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Air quality impact of natural protected areas: A case study of Sarayiçi Tavuk Forest, Edirne, Türkiye

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Abstract: This study investigated the regulatory ecosystem services of Sarayiçi Tavuk Forest, a natural protected urban forest in Edirne, Turkey, with a focus on its ability to improve air quality. The i-Tree Canopy Tool was used to categorise land-cover classes within the forest and assess air quality impacts using pollutant removal and carbon sequestration estimates. The results show that the Sarayiçi Tavuk Forest eliminates 5,014.68 kg/yr of pollutants, sequesters 183,000 kg/yr of carbon, and stores a total of 4,596,680 kg of carbon throughout the lifespan of its trees. The economic value of these regulatory ecosystem services is estimated at 864,177 USD annually and substantially improves air quality. The results of this study provide valuable insights for researchers, landscape managers, and policymakers involved in regional planning, decision-making, and green space improvement in cities. This study highlights the vital role of natural protected urban forests in improving air quality and underscores the need for their preservation and integration into landscape and urban planning strategies for sustainable development in response to 21st-century challenges.
Keywords: Air quality impact, Ecosystem services, Natural protected Area, i-Tree Canopy, Sarayiçi Tavuk Forest

Doğal sit alanlarının hava kalitesine etkisi: Sarayiçi Tavuk Ormanı, Edirne, Türkiye

Özet: Bu çalışmada, Edirne'de doğal sit alanı statüsünde olan Sarayiçi Tavuk Ormanı'nın sağladığı düzenleyici ekosistem hizmetleri incelenerek, hava kalitesi iyileştirme etkisi hesaplanmıştır. Çalışmada i-Tree Canopy v.7.1 kullanılarak, Sarayiçi Tavuk Ormanı arazi örtüsü sınıflandırılmış ve arazi örtüsünün hava kalitesine olan etkisi: kirleticilerin uzaklaştırılması, karbon tutulması ve depolanması tahminleri aracılığıyla değerlendirilmiştir. Sonuçlar, Sarayiçi Tavuk Ormanı'nın yılda 5,014.68 kg kirletici gaz ve partikülü ortadan kaldırdığını, yılda 183,000 kg karbon tuttuğunu ve ormandaki ağaçların toplam 4,596,680 kg karbon depoladığını göstermektedir. Bu düzenleyici ekosistem hizmetlerinin ekonomik değeri yılda 864,177 USD olarak tahmin edilmekte olup, hava kalitesini önemli ölçüde artırmaktadır. Bulgular, kentsel ve peyzaj planlama üzerine çalışan araştırmacılar ile karar alma süreçlerinde çalışan yönetici ve politikacılar için kent ormanlarının ekolojik ve ekonomik değerini ortaya koymaktadır. Bu çalışma, doğal sit alanı statüsünde olan kent ormanların hava kalitesini artırmadaki önemli rolünü vurgulamakta ve kent ormanlarının 21. yüzyılın en önemli zorluklarından olan iklim krizine yanıt olarak peyzaj ve kentsel planlama stratejilerine entegrasyonunun gerekliliğini vurgulamaktadır.
Anahtar kelimeler: Hava kalitesi etkisi, Ekosistem hizmetleri, Doğal sit alanı, i-Tree Canopy, Sarayiçi tavuk ormanı

1. Introduction

Forests provide health, aesthetic, and recreational benefits, while providing vital resources such as food, fodder, fuel, and timber (Turner-Skoff and Cavender, 2019). They form prominent features of urban landscapes (Roy et al., 2012), and offer a range of benefits and functions, ranging from intangible psychological and aesthetic improvements to vital ecosystem services (Aerts and Honnay, 2011; Mori et al., 2017). The primary ecosystem services of forests are classified into four groups: provisioning, regulating, cultural, and supporting (MEA, 2005).

One of the most important regulatory services of forests is their impact on air quality (Smith, 1990). Forests improve air quality by trapping particulate matter and absorbing greenhouse gases (GHGs; Nowak et al., 2014). They can store, filter, and transform pollutants through their physiological characteristics (Nowak et al., 2018) and absorb and filter substantial amounts of carbon dioxide, particulate matter, nitrogen dioxide, and sulphur dioxide annually (Nowak et al., 2014). CO_2 is used in photosynthesis and stored in the tissues of woody plants. SO_2 and NO_2 are absorbed by leaves and removed from the environment (Smith, 1990). Particulate matter, namely $PM_{2.5}$ and PM_{10} (particles of 2.5 and 10 µm in size, respectively), which are among the most harmful components of air pollution (THHP, 2023), are collected on leaf surfaces and then transported into the soil with precipitation (Smith, 1990).

