Enhanced tropospheric ozone and forest ecosystems –

relevance for global carbon storage, forest products and climate change

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Tropospheric Ozone

Rationale :

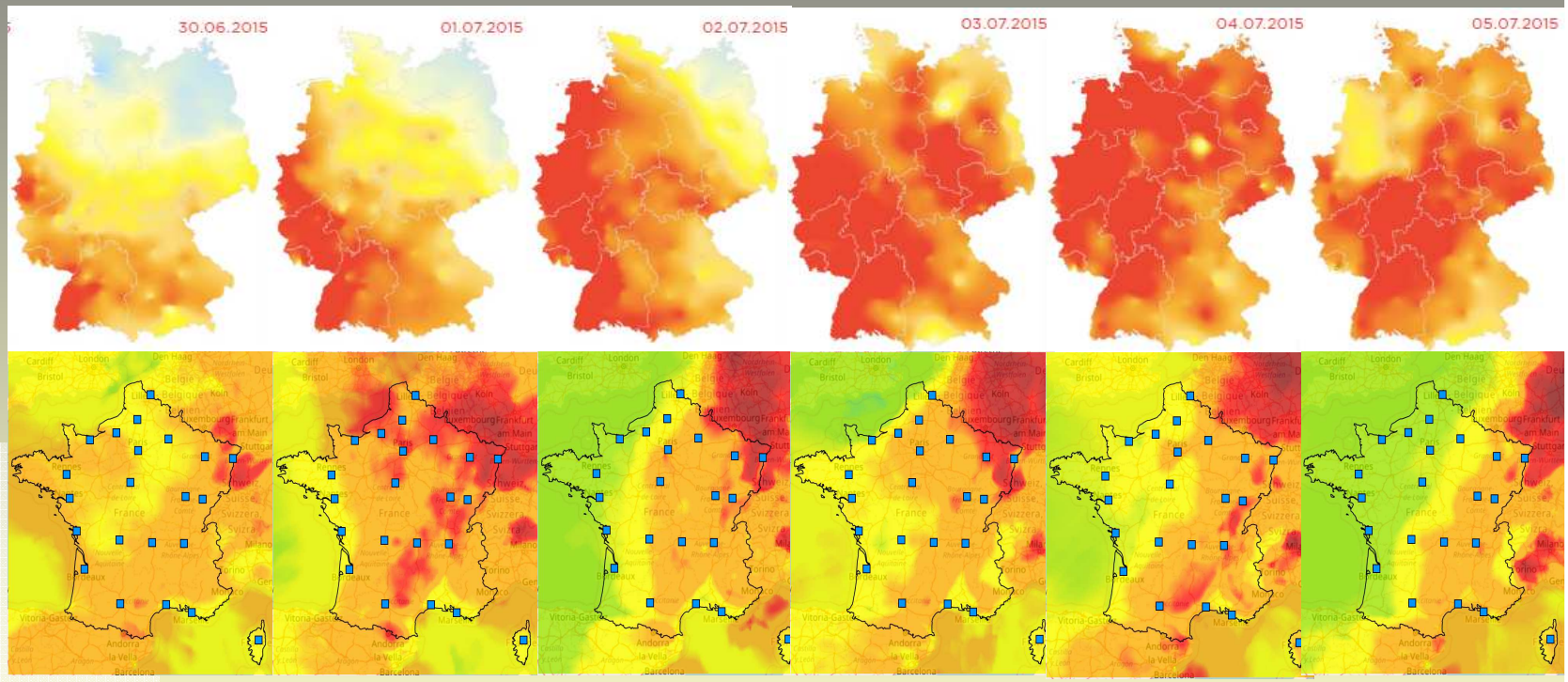
1. **Why enhanced tropospheric ozone of global concern ?**

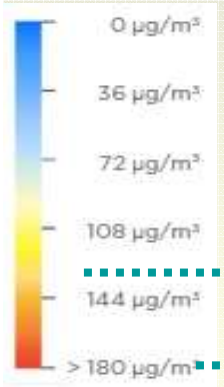
2. Risks for forest ecosystems:
   - previous knowledge
   - current knowledge

3. Relevance for forest products/services ?

4. Needs, Perspectives & Conclusions

Ozone Regimes
France - Germany 2015





60 ppb

90 ppb

Information threshold for public

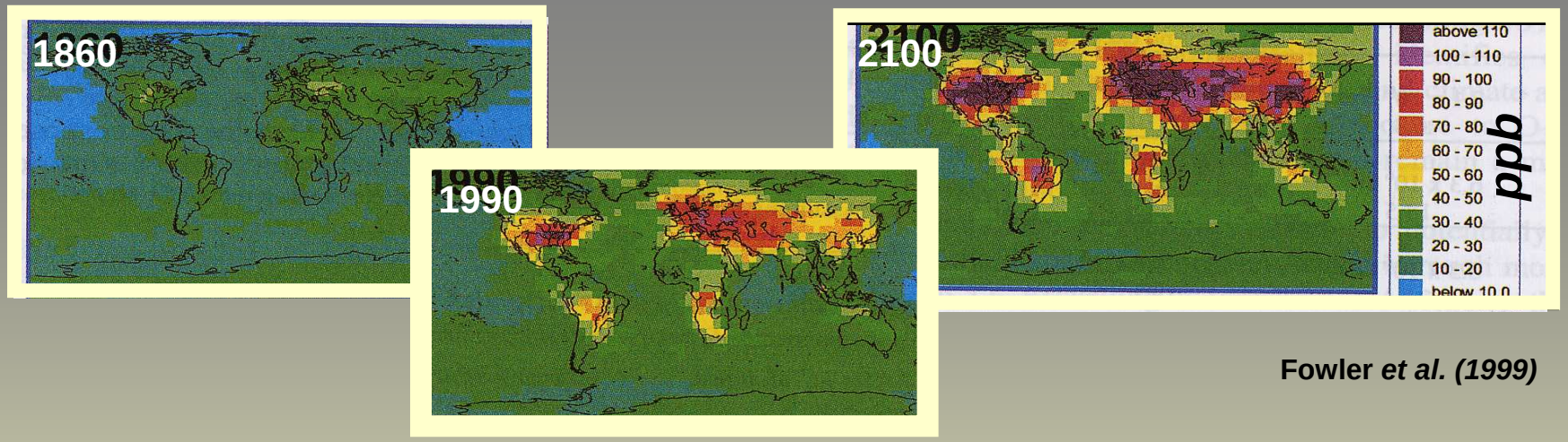
Long-term target

First week in July 2015

Quelle: Umweltbundes-amt und Bundesländer

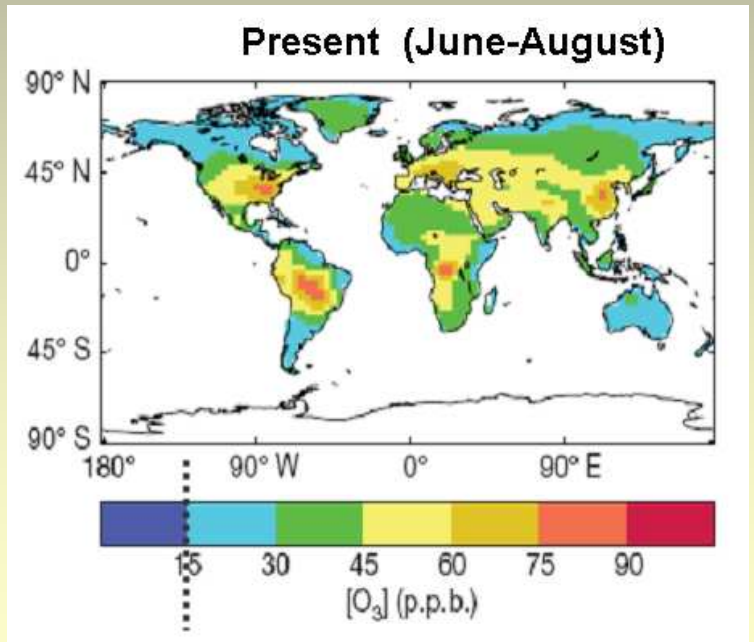
PREV'AIR

http://www2.prevair.org/



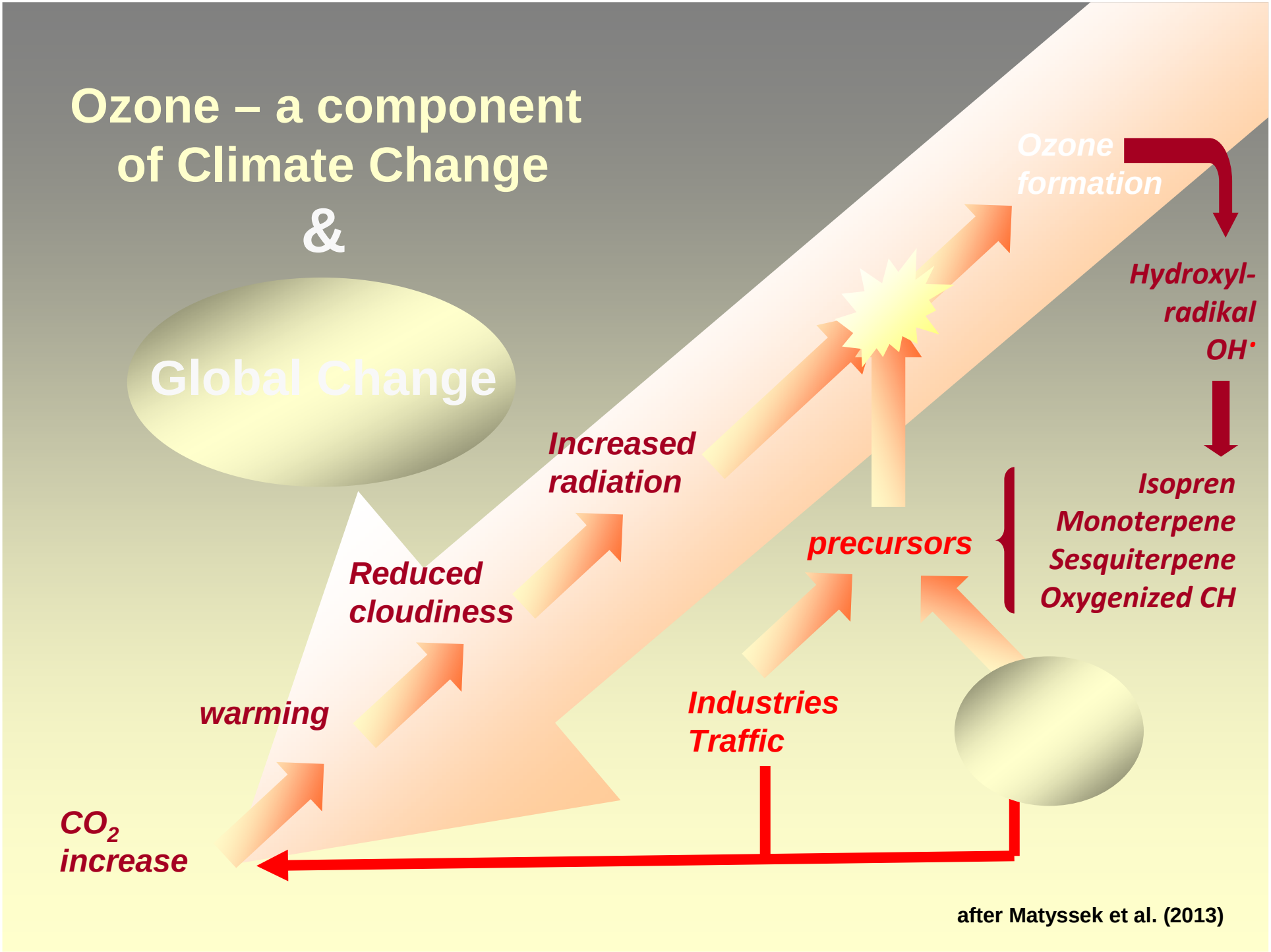
Fowler *et al. (1999)*

Ozone Regimes Worldwide



Pre-industrial

Sitch et al. (2007)


Ozone – a component
of Climate Change
&
Global Change
Ozone
formation
Hydroxyl-
radikal
OH·
Isopren
Monoterpene
Sesquiterpene
Oxygenized CH
precursors
Increased
radiation
Reduced
cloudiness
warming
Industries
Traffic
CO2
increase
after Matyssek et al. (2013)

Air pollution as a component of climate change

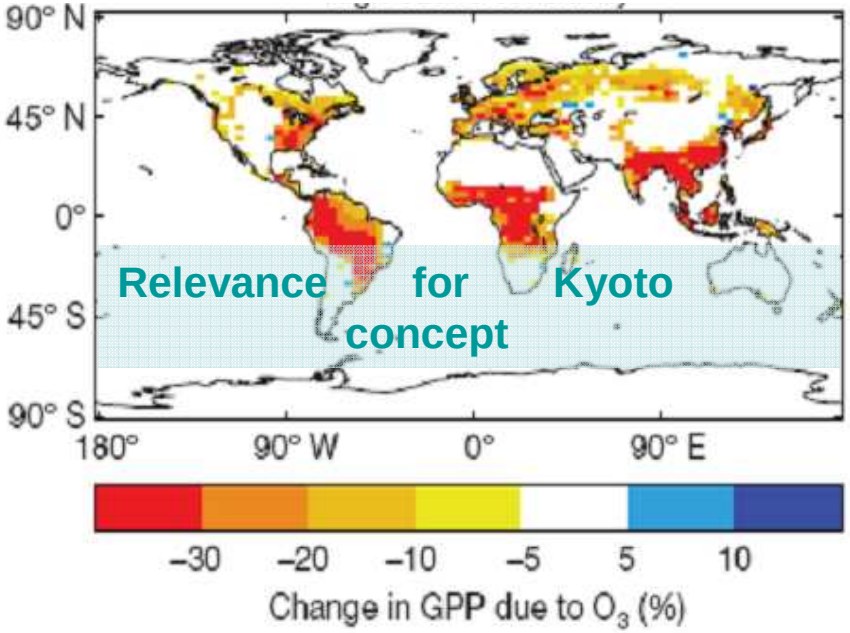
Similarly:
Ireland within the long-range O_3 plume of N-America

