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AIR POLLUTION REMOVAL BY URBAN GREEN IN MILAN TOWN CENTRE RESULTS FROM MODEL ESTIMATIONS AND AIR QUALITY MEASUREMENTS

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Introduction

In the last century there has been a relevant shift of people away from rural areas into cities, that have resulted in a increase of the urbanization. Human activities in urban conurbations are consequently concentrated in a relatively small area and most of them are coupled to emissions of large amount air pollutants, which poses a significant risk to human health and wellbeing [1]. Among these air pollutants, particulate matter (PM) represents one of the most important and widespread threat, responsible for a relevant impact both on health and on the whole environment (including plants and cultural heritage). In this context, urban forests may be particularly important because, beside their well known aesthetic and recreational benefits, they are able to deliver a series of important environmental benefits, defined as Ecosystem Services, such as an improvement of air quality by removing air pollutants from the troposphere 2[[3] [4]. There is, therefore, the need for targeted, effective actions aimed at the reduction of PM concentrations at urban and regional scale. Benefits and functions of urban forests have received growing attention in the last decades from both urban ecology researchers and town planners. The role of trees and shrubs in urban areas are considered crucial in climate mitigation, protecting biodiversity and improving of local air quality due to their potential in removing harmful atmospheric pollutants.
We present here some preliminary results regarding an estimate of air pollutant removal by the urban vegetation of the Milan town, combined with direct measurements of particulate matter measurements. The Urban FORest Effects (UFORE) model [5], developed by the U.S Forest Service has been used to assess air pollutant removal from woody vegetation of Milan city. Field measure of PM has been carried out in order to assess the "real" effect of vegetation on particulate concentration and distribution.

Estimation of air pollution removal by Milan woody vegetation

Methods

The study area

Milan is a densely populated town located in the heart of the Po Valley, a highly urbanized and industrialized area of Northern Italy. Air quality is often poor due to the relevant amounts of air pollutants released by traffic, civil and industrial sources. Indeed, particulate matter and nitrogen dioxide in winter and ozone concentrations in summer exceed the national air quality standards. Air quality is highly influenced by the seasonal meteorology. Critical concentrations are mainly recorded in winter when cold air clings to the soil. Emission of particulate matter (PM10 and PM2.5) in Milan is mainly due to transportation and domestic heating.

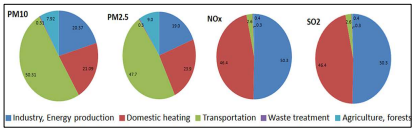


Fig. 1 Yearly air pollutant emissions (INEMAR, 2010)

Input data

The Milan Municipality manages 200 000 trees of public property, belonging to more than 250 species. Vegetated areas are characterised by high levels of exotic species.

Total area	km²	181.8
Population (31-10-2012)	N..	1245957
Population density	N./Km²	6855
Green areas	m²	22148000
Green ares per inahabitant	m2	17.8
Trees (1)	No.	206591
Trees per inhabitant	No.	0.2

Fig. 2 Summary information green public property

In addition there are 616 ha of parks managed by other institutions, 38 ha of city vegetable garden and 2530 ha of agricultural land Milan Municipality. The latter is characterized by the presence of tree lines, natural corridors, and shelterbelts.

