Changing perspective

More (forest) ecology is necessary for air pollution studies

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Outline

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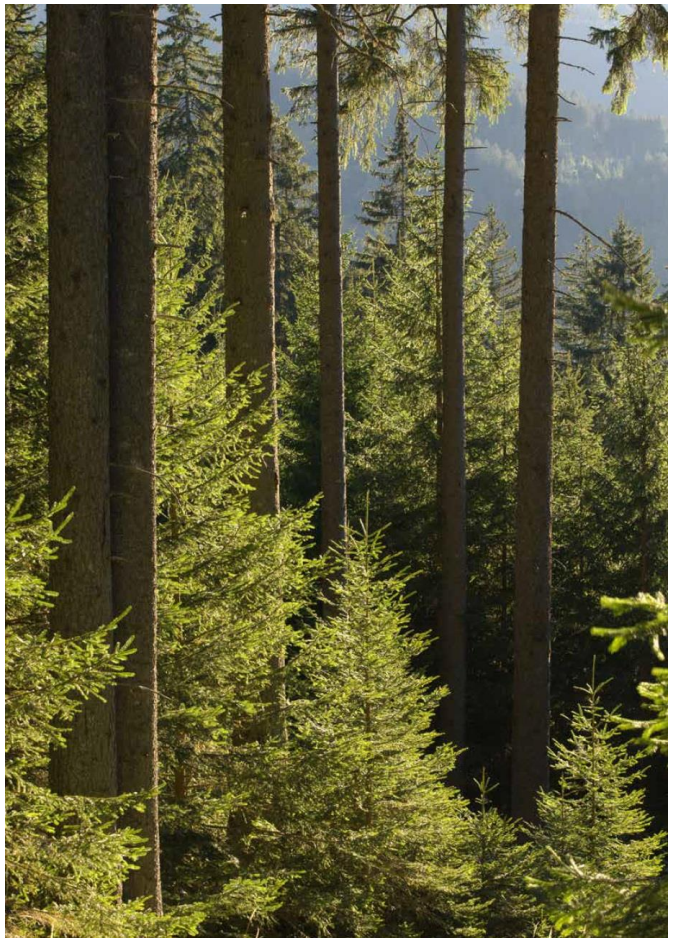
- The example of ground-level ozone
- Towards a broader perspective for air pollution studies



(Photo: PA Trento, Report 2014)

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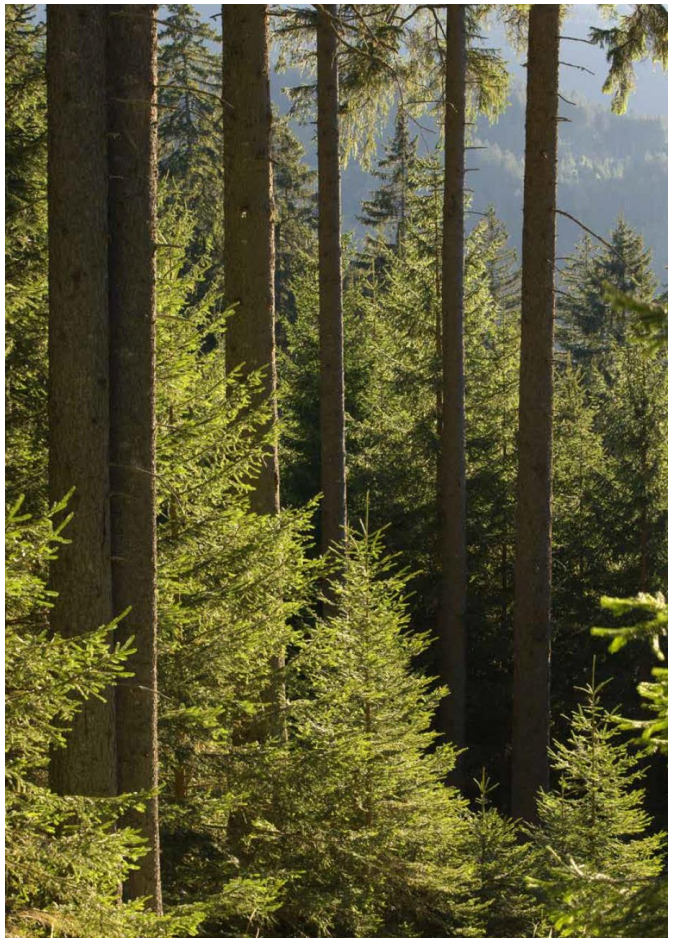

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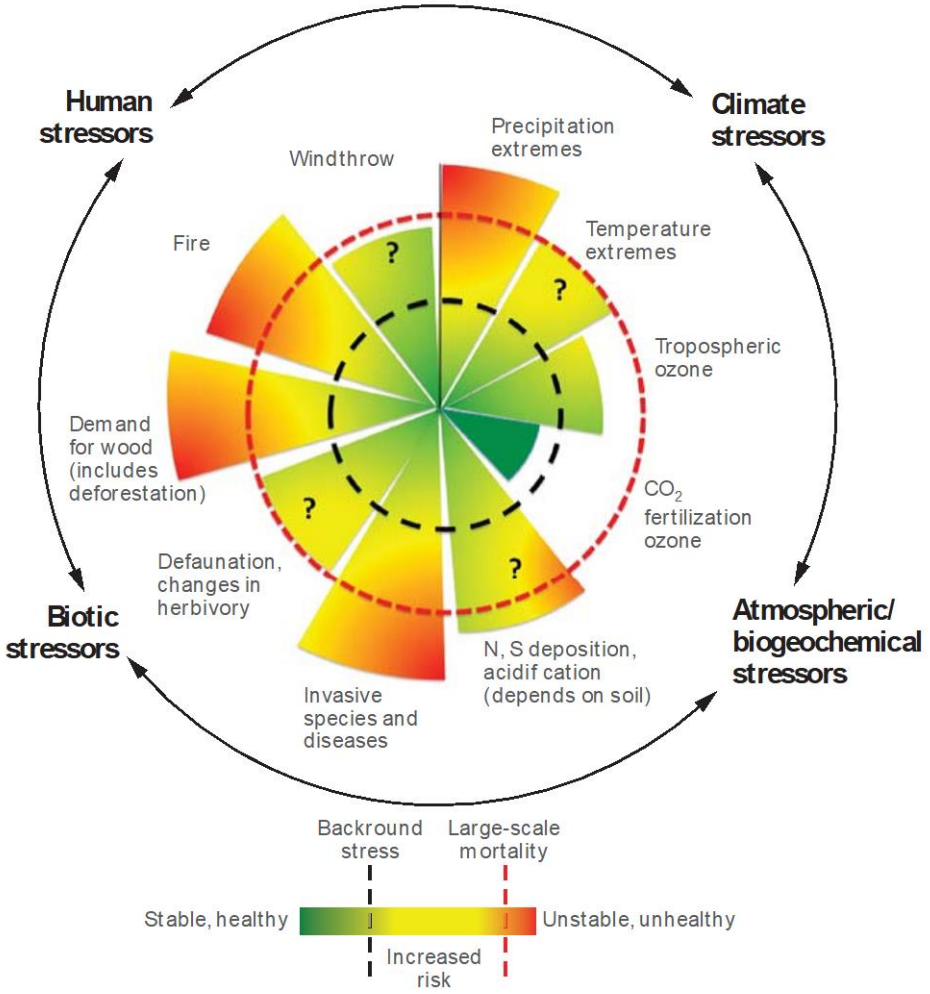
Air pollution is an issue for forests – even today

Oil Sands, Fort Mc Murray, Canada, October 2015

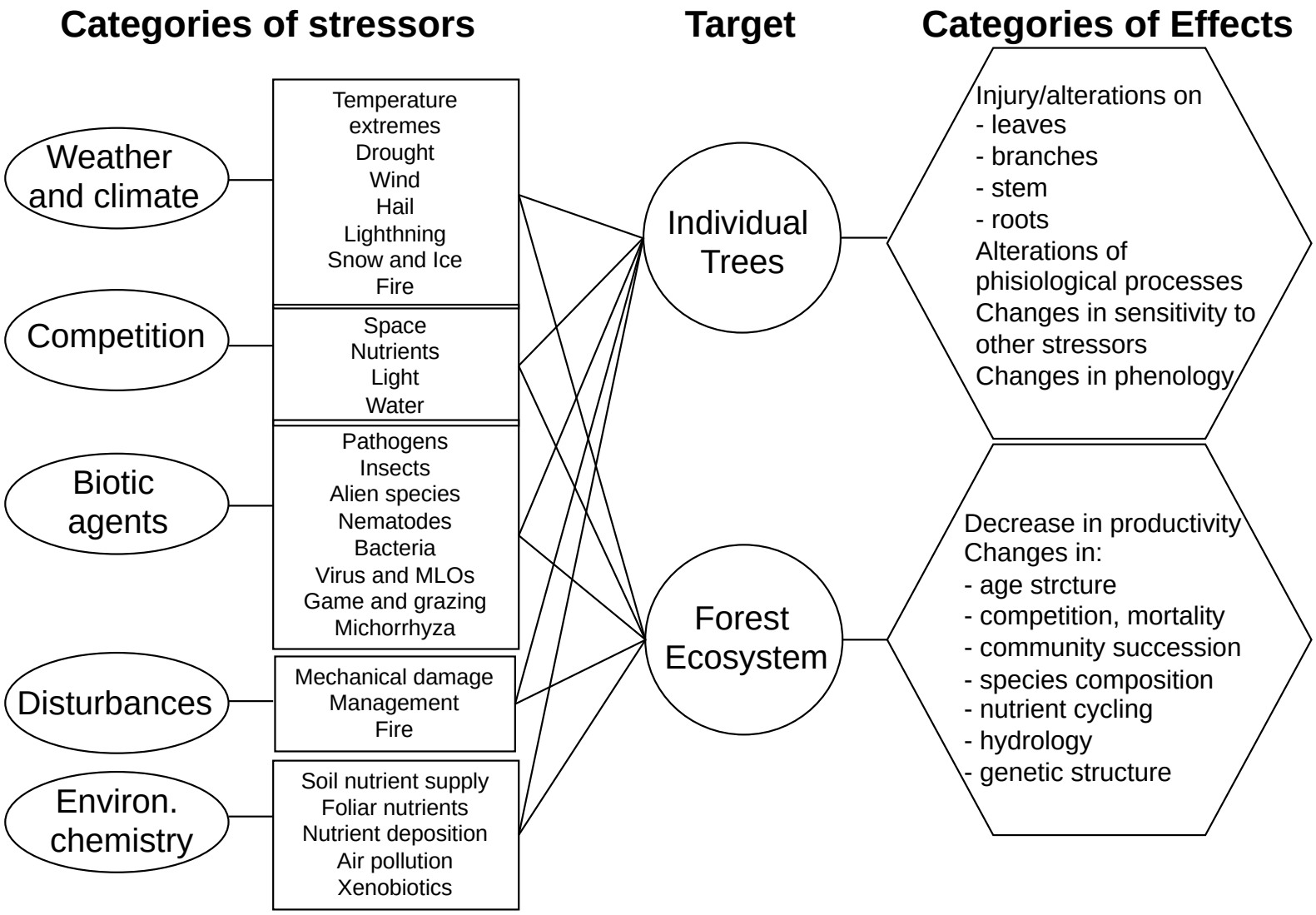
Jack pine
(Pinus banksiana)

…but it is not the only one…



(Trumbore et al., 2015, Science)

…always act in combination…



(Ferretti, 2004, Encyclopedia of Forest Science, Elsevier)

