evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Urban forestry and air pollutants

Carlo Calfapietra

Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.

Urban (and peri-urban) forestry

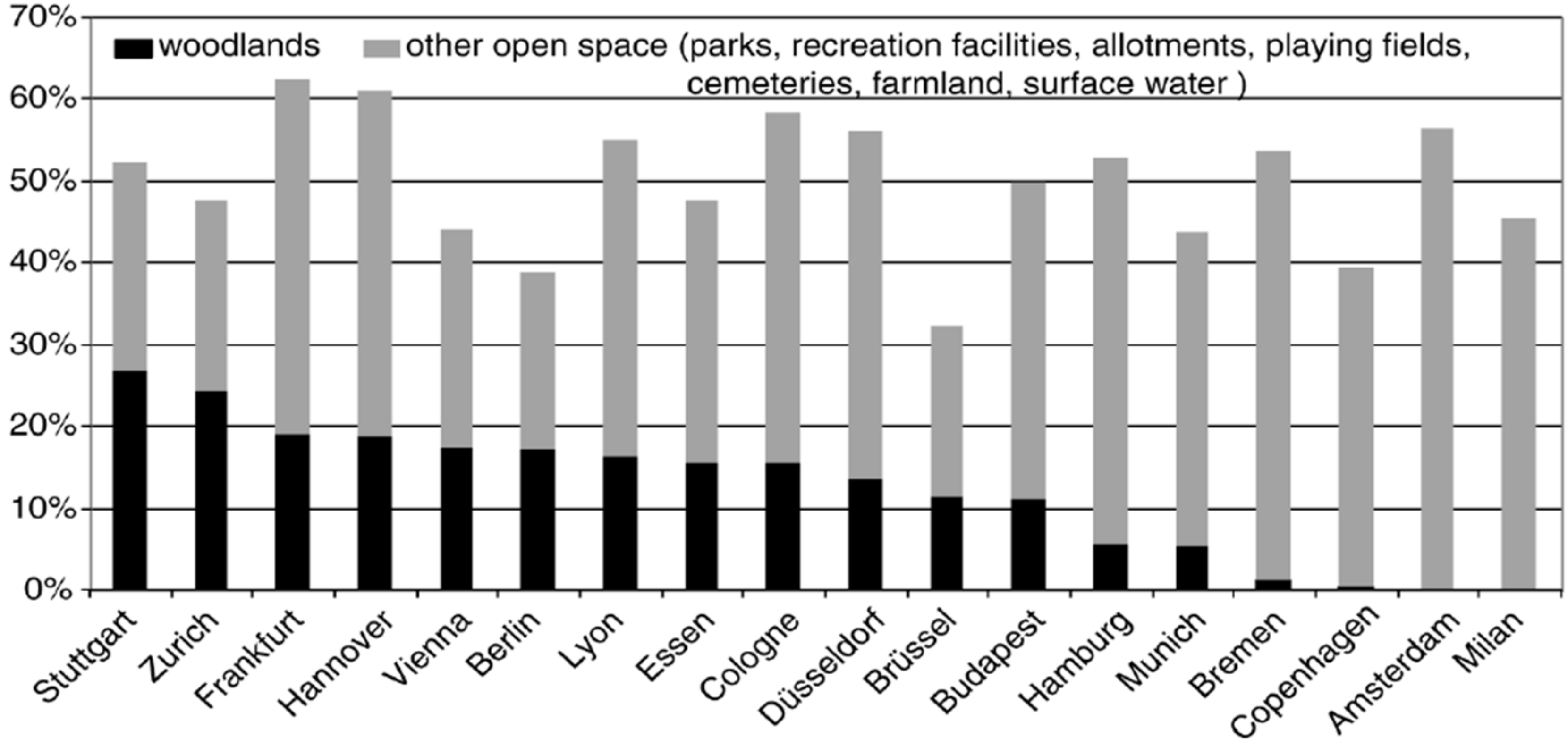
- Trees in streets, squares, parking areas and
- other “grey spaces” with sealed surfaces.

- Trees in parks and other green spaces such
- as yards, gardens, and commercial areas.

- Stands of trees that are often referred to as
- “woodlands” or “woods”.

Randrup et al., 2005

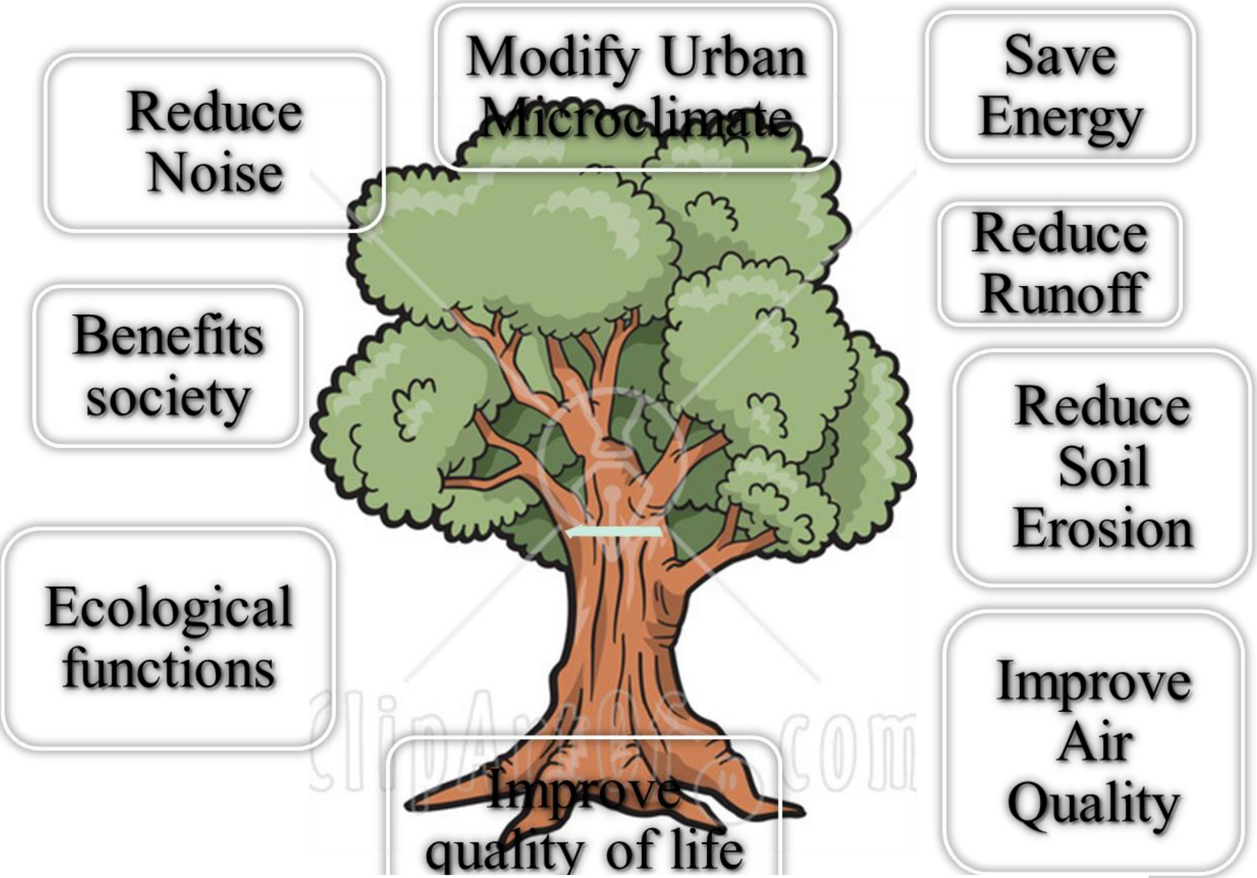
Urban green in Europe



evropský sociální fond v ČR · EVROPSKÁ UNIE · MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY · OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Benefits of urban forestry



Risks of urban forestry

CLIMATE CHANGE

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Interactions of urban forests with atmospheric pollutants:

Evidences from laboratory, field and modeling

Introduction

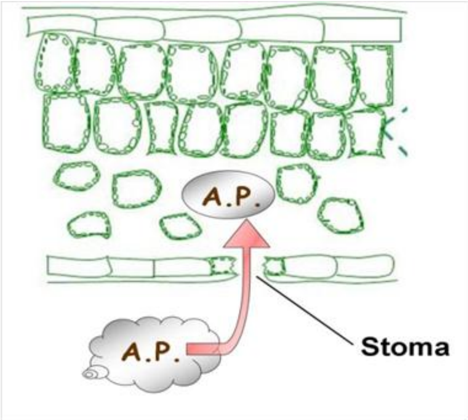
- Acute exposure: high concentration for short periods
- Chronic exposure: low concentrations for long periods

