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Benefits and costs of street trees in Lisbon, Portugal

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ABSTRACT

It is well known that urban trees produce various types of benefits and costs. The computer tool i-Tree STRATUM helps quantify tree structure and function, as well as the value of some of these tree services in different municipalities. This study describes one of the first applications of STRATUM outside the U.S. Lisbon's street trees are dominated by *Celtis australis* L., *Tilia* spp., and *Jacaranda mimosifolia* D. Don, which together account for 40% of the 41,247 trees. These trees provide services valued at $8.4 million annually, while $1.9 million is spent in their maintenance. For every $1 invested in tree management, residents receive $4.48 in benefits. The value of energy savings ($6.20/tree), CO_2 reduction ($0.33/tree) and air pollutant deposition ($5.40/tree) were comparable to several other U.S. cities. The large values associated with stormwater runoff reduction ($47.80/tree) and increased real estate value ($144.70/tree) were substantially greater than values obtained in U.S. cities. Unique aspects of Lisbon's urban morphology and improvement programs are partially responsible for these differences.

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Introduction

More than two thirds of Europe's population lives in urban areas (Forrest et al., 1999). The same trend is also observed in Portugal where the Metropolitan Area of Lisbon, covering only 3.3% of the area of the country, has around 3 million inhabitants, about 30% of the total. Although population growth and urbanization have resulted in economic growth and opportunity, they have also adversely impacted the environment and quality of life in cities.

Urban landscapes planted with trees can minimize many of the environmental impacts of urban growth by improving the chemical and physical environment: moderating urban heat islands; improving urban hydrology and air quality; reducing noise levels and the energy requirements of the city (Pauleit and Duhme, 2000; Fang and Ling, 2005; Konijnendijk et al., 2005). Trees in the urban context can increase biodiversity and afford numerous other benefits of an aesthetic, psychological and socio-economic nature (Schoeder and Cannon, 1983; Ulrich, 1985; Kaplan and Kaplan, 1989; Huang et al., 1992; Kaplan, 1992; McPherson et al., 1994; Sullivan and Kuo, 1996; Wolf, 1999; Nowak, 2001).

Trees provide a host of environmental, social, economic, aesthetic, and health benefits that are often disregarded because their monetary worth is unknown (Konijnendijk, 2008). Conversely, pressures on municipal budgets drive management decisions aimed at reducing expenditures. Sometimes trees are prematurely removed, not replaced, and inadequately maintained because controlling costs outweighs management aimed at increasing their health and the ecosystem services they provide over the long term (Carreiro et al., 2008). A computer program called STRATUM (Street Tree Resource Analysis Tool for Urban forest Managers) quantifies urban forest structure, function, management needs, and benefits as well as management costs. Released in 2006 by the USDA Forest Service as part of the i-Tree software suite, STRATUM has been used to value tree services in many U.S. cities. For example, the cities of Fort Collins, CO, Cheyenne, WY, Bismarck, ND, Berkeley, CA, and Glendale, AZ spent US$13–65 annually per tree, while benefits ranged from $31 to $89/tree (McPherson et al., 2005). For every dollar invested in management, benefits returned annually ranged from $1.37 to $3.09. New York City, Boise, Minneapolis and many other cities found that monetizing the value of their municipal forest service's led to increased appreciation of trees and tangible program enhancements.

This paper describes application of i-Tree STRATUM in Lisbon, Portugal. The goal of this study is to generate objective data on the value of services provided by Lisbon's street trees as a foundation for assessing return on investment in their management. Results for Lisbon are compared with several U.S. cities and limitations to applying i-Tree STRATUM in cities outside the U.S are discussed. Directions for future research to spur municipal forest benefit–cost assessments in Europe are suggested.

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Methods

The city of Lisbon

Lisbon, the capital city of Portugal, occupies an area of 8477 ha with a resident population of 564,000 as reported for 2001 by the Portuguese National Statistical Institute. Various parts of the centre of the capital have lost population while at the same time there has been considerable population growth in suburban areas. Large numbers of people commute to and from Lisbon every day. As a consequence, Lisbon suffers from traffic jams and atmospheric pollution, which take their toll on the residents' quality of life. In these circumstances, urban green spaces and street trees have a particularly important role to play, as they can make a major contribution to mitigating these adverse impacts.

