Monitoring and assessing the role of vegetation on air quality and on climate change mitigation in urban areas

Carlo Calfapietra

Acting Director

CNR-IRET, Research Institute on Terrestrial Ecosystems, Porano, Montelibretti, Napoli, Firenze, Pisa, Sassari

Email: carlo.calfapietra@cnr.it
www.carlocalfapietra.com

INCREASED ATTENTION TOWARDS CO₂ REDUCTION THROUGH URBAN FORESTRY

- *2008* - The *European Commission* launched the Covenant of Mayors to oblige European cities to establish an *Action Plan* to reduce their CO_2 emissions by over 20% through activities and practices including the addition of *more plants* in urban areas and the sustainable *management* of the *green spaces*

- *2015* - Even stronger Focus on Carbon mitigation potential at urban level after COP21 in Paris

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Opinion

CellPress

Urban plant physiology: adaptation-mitigation strategies under permanent stress

Carlo Calfapietra[1,2], Josep Peñuelas[3,4], and Ülo Niinemets[5,6]
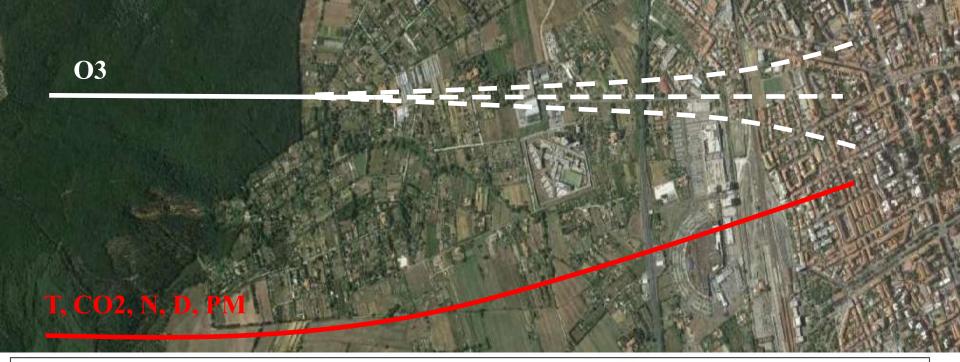
[1] Institute of Agro-Environmental and Forest Biology (IBAF), National Research Council (CNR), Viale Marconi 2, Porano (TR), Italy
[2] Czechglobe, Global Change Research Centre, Academy of Sciences of the Czech Republic, v.v.i., Bělidla 986/4a, 603 00 Brno, Czech Republic
[3] CSIC, Global ecology Unit CREAF-CSIC-UAB, Bellaterra 08193, Catalonia, Spain
[4] CREAF, Bellaterra 08193, Catalonia, Spain
[5] Estonian University of Life Sciences, Kreutzwaldi 1, 51014 Tartu, Estonia
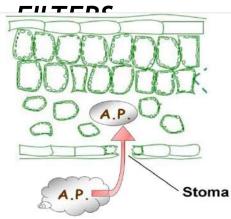[6] Estonian Academy of Sciences, Kohtu 6, 10130 Tallinn, Estonia
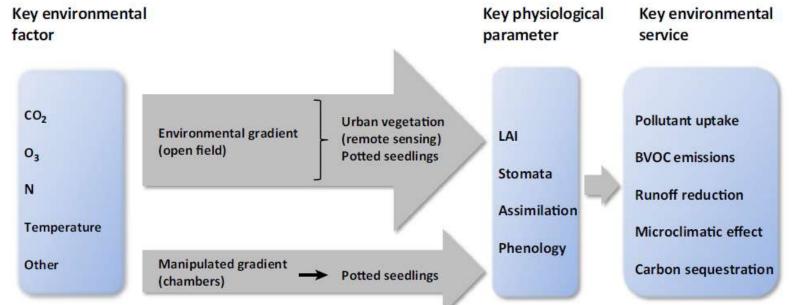
O3

T, CO2, N, D, PM

Key environmental factor			Key physiological parameter	Key environmental service

CO₂
O₃
N
Temperature
Other

Environmental gradient (open field)

Urban vegetation (remote sensing)
Potted seedlings

Manipulated gradient (chambers) → Potted seedlings

LAI
Stomata
Assimilation
Phenology

Pollutant uptake
BVOC emissions
Runoff reduction
Microclimatic effect
Carbon sequestration

TRENDS in Plant Science

Urban Trees: ACTIVE and PASSIVE natural AIR FILTERS

Atmospheric **Pollutants** *Mitigation*

- *Stomatal uptake* (NOx; SO_2; O_3; CO)
- *Capture* - dry deposition (PM)
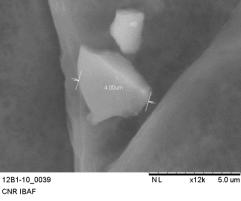
Pollutant: **Particulate Matter** (PM 10; 2.5)

- **Diffused** *Airborne particles* - an 10 μm and 2.5 μm

Highly **diffused**
Dangerous

Assessing interactions between air pollutants uptake by urban forests
(mainly O3, NOx and PM) and possible role of BVOCs

Big cuvette measurements
of leaf gas exchange

campaign using eddy
covariance technique

Application and
validation of models

Laboratory ⟶ Field

GIS+Modelling

Laboratory cuvette results
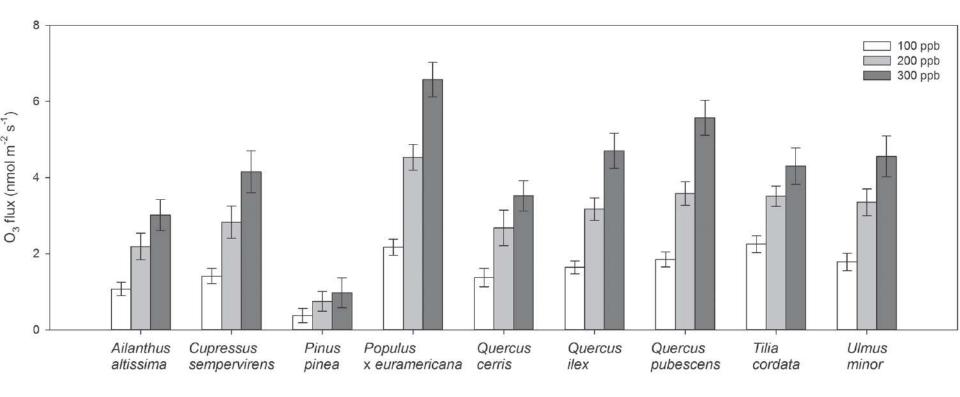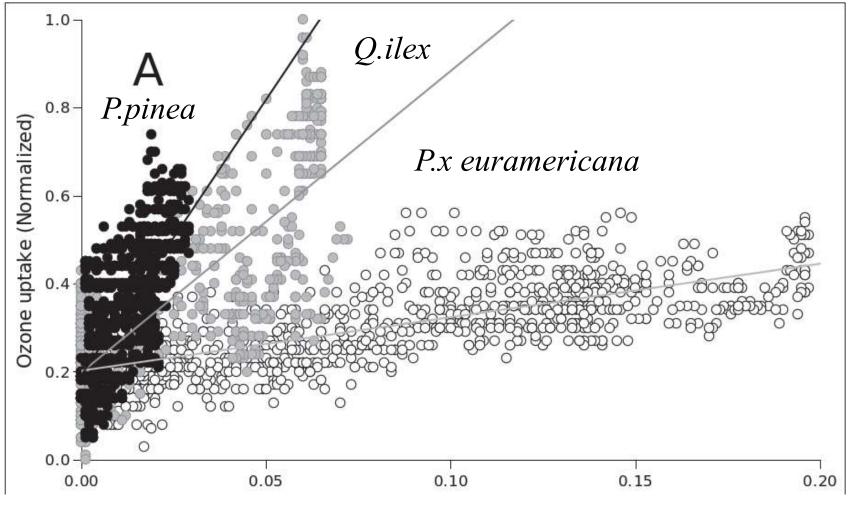
Calfapietra et al. 2016

