Nitrogen Deposition as a Threat to European Terrestrial Biodiversity

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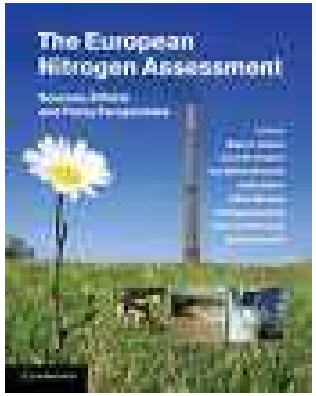
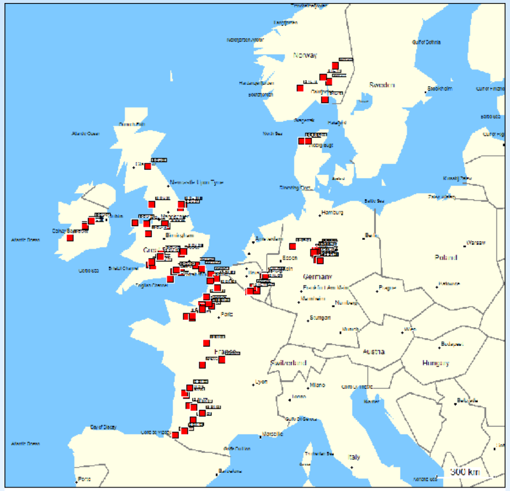
Talk Outline

- What is the evidence that reactive N *can* reduce terrestrial biodiversity? (R. Bobbink talk, Saturday)
- What is the evidence that reactive N *is* reducing terrestrial biodiversity in Europe?
- What are the most vulnerable vegetation types and ecosystems?
- To what extent do different approaches agree?
- Conclusions



What is the evidence for N-driven biodiversity decline?

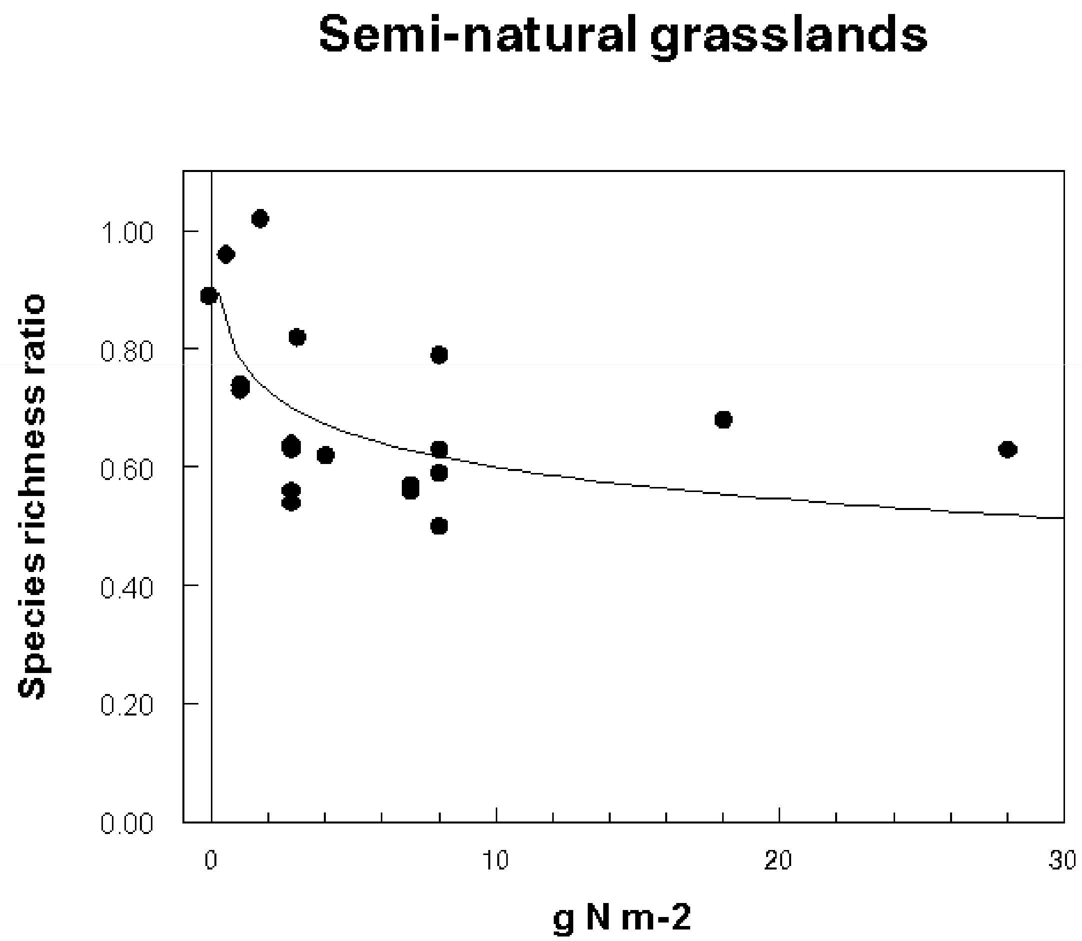


- Field Manipulation Experiments
- Surveys along deposition gradients
- Re-surveys over time

Field Manipulation Experiments

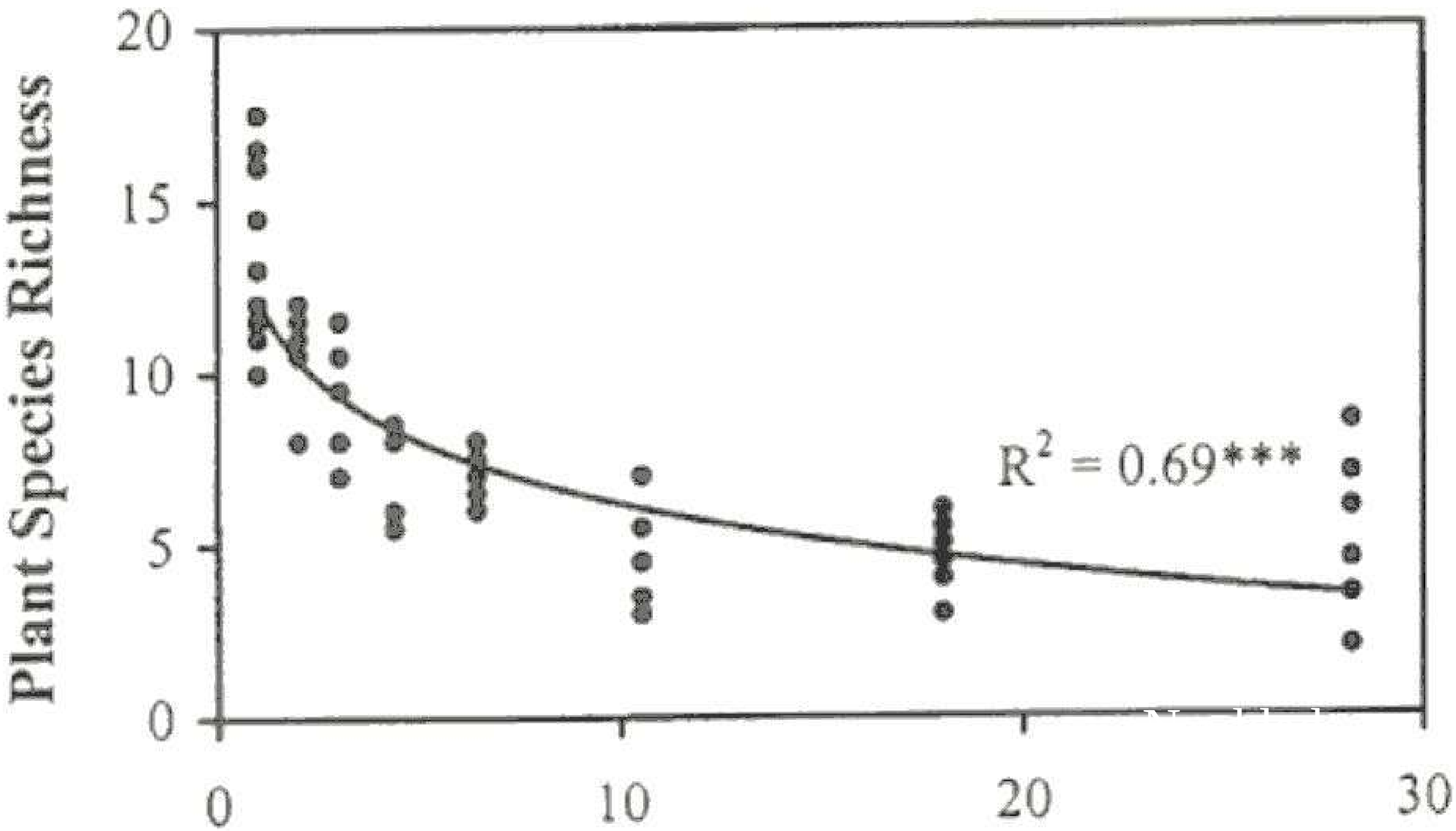
- **Advantages**: Can provide information on changes over time, can suggest cause-effect relationships, can identify thresholds
- **Disadvantages**: typically assess relatively short-term responses (few exceed 20 years), potential for artefacts (e.g. high N concentrations), systems may already be impacted by N

