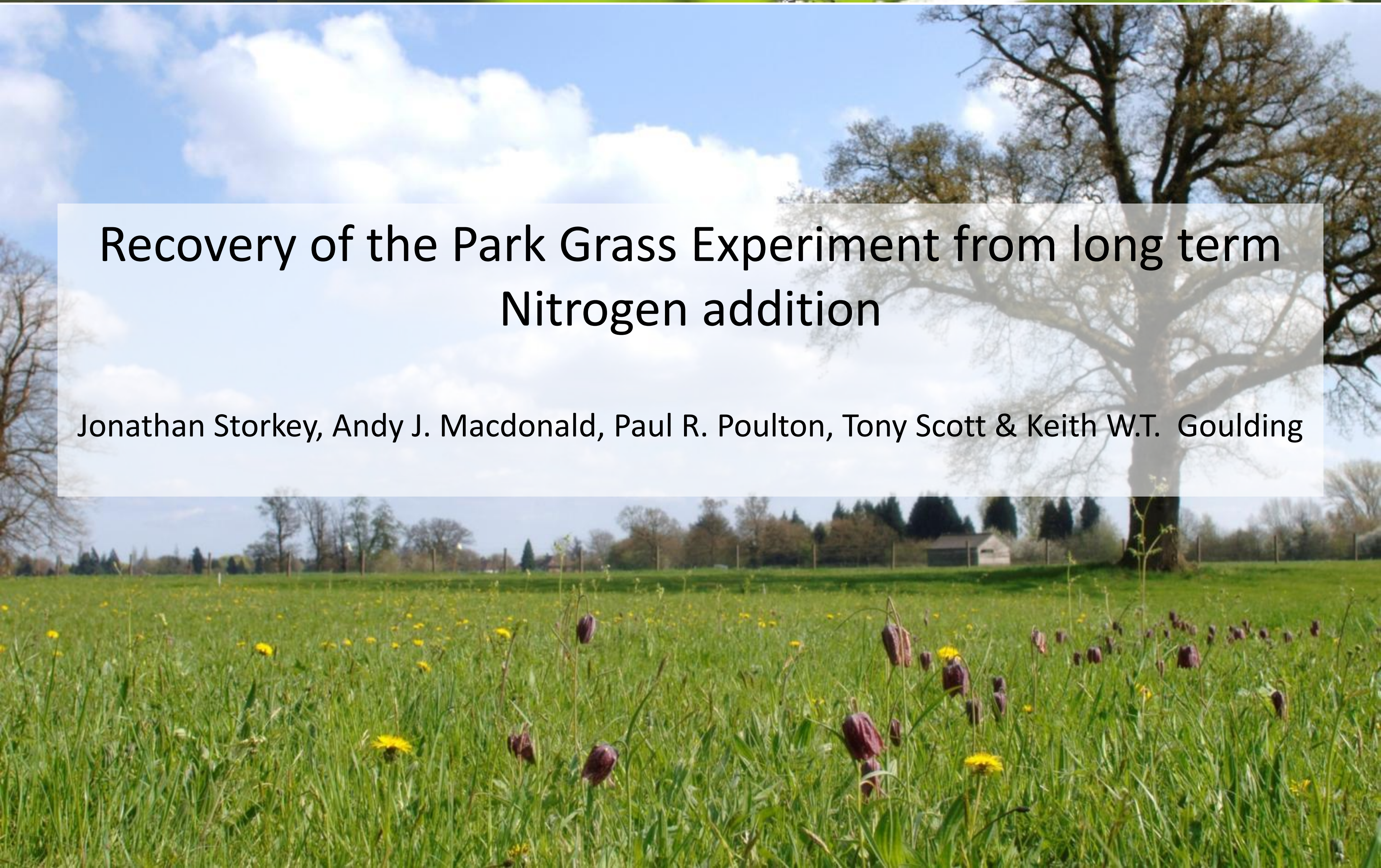
Rothamsted Research

where knowledge grows

Recovery of the Park Grass Experiment from long term Nitrogen addition

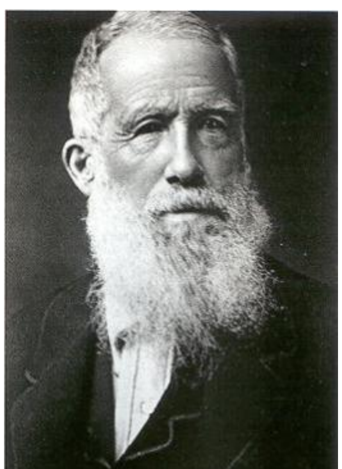
Jonathan Storkey, Andy J. Macdonald, Paul R. Poulton, Tony Scott & Keith W.T. Goulding



The Rothamsted Long Term Experiments

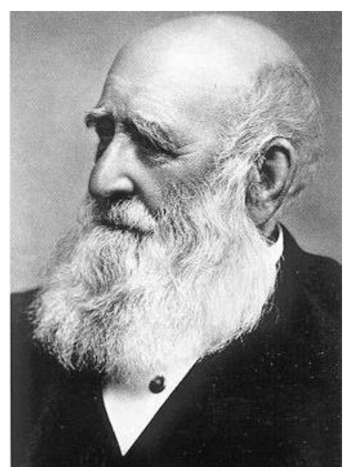
ROTHAMSTED RESEARCH

Earliest Rothamsted experiment (Broadbalk) started 1843, Park Grass is the 'youngest' (160 yrs old)



Sir John Bennet

Lawes

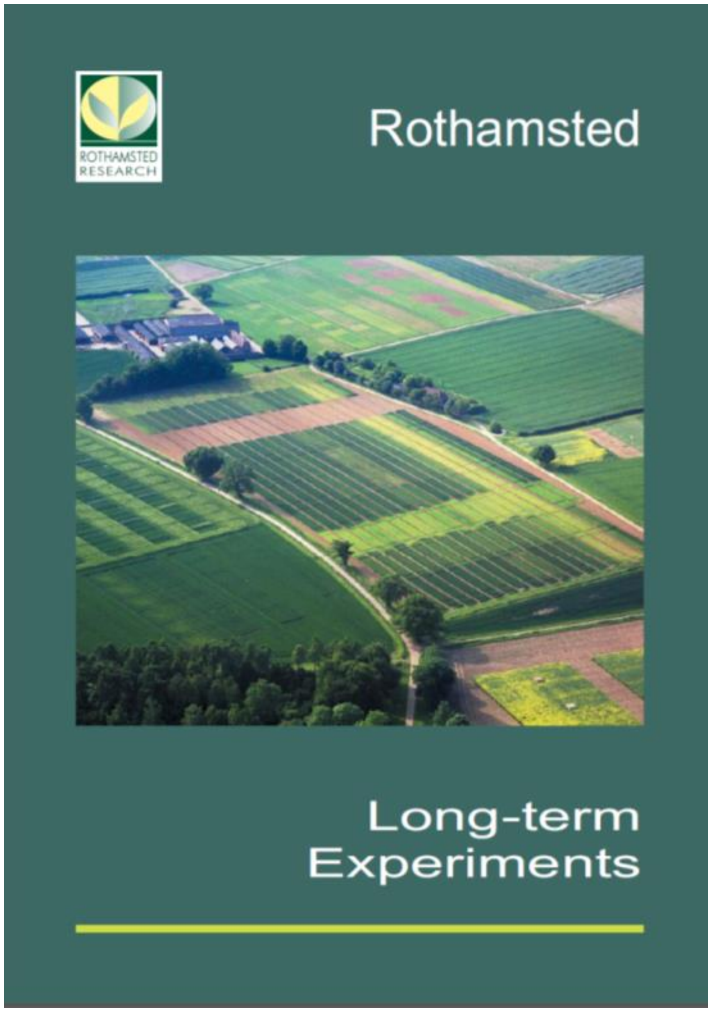


Sir Joseph Henry

Gilbert

BBSRC bioscience for the future

Classical Experiments



- Broadbalk Winter Wheat
- Broadbalk and Geescroft Wildernesses
- Park Grass
- Hoosfield Spring Barley
- Exhaustion Land
- Hoosfield Wheat and Fallow
- Garden Clover
- Barnfield
- Agdell

http://www.rothamsted.ac.uk/resources/LongTermExperiments.pdf

The Rothamsted archive

The archive contains about 300,000 grain, straw, herbage, soil, fertilizer and manure samples, some dating back to 1843.