Laboratory cuvette results
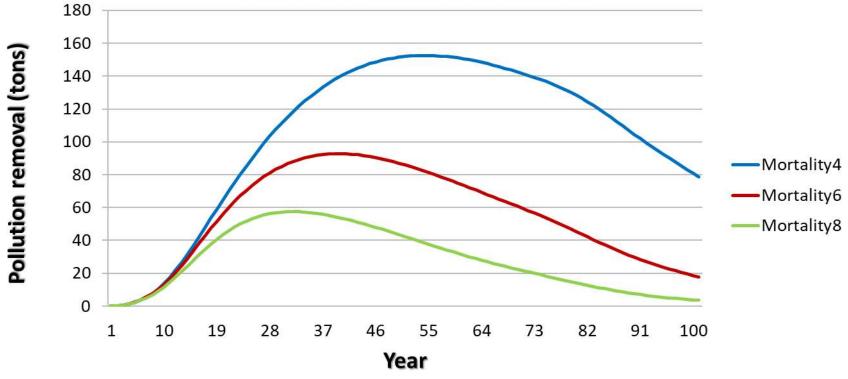
Calfapietra et al. 2016

Applying UFORE Population Projector in New York
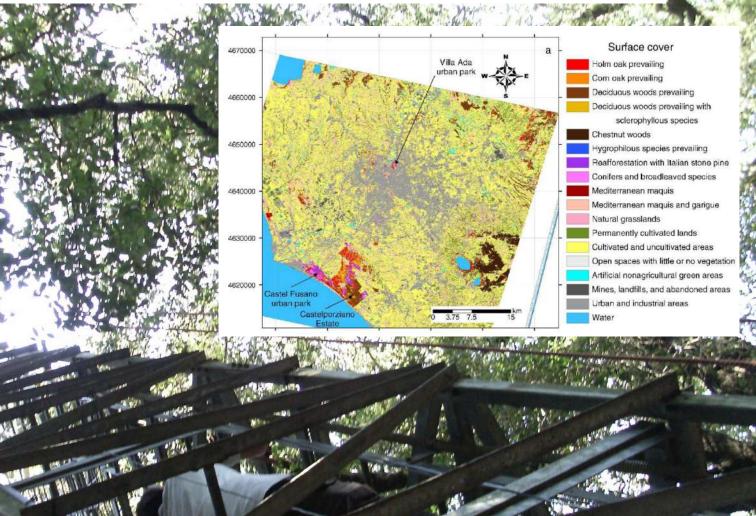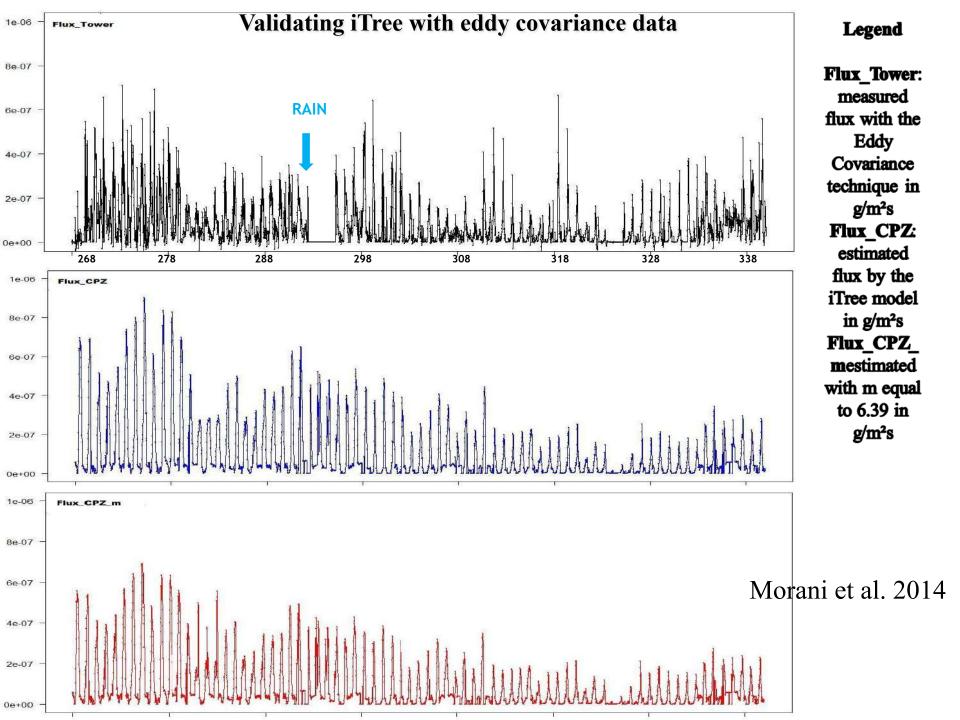
Peak values : 152.6, 92.8, 57.5 **(tons/year)**

Morani et al. 2011

Surface cover
- Holm oak prevailing
- Corn oak prevailing
- Deciduous woods prevailing
- Deciduous woods prevailing with sclerophyllous species
- Chestnut woods
- Hygrophilous species prevailing
- Reafforestation with Italian stone pine
- Conifers and broadleaved species
- Mediterranean maquis
- Mediterranean maquis and garigue
- Natural grasslands
- Permanently cultivated lands
- Cultivated and uncultivated areas
- Open spaces with little or no vegetation
- Artificial nonagricultural green areas
- Mines, landfills, and abandoned areas
- Urban and industrial areas
- Water

Validating iTree with eddy covariance data

Flux_Tower

RAIN

Flux_CPZ

Flux_CPZ_m

268 278 288 298 308 318 328 338

Morani et al. 2014

Legend

Flux_Tower: measured flux with the Eddy Covariance technique in g/m²s

Flux_CPZ: estimated flux by the iTree model in g/m²s

Flux_CPZ_m estimated with m equal to 6.39 in g/m²s

Validating iTree with eddy covariance data

Cumulative flux over the entire period

The original model (CPZ) overestimates the ozone flux measured by the tower by 18.4% while the modified model (CPZ_m) overestimates the observed ozone flux by only 0.7%.