Species richness across experiments (3+ years) in relation to exceedence of critical load: maximum decline ~45%



Bobbink 2007

Cedar Creek, Minnesota: 14-year N addition: maximum decline in species richness ~70%



N addition (g N/m2/y)

Haddad et al 2000

Species richness reduction versus local extinction

UK: Nine long-term N-manipulation experiments in grassland, heathland and bogs, some >20 years old (UK Review of Transboundary Air Pollution, in press)

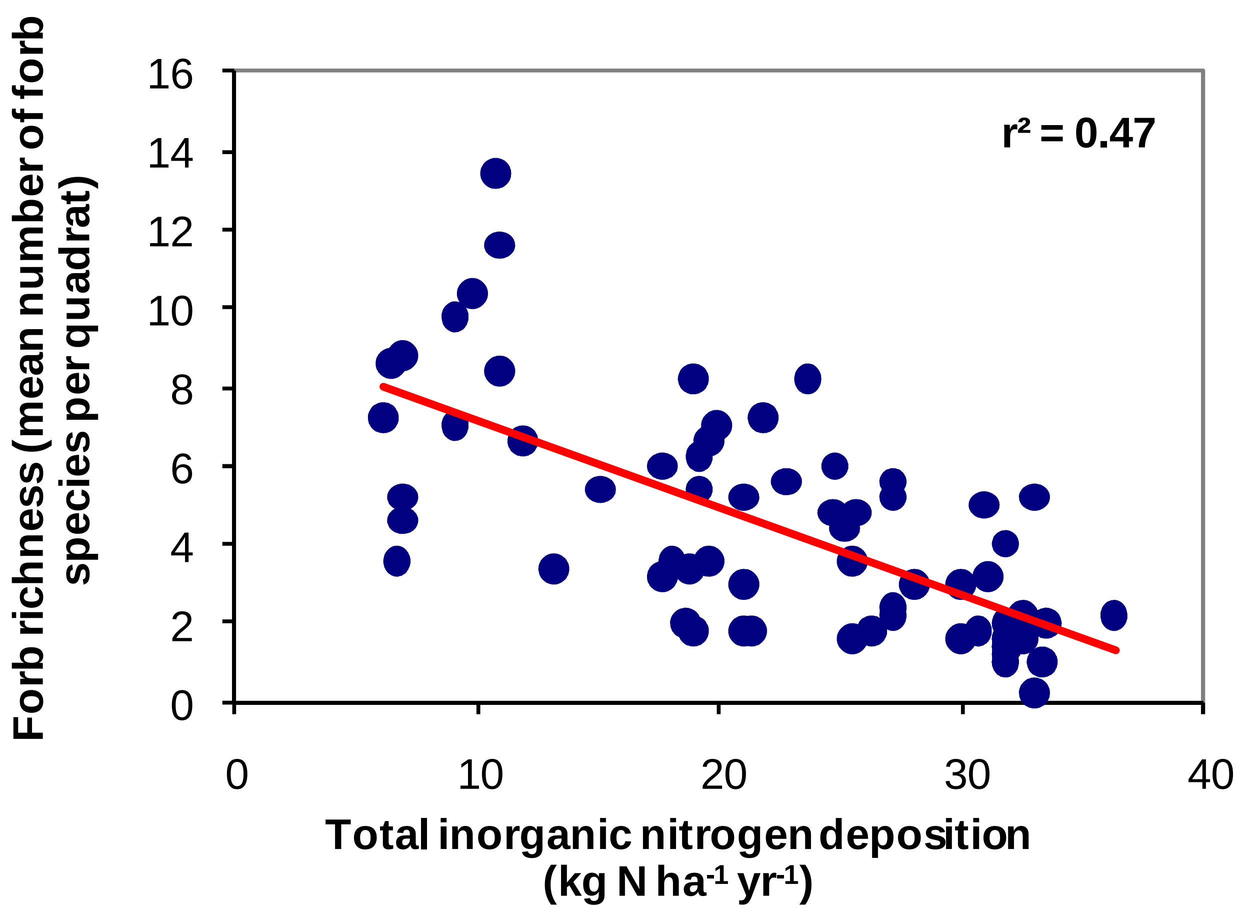
'…in no experiment across all sites has any higher plant species been completely lost from N-treated plots'

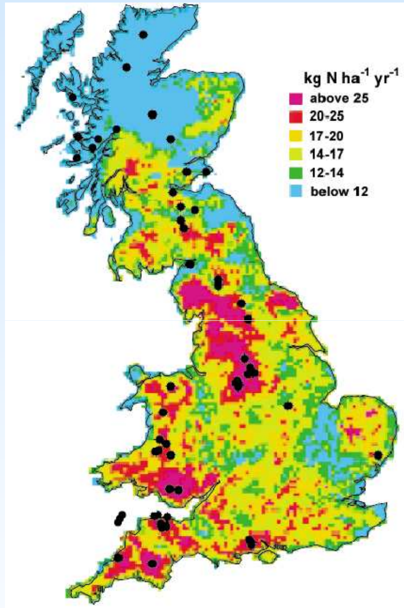
Surveys along N-deposition gradients

- **Advantages**: can provide insights into longer-term responses, can cover a wide range of N-deposition, avoid experimental artefacts
- **Disadvantages**: cannot prove causality, other drivers on diversity need to be accounted for

