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MEASURING AIR QUALITY IMPACTS OF GREEN AREAS AND ECOSYSTEM SERVICES (ESS) USING WEB-BASED I-TREE CANOPY TOOL: A CASE STUDY IN ISTANBUL

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ABSTRACT: In this study, it was aimed to evaluate the regulating ecosystem services for improving the air quality provided in the Kuzguncuk Neighborhood, which is located within the borders of Üsküdar district of Istanbul province. In this context, 5500 random points were identified within the boundaries of the research area by using the i-Tree canopy tool, which is a web-based tool. The land cover represented by each point is grouped into five classes: *i)* Tree/Shrub (tree and tall shrub vegetations), *ii)* Grass/herbaceous (areas covered with herbaceous vegetation, *iii)* Soil/Bare Ground (soil surface with little or no vegetation), *iv)* Impervious Surfaces (building, structures, asphalt, impervious roads, etc.) and *v)* Water (areas with streams or stagnant water). According to these classifications, the annual amount of carbon sequestered by the tree-shrub canopy in the Kuzguncuk neighborhood, the amount of CO_2, the amount of carbon they stored over their lifetimes, the amount of CO_2, and their economic contribution have been calculated. Additionally, the amount of significant air pollutants removed by this canopy, such as carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter $PM_{2.5}$ and PM_{10}, and the economic benefits of removing these pollutants have been determined. The results showed that trees sequestered 855.93 tons of CO_2 annually and stored 21,495.71 tons of CO_2 in the neighborhood, 46.05% of which is covered with canopy. However, it was calculated that 69.94 kg of CO, 381.39 kg of NO_2, 3,798.45 kg of O_3, 240.34 kg of SO_2, 184.57 kg of $PM_{2.5}$ and 1,272.34 kg of PM_{10} particulate matter were removed from the atmosphere in a year by the vegetation cover. It has been calculated that the economic contribution provided by this removal is $ 2,251 per year. This study reveals the ecological and economic importance of green spaces for ecosystem services studies in urban areas by considering a neighborhood scale in determining the ecosystem services provided by the canopy cover. It is thought that the numerical values obtained in this sample region will contribute to urban planning strategies in terms of green infrastructures for future studies.

Keywords: Ecosystem services, air quality, i-Tree canopy tool, Kuzguncuk, İstanbul.

YEŞİL ALANLARIN HAVA KALİTESİ ETKİLERİ VE EKOSİSTEM SERVİSLERİNİN (ES) WEB TABANLI I-TREE CANOPY ARACI KULLANARAK ÖLÇÜLMESI: İSTANBUL'DA BIR VAKA ÇALIŞMASI

