Società di Ortoflorofrutticoltura Italiana
Dipartimento di Agricoltura Alimentazione e Ambiente
XIII GIORNATE SCIENTIFICHE SOI | 22-23 GIUGNO 2021

Use of evergreen shrub barriers to reduce pollution by traffic: a long-term experiment to study the dynamics of fine particles during different seasons and in different environmental situations

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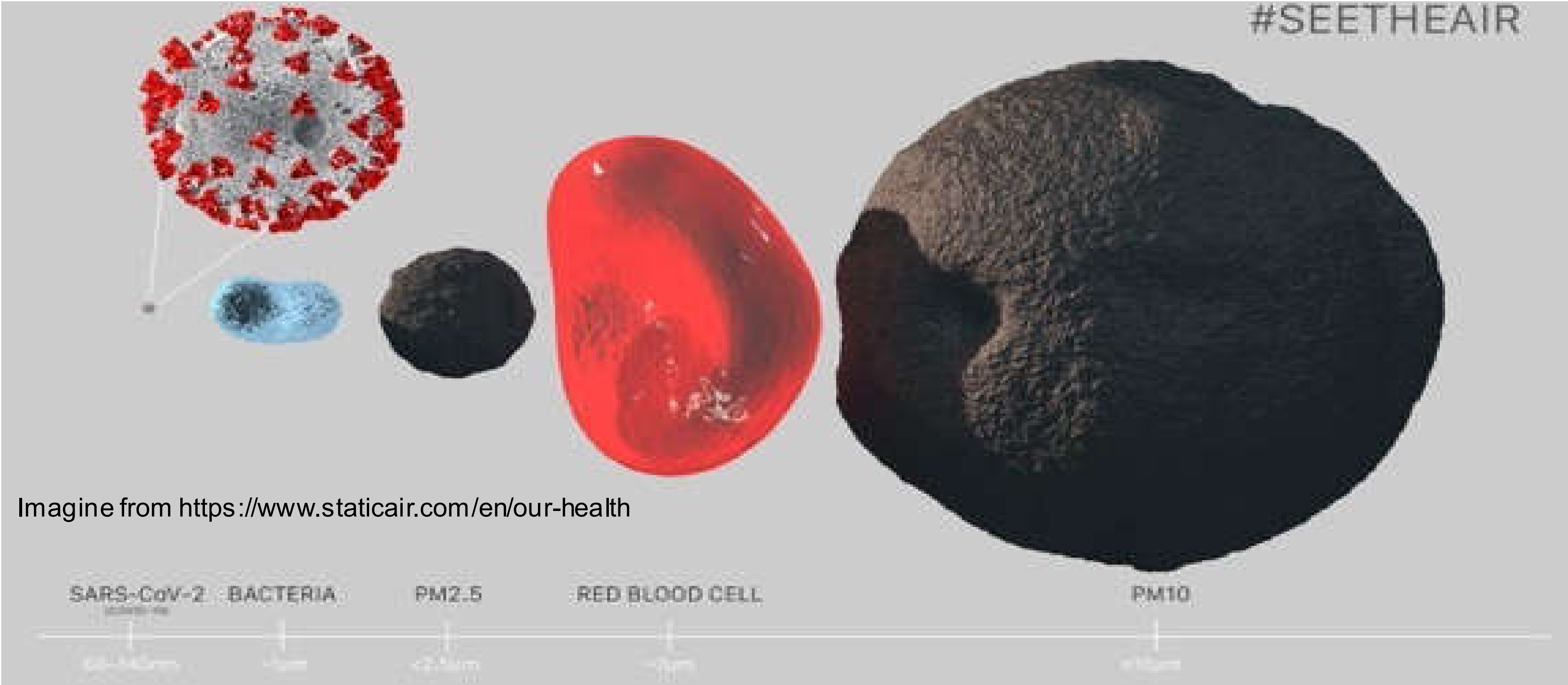
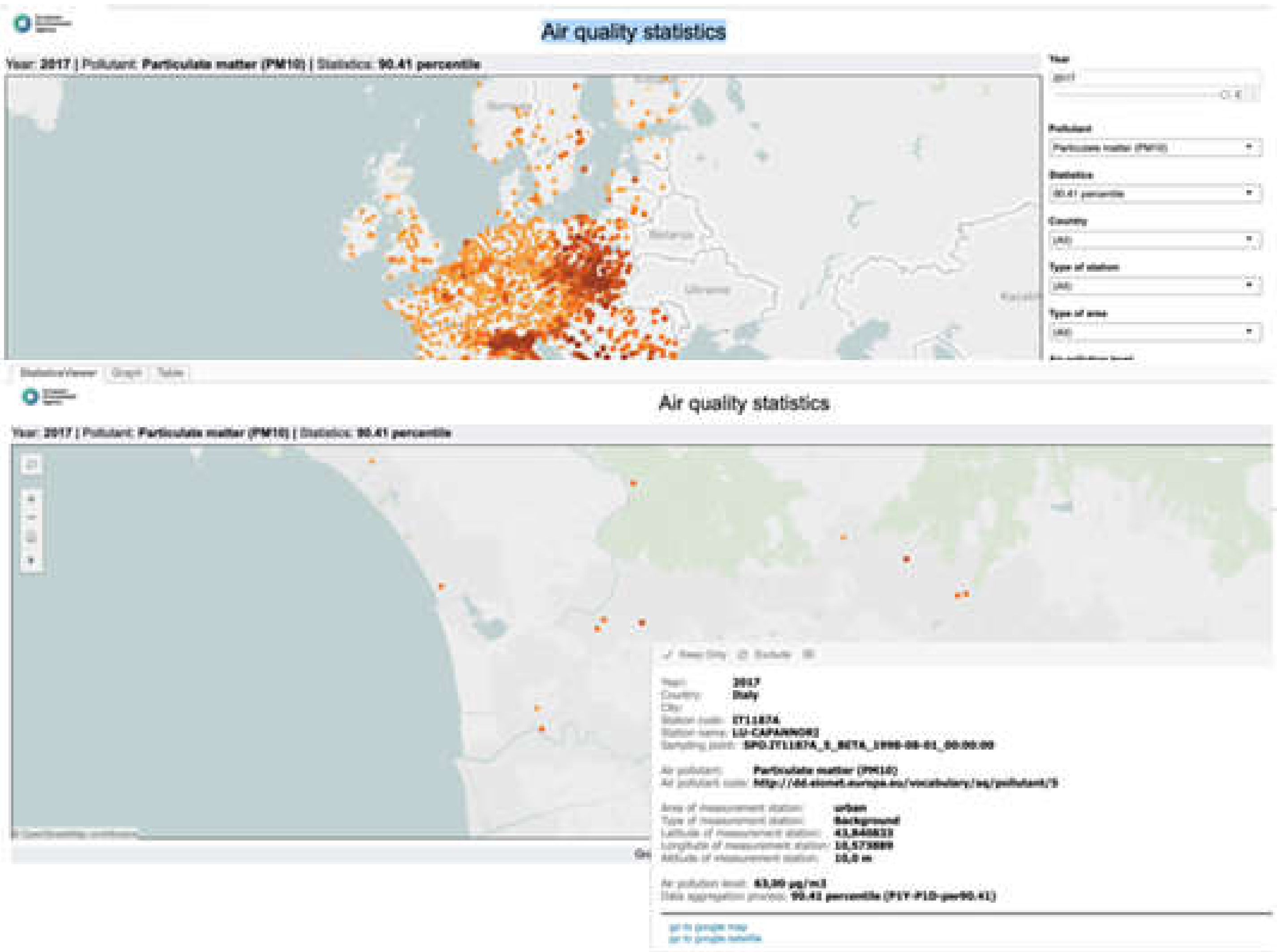
Particulate matter (**PM**) is the principal air pollutant composed of solid and liquid substances as **heavy metals**, black carbon, polycyclic aromatic hydrocarbons (PAH) and other substances



