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Research Article
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Assessing ecosystem services of urban green spaces: the case of Eugene Pioneer Cemetery, Eugene, OR (USA)*

Kentsel yeşil alanlardaki ekosistem servislerinin hesaplanması: Eugene Pioneer Mezarlığı, Eugene, Oregon (ABD)

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ABSTRACT

Objective: The objective of this study was to quantify four regulating ecosystem services; carbon sequestration and storage, avoided run-off, air pollution removal by trees and oxygen production in the Eugene Pioneer Cemetery, OR (USA).

Material and Methods: For data preparation the field data of trees was collected on paper data sheets. Collected data in the field were land-use type, tree species, diameters of breast height-DBH (cm), total tree height (m), live crown height (m), crown base height (m), and crown percent missing. In data analysis I-Tree Eco model version 6 developed by the U.S. Forest Service, Northern Research Station was used.

Results: The gross sequestration of the cemetery trees is about 7,136 metric tons of carbon per year. Trees in the cemetery were estimated to store 1,610 metric tons of carbon. The trees and shrubs of the cemetery help to avoid run-off by an estimated 452 cubic meters a year. It was estimated that trees remove 143,9 kilograms of air pollutions. Trees in the cemetery were estimated to produce 19,03 metric tons of oxygen per year.

Conclusion: This study recommends large green areas (large permeable surfaces) and trees with large crowns in the planting design as a better solution for regulating ecosystem services.

Keywords: Green areas, ecosystem services, I-Tree Eco, cemetery

ÖZ

Amaç: Bu çalışmanın amacı, Eugene Pioneer Mezarlığı, Oregon (ABD) 'de, dört düzenleyici ekosistem servisini ölçmektir; bunlar karbon tutulması ve depolanması, yüzey akışının önlenmesi, hava kirleticilerinin tutulması ve oksijen üretimidir.

Materyal ve Yöntem: Veri hazırlama aşamasında ağaçlara ilişkin ölçülen veriler kâğıt üzerine kaydedilmiştir. Arazi kullanım türü, ağaç türleri, ağacın göğüs yüksekliğindeki çapı-DBH (cm), ağaç yüksekliği (m), canlı taç yüksekliği (m), tacın yerden yüksekliği (m), kayıp taç yüzdesi. Veri analizinde I-Tree Eco model versiyon 6 kullanılmıştır.

Araştırma Bulguları: Mezarlıktaki ağaçlar brüt olarak yılda yaklaşık 7.136 ton karbonu tutmakta ve 1.610 ton karbonu depolamaktadır. Alandaki bitkiler yılda yaklaşık 452 m^3 bir yüzey akışı engellemekte ve 143,9 kg hava kirleticisini ortadan kaldırmaktadır. Son olarak mezarlıktaki ağaçların yıllık 19,03 ton oksijen ürettiği hesaplanmıştır.

Sonuç: Bu çalışma, daha iyi düzenleyici ekosistem servislerini üretebilmek için geniş taçlı ağaçların kullanıldığı, büyük bölümü geçirgen olan geniş yeşil alanların tasarımını önermektedir.

Anahtar sözcükler: yeşil alanlar, ekosistem servisleri, I-Tree Eco, mezarlık

INTRODUCTION

Urban ecosystems provide several services such as carbon storage and sequestration, removal of air pollutants, reduction of storm water run-off, decreased heat stress, and improved local climatic conditions (Bolund & Hunhammar, 1999; Alberti, 2005; Forman, 2014), which are very valuable to city dwellers.

Urban green spaces play a pivotal role in maintaining and/or providing ecosystem services (ES) that occur in many forms which include social, ecological and psychological fields (Chiesura, 2004; Zhou & Wang, 2011). It is important to note that the type and amount of ES provided will vary with each green space vegetation type (Mexia et al., 2018). Although existence of different plant layers is important (Forman, 2014), trees are mostly responsible for providing directly and/or facilitating many of the services in green spaces. Therefore, trees are generally the major subject of the studies in calculating ES (Nowak et al., 2006; Nowak et al., 2014; Selmi et al.,2016; Coskun Hepcan & Hepcan, 2017, 2018; Parsa et al., 2020). However, old growth trees with large canopies should be underlined for providing ES (Coskun Hepcan & Hepcan, 2017).

