An application of dynamic modelling to produce site-specific critical loads

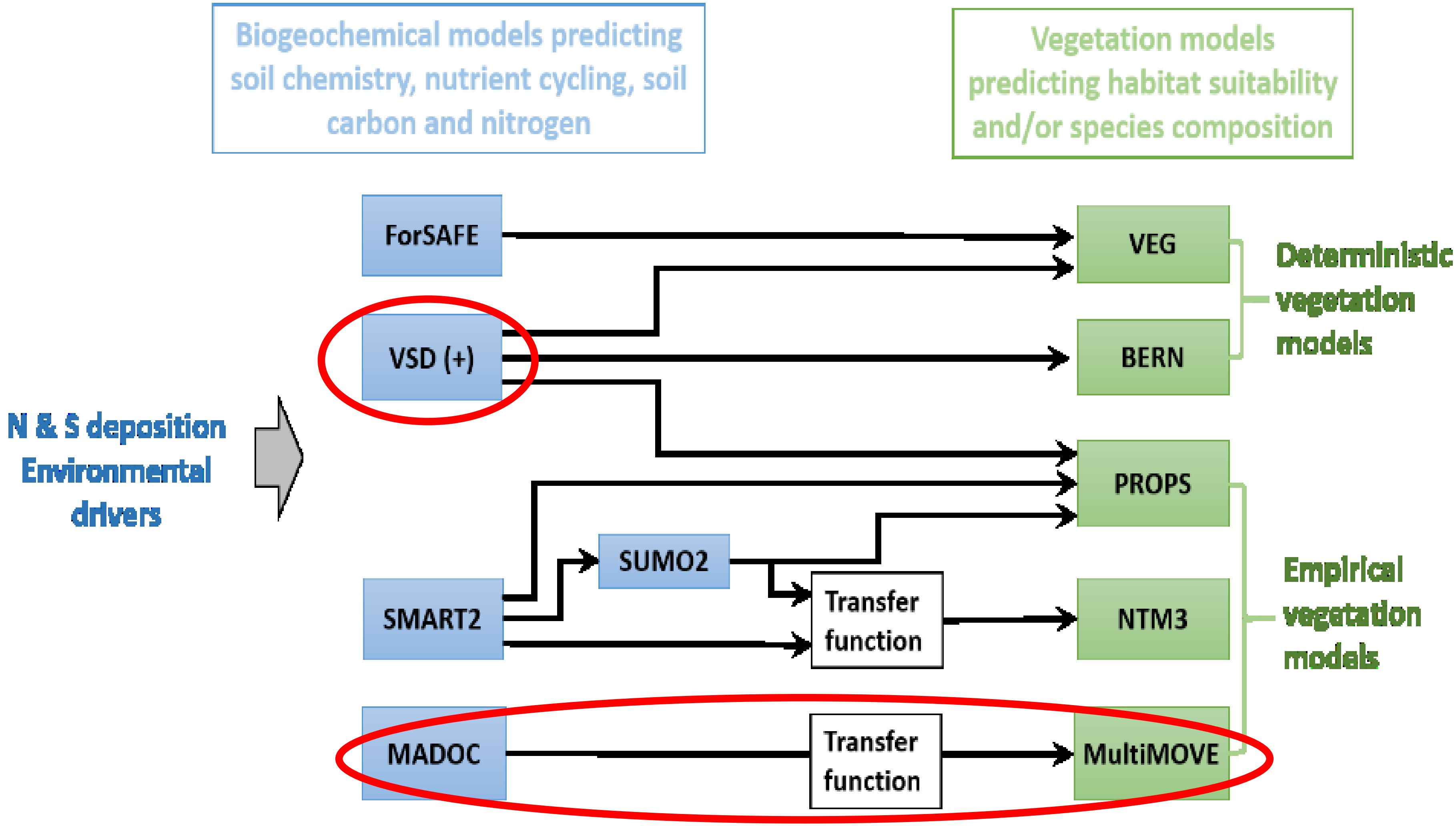
Chris Field (MMU), Ed Rowe (CEH), Rob Kinnersley (EA) and Sarah Watkins (EA)

contact: c.field@mmu.ac.uk

Agenda

- Overview of dynamic models
  - Biogeochemical
  - Vegetative
- Focus on ESI and Skipwith Common
  - ESI site monitored information
- Application of Dynamic models
  - VSD+ and MADOC/MultiMOVE
  - scenario investigation
- Site specific Critical loads
  - for acidity
  - and new CLbiodiv

