World Forum on Urban Forests

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The function of urban green areas in controlling air pollution

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The UN Sustainable Development Goals 2015-2030

Why air quality matters

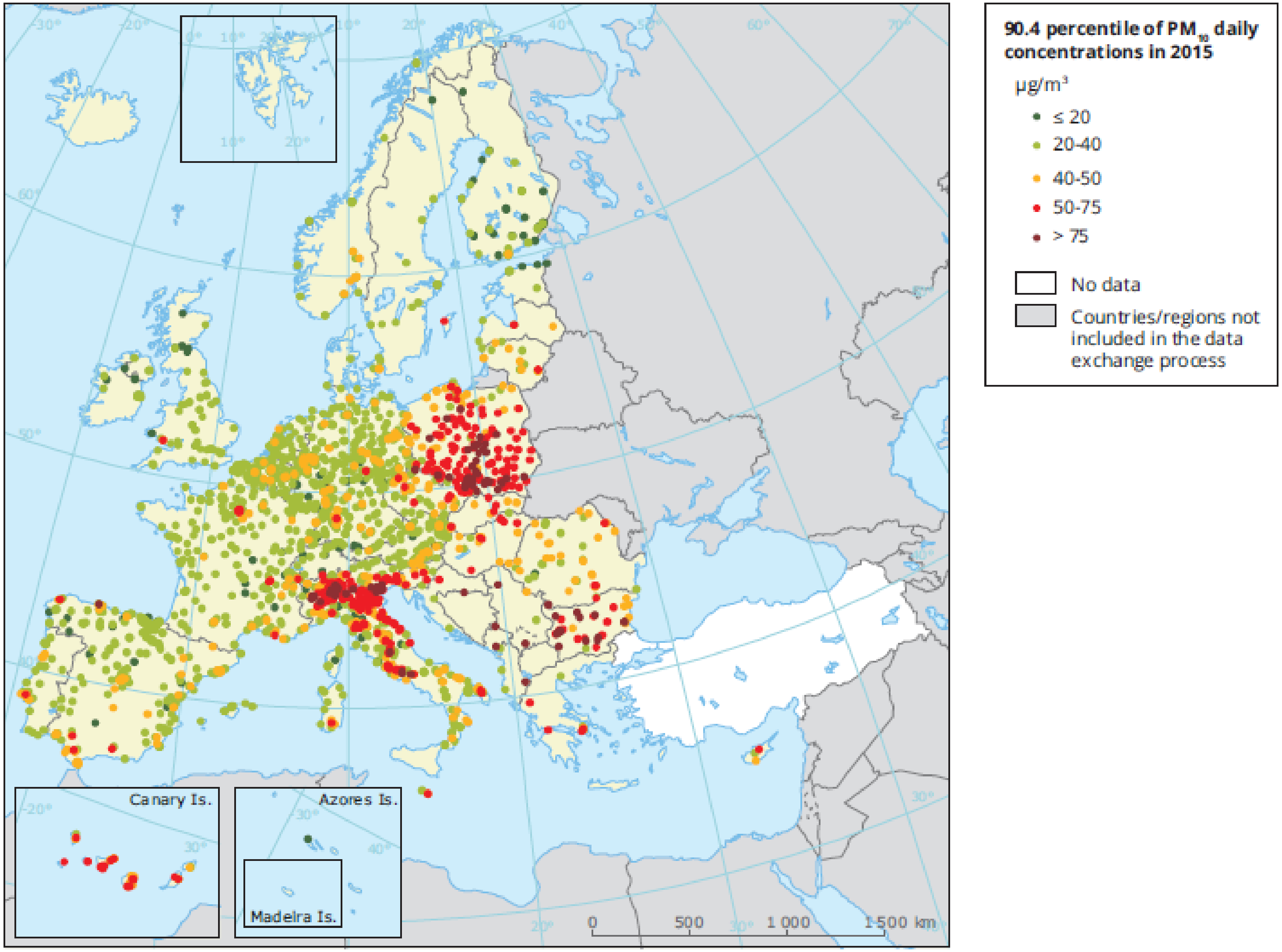
Figure 1.1 **How air pollution relates to the UN Sustainable Development Goals**

1	Reducing air pollution can help families become healthier, save on medical expenses, and improve productivity.	9	Power generation, industry and transportation are large contributors to air pollution. A new focus on decreasing energy consumption and on improving sustainable and public transportation could progressively reduce pollution.
2	Air pollution can cause crop damage and affect food quality and security.	11	Urban areas significantly contribute to air pollution. Making cities sustainable could progressively improve the air quality.
3	Air pollution poses a major threat to human health. It is linked to respiratory infection and cardiovascular disease. It causes increases in population morbidity and mortality.	12	Chemicals released into the air increase air pollution and contribute to harmful effects on human health. Responsible production and consumption could help to reduce these harmful chemicals.
6	Pollutants such as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from open fires and the combustion of fossil fuels mix with precipitation causing harmful acid rain that can compromise water quality.	13	Combustion of fossil fuels plays a key role in the process of climate change, which places food, air and water supplies at risk, and poses a major threat to human health.
7	Electricity from renewable energy rather than fossil fuels offers significant public health benefits through a reduction in air pollution.	14	Deposition of air pollutants on water may negatively affect its quality and life under water. It can lead to eutrophication and acidification of fresh water bodies, and accumulation of toxic metals and Persistent Organic Pollutants (POPs) in fresh and marine waters.
8	Air pollution impacts on health, crop and forest yields, ecosystems, the climate and the built environment, with consequences for productivity and economic growth. Ambient and indoor air pollution also has negative effects on the working environment and its safety.	15	Emissions from combustion of fossil fuels mixed with precipitation cause acid rains that pose a major threat to forests and ecosystems.

The last EEA report on air quality in EU

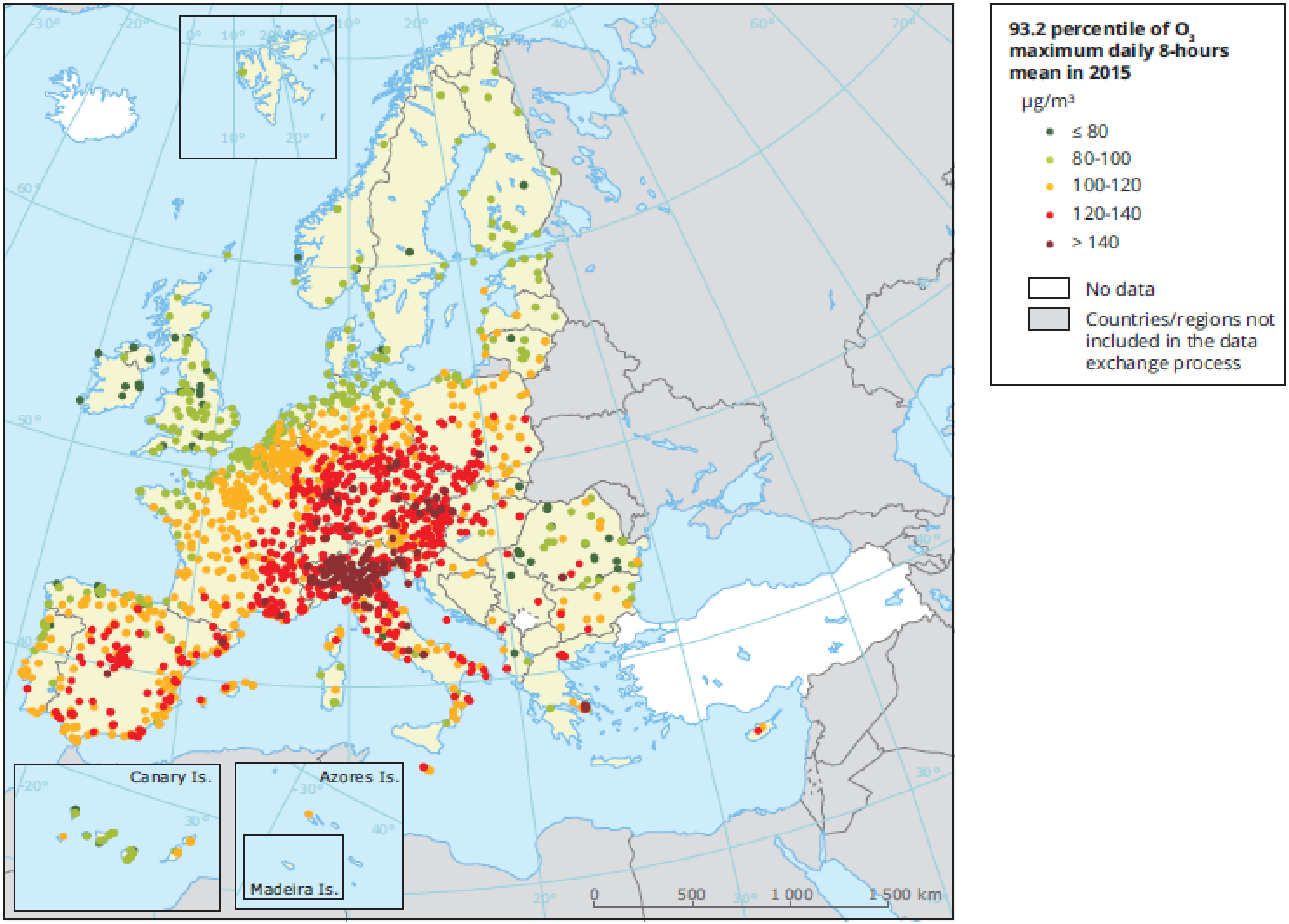
Concentration of PM10 in EU (daily values)

Map 4.1 **Concentrations of PM_{10}, 2015 — daily limit value**



Concentration of ozone in EU

Map 5.1 **Concentrations of O_3 in 2015**



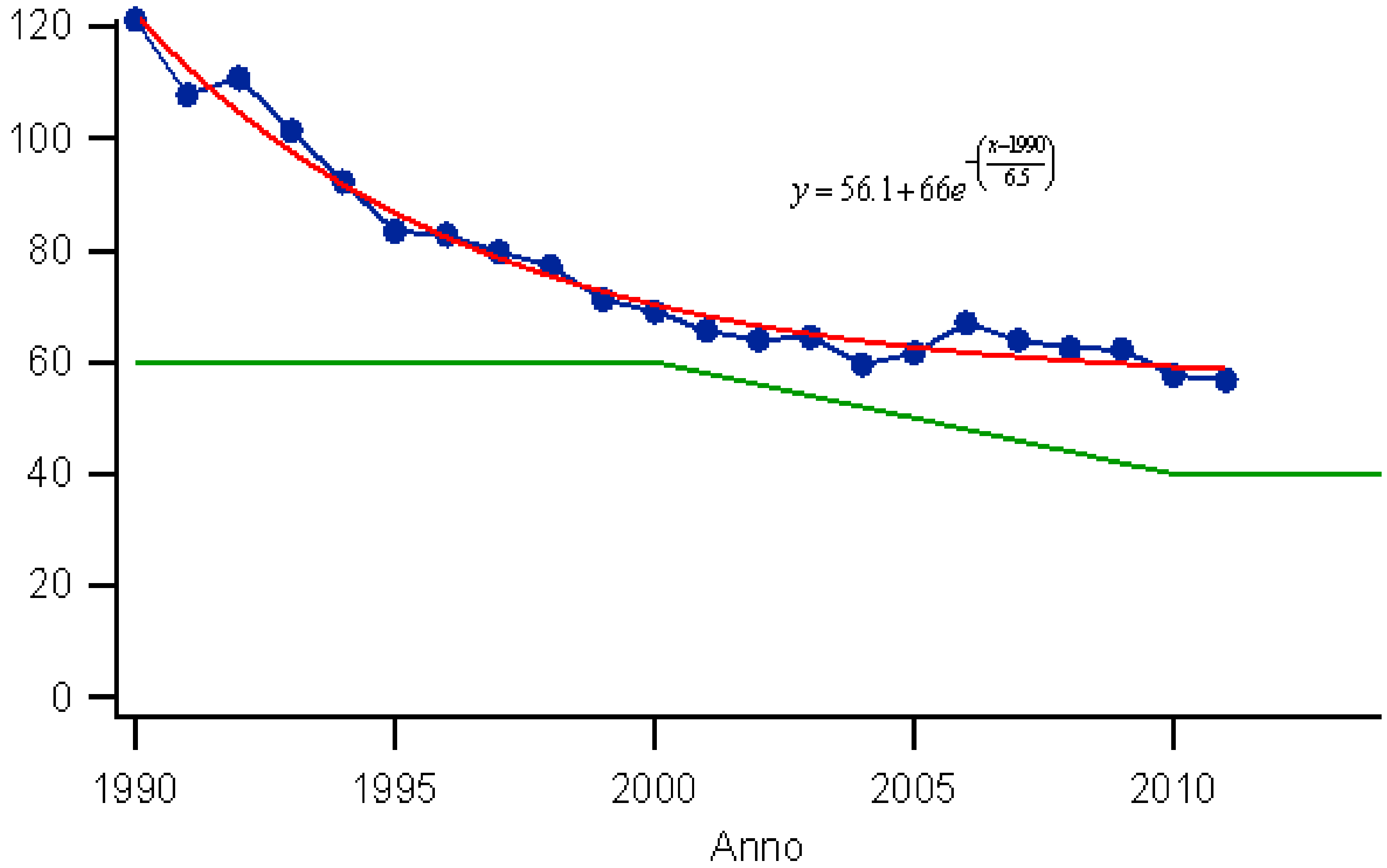
EU population exposed to air pollutants

Table ES.1 **Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (minimum and maximum observed between 2013 and 2015)**

