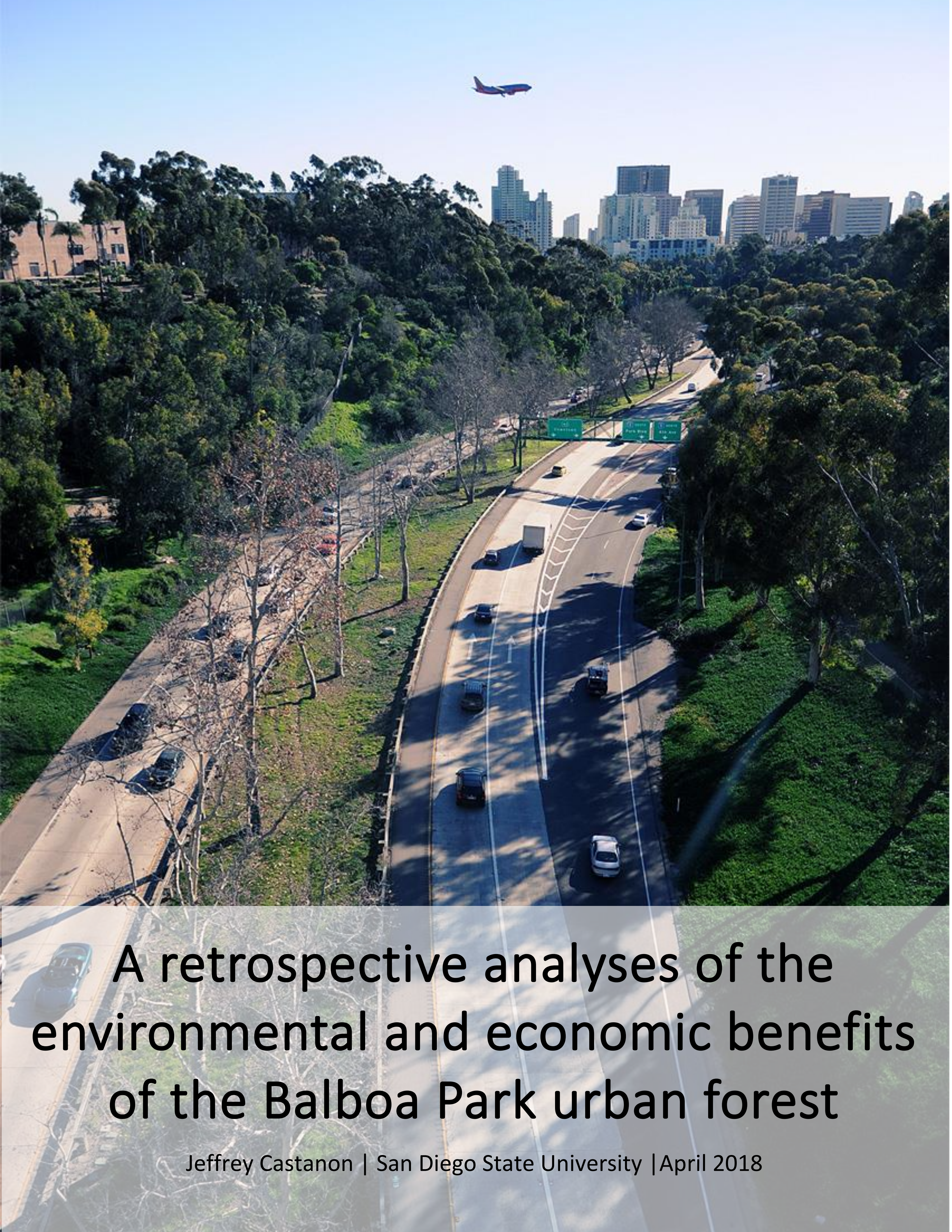

A retrospective analyses of the environmental and economic benefits of the Balboa Park urban forest

Jeffrey Castanon | San Diego State University |April 2018

Abstract

Urban planners have long understood the need to provide urban residents with access to natural landscapes such as urban forests. The presence of these green spaces increases resident's quality of life and provides communities with an array of environmental and economic benefits. Fully quantifying these benefits is difficult as many valuation methods (such as hedonic analysis and contingent valuation methods) may capture local/perceived amenity values but may not fully capture environmental benefits such as carbon sequestration, air pollution removal, and avoided storm water runoff. As such, there is a need to utilize methods that fully quantify the environmental and economic benefits of urban forests to ensure they are properly valued in planning and policy decision-making. This paper quantifies the environmental benefits of Balboa Park, the largest urban cultural park in the United States, using a rich tree census from 1998 paired with state-of-the-art urban forest modeling software. In 1998 alone, trees in the urban forest stored an estimated 5.8 thousand metric tonnes (mT) of carbon ($828 thousand) and carried a structural value of $65.4 million. Annually, the forest was capable of sequestering 218.5 mT of carbon ($31.3 thousand/year), removing 7.9 mT of pollutants ($71.5 thousand/year), and intercepting 4.3 thousand cubic meters of surface runoff ($10 thousand/year). Taken together, these environmental services alone are enough to offset approximately 1/3 of all annual maintenance costs in the park.

