Impacts of Climate Change on Mediterranean Ecosystems

Synthèse des connaissances sur les impacts du changement climatiques sur les écosystèmes du pourtour de la Méditerranée

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Outline:

1) Mediterranean ecosystem responses to climate change

2) Biodiversity and ecosystem multifunctionality

3) Mitigation: Sustainable water management in agroforestry systems and “Climate proof” model plants

4) Biogenic volatile organic compounds (BVOC): a case-study in biosphere-atmosphere interactions

Biological responses to climate change

Plants have 4 possibilities to face any ecological change:

- **Phenotypic response (plasticity** / acclimatization): plants will continue to survive, grow and reproduce locally because their biological requirements are flexible.

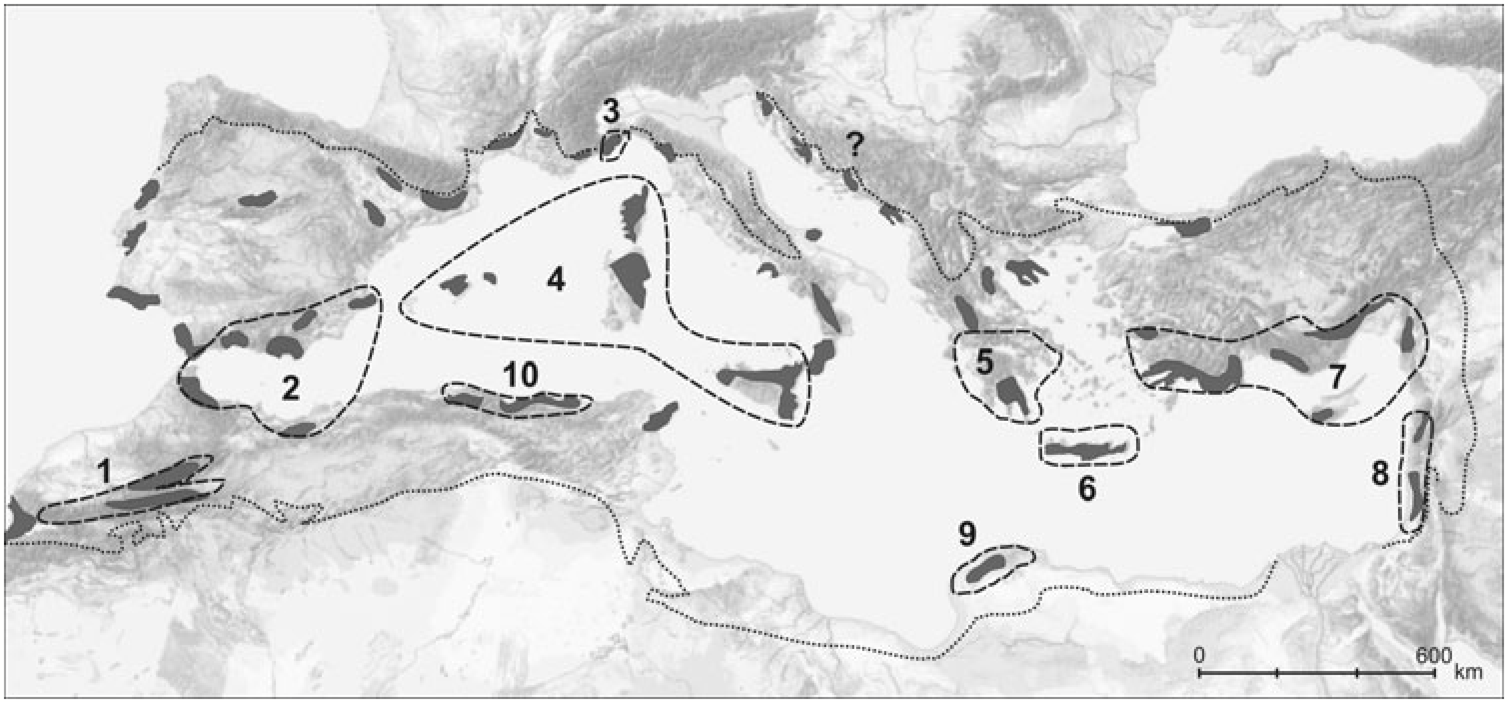
- **Genotypic response (adaptation)**: selection of progeny with highest fitness.

- **Migration**: movement through **dispersal** (regeneration under friendlier environments after long distance dispersal or hybridization).

- **Extinction**.

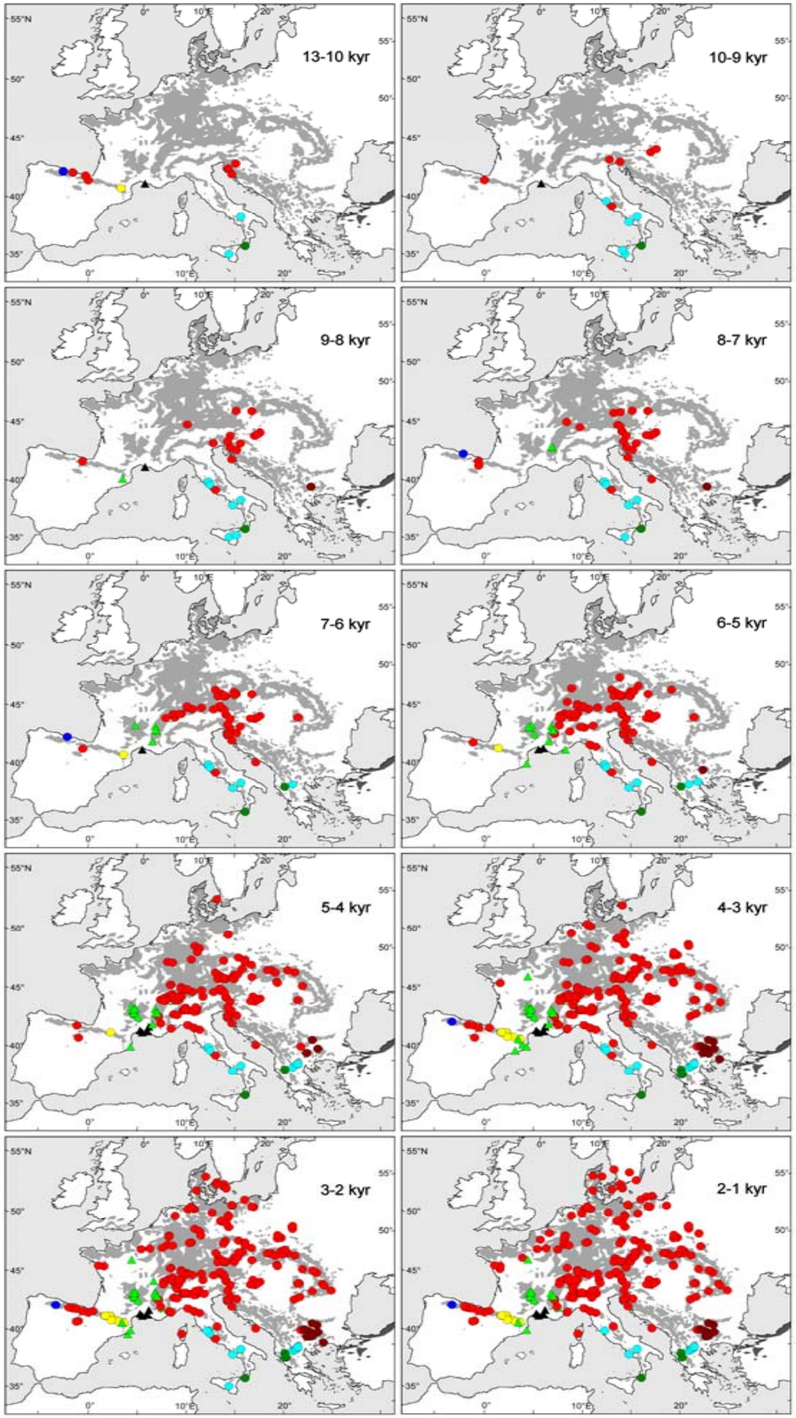
The Mediterranean forest: a threatened hotspot of diversity

A biodiversity hotspot with over 11,000 endemic plants



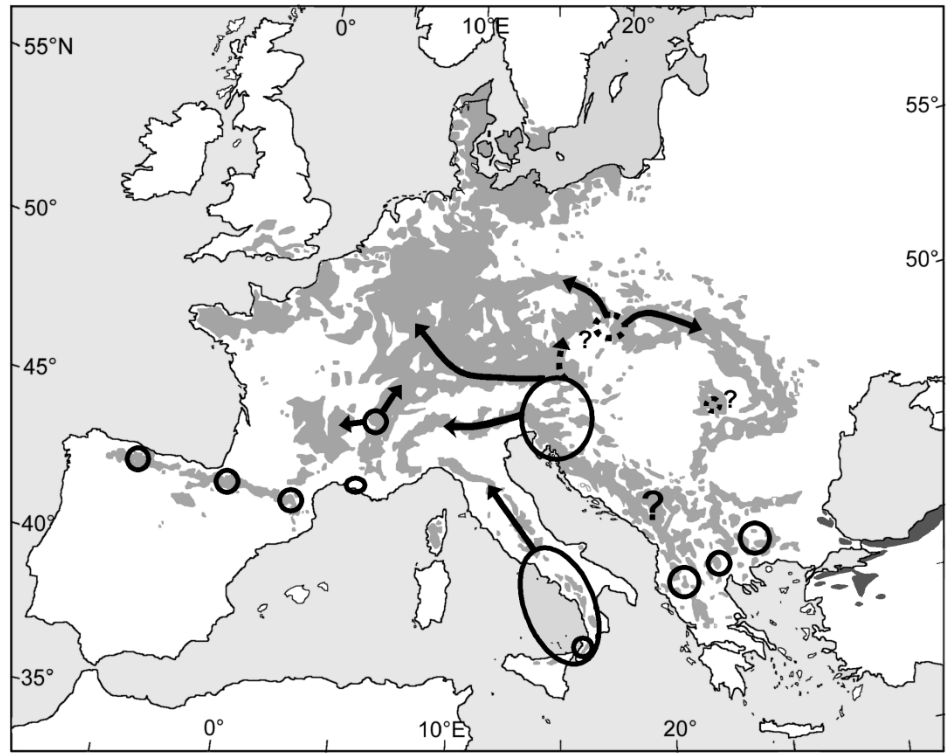
• 52 putative refugia within the Mediterranean region (resulting from the analysis of the phylogeographical patterns of 82 plant species, including 41 trees)
• 10 regional hotspots of plant biodiversity

(Médail & Diadema 2009 J. Biogeogr.)



