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Research Article

THE EFFECT OF GREEN AREAS ON AIR QUALITY IN THE CONTEXT OF ECOSYSTEM SERVICES: CASE STUDY ÇANAKKALE

Beyzanur Karaca[1 a] * – Asst. Prof. Aylin Çelik Turan [2 b]

[1] Çanakkale Onsekiz Mart University, Graduate Education Institute Landscape Architecture Department, Çanakkale,Türkiye
[2] Çanakkale OnsekizMart University, Faculty of Architecture and Design, Landscape Architecture Department, Çanakkale,Türkiye

**Corresponding Author:*
E-mail: beyzanurkaracaa.07@gmail.com

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a: ORCID 0009-0003-3494-9222, b: ORCID 0000-0002-1672-1254

ABSTRACT. Climate change is one of the most significant environmental challenges threatening urban ecosystems and undermining sustainability worldwide. Rising temperatures, air pollution, and intensive urbanization directly affect the quality of life in cities and constrain the natural functions of ecosystems. In this context, urban green spaces play a critical role in terms of ecosystem services. Green spaces contribute to the improvement of urban air quality through functions such as carbon sequestration, reduction of fine particulate matter, regulation of microclimate, and support for biodiversity. However, the per capita amount of green space and the integration of green corridors into urban infrastructure systems often remain below international standards, which limits the realization of ecological and recreational benefits.

This study examines the per capita availability of green spaces and their carbon sequestration capacities, as well as their impacts on air quality, with a focus on the city center of Çanakkale and the Kepez district. Carbon sequestration calculations, GIS-based spatial analyses, and ecosystem service valuation methods were employed to model the contributions of green spaces to urban air quality. The findings highlight the importance of the environmental impacts of green spaces within the framework of ecosystem services and emphasize their integration into urban planning processes. The case of Çanakkale demonstrates that green space planning can serve as a strategic tool for climate change adaptation in small- and medium-sized cities. In this respect, the study aims both to contribute to the academic literature and to provide a guiding model for local governments in sustainable urban planning.

Keywords: *urban green space, carbon sequestration, gis, ecosystem services*

INTRODUCTION

The impacts of climate change are becoming increasingly visible in urban areas today. Rising heat waves, sudden and intense precipitation events, and the urban heat island effect place significant pressure on infrastructure systems while simultaneously threatening human health (1). This situation underscores the necessity of making cities more resilient to climate change. In this context, urban green spaces are positioned at the core of climate adaptation strategies, not only for their aesthetic or recreational values but also for the ecosystem services they provide.

Green spaces fulfill multiple functions, including improving air quality, regulating temperature, facilitating rainwater infiltration into soil, and offering opportunities for physical activity and social interaction to urban residents. The World Health Organization WHO, 2016 [3] emphasizes that access to green spaces reduces stress levels, promotes physical activity, and generates positive effects on overall health. These findings demonstrate that green spaces provide not only environmental but also social and economic benefits.

In recent years, green infrastructure systems—such as parks, afforestation areas, green roofs, and rain gardens—have been proven effective in mitigating urban heat island effects (4). Green infrastructure also enhances urban resilience by delivering multifunctional benefits such as carbon sequestration, biodiversity conservation, and improvements in urban quality of life (5,6). These diverse contributions render green infrastructure not merely an environmental solution but also a fundamental component of social and economic sustainability.

The preservation and expansion of urban green spaces have become a strategic necessity in the face of pressures exerted by climate change on cities. Kuittinen et al. 2025 [7] highlight that green spaces play a critical role in combating climate change and in the creation of sustainable cities. Accordingly, the planning and management of green spaces should be regarded as a strategy that supports not only environmental benefits but also the social cohesion and economic vitality of cities.

Therefore, this study aims to provide a scientific framework for sustainable urban planning by examining the role of urban green spaces in ecosystem services and climate change adaptation processes. Although numerous studies in the literature have addressed ecosystem services of green spaces, their holistic consideration in the context of climate change adaptation remains limited. The primary contribution of this study is to develop a comprehensive approach that evaluates the ecological, social, and economic functions of green spaces together, thereby enhancing the resilience of cities against climate change.

