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The Value of Scattered Greenery in Urban Areas: A Hedonic Analysis in Japan

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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 green space from high-resolution satellite images and combine these data with data on both condominium sales and rentals to estimate hedonic pricing models. We find that scattered urban greenery within 100 m significantly increases housing prices, while more distant scattered greenery does not. Scattered greenery is highly valued near highways, and the prices of inexpensive and small for-sale and 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.

Keywords Environmental amenities · Urban greenness · Hedonic housing price model · Housing value · Remote sensing

JEL Classification Q51 · R3 · R21 · Q57

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 (Taylor and Hochuli 2017). However, green amenities, such as urban forests, parks, and street trees, are public goods with many positive

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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. Environmental economists also value parks and urban forests to investigate the optimal amount of urban greenery. However, scattered greenery such as street trees and yard bushes is often ignored compared to parks and urban forests, and previous studies tell us little about the value of such greenery. Hence, this study investigates the value of scattered greenery using a hedonic approach.

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). By decomposing the explicit equilibrium price paid for the property as a whole into implicit values for each of the property's characteristics (e.g., the distance from hospitals or the amount of surrounding greenery), we can analyze the preferences that home buyers have 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; Tyrväinen and Miettinen 2000). Previous studies have suggested that urban green amenities have a generally positive impact on real estate prices (Czembrowski and Kronenberg 2016; Perino et al. 2014; Siriwardena et al. 2016). Previous studies have also shown that people's willingness to pay for greenery varies greatly depending on the characteristics of the greenery (type, use, size, etc.), the people (age, income, education, etc.), and the residential environment (population density, degree of urbanization, etc.) (Barrio and Loureiro 2010; Czembrowski and Kronenberg 2016; Panduro et al. 2018; Stromberg et al. 2021) 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. A small number of studies have identified positive neighborhood externalities of street trees through field surveys (Donovan and Butry 2010) and visual inspection of aerial images (Pandit et al. 2013). However, such visual identification has the disadvantage of small sample sizes and missing data. Therefore, in recent years, remote sensing with high-resolution aerial or satellite imagery has been used to measure the value of urban greenery (Franco and Macdonald 2018; Sander et al. 2010; Troy and Grove 2008; Tsurumi et al 2018). However, because identifying scattered greenery requires high-resolution satellite imagery that is very costly, most existing studies focus only on cohesive greenery. 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 m pixel resolution) satellite imagery and is combined with large-scale real estate data that include detailed information about various characteristics. 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 evidence for 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. We also reveal the heterogeneity in preferences for green amenities by comparing the transaction 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.

Our results show that a 10% increase in scattered greenery within 100 m of a property increases the price of apartments for sale by 2 to 2.5%. Although it should be noted that the measurement error and confounding effects have not been eliminated, this impact is greater than in previous studies. Conversely, the impact of scattered greenery on rental properties is weak or insignificant. 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.

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. 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 improve the welfare of urban areas. Especially in urban areas, where constructing large open spaces is costly, planting scattered greenery can be an effective policy. 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.

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 Sect. 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 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 to create our GIS data. Satellite images taken on April 30, 2008, and October 13, 2013, the 2 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 m 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 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

[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.".

[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.

[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.

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 m 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 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 the 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 Figs. 4 and 5 show comparisons of high-resolution aerial photographs and NDVI-based green coverage data. Appendix Fig. 4, showing residential areas, illustrates that what is defined as scattered greenery is mainly bushes and trees around houses, beside roads, and along railroad tracks. Appendix Fig. 5, which shows parks with sports fields, indicates that the greenery around parks and sports fields is classified as cohesive greenery. However, a 100 m 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. To address concerns about measurement error due to classification methods, we also checked the robustness using other classification methods.

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.

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

[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.

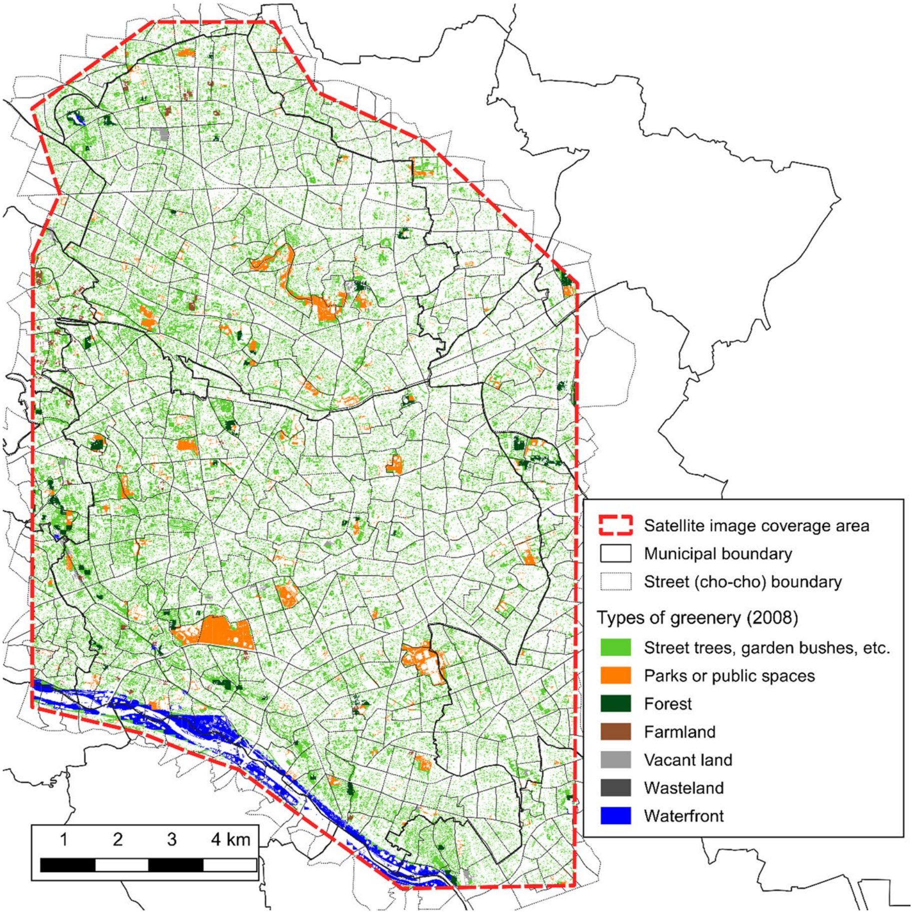

Fig. 1 Green coverage by type in 2008. The location and amount of greenery are based on satellite images from 2008. The classification of green spaces is based on the 2009 Urban Area Land Use Subdivision Mesh Data

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 m intervals up to a maximum of 500 m) around the coordinates of the building's center of gravity and measured the amount of each type of greenery within each buffer.[5] Descriptive statistics are provided in Appendix Table 6.

[5] To facilitate comparison with recent related studies (e.g., Wu and Rowe 2022), 100-m intervals are used. To account for errors caused by the longitude and latitude information of the property and the shape of the building, the nearest greenery is defined as within 100 m. The upper limit is set at 500 m, since the living distance on foot in urban areas in Japan is generally approximately 500 m (Hoshino 2011). To consider the validity of our buffer intervals, we also performed an analysis using 50-m intervals, and the results were consistent (The results can be provided upon request).

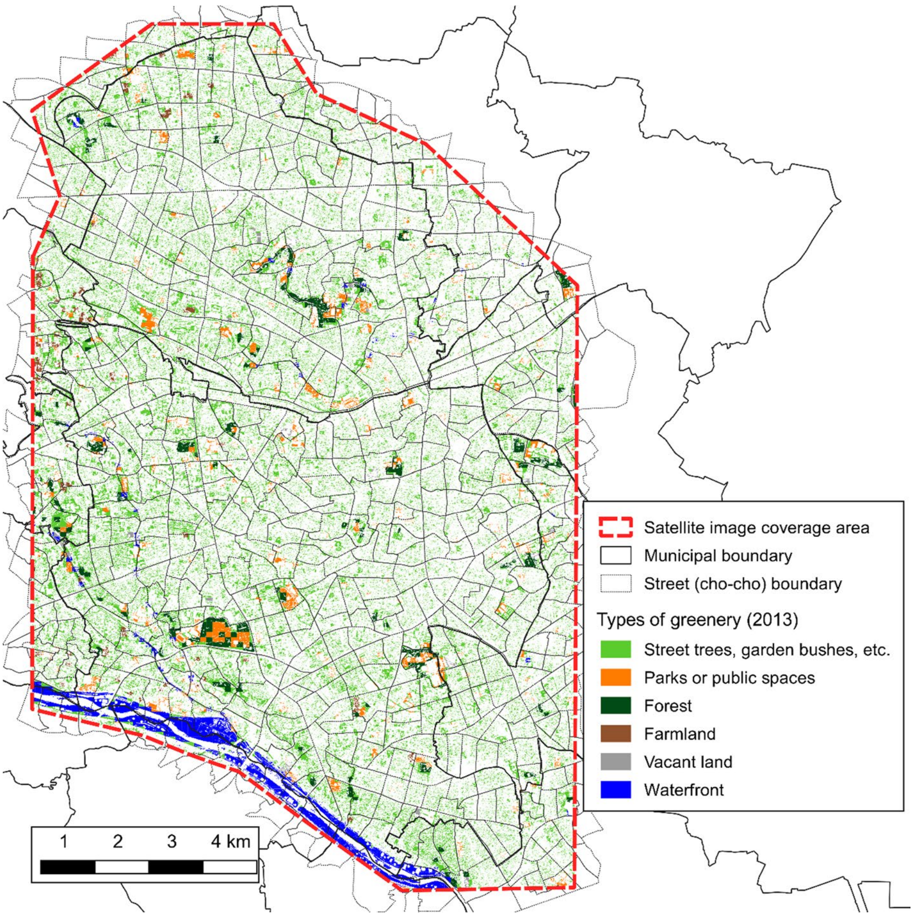

Fig. 2 Green coverage by type in 2013. The location and amount of greenery are based on satellite images from 2013. The classification of green spaces is based on the 2014 Urban Area Land Use Subdivision Mesh Data

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.[6] 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. In total, 17,552 properties for sale and 137,851 properties for rent are used for estimation.[7] 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.[8] Descriptive statistics can be found in Appendix Table 6.

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 m 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 m 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 Table 6.

[6] 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.

[7] Our original property dataset covers the entire Tokyo area, with 146,494 and 895,394 properties for sale and rent, respectively, during the analysis period. Extracting properties from the original dataset for which the exact longitude and latitude can be determined from the address and the property name, the sample size is 142,482 (97.3%) for sales and 744,167 (83.1%) for rentals. Of that sample, 17,847 and 144,534 for sales and rentals, respectively, are located within our satellite coverage. Therefore, the substantial sample survival rates are 98.3% (from 17,847 to 17,552) and 91.1% (from 144,534 to 131,713) for sales and rentals, respectively.

[8] 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.

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.

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

where the dependent variable $\ln(P)_{\text{iyms}}$ is the natural logarithm of the nominal price or rent of property i on street s that was contracted in month m of year y.[9] $\text{Green}_{\text{riyms}}$ 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.[10] Y_y is the fixed effect of the contract year and controls for overall property market variations caused by economic policies and other events in each year. M_m is the fixed effect of the contract month and controls for trends in each month, such as the end of the fiscal year, when the real estate market is more active due to more people moving. S_s is the street fixed effects, flexibly controlling for various unobserved characteristics, such as the culture and living environment common to each street. This specification allows us to estimate the impact of variations in the percentage of scattered greenery within the same street, controlling for property market trends. We estimate Eq. (1) using four separate datasets on sales and rental properties for 2008 and 2013.

While we use the variation in scattered greenery within streets to make our estimates, there may be a concern that the street is a small area, and therefore, the variation is small. The 549 streets included in the study area have an average area and perimeter of 0.213 square kilometers and 2.108 km, respectively. The area of the 100 m radius buffer is 0.0314 square kilometers, which is small compared to the area of the street, so properties located on the same street are exposed to different greenery environments. Thus, even after controlling for street fixed effects, the effects of scattered greenery within the streets remain noteworthy. Figures 1 and 2 show that the same street can have sparse and dense areas of greenery coverage.

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 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.

[9] We also performed an estimation with price/rent per square meter as the explained variable, and the results were very similar to the main results. The results table can be made available upon request.

[10] The study area is a well-developed urban area, and as Figs. 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.

Table 1 Effects of scattered greenery on property prices and rents

	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*	0.019
	(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)	(0.042)
Scattered greenery (200–300 m)	−0.096	−0.159	0.036	0.043
	(0.116)	(0.140)	(0.056)	(0.046)
Scattered greenery (300–400 m)	−0.270*	−0.189	−0.055	0.037
	(0.136)	(0.156)	(0.060)	(0.055)
Scattered greenery (400–500 m)	−0.085	−0.324	−0.024	−0.100
	(0.152)	(0.178)	(0.080)	(0.064)
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 fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9466	0.9485	0.9177	0.9111

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 10

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 m of a property significantly increases the contract price. Scattered greenery more than 100 m from the residence has a barely significant impact.[11] 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 m 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 m increases the price of apartments for sale by approximately 2 to 2.5% (from 740,000 to 930,000 JPY) when evaluated at average housing prices. Sander et al. (2010), who analyzed green space in Minnesota, reported that a 10% increase in the tree canopy within 100 m increased the average housing price by 0.48% and that the average tree canopy within 250 m 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.