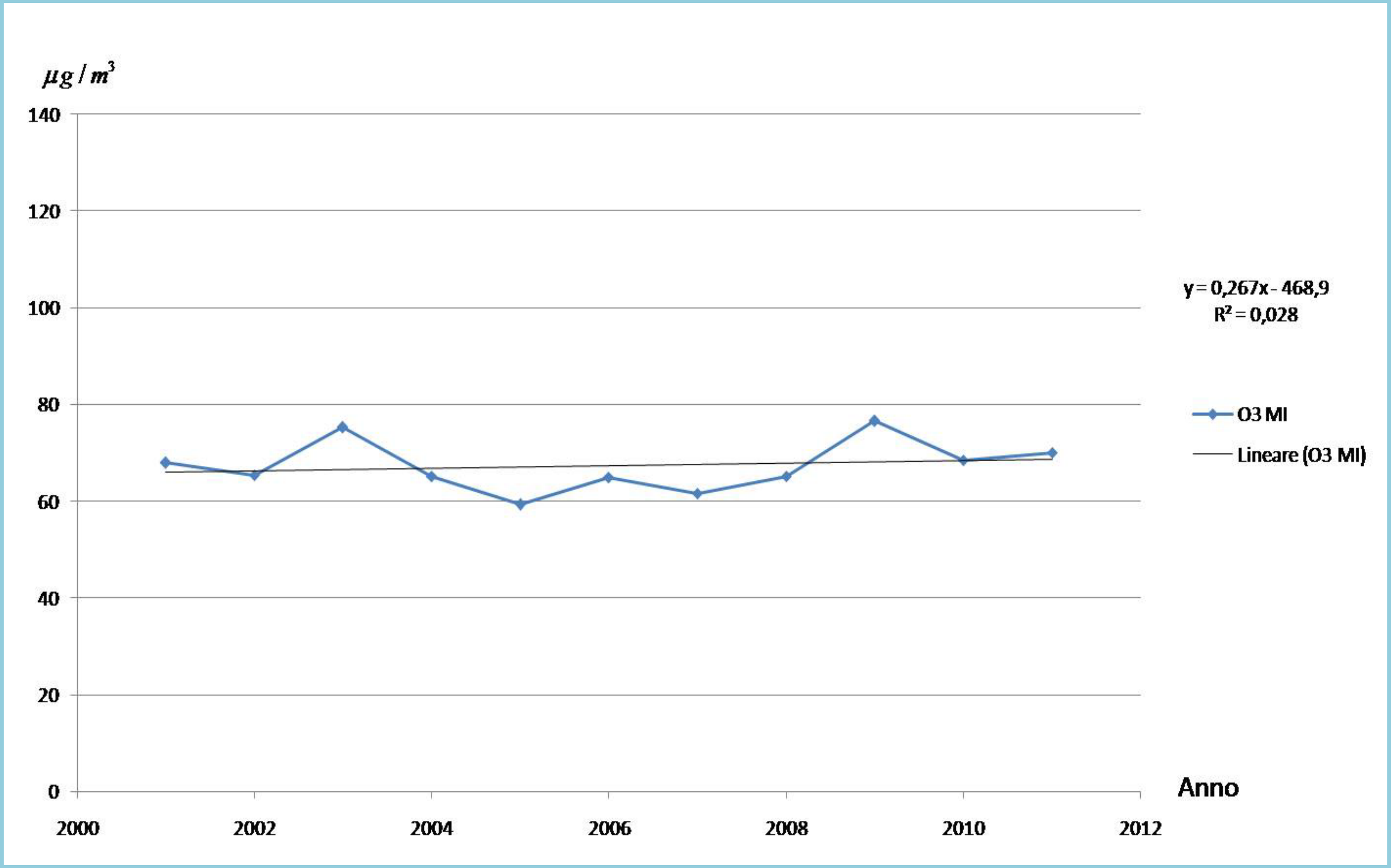
Pollutant	EU reference value ([a])	Exposure estimate (%)	WHO AQG ([a])	Exposure estimate (%)
$PM_{2.5}$	Year (25)	7-8	Year (10)	82-85
PM_{10}	Day (50)	16-20	Year (20)	50-62
O_3	8-hour (120)	7-30	8-hour (100)	95-98
NO_2	Year (40)	7-9	Year (40)	7-9
BaP	Year (1)	20-25	Year (0.12) RL	85-91
SO_2	Day (125)	< 1	Day (20)	20-38

Key				
	< 5 %	5-50 %	50-75 %	> 75 %

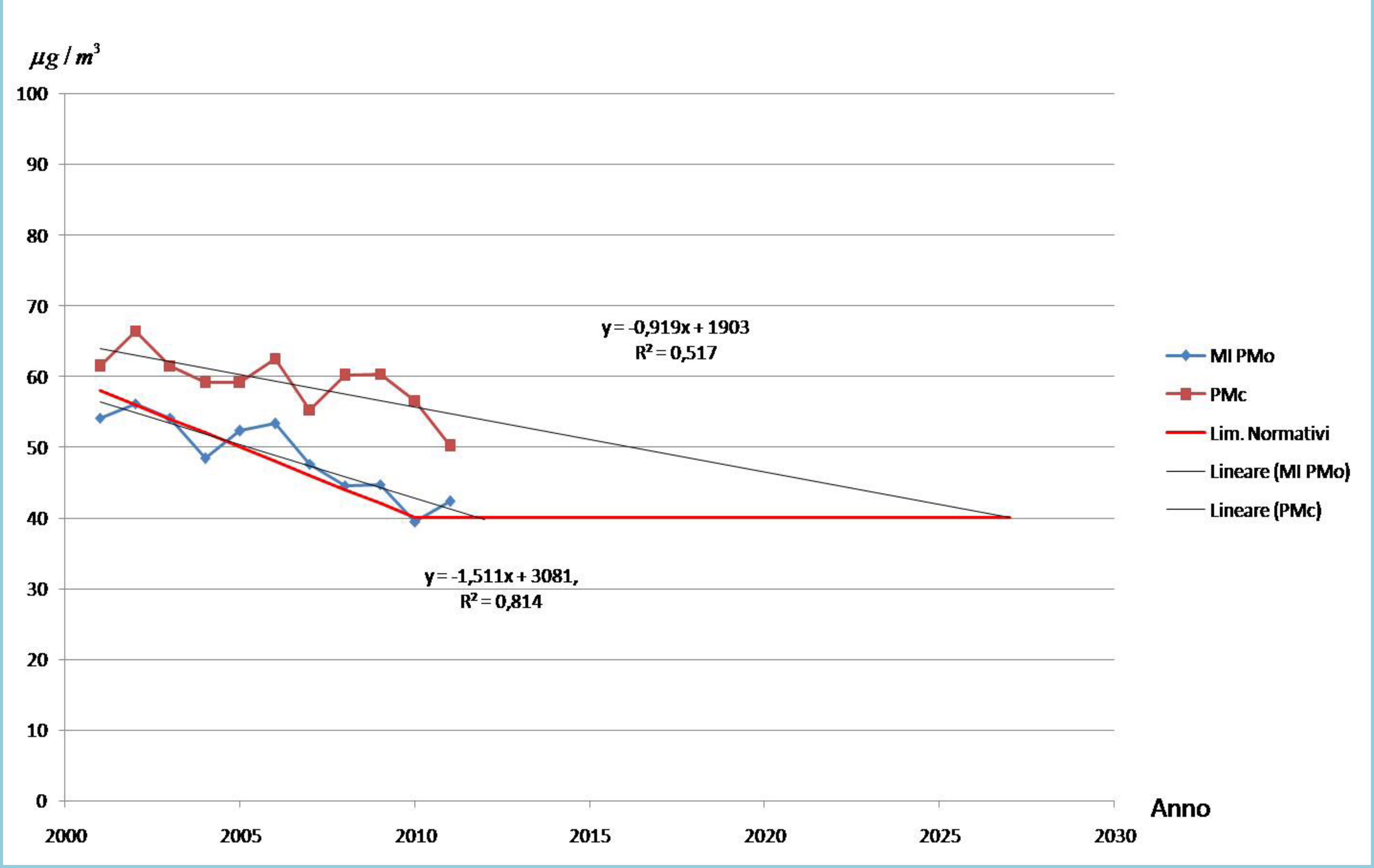
Air pollution in Milan: NO_2 concentration trend



Air pollution in Milan: ozone concentration trend



Air pollution in Milan: PM10 concentration trend



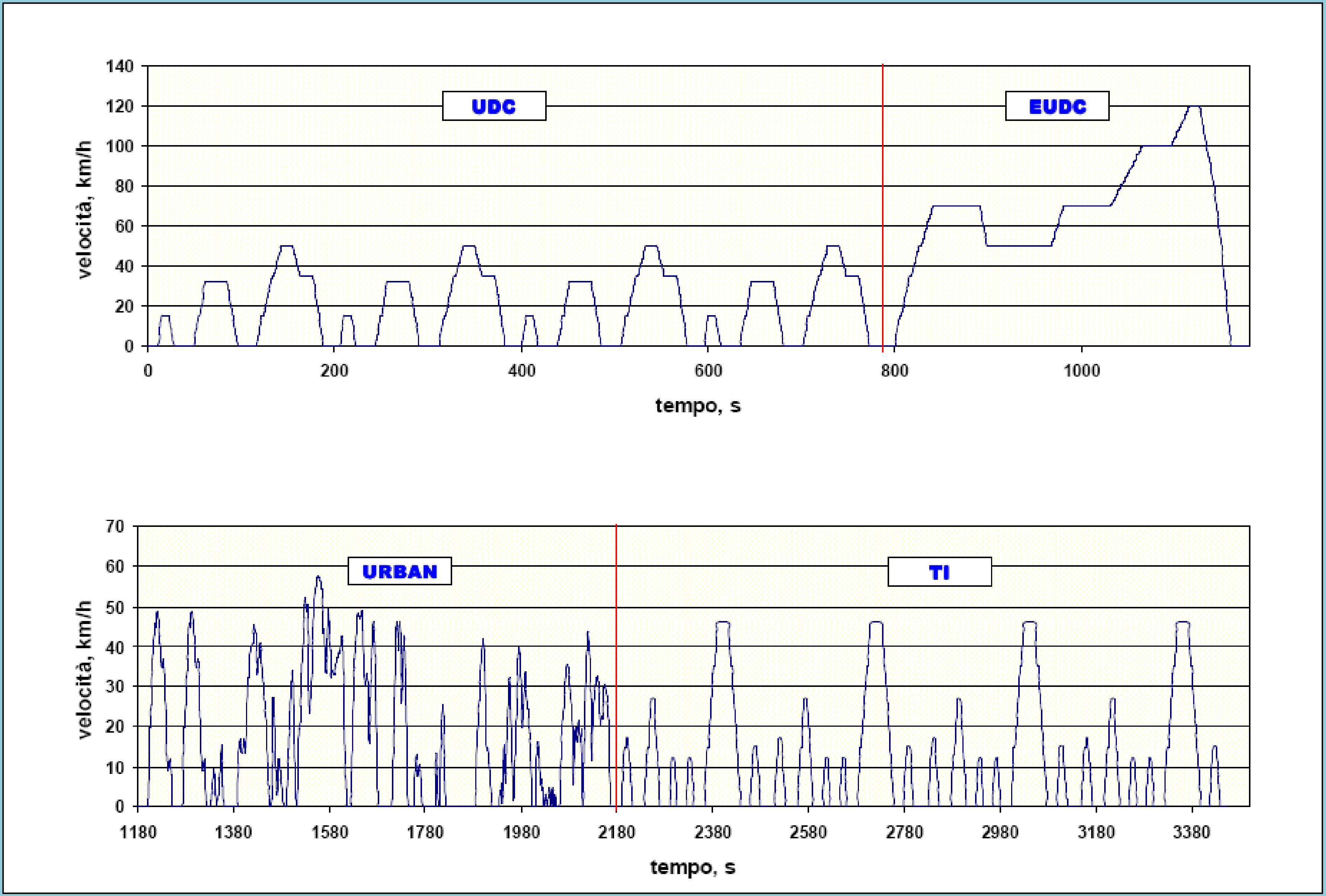
Air pollution in Milan: emission sources

		NO_X	PM10 primario
N. Macrosettore	**Tipologia Macrosettore**	**%**	**%**
1	Produzione energia e trasformazione combustibili	2,18	0,12
2	Combustione non industriale	24,01	10,86
3	Combustione nell'industria	1,51	2,94
4	Processi produttivi	-	2,24
5	Estrazione e distribuzione combustibili	-	-
6	Uso di solventi	0,00	3,61
7	Trasporto su strada	58,85	64,12
8	Altre sorgenti mobili e macchinari	7,63	5,61
9	Trattamento e smaltimento rifiuti	5,76	0,42
10	Agricoltura	0,06	0,42
11	Altre sorgenti e assorbimenti	-	9,66
	Totale	**100 %**	**100 %**

Air pollution in Milan: road traffic emissions

Tipologia veicoli	Combustibile	PM10 primario(t/y)	NO_x(t/y)	PM10 (%)	NO_x(%)
	Benzina senza piombo	3,01	251,04	0,68	5,24
	GPL	0,00	50,80	0,00	1,06
Autoveicoli	Gas naturale	0,00	3,10	0,00	0,06
	Gasolio	83,74	1090,80	18,78	22,76
	Nessun combustibile	70,16	0,00	15,74	0,00
	Benzina senza piombo	0,35	19,67	0,08	0,41
Veicoli LDV (< 3,5 t)	Gasolio	134,70	1583,28	30,21	33,03
	Nessun combustibile[1]	41,60	0,00	9,33	0,00
	Benzina senza piombo	0,00	0,30	0,00	0,01
Veicoli HDV (> 3,5 t) + autobus	Gasolio	51,47	1708,51	11,54	35,64
	Nessun combustibile[1]	24,93	0,00	5,59	0,00
Ciclomotori	Benzina senza piombo	16,78	22,54	3,77	0,47
	Nessun combustibile[1]	2,26	0,00	0,51	0,00
Motocicli	Benzina senza piombo	11,88	63,60	2,66	1,33
	Nessun combustibile[1]	4,94	0,00	1,11	0,00
Totale emissioni (t/y)		**445,81**	**4793,64**	**100%**	**100%**

