Constructing the UK National N Budget

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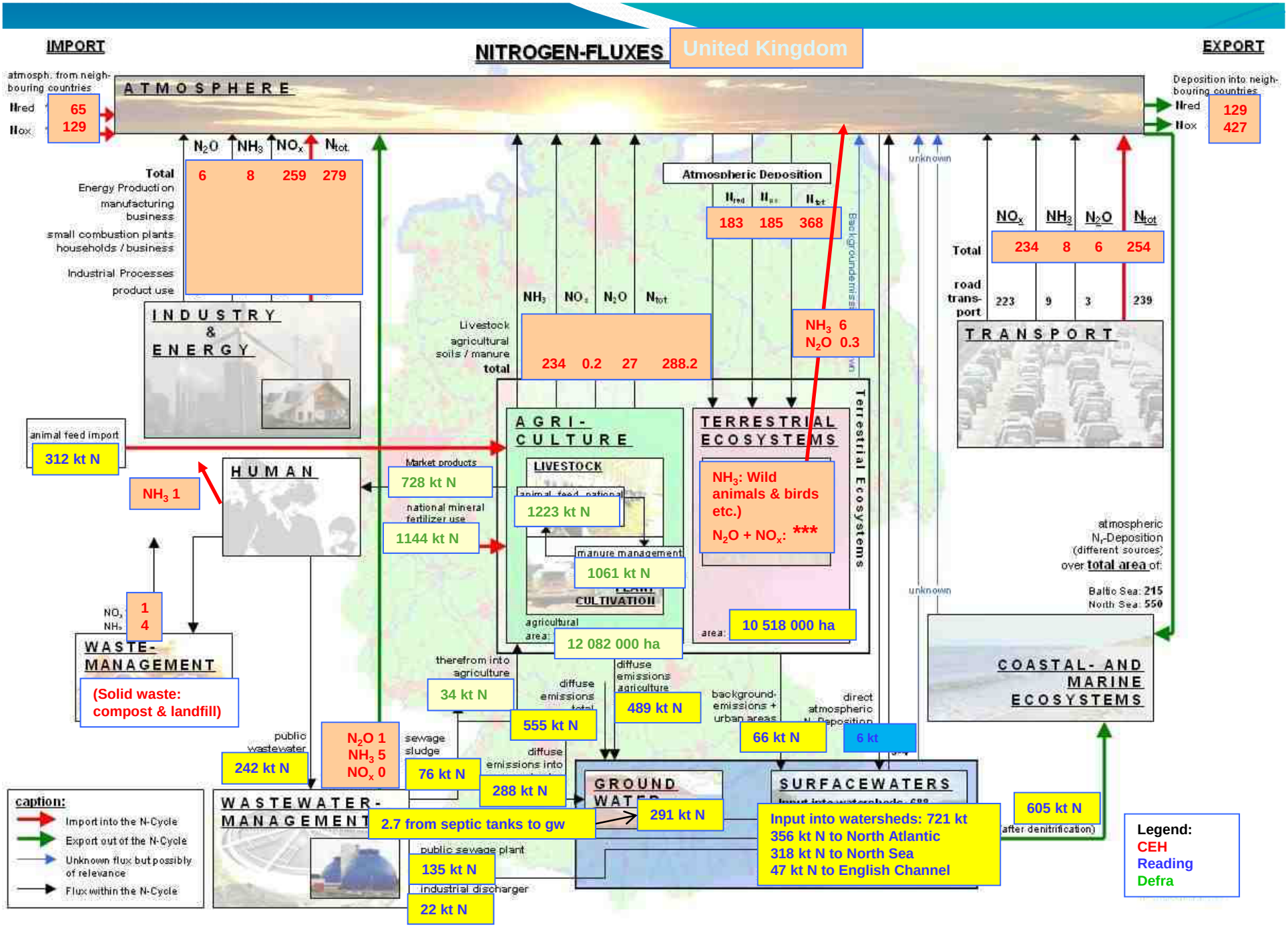

IMPORT
NITROGEN-FLUXES
United Kingdom
EXPORT
atmosph. from neigh-bouring countries
Nred
Nox
65
129
ATMOSPHERE
Deposition into neigh-bouring countries
Nred
Nox
129
427
N2O NH3 NOx Ntot
Total
Energy Production
manufacturing business
small combustion plants households / business
Industrial Processes
product use
6 8 259 279
INDUSTRY & ENERGY
Atmospheric Deposition
Nred Nox Ntot
183 185 368
Background emissions
NOx NH3 N2O Ntot
Total
234 8 6 254
road trans-port
223 9 3 239
TRANSPORT
NH3 N2O NOx Ntot
Livestock agricultural soils / manure total
234 0.2 27 288.2
NH3 6
N2O 0.3
unknown
unknown
animal feed import
312 kt N
HUMAN
NH3 1
AGRI-CULTURE
LIVESTOCK
Market products
728 kt N
national mineral fertilizer use
1144 kt N
1223 kt N
manure management
1061 kt N
CULTIVATION
agricultural area:
12 082 000 ha
TERRESTRIAL ECOSYSTEMS
NH3: Wild animals & birds etc.)
N2O + NOx: ***
area:
10 518 000 ha
Terrestrial Ecosystems
atmospheric Nr-Deposition (different sources) over total area of:
Baltic Sea: 215
North Sea: 550
NOx NH3
1 4
WASTE-MANAGEMENT
(Solid waste: compost & landfill)
therefrom into agriculture
34 kt N
diffuse emissions total
555 kt N
diffuse emissions agriculture
489 kt N
background-emissions + urban areas
66 kt N
direct atmospheric N-Deposition
6 kt
COASTAL- AND MARINE ECOSYSTEMS
public wastewater
242 kt N
N2O 1
NH3 5
NOx 0
sewage sludge
76 kt N
diffuse emissions into
288 kt N
GROUND WATER
291 kt N
SURFACEWATERS
Input into watersheds: 721 kt
356 kt N to North Atlantic
318 kt N to North Sea
47 kt N to English Channel
605 kt N
(after denitrification)
WASTEWATER-MANAGEMENT
2.7 from septic tanks to gw
public sewage plant
135 kt N
Industrial discharger
22 kt N
caption:
Import into the N-Cycle
Export out of the N-Cycle
Unknown flux but possibly of relevance
Flux within the N-Cycle
Legend:
CEH
Reading
Defra