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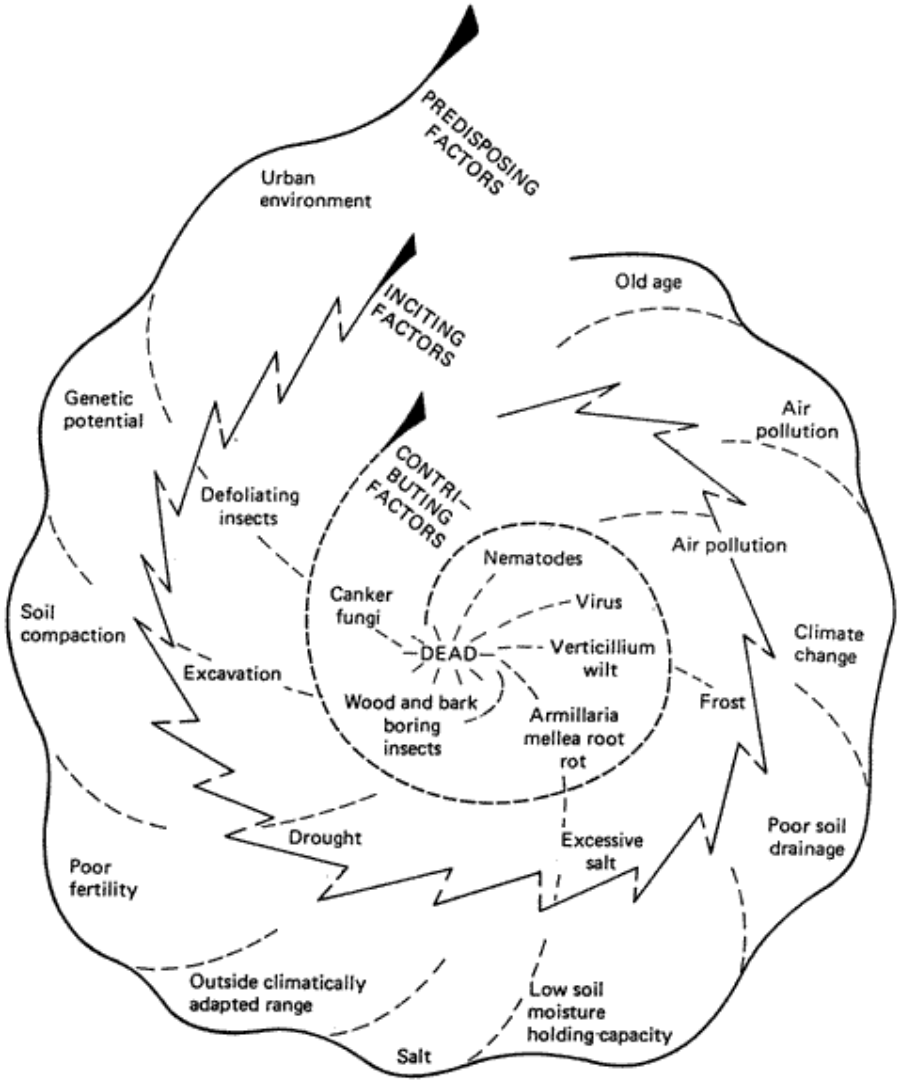

(Manion PD, Tree Disease Concepts, 1991)

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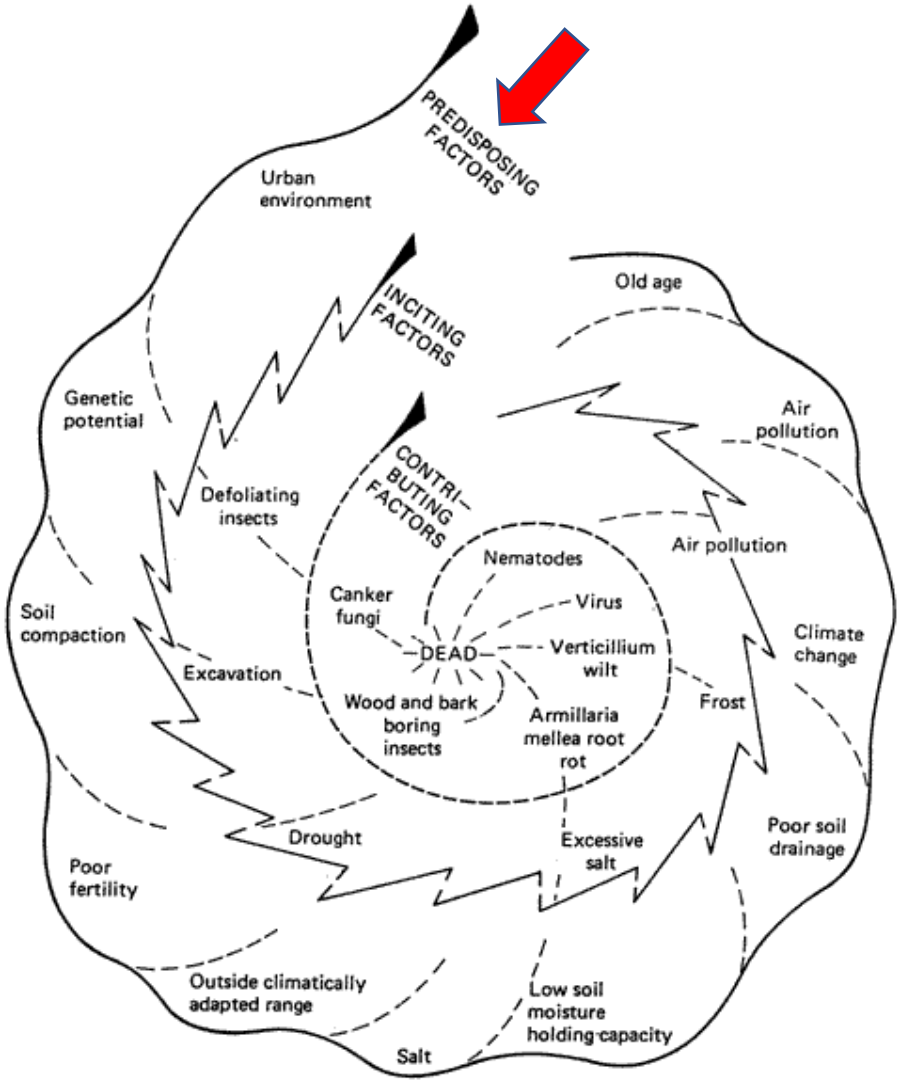

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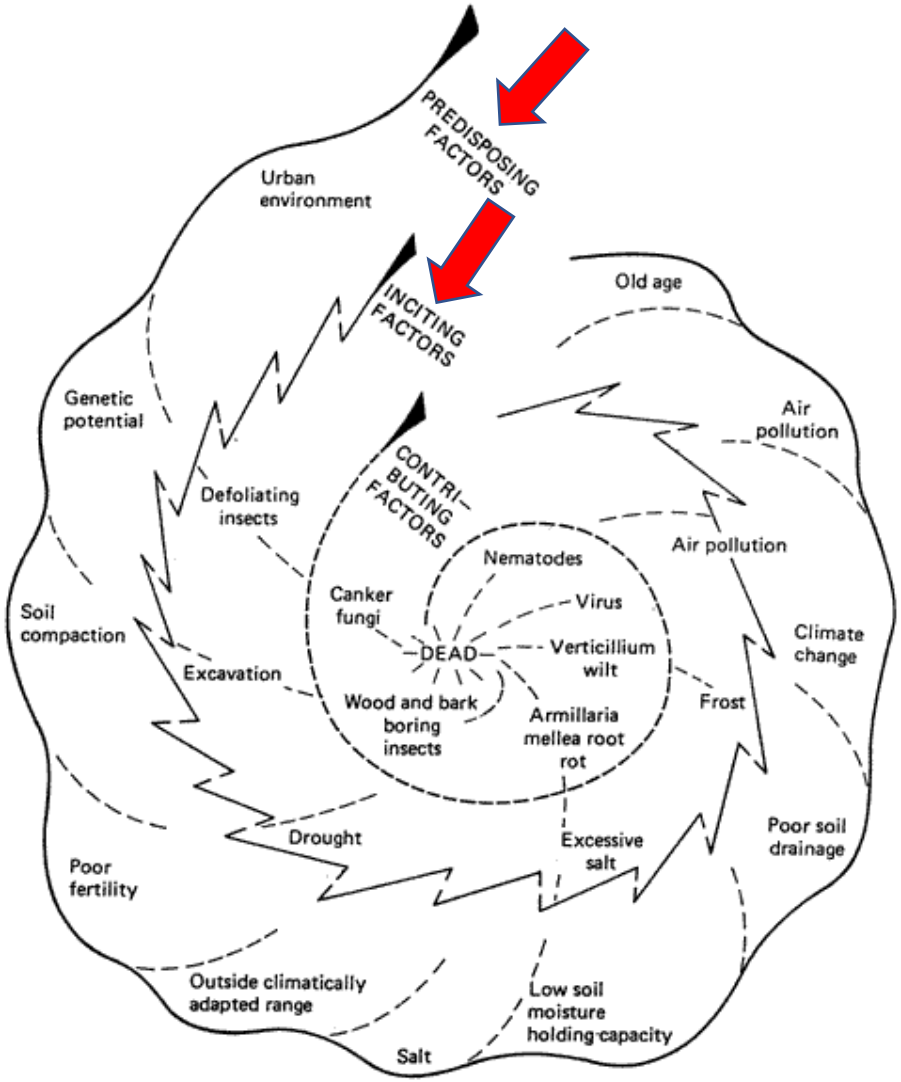

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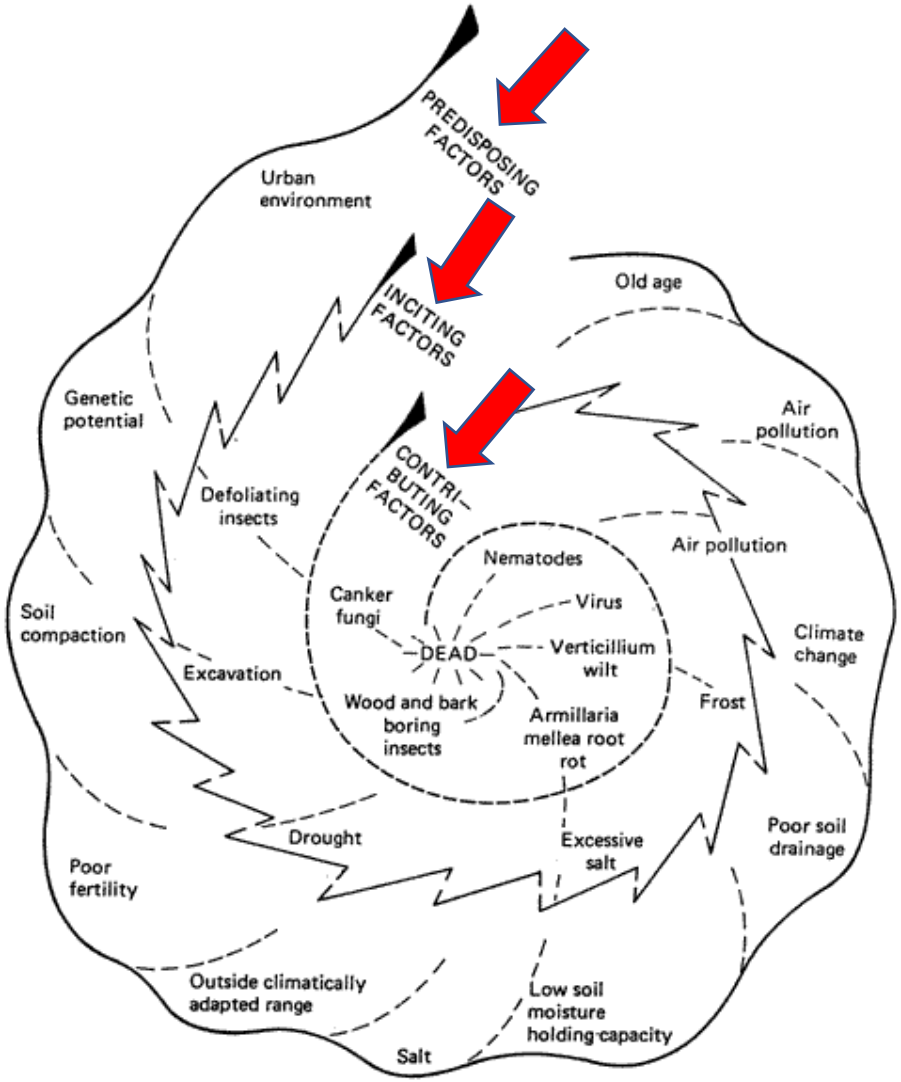

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Critical Levels - Definitions

UN/ECE, 1989	UN/ECE, 1996	UN/ECE, 2004 and subsequent revisions
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Critical Levels - application

UN/ECE, 1989	CLRTAP, 2015	CLRTAP, 2017
"It could be useful to show the degree of critical level excess and number of critical exceedances. ***The degree of damage caused by a given amount of excess, or a given number of exceedances of a critical level may not be inferred using the methodologies suggested***".	"The flux-based critical levels and associated response functions **are suitable for mapping and quantifying impacts at the local and regional scale, including effects on … roundwood supply for the forest sector industry and loss of carbon storage capacity and other beneficial ecosystem services** … Where appropriate, they could be used for assessing **economic losses**."	«The many impacts of O3 have been considered when developing critical levels. Here, we provide critical levels for the potential O_3 effects on: • Crop yield quantity and quality, ... • **Tree biomass for timber production** and potentially as a starting point for **carbon sequestration and biodiversity application**; • Grassland biomass ...»

