

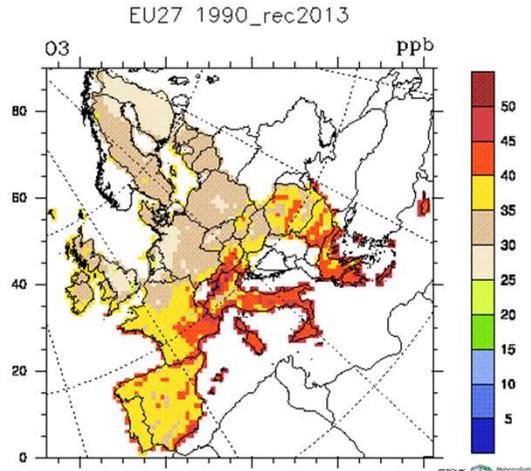
Rischio ozono per la vegetazione forestale: teoria, pratica e realtà

Marco Ferretti¹, Giacomo Gerosa²

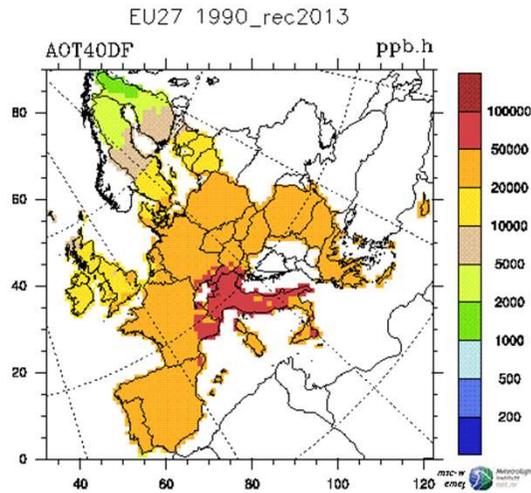
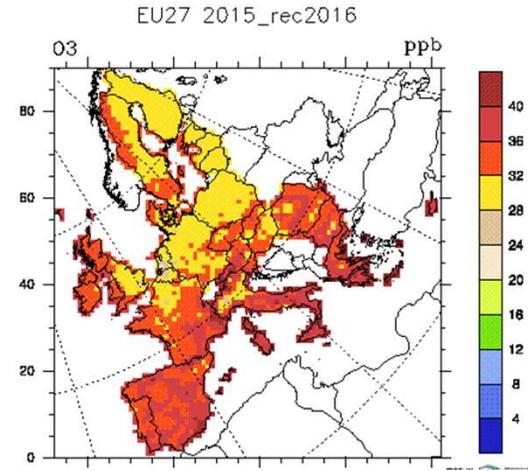
¹*TerraData environmetrics, Monterotondo M.mo, Grosseto, Italy.*
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²*Università Cattolica del Sacro Cuore, via Musei 41, 25121 Brescia*
giacomo.gerosa@unicatt.it

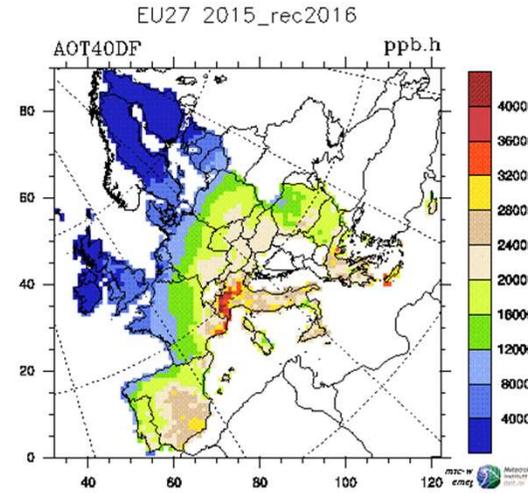
Evidenze di rischio | 1



Ozone
concentrations
ppb



AOT40
ppb h



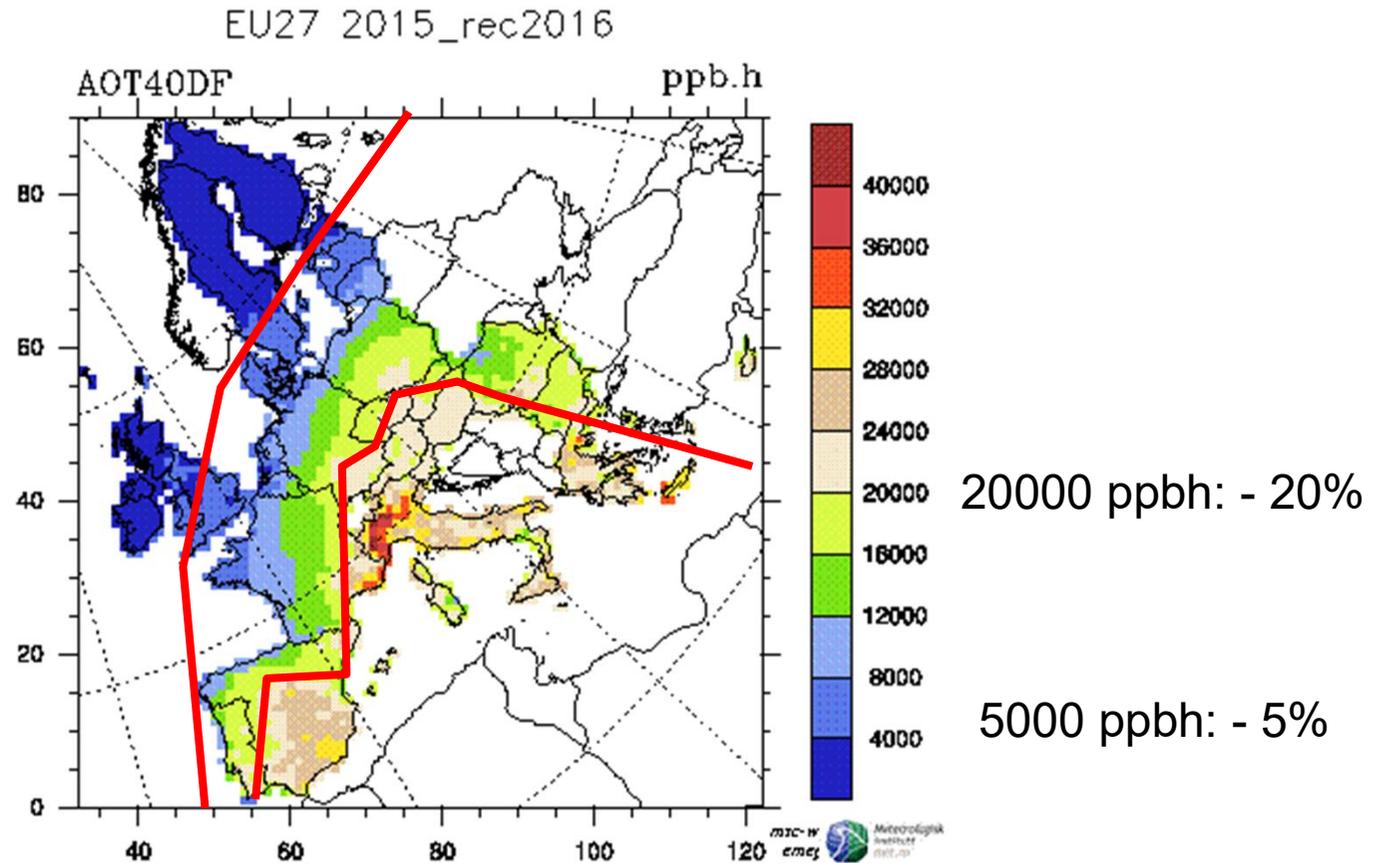
1990

2015

Source: CLRTAP, 2015 www.icpmapping.org; www.emep.org

Evidenze di rischio | 2

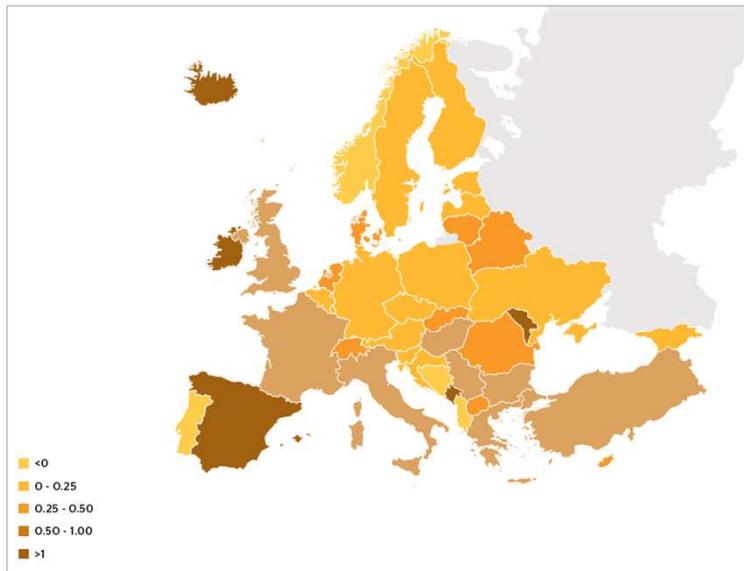
Expected *annual* growth reduction



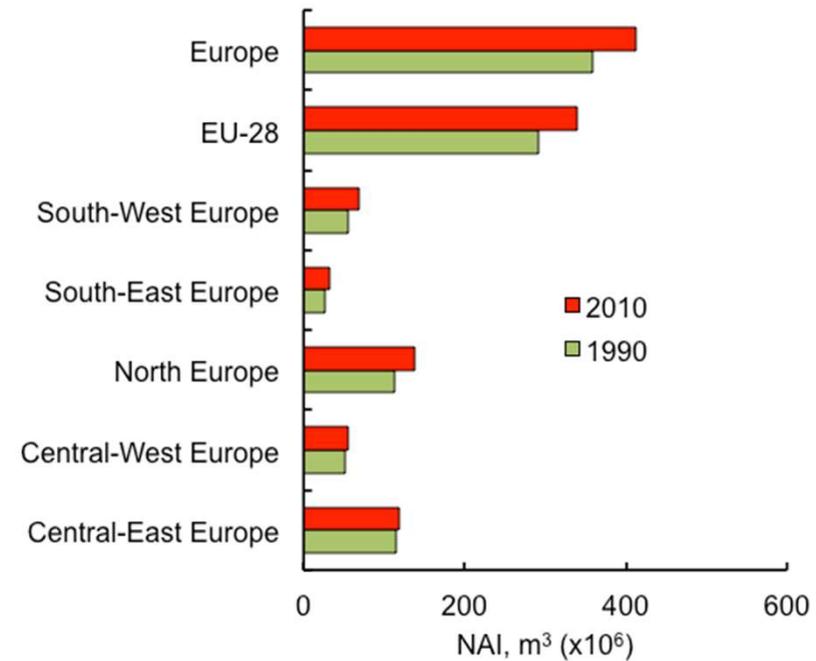
Source: CLRTAP, 2015 www.icpmapping.org; www.emep.org

