CONVEGNO INTERNAZIONALE

"Le città universitarie del XX Secolo e la Sapienza di Roma"

V Sessione

Il Sistema del verde e la città

SAPIENZA
UNIVERSITÀ DI ROMA

Green Infrastructures and Nature-Based solutions to improve regulating Ecosystem Services in Metropolitan Cities

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1. **Introduction**
   - **Natural Capital and Ecosystem Services**
   - **Urban areas and atmospheric pollutants**

2. **Case studies**
   - **Urban and periurban forests**
   - **Green Infrastructure**

3. **Conclusive message**

HORIZON 2020 GOALS – EU BIOBIVERSITY STRATEGY TO 2020

"Nature-based solutions" – "Ecosystem Services and Green Infrastructures"

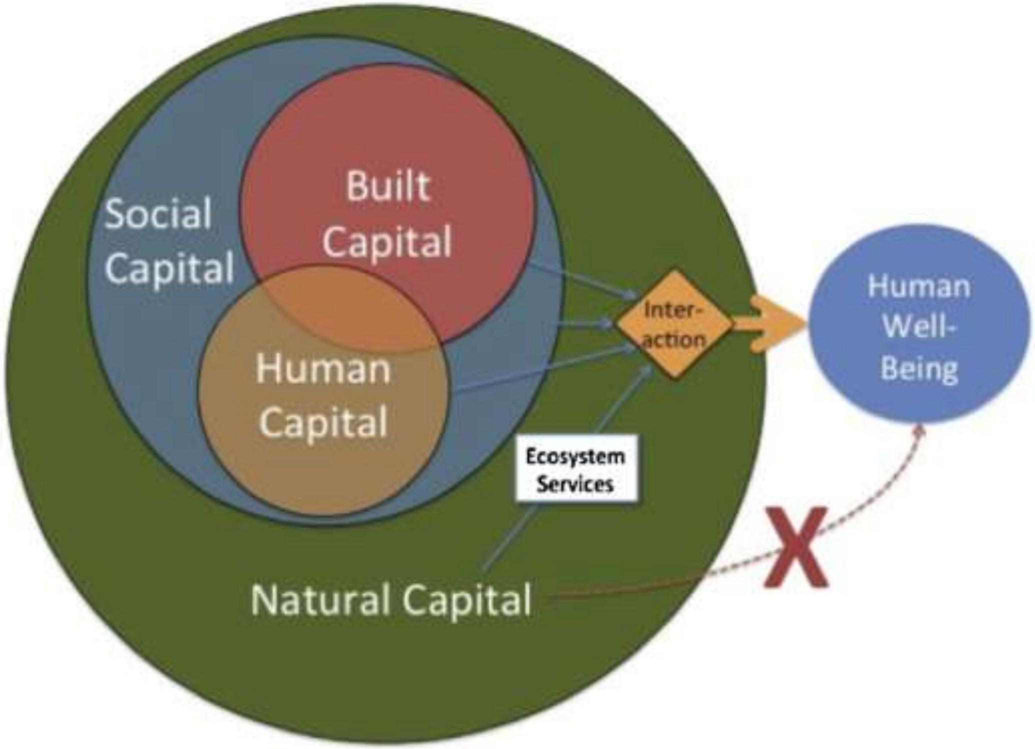
"Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience"

From EC, 2016

Focus on:

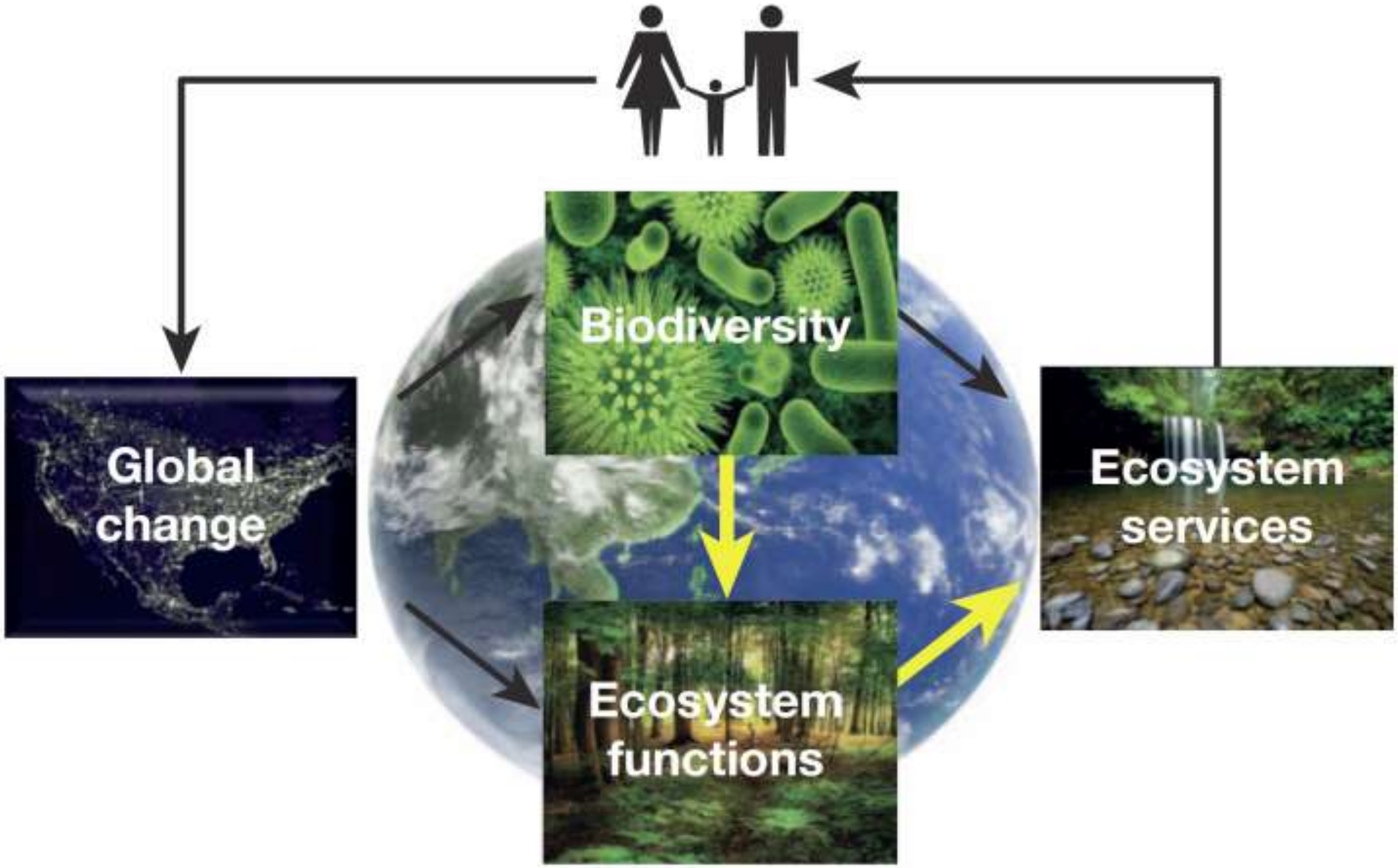
- Territorial resilience
- Renaturing cities

NATURAL CAPITAL AND ECOSYSTEM SERVICES



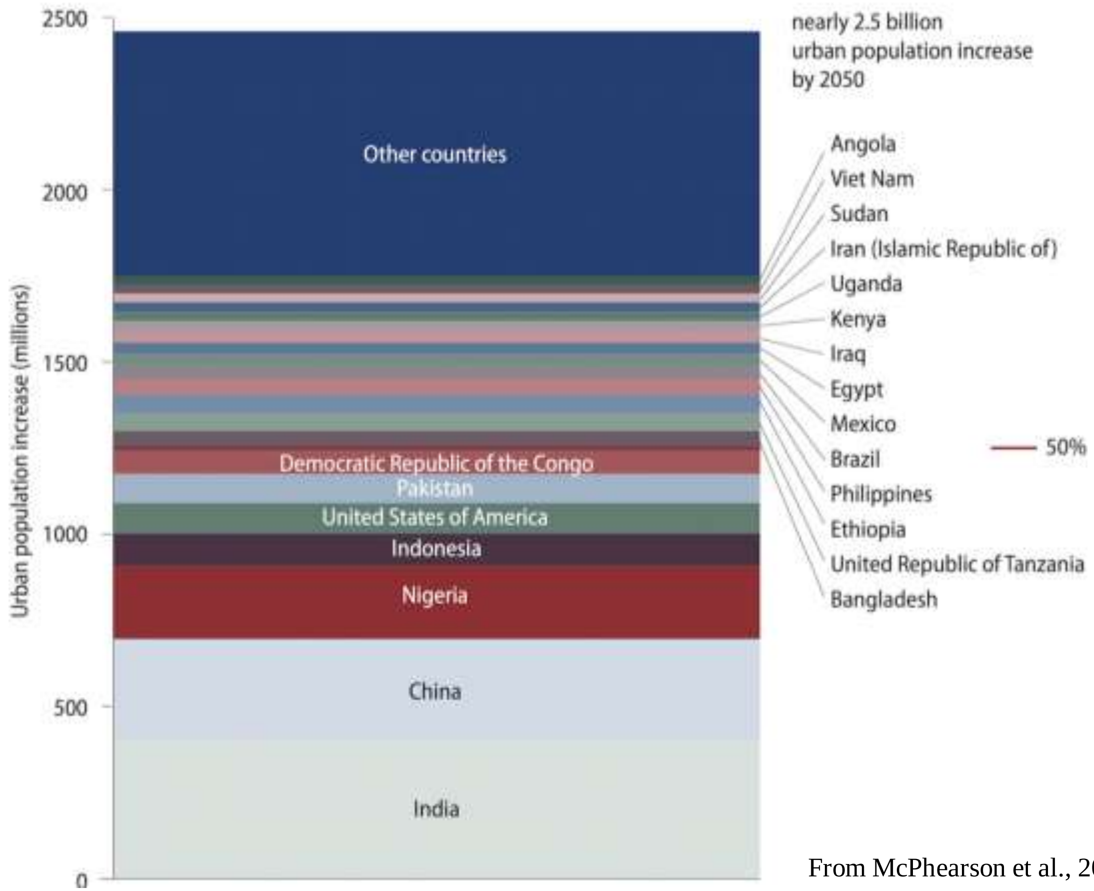
Interaction between built, social, human and natural capital required to produce human well-being. Built and human capital (the economy) are embedded in society which is embedded in the rest of nature. Ecosystem services are the relative contribution of natural capital to human well-being, they do not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

ECOSYSTEM SERVICES, BIODIVERSITY AND HUMAN WELL-BEING



Biodiversity per se, i.e. 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).

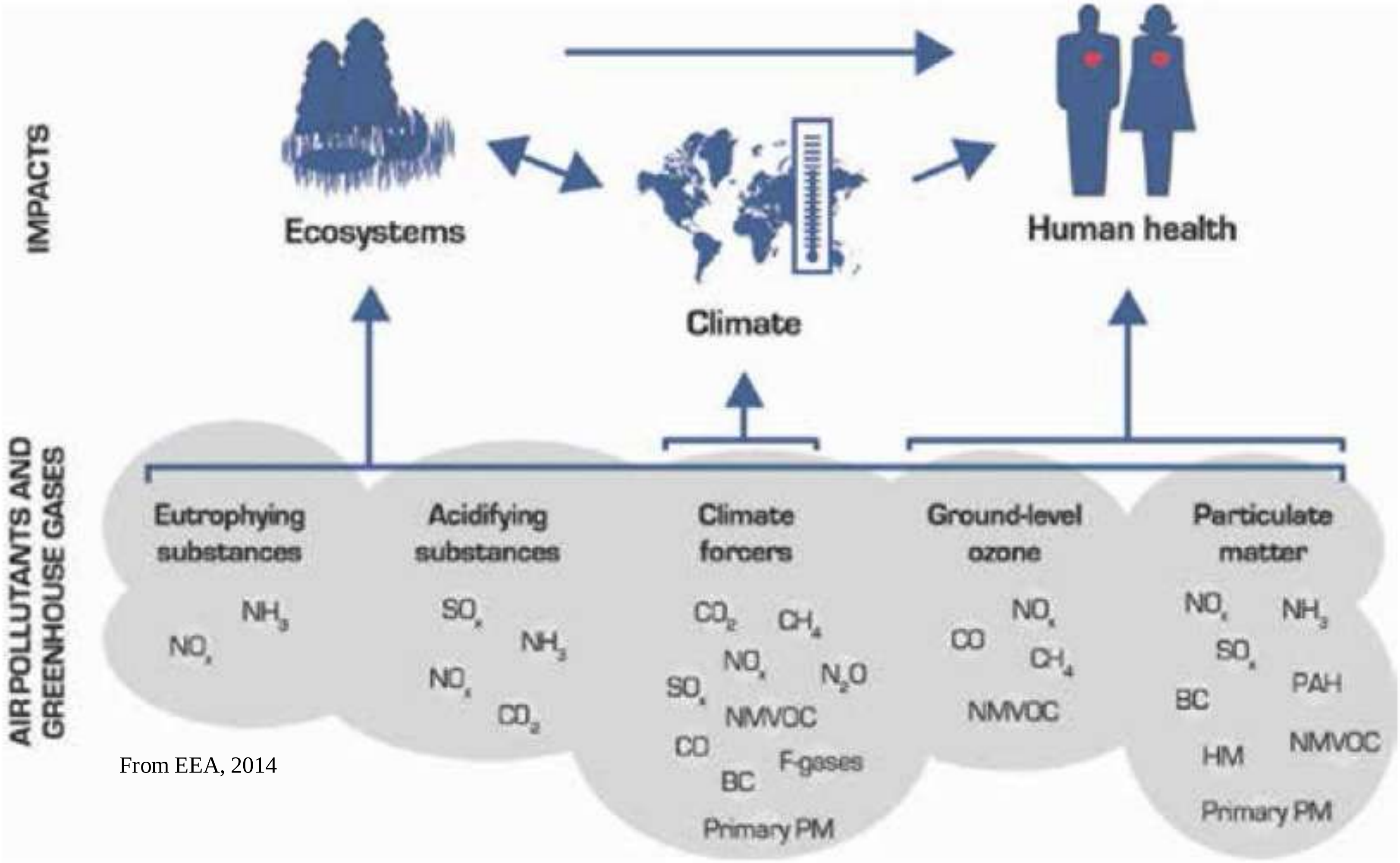
GLOBAL CONTRIBUTION TO THE INCREASE IN URBAN POPULATION BY COUNTRY, 2014 TO 2050



From McPhearson et al., 2016

The countries shown are projected to contribute 2.5 billion or more to the global urban increment between 2014 and 2050. India is projected to add 404 million urban dwellers, China 292 million, and Nigeria 212 million. The United States will continue to add significantly to its urban population, with nearly 90 million new urban inhabitants by 2050 (UN 2014).

GLOBAL CHANGES AND ENVIRONMENTAL POLLUTION



From EEA, 2014

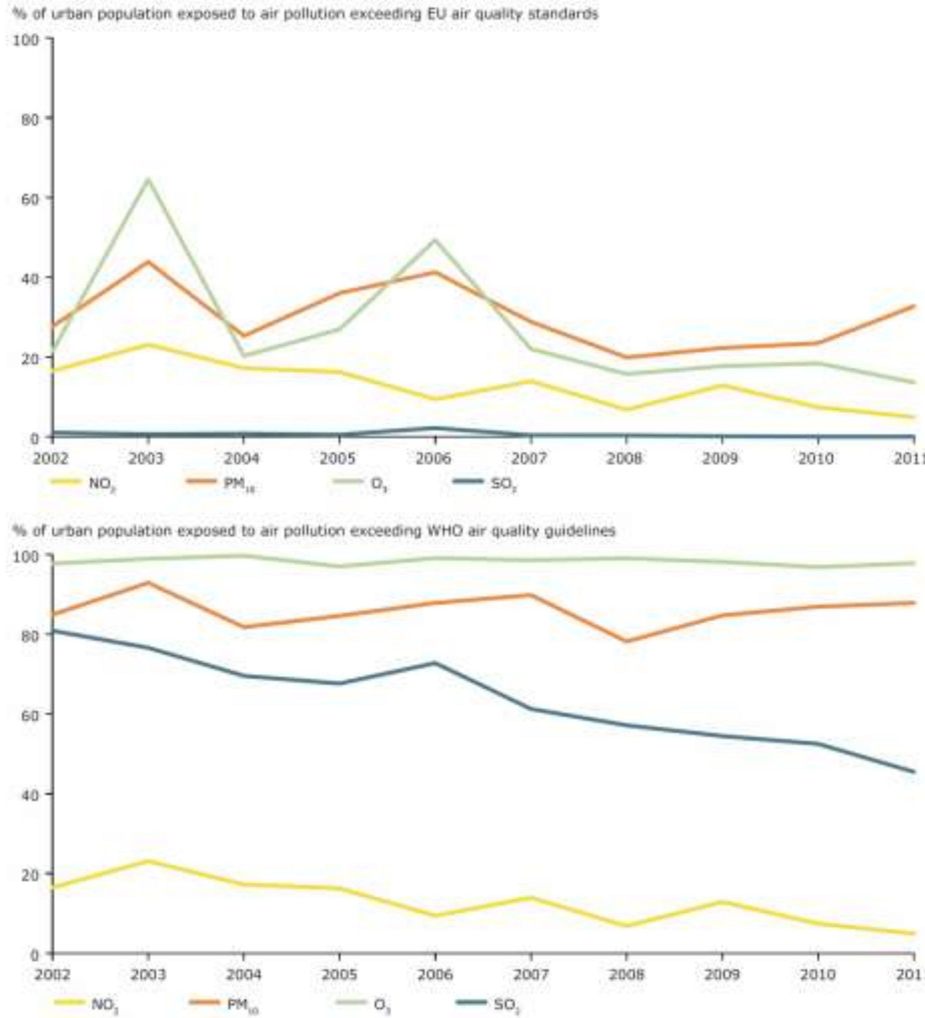
Premature deaths attributable to $PM_{2.5}$, O_3 and NO_2 exposure in 2014 in 41 European countries and the EU-28

Country	Population (1 000)	$PM_{2.5}$ Annual mean (a)	$PM_{2.5}$ Premature deaths (a) $C_0 = 0$	$PM_{2.5}$ Premature deaths (a) $C_0 = 2.5$	NO_2 Annual mean (a)	NO_2 Premature deaths (a) $C_0 = 20$	NO_2 Premature deaths (a) $C_0 = 10$	O_3 SOMO35 (a)	O_3 Premature deaths
Austria	8 507	12.9	5 570	4 520	19.2	1 140	3 630	4 423	260
Belgium	11 181	13.7	8 340	6 860	21.9	1 870	6 470	2 297	190
Bulgaria	7 246	24	13 620	12 280	16.5	740	3 570	2 519	200
Croatia	4 247	15.6	4 430	3 750	15.7	300	1 650	4 503	180
Cyprus	1 172 (a)	17	600	518	12.8	20	130	5 426	30
Czech Republic	10 512	18.6	10 810	9 430	16.8	550	3 640	3 822	310
Denmark	5 627	11.6	3 470	2 740	11	130	790	2 611	110
Estonia	1 316	8.7	750	540	9	10	130	1 991	20
Finland	5 451	7.4	2 150	1 440	8.3	40	450	1 615	60
France	63 798	11	34 880	27 170	17.7	9 330	23 420	3 786	1 630
Germany	80 767	13.4	66 080	54 180	20.2	12 860	44 960	3 287	2 220
Greece	10 927	17	11 870	10 190	14.9	1 660	4 280	5 926	570
Hungary	9 877	17.3	11 970	10 310	17.1	1 210	4 560	3 620	350
Ireland	4 606	9	1 480	1 070	6.1	10	160	868	20
Italy	60 783	15.8	59 630	50 550	22.5	17 290	42 480	5 569	2 900
Latvia	2 001	14.1	2 190	1 810	12.3	60	530	2 213	50
Lithuania	2 943	15.5	3 350	2 830	12.5	60	700	2 457	70
Luxembourg	550	11.9	230	190	19.9	40	180	2 872	10
Malta	425	12	220	180	16	10	100	6 946	20
Netherlands	16 829	13.8	11 200	9 240	21.9	2 560	8 610	2 244	250
Poland	38 018	23	46 020	41 300	15.1	1 700	10 200	3 425	970
Portugal	9 919	8.7	5 170	3 710	13.7	610	2 640	3 519	280
Romania	19 947	17.5	23 960	20 680	16.5	1 860	8 430	1 842	350
San Marino	33	13.5	30	20	14.7	< 5	10	5 949	< 5
Serbia	7 147	21.5	10 770	9 580	19.6	1 380	4 600	2 668	190
Switzerland	8 140	11.6	4 240	3 340	20.9	980	3 560	4 417	220
Total (a)	**534 471**	**14.1**	**428 000**	**356 000**	**18.6**	**78 000**	**241 000**	**3 501**	**14 400**
EU-28 (a)	**502 351**	**14.0**	**399 000**	**332 000**	**18.7**	**75 000**	**229 000**	**3 507**	**13 600**

For $PM_{2.5}$, calculations have been made using a counterfactual concentration (C_0) of 0 $\mu g/m^3$, as in previous years and a C_0 of 2.5 $\mu g/m^3$ to take into account the estimated European background concentration. For NO_2, calculations have been made using C_0 values of 20 and 10 $\mu g/m^3$

From EEA, 2017

AIR QUALITY IN EUROPEAN CITIES



From EEA, 2013 – Air quality in Europe

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).

