CONTRIBUTION OF URBAN CEMETERIES TO ECOSYSTEM SERVICES: EVIDENCE FROM TOURISTIC ANTALYA CITY OF TURKEY

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ABSTRACT:

This study focuses on concretely determining the contribution of cemeteries to the urban ecosystems in Antalya, one of the most important tourism destinations of Turkey. The study covers three cemeteries (Andızlı, Arapsuyu, and Uncalı Cemeteries) located in the city center of Antalya, with an area of 14.02 ha, 5.12 ha, and 22.96 ha, respectively. These areas are classified into two classes as vegetation and non-vegetation to calculate ecosystem services with open access and user-friendly i-Tree Canopy software to calculate the contribution of green areas in the mentioned cemeteries to the regulatory services of the ecosystem. According to the results, the green cover in the Andızlı Cemetery constitutes 81.64% of the total cemetery area and holds 54.35 tons of carbon per year. In terms of combating air pollution, it has been determined that the cemetery contributes to ecosystem services by removing a total of 1085.60 kilos of CO, NO_2, O_3, SO_2, and PM annually. Similarly, with its 4.88% impermeable buildings, 2.93% other impermeable surfaces, 18.55% soil ground, and 73.63% vegetation, the green cover of Arapsuyu Cemetery captures 357.96 kg of pollutants per year. Lastly, Uncalı Cemetery was shown to remove 1466.01 kg of air pollutants and 73.40 tons of carbon. Cemeteries that are part of the green infrastructure system and its contributions to ecosystem services are emphasized among the proposals to be made in line with the 2050 targets of the European Green Deal. In this context, by making legal and administrative additions to the spatial planning throughout the city, the realization of this intention might be accelerated.

1. INTRODUCTION

Cemeteries are a reflection of the history of the countries they are in and are considered sacred places all over the world (Kowarik et al., 2016). Cemeteries also form protected open green spaces which are elements of the urban green infrastructure system (Sallay et al., 2022). The presence of both natural and cultural elements in cemeteries, particularly in urban areas, gives them significant value for their potential to enhance ecosystem services. In Turkey, cemeteries are considered sacred and are primarily used for worship rather than recreation, much like in other predominantly Muslim countries. However, these are still valuable components of the urban green infrastructure system due to their nature as protected green areas. (Quinton and Duinker, 2019; McClaymont and Sinnet, 2021). The green areas of cemeteries provide important contributions to ecosystem services in terms of improving air, water and soil quality, balancing the microclimate and increasing carbon sequestration (Balzan et al., 2021). The status of the ecosystem services provided by cemeteries, the factors that improve or weaken the conditions of these services and all their possible future effects, and the benefits of these services being and staying high quality can have on people can be increased through creating more effective policies and decision-making mechanisms by regional administrations. This study focuses on concretely determining the contribution of cemeteries to the urban ecosystem in the city center of Antalya, one of the most important tourism destinations of Turkey, whose foreign population has increased significantly in parallel with current international developments.

Evaluation of Urban Ecosystem services contributes significantly to learning about the state of the environment and the sustainable management of natural resources and making improvements (Frélichová et al., 2014). A large number of studies have been and continue to be made in the literature on the conservation of biodiversity, the management of ecosystems, sustainable urban life, the maintenance of natural resources, and ecosystem services for human well-being (Reid et al., 2006; Elmqvist et al., 2015; Schmidt et al., 2016; Fagerholm, et al., 2019; McPhearson et al., 2022). The main objectives of evaluating the contribution of green areas to ecosystem services are: to make the value of nature visible, to integrate the value of ecosystem services into urban decision-making processes, and to enable ecosystem services to be managed effectively by developing tools such as maps that identify and quantify these services (Niemelä et al., 2010; Cilliers et al., 2013; Kabisch, 2015). In addition, in the biodiversity and green infrastructure strategies of the European Green Consensus, it is recommended to develop various strategies in order to identify ecosystem services and convert them into digital data, and to create a carbon-neutral environment in the 2030 - 2050 targets (European Commission, 2019). In this context, determining the contribution of urban green spaces such as cemeteries to ecosystem services can help strengthen green space management and conservation efforts by measuring the environmental benefits of green spaces.