Tsurumi and Managi (2015) analyzed the value of green space using the life satisfaction approach for areas close to ours. They indicated that the marginal willingness to pay for a 1% increase in green space within a 100 to 300 m 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 m 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.

The value of rental properties is less affected by scattered greenery than the value of sales properties. There are several possible explanations for the heterogeneous responses of sales and rental properties. First, the difference could be due to the different locations of the sales and rental properties. Second, the structures and/or interiors of the buildings may differ between sales and rental properties. Alternatively, differences in residents' characteristics, such as socioeconomic status and family structure, may lead to heterogeneity in property availability and preferences. Further analysis and consideration of the heterogeneity between sales and rentals are provided in Appendix C.

[11] The results for sales properties with scattered greenery in 2008 indicate that scattered greenery within 300–400 m hurts sales prices. This negative effect is still observed after several robustness checks, but it is not consistent over varying distances or through the analysis years and is of low statistical significance. For scattered greenery away from home, the degree and frequency of contact vary greatly depending on people's living areas and commuting routes. Therefore, data such as visibility and frequency of use are needed to provide robust evidence of the impact of scattered greenery at a distance. Hence, we do not interpret the effect of the far distance band and leave it as a limitation of this study and as a topic for future work.

4.2 Robustness Checks

The results of our series of robustness checks are presented in Table 2. 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 m that are significant, and the impacts at greater distances are provided in Appendix B. Column (2) shows the results using the natural logarithm instead of the percentage of scattered greenery, while column (3) 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 (2) and (3) are consistent with the main results, and our results are robust to changes in the measure of scattered greenery.

Columns (4) through (7) confirm that the main results are not sensitive to changes in the sample. Column (4) 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 (5) excludes the impact of very large apartment buildings with various amenities, such as lush gardens (called high-class tower condominiums in Japan), by excluding properties with more than 10 floors from the sample. Column (6) 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 (7) 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 (8) shows the results of controlling for fixed effects for each street in each year. To our knowledge, there have been no major developments or cross-ward policy changes that could affect the real estate market in any specific area within the analysis period. However, we are concerned that area-specific time-varying effects that we are not aware of could affect the main results. To address this concern, we controlled for and estimated street-specific time-varying effects and found that the results were largely unchanged.

Column (9) 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 (7). Using the distance at which every property has one or more neighbors (approximately 500 m) 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.

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 exhibit 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 2 Robustness checks

	Baseline results	Alternative green space measures		Trimmed samples				Controlling street-level trends	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)	(8)	(9)
Panel A: Sales (2008)									
Scattered greenery (0–100 m)	0.251***	0.023**	0.041***	0.218***	0.210***	0.288*	0.233***	0.225***	0.287**
	(0.057)	(0.007)	(0.009)	(0.058)	(0.062)	(0.128)	(0.058)	(0.063)	(0.099)
Observations	7,872	7,872	7,872	7,084	6,245	1,473	5,898	7,872	1128
Adjusted R-squared	0.9466	0.9465	0.9466	0.9305	0.9495	0.9637	0.9457	0.9589	
Panel B: Sales (2013)									
Scattered greenery (0–100 m)	0.204**	0.014	0.024**	0.151*	0.175*	0.203	0.220**	0.197*	0.231*
	(0.076)	(0.008)	(0.008)	(0.077)	(0.078)	(0.124)	(0.078)	(0.076)	(0.104)
Observations	9,680	9,680	9,680	8,712	7,601	2,146	6,999	9,680	1529
Adjusted R-squared	0.9485	0.9484	0.9484	0.9306	0.9516	0.9629	0.9453	0.9595	
Panel C: Rentals (2008)									
Scattered greenery (0–100 m)	0.055*	0.009**	0.0004	0.024	0.055*	0.042	0.078***	0.052*	0.079*
	(0.027)	(0.003)	(0.004)	(0.020)	(0.028)	(0.052)	(0.022)	(0.026)	(0.039)
Observations	42,165	42,161	42,161	38,030	40,240	6,814	24,278	42,165	3961
Adjusted R-squared	0.9177	0.9177	0.9176	0.9006	0.9158	0.9244	0.9115	0.9250	
Panel D: Rentals (2013)									
Scattered greenery (0–100 m)	0.019	0.003	0.001	-0.016	0.022	0.069*	0.042*	0.022	0.066*
	(0.024)	(0.003)	(0.003)	(0.023)	(0.025)	(0.035)	(0.020)	(0.024)	(0.030)
Observations	89,548	89,547	89,547	81,159	85,653	18,243	44,975	89,548	9107

Table 2 (continued)

	Baseline results	Alternative green space measures		Trimmed samples				Controlling street-level trends	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)	(8)	(9)
Adjusted R-squared	0.9111	0.9111	0.9111	0.8893	0.9087	0.9122	0.9087	0.9155	
Property characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accessibility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Measures of urban greenness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Street × Year fixed effects	No	No	No	No	No	No	No	Yes	No

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 Appendix Table 10, and the parameter estimates and standard errors for the control variables and for scattered greenery more than 100 m away are omitted due to space limitations. The baseline results in column (1) are restated from the estimates in Table 1 for reference. The impact of scattered greenery more than 100 m away is reported in Appendix Table 11

Appendix Table 7 shows the results using dummy variables created by dividing the scattered greenery variable into quintiles. The results show that, in contrast to previous studies, 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, because the study area is a well-developed urban area, it may not have reached the point of "too much" greenery. On the other hand, there is no consistent relationship between the amount of scattered greenery and the magnitude of impact using either the 2008 or the 2013 green coverage data.

Additionally, previous studies analyzing the impact of greenery at certain intervals (e.g., Tsurumi and Managi 2015; Tsurumi et al. 2018) are concerned with the correlation of greenery in each distance band. Appendix Table 7, which shows the correlation of scattered greenery by each distance band, suggests that there may be a nonnegligible correlation between greenery at close distances. We used separate equations for each distance band to estimate the effect of scattered greenery to prevent problems caused by multicollinearity. The results are presented in Appendix Table 9, which shows consistent results with the main results. Therefore, our analysis was not seriously affected by the correlations of scattered greenery by each distance band.

4.3 Alternative Definition of Scattered Greenery

Because our definition of scattered greenery may introduce measurement errors, we need to validate our method of classifying scattered greenery. We performed the analysis using greenery identified by several alternative methods. The results are shown in Table 3. Columns (2) and (3) use the same definition as the main results but more rigorously identify scattered greenery. Column (2) shows the estimation results excluding scattered greenery with a single polygonal mass of 10,000 square meters or more.[12] This reduces the possibility of misidentifying forests and parks as scattered greenery. It should be noted, however, that this increases the possibility of misidentifying spatially contiguous street trees and garden bushes as cohesive greenery. Column (3) presents estimates that exclude scattered greenery adjacent to parks and forests. Both results are consistent with the main results, confirming that scattered greenery misidentification did not seriously affect the results.

Columns (4) and (5) use scattered greenery defined based on digital maps published by the Geospatial Information Authority of Japan instead of the 100-m mesh land use data used in the main analysis. These data are updated constantly and show the condition of buildings and roads around the year 2020.[13] Compared to land use data, these data have the disadvantage of not being able to identify past land use but instead can provide more detailed classifications. Based on the digital map, we visually identified parks, forests, rivers, etc., and created an alternative definition of scattered greenery. Appendix Figs. 6 and 7 show the types of greenery space generated by this definition. The results of the estimation using alternative definitions of greenery are shown in column (4) and are not significantly different from the main results. Column (5) also shows the results of the analysis excluding large polygons, which are consistent with the main results. These analyses confirm that our results are robust to changes in the definition of scattered greenery.

[12] Approximately 34% and 28% of scattered greenery was excluded in 2008 and 2013, respectively.

[13] We have confirmed that the parks, forests, and rivers in our study area have not changed significantly in the last 10–15 years. It should be noted, however, that different measurement errors can occur than in the main analysis.

Table 3 Alternative definitions of scattered greenery

	Baseline results	Classification by land use		Classification by digital map		Division by location of greenery	
		Remove large polygons	Remove boundary area	Identifying by visual inspection	Visual inspection without large polygons	Along roads	Around buildings
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Sale (2008)							
Scattered greenery (0–100 m)	0.251***	0.195**	0.230***	0.214***	0.171**	0.267**	0.303**
	(0.057)	(0.064)	(0.061)	(0.059)	(0.062)	(0.096)	(0.107)
Observations	7872	7872	7612	7872	7872	7872	7872
Adjusted R-squared	0.9466	0.9464	0.9471	0.9465	0.9464	0.9587	0.9587
Panel B: Sale (2013)							
Scattered greenery (0–100 m)	0.204**	0.182*	0.225**	0.162*	0.186*	0.244*	0.301*
	(0.076)	(0.076)	(0.078)	(0.075)	(0.077)	(0.112)	(0.135)
Observations	9680	9680	9409	9680	9680	9680	9680
Adjusted R-squared	0.9485	0.9485	0.9486	0.9485	0.9485	0.9595	0.9595
Panel C: Rent (2008)							
Scattered greenery (0–100 m)	0.055*	0.067*	0.058*	0.061*	0.061	0.054	0.075
	(0.027)	(0.031)	(0.028)	(0.028)	(0.031)	(0.042)	(0.042)
Observations	42,165	42,165	41,308	42,165	42,165	42,165	42,161
Adjusted R-squared	0.9177	0.9177	0.9174	0.9176	0.9176	0.9249	0.9249
Panel D: Rent (2013)							
Scattered greenery (0–100 m)	0.019	0.048	0.028	0.022	0.049*	0.015	0.061
	(0.024)	(0.026)	(0.025)	(0.023)	(0.024)	(0.036)	(0.040)
Observations	89,548	89,547	87,705	89,547	89,547	89,547	89,547
Adjusted R-squared	0.9111	0.9112	0.9110	0.9111	0.9112	0.9155	0.9155
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

Table 3 (continued)

	Baseline results	Classification by land use		Classification by digital map		Division by location of greenery	
		Remove large polygons	Remove boundary area	Identifying by visual inspection	Visual inspection without large polygons	Along roads	Around buildings
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Measures of urban greenness	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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 Appendix Table 10, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 m away are omitted due to space limitations. The baseline results in column (1) are restated from the estimates in Table 1 for reference. The impact of scattered greenery more than 100 m away is reported in Appendix Table 12

Additionally, we used the polygon data of the buildings and defined scattered greenery within 5 m of the buildings as "around buildings" and other greenery as "along roads" for convenience and calculated the green cover separately. Columns (5) and (6) estimate scattered greenery along roads and around buildings as explanatory variables, respectively, and both results are consistent with the main results. The results in column (5), where greenery away from buildings has significant effects on property prices, emphasize that the main results are not driven by expensive properties with green yards. Furthermore, given that greenery around buildings is likely to be on private land and other greenery is likely to be on public land, this result suggests the possibility that people do not distinguish between suppliers of greenery. However, of course, careful interpretation is necessary because this distinction is arbitrary and does not accurately identify public and private greenery.

The results in Table 3 indicate that the main results are not sensitive to changes in the definition of scattered greenery. However, there is variation in the magnitude of the coefficients, and the impact is weakened by the results excluding large polygons in columns (2) and (5), which are based on more conservative definitions. Therefore, it is important to note that the main results are possibly overestimated due to measurement error.

4.4 Subsample Analysis

Table 4 presents the results of the subsample analysis in which the sample used in the main analysis is divided into two parts by the threshold. Appendix Figure 8 shows the results of the subsample analysis in which the sample is divided into quartiles of the variable of interest for robustness checks. Columns (2) and (3) present the results of the estimation by dividing the sample into two parts: (2) greater than the median price or rent and (3) 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 could 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 (4) and (5) of Table 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 the year or whether the property is a rental or a sale. The interpretation could be similar to that of the results in columns (2) and (3), according to which higher-income people living in higher-quality homes are more concerned about green amenities. However, Appendix Figure 8, which shows the results of the subsample analysis by floor size instead of the number of rooms, presents the possibility of a different interpretation. The results show that sales apartments have no specific trend by size, while rental apartments have a significantly positive effect of scattered greenery within 100 m for larger rooms. The results suggest that differences in response to scattered greenery may be due to the heterogeneity of the residents rather than to the quality of the property. Further analysis and discussion of this heterogeneity between sales and rentals are provided in Appendix C.