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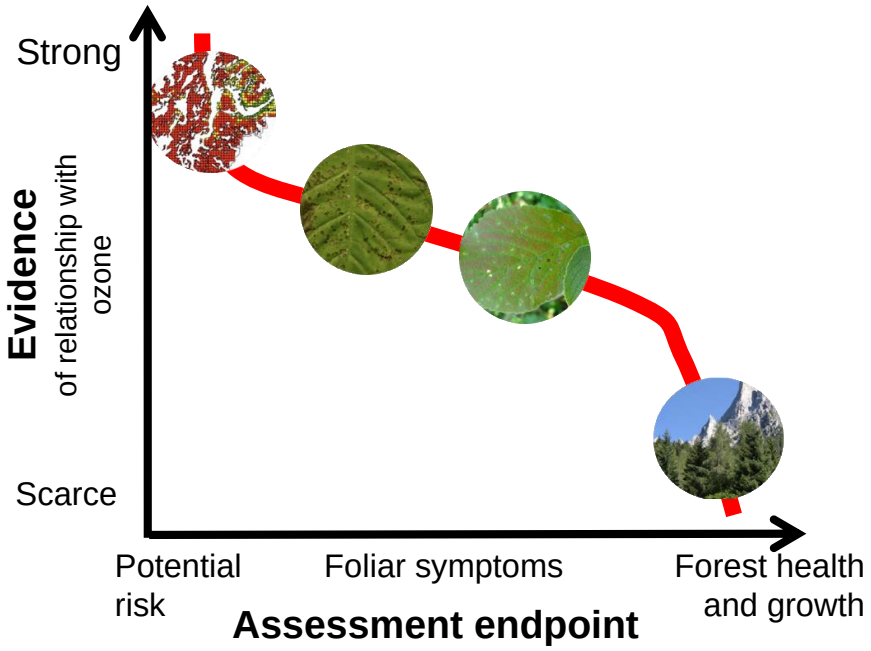
Difficult task, with controversial results

- Straightforward to identify specific foliar symptoms due to air pollution, e.g. ozone.
- Very difficult to disentangle the non-direct non-acute effect of air pollution on unspecific indicators (e.g. defoliation and growth) under “real world” condition”.
- This is a likely reason for controversial results in field studies, e.g. for ozone effects:
  - More important than climate (De Marco et al., 2017)
  - Strong** in Switzerland (Braun et al., 2007, 2014, 2017)
  - Slight* in Sweden (Karlsson et al., 2006).
  - No* or limited effect in Italy (Ferretti et al., 2003, 2007, 2014, 2018).
  - Contrasting* in Czech Republic (e.g. Srameck et al., 2012).



(Gottardini et al., 2018, ESPR)

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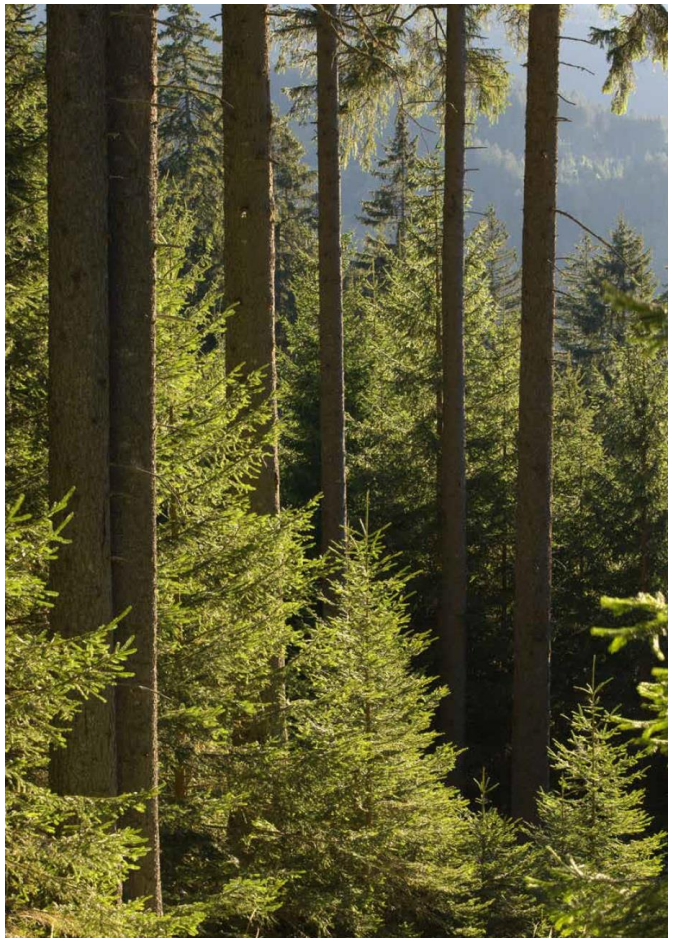

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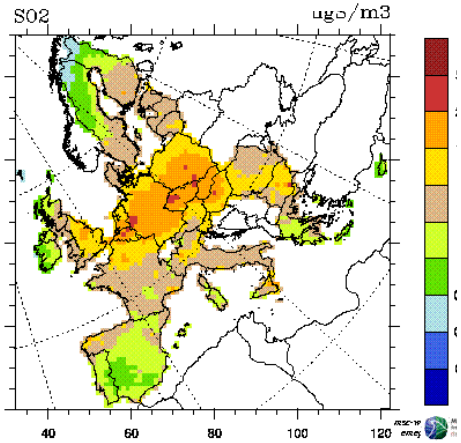
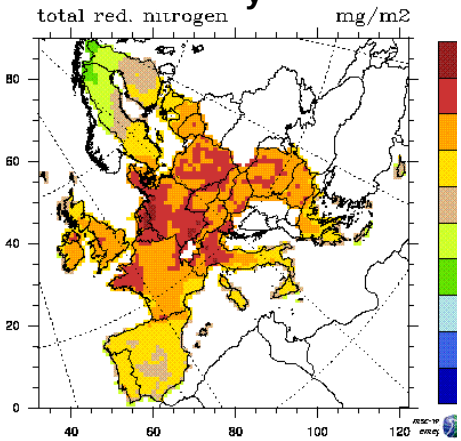
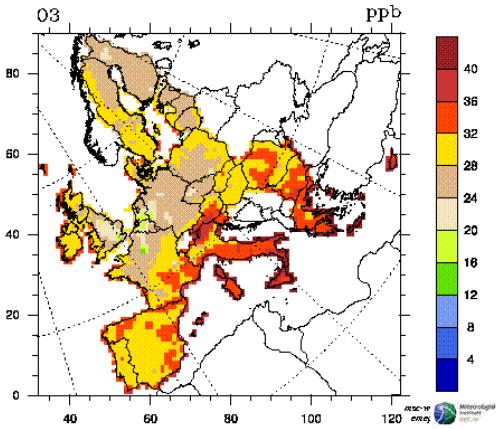
Why ozone? Air pollution in Europe

Sulfur | **NH_y** | **O_3**

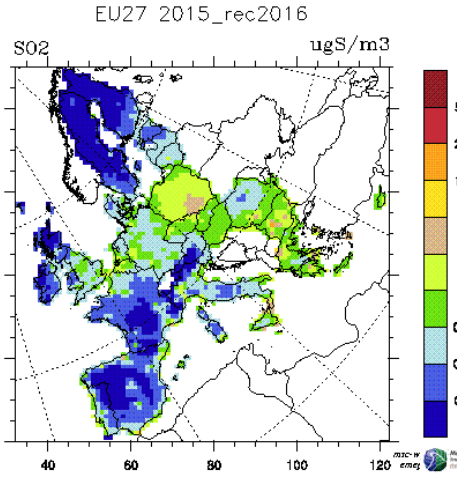
1980

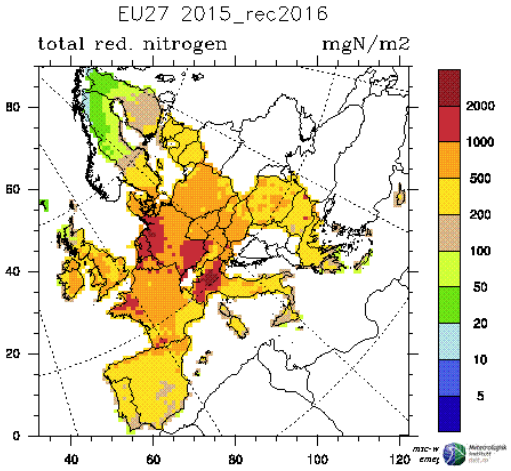


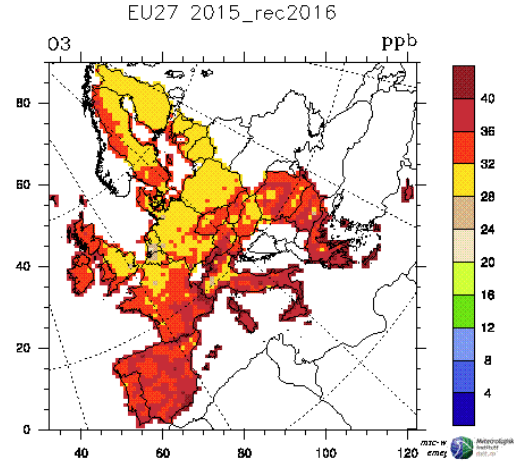




2015







Source: www.emep.org

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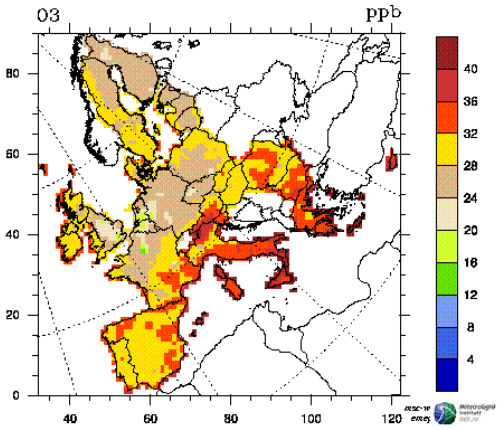

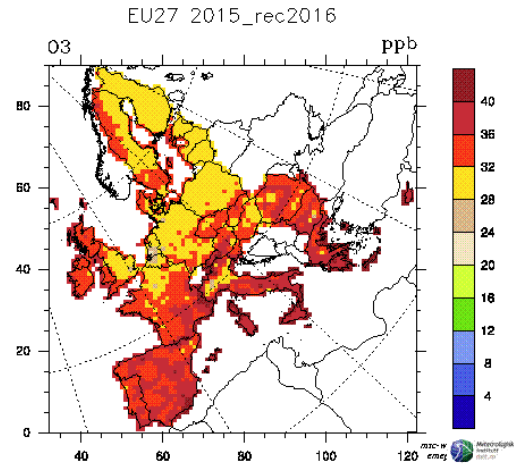

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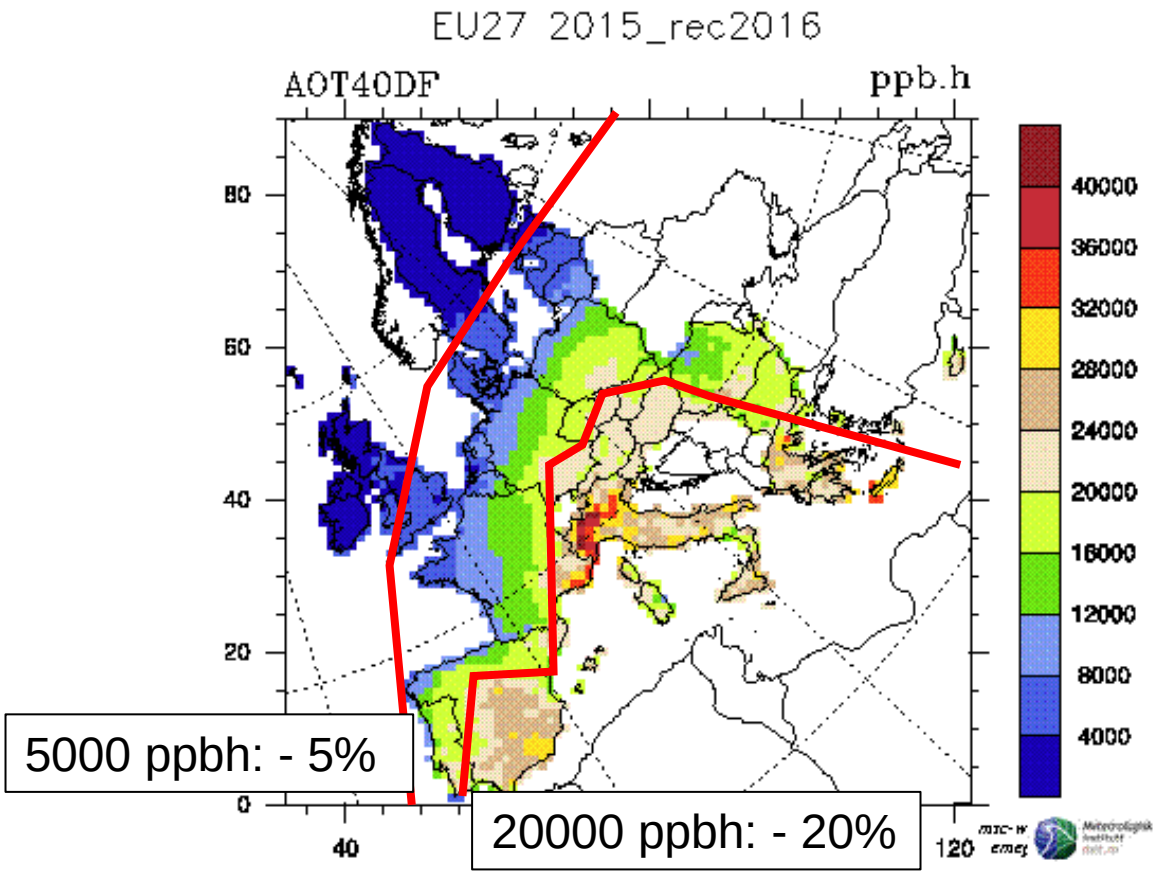
Why Ozone? Evidence for potential risk

