Urban Forestry & Urban Greening 17 (2016) 192–201

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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

Air pollution removal by trees in public green spaces in Strasbourg city, France☆

Wissal Selmi[a,*], Christiane Weber[a], Emmanuel Rivière[b], Nadège Blond[a], Lotfi Mehdi[a], David Nowak[c]

[a] Laboratoire Image, Ville, Environnement LIVE UMR 7362 (CNRS/Université de Strasbourg), 3 rue de l'Argonne, 67000 Strasbourg, France
[b] Association pour la Surveillance et l'Etude de la Pollution Atmosphérique en Alsace (ASPA), 5 rue de Madrid, 67300 Strasbourg, France
[c] USDA Forest Service, Northern Research Station, 5 Moon Library, SUNY-ESF, Syracuse, NY 13210 USA

ARTICLE INFO

Article history:
Received 19 March 2015
Received in revised form 22 April 2016
Accepted 22 April 2016
Available online 28 April 2016

Keywords:
Air pollution
Environmental assessment
France
i-Tree Eco
Urban green spaces
Urban trees

ABSTRACT

This study integrates i-Tree Eco model in order to estimate air pollution removal by urban trees in Strasbourg city, France. Applied for the first time in a French city, the model shows that public trees, i.e., trees managed by the city, removed about 88 t of pollutants during one year period (from July 2012 to June 2013): about 1 ton for CO; 14 tons for NO_2; 56 tons for O_3; 12 tons for $PM_{10coarse}$ (particles with diameter ranging from 2.5 to 10 μm); 5 tons for $PM_{2.5}$ and 1 ton for SO_2. Air pollution removal varied mainly with the tree cover and the level of air pollutants concentrations. Comparison between simulated pollution removal rates and local emissions shows that public trees of Strasbourg reduce about 7% of the emitted $PM_{10coarse}$ in the city's atmosphere; however, effect on other air pollutants is small. Thus, our study reveals that urban trees are a significant element to reduce air pollution but are not the only solution to this problem. It's then recommended to associate planting and managing urban forest resources to other strategies that take into account the urban environment characteristics: built structures, street design, location of local sources; etc.

1. Introduction

Cities concentrate many problems that can affect human well-being (Bolund and Hunhammar, 1999).They hold the majority of human activities and the associated air pollution emissions with consequent adverse health effects including pre-mature mortality and morbidity from cardiovascular and respiratory causes (Brunekreef and Holgate, 2002; Heinrich and Wichmann, 2004; WHO, 2006; Rückerl et al., 2011). Despite efforts conducted by European countries (EU) to reduce air pollutant emissions and improve air quality, urban population are still exposed to high levels of pollutant concentrations that exceed the EU standards to protect human health. For instance, the European Environment Agency (EEA) shows that during 2010 and 2012 respectively 21–30% and 64–83% of the European urban citizens were exposed to particulate matter concentrations above the EU daily limit values (50 μg/m^3) and the World Health Organization (WHO) annual reference level (20 μg/m^3) (EEA, 2014a). In 2011, fine particulate matter ($PM_{2.5}$) concentrations caused about 458 000 premature deaths in Europe (EEA, 2014a). France is no exception to air pollution issues; in 2012 about 5.4% of urban population in France is exposed to PM_{10} concentrations above the EU daily limit value (50 μg/m^3) (EEA, 2014b). In addition, a recent study conducted in Paris between 2007 and 2011 analyzed the link between the increased air pollution and hospital admission. An increase of NO_2, $PM_{2.5}$ and $PM_{10coarse}$ caused a 1.8%, 2.1% and 3.2% increase, respectively, in hospital consultations associated to asthma attacks among children between 2 and 14 years of age (Chatignoux and Host, 2013).