- The factor which takes into account both concentration and lenght of exposure is the "dose"
- Absorbed dose: amount of pollutant uptake by a plant (g m-2)
- Effective dose: amount of pollutant which reaches the protoplast and creates injuries (g m-2)

Trees: ACTIVE and PASSIVE AIR FILTERS

Atmospheric **Pollutants *Mitigation***:

- *Stomatal uptake* (NOx; SO_2; O_3; CO)
- *Capture* - dry deposition (PM)

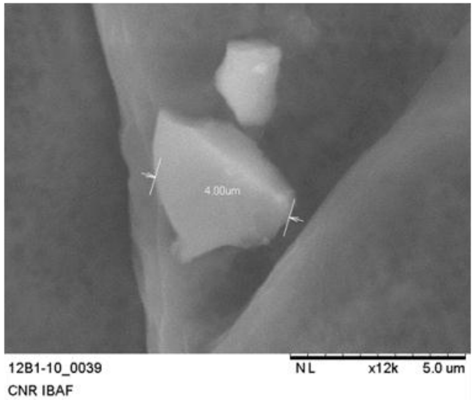


WHO - Tree: ***<u>Quercus ilex</u>*** (holm oak)

- **Representative** tree in Mediterranean/ European UF
- Small leaves/stems **structure**
- **Evergreen**

Pollutant: ***<u>Particulate Matter</u>*** (PM 10; 2.5)

- ***Diffused*** *Airborne particles* -
dimension lower than 10 μm and 2.5 μm

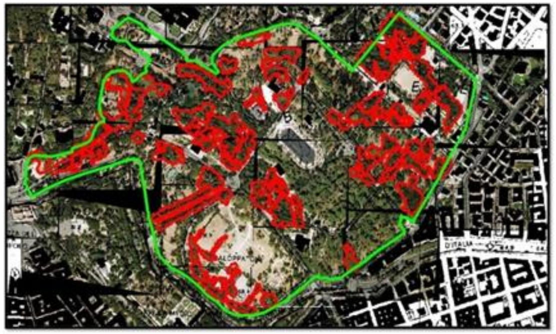


- Highly **diffused**
- **Dangerous**

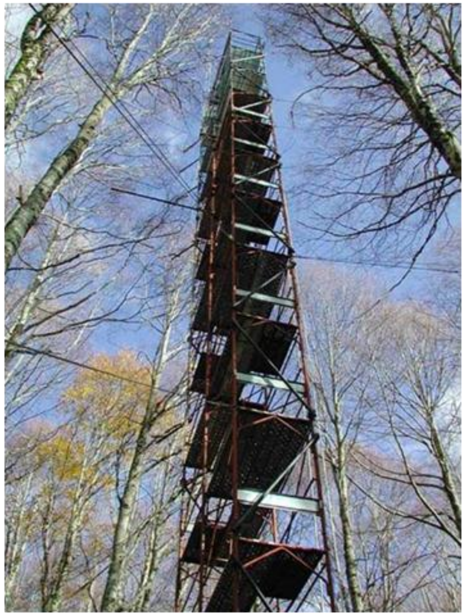
Experimental designs; data flow

Big cuvette measurements of leaf gas exchange

Application and validation of models

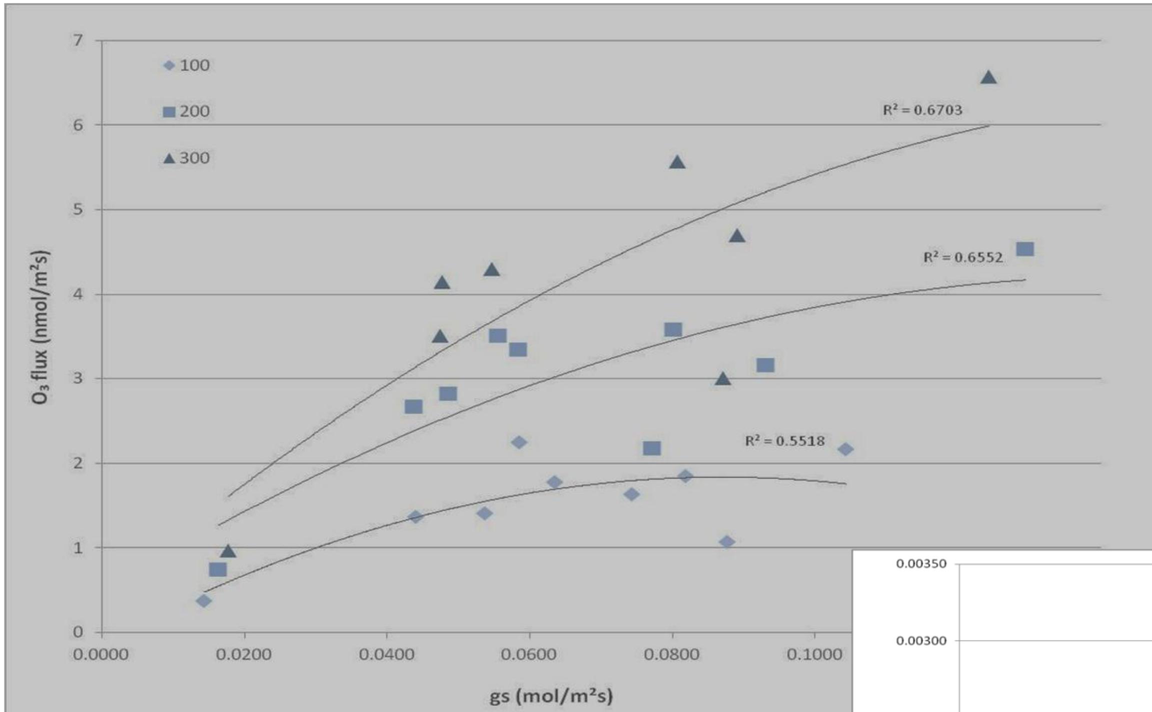


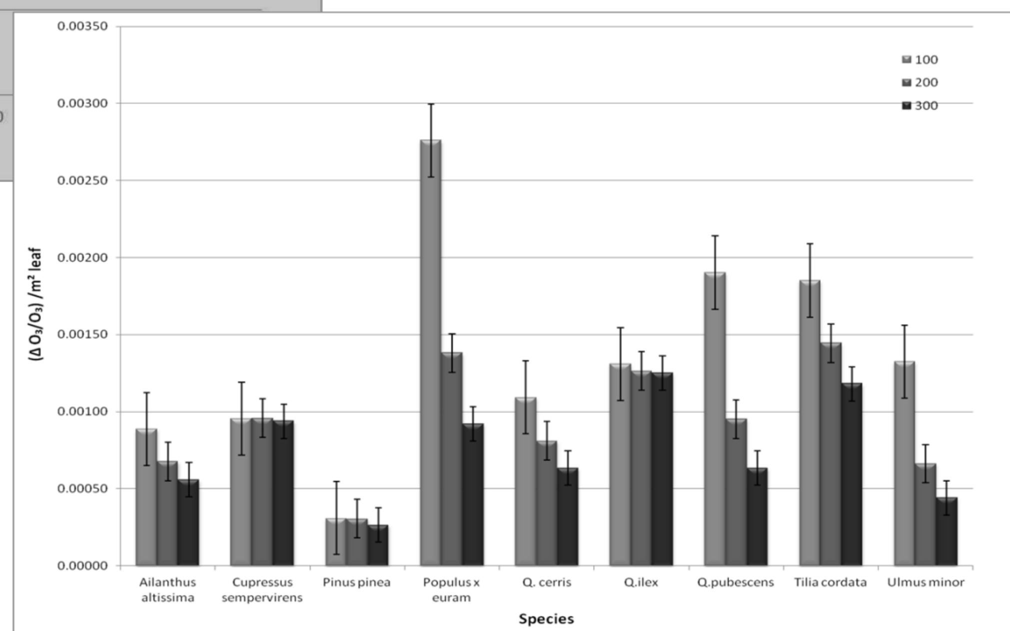
campaign using eddy covariance technique