Expected ***annual*** growth reduction



NAI Europe: 720.6 x 10^6 m^3 (SOEF, 2015)

Source: CLRTAP, 2017 www.icpmapping.org; www.emep.org

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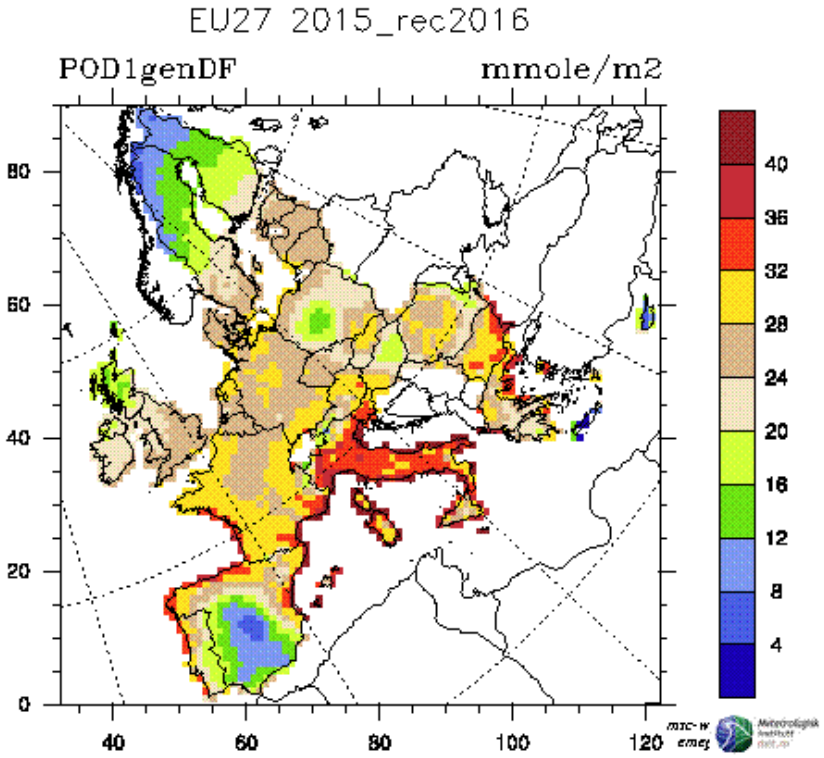

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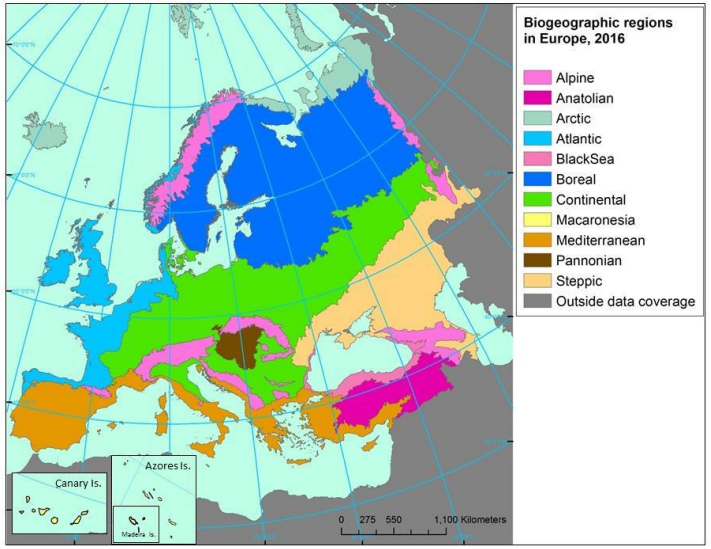
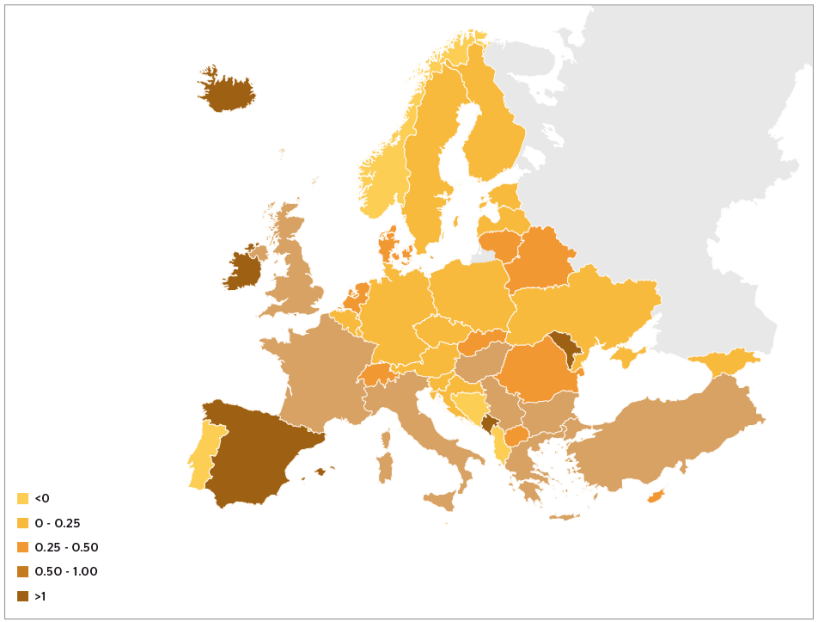
Species	Effect parameter	Biogeo-graphi-cal region*	Potential effect at CL (% annual reduc-tion)	Critical level (mmol m^{-2} PLA)**	Ref10 POD_1 (mmol m^{-2} PLA)	Potential maximum rate of reduction (%) per mmol m^{-2} PLA of POD_1SPEC***
Beech and birch	Whole tree biomass	B,C (A,S,P)	4%	5.2	0.9	0.93
Norway spruce	Whole tree biomass	B,C (A,S,P)	2%	9.2	0.1	0.22
Med. deciduous oaks	Whole tree biomass	M	4%	14.0	1.4	0.32
Med. deciduous oaks	Root biomass	M	4%	10.3	1.4	0.45
Med. evergreen	Above-ground biomass	M	4%	47.3	3.5	0.09

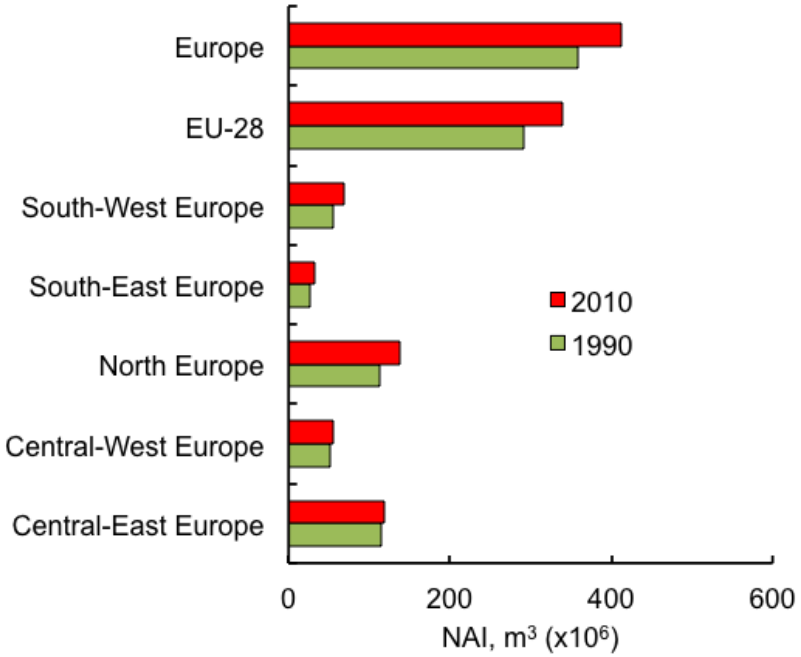


Source: CLRTAP, 2017 www.icpmapping.org; www.emep.org

Contrasting evidence – European forests expands, climb mountains and grow faster.



Forest area, annual changes 1990-2010 (%)



Net Annual Increment, common countries, 1990-2010

Source: SOEF, 2015

High potential risk – contrasting evidence for effects.
What ***else*** does not work?

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Ozone (O_3) exposure at Italian background sites exceeds UN/ECE concentration-based critical levels (CL_{e_c}), if expressed in terms of AOT40. Yet the occurrence of adverse effects of O_3 on forests and crops is controversial. Possible reasons include (i) ability of response indicators to provide an unbiased estimate of O_3 effects, (ii) setting of current CL_{e_c} in terms of cut-off value and accumulation level, (iii) response functions adopted to infer a critical level, (iv) environmental limitation to O_3 uptake and (v) inherent characteristics of Mediterranean vegetation. In particular, the two latter points suggest that critical levels based on accumulated stomatal flux (CL_{e_f}) can be a better predictor of O_3 risk than CL_{e_c}. While this concept is largely acknowledged, a number of factors may limit its applicability for routine monitoring. This paper reviews levels, uptake and vegetation response to O_3 in Italy over recent years to discuss value, uncertainty and feasibility of different approaches to risk assessment.

Keywords: Ozone; Critical levels; AOTx; Stomatal flux; Effects; Mediterranean region

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Ferretti et al., 2007

High potential risk – contrasting evidence for effects. What ***else*** does not work?

- Poor metrics for ozone?
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- Delayed response?
- Effects on roots and mycorrhiza?
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Keywords: Ozone; Critical levels; AOTx; Stomatal flux; Effects; Mediterranean region

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E-mail address: m.ferretti@linnaea.it (M. Ferretti).

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doi:10.1016/j.envpol.2006.05.012

Ferretti et al., 2007

High potential risk – contrasting evidence for effects. What ***else*** does not work?

- Poor metrics for ozone?
- Poor metrics for response?
- Delayed response?
- Effects on roots and mycorrhiza?
- …
- …or
- Unrealistic risk estimation?
- Scarce consideration of key ecological and management factors?

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ScienceDirect
Environmental Pollution 146 (2007) 648–658

ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Measuring, modelling and testing ozone exposure, flux and effects on vegetation in southern European conditions—What does not work? A review from Italy

M. Ferretti [a,*], M. Fagnano [b], T. Amoriello [c], M. Badiani [d], A. Ballarin-Denti [e], A. Buffoni [f], F. Bussotti [a], A. Castagna [g], S. Cieslik [h], A. Costantini [c], A. De Marco [i], G. Gerosa [e], G. Lorenzini [j], F. Manes [k], G. Merola [b], C. Nali [j], E. Paoletti [i], B. Petriccione [m], S. Racalbuto [i], G. Rana [n], A. Ranieri [g], A. Tagliaferri [o], G. Vialetto [i], M. Vitale [k]

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[b] DIAAT, Università di Napoli "Federico II", Naples, Italy
[c] CRA-ISNP, Rome, Italy
[d] BIOMAA, Università Mediterranea di Reggio Calabria, Reggio Calabria, Italy
[e] DMF, Università Cattolica di Brescia, Brescia, Italy
[f] Istituto Ambiente Italia, Milano, Italy
[g] DCBA, Università di Pisa, Pisa, Italy
[h] Joint Research Centre, Ispra, Italy
[i] PROT-ATM, ENEA, Rome, Italy
[j] DCDSL, Università di Pisa, Pisa, Italy
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Ferretti et al., 2007

CLs - Risk for biomass reduction

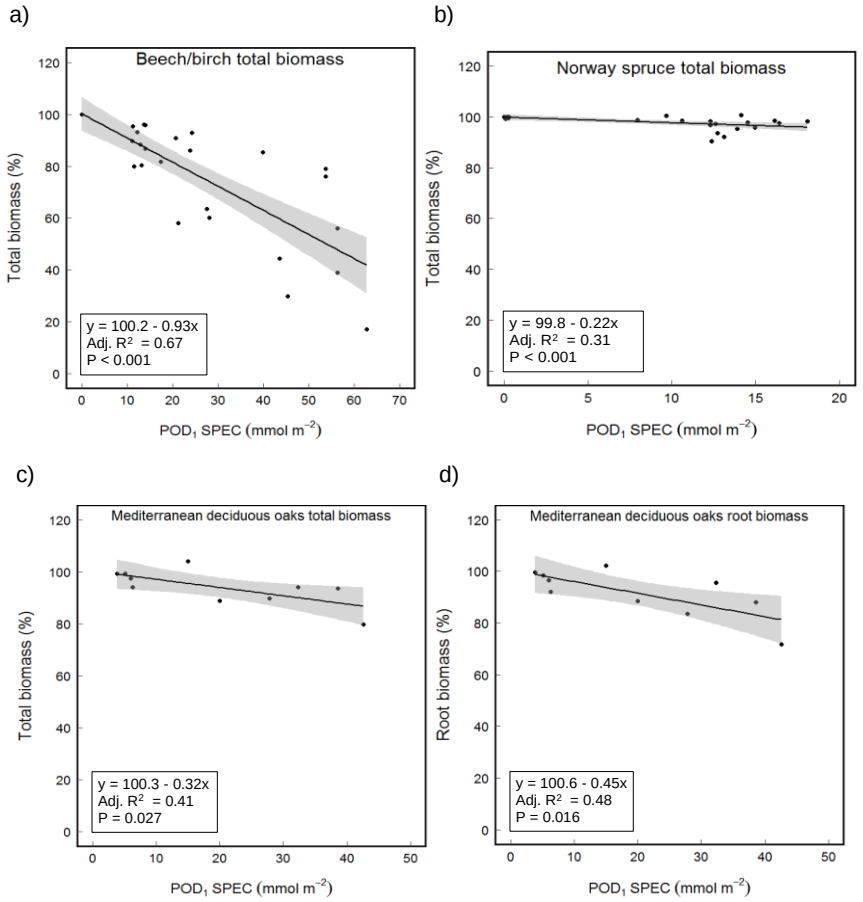
Concentration-based CLs

- Cumulated ozone exposure (AOT_x, ppb h) above a certain concentration (***x***).