Morani et al. 2014

PM deposition - Study Area: *the city of TERNI*

WHERE / WHY: *Terni*

- **Industrial** city: Steel/Chemical factories
- Factories into the urban environment
- Geo morphological characteristics

ThyssenKrupp

Flat plain valley surrounded by mountains

HIGH ATMOSPHERIC POLLUTANTS CONCENTRATIONS

- *EU limits for PM10: 50 µg/m³ for maximum 35 days in one year -*
- *2012: 68 overlay recorded*

BORGO RIVO

CARRARA

VERGA

LE GRAZIE

Sampling Campaigns 2012:
- 4 Environmental Control Stations
- 12 trees
- Upper and Lower Crown
- January and August 2012
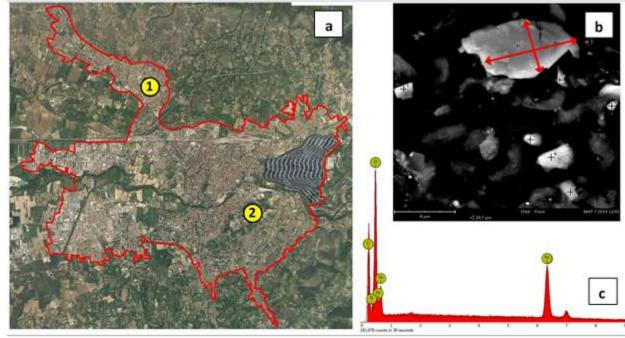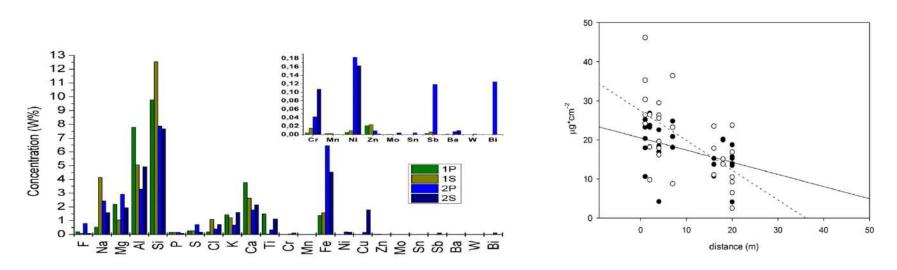
PM deposition - Study Area: *the city of TERNI*

SEM microscopy coupled with EDX

Sgrigna et al. 2015; 2016

Strong focus on air quality mitigation capacity of urban trees by media (particularly for PM)

la Repubblica.it
Il mondo in diretta
24 ore su 24

3 Nov 2016
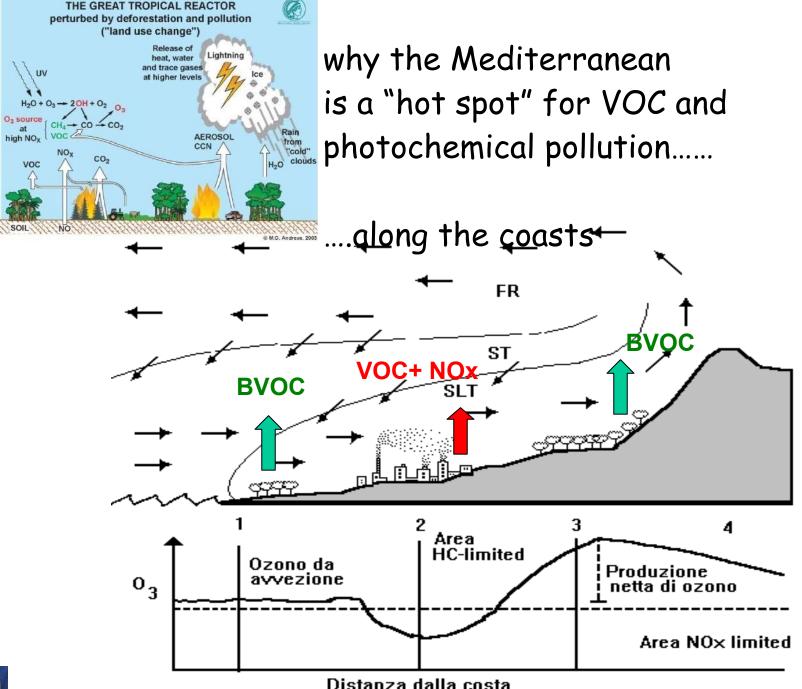
Così gli alberi
salveranno le città

5:39 / 26:00

THE GREAT TROPICAL REACTOR
perturbed by deforestation and pollution
("land use change")