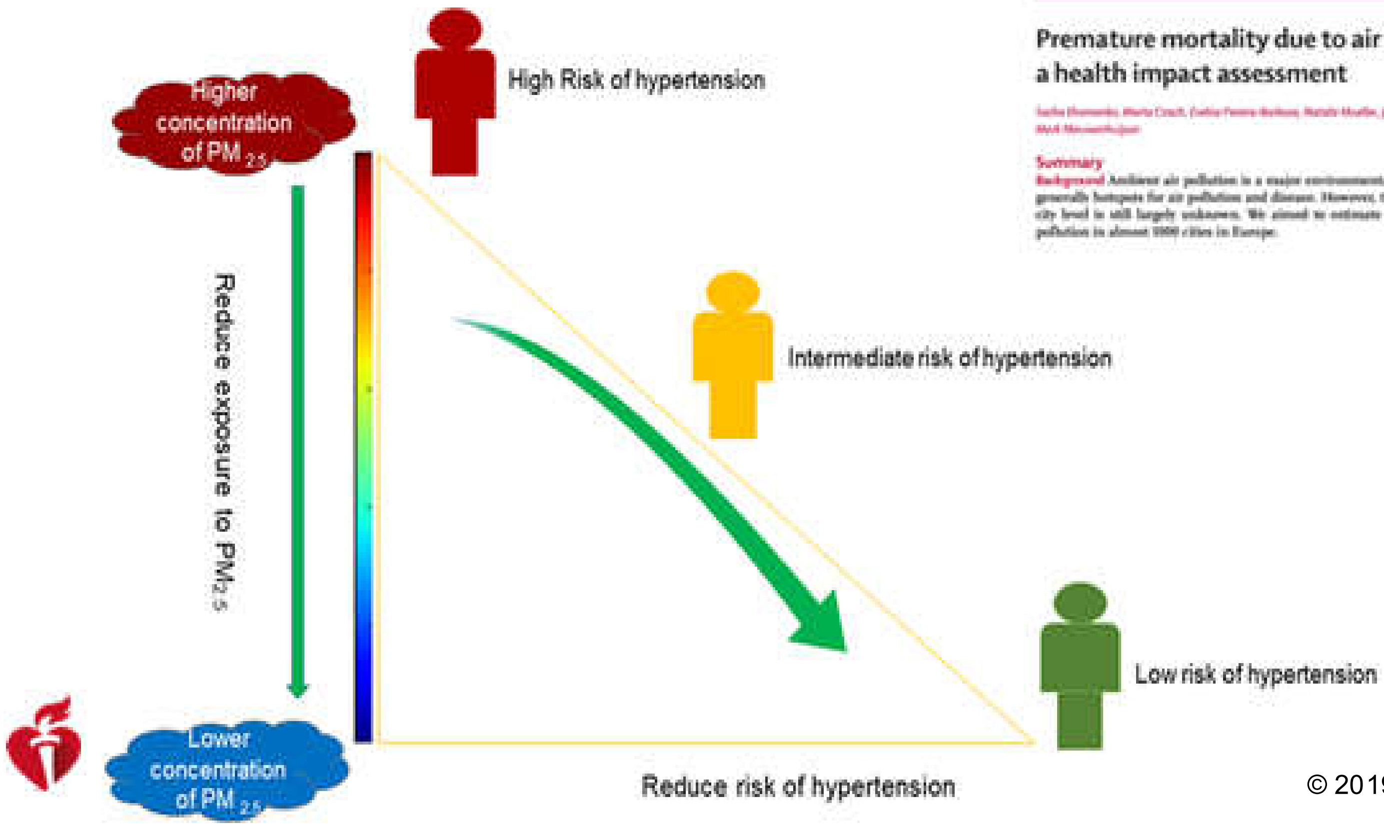
Imagine from https://www.staticair.com/en/our-health


Air quality statistics
Year: 2017 | Pollutant: Particulate matter (PM10) | Statistics: 90.41 percentile
Air quality statistics
Year: 2017 | Pollutant: Particulate matter (PM10) | Statistics: 90.41 percentile


Healthy lung
Lung suffering from
Pneumoconiosis


CO2
COVID-19
LOSMA

Yacong Bo. Hypertension. Dynamic Changes in Long-Term Exposure to Ambient Particulate Matter and Incidence of Hypertension in Adults, Volume: 74, Issue: 3, Pages: 669-677, DOI: (10.1161/HYPERTENSIONAHA.119.13212)