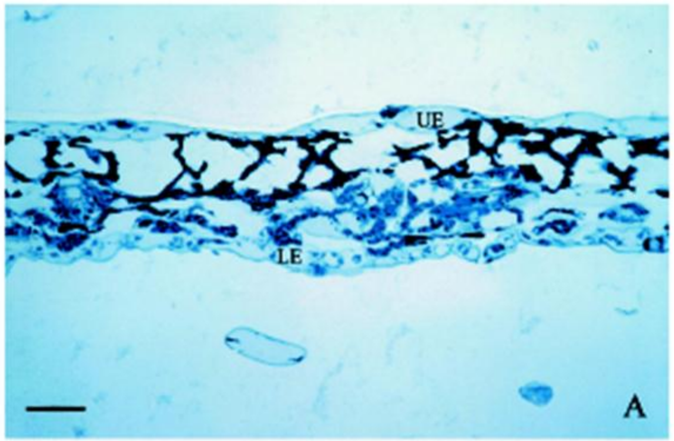
Laboratory —— GIS+Modelling ——→ Field

O_3: Laboratory cuvette results



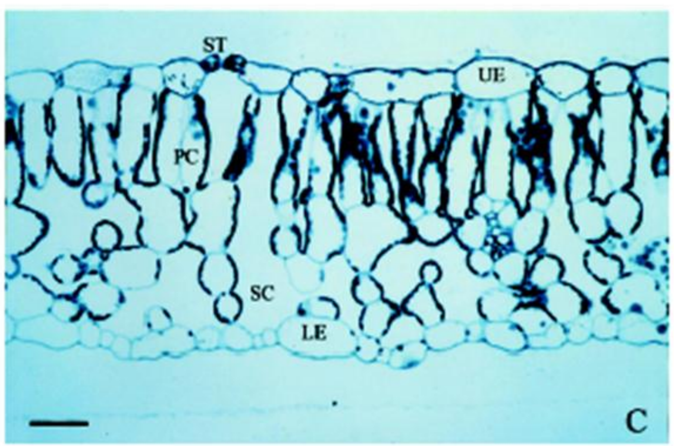


O_3: Anatomical changes



Tobacco leaves

300 ppb ozone

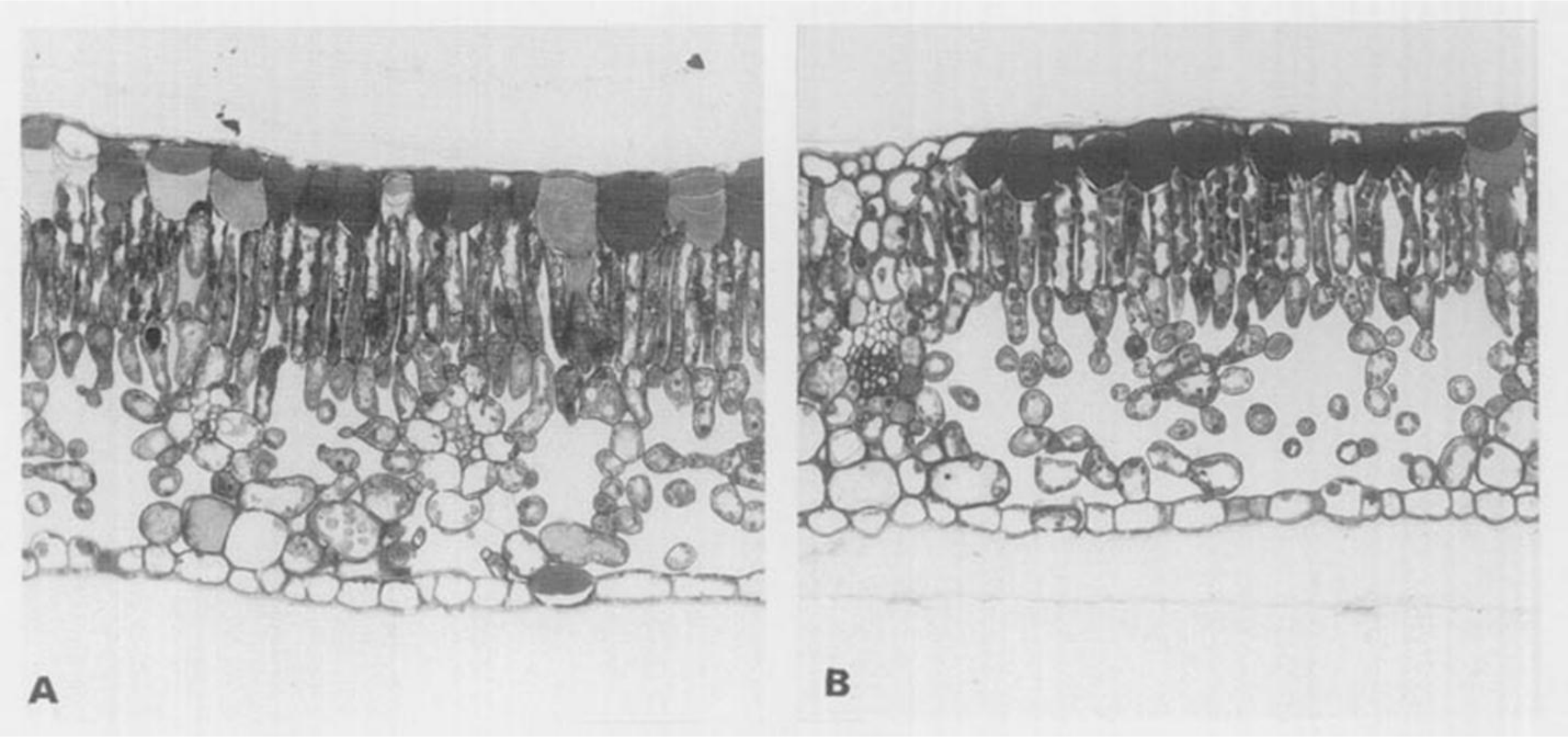


control

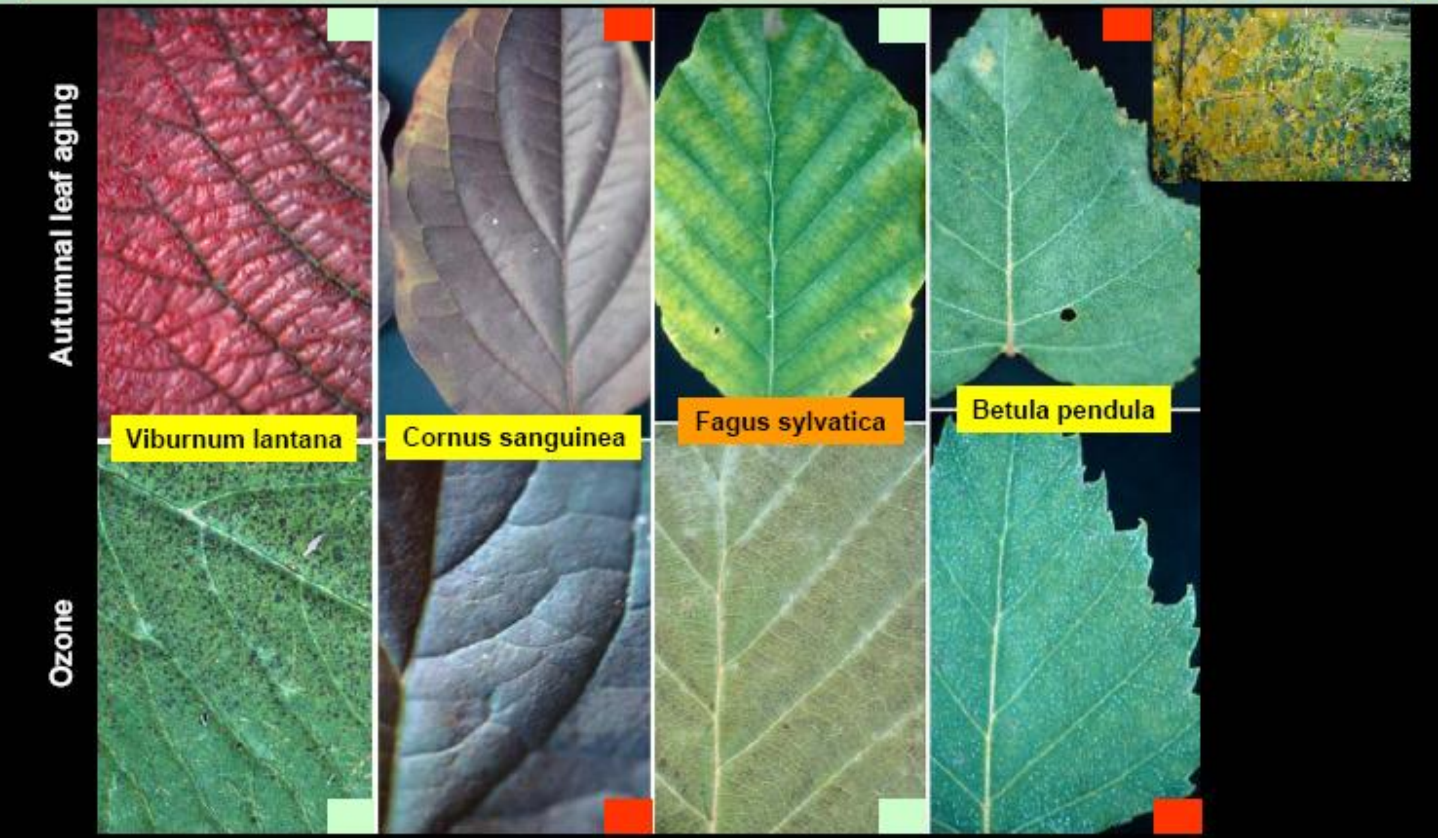
Loreto et al. (2001)