Data are managed and accessed using the Rothamsted Electronic Archive: http://www.era.rothamsted.ac.uk/

Location of the Experiments

ROTHAMSTED RESEARCH

BBSRC bioscience for the future

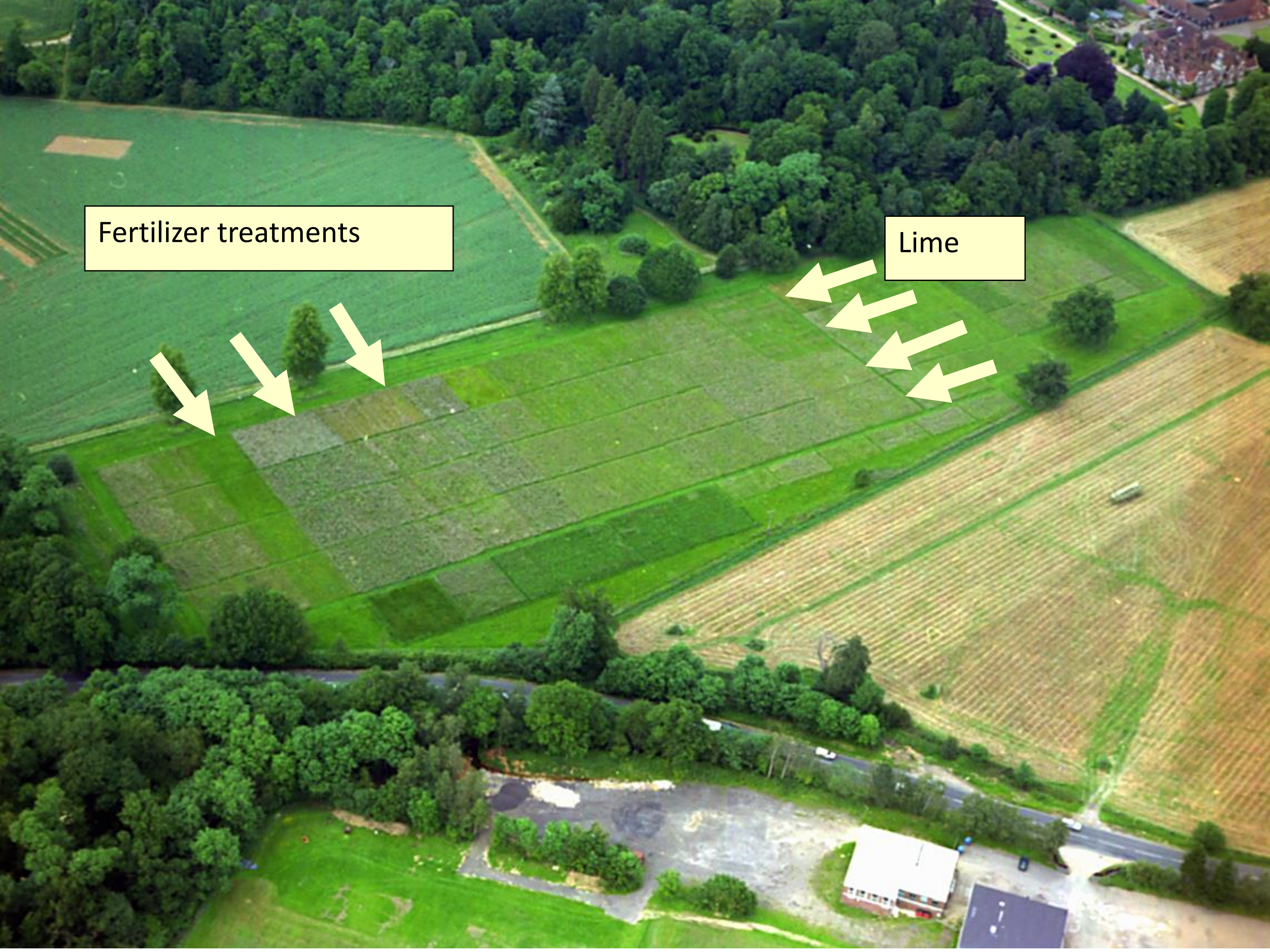
The Park Grass Experiment

• Begun in 1856 as last in a suite of experiments to demonstrate the effect of chemical fertilisers on yield – in this case of hay.

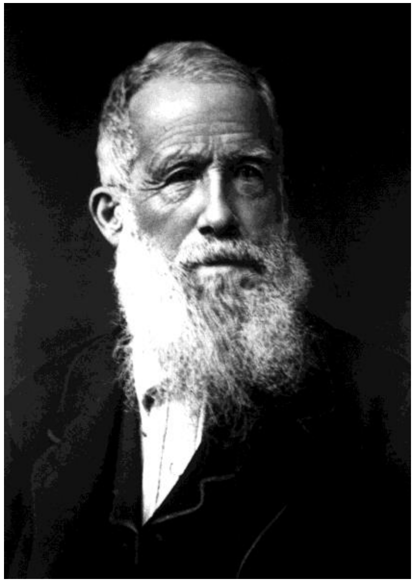
• Originally cut for hay and then grazed by sheep, now cut twice in June and October.

• One treatment, ammonium sulphate acidified the soil so the experiment was split in 1965 into sub-plots with target pH levels achieved by liming.

• Now the longest running ecological experiment in the world.

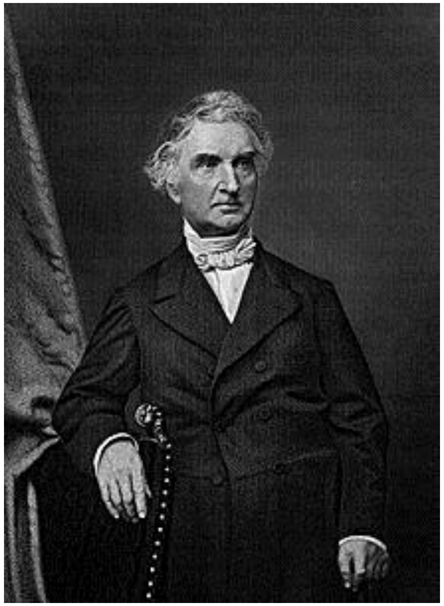

Fertilizer treatments
Lime

The Park Grass Experiment



"The plots had each so distinctive a character in regard to the prevalence of different plants that the experimental Ground looked almost as much as if it were devoted to trials with different seeds as different manures"

Sir John Bennett Lawes

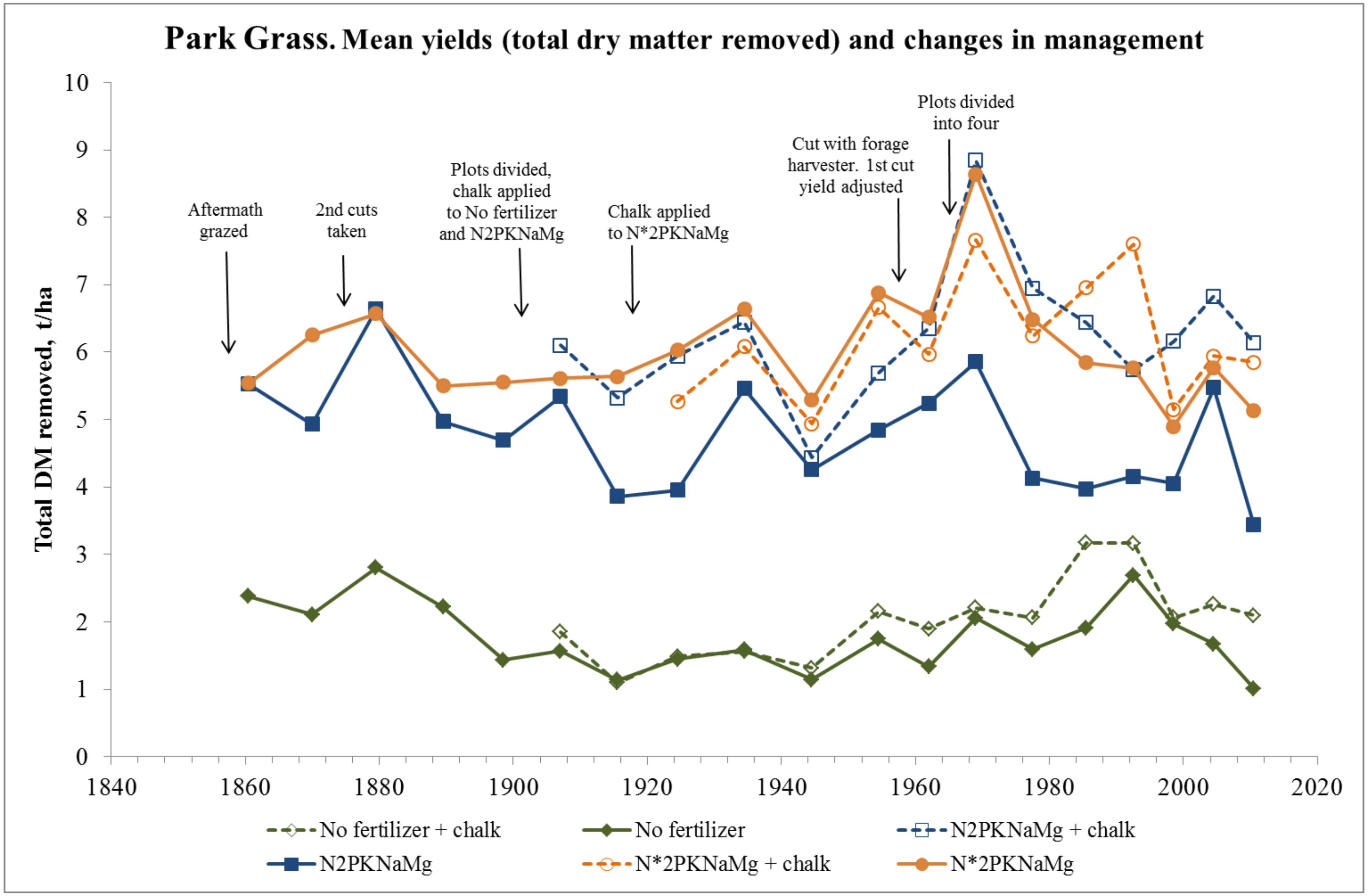


"It is all humbug, most impudent humbug…Lawes and Gilbert hitch on to me like vile vermin and I must get rid of them by all means

