

# The deposition and fate of atmospheric Nitrogen in the UK between 1900 and 2000

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# Objectives

- Describe the current and past N deposition in the UK
- What was the N deposition prior to industrial and agricultural revolution?
- How has it changed ?
- How much N has been deposited (and exported)
- Where is the deposited N?

# Data sources (wet deposition)

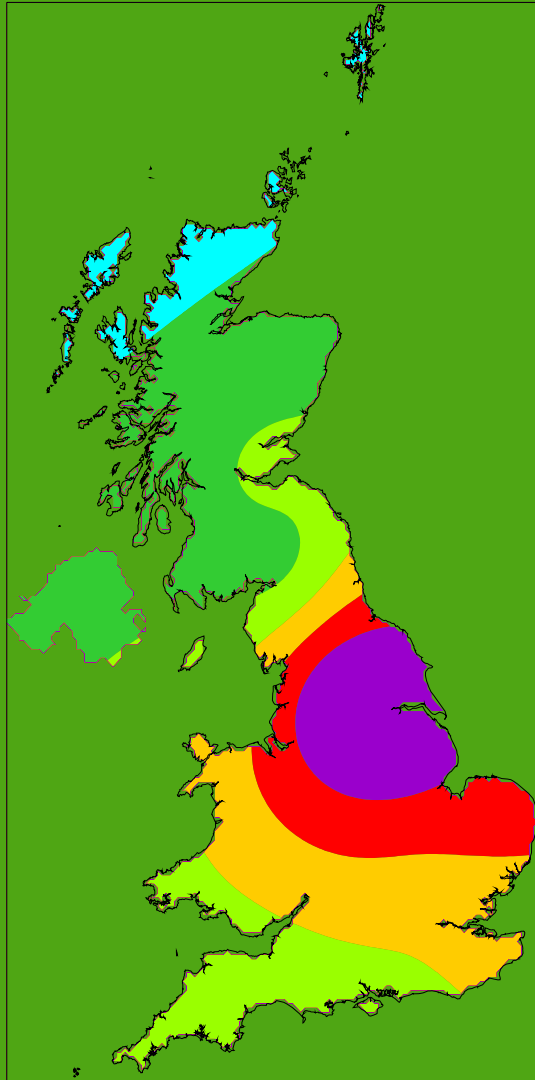
Date	Location	N deposition (kg ha <sup>-1</sup> )
• 1825-1850	France, Germany, UK.	2-20
• 1850-1900	UK, France Germany (Rothamsted, Smith, UK rural and urban sites)	1-20
• 1900-1950	UK, (Rothamsted, Leeds)	3-10
• 1950-1970	(EACN)	2-20
• 1970-1980	(ITE, Met Office, CEGB)	2-20
• 1986-2000	(UK network DEFRA+ECN)	3-30

# Wet Deposition

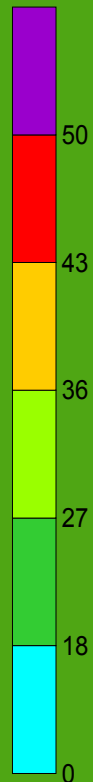
- Prior to 1950, sampling protocols, analytical procedures and sites were too variable and poorly documented to be confident of interpretation.
- Prior to GANE there were no measurement based UK maps prior to 1986
- However, measurements are available from ~1950