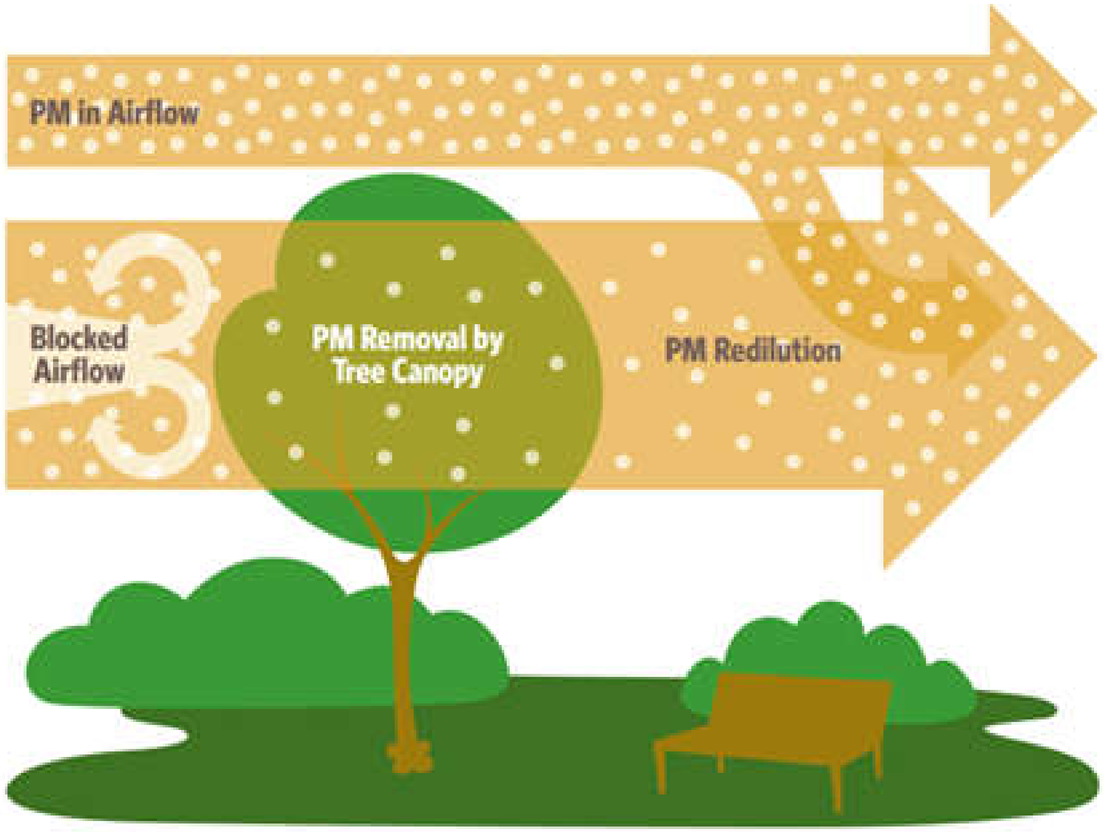

Premature mortality due to air pollution in European cities: a health impact assessment

Summary

Background Ambient air pollution is a major environmental cause of morbidity and mortality worldwide. Cities are generally hotspots for air pollution and disease. However, the exact extent of the health effects of air pollution at the city level is still largely unknown. We aimed to estimate the proportion of annual preventable deaths due to air pollution in almost 1000 cities in Europe.

Plants improve air quality by adsorption and absorption of air pollutants on their surfaces and in their tissues.

The position and structure of the vegetation are very important for pollution abatement



First experiment (Progetto MIA-MIPAAF)

Characterization of 7 evergreen plant species for their air pollution mitigation capacity

M & M

-Plants in open field, disposed in two belts (28x5 m), adjacent to a 4-lanes road

-Leaf metal deposition (Zn, Cd, Pb, Ni, Cu) during 3 samplings (June, August, October)

-Content of metals in rainwater collected at the base of the different species

-Growth parameters (biomass, leaf area, height of plants, crown diameter, LAI)

-Relation between metal deposition and meteorological parameters

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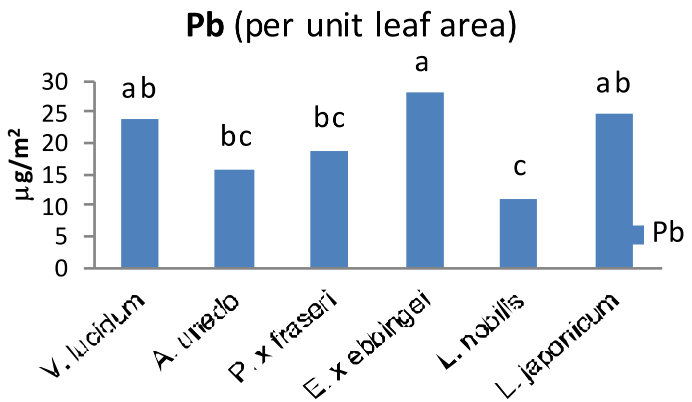
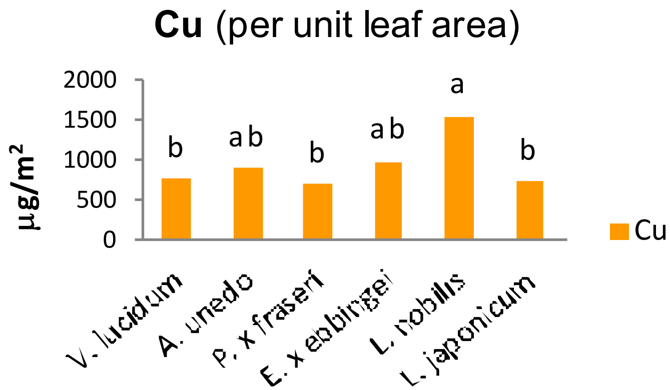
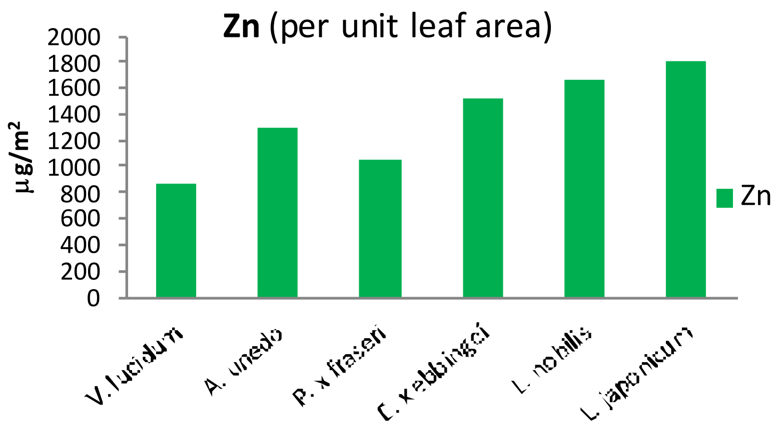
First experiment - Metal adsorption per unit leaf area



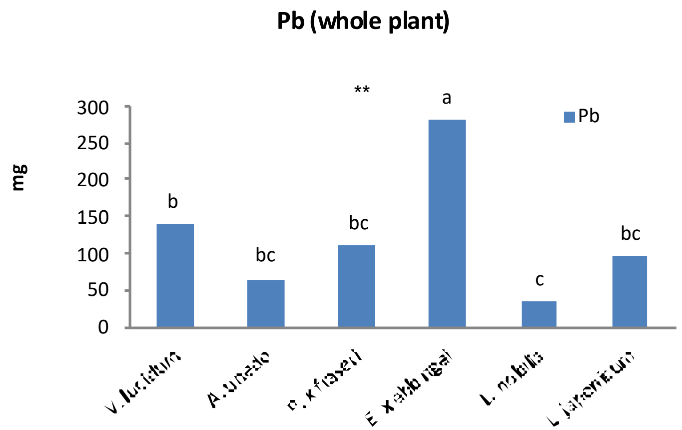


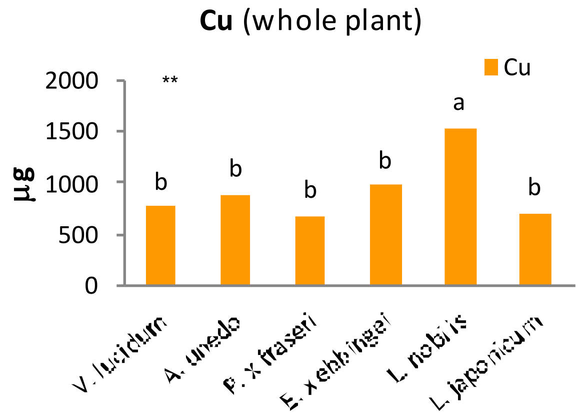


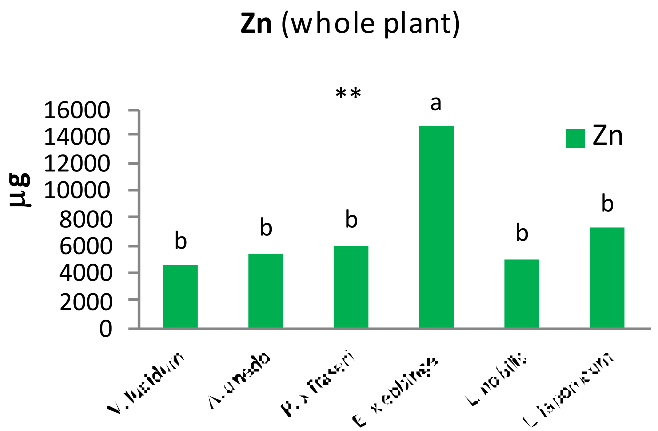
As for zink, removal (per unit leaf area) of cadmium and nichel was similar across species

