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PS 5.3 Changing environment

A fast and ultra-spatially resolved method to monitor PM concentration in cities from PM deposition on urban trees

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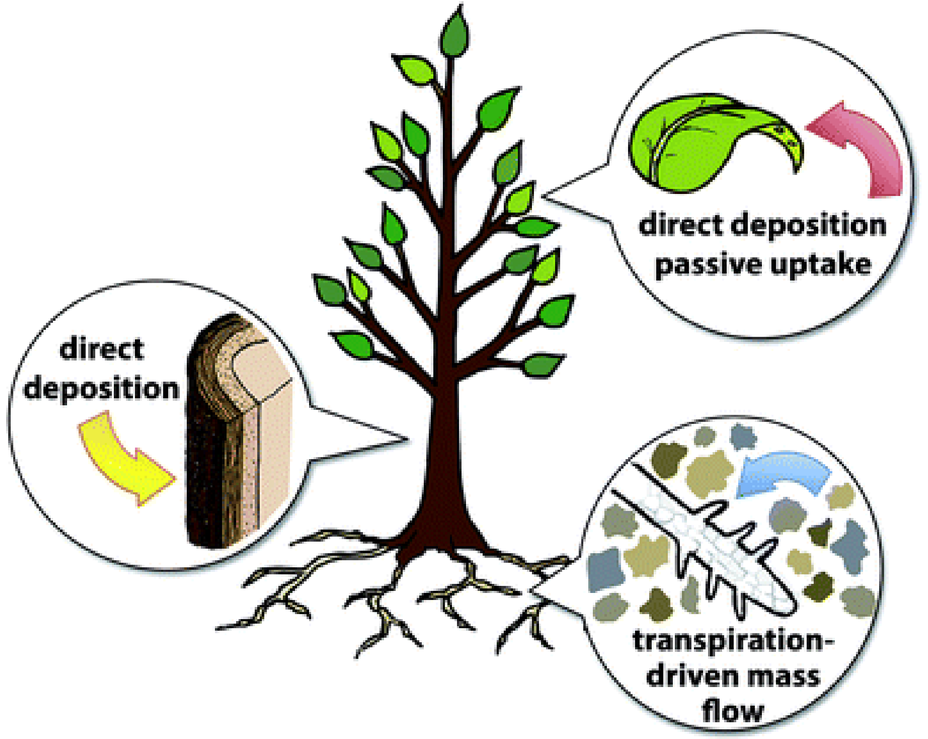
Overview

- Trees are passive filters for air pollutants (NOx, SOx, VOCs, PAHs and PM).
- Gases and PM1.0 are removed by stomatal uptake, PM10 and PM2.5 remain on leaf and bark surfaces (dry and wet deposition).
- The characterization of leaf deposited PM by SEM/EDX can provide an estimation of the PM size distribution, elemental composition and, by combining these results, of the removed PM amount per unit leaf area.
- Each tree can be considered as a monitoring unit of the ultra-spatially resolved monitoring network represented by the urban forest.
- Two case studies: differences in PM deposition as a function of the tree species (Terni) and the tree location (Naples).



Research highlights: natural passive samplers – plants as biomonitors
Vivian S. Lin, Environ. Sci.: Processes Impacts, 2015, **17**, 1137

