DSSR

Discussion Paper No. 128

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July, 2022

Data Science and Service Research
Discussion Paper

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The value of scattered greenery in urban areas: A hedonic analysis in Japan

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Acknowledgments

This work benefited from a project funded by the Housing Research and Advancement Foundation of Japan. Satellite images and vegetation data were collected and generated in cooperation with JAPAN SPACE IMAGING CORPORATION. The views expressed are those of the authors and do not necessarily reflect those of any organizations with which the authors are affiliated.

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Abstract

This study investigates the impact of scattered greenery (street trees and yard bushes), rather than cohesive greenery (parks and forests), on housing prices. We identify urban greenspace from high-resolution satellite images and combine these data with data on both sales and rentals of condominiums to estimate hedonic pricing models. We find that scattered urban greenery within 100 meters significantly increases housing prices, while more distant scattered greenery does not. Scattered greenery is highly valued near highways but is less valued near the central business district (CBD). Additionally, the prices of inexpensive and small for-sale and of for-rent properties are less affected by scattered greenery. These results indicate that there is significant heterogeneity in urban greenery preferences by property characteristics and location. This heterogeneity in preferences for greenery could lead to environmental gentrification since the number of more expensive properties increases in areas with more green amenities.

JEL classifications: Q51, R3, R21, Q57

Keywords: Environmental amenities, Urban greenness, Hedonic house price model, Housing value, Remote sensing

1. Introduction

Urban green spaces provide a variety of benefits, including improved landscapes, air pollution abatement, noise reduction, soil conservation, and mitigation of the heat island effect, and these benefits have a substantial impact on the physical and mental health, quality of life, and overall well-being of residents (Bertram and Rehdanz, 2015; Taylor and Hochuli, 2017). However, green amenities, such as urban forests, parks, and street trees, are public goods with many positive externalities, so in the absence of public intervention, they are underprovided. The attempt to increase agglomeration effects by allocating spaces to more productive uses tends to result in substitution away from or elimination of less competitive uses, such as green amenities, particularly in highly urbanized areas. Therefore, in urban areas in many industrialized countries, local administrations and policy makers have implemented greening policies, such as imposing land use restrictions and planting trees in public spaces. However, if the value of green amenities is not properly measured, the amount of publicly provided green space might be less than optimal, which worsens people's welfare.

Rosen's hedonic pricing framework, as a method for measuring the value of urban green amenities, has been widely used in the fields of urban and environmental economics (Rosen, 1974). The general hedonic pricing approach assumes that the buyer of a home is paying for the amenities and services provided by the environment surrounding the house in addition to the property itself. By estimating housing prices as a function of various characteristics that are bundled with the housing, such as the distance from a hospital or the amount of greenery, we can derive an implicit value (willingness to pay, WTP) for each characteristic. As the availability of geographic data on land use has increased, numerous studies have used hedonic pricing approaches to measure the value of urban green space (e.g., Baranzini and Schaerer, 2011; Gibbons et al., 2014; Sander et al., 2010; Tyrväinen and Miettinen, 2000). Previous studies have suggested that urban green amenities have a generally positive impact on real estate prices (Brander and Koetse, 2011; Czembrowski and Kronenberg, 2016; Perino et al., 2014; Siriwardena et al., 2016).

Many recent studies have focused on the variety of green spaces and the heterogeneity in green-space preferences (Stromberg et al., 2021). According to Barrio and Loureiro (2010), who conducted a broad survey of studies on the value of greenery, people's WTP for greenery varies greatly depending on the type of greenery, the residential environment, and the characteristics of the people. For example, Czembrowski and Kronenberg (2016) classified green spaces into several categories by type, use, and size and showed that each dimension has different impacts. Panduro et al. (2018) also found that heterogeneous preferences for the same type of green space depend on the socioeconomic and demographic characteristics of households. Most of these existing studies have considered greenery of a certain size (i.e., cohesive greenery), such as parks and forests, as “urban green space” and have classified such spaces according to their use (e.g., sports fields, landscape preservation, and air quality improvement).

In contrast to the richness of studies of cohesive green space, prior research has provided little information about the value of scattered greenery, such as street trees and yard bushes. Unlike parks and forests, for which official statistics and geographic data are more widely available, such scattered greenery is not mapped, and data often do not exist. Measuring the value of scattered greenery requires very detailed vegetation data at the street or site level, which can be costly to obtain. Therefore, scattered greenery has been either overlooked or intentionally excluded from analyses (Perino et al., 2014), although its total area is large and could have a meaningful effect on people.

To bridge the gap in the current literature, this study investigates the value of street trees and yard bushes. Green density is calculated using the normalized difference vegetation index (NDVI) from high-resolution (1.5-meter pixel resolution) satellite imagery and is combined with large-scale real estate data that include detailed information about various characteristics to provide insights into the value of scattered greenery. The analysis covers the area around the Setagaya and Suginami wards in Tokyo, the most urbanized residential areas near the center of Japan. We also used greenery data from two different years, 2008 and 2013, to analyze changes in effects over time.

Our results show that a 10% increase in scattered greenery within 100 meters of a property increases the price of apartments for sale by 2% to 2.5%. Conversely, the impact of scattered greenery on rental properties is weak or insignificant. These main results are not sensitive to changes in the estimation specification or variable definitions and are robust to changes in the sample. We also find that the value of scattered greenery depends greatly on the characteristics of the property and its location. Street trees are highly valued along highways because of their role in mitigating noise and emissions. Higher priced and roomier properties are associated with higher values for greenery, but this outcome is also due to the large supply of both good-quality properties and greenery in areas suitable for habitation. Furthermore, the analysis of changes in effects over time suggests that there might be a gradual increase in the heterogeneity of the value of greenery by property price and quality.

Scattered greenery is especially important in urban areas where available land is scarce and pricey. In urban areas, high land prices often prevent the construction of additional parks, urban forests, and other large open spaces. Additionally, converting existing residential and commercial areas into green space is a very costly alternative because it undermines the attractiveness of the city as a center of productive activity. Therefore, a feasible strategy would be to construct nonexclusive small-scale green spaces and plant scattered greenery. Prior studies have pointed not only to the benefits of using greenery, such as exercise and recreation, but also to the benefits of the existence of greenery, such as improved air quality and temperature, and the benefits of seeing greenery, such as stress reduction (Mullaney et al., 2015). Such effects can be achieved even with scattered greenery, which does not require large tracts of land, so if scattered greenery has a positive impact on property values, it might additionally improve the welfare of urban areas. Therefore, knowing what function scattered greenery performs in a city and where and to whom it provides utility is expected to generate new insights for urban planning. In recent years, the uneven distribution of urban green space and environmental gentrification has become an issue, and it is also important to understand the widely scattered greenery that exists in cities from an environmental justice perspective.

Despite the potential benefits of scattered greenery, there is a lack of empirical evidence for the value of scattered greenery and the heterogeneity of its impacts. A small number of studies have examined the impact of tree cover on property values by generating data through sight counts of trees. Donovan and Butry (2010), who counted street trees during a detailed field survey, found that street trees within 100 feet significantly increased real estate prices. Pandit et al. (2013) visually identified street trees from aerial images and found positive neighborhood externalities due to broadleaf street trees. However, such visual identification of street trees is very costly, making it difficult to target large areas or multiple regions and thus results in the disadvantage of small sample sizes and missing data. Additionally, the field survey did not reveal greenery in hard-to-see areas such as behind walls, and grasses and bushes other than trees were completely overlooked, so their value was not revealed. Therefore, remote sensing with high-resolution aerial or satellite imagery has been used in recent years (Franco and Macdonald, 2018; Tsurumi et al., 2018). Troy and Grove (2008) used remote sensing to study the heterogeneous impact of parks on the real estate market in Baltimore, Maryland, U.S. Sander et al. (2010) estimated the value of urban tree cover in Dakota and Ramsey counties, Minnesota, U.S., and found that a 10% increase in tree cover within 100 meters increased the average home sale price by $1371 (0.48%) and that a 10% increase within 250 meters increased the average price by $836 (0.29%). However, the resolution of the images used by Sander et al. (2010) was 30 meters, and since one pixel on an image represented 30 meters of ground surface, nothing is revealed about the value of scattered greenery because it cannot be identified. To our knowledge, few studies have analyzed the impact of scattered greenery on property values using large sample sizes and detailed green coverage data.

We contribute to the literature on the evaluation of urban green spaces by identifying greenery in detail using satellite images that have a higher resolution than those used in existing studies. Using satellite images that allow us to identify trees and bushes on a plant-by-plant basis, we can determine the amount of greenery covering a large area without missing anything and provide robust evidence for the value of scattered greenery. Our results highlight the high value of trees and bushes along roadsides, which has been overlooked in previous studies. Additionally, while existing studies have emphasized the availability of green spaces such as parks and forests, our results indicate that greenery that is not directly usable is also considered an important amenity. These results generate new insights for development plans in cities where land is scarce and expensive.

We also reveal the heterogeneous valuations of green amenities by property characteristics and location by combining detailed green coverage data with rich real estate transaction data for both sales and rentals. Most previous studies have focused on either sales or rentals or on highly homogeneous real estate markets and might have overlooked heterogeneity in the ways in which green amenities affect the market. However, Łaszkiewicz et al. (2019) suggested that greenery could be a luxury item and that people with higher incomes might seek better-quality green amenities. We identify the heterogeneity in preferences for green amenities by comparing the transactions data on properties for sale, which are more expensive and longer-term investments, with those on properties for rent, which are less expensive and shorter-term holdings. Additionally, we contribute to the discussion about environmental gentrification by finding suggestive evidence that such heterogeneity in preferences could lead to residential segregation or stratification.

The paper proceeds as follows. Section 2 describes the study area and details the data used in this study. Section 3 presents the empirical strategy. Section 4 presents the main results, a series of robustness checks, and insights into the underlying mechanism. Section 5 discusses the policy implications, and Section 6 concludes the study.

2. Data and settings

2.1. Study area

Our study area covers the Setagaya and Suginami wards, which are located in the western part of central Tokyo, the capital of Japan. The satellite images used to create the green coverage data cover an area of approximately 131 km^2, including 545 streets.[1] This area is adjacent to the central business district (CBD) of Tokyo and is one of the most attractive real estate markets in Japan. The 2010 population (and density) of the Setagaya and Suginami wards was approximately 880,000 (15,000/km^2) and 550,000 (16,000/km^2), respectively. The area has many high-income residents: the average taxable income across residents in all municipalities in 2010 was 2,765,000 JPY, whereas the average for the Setagaya and Suginami wards was 4,971,000 JPY and 4,354,000 JPY, respectively. Consequently, land and housing prices are also known to be quite high.

This area is considered to be a "just right" residential area, with the central commercial area to the east and the suburbs to the west. The entire area is fairly well developed, with very little farmland, wasteland, or vacant land. There are several forests, but they are all managed planted forests within parks; there are no natural forests. To maintain a comfortable residential environment, there is a large amount of scattered greenery, with street trees along the roads and bushes surrounding buildings. Therefore, we can identify the impact of scattered greenery in a

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[1] Technically, these passages are not streets but are called "cho-chos." A cho-cho is the smallest geographical unit in Japan and is similar in concept to a street in the U.S. For simplicity, this paper uses the term "street."

highly developed city while reducing the problem of misidentification of greenery areas.

2.2. Urban greenness

We use Maxar Technologies' high-resolution optical satellite imagery to identify green-covered areas in to create our GIS data. Satellite images taken on April 30, 2008, and October 13, 2013, the two days with the least cloud cover among the available dates in 2008 and 2013, were used.[2] The images include four spectral bands, the blue-green-red visible bands and the near-infrared band, and are available with a 1.5-meter spatial resolution. We created our NDVI image data using the red (R) and near-infrared (NIR) spectral bands to extract green-covered areas. NDVI is calculated as $(NIR - R)/(NIR + R)$ and indicates the relative greenness of the pixels. Because plants absorb visible (red) light during photosynthesis, and plant cell structures reflect near-infrared light, NDVI is used as a relative indicator of greenness (Franco

[2] We assume that using April data from one year and October data from another year does not cause serious problems because the region does not experience significant changes in plant conditions except during the winter (December-February). However, given the concern that the difference in green cover between 2008 and 2013 is due to the month of observation, this study does not focus on the increase or decrease in green cover from 2008 to 2013 but only on the change in the impact of green cover on the real estate market in each year. Due to budget constraints, other data were not available, and this study is limited by the inability to consider changes in vegetation due to seasonal differences.

and Macdonald, 2018). In general, an NDVI value close to 1 represents rich greenery, while an NDVI value close to -1 represents a water area. We focus on pixels with high NDVI values and subsequently process the data by changing the threshold value and checking for false positives to produce the most appropriate identification of green coverage.[3]

The green coverage data generated based on the NDVI values tells us only that the area has green cover and does not allow us to identify the type of greenery that is present. Therefore, we identify the type of greenery by combining our NDVI data with the Urban Area Land Use Subdivision Mesh Data published by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). These GIS data are based on satellite images and field surveys and identify land at the 100-meter mesh (100-square meter) level for each type of use (rice fields, agricultural land, forests, building lots, roads, parks, rivers, etc.). We match the 2009 and 2014 Urban Area Land Use Subdivision Mesh Data to the 2008 and 2013 green coverage data, respectively.

