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Comparison of the amount of CO_2 released during plant maintenance processes in traditional and xeriscape projects

Klasik ve kurakçıl peyzaj yaklaşımlarına göre tasarlanan parkların bitkisel bakım işlemleri sırasında salınan CO_2 miktarının karşılaştırılması

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ABSTRACT

Objective: It is aimed to calculate and compare the amount of CO_2 released during the plant maintenance processes of parks designed according to traditional and xeriscaping approaches.

Materials and Methods: The study area's dry periods were documented using the De Martonne Drought Index and Walter hydrometric diagrams. Proposed projects were designed, and the amounts of CO_2 released during annual plant maintenance operations implemented in existing and proposed projects were calculated and compared using the carbon footprint approach. Carbon footprints from personnel and equipment were calculated separately.

Results: The results have shown that parks designed according to the traditional landscaping approach result in approximately 649.300% more CO_2 emissions from personnel and % 200.1 more CO_2 emissions from equipment during annual plant maintenance operations when compared to xeriscapes. In existing projects, the largest carbon emissions were determined to be due to electricity consumption from drilling during irrigation. Lawn mowers were found to be the most frequently used piece of garden equipment in existing parks, contributing to the highest carbon emissions.

Conclusion: Since the plant maintenance operations applied to xeriscape design reduce the water and carbon footprint, it will make great contributions to ecology and economy, especially in the fight against and adaptation to climate change.

Keywords: Carbon footprint, climate change, drought, landscape, park design

ÖZ

Amaç: Klasik ve kurakçıl peyzaja göre tasarlanan parkların bitkisel bakım işlemleri sırasında salınan CO_2 miktarının hesaplanması ve karşılaştırılması amaçlanmıştır.

Materyal ve Yöntem: Araştırma alanının kurak dönemleri De Martonne Kuraklık İndeksi ve Walter hidrometrik diyagramlarıyla ortaya konulmuştur. Öneri projeler tasarlanmış, mevcut ve öneri projelere uygulanacak yıllık bitkisel bakım işlemleri sırasında salınan CO_2 miktarları karbon ayak izi yaklaşımıyla hesaplanmış ve karşılaştırılmıştır. Personelden ve ekipmandan salınan karbon ayak izi ayrı ayrı hesaplanmıştır.

Araştırma Bulguları: Yıllık bitkisel bakım işlemleri sırasında klasik peyzaj yaklaşımına göre tasarlanan parkların, kurakçıl peyzaja göre personelden kaynaklı yaklaşık %649.300, ekipmandan kaynaklı ise % 200.1 daha fazla CO_2 salınımına yol açtığı tespit edilmiştir. Mevcut projelerde en fazla karbon salınımının sulama sırasında sondajdan kaynaklı elektrik tüketimine bağlı olduğu belirlenmiştir. Çim biçme makinesinin mevcut parklarda en sık kullanılan ve en fazla karbon salınımına neden olan bahçe ekipmanı olduğu belirlenmiştir.

Sonuç: Kurakçıl peyzaj tasarımına uygulanacak bitkisel bakım işlemlerinin az olmasından dolayı su ve karbon ayak izini küçülttüğü için iklim değişikliğiyle mücadele ve adaptasyonda özellikle ekolojiye ve ekonomiye büyük katkılar sunacaktır.

Anahtar sözcükler: Karbon ayak izi, iklim değişikliği, peyzaj, kuraklık, park tasarımı

INTRODUCTION

Climate change is the world's foremost problem. It is known that it results from global warming, leading to extreme weather events, reduced biodiversity, and adverse effects on food, water, ecosystems, etc. (Wandana et al., 2021). The initial noticeable impact of climate change is that the rise in temperature has led green areas, created with traditional landscape principles that prioritize aesthetics, to require more frequent watering, resulting in significant water use.

Due to severe drought conditions, water use in Denver, USA were restricted, and irrigation in lawn areas and gardens were banned. Consequently, the plants in the gardens withered, causing landscape architects in Denver to promote what they called "Xeriscaping", which emerged in the early 1980s, allowing the maintenance of conventional aesthetics with low water consumption (Welsh, 2000). For the purpose of adaptation to climate change, the xeriscape approach can provide substantial savings in irrigation for green areas. The main factor accelerating climate change is the rise in CO_2 emissions in the atmosphere, which has the highest rate among greenhouse gases (Nunes et al., 2020; Malhi et al., 2021). Carbon footprint is the measure of the damage caused to the environment by human activities (e.g., transportation, heating, electricity consumption, and purchased products, etc.) considering the amount of greenhouse gas produced, measured in units of carbon dioxide (Anonymous, 2024a). It is believed that all professional disciplines need to develop strategies to reduce carbon footprints in order to slow down climate change. Ingram (2012) and Ingram et al. (2016) measured the carbon footprint of a plant species in their studies, while Park et al. (2021) measured the carbon footprint in landscape tree production. The review of national and international literature indicates that no research has previously calculated and compared the amount of CO_2 emitted during the annual plant maintenance of traditional and xeriscape projects.