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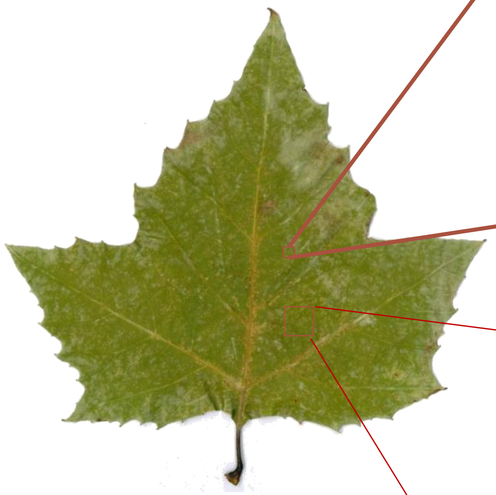
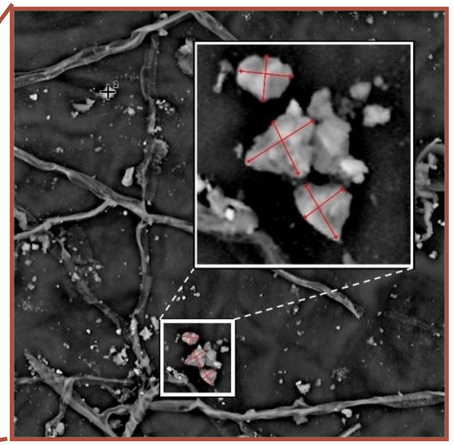
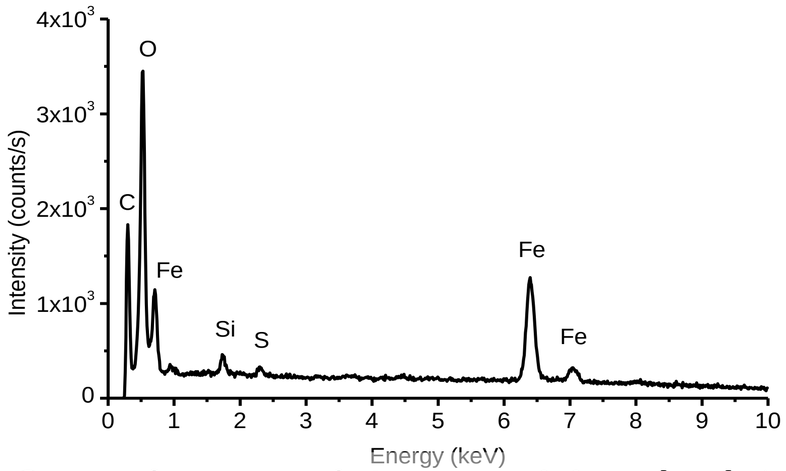
PM quantification by SEM/EDX



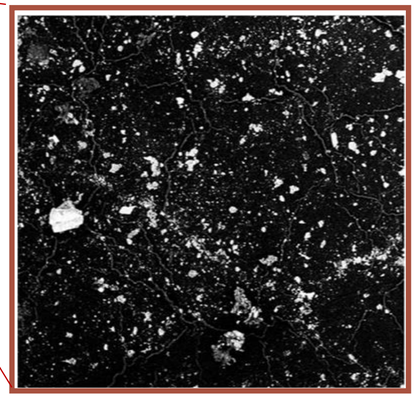


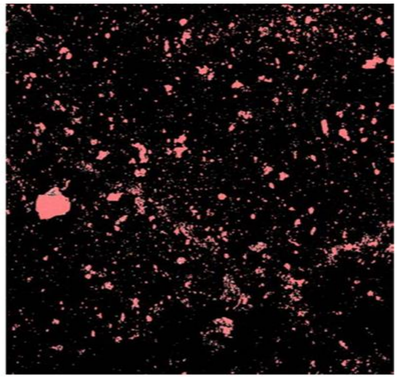


$$W_{\%_x} = \frac{\sum_{i=1}^{N} C_{x_i} \times V_i}{\sum_{i=1}^{N} V_i}$$

Baldacchini et al., ES&T 2017

Particle size (V_i) & Elemental Composition (C_{xi}) → Weighted Percentage ($W_{\%x}$)





$$M = \sum_{x} \frac{W_{\%x} \cdot V_{PMtot} \cdot am_x}{A_{leaf}}$$

Sgrigna et al., to be submitted

PM total volume (V_{PMtot}) per imaged leaf area (A_{leaf}) by grain analysis & $W_{\%i}$ → PM mass per unit leaf area (M)

