1ST INTERNATIONAL WORKSHOP
"PLANT PHYSIOLOGY IN THE URBAN ENVIRONMENT"

Pisa, 23 June 2014
Department of Food, Agriculture and Environment
The University of Pisa

TreeCity
*An International Project for a Better Quality of Life in Our Cities*
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SAPIENZA UNIVERSITÀ DI ROMA

# Ecosystem Services of urban trees: The case of Rome

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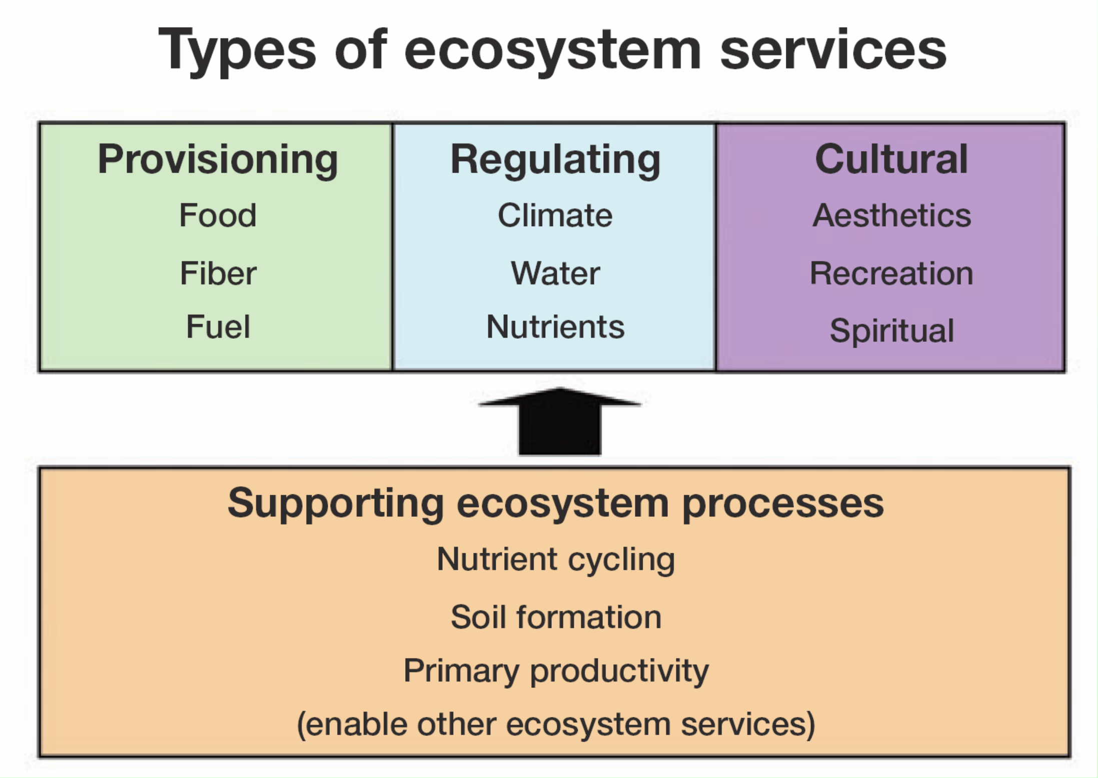
# ECOSYSTEM SERVICES

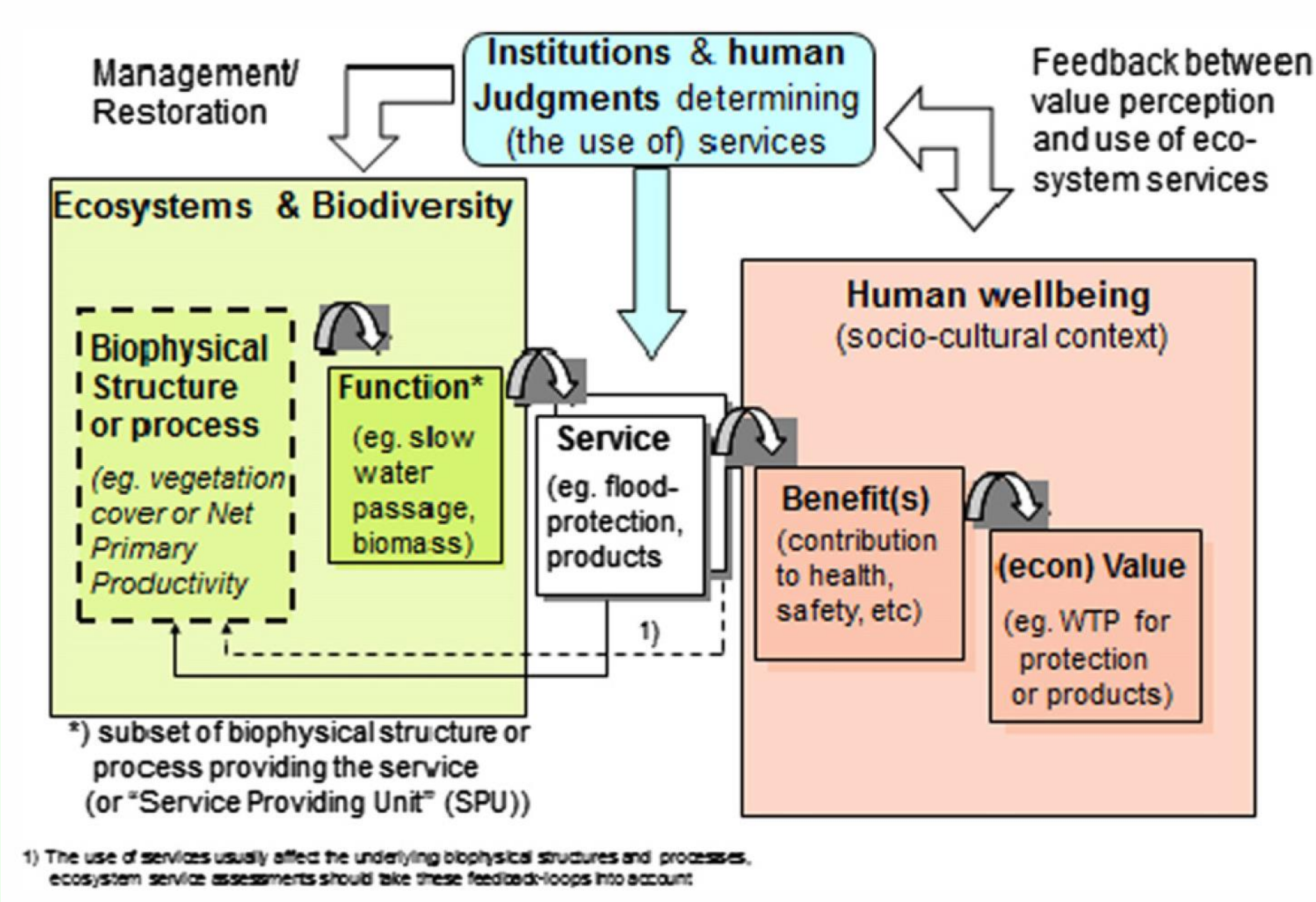
“The conditions and processes through which natural ecosystems, urban green, and the species that make them up, sustain and fulfil human life” (Daily, 1997)

“The benefits people obtain from ecosystems” (Millennium Ecosystem Assessment, 2005)



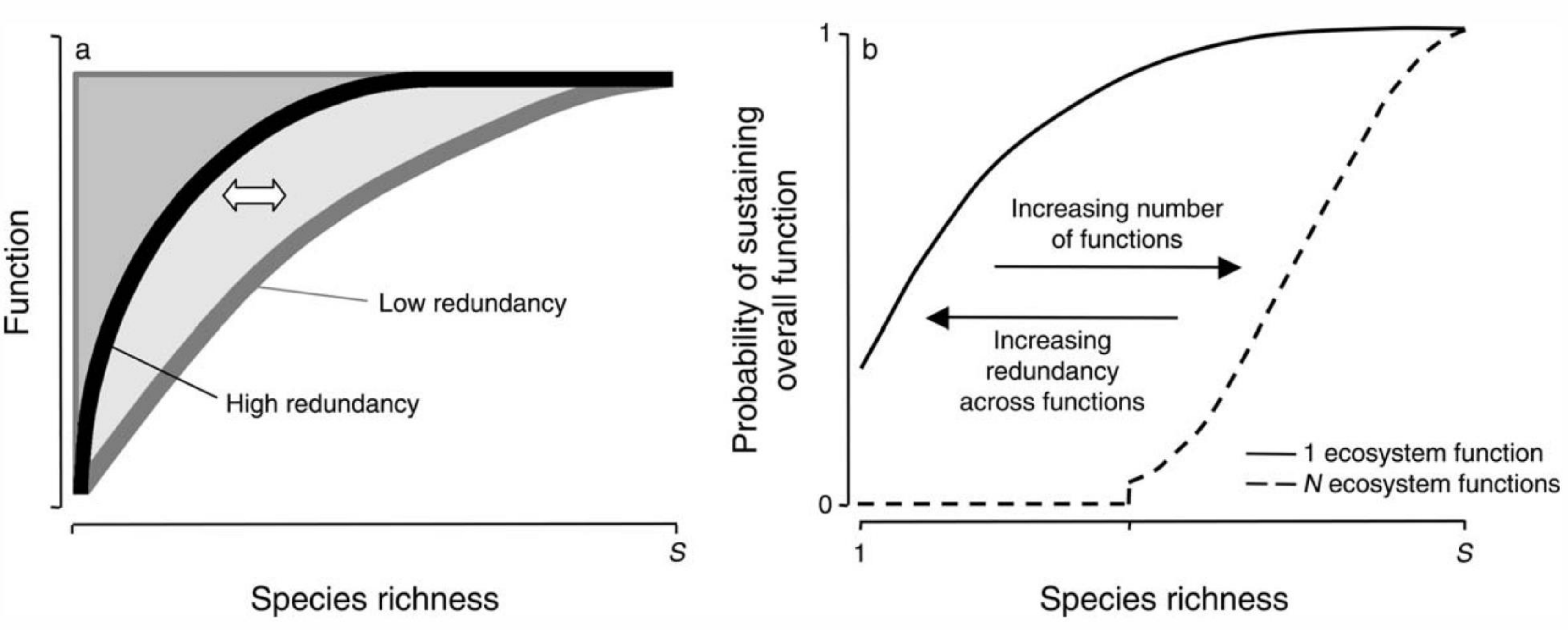

Ecosystem-services framework based on the Millennium Ecosystem Assessment
(From Pataki et al., 2011)

# ECOSYSTEM SERVICES



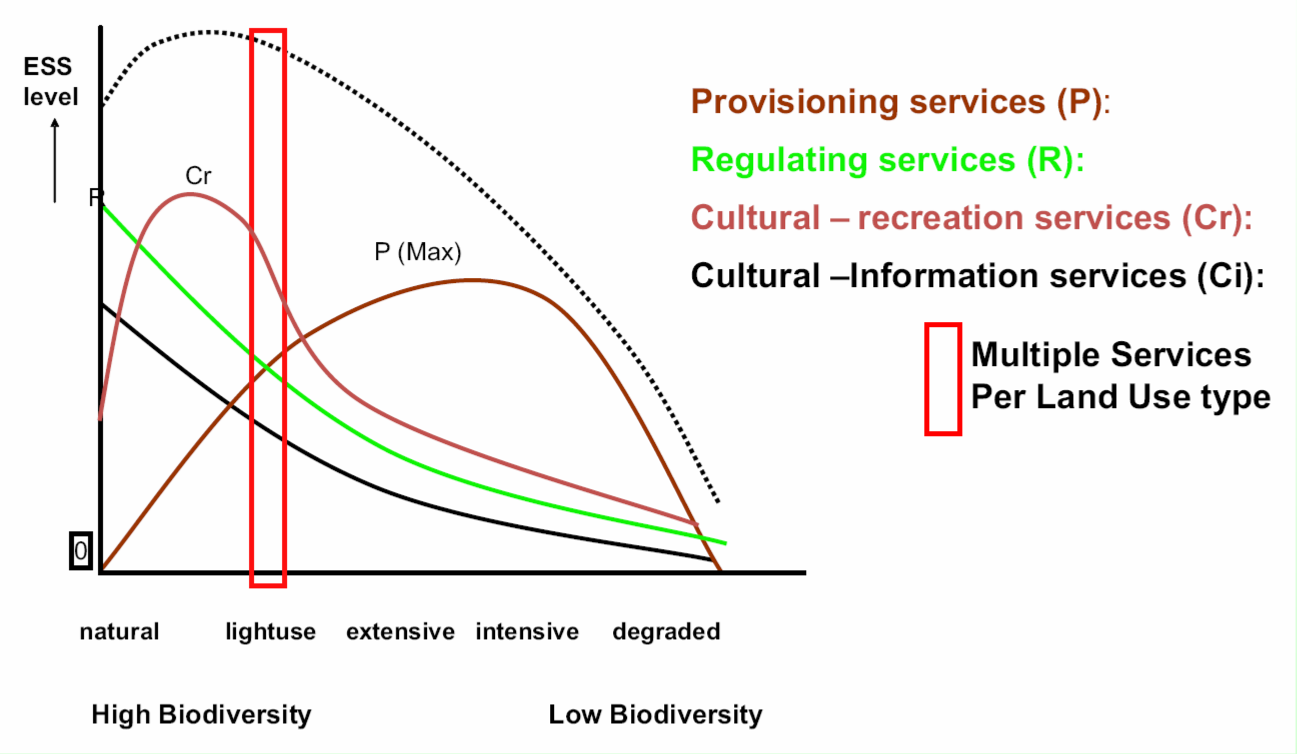

The Economics of Ecosystems and Biodiversity (TEEB) overview diagram.
(From: Braat & De Groot, 2012).

# BIODIVERSITY AND ECOSYSTEM FUNCTIONS




The effects of species loss on ecosystem function for hypothetical communities. (From: Gamfeldt et al., 2008)

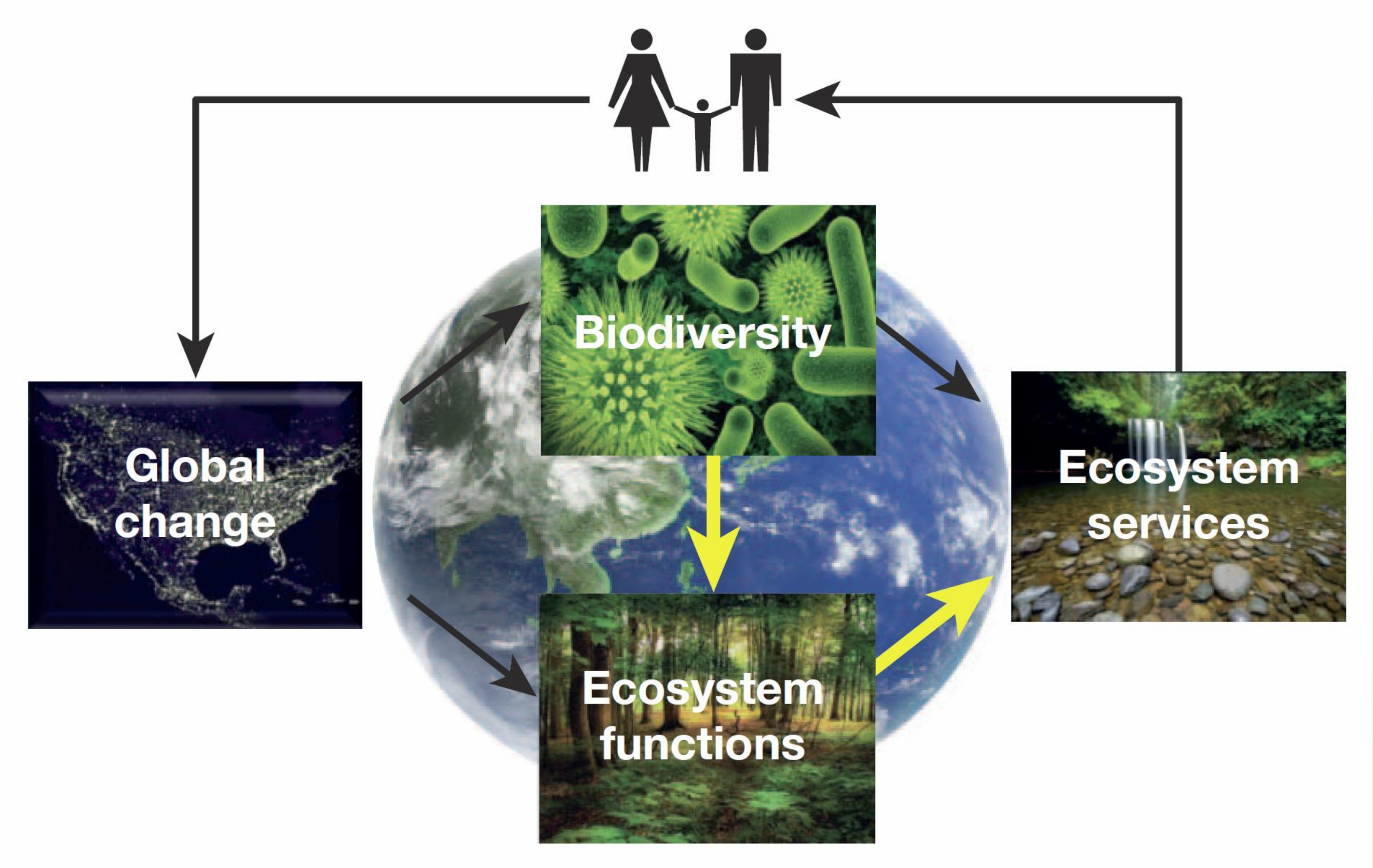
# BIODIVERSITY AND ECOSYSTEM SERVICES




Land use, biodiversity and multiple ecosystem services

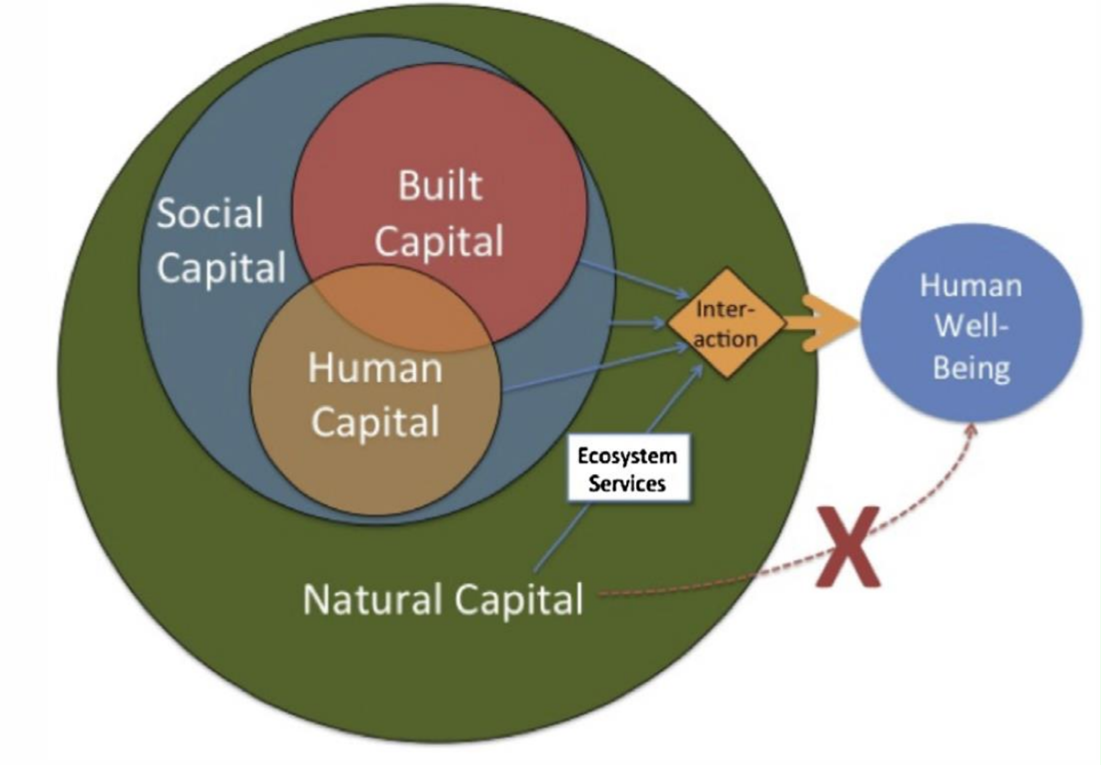
(From: Braat & de Groot, 2012)