Table 4 Subsample analysis

	Baseline results	Housing prices or rents		Number of rooms		Distance from highway		Distance from CBD	
		High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Sales(2008)									
Scattered greenery (0–100 m)	0.251***	0.211**	0.177*	0.288***	0.187	0.098	0.397***	0.291***	0.133
	(0.057)	(0.065)	(0.084)	(0.060)	(0.127)	(0.078)	(0.082)	(0.074)	(0.087)
Avg.%-age of greenery within 500 m	17.36%	18.2%	16.5%	18.1%	15.1%	17.9%	16.8%	20.8%	13.9%
Observations	7872	3936	3936	5828	2044	3936	3936	3936	3936
Adjusted R-squared	0.9466	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)	0.204**	0.297***	0.030	0.183*	0.105	0.097	0.321**	0.278**	0.068
	(0.076)	(0.071)	(0.113)	(0.084)	(0.144)	(0.122)	(0.102)	(0.096)	(0.122)
Avg.%-age of greenery within 500 m	14.01%	14.9%	13.2%	14.8%	12.3%	14.5%	13.6%	16.2%	11.8%
Observations	9680	4840	4840	6663	3017	4837	4843	4838	4842
Adjusted R-squared	0.9485	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)	0.055*	0.075	0.034	0.087	0.028	0.073*	0.040	0.055	0.032
	(0.027)	(0.042)	(0.025)	(0.053)	(0.026)	(0.033)	(0.042)	(0.036)	(0.043)
Avg.%-age of greenery within 500 m	16.24%	16.0%	16.5%	17.5%	15.8%	16.7%	15.7%	19.4%	13.1%
Observations	42,165	20,927	21,238	9778	32,387	21,082	21,083	21,082	21,083
AdjustedR-squared	0.9177	0.8985	0.6013	0.9214	0.8699	0.9120	0.9245	0.9223	0.9156
Panel D: Rentals (2013)									
Scattered greenery (0–100 m)	0.019	0.089**	0.005	0.118**	−0.015	0.022	0.029	0.038	−0.019
	(0.024)	(0.033)	(0.028)	(0.039)	(0.026)	(0.036)	(0.032)	(0.027)	(0.044)
Avg.%-age of greenery within 500 m	13.35%	13.2%	13.5%	14.2%	13.1%	13.9%	12.8%	15.5%	11.2%
Observations	89,548	43,831	45,717	19,341	70,207	44,773	44,775	44,774	44,774
Adjusted R-squared	0.9111	0.8789	0.6497	0.9123	0.8740	0.9083	0.9156	0.9150	0.9081

Table 4 (continued)

	Baseline results	Housing prices or rents		Number of rooms		Distance from highway		Distance from CBD	
		High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Property characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accessibility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Measures of urban greenness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. CBD stands for central business district. The independent variables are the same as those listed in Appendix Table 10, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 m away are omitted due to space limitations. The baseline results in column (1) are restated from the estimates in Table 1 for reference. The impact of scattered greenery more than 100 m away is reported in Appendix Table 13

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 (6) and (7) of Table 4 show the results of an estimation that uses subsamples divided by the median distance to the highway. The results in column (6) 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 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 rental properties here also respond differently than the sales properties, and the scattered greenery is not highly valued with proximity of the highway.

Columns (8) and (9) of Table 4 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. However, the results shown in Appendix Figure 8 indicate that for sales properties, scattered greenery has a strong and significant impact on property values in the first and third quartile subsamples of distance to the CBD. The valuation of greenery can depend on where it is located and who evaluates it. Greenery is highly valued in places where there is little greenery or where pollution is severe, while its valuation is relatively low in places where greenery is abundant. Additionally, people at higher health risk, those who prefer a good living environment, and those who live in the same location for longer may appreciate greenery. The area near the CBD has less greenery and is less hospitable but tends to be populated by younger, healthier, and more relocatable students and workers. Therefore, this nonmonotonic relationship could be caused by two conflicting effects: the value of greenery is higher around the CBD, whereas those who prefer greenery live further away from the CBD (Picard and Tran 2021; Schindler et al. 2018). However, this result should be interpreted with caution since defining Tokyo Station as the CBD is arbitrary and the relationship between the distance from the CBD and real estate prices involves a variety of mediator variables that are not considered here.

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.

4.5 Residential Environment and House Quality

Table 5 shows the estimated results when variables measuring property quality and neighborhood amenities 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 m increases. Unlike the main results for price and rent as the explained variables, 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, and higher-quality homes 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.

Columns (5) through (8) present the estimation results with the number of public facilities within a 500 m radius of the property as the explained variable. Column (5) uses the number of post offices as the explained variable, which is not statistically significant except for rental properties around 2008. Columns (6), (7), and (8) present the results with the number of cultural facilities, such as libraries and sports centers, the number of train stations, and the number of bus stops as explained variables, respectively. Scattered greenery within a 100 m radius has no significant effect on the amount of these public amenities, suggesting that scattered greenery and public amenities around residences may not interact.

However, Appendix Table 14, which reports the coefficients for the greenery variables above a 200 m radius, suggests that there is a negative relationship between the amount of scattered greenery between a 200 and 400 m radius and the number of stations and bus stops. The area around public transportation facilities is noisy, with many commercial areas, making it less valuable as a residential area. Therefore, residential areas could be formed a few hundred meters away from them, where much scattered greenery could be planted and comfortable dwellings could be built. Our results should be interpreted with caution, as such land use decisions may bias the results.

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

Table 5 Effects of scattered greenery on property quality and surrounding amenities

	Quality				Amenity			
	Number of rooms	ln(Sq. metres)	ln(Age of property)	Number of floors in the building	Number of post offices	Number of cultural facilities	Number of station	Number of bus stop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sales (2008)								
Scattered greenery (0–100 m)	0.914***	0.707***	0.322	4.46**	−0.059	−0.104	0.201	−0.473
	(0.264)	(0.163)	(0.322)	(1.72)	(0.230)	(0.586)	(0.202)	(0.723)
Observations	7872	7872	7872	7872	7872	7872	7872	7872
Adjusted R − squared	0.2794	0.3634	0.3300	0.6293	0.6793	0.8479	0.7899	0.8383
Panel B: Sales (2013)								
Scattered greenery (0–100 m)	1.34***	0.935***	0.256	4.29*	−0.365	−1.49	0.024	−0.965
	(0.310)	(0.196)	(0.352)	(1.87)	(0.281)	(0.777)	(0.233)	(0.919)
Observations	9680	9680	9680	9680	9680	9680	9680	9680
Adjusted R − squared	0.3156	0.3840	0.3110	0.6562	0.6832	0.8301	0.7824	0.8197
Panel C: Rentals (2008)								
Scattered greenery (0–100 m)	0.327*	0.415***	0.392	0.529	0.437*	0.025	0.200	0.155
	(0.137)	(0.112)	(0.260)	(0.601)	(0.194)	(0.454)	(0.161)	(0.607)
Observations	42,165	42,165	42,165	42,165	42,224	42,224	42,224	42,161
Adjusted R − squared	0.1254	0.1687	0.1301	0.4951	0.5889	0.8171	0.7277	0.8124
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.582***	0.496***	0.132	−0.319	0.234	−0.011	−0.046	−0.043
	(0.143)	(0.109)	(0.236)	(0.603)	(0.215)	(0.421)	(0.173)	(0.582)
Observations	89,548	89,548	89,548	89,548	89,863	89,863	89,863	89,548
Adjusted R − squared	0.1104	0.1415	0.0756	0.4599	0.5909	0.8037	0.7308	0.8260
Property characteristics	No	No	No	No	Yes	Yes	Yes	Yes
Neighborhood characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5 (continued)

	Quality				Amenity			
	Number of rooms	ln(Sq. metres)	ln(Age of property)	Number of floors in the building	Number of post offices	Number of cultural facilities	Number of station	Number of bus stop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Accessibility characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Measures of urban greenness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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 Appendix Table 10 except for property characteristics, and the parameter estimates and standard errors for the control variables and scattered greenery more than 100 m away are omitted due to space limitations. The impact of scattered greenery more than 100 m away is reported in Appendix Table 14 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 converting land already in use into green space would be very costly, it would be beneficial to consider installing scattered greenery that does not require much space.

The main results indicate that a 10 percentage-point increase from the average in scattered greenery within 100 m of a property increases the property price by 2 to 2.5%. Since the average price per square meter of property for sale is approximately 620,000 JPY, the amount of increase is between 12,400 and 15,500 JPY. For simplicity, we assume that there is a uniform impact on sales properties within a 100 radius of the scattered greenery and that the amount of willingness to pay for the scattered greenery does not diminish with distance.[14] This is a strong assumption and an estimate of the upper limit of the scattered greenery effect. Under this assumption, the benefits from all sales properties within a 100 m radius of the scattered greenery are calculated to be approximately 36,054,240 JPY to 45,067,800 JPY. For reference, using the interest rate of 4% presented in the Manual for Cost−Benefit Analysis provided by the Ministry of Land, Infrastructure, Transport and Tourism, the present value of the cost of scattered greenery per square meter is 12,821 JPY.[15] Therefore, the present value of the total cost to increase the scattered greenery within 100 m by 10 percentage points is approximately 40,257,940 JPY. In a cost−benefit approach, if we assume that all greenery is publicly supplied, the benefit of adding scattered greenery is equal to or greater than the cost.

Several points should be noted when interpreting the results of the cost−benefit analysis. First, the main results possibly overestimate the potential measurement error and confounding factors. Second, scattered greenery includes privately supplied greenery, such as trees in a home’s yard; thus, the value of public greenery must be considered net of such greenery. Third, the cost of additions and maintenance varies greatly depending on the types of trees and grasses. Fourth, the effect of scattered greenery decreases in proportion to distance. Additionally, although of low statistical significance, the main results suggest that scattered greenery more than 100 m from the property could hurt the property value. Finally, as noted in previous studies, too much greenery may have a negative impact. Therefore, our cost−benefit analysis estimates are likely to be overestimated. Even so, the addition of scattered greenery could be beneficial compared to the addition of cohesive greenery, which is an alternative method of supplying greenery. Since the average land price in Setagaya is approximately 700,000 yen per square meter, it is very costly to convert a certain-sized piece of land into green space. Therefore, the

[14] Based on the 2013 Housing and Land Survey, the density of floor space of sales apartments in the entire Setagaya and Suginami wards is approximately 9.26%.

[15] Since the cost of greenery in Setagaya is not available, only the values for Suginami are used here. Costs vary widely depending on the type of tree or grass, but average values are used here. Additionally, since we know only the cost per tree for street trees, we assume, based on our data, that approximately 25 square meters of green coverage is associated with one street tree. According to the 2018 Tokyo Greening White Paper, the average additional and maintenance costs per square meter of street trees (planted strips) in Suginami are 1,140 JPY (1,072 JPY) and 569 JPY (208 JPY), respectively. Since the ratios of the area of street trees and planted strips in Suginami Ward is 72% and 28%, respectively, we estimate that the average additional and maintenance cost per square meter of scattered greenery would be approximately 1,121 JPY and 468 JPY, respectively.

addition of scattered greenery without the need for land purchase costs can be a useful way to improve the residential environment.

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, the effect of distance from the central business district on the relationship between scattered greenery and housing prices is nonmonotonic. While scattered greenery could potentially be appreciated closer to the central business district, those who prefer greenery may reside farther from the central business district. Alternatively, housing prices near the central business district are extremely high, and many people may not be able to afford to pay the price premium for a quality environment. Furthermore, the effects of scattered greenery around the central business district, such as reducing air pollution and the heat island effect, cannot be ignored. Therefore, we are concerned that our results do not adequately capture preferences for scattered greenery. Future work should investigate the valuation of scattered greenery using detailed geographic data and data on individuals' potential preferences.

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. We are not sure whether the residents of rental properties do not care about greenery or do not have the ability to pay for it, but in any case, scattered greenery does not have a significant impact on market rents. 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 the value of more expensive, larger properties are significantly affected by scattered greenery, while the value of less expensive, smaller properties is hardly affected at all. The results also indicate that this pattern could become stronger over time. This finding suggests that landscape preservation, relaxation, and the other benefits of scattered greenery might be available only to 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 Fig. 3. We divide the dataset by quartiles of the amount of scattered greenery within a 500 m radius of each property and plot the change over time in the number of contracted properties by price range within each subsample. To account for average changes in real estate prices over time, price quartiles are produced by year. 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 green space, 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. However, rental properties tend not to be suitable for long-term residence because they do not qualify for mortgage tax breaks. Appendix Table 18 shows that few people reside in rental properties for long periods of time, with approximately 70% having lived on the property for less than 7 years. Therefore, residents of rental properties may not fully benefit from scattered greenery.

Our main results and the suggestive evidence provided by Fig. 3 indicate that transactions for relatively expensive housing are increasing in areas with greenery and other environmental amenities. This means that the cost of residing in a good-quality environment is gradually increasing. Because urban greenery has the externalities of pleasant livability, clean air, and comfortable temperatures, it is supplied and managed by the local government. Therefore, the concern is unequal access to a good environment, which is a public

