



LIFE-18 PRE IT 003 -  
The VEG-GAP  
project has  
received funding  
from the LIFE  
Programme of the  
European Union



# Strategie di riforestazione urbana: impatto sull'inquinamento atmosferico e sulla mortalità a lungo termine associata alla temperatura



**Bologna**  
Popolazione: 390,849 abitanti  
Area: 140,8 km<sup>2</sup>  
**Madrid**  
Popolazione: 3,141, 991 abitanti  
Area: 604,3 km<sup>2</sup>  
**Milano**  
Popolazione: 1,378,689 abitanti  
Area: 181,7 km<sup>2</sup>



<https://veggapplatform.enea.it/>  
<https://www.lifeveggap.eu/>

Vegetation for cleaner air and better climate: a holistic integration towards future cities

VEG-GAP Information Platform Access

Download here the Layman's report

Download here the Vegetation for urban green air quality plans

Twitter

Facebook

The VEG-GAP project works on developing a strategy for providing new reliable information in support of designing urban Air Quality Plans (AQPs) considering the urban vegetation ecosystems characteristics such as plant type and state, green area extension, etc.

The multiple vegetation ecosystems services will be evaluated in an integrated way through multi-scale and multi-pollutant approaches resembling the real-world as much as possible.

The vegetation ecosystems contributions both as a sources and sinks of air pollution, its effects on air temperature and further impact on air quality will be simultaneously investigated. This will contribute to a better understanding and evaluation of the possible risks and benefits for human health and ecosystems themselves associated with air pollution changes induced by vegetation/ecosystems changes which is another project objective.

Bologna, Madrid and Milan are the cities where the work will be implemented.

The main project aims are:

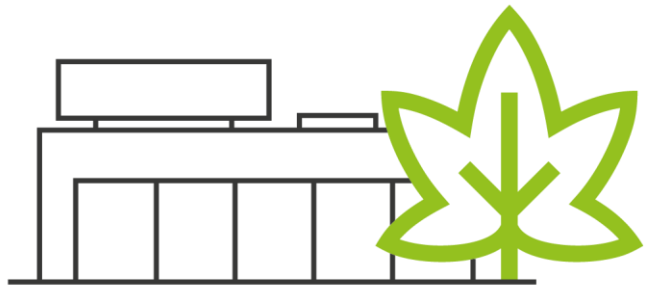
- to make available for the first time a framework of instruments (guidelines, support tools and information platform) that consistently consider the linkages between air pollution and vegetation characteristics in the development of effective control strategies
- to provide recommendations for improving the legislation aimed to maintain and improve air quality in European cities

Mihaela Mircea



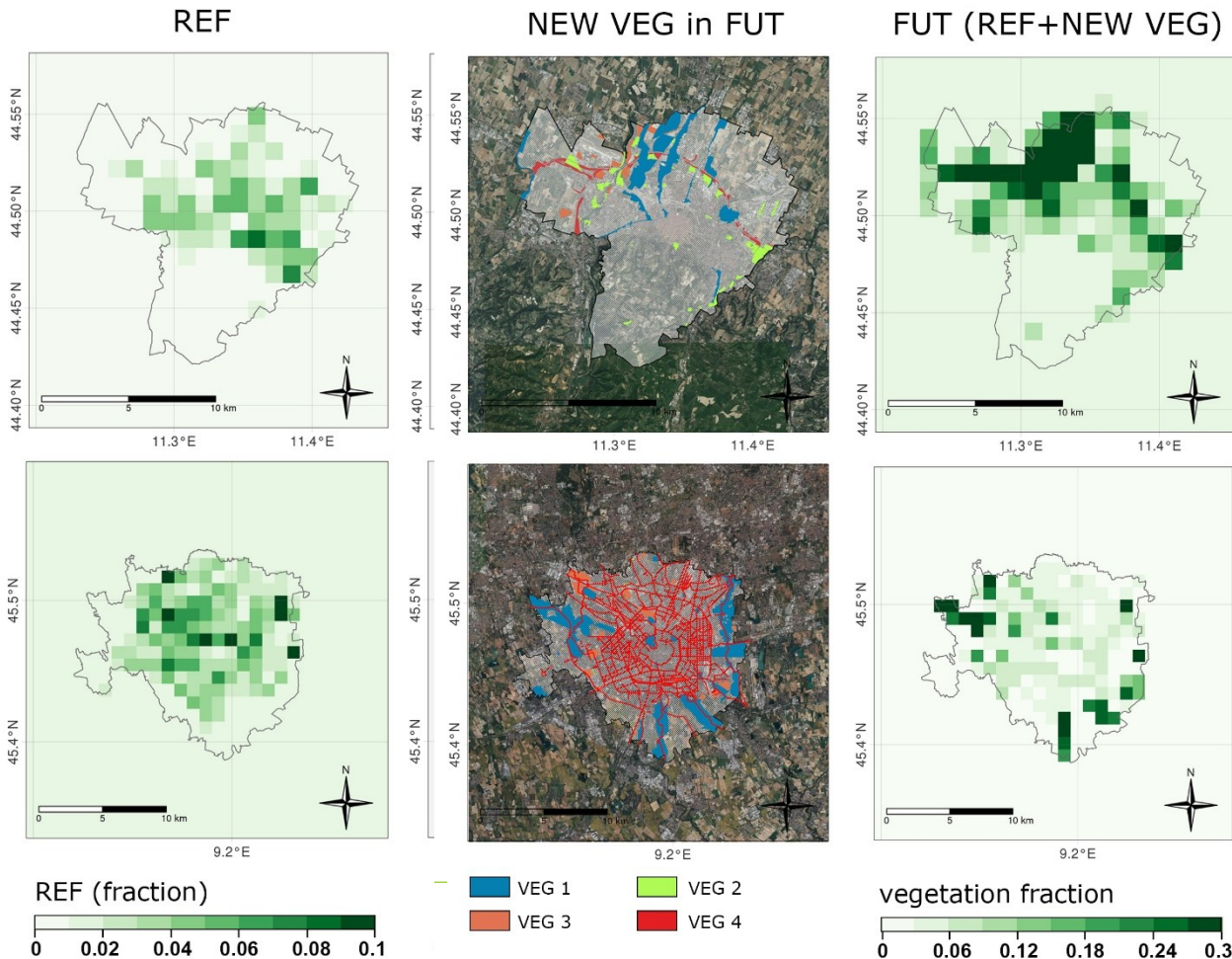
UNIVERSIDAD  
POLITÉCNICA  
DE MADRID





# Strategie di riforestazione urbana: impatto sull'inquinamento

(Mircea&Briganti&Russo et al., 2024)



## Bologna

- VEG1: redevelopment of historic areas, indicated in blue, including those already green;
- VEG2: the greening of strategical areas for the green system of Bologna, indicated in yellow;
- VEG3: greening of disused extraction and manufacturing areas, indicated in orange
- VEG4: requalification of areas adjacent to motorways, indicated in red for which there is an intentional but not yet a formally operational plan.

## Milano (2030)

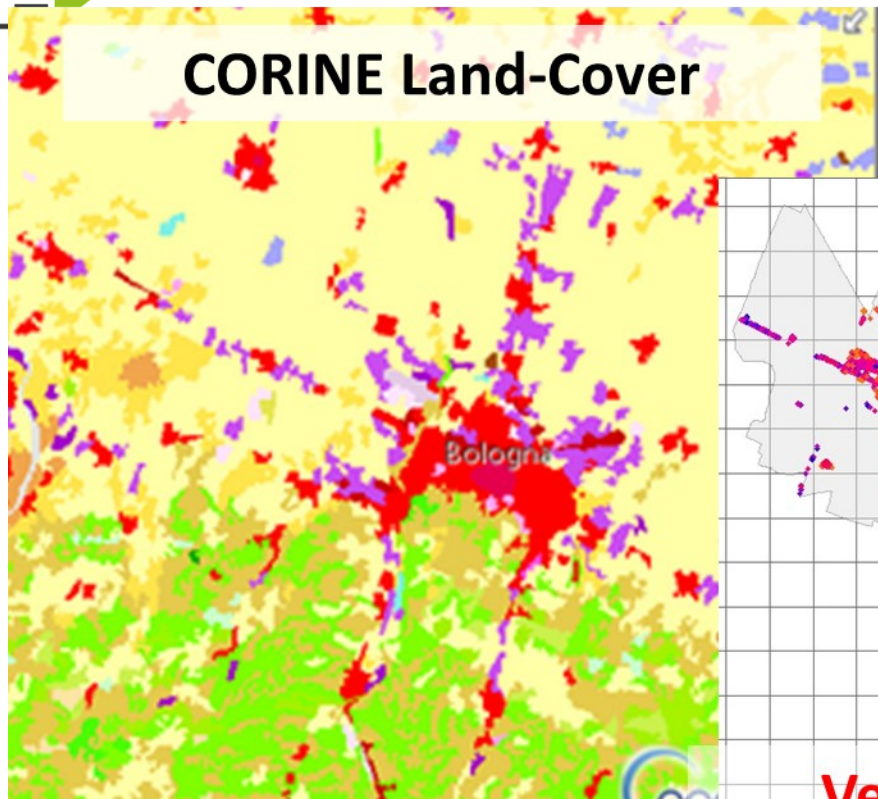
- VEG1: infrastructure for increasing ecological performance: large areas that include already-green zones, cemeteries, and quarries with lakes, indicated in blue, where vegetation cover will be requalified and new trees will be planted;
- VEG2: small public urban areas where new desealing and forestation projects will be developed, indicated in yellow;
- VEG3: creation of 20 new public parks, partially requalifying dismissed railway yards, indicated in orange
- VEG4: creation of ecological connecting corridors based on enhancing vegetation in already available roads for cyclists and pedestrians, indicated in red.