O_3: Anatomical changes – *B. pendula*

control leaves **O3 fumigated leaves**



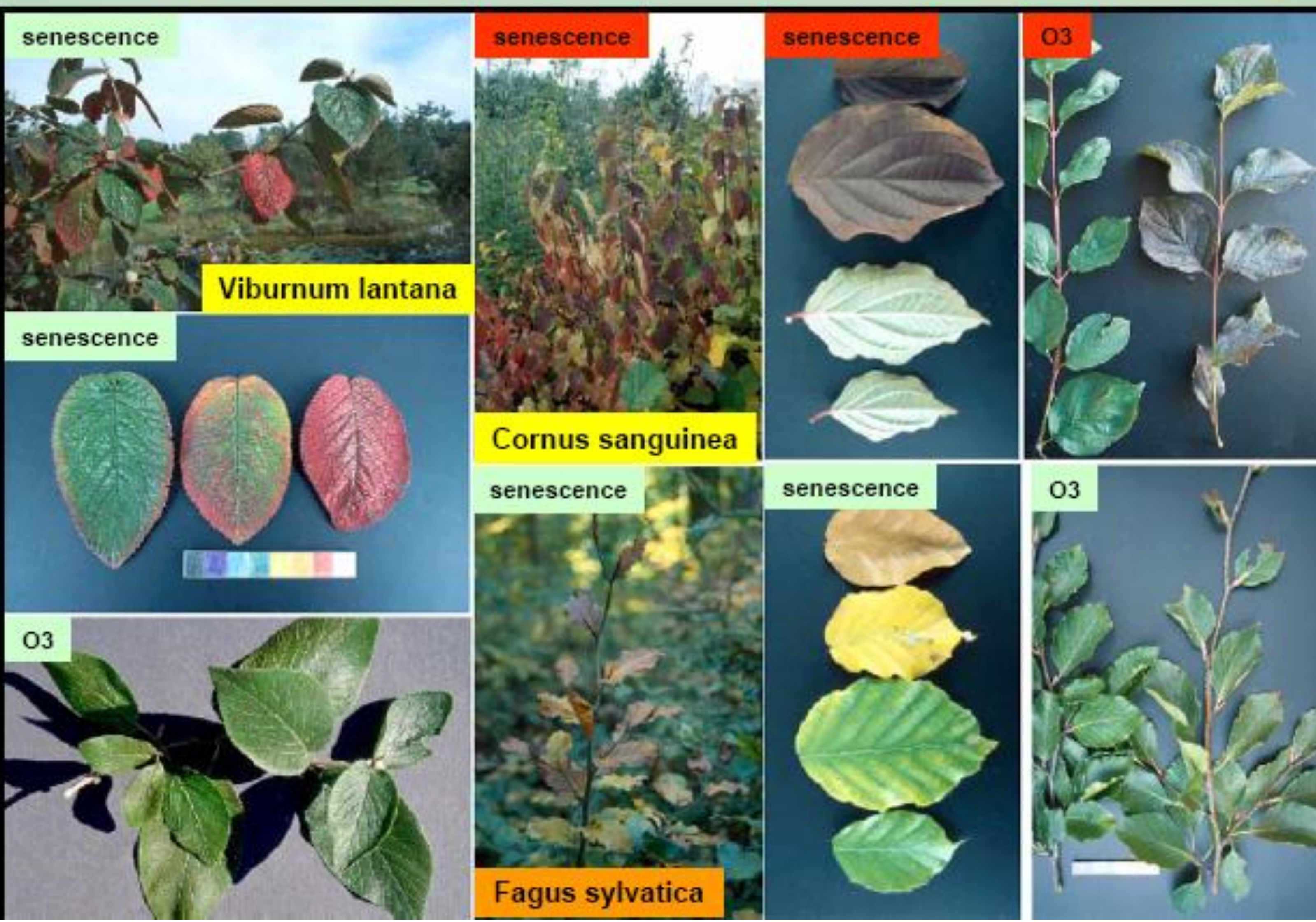
Similarity of leaf symptoms



Comparison between senescence and ozone symptoms

similar

different



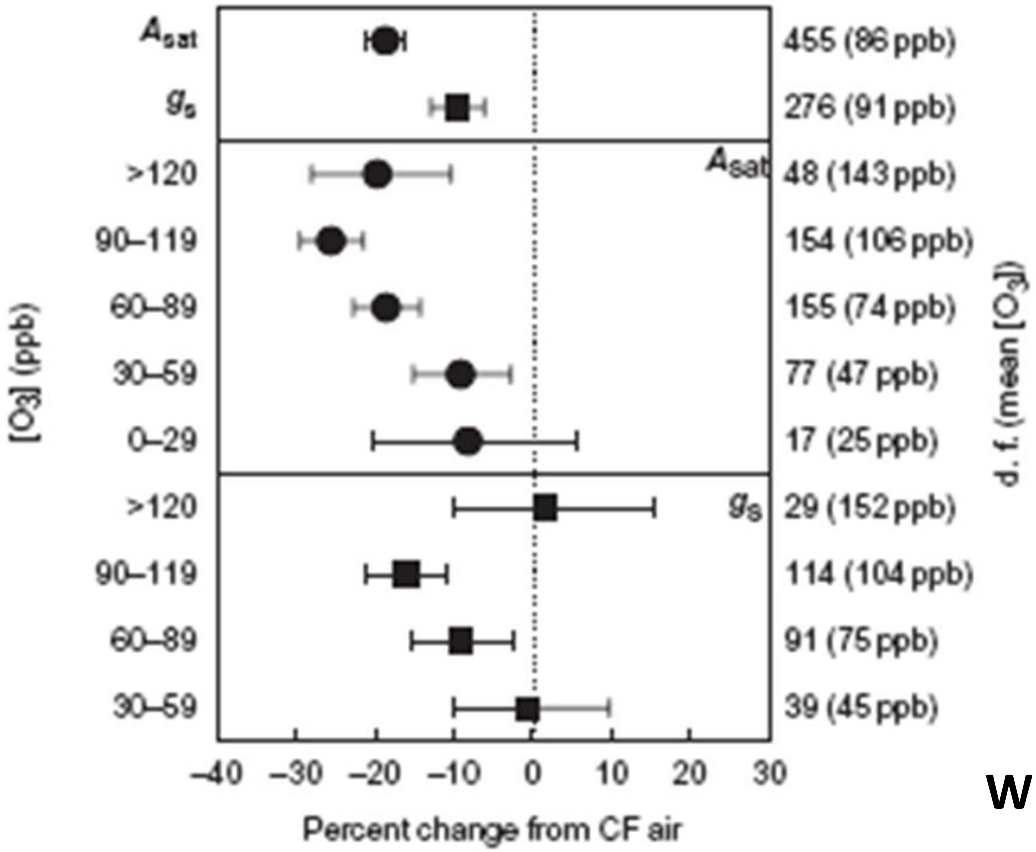
O_3 effect: leaf/plant level

(Felzer et al. 2007)