# BIODIVERSITY AND ECOSYSTEM SERVICES



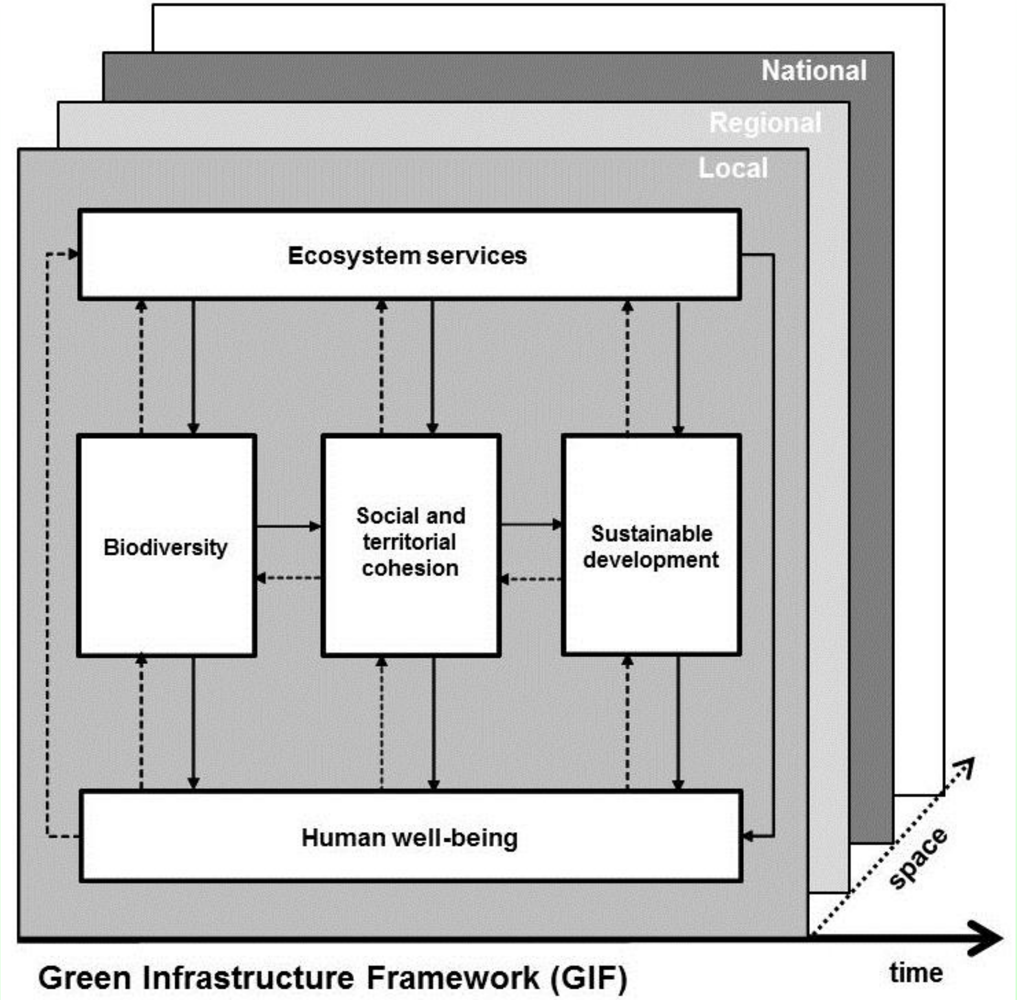

Biodiversity per se—that is, the variety of genes, species, or functional traits in an ecosystem—has an impact on the functioning of that ecosystem and, in turn, the services that the ecosystem provides to humanity (From: Cardinale et al., 2012).

# ECOSYSTEM SERVICES AND NATURAL CAPITAL




Interaction between built, social, human and natural capital required to produce human well-being. Built and human capital (the economy) are embedded in society which is embedded in the rest of nature. Ecosystem services are the relative contribution of natural capital to human well-being, they do not flow directly. It is therefore essential to adopt a broad, transdisciplinary perspective in order to address ecosystem services (From: Costanza et al., 2014).

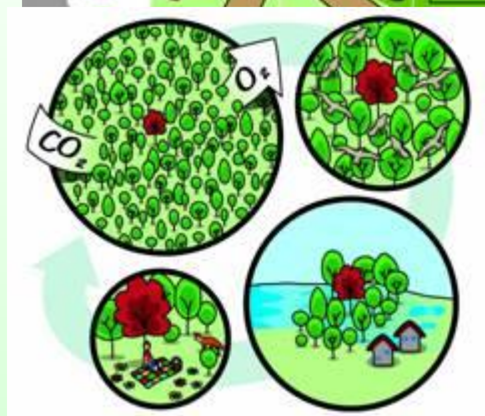
# GREEN INFRASTRUCTURE

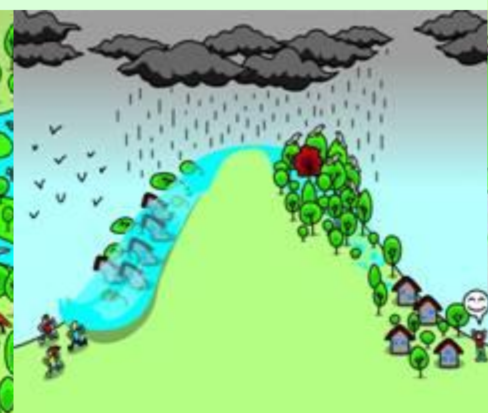



The Green Infrastructure Framework (GIF) consists of five main blocks each one corresponding to a specific function or bundle of functions. Each block is directly or indirectly linked to the others to mark the interrelation between the various functions and benefits related to Green Infrastructure

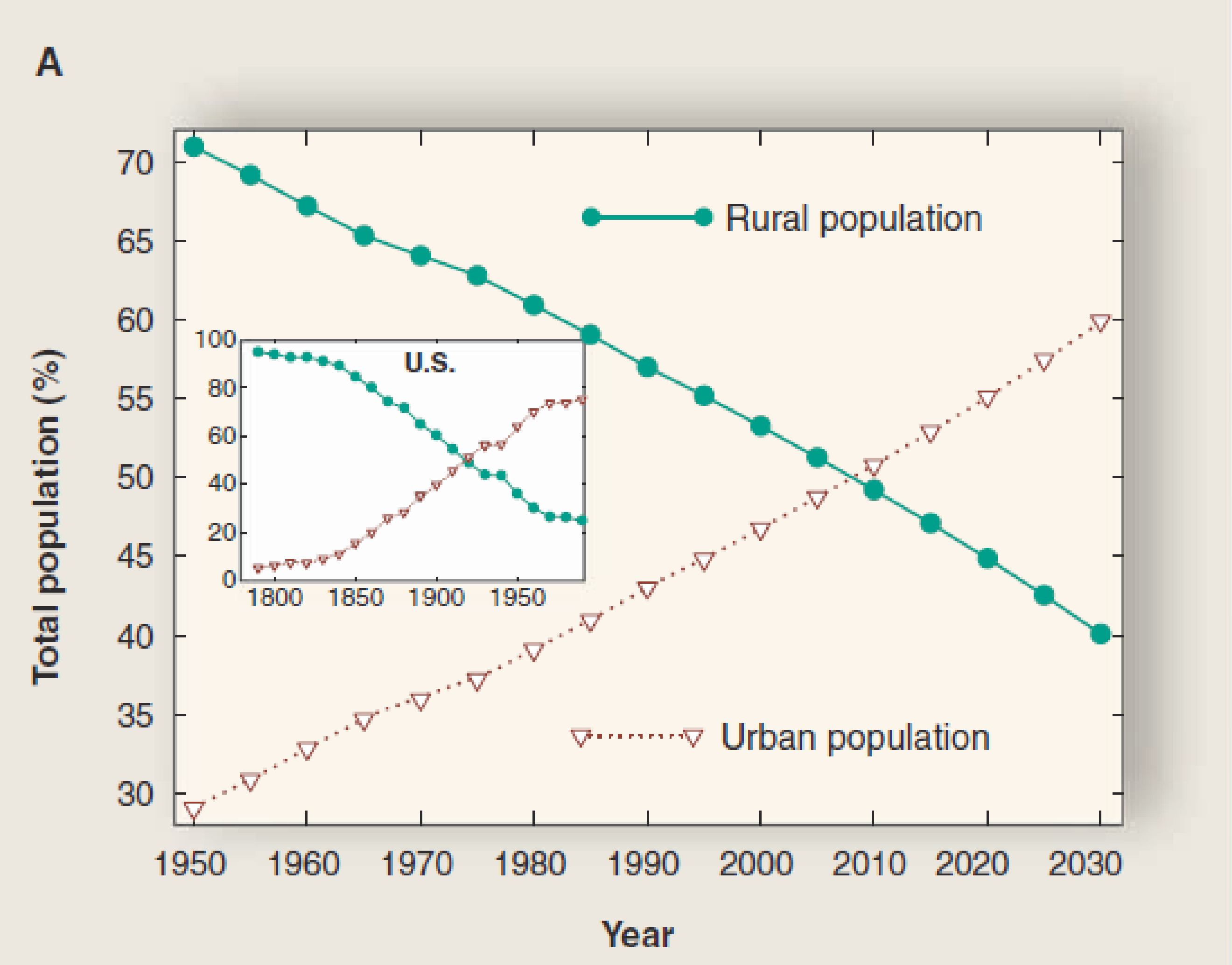
(From: Lafortezza et al., 2013).

# GREEN INFRASTRUCTURE



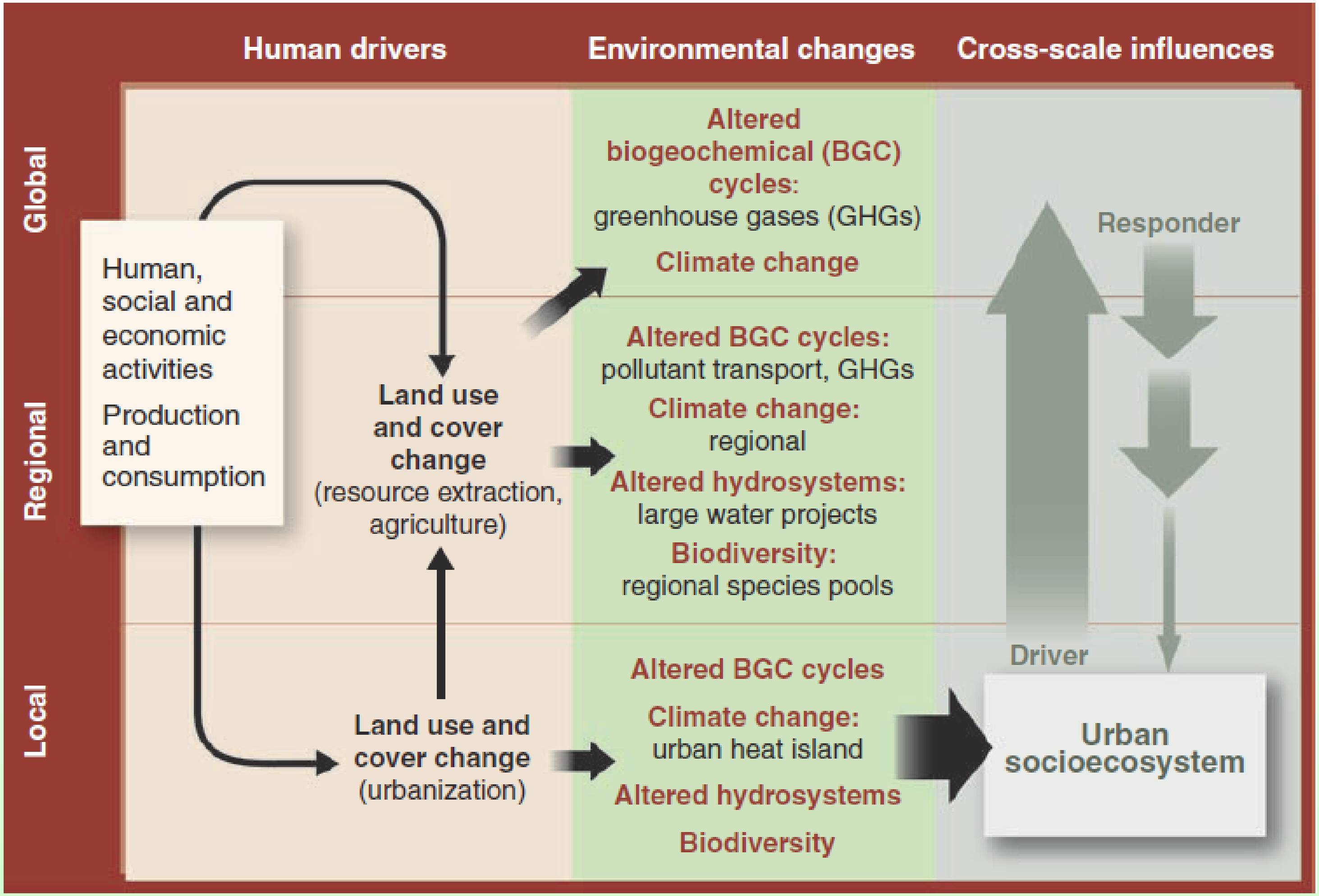



# CHANGE IN THE WORLD POPULATION DISTRIBUTION




Change in world urban and rural population (%) from 1950 to 2030 (projected). Inset shows comparable data for the United States from 1790 to 1990 (Modified from Grimm et al., 2008).

# Urban “sociecosystem” and environmental alterations




Framework showing urban socioecosystem (lower right) as a driver of (upward arrows) and responder to (downward and horizontal arrows) environmental change. Land change to build cities and support their populations drives local to global alterations of biogeochemical cycles, climate, hydrosystems, and biodiversity. Large local environmental changes are greater than those that filter down from global environmental change (horizontal black arrow). Not all possible interactions and drivers are shown (Modified from Grimm et al., 2008).

# AIR QUALITY IN EUROPEAN CITIES


Percentage of urban population in the European Union exposed to air pollution levels exceeding the EU air quality standards (top) and WHO air quality guidelines (bottom). (From: EEA, 2013 – Air quality in Europe).

# EU AIR QUALITY STANDARDS AND WHO AIR QUALITY GUIDELINES: OZONE

**Table 3.1 Air quality standards for $O_3$ as defined in the Air Quality Directive**

| Objective | Period | Target or threshold value | Number of allowed exceedances |
|---|---|---|---|
| Human health | Daily maximum 8-hour mean | 120 μg/m³ ([b]) | 25 days per year averaged over three years |
| Vegetation | AOT40 accumulated over May–July | 18 000 (μg/m³).h averaged over five years | |
| LTO health | Daily maximum 8-hour mean | 120 μg/m³ | |
| LTO vegetation | AOT40 accumulated over May–July | 6 000 (μg/m³).h | |
| Information | One hour | 180 μg/m³ | |
| Alert ([a]) | One hour | 240 μg/m³ | |

**Note:** ([a]) To be measured over three consecutive hours.

([b]) Target value to be met by 1 January 2010.

**Source:** EU, 2008c.

| **WHO GUIDELINES** (World Health Organization, 2006) | |
|---|---|
| **$\mu g\ m^{-3}$** | **8-hour mean** |
| $O_3$ | 100 |

# EU AIR QUALITY STANDARDS AND WHO AIR QUALITY GUIDELINES:

# PARTICULATE MATTER

**Air quality limit and target values for $PM_{10}$ and $PM_{2.5}$ as given in the Air Quality Directive**

| Size fraction | Averaging period | Value | Comments |
|---|---|---|---|
| $PM_{10}$, limit value | One day | 50 µg/m³ | Not to be exceeded on more than 35 days per year. To be met by 1 January 2005 |
| $PM_{10}$, limit value | Calendar year | 40 µg/m³ | To be met by 1 January 2005 |
| $PM_{2.5}$, target value | Calendar year | 25 µg/m³ | To be met by 1 January 2010 |
| $PM_{2.5}$, limit value | Calendar year | 25 µg/m³ | To be met by 1 January 2015 |
| $PM_{2.5}$, limit value (a) | Calendar year | 20 µg/m³ | To be met by 1 January 2020 |
| $PM_{2.5}$, exposure concentration obligation (b) | | 20 µg/m³ | 2015 |
| $PM_{2.5}$ exposure reduction target (b) | 0–20 % reduction in exposure (depending on the average exposure indicator in the reference year) to be met by 2020 | | |

**Note:** (a) Indicative limit value (Stage 2) to be reviewed by the Commission in 2013 in the light of further information on health and environmental effects, technical feasibility and experience of the target value in EU Member States.

