Dryland Ecosystems and Climate Change

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CLIMATE CHANGE: marine and mountain ecosystems in the Mediterranean region
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Veli Lošinj, Croatia,
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Outline:

1) Dryland ecosystem functions

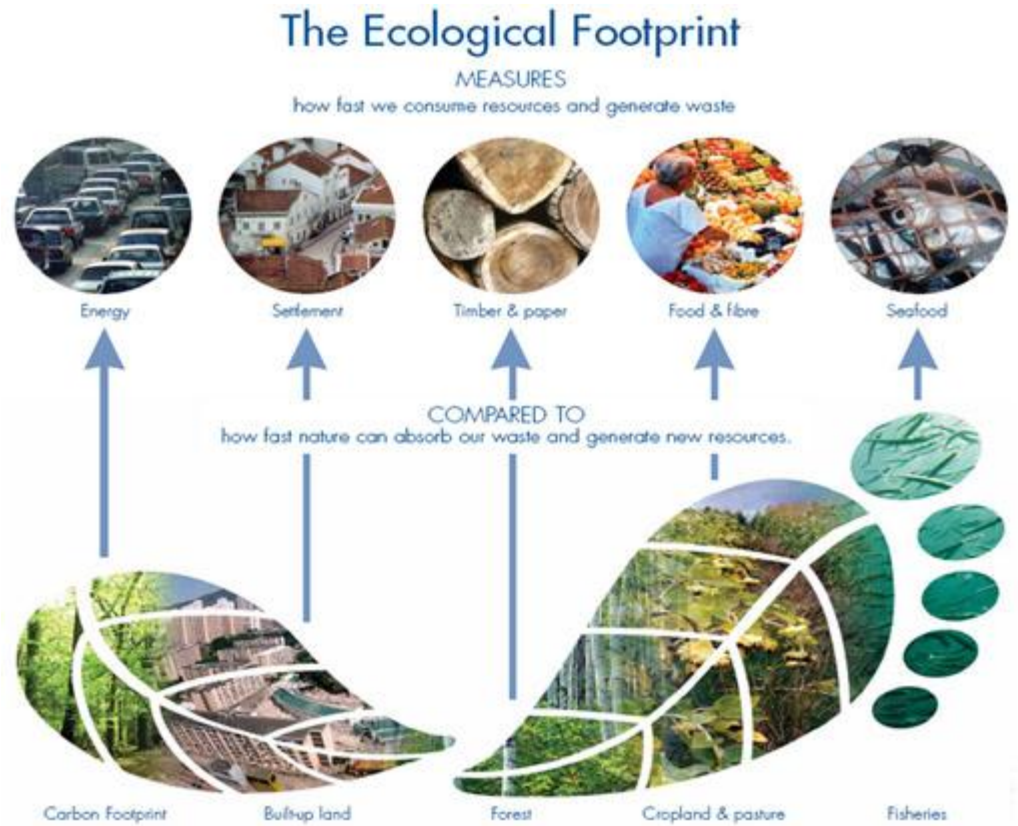
2) Sustainable water management in agroforestry systems

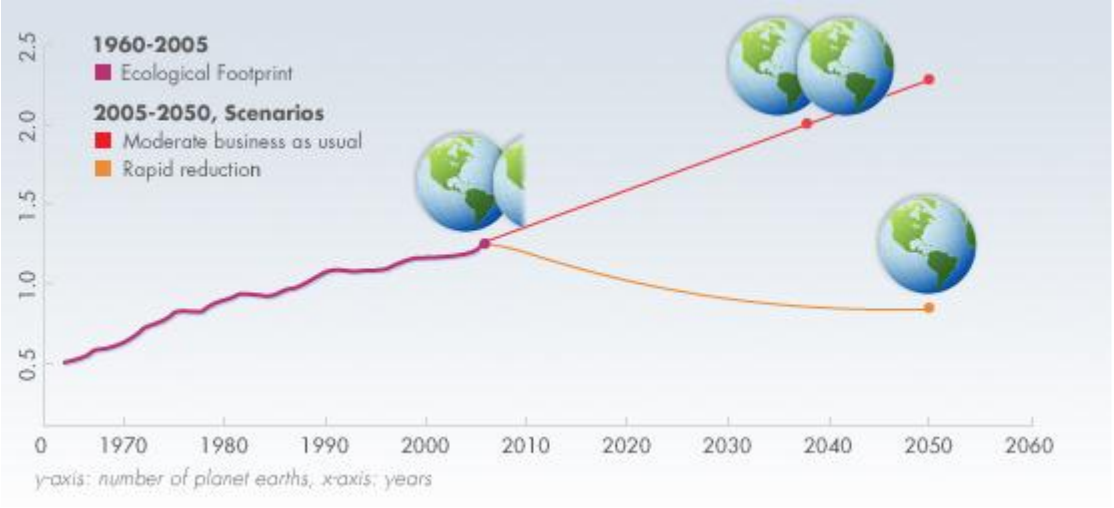
3) “Climate proof” model plants

4) Phenotyping methods: high-throughput screening of potential drought resistant donors in the field

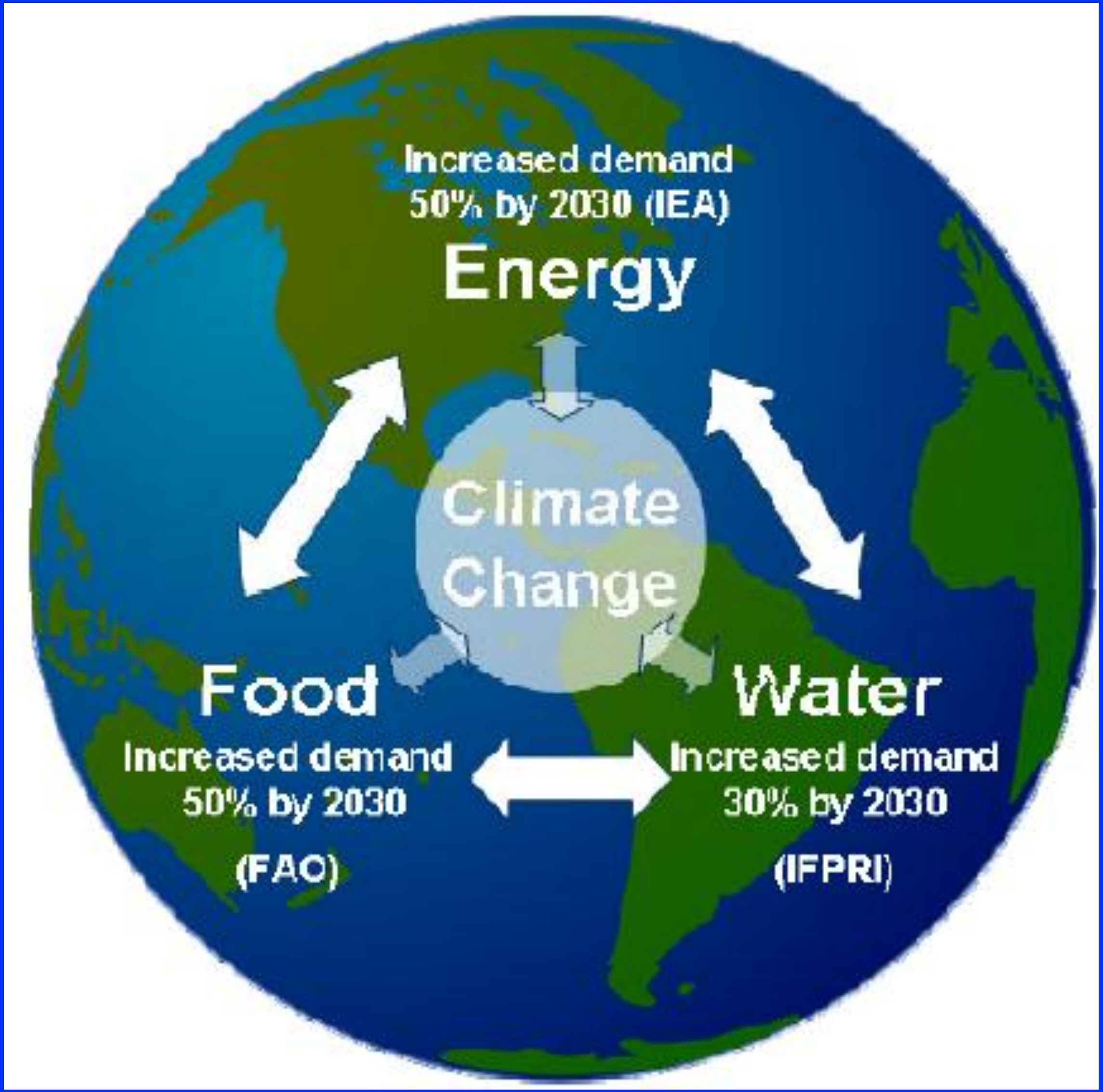
5) Biogenic volatile organic compounds (BVOC): a case-study in biosphere-atmosphere interactions

Global change is happening **now**, and we are responsible for it





The 2030 “Perfect Storm” Scenario: World’s rapidly growing demand for food, energy, water and land (Beddington 2009)



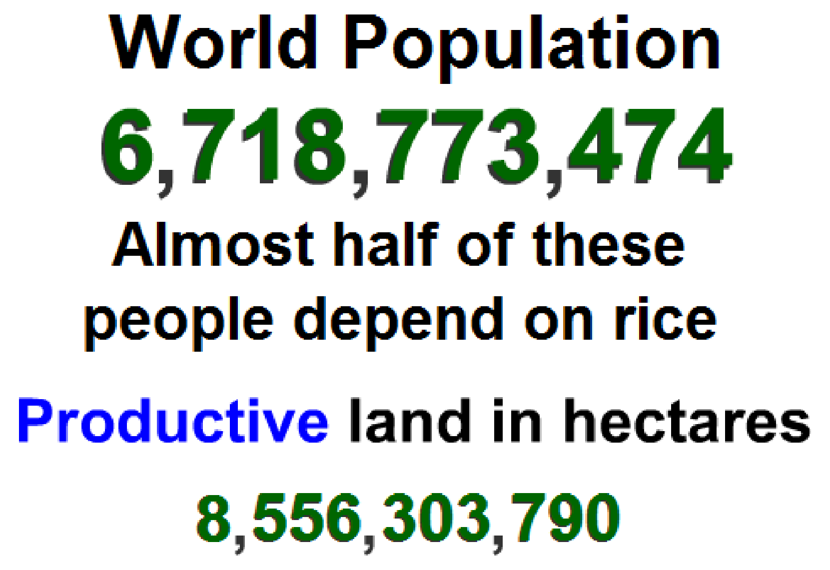
Increased demand
50% by 2030 (IEA)
Energy

Climate Change

Food
Increased demand
50% by 2030
(FAO)

Water
Increased demand
30% by 2030
(IFPRI)

November 20 , 2008



World Population

6,718,773,474

Almost half of these people depend on rice

Productive land in hectares

8,556,303,790

August 28, 2012

343,909,883

World Population

7,062,683,357

Almost half of these people depend on rice

Productive land in hectares

8,540,798,990

-15,504,800

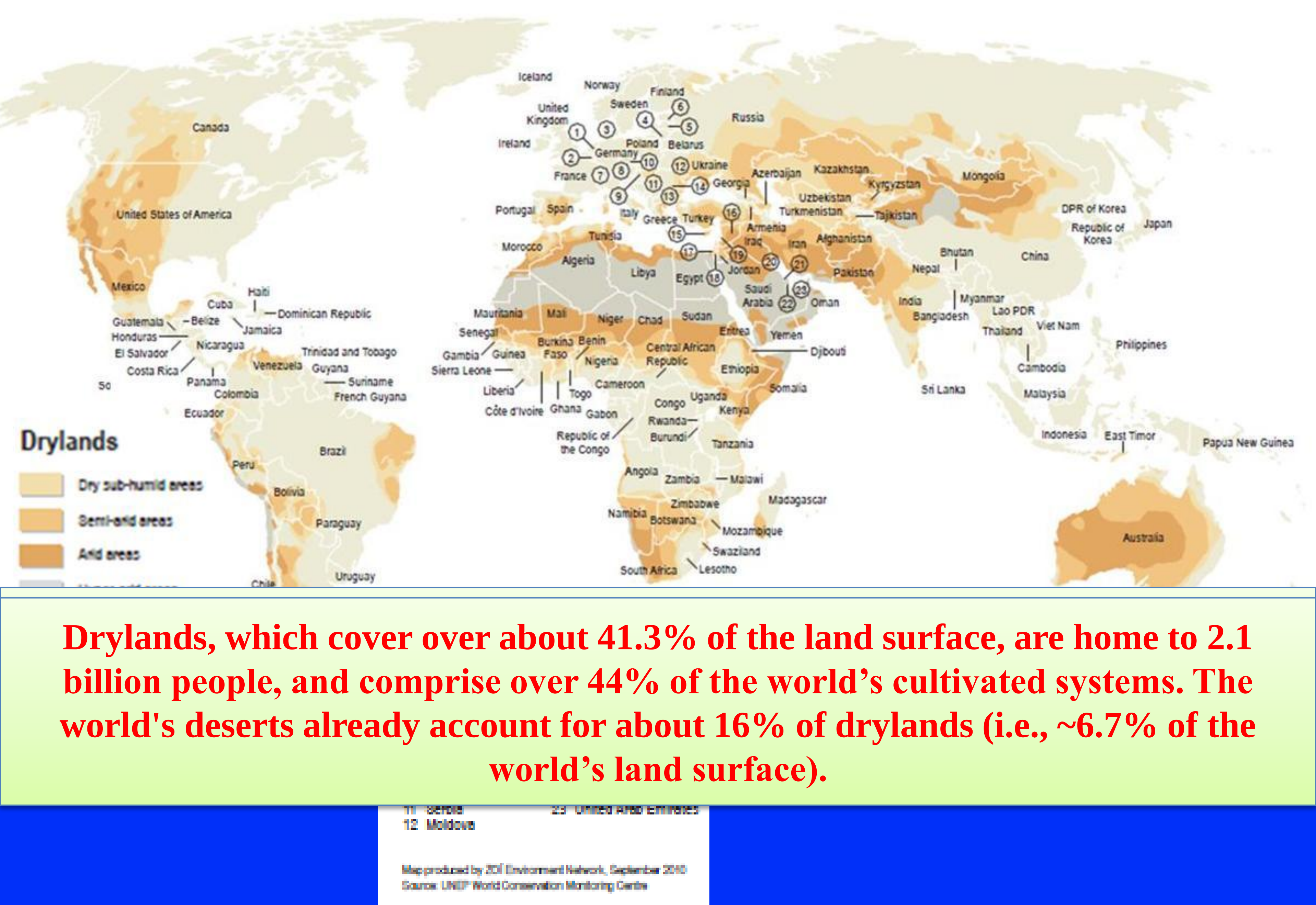
Food

908,355,741	Undernourished people in the world
1,562,167,889	Overweight people in the world
520,722,630	Obese people in the world
14,246	People who died of hunger today
$ 221,686,660	Money spent for obesity related diseases in the USA today
$ 88,064,001	Money spent on weight loss programs in the USA today

Environment

3,425,385	Forest loss this year (hectares)
4,611,495	Land lost to soil erosion this year (ha)
22,101,939,666	CO_2 emissions this year (tons)
7,903,936	Desertification this year (hectares)
6,449,861	Toxic chemicals released in the environment this year (tons)

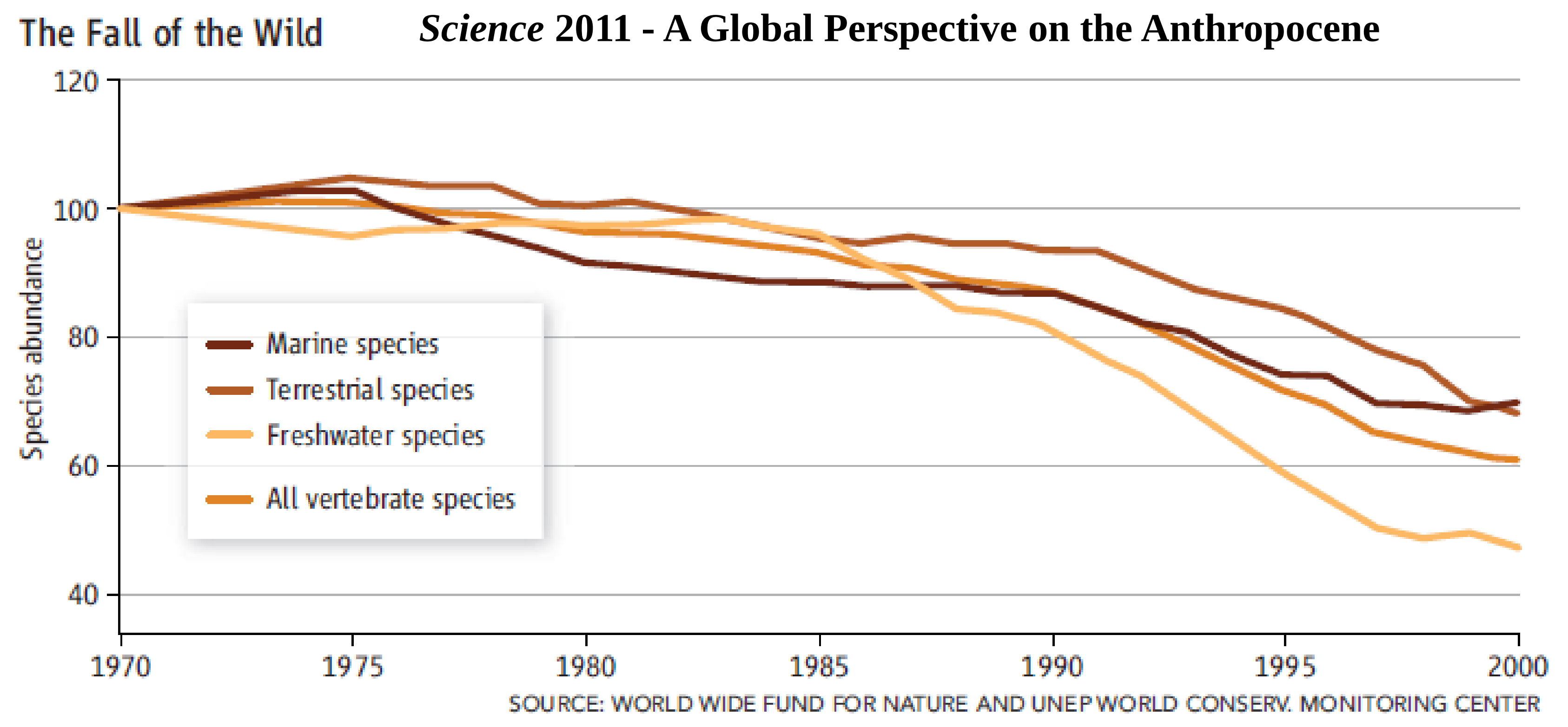
IPCC 2008 - Climate Change and Water



Map produced by ZOI Environment Network, September 2010
Source: UNEP World Conservation Monitoring Centre

Drylands, which cover over about 41.3% of the land surface, are home to 2.1 billion people, and comprise over 44% of the world’s cultivated systems. The world's deserts already account for about 16% of drylands (i.e., ~6.7% of the world’s land surface).