# EACN data (Ericsson et al)

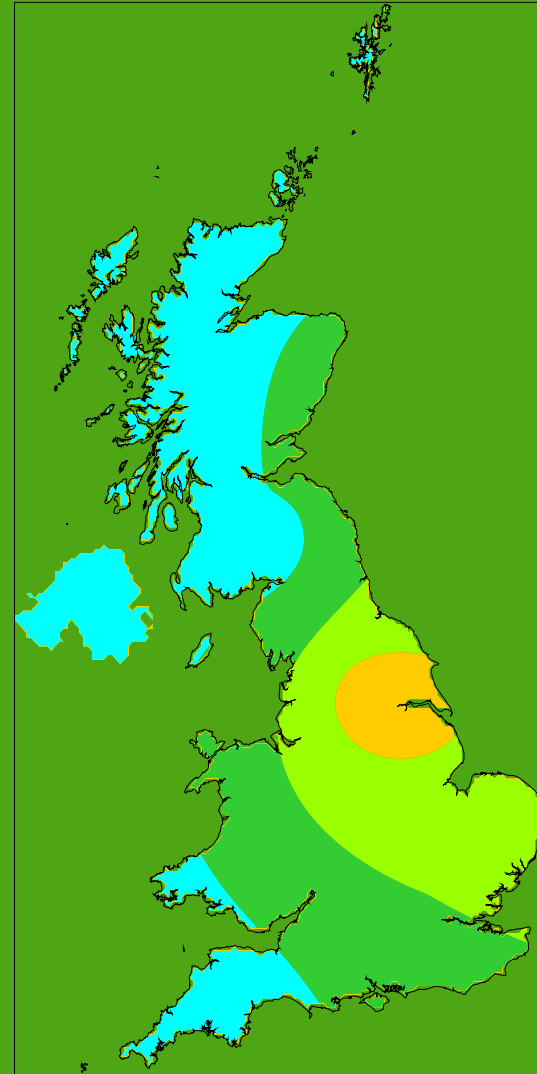
1958  $\text{NH}_4$  concentration



ueq  $\text{NH}_4\text{-N I-1}$



1958  $\text{NO}_3$  concentration

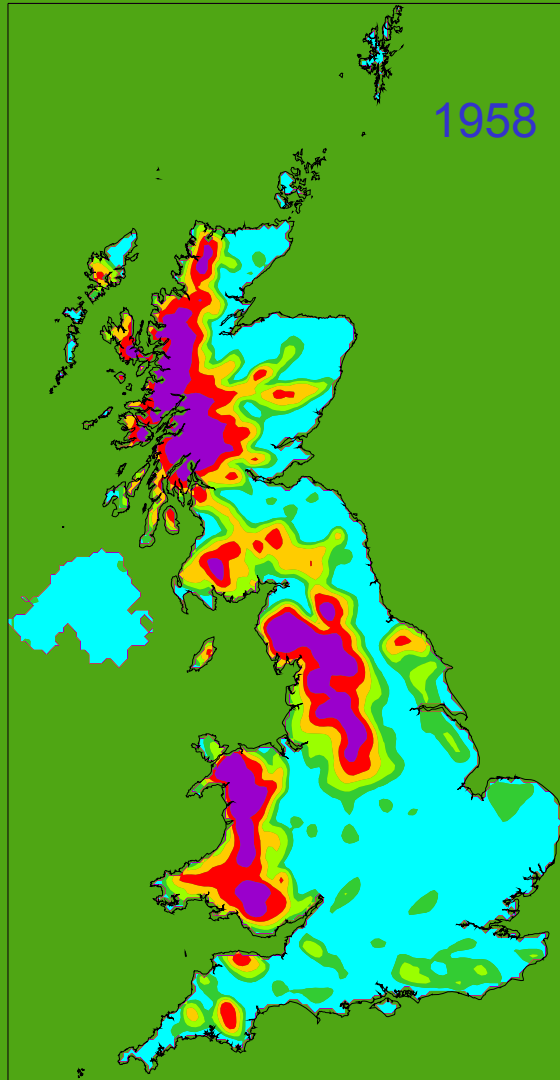


ueq  $\text{NO}_3\text{-N I-1}$

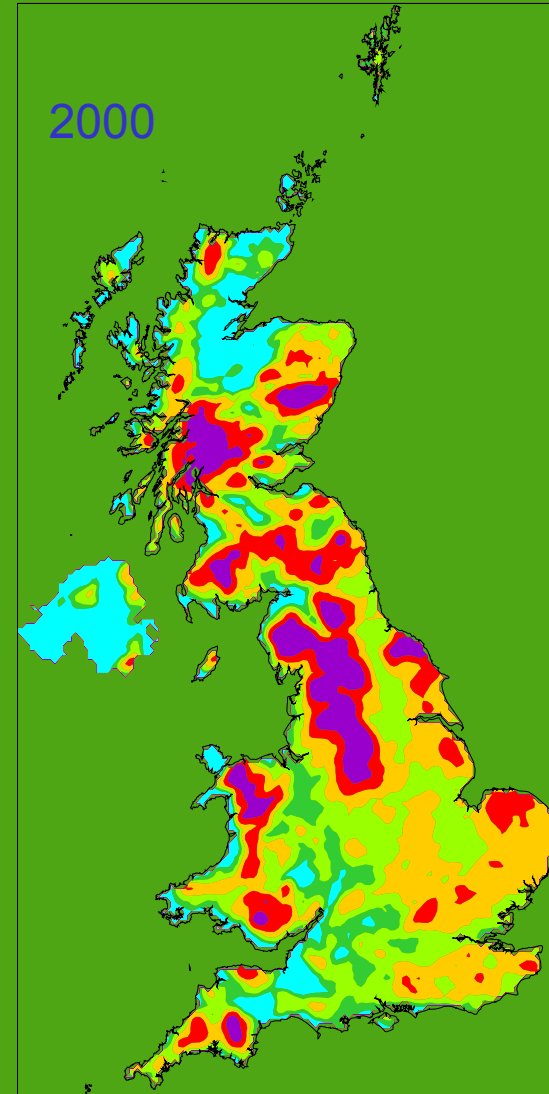
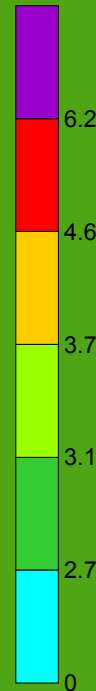


# Wet deposition $\text{NO}_3$ -N

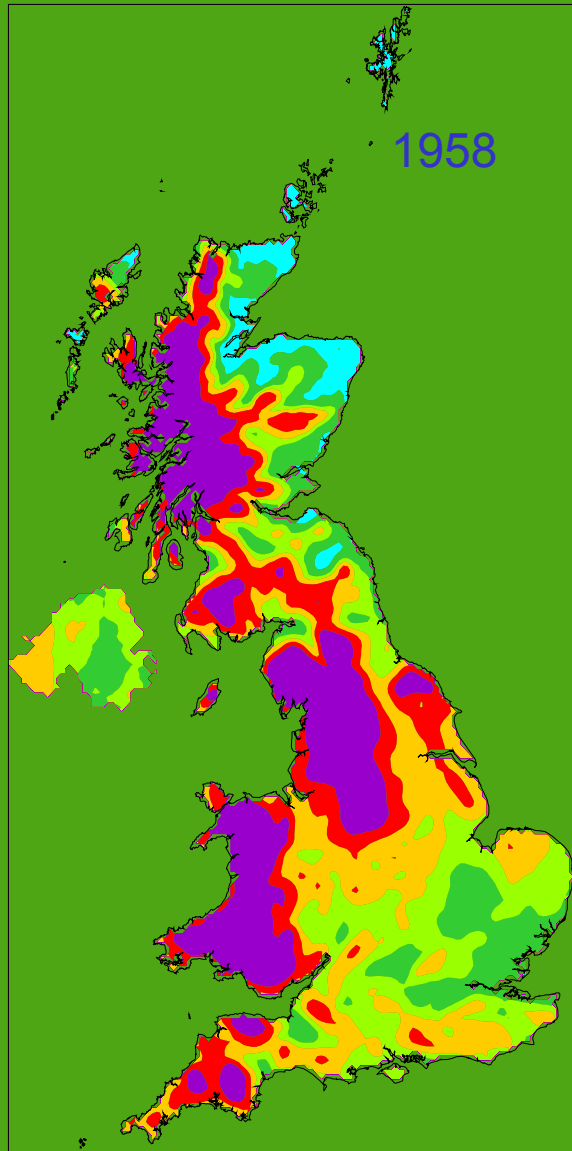
GLOBAL NITROGEN ENRICHMENT



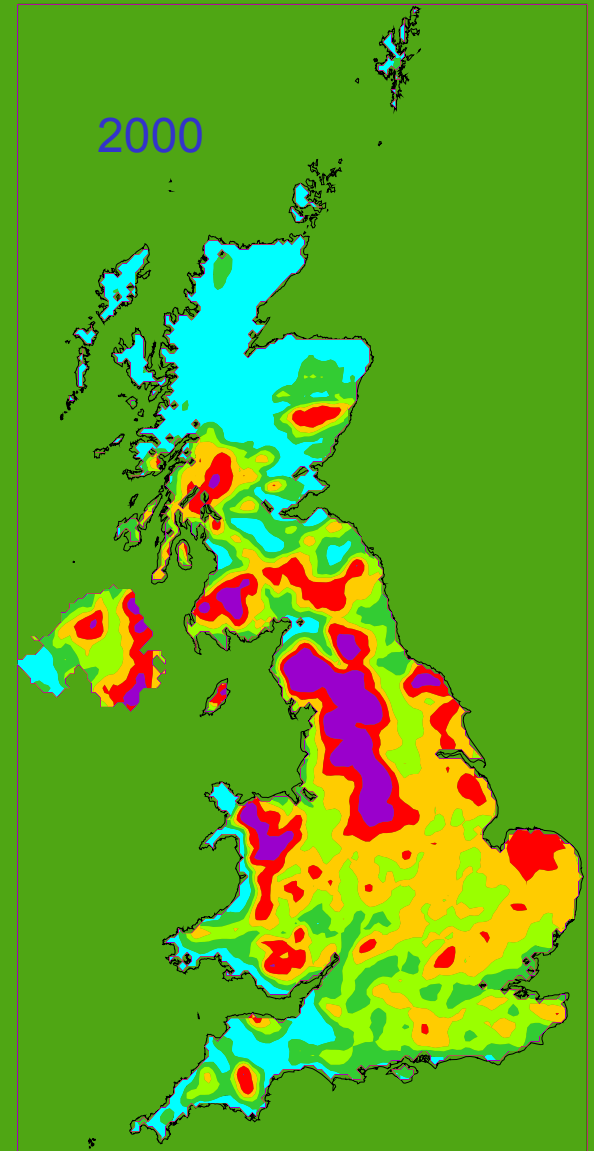
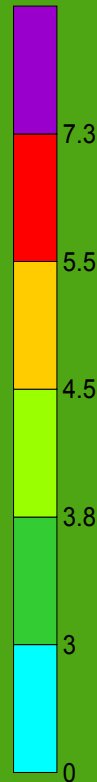
kg N ha<sup>-1</sup> yr<sup>-1</sup>