Baron Justus von Liebig

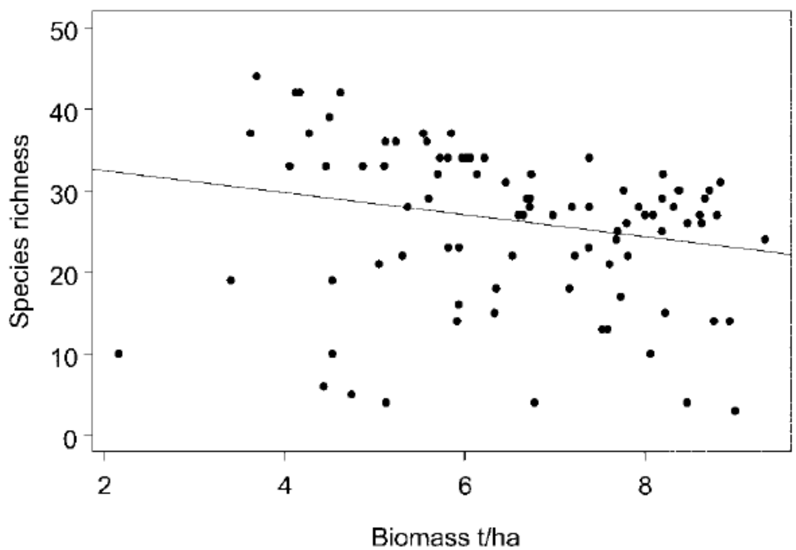
The Park Grass Experiment

The Park Grass Experiment: yield

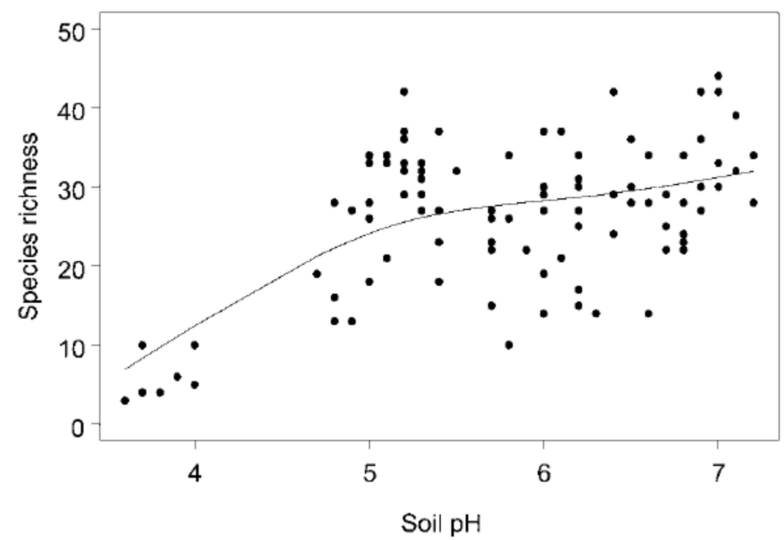


The Park Grass Experiment: drivers of diversity

Competitive exclusion



Species pool size effect



Productivity suppresses species diversity as opposed to species diversity promoting productivity

Crawley, M.J., Johnston, A.E., Silvertown, J., Dodd, M., de Mazancourt, C., Heard, M.S., Henman, D.F. & Edwards, G.R. (2005) Determinants of species richness in the park grass experiment. *American Naturalist,* **165,** 179-192.

Transition plots (N withheld since 1989)

Research questions

- How do plots respond to change of treatment (withholding Nitrogen) in context of variability in ‘control’ plots?

Control plot b – no fertiliser

End plot b – PKNaMg

Transition plot b – (N2)PKNaMg

Start plot b – N2PKNaMg

Transition plots (N withheld since 1989)

Methods remain largely the same!

ROTHAMSTED RESEARCH

BBSRC
bioscience for the future

We were expecting to see a legacy of N application…

ROTHAMSTED RESEARCH

ECOLOGY LETTERS

Ecology Letters, (2013) **16**: 454–460 doi: 10.1111/ele.12066

LETTER

Low biodiversity state persists two decades after cessation of nutrient enrichment

Forest Isbell,[1]* David Tilman,[1,2] Stephen Polasky,[1,3] Seth Binder[1,3] and Peter Hawthorne[3,4]

Abstract

Although nutrient enrichment frequently decreases biodiversity, it remains unclear whether such biodiversity losses are readily reversible, or are critical transitions between alternative low- and high-diversity stable states that could be difficult to reverse. Our 30-year grassland experiment shows that plant diversity decreased well below control levels after 10 years of chronic high rates (95–270 kg N ha^{-1} $year^{-1}$) of nitrogen addition, and did not recover to control levels 20 years after nitrogen addition ceased. Furthermore, we found a hysteretic response of plant diversity to increases and subsequent decreases in soil nitrate concentrations. Our results suggest that chronic nutrient enrichment created an alternative low-diversity state that persisted despite decreases in soil nitrate after cessation of nitrogen addition, and despite supply of propagules from nearby high-diversity plots. Thus, the regime shifts between alternative stable states that have been reported for some nutrient-enriched aquatic ecosystems may also occur in grasslands.

Keywords

Alternative stable states, fertilisation, grasslands, hysteresis, nitrogen deposition, recovery, regime shift.

Ecology Letters (2013) **16**: 454–460

BBSRC
bioscience for the future

…but observed a different response on Park Grass

ROTHAMSTED RESEARCH

LETTER

doi:10.1038/nature16444

Grassland biodiversity bounces back from long-term nitrogen addition

J. Storkey[1], A. J. Macdonald[1], P. R. Poulton[1], T. Scott[1], I. H. Köhler[2]†, H. Schnyder[2], K. W. T. Goulding[1] & M. J. Crawley[3]

The negative effect of increasing atmospheric nitrogen (N) pollution on grassland biodiversity is now incontrovertible[1–3]. However, the recent introduction of cleaner technologies in the UK has led to reductions in the emissions of nitrogen oxides, with concomitant decreases in N deposition[4]. The degree to which grassland biodiversity can be expected to 'bounce back' in response to these improvements in air quality is uncertain, with a suggestion that long-term chronic

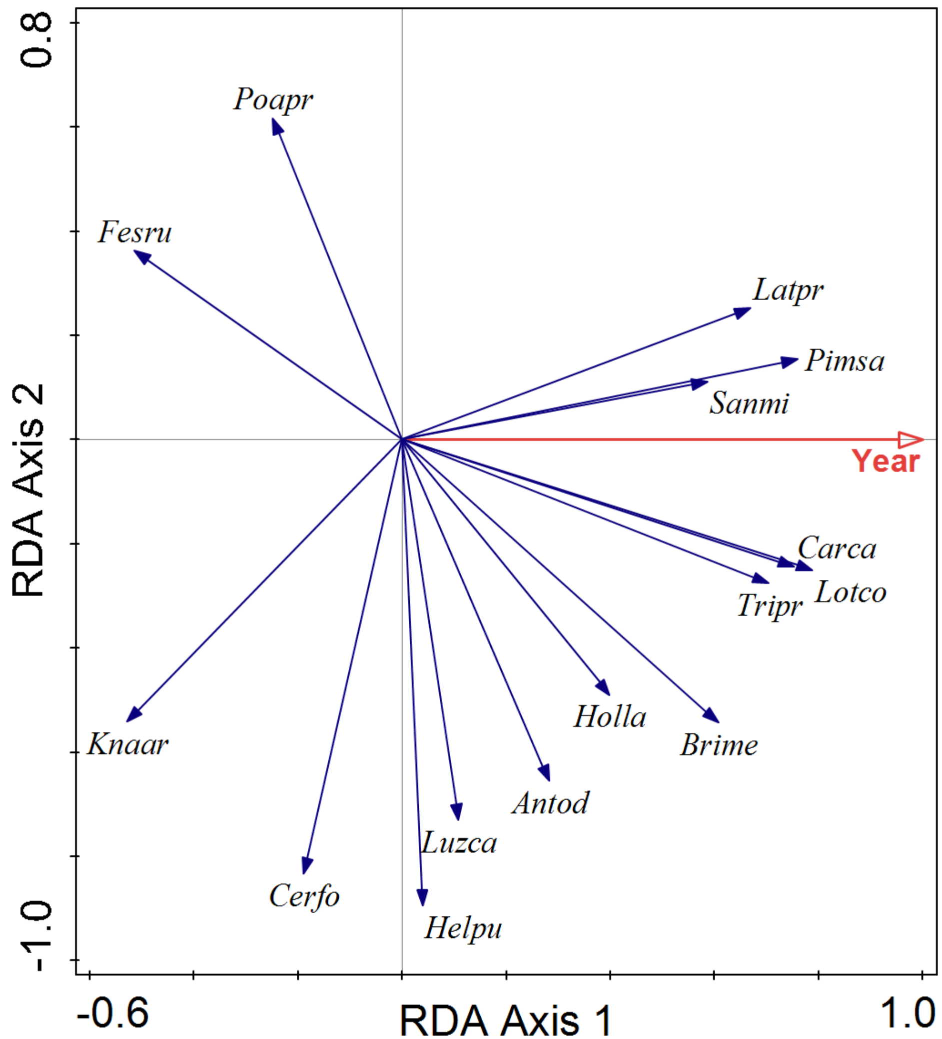
deposition). Park Grass is in a semi-urban environment, close to a road and on the edge of the town of Harpenden, which act as local sources of atmospheric pollutants[4,10]. Local measurements of ammonium and nitrate deposited in rainfall show that they have both declined by a comparable amount since 1985, and reflect the current national downward trend in total N emissions (Fig. 1). Our measurements did not

Storkey J. *et al.* (2015) *Nature* **528**: 401-404.