Evidenze di rischio | 3

Le foreste europee si espandono e crescono di più



Forest area, annual changes 1990-2010 (%)

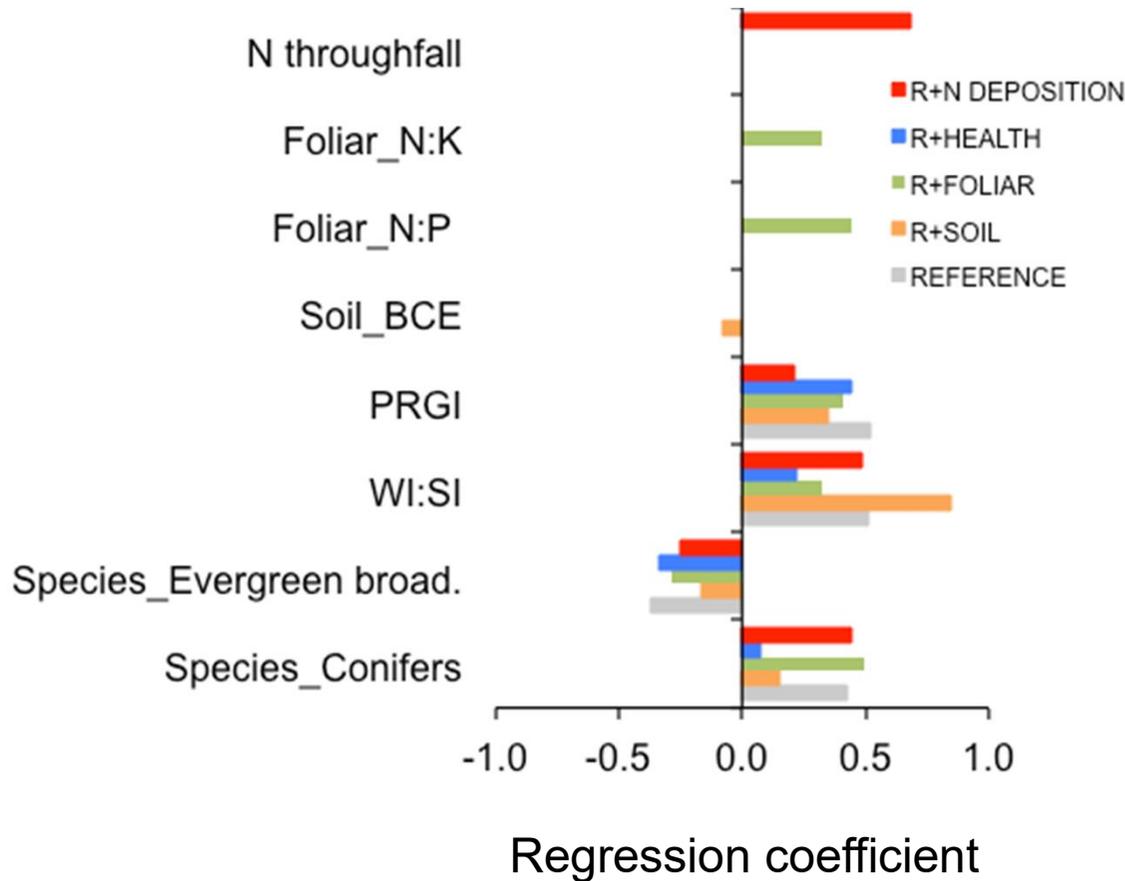


Net Annual Increment, 1990-2010

Source: SOEF, 2015

Evidenze di rischio | 4

Limitati effetti misurabili sull'accrescimento nei siti di monitoraggio italiani



Global Change Biology
 Global Change Biology (2014), doi:10.1111/gcb.12392

On the tracks of Nitrogen deposition effects on temperate forests at their southern European range – an observational study from Italy

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Abstract
 We studied forest monitoring data collected at permanent plots in Italy over the period 2000–2009 to identify the possible impact of nitrogen (N) deposition on soil chemistry, tree nutrition and growth. Average N throughfall (N-NO₃-N-NH₄) ranged between 4 and 29 kg ha⁻¹ yr⁻¹, with Critical Loads (CLs) for nutrient N exceeded at several sites. Evidence is consistent in pointing out effects of N deposition on soil and tree nutrition: topsoil exchangeable base cations (BCE) and pH decreased with increasing N deposition, and foliar nutrient ratios (especially N:P and N:K) increased. Comparison between bulk openfield and throughfall data suggested possible canopy uptake of N, leveling out for bulk deposition 4–6 kg ha⁻¹ yr⁻¹. Partial Least Square (PLS) regression revealed that – although stand and meteorological variables explained the largest portion of variance in relative basal area increment (BAI_{rel} 2000–2009) – N-related predictors (topsoil BCE, C:N, pH, foliar N-ratios; N deposition) nearly always improved the BAI_{rel} model in terms of variance explained (from 78.2 to 93.5%) and error (from 2.98 to 1.30%). N deposition was the strongest predictor even when stand, management and atmosphere-related variables (meteorology and topographic ozone) were accounted for. The maximal annual response of BAI_{rel} was estimated at 0.074–0.089% for every additional kgN. This corresponds to an annual maximal relative increase of 0.13–0.14% of carbon sequestered in the above-ground woody biomass for every additional kgN, i.e. a median value of 1.99 kgC per kgN ha⁻¹ yr⁻¹ (range: 50–504 kgC per kgN, depending on the site). Positive growth response occurred also at sites where signs of possible, perhaps recent N saturation were detected. This may suggest a time lag for detectable N effects, but also that, under continuous high N input, the reported positive growth response may be not sustainable in the long-term.

Keywords: CONIFOPOR forest monitoring, growth and carbon sequestration, N critical loads, PLS regression, soil and foliar nutrients

Received 22 November 2013 and accepted 7 February 2014

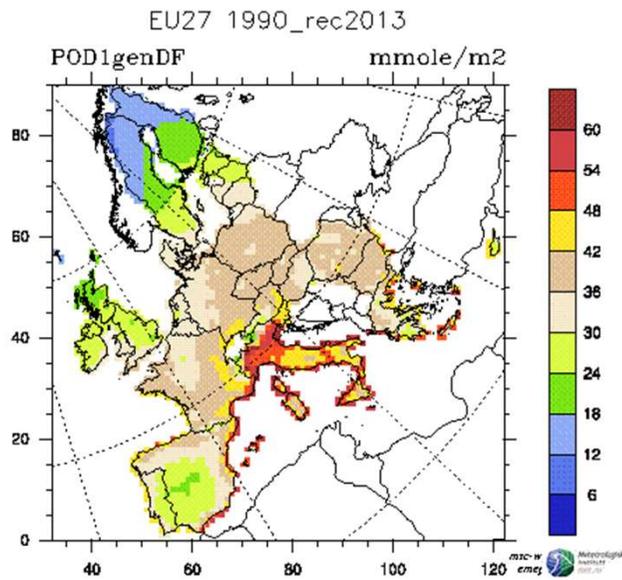
Introduction
 Human activity has substantially altered the nitrogen (N) cycle and now dominates the creation of reactive N in Europe, America and Asia (Carlfield et al., 2010). Such a production has increased globally from ca. 15 TgN yr⁻¹ (1840) to ca. 156 TgN yr⁻¹ (early 1990s), with a projected increase up to ca. 270 TgN yr⁻¹ by 2050 (Galwey et al., 2006). Alongside, total atmospheric emissions of NO_x and NH₃ increased from 23 TgN yr⁻¹ in 1840–1893 to 93 (early 1990s) and 189 TgN yr⁻¹ (projected 2050) (Galwey et al., 2004), with a dramatic increase of N concentration in atmospheric precipitation on (Brimblecombe & Sudman, 1992), and a resulting three- to fivefold increase of deposition of reactive N (Duenha et al., 2007). A further deposition increase by a factor of 2.5 is projected at global level by the end of the century (Lamareque et al., 2005).