Acknowledgments

I would like to extend my deepest gratitude to Ryan Abman who served as research advisor to this project; his guidance and wisdom was paramount to the success of this study. Special thanks are also extended to Jaqueline Higgins who provided mentorship and the original 1998 tree inventory on which this research was conducted; without her this study would not have been possible. I am also grateful to the Balboa Park Conservancy and the San Diego Department of Parks and Recreation whose hard work and dedication has truly helped make Balboa Park the crown jewel of San Diego.

Cover: The Balboa Park urban forest frames the Cabrillo Freeway looking towards downtown San Diego.

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Introduction

Economists have identified multiple approaches to capture the economic value of ecosystem services provided by urban forests. Such methods include the hedonic pricing method, which seeks to capture consumers' marginal willingness-to-pay (MWTP) by correlating changes in housing prices and their proximity to an urban forest, and the contingent valuation method, which utilizes surveys to capture consumers' MWTP. However, due to environmental complexities, these valuations are often based off of imperfect understandings of environmental processes, functions, and values and may ultimately undervalue vital ecosystem services (Robinson et al. 2014). As such, there is a need to utilize methods that fully quantify the environmental and economic benefits of urban forests to ensure they are properly valued in planning and policy decision-making.

Balboa Park's urban forest provides the City of San Diego and its 1.4 million residents with a number of environmental and economic benefits. The park's urban forest provides wildlife habitat, aesthetic appeal, and visual barriers; reduced air temperatures, improved water quality, and mitigated air and noise pollution (Nowak, 2016). Recent developments in high quality, user-friendly online software to assess the economic and environmental benefits of urban forests, such as the iTree Eco modeling software developed by the U.S. Forest Service and Davey Tree Company, have made it easier to quantify these benefits (Dolesh, 2013). To date there has never been a study conducted that quantifies the environmental and economic benefits of the Balboa Park urban forest.

In 1998, the City of San Diego Department of Parks and Recreation published the first comprehensive horticultural inventory of Balboa Park. Using these data and the iTree Eco modeling software developed by the U.S. Forest Service, this study quantifies the historic economic and environmental benefits of the Balboa Park urban forest. This includes the human health costs of removing ozone, nitrogen dioxide, sulfur dioxide, and fine particulate matter from the air; the quantity of surface water runoff that is reduced annually; and the annual quantity and value of climate mitigation through carbon storage in the trees tissues. This study shows that in 1998, the forest was capable of annually sequestering 218.5 mT of carbon ($31.3 thousand/year), removing 7.9 mT of pollutants ($71.5 thousand/year), and intercepting 4.3 thousand cubic meters of surface runoff ($10 thousand/year). Moreover, in 1998 alone, the urban forest stored an estimated 5.8 thousand metric tonnes (mT) of carbon ($828 thousand) and carried a structural value of $65.4 million.

This retrospective analysis concludes that the Balboa Park urban forest provides the City of San Diego with significant environmental and economic benefits. Likewise, this study provides a baseline understanding of the composition and functions of the largest urban cultural park in the United States of America. This study, when compared to current and future studies, will provide researchers with a better understanding of how urban forests change over time, key forces of change, current management needs, and future trends in forest health and productivity. Lastly, this study provides natural resource economists with an alternative method to determine the value of the ecosystem services provided by urban forests.

Background

Balboa Park is a 1,200-acre urban cultural park overlooking Downtown San Diego and is the largest urban cultural park in North America. The park began in 1868 as 1,400 acres of land set aside by San Diego civic leaders. Balboa Park's urban forest began development in 1892 when horticulturalist Kate O. Sessions began planting trees in the park in exchange for 30 acres of land for her nursery. In 1902, landscape architect Samuel Parsons developed a comprehensive plan for Balboa Park and planting development continued. By 1910 the park's natural landscape began to look much as it does presently. The infrastructure of the cultural park's center was developed for the Panama-California Exposition of 1915-16 and the California Pacific Exposition of 1935-36. Balboa Park now represents more than 100 years of planned horticultural development to create the largest urban park in the city of San Diego.

In December 2015, the City of San Diego approved a Climate Action Plans, which calls for achieving 15% urban tree canopy coverage by 2020 and 35% urban tree coverage by 2035 to reduce GHG emissions. To meet this objective the City of San Diego Planning Department adopted an Urban Forestry Management Plan on January 24, 2017. This plan recognizes the need to obtain a comprehensive understanding of the San Diego urban forest to meet the goal of increasing the City's urban tree canopy cover and maximize the benefits of trees. At this time, there have been no major longitudinal urban tree studies conducted on the San Diego urban forest; however, a comprehensive horticultural inventory of Balboa Park published in 1998 provides the opportunity to conduct a retrospective analysis of the Balboa Park urban forest, which can provide a baseline for future studies.

Methods

The estimates in this study are based off the Balboa Park Tree Survey Report published in 1998 by the City of San Diego Park and Recreation Department. Field data was collected on the Central Mesa in 1991-92, West Mesa in 1995, and East Mesa in 1997. The inventory contains tree quantity, species, vertical height, DBH and location (City of San Diego, 1998).