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



The Fall of the Wild

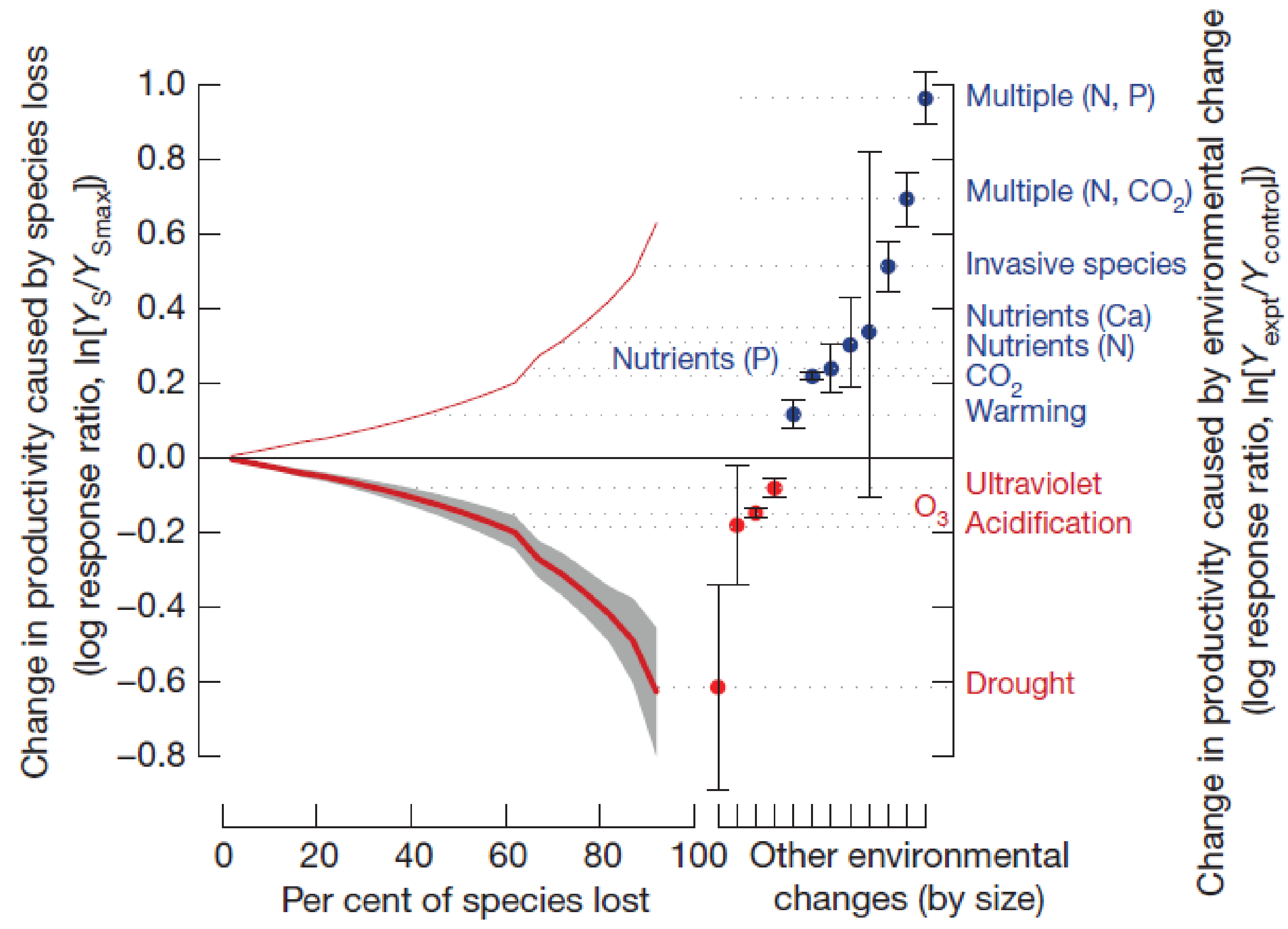
***Science* 2011 - A Global Perspective on the Anthropocene**

SOURCE: WORLD WIDE FUND FOR NATURE AND UNEP WORLD CONSERV. MONITORING CENTER

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

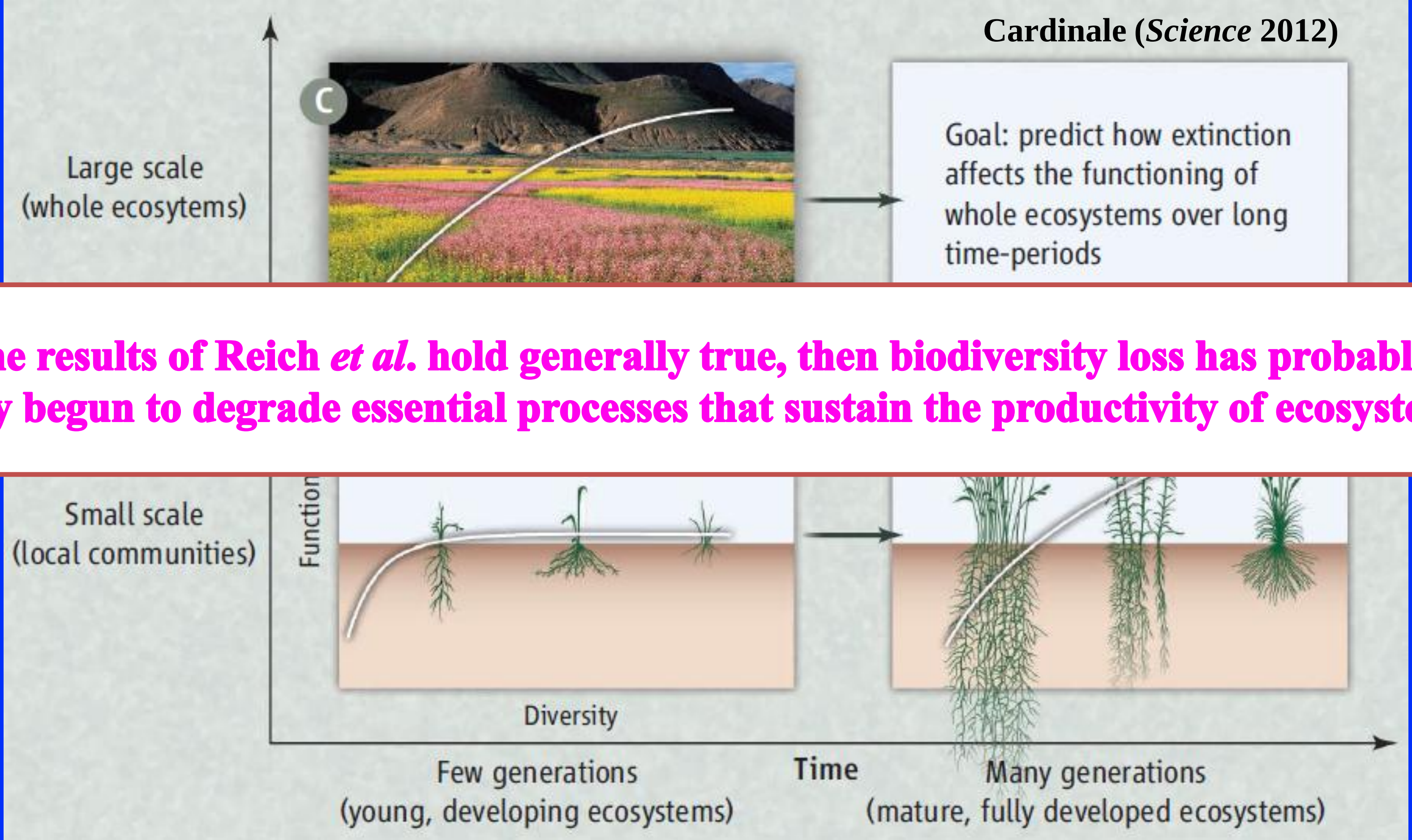
Biodiversity loss: A major driver of ecosystem change

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). Thick red line, lower productivity as species richness decreases. The thin red line shows the inverse of the thick red line to allow comparison of effect magnitudes with environmental changes with positive effects. Dotted grey lines show the mean effect of each environmental change for comparison with the effect of richness.**

Impacts of Biodiversity Loss Escalate Through Time as Redundancy Fades (Reich *et al*., *Science* 2012)

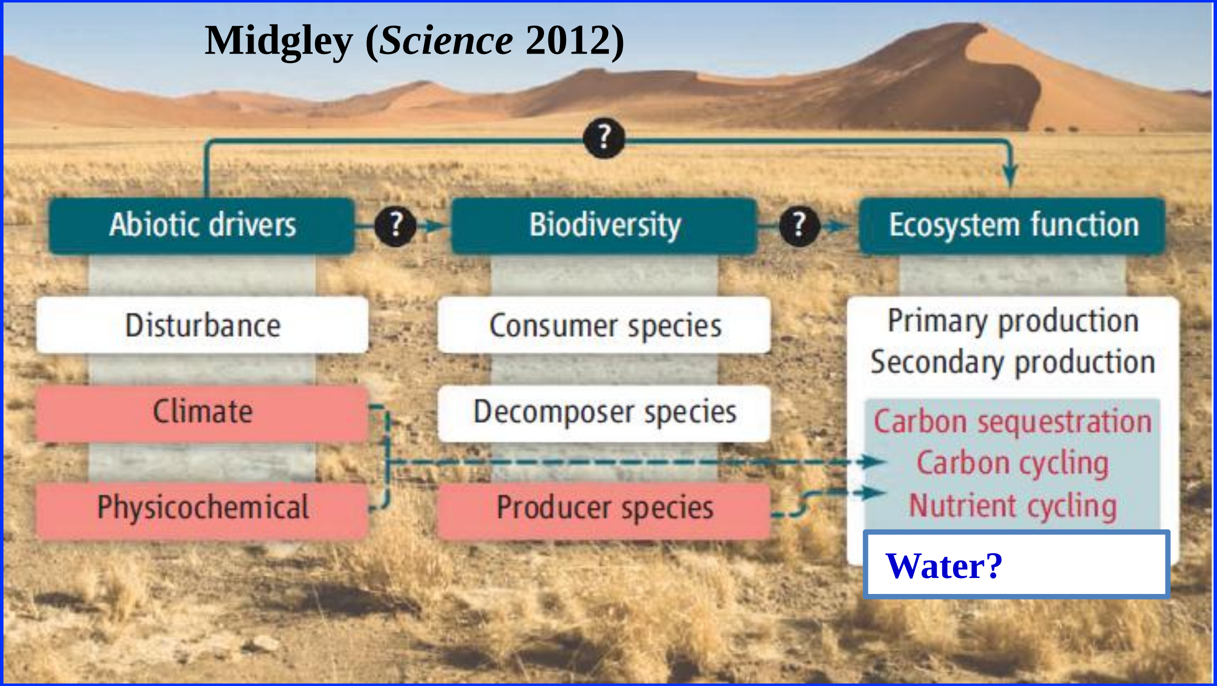

Cardinale (*Science* 2012)

If the results of Reich *et al*. hold generally true, then biodiversity loss has probably already begun to degrade essential processes that sustain the productivity of ecosystems.

Scaling diversity-function relationships. Ecosystem functions like nutrient cycling and biomass production are positively related to biodiversity, but that relationships saturate at relatively low levels of diversity (A). The effects of diversity on biomass productivity increased and became less saturating over time (B). Short-term experiments may thus underestimate the number of species needed to maintain ecosystem-level processes. If the results prove to be general, Reich et al. (Science 2012) will have quantified how the ecological impacts of extinction scale through time (A to B). If others can similarly quantify how diversity-function relationships change with the spatial extent of studies (A to C), we would have scaling relationships to estimate the fraction of species needed to maintain ecological processes in more realistic ecosystems (D).

Biodiversity and Ecosystem Multifunctionality

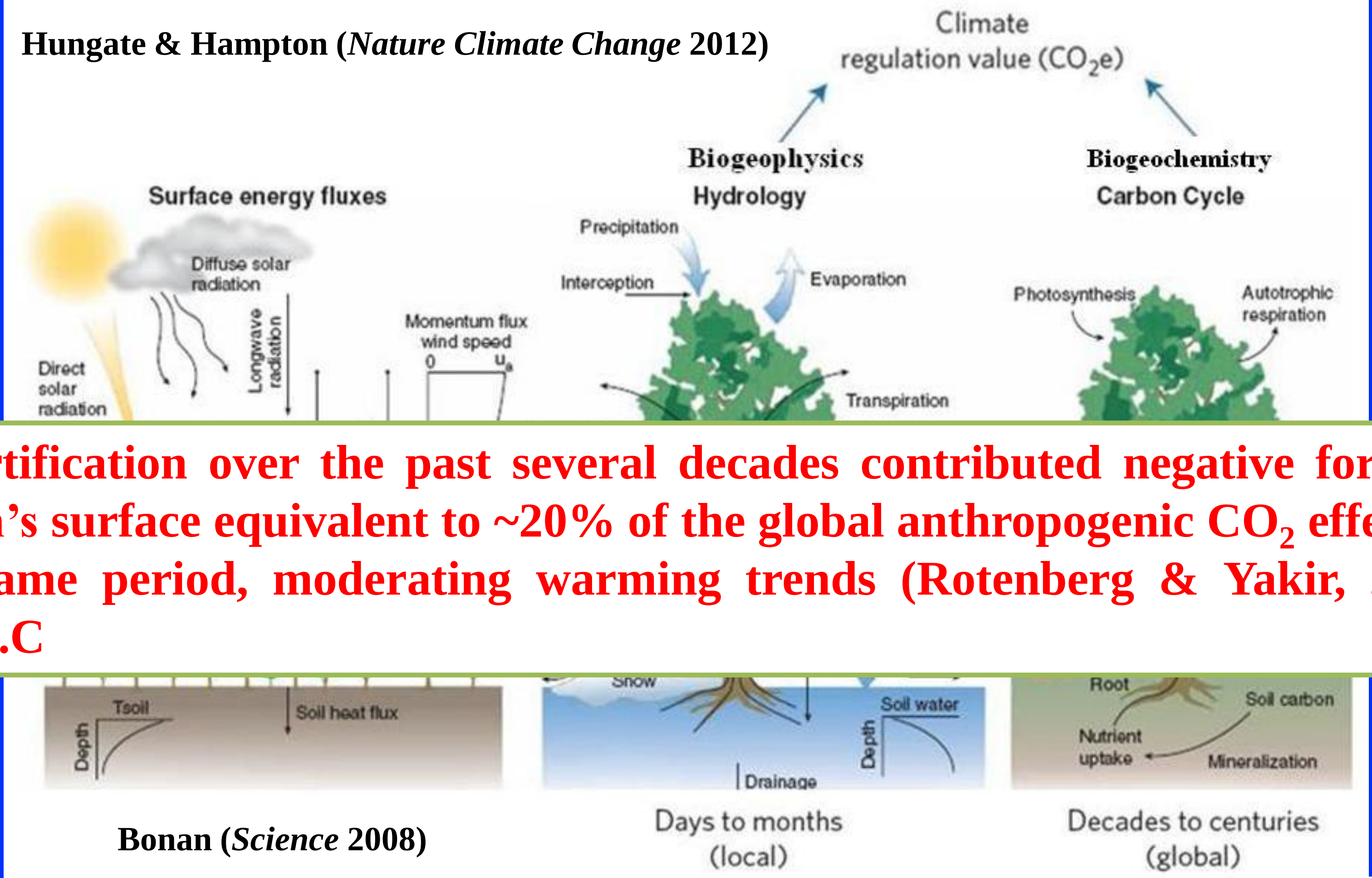
Maestre *et al.* (*Science* 2012): The relationship between species richness and dryland ecosystem multifunctionality (the ability of ecosystems to maintain multiple functions, such as carbon storage, productivity, and the buildup of nutrient pools) rises steeply with fewer than five species and then 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.



Midgley (*Science* 2012)

***A framework for testing the biodiversity ecosystem function*. 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 categories (indicative elements elaborated below blue boxes).**

Ecosystem influences on climate over space and time


Hungate & Hampton (*Nature Climate Change* 2012)

Bonan (*Science* 2008)

Desertification over the past several decades contributed negative forcing at Earth's surface equivalent to ~20% of the global anthropogenic CO_2 effect over the same period, moderating warming trends (Rotenberg & Yakir, *Science* 2010).C

The world's biosphere influence climate through three major categories of feedbacks: physical, chemical, and biological processes that affect planetary energetics, the hydrologic cycle, and atmospheric composition. Global and long-term biogeochemical influences involve exchange of greenhouse gases between ecosystems and the atmosphere. Regional and shorter-term biogeophysical influences involve the balance between incoming solar radiation and reflection, and how absorbed radiation is partitioned between latent and sensible heat.

Contribution of Semi-Arid Forests to the Climate System (Rotenberg & Yakir, *Science* 2010)

A planted pine forest at the dry timberline (285 mm mean precipitation) at the edge of the Negev desert in southern Israel.

Courtesy of Dan Yakir

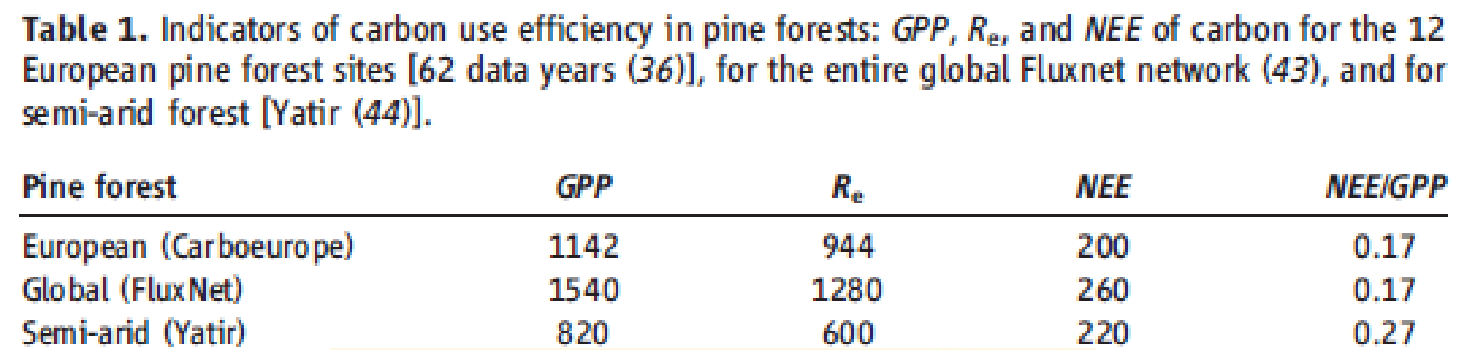


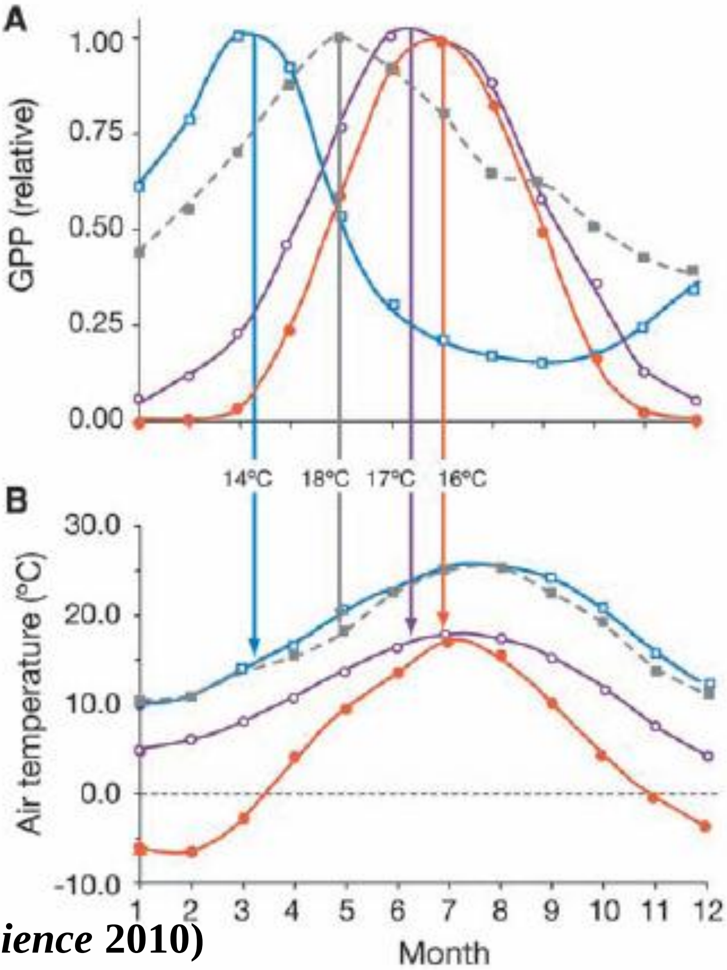
Table 1. Indicators of carbon use efficiency in pine forests: *GPP*, R_e, and *NEE* of carbon for the 12 European pine forest sites [62 data years (*36*)], for the entire global Fluxnet network (*43*), and for semi-arid forest [Yatir (*44*)].

Pine forest	*GPP*	R_e	*NEE*	*NEE/GPP*
European (Carboeurope)	1142	944	200	0.17
Global (FluxNet)	1540	1280	260	0.17
Semi-arid (Yatir)	820	600	220	0.27

	Rain (mm)
Yatir forest:	285
Fluxnet mean:	500-2000

The Yatir forest adjusted its metabolism to reduce the impact of severe temperature and water stress. This homeostatic-like ecosystem-level behaviour resulted in a high net ecosystem CO_2 exchange to gross primary productivity ratio and in displacement of the timing of biological activity (i.e. peak of carbon uptake) to early spring, leading to net carbon uptake slightly lower than mean global pine forests and slightly larger than average European pine forests i.e. 2.3, 2.5 and 2.0 metric tons per hectare, respectively.

Fig. 1. Annual patterns in (**A**) GPP, monthly means based on 0.5-hour values from Carboeurope database (36) and normalized as GPP/GPP_{max}, and (**B**) air temperature (monthly mean) in 4 representative European pine forest sites (out of the 12 Carboeurope pine forest sites examined; other sites omitted for clarity but are within same range). Vertical lines indicate the air temperature at time of peak activity. Sites are Yatir, Israel (blue); El Salar, Spain (gray); Brasschaat, Belgium (purple); and Hyytiala, Finland (orange).