Specifically, if the land use category is buildings, roads, or railroads, then the greenery in the area overlapping that mesh is identified as “scattered greenery.” This definition is reasonable because the greenery present in areas used for buildings and roads consists of the

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[3] The green coverage identified using only NDVI images contains misclassified objects. Therefore, we confirmed and corrected these misclassified areas with the support of JAPAN SPACE IMAGING CORPORATION, a company specializing in satellite image manipulation.

trees between roads and sidewalks or the bushes around buildings. Similarly, if the land use category is farmland, wasteland, or vacant land, the category is “farmland and vacant land greenery”; if the category is rivers or lakes, the category is “waterfront greenery”; and if the category is forests, parks, or public facilities, the category is “park and public facility greenery”.

The Urban Area Land Use Subdivision Mesh Data define the land use for the entire mesh as use that accounts for the largest percentage within each mesh. Thus, if the mesh consists of 70% buildings and 30% parks, it is assigned a land use of “buildings,” and the greenery in the parks is thus defined as scattered greenery. However, the greenery in such small parks can be thought of as similar to street trees or garden bushes because of their low availability for specific purposes, such as exercise and recreation. Appendix Figures A1 and A2 show comparisons of high-resolution aerial photographs and NDVI-based green coverage data. Figure A1, showing residential areas, illustrates that what is defined as scattered greenery is mainly bushes and trees around houses, beside roads, and along railroad tracks. Figure A2, which shows parks with sports fields, indicates that the greenery around parks and sports fields is classified as cohesive greenery. However, the 100-meter mesh is used, so the greenery at the boundary of the park is classified as scattered greenery. Although such classification errors potentially bias the results, the boundary between parks and other areas is not clearly defined, and the area is small, so the analysis in this study considers the area as scattered greenery.

Figures 1 and 2 show the green areas by type in 2008 and 2013, respectively. As shown, even the data classified at the 100-square meter level are sufficiently smooth to distinguish between the different types of greenery.[4] Many green areas are spread throughout the study area, emphasizing the importance of scattered greenery in urban areas. The locations of the green areas did not change significantly between 2008 and 2013, but the percentage of green coverage decreased slightly. Scattered greenery accounted for approximately 18.5% of the area in 2008 and approximately 14.9% in 2013. Of course, these figures should be interpreted with caution since the decrease could have been caused by the difference in the dates of observation or the processing of the satellite images.

[4] In the 2009 Urban Area Land Use Subdivision Mesh Data, forests within parks are classified as "parks,", but in 2014 they are classified as "forests.". This is because the category classification was changed by the MLIT and not because the actual land use has changed. Since almost all forests in the area are within a parks, parks and forests are treated the same as when creating the variables.

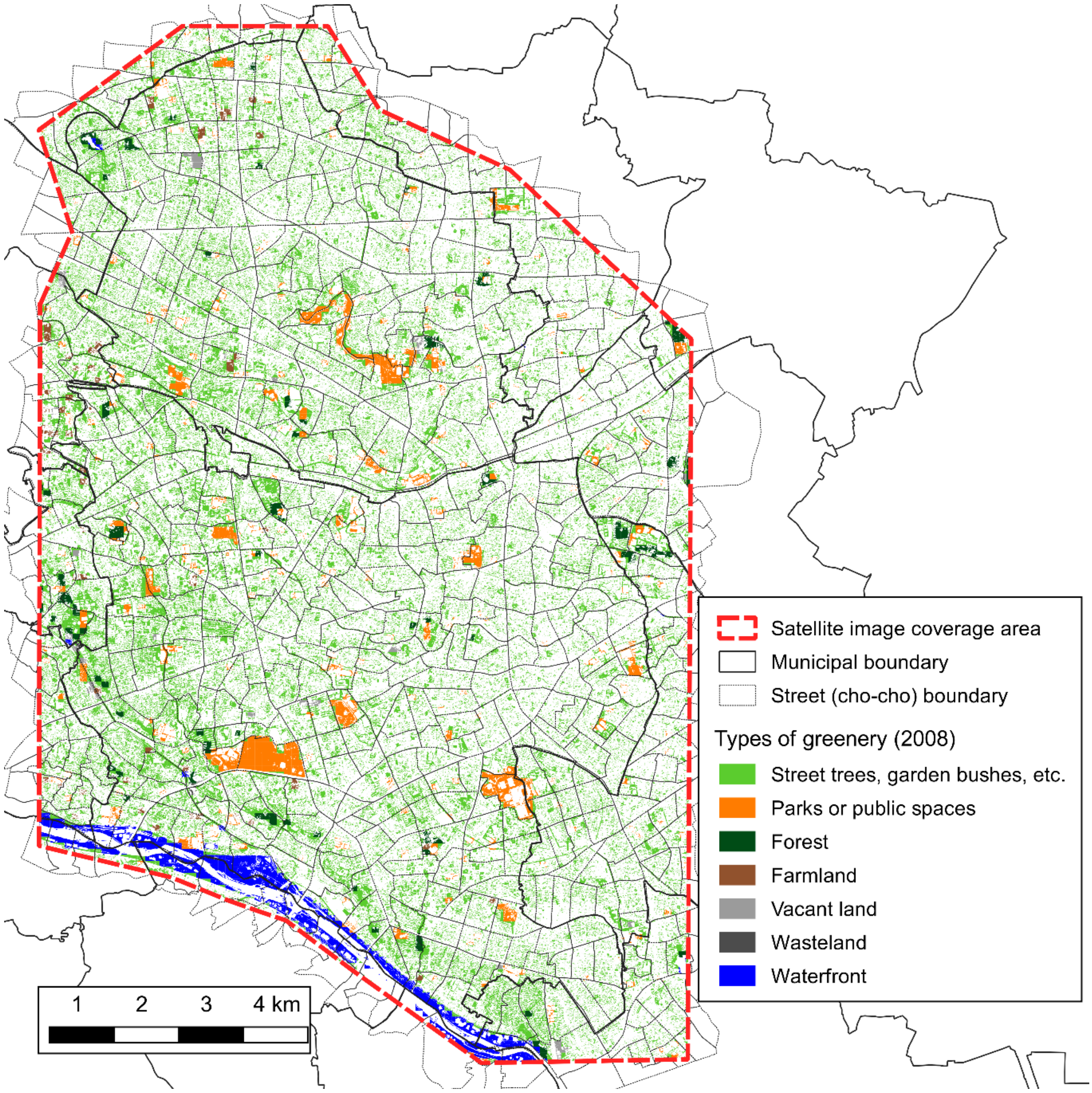

Figure 1. Green coverage by type in 2008

Note: The location and amount of greenery are based on satellite images from 2008. The classification of green spaces is based on the 2009 Urban Area Land Use Subdivision Mesh Data.

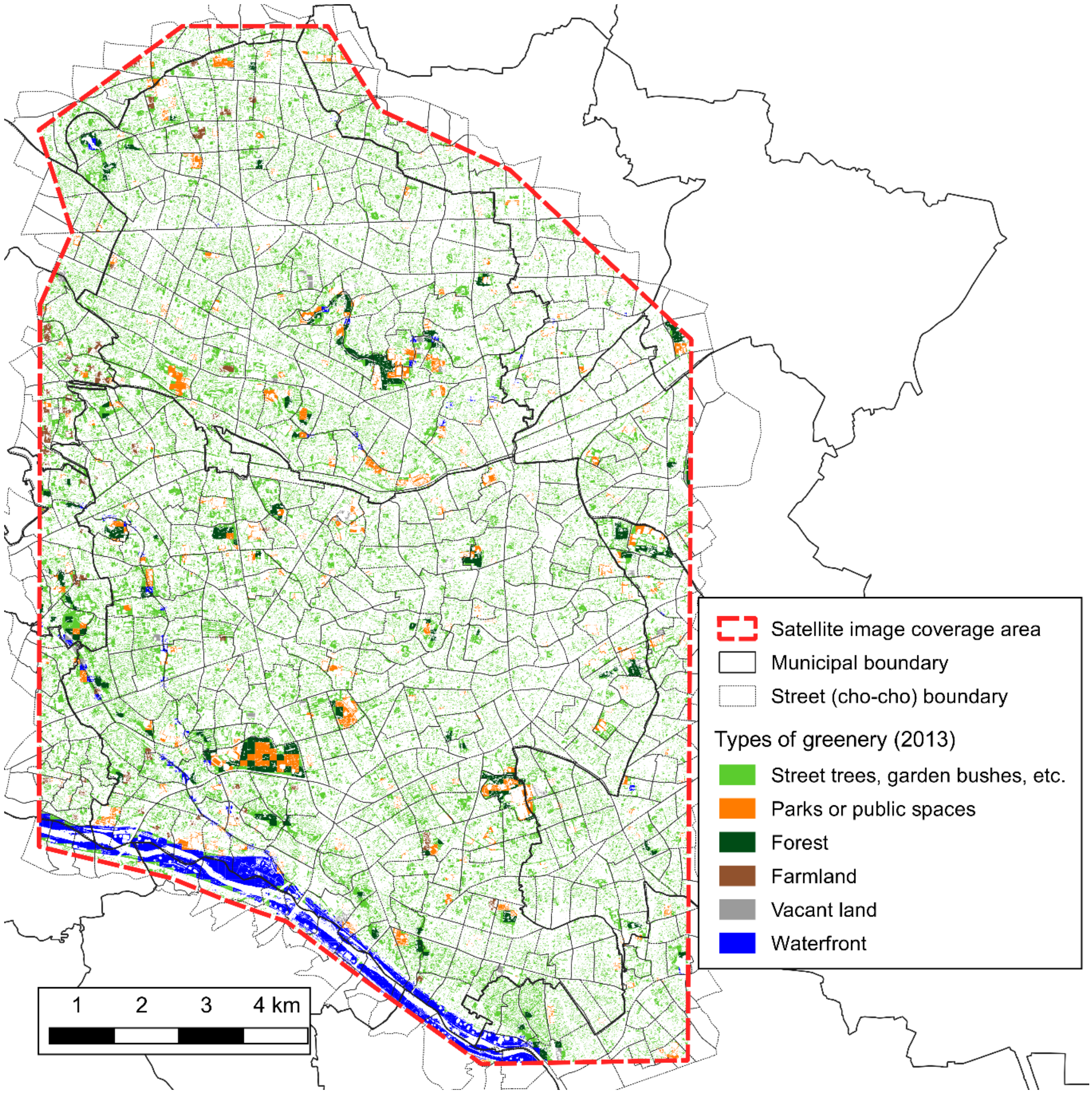

Figure 2. Green coverage by type in 2013

Note: The location and amount of greenery are based on satellite images from 2013. The classification of green spaces is based on the 2014 Urban Area Land Use Subdivision Mesh Data.

Most studies related to urban green space have focused on two different measures: the distance to a green space and the amount of green space. Unlike parks and other large open spaces, scattered greenery is not something people travel to and use. The effects of scattered greenery include improved air quality due to its presence and reduced stress due to a beautiful landscape. Therefore, it is not the distance to the nearest scattered greenery but the total amount of scattered greenery around the property that matters. We constructed five doughnut-shaped concentric buffers (defined at 100-meter intervals up to a maximum of 500 meters) around the coordinates of the building's center of gravity and measured the amount of each type of greenery within each buffer. Descriptive statistics are provided in Appendix A3.

2.3. Property data

We use housing transaction data provided by the Real Estate Transaction Promotion Center (RETPC), an association of real estate agents. The RETPC provides the largest Multiple Listing Service (MLS) in Japan, called the Real Estate Information Network System (REINS). REINS contains records of contracts for the properties handled by each member real estate agent, and its database includes transaction information for the property (contract price or rent, date of contract, exact address of the building, and various property characteristics). This dataset includes both sales and rentals of apartments for residential purposes. We convert building addresses into longitude and latitude coordinates and then merge the real estate data with the other variables based on these coordinates.

For our analysis, we use the sales and apartment rentals that were transacted in the analyzed area during the 10 years from 2006 to 2015.[5] Because green coverage does not change substantially over a few years, the 2008 and 2013 green coverage data are connected to property data from 2006 to 2010 and from 2011 to 2015, respectively. We removed from our sample properties for which the exact latitude and longitude were unknown, that were missing primary characteristics, that had extremely high or low prices or rents, or that suffered from suspected typographical errors. Totals of 17,552 properties for sale and 137,851 properties for rent are used for estimation. Each property observation includes information about the number of rooms, the square footage, the age of the building, the floor on which it is located, the number of floors in the building, the type of layout, the type of building structure, and the zone of the location.[6] Descriptive statistics can be found in Appendix A3.

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[5] Apartments (condominiums) are important when effectively using small, densely populated areas, such as those in Tokyo, and are the main option for residential housing. Our data include detached properties, but the number of transactions is very small, and the transaction prices are extremely high. Additionally, detached houses are able to have more greenery in their own yards, causing endogeneity problems in the estimation. Thus, we focus on the price of or rent for apartments.