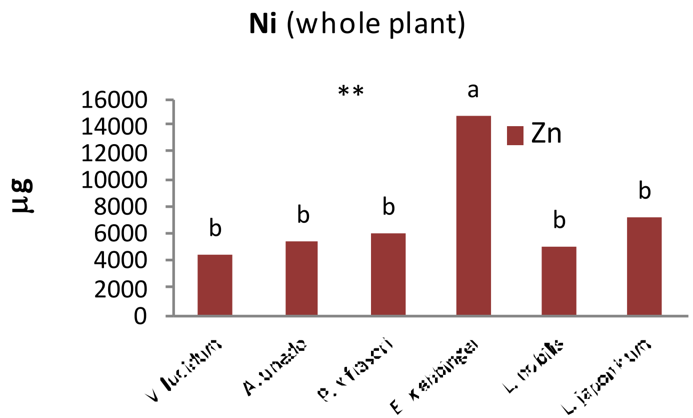
First experiment - Metal adsorption of the whole plant

Leaf area differed among species: *E. x ebbingei* had, on average, two- or three-times larger leaf area if compared to the other species









Results

- ***E. x ebbingei***, ***V. lucidum*** and ***L. japonicum*** showed the highest Pb deposition per unit area (1.9 -2.3 x 10^{-3} µg cm^{-2}). ***E. x ebbingei*** showed the highest values per whole plant.

- ***E. x ebbingei***, had the highest whole plant leaf accumulation of almost all the measured metals mainly due to the faster and higher growth.

- **Rain** and **Wind speed** were found to influence the metal deposition (Data not shown).

E. x ebbingei

L. japonicum

V. lucidum

Urban Forestry & Urban Greening

Deposition of traffic-related air pollutants on leaves of six evergreen shrub species during a Mediterranean summer season

Jacopo Mori, Arne Sæbø, Hans Martin Hanslin, Angela Teani, Francesco Ferrini, Alessio Fini, Gianluca Burchi

Arboriculture & Urban Forestry 42(5): September 2016

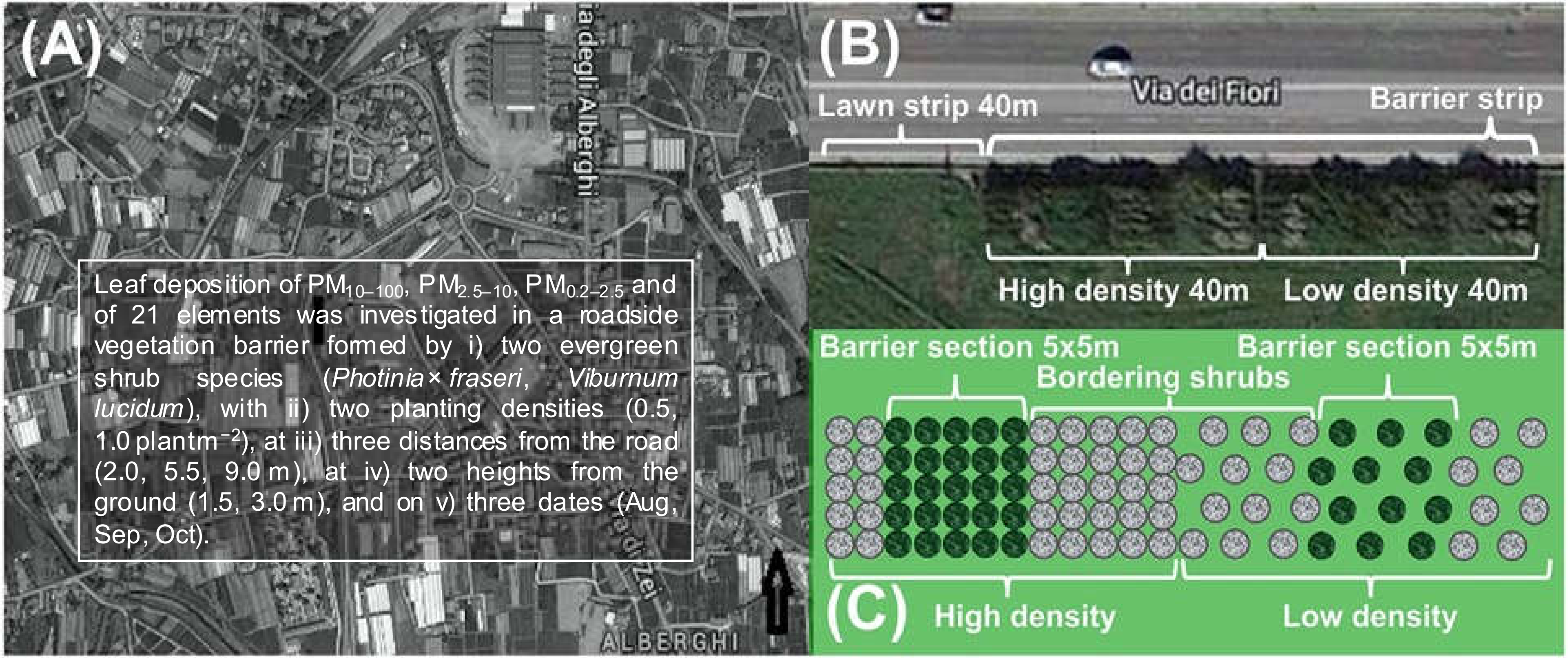
Arboriculture & Urban Forestry 2016. 42(5): 329–345

ISA

Carbon Uptake and Air Pollution Mitigation of Different Evergreen Shrub Species

Jacopo Mori, Alessio Fini, Gianluca Burchi, and Francesco Ferrini

Second experiment: Air pollution deposition on a roadside vegetation barrier in a Mediterranean environment: Combined effect of evergreen shrubspecies and planting density



Leaf deposition of $PM_{10–100}$, $PM_{2.5–10}$, $PM_{0.2–2.5}$ and of 21 elements was investigated in a roadside vegetation barrier formed by i) two evergreen shrub species (*Photinia × fraseri*, *Viburnum lucidum*), with ii) two planting densities (0.5, 1.0 plant m^{-2}), at iii) three distances from the road (2.0, 5.5, 9.0 m), at iv) two heights from the ground (1.5, 3.0 m), and on v) three dates (Aug, Sep, Oct).


Science of the Total Environment

Air pollution deposition on a roadside vegetation barrier in a Mediterranean environment: Combined effect of evergreen shrub species and planting density

- *V. lucidum* had more $PM_{2.5–10}$ and $PM_{0.2–2.5}$ on leaves than *P.* × *fraseri*, while most elements were higher in *P.* × *fraseri*.