# Wet deposition $\text{NH}_4\text{-N}$



kg N ha<sup>-1</sup> yr<sup>-1</sup>



# Dry deposition $\text{NH}_3$ , $\text{NO}_2$ , $\text{HNO}_3$ , aerosols

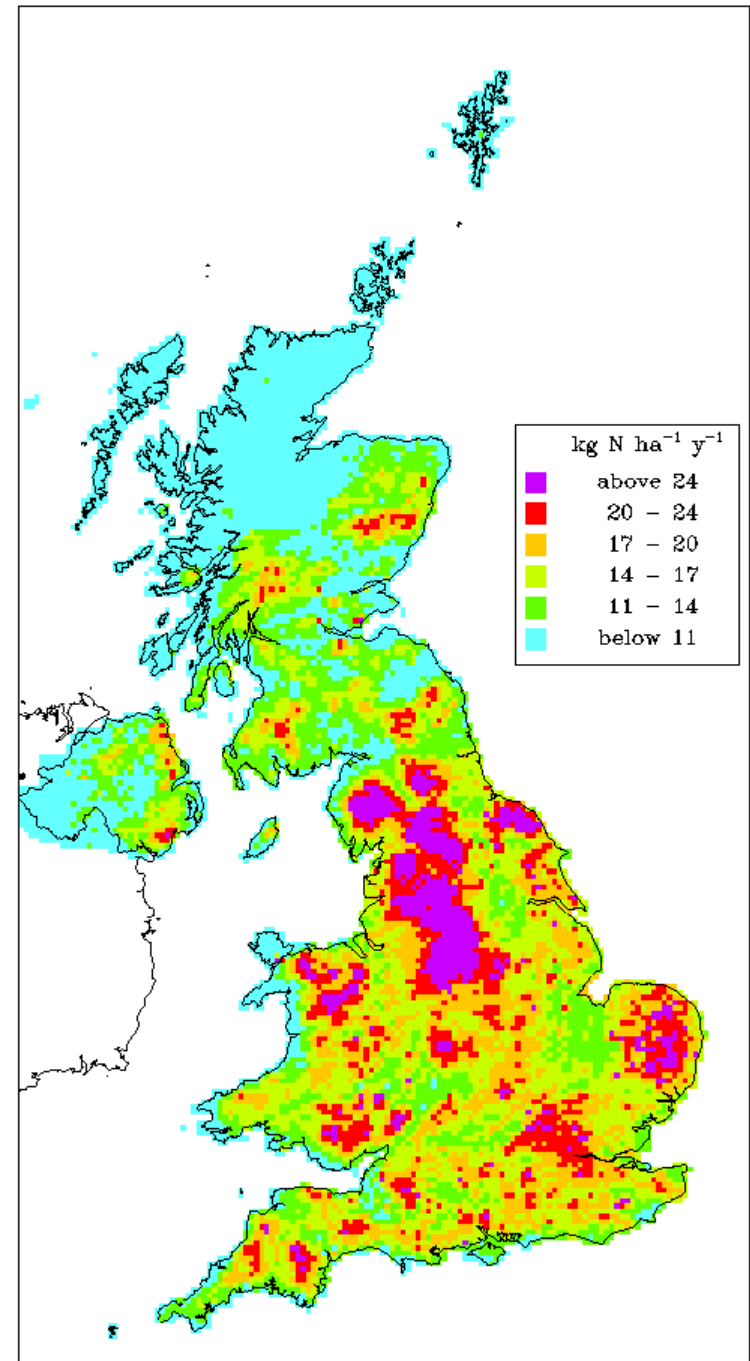
- Very few concentration measurements of  $\text{NH}_3$ ,  $\text{NO}_2$  or  $\text{HNO}_3$  before 1970
- Very few measurements of dry deposition prior to 1980
- UK concentration monitoring network for  $\text{NO}_2$  1986-2002
- UK concentration monitoring network for  $\text{NH}_3$  1996-2002
- UK concentration monitoring network for  $\text{HNO}_3$  2000-2002
- Dry deposition monitoring 3 sites, for model development and testing

# Total Nitrogen deposition in the UK 2001

Comprises,  $\text{NO}_3$ ,  $\text{NH}_4$  wet deposition,  
corrected for seeder-feeder effects,  
Cloud deposition  $\text{NO}_3$ ,  $\text{NH}_4$ ,  
 $\text{NH}_3$ ,  $\text{NO}_2$ ,  $\text{HNO}_3$  dry deposition from measured concentration fields.