BBSRC bioscience for the future

Is there a temporal trend on control plot, 3b, (1991-2012)?

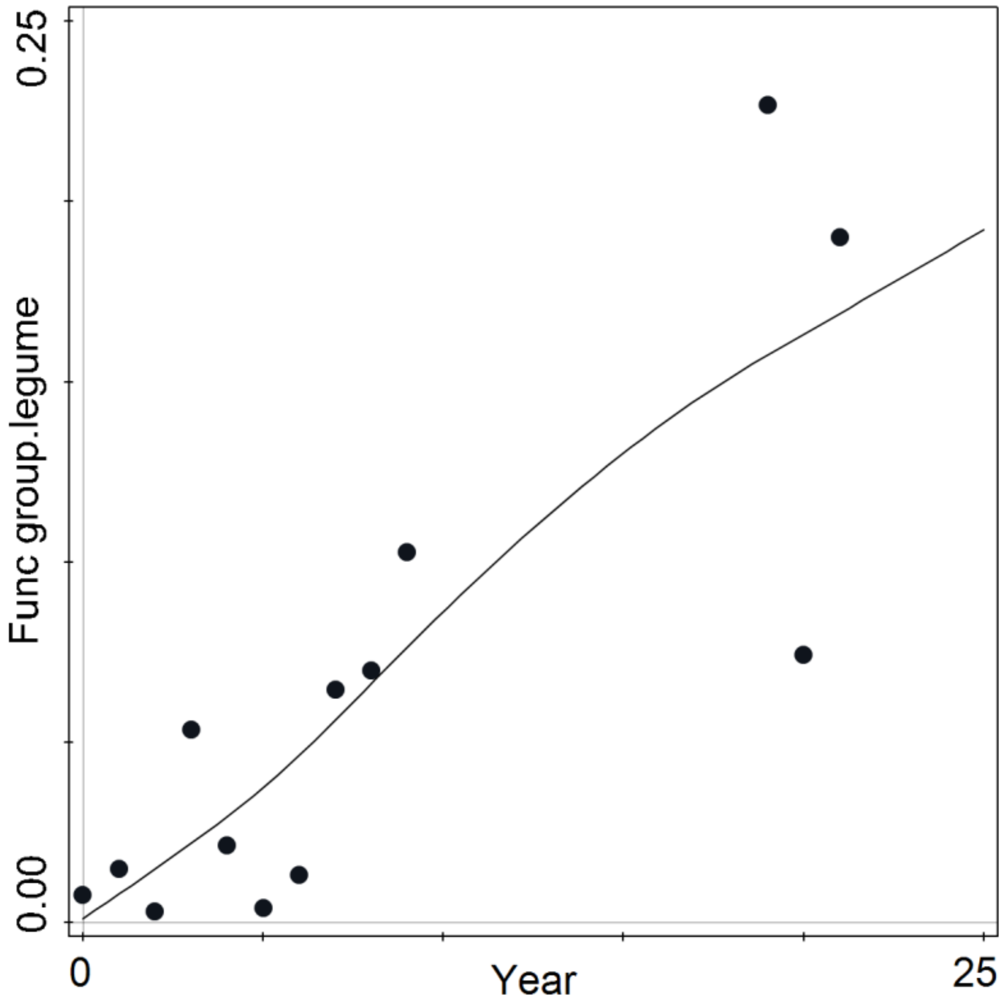
ROTHAMSTED RESEARCH



A significant temporal trend was identified on the control plot ($p<0.002$) explaining 20% of the variance between years.

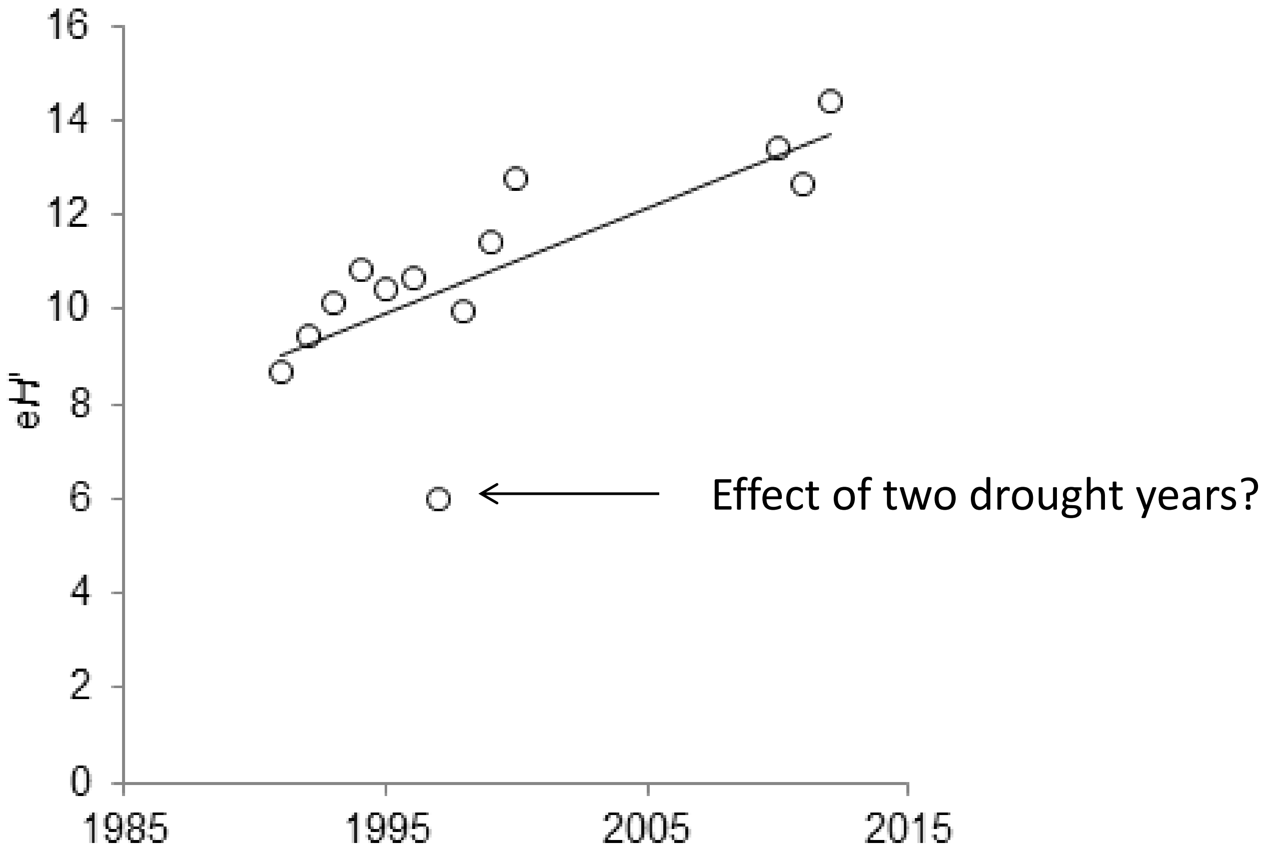
BBSRC
bioscience for the future

Legumes increased over the time period on control plot.



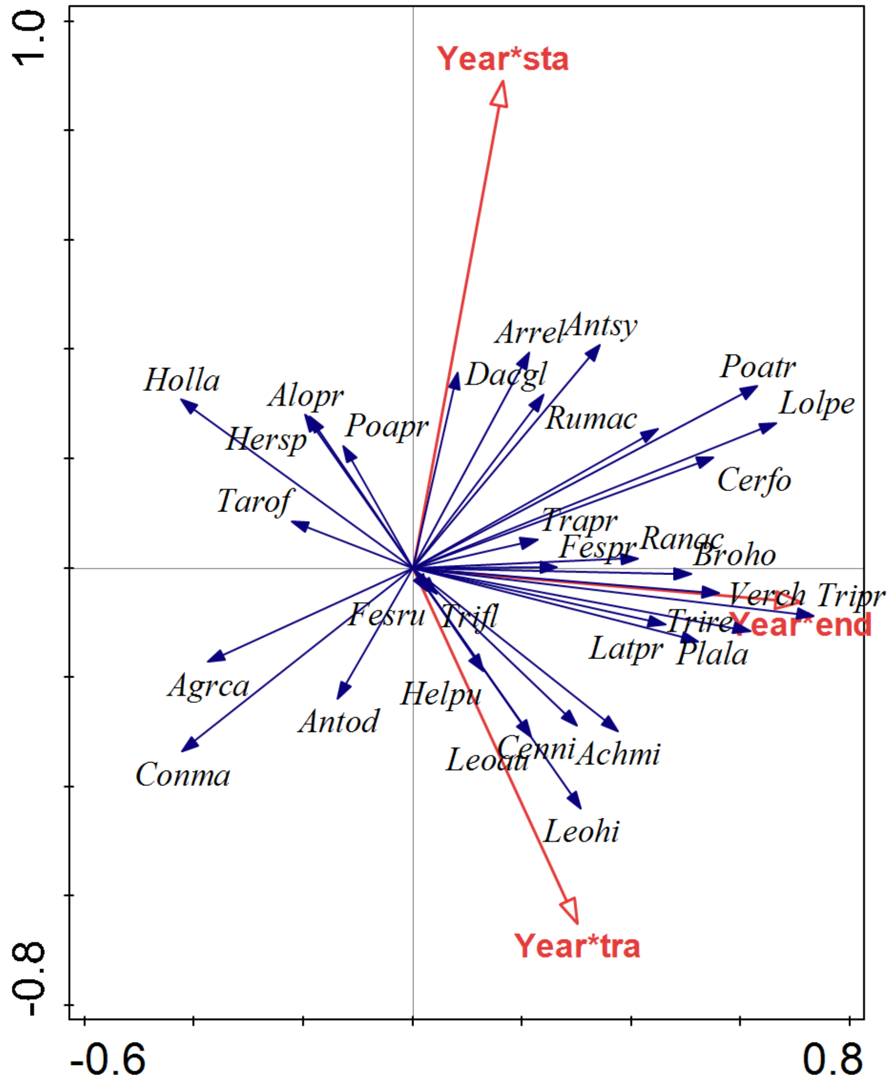
...which was largely responsible for increasing diversity.

