Urban Forestry & Urban Greening 16 (2016) 43–49

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

An index to identify suitable species in urban green areas

Maria Jesus Garcia-Garcia[a,*], Alvaro Sánchez-Medina[b], Eva Alfonso-Corzo[b], Concepcion Gonzalez Garcia[b]

[a] *Technical University of Madrid, E.T.S.I. Montes, Ciudad Universitaria, Avenida de la Moreras s/n, 28040 Madrid, Spain*
[b] *Technical University of Madrid. E.T.S.I. Montes, Madrid, Spain*

ARTICLE INFO

Article history:
Received 25 February 2015
Received in revised form 19 January 2016
Accepted 23 January 2016
Available online 25 January 2016

Keywords:
Health status
Species suitability
Urban management
Urban trees
Vegetation damage

ABSTRACT

This paper presents a method that allows sorting of tree and shrub species according to their suitability for planting in urban areas of Madrid (Spain). Suitability was determined from a weighted index for each species according to the severity of damage (biotic, abiotic, and anthropogenic; stem wounds are the main problem in trees, while dead plants are the most important problem in shrubs, seasonal flowers, and vines) and to risk, which was obtained from a new measure, observed Species per Green Area per Year (SAYs). The greater the number of damaged SAYs, the less suitable a species was considered for outdoor planting. For this purpose, 49 green areas corresponding to 141 ha were sampled during 2005–2008. The tree species least recommended for planting include *Robinia pseudoacacia*, Ulmus sp., *Acer negundo*, Platanus × hybrid, Populus Boolleana. The shrubs least recommended for planting are *Nerium oleander*, Cotoneaster sp., *Euonymus europaeus*, *Pyracantha coccinea*, and *Pittosporum tobira*. Statistical analysis reveals that native species have a lower percentage of damaged SAYs than non-native species.

Introduction

Urban tree sustainability is a critical aspect of management greenspaces, according to forestry experts. Some authors have classified commonly used species in Europe by their drought resistance and winter robustness (Roloff et al., 2009) or proposed lists of suitable species for certain uses in urban paved sites (Sjöman and Nielsen, 2010) based on characteristics such as a species' ability to capture polluting particles (Yang et al., 2015) or its suitability to the restoration of degraded landscapes (Kim and Lee, 2005). With effective planning and management, urban trees can provide a wide range of important benefits to city inhabitants. These benefits are economic as well as physical, energetic, biological, and social (Dwyer et al., 1992; Georgi and Kafiriadis, 2006; Christopoulou et al., 2007; Notaro and De Salvo, 2010; Leuzinger et al., 2010).

The city of Madrid has over 225,000 trees in its streets, as well as over 1500 green areas that occupy nearly 10% of the city surface. Consequently, green spaces and urban trees are highly rated in Madrid (Alfonso-Corzo, 2009). Management of this heritage is increasingly complex and expensive, necessitating studies that provide results applicable to the improvement of this management.

Previous studies have focused on generating lists of species according to their functions or use in the city. Thus, the United States Department of Agriculture developed software that enables the selection of tree species according to the desired environmental effects or functional benefits (Nowak, 2008). Vlachokostas et al. (2014) presented a scheme for decision-making to prioritize trees for planting in Thessalonica (Greece). Dwyer et al. (2003) explained how diversity, connectivity, and dynamics in urban forests establish a management frame, which in turn determines forestry structure, sanitary sustainability, and other functions and benefits associated with the use of particular species. Although the loss of biodiversity in ecosystems is a current problem, cities have the potential to increase it (Sjöman et al., 2012a), a potential that must be recognized by urban-forest managers (Alvey, 2006). On the other hand, trees in urban environments are less stable in terms of shape and size than are trees in natural environments (Kontogianni et al., 2011). For example, a study carried out in Massachusetts with a multisource geographical information system (Hostetler et al., 2013) confirmed a loss of canopy from urban trees over a 40-year period. In addition to pollution, other factors reduce the development of urban trees, such as increased difficulty with water retention (Nielsen et al., 2007), planting design and methods (Dwyer et al., 1992), and location (Iakovoglou et al., 2002). One of the most important factors in the selection of trees for urban environments is the existence of an increase in pathogenic agents. Numerous studies have evaluated the health of urban

---

[*] Corresponding author. Tel.: +34 913367110.
E-mail address: mariajesus.garcia.garcia@upm.es (M.J. Garcia-Garcia).

http://dx.doi.org/10.1016/j.ufug.2016.01.006
1618-8667/

forests (Johnston and Shimada, 2004; Ning et al., 2008; Kontogianni et al., 2011; Mingaleva et al., 2011; Song et al., 2005), but not all of these studies were financed or aided by public administrations because of high costs or a lack of resource allocation (Fan et al., 2012), a problem that has inspired new measurement techniques (Hostetler et al., 2013) to lower costs. This cost-reduction effort is significant because related studies have revealed social (Johnston and Shimada, 2004; Mingaleva et al., 2011) and economic benefits of urban trees.

In this framework, it would be useful to develop a tool for selecting species that are well-adapted and suitable to city conditions and that are recommended for planting.

This ranking of species has been used in other studies (Impens and Delcarte, 1979; Raupp and Noland, 1984; Nielsen et al., 1985; Rodriguez-Barreal, 2000). However, there is a lack of literature that includes the phytosanitary status of ornamental vegetation as a criterion.