Urban Green and Ecosystem Services

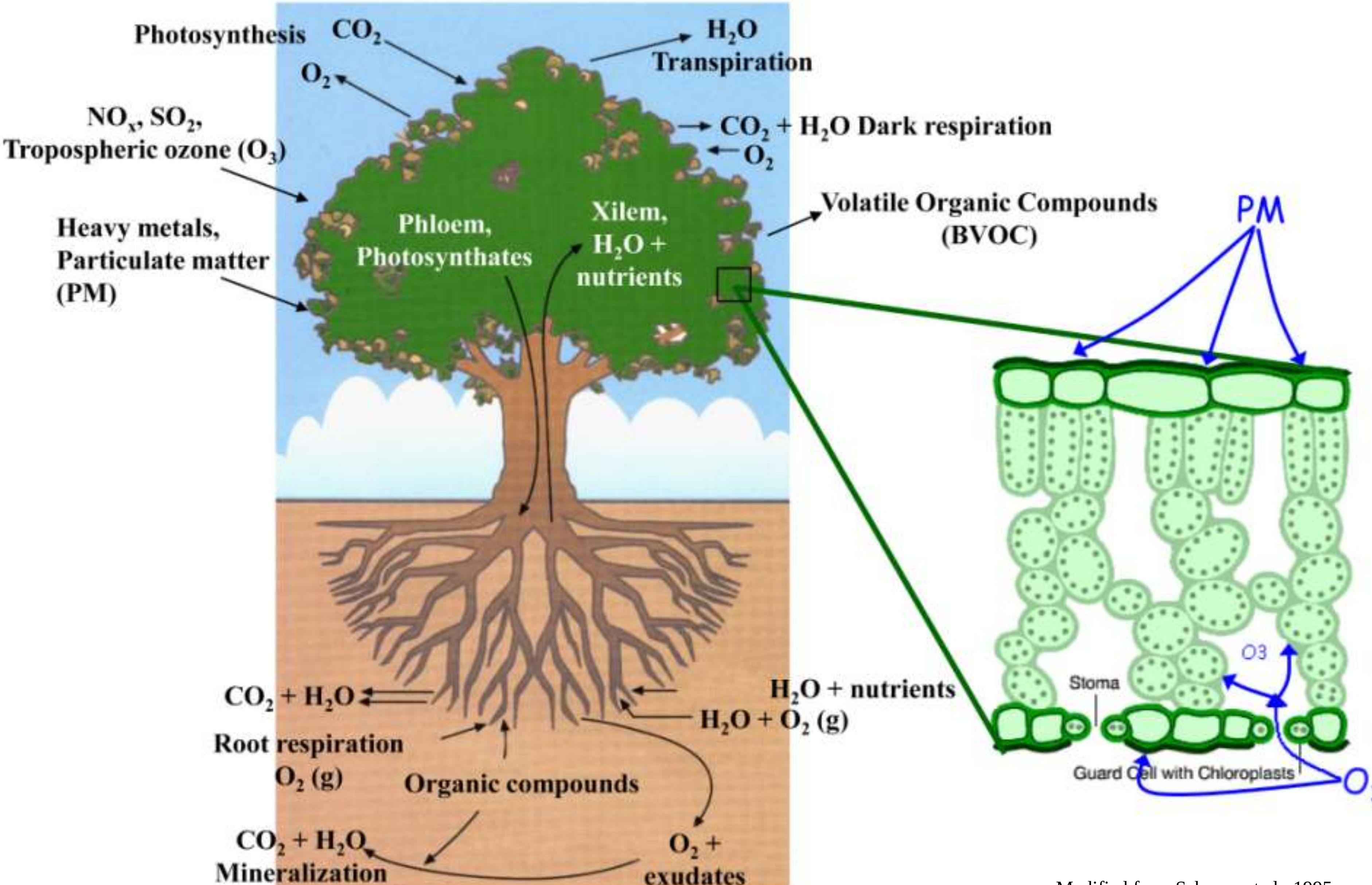
As ecosystem services are by definition addressed to human well-being, it is of paramount importance to quantify their overall performance, stability, and value in cities where human population density is highest (Dearborn and Kark 2009).

	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).

Soil–plant–atmosphere relations and interactions with atmospheric

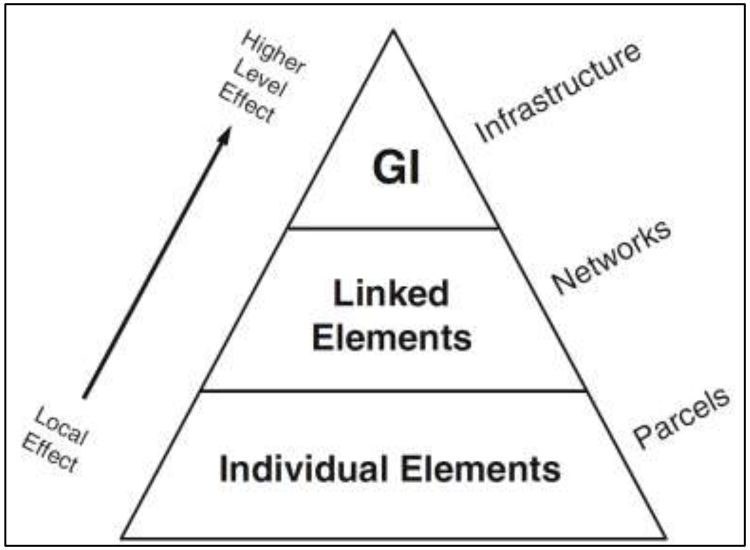


Modified from Schnoor et al., 1995

CATEGORIZATION OF ECOSYSTEM SERVICES SUPPORTED BY GREEN INFRASTRUCTURE

Category of Service	Ecosystem Service
Provisioning	Water quantity and quality Food quantity and quality Medicine
Regulating	Air quality Infectious disease modulation Climate regulation
Cultural	Physical activity Mental health Social capital

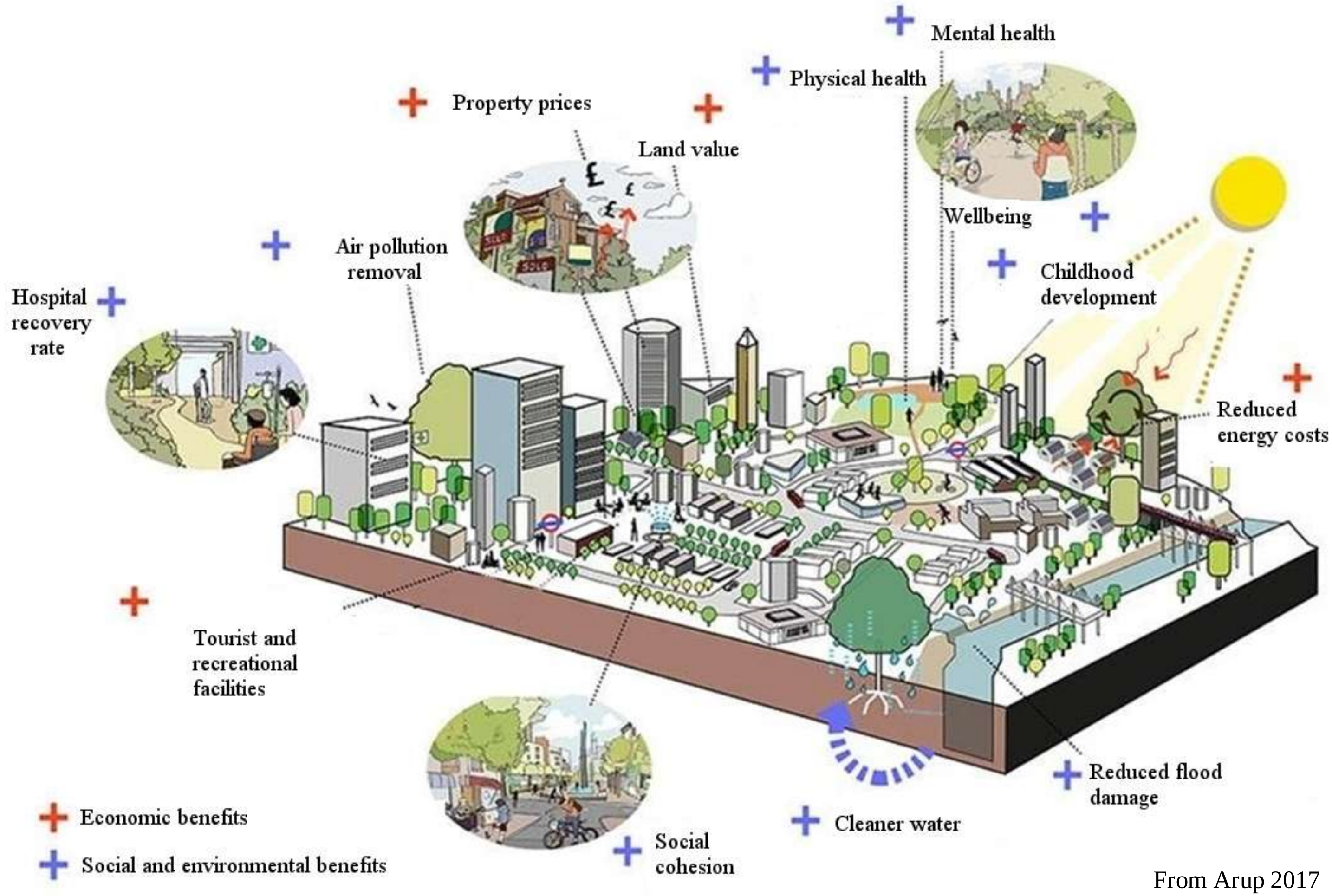
From Coutts & Hahn, 2015



From Hansen & Pauleit, 2014

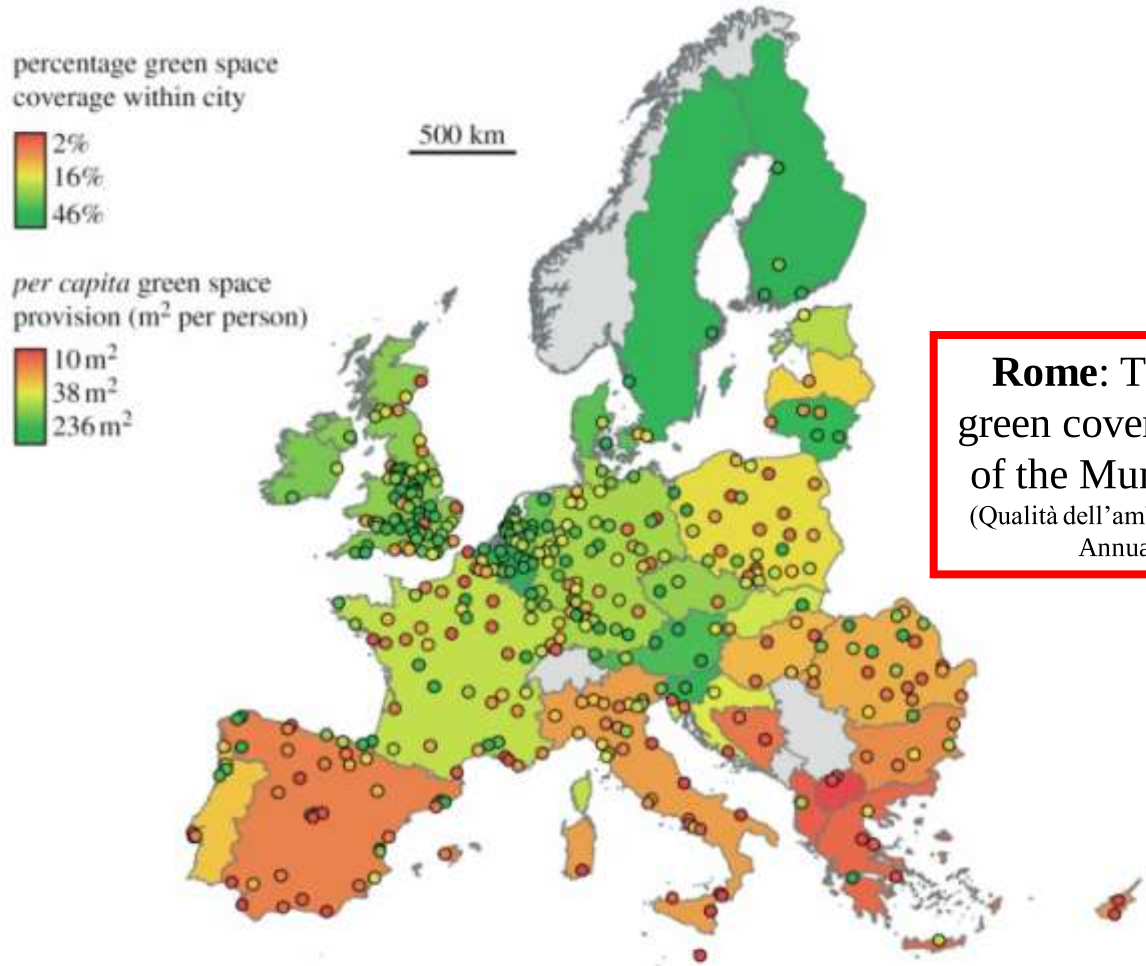
URBAN GREEN INFRASTRUCTURE AND ECOSYSTEM SERVICES

Urban vegetation can affect directly or indirectly local and regional air quality (effects on microclimate, removal of pollutants) (Manes et al., 2012; Nowak et al., 2014)