ROTHAMSTED RESEARCH



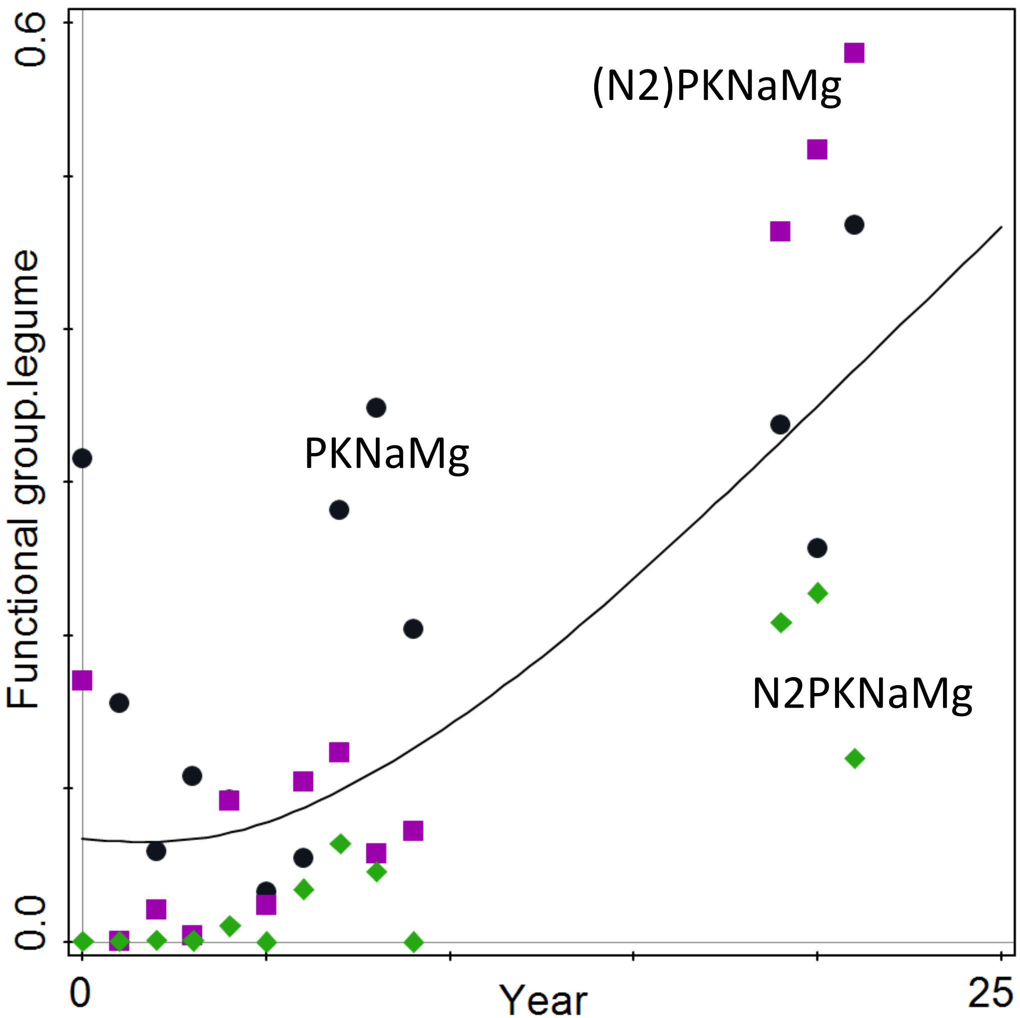
BBSRC
bioscience for the future

What about the transition plots?



Primary axis was driven by increased abundance of legumes and forbs on the PKNaMg plot.

Response of legumes on transition plots

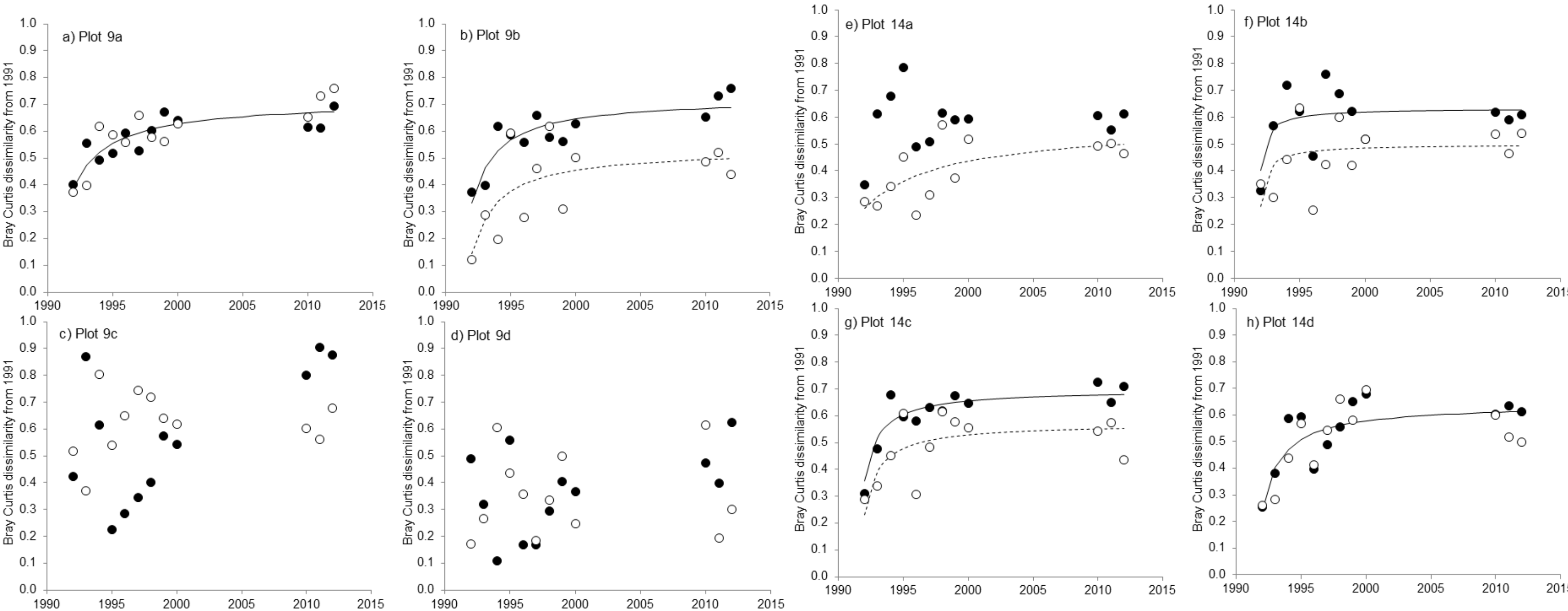


Similar response as on control plot but greater increase of legumes on transition treatment (as you would expect).

But not diverging from start plot as much as was expected – environment over-riding management?

