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CNR IRET Conference

Rome, February 18th-19th, 2025

CNR IRET Istituto di Ricerca sugli Ecosistemi Terrestri

An experimental infrastructure for realistic experiments in Mediterranean Europe – FO_3X (Free air O_3 eXposure)

E. Marra[1], E. Paoletti [1,2], B.B. Moura [1,2], J. Manzini [1,3], A. Viviano [1,3], L. Lazzara [1], Y. Hoshika [1,2]

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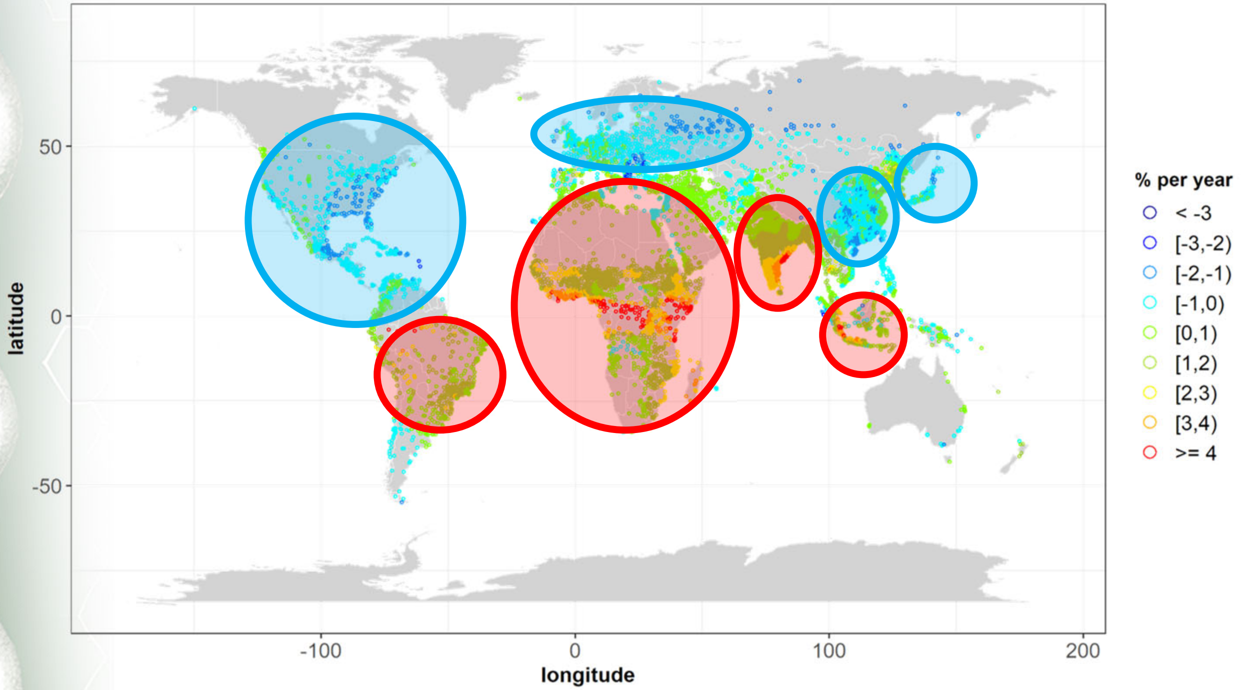
Tropospheric ozone (O_3)

Tropospheric ozone (O_3 **- close to the Earth's surface**) is a **secondary air pollutant** that forms as a result of **photochemical reactions**.

Ozone concentrations over the last 20 Years



-1-2% $year^{-1}$ (air quality regulations)
North America
Central America
Northern Europe
Japan
Southeast China

+ 1-2% $year^{-1}$ (developing regions)
South America
Africa
Middle East
South Asia

+ 3% $year^{-1}$ (rapid industrialization/urbanization)
Equatorial Africa
India

Global trends (2000-2019) in urban areas (> 50,000 inhabitants) show that ozone levels are still increasing - **people and ecosystems are being exposed to dangerous levels of ozone**.