Fagus sylvatica

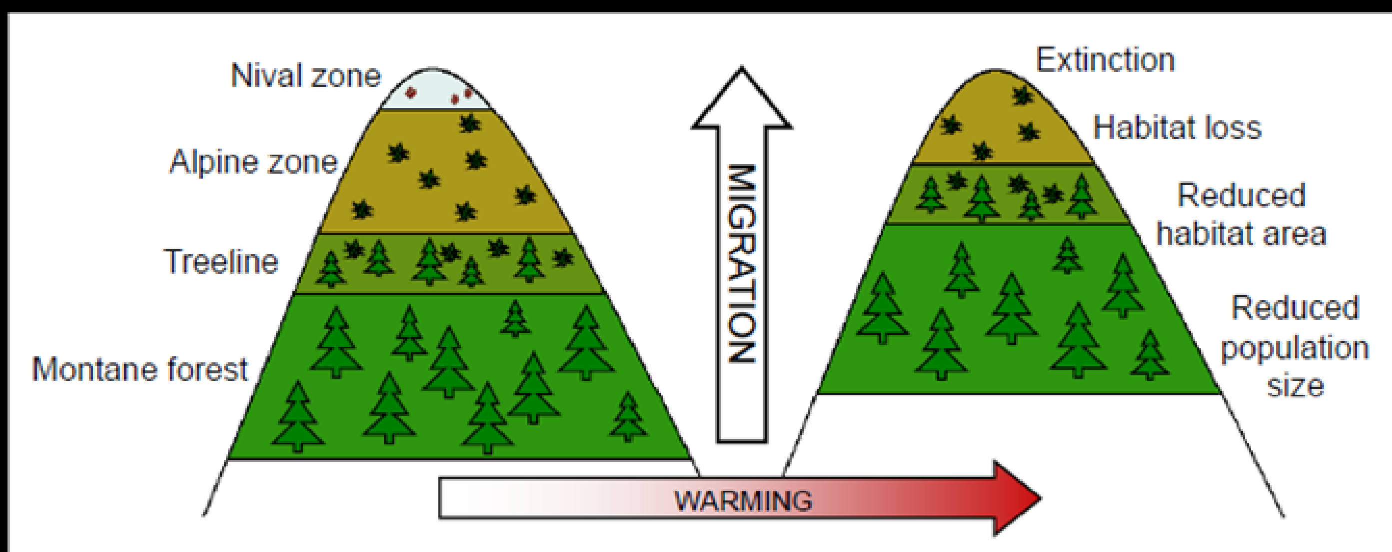
(Magri *et al.*, 2006)



Running towards better habitats

Global meta-analyses documented significant range shifts averaging **6.1 km per decade towards the poles (or metres per decade upward),** and significant mean advancement of spring events by 2.3 days per decade.

…consequently upward migration in mountains is associated with a reduction in habitat area, reduced population sizes and increased extinction risk



…the so called 'Elevator to Extinction'

Increasing Sustainability of European Forests:
Modelling for Security Against Invasive Pests and Pathogens under Climate Change.

ISEFOR

Defining the threats to European forest ecosystems

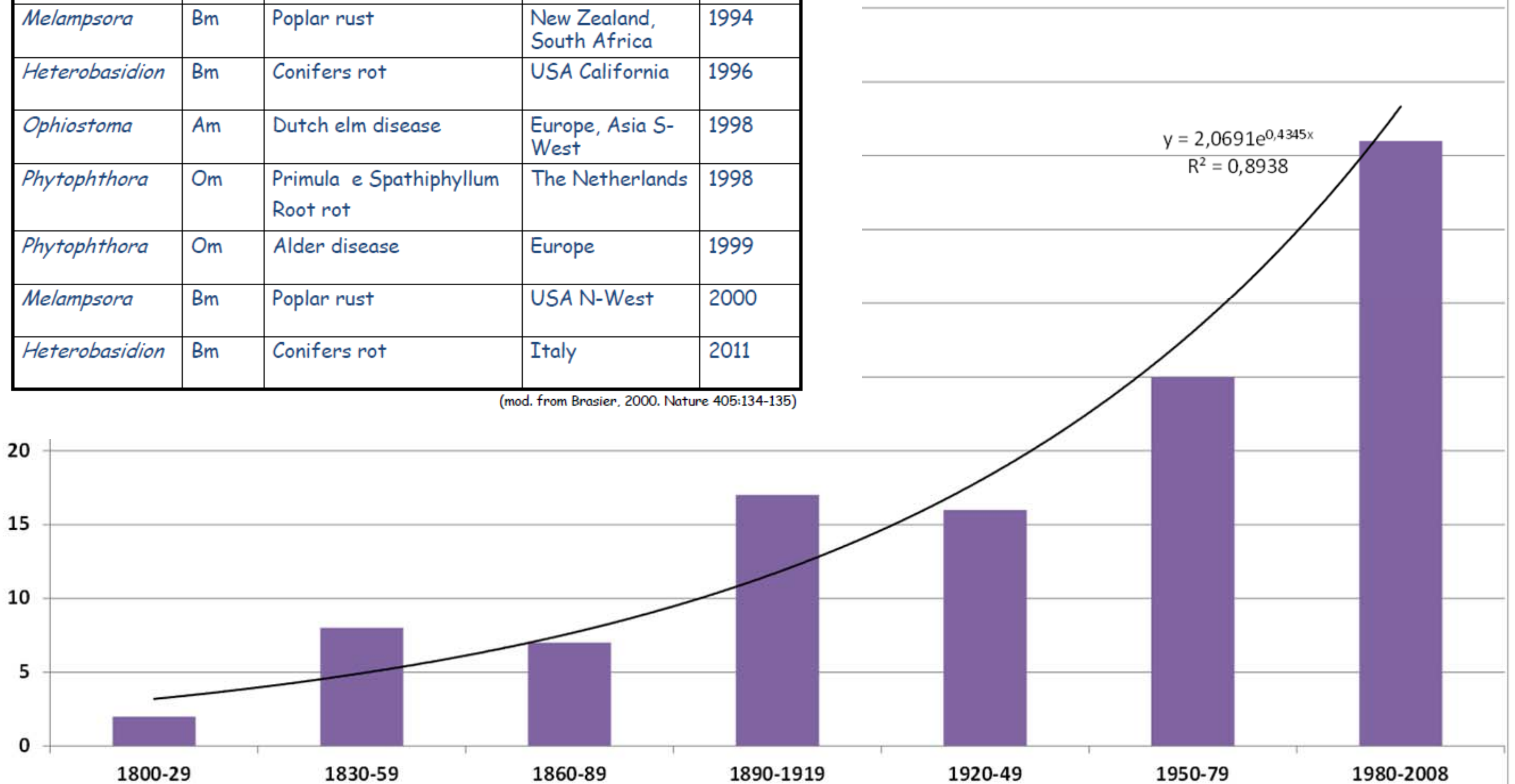
Total established forest pathogens

New pathogens: the rise of hybrids

Genus	Order	Host and disease	Place	Date
Melampsora	Bm	Poplar rust	New Zealand, South Africa	1994
Heterobasidion	Bm	Conifers rot	USA California	1996
Ophiostoma	Am	Dutch elm disease	Europe, Asia S-West	1998
Phytophthora	Om	Primula e Spathiphyllum Root rot	The Netherlands	1998
Phytophthora	Om	Alder disease	Europe	1999
Melampsora	Bm	Poplar rust	USA N-West	2000
Heterobasidion	Bm	Conifers rot	Italy	2011

(mod. from Brasier, 2000. Nature 405:134-135)

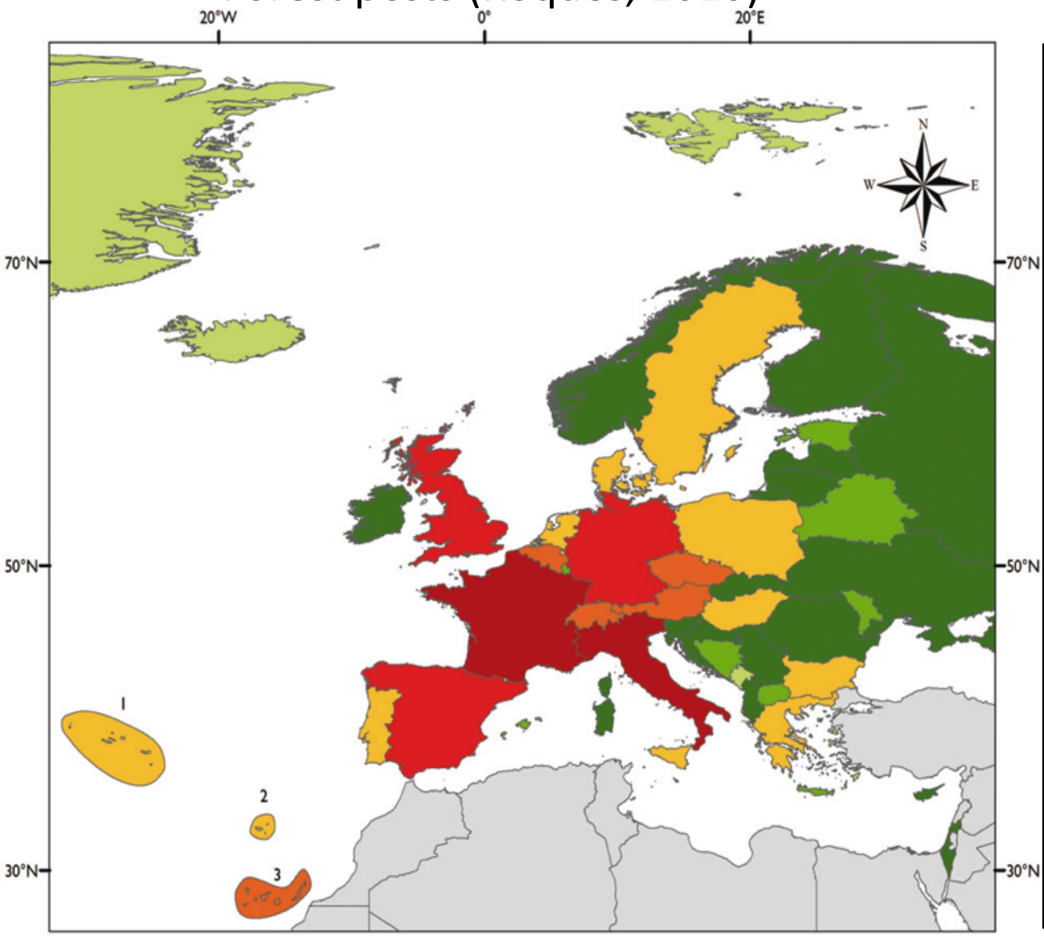
Santini *et al.*, New Phytol. 2013



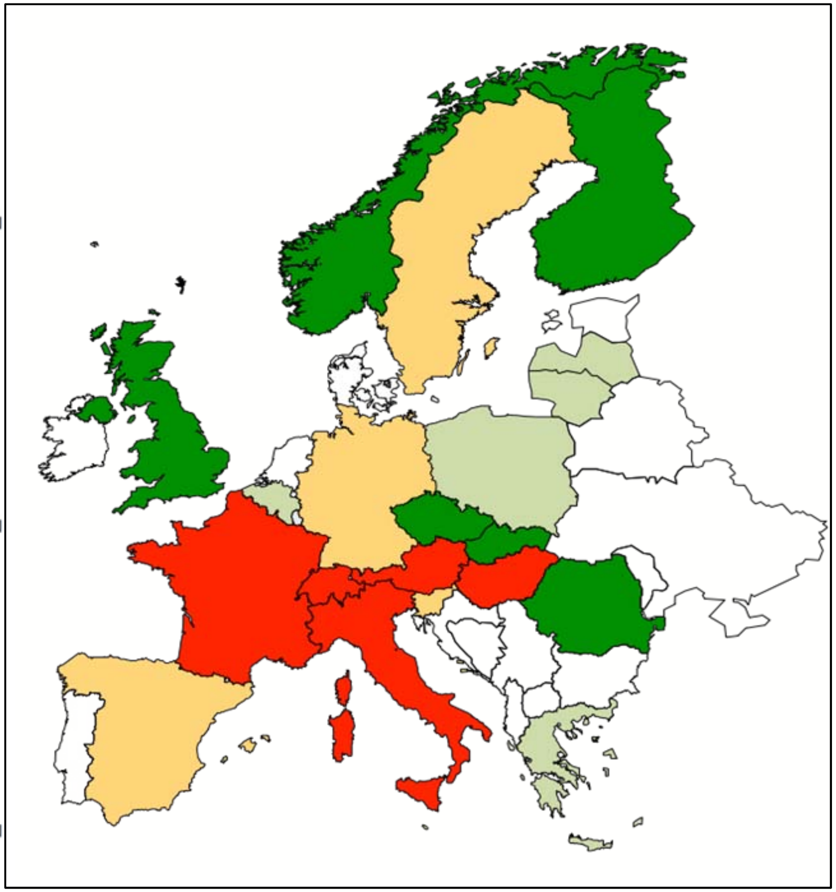
Amount of Invasive P&P per country

- ⟶ +

Forest pests (Roques, 2010)