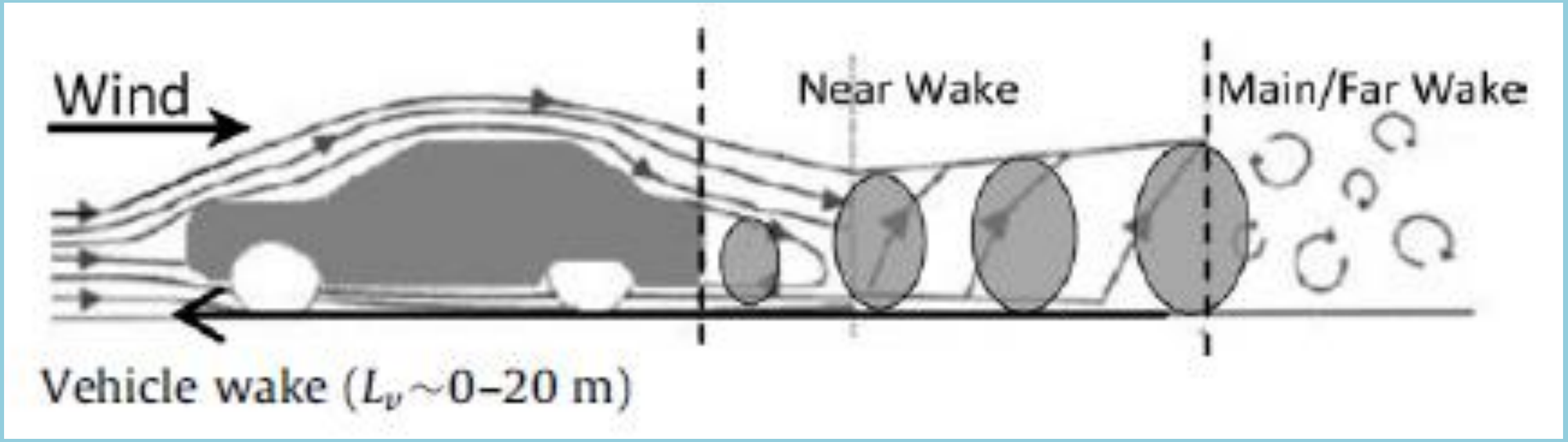
Factors influencing traffic emission: the driving cycle



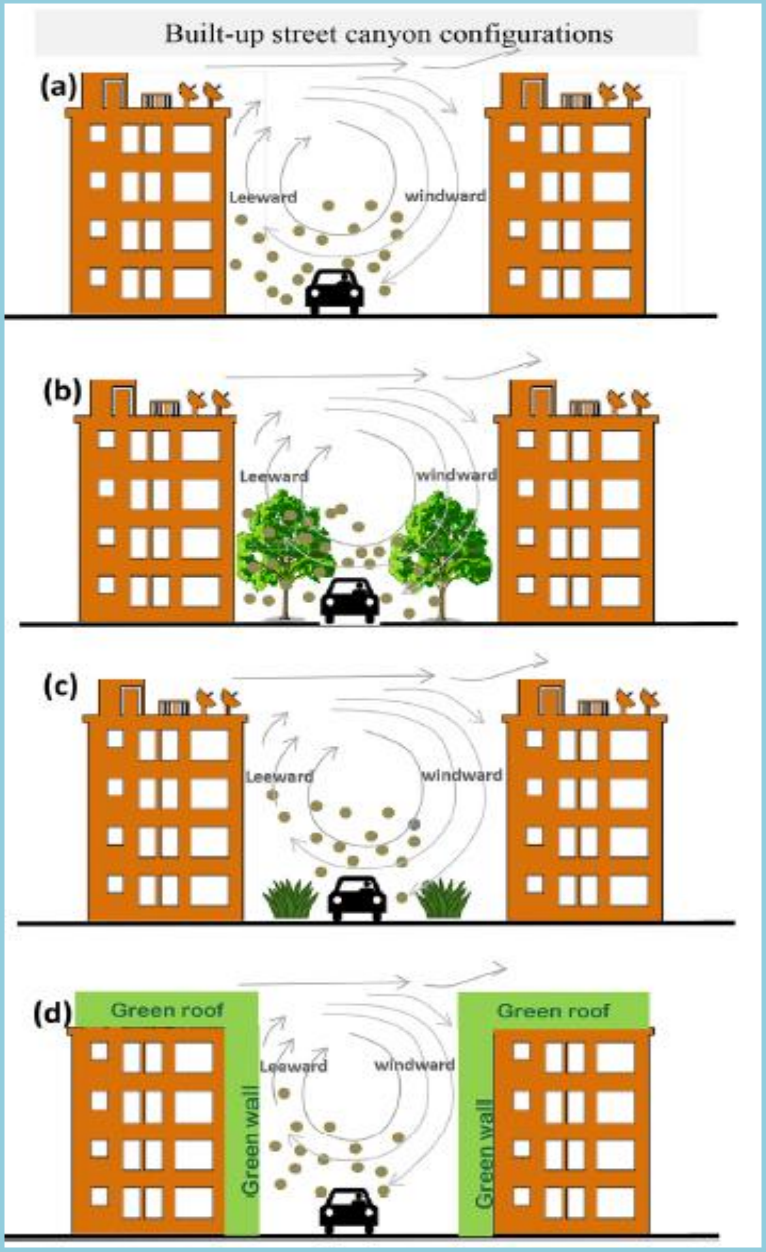
Factors influencing traffic emissions: the resuspension

$$u = AU\left(\frac{x}{h}\right)^{-m} f\left[\frac{z}{\delta(x)}, \frac{y}{\delta(x)}\right]$$

