2005 Maps of Ammonia emissions from agriculture, waste, nature and other miscellaneous sources for the NAEI

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EXECUTIVE SUMMARY

Modelling and mapping UK ammonia emissions from agriculture, nature, waste disposal and other miscellaneous sources

1. Ammonia emission estimates for 2005 were spatially distributed for agriculture (SNAP Codes 10.1, 10.3 and 10.5), natural sources (SNAP Code 11.7), waste disposal (SNAP Code 9.4), sewage works and sewage sludge spreading (SNAP Code 9.10), solvents (SNAP Code 6.4) and other miscellaneous sources for the UK.

2. Agricultural emission sources (livestock manures, cultures with fertilisers and field burning) were distributed using the CEH/University of Edinburgh AENEID model, which incorporates agricultural census data, landcover data, agricultural practice information (e.g. fertiliser application rates, stocking densities) and emission source strength data from the NARSES UK NH_3 Emissions Inventory for 2005 (Misselbrook *et al.* 2006).

3. The non-agricultural sources listed above were spatially distributed using AENEID on the basis of a combination of population census data, landcover data, data from the devolved authorities on landfill sites and sewage works, mammal distribution data from the Biological Records Centre (BRC), seabird census data (Seabird2000 survey, JNCC), locations of composting plants etc.

Emission source strength estimates

4. The UK estimate of NH_3 emissions from agriculture decreased by 21.5 kt NH_3 between 2004 and 2005, with 284.9 and 263.4 kt NH_3 emitted, respectively. This includes decreases in livestock emissions by 22.5 kt NH_3 and increases in fertiliser emissions from crops and cut grassland by 1.0 kt NH_3.

5. Most of the difference in livestock emissions is due to revisions in model parameters rather than due to real changes from 2004 to 2005. These revisions include improved estimates of N excretion for different livestock categories, cattle housing periods, calculation methods of hard standings emissions etc. Real year-on-year changes are estimated to account for a small decrease in the total emission of 1.3 kt NH_3. This decrease is mainly due to decreases in livestock numbers for cattle, sheep, pigs and poultry, offset by increased fertiliser application to crops and conserved grass as well as an increase in the proportion of urea applied (Misselbrook *et al.* 2006).

6. Emission source strength data for non-agricultural sources were used as agreed with AEAT under the NAEI project in late 2006, using the totals reported by CEH (Dragosits *et al*. 2006), with the exception of NH_3 emissions from sewage, where old data from 2004 were accidentally included in the official submission by AEA instead of new estimates from Dragosits *et al*. (2006). Hence the 2004 emission map for sewage has not been updated, to keep the total emissions consistent for the submitted tables and associated maps.

7. All NH_3 emission maps correspond to the totals reported in the NAEI for 2005, with the exception of "nature" sources, where emissions from seabirds were mistakenly reported by Dragosits *et al.* (2006) as 3.0 kt NH_3-N, but should have been reported as 3.0 kt NH_3 (or 2.44 kt NH_3-N). As emissions from "nature" sources are not officially submitted to international bodies, but reported in the NAEI for completeness and for modelling purposes, to account for all known NH_3 emissions, the total has been mapped for the correct values.

CONTENTS

1. INTRODUCTION

1.1. Background

Emissions of ammonia for 2005 were spatially distributed using the AENEID model (Dragosits et al. 1998) and mapped for the UK for SNAP codes 6 (use of solvents), 9 (waste disposal, excluding incineration), 10 (agriculture) and 11 (other sources and sinks, including natural sources). This report briefly describes the methodology used for the sources listed above, including any changes in the methodology and the consequences of these changes.

The agricultural emission estimates (livestock manures and fertiliser application) are coordinated with results from Defra project AC0102 (NH_3 inventory by Misselbrook *et al*., IGER North Wyke; see Table 1). Non-agricultural emission estimates are coordinated with the values submitted to Defra by AEAT under this project in early 2006 (see Table 1).

The current contract exploits the expertise of CEH in spatially distributing emissions from agricultural sources, nature and other miscellaneous sources, and complements the expertise of AEAT regarding combustion, industry and transport sources.

Table 1: UK ammonia emissions (SNAP Codes 6, 9, 10, 11) as collated by AEAT from IGER and CEH data.

