Nitrogen saturation of terrestrial ecosystems: an update

Bridget Emmett
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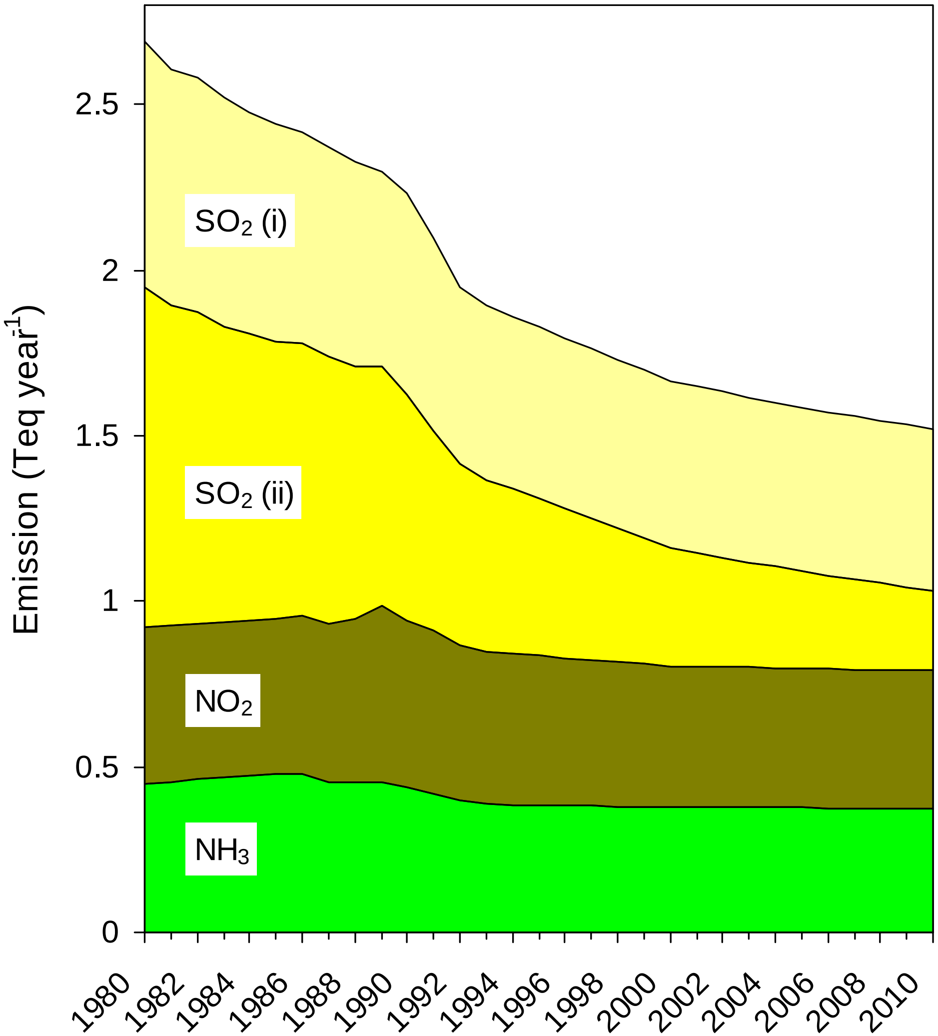
With thanks to:
Filip Moldan, (IVL)
Roland Bobbink (University of Utrecht)
Lindsay Rustad (Durham, NH) and her co-authors
Laurence Jones, Mark Sutton and Steve Hughes et al (CEH)
Chris Curtis (UCL)
UKREATE consortium (www.bangor.ceh.ac.uk/terrestrial-umbrella)
for permission to use data but no responsibility for my conclusions

Major reductions in sulphur emissions across EMEP but nitrogen remains a problem



All shown as acid equivalent emissions in Europe

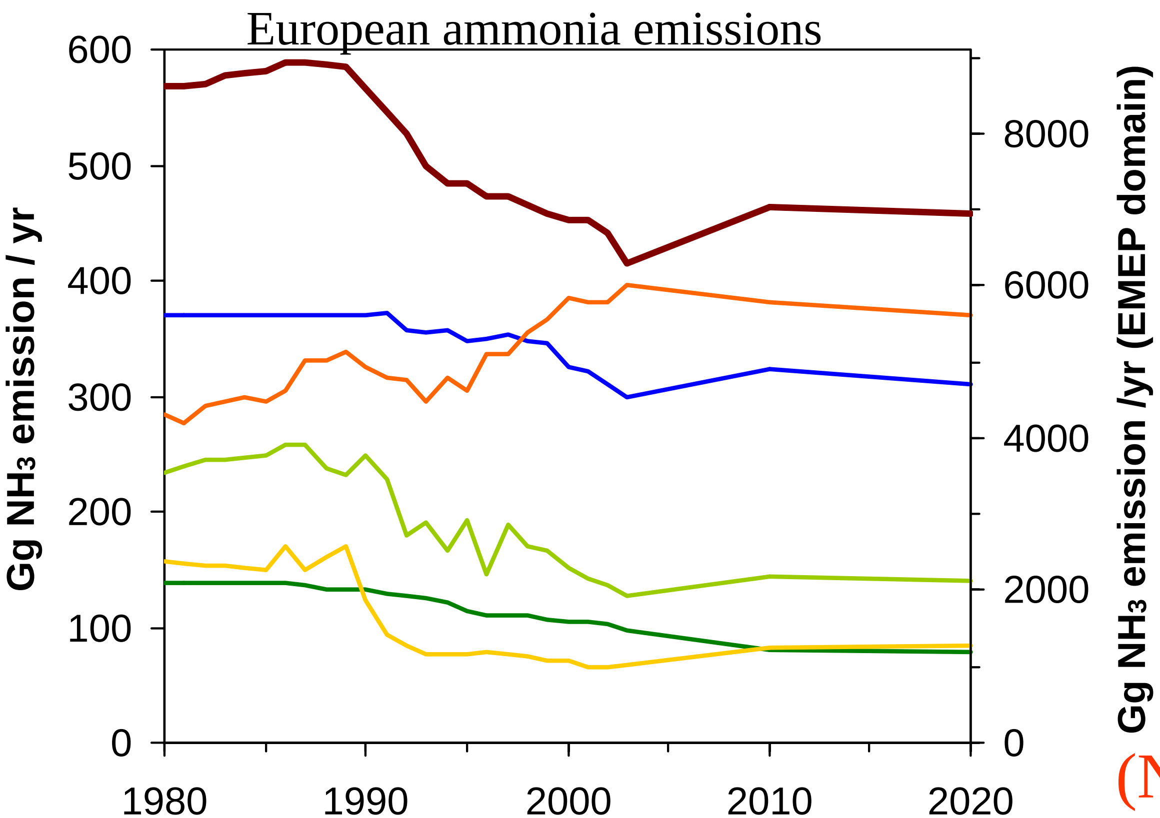
European SO_2 emissions divided into:

i) Countries committed to significant S reductions, Countries and other areas

ii) without significant reduction

(Analysis of EMEP data from late 1990s)

Ammonia have an increasingly large role to play in eutrophication and acidification of systems as only small reductions projected

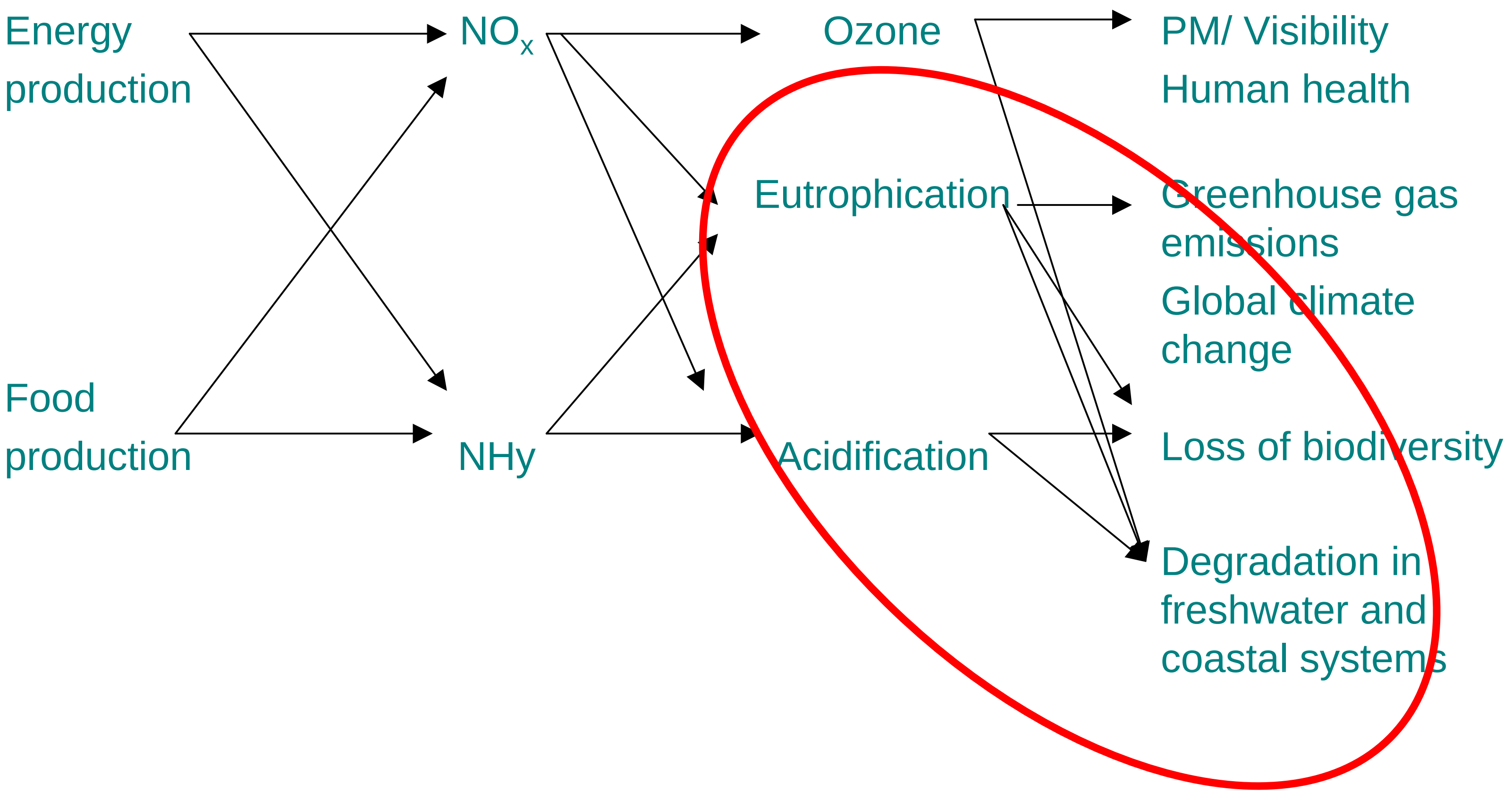


Expected changes (1990-2010)
-13%
-39%
-42%
-33%
+17%
-18%

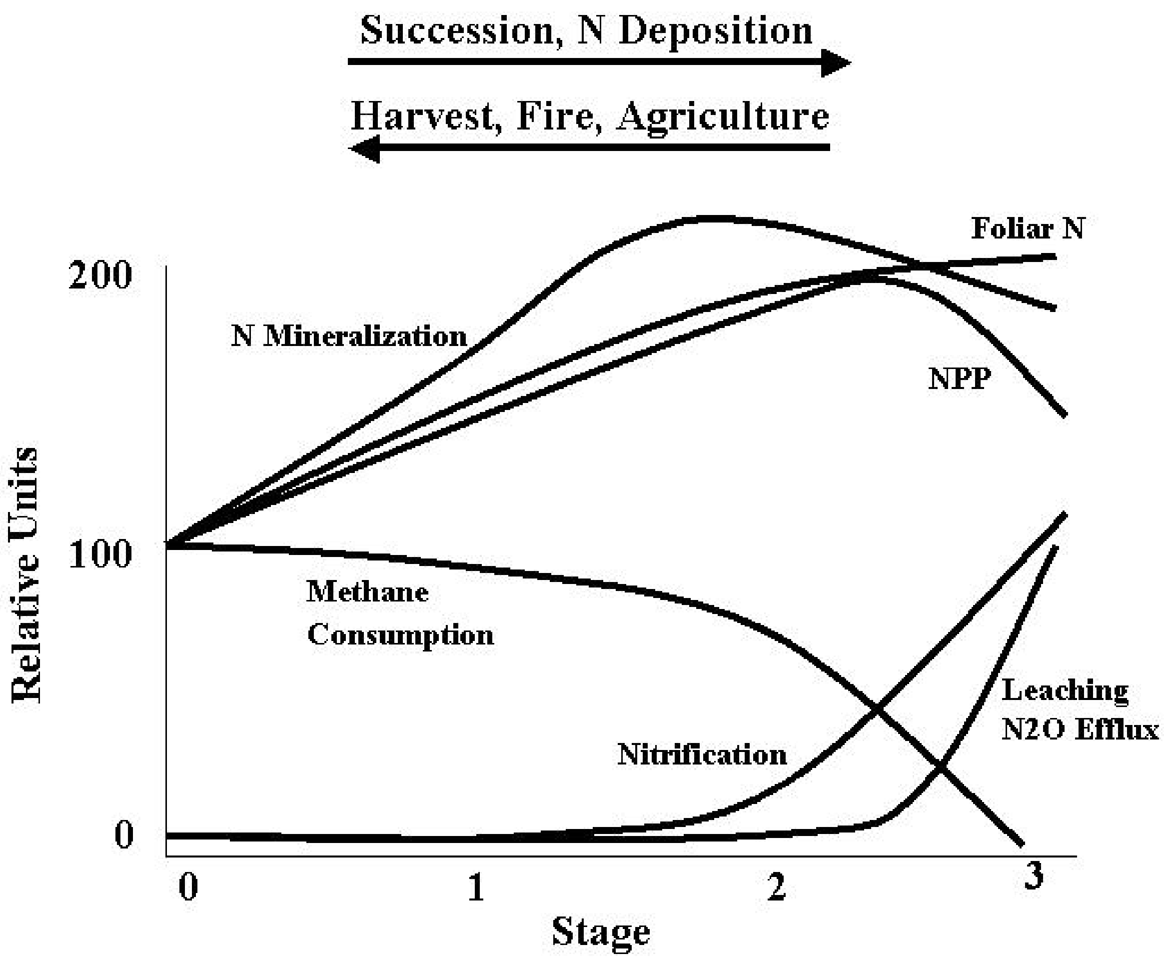
NL & DK: detailed NH_3 policies
HU: 1989 revolution
UK: few NH_3 abatement policies
ES: expansion of agriculture

(New analysis based on data reported to EMEP for 2005)