Prognoses for the 21st century

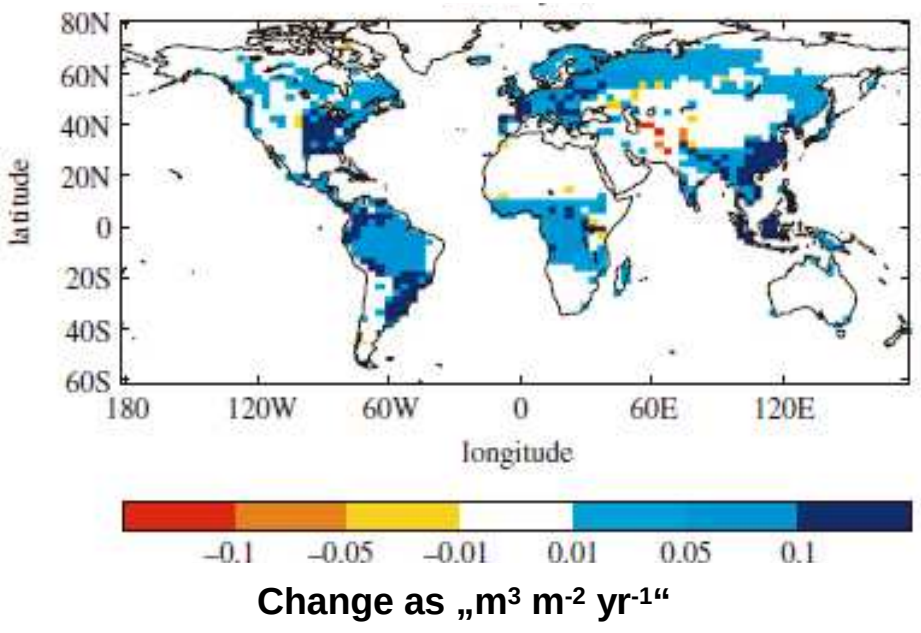
O_3 mitigates global C sink strength & enhances water run-off

O_3 impact on

gross primary productivity (GPP) & water run-off



Sitch et al. (2007)



Huntingford et al. (2011)

So far:

based on modeling, not empirically validated

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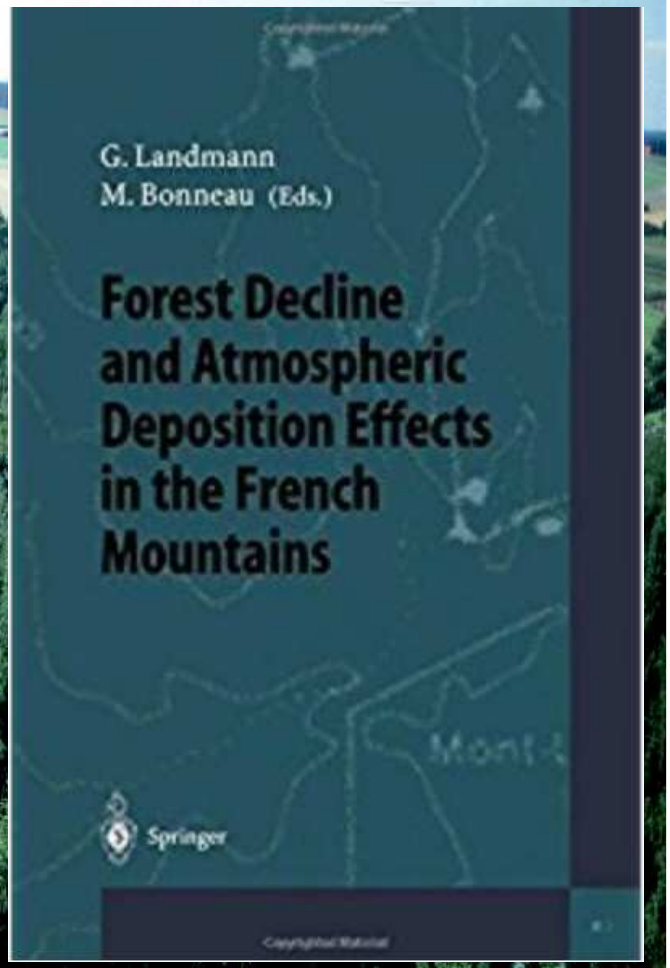
Ozone impact on forest ecosystems

1980/90s: Prognoses of discussions on Novel Forest Decline

Belief: Ozone = sudden tree killer, leaving savannas only in Central Europe

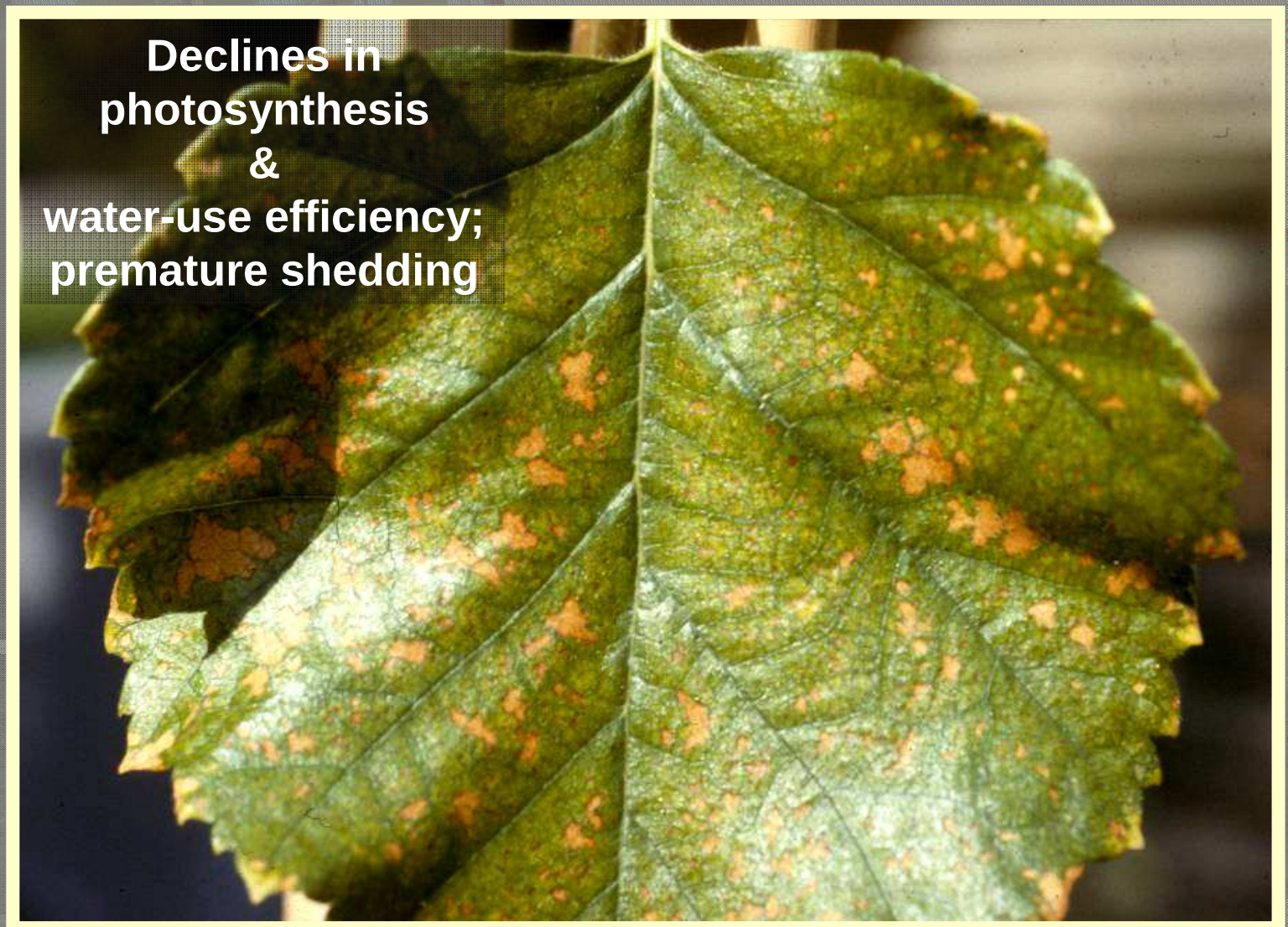
Krause et al. (1986)
Forest decline in Europe,
Development and possible causes
Water, Soil & Air Pollution 31: 647–668

1995



French program Deforpa

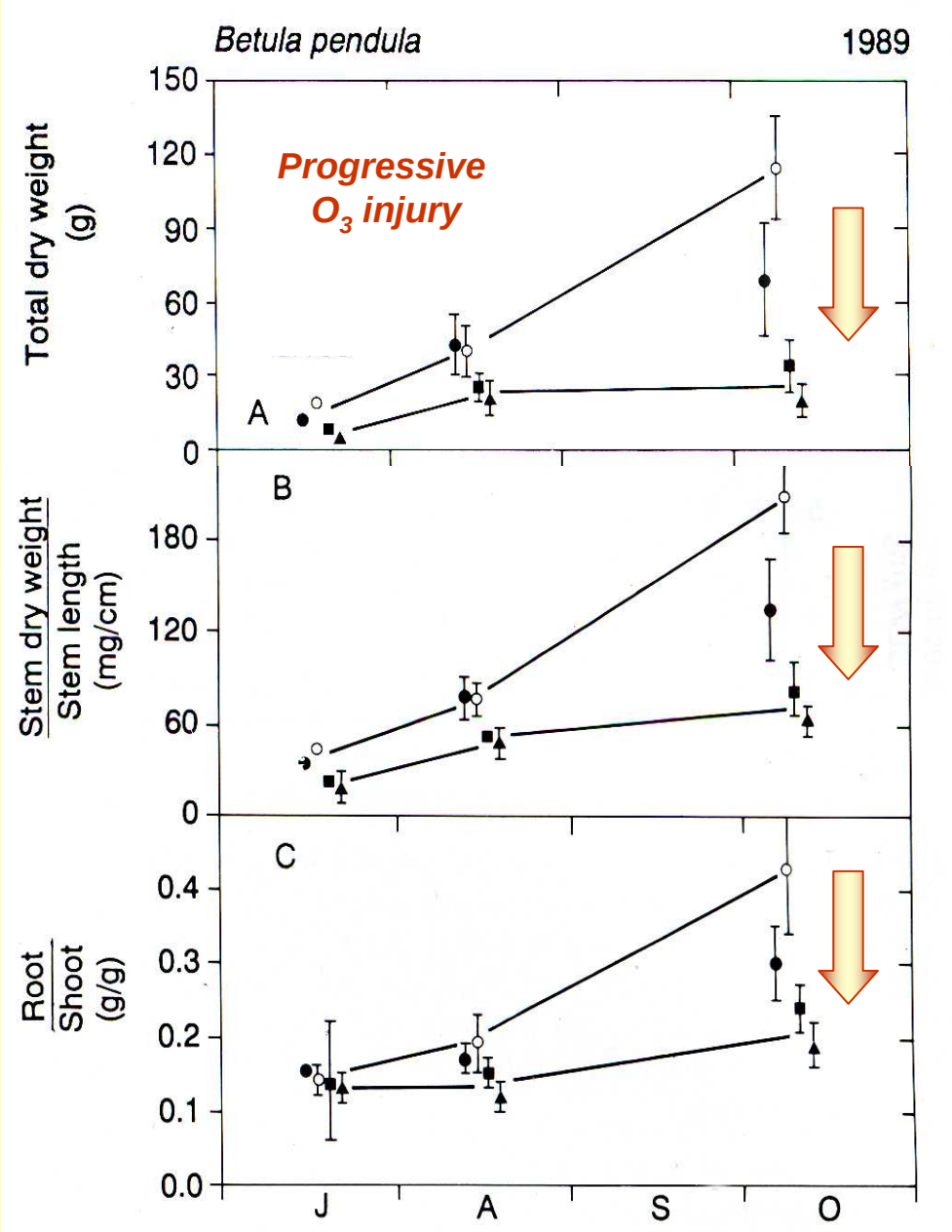
Betula pendula Advanced O_3 injury



HOWEVER: Representativeness for forest ecosystems doubtful !

Matyssek et al. (1990, 1998)

.... from chamber studies:



Matyssek et al. (1992)

Stagnation of biomass production

„slimming“ stem shape

Reduced root relative to shoot growth

Often high O_3 sensitivity under chamber conditions:

→ non-limiting conditions (water, nutrients)

→ fast-growing, juvenile individuals

→ absence of competition

→light-demanding pioneer tree species

Questions:

→ similar outcome under free-air O_3 release systems ?

→with competing forest trees under stand conditions ?

→ adult trees of climax species ?