DBH was measured for all trees over 1” diameter to the nearest 1/8th of an inch at 4.5’above the ground. DBH for trees growing in a horizontal direction were measured 4.5’ from the base of the tree. Trees with branches or bulges at 4.5’ above the ground were documented using the average diameter from measurements taken about and below the branch of bulge. Trees, which were forked below 4.5’, were measured using the largest stem diameter at 4.5’ while noting the diameter of any other stems greater than 12”. For large groves of trees of similar size and species the average DBH of ten trees was calculated within the grid square and the total quantity of similar sized trees was documented. Individual trees of different size and species within the grid square were documented separately. Trees with a DBH less than 1” were not counted (City of San Diego, 1998).

Vertical height was measured with a clinometer and recorded to the nearest five feet. For areas with large groves of the same size and species the average height of ten trees was calculated within the grid square and the total quantity of similar sized trees was documented. Individual trees of different size and species within the grid square were documented separately. Trees under four feet tall were not counted (City of San Diego, 1998).

Location was documented using a physical grid surveyed by the City of San Diego Engineering Department. Surveyors laid out 250x250ft grid squares throughout the park with concrete cores topped with brass markers. Location of trees within each grid square was documented using the number corresponding to the markers in the Southwest corner of the grid square (City of San Diego, 1998).

Data from the *Balboa Park Tree Survey Report* were analyzed using the iTree Eco modeling software. ITree Eco is a peer-reviewed software suit from the USDA Forest Service, which provides analysis and assessment of urban forest benefits (Pincetl et al., 2013). ITree Eco uses the Urban Forest Effects (UFORE) computer model and standard field, air pollution, and meteorological data to quantify urban forest structure and various forest related benefits. The model quantifies species composition and diversity, diameter distribution, tree density and health, leaf area, leaf biomass; hourly volatile organic compound (VOC) emissions; total carbon stored and net carbon sequestered annually; and hourly pollution removal percent improvement in air quality by the urban forest (Nowak and Crane, 2000).

The original inventory reported data for 15,271 individual trees. Of these trees, 14,982 were included in this study. 204 trees were omitted due to a tree height less than breast height (4.5 feet), 42 trees were omitted due to a reported DBH of zero, 39 trees were omitted because the species was not recognized by the iTree Eco software, and 4 were omitted due to missing data.

Hourly pollution removal and improvement in air quality are calculated for ozone (O3), sulfur dioxide (SO2), nitrogen dioxide (NO2), and particulate matter (PM). Estimates are derived from calculated hourly tree-canopy resistances for O3, SO2, and NO2 based on a hybrid of bigleaf and multi-layer canopy deposition models (Baldocchi, 1988; Baldocchi et al., 1987; Nowak, 2016). Pollution and weather data for 1998 was unavailable within the iTree Eco modelling software. The model was run using data from 2005 which was the most similar data available within iTree Eco.

The value of pollutant removal is estimated as the economic value associated with avoided human health impacts (Nowak, 2016). Monetary value resulting from changes in pollutant concentrations due to removal by trees was calculated using the U.S. EPA's Environmental Benefits Mapping and Analysis Program (BenMap) which uses local pollution and population data to estimate the health impacts of human exposure to changes in air quality and the economic value of those changes (Nowak et al., 2014; Nowak, 2016; U.S. Environmental Protection Agency, 2012)

Carbon storage in the aboveground tissue of urban trees was calculated as 40% of the dry weight biomass of each tree, which was derived using forest-derived equations from literature and field, measured tree data. (Nowak, 1994; Nowak, 2016; Nowak and Crane, 2002; Nowak et al., 2002b). Carbon sequestration was calculated using estimates of average annual tree growth (Nowak, 2016).

ITree Eco uses a value of $143.00/mT of carbon. This value is derived from the Interagency Working Group on Social Cost of Green House Gases Technical Supporting Document (2016). This document estimates the social cost of CO2 in 2015, with a 3% discount rate to be $36/mT in 2007 dollars. This value was conservatively converted to 2017 dollars to reach a value of $39/mT of CO2. A ratio of 44:12, based on the atomic weight of CO2 and carbon, was then used to convert $39/mT CO2 to $143/mT C as shown below (Henning, 2017).

$$\$39/mTCO_2 \times \frac{\frac{44g}{mol}CO_2}{\frac{12g}{mol}C} = \$143/mT\ C$$

Results

Summary

To retrospectively analyze the environmental and economic benefits of the Balboa Park urban forest a complete inventory of the park's trees published in 1998 was processed using iTree Eco modelling software. The results of this report have been summarized in Table 1.

Table 1. – Summary of the Balboa Park urban forest, Balboa Park, 1998

Feature	Estimate
Number of trees	14,982
Tree cover	78.36 hectares
Most common species of trees	Sugar gum eucalyptus, Red gum eucalyptus, Silver dollar eucalyptus
Percent of trees less than 15.2 cm diameter*	24.6%
Pollution removal	7.949 mT
Carbon storage	5.794 thousand mT
Carbon storage value	$828 thousand
Carbon sequestration	218.5 mT/ year
Carbon sequestration value	$31.3 thousand/ year
Oxygen production	582.8 mT/ year
Avoided runoff	4.267 thousand cubic meters/ year
Avoided runoff value	$10.1 thousand/ year
Structural value	$64.5 million

*Diameter measurements were taken at breast height (DBH)

Note: mT = 1000 kilograms. Monetary values ($) are reported in US Dollars.