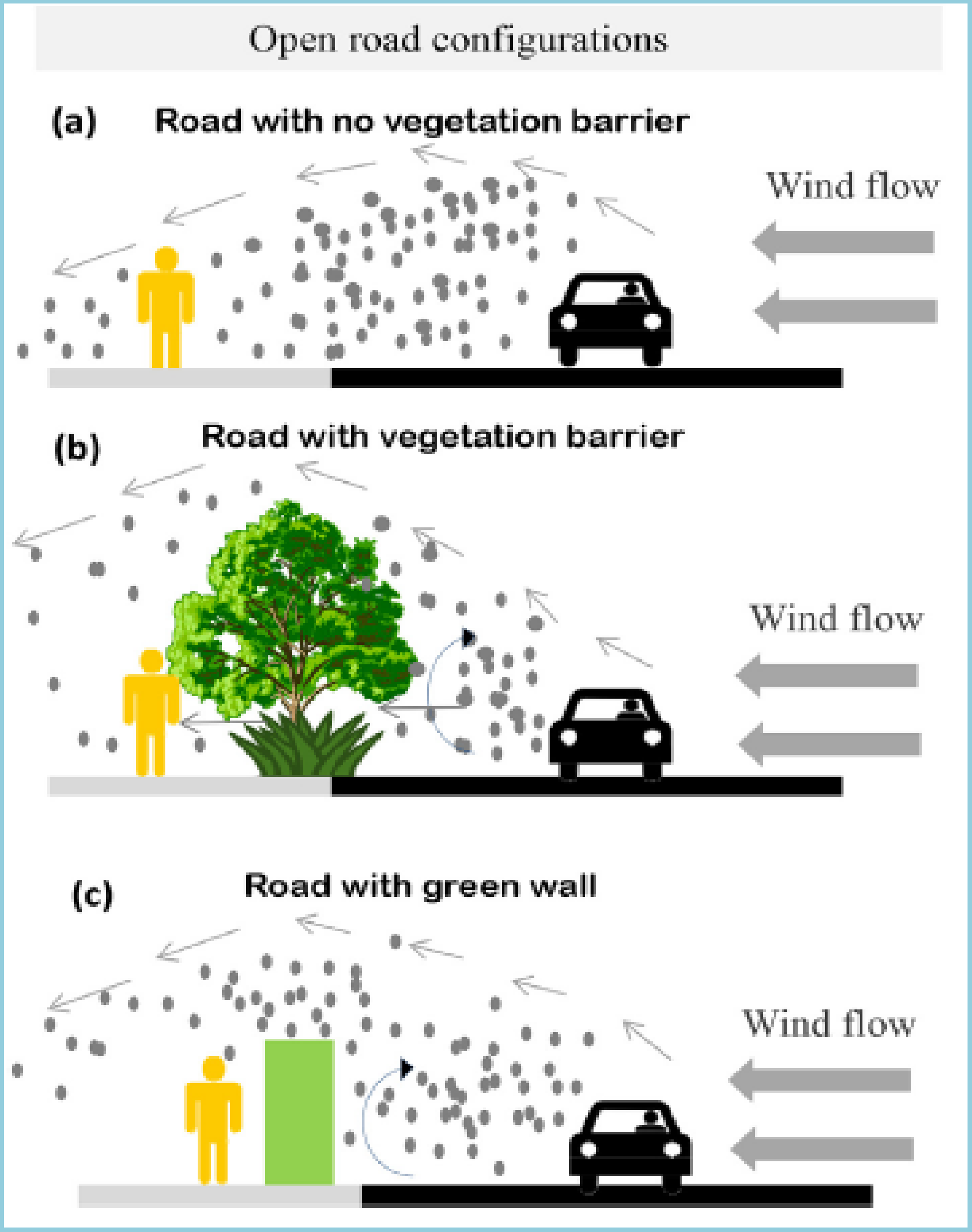
Far – wake solution



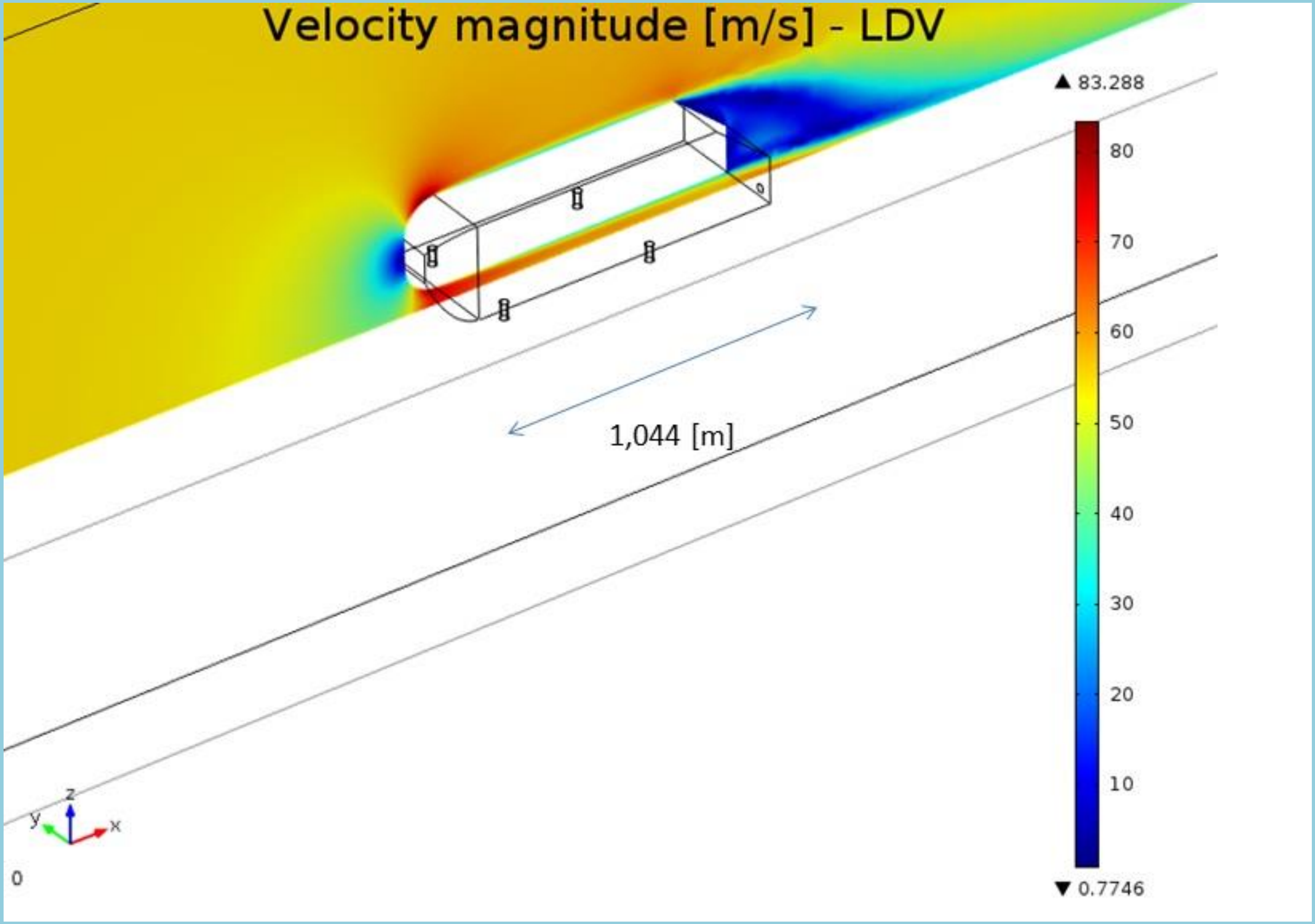
Resuspension in a street canyon



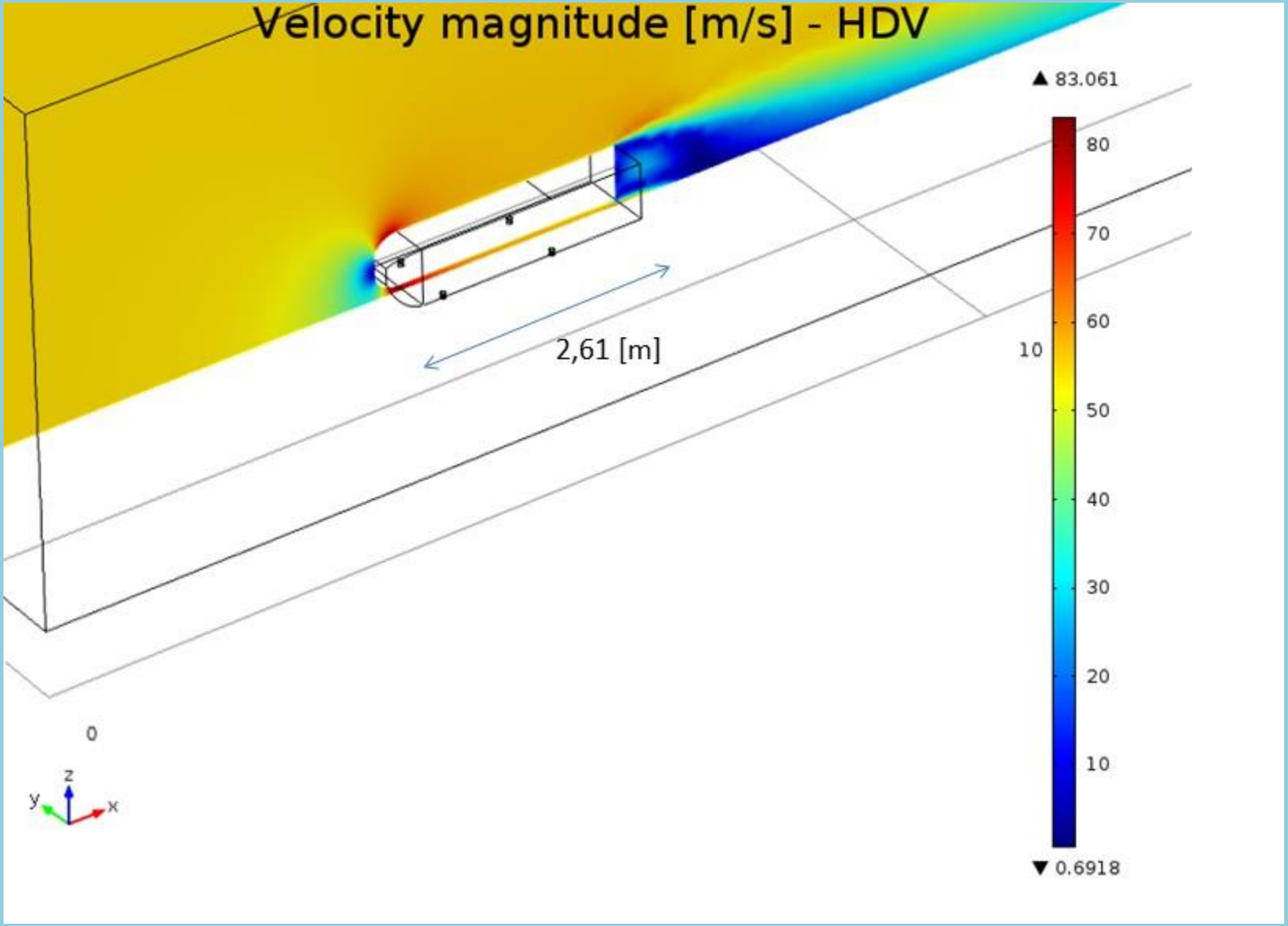
Resuspension in an open road



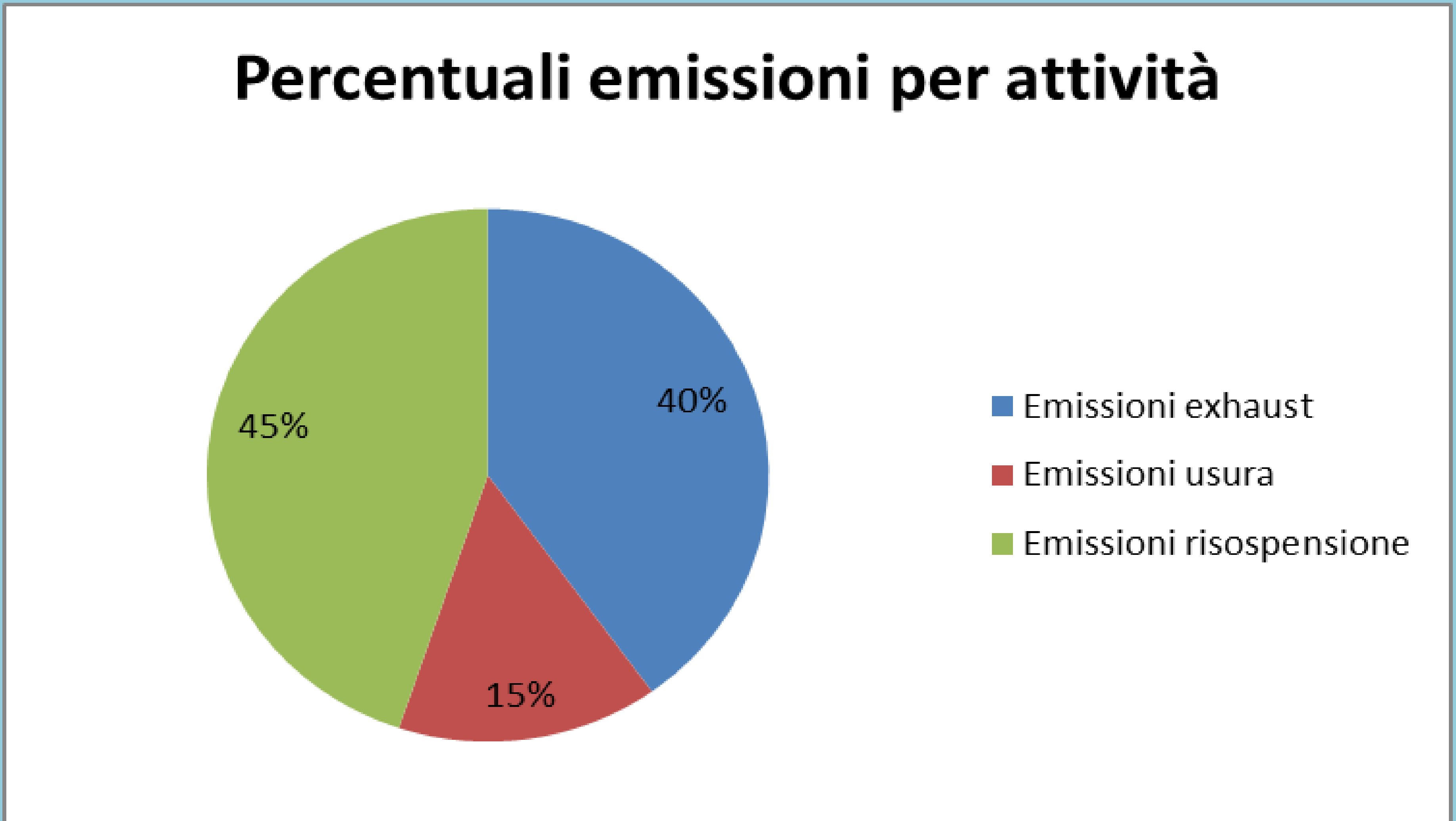
PM resuspension: model simulation - LDV



PM resuspension: model simulation - HDV

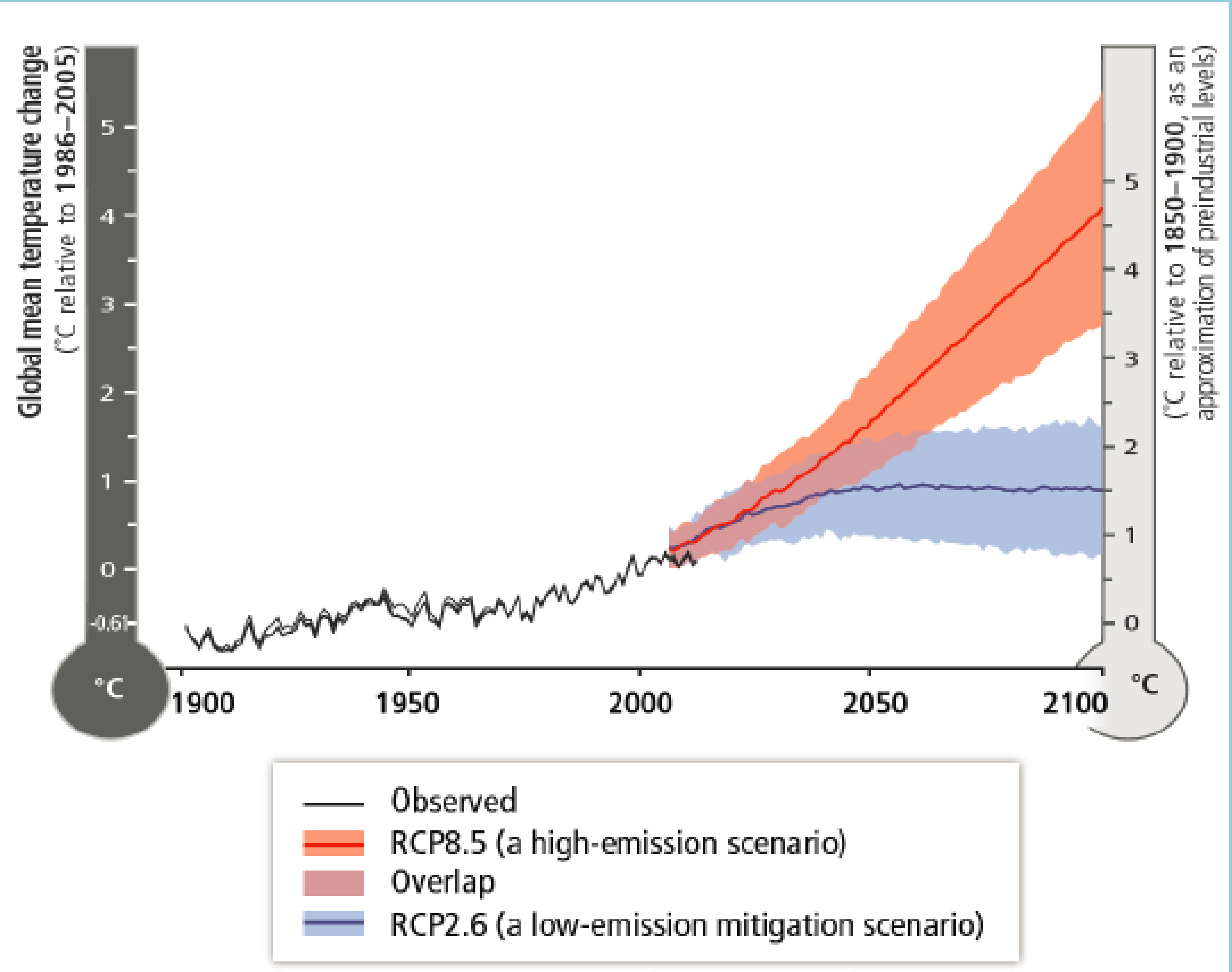


The overall contribution of resuspension

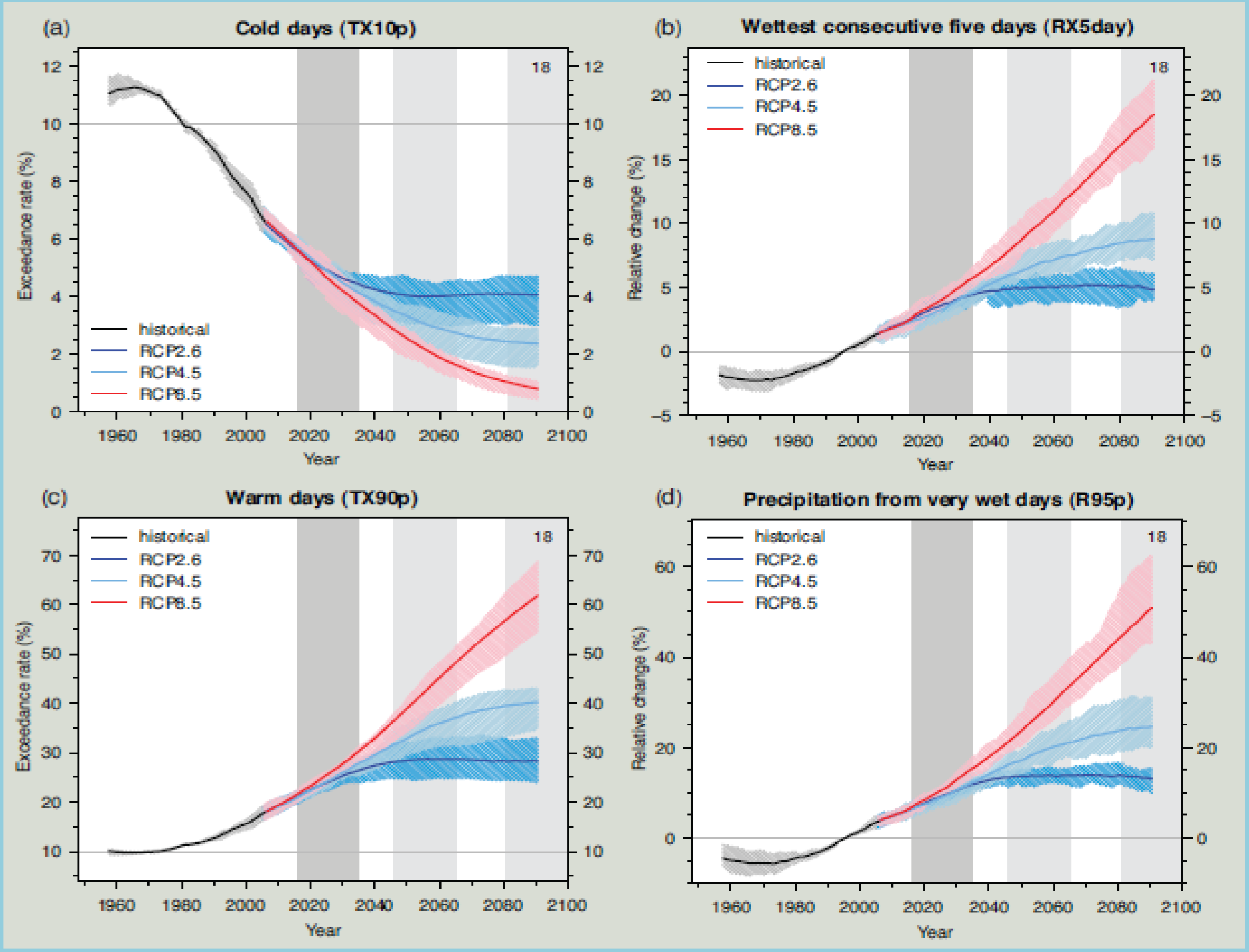


The local impact of climate change

Expected temperatures under different scenarios



CC-dependent extreme weather events

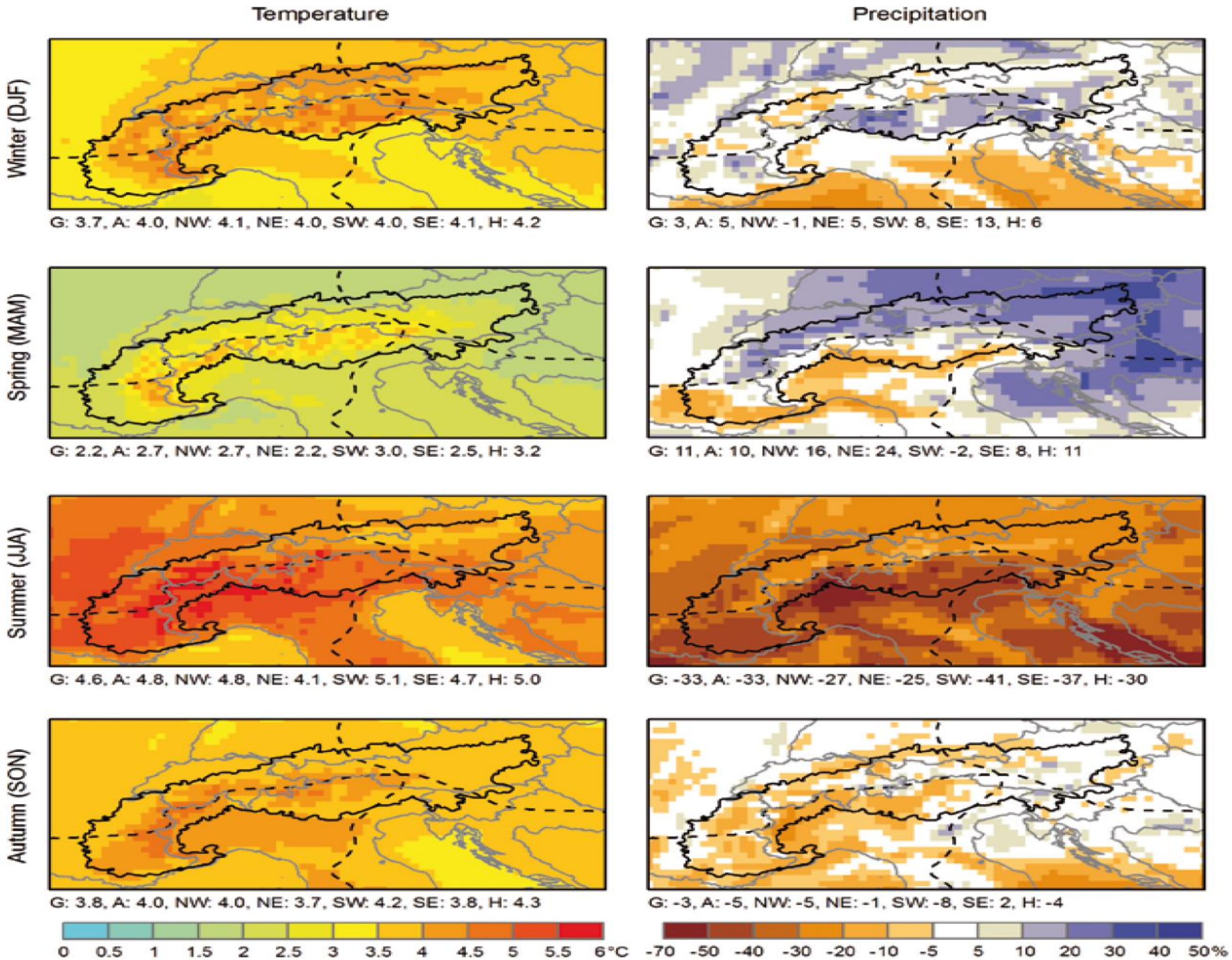


Climatic regions in Europe

Source: Espon 2013, Climate Project

Climate change and air quality