why the Mediterranean is a "hot spot" for VOC and photochemical pollution……

….along the coasts
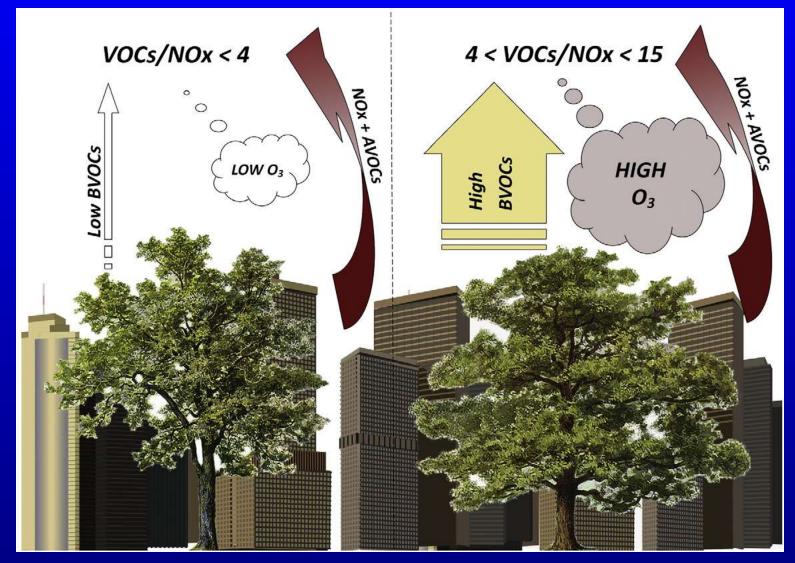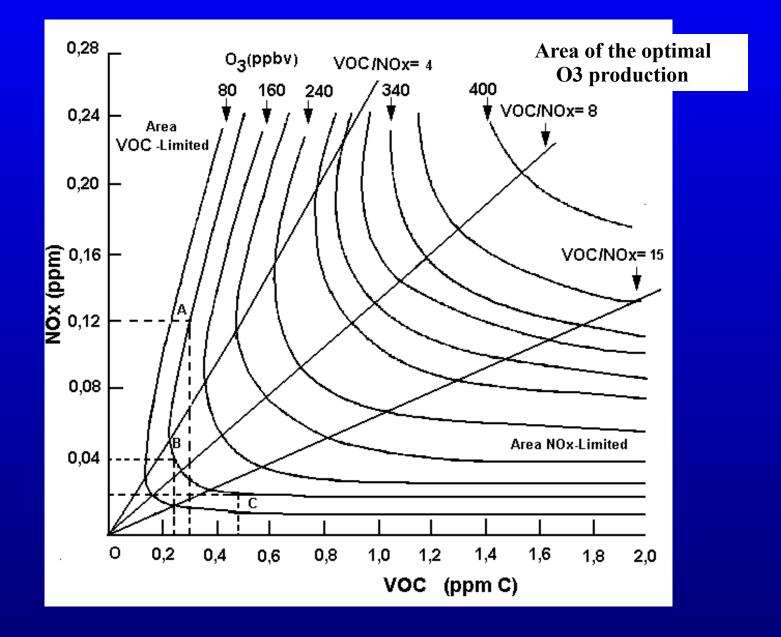
Low BVOC emitting species in urban environment are recommended

(Calfapietra et al. 2013)

Area of the optimal O3 production

High BVOC-emitters

Quercus spp.

Platanus spp

Populus spp

Salix spp.

Reeds
(Phragmites,
Arundo….)

Eucalyptus spp.

Is it higher the O_3 removal by trees or the O_3 induced by BVOC emission of those trees?
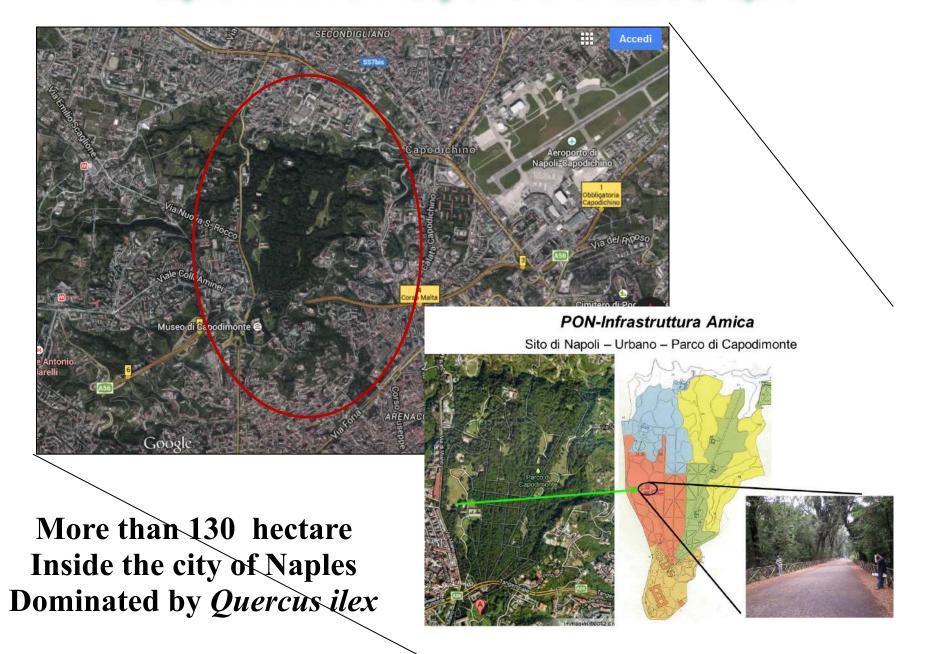
Table 3

Ozone removed and total VOC emitted in a year (g/tree) in two UFORE case studies in Italy: Milan (Porta Venezia gardens; Siena and Buffoni, 2007) and a tramway under construction in Florence (Line 1 and 3; Paoletti, unpublished).

Milan			Florence		
Species	O_3 removal	VOC emission	Species	O_3 removal	VOC emission
Acer platanoides	45	86	Acacia dealbata	603	1103
Aesculus hippocastanum	71	135	Acer campestre	26	354
Ilex aquifolium	26	135	Acer negundo	137	442
Magnolia sp.	60	179	Aesculus hippocastanum	257	372
Taxus baccata	70	143	Ailanthus altissima	174	320
Tilia sp.	84	83	Catalpa bignonioides	43	407
Quercus robur	45	345	Cedrus atlantica	924	213
			Cedrus deodara	644	173
			Celtis australis	230	348
			Cercis siliquastrum	0	62
			Chamaecyparis lawsoniana	52	42
			Crataegus sp.	44	279
			Cupressus sempervirens	260	313
			Fraxinus sp.	280	224
			Laurus nobilis	296	249
			Ligustrum lucidum	54	435
			Liquidambar styraciflua	13	688
			Magnolia sp.	85	318
			Olea europaea	35	200
			Paulownia tomentosa	125	853
			Pinus pinea	179	385
			Platanus acerifolia	140	276
			Populus alba	193	467
			Populus nigra	353	327
			Prunus armeniaca	14	698
			Prunus cerasifera	52	311
			Quercus ilex	112	341
			Quercus rubra	65	312
			Robinia pseudacacia	30	320
			Tilia cordata	193	332
			Ulmus sp.	216	307