Particulate matter and greenhouse gases, produced by human activities such as heating, transportation, industry, and electricity generation, manifest themselves as a mixture of suspended solid and liquid particles in the air. This mixture contributes to many respiratory, cardiovascular, and nervous system disorders, including cancer (Perez et al., 2015). CO_2, in particular, leads to the greenhouse effect, which increases air temperature and stimulates the urban heat island effect in cities (Beckett et al., 1998). Therefore, air quality improvement has become imperative for urban residents as

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well as local and national authorities (Watts et al., 2015; MoEUCC, 2024a). In light of climate change and the adaptation requirements of cities in the 21st century (Tomlinson et al., 2011), the role of urban forests in air quality regulation has gained significant attention (Brack, 2002; Loughner et al., 2012; Nowak et al., 2014; Rahaman et al., 2021). Therefore, scientific studies assessing the regulatory ecosystem services of forests have gained prominence.

Escobedo et al. (2008) assessed the advantages of air purification by urban forests in Santiago and compared them with other effective air purification methods for pollutant removal. Similarly, Nowak et al. (2008) applied a ground-based method for ecosystem services assessment of urban forests in 14 United States cities, while Martin et al. (2012) analysed differences in carbon storage, carbon sequestration, and air pollution removal between protected and maintained forests in the USA. Hepcan and Hepcan (2017) assessed tree cover in the Ege University Housing Campus in İzmir and evaluated its effectiveness in removing harmful pollutants from the atmosphere. Tonyaloğlu et al. (2021) examined fragmented and scattered tree structures in Aydın City and calculated their impact on air quality at a city-scale

Ahern et al. (2014) emphasised the importance of quantifying ecosystem services through mathematical approaches. The i-Tree Canopy tool has been used to calculate the impact of trees on air quality (Nowak, 2021), evaluating the ability of forests to improve air quality by removing harmful substances from the air, and estimating the annual volume of various pollutants removed by trees (Qian et al., 2019). Given the constant and rapid changes in urban environments in the 21st century, the i-Tree Canopy tool provides a cost-effective, rapid, flexible, and practical assessment option for researchers, landscape managers, city planners, and policymakers.

Sarayiçi Tavuk Forest, a historically and ecologically valuable urban green space, is located in the central (Merkez) district of Edirne, covering 70.62 ha Access to Sarayiçi Tavuk Forest is via historic Ottoman bridges: Bönce (constructed in 1452) and Saray (constructed in 1554). The area includes a hunting pavilion (constructed in 1671) and the Mehmed Mansion, adding to the urban green space's ecological and cultural significance. In 2019, the Sarayiçi Tavuk Forest was designated as a 'Natural Site-Qualified Natural Conservation Area' and a 'Natural Site-Sustainable Conservation and Controlled Use Area' (MoEUCC, 2024b).

When forests are designated as protected areas, their role in providing ecosystem services becomes more prominent (Hayes and Ostrom, 2005). However, research on ecosystem services in forests classified as naturally protected sites in Türkiye is lacking. Başak et al. (2022) found that only 22.3% of studies on ecosystem services were carried out within strictly protected areas, notably biodiversity hotspots, in Türkiye. Moreover, these studies predominantly focused on a single dimension—cultural ecosystem services—or simultaneously addressed provisioning, regulating, and cultural ecosystem services.

As our understanding of the importance of natural protected areas and urban forests has increased, the need for in-depth information on regulating ecosystem services, with a focus on air quality improvement, has emerged as a key concern. The aim of this study was to bridge this knowledge gap and shed light on the critical importance of natural protected areas, particularly their role in regulating ecosystem services such as air quality improvement in Edirne, Türkiye. To the best of our knowledge, this is the first study to assess the current air quality impacts of a natural protected area in Edirne: Sarayiçi Tavuk Forest. Furthermore, the methodology applied here can inform future studies on air quality impact assessments of urban forests at the city-wide level.

