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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Examination of Ecosystem Services: A Case Study of Amasya University Hakimiyet Campus

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Abstract: Background: Population growth, increasing vehicle numbers, unplanned urbanization and rural-urban migration are reducing green spaces and exacerbating environmental problems such as air, water and noise pollution. In this context, university campuses serve as important small-scale urban models that play a crucial role in maintaining environmental and social well-being within urban ecosystems. Objectives: To evaluate the regulating ecosystem services provided by the tree canopy at Amasya University Hâkimiyet Campus (AUHC), such as air quality, energy savings, and carbon storage. Method: In this study, the land cover and ecosystem services of the AUHC were assessed using the i-Tree Canopy model. Six land cover classes defined for the study area (tree/shrub, grass/herbaceous vegetation, soil/bare ground, impervious buildings, impervious roads, other impervious surfaces) were assessed using 4000 random points and ecosystem services such as air quality were calculated. Results: The tree and shrub canopy covering 31.30% of the AUHC removes 261.53 kg of gaseous and particulate pollutants from the air annually, sequesters 36.57 tons of carbon, and stores a total of 918.42 tons of carbon. The economic value of these ecosystem services was calculated as $758 for air pollution removal and $44420 for carbon storage. The land cover distribution of the campus shows that 57.35% consists of impervious surfaces (buildings, roads) and 42.05% is green space. Conclusion: The tree canopy at the AUHC makes a significant contribution to ecosystem services such as improved air quality, carbon sequestration and storage, and these contributions and economic benefits could be further enhanced by increasing tree cover.

Keywords: open green spaces, carbon amount, i-tree canopy, amasya university hakimiyet campus, amasya.

Ekosistem Hizmetlerinin Amasya Üniversitesi Hâkimiyet Yerleşkesi Örneğinde İrdelenmesi

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Öz: Arka Plan: Nüfus artışı, artan araç sayısı, plansız kentleşme ve kırsaldan kente göç, yeşil alanları azaltmakta ve hava, su ve gürültü kirliliği gibi çevresel sorunları artırmaktadır. Bu bağlamda, üniversite kampüsleri, kentsel ekosistemlerin çevresel ve sosyal refahını sürdürmede önemli bir rol oynayan küçük ölçekli kentsel modeller olarak hizmet etmektedir. Amaç: Amasya Üniversitesi Hâkimiyet Kampüsü'ndeki (AÜHK) ağaç örtüsünün sağladığı düzenleyici ekosistem hizmetlerini (hava kalitesi, enerji tasarrufu ve karbon depolama gibi) değerlendirmektir. Yöntem: Bu çalışmada, AÜHK'ndeki arazi örtüsü ve ekosistem hizmetleri, i-Tree Canopy modeli kullanılarak değerlendirildi. Çalışma alanı için tanımlanan altı arazi örtüsü sınıfı (ağaç/çalı, çim/otsu bitki örtüsü, toprak/bitkisiz alan, geçirimsiz yapılar, geçirimsiz yollar, diğer geçirimsiz yüzeyler) 4000 rastgele nokta üzerinden değerlendirildi ve hava kalitesi gibi ekosistem hizmetleri hesaplandı. Bulgular: AÜHK'nün %31,30'unu kaplayan ağaç ve çalı örtüsü, yıllık olarak havadan 261,53 kg gaz ve partikül kirleticiyi temizlemekte, 36,57 ton karbonu tutmakta ve toplamda 918,42 ton karbon depolamaktadır. Bu ekosistem hizmetlerinin ekonomik değeri, hava kirliliğini temizleme için 758$ ve karbon depolama için 44420$ olarak hesaplanmıştır. Kampüsün arazi örtüsü dağılımı, %57,35'inin geçirimsiz yüzeyler (binalar, yollar) ve %42,05'inin yeşil alanlar olduğunu göstermektedir. Sonuç: AÜHK'ndeki ağaç örtüsünün hava kalitesini iyileştirme, karbon yakalama ve depolama gibi ekosistem hizmetleri açısından önemli katkılar sağladığını, ancak ağaç örtüsünün artırılmasıyla bu katkıların ve ekonomik faydaların daha da artabileceğini göstermektedir.