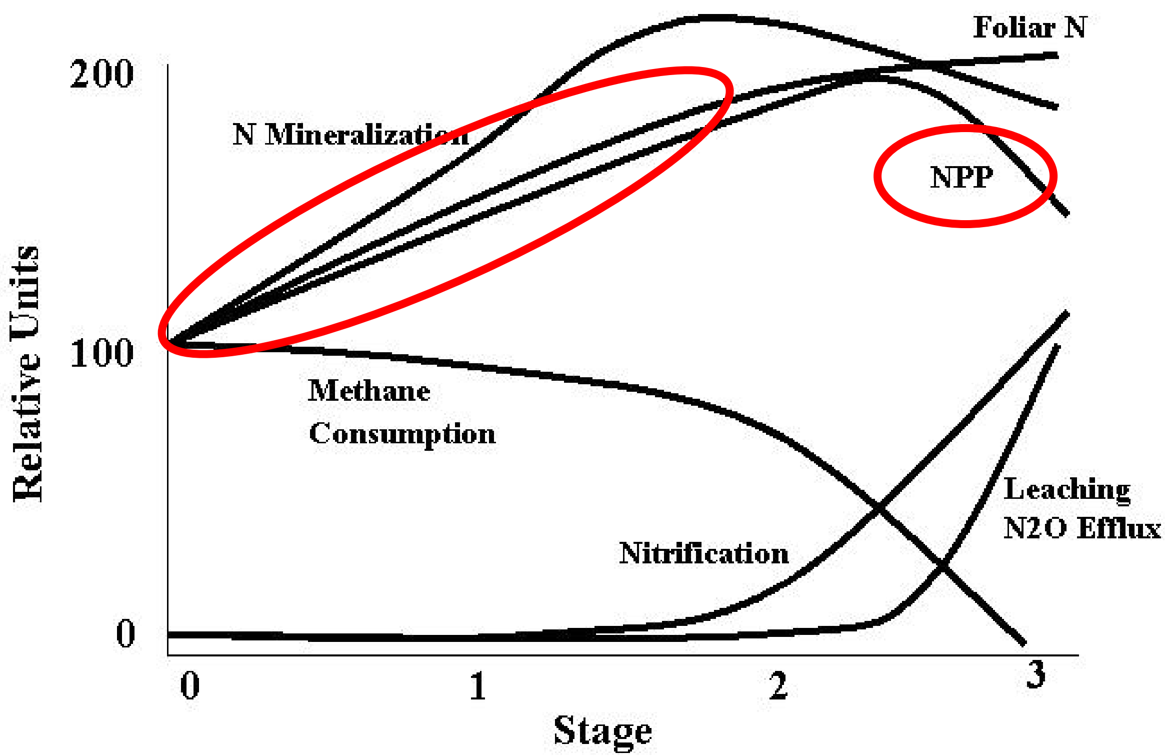
Negative effects of nitrogen emissions



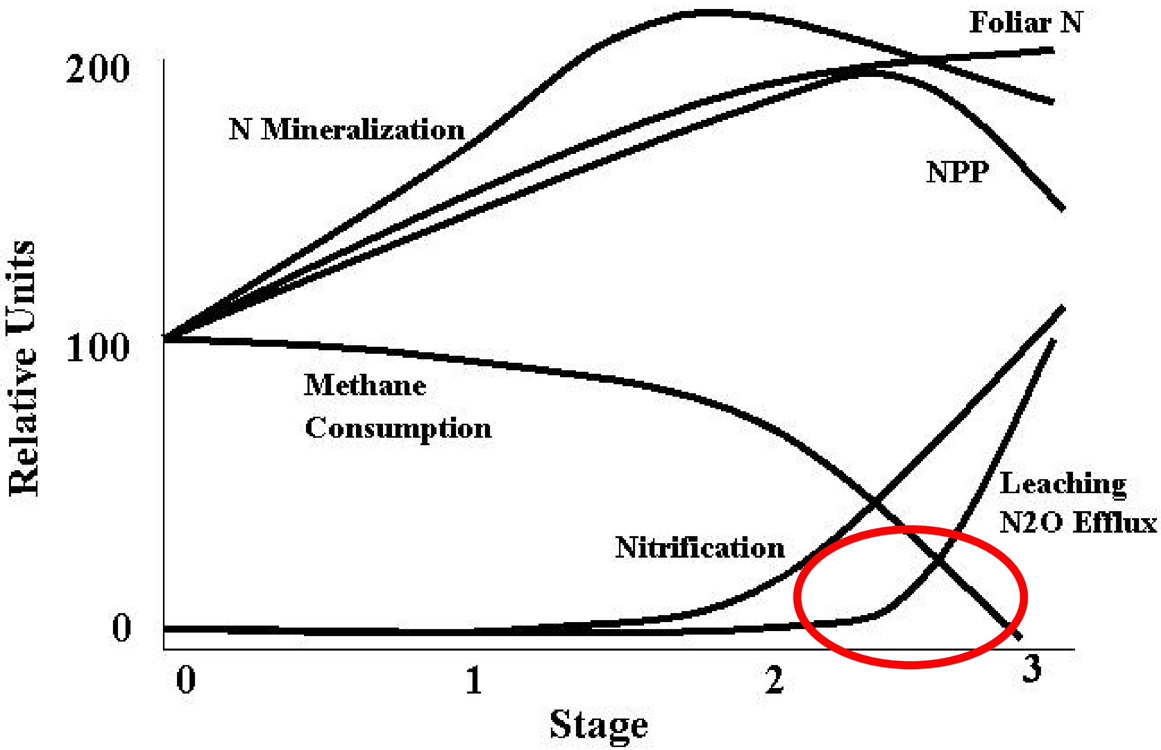
Proposed pathway to nitrogen saturation (Aber et al. 1998)



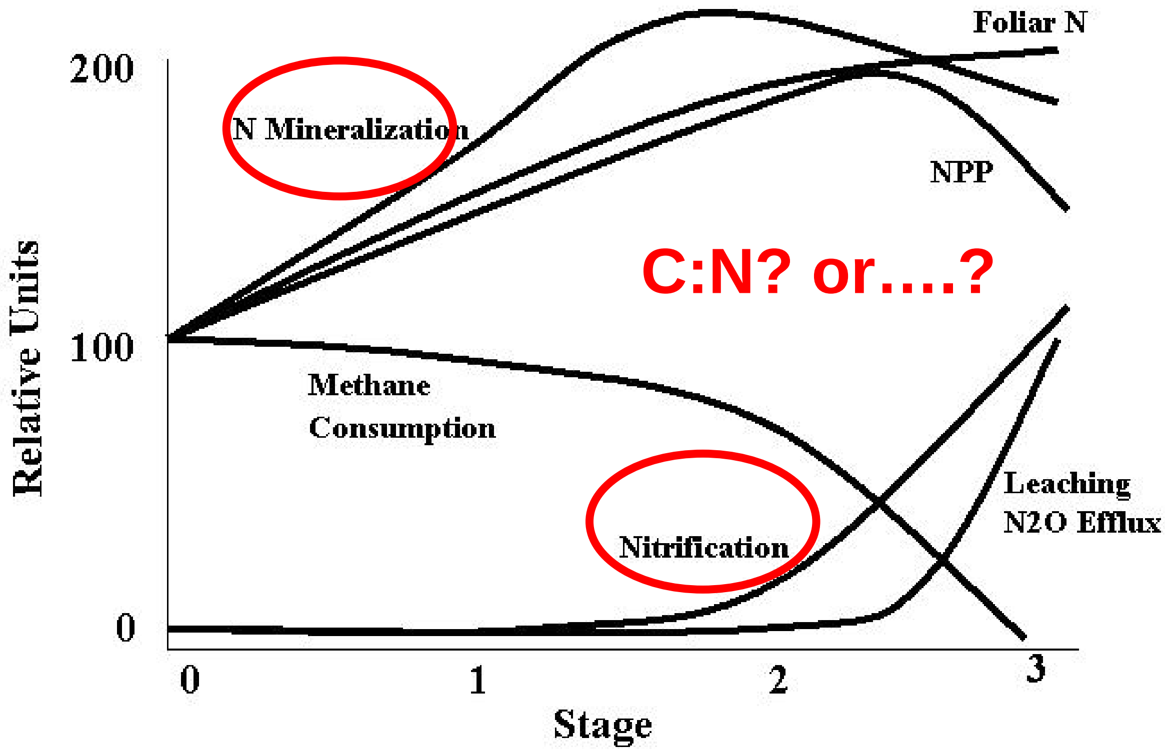
1. What evidence do we have for biodiversity changes, are changes greater at different stages and does N form matter?



2. What evidence do we have for increased nitrate leaching and when does it occur?



3. What are the best indicators of ecosystem N status and what should drive our models?



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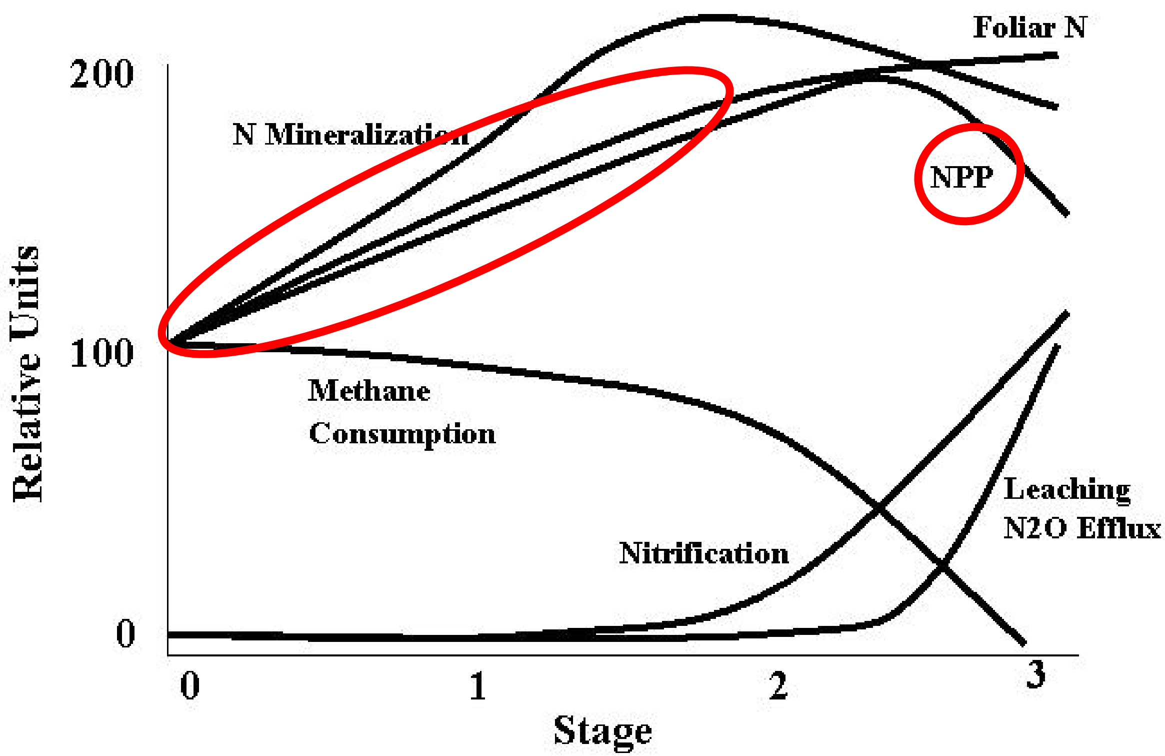

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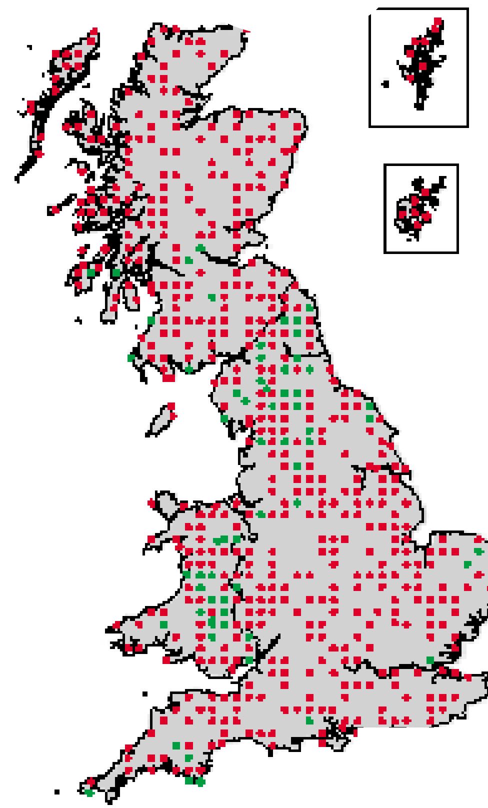
Monitoring programmes are essential to assess biodiversity changes

Countryside Survey
www.CS2000.org.uk



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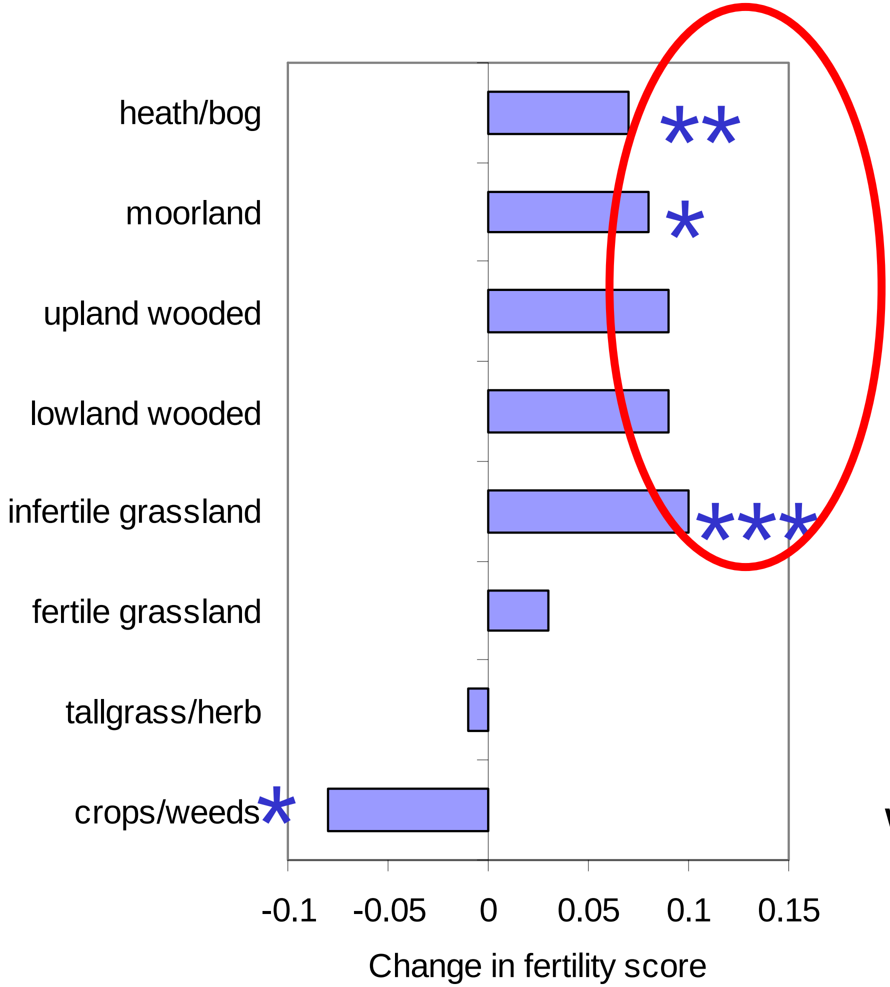
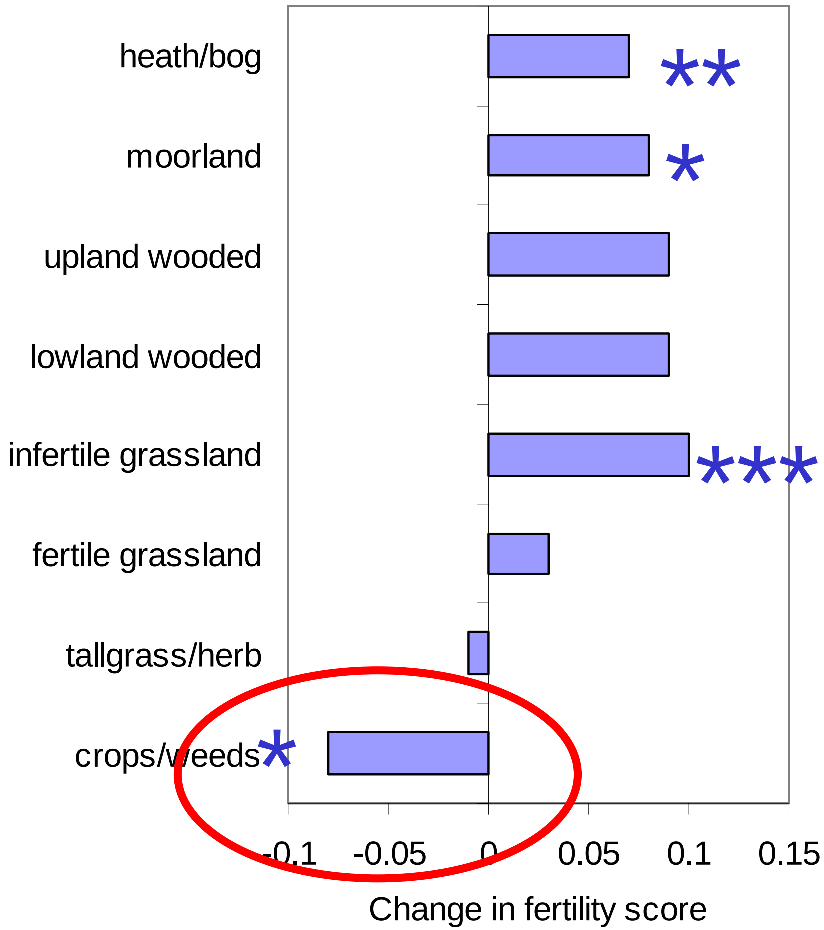
An increase in species with high ‘N fertility’ score in low nutrient habitats (CS2000 data for 1990-98)



www.CS2000.org.uk

A reduction in species with high fertility score in agricultural systems (CS 2000 data for 1990-98)