5 km x 5 km resolution

Total deposition of nitrogen – 2001

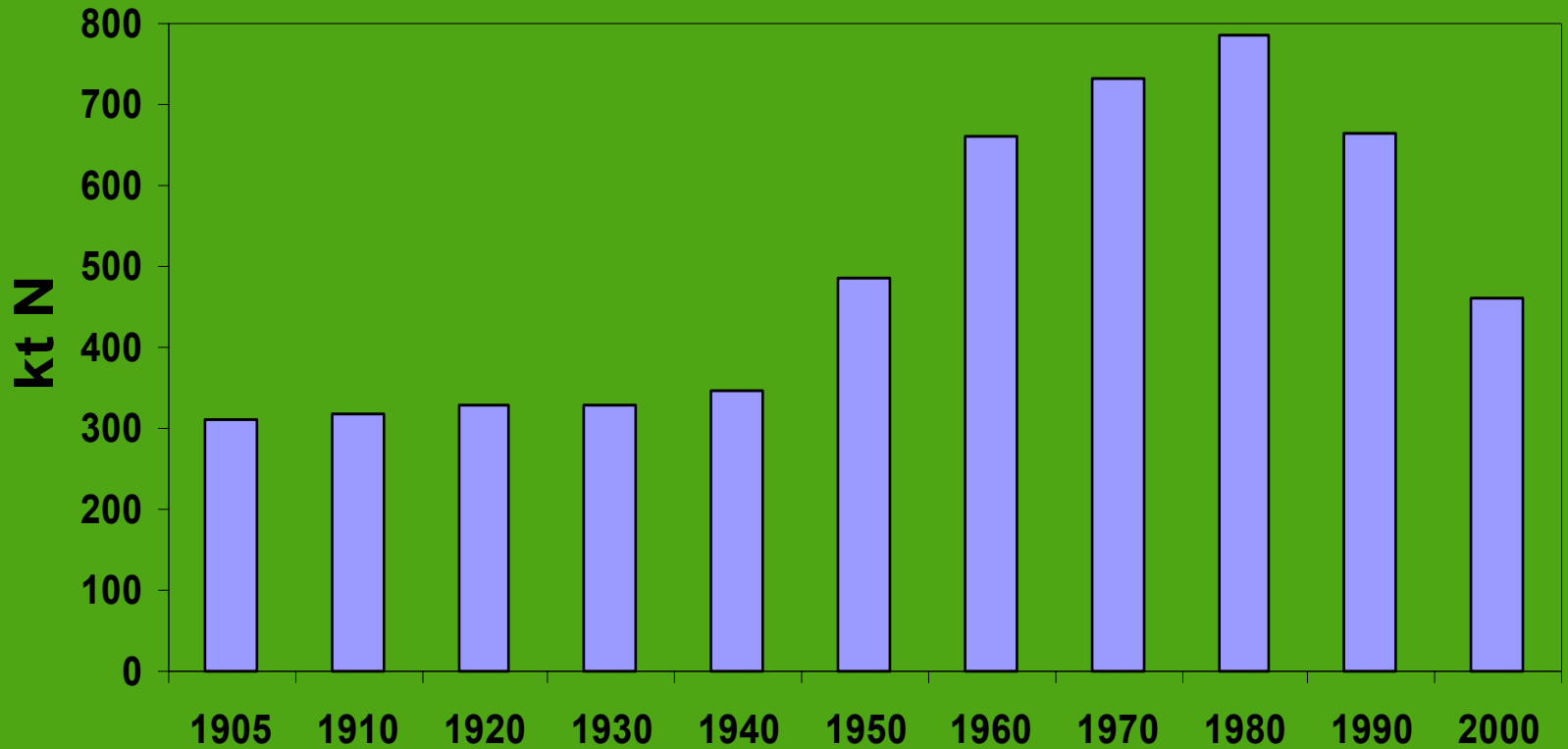


**Need to estimate deposition pre 1950**

# Emissions

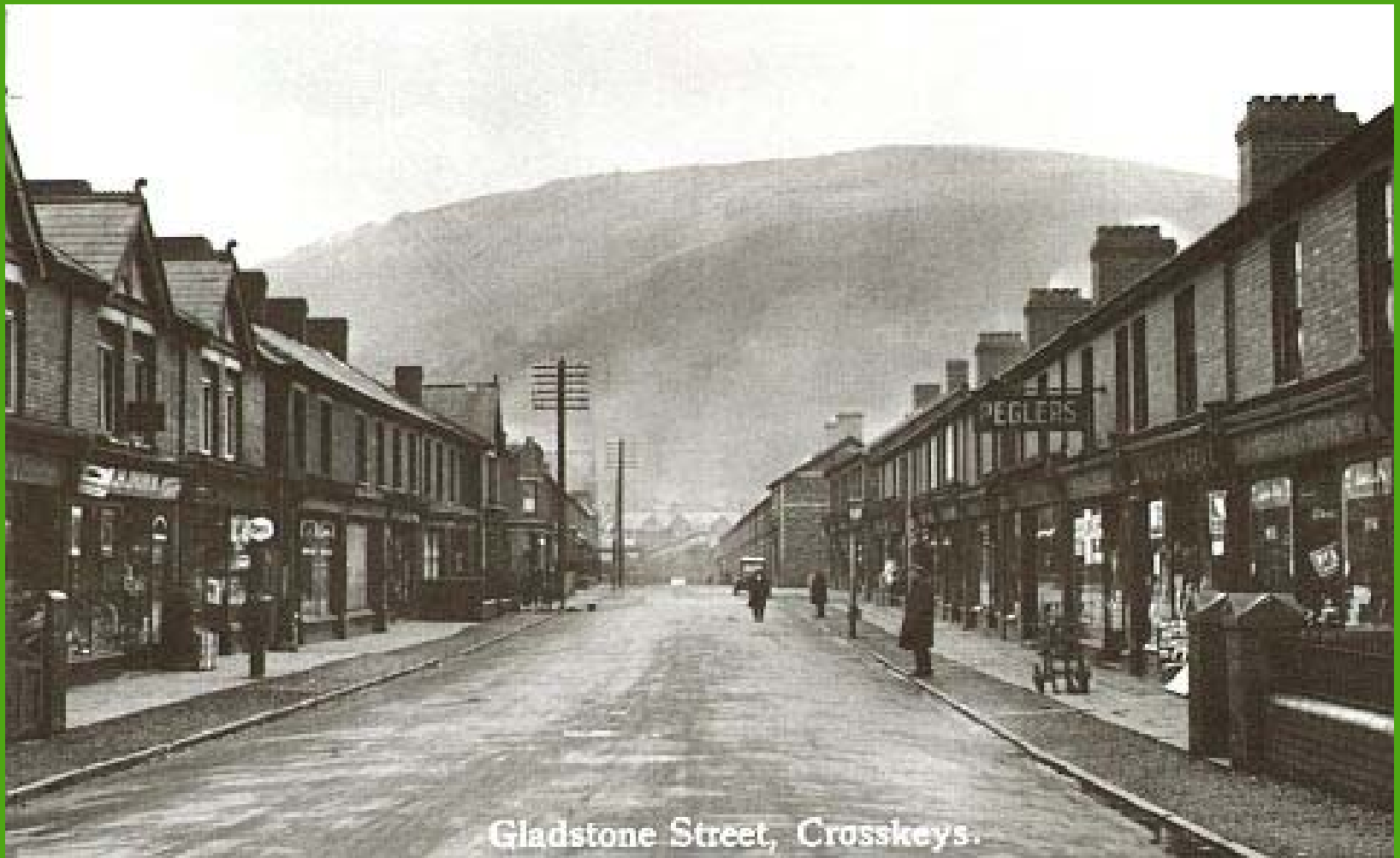
- Much better known than concentrations in earlier decades
- Statistics available on source activities
- Most work to date on oxidized N
- Little work on early reduced N emissions

# Oxidized N Emissions UK



# Reduced N Emissions UK

Agricultural emissions have not always been the main source

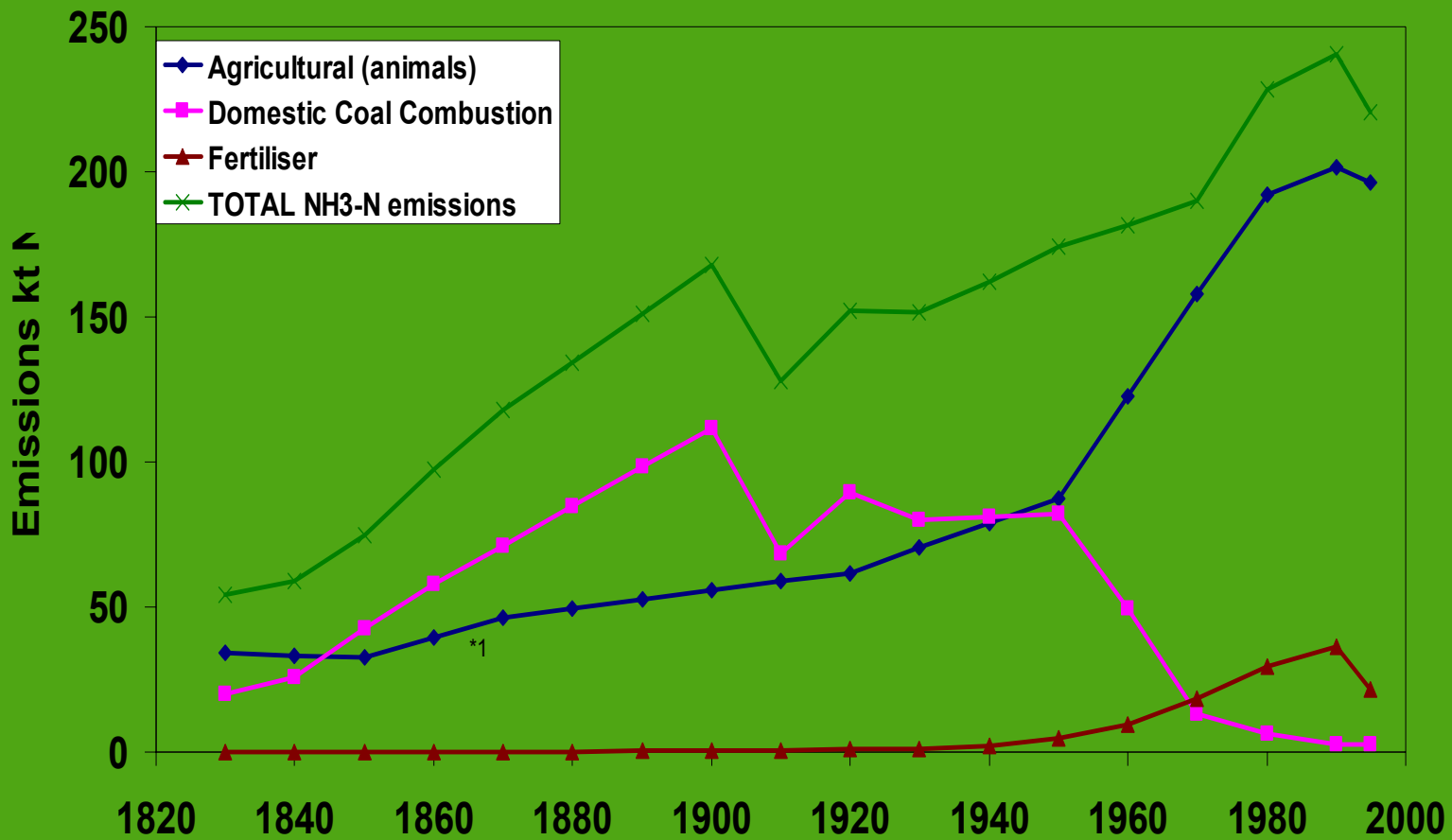


Gladstone Street, Crosskeys.

- Emission from coal combustion?
- Domestic coal contains 1.5% N
- At low temperatures and limited oxygen supply N emitted as  $\text{NH}_3$
- A conservative estimate of  $\text{NH}_3$  emission from coal (Robbins Robinson 1972) was used  $0.82 \text{ kg NH}_3 \text{ Tonne}^{-1}$ , this represents 5% of the fuel N.