Rotenberg & Yakir (*Science* 2010)

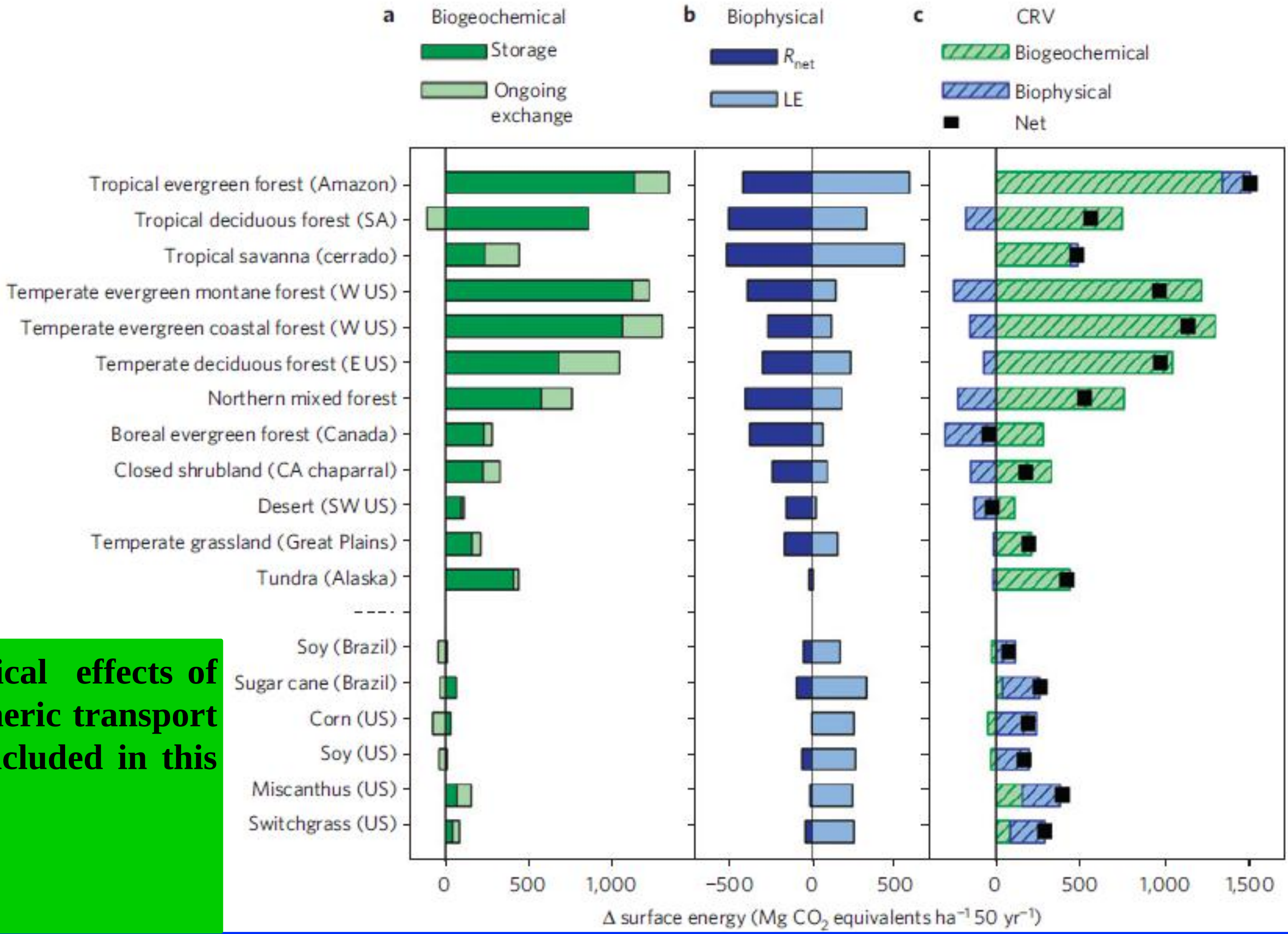
The substantial amount of carbon sequestered modified the surface energy balance: the plantation of the Yatir forest initially caused a regional warming because of the decreased albedo, but about 40 years after planting the balance between the albedo heating effect and the carbon sequestration driven cooling effect was reached. However, considering the positive radiative forcing caused by the observed suppression in longwave radiation, the time needed to reach a net cooling effect would be about 80 years after planting in the worst-case scenario (Rotenberg & Yakir, *Science* 2010).

A global program of dryland reforestation may initially cause regional warming as these new forests modify the surface energy balance, but will pay dividends in the long term as these forests become substantial global carbon sinks.

The climate regulation value of ecosystems should not only include their biogeochemical influences, but also their biogeophysical ones (Anderson-Teixeira *et al*., *Nature Climate Change* 2012).

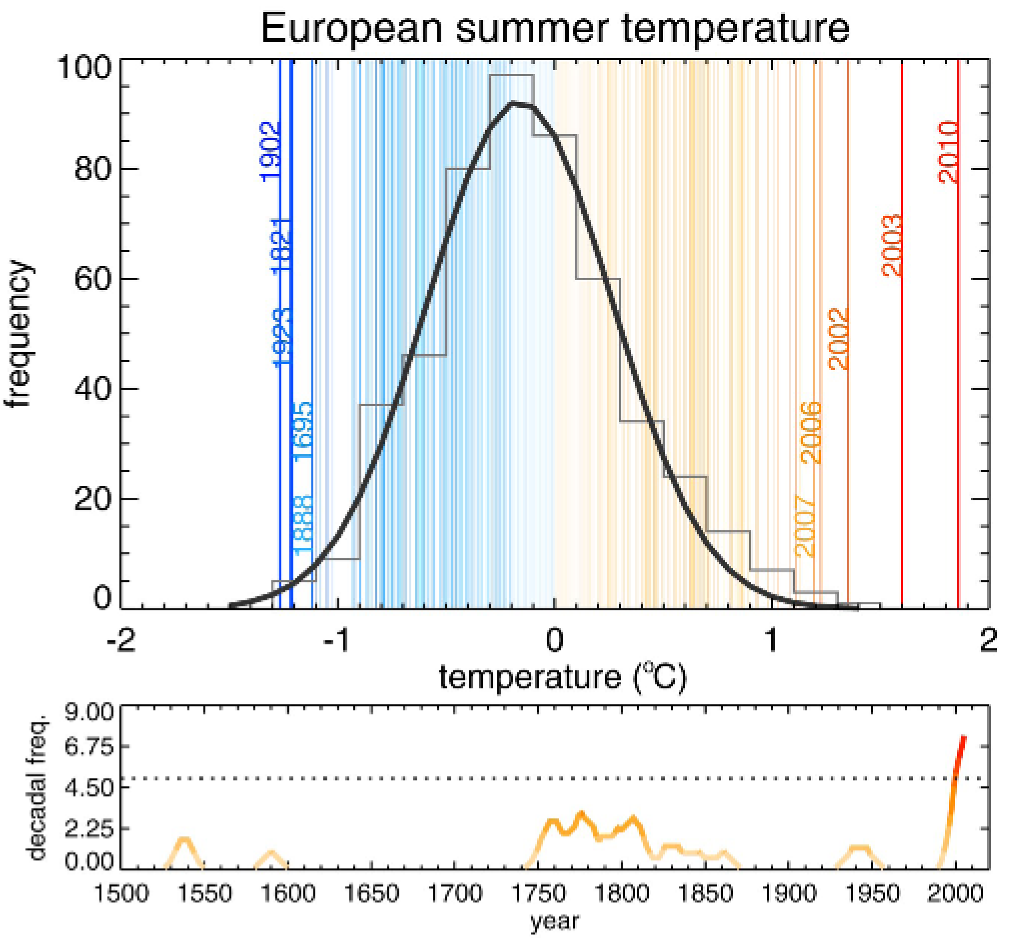
Anderson-Teixeira *et al*. (*Nature Climate Change* 2012) propose a novel way to combine biogeochemical and biogeophysical climate regulation services into an integrated index of ecosystem climate regulation value (CRV): expressing the local biogeophysical influences on the global scale, integrating them over time and converting them into the common unit of carbon markets - CO_2 equivalents.

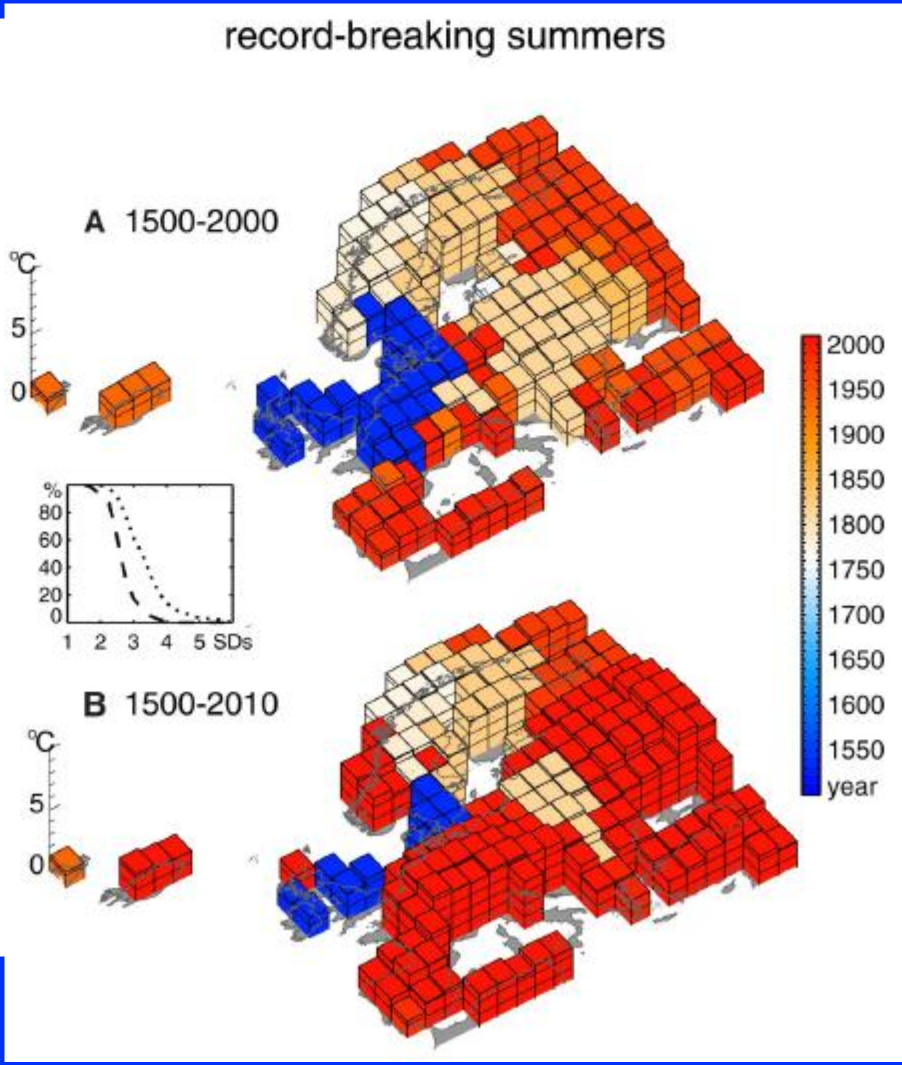
Because the non-local biophysical effects of changes in atmospheric transport of water are not included in this calculation, CRV does not characterize net effects on global climate, but rather provides an integrated index of the direct effects of land clearing on the land surface energy budget.



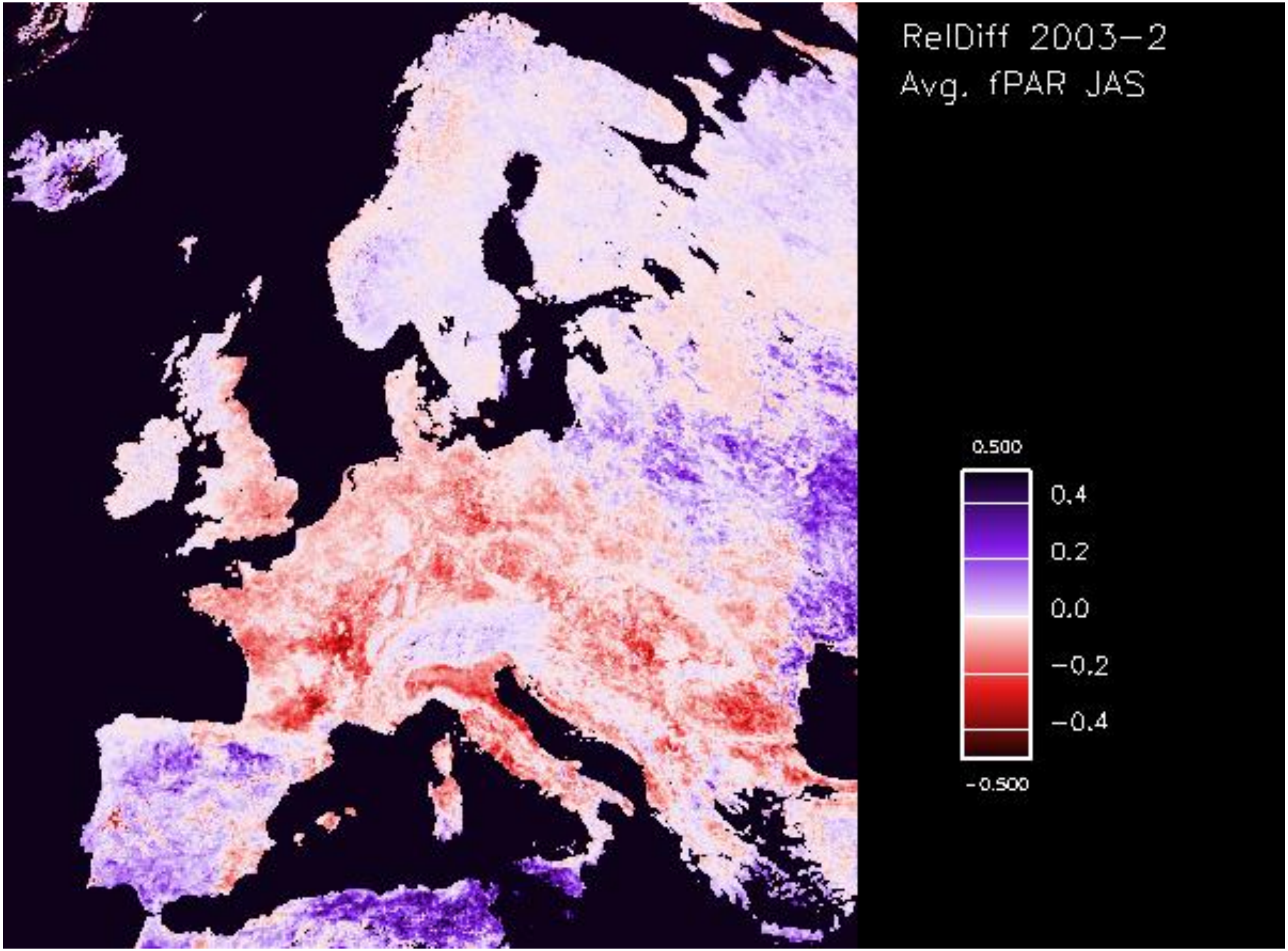
Non-local biophysical effects of changes in atmospheric transport of water are not included in this CRV metric:
Planetary albedo?
Biotic pump?

Biogeochemical and biophysical climate services (relative to a bare-ground baseline) of 18 natural and agricultural ecoregions of the Americas **(Anderson-Teixeira *et al.*, *Nature Climate Change* 2012). *a,b*, Contributions from GHGs (*a*), including both the GHGs that would be released on land clearing and ongoing GHG exchange, and Δ*R*n and Δ*LE* (*b*), extrapolated to the global scale by dividing local effect by global surface area (indirect effects excluded). *c*, These are combined to yield an integrated measure of climate regulation value (CRV). Values are calculated over a 50-year time frame.**





'Mega-heatwaves' such as the 2003 and 2010 events broke the 500-yr long seasonal temperature records over approximately 50% of Europe. According to regional multi-model experiments, the probability of a summer experiencing 'megaheatwaves‘ will increase by a factor of 5 to 10 within the next 40 years (Barriopedro *et al.*, *Science* 2011).



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

Dai (*WIREs Climate Change* 2011): Drought under global warming

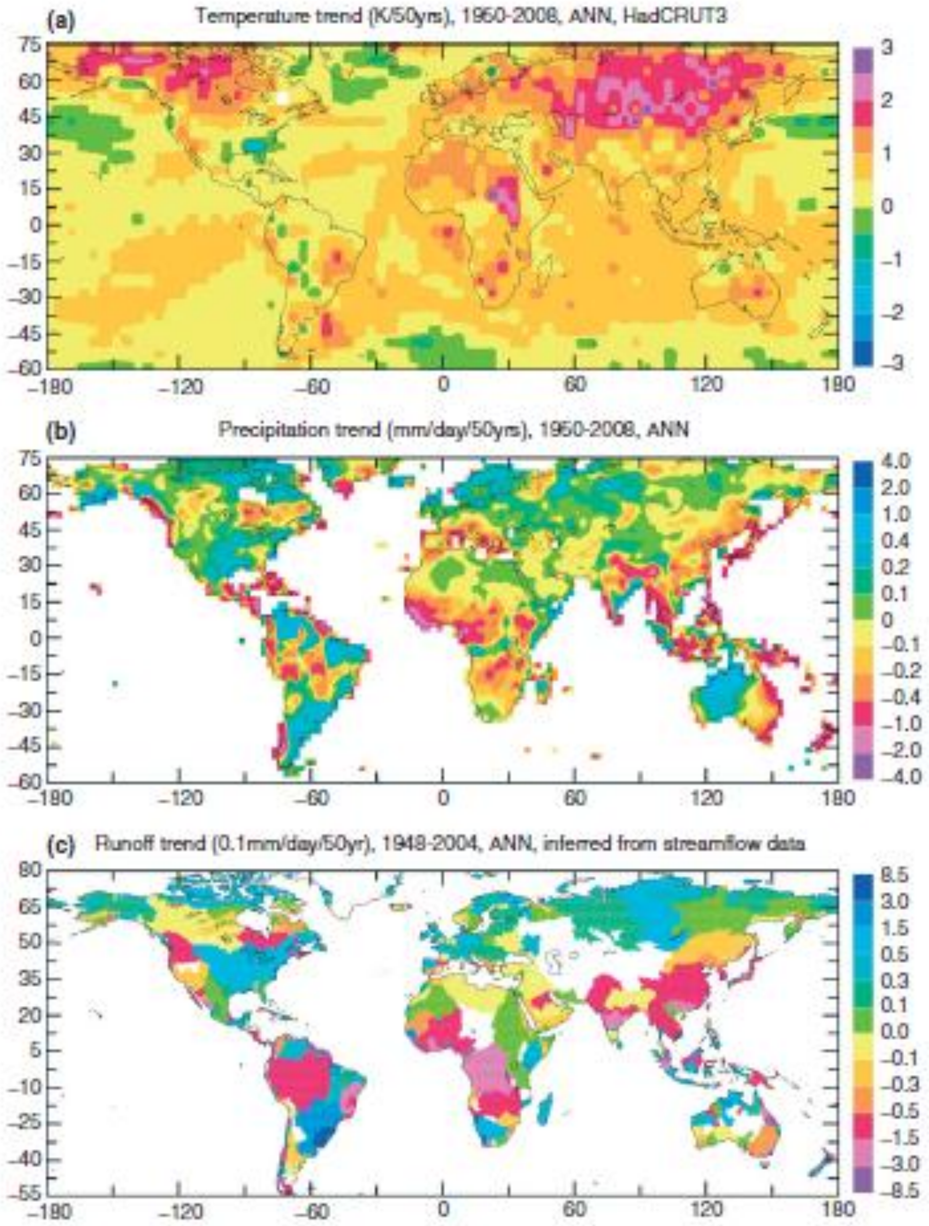
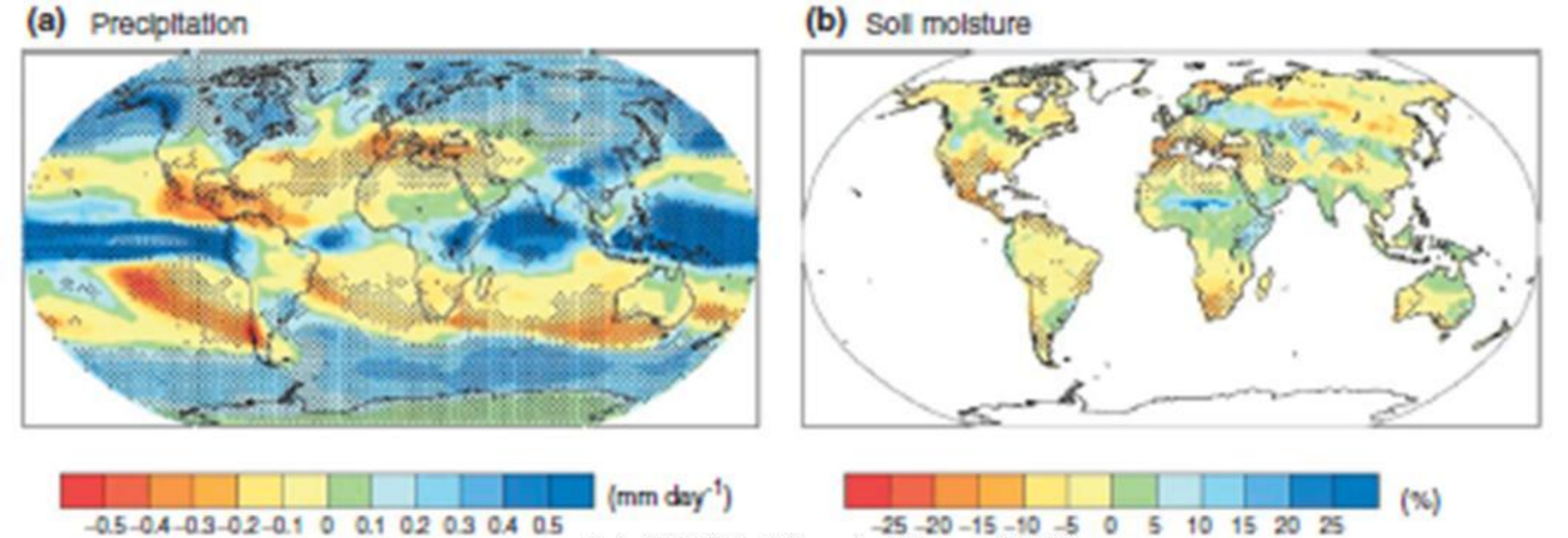


FIGURE 5 | Trend maps for observed annual (a) surface air temperature (from HadCRUT3: http://www.cru.uea.ac.uk/cru/data/temperature/), (b) precipitation (see text for data sources), and (c) runoff inferred from streamflow records. (Panel c reprinted with permission from Ref 99. Copyright 2002 American Meteorological Society.)

