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Assessing regulating ecosystem services provided by the Ege University Rectorship Garden

Cigdem Coskun Hepcan*, Serif Hepcan

Ege University Faculty of Agriculture, Department of Landscape Architecture, 35100, Bornova, Izmir, Turkey

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ABSTRACT

Urban ecosystem services are generated in a diverse set of natural and managed urban green areas, including parks, urban forests, cemeteries, vegetated corridors, vacant lots, gardens, yards, and campus areas. Private gardens are generally undervalued for the ecosystem services they provide along with the other urban green areas.

This paper aims to calculate three regulating ecosystem services; runoff retention, carbon storage and sequestration generated by the Ege University Rectorship Garden, which is one of the few former Levantine gardens remaining in the highly urbanized Bornova district in İzmir. The carbon storage and sequestration capacity of the trees in the area was calculated based on allometric equations. Runoff retention was computed by using the SCS-CN method. Findings show that pervious surfaces cover approximately two-thirds of the garden with 1203 trees. The estimated carbon storage of both the above and below-ground parts of the trees in the garden is 648.25 t. The total annual carbon sequestration rate is estimated to be 7.87 t $year^{-1}$ (0.10 kg m^{-2}). The potential storm water runoff value was predicted to be approximately 7,018.9 m^3. This indicates that the garden has a high value of runoff retention and substantial capacity carbon storage and sequestration.

It can be concluded that private gardens and associated ecosystem services in urban landscapes can play an important role in enhancing the quality of life in cities. Therefore, an integral approach is needed where all types of green areas are planned and managed in a systematic way, so that they can provide maximum services.

1. Introduction

ests, gardens, yards, campus areas, vacant lands and cemeteries provide countless vital ecosystem services (ES) for urban dwellers (McDonald and Marcotullio 2011; Cameron and Blanusa 2016; Elmqvist et al., 2015). They generate provisioning services like food (Bagdon et al., 2016; Alamgir et al., 2016), regulating services that include air filtration, carbon sequestration, microclimate regulation, run-off mitigation (Forman 2014; Nowak et al., 2006; Selmi et al., 2016), habitat and supporting services like pollination (Bagdon et al., 2016), and cultural services such as opportunities for recreation and environmental education (Chiesura 2004; Andersson et al., 2015). There is no doubt that ES have substantial impacts on the quality of life and resilience of urban landscapes (Gomez-Baggethun et al., 2013).

It is obvious that there is a growing interest in the quantification of urban ES. Most of the studies have focused on calculating the ES of urban forests (Nowak et al., 2013a; Nowak et al., 2002a), urban parks (Buchel and Frantzeskaki 2015; Langemeyer et al., 2015), urban gardens (Breuste and Artmann, 2015; Speak et al., 2015; Camps-Calvet et al., 2016) campuses (Vishnu and Patil 2016) and green infrastructure (Derkzen et al., 2015; Kim et al., 2015; Selmi et al., 2016).

There are different ways to calculate ES. In recent years scientists have focused on developing models and equations in order to calculate different ES such as inVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), CUFR Tree Carbon Calculator (CTCC), EnviroAtlas, UFORE (Urban Forest Effects Model), and I-tree Eco (Tallis et al., 2011; CUFR, 2008; Pickard et al., 2015; USDA Forest Service, 2015).

Although private gardens are important components of urban landscapes (Coskun Hepcan and Ozeren Alkan, 2017; Ross et al., 2012) with their diverse vegetation layers (trees, shrubs, herbaceous plants and grasses) and provide habitats for many species (Weather, 1999), they have often been undervalued in the ES they can provide because of their size (Breuste et al., 2015). For instance, a recent study by Kuittinen et al. (2016) stated that large private gardens in the urban landscape of Finland make a large contribution to carbon uptake.

It is very important to include every single open and green area in urban landscapes in the quantification process of ES regardless of their size (Radford and James 2013) in order to get a full picture of the

* Corresponding author.
E-mail addresses: cigdem.coskun.hepcan@ege.edu.tr (C. Coskun Hepcan), serifhepcan@gmail.com (S. Hepcan).

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services being provided.

The urban landscape in the Bornova district is dominated by multistory attached apartment blocks with very small or no gardens. Private gardens comprise only about 6% of the city of Bornova. It is also worth mentioning that the Bornova district is famous for Levantine houses and gardens. Levantine gardens are invaluable not only for their architectural and cultural values but also for habitat values with their diverse vegetation cover and large old growth trees acting like carbon sink. The Ege University Rectorship Garden is one of the former Levantine gardens remaining in Bornova. That makes it one of the few unique heritage green spaces in the urban landscape of the district. Therefore, the Rectorship garden was chosen as a study area to prove its value in terms of ES. It is also hoped that the Rectorship garden would be a good example to show how ES could be provided by private gardens in the Bornova district.

The following research questions have been investigated in this paper; (1) How much carbon could be stored and sequestrated by trees in the garden and (2) How much rainwater could be retained by the garden?

2. Study area

The Rectorship Garden (38° 27′ 38″ and 38° 27′ 50″ N, 27° 13′ 29″ and 27° 13′ 13″ E) is a part of the Ege University campus in the Bornova district in the Izmir Metropolitan area, Turkey. It encompasses about 7.2 ha area (Fig. 1).

