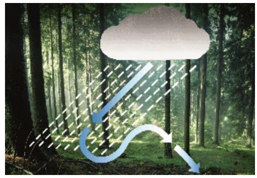
Clean Air 40 YEARS

wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution



# Nitrogen deposition and terrestrial plant biodiversity

James Weldon, ICP IM

# THREATS TO EUROPEAN FOREST BIODIVERSITY

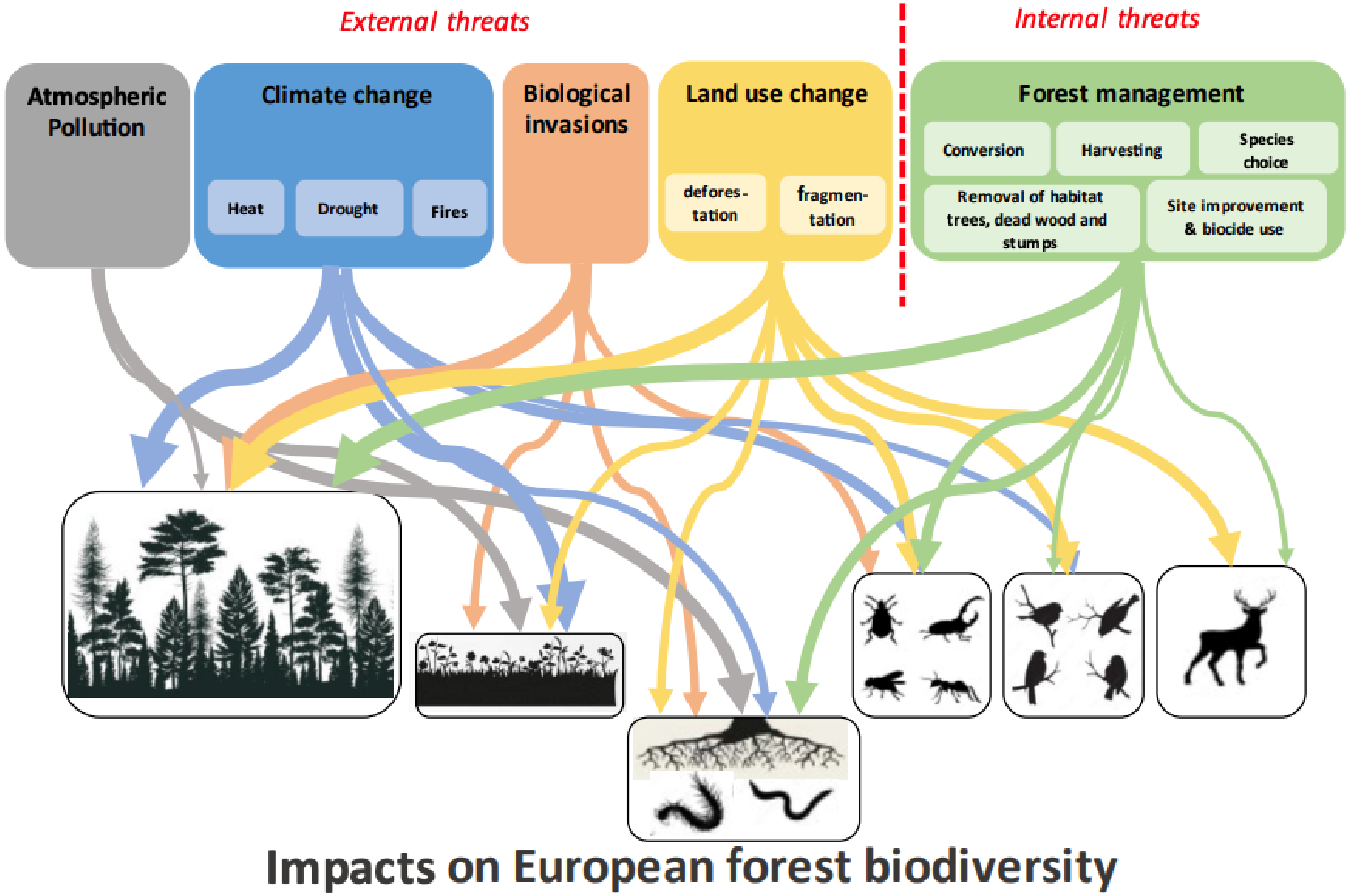
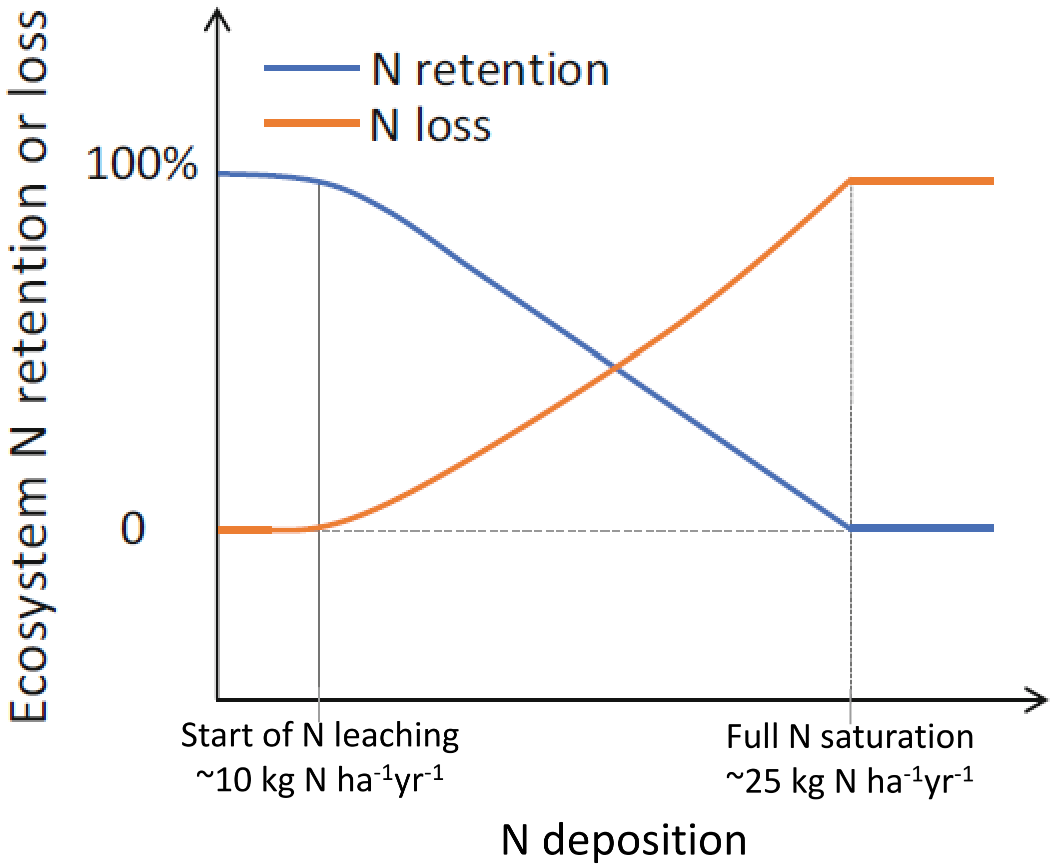