2. Material and method

2.1. Study area

Sarayiçi Tavuk Forest is located 2.5 km far from the centre of Edirne Merkez District and adjacent to the Tunca River (41°41'47.21" N 26°33'37.67" E; Figure 1).

The forest served as a hunting ground during the Ottoman era, and the palace introduced various animals for hunting and planted diverse tree species, enriching the forest's plant and bird species (Özer, 2013). Usal (2006) characterised this area as a botanical laboratory and noted the presence of various medicinal herbs and bulbous plants. Marangoz (2022) identified tree and shrub species in Tavuk Forest as: *Acer negundo, Hedera helix, Robinia pseudoacacia, Biota orientalis, Laburnum anagyroides, Rosa canina, Celtis australis, Morus alba, Salix alba, Cercis siliquastrum 'Alba', Quercus cerris, Salix babylonica, Clematis vitalba, Quercus robur, Ulmus laevis, Eleagnus angustifolia, Platanus orientalis, Ulmus minor, Euonymus japonica, Populus alba, Thuja occidentalis, Fraxinus angustifolia, Populus nigra, Gleditschia triacanthos,* and *Prunus spinosa*. Known for its rich vegetation, the forest is home to approximately 70 bird species.

2.2. Calculating air quality impact

The air quality impact assessment was conducted using the i-Tree Canopy Tool v7.1 (a web-based GIS tool), developed by the USDA Forest Service (Nowak, 2021). To assess the air quality impact of the Sarayiçi Tavuk Forest, land-cover classes within the study area were first classified using the random point sampling method, which works in conjunction with Google Earth satellite imagery (Nowak, 2021). Examples of targeted land-cover classes are shown in Figure 2.

Figure 1. Study area

Figure 2. Visual representations of targeted land-cover classes: (1) Grass/Herbaceous, (2) Impervious Building, (3) Impervious Other, (4) Impervious Road, (5) Soil/Bare Ground, (6) Tree/Shrub (Source: Aerial Images from Google Earth Pro)

The analysis in i-Tree Canopy involved four steps. (1) Defining the boundaries of the study area using high-resolution Google Earth satellite images. (2) Identifying land-cover classes, including: 'Tree/Shrub' (trees and tall shrubs), 'Grass/Herbaceous' (covered areas with herbaceous vegetation), 'Soil/Bare Ground' (soil surfaces with scant or no vegetation), 'Impervious Buildings', 'Impervious Roads', and 'Impervious Other' (buildings, roads, and other impervious surfaces). (3) Generating 1,000 random sampling points within the study area, each assigned to a specific land-cover type, to assess the land-cover types in the Sarayiçi Tavuk Forest. To ensure accuracy with a confidence level of > 95% and a standard error of < 1.6%, 1,000 random points were used in accordance with the recommendations of the i-Tree Canopy user guide (https://canopy.itreetools.org/). (4) Based on the current regulatory requirements for tree/shrub cover area, ecosystem services and its benefits were estimated using i-Tree Canopy Tool that calculates carbon sequestration and storage and the removal of nitrogen dioxide, ozone, sulphur dioxide, PM2.5 and PM10 as well as their monetary value (Nowak et al., 2014; Nowak et al., 2018). The coefficient values for carbon estimations are based on the average carbon density per unit of canopy cover in urban areas. USA based average values were used to calculate the air pollutant removal rates, carbon sequestration and carbon storage values, as well as the economic values provided by a unit tree/shrub in the i-Tree Eco and statistically standardised based on USA cases (Çakmak and Can, 2020; Nowak, 2021).

3. Results and discussion

The land-cover classes, as well as random points (N), percentage and area for each land-cover class, percentage and area of all land-cover classes, standard error rates, and distribution of random sampling points are shown in Figure 3 and Table 1.

The dominant land-cover class in the study area was Tree/Shrub (84.72%, 59.83 ha). This was followed by Grass/Herbaceous (7.59%, 5.36 ha) and Soil/Bare Ground (4.30%, 3.03 ha). The least prevalent land-cover was impervious surfaces (3.40% ratio, 2.40 ha). Standard deviation values of < 1 indicated that the point distributions across the land-cover classes in the study area were equally weighted for all classes.