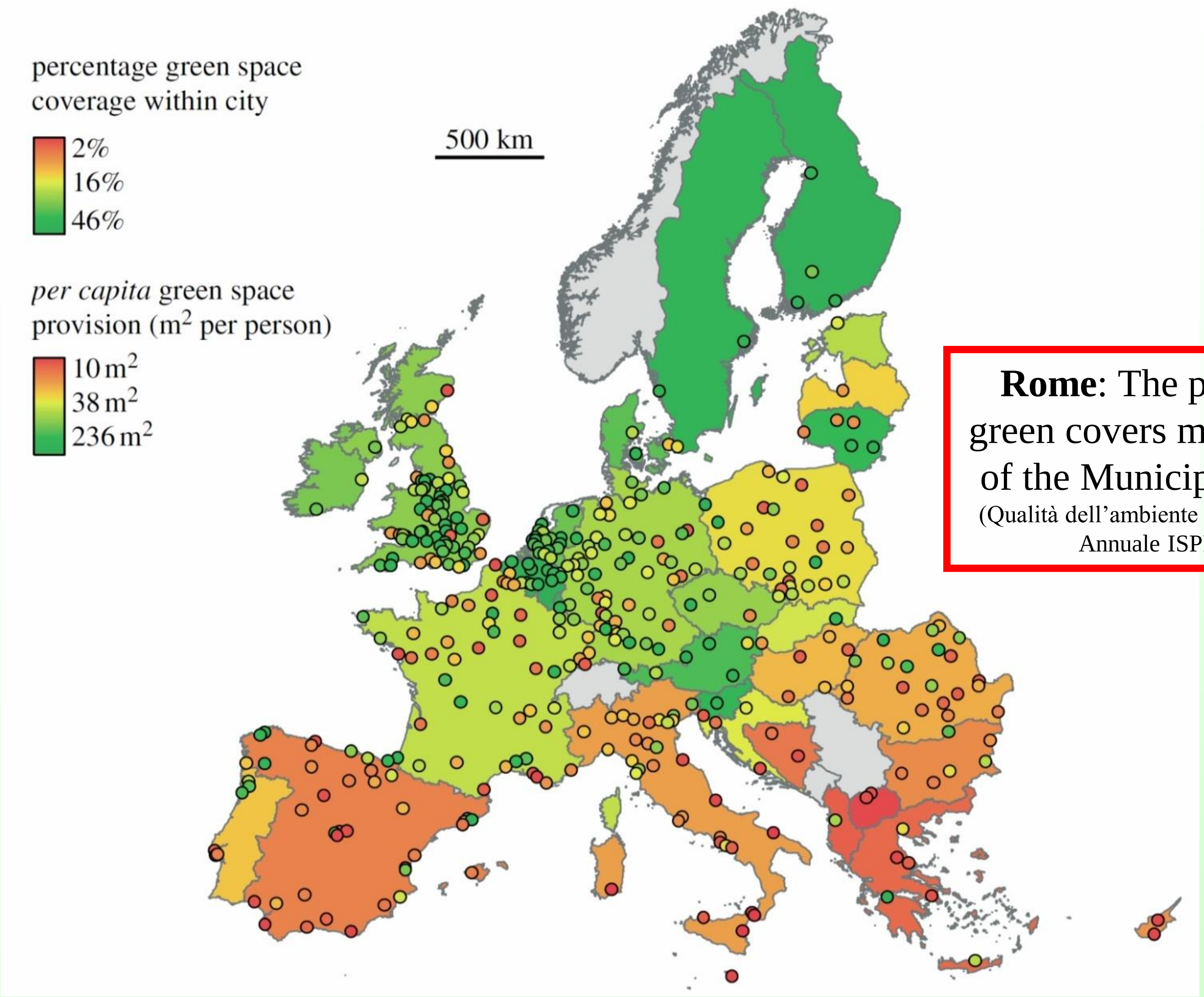
(b) Based on a three-year average of concentration measurements in urban background locations in zones and agglomerations throughout the territory of a Member State.

**Source:** EU, 2008c.

**WHO GUIDELINES**
(World Health Organization, 2006)

| µg m$^{-3}$ | 24 hour mean | Annual mean |
|---|---|---|
| $PM_{10}$ | 50 | 20 |
| $PM_{2.5}$ | 25 | 10 |

# URBAN GREEN SPACE COVERAGE IN EUROPE




**Rome**: The public urban green covers more than 20% of the Municipality surface
(Qualità dell'ambiente Urbano. V Rapporto Annuale ISPRA, 2008)

Points representing cities are coloured according to proportional coverage by urban green space within the city. Country polygons are coloured according to per capita green space provision for its urban inhabitants. Data unavailable for countries shaded grey (From: Fuller and Gaston, 2009)

# Urban Systems and Ecosystem Services

As ecosystem services are by definition addressed to human well-being, it is of paramount importance to quantify their overall performance, stability, and value in cities where human population density is highest (Dearborn and Kark 2009).

| | Street tree | Lawns/parks | Urban forest | Cultivated land | Wetland | Stream | Lakes/sea |
|---|---|---|---|---|---|---|---|
| Air filtering | X | X | X | X | X | | |
| Micro climate regulation | X | X | X | X | X | X | X |
| Noise reduction | X | X | X | X | X | | |
| Rainwater drainage | | X | X | X | X | | |
| Sewage treatment | | | | | X | | |
| Recreation/cultural values | X | X | X | X | X | X | X |

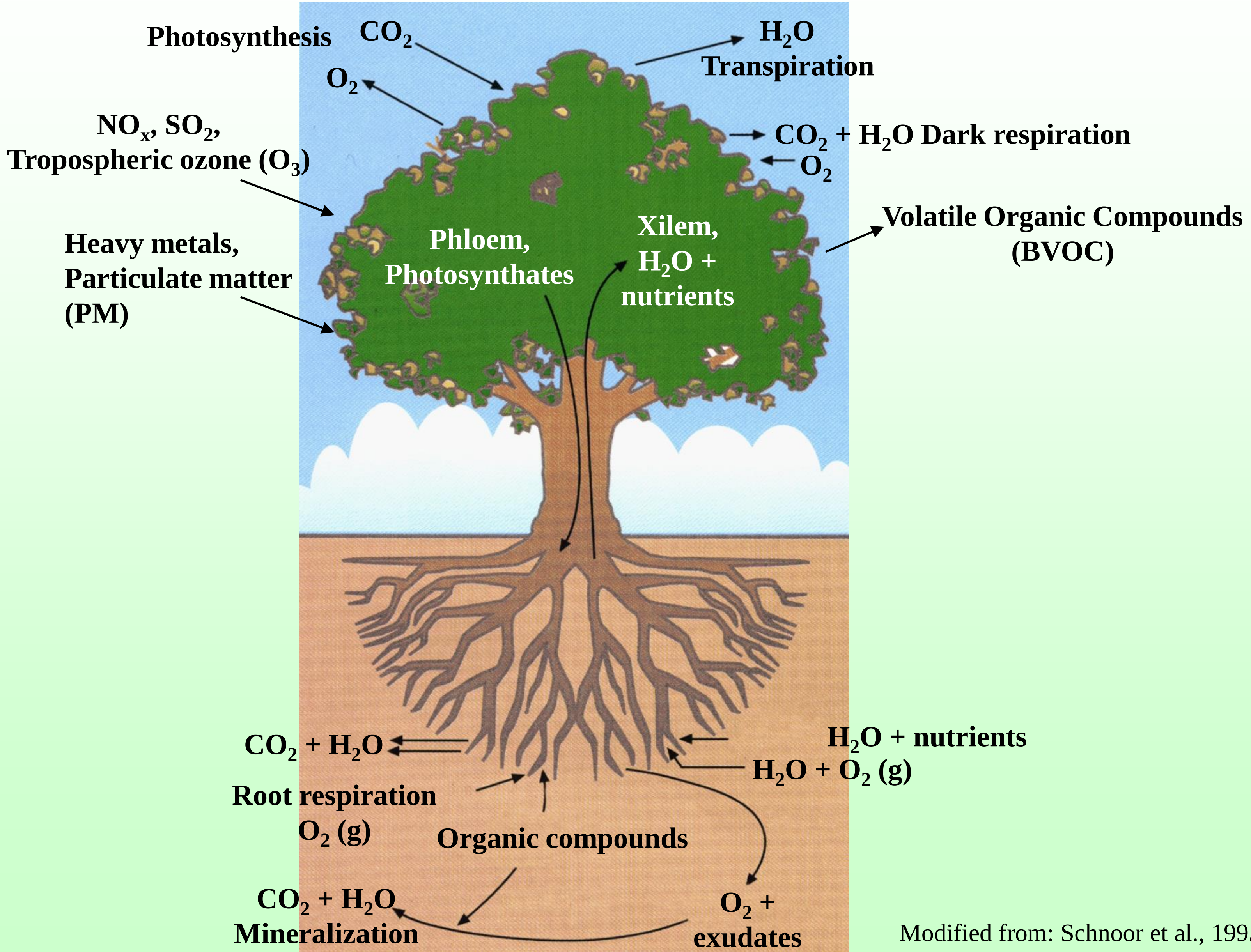
Urban ecosystems generating local and direct services (from the case study of Stockholm).
(From Bolund and Hunhammar, 1999).

# “FUNCTIONS” OF URBAN GREEN

| | |
|---|---|
| Social benefits | Recreation opportunities, improvement of home and work environments, impacts on physical and mental health. Cultural and historical values of green areas |
| Aesthetic and architectural benefits | Landscape variation through different colors, textures, forms and densities of plants. Growth of trees, seasonal dynamics and experiencing nature. Defining open space, framing and screening views, landscaping buildings |
| Climatic and physical benefits | Cooling, wind control, impacts on urban climate through temperature and humidity control. Air pollution reduction, sound control, glare and reflection reduction, flood prevention and erosion control |
| Ecological benefits | Biotopes for flora and fauna in urban environment |
| Economic benefits | Value of market-priced benefits (timber, berries, mushrooms ect.), increased property values, tourism |

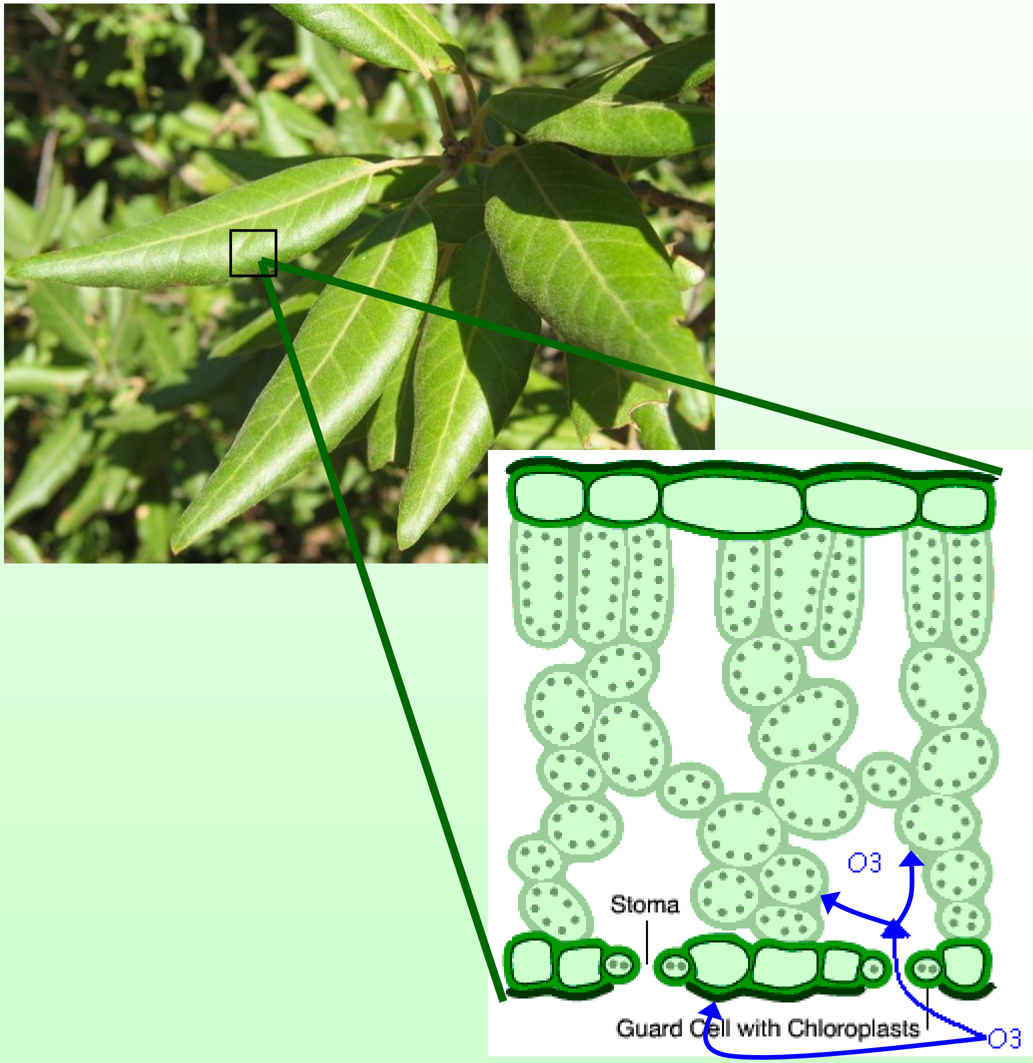
(adapted from Tyrväinen, 1999)

# Soil – plant – atmosphere relations and interactions with atmospheric pollutants




Modified from: Schnoor et al., 1995

# Reactions of ozone with plants can be classified as three types (Mudd, 1996):




-reactions in the **solid phase** (i.e., with cuticular components of leaves);

-reactions in the **gas phase** (i.e., reactions with hydrocarbons emitted by plants);

- reactions in the **liquid phase** that require dissolution of ozone in aqueous media, followed by reaction with lipids, proteins or other cellular components

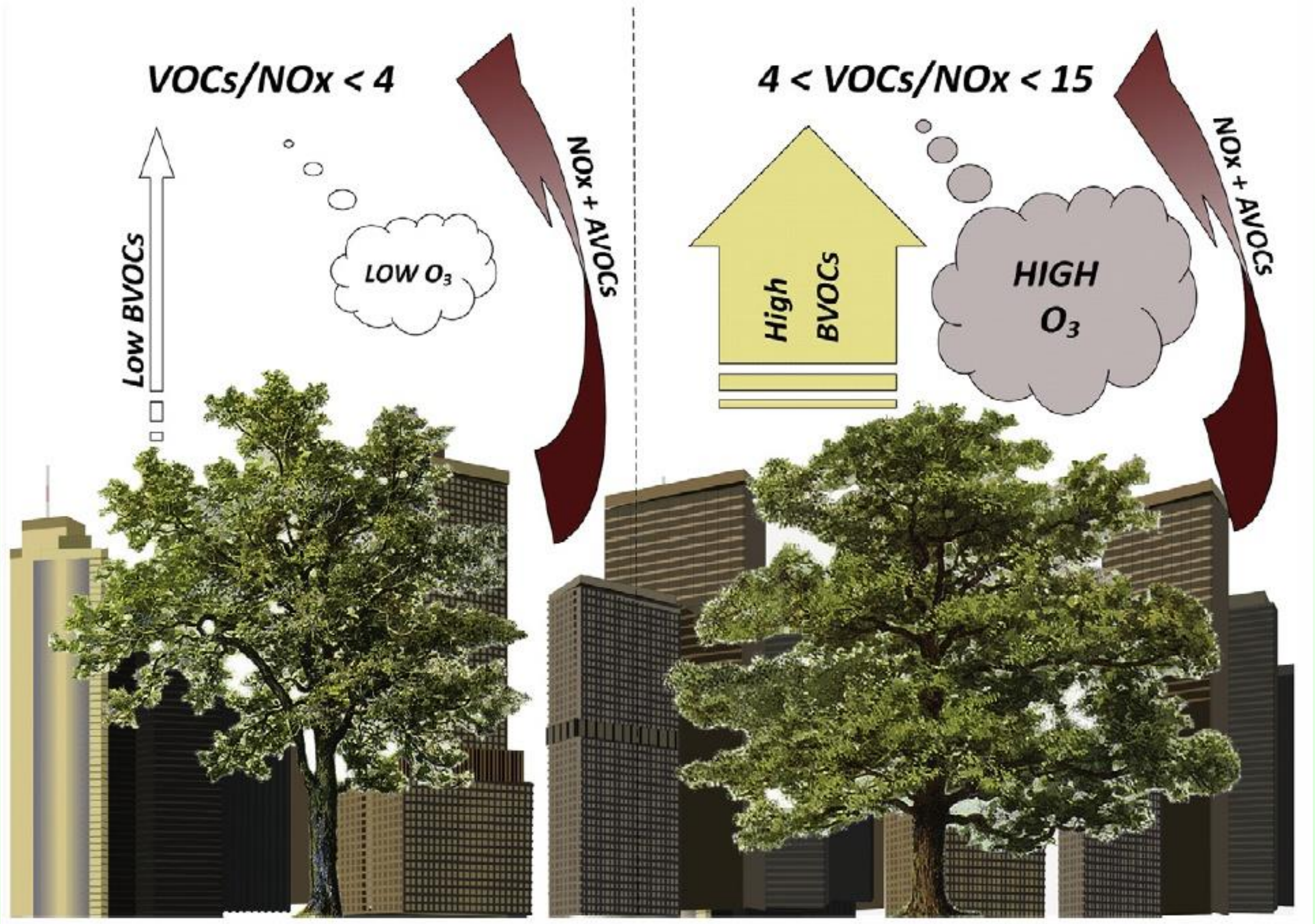
# BVOC emission from urban forest species

Main tree species of urban forestry in Rome with their emission trait

(adapted from Calfapietra et al. 2009 and Steinbrecher et al., 2009)

| Species | Isoprene Emission | Monoterpene Emission |
|---|---|---|
| *Acer sp.* | * | Low |
| *Cupressus sempervirens* | * | * |
| *Eucalyptus sp.* | High | Medium |
| *Juniperus sp.* | * | Low |
| *Laurus nobilis* | * | * |
| *Olea europea* | * | * |
| *Quercus pubescens* | High | * |
| *Quercus cerris* | * | * |
| *Quercus ilex* | * | High |
| *Quercus suber* | * | Medium |
| *Pinus pinea* | * | Medium |
| *Pinus halepensis* | * | Low |
| *Platanus x acerifolia* | Medium | * |
| *Robinia pseudoacacia* | Medium | * |
| *Tilia cordata* | * | * |
| *Ulmus minor* | * | * |

Emission rates for the different species are listed as:
* cells: emission rates absent or considered negligible (below 1 µg $g^{-1}$ $h^{-1}$),
Low: emission rates ranging from 1 to 3 µg $g^{-1}$ $h^{-1}$;
Medium: emission rates ranging from 3 to 20 µg $g^{-1}$ $h^{-1}$;
High: emission rates above 20 µg $g^{-1}$ $h^{-1}$
Monoterpene emission includes both the monoterpene synthesis emission (light and temperature dependent) and the monoterpene pool emission (temperature dependent).




Effect of BVOC emission by urban trees on $O_3$ formation. As in several cities and conditions $VOC/NO_x$ ratio is <4, thus $O_3$ formation is VOC-limited, the use of low BVOC emitter could help to keep this ratio low and thus also $O_3$ at low levels (left panel). On the other hand the use of high BVOC emitters could move the $VOC/NO_x$ ratio toward optimal values for $O_3$ formation, thus favoring high $O_3$ levels. This is an exemplification provided that $NO_x$ and AVOC emissions remain constant (From Calfapietra et al., 2013).

# The European Project

HEREPLUS

HEalth Risk IN URBAN SYSTEMS
from Enviromental Pollution Levels

**http://www.hereplusproject.eu/**

• Financed under the Seventh European Framework Programme – Theme 6: Environment (including Climate Changes);

• Involved10 Partecipants from 6 different Countries:

- **Italiy**: Università di Roma “La Sapienza” – Dipartimento di Biologia Ambientale and Dipartimento di Medicina Sperimentale (Scientific Coordinators), Consorzio Sapienza Innovazione (Management), Joint Research Centre – Institute for Health and Consumer Protection, Consiglio Nazionale delle Ricerche (CNR).
- **Germany**: The Technische Universität Dresden.
- **Spain**: Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Spanish National Institute for Health Carlos III - Air Pollution Division.
- **Greece**: The Academy of Athens – Research Centre for Atmospheric Physics and Climatology.
- **Serbia**: Faculty of Medicine University of Belgrade.
- **United Kingdom**: Keele University - Centre for Health Planning and Management.