**Figure 5.** The relationships between major threats to biodiversity in European forests and particular groups of species (from left to right: trees, understory vegetation, soil organisms, insects, birds, mammals). The thickness of the arrows indicates the estimated magnitude of effects based on expert opinion. Indirect effects, such as changes in forest stand structure, are not represented.

Muys et al, 2022

# Nitrogen and plant communities

- Conceptual model of N retention and loss in ecosystems (after Du, E. 2022)
- Two thresholds:
  1) Where N starts leach from ecosystem
  2) Fully N saturated ecosystem
- Levels in figure varies between ecosystems



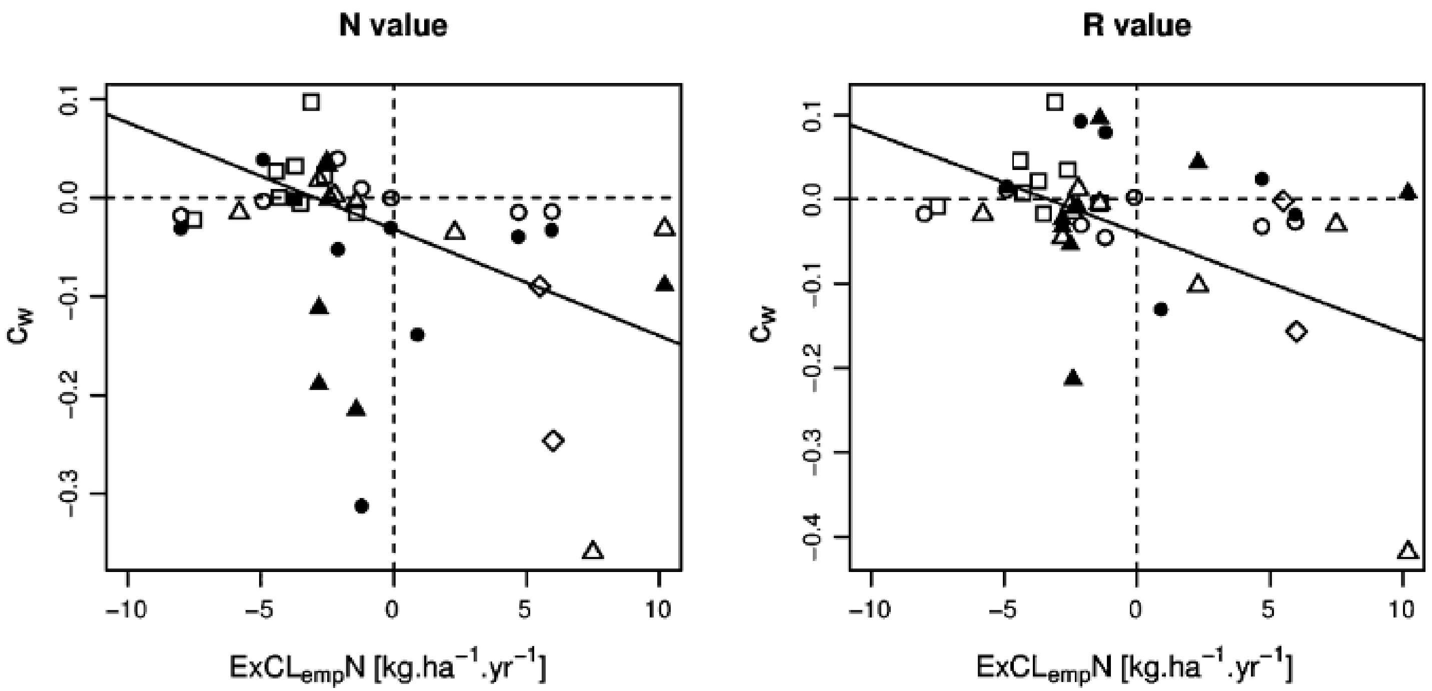

Du, E. 2022

# Biodiversity?

- Limited data on many taxonomic groups
- Best data on vascular plants, less so bryophytes and lichens
- Very little data on any kind of animals
- Terrestrial biodiversity - forest understorey vegetation