ÖZET: Bu çalışmada, İstanbul ili Üsküdar ilçesi sınırları içinde yer alan Kuzguncuk Mahallesinde sağlanan hava kalitesinin iyileştirilmesine yönelik düzenleyici ekosistem hizmetlerinin değerlendirilmesi amaçlanmıştır. Bu kapsamda web-tabanlı bir araç olan i-Tree canopy aracı kullanılarak araştırma alanı sınırları içerisinde 5500 adet rastgele nokta tanımlanmış ve her bir noktanın temsil ettiği arazi örtüsü i) Ağaç/Çalı (ağaç ve boylu çalı vejetasyonları), ii) Çim/otsu bitkiler (otsu bitki örtüsüyle kaplı alanlar, iii) Toprak/Çıplak Zemin (bitki örtüsünün az olduğu veya olmadığı toprak yüzeyleri), iv) Geçirimsiz Yüzeyler (bina, yapılar, asfalt, geçirimsiz yollar vb.) ve v) Su (akarsu veya durgun su bulunan alanlar) olmak üzere beş sınıf olarak gruplandırılmıştır. Bu sınıflara göre, Kuzguncuk mahallesindeki ağaç-çalı örtüsünce tutulan yıllık karbon miktarı, CO_2 miktarı ve yaşamları süresince depoladığı karbon miktarı, CO_2 miktarı ve bunların sağladığı ekonomik katkı hesaplanmıştır. Ayrıca bu örtünün karbon monoksit (CO), nitrojen dioksit (NO_2), ozon (O_3), kükürt dioksit (SO_2) gazlarını ve ince partikül $PM_{2,5}$ ve PM_{10} parçacıkları içeren önemli hava kirleticilerini uzaklaştırma miktarları ile bu kirleticilerin uzaklaştırılmasının sağladığı ekonomik katkı belirlenmiştir. Sonuçlar %46,05'i taç örtüsüyle kaplı olan mahallede ağaçların yıllık 855.93 ton CO_2 tuttuğunu ve 21,495.71 ton CO_2 depoladığını göstermiştir. Bununla birlikte, bitki taç örtüsünce bir yılda atmosferden 69.94 kg CO, 381.39 kg NO_2, 3,798.45 kg O_3, 240.34 kg SO_2, 184.57 kg $PM_{2.5}$ ve 1,272.34 kg PM_{10} parçacık madde uzaklaştırıldığı hesaplanmıştır. Bu uzaklaştırmanın sağladığı ekonomik katkının ise yıllık \$2,251 olduğu hesaplanmıştır. Bu çalışma, taç örtüsü sayesinde sağlanan ekosistem hizmetlerini belirlemede bir mahalle ölçeğini ele alarak, yeşil alanların kentsel alanlardaki ekosistem hizmetleri çalışmaları için ekolojik ve ekonomik önemini ortaya koymaktadır. Bu örnek bölgede elde edilen sayısal değerlerin gelecek çalışmaları için yeşil altyapılar açısından kentsel planlama stratejilerine yönelik katkı sağlayacağı düşünülmektedir.

Anahtar kelimeler: Ekosistem hizmetleri, hava kalitesi, i-Tree canopy aracı, Kuzguncuk, İstanbul.

INTRODUCTION

Today, rapid urbanization and the irreversible transformation of natural ecosystems (McKinney, 2002) are changing our world rapidly and causing unhealthy areas to emerge. This causes environmental problems to become more and more threats (Demir & Demirel, 2018; Topal, 2022a). In addition to problems such as improper land use, production and consumption pressures, decrease in biodiversity, deforestation, flood, drought, urban heat island effect, decrease in water quality, toxic wastes and high energy consumption, pollution in cities has become important problems (Vafa-Arani et al., 2014; Korkut et al., 2017a; Topal, 2022b). One of the most important of these pollution problems is undoubtedly urban air pollution, which continues to be a significant risk in many parts of the world (Mayer, 1999; Saksena, 2011; Oltra et al., 2017; Yang et al., 2020). Urban air pollution, which is a complex mixture of gaseous and particulate components (Seinfeld, 1989), is a serious problem both in terms of potential health risks (Mage et al., 1996; Ghose et al., 2005; Ilyas et al., 2010; Leung, 2015) and affecting the development of cities (He et al., 2002; Vlachokostas et al., 2011). In this context, urban activities, in addition to being sources of air pollution on a local scale, also increase greenhouse gas concentrations on a global scale (Fenger, 1999; Fan et al., 2020).

Urban air pollution is especially effective in Istanbul, as it is in developing countries and many fast-developing cities (Yang et al., 2005; Zhang et al., 2007) of the world. According to the Dark Report 2022 published by the Right to Clean Air Platform in 2023, it is reported that air pollution is at high levels in the cities of Istanbul and Ankara, especially in districts where coal is burned for heating and where construction and traffic are intense. These cities are among the major cities of Türkiye. Especially in Istanbul, almost all of the population except some regions breathe unhealthy air in terms of particulate matter according to the World Health Organization (WHO). As a matter of fact, when the risks that cause death in Türkiye are listed, air pollution ranks 5th. According to the study carried out by the Right to Clean Air Platform, it has been calculated that 4,848 people lost their lives in Istanbul in 2021 due to diseases related to air pollution (Right to Clean Air Platform, 2018).