Concern about the actual and potential effects of high N deposition on forests embraces almost all forest ecosystem's compartments, including vegetation, soil

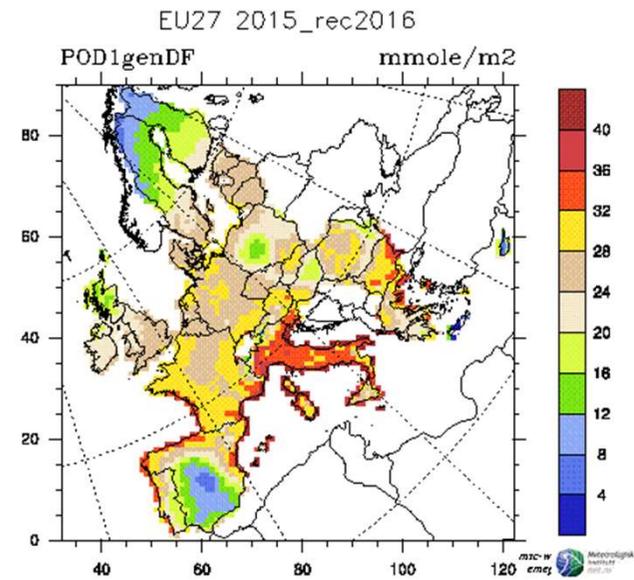
Correspondence: M. Ferretti, tel./fax: +39 0566 916681, email: mferretti@terraidea.it

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Evidenze di rischio | 5



1990

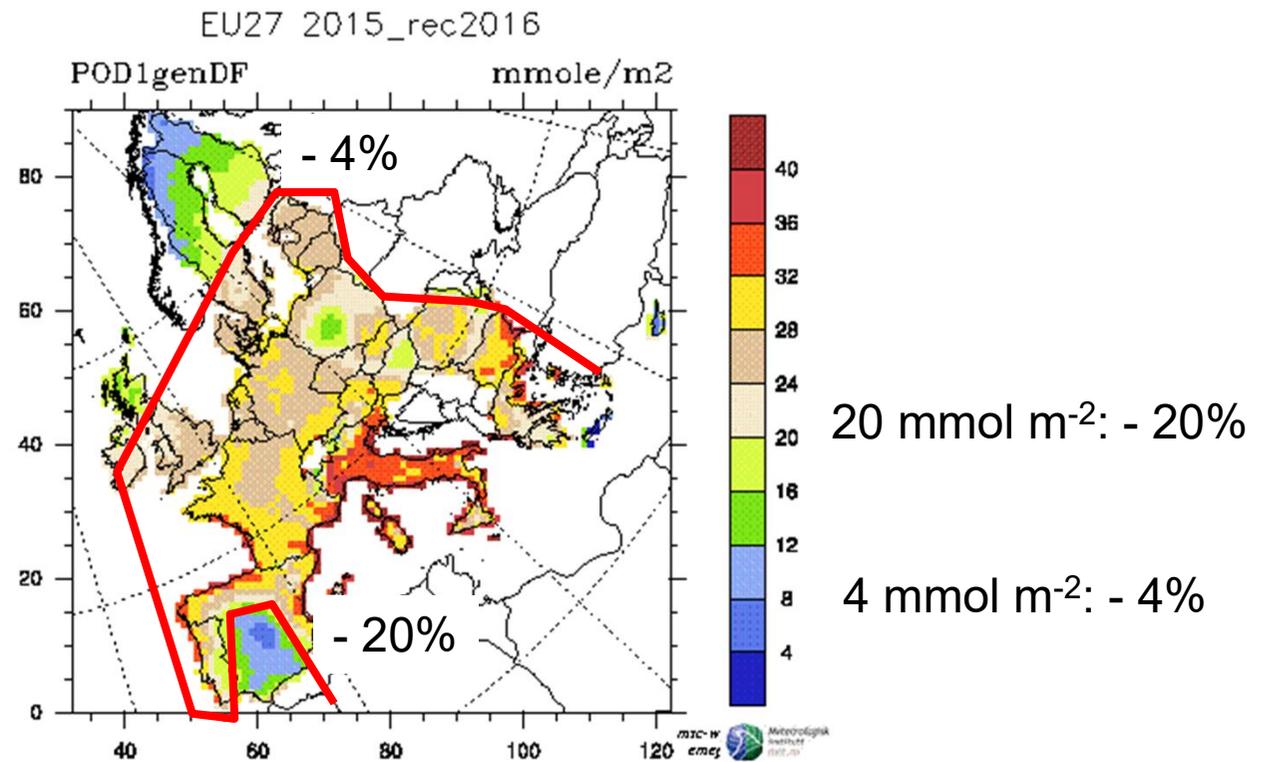


2015

Source: www.emep.org

Evidenze di rischio | 6

Expected *annual* growth reduction



Source: CLRTAP, 2015 www.icpmapping.org; www.emep.org

Rischio alto – effetti bassi: what *else* does not work?

- Metriche inefficaci?
- Risposta ritardata?
- Effetti sull'apparato ipogeo?
- Risposta aspecifica?
- ...
- ...o valutazioni di rischio poco realistiche, distorte da vari fattori?

Available online at www.sciencedirect.com

 ScienceDirect
Environmental Pollution 146 (2007) 648–658
www.elsevier.com/locate/envpol

ENVIRONMENTAL POLLUTION

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,
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^d BROMAA, 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
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Received 23 January 2006; received in revised form 9 May 2006; accepted 11 May 2006

While the flux-based approach is scientifically sounder, a more practical concentration-based approach is still necessary for routine monitoring.

Abstract

Ozone (O₃) exposure at Italian background sites exceeds UN/ECE concentration-based critical levels (CL_c), if expressed in terms of AOT40. Yet the occurrence of adverse effects of O₃ on forests and crops is controversial. Possible reasons include (i) ability of response indicators to provide an unbiased estimate of O₃ effects, (ii) setting of current CL_c in terms of cut-off value and accumulation level, (iii) response functions adopted to infer a critical level, (iv) environmental limitation to O₃ uptake and (v) inherent characteristics of Mediterranean vegetation. In particular, the two latter points suggest that critical levels based on accumulated stomatal flux (CL_f) can be a better predictor of O₃ risk than CL_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 O₃ in Italy over recent years to discuss value, uncertainty and feasibility of different approaches to risk assessment. © 2006 Elsevier Ltd. All rights reserved.

Keywords: Ozone; Critical levels; AOT₄₀; Stomatal flux; Effects; Mediterranean region

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doi:10.1016/j.envpol.2006.05.012

Rischio alto – effetti bassi: what *else* does not work?

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Schema della presentazione

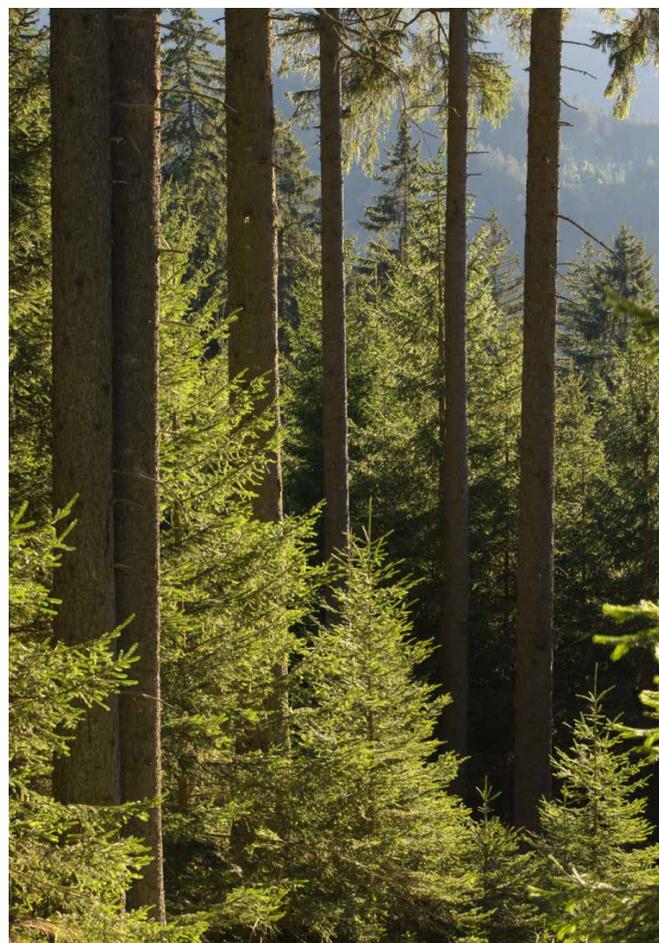
- Teoria: “risk assessment” in ambito ozono
- Pratica: cosa condiziona la definizione dei CLs e la loro applicazione
- Realtà: un confronto
- Conclusioni e domande



(Photo: PAT Report 2014)

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(Photo: PAT Report 2014)

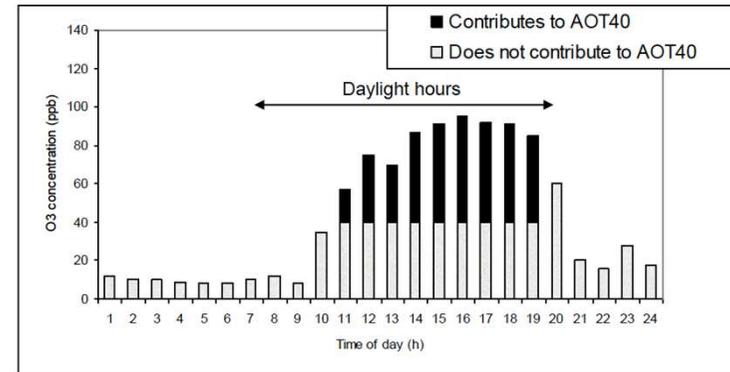
Livelli critici (Critical Levels - CLs)