- Most pollutants decreased at increasing distances from the road and were higher at 1.5 m from the ground compared to 3.0 m.

- Higher planting density in *P.* × *fraseri* enhanced the deposition of $PM_{10–100}$ and $PM_{2.5–10}$, while in *V. lucidum*, the planting density did not affect the depositions.

- Black $PM_{10–100}$ decreased a long distance from the road and was entirely composed of carbon and oxygen, which was thus identified as black carbon from fuel combustion.

- The vegetation barrier had a higher deposition of most PM fractions at 5.5–12.5 m, while in the lawn area, depositions did not change. At 19.5 m, the $PM_{10–100}$ was 32% lower behind the barrier than in the lawn area.

- In conclusion, the vegetation barrier changed the deposition dynamics of pollutants compared to the lawn area. These results strengthen the role of vegetation barriers and shrub species against air pollution and may offer interesting insights for the use of new road green infrastructures to improve air quality.

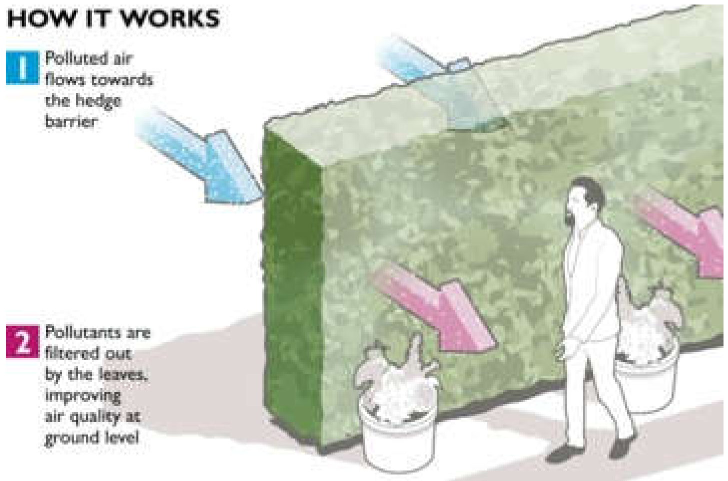
Third experiment:
Comparing different methodologies to quantify particulate matters accumulation on plant leaves funded by Fondazione Cassa di Risparmio di Lucca

Different methodologies for quantifying PMx were compared

PMx quantification methods:
1. **Microscopical analysis**
2. **Filtration methods**

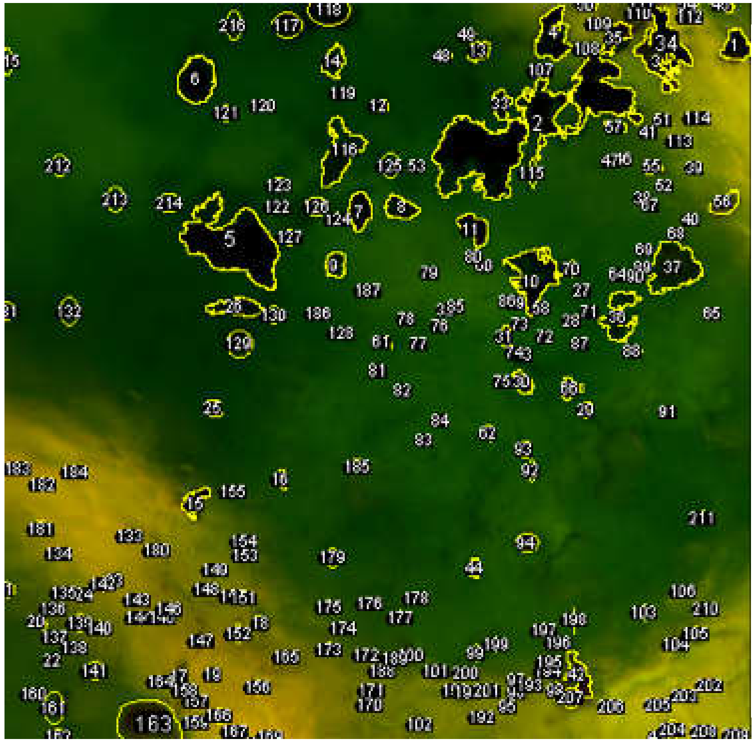
Leaf trait were correlated to the species capacity to accumulate PMx

Leaf traits:
1. **Leaf area (LA)**
2. **specific leaf area (SLA)**
3. **leaf dissection index (LDI)**
4. **leaf roundness**



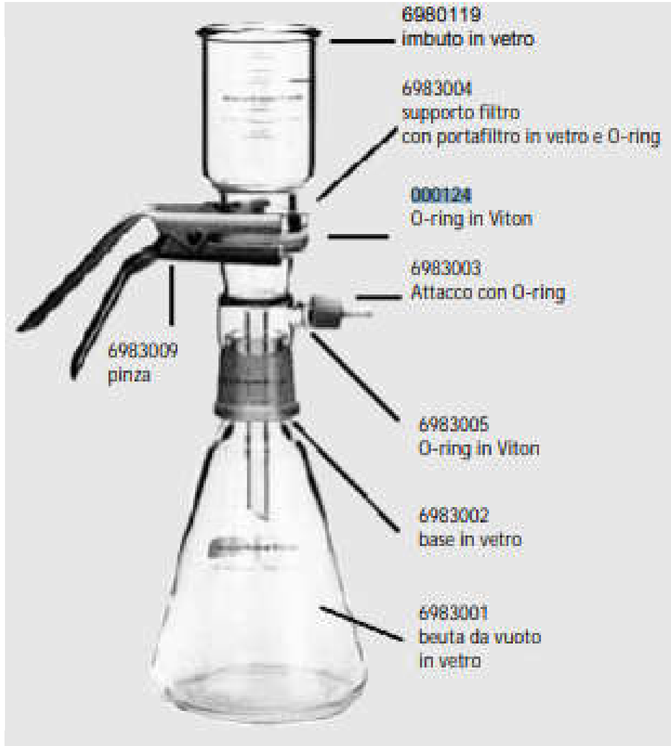
Microscopical analysis

Particle analysis using ImageJ



A sx.: Particle analysis using ImageJ: images obtained by an optical microscope leaves analysis were used to identify Pmx.