MATERIALD AND METHODS

This research was conducted in Çanakkale Province, located in the Marmara Region of Turkey. Çanakkale holds a strategic position connecting the continents of Asia and Europe and encompasses significant ecological and socio-economic characteristics along the Dardanelles Strait. The study area covers the city center of Çanakkale and the Kepez district. A map of the study area is presented in Figure 1.

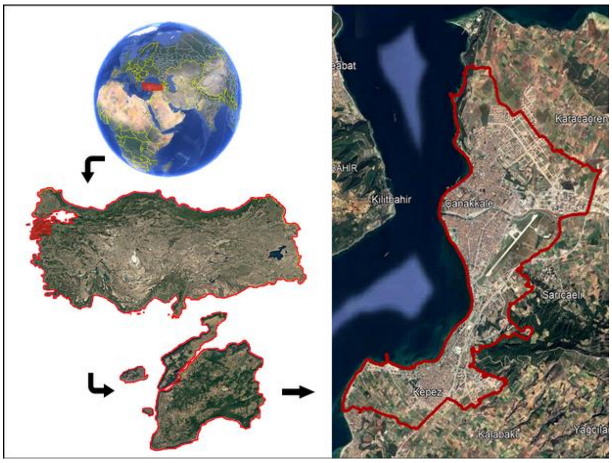

Fig. 1. *Study Boundary (source: generated from Google Earth Pro, 2025).*

Within the study boundaries, there are nine neighborhoods and one military security zone. However, only six of these neighborhoods were designated as the project area. These are: Esenler Neighborhood, Cevatpaşa Neighborhood, Kemalpaşa Neighborhood, İsmetpaşa Neighborhood, Barbaros Neighborhood, and the Kepez District. Among these, Esenler Neighborhood constitutes the largest share of the project area in terms of spatial density. These areas are presented in Figure 2.

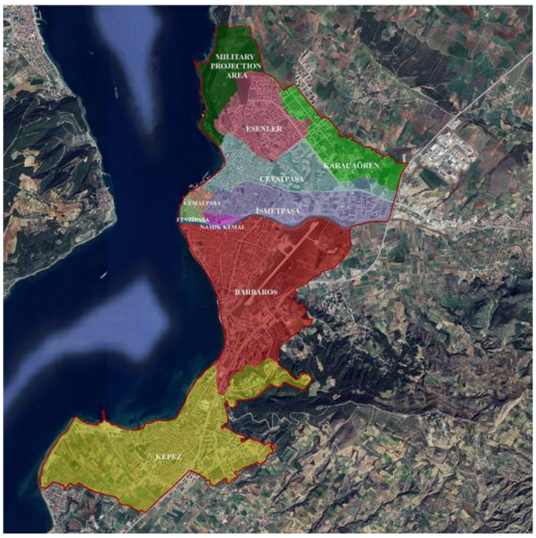

Fig. 2. *Neighborhood map (source: generated from Google Earth Pro, 2025).*

The parks within the study area were color-coded according to neighborhoods. Esenler Neighborhood (pink) contains a total of 17 green infrastructure areas, consisting of 14 parks, 1 picnic area, 1 monument site, and 1 afforestation area. Cevatpaşa Neighborhood (blue) includes 7 areas, comprising 5 parks, 1 monument site, and 1 cemetery. Kemalpaşa Neighborhood (orange) encompasses 2 areas: 1 square and 1 park. İsmetpaşa Neighborhood (purple) contains 3 areas, including 2 parks and 1 monument site. Barbaros Neighborhood (red) consists of 10 park areas. Kepez Neighborhood (yellow) includes a total of 6 park areas within the scope of the study. The research was conducted on a total of 43 selected green spaces, from which relevant data were collected. This representation is illustrated in Figure 3.

Fig. 3-1. *Neighborhood map (source: generated from Google Earth Pro, 2025).*

Fig. 3-2. *Neighborhood map (source: generated from Google Earth Pro, 2025).*

CONCLUSION AND DISCUSSION

The Energy Information Administration (1998) table was employed as the methodological basis for this study [9]. The primary aim of the research is to calculate the total annual carbon sequestration of green spaces located in the city center of Çanakkale, applying the carbon retention method developed by the Energy Information Administration. The table utilized in the research is presented in Figure 4.