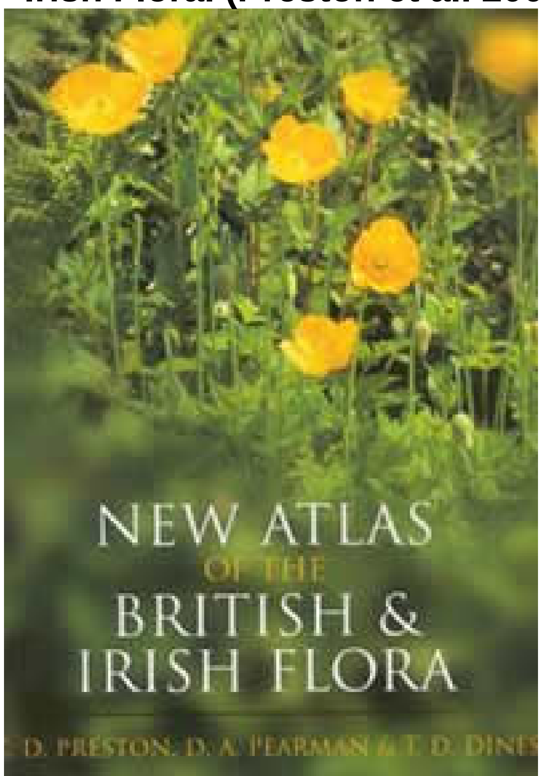


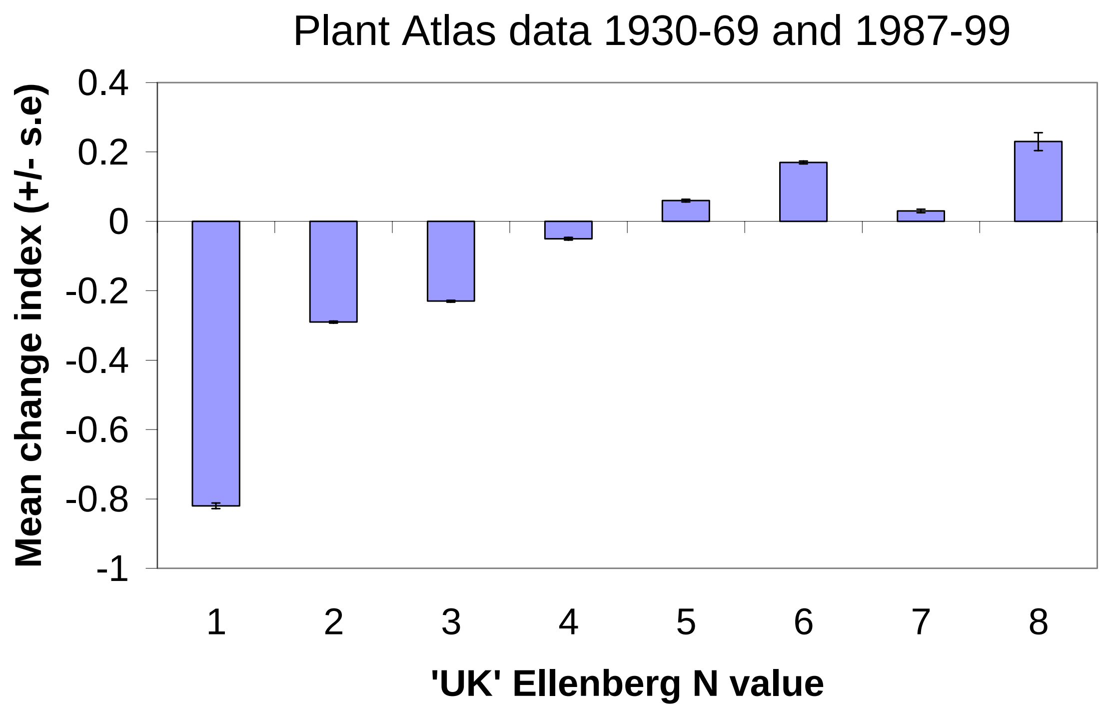
www.CS2000.org.uk

Species level monitoring: shift in range of species observed

New Plant Atlas of the British and

Irish Flora. (Preston et al. 2002)

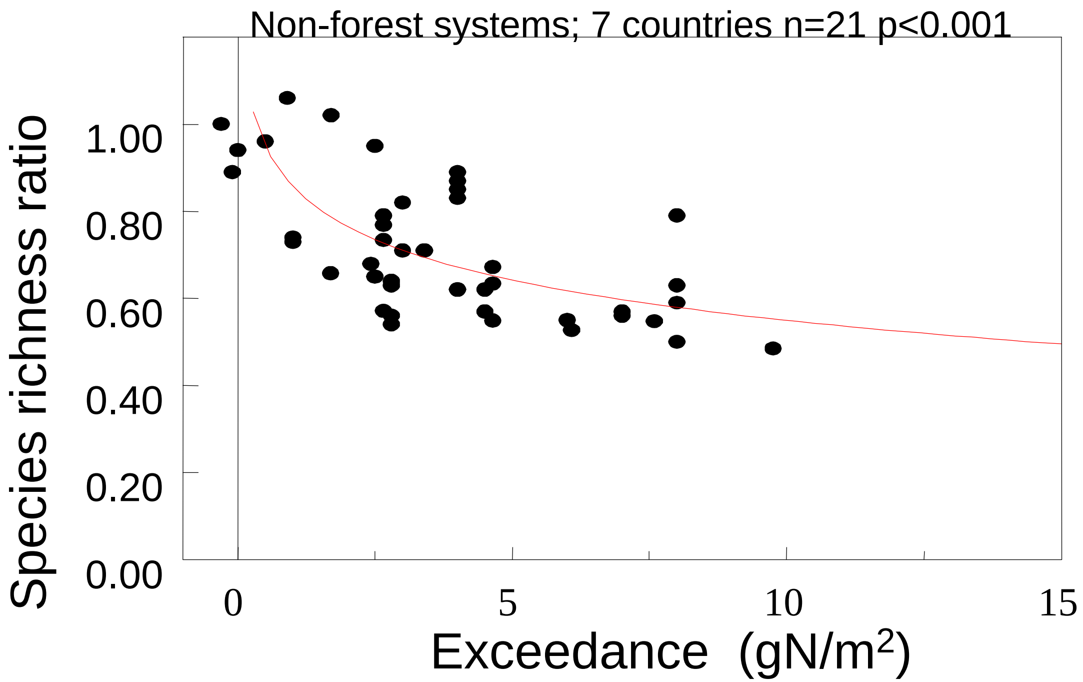




1600 recent recorders. Relative change in comparison to 'average' species for 100 species which shown the greatest change analysed for trends
Changes summarised for 10km square to reduce local sources of variability
2788 10km squares. 1524 taxa

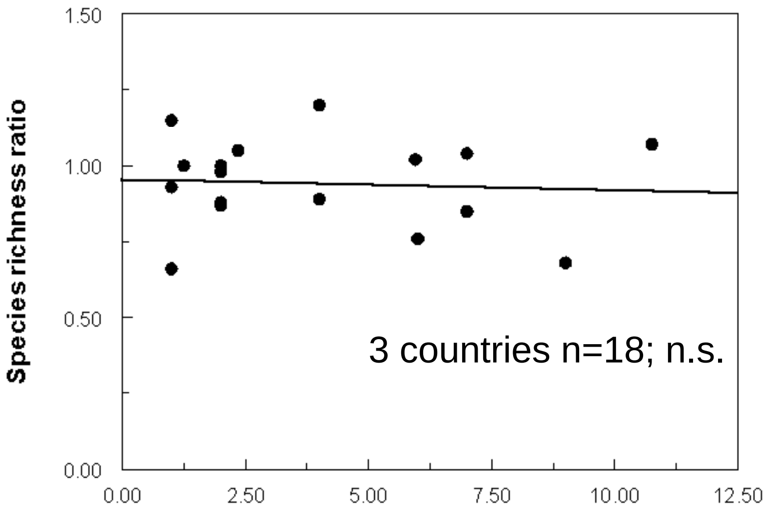
Experimental evidence: Synthesis of N addition studies and impacts on species richness….

(Roland Bobbink, Univ Utrecht, In Prep)

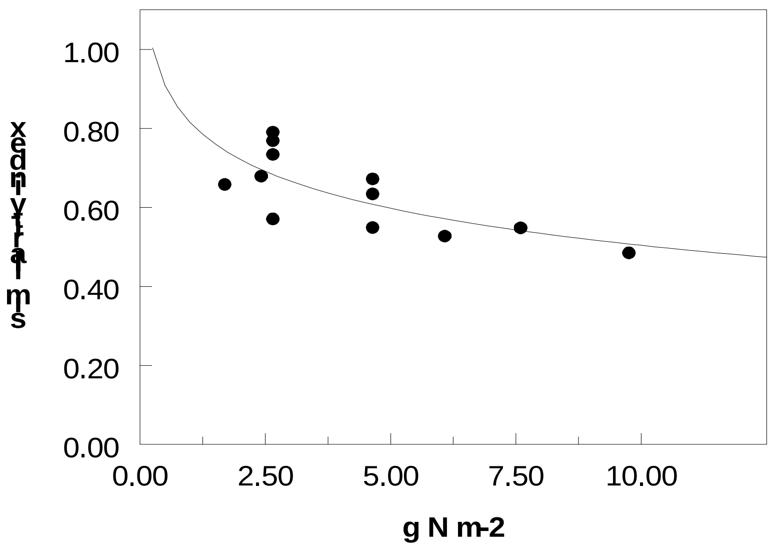


For boreal forests only see the relationship if look at ‘characteristic’ species….

(Roland Bobbink, Univ. Utrecht, In Prep)

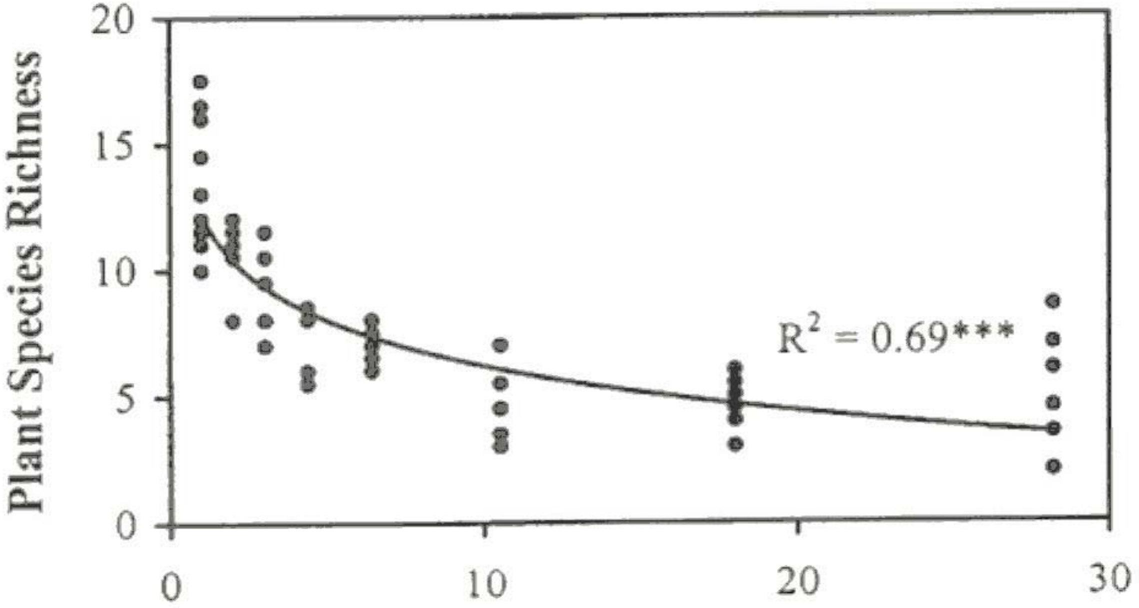


Sweden; 7 locations data by Van Dobben



Similar to pattern was observed in long term USA study

Haddad et al. (2000) Oecologia124:73-84
Abandoned prairie grassland



N addition (gN/m^{2}/yr^{-1}))

UK studies indicate that areas with history of N deposition may have already lost sensitive species

UK long term N addition studies run by:

Simon Caporn, Jackie Carroll (Manchester Metropolitan University),

Sally Power (Imperial College London),

Jonathan Leake, John Lee (University of Sheffield),

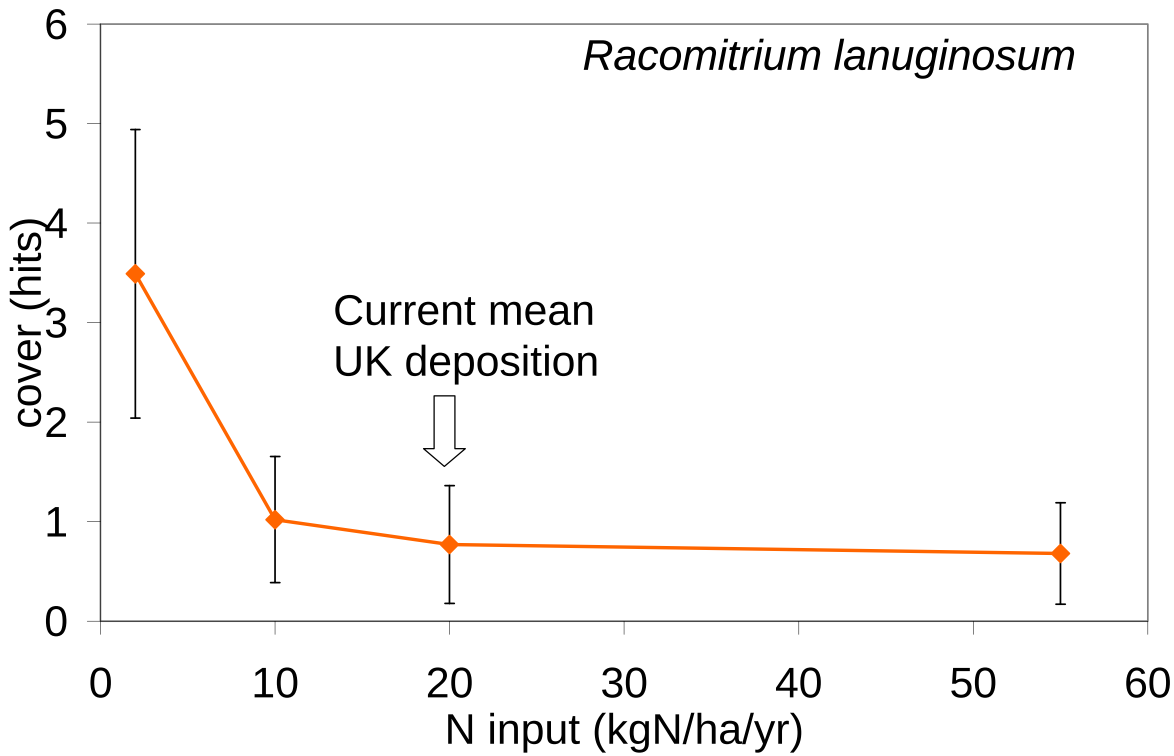
Bridget Emmett (CEH) & John Wildig (ADAS)

www.bangor.ceh.ac.uk/terrestrial-umbrella

Number of higher plant species lost = 0

Nitrogen reduction experiment on acid grassland cores also suggest greatest change at low deposition

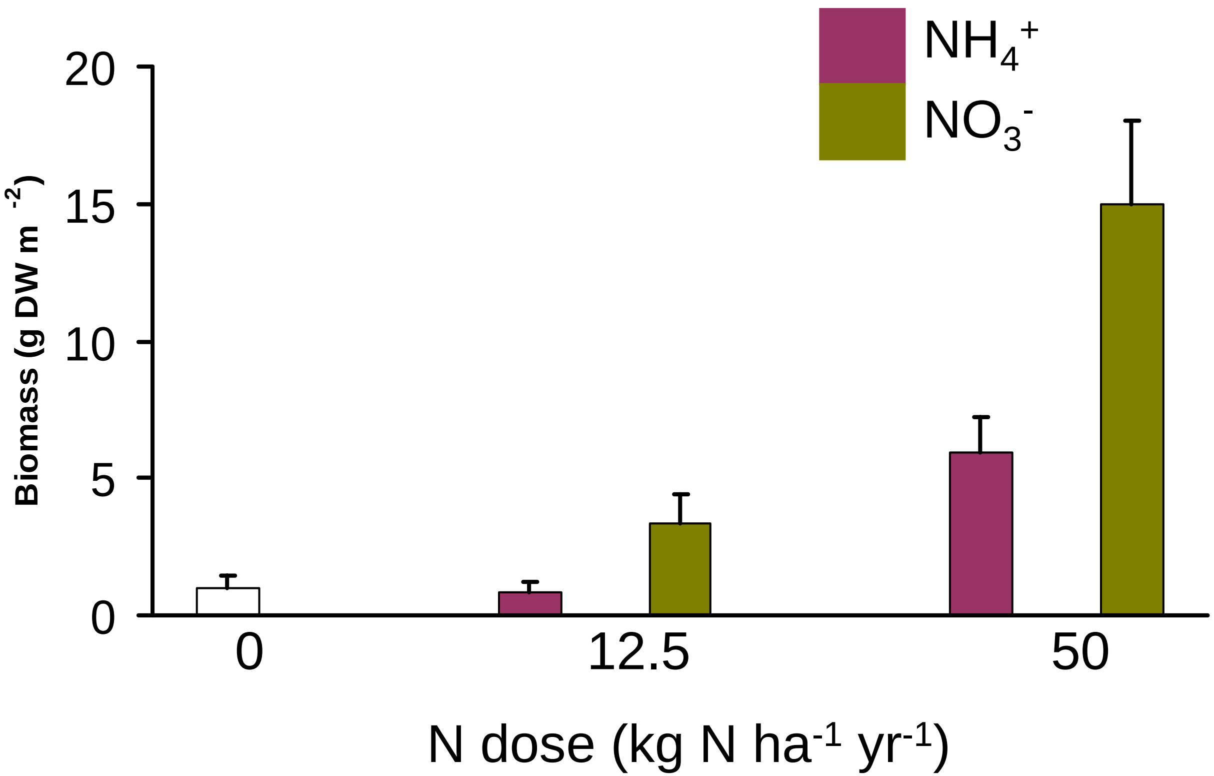
Laurence Jones (2005) CEH Bangor/U Sheffield



