Linking biogeochemical indicators in soil and vegetation to species change

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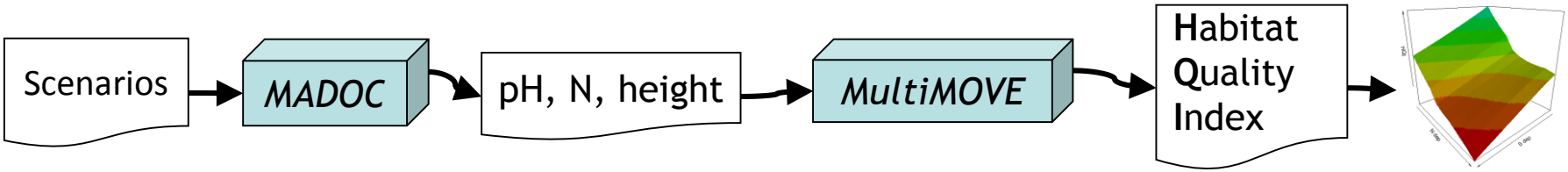
Outline

- Brief introduction to MADOC-MultiMOVE-HQI
- Improved transfer functions from biogeochemical indicators to trait-means
- Effects on biodiversity-based critical loads (CL_{biodiv})
- Are biodiversity predictions useful?
- Conclusions

MADOC-MultiMOVE-HQI

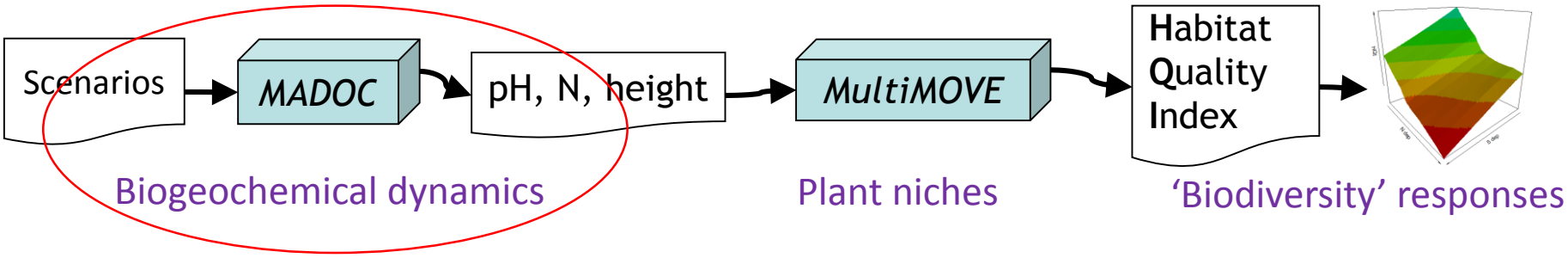


Biogeochemical dynamics

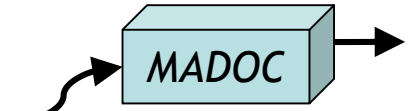
Plant niches

'Biodiversity' responses

MADOC



- N & S deposition
- Temperature
- Annual precipitation
- Cation exch. capacity



- Soil pH, C/N and mineralisable N
- Peak standing biomass

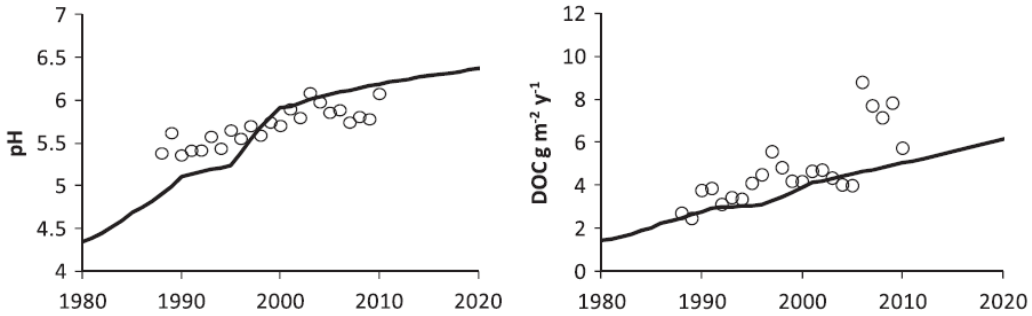
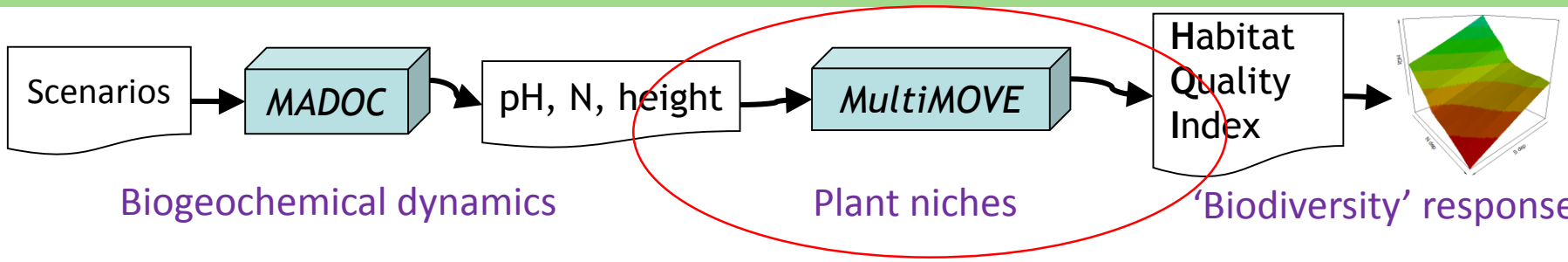


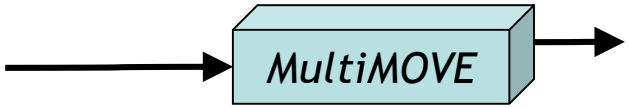
Fig. 5. Observed (dots) and predicted (lines) values for: a) pH and b) DOC at an example Acid Waters Monitoring Network site (Dargall Lane).

Rowe et al. (2014) Environmental Pollution 184: 271-282

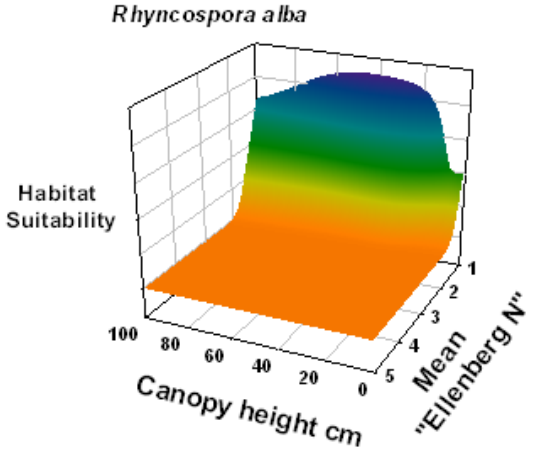
MultiMOVE



- Mean scores for environmental traits:
  Ellenberg N, F & R
  Grime height-score
- Annual precipitation
- Max and min temperature

