Tracing atmospheric inputs throughout the nitrogen cycle -

review from a European forest monitoring perspective

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3rd ICP Forests Science Conference

Introduction

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„ outcome of the five-year European Nitrogen Assessment, ... together 200 experts“

Mark A. Sutton, Oene Oenema, Jan Willem Erisman, Adrian Leip, Hans va
Wilfried Winiwarter

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Nature **472**, 159–161 (14 April 2011) | doi:10.1038/472159a
Published online 10 April 2011

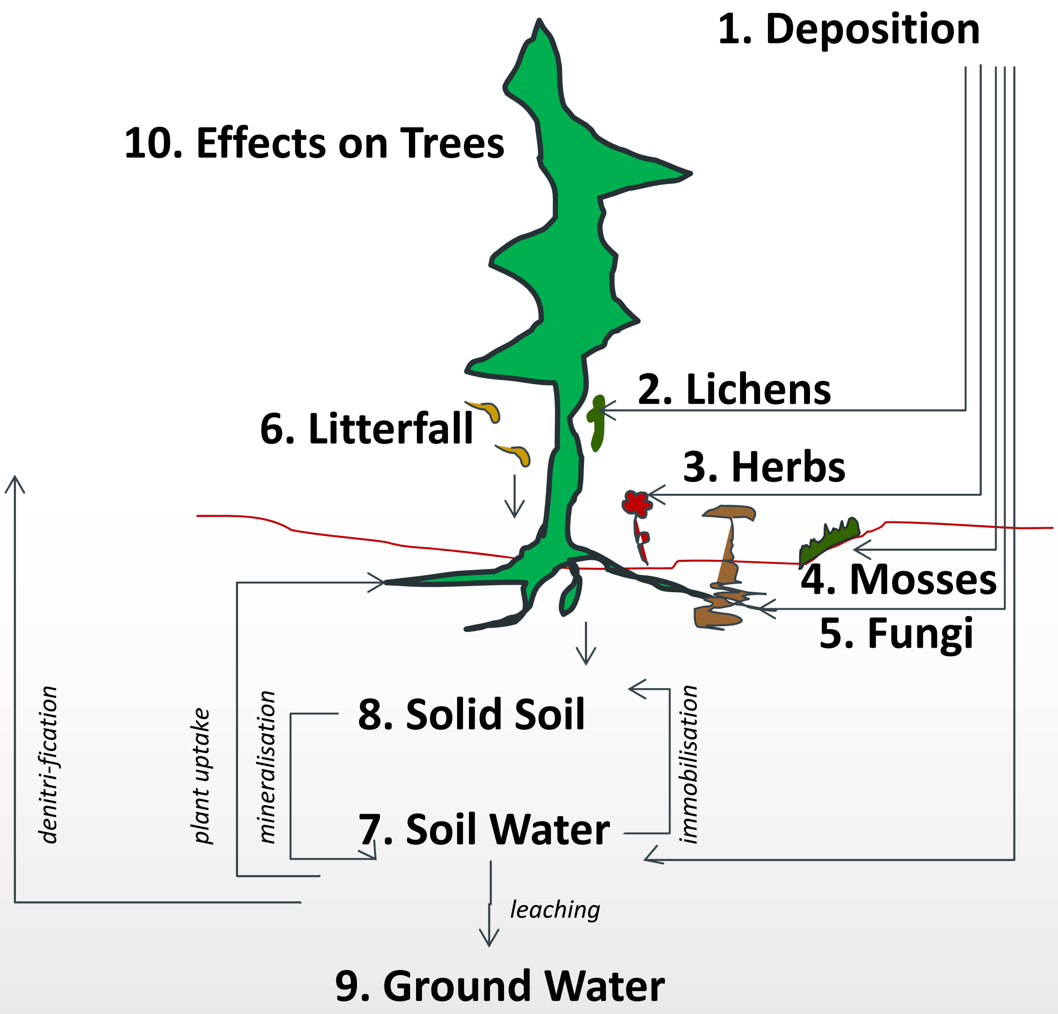
I. LEITH; M. SUTTON

Ammonia can kill tree-living plants (left), replacing them with algal slime.

"In forests, ammonia pollution encourages the growth of algal slime that can suffocate … mosses and lichens (see picture) …. NH_3 and NO_x emissions have reduced forest biodiversity by more than 10% over two-thirds of Europe."

Where has ICP Forests been after 25 years forest monitoring?

Contents



+ Discussion,
Outlook
Conclusions

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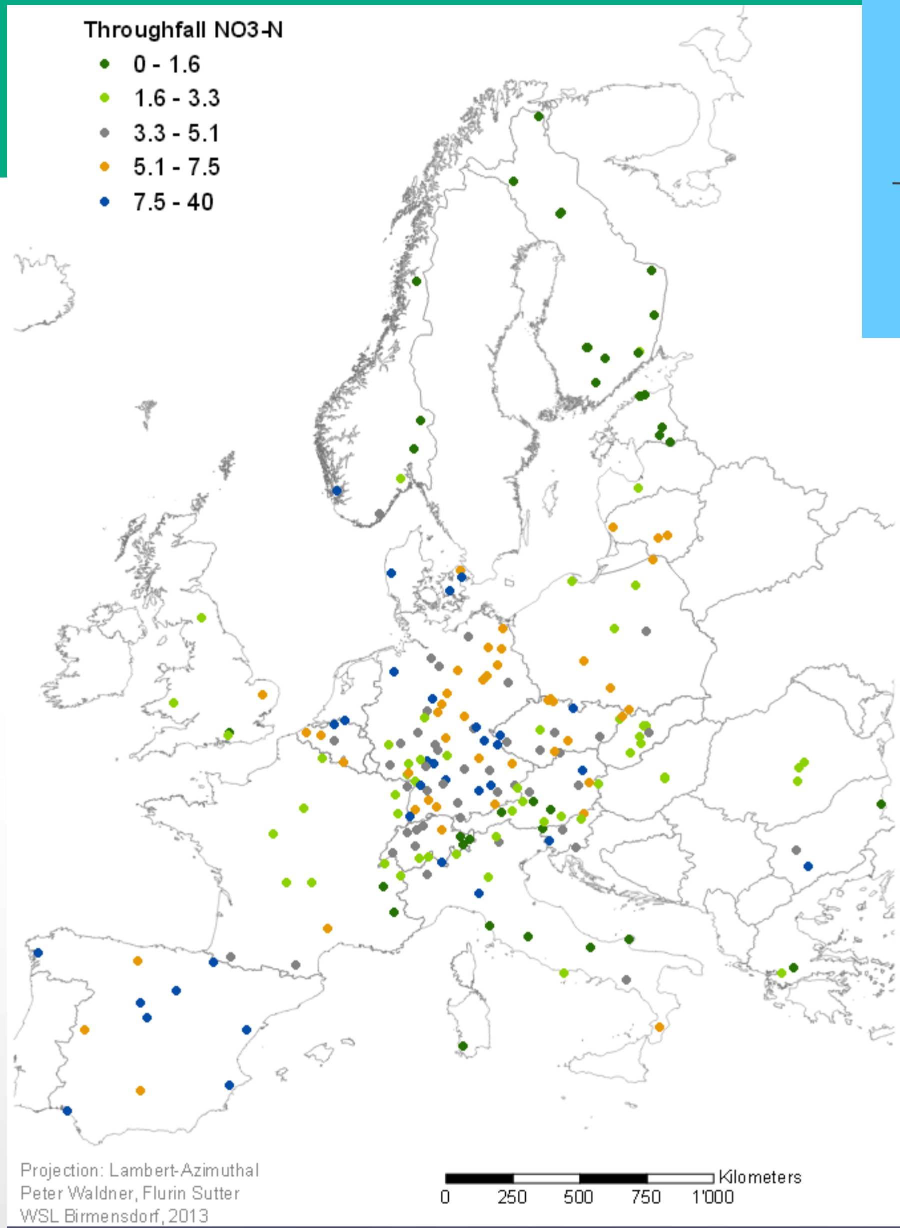
1. Deposition