Anahtar kelimeler: Açık yeşil alanlar, karbon miktarı, i-tree canopy, amasya üniversitesi hâkimiyet yerleşkesi, amasya.

INTRODUCTION

Over time, the increasing population and number of vehicles in cities, together with unplanned urbanization and rural-urban migration, have led to a reduction in green spaces and along with a growth in various environmental concerns, including air pollution, noise pollution, and water pollution. These factors have resulted in cities becoming unique ecosystems with their own characteristics. Urban ecosystems require sustainable planning and design decisions and implementation that balance conservation and use to ensure both environmental and social well-being.

The reduction and deterioration of green spaces in urban ecosystems negatively influence human health as well as the environment (Doğan and Eroğlu, 2021; Şahin Körmeçli, 2023). In addition, the increase in asphalt and building density, as well as the increase in pollutants from vehicular traffic and other production methods, directly affects ecosystem services such as global climate regulation (carbon storage) and ecological integrity in urban ecosystems (Aktaş et al., 2022). The presence of vegetation plays a crucial role in improving urban ecosystems by acting as a carbon sink, contributing significantly to urban ecology and mitigating the urban heat island effect. Depending on the density of vegetation, it also helps to trap particulate matter from the air (Ersoy Tonyaloğlu, 2023; Oğuztürk and Murat, 2023).

Ecosystem services encompass the benefits derived from ecosystem functions that serve humans, either directly or indirectly (services related to provision, regulation, habitat or support, and cultural aspects). The aim is to increase green spaces in cities and strengthen their connection with each other and with rural green spaces (MEA, 2005; Tülek and Ersoy Mirici, 2019). Plants, especially trees, perform many functions such as providing shade, cooling the air, reducing the heat island effect, storing CO_2, removing pollutants to clean the air, enriching the soil with organic matter such as leaves, branches and fruits, aerating the soil with their roots, providing food and shelter for wildlife, preventing surface runoff of rainwater, recharging groundwater sources, reducing wind and rain erosion, filtering noise, reducing energy consumption and increasing property values (Forman, 2014; Çorbacı and Ekren, 2021). These functions, defined as ecosystem services, vary depending on the species, age and characteristics of the environment in which the plants are located (Coşkun Hepcan and Hepcan, 2017; Sarı et al., 2020). Therefore, green spaces in cities are especially important in terms of ecosystem services (Bolund and Hunhammar, 1999; Forman, 2008; Derkzen et al., 2015). A study by Dogmusoz (2023) examined the costs and benefits of a green roof at Izmir Kâtip Celebi University to assess the economic feasibility of such projects in Izmir, Türkiye. The advantages were categorized into two groups: public and individual. Additionally, the study identified other benefits that were not easily quantifiable. Physical units were employed to measure each benefit and cost. The findings showed a positive Net Present Value (NPV) for the green roof project, indicating that it is a worthwhile investment with both public and individual advantages.

In many countries, university campuses, which are considered small-scale cities, play a key role in urban landscapes due to their dense structural elements (buildings, roads, hard surfaces) and high population (Ertekin and Çorbacı, 2010; Wibowo et al., 2019; Wang et al., 2021; Ercan Oğuztürk and Pulatkan, 2023). University campuses are not only institutions that provide education and facilities for cities, but also dynamic and multifaceted spaces that contribute to the social, cultural, economic, and environmental fabric of urban landscapes (Colding and Barthel, 2017; Çorbacı, 2017; Çorbacı et al., 2020). Furthermore, university campuses, with their green spaces, diverse vegetation and educational opportunities, enhance urban ecosystems and support the provision of ecosystem services that benefit human health, ecological diversity and the overall wellbeing of urban residents (Doğan et al., 2023; Srivanit and Hokao, 2013).