Paoletti et al. 2009

**More than 130 hectare
Inside the city of Naples
Dominated by *Quercus ilex***

PON-Infrastruttura Amica

Sito di Napoli – Urbano – Parco di Capodimonte

EDDY COVARIANCE TOWER

- **CO_2 / H_2O**   Li-COR LI-7200

- **Methane**   Li-COR LI-7700

- **Particulate matter**   FAI OPC Multichannel Monitor

- **NO_x**   Ecophysics CLD 88 Yp NO_x analyzer

- **N_2O** N_2O analyzer Thermo 46i

- **Ozone**   Dasibi 1108 slow analyzer

                    Sextant fast ozone analyzer

- **PTR-TOF-MS 8000**   Acetaldehyde, benzene, toluene, monoterpen

    isoprene, methanol, many others
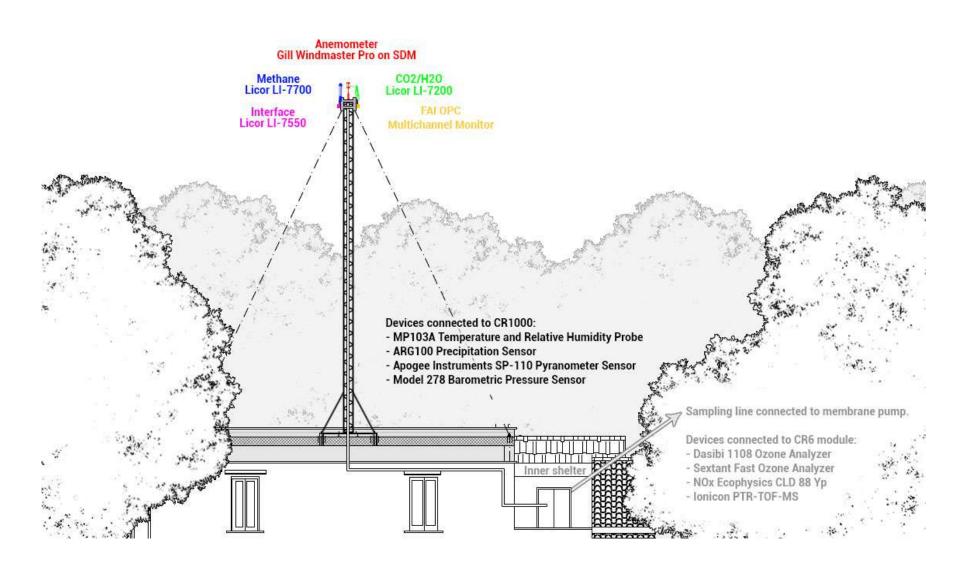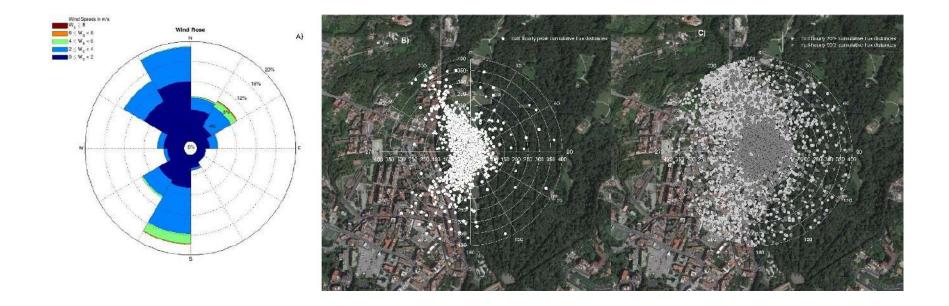
- **Gill Windmaster Pro Anemometer**
  - ARG100 Precipitation Sensor
  - Apogee Instruments SP-110 Pyranometer Sensor
  - Model 278 Barometric Pressure Sensor
  - MP103A Temperature and Relative humidity Probe

1M € TOTAL INVESTMENT
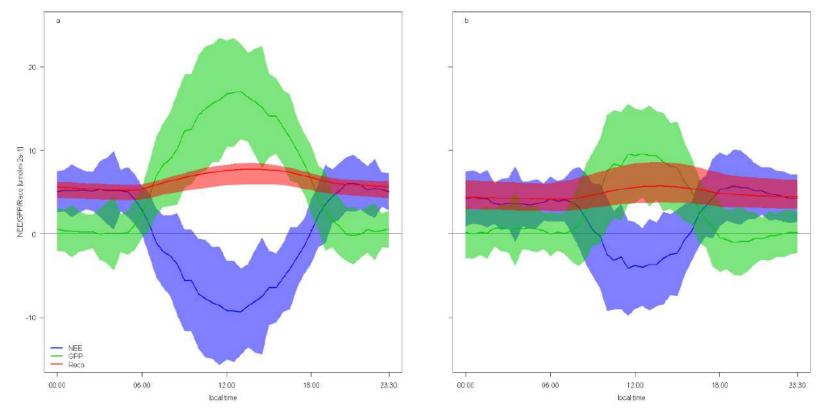
MAIN INFO on INSTRUMENTATION

Analyzer	Datalogger	Signal	Freq
Anemometer Gill Windmaster Pro on SDM	CR6	SDM Digital	10 Hz
"	LI7550		10 Hz
CO_2/H_2O LI-7200	LI7550		10 Hz
Methane LI-7700	LI7550		10 Hz
FAI OPC MULTICHANNEL MONITOR	Hard Disk	Digital	4 Hz
Dasibi 1108 Ozone Analyzer	CR6	Analog	0.5 Hz
Sextant Fast Ozone Analyzer	CR6	Analog	10 Hz
N_2O analyzer Thermo 46i	CR6		1 Hz
NO_x Ecophysics CLD 88 Yp	CR6	Analog	1 Hz
→		Serial	8 Hz
PTR-TOF-MS	Hard Disk	Digital	10 Hz
ARG100 Precipitation Sensor	CR1000	Analog	30 min. avg.
Apogee Instruments SP-110 Pyranometer Sensor	CR1000	Analog	30 min. avg.
Model 278 Barometric Pressure Sensor	CR1000	Analog	30 min. avg.
MP103A Temperature and Relative Humidity			30 min.

Anemometer
Gill Windmaster Pro on SDM

Methane
Licor LI-7700

CO2/H2O
Licor LI-7200

Interface
Licor LI-7550

FAI OPC
Multichannel Monitor

Devices connected to CR1000:
- MP103A Temperature and Relative Humidity Probe
- ARG100 Precipitation Sensor
- Apogee Instruments SP-110 Pyranometer Sensor
- Model 278 Barometric Pressure Sensor

Sampling line connected to membrane pump.

Devices connected to CR6 module:
- Dasibi 1108 Ozone Analyzer
- Sextant Fast Ozone Analyzer
- NOx Ecophysics CLD 88 Yp
- Ionicon PTR-TOF-MS

Inner shelter

Wind distribution for the period March 2015 – April 2016 (panel a). Half hourly cumulative fluxes distances representing the peak (white circles) (panel b), 70% (dark grey circles) and 90% (light grey circles) (panel c) for the period March 2015 – April 2016. Cumulative fluxes distances were calculated using the footprint model of Kljun et al. (2004).

