has the greatest (23.00%) (Osaka City 2021a). Osaka City has little natural greenery, such as mountains and forests, and the city has been working to increase the amount of greenery mainly through establishing urban parks based on city planning (Osaka City 2021b). However, having the least number of urban parks among the government-ordinance-designated cities is considered a problem. While the average park area per capita for all the government-ordinance-designated cities is 6.9 m²/person, Osaka City has 3.5 m²/person (Ministry of Land, Infrastructure, Transport and Tourism 2022). Therefore, Osaka City is the best subject in Japan for examining the relationship between socioeconomic disparities and access to urban parks. In addition, the conclusions of this study may be directly reflected in Osaka City's urban policies.

2-2 Urban park polygons

The polygon data of parks were obtained from “Urban Parks and Green Spaces (Polygons)” provided by the Osaka City Construction Bureau, acquired on October 22, 2021, and “City Planning Parks and Green Spaces (Polygons)” provided by the Osaka City Planning Bureau, acquired on October 26, 2021. Kyuho-ji Ryokuchi and Tsurumi-Ryokuchi, two large-scale parks, have some park sites that extend outside the

city boundaries; however, we included the extended areas in the analysis by considering the actual situation of the park use. Google Earth Pro was used to remove parks that had not yet been developed and playgrounds located within facilities. The polygon data of urban parks with the above modifications are presented in Figure 1.

2-3 SES proxy indicators and basic resident attributes by subregion

The Census is Japan's only survey that covers all individuals and households living in the country, and it is conducted every five years. To conduct spatial analysis at higher resolution, we used data from the Census Subregional Tabulations (*Kokusei Chosa Shochiiki Shukei*), statistics compiled by dividing the entire Japan into approximately 220,000 survey area units as subregions. The subregions are units based on *Cho Cho* and *Aza*, which are smaller than cities, towns, and villages, and are the smallest spatial units for tabulations published by the Statistics Bureau of Japan in the Census. We derived four SES proxy indicators (occupation, educational background, homeownership, and marital status) from the 2020 Census Subregional Tabulations surveyed in October 2020, in addition to the property tax roadside land price, which was socioeconomic and geographic data publicly available in Osaka City.

For occupation, we calculated the average percentage of “Professional and Engineering Workers” and “Administrative and Managerial Workers” in each subregion, as they are considered high-income earners (Shavers 2007; Yoshimura 2013; Yasumoto *et al.* 2021). This average will be called “the professional and managerial occupation percentage average.”

Higher educational attainment is associated with a higher likelihood of working in an occupation that is considered to have a high social status or provide a high income (Lahelma *et al.* 2004). Therefore, educational background can be used as an indicator in

studies dealing with SES (Cradock *et al.* 2005; Dai 2011). In this study, we calculated the average number of years of schooling in each subregion by allocating values according to educational background: 9 for junior high school graduates, 12 for high school graduates, 14 for technical and junior college graduates, 16 for university graduates, and 18 for graduate school graduates. This value will be referred to as “years of schooling.”

It is known that there is a positive correlation exists between individual income and land prices (Kabba and Li 2011). Therefore, we assume that the land price represents SES primarily in terms of housing costs because it is related to the purchase or rental price of a house and the amount of property tax paid. We analyzed the property tax roadside land price, which is the unit price of land used to calculate the fixed property tax assessment value of land, and represents the price of a standard piece of land adjacent to a road. We calculated the average property tax roadside land prices within each subregion, weighted by the length of roads, as land prices were provided for each section of the roads.

We used the homeownership percentage as a proxy indicator of income (Shavers 2007; Wendel *et al.* 2011) and calculated it in each subregion. In Japan, people who have never married tend to have a more challenging economic situation than married people (Nagai 2016). We calculated the percentage of married people in each subregion. Finally, we also calculated basic resident attributes in each subregion: the percentage of the juvenile population under 15 years old, the percentage of the working-age population between 15 and 65 years old, the percentage of the elderly population 65 years or older, and the percentage of the male population.

To calculate SES proxy indicators, we obtained the following data from the 2020 Census Subregional Tabulations: “Employment Status and Occupation (Major Groups),” “Type of Last School Completed,” “Private Household Members by Tenure of Dwelling,” and “Marital Status.” In census data, areas with small populations are set as “secret areas” to prevent the identification of individuals, and their statistical information is combined with that of neighboring areas. In this study, the polygons of the 28 secret areas were combined with those of the neighboring areas. Additionally, we obtained property tax roadside land price data from the Osaka City Finance Bureau on July 2, 2021. Household income data are limited and cannot be obtained from the Japanese Census. For basic resident attributes, we obtained data on “Population by Sex and Age (Five-year Groups)” from the 2020 Census Subregional Tabulations.

Income level may better represent SES, but the Japanese Census does not include items on annual income or savings. Meanwhile, the annual income per household is surveyed using the Family Income and Expenditure Survey. However, it is a sample survey of approximately 9,000 households nationwide (Ministry of Internal Affairs and Communications 2023). It is not suitable for examining geographic distribution at the subregional level, as in this study. Therefore, income level was not used as a proxy SES indicator in this study.

2-4 Classification of urban parks

We used two data sources from the Osaka City Construction Bureau and the Osaka City Planning Bureau to cover as many urban parks as possible. Not all parks were identified as urban parks by the Ministry of Land, Infrastructure, Transport and Tourism and were assigned a park type. Although some studies have analyzed access to urban parks by focusing on specific park types (Shimomura *et al.* 1995; Hanaoka *et al.* 2000), residents

usually use urban parks without being aware of their administrative designation. Therefore, we analyzed all parks considering that attraction distance and residents' park use vary depending on park size (Holman *et al.* 1996; Giles-Corti *et al.* 2005). Accordingly, we classified urban parks in Osaka City into three classes according to their size: large (≥ 8 ha), medium (1–8 ha), and small (< 1 ha) parks. We set the upper threshold at 8 ha because all Comprehensive Parks, Sports Parks, and Regional Parks are ≥ 8 ha, and the lower threshold at 1 ha because all City Block Parks are < 1 ha.

2-5 Evaluation of access from each subregion to urban parks

According to the Ministry of Land, Infrastructure, Transport and Tourism's 2014 survey on urban park usage, the park types with larger area had the greater proportion of users who come from far away in terms of the estimated distance from the respondent's address to the park (Ministry of Land, Infrastructure, Transport and Tourism 2014). The top three distance categories were " ≤ 250 m," "250–500 m," and "500 m to 1 km" for the City Block Parks, "250–500 m," "500 m to 1 km," and "1–2.5 km" for Neighborhood Parks and Community Parks. On the other hand, the distance categories for Comprehensive Parks and Sports Parks were "1–2.5 km," "2.5–5 km," and "5–10 km." Although the access to urban parks to residents is influenced by spatial and cultural factors, such as the quantity and quality of green space and user characteristics (Giles-Corti *et al.* 2005), physical activity increases substantially for residents living within walking distance of green space compared to those living farther out (Gordon-Larsen *et al.* 2006). Therefore, having urban parks close to residential areas is essential. This study examined the area and number of urban parks within a 1-km radius to evaluate the access of neighborhood residents. This buffer size is consistent with the neighborhood walking distance reported in previous studies (Moudon *et al.* 2006;

Mouratidis and Yiannakou 2022; Bartzokas-Tsiompras and Bakogiannis 2023; Kim *et al.* 2023). Furthermore, children and the elderly, who are in high demand for parks, can have limited means of transportation. The existence of urban parks within easy walking distance would, therefore, benefit them. This study also examined the area and number of urban parks within a 250-m radius. This buffer size corresponds to the attraction distance of City Block Parks before the 2003 revision of the enforcement ordinance of the Urban Parks Act (Ministry of Land, Infrastructure, Transport and Tourism 2018). Miwa (2023) pointed out that the main place parents go out with their young children is the City Block Parks. In addition, the 2010 Nationwide Urban Transportation Characteristics Survey (*Zenkoku Toshi Kotsu Tokusei Chosa*) showed that 27% of people aged 75 and above in the three major metropolitan areas could walk less than 300 m (Ministry of Land, Infrastructure, Transport and Tourism 2015). This suggests that people who have difficulty walking long distances need to have urban parks nearby, such as those within the attraction distance of City Block Parks.

To evaluate access to urban parks from subregions, buffers with a radius of 1,000 m or 250 m were created from the center of gravity of each subregion polygon using ArcGIS Pro ver. 3.2 (ESRI). The area and number of urban parks within the buffer were then aggregated within each subregion for the small, medium, and large urban parks. Because the buffers of the subregions near the city boundaries included areas outside the city, we calculated the area and number of urban parks per unit area as indicators of access to urban parks by dividing the area or number of urban parks by the buffer area inside the city.

2-6 Statistical analysis

First, a simple tabulation and bivariate correlation analysis were conducted for the SES proxy indicators and the basic resident attributes using SPSS Statistics ver. 28 (IBM) to examine the association between the variables. Then, we conducted a Hot-Spot Analysis using ArcGIS Pro ver. 3.2 (ESRI) to examine the spatial distribution tendency of the SES proxy indicators. The Hot-Spot Analysis calculates the Getis-Ord G_i^* statistic for each feature or subregion, and statistically indicates where features with high or low values cluster spatially. The conceptualization of spatial relationships was set to the Optimal Fixed Distance Band, and the distance band or distance threshold was set to a minimum value of 1.264 km.

Next, to understand the association between the SES proxy indicators and access to urban parks, a bivariate correlation analysis was conducted for the SES proxy indicators recognized as effective in Osaka City in the previous step.

Finally, to analyze the spatial association between the SES proxy indicators and access to urban parks, we conducted a Hot Spot Analysis Comparison using data generated by the previous Hot-Spot Analysis. Hot Spot Analysis Comparison is an analytical method that compares two layers of hot spot analyses and indicates spatial areas that have a significant statistical association between the two layers. The number of neighbors, specifying the number of additional neighboring features used in the comparison, was set to eight. The number of permutations, which specified the number of random pairings for each feature when the expected similarity value was estimated under the assumption that the two layers were independent, was set to 999. The similarity weighting method was set to the fuzzy weights option, which allows fuzzy (non-binary) similarity weights to be determined by the closeness of the significance

levels between the two layers. Features that were not significant were excluded. The significance level for this analysis was set at 5%.

3. Results

3-1 Basic statistics of urban parks

In the target area, 812 were small urban parks (Figure 2, Table 1)—mainly City Block Parks and Neighborhood Parks—, 98 medium urban parks (Figure 3), and 20 large urban parks (Figure 4). Large urban parks included Comprehensive Parks, Sports Parks, and Regional Parks such as Tsurumi Ryokuchi, Kyuhoji Ryokuchi and Suminoe Park, and Yodogawa River Park.

3-2 Correlation between SES proxy indicators

The targeted subregions in this study comprised 1,793 areas, excluding non-residential areas; the characteristics of the SES proxy indicators and resident demographics are displayed in Table 2.

Because of the Hot-Spot Analysis, the distribution of the professional and managerial occupation percentage average had hot spots in the center of the city, from north to south, and cold spots in the margins (Figure 5). The distribution of the years of schooling was the same as that of the professional and managerial occupation percentage average (Figure 6). The distribution of roadside land price had hot spots in the city's center and cold spots in the margins (Figure 7). The distribution of the homeownership percentage had hot spots in the southeastern and western parts of the city and cold spots mainly in the northern and central areas (Figure 8). The distribution

of the married people percentage was similar to that of the homeownership percentage (Figure 9).

The results of the bivariate correlation analysis between the SES proxy indicators (Table 3) indicated that the professional and managerial occupation percentage average and the years of schooling were strongly positively correlated ($r = 0.836$). The professional and managerial occupation percentage average and roadside land price were moderately positively correlated ($r = 0.440$). The year of schooling and roadside land price were moderately positively correlated ($r = 0.519$). The homeownership and married people percentages were moderately positively correlated ($r = 0.611$).