In recent times, the i-Tree Canopy (iTC) model, developed by the United States Department of Agriculture Forest Service and utilizing a random point sampling approach, has been applied to assess the ecosystem services provided by green spaces, factoring in canopy cover. The iTC tool, which is web-based, evaluates all shrub and tree vegetation in the study area under a single class and estimates the regulating services and their economic valuation (Hilde and Paterson, 2014; USDA, 2021).

Coşkun Hepcan and Hepcan (2017) demonstrated that the canopy cover of Ege University Housing Campus provides regulating ecosystem services that improve air quality. Çakmak and Can (2020) analyzed the role of trees in improving air quality in Ankara Mamak and assessed the economic value of these contributions. Ersoy et al. (2021) investigated the effects of trees and tall shrubs on air quality in Aydın Efeler and emphasized the importance of maintaining green spaces. Şahin Arslan (2021) highlighted the importance of green spaces in improving air quality by investigating the ability of trees in the Çorum Bahçelievler neighborhood to remove air pollutants. Ustun Topal and Demirel (2023) assessed the ecosystem services that improve air quality in the Kuzguncuk neighborhood of Üsküdar, Istanbul, highlighting the environmental and economic importance of green spaces. Şahin Körmeçli (2023) investigated the contributions of vegetation cover in Ankara Altınpark to air quality and determined the economic value of these contributions. Konakoğlu and Şenses (2023) studied the effects of GNSS technology on positioning accuracy in forested areas, highlighting the advantages of the Precise Point Positioning (PPP-AR) technique. Malkoç (2024) analyzed the ecosystem services provided by the Edirne Sarayiçi Tavuk Forest for air quality and assessed the economic value of these services. Elma and Ortaçeşme (2024) highlighted the impact of urbanization and increasing population density on green spaces and addressed the importance of these areas during the Covid-19 pandemic.

While these studies analyze ecosystem services such as air quality and carbon storage in specific cities or regions, your research emphasizes the role of university campuses in environmental and social well-being by considering the Amasya University Hâkimiyet Campus as a small-scale urban model. In addition, the identification of six different land cover classes provides a more detailed and systematic approach. By analyzing an educational institution such as Amasya University, your work makes a practical contribution to the academic literature by providing concrete recommendations for the improvement and conservation of green spaces.

This study addresses the concept of university campuses as small-scale city models, with Amasya University Hâkimiyet Campus selected as the study area. The aim of the study is to assess the regulating ecosystem services provided by the tree canopy at the campus, such as air quality, energy savings and carbon storage, using the web-based iTC tool.

MATERIAL AND METHOD

The Hâkimiyet Campus of Amasya University, located within Amasya Province's central district in Türkiye, was selected as the focus of this study. The campus is specifically located on Muhsin Yazıcıoğlu Street. The campus consists of the A-B-C blocks of the Faculty of Education, a conference hall, the central library building, the rectorate building and sports grounds (Figure 1). It is located 2.5 km from the center of Amasya. The campus is within walking distance of the city center, and it takes approximately 7 minutes by car to reach the city center via Muhsin Yazıcıoğlu Street.