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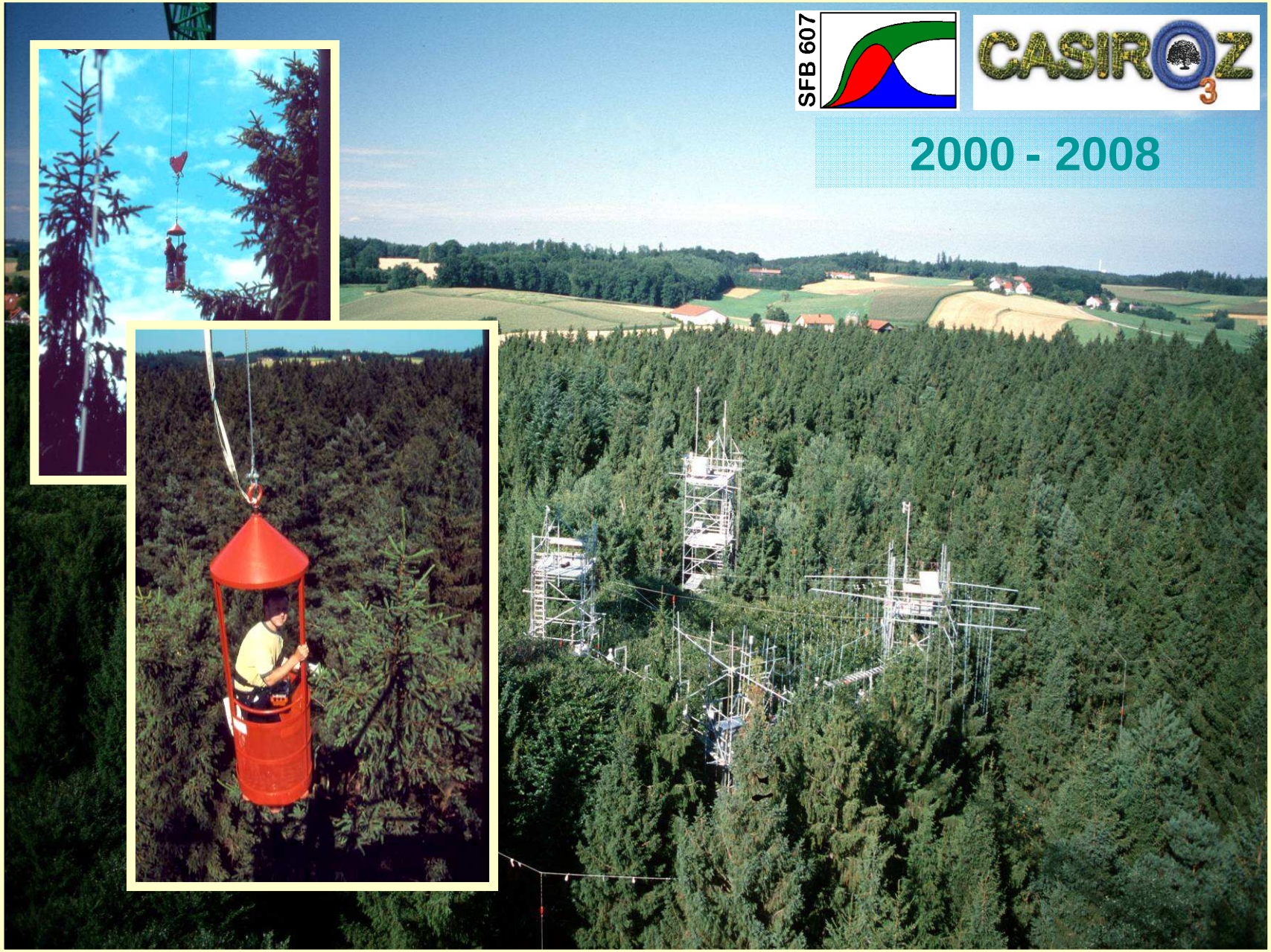
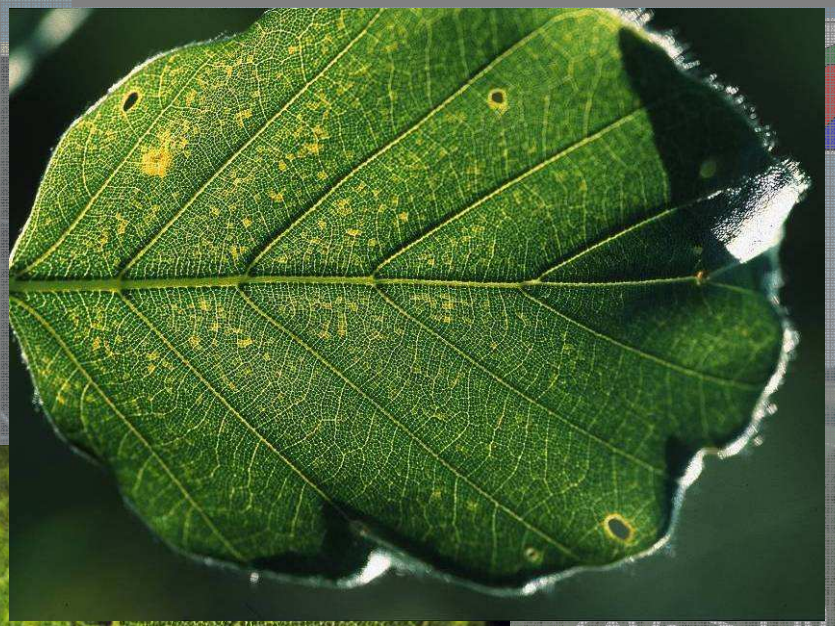
Experimental site „Kranzberg Forest“

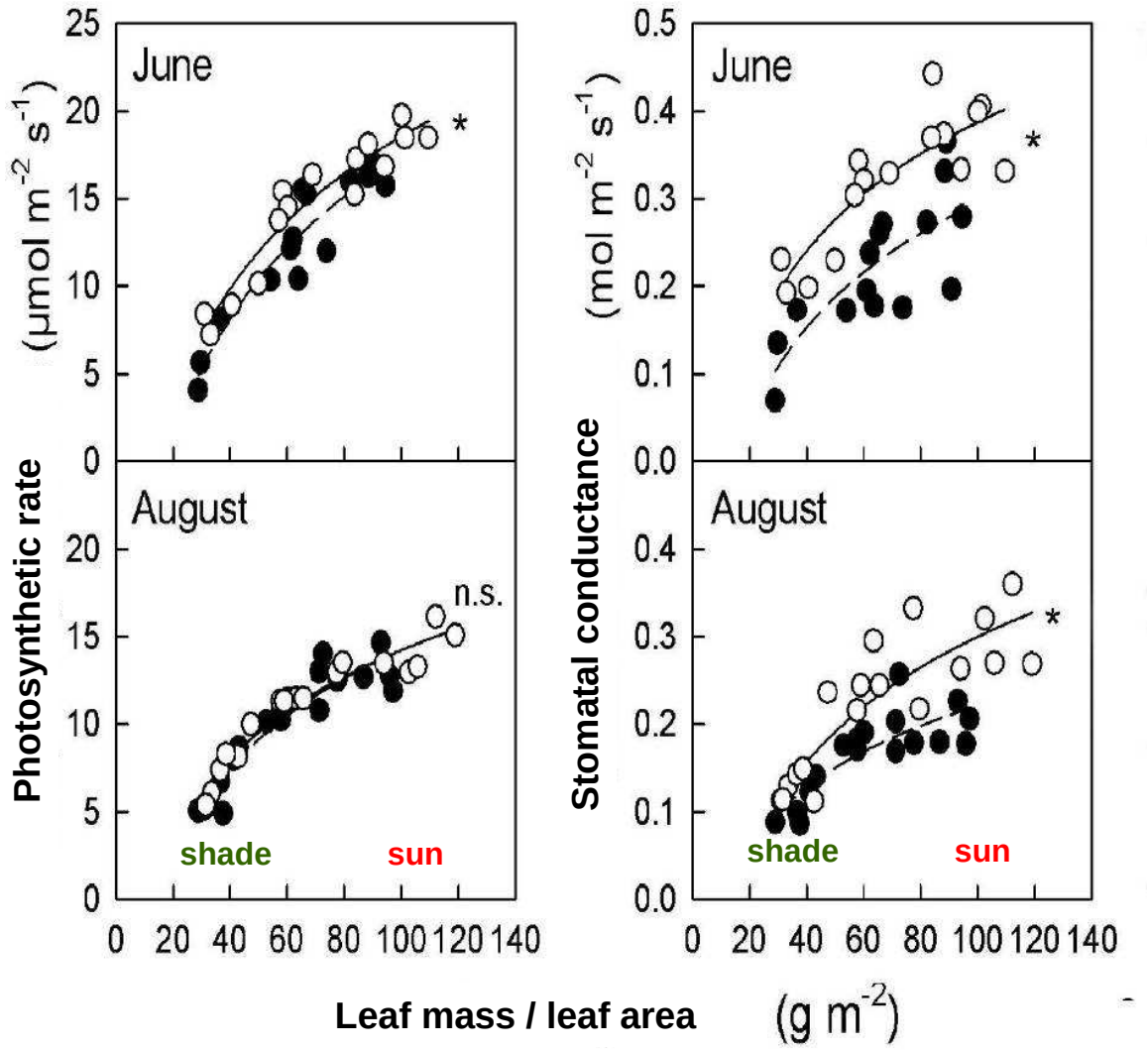


Experimental s

Incipient O_3 injury



Fagus sylvatica Leaf level



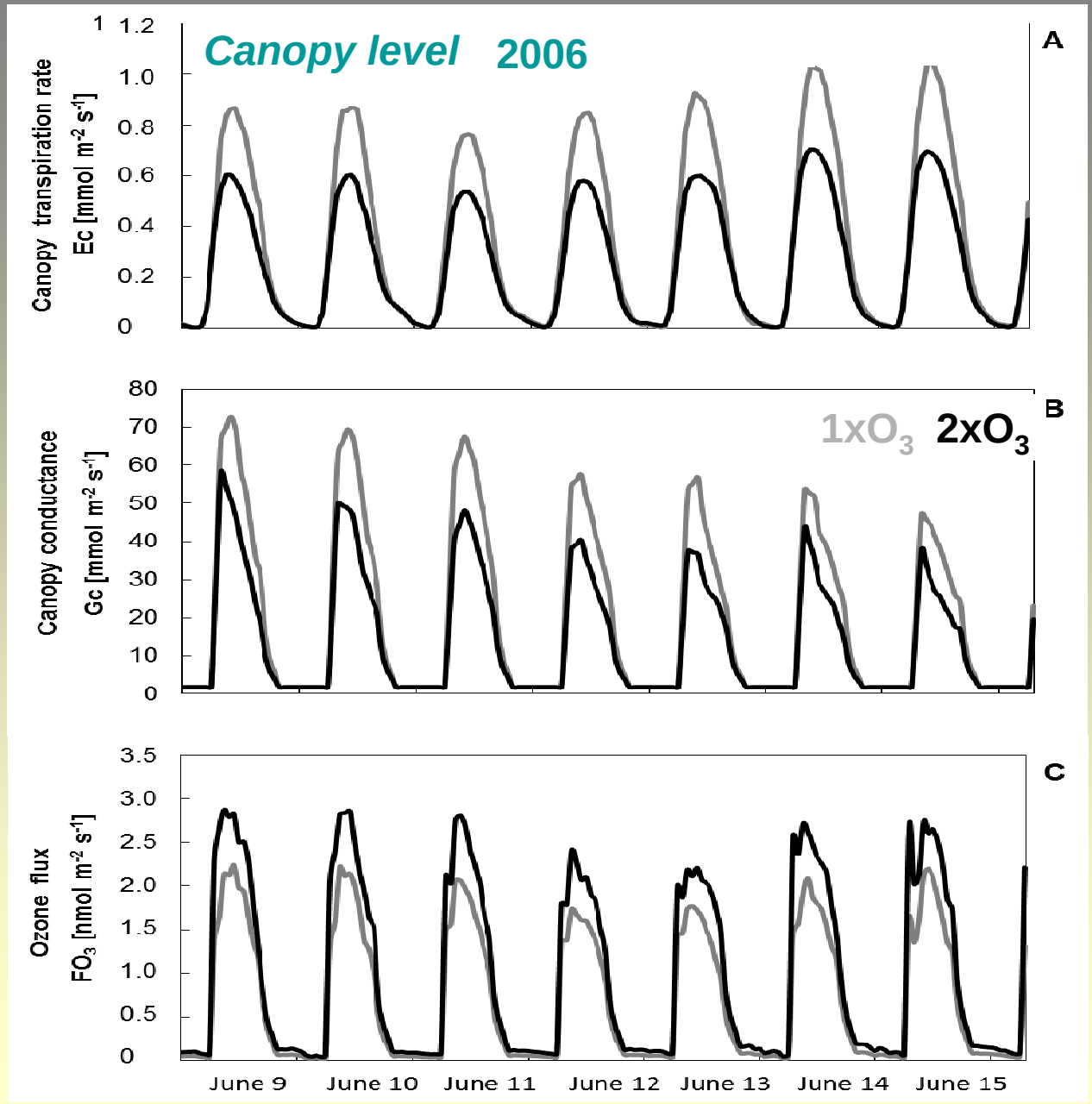
○ 1 x O_3
● 2 x O_3

Increasing water-use efficiency

Kitao et al. (2009)