Urban Forest Characteristics and Demographics

In 1998 the Balboa Park urban forest had an estimated 14,982 trees with 308 individual tree species documented. The three most common tree species were Sugar gum eucalyptus (*Eucalyptus cladocalyx*), Red gum eucalyptus *(Eucalyptus camaldulensis*), and Silver dollar eucalyptus (*Eucalyptus polyanthemos*). The 10 most common tree species made up 54.6 percent of all trees in the park (Fig. 1) The DBH of trees in Balboa Park ranged from 2.6 cm to 304.8 cm. The average DBH of all trees was 33.7 cm (13.3 in) with 79% of trees having a DBH less than or equal to 45.7 cm (Fig. 2).

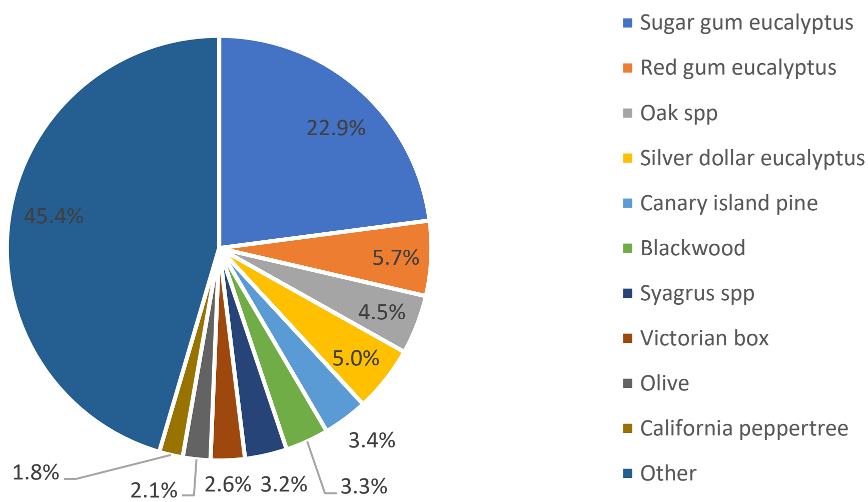

Figure 1. – Tree species composition as a percentage of all trees , Balboa Park, 1998

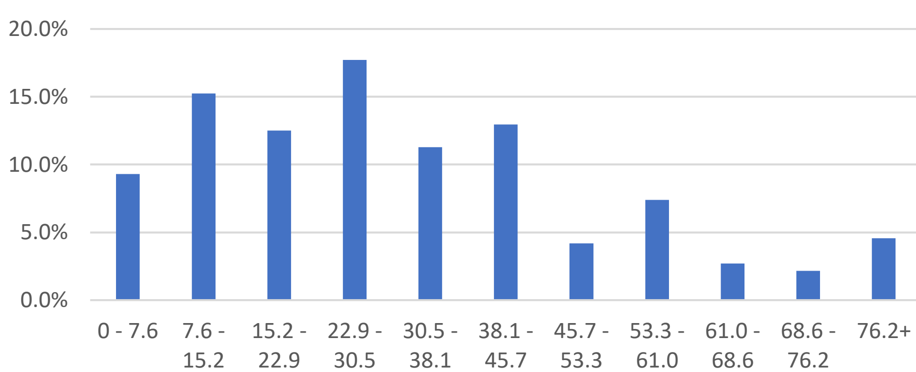

Figure 2. – Percent of tree population by DBH class, Balboa Park, 1998

The Balboa Park urban forest is comprised of both native and non-native tree species. In 1998, approximately 9 percent of the trees documented were native to North America and 4 percent were native specifically to California. Non-native species constituted 91 percent of the total tree population with most (54 percent) of the trees being native to Australia (Fig. 3). Of the 308 tree species in Balboa Park, California peppertree, Brazilian peppertree, and Blue gum eucalyptus are identified as invasive by the California Invasive Species Advisory Committee (2010). These three invasive species comprised 3.5 percent of the total tree population.

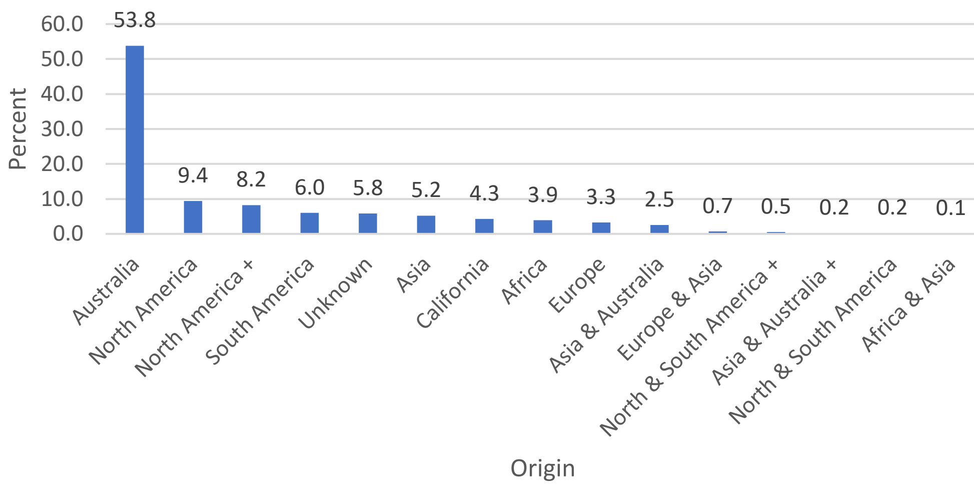

Figure 3. – Percent of tree population by area of native origin, Balboa Park, 1998
Note: The plus sign (+) indicates the tree species is native to another continent other than those listed in the grouping