Urban open and green spaces, especially those containing large trees, have significant potential to capture carbon in the atmosphere and reduce the effects of climate change in cities (Vasagadekar et al., 2023). Park et al. (2021) stated that trees not only capture carbon during their development process, but also cause carbon emissions due to their production, transportation, planting, management, removal, disposal, and recycling throughout their life cycle. Despite the fact that increasing the quantity of green areas is beneficial due to their carbon storage properties in order to mitigate the effects of climate change, utmost attention must be paid to their quality. Green areas designed with a traditional landscape approach require regular maintenance operations, during which landscape equipment that usually requires fossil fuel are used, leading to carbon emissions. Rather than focusing solely on aesthetic factors when selecting plants, design choices should account for their appropriateness in relation to the local ecology and ongoing maintenance needs throughout the plants' lifespan. Xeriscape designs, noted for their water saving, will offer great ecological and economic benefits in combating and adapting to climate change, as they will have lower carbon emissions due to less need for plant maintenance and garden equipment to be used in the process.

This study aims to redesign two parks in Konyaaltı and Döşemealtı districts of Antalya province, originally designed using a traditional landscape approach, by employing the xeriscaping approach, as a proposal, and to create annual plant maintenance programmes as well as estimating and comparing the amount of CO_2 emitted to the atmosphere from the personnel and equipment used in the maintenance stages, with the formulas created.

MATERIALS and METHODS

The main materials of the study consist of two parks, each selected in accordance with the purpose of the study, from Döşemealtı and Konyaaltı central districts of Antalya province. One of the parks is in Gürsu region of Konyaaltı district and the other one in Düzlerçamı region of Döşemealtı district. The study was conducted between 2020 and 2024 (Figure 1) by using AutoCAD in the design of the projects and Microsoft Excel to create various graphics and tables and make calculations.

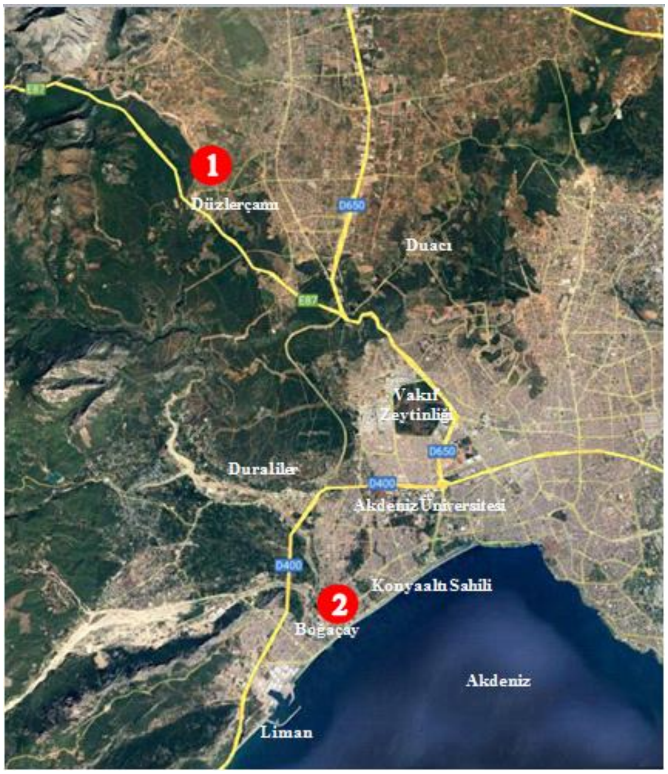

Figure 1. Location of sample parks (using Anonymous, 2024b) **1: Sample park area in Döşemealtı district, 2: Sample park area in Konyaaltı district.*

Şekil 1. *Örnek parkların konumu (Anonymous, 2024b'den yararlanılarak) *1: Döşemealtı ilçesindeki örnek park alanı, 2: Konyaaltı ilçesindeki örnek park alanı.*

The research was conducted in two formats- field and office-, involving five stages. In the initial stage of the study, data was gathered regarding the climate features of Antalya, as well as climate change, xeriscaping and carbon footprints. At this stage, data on parks obtained from Döşemealtı and Konyaaltı Municipalities and climate data sourced from MGM were utilised. In addition, precipitation and temperature data were used to determine the dry periods of the research zones with the De Martonne drought index and Walter (1970) hydrometric diagrams.

According to the Anonymous (2016), the parameters included in the formula of the De Martonne drought determination method are the annual average temperature and annual total precipitation values. The annual drought index (I_{DM}) value is obtained with the calculation made according to Formula 1.

$$I\mathrm{DM} = \frac{P}{T+10} \quad (1)$$

I_{DM}: Annual drought index, P: Annual total precipitation (mm), T: Annual mean temperature (°C)

De Martonne monthly drought index values are calculated according to the following formula 2.

$$IM = \frac{12.P'}{T'+10} \quad (2)$$

I_M: Monthly drought index, P': Monthly total precipitation (mm), T': Monthly average temperature (°C)

In these formulas, the +10 value added to the T and T' values is a coefficient used to make the negative temperature value in some places positive. Table 1 shows the climate characteristics for the I_{DM} and I_M values calculated according to the De Martonne formula.

Table 1. De Martonne index values and climate characteristics (Anonymous, 2016)

Çizelge 1. *De Martonne indeks değerleri ve iklim özelliği (Anonymous, 2016)*

I_{DM}	Climatic features
Less than 5	Arid
5 – 10	Semi-arid
10 – 20	Semi-arid to Humid
20 – 30	Semi-humid
30 – 60	Humid
More than 60	Very humid

The arid periods of the research area were revealed by drawing Walter (1970) hydrometric diagrams according to the annual average temperature (°C) and average precipitation (mm) values.