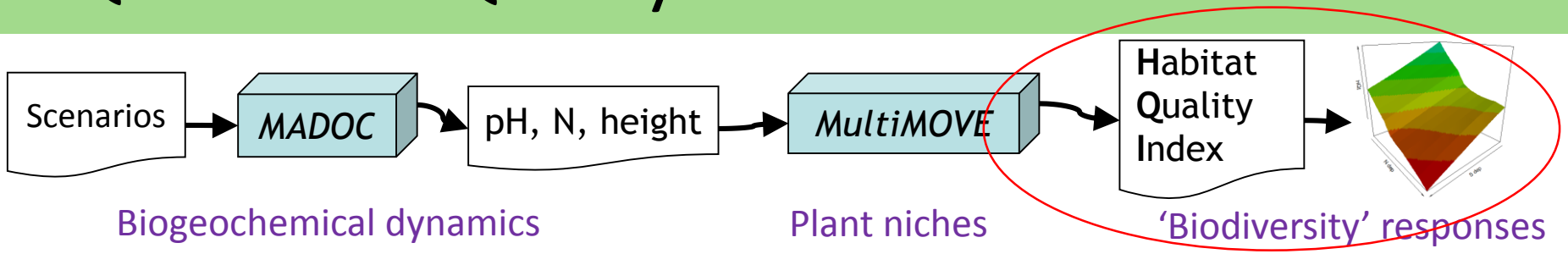


- Habitat-suitability for 1342 species



Henrys et al. (2015) New J Botany 5, 89-100

HQI: Habitat Quality Index

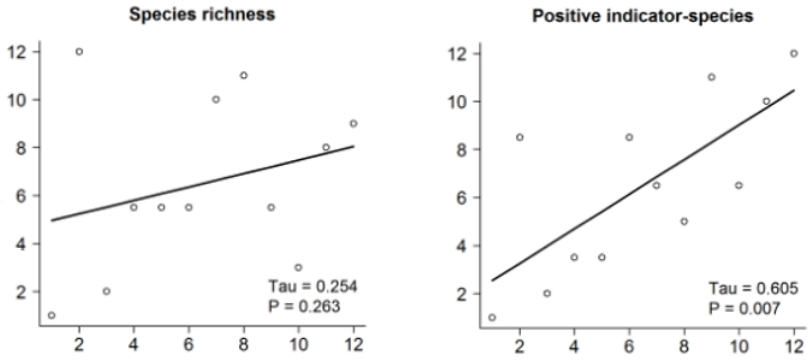


- Habitat-suitability
- List of positive indicator species

→ HQI →

- "Biodiversity"

Ranking according to metric

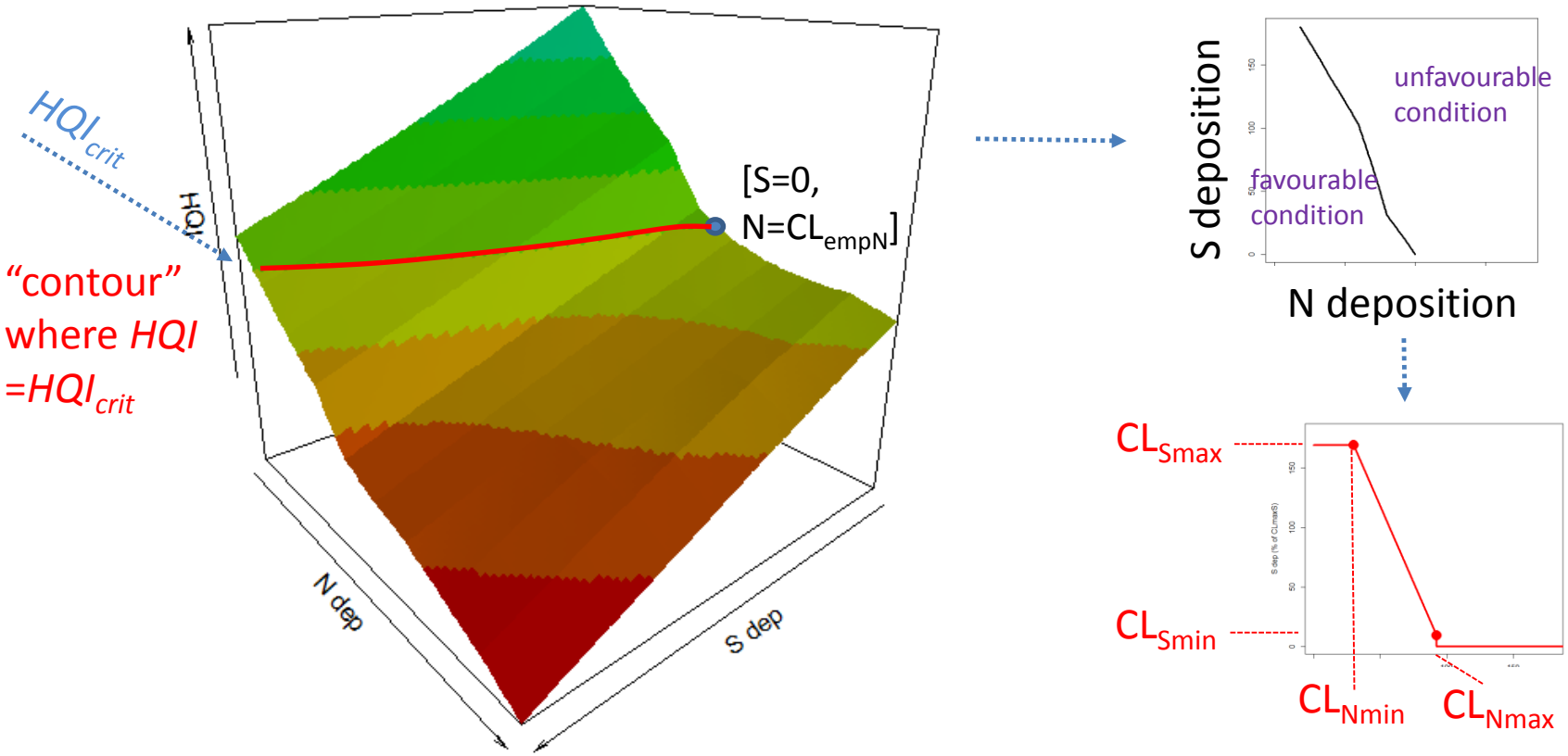


Ranking according to specialists

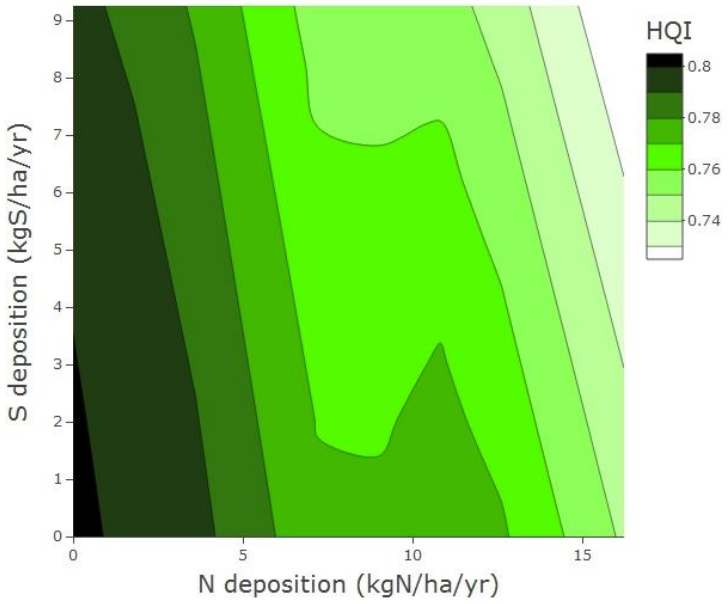
Rowe et al. (2016) PLOS-ONE.
doi:10.1371/journal.pone.0161085