# Vascular plants

- Data from 28 forest sites (ICP IM/Forests)
- Cover of plant species which prefer nutrient-poor soils decreased the more N deposition exceeded the empirical critical load (CL) for eutrophication
- No increase in nitrophilous species
- Newly recruited species were mainly nitrophilous

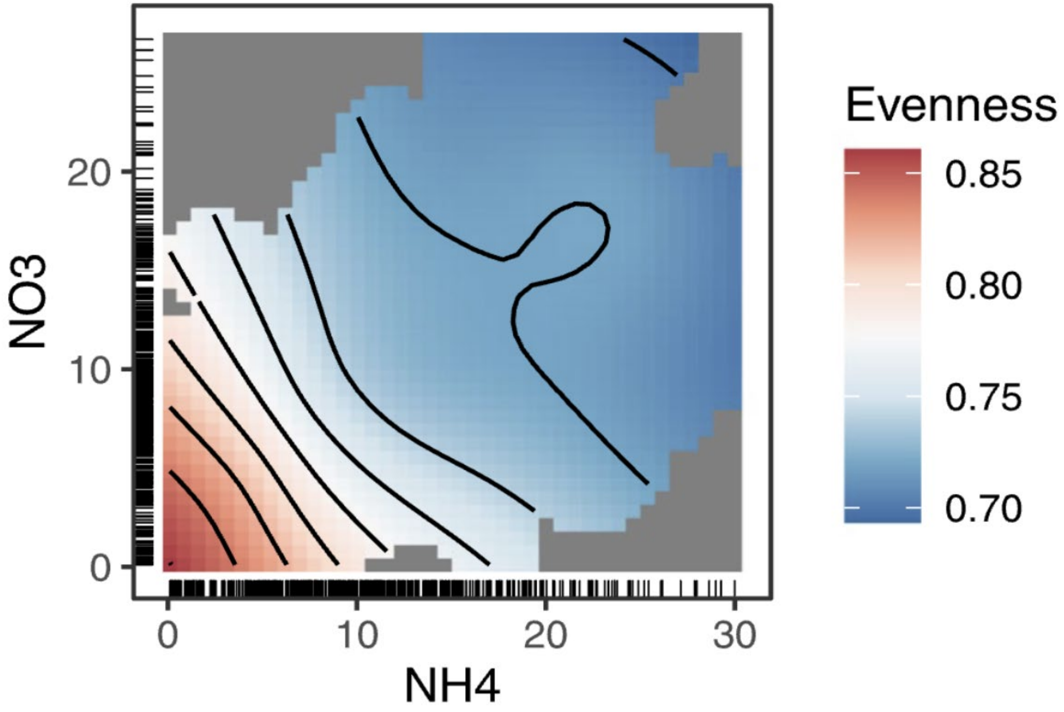



*Relationships between weighted averaged changes (cw) of the cover of forest floor plant species groups and CL exceedance (ExCLempN)*

Dirnböck et al, 2014

# Bryophytes

- Bryophyte data from ICP Forests and IM plots (1994-2016)
- Increased N preference and decreased species evenness, but no change in richness
- Increased dominance of nitrophilous species
- Small effect size at current deposition levels
- Losses before data available?




Species eveness response to N deposition

Weldon et al., 2022

# Epiphytic lichens

- 83 plots in 10 European countries (ICP Forests)
- Pollutant deposition explained 56.7% of the variance in macrolichen abundance
- 34.3% due to overall N deposition and 22.4% was the independent effect of sulphate deposition