Figure 2.6 Seasonal changes in precipitation and temperature up until the end of the 21st century, according to CLM scenario A1B

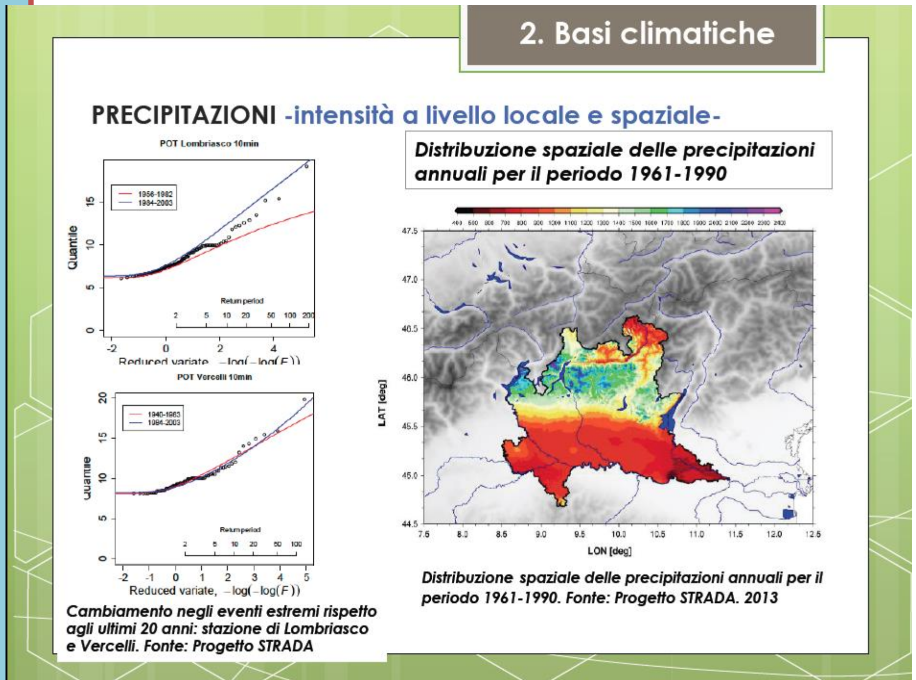


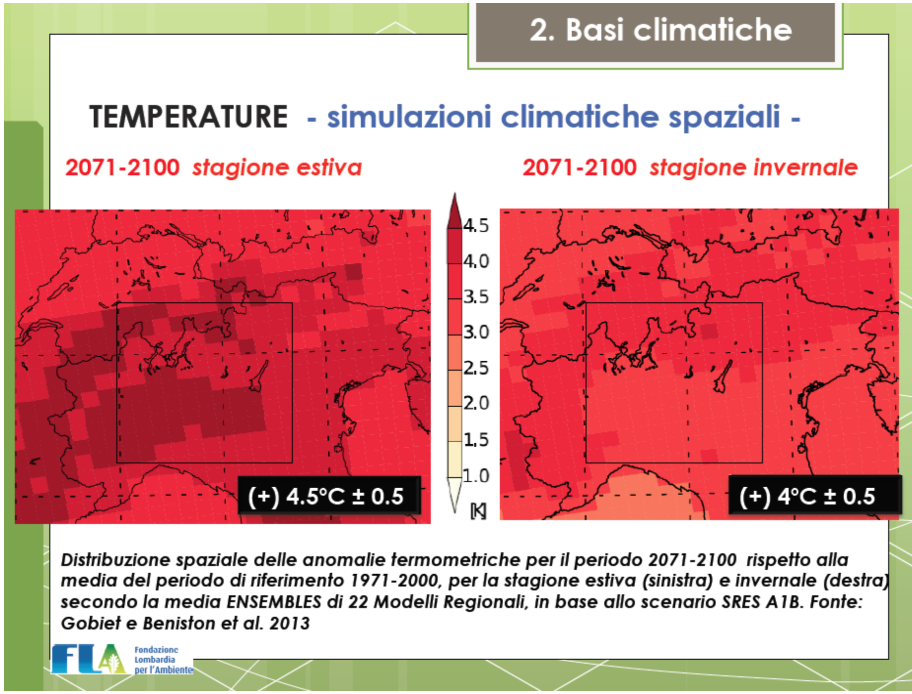
Note: Left: absolute difference in temperature. Right: relative difference in precipitation. Regional statistics: G = Greater Alpine Region, A = Alps, NW = north-western Alps, NE = north-eastern Alps, SW = south-western Alps, SE = south-eastern Alps, H = higher than 1 500 m. Seasons are: Winter (December, January, February) Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November).

Source: EURAC, 2008, based on data from CLM climate scenarios (Lautenschalger *et al.*, 2008).