Source	SNAP Code	SNAP / NFR Code	Best estimate (kt NH_3)
Human breath & sweat, babies' nappies and smoking	0	7 + z_5E	1.54
Appliances &household products (solvents)	6.4	3D	1.22
Sewage works and sewage spreading	9.10	6B	8.67
Landfill	9.4	6A	4.05
Agricultural fertilizers	10.1	4D1	35.58
Biomass burning	10.3	4F	1.94
Livestock manures	10.5	4B1,3,6,8,9	227.82
Pets and non-agricultural horses	11.7.2	4B13	17.86
Nature (wild mammals, seabirds, pheasants)	11.7.3	z_5E	6.36 (7.01) *
Composting	10..2	4D1	1.63

* Emissions from seabirds were submitted by CEH to AEAT as 3.0 kt NH_3-N (leading to a total emission sof 7.01 kt NH_3 from "nature" sources, however this value was in fact 3.0 kt NH_3 (i.e. 2.44 kt NH_3-N). The correct total for "nature" is therefore 6.36 kt NH_3. This figure was used for mapping.

NB: The mapped data also contain NH_3 emissions of agricultural sources for the Isle of Man, thus the total mapped emissions are slightly larger than the UK totals shown in Table 1.

1.2. Work schedule/deliverables

- Task 1: Acquiring source data (agricultural census) from the devolved authorities for spatially distributing agricultural ammonia emissions from livestock manures and fertiliser application.
- Task 2: Modelling NH_3 emissions from agricultural sources at a 5km grid resolution and SNAP level 2 using the AENEID model, and converting results for Northern Ireland to the OS GB grid.
- Task 3: Modelling the spatial distribution of NH_3 emissions for SNAP codes 6 (solvents), 9 (waste disposal, excluding incineration) and 11 (other sources and sinks,

including natural sources) in the AENEID model at a 5 km grid resolution and SNAP level 2, using various auxiliary datasets.

- Task 4: Providing a description of the methodology, highlighting changes and their consequences.

2. METHODS

2.1. Spatial distribution of NH_3 emissions from agricultural sources (SNAP Code 10)

Agricultural census data for 2005 were acquired from the devolved authorities, i.e. Defra, SEERAD, Welsh Assembly, DARDNI and the Isle of Man Government. The census data for the different countries were aggregated to NARSES categories (see Appendix A), to ensure compatibility between the different countries' systems.

For the year 2005, the agricultural NH_3 emission inventory was mapped using output from the NARSES model (Misselbrook *et al.* 2006, Defra project AC0102). As in previous years, detailed emission source strength estimates were derived for the main livestock emission components (livestock housing, manure storage, landspreading of manures, livestock grazing) and fertiliser application rates to different crops from the British Survey of Fertiliser Practice for 2005 (BSFP 2006). These were applied in the AENEID model, and livestock and fertiliser emissions distributed to different land cover types (e.g. arable land, improved grass, part-improved grass, rough grazing etc.) derived from the CEH landcover map (LCM2000).

The resulting spatially distributed emission estimates were then aggregated to emissions from **livestock manures** (SNAP Code 10.5) and **cultures with fertilisers** (SNAP Code 10.1, i.e. emissions from crops and cut grass), and checked for consistency with the NARSES inventory (NB: The mapped data also contain NH_3 emissions from agricultural sources for the Isle of Man, thus the total mapped emissions are slightly larger than the UK totals shown in Table 1.).

Emissions from **biomass burning** (SNAP Code 10.3) are mainly associated with stubble burning on cereal fields. Ammonia emissions from this source were spatially located according to the distribution of cereal crops in the Agricultural Census 2005.

2.2. Spatial distribution of NH_3 emissions from other sources (SNAP Codes 6, 9 and 11)

2.2.1. EMISSIONS FROM HOUSEHOLD PRODUCTS (SOLVENTS) – SNAP CODE 6.4

The most suitable spatial distribution for these sources is to scale by population (UK Population Census 2001, adjusted to account for mid-2005 population estimates), considering that emissions occur from normal household activities such as cleaning with products containing ammonia, hair perming, levelling floors using latex screed, refrigerants etc.

2.2.2. EMISSIONS FROM LANDFILL – SNAP CODE 9.4

For the spatial distribution of ammonia emissions from landfill sites, it was assumed that the composition of landfilled materials was equal over the UK, and that amounts of landfill in the different parts of the UK was related to human population numbers.

For **Scotland**, locations and size of landfill sites were available from the Scottish Environmental Protection Agency (SEPA).

For **England and Wales**, data were downloaded from the Environment Agency (EA) website (http://www.environment-agency.gov.uk). These data contained information regarding

addresses of landfill sites, and a classification by size (large/medium/small), and they were located spatially by converting postcodes to OS Grid references. However, when these point sources were mapped initially, it was found that the density of English and Welsh landfill sites was much lower than for Scotland. It was therefore decided that using only these sites for the distribution of ammonia emissions from landfill would create artificial hot spots for the sites that were mapped. Thus only 69% of the landfill emissions (derived from comparison with detailed Scottish data) were mapped onto these point sources. The remaining 31% were distributed by population, excluding areas with a population density greater than 1000 people per square kilometre as an approximation.