[6] The zones of a location define the types of buildings that can be constructed in these areas (low-rise residential, high-rise residential, commercial, industrial, etc.), and the building-to-land ratio and floor-area ratio are also defined for each zone. By controlling for the fixed effects of the zones, the estimation considers the effects of confounders such as the size of the yard and the height of the building.

2.4. Other control variables

We control for a variety of characteristics that can affect property values. We prorate the census-based street-level population, household count, population younger than 20, and population older than 65 within a 500-meter radius of the property to create variables for the demographic characteristics around the property. To control for real estate market conditions around the properties, we generated the number of transactions, the average price or rent, and the average ground floor level for each property within a 500-meter radius for both sales and rental properties. Additionally, we obtained GIS data on various government statistics regarding the locations of hospitals, schools, police stations, fire stations, post offices, parks, museums, libraries, sports fields, martial arts facilities, swimming pools, municipal offices, stations, bus stops, major roads, highways, Tokyo Station (the CBD), and the Tama River, and we calculated the distances from the properties to the nearest instance of each type of amenity. These accessibility measures are logarithmically transformed because the effect of access to amenities is expected to decrease as distance increases. Descriptive statistics can be found in Appendix A3.

3. Empirical strategy

Hedonic property pricing models have been widely used to estimate the contribution of various characteristics to the value of a property. This paper uses a hedonic model to estimate the marginal implicit price of scattered greenery. The estimation equation is as follows.

$$\ln(P)_{iyms} = \alpha + \sum_{r=1}^{5} \beta_r Green_{riyms} + X_{iyms} + Y_y + M_m + S_s + \varepsilon_{iyms} \quad (1)$$

where the dependent variable $\ln(P)_{iyms}$ is the natural logarithm of the price or rent of property i on street s that was contracted in month m of year y. $Green_{riyms}$ represents the percentage of scattered greenery within the r-th concentric buffer from the center of property i. The coefficient β_r measures the value of the greenery within the r-th buffer. X_{iyms} controls for various characteristics, such as property characteristics, neighborhood characteristics, accessibility characteristics, and other green coverage.[7] Y_y, M_m, and S_s control for the contract year, contract month, and street fixed effects, respectively. We estimate Eq. (1) using four separate datasets on sales and rental properties for 2008 and 2013.

The hedonic model in Eq. (1) does not consider spatial relationships among the observations. In estimating hedonic price models, heteroskedasticity and spatial autocorrelation issues can render ordinary least squares (OLS) estimators inefficient. Some previous studies have considered spatial dependence by applying spatial hedonic models using

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[7] The study area is a well-developed urban area, and as Figures 1 and 2 show, the other types of greenery (e.g., parks and waterfront greenery) are scarce and unevenly distributed. Therefore, this study uses green spaces other than scattered greenery as a control variable only and does not provide a detailed interpretation of the corresponding impact.

spatial weight matrices that define adjacencies (e.g., Sander et al., 2010; Votsis, 2017). However, since our data contain separate rooms in the same building, some samples have a common longitude and latitude (i.e., zero distance), making it difficult to define the spatial weight matrix. Additionally, we have the technical problem that maximum likelihood estimation is difficult due to the large sample size and large number of independent variables.

We therefore report our estimation results from a general hedonic pricing model that controls for various amenities and fixed effects as our main results. While not accounting for spatial dependence might seem problematic, Mueller and Loomis (2008) confirmed that estimates obtained by accounting for spatial autocorrelation in a hedonic property model are nearly identical to OLS estimates. We also estimated a spatial error model using samples that use only properties with unique latitudes and longitudes as a robustness check, but the results were almost identical to those obtained using OLS. Therefore, the presence of spatial dependence should not seriously affect our results.

4. Results

4.1. Main results

Table 1 shows the main results. Columns (1) and (2) are estimated using data on properties for sale and show that scattered greenery within 100 meters of a property significantly increases the contract price. Scattered greenery more than 100 meters from the residence has a barely significant impact. This result is consistent with the results of a previous study (Donovan and Butry, 2010) and suggests that scattered greenery is not something that is accessed for use and is therefore highly valued when it is easily visible on a daily basis (Lo and Jim, 2012; Tsurumi et al., 2018). Columns (3) and (4) present estimation results using data on rental properties. Column (3) uses 2008 data and shows that scattered greenery within 100 meters slightly increases rents, while Column (4) uses 2013 data and shows that scattered greenery at any distance has no significant effect on rents.

Our results show that a 10% increase in scattered greenery within 100 meters increases the price of apartments for sale by approximately 2% to 2.5% (from 740,000 to 930,000 JPY). Sander et al. (2010), who analyzed green space in Minnesota, reported that a 10% increase in the tree canopy within 100 meters increased the average housing price by 0.48% and that the average tree canopy within 250 meters increased the average price by 0.29%. Our estimated impact, which is larger than those in previous works, could be caused by the characteristics of the study area. Our study area has little green space, so the value of greenery could be high (Brander and Koetse, 2011; Siriwardena et al., 2016). Additionally, trees and grasses that reduce noise and pollution might be highly valued due to the high population density and traffic in our study area (Perino et al., 2014; Votsis, 2017). We provide a subsample analysis in the following sections and address the mechanisms underlying the results of these green assessments.

	Properties for sale		Properties for rent	
	2008	2013	2008	2013
	(1)	(2)	(3)	(4)
% Surrounding greenness				
Scattered greenery (0–100 m)	0.251***	0.204**	0.055*	0.016
	(0.057)	(0.076)	(0.027)	(0.024)
Scattered greenery (100–200 m)	-0.137	-0.092	0.019	0.005
	(0.093)	(0.118)	(0.043)	(0.043)
Scattered greenery (200–300 m)	-0.096	-0.159	0.038	0.044
	(0.116)	(0.140)	(0.056)	(0.046)
Scattered greenery (300–400 m)	-0.270*	-0.189	-0.054	0.038
	(0.136)	(0.156)	(0.060)	(0.056)
Scattered greenery (400–500 m)	-0.085	-0.324	-0.023	-0.111
	(0.152)	(0.178)	(0.080)	(0.066)
Property characteristics	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES
Observations	7,872	9,680	43,188	94,663
Adjusted R-squared	0.9424	0.9452	0.9174	0.9106

Table 1. Effects of scattered greenery on property prices and rents

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The full results are provided in Appendix Table A4.

Tsurumi and Managi (2015) analyzed the value of green space using the life satisfaction approach (LSA) for areas close to ours. They indicated that the marginal WTP for a 1% increase in green space within a 100- to 300-meter radius from home is 93,714, which is fairly close to our result. However, Tsurumi and Managi (2015) found that parks and other green spaces within 100 meters have no significant impact. Several previous studies have found that greenery too close to a house has a negative effect or no effect at all on housing prices, but these studies focused their analyses on cohesive green spaces, such as parks and urban forests (Pandit et al., 2013; Stromberg et al., 2021). Too much proximity to a cohesive green space provides disamenities, such as increased noise, decreased public safety, and the presence of unpleasant animals and insects, which can reduce the value of a property. However, scattered greenery is less likely to generate such disamenities, so closer proximity could be important.

Compared to properties for sale, rental properties are less affected by scattered greenery. There could be several explanations for this fact. Individuals entering into a purchase agreement, with its higher price and longer ownership period, might place more importance on the living environment, while those entering into a less expensive and easier rental agreement might place more importance on accessibility to commercial areas, workplaces, schools, etc. Appendix Table A5 shows the number of households within 10 kilometers of the CBD by years of residence in the current house, indicating that the number of years of residence for owned and rented households is quite different. More than 60% of households living in sales properties have lived in their current home for more than 13 years, and about 35% have lived in their current home for more than 28 years. In contrast, about 40% of households living in rental properties have lived in their current homes for less than two years, and about 80% have lived in their current homes for less than 12 years. Therefore, it is plausible to explain that environmental amenities are strongly considered in sales contracts, which are long-term holdings, but not in short-term rental contracts.

Alternatively, there could be heterogeneity in ownership preferences since wealthy people and families are more likely to live in properties for sale, and single individuals are more likely to live in properties for rent. Łaszkiewicz et al. (2019) suggested that green spaces are luxury goods and that individuals with higher incomes might be more environmentally oriented. It is also plausible that families are more likely to be concerned about their residential environments due to a focus on the health and growth of their children. Further insights into these heterogeneities in preferences are also provided in the subsample analyses in the following section.

4.2. Robustness checks

The results of our series of robustness checks are presented in Table 2 and Appendix Table A6. Panels A, B, C, and D show the results using data from the properties for sale in 2008, the properties for sale in 2013, the properties for rent in 2008, and the properties for rent in 2013, respectively. In what follows, due to space limitations, we report only the results for scattered greenery within 100 meters that are significant, and the impacts at greater distances are provided in the Appendix. Column (1) shows the results using the natural logarithm instead of the percentage of scattered greenery, while Column (2) shows the results estimated using a dummy variable that has a value of 1 when the amount of scattered greenery is in the top 25%. The results in Columns (1) and (2) are consistent with the main results, and our results are robust to changes in the measure of scattered greenery.

Columns (3) through (6) confirm that the main results are not sensitive to changes in the sample. Column (3) shows the results after excluding the top and bottom 5% of observations in terms of prices/rents in each sample, confirming that the main results are not driven by extremely expensive or inexpensive properties. Column (4) excludes the impact of very large apartment buildings with various amenities, such as lush gardens (called high-class tower condominiums in Japan), by excluding from the sample properties with more than 10 floors. Column (5) is estimated using only properties contracted in 2008 and 2013 (the years for which the green coverage data were obtained). Although the smaller sample size increases the standard errors and slightly decreases the significance of our results, the magnitudes of the coefficients are consistent. Column (6) confirms that the inclusion of multiple rooms in a single building does not affect the results. Specifically, properties with an exact latitude and longitude match in a contract year are assumed to be in the same building, and average values are calculated for the number of rooms or floors on which rooms are located to create a unique dataset at the year and building levels.

Column (7) shows the results of the estimation after considering spatial dependence. We conduct this estimation using only properties contracted in 2008 and 2013 from the unique sample created in Column (6). Using the distance at which every property has one or more neighbors (approximately 500 meters) as the threshold for adjacency, a spatial weights matrix is created using the inverse of the distance and is analyzed using a spatial error model (SEM). The estimation results from the SEM are in close accordance with the main results estimated with OLS, confirming that spatial dependence does not seriously affect our results.

	Alternative green space measures		Trimmed Samples				Spatial dependence (SEM)
	Natural logarithm	Top 25% dummy	Remove top and bottom 5%	Exclude large-scale properties	Only single year	Only unique buildings	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Sales (2008)							
Scattered greenery (0–100 m)	0.023**	0.041***	0.218***	0.210***	0.288*	0.233***	0.287**
	(0.007)	(0.009)	(0.058)	(0.062)	(0.128)	(0.058)	(0.099)
Observations	7,872	7,872	7,084	6,245	1,473	7,586	1128
Adjusted R-squared	0.9422	0.9423	0.9244	0.9443	0.9452	0.9400	
Panel B: Sales (2013)							
Scattered greenery (0–100 m)	0.014	0.024**	0.151*	0.175*	0.203	0.220**	0.231*
	(0.008)	(0.008)	(0.077)	(0.078)	(0.124)	(0.078)	(0.104)
Observations	9,680	9,680	8,712	7,601	2,146	9,356	1529
Adjusted R-squared	0.9451	0.9451	0.9257	0.9476	0.9512	0.9404	
Panel C: Rentals (2008)							
Scattered greenery (0–100 m)	0.009**	0.0004	0.024	0.056*	0.042	0.078***	0.079*
	(0.003)	(0.004)	(0.020)	(0.028)	(0.052)	(0.022)	(0.039)
Observations	43,188	43,188	39,039	41,263	6,814	35,361	3961
Adjusted R-squared	0.9174	0.9174	0.9017	0.9157	0.9173	0.9093	
Panel D: Rentals (2013)							
Scattered greenery (0–100 m)	0.003	0.001	-0.019	0.019	0.068	0.042*	0.066*
	(0.003)	(0.003)	(0.024)	(0.025)	(0.035)	(0.020)	(0.030)
Observations	94,663	94,663	85,329	90,768	19,266	73,572	9107
Adjusted R-squared	0.9106	0.9106	0.8885	0.9085	0.9110	0.9074	
Property characteristics	YES	YES	YES	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES	YES	YES	YES
Street FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	NO	YES	NO
Month FE	YES	YES	YES	YES	YES	NO	YES

Table 2. Robustness checks

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as in Table A2, and the parameter estimates and standard errors for the control variables and for scattered greenery more than 100 meters away are omitted due to space limitations. The impact of scattered greenery more than 100 meters away is reported in Appendix Table A6.