In the second stage, two sample parks suitable for the study purpose were selected from among the parks located in Döşemealtı and Konyaaltı districts, where field analyses were conducted. In the light of the field analyses and the data obtained, the selected parks were redesigned regarding vegetation and structural elements, aligning with the xeriscaping method, ecology of the region, and sustainable design principles while integrating a climate-friendly approach into the study. The park in Konyaaltı was built in 2015, while the park in Döşemealtı was built in 2016, and the fact that their construction years were close to each other made comparison possible. The park in Konyaaltı is 1,126 m^2, while the park in Döşemealtı is 1,056 m^2, being quite similar in size. Both parks are morphologically close to flat. The plants used in the suggested plant designs were determined by using the plant list created by Çetin (2016) and the information on the care requirements of plant species found in some nurseries within the borders of the Antalya district.

In the third stage of the research, the annual general maintenance processes for the existing and proposed plant design projects were determined. The annual maintenance program applied to the park according to the existing project was created according to the data obtained from the annual routine maintenance and work programs prepared by the Agricultural Engineers and Landscape Architect Chiefs responsible for maintenance operations in Konyaaltı Municipality. Due to the similar size of the existing parks in both districts, along with their design with a traditional landscape approach and the use of similar plant species, an annual plant maintenance program was created for the existing projects and another one for the proposed projects designed with the xeriscaping approach. The annual maintenance programs were divided into two periods as November-March and April-October.

In the fourth stage, the CO_2 amounts released during the annual plant maintenance of the parks, according to the existing and proposed plant projects were calculated and compared using the carbon footprint approach. The carbon footprints caused by plant maintenance was calculated separately as emitted from personnel (labour) and equipment. The CO_2 released due to personnel activities was calculated as liters and CO_2 released due to equipment use as kilograms. According to Doğan (2002), the CO_2 emissions from maintenance personnel were calculated according to the formulas developed within the scope of the study, while those from equipment were calculated according to the formulas developed within the scope of the study. According to Doğan (2002), the amount of CO_2 released into the air by people varies according to their occupation status, and these values are presented in Table 2. Accordingly, the occupation degree of the operator and those responsible for irrigation with drilling was taken as II, and the occupation degree of those using plant maintenance equipment and working in irrigation with water trucks as III.Fuel consumption in automobiles is basically proportional to the engine power/cylinder volume of the vehicle. By examining the fuel consumption of vehicles of different brands and models with the same engine/cylinder volume, average carbon footprint calculations per engine power were made. In general, 2.33 kg of carbon dioxide gas is released by burning 1 liter of gasoline (Bahçeci 2023). In the scope of this study, this value was taken as the basis for the amount of carbon dioxide released by burning gasoline.

Table 2. The amount of CO_2 people emits into the air according to their occupation (Doğan, 2002)

***Çizelge 2**. İnsanların meşguliyet durumlarına göre havaya verdikleri CO_2 miktarı (Doğan, 2002)*

Occupation	Occupation Degree	CO_2 emission amount (lt/h)
Sitting	I	15
Light manual work	II	23
Manual work or slow walking	III	30
Heavy work or fast walking	IV	30

In the existing parks, while automatic irrigation systems are used for watering, electricity is consumed due to drilling activities. The amount of electricity consumed due to drilling varies depending on factors such as the size, power, and depth of the drilling, and since this value can be measured in the existing park in Konyaaltı district, calculations were made accordingly. In this park, the value on the drilling panel was reset before activating the irrigation system and was measured after ½ hour and multiplied by 2 to determine that the hourly consumption was 106,400 kW. According to Ener Rüşen & Koç (2019), calculations are made based on the data, revealing that approximately 0.55 kg of CO_2 is released from 1 kWh of electricity consumption. The amount of CO_2 released due to drilling is shown in Formula 3.

$$DI = t.e.0{,}55\ kg/kWh \tag{3}$$

DI: Amount of CO_2 released from irrigation by drilling, t: Working time (hour), e: one hour of electricity consumption (kWh), 0.55 kg/kWh: CO_2 released from 1 kWh electricity consumption

Based on Engin (2015)'s acknowledgement that 1 liter of fuel emits 2.4 kg CO_2 (eq) in the equation for transportation-related CO_2 emissions in the ready-mix concrete industry, the figure was likewise used as a reference for the water truck. The indicator of this vehicle was examined for the fuel consumption of the water truck and it was found to consume approximately 50 liters of fuel in approximately 100 km. According to the known speed formula (x=v.t), it travels 100 km in 2 hours at 50 km/h, which is the speed limit according to Anonymous (2024c), so the 1-hour fuel consumption was calculated as 25 liters for this study and the CO_2 emissions from irrigation with the water truck operating was formulated. It has been determined that gasoline-powered garden equipment, including a push lawn mower, a pruning saw, a hedge trimmer and a bicycle-type scythe, are generally used in annual plant maintenance. When calculating CO_2 emissions from landscape equipment, firstly the catalogues of such equipment were examined and interviews were made with various companies that sell them, however, no data could be obtained regarding fuel consumption. Consequently, the landscape equipment used by Konyaaltı Municipality was examined in the field, and a method was devised by adding 150 ml of gasoline into the fuel tanks of this machinery to measure with a chronometer in order to find out the duration of gasoline consumption while actively operating in the park, and relevant formulas were created. In summary, when the hourly fuel consumption of such landscape machinery was calculated in the same way, it was found to be 0.53 l/h for a push lawn mower, 0.36 l/h for a pruning saw, 0.56 l/h for a hedge trimmer, and 1.29 l/h for a bicycle scythe. The amount of CO_2 released during landscape equipment and water truck on can be calculated by substituting the values in Formula 4.

$$LW = t.f.c \tag{4}$$

LW: the amount of CO_2 released from landscape equipment and water trucks, t: working time (hour), f: hourly fuel consumption (lt), c: CO_2 emission released from 1 lt or 1 kWh consumption. If the machinery runs on diesel, c=2.33 lt/kg; if it runs on gasoline, then c=2.4 lt/kg.