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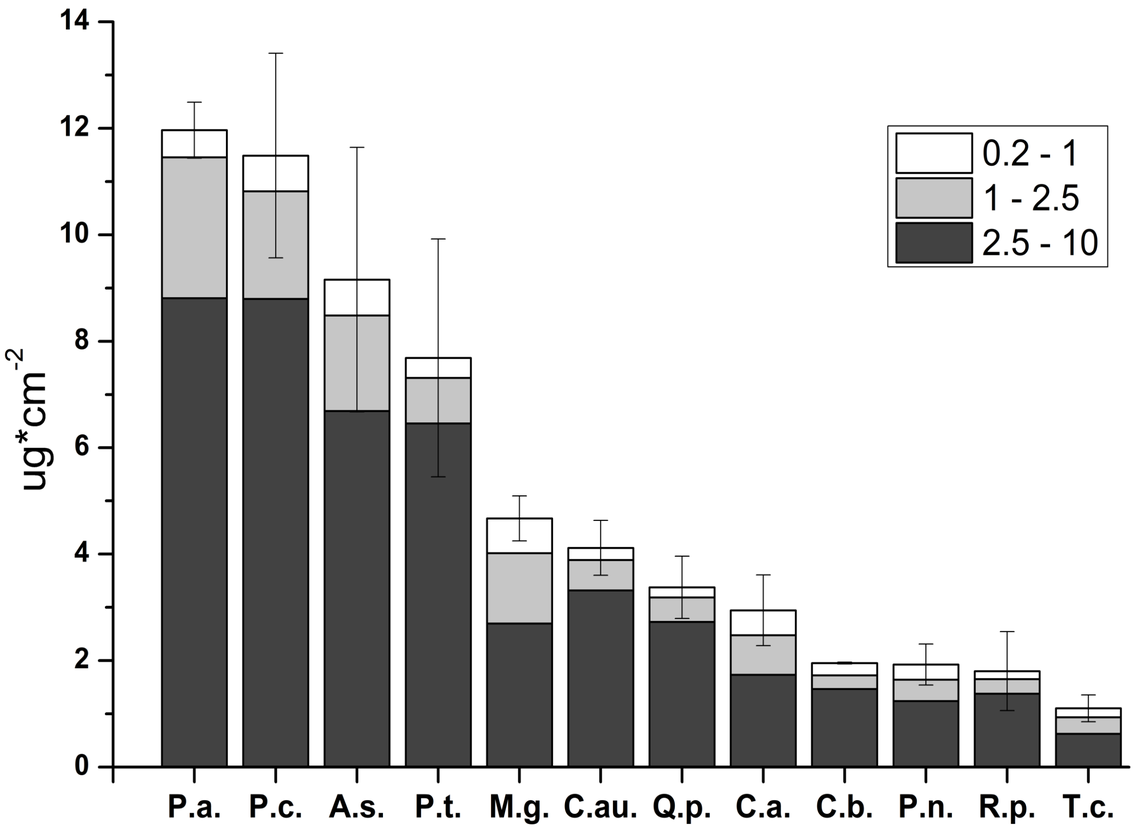
Terni case study: sensitivity to plant species

1 Urban – industrial environment
12 Tree species in a urban park



Acer saccharinum	***A.s.***
Catalpa bignonioides	***C.b.***
Cedrus atlantica	***C.a.***
Celtis australis	***C.au.***
Magnolia grandiflora	***M.g.***
Platanus acerifolia	***P.a.***
Populus nigra	***P.n.***
Populus tremula	***P.t.***
Prunus cerasifera	***P.c.***
Quercus pubescens	***Q.p.***
Robinia pseudoacacia	***R.p.***
Tilia cordata	***T.c.***