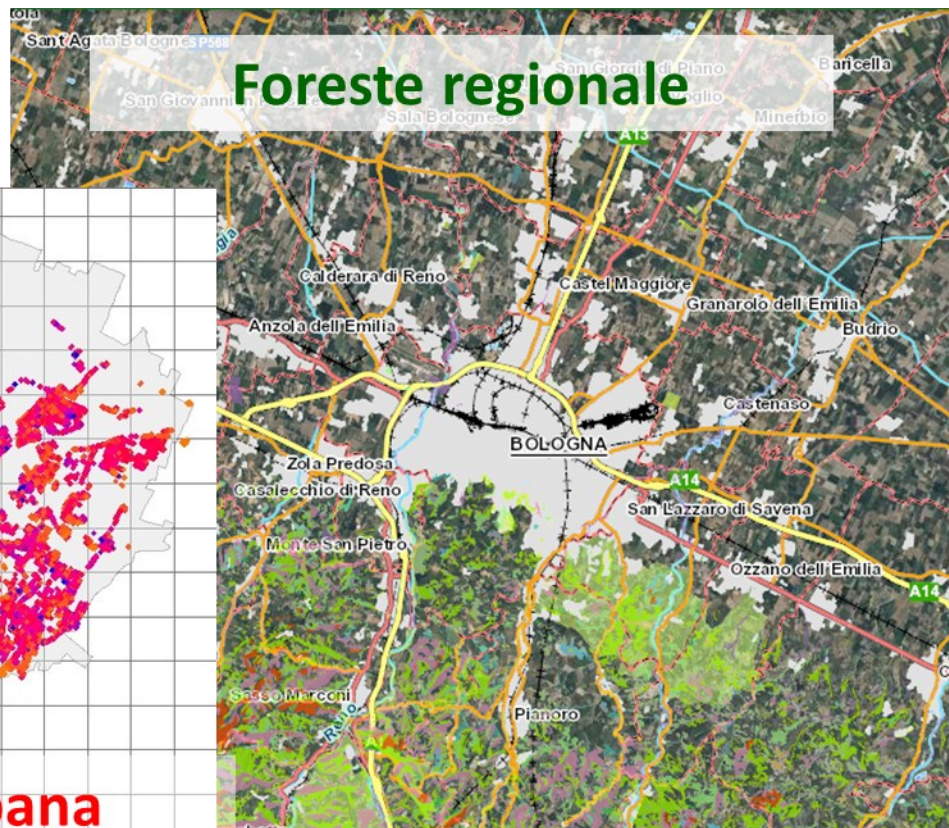
# Vegetazione in città: integrazione sorgenti di dati

- Esempio Bologna

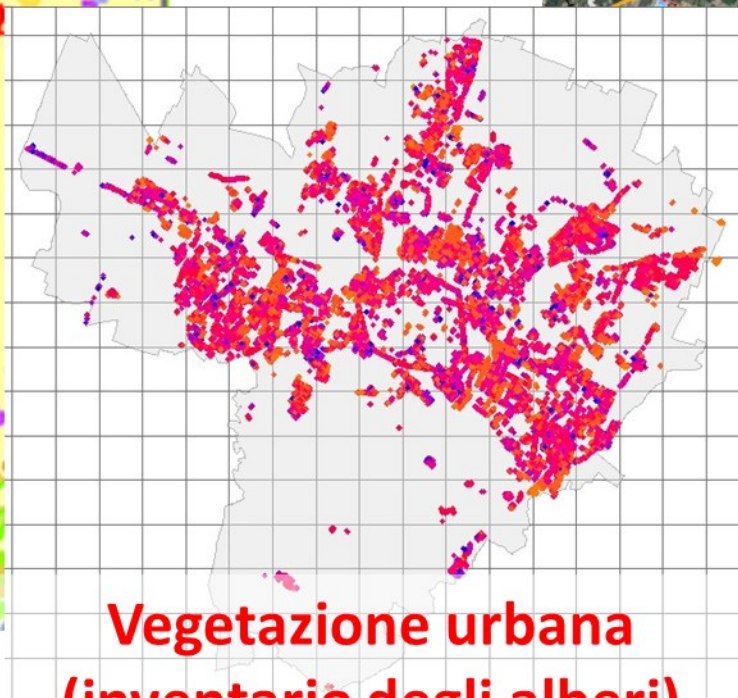
CORINE Land-Cover



Foreste regionale



Vegetazione urbana  
(inventario degli alberi)



Credit Sandro Finardi, ARIANET

# Dal singolo albero all'area occupata da singola specie e all'area occupata da vegetazione



## Modello BVOC



### Emission rates

The real emission rates ( $E_{real}$ ) [ $\mu\text{g m}^{-2} \text{h}^{-1}$ ] is expressed by following eq.:

$$E_{real} = (E_{max}) \cdot (\gamma_S) \cdot (\gamma_C) \cdot (1 + \gamma_L) \cdot (D_B)$$

seasonality     litter     foliar biomass density  
canopy

**Synthesis emission**  
 $E_{L+T}$   
ISOP,OVOC, MTP

$$E_{L+T,max} = BEF_{max} \cdot C_L \cdot C_T$$

**Pool emission**  
 $E_T$   
MTP,SQT

$$E_{T,max} = BEF_{max} \cdot \exp[-\beta(T - T_s)]$$

$C_L$  and  $C_T$  are activity factors accounting for light and temperature,  $\beta$  a diffusion term ranging between 0.07 and 0.9 and generally assumed to be 0.09,  $T$ =leaf temperature ( $^{\circ}\text{K}$ ) and  $T_s$ =303  $^{\circ}\text{K}$ .



### Basal Emission Factors

Nr.	Specie	Foliar biomass density [ $\text{g m}^{-2}$ ]	$E'_{max}$ isoprene	$E'_{max}$ MTS (T+)	$E'_{max}$ MTP (T+)	$E'_{max}$ SQT (T)	$E'_{max}$ OVOC (METHANOL 80%) (L+T)	Leaf seas. type	Seas. Type Karl et al.
1	Acer campestre	270	0	3.5	0	0.001	2	0	dec
2	Acer monspeliense	270	0	2	0	0.001	2	0	dec
3	Acer platanoides	270	0.1	3.5	0	0.001	2	0	dec
4	Acer sp.	270	0	2	0	0.001	2	0	dec
5	Alnus Albovina	-	-	-	-	-	-	-	dec
6	Alnus cordata	270	0	0	0.72	0.001	2	0	dec
7	Alnus glutinosa	270	0	3.5	0	0.001	2	0	dec
8	Alnus incana	270	0	3.5	0	0.001	2	0	dec
9	Alnus sarseda	300	0.1	0	0.2	0.001	2	0	dec
10	Betula pendula	230	0	0	3.5	0.001	2	0	dec
11	Betula pubescens	230	0	2	0.2	0.001	2	0	dec
12	Carpinus betulus	300	0	0.5	0	0.001	2	0	dec
13	Carpinus orientalis	300	0	0	0	0.001	2	0	dec
14	Castanea sativa	300	0	5	0	0.01	2	0	dec
15	Corylus avellana	300	0	0	0	0.001	2	0	dec
16	Fagus sylvatica	320	0	0.5	0.2	0.001	10	0	dec
17	Fraxinus excelsior	270	0	0	0	0.001	2	0	dec
18	Fraxinus ornus	270	0	0	0	0.001	2	0	dec
19	Juglans regia	300	0	0	0	0.1	2	0	dec
20	Ostrya carpinifolia	300	0	0	0	0.001	2	0	dec
21	Populus alba	260	0	0	0	0.001	2	0	dec
22	Populus hybridus	260	0	0	0	0.001	2	0	dec

Sommario

Layer

- alberi\_E32\_Erase
- alberi\_senza\_specie\_E32
- alberi\_E32
  - CL\_CIRC, decodifi\_2
  - 1
  - 2
  - c1
  - C1, < 15 (5 cm)
  - C2, 15 - 30 (5-10 cm)
  - C3, 30 - 45 (10 -15cm)
  - C4, 45 - 60 (15-19 cm)
  - C5, 75 - 90 (19-28 cm)
  - C6, 90 - 110 (28-35cm)
  - C7, 110 - 140 (35-45 cm)
  - C8, 140 - 170 (45-54 cm)
  - C9, 170 - 200 (54-64 cm)
  - C10, 200 - 230 (64-73 cm)
  - C11, 230 - 260 (73-80cm)
  - C12
- Com01012018\_WGS84
- Alberi\_E32\_BO\_perc\_griglia
  - perc\_area
  - 0,000000
  - 0,000001
  - 0,000002 - 0,000012
  - 0,000013 - 0,000208
  - 0,000209 - 0,003691
- carta\_tipi\_forestali\_BO\_MO\_1sp\_perc\_area\_griglia

Tabella

FID	Shape	NUM PT	COD UG	SPECIE	CL H	CL CIRC	PREGIO	decodifica	decodifi 2	decodifi 4	Classe	tronco	coefficiente	chioma
39	Punto	4128	48	Qur	4	C12	S	16 - 23		Quercus robur	C12	<Null>	15	15
46	Punto	13286	1861	Aei	3	C12	N	12 - 16		Aesculus hippocastanum	C12	<Null>	15	15
145	Punto	62185	3081	Tg1	4	C12	N	16 - 23		Tilia intermedia	C12	<Null>	15	15
286	Punto	97822	3411	Poex	4	C12	N	16 - 23			C12	<Null>	15	15
309	Punto	90340	3589	Pon	4	C12	N	16 - 23		Populus nigra	C12	<Null>	15	15
388	Punto	15915	1505	Poa	5	C12	N	>23		Populus alba	C12	<Null>	15	15