Flux-based CLs

- Cumulated phytotoxic dose (POD_y, mmol m^{-2} PLA) above a certain threshold (***y***).

Always based on dose-response relationship (DRRs).



Several sources, in CLRTAP 2017

Derivation of DRRs

“Dose response relationships have been established using experimental data from exposure systems such as open-top chambers that enable plants to be grown under naturally varying climatic conditions for one or more growing seasons.”

CLRTAP, 2015 www.icpmapping.org

Derivation of DRRs

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CLRTAP, 2015 www.icpmapping.org

Real forest, Carpathians, Romania

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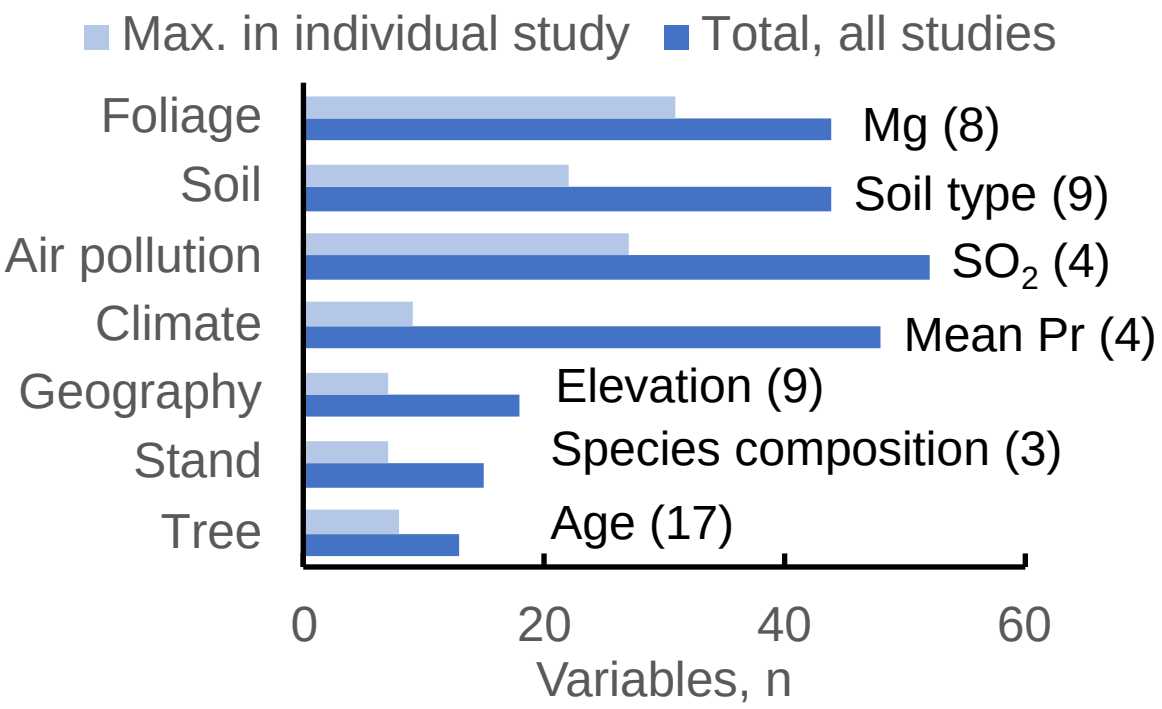
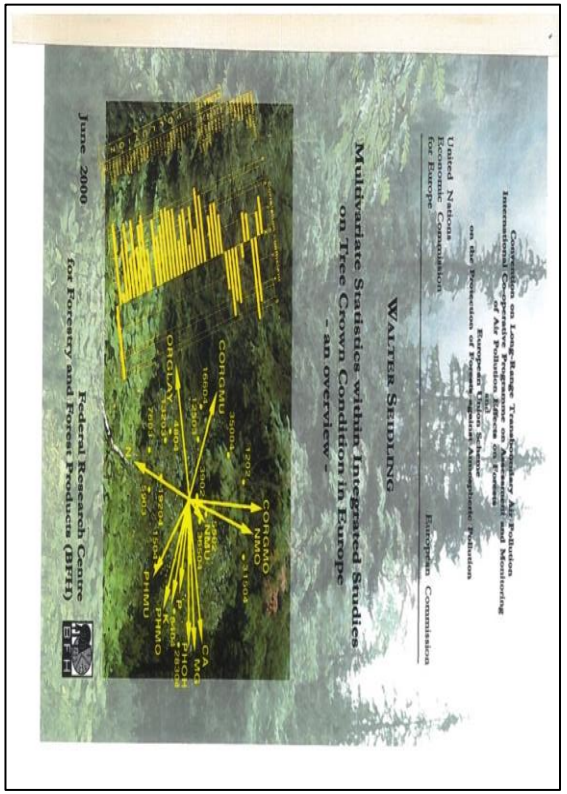
Ferretti et al., 2007

Field studies: a former review (Seidling, 2000)

Evaluation of n=21 multivariate studies published between 1988 and 1999





Based on:
Seidling, 2000. UN/ECE and EC, Geneve and Brussels, 45 ps.

Field studies: a recent review (Braun et al., 2017)

Evaluation of n=11 “epidemiological” studies published between 1995 and 2016

Study	Tree	Stand	Geography	Climate	Air pollution	Soil	Foliage
Sutton et al., 2008	2	1		2	2		
Kint et al., 2012	2	1		1	1		
Roth et al., 2013		1	2	1		1	
McLaughlin and Downing, 1995				3	1		
McLaughlin et al., 2007a; McLaughlin et al., 2007b; Sun et al., 2012.				3	1		
Braun et al., 2014				3	1	1	
Karlsson et al., 2006		1		1	1	1	
De Marco et al., 2015, Sicard et al., 2016a		1		4	2	1	

Science of the Total Environment 603–604 (2017) 785–792

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journal homepage: www.elsevier.com/locate/scitotenv

Epidemiological analysis of ozone and nitrogen impacts on vegetation – Critical evaluation and recommendations

Sabine Braun[a,*], Beat Achermann[b], Alessandra De Marco[c], Håkan Pleijel[d], Per Erik Karlsson[e], Beat Rihm[f], Christian Schindler[g], Elena Paoletti[h]

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HIGHLIGHTS

- Epidemiology of air pollution impacts on vegetation is under strong development.
- Epidemiological data analysis is a good tool to validate dose–response relationships.
- It allows analysis of interactions between environmental impacts and site factors.
- It contributes to the understanding of ecological processes.
- Recommendations on mapping of predictors and on the statistical analysis are made.

ARTICLE INFO

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ABSTRACT

For human health studies, epidemiology has been established as important tool to examine factors that affect the frequency and distribution of disease, injury, and other health-related events in a defined population, serving the purpose of establishing prevention and control programs. On the other hand, gradient studies have a long tradition in the research of air pollution effects on plants. While there is no principal difference between gradient and epidemiological studies, the former address more one-dimensional transects while the latter focus more on populations and include more experience in making quantitative predictions, in dealing with confounding factors and in taking into account the complex interplay of different factors acting at different levels. Epidemiological analyses may disentangle and quantify the contributions of different predictor variables to an overall effect, e.g. plant growth, and may generate hypotheses deserving further study in experiments. Therefore, their use in ecosystem research is encouraged. This article provides a number of recommendations on: (1) spatial and temporal aspects in preparing predictor maps of nitrogen deposition, ozone exposure and meteorological covariates; (2) extent of a dataset required for an analysis; (3) choice of the appropriate regression model and conditions to be satisfied by the data; (4) selection of the relevant explanatory variables; (5) treatment of interactions and confounding factors; and (6) assessment of model validity.

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1. Introduction

1.1. The need for epidemiological studies

The deposition of nitrogen (N) and ozone (O_3) are important drivers of global change and have a high potential for affecting ecosystems (Bytnerowicz et al., 2007). Ground-level O_3 concentrations have

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http://dx.doi.org/10.1016/j.scitotenv.2017.02.225
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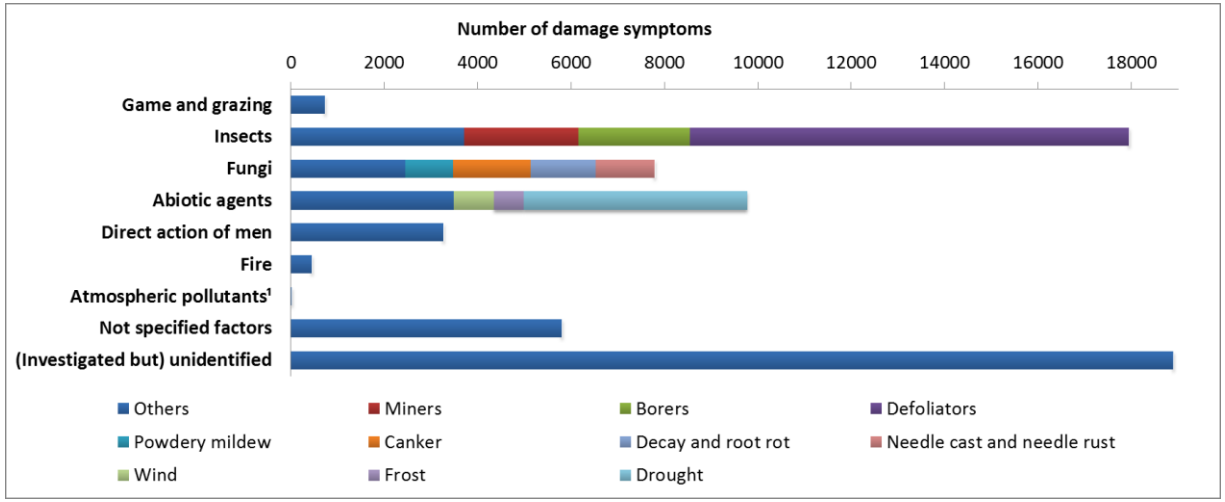
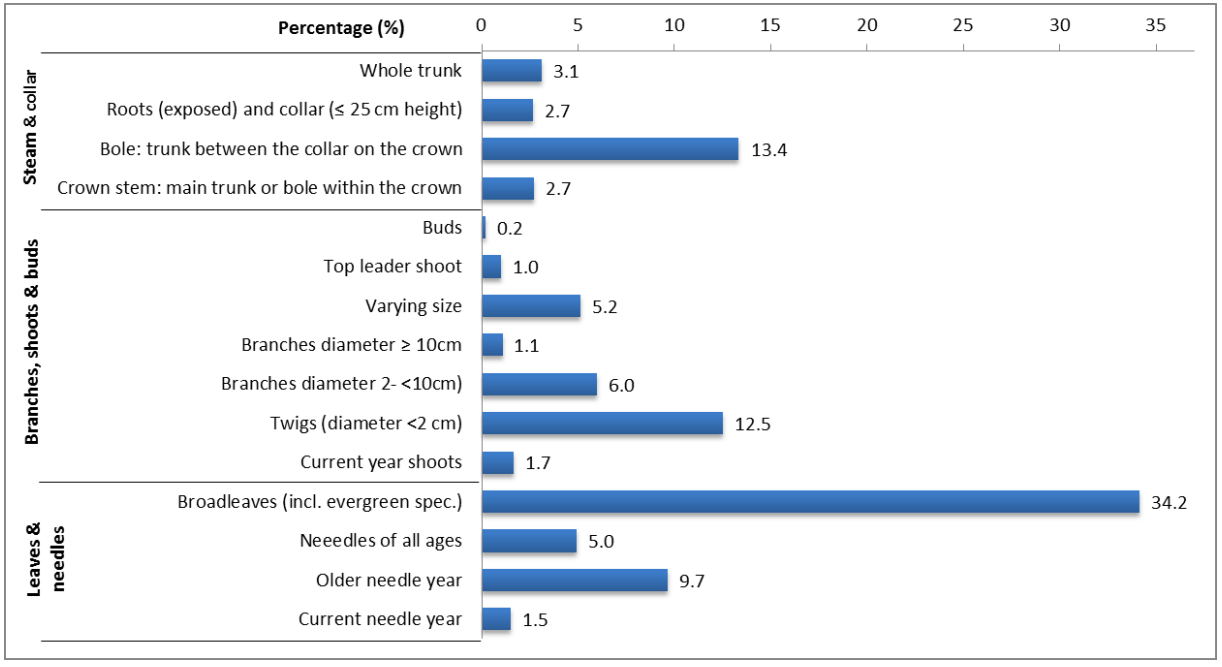
Based on:
Braun et al., 2017, Science of Total Environment.