N reduction **N addition**

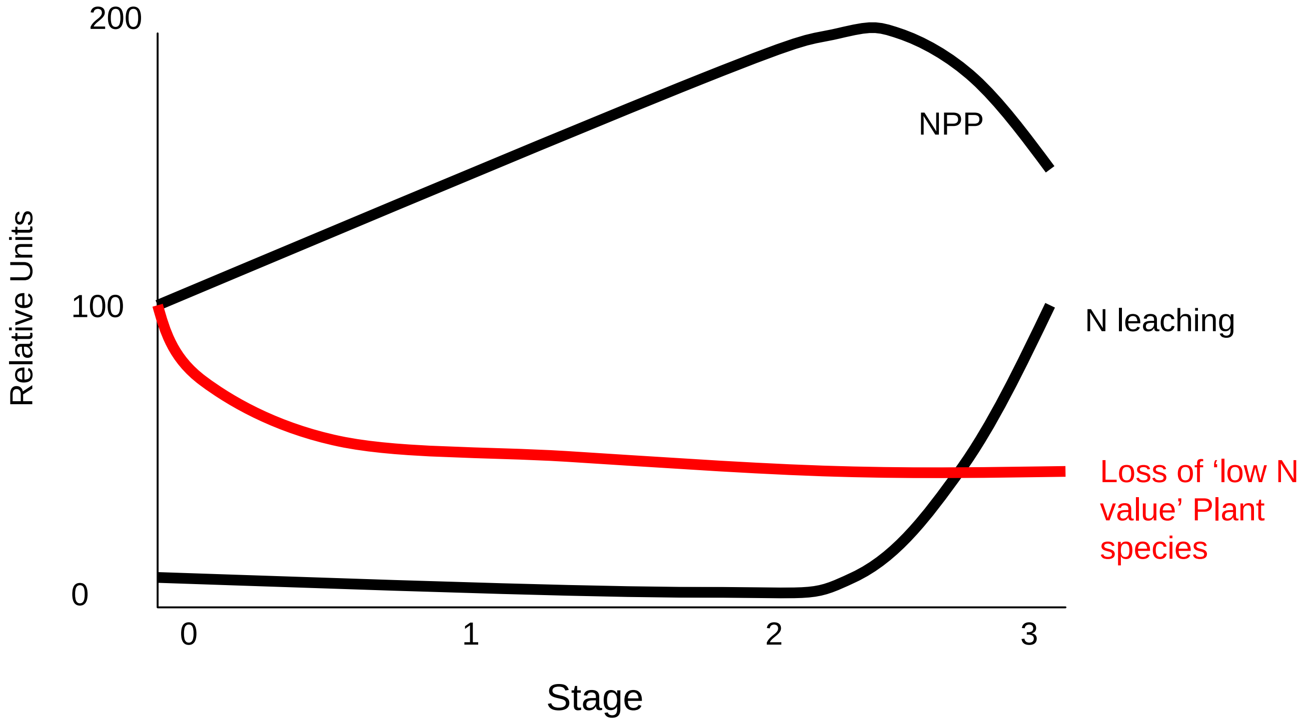
Does form of nitrogen matter? Reduced versus oxidised -N and dry versus wet

One example which is opposite to that normally expected: Biomass of *D. flexuosa* in a four-year N addition experiment to a boreal forest (Nordin et al.Environ Poll. In Press)

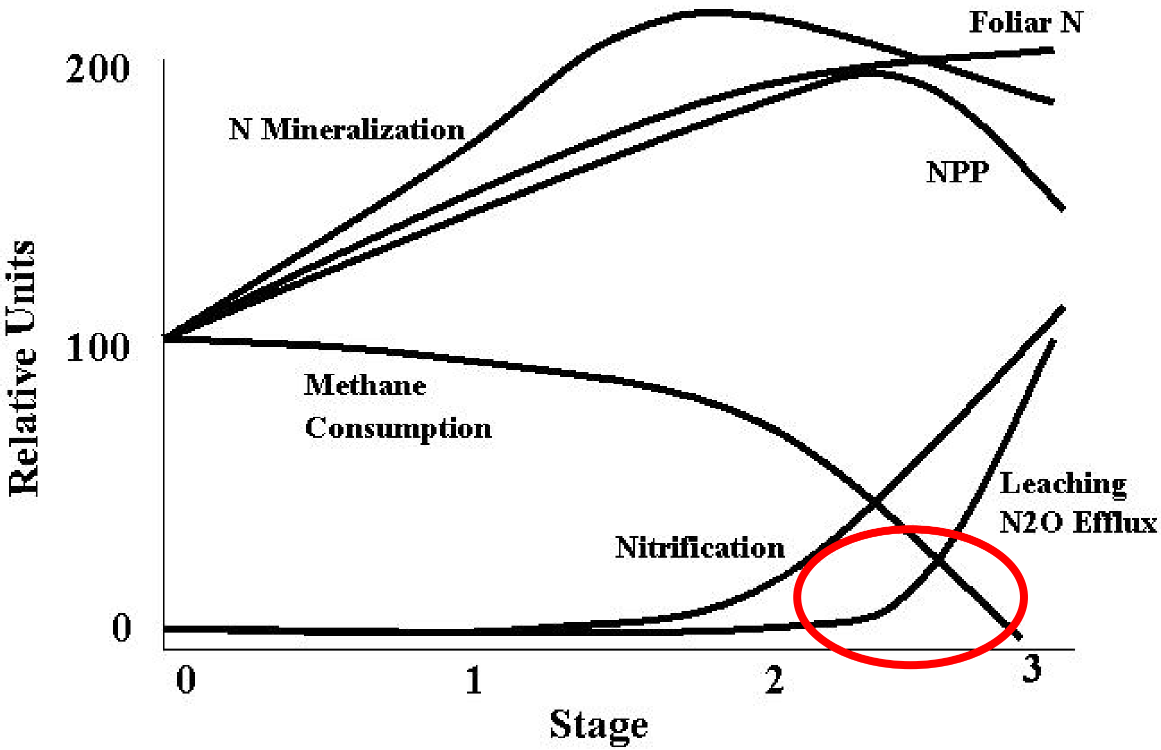


Conclusions (1)

1. Loss of 'low N' plant species occurs early in development of N saturation
2. Rate of species loss declines with N saturation when shifts in dominance observed.
3. We need to identify habitat and species specific responses to N form



2. What evidence do we have for increased nitrate leaching and when does it occur?



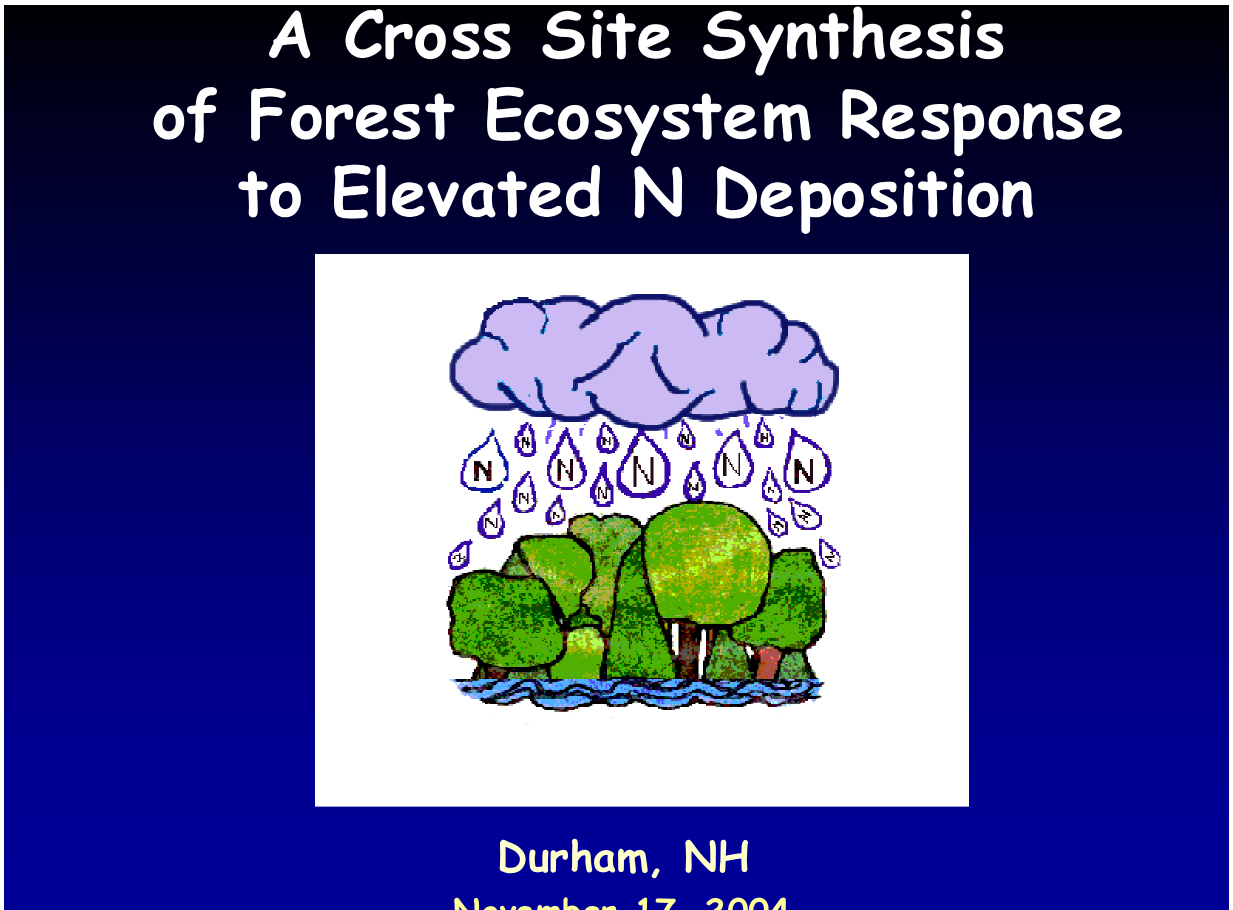
Evidence from long term monitoring

Stoddard et al. 1999 Nature 401:575-578

Table 1 Regional trend

Region	Decade	NO_3^- trend *p*	Slope (μequiv. l^{-1} yr^{-1})
North/central Europe	**1980s**	**0.011**	**+1.3**
	1990s	**≪0.001**	**−2.4**
Nordic countries	**1980s**	**0.002**	**+0.1**
	1990s	0.418	−0.0
Great Britain	1990s	**0.024**	**+0.1**
Maine/Atlantic Canada	1980s	0.829	−0.0
	1990s	0.883	−0.0
Vermont/Quebec	1980s	**<0.001**	**+0.0**
	1990s	0.133	−0.0
South/central Ontario	**1980s**	0.002	+0.0§
	1990s	0.591	−0.0
Adirondack/Catskill mountains	**1980s**	**≪0.001**	**+0.7**‖
	1990s	**≪0.001**	**−2.4**
Midwestern North America	**1980s**	<0.001	+0.1§
	1990s	0.782	−0.0

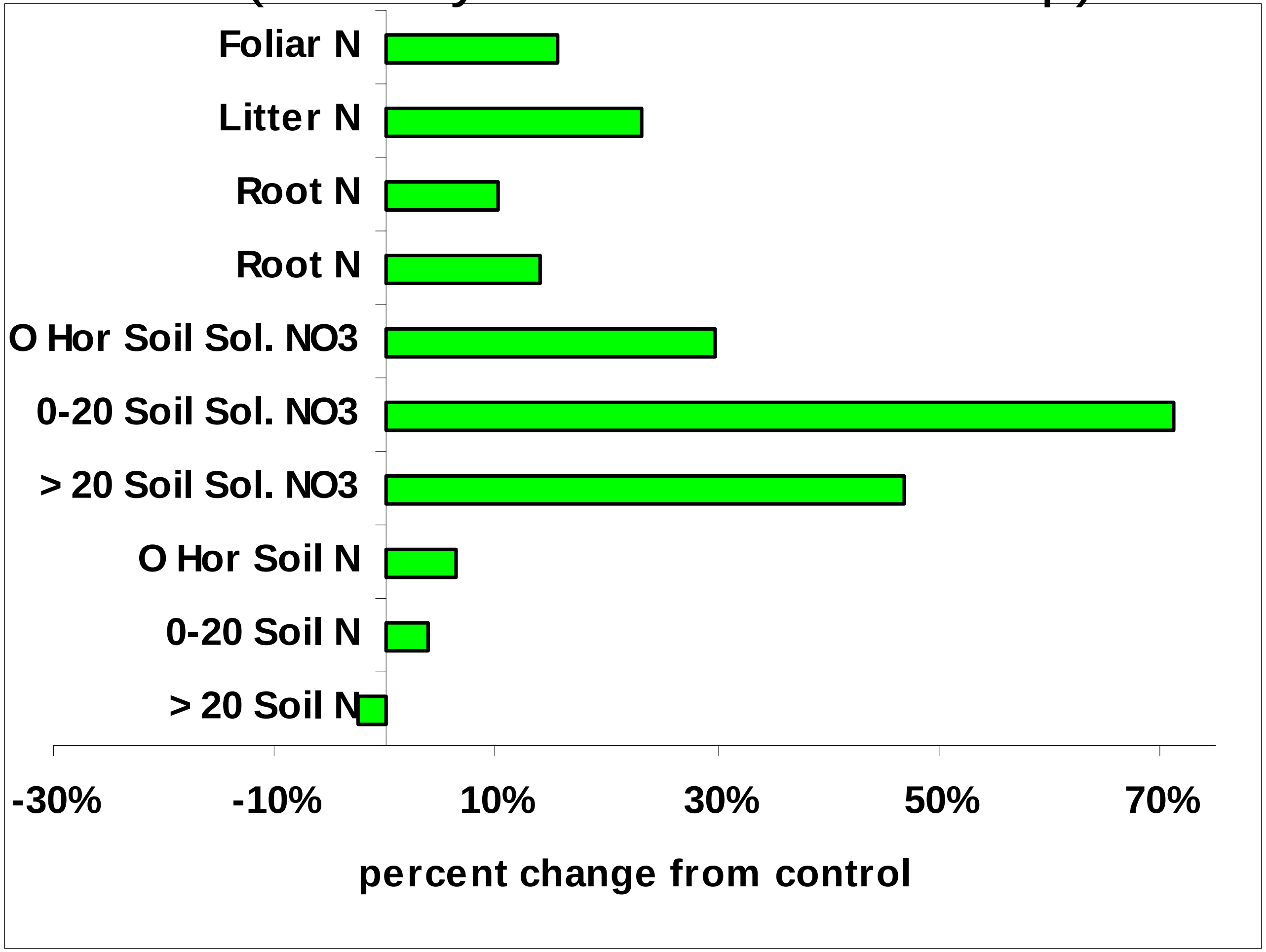
Experiments: Large amount of information for forests (Lindsay Rustad et al. In Prep)