Dynamic model chains

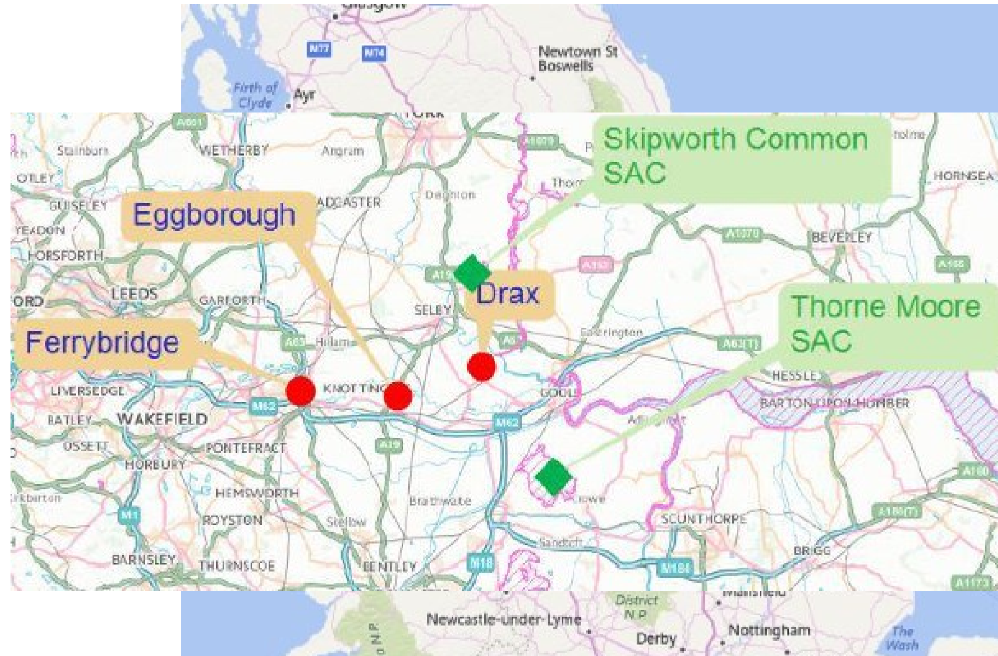


NERC SCIENCE OF THE ENVIRONMENT

Environment Agency

Electricity Supply Industry (ESI) Background

- 2001 the European Union issued a Large Plant Combustion Directive (LPCD, 2001/80/EC)
- typically applied to fossil-fuel power stations and oil refineries
- a monitoring programme was designed to assess the impact of pollutant deposition from several UK ESI sites to selected N2000 sites
    - CEH were the contractor



Manchester Metropolitan University

NERC SCIENCE OF THE ENVIRONMENT

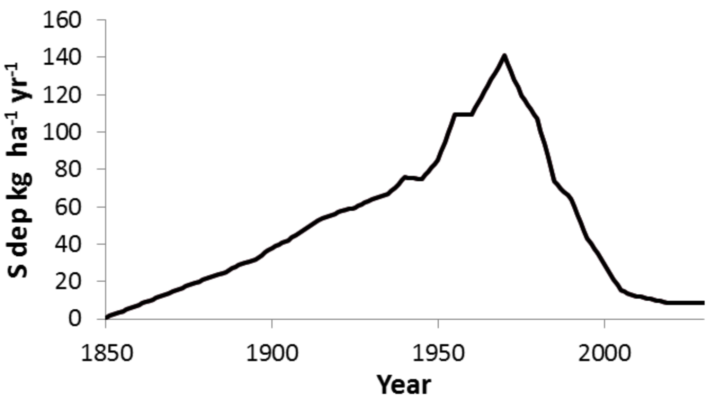
Skipwith Common, North Yorkshire

Environment Agency

Largest single tract of wet [and dry] heathland in England

(keq/ha)	Critical load for Acidity APIS CLmaxN and CLmaxS	APIS CLempN range	2012 monitored	2013 monitored
N deposition	0.80 (wet heath) 1.20 (dry heath)	0.71-1.43	0.93	0.91
S deposition	0.16	-	0.40	0.37