From Arup 2017

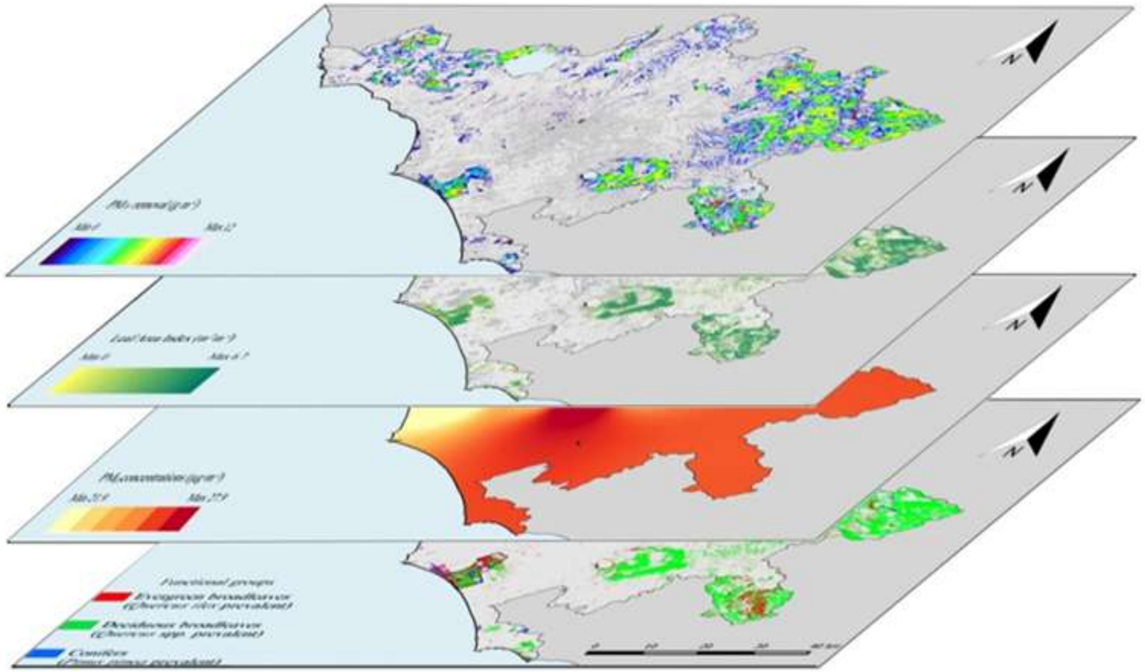
URBAN GREEN SPACE COVERAGE IN EUROPE

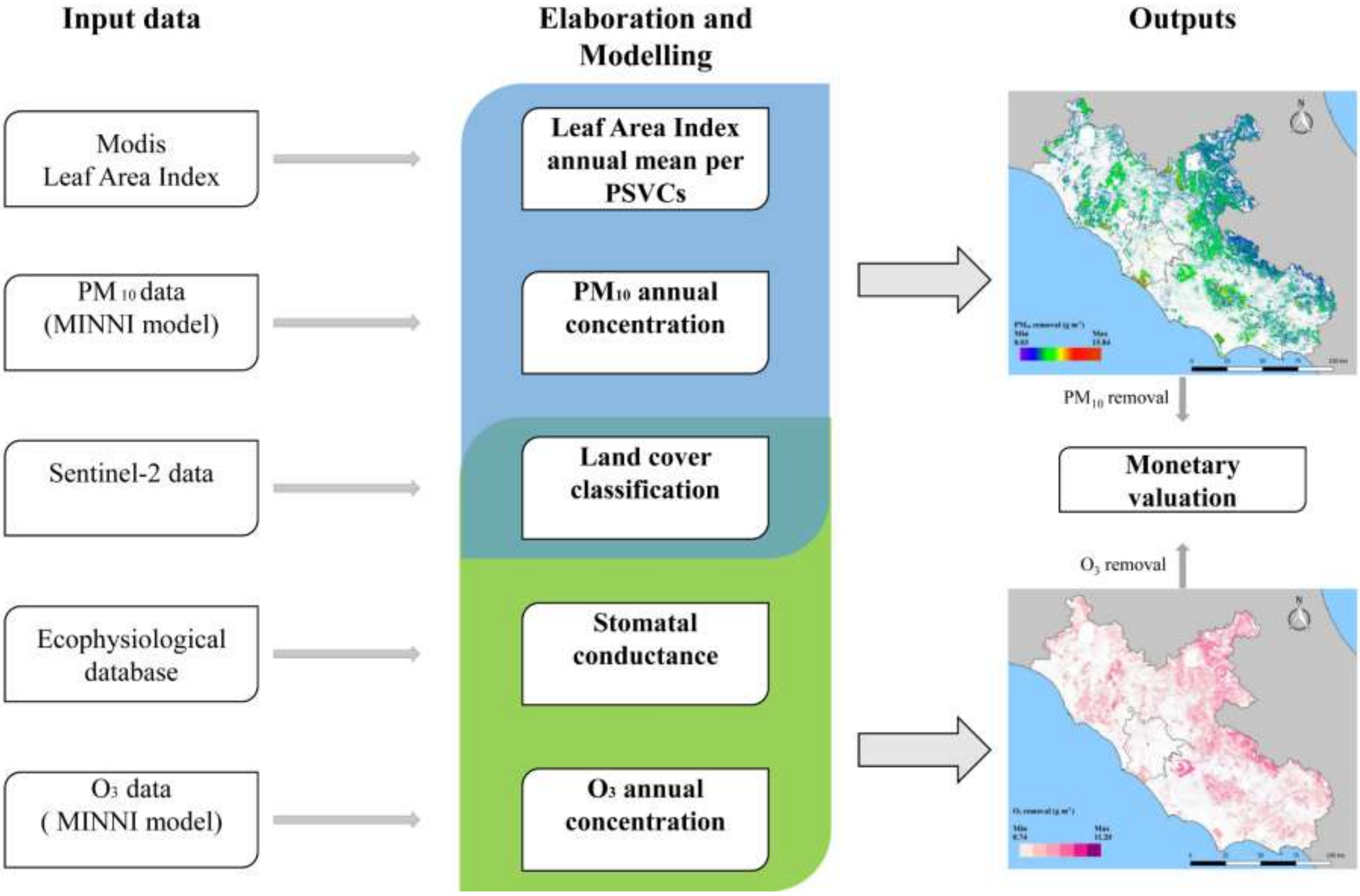


Rome: The public urban green covers more than 20% of the Municipality surface (Qualità dell'ambiente Urbano. V Rapporto Annuale ISPRA, 2008)

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).

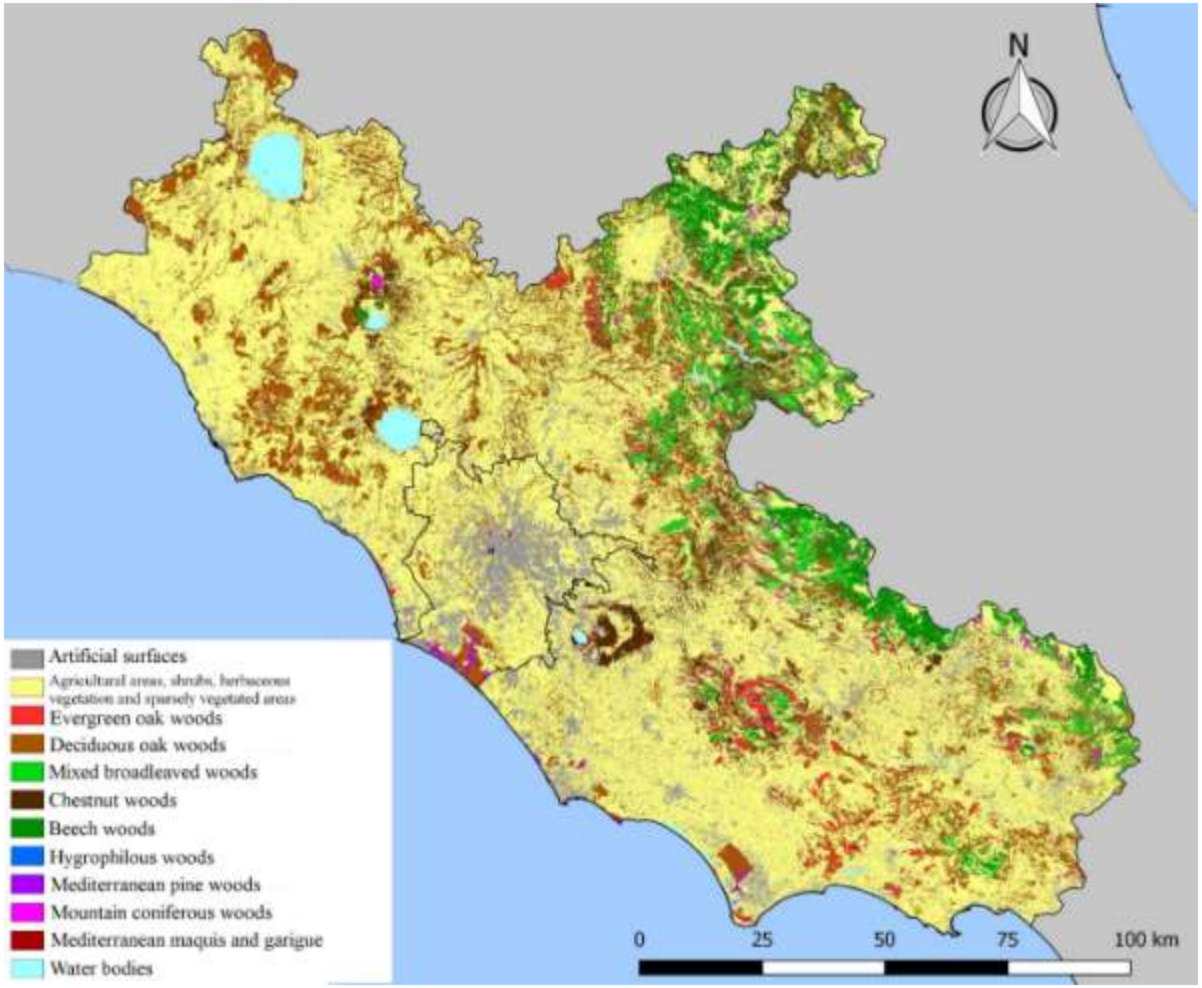
CASE STUDIES





From Fusaro et al., 2017 - *Remote Sensing*

Land cover classification of the Latium region



Map obtained by supervised classification of Sentinel-2 images recorded from 25 June to 3 September 2016. The area inside the outline represents the Municipality of Rome

From Fusaro et al., 2017 - *Remote Sensing*

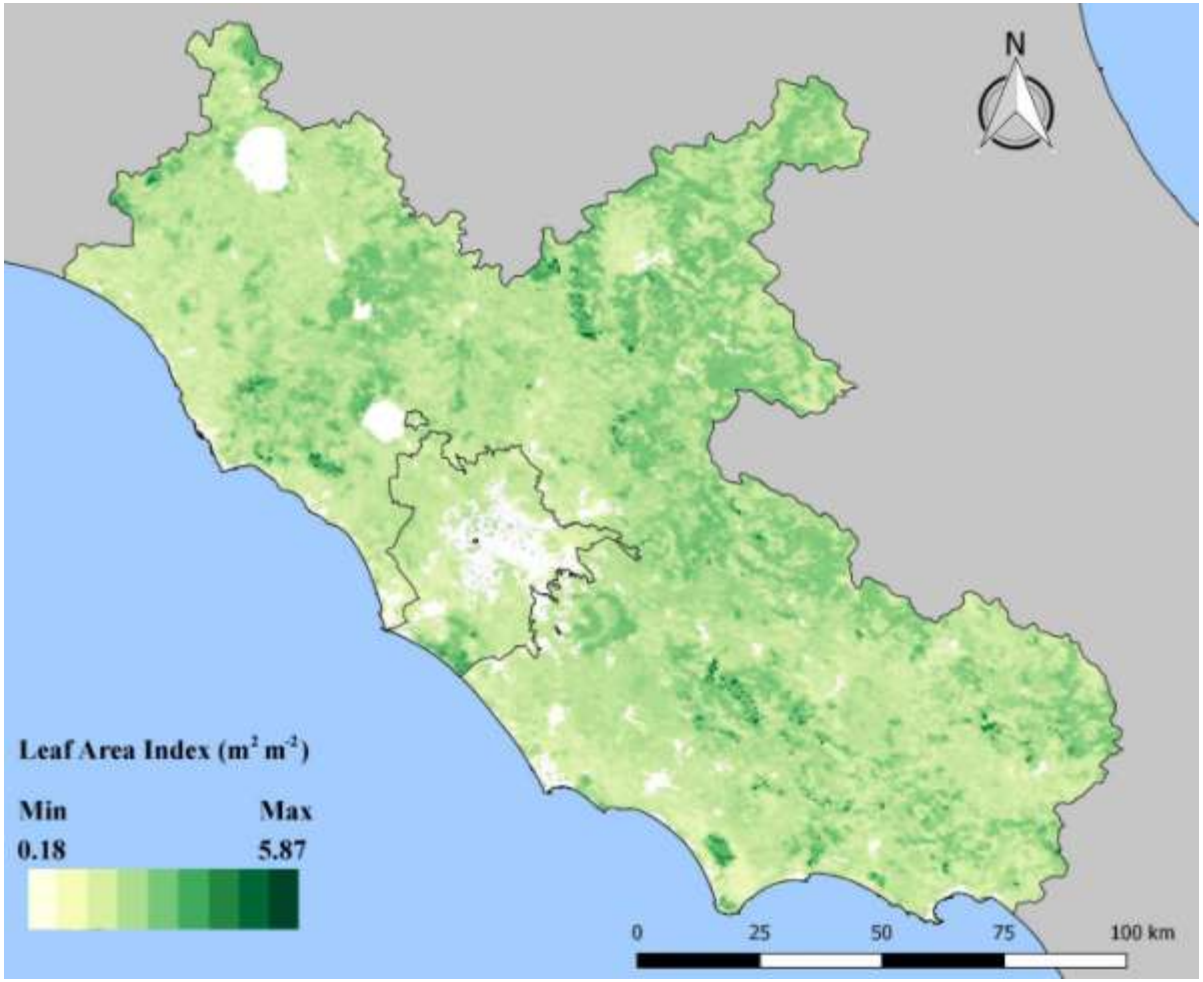
Land cover classification of the Latium region: Phisiognomic-Structural Vegetation Classes (PSVC)s

PSVCs	Municipality of Rome	Latium Region
Evergreen oak woods	407.2	51,542.4
Deciduous oak woods	11,746.9	210,418.7
Mixed Broadleaved woods	10.6	71,427.9
Chestnut woods	143.0	80,075.1
Beech woods	0.0	58,256.9
Hygrophilous woods	0.0	1665.9
Mediterranean pine woods	2410.8	3591.8
Mountain Coniferous woods	207.9	12,300.0
Mediterranean maquis	511.2	5829.2
Total	15,437.6	495,107.9

Surface cover (ha) of nine Phisiognomic-Structural Vegetation Classes (PSVC)s in the Municipality of Rome and in the Latium region.

From Fusaro et al., 2017 - *Remote Sensing*

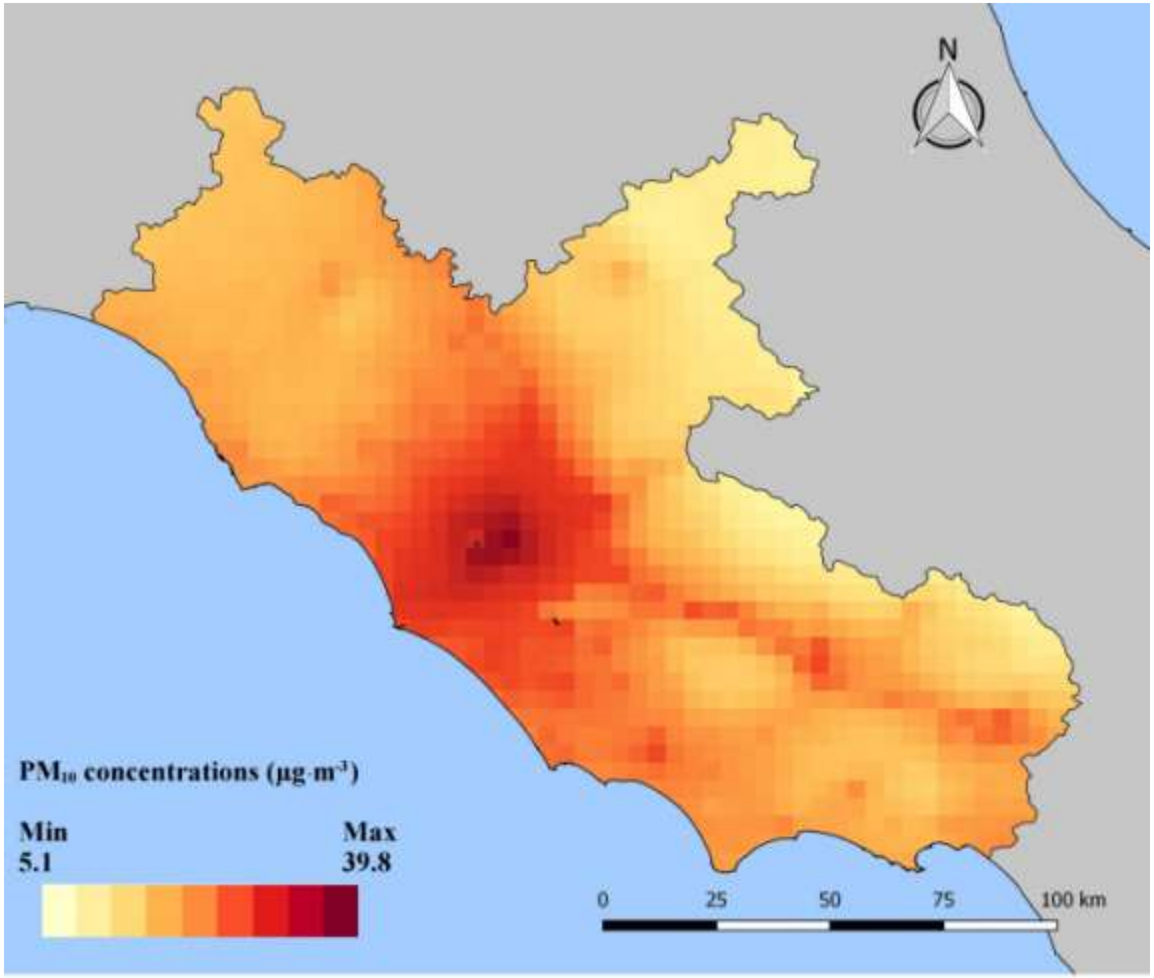
Leaf Area Index of the Latium region



Leaf Area Index map derived from MODIS LAI product (2016)

From Fusaro et al., 2017 - *Remote Sensing*

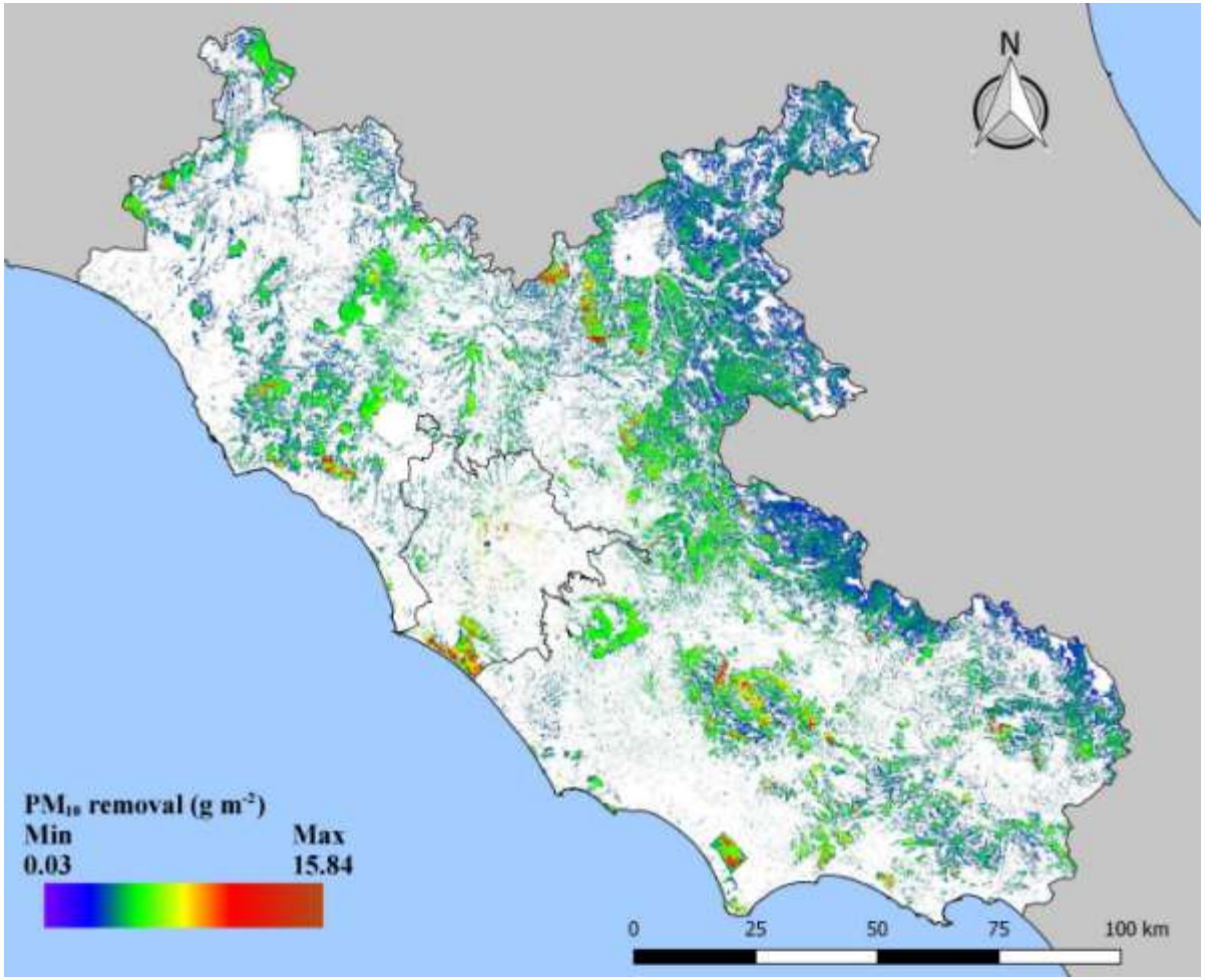
PM_{10} concentrations of the Latium region