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.

Teleconnection between the global climate system, drought and desertification: climate regulation value

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

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

Ecosystems are sensitive to climate, but the converse is also true: ecosystems strongly influence the climate system.

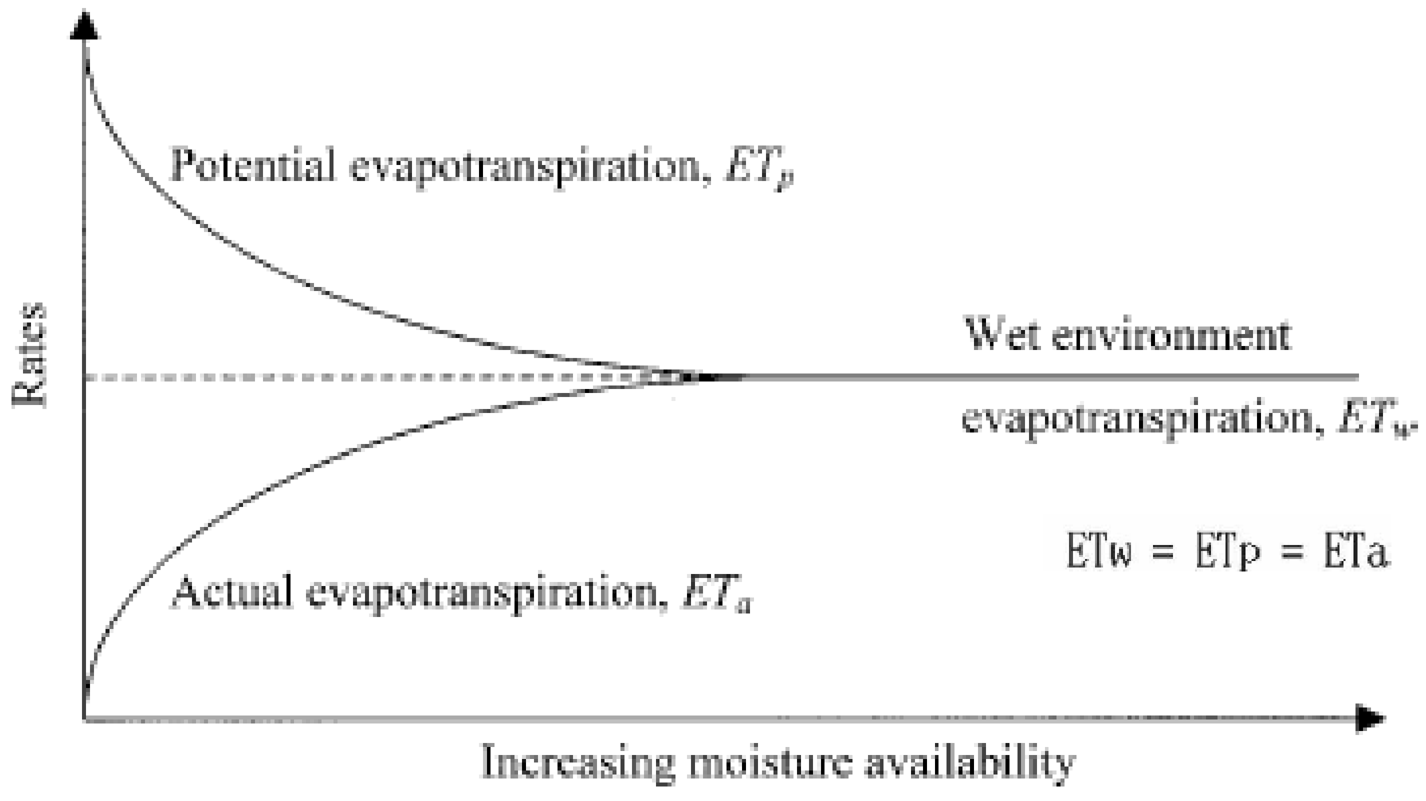
The biotic pump

Biotic pump of atmospheric moisture as driver of the hydrological cycle on land

Water vapour from coastal forests and oceans quickly condenses to form droplets and clouds. Makarieva and Gorshkov (2007) point out that the gas takes up less space as it turns to liquid, lowering local air pressure. Because evaporation is stronger over the forest than over the ocean, the pressure is lower over coastal forests, which suck in moist air from the ocean. This generates wind that drives moisture further inland. As a result, giant winds transport moisture thousands of kilometres into the interior of a continent.

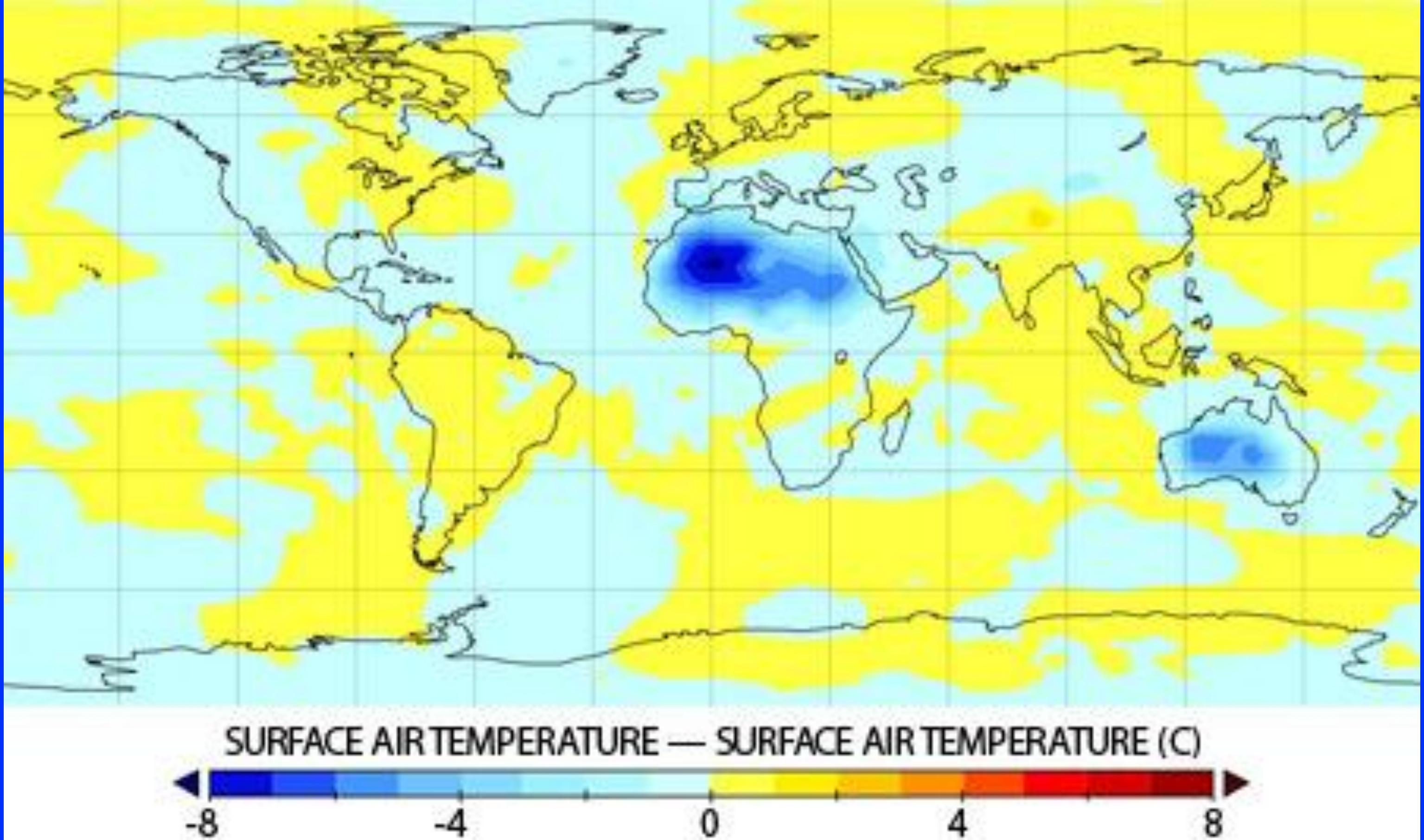
Makarieva and Gorshkov, 2007

The hypothesis of the complementary relationship between ETa and ETp in regional evapotranspiration (Bouchet, *Proc. IASH General Assembly* 1963).



The CR states that under constant energy input and away from sharp discontinuities there exists a complementary feedback mechanism between actual (ETa) and potential (ETp) evapotranspiration that causes changes in each to be complementary, that is, a unit decrease in Ea causes a unit increase in Etp (Hobbins *et al*., Water Resources Research 2001; Ozdogan *et al*., Journal of Hydrometeorology 2006).

Green dream (*ScienceNOW Daily News* 2009)



Planting and irrigating forests would cause surface air temperatures to drop by 4° to 8°C (Ornstein *et al.*, *Climatic Change* 2009: Irrigated afforestation of the Sahara and Australian Outback to end global warming).

Some experiences of international cooperation to combat desertification (Israel, Morocco, Tunisia, Egypt, Algeria, Pakistan, Argentina)

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

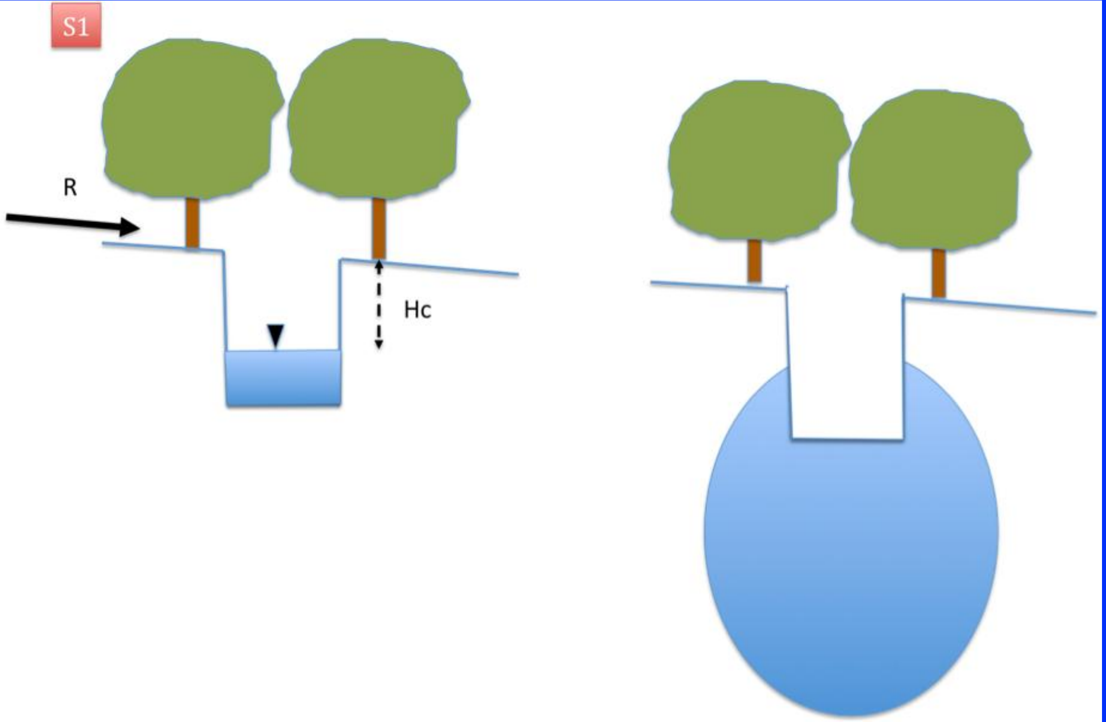
Sustainable water management (new water-saving irrigation techniques, water harvesting, use of secondary treated waste-water)

Sustainable water management (new water-saving irrigation techniques, water harvesting, use of secondary treated waste-water)

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

- Design and development of a system that will use partially treated wastewater for ferti-irrigation of a 10 hectares 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 erosion

Water harvesting



Schematic description of the proposed trench system. The arrows indicate direction of flow and R is the runoff collected between two adjacent trenches. Cross-sectional view of flooded trench with Hc indicating the maximum height collected runoff water should reach (left) and the resulting hypothetical distribution of collected water in the soil (right).

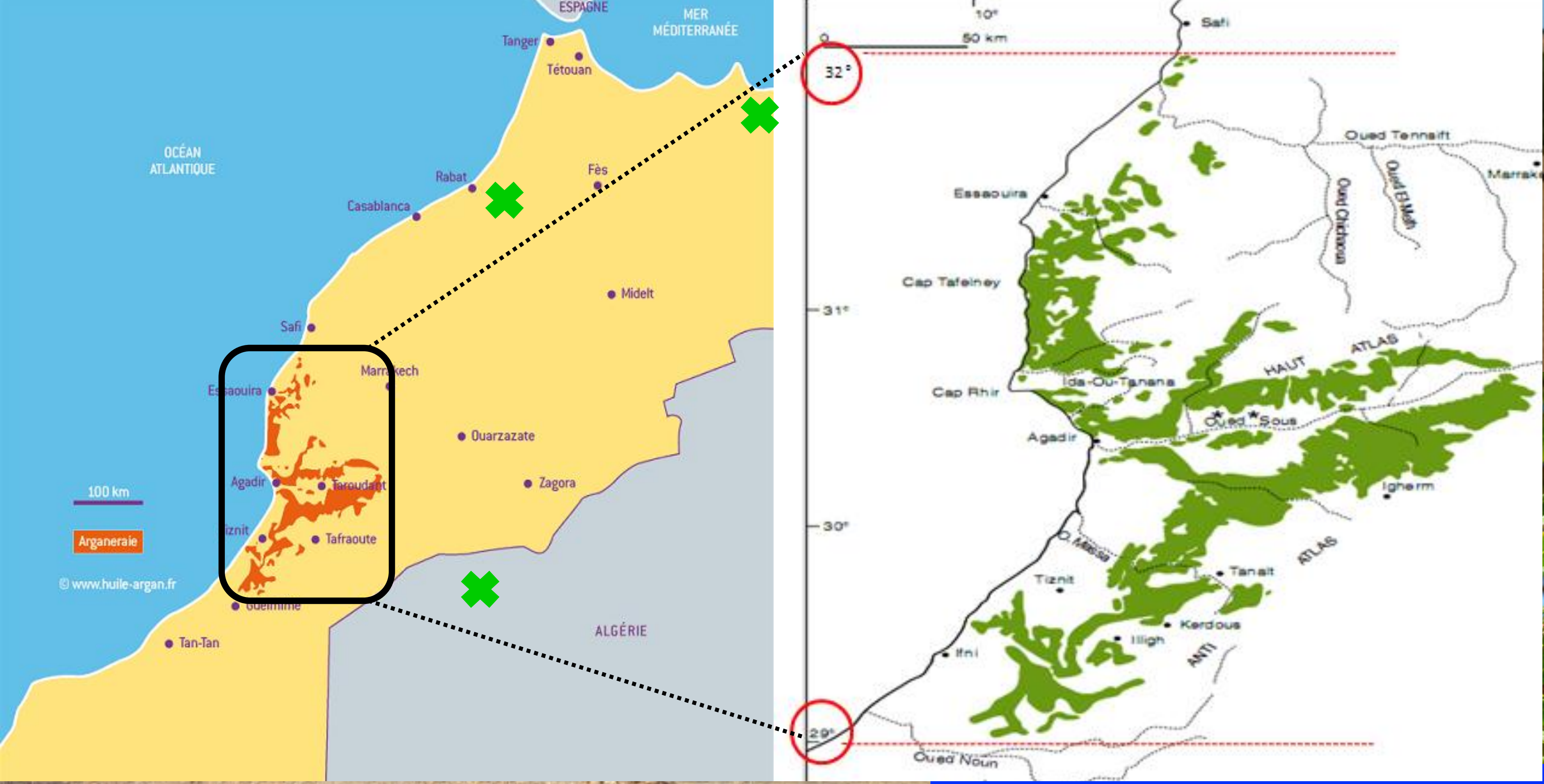
Agrfor-Vallerani system: Continuous furrows (*a*), furrow cross-section (*b*) and (*c*) example of mini-trenches.

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

Dryland ecosystem functioning and resilience

Identification of “climate proof” model plants as potential new crops and/or for rehabilitation of degraded drylands

The objective of our research is to study the ecological characteristics and water use efficiency of different functional types within arid land ecosystems of desertification gradient in order to find out suitable plant species and vegetation patterns for rehabilitation of lands degraded to various degrees: Fingerprinting (i.e., genetic characterization using ecophysiological, morphologic and molecular techniques) and selection of superior indigenous landraces of plants with improved tolerance to drought in the local farming systems).



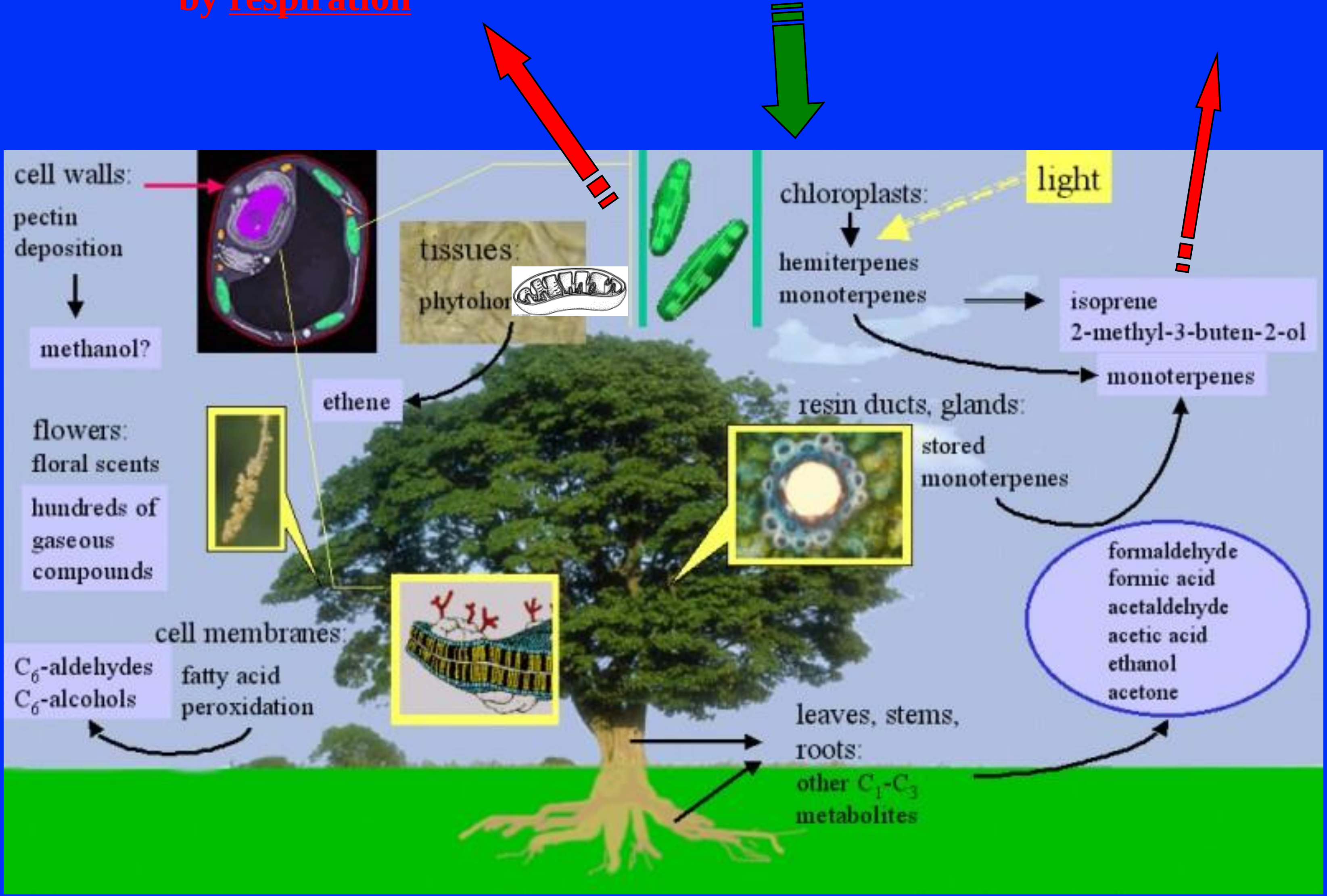
Argan (*Argania spinosa*) is an endemic tree of south-western Morocco where it is adapted to grow in harsh environments (extreme drought and poor soil, i.e. in a region where rainfall hardly exceeds 200 - 300 mm/year, and at times stays well below 120 mm/year), where it plays vital roles in protecting 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.