The National Air Quality Index in Türkiye was created by adapting the EPA (U.S. Environmental Protection Agency) Air Quality Index to our national legislation and limit values. Accordingly, the air quality index is calculated for 5 main pollutants: particulate matter (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) (İstanbul Metropolitan Municipality, 2023). Most of the SO_2 gas originates from activities such as thermal power plants, industries producing by processing raw materials, oil refineries, cement plants, domestic fuels, forest fires, volcanic activities. Two important sources of NO_X gases are motor vehicles and thermal power plants. Most of the CO in the urban atmosphere also comes from vehicles. O_3 gas can arise from pollutants in anthropogenic sources such as power plants, refineries, chemical plants. PMs, one of the most dangerous pollutants, are generally formed by the combustion of solid and liquid fuels, combustion processes such as vehicles using diesel and leaded gasoline, thermal power plants, some industrial activities and the conversion of atmospheric gases (Zhang et al., 2007; Morcalı & Akan, 2017; Zencirci & Işıklı, 2017; Pace et al., 2021). The increase in air pollution through these gases also increases the urban heat island effect in cities (Hepcan & Hepcan, 2017; Yıldız et al., 2017).

According to Kurdoğlu et al. (2011), urban heat island effect and climate control can be achieved thanks to the open green space systems that are designed correctly within the urban ecosystem. In this context, increasing green areas in cities and adopting an integrated approach with urban green areas are accepted as an effective way in this struggle. In this context, urban green infrastructure, which provides ecosystem services that ensure the sustainability of cities, emerges as an important concept (Demirel et al., 2005; Mills et al., 2015; Korkut et al., 2017b; Ghorbankhani et al., 2023).

It is very important to define and evaluate ecosystem services (ES), defined by Daily (1997) as “the conditions and processes through which natural ecosystems and the species that make them up sustain and fulfill human life” (Daily, 1997). Likewise, these definitions and assessments can guide decisions about the conservation of biodiversity, the use and management of resources necessary for life (Bolund & Hunhammar, 1999; Jax et al., 2013; Balvanera et al., 2017). However, by measuring ecosystem services and the supply and demand for these services, it is a binding issue to find solid indicators in order to make sound predictions for the future situation (Balvanera et al., 2017). In this context, estimating the benefits and costs of improving air quality from ecosystem services has been very important

(Krupnick & Portney, 1991), and in the past few decades, progress has been made in understanding the production and threats to ESs, calculating and analyzing the value of ESs (Fu et al., 2013). On the other hand, these services are also an important focal point for the sustainable development goals (SDGs) (Kim & Kang, 2022).

At the point where today's technology has come, web-based models using geospatial technologies have been produced. The i-Tree model is one of the most common models used to estimate pollutant removal from urban vegetation with Computational Fluid Dynamics (CFD) simulations, and utility calculations of ESs can be made (King & Locke, 2013; Olivatto, 2019; Pace et al., 2021; Ghorbankhani et al, 2023). When the studies carried out with i-Tree canopy are examined, it is seen that studies are carried out at different scales, from the scale of the residential environment to the scale of the neighborhood, district and city. However, researches show that studies on the calculation of ecosystem services are generally carried out in natural areas (Hepcan & Hepcan, 2017; Çakmak & Can, 2020), and this indicates that there is a need to carry out and increase studies on the calculation of ecosystem services of urban areas in this context.

Accordingly, this study focuses on Istanbul, one of our major cities with the highest air pollution. In the study, Kuzguncuk Neighborhood of Üsküdar district, located on the Anatolian side, which is one of the neighborhoods of Istanbul with high green area cover, was chosen as the research area. In this study, the aim is to calculate and analyze the ecosystem services (ES) provided by the tree-shrub canopy in the research area in terms of air quality using the i-Tree Canopy v7.1 tool. In this context, the annual amount of carbon stored by the tree-shrub cover in the Kuzguncuk Neighborhood, the amount of CO_2 and the amount of carbon stored during their lifetime, the amount of CO_2 and the amount of removal and retention of important air pollutants containing carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2) gases and fine particulate $PM_{2.5}$ and PM_{10} particles, as well as the economic contribution provided by the removal of these pollutants, were calculated.