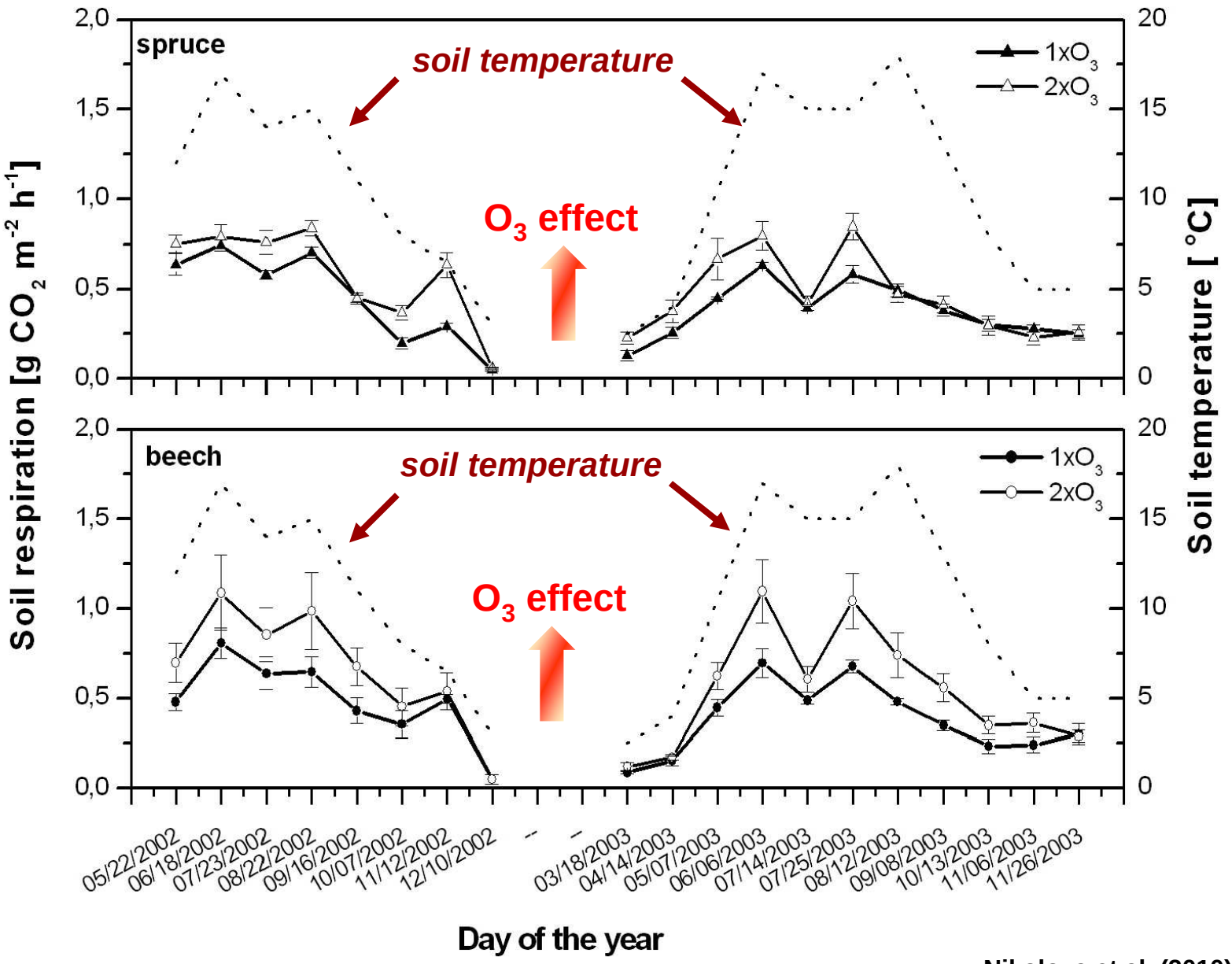
Enhanced O_3 lowers water comsumption

Fagus sylvatica



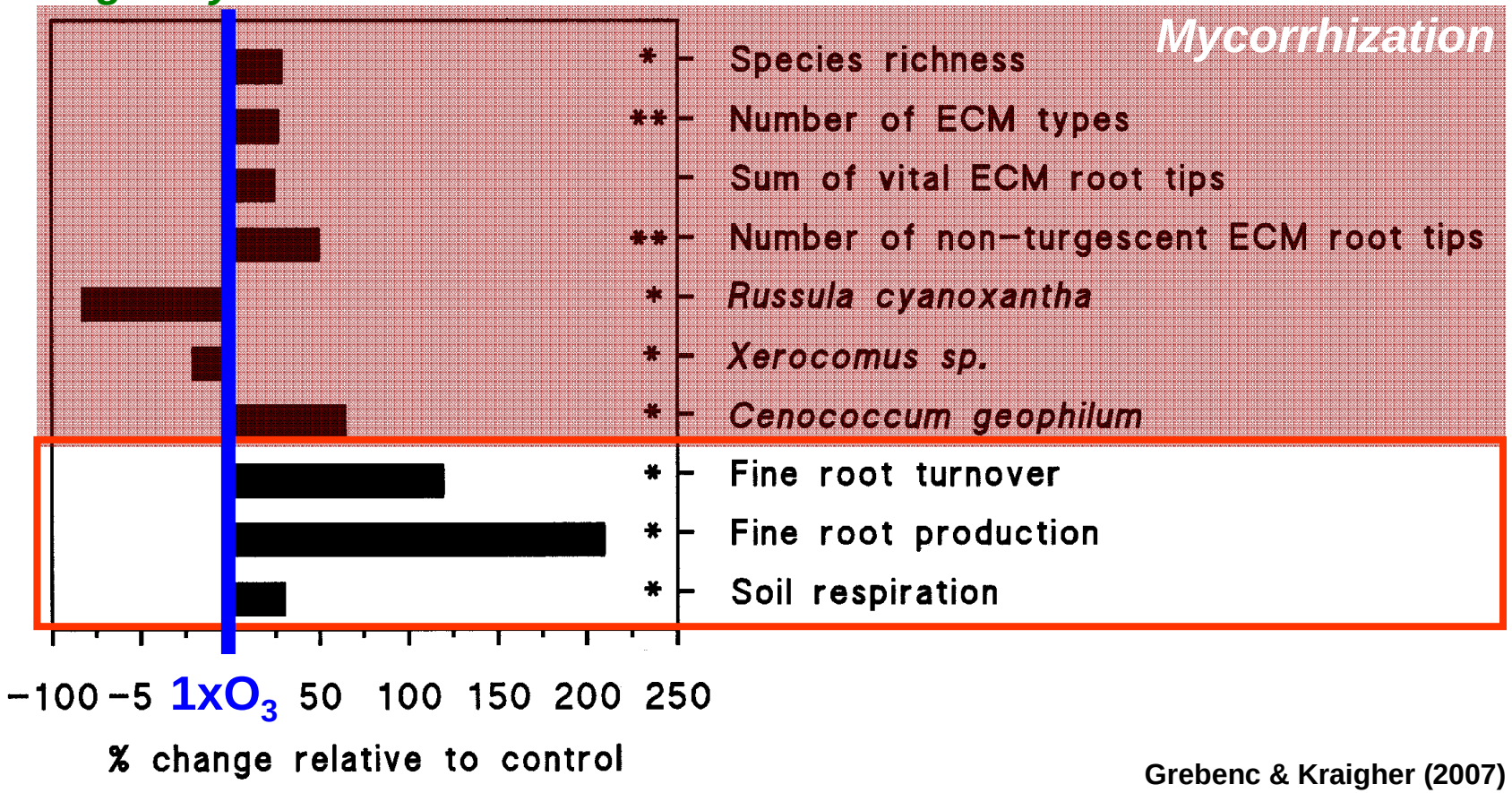
Matyssek et al. (2015)

Nevertheless: distinct belowground O_3 effects



Nikolova et al. (2010)

Belowground Ozone Effects



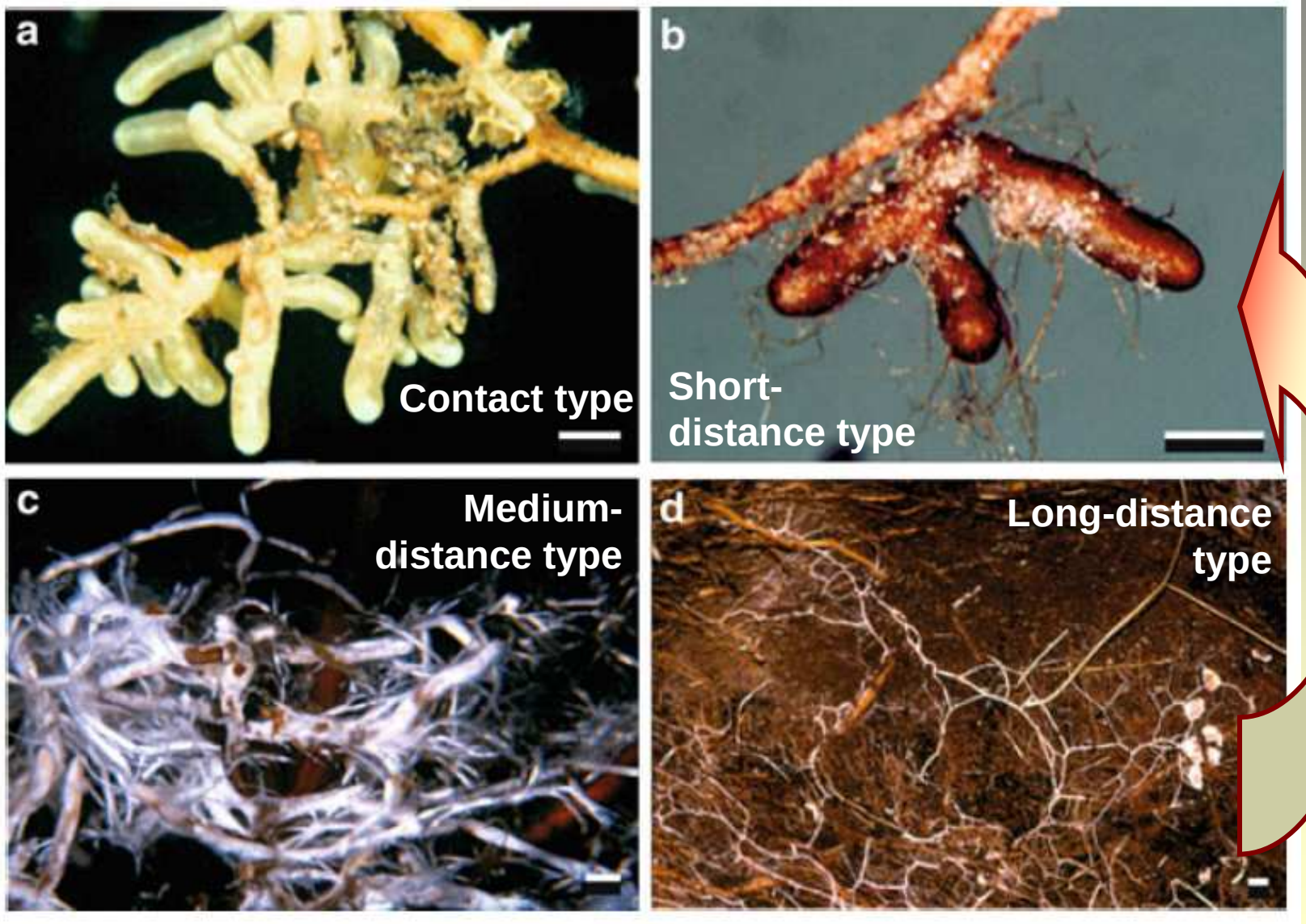
Grebenc & Kraigher (2007)
Nikolova et al. (2010)

from Matyssek et al. (2010)

Picea abies: O_3 changes expolaration types

Lactarius cf. *uvidus*

Genea hispidula



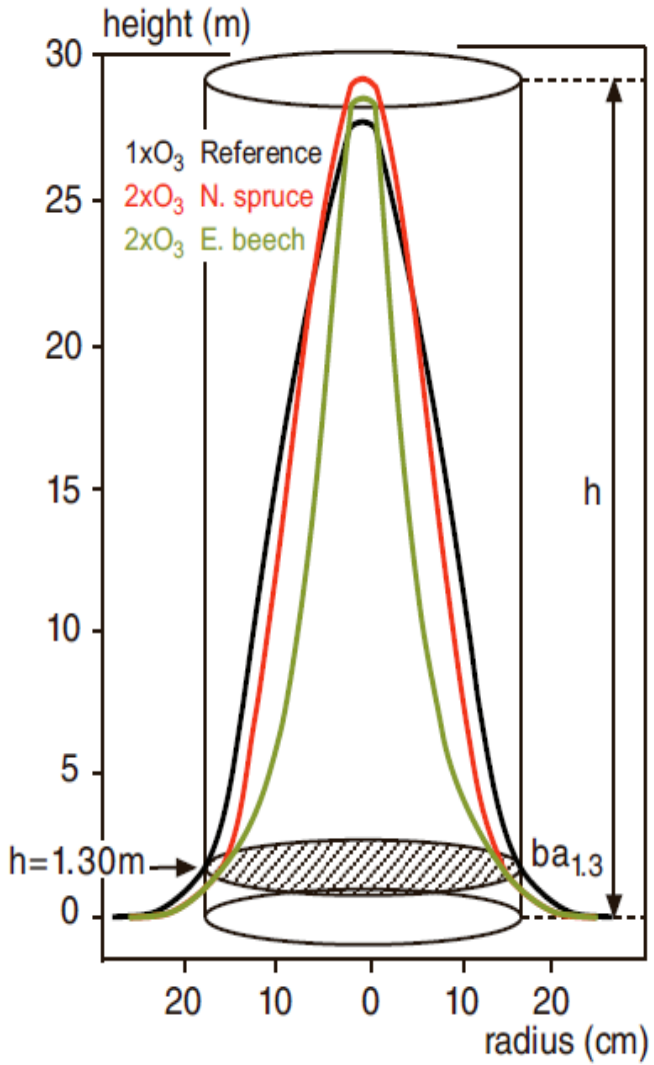
O_3 *effect*

Cortinarius alboviolatius

Suillus plorans

Agerer et al. (2012)

Changes in height-diameter relationship



Black = 1xO3 ➔ both tree species

Red = 2xO3 ➔ *Picea abies*

Green= 2xO3 ➔ *Fagus sylvatica*

Effect after eight years of $2xO_3$ exposure:

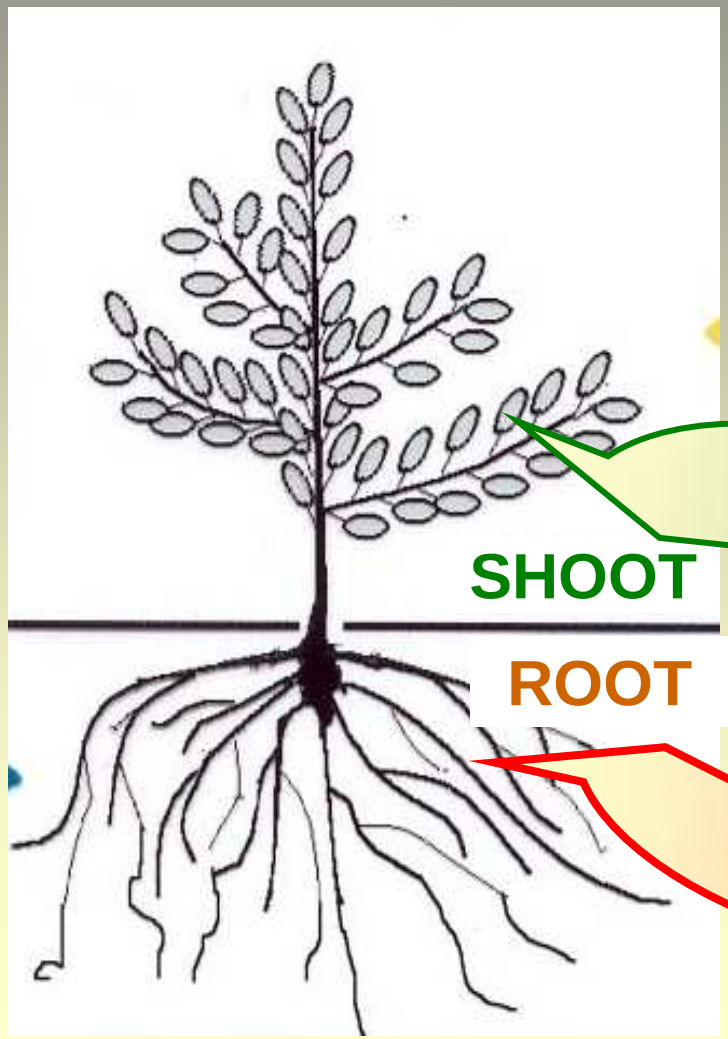
Spruce: +/- stable 0.5 m^3 ha^{-1} yr^{-1}

Beech: loss of - 10 m^3 ha^{-1} yr^{-1}

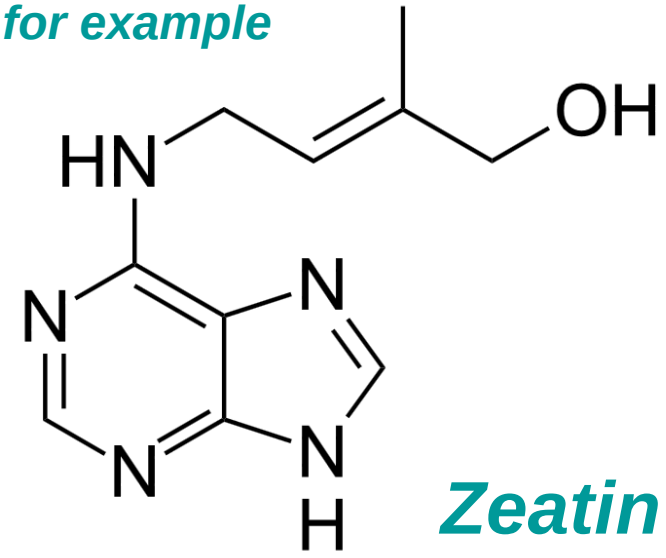
- 44 %

Pretzsch et al. (2010)
Matyssek et al. (2010a,b)