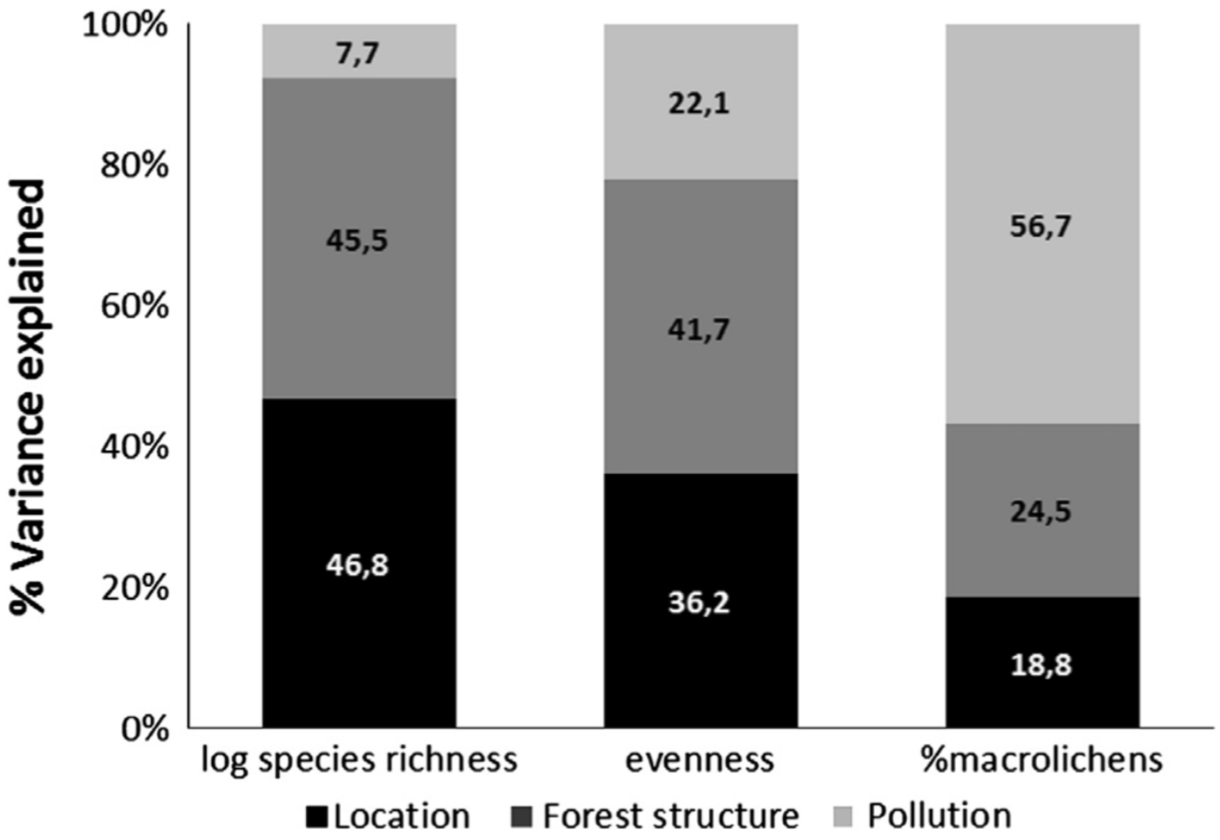



**Fig. 3.** Hierarchical partitioning of independent effects. All forest types.

Giordani et al., 2014

# Weak recovery – epiphytic lichens

- Epiphytic lichen data Swedish IM sites, 1996 -2015
- Significant improvements in air quality
- At most polluted site, decline in richness and diversity (also increased homogenisation)
- Loss of N, S tolerant species but lack of new sensitive species

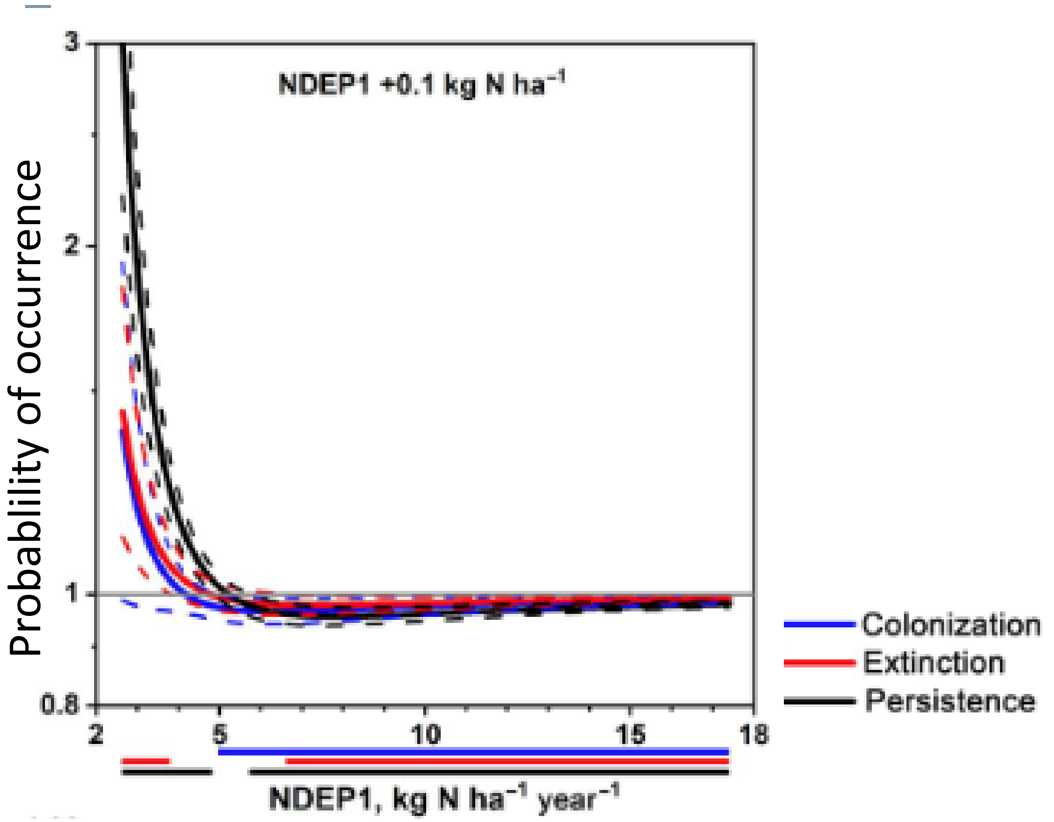
*Highest S, N deposition* → *Lowest S, N deposition*

| | Gårdsjön | Aneboda | Kindla | Gammtratten |
|---|---|---|---|---|
| Richness | -** | -* | + | + |
| Diversity | -* | -** | - | + |

Weldon & Grandin, 2021

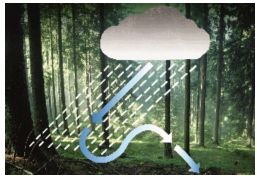
# Weak recovery – epiphytic lichens

- Dispersal limitation from a depleted regional species pool adversely affecting recolonisation?
- Continuing deposition affecting most sensitive species
- “Industrial forestry, in combination with nitrogen, is the main driver of lichen declines. Nitrogen deposition has decreased but is apparently still sufficiently high to prevent recovery.” (Esseen et al. 2022)




Steep reduction in probability of hair lichen occurrence with increasing N deposition (Esseen et., al, 2022)

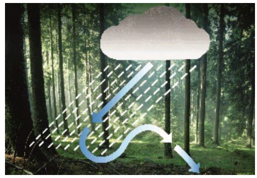
Esseen et al., 2022



# Review of observational and experimental studies

- Large-scale monitoring data find shifts in understory community composition in response to high levels of N deposition but do not show clear responses to decreasing N deposition.
- The recovery of understory vegetation from high N inputs is possible but long time-lags (decades) are expected.
- In regions where high N deposition eradicated source populations, recolonisation will be difficult.
- This delay in the response of understory vegetation to decreases in N deposition partly explains the absence of corresponding trends in Europe-scale observational studies.
- Other factors important...