Table 1. Area and percentage of each land-cover class in the Sarayiçi Tavuk Forest

Cover class	Points (N)	% Cover ± SE	Area (ha) ± SE
Grass/Herbaceous	76	7.59 ± 0.84	5.36 ± 0.59
Impervious Buildings	20	2.00 ± 0.44	1.41 ± 0.31
Impervious Other	2	0.20 ± 0.14	0.14 ± 0.10
Impervious Road	12	1.20 ± 0.34	0.85 ± 0.24
Soil/Bare Ground	43	4.30 ± 0.64	3.03 ± 0.45
Tree/Shrub	847	84.72 ± 1.14	59.83 ± 0.80
Total	1,000	100.00	70.62

SE: Standard Error

Figure 3. Distribution of random sample points (N = 1,000) in Sarayiçi Tavuk Forest

The sensitivity of the i-Tree Canopy tool is directly related to the number of points used in the analysis. In this study, 1,000 points were distributed across the Sarayiçi Tavuk Forest, spanning 70.62 ha This quantity is consistent with acceptable norms, as observed in other studies that utilised the same assessment approach. For example, a study examining tree canopy in Atlantic Beach, Florida, which covers an area of 33.6 km^2, used 1,000 points (Marcus, 2015). Similarly, in a study that examined the tree canopies of 139 green areas in Australia, each region was assigned 1,000 points (Jacobs, 2013).

The i-Tree Canopy tool facilitates the computation of index values for the five key pollutants stipulated in Türkiye's National Air Quality Index: CO, NO_2, O_3, SO_2, and particulate matter (MoEUCC, 2024a). The quantities of pollutants removed from the atmosphere and the amount of carbon sequestrated and stored in the Sarayiçi Tavuk Forest are presented in Table 2. In total, Sarayiçi Tavuk Forest removes 5,014.68 kg of pollutant gases and particles from the air annually.

The amounts of CO and NO_2 removed from the air were estimated to be 75.74 and 418.44 kg/yr, respectively. The amount of O_3 removed was estimated at 3,232.29 kg/yr. The SO_2 removal through canopy was estimated to be 205.70 kg/yr. The amounts of particulate matter removed from the atmosphere by tree/shrub cover in the study area were estimated to be 165.13 kg/yr of $PM_{2.5}$ and 917.39 kg/yr of PM_{10}.

Moreover, the annual carbon sequestration by canopy cover was estimated at 183,000 kg/yr, with total carbon storage reaching 4,596,680 kg (Table 3).

The annual carbon sequestration by trees was estimated at 671,000.13 kg, with total carbon storage estimated at 16,854,000.51 kg (in CO_2 equivalent units). The annual economic value of regulatory ecosystem services that help improve air quality through canopy cover was estimated at 864,177 USD, and the value of carbon sequestered in trees annually was estimated at 34,410 USD. Several studies have focused on the role of forests in reducing carbon emissions and in capturing and storing carbon (Johnson el al., 2011). Natural protected areas, which include tall and aged plants, contribute positively to the urban climate by reducing temperatures in summer and increasing in winter, ensuring urban thermal comfort, and consequently reducing the amount of fossil fuels used for heating and cooling (Tomlinson et al., 2011; Cho et al., 2023). In this context, the presence of protected forests, especially those proximate to urban centres and those characterised by tree and tall shrub cover, holds great potential (Martin et al., 2012; Nowak et al., 2018). The results of this study show that Sarayiçi Tavuk Forest, located close to the city centre, plays a crucial role in improving air quality by removing pollutants, capturing particulate matter, and sequestering carbon from the air.

Table 2. Pollutants removed from the air annually

	Amount (kg) ± SE	Value (USD) ± SE
CO	75.74 ± 1.02	$111 ± $1
NO_2	418.44 ± 5.62	$202 ± $3
O_3	3,232.29 ± 43.44	$9,256 ± $124
SO_2	205.70 ± 2.76	$30 ± $0
PM2.5	165.13 ± 2.22	$19,378 ± $260
PM10*	917.39 ± 12.33	$6,339 ± $85
Total	5,014.68 ± 67.40	$35,316 ± $475