For Critical Loads, Level I: Fischer et al., 2014

Annual nitrate (NO_3^- throughfall deposition in 2011 (in kg ha^{-1}) (Becher, Waldner et al. 2014)

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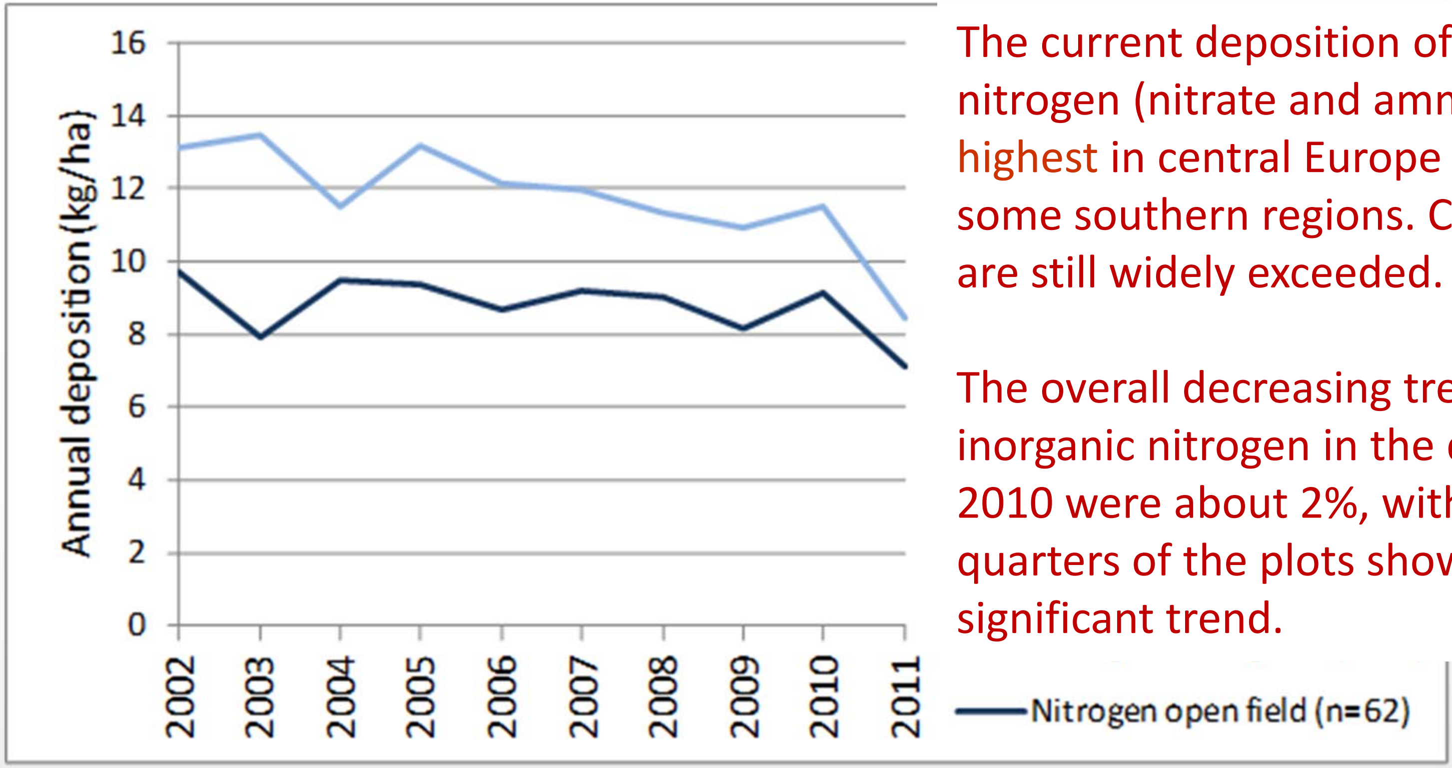
1. Deposition (Waldner et al., 2014)



The current deposition of inorganic nitrogen (nitrate and ammonium) is highest in central Europe as well as in some southern regions. Critical loads are still widely exceeded.

The overall decreasing trends for inorganic nitrogen in the decade to 2010 were about 2%, with three quarters of the plots showing no significant trend.

Development of nitrogen deposition

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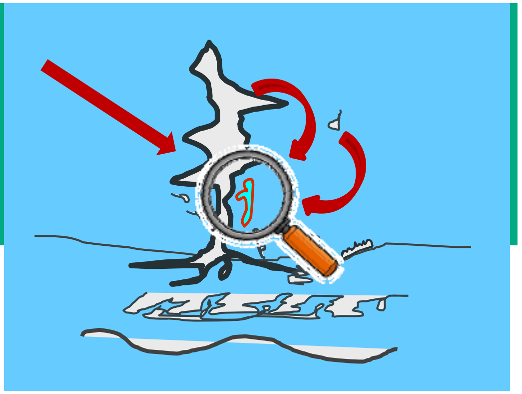
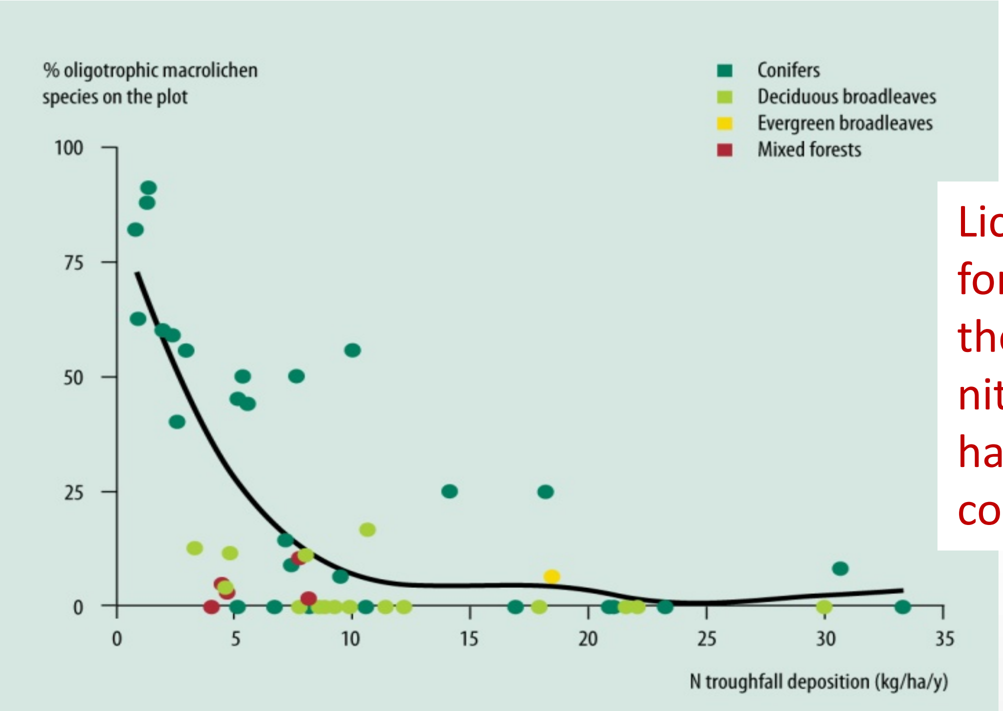
2. Epiphytic lichens (Giordani et al., 2014)





Lichens are very sensitive indicators for nitrogen deposition. On 80% of the plots assessed in 10 countries nitrogen deposition is too high and has altered lichen species composition over the years.