MATERIALS AND METHODS

Research area

Kuzguncuk is a neighborhood that has preserved its natural and cultural structure, located in the district of Üsküdar, on the Anatolian side of the Bosphorus (Koçan & Rüzgar, 2016) (Figure 1). It covers an area of 150.4 ha. According to TUIK's 2022 data, its population is 4.151 (TUIK, 2023). Fethipaşa Grove and Cemilbey Grove are the two important green areas of Kuzguncuk. Kuzguncuk Neighborhood is a residential area located in the valley between two hills consisting of green areas. Among these green areas, Kuzguncuk grove has pine, plane and fir trees and covers an area of 26 hectares. The second green area forming the border is the area behind the Kuzguncuk Park where the kitchen garden and Muslim Graveyard are located. Kuzguncuk kitchen garden, located close to the coast, operates as a community garden with small planting gardens and a community garden where urban agricultural activities can be done. There are important registered mansions in the coastal settlement of Kuzguncuk (Paker, 2009; Aslan, 2020; Erkılıç et al., 2021).

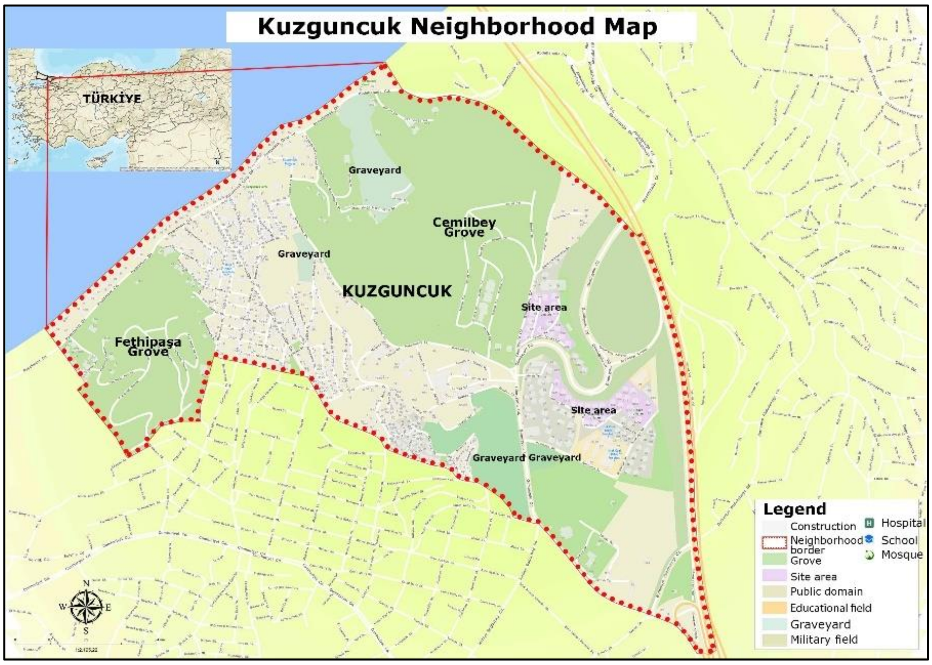

Figure 1. Research area (adapted from Üsküdar Municipality, 2023)

i-Tree Canopy Tool

In the study, using the i-Tree Canopy v7.1 tool developed by USDA Forest Service, the land covers in the research area were classified and the regulating ecosystem services provided by the tree-shrub cover in terms of air quality were calculated and analyzed. i-Tree is a free web-based module developed to evaluate ecosystem services using random point sampling method and working with Google Maps^{TM} satellite imagery (Nowak et al., 2006; Jacobs et al., 2013; Olivatto, 2019; USDA, 2022).