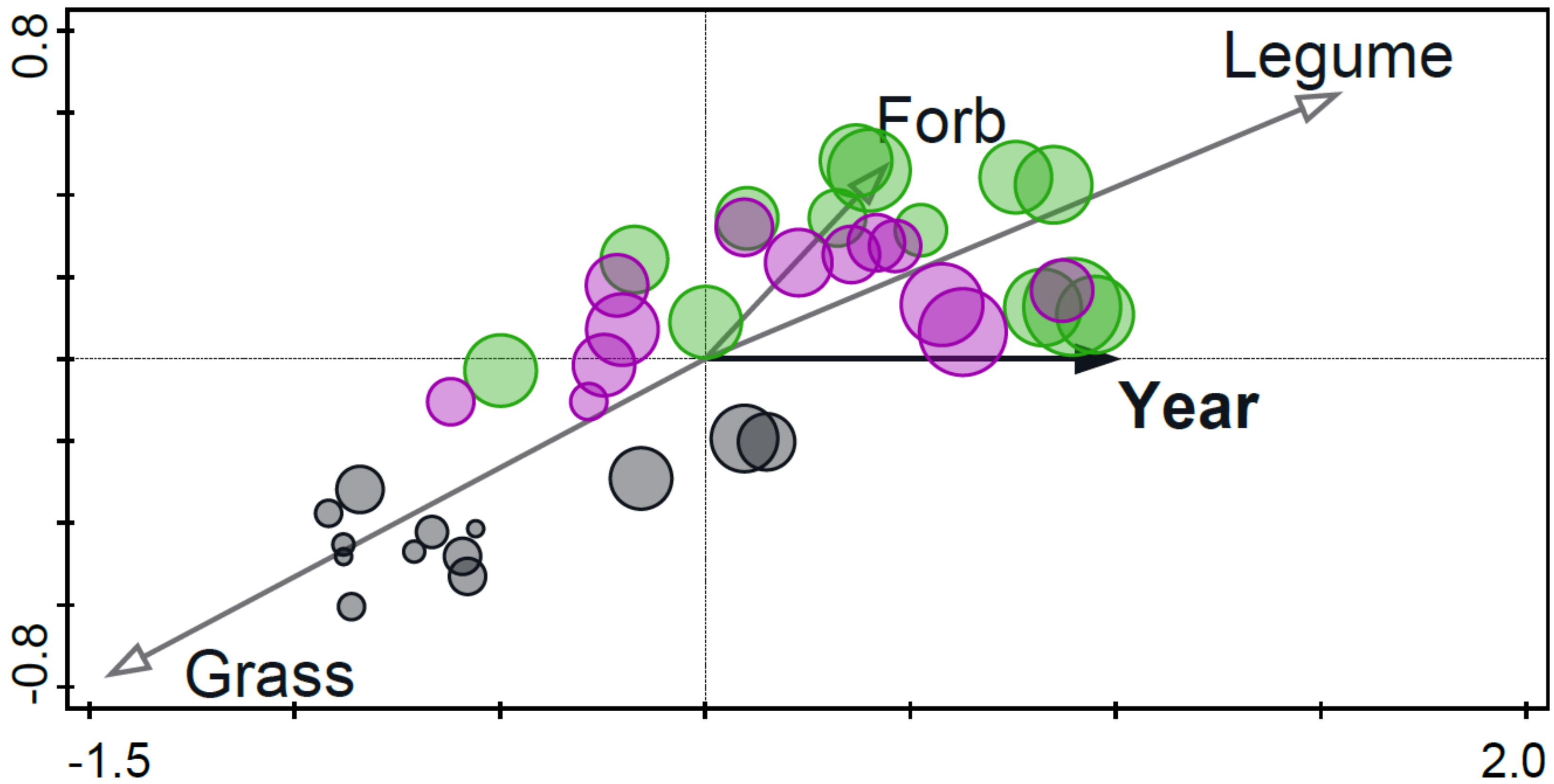
Temporal trend confirmed by Bray-curtis analysis…

ROTHAMSTED RESEARCH

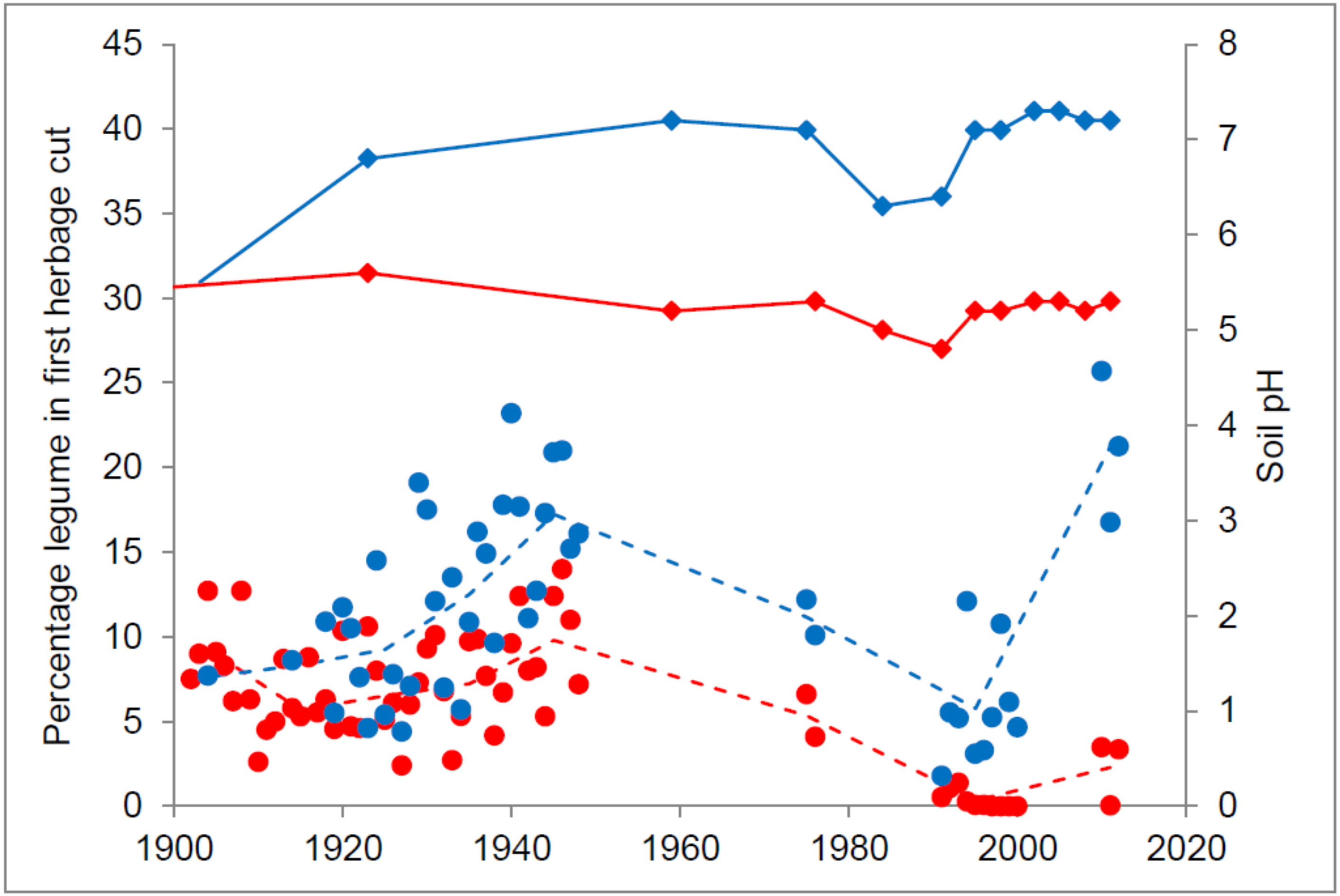


BBSRC
bioscience for the future

…and Redundancy analysis

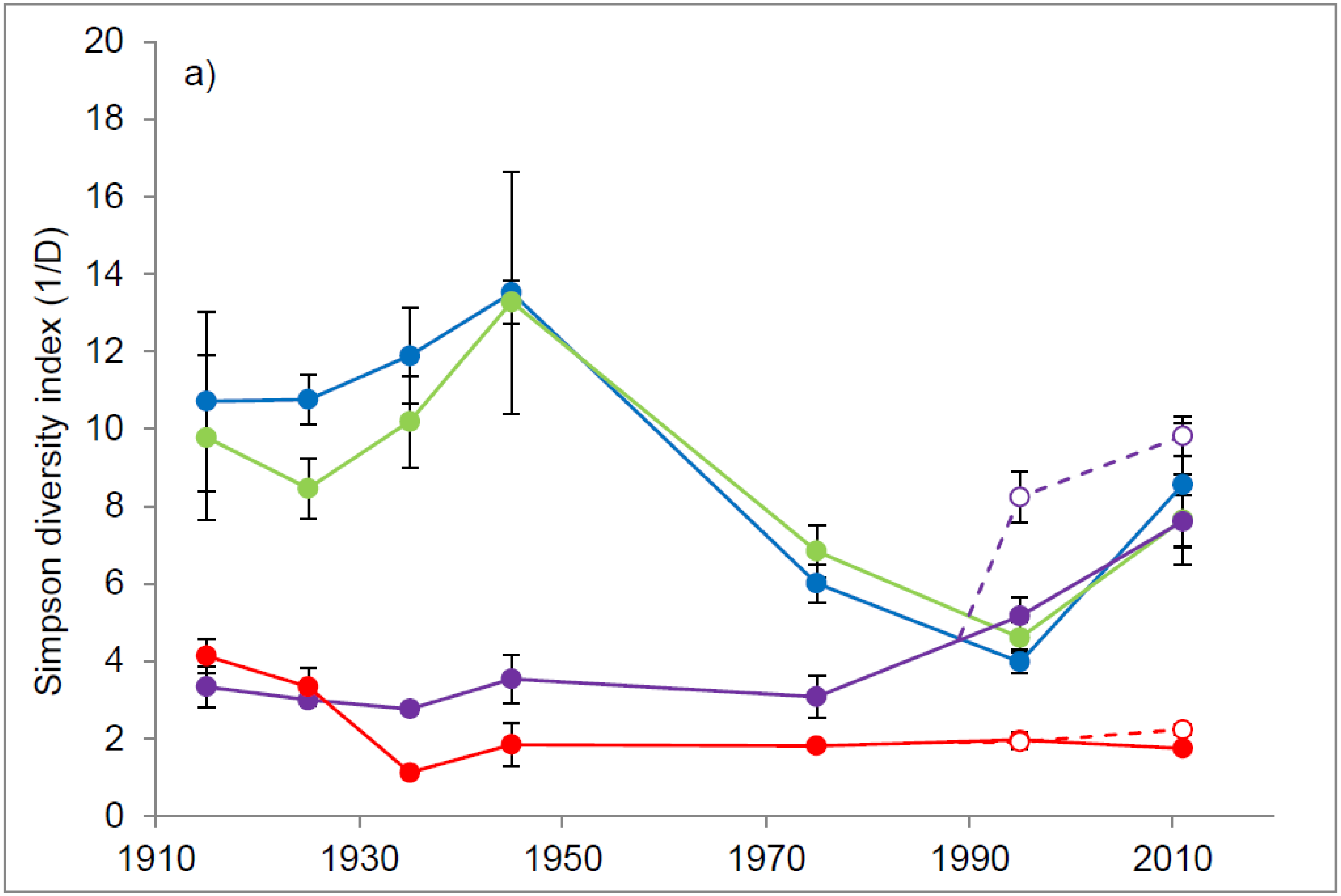


How do these results compare with long term data?