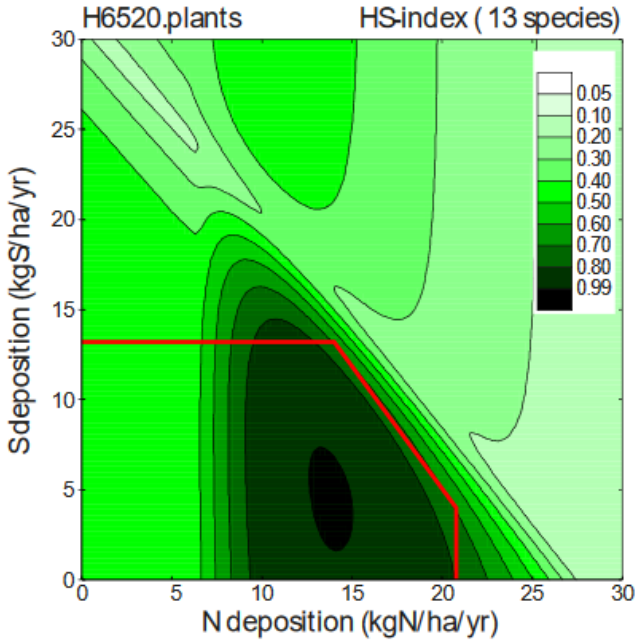
HQI responses to N & S → $CL_{biodiversity}$ function

- Threshold for "damage" assumed to be the HQI value when N deposition is set to the **empirical CL for nitrogen**
- Why would HSI_{crit} not be the value of HSI at CL_{empN} ?



MADOC-MultiMOVE VSD+/PROPS





MMM usually calculates a decline in HQI when N or S increases from zero

Maybe because the MultiMOVE niche models are derived:

- including data from cleaner areas
- with respect to soil available N and vegetation height (not *wrt* N deposition)

…and because tall, dominant species are excluded from positive indicators

However, MultiMOVE needs a score for each species on several environmental axes

Total nitrogen deposition

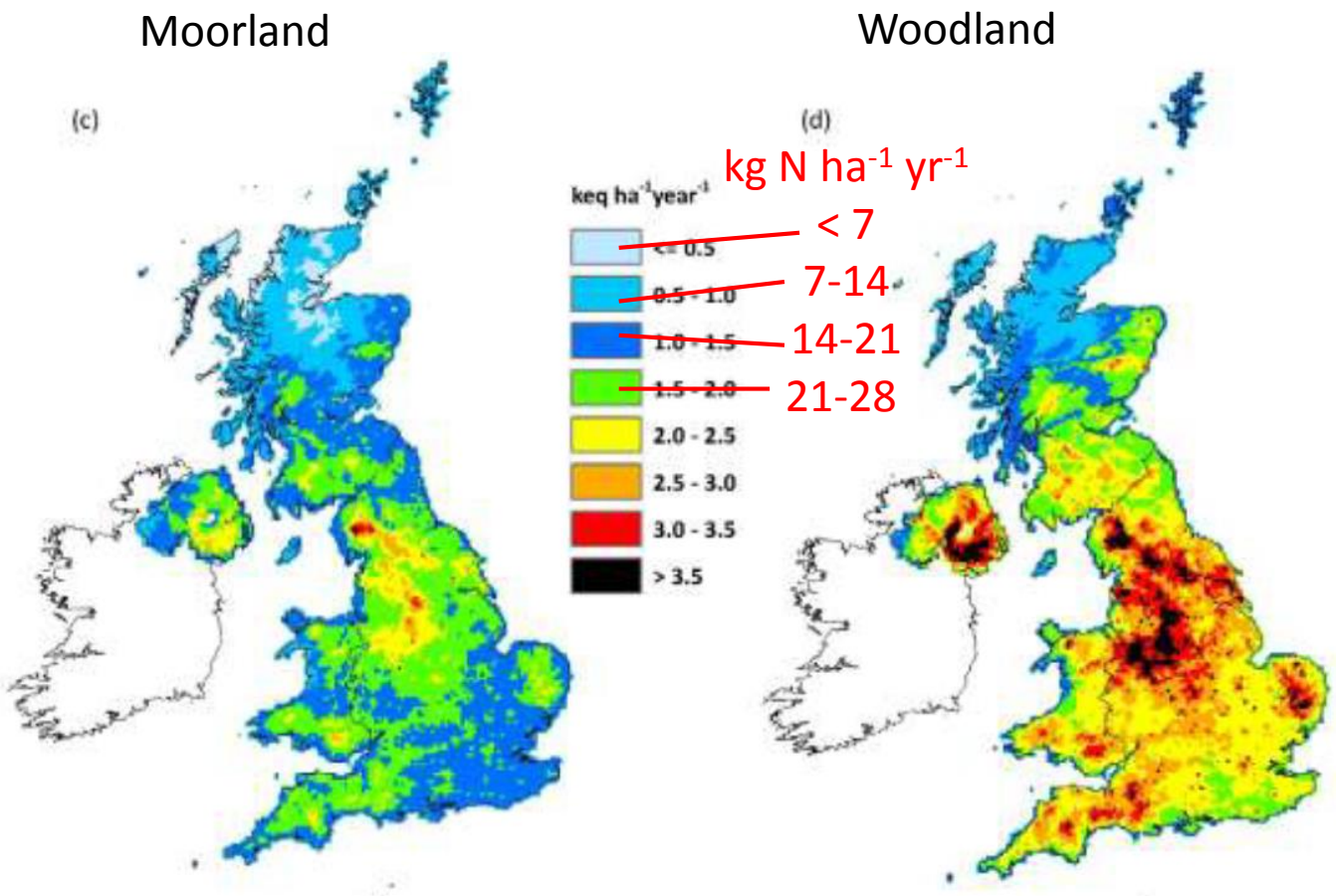
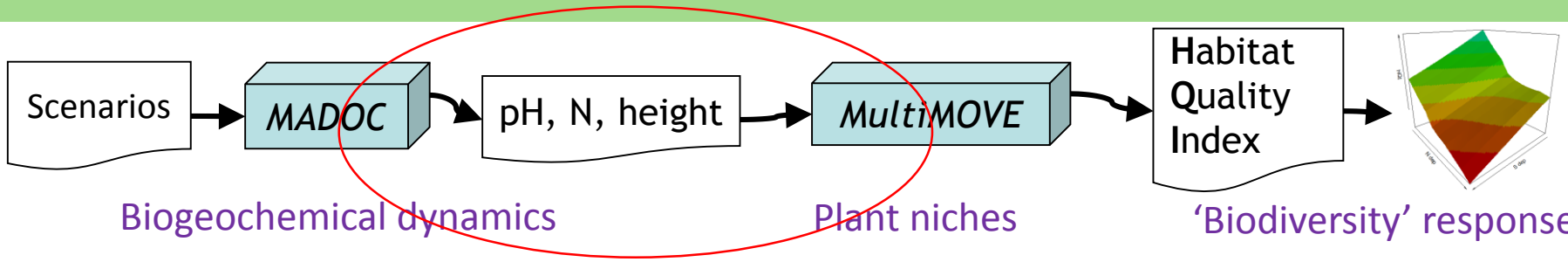


Figure 1.1: CBED deposition for 2013-15: (a) nitrogen (oxidised plus reduced) deposition to moorland; (b) nitrogen (oxidised plus reduced) deposition to woodland; (c) acid (sulphur + nitrogen) deposition

