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Examining the change of Green View Index (GVI) at street-level with GSV and YSV

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Keywords

Street-level, Urban greenery, Green View Index

Abstract

Street-level green areas play a critical role in the visual quality of urban landscapes. Information on these changing live landscape elements can be obtained from street-level images of web-based tools and evaluated in terms of visual impact quality. This assessment can include information on street-level green areas in urban landscape planning and management. This study used street-level images of Google Street View and Yandex Street View to evaluate urban green. Advantageously, GSV and YSV are tools that can provide street-level profile views of urban green. Using this advantage, the Green View Index (GVI) was calculated for selected streets in Kadıköy district of Istanbul, and the change in greenness in the street texture between 2011-2020/2023 was evaluated. It was determined that the green area in the street texture affected by urban transformation decreased, and it was seen that the greenness at the street level can be measured and evaluated through web-based tools.

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Highlights

- Google Street View and Yandex Street View were used for the assessment of street-level urban greenery.
- The Green View Index was calculated to compare the change in urban greenery at street-level.
- Google Street View and Yandex Street View have great potential for future urban planning and design.

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Sokak seviyesindeki Yeşil Görünürlük İndeksinin (GVI) GSV ve YSV ile değişiminin incelenmesi

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Anahtar Sözcükler

Sokak seviyesi, Kentsel yeşil, Yeşil Görünürlük İndeksi

Öz

Sokak seviyesindeki yeşil alanlar, kentsel peyzajların görsel kalitesinde kritik bir rol oynamaktadır. Bu değişen canlı peyzaj elemanlarına ilişkin bilgiler, web tabanlı araçların sokak seviyesindeki görüntülerinden elde edilebilmekte ve görsel etki kalitesi açısından değerlendirilebilmektedir. Bu değerlendirme, kentsel peyzaj planlama ve yönetiminde sokak seviyesi yeşil alan bilgilerine dahil edilebilmektedir. Bu çalışmada, kentsel yeşili değerlendirmek için Google Sokak Görünümü (GSV) ve Yandex Sokak Görünümü'nün (YSV) sokak seviyesi görüntüleri kullanılmıştır. GSV ve YSV'nin kentsel yeşilin sokak seviyesi profil görünümlerini sağlayabilen araçlar olması avantajlıdır. Bu avantaj kullanılarak, çalışmada İstanbul'un Kadıköy ilçesinden seçilen sokaklar için Yeşil Görünüm Endeksi (GVI) hesaplanmış ve 2011-2020/2023 yılları arasında sokak dokusundaki yeşilin değişimi değerlendirilmiştir. Kentsel dönüşümden etkilenen sokak dokusundaki yeşil alanın azaldığı tespit edilmiştir ve sokak düzeyindeki yeşilliğin web tabanlı araçlar aracılığıyla ölçülüp değerlendirilebileceği görülmüştür.

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Öne Çıkanlar

- Sokak düzeyindeki kentsel yeşilliğin değerlendirilmesinde Google Street View ve Yandex Street View kullanıldı.
- Yeşil Görünüm İndeksi, sokak düzeyinde kentsel yeşil alandaki değişimi karşılaştırmak için hesaplandı.
- Google Street View ve Yandex Street View, gelecekteki kentsel planlama ve tasarım açısından büyük bir potansiyele sahiptir.