In the final stage of the study, the CO_2 emissions during the maintenance processes in the parks related to the planting design projects designed with xeriscaping approach were compared with those of the traditional landscaping, and some recommendations were proposed for promoting xeriscaping nationwide, particularly in Antalya, for the purposes of combating against and adapting to climate change.

RESULTS and DISCUSSION

Evaluation of climatic characteristics

This study used the climatic data for the years 1933-2021 obtained from the Antalya Airport's climate station numbered 17300, which is located at 36 latitude, 30 longitude, and 51 m above sea level and belongs to the Anonymous (2022a). Monthly drought index values for different periods were calculated according to the De Martonne formula. The notable values were the arid periods between June and September in the years of 1940-1949, 1950-1959, 1970-1979, 1980-1989, 1990-1999, 2000-2004, and 2020-2021. In addition, it was determined that 5 months out of 12 months were arid and 2 months were semi-arid between 2020 and 2021 (Table 3).

Table 3. Monthly seasonal drought index values of Antalya Airport Station (1933-2021) according to the De Martonne method

Çizelge 3. *De Martonne yöntemine göre Antalya Havalimanı İstasyonu (1933-2021) aylık dönemsel kuraklık indeksi değerleri*

Months	1933-1939	1940-1949	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2004	2005-2009	2012-2014	2015-2019	2020-2021
I	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid
II	Very humid	Very humid	Humid	Very humid	Very humid	Very humid	Very humid	Humid	Very humid	Humid	Humid	Semi-humid
III	Humid	Humid	Humid	Very humid	Humid	Very humid	Humid	Humid	Humid	Semi-humid	Humid	Semi-humid
IV	Semi-arid-Humid	Semi-humid	Semi-arid-Humid	Semi-humid	Semi-arid-Humid	Semi-humid	Semi-humid	Very humid	Humid	Very humid	Semi-arid-Humid	Arid
V	Semi-arid-Humid	Semi-arid	Semi-arid	Semi-arid-Humid	Semi-arid-Humid	Semi-arid	Semi-arid-Humid	Semi-humid	Semi-humid	Semi-arid-Humid	Semi-arid-Humid	Semi-arid
VI	Semi-arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Semi-arid	Arid
VII	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Semi-arid	Arid	Arid	Arid
VIII	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid	Arid
IX	Semi-arid	Arid	Arid	Semi-arid	Arid	Arid	Arid	Arid	Semi-humid	Semi-arid	Semi-arid	Arid
X	Semi-arid-Humid	Semi-humid	Semi-humid	Semi-humid	Humid	Semi-humid	Humid	Semi-arid	Very humid	Humid	Semi-arid-Humid	Semi-arid
XI	Very humid	Humid	Humid	Humid	Humid	Very humid	Very humid	Very humid	Very humid	Humid	Humid	Semi-humid
XII	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid	Very humid

When the arid periods of the research area were calculated by drawing Walter (1970) hydrometric diagrams according to the annual average temperature (°C) and average precipitation (mm) values, it was determined that there was an arid period of approximately 1 month for the years 2005-2009, 3 months for 1933-1939 and 2015-2019, 3.5 months for 1960-1969 and 2012-2014, 4 months for 1970-1979, 1980-1989, 1990-1999, 4.5 months for 1940-1949, 1950-1959 and 2000-2004, and 6.5 months for 2020-2021.

Comparison of existing and proposed plant design projects

Redesign of parks with xeriscaping approach as a proposal

A comprehensive analysis was first conducted in the park and its surroundings. In plant selection, attention was paid to the fact that the species were of Mediterranean origin and/or well adapted to Mediterranean ecological conditions, resistant to diseases and pests with low maintenance requirements, especially irrigation, but with more functional usage areas, and high landscape values in terms of aesthetic features. Vasagadekar et al. (2023) emphasized that natural tree species in parks are a natural solution to increase their ability to absorb atmospheric CO_2 in terms of storing more carbon compared to exotic species. Another advantage of natural plants is that they do not create a waste load on the environment by reducing chemical use. Taking these advantages of the proposed parks into account, emphasis is placed on choosing native plants and grouping those with similar maintenance requirements. Çetin & Mansuroğlu (2018) emphasized that native plants are crucial for reflecting a region's identity and culture and ensuring the continuity of species. Grass species, which are the plant group that consumes the most water in the landscape, require regular maintenance for a pleasant and aesthetic appearance, and some of these processes increase the use of fossil fuels and cause environmental pollution. For all these reasons, grass species are not preferred in either project. In the design, natural rocks are included to imitate the natural appearance of the species used in their natural environment and to provide a natural-like appearance. In addition, various mulch materials are preferred because they offer many benefits such as saving water and providing insulation, preventing weed growth and plants from competing. An aesthetic appearance can be achieved by creating patterns with these mulch materials in different colors and textures. The preferred mulch materials include wood chips, crushed stones, yellow sand, and pumice. In both proposed projects, sand is to be laid widely around the pergolas both for families to rest and for children to have fun playing. Sand also assumes a functional role and increases permeable grounds. Thus, it will also contribute to the nutrition of underground water. It has been planned to lay the packaging wastes of these materials under these mulch materials in order to prevent weed growth. Since mulch materials are sometimes sold in bulk and unpackaged, it could be suggested to lay newspapers under them. Since species with low water consumption and high drought tolerance are preferred in the projects, an irrigation system is not recommended. In extreme cases, additional irrigation with a water truck will be planned, and since this process will rarely be needed, it is believed that it will not have a major impact on carbon emissions. Thus, the use of plastic materials and excavation and filling caused by the irrigation system in the park can be prevented.