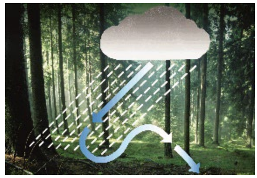
Schmitz et al. 2019



# Context dependancy complicates the issue

- Forest understorey vegetation sensitivity to rates of N deposition varies, depending on the abiotic conditions, the overstorey composition, management, and previous atmospheric deposition
- Deposition history: pre-survey levels of N deposition influence subsequent changes in vegetation
- Environmental conditions such as light availability and herbivory are also important
- Other factors - S deposition, habitat loss and fragmentation, climate impact, and non-native species invasion (see e.g. Perring et al., 2017, 2018)

Perring et al., 2018



# Modeling biodiversity - Habitat Suitability Index

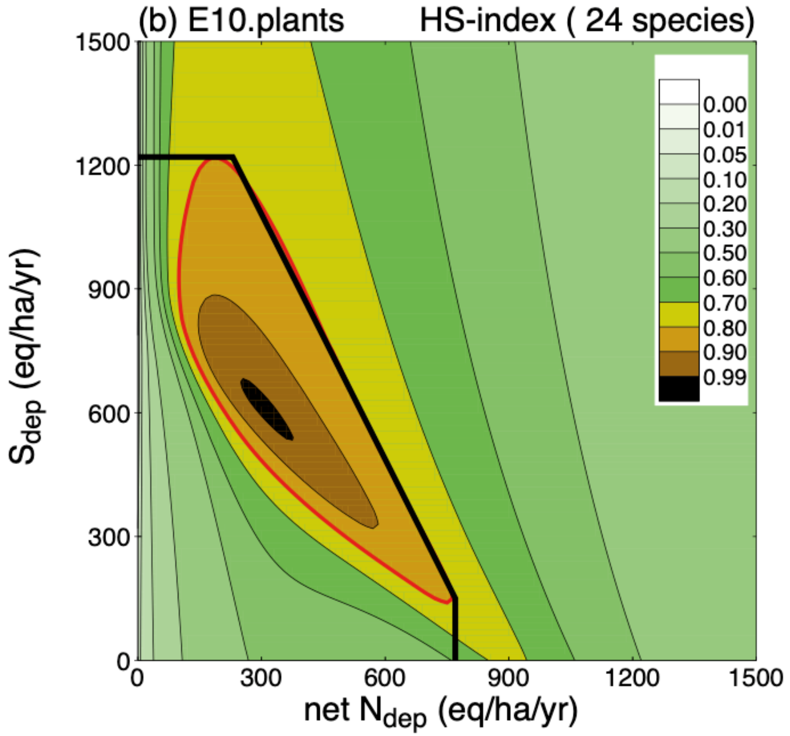
- Habitat Suitability Index (HSI) – based on the probabilities of occurrence of the species of interest
- Predictions from empirical niche functions of distinctive species in a habitat
- Measures of habitat suitability, such as HSI, are directly relevant for habitat management and conservation.

# Critical Loads for Biodiversity

- Critical loads for biodiversity are limits for nitrogen (N) and/or sulphur (S) deposition to prevent plant species from being lost from ecosystems
- Calculating these critical loads is a two-step process:
  1) establish the abiotic parameters at which relevant plant species are at risk of disappearing, and
  2) apply a soil chemistry model to translate those abiotic parameters into the N and S deposition values

# Critical Loads for Biodiversity

## Applied in work done by CCE




*Habitat Suitability Index for a coastal heath, as a function of N and S deposition. Black line is a critical load function*