Hall et al. (2017) Trends Report

2018-19: work on transfer functions



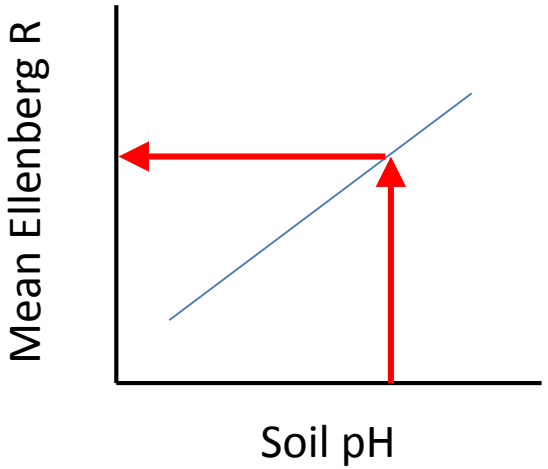
"Transfer functions" relate

soil and vegetation properties:

- Soil pH, C/N & mineralisable N; canopy height

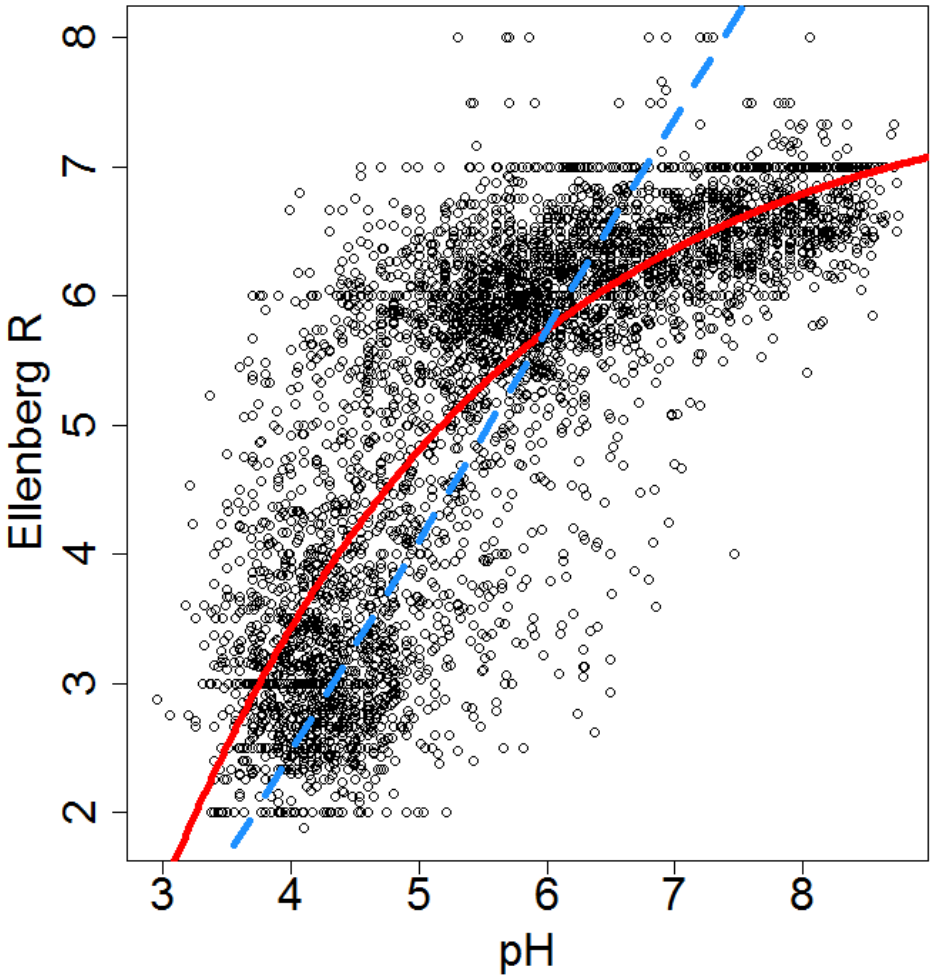
to the environmental axes used in MultiMOVE:

- Mean Ellenberg N (fertility) and R (alkalinity)
- Mean typical height (ground-level shading)



Alkalinity transfer function

- New plots included (now 4487 plots where both Ellenberg R and soil pH recorded)
- Asymptotic curve fitted



Old function:

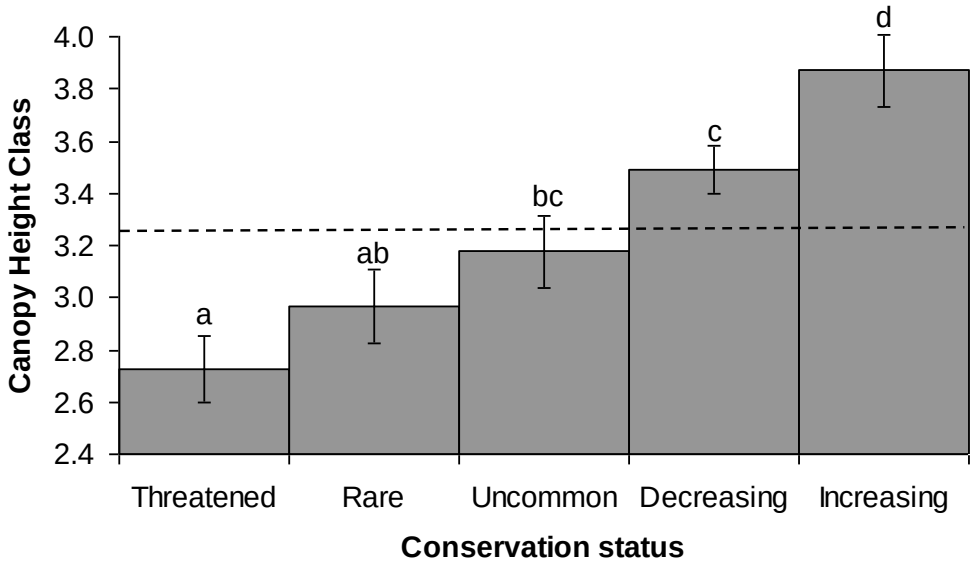
Ellenberg R = 1.64 pH – 4.10

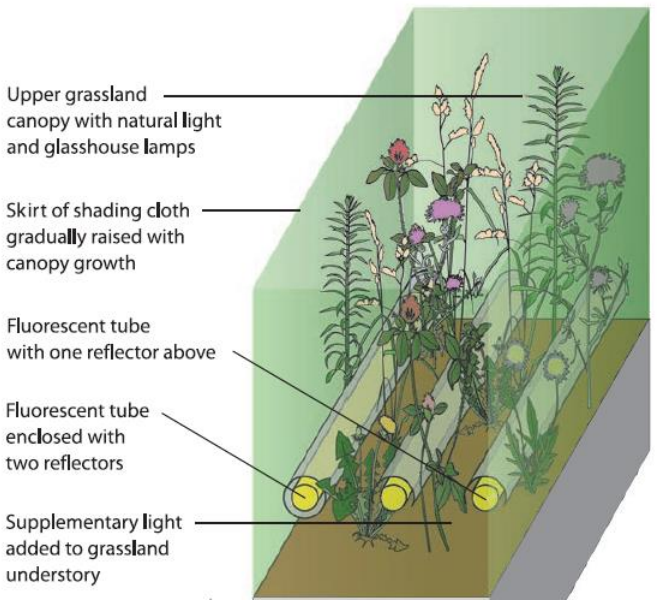
New function:

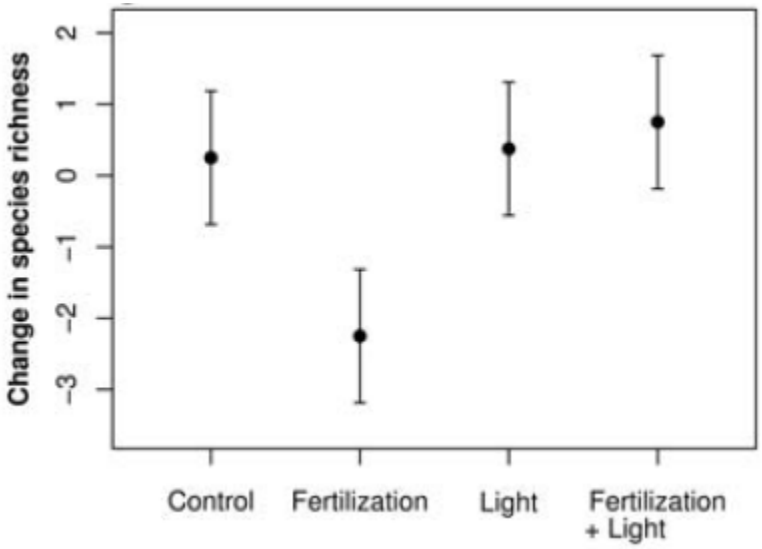
$$\text{Ellenberg R} = 7.68\left(1 - e^{-0.391(pH-2.48)}\right)$$

Ground-level shading

Ground-level light availability is probably the most important environmental factor affected by N pollution







Hodgson et al. (2014) Func Ecol 28: 1284-1291.

Hautier et al. (2009) Science 324 (5927) 636-638.

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Ground-level shading

Unfertilised calcareous grassland
Lotus corniculatus: ‘N’ = 2, ‘L’ = 7

more N --> increasing

- productivity
- ground-level shade
- litterfall

Adjacent woodland ground flora
Urtica dioica: ‘N’ = 8, ‘L’ = 6

Ground-level shading

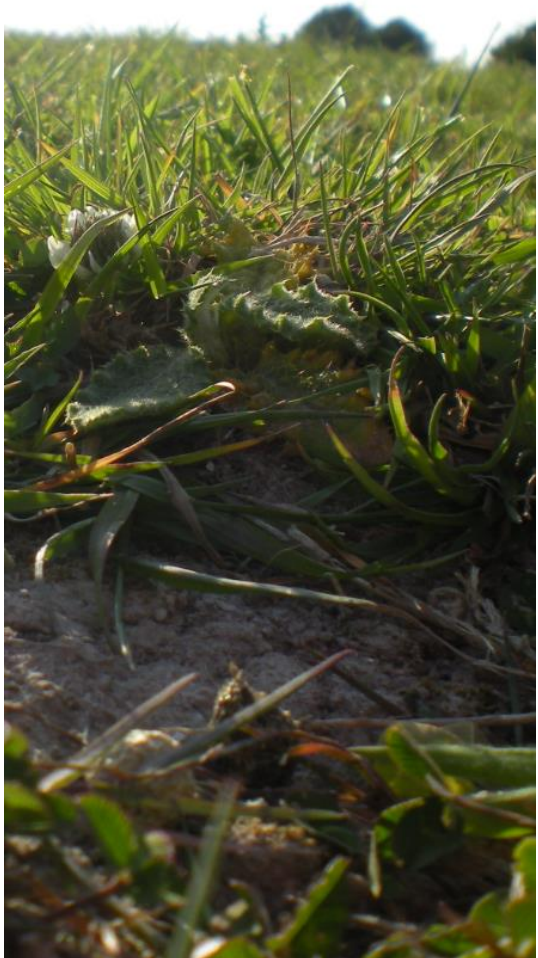
Why do these grasslands have different assemblages, when canopy height is similar?

Unfertilised calcareous grassland
Lotus corniculatus: 'N' = 2, 'L' = 7

Perhaps because more productivity
→ Faster gap closure
→ Less diversity of potential regeneration niches

Need to explore interactions among
- Biomass
- Net Primary Productivity
- Vegetation height
- Mean Ellenberg 'L' score

Fertilised calcareous grassland
Cirsium vulgare: 'N' = 6, 'L' = 7
Trifolium repens: 'N' = 6, 'L' = 7