Evaluation of existing and proposed plant design projects in Döşemealtı district

In the existing project of the park, 27 different plant taxa were preferred, 25.9% of which (*Laurus nobilis* L.*, Liquidambar orientalis, Pinus pinea, Nerium oleander* 'Nana', *Platycladus orientalis, Cynodon dactylon* and *Aloe vera* are of Mediterranean origin. Although *P. orientalis* is a species compatible with the Mediterranean ecology, it seems to be planted very frequently as a hedge plant, a total of 1200. Considering the future diameter of this plant, it is believed that the number of plants should be kept lower. The reason is that adding more plants than necessary in a given area heightens the competition among plants for water and nutrient needs, as well as pruning and other maintenance tasks. In addition, when used as a hedge, they would need regular pruning, and therefore irrigation. A total of 65 kg of grass, approximately 80 gr/m^2, is used in the park. When the plant species in the existing park were evaluated, it was determined that there were plants with low, medium, and relatively high water requirements and that the plant groups with all the maintenance needs, especially irrigation, in the plant design of the park were grasses and shrubs used as hedges. Figure 2 illustrates the existing plant design project of this park.

Figure 2. Current planting design project of the park in Döşemealtı district.

***Şekil 2.** Döşemealtı ilçesindeki parkın mevcut bitkisel tasarım projesi.*

In the proposed plant design project of the park, on the other hand, 18 different plant taxa are preferred and 77.8% of them are of Mediterranean origin. These taxa include *Ceratonia siliqua*, *Cupressus sempervirens, Olea europaea, P. orientalis, Vitex agnus-castus*, *Erica carnea, Lavandula officinalis*, *Myrtus communis, Rosmarinus officinalis*, *Santolina chamaecyparissus, Hedera helix, Sedum rupestre* 'Angelina', *Thymus serpyllum* and *Opuntia ficus-indica* (Çetin, 2016; Anonymous, 2022b). The proposed project involves the use of *Lantana montevidensis*, a non-Mediterranean species that adapts well to the area's ecological conditions, features a sprawling growth habit, produces abundant and vibrant flowers, and has minimal water needs. Due to their succulent structure, drought tolerance, different colour, form and texture, *Aptenia cordifolia, Sedum reflexum* 'Blue Spruce' and *Agave americana* taxa are used to provide diversity in the area. Since these succulent ground covers (*Aptenia cordifolia, Sedum reflexum* 'Blue Spruce') do not require maintenance operations, such as mowing, pruning, and spraying, they also save labour, while their use prevents carbon emissions from personnel and pruning equipment. In the proposed project, *C. siliqua*, which is evergreen and requires little water and maintenance, is deemed appropriate for providing shade on walkways, and *H. helix*, one of the climbing species, is likewise deemed suitable for increasing shading on pergolas and providing a natural and aesthetic appearance with its decorative leaves and evergreen feature. In areas technically allocated as transformer areas, grass and ground cover species that do not form deep roots and do not pose a safety hazard are used or left empty. Since this section was designed as a green area in the current project, *Sedum rupestre* ‘Angelina’ is preferred as an alternative in the proposed project in order to make the transformer area comparable. Mediterranean origin *C. sempervirens* and *V. agnus-castus* are to be used right across from the transformer to screen the transformer area. As stated in Kösa’s (2023) study, the low-medium water requirements of *C. sempervirens* and *V. agnus-castus* species are additional considerations in the selection process. The proposed plant design project of this park is presented in Figure 3.

Figure 3. Proposed plant design project of the park in Döşemealtı district.
Şekil 3. *Döşemealtı ilçesindeki parkın öneri bitkisel tasarım projesi.*

<u>Evaluation of existing and proposed plant design projects in Konyaaltı district</u>

In the existing project of the park, 14 different plant taxa were preferred, 14.3% of which are of Mediterranean origin. These species include *P. orientalis* and *C. dactylon* (Çetin, 2016; Anonymous, 2022b). *Ruellia brittoniana*, which is prominent with its flowers, requires frequent and regular watering, especially in summer. In addition, since it is preferred as a hedge plant in the park, it is regularly pruned, which increases the need for irrigation. A total of approximately 80 gr/m^2, 66.72 kg of grass seed was used in the park. The examination of the species generally preferred in the park showed that it was designed with a medium water demand, high attractiveness in the landscape, and an understanding that prioritized aesthetics. The current planting design project of this park is presented in Figure 4.

Figure 4. Current plant design project of the park in Konyaaltı district.