 # experiments = 57
 # sites = 34
 # countries = 10

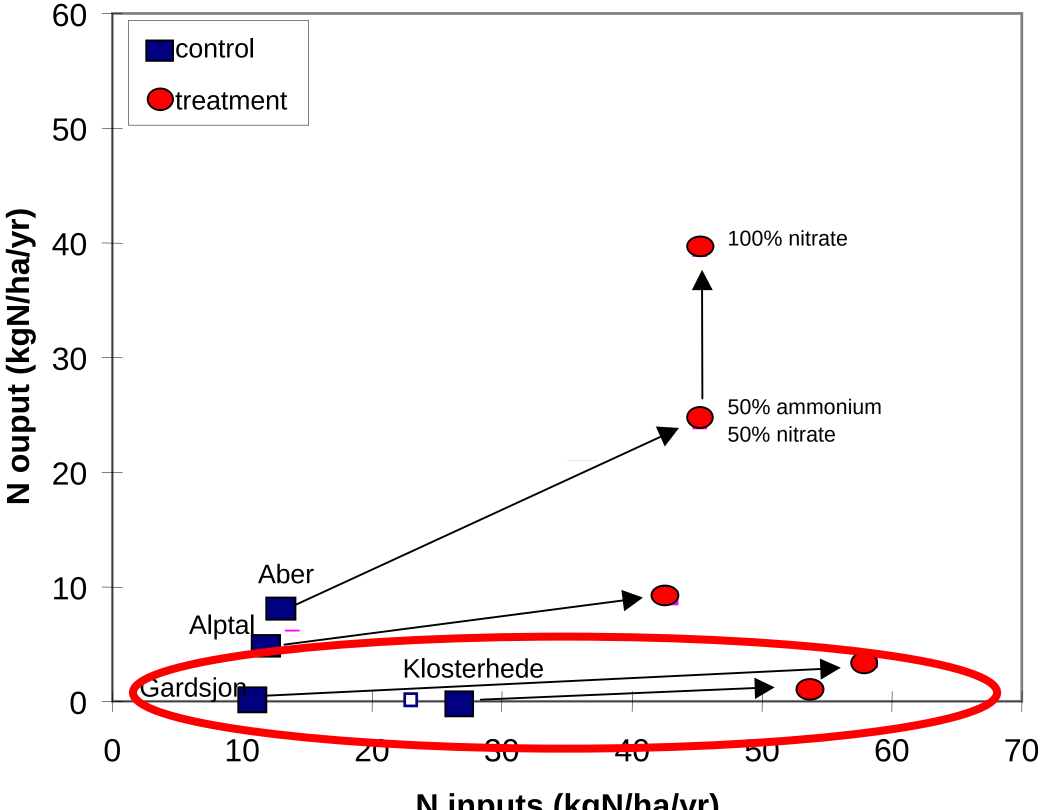
Soil water nitrate is one of the most responsive ecosystem compartments

(Lindsay Rustad et al. In Prep)



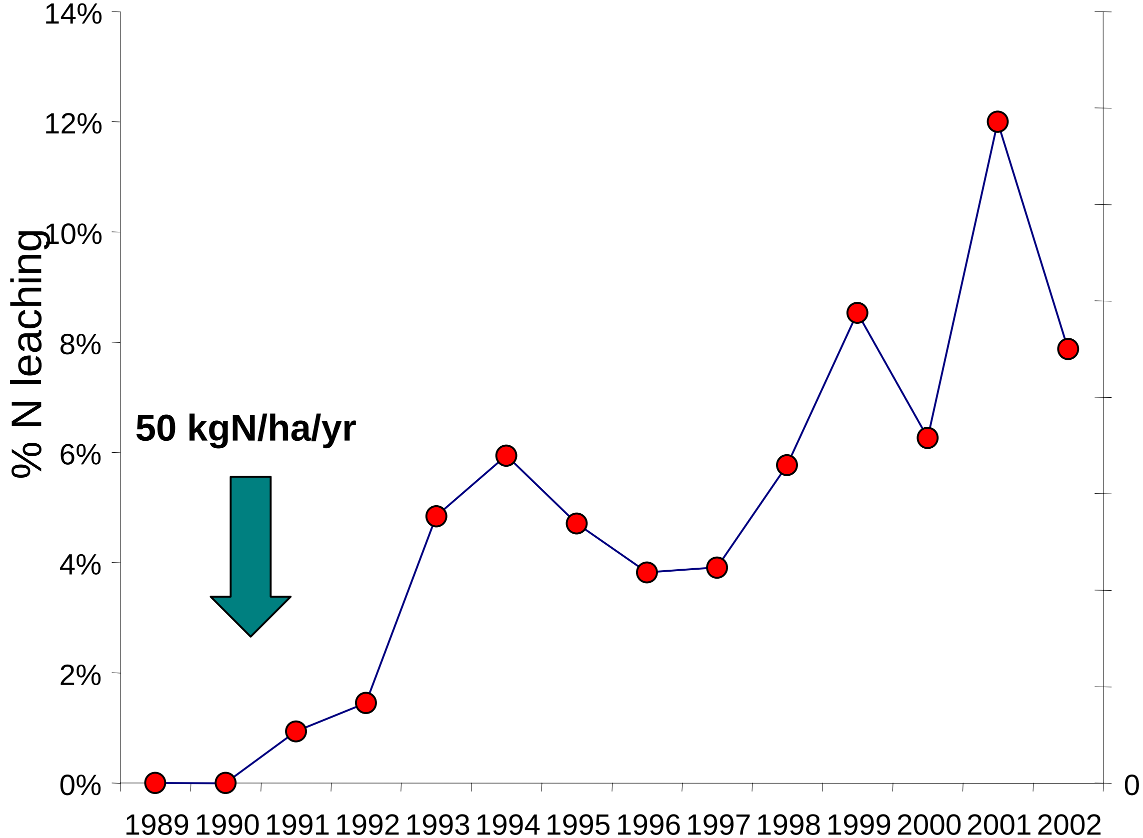
Magnitude of change versus timing?

Response in N output in NITREX N addition sites after 4 - 5 years (Emmett et al. 1998 Ecosystems 1:352-360)



Small magnitude but quick response at Gårdsjön - suggests sensitive but subtle indicator

Filip Moldan (IVL, Sweden) et al., In Press, Environ Pollut



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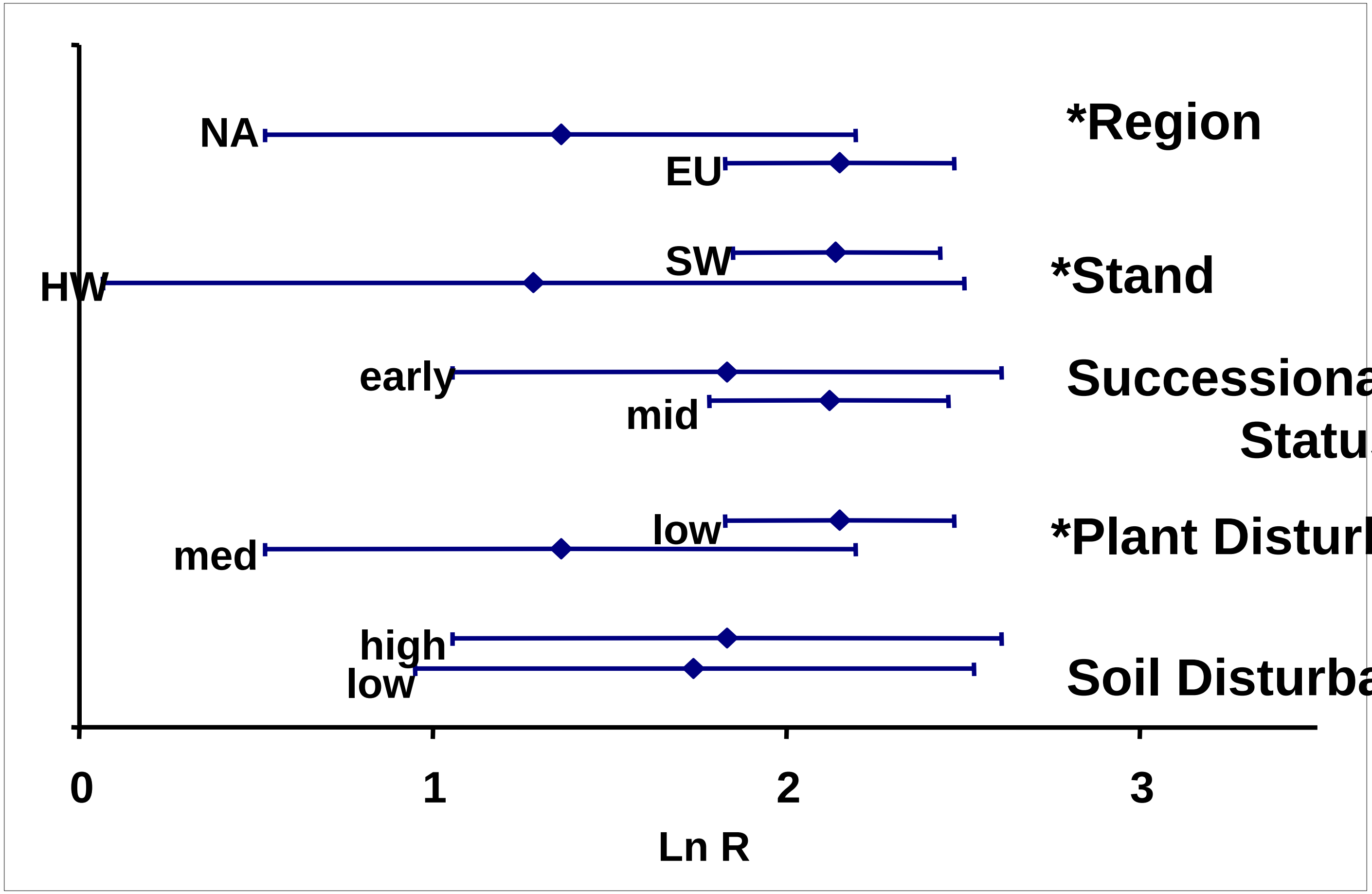
Range of factors affected the sensitivity of soil water nitrate response

(Lindsay Rustad et al. In Prep)

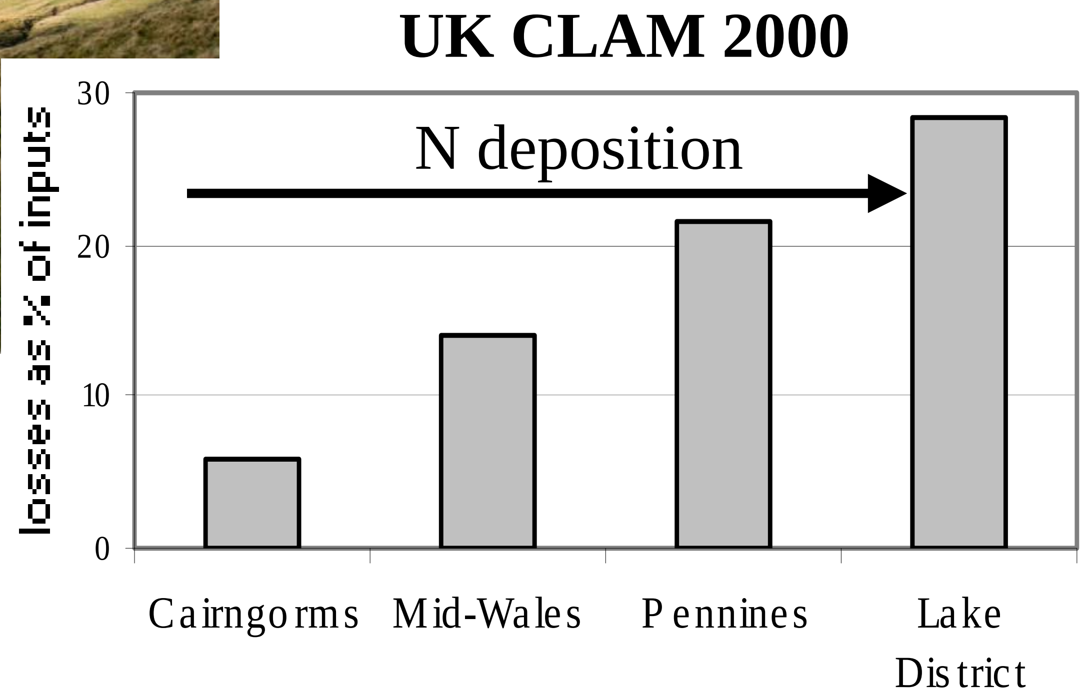


These also affect response of other indicators such as foliar N...

(Lindsay Rustad et al. In Prep)

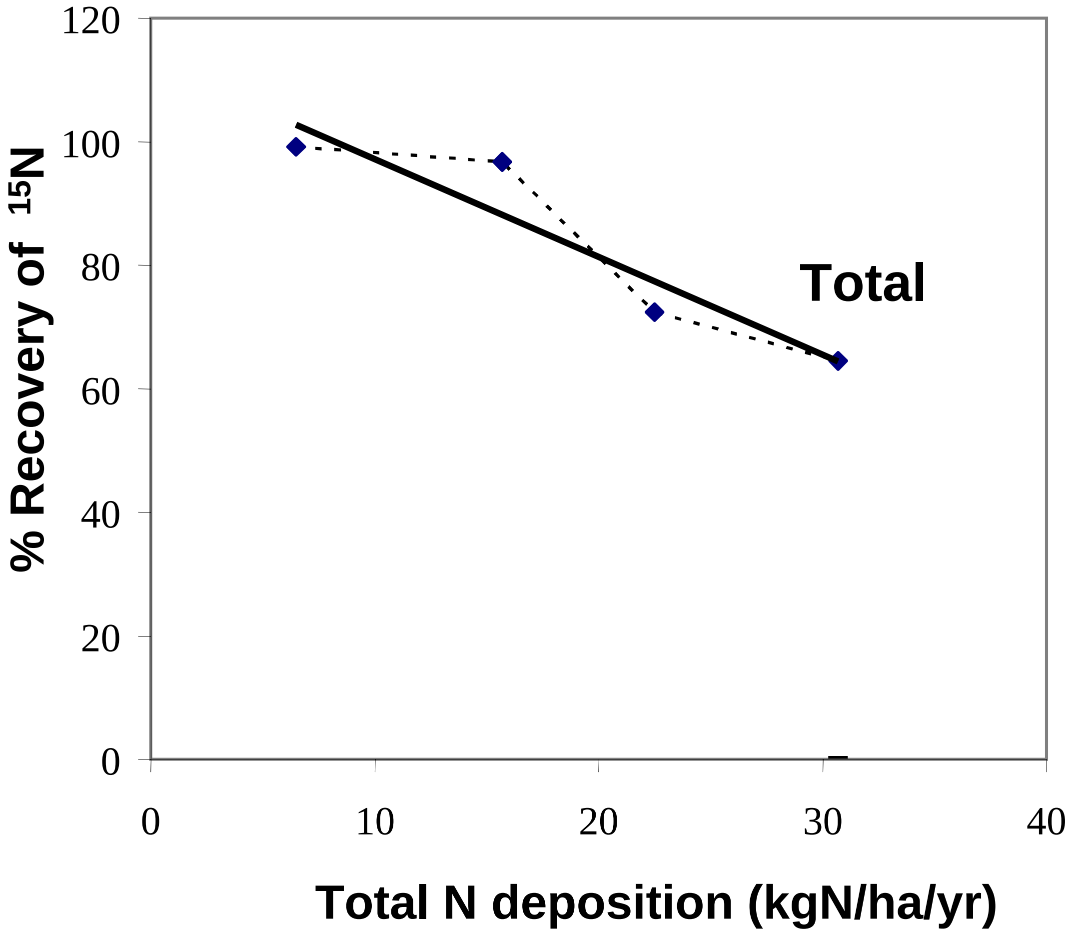
		Foliar N	Litter N	O Hor Root N	Mineral Hor Root N	O Hor Soil Sol. NO3	Mineral Hor Soil Sol. NO3	O Hor Soil N
	# studies	32	15	14	11	4	9	17
	exp(E++)	1.2337	1.4830	1.0618	1.1853	4.0931	7.5368	1.1129
Site Factors	Lat	-	+	ns	ns	-	+	+
	Long	+	-	ns	ns	-	-	-
	Elev	+	-	ns	-	+	-	-
Climate	MAT	-	-	ns	+	-	-	ns
	MAP	-	-	ns	+	-	-	-
Internal N Status	N Dep	-	-	ns	+	+	ns	ns
	O Hor C/N	+	+	ns	+	-	+	+
	Min Hor C/N	+	+	+	-	+	-	+
N TRT	TRT N	+	+	ns	+	-	+	+
	CUMUL. N INPUT	+	+	ns	+	-	+	+

Nitrate leaching is not just an issue for forests systems….