Urban Forest Cover and Leaf Area

Many economic and environmental benefits of urban forests relate directly to the quantity of leaf surface area of its trees. In 1998 trees covered 78.36 hectares (193.63 acres) of Balboa Park and provided 355.7 hectares of leaf area[1]. The most dominant species in terms of leaf area were Sugar gum eucalyptus, Red gum eucalyptus, and Oak spp. The 10 most common species accounted for 69.2% of the total leaf area (Fig. 4).

[1] Leaf area is a measure of one side of a leaf's surface area (Nowak et al, 2014)

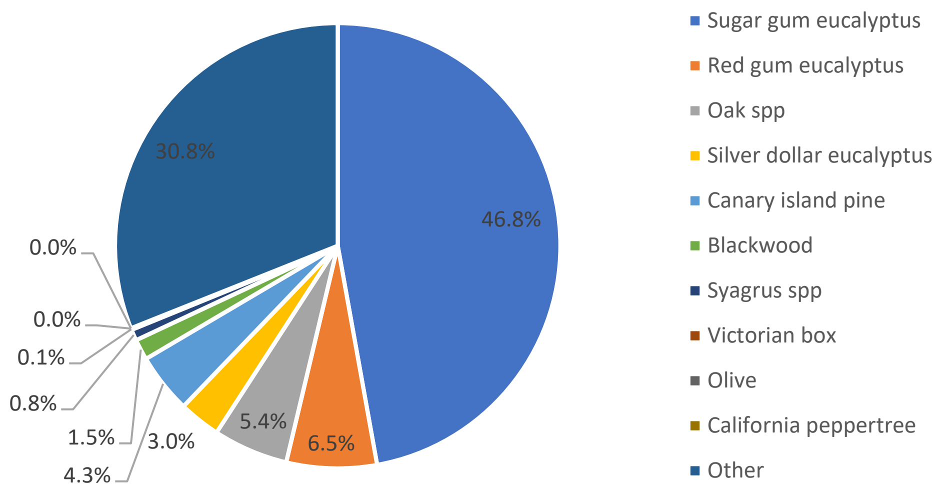

Figure 4. – Tree species leaf area as a percentage of total leaf area, Balboa Park, 1998

Air Pollution Removal

The removal of pollutants from the atmosphere by Balboa Park trees in 1998 was estimated using available pollution and weather data from San Diego International Airport (weather station 722900-23188)[2]. In 1998, the Balboa Park urban forest removed a total of 7.949 mT of pollutants from the atmosphere with an estimated economic benefit of $71.5 thousand. Pollutant removal was greatest for ozone (O3) and particulate matter less than 2.5 microns (PM2.5) (Fig. 5).

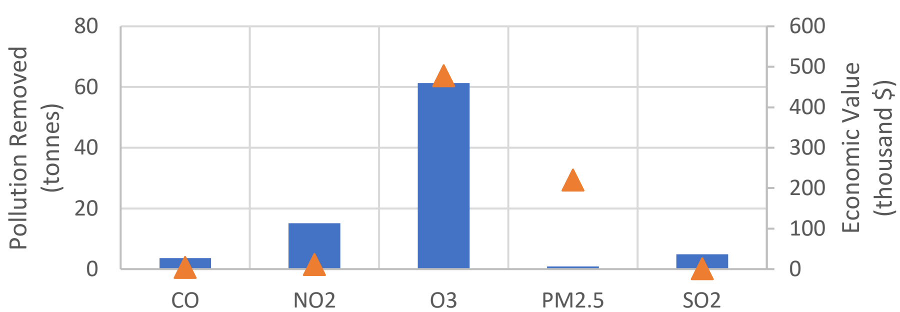

Figure 5. – Annual pollution removal (bars) and associated economic value (points) by urban trees, Balboa Park, 1998

Carbon Storage and Sequestration

Urban trees help to mitigate climate change by sequestering carbon from the atmosphere and storing carbon in their tissue. The annual carbon sequestered and storage increases annually with the size and health of the trees. In 1998, the gross sequestration of carbon by trees in Balboa Park was approximately 218.5 mT of carbon per year with an associated value of $31.3 thousand Fig. 6). The trees in Balboa Park

[2] Pollution and weather data for 1998 was unavailable within the iTree Eco modelling software. The model was run using data from 2005, which was the most similar data available within iTree Eco.

also stored an additional 5,794 mT of carbon worth an estimated $828 thousand (Fig. 7). Sugar gum eucalyptus stored approximately 42.9 percent of the total carbon and 51.2 percent of all sequestered carbon.