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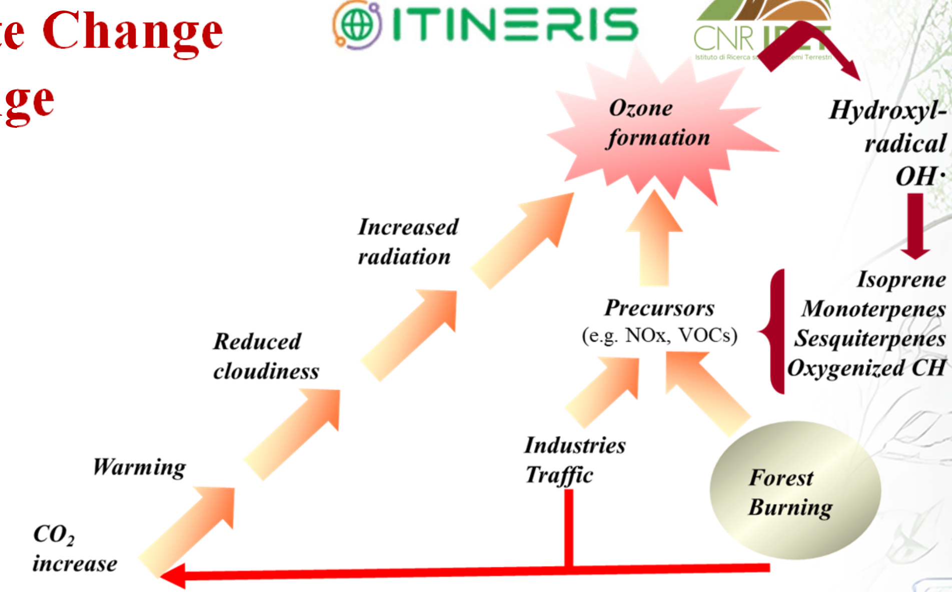
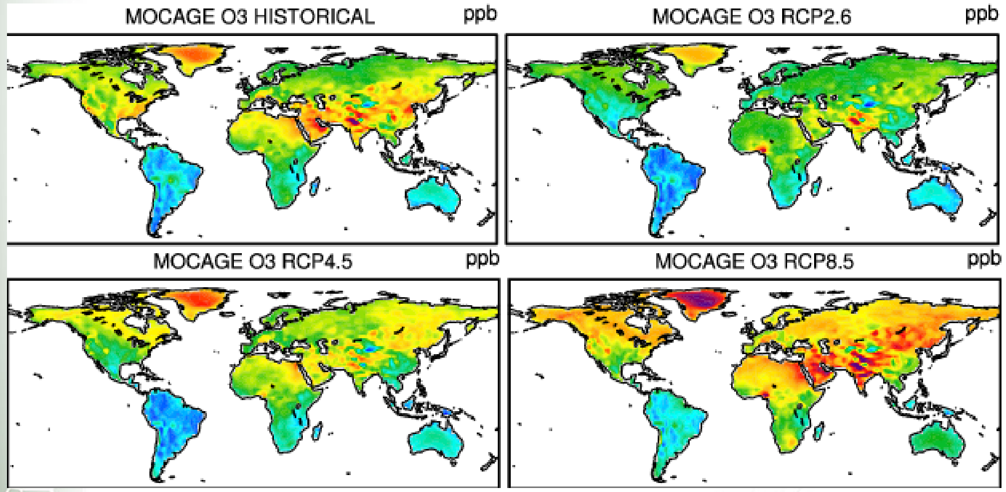
A component of Climate Change & Global Change

Climate change, by **raising temperatures** and increasing **sunlight/radiation**, drives higher O_3 concentrations - **Mediterranean Basin** is particularly vulnerable (**reduced biomass, photosynthetic capacity**).



Emissions scenario for 2100



2100: **40-55 ppb**

Sicard et al., 2017

According to projected emission pathways (RCP), ozone concentrations by 2100 could **decrease by 2-10 ppb under the optimistic** RCP2.6 scenario or **increase by 4-5 ppb** under **the high-emission** RCP8.5 scenario.

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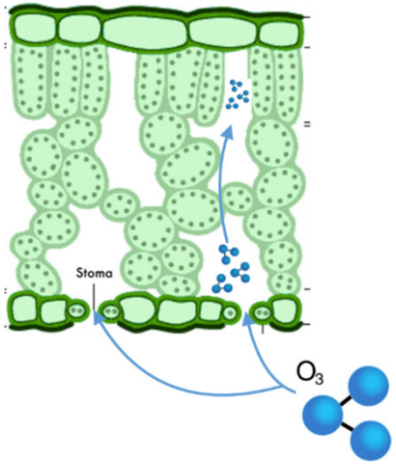
Introduction

Physiology – anatomical



O_3 is taken up through stomata (during photosynthesis) and damages the plant's **physiological** and **biochemical processes**.

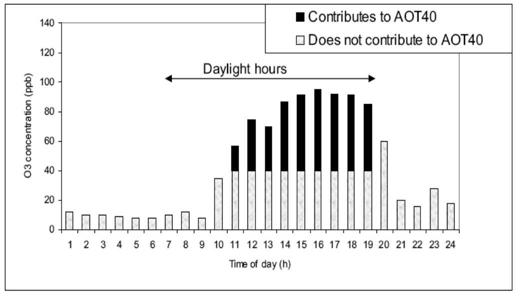
Leaf level – macroscopic

Ozone metrics for plant protection

Exposure-based

(AOT40, Accumulated Ozone exposure over a Threshold of 40 ppb - EU)

- Pros: easy to measure and calculate (**entire growing season**).
- Cons: poorly biologically relevant (**generic index**)