Another issue is the role of native tree species in providing ES. Although there are some studies that indicate the benefits of non-native species in terms of generating ES in cities (Railey et al.,2018), native species perform better in many ways including supporting urban biodiversity and carbon accumulation (Helden et al., 2012; Schwendenmann & Neil, 2014).

In order to maintain and/or improve ES there is a growing interest in the calculation and mapping of ES all over the world (European Commission, 2011). There are different methods available for the quantification and mapping of the supply of ES. They could be either allometric equations such as used by Derkzen et al. (2015), McDonald et al. (2007) and Tratalos et al. (2007), or software applications like I-Tree Eco model (USDAFS, 2008). The I-Tree Eco model uses tree measurements and other data to estimate ES. It provides flexible data collection options, automated processing and detailed reports (USDAFS, 2008). Urban landscapes need to be studied intensively for a better understanding of the urban ecological processes and related ES to develop ES friendly designs and planning approaches.

The quantification and mapping of the supply of ES are key steps in the design of urban green spaces in urban planning for ES provisions and the design of healthier and more resilient urban landscapes (Derkzen et al., 2015).

In this study the quantification of the supply of ES was undertaken in the Eugene Pioneer Cemetery of Eugene, OR (USA). The cemetery was studied because the area includes large old-growth trees that could prove their values in terms of ES. For this purpose four regulating ES were selected and studied; carbon sequestration and storage, avoided run-off, air pollution removal and oxygen production. The I-Tree Eco software application (USDAFS, 2008) was employed to quantify the above-mentioned four regulating ES.

MATERIAL and METHODS

Study area

Eugene, Oregon (USA) was chosen as the study region since some very successful projects such as West Eugene Wetland Partnership (WEW) and The Rivers to Ridges Partnership (R2R) have been undertaken in the planning and protecting of open and green spaces and the key ecosystem functions (Rivers to Ridges Partnership, 2015). In this study, the Eugene Pioneer Cemetery in Eugene was studied (Figure 1).

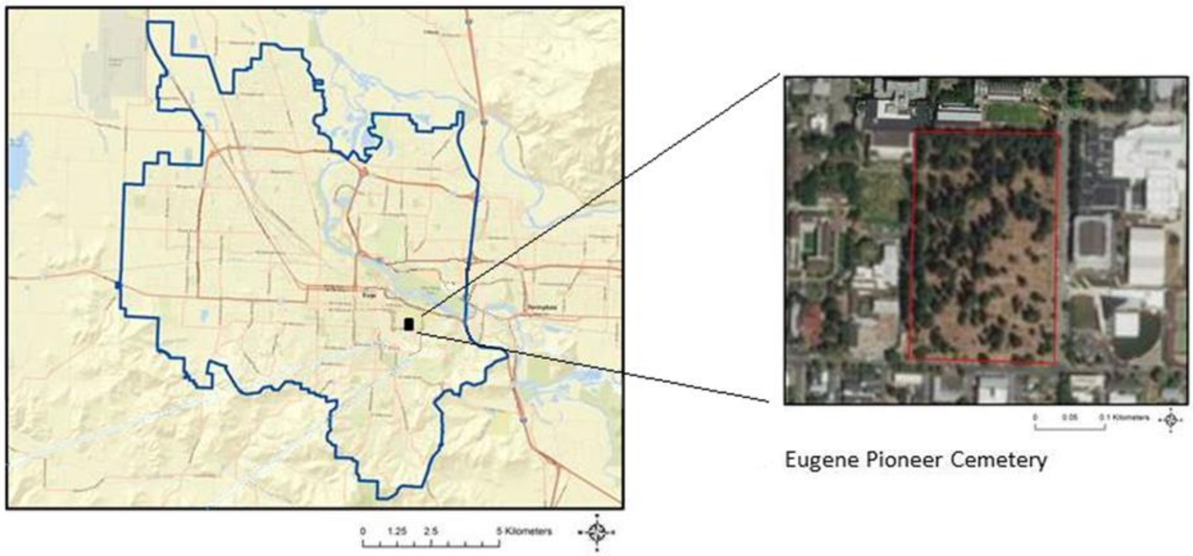

Figure 1. The study area.