• Started 1st September, 2008, lasted for 33 months.

# A summary of the HEREPLUS objectives:

- To develop risk maps relating human health with $O_3$ and $PM_{10}$ concentrations using the ArcGis approach, taking into account existing and validated epidemiological models, for **Rome, Madrid, Athens, Dresden**;

- To contribute to the knowledge of the potential role of different urban vegetation types for mitigating the $O_3$ and $PM_{10}$ pollution levels, and to provide best practices regarding the management of large urban green areas;

- To deliver an Operational Manual of guidelines for managers and administrators appointed to establish urban-environmental measures, which combine risk maps, urban vegetation as a sink for $O_3$ and $PM_{10}$, and minimization of sanitary costs;

- To disseminate guidelines and best practice indications at a European level, also in support of the implementation of the Global Earth Observation System of Systems (GEOSS) initiative and of the Environment and Health Action Plan;

- Coordination among epidemiologists, biostatisticians, environmental scientists, GIS specialists, in order to bringing about a further step towards realizing the full potential of GIS technology in environmental and health research; HEREPLUS will also contribute to the creation of a possible multidisciplinary scientific network.

(Manes et al. 2009 – Italian Journal of Public Health)

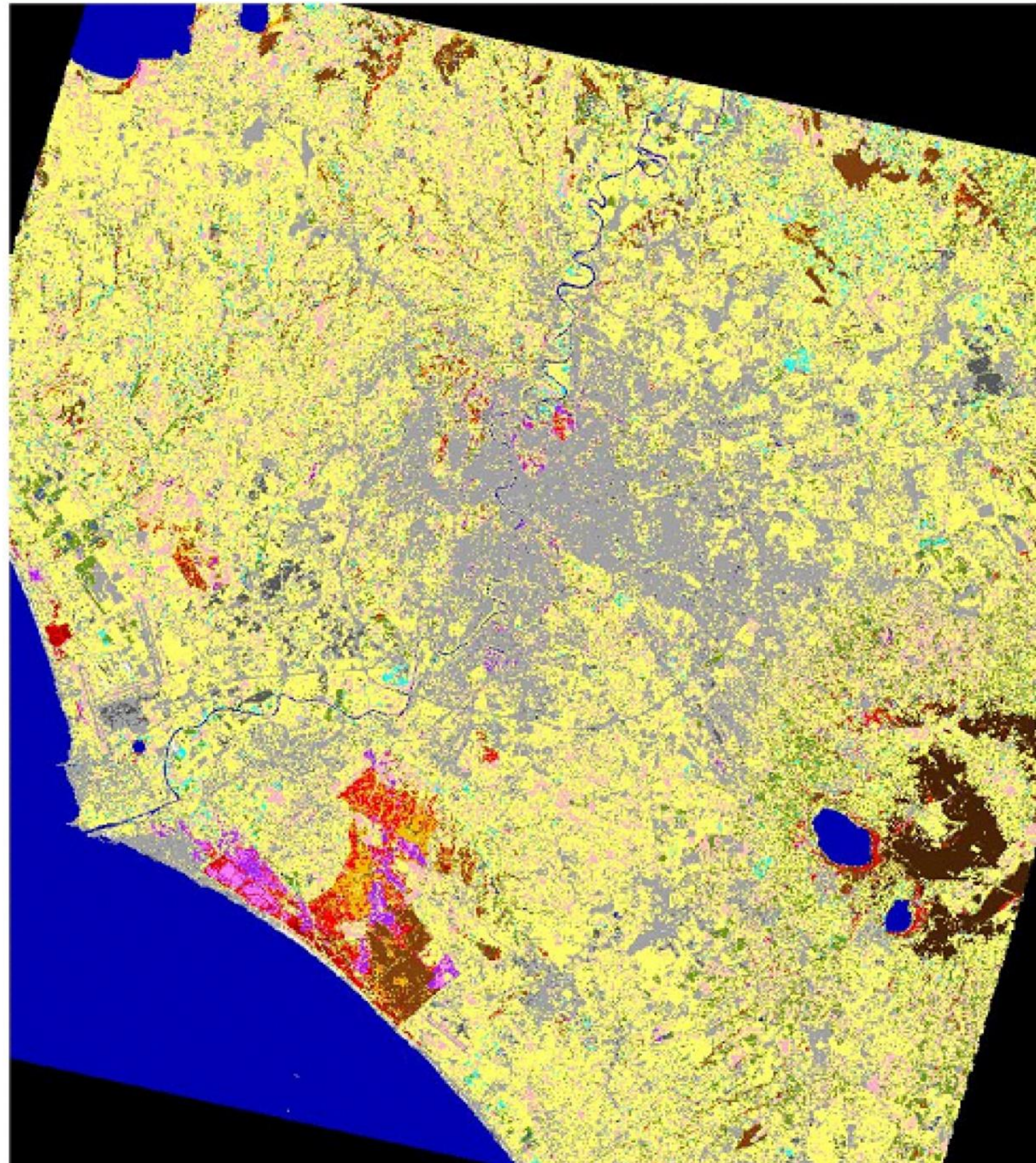
# METROPOLITAN AREA OF ROME

Land cover map of the Rome metropolitan area, based on LANDSAT sensor (1 cell = 30 x 30 m)

scale 1:250000

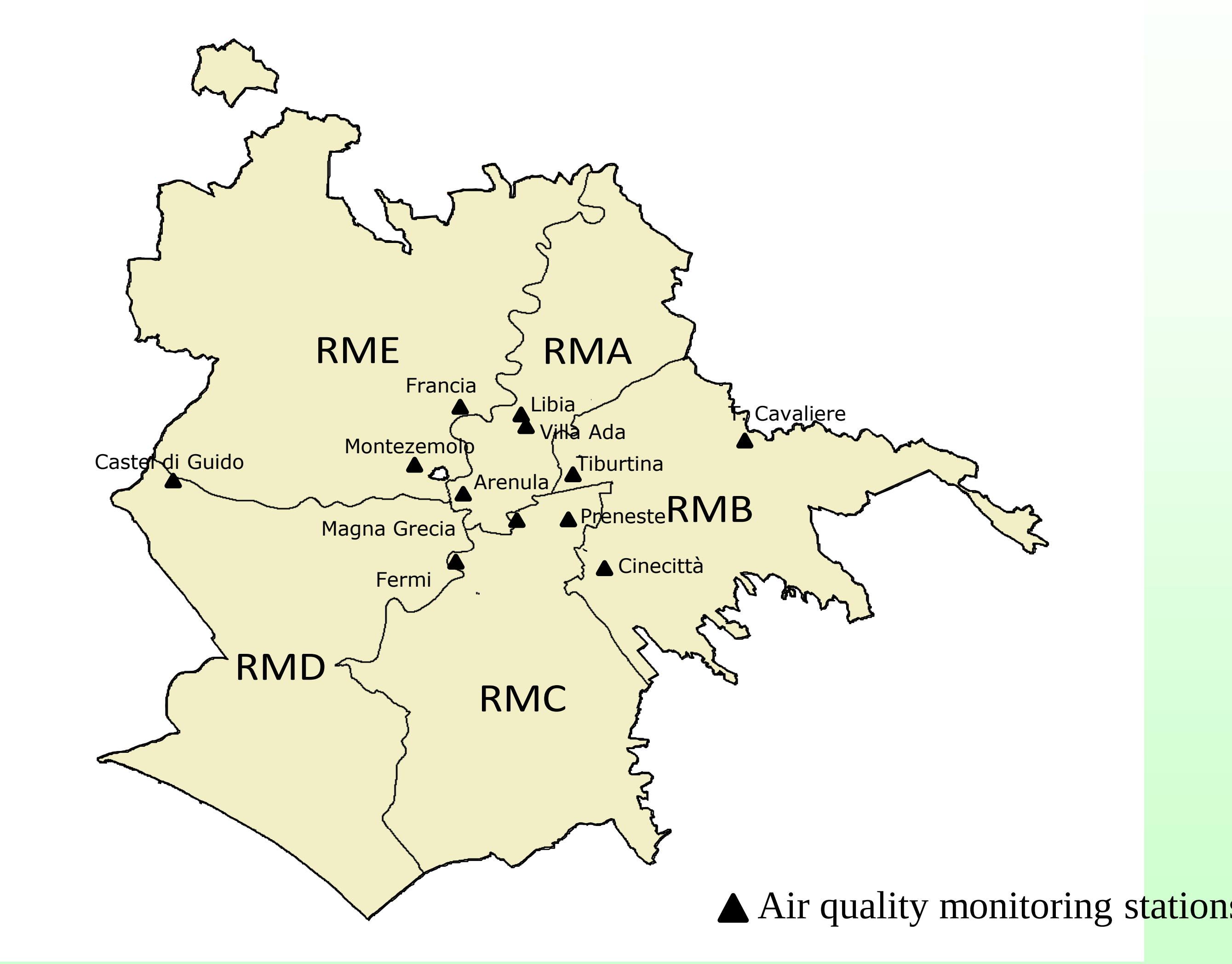

*Legend*

- Holm oaks prevailing
- Cork 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 non-agricoltural green areas
- Mines, landfills and abandoned areas
- Urban and industrial areas
- Waters



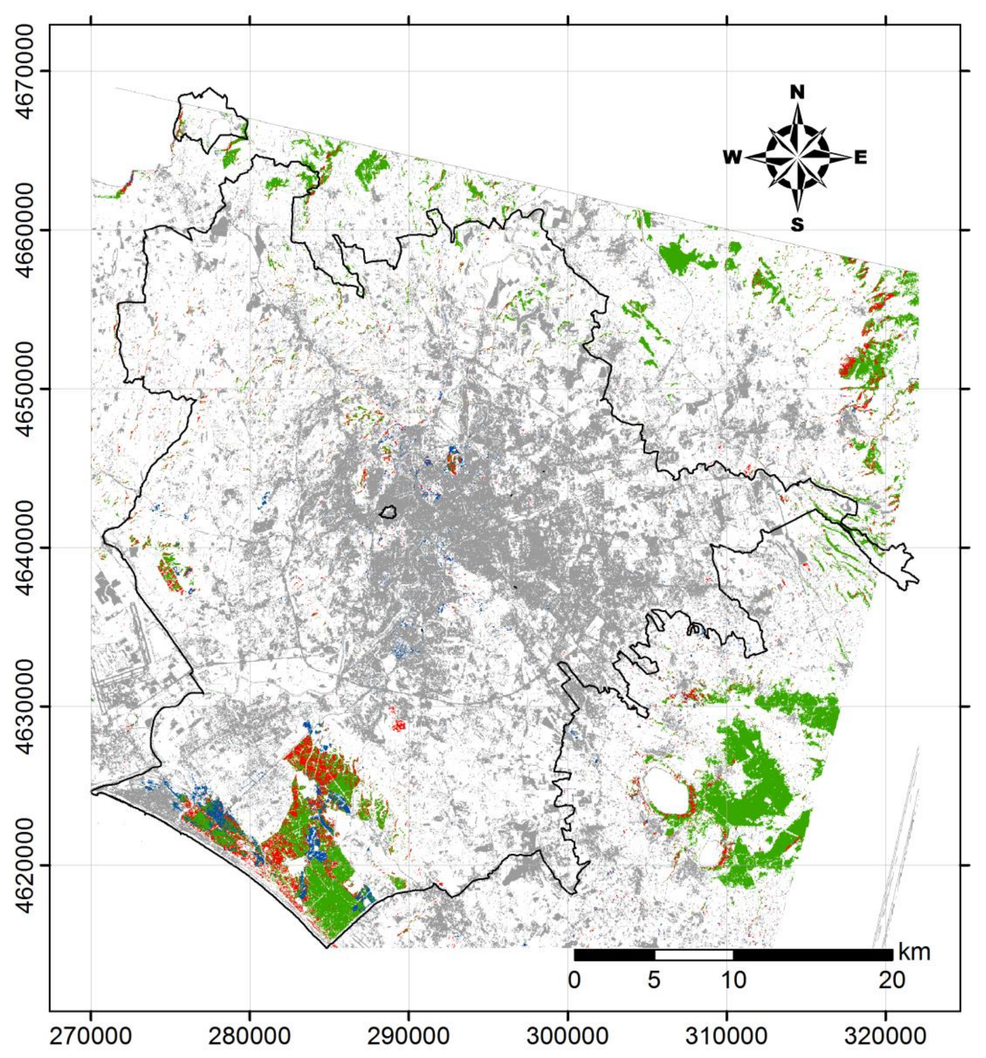
(From Manes et al., 2012)

# Sanitary districts (ASL) of the Municipality of Rome



# Estimate of the amount of $O_3$ and $PM_{10}$ removed by woody vegetation of Rome

For estimating the $O_3$ uptake and $PM_{10}$ deposition, the woody vegetation within the Municipality borders has been divided into three categories, based on leaf type:




- Evergreen broadleaves (2120 ha)
- Deciduous broadleaves (3477 ha)
- Coniferous (1601 ha)
- Total Municipality surface: 128530.6 ha

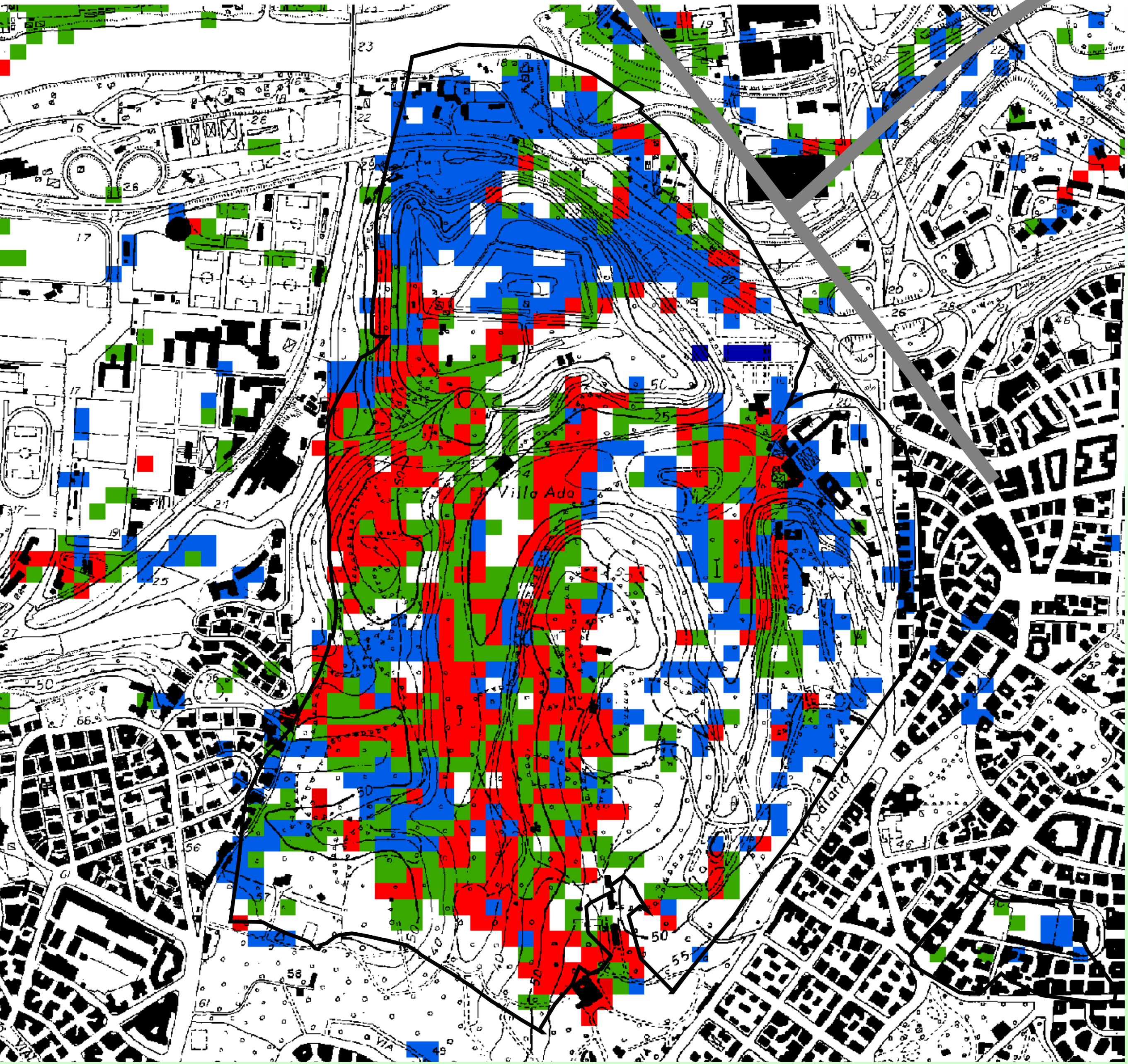
The area covered by each vegetation leaf type was calculated by GIS

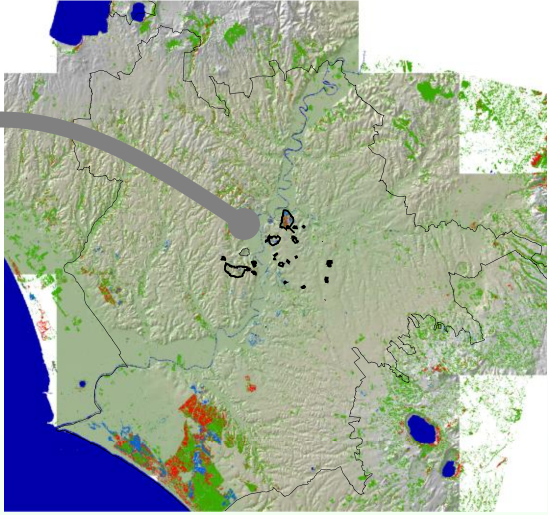
**Legend**

- Evergreen broadleaves (*Quercus ilex* prevalent)
- Deciduous broadleaves (*Quercus spp* prevalent)
- Conifers (*Pinus pinea* prevalent)

(From: Manes et al., 2012)