The role of cytokinins in explaining the O_3 effect on tree stem growth



for example



Zeatin

Molecules with high N demand

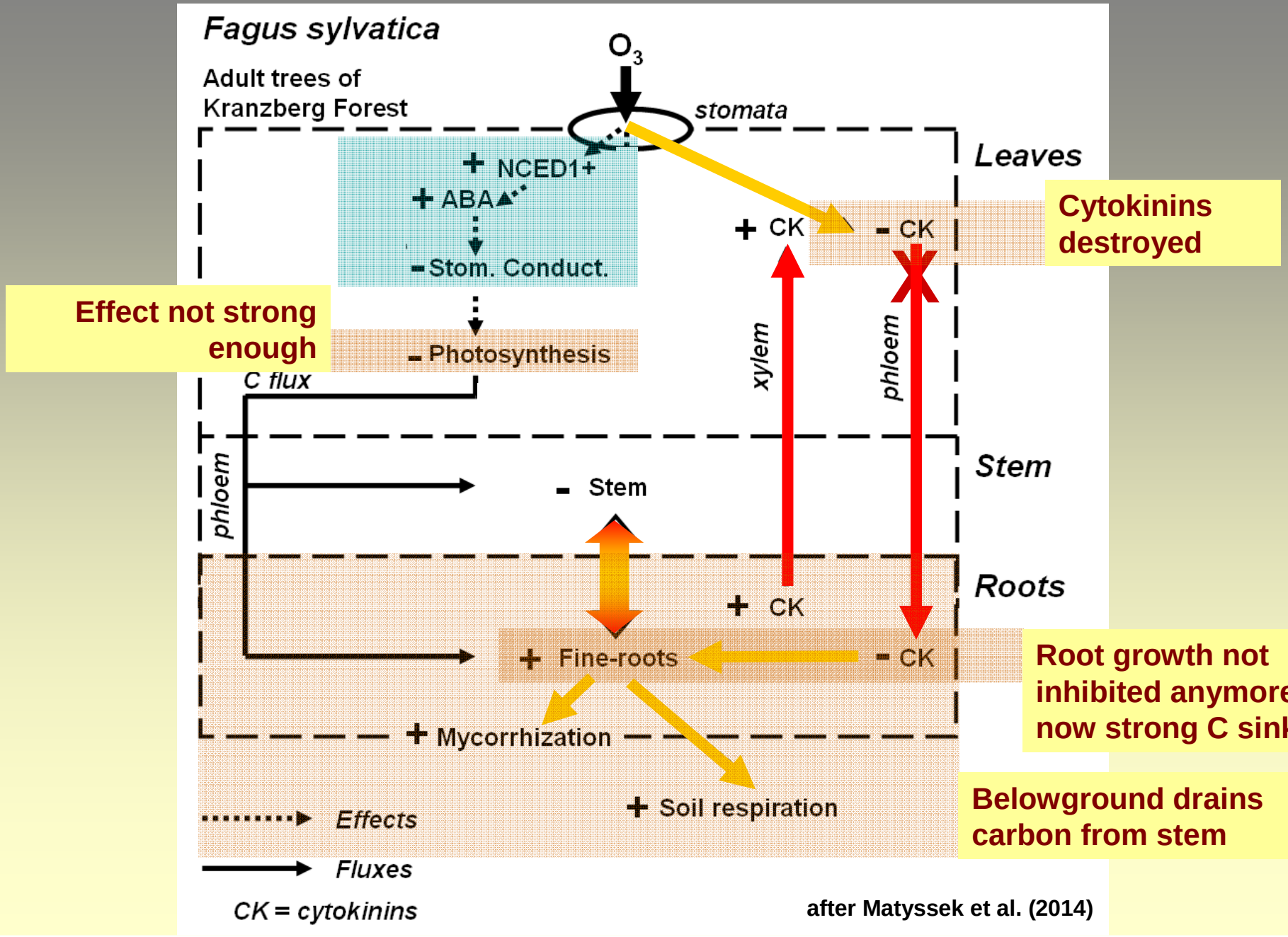
stimulating

inhibiting

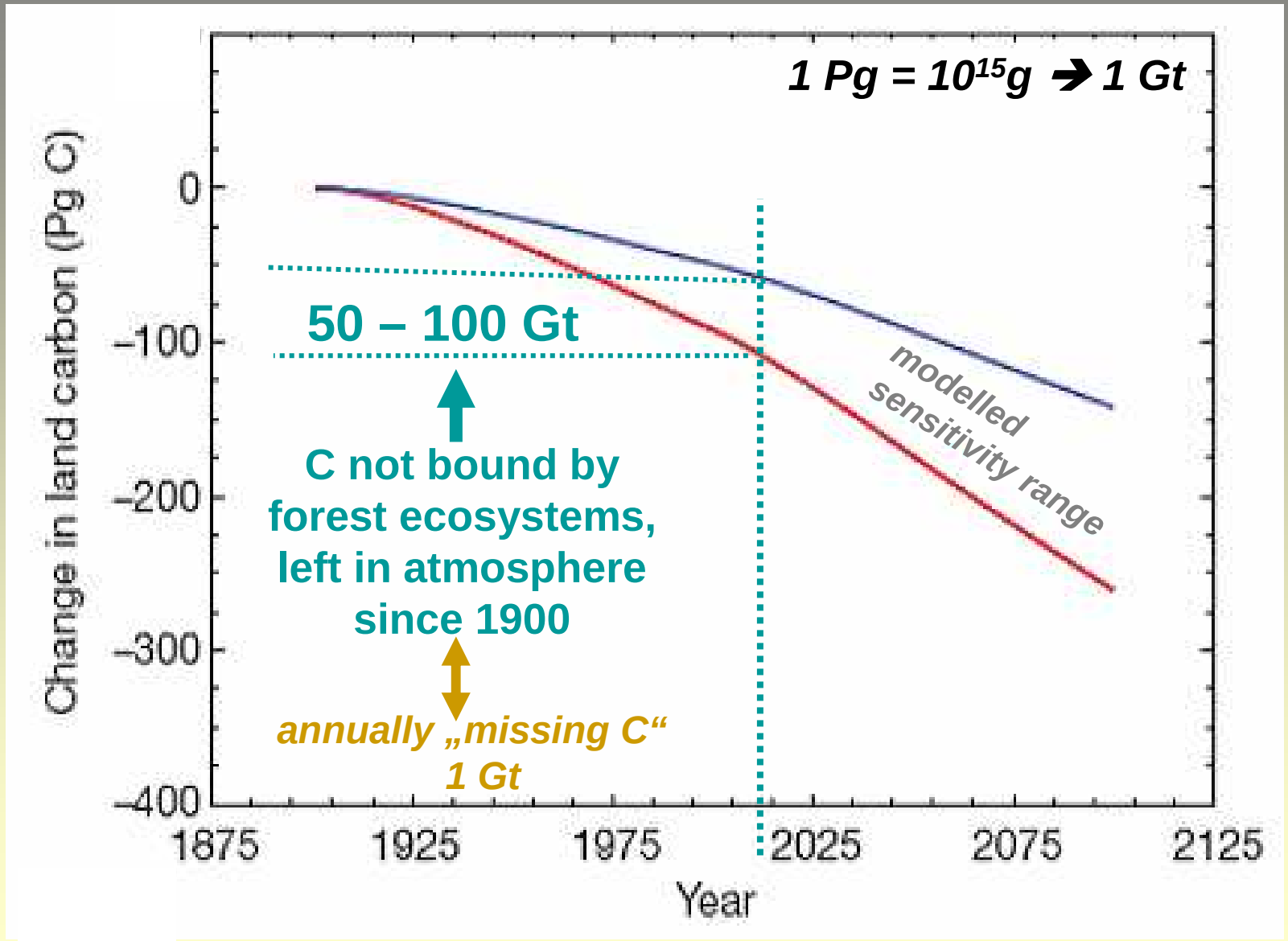
if soil N-rich,

cytokinins

Synopsis: O_3 effects on adult beech trees



Ozone mitigates global carbon sink strength



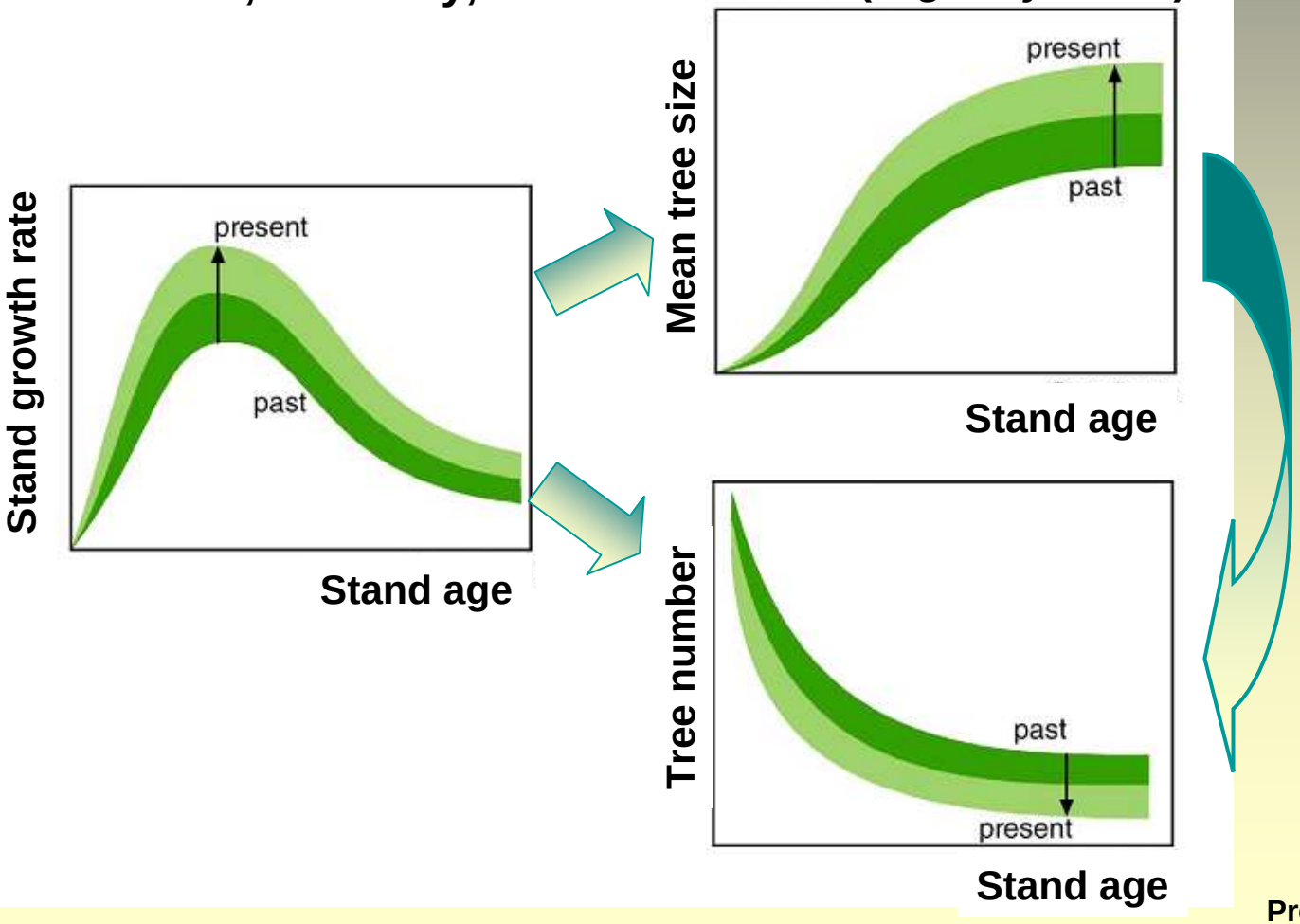
after Sitch et al. (2007)

Speeding up of stand development today driven by N deposition and extending growing seasons

Conflict with conclusions about O_3 impact ?

Central Europe across
Switzerland, Germany, Poland

Beech forests
(*Fagus sylvatica*)



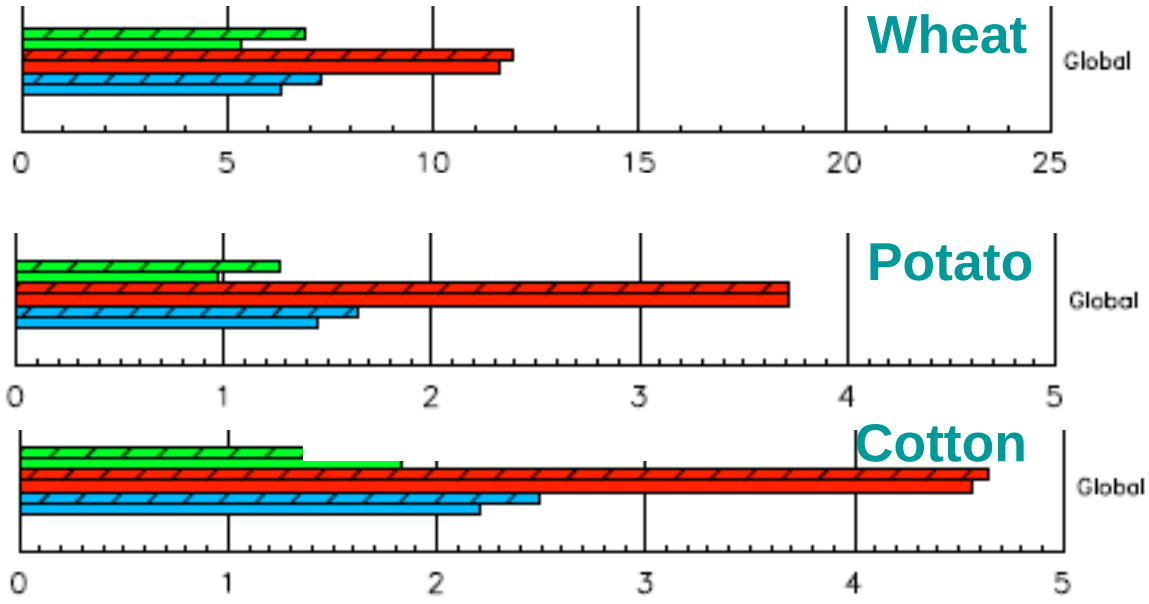
Pretzsch et al. (2014)

Reconciling explanatory model as assumed for crops ?