Variable	O_3 Effect	Examples of primary source	Frequently cited Synthesis Article
Visible injury	⇧	[12]	[95]
Photosynthesis	⬇	[83]	[82]
Stomatal conductance	⇩	[101]	[82]
Dark respiration	⇧	[101]	
Tree biomass	⬇	[36]	[80]
Crop yield	⬇	[65]	[30]
Root growth	⇩	[59,60]	
Decomposition	⇩	[34]	
Nitrogen uptake	⇩	[98]	

White arrow: uncertainties
Black arrow: agreement

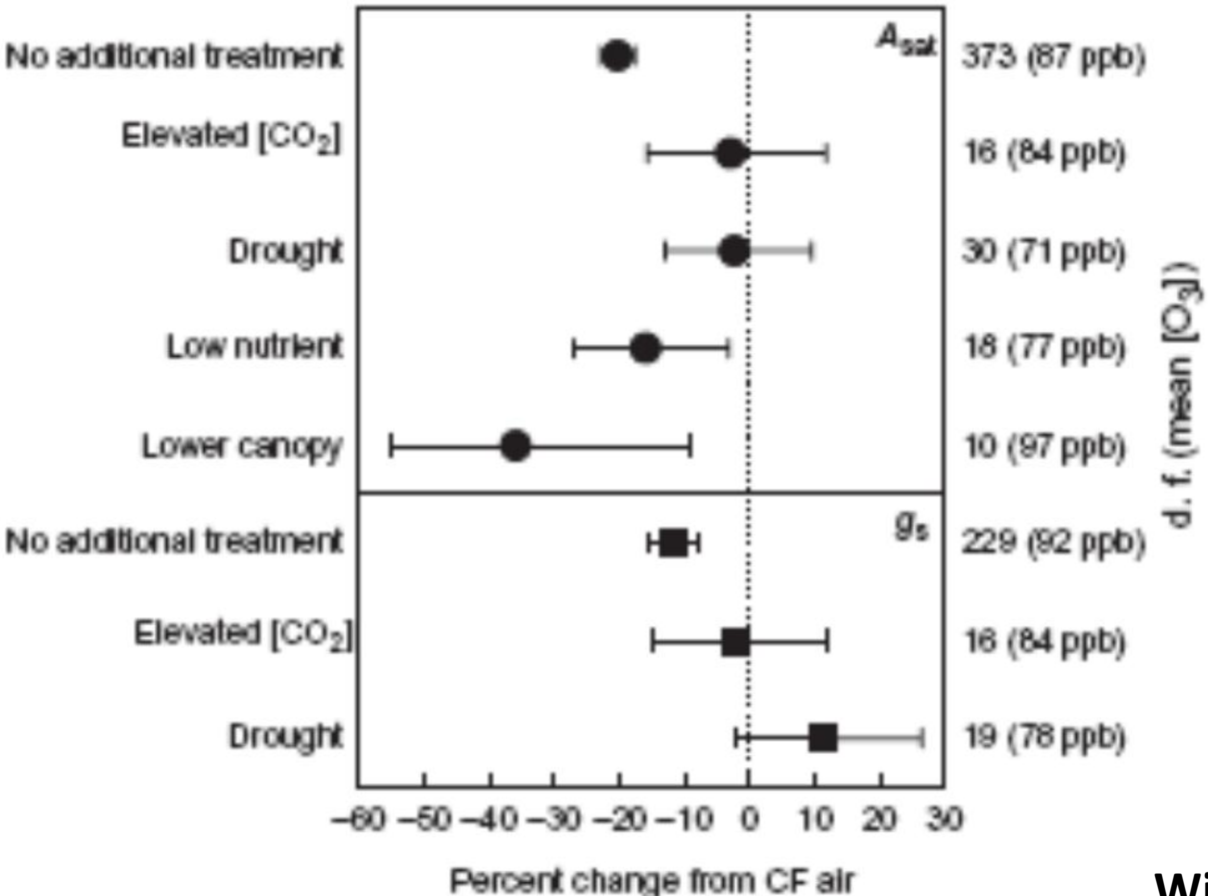
O3 effect on photosynthesis (Asat) and stomata (gs)



Wittig et al. 2005

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Interactions of O_3 effects



Wittig et al. 2005

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

O_3 effects: Whole tree level

O_3 effects: Canopy/ecosystem level

- Aspen-FACE experiment
- Rhinelander, WI, USA
- Established in 1998

- **Treatments**
- Control
- Elevated CO_2 = 550 ppm
- Elevated O_3 = 1.5 x ambient O_3
- Elevated CO_2 + Elevated O_3

- Aspen Clones with different O_3 sensitivity

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Selected results: Gas exchange

Gas exchange	CO2	O3	CO2 + O3
A_{max} lower canopy	n.s.	↓↓	↑(young leaves) ↓(older leaves)
A_{max} whole canopy	↑↑	↓↓	n.s.
Carboxylation efficiency	n.s.	↓	↓↓
Stomatal limitation	↓	n.s.	↓
Stomatal conductance	↓	↓↑	↓
Foliar respiration	n.s.	↑	n.s.
Soil respiration	↑↑	↓	n.s.
Microbial respiration	↑↑	n.s.	n.s.
Stomatal density	n.s.	n.s.	n.s.
Chlorophyll content	↓	↓	↓
Chloroplast structure	↑	↓	↓
O_3 flux	↓	↑↑	↑

Selected results: Growth parameters

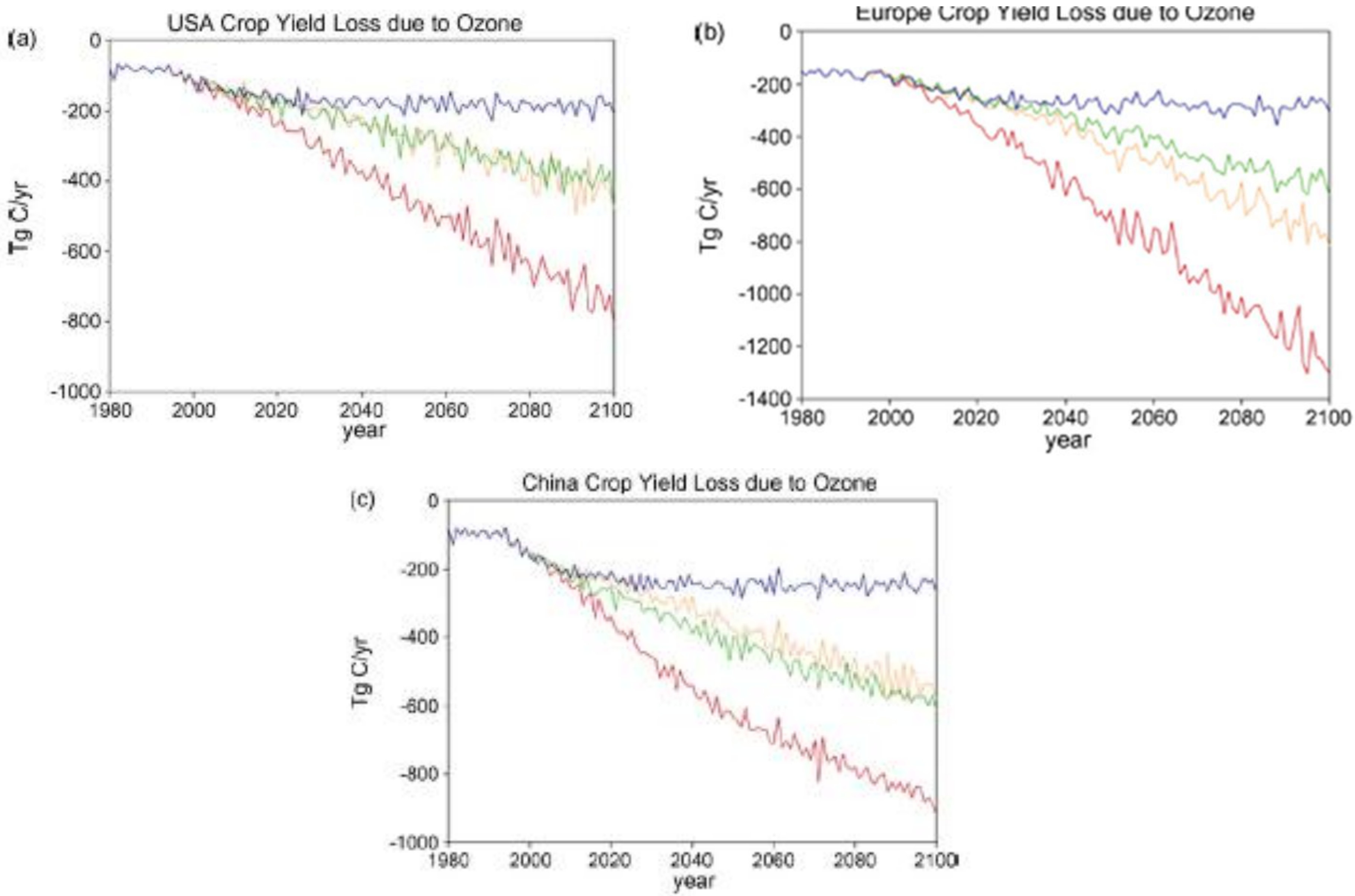
	CO_2	O_3	$CO_2 + O_3$
Growth and productivity			
Leaf thickness	↑	n.s.	n.s.
Leaf size	↑	↓	↓
Leaf area	↑	↓	n.s.
LAI	↑	↓	n.s.
Height growth	↑	↓	n.s.
Diameter growth	↑	↓	n.s.
Volume growth	↑	↓	n.s.
Leaf biomass	↑	↓	n.s.
Stem biomass	↑	↓	↓
Coarse root biomass	↑	↓	n.s.
Fine root biomass	↑	↓	n.s.
Fine root turnover	↑	n.s.	n.s.
Spring budbreak	n.s.	Delayed	n.s.
Autumn budset	Delayed	Early	n.s.
Foliar retention (autumn)	↑↑	↓↓	n.s.