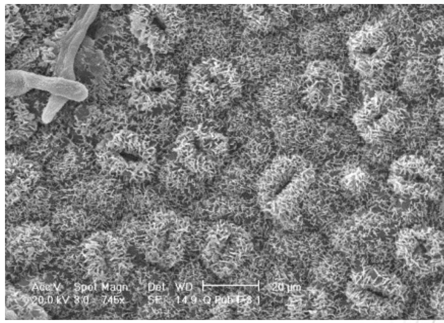
$$AOT40 = \sum \max\left([O_3] - 40, 0\right) \cdot \Delta t$$

Flux-based

(PODy, Phytotoxic Ozone Dose)

- Pros: highly biologically relevant (**specific species – i.e., Fagus, Quercus**).
- Cons: **many variables** to be monitored.

Stomatal conductance (setting critical levels CLs)



$$g_{sO3} = g_{max} \cdot f_{phen} \cdot f_{O3} \cdot f_{light} \cdot \max\{f_{min}, (f_{temp} \cdot f_{VPD} \cdot f_{SWC})\}$$

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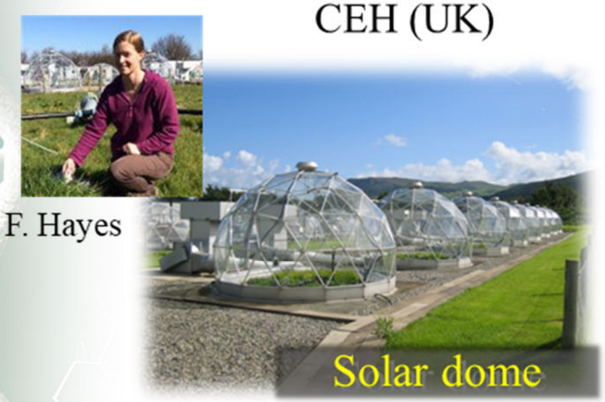
Current ozone exposure experiments in Europe

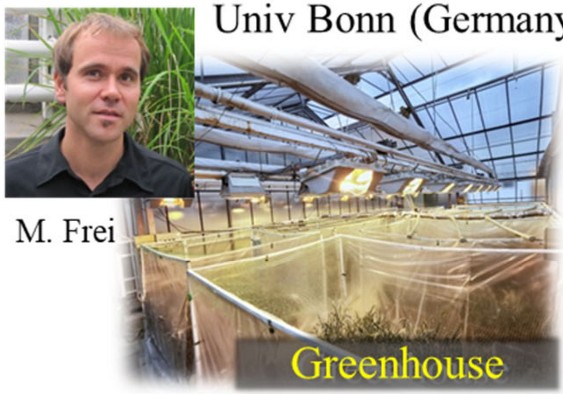
Since the 1970s, controlled and open-top chambers have been used to study the effects of O_3 on plant growth and crop yields – artificial/**controlled conditions** (which may influence how plants absorb O_3) and **plant size.**

CEH (UK)



F. Hayes

Univ Bonn (Germany)



M. Frei

TUM (Germany)

M. Baumgarten

CIEMAT (Spain)

R. Alonso

Univ Pisa (Italy)

G. Lorenzini

CNR (Italy)

E. Paoletti

Y. Hoshika

FACE (**field conditions**) offering a more **realistic open-air environments** to better estimate plant responses to ozone.

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Free-air O_3 eXposure (FO_3X)

5 FACE systems worldwide - FO_3X the only one located in a **Mediterranean climate**

FO_3X

Set-up description:

- The design is a **split-plot experiment**.
- The facility permits to expose the plants to **three levels of O_3 concentrations**. Each O_3 treatment is **replicated three times** (total 9 plots 5 X 5 X 2 m).
- A **vertical network of vent pipes disperses the mixture of ambient air and O_3** (generated from **pure oxygen**) across the plots **to simulate realistic exposure**.
- The air containing **O_3 is injected through 25 teflon tubes** hanging down from a fixed grid above the plants.
- The **O_3** concentration and all main **environmental variables** are continuously monitored.

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Free-air O_3 eXposure (FO_3X)