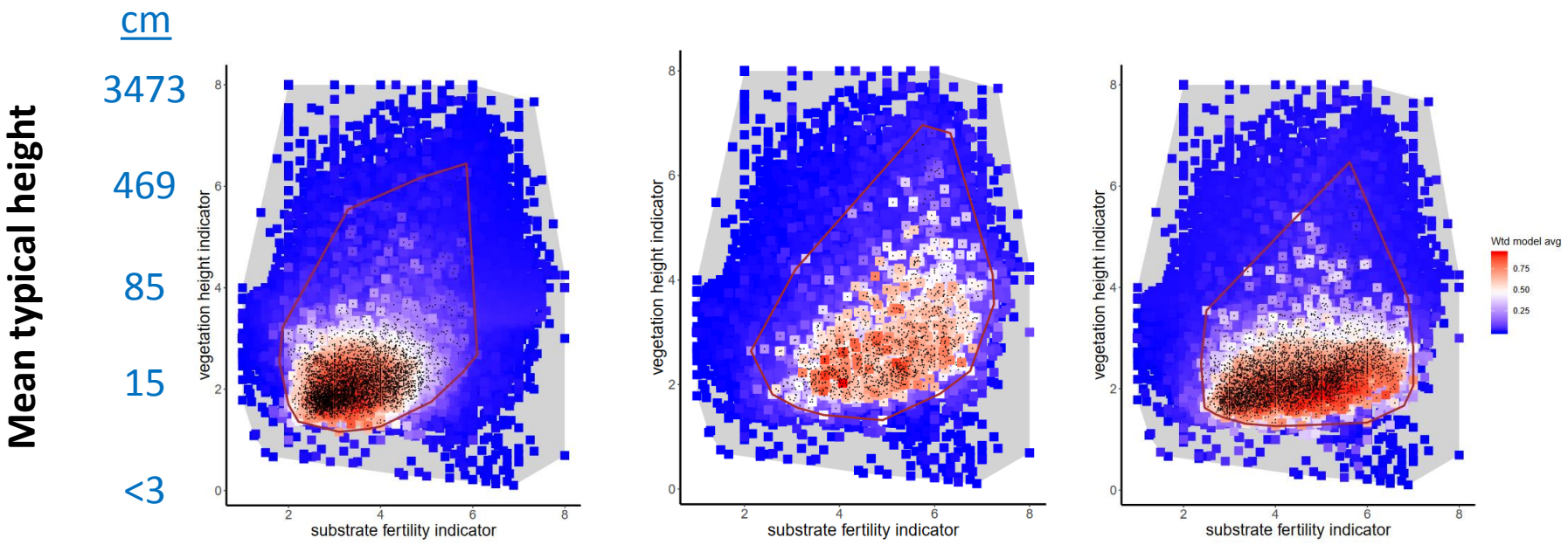


“Mean typical height” has strong effects

Lotus corniculatus

Cirsium vulgare

Trifolium repens

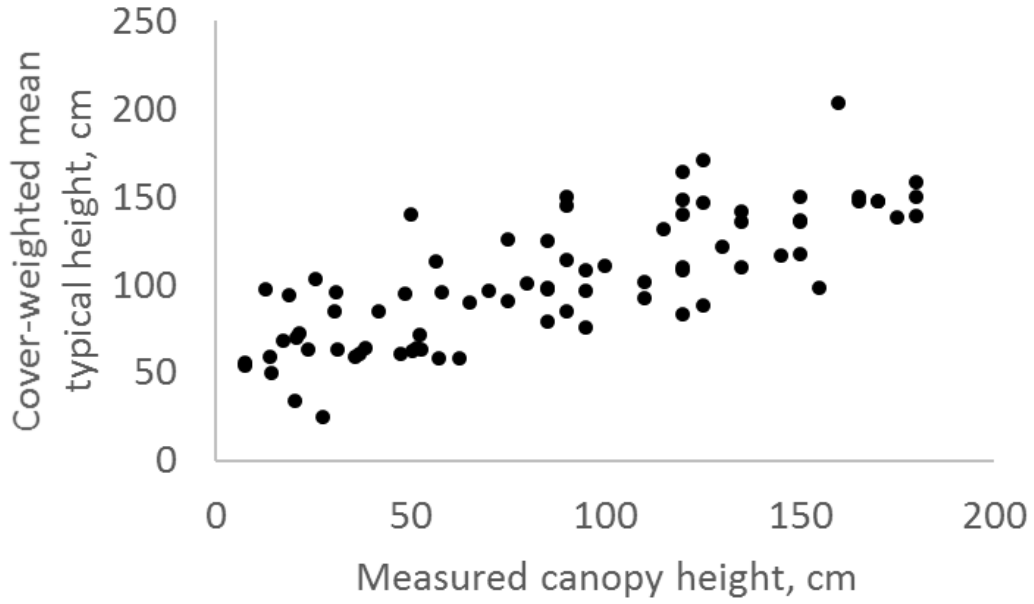


Mean ‘Ellenberg N’ (~ fertility or productivity)

MultiMOVE plotter: Smart, Alison, Jarvis & Wilson (2019) https://shiny-apps.ceh.ac.uk/find_your_niche/

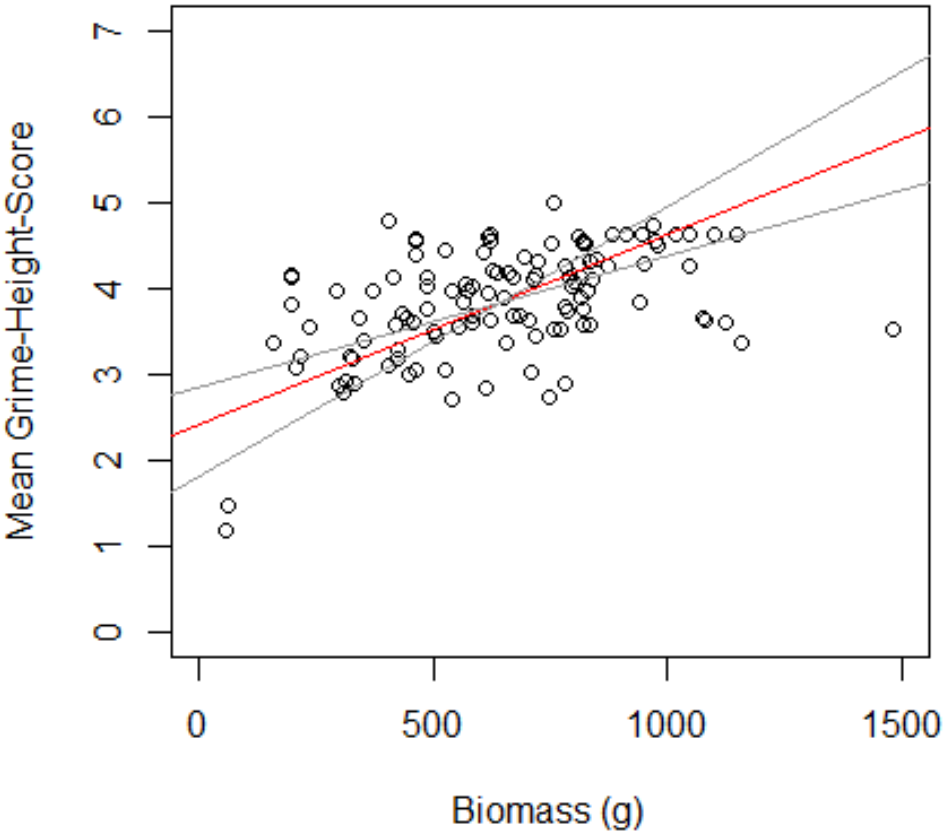
Mean typical height *cf.* measured height

- Cover-Weighted Mean Typical Height reflects measured height
- Canopy height is temporally variable, and measurements can be subjective
- CWMTH may be a better indicator for ground-level shading



Typical Height for each species is the median of the range given in 'Comparative Plant Ecology', Grime et al. (1988). Data from Bracken Survey: Rowe et al. (2016) STOTEN 572: 1636-1644; and Balmacara survey: Pakeman (2011) Ecology 92: 1353-1365