There are many methods for identifying and modeling ecosystem services and their advantages. Especially in the last 10 years, as a result of the developments in remote sensing and geographic information systems, the contributions of ecosystem services can be determined and mapped quickly and with high accuracy with the help of various interfaces such as GIS and similar environments. For example, (i) ESTIMAP models from land cover and land use maps to which it adds other spatial information to map various ecosystem services (Zulian et al., 2014; Stange et al., 2017); (ii) The QUICKScan tool performs a spatial modeling combining expert knowledge with spatial and statistical data, visualizing the results on interactive maps. (Winograd et al., 2014; Dick et al., 2017), (iii) InVEST produces a set of models for mapping and assessing the ecological or economic value of multiple ecosystem services at a local or

regional scale (Arcidiacono et al., 2015; Benra et al., 2021), and (iv) I-Tree Canopy classifies green areas according to the presence of vegetation and quantifies the contribution of green areas to ecosystem services (Olivatto, 2019).

In this study, I-Tree Canopy tool was used to quantify the role of urban cemeteries in regulating ecosystem services. The I-Tree Tools, developed by the USDA Forest Service and other collaborators, are freely available and can be used to assess ecosystem services online. This tool is widely used globally and offers a practical and efficient way to evaluate the presence and absence of tree cover, from individual trees to large forested areas, and their contributions to ecosystem services, as demonstrated in previous studies (Mills et al., 2015; Nowak et al., 2018; Selim et al., 2022). In addition, this tool allows users to make statistically reliable predictions about tree and other cover types, as well as calculating and correcting uncertainties that may occur in forecasts because Google uses aerial images (Selim et al., 2022). In this study, the 3 largest cemeteries of Antalya were chosen as the study area. The land covers of these cemeteries were classified and following values were calculated: carbon monoxide (CO) removed annually, nitrogen dioxide (NO_2) removed annually, ozone (O_3) removed annually, sulfur dioxide (SO_2) removed annually, particulate matter less than 2.5 microns removed annually ($PM_{2.5}$) and finally, particulate matter greater than 2.5 microns and less than 10 microns (PM_{10}) removed annually. Lastly, suggestions have been developed for central and local governments and policy makers to evaluate cemeteries in the creation of green infrastructure systems.

2. MATERIAL AND METHODS

2.1 Study Area

As of the end of 2021, Antalya is the fifth most populous city in Turkey with its 2,619,832 residents. Especially in the summer months, the active population increases with the number of tourists. The area of the city is 20,177 km2 (Antalya Governorship, 2023). The city is between 29° 20'-32°35' east longitudes and 36° 07'-37° 29' north latitudes in southwestern Turkey. (Figure 1).

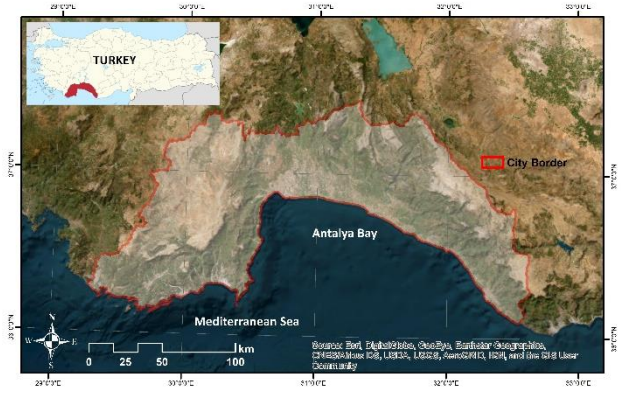

Figure 1. Study area

On average, 77.8% of the province's land is mountainous, 10.2% is plain, and 12% is rough. The climate of Antalya is generally characterized with Mediterranean climate. The average temperature in summer is between 28-36 °C. In January, the average temperature varies between 10-20 °C (Selim et al., 2018; Selim, 2021; Olgun et al., 2022). The cemeteries that are the subject of the study are Uncalı cemetery (22.96 ha), Arapsuyu cemetery (5.12 ha) and Andızlı cemetery (14.02 ha) located in the city center of Antalya (Figure 2, 3, 4).