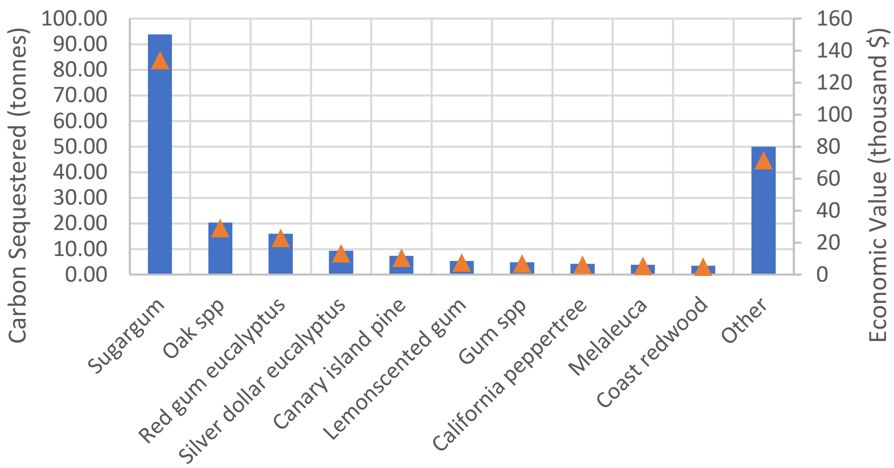

Figure 6. – Estimated annual gross carbon sequestration (bars) and associated economic value (points) for tree species with the greatest sequestration, Balboa Park, 1998

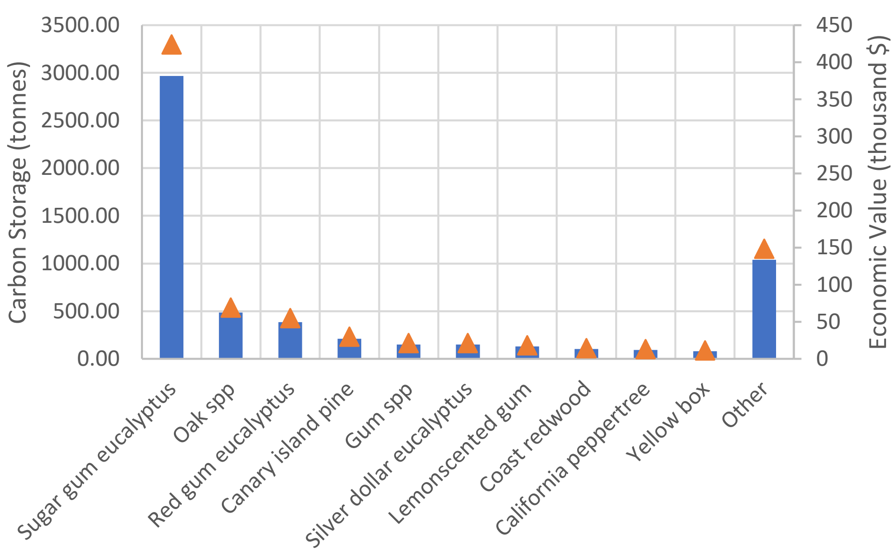

Figure 7. – Estimated carbon storage (bars) and associated economic value (points) for urban tree species with the greatest storage, Balboa Park, 1998

Oxygen Production

In 1998, trees in Balboa Park are estimated to have produced 582.8 mT of oxygen per year (Fig. 8). However, it should be noted that oxygen production of the Balboa Park urban forest is relatively negligible due to the large and stable reservoir of oxygen in the atmosphere and the extensive production of oxygen by aquatic systems.

Table 2. - Top 10 oxygen producing tree species, Balboa Park, 1998

Species	Oxygen Production (mT)	Carbon Sequestration (mT/year)	Number of Trees	Leaf Area (hectare)
Sugar gum eucalyptus	250.13	93.80	3,437	166.30
Oak spp	54.32	20.38	681	19.31
Red gum eucalyptus	42.60	15.98	854	22.97
Silver dollar eucalyptus	24.91	9.34	742	10.65
Canary island pine	19.46	7.30	513	15.42
Lemonscented gum	14.03	5.26	233	7.25
Gum spp	12.91	4.84	161	8.21
California peppertree	11.24	4.22	271	0.78
Melaleuca	10.28	3.85	225	4.30
Coast redwood	9.24	3.46	261	9.60

Avoided Runoff

Surface runoff is a problem in urban environments due to the large amount of impermeable surface. This surface runoff can contribute to the pollution of streams, wetlands, rivers, lakes, and oceans. Urban trees are beneficial in reducing runoff by intercepting precipitation and promoting infiltration and storage of water in the soil. In 1998, the Balboa Park urban forest helped to reduce surface runoff by approximately 4.27 thousand cubic meters/ year. This avoided runoff has an estimated economic value of $10.1 thousand.