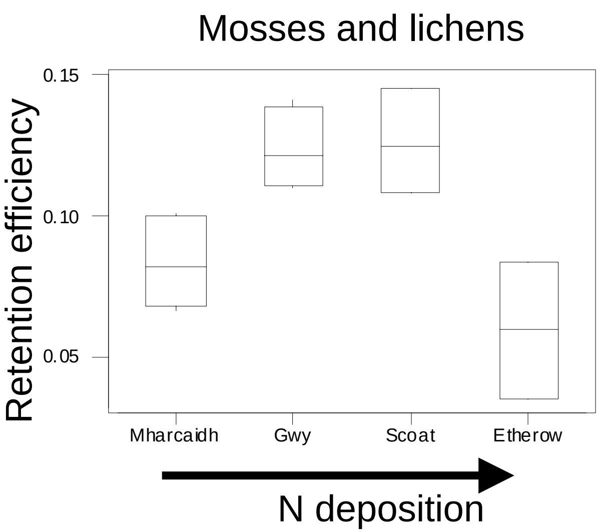
^{15}N was used to examine reasons for this increase in nitrate leaching losses in non-forest systems

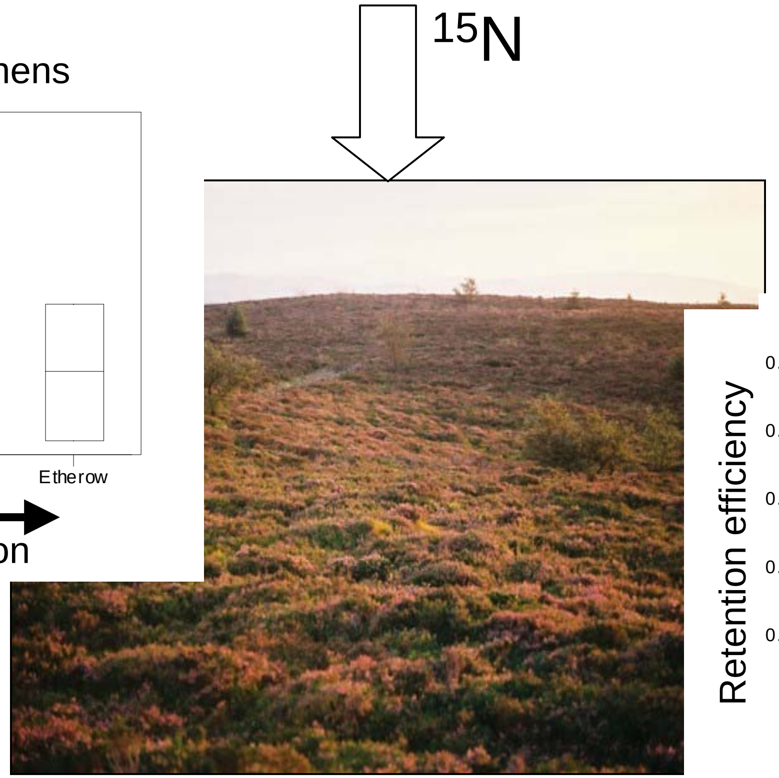
(Curtis et al. (2005) J Appl Ecol)

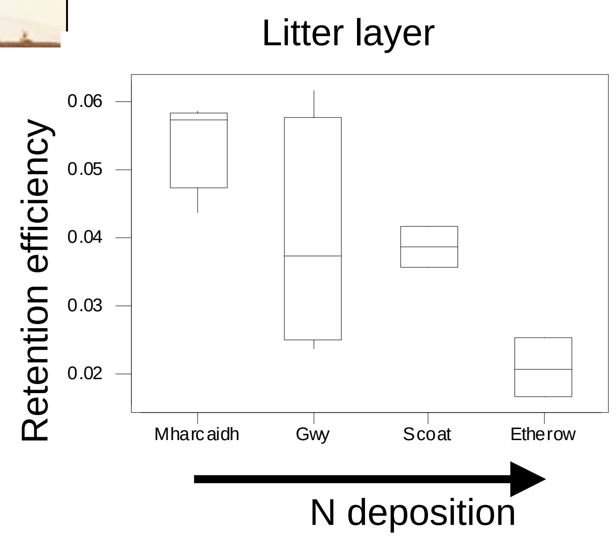


Changes in retention efficiency of vegetation and soils observed

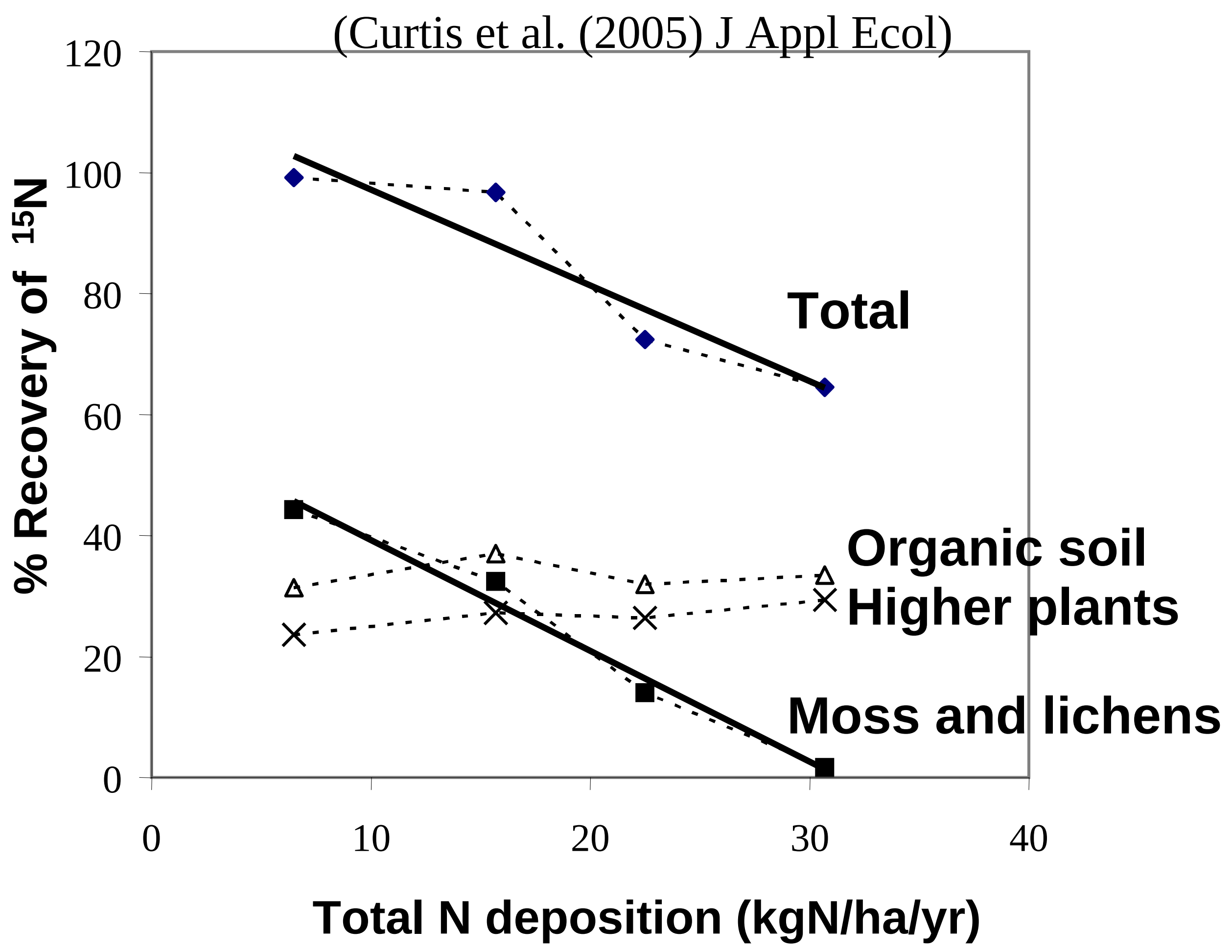
(Curtis et al. 2005, J Appl Ecol)







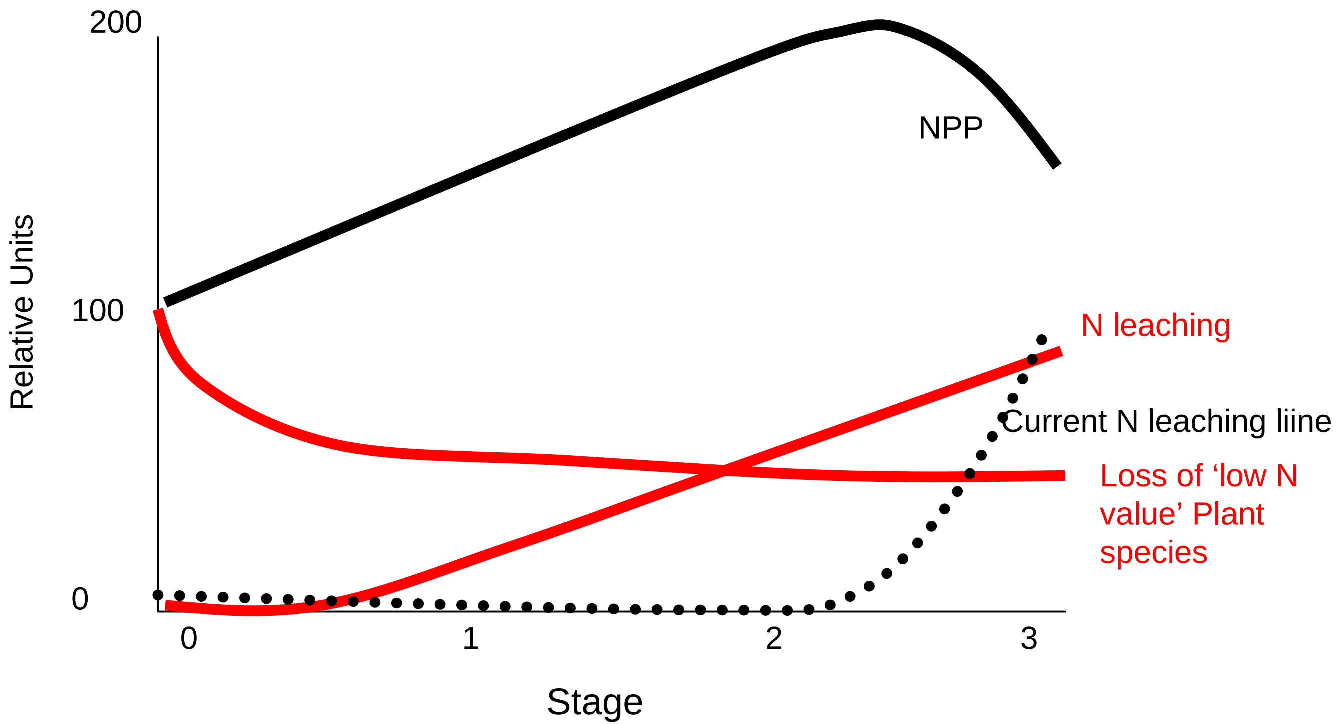
Main cause of reduced ^{15}N retention appeared to be the loss of mosses and lichens



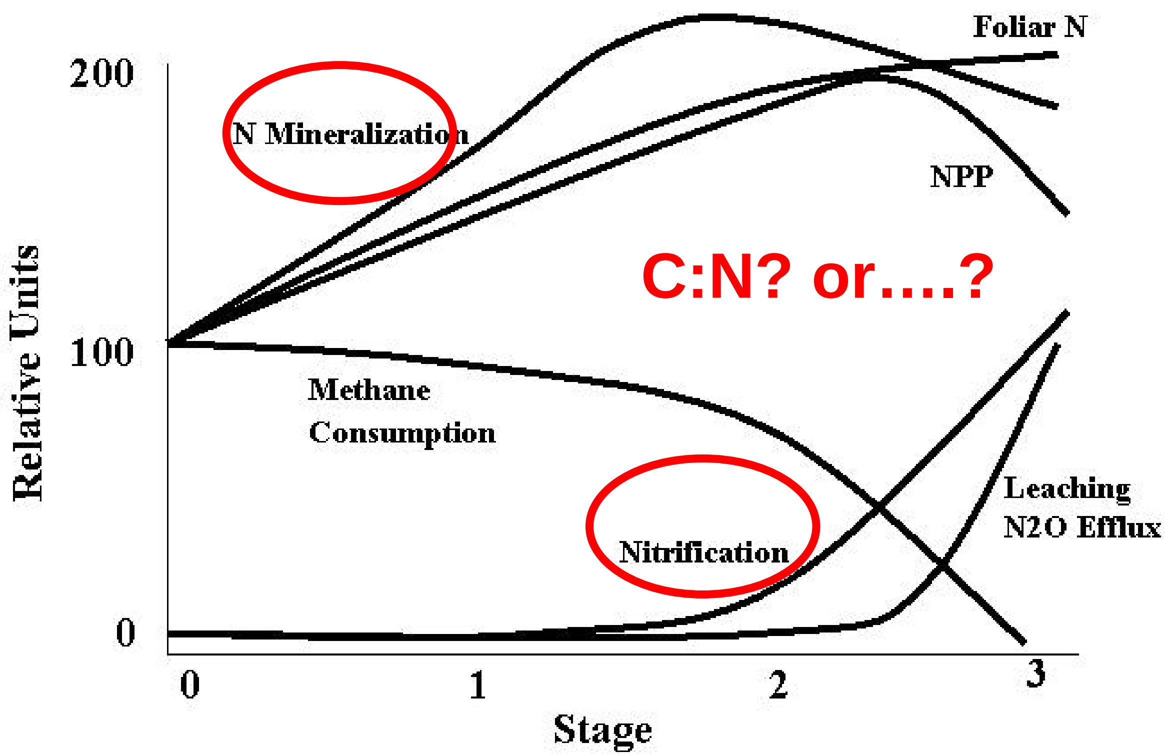
Conclusions

1. Nitrate leaching is one of the most sensitive ecosystem compartments to N addition but there are many confounding factors

2. Loss of lower plants may contribute to onset of nitrate leaching in some systems

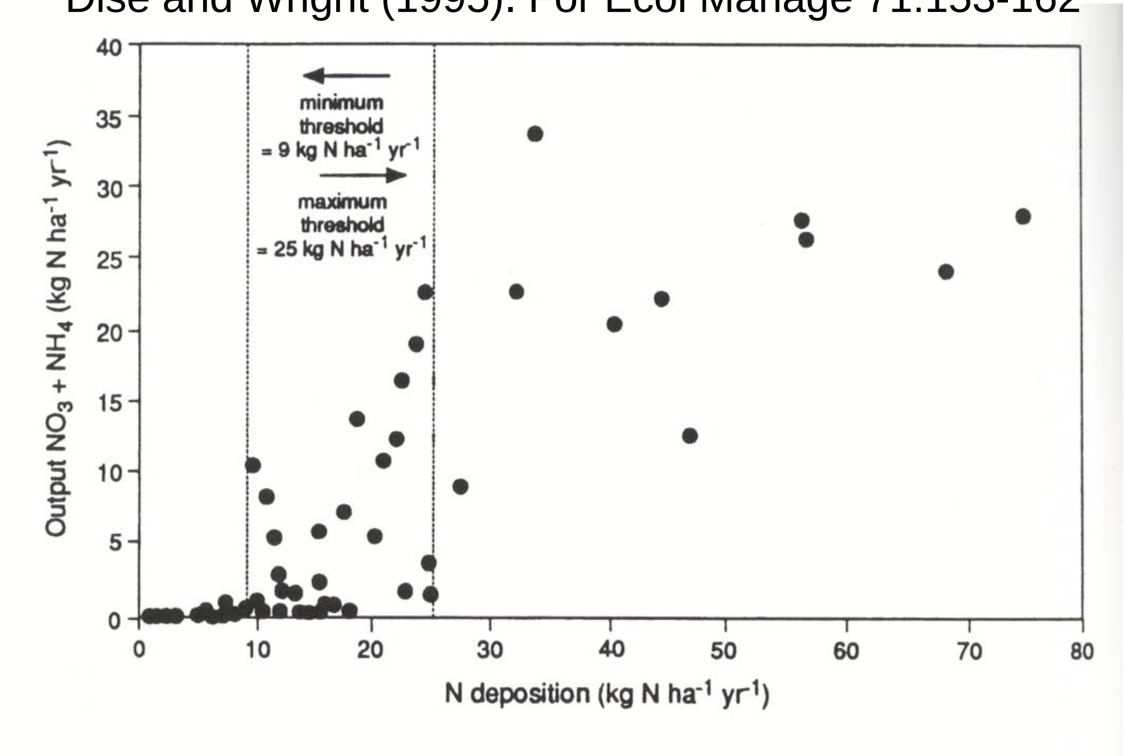


3. What are the best indicators of ecosystem N status and what should drive our models?



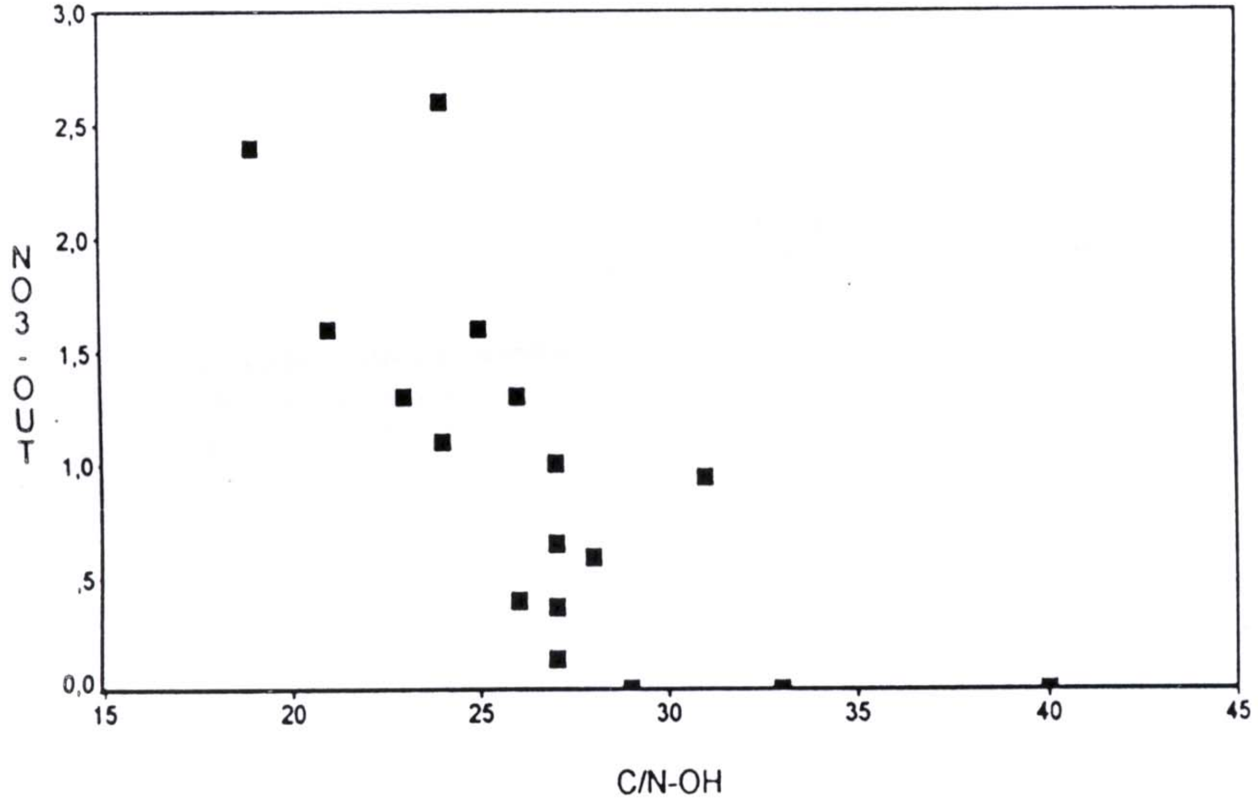
Deposition is the best predictor of nitrate leaching across regions