- Acidity critical loads
  - site exceeds ClmaxN for wet heath but not dry heath
  - site exceeds CLmaxS
- Vegetation critical loads for nitrogen
  - site is low to mid-range for CLempN: 12-14 kg N
- many heathlands across the country will be worse than Skipwith
- *BUT* large historic component at Skipwith



Manchester Metropolitan University

Skipwith site monitored data

Site monitored data from CEH

(Montieth et al 2012, 2013, 2014, 2015)

http://publications.naturalengland.org.uk/publication/9529076

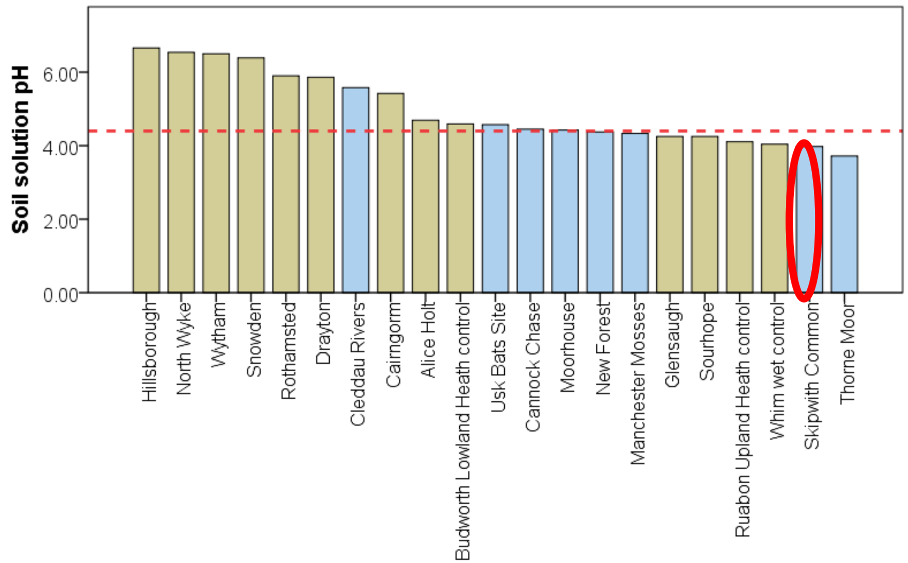
- vegetation poor with low occurrence of CSM +ve indicator forb species
- bryophytes present indicate nutrient enrichment e.g. *Brachythecium rutabulum*
- Multi-MOVE modelling suggests that soil is unsuitable for current species

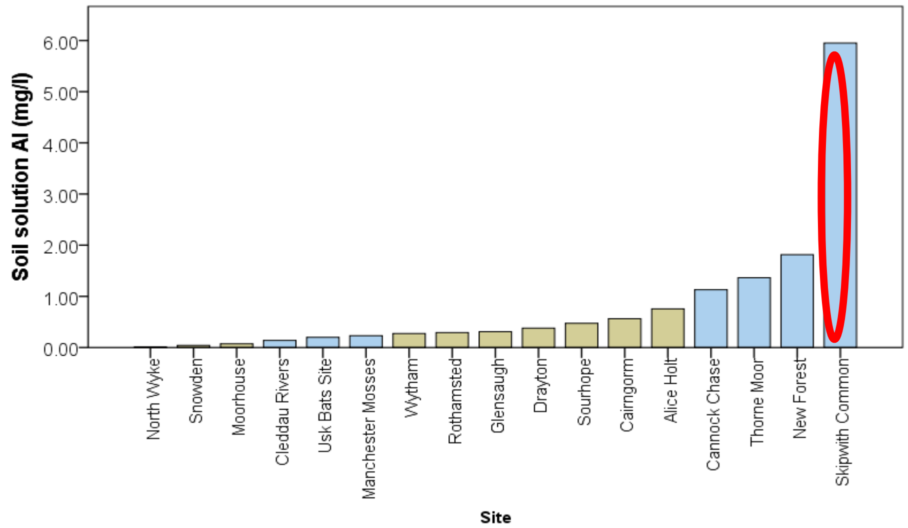
- *Natural England Management data suggests ~ 52% in Unfavourable recovering condition, 48% Favourable*