İletişim

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INTRODUCTION

Urban green areas represent where many plant materials, such as parks, gardens, street trees, tree-lined avenues, shrubs, and grass areas, are essential landscape elements within the city (Cüce & Ortaçeşme, 2020; Gercek & Talih Guven, 2017). These areas offer many benefits the natural environment provides to the citizens and add aesthetic value (H. W. Schroeder & Cannon, 1983). While it provides environmental benefits such as improving air quality, reducing the urban heat island effect, maintaining temperature balance, supporting biological diversity, regulating the water cycle, and reducing noise pollution, it also provides social benefits such as reducing stress, creating a positive impact on a person's mental health, and providing people with opportunities for recreation and relaxation. It has benefits such as providing areas for people to use (Bowler et al., 2010; Bratman et al., 2012; Camacho-Cervantes et al., 2014; Daniels et al., 2018; Wang et al., 2019). Many findings show that people's exposure to outdoor greenery near their homes is intertwined with and essential to their mental and physical health and well-being (Ulrich, 1984; Van Den Bosch & Meyer-Lindenberg, 2019; Wang et al., 2019). From a social perspective, these areas also provide recreational functions for city residents through meeting points and rest (Gül et al., 2009; Kweon et al., 1998; Peters et al., 2010). One of the urban landscapes designed on a micro-scale that interacts directly with the user is urban green areas at the street level. Designing streets and avenues with their green parameters in mind as important public spaces where urban residents leave their homes and mix with the city and public life significantly contributes to the attractiveness and walkability of streets and avenues (H. Schroeder & Cannon, 1983; Valipoor & Dehkordi, 2016). The presence of vegetation as a soft landscape element, along with various elements such as form, size, texture, color, and line, generally increases people's aesthetic score toward urban landscapes (Camacho-Cervantes et al., 2014; Gül et al., 2009). "Green" areas, which also appeal to senses such as seeing, hearing, touching, and smelling, are critical in providing health and making people feel good (Sakıcı et al., 2013). People have positive feelings when exposed to the natural environment(Ulrich, 1981, 1984; Ulrich et al., 1991).

However, despite all the importance of green areas, modern urbanization strategies in urban areas give them little importance, and most of the time, the area they cover is limited or not at all (Camacho-Cervantes et al., 2014; Ezcurra, 1991). Although legislation and regulations take the amount of green space per capita as a reference to measure the existence of these areas, it is challenging to detect the urban landscape at the human eye level and green areas at the street level, especially individual trees and plantings, and to monitor and track the change. In addition, survey and oral interview methods are the most used to measure people's opinions, attitudes, and perceptions regarding street-level profile views of urban greenery (Aksu & Yılmaz, 2018; Koramaz & Türkoğlu, 2014; Özden & Uysal, 2023). The survey method often raises concerns about response bias and assessing subjective judgments (Gupta et al., 2012; Sugiyama et al., 2008). Since measuring this area from the user's perspective is complex and laborious, evaluating the green area at the street level objectively can give a more accurate and precise result (Li et al., 2015; Yao et al., 2012a).

Different studies offer different methods for objective measurement. Remote sensing is one of the most widely used objective methods to measure urban green spaces (Biljecki & Ito, 2021; Gupta et al., 2012). With remote sensing, data is collected from satellite or aerial photographs, and green areas and vegetation can be detected using image processing techniques. The processed data then enables the analysis of urban greenery's density, distribution, and characteristics. It can be used to classify different types of urban green spaces, allowing one to observe the change in the area (Gülçin & Akpınar, 2018; Kim, 2016). However, the remote sensing method cannot capture all the details of urban greenery, and the data collected by sensors cannot provide a detailed profile of street-level green areas (Li et al., 2015). Remote sensing data can be used to determine the amount of urban green space, but it may need to reflect the appearance of green at the street level accurately (Li et al., 2015). The vegetation people see on the street often differs from the overhead view captured by remote sensing methods, making it difficult to assess the actual profile of urban greenery (Li et al., 2015). At the same time, while the dense green texture in an area is selected by remote sensing, differences and diversity in vertical elements such as vertical green gardens or tree crown densities may not be detected in remote sensing (Li et al., 2015; Yang et al., 2009). Therefore, while remotely sensed images can provide valuable data for measuring urban greenness, they often fail to capture what people see and perceive on the ground, typically at street level (Li et al., 2015). Urban green space has been challenging to represent and measure efficiently and accurately at street level.

In many studies conducted at the street level, color photographs and video footage have been used to evaluate spatial features (Ewing & Handy, 2009; Falfán et al., 2018; Israt & Hassan, 2022; Yang et al., 2009). This shows that when images are obtained from different angles at eye level, they provide information about the field and its components (Li et al., 2015; Yang et al., 2009). Taking these sources as a reference, this study calculated the Green View Index (GVI) to evaluate urban greenery, and the yearly change of green texture at the street level was revealed. For this purpose, Google Street View (GSV) and Yandex Street View (YSV) data were used. Google Street View is a service, part of Google Maps, that provides users with street-level panoramic views worldwide. With these images, users can navigate a specific location at a 360-degree angle(Google Maps, 2024). GSV uses photographs taken on the streets using cameras and special equipment equipped with vehicles. By combining images, GSV images can create a continuous 360-degree image of a street scene.