CC adaptation strategy in Lombardy

Climate change evidences and projections

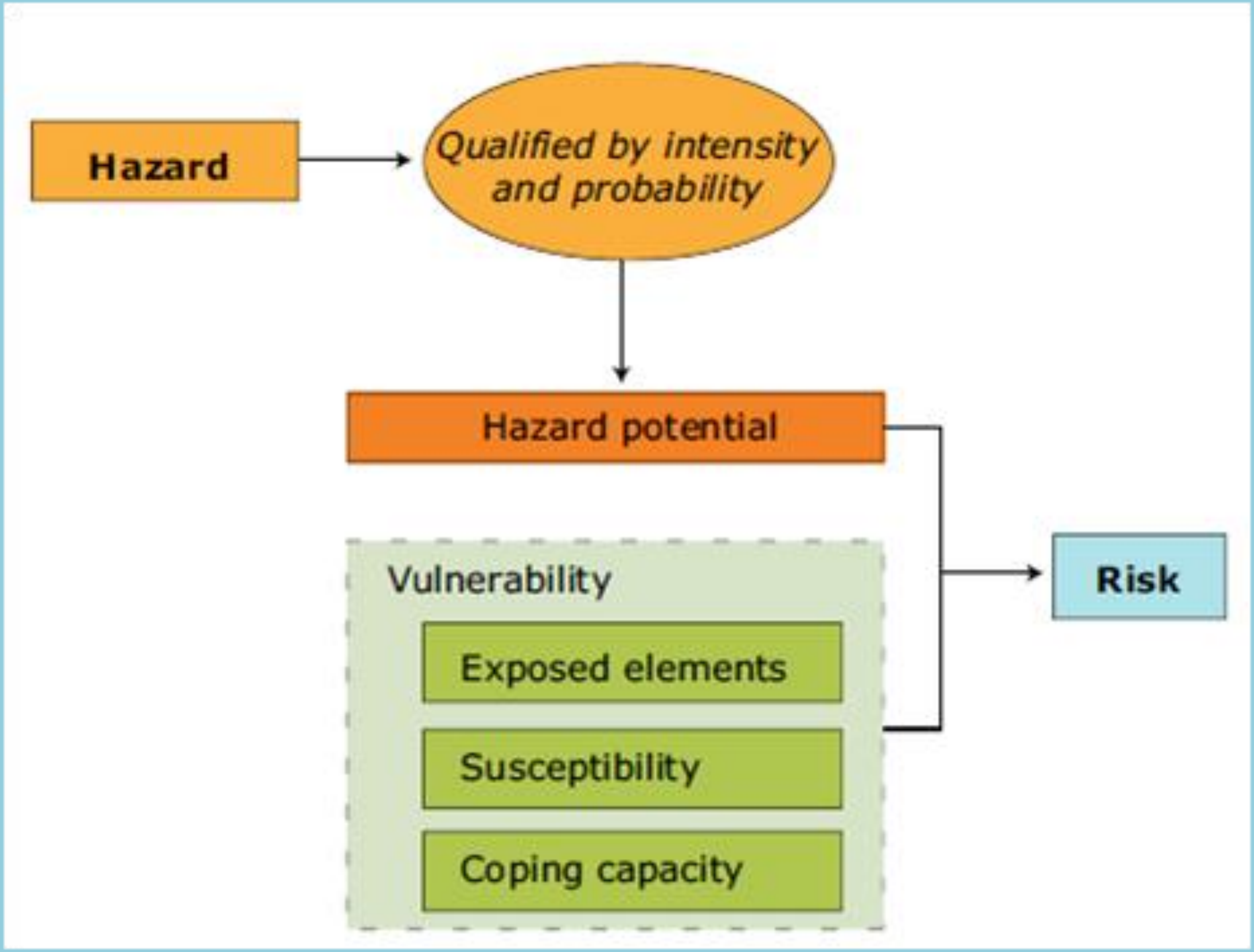




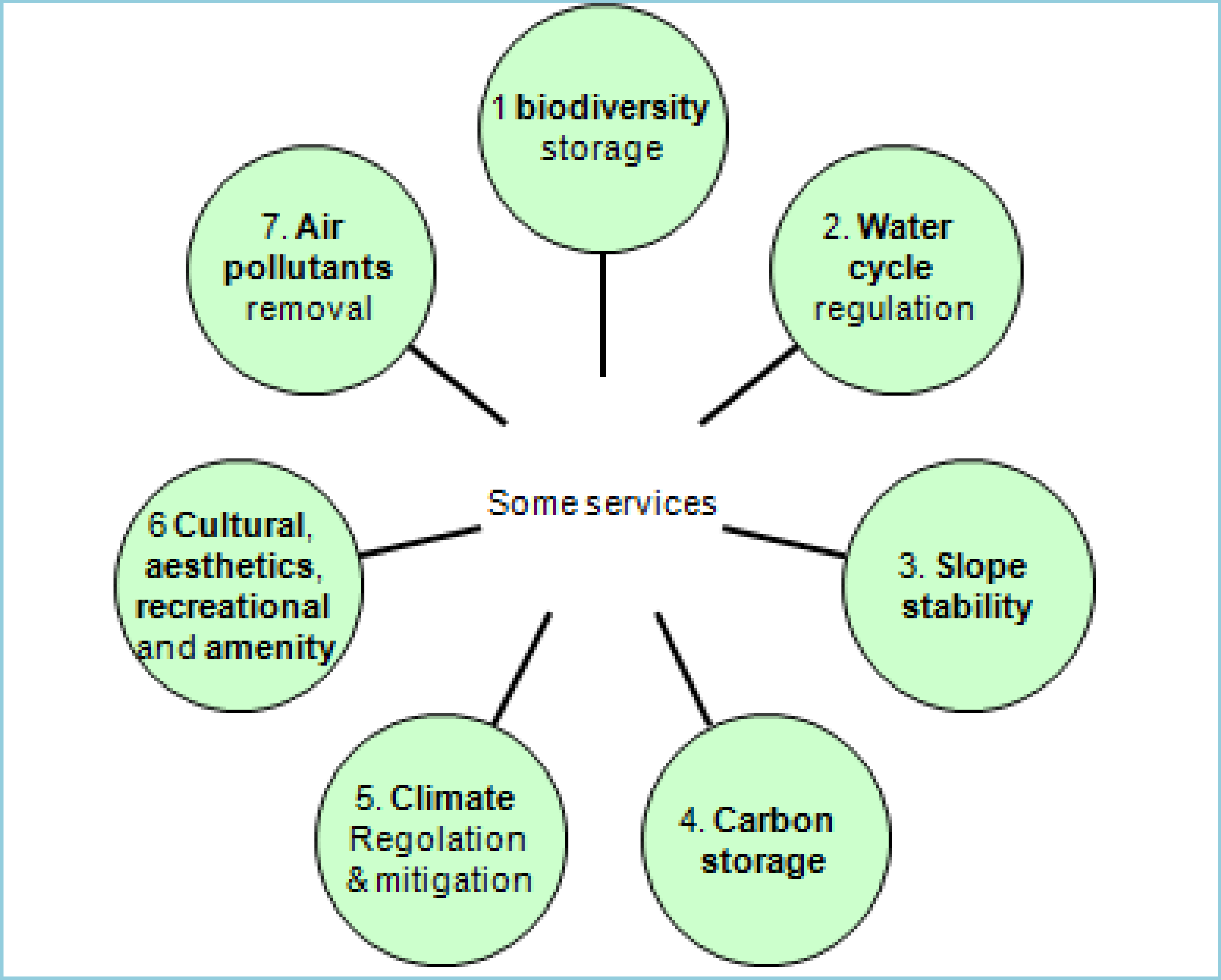
Example of climatic information presented during the workshops. Left: evolution of intense precipitation events during the period 1984-2003 compared with 1958-1982 in two weather stations of the Lombardy territory. Right: map of the rainfalls intensity in the Lombardy territory during the 1961-1990 time period. Source: with data from STRADA Project. 2013

Spatial distribution of the projected thermometric anomalies for the period 2071-2100 compared to mean temperature of the reference period 1971-2000. Source: with data from Gobiet et al. 2013

CC risk assessment and resilience factors



Evaluation of ecosystem services



Lessons learned from previous projects

Research projects on urban vegetation and air pollution

Studio condotto su 5 città negli Stati Uniti (McPherson 2005):

- Spesa annua per albero: 13 - 65 $
- Benefici ricevuti: 1.37 – 3.09 $ per ogni dollaro speso nella gestione

Studio condotto a Davis, California (Maco et al 2003):

- Spesa netta: 449353 $
- Benefici ricevuti: 3.78 $ per ogni dollaro speso nella gestione

Studio condotto nei Paesi Bassi (Maas et al., 2006):

- Nelle aree dove il 90% dell'ambiente intorno al luogo di residenza è verde, solo il 10.2% dei residenti si ammalano, se confrontate con le aree in cui solo il 10% dell'ambiente circostante è verde, dove il 15.5% dei residenti si ammalano.

Studio condotto a Roma (HEREPLUS; Manes et al., 2012):

- In base ai costi unitari delle esternalità (6752 $/ton, Nowak et al., 2006), e alla mortalità associata all'O_3, è stato stimato che il servizio ecosistemico di rimozione dell'O_3 fornito dalla foresta urbana di Roma può essere valutato come rispettivamente pari a circa 2 e 3 milioni $/anno.

Marylebone Road, London

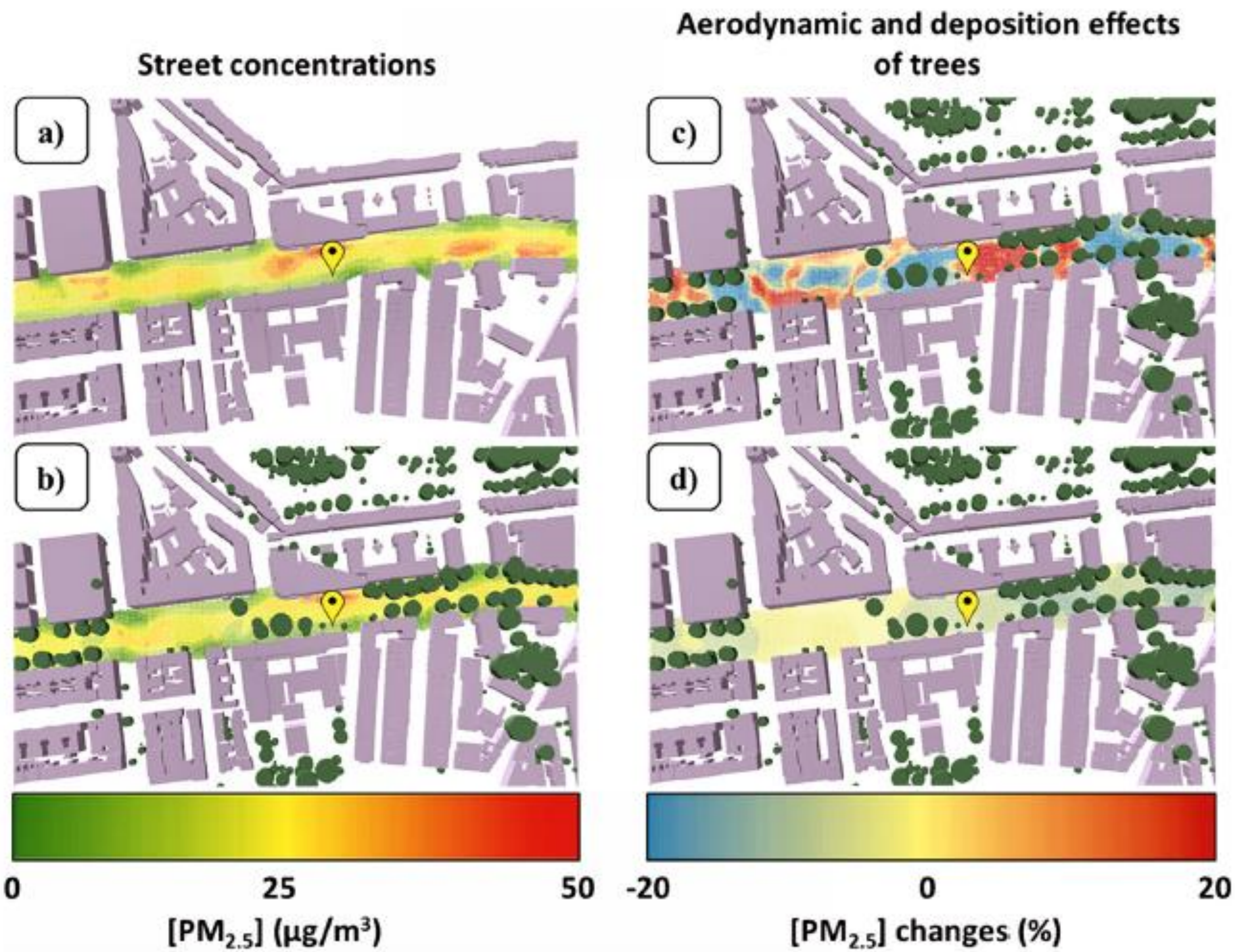
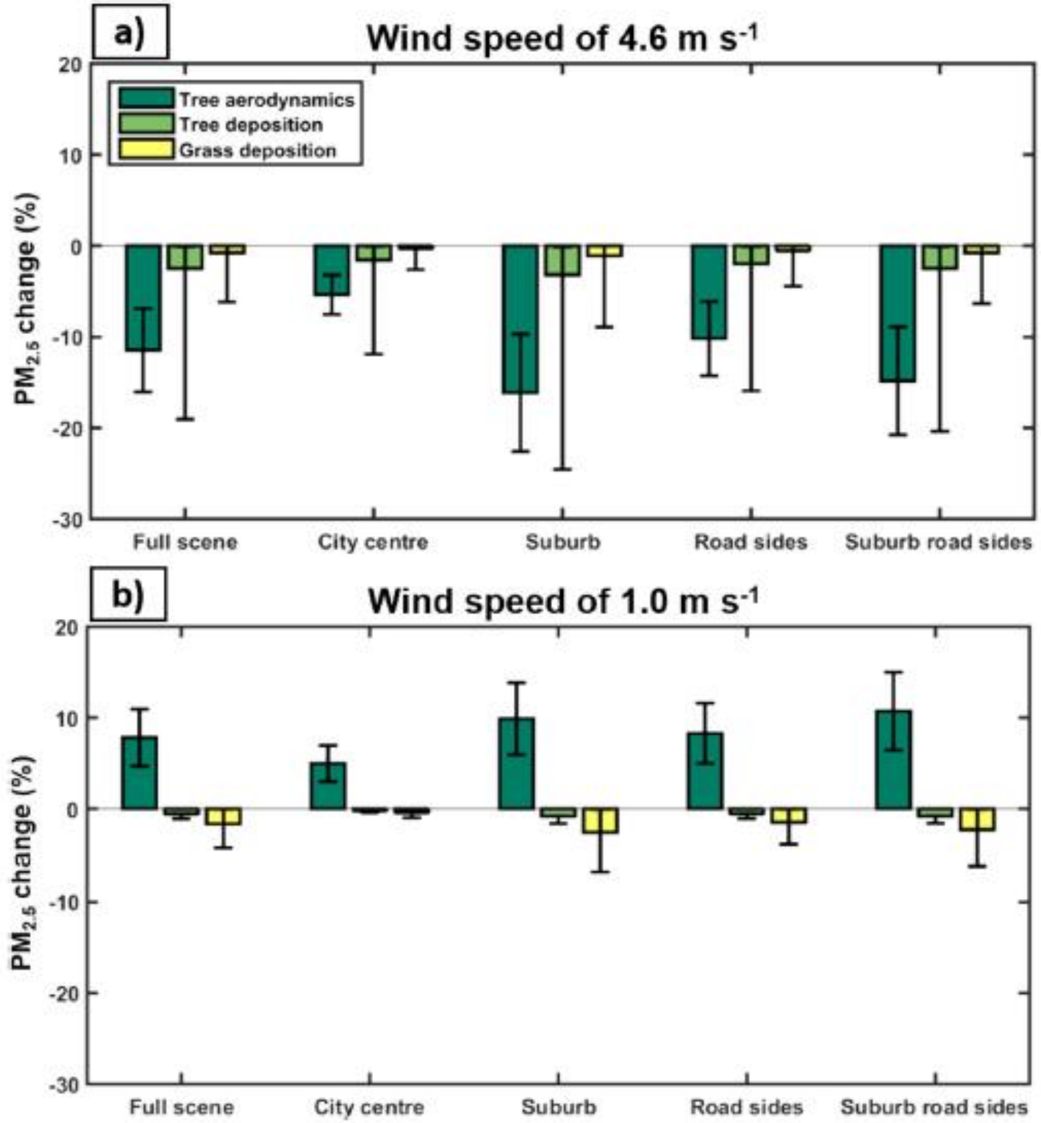


Fig. 8. Street effects of trees in Marylebone Rd at pedestrian height over prevailing wind directions. (a) $PM_{2.5}$ concentrations without trees (CB). (b) $PM_{2.5}$ concentrations with trees in summer (CT2). (c) Aerodynamic effects of trees in summer (%). (d) Loss of $PM_{2.5}$ via deposition on trees in summer (%).

Source: Jeanjean et al. 2017

Effect of trees on PM2.5 as a function of wind



;. 4 Modelled change in traffic-emitted $PM_{2.5}$ concentrations induced by the tree aerodynamics, tree deposition and grass deposition for (a) a wind speed of 4.6 m s^{-1} and (b) a nd speed of 1.0 m s^{-1}.