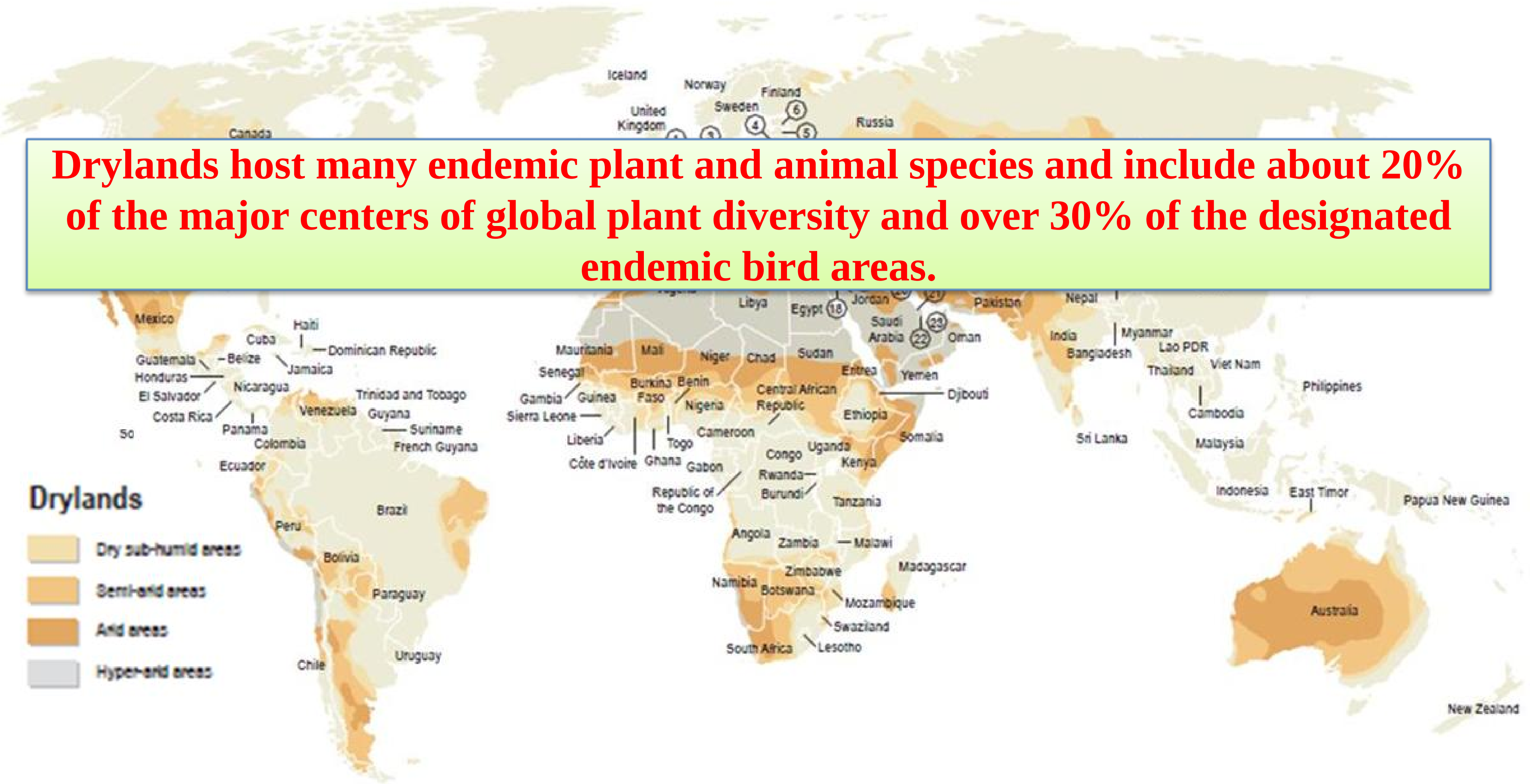


Forest pathogens (Santini et al. 2013)



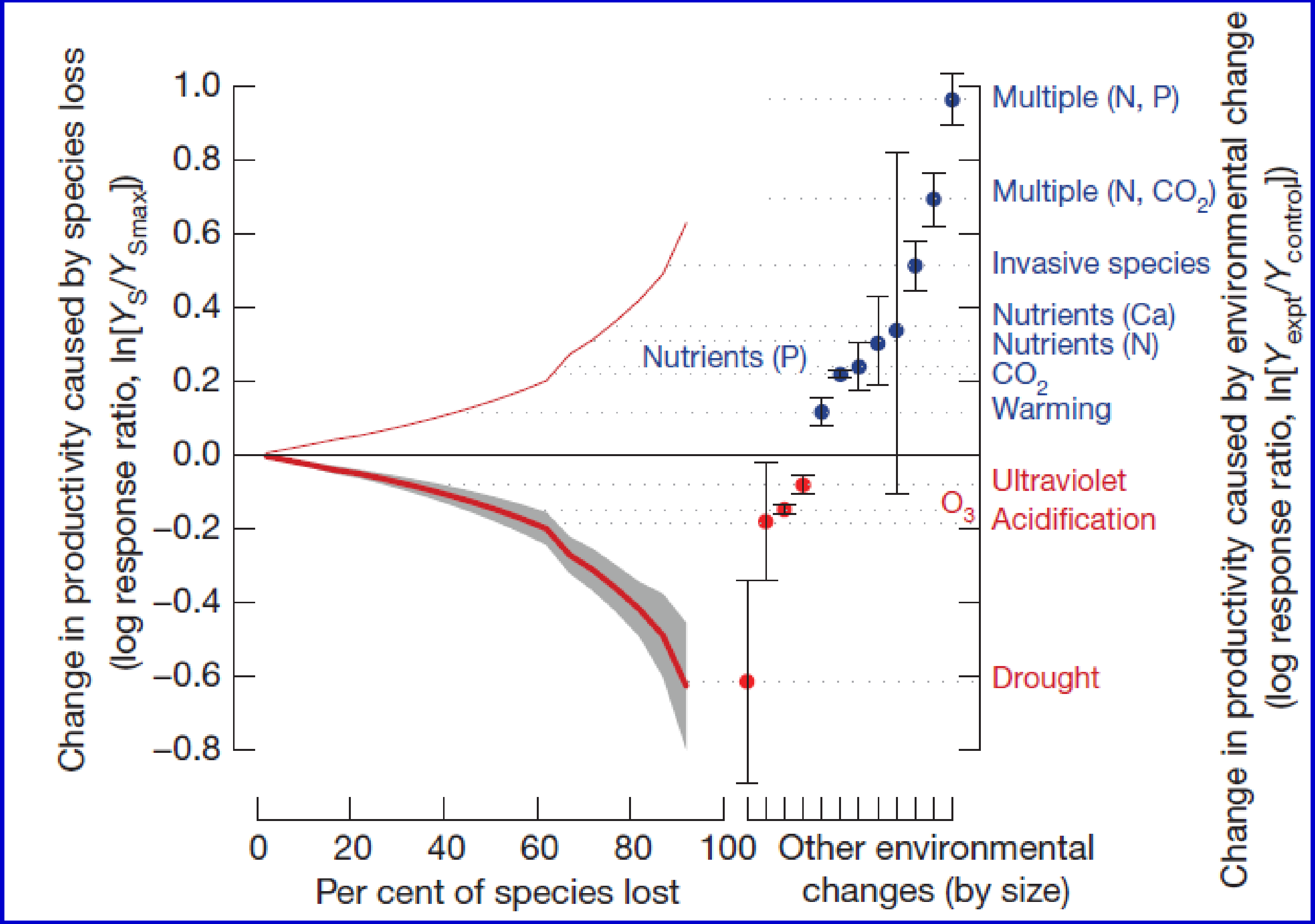
Hooper *et al*. (*Nature* 2012): Biodiversity loss in the 21st century could rank among the major drivers of ecosystem change.

Drylands host many endemic plant and animal species and include about 20% of the major centers of global plant diversity and over 30% of the designated endemic bird areas.



Biodiversity loss: A major driver of ecosystem change

Hooper *et al*. (*Nature* 2012): The effects of species loss on productivity and decomposition are of comparable magnitude to the effects of many other global environmental changes.