Common name	Scientific name	No	% of total	Trunk diameter at dbh cm	Mean height m
Plane trees	*Platanus orientalis/acerifolia*	14127	7.5	13.7	38.5
Honeyberry	*Celtis australis*	9617	5.1	11.8	37.3
Norway maple	*Acer platanoides*	7977	4.2	7.7	18.6
European hornbeam	*Carpinus betulus*	7255	3.9	5.8	12.5
Black locust	*Robinia pseudoacacia*	6916	3.7	8.7	21.7
Black poplar	*Populus nigra*	6021	3.2	10.7	28.7
Lime tree	*Tilia argentata/hybrida spp*	5209	2.8	9.8	26.0
Plane tree (other species)	*Platanus spp*	4885	2.6	15.0	40.2
Northern red oak	*Quercus rubra*	4759	2.5	11.3	26.6
European White Elm	*Ulmus leavis spp*	4724	2.5	11.5	29.8
American sweetgum	*Liquidambar styraciflua*	4720	2.5	6.6	13.6
Sycamore maple	*Acer pseudoplatanus*	4333	2.3	7.6	18.3
Cherry plum	*Prunus cerasifera*	4109	2.2	5.2	13.5
European ash	*Fraxinus excelsior*	4065	2.2	5.9	11.4
Maple ash	*Acer negubdo*	3906	2.1	8.5	24.2
Silver maple	*Acer saccharinum*	3863	2.1	8.7	23.6
Horse-chestnut	*Aesculus hippocastanum*	3688	2.0	11.0	34.8
Small-leaved Lime	*Tilia cordata*	3537	1.9	6.1	13.6
California incense cedar	*Calocedrus decurrens*	3439	1.8	7.4	33.5
English oak	*Quercus robur*	3386	1.8	7.5	17.3
European Beech	*Fagus selvatica*	3384	1.8	8.9	25.6
Pagoda Tree	*Sophora japonica*	3383	1.8	8.9	25.6
Dwarf Elm	*Ulmus pumila*	3196	1.7	12.0	35.9
Japanese Cherry	*Prunus serrulata*	2890	1.5	4.6	10.7
Judas tree	*Cercis siliquastrum*	2453	1.3	5.2	13.3
Tree of heaven	*Ailanthus altissima*	2144	1.1	10.7	30.2
Tulip tree	*Liriodendron tulipifera*	2114	1.1	6.1	11.6
American Linden	*Tilia americana*	2031	1.1	10.0	28.8
Elm	*Ulmus carpinifolia / procera*	1978	1.1	12.5	36.0
Atlas Cedar	*Cedrus atlantica*	1814	1.0	12.3	37.6
Hackberries (excl C. australis)	*Celtis spp*	1710	0.9	11.4	36.5
Field maple	*Acer campestre*	1680	0.9	5.8	12.7
Ginkgo or maidenhair tree	*Ginkgo biloba*	1627	0.9	7.7	15.8
Other species	- - - - - -	43660	25.0	5.9	15.7

Table 1. Main tree species surveyed by the Milan Municiaplity

Model

The Urban FORest Effects (UFORE) model has been used to assess pollutants removal by urban trees. The UFORE model uses vegetation, air pollution, and meteorological data to quantify the hourly amount of pollution removed by the urban forest throughout a year.

Results

According to the model, removal of PM10 by trees managed by the Milan Municipality is mainly performed by deciduous tree species (91% of total removal). Conifers, however, show the highest rate of PM10 interception (6.4 g/m² foliar area), followed by evergreen broadleaves (mainly Ilex aquifolium and Magnolia spp.) with 5.6 g/m² and broadleaf deciduous species (4.2 g/m²). The yearly removal rate exceeds 30 t of PM10, with 60% performed by trees of the Milan Municipality. Old but healthy trees with a large foliar area play a major role in PM10 removal: 27134 trees (15% of the total) remove 50% of the total amount intercepted. Removal rates for the different districts could also be assessed providing suggestions for new tree planting (Fig.3).

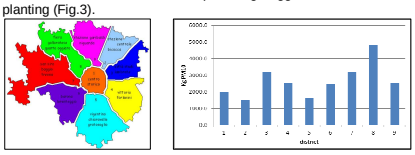
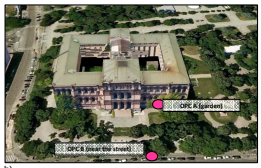


Fig.3 Milan city districts, public trees and PM10 removal in each district

The study provides some practical recommendations regarding urban tree management:
- maintain trees in healthy conditions to increase pollution removal,.
- sustain existing tree cover to maintain pollution removal levels,
- protect large, healthy trees since they have greatest per-tree effects.
- use long-lived trees,
- use low-maintenance trees and invest saved money in new green areas,
- plant trees in polluted or heavily populated areas to maximize tree air quality benefits.
- use conifer and evergreen trees for particulate matter reduction since removal is performed also in winter when concentrations reach their maximum.