3-3 Correlation between SES proxy indicators and resident attributes

The SES proxy indicators were correlated with resident attributes, except for the correlation between the property tax roadside land price and the percentage of male residents (Table 3). The professional and managerial occupation percentage average moderately positively correlated with the percentage of working-age population ($r = 0.507$) and moderately negatively correlated with the percentage of elderly population ($r = -0.522$). Similarly, the years of schooling moderately positively correlated with the percentage of working-age population ($r = 0.694$) and moderately negatively correlated with the percentage of the elderly population ($r = -0.696$). The property tax roadside land price weakly positively correlated with the percentage of working-age population ($r = 0.369$) and weakly negatively correlated with the percentage of elderly population ($r = -0.287$). The homeownership percentage moderately positively correlated with the percentage of juvenile population ($r = 0.446$) and weakly negatively correlated with the

percentage of working-age population ($r = -0.379$). The married people percentage strongly positively correlated ($r = 0.736$) with the percentage of juvenile population.

3-4 Access to urban parks by size and buffer distance

Basic statistics on access to urban parks by size and buffer distance in the 1,793 subregions are displayed in Table 4. The hot-spot analysis revealed that the area of small urban parks within a 250-m buffer from the center of gravity of each subregion was significantly higher in the southern part of the city center and significantly lower in the southern part of the city (Figure 10). The number of small urban parks within the 250-m buffer was significantly higher in the western part of the city and significantly lower in the central and southern parts. When the buffer distance was set at 1,000 m, both the area and number of small urban parks were significantly higher in the western and eastern parts adjacent to the city center and in the southern part of the city center and significantly lower in the northern part of the city center and in the westernmost and southern parts of the city.

The area of medium urban parks within a 250-m buffer was significantly higher in some areas of the western and central parts of the city, and significantly lower areas were sparsely distributed (Figure 11). The number of medium urban parks within the 250-m buffer was significantly higher in the city center and some western parts of the city, and significantly lower areas were sparsely distributed in the city's northern, eastern, and southern parts. When the buffer distance was set at 1,000 m, the area and number of medium urban parks were significantly higher in the western and central parts of the city and significantly lower in the northeastern and southern parts.

The area of large urban parks within a 250 m buffer was significantly higher along the northern rivers and some southern parts of the city and significantly lower in

the eastern and western parts of the city and the southern part of the city center (Figure 12). The number of large urban parks within 250 m was significantly higher in areas along the northern rivers and some southern parts of the city and significantly lower in the northern, eastern, western, and southeast parts of the city and the southern part of the city. When the buffer distance was set at 1,000 m, the area and number of large urban parks were significantly higher along the northern rivers and some southern parts of the city and significantly lower in the northern, eastern, western, and southeast parts of the city and the southern part of the city center.

Bivariate correlation analysis showed that for all the sizes of urban parks, access to urban parks, or the area or number of urban parks, of the same size class were positively correlated, even if access evaluation methods such as area, number, and buffer distance were different (Table 5). The correlation between the area or number of small urban parks and the area or number of medium urban parks was negative in most cases within a 250-m buffer, while it was positive in most cases within 1,000 m. The correlation between the area or number of small urban parks and the area or number of large urban parks was negative regardless of the evaluation method. The correlation between the area or number of medium urban parks and the area or number of large urban parks was negative in most cases.

3-5 Correlation and spatial association between SES proxy indicators and access to urban parks

Based on the abovementioned characteristics of the SES proxy indicators, we examined the relationship between the SES proxy indicators and access to urban parks using the following three indicators, which are considered effective in Osaka City, as discussed

later in Section 4-1: professional and managerial occupation percentage average, years of schooling, and roadside land price (Table 6).

The correlation between the three SES proxy indicators and the number of small urban parks within 250 or 1,000 m was negative ($r = -0.081$ to -0.296). The area of small urban parks within 1,000 m had a negative correlation with professional and managerial occupation percentage average and years of schooling ($r = -0.056$ and -0.060 , respectively), whereas it had a positive correlation with roadside land price ($r = 0.116$).

The correlation between the three SES proxy indicators and the number of medium urban parks within the 250-m buffer was positive ($r = 0.066$ to 0.086). The number of medium urban parks within a 1,000-m buffer positively correlated with roadside land price ($r = 0.096$).

The number of large urban parks within 250 m positively correlated with professional and managerial occupation percentage average ($r = 0.047$) and a negative correlation with roadside land price ($r = -0.047$). The area of large urban parks within 1,000 m positively correlated with professional and managerial occupation percentage average and years of schooling ($r = 0.159$ and 0.161 , respectively) and negatively correlated with roadside land price ($r = -0.064$). The number of large urban parks within 1,000 m positively correlated with professional and managerial occupation percentage average and years of schooling ($r = 0.236$ and 0.279 , respectively).

As a result of the Hot-Spot Analysis Comparison, the northern part of the city center, which was high in the three SES proxy indicators, was cold spots of small urban parks (Figures 13, S5, S8). The western area adjacent to the city center, which was low in the three SES proxy indicators, was a hotspot for small urban parks. The southeastern

part of the city, which was low in the three SES proxy indicators, was a cold spot for small urban parks.

Regarding medium urban parks, the city center, which was high in the three SES proxy indicators, was a hot spot of medium urban parks, except for the innermost center (Figures 14, S6, S9). The western area adjacent to the city center, which was low in the three SES proxy indicators, was a hot spot for medium urban parks. The southeastern part of the city, which was low in the three SES proxy indicators, was a cold spot of medium urban parks, except for the farthest southeast part.

Regarding large urban parks, the northern part of the city center, which was high in the three SES proxy indicators, was a hot spot for large urban parks (Figures 15, S7, S10). The western area adjacent to the city center, low in the three SES proxy indicators, was a cold spot of large urban parks, except for the northwest area along the Yodogawa River. The southeastern part of the city, which was low in the three SES proxy indicators, was a cold spot of medium urban parks.

4. Discussion

4-1 SES proxy indicators

The professional and managerial occupation percentage average, years of schooling, and roadside land price were positively correlated in Osaka City (Table 3). Their distribution was found to be significantly higher in the central area and significantly lower in the fringe areas of the city (Figures 5–7). Compared with the correlation between the professional and managerial occupation percentage average and the years of schooling ($r = 0.836$), the correlation between the professional and managerial occupation

percentage average and the roadside land price ($r = 0.440$), and that between the years of schooling and the roadside land price ($r = 0.519$) were lower (Table 3), suggesting that the roadside land price differed slightly from the other two variables. On the other hand, the distribution trend of the homeownership and married people percentages differed, with significantly higher values in the eastern and southern areas and significantly lower values in the northern and central areas of the city (Figures 8, 9).

Among the five SES proxy indicators examined in this study, the percentages of homeownership and married people may not be appropriate in Osaka City, given the lifestyles of urban residents in Japan. In Osaka City, homeownership decreased from 44.0% in the 2015 Census to 41.6% in the 2020 Census (Osaka City 2022). In addition, the percentage of single-person households increased from 48.6% in the 2015 Census to 53.6% in the 2020 Census. These suggest that an increasing number of people is likely to be choosing not to purchase housing or marry, even if they are socioeconomically well-off. The demand for new owner-occupied houses has been expected to decrease in the Tokyo metropolitan area due to a similar increase in the number of single-person households (Takeuchi 2007). Thus, as in Osaka City, the homeownership percentage and the married percentage may not be effective as SES proxy indicators for large Japanese cities.

The distribution of estimated household expenditures in Osaka City had a concentric pattern and higher in the central business district (Hanaoka *et al.* 2013). In the Osaka metropolitan area, the income level was higher in the area from the city center within the Osaka Loop Line to its south, and conversely, the income level was lower in the ring-shaped areas surrounding those areas (Mizuuchi 2011). Therefore, we thought that the professional and managerial occupation percentage average, the years

of schooling, and the roadside land price were more suitable as SES proxy indicators because the distribution pattern of these three SES proxy indicators were similar to the above previous studies.

As mentioned above, the three variables of professional and managerial occupation percentage average, years of schooling, and roadside land price were considered appropriate proxy SES indicators in Osaka City. However, small differences were also observed among the three variables. Compared to the strong correlation between the professional and managerial occupation percentage and the years of schooling ($r = 0.836$), the correlation between the professional and managerial occupation percentage average and the roadside land price ($r = 0.440$), and the correlation between the years of schooling and the roadside land price ($r = 0.519$) were only moderate (Table 3). In addition, the professional and managerial occupation percentage average and the years of schooling tended to be positively correlated with the area and the number of large urban parks within 250 or 1,000 m. However, the roadside land price tended to be negatively correlated with those (Table 6). Specifically, areas south of the city center, known for schools and rich educational environments, were hotspots for the professional and managerial occupation percentage average and the years of schooling, but were not identified as hotspots for the roadside land price (Figures 5, 6, 7). The professional and managerial occupation percentage average and the years of schooling may be variables more strongly associated with the educational environment than the roadside land price.

4-2 Access to urban parks

Area and number of small urban parks within 250 or 1000 m had negative correlation with those of large urban parks (Table 5), indicating that more small urban parks were

distributed where there were no large urban parks (Figures 10, 12). Similarly, area and number of medium urban parks within 250 or 1000 m often had negative correlation with those of large urban parks (Table 5). These suggest that small and medium urban parks may have been placed in areas where there were no large urban parks. Before World War II, city planning in Osaka City focused on large urban parks. In 1923, the Comprehensive Osaka City Plan, which was approved by the Cabinet, positioned parks as an important component of city planning decisions for the first time, and promoted the development of large urban parks in suburban and central areas of the city (Osaka City 2021b). Subsequently, the Declaration of 100 Years of Greenery was adopted in 1964 (Osaka City 2021b), and the area of urban parks and the number of urban parks increased approximately 2.7 times and 3.3 times, respectively, over the next 40 years (Osaka City 2006), suggesting that the development of small and medium urban parks was expanded during this time.

The correlation between area and the number of small urban parks and those of medium urban parks was basically negative within 250 m from the center of gravity of a subregion (Table 5). However, a positive correlation was observed within 1,000 m. Since the attraction distance for City Block Parks included in small urban parks is 250 m (Ministry of Land, Infrastructure, Transport and Tourism 2018), new small urban parks were possibly not established in areas where medium urban parks already existed.

4–3 SES proxy indicators and access to urban parks

There were basically negative correlations between the SES proxy indicators and the area and number of small urban parks within 250 or 1,000 m (Table 6). However, positive correlations were often found between the SES proxy indicators and the area and number of medium and large parks within 250 or 1,000 m (Table 6). These findings

suggest that across Osaka City, socioeconomically disadvantaged areas tend to have more small urban parks and fewer medium and large urban parks. However, when we analyzed the spatial relationship between the SES proxy indicators and access to urban parks in the subregions of Osaka City, we found that the relationship varied by area as follows:

The relationship between the SES proxy indicators and access to urban parks in Osaka City differed depending on the size of the urban parks. The northern area of the city center was found to have higher values in the three SES proxy indicators, indicating that they were socioeconomically better off and had a greater area and number of large urban parks within 250 or 1,000 m (Figures 15, S7, S10). However, the western area of the city, except for the northwest area along the Yodogawa River, had lower values in the SES proxy indicators, indicating that they were socioeconomically disadvantaged and had a lower area and number of large urban parks but a greater area and number of small and medium urban parks (Figures 13–15, S5–S10). Therefore, it is desirable to introduce large urban parks in this area in the future.

The southeastern part of the city had lower values in the SES proxy indicators and tended to have fewer urban parks regardless of urban park size, except for the farthest southeast part (Figures 13–15, S5–S10). In this area, some subregions had a high percentage of juvenile or elderly population (Figures S1, S3). In Osaka City, the percentage of elderly population in the subregions moderately negatively correlated with the professional and managerial occupation percentage average and the years of schooling ($r = -0.522$ and $r = -0.696$, respectively) and weakly negatively correlated with the roadside land price ($r = -0.287$) (Table 3). This suggests that areas with a high percentage of the elderly population tend to have low socioeconomic conditions.

Previous studies have shown that careful city planning considering environmental equity is required in areas where there are many people with mobility difficulties (children and older adults) and vulnerable people (low-income, minorities, etc.) (Schipperijn *et al.* 2010; Rigolon 2016). Therefore, to properly implement city planning, the first step is to clarify the validity of SES indicators and understand the current situation. This study explored effective SES indicators for Osaka City, Japan, as a case study and clarified areas that should be prioritized for intervention based on the SES indicators and the distribution of urban parks. Appropriate SES indicators are likely to differ between countries and cities with different economic levels and cultural norms; however, the simple method for exploring SES indicators presented in this study is expected to be an approach that can be applied to cities of any background.

