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The importance of local scale for assessing, monitoring and predicting of air quality in urban areas

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ABSTRACT

The importance of the spatial scale for counteracting urban air pollution is highlighted in this work. In particular, the concept of Environmental Areas is used here in a wider sense than the current one. The Environmental Area is an area where the traffic conditions are more favourable for walkability and cycling compared to those of private motor vehicles. This work extends this concept to integrate several approaches coming from dimensional analysis, ecology, urban planning and transport engineering, to define a suitable spatial scale for an estimation of the PM10 removal through the street trees. Results highlight that, within the monitored area (the Monteverde neighbourhood, Rome—Italy), the street trees are able to remove 0.142 $t\,ha^{-1}\,year^{-1}$ of PM10 (about the 57% of the total particulate emission) with a re-suspension from plant canopies of 4%. Results have also demonstrated how is important an effective management of trees and the choice of appropriate trees made in according to the leaves' characteristics but also related to urban context in which trees are placed. We highlight that integrated planning among different elements of the public urban space is of great importance for ameliorating the urban liveability. Moreover, we remark that this Environmental Areas-based approach contributes to promote in citizens a greater knowledge of the territory and awareness of the dynamics that affect it and consequently a wider participation to public decisions concerning the choice, implementation and management of the street trees, reduction of car-based mobility and increase of pedestrian and cyclist mobility.

1. Introduction

The transport system plays a very important role in the economic markets and quality of citizens' life. If it is sustainable and effective, it can be helpful to economic growth and employment, otherwise it becomes a source of high energy consumption, as it happens when a transport system is mainly based on the use of private car (IPCC, 2014). The transport sector produced 7.0 $GtCO_2eq$ of direct GHG emissions (including non-CO_2 gases) in 2010 (IEA, 2012) and hence it was responsible for approximately 23% of total energy-related CO_2 emissions (6.7 GtCO2). The GHG emissions have continued to increase in spite of more efficient vehicles and the pollution abatement policies adopted (Sims et al., 2014). Around 80% of this increase has come from road vehicles. Road traffic is one of the main sources of urban pollution and associated ill health and well-being (Kim et al., 2008; WHO, 2005; Dandy, 2010), and road-traffic derived pollutants are most concentrated within few meters from the road source (Beevers et al., 2013). These effects led to the work-days losses, to increase of chronicle ills and, as a consequence, an increase of national sanitary costs (Hunt, 2011). European Commission pointed out some measures at aiming to reduce traffic volumes as the increase of collective transport, integration of measures for cycling and pedestrian mobility through a new re-organisation of the urban mobility system and its co-related infrastructures (EC, 2011). The European Commission's Air quality standards (CEC, 2008) set standards of atmospheric concentrations for particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2), lead (Pb), carbon monoxide (CO), benzene (C_6H_6), arsenic (As), cadmium (Cd), nickel (Ni) and polycyclic aromatic hydrocarbons (PAH). These represent most atmospheric pollutants in the urban environment. In an assessment of 26 global mega-cities, 24 had annual average PM10 concentrations exceeding the European Community standards (Zhu et al., 2013). In terms of adverse health impacts, PM10 and, more recently, PM2.5 have been identified as the most significant; globally accounting for 3% of cardiopulmonary and 5% of lung cancer deaths (WHO, 2013).

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Functional performances of urban green infrastructures as provider of important ecosystem services may be greatly reduced by the pollutants impact (Manes et al., 2012), although several benefits arise from presence of urban green infrastructures such as active and passive removal of atmospheric pollutants, air temperature reduction through shading and evapotranspiration, changes of the wind patterns, and reduction of the energy use for the functionalities of the buildings, mitigating thus the urban heat island phenomenon (McPherson & Simpson, 1999; Nowak et al., 1998a, 1998b, 2006; Yang et al., 2005; Nowak & Dwyer, 2007; Schäfer et al., 2014). Urban green infrastructure is a green network consisting of parks and historic villas but also public or private gardens, allotments, street trees and urban forests. Several studies investigated the relationship between urban forests and air pollution removal, quantifying the amount of air pollution removed by urban forests (Yang et al., 2005; Escobedo et al., 2011; Leung et al., 2011). Nowak and co-workers (2006) reported a PM10 removal by trees to be on average of 8.0 g m^{-2} in Los Angeles. The air pollutants removal by tree and shrub canopies are different in relation to the pollutant type: PM10 is mainly intercepted by leaf surfaces and hairs and exudates allow to trap the particulate matter and then to be washed out by rain. A portion (on average 50%) of PM10 is re-suspended in the air especially after a long time period without rain, although some evidences have proven that re-suspension is much more limited (4%) at the canopy level (Tiwary et al., 2009).