Experimental studies and effect of the vegetation on PM concentration

a)



b)

Fig.2. a) Aerial view of Museum of Natural History and Ecopass border (red line) b) 3D view of the park sorrounding the Museum

a)

b)

Fig.1. a) OPC Metone Aerocer 531 b) the park, sorrounding the Museum of Natural History at Milano Porta Nuova location

Methods

Particle matter concentration measurements were performed by two OPCs (Optical Particles Counters, Aerocet 531, MetOne, USA) (Fig.1a).The experimental campaign was carried out at the garden of Natural History Museum in the city of Milan (Fig.1b), located at the border of the Ecopass C area, confining to city roads characterized by high levels of vehicular traffic (Fig.2a): Corso Venezia, via Palestro and Bastioni di Porta Venezia. Measures of PM concentration (PM10 and TSP, Total Suspended Particles) were performed into the park of the Museum, behind the tree belt (sample area A) and at the border of the garden fence wall, in front of the main road Corso Venezia (sample area B) (Fig.2b) simultaneously (about 30 meters of distance between the two analyzers). PM data were corrected for the water air content [6] and processed by Statistica software, in order to validate data and perform descriptive statistics analysis (STATISTICA, Statsoft, USA).

Results

The experimental campaign pointed out the capability of the vegetation (trees and hedges –mainly maples-) to abate airborne particulate concentration (Fig.4b). Data show how the percentage of average abatement, due to the green, ranged from about 30% to 20 % for PM_{10} and TSP respectively (Fig.4c). These results are in agreement with other studies on PM distribution carried out in both urban and peri-urban environment [7] [8] pointing out also, how the green is more efficient in abating PM_{10} fraction of particulate matter, rather fine one (as PM1 and PM2.5). Single negative values of abatement on trends are related to rapid changes in micro-meteorological conditions (in particular wind direction and velocity) and to intermittent sources of particulate matter existing within the park (such as runners, bikers and service vehicles). Wind speed (Fig.4a), in the experimental site, ranged from 0 to 2 ms^{-1}. In some cases, studying hi-resolution time data, it is possible to observe an inverse correlation between wind speed and ambient PM concentration due to an increase of air turbulence that enhance pollutant dispersion. Moreover, it interesting to note the abatement effect of the green on peaks of PM (Fig.4b). The high percentage of abatement of PM, measured in the campaign, may be due not only to the removal by the green but even to the different distance of the analyzers from the source of the pollutant (street).

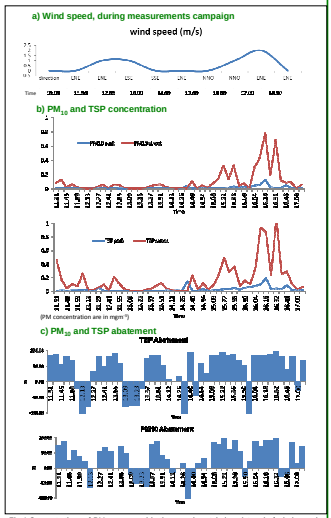


Fig.4 Concentrations of PM_{10} measured in the experimental site: a) trend of wind speed measured during the campaign; b) trend of measured PM_{10} concentrations in bare and vegetated soil; c) percentage of PM_{10} reduction (vegetated compared to bare soil)

Conclusions

These results confirm the effective potential of trees and green barriers (shrubs and hedges) in removing airborne particulate matter, highlighting the functional role of the urban forest and pocket parks in improving urban environment and life quality of citizens and the need to preserve, as well as to increase, urban vegetation. These considerations may be crucial for a sustainable urban planning, providing at region and municipal scale innovative, reliable and effective approach for the reducing of urban air pollution, aimed to an integration into standard regulatory measures such as limitation of traffic and emissions. In the EC political context, *Green Infrastructures* may represent a multifunctional resource capable of providing a wide range of environmental benefits and services. Further studies are in progress in aim to assess the potential role of vegetation (in particular trees and green barriers as shrubs and hedges), in relation to its type and structure, in abating air pollutant concentration, improving air quality and corresponding many ecosystem services, especially in high populated areas.This research confirms that urban vegetation can positively impact local air quality and highlights the need for appropiate public urban planning.

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