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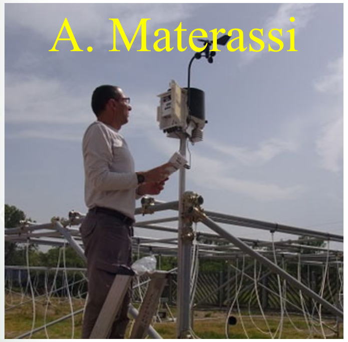
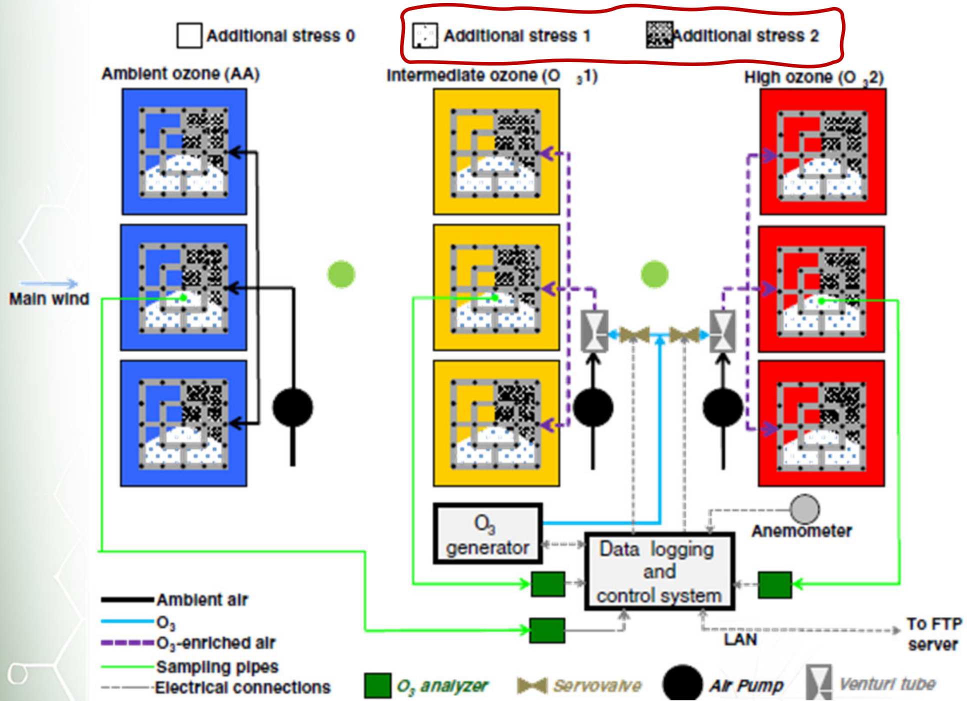
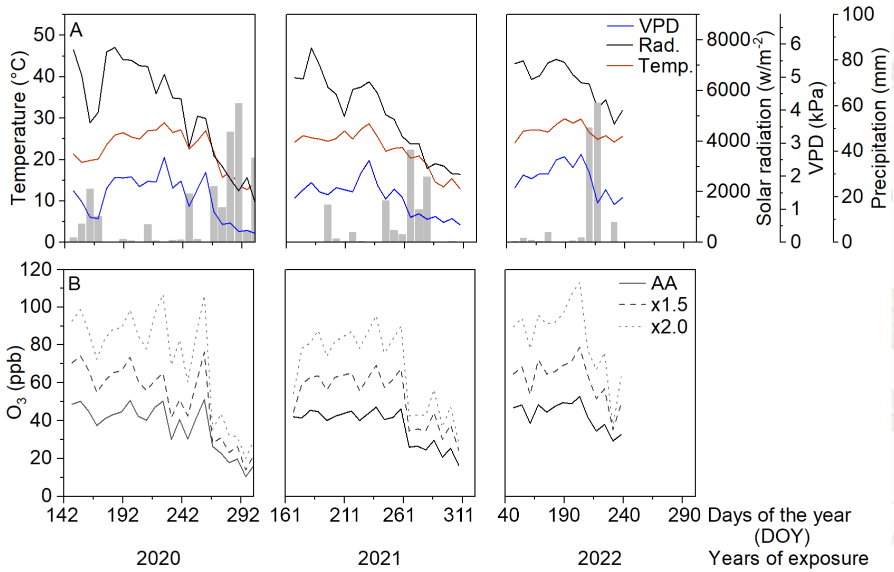


A **meteorological station** monitors the **climate conditions** (temperature, pressure, RH, PAR, GR, wind speed and direction),
air vapor pressure deficit
O_3 concentration, NOx concentration