Soil and soil solution chemistry

- evidence of acidification
  - low soil solution and soil pH
  - High Al in soil solution
  - pH and Al correlated (r=0.45, P=0.025)
  - extractable base cations low
- evidence of eutrophication
  - soil CN low and indicative of leaching
  - soil solution NH_4 high

When compared to data from NE LTMN, ECN and experimental sites (Budworth, Ruabon and Whim), Skipwith appears to be in poor condition.





Trailing CL_{biodiv}: modelling scenarios using MADOC-MultiMOVE

- Habitat Quality Index (HQI) is calculated using 32 CSM positive indicator species
  - HQI = mean suitability across 32 species
- A critical level of HQI (HQ_{crit}) is generated by running model at critical load from 1980 to 2100
  - i.e. what the habitat suitability would be without much of the recent deposition
  - for Skipwith, HQcrit=83%
- The HQI was calculated for a combination of temperature and pollutant scenarios

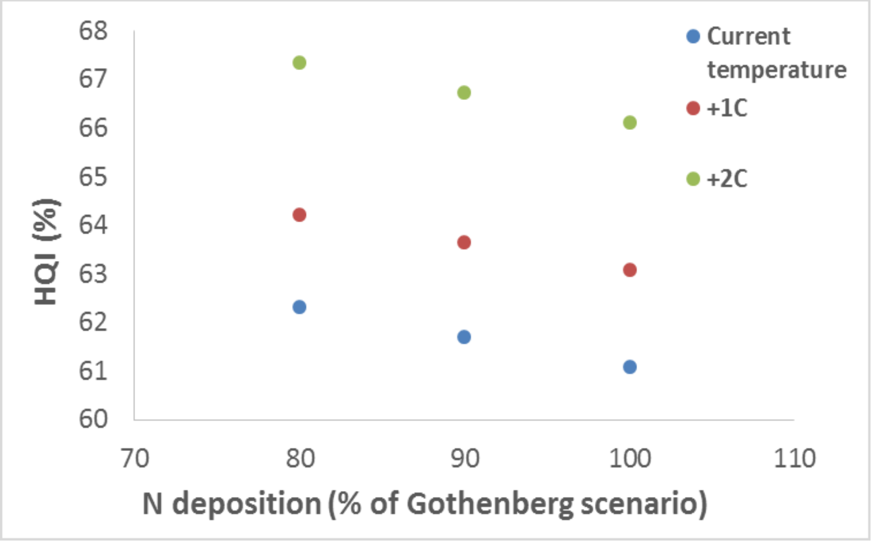
	Decreasing nitrogen % (N) →		
Increasing Temperature (T) °C ↓	N100/T+0	N90/T+0	N80/T+0
	N100/T+1	N90/T+1	N80/T+1
	N100/T+2	N90/T+2	N80/T+2