4) Phenotyping methods
5) Biogenic volatile organic compounds (BVOC)

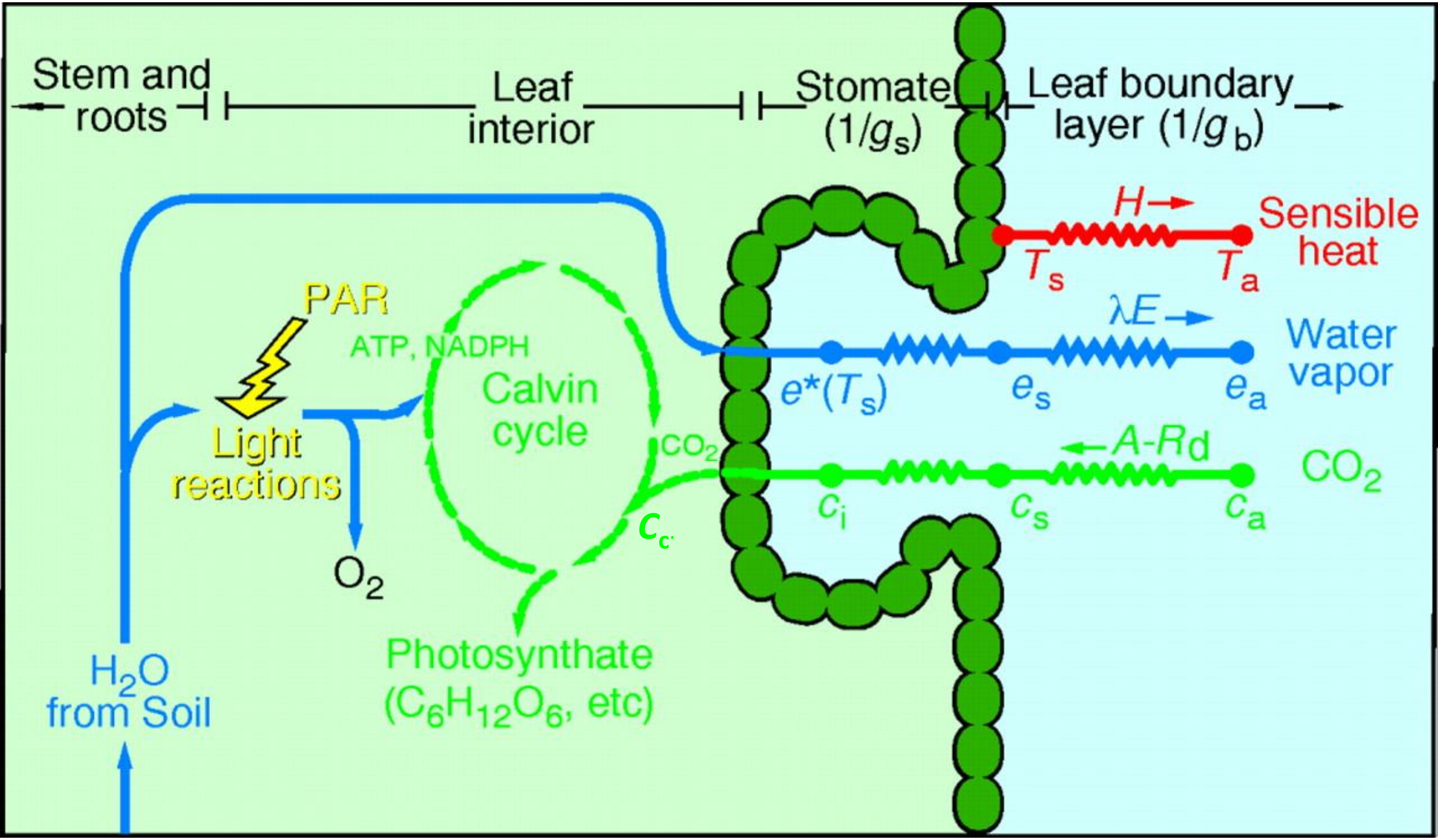
1. CO_2 uptake by **photosynthesis**

2. CO_2 release by **respiration**

3. **BVOCs**



Photosynthesis limitations (CO_2 supply or diffusive resistances)



Journal of Experimental Botany, Vol. 60, No. 8, pp. 2325–2339, 2009

Leaf gas exchange, carbon isotope discrimination, and grain yield in contrasting rice genotypes subjected to water deficits during the reproductive stage

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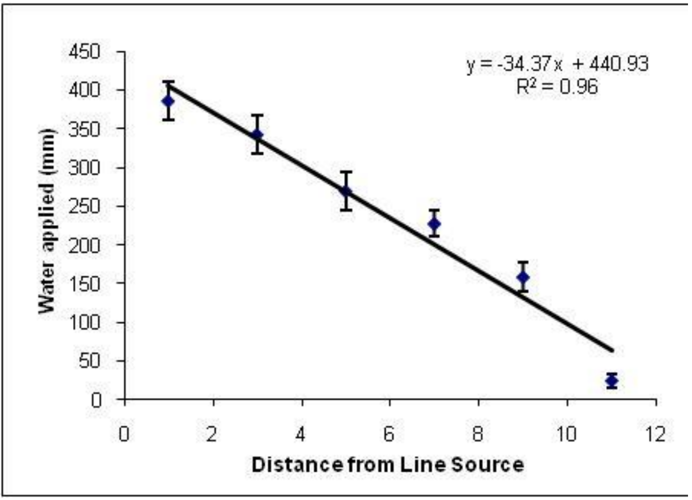
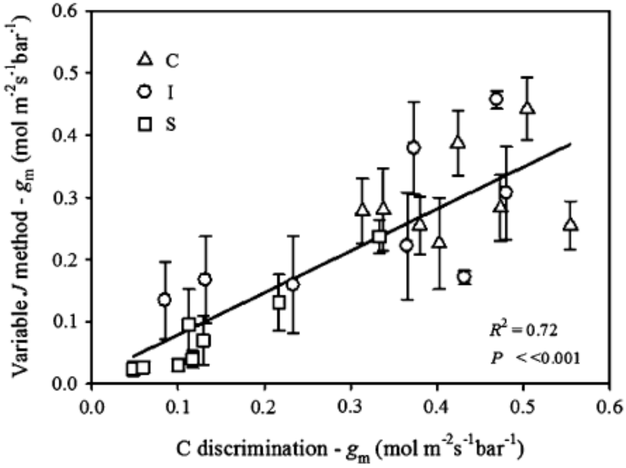
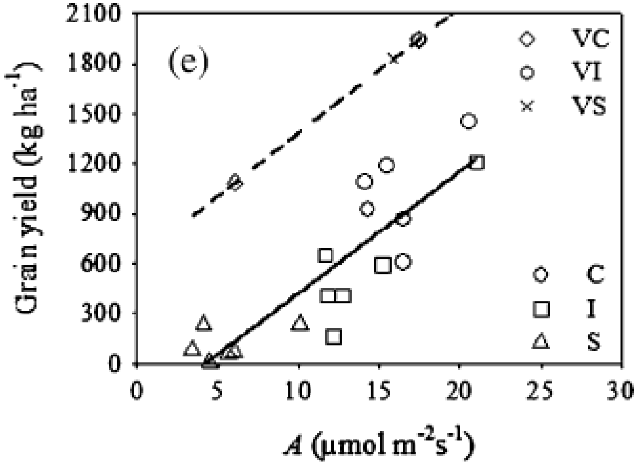
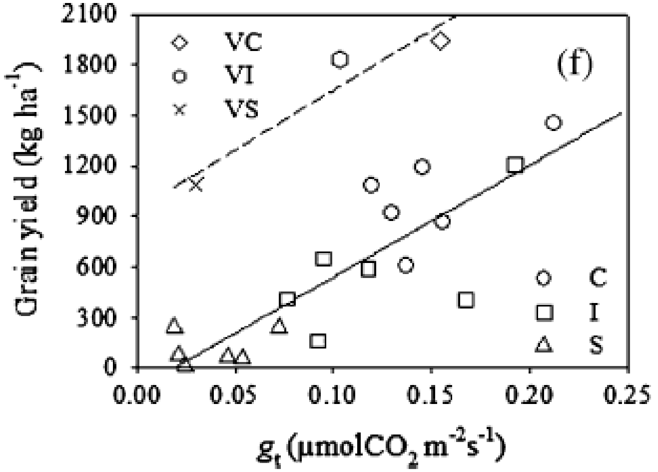
[3] Crop and Environmental Sciences Division, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines

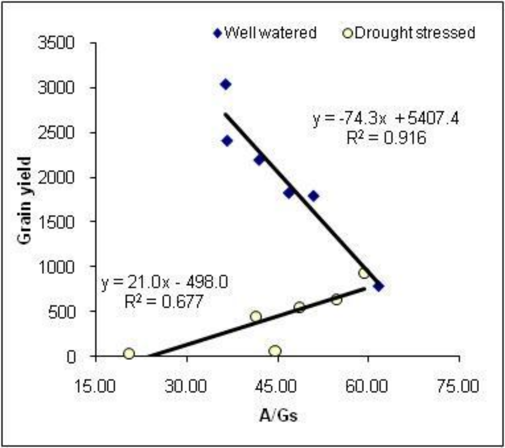


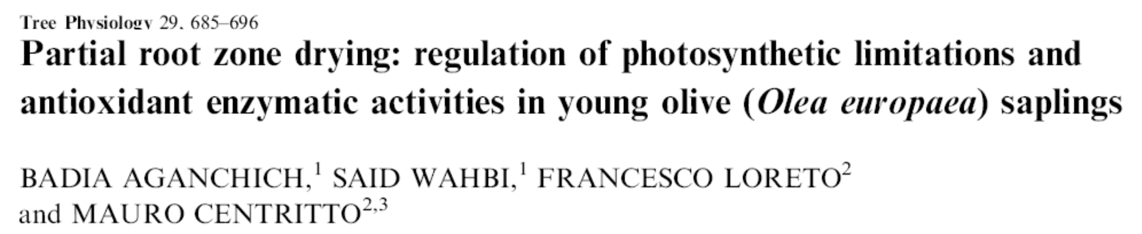


Drip irrigation experiment





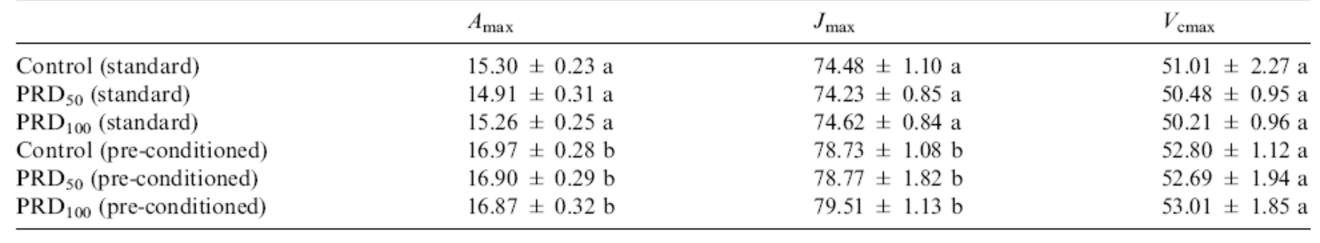




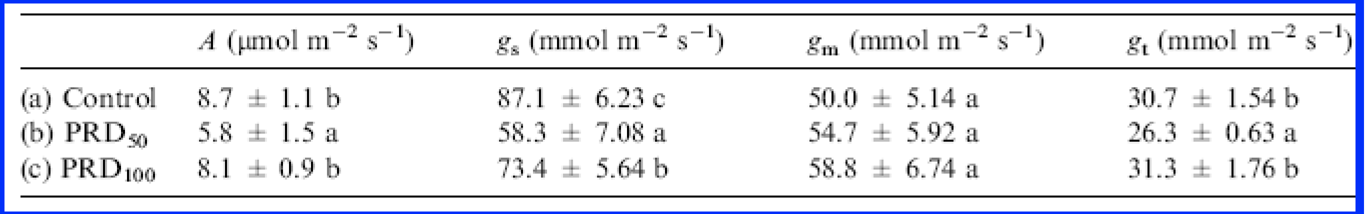
Tree Physiology 29, 685–696

Partial root zone drying: regulation of photosynthetic limitations and antioxidant enzymatic activities in young olive (*Olea europaea*) saplings

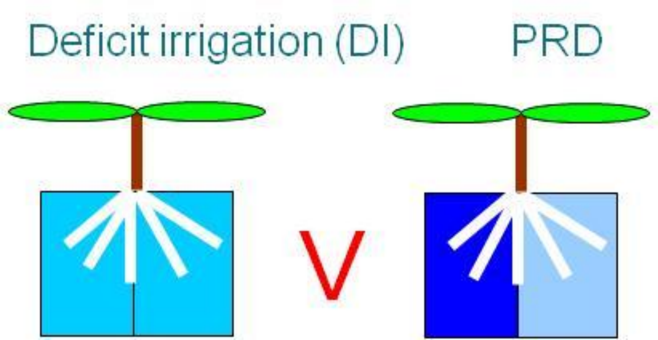
BADIA AGANCHICH,[1] SAID WAHBI,[1] FRANCESCO LORETO[2]
and MAURO CENTRITTO[2,3]



	A_{max}	J_{max}	V_{cmax}
Control (standard)	15.30 ± 0.23 a	74.48 ± 1.10 a	51.01 ± 2.27 a
PRD_{50} (standard)	14.91 ± 0.31 a	74.23 ± 0.85 a	50.48 ± 0.95 a
PRD_{100} (standard)	15.26 ± 0.25 a	74.62 ± 0.84 a	50.21 ± 0.96 a
Control (pre-conditioned)	16.97 ± 0.28 b	78.73 ± 1.08 b	52.80 ± 1.12 a
PRD_{50} (pre-conditioned)	16.90 ± 0.29 b	78.77 ± 1.82 b	52.69 ± 1.94 a
PRD_{100} (pre-conditioned)	16.87 ± 0.32 b	79.51 ± 1.13 b	53.01 ± 1.85 a

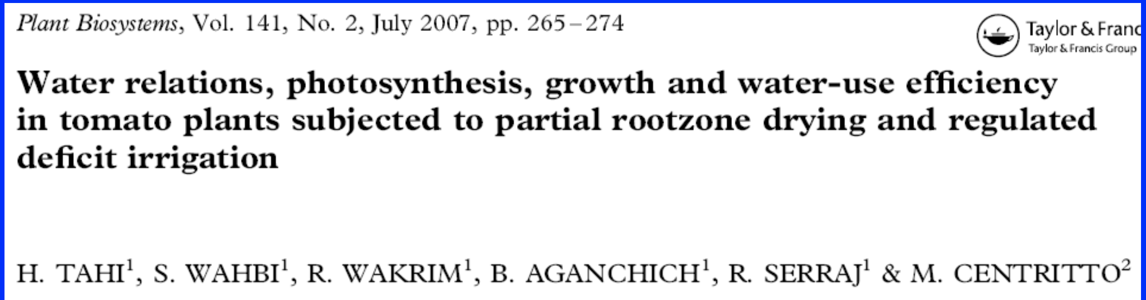


	A (μmol m^{-2} s^{-1})	g_s (mmol m^{-2} s^{-1})	g_m (mmol m^{-2} s^{-1})	g_t (mmol m^{-2} s^{-1})
(a) Control	8.7 ± 1.1 b	87.1 ± 6.23 c	50.0 ± 5.14 a	30.7 ± 1.54 b
(b) PRD_{50}	5.8 ± 1.5 a	58.3 ± 7.08 a	54.7 ± 5.92 a	26.3 ± 0.63 a
(c) PRD_{100}	8.1 ± 0.9 b	73.4 ± 5.64 b	58.8 ± 6.74 a	31.3 ± 1.76 b



Deficit irrigation (DI) PRD

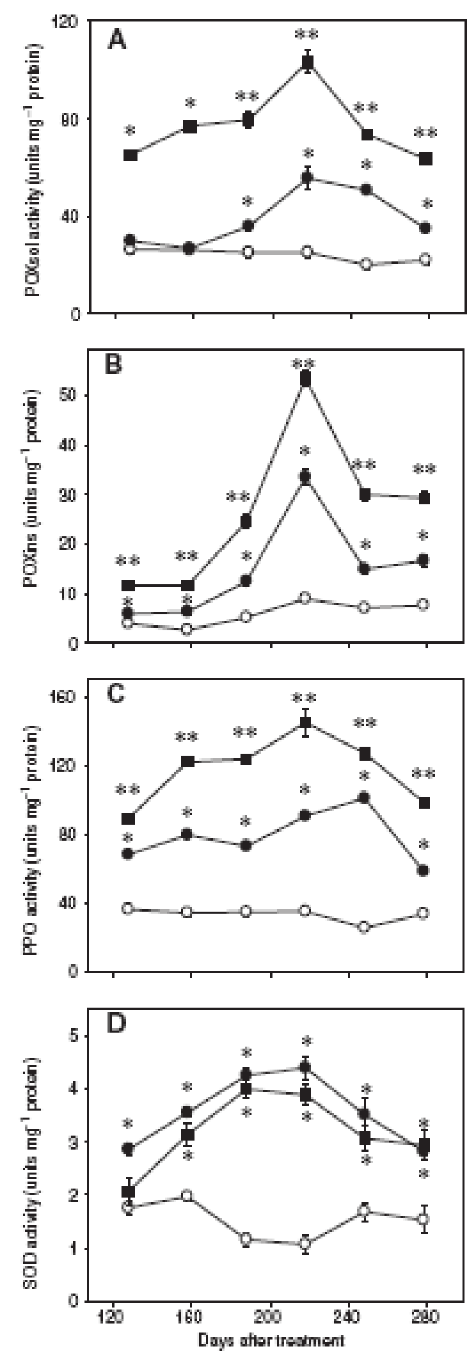
V



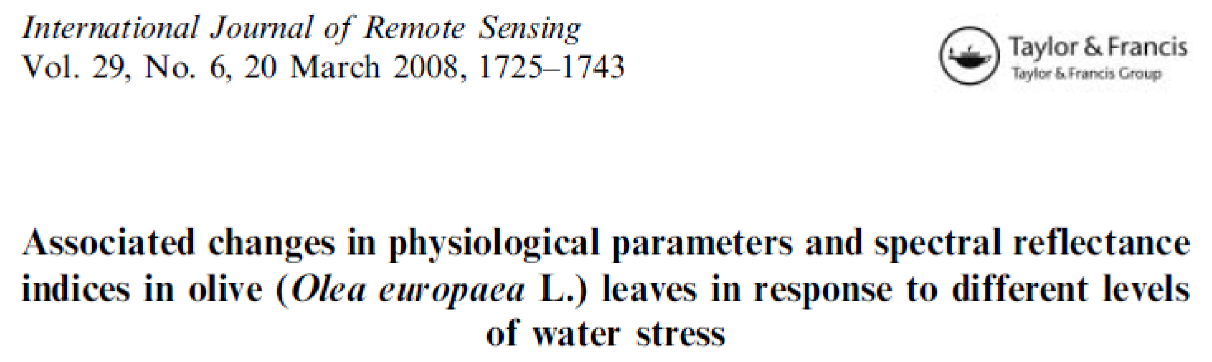
Plant Biosystems, Vol. 141, No. 2, July 2007, pp. 265 – 274

Water relations, photosynthesis, growth and water-use efficiency in tomato plants subjected to partial rootzone drying and regulated deficit irrigation

H. TAHI[1], S. WAHBI[1], R. WAKRIM[1], B. AGANCHICH[1], R. SERRAJ[1] & M. CENTRITTO[2]



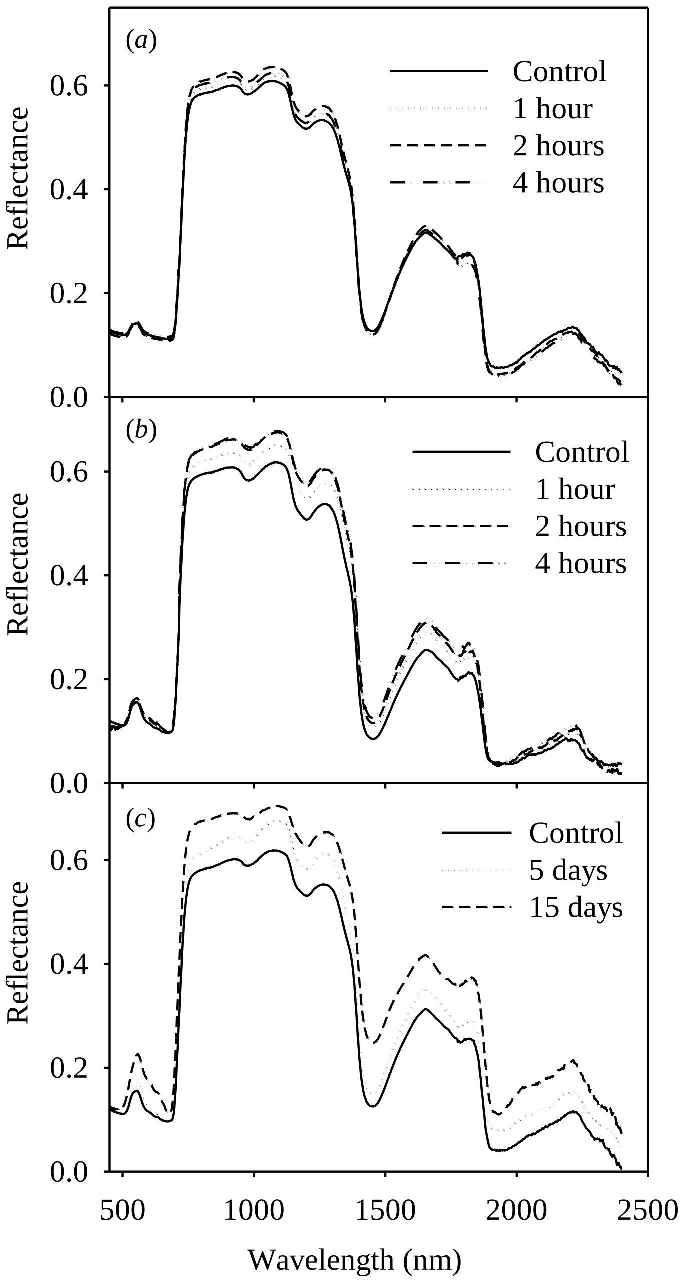
Assessing changes in physiological parameters induced by water stress using remotely sensed vegetation indices