# Detail: Villa Ada Urban Park



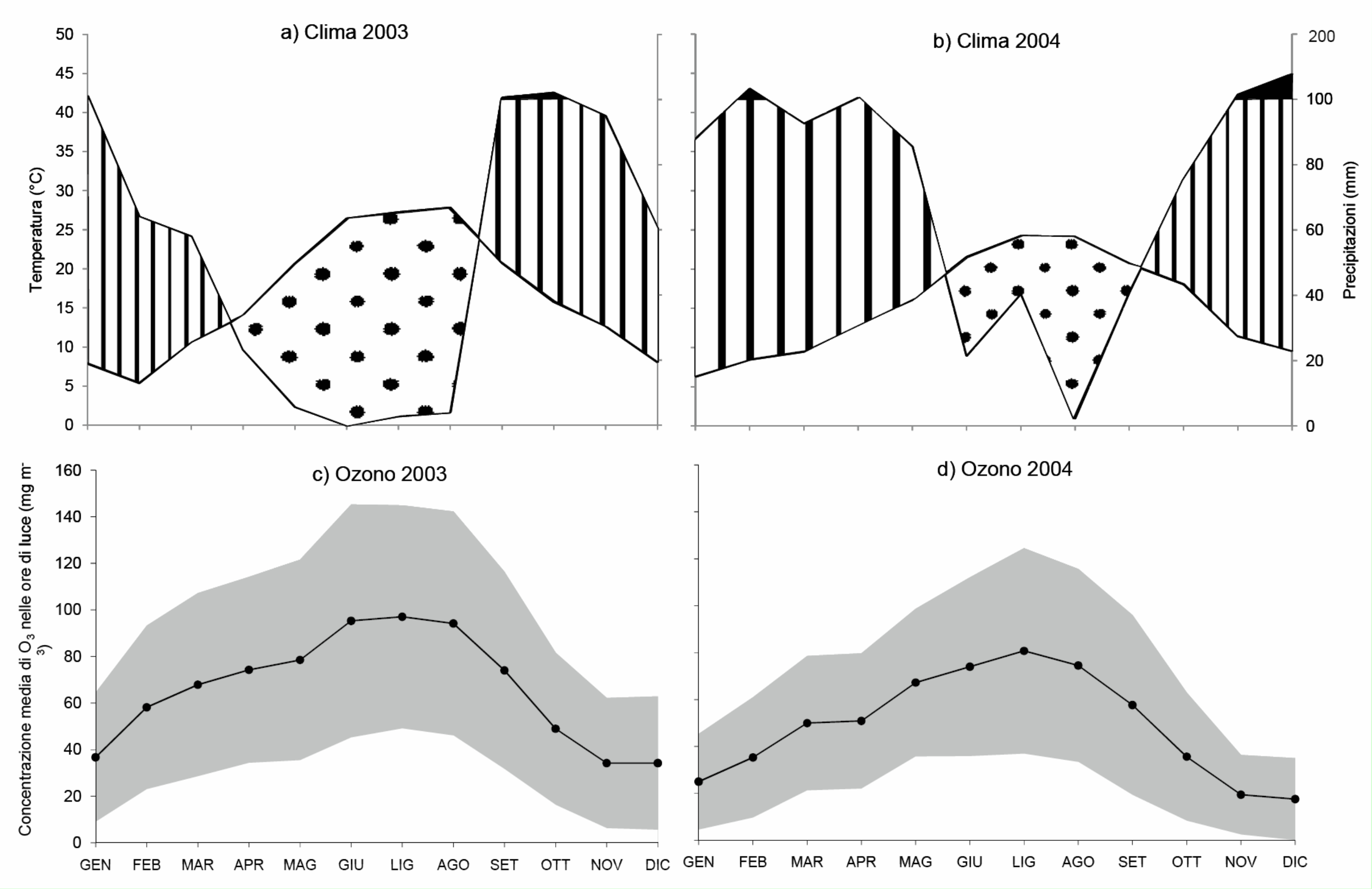



Surface of Villa Ada: 116.37 ha

**Vegetation leaf type:**

- Evergreen broadleaves
- Deciduous broadleaves
- Conifers

# Climate and $O_3$ concentrations in the city of Rome (2003 - 2004)

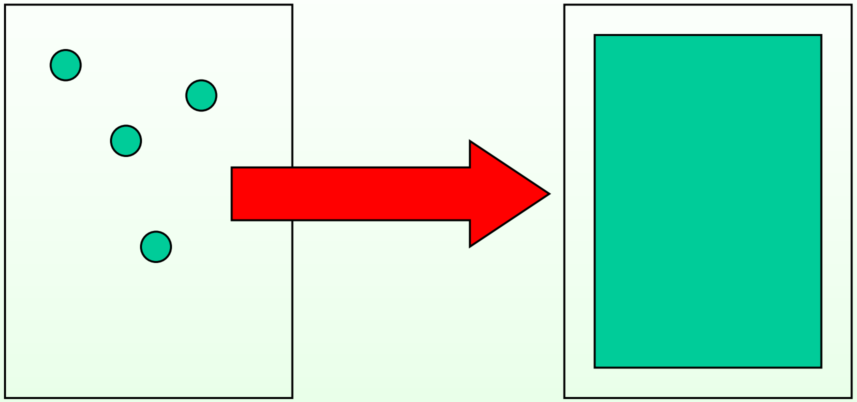



Climograms and $O_3$ concentrations (daylight means) recorded in the Municipality of Rome, years 2003-2004. (From Manes et al., 2012)

# DATA SPATIALIZATION: GEOSTATISTICAL TECHNIQUES

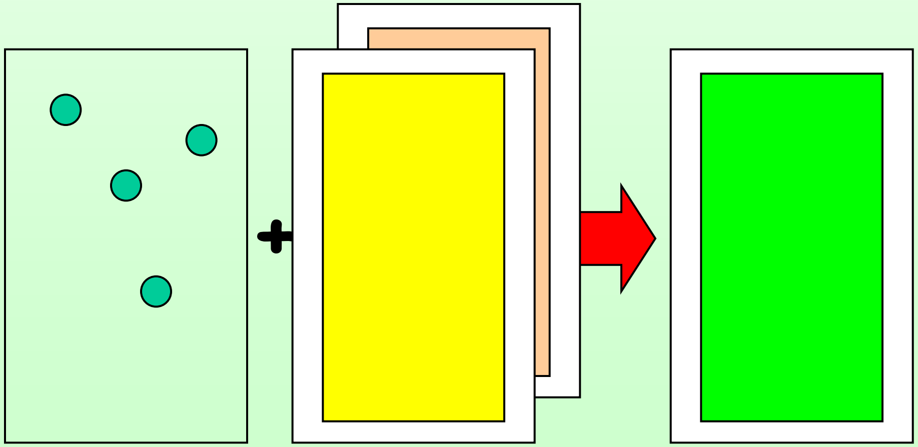
**Ordinary Kriging (K)**:

Linear estimator, spatialization by linear combination of the observed values in the sampler points, by using a spatial autocorrelation function. It doesn’t need ausiliary informations.



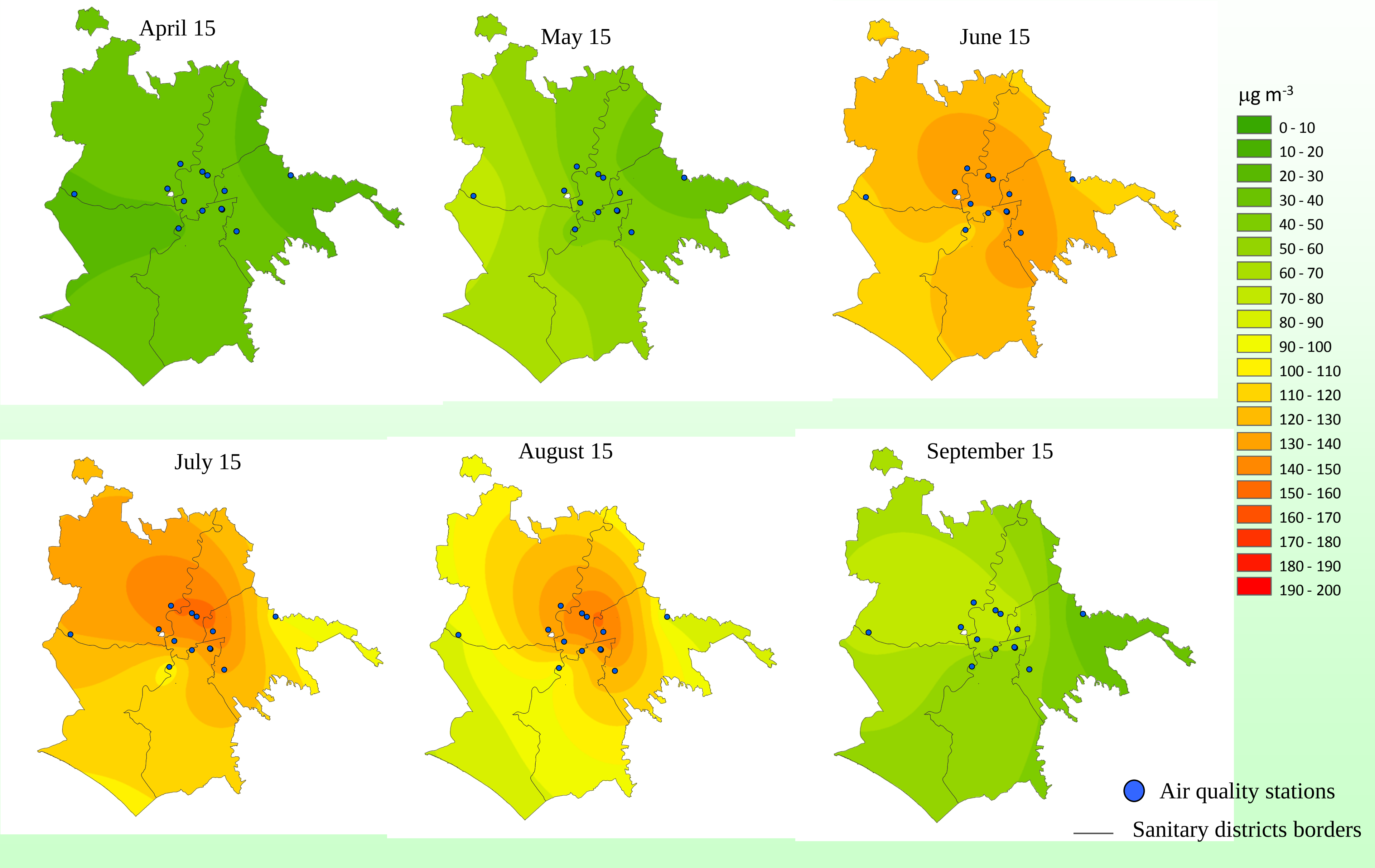
**Disjunctive Cokriging (CK):**

Non linear estimator, spatialization by combination of functions of the observed values in the sampler points, by using an autocross-correlation spatial function. It needs ausiliary informations



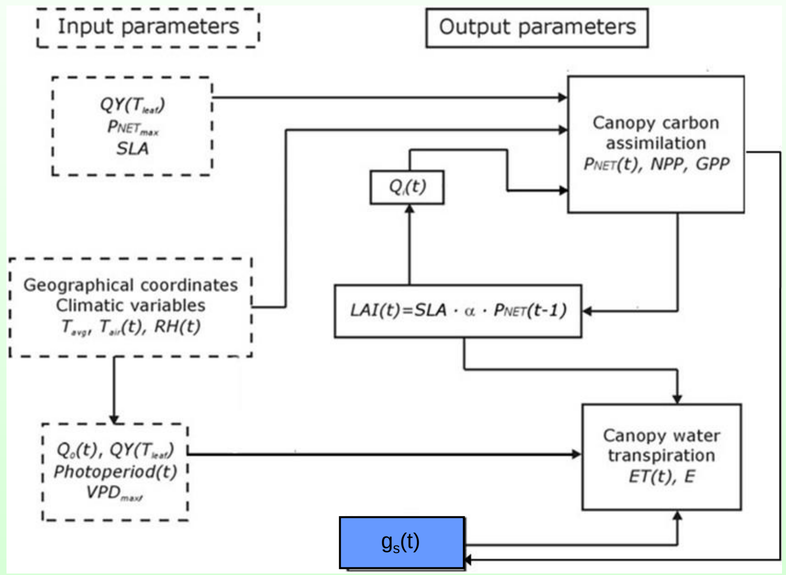
# Examples of daily $O_3$ maps: year 2003

## (Geostatistical approach: Co-Kriging with NOx)



# MODELLING $O_3$ FLUXES: Methodology

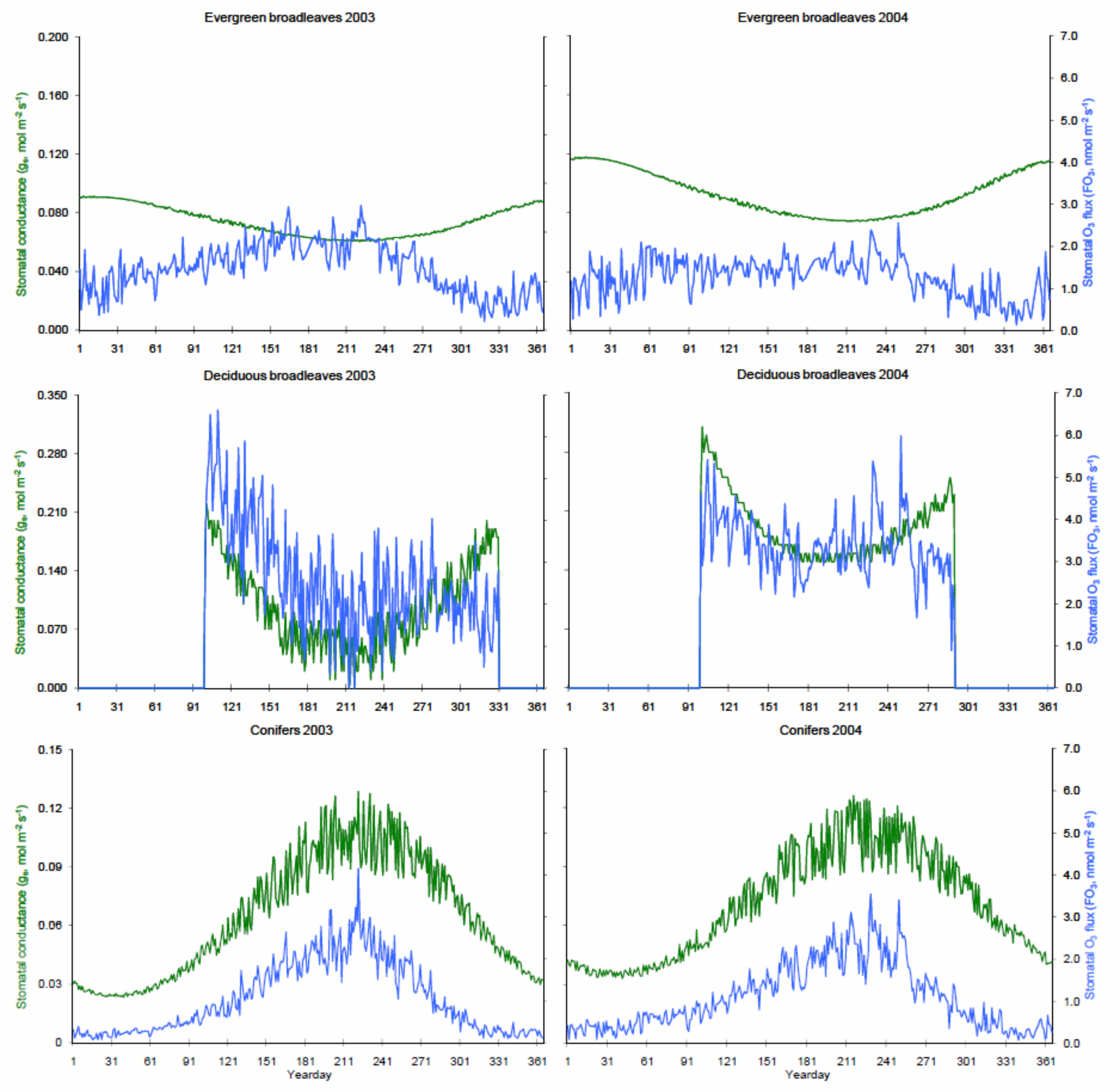
Annual profiles of daily average stomatal conductance for the three main vegetation types have been simulated (MOCA-FLUX model, Vitale et al., 2005), and used to estimate $O_3$ stomatal fluxes as a function of stomatal conductance




$$\boxed{FO_3s = gs \times [O_3] \times 0.613}$$

Where 0.613 is the ratio of water and $O_3$ diffusion coefficents (Nobel, 1983)

# Stomatal flux of $O_3$ (2003 - 2004)

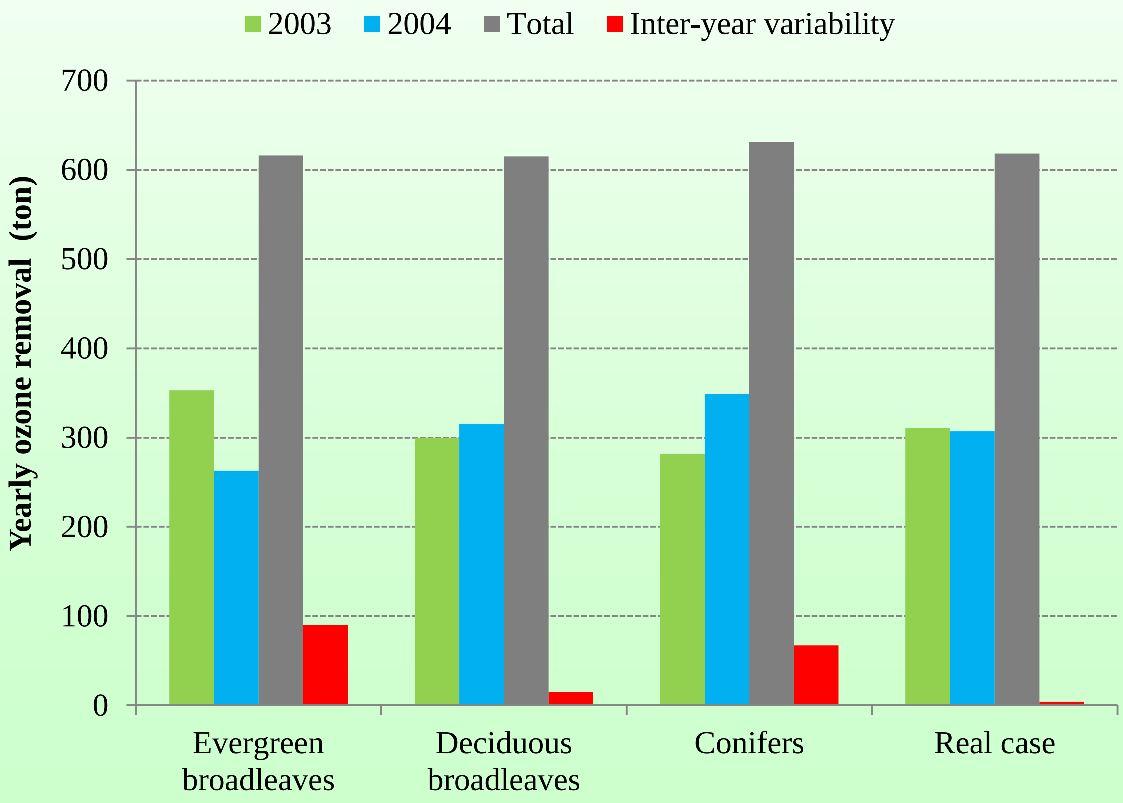



Time series of daily average stomatal conductance and stomatal $O_3$ uptake by the tree functional groups in Rome's municipality in 2003 and 2004

(Modified from Manes et al., 2012)