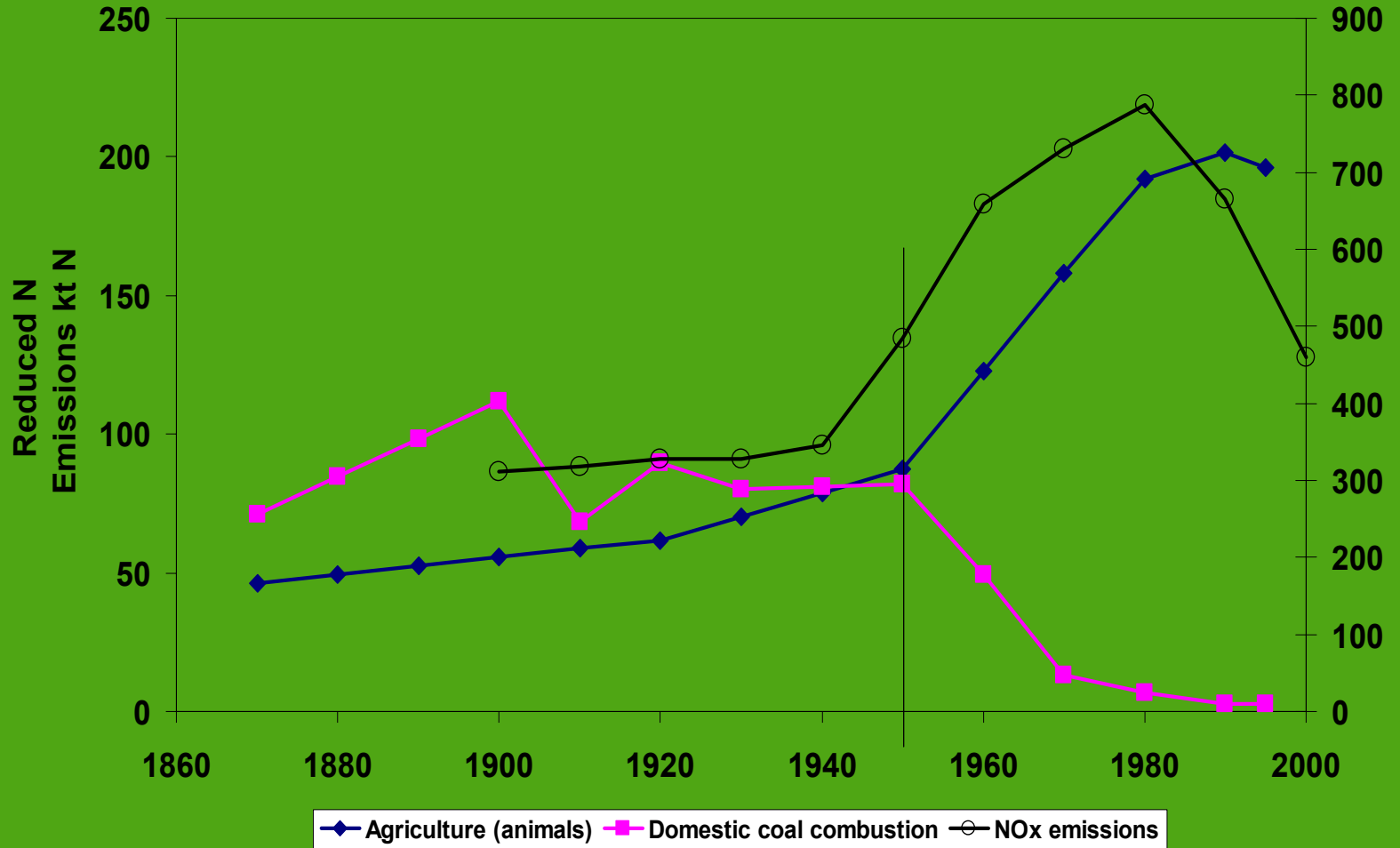


# NH<sub>3</sub>-N Emissions (UK)



\*1- pre 1870, animal numbers scaled according to human population (UK)

# Oxidised and Reduced Nitrogen Emissions



# Constructing the time series

Summary of assumptions

Wet Deposition

- 1986-2000: Data obtained from UK Network (43 sites) S-F modelled
- 1950-1986: Conc. Data from EACN, Met O, ITE, limited data interpolated to generate conc field. → deposition map total adjusted to agree with scaled (UK budget) deposition.
- 1900-1950: Wet deposition scaled with emissions from 1950-2000, assuming linearity between emission and deposition.

# Constructing the time series

## Summary of assumptions

### Dry Deposition

- 1995-2000: Dry deposition, UK  $\text{NO}_2$ ,  $\text{NH}_3$ ,  $\text{HNO}_3$ , measured concentration fields with dry deposition model (Smith et al 1998)
- 1900-1995 Oxidised and reduced N scaled from UK emissions assuming linearity between emission and deposition
- 1830-1870 Reduced Nitrogen (animal numbers pre 1870 scaled according to human population)

# Deposition 1900-2000

- How much N has been deposited (and exported)
- Where is the deposited N?

# UK atmospheric Nitrogen budget (kt N)

Year	Emissions			Deposition			Export		
	Oxidised N	Reduced N	Total N Em	Ox N Depo	RedN Dep	Total depo	Ox N	Red N	Total Expo
1900	312	168	480	66	163	229	246	5	250
1910	318	128	446	67	125	192	251	4	255
1920	327	152	480	69	148	217	258	4	262
1930	327	151	479	69	147	216	258	4	262
1940	345	162	508	73	158	231	272	4	277
1950	484	174	658	102	169	271	382	5	387
1960	659	181	840	139	176	315	520	5	525
1970	731	190	920	154	185	339	577	5	582
1980	787	228	1015	194	222	416	593	6	599
1990	665	241	906	196	234	430	470	7	476
2000	460	263	723	191	211	402	270	52	321
Total	50014	18026	68040	11475	17484	28959	38539	542	39081