With the module, users can classify the land cover in a selected area. Users can reveal the removal of pollutants causing air pollution from the atmosphere by trees according to the types of land cover they have determined, as well as the effects on ecosystem services for the capture and storage of atmospheric carbon with numerical data. Besides, the module is designed to provide easy and accurate estimation of monetary values (Hirabayashi, 2014; Selim et al., 2023). i-Tree recommends 500-1000 search points for studies, but reports that the more points identified, the better the prediction results will be (USDA, 2022). When the literature is reviewed, it is seen that Ghorbankhani et. al. (2023) defined 1515 points for their study conducted on an area of 321 ha in Tehran. Arslan (2021) defined 1500 points for a study conducted on an area of 1643 ha in Çorum. Tonyaloğlu et al. (2021) defined 6500 points for their study conducted on an area of 233.47 ha in Aydın. Hepcan & Hepcan (2017) defined 3000 points for their study conducted on an area of 54.47 ha in İzmir. Olivatto (2019) defined 1110 points for a study conducted on an area of 80 ha in Brazil. In this direction, it is aimed to obtain the results with greater precision by defining 5500 points for our 150.4 ha research area. Indeed, studies have shown that the more points are identified, the better the accuracy of land cover classifications and the lower the standard error rate (under 1 is recommended) (Hepcan & Hepcan, 2017; Hwang & Wiseman, 2020; Ghorbankhani et al, 2023; Rowicki & Bruhn, 2023).

Process Steps

The study was carried out in 4 steps:

1.Step: Within the scope of the study, firstly, the boundaries of the research area were obtained via https://www.openstreetmap.org/ and the data with the “kml” extension was converted into “ESRI shapefile” format with the help of ArcMap 10.8 program, and a digital data format that can be used in the i-Tree canopy module was obtained.

2.Step: Then, using the module, 5500 random points were defined within the boundaries of the research area and the land cover represented by each point was classified. Land cover classes are grouped into five classes: *i)* Tree/Shrub (tree and tall shrub vegetations), *ii)* Grass/herbaceous (areas covered with herbaceous vegetation, *iii)* Soil/Bare Ground (soil surface with little or no vegetation), *iv)* Impervious Surfaces (building, structures, asphalt, impervious roads, etc.) and *v)* Water (areas with streams or stagnant water)

3.Step: In this step, the classes corresponding to each point are defined one by one.

4.Step: In the last step, by running the module, the amount of removal and retention of important air pollutants of the tree-shrub cover in Kuzguncuk Neighborhood and the economic contribution of the removal of these pollutants were calculated.

FINDINGS AND DISCUSSION

Land Cover Types Identified in the Research Area

The land cover types determined in the research area, the random point distributions determined for each class, their areal distributions (%) and standard error rates are shown in Figure 2. The analysis results of the study show that the canopy cover of the tree and tall shrub in the neighborhood covers 69.20 ha and 46.05% of the area. Impervious surfaces consisting of building, structures, asphalt, impervious roads cover 51.85 ha and 34.51% of the area. The third land type in the area is Grass/Herbaceous cover covering 19.80 ha and 13.18% of the area (Figure 3). The standard deviation values below 1 indicate that the point distributions are made in a balanced manner in the land cover classes in the research area (Table 1).