# FUNCTION OF URBAN BIODIVERSITY:
## Stabilization of the $O_3$ removal Ecosystem Service

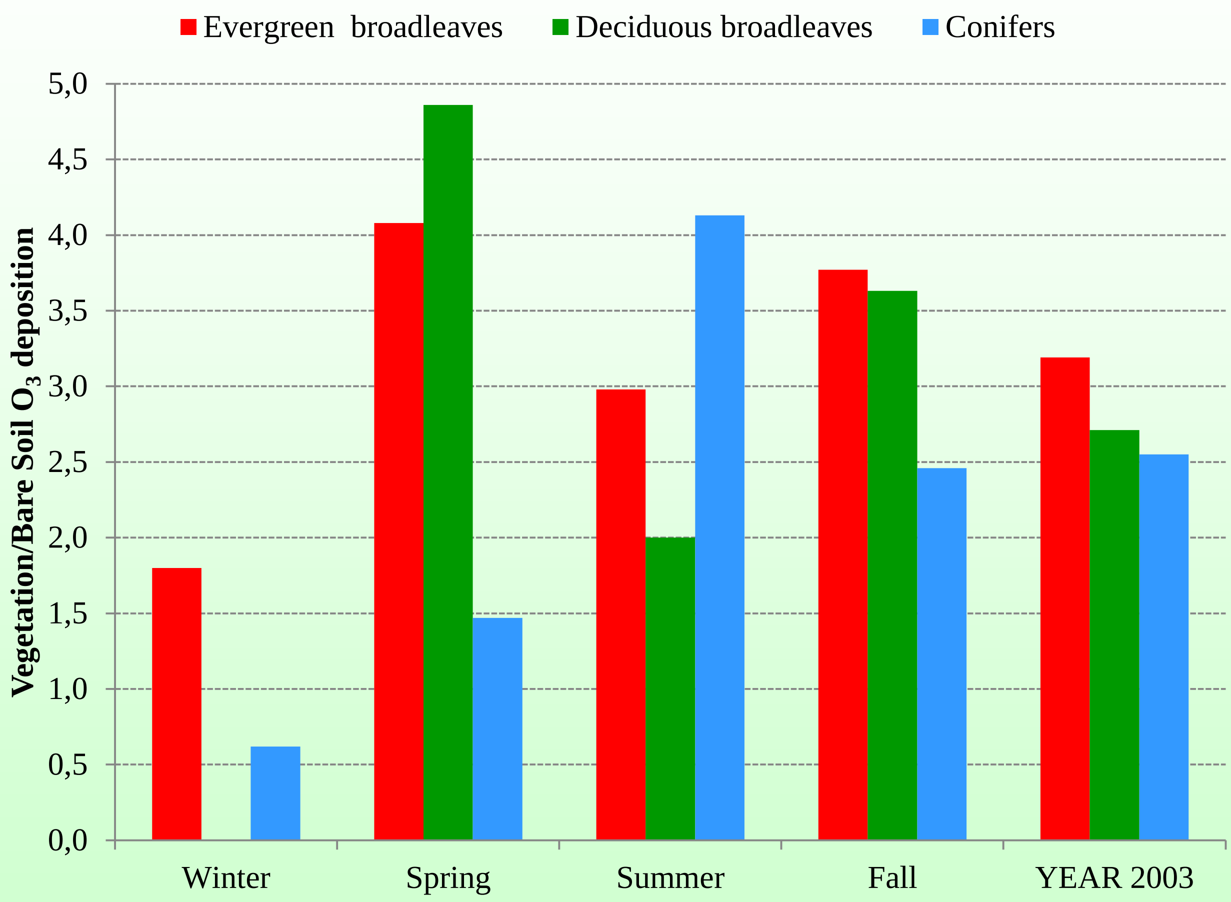
Simulation of yearly $O_3$ removal that would have occurred in the Rome Municipality in 2003 and 2004 if all urban trees would belong to one single vegetation leaf-type, compared to the “real case” of vegetation cover in Rome Municipality (total: 7198 ha) (From Manes et al, 2012).

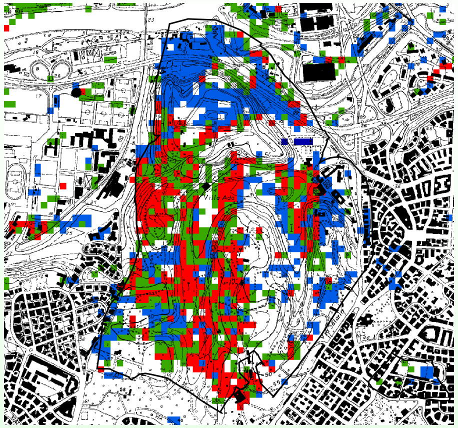



“Real case”:

- Evergreen broadleaves (2120 ha)
- Deciduous broadleaves (3477 ha)
- Conifers (1601 ha)

# MITIGATING ROLE OF URBAN VEGETATION ON $O_3$:
## Case study of the Villa Ada urban park, Rome

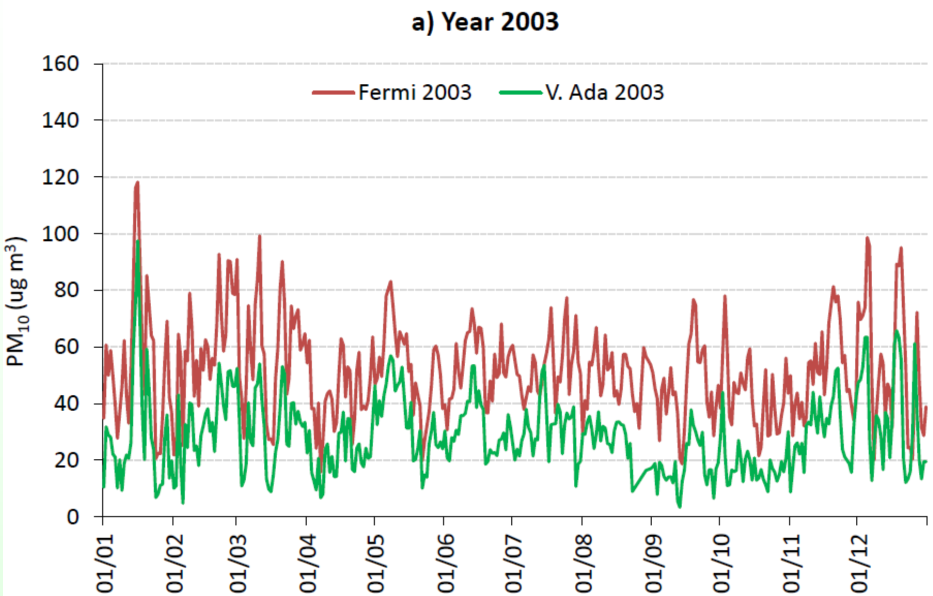


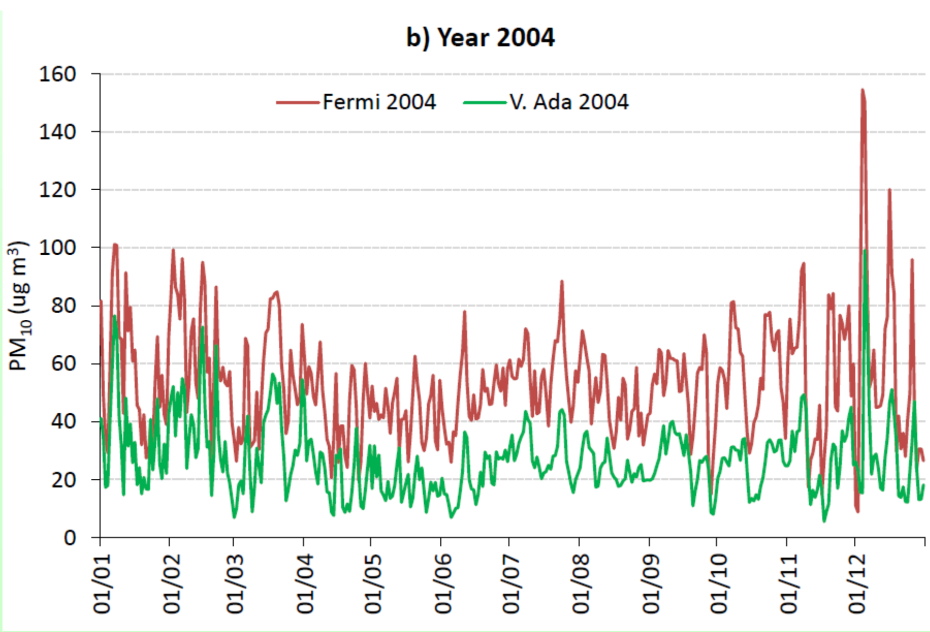



Ratio between $O_3$ fluxes to each vegetation leaf type (“real case”), and $O_3$ deposition to bare soil (“bare soil scenario”), in the Villa Ada green area (116.37 ha), during winter, spring, summer and fall 2003

# MODELLING $PM_{10}$ DEPOSITION

## Input $PM_{10}$ time series, years 2003-2004

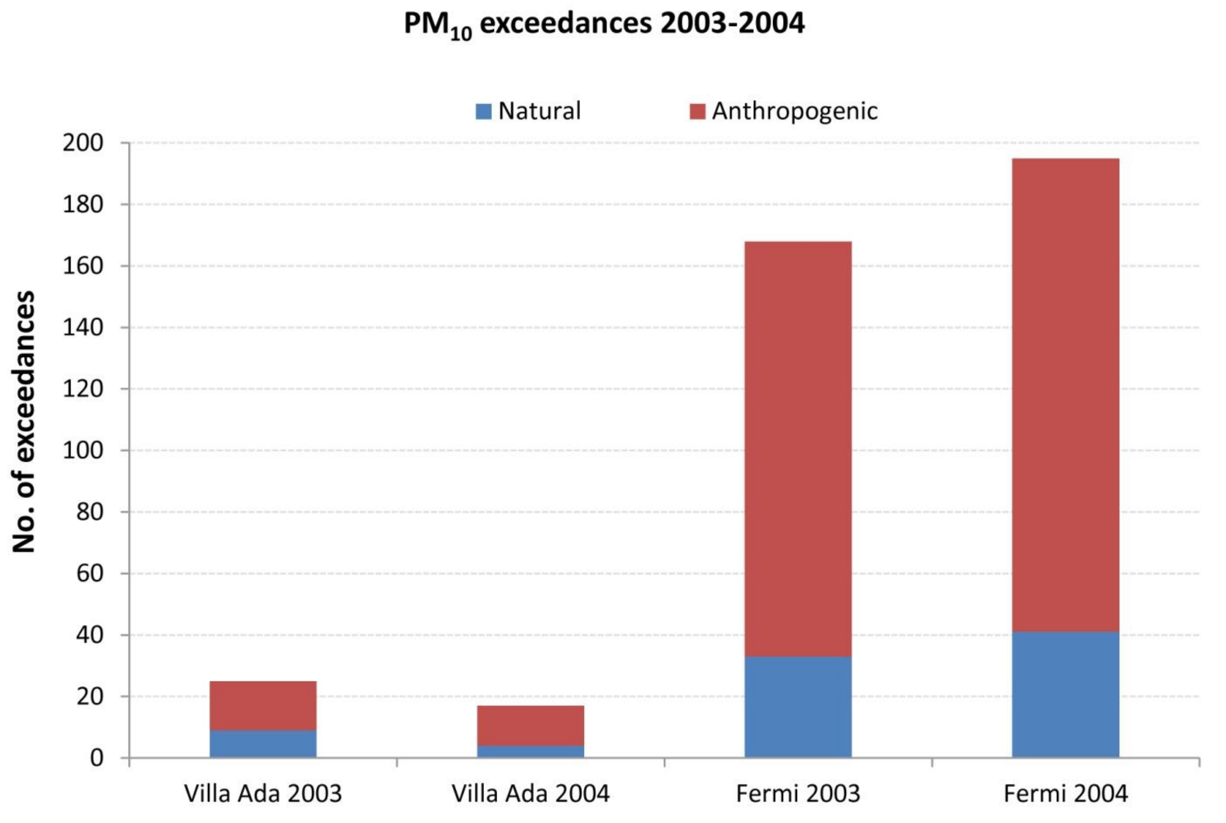



Based on the same methodological approach used for the assessment of ozone uptake, the estimates of the mitigating role of urban vegetation for $PM_{10}$ were calculated by considering the minimum and maximum $PM_{10}$ concentration values recorded in the Municipality of Rome (stations of Villa Ada, urban background, and Fermi, urban traffic, respectively)

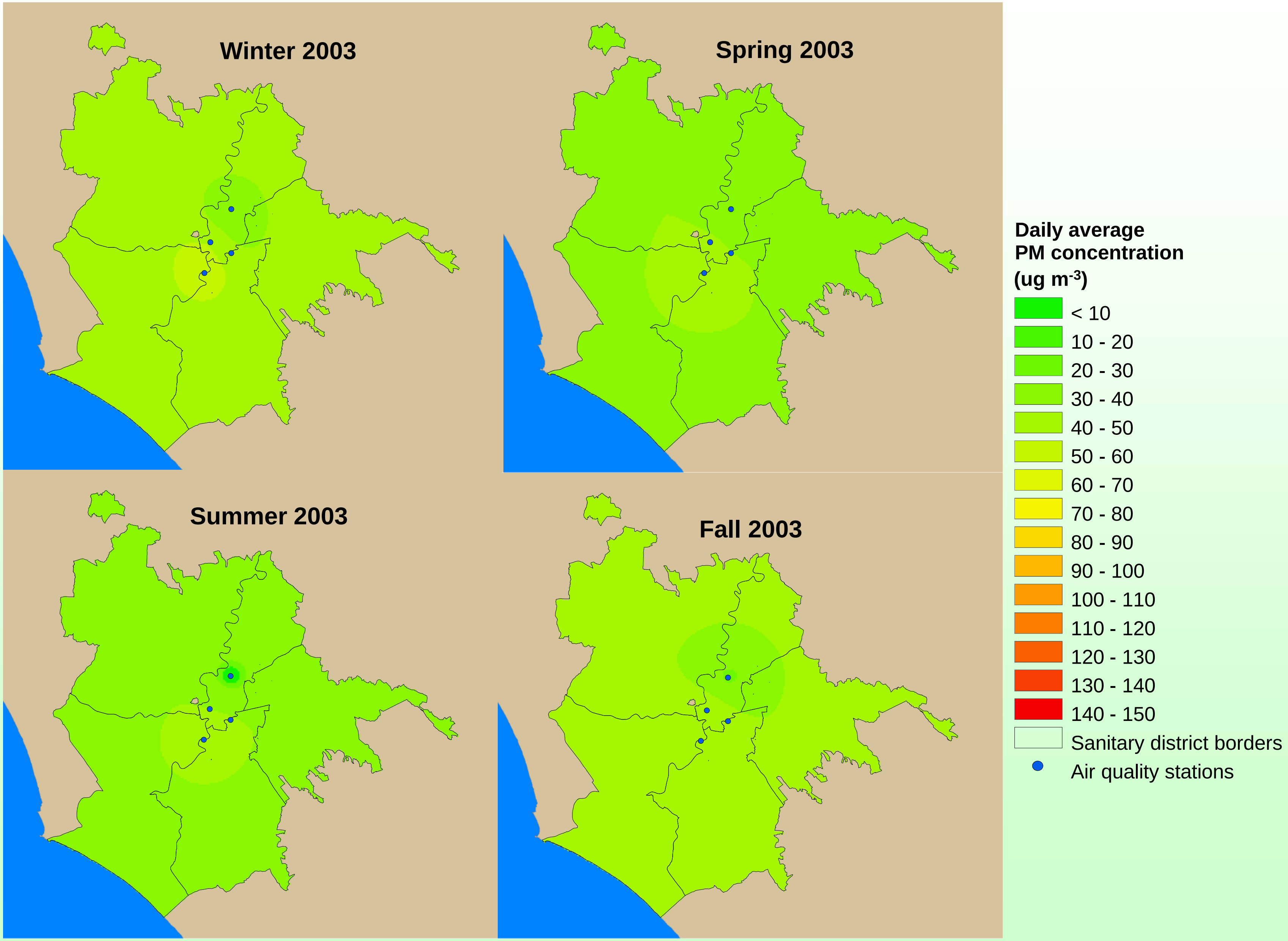
# MODELLING $PM_{10}$ DEPOSITION:

## Input $PM_{10}$ time series, years 2003-2004



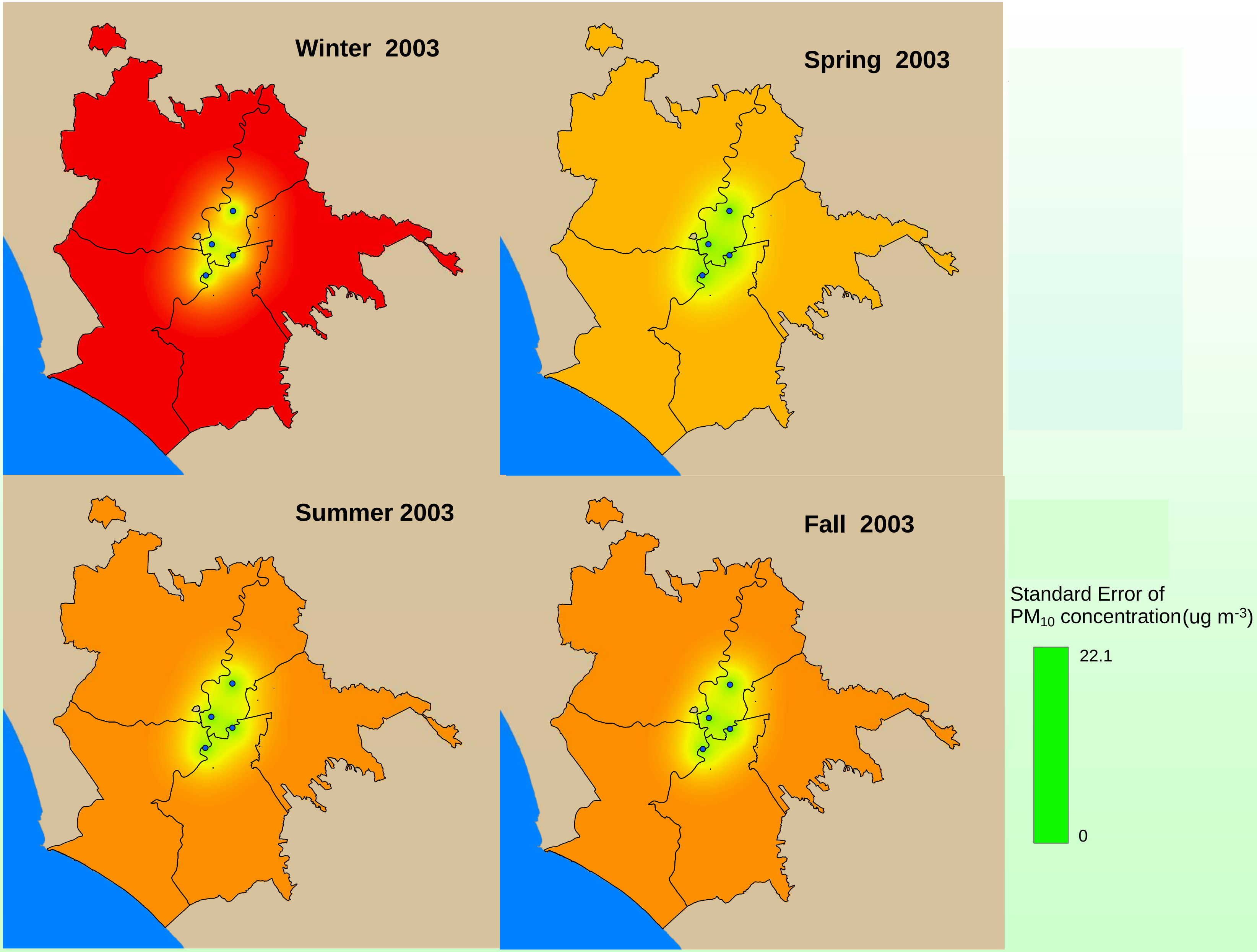

Number of exceedances of the daily limit value for $PM_{10}$ (50 μg/m$^3$) during the years 2003 – 2004, for the monitoring stations of Villa Ada (urban background) and Fermi (urban traffic). Natural events, as transport of Desert Dust, Sea-salt aerosol and Atmospheric Stability at the ground, may be responsible for a relevant fraction of $PM_{10}$ exceedances, particularly measured by non-traffic stations (From: Manes et al., 2014).