***Şekil 1**. Araştırma alanı.*

The Pioneer Cemetery covering 6.67 ha was established in 1872. It is located at East 18th Ave. and University St. adjacent to the campus of the University of Oregon in Eugene (44º 2' 34" and 44º 2' 24" North, 123º 4' 29" and 123º 4' 88" West). The cemetery is full of old-growth and monumental trees. It is limited in size but still has open burial sites. Only about two or three people are still buried in the cemetery each year (EPC, 2018). It has historical significance in Eugene and has a protected status (Figure 2).

Figure 2. The Eugene Pioneer Cemetery.

***Şekil 2**. Eugene Pioneer Mezarlığı.*

Methods

Data preparation and data analysis were the primary steps of the methodology. I-Tree Eco model version 6 developed by the U.S. Forest Service, Northern Research Station, was used to calculate four regulating ecosystem services: carbon sequestration and storage, avoided run-off, air pollution removal and oxygen production. The complete inventory option was selected and all trees were measured and recorded based on the instructions of I-Tree Eco module. Tree measurements are very important for I-Tree to quantify ecosystem services. The quality of the results is closely related to the collection of recommended measurements as well as tree species and DBH data (USDAFS, 2008).

Carbon sequestration and storage; Trees reduce the amount of carbon in the atmosphere by sequestering and storing in their tissues. The size and health of the trees increase the amount of carbon sequestered annually (Abdollahi et al., 2000; Nowak et al., 2002).

Avoided run-off; Storm water run-off is one of the major concerns in urban settings. During rainfall trees and shrubs intercept some of the precipitation while the rest reaches the ground. The amount of the precipitation that does not seep into the soil naturally turns into surface run-off (Hirabayashi, 2012). In built-up areas the amount of run-off increases because of the large impervious surfaces. Trees and shrubs are very useful in terms of reducing surface run-off in urban landscapes. They intercept the rainfall and facilitate infiltration and storage by their root systems in the soil.

Air pollution removal; Air pollution is one of the major problems in urban areas. Urban trees provide valuable service in this case. Air pollution removal estimates are calculated and based on procedures mentioned in Nowak et al. (2014). In this process variables including local tree cover, leaf area index, percent evergreen, weather, pollution, and population data are used to estimate pollution removal rates (g/m^2 tree cover) and values ($\$/m^2$ tree cover). The above mentioned values are applied to the m^2 of the tree cover to estimate total removal and the values of air pollutants such as CO, NO_2, O_3, PM2.5, and SO_2. The removal of five air pollutants by trees was calculated and reported in I-Tree Eco.

Oxygen production; Oxygen production is one of the most significant and underlying benefits of trees in urban landscapes. The annual oxygen production of a tree is tied to the amount of carbon sequestered by the tree biomass (Nowak et al., 2007).

Data preparation

The field data of trees was collected on paper data sheets. The collected data in the field were land-use type, tree species (common and scientific name), and diameters of breast height-DBH (cm), total tree height (m), live crown height (m), crown base height (m), and crown percent missing. The smart phone app Timber Tree Height Estimator developed by Crop Applications, LLC was used to measure the total tree height, live crown height and crown base height of the trees. A measuring tape was used to measure the diameters of breast height (DBH) and crown width (N/S and E/W) of the trees and the direction and distance to the nearest building. The data on the paper sheets were added to the model manually.

Data analysis

I-Tree Eco calculates ES taking into account some data types, such as pollution, climate, elevation, soil and population already available in the model.

In this study ES provided by trees in the study areas was measured using the most recent available data in the model from 2015. Once the field data for the trees was collected and added into the model, I-Tree Eco required a validation process. After checking the data for validation, the model was run to calculate four regulating ES for each green area separately.

RESULTS

Tree characteristics of the cemetery

The Eugene Pioneer Cemetery has 356 trees that cover 40,9% of the entire area. The three most common species are Douglas fir (47,5%), Western red cedar (19,9%), and English holly (11,0%). The overall tree density in the cemetery is 54 trees/hectare. In the cemetery about 84% of the trees are species native to North America, while 80% are native to Oregon. Species exotic to North America make up 16% of the population. Most exotic tree species have an origin from Europe & Asia (14% of the species) (Table 1).