Mean annual PM_{10} concentrations, estimated fom the AMS-MINNI model (year 2010)

From Fusaro et al., 2017 - *Remote Sensing*

PM_{10} removal by 9 PSVCs in the Latium region (year 2010)

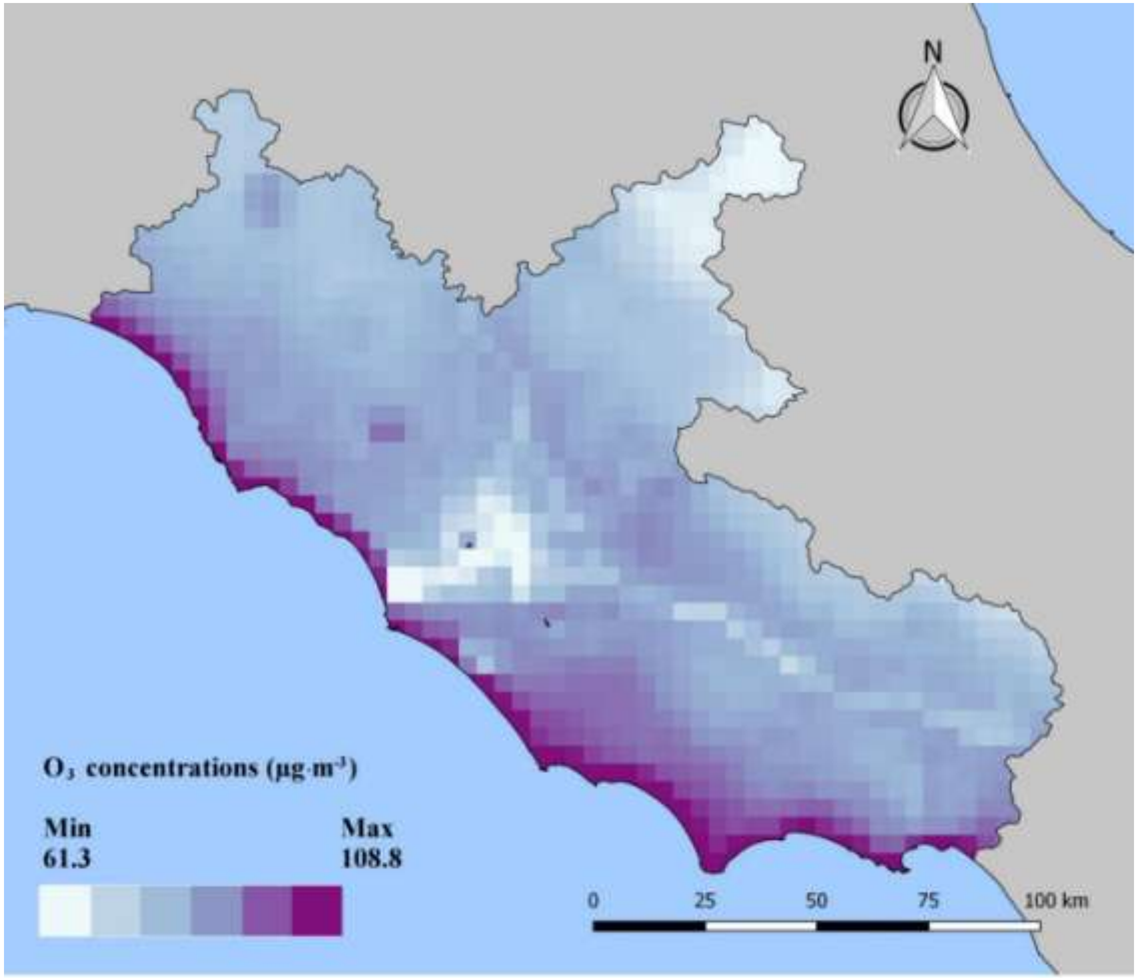


Map of annual PM_{10} removal ($g\ m^{-2}$)

PM_{10} deposition model (Nowak, 1994; Escobedo and Nowak, 2009): $Q = F \times L \times T$

From Fusaro et al., 2017 - *Remote Sensing*

O_3 concentrations of the Latium region

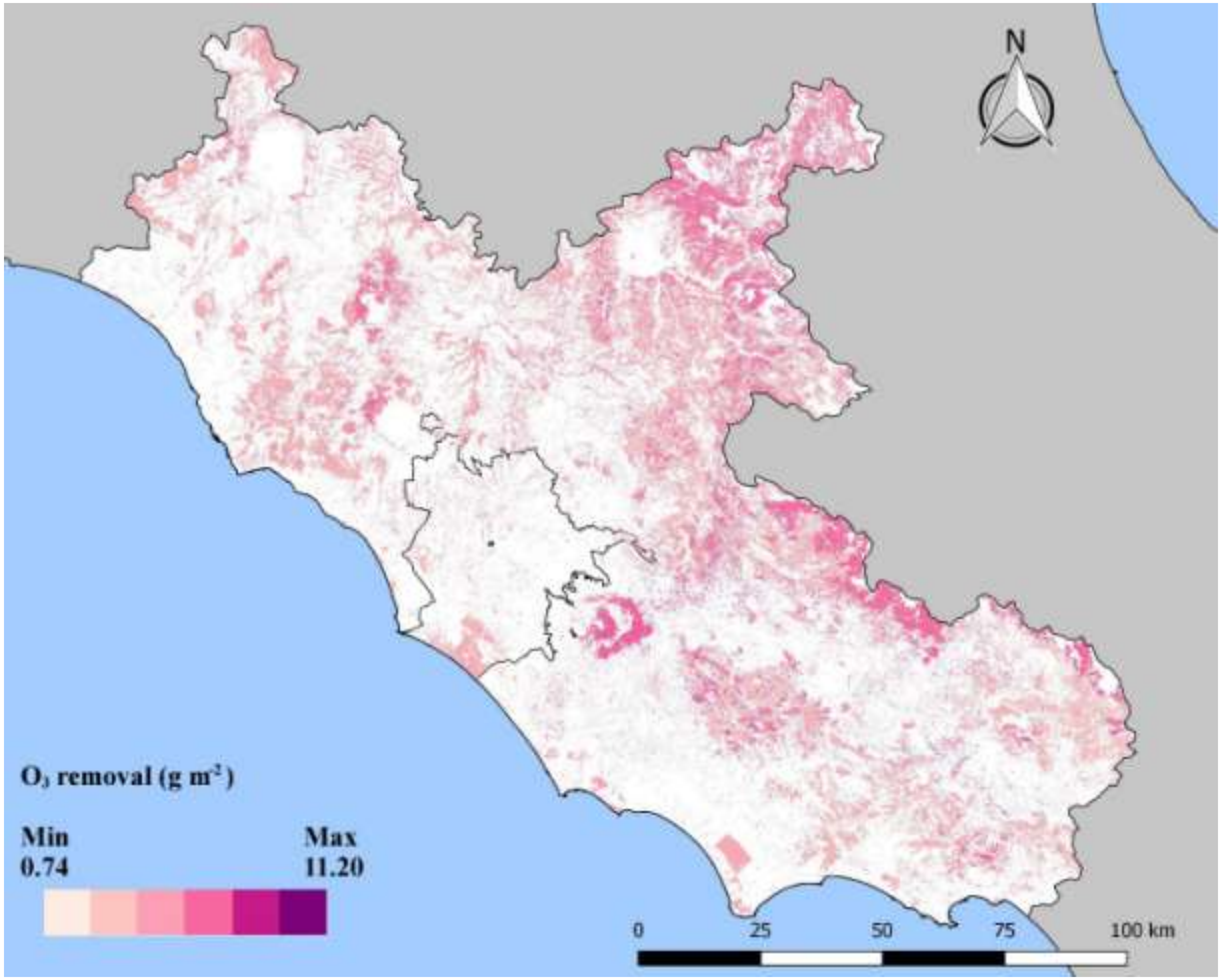


Mean annual O_3, concentrations, estimated fom the AMS-MINNI model (year 2010)

Stomatal O_3 flux model (Manes et al., 2012): $FO_3 = g_s \times [O_3] \times 0.613$

From Fusaro et al., 2017 - *Remote Sensing*

O_3 removal by 9 PSVCs in the Latium region (year 2010)



Map of annual O_3 removal (g m^{-2})

From Fusaro et al., 2017 - *Remote Sensing*

PM_{10} removal by 9 PSVCs and corresponding monetary value

PSVCs (Municipality of Rome)	Mg	$Mg \cdot ha^{-1}$	Value ($€ \cdot 10^6$)
Evergreen oak woods	14.80	0.0363	0.464
Deciduous oak woods	161.73	0.0138	5.071
Mixed broadleaved woods	0.08	0.0075	0.003
Chestnut woods	1.29	0.0090	0.040
Beech woods	n.a	n.a.	n.a
Hygrophilous woods	n.a.	n.a.	n.a.
Mediterranean pine woods	92.00	0.0382	2.885
Mountain coniferous woods	4.59	0.0221	0.144
Mediterranean maquis	19.34	0.0378	0.606
Total	293.83	0.0190	9.213
PSVCs (Latium Region)	**Mg**	**$Mg \cdot ha^{-1}$**	**Value ($€ \cdot 10^6$)**
Evergreen oak woods	1060.53	0.0206	33.254
Deciduous oak woods	1822.75	0.0087	57.154
Mixed broadleaved woods	523.68	0.0073	16.421
Chestnut woods	734.60	0.0092	23.034
Beech woods	351.18	0.0060	11.011
Hygrophilous woods	8.83	0.0053	0.277
Mediterranean pine woods	64.02	0.0178	2.007
Mountain coniferous woods	164.80	0.0134	5.167
Mediterranean maquis	99.31	0.0170	3.114
Total	4829.69	0.0098	151.440

PM_{10} removed in the Municipality of Rome and in the Latium region (year 2010), expressed as total removal (Mg) and removal per hectare ($Mg \cdot ha^{-1}$), and its monetary value ($€ \cdot 10^6$).

From Fusaro et al., 2017 - *Remote Sensing*

O_3 removal by 9 PSVCs and corresponding monetary value

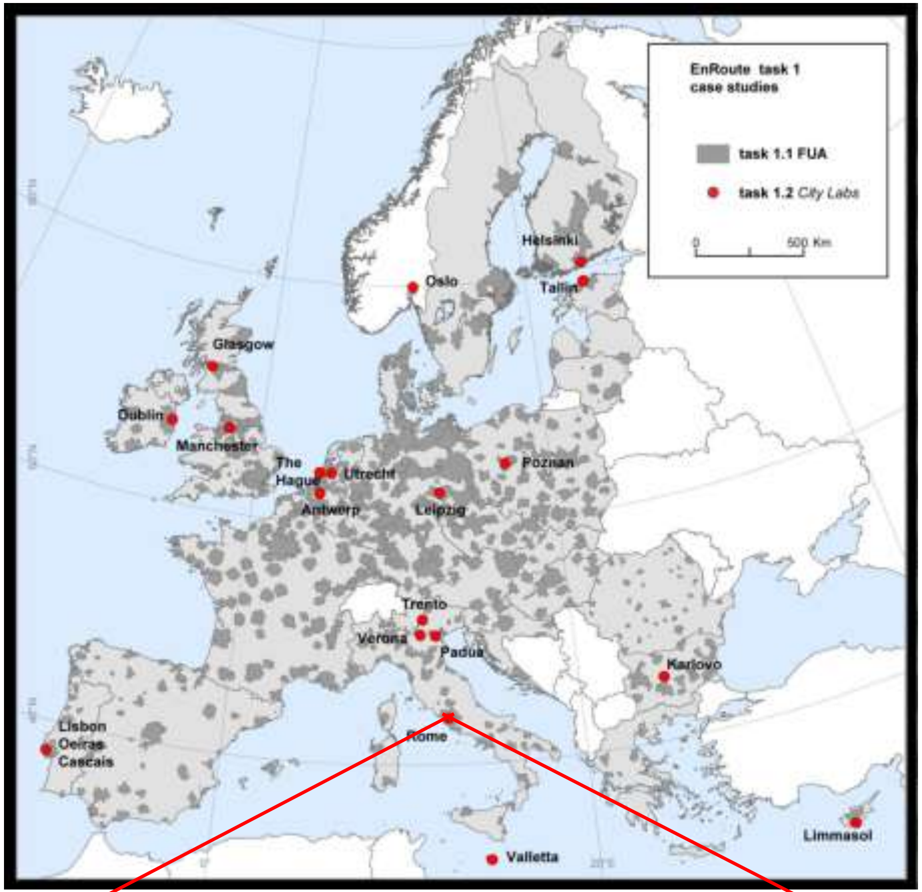
PSVCs (Municipality of Rome)	Mg	Mg·ha^{-1}	Value (€·10^6)
Evergreen oak woods	9.86	0.0242	0.077
Deciduous oak woods	396.32	0.0337	3.091
Mixed broadleaved woods	0.29	0.0274	0.002
Chestnut woods	8.6	0.0601	0.067
Beech woods	n.a.	n.a.	n.a.
Hygrophilous woods	n.a.	n.a.	n.a.
Mediterranean pine woods	47.43	0.0197	0.370
Mountain coniferous woods	3.96	0.0190	0.031
Mediterranean maquis	18.68	0.0365	0.146
Total	485.14	0.0314	3.783
PSVCs (Latium region)	**Mg**	**Mg·ha^{-1}**	**Value (€·10^6)**
Evergreen oak woods	1238.25	0.0240	9.656
Deciduous oak woods	7068.85	0.0336	55.123
Mixed broadleaved woods	1675.61	0.0235	13.066
Chestnut woods	4737.02	0.0592	36.939
Beech woods	3322.55	0.0570	25.909
Hygrophilous woods	162.81	0.0977	1.270
Mediterranean pine woods	72.30	0.0201	0.564
Mixed coniferous woods	101.46	0.0082	0.791
Mediterranean maquis	218.77	0.0375	1.706
Total	18,589.34	0.0375	145.024

O_3 removed in the Municipality of Rome and in the Latium region (year 2010), expressed as total removal (Mg) and removal per hectare (Mg ha^{-1}), and its relative monetary value (€·10^6).

From Fusaro et al., 2017 - *Remote Sensing*

Project: Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute)

EnRoute case studies: 20 City Lab



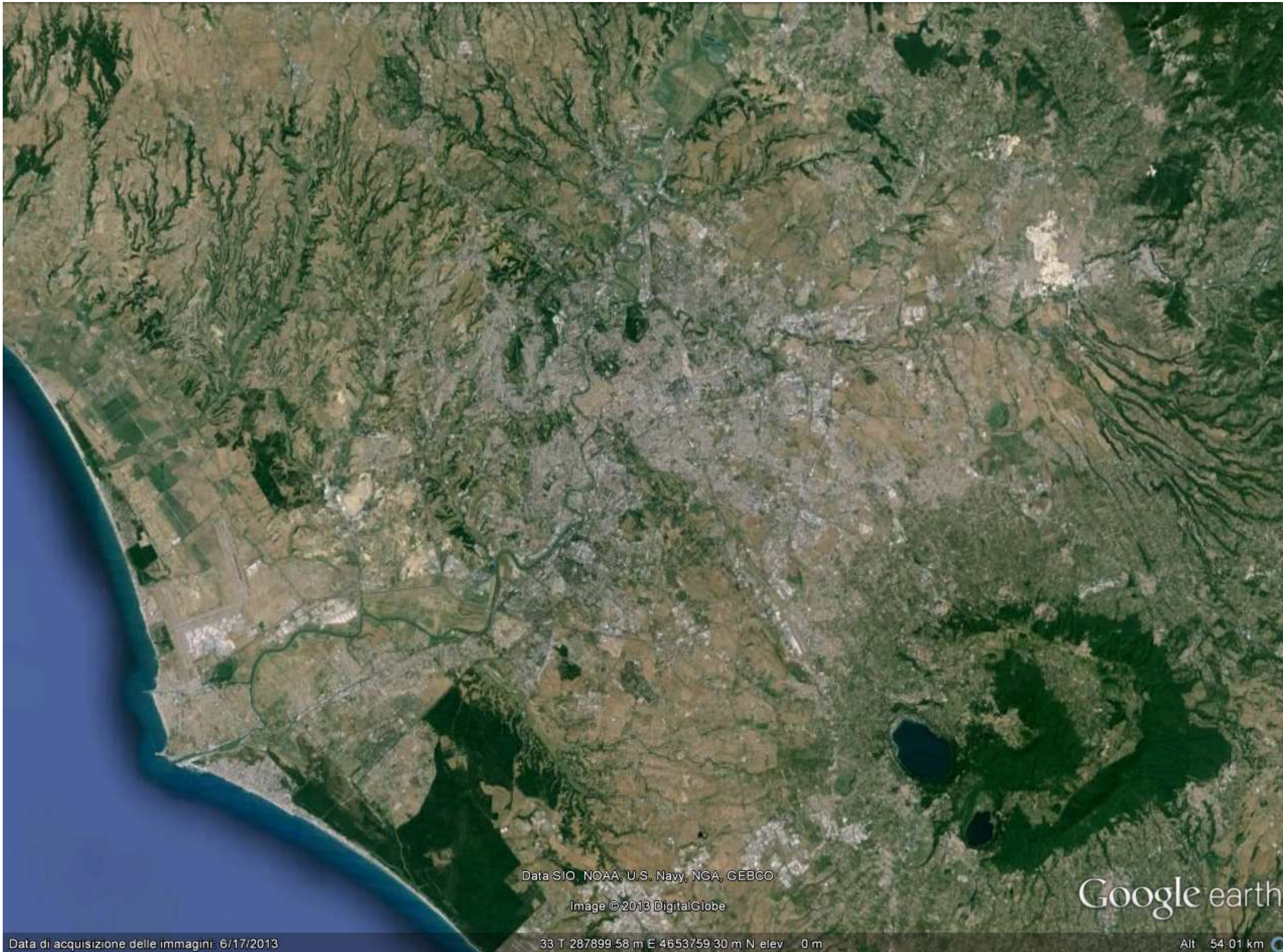
CityLab of the Metropolitan City of Rome
Department of Environmental Biology, Sapienza University

MAIN OBJECTIVES:

- To test and apply the indicator framework of the MAES urban pilot at local and European scale;
- To analyze how science supports policy, considering the effective interactions between the research community and the local practitioners and stakeholders;
- To enhance contacts between communities of practice at different scales in order to exchange experiences and knowledge on mapping, assessment and implementation of urban green infrastructure, urban biodiversity and urban ecosystem services, so as to support the further deployment of urban Green Infrastructure.

EXPECTED OUTCOMES:

- An accepted common framework for the spatially explicit multi-scale assessment of urban green infrastructure and urban ecosystem services;
- An overview of policy opportunities and needs for connecting urban green infrastructure to local policy making;
- A network of organizations involved in the further development and use of green infrastructure at various governance levels in the EU.