We also check whether the amount of scattered greenery has nonlinear effects. Previous studies have suggested that the amount of urban green space and real estate prices or life satisfaction exhibits an inverted U-shaped relationship (Bertram and Rehdanz, 2015; Siriwardena et al., 2016) because too much green space can result in negative impacts, such as noise, soil dust, insect damage, etc. Alternatively, perhaps this nonlinear relationship occurs because more green space is correlated with fewer other important amenities. Table 3 and Appendix Table A7 show the results using dummy variables created by dividing the scattered greenery variable into quintiles. Columns (1) and (2) show the results using sales properties, and in contrast with previous studies, we find that sales prices are significantly higher, especially in areas with more greenery. Scattered greenery, unlike parks and urban forests, is less likely to produce negative externalities, such as noise, or to exclude other amenities. Therefore, too much scattered greenery is not expected to reduce real estate values. Alternatively, it might simply be the case that the study area is a well-developed urban area. Siriwardena et al. (2016) suggested that the value of surrounding green space reaches a maximum at approximately 40% and decreases thereafter, while the scattered greenery in our study area is approximately 15% to 20%. Therefore, it is possible that the study area has not yet reached the point of “too much” greenery.

Among properties for sale, a large amount of scattered greenery is highly valued, which might indicate that a green environment is considered desirable for long-term residence. In contrast, Columns (3) and (4), which present the estimates for rental properties, show different results. There is no consistent relationship between the amount of scattered greenery and the magnitude of the impact using either the 2008 or the 2013 green coverage data. This finding might occur because renters do not live in their properties for long periods, making a green environment less important. To discuss the characteristics of sales and rentals that cause this difference, we next estimate subsamples defined by the price or location of the property.

	Properties for sale		Properties for rent	
	2006-2010	2011-2015	2006-2010	2011-2015
	(1)	(2)	(3)	(4)
Scattered greenery (0–100 m)				
2nd quintile	-0.018	0.015	0.008*	0.003
	(0.010)	(0.011)	(0.004)	(0.004)
3rd quintile	-0.005	0.013	0.003	0.0002
	(0.010)	(0.012)	(0.004)	(0.004)
4th quintile	0.013	0.018	0.013**	0.004
	(0.011)	(0.012)	(0.005)	(0.004)
5th quintile	0.034*	0.052***	0.011	0.002
	(0.013)	(0.015)	(0.006)	(0.004)
Property characteristics	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES
Observations	7,872	9,680	43,188	94,663
Adjusted R-squared	0.9424	0.9453	0.9175	0.9107

Table 3. Nonlinear effects of scattered greenery

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as in Table A2, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 meters away are omitted due to space limitations. The impact of scattered greenery more than 100 meters away is reported in Appendix Table A7.

4.3. Subsample analysis

Table 4 and Appendix Table A8 present the results of the subsample analysis. Columns (1) and (2) present the results of the estimation by dividing the sample into two parts: (1) greater than the median price or rent and (2) less than the median price or rent. For both sales and rentals, we see that the higher-priced properties are more strongly affected by the scattered greenery, and the differences in property prices are more noticeable in 2013. This finding is consistent with related studies showing that people with higher incomes are more concerned about environmental amenities (Fuerst and Shimizu, 2016; Łaszkiewicz et al., 2019). Interestingly, while the analysis using the full sample showed that scattered greenery had a greater impact in 2008, the impact was greater in 2013 when the properties were divided by property price. This outcome come be due to increased residential sorting and segregation in 2013, polarizing the population into two groups: wealthy residents who care about greenery and poor residents who do not.

Columns (3) and (4) show the results of dividing the sample by the number of rooms, i.e., one room or at least two. We can see that properties with two or more rooms are affected by scattered greenery, but single-room properties are not significantly affected regardless of year or whether the property is a rental or a sale. The interpretation could be similar to that for the results in Columns (1) and (2), according to which higher-income people living in higher-quality homes are more concerned about green amenities. Alternatively, it might be more appropriate to say that students and single individuals living in one-room apartments tend to move out after a few years and do not care about the residential environment.

Anderson and West (2006) suggested that open spaces and amenities are valued heterogeneously depending on neighborhood characteristics. Scattered greenery can also be valued not only for its role in maintaining the landscape in residential areas but also for its role in reducing exhaust emissions and noise along busy roads. To check this possibility, Columns (5) and (6) show the results of an estimation that uses subsamples divided by the median distance to the highway. The results in Column (5) for properties far from the highway have a positive coefficient but almost no significance or very weak significance in each of the samples. In contrast, in Column (6), which was estimated using properties close to the highway, for-sale properties are very strongly positively affected by scattered greenery, while rental properties are not significantly affected. This finding is counterintuitive to the results obtained from the price and number of rooms subsamples since the more relatively inexpensive and lower quality properties are located closer to the highway, which could be interpreted as an evaluation of the pollution and noise reduction benefits of scattered greenery rather than its visual benefits (landscaping and relaxation). In other words, different aspects of the same scattered greenery are appreciated depending on where they are located. The finding that there is little heterogeneity in the price of rental properties based on highway distance is consistent with previous arguments that people who live in rental properties do not care much about their living environment.

Columns (7) and (8) show the results from dividing the sample by the median linear distance from the CBD, Tokyo Station. We can see that, among the properties for sale, scattered greenery has a significantly positive impact when the properties are far from the CBD, whereas it has no significant impact when they are close to the CBD. This outcome is the opposite of what related studies (e.g., Votsis, 2017) have found, i.e., that green space is valued positively in areas with higher population densities and less greenery. Our results could be driven by the area around the CBD of Tokyo being too urbanized to be suitable for residence. The areas near the CBD provide housing for those who prefer access to commercial areas over a residential environment, while residential areas farther from the CBD might have a better environment. As in the previous cases, the sales and rental markets behave differently, with rental properties exhibiting less heterogeneous effects based on their distance from the CBD.

The subsample analysis suggests that scattered greenery is valued heterogeneously by property characteristics and location. We can see that residents of larger and pricier properties, as well as those in locations more suitable for residence, value green amenities more highly. Such heterogeneity in valuation has intensified over time, perhaps because the heterogeneity in people's preferences and demands has also affected the supply side of the property market. In other words, high-quality properties with large and plentiful rooms might be supplied in areas with large amounts of greenery, and conversely, small and low-quality properties could be supplied in areas with little greenery. To address this concern, we next analyze the impact of scattered greenery on housing quality.

	Housing prices or rents		# of rooms		Distance from highway		Distance from CBD	
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sales (2008)								
Scattered greenery (0–100 m)	0.211**	0.177*	0.288***	0.187	0.098	0.397***	0.291***	0.133
	(0.065)	(0.084)	(0.060)	(0.127)	(0.078)	(0.082)	(0.074)	(0.087)
Avg. %-age of greenery within 500	18.2%	16.5%	18.1%	15.1%	17.9%	16.8%	20.8%	13.9%
Observations	3,936	3,936	5,828	2,044	3,936	3,936	3,936	3,936
Adjusted R-squared	0.8567	0.8835	0.9172	0.9291	0.9444	0.9435	0.9387	0.9468
Panel B: Sales (2013)								
Scattered greenery (0–100 m)	0.297***	0.030	0.183*	0.105	0.097	0.321**	0.278**	0.068
	(0.071)	(0.113)	(0.084)	(0.144)	(0.122)	(0.102)	(0.096)	(0.122)
Avg. %-age of greenery within 500	14.9%	13.2%	14.8%	12.3%	14.5%	13.6%	16.2%	11.8%
Observations	4,840	4,840	6,663	3,017	4,837	4,843	4,838	4,842
Adjusted R-squared	0.8326	0.9013	0.9089	0.9332	0.9468	0.9455	0.9453	0.9464
Panel C: Rentals (2008)								
Scattered greenery (0–100 m)	0.078	0.035	0.087	0.028	0.073*	0.037	0.055	0.039
	(0.042)	(0.024)	(0.053)	(0.026)	(0.033)	(0.043)	(0.036)	(0.043)
Avg. %-age of greenery within 500	15.9%	16.5%	17.5%	15.8%	16.8%	15.6%	19.3%	13.1%
Observations	21,364	21,824	9,778	33,410	21,593	21,595	21,263	21,925
Adjusted R-squared	0.8940	0.6012	0.9161	0.8751	0.9106	0.9243	0.9203	0.9163
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.090**	0.003	0.118**	-0.013	0.017	0.032	0.037	-0.024
	(0.034)	(0.028)	(0.039)	(0.026)	(0.035)	(0.033)	(0.027)	(0.044)
Avg. %-age of greenery within 500	13.1%	13.5%	14.2%	13.1%	13.9%	12.7%	15.5%	11.4%
Observations	46,776	47,887	19,341	75,322	47,331	47,332	44,425	50,238
Adjusted R-squared	0.8743	0.6574	0.9094	0.8804	0.9063	0.9170	0.9142	0.9079
Property characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES	YES	YES	YES	YES
Street FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 4. Subsample analysis

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those listed in Table A2, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 meters away are omitted due to space limitations. The impact of scattered greenery more than 100 meters away is reported in Appendix Table A8.

4.4. Residential environment and house quality

Table 5 shows the estimated results when variables measuring property quality are used as the explained variable, instead of price or rent. Columns (1) and (2) use the number of rooms and square footage as the explained variables, respectively, and indicate that the size of the property increases as the amount of scattered greenery within 100 meters increases. Unlike the main results for price and rent as the explained variables (shown in Table 1), in these estimations, the results for both sales and rentals are highly significant. Thus, the value of scattered greenery in the main analysis might be overestimated since larger, roomier homes more suitable for habitation tend to be built in greener areas. Interestingly, however, scattered greenery increases the quality of both sales and rentals, but it increases prices only for sales properties. In other words, scattered greenery on properties for sale is valued as a green amenity, but it is not valued as an amenity on properties for rent. Additionally, among both sales and rentals, there is a stronger relationship between scattered greenery and housing quality in 2013 than in 2008. This finding suggests that environmental gentrification might be occurring.

In Column (3), the age of the building is the explained variable, and none of the results are statistically significant. Thus, there is no relationship between scattered greenery and the newness of buildings; qualities such as livability are important. Column (4) shows the results from estimations in which the number of floors in the building is the explained variable, indicating that scattered greenery slightly increases the number of floors in the case of properties for sale. This outcome suggests that areas with more green amenities are in higher demand as residential areas; thus, larger multiunit residential buildings are likely to be built.

	# of rooms	ln(Sq. metres)	ln(Age of property)	# of floors in the building
	(1)	(2)	(3)	(4)
Panel A: Sales (2008)				
Scattered greenery (0–100 m)	0.914***	0.707***	0.322	4.46**
	(0.264)	(0.163)	(0.322)	(1.72)
Observations	7,872	7,872	7,872	7,872
Adjusted R-squared	0.2241	0.3146	0.2786	0.6009
Panel B: Sales (2013)				
Scattered greenery (0–100 m)	1.34***	0.935***	0.256	4.29*
	(0.310)	(0.196)	(0.352)	(1.87)
Observations	9,680	9,680	9,680	9,680
Adjusted R-squared	0.2728	0.3456	0.2680	0.6347
Panel C: Rentals (2008)				
Scattered greenery (0–100 m)	0.325*	0.415***	0.385	0.525
	(0.137)	(0.112)	(0.260)	(0.601)
Observations	43,188	43,188	43,188	43,188
Adjusted R-squared	0.1168	0.1697	0.1817	0.4940
Panel D: Rentals (2013)				
Scattered greenery (0–100 m)	0.579***	0.496***	0.128	-0.323
	(0.143)	(0.110)	(0.236)	(0.602)
Observations	94,663	94,663	94,663	94,663
Adjusted R-squared	0.1148	0.1520	0.1909	0.4705
Property characteristics	NO	NO	NO	NO
Neighborhood characteristics	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES

Table 5. Effects of scattered greenery on property quality

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those in Table A2 except for property characteristics, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 meters away are omitted due to space limitations. The impact of scattered greenery more than 100 meters away is reported in Appendix Table A9.

5. Discussion and policy implications

The findings of this study provide insights into how people value scattered urban greenery. We showed that scattered greenery, such as street trees, significantly increases housing prices. Because the workings of the real estate market reflect resident demand, which is relevant to policy, findings from hedonic price analyses can be used to design policy. Policy makers and urban planners could benefit from increasing property values through a focus on increasing and improving the scattered greenery in urban areas. Further positive impacts might also accrue since higher urban property values induce private investment. Especially in urban areas such as Tokyo, where it is difficult to convert land already in use into green space, it would be beneficial to consider installing scattered greenery that does not require much space. The property price increase from a 10% increase in scattered greenery within 100 meters of a residential location is as high as 2% to 2.5%, likely justifying the cost of providing and maintaining this scattered greenery.

Our results also suggest that scattered greenery is valued heterogeneously depending on its location and users. Since properties along busy streets tend to have lower values due to poor air quality and noise, scattered greenery that can reduce such environmental concerns is highly valued. Therefore, the maintenance of street trees around roads could have a considerable impact on housing prices. In contrast, scattered greenery is rarely appreciated in areas near the CBD, where population density is high and greenery is scarce. Those who value their living environments are unlikely to live in the CBD in the first place since people who prefer urban convenience and access to commercial areas are more likely to reside there. Increasing scattered greenery in such areas might not have the expected impact. However, of course, the effects of scattered greenery, such as reducing air pollution and reducing the heat island effect, cannot be ignored. Such indirect effects should be investigated in the future using more detailed geographical data.