Credit Giuseppe Cremona, ENEA

Sandro Finardi, ARIANET

4  
ALBERI: censimento comunale alberi pubblici (DATO PUNTUALE) – Comune di Bologna

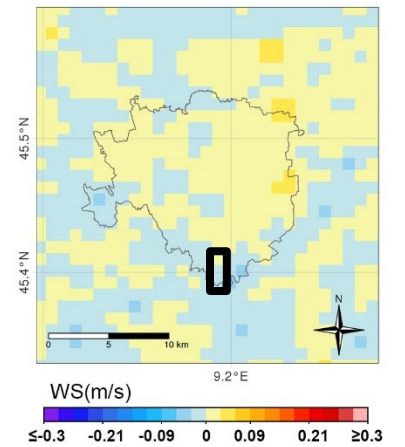
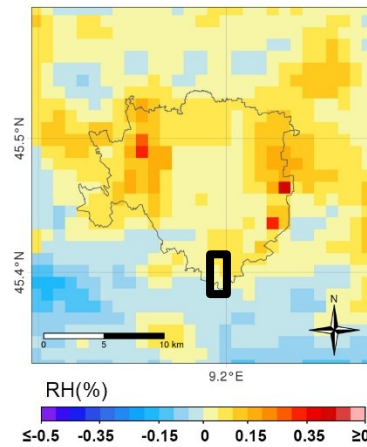
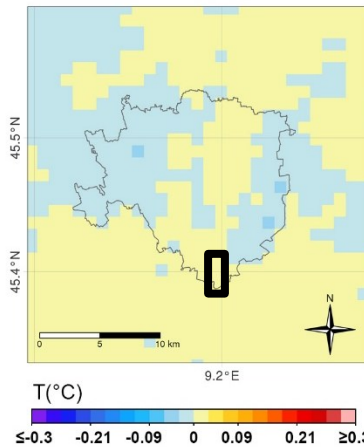
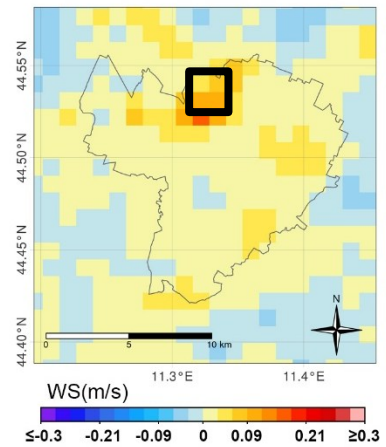
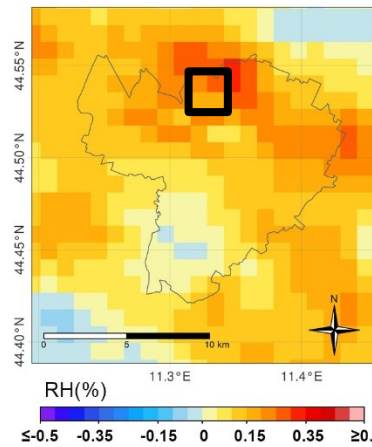
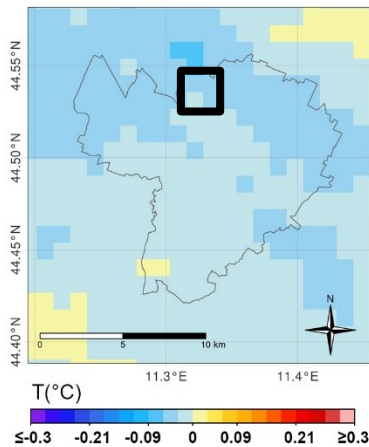
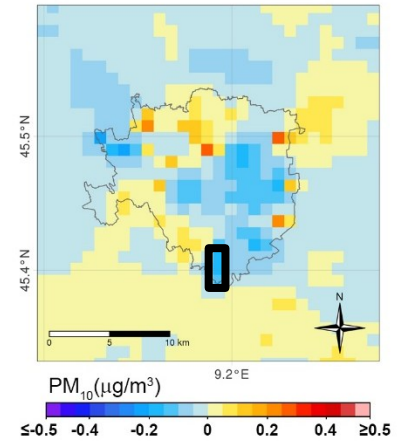
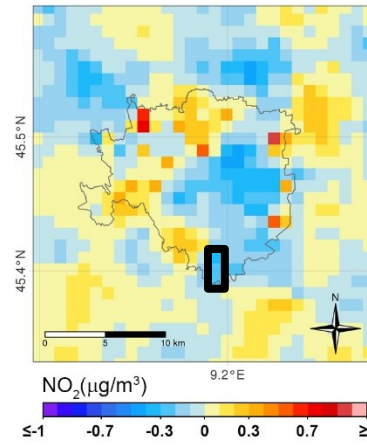
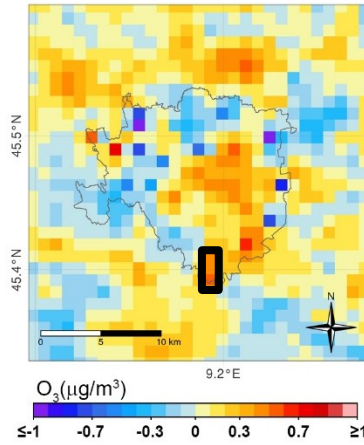
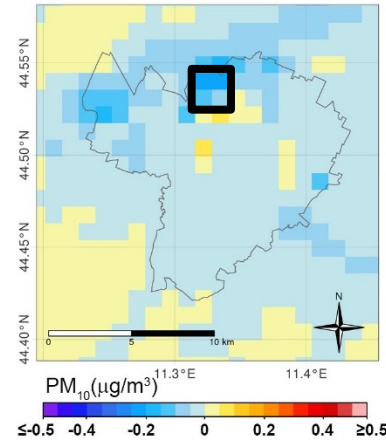
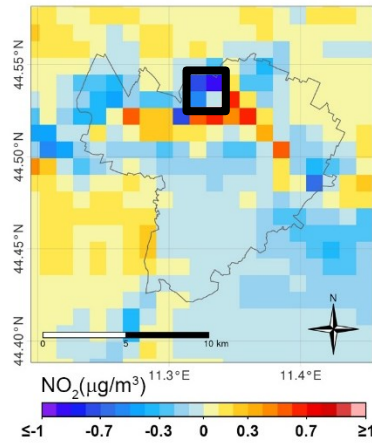
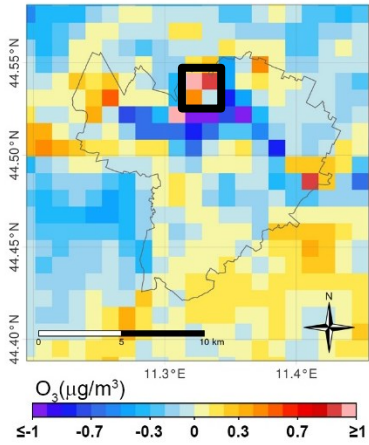


# Effetti della vegetazione futura su T, RH, WS e concentrazioni di O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>: media mensile per luglio 2015, FUT-REF



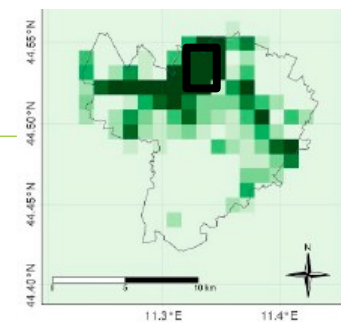
Bologna

Milan



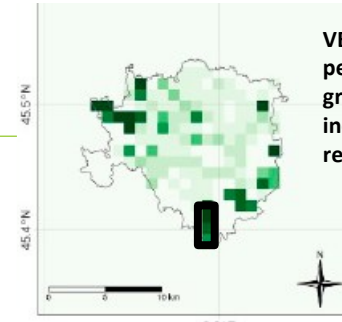
VEG 1: redevelopment of historic areas, indicated in blue, including those already green;

5



FUT (REF+NEW VEG)

Mircea&Briganti&Russo et al.  
(2024)



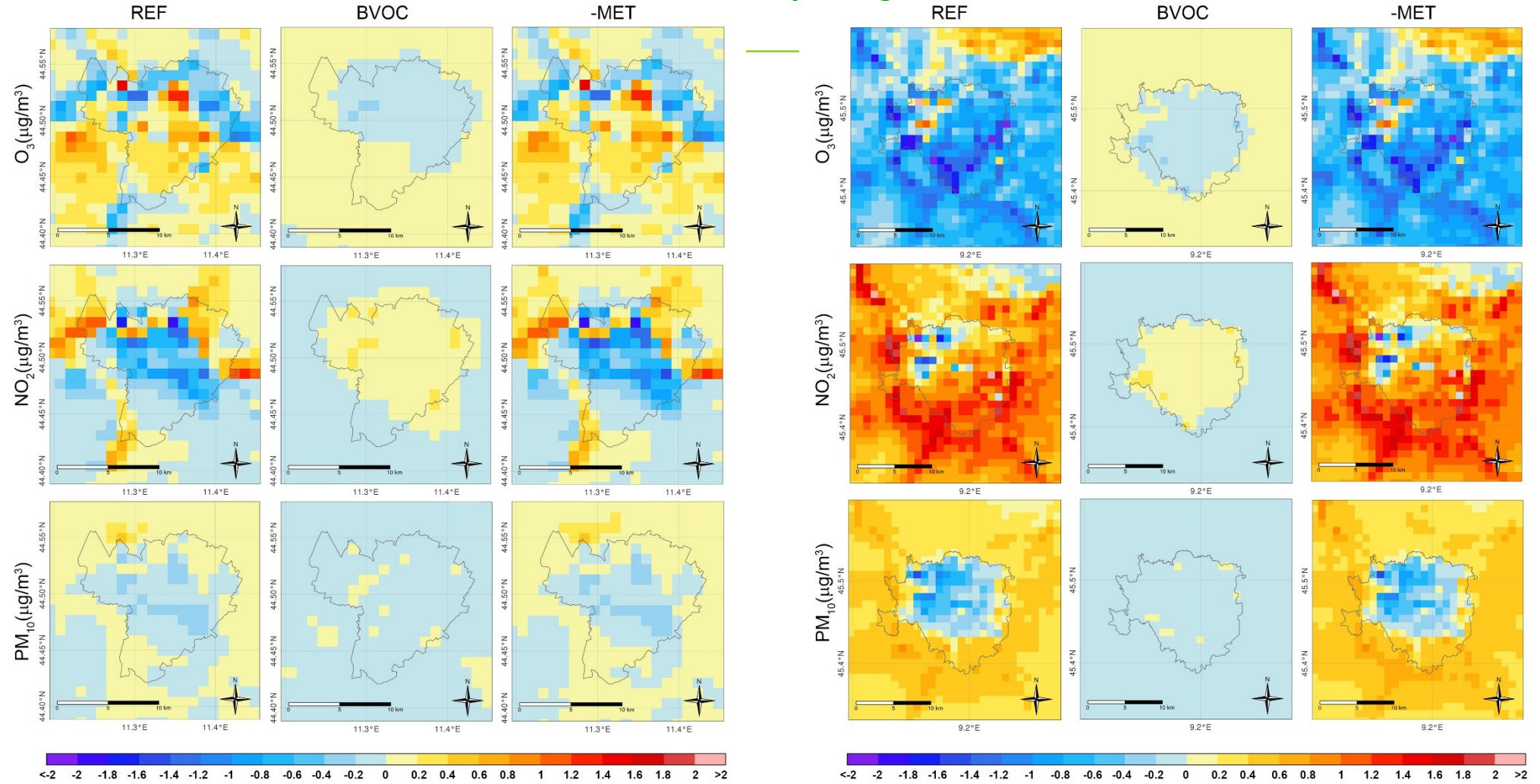
VEG 1: infrastructure for increasing ecological performance: large areas that include already-green zones, cemeteries, and quarries with lakes, indicated in blue, where vegetation cover will be requalified and new trees will be planted;