For **Northern Ireland**, no locations of landfill sites were available, thus emissions were mapped using population density data as described above for England and Wales.

2.2.3. EMISSIONS FROM SEWAGE WORKS AND SEWAGE SLUDGE SPREADING – SNAP CODE 9.10

For the spatial distribution of emissions from **sewage works**, locations of sewage treatment works were downloaded from the Environment Agency website for **England and Wales**, complete with OS Grid references and population equivalents of sewage processing capacity. Together, the recorded sewage works covered a total of 21,182,680 population equivalents, which corresponds to ~ 40% of the population of England and Wales. These sewage works are covered by the Urban Waste Water Treatment Directive, and include only works larger than 10,000 population equivalents. Also, the population equivalents listed do not reflect the amount of sewage processed at the works exactly, but are an indication of the available capacity, and other (non-domestic) sewage will be treated at these locations to a varying extent. However, the larger sewage works are estimated to have higher ammonia emissions due to different processes employed in the sewage treatment.

There are also considerable rural areas with low-density housing, where septic tanks are used rather than sewage works. The rest of the population is assumed to be covered by smaller sewage works not registered on the EA website. Currently there are no estimates of ammonia emissions from septic tanks, which is an area needing further investigation in the future. A spatial assessment of sewage work capacities and population density was carried out, and sewage emissions were spatially distributed by population in areas found to have insufficient coverage by works registered with the EA. Emissions from the sewage works registered with the EA were mapped using the population equivalents supplied.

For **Scotland and Northern Ireland**, emissions from sewage works were spatially distributed by population, excluding densely populated inner-city areas and areas with very low population density, due to lack of spatial data on sewage works.

Landspreading of sewage sludge has increased since the ban on dumping of sewage sludge in the sea in 1999. Only treated sewage is permitted to be spread, and is used on grass, forage crops (excluding crops grown for human consumption such as vegetables etc), for land reclamation and nutrient supply in areas of afforestation. However, only a small part of the agricultural area of the UK receives sewage sludge at present. It is not possible to spatially distribute ammonia emissions from the landspreading of sewage sludge to exactly where they occur, due to a lack of data. Thus, emissions were distributed over all grassland, arable land and areas of coniferous woodland, using a combination of agricultural census and landcover data.

2.2.4. EMISSIONS FROM COMPOSTING

The comprehensive survey of composting facilities in the UK by the Composting Association for 2004/2005 (Boulos *et al.* 2006) contains data from several hundred composting sites in the UK, including amounts and types of materials composted, processes used etc. These data

would be ideal for mapping the spatial distribution of NH_3 emissions from **composting**, but access to the data was not granted by the Composting Association, for reasons of confidentiality. The Composting Association has however expressed interest to work constructively with CEH and Defra in future reviews of NH_3 emissions.

As a surrogate, the best available data source was a list of suppliers from the Composting Association's certification scheme (www.wrap.org.uk). Postcodes for all 75 sites on this list (status November 2005) were converted to OS grid coordinates for the 2004 inventory, however the list has not been updated since, and the UK total of 1.63 kt NH_3 for 2005 was mapped by scaling with the spatial distribution from 2004. Composting emissions were distributed evenly between all sites, in the absence of detailed data (on e.g. size of the operation) for each site. This method does not capture the large differences in emissions from individual sites due to amounts and types of materials composted, and emissions are spread over only a small proportion of the sites surveyed by Boulos *et al.* (2006).

2.2.5. EMISSIONS FROM DOMESTIC ANIMALS (PETS AND NON-AGRICULTURAL HORSES) AND NATURE (WILD MAMMALS, SEABIRDS, PHEASANTS) – SNAP CODE 11.7

For the 2005 inventory, the previously used category "nature" was split into two categories for domestic animals and wild animals and birds. Separate emission maps were produced for:

- non-agricultural horses and pets (cats & dogs)
- nature (wild mammals, seabirds and pheasants)

Emissions from **non-agricultural horses** were distributed using a combination of landcover data (LCM2000) and population census data, while **pets (cats and dogs)** were scaled by population, assuming an even distribution of pets over the UK population, except for densely populated urban areas, where it was assumed that fewer pets lived per human population. It should be noted that populations of wild or semi-wild horses and ponies in areas such as Dartmoor, Exmoor or the New Forest are not mapped specifically, and that the methodology used is a statistical approximation from secondary data (human populations and landcover) at a UK scale.

Emissions from **wild animals** (deer, seals, rabbits and hares, foxes, badgers and feral cats) were distributed for Great Britain using 10 km presence/absence maps from the Biological Records Centre (BRC) based at CEH Monks Wood, landcover data (LCM 2000) and data for Scottish populations for wild deer (Hunt 2003).