Additionally, if it is difficult to establish a new urban park immediately, especially a large-scale park, in a densely populated urban area, the quality of existing small and medium urban parks may be improved. In a study conducted in Boston, USA, areas with more adults who had not graduated from high school tended to have closer distances to playgrounds, whereas areas with a higher percentage of impoverished youth had lower playground safety (Cradock *et al.* 2005). Therefore, in the future, it is expected to analyze not only the area and number of urban parks but also the facilities in urban parks by taking a similar approach to this study.

4-4 Recommendations for policymakers

A low SES is associated with poor health status (Currie 2009; Kivimäki *et al.* 2020). However, promoting exposure to green spaces such as urban parks may reduce income-related health inequality (Mitchell and Popham 2008). Therefore, more active use of population demographics and background characteristics of surrounding

neighborhoods could be helpful when planning and managing green spaces (Schipperijn *et al.* 2010). The method presented in this study allows us to identify areas with low SES and poor access to urban parks. Policymakers can use these results to prioritize the development of urban parks in a socioeconomic context, which may improve living conditions and contribute to reducing health disparities. City planners should be encouraged to consider the socioeconomic conditions of neighborhoods and their accessibility to urban parks when developing and managing urban parks, including creating master plans and guidelines, leveraging private funding through public-private partnerships, and working with residents and non-profits.

5. Conclusion

This study examined effective SES proxy indicators for spatial analysis in Osaka City and investigated the spatial association between SES proxy indicators and access to urban parks by size. The results revealed that the average percentage of professional and managerial workers, years of schooling, and roadside land price may be effective SES proxy indicators in Osaka City. The relationship between the three SES proxy indicators and access to urban parks varied according to their size. The northern area of the city center was found to have higher values of the SES proxy indicators and better access to large urban parks. On the other hand, the western area of the city, except for the northwest area along the Yodogawa River, had lower values of the SES proxy indicators and poorer access to large urban parks but better access to small and medium urban parks. In particular, the southeastern part of the city had lower values in the SES proxy indicators and poorer access to all sizes of urban parks. Urban parks of different sizes

should be located near their residences to encourage residents to engage in diverse activities. If developing new parks in urban areas is difficult, existing parks can be remodeled. The analytical approach presented in this study may help reexamine the siting of urban parks in a socioeconomic context.

This study focused on Osaka City, which has a large socioeconomic disparity in Japan. The results may be applicable to metropolitan areas in Japan where socioeconomic disparities are large. However, it is necessary to verify whether similar results can be obtained in Japan or overseas by using more cases. As the cultural context influences SES proxy indicators, it is essential to select appropriate proxy indicators for each target area. For example, indicators, such as married people percentage, and homeownership percentage may be more directly associated with SES in other areas. Future research needs to clarify the circumstances under which the relationship between low SES and poor access to urban parks manifests, thereby providing lessons on how urban parks should be developed within socioeconomic contexts.

Ethics declarations

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

Ethical approval was not required as this study analyzed publicly available data.

References

- Aoshima I, Uchida K, Ushimaru A, Sato M (2017) Economic valuation of the urban green spaces using life satisfaction data. *Environmental Science* 30(4): 238-249. (in Japanese with English abstract)
- Bartzokas-Tsiompras A, Bakogiannis E (2023) Quantifying and visualizing the 15-minute walkable city concept across Europe: A multicriteria approach. *Journal of Maps* 19(1): 2141143.
- Boone CG, Buckley GL, Grove JM, Sister C (2009) Parks and people: An environmental justice inquiry in Baltimore, Maryland. *Annals of the Association of American Geographers* 99(4): 767-787.
- Cradock AL, Kawachi I, Colditz GA, Hannon C, Melly SJ, Wiecha JL, Gortmaker SL (2005) Playground safety and access in Boston neighborhoods. *American Journal of Preventive Medicine* 28(4) 357-363.
- Currie J (2009) Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature* 47(1): 87-122.
- Dai D (2011). Racial/ethnic and socioeconomic disparities in urban green space accessibility: Where to intervene? *Landscape and Urban Planning* 102(4): 234-244.
- Estabrooks PA, Lee RE, Gyurcsik NC (2003) Resources for physical activity participation: Does availability and accessibility differ by neighborhood socioeconomic status? *Annals of Behavioral Medicine* 25(2): 100-104.

Giles-Corti B, Broomhall MH, Knuiman M, Collins C, Douglas K, Ng K, Lange A, Donovan RJ (2005) Increasing walking: How important is distance to, attractiveness, and size of public open space? American Journal of Preventive Medicine 28(2, Supplement 2) 169-176.

Gordon-Larsen P, Nelson MC, Page P, Popkin BM (2006) Inequality in the built environment underlies key health disparities in physical activity and obesity. Pediatrics 117(2): 417-424.

Hanaoka K Nakaya T, Tabuchi T (2013) Small-area estimates of socio-economic inequalities using a spatial microsimulation approach: A case study of Osaka City, Japan: Annals of the Association of Economic Geographers 59(1): 73-87. (in Japanese with English abstract)

Hanaoka S, Watabe A, Inamura H (2000) A study of the relationship between park user's behavioral characteristics and access mode in large-scale urban parks. Journal of the City Planning Institute of Japan 35: 607-612. (in Japanese with English abstract)

Hanibuchi T, Kawachi I, Nakaya T, Hirai H, Kondo K (2011) Neighborhood built environment and physical activity of Japanese older adults: results from the Aichi Gerontological Evaluation Study (AGES). BMC public health 11: 1-12.

Holman CD, Donovan RJ, Corti B (1996) Factors influencing the use of physical activity facilities: Results from qualitative research. Health Promotion Journal of Australia: Official Journal of Australian Association of Health Promotion Professionals 6(1): 16-21.

Jones AP, Brainard J, Bateman IJ, Lovett AA (2009) Equity of access to public parks in Birmingham, England. *Environmental Research Journal* 3(2): 237-256.

Kabba VTS, Li J (2011) Determinants of urban land price in Freetown, Sierra Leone. *Journal of American Science* 7(2): 213-223.

Kim Y, Corley EA, Won Y, Kim J (2023) Green space access and visitation disparities in the phoenix metropolitan area. *Landscape and Urban Planning* 237: 104805.

Kivimäki M, Batty GD, Pentti J, Shipley MJ, Sipilä PN, Nyberg ST, Suominen SB, Oksanen T, Stenholm S, Virtanen M, Marmot MG, Singh-Manoux A, Brunner E, Lindbohm JV, Ferrie JE, Vahtera J (2020) Association between socioeconomic status and the development of mental and physical health conditions in adulthood: A multi-cohort study. *The Lancet Public Health* 5(3): e140-e149.

Klompaker JO, Hart JE, Bailey CR, Browning MHEM, Casey JA, Hanley JR, Minson CT, Ogletree SS, Rigolon A, Laden F, James P. Racial (2023) Ethnic, and socioeconomic disparities in multiple measures of blue and green spaces in the United States. *Environ Health Perspect* 131(1):17007. doi: 10.1289/EHP11164

Lachowycz K, Jones AP (2014) Does walking explain associations between access to greenspace and lower mortality? *Social Science and Medicine* 107: 9-17.

McConnachie MM, Shackleton CM (2010) Public green space inequality in small towns in South Africa. *Habitat International* 34(2): 244-248.

Lahelma E, Martikainen P, Laaksonen M, Aittomäki A (2004) Pathways between socioeconomic determinants of health. *Journal of Epidemiology and Community Health* 58(4): 327-332.

Ministry of Health, Labor and Welfare (2012) A basic direction for comprehensive implementation of national health promotion.

<https://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/0000047330.pdf> Accessed 6 March 2024

Ministry of Internal Affairs and Communications (2023) Outline of the Family Income and Expenditure Survey. <https://www.stat.go.jp/english/data/kakei/pdf/outline.pdf> Accessed 12 October 2024

Ministry of Land, Infrastructure, Transport and Tourism (2014) Survey of Urban Park Usage in 2014 https://www.mlit.go.jp/toshi/park/toshi_parkgreen_tk_000039.html Accessed 8 November 2021 (in Japanese)

Ministry of Land, Infrastructure, Transport and Tourism (2015) Movement of people in cities: Results of the 2010 Nationwide Urban Transport Characteristics Survey (Part 2) <https://www.mlit.go.jp/common/001087037.pdf> Accessed 5 November 2024 (in Japanese)

Ministry of Land, Infrastructure, Transport and Tourism (2018) Guidelines for implementation of the Urban Parks Act (4th Edition) <https://www.mlit.go.jp/common/001231242.pdf> Accessed 19 December 2023 (in Japanese)

Ministry of Land, Infrastructure, Transport and Tourism (2022) Per capita development of urban parks by prefecture. https://www.mlit.go.jp/toshi/park/content/04_R02.pdf
Accessed 14 November 2022 (in Japanese)

Mitchell R, Popham F (2008) Effect of exposure to natural environment on health inequalities: An observational population study. *The Lancet* 372(9650): 1655-1660.

Miwa (2022) “Infant’s living-sphere” where children grow up together with the town. *The Japanese Journal of Real Estate Sciences* 36(4): 85-89. (in Japanese with English abstract)

Mizuuchi T (2011) Support for vulnerable people and an alternative form of regeneration for the inner city. *City Planning Review* 60(4), 35-38. (in Japanese)

Moudon AV, Lee C, Cheadle AD, Garvin C, Johnson D, Schmid TL, Weathers RD, Lin L (2006) Operational definitions of walkable neighborhood: Theoretical and empirical insights. *Journal of Physical Activity and Health* 3(s1): S99-S117.

Mouratidis K, Yiannakou A (2022) What makes cities livable? Determinants of neighborhood satisfaction and neighborhood happiness in different contexts. *Land Use Policy* 112: 105855.

Nagai A (2016) Characteristics and economic life of never-married people in contemporary Japan. *Japanese Journal of Research on Household Economics* 110: 8-23. (in Japanese)

Osaka City (2006) Project analysis report: Parks and greenery projects

<https://www.city.osaka.lg.jp/shiseikaikakushitsu/cmsfiles/contents/0000010/10240/ryoka.pdf> Accessed 31 January 2022 (in Japanese)

Osaka City (2021a) Osaka City public assistance situation.

<https://www.city.osaka.lg.jp/fukushi/page/0000086901.html> Accessed 28 January 2022 (in Japanese)

Osaka City (2021b) New Osaka City Green Basic Plan.

<https://www.city.osaka.lg.jp/kensetsu/page/0000239835.html> Accessed 5 January 2022 (in Japanese)

Osaka City (2022) Summary of Basic Tabulation Results of the 2020 Population Census.

<https://www.city.osaka.lg.jp/toshikeikaku/cmsfiles/contents/0000549/549394/R2kokusei-jinkou-gaiyou2.pdf> Accessed 12 January 2024 (in Japanese)

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

Sato R, Katayama K, Onishi T (2007) An empirical study on income disparities within metropolitan regions. *Journal of the City Planning Institute of Japan* 42(3): 859-864. (in Japanese with English abstract)

Schipperijn J, Ekholm O, Stigsdotter UK, Toftager M, Bentsen P, Kamper-Jørgensen F, Randrup TB (2010) Factors influencing the use of green space: Results from a Danish national representative survey. *Landscape and Urban Planning* 95(3): 130-137.

Shavers VL (2007) Measurement of socioeconomic status in health disparities research. *Journal of the National Medical Association* 99(9): 1013-1023.

Shimomura Y, Masuda N, Abe D, Yamamoto S, Suzuki K (1995) Study on resident's behavior of block park in neighborhood. *Journal of the Japanese Institute of Landscape Architecture* 58(5): 217-220. (in Japanese with English abstract)

Takeuchi K (2007) Changes in population and household structures and demand for owner-occupied and private rental housing in the Tokyo metropolitan area. Report of NLI Research Institute 47: 35-55. (in Japanese)

Toyoda T (2012) Regional income inequality and spatial structure of metropolitan area: Analysis on municipal differentials in household income. *Journal of Human Sciences and Arts, Faculty of Integrated Arts and Sciences, Tokushima University* 20: 51-62. (in Japanese)

Uesugi M, Yasumoto S (2018) Disparities in accessibility to neighborhood facilities from perspectives of socio-economic residential segregation in Japanese metropolitan area. *Journal of the City Planning Institute of Japan* 53(3): 311-318. (in Japanese with English abstract)

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

Wendel HEW, Downs JA, Mihelcic JR (2011) Assessing equitable access to urban green space: The role of engineered water infrastructure. *Environmental Science and Technology* 45(16): 6728-6734.