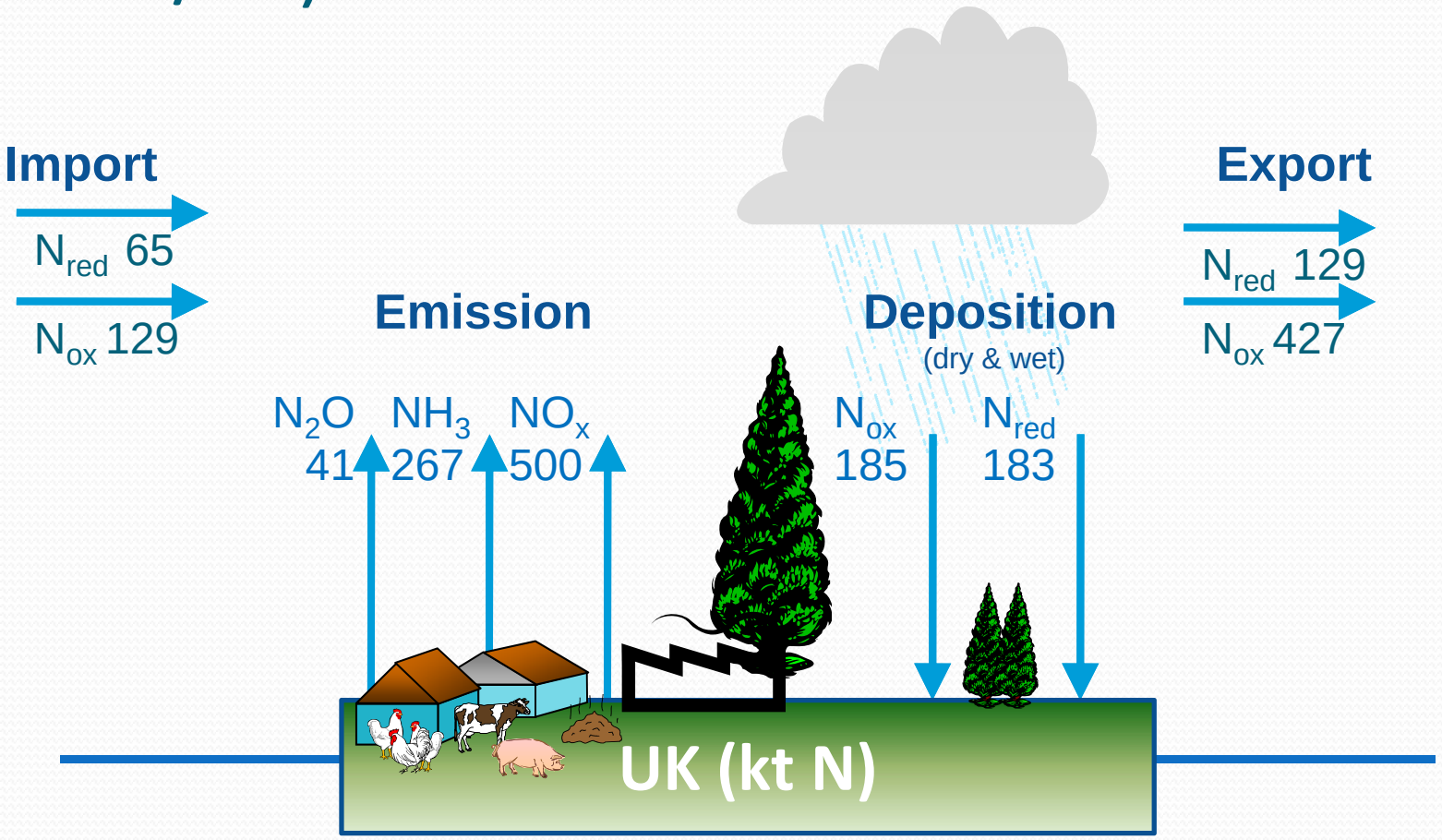
Calculating the UK Food & Feed N balance

- N import in animal feed import is actually food (human) and feed import, based on our national food and feed balance modelling, using the NANI (Net Anthropogenic Nitrogen Inputs) modelling approach developed for NE USA (Howarth, Boyer)

- Our figure for N in animal feed produced nationally (in the Agriculture box) is taken from this same national F&F modelling

- N export from agriculture to humans in market products is taken from this same national modelling work using FAOSTAT Food & Feed spreadsheets for the UK, and the Defra Summary Statistics from the 2008 Agricultural Census

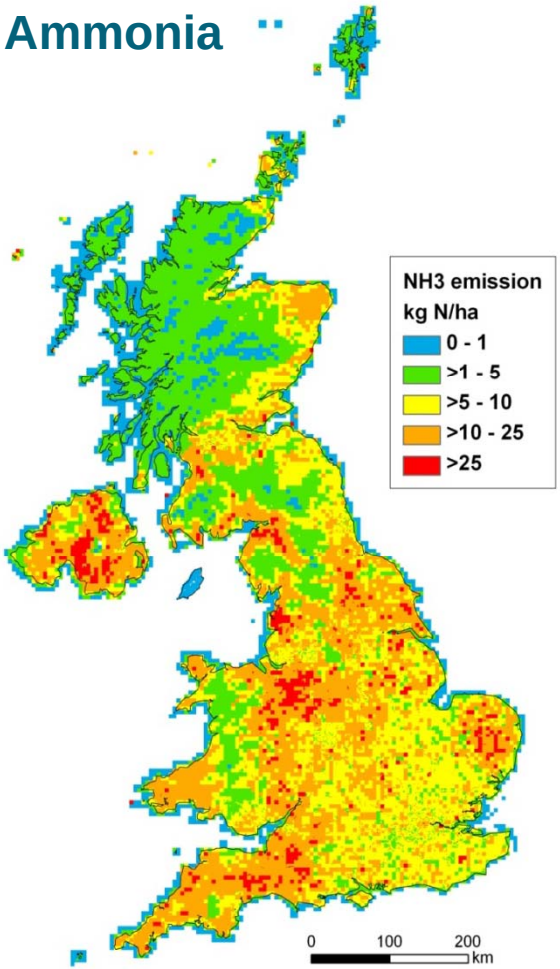
Calculating the UK atmospheric N budget (2005/06)