Furthermore, because individuals with different characteristics differ in their appreciation of scattered greenery, the characteristics of residents must be considered to effectively increase welfare through urban environmental policies. Failure to consider the heterogeneity in people's preferences could lead to policies that disregard equity. Since the prices of properties for sale and rent respond quite differently, we must be careful when discussing not only scattered greenery but also other urban green spaces. People who live in rental properties and who thus tend to move after short periods of time might not care about amenities that have long-term effects, such as the surrounding green environment. Thus, in areas where there are many rental properties or where resident turnover is high (e.g., areas with many students living alone), greenery could be undersupplied. There is also a concern that analyses using the hedonic pricing approach for rental properties might underestimate environmental amenities.

Additionally, the results suggest that more expensive and larger properties are significantly affected by scattered greenery, while less expensive and smaller properties are hardly affected at all and, moreover, that the effects could become stronger over time. This finding suggests that landscape preservation, relaxation, and the other benefits of scattered greenery might be valued only by high-income individuals, which is relevant to the argument that environmental amenities have a luxury dimension (Fuerst and Shimizu, 2016; Łaszkiewicz et al., 2019). Recent urban public policy research has focused on issues of unequal access to environmental amenities and environmental gentrification, in which a quality environment attracts wealthy people, increases land prices, and causes the displacement of the original residents (Melstrom and Mohammadi, 2022; Schaeffer et al., 2016). In urban areas, people face a trade-off between the negative effects of noise or pollution and the positive effects of access to a variety of other amenities, such as commercial facilities and cultural assets. The wealthy can counteract the negative aspects of urban life by living in the greenest areas of the city, but poorer people might not have such an option. Urban greening strategies, while successful from the perspective of wealthy individuals and corporations, could eventually exclude socially vulnerable groups. Previous studies have found that the distribution of urban green space often provides uneven benefits to wealthier (or white nonimmigrant) communities (Wolch et al., 2014).

Because of the price premium charged for high-quality neighborhoods, only people who can afford to pay the additional costs of green space can live in those neighborhoods, while the less wealthy are excluded from neighborhood green space. Additionally, if higher-income people show a preference for environmental goods, more luxurious new developments could be built, land prices could escalate, and only higher-income people could enjoy comfortable green living, which might increase environmental injustice when high-income groups that consume more and have a negative impact on the environment enjoy a good environment, and low-income groups that are less involved in environmental degradation suffer. If such an outcome is caused by the greening policies of cities under the guise of being "for the environment," the problem is even more serious.

Suggestive evidence for these arguments is shown in Figure 3. We divide the dataset by quartiles of the amount of scattered greenery within a 500-meter radius of each property and plot the change over time in the number of contracted properties by price range within each subsample. The left side of the figure shows properties for sale, and the right side shows properties for rent, with (1) and (5) indicating the properties with the most surrounding greenery and (4) and (8) indicating the properties with the least surrounding greenery. For (1), the greenest properties for sale, the number of contracts was approximately the same in all price ranges in 2006, but the difference in the number of transactions by price range gradually increased, with more than twice as many properties in the top 25% of prices being traded as those in the bottom 25% of prices in 2015. The same trend applies to properties for sale in the third quartile of green space in (2), with the number of contracts for more expensive properties increasing over time. In contrast, there is little difference in property prices in the second quartile of the amount of space green, as shown in (3). The properties with the least amount of surrounding greenery, shown in (4), have been relatively inexpensive since 2006, and this trend is continuing. These results are consistent with the environmental gentrification argument that better environments attract higher-income residents and drive out lower-income residents, resulting in increasingly polarized neighborhoods and segregated settlements. Note also that the data are the number of contracts in each year, so the cumulative effect is even stronger.

Unlike for-sale properties, there is not much difference between the amount of greenery and the number of transactions by price range for rental properties. It is worth noting, however, that the number of contracts for expensive rental properties surged around 2010 in areas with little greenery. This surge might have been due to the construction of luxury tower condominiums for the wealthy, suggesting the existence of a different property market from that of properties for sale. Interestingly, even in the main results presented in Table 1, the impact of greenery was barely reflected in rental prices, indicating that, by living in a rental property, one could enjoy the benefits of scattered greenery without paying a premium. It should be noted, however, that rental properties tend to be unsuitable for family residence or long-term ownership because of the small number of rooms and the lack of tax breaks and other incentives available through mortgages.

In summary, urban planners must develop urban strategies that protect not only ecological sustainability but also social sustainability. The establishment of small, scattered green spaces, rather than large urban green spaces where resources tend to be geographically concentrated, could be one solution. Alternatively, complementary anti-gentrification strategies, such as the provision of affordable housing, could be effective (Franco and Macdonald, 2018). Because environmental policies such as urban greening are difficult to overrule, it is necessary to consider who will receive the benefits of greening when designing cities. It is important to adopt an environmental equity perspective, for example, by considering whether green amenities require implicit compensation or whether certain people are excluded from the green amenities.

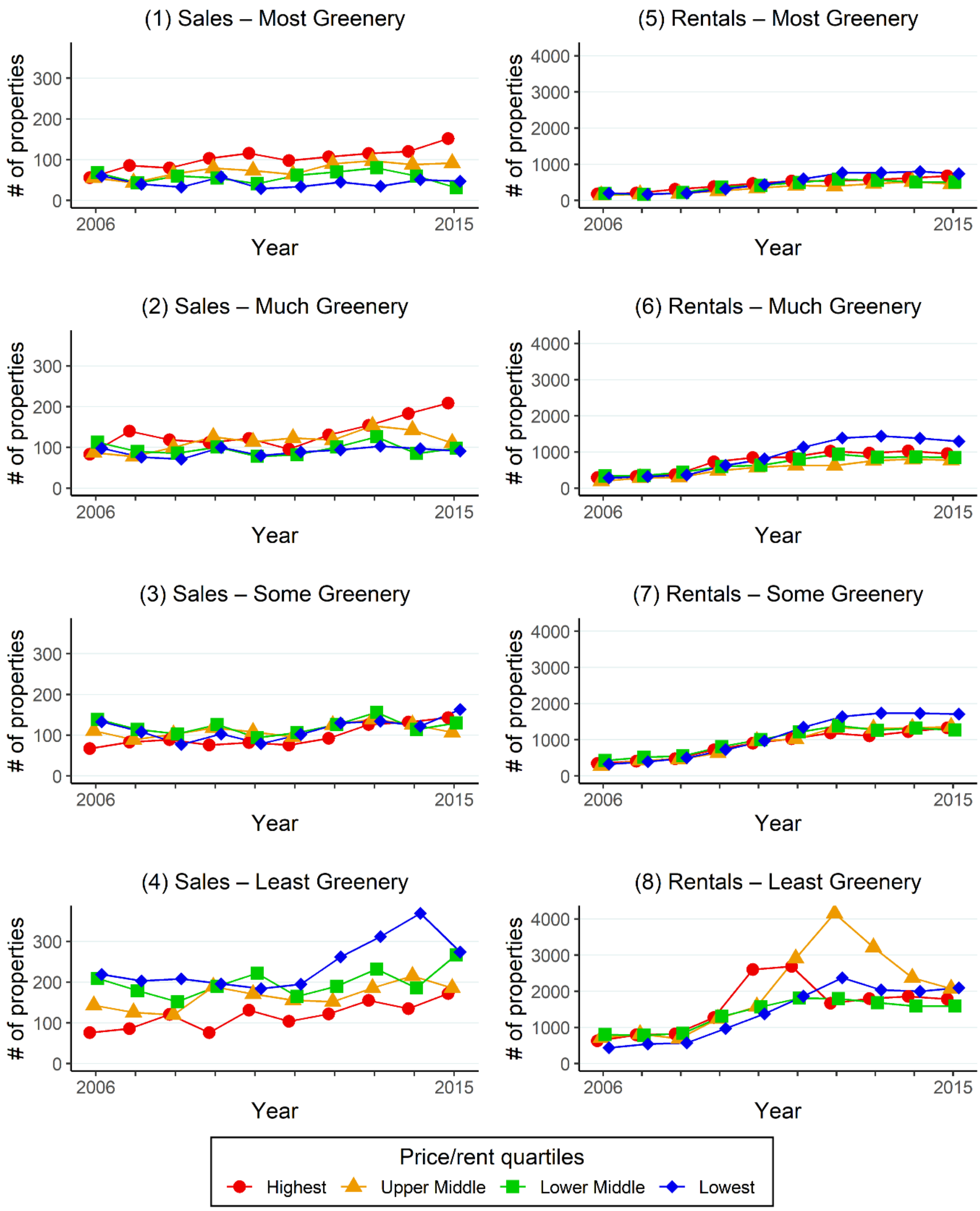

Figure 3. Number of properties traded by greenery and price tier quartile

Note: In each panel, the vertical axis represents the number of properties traded, and the horizontal axis represents the year of the contract. The red circles, yellow triangles, green squares, and blue diamonds correspond to the highest (0%-25%), upper middle (25%-50%), lower middle (50%-75%), and lowest (75%-100%) housing price or rent quartiles, respectively.

6. Conclusions

The value that urban green spaces provide to residents has attracted interest in a variety of fields, not only economics. While many studies have analyzed the value of usable greenery of certain sizes, such as parks and urban forests, using a hedonic pricing approach, we complement this literature by measuring the value of scattered greenery. The results of this study contribute to the literature on the value of urban green space and further our understanding of how these values vary by resident and location characteristics. Since large resources are invested in policies that improve the urban environment, understanding the role of amenities is important for improving the efficiency of public welfare.

Because this study focuses on a very developed urban area, the results should be extrapolated with caution. Scattered greenery might not be valuable in areas with sufficient overall levels of greenery; conversely, it might be more highly valued in areas where green space is scarce. Therefore, our results could be applicable only in cities such as Tokyo. Similar studies for other cities are a future task, for which the use of remote sensing to measure scattered greenery would be useful.

Analyzing the heterogeneity in individual-level preferences for scattered greenery is a limitation of this study, as well as an avenue for future work. Because this study uses a hedonic pricing model with property data, only the average WTP for scattered greenery is revealed. It is important to understand the heterogeneity in preferences at the individual level since individuals with different demographics within a region require different policies. Data including individual preferences, methods such as two-stage hedonic analysis (Panduro et al., 2018) or the LSA (Tsurumi et al., 2018) could be used to reveal preferences for scattered greenery. It would be a fruitful task for the future to determine which characteristics affect whether individuals do or do not receive benefits from scattered greenery.

Declaration of Competing Interest

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

Data Availability Statement

The data on green coverage can be provided upon request. The real estate data are restricted and were used under license for this study. Other geographic data are publicly available and can be freely obtained from official government websites.

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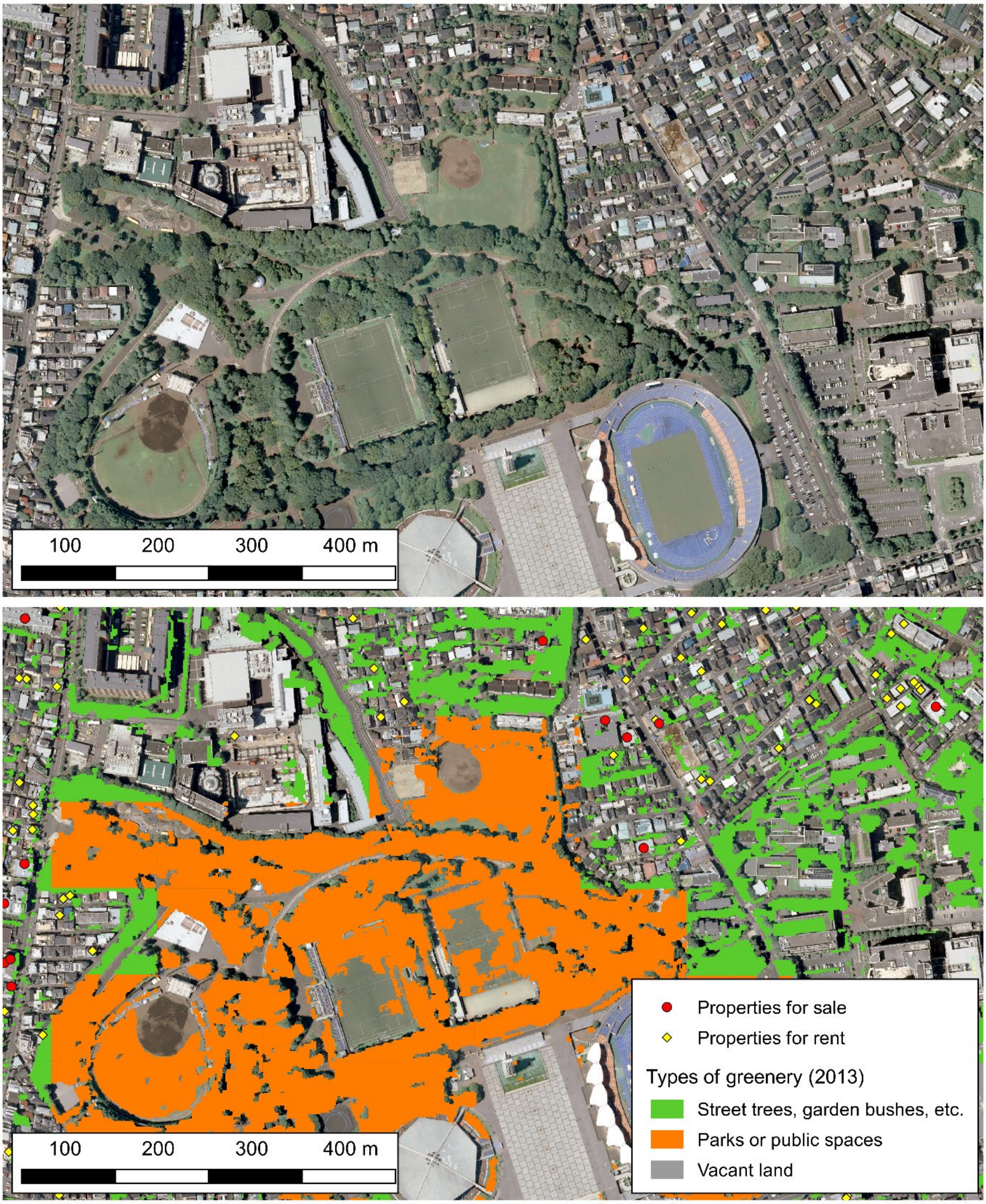
Figure A1. Comparison of aerial photography and NDVI green coverage areas around residential areas

Note: The aerial imagery is based on open data created in 2016, published by Setagaya Ward.