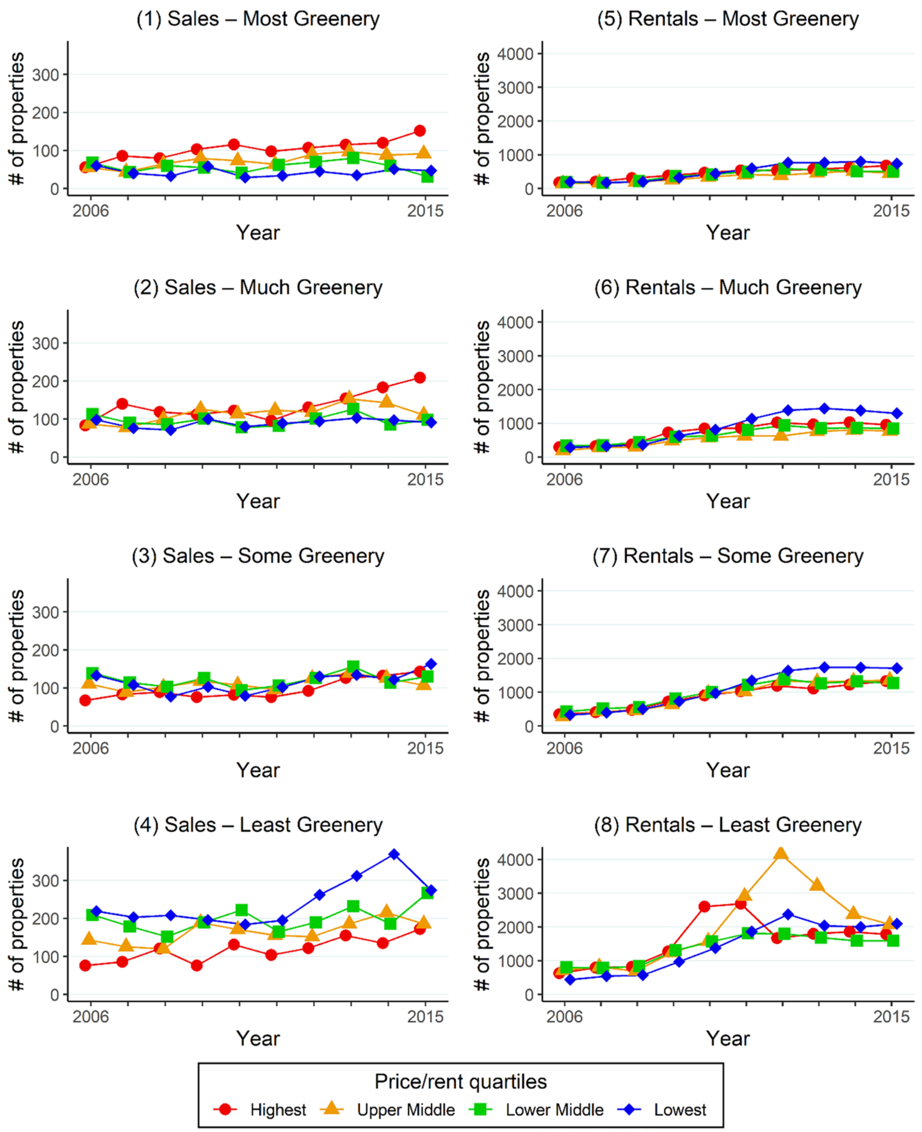

Fig. 3 Number of properties traded by greenery and price tier quartile. In each panel, the vertical axis represents the number of properties traded, and the horizontal axis represents the year of the contract. The red circles, yellow triangles, green squares, and blue diamonds correspond to the highest (0–25%), upper middle (25–50%), lower middle (50–75%), and lowest (75–100%) housing price or rent quartiles, respectively

good, if the cost of living and the uneven distribution of greenery are overlooked. In summary, urban planners should 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 green amenities.

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. The use of satellite imagery taken in the same season each year would allow analysis considering changes in green coverage. Controlling for property fixed effects and analyzing the impact of changes in green coverage would provide further understanding of the value of greenery.

Additionally, some potential concerns remain, and the results of this study should be interpreted with caution. Because our study design and available data do not allow us to control for all potential confounders, concerns about excluded variables remain. Since the possibility of measurement error remains, more detailed identification of scattered greenery, for example, by combining satellite imagery with administrative data, is a future challenge. Using administrative data to identify public and private greenery would provide more policy-meaningful findings.

Analyzing the heterogeneity in individual-level preferences for scattered greenery is a limitation of this study and an avenue for future work. Because this study uses a hedonic pricing model with property data, only the average willingness to pay for scattered greenery is revealed. Additionally, note that since realized housing prices and rents are used, we cannot distinguish between the potential preferences of residents and their actual ability to pay. It is important to understand the heterogeneity in preferences at the individual level since individuals with different demographics within a region require different policies. With data including individual preferences, methods such as two-stage hedonic analysis (Panduro et al. 2018), the life satisfaction approach (Tsurumi et al. 2018), and conjoint choice experiment methods (Hoshino 2011) could be used to reveal preferences for scattered greenery. Furthermore, while this study focused on the impact of scattered greenery around the home, individual-level data such as the frequency of exposure to greenery, commuting routes, and living areas could be used to consider the impact of a wider range of scattered greenery. It would be a fruitful task in the future to determine what types of individuals do or do not benefit from scattered greenery and what they do or do not have the ability to pay for.

Additional figures and tables

See Figs. 4, 5, 6, 7 and 8 and Tables 6, 7, 8 and 9.

Fig. 4 Comparison of aerial photography and NDVI green coverage areas around residential areas. The aerial imagery is based on open data created in 2016, published by Setagaya Ward

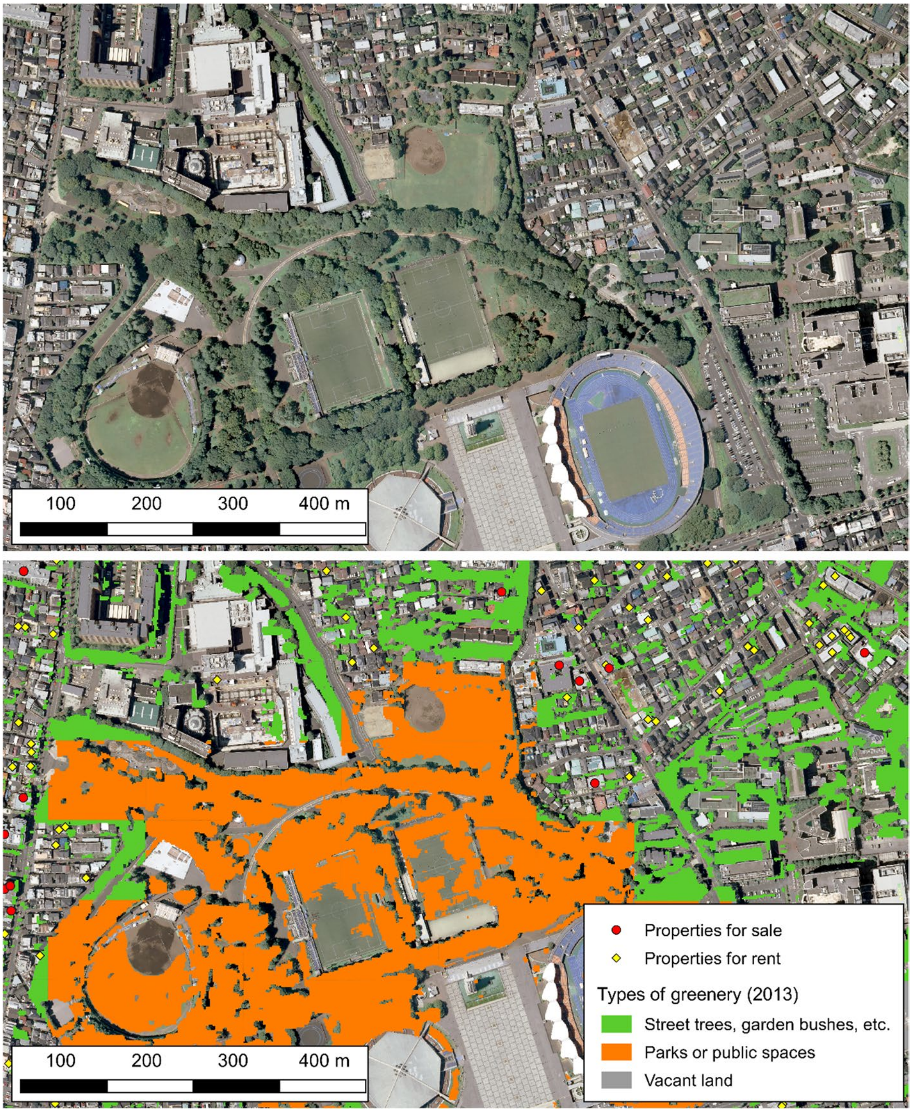

Fig. 5 Comparison of aerial photography and NDVI green coverage areas around the park, including sports fields. The aerial imagery is based on open data created in 2016, published by Setagaya Ward

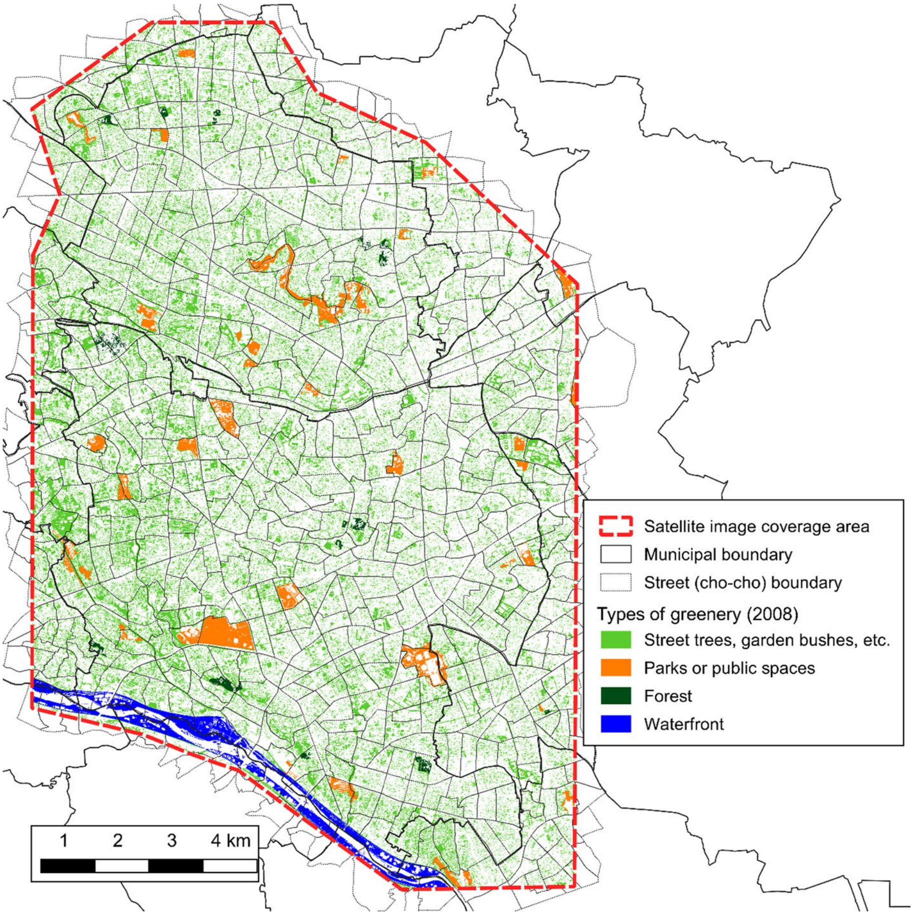

Fig. 6 Green coverage by type in 2008 (classification by digital map). The location and amount of greenery are based on satellite images from 2008. The classification of green spaces is based on the 2022 edition of the digital map published by the Geospatial Information Authority of Japan

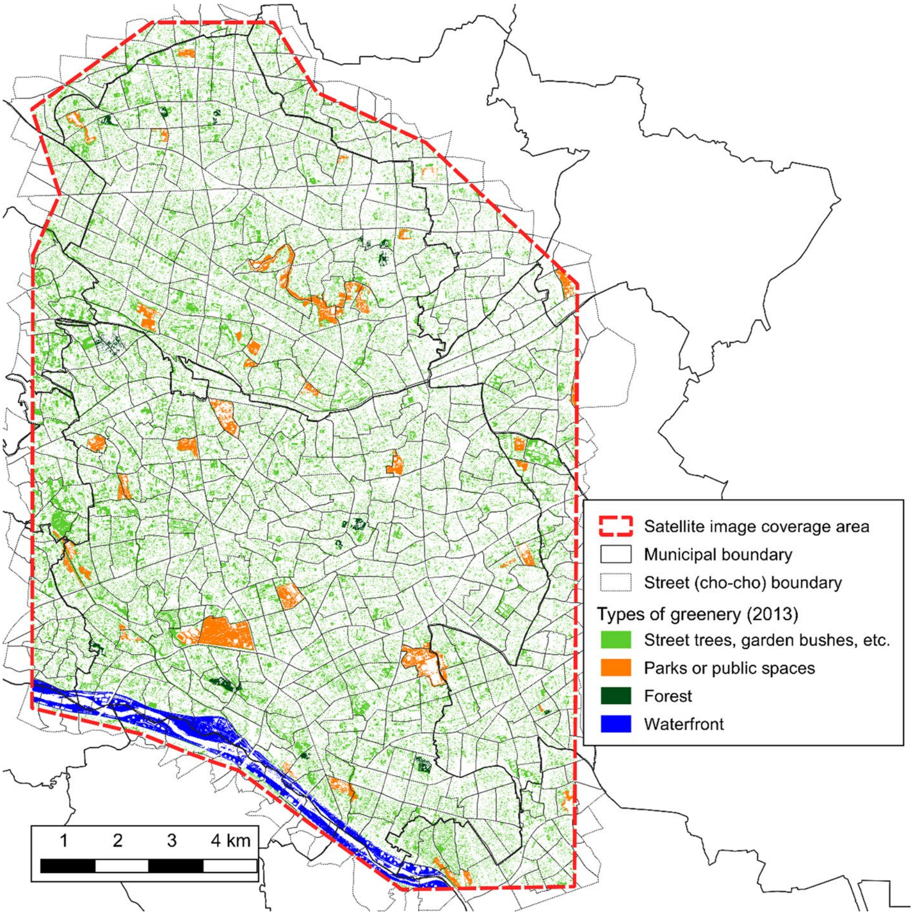

Fig. 7 Green coverage by type in 2013 (classification by digital map). The location and amount of greenery are based on satellite images from 2013. The classification of green spaces is based on the 2022 edition of the digital map published by the Geospatial Information Authority of Japan