***<u>Changes in primary production as a function of per cent local species loss</u>*. Effects of species loss on primary production from 62 studies (379 observations). Dotted grey lines show the mean effect of each environmental change for comparison with the effect of richness.**

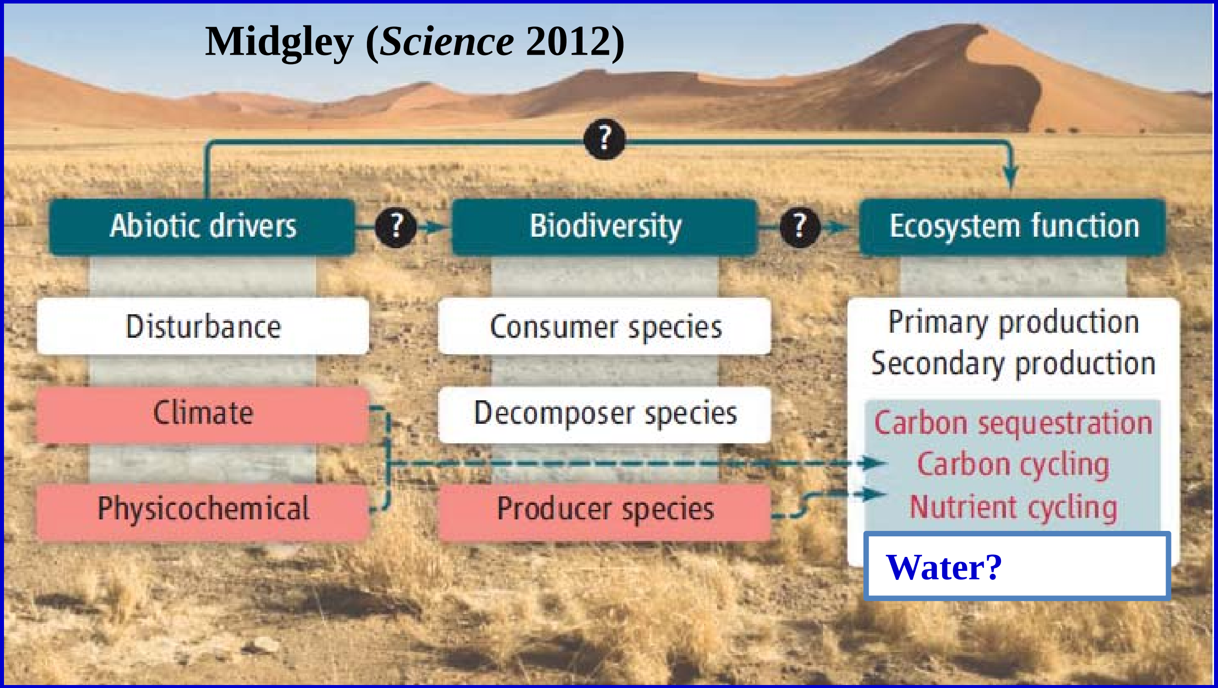
Ecosystem services

(Millennium Ecosystems Assessment 2005 ; FAO 2010)

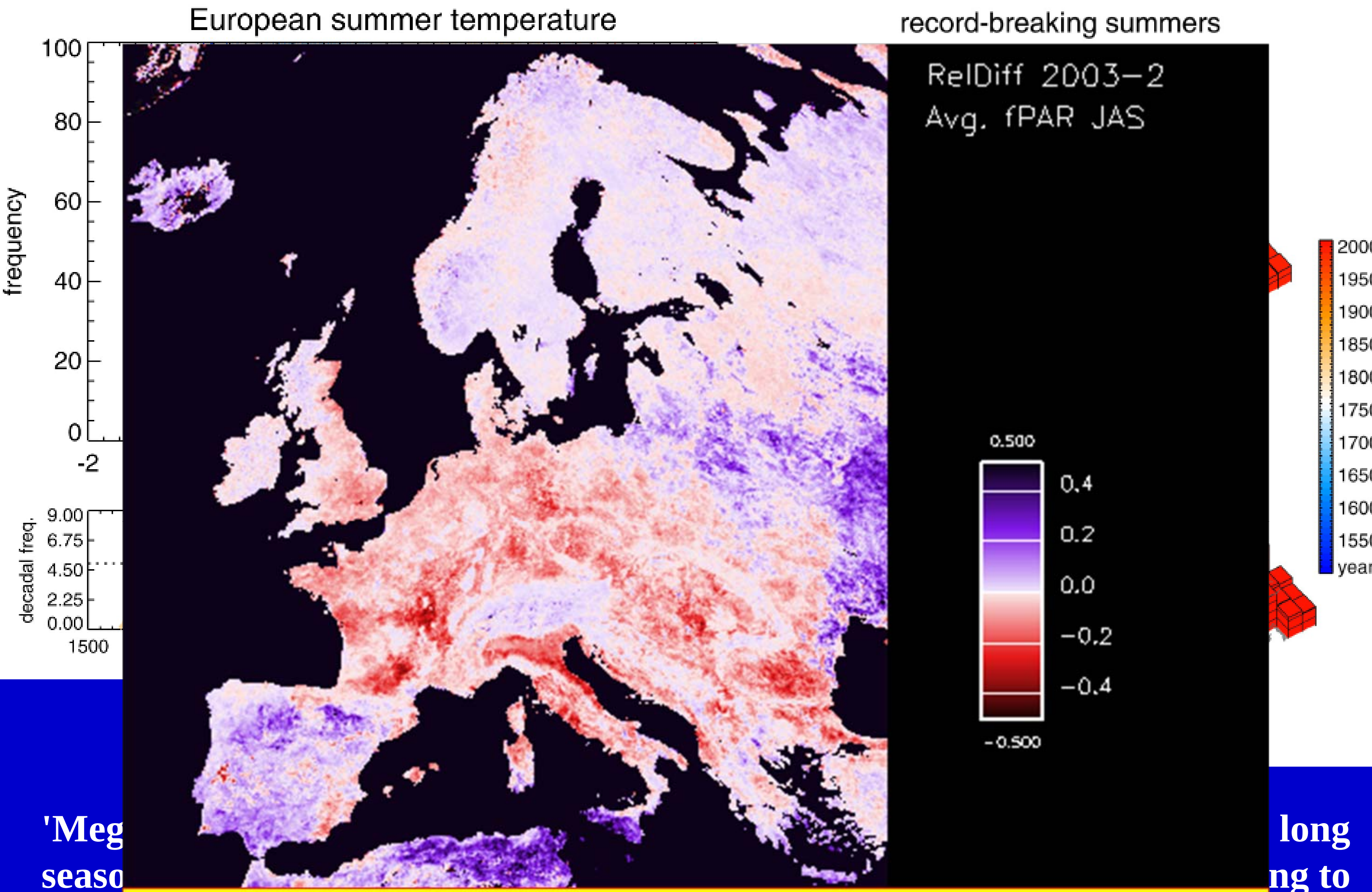
The loss of biodiversity impairs the functioning of natural ecosystems and thus diminish the number and quality of services they provide.

Biodiversity and Ecosystem Multifunctionality

Maestre *et al*. (*Science* 2012): The relationship between species richness and dryland ecosystem multifunctionality (the ability of ecosystems to maintain multiple functions, such as carbon storage, productivity, and the buildup of nutrient pools) rises steeply with fewer than five species and then increases incrementally with the addition of more species. The preservation of plant biodiversity is crucial to buffer negative effects of climate change and desertification in drylands.



***<u>A framework for testing the biodiversity ecosystem function</u>*. Biodiversity and abiotic drivers determine ecosystem function individually and in concert (blue boxes). How they do so cannot be fully answered without assessing the roles of multiple elements within these caegories (indicative elements elaborated below blue boxes).**



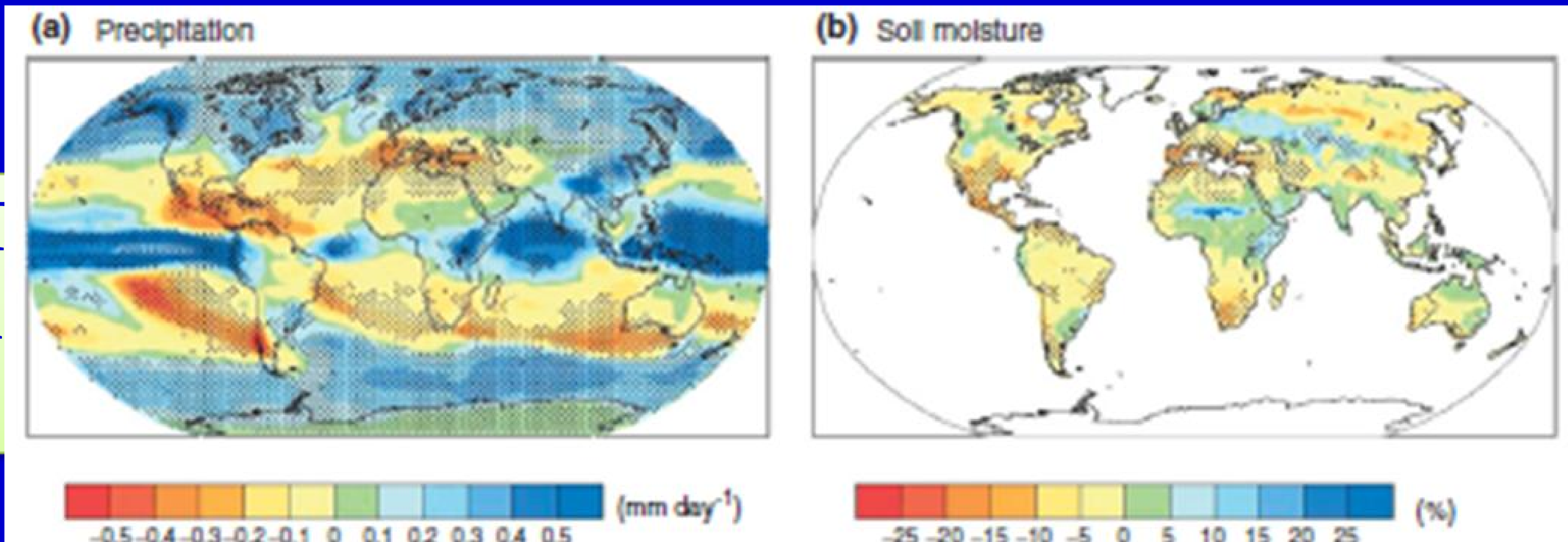
Ecosystem productivity in summer 2003 compared to summer 2002 (as fraction of absorbed PAR)

'Meg ... long seaso ... ng to regio ... ncing 'meg ... years (Barriopedro *et al.*, *Science* 2011).

Tipping point: 'Dust-bowlification'

Romm (The next dust bowl. *Nature* 2011):

Recent studies have projected 'extreme drought' conditions by mid-century over some of the most populated areas on Earth - southern Europe, south-east Asia, large parts of Australia and Africa, etc..



Dai (*WIREs Climate Change* 2011)

Mega-drought threat: Extended or permanent drought over large parts of currently habitable or arable land - a dratic change in climate that will threaten food security and may be isrreversible over centuries.

The coming droughts ought to be a major driver - if not the major driver - of climate policies.

Teleconnection between the global climate system, drought and desertification

Biotic pump of atmospheric moisture as driver of the hydrological cycle on land: Bouchet's (1963) hypothesis of a complementary relationship.