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2013 DigitalGlobe
Google earth
Data di acquisizione delle immagini: 6/17/2013
33 T 287899.58 m E 4653759.30 m N elev 0 m
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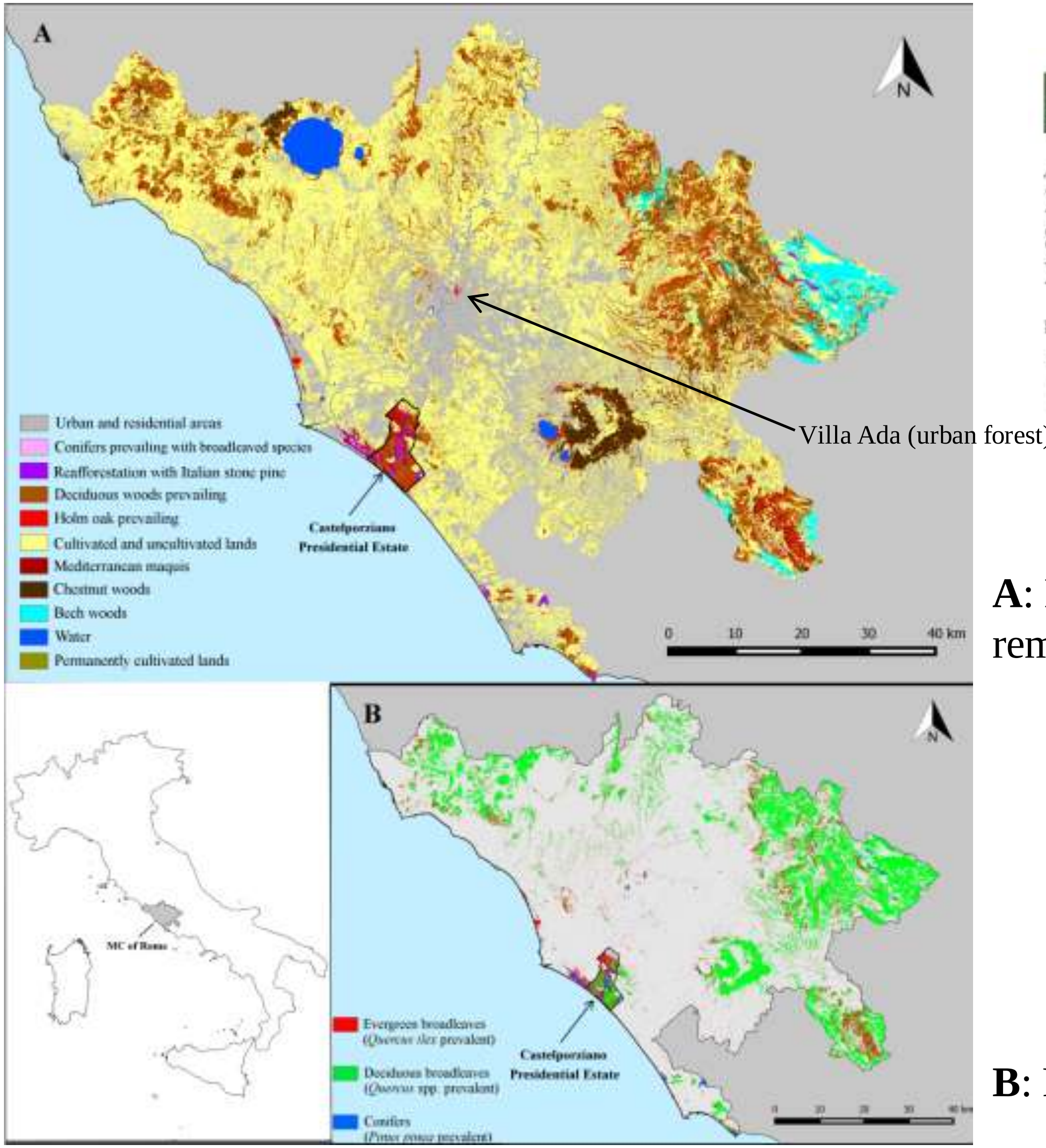
SEASONAL PM_{10} DEPOSITION ON VEGETATION IN THE METROPOLITAN CITY OF ROME AND CASTELPORZIANO PRESIDENTIAL ESTATE (2015)



forests

MDPI

Article

Removal of PM_{10} by Forests as a Nature-Based Solution for Air Quality Improvement in the Metropolitan City of Rome

Federica Marando, Elisabetta Salvatori, Lina Fusaro and Fausto Manes *

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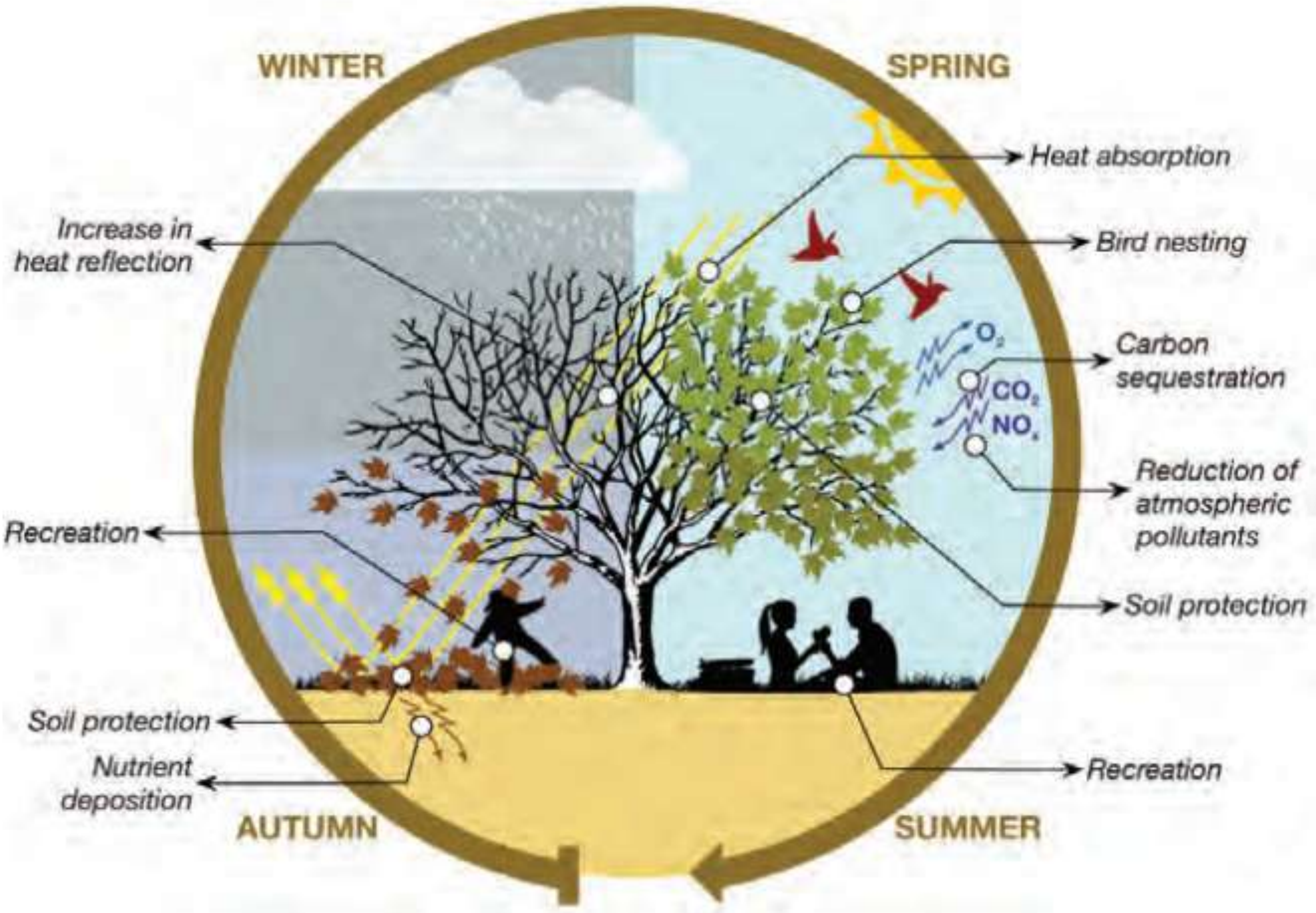
A: Land cover classification (Sentinel 2) of the remotely sensed data

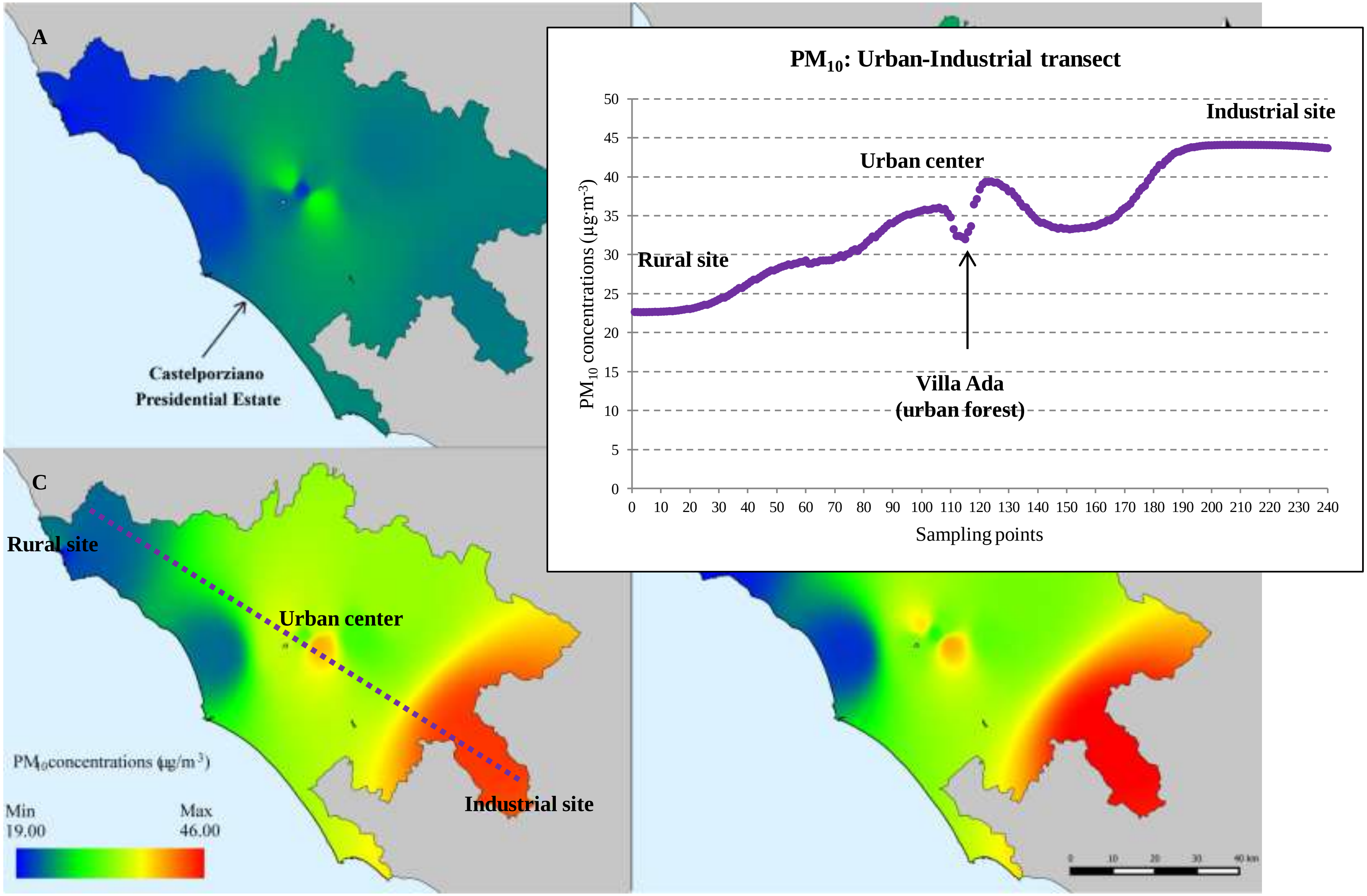
B: Functional groups of vegetation

From Marando et al., 2016 - *Forests*



Example of a within-year ecosystem service supply cycle considering a deciduous tree as the focus of ecosystem service supply (From Burkhard e Maes, 2017).

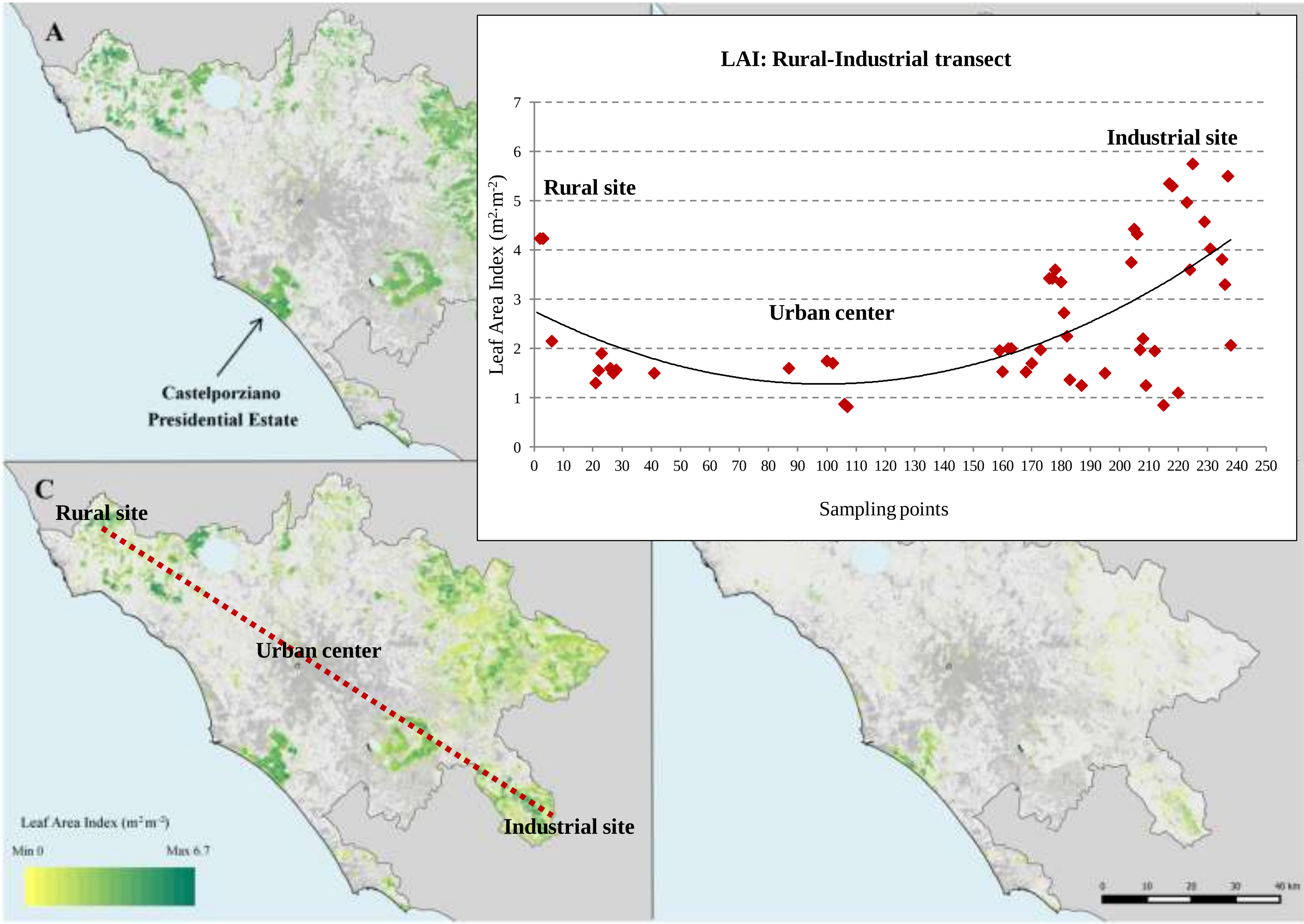
Metropolitan city of Rome: seasonal PM_{10} concentrations (Arpa Lazio monitoring stations, 2015)



A: Spring; B: Summer; C: Autumn; D: Winter

From Marando et al., 2016 - *Forests*

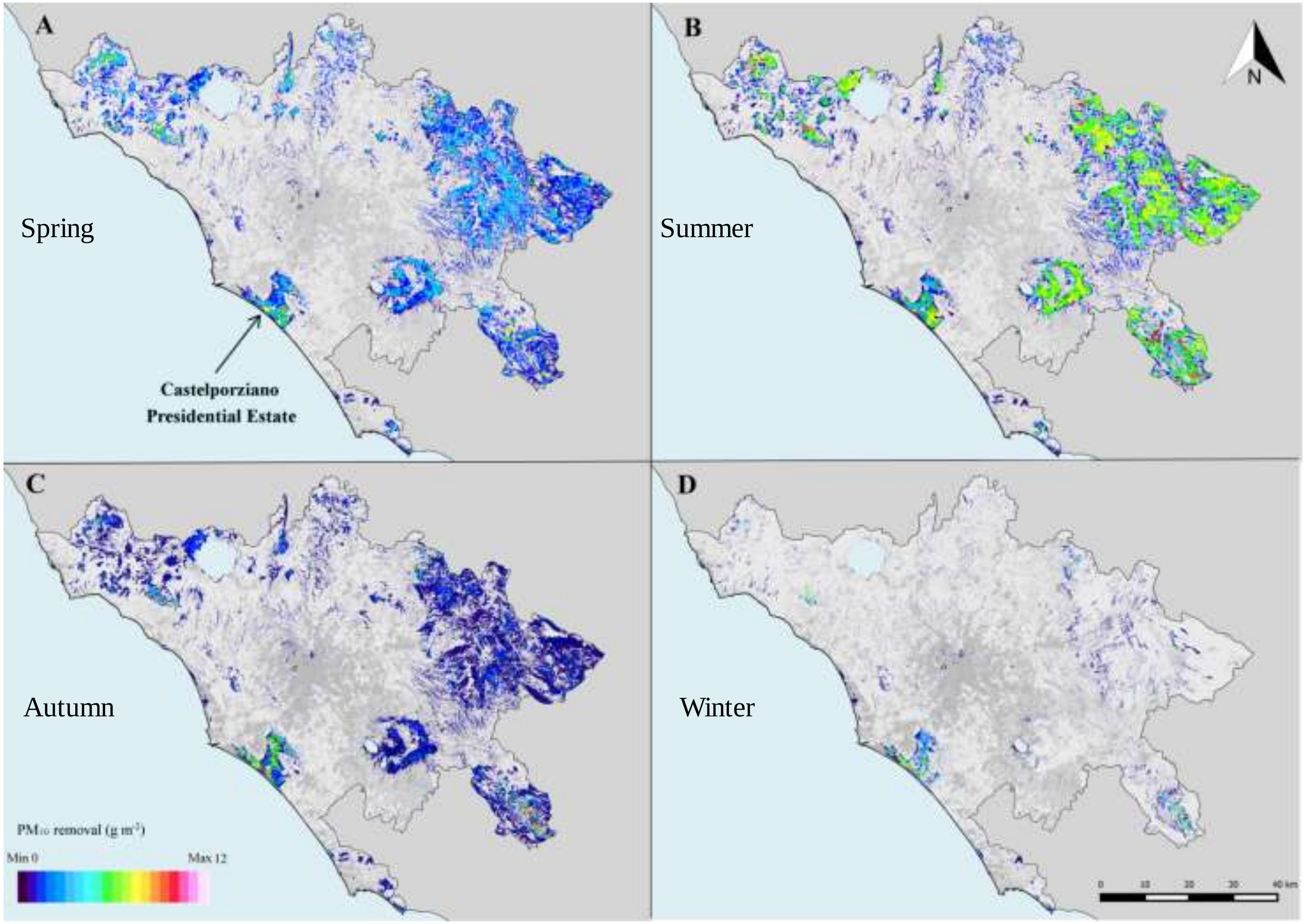
Metropolitan city of Rome: seasonal Leaf Area Index (2015)