# Effetti della meteorologia e delle emissioni biogeniche sulle concentrazioni di O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>: media mensile per luglio 2015



Mircea&Briganti&  
Russo et al. (2024)



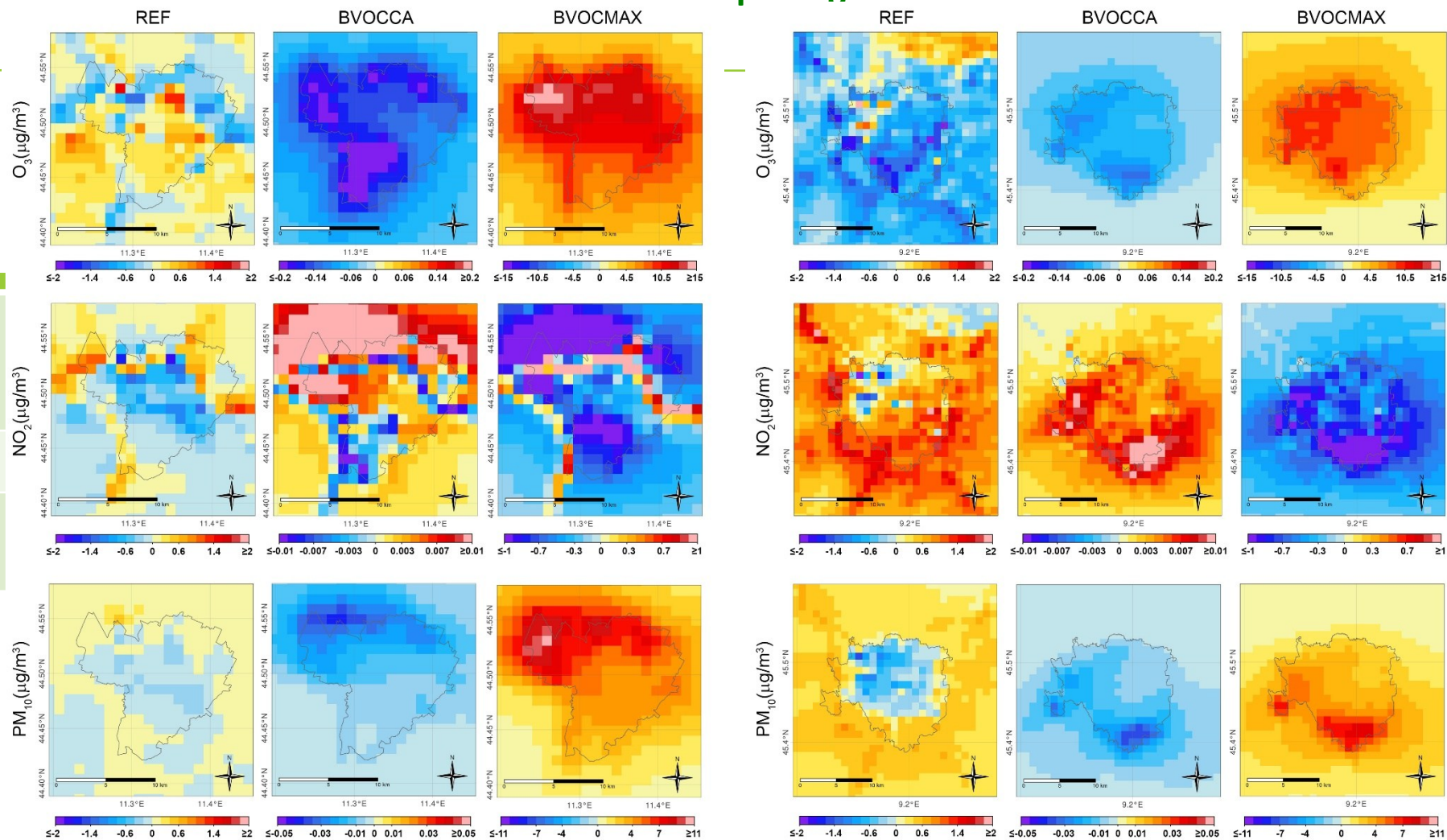
Indicator Name	REF	MET	BVOC
Simulations' differences			
VEG-NOVEG			
NOVEG-VEG_Uncoupled			
VEG-VEG_Uncoupled			
Vegetation effect			
MET		X	
BVOC			X
MET and BVOC	X		

Simulation Name	VEG	NOVEG	VEG_Uncoupled
Input Data			
MM	Present vegetation	Without vegetation	Present vegetation
CTM-land-use	Present vegetation	Without vegetation	Present vegetation
CTM-BVOC emission parameters	With BVOC emissions (PSEM)	Without BVOC emissions	Without BVOC emissions



**Veg  
Gap**  
Vegetation for Urban Green Air Quality Plans

# Effetti delle emissioni biogeniche sulle concentrazioni di O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>: media mensile per luglio 2015



Simulation Name	Foliar Dry Biomass Density (g <sub>dw</sub> m <sup>-2</sup> )	Emission Factor (μg g <sub>dw</sub> <sup>-1</sup> h <sup>-1</sup> )					Leaf Type
		Isoprene (T+L)	MTS (T+L)	MTP (T)	SQT (T)	OVOC (T+L)	
VEG_Celtis Australis	407	0.087	0.365	0.452	0	0.017	Deciduous
VEG_Maximum emissions factors	1340	133.05	43.507	53.825	2	10	Deciduous

Indicator Name	REF	BVOCCA	BVOCMAX
Simulations' differences			
Vegetation effect	VEG-NOVEG	VEG_Celtis Australis-VEG	VEG_Maximum emissions factors-VEG
MET			
BVOC		X	X
MET and BVOC	X		

Simulation Name	Input Data	VEG	NOVEG	VEG_Celtis Australis	VEG_Maximum Emissions Factors
MM		Present vegetation	Without vegetation	Present vegetation	Present vegetation
CTM-land-use		Present vegetation	Without vegetation	Present vegetation	Present vegetation
CTM-BVOC emission parameters		With BVOC emissions (PSEM)	Without BVOC emissions	With BVOC emissions using Celtis Australis emission factors	With BVOC emissions using maximum values of emission factors

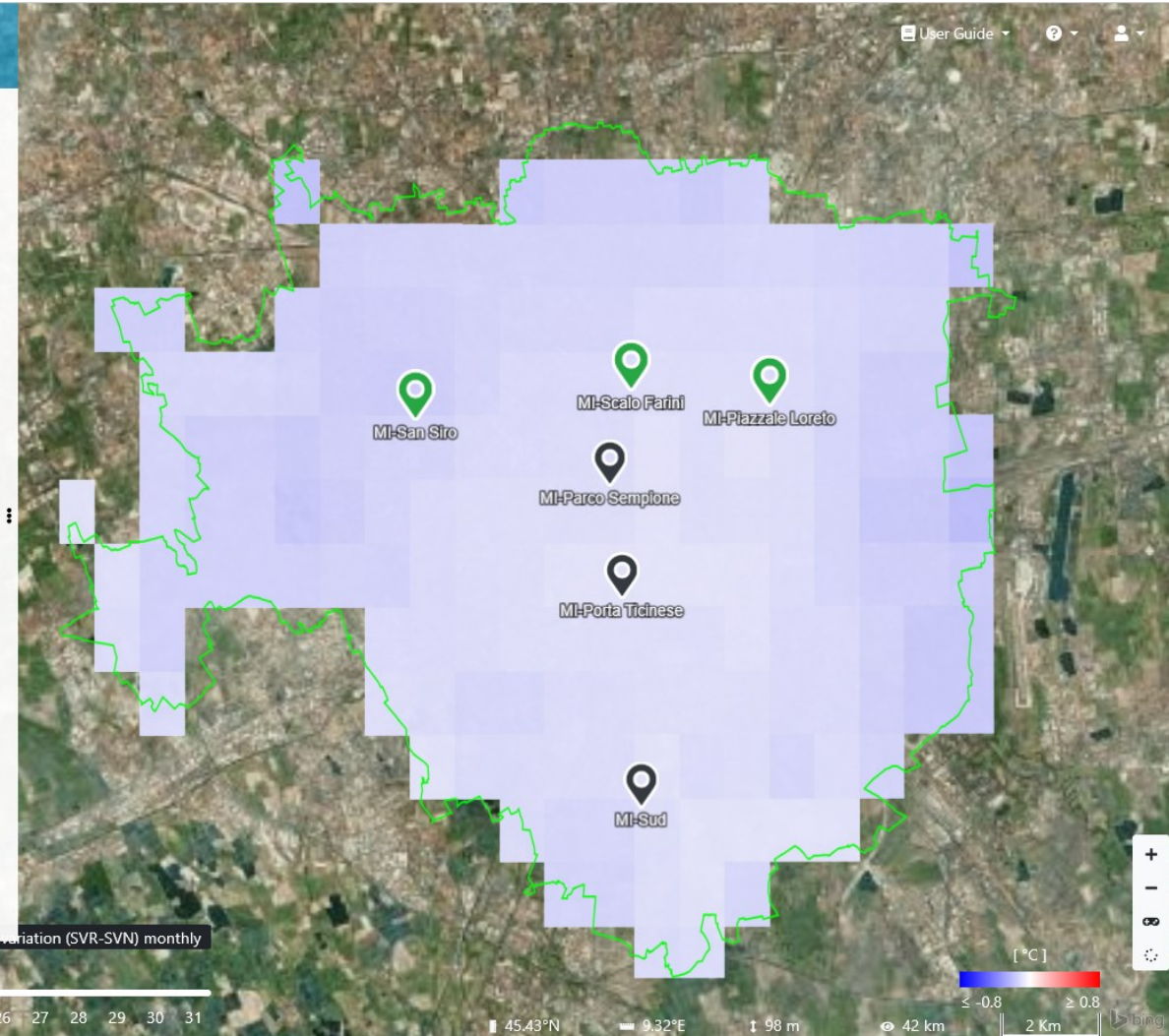
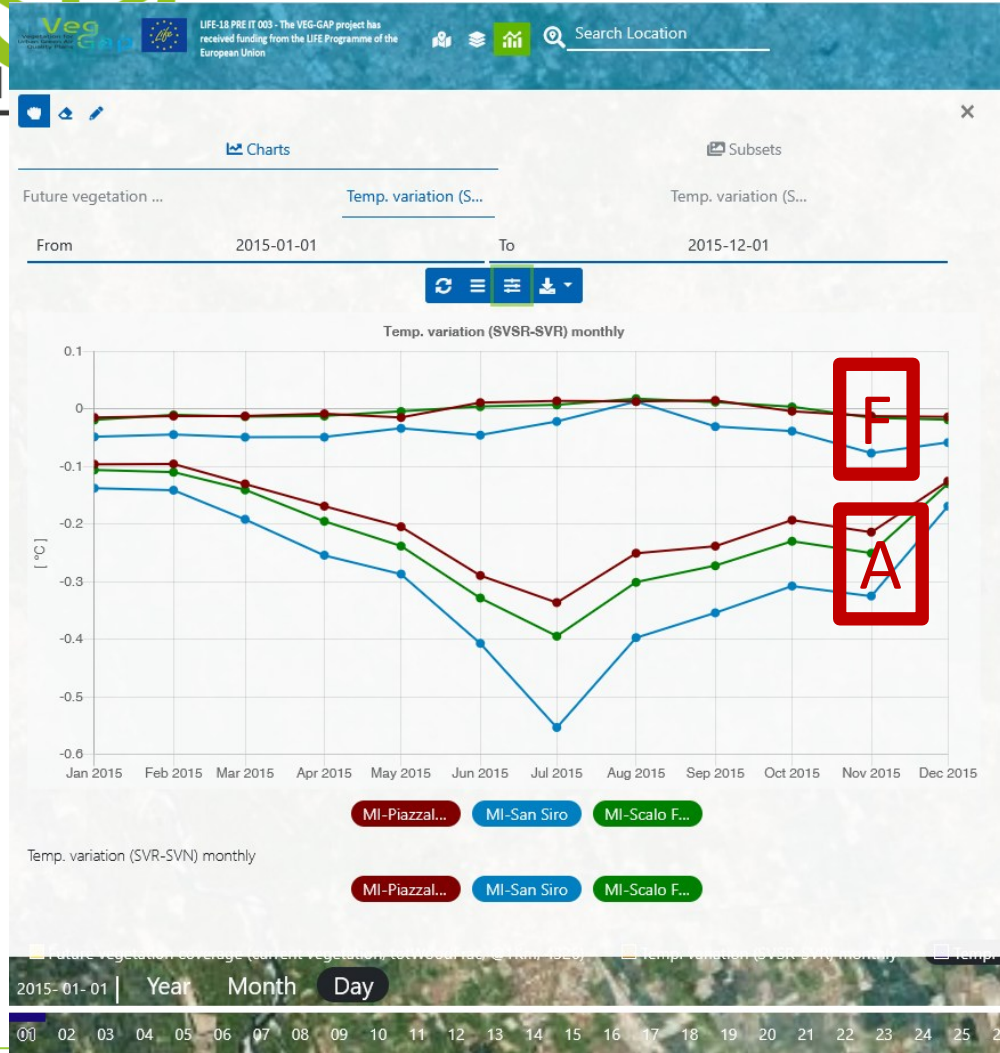
Mircea & Briganti & Russo et al. (2024)