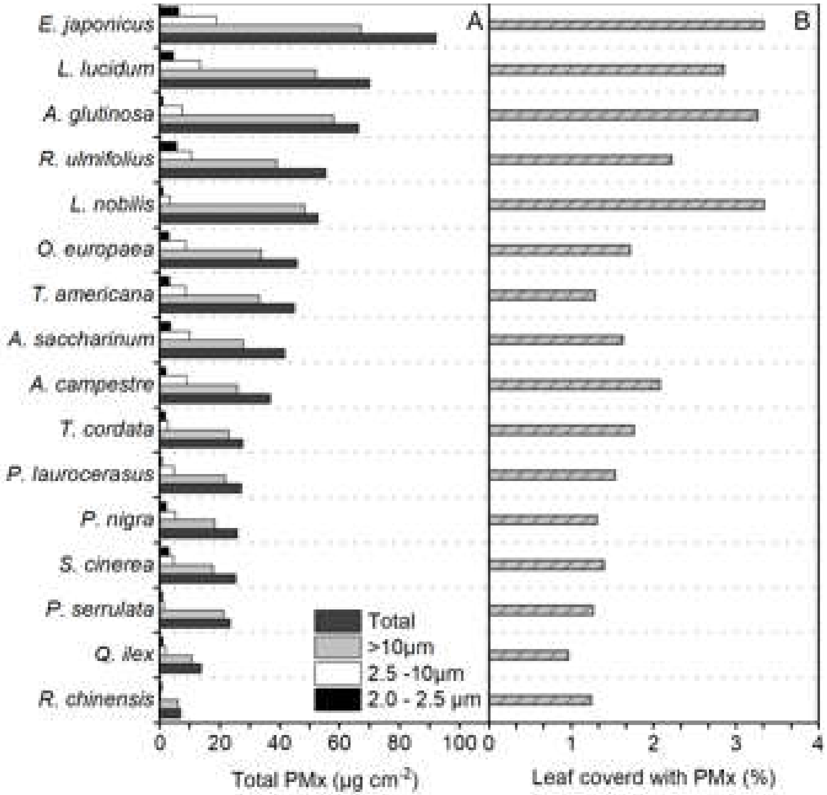
Filtration methods



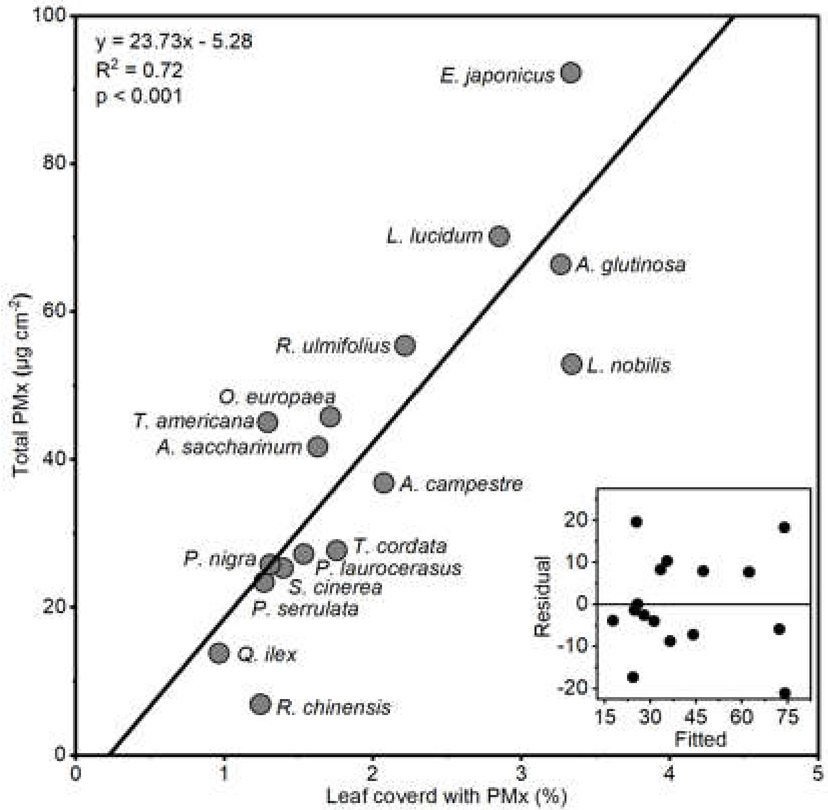
A dx.: Filtration was carried out using an apparatus equipped with a 47 mm glass filter funnel connected to a vacuum pump.

From the 32 species collected, 16 presented more them 1% of leaf area covered with PMx and were selected for the filtration methods

PMx divided by the particle size



Percentage of leaf surface covered to PMx (%)



Regression analysis between both methodologies

-The linear regression between both analyses presented a high coefficient of determination ($R^2 = 0.72$), a statistical significance of $p > 0.001$.

-Both methodologies are comparable at least when the leaves accumulate more than 1% of leaf-covered with PMx.

- Leaves with less the than 1% of leaf-covered with PMx could present a not significant regression due to an underestimation of the analysis with an optical microscope.

Leaf traits

Three leaves per sample were analysed using ImageJ, measuring the leaf traits shown in the table.

Species	Leaf area (LA)	Specific leaf area (SLA)	Leaf dissection index (LDI)	Leaf roundness
E. japonicus	**5.59**	**7.49**	**6.35**	**0.62**
L. lucidum	**27.57**	**6.49**	**5.00**	**0.43**
A. glutinosa	**54.81**	**14.03**	**5.53**	**1.00**
R. ulmifolius	**6.37**	**9.29**	**4.97**	**0.39**
L. nobilis	19.27	8.17	5.16	0.29
O. europaea	5.19	7.15	6.60	0.17
T. americana	**47.39**	**18.69**	**6.65**	**0.83**
A. saccharinum	46.63	12.65	12.29	0.50
A. campestre	**32.85**	**14.22**	**5.79**	**0.68**
T. cordata	**75.56**	**15.95**	**6.13**	**0.99**
P. laurocerasus	**85.48**	**8.52**	**5.09**	**0.36**
P. nigra	39.02	12.08	7.29	0.77
S. cinerea	33.44	9.72	6.04	0.45
P. serrulata	29.42	8.17	4.85	0.56
Q. ilex	12.11	9.57	5.42	0.41
R. chinensis	8.21	21.20	4.71	0.60

Species highlighted are those selected to the multiple regression analysis (they were collected at the same place and time)

Multiple linear regression between PMx parameters and leaf traits, (p-value < 0.1)
A combination in the leaf traits influenced the PMx accumulation

	Variable	Correlation	R^2	p-level
% PMx	LA	-	0.26	**0.072**
	SLA	**-**	**0.69**	**0.022**
	LDI	ni	0.52	0.422
	Leaf roundness	+	0.66	**0.016**
Total PMx	LA	ni	0.26	0.104
	SLA	**-**	**0.69**	**0.093**
	LDI	ni	0.52	0.551
	Leaf roundness	ni	0.66	0.152
PM_{10}	LA	ni	0.26	0.188
	SLA	ni	0.69	0.112
	LDI	ni	0.52	0.809
	Leaf roundness	ni	0.66	0.121
$PM_{2.5}$	LA	-	0.26	**0.034**
	SLA	**-**	**0.69**	**0.072**
	LDI	+	0.52	**0.099**
	Leaf roundness	ni	0.66	0.745
$PM_{0.2}$	LA	-	0.26	**0.054**
	SLA	ni	0.69	0.541
	LDI	ni	0.52	0.347
	Leaf roundness	ni	0.66	0.655

-The % PMx was positively correlated with leaf roundness and negatively correlated with LA and SLA.

-Total PMx was negatively correlated with SLA.

-PM_{10} was not correlated to any leaf trait.

-$PM_{2.5}$ was positively correlated with LDI and negatively correlated with LA and SLA.

-$PM_{0.2}$ was negatively correlated with LA.