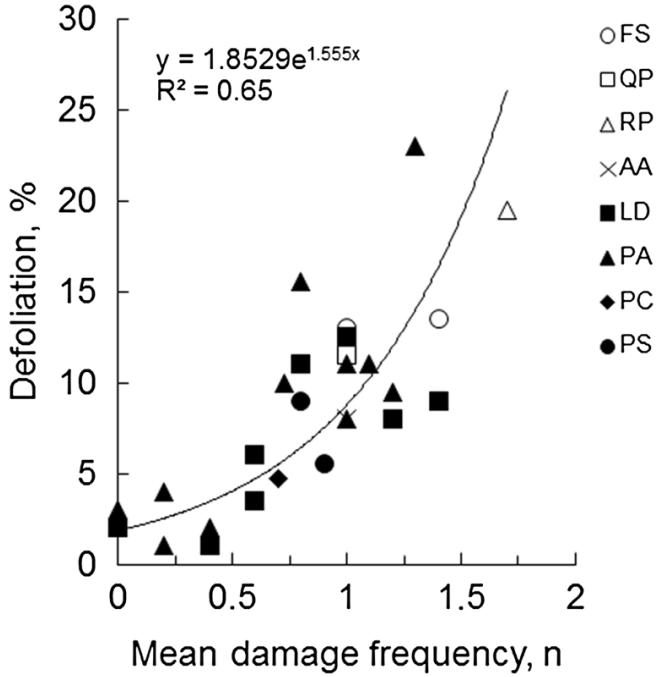
What about... damaging agents?





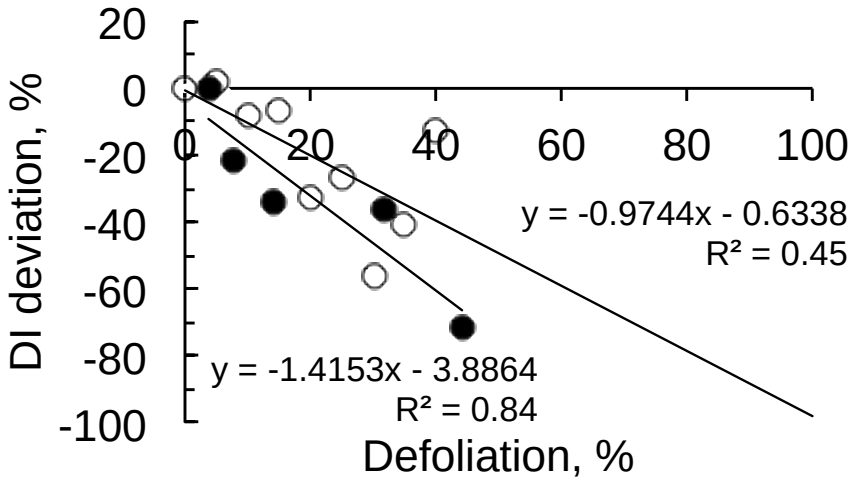
(Michel A, Seidling W, eds., 2017)

Damaging agents affects defoliation that in turn affects growth



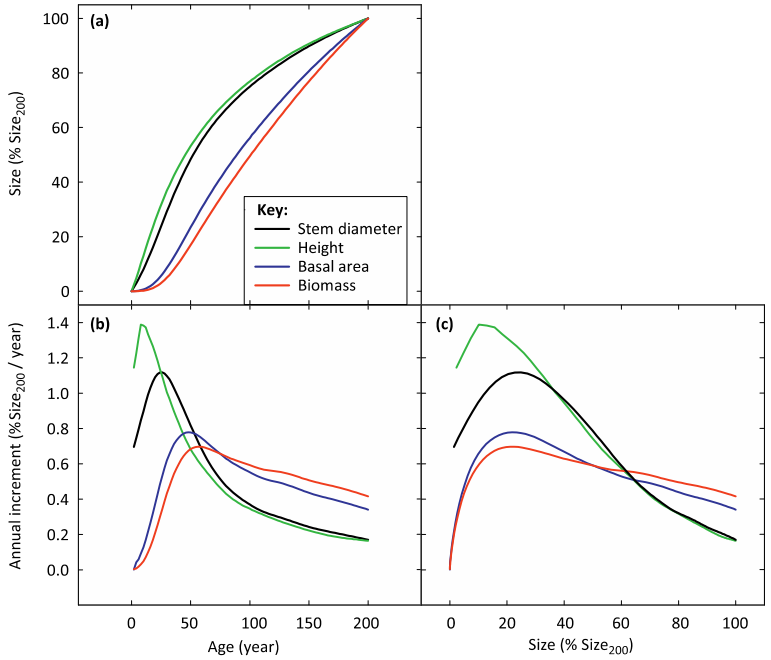
Ferretti et al., 2018, ESPR

Black dots: Trentino, Italy;
White dots: France

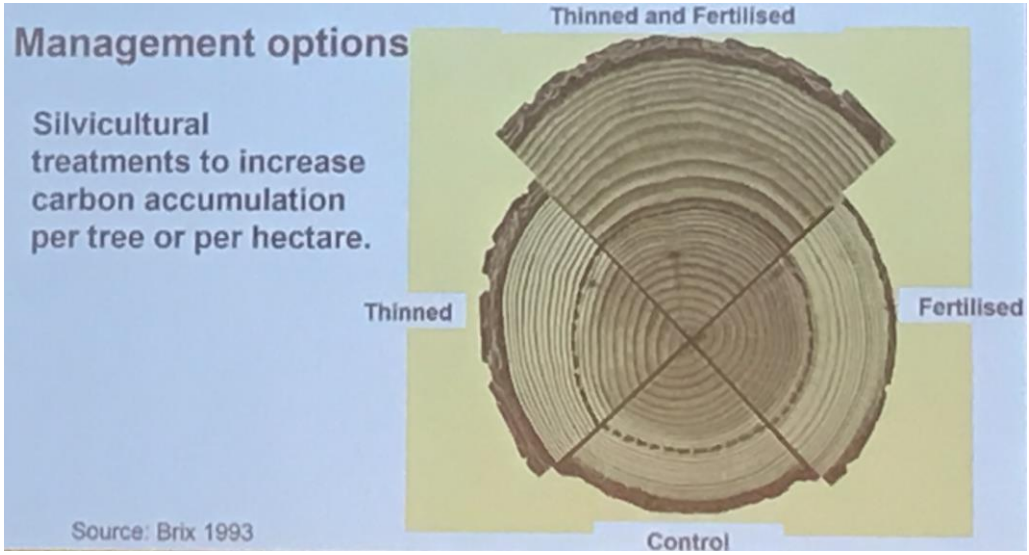


Ferretti et al., in preparation

What about... management and growth dynamics?



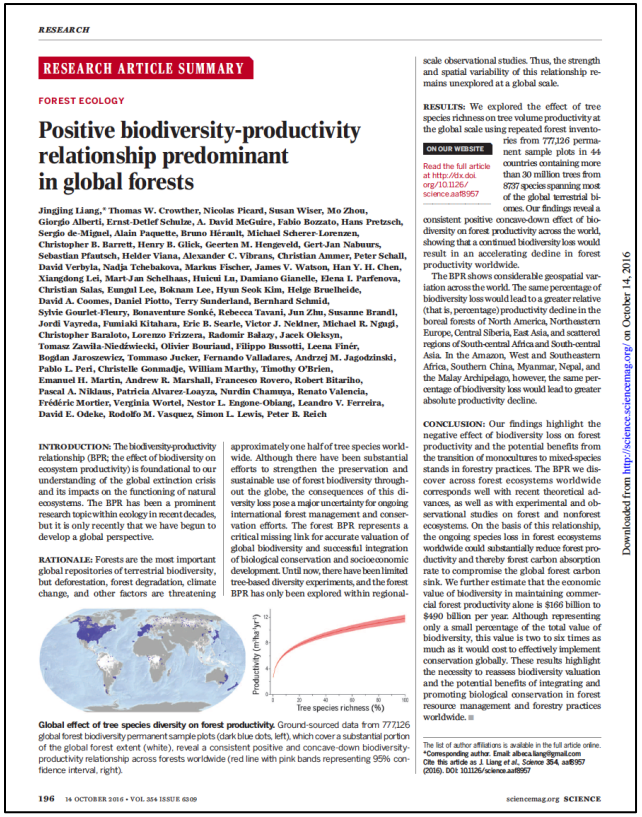
Bowman et al., 2013, Trends in Plant Science



Brix H. 1993. FRDA Report, ISSN 0835-0752: 196. Victoria: Government of Canada, 40.

(Slide after the presentation by Werner Kurz (Canadian Forest Service), held in Freiburg, IUFRO 125th Anniversary Congress, 21st Sept. 2017)

What about… competion, composition, complementarity, biodiversity?



RESEARCH

RESEARCH ARTICLE SUMMARY

FOREST ECOLOGY

Positive biodiversity-productivity relationship predominant in global forests

Jingjing Liang,* Thomas W. Crowther, Nicolas Picard, Susan Wiser, Mo Zhou, Giorgio Alberti, Ernst-Detlef Schulze, A. David McGuire, Fabio Bozzato, Hans Pretzsch, Sergio de-Miguel, Alain Paquette, Bruno Hérault, Michael Scherer-Lorenzen, Christopher B. Barrett, Henry B. Glick, Geerten M. Hengeveld, Gert-Jan Nabuurs, Sebastian Pfautsch, Helder Viana, Alexander C. Vibrans, Christian Ammer, Peter Schall, David Verbyla, Nadja Tchebakova, Markus Fischer, James V. Watson, Han Y. H. Chen, Xiangdong Lei, Mart-Jan Schelhaas, Huicui Lu, Damiano Gianelle, Elena I. Parfenova, Christian Salas, Eungul Lee, Boknam Lee, Hyun Seok Kim, Helge Bruelheide, David A. Coomes, Daniel Piotto, Terry Sunderland, Bernhard Schmid, Sylvie Gourlet-Fleury, Bonaventure Sonké, Rebecca Tavani, Jun Zhu, Susanne Brandl, Jordi Vayreda, Fumiaki Kitahara, Eric B. Searle, Victor J. Neldner, Michael R. Ngugi, Christopher Baraloto, Lorenzo Frizzera, Radomir Bałazy, Jacek Oleksyn, Tomasz Zawiła-Niedźwiecki, Olivier Bouriaud, Filippo Bussotti, Leena Finér, Bogdan Jaroszewicz, Tommaso Jucker, Fernando Valladares, Andrzej M. Jagodzinski, Pablo L. Peri, Christelle Gonmadje, William Marthy, Timothy O'Brien, Emanuel H. Martin, Andrew R. Marshall, Francesco Rovero, Robert Bitariho, Pascal A. Niklaus, Patricia Alvarez-Loayza, Nurdin Chamuya, Renato Valencia, Frédéric Mortier, Verginia Wortel, Nestor L. Engone-Obiang, Leandro V. Ferreira, David E. Odeke, Rodolfo M. Vasquez, Simon L. Lewis, Peter B. Reich

INTRODUCTION: The biodiversity-productivity relationship (BPR; the effect of biodiversity on ecosystem productivity) is foundational to our understanding of the global extinction crisis and its impacts on the functioning of natural ecosystems. The BPR has been a prominent research topic within ecology in recent decades, but it is only recently that we have begun to develop a global perspective.

RATIONALE: Forests are the most important global repositories of terrestrial biodiversity, but deforestation, forest degradation, climate change, and other factors are threatening approximately one half of tree species worldwide. Although there have been substantial efforts to strengthen the preservation and sustainable use of forest biodiversity throughout the globe, the consequences of this diversity loss pose a major uncertainty for ongoing international forest management and conservation efforts. The forest BPR represents a critical missing link for accurate valuation of global biodiversity and successful integration of biological conservation and socioeconomic development. Until now, there have been limited tree-based diversity experiments, and the forest BPR has only been explored within regional-scale observational studies. Thus, the strength and spatial variability of this relationship remains unexplored at a global scale.

RESULTS: We explored the effect of tree species richness on tree volume productivity at the global scale using repeated forest inventories from 777,126 permanent sample plots in 44 countries containing more than 30 million trees from 8737 species spanning most of the global terrestrial biomes. Our findings reveal a consistent positive concave-down effect of biodiversity on forest productivity across the world, showing that a continued biodiversity loss would result in an accelerating decline in forest productivity worldwide.