Dise and Wright (1995). For Ecol Manage 71:153-162



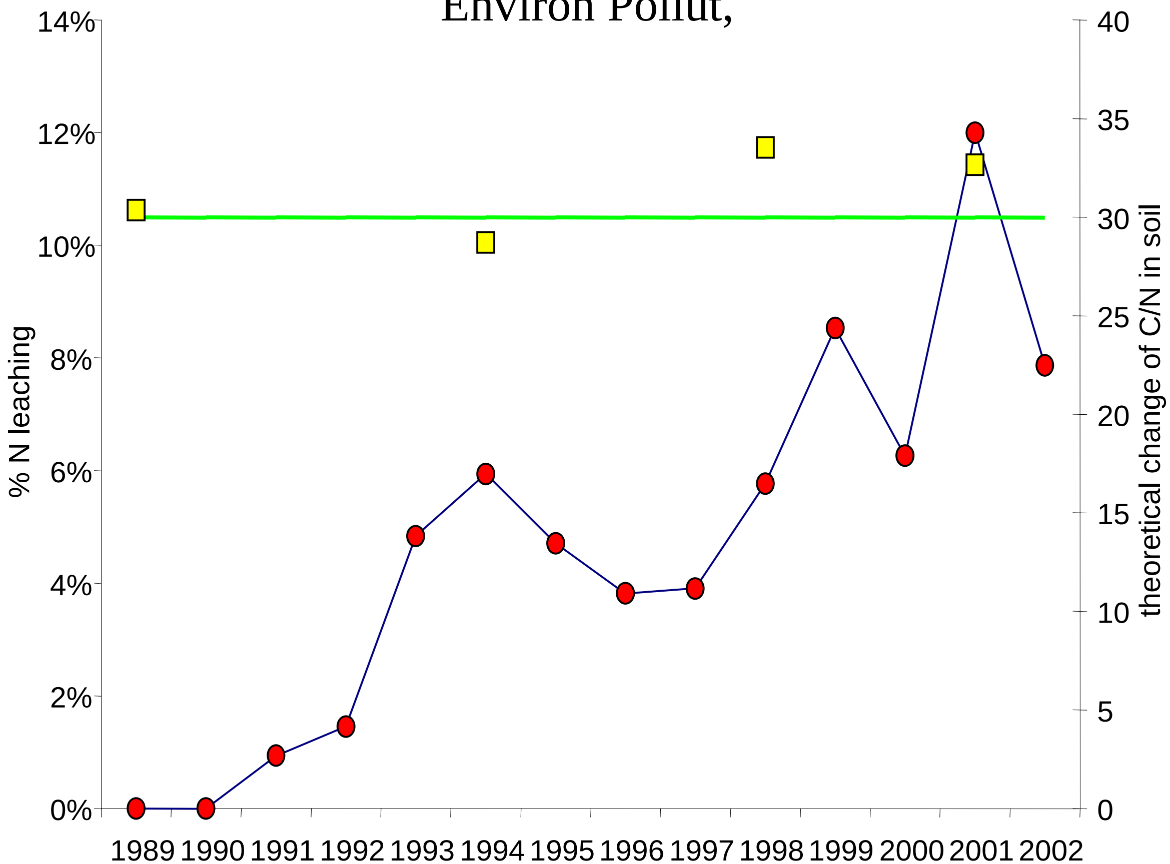
C:N can help explain some of the vaiability

Matzner and Grosholz (1997) Forstw. Cbl. 116:39-44



But nitrate can increase with no change in soil C/N

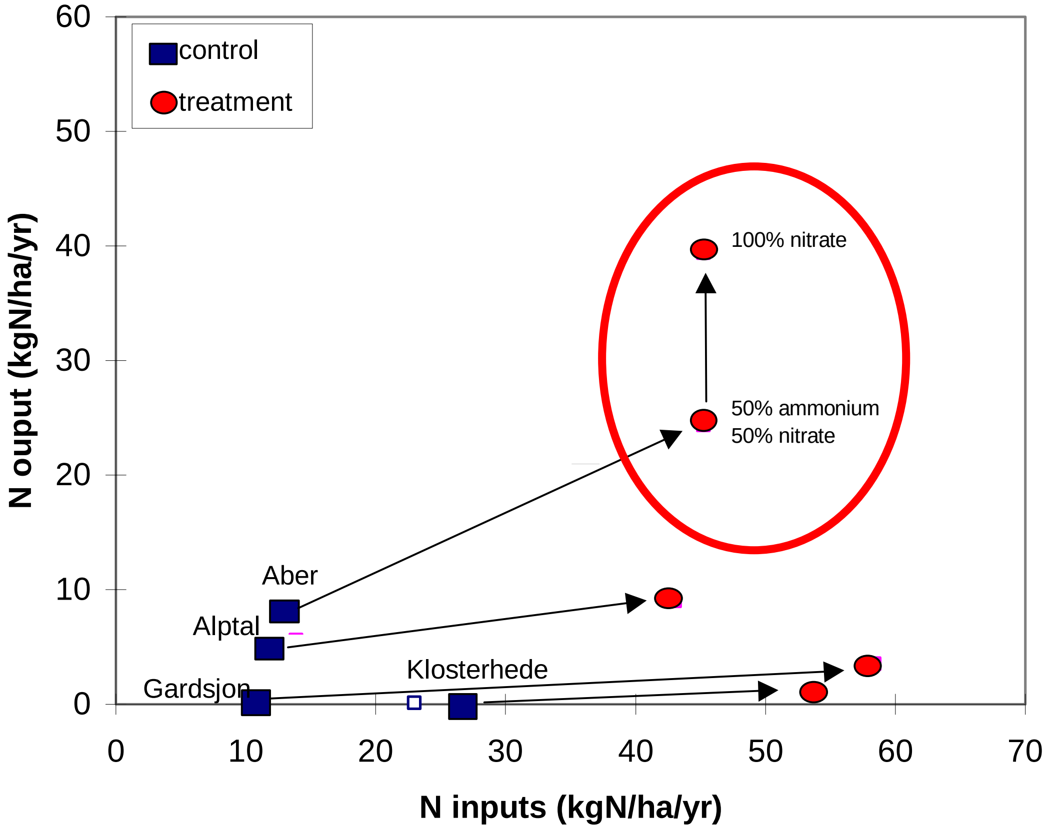
Gardsjon forest, Filip Moldan (IVL) et al. In press, Environ Pollut,



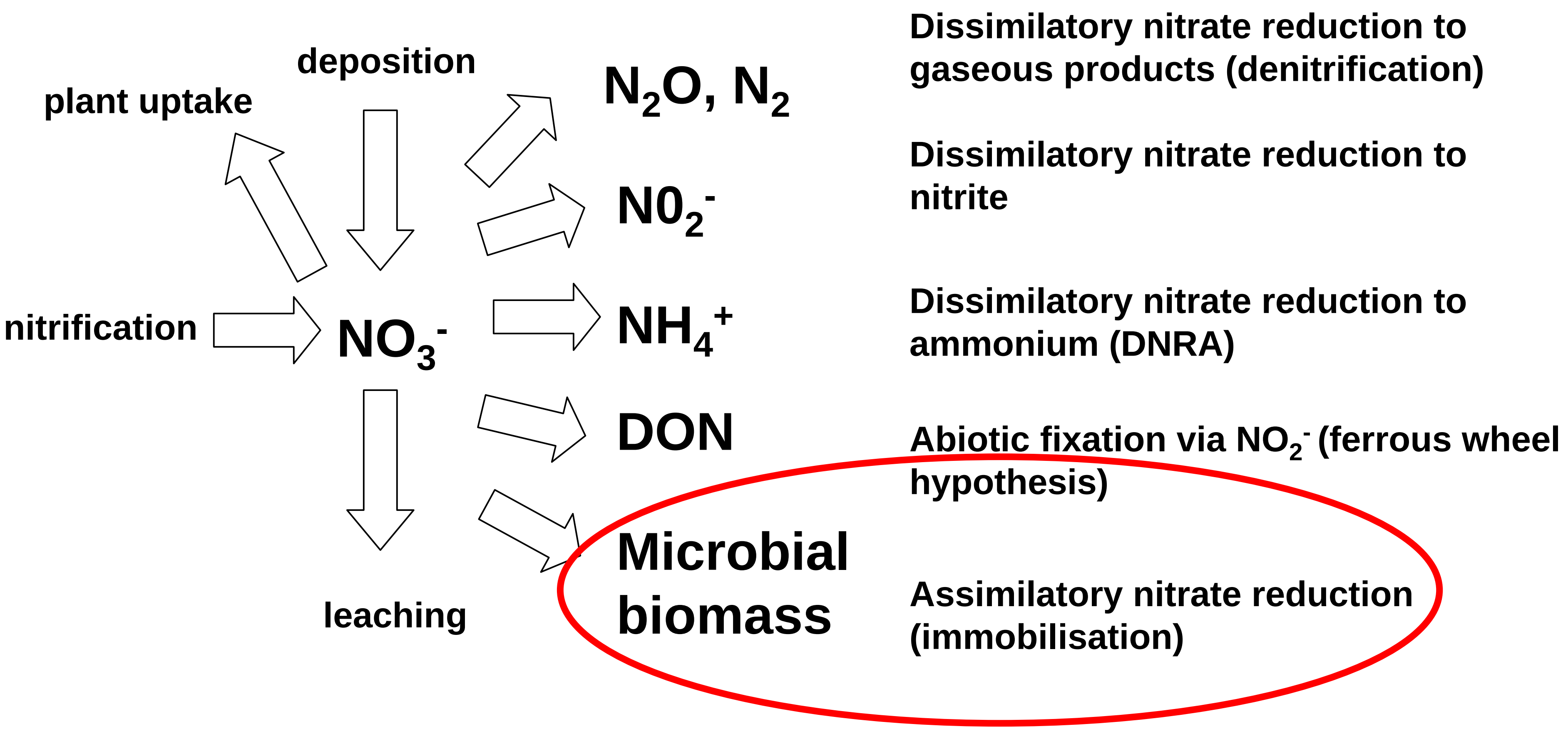
Source of the leached nitrate in early stages is recently deposited nitrate

Response in N output in NITREX N addition sites after 4 - 5 years

(Emmett et al. 1998 Ecosystems 1:352-360)



Fate of nitrate in terrestrial systems



Suppression of nitrate immobilisation by ammonium (no effect of carbon)

Bradley 2001. Ecology Letters 4:412-416

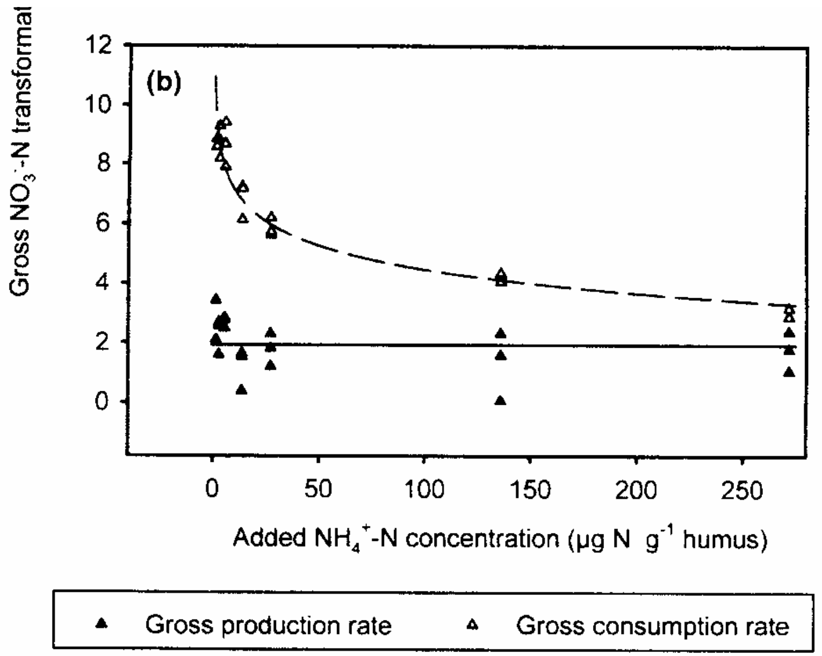
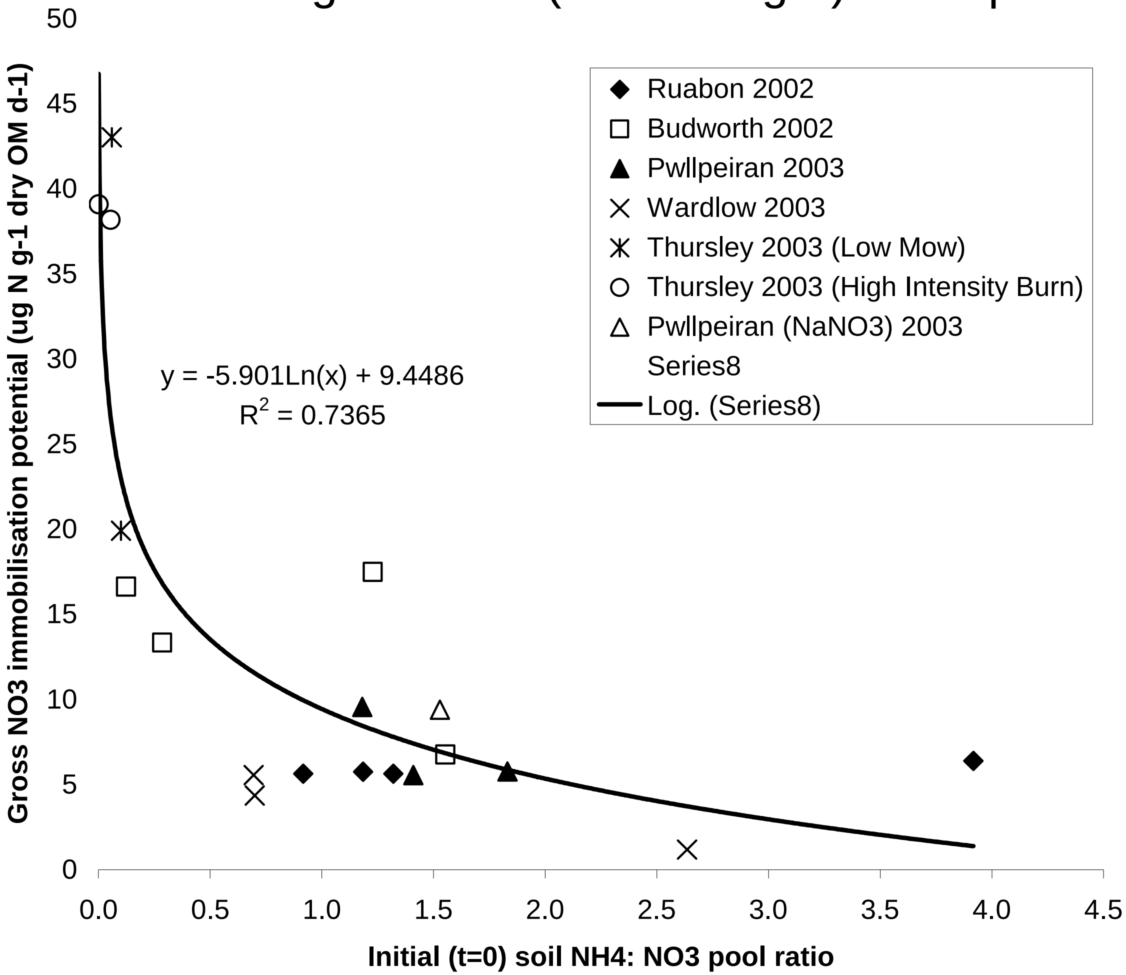