Acid Grassland Survey – Great Britain

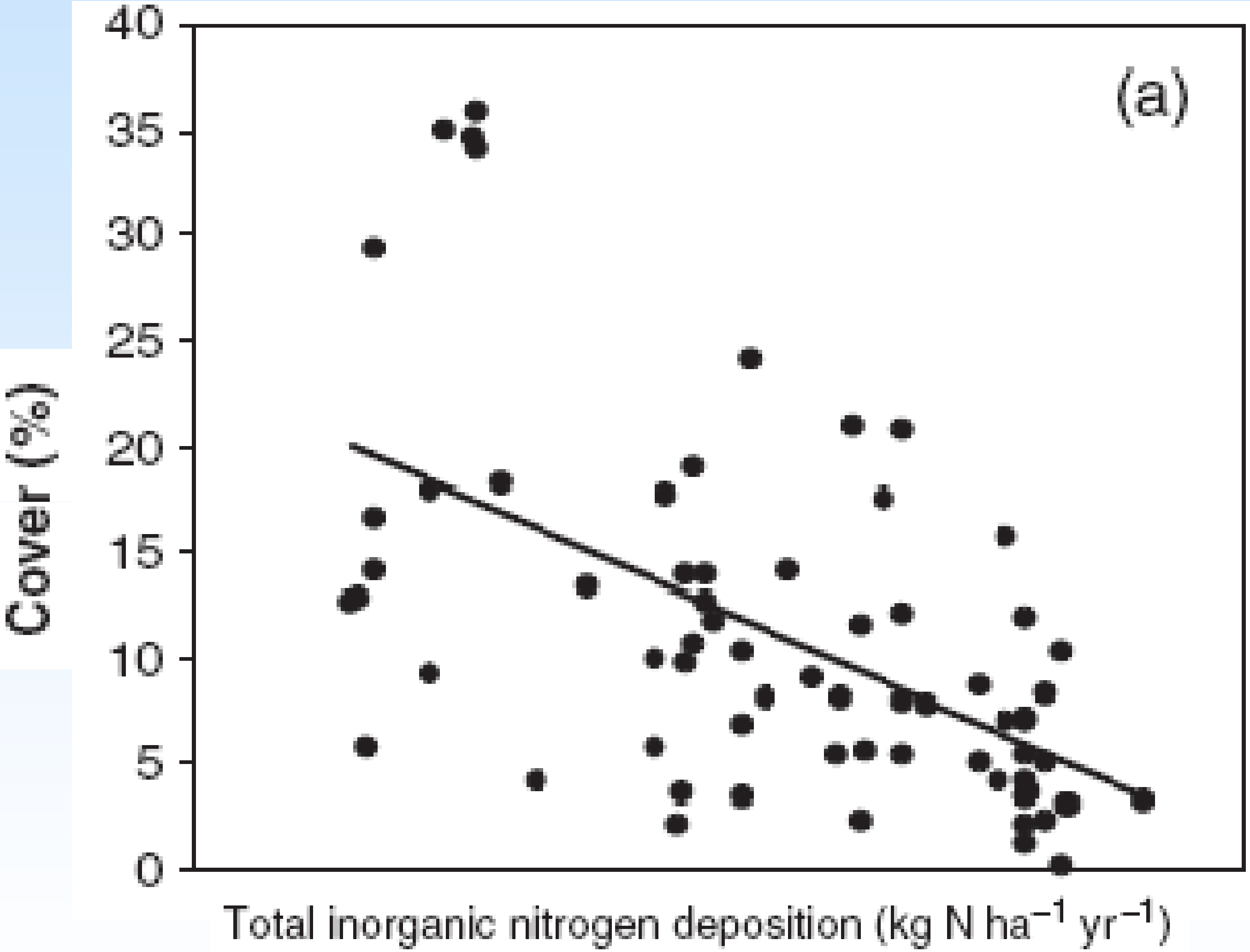
Forbs decline the most, in both richness…





Stevens et al. 2006

…And cover



Stevens et al. 2006

The Bottom Line:

Between the **lowest** (5) and **average** (17) ranges of N deposition in Great Britain…

- Forb species richness declines by **36%** (8.3 → 5.6 species)
- Forb cover declines by **25%** (20% → 15%)

Between the **lowest** and **highest** (36) ranges …

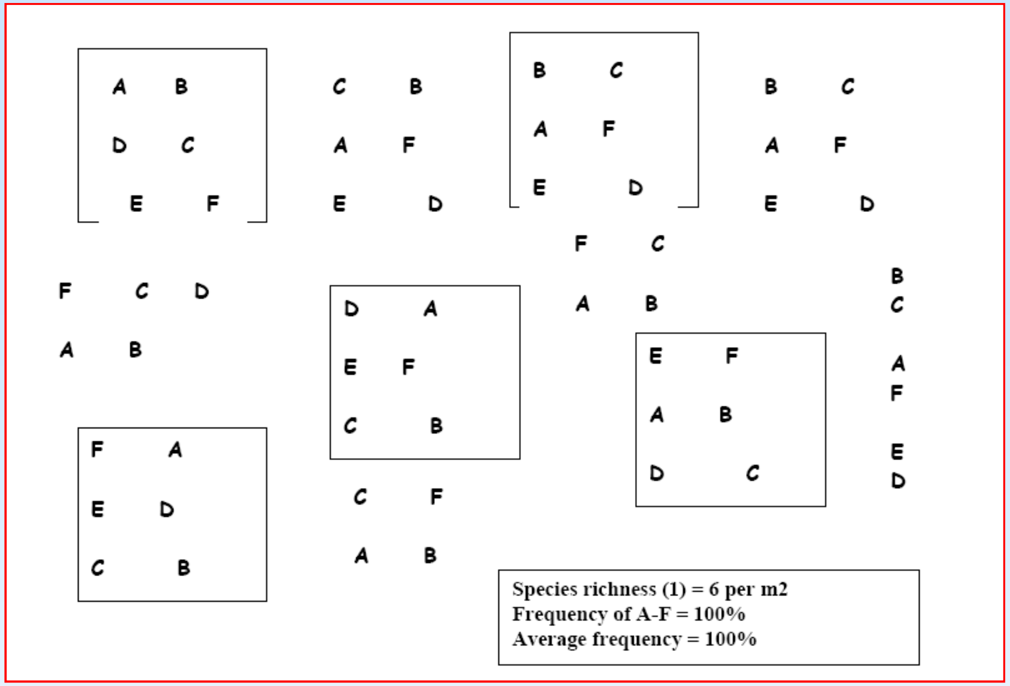
- Forb species richness declines by **76%** (8.3 → 1.3 species)
- Forb cover declines by **75%** (20% → 5%)

Still, species are generally not ‘lost’ (Stevens, pers. comm)

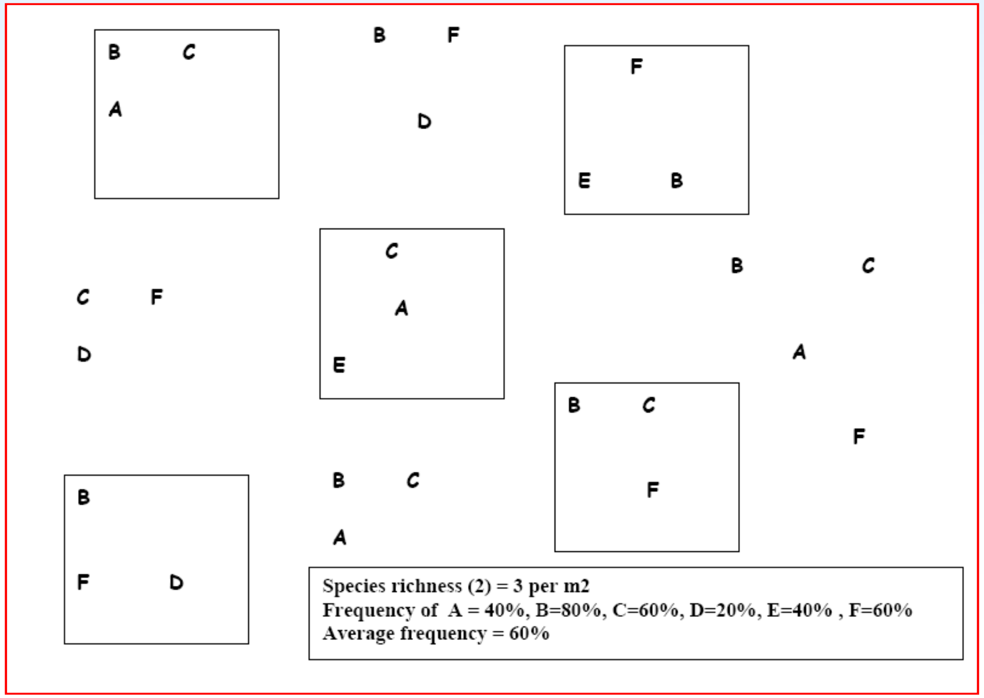
(so, what is happening?)