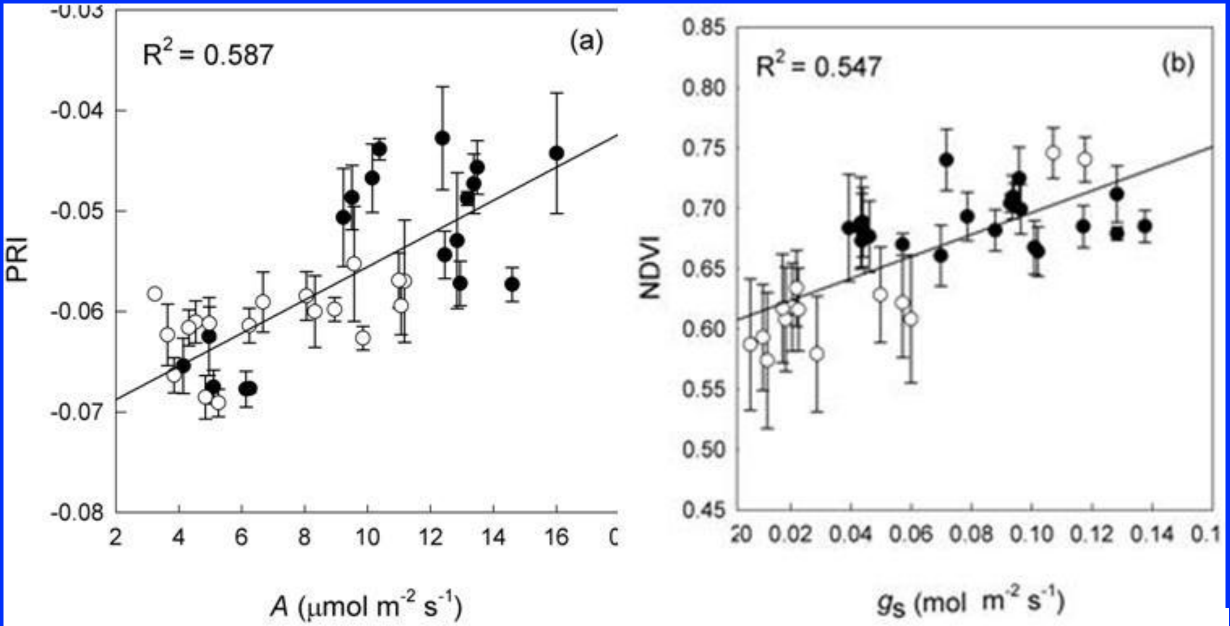
International Journal of Remote Sensing
Vol. 29, No. 6, 20 March 2008, 1725–1743

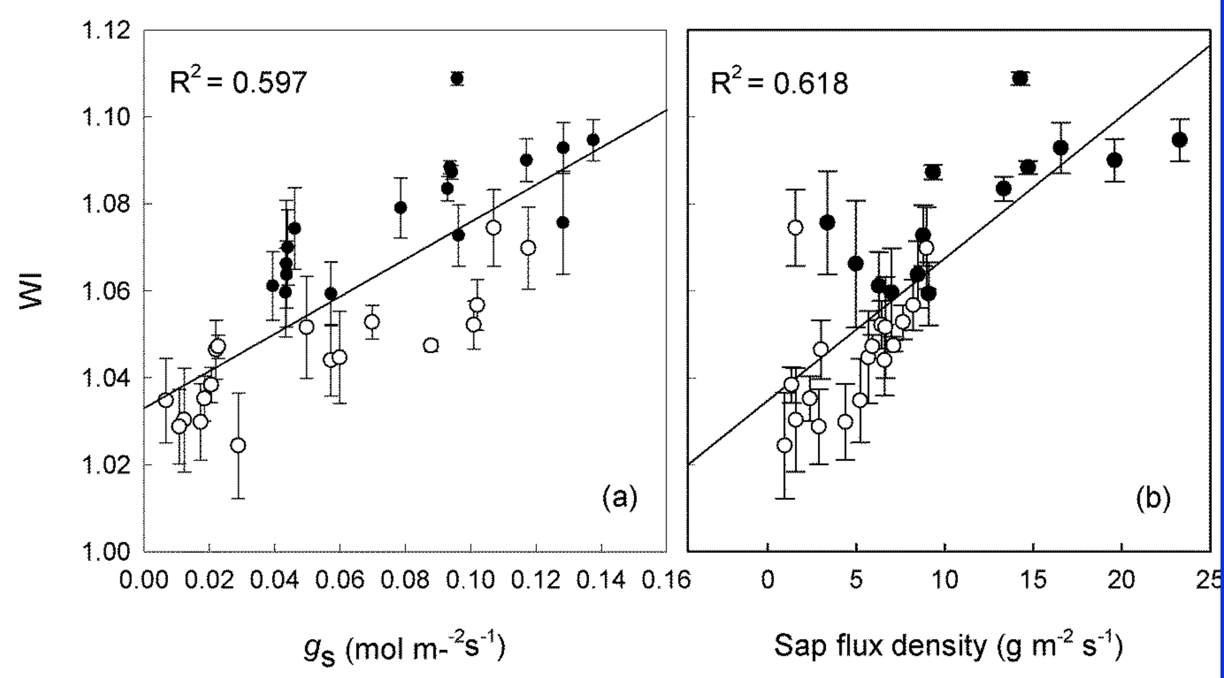
Taylor & Francis
Taylor & Francis Group

Associated changes in physiological parameters and spectral reflectance indices in olive (*Olea europaea* L.) leaves in response to different levels of water stress



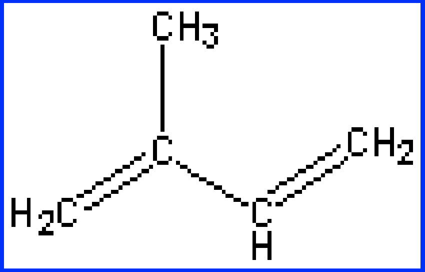
Marino *et al.*, *Scientia Horticulturae*, in press





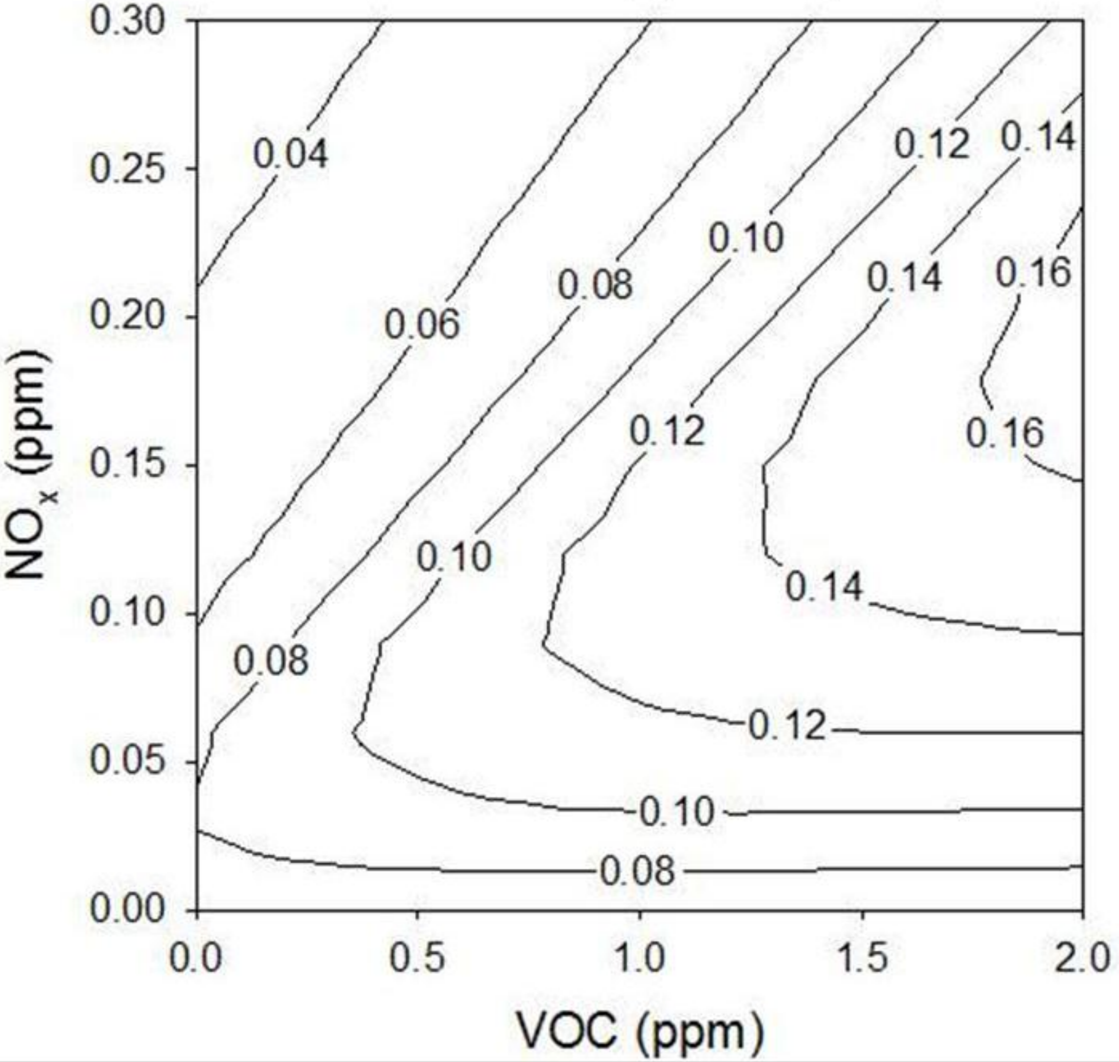
5) Biogenic volatile organic compounds (BVOC): a case-study in biosphere-atmosphere interactions

Terpenoids, or terpenes, are derived by repetitive fusion of branched five-carbon units, these monomers generally are referred to as isoprene units. For these reasons, the volatile terpenoids are often called isoprenoids



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).**



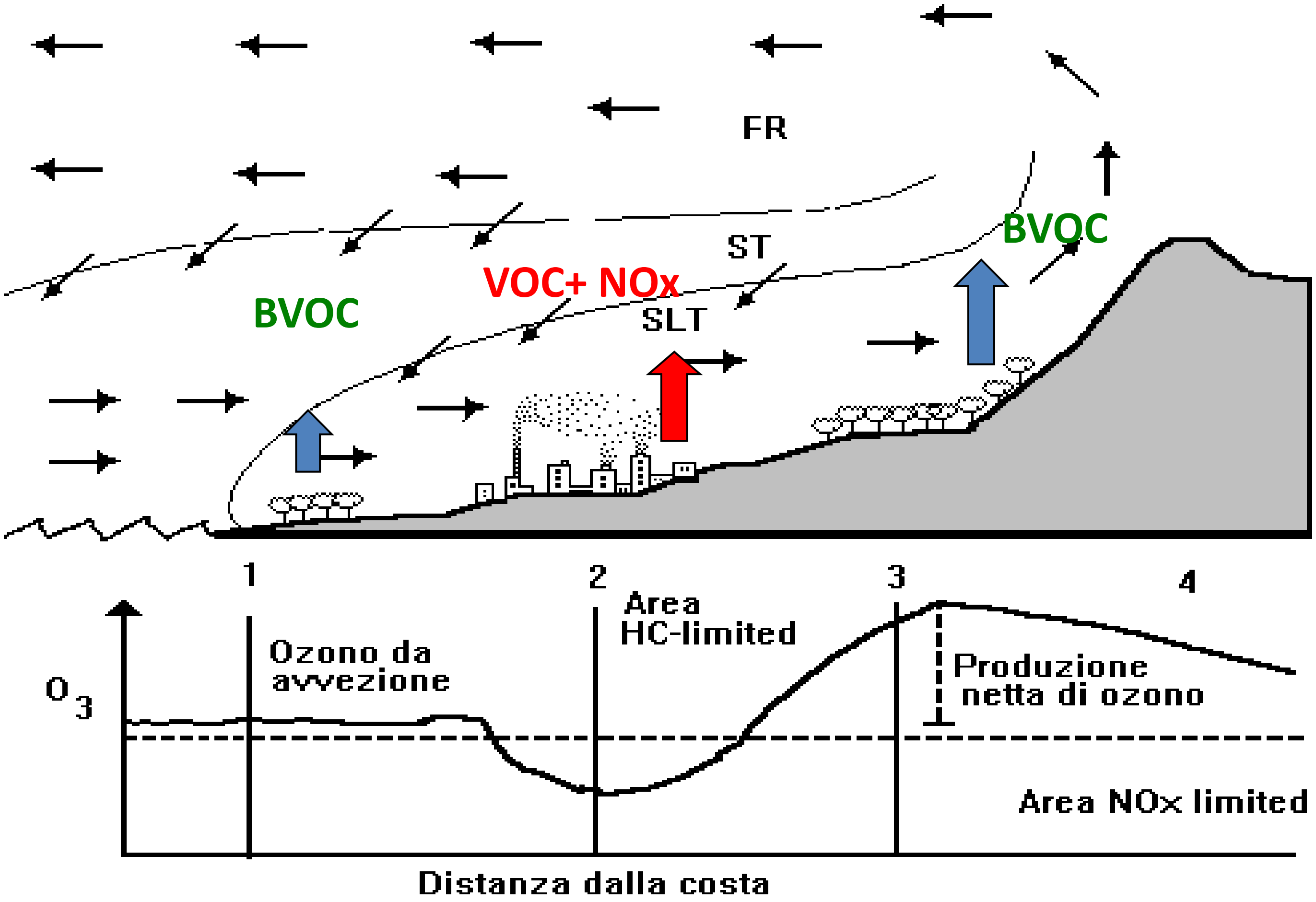
Bernacchi *et al.*, (2012 in press).

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

why the Mediterranean
is a “hot spot” for BVOC and
photochemical pollution……

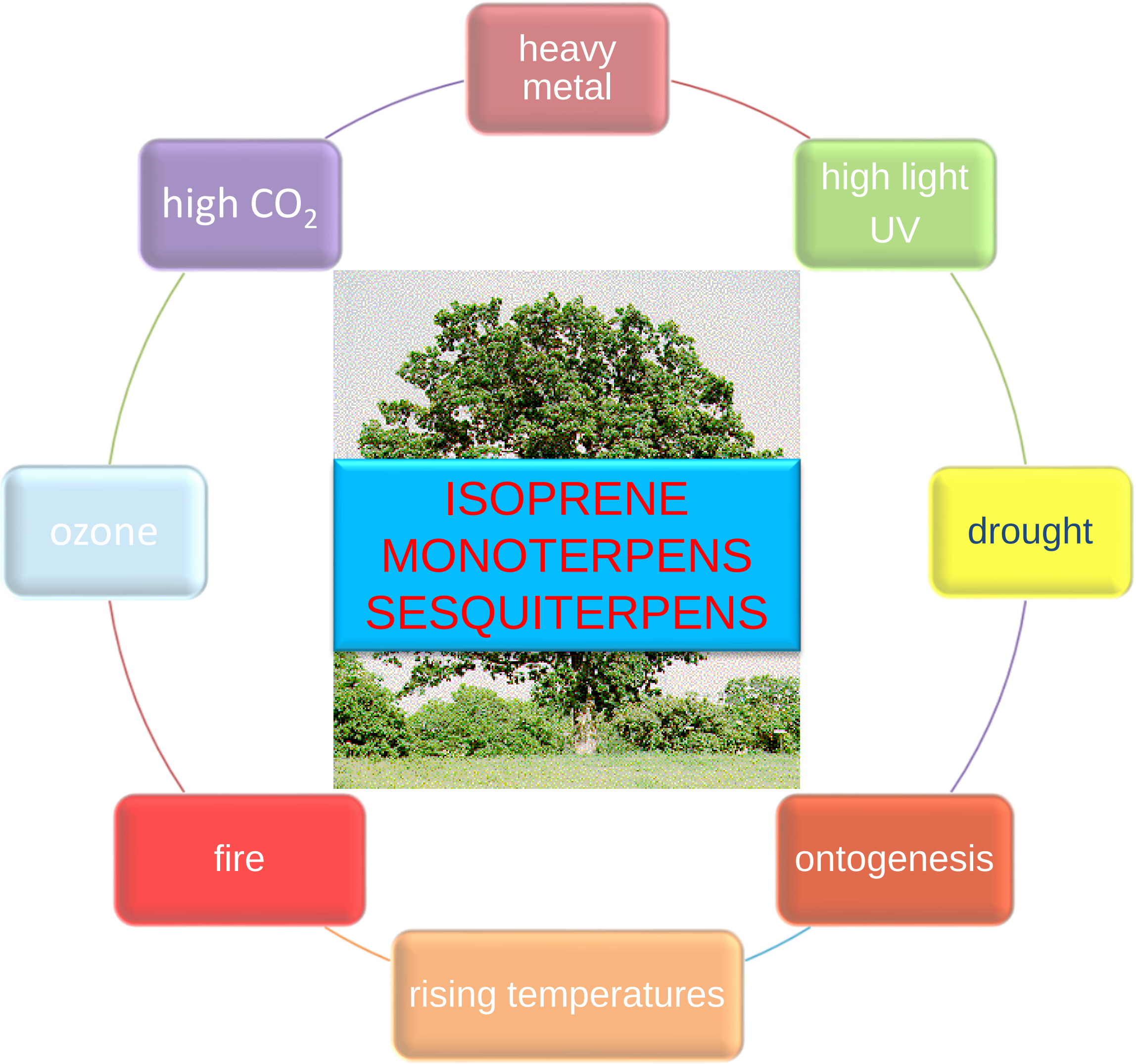
….along the coasts



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

BVOC from the biological perspective: open questions.