Table 1. Most common species in the cemetery

***Çizelge 1**. Mezarlıkta en çok bulunan türler*

Species name	*Scientific Name*	% Population
Douglas fir	*Pseudotsuga menziesii*	47.5
Western red cedar	*Thuja pilicata*	19.9
Oregon white oak	*Quercus garryana*	8.1
English holly	*Ilex aquifolium*	11.0
Big leaf maple	*Acer macrophyllum*	1.4
Pacific madrone	*Arbutus menziesii*	2.2
Black walnut	*Juglans nigra*	1.1
Japanese cherry	*Prunus serrulata*	1.7
Oneseed hawthorn	*Crataegus monogyna*	2.0
Brewer's weeping spruce	*Picea breweriana*	1.1

Carbon sequestration and storage

The gross sequestration of the cemetery trees is about 7,136 metric tons of carbon per year with an associated value of $1,020. Trees in the cemetery are estimated to store 1,610 metric tons of carbon. Of the species sampled, Douglas fir stores and sequesters the most carbon (approximately 54,6% of the total carbon stored and 31,1% of all sequestered carbon) (Figure 3).

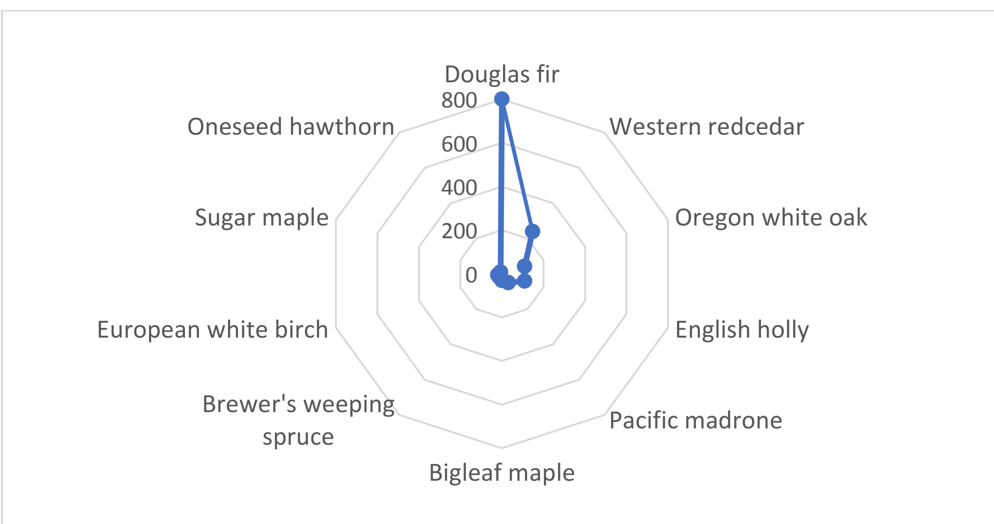

Figure 3. Estimated carbon storage (points) and values (bars) for tree species with the greatest storage.

***Şekil 3**. En fazla karbon depolayan türler ve depoladıkları karbon miktarları.*

Avoided run-off

The trees and shrubs of the pioneer cemetery help reduce surface run-off by an estimated 452 cubic meters a year with an associated value of $1,100. The avoided runoff estimate is done based on local weather from the user-designated weather station. In the cemetery the total annual precipitation in 2015 was 83,1 centimeters (Figure 4).