Percentage of lichen species adapted to nutrient poor conditions and nitrogen deposition on 83 plots. It was possible to determine a nitrogen critical load of 2.4 kg ha^{-1} yr^{-1}.

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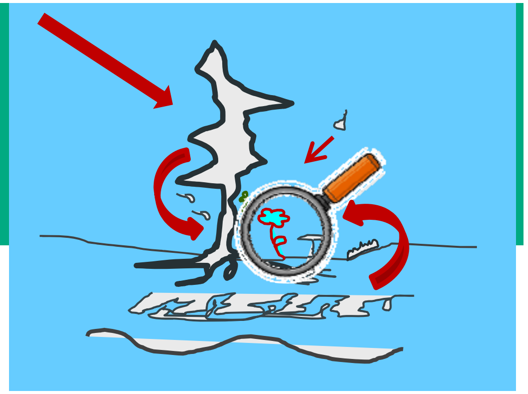
3. Ground vegetation (Seidling et al., 2008)



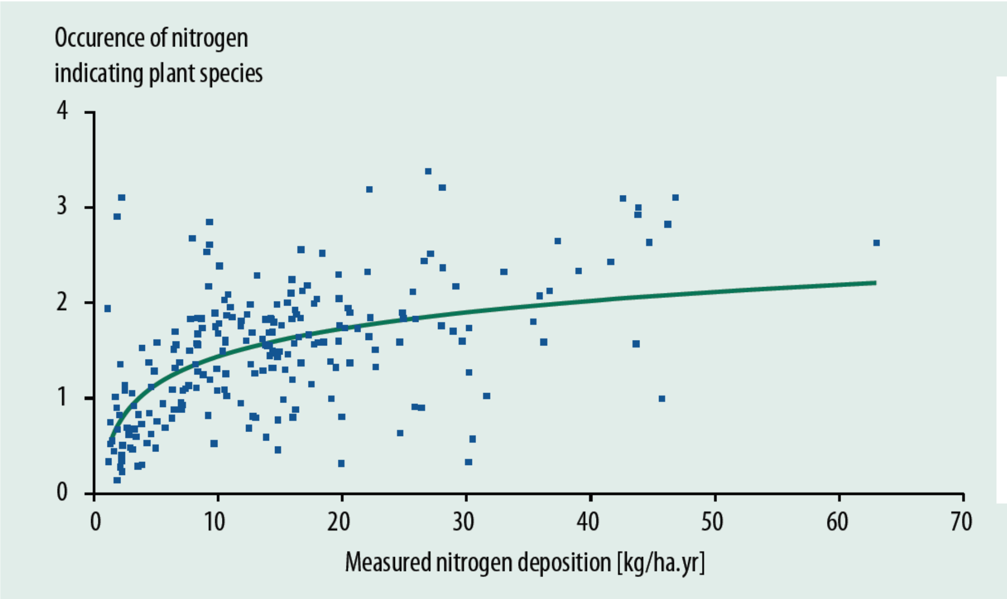
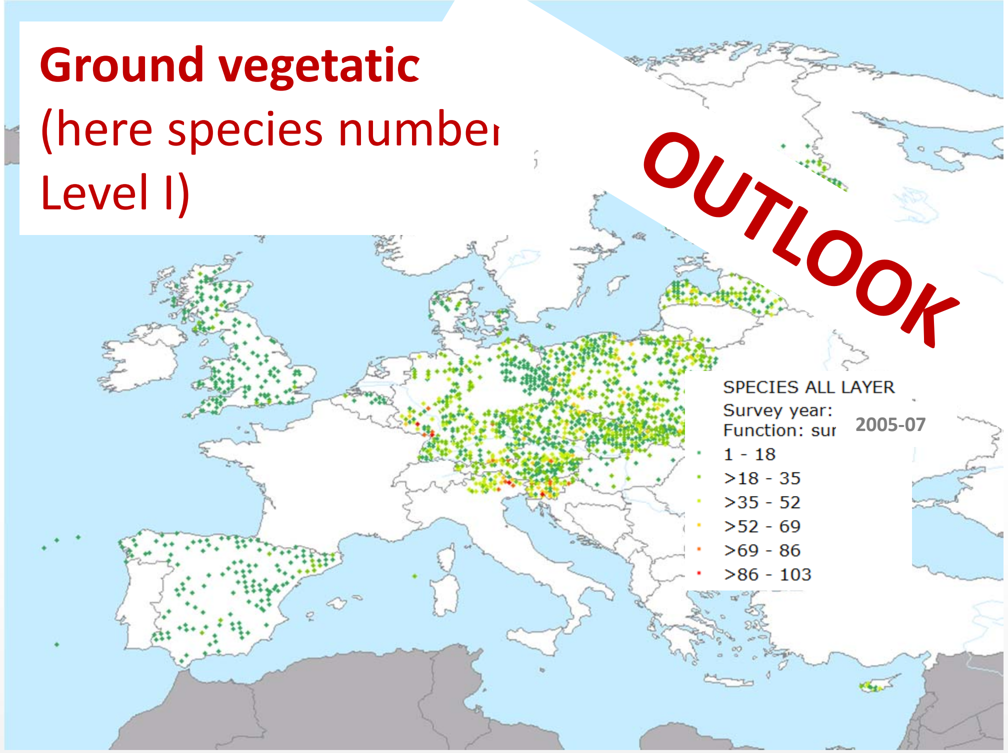


Figure 3-19: Relationship between the occurrence of nitrogen-indicating plants (4th DCA axis) and nitrogen deposition for 224 plots. Ground vegetation significantly reflects the measured nitrogen deposition under the forest canopy of the plots.

"The vegetation appeared to be largely determined by the 'traditional' factors soil, climate, and tree species, but there was a small but statistically significant effect of atmospheric deposition." (van Dobben and de Vries, 2010)

3. Ground vegetation (Canullo et al. ? 2015 ? ;-)



... as function of stand,
`‐po, soil, climate ... = ?

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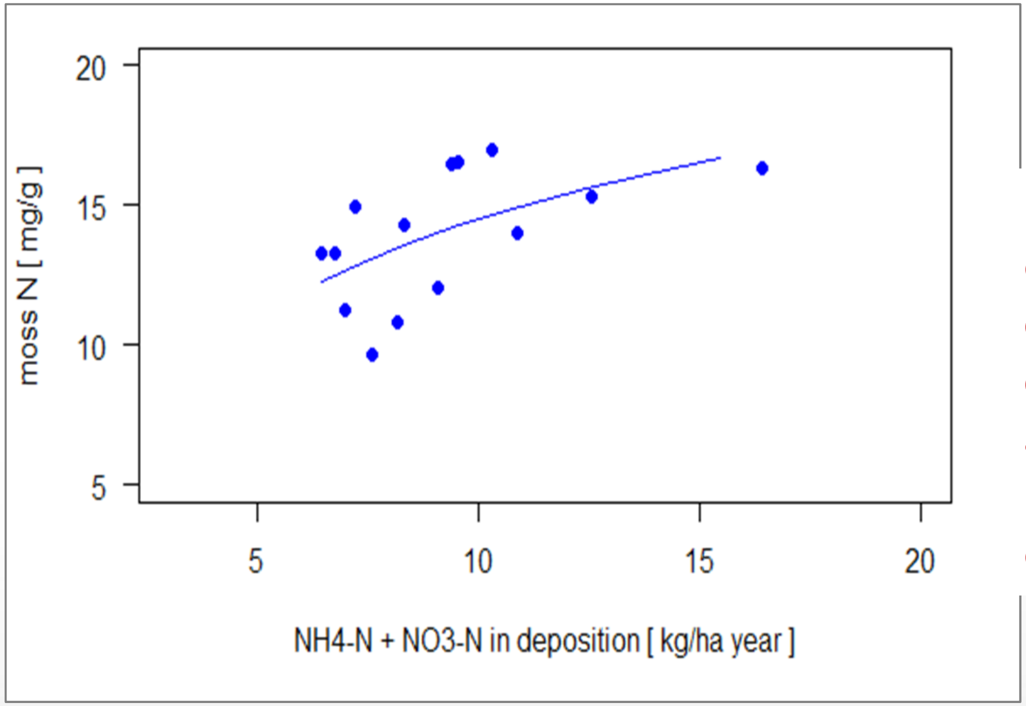
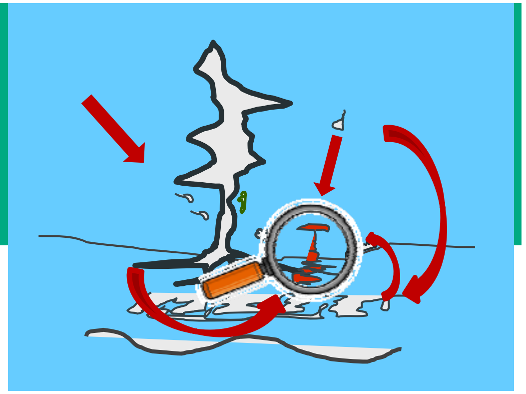
4. Mosses (Skudnik et al., 2014)