Isoprenoid emission in a changing environment



heavy metal

high light UV

drought

ontogenesis

rising temperatures

fire

ozone

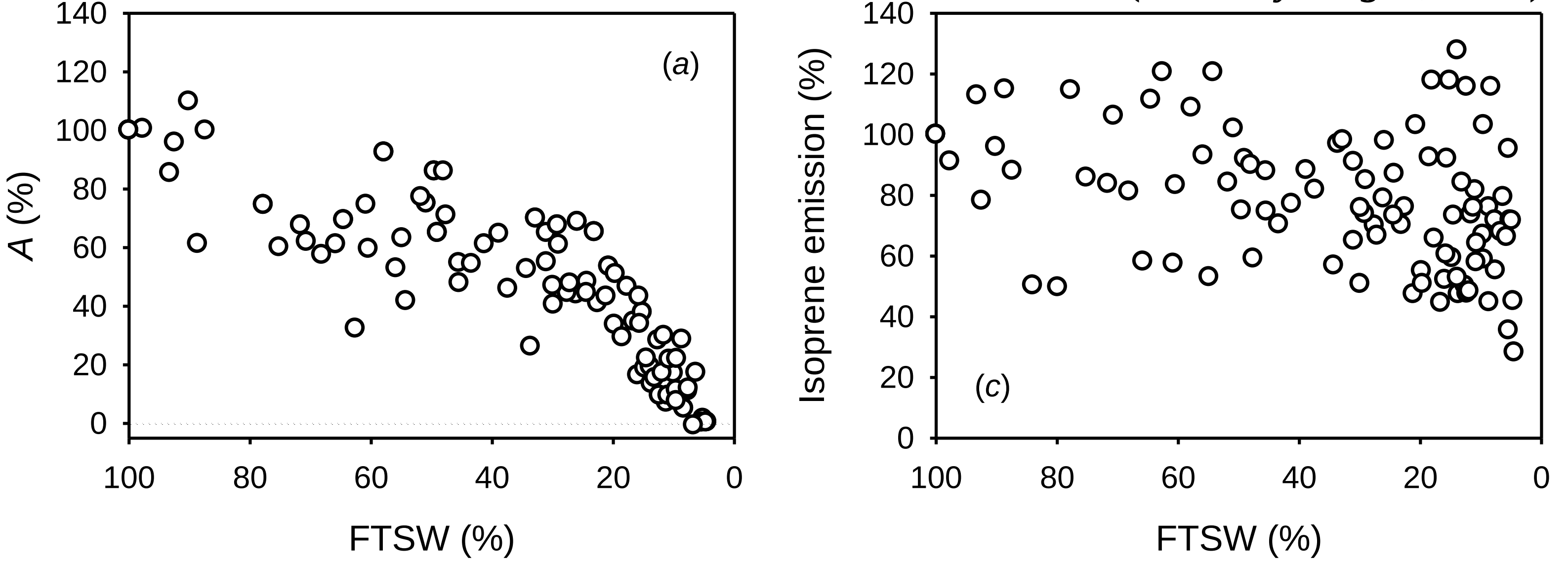
high CO_2

ISOPRENE
MONOTERPENS
SESQUITERPENS

Drought kinetics

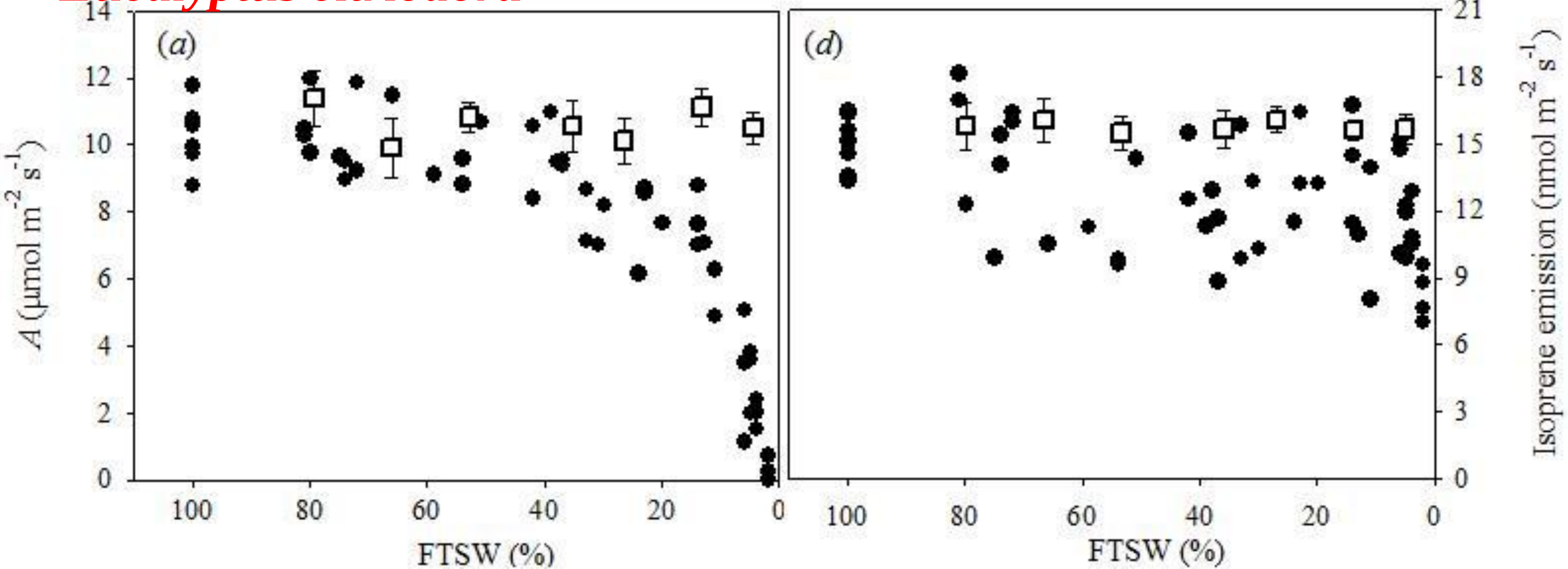
Poplar

Brilli *et al*. (*New Phytologist*, 2007)



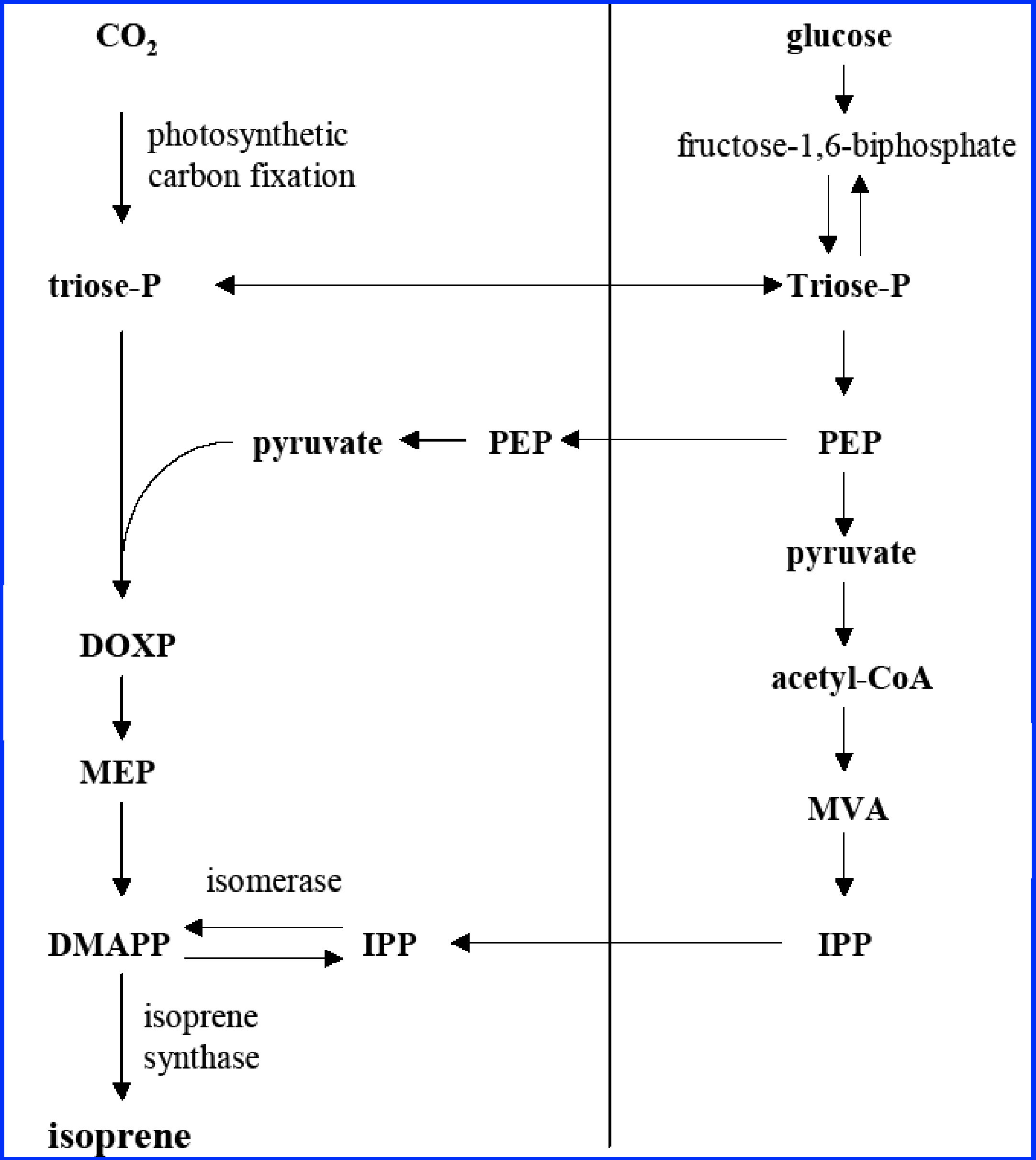
Eucalyptus citriodora

Brilli *et al*. (*Journal of Experimental Botany*, submitted)



Chloroplast: ***DOXP pathway***

Cytosol: ***MVA pathway***



CO_2

photosynthetic carbon fixation

triose-P

pyruvate

PEP

DOXP

MEP

isomerase

DMAPP

IPP

isoprene synthase

isoprene

glucose

fructose-1,6-biphosphate

Triose-P

PEP

pyruvate

acetyl-CoA

MVA

IPP

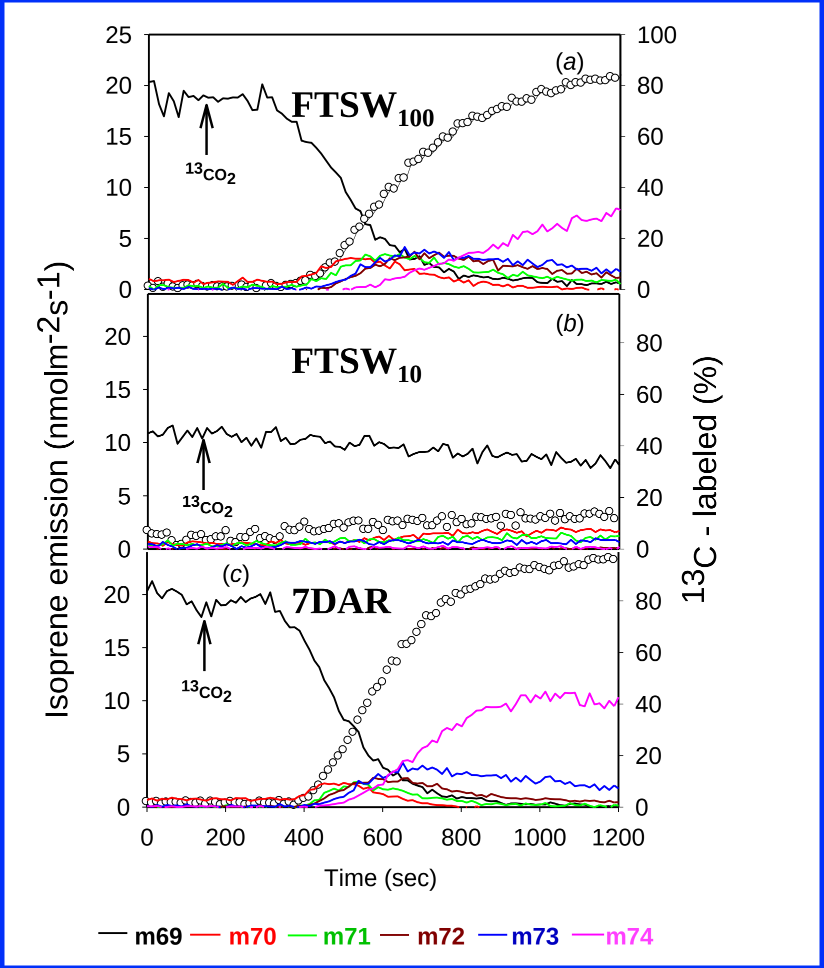
Non-stored isoprenoids are emitted through a novel chloroplastic pathway

Photosynthesis-dependent

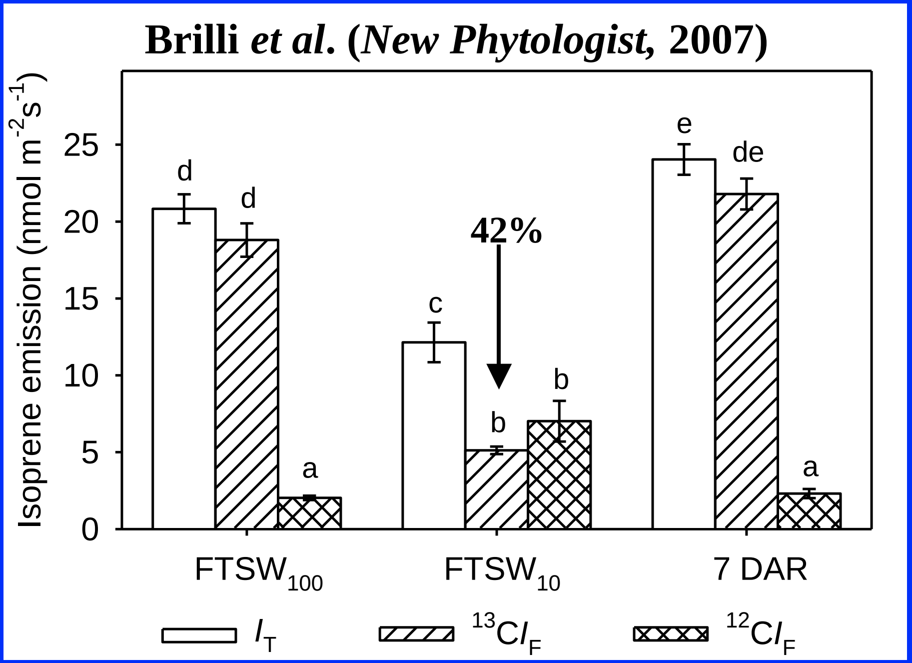
Schematic representation of the mevalonate-independent isoprene biosynthesis pathway, and possible coupling to cytosolic glucose metabolism through the mevalonate-dependent pathway.

DOXP: 1-Deoxy-D-xylulose-5-phosphate
DMAPP: dimethylallyl diphosphate
IPP: isopenthenyl diphosphate
MEP: 2-C-methyl-D-erythritol-4-P
MVA: mevalonic acid
PEP: phosphoenolpyruvate

$^{13}CO_2$ incorporation in the isoprene molecule assessed by Proton Transfer Reaction - Mass Spectrometry: *in vivo* assessment of the contribution of alternative carbon sources for isoprene production



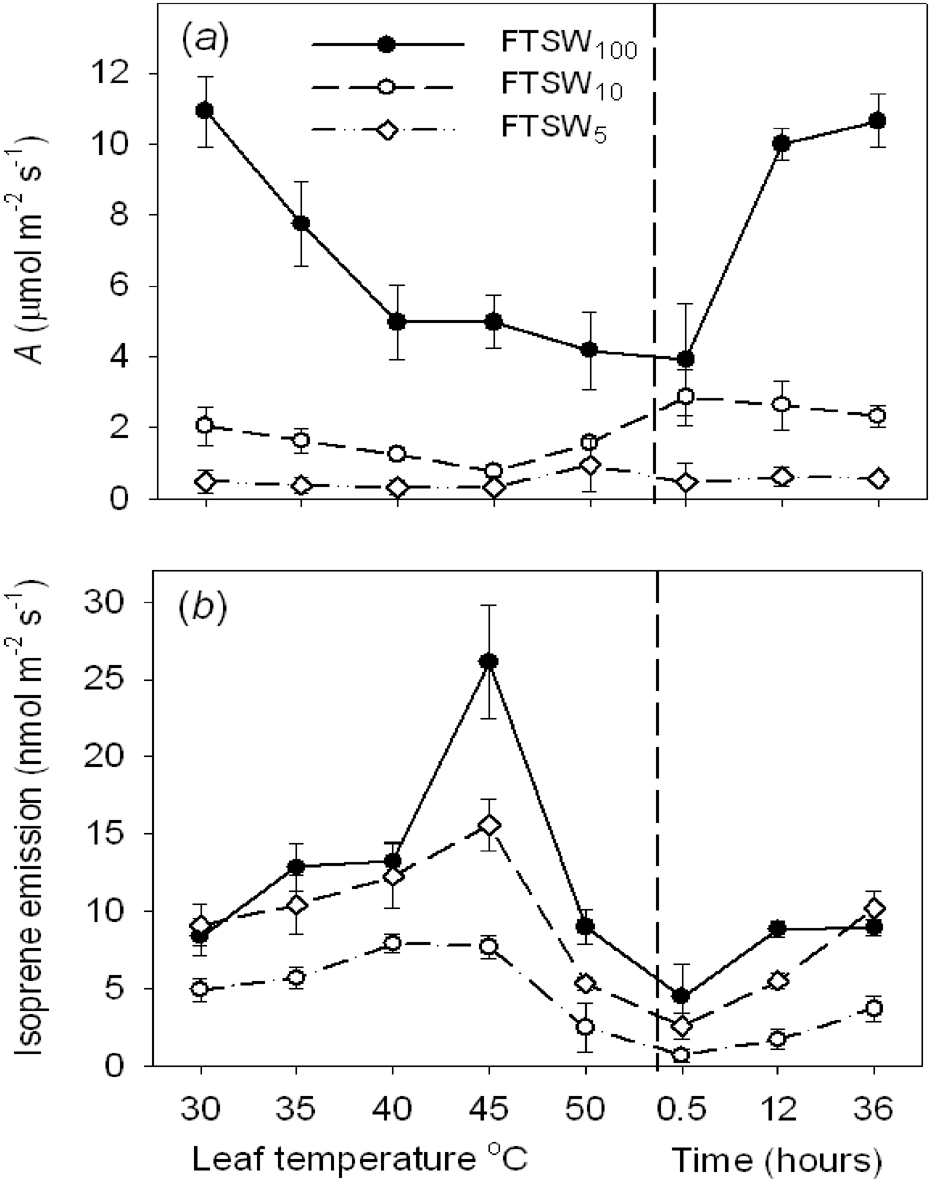
Different colors identify m/z 69 (unlabelled isoprene) and 70-74 (partially or totally labeled isoprene). Circles = percentage of ^{13}C in the total carbon emitted as isoprene.



Emission of total isoprene (I_T) and of its ^{13}C ($^{13}CI_F$) and ^{12}C (^{12}C I_F) isotope fractions measured after 15 min of $^{13}CO_2$ fumigation. The ^{12}C isotope fraction corresponds to the mass 69^+ (i.e. unlabeled isoprene isotope), whereas the ^{13}C isotope fraction is given by the sum of the isotope masses 70^+-74^+ (assuming that if the $^{13}CO_2$ fumigation had lasted longer all the isotopes masses 70^+-73^+ would have been converted in the isotope mass 74^+).

Interaction between drought and rising temperature

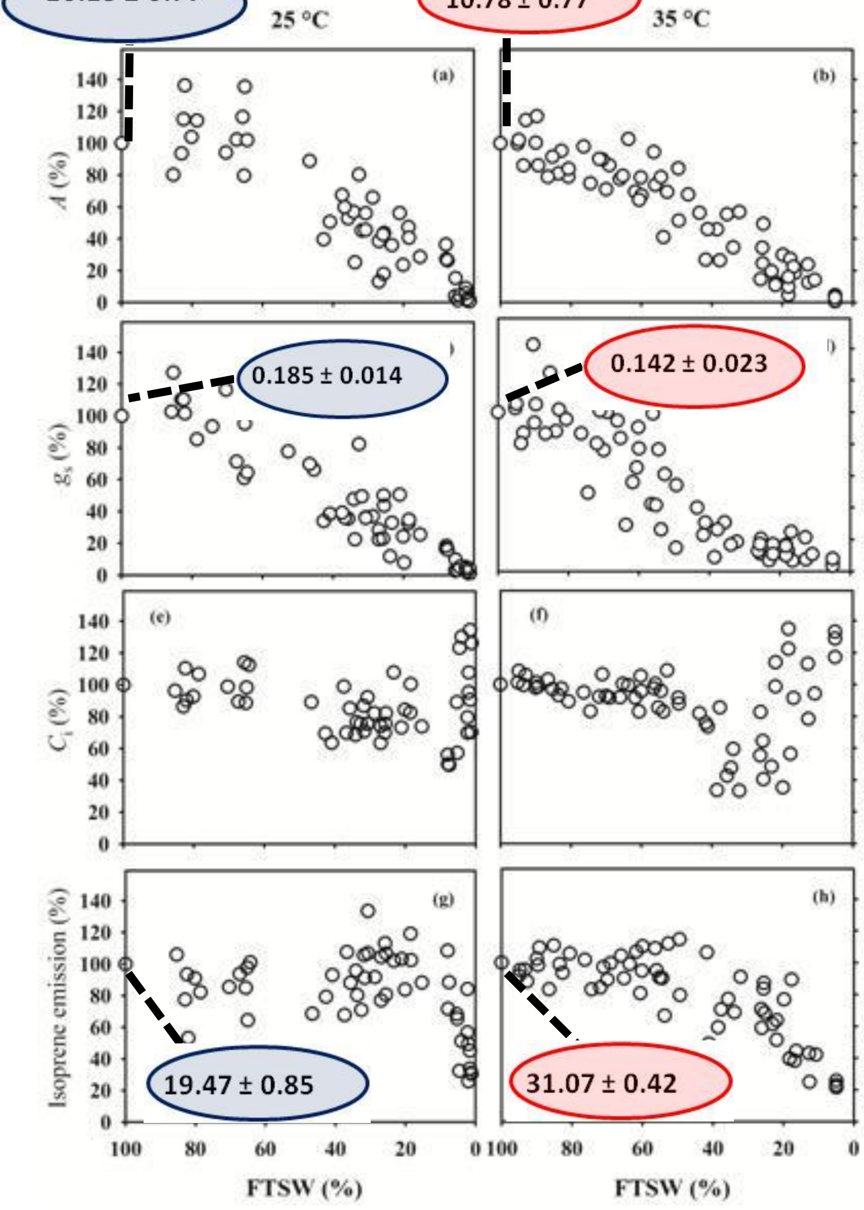
Brilli *et al*. (*Journal of Experimental Botany*, submitted)



$$\mathrm{FTSW} = \frac{(\mathrm{Daily}_{\mathrm{pot\ weight}} - \mathrm{Final}_{\mathrm{pot\ weight}})}{(\mathrm{Initial}_{\mathrm{pot\ weight}} - \mathrm{Final}_{\mathrm{pot\ weight}})}$$