This article reports the results of several works done for the Madrid Council as part of an agreement with the Technical University of Madrid. We evaluated the damaged species with an index that allowed us to develop an economically advantageous analysis to better inform public managers about decision making regarding trees and shrub planting. We assembled a list of species that are less well suited to growth in the green spaces of Madrid. We consider the phytosanitary approach to be of great interest because the sustainability of species in urban green environments is directly linked with their health status (Cregg and Dix, 2001). Also, sustainability is related to costs associated with management of urban green spaces, which could mean an extraordinary cost within the municipal budgets (Escobedo et al., 2011) or a large loss because of pests (Raupp et al., 2006; Laćan and McBride, 2008).

Methods

In this study, we applied a phytosanitary point of view to analyze an inventory of trees and shrubs species in various urban environments in Madrid. The project consisted of inventorying the damage suffered by trees growing in the green spaces of six Madrid districts from 2005 to 2008 (Saiz de Omeñaca, 2012). Data from the study ordered by the Madrid Council were analyzed for the preparation of this report. Preliminary results were discussed at the International Union of Forest Research Organizations Congress, 2009 (Alfonso Corzo et al., 2009).

An inventory was compiled of the damage suffered by trees and shrubs species in six districts of Madrid. Forty-nine green spaces were sampled, corresponding to 141 ha, 16% of the total green surface of Madrid. This sampling was carried out in the years 2005, 2006, 2007, and 2008. Each green area was visited several times over at least two years and in two different seasons (at least once in spring and once in autumn or well into winter).

The Species Area Year (SAY) (Alfonso Corzo et al., 2009) was selected as a measurement unit to quantify the frequency, cause, and extent of damage to urban trees. SAY is defined as the observation of a species (S) growing in a particular green area (A) per year (Y). Consequently, there is a damaged SAY when an individual from a particular species is affected by a damaging agent in a green space that is visited in a given year. More than one damaged SAY occurs when the same species has suffered from several damaging agents; this repeated damage is not necessarily present in the same individual but affects the same green area and is observed in the same year. The SAY was specifically developed to make the reviewing and monitoring of the health of urban trees economically viable.

All damaged SAYs were compiled with knowledge of the damaging agent. An index was conceived and applied to quantify the proportion of damaged SAYs by species and severity of damage. Therefore, the higher the number of damaged SAYs, the more unsuitable a given species is to be grown as ornamental vegetation in Madrid.

Table 1
Coefficients to weight damage according to severity in the tree stratum.

Damage severity	Coefficient	Code
Dangerous	0.5	A
Quite serious	0.3	B
Less serious	0.2	C
Acceptable	0.1	D

Table 2
Specific damage coefficients for the bush stratum.

Type of damage	Disease	Coefficient	Code
Bacteria and prokaryotes	Biotic	0.2	C
Poorly formed trees	Other damage	0.1	D

A coefficient was also created to weight all observed damages according to severity (Table 1). This coefficient was developed with the aid of an expert panel on urban trees in the city of Madrid, who applied it to the set of observed damages (Appendix A).

Damage is classified as dangerous in the tree stratum (highest coefficient, 0.5) when it may be dangerous for people and their goods, severely affecting the phytosanitary status of the tree, even with a risk of falling. Quite-serious damage, classified with a lower coefficient (0.3), implies a reduction in the life expectancy of the tree. The coefficient for less-serious damage (0.2) reflects damage that troubles both plants and the users of green spaces. From a sanitary point of view, this type of damage is not greatly relevant, although it can be aesthetically important. Finally, acceptable damage is assigned the lowest coefficient (0.1); acceptable damage produces minimal problems, aesthetic or sanitary.

The same classification scheme was used for the shrub stratum. However, the severity classes for shrubs were not based on the same concepts, since shrubs are usually considered to not be hazardous to people due to their size. Therefore, dangerous and quite-dangerous damage is not assessed; the new damage types included in the classification (Table 2) were (1) bacteria and prokaryotes (Saiz de Omeñaca, 2012) and (2) poorly formed trees. The first category encompasses damage that causes rot in the tree stratum (implying danger), but this damage only affects the rosebay in the bush stratum (causing tuberculosis). In bushes, a poorly structured stem refers to grown individuals.

The index for every species was calculated as the sum of the products of each damage type's frequency multiplied by its coefficient and weighed with the damaged SAY for the corresponding species (expressed as a decimal):

$$I_{\text{species}} = \sum \frac{(\text{Damage}_i \times \text{Coefficient}_i)}{\text{SAY}_{\text{damageSpecies}}}$$

This strategy yielded an assessment of the suitability of every observed species. The most-suitable species (those that suffer less damage) were associated with lower indices. Accumulation of damage in some species was evident, prompting us to conduct a statistical independence analysis through a contingency table (Milton, 2001) by categorizing species as native or non-native. The native condition of the species was determined using the definition given by Pyšek: “Native (indigenous) species is one which evolved in the area or which arrived there by one means or another before the beginning of the Neolithic period or which arrived there since that time by a method entirely independent of human activity” (Pyšek, 1998). We also used the definition for non-native species: “alien (introduced, exotic, adventive) species is one which reached the