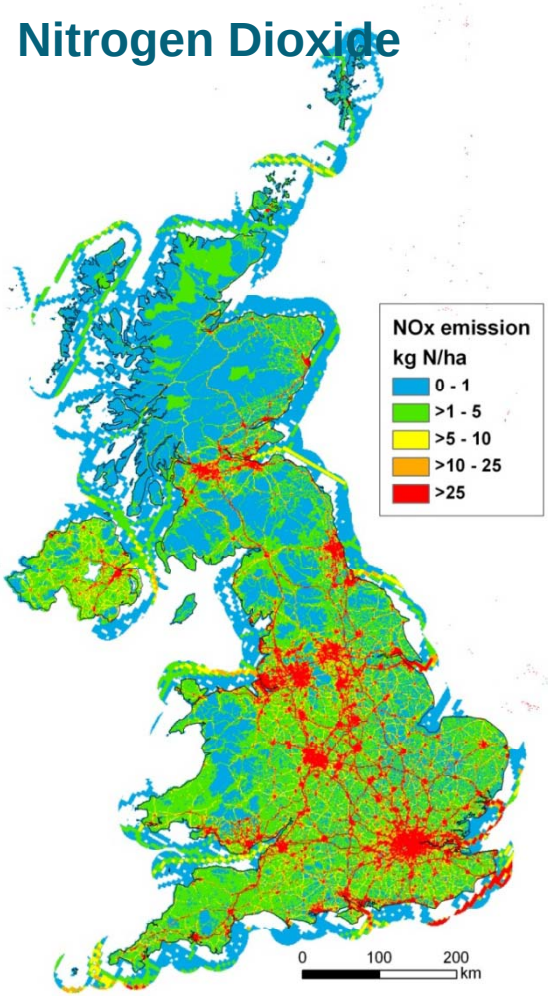
Version 2 will be available shortly

UK atmospheric N emissions

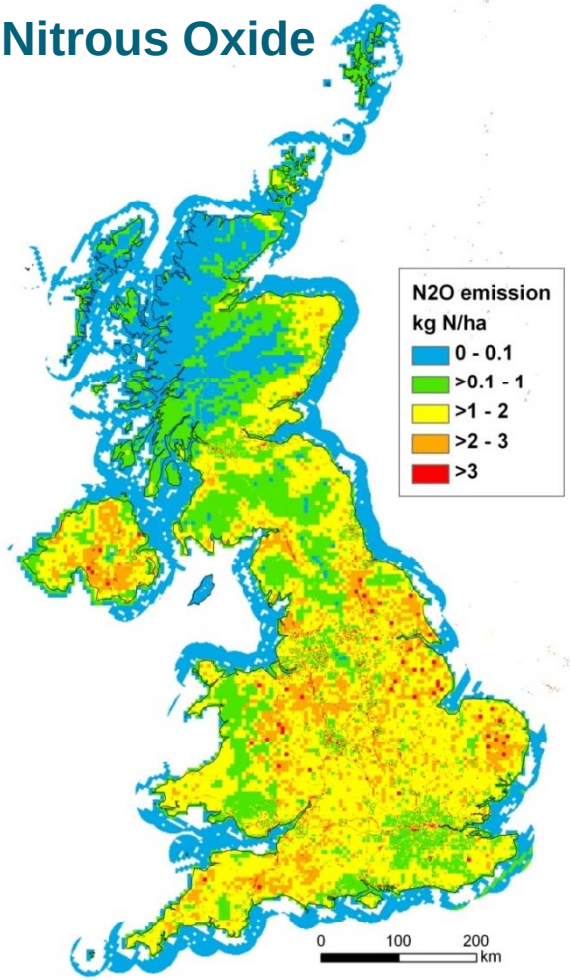
Ammonia



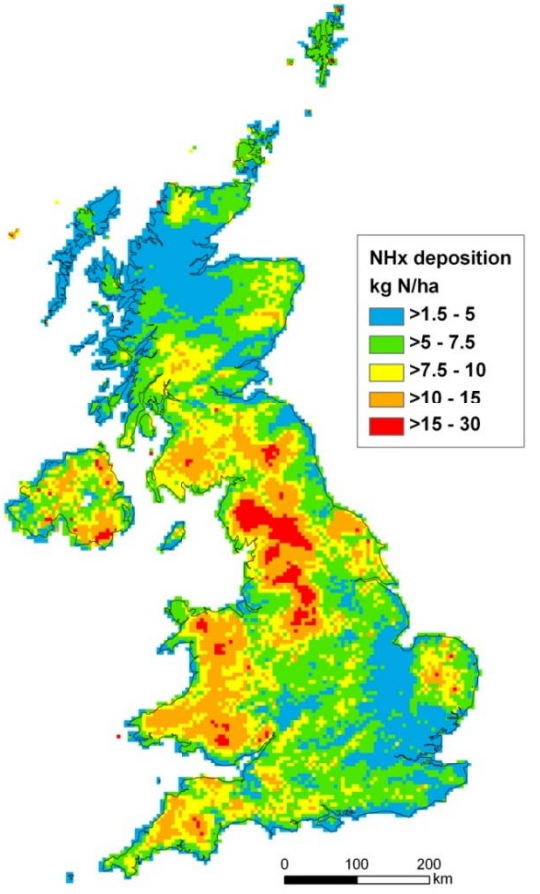
Nitrogen Dioxide

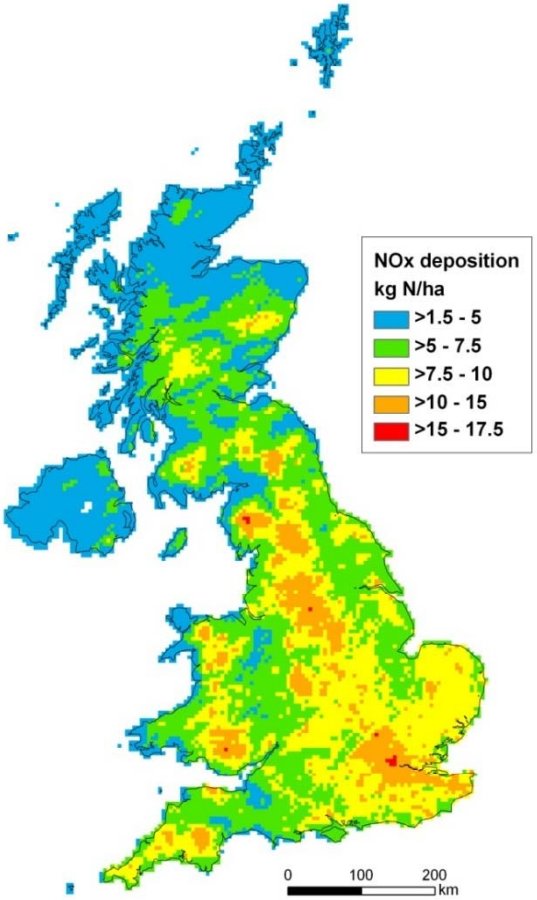


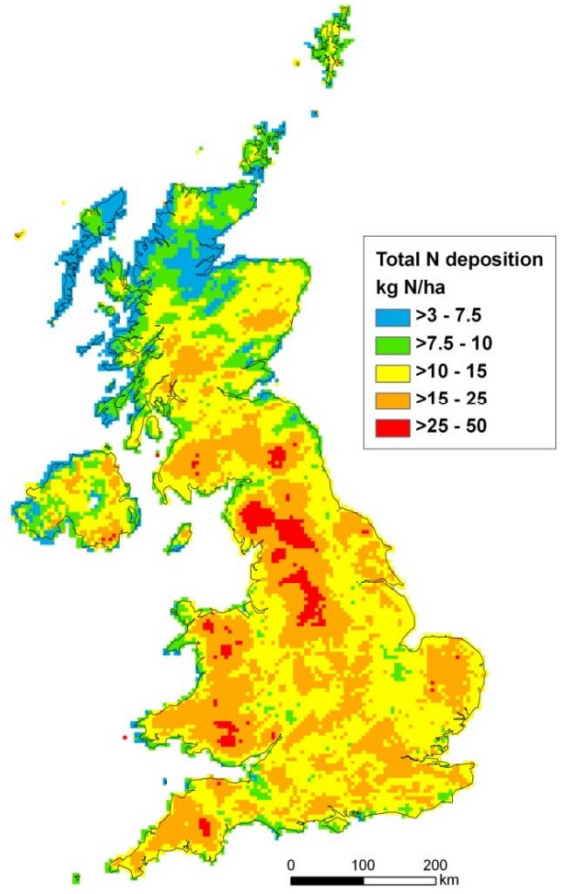
Nitrous Oxide



UK atmospheric N deposition







Reduced N + Oxidised N = Total N deposition

Calculating N deposition to UK surface waters

- For direct deposition to surface waters, we have taken national census data for standing waters in mainland GB (213,911 ha) plus Lough Neagh (39,200 ha) and Lough Erne (10,384 ha) in N Ireland, giving 263495 ha in total, rounded it up to 300000 ha to take account of all the rivers missing for the UK and the loughs missing from NI.

- The total surface water area is then multiplied by an average of 20 kg N deposition (total)/ha to give 6M kg N or 6 kt N direct deposition to surface waters.

- This figure has a high degree of uncertainty attached!

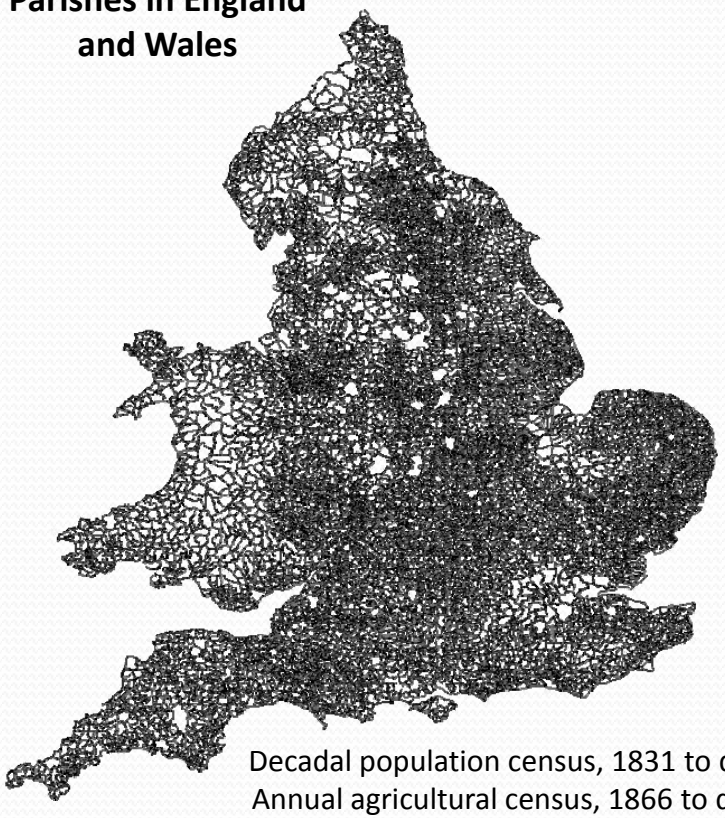
Calculating the UK terrestrial N budget (2004)

- The N budgets for agricultural and non-agricultural systems are calculated separately
- The N balance for UK agricultural systems is calculated as a farm gate balance (Defra), accounting for:
  - fertiliser use
  - manure management
  - N fixation by crops and grass
  - sewage waste applications, and
  - atmospheric N inputs to all agricultural land by crop type.
  - Animal feed imports
  - Offtake of N in arable and livestock products and through manure incineration

Calculating the total UK agricultural land area (by crop type)

UK agricultural **land use** has been estimated from the annual agricultural census returns, available annually for every parish (c. 1km2 in area) from 1866 to date