STRATUM reference cities

Application of STRATUM in European cities is not straightforward because data requirements are intensive and developed for U.S. cities. STRATUM's benefit calculations are based on tree growth, geographic, and economic data for 16 different U.S. reference cities. Each reference city represents a region wherein climate and the types of tree species are relatively similar. The 16 U.S. regions were aggregated from 45 Sunset climate zones (Brenzel, 2001). The reference city in each region had an updated computer inventory of street trees for sampling and reliable information on program expenditures. A sample of approximately 30–70 randomly selected trees from each of the most abundant species was surveyed in each reference city to (1) establish relations between tree age, size, leaf area and biomass, (2) estimate growth rates, and (3) collect other data on tree health, site conditions, and sidewalk damage. At the same time, geographic and economic information were collected as input to numerical models of tree benefits.

Resources were available to sample Lisbon's street tree population, but not sufficient to conduct a full reference city analysis for Lisbon. For example, data were not available to determine the age of sampled street trees. Without tree age information it is difficult to develop growth curves for each species. One option was to use STRATUM data for the U.S. region and reference city most similar to Lisbon. This approach had the virtue of being easiest to implement, but results would be first-order approximations. Also, criteria for determining which U.S. reference city to use would need to be developed. For example, should the U.S. city be selected based on similar tree species to Lisbon, air temperatures, precipitation patterns, or other criteria?

Another approach was to use tree growth data from U.S. reference cities, but Lisbon data as input to the numerical models that calculate tree benefits. While more labor intensive than the first approach, this tact produces more accurate results because data on climate, buildings, air pollutant concentrations, and rainfall patterns are specific to Lisbon instead of its U.S. surrogate. In this study the second approach is applied to quantify benefits and costs of Lisbon's street tree population.

Collecting tree data

The population of interest is all street trees in the city of Lisbon. An inventory of all 33,232 trees was completed in 2003 under supervision of the Gardens Department of the Municipality of Lisbon. Because this inventory did not contain detailed information required by the STRATUM analysis, the population was sampled in 2006 following protocols published in the STRATUM User Manual (CUFR, 2006).

First, four management zones were identified corresponding to different groups of parishes (*freguesias*) in Lisbon (Fig. 1). Zone 1 consisted of parishes with the lowest density of street trees, including older areas with few trees and modern areas where street trees are fully integrated within the geometric grid of the city.

Zone 2 included a series of parishes that were developed in the second half of the 20th century according to a town planning system in which street trees were set into a residential fabric. In this zone, green areas, ranging from squares and parks to private gardens, are relatively large.

Zone 3 had the highest density of trees. It consisted of parishes that collectively represent the transition between the old city (zone 4) and the areas occupied from the time of the Great Lisbon Earthquake (1755) until the 20th century.

Zone 4 was composed of old city parishes with similar tree density and species profile; organic urban layout (of Medieval origin); narrow streets with few spaces for plantings and no geometric pattern. They also had a similar topography – south-facing with steep

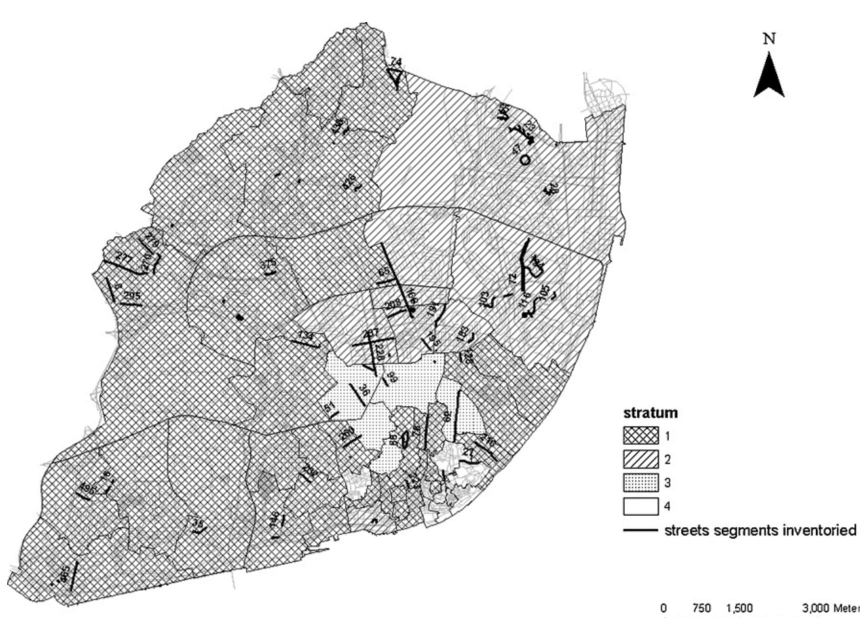

Fig. 1. Location of street segments inventoried in the city of Lisbon (summer 2005), and the four strata are represented.

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