Using urban images created with computer technology in current studies creates significant opportunities for street-level urban studies and planning (Biljecki & Ito, 2021; Ki & Lee, 2021; Liu & Sevtsuk, 2024; Sánchez & Labib, 2024). Although remote sensing, one of these methods, is an essential tool for detecting urban greenery, more is needed to detect greenery at the street level. While green area data generated from remotely sensed data can successfully measure urban greenery, more is needed to evaluate the profile views of urban greenery at the street level. The profile view of urban vegetation that people see on the ground is different from the view from above captured by most remote sensing methods.(Li et al., 2015)

The main research question of this study is: *Can street-level urban green be measured with web-based tools, or can its change be observed?* From this point of view, I wanted to see whether GSV and YSV images could help evaluate street greenery seen with the human eye using a GVI based on studies suggesting that this application can be effective and efficient.

This study aims to evaluate urban green's status and measure the change using web-based technology. While the size and quality of green areas are determined with urban plans at the upper scale, it is more challenging to collect and evaluate the current urban green data at the lower scale and street level. This study aims to evaluate the existence of greenery at the street level on selected streets using images provided by web-based tools. The urban green evaluation was made on selected streets within the scope of the data provided and published by web-based tools on a yearly basis. In the field study, the change in the status of urban green before and after the urban transformation was determined, especially since the streets were selected from a neighborhood where urban transformation was experienced.

STUDY AREA

The research was carried out empirically on the street selected from the Bostancı neighborhood of the Kadıköy district of Istanbul (Figure 1). The area where the street was chosen is an area undergoing urban transformation. While there were previously three or four-story, split-plan apartments and detached houses with gardens in the region, with the urban transformation after the earthquake, floor heights increased, apartment gardens decreased, and real estate values increased in the area (Berkmen & Turgut, 2019). The opening of rail systems such as the metro and Marmaray in the area has also increased its value. It is mainly inhabited by a population in a good socio-economic situation. With the urban transformation in the region, areas such as the front garden and backyard have sometimes turned into parking lots, thus reducing the amount of green space at street level. With increasing floor height, the height/width ratios in the street morphology have changed, and the view of the sky has decreased. As seen in Figure 2, the silhouette change in the last 50 years is observed.

While selecting the sample, an area would provide data at the expected level, as in studies measuring the Green View Index and its characteristics. Attention was paid to the number of data obtained from the streets rather than the number of streets.

Figure 1. Study area (Open Street Map, 2024).

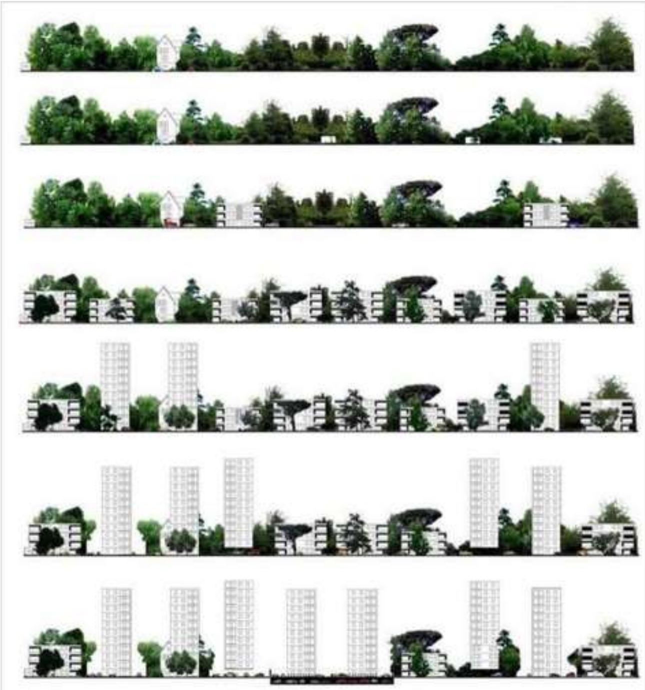

Figure 2. The silhouette change in Bagdat Street in the last 50 years (Drawing: İrem Mollaahmetoğlu - Ferhan Yürekli).