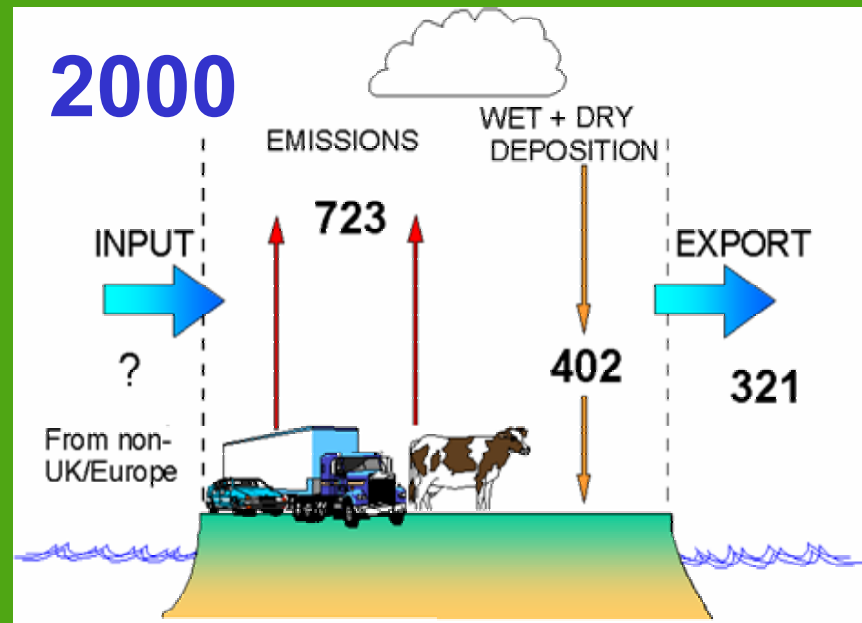
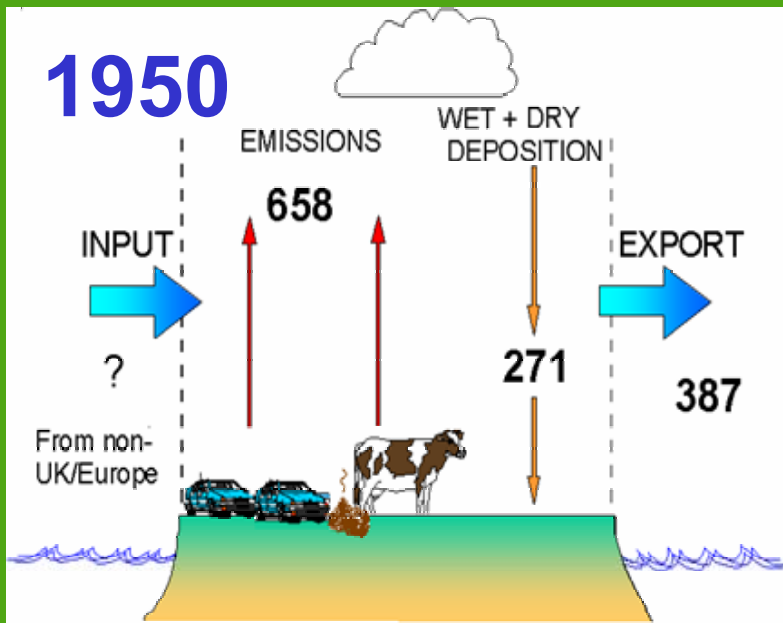
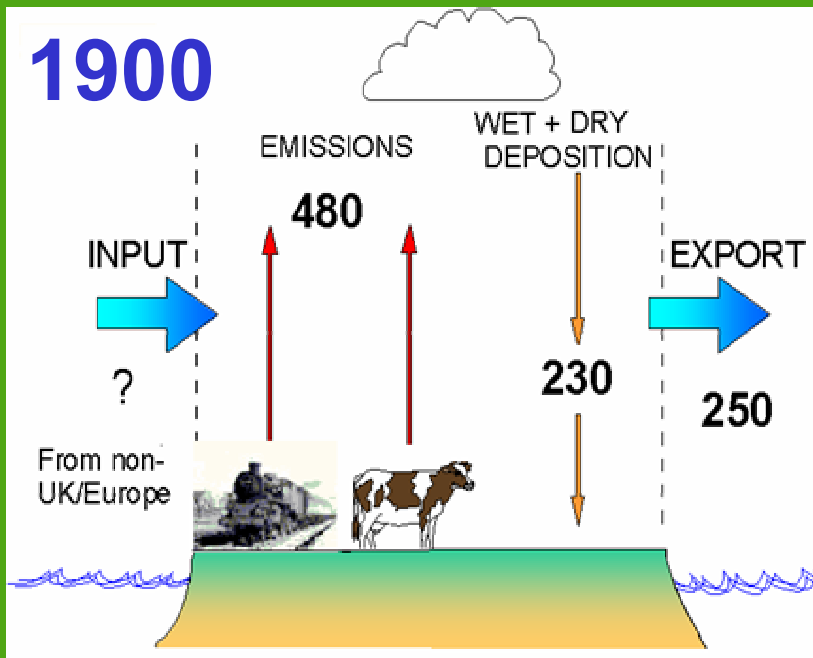
# UK atmospheric Nitrogen budget 1900-2000

A few statistics

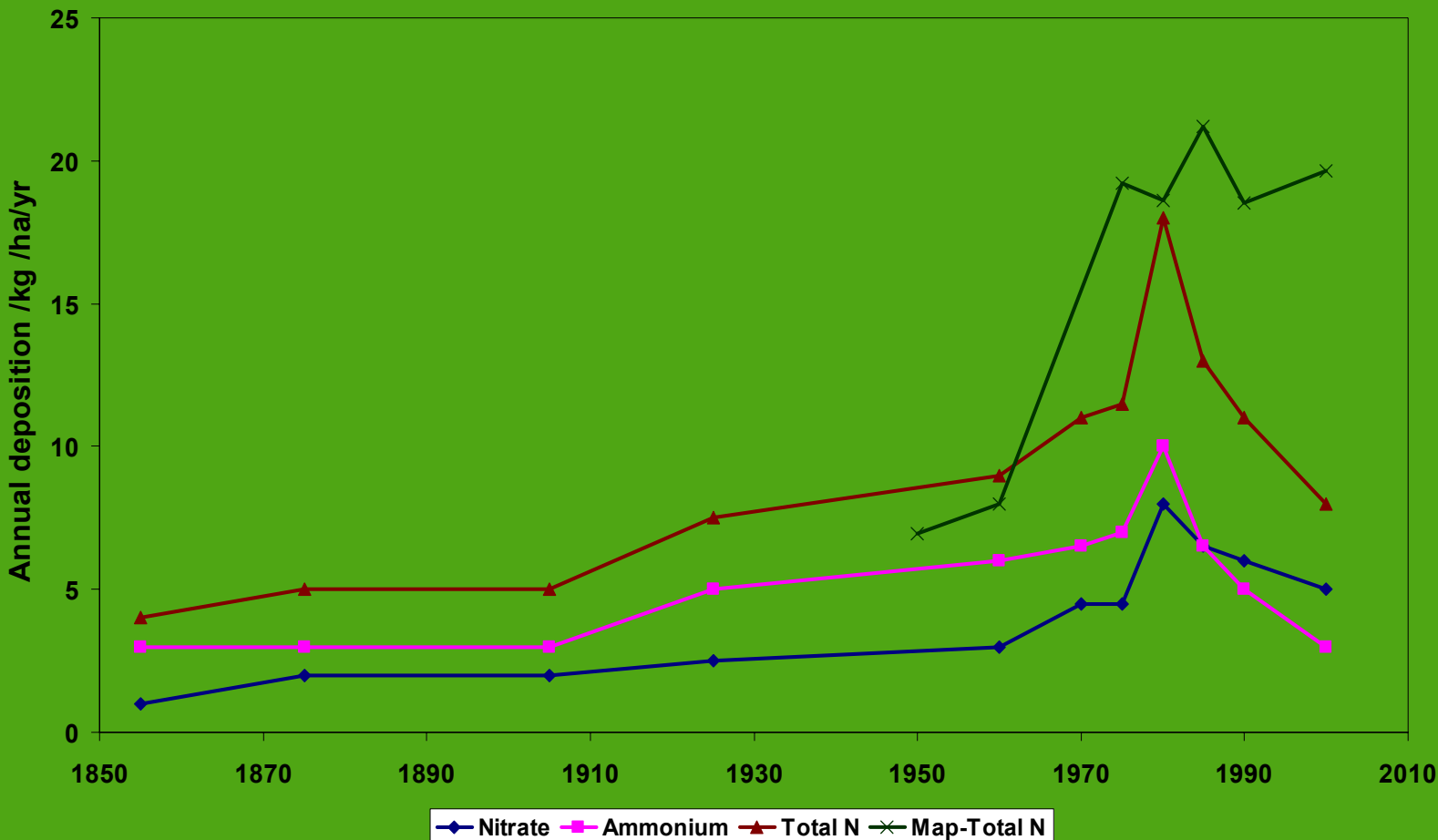
		M tonne N	
		Oxidized	Reduced
• Total Emissions	68	50	18
• Total Deposition	29	12	17
• Export to the global atmosphere	39		

(Current global emissions ~120 M tonnes –N)