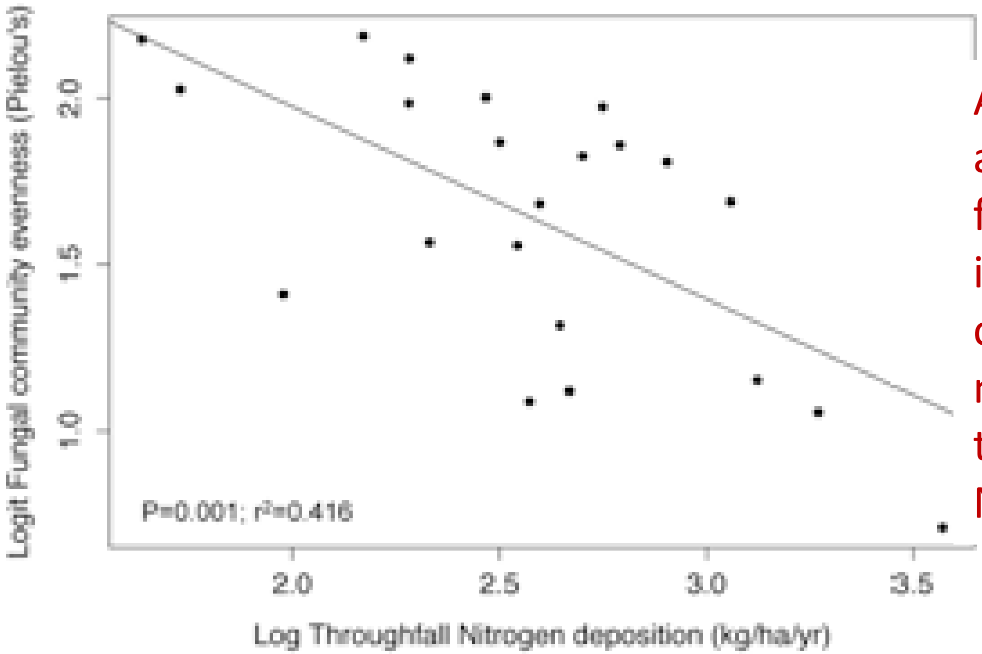


Measured results show clear effects of N deposition on N concentrations in mosses and confirm the usefulness of mosses as bioindicators, as already implemented in larger context, e.g. ICP Vegetation.

Case study on 14 ICP Forests Level II plots in Slovenia (8), Austria (3), Italy (2) and Croatia (1) reveals significant relation between nitrogen concentration in moss (*Hypnum cupressiforme*) and N open field depositions

5. Fungi (Suz et al., submitted)





At the European scale, eutrophication and acidification drive ecto-mycorrhizal fungi communities through their impacts on tree roots, fungi and soil condition. The critical N load for mycorrhizal diversity and evenness in the oak forests sampled is 9.5 - 13 kg N.ha^{-1}.yr^{-1}.

Eveness of fungi species and N deposition based on 22 ICP Forests **oak** plots, in 9 countries, including roots from 2,112 soil cores and analysis of over 6,300 mycorrhizas.

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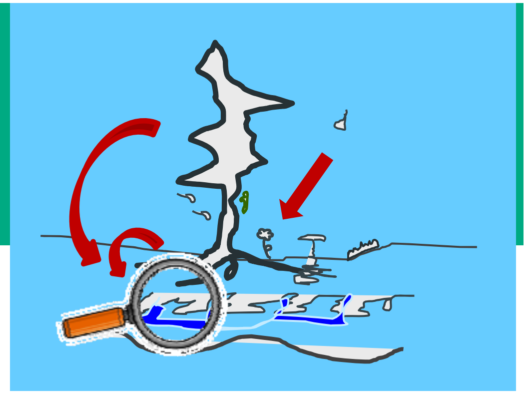
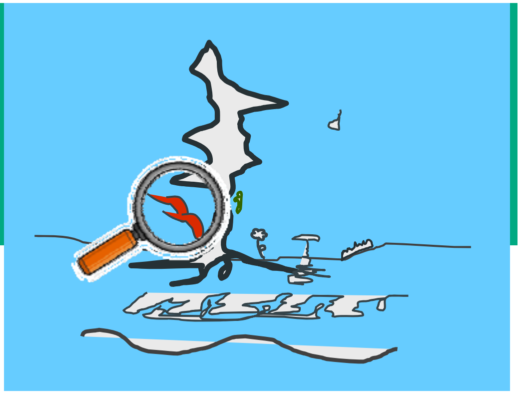
6. Soil Water (Graf Pannatier, 2014)



Soil water is a fast reacting N pool in forest ecosystems. Critical limits are widely exceeded. There is no general time trend. Local site and stand parameters have stronger influences on short term peaks and variation than deposition

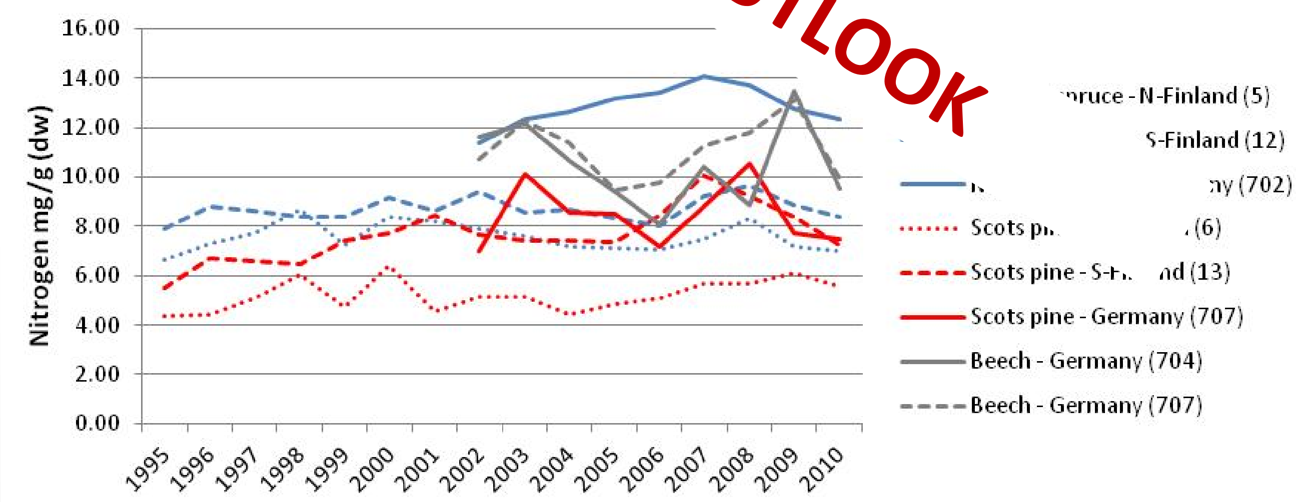
* The critical limit of 1 mg N L^{-1} leading to nitrate leaching was exceeded in the mineral subsoil in 50% of the 173 selected Level II plots, in particular in the Netherlands and Belgium (Iost et al. 2011).
* Literature study (27 publications): no clear time trends, locally varying situations, increase mostly when N-cyle disrupted (fellings, calamities, tree vitality, water regime)