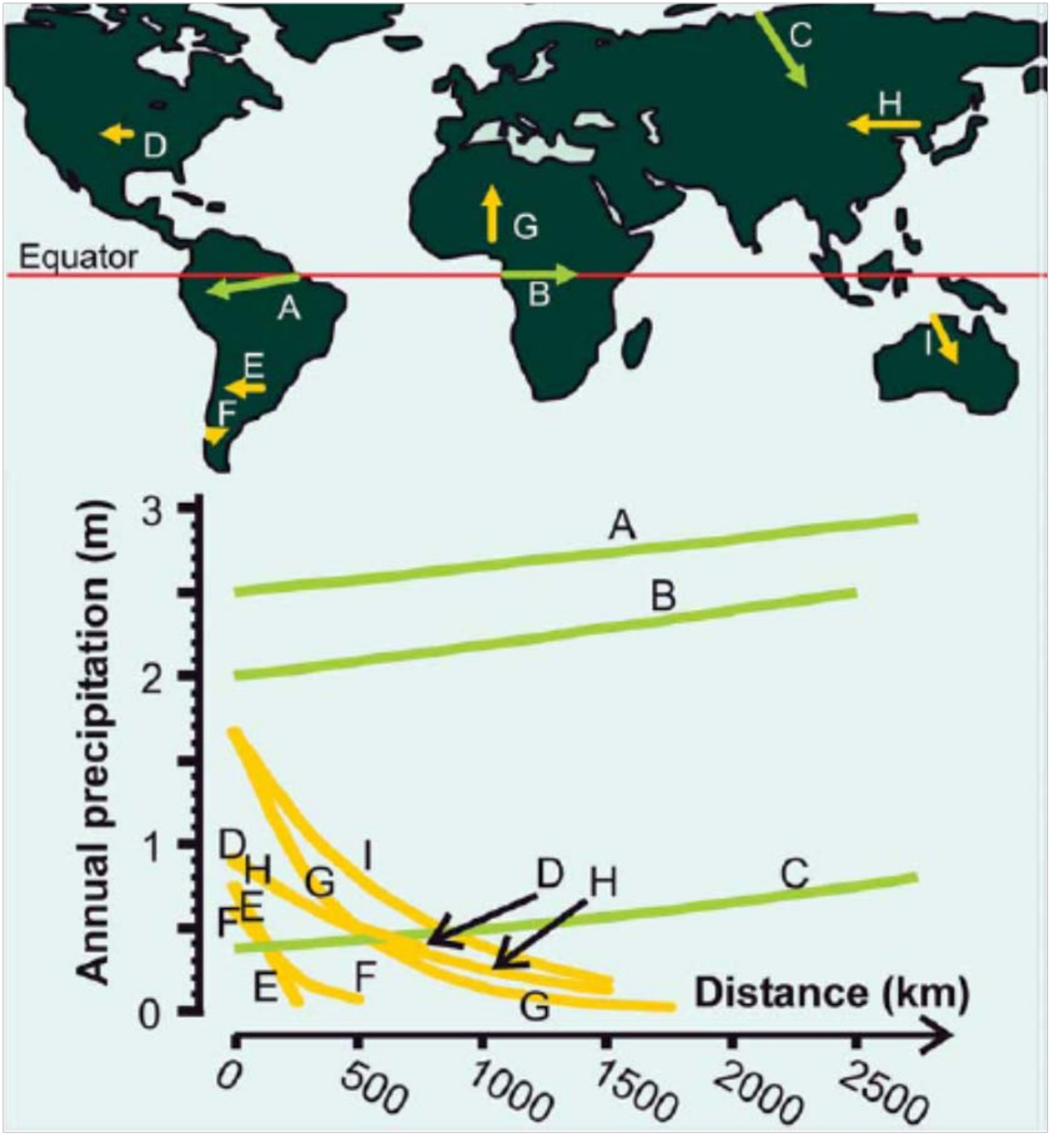
Coastal forests create giant winds that push water thousands of kilometres inland

The volumes of water involved in this process can be huge. More moisture typically evaporates from rainforests than from the ocean. The Amazon rainforest, for example, releases 20 trillion litres of moisture every day.

The Biotic Pump mechanism

Sheil and Murdiyarso, 2009 (from concepts and data of Makarieva and Gorshkov, 2007)

The Biotic Pump



Sheil and Murdiyarso, 2009 (from concepts and data of Makarieva and Gorshkov, 2007)

Some experiences of international cooperation to combat aridity

(Morocco, China, Tunisia, Egypt, Algeria, Pakistan, Argentina)

Sustainable agricultural water management (water-saving irrigation techniques, water harvesting, use of secondary treated urban wastewater)

Making good use of superior landraces of plants that have evolved historically in the harsh environments of the dry regions (natural plant germplasm)

Sustainable agricultural water management (water-saving irrigation techniques, water harvesting, use of secondary treated urban wastewater)

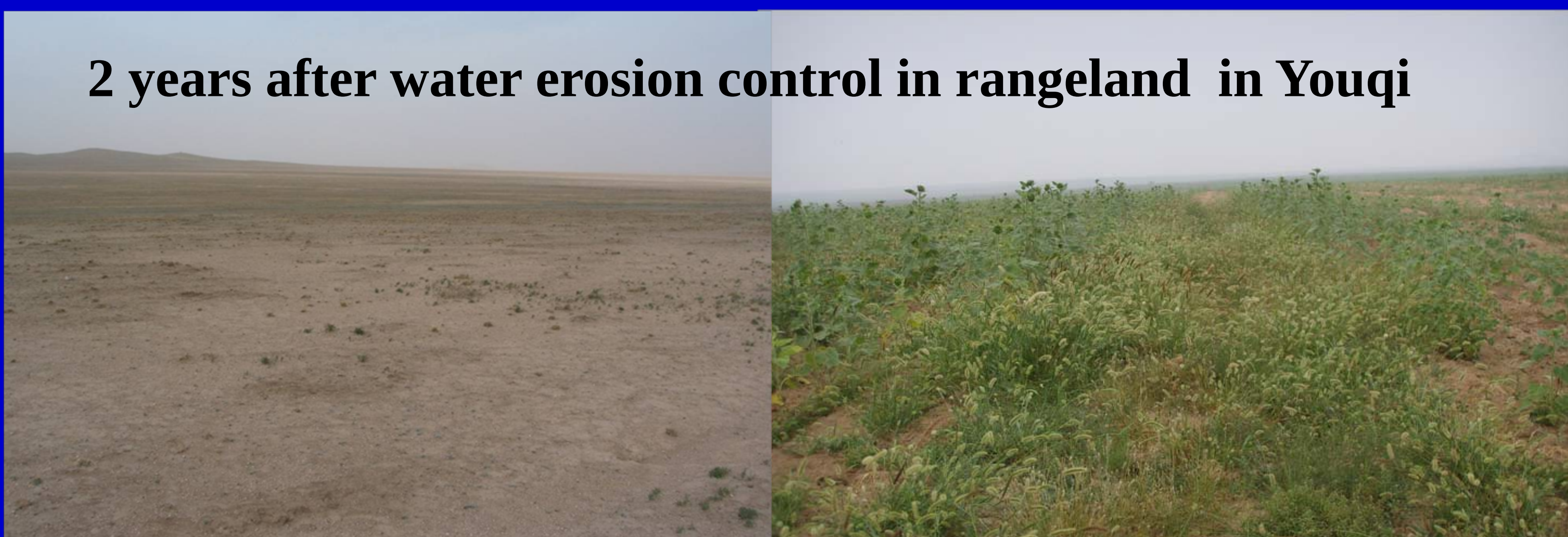
Use of Treated Waste-Water
(FAO Project GCP/RAB/013/ITA)


Pedro BERLINER

Courtesy of the Chinese Academy of Forestry & Inventory

4 years after afforestation in Youqi

2 years after water erosion control in rangeland in Youqi



RECOVERY OF URBAN WASTEWATER FOR AGROFORESTRY APPLICATIONS

FAO Project GCP/RAB/013/ITA 1/3

Support to 4 Mediterranean countries to improve afforestation and reforestation practices in forestry and agroforestry systems through the use of treated wastewater

Recovery of urban wastewater for fertigation of energy crop, tree crop and forestry production systems

***Conventional scheme*: generation of high quality water and sludge. In Europe, conventional treatments remove from wastewater:**
25 Mton of organic matter;
2,5 Mton of N compounds;
500.000 ton of phosphate.
Cost: 20 billion € y^{-1}.

In Italy about 2.000 Mm^3 y^{-1} of wastewater is dumped: in rivers or directly into the sea. This water could be used to fertigate 500.000 ha.

Secondary treated wastewater: "green" technologies for wastewater treatment, wastewaters can be turned into resources for irrigation and recovery of energy, nutrients and organic matter

The role of wastewater in agro-forestry application

Simplified treatment system for reuse of wastewater in agriculture and forestry: Ten years of fertigation results on a olive tree culture in southern Italy (Palese *et al*., *Agriculture*, *Ecosystems and Environment* 2009).

CO_2 fixed in the two management systems

(average 2000-2008) (t ha^{-1} year^{-1})

	Sustainable		Conventional	
	DM	**CO_2 Fixed**	**DM**	**CO_2 Fixed**
Fruits	4,9	9,0	2,1	3,8
Vegetation cover	7,6	13,9	-	-
Pruning material	3,3	6,0	2,6	4,8
Leaves	0,9	1,6	0,9	1,6
TOTAL	**16,7**	**30,5**	**5,6**	**10.2**

Use of Secondary Treated Urban Wasteater
(FAO Project GCP/RAB/013/ITA)

- **Design and development of a system that will use partially treated wastewater for fertigation of a 10 hectare palm tree section of the Green Belt of Marrakech**

- **Creation of a buffer zone of planted forests species to protect the green belt and reduce soil erosionw**

General scheme of multifunctional green belt proposed for Marrakech

Desert/ steppe

Wadi

Tamarix spp.