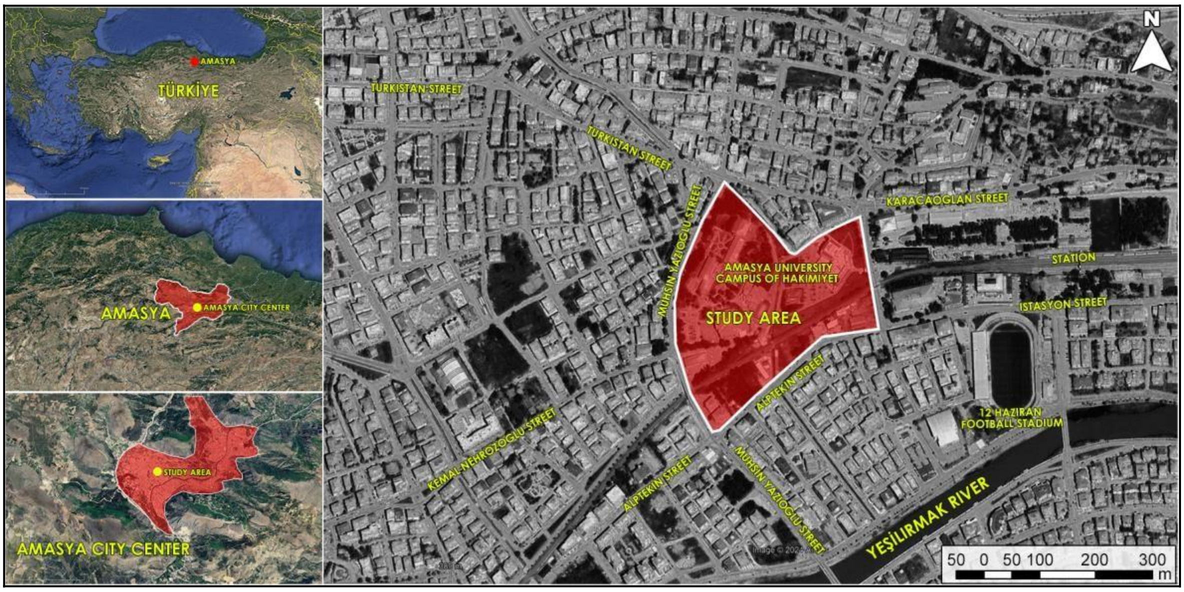

Figure 1. The study area.

This study used the i-Tree Canopy (iTC) model, developed by the United States Department of Agriculture Forest Service (USDA), which uses a random point sampling method. The iTC application is used in three main stages: defining the boundaries of the study area, identifying the types of land cover within the study area, and classifying the land cover based on random point sampling. After defining the boundaries of the study area in iTC, six land cover classes defined in the tool were evaluated in the study area.

These are:

(1) Tree/Shrub (tree and tall shrub vegetation),

(2) Grass/Herbaceous (areas covered with herbaceous vegetation),

(3) Soil/Bare Ground (soil surfaces with little or no vegetation),

(4) Impervious Buildings,

(5) Impervious Roads, and

(6) Other Impervious Surfaces.

In the study area, the tree canopy and other land cover were identified and the regulatory ecosystem services provided in terms of air quality were calculated using 4000 random points. Although the iTC tool manual recommends using a total of 500-1000 points, this study aimed to increase accuracy by ensuring that the margin of error for each land cover type was less than ±1. Finally, the results obtained from the iTC tool were reported and used for evaluation and recommendations.

RESULTS AND DISCUSSION

The Hâkimiyet Campus of Amasya University has academic buildings (Faculty of Education A-B-C Blocks), an administrative building (Rectorate Building) and sociocultural buildings (Conference Hall, Central Library Building). The campus transport infrastructure consists of roads for vehicles and pedestrians. Car parks, which are an essential element of the transport system, are located parallel to the road. There is a large car park with an impermeable concrete surface near the Rectorate and Library buildings. There are no cycle paths within the campus. The green space system of the campus consists of areas outside the campus buildings and transport networks (Kurt Konakoğlu and Celik, 2023). In a study conducted by Kurt Konakoğlu and Keskiner (2021), 30 different plant taxa were identified on the campus, including 16 deciduous trees and shrubs, 8 evergreen trees and shrubs, and 6 shrubs.

In this study, the iTC tool was used to randomly sample 4000 points based on satellite imagery of the campus. This application uses aerial imagery to assess land cover in each area and classifies it into seven categories: trees/shrubs, grass/herbaceous plants, soil/bare ground, impervious buildings, impervious roads, other impervious surfaces, and water surfaces.