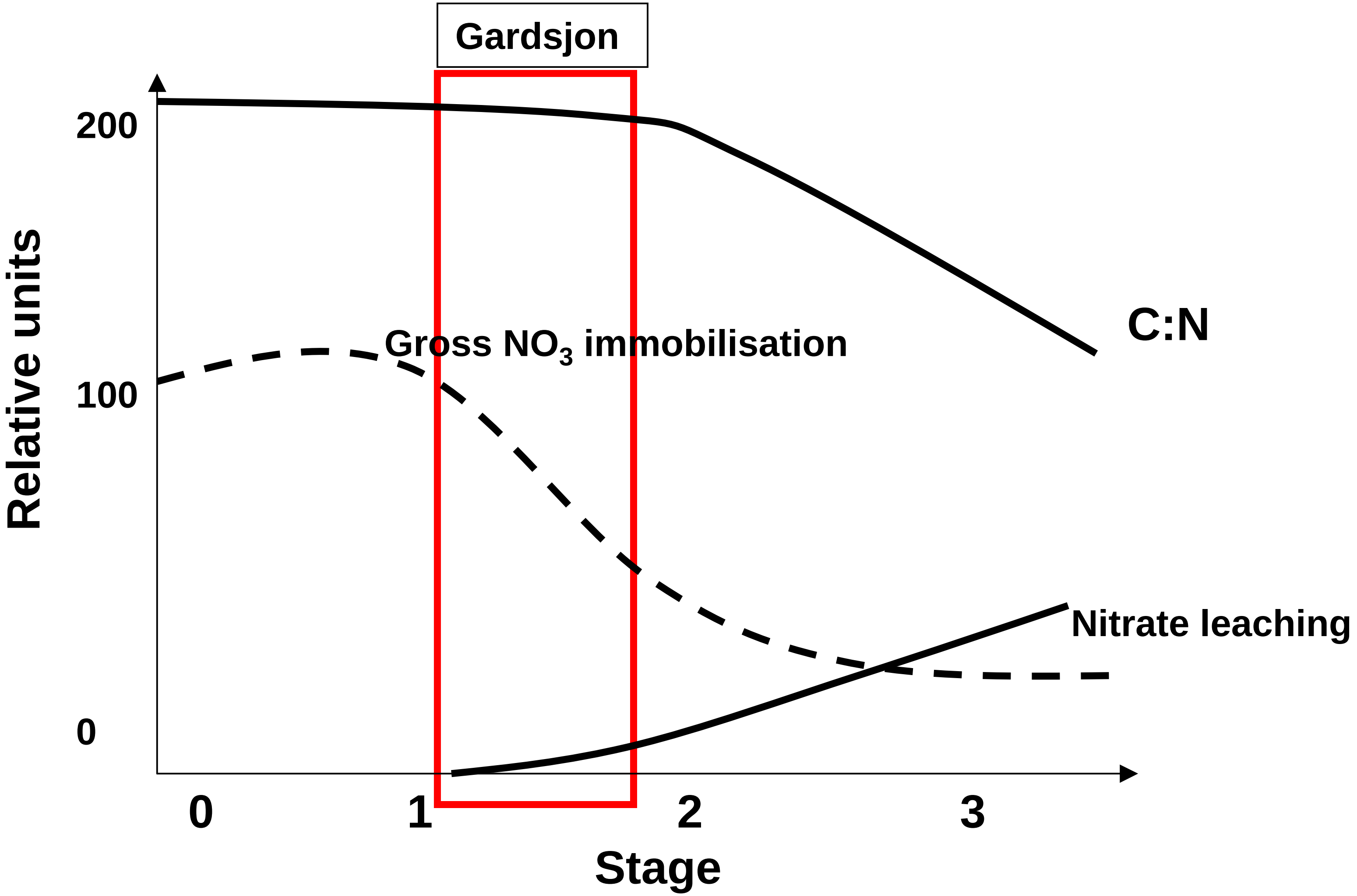
Figure 1 Response of gross NO_3^- production and consumption rates to incremental rates of glucose-C amendments (note log scale) (A) and NH_4^+ amendments (B); some data points overlap.

$NH_4:NO_3$ may provide indicator of change of microbial immobilisation of nitrate

S.Hughes et al. (CEH Bangor) In Prep



High NH_4/NO_3 ratios result in nitrate leaching without a change in C:N due to reduction in microbial uptake. C:N still useful indicator to identify difference between early and late stages.

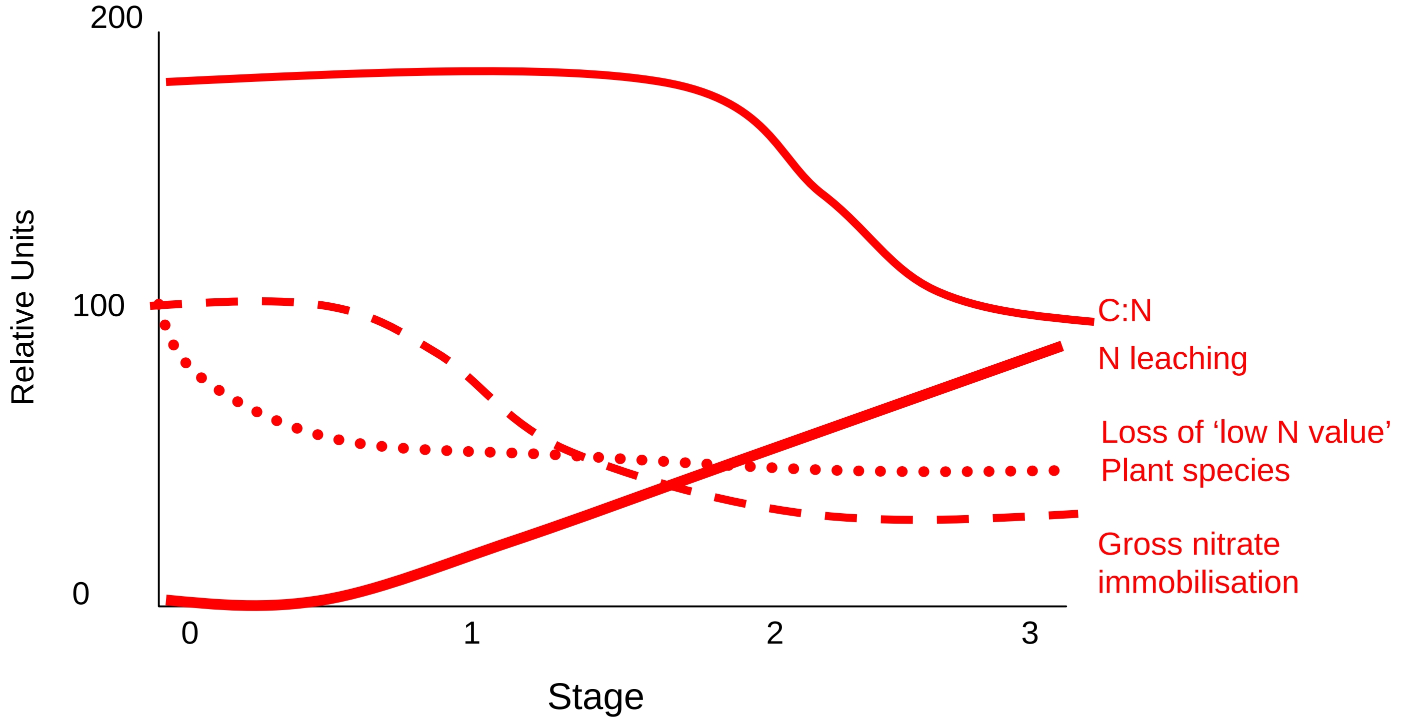


Conclusions (3)

1. Reduced nitrate immobilisation may be the cause of the onset of nitrate leaching

2. This can occur before any change in soil C:N

3. Combination of deposition, soil C/N, total soil C store and soil NH_4/NO_3 may be useful as best predictor/indicator



Where next for nitrogen research?

- **Ammonia!**
- **Development of models to link biogeochemistry with biodiversity which needs...**
- **Integrated national monitoring of vegetation, soils and water**
- **Interactions with other drivers (climate, land management, ozone)**
- **Impacts on biodiversity in aquatic systems (freshwater and marine)**
- **Contribution to greenhouse gas emissions and carbon sink**

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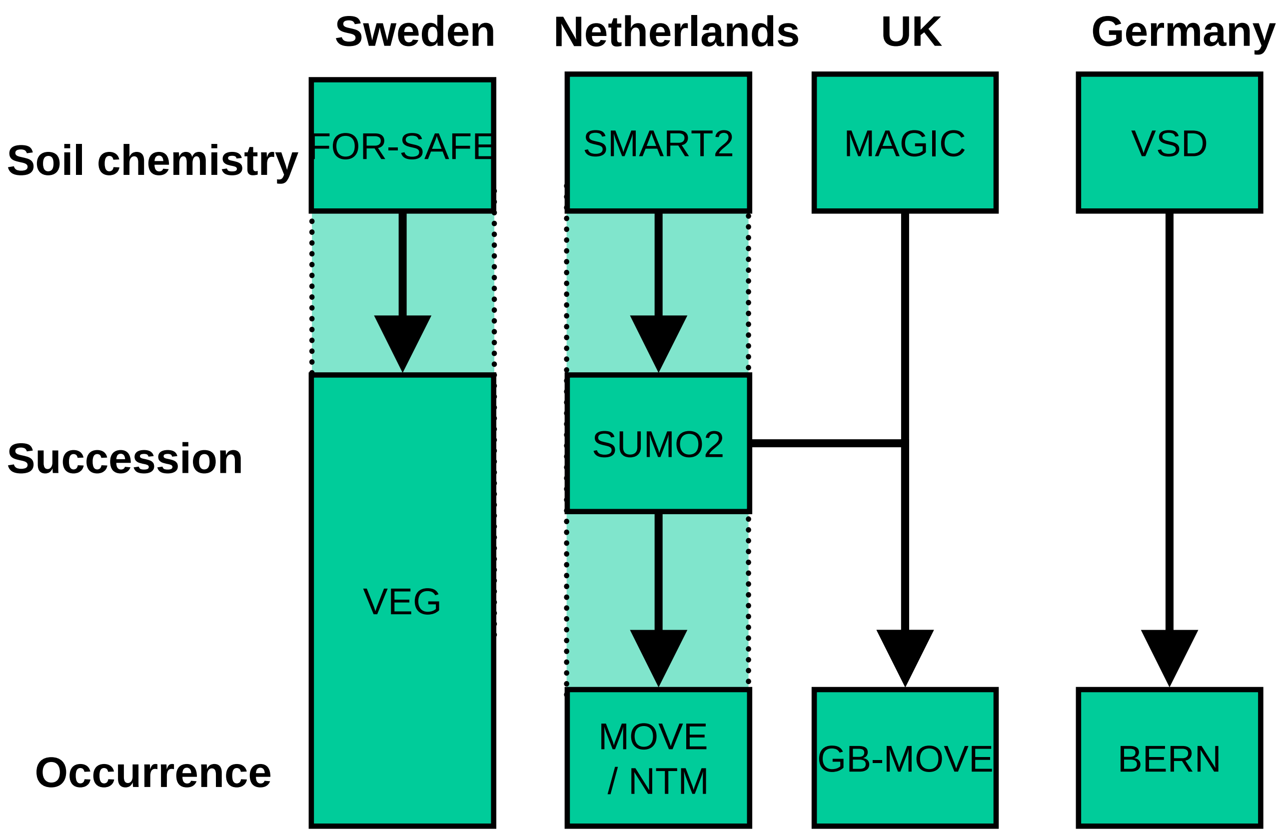
WGE Joint Expert Group on Dynamic Modelling: Workshop on Nitrogen Modelling

Brighton, UK 25-27th Oct 2005

Review of model chains for predicting N effects on biodiversity
(Rowe et al. 2005: contact ecro@ceh.ac.uk for copy)

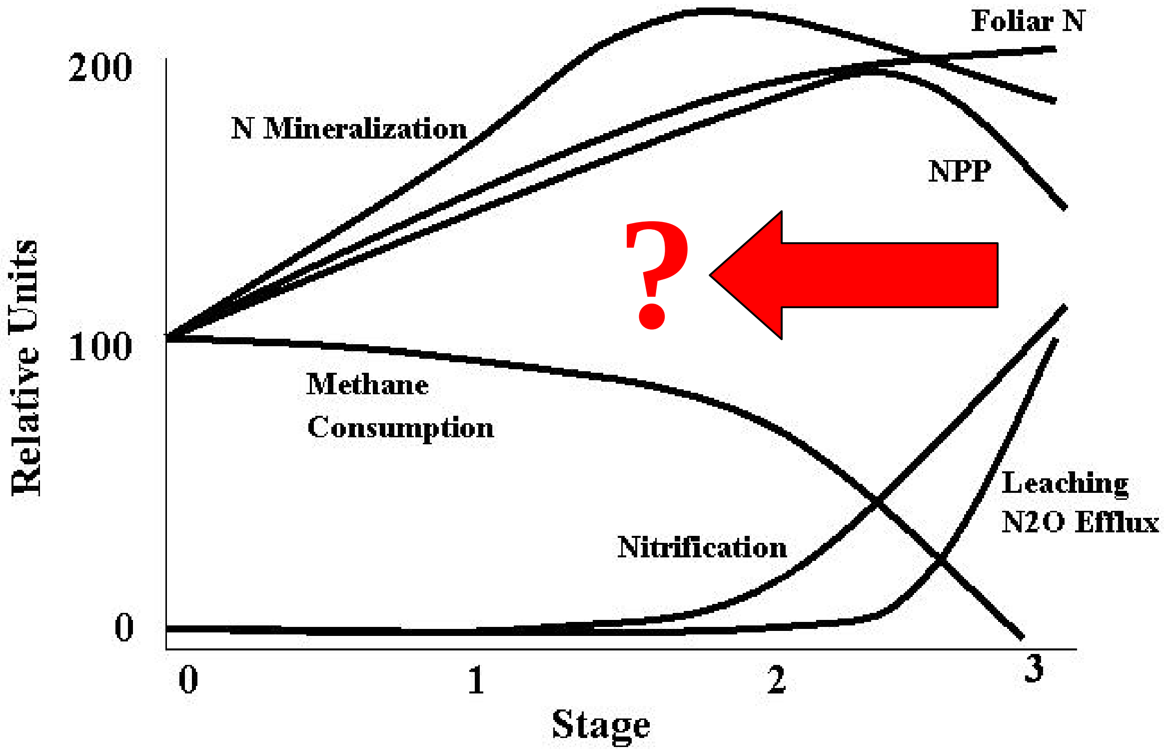


Most use linked vegetation/soil calibration datasets - we need more!

	Calibration relevés			Number of species / communities with derived models			
Model	**Number**	**Location**	**Habitats**	**Vascular plants**	**Bryo-phytes**	**Lichens**	**Communities**
VEG	*	Sweden	Various	5			41
MOVE	ca. 100000	Nether-lands	Various	900†	-	-	-
NTM3	33706	Nether-lands	Various	-	-	-	††
GBMOVE	32483	UK	Various	1046	233	74	-
BERN	5218	N German lowlands and hilly area	Forest, extensive grassland, pasture, heath, bog	720*	-	-	674

* Based on an unspecified number of published studies and empirical observations
† Vascular plants and bryophytes not distinguished
†† Any number of communities, provided at least 50 relevés are available

Finally, recovery is the future (we hope) - what are the dynamics and endpoint of recovery?



Thank you