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

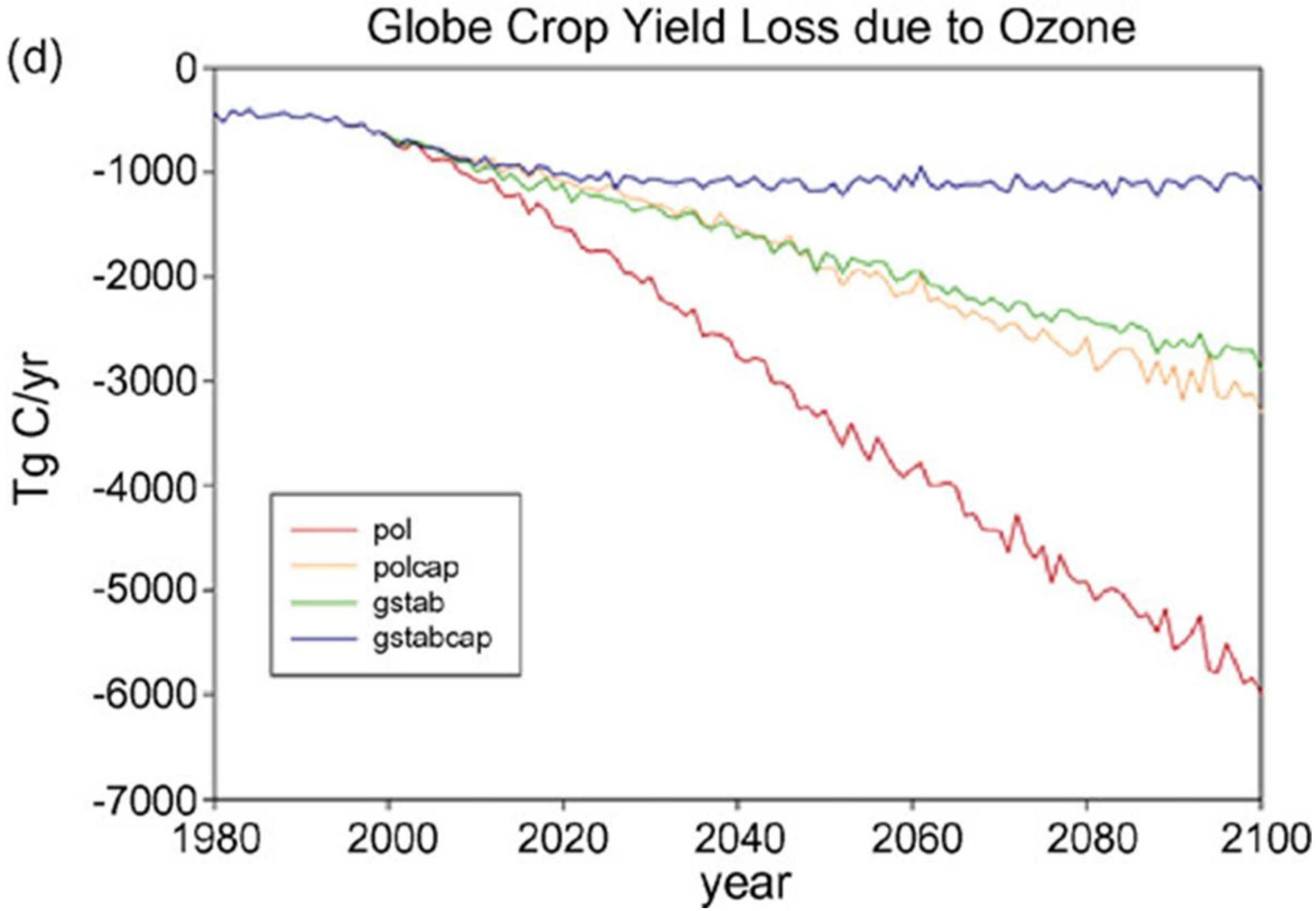
Selected results: Ecosystem interactions

	CO_2	O_3	$CO_2 + O_3$
Trophic interactions			
Melampsora leaf rust	n.s.	↑↑	↑↑
Aspen aphids	n.s.	n.s.	n.s.
Birch aphids	n.s.	n.s.	n.s.
Aspen Blotch Leafminer	↓	↓	↓
Forest Tent Caterpillar	n.s.	↑	n.s.
Oberea woodborer	↑	n.s.	↑
Ecosystem level			
NPP	↑	↓	n.s.
Litter decomposition (*k* value)	↓	n.s.	↓
Nutrient mobilization	↑↑	n.s.	↑
Water-use efficiency	↑	↓	↑
Soil moisture	↑	↑	↑
Competitive indices	↑	↓	↓↓
Soil invertebrate diversity	n.s.	↓	↓
Microbial enzymes	↑	n.s.	n.s.
Microbial biomass	↑	n.s.	n.s.