The land cover types identified at the campus and the number of random points used for each land cover type, along with the total areas (m², %) and standard deviation rates for each land cover type are presented in Table 1. Of these points, 1252 are tree/shrub (29663.455 m²), 430 are grass/herbaceous (10238.545 m²), 24 are soil/bare ground (526.09 m²), 650 are impervious buildings (15054.304 m²), 1474 are impervious roads (35207.648 m²) and 170 are other impervious surfaces (3723.107 m²).

The distribution of points within the land cover classes on the campus, from highest to lowest percentage, is as follows 36.85% impervious roads, 31.30% trees/shrubs, 16.25% impervious buildings, 10.75% grass/herbaceous plants, 4.25% other impervious surfaces and 0.60% soil/bare ground (Figure 2).

Table 1. i-Tree Canopy tool land cover classes and their spatial distributions.

Land Cover Class	Land Cover Description	Number of Random Points	Percentage Covered (%)	Standard Deviation (± SD)	Area (m^2)
Tree/Shrub	Areas covered with trees and tall shrubs	1252	31.30	± 0,73	29663.455 m^2
Grass/Herbaceous Plants	Areas covered with grass and herbaceous plants	430	10.75	± 0,49	10238.545 m^2
Soil/Bare Ground	Surfaces with sparse or no vegetation cover	24	0.60	± 0,12	526.09 m^2
Impervious Buildings	All buildings and other structural elements	650	16.25	± 0,58	15054.304 m^2
Impervious Road	Roads made of asphalt, concrete, etc.	1474	36.85	± 0,76	35207.648 m^2
Other Impervious Surfaces	Areas covered with artificial ground materials	170	4.25	± 0,32	3723.107 m^2
Water Surfaces	Artificial and natural water surfaces	0	0.00	±0,00	0.00 m^2
Total		**4000**	**100.00**		**94413.150 m^2**

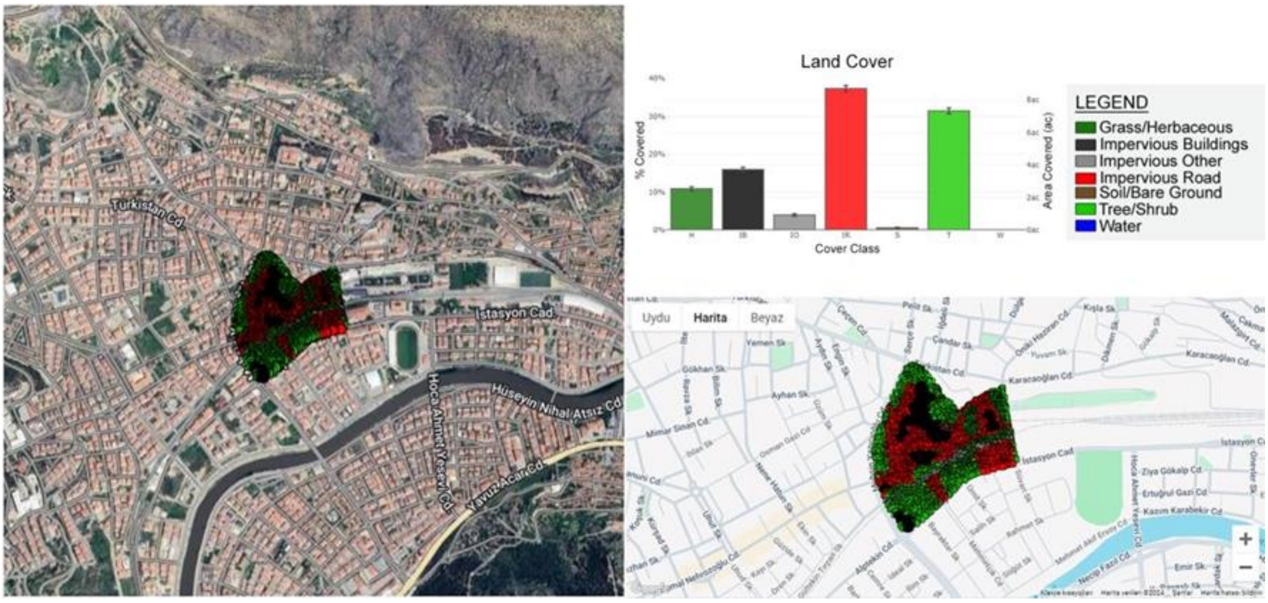

Figure 2. Distribution of sample points within land classes in the study area.