Source: Abhijith, et al. 2017

Effect of pollutants reduction

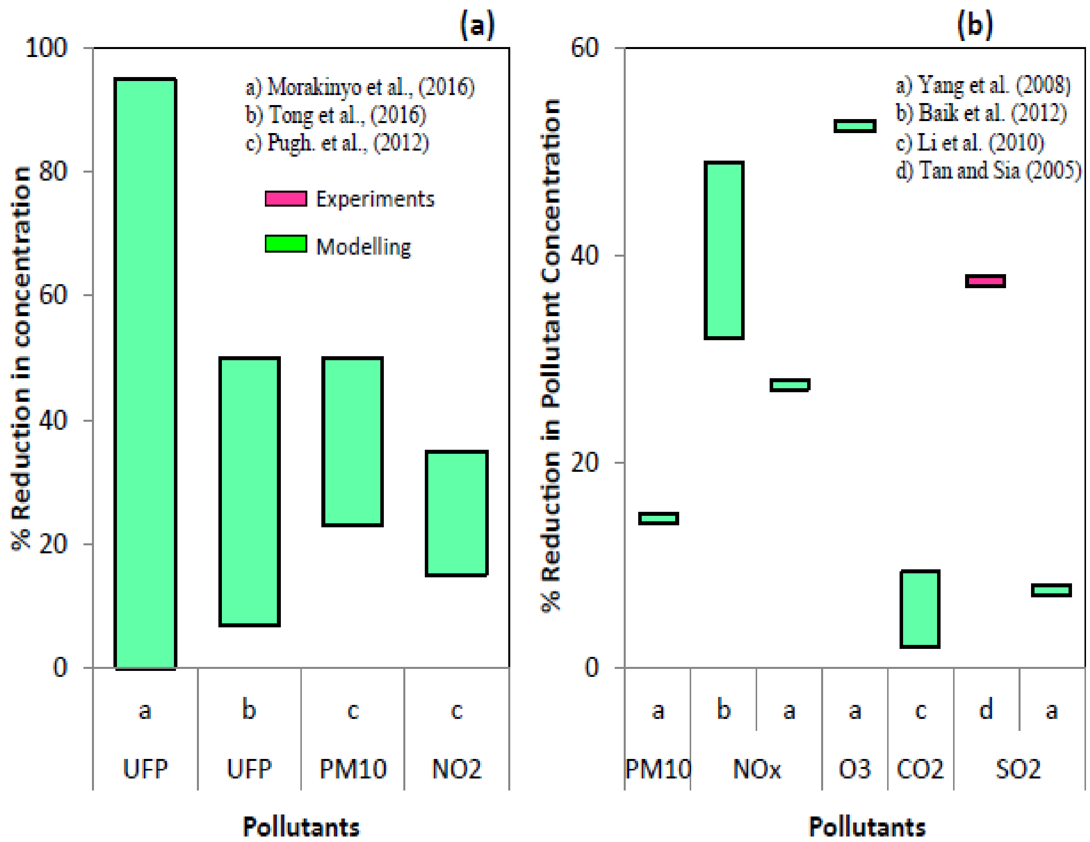


Fig. 5. Published percentage reduction in pollutant concentration with (a) green walls to green wall free case and (b) green roof to green roof free case. Bars show the reported range of reduction by respective studies.

Source: Abhijith, et al. 2017

Our project

The Fulvio Testi Avenue project

The function of green urban areas in the control of air pollution

ERSAF RegioneLombardia

Città metropolitana di Milano

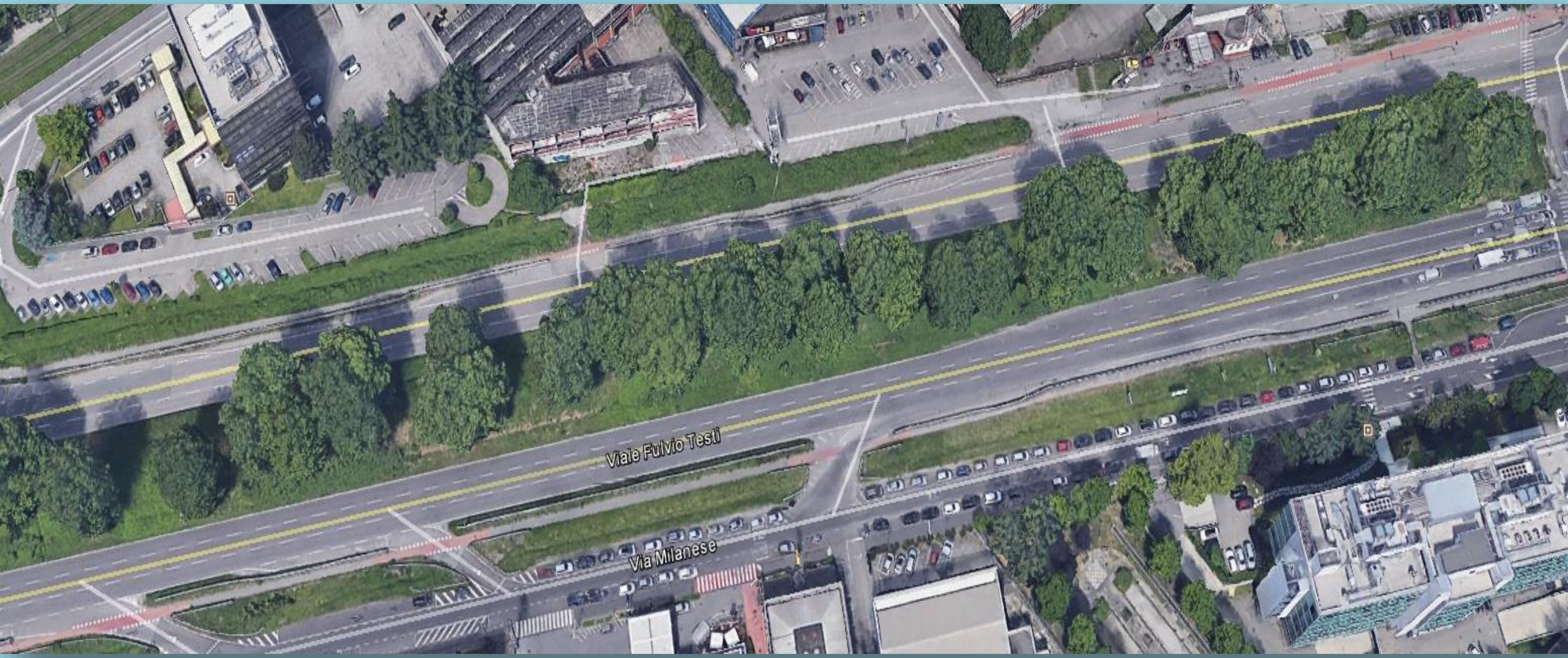
"RIPRISTINO DI UNA FASCIA VERDE IN VIALE FULVIO TESTI E CONTESTUALE STUDIO DELLO SCHEMA DI IMPIANTO ARBOREO MIGLIORE PER MASSIMIZZARE L'ASSORBIMENTO DEGLI INQUINANTI ATMOSFERICI"

Project's goals

- Safety measures for the avenue green area
- Urban landscape upgrading
- Open-field experiment for local air pollution control

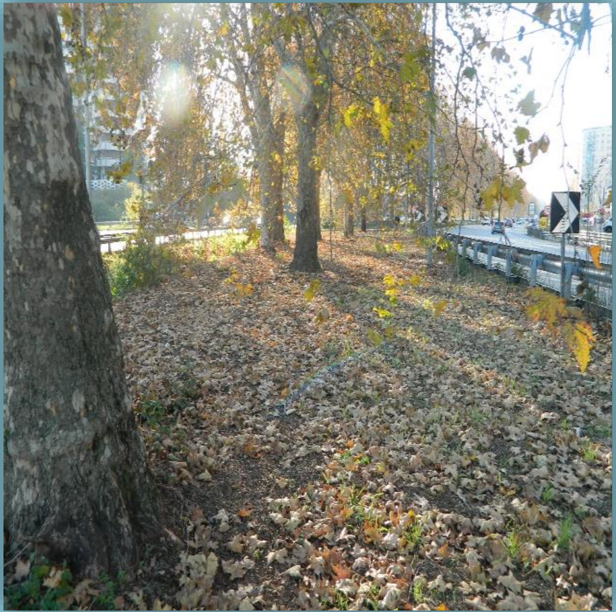
The urban area involved

The present vegetation



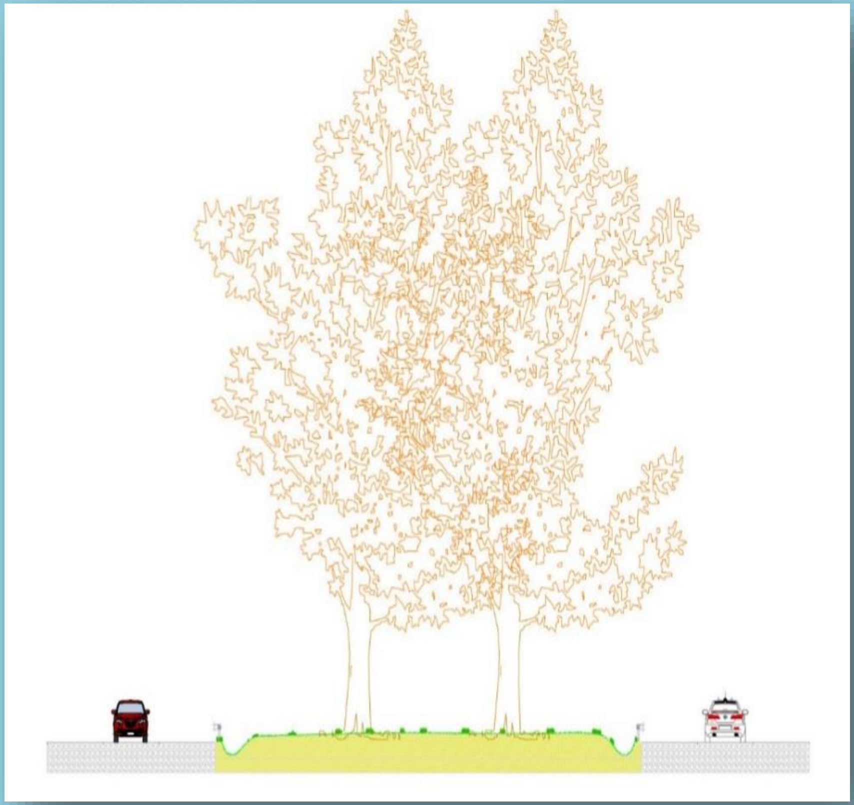
A double row of more than 200 plane trees (*Platanus spp.)* is placed in the middle of the two carriageways of Testi Avenue, mingled with allochtonous invasive weeds and bushes (like Revnoutria or Ailanthus).

Testi Avenue in autumn 2017

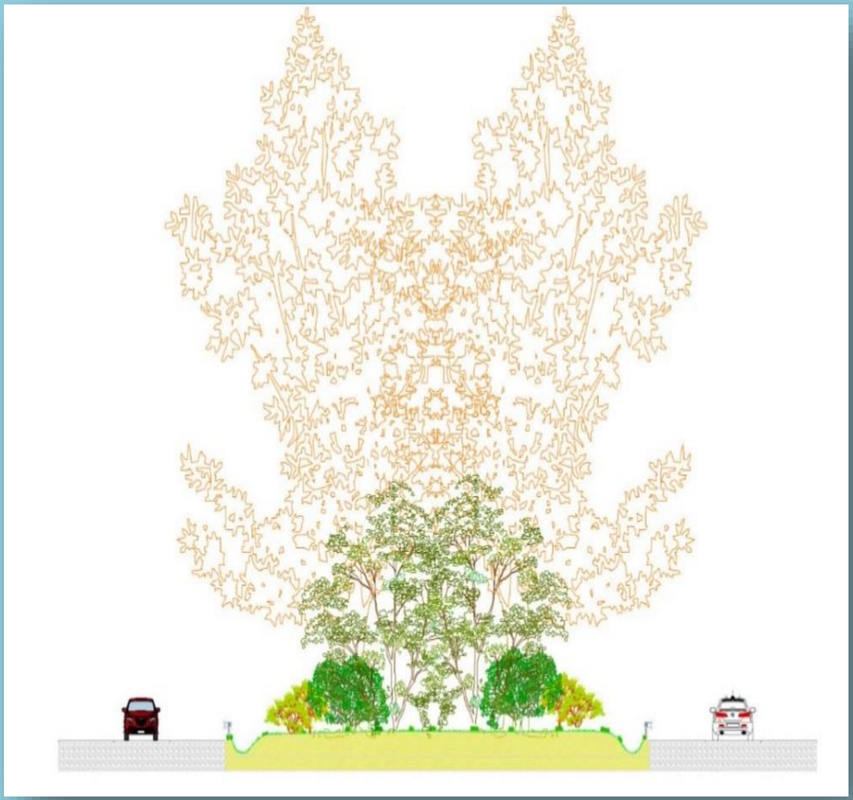


How to improve the green structure of the avenue?

- Removing weeds and other unwanted sprouts
- Planting two hedges of autochthonous species



Present situation
(without hedges)



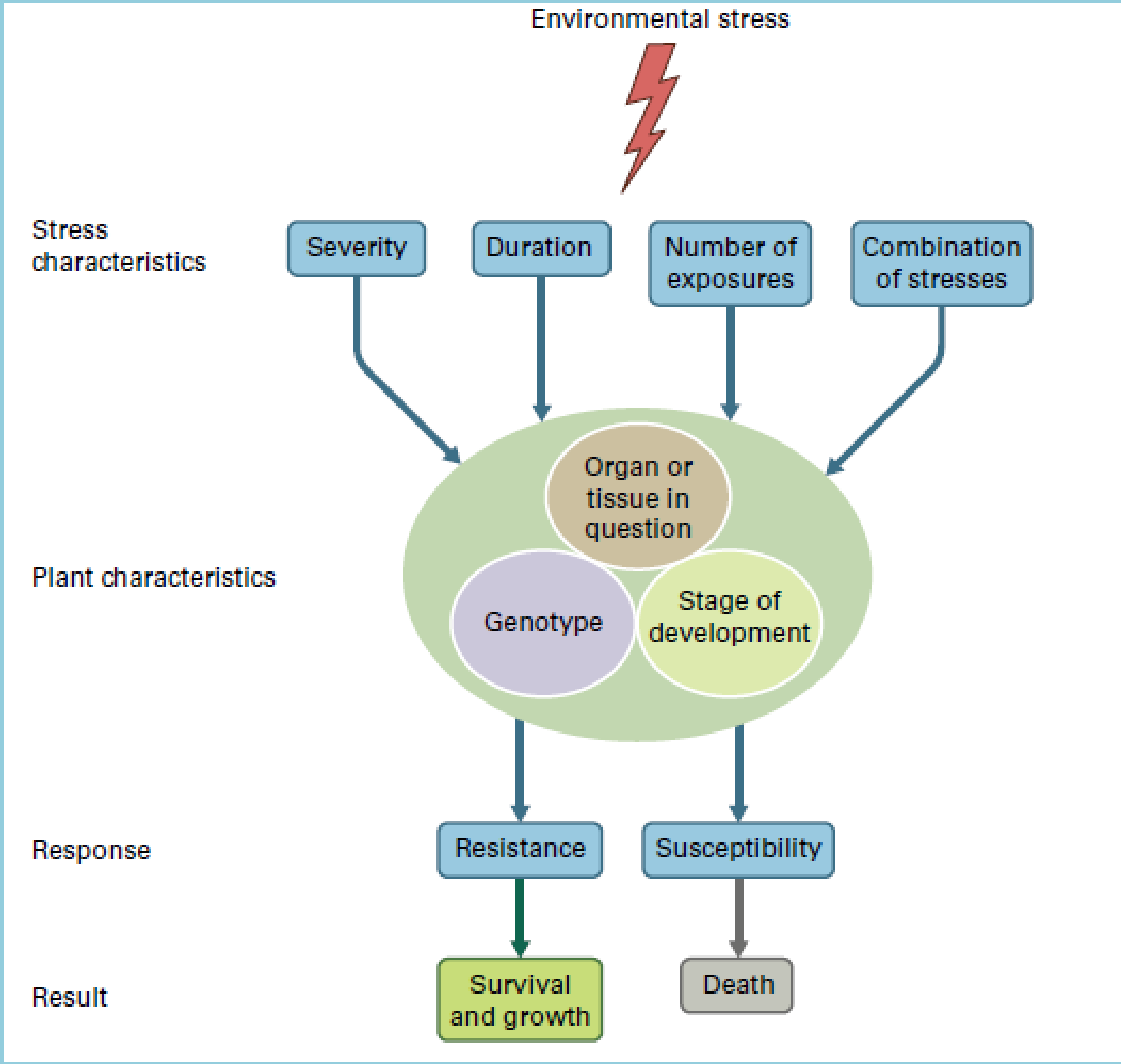
Future layout
(with hedges)