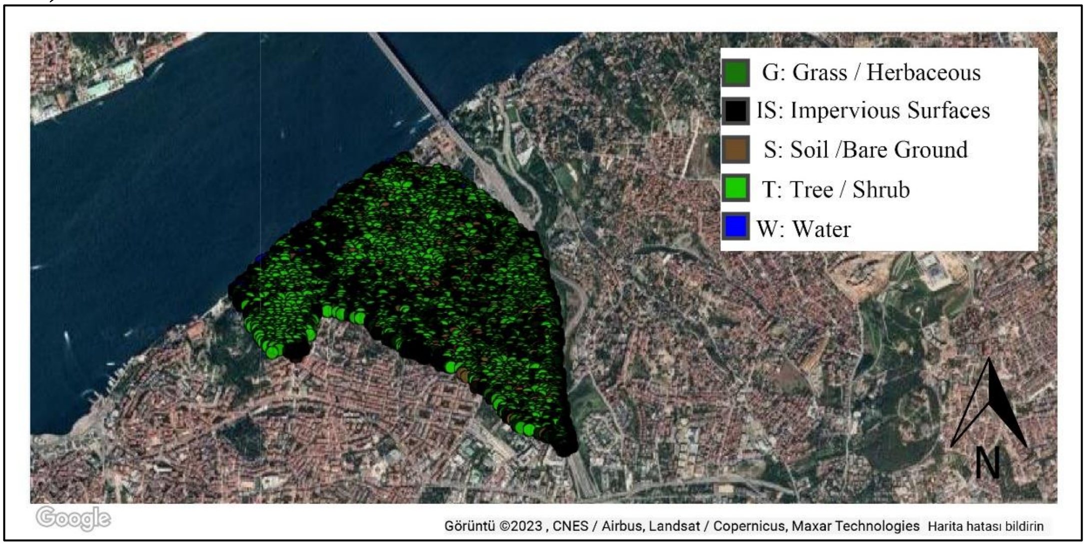

Figure 2. Land Cover Types Identified in Kuzguncuk Neighborhood And 5500 Randomly Generated Classification Points

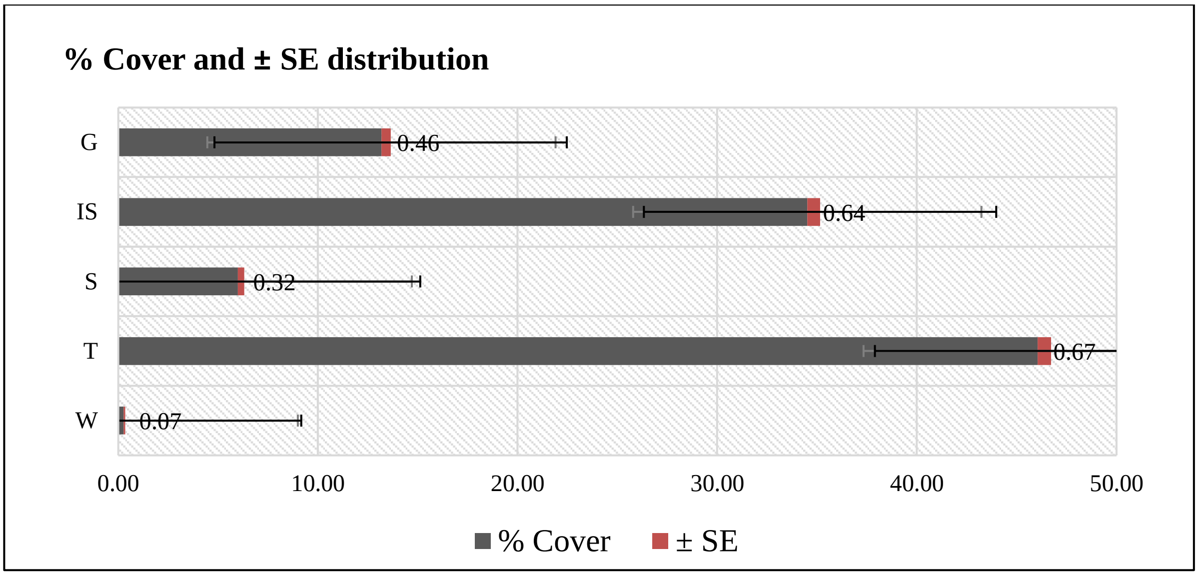

Figure 3. % Cover And ± SE Distributions of Land Cover Types Identified in Kuzguncuk Neighborhood

Table 1. Detailed Analysis Results for Land Cover Types in Kuzguncuk Neighborhood

Abbr.	**Cover Class**	**Description**	**Points**	**% Cover ± SE***
G	Grass/Herbaceous	Areas covered with herbaceous vegetation	725	13.18 ± 0.46
IS	Impervious Surfaces	Building, structures, asphalt, impervious roads	1898	34.51 ± 0.64
S	Soil/Bare Ground	Soil surface with little or no vegetation	329	5.98 ± 0.32
T	Tree/Shrub	Tree and tall shrub vegetations	2533	46.05 ± 0.67
W	Water	Areas with streams or stagnant water	15	0.27 ± 0.07
Total			5500	100.00