According to the assessment, more than half (57.35%) of the campus consists of buildings, roads and other impervious surfaces (53985.059 m²). Almost half (42.05%) of the campus area is covered with trees/shrubs and grass/herbaceous plants (39902 m²). Open areas with bare soil or no vegetation represent 0.60% of the total study area, with a surface area of 526.09 m².

As a result of the land cover classification conducted using the iTC tool, the pollutants removed from the atmosphere, the amounts of carbon captured and stored, and their monetary values ($) for the regulatory ecosystem services of the campus are shown in Table 2. The trees on the campus remove a total of 261.53 kg of gaseous and particulate pollutants from the air annually, while the estimated annual amount of carbon captured by the tree canopy is 36.57 tons, and the total amount of carbon stored by the tree canopy is calculated to be 918.42 tons. The economic benefit associated with the removal of gaseous and particulate pollutants by the tree/shrub canopy covering 31.30% of the study area is calculated to be $758, while the estimated economic value associated with the carbon captured and stored is $44420. The highest potential regulatory service and economic benefit of the campus tree canopy in terms of air quality is identified as the service value provided for the annual removal of ozone (O_3) and particulate matter (PM_{10}) from the air.

Table 2. Regulatory ecosystem services provided by the tree cover in the study area.

Abbr.	Pollutants Removed from the Atmosphere	Amount	± SD	Value ($)	± SD
CO	Carbon monoxide (annual)	3.16 kg	± 0.07	5	± 0
NO_2	Nitrogen dioxide (annual)	12.50 kg	± 0.29	2	± 0
O_3	Ozone (annual)	150.63 kg	± 3.53	97	± 2
SO_2	Sulfur dioxide (annual)	26.97 kg	± 0.63	0	± 0
$PM_{2.5}$	Particulate matter (annual)	7.87 kg	± 0.19	204	± 5
PM_{10}	Particulate matter (annual)	60.40 kg	± 1.42	450	± 11
CO2seq	Carbon dioxide sequestered by woody plants (annual)	36.57 ton	± 0.86	1701	± 40
CO2stor	Carbon dioxide stored by woody plants (annual)	918.42 ton	± 21.51	42719	± 1001

*The currency is in USD and has been rounded. Standard deviation for removal and benefit amounts are based on the standard deviation of sampled and classified points. SD: Standard Deviation.

Comparing the estimated values in Table 2 for the study area with the values obtained in other studies, it can be stated that the campus has average values both in terms of tree cover and potential regulating services that can be obtained. In a study conducted by Coşkun Hepcan and Hepcan (2017) on the Ege University Housing Campus, it was calculated that the trees on the campus remove a total of 289.27 kg of gaseous and particulate pollutants from the air annually. The estimated annual amount of carbon captured by the canopy is 321.57 tons, and the total amount of carbon stored by the canopy is 8107.86 tons.

The economic benefit related to the removal of gaseous and particulate pollutants by the tree/shrub canopy is calculated to be $845.96, while the estimated economic value corresponding to the carbon captured and stored is $405030.13. In the study conducted by Dilaver et al. (2017) at Ankara University Tandoğan Campus, it was calculated that the trees on the campus remove a total of 17935.30 kg of gaseous and particulate pollutants from the air annually, while the total amount of carbon stored by the tree canopy is 160813.24 tons.

In the study conducted by Ersoy Tonyaloğlu (2023) on the central campus of Aydın Adnan Menderes University, it was calculated that the trees on the campus remove a total of 77.15 kg of gaseous and particulate pollutants from the air annually, with the estimated annual amount of carbon captured by the canopy being 34.98 tons, and the total amount of carbon stored by the canopy being 878.44 tons. The economic benefit associated with the removal of gaseous and particulate pollutants by the tree/shrub canopy covering 12.73% of the study area is calculated to be $8.80, while the estimated economic value associated with the carbon sequestered and stored is $294.74.