# Examples of seasonal maps of $PM_{10}$: year 2003




(From: Manes et al., 2014)

# Standard error maps of the Kriging models for $PM_{10}$



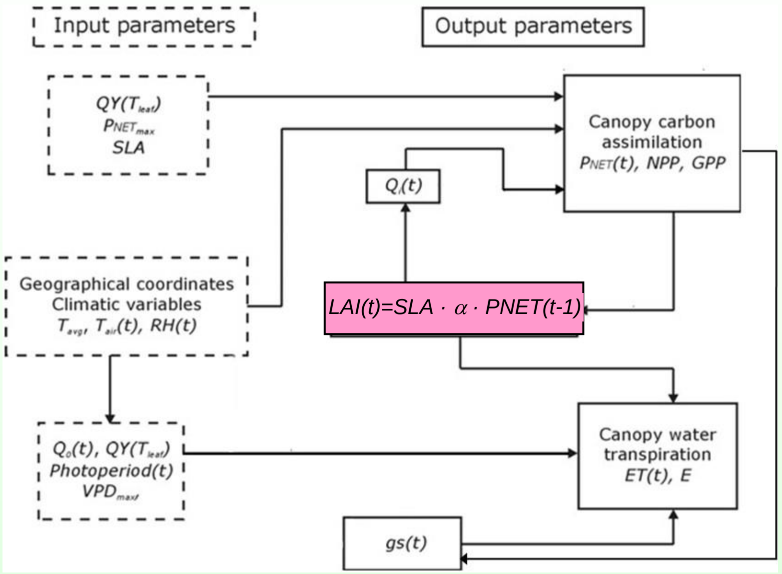

(From: Manes et al., 2014)

# MODELLING $PM_{10}$ DEPOSITION: Methodology

To calculate the $PM_{10}$ removal by tree vegetation in Rome municipality, the equations reported by Nowak (1994) were used:

$$Q = F \times L \times T$$

Where:
- Q is the pollutant amount removed by tree vegetation
- F is the pollutant deposition flux
- L is the total canopy cover in a given site, i.e. the LAI estimated by the MOCA-Flux Model (Manes et al., 2012)
- T is the reference time interval




Annual profiles of daily average Leaf Area Index (LAI) for the three main vegetation types have been simulated by the MOCA-Flux model (Manes et al., 2012)

The flux F is calculated as:

$$F = V_d \times C$$

Where:

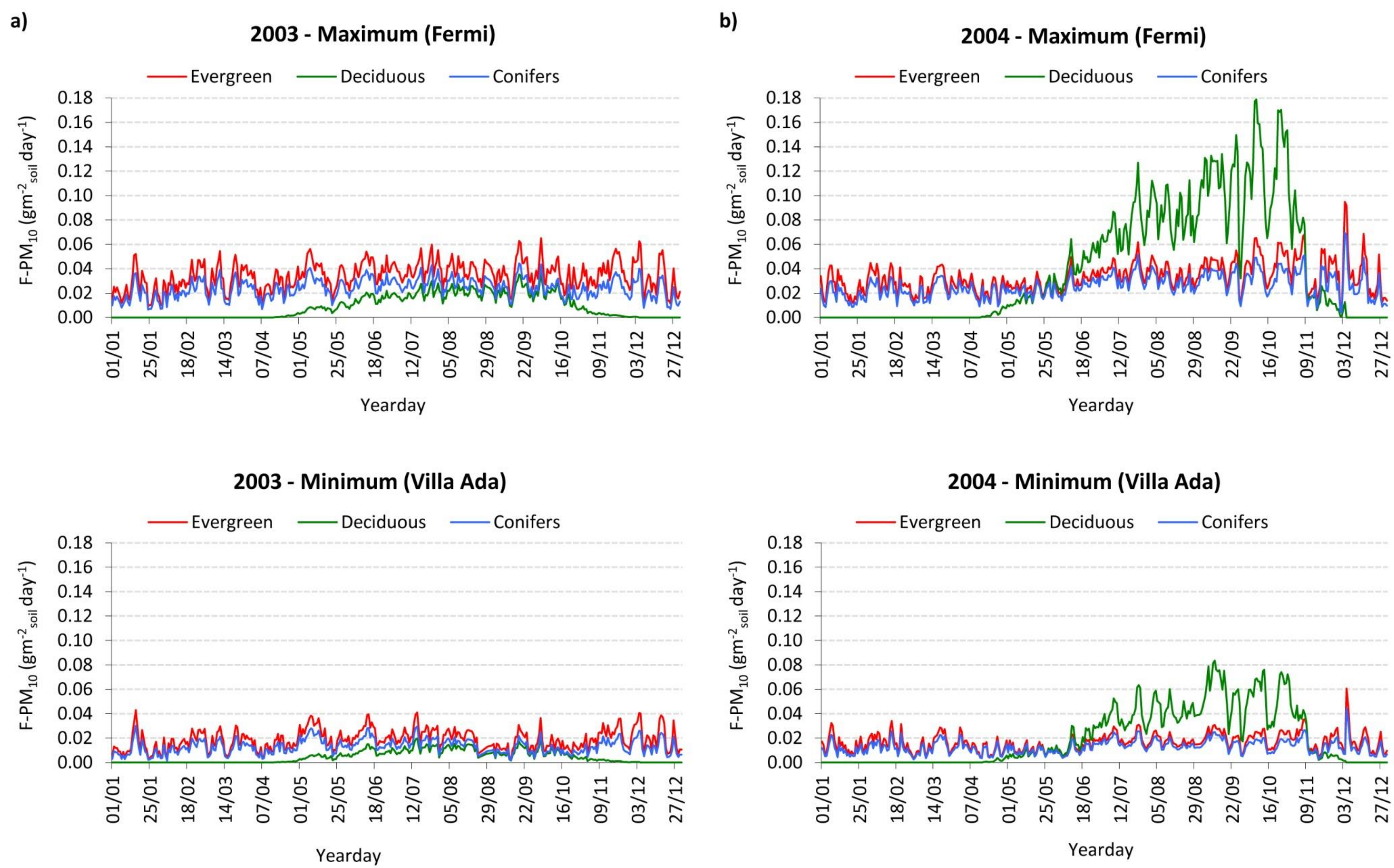
- $V_d$ is the dry deposition velocity of a given air pollutants
- C is the pollutant concentration in air

Following Escobedo & Nowak (2009), the $V_d$ for $PM_{10}$ was set to a median value of 0.0064 m $s^{-1}$ (Lovett, 1994) based on a LAI = 6 and then adjusted to the actual LAI, estimated by MOCA-Flux:

$$V_d(t) = 0.0064 \times \frac{LAI(t)}{6}$$

A 50% resuspension rate of particles back to the atmosphere was considered (Zinke, 1967).

# Modelling $PM_{10}$ deposition for the three vegetation leaf-types during the years 2003 and 2004



# MODELLING $PM_{10}$ DEPOSITION:

## Estimates of the total $PM_{10}$ removed by woody vegetation

The total amount of $PM_{10}$ removed by woody vegetation in 2003 and 2004 were obtained by integrating the mean daily deposition flux over the annual series (From: Manes et al., 2014):

| **Total $PM_{10}$ removed(t/$ha_{soil}$ per year)** | **2003** | | **2004** | |
|---|---|---|---|---|
| | **minimum** | **maximum** | **minimum** | **maximum** |
| Evergreen | 0.068 | 0.125 | 0.060 | 0.120 |
| Deciduous | 0.016 | 0.032 | 0.072 | 0.149 |
| Conifers | 0.048 | 0.088 | 0.047 | 0.094 |

**Yang et al. (2005) for the area of Beijing**, China, for the year 2002, reported a total pollutants removal by urban vegetation of 27.5 g/m$^2$; $PM_{10}$ was said to represent 61% of this amount, i.e. 16.7 g/m$^2$ = **0.167 t/ha**

# MODELLING $PM_{10}$ DEPOSITION:

## Estimates of the total $PM_{10}$ removed by woody vegetation

**Total $PM_{10}$ removed (t per year) - Rome municipality**

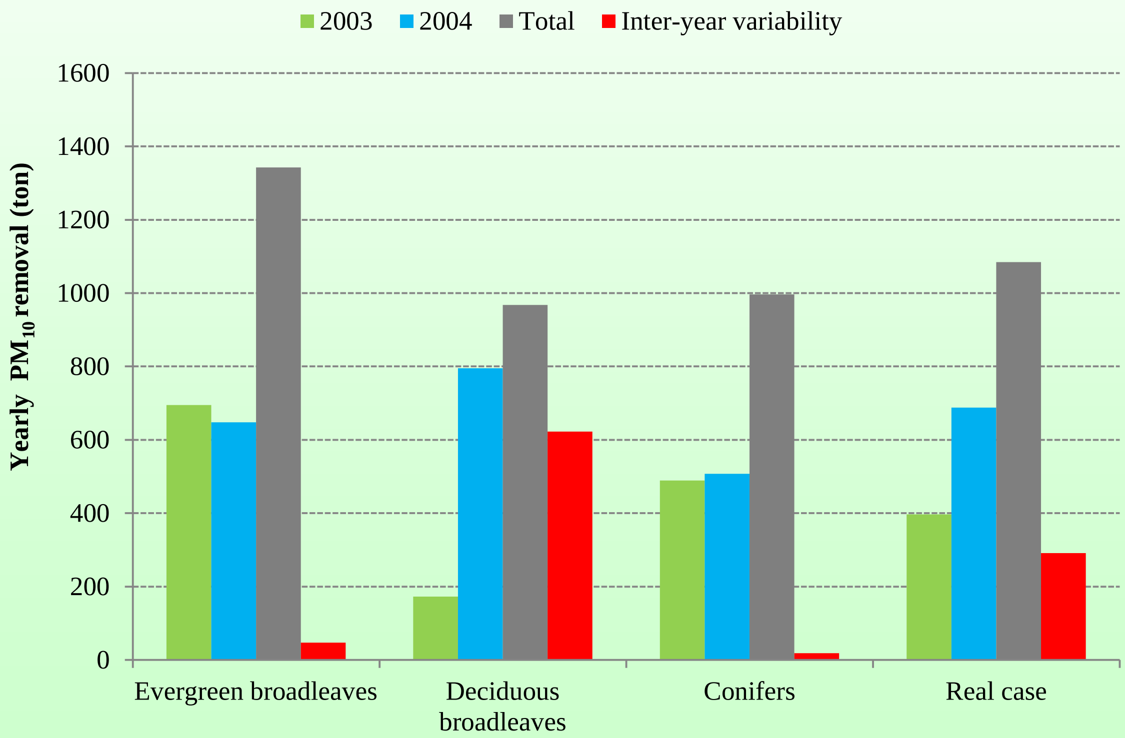
| | **2003** | | **2004** | |
|---|---|---|---|---|
| | **minimum** | **maximum** | **minimum** | **maximum** |
| Evergreen (2120 ha) | 144.3 | 265.8 | 127.6 | 255.3 |
| Deciduous (3477 ha) | 56.3 | 111.3 | 250.3 | 519.1 |
| Conifers (1601 ha) | 76.1 | 140.2 | 75.5 | 151.3 |
| Total (7198 ha) | 276.7 | 517.3 | 453.4 | 925.6 |

Total $PM_{10}$ removed in 2003 and 2004 by woody vegetation in the Rome Municipality. Minimum and maximum values are provided, based on the cumulated deposition fluxes (t/ha $_{soil}$ per year), and based on the area covered by each functional group (in brackets) (From: Manes et al., 2014).

# FUNCTION OF URBAN BIODIVERSITY:

## Synergy for the $PM_{10}$ removal Ecosystem Service

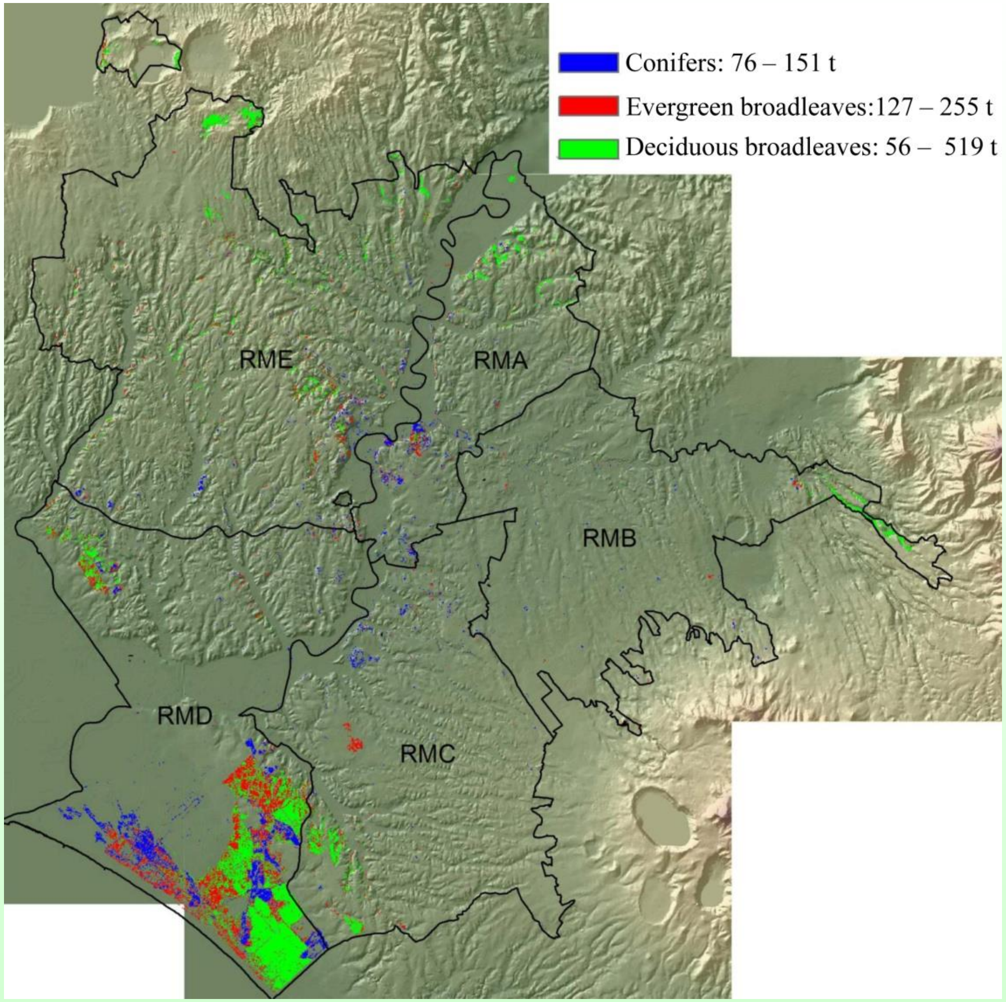
Simulation of yearly $PM_{10}$ removal that would have occurred in the Rome Municipality in 2003 and 2004 if all urban trees would belong to one single vegetation leaf-type, compared to the "real case" of vegetation cover in Rome Municipality (total: 7198 ha) (From: Manes et al., 2014)




"Real case":

- Evergreen broadleaves (2120 ha)
- Deciduous broadleaves (3477 ha)
- Conifers (1601 ha)

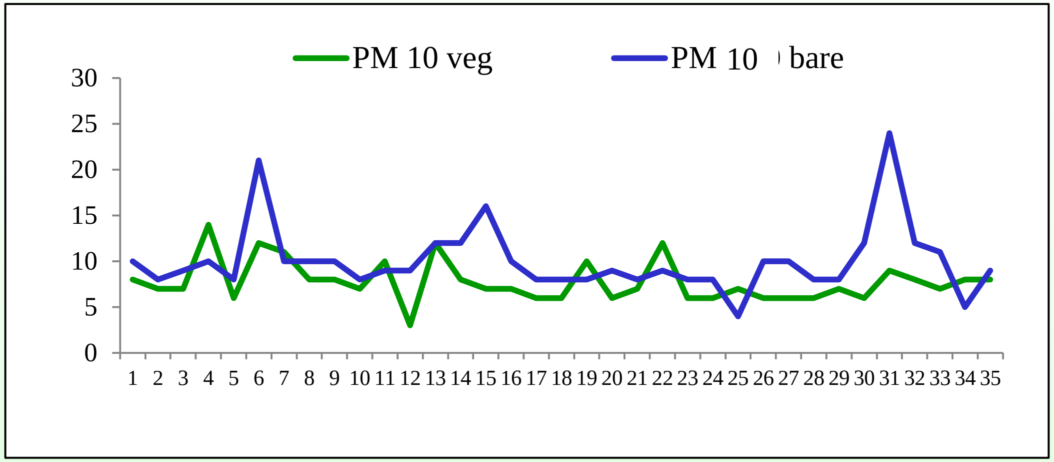
# ECOSYSTEM SERVICE MAP OF $PM_{10}$ REMOVAL

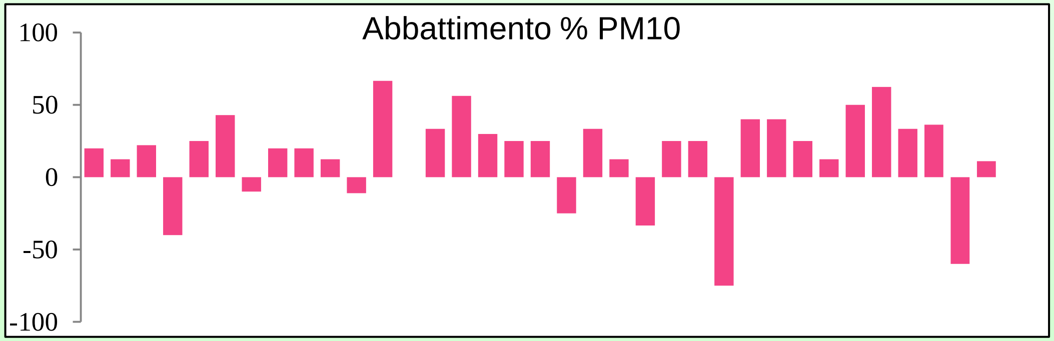



Map of the Ecosystem Service of $PM_{10}$ removal (min-max t per year) by the three functional groups in the Municipality of Rome, highlighting the difference in the air quality ameliorating capacity of the groups. The borders of the five Sanitary District (RMA, RMB, RMC, RMD, RME), as well as that of the whole Municipality, are marked in black (From: Manes et al., 2014).