Wüstemann H., Kalisch D, Kolbe J (2017) Access to urban green space and environmental inequalities in Germany. *Landscape and Urban Planning* 164: 124-131

Yasumoto S, Jones A, Shimizu C (2014) Longitudinal trends in equity of park accessibility in Yokohama, Japan: An investigation into the role of causal mechanisms. *Environment and Planning A* 46(3): 682-699.

Yasumoto S, Nakaya T, Jones AP (2021) Quantitative environmental equity analysis of perceived accessibility to urban parks in Osaka Prefecture, Japan. *Applied Spatial Analysis and Policy* 14: 337-354.

Yoshimura D (2013) The trend of occupational classification and the boundary of knowledge society. *The Otemon Economic Review* 48(1): 37-60. (in Japanese)

Figure captions

Fig. 1 Distribution of urban parks in the target area

Fig. 2 Small urban parks in the target area

Fig. 3 Medium urban parks in the target area

Fig. 4 Large urban parks in the target area

Fig. 5 Hot and cold spots for professional and managerial occupation percentage
average in 1,793 subregions

Fig. 6 Hot and cold spots for the year of schooling in 1,793 subregions

Fig. 7 Hot and cold spots for property tax roadside land price in 1,793 subregions

Fig. 8 Hot and cold spots for the homeownership percentage in 1,793 subregions

Fig. 9 Hot and cold spots of the married people percentage in 1,793 subregions

Fig. 10 Hot and cold spots for access to small urban parks in 1,793 subregions

Fig. 11 Hot and cold spots of access to medium urban parks in 1,793 subregions

Fig. 12 Hot and cold spots of access to large urban parks in 1,793 subregions

Fig. 13 Spatial association between professional and managerial occupation percentage
average and access to small urban parks in 1,793 subregions

Fig. 14 Spatial association between professional and managerial occupation percentage
average and access to medium urban parks in 1,793 subregions

Fig. 15 Spatial association between professional and managerial occupation percentage
average and access to large urban parks in 1,793 subregions

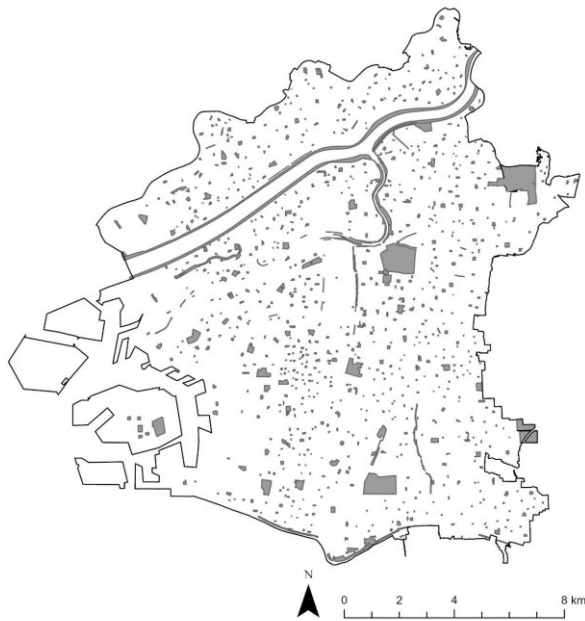


Fig. 1 Distribution of urban parks in the target area

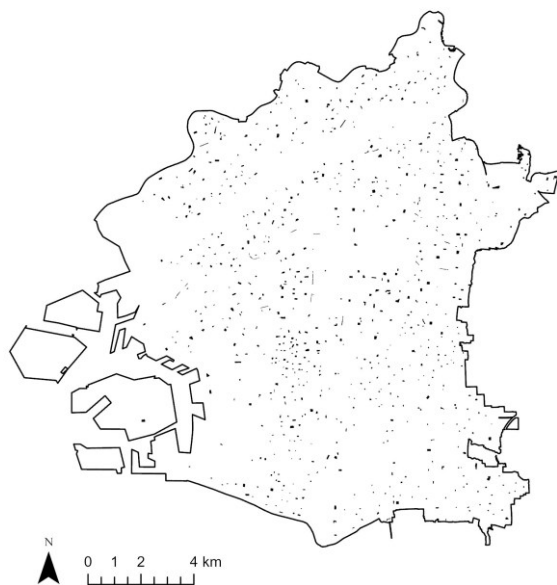


Fig. 2 Small urban parks in the target area

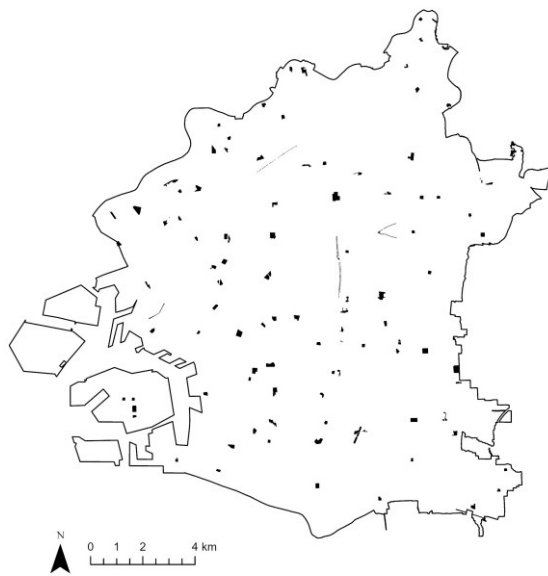


Fig. 3 Medium urban parks in the target area

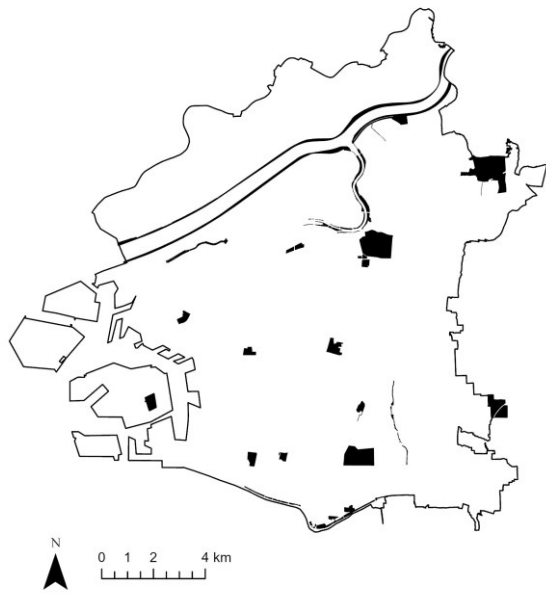


Fig. 4 Large urban parks in the target area

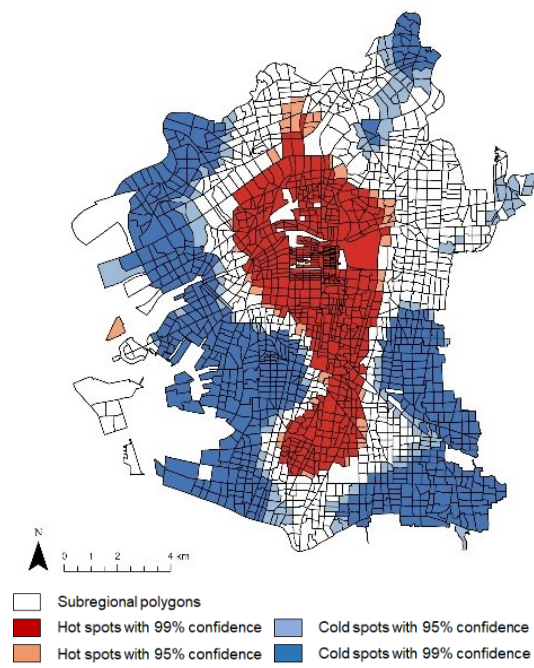


Fig. 5 Hot and cold spots for professional and managerial occupation percentage average in 1,793 subregions

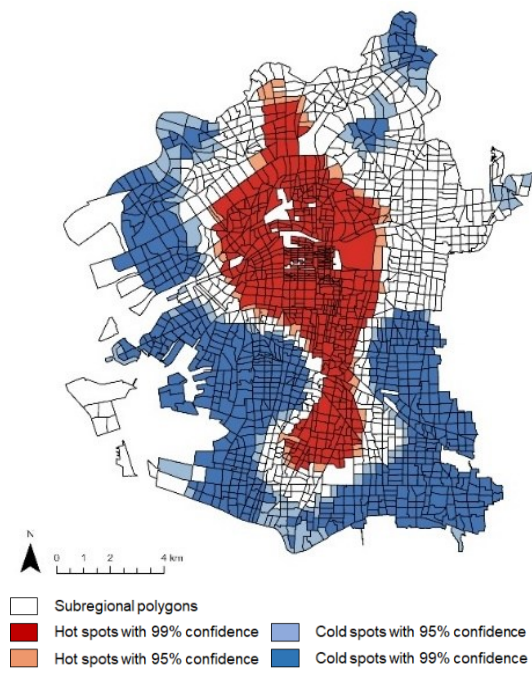


Fig. 6 Hot and cold spots for the year of schooling in 1,793 subregions



Fig. 7 Hot and cold spots for property tax roadside land price in 1,793 subregions