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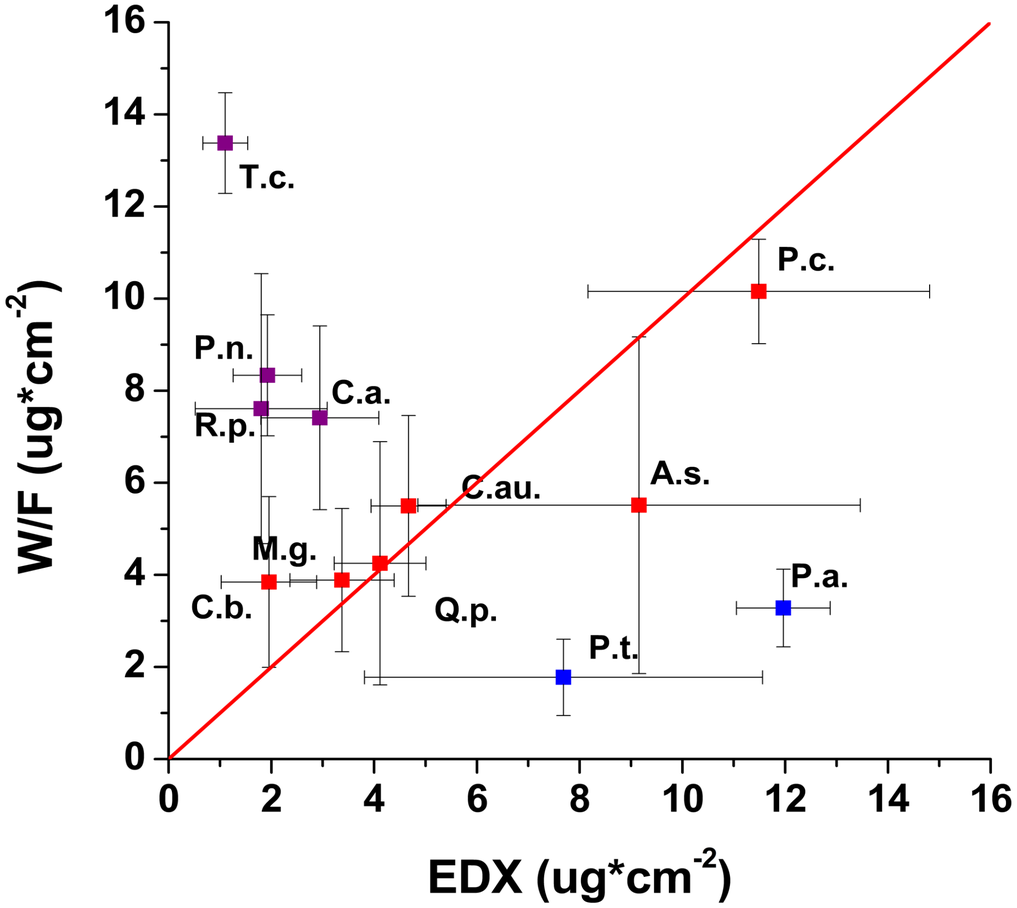
Terni case study: comparison with W/F

- Leaf deposited PM amount per unit leaf area as estimated by SEM/EDX has been compared with what obtained by Washing/Filtration (WF) technique on the same samples (Dzierzanowski et al., International Journal of Phytoremediation 13 (2011) 1037)

- The PM amount per unit leaf area as obtained by the two techniques is within the same order of magnitude

- The tree species cluster in 3 classes, as a function of the ratio between the two estimates: very good correlation (WF/EDX ≈ 1), higher WF estimation (WF/EDX > 1), higher SEM/EDX estimation (WF/EDX < 1)