# Nitrogen Budget UK K tonnes y<sup>-1</sup>

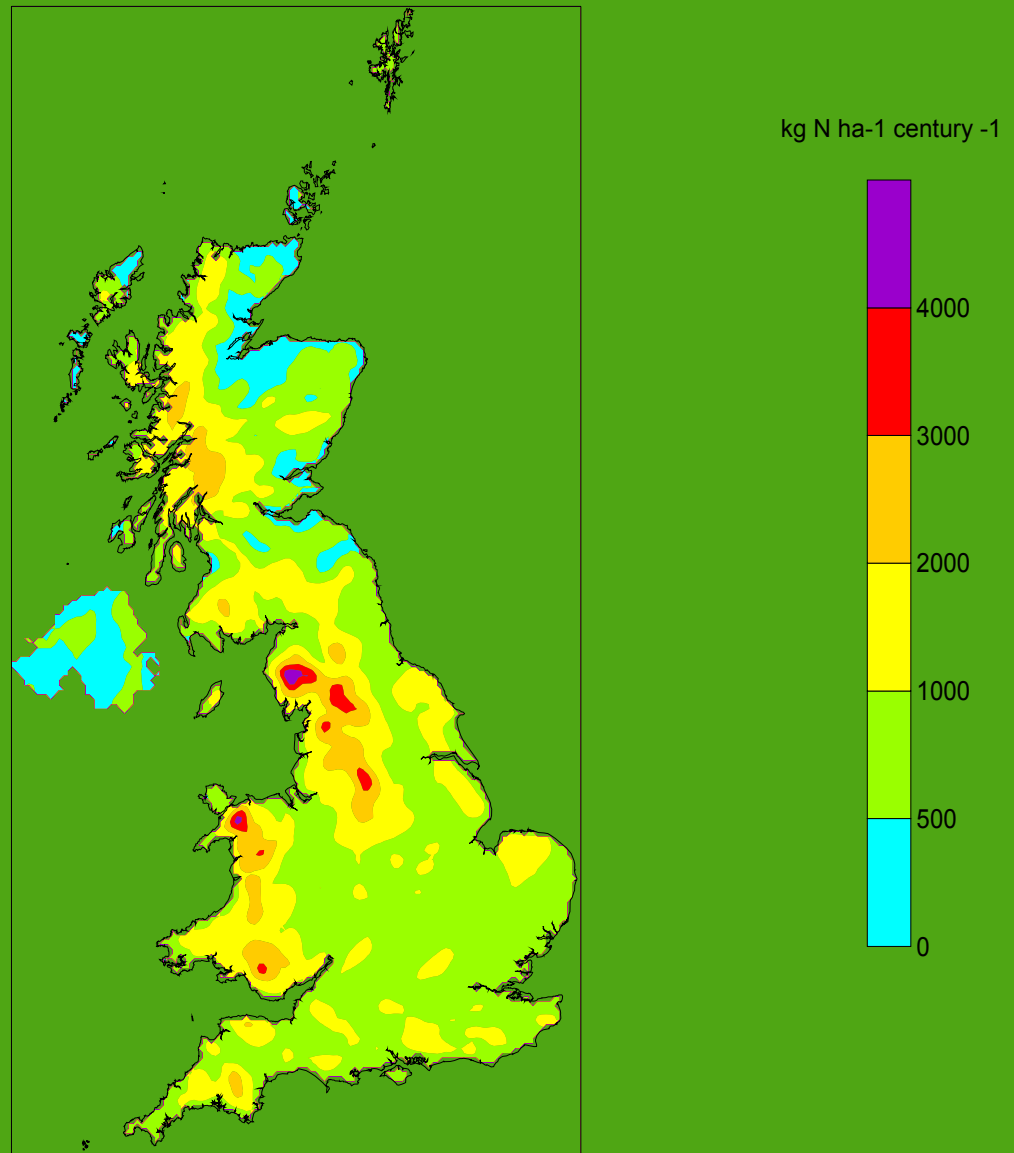


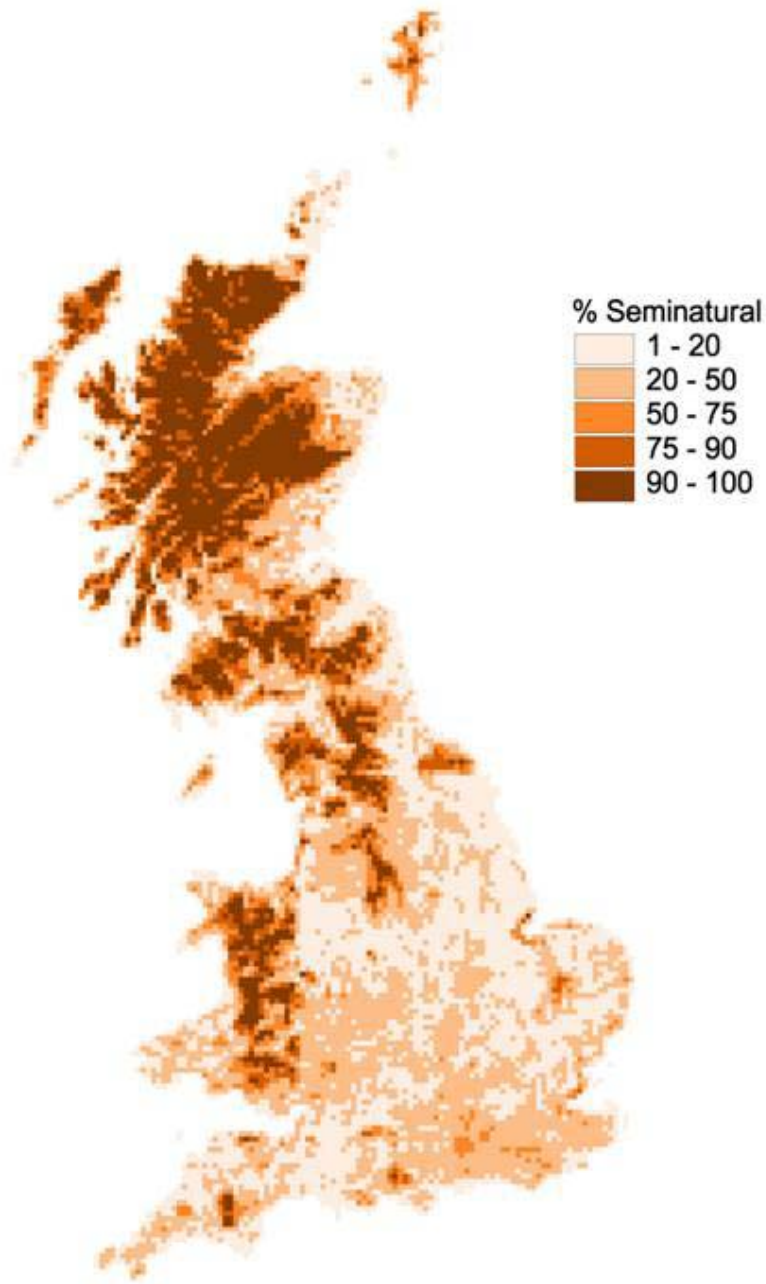
# Annual deposition ( $\text{kg ha}^{-1} \text{ y}^{-1}$ ) of N at Rothamsted Experimental Station from 1855 to 1995. Data points are 5-yr means. (From Goulding et al. 1998)