FO_3X





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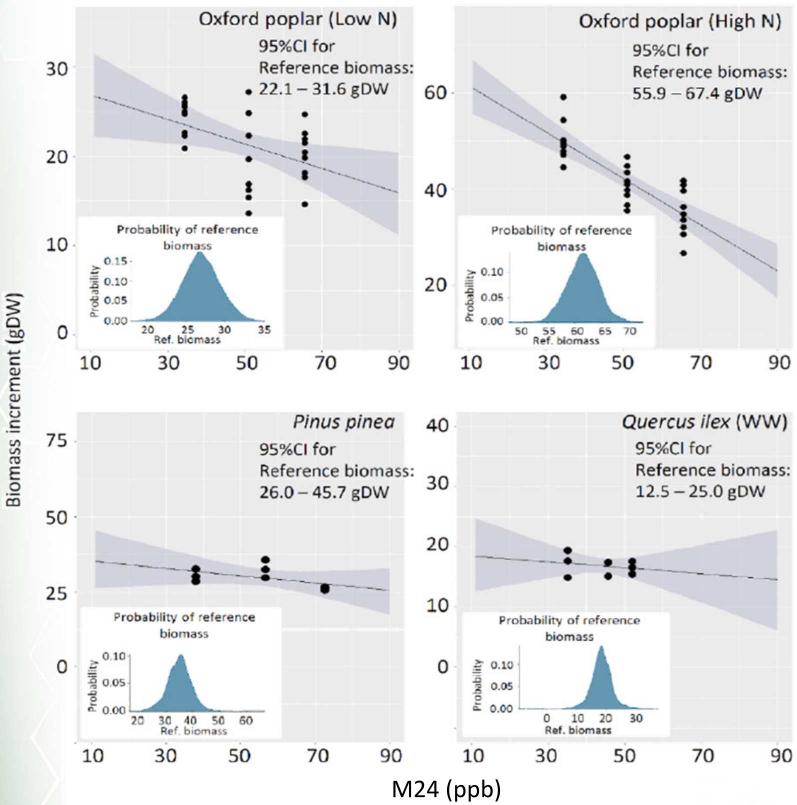
Ozone Risk Assessment

The application of various **treatments (differing O_3)** allows to analyze the relationship between **O_3 and biomass** variation. It is possible to **parameterize** species-specific gs and establish **Critical levels** (CLs - i.e. **4 or 5% decrease in biomass or yield**), defined by the Phytotoxic Ozone Dose (**POD**).



Species	PODy (mmol m^{-2})	CL	Reference
Saccharum officinarium	POD_2	1.04	Moura et al., 2018
Quercus ilex	POD_0	6.90	Hoshika et al., 2018
Quercus pubescentis	POD_0	6.90	Hoshika et al., 2018
Quercus robur	POD_0	3.60	Hoshika et al., 2018
Populus oxford	POD_4	4.60	Lu Zhang et al., 2018
Moringa oleifera	POD_4	1.10	Moura et al., 2021
Eugenia unifolia	POD_0	3.60	Engela et al., 2021
Vitis vinifera	POD_3	5.21	Moura et al., 2024

Setting the CLs allows to identify the threshold of **susceptibility** to **O_3** to prevent **detrimental effects**

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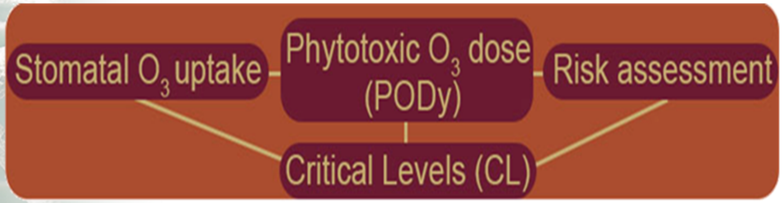
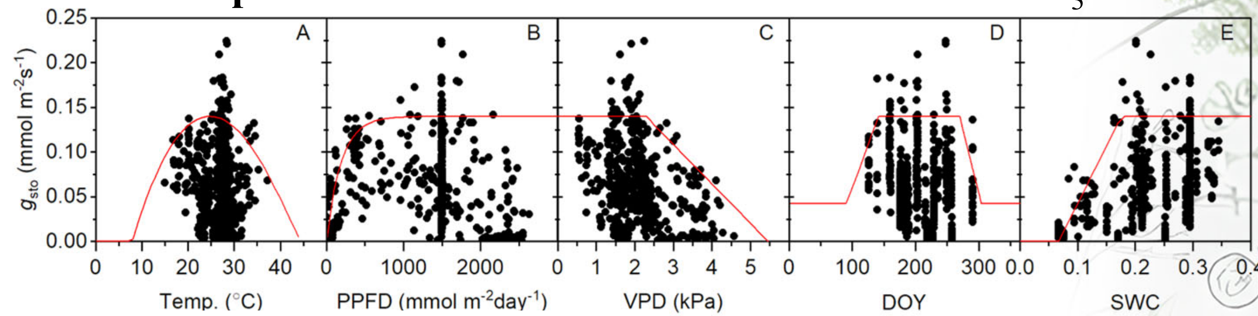
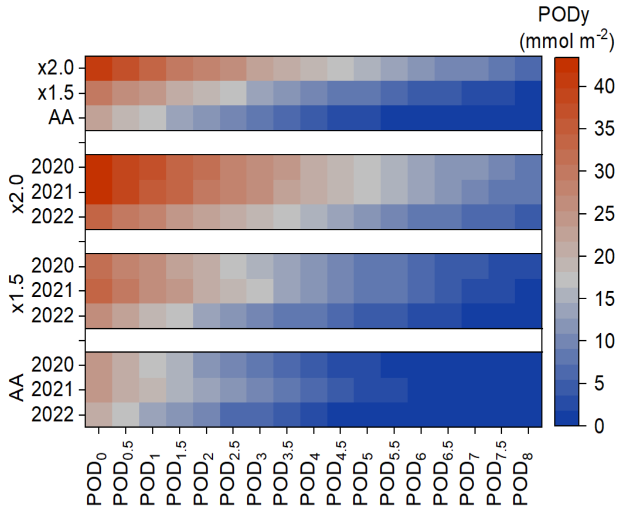
Risk assessment – How O_3 affects grapevine production