1. Fire wood
2. Shade and fodder for domestic animals
3. Honey

Phoenix dactylifera

1. Tourist attraction
2. Dattiers

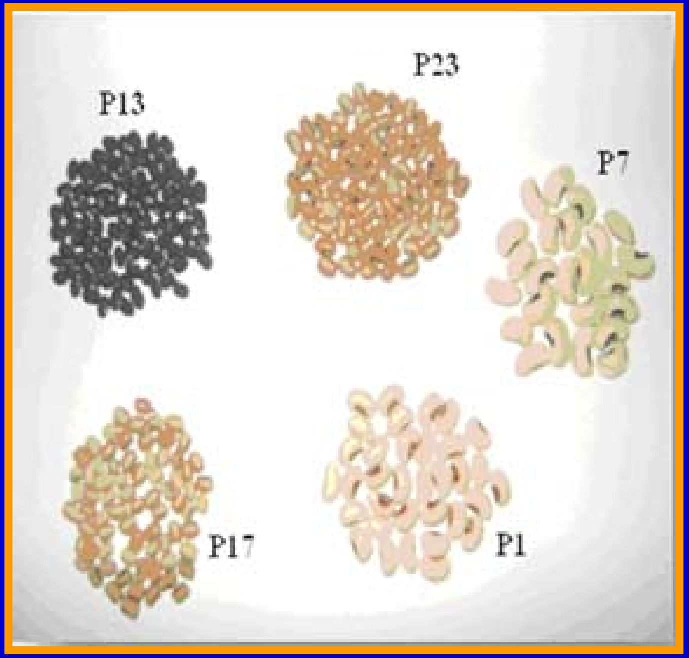
Functions

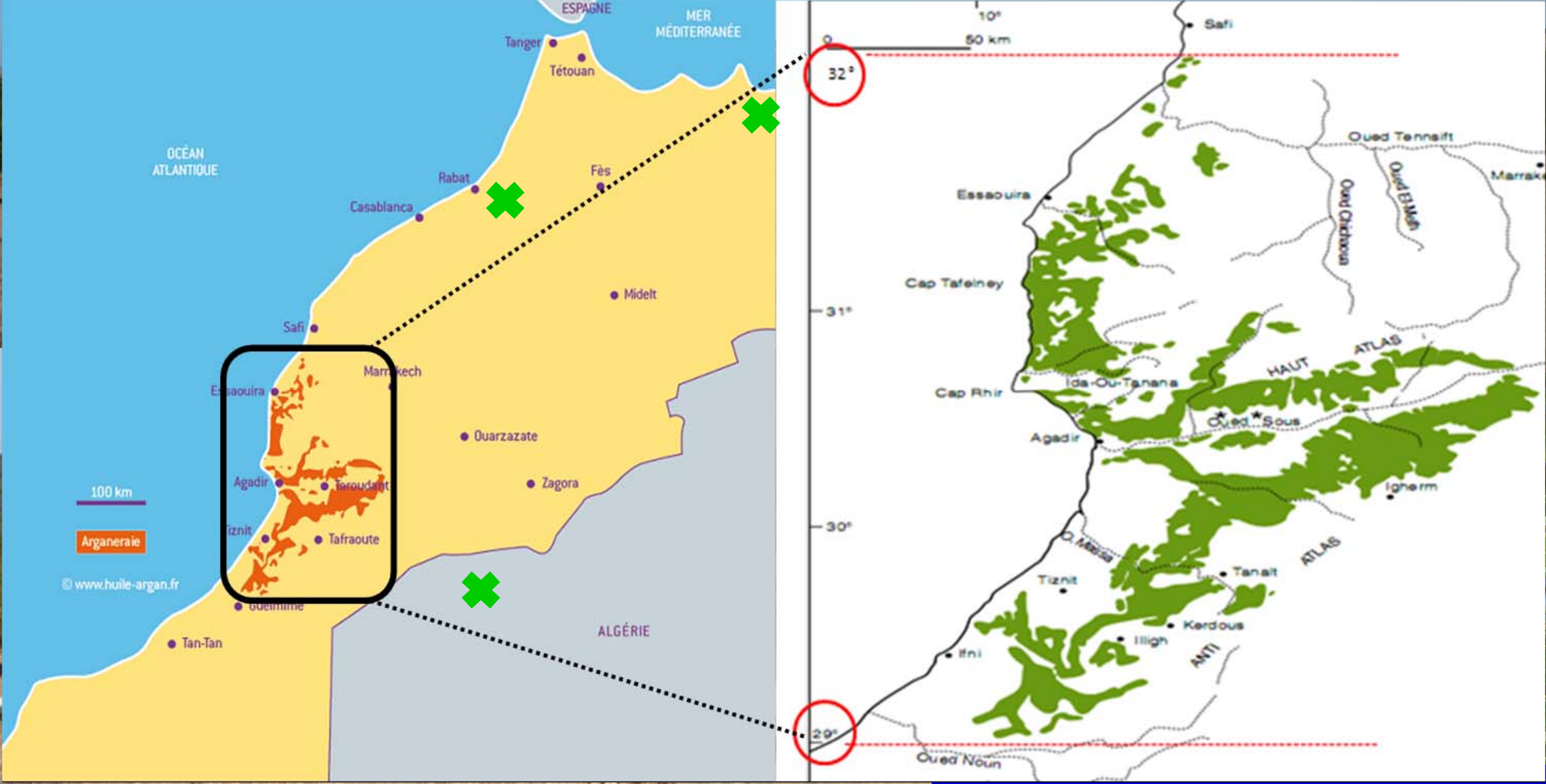
1. Combat desertification
2. Landscape improvement
3. Biodiversity conservation

Multifunctional green belt

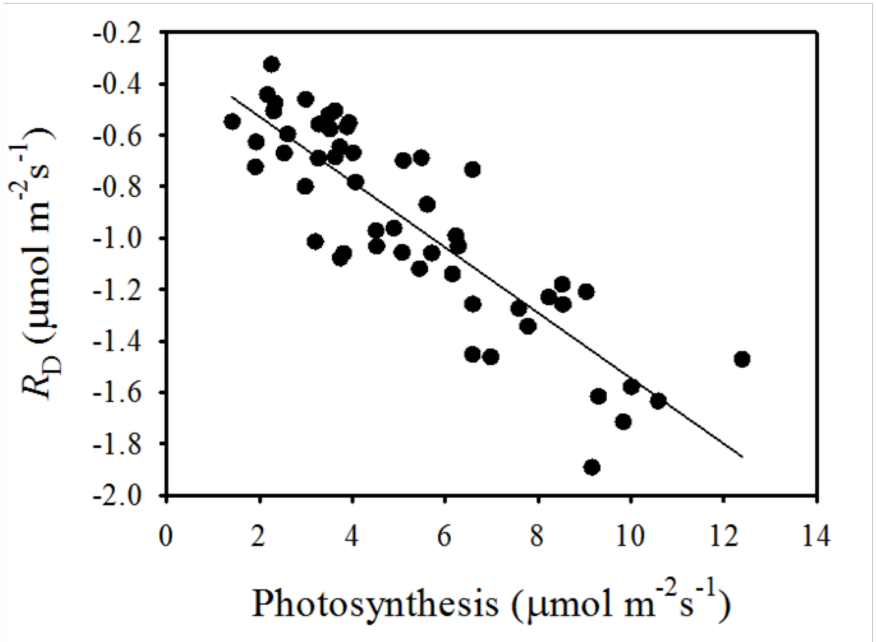
Complementary species:
***Acacia* ssp, *Prosopis* ssp, *Salvadora persica* etc.**
(to improve the ecological stability of the ecosistem)

Making good use of superior landraces of plants that have evolved historically in the harsh environments of the dry regions (natural plant germplasm)

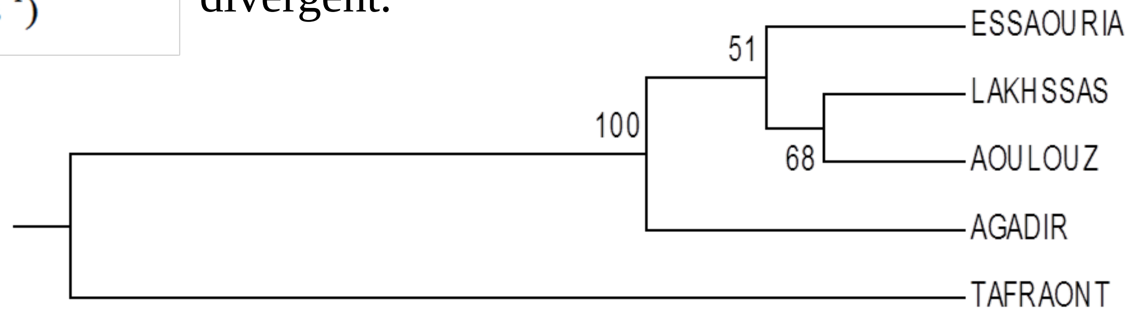


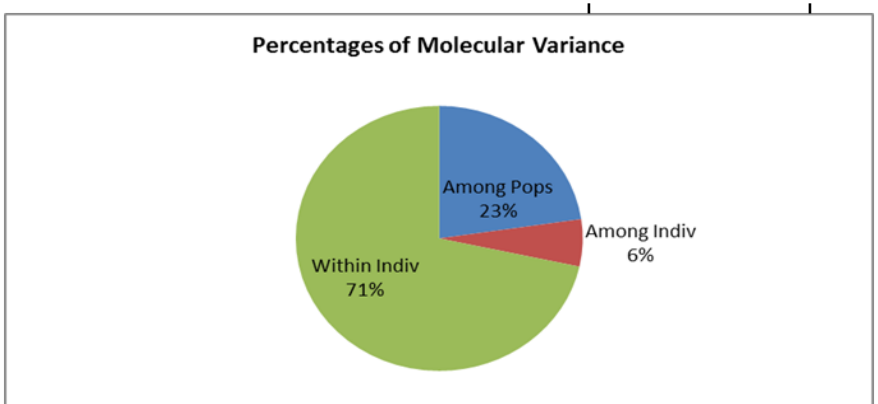


Argan (*Argania spinosa*) is an endemic tree of south-western Morocco where it is adapted to grow in harsh environments (extreme drought and poor soil, i.e. in a region where rainfall hardly exceeds 200 - 300 mm/year, and at times stays well below 120 mm/year), where it plays vital roles in protecting the environment by slowing down desertification. Each part of the tree is usable: wood is used as fuel, leaves constitutes a fodder for goats and camels, whereas the oleaginous fruits of argan tree are used for the extraction of a very high quality oil (argan oil) that provides up to 25% of the dweller daily lipid diet, but that has also important cosmetic and medicinal utilizations.



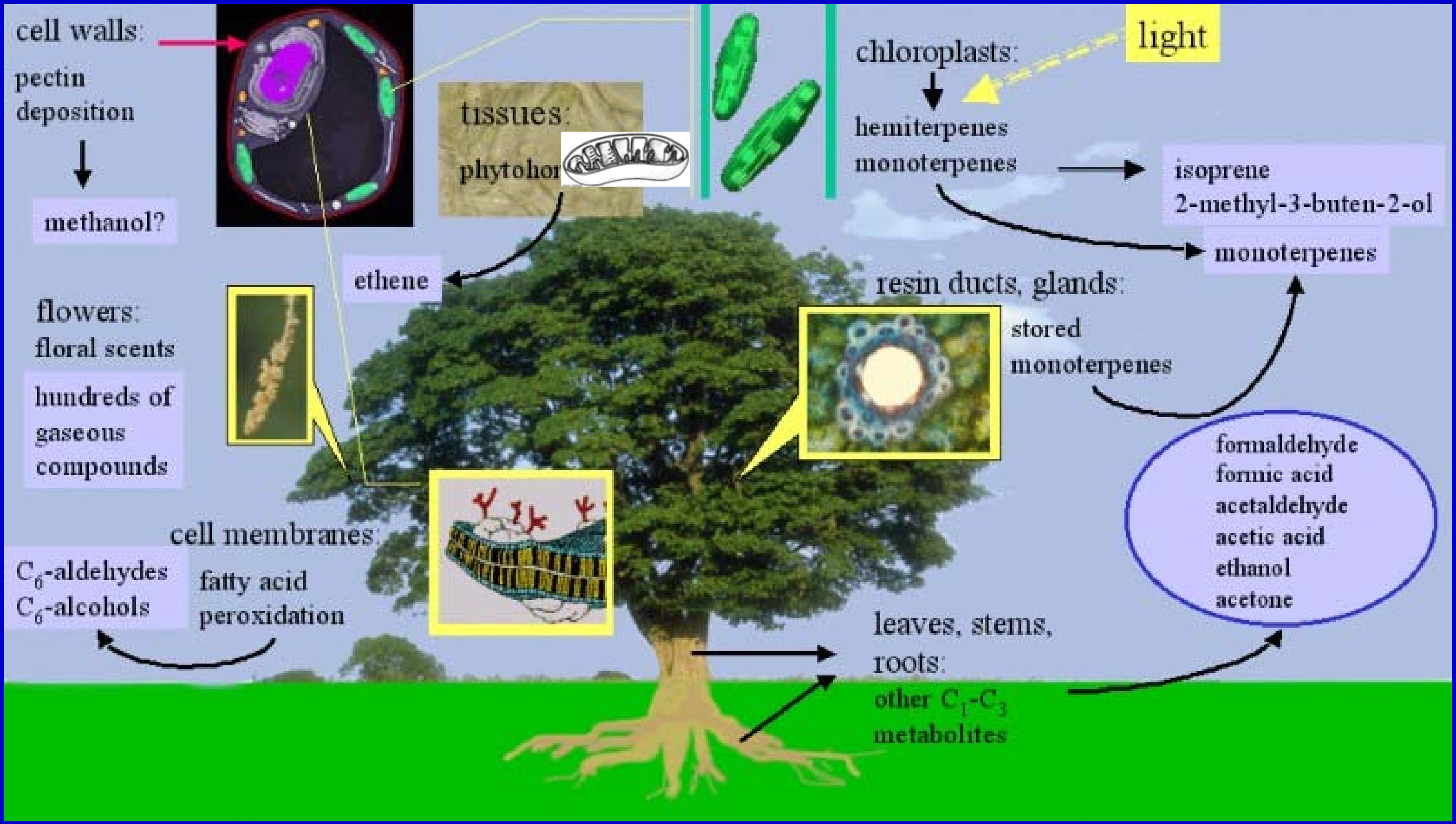
UPGMA based on Nei distance a lower level of genetic divergence between the populations Lakhassas and Oulouz was observed, while the Tafraont population appeared the most divergent.