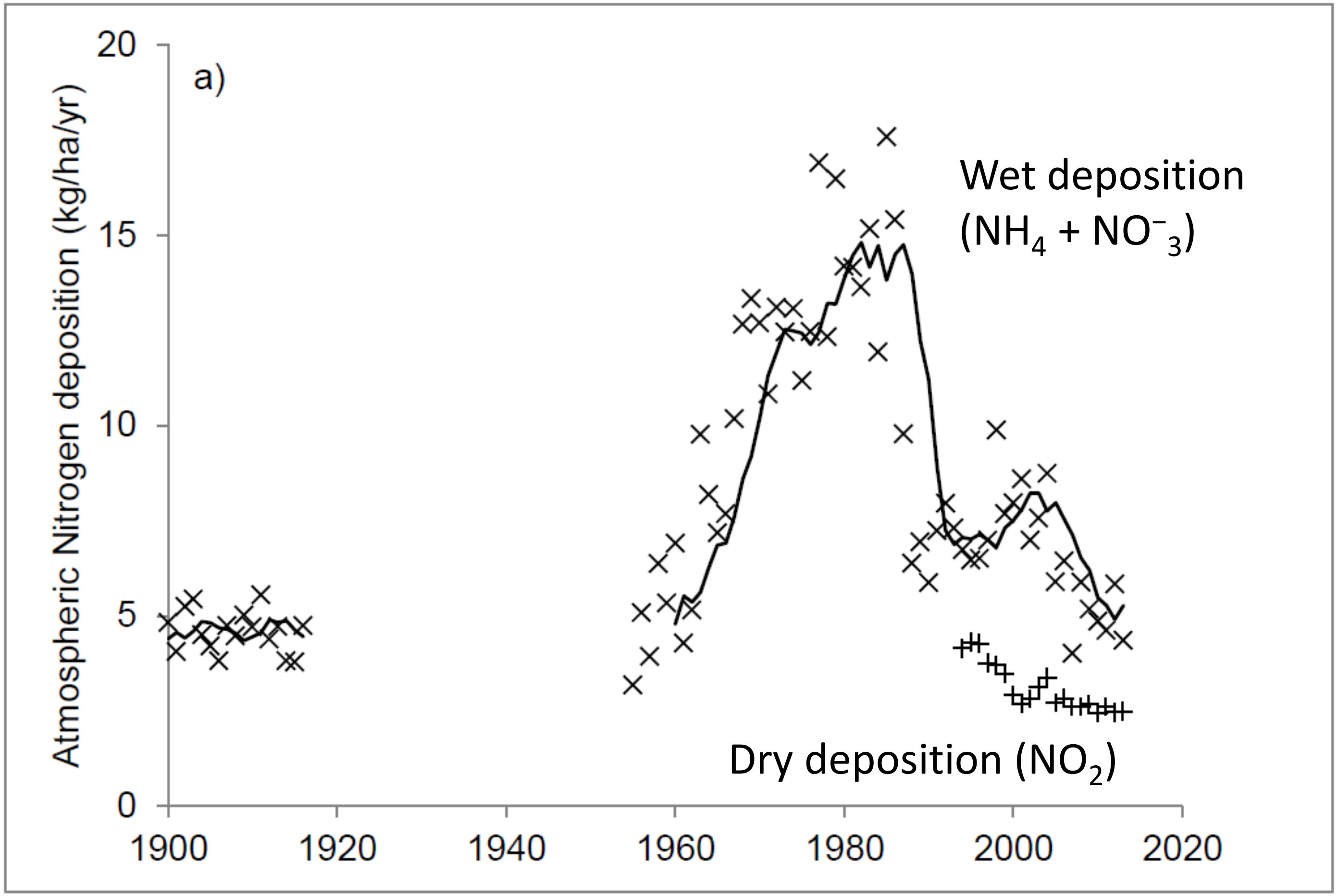


BBSRC
bioscience for the future

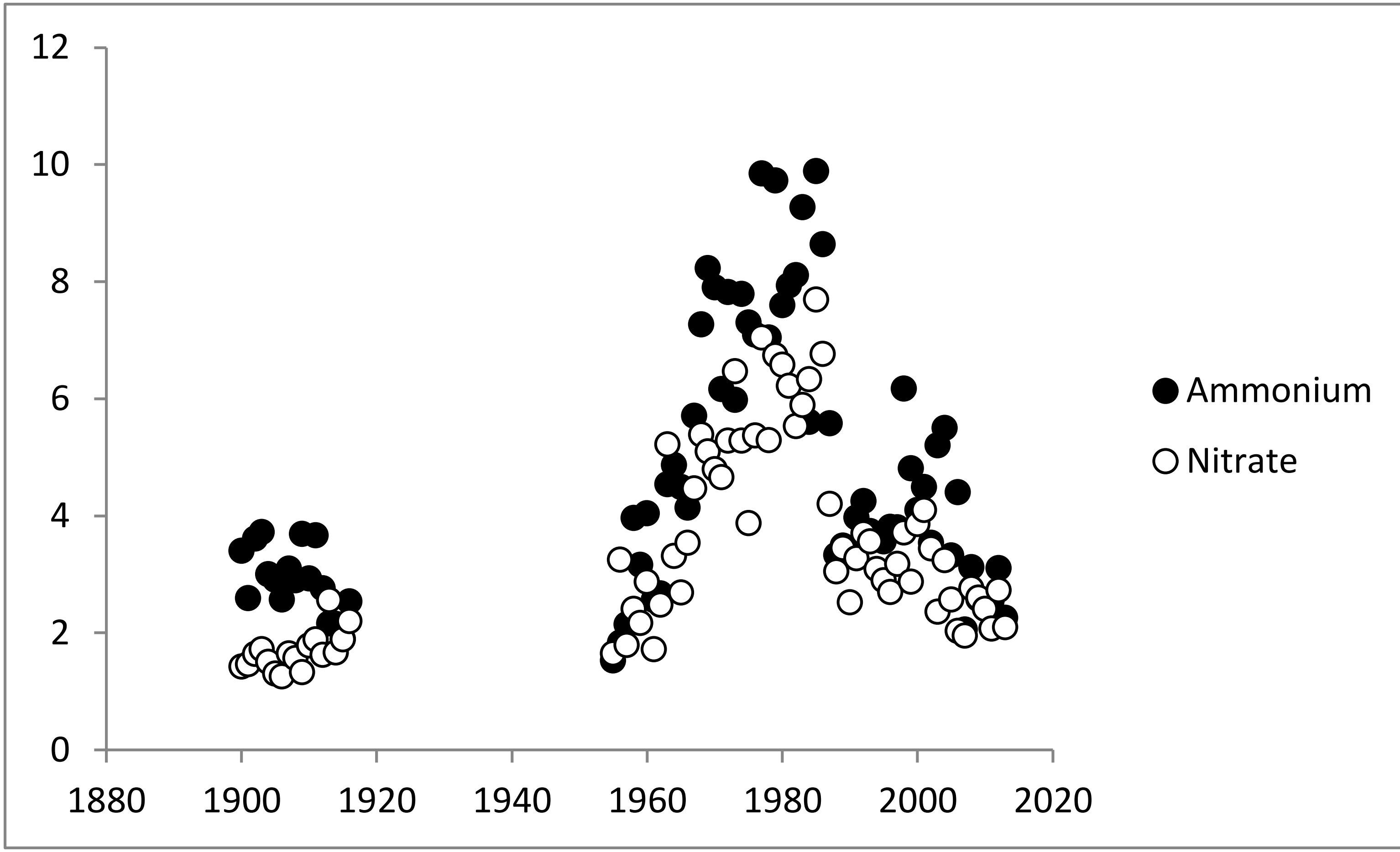
How do these results compare with long term data?



Changes in Nitrogen deposition became the most likely explanation of the results



Changes in Nitrogen deposition became the most likely explanation of the results



Where were measurements taken?