Stomatal conductance in different **environmental conditions**. Example of **parameterization of the DO3SE** model for POD_3





Parameter		Unit	*V. vinifera*
g_{max}		mmol H_2O m^{-2} s^{-1}	140
f_{min}		fraction	0.028
f_{temp}	T_{max}	°C	45
	T_{opt}	°C	25
	T_{min}	°C	8
f_{light}	a	(constant)	0.0052
f_{VPD}	VPD_{max}	kPa	2.3
	VPD_{min}	kPa	5.3
	SGS	day	April 01
	EGS	day	October 31
f_{phen}	f_{phen_a}	(fraction)	0.3
	f_{phen_b}	days	50
	f_{phen_c}	days	34
f_{swc}	SWCcrit	m^3 m^{-3}	0.176

A three-year free-air experimental assessment of ozone risk on the perennial *Vitis vinifera*

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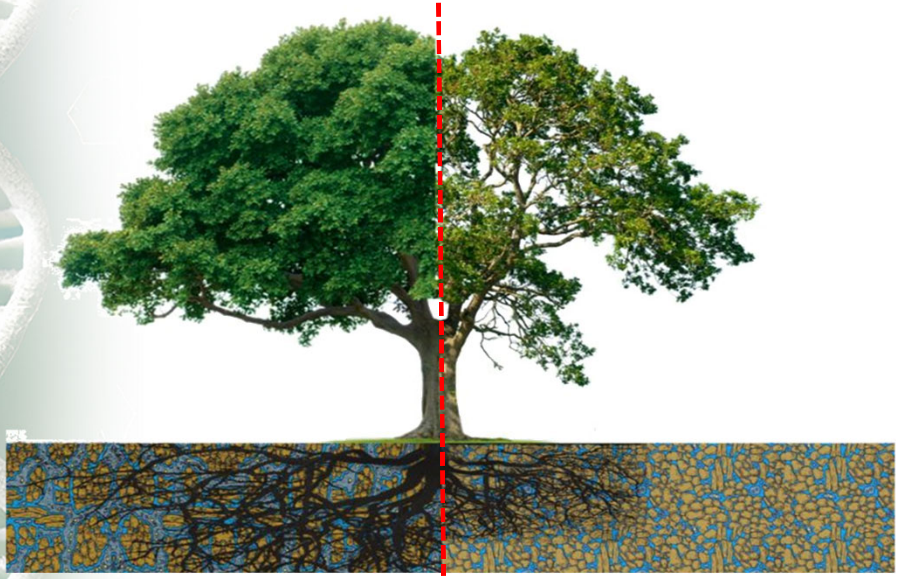
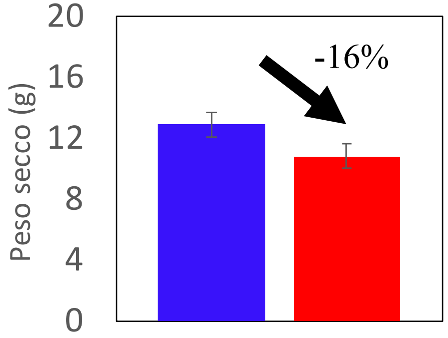
Ozone highly reduces root growth

Clean air | Ozone

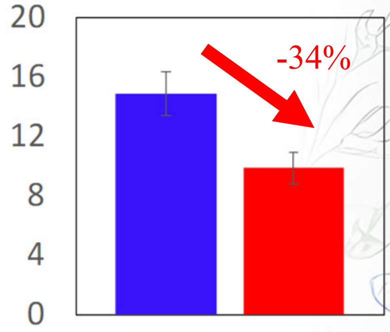


Poplar Oxford clone

Above-ground (stem + branch + leaf)



Below-ground (Roots)



FO_3X potted plants allow for the estimation of root system development.

The **decrease in biomass** is more pronounced in the **roots** compared to the above-ground parts.