***Şekil 4**. Konyaaltı ilçesindeki parkın mevcut bitkisel tasarım projesi.*

In the proposed project, 20 different plant taxa are preferred to increase the diversity of species, 70% of which are of Mediterranean origin. *Cercis siliquastrum*, *C. sempervirens, L. nobilis, Pistacia terebinthus*, *Tamarix tetrandra*, *V. agnus-castus, M. communis, R. officinalis, S. chamaecyparissus, Spartium junceum, Jasminum fruticans*, *T. serpyllum, Sedum rupestre* 'Angelina' and *A. vera* are the taxa of Mediterranean origin (Çetin, 2016; Anonymous, 2022b). In addition to these, the proposed project involved the use of *Lantana montevidensis*, that has a sprawling growth habit, abundant and showy flowers with a very low water requirement, though it is of foreign origin, and also *Carpobrotus acinaciformis, Sedum reflexum* 'Blue Spruce', *Agave americana*, *Aloe variegate,* and *Euphorbia tirucalli* taxa, which have low irrigation requirements because they store water in their bodies. In addition, it is thought that these succulent species will create diversity in the landscape with their interesting forms and leaves. *C. sempervirens* and *P. terebinthus* are planted in rows on the side of the park closest to the school due to their shielding from the noise coming from the school and their visual appeal. *C. siliquastrum* is preferred to provide shade for the walkways and to add color to the park with its pink flowers. *Jasminum fruticans*, which has attractive features in plant design with its pleasant scent and yellow decorative flowers as well as providing a lively and pleasant appearance as an alternative to the wooden roofed canopies in the existing project, is to be used to shade the pergolas. The proposed planting design project of this park is presented in Figure 5.

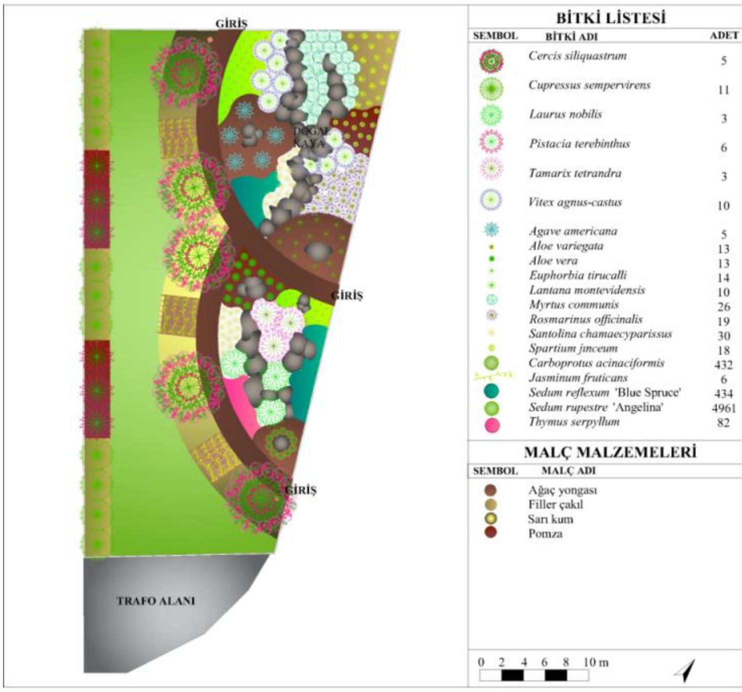

Figure 5. Proposed plant design project of the park in Konyaaltı district.

Şekil 5. *Konyaaltı ilçesindeki parkın öneri bitkisel tasarım projesi.*

Calculation and comparison of CO_2 amounts released during annual plant maintenance of parks according to existing and proposed plant design projects

<u>Calculation of plant maintenance processes applied to existing parks between November and March and the amount of CO_2 released</u>

General maintenance operations applied during this period include irrigation, lawn mowing, weeding, pruning, and scything. A total of 1150 lt CO_2 was released from personnel and 331.068 kg CO_2 from equipment in the November-March period due to the plant maintenance of the existing projects in Döşemealtı and Konyaaltı districts (Table 4).

Table 4. Plant maintenance program of existing parks and amount of CO_2 released between November and March

Çizelge 4. *Mevcut parkların Kasım-Mart dönemi bitkisel bakım programı ve salınan CO_2 miktarı*

Plant maintenance procedures (November and March)	Equipment used	Amount of CO_2 released by personnel (lt)	Amount of CO_2 released from equipment (kg)
Irrigation	Drilling	10 times (1 time in 15 days for 1/2 hour) 115 lt	292.6
Mowing the lawn	Push Lawn Mower	10 times (1 time in 15 days for 2 hours) 600 lt	24.698
Weed cleaning	Manual	5 times (1 time per month for 1.5 hours) 225 lt	None
Pruning	On Trees (High Branch Pruning Saw), On Shrubs (Hedge Cutting and Trimming Machine)	3 times (Hard pruning of trees once a season for 1 hour, 2 times a season, shape pruning of shrubs once every 2 months for 1.5 hours) 120 lt	Trees 0.839 Shrubs 3.914
Scything	Bicycle Type Scythe	3 times (1 hour to walking paths) 90 lt	9.017
	TOTAL	1150 lt	331.068

<u>Calculation of plant maintenance operations to be executed in the proposed parks between November and March and the amount of CO_2 estimated to be released</u>

Maintenance processes to be applied during this period includes irrigation, weeding, pruning, and trimming. It is estimated that 255 lt of CO_2 will be released from the personnel and 63,425 kg of CO_2 from the equipment in the November-March period due to the plant maintenance of the proposed projects in Döşemealtı and Konyaaltı districts (Table 5).