7. Litterfall (Ukonmaanaho)



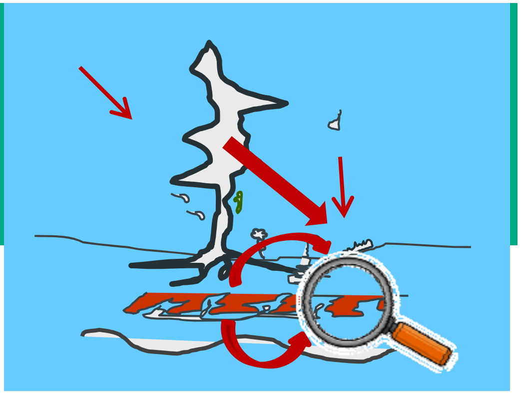
* High concentrations i   low concentrations in North Europe. Time trend   nt.

OUTLOOK



Nitrogen concentrations in litterfall on 6 ICP Forests plots

8. Soil C/N (Cools et al., 2014.)



	N plots	High N status C:N < 25	Intermediate N status 25 ≤ C:N ≤ 30	Low N status C:N > 30
Scots pine	1291	326 (25%)	431 (33%)	534 (41%)
Norway spruce	927	425 (46%)	368 (40%)	134 (15%)
Maritime pine	103	10 (9.7%)	20 (19%)	73 (71%)
Aleppo pine	90	20 (22%)	28 (31%)	42 (47%)
All coniferous stands	*2745*	*924 (34%)*	*922 (34%)*	*899 (33%)*

"Tree species is the major factor explaining C:N ratios in European forest soils (forest floor and topsoil); deposition played a smaller and at the European scale inconsistent role (<10% relative importance)" (Cools et al., 2014)

The number of coniferous ICP Forests plots on Level I by main coniferous tree species with high, intermediate and low N status according to the C:N ratio of the forest floor (Gundersen et al., 2006)
(=> Not much general difference between conifers and broadleaves, but between species)

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9. Ground water

OUTLOOK

Conclusive results on national le

Level II based work on European leve ... g. NitLeach)

…

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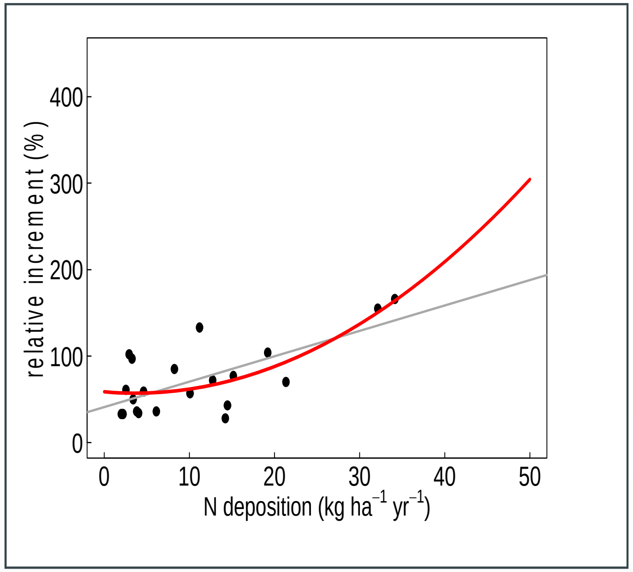
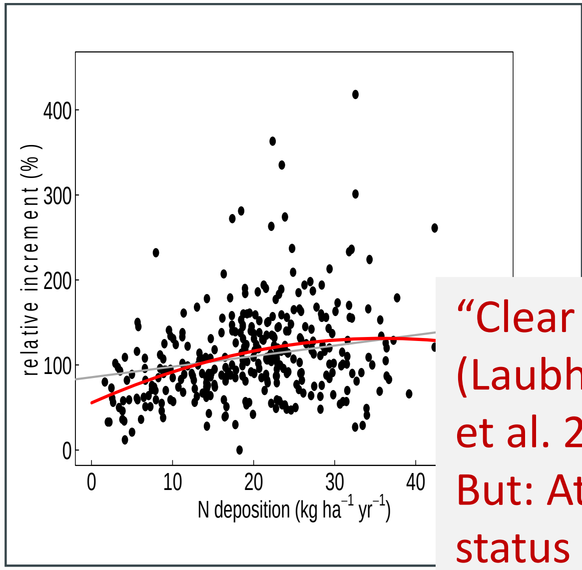
10. Trees: growth (Etzold et al.)



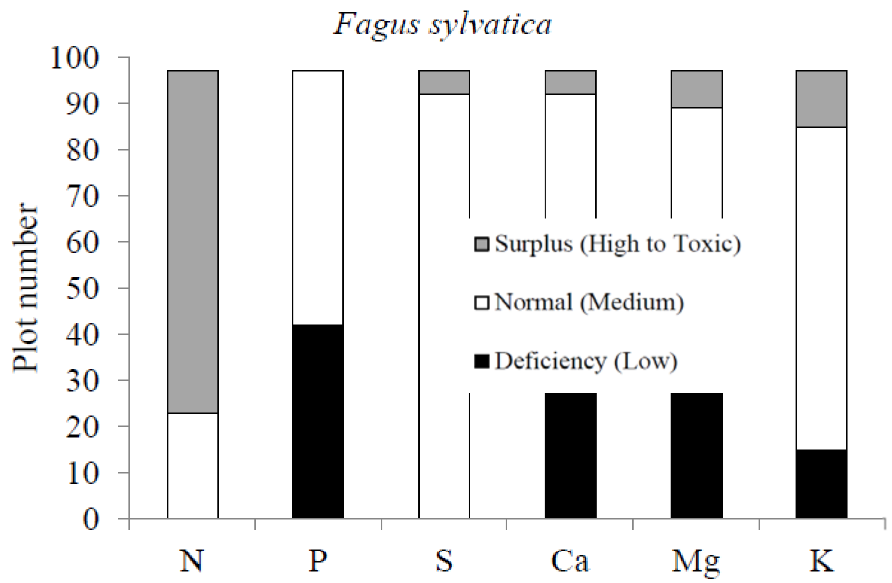
Sensitive sites with low N status



All sites

"Clear fertilization effect of N" (Laubhann et al., 2009, Solberg et al. 2009, De Vries et al., 2014). But: At sites with low nitrogen status in the soil N deposition increases growth. But half of the sites are already nitrogen saturated and the high atmospheric inputs lead to reduced growth (Etzold et al.).