Example: Species richness reduction of 50%, but all species present

Species richness: 6 →



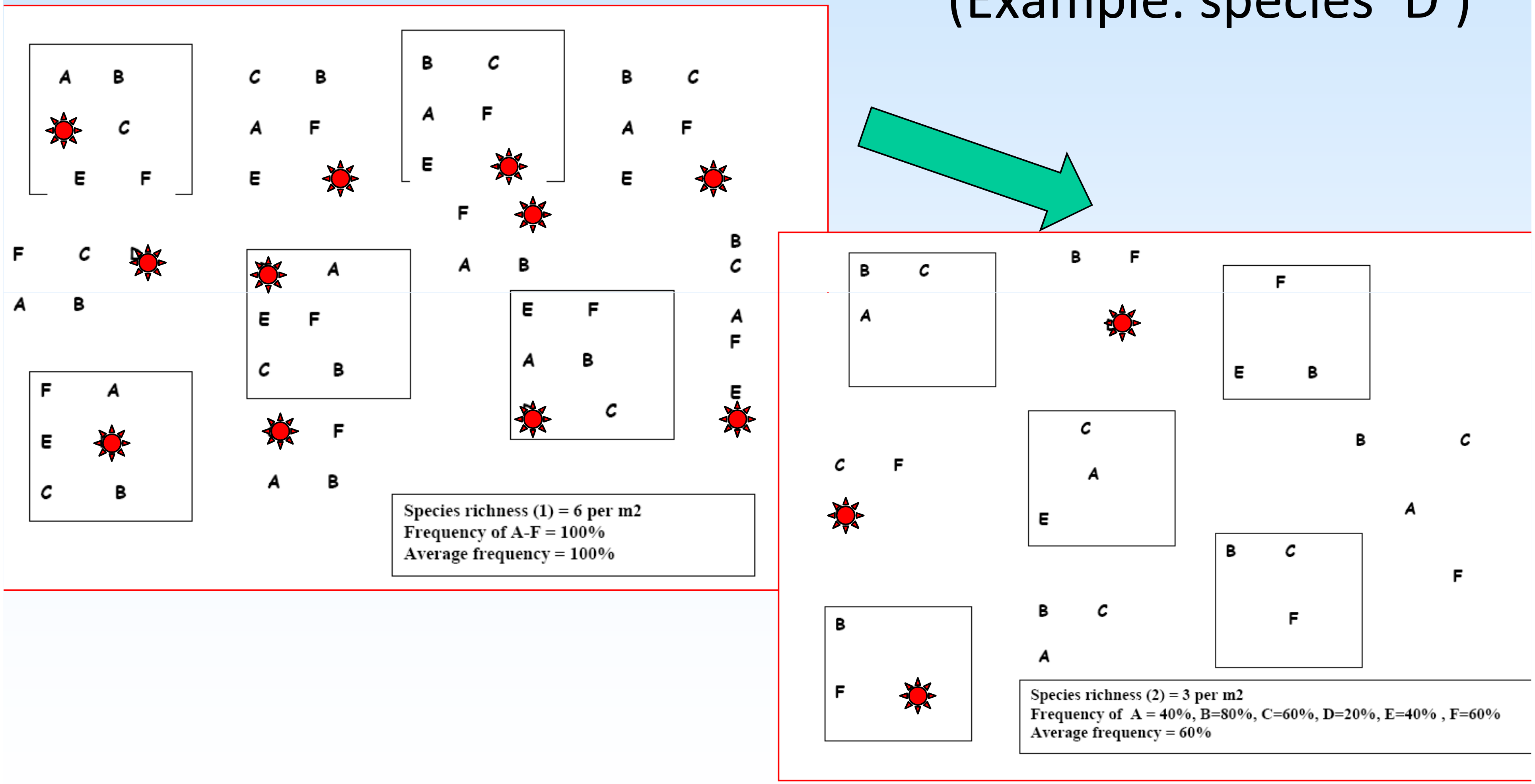
Species richness: 3 →



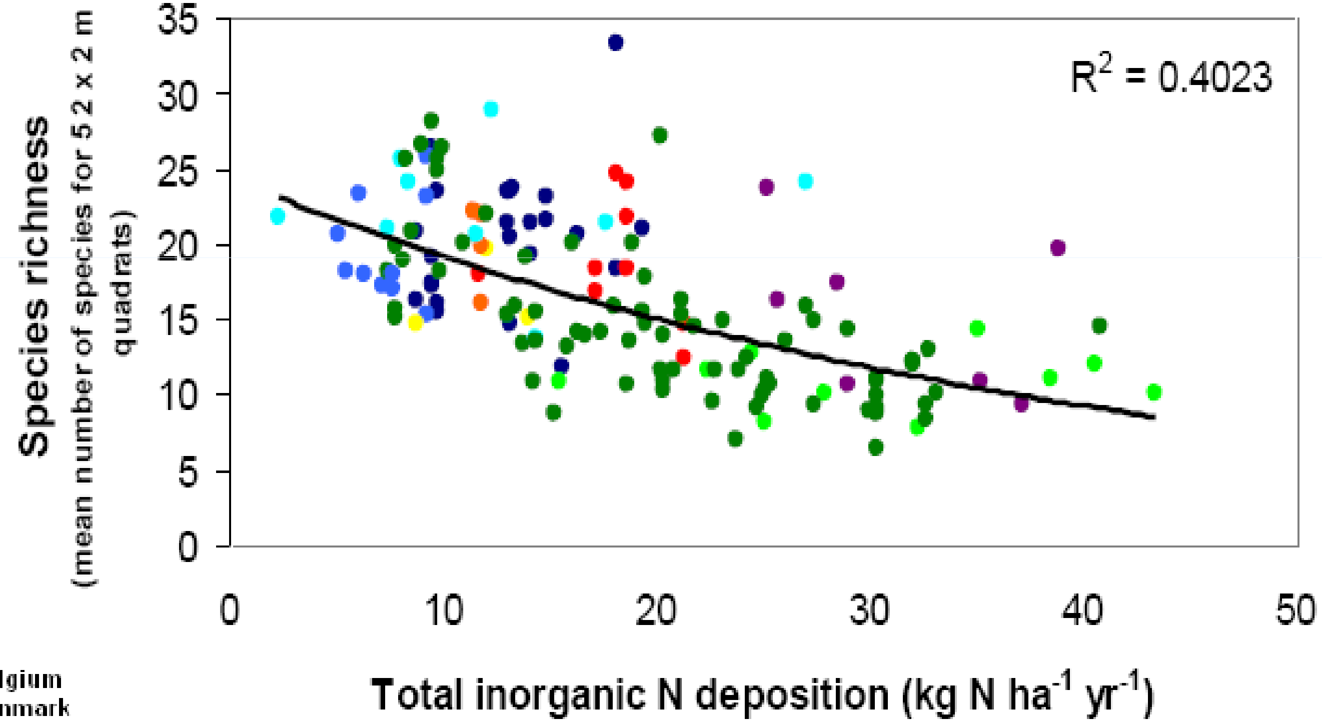
So, rather than local extinction …

The frequency of at least one species has declined

(Example: species 'D')