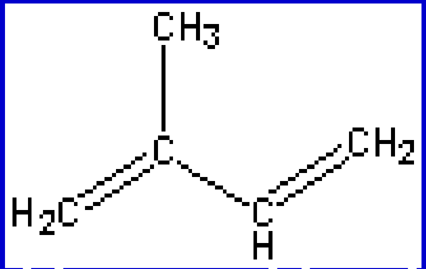




The Amova analysis indicated a 71% of variation within individuals while the variation among populations is 23%

Biogenic volatile organic compounds (BVOC)

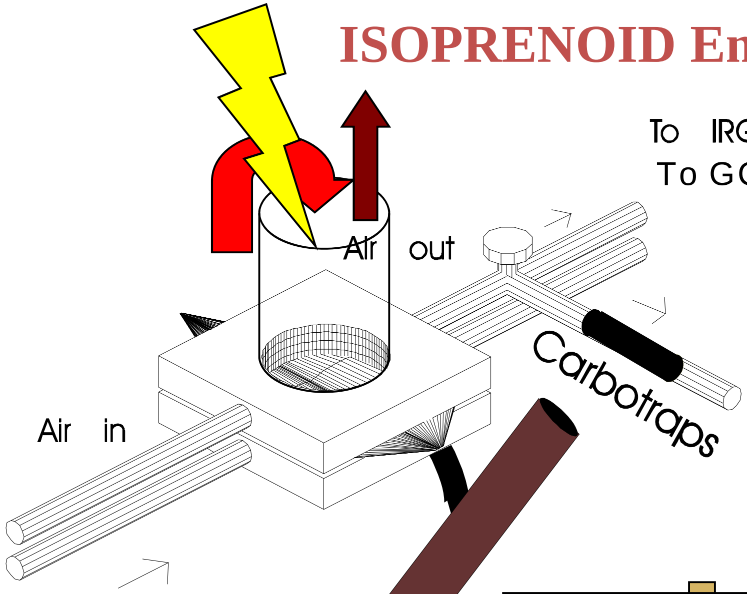




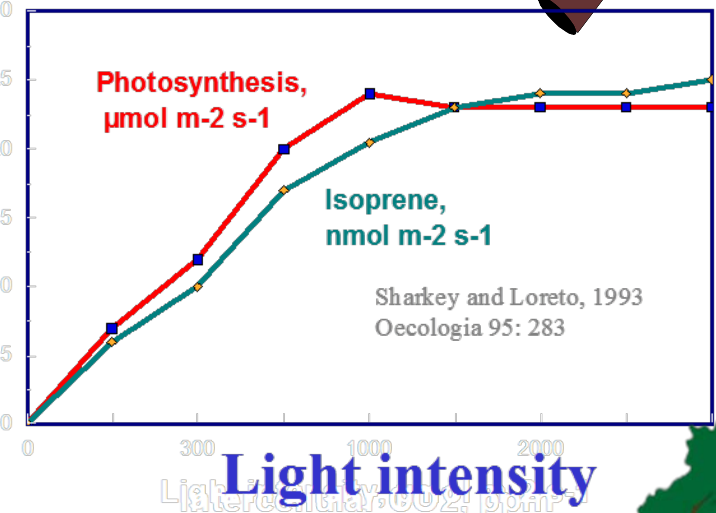
2-methyl 1,3 butadiene = ISOPRENE

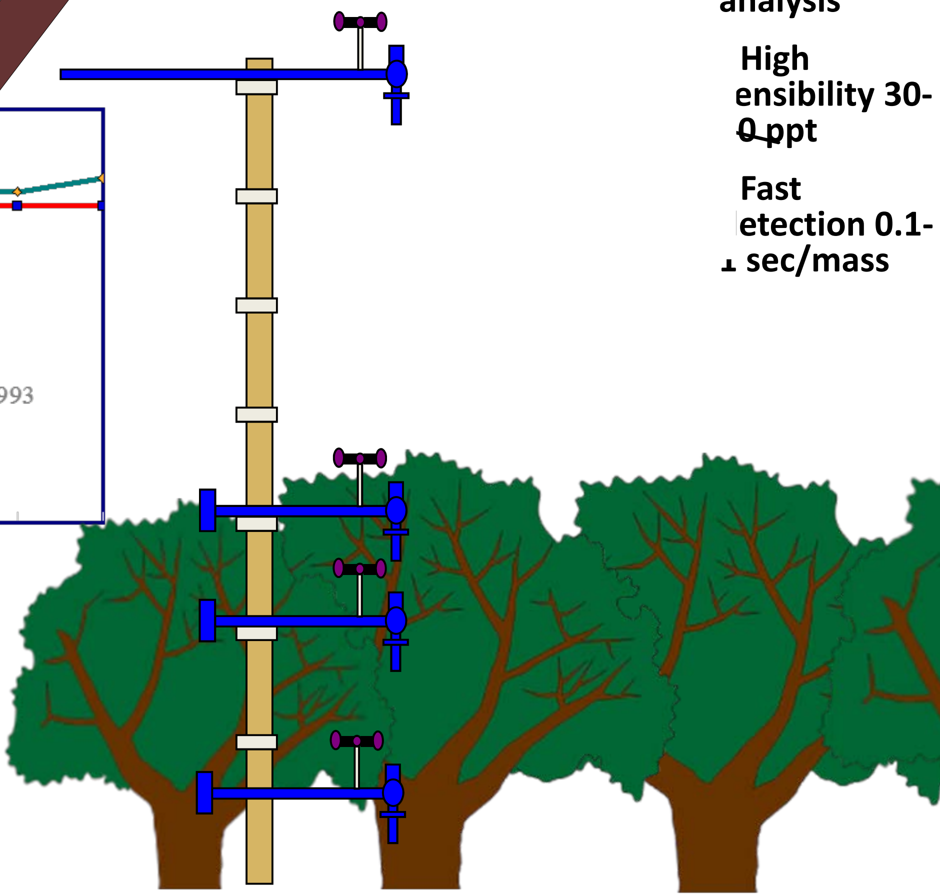
Estimated isoprenoid emission: 1.1-1.5 Pg C per year on the global scale (the same order of magnitude than methane emissions).

ISOPRENOID Emissions



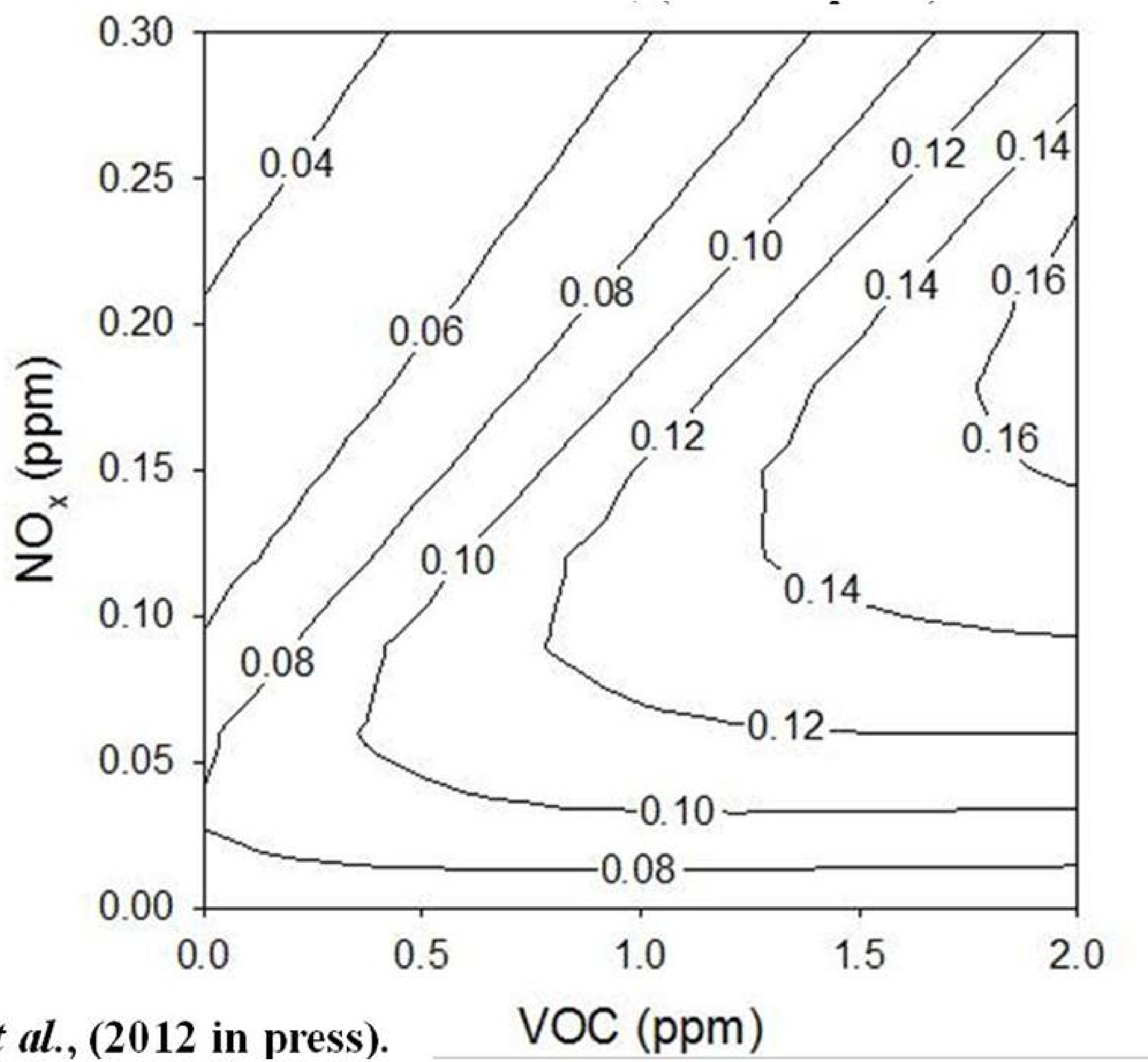
(Proton Transfer Reaction Mass Spectrometer)