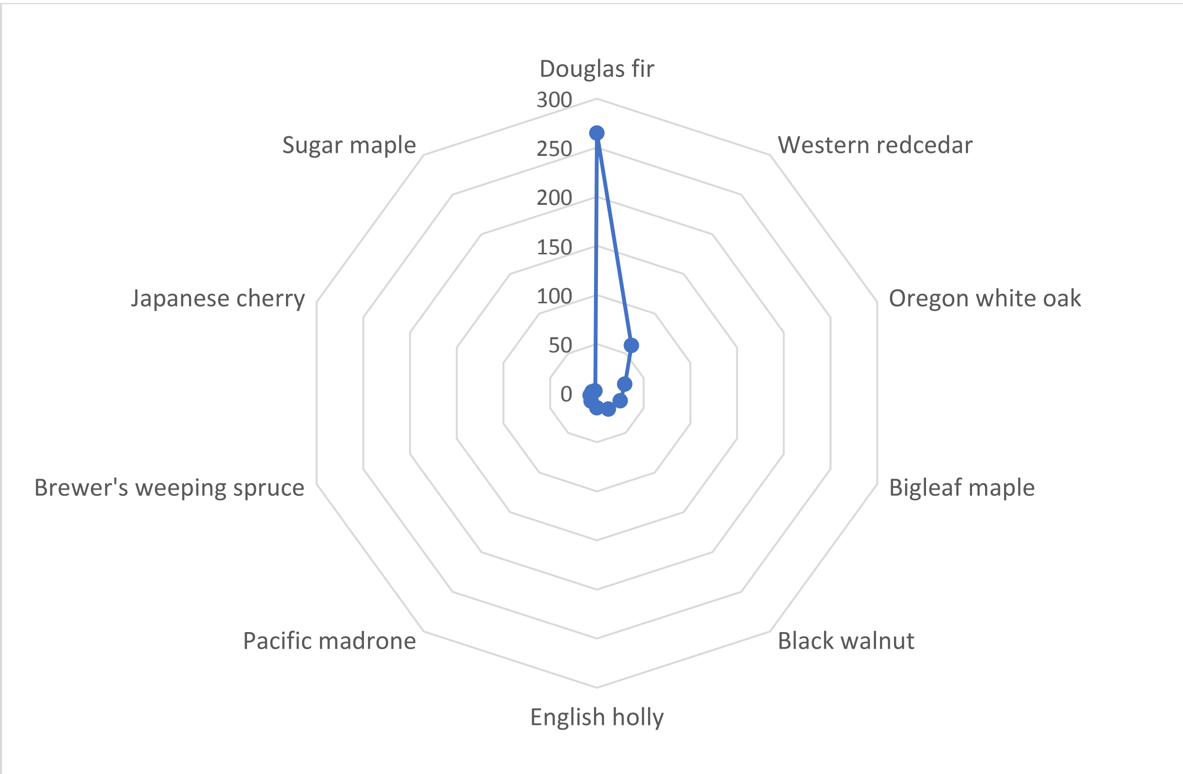

Figure 4. Avoided runoff (points) and value (bars) for species with greatest overall impact of run-off.

Şekil 4. *Yüzey akışa en fazla etki eden türler ve engelledikleri miktarlar.*

Air pollution removal by trees

Pollution removal by trees in the cemetery was estimated using field data and recent available pollution and weather data. Pollution removal was greatest for ozone (Figure 5). It was estimated that trees remove 143,9 kilograms of air pollution per year which includes ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO_2) with an associated value of $2,000.

In 2015, the trees in the cemetery emitted an estimated 99,49 kilograms of volatile organic compounds (VOCs) (25,29 kilograms of isoprene and 74,2 kg of monoterpenes). Emissions vary among species based on the species characteristics and the amount of leaf biomass. Some genera such as oaks are high isoprene emitters.

82 % of the urban forest's VOC emissions are from Douglas fir and Oregon white oak. These VOCs are precursor chemicals to ozone formation.