Abbreviations: ASPA, "*Association pour la Surveillance et* l'Etude *de la Pollution Atmosphérique en Alsace*" (Non-profit organization for monitoring and studying atmospheric pollution in Alsace); CIGAL, "*Coopération pour l'information géographique en Alsace*" (Cooperation for geographic information in Alsace); DBH, diameter at breast height; EEA, European Environment Agency; EMEP/EEA, European Monitoring and Evaluation Program/European Environment Agency; EMS, "*Eurométropole de Strasbourg*"(Eurometropolis of Strasbourg); LAI, Leaf Area Index; MEDDE, "*Ministère de l'Écologie, du Développement Durable et de l'Énergie*"(Ministry of ecologysustainable development and energy); NOAA, National Oceanic and Atmospheric Administration; PADD, "Projet d'Aménagement et de Développement Durable" (Project of Planning and Sustainable Development); SERTIT, "*Service régional de traitement d'image et de télédétection*" (Regional Service of Image Treatment and Remote Sensing); UFORE, Urban Forest Effects Model; UNEP, "Union National des Entreprises du Paysage"(national union of landscape companies); VOC, volatile organic compounds; WHO, World Health Organization.

☆ This study is a first-time estimate in France that assesses the role of urban trees to reduce air pollution. Comparison of removal rates with emissions rates in Strasbourg city shows that trees modestly remove air pollution.

* Corresponding author.
E-mail address: wissalselmi@yahoo.fr (W. Selmi).

http://dx.doi.org/10.1016/j.ufug.2016.04.010
1618-8667/

In April 2015, the European commission warned the French government because European limits for particle matter were not being met in some cities (Sénat, 2015). Hence, several policy instruments have to be implemented to meet European air quality directives. For example, the French Ministry of Ecology, Sustainable Development and Energy (MEDDE) has launched a program called “respirable cities” where 20 local authorities, including the Strasbourg metropolis will implement actions regarding transportation, energy use, and city planning. This initiative is designed to improve air quality in the medium term. Additionally an “air quality certificate” will promote use of low emission vehicles in city centers (MEDDE, 2015). These actions will complement other local measures such as the current development of public transportation and renewable energy production and use. Policies to reduce air pollution focus on the reduction of the emissions that are the main driver of the air pollution.

Some studies have suggested that new materials for buildings could contribute to air pollution reduction (Boonen et al., 2015; Angelo et al., 2013; Boonen and Beeldens, 2013; Chen and Poon, 2009; etc.), others show that planting vegetation has a substantial effect on air pollution (Escobedo et al., 2011; Currie and Bass, 2008; Nowak et al., 2006; etc.). The advantage of planting trees in the city is not only to reduce air pollution but also to answers to other social needs (e.g., recreation, cultural, aesthetic, etc.) without additional cost. However, while urban trees are considered as one key element to improve urban environment, its potential is often not considered in urban policies documents.

A growing number of studies have identified and quantified various ecosystem services provided in urban context like reduction of air pollution due to dry deposition function (Nowak, 2000; Nowak et al., 2006); regulation of temperature (e.g., shading and evapotranspiration) with the consequent reduction of the urban heat island (Yang et al., 2005) and carbon sequestration with its consequence on Climate Change mitigation. Nevertheless few disservices are noted in specific cases: emissions of volatile organic compounds (VOC) by trees (Owen et al., 2003) and local increase of air pollution in case of densely trees plantation (Tiwary and Kumar, 2014). A simulation of trees and shrubs effects on particle dispersion at the street scale in Strasbourg city showed an increase of particle concentration in street canyon planted with densely trees foliation (Wania et al., 2012). Despite the recognition of these services and disservices, the lack of information about the potential of trees to alleviate urban environment problem and the underlying trees-atmosphere interactions is still important. This knowledge gap is due to the complexity of the physical and chemical processes involved in the trees-atmosphere interactions within urban areas and the lack of numerical models that quantify these processes (Cherlin et al., 2015). Hence, models like Citygreen, UFORE (Urban Forest Effects Model now known as i-Tree) and STRATUM (now known as i-Tree streets) were developed to assess these interactions, to quantify ecological services and disservices provided by urban trees and to provide more comprehensive analysis.