Centritto *et al.* (*Tree Physiology*, 2011)

$$\mathrm{SWC} = \frac{(\mathrm{Daily}_{\mathrm{pot\ weight}} - \mathrm{Soil}_{\mathrm{dry\ mass}})}{(\mathrm{Initial}_{\mathrm{pot\ weight}} - \mathrm{Soil}_{\mathrm{dry\ mass}})}$$



16.13 ± 0.77

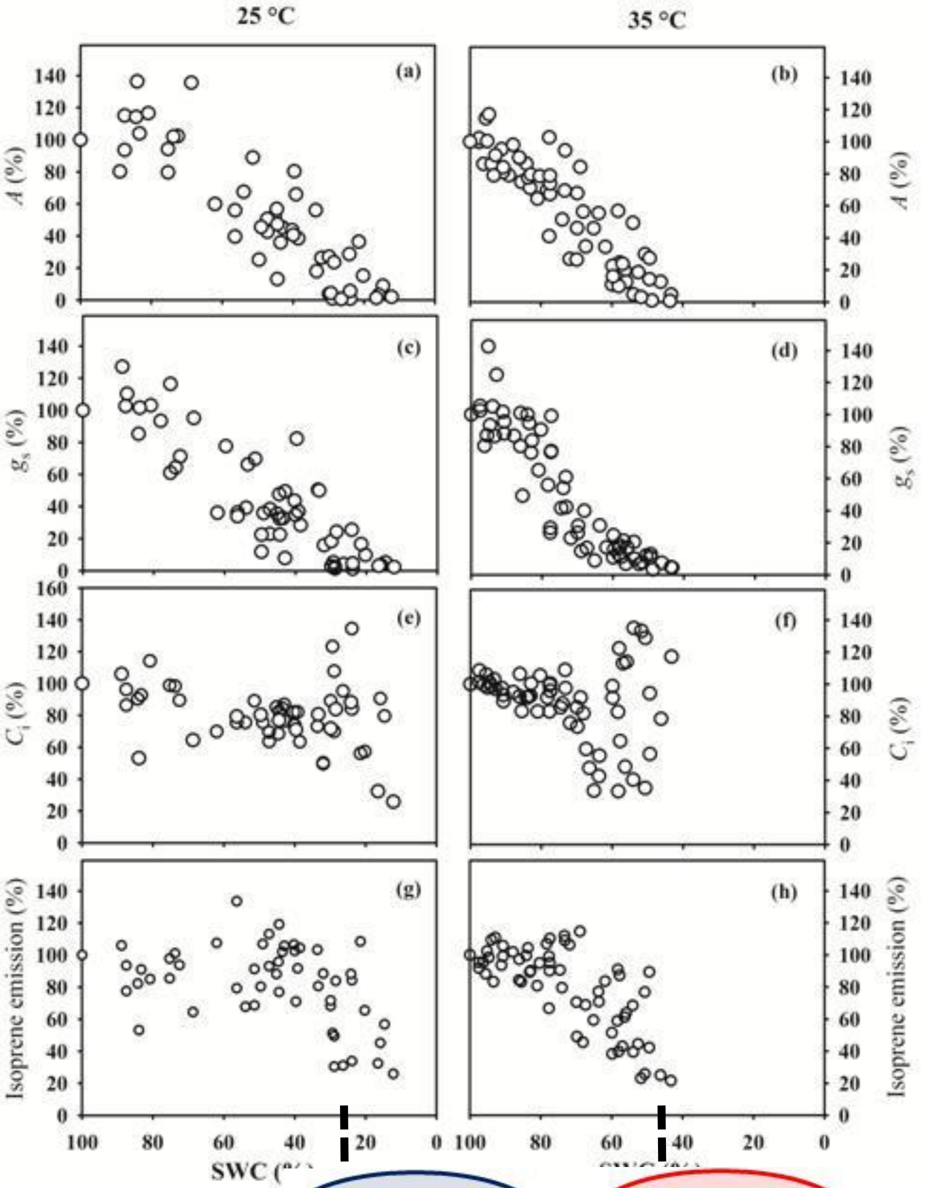
10.78 ± 0.77

0.185 ± 0.014

0.142 ± 0.023

19.47 ± 0.85

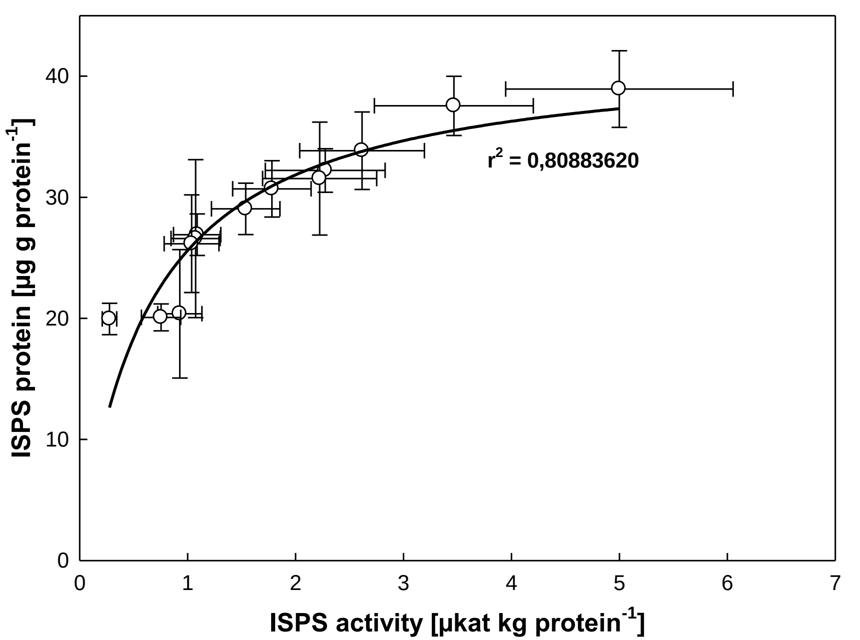
31.07 ± 0.42



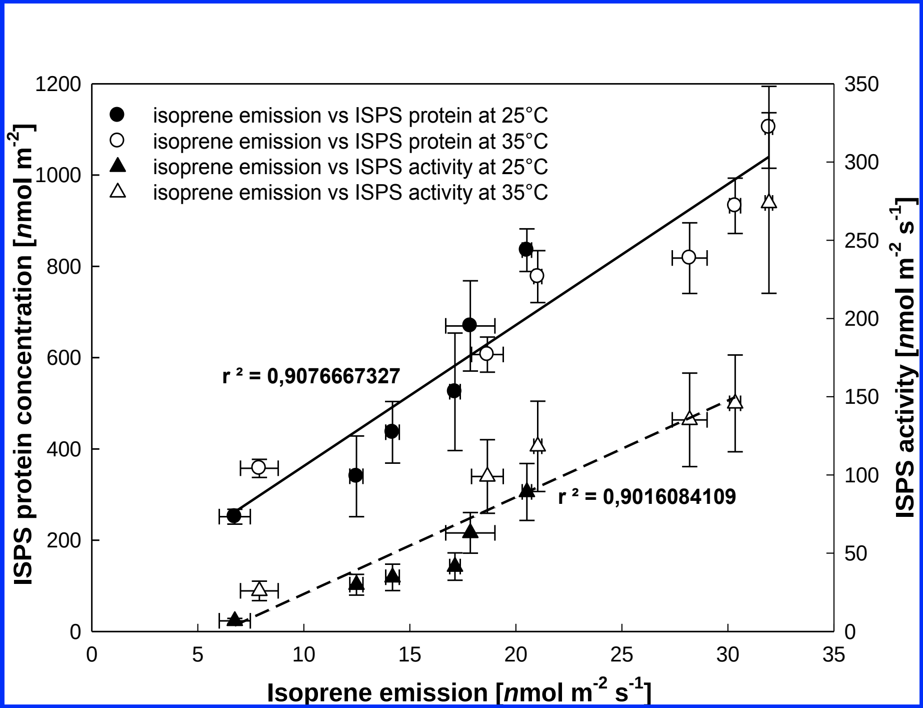
30.22 ± 2.02

45.16 ± 2.84

Fortunati et al, The Plant Journal (2008)



Correlation between isoprene synthase concentration and ISPS activity of *Populus nigra* plants grown at 25 and 35 °C under drought stress

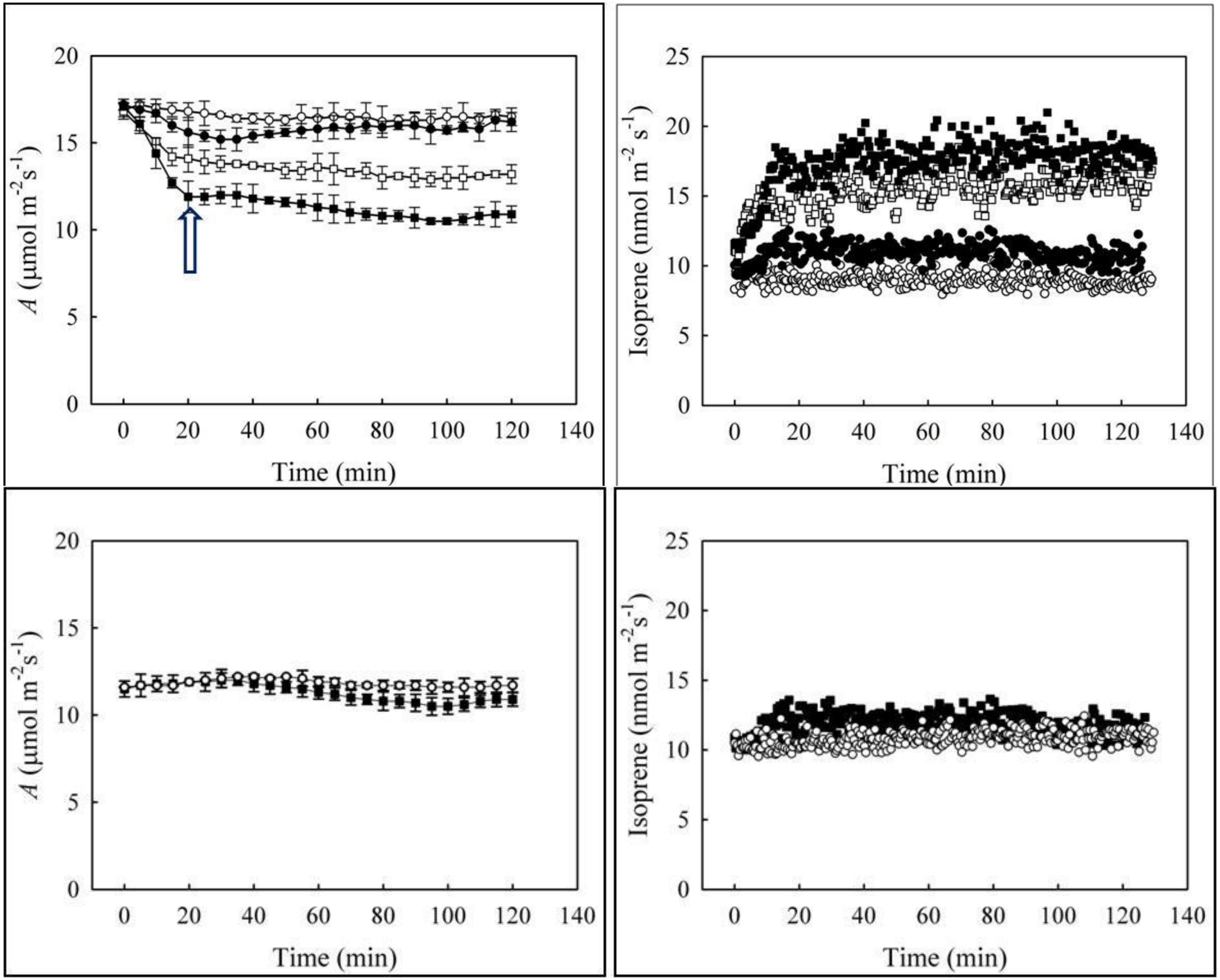


Correlation between isoprene emission and ISPS concentration in plants grown at 25 (●) and 35 °C (○), and the correlation between isoprene emission and ISPS activity of plants grown at 25 °C (▲) and 35 °C (△).

The mRNA transcript level, protein concentration and activity of isoprene synthase (ISPS) changed in concert with isoprene emission during drought stress.

UV-A intensity-response relationships

Pallozzi *et al*. (*Physiologia Plantarum*, in press)



○ 30 W m^{-2} ● 60 W m^{-2} □ 90 W m^{-2} ■ 120 W m^{-2}

UV-A intensity-response relationships

Pallozzi *et al*. (*Physiologia Plantarum*, in press)

	Flavonoids		**Chlorophyll**	
	Adaxial surface	*Abaxial surface*	*Adaxial surface*	*Abaxial surface*
Middle of July	0.73 ± 0.03 a	0.55 ± 0.01	4.75 ± 0.08	2.94 ± 0.09
Middle of September	1.35 ± 0.09 b	0.53 ± 0.01	4.40 ± 0.07	2.79 ± 0.08

UV-B effects on isoprene emission from transgenic tobacco

Isoprenoid emissions in response to blue light: *Populus x canadensis*, *Quercus ilex* and *Citrus reticulata*

Fire

High temperatures → **Isoprenoids emissions**

Schinus molle
Eucalyptus citriodora
Quercus ilex

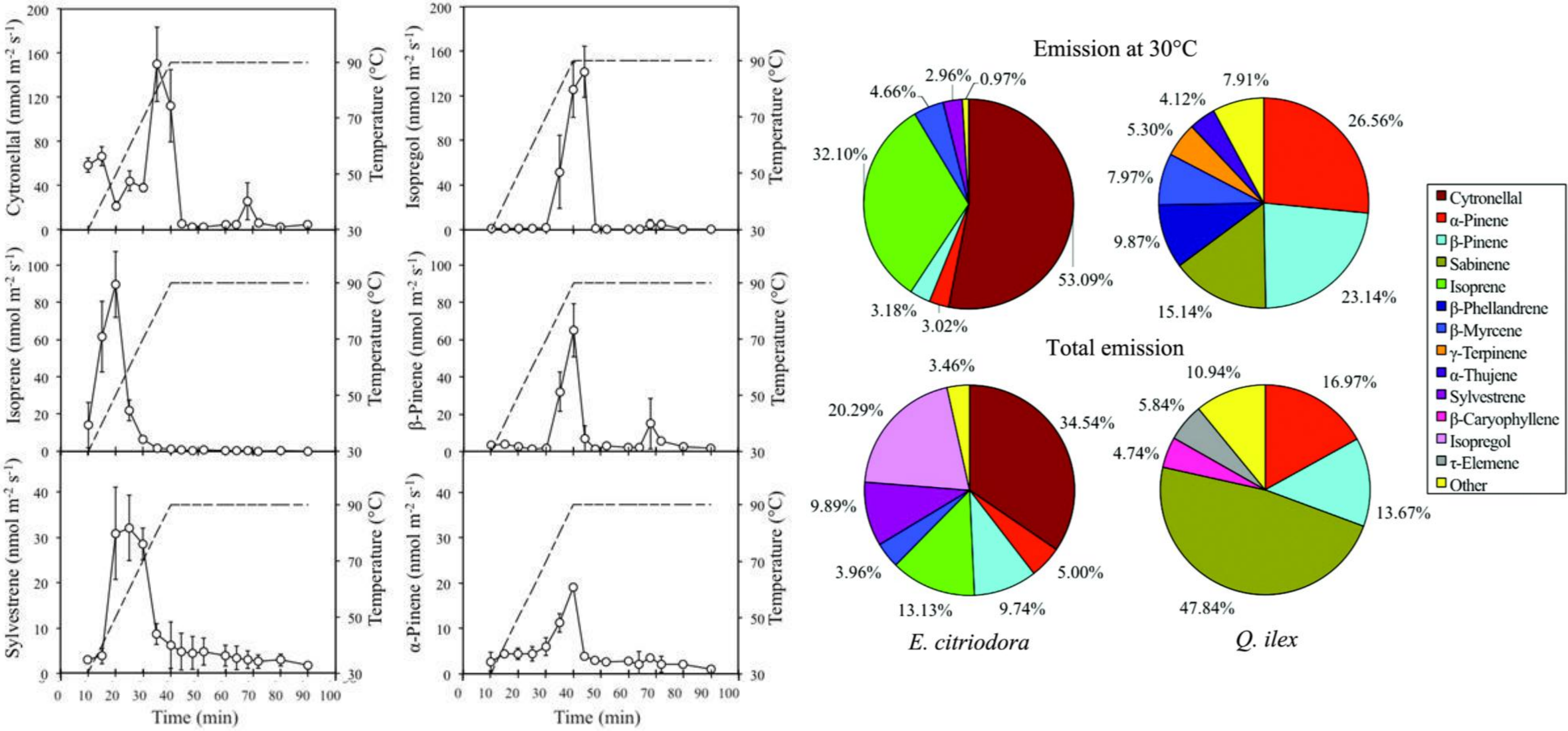
Schinus molle

Photosynthesis rates in *Schinus molle* planted at the distance of 2, 3 and 4 m from the plot edge before the fire and after 4, 24 and 48 hours after the fire event.

	2 m	3 m	4 m
Before fire	4.34 ± 0.93		
4 h	-1.8 ± 1. 70	0.37 ± 1.86	5.1 ± 0.14
24 h	9.75 ± 1.38	9.25 ± 3.08	7.20 ± 0.60
48 h	9.27 ± 0.80	11.88 ± 1.53	10.33 ± 0.36

Emission of the most abundant monoterpenes (nmol m^{-2}s^{-1}) by *Schinus molle* planted at the distance of 2, 3 and 4 m from the plot edge before the fire and after 4, 24 and 48 hours after the fire event.

Monoterpene	2 m	3 m	4 m	
Before fire				
α-phellandrene	9.27 ± 0.75			
α-pinene	9.58 ± 1.55			
β-phellandrene	507.88 ± 88.37			
β-pinene	12.39 ± 0.80			
β-myrcene	103.28 ± 64.53			
2-carene	2.758 ± 0.726			
sylvestrene	13.547 ± 6.506			
ocimene	4.446 ± 1.685			
Terpinen	5.470 ± 1.822			
lterpinolen	1.250 ± 0.305			
α-phellandrene	2.291 ± 0.411	0.968 ± 0.057	0.702 ± 0.106	***4 h***
α-pinene	12.343 ± 5.194	1.833 ± 0.189	1.430 ± 0.330	
β-phellandrene	113.676 ± 17.491	53.063 ± 2.389	31.959 ± 2.283	
β-pinene	10.176 ± 3.093	3.035 ± 0.286	2.053 ± 0.269	
β-myrcene	21.056 ± 1.148	15.690 ± 1.182	10.401 ± 0.749	
2-carene	1.367 ± 0.175	0	0	
sylvestrene	7.183 ± 0.095	2.812 ± 0.474	1.438 ± 0.233	
ocimene	0.655 ± 0.063	0	0	
Terpinen	4.257 ± 1.236	1.645 ± 0.231	1.122 ± 0.077	
lterpinolen	0.820 ± 0.080	0	0	
α-phellandrene	0.299 ± 0.012	0.194 ± 0.097	0	***24 h***
α-pinene	0.361 ± 0.065	0.608 ± 0.033	0.669 ± 0.016	
β-phellandrene	9.941 ± 1.522	6.870 ± 0.094	4.238 ± 0.503	
β-pinene	0.264 ± 0.016	0.658 ± 0.053	0.470 ± 0.094	
β-myrcene	0	0	0	
2-carene	0.316 ± 0.023	0.416 ± 0.070	0.619 ± 0.042	
sylvestrene	0.349 ± 0.027	0	0	
ocimene	0	0	0	
Terpinen	0	0	0	
lterpinolen	0	0	0	
α-phellandrene	0	0.128 ± 0.011	0	***48 h***
α-pinene	0.076 ± 0.009	1.991 ± 0.199	0.073 ± 0.006	
β-phellandrene	0	8.200 ± 0.589	0.512 ± 0.062	
β-pinene	0	2.241 ± 0.306	0.082 ± 0.008	
β-myrcene	0	0	0	
2-carene	0	0	0	
sylvestrene	0	0.561 ± 0.063	0.456 ± 0.051	
ocimene	0	0	0	
Terpinen	0	0	0	
lterpinolen	0	0	0	


Cytronellal (nmol m-2 s-1)
Isoprene (nmol m-2 s-1)
Sylvestrene (nmol m-2 s-1)
Isopregol (nmol m-2 s-1)
β-Pinene (nmol m-2 s-1)
α-Pinene (nmol m-2 s-1)
Temperature (°C)
Time (min)
0
10
20
30
40
50
60
70
80
90
100
120
160
200
Emission at 30°C
Total emission
E. citriodora
Q. ilex
53.09%
32.10%
4.66%
2.96%
0.97%
3.18%
3.02%
26.56%
23.14%
15.14%
9.87%
7.97%
5.30%
4.12%
7.91%
34.54%
20.29%
9.89%
3.96%
13.13%
9.74%
5.00%
3.46%
16.97%
13.67%
47.84%
4.74%
5.84%
10.94%
Cytronellal
α-Pinene
β-Pinene
Sabinene
Isoprene
β-Phellandrene
β-Myrcene
γ-Terpinene
α-Thujene
Sylvestrene
β-Caryophyllene
Isopregol
τ-Elemene
Other

Thank you!