Figure A2. Comparison of aerial photography and NDVI green coverage areas around the park, including sports fields



Note: The aerial imagery is based on open data created in 2016, published by Setagaya Ward.

Table A3. Summary statistics

	Properties for sale				Properties for rent			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Property characteristics								
Property price/rent (10,000 JPY)	3704.351	2091.835	230.700	25017.755	9.410	4.445	1.000	187.500
# of rooms	2.099	0.852	1.000	7.000	1.256	0.539	1.000	22.000
Square meters	59.858	24.664	8.710	235.580	30.426	19.580	2.510	2624.000
Age of property (in years)	18.573	12.034	0.000	83.384	17.997	11.243	0.000	88.047
# of floors in the building	7.075	4.081	1.000	42.000	3.719	2.494	1.000	85.000
Floor where located	3.879	2.956	-2.000	36.000	2.355	1.649	-2.000	32.000
Neighborhood characteristics								
Population (1000/m2)	13.474	3.174	4.381	21.108	14.039	2.896	4.214	21.108
# of households (1000)	7.330	2.410	1.826	13.460	7.797	2.234	1.726	13.460
% under 19 years old	0.133	0.033	0.067	0.237	0.125	0.028	0.067	0.237
% over 65 years old	0.184	0.018	0.122	0.285	0.187	0.016	0.122	0.309
# of properties for sale	70.134	31.449	5.000	190.000	66.043	30.586	1.000	194.000
Avg. property price (10,000 JPY)	3392.695	919.035	1677.500	8343.885	3248.818	846.476	0.000	8433.533
Avg. # of floors in for-sale properties	6.136	1.200	3.000	9.982	6.036	1.163	0.000	10.273
# of properties for rent	544.688	265.199	32.000	1326.000	624.074	246.918	23.000	1397.000
Avg. property rent (10,000 JPY)	9.916	1.631	7.083	21.458	9.581	1.413	6.984	25.207
Avg. # of floors in for-rent properties	3.470	0.612	2.100	6.897	3.470	0.612	2.100	6.897
Accessibility characteristics								
Distance to a hospital	147.578	96.753	0.000	647.299	139.153	89.069	0.000	716.790
Distance to a school	299.645	141.779	8.165	909.876	295.600	133.067	6.192	909.876
Distance to police	359.892	188.376	8.626	1125.649	354.552	172.349	2.351	1147.036
Distance to a fire station	782.562	401.598	12.190	2059.778	768.846	361.935	4.973	2133.190
Distance to a post office	311.196	154.028	6.918	985.770	306.658	140.326	1.616	1022.223
Distance to a park	186.010	103.974	4.474	655.871	206.085	110.914	1.371	706.357
Distance to a museum or gallery	1236.599	667.501	25.658	3182.323	1238.781	679.883	17.610	3187.883
Distance to a library	599.255	269.295	3.628	1683.342	583.507	259.381	3.628	1738.656
Distance to a playground	949.538	478.935	36.301	2751.802	1028.072	525.480	10.595	2789.267
Distance to a budojo	1306.542	597.711	32.621	3099.050	1340.025	594.595	18.768	3109.548
Distance to a pool	1387.742	647.786	98.793	3117.698	1450.926	627.067	11.543	3095.457
Distance to city hall	2926.297	1603.595	55.909	10695.031	2609.357	1548.949	39.596	10726.757
Distance to a station	491.132	310.780	0.702	1882.441	432.231	265.306	0.591	1987.998
Distance to a bus stop	159.710	109.229	8.955	740.180	180.040	124.704	2.005	804.535
Distance to a major road	314.393	308.921	0.028	1632.718	333.917	288.799	0.006	1703.577
Distance to the highway	1434.394	1080.814	11.479	4694.255	1538.345	1146.391	5.854	4694.255
Distance to Tokyo Station	13217.977	2577.661	8106.727	18701.929	12734.248	2440.231	8091.710	19031.638
Distance to the Tama River	5650.367	3018.419	109.113	11736.019	6216.442	2928.325	104.893	11768.117
Surrounding green spaces (2008)								
Farm or vacant land (0–100 m)	0.003	0.021	0.000	0.328	0.001	0.011	0.000	0.587
Farm or vacant land (100–200 m)	0.003	0.018	0.000	0.259	0.002	0.011	0.000	0.229
Farm or vacant land (200–300 m)	0.003	0.014	0.000	0.174	0.002	0.011	0.000	0.212
Farm or vacant land (300–400 m)	0.003	0.010	0.000	0.122	0.002	0.010	0.000	0.156
Farm or vacant land (400–500 m)	0.003	0.009	0.000	0.118	0.002	0.008	0.000	0.125
Waterfront (0–100 m)	0.001	0.013	0.000	0.429	0.000	0.008	0.000	0.440
Waterfront (100–200 m)	0.002	0.020	0.000	0.444	0.001	0.012	0.000	0.482
Waterfront (200–300 m)	0.003	0.024	0.000	0.417	0.001	0.015	0.000	0.486
Waterfront (300–400 m)	0.004	0.027	0.000	0.431	0.001	0.017	0.000	0.445
Waterfront (400–500 m)	0.005	0.031	0.000	0.333	0.002	0.018	0.000	0.380
Park or public space (0–100 m)	0.007	0.027	0.000	0.467	0.005	0.026	0.000	0.685
Park or public space (100–200 m)	0.014	0.036	0.000	0.394	0.010	0.033	0.000	0.467
Park or public space (200–300 m)	0.018	0.038	0.000	0.419	0.015	0.033	0.000	0.442
Park or public space (300–400 m)	0.020	0.035	0.000	0.480	0.017	0.032	0.000	0.482
Park or public space (400–500 m)	0.021	0.035	0.000	0.348	0.018	0.031	0.000	0.390
Scattered greenery (0–100 m)	0.160	0.092	0.002	0.595	0.144	0.076	0.000	0.727
Scattered greenery (100–200 m)	0.169	0.072	0.023	0.490	0.157	0.063	0.022	0.531
Scattered greenery (200–300 m)	0.172	0.063	0.041	0.428	0.160	0.058	0.042	0.462
Scattered greenery (300–400 m)	0.174	0.059	0.043	0.454	0.164	0.055	0.038	0.421
Scattered greenery (400–500 m)	0.177	0.057	0.056	0.412	0.166	0.052	0.053	0.428

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Surrounding green spaces (2013)								
Farm or vacant land (0–100 m)	0.002	0.014	0.000	0.233	0.001	0.011	0.000	0.394
Farm or vacant land (100–200 m)	0.002	0.012	0.000	0.137	0.002	0.009	0.000	0.163
Farm or vacant land (200–300 m)	0.003	0.010	0.000	0.118	0.002	0.009	0.000	0.130
Farm or vacant land (300–400 m)	0.003	0.008	0.000	0.098	0.002	0.007	0.000	0.102
Farm or vacant land (400–500 m)	0.002	0.007	0.000	0.068	0.002	0.007	0.000	0.116
Waterfront (0–100 m)	0.001	0.013	0.000	0.414	0.001	0.010	0.000	0.415
Waterfront (100–200 m)	0.003	0.020	0.000	0.459	0.001	0.012	0.000	0.470
Waterfront (200–300 m)	0.004	0.025	0.000	0.412	0.002	0.015	0.000	0.473
Waterfront (300–400 m)	0.005	0.028	0.000	0.459	0.002	0.017	0.000	0.461
Waterfront (400–500 m)	0.007	0.034	0.000	0.358	0.003	0.020	0.000	0.393
Park or public space (0–100 m)	0.007	0.027	0.000	0.450	0.006	0.026	0.000	0.602
Park or public space (100–200 m)	0.014	0.035	0.000	0.338	0.010	0.030	0.000	0.440
Park or public space (200–300 m)	0.018	0.035	0.000	0.364	0.015	0.030	0.000	0.381
Park or public space (300–400 m)	0.019	0.033	0.000	0.376	0.016	0.029	0.000	0.380
Park or public space (400–500 m)	0.021	0.033	0.000	0.311	0.018	0.029	0.000	0.375
Scattered greenery (0–100 m)	0.130	0.073	0.004	0.492	0.119	0.060	0.000	0.510
Scattered greenery (100–200 m)	0.137	0.056	0.023	0.397	0.129	0.048	0.013	0.398
Scattered greenery (200–300 m)	0.139	0.047	0.030	0.333	0.131	0.043	0.030	0.391
Scattered greenery (300–400 m)	0.141	0.044	0.037	0.315	0.134	0.039	0.035	0.382
Scattered greenery (400–500 m)	0.142	0.041	0.044	0.325	0.135	0.038	0.041	0.352
# of layout types		9				9		
# of structure types		9				9		
# of zoning types		10				10		
# of streets		506				545		
# of properties		17,552				137,851		

Note: Layout refers to the room layout as defined by the numbers of living rooms, dining rooms, and kitchens. Structure refers to the construction materials used, such as wood or reinforced concrete. Zoning refers to the land use zone, i.e., commercial or industrial zones, as defined by the City Planning Act; zoning regulates the types and sizes of buildings that can be built.

Table A4. Effects of scattered greenery on property prices and rents (full results)

	Properties for sale		Properties for rent	
	2008	2013	2008	2013
	(1)	(2)	(3)	(4)
Property characteristics				
# of rooms	0.015***	0.010*	0.043***	0.048***
	(0.004)	(0.004)	(0.004)	(0.004)
ln(Sq. meters)	1.02***	1.01***	0.608***	0.603***
	(0.015)	(0.013)	(0.010)	(0.011)
ln(Age of property)	-0.278***	-0.309***	-0.086***	-0.096***
	(0.005)	(0.007)	(0.002)	(0.001)
# of floors in the building	-0.003*	0.0001	0.003***	0.006***
	(0.001)	(0.001)	(0.0009)	(0.0008)
Floor where located	0.012***	0.010***	0.011***	0.011***
	(0.001)	(0.0010)	(0.0007)	(0.0007)
Neighborhood characteristics				
Population (per 1000)	0.010	0.006	-0.002	-0.0007
	(0.024)	(0.026)	(0.010)	(0.008)
# of households (per 1000)	-0.018	-0.019	0.004	-0.002
	(0.040)	(0.043)	(0.017)	(0.013)
% of population under 19	-2.31*	-3.93**	-0.997	-1.36***
	(1.13)	(1.20)	(0.515)	(0.396)
% of population over 65	0.355	-0.677	-0.310	-0.456
	(0.703)	(0.626)	(0.242)	(0.246)
ln(# of properties for sale)	0.016	-0.011	0.010	0.017
	(0.038)	(0.041)	(0.018)	(0.014)
ln(Avg. property price)	0.003	0.267***	0.010	0.023
	(0.075)	(0.074)	(0.039)	(0.030)
Avg. # of floors in for-sale properties	-0.029	-0.059*	0.005	0.009
	(0.023)	(0.025)	(0.010)	(0.010)
ln(# of properties for rent)	0.020	0.063*	-0.010	-0.006
	(0.026)	(0.026)	(0.009)	(0.008)
ln(Avg. property rent)	0.093*	0.102*	0.016*	0.007
	(0.043)	(0.044)	(0.008)	(0.005)
Avg. # of floors in for-rent properties	0.013	0.024*	-0.0005	0.005
	(0.008)	(0.010)	(0.004)	(0.003)
Accessibility characteristics				
ln(Distance to a hospital)	-0.001	-0.0007	-0.0008	-0.003
	(0.005)	(0.005)	(0.002)	(0.002)
ln(Distance to a school)	-0.002	0.002	-0.005	-0.002
	(0.007)	(0.008)	(0.003)	(0.003)
ln(Distance to police)	0.007	0.011	-0.0001	-0.0007
	(0.007)	(0.008)	(0.003)	(0.002)
ln(Distance to a fire station)	-0.012	-0.013	-0.001	0.005
	(0.009)	(0.011)	(0.005)	(0.003)
ln(Distance to a post office)	0.002	0.003	0.002	0.003
	(0.006)	(0.007)	(0.003)	(0.002)
ln(Distance to a park)	-0.006	0.0003	0.003	0.0004
	(0.005)	(0.006)	(0.002)	(0.002)
ln(Distance to a museum or gallery)	-0.015	-0.021	-0.009	-0.002
	(0.015)	(0.016)	(0.007)	(0.006)
ln(Distance to a library)	-0.0008	-0.007	0.002	0.001
	(0.010)	(0.011)	(0.004)	(0.003)
ln(Distance to a playground)	-0.042*	-0.053**	0.003	0.002
	(0.019)	(0.020)	(0.008)	(0.007)
ln(Distance to a budojo)	0.024	0.012	-0.007	0.005
	(0.019)	(0.021)	(0.009)	(0.008)
ln(Distance to a pool)	0.018	0.008	-0.015*	-0.007
	(0.017)	(0.020)	(0.007)	(0.008)
ln(Distance to a city hall)	0.022	-0.003	-0.007	-0.005
	(0.022)	(0.028)	(0.008)	(0.008)
ln(Distance to a station)	-0.029***	-0.025**	-0.008**	-0.005
	(0.007)	(0.009)	(0.003)	(0.003)
ln(Distance to a bus stop)	-0.004	0.001	0.0005	0.004*
	(0.005)	(0.005)	(0.003)	(0.002)