Izmir has a Mediterranean climate characterized by dry-hot summers and mild-rainy winters. The average annual minimum and maximum temperatures are 13.4 and 22.6 °C. Most of the total rainfall is distributed in autumn and winter from September to March and mean annual rain is 695 mm (Meterological Service, 2017).

Bornova was one of the suburbs of Izmir in the early 1900′s. Mostly merchant families, called Levantines, settled in Bornova in luxury villas with large gardens. Starting after the 1960′s, urbanization in Bornova took place in a similar fashion as Izmir where the urban landscape pattern has been dramatically changed and agricultural areas and low-density housing have been replaced by high density developments in the form of multistory apartments (Hepcan et al., 2013). Unfortunately in this period many single-family houses with large gardens have disappeared. Although Levantine gardens represent the valuable historic and cultural heritage of Bornova, only a few remaining houses and gardens have been preserved. Some of them were converted to commercial uses like a boutique hotel, museum or restaurants.

The Rectorship garden was established in the 18th century by a Levantine family (Sonmez 2010). It has been owned by Ege University since 1960 and used as an administrative campus. Thus, it is not open to the public.

It contains 131 different plant species both native and exotic, including some monumental trees around 400 years old (Coskun Hepcan et al., 2015) (Fig. 1). Therefore it provides valuable habitats with high biodiversity of plants, birds and insects (Coskun Hepcan and Ozeren Alkan, 2017).

3. Material and method

3.1. Material

The land cover map was derived from orthorectified WorldView2 (Pan + MS bundle, 0.5 m ground resolution, dated September 2013) image by screen digitizing using ArcInfo 10 (ESRI, 2006).

The land cover map of the garden was classified into five classes to define pervious and impervious spaces as (1) buildings, (2) green areas (lawn areas with plant cover and olive plantation), (3) soil (bare soil without grassy plant cover), (4) pavements (paving stone) and (5) water bodies (artificial ponds).

The plant cover data was obtained from the Rectorship Garden Atlas of Plants book (Coskun Hepcan et al., 2015). The tree data was updated. The heights of the trees were measured in the field by using a blumeleiss. The diameters of breast height (DBH) of the trees were measured at 1.37 m (4.5 feet) above the ground using a measuring tape. The meteorological data was provided by Turkish State Meteorological Service (TSMS, 2017).

3.2. Method

The method is composed of the calculation of regulating ES including the carbon sequestration and run off retention in the study area.

3.2.1. Carbon storage and sequestration

Trees can reduce the amount of carbon in the atmosphere by providing a net increase in new growth (carbon) every year (i.e., growth > decomposition). The amount of carbon annually sequestered is typically greatest in large healthy trees. The process by which a tree removes carbon from the atmosphere is called carbon sequestration. The amount or weight of carbon currently accumulated by a tree is considered carbon storage (Nowak et al., 2012).

Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing carbon as biomass (Nowak et al., 2002b). Carbon stored in a tree is proportional to its biomass, which increases with its diameter, height, and canopy spread (McPherson 1998). The amount of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted and the density of the tree's wood (Jana et al., 2010).

The net long-term CO_2 source/sink dynamics of forests change through time as trees grow, die and decay. Humans can influence and affect the CO_2 source/sink dynamics of the trees by harvesting/trimming of biomass or relieving fossil fuel emissions (Nowak et al., 2002b). Trees in urban areas (i.e., urban forests) currently store carbon, which can be emitted back to the atmosphere after tree death and sequester carbon as they grow (Nowak 1994).

There are many different approaches and methods that can be explored to estimate the overall carbon sequestration and storage of an area. Most models and methods use certain parameters of an individual tree, such as age, diameter, height and species, and the region where the tree is located.

In this research the amount of carbon storage by trees was calculated in three steps by using allometric equations; (1) determine the aboveground biomass of the tree, (2) determine the dry weight of the tree, (3) determine the weight of carbon in the tree.

The aboveground biomass of the tree was calculated by the equations;

$W = 0.25D^2H$, for trees with $D < 11$ inch,

$W = 0.15D^2H$, for trees with $D \geq 11$ inch (Alexander et al., 1986).

Where W = Aboveground weight of the tree in pounds, D = Diameter of the trunk in inches, and H = Height of the tree in feet. Before doing the calculations all tree measurements were converted from metric to feet and inches.

Above-ground biomass is converted to whole tree biomass based on a root-to-shoot ratio of 0.26 (Cairns et al., 1997). Equations that compute fresh weight biomass are multiplied by species specific conversion factors to yield dry weight biomass. These conversion factors, derived from average moisture contents of species given in the literature averaged 0.48 for conifers and 0.56 for hardwoods (Nowak et al., 2002a). Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations. To adjust for this difference, biomass results for urban trees were multiplied by 0.8 (Nowak 1994). The average carbon content is generally 50% of the tree's total volume. Therefore, to determine the weight of carbon in the tree, dry weight of the tree was multiplied by 0.5 (Birdsey 1992; Chow and Rolfe