In France, the assessment of ecosystem services provided by urban green spaces has been lacking. This dearth of information is associated with an absence of a conceptual framework and the reluctance of some French researchers to use the “ecosystem service” concept as it is always considered as an exclusively economic concept (Froger et al., 2012). Therefore, as shown by Selmi (2014), the economic evaluation is emphasized at the expense of understanding the potential of vegetation to provide ecosystem services. To better understand this issue, this study is a first order estimation of one ecosystem service (air pollution removal) provided by trees in a French city. We present the underlying ecological assessment, showing that it could provide relevant information to guide urban planning and management. The main objective of this study is to quantify the amount of air pollution removed by urban trees using i-Tree model (Nowak et al., 2008) in Strasbourg city, France.

Designed and developed by U.S. Department of Agriculture, Forest Service and several partner organizations (www.itreetools.org), the i-Tree Eco assesses urban forest structure and consequent ecosystem services and value. It has been used in several European cities including Barcelona, Spain (Chapparo and Terradas, 2009; Baro et al., 2014); Torbay, United Kingdom (Rogers et al., 2011) and Florence, Italy (Paoletti et al., 2010) to demonstrate the potential of urban trees to improve environmental quality at the city scale. This paper presents an application of i-Tree Eco model in Strasbourg City and evaluates the removal rates in comparison with local emissions rates. It also discusses and offers in-depth perspectives to develop integrated green spaces management and sustainable urban policies to alleviate air pollution.

2. Methods

2.1. Study area

This study was conducted in Strasbourg, France (7830 ha; 48°35′N and 7°45′W) in North East France (Fig. 1). The city's population reached about 275 000 inhabitants in 2011 (INSEE, 2011). The climate of Strasbourg is continental with an average monthly temperature of 2 °C in January and 19 °C in June. The mean annual precipitation is 665 mm (Meteo France website: http://www.meteofrance.com/accueil). The Strasbourg Eurometropolis website (EMS) mentioned that the city has 400 ha of parks and is the only European city with protected alluvial forests around its outskirts, with three great forests: Neuhof (757 ha); Robertsau (493 ha) and Rohrschollen (309 ha) (EMS, 2013).

Though all trees in Strasbourg have an impact on air quality, this study focuses on urban trees located in public green spaces and street tree resources as this is the urban forest resource that could be managed via public funding. We assessed public urban green spaces as defined by Young (2010): “publicly managed natural resources assets in a city including street trees, parks, and natural areas”. Privately managed spaces were then excluded.

2.2. Air pollution removal: i-Tree eco model application

Modeling air pollution removal by trees in Strasbourg city was performed using the i-Tree Eco model. It combines trees data (number of trees; species; tree height; diameter at breast height (DBH); height to crown; tree cover; etc.) with local environmental data (hourly meteorological data; air pollution concentration data; etc.) to estimate hourly pollution removal by trees and shrub (Nowak and Crane, 2000; Nowak et al., 2006, 2014).

Since the main objective of this paper is to quantify air pollution removal by trees in public green spaces in Strasbourg, we focus only on the i-Tree Eco dry deposition (air pollution removal) module. The following paragraphs describe: (i) data collection and (ii) the calculation processes of air pollution removal.

2.2.1. Data collection

To perform air pollution removal quantification, the i-Tree model requires several types of data. Tree structure information (tree cover, leaf area index, percent evergreen) was input to the model along with local weather and pollution data. Boundary layer height data were also used to estimate percent air quality improvement due to the pollution removal by trees.

2.2.1.1. Sampling scheme and tree cover data. Tree structure information was collected following i-Tree Eco guidelines (i-Tree Eco User's Manual, 2013). The sampling design and data collection were carried out in four steps: (i) delimiting the public green spaces