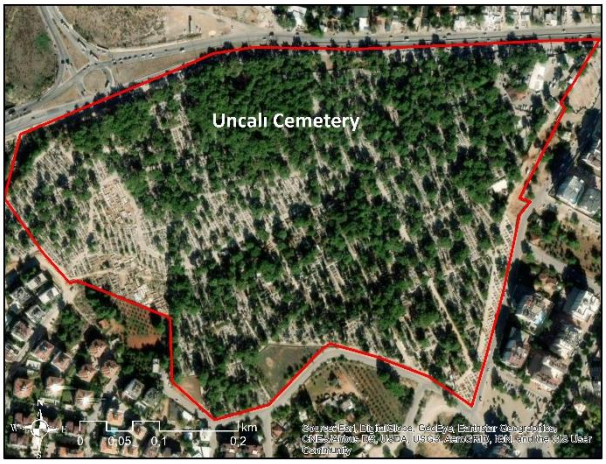

Figure 2. Uncalı cemetery

Figure 3. Arapsuyu cemetery

Figure 3. Andızlı cemetery

Uncalı cemetery at 36°53'53.57"N and 30°37'29.17"E coordinates, Arapsuyu cemetery at 36°52'49.52"N and 30°39'19.76"E coordinates and Andızlı cemetery at 36°53'37.96"N and 30°42'31.54"E coordinates. The dominant plant species in cemeteries is mostly Cupressus Sempervirens. In addition, Pinus brutia and Pinus pinea populations are also present.

2.2 Method

The study employed the I-Tree canopy tool and a recent Google Earth satellite image as the primary data sources. The region's zoning plans were also utilized to establish the boundaries of the relevant cemeteries, with the process of digitization being conducted via ArcGIS 10.4.1 software (see Figure 4).

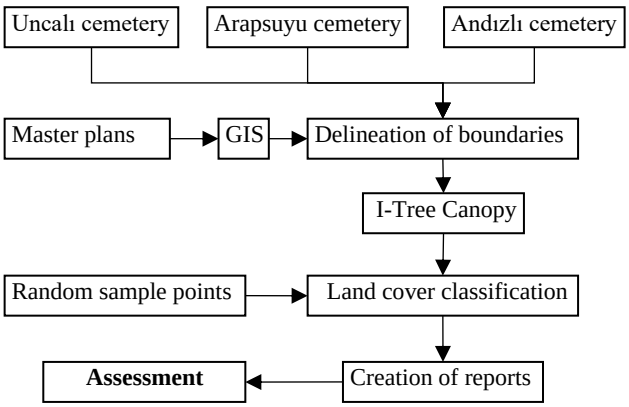

Figure 4. Method flowchart

The study consists of 3 main stages: determining the boundaries of the cemetery, assigning a sufficient number of sampling points, and creating analysis reports. In the first stage, the boundaries determined in the zoning plans were transferred to the I-Tree canopy software. Then, sufficient number of sampling points were assigned for each cemetery to capture the minimum standard error (SE) predicted by the mentioned software. Land cover is divided into 4 classes: buildings, impervious surface, soil ground and tree cover. Buildings are defined as "areas with impervious cover occupied by buildings". Impervious surface is defined as "areas with other impervious cover (e.g., pavements, roads, parking lots and surface areas covered with concrete, key parquet stone coating)". Soil ground is defined as "soil surface" or" bare areas without vegetation". Finally, tree cover was defined as "areas covered with trees and tall bush vegetation". I-Tree Eco software and literature information (Ersoy Tonyaloğlu & Atak, 2021; Selim & Atabey, 2020) were used to calculate the contribution of the land cover per unit area to the regulation services of the ecosystem. After classification, reports of each cemetery were created within the scope of the CO, NO_2, O_3, SO_2, $PM_{2.5}$ and PM_{10} values of the tree cover, and numerical values were obtained based on air pollution and carbon sequestration. Finally, the findings were interpreted by discussing with the literature information within the scope of the contributions of the related cemeteries to the ecosystem services.

3. RESULTS

The carbon holding capacity of the cemeteries, which are an important part of the urban green space system, and the amount of their effects on reducing air pollution have been determined. The cemeteries, located in the city center of Antalya and dominated by vegetation, provide important contributions to the urban ecosystem and urban ecosystem services. Uncalı cemetery (Table 1), 67.29% of which is covered with tree cover, absorbs 73.40 tonnes of carbon annually.

Cover Class	Points	% Cover ± SE	Area (ha) ± SE
Impervious Building	12	0.52 ± 0.15	0.12 ± 0.03
Impervious Other	48	2.09 ± 0.30	0.48 ± 0.07
Soil/Bare Ground	691	30.10 ± 0.96	6.91 ± 0.22
Tree/ Shrub	1545	67.29 ± 0.98	15.45 ± 0.22
Total	2296	100.00	22.96

Table 1. Land cover classes of Uncalı cemetery.