SE: Standard Error

The dominant tree and shrub species in Sarayiçi Tavuk Forest are *Acer negundo, Hedera helix, Robinia pseudoacacia, Biota orientalis, Laburnum anagyroides, Rosa canina, Celtis australis, Morus alba, Salix alba, Cercis siliquastrum 'Alba', Quercus cerris, Salix babylonica, Clematis vitalba, Quercus robur, Ulmus laevis, Eleagnus angustifolia, Platanus orientalis, Ulmus minor, Euonymus japonica, Populus alba, Thuja occidentalis, Fraxinus angustifolia, Populus nigra, Gleditschia triacanthos,* and *Prunus spinosa*. It is possible to assess the carbon storage or sequestration in different tree species (Durkaya and Durkaya, 2018). However, for statistical estimations of air quality and its associated economic value, the i-Tree Canopy tool considers the canopy cover of all trees and tall shrubs collectively, without distinguishing between species (Hilde and Paterson, 2014; Nowak, 2021). While this may be viewed as a limitation in accurately determining the precise values of ecosystem services and economic returns, large-scale studies conducted across extensive areas, facilitated by the simple, rapid, and cost-effective assessments provided by the i-Tree Canopy Tool, are crucial to well-founded urban and landscape planning decisions.

Understanding urban components such as urban forests and their economic value, along with regulatory ecosystem services, is crucial for citizens and local authorities. In this study, the annual economic value of the regulatory ecosystem services provided by the tree canopy, covering approximately 84.72% (Table 1) of the selected sample area for air quality improvement, was calculated to be approximately 69.726 USD (Table 2). Almost half of this contribution comes from annual carbon sequestration of trees in the study area. Additionally, the total amount of carbon stored over the life span of trees in the Sarayiçi Tavuk Forest is valued at 864,177 USD (Table 3). Numerous studies conducted in different areas have evaluated the economic contribution of urban forests to improving air quality. In Chicago, for example, Nowak et al. (2013) calculated the value of ecosystem services of open-green spaces to be 137 USD million; Hepcan and Hepcan (2017) calculated the economic value of Ege University housing complex to be approximately 112,000 USD. Similar studies conducted worldwide have also found high annual economic value contribution for regulatory ecosystem services, depending on the size and whether the forest is rural or urban. Considering these economic values and regulatory ecosystem services into account, urban forests contribute significantly to the urban economy, even if it is just to improve air quality.

Globally, numerous studies have assessed ecosystem services in rural landscapes, while research on urban landscapes accounts for only 10% of studies (Gómez-Baggethun and Barton, 2013; Derkzen et al., 2015). Likewise, Başak et al. (2022) showed that the majority of ecosystem services studies in Türkiye are predominantly conducted in rural landscapes such as Düzlerçam Forests (Balkiz, 2016), Istanbul Ömerli Basin (Albayrak, 2012), and Sultan Sazlığı National Park (Yıldız et al., 2023). This study represents an additional contribution to the assessment of regulatory ecosystem services in the urban forests of Türkiye.

Table 3. Tree benefit estimates of carbon

	Amount (kg) ± SE	CO_2 Equiv. (kg) ± SE	Value (USD) ± SE
C Sequestered Annually in Trees	183,000 ± 2.46	671.13 ± 9.02	$34,410 ± $462
C Stored in Trees (not an annual rate)	4,596,680 ± 61.78	16,854,000.51 ± 226.53	$864,177 ± $11,615

i-Tree Canopy is a rapid, pragmatic, and user-friendly tool designed to assess regulatory ecosystem services and their economic value. Although it is predominantly utilised in the United States, its application extends to various countries, including China, the United Kingdom, Canada, Australia, Switzerland, İran, and Türkiye (Hilde and Paterson, 2014; Qian et al., 2019; Ghorbankhani et al., 2023; Selim et al., 2023). The results obtained with this tool provide transparent data that illustrates the advantages associated with urban forests and vegetation.

One criticism of i-Tree Canopy is its reliance on baseline data, including carbon estimations, and air pollution removal capacities and their monetary values, which are statistically standardised based on calculations in the United States (Tuğluer and Gül, 2018; Çakmak and Can, 2020). The limitations associated with carbon estimations aligns with the limitations of the tree biomass estimates because both coefficient values are correlated. Nevertheless, it is noteworthy that this tool is increasingly being used in various countries and the carbon estimates are standardized values per unit of tree cover that are comparable to estimates for U.S. forests and from other cities around the world (Nowak et al., 2013). Its ease of use, swift results, and high accuracy in assessing air quality regulatory ecosystem services have led to widespread global adoption of the tool; coupled with the development of country-specific coefficients for regions of interest, is expected to facilitate the achievement of more accurate and precise results.