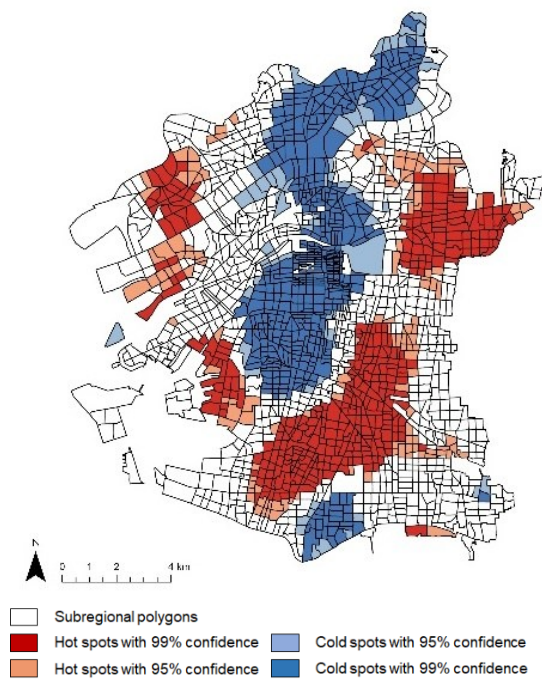


Fig. 8 Hot and cold spots for the homeownership percentage in 1,793 subregions

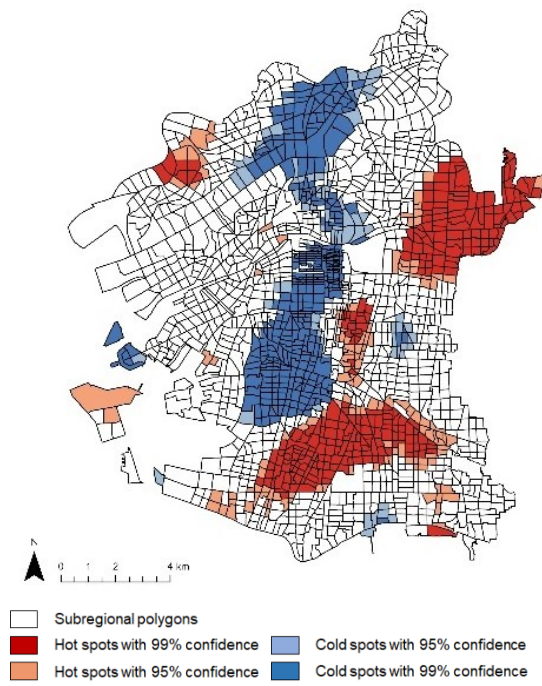


Fig. 9 Hot and cold spots of the married people percentage in 1,793 subregions

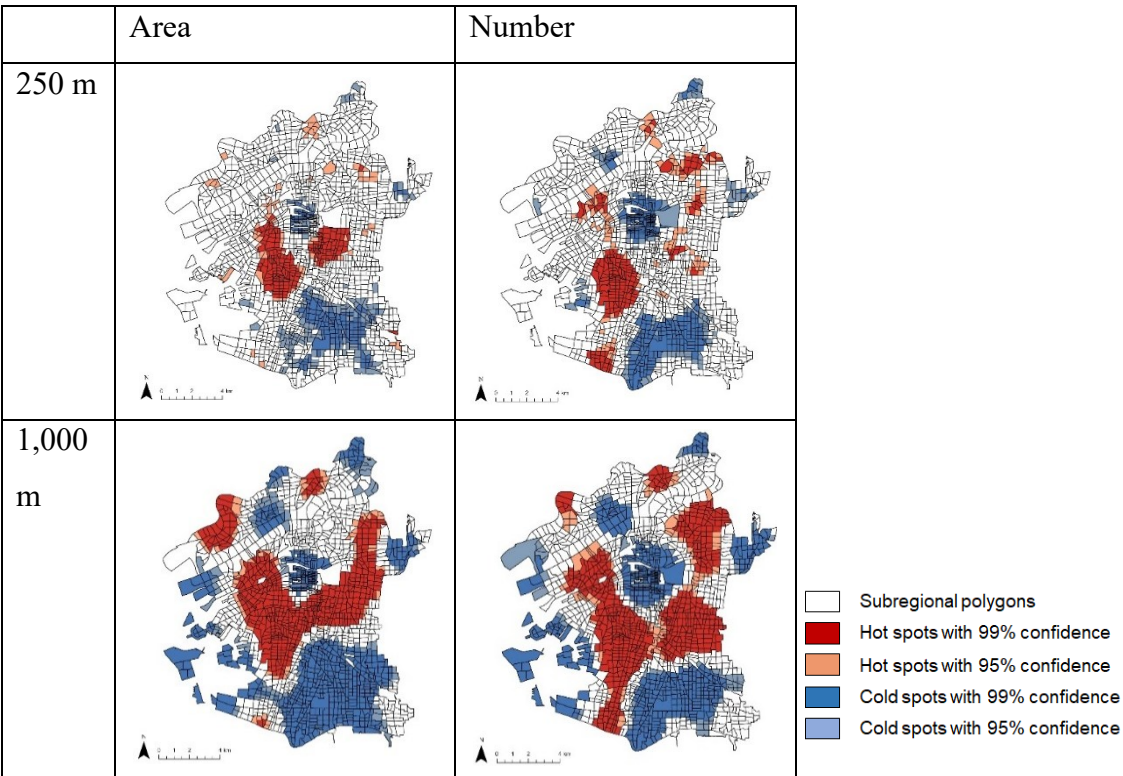


Fig. 10 Hot and cold spots for access to small urban parks in 1,793 subregions

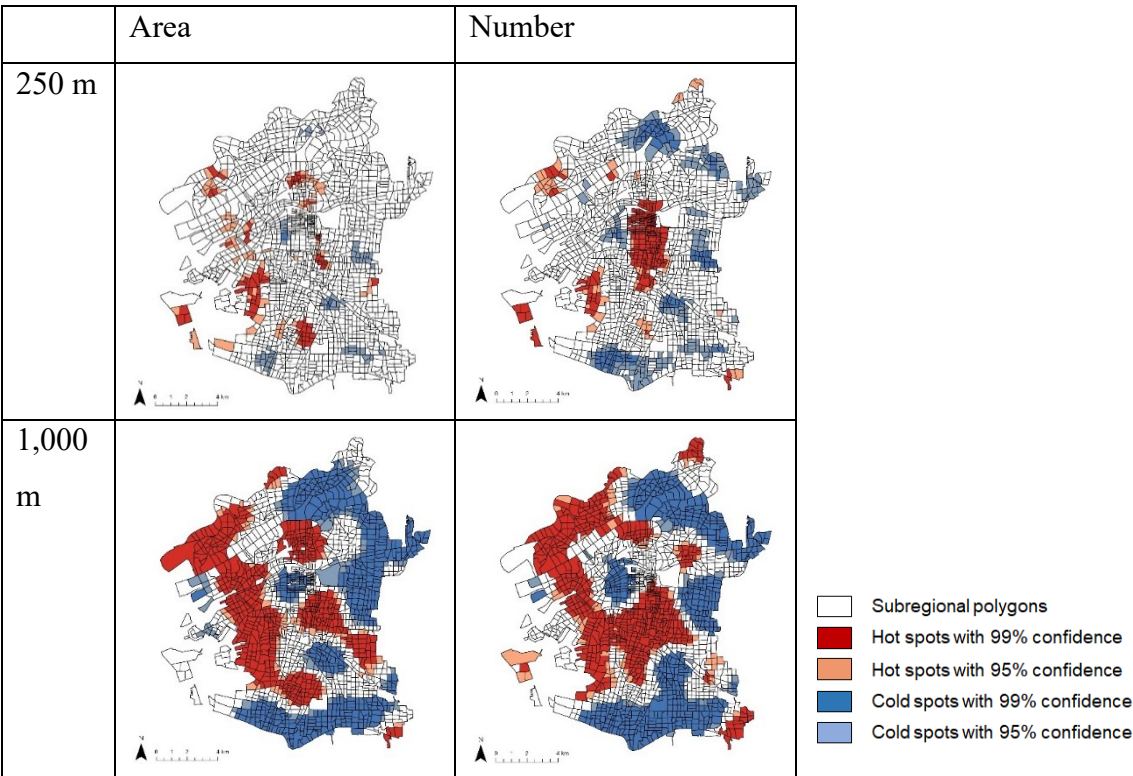


Fig. 11 Hot and cold spots of access to medium urban parks in 1,793 subregions

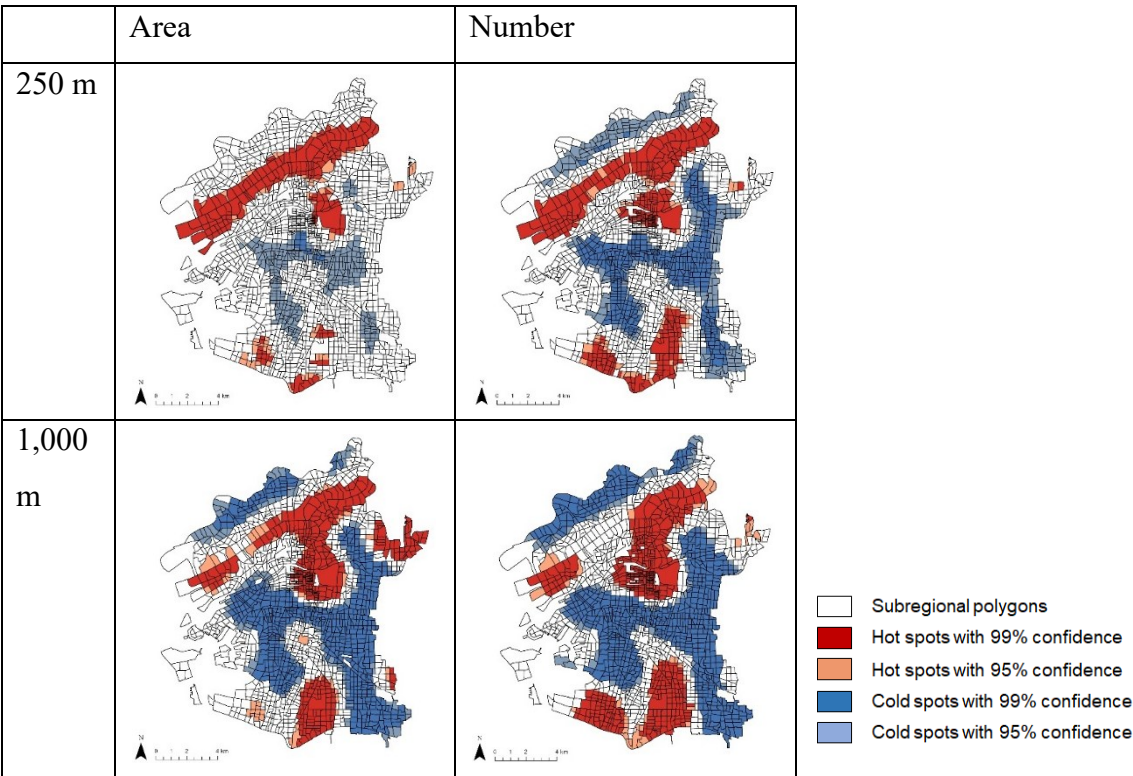


Fig. 12 Hot and cold spots of access to large urban parks in 1,793 subregions

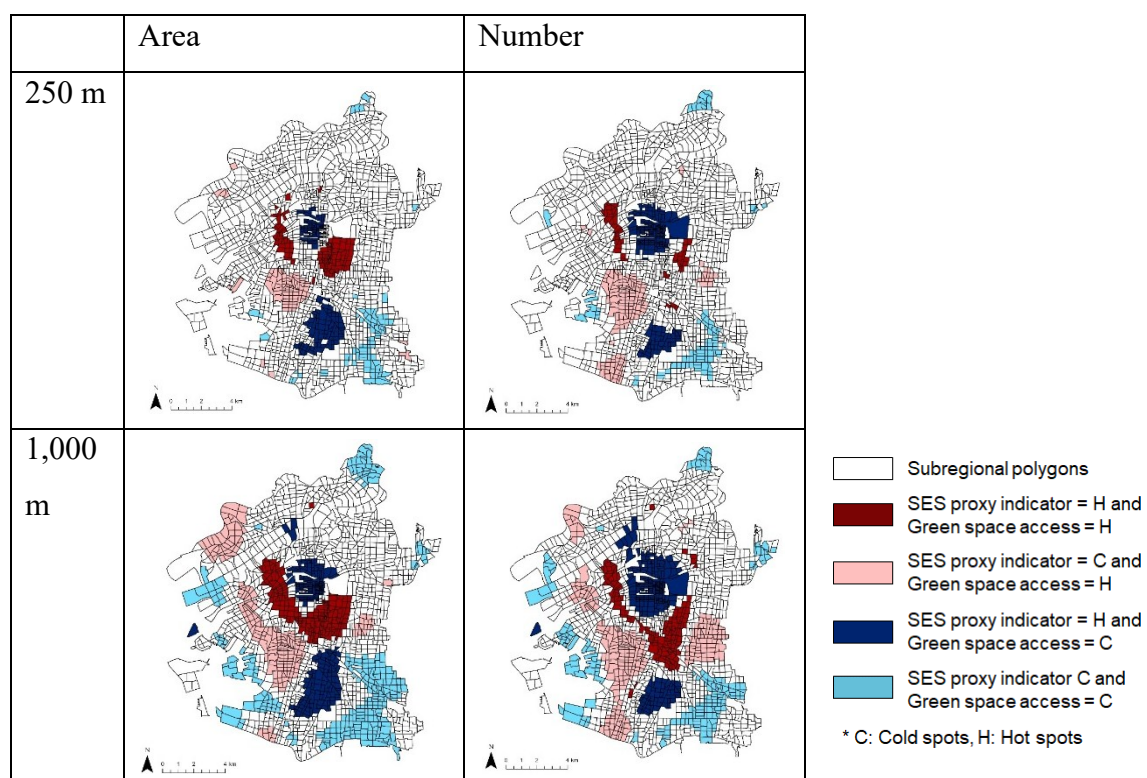


Fig. 13 Spatial association between professional and managerial occupation percentage average and access to small urban parks in 1,793 subregions