Intercontinental trans-boundary contributions to ozone-induced crop yield losses in the Northern Hemisphere

M. J. Hollaway[1], S. R. Arnold[1], A. J. Challinor[1], and L. D. Emberson[2]

(2012) Biogeosciences



Increase in production (Mt)

without O_3 precursors

Global increase in productivity upon 100 % reduction of NOx emissions in

Europe

SE Asia

N America

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Example of socio-economic assessment for forests

AMBIO 34: 32-40 (2005)

Per Erik Karlsson, Håkan Pleijel, Mohammed Belhaj, Helena Danielsson, Bo Dahlin, Mikael Andersson, Max Hansson, John Munthe and Peringe Grennfelt

Economic Assessment of the Negative Impacts of Ozone on Crop Yields and Forest Production. A Case Study of the Estate Östads Säteri in Southwestern Sweden

Ground level ozone concentrations, in combination with the prevailing climate, at the estate Östads Säteri in southwestern Sweden were estimated to reduce the yield of wheat and potato ranging between 5% and 10%. Occasionally, in years with the highest ozone concentrations and/or climatic conditions favoring high rates of ozone uptake to the leaves, yield loss levels above 10% may occur. Based on simple extrapolation, these ozone-induced reductions of crop yields at Östads Säteri represent a potential total annual yield loss in Sweden in the range of 24.5 million Euro for wheat and 7.3 million Euro for potato, respectively. A simulation of forest growth at Östad Säteri predicted that prevailing mean ozone exposure during 1992–2002 had the potential to reduce forest growth by 2.2% and the economic return of forest production by 2.6%. Using this value for extrapolation to the national level, the potential annual economic loss for Sweden due to negative impacts of ozone on forest production would be in the range of 56 million Euro (2004 prices).

of ground-level ozone on forest and crop growth as recently presented in the Mapping Manual (7) of the LRTAP convention. It is focussed on a specific site, the estate Östads Säteri in southwestern Sweden, where detailed information on ozone concentrations, local climate and growth conditions for crops and forest were available.

DESCRIPTION OF THE ESTATE ÖSTADS SÄTERI

The estate Östads Säteri is situated in the interior of southwestern Sweden (8) in a hilly landscape dominated by forested areas. The estate consists, in total, of approximately 5000 ha, with about 3700 ha forest and 630 ha arable land (Fig. 1). The climate is continental (9) with low nighttime temperatures and frequent air inversions during the summer nights. The climate is humid with a mean annual precipitation of 700 mm and a mean annual temperature of 7ºC. Agriculture used to be more extensive in this type of landscape. Although yields tend to be somewhat lower, as compared to the most fertile intensively managed agricultural areas of southern Sweden, most important Swedish crops can be commercially grown in the

Otherwise:
O_3 effects on forest ecosystem services hardly known

Sweden:

Loss of 56 million Euro per year

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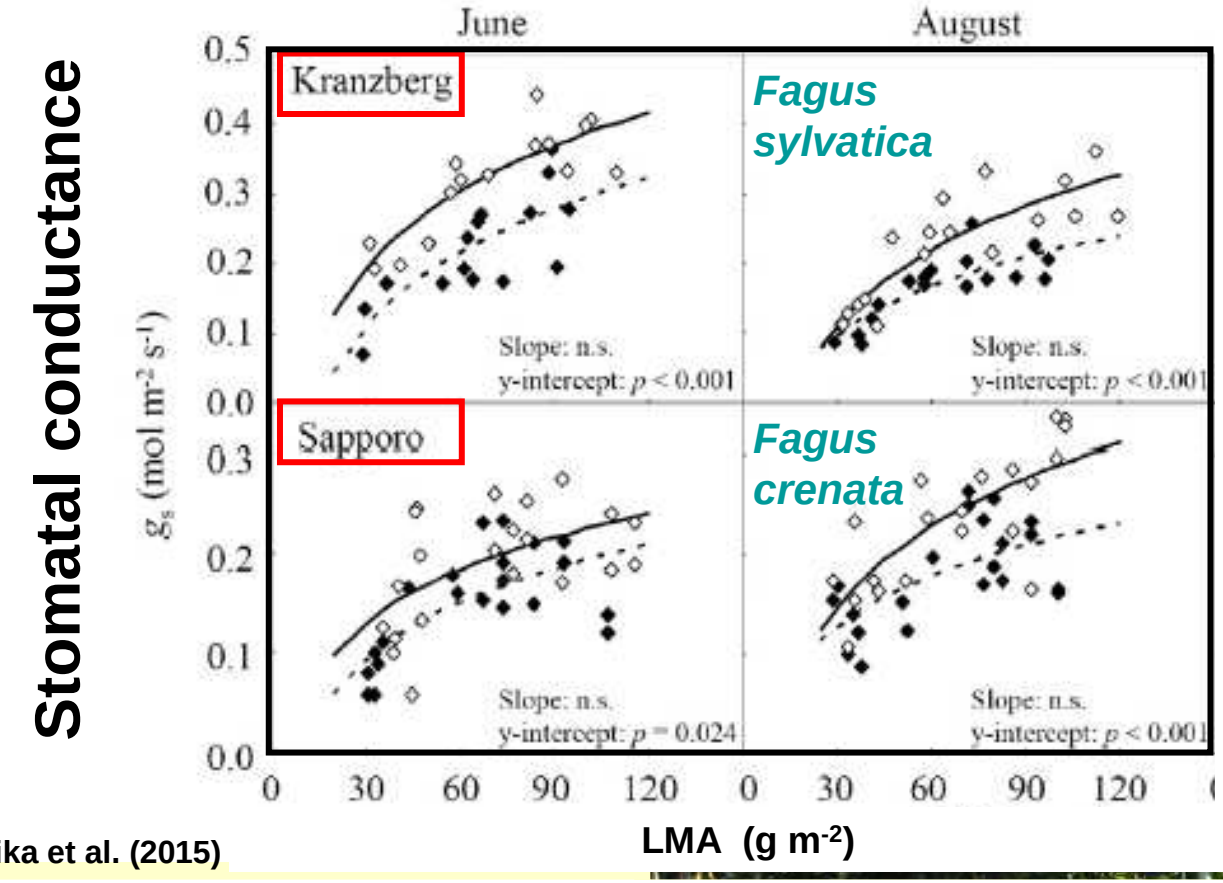
How safely can we predict

tree & forest ecosystem response to ozone ?

Free-air O_3 fumigation for beech, birch & oak in Sapporo/Japan



In both cases:

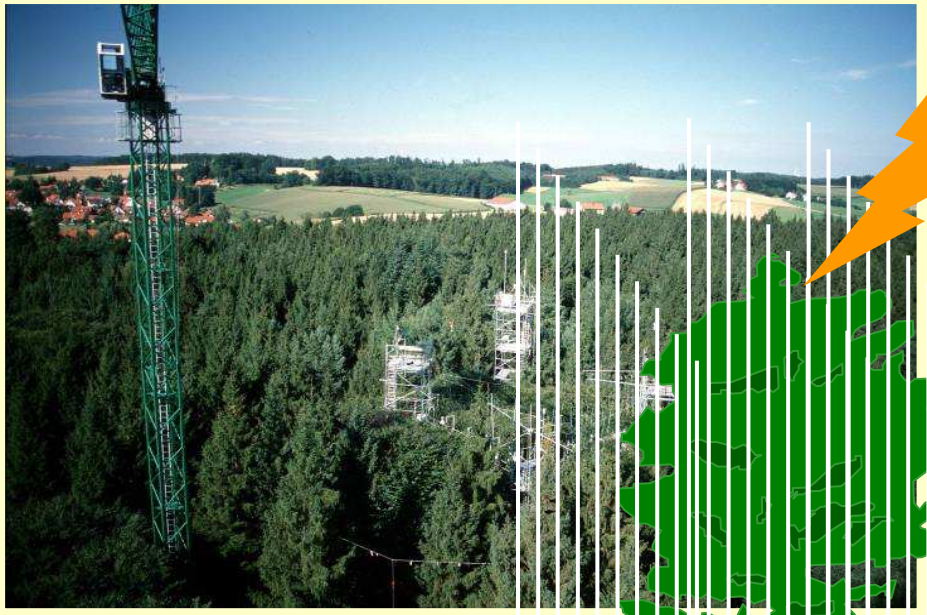
significant decline in stomatal conductance

but no decline in photosynthesis (not shown)

Hoshika et al. (2015)

Kranzberg Forest

Free-air canopy fumigations



O_3

O_3

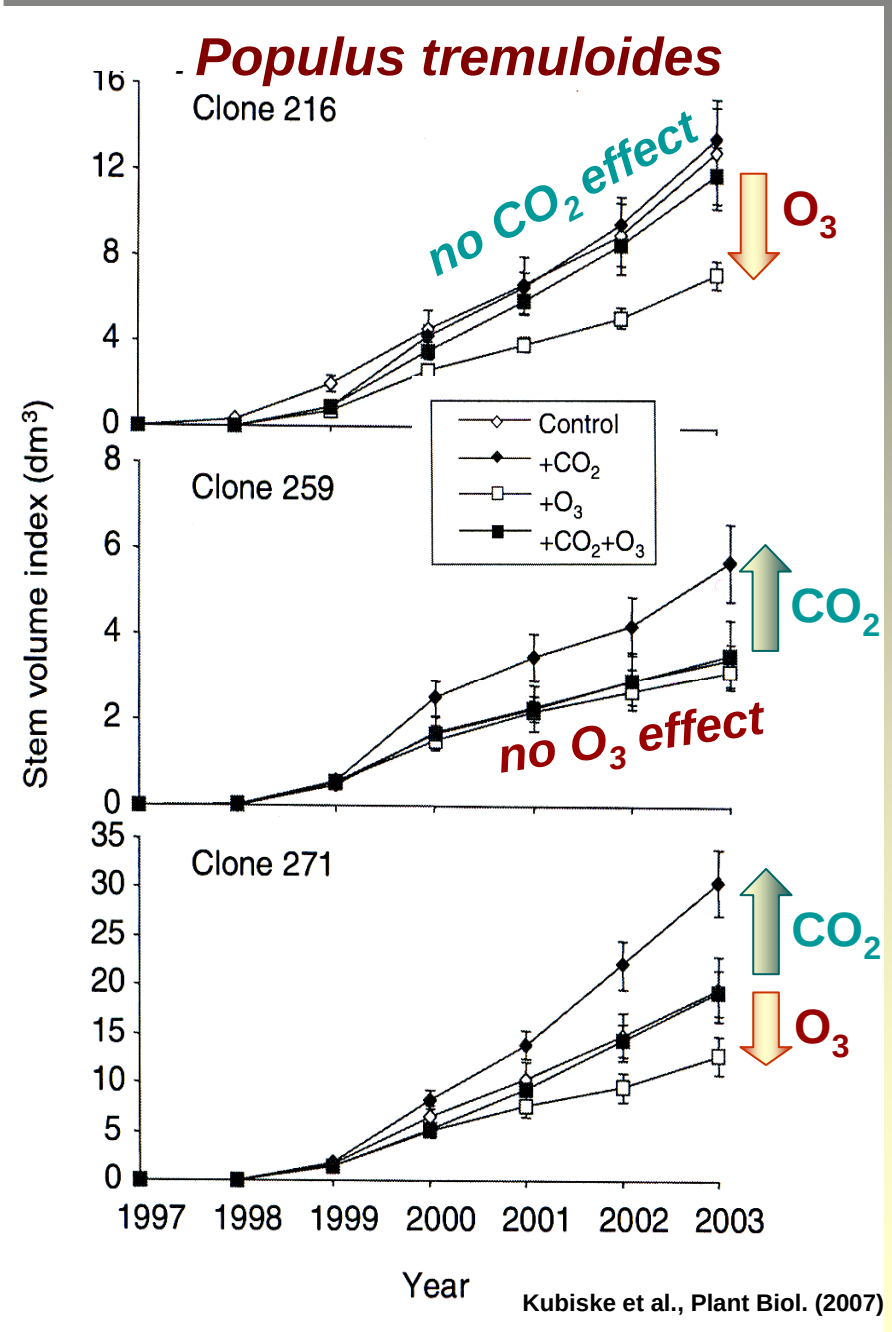
CO_2

Fagus sylvatica
Picea abies

Populus tremuloides
Betula papyrifera
Acer saccharum

Above & belowground assessments

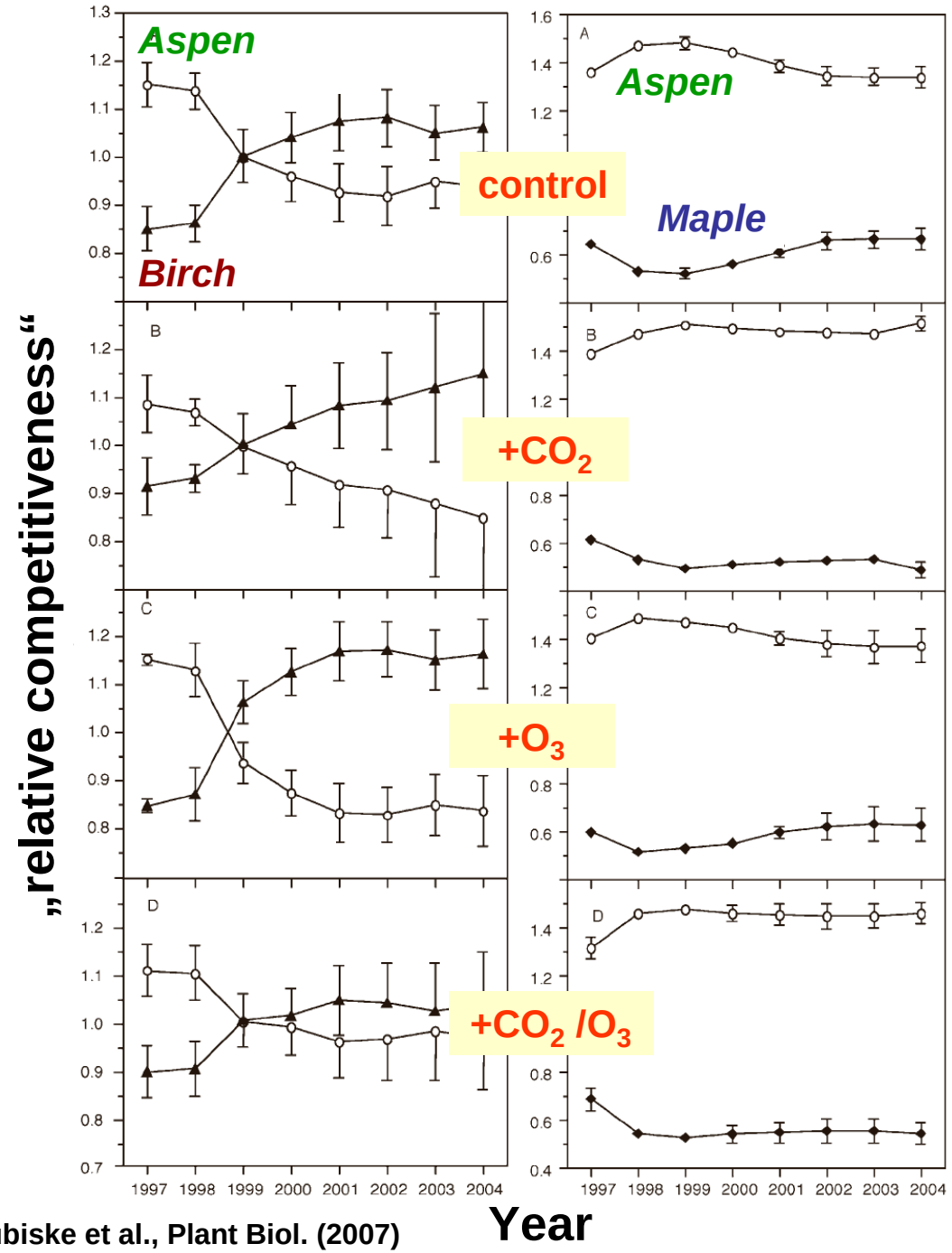
Starting with the genotype ....