Augmenting both the quantity and quality of nationally protected urban forests, preserving trees and shrubs, and promoting biodiversity is expected to enhance regulating ecosystem services. This, in turn, is expected to positively impact citizens' budgets and contribute to the local economy, particularly through initiatives to improve air quality and reduce electricity and fossil fuel consumption for heating and cooling. Furthermore, studies based on ecosystem services will play a crucial role in disseminating such research to other cities in Türkiye. This alignment with international standards and principles facilitates the integration of study outcomes into local and regional planning and management processes.

4. Conclusion

The results of this research demonstrate the vital regulatory ecosystem services and economic value of a naturally protected urban forest in Edirne Merkez District. The extensive and dense canopy of the Sarayiçi Tavuk Forest removes 183,000 kg of C from the atmosphere annually and stores 4,596,680 kg of C throughout the lifespan of its trees. However, while this study concentrated on one area of Merkez District, comparable contributions from other urban green spaces with similar attributes would collectively increase these values. Moreover, the unique characteristics of the Sarayiçi Tavuk Forest not only make it a valuable component of urban green space in Merkez District but also serve as a prime example of natural protected areas in terms of regulatory ecosystem services. Along with analysing the status of the comprehensive knowledge gap on the ability of urban forests to regulate ecosystem services in Türkiye, especially Edirne, the results of this study provide spatially explicit information on the ability to improve air quality in Sarayiçi Tavuk Forest.

The structure and presence of urban green spaces requires vigilant protection against the pressure of urban expansion. Additionally, the contemporary surge in population and impervious surfaces in urban areas have highlighted the role of forests in regulating air quality. Therefore, Sarayiçi Tavuk Forest is crucial for the citizens of Edirne. The estimated ecosystem and monetary values of the Tavuk Forest are based on values per unit of tree cover in USA, where more comprehensive research based on local values (e.g. above/below ground biomass, and tree species) could result in higher ecosystem services and monetary values of Sarayiçi Tavuk Forest. The results of this study offer valuable insights for urban and landscape planners concerned with the maintenance of urban green spaces, at home and abroad. Recognising the importance of urban green areas and their regulatory ecosystem services and economic benefits can promote sustainable development in cities. In addition, uncovering the air quality impact of Sarayiçi Tavuk Forest will provide a basis for researchers, landscape managers, city planners, and policymakers to conduct ecosystem service-based research at a citywide scale while considering the urgent need for climate change adaptation and mitigation in the 21st century.

References

Aerts, R., Honnay, O., 2011. Forest restoration, biodiversity and ecosystem functioning. BMC Ecology, 11:1-10.

Ahern, J., Cilliers, S., Niemelä, J., 2014. The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. Landscape and Urban Planning, 125: 254–259.

Albayrak, İ., 2012. Applicability of ecosystem services based watershed management model in Istanbul–Omerli Case. PhD Thesis, The Technical University of İstanbul, Graduate School of Natural and Applied Sciences, İstanbul.

Balkiz, O., 2016. Assessment of the socio-economic values of goods and services provided by Mediterranean forest ecosystems - Düzlerçamı Forest, Turkey. Orman Genel Müdürlüğü, Doğa Koruma Merkezi and Plan Bleu, Valbonne. https://openknowledge.fao.org/server/api/core/bitstreams/f8456239-28f5-4b16-98a6-9b551332f481/content, Accessed: 31.05.2024.

Başak, E., Pamukcu-Albers, P., Karabulut, A.A., Demirbaş Çağlayan, S., Besen, T., Erpul, G., Balkız, Ö., Çokçalışkan, B.A., Per, E., Atkin, G., 2022. Ecosystem services studies in Turkey: A national-scale review. Science of the Total Environment, 844: 157068.

Beckett, K.P., Freer-Smith, P.H., Taylor, G., 1998. Urban woodlands: their role in reducing the effects of particulate pollution. Environmental Pollution, 99(3): 347–360.

Brack, C.L., 2002. Pollution mitigation and carbon sequestration by an urban forest. Environmental Pollution, 116(1): 195–200.