ROTHAMSTED RESEARCH

BBSRC
bioscience for the future

Effect of N deposition in context of treatments

ROTHAMSTED RESEARCH

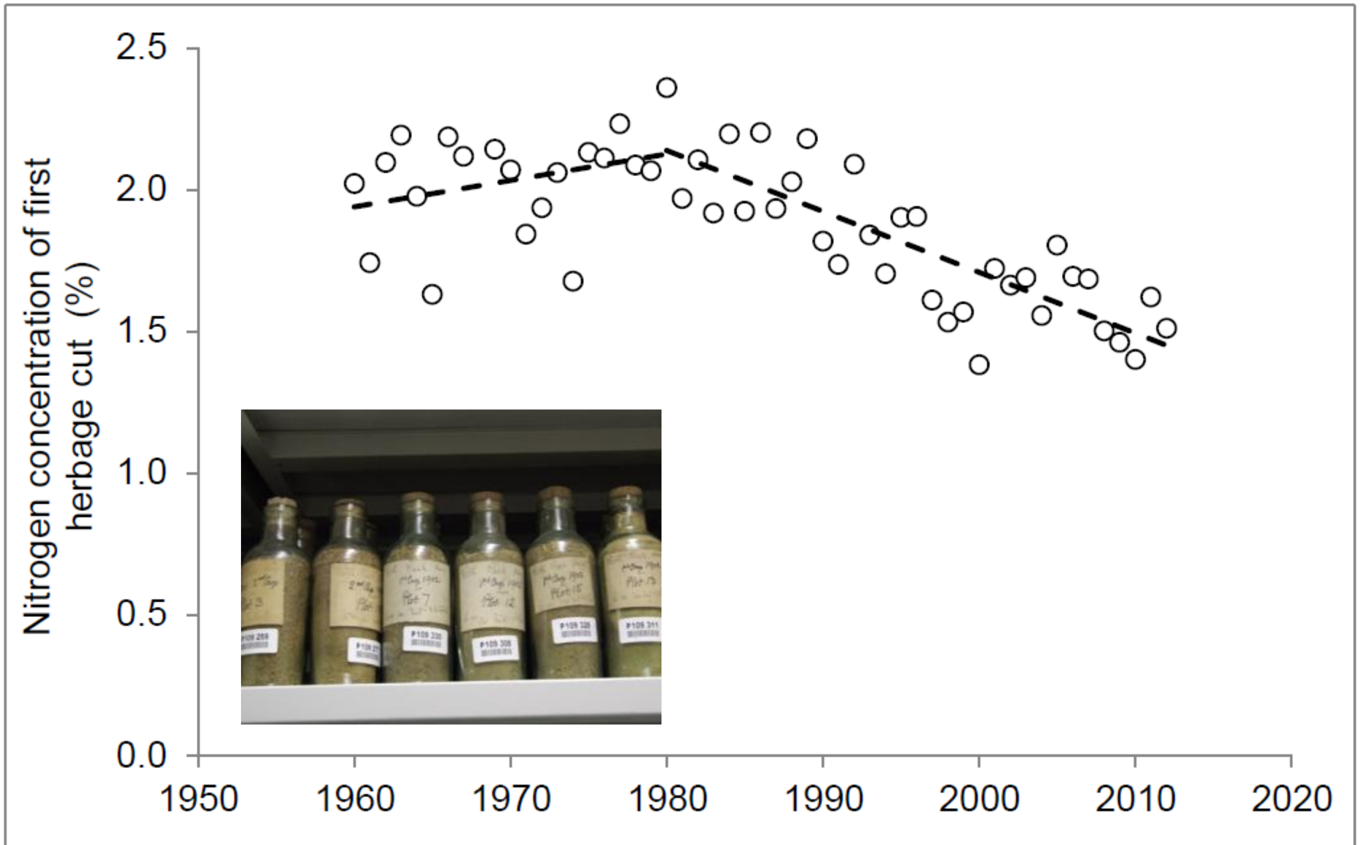
Response variable	Explanatory variable	Estimate (s.e.)	*F* statistic	Degrees of freedom	*P* value
Species number	pH	0.20 (0.035)	44.2	366	**<0.001**
	+N:48kgha^{-1*}	-0.92 (0.346)	11.5	27	**<0.001**
	96kgha^{-1}	-0.47 (0.210)			
	144kgha^{-1}	-1.28 (0.467)			
	+Phosphorous	ns	2.6	26	0.120
	N Deposition$_{3\ year}$	-0.09 (0.028)	9.8	11	**0.010**
eH'	pH	0.18 (0.044)	28.3	134	**<0.001**
	+N:48kgha^{-1}	-0.71 (0.291)	11.3	23	**<0.001**
	96kgha^{-1}	-0.47 (0.174)			
	144kgha^{-1}	-1.14 (0.389)			
	+Phosphorous	ns	0.4	21	0.514
	N Deposition$_{5\ year}$	-0.08 (0.033)	6.9	11	**0.023**
Proportion of Legumes	pH	0.55 (0.151)	13.9	298	**<0.001**
	+N:48kgha^{-1}	-2.87 (1.739)	6.8	43	**<0.001**
	96kgha^{-1}	-2.33 (0.625)			
	144kgha^{-1}	-5.08 (2.304)			
	+Phosphorous	2.23 (0.672)	11.1	23	**0.003**
	N Deposition$_{5\ year}$	-0.55 (0.185)	8.8	10	**0.014**
Proportion of Grass	pH	-0.85 (0.088)	110.4	115	**<0.001**
	+N:48kgha^{-1}	1.07 (0.265)	31.7	24	**<0.001**
	96kgha^{-1}	1.63 (0.489)			
	144kgha^{-1}	3.04 (0.265)			
	+Phosphorous	ns	0.0	19	0.997
	N Deposition$_{5\ year}$	0.27 (0.122)	4.8	11	**0.050**

*Effect size of additional N fertiliser expressed in relation to plots receiving no added nitrogen.

BBSRC bioscience for the future

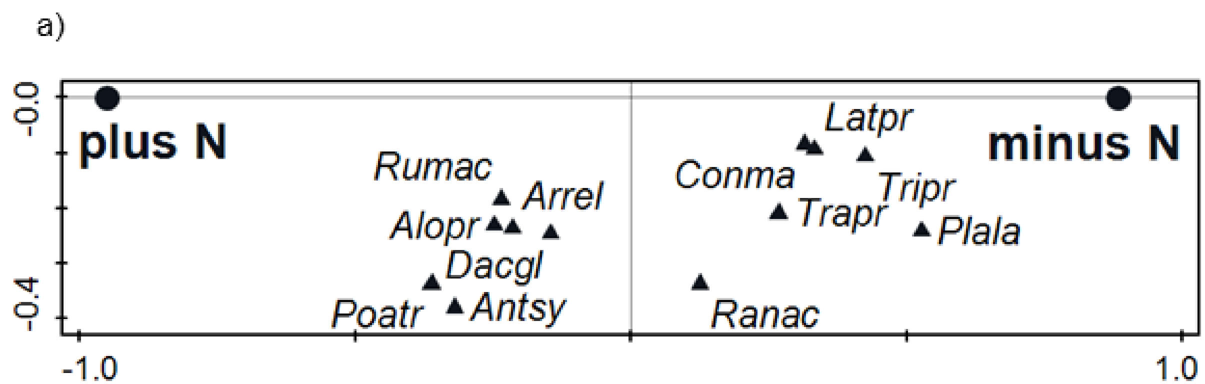
Further evidence from archive samples

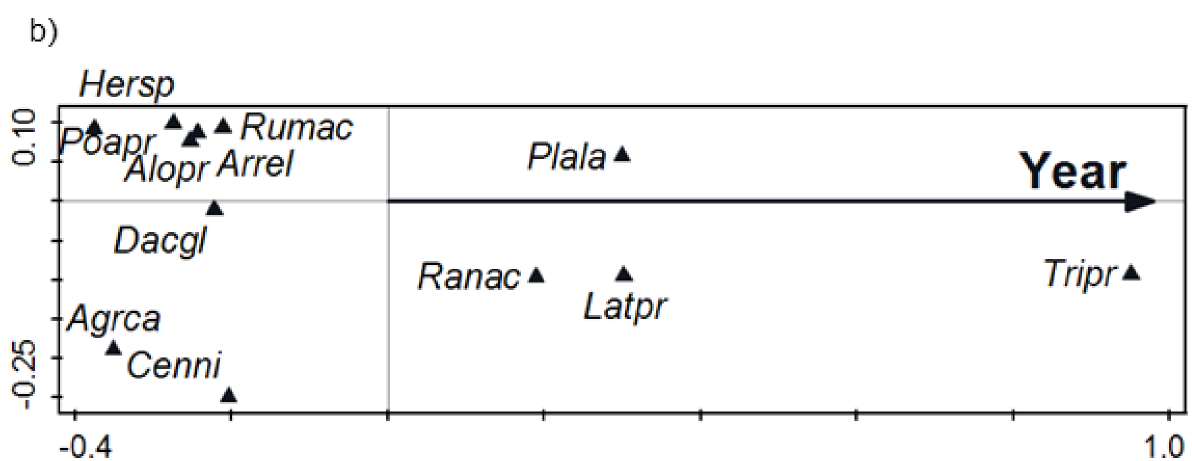
ROTHAMSTED RESEARCH



BBSRC
bioscience for the future

Which species are responding?





Concluding thoughts

Why do we see a rapid recovery from cessation of N addition on Park Grass?

Twice yearly cutting and removal of biomass removes nutrients and creates a regular disturbance that prevents build up of litter and competitive dominance.

The magnitude of decreases in N deposition are greater than those reported elsewhere, why?

The relative impact of N deposition on community dynamics is greater than an equivalent addition of N fertiliser, why?


Thank you