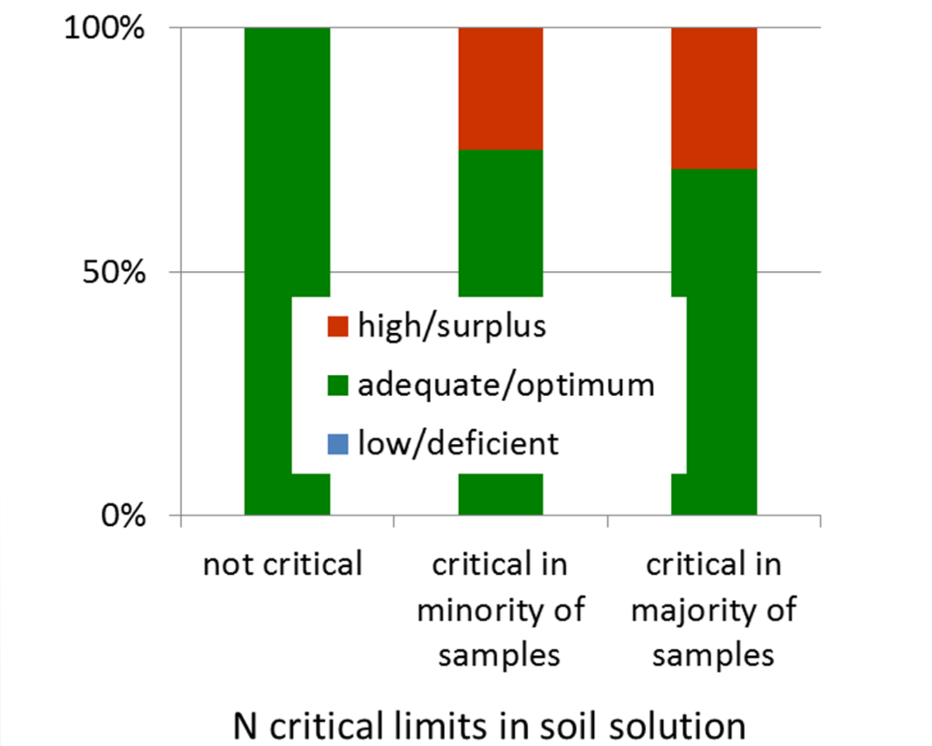
10. Trees: foliage (Jonard et al. subm.)



In species and regions with low N deposition (pine and spruce in North) N is still limiting tree growth. In Central Europe with higher depositon, N is no longer limiting (beech).
N depo affects trees by nutrient imbalances (alarming N:P ratios!) and reduced root growth and uptake.

Plot distribution according to their foliar nutrient status determined by comparing the mean foliar concentration of the current-year leaves with the thresholds set by Mellert and Göttlein (2012) for N, P, Ca, Mg and K and by Stefan *et al.* (1997) for S

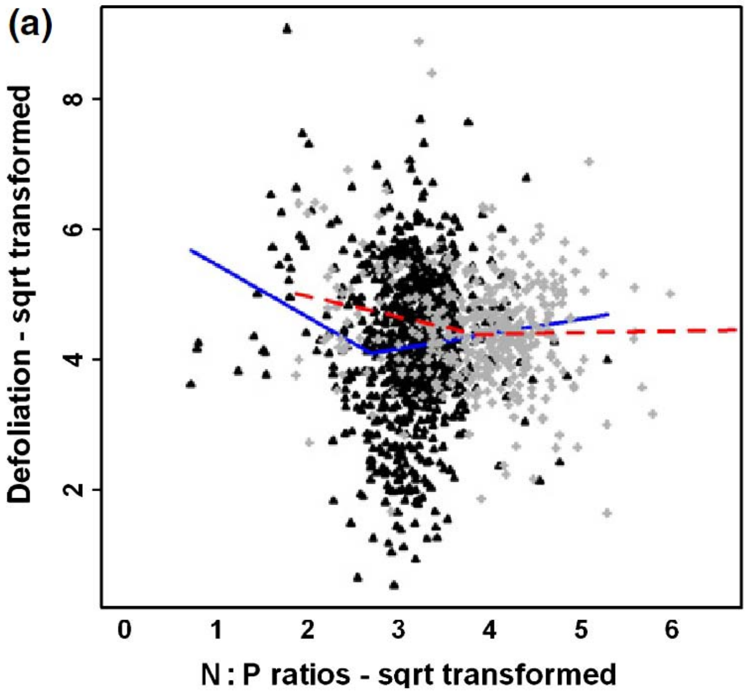
10. Trees: foliage (Waldner et al. subm.)



"Mineral nitrogen concentration in soil solution and throughfall nitrogen deposition concentration might at least be similarly important factors for foliage N"

% of plots in foliar nutrition classes at different nitrogen status in soil solution, *Fagus sylvatica*.

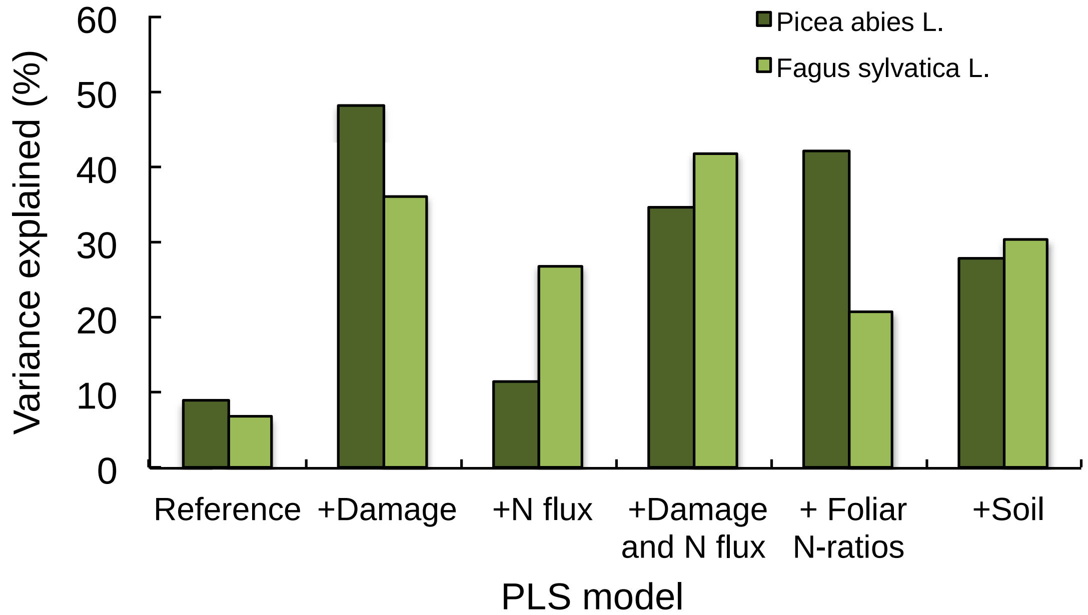
10. Trees: foliage (Veresoglou et al., 2014)



„ Increases in N availability appear, at least for conifers, to have a negative effect on tree health even under N-limiting conditions… Consequently, increases in defoliation may represent a warning symptom of high N deposition provided that other causes of defoliation are ruled out.”

N : P ratios and defoliation. Black triangles, conifers; grey crosses, broadleaves; continuous line, segmented line for conifers; discontinuous line, segmented line for broadleaves .

10. Trees: defoliation (Ferretti et al.)



Variance of deoliation explained by the six PLS regression
Each variable(s) is added to the reference model at subsec

The combined addition of damage symptoms and N flux resulted in the best model performance in beech.
"Relationships of air pollution with crown condition appear to be weak while climatic factors appear to be more important drivers." (De Vries et al., 2014)

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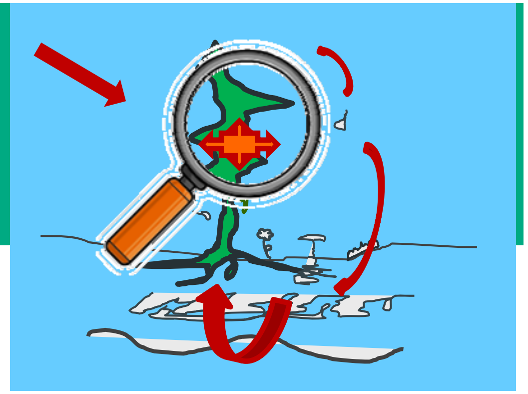
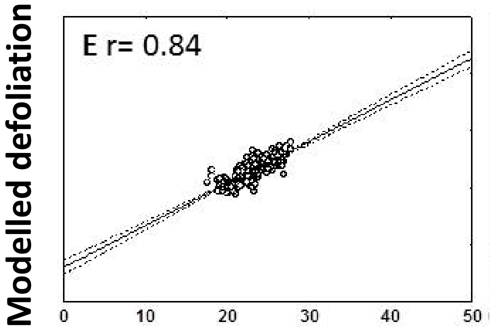
10. Trees: defoliation (De Marco et al., subm.)