Parishes in England and Wales



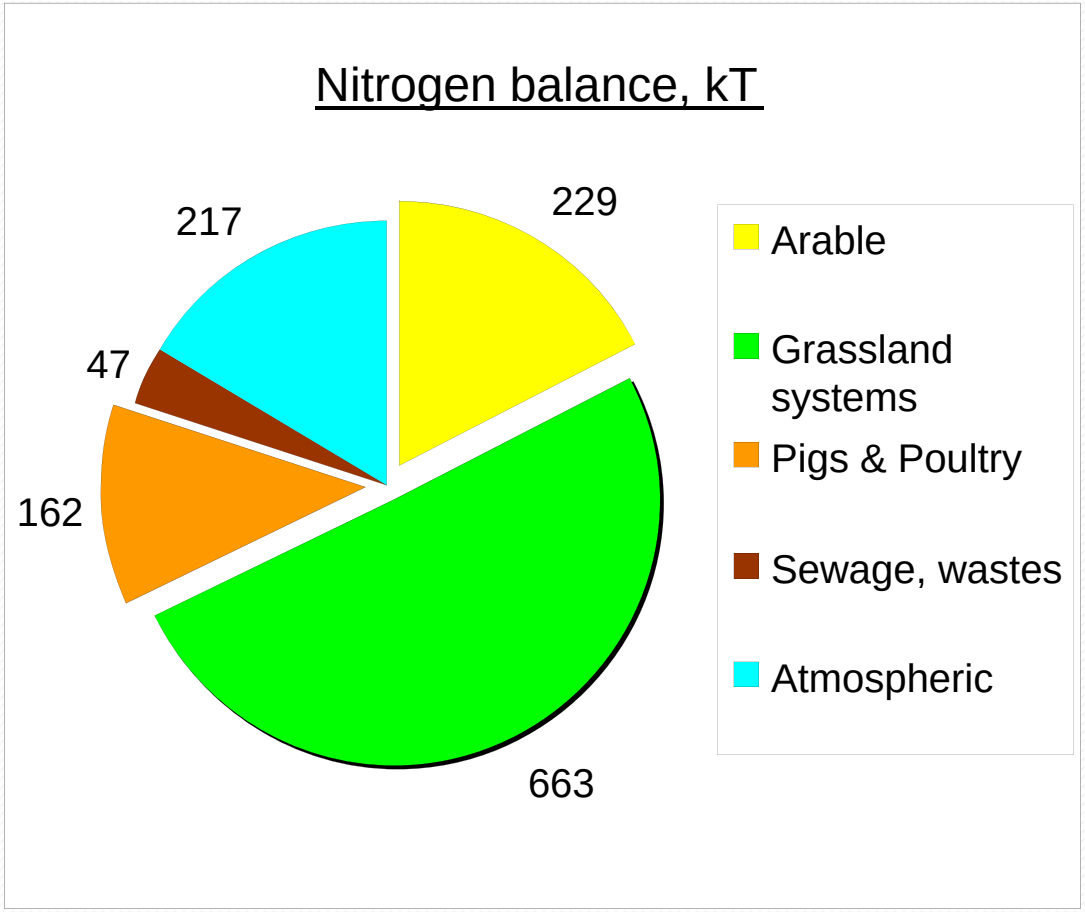
Decadal population census, 1831 to date
Annual agricultural census, 1866 to date

Land, crops & livestock	Average	2007	2008
Tables 3.1 & 3.2 Agriculture in the United Kingdom 2008	1997-99		prov.
Land use		Thousand hectares	
Crops	4 890	4 439	4 740
Bare fallow	32	165	195
All grass under 5 years old	1 311	1 176	1 141
All grasses over 5 years old	5 365	5 965	6 036
Sole right rough grazing	4 618	4 313	4 359
Set aside	397	440	-
Other land and woodland	775	954	993
Total area on agricultural holdings	17 387	17 452	17 464
Common rough grazing	1 225	1 238	1 238
Crop areas		Thousand hectares	
Cereal crops	3 358	2 885	3 274
Other arable crops	1 182	1 170	1 152
Potatoes	169	140	144
Horticulture	181	169	170

Calculating the National Farm Gate N balance (2004)

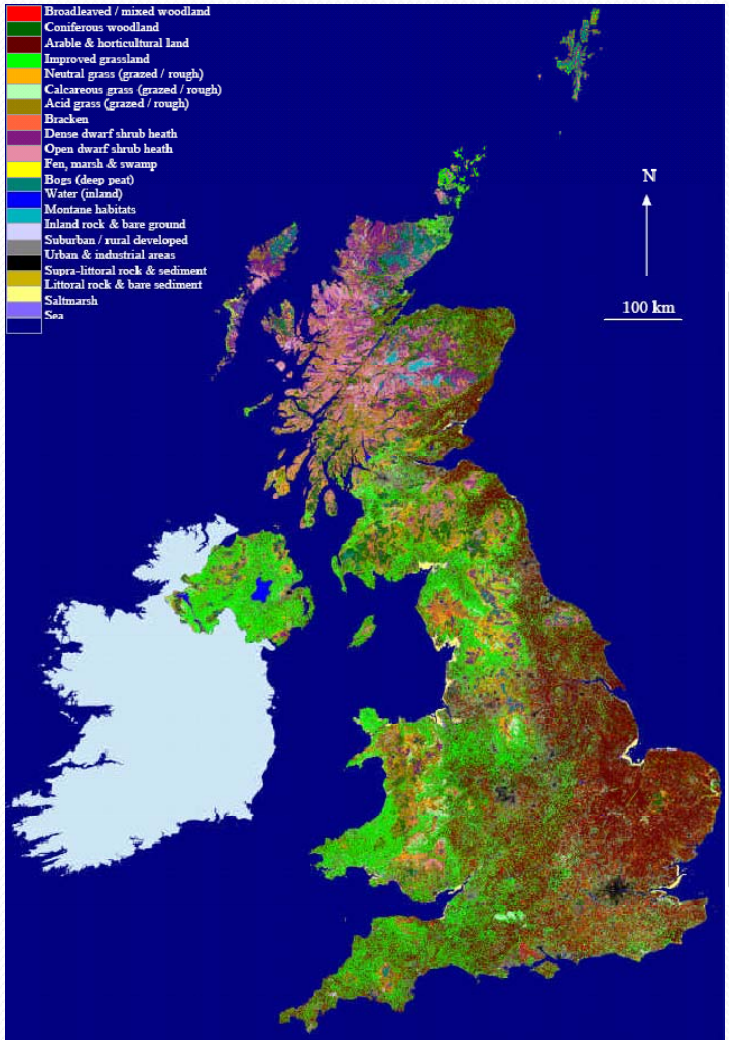
Inputs kT	England	Wales	Scotland	N Ireland	UK
Fertiliser	878	87	185	97	1246
N Fixation	87	6	8	4	105
Livestock feeds	320	34	47	55	455
Atmospheric	158	20	24	15	217
Sewage / wastes	39	3	5	1	47
Total inputs	1481	149	268	172	2070
Outputs kT					
Arable crops	448.6	5.6	53.9	4.5	512.5
Livestock products	155.8	16.8	30.7	33.4	236.7
Manure incinerated	15.6	0.0	3.3	0.0	18.9
Total outputs	619.9	22.4	87.9	37.9	768.1
Balance kT	860.6	126.7	179.9	134.6	1301.9
kg/ha managed agricultu	106.4	106.9	96.6	150.2	108.2