**Veg Gap**  
Vegetation for Urban Green Air Quality Plans



# ADVANCED: l'effetto vegetazione **attuale (A)** e **futura(F)** sulla temperatura Milano

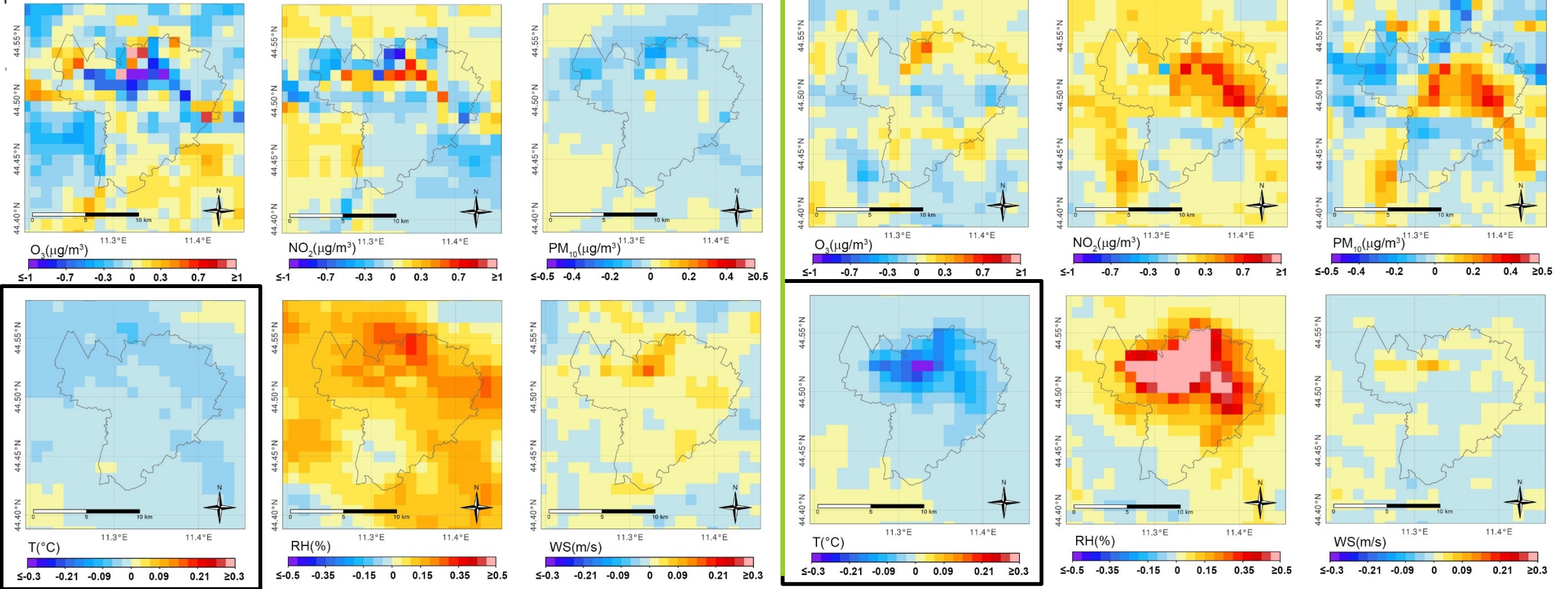


<https://veggaplatform.enea.it/>



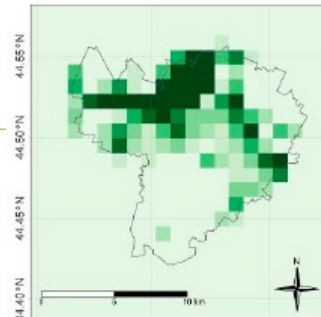
# Effetti della vegetazione futura su T, RH, WS e concentrazioni di O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>: media mensile per luglio e gennaio 2015, FUT-REF