A: Spring; B: Summer; C: Autumn; D: Winter

From Marando et al., 2016 - *Forests*

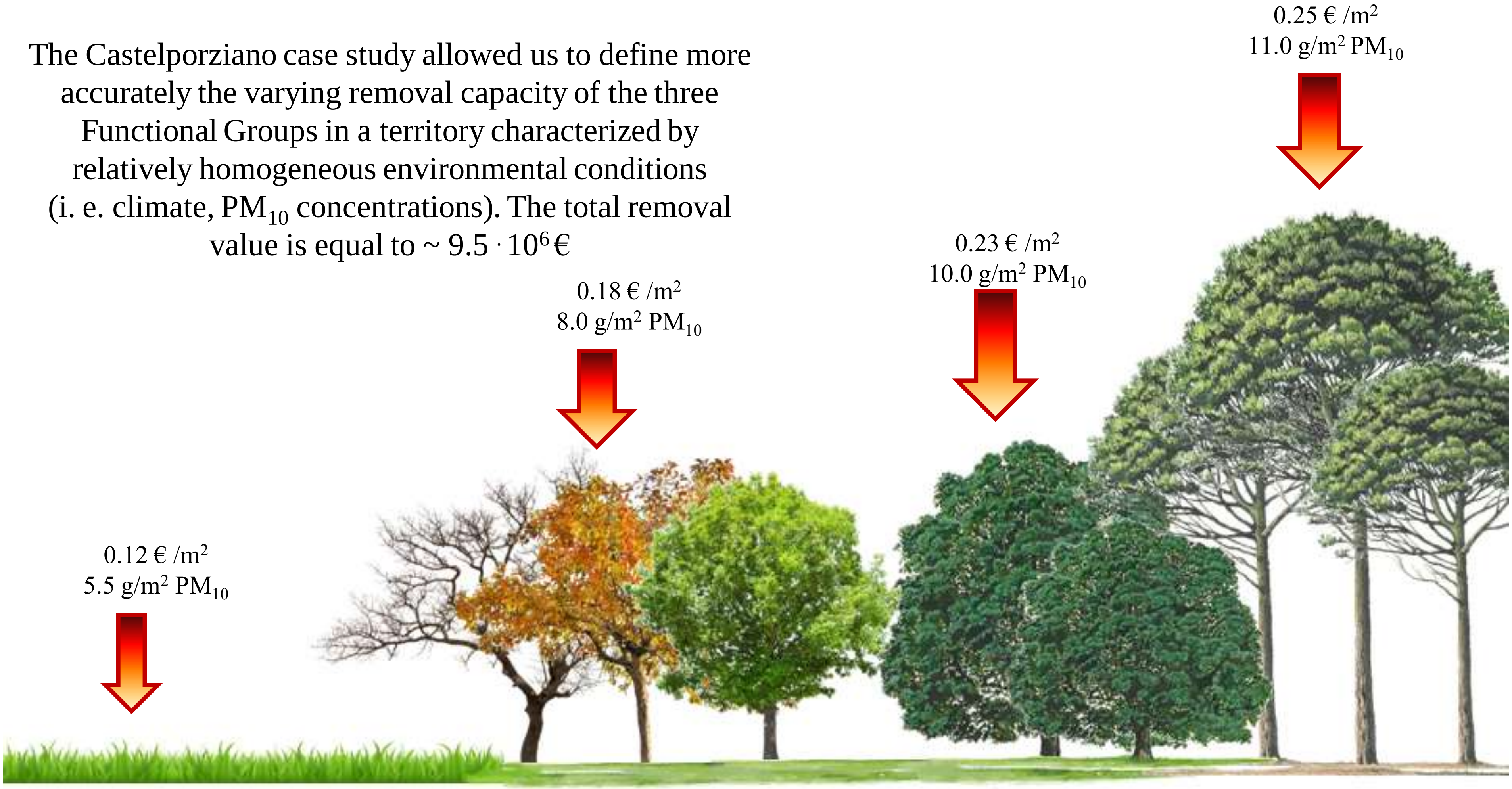
Seasonal PM_{10} deposition on vegetation in the metropolitan city of Rome (2015)



From Marando et al., 2016 - *Forests*

Different PM_{10} removal capacity of the three Functional Groups
(Castelporziano Presidential Estate)

The Castelporziano case study allowed us to define more accurately the varying removal capacity of the three Functional Groups in a territory characterized by relatively homogeneous environmental conditions (i. e. climate, PM_{10} concentrations). The total removal value is equal to ~ $9.5 \cdot 10^6$ €



Schematic representation of the air quality improvement function (g m^{-2} of PM_{10} removed) performed by different plant types (grasses, deciduous broadleaves, evergreen broadleaves, conifers) and relative monetary value on the basis of externality values (EEA, 2014)

PM_{10} AND O_3 REMOVAL IN 10 METROPOLITAN CITIES (2003)

Ecological Indicators 67 (2016) 425–440

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journal homepage: www.elsevier.com/locate/ecolind

Regulating Ecosystem Services of forests in ten Italian Metropolitan Cities: Air quality improvement by PM_{10} and O_3 removal

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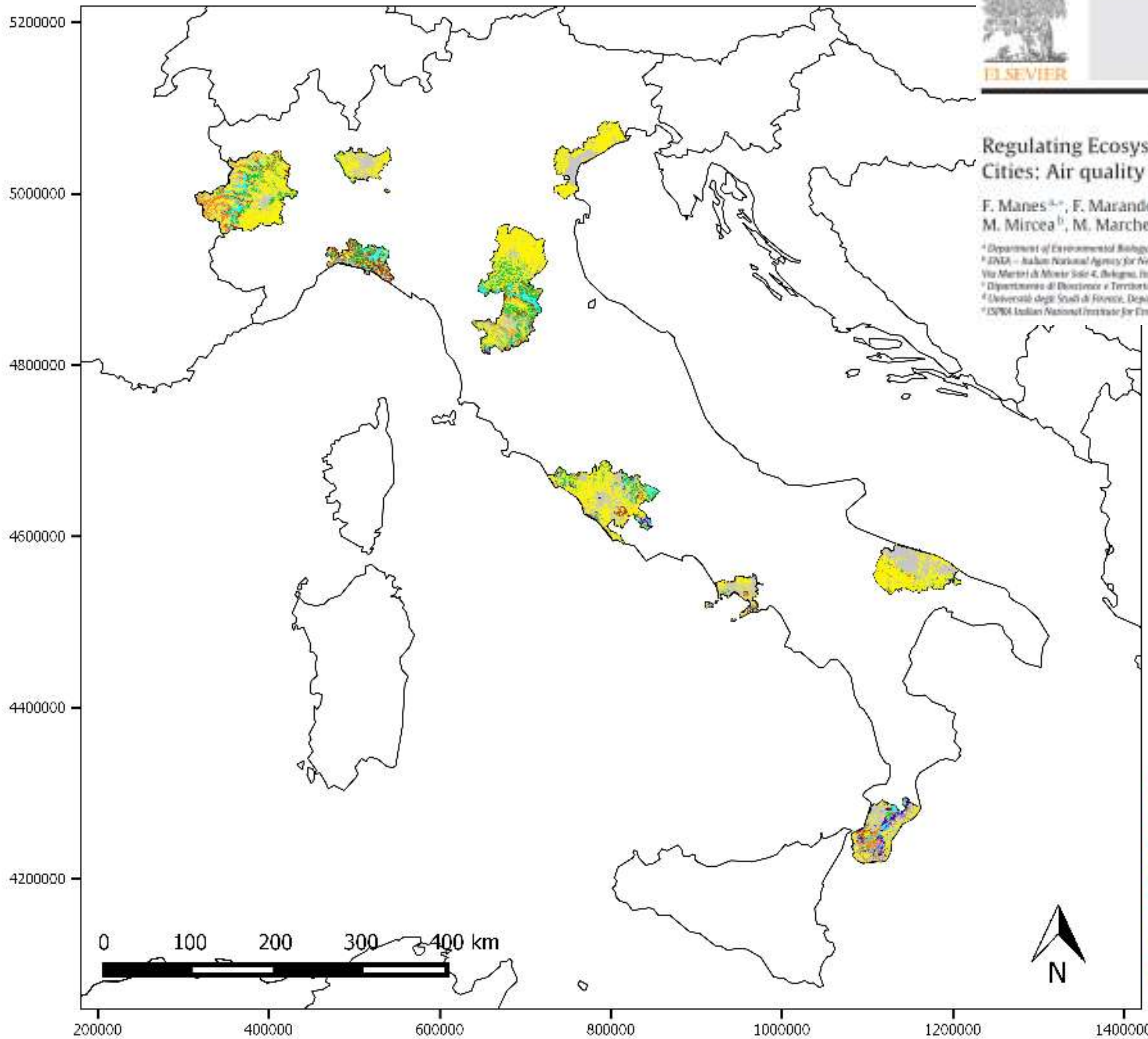


MONETARY EVALUATION OF PM_{10} AND O_3 REMOVAL

10 metropolitan cities: monetary evaluation of PM_{10} and O_3 removal for the year 2003

A total of 47 Million USD for PM_{10} adsorption and
of 297 Million USD for O_3 absorption
from the Physiognomic-Structural Categories of vegetation
in the 10 metropolitan cities

Corresponding to a value of ~ 56 USD per hectare forPM$_{10}$
and ~ 353 USD per hectare for O_3

Externality values established for the US by Murray et al. (1994), and adjusted according to the producer's price index for the year 2007 (U.S. Department of Labor, 2013; Baró et al., 2014)

- PM_{10}: 6614 USD per Mg
- O_3 : 9906 USD per Mg

Total forested area (hectares)

Turin	Venice	Milan	Genoa	Bologna	Florence	Rome	Naples	Bari	Reggio Calabria	**Total**
195149	862	5482	120946	79008	162891	111956	17077	17815	129322	**840507**

From Manes et al., 2016 – *Ecological Indicators*

TAKE HOME MESSAGES

Our study highlights the importance of **Green Infrastructures in urban and natural areas** and the need to preserve **ecosystem functions to sustain the provision of Ecosystem Services**.

Structural characteristics (LAI) and functional diversity (stomatal conductance) of urban and periurban forests are the main factors affecting the removal of particulate matter and tropospheric ozone, respectively.

This highlights **the importance, in a global changing environment, of the synergic action of different plant types in the removal of air pollutants**.

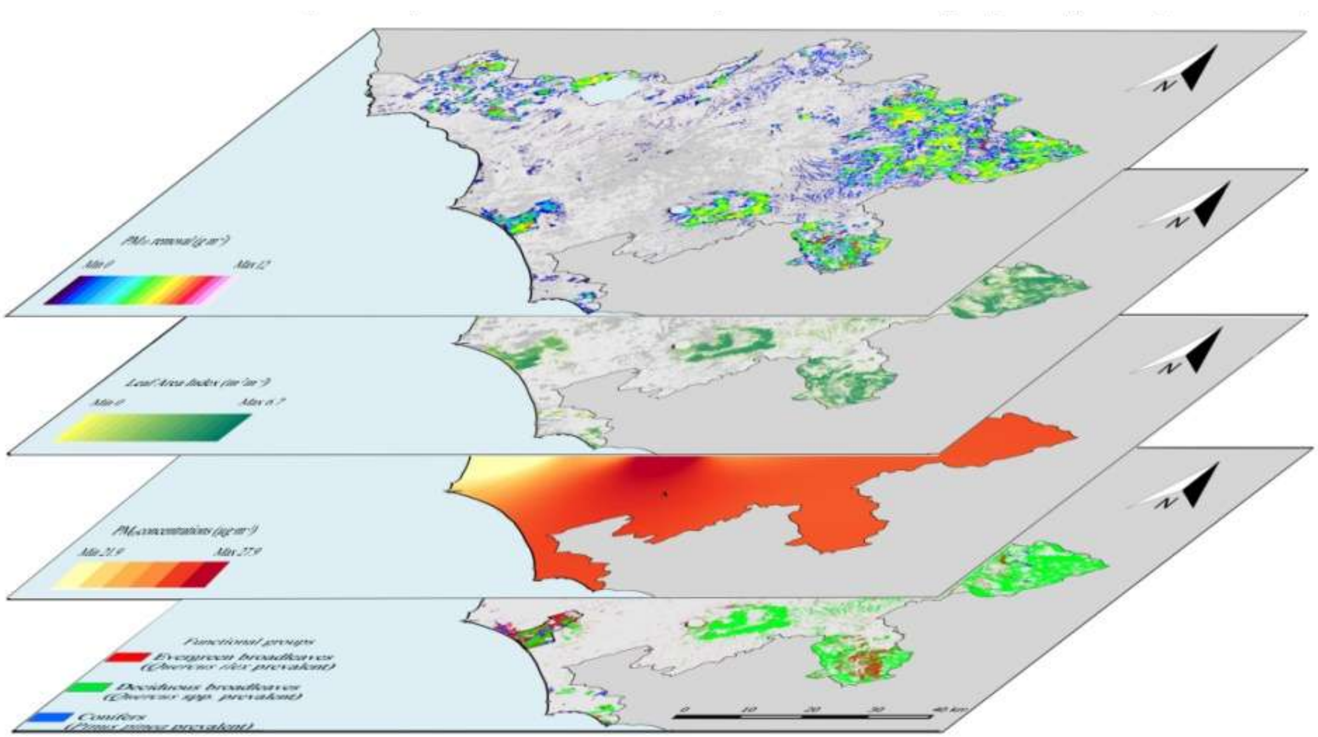
The synergic action of the different plant types is further highlighted by analyzing seasonality: deciduous species show high removal rates in spring and summer, while the overall yearly removal is higher for evergreen species, due to their capacity to remove pollutants also in winter months.

This study **quantified the environmental benefits, even in monetary terms, provided by natural Green Infrastructures**, also in the view to foster urban resilience.

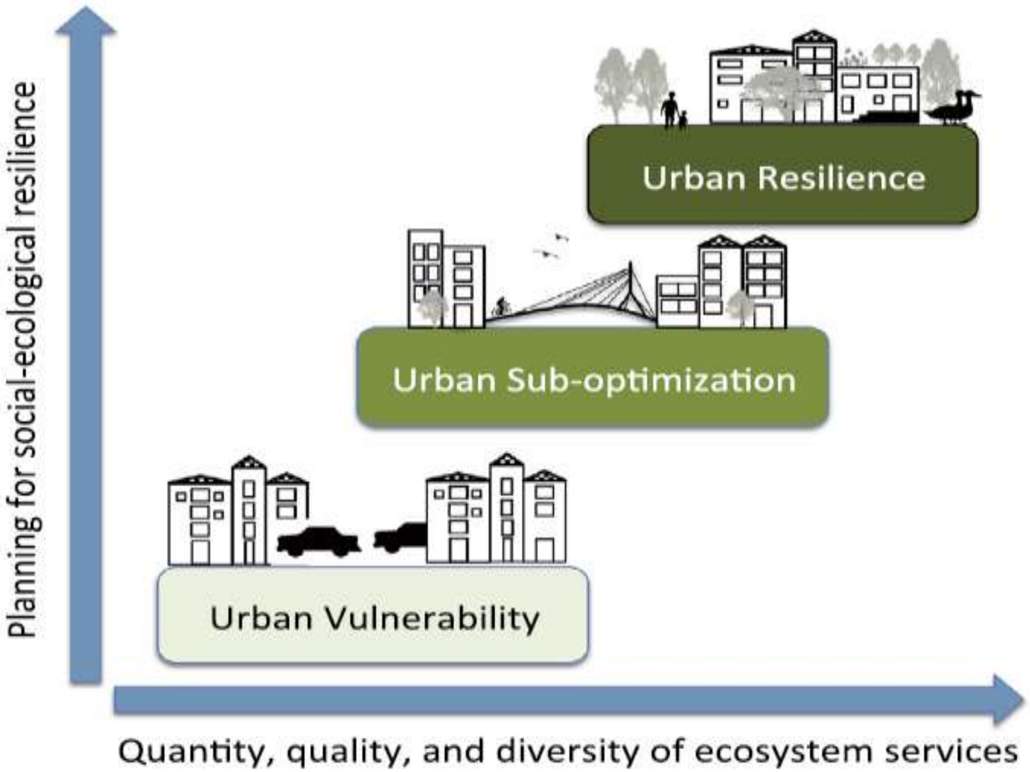
European sustainability goals to 2020 may be achieved by increasing forest cover and functional diversity, especially in urban areas, characterized by high pollution levels.

Multidisciplinary guidelines are required to help policy-makers to implement specific **Nature-Based Solutions** that can improve human health and well-being in urban and periurban areas, **as highlighted by the EnRoute EU Project**.

THANK YOU FOR YOUR ATTENTION!



URBAN RESILIENCE



Urban resilience can be fostered by incorporating urban ES in planning, design and management of urban social–ecological systems. A social–ecological approach for cities is critical to safeguard a resilient supply of ES in the long-term to ensure urban human well-being (Schewenius et al., 2014; Elmqvist et al., 2014). However, safeguarding urban ES requires recognizing and incorporating the multiple values of ES in planning and governance. As urban planning and governance for social–ecological resilience increases, together with conservation of and management for increased quality, quantity, and diversity of urban ES, resilience at multiple scales can be improved. (From McPherson et al., 2015).