UK Farm Gate N balance: 2004

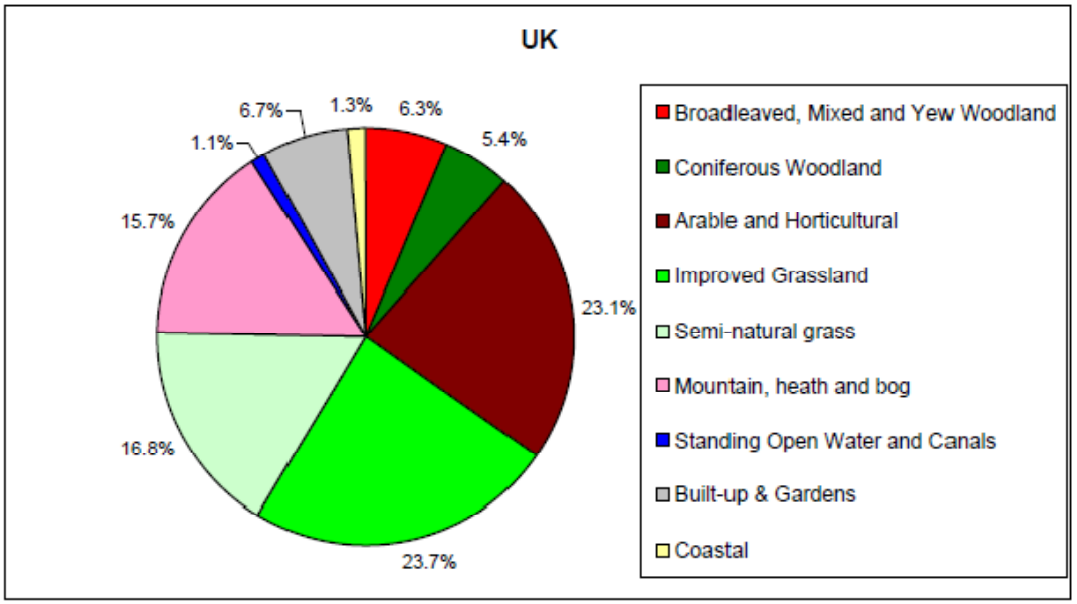


After allowing for poultry manure incineration

Calculating the total UK non-agricultural land area (by land cover type) (2000)



UK non-agricultural **land cover** has been estimated from satellite data using the CEH Land Cover Map 2000,



Land cover class aggregation (LCM 2000)

LCM2000 Subclasses	England	Wales	England & Wales		Scotland		NI		UK	
	LCM2000	LCM2000	LCM2000	FS	LCM2000	FS	LCM2000	FS	LCM2000	FS
Broad-leaved / mixed woodland	**10963**	**1609**	**12572**	**11710**	**2687**	**3000**	**341**	**510**	**15600**	**15220**
Coniferous woodland	**2990**	**1435**	**4425**	**3800**	**8454**	**9930**	**660**	**610**	**13540**	**14350**
Arable cereals	19873	181	20054		1799		0		21853	
Arable horticulture	27698	849	28547		5136		992		34675	
Non-rotational horticulture	695	0	695		408		0		1103	
Arable & Horticultural	**48266**	**1030**	**49296**	**46090**	**7342**	**6390**	**992**	**590**	**57630**	**53070**
Improved grassland	30183	7720	37903		10321		9049		57272	
Setaside grass	1777	18	1796		5		0		1801	
Improved grassland	**31960**	**7738**	**39699**	**44310**	**10326**	**10510**	**9049**	**5680**	**59073**	**60500**
Neutral grass	5008	1347	6355		4415		1742		12512	
Calcareous grass	7884	1470	9354		1293		460		11107	
Acid grass	2787	3188	5975		8508		1310		15793	
Bracken	706	294	999		893		17		1909	
Fen, marsh, swamp	180	16	196		1		80		278	
Semi-natural grass and bracken	**16564**	**6315**	**22879**	**15120**	**15110**	**14460**	**3610**	**3400**	**41600**	**33000**
Dense dwarf shrub heath	1331	580	1911		5163		453		7527	
Open dwarf shrub heath	1317	549	1867		16847		782		19496	
Bog (deep peat)	1056	58	1114		4020		523		5657	
Montane habitats	0	0	0		3971		0		3971	
Inland Bare Ground	1112	265	1377		785		78		2241	
Mountain, heath & bog	**4817**	**1453**	**6269**	**7722**	**30786**	**31260**	**1837**	**1670**	**38892**	**39230**
Water (inland)	**581**	**94**	**675**	**1060**	**1420**	**850**	**677**	**n/a**	**2771**	**n/a**
Suburban/rural developed	9527	689	10216		1169		439		11823	
Continuous Urban	4262	171	4432		314		67		4813	
Built up areas and gardens	**13788**	**860**	**14648**	**11800**	**1483**	**1510**	**506**	**n/a**	**16637**	**n/a**
Supra-littoral rock	0	0	0		19		1		20	
Supra-littoral sediment	85	33	118		48		12		178	
Littoral rock	5	5	10		46		13		68	
Littoral sediment	141	75	216		146		40		402	
Saltmarsh	201	43	244		31		1		276	
Coastal	**433**	**155**	**588**	**743**	**290**	**820**	**67**	**30**	**945**	**1593**
TOTAL	**130362**	**20689**	**151051**	**142355**	**77898**	**78730**	**17739**	**n/a**	**246688**	**n/a**

Footnotes:
LCM2000 statistics from a full count of cover based on a 25 m grid

Calculating N emissions and N export to freshwaters from non-agricultural land

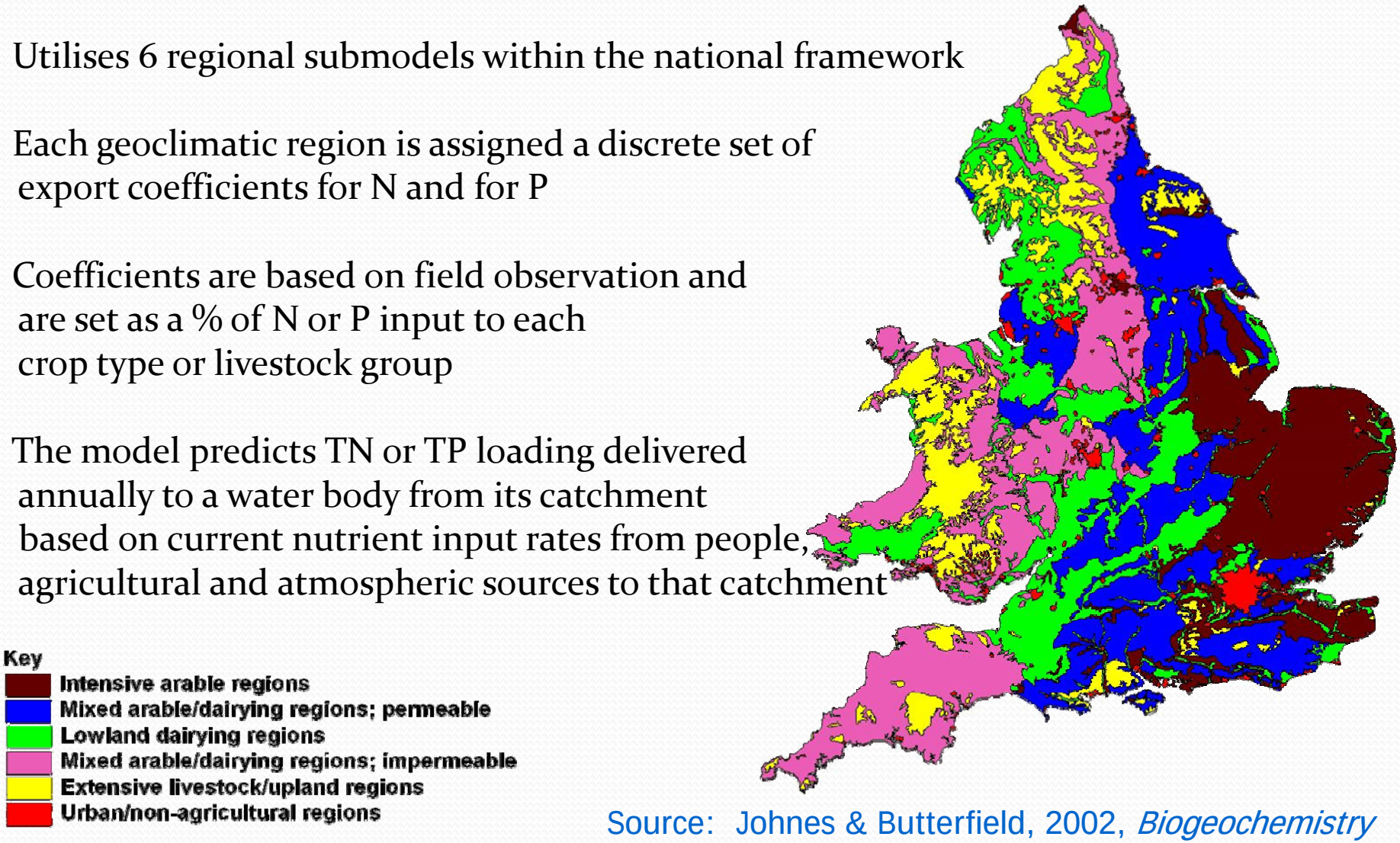
- Background export of N to waters from woodland, rough grazing, moorland to surface waters is estimated as 10 kg/ha.
- It is a rough estimate which has always worked well in agricultural catchments (where the agricultural N signal is large)
- It may be less reliable in the N and W of the UK where agriculture is less intensive.
- N emissions to the atmosphere from non-agricultural land are calculated using the atmospheric N budget described above