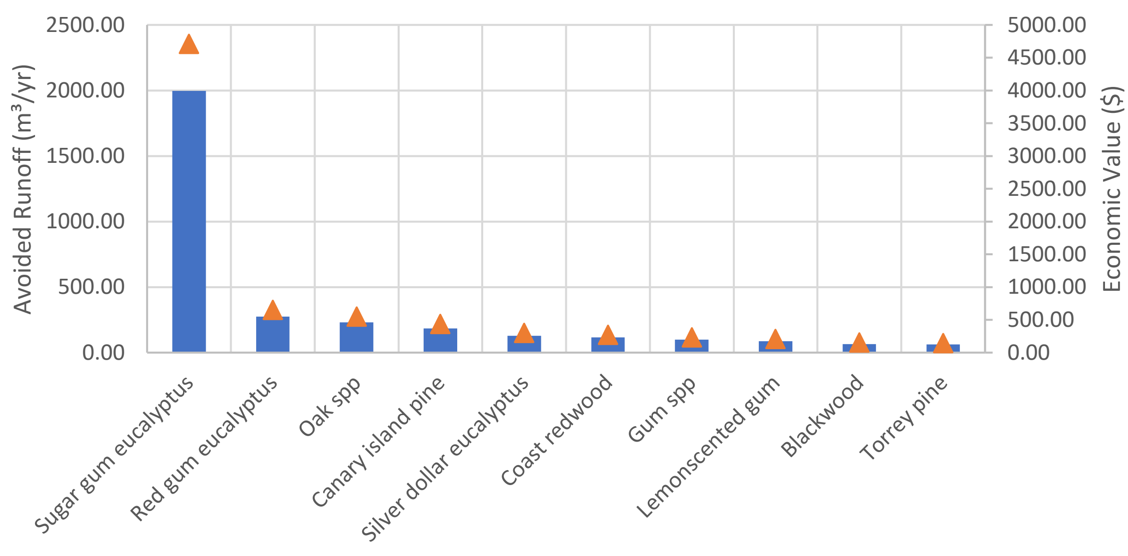

Figure 8. – Avoided runoff (bars) and associated economic value (points) for tree species with the greatest overall impact on runoff, Balboa Park, 1998

Structural Value

Urban forests have a structural value based off the economic value of the trees themselves based off the cost of replacing a tree with a similar tree. The structural value of individual trees increases each year as they grow in size. In 1998, the structural value of the Balboa Park urban forest is estimated to be $64.5 million. The tree species with the highest structural value were Sugar gum eucalyptus, Torrey pine, and Oak spp (Fig. 9). Through proper management, the value and benefits of the urban forest will increase; however, if the amount of healthy trees declines, the value and benefits of the urban forest may decrease.

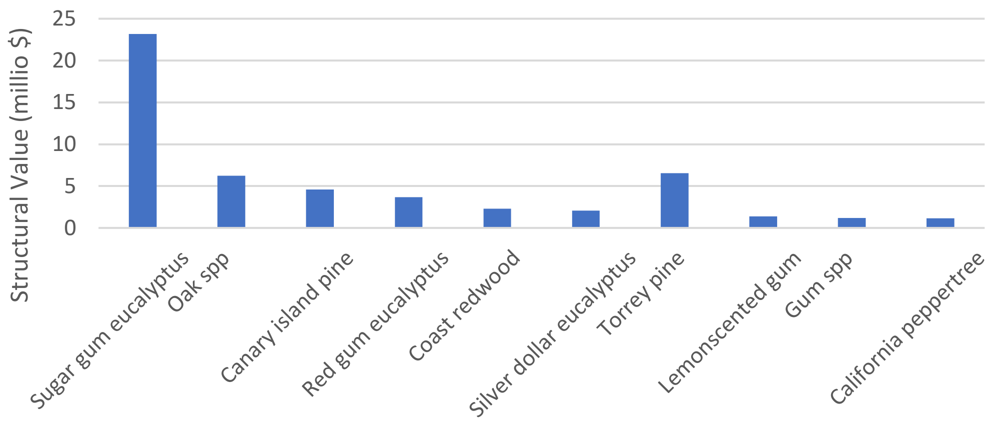

Figure 9. – Tree species with the greatest structural value, Balboa Park, 1998

Quantification of Environmental Benefits

Understanding the economic and environmental benefits of urban trees is vital to justify investment and improve stewardship; however, it is also important to consider the associated costs of maintaining an urban forest (Song et al., 2018). Likewise, comparing the cost of maintaining an urban forest to its economic benefits is important for illustrating the magnitude of said benefits. A City of San Diego memorandum from 2001 concluded that the proper maintenance of the Balboa Park urban forest would require an annual budget of $318 thousand. This budget includes funding for two tree crews, equipment assignment and usage, supplemental contractual tree work, and new tree purchases (Metro Parks Division, 2001). The different in the net annual benefit and net annual cost of the Balboa Park urban forest is estimated to be -$293 thousand. (Table 3). Altogether, the annual net economic benefits of the urban forest offset the forests maintenance costs by 35.5%.

Table 3. – Net economic benefits of the Balboa Park urban forest, Balboa Park, 1998

Feature	Economic Value ($)
Structural Value	64,547,286.83
Carbon Storage	828,476.26
Sum of existing benefits	**65,375,763.09**
Pollution removal	71,484.11
Carbon sequestration	31,251.08
Avoided runoff	10,073.78
Sum of annual benefits	**112,808.97**
Personnel and contractual costs	318,137.19
Equipment usage and assignment charges	37,924.00
New tree purchases	50,000.00
Sum of annual costs	**318,137.19**
(Annual Benefits / Annual Costs) × 100%	**35.46%**

Conclusion and Discussion

In 1998, the Balboa Park urban forest provided the city of San Diego and its residents with significant environmental and economic benefits. The parks 15 thousand trees, represented by 308 different species, provided a tree cover of over 78 hectares. This canopy provided a direct benefit to environmental and human health by removing nearly 8 mT of pollutants per year from the atmosphere. The urban forest also provided environmental and economic benefits by sequestering 219 mT of carbon per year and storing an estimated 5.8 thousand mT of carbon. The annual economic benefit of these environmental benefits is $112.8 thousand, which accounts for over 1/3 of the cost to maintain the Balboa Park urban forest. In the future, this study can be used as a baseline measurement to monitor changes in the structure and function of the Balboa Park urban forest.