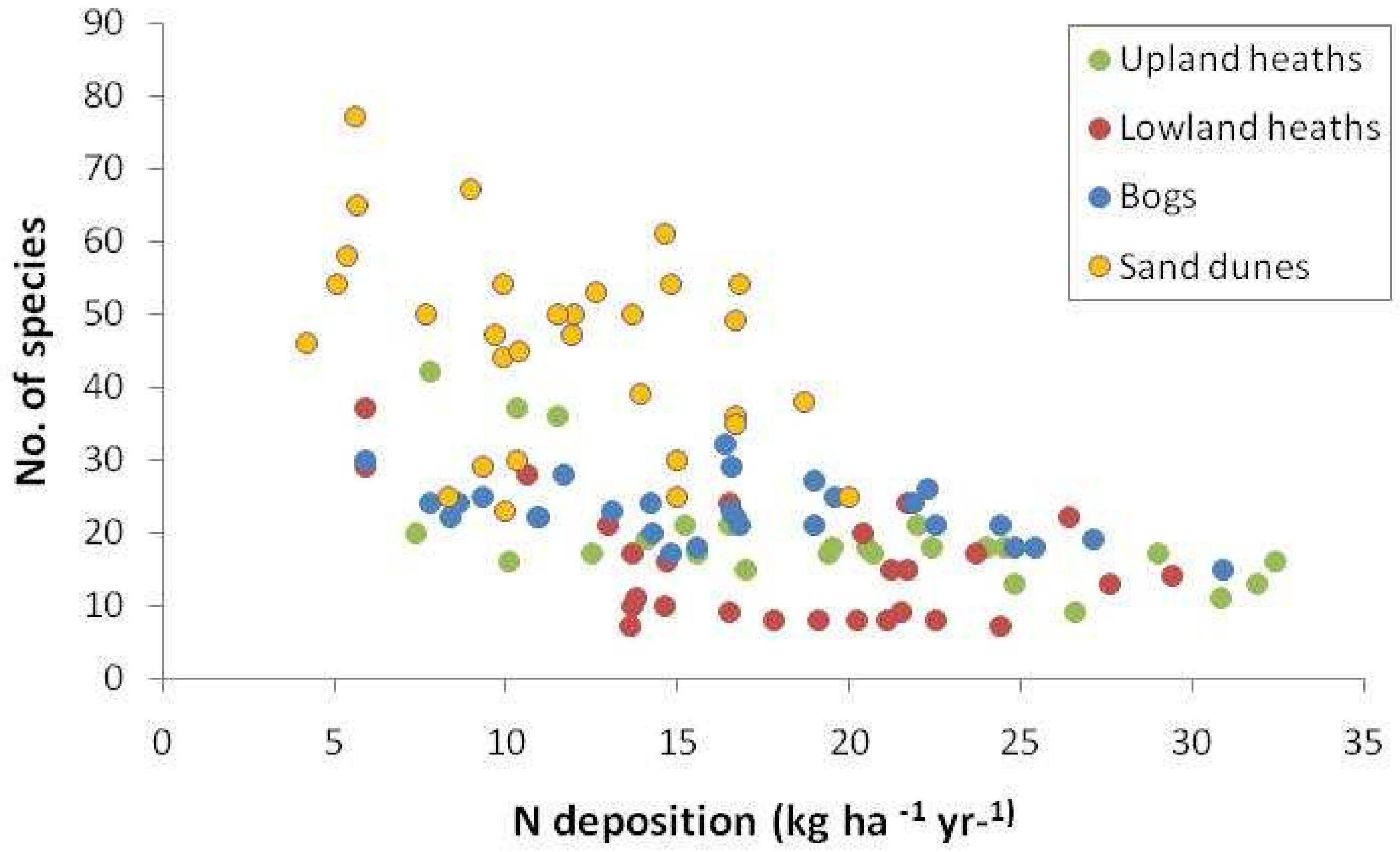


Acid grassland richness **across Europe** declines in direct proportion to atmospheric N deposition



Stevens et al. 2010, BEGIN project

Recent surveys in heathland, bogs and sand dunes in the UK show similar relationships – but not calcareous grasslands



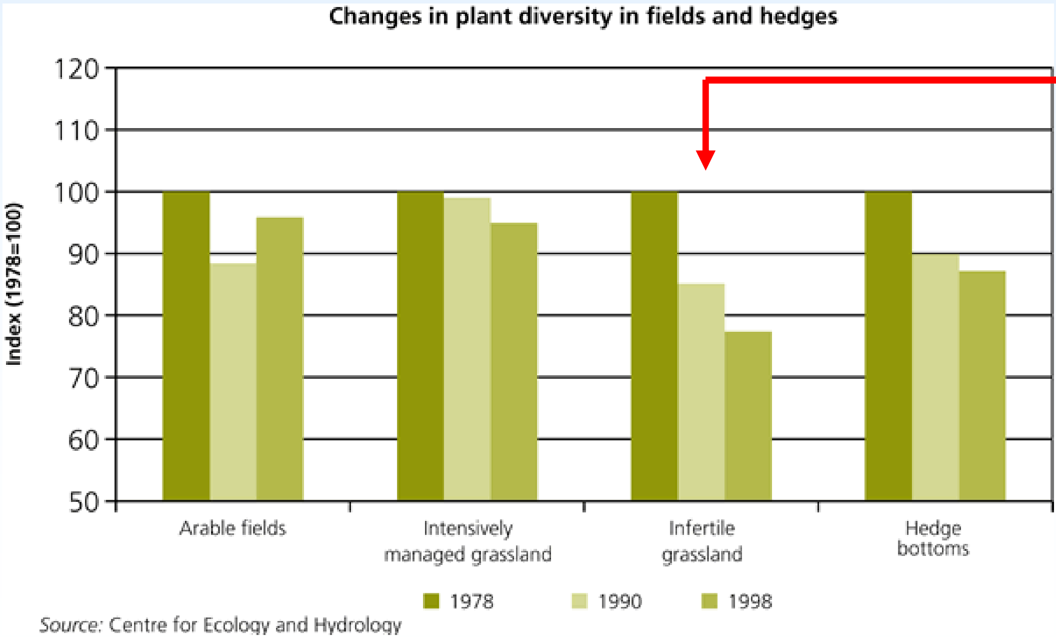
Field et al. in prep; van den Berg et al. 2010

Re-surveys

- **Advantages**: only type of evidence that can directly identify changes occurring over long periods of time, without experimental manipulation
- **Disadvantages**: confounding influence of other factors (e.g. land use, climate, etc), locating sites, methodology changes, incomplete records, data accessibility, etc.

Results from ecological surveillance networks

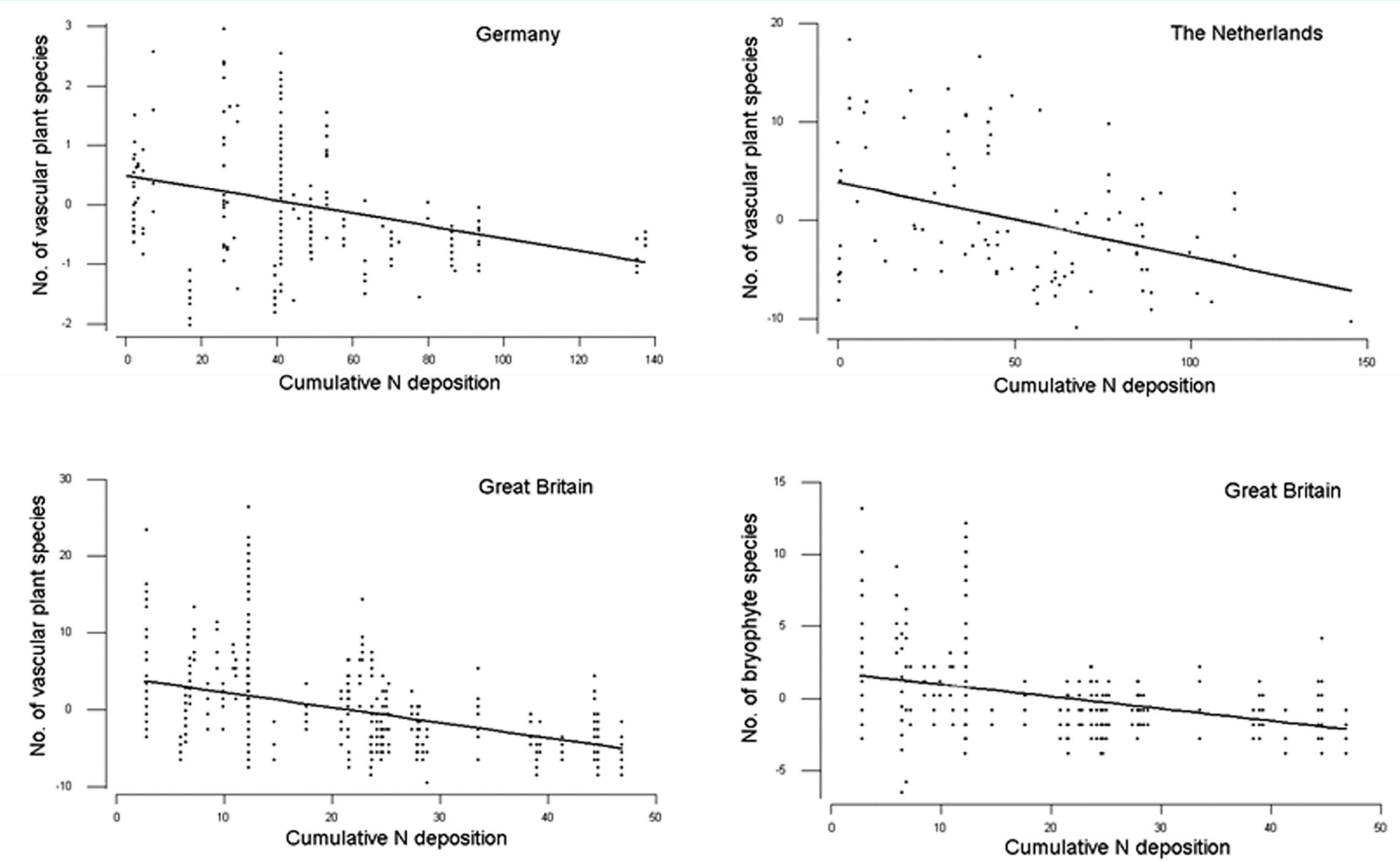
- **Decline** in species characteristic of **low-nutrient conditions**, **increase in nitrophilic plant species** in UK, Spain and Portugal
- **Relations to N**: UK Countryside Survey (1978-98-07) suggests that biodiversity in high-N regions was **already lower in the 1970s**, with **little change** since (RoTAP, 2010). **Exception: Scotland.**