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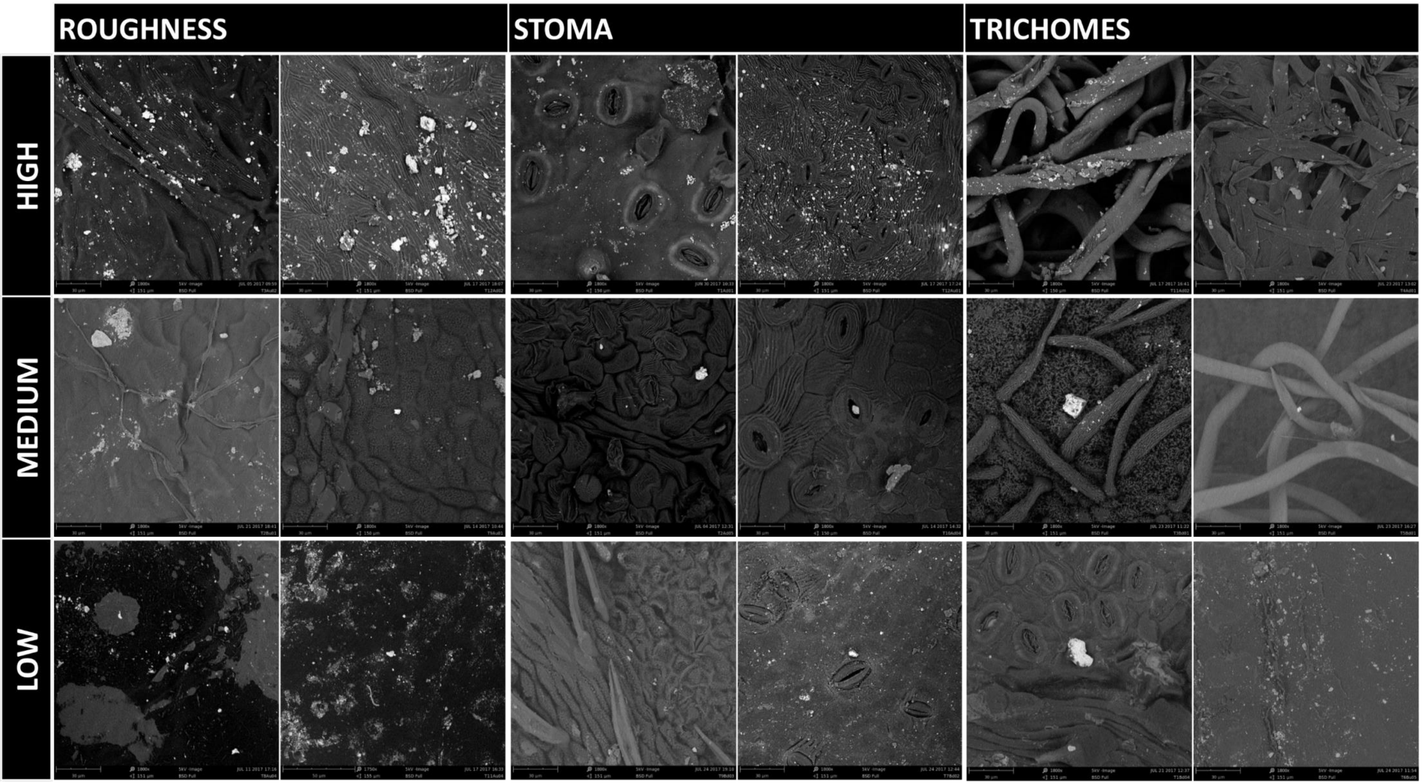
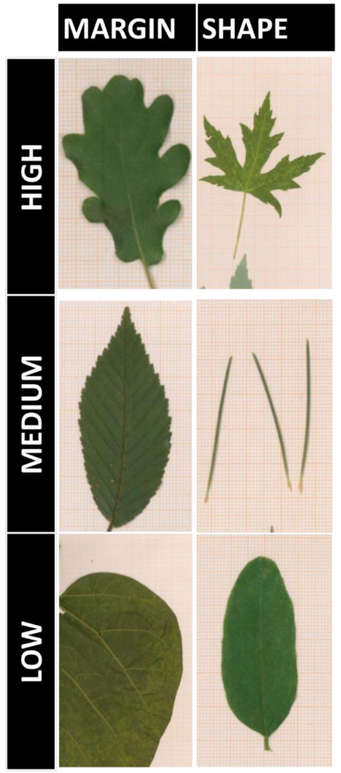
Terni case study: differences in leaf morphology

MICROMORPHOLOGY
- Roughness (Density %; Type; Dimension (um)
- Stoma (Density #*cm^{-2})
- Trichomes (Density % cover)



MACROMORPHOLOGY
- Leaf shape and margin
- Foliage (evergreen/deciduous)
- Leaf expansion (exposure time)