This is the first assessment of the environmental and economic benefits of the Balboa Park urban forest ever conducted. The iTree Eco modelling software helped to determine the past condition of the Balboa Park urban forest as well as quantify the associated benefits provided by the trees within the park. This retrospective analysis provides future researchers with the opportunity to conduct a longitudinal study of the Balboa Park urban forest.

Future studies should take into consideration that the iTree Eco model was run using 2005 pollution and weather data rather than data from 1998. The iTree software does not contain data beyond 2005 and a custom analysis cannot be run within the software. 2005 pollution and weather data was used because it was the oldest data set available and most closely resembled the pollution and weather data from 1998; however, it should be noted that precipitation levels were greater in 2005 than 1998. As such, if the model were run using pollution and weather data from 1998, one would expect the economic benefits from pollution removal and avoided runoff to be lower than reported in this study.

Another consideration when discussing the economic and environmental benefits of the Balboa Park urban forest is how carbon removal from the atmosphere is valued. The economic benefits from carbon sequestration and storage used in this study are based off research conducted by the Interagency Working Group on the Social Cost of Carbon. The valuation iTree Eco uses is conservatively based off the agencies figure for 3% discount rate for 2015. There are a number of different estimates for the social cost of carbon that vary due to differences in models, discount rates, emission scenarios, etc. An analyses of carbon pricing is beyond the scope of this study; however, it should be noted that there are multiple values attributed to the social cost of carbon.

Lastly, the Balboa Park Conservancy is currently conducting a complete tree inventory for the first time since 1998. Once finished, the 2018 inventory will be processed using the same methods used in this study to assess the environmental and economic benefits of the Balboa Park urban forest. This will allow future researchers to analyze how the Balboa Park urban forest has changed over a twenty-year period. The Balboa Park urban forest has experienced a number of stressors including drought, invasive species, and budget constraints to name a few. Understanding how the Balboa Park urban forest has responded to these and other factors over the last two decades will help managers and policy makers in future decision making to achieve the cities goal of reaching a 35% urban tree cover by 2035.

Bibliography

Baldocchi, D. 1988. A multi-layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment. 22: 869-884.

Baldocchi, D.D.; Hicks, B.B.; Camara, P. 1987. A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21: 91-101.

California Invasive Species Advisory Committee. 2010. The California Invasive Species List. CA: Invasive Species Council of California. http://www.iscc.ca.gov/docs/CaliforniaInvasiveSpeciesList.pdf

Dolesh, R. J. 2013. Trees and urban forests. Parks & Recreation, 48, 35-36,70. http://libproxy.sdsu.edu/login?url=https://search-proquestcom.libproxy.sdsu.edu/ docview/1449565497?accountid=13758

Henning, Jason (2017). Social cost of carbon. I-Tree tools user forum. https://forums.itreetools.org/viewtopic.php?f=8&t=1219

Interagency Working Group on Social Cost of Carbon, United States Government. 2016. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. http:// www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf

Mcpherson, E. G., Nowak, D., Heisler, G., Grimmond, S., Souch, C., Grant, R., & Rowntree, R. 1997. Quantifying urban forest structure, function, and value: The Chicago urban forest climate project. Urban Ecosystems, 1(1), 49-61. http://dx.doi.org.libproxy.sdsu.edu/10.1023/A:1014350822458

Metro Parks Division (2001). Balboa Park Forest Report. San Diego.

Nowak, D. J. 2016. Austin's urban forest, 2014. Newtown Square, PA: United States Department of Agriculture, Forest Service, Northern Research Station.

Nowak, D.J.; Crane, D.E. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. U.S. Department of Agriculture, Forest Service, North Central Research Station: 714-720.

Nowak, D.J.; Hirabayashi, S.; Bodine, A.; Greenfield, E.J. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193: 119-129.

Pincetl, S., Gillespie, T., Pataki, D. E., Saatchi, S., & Saphores, J. 2013. Urban tree planting programs, function or fashion? Los Angeles and urban tree planting campaigns. GeoJournal, 78(3), 475-493. http://dx.doi.org.libproxy.sdsu.edu/10.1007/s10708012-9446-x

Robinson, D., I. Fraser, E. Dominati, B. Davíðsdóttir, J. Jónsson, L. Jones, S. Jones, M. Tuller, I. Lebron, K. Bristow, D. Souza, S. Banwart, and B. Clothier. 2014. On the Value of Soil Resources in the Context of Natural Capital and Ecosystem Service Delivery. Soil Science Society of America Journal 78:685.

Song, X., Tan, P., Edwards, P. and Richards, D. (2018). The economic benefits and costs of trees in urban forest stewardship: A systematic review. Urban Forestry & Urban Greening, 29, pp.162-170.

U.S. Environmental Protection Agency. 2012. Environmental benefits mapping and analysis program (BenMAP version 4.0). Washington, DC: U.S. Environmental Protection Agency. http://www.epa.gov/air/benmap/