METHODOLOGY

The study aims to evaluate the change in the Green View Index on the street by using web-based imagery. To measure the index, reference was made to the methods used in the studies conducted by Li et al (2015) and Yang et al(2009). These studies measuring the Green View Index use street-level photographs in their methods. Photographs, other than remote sensing, have been used to efficiently and accurately represent and measure urban greenery at the street level (Li et al., 2015; Meitner, 2004; Yang et al., 2009; Yao et al., 2012b). In studies measuring the Green View Index at street level, photographs were the primary material used not from a single perspective but from 4 directions (north, east, west, south) or six different directions at a 360-degree angle from each randomly created measurement point. (Li et al., 2015; Yang et al., 2009; Yao et al., 2012b). When photographs are used to determine the greenery at the street level, specific measurements can be made, and the differences in the green area levels on the streets in the example can be determined (Figure 3a-3b). The first photo has a green view index of around 60%, while the second photo has a GVI below 1%, with a tree just visible in the distance.

a. 

b. 

Figure 3.a. DSI Street, Eskişehir (YSV, 2024), b. Direkçibaşı Street, Dolapdere, Istanbul (YSV, 2024).

Figure 4 showcases the GSV of Çağlar Street, a street in the Bostancı neighborhood of Istanbul. This perspective is a pedestrian's view, was captured using GSV and YSV. These innovative tools granted us a 360-degree view of the street and its surroundings, enriching our understanding of the street's environment. Using these types of images, a method was used to measure a street's GVI. In particular, a street where the greenery in the street texture was observed to decrease after urban transformation was selected, and this situation was tried to be proven. Steps of method:

-Each GSV and YSV points were determined by proceeding in a specific direction on the street

-Year-based data for each point was recorded

-In each recorded image, the pixel value of the green texture was found using the Photoshop program

-The GVI value of each point was found

-Compared the GVI for each point

Figure 4. 2020-GSV view (GSV, 2020).

The study recorded images moving in a specific direction from all the shooting points in 2011-YSV, 2020-GSV, and 2023-GSV on the selected street. For comparison, 2011 YSV and two years' GSV data, 2020-2023, were combined and used. The reason for combining the two data is that the data for the first part of the street is 2020, and the data for the second part is 2024. To observe the change, the data were combined, and GVIs were compared to those in 2011-YSV. Position parameters are seen as red dots in Figure 5. In total, data was taken from a total of 57 points on the road, including 24 points from 2011-YSV, 8 points from 2020-GSV, and 25 points from 2023 GSV-2023 (Figure 5).