SLA is an easy-to-measure leaf trait recommended for distinguishing between low and high net particle accumulator species (Muhammad et al. 2019)

Conclusions

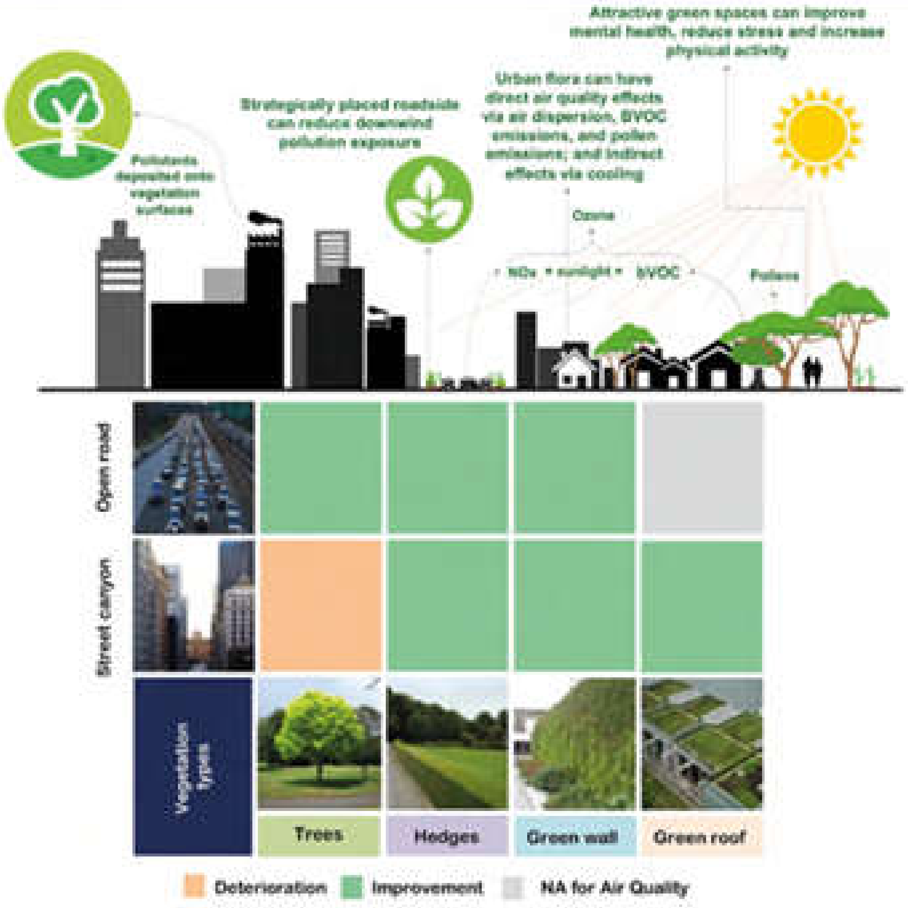
1. PMx accumulation is better understood when a combination of methods is applied

2. Multiple methods can be used as a preliminary study to choose the most appropriate for specific research goals

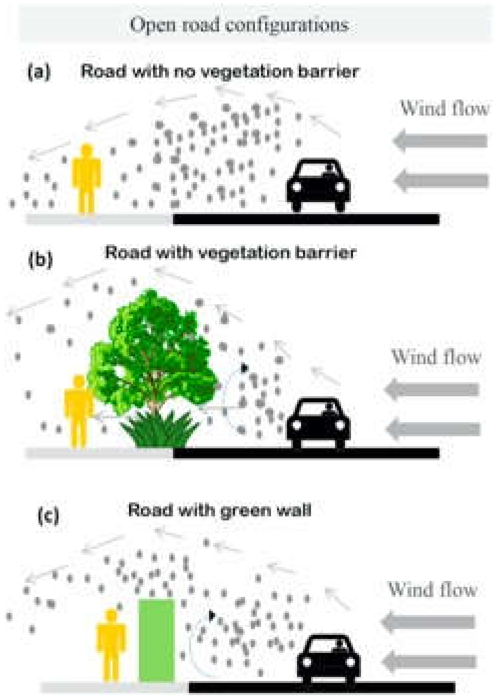
3. When working with large sample sizes, only the filtration methods can be promising and the microscopical method can be used as a screening tool to separate target samples

4. The relationship between PMx accumulation and the leaf traits can be better explained by a conjunction of leaf traits

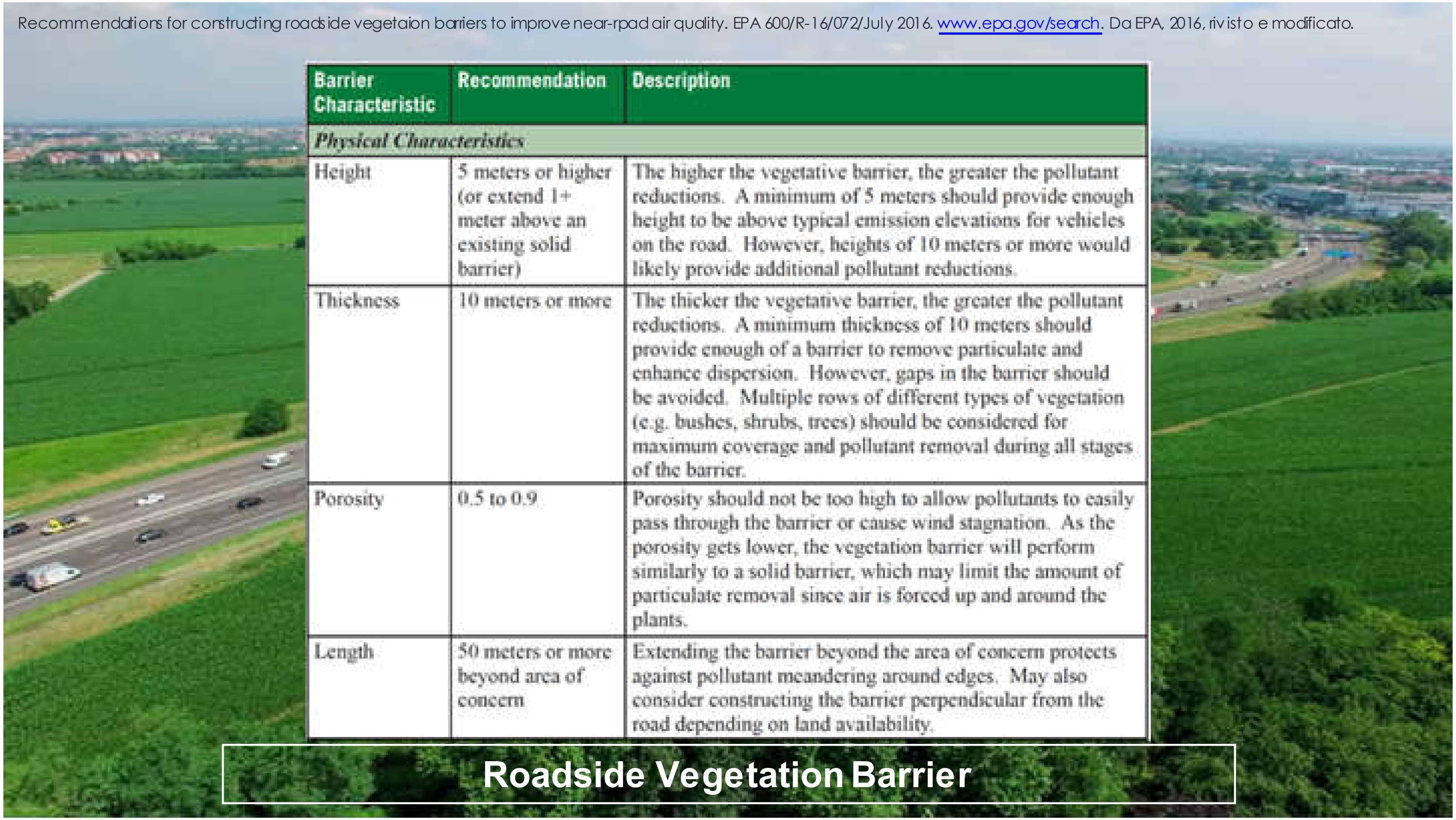
5. The leaf traits are important to be consider when choosing species for PMx quantification, especially when working in long-term monitoring programs