UN/ECE, 1989	UN/ECE, 1996	UN/ECE, 2004 and subsequent revisions
<p>The concentration of pollutants in the atmosphere above which direct* adverse effects** on receptors***, such as plants, ecosystems or materials may occur according to present knowledge.</p> <p>*not mediated by soil</p> <p>**on: physiology, biochemistry, growth, vitality, ecosystem structure, function, diversity</p> <p>***may or may not be the most sensitive one in a given region.</p>	<p>The concentration of pollutants in the atmosphere above which adverse effects occur on sensitive receptors, such as human beings, plants, ecosystems or materials according to present knowledge.</p>	<p>the concentrations, cumulative exposure or cumulative stomatal flux of atmospheric pollutants above which direct adverse effects on sensitive vegetation may occur according to the present knowledge.</p>

Definizione dei CLs per l'ozono

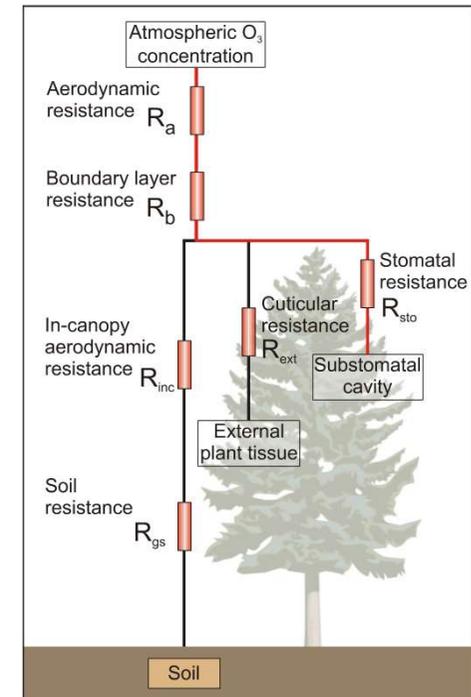
Concentration-based

- Metrica: esposizione cumulata (AOT_x , ppb h) sopra una certa soglia di concentrazione (x).
- Input: concentrazione di ozono al top della copertura.
- Procedura: relazione dose-risposta.



Flux-based

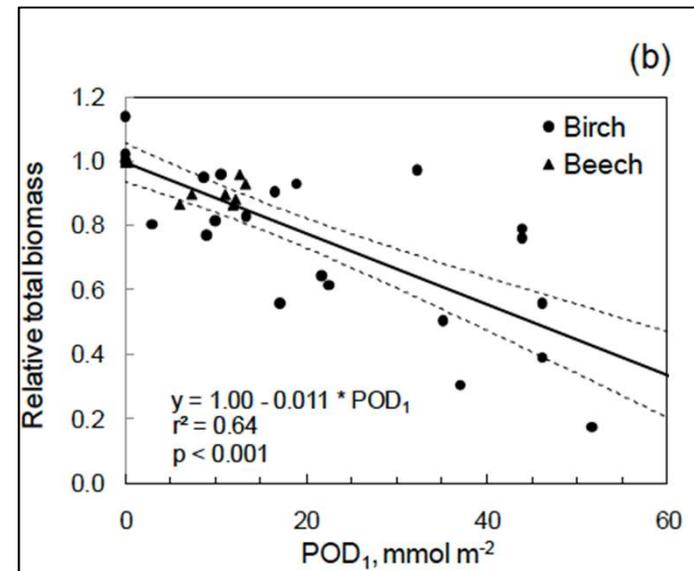
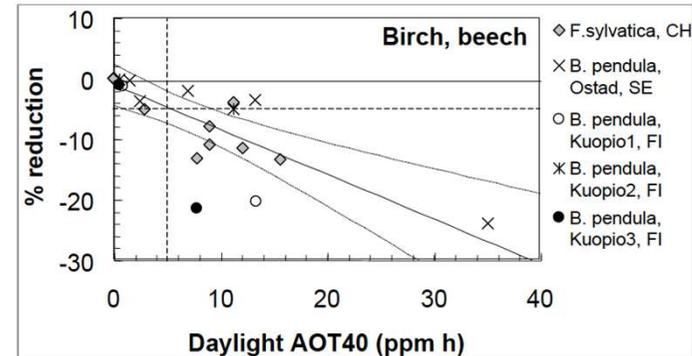
- Metrica: dose fitotossica accumulata (POD_y , mmol m⁻² PLA) sopra una certa soglia di flusso stomatico (y).
- Input: concentrazione di ozono al top della copertura; modellizzazione del flusso stomatico.
- Procedura: relazione dose-risposta.



Dose - risposta

“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



Schema della presentazione

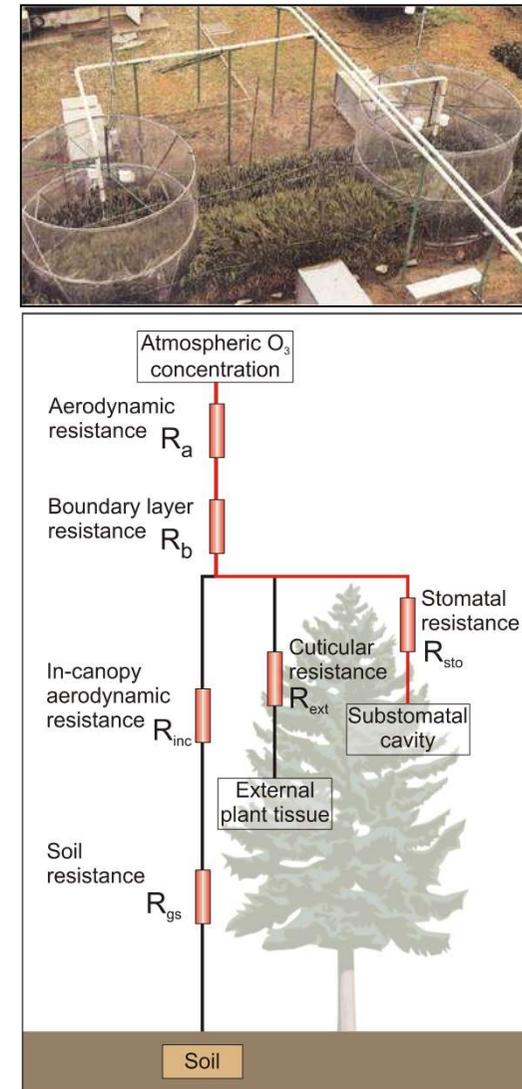
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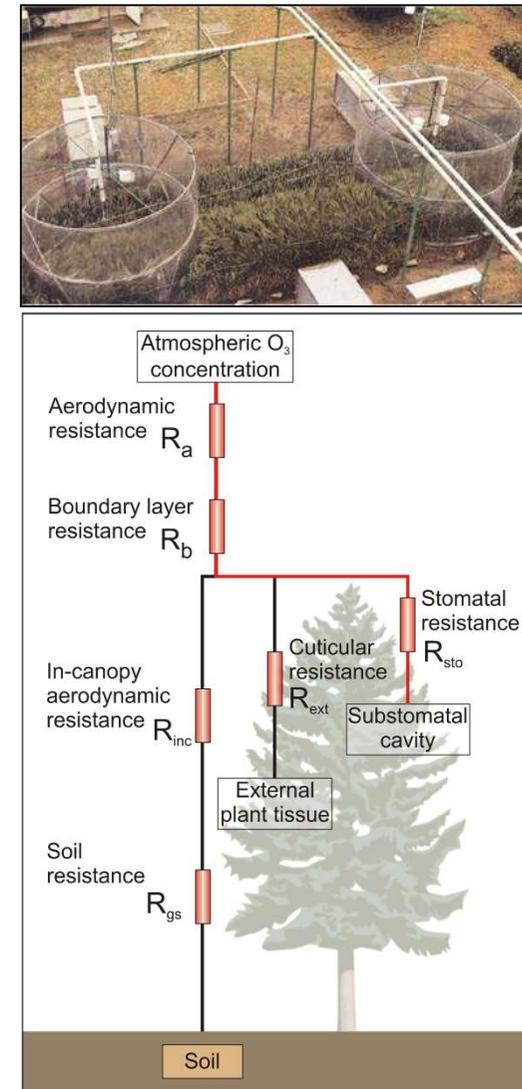
Principali sorgenti di distorsione

- Definizione dei CLs
 - Sistema sperimentale (fumigazione / sottrazione)
 - Materiale e condizioni sperimentali
 - Comuni a entrambi gli approcci
- Applicazione nella pratica
 - Assunzioni modellistiche
 - Origine dei dati [O3]
 - Conduttanza stomatica
 - ...e altro
 - Quasi esclusive dell'approccio flux-based.



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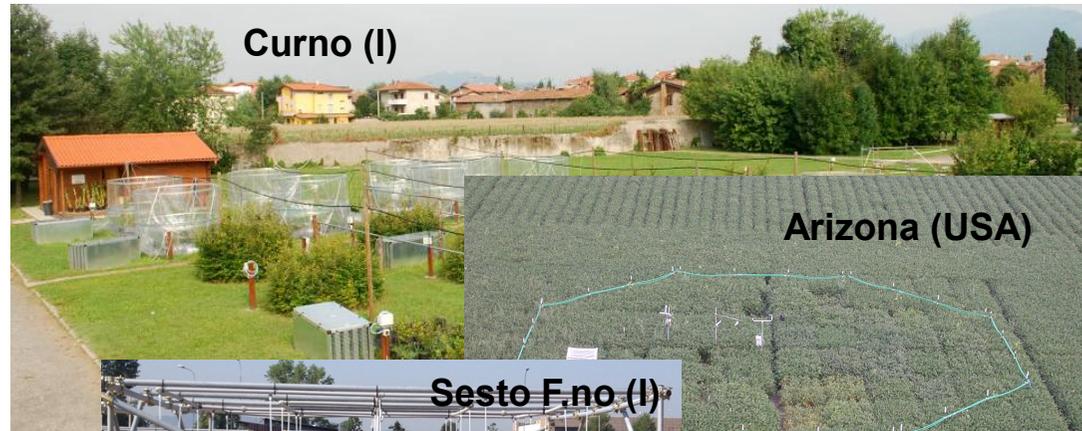
Sistemi sperimentali - limitazioni

- Continuous stirred chambers (phytotrones) (CSC)
 - Luce e microclima (T)
- Solar Domes (SD):
 - Microclima (Pr)
- Open-top Chambers (OTC)
 - Microclima (T)
- Free-Air enrichment (FACE):
 - Omogeneità di fumigazione
 - Alterazione gradiente verticale di [O₃]

Bangor (UK)



Curno (I)



Arizona (USA)

Sesto F.no (I)



(courtesy: Y Hoshika)

Condizioni sperimentali - giovani vs. maturi



Condizioni sperimentali - condizioni di crescita

In vaso (artificiale, omogeneo) o in suolo (naturale, eterogeneo)



Condizioni sperimentali - irrigazione

Irrigazione continua

- massima conducibilità all'ozono.
- Nessuna interferenza con il fattore acqua.
- Irreale.