Leaf PM Accumulation index A_i

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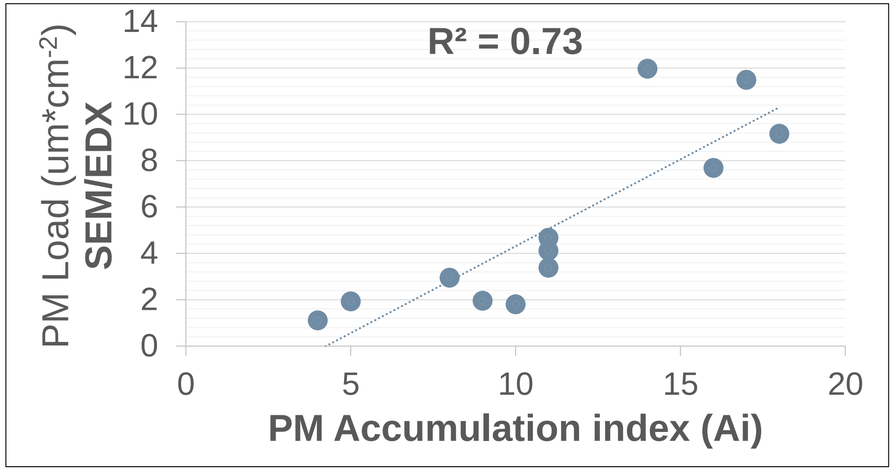
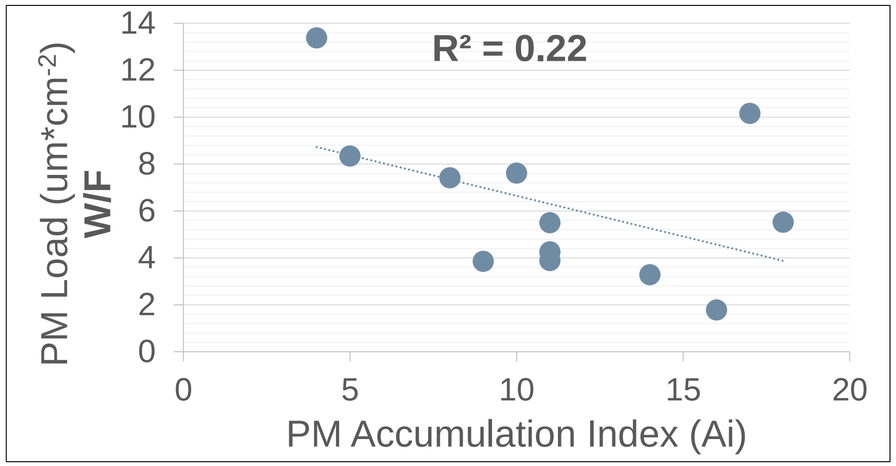
Terni case study: leaf PM Accumulation index (A_i)

	Micromorphology					Macromorphology			
Species	Rough Area	Rough Type	Grooves dim	Stom. Dens	Trich. Dens	leaf exp	leaf type	foliage	A_i
C.au.	1	3	1	3	0	2	1	0	**11**
C.b.	2	2	2	2	1	0	0	0	**9**
A.s.	2	3	2	3	1	3	4	0	**18**
P.t.	2	3	3	2	3	1	2	0	**16**
Q.p.	1	3	1	2	1	2	1	0	**11**
C.a.	0	0	0	1	0	3	1	3	**8**
P.n.	0	0	0	1	0	2	2	0	**5**
T.c.	0	0	0	1	1	1	1	0	**4**
R.p.	3	1	2	1	1	1	1	0	**10**
P.a.	2	3	2	2	0	1	4	0	**14**
M.g.	0	0	0	2	3	3	0	3	**11**
P.c.	3	3	3	3	0	3	2	0	**17**



Good correlation, according with literature



No correlation

- Overestimation due to leaf material wash out (from SEM images)
- Undestimation?

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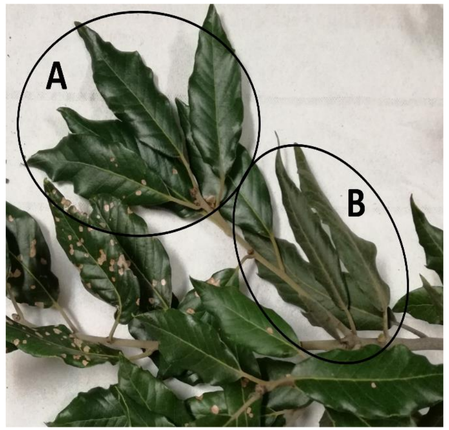
Naples case study: spatial sensitivity

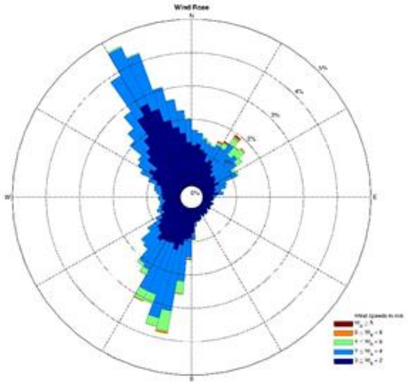
- *Quercus ilex* tree plants, same age leaf sampling