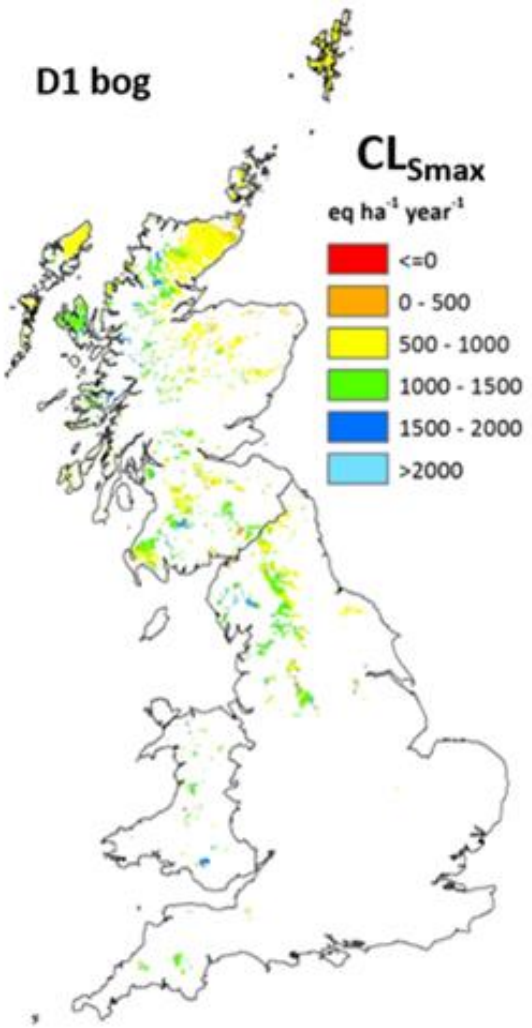
From biomass to mean typical height



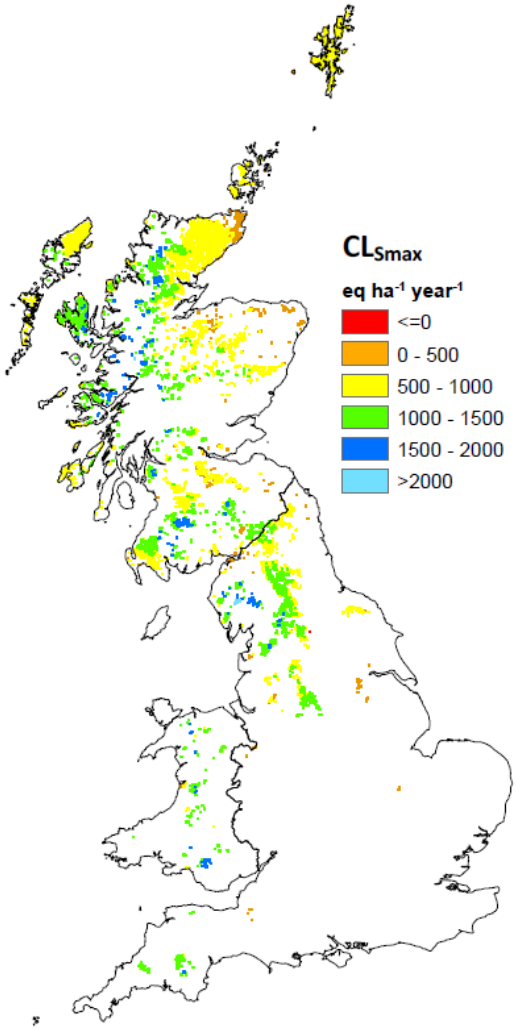
- Few data points (biomass is rarely measured with floristic composition)
- Not a tight relationship
- Fitted with ‘Type 2’ regression (Ranged Major Axis), to avoid compressing the y axis

Cl_{biodiv} functions using revised model

Old



Revised



- 2019 map is only ca. 50% of all bog 1 km^2 squares
- Colours not directly comparable
- Little overall change

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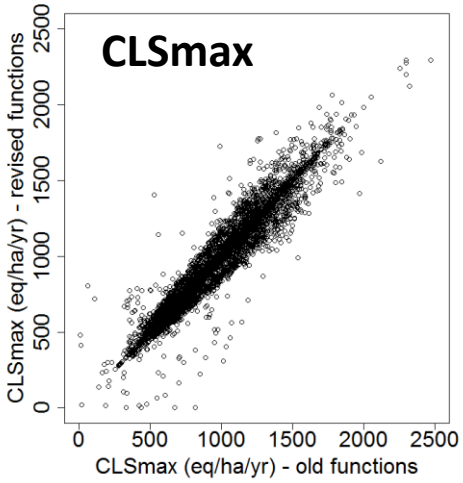
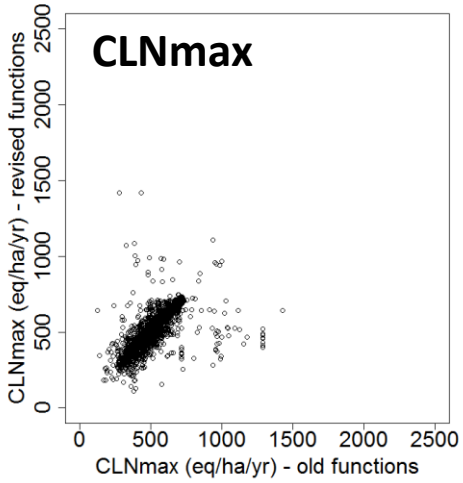
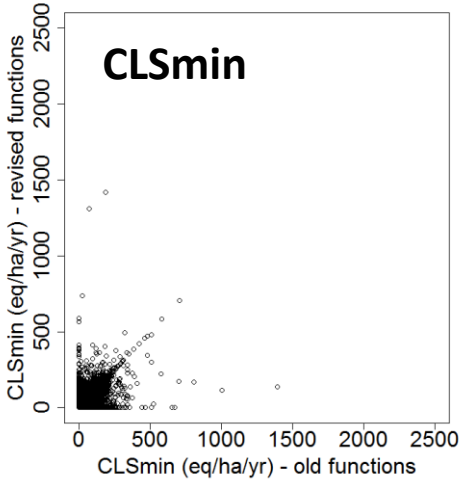
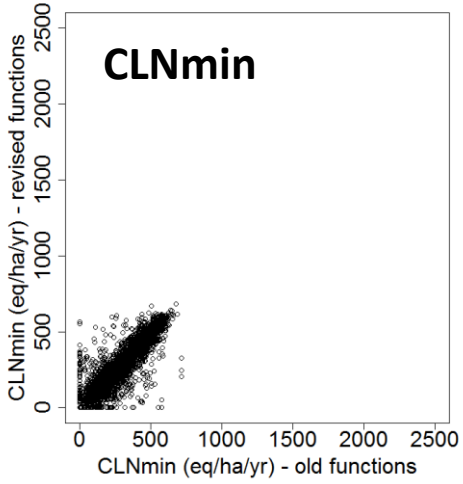
Changes due to model revision

Revised



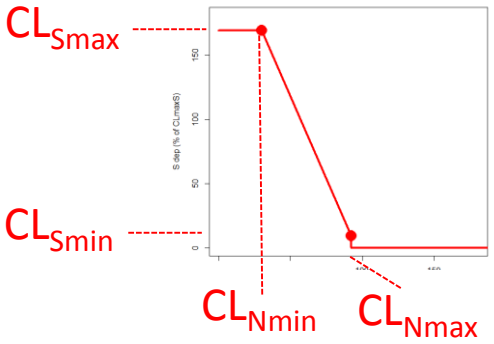






Old

- New transfer functions result in a new response surface to N and S deposition
- … and new values for the two nodes for CL_{biodiv}
- No systematic change – new values for CLSmax, in particular, are similar



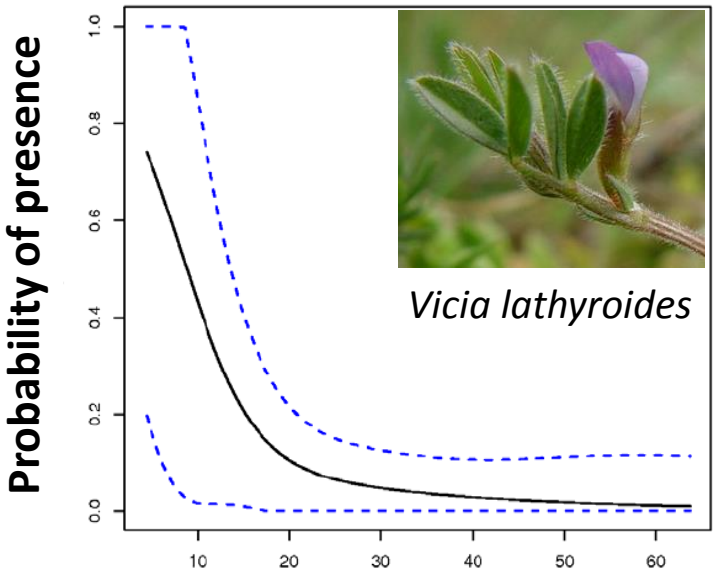
Are biodiversity predictions useful?