Modelling by Ed Rowe, CEH Bangor

MADOC-MultiMOVE Habitat suitability results

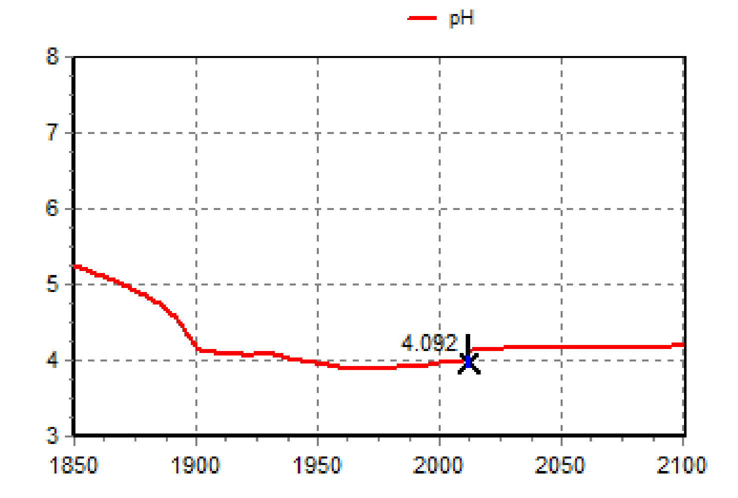
- all the scenarios modelled produce a HQI substantially below the HQ_{CRIT} by 2100
- climate change improves HQI more than a 20% cut in N deposition!
  - some species e.g. *Sedum acre* do well under climate change
  - the south east is more diverse for vascular plants
- specific bryophytes are not included as CSM +ve indicator species
  - UK 20% of Eu plants but 60% of Eu bryophytes

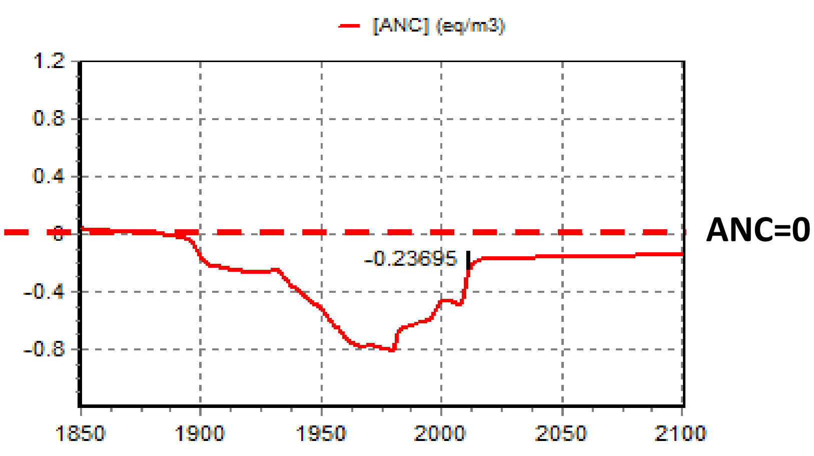
HQ_{CRIT}=83%



Sedum acre
www.thewildflowersociety.com

VSD+ modelling of Critical load for acidity



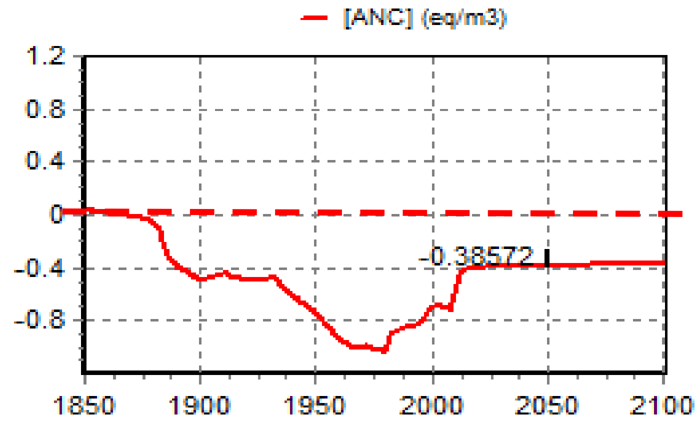


- calibrated using site observations of soil pH, CN and base saturation.
- Model responds to changes in dep. and predicts pH/Al well
  - accuracy decreases as organic component increases
- Heathland critical load for acidity based on ANC=0
  - last hit in 1890!