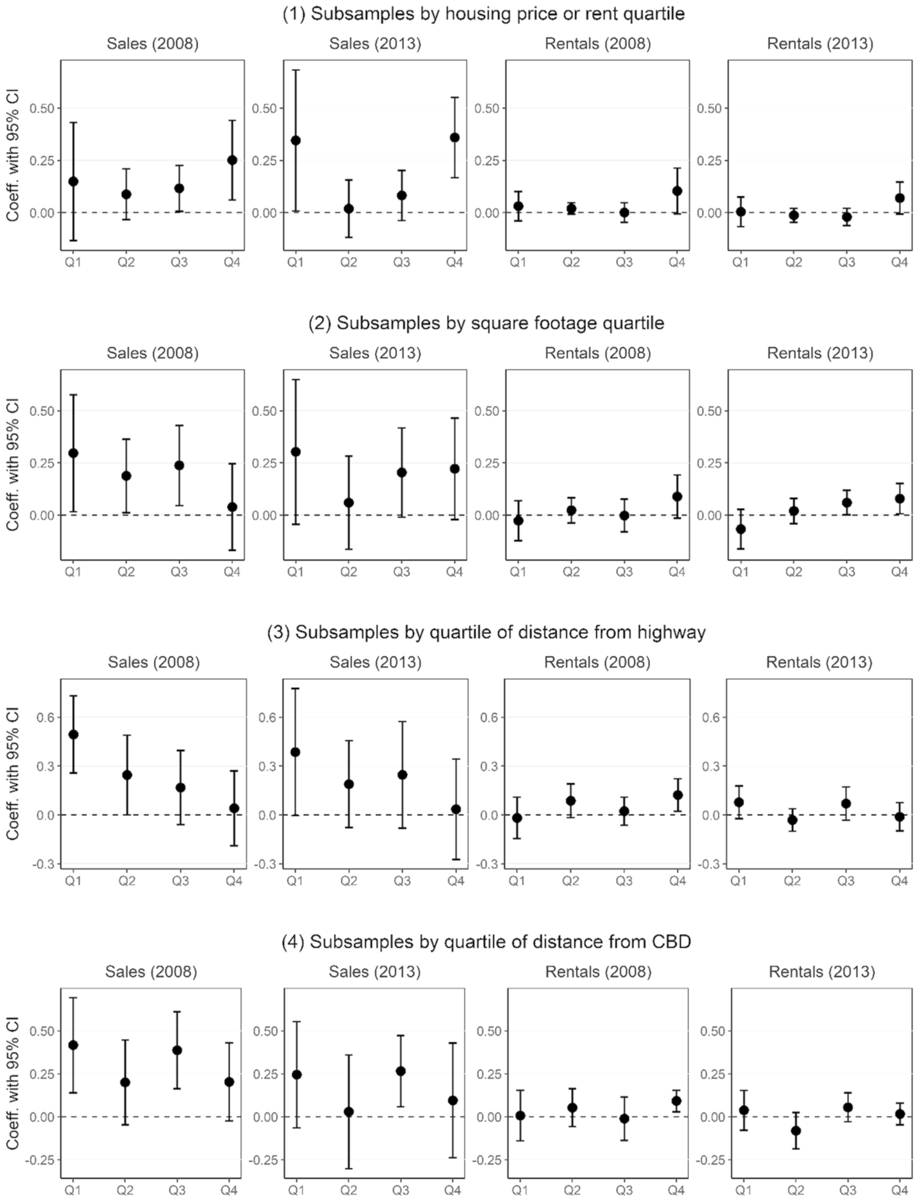

Fig. 8 Subsample analysis by quartiles. In each panel, each point represents the coefficient of scattered greenery within 100 m, estimated using subsamples from the first through fourth quartiles, respectively, as indicated by the horizontal axis. The confidence intervals around the point estimates reflect 95% confidence intervals, and standard errors are adjusted for clustering at the street level. The independent variables are the same as those listed in Appendix Table 10

Table 6 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	25,017.755	9.339	4.534	1.000	187.500
Number of rooms	2.099	0.852	1.000	7.000	1.268	0.549	1.000	22.000
Square meters	59.858	24.664	8.710	235.580	30.144	19.952	2.510	2624.000
Age of property (in years)	18.573	12.034	0.000	83.384	18.711	10.991	0.000	88.047
Number of floors in the building	7.075	4.081	1.000	42.000	3.799	2.523	1.000	85.000
Floor where located	3.879	2.956	−2.000	36.000	2.395	1.673	−2.000	32.000
Neighborhood characteristics								
Population (1000/m2)	13.474	3.174	4.381	21.108	13.987	2.952	4.214	21.108
Number of households (1000)	7.330	2.410	1.826	13.460	7.809	2.284	1.726	13.460
% under 19 years old	0.133	0.033	0.067	0.237	0.123	0.028	0.067	0.237
% over 65 years old	0.184	0.018	0.122	0.285	0.188	0.016	0.122	0.309
Number of properties for sale	70.134	31.449	5.000	190.000	65.253	31.065	1.000	194.000
Avg. property price (10,000 JPY)	3392.695	919.035	1677.500	8343.885	3195.136	827.764	0.000	8433.533
Avg. Number of floors in for − sale properties	6.136	1.200	3.000	9.982	6.066	1.181	0.000	10.273
Number of properties for rent	544.688	265.199	32.000	1326.000	627.293	252.144	23.000	1397.000
Avg. property rent (10,000 JPY)	9.916	1.631	7.083	21.458	9.566	1.444	6.984	25.207
Avg. Number 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	137.888	90.924	0.000	716.790
Distance to a school	299.645	141.779	8.165	909.876	298.043	135.639	6.192	909.876
Distance to police	359.892	188.376	8.626	1125.649	356.005	176.185	2.351	1147.036
Distance to a fire station	782.562	401.598	12.190	2059.778	747.050	355.572	4.973	2133.190
Distance to a post office	311.196	154.028	6.918	985.770	301.774	141.680	1.616	1022.223
Distance to a park	186.010	103.974	4.474	655.871	198.062	106.909	1.371	706.357

Table 6 (continued)

	Properties for sale				Properties for rent			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Distance to a museum or gallery	1236.599	667.501	25.658	3182.323	1280.725	666.535	17.610	3187.883
Distance to a library	599.255	269.295	3.628	1683.342	583.441	265.356	3.628	1738.656
Distance to a playground	949.538	478.935	36.301	2751.802	998.020	518.376	10.595	2789.267
Distance to a budojo	1306.542	597.711	32.621	3099.050	1313.598	595.259	18.768	3109.548
Distance to a pool	1387.742	647.786	98.793	3117.698	1424.573	629.237	11.543	3095.457
Distance to city hall	2926.297	1603.595	55.909	10,695.031	2693.872	1533.177	39.596	10,726.757
Distance to a station	491.132	310.780	0.702	1882.441	434.915	271.119	0.591	1987.998
Distance to a bus stop	159.710	109.229	8.955	740.180	185.006	125.387	2.005	804.535
Distance to a major road	314.393	308.921	0.028	1632.718	334.221	295.448	0.006	1703.577
Distance to the highway	1434.394	1080.814	11.479	4694.255	1559.114	1168.662	5.854	4694.255
Distance to Tokyo Station	13,217.977	2577.661	8106.727	18,701.929	12,749.490	2495.398	8091.710	19,031.638
Distance to the Tama River	5650.367	3018.419	109.113	11,736.019	6322.208	2953.552	104.893	11,768.117
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	0.009	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	0.016	0.000	0.486
Waterfront (300–400 m)	0.004	0.027	0.000	0.431	0.002	0.017	0.000	0.445
Waterfront (400–500 m)	0.005	0.031	0.000	0.333	0.002	0.019	0.000	0.380
Park or public space (0–100 m)	0.007	0.027	0.000	0.467	0.005	0.027	0.000	0.685

Table 6 (continued)

	Properties for sale				Properties for rent			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Park or public space (100–200 m)	0.014	0.036	0.000	0.394	0.011	0.034	0.000	0.467
Park or public space (200–300 m)	0.018	0.038	0.000	0.419	0.015	0.034	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	0.019	0.031	0.000	0.390
Scattered greenery (0–100 m)	0.160	0.092	0.002	0.595	0.145	0.078	0.000	0.727
Scattered greenery (100–200 m)	0.169	0.072	0.023	0.490	0.157	0.065	0.022	0.531
Scattered greenery (200–300 m)	0.172	0.063	0.041	0.428	0.162	0.059	0.042	0.462
Scattered greenery (300–400 m)	0.174	0.059	0.043	0.454	0.165	0.056	0.038	0.421
Scattered greenery (400–500 m)	0.177	0.057	0.056	0.412	0.167	0.053	0.053	0.428
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	0.010	0.000	0.163
Farm or vacant land (200–300 m)	0.003	0.010	0.000	0.118	0.002	0.010	0.000	0.130
Farm or vacant land (300–400 m)	0.003	0.008	0.000	0.098	0.002	0.008	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	0.018	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	0.027	0.000	0.602
Park or public space (100–200 m)	0.014	0.035	0.000	0.338	0.011	0.031	0.000	0.440
Park or public space (200–300 m)	0.018	0.035	0.000	0.364	0.015	0.031	0.000	0.381
Park or public space (300–400 m)	0.019	0.033	0.000	0.376	0.017	0.030	0.000	0.380

Table 6 (continued)

	Properties for sale				Properties for rent			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Park or public space (400–500 m)	0.021	0.033	0.000	0.311	0.019	0.029	0.000	0.375
Scattered greenery (0–100 m)	0.130	0.073	0.004	0.492	0.118	0.061	0.000	0.510
Scattered greenery (100–200 m)	0.137	0.056	0.023	0.397	0.129	0.049	0.013	0.398
Scattered greenery (200–300 m)	0.139	0.047	0.030	0.333	0.132	0.043	0.030	0.391
Scattered greenery (300–400 m)	0.141	0.044	0.037	0.315	0.134	0.040	0.035	0.382
Scattered greenery (400–500 m)	0.142	0.041	0.044	0.325	0.136	0.038	0.041	0.352
Number of layout types	8				9			
Number of structure types	9				9			
Number of zoning types	10				10			
Number of streets	506				545			
Number of properties	17,552				1,31,713			

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 7 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*	0.004
	(0.010)	(0.011)	(0.004)	(0.004)
3rd quintile	−0.005	0.013	0.003	0.0008
	(0.010)	(0.012)	(0.004)	(0.004)
4th quintile	0.013	0.018	0.013**	0.003
	(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	−0.0004
	(0.011)	(0.013)	(0.004)	(0.004)
3rd quintile	0.006	−0.005	−0.004	0.002
	(0.013)	(0.014)	(0.005)	(0.004)
4th quintile	0.004	−0.015	−0.002	0.002
	(0.015)	(0.016)	(0.006)	(0.005)
5th quintile	−0.020	−0.010	−0.0002	0.002
	(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	0.003
	(0.014)	(0.014)	(0.006)	(0.005)
4th quintile	−0.011	−0.004	0.011	0.005
	(0.015)	(0.016)	(0.006)	(0.005)
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	−0.002
	(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	0.002	−0.002
	(0.013)	(0.013)	(0.006)	(0.004)
3rd quintile	0.005	0.007	−0.0009	−0.004
	(0.015)	(0.016)	(0.007)	(0.005)

Table 7 (continued)

	Properties for sale		Properties for rent	
	2006–2010	2011–2015	2006–2010	2011–2015
	(1)	(2)	(3)	(4)
4th quintile	−0.0001	0.004	0.0004	−0.003
	(0.018)	(0.017)	(0.008)	(0.005)
5th quintile	0.0006	−0.008	−0.0004	−0.006
	(0.021)	(0.019)	(0.011)	(0.006)
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 fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	7872	9680	42,161	89,547
Adjusted R-squared	0.9468	0.9487	0.9178	0.9112

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 Appendix Table B1. The parameter estimates and standard errors for the control variables, which are omitted due to space limitations, are consistent with the main results

Table 8 Correlations among scattered greenery by distance band

	0–100 m	100–200 m	200–300 m	300–400 m	400–500 m
Panel A: Sales (2008)					
0–100 m	1.000				
100–200 m	0.717	1.000			
200–300 m	0.582	0.775	1.000		
300–400 m	0.528	0.671	0.821	1.000	
400–500 m	0.505	0.624	0.717	0.855	1.000
Panel B: Sales (2013)					
0–100 m	1.000				
100–200 m	0.706	1.000			
200–300 m	0.540	0.730	1.000		
300–400 m	0.491	0.611	0.759	1.000	
400–500 m	0.447	0.536	0.636	0.783	1.000
Panel C: Rentals (2008)					
0–100 m	1.000				
100–200 m	0.699	1.000			
200–300 m	0.574	0.786	1.000		
300–400 m	0.513	0.681	0.827	1.000	
400–500 m	0.481	0.633	0.727	0.842	1.000
Panel D: Rentals (2013)					
0–100 m	1.000				
100–200 m	0.653	1.000			
200–300 m	0.495	0.725	1.000		
300–400 m	0.455	0.609	0.764	1.000	
400–500 m	0.415	0.556	0.649	0.795	1.000

Table 9 Individual estimations by distance bands of scattered greenery

	Properties for sale		Properties for rent	
	2008	2013	2008	2013
	(1)	(2)	(3)	(4)
Panel A: Scattered greenery (0–100 m)	0.249***	0.219**	0.061*	0.018
	(0.054)	(0.071)	(0.026)	(0.025)
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9465	0.9484	0.9176	0.9111
Panel B: Scattered greenery (100–200 m)	−0.025	0.044	0.055	0.015
	(0.088)	(0.110)	(0.040)	(0.040)
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9462	0.9483	0.9176	0.9111
Panel C: Scattered greenery (200–300 m)	−0.151	−0.127	0.036	0.063
	(0.109)	(0.133)	(0.050)	(0.043)
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9462	0.9483	0.9176	0.9111
Panel D: Scattered greenery (300–400 m)	−0.322*	−0.239	−0.072	0.032
	(0.134)	(0.152)	(0.056)	(0.054)
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9463	0.9483	0.9176	0.9111
Panel E: Scattered greenery (400–500 m)	−0.064	−0.289	−0.061	−0.118*
	(0.148)	(0.173)	(0.071)	(0.058)
Observations	7872	9680	42,165	89,548
Adjusted R-squared	0.9462	0.9483	0.9176	0.9111
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 fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes

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 Appendix Table B1. The parameter estimates and standard errors for the control variables are omitted due to space limitations

Full Results of the Main Estimations

See Tables 10, 11, 12, 13 and 14.