** SE: Standard error*

Calculation of ESs in terms of Air Quality

According to the analysis results of the study, the annual amount of carbon sequestered by woody plants in Kuzguncuk Neighborhood was 233.44 tons, the amount of CO_2 855.93 tons, the amount of carbon stored during their lifetime was calculated as 5,862.47 tons, and the amount of CO_2 was calculated as 21,495.71 tons. It has been calculated that $39,813 economic value is provided from this annual storage benefit, and $999,848 economic value is provided from the lifetime storage benefit (Table 2).

Table 2. Tree Benefit Estimates for Carbon and CO_2

Description	Carbon (T)*	±SE*	CO_2 Equiv. (T)*	±SE*	Value (USD)	±SE*
Sequestered annually in trees	233.44	±3.41	855.93	±12.49	$39,813	±581
Stored in trees (not an annual rate)	5,862.47	±85.55	21,495.71	±313.70	$999,848	±14,591

Notes: Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Amount sequestered is based on 1.365 T of Carbon, or 5.005 T of CO_2, per ac/yr and rounded. Amount stored is based on 34.281 T of Carbon, or 125.697 T of CO_2, per ac and rounded. Value (USD) is based on $170.55/T of Carbon, or $46.51/T of CO_2 and rounded. (English units: T = tons (2,000 pounds), ac = acres), SE: Standard error

In the study, the amount of CO gas removed from the air was calculated as 69.94 kg. When other studies carried out in urban areas are examined, this value was calculated as 87.48 kg in a study carried out in an urban area of approximately 321 ha covering Nahjol-Balaghe and Pardisan region in Tehran. Tehran's largest and most important urban forests are located in this area (Ghorbankhani et al., 2023). Compared to our study area, although the area where this study was carried out is more than two times larger than the area we have studied, the CO removal rates were found to be close. This reveals an important and remarkable result in terms of showing how great an ecosystem service the canopy of green areas in Kuzguncuk is, even according to this value alone. This value was found as 143.65 kg in Bahçelievler Neighborhood, which has an area of 1643 ha in Çorum province (Arslan, 2021). In another study carried out for the 34200 ha Mamak district of Ankara, it was calculated as 2470 kg (Çakmak & Can, 2020). Again, when these values are proportioned in terms of area, the results reveal the high ecological potential of Kuzguncuk, rich in vegetation.

In our study, the amount of NO_2 gas removed from the air was calculated as 381.39 kg. For the Irish capital city Dublin, this value was calculated as 99.4 kg in a 302 ha study area (Mills et al., 2015), and 13019 kg in 1651 ha in another study was carried out in Tehran D16 (Vahidi et al., 2023). When these values are proportioned in terms of area, it was seen that they were higher than the value calculated for the city of Dublin and lower than the study carried out in Tehran.

In our study, the amount of O_3 removed from the air was found to be 3.798.45 kg. This value was calculated as 1,821.60 kg in the study carried out in 6 neighborhoods of 233.47 ha in Aydın (Tonyaloğlu et al, 2021), 7,801.47 kg in Bahçelievler Neighborhood in Çorum (Arslan, 2021), and 1540 kg in the study carried out in an 80 ha urban area in Portugal Park (or Taquaral Lake) in Brazil (Olivatto, 2019). When proportioned in terms of area, this value we calculated for Kuzguncuk was found to be above the values for other study areas.

In the study, the amount of SO_2 removed from the air by the canopy cover was calculated as 240.34 kg. This value was calculated as 11820 kg for the 8500 ha city of Springfield in the US state of Massachusetts (Bloniarz, 2014), 48.8 kg for the Dublin urban area (Mills et al., 2015), and 237.57 kg for the Nahjol-Balaghe and Pardisan districts in Tehran (Ghorbankhani et al., 2023). When the values are proportioned in terms of area, it is seen that the calculated value in the study is higher than the studies carried out in these regions.