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ln(Distance to a major road)	0.017***	0.022***	0.003	0.004**
	(0.004)	(0.005)	(0.002)	(0.001)
ln(Distance to a highway)	0.012	0.025**	0.002	0.005
	(0.007)	(0.009)	(0.003)	(0.003)
ln(Distance to Tokyo Station)	-0.503**	-0.390*	-0.149	-0.130
	(0.183)	(0.181)	(0.088)	(0.076)
Ln(Distance to the Tama River)	-0.100	0.012	0.002	-0.002
	(0.058)	(0.066)	(0.029)	(0.021)
% Surrounding greenness				
Farm or vacant land (0–100 m)	0.170	0.342	0.181	-0.060
	(0.202)	(0.312)	(0.141)	(0.069)
Farm or vacant land (100–200 m)	0.441	0.184	-0.359*	0.187
	(0.252)	(0.268)	(0.154)	(0.123)
Farm or vacant land (200–300 m)	-0.148	-0.098	0.208	0.171
	(0.389)	(0.448)	(0.203)	(0.180)
Farm or vacant land (300–400 m)	-0.333	-0.618	-0.108	-0.121
	(0.321)	(0.545)	(0.150)	(0.188)
Farm or vacant land (400–500 m)	0.702	0.341	-0.293	0.121
	(0.385)	(0.637)	(0.180)	(0.206)
Waterfront (0–100 m)	0.114	-0.329	0.549*	0.049
	(0.224)	(0.303)	(0.219)	(0.124)
Waterfront (100–200 m)	-0.309	0.188	-0.213	0.063
	(0.267)	(0.292)	(0.136)	(0.138)
Waterfront (200–300 m)	-0.327	0.073	0.242	-0.037
	(0.208)	(0.221)	(0.210)	(0.107)
Waterfront (300–400 m)	0.057	-0.697***	-0.310	-0.122
	(0.206)	(0.162)	(0.231)	(0.163)
Waterfront (400–500 m)	0.020	0.384	0.631	0.241
	(0.296)	(0.255)	(0.350)	(0.296)
Park or public space (0–100 m)	-0.056	-0.112	0.009	-0.014
	(0.137)	(0.148)	(0.062)	(0.050)
Park or public space (100–200 m)	-0.028	0.094	0.081	0.069
	(0.140)	(0.160)	(0.084)	(0.058)
Park or public space (200–300 m)	-0.007	-0.324	-0.087	-0.075
	(0.184)	(0.214)	(0.088)	(0.069)
Park or public space (300–400 m)	-0.088	-0.105	0.002	-0.019
	(0.190)	(0.235)	(0.086)	(0.079)
Park or public space (400–500 m)	0.167	-0.137	-0.034	-0.069
	(0.206)	(0.240)	(0.082)	(0.065)
Scattered greenery (0–100 m)	0.251***	0.204**	0.055*	0.016
	(0.057)	(0.076)	(0.027)	(0.024)
Scattered greenery (100–200 m)	-0.137	-0.092	0.019	0.005
	(0.093)	(0.118)	(0.043)	(0.043)
Scattered greenery (200–300 m)	-0.096	-0.159	0.038	0.044
	(0.116)	(0.140)	(0.056)	(0.046)
Scattered greenery (300–400 m)	-0.270*	-0.189	-0.054	0.038
	(0.136)	(0.156)	(0.060)	(0.056)
Scattered greenery (400–500 m)	-0.085	-0.324	-0.023	-0.111
	(0.152)	(0.178)	(0.080)	(0.066)
Layout, structure, and zoning dummies	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES
Observations	7,872	9,680	43,188	94,663
Adjusted R-squared	0.9424	0.9452	0.9174	0.9106

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively.

Table A5. Number of households by years living in the current house (within 10 kilometers of CBD)

	Owned houses		Rented houses	
	# of households	Ratio	# of households	Ratio
Years of residence				
0–2 years	47,300	8.23%	201,200	40.41%
3–7 years	93,600	16.30%	145,400	29.20%
8–12 years	73,200	12.74%	50,800	10.20%
13–17 years	73,700	12.83%	26,500	5.32%
18–22 years	56,000	9.75%	22,400	4.50%
23–27 years	25,700	4.47%	12,600	2.53%
28–37 years	54,400	9.47%	16,100	3.23%
38–47 years	45,900	7.99%	14,800	2.97%
Over 48 years	104,600	18.21%	8,100	1.63%
Total	574,400		497,900	

Note: Created using data from the 2018 Housing and Land Survey (Statistics Bureau, Ministry of Internal Affairs and Communications). The central point of the CBD is the former Tokyo Metropolitan Government Building (now the Tokyo International Forum) in Chiyoda-ku, Tokyo.

Table A6. Robustness checks

	Alternative green space measures		Trimmed Samples				Spatial dependence (SEM)
	Natural logarithm	Top 25% dummy	Remove top and bottom 5%	Exclude large-scale properties	Only single year	Only unique buildings	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Sales (2008)							
Scattered greenery (0–100 m)	0.023**	0.041***	0.218***	0.210***	0.288*	0.233***	0.287**
	(0.007)	(0.009)	(0.058)	(0.062)	(0.128)	(0.058)	(0.099)
Scattered greenery (100–200 m)	-0.009	-0.023*	-0.088	-0.106	-0.234	-0.143	-0.232
	(0.014)	(0.010)	(0.088)	(0.097)	(0.211)	(0.097)	(0.148)
Scattered greenery (200–300 m)	-0.012	0.011	-0.065	-0.089	0.419	-0.093	0.451*
	(0.017)	(0.010)	(0.116)	(0.123)	(0.300)	(0.122)	(0.217)
Scattered greenery (300–400 m)	-0.057**	-0.006	-0.286*	-0.224	-0.772*	-0.245	-0.748**
	(0.022)	(0.011)	(0.137)	(0.148)	(0.301)	(0.142)	(0.245)
Scattered greenery (400–500 m)	0.002	-0.004	-0.127	-0.123	0.024	-0.044	0.103
	(0.025)	(0.010)	(0.150)	(0.157)	(0.305)	(0.152)	(0.269)
Observations	7,872	7,872	7,084	6,245	1,473	7,586	1128
Adjusted R-squared	0.9422	0.9423	0.9244	0.9443	0.9452	0.9400	
Panel B: Sales (2013)							
Scattered greenery (0–100 m)	0.014	0.024**	0.151*	0.175*	0.203	0.220**	0.231*
	(0.008)	(0.008)	(0.077)	(0.078)	(0.124)	(0.078)	(0.104)
Scattered greenery (100–200 m)	-0.009	0.0005	-0.059	-0.035	0.139	-0.075	-0.008
	(0.015)	(0.010)	(0.120)	(0.125)	(0.189)	(0.114)	(0.167)
Scattered greenery (200–300 m)	-0.022	-0.001	-0.220	-0.198	0.067	-0.098	0.123
	(0.019)	(0.010)	(0.139)	(0.144)	(0.223)	(0.142)	(0.210)
Scattered greenery (300–400 m)	-0.040	0.007	-0.136	-0.109	-0.013	-0.064	-0.048
	(0.023)	(0.010)	(0.147)	(0.152)	(0.264)	(0.153)	(0.241)
Scattered greenery (400–500 m)	-0.047	-0.014	-0.345*	-0.336	-0.408	-0.341	0.411
	(0.026)	(0.009)	(0.171)	(0.190)	(0.325)	(0.180)	(0.273)
Observations	9,680	9,680	8,712	7,601	2,146	9,356	1529
Adjusted R-squared	0.9451	0.9451	0.9257	0.9476	0.9512	0.9404	
Panel C: Rentals (2008)							
Scattered greenery (0–100 m)	0.009**	0.0004	0.024	0.056*	0.042	0.078***	0.079*
	(0.003)	(0.004)	(0.020)	(0.028)	(0.052)	(0.022)	(0.039)
Scattered greenery (100–200 m)	0.002	0.0007	-0.013	0.026	-0.018	0.026	-0.050
	(0.006)	(0.004)	(0.033)	(0.043)	(0.077)	(0.036)	(0.063)
Scattered greenery (200–300 m)	0.007	0.006	-0.010	0.048	0.082	0.043	0.053
	(0.009)	(0.005)	(0.042)	(0.056)	(0.103)	(0.041)	(0.082)
Scattered greenery (300–400 m)	-0.008	-0.004	0.004	-0.077	-0.121	-0.021	-0.119
	(0.009)	(0.005)	(0.048)	(0.059)	(0.111)	(0.050)	(0.092)
Scattered greenery (400–500 m)	-0.006	-0.001	-0.008	-0.027	-0.035	0.042	0.006
	(0.013)	(0.006)	(0.053)	(0.082)	(0.150)	(0.053)	(0.103)
Observations	43,188	43,188	39,039	41,263	6,814	35,361	3961
Adjusted R-squared	0.9174	0.9174	0.9017	0.9157	0.9173	0.9093	
Panel D: Rentals (2013)							
Scattered greenery (0–100 m)	0.003	0.001	-0.019	0.019	0.068	0.042*	0.066*
	(0.003)	(0.003)	(0.024)	(0.025)	(0.035)	(0.020)	(0.030)
Scattered greenery (100–200 m)	0.003	0.0005	-0.027	-0.002	0.071	0.004	0.034
	(0.006)	(0.003)	(0.039)	(0.042)	(0.064)	(0.031)	(0.048)
Scattered greenery (200–300 m)	0.006	0.004	0.034	0.050	0.064	0.031	0.048
	(0.006)	(0.003)	(0.043)	(0.046)	(0.069)	(0.039)	(0.059)
Scattered greenery (300–400 m)	0.006	0.004	-0.010	0.027	-0.086	0.004	-0.119
	(0.007)	(0.003)	(0.053)	(0.057)	(0.089)	(0.046)	(0.070)
Scattered greenery (400–500 m)	-0.015	-0.002	-0.130*	-0.123	-0.013	-0.045	-0.045
	(0.009)	(0.004)	(0.058)	(0.068)	(0.096)	(0.053)	(0.079)
Observations	94,663	94,663	85,329	90,768	19,266	73,572	9107
Adjusted R-squared	0.9106	0.9106	0.8885	0.9085	0.9110	0.9074	
Property characteristics	YES	YES	YES	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES	YES	YES	YES
Street FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	NO	YES	NO
Month FE	YES	YES	YES	YES	YES	NO	YES

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those listed in Table A4. The parameter estimates and standard errors for the control variables, which are omitted due to space limitations, are consistent with the main results.