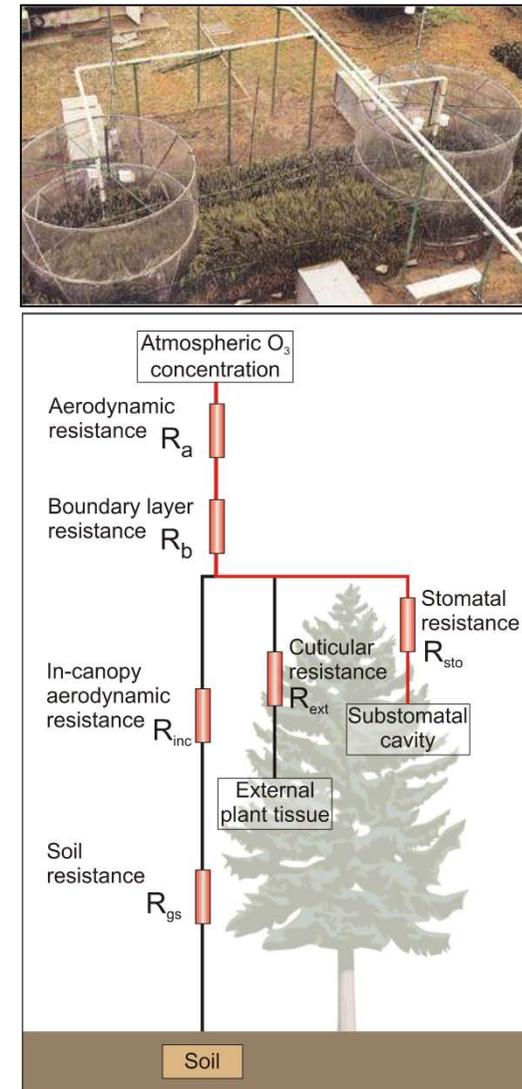
Pioggia "naturale"

- Interferenza del fattore acqua (drought x O3) nella risposta



Principali sorgenti di distorsione

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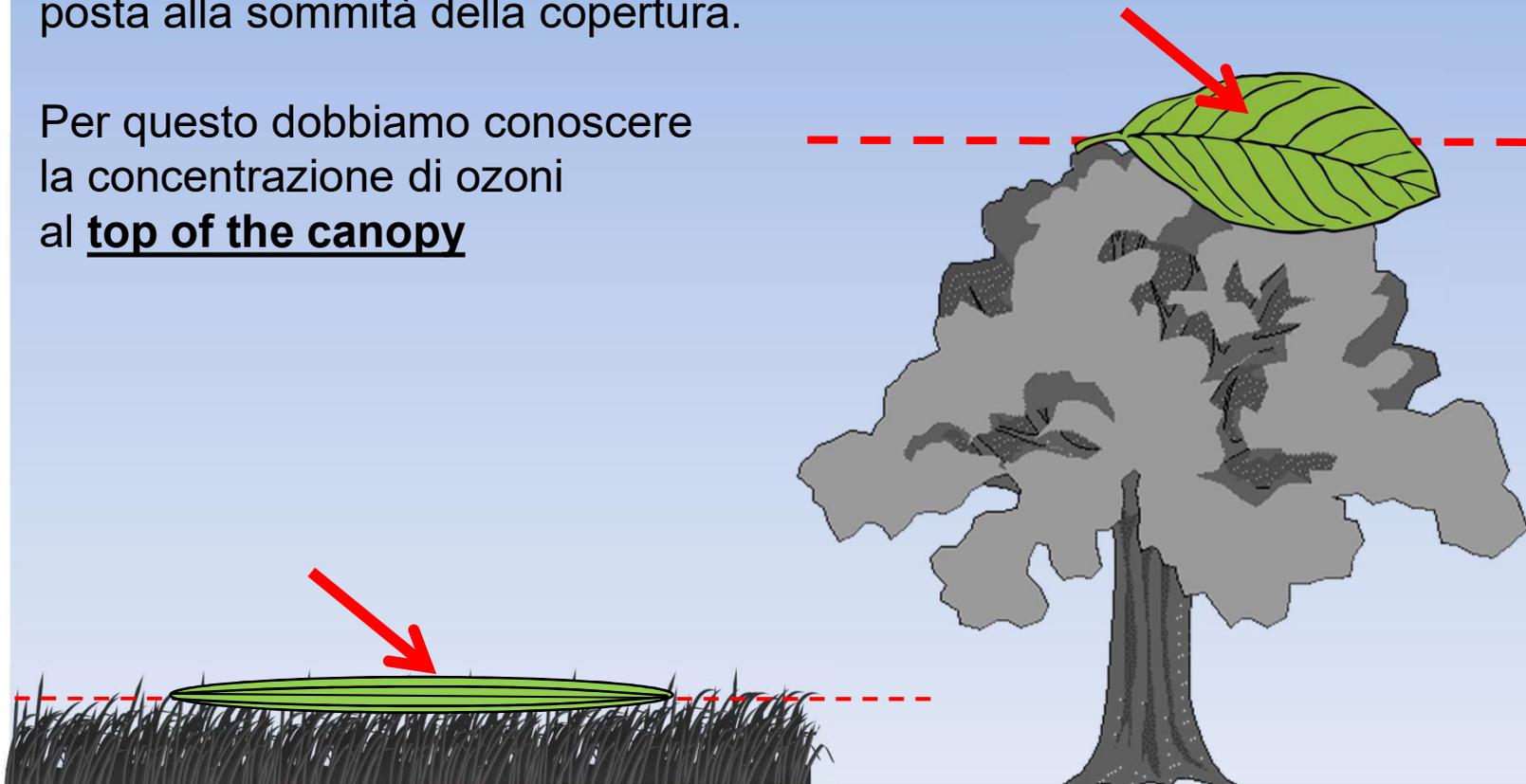


Copertura forestale “semplificata”

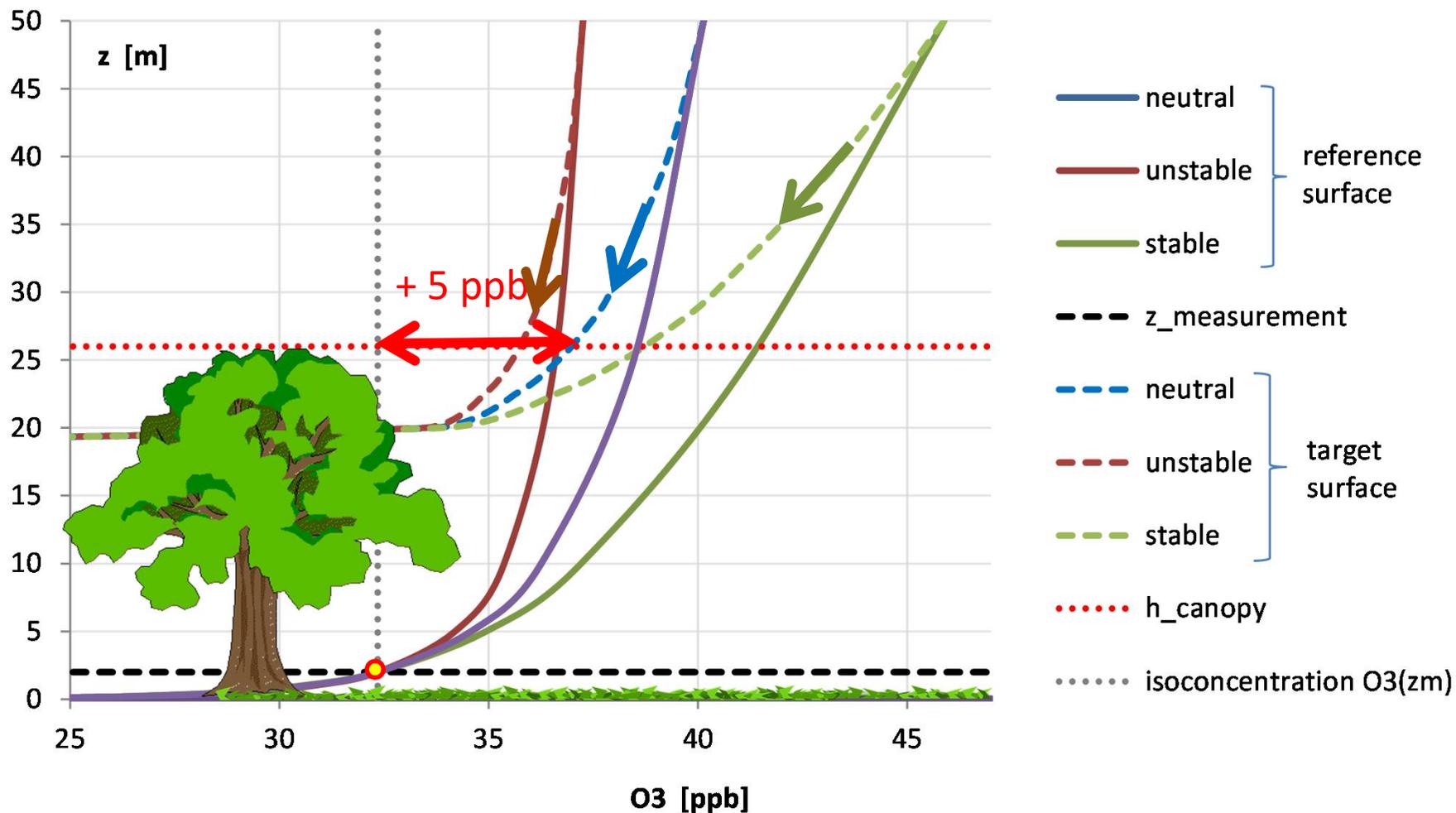
La dose di una sola foglia come descrittore della dose dell'intera pianta

Il Manuale UN/ECE parla della dose assorbita da UNA SOLA FOGLIA posta alla sommità della copertura.