UK: 23% reduction in diversity of infertile grasslands 1978-98

Gemeno, 2009, Preston et al. 2002, Carey et al. 2008, RoTAP 2010, Defra 2004

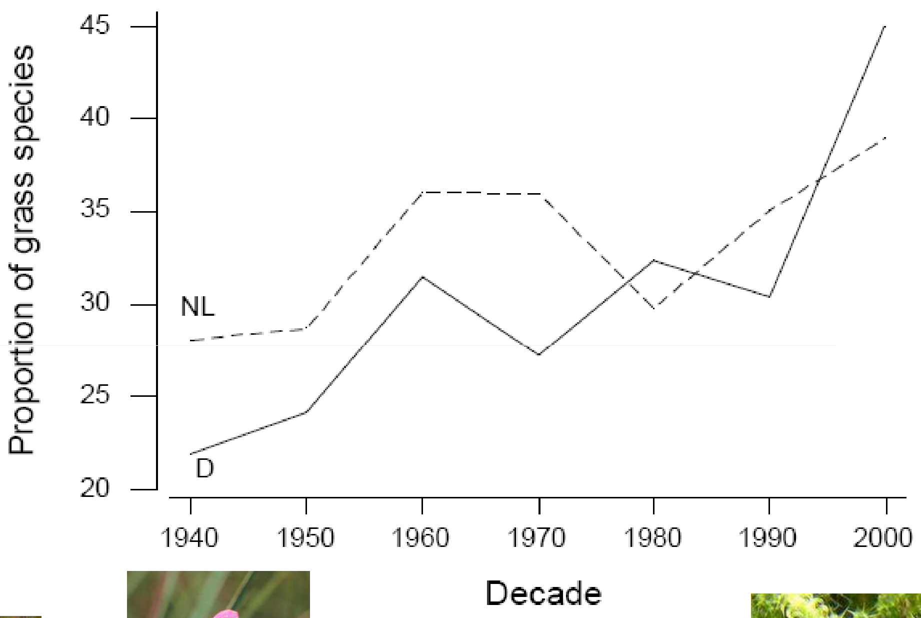
Meta-analysis of grassland species data collected over the last 70 years



Dupre et al. 2010

Losers: forbs, sensitive mosses

Winners: grasses, tolerant mosses



Most vulnerable habitats in Europe

Strong Evidence:

- Grassland
- Heathland
- Peatland
- Forests
- Coastal Dune

More limited evidence

- Mediterranean shrubland
- Tundra
- Arctic and alpine

Photo: R. Bobbink

Do the different approaches agree - quantitatively?

(but ‘back-of-the envelope’)

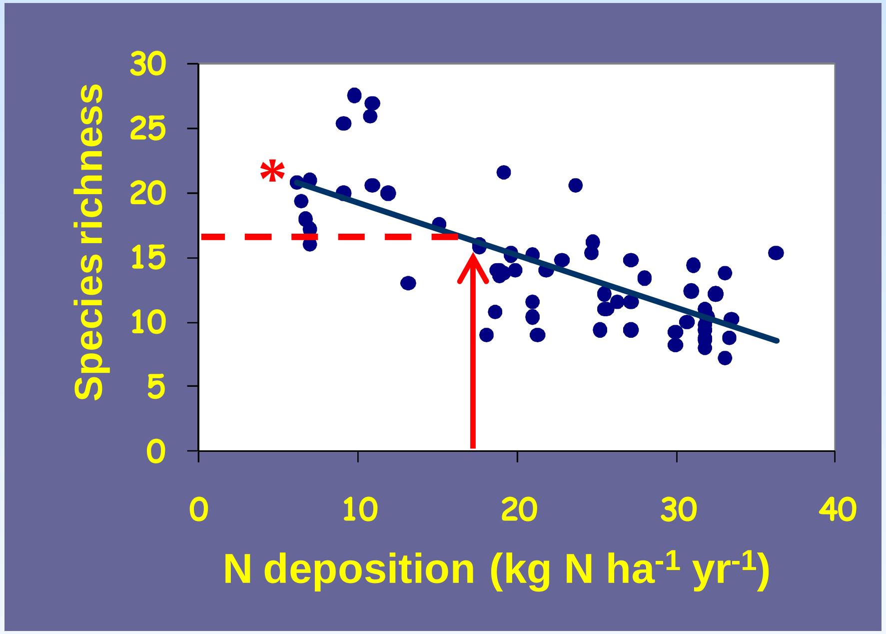
Acid Grassland Surveys: assume N deposition at current levels for 40 years

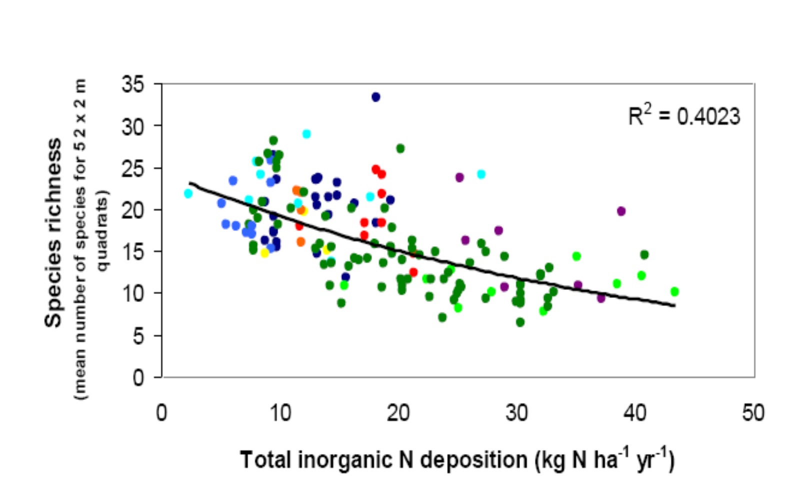
Then: the mean N deposition in Europe (17 kg N ha^{-1} y^{-1}) equates to a **total cumulative 680 kg N.**

Between the lowest pollution sites (5 kg N ha^{-1} y^{-1}, or 200 kg N) and those receiving the mean N deposition, species richness declines from **21.3 to 16.4 (23%).**