Table 5. Plant maintenance program of the proposed park projects and the amount of CO_2 estimated to be released between November and March

Çizelge 5. *Öneri Projelerin Kasım-Mart dönemi bitkisel bakım programı ve salınan CO_2 miktarı*

Plant maintenance procedures (November-March)	Equipment used	Amount of CO_2 released by personnel (lt)	Amount of CO_2 released from equipment (kg)
Irrigation	Water truck	2 times (2 times in season for 1/2 hour) 30 lt	60
Weed cleaning	Manual	3 times (once every 2 months for 2 hours) 180 lt	None
Pruning	On Trees (High Branch Pruning Saw)	1 time (Hard pruning of trees once a season for 1/2 hour) 15 lt	0.419
Scything	Bicycle Type Scythe	1 time (1 time per season, 1 hour on walking paths) 30 lt	3.006
	TOTAL	255 lt	63.425

<u>Calculation of plant maintenance processes applied to the existing parks between April and October and the amount of CO_2 released</u>

Maintenance processes applied during this period include irrigation, lawn mowing, weed cleaning, pruning, trimming, and spraying. It has been determined that 4791 liters of CO_2 from personnel and 234,635 kg of CO_2 from equipment were released during the April-October period due to the plant maintenance of existing projects in Döşemealtı and Konyaaltı districts (Table 6).

<u>Calculation of plant maintenance operations to be executed in the proposed parks between April and October and the amount of CO_2 estimated to be released</u>

Maintenance processes to be applied during this period include irrigation, weeding, pruning and trimming. It has been estimated that during the plant maintenance of the proposed projects in Döşemealtı and Konyaaltı districts, 660 lt of CO_2 will be released from the personnel and 219,273 kg of CO_2 from the equipment in the April-October period (Table 7).

Table 6. Plant maintenance program of existing parks for the period April-October and the amount of CO_2 released

Çizelge 6. *Mevcut parkların Nisan-Ekim dönemi bitkisel bakım programı ve salınan CO_2 miktarı*

Plant maintenance procedures (April-October)	Equipment used	Amount of CO_2 released by personnel (lt)	Amount of CO_2 released from equipment (kg)
Irrigation	Drilling	84 times (3 times a week for 1/2 hour) 966 lt	117.04
Mowing the lawn	Push Lawn Mower	28 times (Once a week for 2 hours) 1680 lt	69.154
Weed cleaning	Manuel	28 times (1 time per week for 1.5 hours) 1260 lt	None
Pruning	Hedge Cutting and Trimming Machine	14 times (1 time in 15 days, 1.5 hours of pruning of bushes) 630 lt	27.401
Scything	Bicycle Type Scythe	14 times (once in 15 days, 1/2 hour walking paths) 210 lt	21.04
Spraying	Manually operated backpack sprayer	3 times (herbiside application to walkways 3 times a season, 1/2 hour) 45 lt	None
	TOTAL	4791 lt	234.635 kg

Table 7. Plant maintenance program in the proposed park projects for the April-October period and the amount of CO_2 estimated to be released

***Çizelge 7.** Öneri parkların Nisan-Ekim dönemi bitkisel bakım programı ve salınan CO_2 miktarı*

Plant maintenance procedures (April-October)	Equipment used	Amount of CO_2 released by personnel (lt)	Amount of CO_2 Released from Equipment (kg)
Irrigation	Water truck	7 times (1 time per month for 1/2 hour) 105 lt	210
Weed cleaning	Manual	7 times (Once a month for 2 hours) 420 lt	None
Pruning	Hedge Cutting and Trimming Machine	5 times (1 time in 45 days, 1/2 hour for shaping the bushes) 75 lt	3.262
Scything	Bicycle Type Scythe	2 times (2 times a season, 1 hour to walking paths) 60 lt	6.011
	TOTAL	660 lt	219.273

Comparison of CO_2 emissions during annual plant maintenance of parks according to existing and proposed plant design projects

When comparing the current traditional landscape projects in Antalya Döşemealtı and Konyaaltı districts with the proposed xeriscaping-designed projects regarding carbon emissions from annual plant maintenance processes, it was found that the current projects (5941 lt) produced approximately 649.300% more carbon emissions than the proposed projects (915 lt) due to personnel, while the current projects (565,703 kg) resulted % 200.1 more carbon emissions than the proposed projects (282.698 kg) attributed to equipment use. It was determined that the highest amount of CO_2 released from equipment during annual plant maintenance processes occurred during irrigation operations in both existing traditional landscape projects (409.64 kg) and proposed xeriscape projects (270 kg) (Table 8). Similarly, Park et al. (2021) determined that the two largest sources of carbon emissions in landscape tree cultivation are irrigation and fertilization operations, and that 33-55% of all emissions are produced in irrigation in particular. In existing parks designed according to the traditional landscape design approach, 47 hours of irrigation is needed annually, while 4.5 hours are believed to be sufficient in proposed parks designed according to xeriscaping. In addition, it has been determined that the labour spent for the irrigation process of existing projects is 10,444 times that of proposed projects (Table 8). We have been informed that when existing parks are to be irrigated, the personnel need to go to there every time to manually open the conditioner and operate the drilling. Since vehicles are required to go to the drilling, fossil fuel consumption occurs again, thereby increasing the carbon footprint. In addition, since electricity is consumed while drilling is running, carbon emissions increase. In existing parks designed with a traditional landscape approach in Döşemealtı and Konyaaltı districts, the duration of annual maintenance processes is 6,852 times more than that of proposed parks designed with xeriscaping (Table 9). In another study conducted in Antalya, the current state of the park was contrasted with the proposed project designed with xeriscaping, revealing that the proposed project would save 43.31% in annual maintenance costs, with the observation that 51.38% of the current state of the park was covered with grass being the main factor causing the increase in maintenance costs (Çetin 2016; Çetin et al., 2018). Moreover, the highest amount of CO_2 was released from the push lawn mower among the landscape equipment used in the current projects. In Döşemealtı and Konyaaltı districts, existing parks designed using a traditional landscape approach require 76 hours of lawn mowing each year, but opting against grass in the proposed parks using a xeriscape design is likely to significantly help in lowering carbon emissions from personnel and equipment during maintenance.