## Bologna

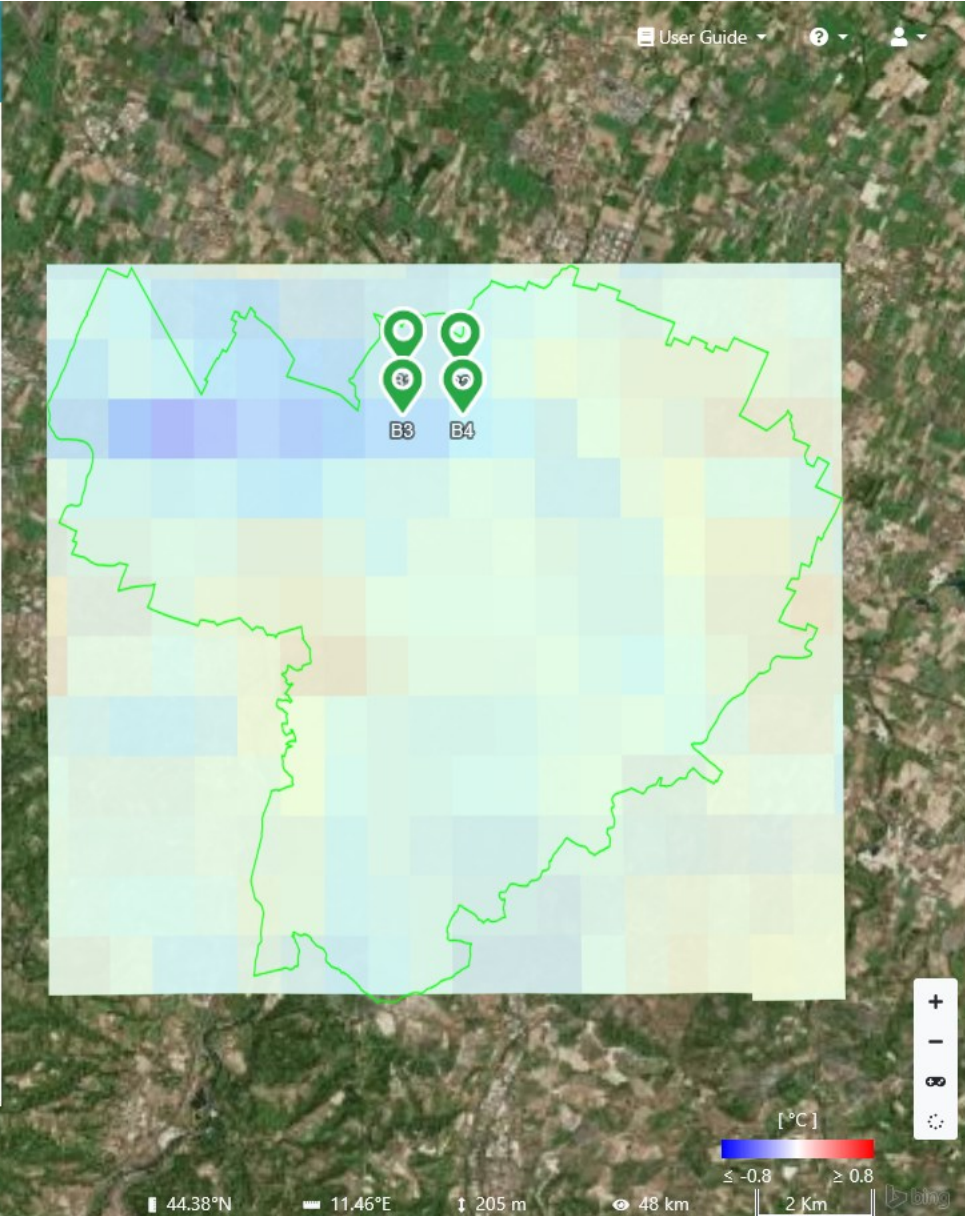
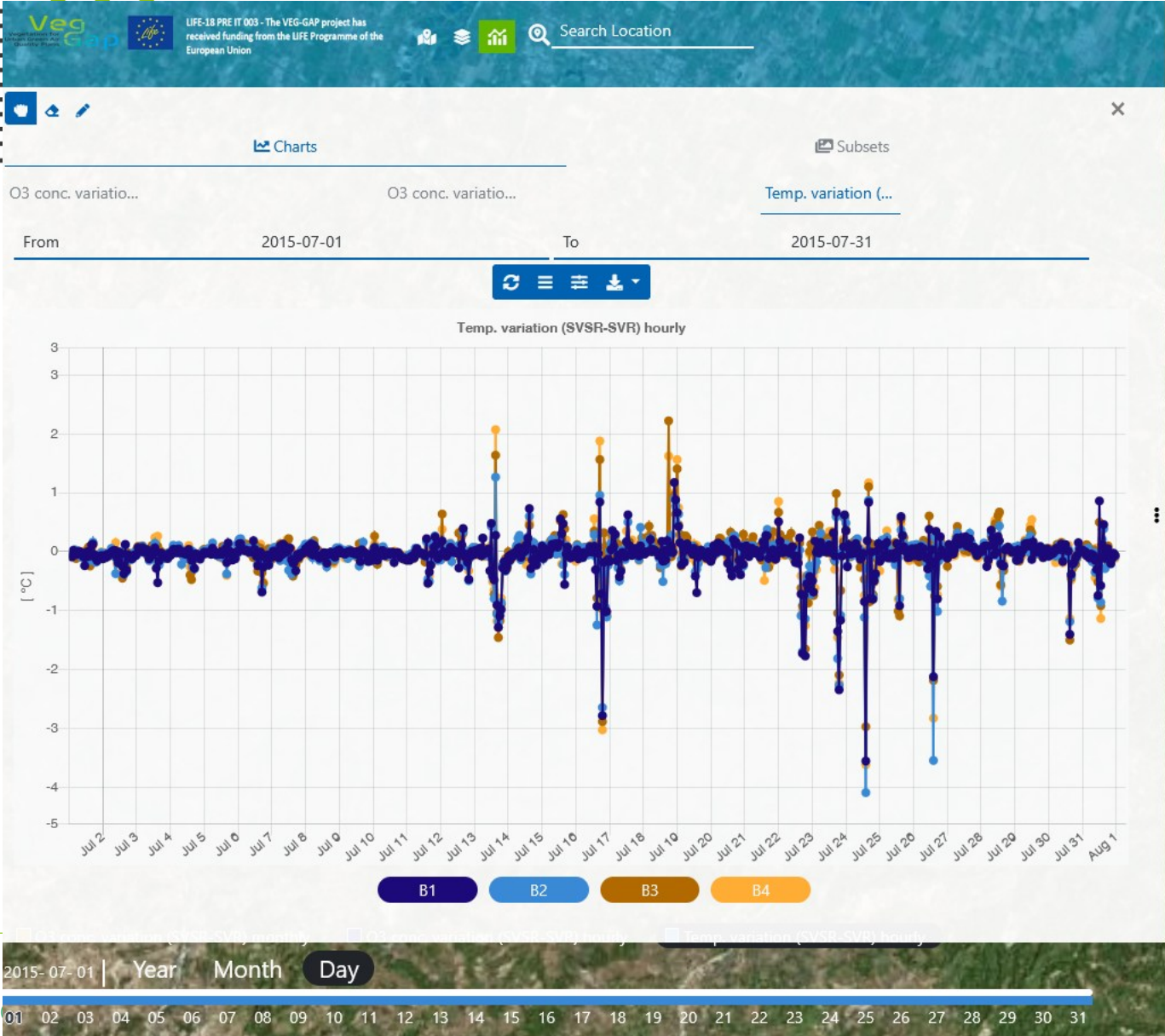


luglio

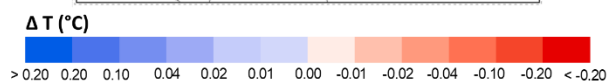
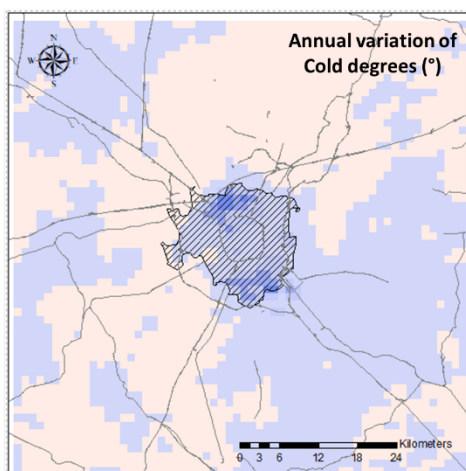
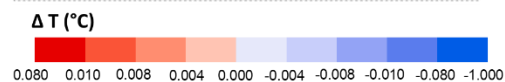
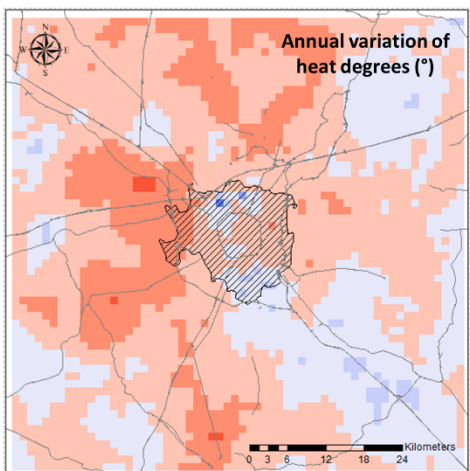
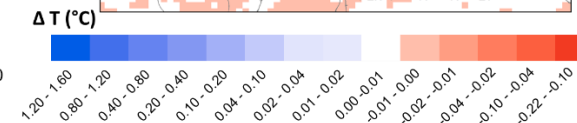
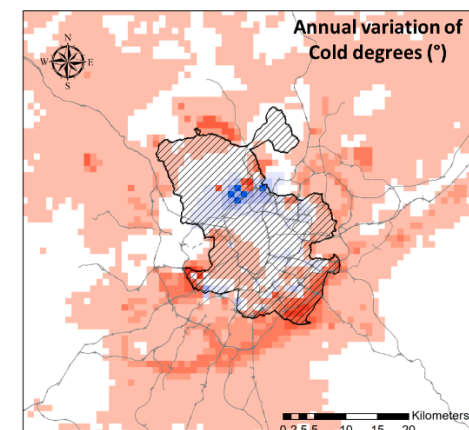
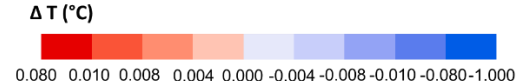
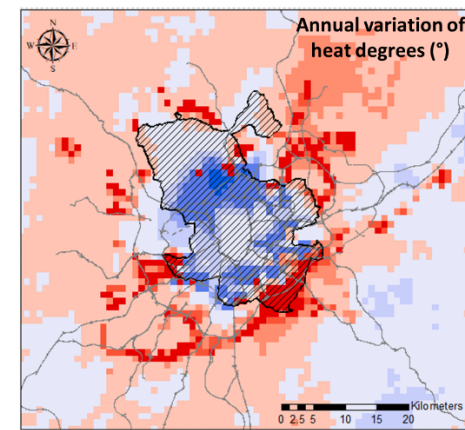
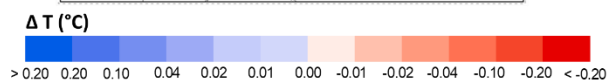
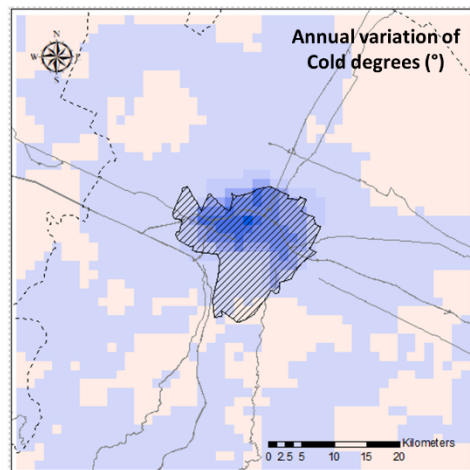
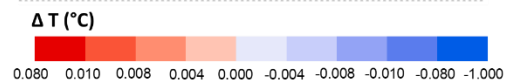
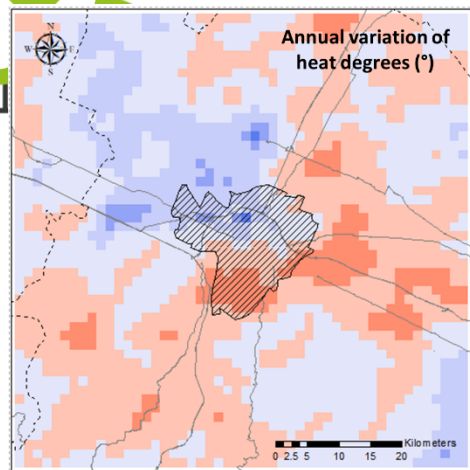
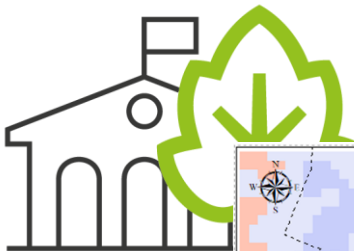
gennaio



# Effetti della vegetazione futura sulla temperatura Bologna, FUT-REF



# Rinverdimento urbano e mortalità: gradi caldi e gradi freddi



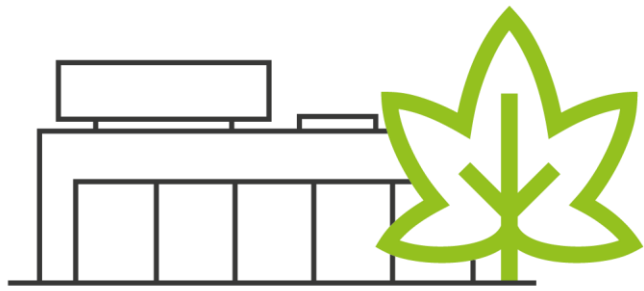
**Table 1.** Minimum mortality temperature and percent excess relative risks (ERR) per 1 °C change in temperature (from [Armstrong et al., 2017](#)).