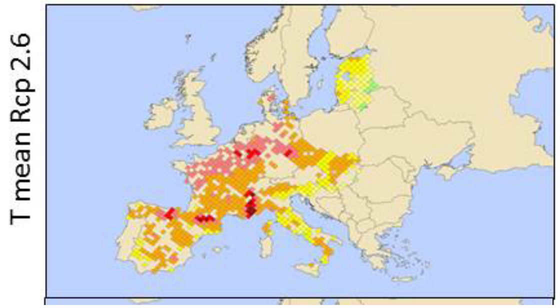


Observed defoliation

OUTLOOK: climate !

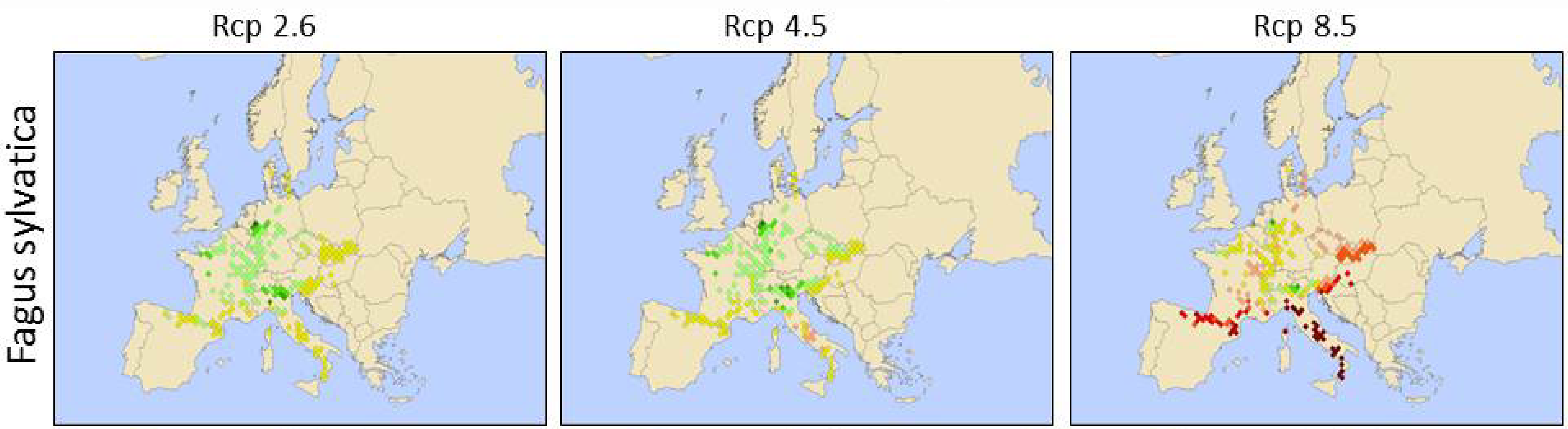
rest Analysis
(Vita nted) +
General R odel
=> Observed v
predicted defoliatio
values for *Fagus sylvatic*

+



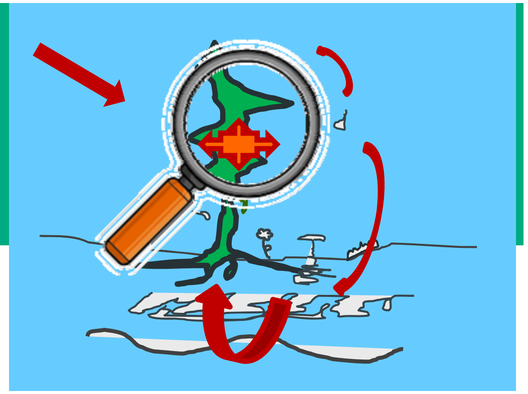
Climate (and depo) scenarios

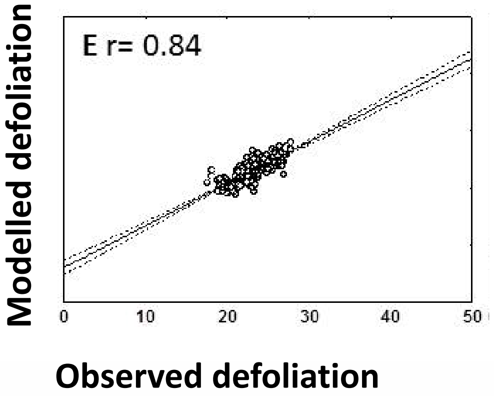
=



Delta % of crown defoliation in 2030 respect to the present in three climatic scenarios (with identical N depo) in *Fagus sylvatica*.

10. Trees: defoliation (De Marco et al., subm.)

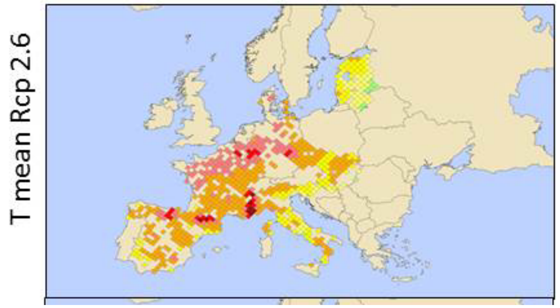




rest Analysis (Vita… …nted) + General R… …odel => Observed v… predicted defoliatio… values for *Fagus sylvatic*…

OUTLOOK: climate !