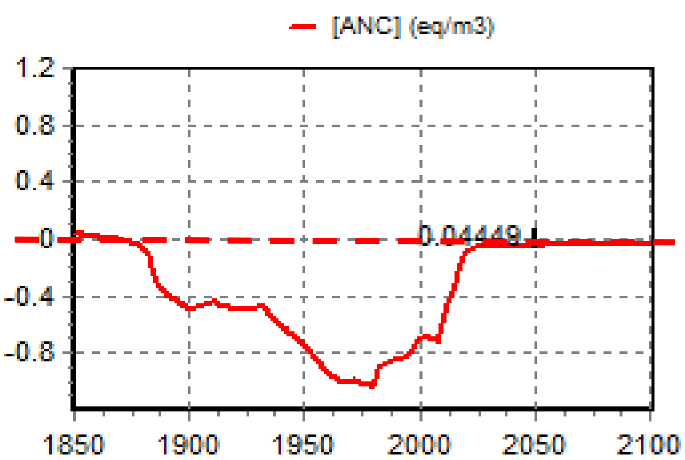
Investigating recovery scenarios using VSD+

- amount of N removed through management is important
  - considered in CL but is site actually managed?
- Critical load for acidity (using ANC=0) not met until both N and S deposition have reduced by 50%

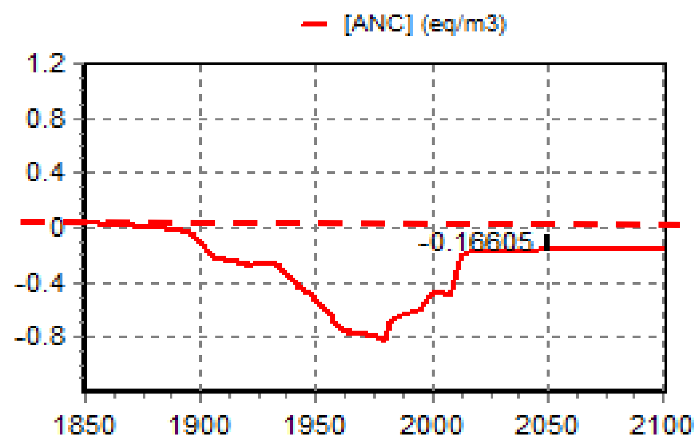
Current dep + wet heath mgmt. -4.5 kg



N & S -50%, dry heath mgmt. -10 kg pa

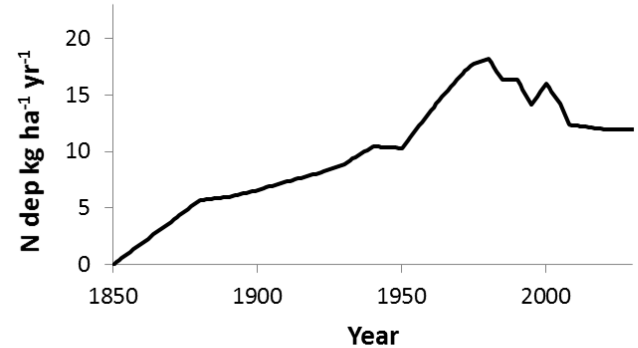


Current dep + dry heath mgmt. -10 kg



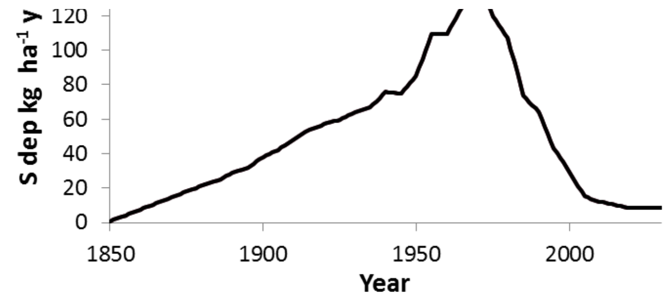
Comparison of critical loads

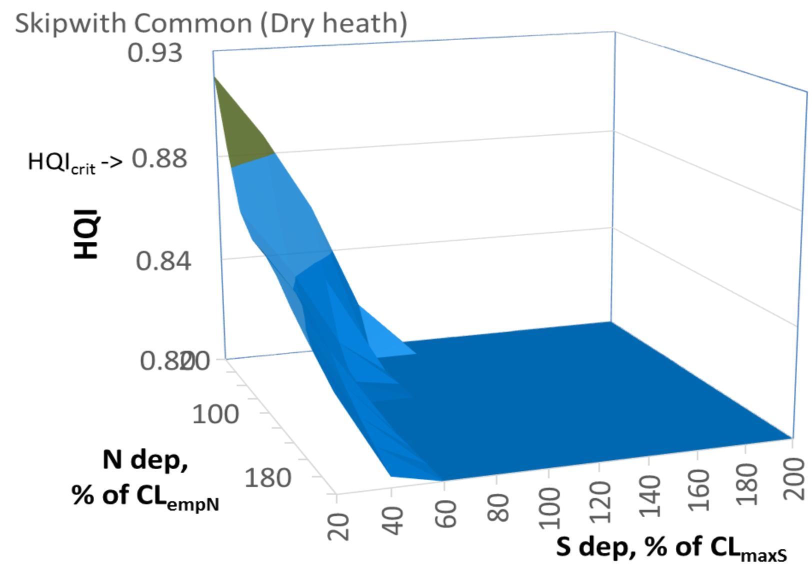
CL acidity	Conventional (APIS)	Modelled (VSD+)
CLmaxS	0.16	0.11
CLmaxN	0.82	0.77 (wet heath) 1.17 (dry heath)



CLbiodiv

- site appears very sensitive to even small levels of acid deposition
- at current N deposition, no level of S will enable CL to be met
- at current S deposition, no level of N will enable CL to be met
- both N and S need to fall by more than 50%





Summary

- empirical critical loads may not always be appropriate for a site that has been subjected to long-term pollution
- dynamic models consider long-term pollution and enable scenario investigation (e.g. polluter life-span)
  - CL's modelled this way may be much lower than conventional CL's
- opportunity for CL_{biodiv} linked to conservation outcomes
  - care taken when developing species lists and establishing thresholds
- realistic and even extreme reductions in pollution may not result in recovery of habitat quality
- many sites may need 'resetting' to remove N and S pools/acid effects or to offset current deposition
  - lime addition, topsoil stripping or active management (e.g. Storkey et al, 2015; Jones et al, in prep)

Acknowledgements

- tremendous support from CEH staff: Ed Rowe, Jane Hall, Chris Evans, Ed Tipping, Simon Smart, Peter Henry's and others
- much advice from conservation agency staff
- Rob Kinnersley and Sarah Watkins for guidance throughout year