Table 10 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				
Number of rooms	0.015***	0.010*	0.043***	0.045***
	(0.004)	(0.004)	(0.004)	(0.004)
ln(Sq. meters)	1.02***	1.01***	0.608***	0.608***
	(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)
Number of floors in the building	−0.003*	0.0001	0.003***	0.006***
	(0.001)	(0.001)	(0.0009)	(0.0007)
Floor where located	0.012***	0.010***	0.011***	0.011***
	(0.001)	(0.0010)	(0.0007)	(0.0006)
Neighborhood characteristics				
Population (per 1000)	0.010	0.006	−0.002	−0.002
	(0.024)	(0.026)	(0.010)	(0.008)
Number of households (per 1000)	−0.018	−0.019	0.004	−0.0002
	(0.040)	(0.043)	(0.017)	(0.013)
% of population under 19	−2.31*	−3.93**	−0.986	−1.30***
	(1.13)	(1.20)	(0.516)	(0.385)
% of population over 65	0.355	−0.677	−0.296	−0.442
	(0.703)	(0.626)	(0.242)	(0.240)
ln(Number of properties for sale)	0.016	−0.011	0.011	0.017
	(0.038)	(0.041)	(0.018)	(0.014)
ln(Avg. property price)	0.003	0.267***	0.008	0.029
	(0.075)	(0.074)	(0.039)	(0.030)
Avg. Number of floors in for-sale properties	−0.029	−0.059*	0.006	0.006
	(0.023)	(0.025)	(0.010)	(0.009)
ln(Number of properties for rent)	0.020	0.063*	−0.011	−0.005
	(0.026)	(0.026)	(0.009)	(0.008)
ln(Avg. property rent)	0.093*	0.102*	0.017*	0.008
	(0.043)	(0.044)	(0.008)	(0.005)
Avg. Number of floors in for-rent properties	0.013	0.024*	−0.0006	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	−0.004	−0.003
	(0.007)	(0.008)	(0.003)	(0.002)
ln(Distance to police)	0.007	0.011	−0.0002	−0.0003
	(0.007)	(0.008)	(0.003)	(0.002)
ln(Distance to a fire station)	−0.012	−0.013	−0.001	0.004
	(0.009)	(0.011)	(0.005)	(0.003)

Table 10 (continued)

	Properties for sale		Properties for rent	
	2008	2013	2008	2013
	(1)	(2)	(3)	(4)
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	0.0002
	(0.005)	(0.006)	(0.002)	(0.002)
ln(Distance to a museum or gallery)	−0.015	−0.021	−0.010	−0.002
	(0.015)	(0.016)	(0.007)	(0.006)
ln(Distance to a library)	−0.0008	−0.007	0.002	0.002
	(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	0.004
	(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)	(0.007)
ln(Distance to a city hall)	0.022	−0.003	−0.007	−0.003
	(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	0.0003	0.005*
	(0.005)	(0.005)	(0.003)	(0.002)
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	−0.129
	(0.183)	(0.181)	(0.088)	(0.076)
Ln(Distance to the Tama River)	−0.100	0.012	0.003	−0.006
	(0.058)	(0.066)	(0.029)	(0.021)
% Surrounding greenness				
Farm or vacant land (0–100 m)	0.170	0.342	0.182	−0.075
	(0.202)	(0.312)	(0.142)	(0.074)
Farm or vacant land (100–200 m)	0.441	0.184	−0.356*	0.185
	(0.252)	(0.268)	(0.154)	(0.121)
Farm or vacant land (200–300 m)	−0.148	−0.098	0.209	0.181
	(0.389)	(0.448)	(0.203)	(0.175)
Farm or vacant land (300–400 m)	−0.333	−0.618	−0.108	−0.126
	(0.321)	(0.545)	(0.150)	(0.182)
Farm or vacant land (400–500 m)	0.702	0.341	−0.293	0.073
	(0.385)	(0.637)	(0.180)	(0.207)
Waterfront (0–100 m)	0.114	−0.329	0.550*	0.054
	(0.224)	(0.303)	(0.219)	(0.123)

Table 10 (continued)

	Properties for sale		Properties for rent	
	2008	2013	2008	2013
	(1)	(2)	(3)	(4)
Waterfront (100–200 m)	−0.309	0.188	−0.212	0.066
	(0.267)	(0.292)	(0.136)	(0.136)
Waterfront (200–300 m)	−0.327	0.073	0.242	−0.043
	(0.208)	(0.221)	(0.210)	(0.109)
Waterfront (300–400 m)	0.057	−0.697***	−0.311	−0.107
	(0.206)	(0.162)	(0.231)	(0.163)
Waterfront (400–500 m)	0.020	0.384	0.629	0.231
	(0.296)	(0.255)	(0.351)	(0.294)
Park or public space (0–100 m)	−0.056	−0.112	0.009	−0.016
	(0.137)	(0.148)	(0.062)	(0.050)
Park or public space (100–200 m)	−0.028	0.094	0.081	0.080
	(0.140)	(0.160)	(0.084)	(0.058)
Park or public space (200–300 m)	−0.007	−0.324	−0.087	−0.084
	(0.184)	(0.214)	(0.088)	(0.069)
Park or public space (300–400 m)	−0.088	−0.105	0.001	−0.006
	(0.190)	(0.235)	(0.086)	(0.078)
Park or public space (400–500 m)	0.167	−0.137	−0.035	−0.060
	(0.206)	(0.240)	(0.082)	(0.063)
Scattered greenery (0–100 m)	0.251***	0.204**	0.055*	0.019
	(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)	(0.042)
Scattered greenery (200–300 m)	−0.096	−0.159	0.036	0.043
	(0.116)	(0.140)	(0.056)	(0.046)
Scattered greenery (300–400 m)	−0.270*	−0.189	−0.055	0.037
	(0.136)	(0.156)	(0.060)	(0.055)
Scattered greenery (400–500 m)	−0.085	−0.324	−0.024	−0.100
	(0.152)	(0.178)	(0.080)	(0.064)
Layout, structure, and zoning dummies	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	7872	9680	42,165	89,548
Adjusted R − squared	0.9466	0.9485	0.9177	0.9111

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 11 Robustness checks

	Alternative green space measures		Trimmed samples				Control street – level trends	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)	(8)
Panel A: Sales (2008)								
Scattered greenery (0–100 m)	0.023**	0.041***	0.218***	0.210***	0.288*	0.233***	0.225***	0.287**
	(0.007)	(0.009)	(0.058)	(0.062)	(0.128)	(0.058)	(0.063)	(0.099)
Scattered greenery (100–200 m)	−0.009	−0.023*	−0.088	−0.106	−0.234	−0.143	−0.147	−0.232
	(0.014)	(0.010)	(0.088)	(0.097)	(0.211)	(0.097)	(0.103)	(0.148)
Scattered greenery (200–300 m)	−0.012	0.011	−0.065	−0.089	0.419	−0.093	−0.072	0.451*
	(0.017)	(0.010)	(0.116)	(0.123)	(0.300)	(0.122)	(0.121)	(0.217)
Scattered greenery (300–400 m)	−0.057**	−0.006	−0.286*	−0.224	−0.772*	−0.245	−0.359*	−0.748**
	(0.022)	(0.011)	(0.137)	(0.148)	(0.301)	(0.142)	(0.145)	(0.245)
Scattered greenery (400–500 m)	0.002	−0.004	−0.127	−0.123	0.024	−0.044	−0.007	0.103
	(0.025)	(0.010)	(0.150)	(0.157)	(0.305)	(0.152)	(0.169)	(0.269)
Observations	7872	7872	7084	6245	1473	5898	7872	1128
Adjusted R – squared	0.9465	0.9466	0.9305	0.9495	0.9637	0.9457	0.9589	
Panel B: Sales (2013)								
Scattered greenery (0–100 m)	0.014	0.024**	0.151*	0.175*	0.203	0.220**	0.197*	0.231*
	(0.008)	(0.008)	(0.077)	(0.078)	(0.124)	(0.078)	(0.076)	(0.104)
Scattered greenery (100–200 m)	−0.009	0.0005	−0.059	−0.035	0.139	−0.075	−0.083	−0.008
	(0.015)	(0.010)	(0.120)	(0.125)	(0.189)	(0.114)	(0.121)	(0.167)
Scattered greenery (200–300 m)	−0.022	−0.001	−0.220	−0.198	0.067	−0.098	−0.132	0.123
	(0.019)	(0.010)	(0.139)	(0.144)	(0.223)	(0.142)	(0.145)	(0.210)
Scattered greenery (300–400 m)	−0.040	0.007	−0.136	−0.109	−0.013	−0.064	−0.138	−0.048
	(0.023)	(0.010)	(0.147)	(0.152)	(0.264)	(0.153)	(0.161)	(0.241)

Table 11 (continued)

	Alternative green space measures		Trimmed samples				Control street – level trends	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)	(8)
Scattered greenery (400–500 m)	−0.047	−0.014	−0.345*	−0.336	−0.408	−0.341	−0.342	0.411
	(0.026)	(0.009)	(0.171)	(0.190)	(0.325)	(0.180)	(0.179)	(0.273)
Observations	9680	9680	8712	7601	2146	6999	9680	1529
Adjusted R-squared	0.9484	0.9484	0.9306	0.9516	0.9629	0.9453	0.9595	
Panel C: Rentals (2008)								
Scattered greenery (0–100 m)	0.009**	0.0004	0.024	0.055*	0.042	0.078***	0.052*	0.079*
	(0.003)	(0.004)	(0.020)	(0.028)	(0.052)	(0.022)	(0.026)	(0.039)
Scattered greenery (100–200 m)	0.002	0.0007	−0.013	0.026	−0.018	0.026	0.021	−0.050
	(0.006)	(0.004)	(0.033)	(0.043)	(0.077)	(0.036)	(0.040)	(0.063)
Scattered greenery (200–300 m)	0.006	0.006	−0.014	0.046	0.082	0.043	0.025	0.053
	(0.009)	(0.005)	(0.042)	(0.056)	(0.103)	(0.041)	(0.053)	(0.082)
Scattered greenery (300–400 m)	−0.008	−0.004	−0.0008	−0.078	−0.121	−0.021	−0.040	−0.119
	(0.009)	(0.005)	(0.048)	(0.059)	(0.111)	(0.050)	(0.059)	(0.092)
Scattered greenery (400–500 m)	−0.006	−0.001	−0.010	−0.028	−0.035	0.042	−0.028	0.006
	(0.013)	(0.006)	(0.053)	(0.082)	(0.150)	(0.053)	(0.074)	(0.103)
Observations	42,161	42,161	38,030	40,240	6,814	24,278	42,165	3961
Adjusted R-squared	0.9177	0.9176	0.9006	0.9158	0.9244	0.9115	0.9250	
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.003	0.001	−0.016	0.022	0.069*	0.042*	0.022	0.066*
	(0.003)	(0.003)	(0.023)	(0.025)	(0.035)	(0.020)	(0.024)	(0.030)
Scattered greenery (100–200 m)	0.002	0.0003	−0.037	−0.012	0.072	0.004	0.010	0.034
	(0.005)	(0.003)	(0.038)	(0.041)	(0.064)	(0.031)	(0.041)	(0.048)

Table 11 (continued)

	Alternative green space measures		Trimmed samples				Control street – level trends	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)	(8)
Scattered greenery (200–300 m)	0.006	0.003	0.037	0.049	0.063	0.031	0.035	0.048
	(0.006)	(0.003)	(0.042)	(0.046)	(0.069)	(0.039)	(0.045)	(0.059)
Scattered greenery (300–400 m)	0.006	0.005	−0.006	0.025	−0.085	0.004	0.048	−0.119
	(0.007)	(0.003)	(0.051)	(0.056)	(0.089)	(0.046)	(0.054)	(0.070)
Scattered greenery (400–500 m)	−0.013	−0.001	−0.118*	−0.111	−0.015	−0.045	−0.105	−0.045
	(0.008)	(0.003)	(0.056)	(0.067)	(0.096)	(0.053)	(0.064)	(0.079)
Observations	89,547	89,547	81,159	85,653	18,243	44,975	89,548	9107
Adjusted R-squared	0.9111	0.9111	0.8893	0.9087	0.9122	0.9087	0.9155	
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 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Month fixed effects	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Street × Year fixed effects	No	No	No	No	No	No	Yes	No

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 Appendix Table B1. The parameter estimates and standard errors for the control variables, which are omitted due to space limitations, are consistent with the main results