→Resistance against drought

→Stability of trees

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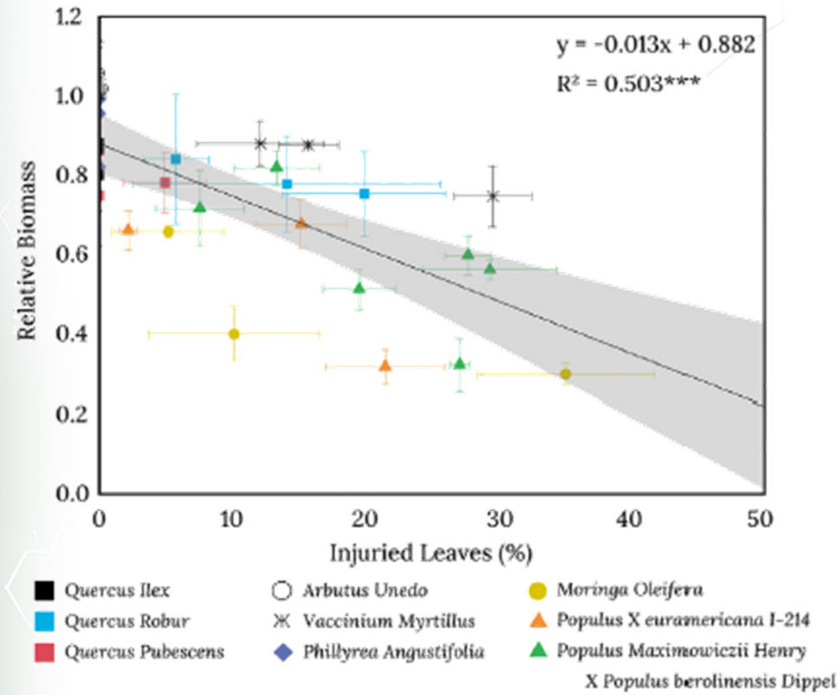

Fig. 3. Decrease of relative biomass with increasing visible foliar ozone injury in plants exposed to season-long ozone FACE experiments. The original results are published in (Moura et al., 2021; Hoshika et al., 2018; Zhang et al., 2018; Pellegrini et al., 2021; Hoshika et al., 2022)or unpublished (A. unedo, P. x euramericana). The total biomass is expressed as ratio of the control plants (exposed to ambient ozone exposure) versus the plants exposed to enriched ozone atmospheres (usually 1.5- and 2.0-times ambient ozone). The number of visibly injured leaves is expressed as a percentage of the total number of leaves. Bars show the standard errors. The linear regression line shows 95% confidence intervals in grey.

Biomass and VFI

Biomass losses increase with increasing visible foliar injury under O_3 exposure

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Towards long-term sustainability of stomatal ozone flux monitoring at forest sites

Elena Paoletti[1,*], Pierre Sicard[2], Yasutomo Hoshika[1], Silvano Fares[3], Ovidiu Badea[4], Diana Pitar[4], Ionel Popa[4], Alessandro Anav[5], Barbara Baesso Moura[1], Alessandra De Marco[5]

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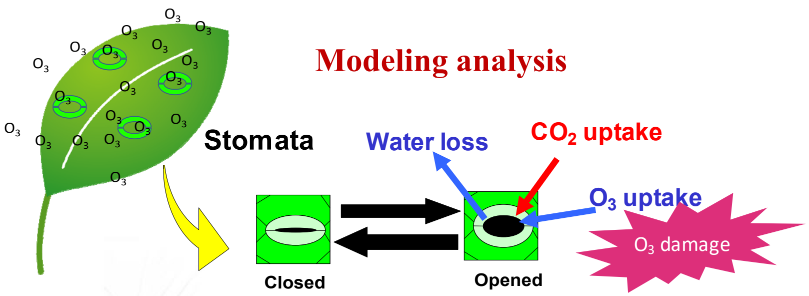
National and international collaborations (Since 2015)

10 countries - UNICAMP, IPA, Univ Sao Paulo (**Brazil**), CAS, NUIST, North East Agr Univ (**China**), CFI (**Croatia**), INRA, Univ Lorraine, ARGANS (**France**), Univ Freiburg, Univ Würzburg (**Germany**), UNIPI, UNIFI, UNITUS, CREA, Roma Sapienza Univ, ENEA (**Italy**), Univ Hokkaido, TUAT (**Japan**), INCDS (**Romania**), SFI (**Slovenia**), WSL (**Switzerland**), **and 48 visiting researchers.**

29 Plant species fumigated at FO$_3$X so far: *Acer platanoides* L. var. "Crimson king", *Alnus glutinosa* (L.) Gaertn, *Arbutus unedo* L., *Carpinus betulus* L., *Coffea arabica* L., *Cupressus sempervirens* L., *Moringa oleifera* Lam., *Ostrya carpinifolia* Scop., *Populus × canescens* (Aiton) Sm., *Populus deltoides W. Bartram ex Marshall x Populus nigra* L. clone i21, *Populus maximowiczii Henry x Populus berolinensis* Dipper – Oxford clone, *Passiflora edulis* Sims., *Phaseolus vulgaris* L., *Phillyrea angustifolia* L., *Phoenix dactylifera* L., *Pinus halepensis* Mill., *Pinus pinaster* Aiton., *Pinus pinea* I., *Punica granatum* I., *Quercus ilex* I., *Quercus pubescens* Wild., *Quercus robur* I., *Robinia pseudoacacia* I., *Rubus ulmifolius* Schott., *Saccharum officinarum* L.