Cho, Y.Il, Yoon, D., Lee, M.J., 2023. Comparative analysis of urban heat island cooling strategies according to spatial and temporal conditions using unmanned aerial vehicles (UAV) Observation. Applied Sciences, 13(18): 10052. https://doi.org/10.3390/app131810052.

Çakmak, M.H., Can, M., 2020. Assessing regulating ecosystem services for improving the air quality of Mamak district (Ankara). Bilge International Journal of Science and Technology Research, 4(2): 141–149.

Derkzen, M.L., van Teeffelen, A.J.A., Verburg, P.H., 2015. Review: Quantifying urban ecosystem services based on high-resolution data of urban green space: An assessment for Rotterdam, the Netherlands. Journal of Applied Ecology, 52(4): 1020–1032.

Durkaya, B., Durkaya, A., 2018. Orman Biokütlesinin Atmosfere Katkısı. APJES, 6(1): 56–63. https://doi.org/10.21541/apjes.290427.

Escobedo, F.J., Wagner, J.E., Nowak, D.J., De La Maza, C.L., Rodriguez, M., Crane, D.E., 2008. Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. Journal of Environmental Management, 86(1): 148–157.

Ghorbankhani, Z., Zarrabi, M.M., Ghorbankhani, M., 2023. The significance and benefits of green infrastructures using I-Tree canopy software with a sustainable approach. Environment, Development and Sustainability, 26:14893–14913.

Gómez-Baggethun, E., Barton, D.N., 2013. Classifying and valuing ecosystem services for urban planning. Ecological Economics, 86: 235–245.

Hayes, T., Ostrom, E., 2005. Conserving the World's Forests: Are Protected Areas the Only Way? Indiana Law Review, 38: 595–617.

Hepcan, C.C., Hepcan S., 2017. Ege Üniversitesi lojmanlar yerleşkesinin hava kalitesinin iyileştirilmesine yönelik düzenleyici ekosistem servislerinin hesaplanması. Ege Üniversitesi Ziraat Fakültesi Dergisi, 54(1): 113–120.

Hilde, T., Paterson, R., 2014. Integrating ecosystem services analysis into scenario planning practice: Accounting for street tree benefits with i-Tree valuation in Central Texas. Journal of Environmental Management, 146: 524–534.

Jacobs, P., 2013. Temperature and Energy. Thermodynamics, Imperial College Press, London, UK.

Johnson, T.M., Guttikunda, S., Wells, G.J., Artaxo, P., Bond, T.C., Russel, A.G., Watson, J.G., West, J., 2011. Tools for Improving Air Quality Management: A Review of Top-down Source Apportionment Techniques and Their Application in Developing Countries. ESMAP formal report; no. 339/11. World Bank, Washington, DC. http://hdl.handle.net/10986/17488.

THHP, 2023. Kara Rapor 2022 Hava Kirliliği ve Sağlık Etkileri. TemizHavaHakkıPlatformu.https://www.temizhavahakki.org/wp-content/uploads/2023/03/KaraRapor_v6.pdf, Accessed:31.05.2024.

Loughner, C.P., Allen, D.J., Zhang, D.L., Pickering, K.E., Dickerson, R.R., Landry, L., 2012. Roles of urban tree canopy and buildings in urban heat island effects: parameterization and preliminary results. journal of applied meteorology and climatology, 51(10): 1775–1793.

Marangoz, Ç.G., 2022. Edirne Tavuk ormanı florası ve farmasötik özelliklerinin araştırılması. Yüksek Lisans Tezi, Trakya Üniversitesi, Sağlik Bilimleri Enstitüsü, Edirne.

Marcus, C., 2015. Tree Canopy Assessment City of Atlantic Beach, Florida. Legacy Arborist Services, USA.

Martin, N.A., Chappelka, A.H., Loewenstein, E.F., Keever, G.J., 2012. Comparison of carbon storage, carbon sequestration, and air pollution removal by protected and maintained urban forests in Alabama, USA. International Journal of Biodiversity Science, Ecosystem Services and Management, 8(3): 265–272.

MEA, 2005. Ecosystems and Human Well-Being, Synthesis, www.islandpress.org, Accessed: 31.05.2024.

MoEUCC, 2024a. Ministry of Environment, Urbanisation and Climate Change, National air quality monitoring stations web site, https://sim.csb.gov.tr/Services/AirQuality, Accessed:31.05.2024.