Refereces

- Field, C., Dise, N. B., Payne, R. J., Britton, A., Emmett, B. A., Helliwell, R., Hughes, S., Jones, L. M., Leake, J. R., Phoenix, G., Power, S., Sheppard, L., Southon, G., Stevens, C. and Caporn, S. J. M. (2014). "Nitrogen drives plant community change across semi-natural habitats." Ecosystems **17: 864-877.**
- Henrys, P., Rowe, E. C., Evans, C. D., Emmett, B. A., Smart, S. M. and Butler, A. (2013). MultiMOVE: A Package of niche models for British vegetation, NERC Environmental Information Data Centre.
- Henrys, P. A., Smart, S. M., Rowe, E. C., Jarvis, S. G., Fang, Z., Evans, C. D., Emmett, B. A. and Butler, A. (2015). "Niche models for British plants and lichens obtained using an ensemble approach." New Journal of Botany **5(2): 89-100.**
- Posch, M., Hettelingh, J. P., Slootweg, J. and Reinds, G. J. (2014). Deriving critical loads based on plant diversity targets. CCE Status Report 2014: Modelling and Mapping the impacts of atmospheric deposition on plant species diversity in Europe. J. Slootweg, M. Posch, J.-P. Hettelingh and Mathijssen. The Netherlands, ICP Modelling and Mapping Coordination Centre for Effects.**: 41-46.**
- Rowe, E. C., Ford-Thompson, A., Monteith, D., van Hinsberg, A., Smart, S., Henrys, P. and Ashmore, M. (2014). A biodiversity metric for interpreting outputs of models of atmospheric nitrogen pollution impacts on habitats., Final report on Defra project AQ0828, "Research to define a biodiversity metric to inform the UK's response to the CCE 'Call for Data 2012-2014'. CEH project NEC04988. Centre for Ecology and Hydrology, ECW, Deiniol Road, Bangor, LL57 2UW, UK.**: 90.**
- Rowe, E. C., Ford-Thompson, A. E. S., Smart, S. M., Henrys, P. A. and Ashmore, M. R. (submitted). "Deriving a metric of terrestrial habitat quality using qualitative and quantitative methods." Ecological Indicators.
- Sverdrup, H. U. and Belyazid, S. (2015). "Developing an approach for Sweden, Switzerland, United States and France for setting critical loads based on biodiversity including management, pollution and climate change." Ecological Modelling **306: 35-45.**
- Tipping, E., Rowe, E. C., Evans, C. D., Mills, R. T. E., Emmett, B. A., Chaplow, J. S. and Hall, J. R. (2012). "N14C: A plant–soil nitrogen and carbon cycling model to simulate terrestrial ecosystem responses to atmospheric nitrogen deposition." Ecological Modelling **247(0): 11-26.**

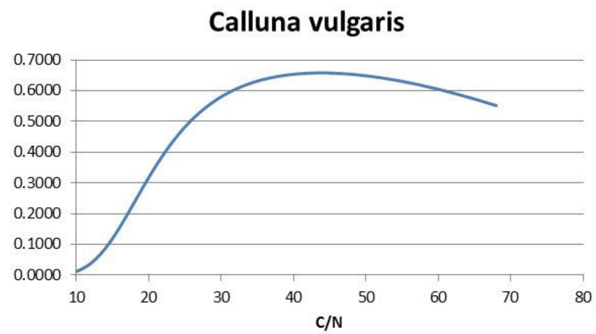
Model performance from literature review

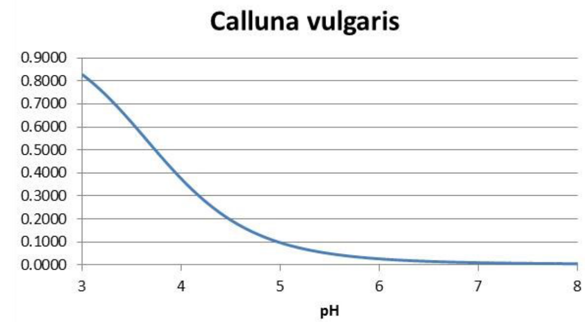
- **Biogeochemical** models have been tested across many sites
  - good predictors of base cations, pH
- Application at regional or site specific scale (if specific information known)
  - Trade off in detail vs regional application
- Many weaker at CN pools
- Plant available N difficult to define

Hs_V =(β1.Mean Ellenberg fertility) + (β 2.Mean Ellenberg wetness) + (β3.Mean Ellenberg soil pH) + (β4. cover-weighted canopy height) + (β5-7. Climate variables)

From (Montieth et al. 2013)

- **Vegetation** models less proven
- Empirical models use relationships between plant species occurrence and environmental factors
  - rely on training data from large datasets (CS, NVC, BSBI)
  - rare species not considered
  - predict habitat suitability not actual occurrence/cover
  - use soils or vegetation data to predict Ellenberg values
- Ellenberg N difficult to define





MADOC model performance at Skipwith

- Soil C/N modelled since the last glaciation matched observed values very accurately
- pH was slightly over estimated - observed value (3.98)
  - but within range of measured values (3.89-4.11)
- NO_3 over predicted, NH_4 under predicted
  - observed data heterogeneous, model outputs in the same order of magnitude