O_3 effects: Biosphere level



Prediction of global crop yield

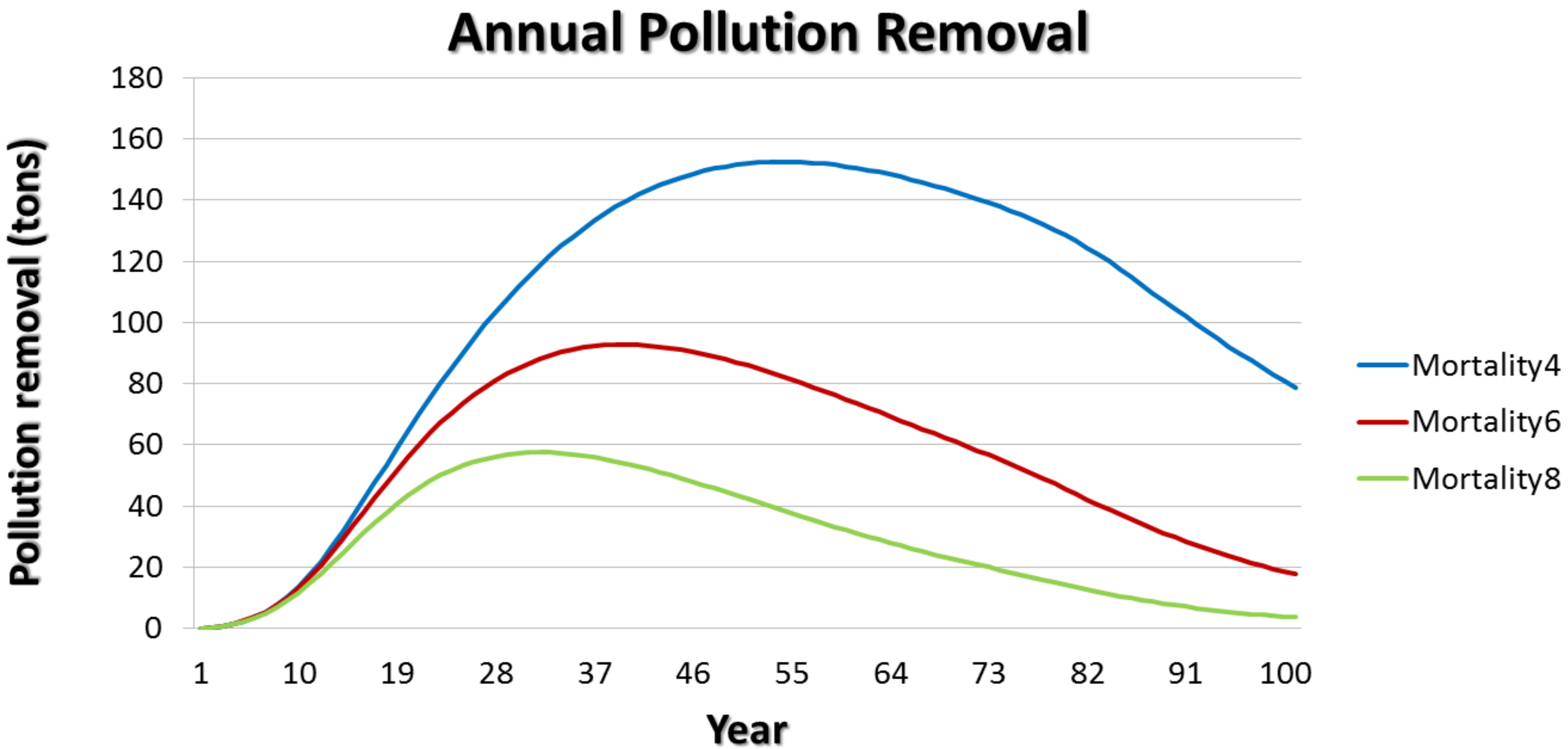


Modelling: UFORE model

- Urban Forest Effects (UFORE) model
  - UFORE-A: Anatomy of the Urban Forest
  - UFORE-B: Biogenic Volatile Organic Compound (VOC) Emission
  - UFORE-C: Carbon Storage and Sequestration
  - UFORE-D: Dry Deposition of Air Pollution
  - UFORE-E: Energy Conservation

Application of UFORE model

Morani et al. 2011, Environmental Pollution

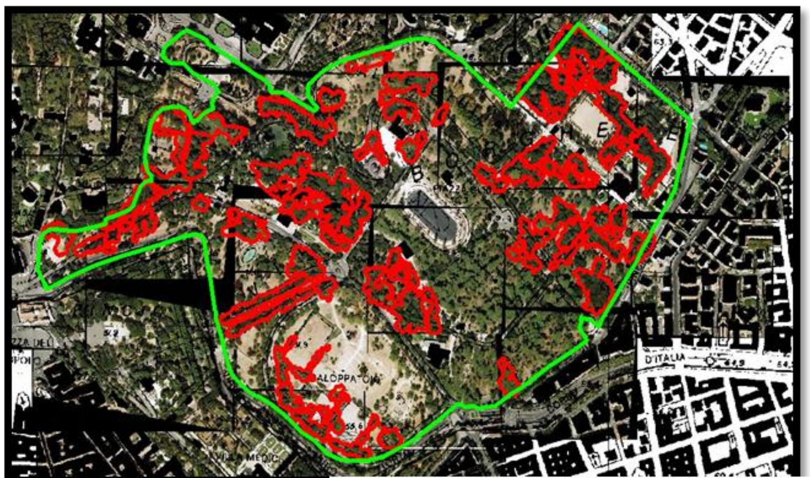


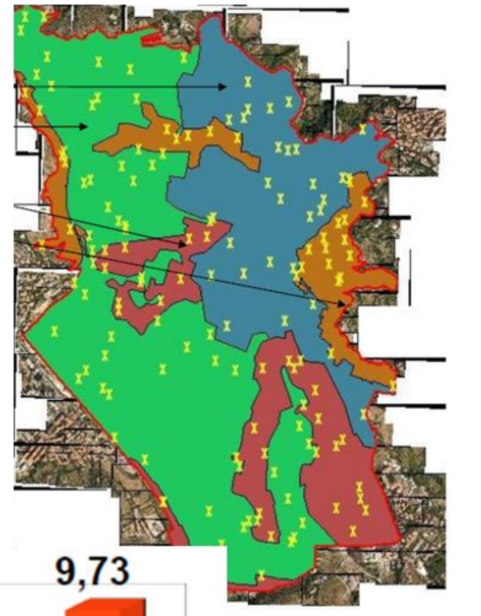
Peak values : 152.6, 92.8, 57.5 (tons/year)

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

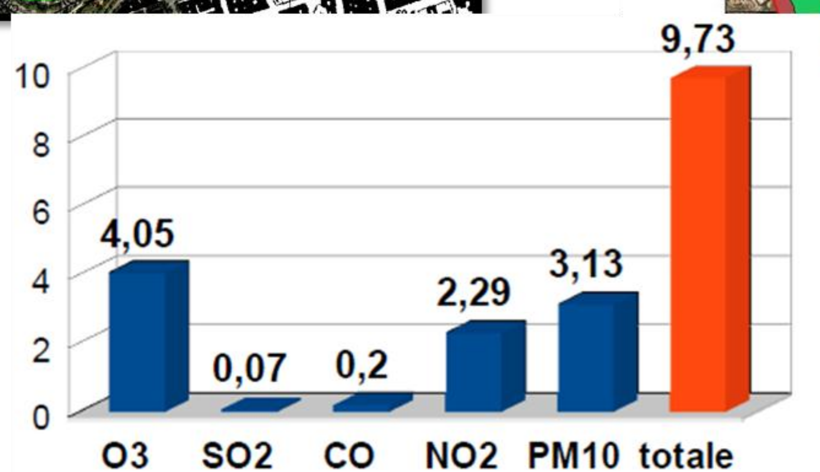
Application of UFORE model:
Case studies