City	MMT (°C)	Heat ERR% (95% Confidence Interval)	Cold ERR% (95% Confidence Interval)
Madrid	21.4	3.2 (0.6, 5.8)	2.7 (1.5, 3.9)
Milano and Bologna	21.8	8.3 (2.5, 14.4)	-1.1 (-5.2, 3.3)

de Andrés et al. (2025)

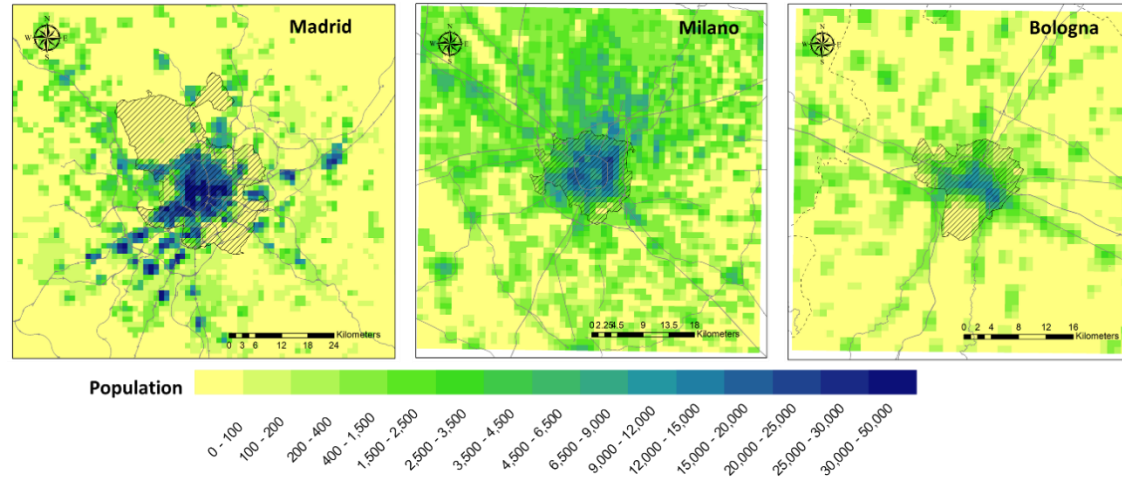
- $heat\_degrees_{i,t} = \sum_{d=1}^{365} \{ \max[(temp_{i,t,d} - MMT_i), 0] \} / 365$ , with  $temp_{i,t,d}$  being mean temperature on day  $d$ , year  $t$ , location  $i$ .
- $cold\_degrees_{i,t} = \sum_{d=1}^{365} \{ \max[(MMT_i - temp_{i,t,d}), 0] \} / 365$ .





# Rinverdimento urbano e riduzione della mortalità indotta dalla temperatura

Distribuzione spaziale della popolazione totale nelle tre città selezionate.



$$\Delta M = M_0 \cdot [1 - e^{\beta \cdot \Delta T}] \cdot P$$

$\Delta M$  è la differenza tra il numero di decessi attribuibili alle variazioni di temperatura  $\Delta T$

$M_0$  è il tasso di mortalità di base

$P$  è la popolazione per l'anno di riferimento o lo scenario di base

$\beta$  è l'aumento frazionario di RR per °C (ERR%/100).

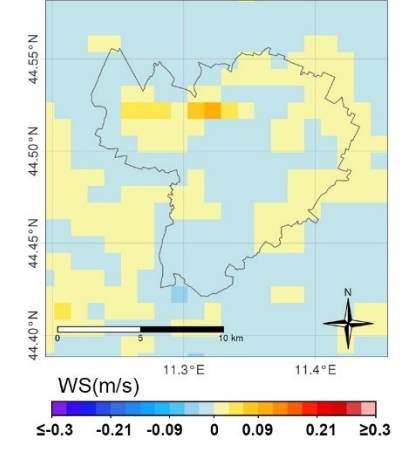
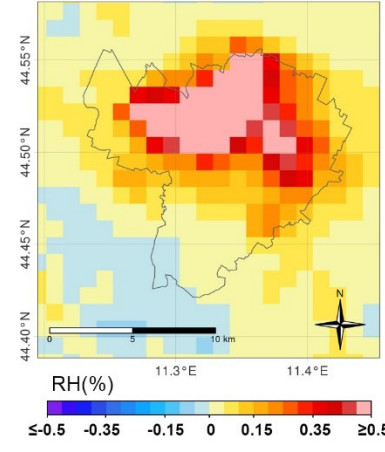
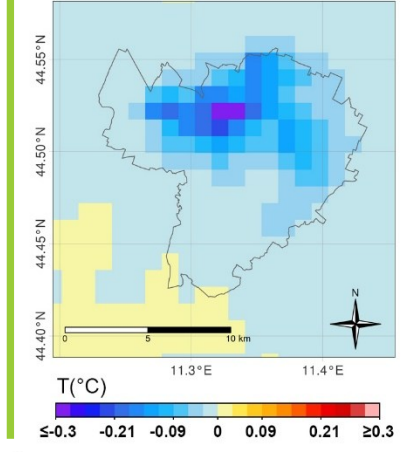
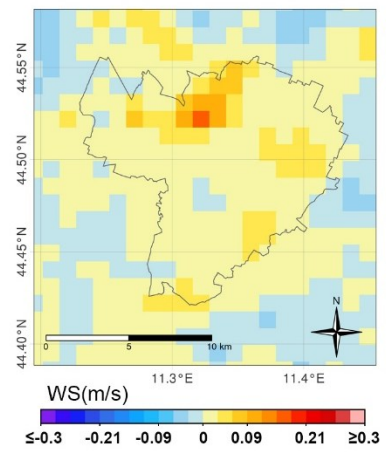
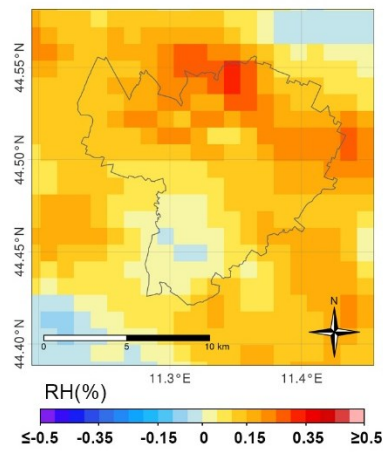
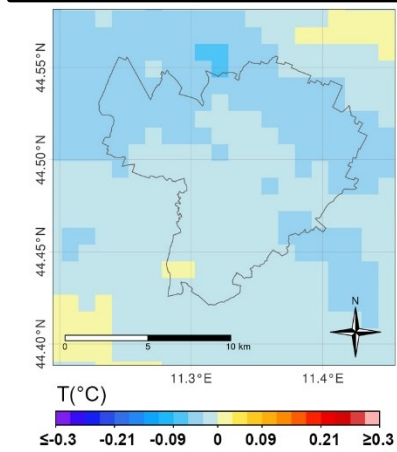
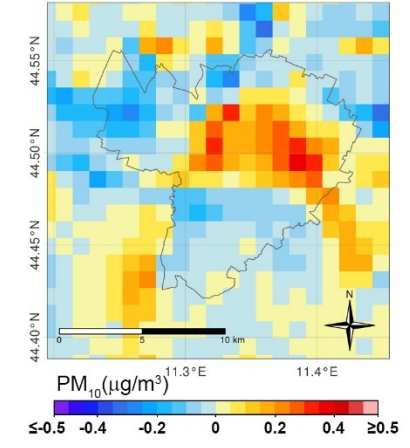
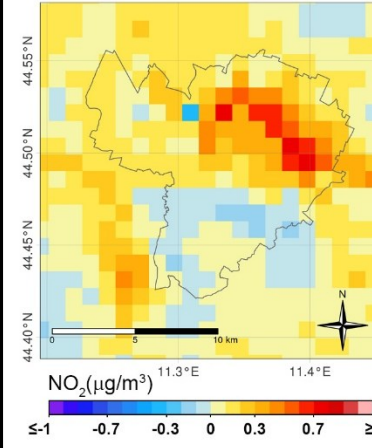
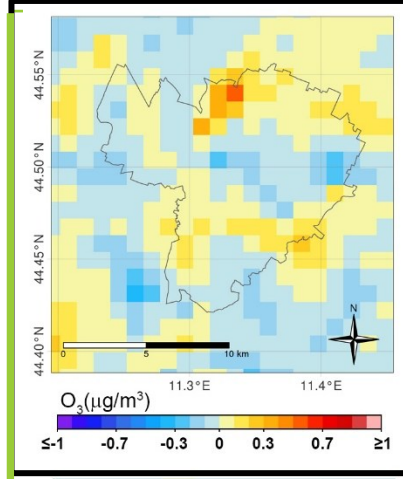
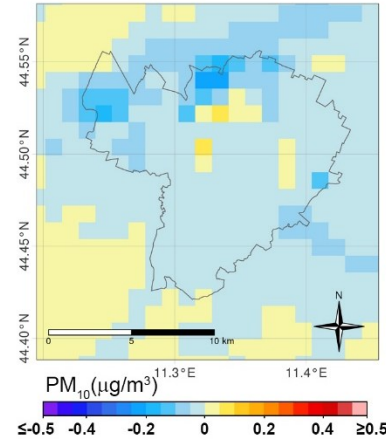
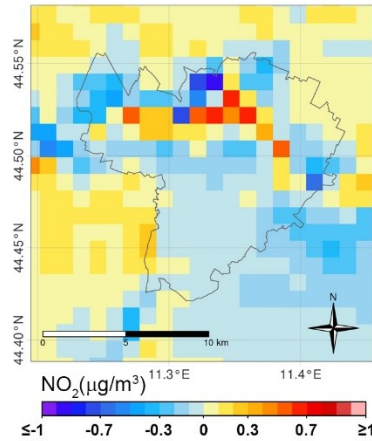
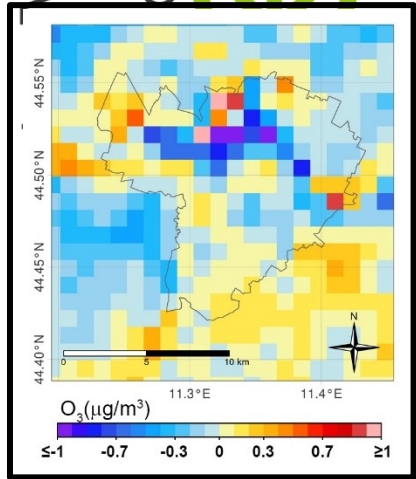
Variazioni della mortalità cumulativa (decessi annuali totali) indotte da futuri interventi di rinverdimento