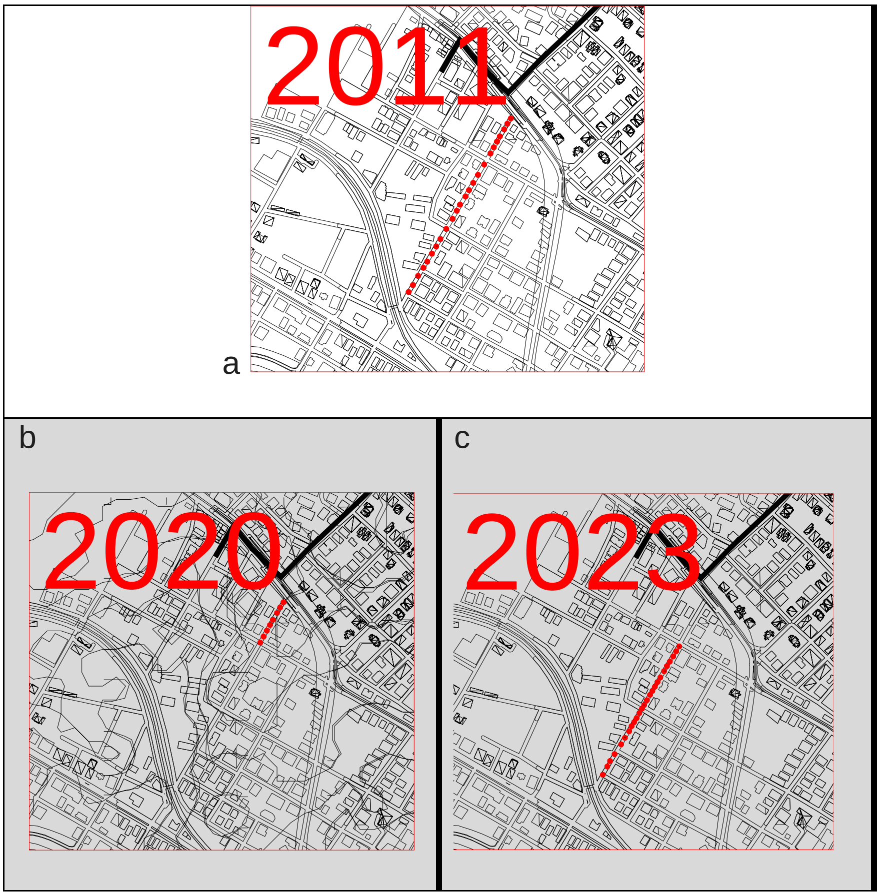

Figure 5.a. 2011-YSV points, b. 2020-GSV points, c. 2023-GSV points.

Since GSV and YSV obtained images with similar content, the view of the street was created using the two sources together. In order to calculate the green areas that a pedestrian can see while walking, a single-angle image was captured from each point.

The images were recorded starting from the beginning of the street and moving from northeast to southwest. By setting the person's focal point to 60 degrees, image recordings along the street were used at this angle.

In the images, road trees on the street, trees, shrubs, ground cover plants in apartment gardens, and potted plants on the street and on the balcony were evaluated for green visibility. Green texture analysis was performed on the images published by GSV and YSV on the street using Adobe Photoshop. Since some of the images obtained were taken in winter, an area definition was made considering the approximate diameter of the trees here. Since the 2023 images coincide with the winter month, there are no leaves on deciduous trees, such as plane trees, except for evergreen plants. For this reason, the selection was made by considering the trees' forms and crown structures, and the green view index was calculated accordingly. There may be a margin of error in the areas where the green texture is present in the photographs since the selections are made manually and by selecting the magic tool in Adobe Photoshop.

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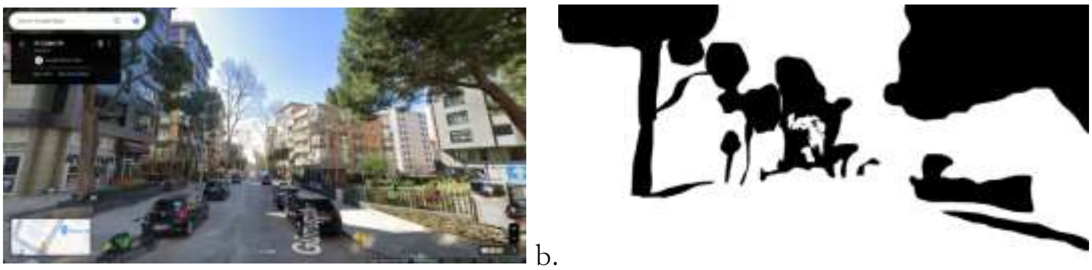
a.  b.

Figure 6a. Original view in GSV b. Selecting green vegetation with Photoshop.

The images were created as in Figure 6 and 57 green view index (GVI) was calculated (Li et al., 2015; Yang et al., 2009). GVI is obtained by multiplying the ratio of the number of pixels covered by the green texture by one hundred to the total number of pixels of the image.

Equation 1. Green View Index formula.

$$\text{Green view index} = 100x\frac{Total\ number\ of\ green\ pixels\ in\ the\ image}{Total\ number\ of\ pixels\ in\ the\ image}$$

Table 1. Total pixels, number of green cover pixels, and green view index ratio of GSV and YSV images.