Calculating N export to UK freshwaters from agricultural land

- There is no reliable national scale monitoring data for TN flux in UK waters
- N export to surface waters and groundwaters is calculated using national scale export coefficient modelling, validated against observed TN loading data for 60 UK catchments
- The modelling year is currently 1995, and needs to be updated
- The figures for diffuse emissions (to water) from agriculture are based on best available national estimates, but there are caveats:
  - **The data for N. Ireland and Scotland are for nitrate and not for TN. We have increased these on the basis that nitrate is typically 60% of the TN load in intensively monitored catchments in the UK, but they need updating as they are for the 1990s and should be based on observed/modelled TN instead.**

The UK export coefficient modelling approach

- Based on 6 quasi-homogenous landscape units with generic environmental controls on nutrient retention and export
- Utilises 6 regional submodels within the national framework
- Each geoclimatic region is assigned a discrete set of export coefficients for N and for P
- Coefficients are based on field observation and are set as a % of N or P input to each crop type or livestock group
- The model predicts TN or TP loading delivered annually to a water body from its catchment based on current nutrient input rates from people, agricultural and atmospheric sources to that catchment



Source: Johnes & Butterfield, 2002, *Biogeochemistry*

Testing the model: applications to major UK surface water catchments

- Coefficients for each region have been calibrated and validated against observed water quality data for one catchment

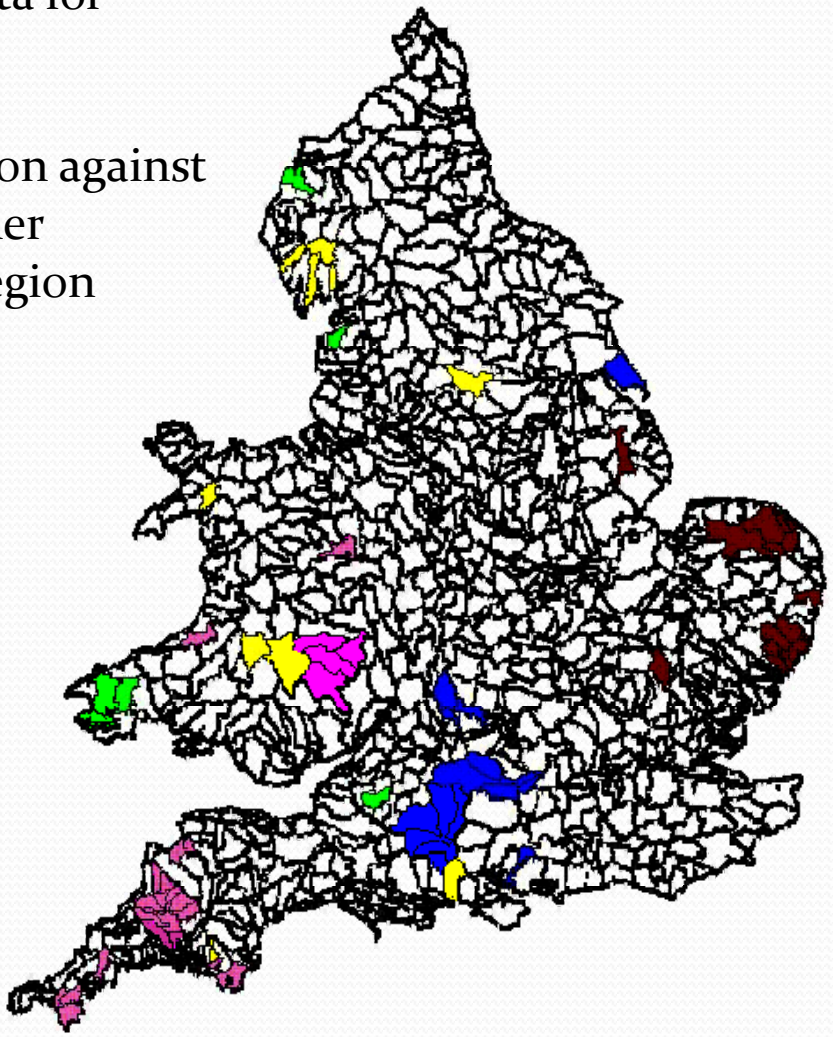
- Coefficients are then validated for each region against observed water quality data in at least 4 other catchments lying within that geoclimatic region

- Model has been applied to 60 catchments in England & Wales with 128 water years of high frequency TN monitoring data.

- Model fit is good with observed data

  N: $r^2 = 0.98$, $n = 128$

  [P: $r^2 = 0.98$, $n = 98$]



Calculating the groundwater/surface water split for UK diffuse N export

- The split between diffuse emissions to groundwater as opposed to surface water is achieved based on our national base flow data, derived from hydrograph separation on data from our national monitoring network, cross-referenced against our Baseflow Index data derived from the HOST (Hydrology of Soil Types) system.

- Ideally we should apply the HOST data at 1 or 5 km grid square resolution to our modelled estimates of TN flux from agriculture (also at 1 or 5 km grid square resolution) and then calculate TN flux to surface waters and groundwaters at 5km grid square resolution, finally adding these together to derive the national estimate

- We don't have the resources to do this at present.

Calculating the groundwater/surface water split for UK diffuse N export

Reporting region	Catchment area (km2)	BFI	area weighted BFI	contribution to national BFI
EA WALES	21262	0.45	9568	0.0402
EA NORTH WEST	14445	0.42	6067	0.0255
EA SOUTH WEST (to N Atlantic)	10400	0.45	4680	0.0197
EA SOUTH WEST (to E Channel)	10402	0.65	6761	0.0284
EA SOUTHERN	10604	0.65	6893	0.0289
EA THAMES	12917	0.70	9042	0.0380
EA ANGLIAN	26795	0.70	18757	0.0788
EA MIDLAND (TRENT)	11538	0.65	7500	0.0315
EA MIDLAND (SEVERN)	11000	0.65	7150	0.0300
EA NORTH EAST	22777	0.48	10933	0.0459
N. IRELAND	14133	0.42	5936	0.0249
SEPA SCOTLAND WEST	20525	0.35	7184	0.0302
SEPA SCOTLAND EAST	17810	0.50	8905	0.0374
SEPA SCOTLAND NORTH (to N Sea)	17000	0.35	5950	0.0250
SEPA SCOTLAND NORTH (to N Atl.)	16530	0.50	8265	0.0347
Total area (km2)	**238138**			
Average BFI		**0.528**		
Area weighted average BFI				**0.520**
			diffuse ag N export to gw	**=52% of total ag N export =288**
			3% export from industrial	**21.7**

Calculating N export from wastewater management and industrial discharges

- The data for N exported from wastewater management as Sewage Sludge (and thence applied to agricultural land) are calculated from the TAPAS modelling work undertaken by Defra

- Our figure for industrial discharges (to surface waters) is based on a publication on the P budget for the UK which suggests 3% of P export to waters is from industrial discharges. Best estimate available at the moment, and comparable to Till's estimate of 2.4% for Germany

- Our figure for public wastewater is based on a per capita excretion rate, and average national N removal rates through primary, secondary and tertiary treatment.

- For the UK, we also assume 2.7 kT of N is retained in Septic Tanks and never removed through pumping. We assume that this eventually leaches to groundwater and have added it to our estimate of diffuse N leaching to groundwater from agricultural sources.