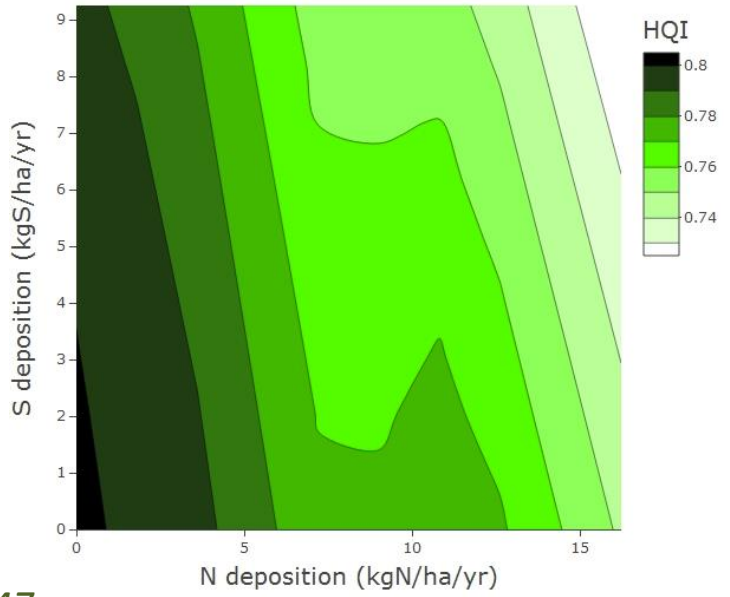
Concerns about “biodiversity” are often about extinction

- the forever-extinction of species
- the extinction of local experience of habitats and species

Basing a biodiversity metric on “positive indicator species” reflects this concern, because some species matter more than others.

But do “Habitat Quality Index” or “Habitat Suitability Index” really speak to people?





Stevens et al. 2011 JNCC 447

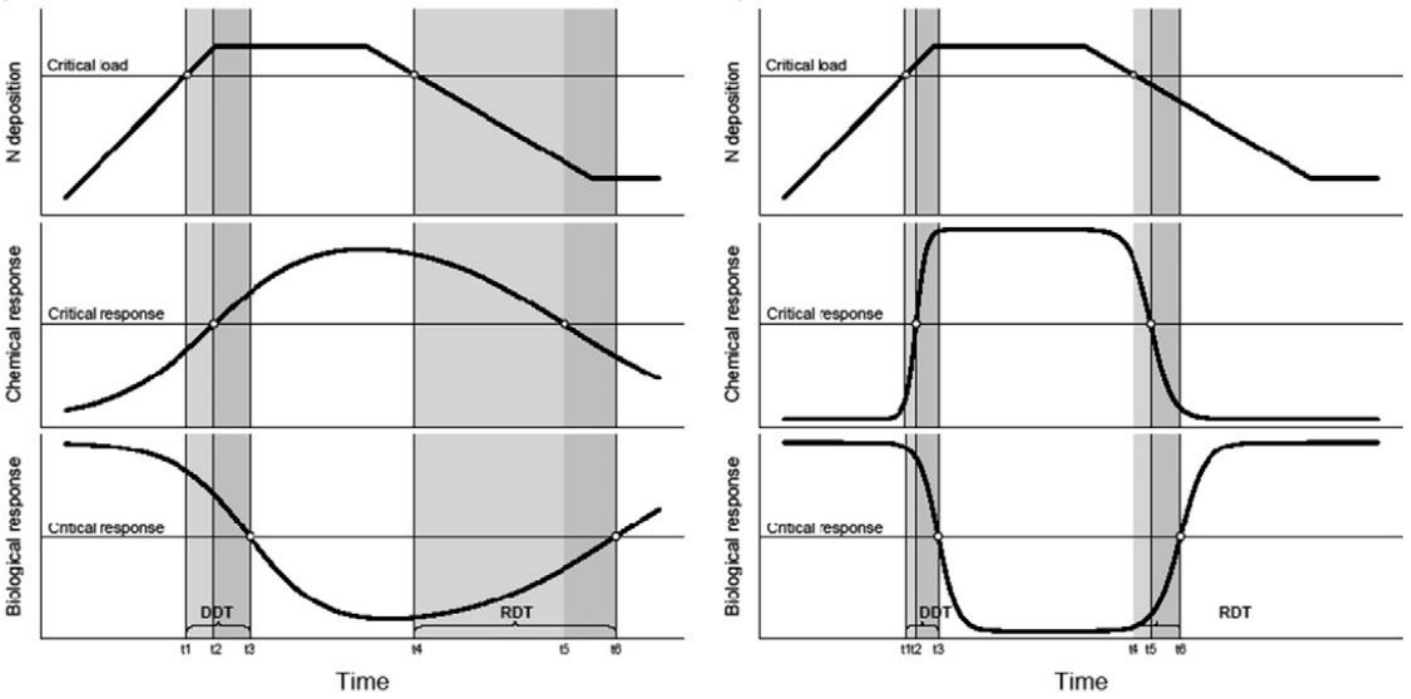
Is dynamic modelling useful?

Allows assessment of chemical delay times for damage/recovery, and of target loads
…if response indicators are based on ***exposure***, e.g. soil pH, soil available N

N deposition

Chemical response

Biological response



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Rowe et al 2017 Biol Cons 212: 454-463, Adapted from Posch et al. 2004 Mapping Manual: Dynamic Modelling

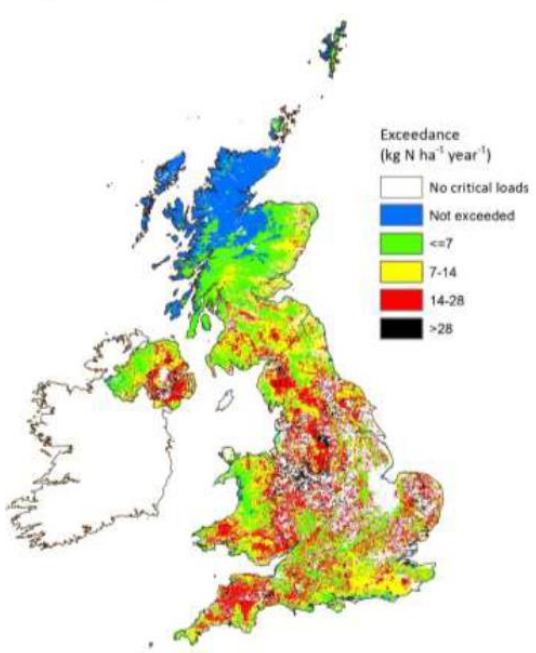
Ways forward – we could…

- Persist: promote ***Habitat Suitability for Positive Indicator Species*** as a useful summary metric of biodiversity, and suggest that maps of CL_{biodiv} exceedance be used to support policy development
- Focus on **midpoint** indicators, i.e. biogeochemical indicators that the system is changing (soil pH, Ca/Al ratio, available N, foliar N, etc.)
- Focus on **particular species** that people appreciate and are affected by air pollution

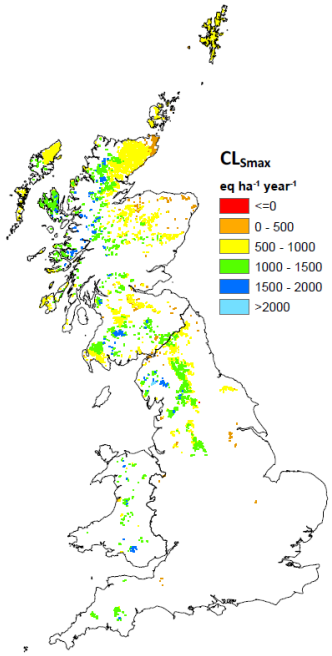



Conclusions

- The UK NFC is continuing to improve models that predict biodiversity change
- Biodiversity loss is an important negative effect of N and S pollution
- Biodiversity-based critical load exceedance reflects impact on what people care about, i.e. it is an **endpoint** metric, not a **midpoint** (e.g. pH) or **pressure** (e.g. AAE) metric



AAE: Average Accumulated Exceedance



CL_{Smax} from CL_{biodiv}