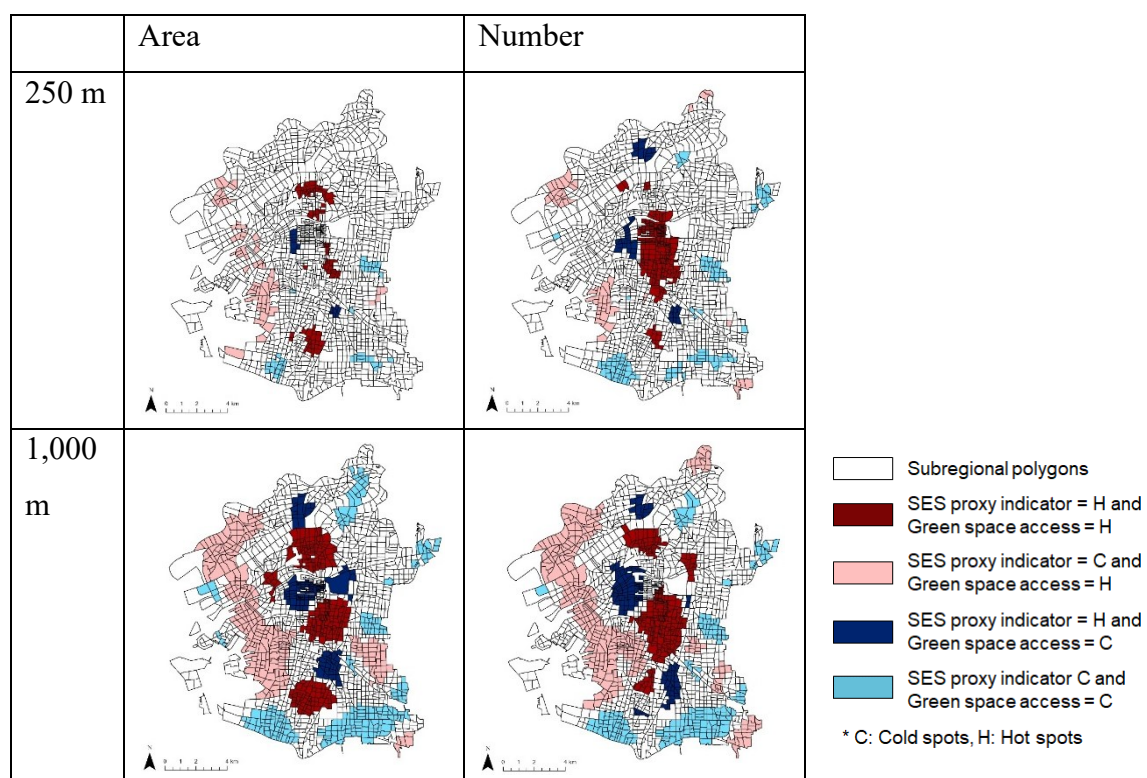


Fig. 14 Spatial association between professional and managerial occupation percentage average and access to medium urban parks in 1,793 subregions

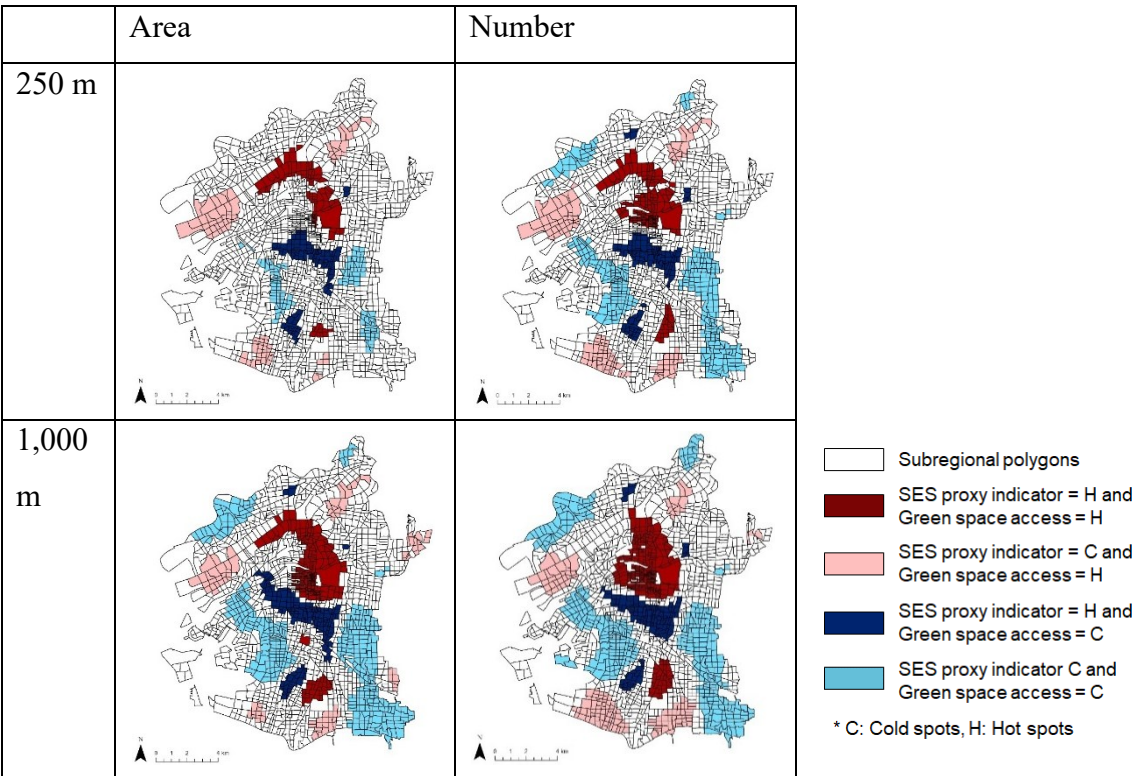


Fig. 15 Spatial association between professional and managerial occupation percentage average and access to large urban parks in 1,793 subregions

Table 1 Basic statistics on the area of urban parks by size

	Area (ha)				Number of Parks
	Mean	S.D.	Min	Max	
Small urban parks	0.26	0.22	0.02	1.00	812
Medium urban parks	2.20	1.34	1.00	7.47	98
Large urban parks	43.52	59.50	8.09	249.87	20

Table 2 Basic statistics on SES proxy indicators and resident attributes in the 1,793 subregions

	Mean	S.D.	Min	Max
Professional and managerial occupation percentage average (%)	45.39	4.21	0	46.32
Years of schooling (year)	13.16	0.90	10.34	16.00
Property tax roadside land price (1,000 JPY/m ²)	252.13	218.22	40.27	1094.96
Homeownership percentage (%)	42.75	20.20	0	100
Married people percentage (%)	51.71	8.91	3.33	87.50
Percentage of juvenile population (%)	10.26	4.19	0	31.25
Percentage of working-age population (%)	64.00	9.94	15.87	100
Percentage of elderly population (%)	25.74	10.38	0	80.07
Percentage of male residents (%)	48.49	0.13	23.71	100

Table 3 Bivariate correlation analysis between SES proxy indicators and resident attributes in 1,793 subregions

		Socioeconomic status (SES) proxy indicators					Resident attributes			
		Professional and managerial occupation percentage average (%)	Years of schooling (year)	Property tax roadside land price (1,000 JPY/m ²)	Homeownership percentage (%)	Married people percentage (%)	Percentage of juvenile population (%)	Percentage of working-age population (%)	Percentage of elderly population (%)	Percentage of male residents (%)
Professional and managerial occupation percentage average (%)	Pearson's correlation coefficient	1.000								
Years of schooling (year)	Pearson's correlation coefficient	0.836 **	1.000							
	Significance probability	0.000								
Property tax roadside land price (1,000 JPY/m ²)	Pearson's correlation coefficient	0.440 **	0.519 **	1.000						
	Significance probability	0.000	0.000							
Homeownership percentage (%)	Pearson's correlation coefficient	0.025	-0.016	-0.142 **	1.000					
	Significance probability	0.293	0.489	0.000						
Married people percentage (%)	Pearson's correlation coefficient	0.137 **	0.154 **	-0.074 **	0.611 **	1.000				
	Significance probability	0.000	0.000	0.002	0.000					
Percentage of juvenile population (%)	Pearson's correlation coefficient	0.089 **	0.078 **	-0.164 **	0.446 **	0.736 **	1.000			
	Significance probability	0.000	0.001	0.000	0.000	0.000				
Percentage of working-age population (%)	Pearson's correlation coefficient	0.507 **	0.694 **	0.369 **	-0.379 **	-0.167 **	-0.104 **	1.000		
	Significance probability	0.000	0.000	0.000	0.000	0.000	0.000			
Percentage of elderly population (%)	Pearson's correlation coefficient	-0.522 **	-0.696 **	-0.287 **	0.183 **	-0.137 **	-0.304 **	-0.916 **	1.000	
	Significance probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Percentage of male residents (%)	Pearson's correlation coefficient	-0.145 **	-0.156 **	0.038	-0.141 **	-0.251 **	-0.218 **	-0.051 *	0.137 **	1.000
	Significance probability	0.000	0.000	0.104	0.000	0.000	0.000	0.030	0.000	

n = 1793, **p* < .05, ***p* < .01

Table 4 Basic statistics on access to urban parks by size and buffer distance in 1,793 subregions

		Mean	S.D.	Min	Max
Small urban parks					
250 m buffer	Area (ha/ha)	0.012	0.014	0	0.082
	Number (/ha)	0.059	0.053	0	0.357
1,000 m buffer	Area (ha/ha)	0.011	0.005	0	0.035
	Number (/ha)	0.046	0.020	0	0.153
Medium urban parks					
250 m buffer	Area (ha/ha)	0.011	0.032	0	0.345
	Number (/ha)	0.011	0.022	0	0.122
1,000 m buffer	Area (ha/ha)	0.011	0.008	0	0.040
	Number (/ha)	0.006	0.004	0	0.021
Large urban parks					
250 m buffer	Area (ha/ha)	0.020	0.074	0	1.000
	Number (/ha)	0.008	0.020	0	0.153
1,000 m buffer	Area (ha/ha)	0.032	0.051	0	0.437
	Number (/ha)	0.003	0.003	0	0.013

Table 5 Bivariate correlation analysis of access to urban parks by size and buffer distance

		Urban park size													
		Buffer distance		Small				Medium				Large			
				250 m		1000 m		250 m		1000 m		250 m		1000 m	
Urban park size	Buffer distance			Area (ha/ha)	Number (/ha)	Area (ha/ha)	Number (/ha)	Area (ha/ha)	Number (/ha)	Area (ha/ha)	Number (/ha)	Area (ha/ha)	Number (/ha)	Area (ha/ha)	Number (/ha)
Small	250m	Area (ha/ha)	Pearson's correlation coefficient	1.000											
			Significance probability												
	1000 m	Number (/ha)	Pearson's correlation coefficient	0.636 **	1.000										
			Significance probability	0.000											
		Area (ha/ha)	Pearson's correlation coefficient	0.410 **	0.440 **	1.000									
			Significance probability	0.000	0.000										
Medium	250m	Number (/ha)	Pearson's correlation coefficient	0.765 **	0.530 **	0.765 **	1.000								
			Significance probability	0.000	0.000	0.000									
	1000 m	Area (ha/ha)	Pearson's correlation coefficient	-0.144 **	-0.156 **	-0.019	-0.024	1.000							
			Significance probability	0.000	0.000	0.415	0.315								
		Number (/ha)	Pearson's correlation coefficient	-0.141	-0.188 **	-0.078 **	-0.110 **	0.673 **	1.000						
			Significance probability	0.000	0.000	0.001	0.000	0.000							
Large	250m	Area (ha/ha)	Pearson's correlation coefficient	0.017	0.006	0.122 **	0.068 **	0.226 **	0.229 **	1.000					
			Significance probability	0.466	0.800	0.000	0.004	0.000	0.000						
	1000 m	Number (/ha)	Pearson's correlation coefficient	0.020	0.011	0.049 *	0.030	0.146 **	0.242 **	0.689 **	1.000				
			Significance probability	0.400	0.651	0.037	0.204	0.000	0.000	0.000					
	250m	Area (ha/ha)	Pearson's correlation coefficient	-0.113 **	-0.146 **	-0.124 **	-0.126 **	-0.071 **	-0.060 *	-0.130 **	-0.100 **	1.000			
			Significance probability	0.000	0.000	0.000	0.000	0.003	0.011	0.000	0.000				
	1000 m	Number (/ha)	Pearson's correlation coefficient	-0.083 **	-0.140 **	-0.181 **	-0.195 **	-0.096 **	-0.082 **	-0.183 **	-0.147 **	0.656 **	1.000		
			Significance probability	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000			
		Area (ha/ha)	Pearson's correlation coefficient	-0.068 **	-0.127 **	-0.241 **	-0.315 **	-0.061 **	-0.019	-0.219 **	-0.220 **	0.470 **	0.527 **	1.000	
			Significance probability	0.004	0.000	0.000	0.000	0.010	0.433	0.000	0.000	0.000	0.000		
	1000 m	Number (/ha)	Pearson's correlation coefficient	-0.072 **	-0.127 **	-0.276 **	-0.344 **	-0.047 *	0.024	-0.188 **	-0.214 **	0.247 **	0.392 **	0.630 **	1.000
			Significance probability	0.002	0.000	0.000	0.000	0.049	0.319	0.000	0.000	0.000	0.000	0.000	