	foto	2011-YSV	TOPLAM PİXEL	YEŞİL PİXEL	yeşil görüş ORANI	foto	August 2020-GSV	TOPLAM PİXEL	YEŞİL PİXEL	yeşil görüş ORANI	foto	2023-GSV	TOPLAM PİXEL	YEŞİL PİXEL	yeşil görüş ORANI
Çağlar Sokak 1-minibusten giriş	1		3980160	2033386	51,09	1		3740800	474297	12,68					
	2		3951360	1803643	45,65	2		2756160	235652	8,55					
	3		3974400	1162462	29,25	3		2764386	617911	22,35					
	4		3968640	840310	21,17	4		2742508	485765	17,71					
	5		3962880	1791106	45,20	5		2161742	969512	44,85					
	6		3951360	2010239	50,87	6		2225952	715761	32,16					
	7		3957120	1554826	39,29	7		2763600	1578316	57,11					
	8		4034956	1351786	33,5018771	8		3848480	2160075	56,12800378					
	9		3934080	1258171	31,98132727						9		3951360	1170255	29,62
	10		3954372	1455199	36,79974975						10		4017852	1420084	35,34
	11		3957576	1465816	37,03822744						11		4043656	1625008	40,19
	12		3957120	1770779	44,74918628						12		4034956	1421815	35,24
	13		3954372	1470887	37,19647519						13		4043520	1442705	35,68
	14		3951624	1074360	27,18780937						14		4055040	1402996	34,60
	15		3962880	1230317	31,04603218						15		4057980	1157576	28,53
	16		3962880	1311843	33,10327338						16		4055040	460193	11,35
	17		3962880	1507095	38,03029615						17		4049408	1456300	35,96328155
	18		3962880	1417402	35,76696746						18		4049280	1402008	34,62363679
	19		3962880	1924107	48,55324915						19		3965884	357084	9,003894214
	20		4043520	1243325	30,74858044						20		4049280	968861	23,92674747
	21		4043520	1135902	28,09191002						21		4055040	1264984	31,19535196
	22		4043520	1585874	39,22013493						22		4037904	1312214	32,49740459
	23		4043520	479121	11,84910672						23		4049280	666220	16,45280149
	24		4043520	603341	14,92118253						24		4043520	830563	20,54059334
											25		4026240	1171740	29,10258703
											26		4072320	1587192	38,97512966
											27		4043520	1662223	41,10831652
											28		4049280	1064016	26,27667141
											29		4043520	1400835	34,64394884
											30		4066560	1026871	25,25158857
											31		4060800	1792053	44,13054078
											32		4037760	1929131	47,77725769
											33		4083840	103161	2,526078397
					35,97				2020	31,44					29,78

RESULTS

Looking at the results obtained from the images obtained, a GVI was obtained for each determined point on the street. In this way, it can be determined in which area on the street the green density increases or in which area it decreases. When comparing 2011 with 2020 and beyond in terms of GVI, it is seen that green vegetation decreased by 5% (Table 2). The presence of green areas has decreased in the changing urban texture due to urban transformation. In this way, a point-by-point green area analysis is also made. While the change in green on the street is observed, comparisons can be made to determine at which points the amount of green decreases or increases.

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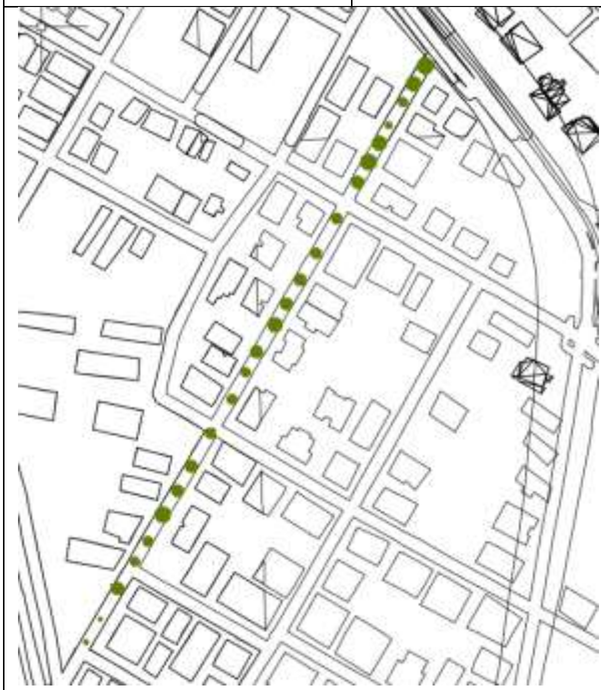
Table 2. 2011 and 2020/2023 average GVI values.