Per questo dobbiamo conoscere la concentrazione di ozoni al top of the canopy



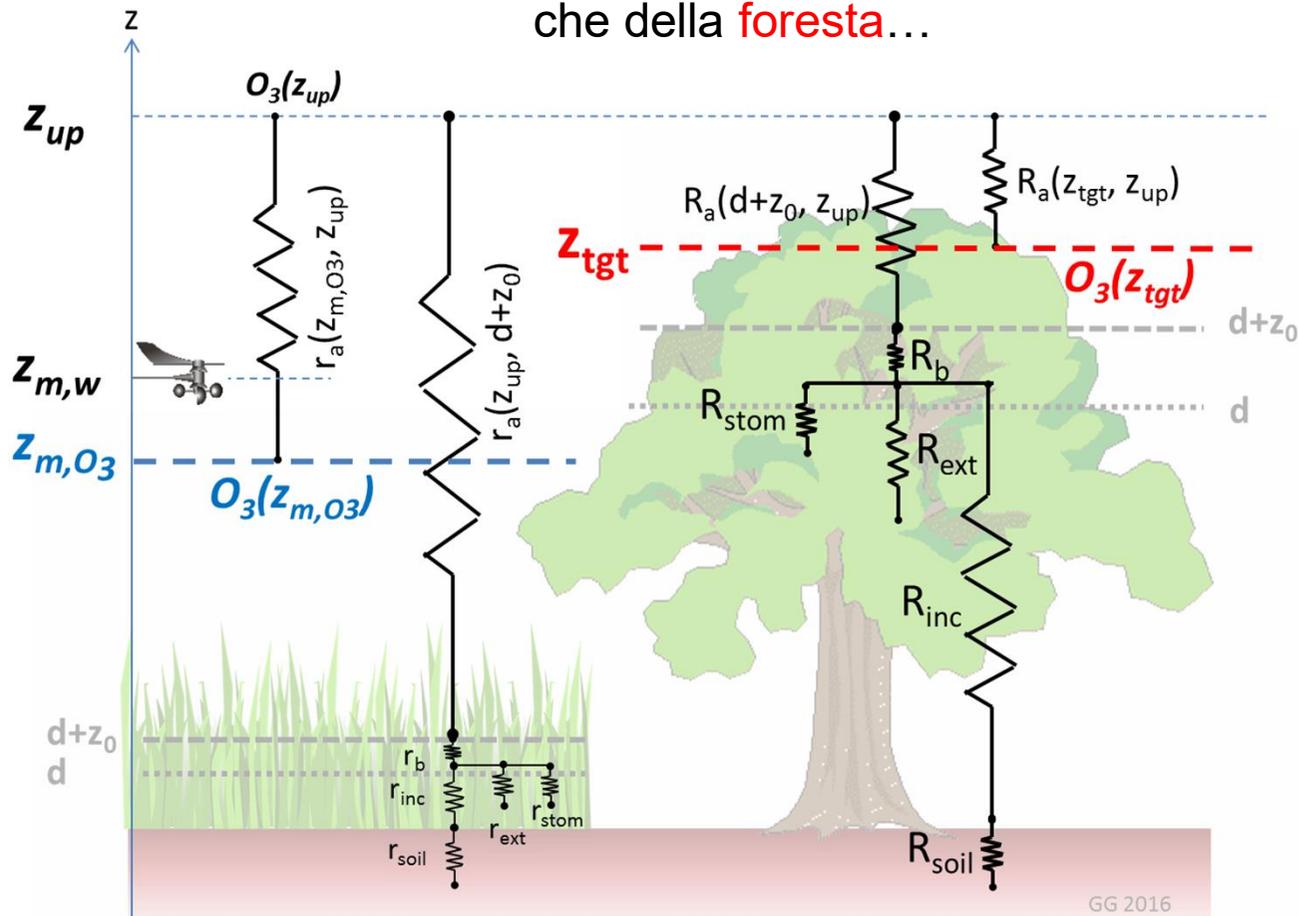
Gradienti verticali di [O3]



→ L'impiego acritico delle concentrazioni di O3 misurate e.g. su prato conduce d una sottostima della dose

Gradienti verticali di [O3]

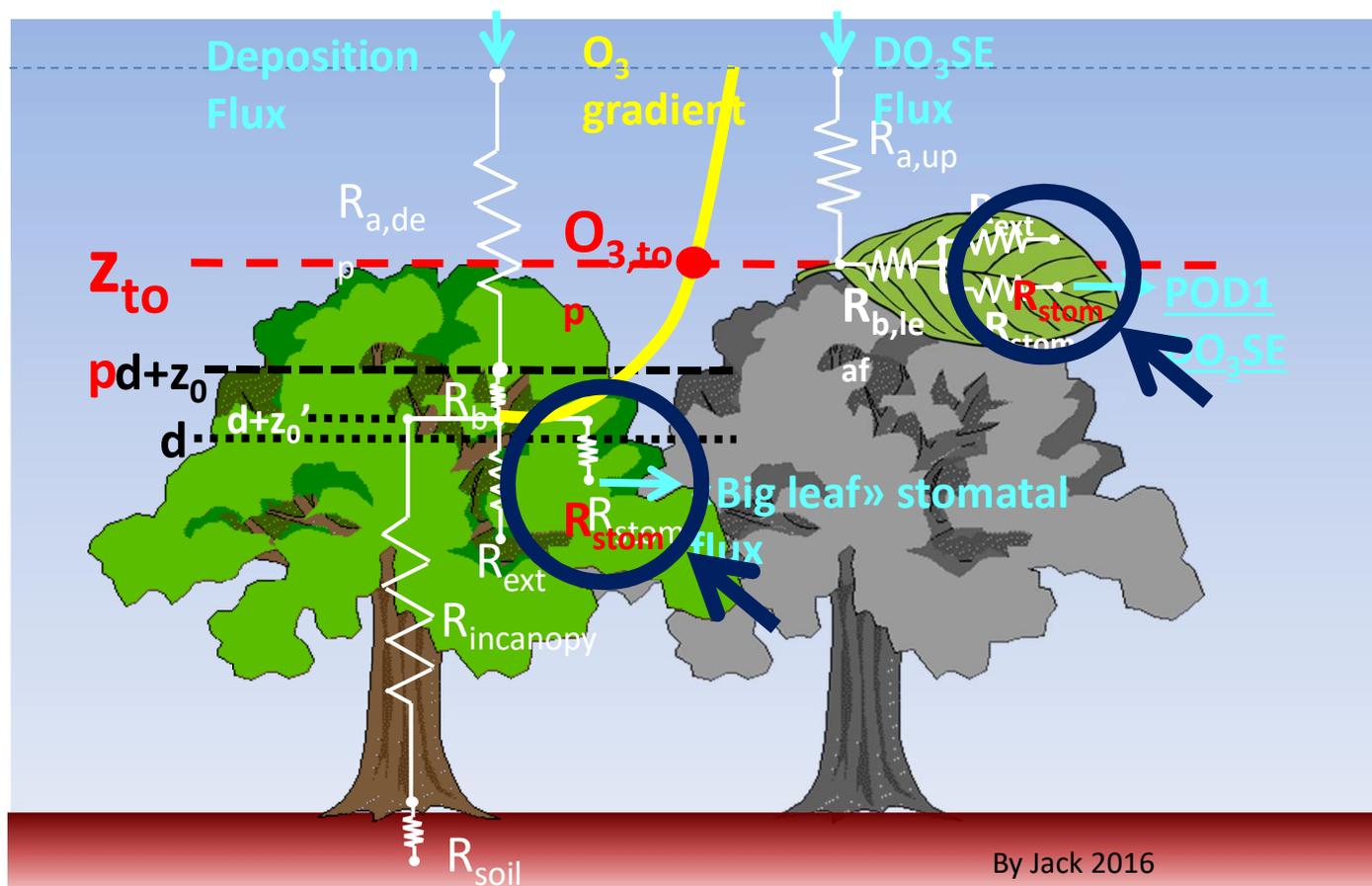
Ma per far stimare [O3] al top della copertura questo abbiamo bisogno di modellare sia il comportamento del **prato** che della **foresta**...