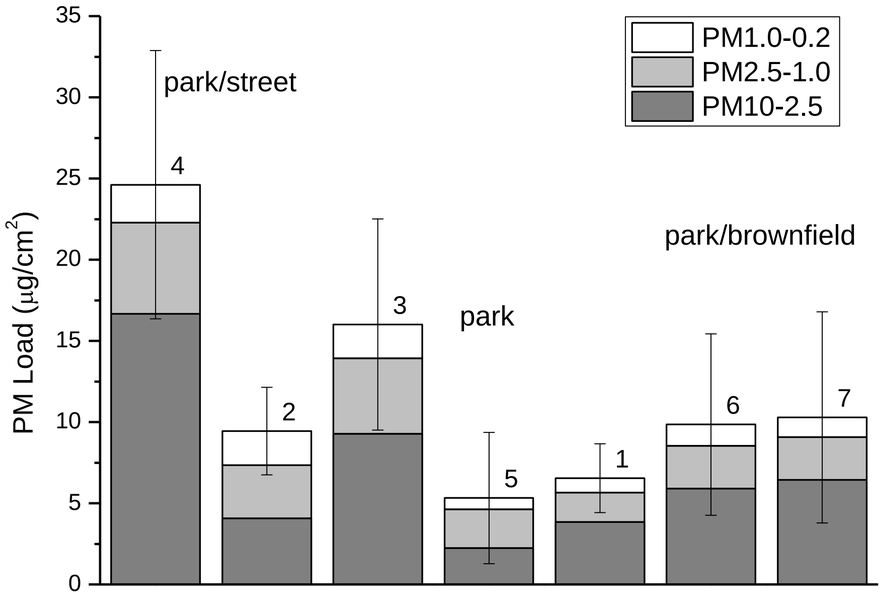
- Seven plants in different park sites (park/street border, full park, park/brownfield border), along two transects following the main wind directions

- Leaf deposited PM amount per unit leaf area as estimated by SEM/EDX is comparable with what obtained by W/F technique

→ **HIGH SPATIAL VARIABILITY IN PM10 LOAD FROM SEM/EDX**







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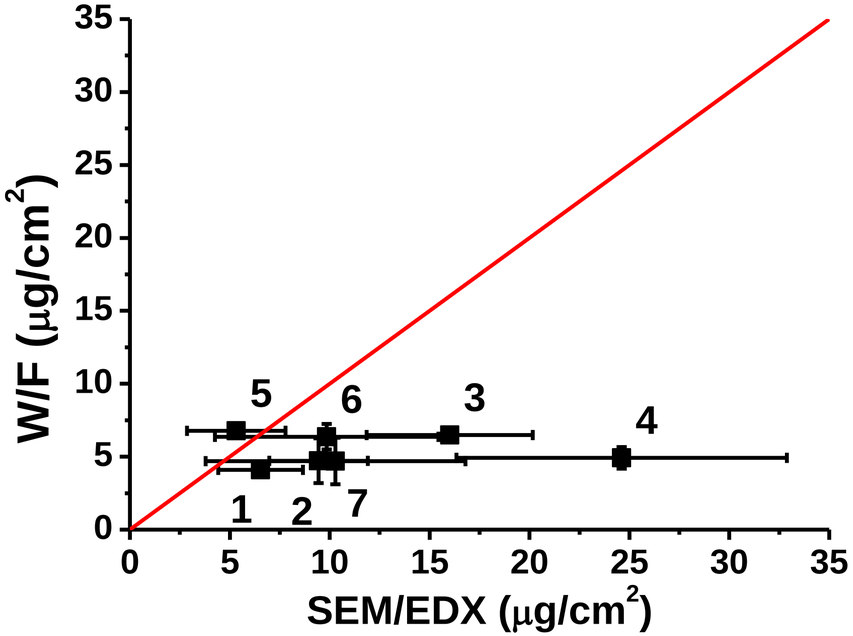
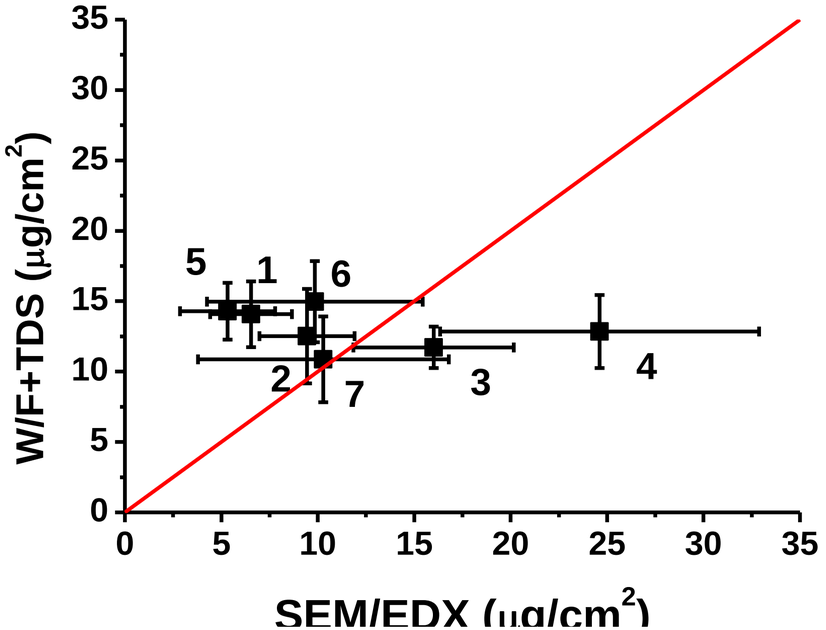
Naples case study: comparison with W/F