Table 8. The amount of CO_2 released during annual vegetative maintenance of parks according to existing and proposed projects

Çizelge 8. *Mevcut ve öneri projelere göre parkların yıllık bitkisel bakımı sırasında salınan CO_2 miktarı*

Annual plant maintenance processes	Existing Projects		Proposed Projects	
	Amount of CO_2 to be released by personnel (lt)	Amount of CO_2 to be released from equipment (kg)	Amount of CO_2 to be released by personnel (lt)	Amount of CO_2 to be released from equipment (kg)
Irrigation	1081	409.64	135	270
Mowing the lawn	2280	93.852	0	0
Weed cleaning	1485	0	600	0
Pruning	750	32.154	90	3.681
Scything	300	30.057	90	9.017
Spraying	45	0	0	0
TOTAL	5941	565.703	915	282.698

Table 9. Duration of annual plant maintenance operations of parks according to existing and proposed projects (hours)

Çizelge 9. *Mevcut ve öneri projelere göre parkların yıllık bitkisel bakım işlemlerinin süresi (saat)*

Annual Plant Maintenance Processes	Existing Projects			Proposed Projects		
	November-March (hours)	April-October (hours)	Total Annual (hours)	November-March (hours)	April-October (hours)	Total Annual (hours)
Irrigation	5	42	47	1	3.5	4.5
Mowing the lawn	20	56	76	0	0	0
Weed cleaning	7.5	42	49.5	6	14	20
Pruning	4	21	25	0.5	2.5	3
Scything	3	7	10	1	2	3
Spraying	0	1.5	1.5	0	0	0
		TOTAL	209		TOTAL	30.5

CONCLUSION AND RECOMMENDATIONS

As a consequence, the climate analyses conducted in this study reveals that in Antalya, where approximately 7 months of the year are arid and semi-arid, xeriscape practices are no longer just a subject of discussion but should be implemented in landscape architecture projects. Xeriscapes allow for sustainable, functional, and aesthetic landscapes that require less maintenance and cause less damage to the environment during maintenance operations. In planting design projects, in addition to aesthetics and functionality, analyzing carbon emissions during the life cycles of plants is of great importance in terms of minimizing the damage to nature caused by their use. As emphasized by researchers such as Ingram (2012), Ingram et al. (2016) and Park et al. (2021), plant production should be conducted by analyzing the life cycle of plants and considering their effects on carbon emissions. There is no doubt that the choice of materials in landscape design will be beneficial in mitigating the effects of climate change. This study, on the other hand, examines the plant landscape projects designed with different approaches (traditional and xeriscape) as a whole, measures the carbon footprint within the scope of annual plant maintenance, and provides practical results directly for implementation. For this reason, the findings of this study hold significant value. If correct landscape designs are not implemented, carbon is to be released continuously due to plant maintenance. When the current traditional landscape projects in Döşemealtı and Konyaaltı districts and the proposed xeriscape projects are compared in terms of annual CO_2 emissions, it has been determined that the current projects cause approximately 649.300% more CO_2 emissions due to personnel and % 200.1 more CO_2 emissions due to equipment than the proposed projects due to annual plant maintenance operations. These differences are especially due to grass and hedge plants that require regular maintenance. It has been determined that the highest carbon emission in plant maintenance operations in the current projects is due to electricity consumption while drilling during irrigation operations. It could be suggested that if plants that require regular irrigation are to be preferred in the parks, the use of an automatic smart irrigation system that saves water thanks to the remotely controlled weather monitoring systems will also be a rational choice. It has also been determined that the push mower is the most frequently used garden equipment in existing parks (76 hours per year) and the one that causes the most carbon emissions. Considering the large water requirement and carbon footprint of grass, along with the natural resources it depletes and contaminates, as well as for the sake of our future, it is believed that it should not be preferred beyond athletic fields. R&D studies should be carried out on alternatives that can be used instead of grass in sports areas. The use of predominantly natural plant species in proposed xeriscape designs has also reduced maintenance requirements and CO_2 emissions resulting from maintenance. As stated by Çetin & Mansuroğlu (2018), nursery owners should focus on natural plant production and produce these plants at low costs, rather than importing plants from abroad at high costs.

In this study, it has been quantitatively demonstrated that the carbon footprint and annual maintenance period due to annual plant maintenance operations in existing parks designed according to the traditional landscape approach are higher than that in the proposed parks designed according to the xeriscape.

As a result, the traditional landscape design approach, which prioritizes aesthetics in plant selection, should be abandoned in favour of the xeriscaping approach. In xeriscapes, since there is less need for plant maintenance, the damage to the environment and natural resources is also less, which is believed to benefit both ecology and economy, especially by decreasing water usage and carbon emissions in the battle against and adaptation to global climate change.

Data Availability

Data will be made available upon reasonable request.

Author Contributions

Conception and design of the study: NÇ, SM; analysis and interpretation of data: NÇ, SM, SK; statistical analysis: NÇ, SM; visualization: NÇ, SM; writing manuscript: NÇ, SM, SK.

Conflict of Interest

There is no conflict of interest between the authors in this study.

Ethical Statement

We declare that an ethics committee is not required for this study.

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