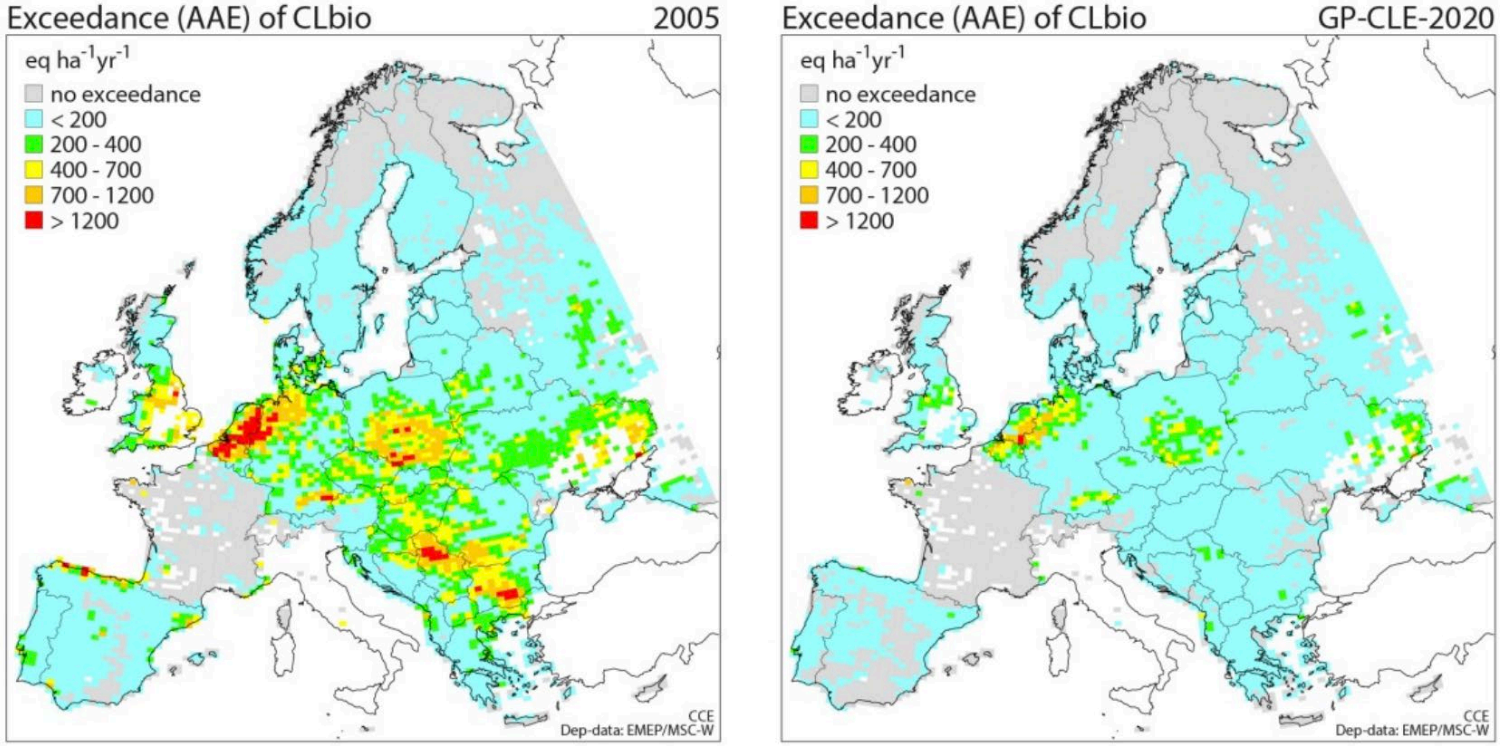
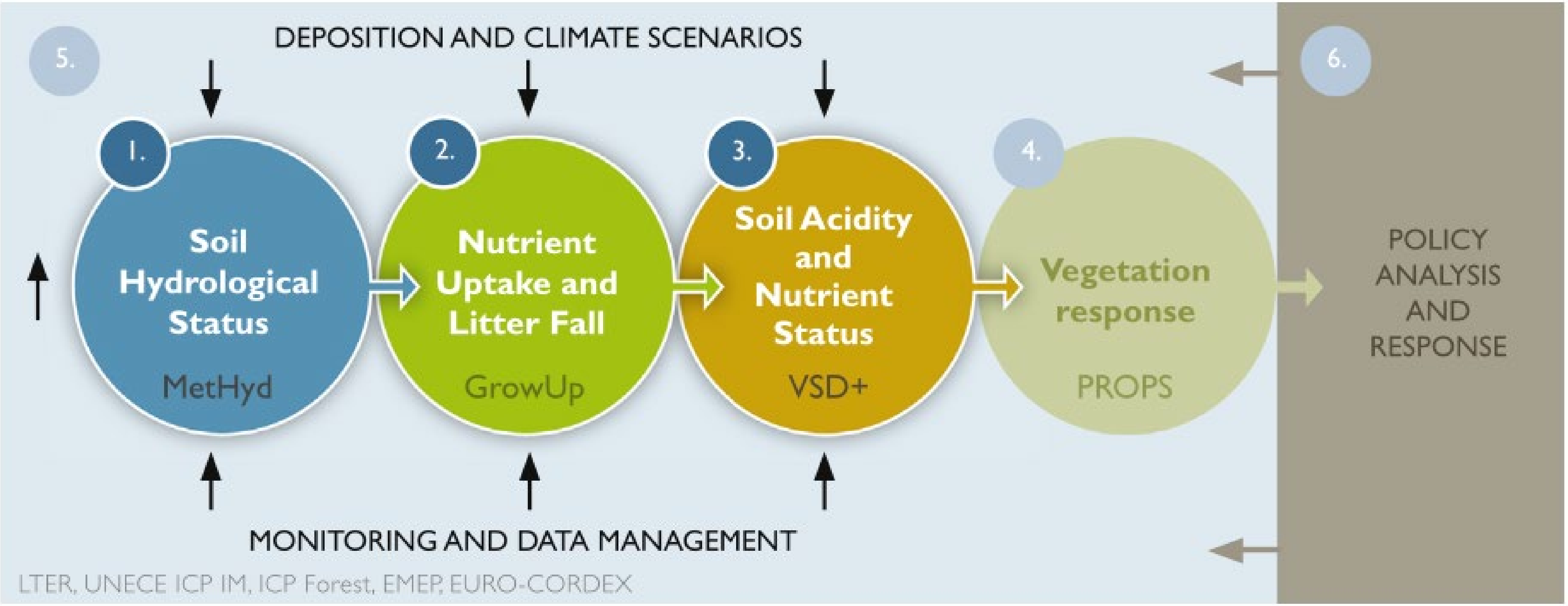



***Figure 1.7 Computed ecosystem area at risk of loss of biodiversity in 2005 (left) and 2020 (right) affecting 27% and 12%, respectively, of an ecosystem area of 2.1 million km² covering 23 habitats including data submitted by NFCs***