Reporting year:								
A. Species characteristics			B. Tree age	C. Number of trees at age 0 age	D. Survival factor	E. Number of surviving trees	F. Annual retention rate	G. Stored carbon
Name	Tree type	Growth rate						
Total stored carbon								
Total stored CO_2 equivalent *3.67								
Stored CO_2 short ton equivalent /2000								

Fig. 4. *Carbon Sequestration Chart of Urban Trees (Energy Information Administration (1998).*

Carbon sequestration was calculated in kilograms. In estimating the carbon retention of urban trees, the following variables were employed:

- Column A: Code data related to tree species, type, and growth rate.
- Column B: The time span from the planting date to the current date.
- Column C: The actual age of the tree.
- Column D: Survival factor data.
- Column E: The number of surviving trees, calculated by multiplying the survival factor by the actual age.
- Column F: Annual carbon sequestration rate, derived from Table 4.
- Column G: The product of the number of surviving trees and the annual carbon sequestration rate. The resulting carbon sequestration value is expressed in pounds (lbs). Multiplying this value by 3.67 yields the equivalent total carbon dioxide sequestration (in pounds). The short ton equivalent of carbon dioxide sequestration is obtained by dividing by 2000.

These parameters assist in estimating the annual carbon sequestration of each tree and enable a more accurate evaluation of the ecological contribution of urban green spaces.

Furthermore, the neighborhoods within the study area were assessed in terms of existing green space conditions and per capita green space availability. From an area-based perspective, considering both surface area and accessibility to green spaces, Kemalpaşa Neighborhood emerges as the most advantageous location. This distribution is illustrated in Figure 5.

NEİGHBORHOOD	POPULATION	GREEN AREA	GREEN AREA PER CAPİTA
KEMALPAŞA	23109	2562,2	9,02
İSMETPAŞA	24763	7315	3,4
CEVATPAŞA	23109	41930,7	0,55
BARBAROS	62690	68889,5	0,1
ESENLER	29775	56382,7	0,52
KEPEZ	36264	48195	0,75

Fig. 5. *Current status of green spaces by neighborhood*

Each green space was visited individually and assessed on-site; carbon sequestration values were calculated separately according to the specific characteristics of each area. The tables generated using the Energy Information Administration 1998 [9] methodology (U.S. Energy Information Administration, 1998) are presented for one study site from each neighborhood. In total, six green spaces were subjected to carbon sequestration calculations. These are illustrated in Figure 6.

Reporting Year:2024 emekli öğretmen ağaçlandırması									
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
Name	tree type	growth rate						
pinus pinea	c	m	19	32	0,472	15,104	15,7	237,1328
acacia penninervis	h	f	18	2	0,495	0,99	36,3	35,937
catalpa	h	m	8	48	0,603	28,944	9,1	263,3904
prunus armeniaca	h	m	12	47	0,551	25,897	9,1	235,6627
cupressus sempervirens	c	s	18	32	0,469	15,008	6,6	99,0528
robinia pseudoacacia	h	s	16	42	0,490	20,58	8,6	176,988
cupressus lusitanica	c	f	16	42	0,516	21,672	23,2	502,7904
Total Stored Carbon								1550,9541
Total Stored CO_2 Equivalent × 3.67								5692,00155
Stored CO_2 Short Ton Equivalent/2000								2,84600077

Fig. 6-1. *Carbon sequestration values of parks in Esenler Neighborhood*

Reporting Year:2024 ingiliz mezarlığı								
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
Name	tree type	growth rate						
cupressus sempervirens	c	s	28	21	0,375	7,875	11,2	88,2
Total Stored Carbon								88,2
Total Stored CO_2 Equivalent × 3.67								323,694
Stored CO_2 Short Ton Equivalent/2000								0,161847