- PM amount is underestimated by W/F
- **Spatial variability is underestimated by W/F**



- ***Naples is a sea city***
- ***One transect (4-5-1-7) is along the sea wind direction***
- ***High salt concentration in leaf deposited PM***

- A raw estimation of the Total Dissolved Solid (TDS),via Electrical Conductance (EC) measurements of the W/F residual water, partially recovers the linear correlation
- **Soluble PM is missing in W/F**



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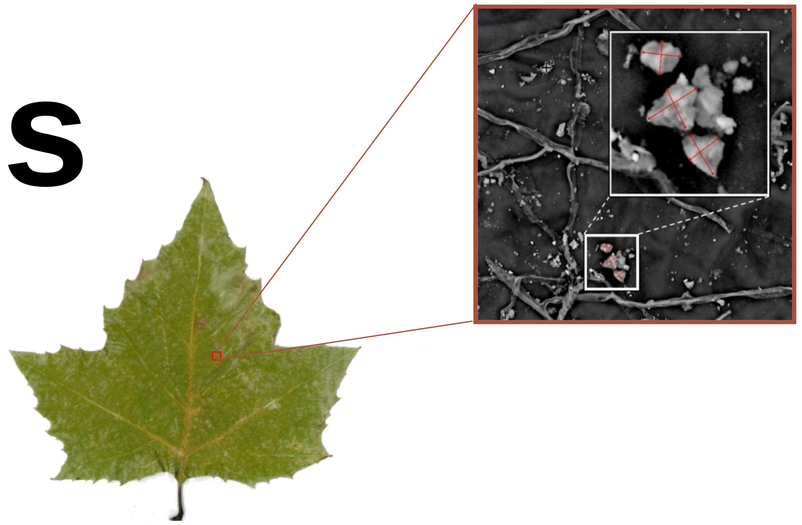
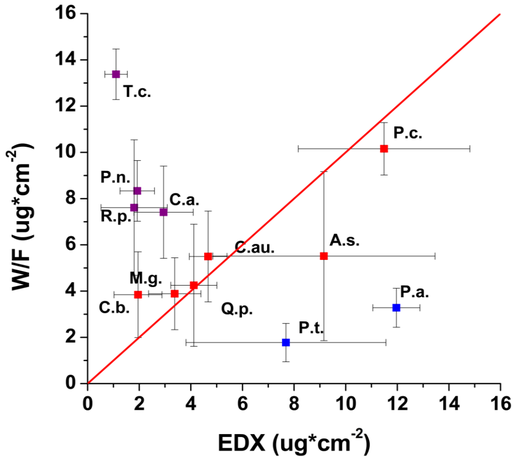
Conclusions



- Leaf deposited PM per unit leaf area can be estimated by SEM/EDX, by combining PM morphological data by SEM imaging with particle elemental composition from EDX

- The PM load estimated by SEM/EDX is more reliable than that obtained by leaf washing/filtration technique, avoiding mistakes due to leaf material washing and taking into account also the water soluble PM



- The PM load estimated by SEM/EDX is highly sensitive to the tree location, rendering trees efficient PM passive samplers in urban environment, with ultra-high spatial resolution, ***provided that the same, suitable, tree species is selected.***