MoEUCC, 2024b. Ministry of Environment, Urbanisation and Climate Change, General Directorate of Protection of Natural Assets web site, https://tvk.csb.gov.tr/edirne-merkez-sarayici-tavuk-ormani-tescil-ilani-duyuru-396943, Accessed:31.05.2024.

Mori, A.S., Lertzman, K.P., Gustafsson, L., 2017. Biodiversity and ecosystem services in forest ecosystems: a research agenda for applied forest ecology. Journal of Applied Ecology, 54(1): 12–27.

Nowak, D.J., Crane, D.E., Stevens, J.C., Hoehn, R.E., Walton, J.T., Bond, J., 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry, 34(6): 347–358.

Nowak, D.J., Hoehn, R.E., Bodine, A.R., Crane, D.E., Dwyer, J.F., Bonnewell, V., Watson, G., 2013. Urban Trees and Forests of the Chicago Region. Resource Bulletin, NRS-84. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E., 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution, 193: 119–129.

Nowak, D.J., Hirabayashi, S., Doyle, M., Mcgovern, M., Pasher, J., 2018. Air pollution removal by urban forests in Canada and its effect on air quality and human health. Urban Forestry and Urban Greening, 29: 40–48.

Nowak, D.J., 2021. Understanding i-Tree: 2021 Summary of Programs and Methods. (General Technical Report NRS-200). Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 100 p. plus 14 appendixes.

Özer, M., 2013. Edirne Yeni Saray (Saray-i Cedîd-i Amire) kazısı 2009 yılı çalışmaları. Sanat Tarihi Dergisi, 22(2): 1–43.

Perez, L., Grize, L., Infanger, D., Künzli, N., Sommer, H., Alt, G.-M., Schindler, C., 2015. Associations of daily levels of PM10 and NO 2 with emergency hospital admissions and mortality in Switzerland: Trends and missed prevention potential over the last decade. Environmental Research, 140: 554–561.

Qian, W., Zhongxia, Z., Ping, W., 2019. An assessment of ecosystem services of urban green spaces based on i-Tree. Journal of Landscape Research, 11(1): 53.

Rahaman, S., Jahangir, S., Haque, M.S., Chen, R., Kumar, P., 2021. Spatio-temporal changes of green spaces and their impact on urban environment of Mumbai, India. Environment, Development and Sustainability, 23(4): 6481–6501.

Roy, S., Byrne, J., Pickering, C., 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban Forestry and Urban Greening, 11(4): 351–363.

Selim, S., Dönmez, B., Kilçik, A., 2023. Determination of the optimum number of sample points to classify land cover types and estimate the contribution of trees on ecosystem services using the I-Tree Canopy tool. Integrated Environmental Assessment and Management, 19(3): 726–734.

Smith, W.H., 1990. Air Pollution and Forest. Interactions between Air Contaminants and Forest Ecosystems. Springer New York, NY, USA.

Tomlinson, C.J., Chapman, L., Thornes, J.E., Baker, C.J., 2011. Including the urban heat island in spatial heat health risk assessment strategies: A case study for Birmingham, UK. International Journal of Health Geographics, 10(1): 1–14.

Tonyaloğlu, E.E., Kesgin, A.B., Yiğit, M., 2021. Düzenleyici Ekosistem Hizmetlerinden Hava Kalitesinin Efeler -Aydın Örneğinde İncelenmesi. Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi, 18(1): 119–125.

Tuğluer, M., Gül, A., 2018. The use of UFORE model for determination of environmental effects and value of urban trees; case study of Isparta city. Turkish Journal of Forestry, 19(3): 293–307.

Turner-Skoff, J., Cavender, N., 2019. The benefits of trees for livable and sustainable communities. Plants People Planet, 1(4): 323–335.

Usal, A., 2006. Edirne Tarihi ve Kültürü. Edirne Vergi Dairesi Başkanlığı, Edirne, Türkiye.

Watts, N., Adger, W., Costello, A., 2015. Health and climate change: policy responses to protect public health. The Lancet, 386(10006): 1861–1914.

Yıldız, R., Yücel, C., Katırcıoğlu, G., 2023. Korunan alanların sürdürülebilirliğinde planlama ve yönetim: Kayseri Sultan Sazlığı. Planlama, 33(2): 324–339.