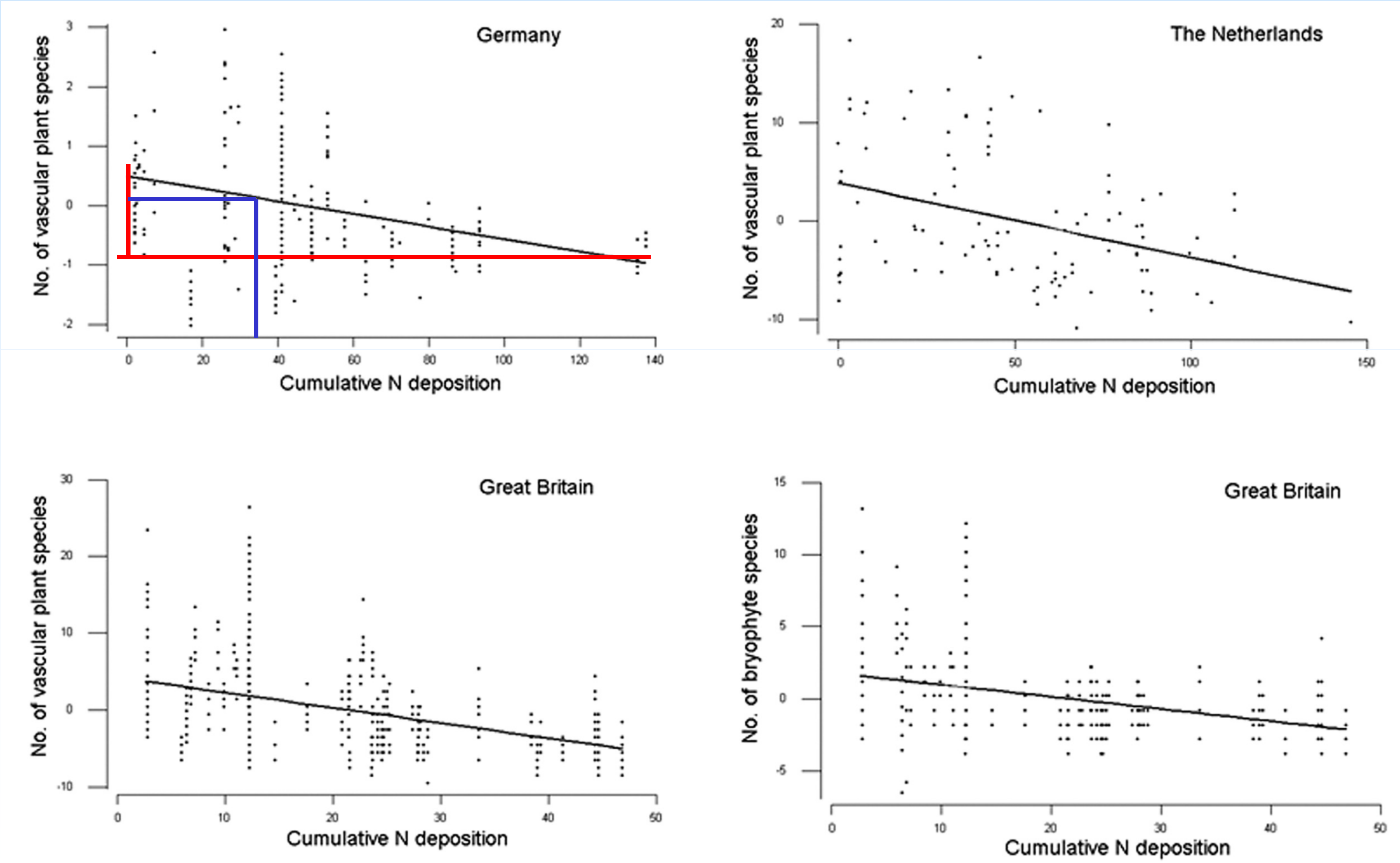
Across Europe: **22.0 to 16.5 species (25%)** reduction.

The 'excess' N due to pollution is ~700-200 = **500 kg N**



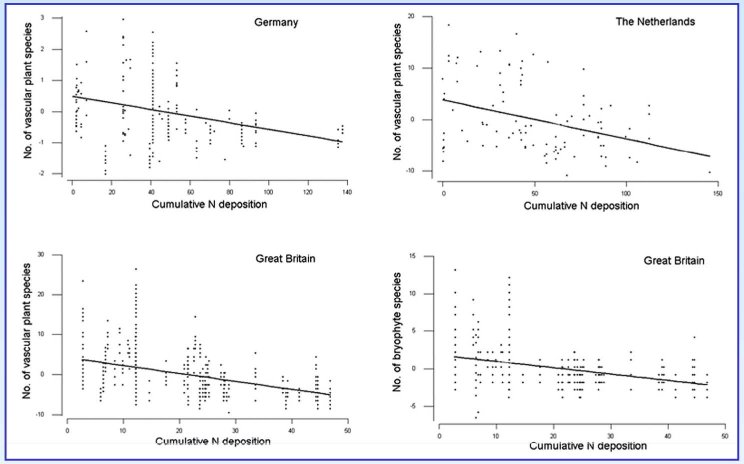


Re-surveys: define range of species richness from lowest to highest N deposition, calculate % change



Species richness change from baseline year to 500 kg ha^{-1} cumulative N (35 kmol N ha^{-1})

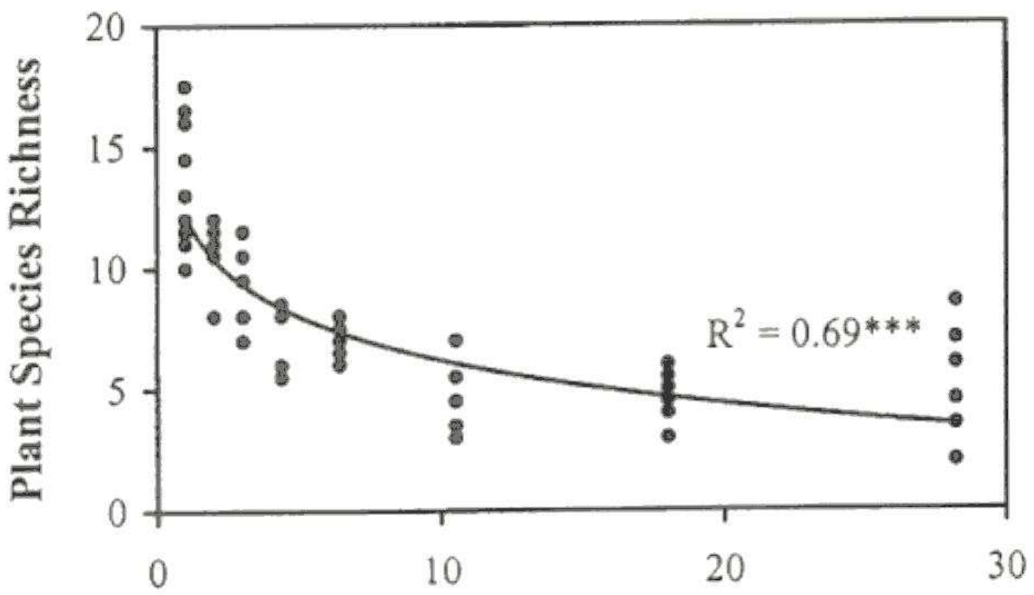
- Germany: 23%
- Netherlands: 18%
- UK: 71% (!)



But, EMEP is thought to strongly underestimate N deposition for this part of the UK (D.Fowler, CEH Edinburgh, pers comm).

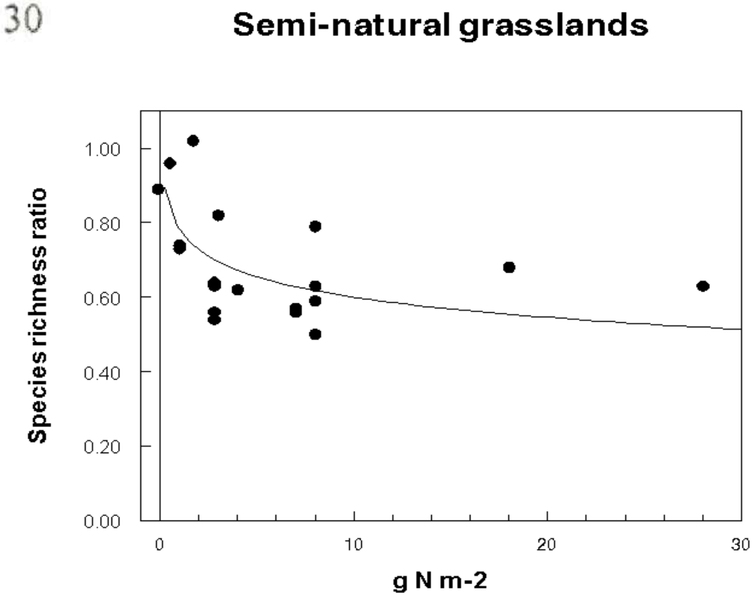
Weighting EMEP by the UK national model , the species richness change is 25%

