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A multiple criteria decision-making approach to put forward tree species in urban environment

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ABSTRACT

Trees are vital for improving urban climate in many aspects and dimensions, especially for densely populated environments characterized by high levels of air pollution. This paper presents a decision-making scheme for benchmarking and prioritizing tree species in urban environments. Public authorities in real-life cases put forward trees species based mainly on cost or aesthetics criteria. In contrast to most-real life cases, the proposed approach facilitates the inclusion of multiple criteria to support decision-making i.e. life span, required growth space, planting capability in built environment, aesthetics, tolerance, pollution attenuation, adaptation to local climate, crown density, cost, and potential allergenicity of species. The framework combines two multi-criteria methods to provide an optimal ranking and enhance the robustness of decision-support. The approach is implemented for the center of Thessaloniki, Greece. Mulberry, sweetgum, scholar tree and hackberry are highly ranked and can be considered as excellent alternatives considering their combined performances to all criteria. A thorough sensitivity analysis by varying parameter values demonstrates the robustness of the corresponding ranking. Although there are gaps of knowledge and uncertainties, especially in the quantification of air pollution attenuation, the proposed

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approach provides a roadmap for decision-makers to put forward tree species in an organized manner.

1. Introduction

The quality of urban climate has become an issue of critical importance for urban sustainability and a major challenge for environmental managers and public authorities around the globe. Urban areas are characterized by high levels of both population density and air pollution, one of the major factors which adversely affect environmental quality, with profound negative effects on human health and well-being. A consensus among public health experts reveals that air pollution, even at current ambient levels, aggravates morbidity (especially respiratory and cardiovascular diseases) and leads to premature mortality (e.g. Pope et al., 2011; Kassomenos et al., 2011; Curtis et al., 2006). Apart from the health risks through the inhalation of gases and particles, urban air pollution is the source of other problems such as accelerated corrosion and deterioration of materials, damage to historical monuments and buildings and damage to agricultural crops around the city (Vlachokostas et al., 2010).

Promoting the planting of tree species in streets, sidewalks and parks play an important role in mitigating air pollution in urban conurbations (Paolleti et al., 2011; Sjöman and Nielsen, 2010) through dry deposition. Gaseous pollutants are absorbed through stomata during photosynthesis and respiration, whereas particulate matter is transported to leaf surfaces by gravity sedimentation or impaction (Yin et al., 2011). Various studies have investigated the removal rate and resuspension of particulate matter. According to McDonald et al. (2007) an increase of tree cover from 3.6% to 8% in Glasgow, resulted in a reduction of 2% in PM_{10} concentration. Urban canopies in Greater London Area are estimated to reduce PM_{10} concentrations by 0.7–1.4% (Tallis et al., 2011). Nowak et al. (2006, 2013), estimated that annual air quality improvements in U.S. cities due to air pollution removal by urban trees was 0.2–1% for PM_{10}, 0.1–0.6% for NO_2, less than 0.005% for CO and 0.05–0.24% for $PM_{2.5}$.

Apart from air quality improvement, tree species may also affect air quality negatively, by causing allergenic effects or by emitting volatile organic compounds (Setälä et al., 2013). However, benefits are – in general – much more than potential costs, since tree species contribute to noise pollution abatement as well as to the esthetic appeal of an urban environment. The physiological and perceptual functions to humans, including visual and sensory benefits should be definitely underlined. Furthermore, street trees can reduce air conditioning loads by shading adjacent buildings and lowering air temperatures, which enhances energy saving potential and cooling effect (Leuzinger et al., 2010; Akbari et al., 2001). Furthermore, they can contribute to stormwater reduction, since tree crowns have the ability to store water. Tree species – and green spaces in general – have been found to benefit many aspects of health and well-being enabling local residents to live in a better urban environment. On this basis, planting tree species along streets and sidewalks is vital for improving urban climate's status in many aspects and dimensions, especially for densely populated environments that are characterized by high levels of air pollution.

Planting tree species is also a crucial issue for the public authorities of the municipality of Thessaloniki, Greece. Thessaloniki is considered as one of the most polluted cities in Europe, especially with respect to airborne particles and photochemical air pollution (Saffari et al., 2013; Moussiopoulos et al., 2009). According to a recent study for the area, 10,200 Years of Life Lost (YOLL) and approximately 450 new cases of chronic bronchitis can be attributed to increased chronic exposure to PM_{10}. Cardiac and respiratory hospital admissions for the entire population are estimated in the order of 1,100 and can be attributed both to particulate and photochemical air pollution (Vlachokostas et al., 2012a). Based on the official data of the Directorate of Urban Environment Management, the total amount of planted trees reaches 40,000 in the municipality. The area of green spaces approximates 95 ha (total area approximates 1,850 ha), which brings forth a 5.1% of green space coverage in the area, much lower than the estimated 18.6% EU average (Fuller and Gaston, 2009). Thessaloniki's "per capita green space provision" indicator approximates 2.6 m^2/citizen. This stands significantly low compared