Fig. 6-2. *Carbon sequestration values of parks in İsmetpaşa Neighborhood*

Reporting Year:2024 cumhuriyet meydanı								
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
Name	tree type	growth rate						
pinus pinea	c	m	19	32	0,472	15,104	15,7	237,1328
acacia penninervis	h	f	18	2	0,495	0,99	36,3	35,937
catalpa	h	m	8	48	0,603	28,944	9,1	263,3904
prunus armeniaca	h	m	12	47	0,551	25,897	9,1	235,6627
cupressus sempervirens	c	s	18	32	0,469	15,008	6,6	99,0528
robinia pseudoacacia	h	s	16	42	0,490	20,58	8,6	176,988
cupressus lusitanica	c	f	16	42	0,516	21,672	23,2	502,7904
Total Stored Carbon								1550,9541
Total Stored CO_2 Equivalent × 3.67								5692,00155
Stored CO_2 Short Ton Equivalent/2000								2,84600077

Fig. 6-3. *Carbon sequestration values of parks in Kemalpaşa Neighborhood*

Reporting Year:2024 cevatpaşa parkı								
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
name	tree type	growth rate						
Fraxinus excelsior	c	f	11	4	0,576	2,304	14,7	33,8688
Fraxinus excelsior	c	f	7	2	0,630	1,26	8,9	11,214
Ulmus Glabra	h	m	11	3	0,564	1,692	12,3	20,8116
Platanus oriental	h	f	18	1	0,495	0,495	36,3	17,9685
Punica granatum	h	m	9	2	0,589	1,178	10,2	12,0156
Quercus rubra	h	m	17	1	0,493	0,493	19,4	9,5642
Fraxinus excelsi	c	f	19	2	0,484	0,968	28,8	27,8784
Fraxinus excelsi	c	f	15	3	0,527	1,581	21,4	33,8334
Total Stored Carbon								167,1545
Total Stored CO_2 Equivalent × 3.67								613,457015
Stored CO_2 Short Ton Equivalent/2000								0,30672851

Fig. 6-4. *Carbon sequestration values of parks in Cevatpaşa Neighborhood*

Reporting Year:2024 fatih duru parkı								
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
name	tree type	growth rate						
Cupressus arizonica	c	f	10	8	0,589	4,712	13,2	62,1984
Acacia penninervis	h	f	8	10	0,616	6,16	15,5	95,48
Oleae europaea	h	s	8	4	0,603	2,412	4,6	11,0952
pinus pinea	c	m	8	4	0,603	2,412	5,8	13,9896
Total Stored Carbon								182,7632
Total Stored CO_2 Equivalent × 3.67								670,740944
Stored CO_2 Short Ton Equivalent/2000								0,33537047

Fig. 6-5. *Carbon sequestration values of parks in Barbaros Neighborhood*

Reporting Year:2024 musaddin kapucu piknik alanı								
A. Species Characteristics			B. Tree Age	C. Number of Trees at Age 0	D. Survival Factor	E. Number of Surviving Trees	F. Annual Retention Rate	G. Stored Carbon
Name	tree type	growth rate						
pinus pinea	c	f	24	257	0,435	111,795	39,1	4371,1845
Total Stored Carbon								4371,1845
Total Stored CO_2 Equivalent × 3.67								16042,2471
Stored CO_2 Short Ton Equivalent/2000								8,02112356

Fig. 6-6. *Carbon sequestration values of parks in Kepez District*

NAME	NEIGHBORHOOD	POPULATION	GREEN AREA	CARBON SEQUESTRATION
sinan cemgil parkı	esenler	29775	2264	0,50
çakader parkı	esenler	29775	651	0,21
muhtarlık	esenler	29775	2611,7	786
adnan kahveci piknik alanı	esenler	29775	4357	1,68
Kale-i sultaniye	cevtpaşa	23109	10185	1,80
ingiliz mezarlığı	ismetpaşa	25.221	3028	0,16
köy enstütüleri	esenler	29775	1308	0,62
can dostlar	esenler	29775	2126	2
chp kadın kolları parkı	esenler	29775	1702	0,40
emekli öğretmen ağaçlandırması	esenler	29775	1060	2,8
zübeyde hanım parkı	esenler	29775	1913	0,4
ışılay parkı	esenler	29775	2184	0,3
uğur mumcu parkı	esenler	29775	1968	455
cumhuriyet meydanı	kemalpaşa	1.525	1110,8	0,4
morabbin parkı	cevatpaşa	23109	377,9	0,5
hamidiye şehitliği	barbaros	62690	505,2	0,1
özgürlük parkı	esenler	29775	22571	2,2
barışkent parkı	esenler	29775	1246	0,4
masal parkı	esenler	29775	2552	0,04
75.yıl parkı	barbaros	62690	16099	1
barbaros parkı	barbaros	62690	537,9	0,06
cocuk parkı2	barbaros	62690	141,4	0,03