About 30 scientific research papers published.

Morphological measurements



Physiological measurements

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Future FO_3X
«Open for collaborations»

How to implement face – instruments and tools to assess and validate the O_3-VFI:

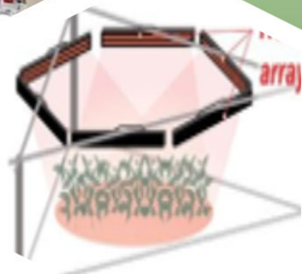
Licor

Porometer

Leica

HeatFACE

$CosmO_3FACE$



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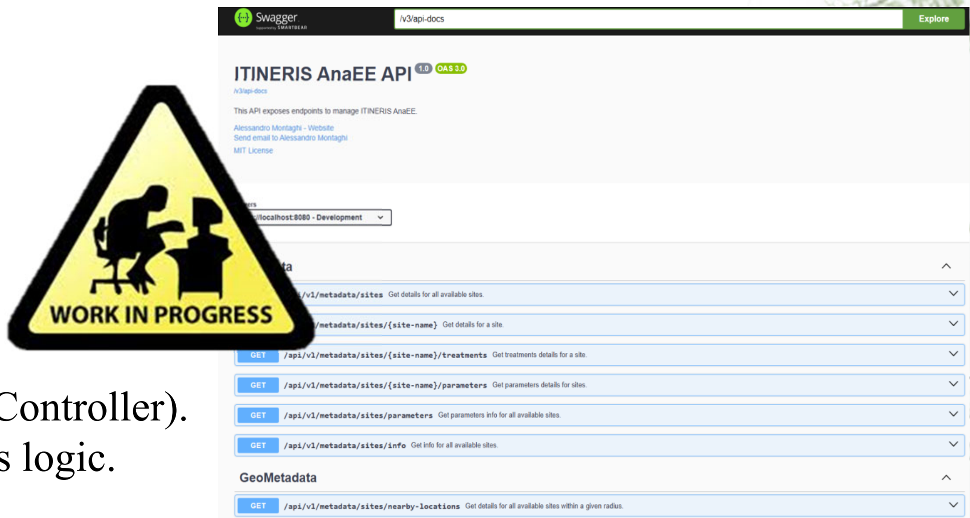
Enhancing Environmental Research with ITINERIS Metadata Base

Background:

- Environmental data are crucial for understanding global changes.
- Current practices often hinder data accessibility and sharing.

ITINERIS Goals:

- Establish ITINERIS Hub for unified access to environmental data.
- Focus on high-quality metadata for efficient data exploration.



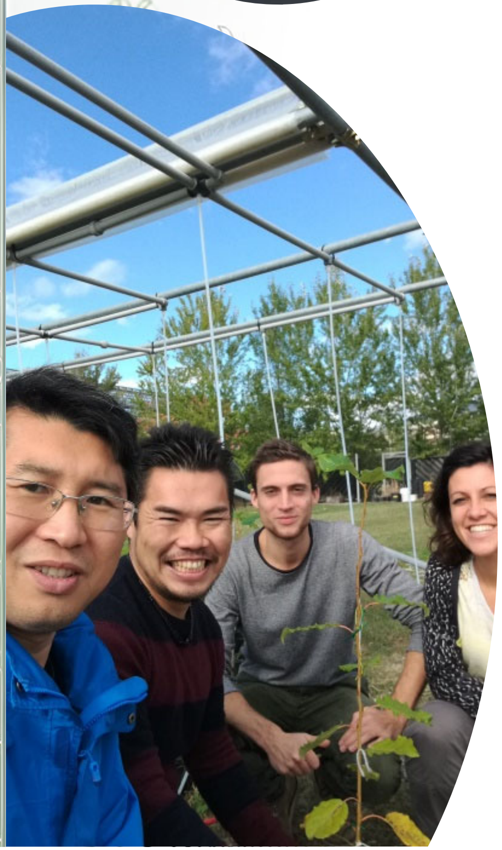
Methods:

- Implemented metadata base using MVC architecture (Model-View-Controller).
- Model (Service Layer, Repository Layer) manages data and business logic.
- View (Swagger UI) facilitates user interface and data presentation.
- Controller manages data flow between Model and View, exposing RESTful APIs.
- MongoDB chosen for scalable data management without predefined schema.

Conclusion:

- Continuous improvement of metadata base through stakeholder collaboration.
- Promotes harmonization, standardization, and data sharing across ITINERIS infrastructures.
- Initial step towards establishing ITINERIS Hub for comprehensive environmental research.

#harmonization
#collaboration
#implementation



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Thank you!