Villa Borghese

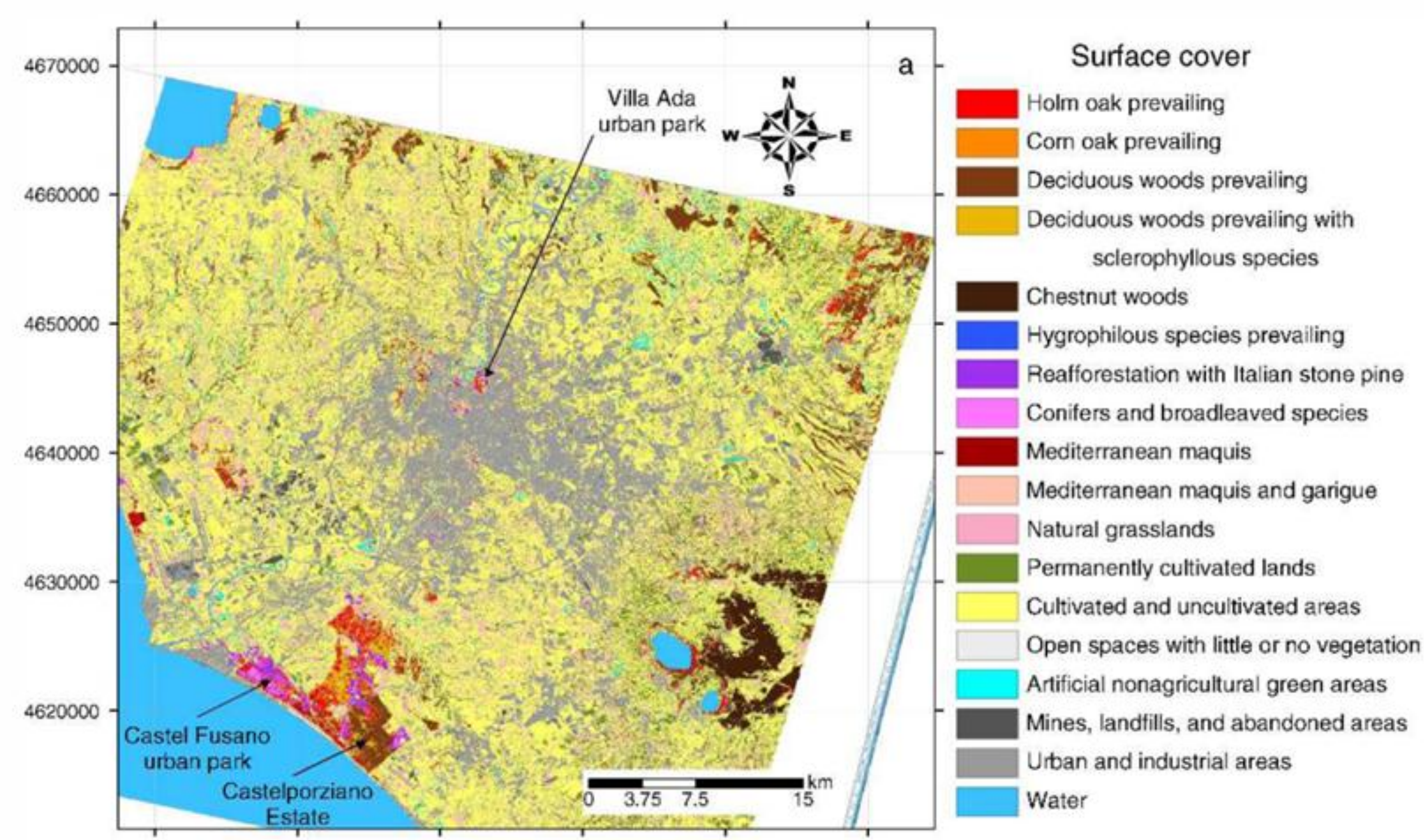




$g\ m^{-2}\ y^{-1}$

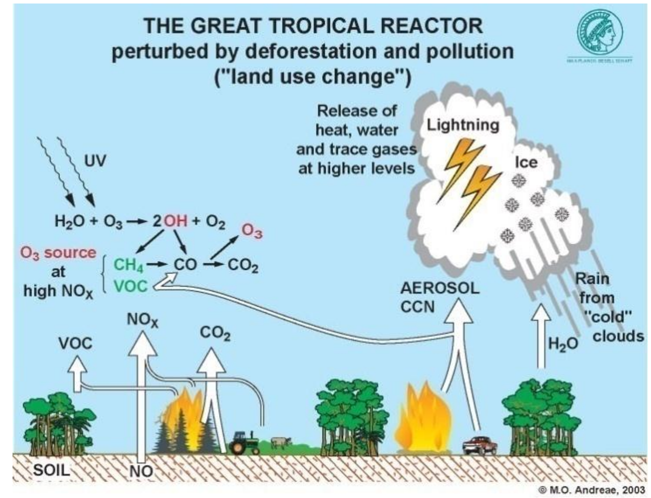


Validation of model with eddy data



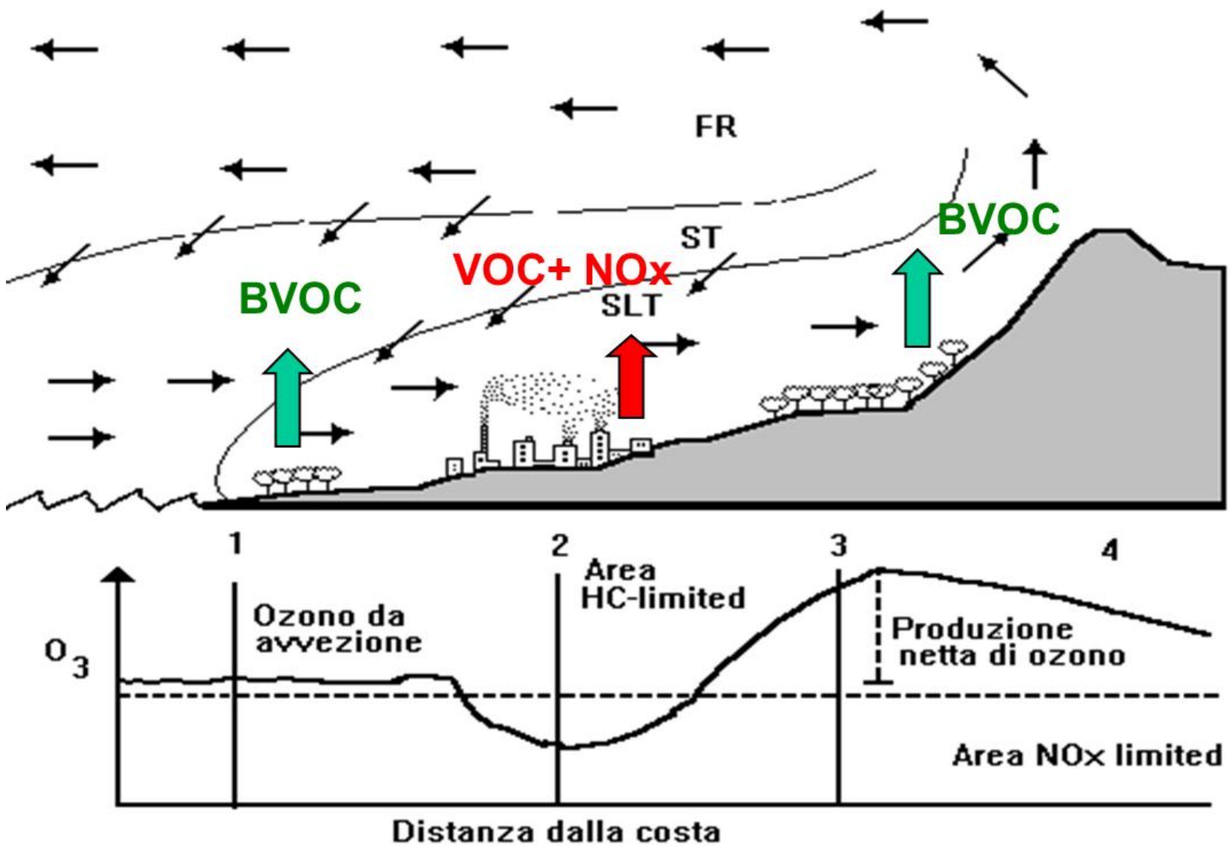
Interactions between O_3 and VOCs

- VOC and ozone formation
  - NO2+ sunlight -- > NO + O
  - O + O2 -- > O3
  - O3+ NO -- > NO2+ O2



- hydrocarbons (such as VOCs), through reactions with the radicals OH, induce an increase of NO2 to the detriment of NO, with consequent increase of ozone concentration
- OFP (Ozone Forming Potential)
  - $OFP_{species} = B[(E_{iso}R_{iso}) + (E_{mono}R_{mono})]$
  - B is the biomass factor [(g leaf dry weight m-^{2} ground area)], Eiso and Emono are species-specific mass emission rates [(µg VOC) g^{-1} leaf dry weight day^{-1}] for isoprene and monoterpenes Riso and Rmono are reactivity factors [g O_3 g^{-1} VOC]
  - Benjamin & Winer, 1998

Mediterranean: “hot spot” for VOC and photochemical pollution



Are urban trees sink or source of O_3?

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

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

Paoletti et al. 2009

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

BVOC emission in urban environment

- We are now able to measure uptake of pollutants by plants in different ways and rather accurately especially for some pollutants
- Air pollutant uptake by urban trees can improve air quality in our cities but …
  - BVOC emissions from the same trees can have important implications for O_3 levels
- BVOC-O_3 interactions are really complex both in the short-term and in the long-term however it is generally highly recommended to avoid strong BVOC emitters especially around urban environments

Perspectives

- We are now able to clone the isoprene synthase gene from many species
- If the protective benefits are small and if the stimulating role on ozone uptake is small then it might be better to engineer those plants that do make isoprene to no longer make it and use these transgenic lines for tree plantations and around urban environments

Eddy Covariance
PTR-TOF (VOC)
Fast O_3 analyzer
NOx analyzer
Cond. Part. Counter

Project PON-Infrastruttura

Establishment of a high-technology urban site in Park of Capodimonte (Naples) for the study of the exchanges between the urban forestry and

Green Infrastructure approach: linking environmental with social aspects in studying and managing urban forests

(GreenInUrbs)

Carlo Calfapietra, Chair

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

COST Action Objectives

- To collate recent (qualitative and quantitative) findings from national or international programmes about the ecosystem services provided by GI and UF.
- To compare different approaches and conditions (climatic, socio-cultural, economic and urban planning) in the countries involved, in order to develop best practice guidelines for GI managers and decision makers to assist in the maximization of benefits from GI and UF.
- To define environmental and social indicators and thresholds in order to improve the environmental quality of our cities, and consequently the quality of life of European citizens.
- To provide scientific evidence in order to implement those best practice into legislation both at local, national and European level
- To identify the main priorities and challenges in terms of future research on GI and UF

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

www.greeninurbs.com