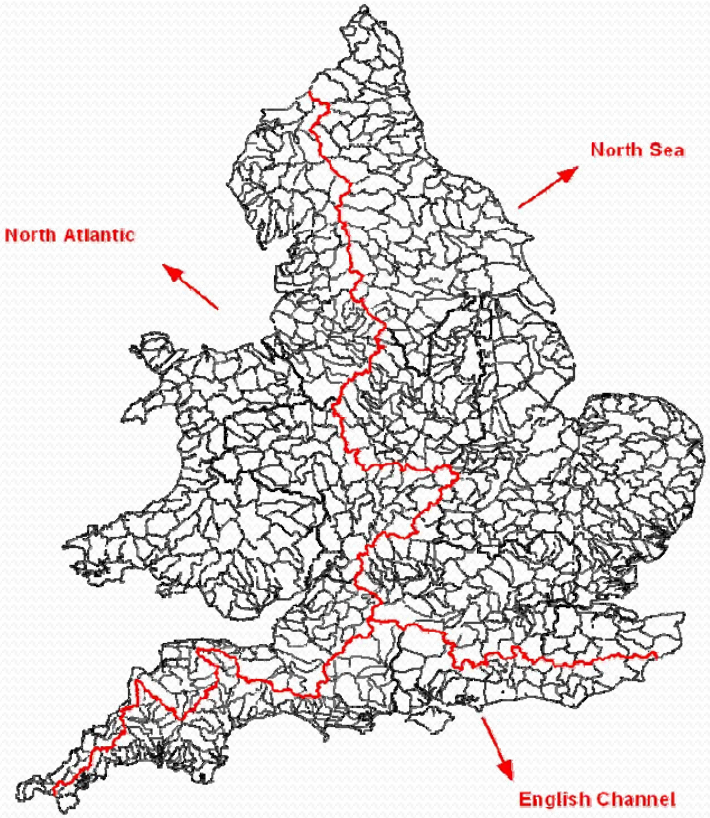
Calculating N export to UK coastal waters

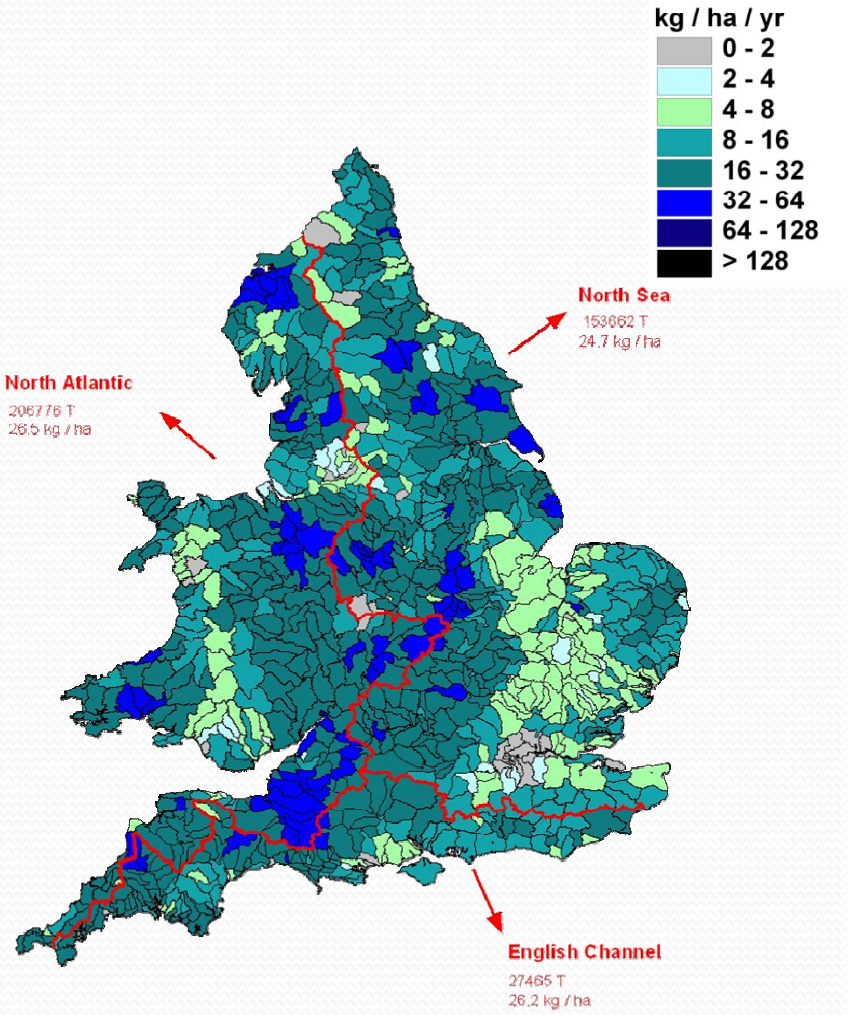
- We have separated our Input to coastal waters into the exports (from Surface Waters) to the North Sea, North Atlantic and English Channel:
  - The inputs to Scotland are split into N Sea and N Atlantic watersheds.
  - The inputs from NI go direct to the N Atlantic watershed.
  - The inputs from Wales go direct to the N Atlantic waters
  - The inputs from England go to the English Channel, the N Sea and the N Atlantic watersheds.

- To calculate the final flux to coastal and marine ecosystems we apply a denitrification rate of 16% (based on the work of Mark Trimmer, Queen Mary College London, on the East Coast estuaries).

- This may be inappropriate for the wetter and marginally colder systems of the west coast of the UK, but we do not have any other data to use for these systems, at present.