City	$\Delta T$ (°C)		$\Delta M$ (95% Confidence Interval in Brackets)		
	Heat	Cold	Heat Deaths	Cold Deaths	Net Change in Temperature-Related Mortality
Madrid	-7.7	6.5	-7.4 (-1.4, -13.4)	3.2 (1.8, 4.7)	-4.1 (-11.6, 3.3)
Milano	0.1	2.4	0.9 (0.3, 1.6)	-2.1 (-10.0, 6.3)	-1.2 (-9.7, 8.0)
Bologna	-0.7	2.0	-0.4 (-0.1, -0.6)	-3.0 (-14.1, 8.9)	-3.4 (-14.3, 8.8)

# Effetti della vegetazione futura su T, RH, WS e concentrazioni di O<sub>3</sub>, NO<sub>2</sub>, PM<sub>10</sub>: media mensile per luglio e gennaio 2015, FUT-REF

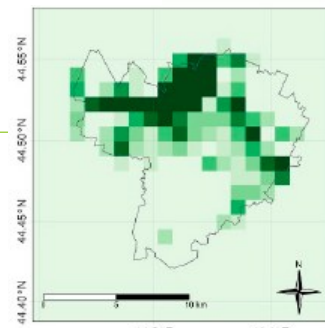


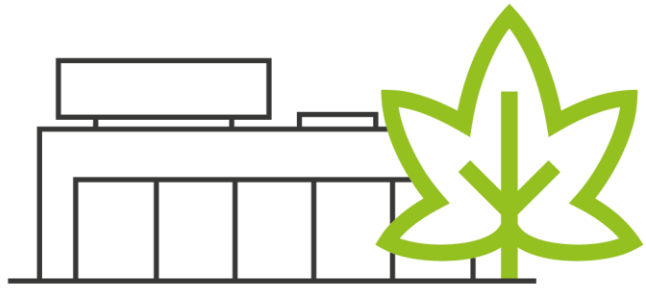
## Bologna



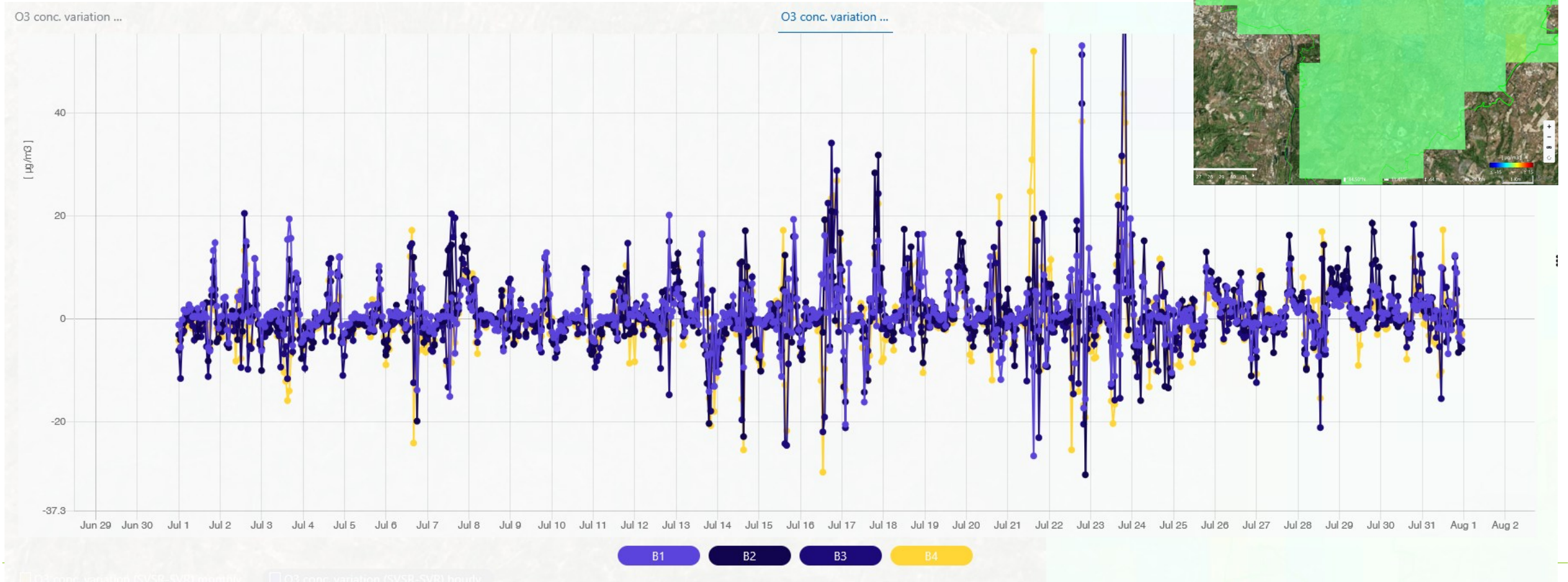
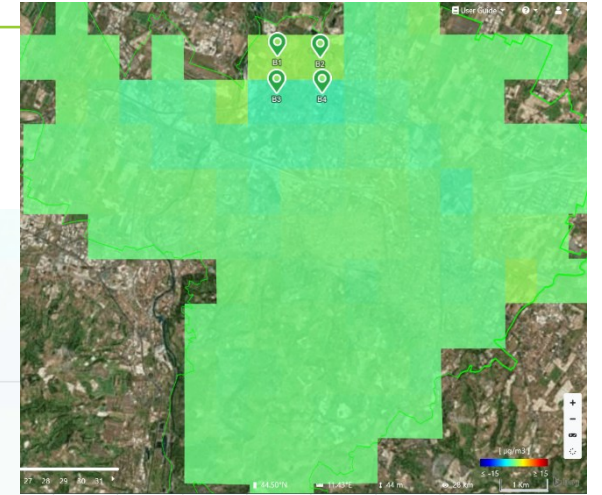
## luglio

## gennaio





# Effetti della vegetazione futura sulle concentrazioni orari di O<sub>3</sub> Bologna, FUT-REF



# Take-Home Message

La distribuzione degli inquinanti in città è determinata dalla morfologia del territorio, dalla presenza di vegetazione e dalle sorgenti emissive.

Decisioni sostenibili a tutela della salute umana e della biodiversità richiedono un approccio integrato, basato su un unico piano che coordini il piano di qualità dell'aria e del clima, il piano del verde e il piano regolatore generale.





LIFE-18 PRE IT 003 - The VEG-GAP project  
has received funding from the LIFE  
Programme of the European Union

# Grazie per l'attenzione!

# Veg Gap

Vegetation for  
Urban Green Air  
Quality Plans



<https://www.lifeveggap.eu/>  
[mihaela.mircea@enea.it](mailto:mihaela.mircea@enea.it)



Article

## Assessment of Air Quality and Meteorological Changes Induced by Future Vegetation in Madrid

David de la Paz <sup>1</sup>, Juan Manuel de Andrés <sup>1</sup>, Adolfo Narros <sup>1</sup>, Camillo Silibello <sup>2</sup>, Sandro Finardi <sup>2</sup>, Silvano Fares <sup>3,4</sup>, Luis Tejero <sup>5</sup>, Rafael Borge <sup>1,\*</sup> and Mihaela Mircea <sup>6</sup>



Article

## The Role of Vegetation on Urban Atmosphere of Three European Cities—Part 1: Evaluation of Vegetation Impact on Meteorological Conditions

Massimo D'Isidoro <sup>1,\*</sup>, Mihaela Mircea <sup>1,\*</sup>, Rafael Borge <sup>2</sup>, Sandro Finardi <sup>3</sup>, David de la Paz <sup>2</sup>, Gino Briganti <sup>1</sup>, Felicita Russo <sup>1</sup>, Giuseppe Cremona <sup>1</sup>, Maria Gabriella Villani <sup>1</sup>, Mario Adani <sup>1</sup>, Gaia Righini <sup>1</sup>, Lina Vitali <sup>1</sup>, Milena Stracquadanio <sup>1</sup>, Rossella Prandi <sup>4</sup> and Giuseppe Carlino <sup>4</sup>



Article

## The Role of Vegetation on Urban Atmosphere of Three European Cities. Part 2: Evaluation of Vegetation Impact on Air Pollutant Concentrations and Depositions

Mihaela Mircea <sup>1,\*</sup>, Rafael Borge <sup>2</sup>, Sandro Finardi <sup>3</sup>, Gino Briganti <sup>1</sup>, Felicita Russo <sup>1</sup>, David de la Paz <sup>2</sup>, Massimo D'Isidoro <sup>1</sup>, Giuseppe Cremona <sup>1</sup>, Maria Gabriella Villani <sup>1</sup>, Andrea Cappelletti <sup>1</sup>, Mario Adani <sup>1</sup>, Ilaria D'Elia <sup>1</sup>, Antonio Piersanti <sup>1</sup>, Beatrice Sorrentino <sup>1</sup>, Ettore Petralia <sup>1</sup>, Juan Manuel de Andrés <sup>2</sup>, Adolfo Narros <sup>2</sup>, Camillo Silibello <sup>3</sup>, Nicola Pepe <sup>3</sup>, Rossella Prandi <sup>4</sup> and Giuseppe Carlino <sup>4</sup>



Article

## City-Scale Revegetation Strategies Impact on the Temperature-Related Long-Term Mortality: A Quantitative Assessment in Three Cities in Southern Europe

Juan Manuel de Andrés <sup>1</sup>, Ilaria D'Elia <sup>2</sup>, David de la Paz <sup>1</sup>, Massimo D'Isidoro <sup>2</sup>, Felicita Russo <sup>2</sup>, Mihaela Mircea <sup>2</sup>, Maurizio Gualtieri <sup>3</sup>, Sotiris Vardoulakis <sup>4</sup> and Rafael Borge <sup>1,\*</sup>



Article

## Vegetation Effects on Air Pollution: A Comprehensive Assessment for Two Italian Cities

Mihaela Mircea <sup>1,\*</sup>, Gino Briganti <sup>1,\*</sup>, Felicita Russo <sup>1,\*</sup>, Sandro Finardi <sup>2</sup>, Camillo Silibello <sup>2</sup>, Rossella Prandi <sup>3</sup>, Giuseppe Carlino <sup>3</sup>, Massimo D'Isidoro <sup>1</sup>, Andrea Cappelletti <sup>1</sup> and Giuseppe Cremona <sup>1</sup>