Emissions from **pheasants** were included in this category. The spatial distribution was derived from a combination of landcover data (feeding of pheasants occurring in woodlands) and a county map of numbers of pheasants shot, provided by the Game Conservancy Trust.

Emissions from **seabirds** were spatially distributed according to the approach of Wilson *et al*. (2004a, 2004b). During 2006, new data from the JNCC seabird census carried out during 1998-2002 were made available. These data, collected along segments of the coast, sea cliffs and other bird colonies, including some inland colonies, were processed, the seabird emissions model (Wilson *et al.* 2004a, 2004b) applied and the results mapped for the 2005 NH_3 inventory. Since the submission of the 2005 non-agricultural emissions data in December 2006 (Dragosits *et al.* 2006), it has been discovered that the seabird emissions total has been mistakenly reported as 3.0 kt NH3-N, but the correct value is in fact 3.0 kt NH_3, i.e. 2.44 kt NH3-N. For the mapping of natural sources, the correct total rather than the originally reported number was used (see also Table 1).

Emissions from the sources described above were aggregated to a) non-agricultural horses and pets and b) natural sources at a 5 km grid resolution for inclusion in the NAEI, and checked against the total submitted in December 2006.

2.2.6. EMISSIONS FROM OTHER SOURCES (HUMAN BREATH & SWEAT, SMOKING AND BABIES' NAPPIES – SNAP CODE 0.0

The most suitable spatial distribution for these sources is to scale by population, assuming an equal distribution of these sources within the UK population. Emissions from these sources were aggregated to a 5 km grid resolution for inclusion in the NAEI, and checked against the total submitted in December 2006.

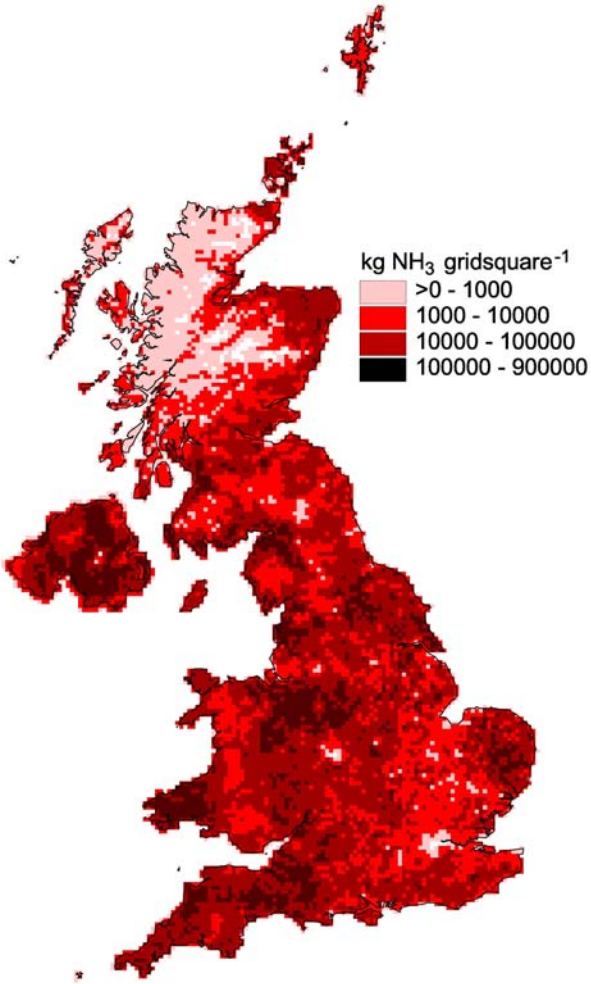
3. RESULTS - AMMONIA EMISSION MAPS FOR 2005

The following maps were produced for the UK for 2005:

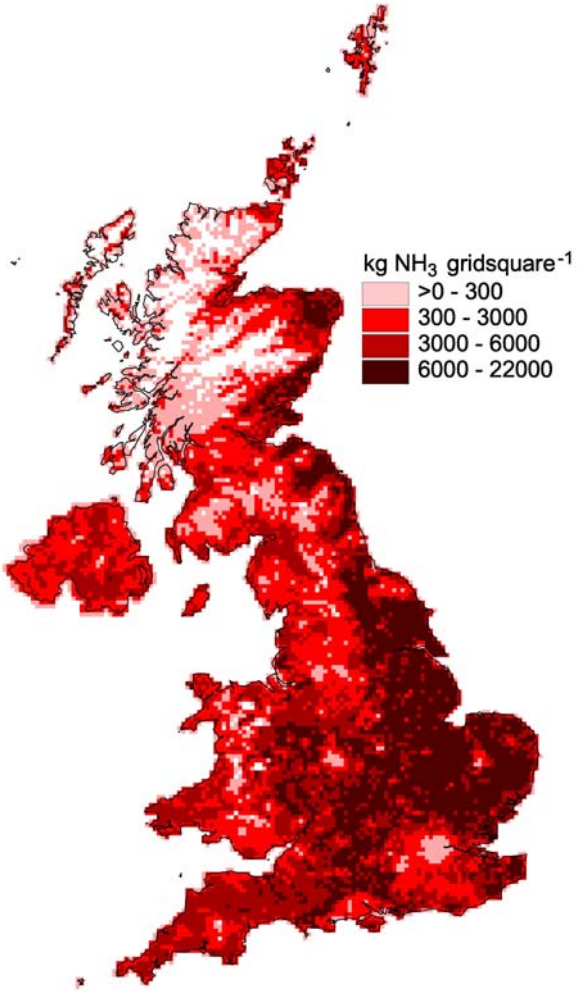
- livestock manures – SNAP Code 10.5
- agricultural and non-agricultural fertilisers – SNAP Code 10.1
- nature (wild mammals, seabirds, pheasants) – SNAP Code 11.7
- non-agricultural horses and pets (cats, dogs)
- landfill – SNAP Code 9.4
- sewage works and landspreading of sewage sludge – SNAP Code 9.10
- household products (solvents) – SNAP Code 6.4
- composting – SNAP Code 10.2
- biomass burning – SNAP Code 10.3
- human breath and sweat, smoking and babies' nappies – SNAP Code 0.0

The units for all maps are kg ammonia (NH_3) per gridsquare. All UK maps were produced on the Ordnance Survey GB Grid at a resolution of 5 km x 5 km.

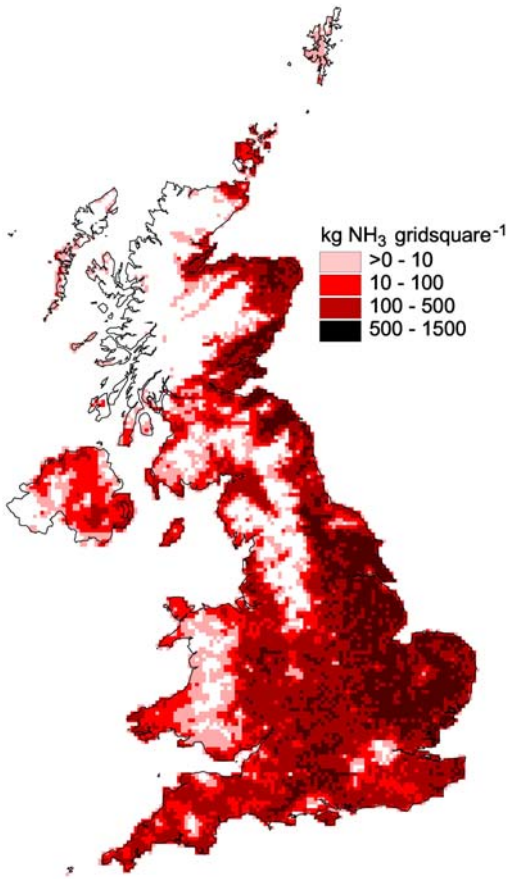
All maps were delivered to AEAT by e-mail.