N-addition experiments

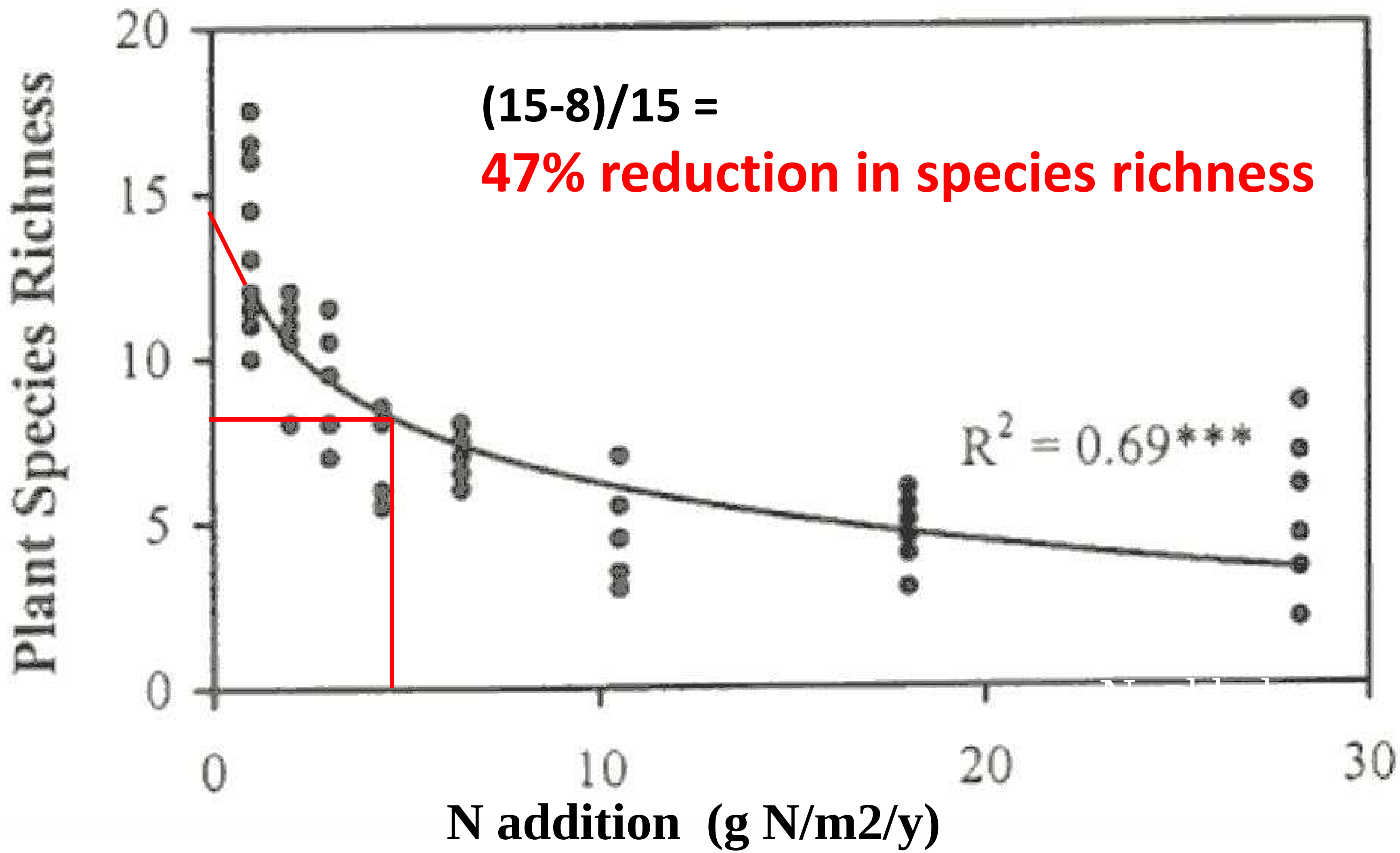


Cedar Creek, Minnesota

Bobbink et al. compilation



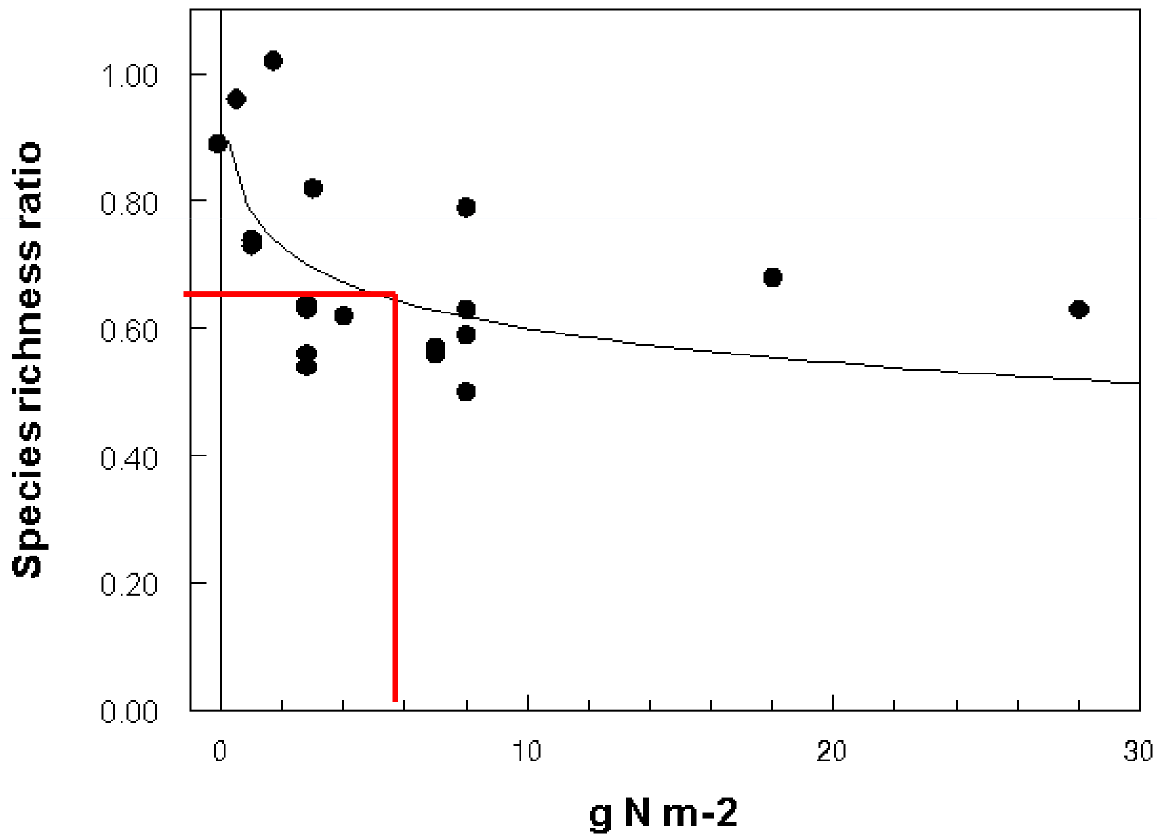
Cedar Creek: to reach 500 kg N ha^{-1} after 14 years, need 36 kg N ha^{-1} y^{-1} ≈ species richness of 8



Haddad et al 2000

N-addition experiments: assume mean 7 year experiment. To reach 500 kg after 7 years, need 70kg N ha^{-1} y^{-1}, or 60 kg above CL

=35% reduction in species richness



Bobbink 2007

Summary of evidence: impact of mean N deposition on species richness of acid grasslands:

Spatial surveys and temporal re-surveys are very consistent, indicating a mean species richness reduction of 23% (range 18-25)

N-addition experiments indicate a higher rate of decline (35-50%)

Conclusions

- Three complementary lines of evidence agree that N deposition has caused, and continues to cause, a **significant loss of vegetation diversity** in European terrestrial ecosystems.
- **Forbs, mosses, and lichens** are particularly sensitive.
- This is probably the product of **many years** of N deposition.
- At **high N deposition**, many sensitive species have **already declined**, and there is evidence of a **plateau**. **Low N-deposition areas** are at the most risk of **losing more diversity**.
- Therefore, a major aspect of N pollution control policies should be **protecting ecosystems receiving low N deposition**.
- **Recovery from high N deposition** may take many years, and may in cases require **management intervention**.

Acknowledgements:

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Hylocomium splendens
Plantago lancolata
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Thank you
Calluna vulgaris
Lotus corniculatus
Euphrasia officinalis