Table A7. Nonlinear effects of scattered greenery

	Properties for sale		Properties for rent	
	2006-2010	2011-2015	2006-2010	2011-2015
	(1)	(2)	(3)	(4)
Scattered greenery (0–100 m)				
2nd quintile	-0.018	0.015	0.008*	0.003
	(0.010)	(0.011)	(0.004)	(0.004)
3rd quintile	-0.005	0.013	0.003	0.0002
	(0.010)	(0.012)	(0.004)	(0.004)
4th quintile	0.013	0.018	0.013**	0.004
	(0.011)	(0.012)	(0.005)	(0.004)
5th quintile	0.034*	0.052***	0.011	0.002
	(0.013)	(0.015)	(0.006)	(0.004)
Scattered greenery (100–200 m)				
2nd quintile	0.016	-0.009	-0.006	-0.0003
	(0.011)	(0.013)	(0.004)	(0.004)
3rd quintile	0.006	-0.005	-0.004	0.003
	(0.013)	(0.014)	(0.005)	(0.005)
4th quintile	0.004	-0.015	-0.002	0.003
	(0.015)	(0.016)	(0.006)	(0.006)
5th quintile	-0.020	-0.010	-0.0001	0.003
	(0.017)	(0.018)	(0.007)	(0.006)
Scattered greenery (200–300 m)				
2nd quintile	0.005	0.007	0.006	0.002
	(0.011)	(0.013)	(0.005)	(0.004)
3rd quintile	-0.008	-0.014	0.003	0.002
	(0.014)	(0.014)	(0.006)	(0.005)
4th quintile	-0.011	-0.004	0.011	0.005
	(0.015)	(0.016)	(0.006)	(0.006)
5th quintile	-0.009	-0.001	0.012	0.006
	(0.018)	(0.018)	(0.008)	(0.006)
Scattered greenery (300–400 m)				
2nd quintile	-0.005	-0.013	-0.003	-0.007
	(0.013)	(0.011)	(0.005)	(0.005)
3rd quintile	-0.019	-0.015	-0.007	-0.0005
	(0.014)	(0.014)	(0.006)	(0.005)
4th quintile	-0.030	-0.021	-0.010	0.003
	(0.016)	(0.015)	(0.006)	(0.006)
5th quintile	-0.029	-0.019	-0.013	0.001
	(0.019)	(0.017)	(0.008)	(0.006)
Scattered greenery (400–500 m)				
2nd quintile	-0.003	0.010	0.001	-0.002
	(0.013)	(0.013)	(0.006)	(0.004)
3rd quintile	0.005	0.007	-0.0008	-0.005
	(0.015)	(0.016)	(0.007)	(0.005)
4th quintile	-0.0001	0.004	0.0005	-0.004
	(0.018)	(0.017)	(0.008)	(0.005)
5th quintile	0.0006	-0.008	-0.0004	-0.007
	(0.021)	(0.019)	(0.011)	(0.007)
Property characteristics	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES
Observations	7,872	9,680	43,188	94,663
Adjusted R-squared	0.9424	0.9453	0.9175	0.9107

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those listed in Table A4. The parameter estimates and standard errors for the control variables, which are omitted due to space limitations, are consistent with the main results.

Table A8. Subsample analysis

	Housing prices or rents		# of rooms		Distance from highway		Distance from CBD	
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sales (2008)								
Scattered greenery (0–100 m)	0.211**	0.177*	0.288***	0.187	0.098	0.397***	0.291***	0.133
	(0.065)	(0.084)	(0.060)	(0.127)	(0.078)	(0.082)	(0.074)	(0.087)
Scattered greenery (100–200 m)	-0.041	-0.240	-0.118	-0.100	-0.309*	-0.023	-0.131	-0.127
	(0.088)	(0.146)	(0.099)	(0.210)	(0.126)	(0.143)	(0.131)	(0.148)
Scattered greenery (200–300 m)	0.003	-0.239	-0.189	0.179	-0.099	-0.101	-0.143	0.016
	(0.125)	(0.168)	(0.132)	(0.244)	(0.166)	(0.172)	(0.154)	(0.164)
Scattered greenery (300–400 m)	-0.093	-0.489*	-0.136	-0.461	-0.208	-0.448*	0.172	-0.923***
	(0.157)	(0.217)	(0.140)	(0.291)	(0.202)	(0.193)	(0.180)	(0.204)
Scattered greenery (400–500 m)	-0.025	0.154	-0.140	-0.030	-0.021	-0.141	-0.174	-0.106
	(0.166)	(0.195)	(0.159)	(0.271)	(0.209)	(0.229)	(0.211)	(0.201)
Avg. %-age of greenery within 500 m	18.2%	16.5%	18.1%	15.1%	17.9%	16.8%	20.8%	13.9%
Observations	3,936	3,936	5,828	2,044	3,936	3,936	3,936	3,936
Adjusted R-squared	0.8567	0.8835	0.9172	0.9291	0.9444	0.9435	0.9387	0.9468
Panel B: Sales (2013)								
Scattered greenery (0–100 m)	0.297***	0.030	0.183*	0.105	0.097	0.321**	0.278**	0.068
	(0.071)	(0.113)	(0.084)	(0.144)	(0.122)	(0.102)	(0.096)	(0.122)
Scattered greenery (100–200 m)	-0.149	-0.147	-0.013	-0.230	-0.156	-0.015	-0.113	0.087
	(0.108)	(0.152)	(0.127)	(0.213)	(0.177)	(0.162)	(0.144)	(0.193)
Scattered greenery (200–300 m)	-0.103	-0.298	-0.181	0.022	-0.166	-0.198	-0.271	0.064
	(0.145)	(0.190)	(0.154)	(0.275)	(0.206)	(0.195)	(0.178)	(0.218)
Scattered greenery (300–400 m)	0.203	-0.512*	0.018	-0.620	-0.398	-0.054	0.023	-0.552*
	(0.180)	(0.244)	(0.164)	(0.333)	(0.220)	(0.234)	(0.195)	(0.257)
Scattered greenery (400–500 m)	-0.092	-0.539*	-0.122	-0.763*	-0.268	-0.405	-0.268	-0.210
	(0.189)	(0.249)	(0.193)	(0.385)	(0.263)	(0.241)	(0.220)	(0.315)
Avg. %-age of greenery within 500 m	14.9%	13.2%	14.8%	12.3%	14.5%	13.6%	16.2%	11.8%
Observations	4,840	4,840	6,663	3,017	4,837	4,843	4,838	4,842
Adjusted R-squared	0.8326	0.9013	0.9089	0.9332	0.9468	0.9455	0.9453	0.9464
Panel C: Rentals (2008)								
Scattered greenery (0–100 m)	0.078	0.035	0.087	0.028	0.073*	0.037	0.055	0.039
	(0.042)	(0.024)	(0.053)	(0.026)	(0.033)	(0.043)	(0.036)	(0.043)
Scattered greenery (100–200 m)	0.054	-0.011	0.162	-0.032	0.002	0.022	0.051	0.002
	(0.070)	(0.038)	(0.087)	(0.040)	(0.051)	(0.068)	(0.055)	(0.064)
Scattered greenery (200–300 m)	0.048	0.081	0.128	-0.002	0.003	0.097	0.080	-0.074
	(0.082)	(0.048)	(0.103)	(0.050)	(0.066)	(0.089)	(0.072)	(0.083)
Scattered greenery (300–400 m)	-0.062	-0.010	-0.020	-0.032	0.057	-0.161	-0.048	-0.011
	(0.090)	(0.061)	(0.125)	(0.056)	(0.080)	(0.083)	(0.084)	(0.090)
Scattered greenery (400–500 m)	0.015	0.035	0.133	-0.051	0.002	-0.099	0.088	-0.191
	(0.124)	(0.070)	(0.155)	(0.064)	(0.084)	(0.132)	(0.105)	(0.119)
Avg. %-age of greenery within 500 m	15.9%	16.5%	17.5%	15.8%	16.8%	15.6%	19.3%	13.1%
Observations	21,364	21,824	9,778	33,410	21,593	21,595	21,263	21,925
Adjusted R-squared	0.8940	0.6012	0.9161	0.8751	0.9106	0.9243	0.9203	0.9163
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.090**	0.003	0.118**	-0.013	0.017	0.032	0.037	-0.024
	(0.034)	(0.028)	(0.039)	(0.026)	(0.035)	(0.033)	(0.027)	(0.044)
Scattered greenery (100–200 m)	0.012	0.006	0.002	0.011	-0.015	0.048	-0.018	0.041
	(0.065)	(0.040)	(0.065)	(0.047)	(0.054)	(0.062)	(0.047)	(0.075)
Scattered greenery (200–300 m)	0.023	0.043	0.015	0.034	0.053	0.011	0.105	-0.104
	(0.073)	(0.053)	(0.085)	(0.053)	(0.062)	(0.075)	(0.054)	(0.084)
Scattered greenery (300–400 m)	0.062	0.002	0.140	0.030	0.226**	-0.179	0.063	0.044
	(0.078)	(0.059)	(0.092)	(0.063)	(0.072)	(0.092)	(0.065)	(0.095)
Scattered greenery (400–500 m)	-0.152	-0.130*	-0.103	-0.072	-0.064	-0.257*	-0.050	-0.303**
	(0.082)	(0.065)	(0.104)	(0.071)	(0.084)	(0.106)	(0.082)	(0.113)
Avg. %-age of greenery within 500 m	13.1%	13.5%	14.2%	13.1%	13.9%	12.7%	15.5%	11.4%
Observations	46,776	47,887	19,341	75,322	47,331	47,332	44,425	50,238
Adjusted R-squared	0.8743	0.6574	0.9094	0.8804	0.9063	0.9170	0.9142	0.9079
Property characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Neighborhood characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES	YES	YES	YES	YES
Street FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those listed in Table A4. the parameter estimates and standard errors for the control variables are omitted due to space limitations.

Table A9. Effects of scattered greenery on property quality

	# of rooms	ln(Sq. metres)	ln(Age of property)	# of floors in the building
	(1)	(2)	(3)	(4)
Panel A: Sales (2008)				
Scattered greenery (0–100 m)	0.914***	0.707***	0.322	4.46**
	(0.264)	(0.163)	(0.322)	(1.72)
Scattered greenery (100–200 m)	0.056	0.261	-1.11*	1.09
	(0.399)	(0.251)	(0.492)	(1.78)
Scattered greenery (200–300 m)	0.476	0.094	-0.604	-1.15
	(0.499)	(0.313)	(0.607)	(2.54)
Scattered greenery (300–400 m)	0.639	0.187	-1.21	-6.19
	(0.635)	(0.407)	(0.764)	(3.60)
Scattered greenery (400–500 m)	0.108	0.003	-1.46	-5.44
	(0.735)	(0.448)	(0.837)	(3.39)
Observations	7,872	7,872	7,872	7,872
Adjusted R-squared	0.2241	0.3146	0.2786	0.6009
Panel B: Sales (2013)				
Scattered greenery (0–100 m)	1.34***	0.935***	0.256	4.29*
	(0.310)	(0.196)	(0.352)	(1.87)
Scattered greenery (100–200 m)	-0.109	-0.153	-0.254	3.82
	(0.481)	(0.305)	(0.494)	(2.12)
Scattered greenery (200–300 m)	1.08	0.092	-0.057	-1.01
	(0.629)	(0.395)	(0.758)	(3.05)
Scattered greenery (300–400 m)	-0.213	-0.687	-1.15	-5.00
	(0.699)	(0.485)	(0.831)	(3.92)
Scattered greenery (400–500 m)	0.310	-0.698	1.97*	4.43
	(0.792)	(0.536)	(0.940)	(5.67)
Observations	9,680	9,680	9,680	9,680
Adjusted R-squared	0.2728	0.3456	0.2680	0.6347
Panel C: Rentals (2008)				
Scattered greenery (0–100 m)	0.325*	0.415***	0.385	0.525
	(0.137)	(0.112)	(0.260)	(0.601)
Scattered greenery (100–200 m)	0.023	0.080	-0.345	0.934
	(0.200)	(0.172)	(0.390)	(0.917)
Scattered greenery (200–300 m)	0.118	-0.056	0.751	-1.22
	(0.247)	(0.198)	(0.468)	(1.24)
Scattered greenery (300–400 m)	-0.329	0.047	-0.638	-1.09
	(0.310)	(0.257)	(0.600)	(1.54)
Scattered greenery (400–500 m)	0.788*	0.079	0.658	-1.59
	(0.375)	(0.334)	(0.603)	(1.35)
Observations	43,188	43,188	43,188	43,188
Adjusted R-squared	0.1168	0.1697	0.1817	0.4940
Panel D: Rentals (2013)				
Scattered greenery (0–100 m)	0.579***	0.496***	0.128	-0.323
	(0.143)	(0.110)	(0.236)	(0.602)
Scattered greenery (100–200 m)	-0.130	0.084	-0.109	0.252
	(0.200)	(0.173)	(0.349)	(0.953)
Scattered greenery (200–300 m)	-0.070	-0.001	0.153	0.452
	(0.246)	(0.215)	(0.446)	(1.23)
Scattered greenery (300–400 m)	-0.474	-0.161	0.282	-0.169
	(0.278)	(0.245)	(0.487)	(1.55)
Scattered greenery (400–500 m)	0.501	0.449	-0.753	-2.89
	(0.324)	(0.310)	(0.594)	(1.83)
Observations	94,663	94,663	94,663	94,663
Adjusted R-squared	0.1148	0.1520	0.1909	0.4705
Property characteristics	NO	NO	NO	NO
Neighborhood characteristics	YES	YES	YES	YES
Accessibility characteristics	YES	YES	YES	YES
Measures of urban greenness	YES	YES	YES	YES
Street FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Month FE	YES	YES	YES	YES

Note: Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. The independent variables are the same as those listed in Table A4 except for the property characteristics. The parameter estimates and standard errors for the control variables are omitted due to space limitations.