Table 12 Alternative definitions of scattered greenery

	Classification by land use		Classification by digital map		Division by location of greenery	
	Remove large polygons	Remove boundary area	Identifying by visual inspection	Visual inspection without large polygons	Along roads	Around buildings
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Sale (2008)						
Scattered greenery (0–100 m)	0.195**	0.230***	0.214***	0.171**	0.267**	0.303**
	(0.064)	(0.061)	(0.059)	(0.062)	(0.096)	(0.107)
Scattered greenery (100–200 m)	−0.016	−0.143	−0.174	−0.057	−0.288	−0.161
	(0.121)	(0.098)	(0.095)	(0.115)	(0.166)	(0.177)
Scattered greenery (200–300 m)	0.075	−0.052	−0.110	0.099	−0.160	0.038
	(0.124)	(0.117)	(0.117)	(0.125)	(0.191)	(0.199)
Scattered greenery (300–400 m)	−0.262	−0.278	−0.178	−0.267	−0.358	−0.491
	(0.159)	(0.143)	(0.133)	(0.156)	(0.198)	(0.257)
Scattered greenery (400–500 m)	0.062	−0.108	0.002	0.050	−0.147	0.104
	(0.179)	(0.156)	(0.142)	(0.173)	(0.232)	(0.279)
Observations	7872	7612	7872	7872	7872	7872
Adjusted R-squared	0.9464	0.9471	0.9465	0.9464	0.9587	0.9587
Panel B: Sale (2013)						
Scattered greenery (0–100 m)	0.182*	0.225**	0.162*	0.186*	0.244*	0.301*
	(0.076)	(0.078)	(0.075)	(0.077)	(0.112)	(0.135)
Scattered greenery (100–200 m)	−0.087	−0.071	−0.030	−0.040	−0.085	−0.177
	(0.125)	(0.121)	(0.105)	(0.118)	(0.167)	(0.211)
Scattered greenery (200–300 m)	−0.164	−0.160	−0.288*	−0.166	−0.250	0.221
	(0.155)	(0.146)	(0.135)	(0.166)	(0.186)	(0.256)
Scattered greenery (300–400 m)	−0.456*	−0.238	−0.198	−0.323	0.096	−0.689*
	(0.179)	(0.161)	(0.159)	(0.178)	(0.210)	(0.325)

Table 12 (continued)

	Classification by land use		Classification by digital map		Division by location of greenery	
	Remove large polygons	Remove boundary area	Identifying by visual inspection	Visual inspection without large polygons	Along roads	Around buildings
	(1)	(2)	(3)	(4)	(5)	(6)
Scattered greenery (400–500 m)	−0.342	−0.370*	−0.162	−0.227	−0.349	−0.253
	(0.210)	(0.183)	(0.176)	(0.214)	(0.270)	(0.331)
Observations	9680	9409	9680	9680	9680	9680
Adjusted R-squared	0.9485	0.9486	0.9485	0.9485	0.9595	0.9595
Panel C: Rent (2008)						
Scattered greenery (0–100 m)	0.067*	0.058*	0.061*	0.061	0.054	0.075
	(0.031)	(0.028)	(0.028)	(0.031)	(0.042)	(0.042)
Scattered greenery (100–200 m)	0.019	0.016	0.009	0.037	0.042	−0.005
	(0.050)	(0.044)	(0.045)	(0.055)	(0.063)	(0.061)
Scattered greenery (200–300 m)	0.073	0.045	0.016	0.060	0.010	0.067
	(0.072)	(0.058)	(0.056)	(0.067)	(0.077)	(0.085)
Scattered greenery (300–400 m)	−0.105	−0.073	−0.063	−0.103	−0.021	−0.072
	(0.070)	(0.060)	(0.061)	(0.070)	(0.084)	(0.092)
Scattered greenery (400–500 m)	0.002	−0.032	−0.050	0.014	−0.077	0.020
	(0.088)	(0.082)	(0.077)	(0.087)	(0.099)	(0.118)
Observations	42,165	41,308	42,165	42,165	42,165	42,161
Adjusted R-squared	0.9177	0.9174	0.9176	0.9176	0.9249	0.9249
Panel D: Rent (2013)						
Scattered greenery (0–100 m)	0.048	0.028	0.022	0.049*	0.015	0.061
	(0.026)	(0.025)	(0.023)	(0.024)	(0.036)	(0.040)
Scattered greenery (100–200 m)	0.045	−0.004	0.025	0.041	0.025	−0.047
	(0.047)	(0.043)	(0.037)	(0.043)	(0.059)	(0.064)

Table 12 (continued)

	Classification by land use		Classification by digital map		Division by location of greenery	
	Remove large polygons	Remove boundary area	Identifying by visual inspection	Visual inspection without large polygons	Along roads	Around buildings
	(1)	(2)	(3)	(4)	(5)	(6)
Scattered greenery (200–300 m)	0.079	0.023	0.049	0.082	−0.072	0.215**
	(0.054)	(0.048)	(0.043)	(0.051)	(0.064)	(0.079)
Scattered greenery (300–400 m)	0.024	0.041	0.033	0.054	0.072	0.028
	(0.069)	(0.055)	(0.054)	(0.066)	(0.079)	(0.096)
Scattered greenery (400–500 m)	−0.145	−0.112	−0.103	−0.102	−0.200*	−0.029
	(0.074)	(0.065)	(0.061)	(0.070)	(0.080)	(0.117)
Observations	89,547	87,705	89,547	89,547	89,547	89,547
Adjusted R-squared	0.9112	0.9110	0.9111	0.9112	0.9155	0.9155
Property characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Accessibility characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Measures of urban greenness	Yes	Yes	Yes	Yes	Yes	Yes
Street fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

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 Appendix Table B1. The parameter estimates and standard errors for the control variables are omitted due to space limitations

Table 13 Subsample analysis

	Housing prices or rents		Number 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	3936	3936	5828	2044	3936	3936	3936	3936
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)

Table 13 (continued)

	Housing prices or rents		Number of rooms		Distance from highway		Distance from CBD	
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
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	4840	4840	6663	3017	4837	4843	4838	4842
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)	0.075	0.034	0.087	0.028	0.073*	0.040	0.055	0.032
	(0.042)	(0.025)	(0.053)	(0.026)	(0.033)	(0.042)	(0.036)	(0.043)
Scattered greenery (100–200 m)	0.043	−0.008	0.162	−0.032	0.007	0.024	0.049	0.005
	(0.069)	(0.038)	(0.087)	(0.040)	(0.052)	(0.067)	(0.055)	(0.064)
Scattered greenery (200–300 m)	0.041	0.083	0.128	−0.005	0.009	0.080	0.084	−0.075
	(0.083)	(0.049)	(0.103)	(0.050)	(0.066)	(0.087)	(0.072)	(0.082)
Scattered greenery (300–400 m)	−0.052	−0.014	−0.020	−0.032	0.077	−0.164*	−0.045	−0.020
	(0.090)	(0.062)	(0.125)	(0.056)	(0.079)	(0.082)	(0.084)	(0.091)
Scattered greenery (400–500 m)	0.0009	0.048	0.133	−0.053	0.0006	−0.092	0.091	−0.190
	(0.122)	(0.070)	(0.155)	(0.064)	(0.085)	(0.130)	(0.104)	(0.117)
Avg. %-age of greenery within 500 m	16.0%	16.5%	17.5%	15.8%	16.7%	15.7%	19.4%	13.1%
Observations	20,927	21,238	9,778	32,387	21,082	21,083	21,082	21,083
Adjusted R-squared	0.8985	0.6013	0.9214	0.8699	0.9120	0.9245	0.9223	0.9156
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.089**	0.005	0.118**	−0.015	0.022	0.029	0.038	−0.019
	(0.033)	(0.028)	(0.039)	(0.026)	(0.036)	(0.032)	(0.027)	(0.044)

Table 13 (continued)

	Housing prices or rents		Number of rooms		Distance from highway		Distance from CBD	
	High	Low	High	Low	High	Low	High	Low
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Scattered greenery (100–200 m)	−0.005	0.015	0.002	−0.001	−0.008	0.008	−0.019	0.015
	(0.061)	(0.040)	(0.065)	(0.046)	(0.057)	(0.057)	(0.046)	(0.074)
Scattered greenery (200–300 m)	0.011	0.039	0.015	0.037	0.073	−0.001	0.106*	−0.110
	(0.069)	(0.054)	(0.085)	(0.052)	(0.064)	(0.068)	(0.054)	(0.083)
Scattered greenery (300–400 m)	0.079	−0.001	0.140	0.013	0.232**	−0.184*	0.058	0.060
	(0.072)	(0.060)	(0.092)	(0.061)	(0.075)	(0.082)	(0.065)	(0.097)
Scattered greenery (400–500 m)	−0.162*	−0.113	−0.103	−0.064	−0.050	−0.223*	−0.049	−0.279*
	(0.080)	(0.065)	(0.104)	(0.069)	(0.089)	(0.096)	(0.081)	(0.112)
Avg. %-age of greenery within 500 m	13.2%	13.5%	14.2%	13.1%	13.9%	12.8%	15.5%	11.2%
Observations	43,831	45,717	19,341	70,207	44,773	44,775	44,774	44,774
Adjusted R – squared	0.8789	0.6497	0.9123	0.8740	0.9083	0.9156	0.9150	0.9081
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 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors clustered at the street level appear in parentheses. *, **, and *** indicate statistical significance at the 5%, 1%, and 0.1% levels, respectively. CBD stands for central business district. The independent variables are the same as those listed in Appendix Table B1. The parameter estimates and standard errors for the control variables are omitted due to space limitations

Table 14 Effects of scattered greenery on property quality and surrounding amenities

	Property quality				Surrounding amenity			
	Number of rooms	ln(Sq. metres)	ln(Age of property)	Number of floors in the building	Number of post offices	Number of cultural facilities	Number of station	Number of bus stop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sales (2008)								
Scattered greenery (0–100 m)	0.914***	0.707***	0.322	4.46**	−0.059	−0.104	0.201	−0.473
	(0.264)	(0.163)	(0.322)	(1.72)	(0.230)	(0.586)	(0.202)	(0.723)
Scattered greenery (100–200 m)	0.056	0.261	−1.11*	1.09	0.411	0.869	−0.006	−4.53***
	(0.399)	(0.251)	(0.492)	(1.78)	(0.432)	(0.964)	(0.424)	(1.29)
Scattered greenery (200–300 m)	0.476	0.094	−0.604	−1.15	−1.14*	1.14	−0.728	−1.07
	(0.499)	(0.313)	(0.607)	(2.54)	(0.537)	(1.54)	(0.457)	(1.65)
Scattered greenery (300–400 m)	0.639	0.187	−1.21	−6.19	0.649	−0.344	−1.33*	−4.85*
	(0.635)	(0.407)	(0.764)	(3.60)	(0.645)	(1.71)	(0.578)	(2.06)
Scattered greenery (400–500 m)	0.108	0.003	−1.46	−5.44	−1.74*	−0.284	−1.62**	−4.35*
	(0.735)	(0.448)	(0.837)	(3.39)	(0.711)	(1.84)	(0.614)	(2.19)
Observations	7,872	7,872	7,872	7,872	7,872	7,872	7,872	7,872
Adjusted R-squared	0.2794	0.3634	0.3300	0.6293	0.6793	0.8479	0.7899	0.8383
Panel B: Sales (2013)								
Scattered greenery (0–100 m)	1.34***	0.935***	0.256	4.29*	−0.365	−1.49	0.024	−0.965
	(0.310)	(0.196)	(0.352)	(1.87)	(0.281)	(0.777)	(0.233)	(0.919)
Scattered greenery (100–200 m)	−0.109	−0.153	−0.254	3.82	0.117	1.19	0.182	−5.54***
	(0.481)	(0.305)	(0.494)	(2.12)	(0.482)	(1.21)	(0.458)	(1.58)
Scattered greenery (200–300 m)	1.08	0.092	−0.057	−1.01	−0.568	3.66*	−0.486	−5.14*
	(0.629)	(0.395)	(0.758)	(3.05)	(0.660)	(1.69)	(0.515)	(2.38)
Scattered greenery (300–400 m)	−0.213	−0.687	−1.15	−5.00	1.11	1.76	−2.05*	−6.69*
	(0.699)	(0.485)	(0.831)	(3.92)	(0.744)	(1.87)	(0.823)	(2.65)
Scattered greenery (400–500 m)	0.310	−0.698	1.97*	4.43	−0.966	0.862	−1.78**	−4.29
	(0.792)	(0.536)	(0.940)	(5.67)	(0.820)	(2.48)	(0.636)	(2.97)

Table 14 (continued)