← Reference surface → ← Target surface →

Gradienti verticali di [O₃]

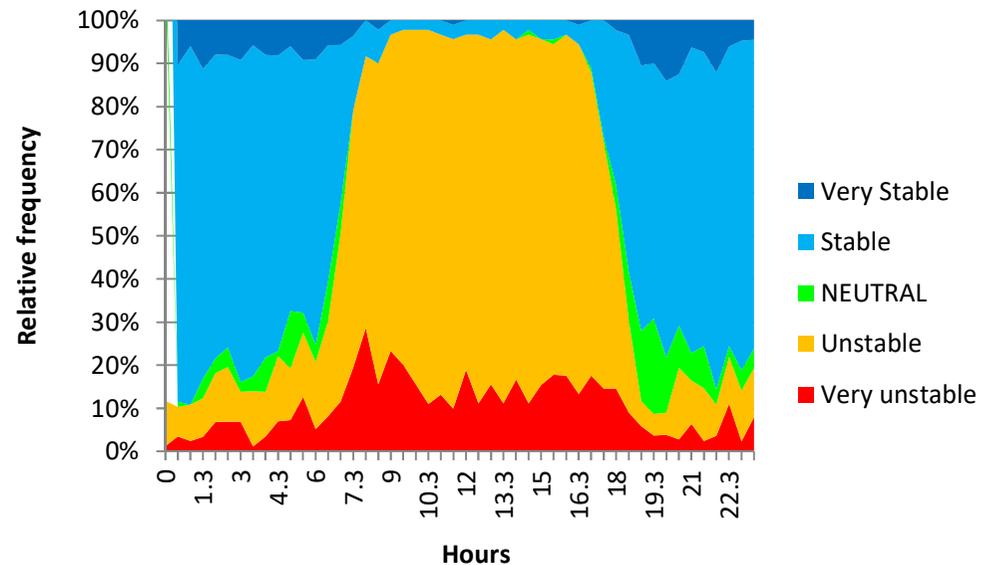
Anche nel caso più semplice (misure disponibili SOPRA la foresta),
per stimare la concentrazione di ozono sopra la foresta dobbiamo conoscere il
flusso di ozono nella foresta.



Stabilità atmosferica

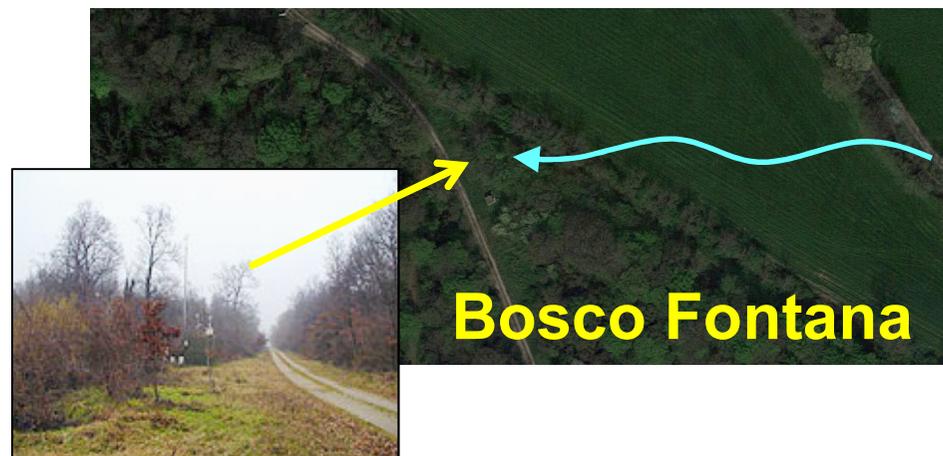
- L'assunzione di **neutralità** dell'atmosfera (necessaria per la proiezione al top della copertura), non è quasi mai realizzata nella realtà.
- Considerevoli distorsioni (-8%; +97%) di POD1 a seconda delle condizioni di stabilità coinvolte e della versione di modello (con o senza correzione per l'altezza reale) (dati Bosco Fontana).

Bosco Fontana, Italy
May – July 2013



Origine dei dati [O3]

- Localizzazione centraline su superfici inadatte al carico dei flussi
- Incluse quelle suburbane (manaca omogeneità orizzontale, fetch).
- Incluse quelle rurali/remote, talvolta schermate o poste addirittura sotto la vegetazione.



Conduttanza stomatica (rivedere)

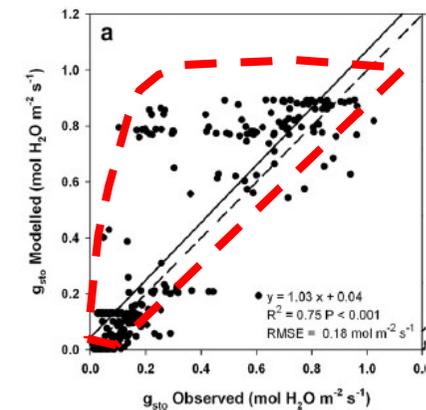
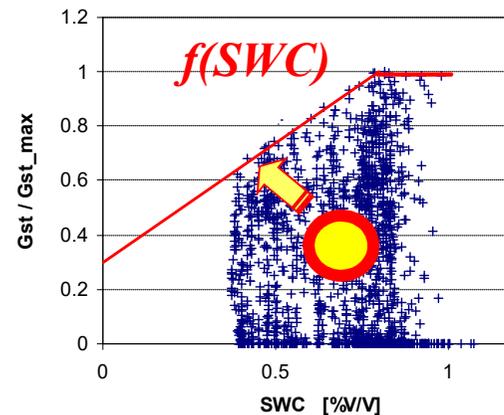
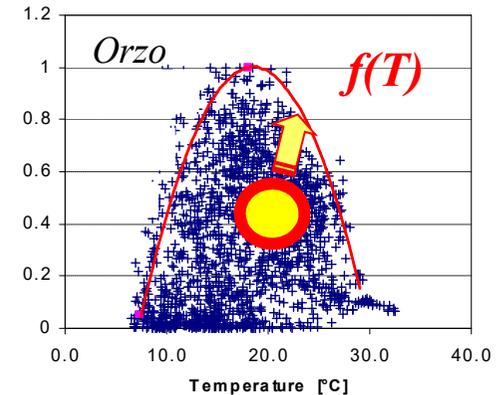
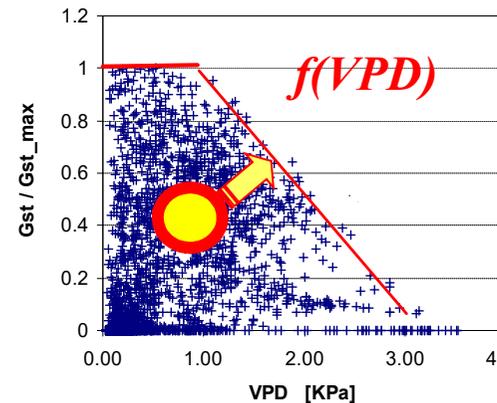
- POD1 requires modeling stomatal conductance.
- Jarvis's resistance multiplicative model (Jarvis, 1976)

For each species there is a maximum stomatal conductance g_{max} (expressed by plants under optimal conditions)

Under limiting condition, g is only a fraction of g_{max}

Species-specific functions necessary for limiting factors

Tendency to overestimate



Gonzales-Fernandez et al., 2013

$$g_w = g_{max_w} \cdot f(\text{PAR}) \cdot f(\text{VPD}) \cdot f(\text{SWC}) \cdot f(\text{T}) \cdot f(\text{WS}) \cdot f(\text{CO}_2) \cdot f(\text{O}_3) \cdot \dots$$

$$g_{Stom, O_3} = g_w \cdot 0.662$$

Ricorsività

- $F_{\text{stom}}O_3$ richiede f_{O_3} (per il calcolo di g_{stom}) che a sua volta dipende dall' $F_{\text{stom}}O_3$ ricevuto....
→ *l'assorbimento prolungato di ozono danneggia la funzionalità stomatica*
- Il calcolo di $F_{\text{stom}}O_3$ richiede f_{PHEN} (per il calcolo di g_{stom}) che a sua volta dipende dall' $F_{\text{stom}}O_3$ ricevuto....
→ *l'assorbimento di ozono determina una senescenza fogliare e una filloptosi precoce*
- Il calcolo di $F_{\text{stom}}O_3$ richiede la concentrazione di **O_3 al top canopy**, che a sua volta dipende dal $F_{\text{stom}}O_3$
→ *La concentrazione di ozono sopra la copertura dipende da quanto attivamente la copertura sta rimuovendo (i.e. assorbendo) ozono.*



$$g_w = g_{max_w} \cdot f(\text{PAR}) \cdot f(\text{VPD}) \cdot f(\text{SWC}) \cdot f(\text{T}) \cdot f(\text{WS}) \cdot f(\text{CO}_2) \cdot f(\text{O}_3) \cdot \dots$$

...e diversi altri aspetti

- Modelli “aggiustati con il cacciavite”
- Ozono nella camera sottostomatica
- Soglia di detossificazione, y