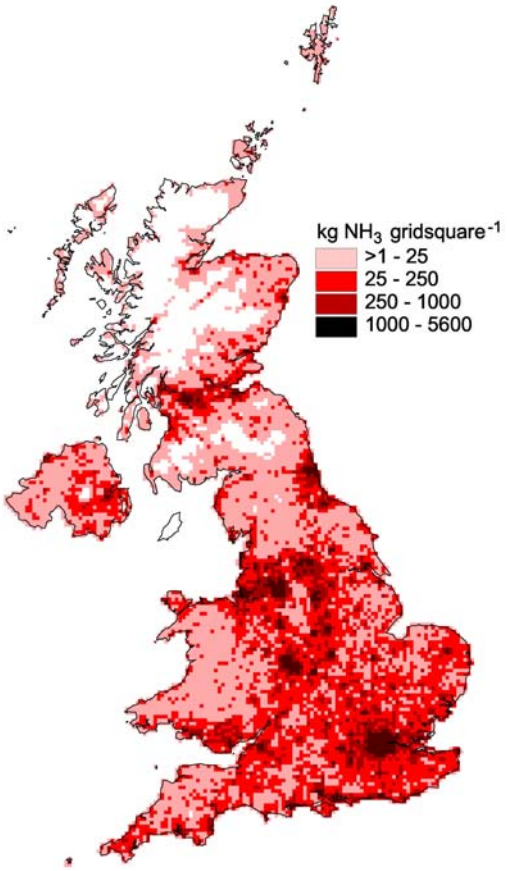
Ammonia emissions from livestock manure



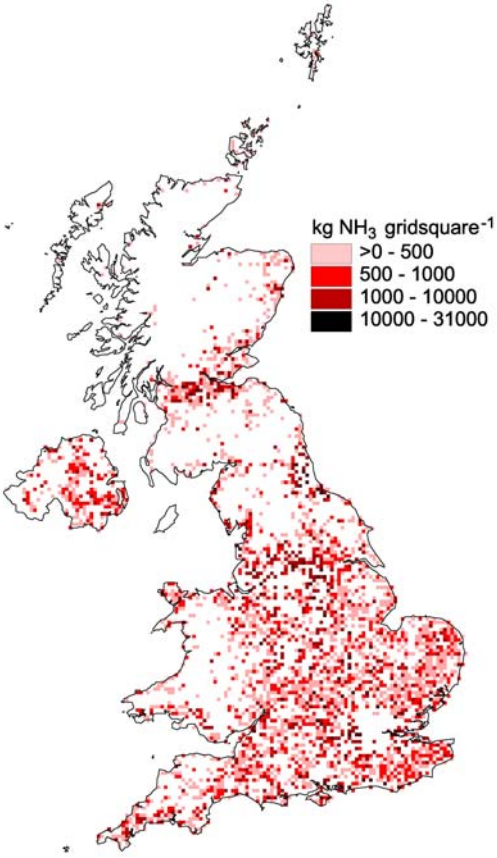
Ammonia emissions from fertilisers



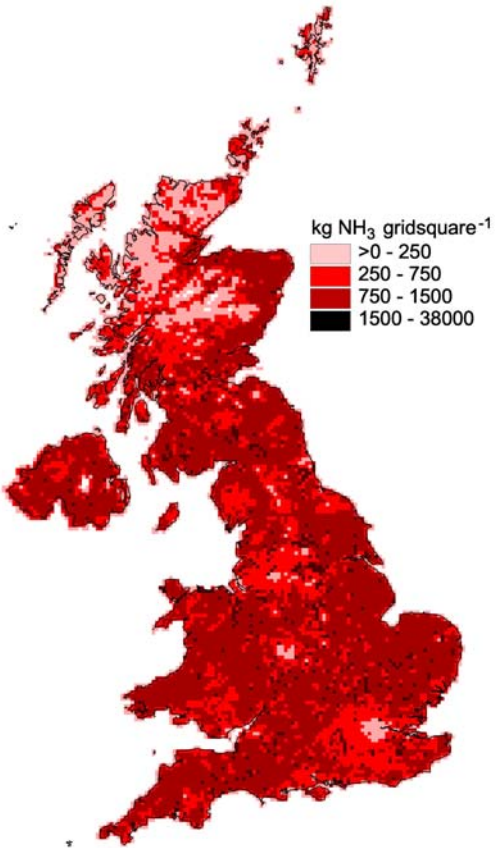
Ammonia emissions from biomass burning



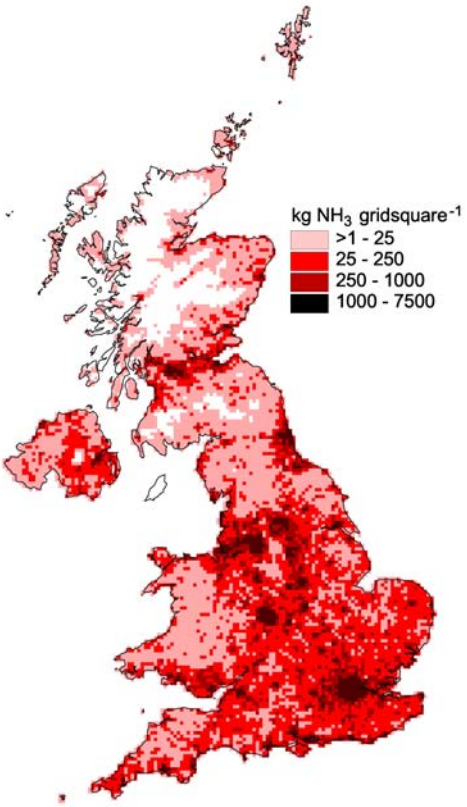
Ammonia emissions from solvents



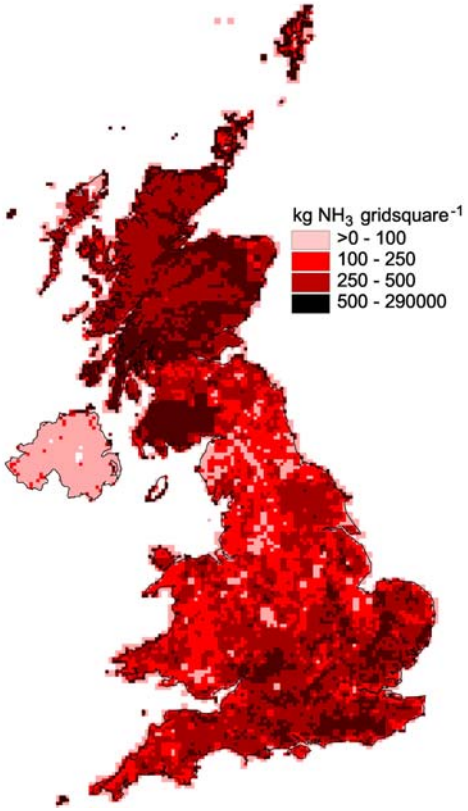
Ammonia emissions from landfill



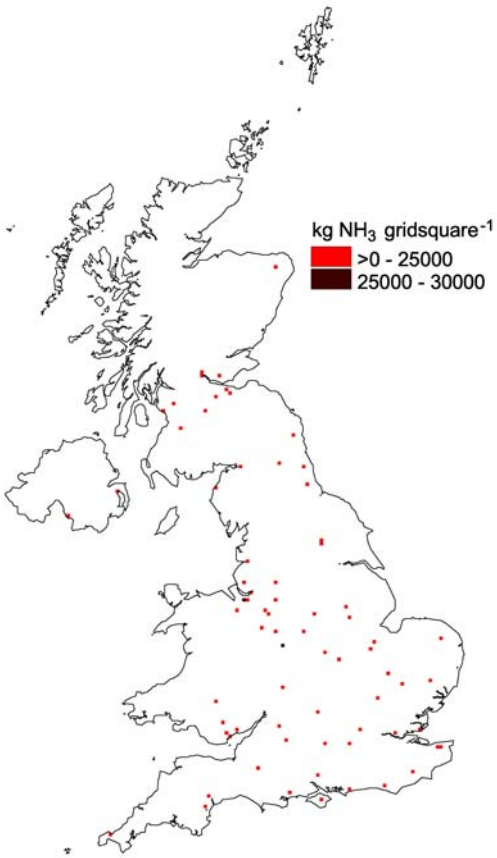
Ammonia emissions from sewage



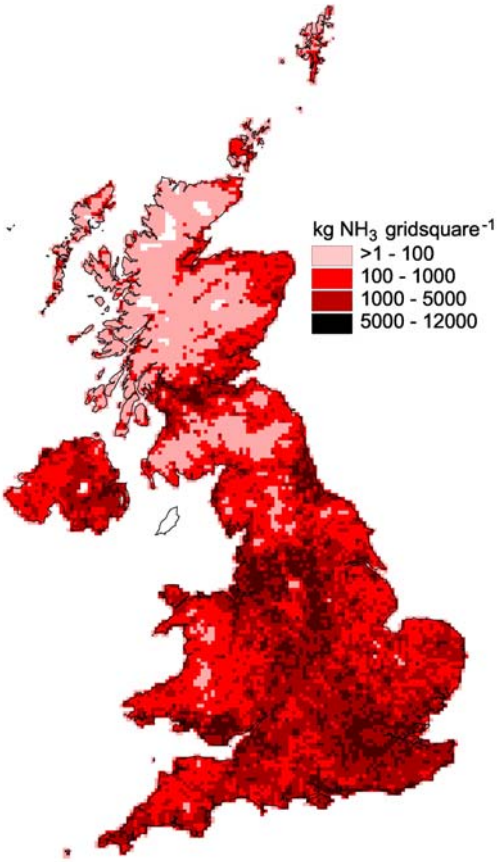
Ammonia emissions from humans



Ammonia emissions from nature (wild mammals, seabirds, pheasants)



Ammonia emissions from composting plants



Ammonia emissions from pets (cats and dogs) and non-agricultural horses

4. MAJOR CHANGES AND CONSEQUENCES

4.1. Changes in emissions from agricultural sources

Overall, the estimate of NH_3 emissions from UK agriculture decreased by 21.5 kt NH_3 between 2004 and 2005, with 284.9 and 263.4 kt NH_3 emitted, respectively. This includes decreases in livestock emissions by 22.5 kt NH_3 and increases in fertiliser emissions from crops and cut grassland by 1.0 kt NH_3.

Most of the difference in livestock emissions is due to revisions in model parameters rather than due to real changes from 2004 to 2005. These revisions include improved estimates of N excretion for different livestock categories, cattle housing periods, calculation methods of hard standings emissions etc. Real year-on-year changes are estimated to account for a small decrease in the total emission of 1.3 kt NH_3. This decrease is mainly due to decreases in livestock numbers for cattle, sheep, pigs and poultry, offset by increased fertiliser application to crops and conserved grass as well as an increase in the proportion of urea applied (Misselbrook et al. 2006).