The BPR shows considerable geospatial variation across the world. The same percentage of biodiversity loss would lead to a greater relative (that is, percentage) productivity decline in the boreal forests of North America, Northeastern Europe, Central Siberia, East Asia, and scattered regions of South-central Africa and South-central Asia. In the Amazon, West and Southeastern Africa, Southern China, Myanmar, Nepal, and the Malay Archipelago, however, the same percentage of biodiversity loss would lead to greater absolute productivity decline.

CONCLUSION: Our findings highlight the negative effect of biodiversity loss on forest productivity and the potential benefits from the transition of monocultures to mixed-species stands in forestry practices. The BPR we discover across forest ecosystems worldwide corresponds well with recent theoretical advances, as well as with experimental and observational studies on forest and nonforest ecosystems. On the basis of this relationship, the ongoing species loss in forest ecosystems worldwide could substantially reduce forest productivity and thereby forest carbon absorption rate to compromise the global forest carbon sink. We further estimate that the economic value of biodiversity in maintaining commercial forest productivity alone is $166 billion to $490 billion per year. Although representing only a small percentage of the total value of biodiversity, this value is two to six times as much as it would cost to effectively implement conservation globally. These results highlight the necessity to reassess biodiversity valuation and the potential benefits of integrating and promoting biological conservation in forest resource management and forestry practices worldwide. ■

ON OUR WEBSITE

Read the full article at http://dx.doi.org/10.1126/science.aaf8957

Global effect of tree species diversity on forest productivity. Ground-sourced data from 777,126 global forest biodiversity permanent sample plots (dark blue dots, left), which cover a substantial portion of the global forest extent (white), reveal a consistent positive and concave-down biodiversity-productivity relationship across forests worldwide (red line with pink bands representing 95% confidence interval, right).

The list of author affiliations is available in the full article online.
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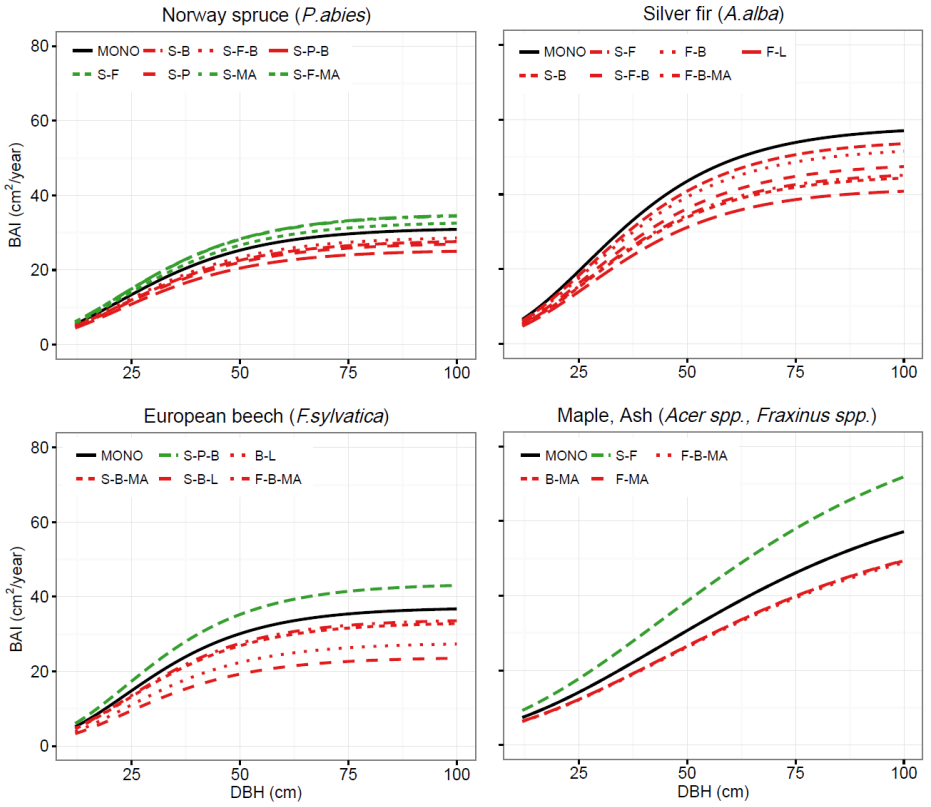
Cite this article as J. Liang et al., Science 354, aaf8957 (2016). DOI: 10.1126/science.aaf8957

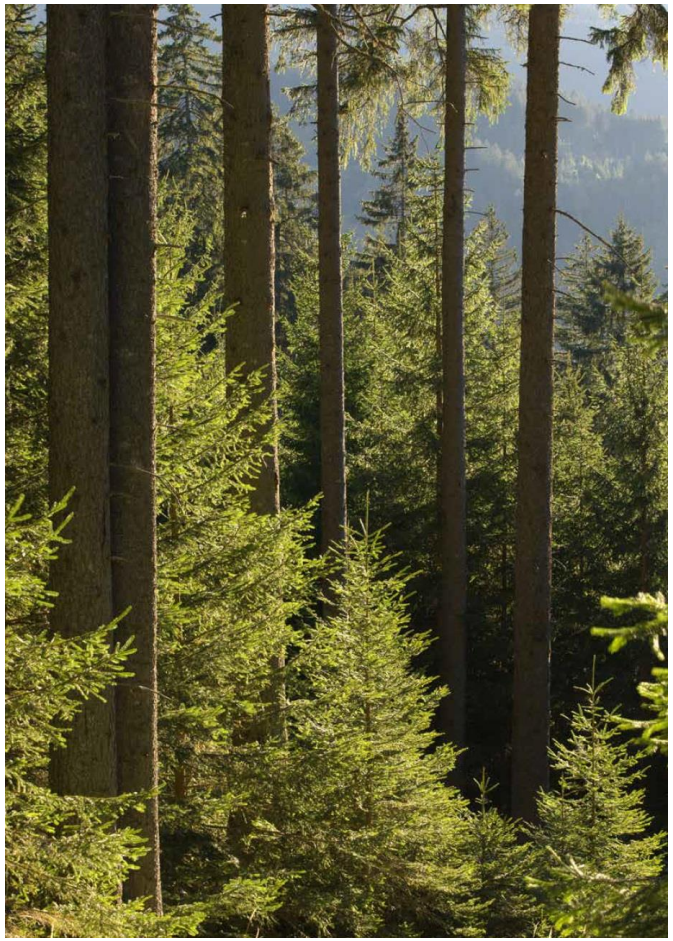
Liang et al., 2017, Science



Mina et al., 2017, Journal of Ecology

Outline

- Background: why this presentation?
- The example of ground-level ozone
- Towards a broader perspective for air pollution studies.

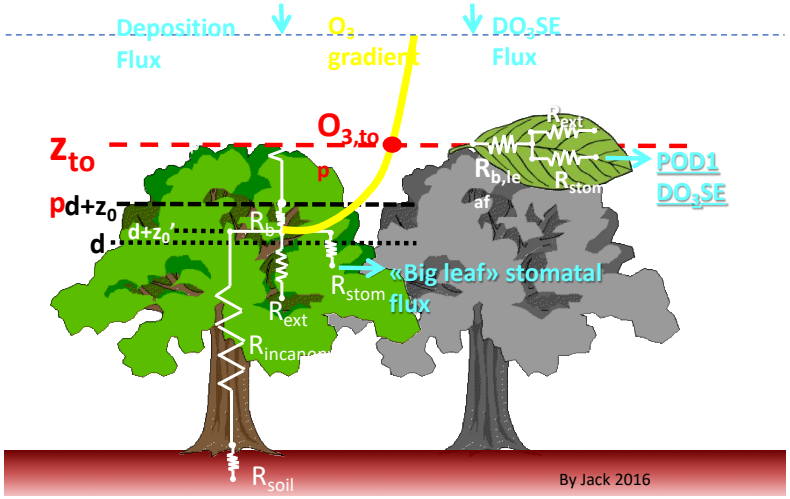


(Photo: PA Trento, Report 2014)

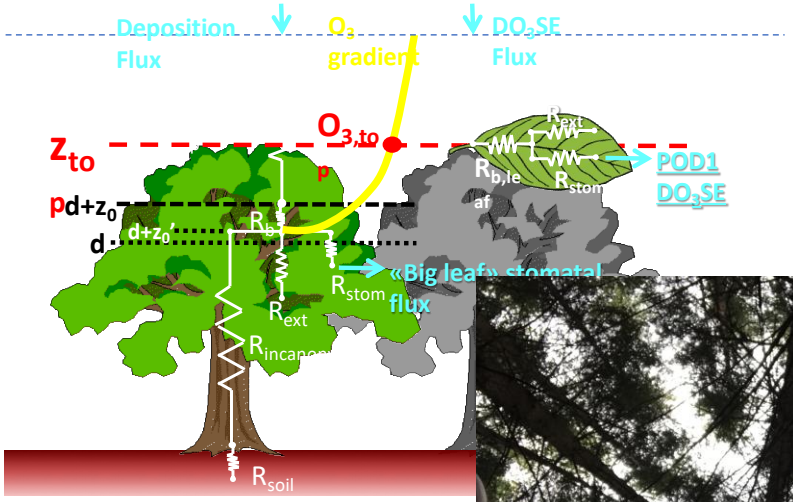
Back to Critical Levels' application

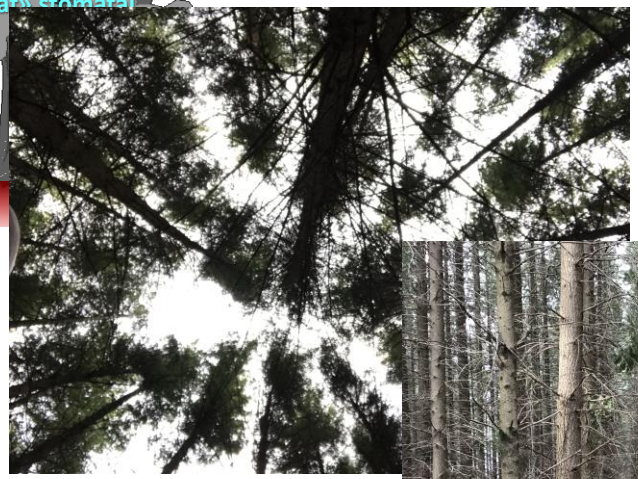
UN/ECE, 1989	CLRTAP, 2015	CLRTAP, 2017
"It could be useful to show the degree of critical level excess and number of critical exceedances. ***The degree of damage caused by a given amount of excess, or a given number of exceedances of a critical level may not be inferred using the methodologies suggested***".	"The flux-based critical levels and associated response functions **are suitable for mapping and quantifying impacts at the local and regional scale, including effects on … roundwood supply for the forest sector industry and loss of carbon storage capacity and other beneficial ecosystem services** … Where appropriate, they could be used for assessing **economic losses**."	«The many impacts of O3 have been considered when developing critical levels. Here, we provide critical levels for the potential O_3 effects on: • Crop yield quantity and quality, ... • **Tree biomass for timber production** and potentially as a starting point for **carbon sequestration and biodiversity application**; • Grassland biomass ...»