$n = 1793$, * $p < .05$, ** $p < .01$

Table 6 Bivariate correlation analysis between SES proxy indicators and access to urban parks by size and buffer distance

Urban park size		Small				Medium				Large			
Buffer distance		250 m		1000 m		250 m		1000 m		250 m		1000 m	
		Area	Number	Area	Number	Area	Number	Area	Number	Area	Number	Area	Number
Professional and managerial occupation percentage average (%)	Pearson's correlation coefficient	-0.007	-0.130 **	-0.056 *	-0.236 **	0.021	0.068 **	0.038	0.013	0.040	0.047 *	0.159 **	0.236 **
	Significance probability	0.769	0.000	0.018	0.000	0.363	0.004	0.107	0.569	0.090	0.045	0.000	0.000
Years of schooling (year)	Pearson's correlation coefficient	-0.012	-0.154 **	-0.060 *	-0.296 **	0.006	0.086 **	0.029	-0.015	0.023	0.034	0.161 **	0.279 **
	Significance probability	0.621	0.000	0.011	0.000	0.801	0.000	0.220	0.526	0.340	0.148	0.000	0.000
Property tax roadside land price (1,000 JPY/m ²)	Pearson's correlation coefficient	-0.018	-0.081 **	0.116 **	-0.075 **	-0.001	0.066 **	0.028	0.096 **	-0.046	-0.047 *	-0.064 **	0.036
	Significance probability	0.459	0.001	0.000	0.001	0.970	0.005	0.238	0.000	0.053	0.047	0.007	0.125

$n = 1793$, * $p < .05$, ** $p < .01$

Electronic supplementary material

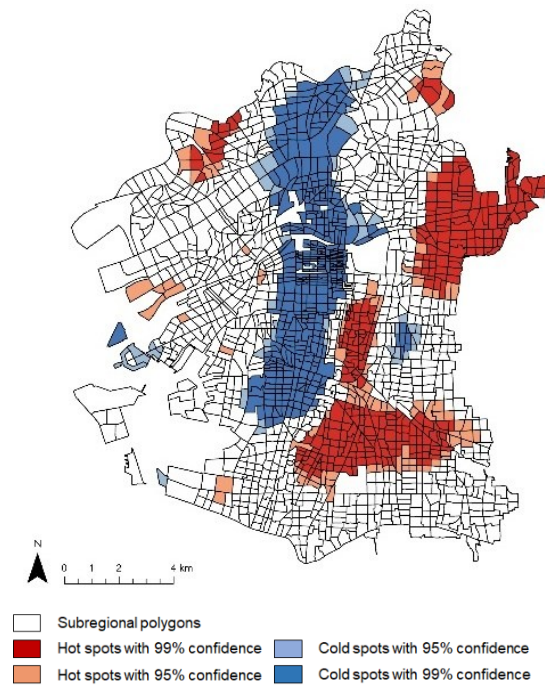


Fig. S1 Hot and cold spots of the percentage of juvenile populations in 1,793 subregions

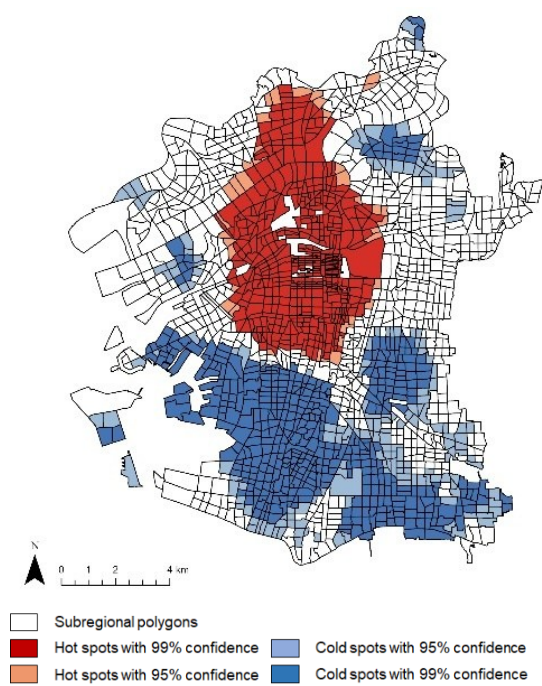


Fig. S2 Hot and cold spots of the percentage of working-age populations in 1,793 subregions

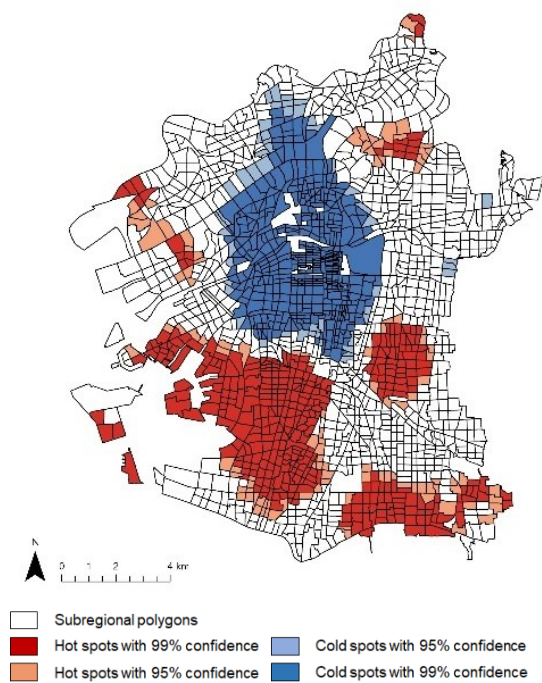


Fig. S3 Hot and cold spots of the percentage of elderly populations in 1,793 subregions

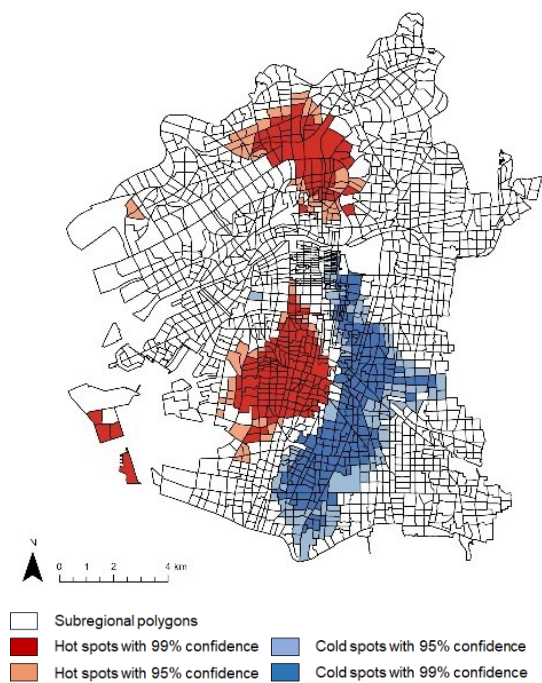


Fig. S4 Hot and cold spots of the percentage of male residents in 1,793 subregions

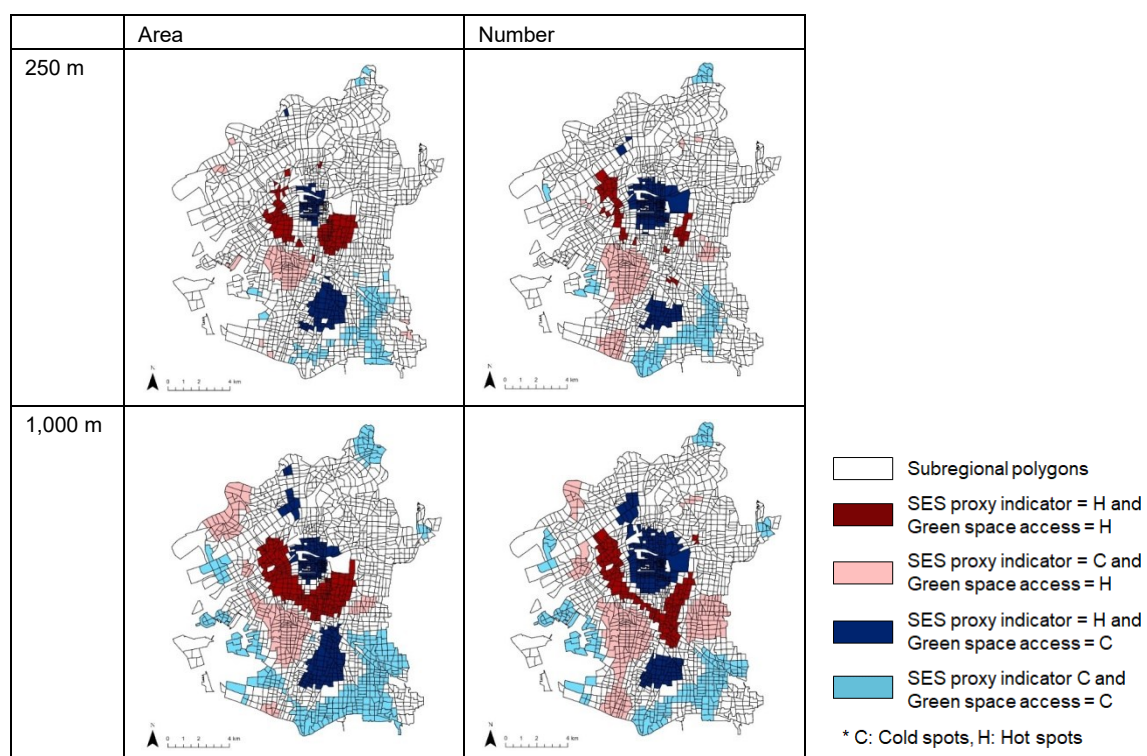


Fig. S5 Spatial association between years of schooling and access to small urban parks
in 1,793 subregions

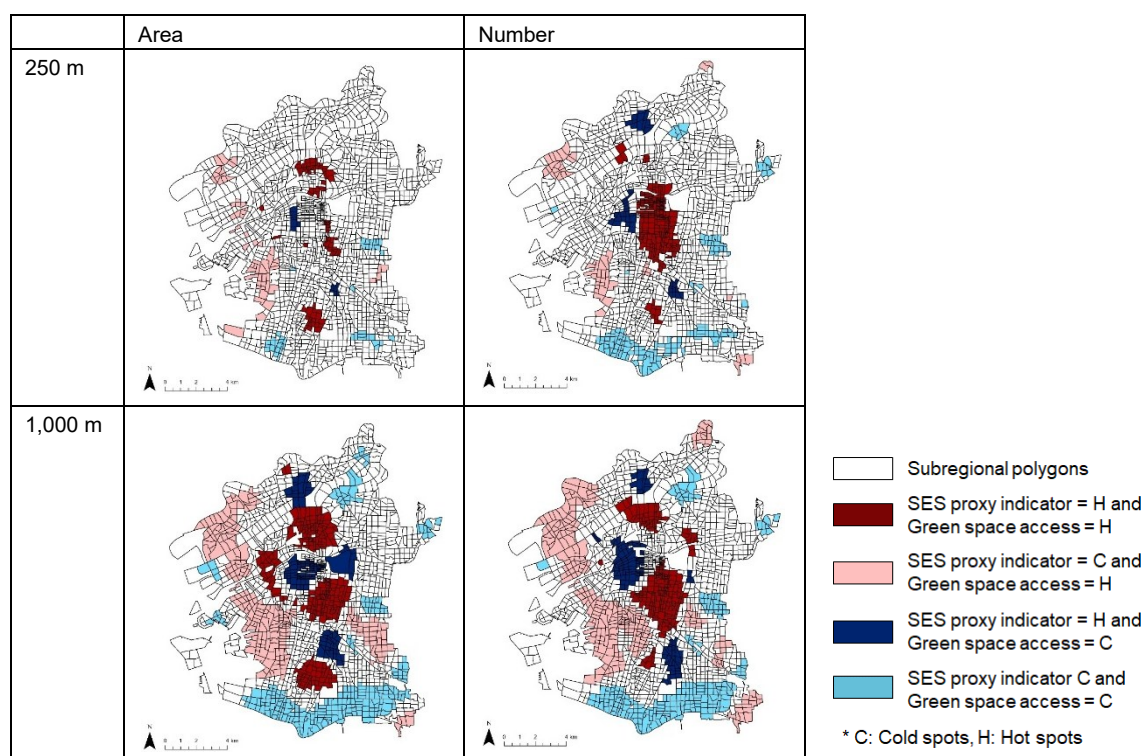


Fig. S6 Spatial association between years of schooling and access to medium urban parks in 1,793 subregions