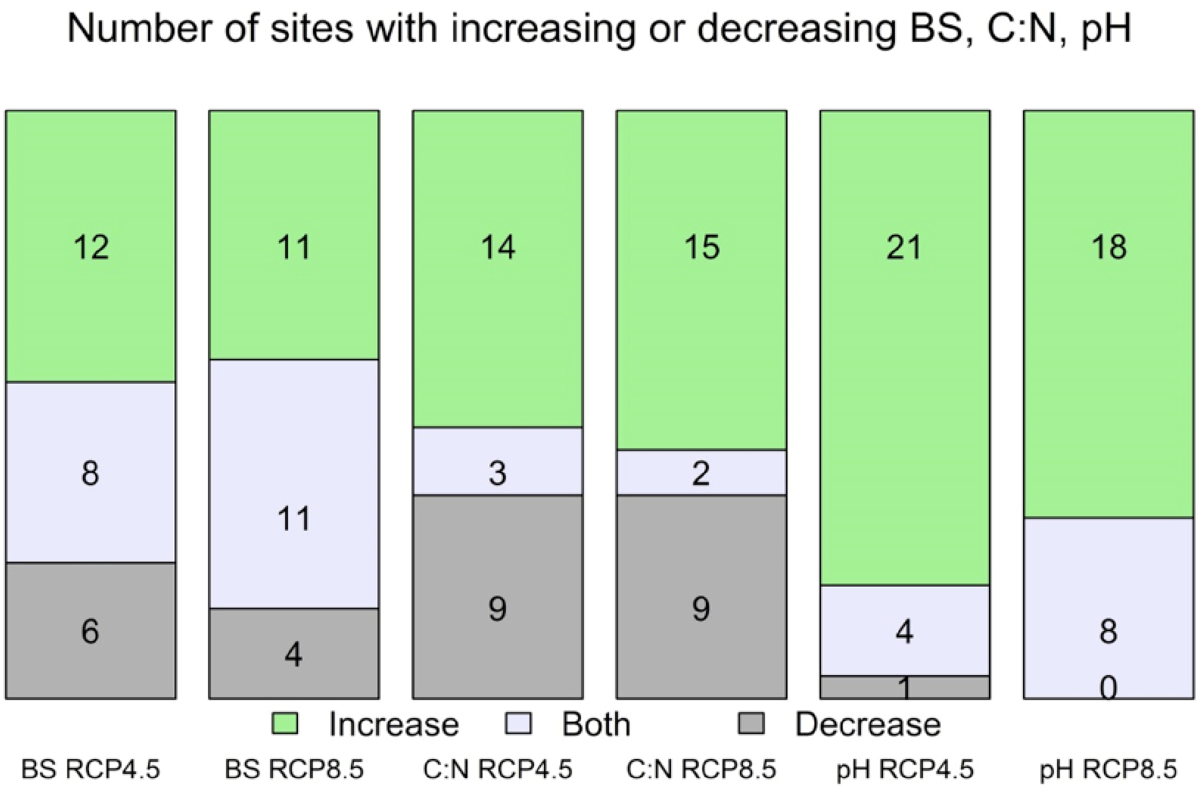
# Dynamic modeling




Holmberg et al., 2018

# Dynamic modeling – soil chemistry

- Calibrated VSD+ at 26 sites (ICP Forests, ICP IM) and simulated key soil properties under projected deposition of N and S, and climate warming until 2100
- Simulated soil conditions improved under projected decrease in deposition and current climate conditions: higher pH (80% of sites), BS (62%) and C:N (46%)
- Results needed to model biodiversity…