Guidolotti et al. 2017
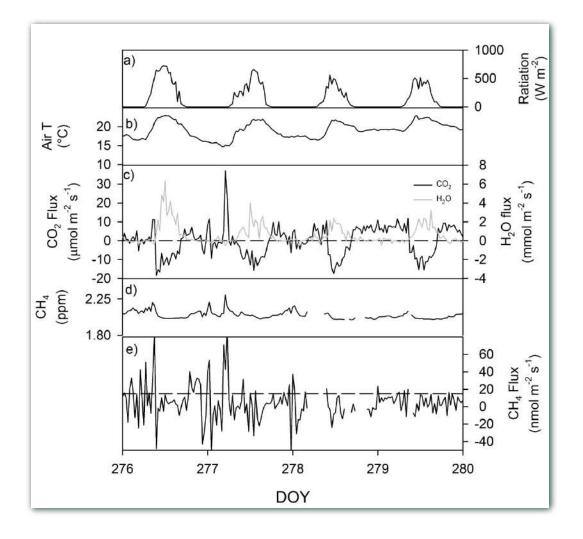
Diurnal patterns of NEE (blue), GPP (green) and RECO (red) for the summer period (panel a, April-September) and the winter period (panel b, October-March). The solid lines and shaded bands represent the average and standard deviation of the half-hour flux, respectively.

Guidolotti et al. 2017
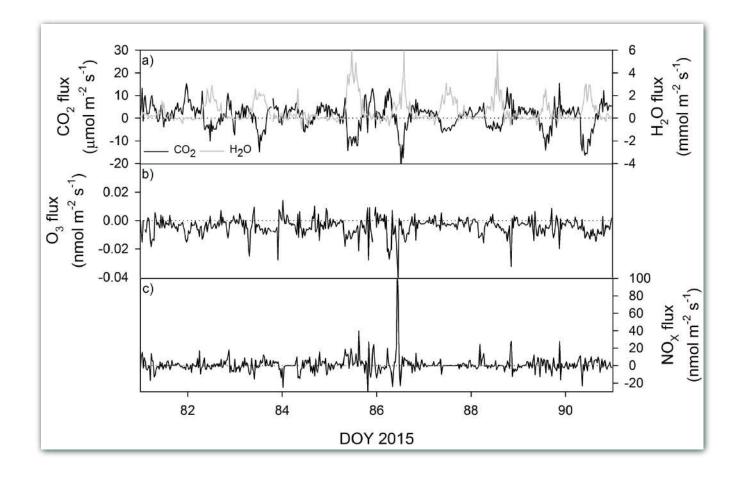
Concentrations and fluxes at the end of March 2015

Guidolotti et al. 2017

GHG concentrations and fluxes at the end of the summer 2015

Guidolotti et al. 2017

Fluxes at the end of the summer 2015
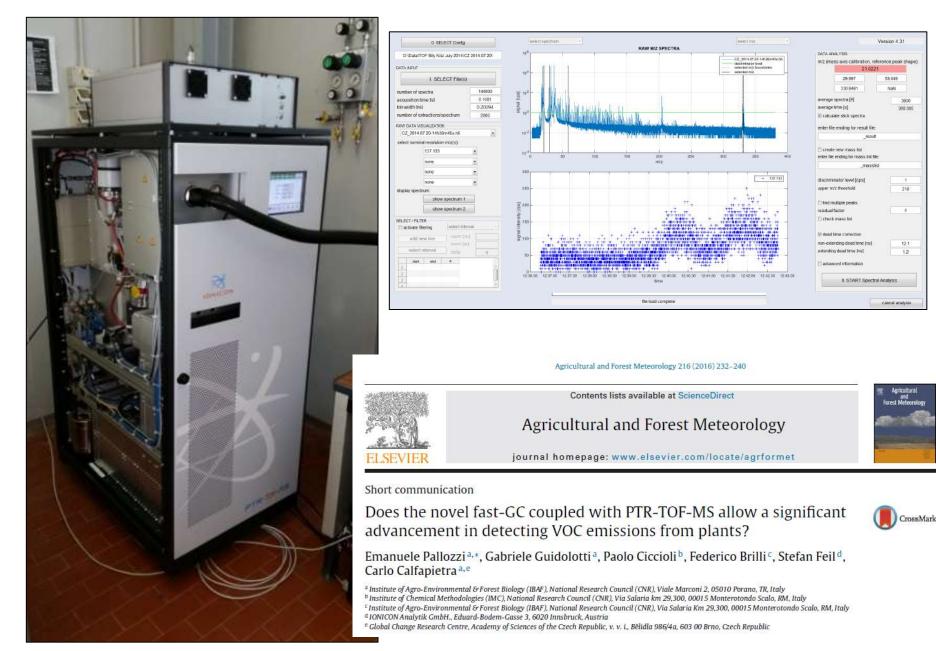
Guidolotti et al. 2017

PTR-TOF Mass Spectrometer coupled with Fast-GC

Short communication

Does the novel fast-GC coupled with PTR-TOF-MS allow a significant advancement in detecting VOC emissions from plants?

CrossMark

Emanuele Pallozzi[a,*], Gabriele Guidolotti[a], Paolo Ciccioli[b], Federico Brilli[c], Stefan Feil[d], Carlo Calfapietra[a,e]

[a] Institute of Agro-Environmental & Forest Biology (IBAF), National Research Council (CNR), Viale Marconi 2, 05010 Porano, TR, Italy
[b] Institute of Chemical Methodologies (IMC), National Research Council (CNR), Via Salaria km 29,300, 00015 Monterotondo Scalo, RM, Italy
[c] Institute of Agro-Environmental & Forest Biology (IBAF), National Research Council (CNR), Via Salaria Km 29,300, 00015 Monterotondo Scalo, RM, Italy
[d] IONICON Analytik GmbH., Eduard-Bodem-Gasse 3, 6020 Innsbruck, Austria
[e] Global Change Research Centre, Academy of Sciences of the Czech Republic, v. v. i., Bělidla 986/4a, 603 00 Brno, Czech Republic

Need of establishing a net of such innovative urban park sites because of:

•Interest in accounting C sink capacity of urban forests to be accounted in carbon credits strategy

•Interest in understanding interactions between anthropogenic and biogenic compounds in urban environments