	Property quality				Surrounding amenity			
	Number of rooms	ln(Sq. metres)	ln(Age of property)	Number of floors in the building	Number of post offices	Number of cultural facilities	Number of station	Number of bus stop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observations	9,680	9,680	9,680	9,680	9,680	9,680	9,680	9,680
Adjusted R-squared	0.3156	0.3840	0.3110	0.6562	0.6832	0.8301	0.7824	0.8197
Panel C: Rentals (2008)								
Scattered greenery (0–100 m)	0.327*	0.415***	0.392	0.529	0.437*	0.025	0.200	0.155
	(0.137)	(0.112)	(0.260)	(0.601)	(0.194)	(0.454)	(0.161)	(0.607)
Scattered greenery (100–200 m)	0.031	0.080	−0.318	0.951	−0.261	0.395	−0.175	−2.11*
	(0.200)	(0.172)	(0.389)	(0.917)	(0.301)	(0.729)	(0.309)	(0.926)
Scattered greenery (200–300 m)	0.078	−0.056	0.625	−1.30	−1.27**	0.504	−0.999*	−2.92*
	(0.245)	(0.198)	(0.455)	(1.24)	(0.430)	(0.906)	(0.415)	(1.45)
Scattered greenery (300–400 m)	−0.328	0.047	−0.634	−1.09	−0.838	−1.11	−1.39**	−5.81***
	(0.310)	(0.257)	(0.599)	(1.54)	(0.485)	(1.28)	(0.424)	(1.58)
Scattered greenery (400–500 m)	0.758*	0.078	0.562	−1.65	−1.19*	−1.65	−0.591	−3.71*
	(0.373)	(0.334)	(0.596)	(1.35)	(0.501)	(1.54)	(0.481)	(1.82)
Observations	42,165	42,165	42,165	42,165	42,224	42,224	42,224	42,161
Adjusted R-squared	0.1254	0.1687	0.1301	0.4951	0.5889	0.8171	0.7277	0.8124
Panel D: Rentals (2013)								
Scattered greenery (0–100 m)	0.582***	0.496***	0.132	−0.319	0.234	−0.011	−0.046	−0.043
	(0.143)	(0.109)	(0.236)	(0.603)	(0.215)	(0.421)	(0.173)	(0.582)
Scattered greenery (100–200 m)	−0.124	0.084	−0.093	0.261	−0.594	0.866	−0.350	−3.71***
	(0.200)	(0.173)	(0.348)	(0.953)	(0.362)	(0.757)	(0.344)	(1.07)
Scattered greenery (200–300 m)	−0.082	0.008	0.111	0.437	−0.979	2.10	−1.24**	−4.10*
	(0.246)	(0.215)	(0.444)	(1.23)	(0.531)	(1.16)	(0.443)	(1.70)

Table 14 (continued)

	Property quality				Surrounding amenity			
	Number of rooms	ln(Sq. metres)	ln(Age of property)	Number of floors in the building	Number of post offices	Number of cultural facilities	Number of station	Number of bus stop
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Scattered greenery (300–400 m)	−0.465	−0.167	0.309	−0.156	−1.09*	−0.076	−1.61**	−7.15***
	(0.279)	(0.245)	(0.487)	(1.55)	(0.545)	(1.37)	(0.516)	(1.66)
Scattered greenery (400–500 m)	0.486	0.457	−0.797	−2.91	−1.28*	0.550	−1.33*	−6.18**
	(0.324)	(0.310)	(0.593)	(1.83)	(0.604)	(1.82)	(0.552)	(1.99)
Observations	89,548	89,548	89,548	89,548	89,863	89,863	89,863	89,548
Adjusted R – squared	0.1104	0.1415	0.0756	0.4599	0.5909	0.8037	0.7308	0.8260
Property characteristics	No	No	No	No	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 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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 Appendix Table 10 except for the property characteristics. The parameter estimates and standard errors for the control variables are omitted due to space limitations

Comparison of Sales and Rental Properties

See Tables 15, 16, 17 and 18.

Table 15 Estimated results using rental properties near sales properties

	Baseline results		Closest rental properties to sales properties		Within 100 m of the nearest sales properties		Identical buildings to the sales properties	
	2008	2013	2008	2013	2008	2013	2008	2013
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% Surrounding greenness								
Scattered greenery (0–100 m)	0.055*	0.019	0.082*	0.040	0.005	0.022	0.132	0.039
	(0.027)	(0.024)	(0.042)	(0.046)	(0.043)	(0.048)	(0.087)	(0.054)
Scattered greenery (100–200 m)	0.019	−0.005	0.016	0.051	0.043	−0.0002	0.026	0.108
	(0.043)	(0.042)	(0.061)	(0.074)	(0.066)	(0.072)	(0.130)	(0.114)
Scattered greenery (200–300 m)	0.036	0.043	0.047	0.032	−0.033	0.091	0.194	0.197
	(0.056)	(0.046)	(0.094)	(0.104)	(0.110)	(0.103)	(0.152)	(0.126)
Scattered greenery (300–400 m)	−0.055	0.037	−0.034	−0.047	−0.069	−0.054	0.063	−0.023
	(0.060)	(0.055)	(0.095)	(0.096)	(0.101)	(0.103)	(0.187)	(0.145)
Scattered greenery (400–500 m)	−0.024	−0.100	0.123	−0.098	0.124	−0.045	0.097	−0.040
	(0.080)	(0.064)	(0.101)	(0.117)	(0.115)	(0.116)	(0.206)	(0.167)
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 fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,165	89,548	7872	9680	6427	8687	2990	9458
Adjusted R-squared	0.9177	0.9111	0.9449	0.9364	0.9464	0.9378	0.9630	0.9480

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 Appendix Table 10, and the parameter estimates and standard errors for the control variables are omitted due to space limitations. The baseline results in columns (1) and (2) are restated from the estimates in Table 1 for reference

Table 16 Number of households by household type and income (Setagaya and Suginami, 2013)

	Owned houses				Rented houses			
	Family	Single	Total		Family	Single	Total	
Household income (10,000 JPY)								
0–300	22,030	31,310	56,450	18.60%	23,200	101,380	127,510	34.30%
300–500	41,210	18,260	63,000	20.76%	30,720	72,630	106,930	28.76%
500–700	31,390	10,100	43,120	14.21%	21,040	25,140	48,240	12.98%
700–1,000	40,810	8480	50,990	16.80%	17,890	10,400	29,420	7.91%
1000–1500	37,580	3920	42,480	14.00%	9870	3110	13,470	3.62%
1500 or more	22,890	1650	25,470	8.39%	4070	980	5,320	1.43%
Unknown	1040	9210	21,950	7.23%	440	28,390	40,910	11.00%
Total	196,930	82,930	3,03,460		107,200	242,040	3,71,780	

Created using data from the 2013 Housing and Land Survey (Statistics Bureau, Ministry of Internal Affairs and Communications). The sum of the number of households in each category may not equal the total number because some households live in nonmarket housing, such as public housing or company housing. Households include family and single as well as unrelated individuals living together, but the percentages are small and therefore omitted

Table 17 Number of households by head count (Setagaya and Suginami, 2013)

	Owned houses		Rented houses	
	Number of households	Ratio	Number of households	Ratio
Number of household members				
1	82,930	27.33%	2,42,040	65.10%
2	96,210	31.70%	72,460	19.49%
3	63,150	20.81%	33,730	9.07%
4	45,700	15.06%	18,910	5.09%
5	11,150	3.67%	3,690	0.99%
6	3040	1.00%	720	0.19%
7 or more	1280	0.42%	230	0.06%
Total	3,03,460		3,71,780	

Created using data from the 2013 Housing and Land Survey (Statistics Bureau, Ministry of Internal Affairs and Communications). The sum of the number of households in each category may not equal the total number because some households live in nonmarket housing, such as public housing or company housing

Table 18 Number of households by years living in the current house (within 10 km of CBD)

	Owned houses		Rented houses	
	Number of households	Ratio	Number of households	Ratio
Years of residence				
0–2 years	47,300	8.23%	2,01,200	40.41%
3–7 years	93,600	16.30%	1,45,400	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	1,04,600	18.21%	8,100	1.63%
Total	5,74,400		4,97,900	

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 Ward, Tokyo. The sum of the number of households in each category may not equal the total number because some households live in nonmarket housing, such as public housing or company housing

Our findings indicate that sales and rental properties are heterogeneously affected by scattered greenery. This appendix provides some analysis and discussion of the causes. First, the locations of the sales and rental properties could be different. Rental properties tend to be located near commercial areas because they are preferred by single people and students, who are more likely to move within short periods. In contrast, sales properties tend to be in quiet residential areas because they are more likely to be owned by family households that remain in place for a long time. To address this concern, we created a subsample of the closest rental apartments to each of the sales apartments in our data. If the closest rental property overlapped, the second, third, and so on were matched, and all properties were matched on a one-to-one correspondence. If location is an important cause, then rental properties that are similar in environment to sales properties could be significantly affected by scattered greenery.

Columns (3) and (4) of Appendix Table 15 present the estimation results using a subsample of rental properties in a similar environment to the sales properties, and the results are almost the same as the main results. To focus on rental properties that are more similar in the surrounding environment to the sales property, we also conducted an analysis using only rental properties within 100 m of the corresponding sales property. The results are shown in columns (5) and (6) and indicate that the rental properties are not significantly affected by scattered greenery. Additionally, we estimated using rental properties included in buildings where rooms have been marketed as sales properties. Columns (7) and (8) present the results, showing that even if the surrounding environment is the same as that of a sales property, rental property is not affected by scattered greenery. The results indicate that location does not explain the heterogeneous responses between sales and rentals. Additionally, since rooms in the same building respond differently to sales and rentals, it is unlikely that the difference between sales and rentals is caused by the surrounding environment or interior design. The results in Appendix Table 15 also indicate that the amount of scattered greenery and the quality of housing are associated with both sales and rental properties. Therefore, the heterogeneous response of sales and rental properties could be due to the characteristics of the residents.

Residents of sales and rental properties differ greatly in income, age, number of family members, and other characteristics, resulting in marked variations in the number of years lived on the properties. Unfortunately, our property data do not provide information on resident characteristics. As an alternative, we attempt to explain the causes of the difference in response between sales and rental properties based on the average resident demographics of the study area and the findings of previous studies. Some previous studies focused on the heterogeneity of residential environment preferences.

According to Hoshino (2011), who conducted a survey of Tokyo residents, accessibility to commercial areas is preferred, on average, but 30% of respondents did not want to live in commercial areas, suggesting strong heterogeneity in residential location preferences. People's preferences are heterogeneous by socioeconomic characteristics, with people from higher socioeconomic backgrounds tending to have a higher willingness to pay for urban green spaces (Schindler et al. 2018) and preservation of greenery (Tian et al 2020). Łaszkiewicz et al. (2019) also suggested that green space is a luxury good and that individuals with higher incomes are likely to be more environmentally oriented. In our study area, residents of sales properties have higher incomes, on average, than residents of rental properties. Appendix Table 16 shows that the ratio of households with more than 5 million JPY income is approximately 60% for sales properties but approximately 37% for rental properties. Therefore, the income of residents could be the source of heterogeneity in their response to scattered greenery.

The composition of households in sales and rental properties differs considerably. In Japan, couples and families with children tend to live in sales properties, while singles and university students tend to live in rental properties. Appendix Table 16 shows that in the study area, approximately 65% of family households live in sales properties, in contrast to approximately 25% of singles who live in sales properties. Additionally, approximately 40% of households living in sales properties have three or more members, while only approximately 15% of households living in rental properties have three or more persons (Appendix Table 17). Hammitt and Haninger (2017) indicate that the willingness to pay to reduce the risk of others in the household is significantly greater than the willingness to pay to reduce one's own risk. It has also been suggested that elderly people and children, who are physically weaker and more concerned about health risks, tend to value greenery that improves air quality (Cameron et al. 2010; Liu, Hanley, and Cambpell, 2020). Therefore, the family structure of the residents could also be a factor explaining the heterogeneity of responses to scattered greenery. The results of the subsample analysis, which showed that even for sales properties, single rooms are not affected by scattered greenery, suggest that not being a single person could be an important cause of the difference. The finding that only property buyers, not renters, appreciate scattered greenery near highways is also consistent with the fact that elderly people and children, who are more concerned about health risks, tend to live in sales properties.

There are several reasons for such differences in resident characteristics between sales and rentals, but the mortgage tax break could be one reason. In Japan, if one purchases a house with a loan, 0.7% of the outstanding loan balance each year is deducted from income tax for up to 13 years. Therefore, it is more beneficial to buy a residence than to rent one if one lives in the same location for many years. In contrast, if one is likely to move within several years or does not have sufficient income to qualify for a loan, one chooses to live in a rental property.[16] Therefore, families with children and elderly people who do not frequently relocate tend to live on sales properties; conversely, students or singles tend to live on rental properties.

Appendix Table 18 shows the number of households within 10 km 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 approximately 35% have lived in their current home for more than 28 years. In contrast, approximately 40% of households living in rental properties have lived in their current homes for less than 2 years, and approximately 80% have lived in their current homes for less than 12 years.[17] While residents of rental properties can easily move out if they encounter undesirable surroundings, this is not the case for sales properties. Thus, residents of sales properties are likely to value the surrounding environment more. Additionally, the surrounding environment, such as good air quality and beautiful landscapes, affects people's physical and mental health over time. Therefore, the expected years of residence could lead to heterogeneity in the valuation of the surrounding environment.

We note that the explanations given above are only suggestive evidence. These factors, such as socioeconomic background, income, number of household members, and years of residence, are correlated with each other. For example, people from higher socioeconomic backgrounds may have higher annual incomes and be therefore more likely to marry and have children, resulting in longer residence in larger homes. It is also important to note that the difference in response between sales and rental properties does not necessarily indicate people's potential preferences. Because the hedonic pricing approach focuses on the value realized in the market, it cannot identify whether residents are not interested in scattered greenery or do not have the ability to pay or whether homes with the combination of desired characteristics do not exist in the market (Sander and Zhao 2015). Therefore, the mechanisms behind the heterogeneity of sales and rental properties need to be analyzed using more detailed data and precise methodologies.

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[16] Those who are concerned about risks, such as problems with neighbors or damage from disasters, could live in rental properties that are easy to move out of.

[17] The singles who most commonly live in rental properties in urban areas in Japan are university students. In Japan, universities are concentrated in large cities; thus, many university students leave their hometowns to live alone. Therefore, many students reside near the university only for four years while completing their studies and move out when they graduate.

Data Availability 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.

Declarations

Conflict of 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.

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