2011-YSV		2020 GSV+2023 GSV	
24 locations Average GVI	35,94	33 locations Average GVI	30,61
			

CONCLUSION

The study first concluded, "Urban green space at street level can be measured, and its change can be observed with web-based tools." At the same time, this study proposes using GSV and YSV images to evaluate street greenery in an urban area. Google and Yandex create GSV and YSV images on the ground, with a viewing angle similar to that of pedestrians, to evaluate the street greenery and observe its change.

Using the GVI index used in the study by Li et al. (2005) and Yang et al.(2009) as a reference, GVI was measured for a street in the Bostancı district of Istanbul. The results showed that GSV and YSV images could be evaluated when monitoring urban greenery on the street.

The images used were evaluated based on human eye level in one direction. Images are taken from a single perspective because the human eye only watches the street from a single perspective while walking. It is not humanly possible to provide a perspective in every direction. Therefore, a measurement with this methodology is sufficient to evaluate urban green.

However, some points in the method must be reconsidered. Although Google and Yandex obtain street views, obtaining an image in the desired time period is difficult. Only temporal patterns provided by the data can be used. The second problem is that in the method used, images are recorded manually, and although selections are tried to be made precisely with software, errors, and shifts may occur. Selecting the green area in the image is difficult and time-consuming. The method is open to debate in terms of applicability when more data are available.

Another problem is that moving elements, such as vehicles and people, are present in the images, and the green texture may be invisible or shadowed. This situation makes actual measurement difficult. Another problem is that GSV and YSV need more viewing points.

This study conducted a comprehensive street-level analysis to maximize the utilization of Google Street View (GSV) and Yandex Street View (YSV) opportunities. Instead of selecting random points from the streets of Bostancı district, the aim was to use all the existing point data from the beginning to the end of the street. Since it was an experimental study, its scope was limited in this way.

By comparing data from post-2011 to post-2020, the Green View Index (GVI) was evaluated, revealing significant insights. The findings indicate that GVI data effectively assess and monitor green area information typically provided by remotely sensed images. This methodology demonstrates that GVI can serve as a relatively objective metric for gauging urban greenness at the street level. Consequently, GVI emerges as a valuable tool for urban landscape planning and management, offering a scientific basis for protecting and developing green spaces.

GVI's ability to provide a nuanced, street-level perspective on urban greenery complements traditional remote sensing techniques, enriching the dataset available to urban planners. This is particularly pertinent in densely built environments where tree canopies and smaller green spaces might be underrepresented in broader-scale imagery. Furthermore, the temporal comparison between data from 2011 and 2020 underscores the dynamic nature of urban green spaces, capturing changes and trends that might inform future urban development and environmental policies.

As cities continue to grow and evolve, integrating GVI into urban planning processes ensures that green spaces are preserved and strategically enhanced to improve urban livability. By providing detailed, on-the-ground data, GVI supports a more granular approach to urban greening initiatives, facilitating targeted interventions where they are most needed. This proactive use of GVI data can help mitigate the urban heat island effect, enhance biodiversity, and improve city residents' overall quality of life.

In conclusion, the Green View Index is a robust tool for objectively measuring street-level greenness. Its application in urban landscape planning and management is suitable and essential for the sustainable development of green spaces. As a result, GVI offers urban planners and policymakers a valuable resource to guide efforts in protecting and expanding urban greenery, ultimately contributing to creating healthier and more sustainable cities.

Conflict of Interest Statement | Çıkar Çatışması Beyanı

Araştırmanın yürütülmesi ve/veya makalenin hazırlanması hususunda herhangi bir çıkar çatışması bulunmamaktadır.

There is no conflict of interest for conducting the research and/or for the preparation of the article.

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Ethical Statement | Etik Beyanı

Araştırma etik standartlara uygun olarak yapılmıştır.

All procedures followed were in accordance with the ethical standards.

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Author Contribution Statement | Yazar Katkı Beyanı

AUTHOR 1: (a) Idea, Study Design, (b) Methodology, (c) Literature Review, (f) Data Collection, (g) Analyses, (h) Writing Text.

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