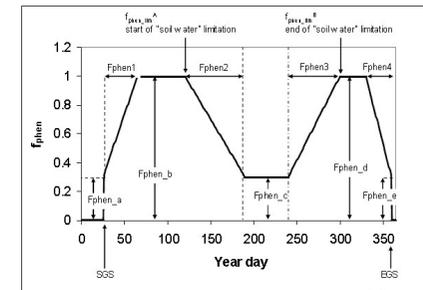
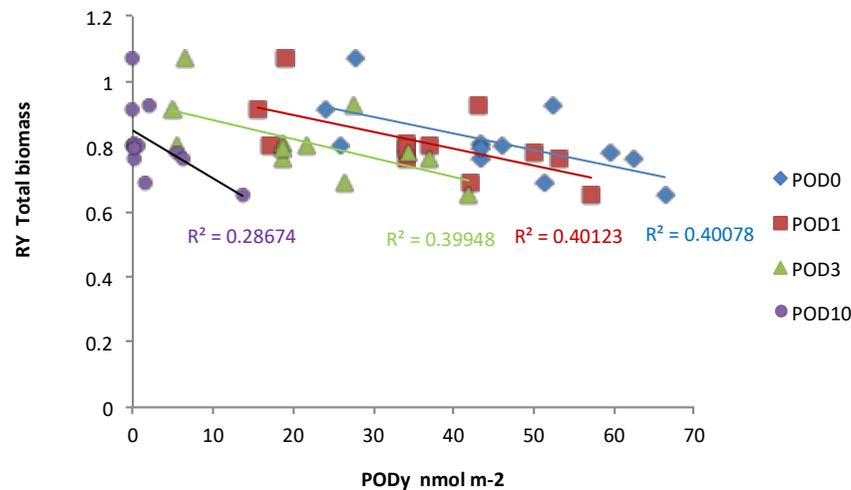
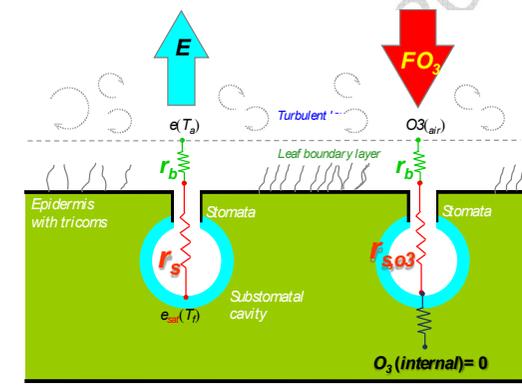


Figure III.9 : An illustration of the formulation of f_{phen} for forest trees



Schema della presentazione

- Teoria: “risk assessment” in ambito ozono
- Pratica: cosa condiziona la definizione dei CLs e la loro applicazione
- **Realtà: un confronto**
- Conclusioni e domande



(Photo: PAT Report 2014)

Teoria e realtà | 1

Esposizione all'ozono	Assunzioni modelli	Realtà
Bersaglio	Foglia sommitale	Intera chioma
Origine dati meteo e ozono	Da misure sopra la copertura	Da centraline che misurano sopra superfici artificiali e sotto la copertura
Gradienti verticali di ozono	Atmosfera neutrale	Raramente neutrale
	I gradienti determinano l'esposizione e dunque il flusso	I gradienti dipendono dal flusso (ricorsività «in agguato»)
Concentrazione di ozono intra-canopy	= 0	Molto \neq 0 !

Teoria e realtà | 2

Modellizzazione	Assunzioni modelli	Realtà
Tipo di modello	Jarvisiano (g dipende solo dai parametri ambientali)	g e fotosintesi sono dinamicamente interrelate con un feedback negativo.
Risposta del modello	Statica (non dipende da t)	Ricorsività «in agguato» (e.g. fO_3 , $fPHEN$)
g_{max}	Costante, geneticamente determinata	Problemi nella determinazione di g_{max} : il valore trovato riflettere le condizioni di misura
Funzioni modificanti g	g risponde alle funzioni f come postulato	g non risponde sempre come postulato, costringendo a modifiche spesso arbitrarie delle f
Capacità di predire la g	Assunta OK, almeno per i valori medi	Generalmente povera per i valori istantanei (orari) → intrinseca tendenza alla sovrastima

Teoria e realtà | 3

Calcolo PODy	Assunzioni modelli	Realtà
[O3] nella cavità sottostomatica	=0 (R mesofillo =0)	Probabilmente > 0 (R mesofillo >0) (e.g. Moldau & Bichele, 2001)
Detossificazione	Soglia «arbitraria» di flusso Y ottenuta sulla base di considerazioni puramente statistiche	Soglia sconosciuta, variabile in funzione dello stato fisiologico
Periodo di accumulo	SGS e EGS può essere predetta dalle somme termiche (o dalla latitudine)	Difficoltà di reperire le dati di T in ambiente remoto/montano. SGS ed EGS dipende molto da esposizione del versante e microclima. EGS dipende anche dagli stress (e.g. idrici) sperimentati durante la stagione. L'ozono assorbito causa senescenza precoce. (Ricorsività «in agguato»)

Teoria e realtà | 4

Dose - risposta	Assunzioni	Realtà
Condizioni sperimentali	Minima alterazione naturalità	Bias introdotti dai sistemi di fumigazione/filtrazione
Materiale sperimentale	Rappresentativo, tutto sommato	In genere piante giovani
Dose somministrata	Uguale alla realtà	Sovraddosata (e.g. per la mancanza di gradienti verticali)
Risposta considerata	Biomassa epigea	La maggior parte degli effetti è spesso a carico delle radici e non della parte epigea
Relazioni dose-danno pubblicate	Rappresentative del reale effetto dell'ozono	Distorsione (sovrastima del danno) perché mancano gli esperimenti con risultati «negativi».
	Approccio di massima protettività (si considerano solo le specie e le cv ritenute più sensibili)	Assemblaggio di specie diverse

Produttività e biodiversità

- La produttività delle foreste è condizionata (tra l'altro) dalla loro biodiversità (Liang et al., 2016).
- Non considerata negli esperimenti per settare i CLs.
- Non considerata nelle stime di rischio.

RESEARCH

RESEARCH ARTICLE SUMMARY

FOREST ECOLOGY

Positive biodiversity-productivity relationship predominant in global forests

Jingling 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 Liu, Damiano Gianelle, Elena I. Parfenova, Christian Salas, Eunghil Lee, Boknam Lee, Hyun Seok Kim, Helge Bruelheide, David A. Coomes, Daniel Piotta, Terry Sunderland, Bernhard Schmid, Sylvie Gonfret-Fleury, Bonaventure Sonké, Rebecca Taran, Jun Zhu, Susanne Brandt, Jordi Vayreda, Fumiaki Kitahara, Eric B. Searle, Victor J. Neldner, Michael R. Ngugi, Christopher Baraloto, Lorenzo Frizzera, Radomir Balazy, Jacek Oleksyn, Tomasz Zawila-Niedzwiecki, Olivier Bouriaud, Filippo Bussotti, Leena Finér, Bogdan Jaroszewicz, Tommaso Jucker, Fernando Valladares, Andrzej M. Jagodzinski, Pablo L. Peri, Christelle Gomadje, William Marthy, Timothy O'Brien, Emanuel H. Martin, Andrew R. Marshall, Francesco Rovero, Robert Bjartho, Pascal A. Niklaus, Patricia Alvarez-Loyza, Nurdin Chamnya, Renato Valencia, Frédéric Mortier, Virginia 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-

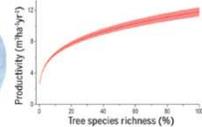
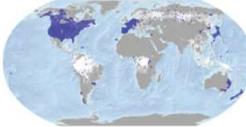
scale observational studies. Thus, the strength and spatial variability of this relationship remains unexplored at a global scale.

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. ■

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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).

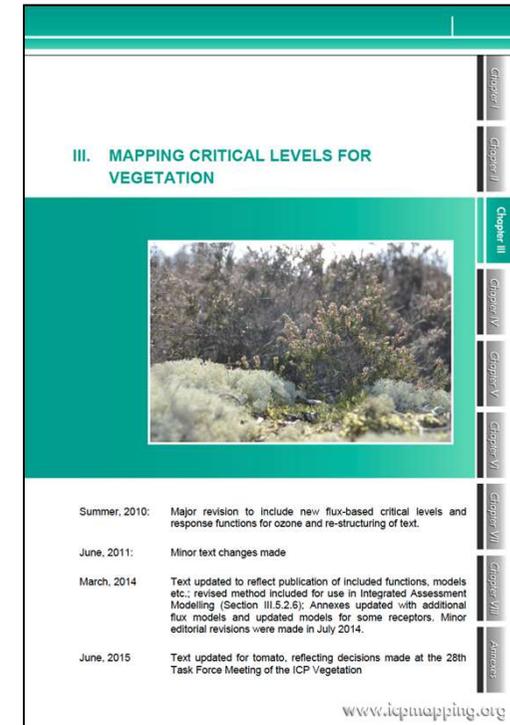
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Alla fine...

Basis	Regressions	Species	
		Beech, birch	Norway spruce
AOT40	Experiments, n	5	not reported
	Datapoints, n	21	not reported
	R ²	0.62	0.79
	P for the slope	<0.01	<0.01
POD1	Experiments, n	14	8
	Datapoints, n	38	27
	R ²	0.64	0.55
	P for the slope	<0.001	<0.001



Schema della presentazione

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(Photo: PAT Report 2014)

The time They Are A-Changin’

“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*”.

(UN/ECE, 1989)

“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 food security (crops), roundwood supply for the forest sector industry and loss of carbon storage capacity and other beneficial ecosystem services (forest trees)**... Where appropriate, they could be used for assessing **economic losses**.”

(CRTAP, 2015)

Conclusioni

- Molto in disaccordo con l'ultima affermazione.
- Le stime di rischio (sia basate su AOT40 che sui flussi) danno un'idea piuttosto approssimata e poco realistica del rischio ozono per la vegetazione.
- Non sembrano esserci grosse differenze pratiche: sbagliamo più o meno con entrambi gli approcci...
- ...ma per poter sbagliare con i flussi dobbiamo complicarci molto la vita.
- Inadatti come standard normativo.
- Parafrasando: *tutte le stime di rischio sono sbagliate, ma qualcuna è più sbagliata di altre.*

Vecchie domande, nessuna risposta

(Ferretti and Emberson, 2006)

- At what extent the prediction benefits arising from the flux approach are counteracted by the uncertainty inherent to the approximation needed at the various modelling steps?
- Is it really possible to define AQ standards taking into account the flux approach?
- If yes, how regulatory agencies can control if flux-based AQ standards are attained?
- Since flux does not depend only on ozone, what action might be undertaken when standards were exceeded?



Una nota personale



Grazie!