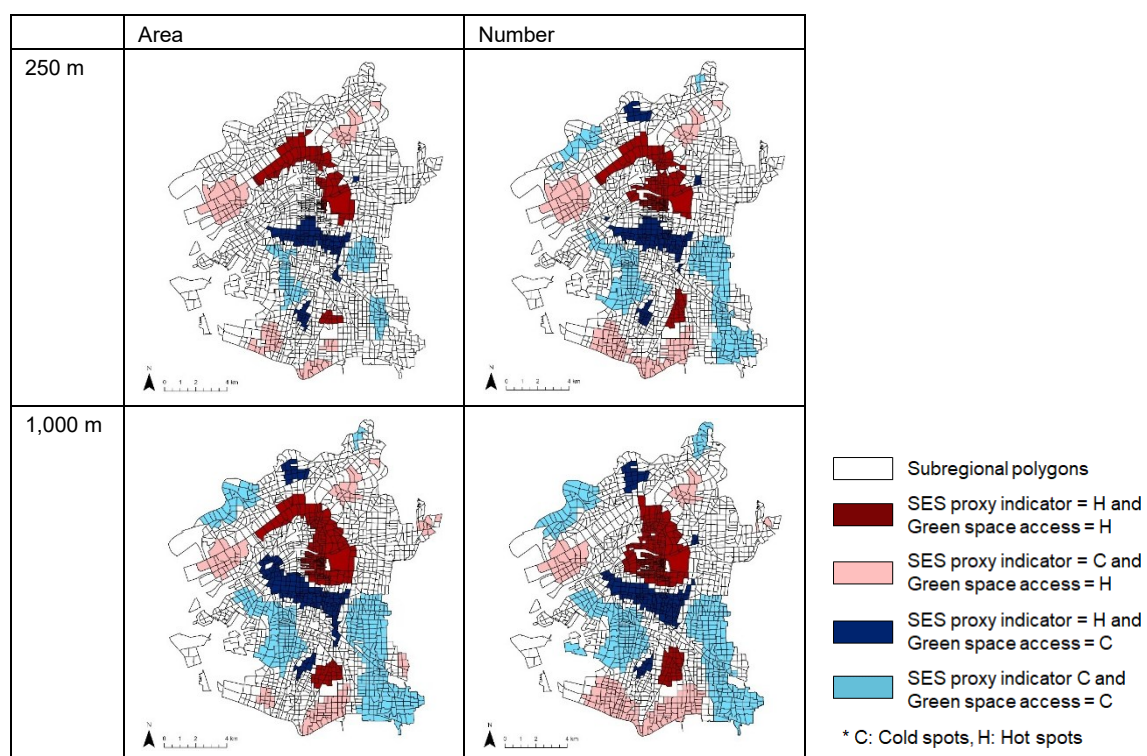


Fig. S7 Spatial association between years of schooling and access to large urban parks
in 1,793 subregions

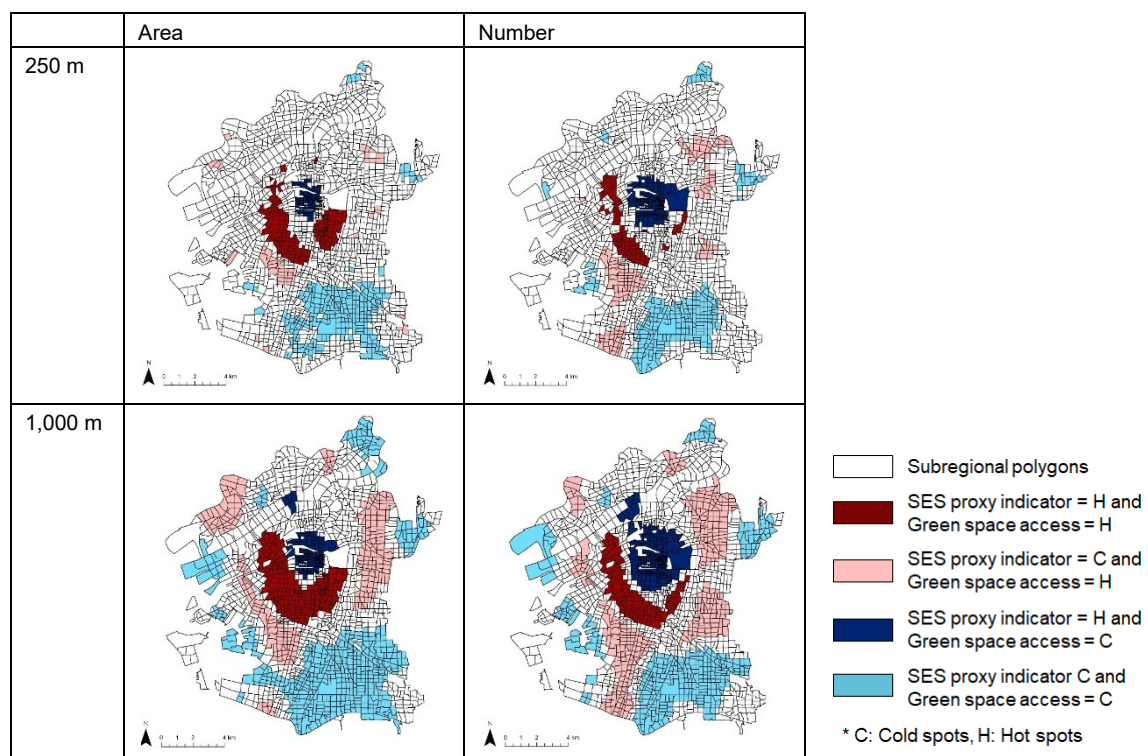


Fig. S8 Spatial association between property tax roadside land price and access to small urban parks in 1,793 subregions

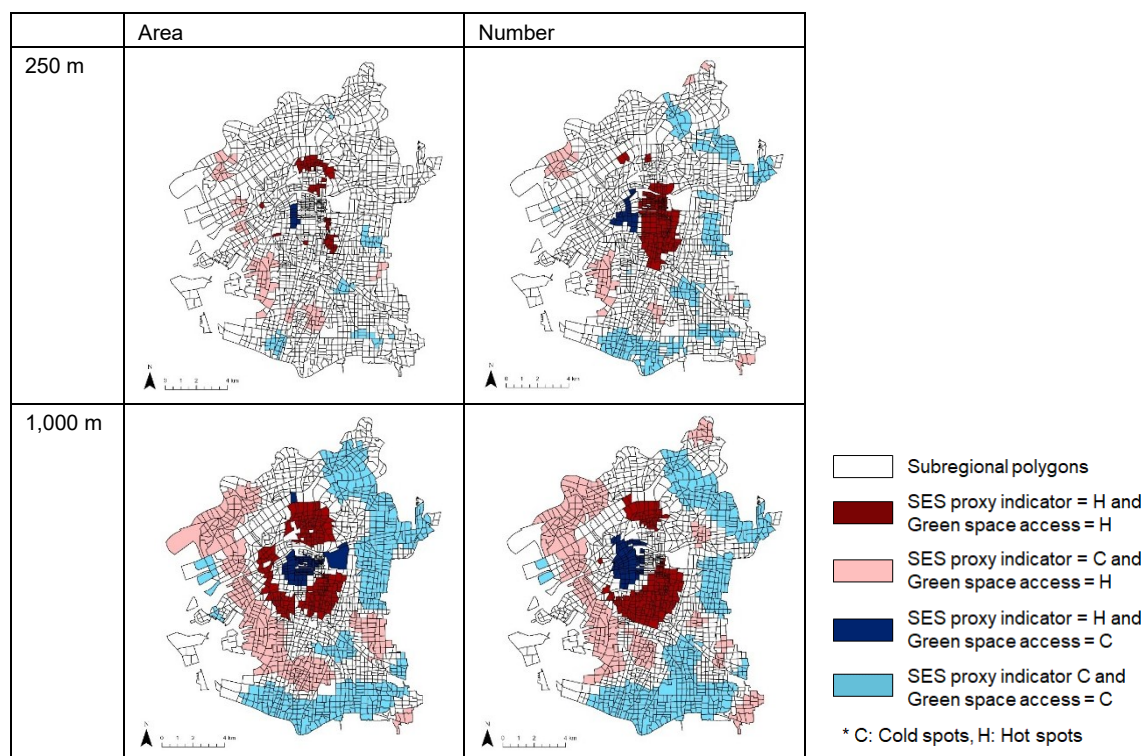


Fig. S9 Spatial association between property tax roadside land price and access to medium urban parks in 1,793 subregions

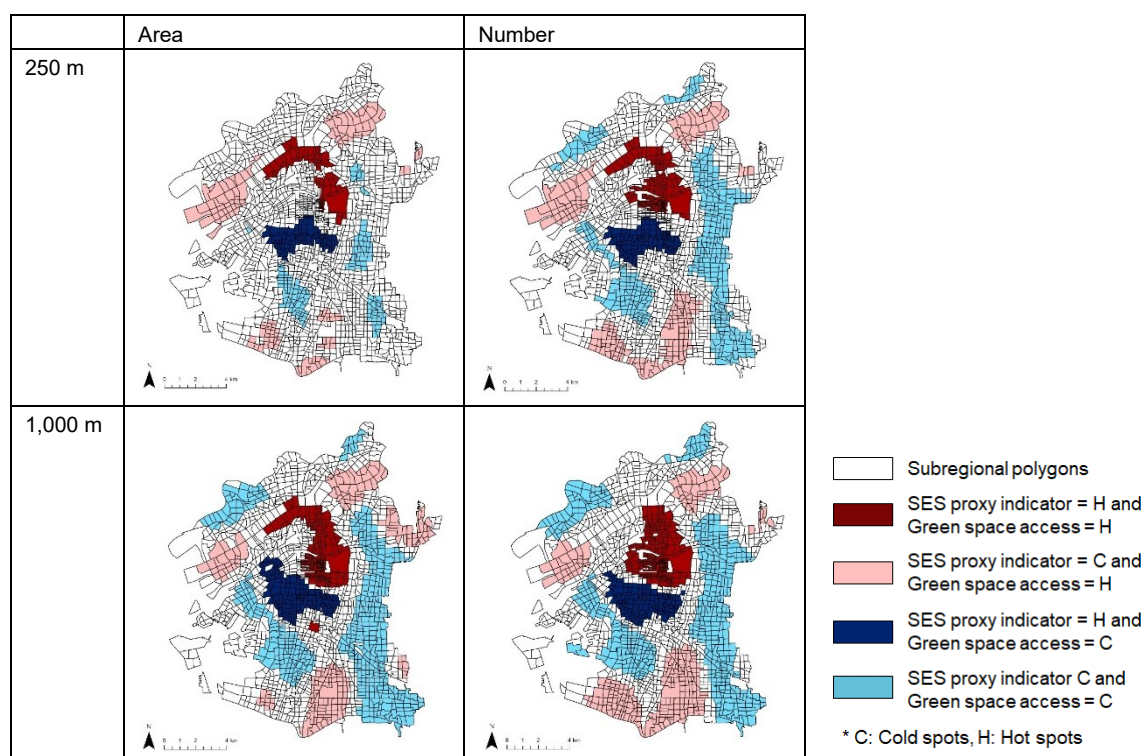


Fig. S10 Spatial association between property tax roadside land price and access to large urban parks in 1,793 subregions