The amount of particulate matter removed from the atmosphere by the vegetation in the study area in a year was calculated as 184.57 kg for $PM_{2.5}$ and 1,272.34 kg for PM_{10}, respectively. This value has been calculated as 379.09 kg and 2,613.20 kg for Çorum Bahçelievler Neighborhood (Arslan, 2021), and 9080 kg and 62570 kg for the city of Springfield, respectively (Bloniarz, 2014). When the values are proportioned in terms of area, it is seen that the calculated value in the study is higher than the studies carried out in these regions. These results reveal that the green area distribution of our study area, Kuzguncuk, is at a good level and it makes a positive contribution in terms of removing particulate matter from the atmosphere (Table 3).

Table 3. Tree Benefit Estimates for Air Pollution

Abbr.	Description	Amount (kg)	±SE	Value (USD)	±SE
CO	Carbon Monoxide removed annually	69.94	±2.25	$7	±0
NO_2	Nitrogen Dioxide removed annually	381.39	±12.27	$11	±0
O_3	Ozone removed annually	3,798.45	±122.21	$588	±9
SO_2	Sulfur Dioxide removed annually	240.34	±7.73	$2	±0
$PM_{2.5}$	Particulate Matter less than 2.5 microns removed annually	184.57	±5.94	$1,216	±18
PM_{10}*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	1,272.34	±40.94	$427	±6

Notes: Currency is in USD and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Air Pollution Estimates are based on these values in lb/ac/yr @ $/lb/yr and rounded: CO 0.902 @ $0.04 | NO_2 4.917 @ $0.01 | O_3 48.968 @ $0.07 | SO_2 3.098 @ $0.00 | $PM_{2.5}$ 2.379 @ $2.99 | PM_{10} 16.403 @ $0.15 (English units: lb = pounds, ac = acres), SE: Standard error*

CONCLUSION

Istanbul, a metropolis where the population and construction is quite dense, is one of our cities where air pollution is experienced most effectively. The results of this study, carried out in the Kuzguncuk Neighborhood of Istanbul, showed that the canopy cover here provided economic benefits of $39,813 and $999,848 in terms of carbon sequestration and storage, respectively. In addition, it has shown that it removes a total of 5,947.03 kg of important pollutants, including CO, NO_2, O_3, SO_2, $PM_{2.5}$, PM_{10} from the air. It has been calculated that this removal contributes a total of $2,251 annually in terms of economy. It is thought that Tree/Shrub cover, which covers an area of 46.05%, and large mass green areas such as groves and graveyards, which are concentrated in the green structure of Kuzguncuk, are effective in the emergence of this result.

This study was carried out with the i-Tree Canopy tool, which offers a web-based platform. In today's world, where digital technologies and studies on web-based applications are rapidly developing and becoming widespread, it is possible to obtain information quickly, practically and economically with calculation tools such as i-Tree. Thanks to the simulations that can be prepared with such applications, it is possible to obtain quantitative and parametric results by creating future scenarios for green infrastructure. In this context, the development and dissemination of such software will be beneficial for the management of green areas.

On the other hand, it should not be forgotten that these calculations made with i-Tree are based on estimation and information such as the age of the plant, canopy width (Çakmak & Can, 2020), stem width (Arslan, 2021), whether it has shed leaves, and the condition of the cones are also important (Fares et al., 2020) in the ES calculations. Although this situation is considered as the limitations of the calculations of ESs made with i-Tree, it is important in terms of presenting general data on the study areas.

As a result, in this study, the importance of green areas for cities has been emphasized and the ES service provided by green areas has been evaluated on an exemplary area. The results of this study are important in terms of protecting green areas in our cities, encouraging more green areas by creating new green areas, and being a guide in the development of strategies and policies for urban planning.

AUTHOR CONTRIBUTIONS

Tuğba Üstün Topal: Designing the study, obtaining and organizing the data, analysis interpretation of the results, writing and reviewing the manuscript and supervising. **Öner Demirel**: Designing the study, organizing the data, writing and reviewing the manuscript and supervising.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS COMMITTEE APPROVAL

This study does not require any ethics committee approval.

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