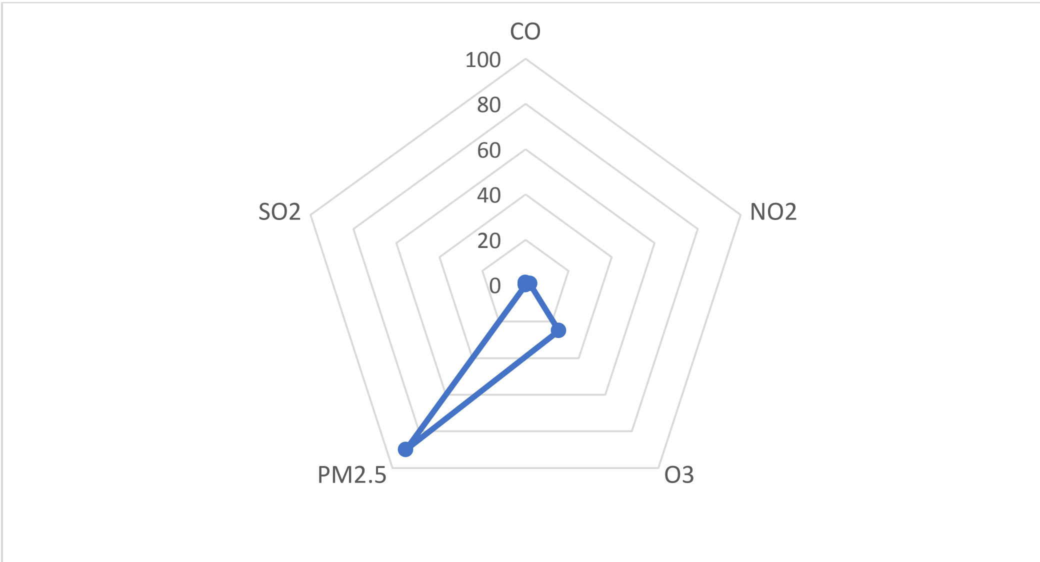

Figure 5. Annual pollution removal (points) and value (bars) by trees.

***Şekil 5**. Ağaçların yıllık olarak tuttuğu hava kirleticilerinin miktarları.*

Oxygen production

The trees in the cemetery were estimated to produce 19,03 metric tons of oxygen per year (Table 2). Douglas fir takes the lead among trees in this case. However, it should be kept in mind that there is already a large amount of oxygen in the atmosphere and the role of the aquatic system in oxygen production is very significant (Nowak et al., 2007).

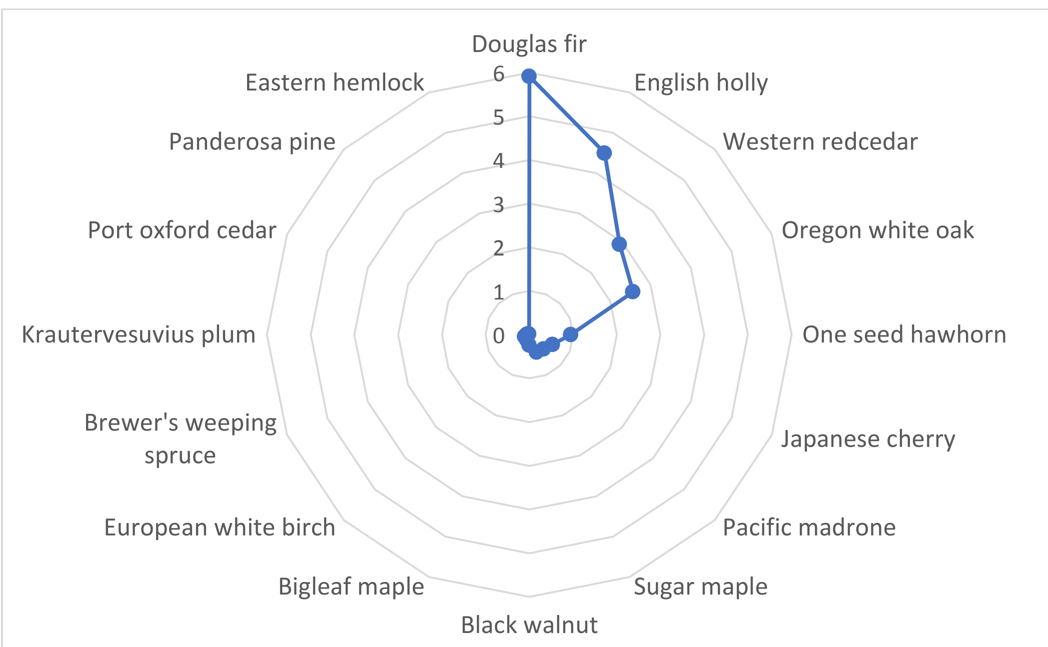

Figure 6. Annual oxygen production (kg) by trees.

***Şekil 6**. Ağaçların yıllık olarak urettigi oksijen miktarları.*

DISCUSSION and CONCLUSIONS

In this study, the Eugene Pioneer Cemetery was studied since it includes many old-growth large trees that could quantitatively show its value in terms of ES as a historically significant area. Four regulating ES have been calculated; carbon sequestration and storage, avoided run-off, air pollution removal and oxygen production. It is important to mention that above-mentioned services are also quite relevant to human health in urban landscapes (Derkzen et al., 2015).