An overview of the relationship between air quality and green infrastructure with a matrix offering local-scale implementation impacts. (Adapted from Kumar et al., 2019, and Abhijith et al., 2017)



Recommendations for constructing roadside vegetaion barriers to improve near-rpad air quality. EPA 600/R-16/072/July 2016. www.epa.gov/search. Da EPA, 2016, rivisto e modificato.



Barrier Characteristic	Recommendation	Description
Physical Characteristics		
Height	5 meters or higher (or extend 1+ meter above an existing solid barrier)	The higher the vegetative barrier, the greater the pollutant reductions. A minimum of 5 meters should provide enough height to be above typical emission elevations for vehicles on the road. However, heights of 10 meters or more would likely provide additional pollutant reductions.
Thickness	10 meters or more	The thicker the vegetative barrier, the greater the pollutant reductions. A minimum thickness of 10 meters should provide enough of a barrier to remove particulate and enhance dispersion. However, gaps in the barrier should be avoided. Multiple rows of different types of vegetation (e.g. bushes, shrubs, trees) should be considered for maximum coverage and pollutant removal during all stages of the barrier.
Porosity	0.5 to 0.9	Porosity should not be too high to allow pollutants to easily pass through the barrier or cause wind stagnation. As the porosity gets lower, the vegetation barrier will perform similarly to a solid barrier, which may limit the amount of particulate removal since air is forced up and around the plants.
Length	50 meters or more beyond area of concern	Extending the barrier beyond the area of concern protects against pollutant meandering around edges. May also consider constructing the barrier perpendicular from the road depending on land availability.

Roadside Vegetation Barrier

Recommendadtions for constructing roadside vegetaion barriers to improve near-rpad air quality. EPA 600/R-16/072/July 2016. www.epa.gov/search. Da EPA, 2016, rivisto e modificato.

Barrier Characteristic	Recommendation	Description
Vegetation Characteristics		
Seasonal Effects	Vegetation not subject to change by season	Vegetative barrier characteristics must be consistent throughout all seasons and climatic conditions in order to ensure effective pollutant reductions.
Leaf Surface	Complex waxy and/or hairy surfaces with high surface area	Leaf surfaces with complex and large surface areas will capture and contain more particulate pollutants as air passes through the structure.
Air Emissions	Vegetation with low or no air emissions	Vegetation used for roadside barriers should not be sources of air pollution, either at the local or regional scale.
Pollution and Stress Resistant	Resistant to effects of air pollution and other stressors	Vegetation must be able to survive and maintain its integrity under the high pollution levels and stress that can occur near roads in order to provide effective pollution reductions from traffic emissions. In addition to air pollution, other stressors can include salt and sand for winter road conditioning and noise impacts

Recommendations for constructing roadside vegetaion barriers to improve near-rpad air quality. EPA 600/R-16/072/July 2016. www.epa.gov/search. Da EPA, 2016, rivisto e modificato.

Barrier Characteristic	Recommendation	Description
Other Considerations		
Maintenance	Plan must be in place to properly maintain vegetative barrier	Proper vegetation maintenance must be provided in order for the barrier to survive and maintain its integrity to provide effective pollution reductions from traffic emissions.
Water Runoff	Contain surface water runoff and improve water quality	Roadside vegetative barriers constructed appropriately can provide an added benefit of controlling and containing surface water runoff from the road, which can also improve local water quality.
Drought Resistant	Choose species resistant to drought and flooding	Many regions face climatic conditions of extended drought followed by localized flooding. Vegetative barrier must maintain its integrity under these conditions in order to provide effective pollution reductions.
Native Species	Choose native species	Native species will be more robust and resistant to climatic conditions in the area of interest; thus, maintaining its integrity under these conditions in order to provide effective pollution reductions.
Non-invasive	Choose non-invasive species	The use of non-invasive species will ensure effective pollutant reductions without potential unintended consequences from invasive species adversely effecting nearby land uses.
Non-poisonous	Choose non-poisonous species if sensitive populations will be nearby	Non-poisonous species are strongly encouraged and should be used if the barrier will be at a location with sensitive populations, such as elementary schools, parks, and recreation fields where small children may be active and in close contact.
Roadway Safety	Maintains safety for drivers on the road; conforms to local safety and permit requirements	Prior to planting, ensure vegetation plan will meet all safety and other local permit requirements (e.g. local highway department, city planning department) to preserve sight-lines and vegetation compatibility while avoiding potential wildlife/auto accidents and obstruction of outdoor advertising.

Review n. 34 – *Italus Hortus* 25 (1), 2018: 13-22 doi: 10.26353/j.itahort/2018.1.1322

Air pollution mitigation by urban greening

Jacopo Mori[1*], Francesco Ferrini[1], Arne Saebo[2]
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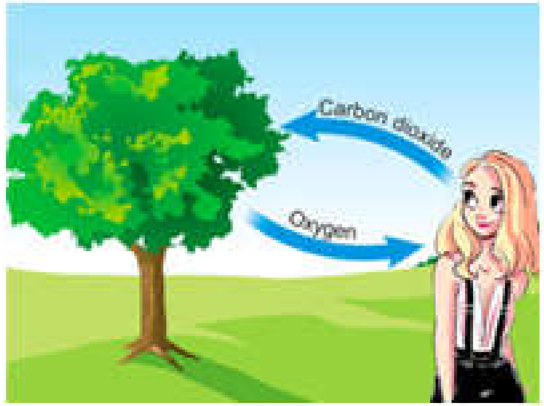
How to plan green areas for air quality improvement:

- Low-maintenance and fast-growing species with a medium to long-lifetime are preferable
- Evergreen species have generally a higher potential compared to deciduous species (beware to possible vulnerability to pollution)
- Species with hairs, thricomes and waxes have generally a greater interception of air pollutants, but total leaf area should have priority
- The environment surrounding the planting site should be highly considered (street canyons vs open roadside areas)
- Regarding roadside vegetation barriers, species with a considerable height, width and a high LAI (Leaf Area Index or high LAD - Leaf Area Density) are recommended



Thanks for the attention