Factors considered in plant species selection

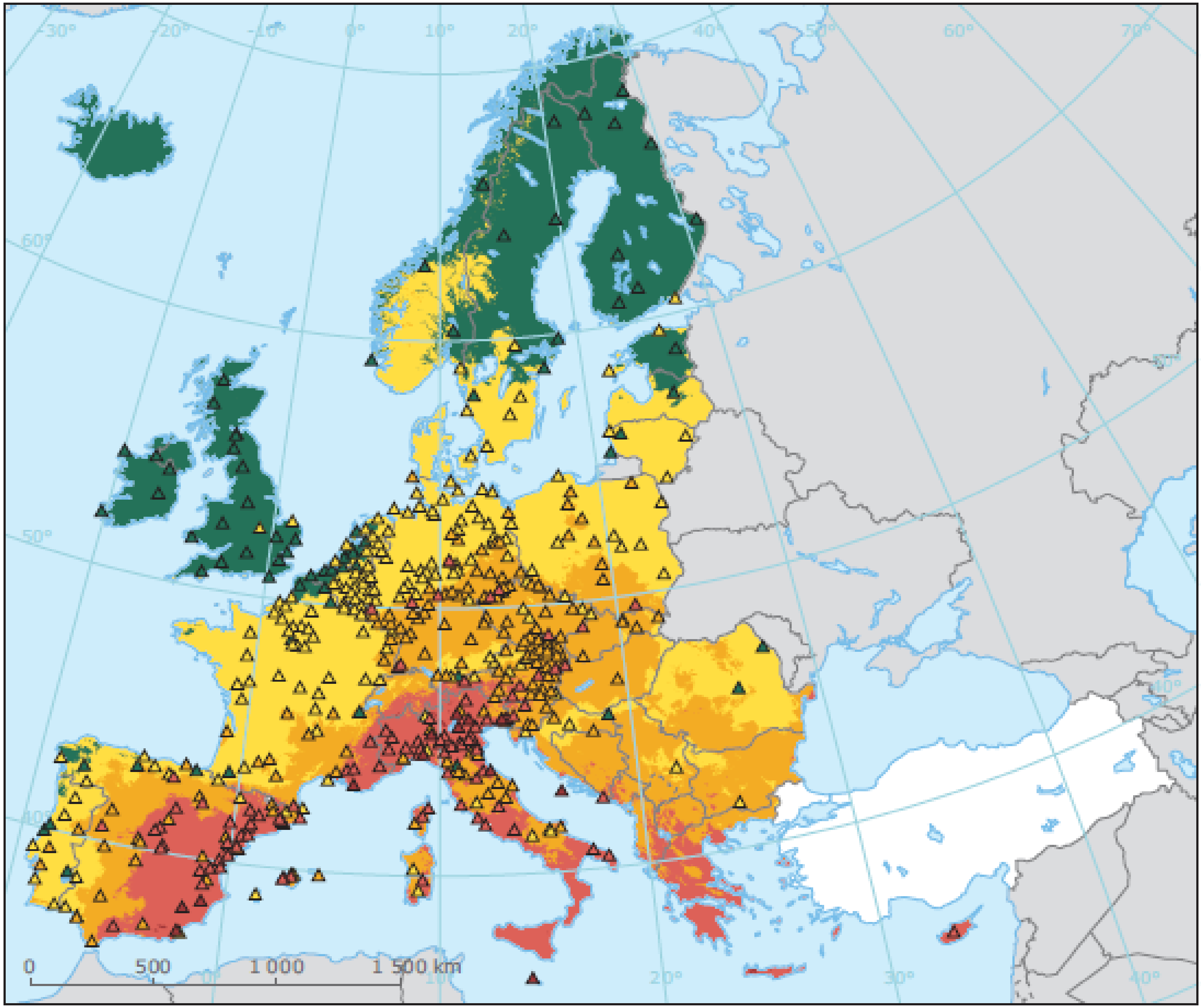
Resistance to abiotic stress

- Water deficit and dehydration
- Freezing and chilling
- Flooding and oxygen deficit
- Oxygen stress
- Ozone pollution
- Heat stress
- Toxicity factors

Stress drivers and resilience factors



Impact of present ozone levels on tree species in EU



Rural concentration of the ozone indicator AOT40 for forest, 2014

△ Rural background station

μg.m⁻³.h

- < 10 000
- 10 000-20 000
- 20 000-30 000
- 30 000-50 000
- > 50 000

- No available data
- Countries/regions not included in the data exchange process

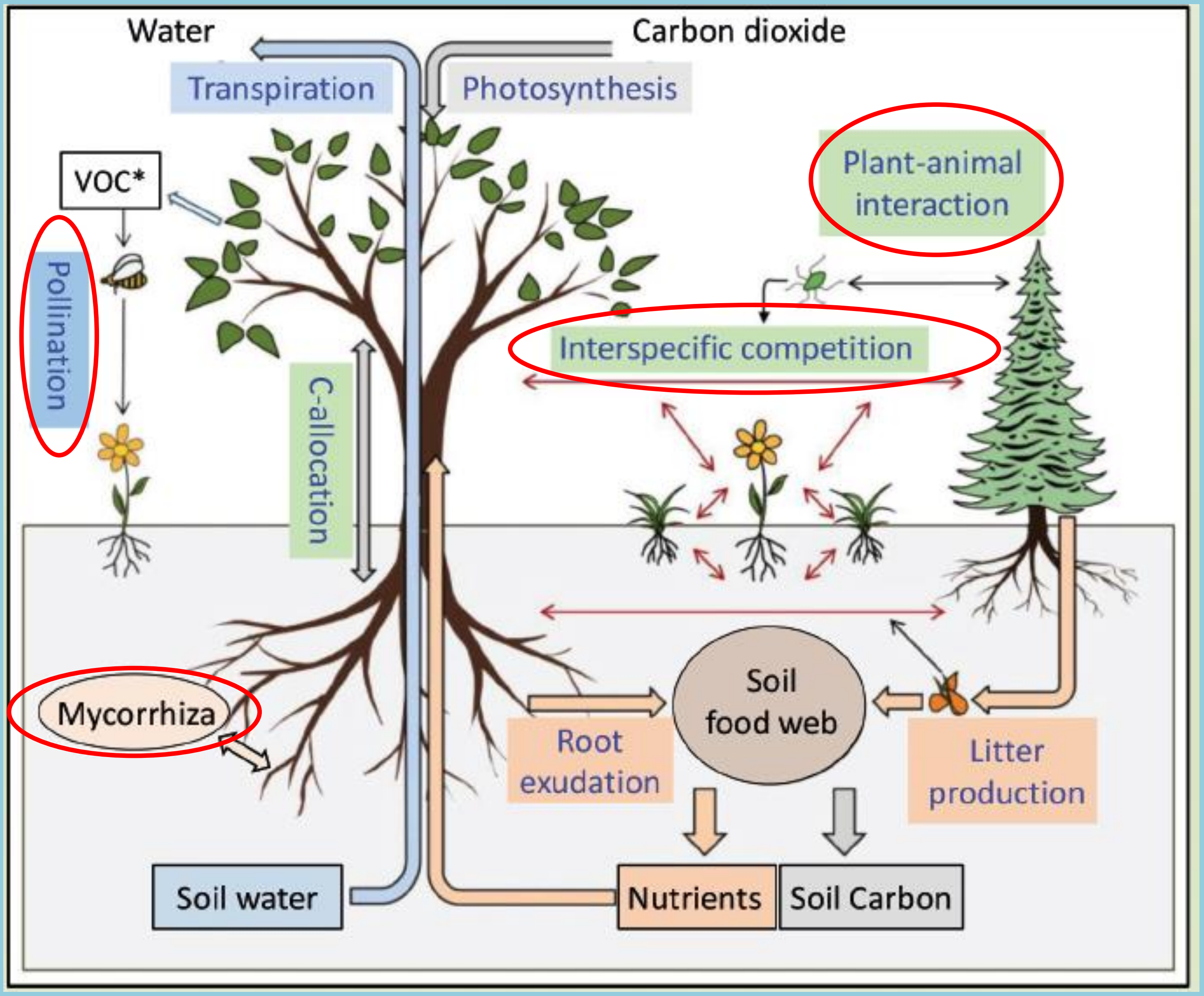
Source: ETC/ACM, 2017b.

Sensitivity of trees to ozone

Salix glabra
Salice glabro

Fraxinus excelsior
*Fr*assino maggiore

Impact of ozone on biodiversity



Source: WGE 2016, Report on biodiversity

How to design a good hedge

1a. Select the most suitable plant species

Carpinus betulus
Cornus sanguinea
Corylus avellana
Cotinus coggygria
Crataegus monogyna
Elaeagnus rhamnoides
Euonymus europaeus
Forsithya spp.
Laurus nobilis
Ligustrum vulgare
Rhamnus catharticus
Rosa canina
Rosa rubiginosa
Ruscus aculeatus
Prunus spinosa
Pyracantha coccinea
Taxus baccata
Viburnum opulus

How to design a good hedge

1b. Favor ecologicical habitats and corridors

Even if not required by the current regulation, most of the bushes, shrubs and little trees have been chosen among the autochthonous species recommended by the regional authorities.

Other species have been chosen for their beautiful flowering or the fruits particularly attracting for birds, pollinators and city's little mammals.

How to design a good hedge

1c. Select evergreen species

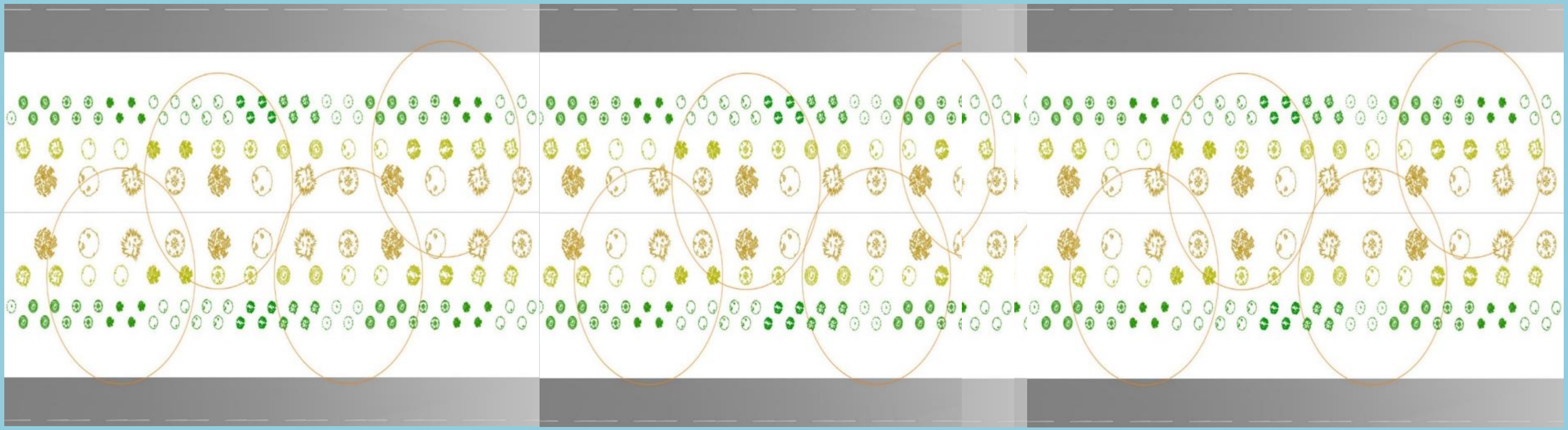
Evergreen species have been also chosen to ensure a more effective capture of fine particulate even during the winter season.

How to design a good hedge

2. The planting layout

Planting trees more distant than usual helps reducing the interference of the plane trees and the amount of maintenance works.

Moreover every bush will have more space for his growth.



How to design a good hedge

3. The importance of the stock type

The stock type has grown in the ERSAF Regional Forestal Nursery in Curno (BG) from seed of autochthonous species collected in Lombardy.




Soil & Air monitoring

Soil chemistry

- Physical and chemical parameters (texture, CEC etc)
- Fertility factors (C/N ratio, macro amd micronutrients)
- Pollution by heavy metals ,
- Pollution by traffic-related hydrocarbons

Air quality

- Ozone
- Nitrogen oxides (NO_2)
- Fine particulate (PM10, PM2.5)

The air quality monitoring instrumentation

The passive minitoring

The passive samplers

Acknowledgments

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- Andrea Modesti *Regional Forest Agency of Lombardy*
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- Giusi Rabotti *FLA, Urban Forestry expert*


Thank you for your kind attention