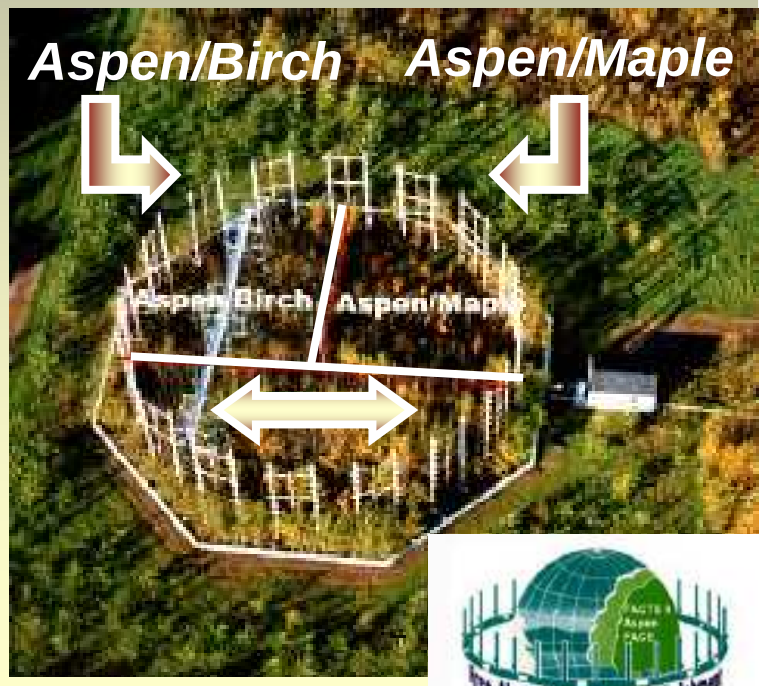
Kubiske et al., Plant Biol. (2007)

Genotype determines sensitivity

Kind of competition determines effects of O_3, and CO_2, on „relative competitiveness“

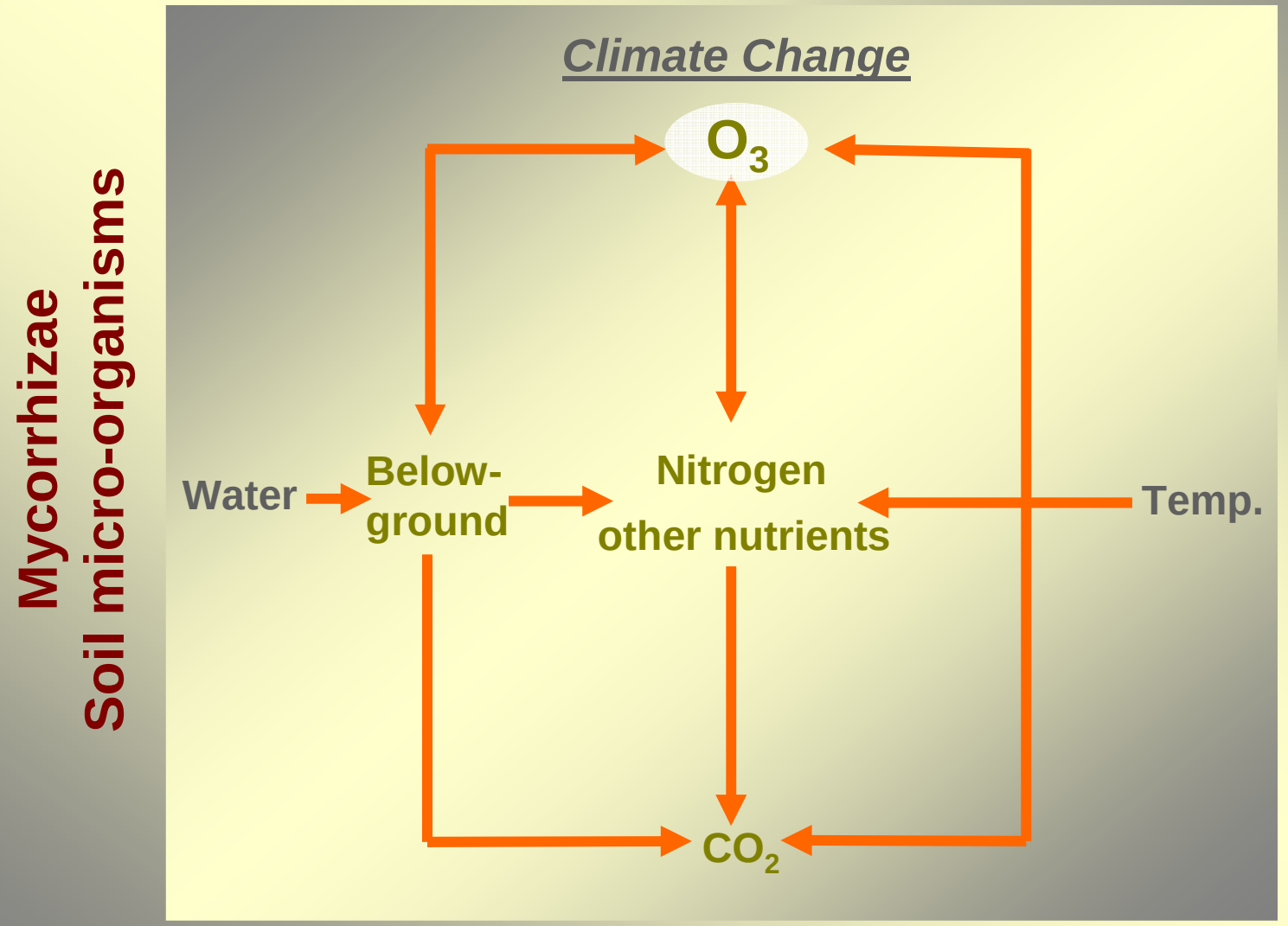


Kubiske et al., Plant Biol. (2007)



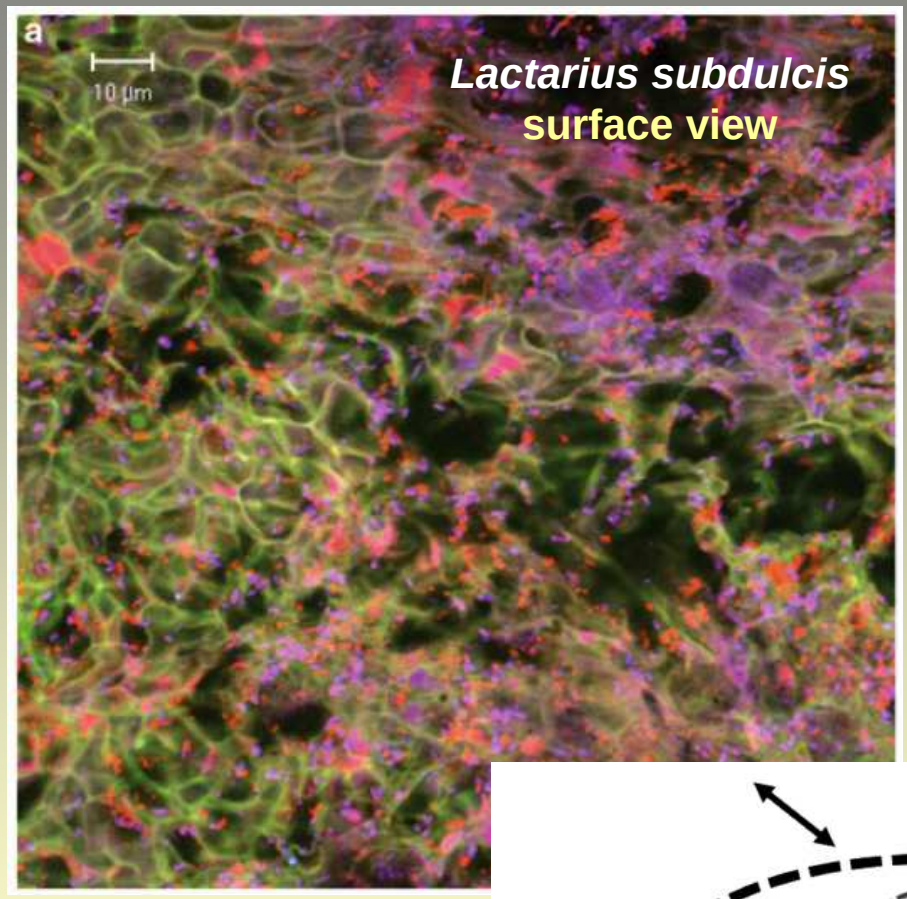
Ozone Part of Factorial Complexes

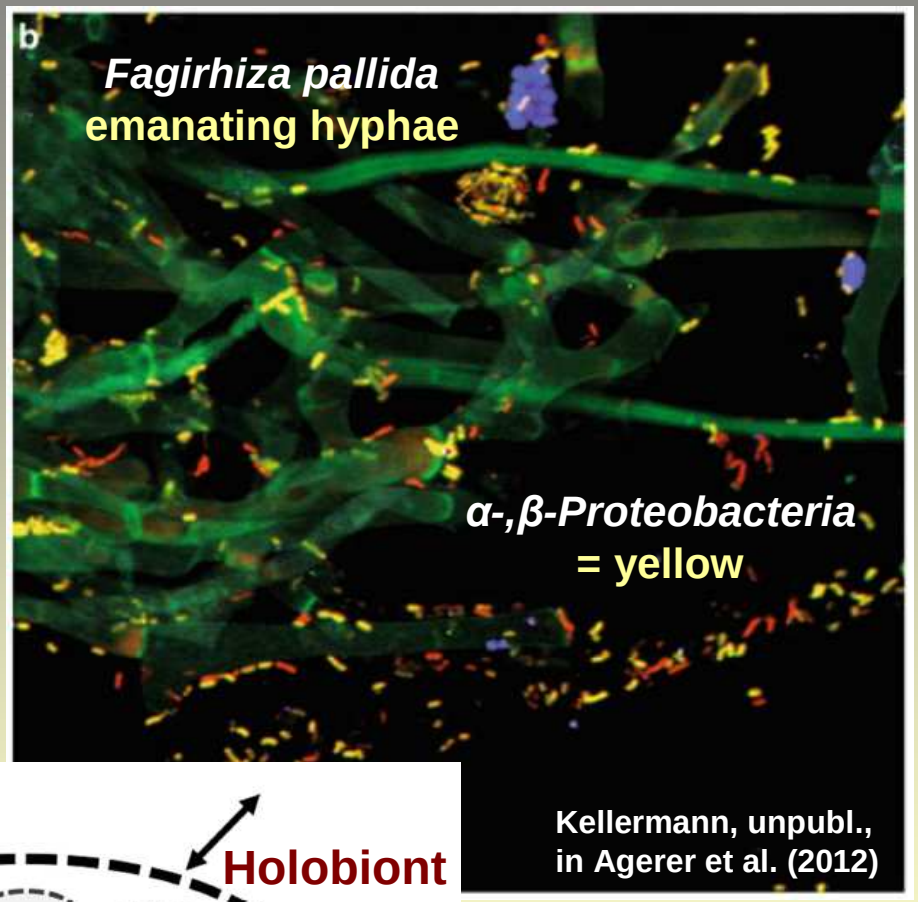
Biotic-abiotic interactions driving plasticity in stress response

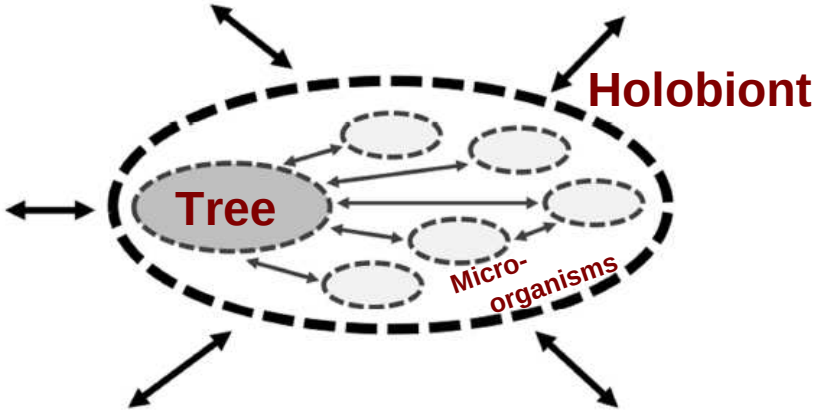


Matyssek et al. (2013)