•Interest in understanding pollutant mitigation potential by urban forests

ICOS Italia

STATION		TYPE	CLASS	PI
Castelporziano2		ECO	Class 1	Silvano Fares
Borgo Cioffi		ECO	Class 1	Enzo Magliulo
Renon		ECO	Class 2	Leonardo Montagnani
Pramaggiore	ECO	Class 2	Andrea Pitacco	
Monte Bondone	ECO	Class 2	Damiano Giannelle	
Capodimonte	ECO	Associated	Carlo Calfapietra	
Arca di Noè		ECO	Associated	Donatella Spano
Bosco Fontana	ECO	Associated	Giacomo Gerosa	
Torgnon		ECO	Associated	Edoardo Cremonese
Collelongo		ECO	Associated	Giorgio Matteucci
Bonis		ECO	Associated	Giorgio Matteucci
Beano		ECO	Associated	Alessandro Peressotti
Monte Cimone	ATM	Class 1	Paolo Cristofanelli	
Lampedusa		ATM	Class 1	Giorgio di Sarra
Plateau Rosa	ATM	Class 2	Francesco Apadula	
Potenza		ATM	Class 1	Lucia Mona
Lamezia terme	ATM	Associated	Claudia Calidonna	
Lecce		ATM	Associated	Daniele Contini
Monte Curcio	ATM	Associated	Francesca Sprovieri	
Capo Granitola	ATM	Associated	Angela Marinoni	
Ny Alesund		ATM	Associated	Vito Vitale
Miramare		OCE	Class	Michele Giani
Paloma		OCE	Class	Anna Luchetta
E2M3A		OCE	Class	Vanessa Cardin
W1M3A		OCE	Class	Roberto Bozzano
Lampedusa		OCE	Associated	da definire

More sites hopefully implemented with the 14M€ project PROICOS_MED

COST FP1204 GreenInUrbs

www.greeninurbs.com

...tructure approach: linking environmental with social aspects in studying and managing urban forests (GreenInUrbs) 2013-2017
Chair: Carlo Calfapietra

countries involved

35 COST countries
4 Neighbour countries
2 non-COST countries
FAO
About 200 people involved so far

European Commission Environment Nature & Biodiversity

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NATURE & BIODIVERSITY

- EU Biodiversity Policy
- EU Nature Legislation
- Natura 2000 Network
- Species protection
- Green Infrastructure
- Invasive Alien Species
- Climate Change
- Partnerships
- Knowledge Base
- Information

NATURE & BIODIVERSITY

- EU Biodiversity Policy ▸
- EU Nature Legislation ▸
- Natura 2000 Network ▸
- Species protection ▸
- Green Infrastructure
- Invasive Alien Species

Illustrations of the Green Infrastructure concept

What is Green Infrastructure?
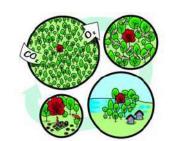
Green bridges and eco-ducts re-connect natural areas that have been artificially divided, by roads or railway lines for example. They reduce accidents involving wild animals and cars – which in France alone, for example, caused damages of about 150 mio. EUR in total. Green bridges also allow animals to move easily and safely from one area to another, and help plant species to spread. This gives animals more space to find food and shelter, and allows populations of the same species to interact, improving the overall resilience of the species.
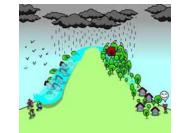
Developments have to be made in a way that does not destroy the future potential of a site. With the right kind of planning, different needs can be taken into account, and the right balance can be kept. Investments can be made in every kind of environment – even in densely populated urban areas – in a way that is beneficial for people and the economy, while still leaving room for nature.

On 19 November 2010, the European Commission organized a conference called Green Infrastructure Implementation.

"Green Infrastructure serves the interests of both people and nature. **It can be defined as a strategically planned network of high quality green spaces and other environmental features**. ....Green Infrastructure includes natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas."

On 6 May 2013
The Commission has adopted a Green Infrastructure Strategy, 'to promote the deployment of green infrastructure in the EU in urban and rural areas'.

GreenInUrbs structure and responsible people

- **Chair**: Carlo Calfapietra, IT; **Vice-Chair**: David Pearlmutter, IL

- **WG1** Environmental services of GI and UF and implications of climate change (R. Samson, B)

- **WG2** Social/cultural services of GI and UF (Liz O' Brien, UK)

- **WG3** Governance of UF in a GI approach (S. Krajter Ostoic, HR)

- **WG4** Task Force on Integration and Dissemination to stakeholders (G. Sanesi, IT)

- **STSM Coordinator**: Rocio Alonso, ES (funded more than 40 STSMs so far)

Workshops

Functional traits of urban trees: air pollution mitigation potential

543
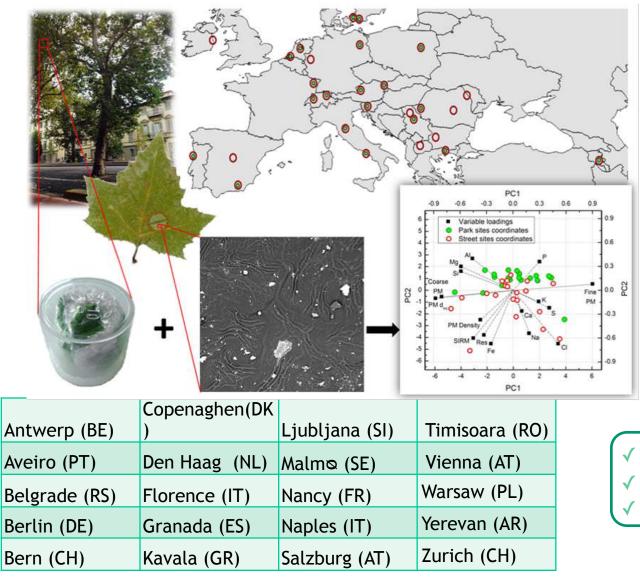
Rüdiger Grote[1*], Roeland Samson[2], Rocío Alonso[3], Jorge Humberto Amorim[4], Paloma Cariñanos[5], Galina Churkina[6], Silvano Fares[7], Didier Le Thiec[8], Ülo Niinemets[9], Teis Norgaard Mikkelsen[10], Elena Paoletti[11], Abhishek Tiwary[12], and Carlo Calfapietra[13,14]

In an increasingly urbanized world, air pollution mitigation is considered one of most important issues in city planning. Urban trees help to improve air quality by facilitating widespread deposition of various gases and particles through the provision of large surface areas as well as through their influence on microclimate and air turbulence. However, many of these trees produce wind-dispersed pollen (a known allergen) and emit a range of gaseous substances that take part in photochemical reactions – all of which can negatively affect air quality. The degree to which these air-quality impacts are manifested depends on species-specific tree properties: that is, their "traits". We summarize and discuss the current knowledge on how such traits affect urban air pollution. We also present aggregated traits of some of the most common tree species in Europe, which can be used as a decision-support tool for city planning and for improving urban air-quality models.