The gross sequestration of trees in the cemetery is about 7,136 metric tons of carbon per year. Trees are estimated to store 1,610 metric tons of carbon. Carbon sequestration rate of the cemetery is a little less than the one calculated by Coskun Hepcan & Hepcan, 2018 in the Rectorship garden (7,87 metric ton/year). In terms of carbon storage on the other hand, the cemetery has performed better than the Rectorship garden because the garden has stored only 648 metric ton.

Plant cover of the pioneer cemetery helps reduce surface run-off by an estimated 452 cubic meters a year. This indicates that the Rectorship garden has a significantly higher capacity of potential runoff retention rate than the cemetery because the storm water runoff rate is estimated to be nearly 7,018.9 cubic meters in the garden (Coskun Hepcan & Hepcan, 2018).

Urban trees remove large amounts of air pollution that helps improve air quality in urban landscapes (Nowak et al., 2006; Selmi et al., 2016). In the present study, it was estimated that trees in the cemetery remove 143,9 kilograms of air pollution per year which includes ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO_2). Similarly, Coskun Hepcan & Hepcan (2017) estimated an air pollution removal rate at the Ege University housing campus in Izmir, Turkey. The findings show that plant cover of the campus removed about 28.70 kg of CO, 143.85 kg of NO_2, 1.58 tons of O_3, 90.6 kg of SO_2, and 69.61 kg PM2.5 per year.

There are a number of methods and equations for assessing ES. The present study used I-Tree Eco model. The model uses tree measurements and other data to estimate ecosystem services and structural characteristics of the tree cover. Eco model provides sampling and data collection protocols, flexible data collection options, automated processing and detailed reports (USDAFS, 2008). It is easy to use and calculate multiple ES simultaneously. But, depending upon the purpose of the study and output requirements, it needs an exact field data set as instructed in the manual of the model for the accuracy of the results. It is important to note that gathering data and entering them into the model requires significant amount of time and effort.

In quantifying carbon storage two factors are important. The first is biomass volume that is associated with the carbon storage capacity of trees. The second is vegetation type (Derkzen et al., 2015). Vegetation type is considered to be highly important by Mexia et al. (2018) and Parsa et al. (2020). Their results showed that some ecosystem services varied greatly with vegetation type. Carbon sequestration for instance was positively influenced by tree density.

Integrating the concept and the principles of ES into a green space design and management is very important, but the adaptation of this concept by spatial planners into urban planning practices may be even more important (Hubacek & Kronenberg, 2013).

In the case of run-off retention, urban green spaces with large pervious surfaces can play an important role, but some storm water facilities such as filter strips, dry detention ponds, infiltration strips, and bio-swales would also be helpful in reducing storm water run-off volume. Thus, a holistic approach that includes both large green spaces with large pervious surfaces and storm water facilities (see Strom et al., 2013) are required to deal with storm water runoff in a sustainable way in cities.

Tree cover of urban green areas in general is composed of a mix of native and exotic species. Consequently, with the contribution of exotic species, urban green areas often have higher tree diversity than the surrounding native landscapes. This raises a question mark about the use of native versus exotic species in providing ES in cities. Although there are some studies that indicated the benefits of non-native species in terms of generating ES such as Railey et al. (2018), it seems that native species perform much better for providing ES including urban biodiversity and carbon accumulation (Helden et al., 2012; Schwendenmann and Neil, 2014). The Eugene Pioneer Cemetery is distinguished by its size and old-growth trees and protected area status. More importantly, a majority of the trees in the cemetery are native to Oregon and North America. For instance, none of the 16 tree species in the cemetery are identified as invasive on the state invasive species list (Oregon Invasive Species Council, 2014). Thus, this study recommends large green areas (large pervious surfaces) and trees with large crowns as a better solution for regulating ES.

As a conclusion, it could be stated that large green spaces that contain large unsealed surfaces and a dense tree-cover composed of mostly big trees are highly recommended in terms of maximizing ES although there is no single urban green space type working equally in favor of all ES (Derkzen et al., 2015; Mexia et al., 2018).

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