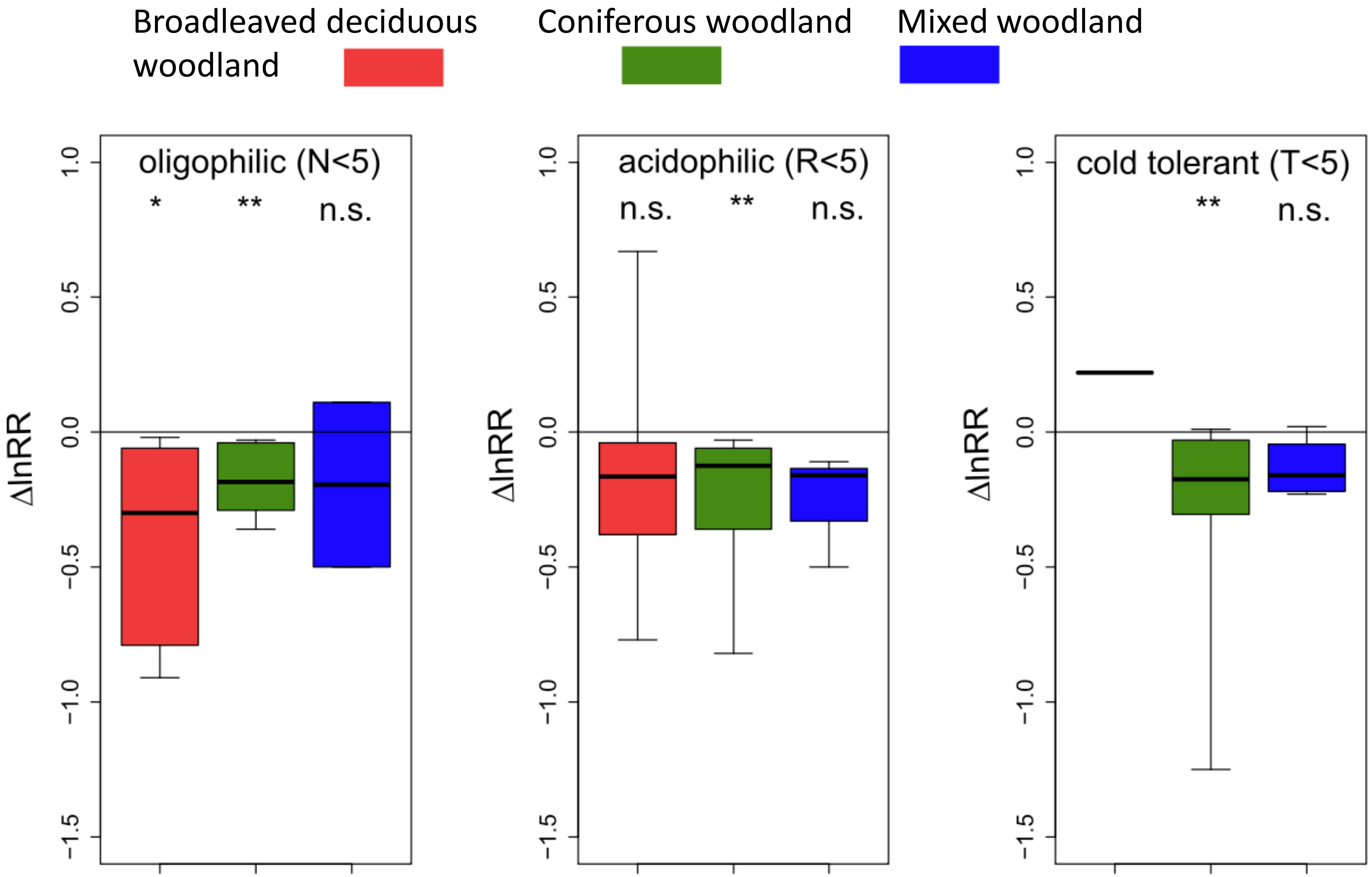



*Simulated change in soil variables from the year 2000 to 2100. Increase/decrease defined as BS or C:N more than 5% or pH more than 0.02 pH units higher/lower than in 2000. Simulations performed with deposition scenario CLE and twelve RCP4.5 and twelve RCP8.5 climate scenarios.*

Holmberg et al., 2018

# Modeling vegetation

- Compare present with projections for 2030/50
- Change in oligophilic, acidophilic, and cold-tolerant plant species
- Model predictions (PROPS) indicate oligophilic species will further decrease
- Confounding processes - climate effects and decreases in sulphur deposition
- Decreases in N deposition to 2030 will most likely be insufficient to allow recovery from eutrophication

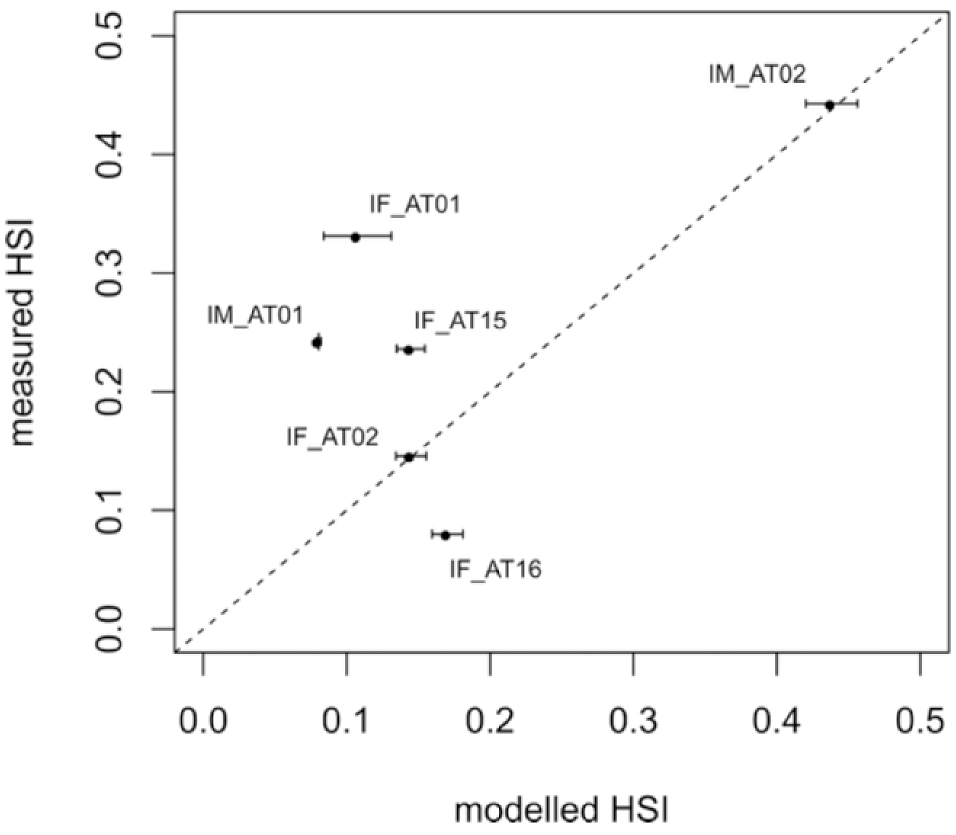



*Effects of current legislation deposition (CLE) on trends in oligophilic (N<5), acidophilic species (R<5), and cold- tolerant (T<5) plant species until 2030*

Dirnböck et al., 2018

# Modeling vegetation

- VSD+/PROPS with data from Austrian forest sites
- Climate change scenarios caused an increase of the occurrence probability of oligotrophic species due to a higher N immobilisation in woody biomass leading to soil N depletion
- As a consequence, climate change offset eutrophication from N deposition
- Modelling niches reveals trends but also indicates the difficulties at site scale
- Other factors affect realised niche…




*R2 between modelled and measured HSI was 0.36 but not significant (p = 0.201). Six sites with vegetation records between 1996 and 2007 were used. The 1:1 line is dashed.*

Dirnböck et al., 2017

# Challenges

- Context dependant. Other factors important – management, dispersal limitation, herbivory…
- Inter-species competition?
- Model epiphytes? Responsive, avoid complexities of soil modelling
- No immediate change in biodiversity with reduced deposition to below critical loads- need to ask what will it look like in 20, 50 years
- Predictions about species composition in several decades linked to N have to take climate change into consideration, conditions may be suitable for a very different set of species solely due to climate

# Thank you for your attention!