Table 2: Differences between the 2004 and 2005 inventories for NH_3 emissions from UK agriculture (adapted from Misselbrook *et al.* 2005)

	2004 kt NH_3	2005 kt NH_3	difference kt NH_3	difference %
All cattle	163.3	147.7	-15.6	-9.6%
All Sheep, Goats & Deer	18.6	14.2	-4.4	-23.7%
Pigs	25.6	27.3	+1.7	+6.6%
All Poultry	38.5	34.2	-4.3	-11.2%
Horses	4.21	4.25	+0.04	+1.0%
Livestock total	**250.3**	**227.8**	**-22.5**	**-9.0%**
N fertilisers	34.6	35.6	+1.0	+2.9%
Agriculture total	**284.9**	**263.4**	**+21.5**	**-7.5%**

4.2. Changes in emissions from non-agricultural sources

The main changes in non-agricultural emissions between 2004 and 2005 are due to increases in emissions from race/competition horses, dogs and composting, and decreases in emissions from sewage sludge, non-race horses and landfill. Some of these changes are due to real changes in source activities, others at least partly due to new information becoming available, both in terms of source populations and source strength (Dragosits *et al.* 2006).

Due to an error in reporting in the NAEI, the new emission estimate from sewage sludge spreading by Dragosits et al. (2006) has not been included in the official submission of the NAEI, and the 2004 values were carried forward. To keep the reported tabulated emissions and associated spatial distributions consistent, the 2004 emission map for sewage has not been updated this year.

Emissions previously aggregated under “nature” sources are now provided to the NAEI as two separate maps: non-agricultural horses and pets (cats, dogs); nature (wild mammals, seabirds, pheasants), to accommodate reporting procedures which include non-agricultural horses and pets but exclude wild animals and birds.

5. CONCLUSIONS

New ammonia emission maps were derived for the UK, for inclusion in the 2005 version of the NAEI for agriculture (SNAP Codes 10.1, 10.3 and 10.5), natural sources (SNAP Code 11.7), waste disposal (SNAP Code 9.4), sewage works and sewage sludge spreading (SNAP Code 9.10), solvents (SNAP Code 6.4) and other miscellaneous sources for the UK.

Agricultural emission sources (livestock manures, cultures with fertilisers and field burning) were distributed using the CEH/University of Edinburgh AENEID model, which incorporates agricultural census data, landcover data, agricultural practice information (e.g. fertiliser application rates, stocking densities) and emission source strength data from the NARSES UK NH_3 Emissions Inventory (Misselbrook *et al*. 2006).

The non-agricultural sources listed above were spatially distributed using a combination of population census data, landcover data, data from the devolved authorities on landfill sites and sewage works, mammal distribution data from the Biological Records Centre (BRC) etc. The work also included a new distribution of NH_3 emissions from seabirds, using data from the Seabird 2000 survey (Mitchell *et al.* 2004), provided by the JNCC.

ACKNOWLEDGEMENTS

The authors are grateful to Defra, who are funding this work as part of the National Ammonia Emissions Inventory (NAEI), and to the Biological Records Centre (CEH Monks Wood) for wild mammal distribution data from records compiled by the Mammal Society, to the JNCC for data from the Seabird 2000 survey, the British Deer Society, the Game Conservancy Trust, and others.

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APPENDIX A - NARSES CATEGORIES

Cattle

1 Dairy cows & heifers
2 Dairy heifers in calf, 2 years +
3 Dairy heifers in calf, <2 years
4 Beef cows & heifers
5 Beef heifers in calf, 2yrs +
6 Beef heifers in calf, <2 years
7 Bulls >2yrs
8 Bulls 1-2yrs
9 Other cattle, 2yrs +
10 Other cattle, 1-2yrs
11 Other cattle, <1yr

Sheep

12 Sheep
13 Lambs, under 1 year old

Pigs

14 Sows in pig & other sows
15 Gilts in pig & barren sows
16 Gilts > 50kg not yet in pig
17 Boars
18 Other pigs, 110kg and over
19 Other pigs, 80-110kg
20 Other pigs, 50-80kg
21 Other pigs, 20-50kg
22 Other pigs, under 20kg

Poultry

23 Layers
24 Breeding birds
25 Broilers
26 Pullets
27 Turkeys
28 Other poultry

Other livestock

29 Horses
30 Goats
31 Deer

Crops

32 Set-aside land
33 Wheat
34 Winter Barley
35 Spring Barley
36 Sugar beet
37 Oilseed rape
38 Potatoes
39 Other cereals
40 Other root crops
41 Other crops
42 Vegetables for human consumption
43 (Soft) Fruit
44 Bulbs, flowers and nursery stock
45 Grassland less than 5 years old
46 Permanent grassland