Seasonal PM_{10} deposition on vegetation in the Castelporziano Presidential Estate (year 2015)

Deciduous		Evergreen		Conifers	
Mg	Mg ha^{-1}	Mg	Mg ha^{-1}	Mg	Mg ha^{-1}

	Deciduous			Evergreen			Conifers		
	Mg	Mg· ha^{-1}	Value (€ 10^6)	Mg	Mg· ha^{-1}	Value (€ 10^6)	Mg	Mg· ha^{-1}	Value (€ 10^6)
Spring	60.74	0.032	1.40	53.18	0.026	1.22	19.48	0.026	0.45
Summer	75.90	0.040	1.75	58.87	0.029	1.35	22.02	0.029	0.51
Autumn	18.68 *	0.010 *	0.43 *	56.06	0.028	1.29	25.80	0.034	0.59
Winter				27.18	0.013	0.62	14.55	0.019	0.33
Total	155.32	0.08	3.57	195.28	0.10	4.49	81.85	0.11	1.88

The Castelporziano case study allowed us to define more accurately the varying removal capacity of the three Functional Groups in a territory characterized by relatively homogeneous environmental conditions (i. e. climate, PM_{10} concentrations)

(From Marando et al., 2016 - *Forests*)

Monetary valuation of PM_{10} and O_3 removal

Externality values: estimated social cost of pollution (i.e. human health, environmental impact and material damage) that is not considered in the market price of the goods or services that caused the pollution, expressed in cost per Mg of each pollutant

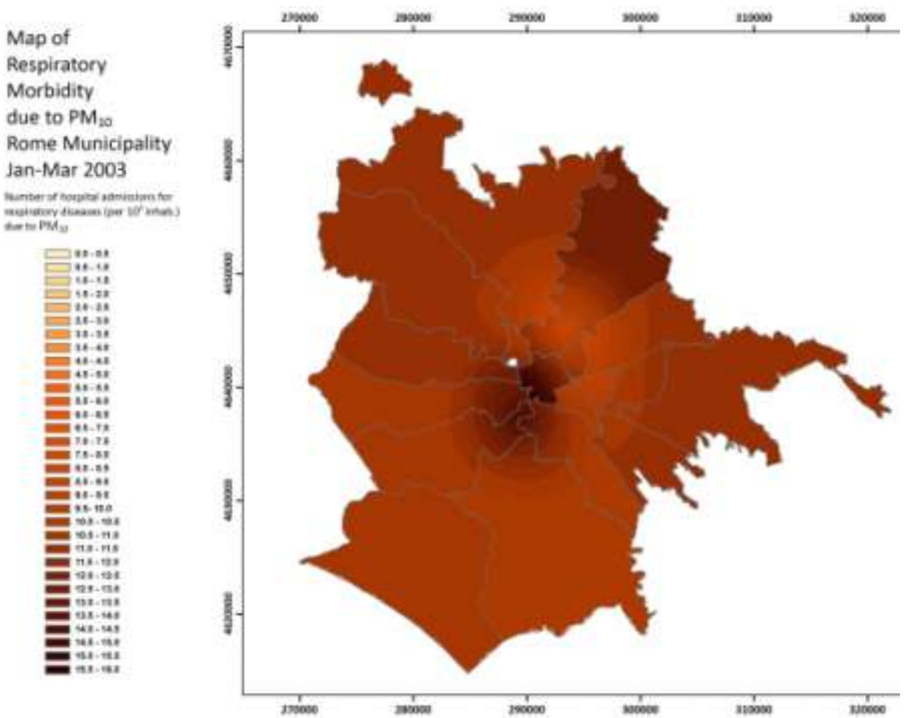
- PM_{10} : 22,990 Euros per Mg
- O_3 : 4,419 Euros per Mg

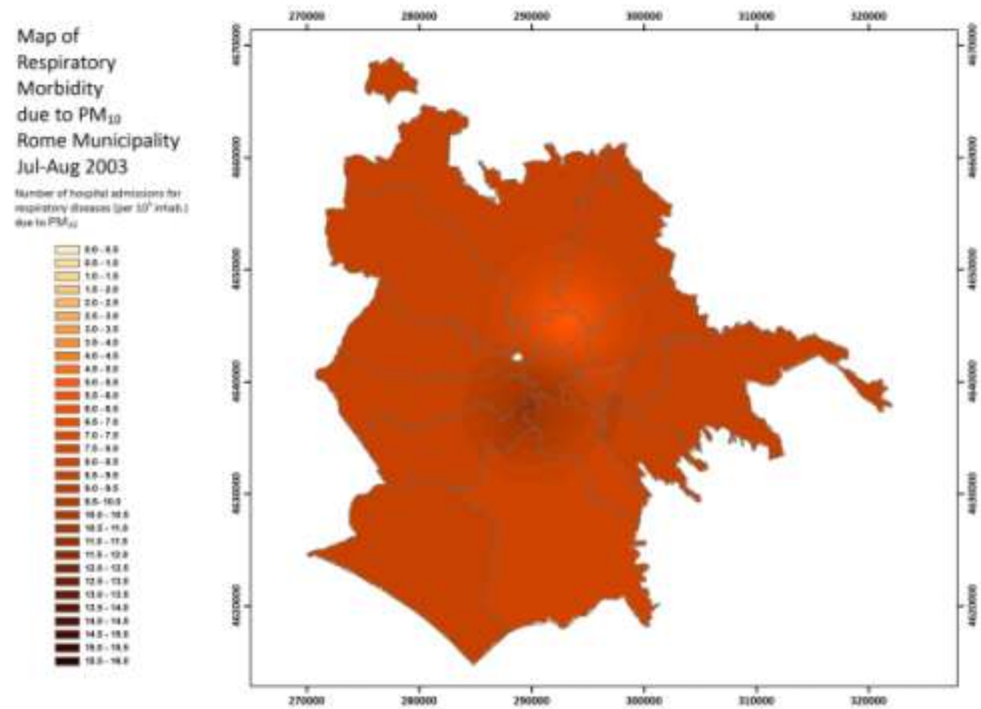
(EEA, 2014)

EXAMPLES OF HEALTH RISK MAPS: YEAR 2003

Number of hospital admission for respiratory diseases attributable to PM_{10} (for 10^5 inhabitants)

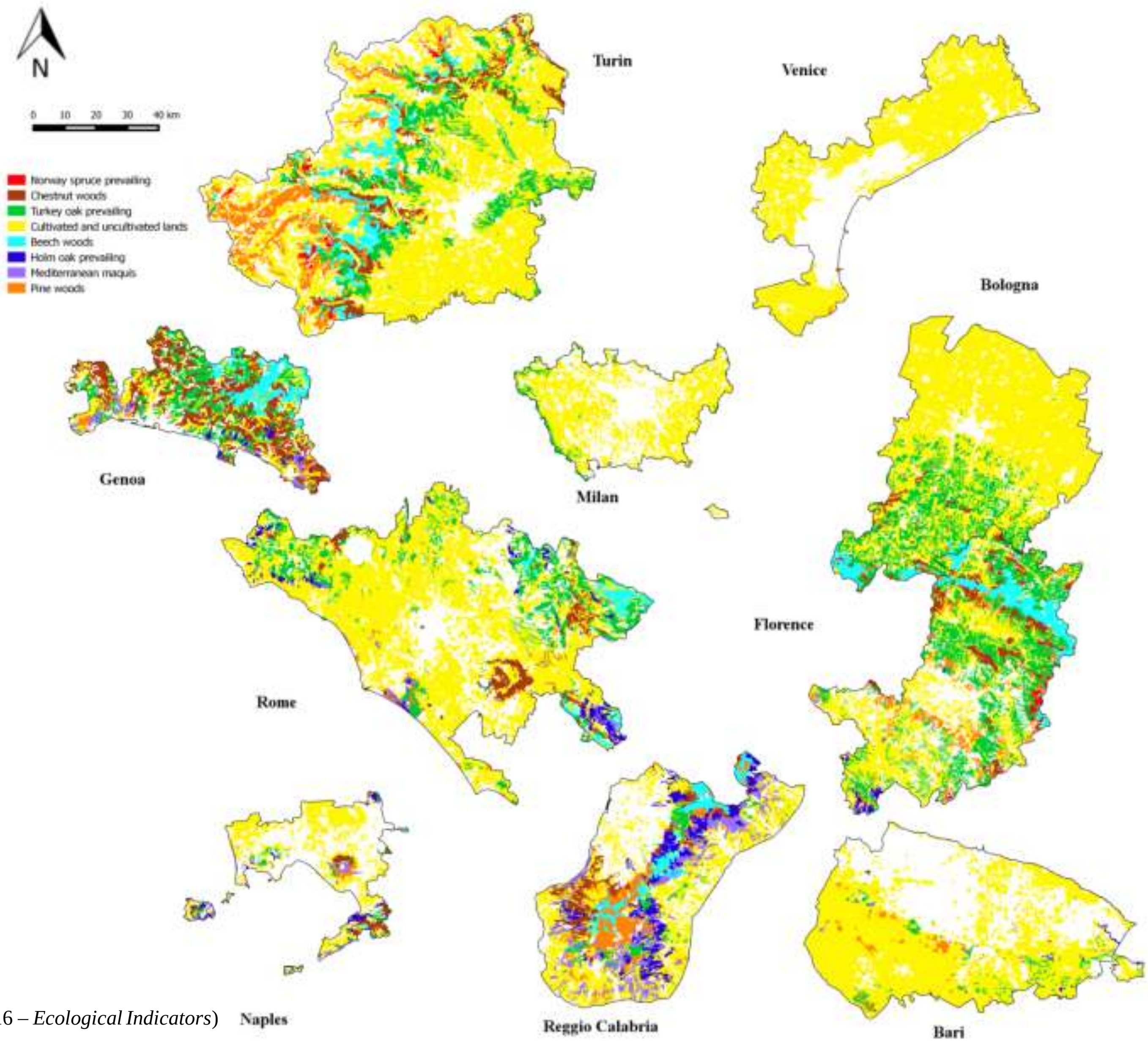
January-March and July-August





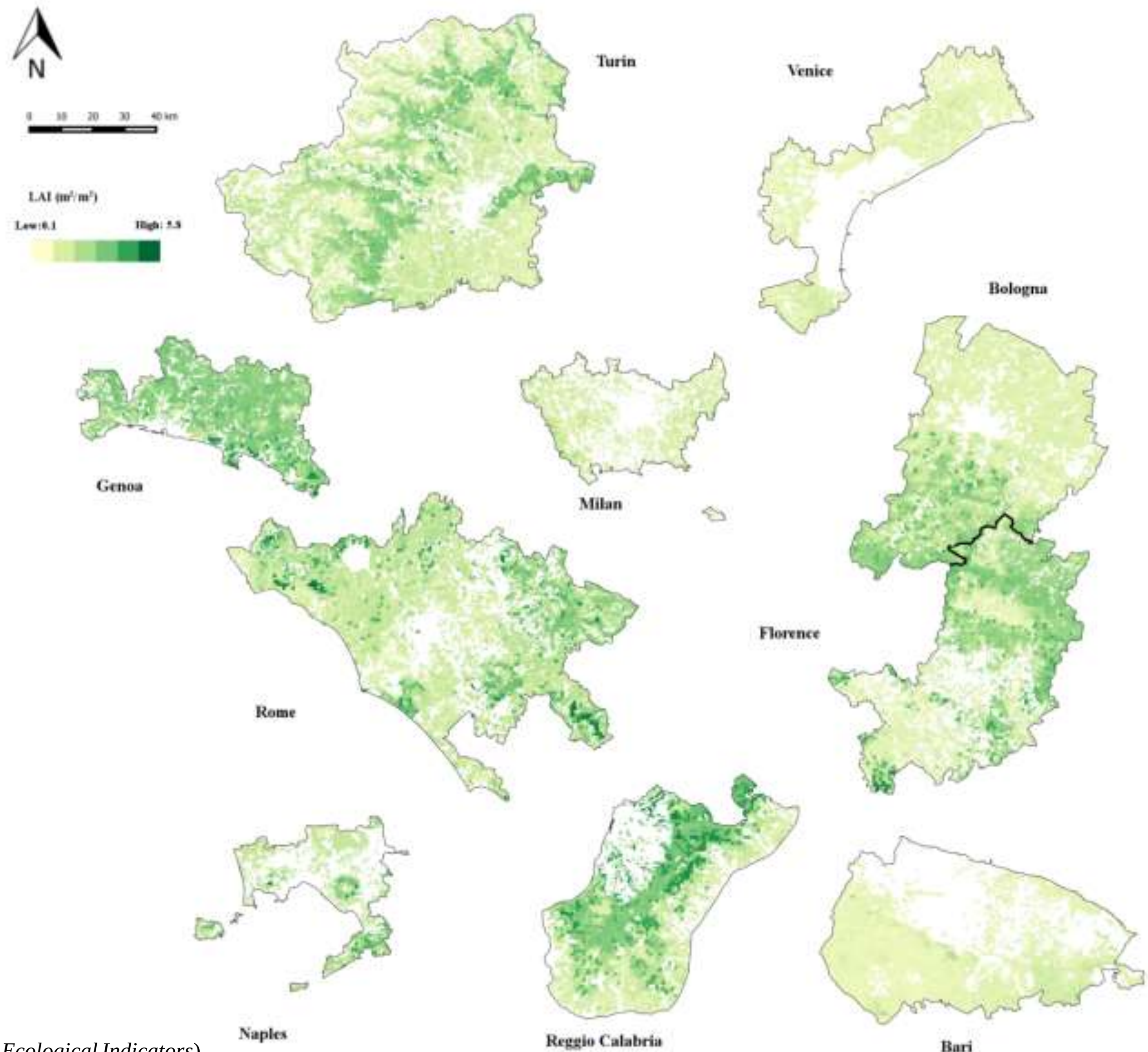
(From: Mannocci et al., 2014 – *Igiene e Sanità Pubblica*)

Physiognomic-Structural Vegetation Categories in the 10 metropolitan cities



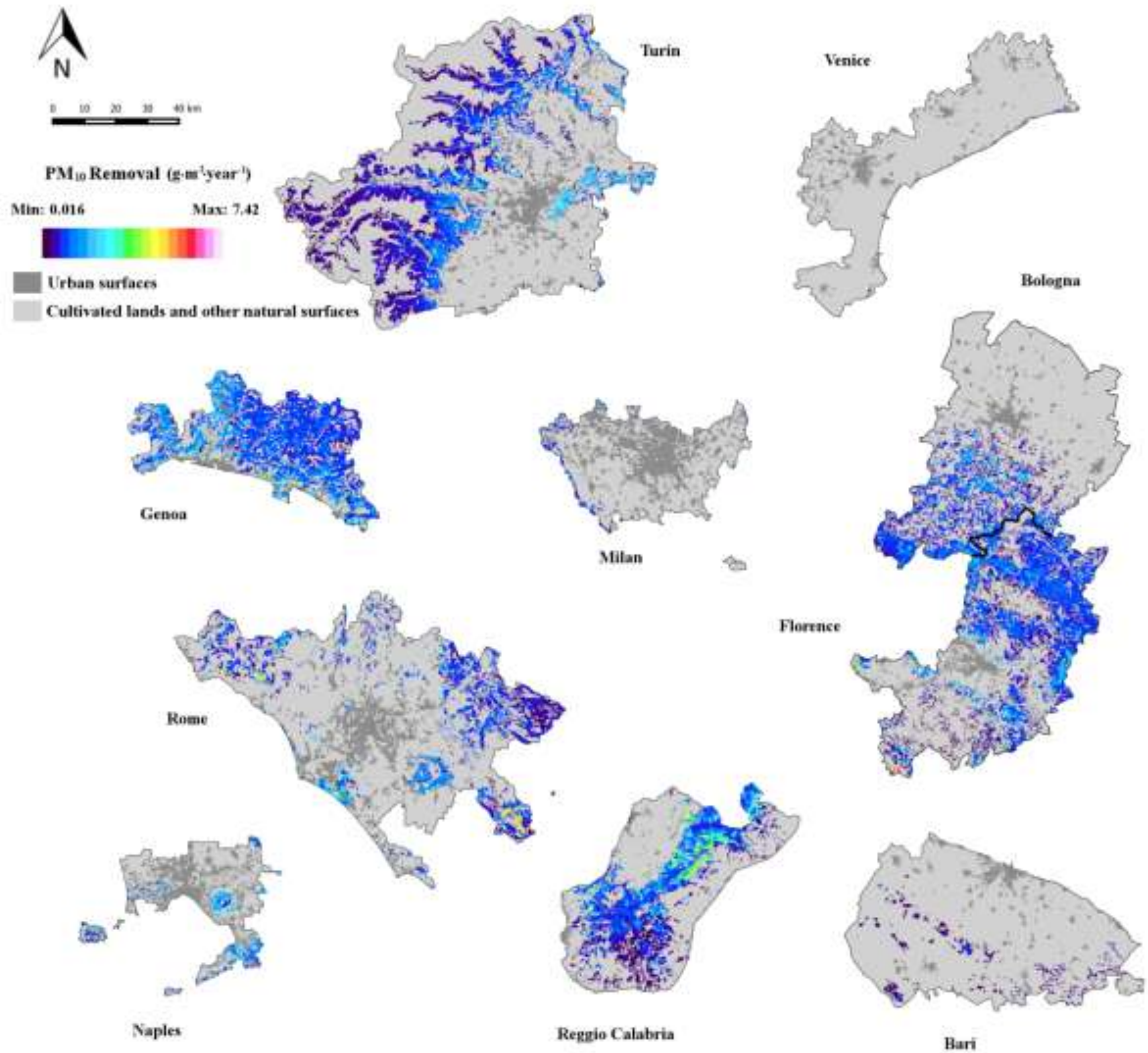
(From Manes et al., 2016 – *Ecological Indicators*)

10 Metropolitan cities: Leaf Area Index



(From Manes et al., 2016 – *Ecological Indicators*)

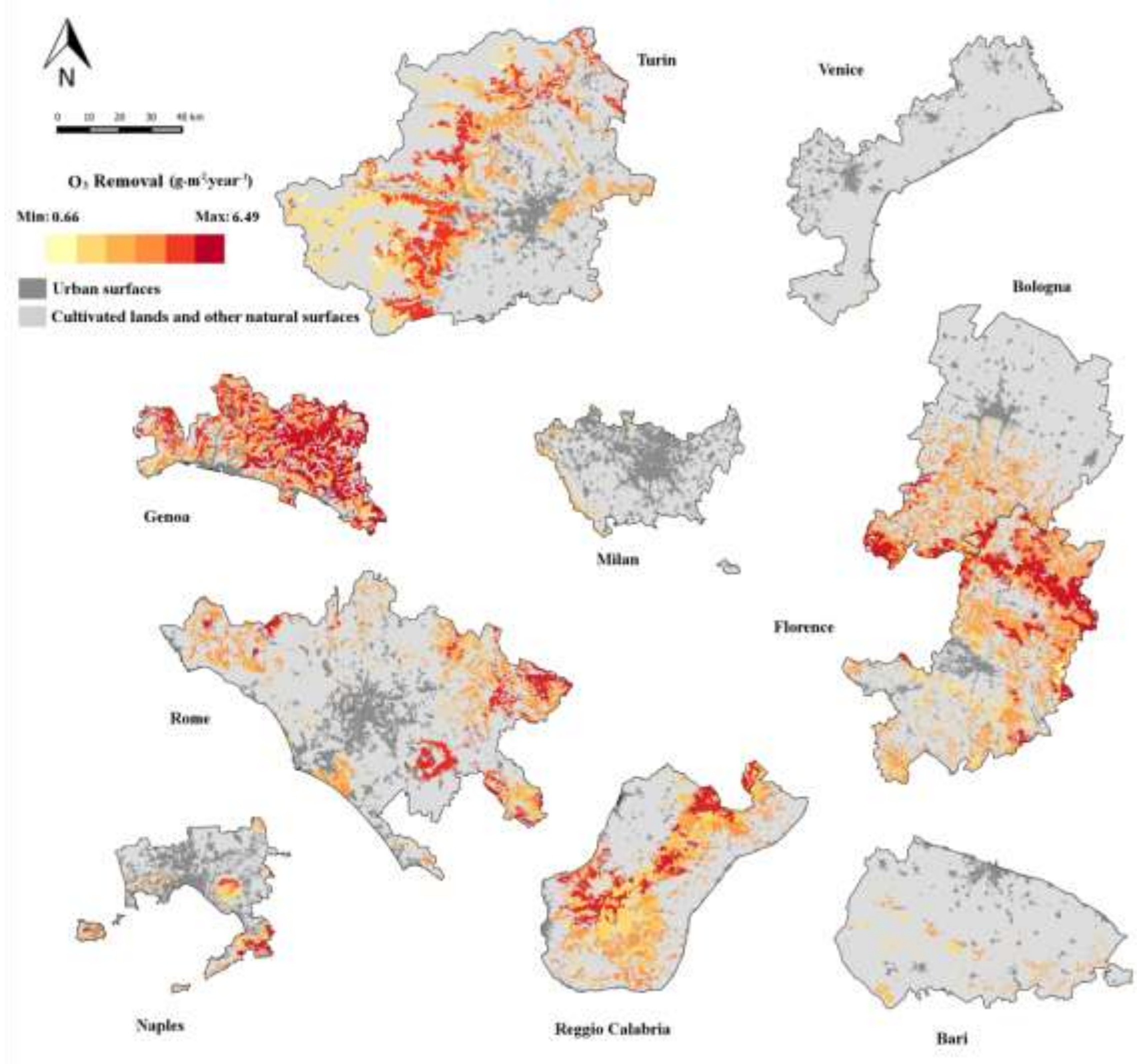
PM_{10} removal by 7 PSVCs in the 10 metropolitan cities