# Total N deposition – 1900-2000

The Nitrogen  
is not uniformly  
deposited

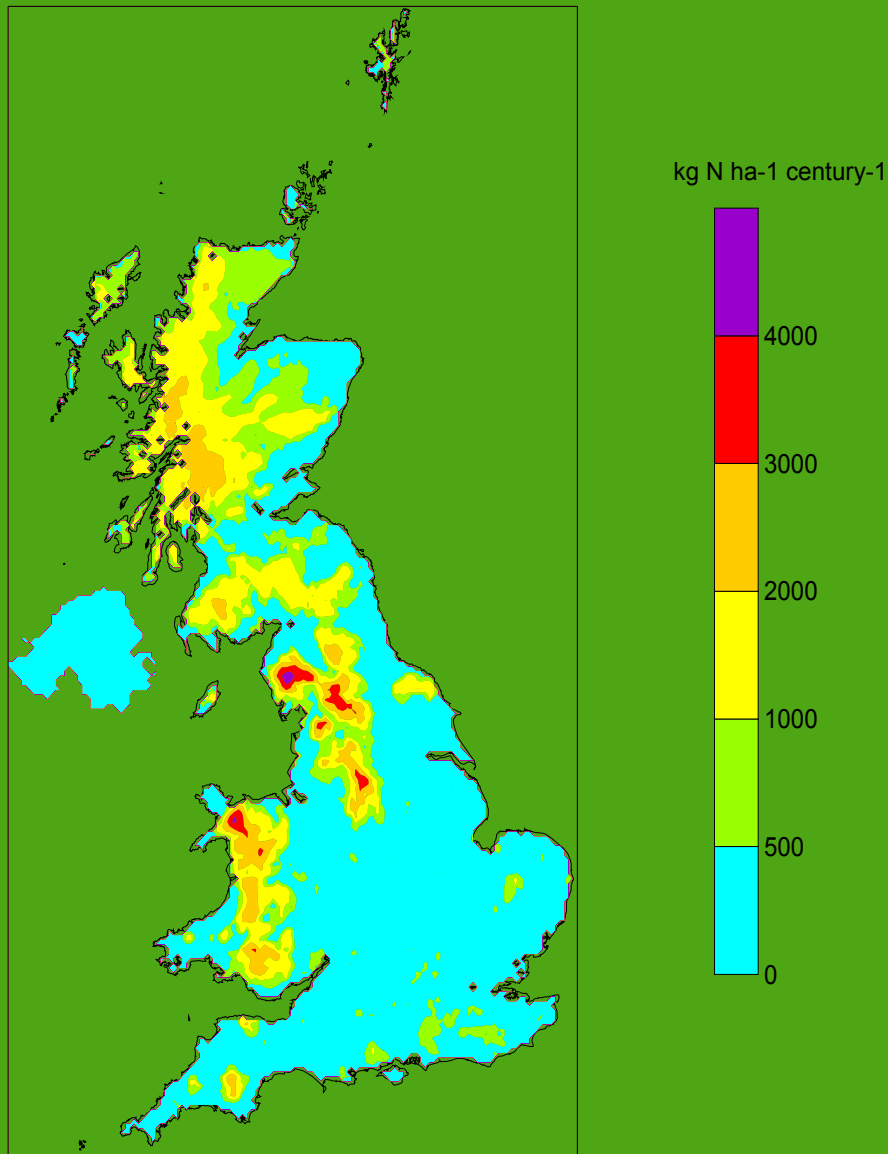




## Semi-natural land cover (%)

**47% of the total  
area is semi-  
natural**

# N deposition on semi-natural UK from 1900-2000



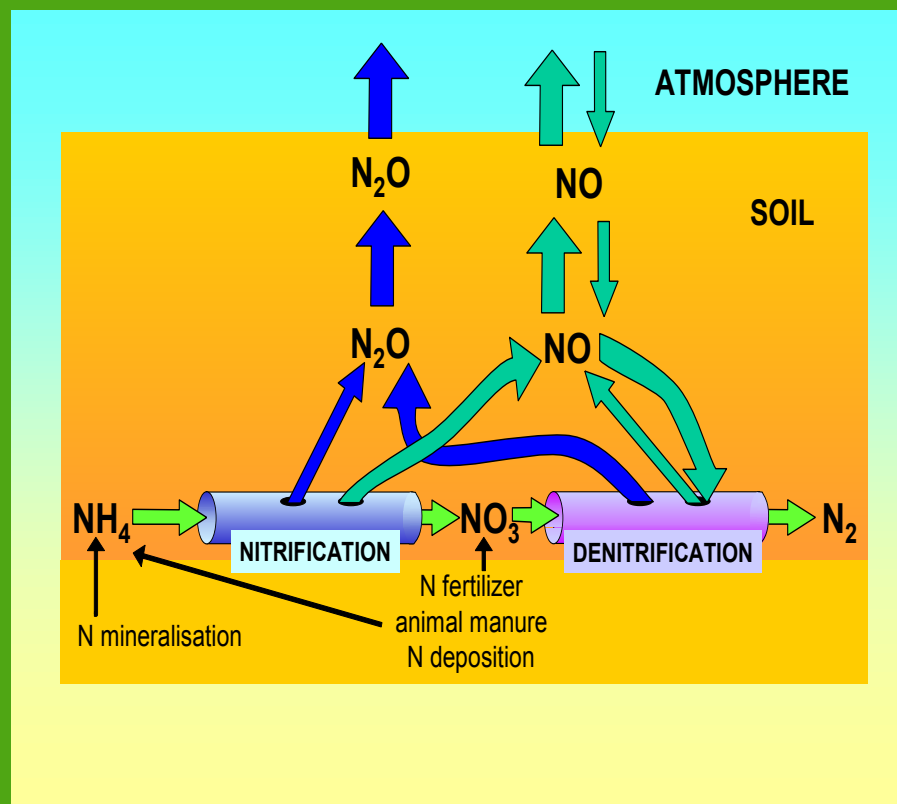
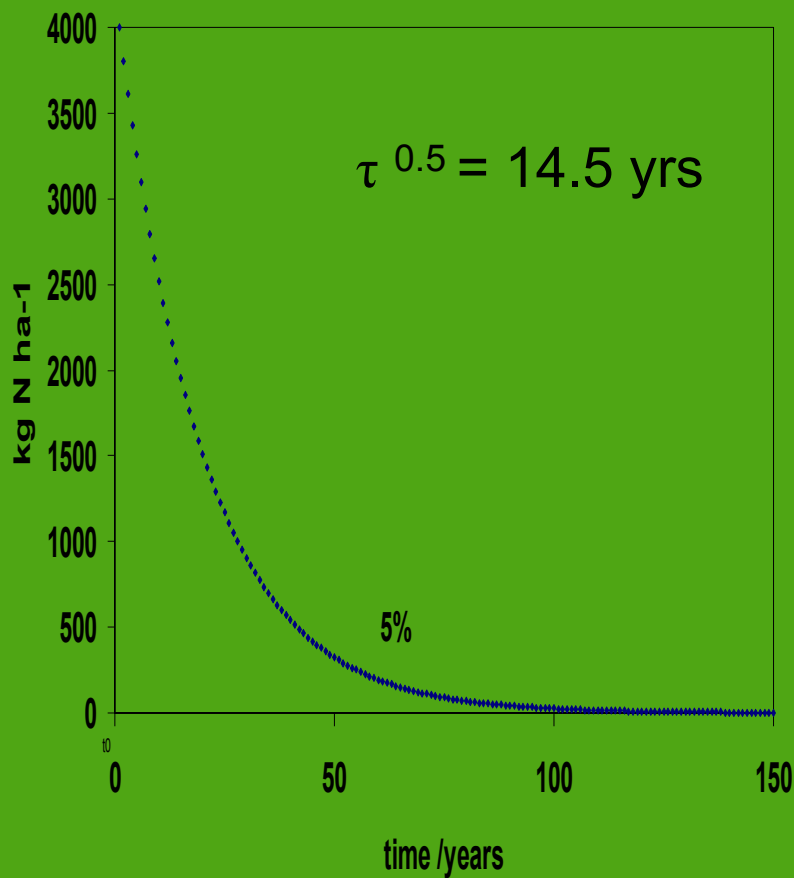
# Where has the Nitrogen gone?

- Total of 29 Mt N deposited (100 years) on the UK
  - 18 Mt deposited on semi-natural land
  - Range of N deposition : 0.5 – 5 t ha<sup>-1</sup>
  - Denitrification N<sub>2</sub> and NO<sub>3</sub> leaching < 5%
  - N content on semi-natural soils 0.5 – 2 t ha<sup>-1</sup>
- The enhancement in semi-natural soils/vegetation should be detectable



# Recovery

- Returning the soil N to the atmosphere as N<sub>2</sub>
- Rate coefficient (land use, soil, climate)



# CONCLUSIONS

- A chronology of N deposition in the UK 1900 to 2000 has been constructed.
- New maps of UK N deposition extending the monitoring record back from 1986 to the 1950s have been produced. (UK budgets back to 1900).
- 68 M tonnes N emitted, 29 M tonnes deposited in UK, (60% reduced form), 39 Mt exported to the global atmosphere.
- Of the 29Mt N deposited, 18 Mt on semi-natural soil/vegetation, especially in uplands.
- The N deposition on semi-natural ecosystems includes  $10^6$ ha receiving  $> 2$  tonnes  $\text{ha}^{-1}$ , should be detectable and has a long lifetime in wet acid soils.