Functional understanding requires focus on mycorrhizal-bacterial interactions







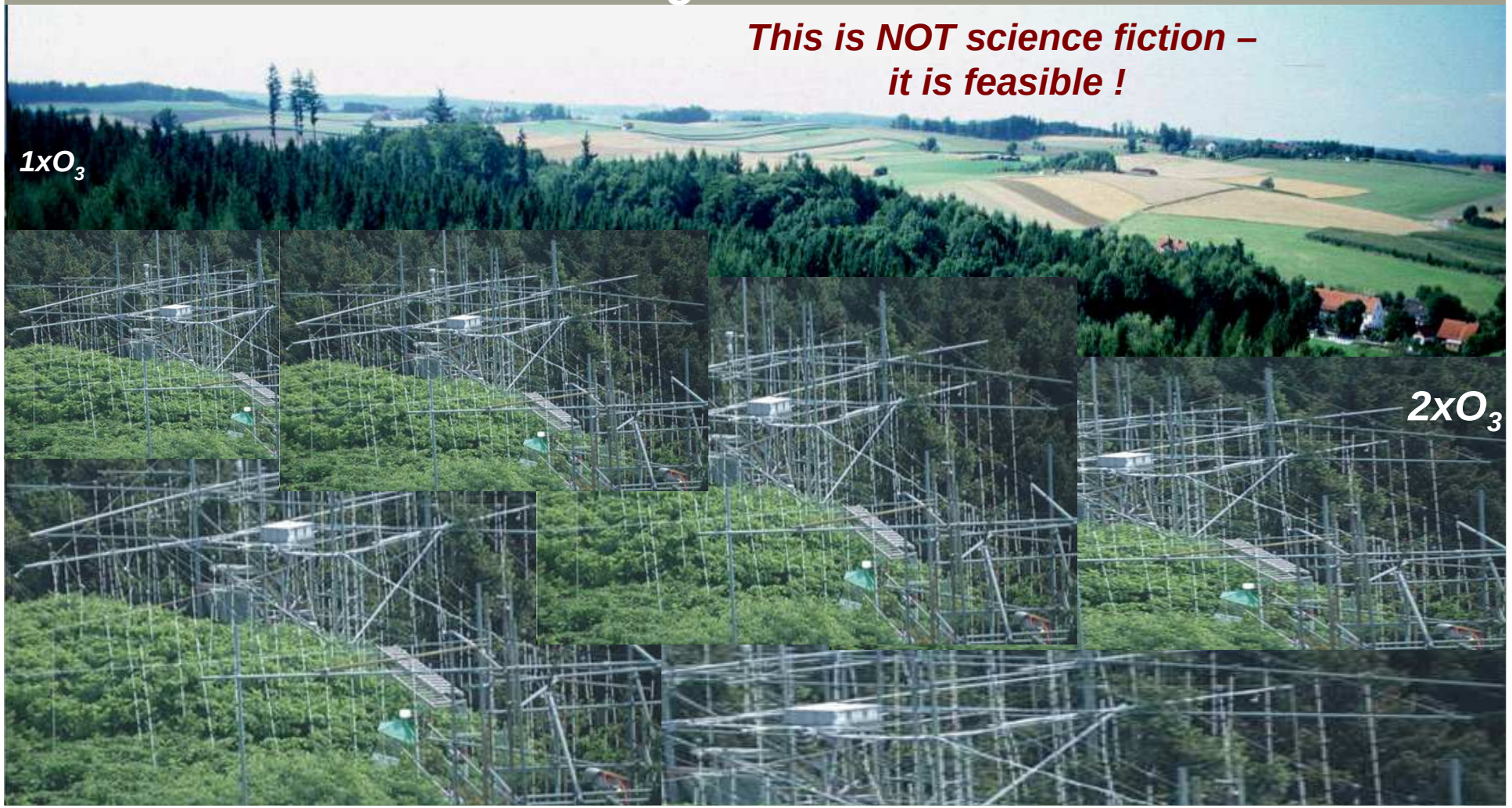
Holobiontic approaches mandatory

co-evolutionary unity

zu Castell et al. (2015)

Expanding the Kranzberg Forest Free-Air O_3 Fumigation Approach

towards forest ecosystem (i.e. „hectare basis“) & long-term scales



Conclusions & Challenges:

Risk abatement concepts ?

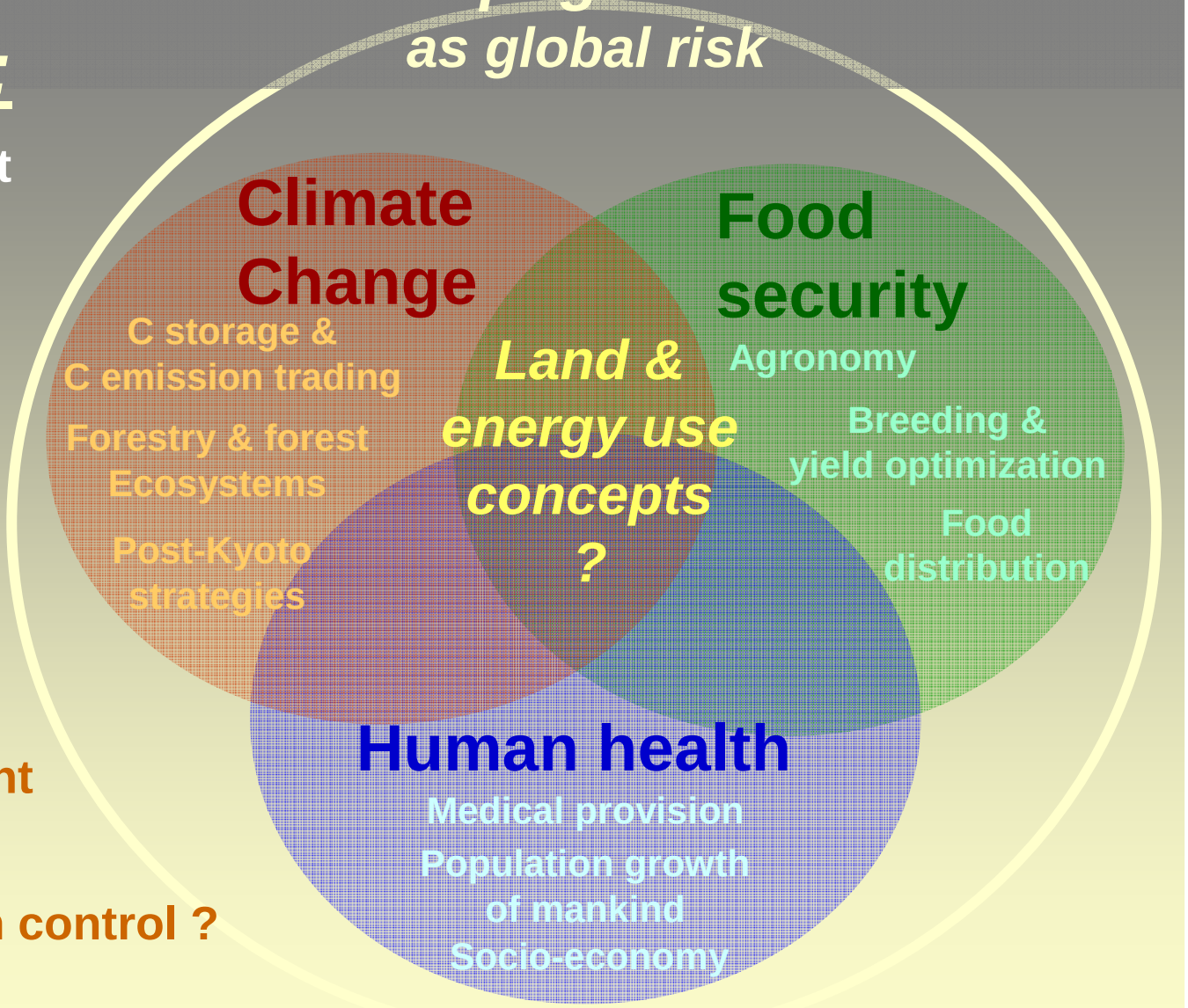
„Clean Development Mechanism“ ?

Knowledge & research?

Evaluation & defining ecosystem services

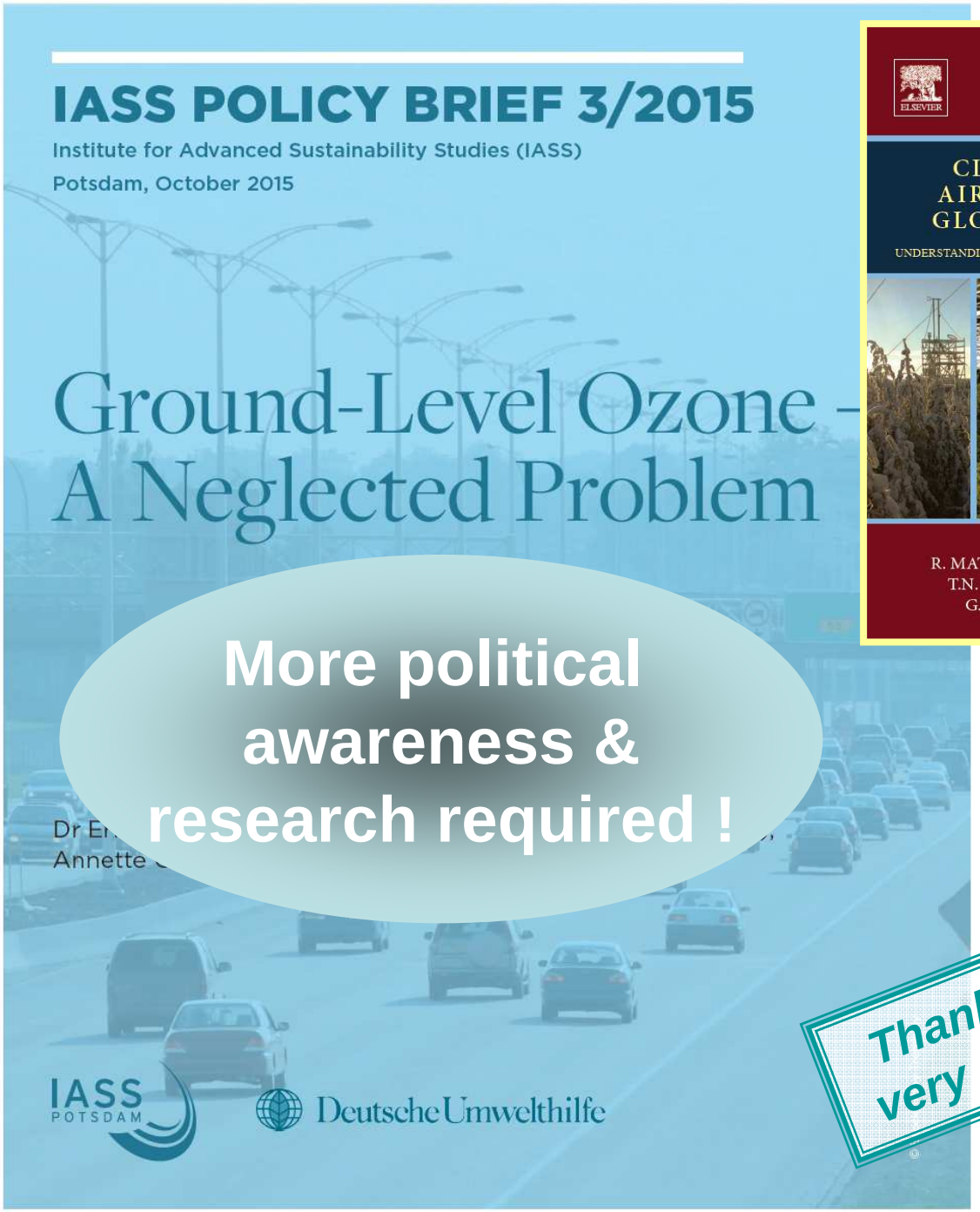
Mixed-management concepts

Sustainability & birth control ?



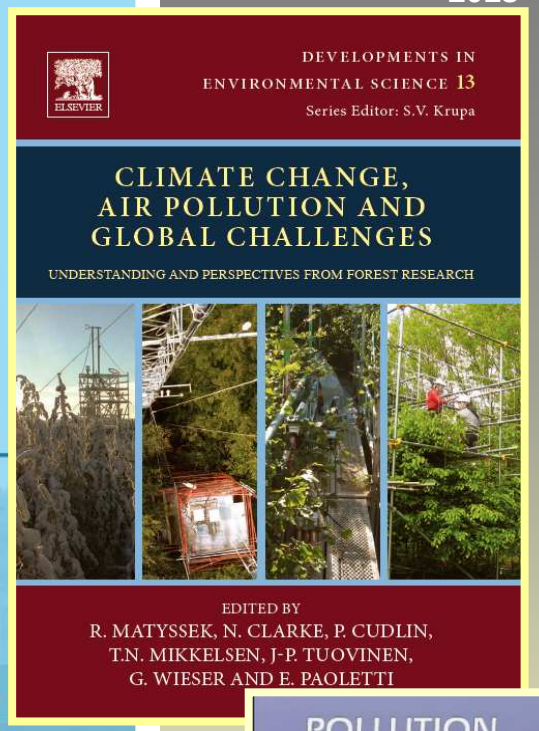
Reconciling stakeholder conflicts

Balanced concepts for policy making

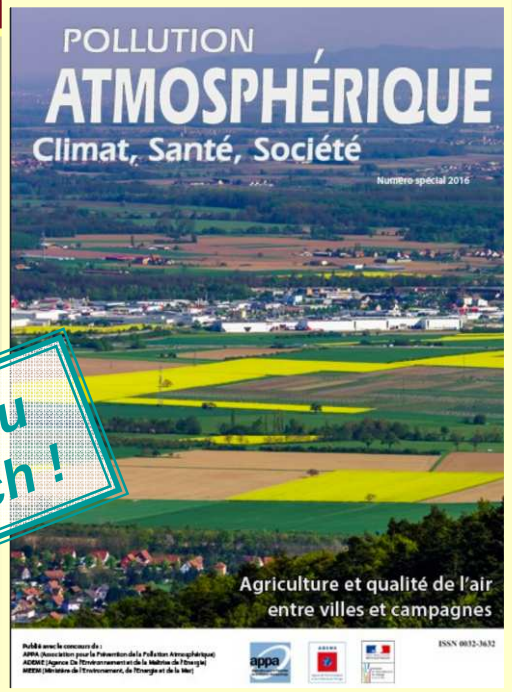


More political awareness & research required !

2013



2016



Thank you very much !