+



Climate (and depo) scenarios

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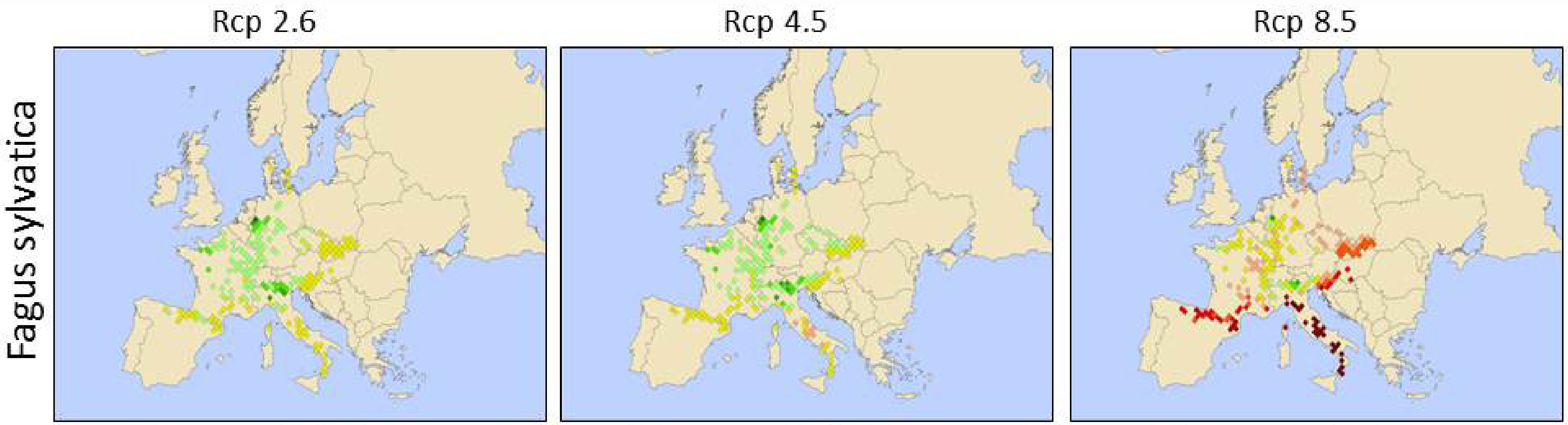
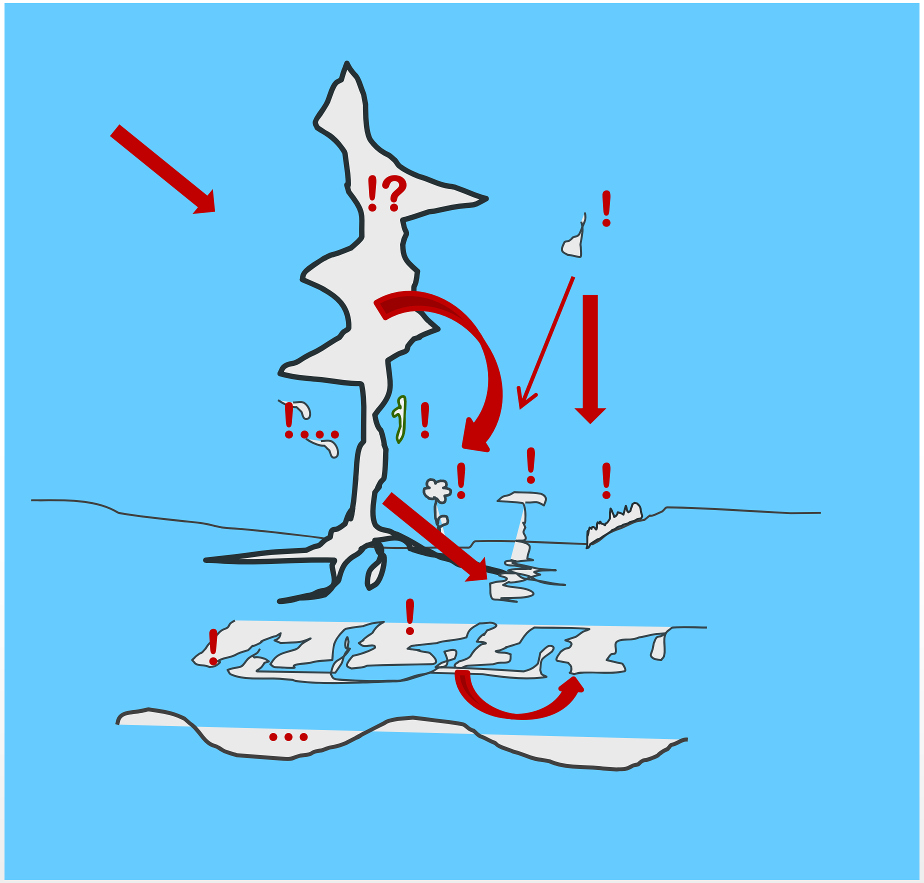


Delta % of crown defoliation in 2030 respect to the present in three climatic scenarios (with identical N depo) in *Fagus sylvatica*.

Outlook and discussion



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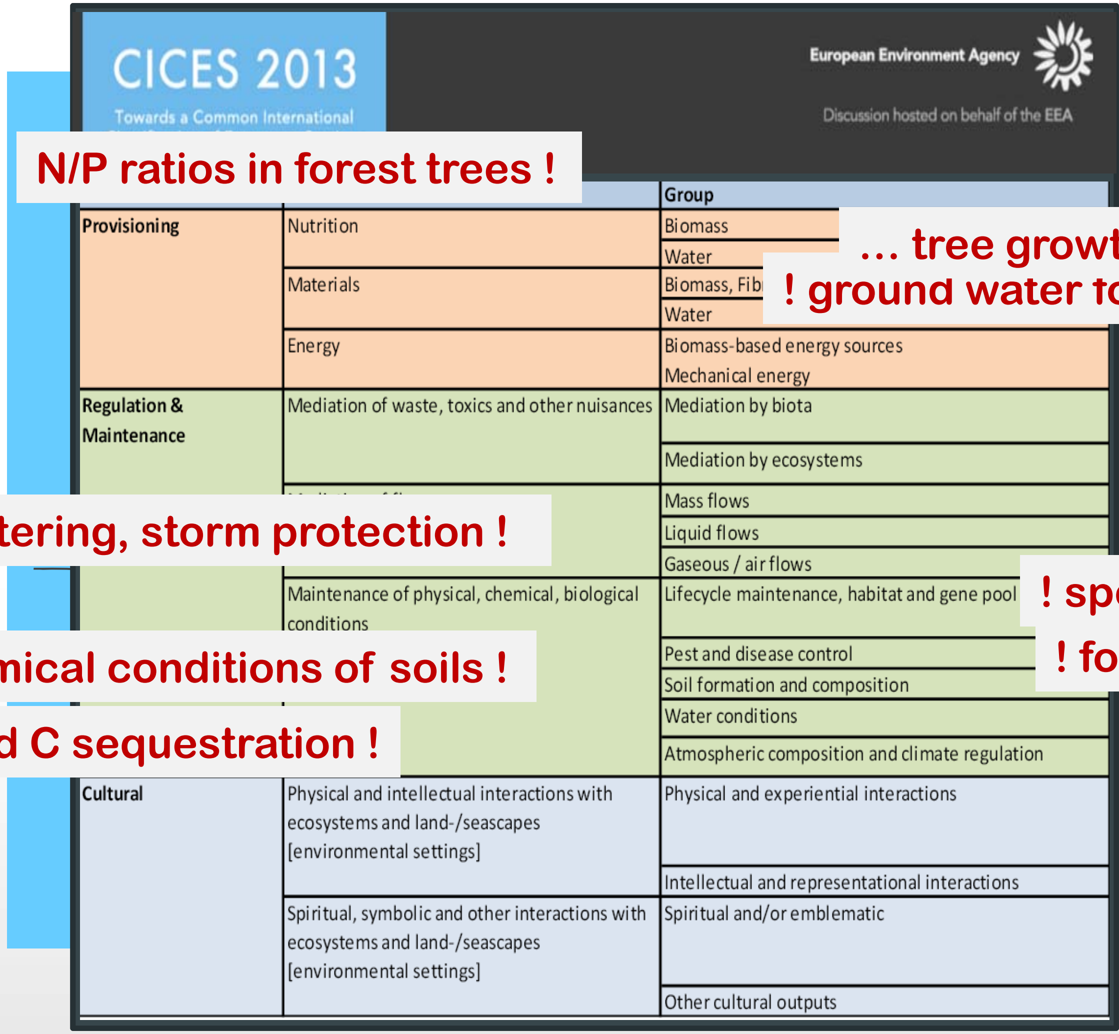

CICES 2013

Towards a Common International

European Environment Agency

Discussion hosted on behalf of the EEA

		Group
Provisioning	Nutrition	Biomass
		Water
	Materials	Biomass, Fib
		Water
	Energy	Biomass-based energy sources
		Mechanical energy
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota
		Mediation by ecosystems
	[illegible]	Mass flows
		Liquid flows
		Gaseous / air flows
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool
		Pest and disease control
		Soil formation and composition
		Water conditions
		Atmospheric composition and climate regulation
Cultural	Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings]	Physical and experiential interactions
		Intellectual and representational interactions
	Spiritual, symbolic and other interactions with ecosystems and land-/seascapes [environmental settings]	Spiritual and/or emblematic
		Other cultural outputs

N/P ratios in forest trees !

… tree growth

! ground water for drinking

air filtering, storm protection !

! species shifts

! forest health

bio-geochemical conditions of soils !

N related C sequestration !

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Outlook and discussion

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