2.09% of Uncalı cemetery is classified as impervious other and 30.10% as soil/bare ground. The effect of the cemetery on reducing air pollution is given in Table 2.

Abbr.	Description	Amount (kg)	±SE
CO	Carbon Monoxide removed annually	22.45	±0.33
NO_2	Nitrogen Dioxide removed annually	104.49	±1.52
O_3	Ozone removed annually	989.36	±14.40
SO_2	Sulfur Dioxide removed annually	20.64	±0.30
$PM_{2.5}$	Particulate Matter less than 2.5 microns removed annually	43.89	±0.64
PM_{10}*	Particulate Matter 2.5<PM<10 microns removed annually	285.18	±4.15
Total		1,466.01	±21.33

Table 2. Contribution of Uncalı cemetery to ecosystem services

It is estimated that Uncalı Cemetery's contribution to ecosystem services that reduce the effects of air pollution is 1,466,01 kg per year.

Arapsuyu cemetery, on the other hand, is a small cemetery with an area of 5.12 ha compared to other cemeteries (Table 3). The annual carbon holding capacity of the vegetation in this cemetery is 17.81-tonnes.

Cover Class	Points	% Cover ± SE	Area (ha) ± SE
Impervious Building	104	5.22 ± 0.50	0.27 ± 0.03
Impervious Other	59	2.96 ± 0.38	0.15 ± 0.02
Soil/Bare Ground	372	18.66± 0.87	0.96 ± 0.04
Tree/ Shrub	1459	73.17 ± 0.99	3.75± 0.05
Total	1994	100.00	5.12

Table 3. Land cover classes of Arapsuyu cemetery.

73.17% of the Arapsuyu cemetery is covered with vegetation and consists of Cupressus sempervirens populations. Arapsuyu cemetery absorbs 5.45 kg of CO, 240.06 kg of O3 and 5.01 kg of SO2 per year (Table 4).

Abbr.	Description	Amount (kg)	±SE

CO	Carbon Monoxide removed annually	5.45	±0.07
NO_2	Nitrogen Dioxide removed annually	25.35	±0.34
O_3	Ozone removed annually	240.06	±3.26
SO_2	Sulfur Dioxide removed annually	5.01	±0.07
$PM_{2.5}$	Particulate Matter less than 2.5 microns removed annually	10.65	±0.14
PM_{10}*	Particulate Matter 2.5< PM<10 microns removed annually	69.20	±0.94
Total		355.71	±4.82

Table 4. Contribution of Arapsuyu cemetery to ecosystem services

Arapsuyu cemetery is spread over a smaller area compared to other areas in the study and its contribution to urban ecosystem services has been estimated as 355.71 kg in total.

Andızlı cemetery, on the other hand, has the largest green cover with an area of 14.02 ha and 81.64% vegetation (Table 5). Andızlı cemetery cleans 54.35-tonnes of carbon from the city annually.

Cover Class	Points	% Cover ± SE	Area (ha) ± SE
Impervious Building	13	0.93 ± 0.26	0.13 ± 0.04
Impervious Other	52	3.71 ± 0.51	0.52 ± 0.07
Soil/Bare Ground	192	13.71 ± 0.92	1.92 ± 0.13
Tree/ Shrub	1143	81.64 ± 1.03	11.44 ± 0.15
Total	1400	100.00	14.02

Table 5. Land cover classes of Arapsuyu cemetery.

The CO clearance amount of the Andızlı cemetery was estimated to be 16.62 kg, the NO_2 removal amount to 77.38 kg and the O_3 removal amount to 732.63 kg (Table 6).

Abbr.	Description	Amount (kg)	±SE
CO	Carbon Monoxide removed annually	16.62	±0.21
NO_2	Nitrogen Dioxide removed annually	77.38	±0.98
O_3	Ozone removed annually	732.63	±9.28
SO_2	Sulfur Dioxide removed annually	15.29	±0.19
$PM_{2.5}$	Particulate Matter less than 2.5 microns removed annually	32.50	±0.41
PM_{10}*	Particulate Matter 2.5< PM<10 microns removed annually	211.18	±2.68
Total		1,085.60	±13.76

Table 6. Contribution of Andızlı cemetery to ecosystem services

The total contribution of the Andızlı cemetery to ecosystem services within the scope of reducing the effects of air pollution is approximately 1 ton per year.