- ***On line* analysis**
- **High ensibility 30-0 ppt**
- **Fast etection 0.1-1 sec/mass**

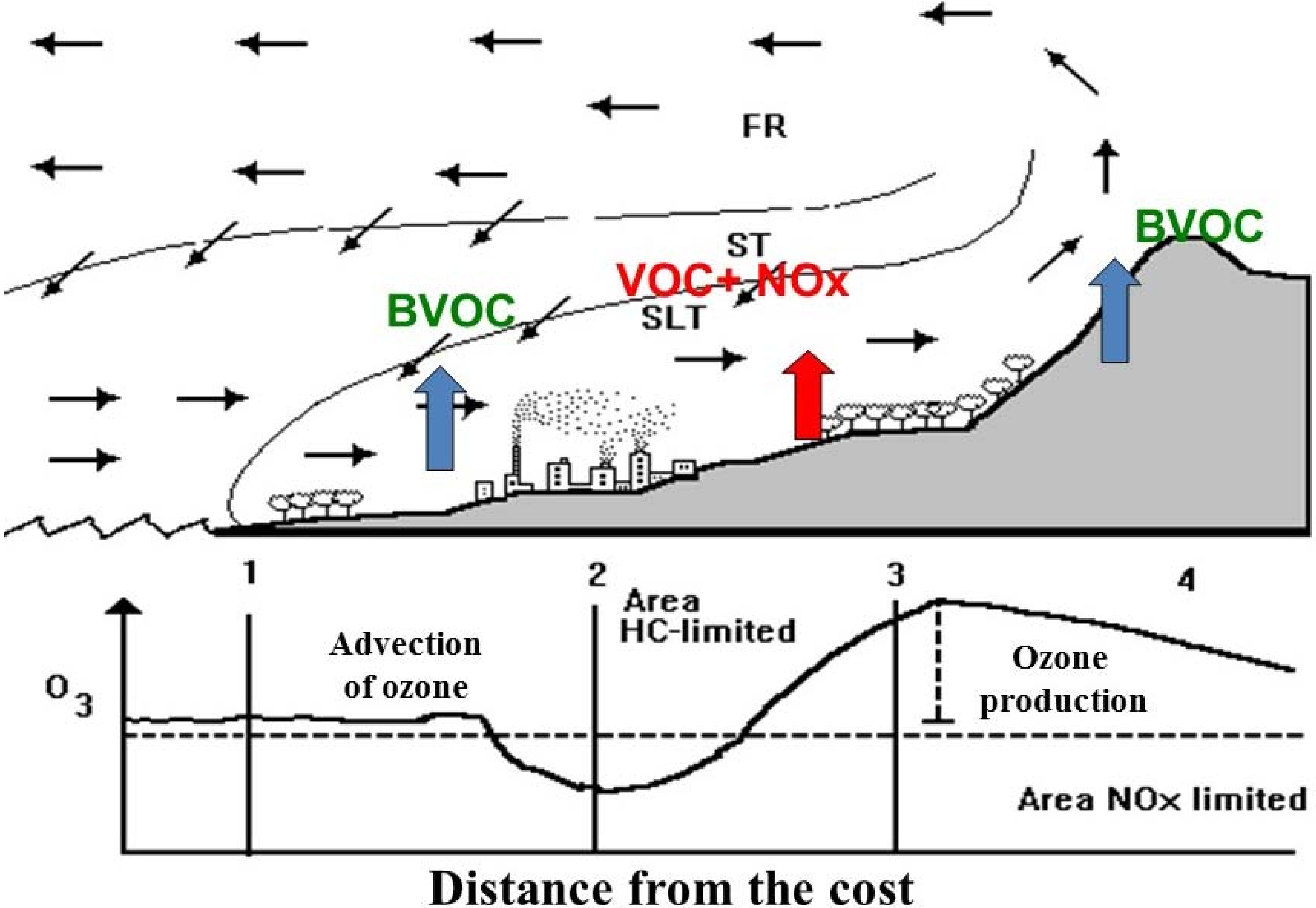
The future of BVOC – how pollution and climate change influences BVOC emission



Bernacchi *et al.*, (2012 in press).

An ozone isopleth graph modeled for Champaign, IL USA on August 15, 2008. The lines on the plot show the predicted ozone concentration (ppm) for a given concentration of the two main precursors, nitrogen oxides (NO_x) and volatile oxygenic compounds (VOC).

Loreto and Ciccioli 2008



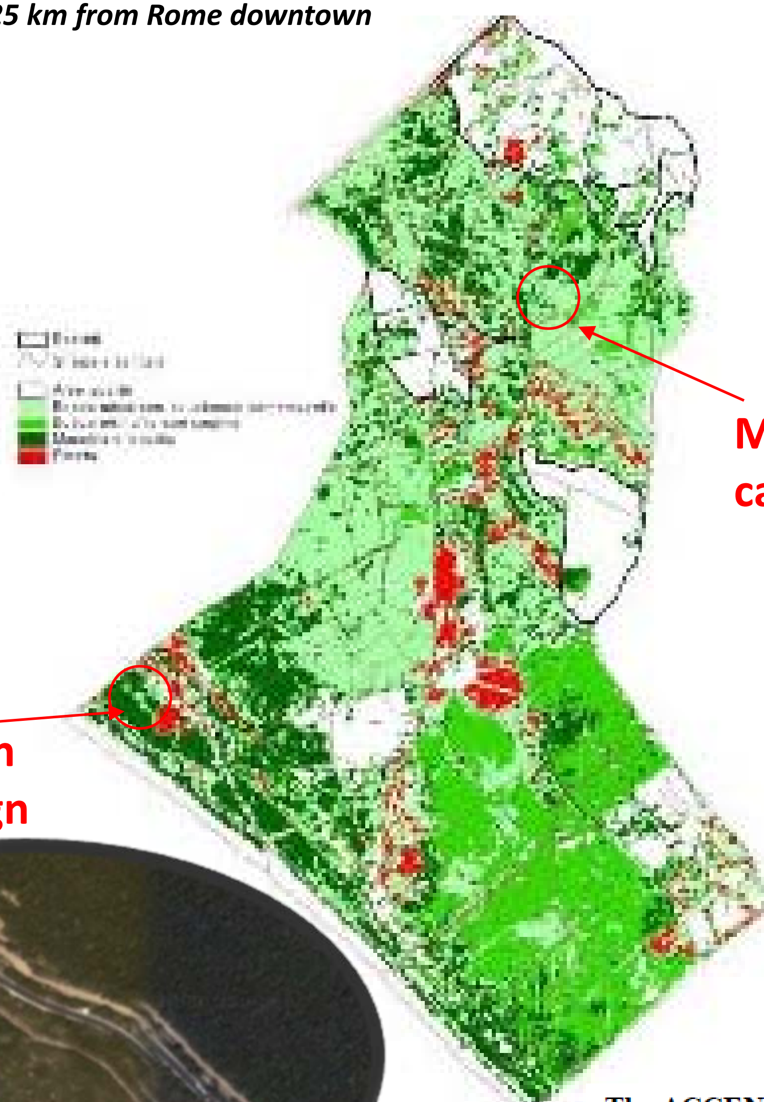
The Mediterranean is a "hot spot" for BVOC and photochemical pollution……

….along the coasts

This type of local circulation combined with the spatial distribution of VOC and NOx sources, fully exploits the potential of BVOC as components of photochemical pollution: BVOC from terrestrial ecosystems are often injected in air masses characterized by maximum efficiency in ozone production.

Castelporziano, an "Urban" forest

~ 6000 ha, 25 km from Rome downtown



Mixed Oak & pine site in 2011 field campaign

Dune coastal site in 2007 field campaign

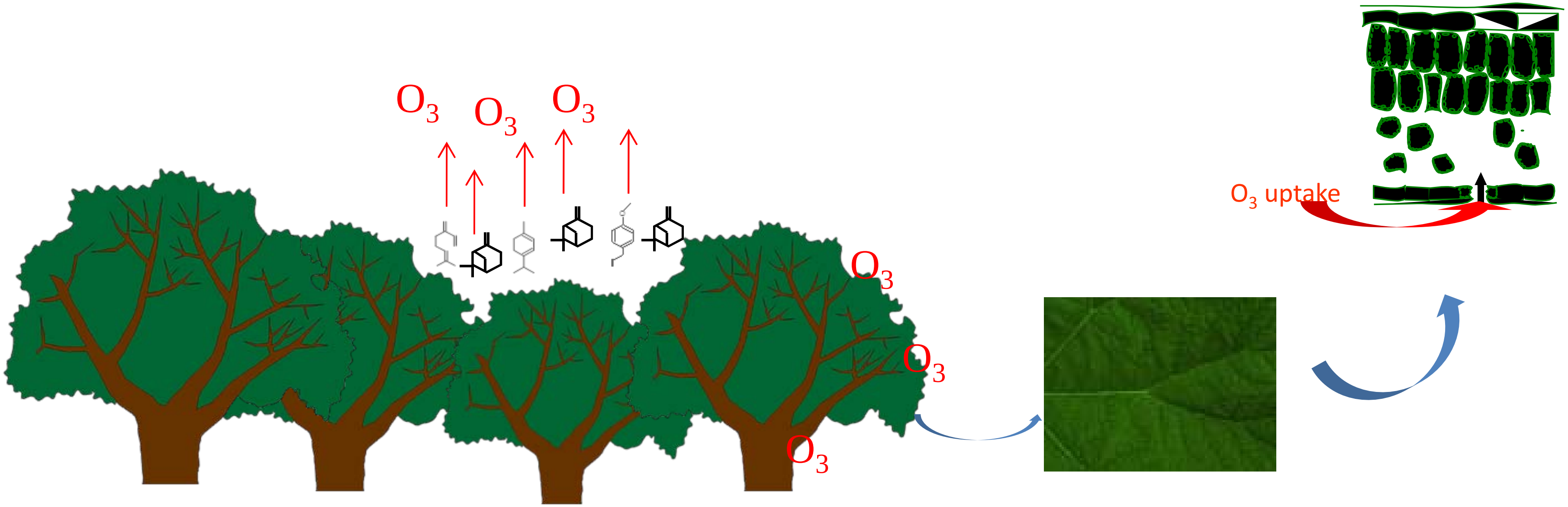
Biogeosciences

The ACCENT-VOCBAS field campaign on biosphere-atmosphere interactions in a Mediterranean ecosystem of Castelporziano (Rome): site characteristics, climatic and meteorological conditions, and eco-physiology of vegetation

S. Fares[1,2], S. Mereu[3], G. Scarascia Mugnozza[1], M. Vitale[3], F. Manes[3], M. Frattoni[4], P. Ciccioli[4], G. Gerosa[5], and F. Loreto[1]

Ozone sinks in plant ecosystems

1. Stomatal sink. Stomatal opening regulate leaf ozone uptake and largely contribute to ozone removal in the atmosphere



2. Surface deposition on cuticles and soil. Adsorption processes

3. Chemistry in the gas phase. Reactions between BVOC and ozone

"Non-stomatal uptake"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Thank you!