Calculating N export to UK coastal waters

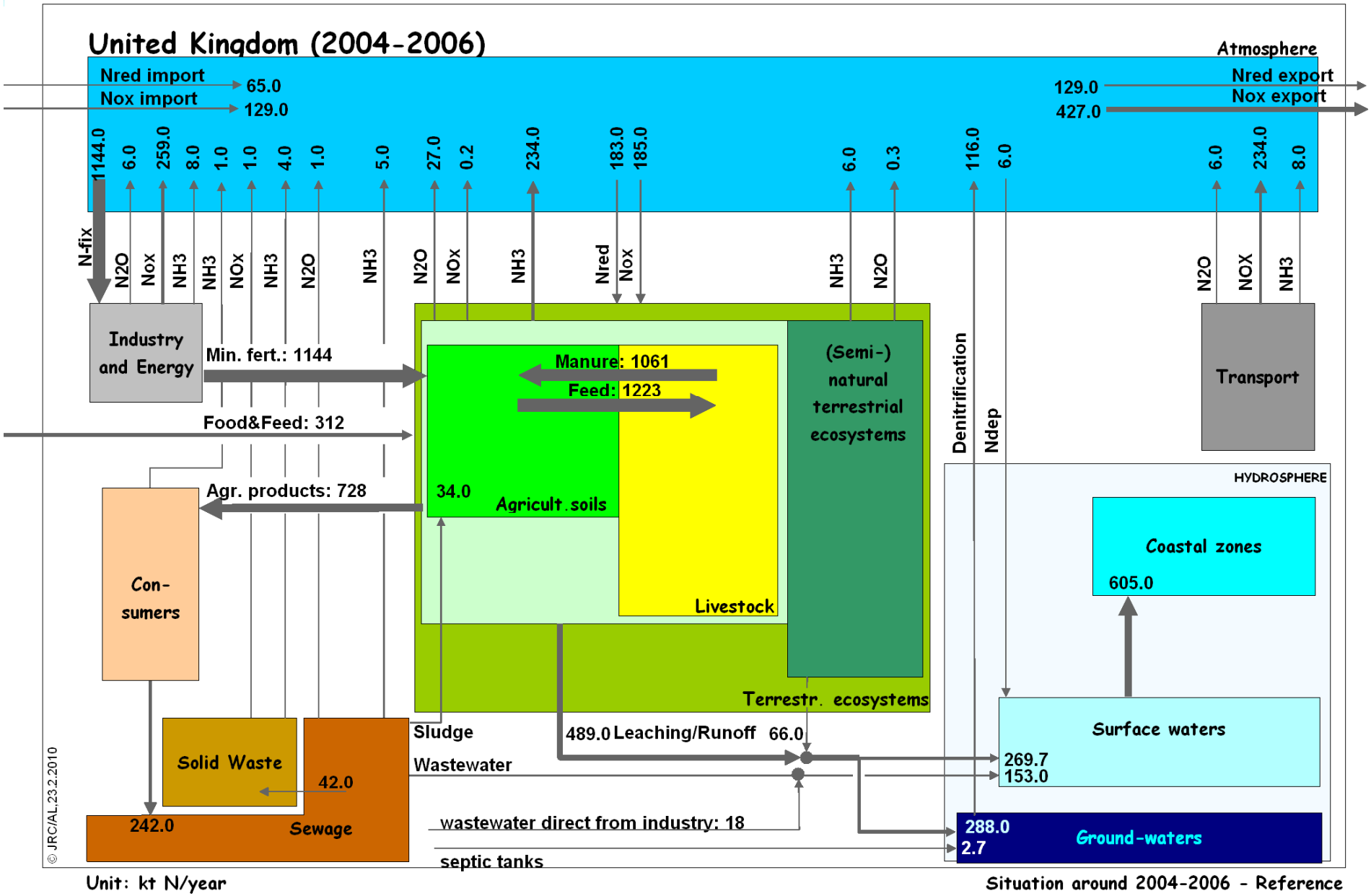




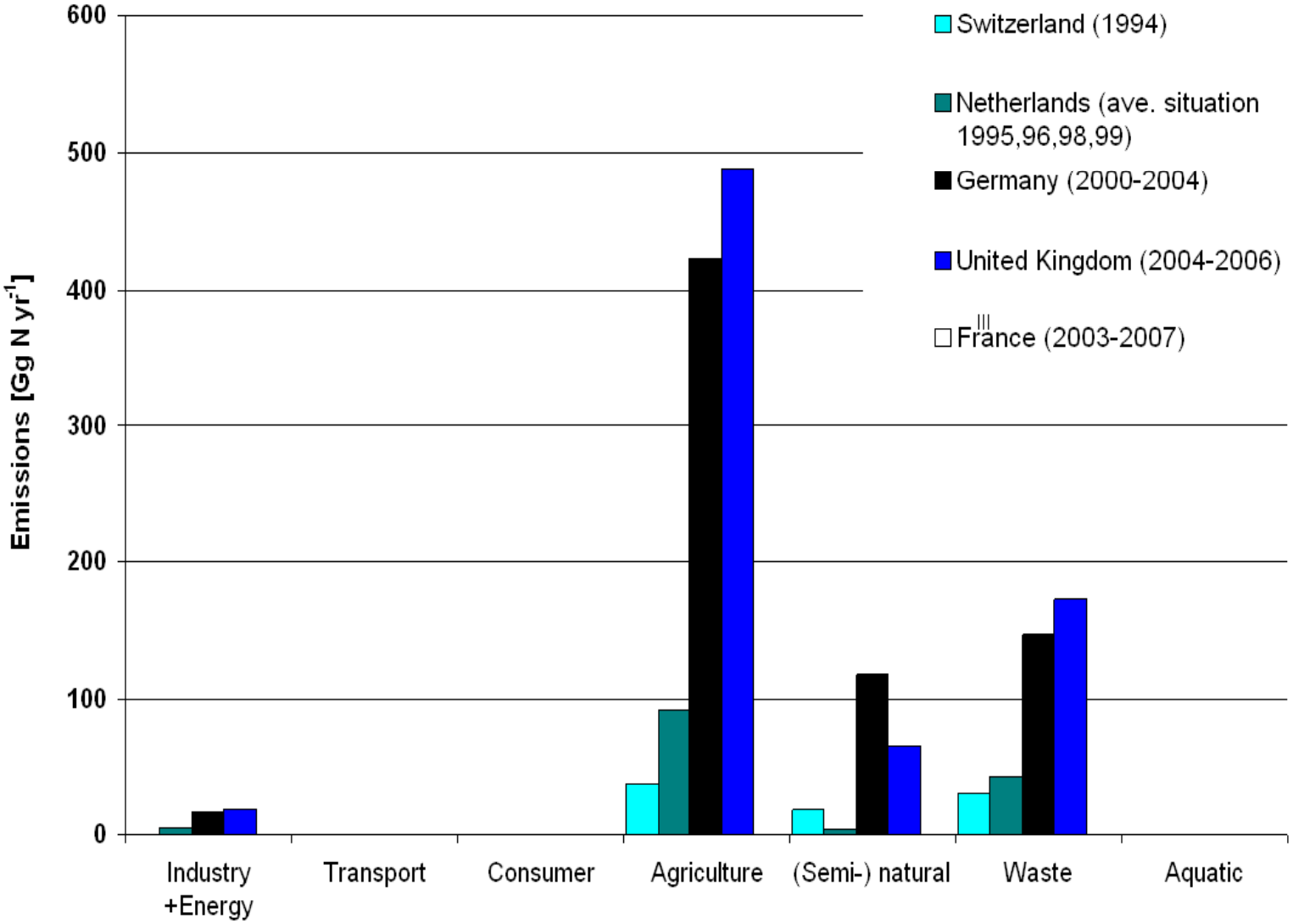
Calculating N export to coastal waters from all diffuse and point sources

Region	People	N input kt	N export kt	Diffuse (ag) N	Point N (STWs & septic leachate)	Other diffuse (terrestrial)	Direct dep to waters	Industrial discharges	septic tanks discharges to gw	Total N export to coastal waters
N Ireland	1,775,000	6.99	3.91							
Wales	2,993,000	11.8	6.58							
W Scotland	2,739,000	10.8	6.03							
South West England (1/2)	2,580,000	10.2	5.68							
North West England	7,044,480	27.8	15.5							
West Midlands	5,518,228	21.7	12.1							
N Atlantic watersheds	**22,649,708**	**89.2**	**49.8**	**260**	**50**	**30**	**3.5**	**11**	**1**	**356**
London	8,652,067	34.1	19.0							
East of England	6,638,913	26.2	14.6							
East Midlands	4,386,284	17.3	9.65							
North East England	2,614,500	10.3	5.75							
South East England (3/4)	6,217,210	24.5	13.7							
Yorkshire & Humber	5,184,263	20.4	11.4							
N Sea watersheds	**33,693,237**	**133**	**74.1**	**201**	**74**	**30**	**2**	**10**	**1**	**318**
South West England (1/2)	2,580,000	10.2	5.68							
South East England (1/4)	2,400,000	9.5	5.28							
English Channel watersheds	**4,980,000**	**19.6**	**11.0**	**28**	**11**	**6**	**0.5**	**1**	**0.7**	**47.2**
Total	**61,322,945**	**242**	**135**	**489**	**135**	**66**	**6**	**22**	**2.7**	**721**

Net N export to coastal waters (-16% estuarine denitrification) ***605***


United Kingdom (2004-2006)
Atmosphere
Nred import
Nox import
65.0
129.0
Nred export
Nox export
129.0
427.0
1144.0
6.0
259.0
8.0
1.0
1.0
4.0
1.0
5.0
27.0
0.2
234.0
183.0
185.0
6.0
0.3
116.0
6.0
6.0
234.0
8.0
N-fix
N2O
Nox
NH3
NH3
NOx
NH3
N2O
NH3
N2O
NOx
NH3
Nred
Nox
NH3
N2O
N2O
NOX
NH3
Industry and Energy
Min. fert.: 1144
Manure: 1061
Feed: 1223
(Semi-) natural terrestrial ecosystems
Transport
Denitrification
Ndep
Food&Feed: 312
HYDROSPHERE
Agr. products: 728
34.0
Agricult. soils
Coastal zones
605.0
Con-sumers
Livestock
Terrestr. ecosystems
Surface waters
269.7
153.0
Solid Waste
42.0
Sludge
489.0 Leaching/Runoff
66.0
Wastewater
242.0
Sewage
wastewater direct from industry: 18
288.0
2.7
Ground-waters
septic tanks
© JRC/AL.23.2.2010
Unit: kt N/year
Situation around 2004-2006 - Reference

Absolute nitrogen emissions to the hydrosphere for the main sectors/compartments (Leip et al)



Absolute nitrogen emissions to the atmosphere for the main sectors/compartments (Leip et al.)