Fig. 7-1. *Total Carbon Sequestration of Urban Green Spaces*

NAME	NEIGHBORHOOD	POPULATION	GREEN AREA	CARBON SEQUESTRATION
cevatpaşa parkı	cevatpaşa	23109	510	0,3
rotary parkı	cevatpaşa	23109	1629	0,5
500.yıl parkı	cevatpaşa	23109	11121,8	1,7
muammer aksoy parkı	kemalpaşa	1.525	1451,4	0,60
cami parkı	esenler	29775	2454	0,2
sağlıklı yaşam parkı	barbaros	62690	3973,5	0,1
fatih duru parkı	barbaros	62690	1460	0,3
ahmet taner kışlalı	barbaros	62690	844	0,3
hamidiye tabyası	barbaros	62690	31459,5	1,4
osnabrük parkı	barbaros	62690	2720	1,6
sarıçay parkı	ismetpaşa	25.221	4287	7,9
yeni kordon	barbaros	62690	11149	0,7
şahika encümen parkı	kepez	36264	1202	1,2
kordon parkı	kepez	36264	359	0,04
şehit murat düger parkı	kepez	36264	1414	0,5
vazo parkı	kepez	36264	1302	0,8
metin topsoy parkı	kepez	36264	343	0,3
musaddin kapucu piknik alanı	kepez	36264	43575	8
başkan fip parkı	esenler	29775	2417	0,3
çocuk parkı2	esenler	29775	2998	0,03
halk bahçesi	cevatpaşa	23109	18107	0,04
			toplam:1283,41	

Fig. 7-2. *Total Carbon Sequestration of Urban Green Spaces*

Thus, carbon sequestration data were obtained both at the neighborhood level and for individual green spaces. Consequently, the study aims to emphasize the impact of urban green spaces in the city center of Çanakkale on air quality, providing valuable insights and outputs for multiple professional disciplines such as urban planning, environmental science, landscape architecture, and climate policy.

RESULTS

Analyses reveal that the proportion of green spaces in the city center of Çanakkale is approximately 1.39%. This level is insufficient for residents to access green areas, engage in recreational activities, rest in shaded spaces, and benefit from ecosystem services. While current zoning regulations stipulate 10 m² of active green space per capita, our study calculated only about 1.11 m². This indicates that the available green spaces are inadequate to meet both the physical and psychological needs of urban residents [10].

The insufficiency of green spaces creates serious problems not only at the spatial scale but also in terms of ecosystem services. Limited green space exacerbates the urban heat island effect, causing higher perceived temperatures in summer, negatively affects air quality, and fails to meet recreational needs. Moreover, it contributes to biodiversity loss, reduced soil permeability, and increased surface runoff, thereby elevating flood risk. In this context, it is crucial for urban planning processes to reconsider existing green space strategies and to develop policies aimed at expanding green corridors, parks, and ecological networks [11].

Our findings demonstrate that the existing green spaces sequester approximately 1,286.02 tons of carbon (C) annually. This amount offsets only a small fraction of the 746,000 tons of CO_2-e greenhouse gas emissions recorded in 2019 according to the Çanakkale Provincial Climate Change Action Plan. Nevertheless, the results highlight the critical role of vegetation in reducing local emissions and the tangible contributions of ecosystem services to climate change mitigation [12].

Therefore, increasing urban green spaces will not only provide recreational benefits but also enhance carbon sequestration capacity, serving as an important tool in mitigating the impacts of climate change. Accordingly, new planning strategies to be implemented in the city center of Çanakkale should focus on strengthening ecological networks, conserving biodiversity, improving stormwater management, and enhancing the quality of life of urban residents, in line with sustainability principles.

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