The results of the study show that, considering their area size and tree cover rate, the cemetery with the highest contribution to the ecosystem services of the city among the three studied cemeteries is the Uncalı cemetery. Uncalı cemetery has an annual sequestration value of 1466.01 kg of CO, NO_2, O_3, SO_2, $PM_{2.5}$ and PM_{10}. This is followed by the Andızlı cemetery with 1085.60 kg and the Arapsuyu cemetery with 355.71 kg, respectively. The annual total carbon sequestration amount of these three cemeteries in the whole city is 145.56 tons. In other words, these cemeteries absorb a significant amount of carbon in the atmosphere. As the area and tree cover rate increases, the contributions provided by the cemeteries also increase. However, as can be seen from the maps produced, these cemeteries are independent of other green areas in the city and their ecological connections have not been established. Hence, they are isolated ecosystems.

4. CONCLUSIONS

Regulating services, provisioning services, cultural services and supporting services of urban ecosystems are vital for the health, sustainability and resilience of urban environments (Evans et al., 2022). The increasing population and the pressure of global climate change on urban environments necessitate the creation and maintenance of green infrastructure systems (Lourdes et al., 2022). Similar to urban parks, cemeteries represent an important part of the urban ecosystem as a semi-natural habitat for many plant and animal species. Although cemeteries have limited use, they are an important part of the urban green infrastructure network (Sallay et al., 2022). Since the 2000s, ecosystem services and green infrastructure approaches have begun to be considered more holistically in spatial planning applications involving urban systems (Ersoy Mirici, 2022). The European Commission posits that ecosystem services serve as a supplementary mechanism to green infrastructure, and it is crucial to ascertain the role of individual components of the green infrastructure system, such as cemeteries, in providing ecosystem services (Klimanova et al., 2018; Marando et al., 2022). Cemeteries constitute an array of ecosystem services and diverse habitat types as constituents of green infrastructure in urban localities (Długoński et al., 2022). Cemeteries play a significant role in augmenting the contribution of ecosystem services towards enhancing the adaptability and resilience of cities to climate change. The European Commission advocates for the integration of distinct green spaces, including cemeteries, into a systematically planned green infrastructure system, along with their ecological connectivity (Lanzas et al., 2019).

The results obtained from this study clearly indicate that urban cemeteries contribute significantly to the regulatory services of the ecosystem. Especially considering the reduction of carbon sequestration and air pollution effects, the vegetation in the cemeteries contributes significantly to the regulatory services of the ecosystem. Regulating the microclimate and creating habitat for urban wildlife can be listed as other roles of these cemeteries. Nonetheless, in the urban setting of Antalya, where population density is high and mobility is frequent, cemeteries are disconnected from the surrounding green spaces and remain confined within the city. It is not linked to other components of the green infrastructure system such as urban parks, rivers, ecological corridors and other green spaces. This limits the potential contribution of related cemeteries to ecosystem services. Because interconnected green spaces have the capacity to provide ecosystem services to a large extent (Phillips et al.,

2020). In accordance with the patch-corridor-matrix paradigm of landscape ecology, cemeteries, viewed as a component of the landscape patch, can serve as an integral part of the green infrastructure system in tandem with ecological corridors. Thus, increases the connectivity possibility between important patches, such as cemeteries, urban parks, roads, urban rivers and other green spaces (Peng et al., 2017). This system, including cemeteries, creates resilient ecosystems that play an important role in supporting the ecological structure, such as integrating landscapes, eliminating the isolated island effect, ensuring the spread and gene flow of species, regulating the microclimate, reducing urban heat island effects, etc. Also, as the European Green Deal states under the heading “Restoring biodiversity and ecosystem services”, resilient ecosystems are natural absorbers of atmospheric CO2 and can support adaptation to climate change (European Commission, 2020).
As a result, cemeteries, which have been determined to make significant contributions to ecosystem services based on numerical data, should be integrated into a comprehensive green infrastructure plan. Ecological connections with other components of the urban green infrastructure system should be established. This will increase their current contributions to ecosystem services and facilitate the city's adaptation to climate change.

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