Ege University's residential campus was established in 1960, Ankara University's Tandoğan campus in 1942, and Aydın Adnan Menderes University's central campus in 1992. Although campus use patterns and establishment dates are influential in both this study and the findings of Coşkun Hepcan and Hepcan (2017), Dilaver et al. (2017), and Ersoy Tonyaloğlu (2023), it is clear that the potential benefits of high tree cover are noteworthy. In addition to these campus-scale studies, Yin et al. (2011) and Kim and Coseo (2018) used the iTC tool at the city scale, Ersoy Tonyaloğlu et al. (2021) and Şahin Körmeçli (2023) at the district scale, and Ghorbankhani et al. (2023) and at the neighborhood scale, Ustun Topal and Demirel (2023) highlighted how vegetation contributes to reducing carbon emissions while capturing and storing carbon in urban areas.

This study shows that the tree canopy, which covers 31.30% of the total area of the Hâkimiyet Campus of Amasya University, provides high economic benefits.

CONCLUSION AND RECOMMENDATIONS

Population growth and urbanization in cities adversely affect air quality. The decrease in vegetated areas and the expansion of impervious surfaces within urban ecosystems have contributed to the urban heat island effect and increased carbon emissions. In this context, this study seeks to emphasize the ecological and economic significance of green spaces on university campuses, which serve as small-scale urban models, particularly in terms of their ecosystem services.

The research focuses on the regulating ecosystem services derived from tree cover and their associated monetary values on university campuses, where environmental impacts are increasingly important, using the Hâkimiyet campus of Amasya University as a case study. The i-Tree Canopy (iTC), a web-based application, was employed to analyze the impact of campus vegetation on air quality improvement carbon capture/storage and economic benefits, considering six land cover types and their spatial distribution over 4000 randomly selected points. Findings showed that the tree and shrub canopy, covering 31.30% of the study area, effectively removes 261.53 kg of gaseous and particulate pollutants from the air, captures 36.57 tons of carbon, and sequesters 918.42 tons of carbon. The economic benefit of the pollutant removal is estimated at $758, while the estimated economic value corresponding to the carbon captured and stored is $44420. This contribution value represents the sum of the calculations for carbon storage, capture and removal of air pollutants. Increasing the diversity of tree and shrub species on campus would increase the ecosystem benefits. Among the pollutants removed from the air, ozone (O_3), which has a significant impact on climate change, provides the highest benefit. Therefore, campuses with dense vegetation have a significant impact in diminishing the effects of greenhouse gases in the context of climate change.

Although iTC provides estimates based on canopy cover rather than speciesbased assessments, it contributes to the assessment of deficiencies at different scales and the development of urban ecosystems. Comprehensive studies should be conducted in our country to establish databases and develop methods and modules for assessing the species-specific contributions of campuses to the ecosystem.

This study reveals that the low tree cover on the campus is a limiting factor in terms of regulatory ecosystem services. However, considering the potential for increasing tree cover, it can be concluded that the campus has a good potential for increasing regulatory ecosystem services and their associated economic benefits, both within the campus and for the city. However, improving and increasing tree cover will require significant investment. As shown in this study, it is essential to make general estimates and assessments of the benefits (ecosystem services and economic) provided by tree cover alongside other land cover types, especially for large areas.

Finally, campuses, which can be seen as small city models, must not overlook the importance of maintaining existing trees and tall shrubs and enhancing biodiversity. Prioritizing species that support biodiversity and are suited to local climatic conditions, especially native species, will help to improve and increase tree cover. Even though young trees and shrubs contribute fewer ecosystem services than mature ones, increasing the diversity and number of these younger plants will remain vital for ecosystem services and economic benefits.

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