# Villa Ada – effect of vegetation on $PM_{10}$ concentration

## Experimental measurements on "bare soil" and "vegetated soil" (trees+shrubs)




**OPC (Optical Particles Counter)**
**METONE mod. Aerocet 531**

**Principle of measurement**
***light scattering***

**[PM10] mean** **($\mu gm^{-3}$):** 10 (bare soil), 7.7 (vegetated soil)
**% mean abatement:** 16%

# THE PROJECT PRIN “TREECITY”
# Planning the green city in the Global Change era

**Organization of TreeCity:**

- WP1: City plant systems as an open lab to evaluate urban quality and stress conditions;
- WP2: Contribution of city plant ecosystems to quality of life;
- WP3: Combined stress induction in controlled environments to simulate a 2050 scenario;
- WP4: Integrated modelling;
- WP5: Dissemination;
- WP6: Project coordination.

**TreeCity**

*An International Project for a Better Quality of Life in Our Cities*

*Sponsored by* MIUR PRIN

**RESEARCH UNITS PARTICIPATING IN TREECITY**

**UR-PI**: Università di Pisa, Dipartimento di Coltivazione e Difesa delle Specie Legnose (COORDINATOR)
**UT-TUS**: Università degli Studi della Tuscia, Dipartimento per la Innovazione nei Sistemi Biologici, Agroalimentari e Forestali (DIBAF)
**UR-UNICATT**: Università Cattolica del Sacro Cuore, Dipartimento di Matematica e Fisica
**UR-CNRFI**: Consiglio Nazionale delle Ricerche, Istituto per la Protezione delle Piante
**UR-ROMA**: Università degli Studi di ROMA "La Sapienza" Dipartimento di Biologia Ambientale
**UR-PA**: Università degli Studi di Palermo, Dipartimento di DEMETRA
**UR-FI**: Università degli Studi di Firenze Dipartimento di Scienze delle Produzioni Vegetali, del Suolo e dell'ambiente Agroforestale (DIPSA)
**UR-TS**: Università degli Studi di Trieste, Dipartimento di Scienze della Vita

The 8 National RU are also supported by 9 foreign Research Institutions.

# THE PROJECT PRIN "TREECITY"

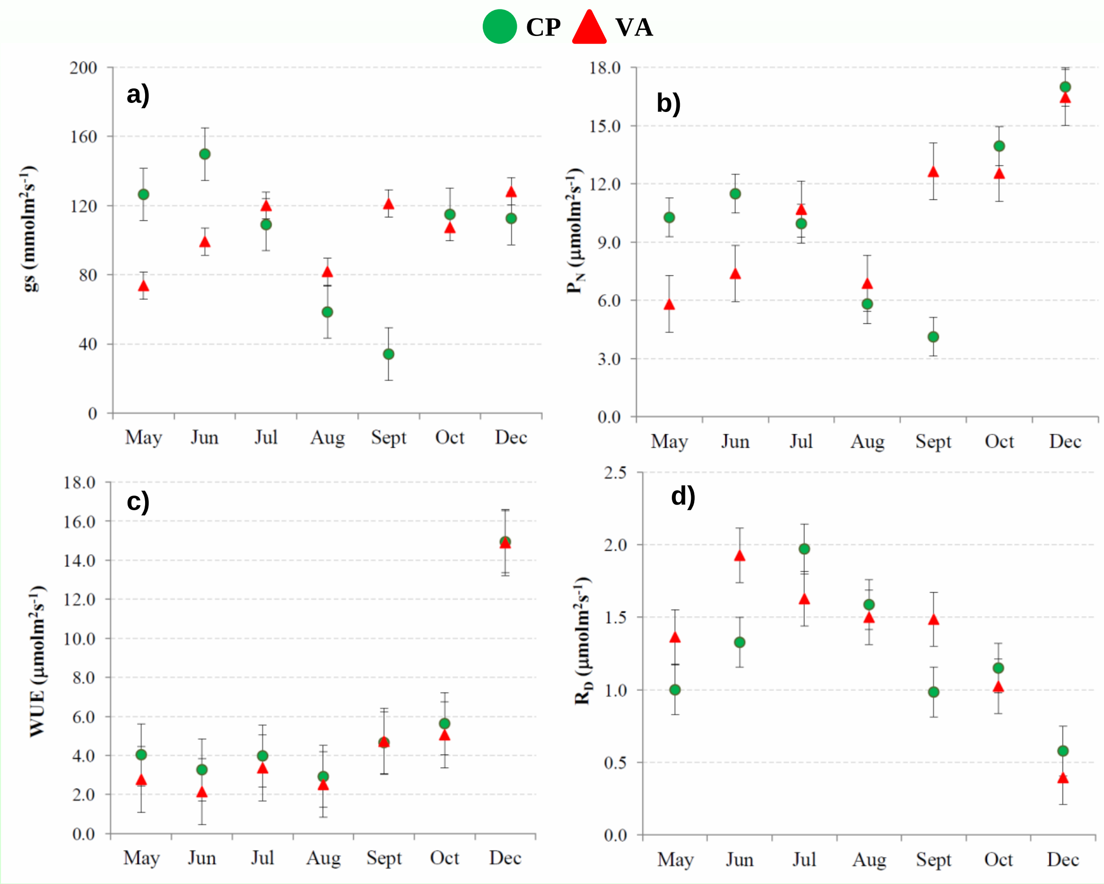
**Objectives of the Research Unit-ROMA:**

a) To assess the functional performance of *Quercuis ilex* L. in two green areas of Rome: the urban park of Villa Ada, and the natural periurban forest of the Castelporziano Presidential Estate;

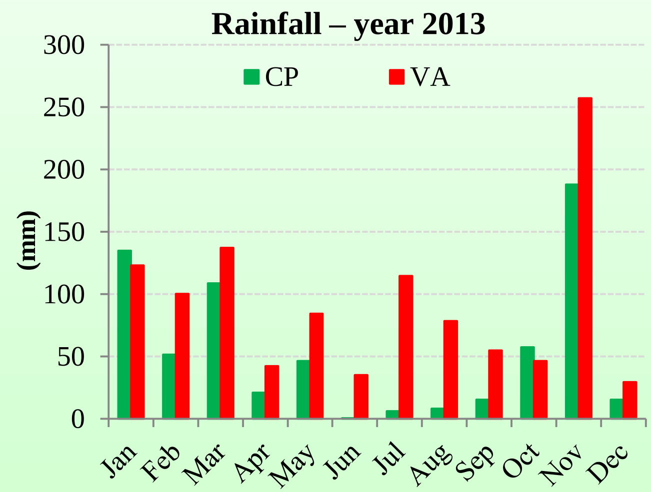
b) To quantify the contribution of urban and periurban forests to the quality of human life, by assessing their ecosystem service of air quality improvement.

# THE PROJECT PRIN “TREECITY”

## Gas exchanges measurements on *Q. ilex*, Villa Ada and Castelporziano




| | T (°C) | | VPD (mbar) | |
|---|---|---|---|---|
| | **CP** | **VA** | **CP** | **VA** |
| **May** | 26.4± 2.5 | 29.1± 2.0 | 27.0± 6.3 | 33.5± 3.7 |
| **June** | 32.6± 1.1 | 35.7± 1.8 | 32.1± 3.2 | 42.7± 6.8 |
| **July** | 31.9± 1.1 | 32.7± 1.6 | 28.3± 2.9 | 34.3± 4.5 |
| **August** | 32.8± 0.9 | 33.3± 2.0 | 36.7± 3.2 | 40.0± 7.6 |
| **September** | 27.8± 2.1 | 27.7± 1.2 | 28.6± 5.2 | 27.7± 3.0 |
| **October** | 28.4± 1.2 | 28.0± 3.2 | 26.6± 2.1 | 30.0± 6.3 |
| **December** | 18.1± 1.9 | 15.9± 2.8 | 12.7± 2.2 | 11.8± 2.9 |




Seasonal trend of gas exchanges measured in the two study sites (daily mean ± S.E.). In VA, $g_s$ and $P_N$ are significantly lower than in CP during spring, in correspondence to the higher T and VPD of the urban site (see Table). Coherently, in May and June dark respiration rates are higher in VA than in CP. From June to September a difference in rainfall is evident between the two sites, which resulted in lower gas exchanges values of CP in September. Interestingly, the Water Use Efficiency is similar in the two sites.

# URBAN GREEN: COST/BENEFITS ANALYSIS

## A study in 5 cities in the United States (McPherson, 2005):

- Annual cost per tree: 13 - 65 $
- Benefits: 1.37 – 3.09 $ for each dollar spent in the urban forest management

## A study in Davis, California (Maco et al., 2003):

- Net cost: 449353 $
- Benefits: 3.78 $ for each dollar spent in the urban forest management

## A study in the Netherlands (Maas et al., 2006):

- In areas where 90% of the environment around the home is green, only 10.2% of the residents feel unhealthy, as compared with areas in which 10% of the environment is green, where 15.5% of the residents feel unhealthy.

## Our study in Rome (Manes et al., 2012; HEREPLUS):

- $O_3$: Based on published unitary costs of externalities (6752 $/ton, Nowak et al., 2006), and of mortality associated with $O_3$, it has been estimated that the Ecosystem Service of $O_3$ removal from the Rome urban forest can be prudentially valued to roughly $2 and $3 million/yr, respectively.
- $PM_{10}$: Epidemiological studies reports that a reduction of the $PM_{10}$ concentration by 10% could avoid a 1.8% of deaths (all causes, excluding accidents) in people older than 30 years of age (Martuzzi et al., 2006). Therefore, considering on the basis of our findings a mean $PM_{10}$ abatement of 10% by the urban vegetation of Rome, about 180 deaths/year for the same city can be saved, in relation to the interannual climatic variation. Using a value of a statistical life of $1 million, the ecosystem service of $PM_{10}$ removal can be prudentially valued to roughly $180 million/yr.

# CONCLUSIVE REMARKS:

## Major Motivations for Urban Biodiversity Conservation

Benefits to nature

Benefits to humans

- Preserve local biodiversity in an urbanizing environment and protect important populations or rare species;
- Create stepping stones or corridors for natural populations;
- Understand and facilitate responses to environmental changes;
- Connect people with nature and provide environmental education;
- Provide ecosystem services;
- Fulfill ethical responsibilities;
- Improve human well-being.

(Modified from Dearborn and Kark, 2009)

# CONCLUSIVE REMARKS:

## Urban forest, air pollution mitigation and Ecosystem Services

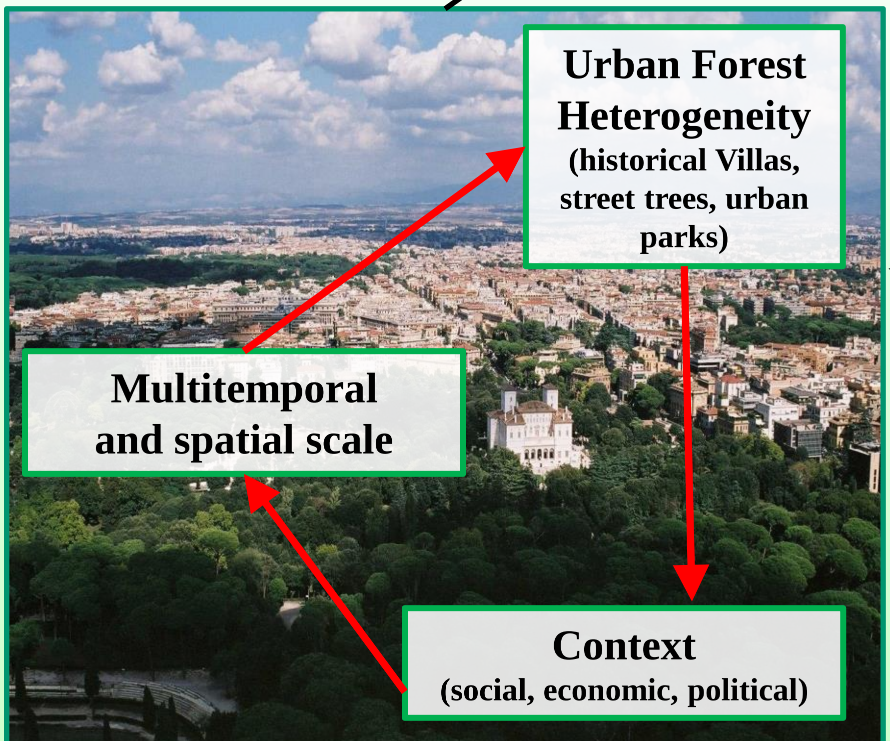
**Management**
**(action, intensity)**

**Ecosystem Structure**:
Main vegetation types

Humans manage, actively or not, their ecosystem structure, this yields ecosystem functions

**Ecosystem Function**:
Ecophysiological behaviour

Context, scale, and heterogeneity determine whether a particular end product of an ecosystem is a service or disservice and informs management




Context, scale, and heterogeneity determine whether a particular end product of an ecosystem is a service or disservice

**Ecosystem Services/Disservices**

$O_3$ and $PM_{10}$ removal

BVOC, allergies

(Adapted from Escobedo et al., 2011)

# CONCLUSIONS

These results point out the different morpho-functional response of the three considered vegetation types (evergreen, deciduous and conifers) in different climatic conditions, which may be of particular interest for management strategies aimed at increasing pollution removal performance by urban green, in the context of global change.

The synergism observed, being due to the specific seasonal phenological and ecophysiological dynamics of the three leaf types, highlights the need to preserve biodiversity, particularly in urban areas and in a climate change context.

Green Infrastructures, natural and constructed, and their biodiversity represent an important resource that have to be preserved, increased and sustained, in aiming to improve the quality of air and of the whole environment, especially in dense populated metropolitan areas.

Our results confirm the crucial role of vegetation in supporting significant Ecosystem Services as air quality improvement, highlighting the importance of biodiversity and green infrastructures to sustain and enhance benefits provided by parks and urban forests.

The European Strategy towards 2020 aims to achieve the key objectives “to halt the loss of biodiversity and the degradation of Ecosystem Services, and to restore them if possible”.

Protection, requalification and increase of both urban green and forested suburban areas, through specific management plans, is therefore fundamental for a sustainable development of metropolitan areas

# Thank you for your attention!

**Department of Environmental Biology,**
**Sapienza University of Rome**

**Research group of the**
**Laboratory of Functional Ecology:**

**Fausto Manes**
**Elisabetta Salvatori**
**Lina Fusaro**
**Valerio Silli**

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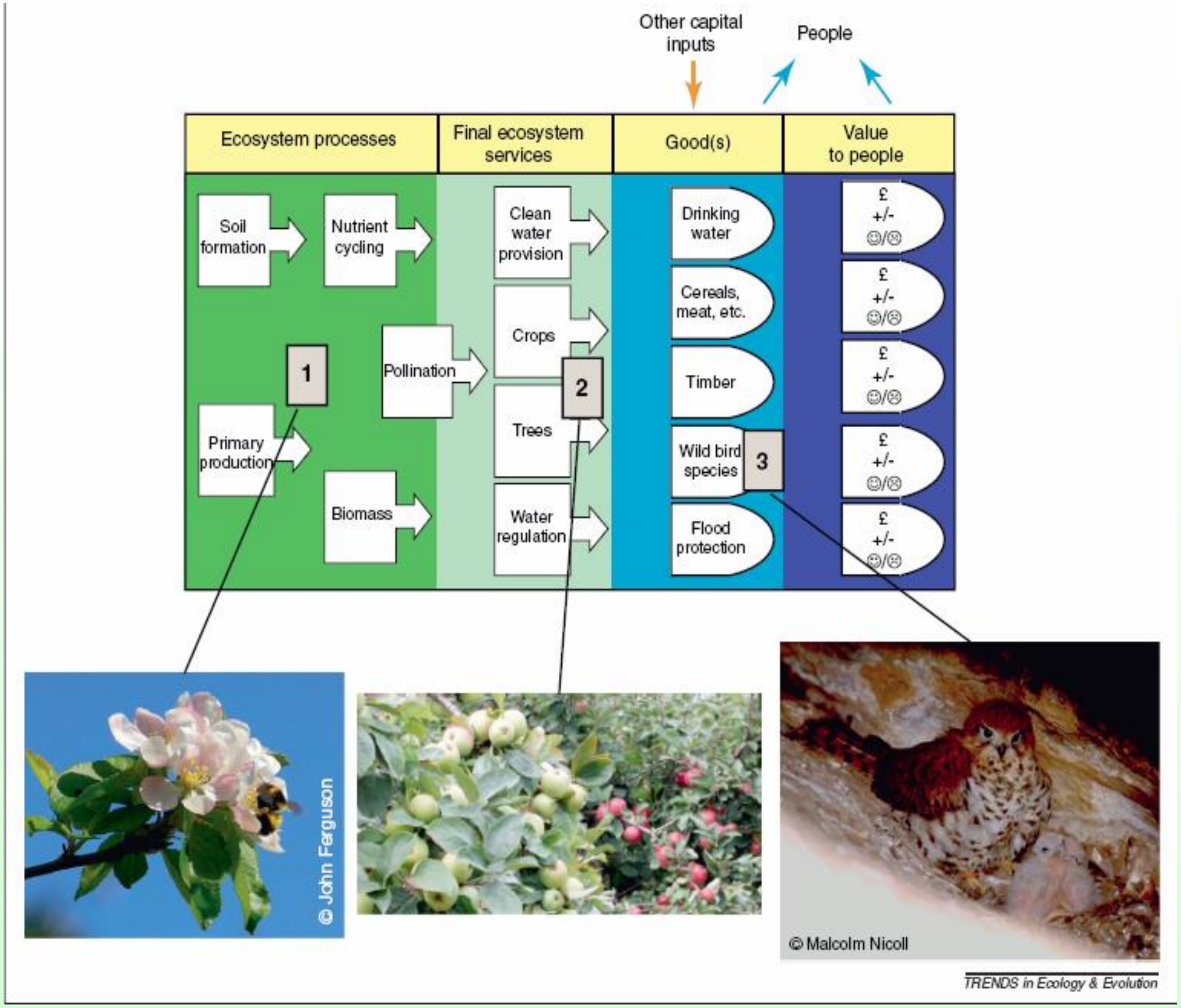
# ECOSYSTEM SERVICES




Schematic diagram of a selection of ecosystem processes and services that illustrates how ecosystem processes are linked to final ecosystem services and the goods and values they generate for people. The final ecosystem services are the outcomes from ecosystems that directly lead to good(s) that are valued by people. The full value is not only from the ecosystem but depends on the addition of inputs from society (other capital inputs) and the value is often context dependent. The final value of the good(s) is therefore attributable to both the ecosystem and human inputs. Values might be monetary (£), quantitative and non monetary (1/+) and/or qualitative( ☺ / ☹). (From Mace et al., 2012)