PM_{10} deposition model (Nowak, 1994; Escobedo and Nowak, 2009) $Q = F \times L \times T$

(From Manes et al., 2016 – *Ecological Indicators*)

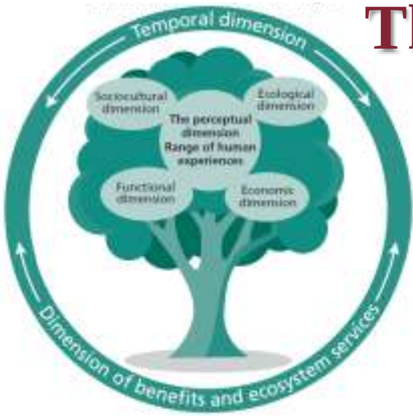
O_3 removal by 7 PSVCs in the 10 metropolitan cities



O_3 Stomatal conductance model (Manes et al., 2012) $FO_3 = g_s \times [O_3] \times 0.613$

(From Manes et al., 2016 – *Ecological Indicators*)

The urban forests design has different dimensions



The social, functional, ecological and economic dimensions interact with the perceptual dimension over time to provide ecosystem services and other benefits. *Guidelines on urban and peri-urban forestry*, *FAO, Rome (2016)*

Significance of urban forest type for human health and well-being

Urban forest type	Significance (on a scale of 1–5*)
Peri-urban forests and woodlands	🌳🌳🌳🌳🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳🌳🌳🌳🌳
Trees on streets or in public squares	🌳🌳🌳🌳🌳
Other green spaces with trees	🌳🌳🌳🌳🌳

* Where 1 = very low significance and 5 = very high significance.

Significance of urban forest type for biodiversity and landscapes

Urban forest type	Significance (on a scale of 1–5*)
Peri-urban forests and woodlands	🌳🌳🌳🌳🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳🌳🌳
Trees on streets or in public squares	🌳🌳
Other green spaces with trees	🌳🌳🌳

* Where 1 = very low significance and 5 = very high significance.

Significance of urban forest type for climate change

Urban forest type	Significance (on a scale of 1–5*)	
	Climate-change mitigation	Climate-change adaptation
Peri-urban forests and woodlands	🌳🌳🌳🌳🌳	🌳🌳🌳🌳🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳	🌳🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳	🌳🌳🌳🌳
Trees on streets or in public squares	🌳	🌳🌳🌳🌳
Other green spaces with trees	🌳🌳	🌳🌳🌳🌳

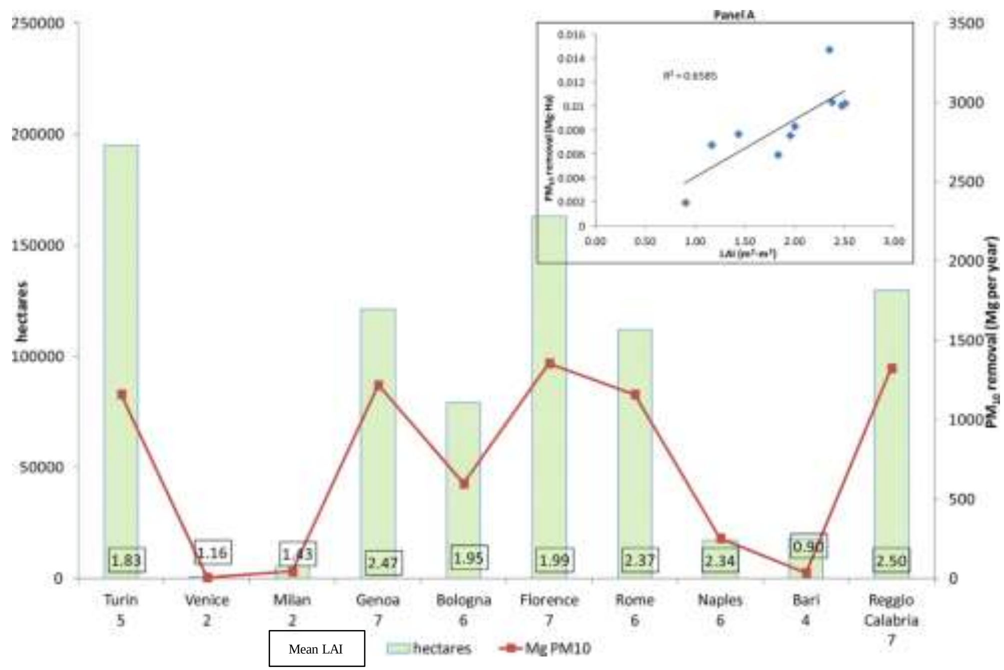
* Where 1 = very low significance and 5 = very high significance.

Significance of urban forest type for sociocultural values

Urban forest type	Significance			
	Recreation	Education	Social cohesion	Social security and equity
Peri-urban forests and woodlands	🌳🌳🌳🌳	🌳🌳🌳🌳🌳	🌳🌳	🌳
City parks and urban forests (>0.5 ha)	🌳🌳🌳🌳🌳	🌳🌳🌳🌳	🌳🌳🌳🌳🌳	🌳🌳🌳🌳
Pocket parks and gardens with trees (<0.5 ha)	🌳🌳🌳	🌳	🌳🌳🌳	🌳🌳🌳🌳
Trees on streets or in public squares	🌳	🌳	🌳	🌳🌳🌳🌳🌳
Other green spaces with trees	🌳🌳🌳	🌳🌳🌳	🌳🌳	🌳🌳🌳

* Where 1 = very low significance and 5 = very high significance.

10 metropolitan cities: PM_{10} deposition on vegetation



- Prevailing holm oak woods are the most efficient PSVC, followed by Mediterranean maquis.
- Coniferous species are more effective than deciduous broadleaved species.
- Positive relationship between deposition values, green cover extension and LAI
- In particular, PM_{10} removal is influenced mostly by LAI ($R^2 = 0.66$, $p < 0.01$), rather than PM_{10} concentration ($R^2 = 0.01$, $p > 0.05$)

Annual PM_{10} deposition estimated for the PSVCs in the 10 MCs for the year 2003 (total, Mg, and per m^2, as $g\,m^{-2}$); (n.d.: not detectable). The table also shows the mean values of PM_{10} deposition per m^2 for each PSVC.

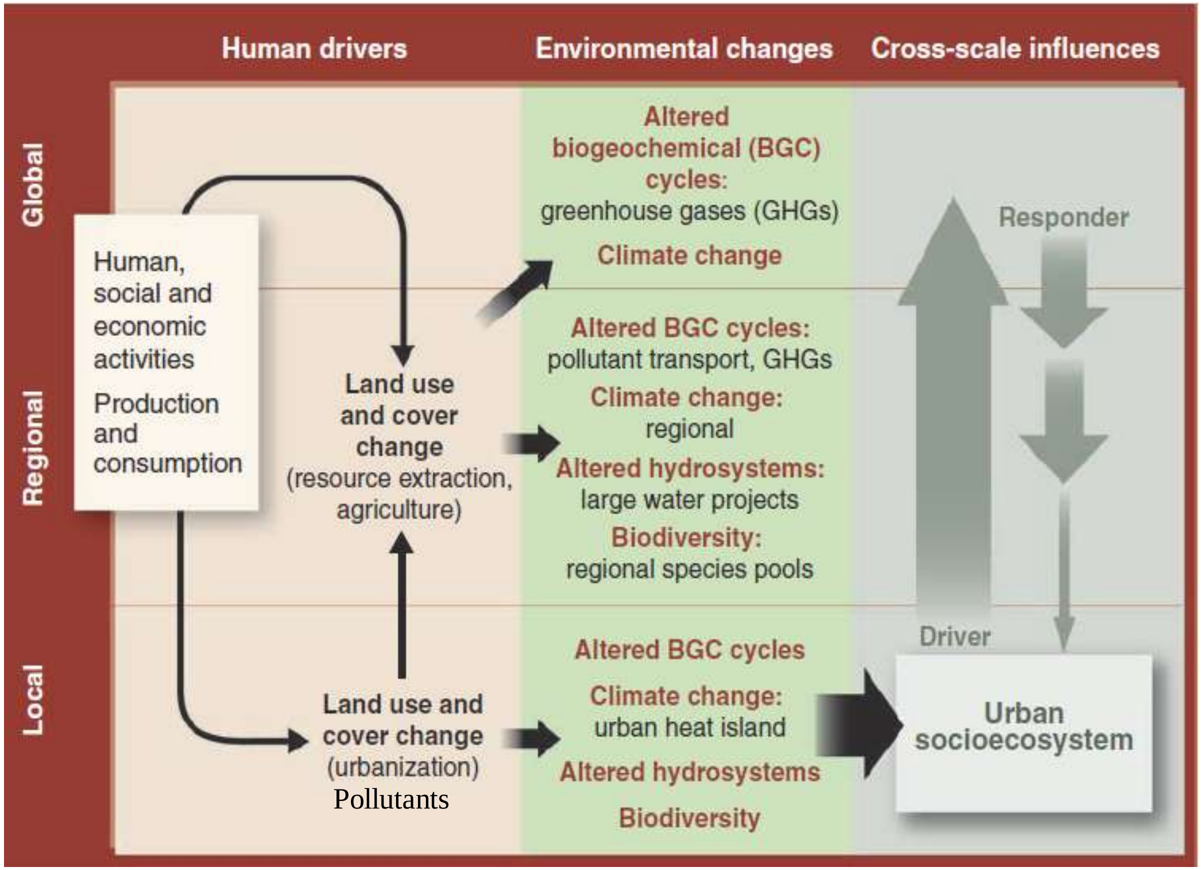
	Holm oak prevailing		Mixed deciduous woods		Pine woods		Norway spruce prevailing		Chestnut woods		Beech woods		Mediterranean maquis		Total		
	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g \cdot m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Normalized ($g\,m^{-2}$)	Total (Mg)	Total forested area (ha)
Turin			0.76	557.5	0.37	195.2	0.49	23.2	0.74	231.4	0.47	152.9			0.59	1160.26	195,149
Venice			0.13	0.2	0.83	5.6									0.67	5.83	861.6
Milan			0.78	42.1	n.d.	n.d.									0.77	42.38	5481.5
Genoa	2.26	70.8	0.91	322.5	1.68	87.3	1.09	7	0.98	524.1	0.71	127.5	1.54	78.3	1.00	1217.58	120,945.7
Bologna			0.72	449.6	1.67	30.9	1.31	3.2	0.80	50.1	0.79	63	0.72	0.6	0.75	597.45	79,008.4
Florence	3.13	88.9	0.62	570.4	1.36	288	1.63	34.6	0.73	162.7	0.85	185	3.83	26.5	0.83	1356.25	162,891.4
Rome	2.54	298.2	0.78	478.2	1.32	51.1			1.02	199.7	0.42	45.1	2.00	87.6	1.04	1159.91	111,955.5
Naples	1.63	63	1.29	47.7	2.69	43.5			1.38	59.6	1.31	2.1	1.05	36.2	1.47	252	17,077.3
Bari	0.34	4.5	0.14	13	0.25	14.4							0.19	2.6	0.19	34.46	17,814.9
Reggio Calabria	1.66	459	0.73	75.7	0.99	246.1	1.25	3.2	0.95	135.3	0.77	137.3	0.79	267.2	1.02	1323.83	129,321.8
Mean value	1.93		0.69		1.13		1.11		0.94		0.75		1.39		0.84		
Total																7149.7	

(From Manes et al., 2016 – *Ecological Indicators*)

Stomatal conductance

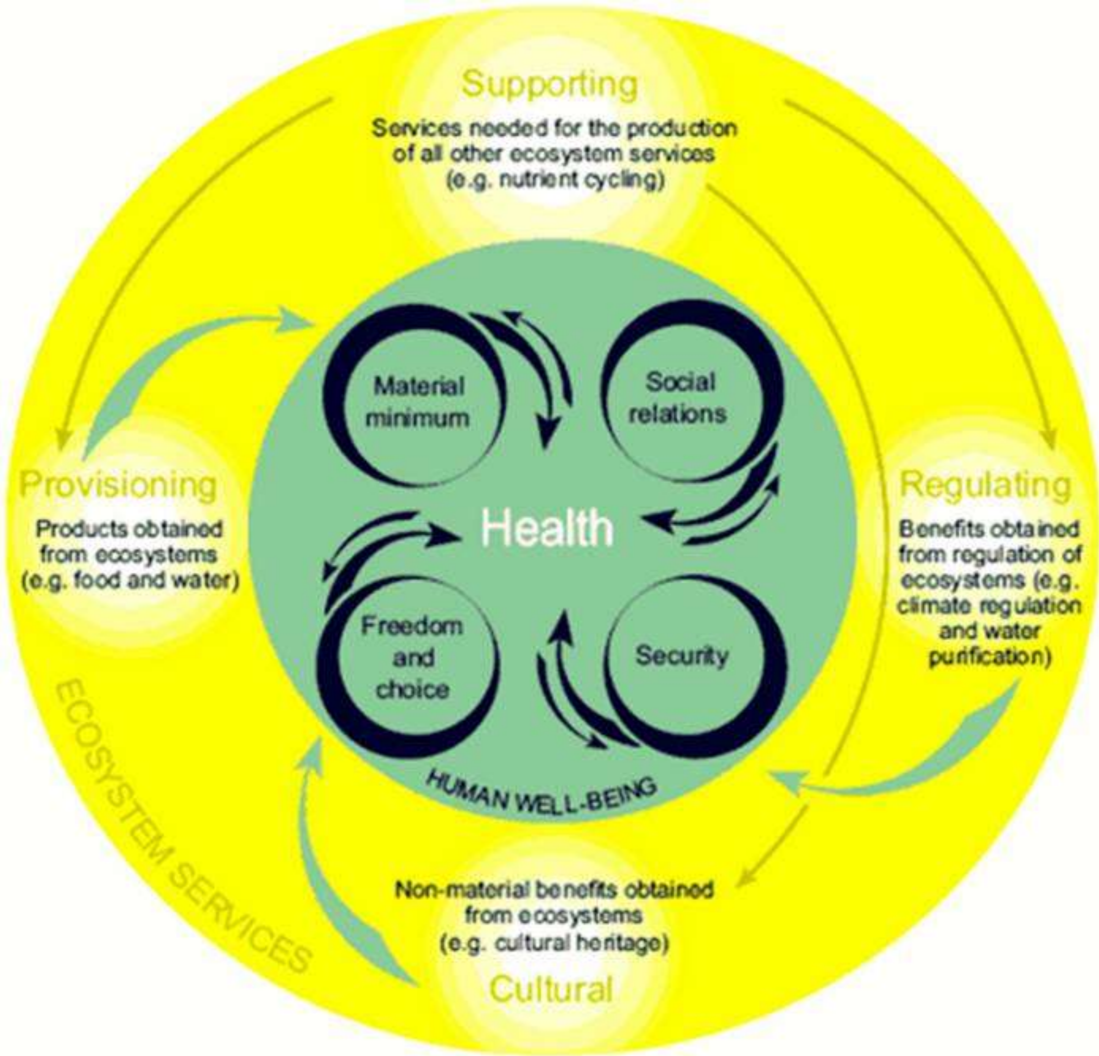
Phisyognomic-Structural Category of Vegetation	Mean g_s (mol/m^{2}s)
Holm oak prevailing (*Quercus ilex*)	0.1
Deciduous oak prevailing (*Quercus cerris*)	0.14
Pine woods (*Pinus pinea*)	0.08
Chestnut woods (*Castanea sativa*)	0.25
Beech woods (*Fagus sylvatica*)	0.25
Mediterranean maquis (*Quercus ilex, Arbutus unedo, Phillirea angustifolia*)	0.15
Norway spruce prevailing (*Picea Abies*)	0.036

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).

ECOSYSTEM SERVICES AND HEALTH



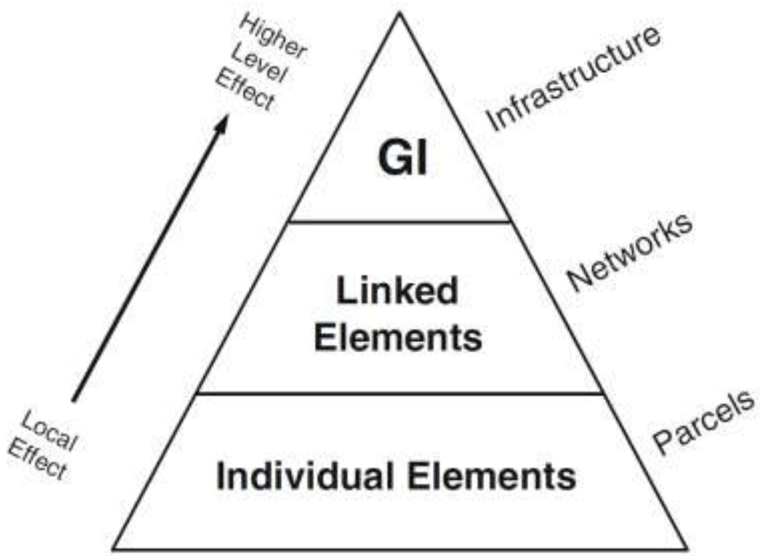
(From Coutts & Hahn, 2015 - *Int. J. Environ. Res. Public Health*)

GREEN INFRASTRUCTURE

Action 6 of the EU Biodiversity Strategy to 2020 set priorities to restore and promote the use of Green Infrastructure

6a) By 2014, Member States, with the assistance of the Commission, will develop a strategic framework to set priorities for ecosystem restoration at sub-national, national and EU level.

6b) The Commission will develop a Green Infrastructure Strategy by 2012 to promote the deployment of Green Infrastructure in the EU in urban and rural areas, including through incentives to encourage up-front investments in green infrastructure projects and the maintenance of Ecosystem Services, for example through better targeted use of EU funding streams and Public Private Partnerships.



Multifunctionality of GI can be assessed at different spatial levels

From Hansen & Pauleit, 2014