Participation to the sampling campaign on PM deposition on plane trees across Europe

SIRM (Saturation isothermal remanent magnetization)+ SEM-EDX analysis

Antwerp (BE)	Copenaghen (DK)	Ljubljana (SI)	Timisoara (RO)
Aveiro (PT)	Den Haag (NL)	Malmø (SE)	Vienna (AT)
Belgrade (RS)	Florence (IT)	Nancy (FR)	Warsaw (PL)
Berlin (DE)	Granada (ES)	Naples (IT)	Yerevan (AR)
Bern (CH)	Kavala (GR)	Salzburg (AT)	Zurich (CH)
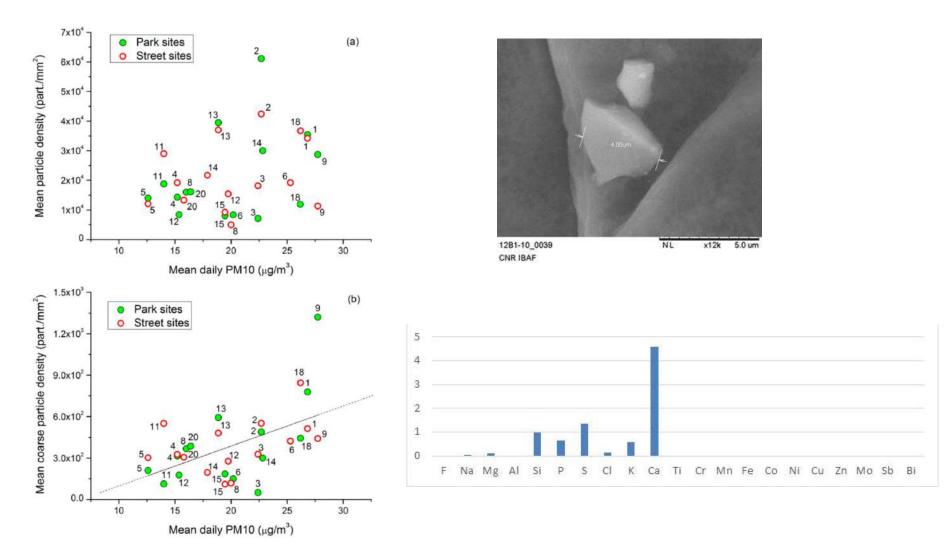
✓   17 Countries
✓   20 Cities
✓   25/08/14 – 15/09/14

Baldacchini et al, 2017, Environmental Science & Technology

SEM-EDX analyses

Baldacchini et al, 2017, Environmental Science & Technology

JEQ

JOURNAL OF
ENVIRONMENTAL QUALITY

JEVQAA 45(1)1–375(2016)

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skyp

The Urban Forest and Ecosystem Services – Tree, Street and City Scale

Guest editors:
Dr Stephen Livesley (The University of Melbourne, AUS)
sjlive@unimelb.edu.au
Dr Carlo Calfapietra (National Research Council, ITA)
carlo.calfapietra@ibaf.cnr.it
Dr Greg McPherson (USDA Forest Service, USA)
egmcpherson@ucdavis.edu

» Earth Sciences & Geography

Future City

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The Urban Forest

Cultivating Green Infrastructure for People and the Environment

Editors: **Pearlmutter**, D., **Calfapietra**, C., **Samson**, R., **O'Brien**, L., **Krajter Ostoić**, S., **Sanesi**, G., **Alonso del Amo**, R. (Eds.)

Provides the first comprehensive catalog of tree species that is cross-correlated with the ecosystem services they provide in different regions of Europe

» see more benefits

Guideline
for practitioners and policy makers

SPECIFIND: Choose the Best TREE SPECIES for Your City

Specifind

Fill in the form specifying your interests and start searching for arboreal plants from which you can get more benefits.

Login

Search Species

Tree Hight

☐ Height at Maturity   Min | Max | m

Locality

Nation   select

Locality   select

Benefits *

☐ Pollutant Removal   ⦿ Overall ○ Specific

   Overall Rate   0 (select)

☐ Low VOC Emissions   0 (select)

   Low Allergenicity   0 (select)

☐ Carbon Storage   0 (select)

☐ Air Temperature Reduction   0 (select)

☐ Select All

↑___ Show in Report

Report

Estimate Values per Area Unit   ☐

Generate Report per   ⦿ Specie ○ Genus

Show   All

In the report you will get a list of the most used tree species for urban greenery, arranged according to a score (rank) expressing the degree of compliance with chased requirements.

Climatic and site requirements are measured (if you specify the location), the correspondence to the possible required height and the value of the potential environmental benefits of species, weighted according to the specified scale of importance from 0 to 10 (*) .

In the report there are reported indicative benefit estimates for single adult plant (or m²), too, if required to display them.

Generate Report **Reset**

European Commission

Towards an
EU Research and Innovation policy agenda for

Nature-Based Solutions & Re-Naturing Cities

*Final Report of the Horizon 2020
Expert Group on 'Nature-Based Solutions
and Re-Naturing Cities'
(full version)*

Research and Innovation

"Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience.

Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions"

Source: EU Research and Innovation policy agenda on Nature-Based Solutions

European
Commission

European Commission leader in NBS and environmental protection

What is NBS?

What is NBS?

green infrastructure toolkit

GEORGETOWN CLIMATE CENTER
A Leading Resource for State and Federal Policy

NBS IMPLEMENTATION PROCESS

- Multistakeholders

- Co-design; Co-implementation; Co-management

- Multipurpose

- Cost-effective

- Locally-adapted

- Easily upscaled spatially and temporally

- Effectiveness assessment

We are now able to quantify ES e DES provided by UF and NBS and this should emerge in all plans and projects

An impact evaluation framework to support planning and evaluation of nature-based solutions projects

An EKLIPSE Expert Working Group report

Horizon 2020
European Union Funding
For Research & Innovation
Grant agreement 690474

ProGIReg
«Productive Green Infrastructure for post-industrial urban regeneration»

2018-2023
11M€

Ministero dell'Istruzione dell'Università e della Ricerca

Dipartimento per la formazione superiore e per la Ricerca

Direzione Generale per il Coordinamento, la promozione e la valorizzazione della Ricerca

PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2017
Prot. 20173RRN2S

PART A

1. Action line

Main line/Linea Principale

2. Research project title

Establishing Urban FORest based solutions In Changing Cities (EUFORICC)

CNR-IRET: Coordinator
Unimolise
UniBari
UniTuscia
UniFirenze
UniRoma3

Calfapietra Lab

carlo.calfapietra@cnr.it
www.carlocalfapietra.com

Chiara Baldacchini, Researcher
Giovanni de Simoni, Technician
Sara Di Giovanni, master student
Raffaela Esposito, phD
Olga Gavrichkova, Researcher
Gabriele Guidolotti, Researcher
Ilaria Lusini, postdoc
Michele Mattioni, engineer
Mauro Medori, phD
Enrica Nestola, phD
Emanuele Pallozzi, Technologist
Gaspare Perconti, master student
Federica Revoltella, phD
Andrea Scartazza, Researcher
Gregorio Sgrigna, postdoc
Claudia Tarmati, master student