Trees and forests beyond the sunlit leaf

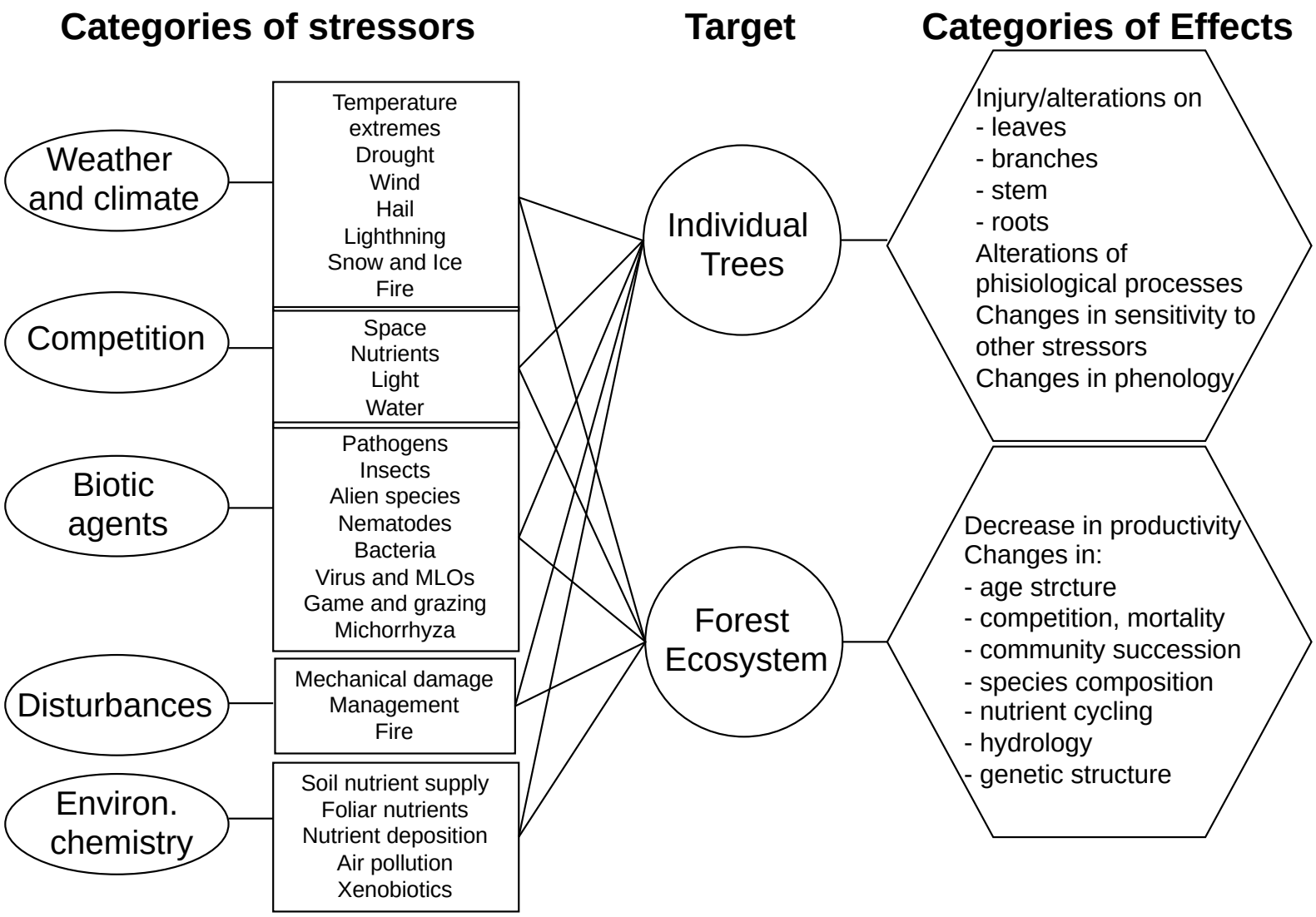


Trees and forests beyond the sunlit leaf





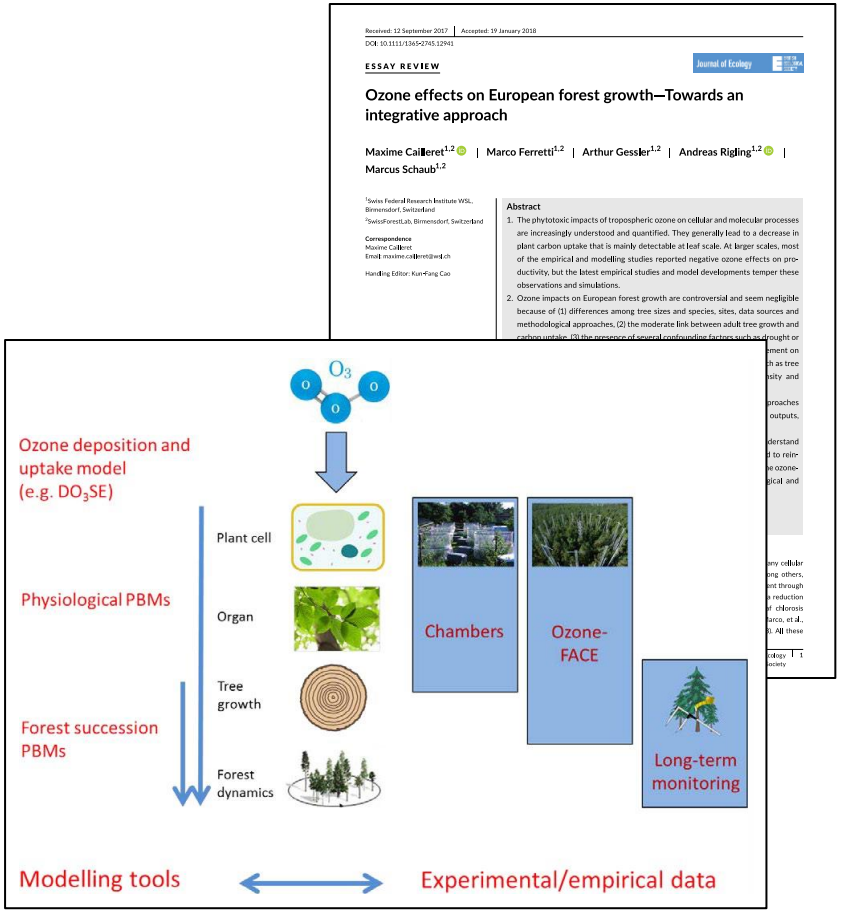
Back to the many factors



(Ferretti, 2004, Encyclopedia of Forest Science, Elsevier)

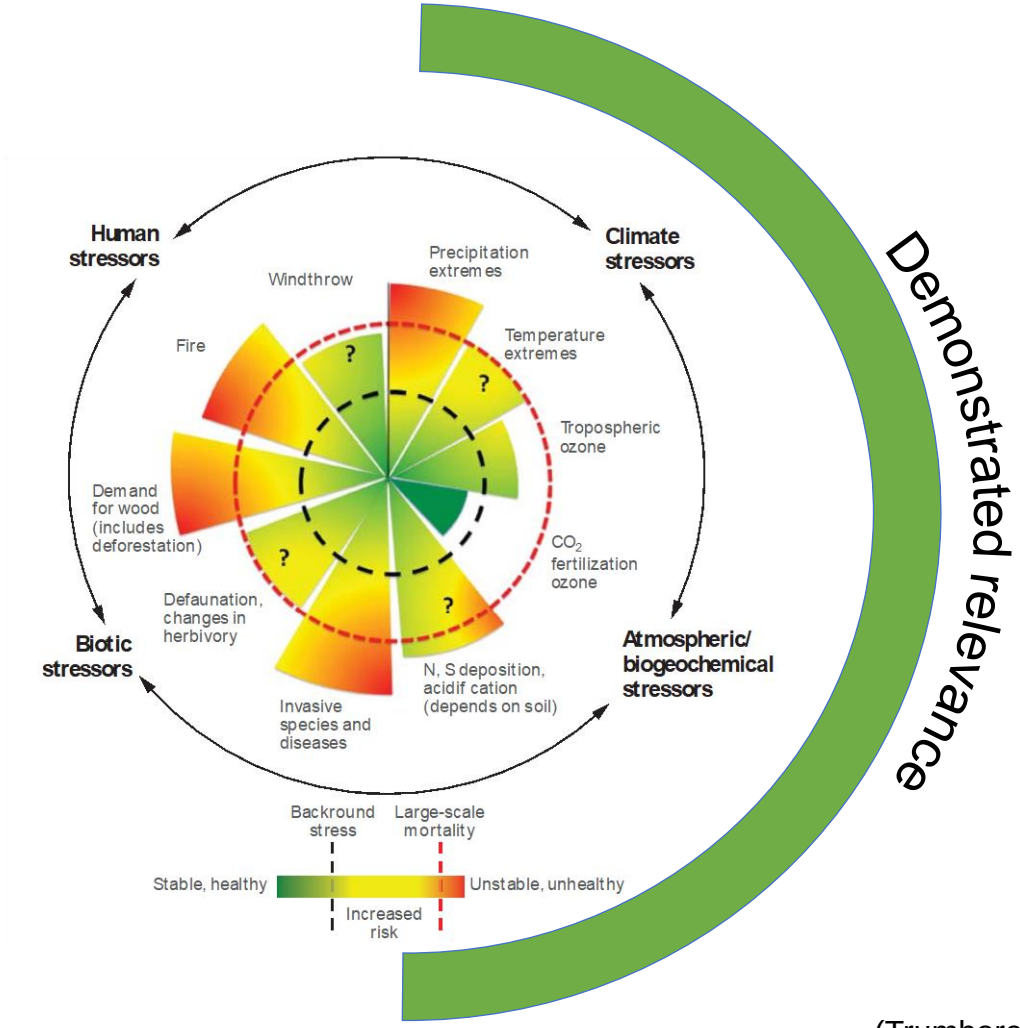
Need to integrate other sources of data into risk assessment and DRRs

- **Integration across platforms**
  - Terrestrial, proximal, remote.
- **Integration across approaches and scales**
  - Monitoring, inventories, ecological research, experiments and dynamic models.
- **Integration among driving forces**
  - Biotic, abiotic, incl. competition and management.
- **Data catalogue**
  - Management
  - Management history
  - Below-ground tree compartments.



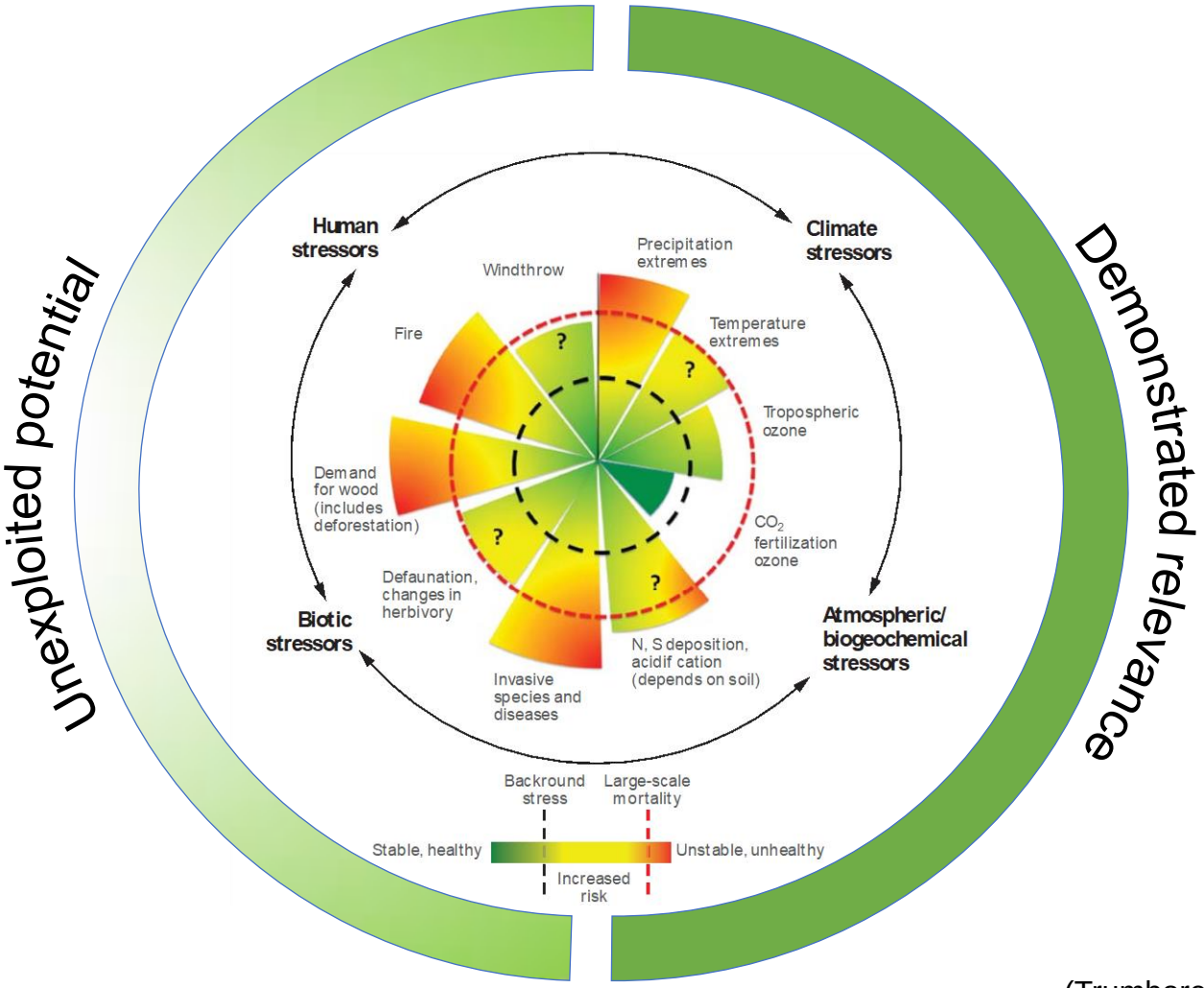
Cailleret et al., 2018, Journal of Ecology

ICP Forests relevance



(Trumbore et al., 2015, Science)

ICP Forests relevance



(Trumbore et al., 2015, Science)

Conclusions: back to ecology and management

Most studies (e.g. experiments to set CLs; field observational studies) were developed from a relatively narrow perspective. Useful at the beginning, now they are unrealistic especially in view of a broader target for risk assessment (from negative effects unrelated to other factors to impact on C sequestration, timber production and biodiversity).

Studies should consider the role of “traditional” ecological driving forces, inherent dynamics, and management and their interactions. Their inclusion is as important as the choice of a good statistical approach.

ICP Forests can have an important role here: providing data, implement its data catalogue to allow full consideration of important ecological and management factors and promoting co-operation (e.g., with other ICPs) and integrated studies are pivotal for fulfilling scientific tasks and mandate from the LRTAP convention.