Quantitative evaluation of these processes has been object of extensive studies and now there is consensus that the green infrastructures represent an important component to be included in all strategies for protecting and improving air quality (Detwiler, 2012; EPA, 2014; Currie & Bass, 2008). The mapping and planning of green infrastructures must take charge of the issue of mitigation of urban pollution by suggesting appropriate methodologies based on effective analyses and tools. For example, the role of the green network for the cooling of the air during summer months and removal of pollutants should be integrated in the Sustainable Energy Action Plan (SEAP), in order to have economic and environmental benefits for citizens through the reduction of energy use (i.e. air conditioning) and the amplification of the results of policies focused on the reduction of the private car-based mobility. In this frame, urban planning may play a very important role to define suitable urban green infrastructures within the connective urban space that is represented by open public space without the green areas, which are effective in reducing air pollution and mitigating the urban climate.

It is important, now, to refer at urban studies that have taken in consideration the neighbourhood dimension as a basic unit of an ensemble of public open spaces interconnected by avenues and paths in an unitary assembly, which constitutes the system of places that have value for residents. These studies have identified some elements such as centres, edges, entrances and pathways, characterising places where inhabitants identify themselves (Lynch, 1960; Castells, 1997; Colarossi, 2008). In other studies, coming from urban planning and transport engineering taking in consideration the road accessibility, several unitary urban sizes were considered. In fact, in terms of transport studies we can talk about "Environmental Area (EA)" (Buchanan, 1963; SWOV, 2010) while in terms of urban planning we can talk about 'Elementary Urban Unit' (Vittorini, 1988) or "Supermanzana" (Rueda et al., 2008). Importantly, these unitary sizes (Table 1) refer to a general circulation pattern where the main road system represents the elements of the edge. In these streets the speeds are more elevated and the flows separation criteria among the different typologies of transportation (cars, pedestrians, cyclists, public transport) are adopted. The second level of circulating network is internal at the area and is represented by roads where the speeds are low and the space sharing is adopted (Buchanan, 1963; Ortolani, 2014). Although Environmental Area and neighbourhood are coincident in terms of spatial dimensions, neighbourhoods are different each to other for urban structure and shape, density, morphology and building typology, and for presence of facilities and services. As a consequence, it seems appropriate to take the concept of Environmental Areas and extend it in order to integrate several approaches coming from dimensional analysis, ecology and urban planning to define a suitable spatial scale for an estimation of the PM10 removal through street trees. The Environmental Areas Strategy (Ortolani, 2014) represents a suitable planning tool. It allows to better define an urban area that is responding to requirements such as: homogeneity in terms of urban morphology and building typology, density, etc.; ability to promote in citizens a greater knowledge of the territory and awareness of the dynamics that affect it; ability to affect the urban liveability and pedestrian and cyclist accessibility; ability to assess the effectiveness of the green network or parts of it as the street trees, in the mitigation of urban pollution.

The EA Strategy assumes that suitable areas have (or should have) the following requirements (Ortolani, 2014):

a) size and elements (centre, entrances, edges, paths) that make it recognizable to inhabitants;
b) to represent an area surrounded by roads where the principles of separation of flows and space sharing are applied;
c) to include facilities and equipment useful for carrying out of everyday life.

Table 2 reports a comparison of these parameters with different characteristics of urban settlements belonging to different kinds of EA (Ortolani, 2014). There are also parts of the city which are not included into the above reported requirements, although they belong to the bordering or urban core. These areas have, in fact, characteristics that do not allow a real intervention of recovery in accord to the EA's criteria (i.e. very small settlements and devoid of structure), but allow specific and single interventions only.

The EA Strategy is, therefore, used here to define a representative test area where the green network and overall citizens' movements are considered as important elements of the Environmental Area. To get this linkage is necessary to consider the neighbourhood as a significant and perceptible minimum area. Depending on the formal and structural characteristics, the neighbourhood can be distinguished in different types of Environmental Area (EA). Based on this categorical division, the Monteverde neighbourhood, near the downtown of Rome, has been chosen as a test area (Fig. 1). This is a B type area (Table 2) and it is part of the consolidated urban tissue, where actions focused on the amelioration of air quality are addressed to a limited range (i.e. reduction of

Table 1
Proposed sizes for the Environmental Areas, Supermanzana and Urban Elementary Units.

	Minimum dimension	Maximum dimension	Source
Environmental Area	0.2 km^2	1 km^2	Institute for Road Safety Research—SWOV (2010)
	0.3 km^2	0.7 km^2	Swiss Touring Club—TCS (2008)
Urban Elementary Unit	/	1 km^2	Vittorini (1988)
Supermanzana	/	0.16 km^2	Agencia de Ecologia Urbana de Barcelona (Rueda et al., 2008)

Source: TCS (2008); available at https://issuu.com/touring-online/docs