Report

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The spatial distribution of ammonia, methane and nitrous oxide emissions from agriculture in the UK 2008

Annual Report to Defra (Project AC0112)

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EXECUTIVE SUMMARY

Modelling and mapping UK ammonia emissions from agriculture

Defra project AC0112

- Agricultural emissions of ammonia, methane and nitrous oxide for 2008 were spatially distributed across the UK, and maps produced.
- 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 2008 (Misselbrook *et al.* 2009).
- All emission maps correspond to the totals reported by North Wyke Research (NWR) for 2008 (Misselbrook *et al*. 2009).

CONTENTS

1. INTRODUCTION

1.1. Background

Emissions of ammonia, methane and nitrous oxide for 2008 were spatially distributed using the AENEID model (Dragosits *et al.* 1998, Hellsten *et al.* 2008) and mapped for the UK. 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 for ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O) are derived annually under Defra project AC0112 (inventories by Misselbrook *et al*. and Cardenas at North Wyke Research; see Table 1). The current contract exploits the expertise of CEH in spatially distributing emissions from agricultural sources, and complements the expertise of North Wyke Research (NWR) in producing UK emission estimates from experimental data, peer-reviewed literature and agricultural management practices, including mitigation options.

Due to data licensing restrictions in relation with the Data Protection Act, the detailed 5 km model output can currently only be shown as "emissions from livestock" rather than for individual livestock sectors.

Table 1: UK emissions of ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O) for 2008, as collated by NWR and mapped by CEH (in kt yr^{-1}).

Gas	Source	UK emission (kt) 2008
NH_3	Livestock manure	197.7 kt NH_3
	Fertiliser application	31.8 kt NH_3
	Total agriculture	**229.5 kt NH_3**
CH_4	Enteric fermentation	731.0 kt CH_4
	Livestock manure	135.2 kt CH_4
	Total agriculture	**866.2 kt CH_4**
N_2O	Crops & soils	75.2 kt N_2O
	Livestock manure	6.6 kt N_2O
	Total agriculture	**81.8 kt N_2O**

1.2. Annual work schedule/deliverables

- Task 1: To acquire source data (agricultural census) from the devolved authorities for spatially distributing agricultural ammonia emissions from livestock manures and fertiliser application.
- Task 2: To model NH_3, CH_4 and N_2O emissions from agricultural sources at a 5 km grid resolution using the AENEID model for the UK, including conversion of results for Northern Ireland from the Irish Ordnance Survey Grid to the Great Britain Ordnance Survey Grid (OSGB).
- Task 3: To provide a short report describing the methodology and results, highlighting any changes and their consequences.
- Task 4: To streamline the inventory process jointly between CEH and NWR. This includes updating the CEH AENEID model to match inventory requirements, e.g., for dealing with new livestock categories supplied by the devolved authorities.

- Task 5: To submit the spatial datasets to AEA for inclusion in the National Atmospheric Emission Inventory (NAEI) and Greenhouse Gas Inventory (GHGI).

2. METHODS - SPATIAL DISTRIBUTION OF NH_3, CH_4 AND N_2O EMISSIONS FROM AGRICULTURAL SOURCES

Agricultural census/survey data for 2008 were acquired at the finest available spatial resolution from the devolved authorities in the UK, i.e. Defra (England), the Scottish Executive (Scotland), Welsh Assembly (Wales) and DARDNI (Northern Ireland). The census data for the different countries were aggregated to a common set of categories, referred to as the "NARSES categories" (see Appendix A), to ensure compatibility between the different countries' systems.

It should be noted that the Welsh Assembly did not supply any spatial data for the 2008 inventory again, and the 2006 spatial distribution was used to scale the 2006 total numbers for each NARSES category for Wales, as supplied to NWR by the Welsh Assembly during the inventory compilation in 2009.

The agricultural emission inventory for NH_3 was mapped using output from the NARSES model at NWR (Misselbrook *et al*. 2009, Defra project AC0112). As in previous years, detailed emission source strength estimates were derived for the main livestock emission components (housing, manure storage, landspreading of manures, grazing) for each NARSES category. Average fertiliser N application rates to different crops were taken from the British Survey of Fertiliser Practice for 2008 (BSFP 2009).

These detailed data were applied in the AENEID model (Dragosits *et al.* 1998, Hellsten *et al.* 2008), which distributes livestock and fertiliser emissions to different land cover types (e.g. arable land, improved grass, part-improved grass, rough grazing etc.) derived from the CEH landcover map (LCM2000).

Methane emissions from agriculture were distributed using the greenhouse gas version of the AENEID model (Sutton *et al.* 2004, 2006), which takes account of the spatial location of the CH_4 sources (i.e. animals and manures) specifically. Nitrous oxide emissions from livestock manures were distributed using the N_2O version of AENEID, while the spatial distribution of N_2O emissions summarised under "soils" includes a number of different sources, which were modelled mapped as follows:

- Fertiliser application (18.7 kt N_2O): Emissions from this source were spread via the AENEID output for all crops and grassland, combined with detailed data on fertiliser application rates from the British Survey of Fertiliser Practice for 2008 (BSFP 2009).
- Grazing and manure spreading (20.9 kt N_2O): Emissions from this source were calculated via N excretion rates of grazed livestock combined with the spatial distribution of grazed livestock from AENEID and the manure spreading calculations used in AENEID.
- Leaching (20.2 kt N_2O): Emissions from this source were spread via the AENEID output for all crops and grassland.
- Crop residues (9.0 kt N_2O): Emissions from this source were spread evenly over all NARSES crop categories, excluding grassland, fruit and nursery stock etc.
- Nitrogen deposition to agricultural land (4.8 kt N_2O): This source originates from re-emission of N deposited to agricultural land as N_2O, and has been distributed using a combination of the spatial distribution of agricultural land from AENEID and the current CEH estimates of N deposition for the UK.

- Legumes (0.6 kt N_2O): Emissions from this source were spread via the spatial distribution of the NARSES category "other crops", which contains legumes such as peas and beans from the agricultural census.
- Biological fixation of nitrogen (N) by improved grassland (0.6 kt N_2O): This source mainly originates from clover on organic farms, which were assumed to be distributed evenly among all farms in the UK. The total emissions from this source were distributed using the spatial distribution of agricultural grassland from the AENEID model.
- Histosols (0.5 kt N_2O): Histosols are agricultural soils with a high organic carbon content. A dataset was derived by combining a map of % organic carbon and the CEH landcover map (LCM2000). N_2O emissions from this source were distributed over the resulting map of suitable agricultural land.

The resulting spatially distributed N_2O emission estimates were individually checked for consistency with the BBSRC inventory and then aggregated to the categories listed in Table 1 (above). It should be noted that N_2O emissions from the application of livestock manures are included in the "soils" category, rather than with livestock emissions, as is usual for NH_3.

The resulting spatially distributed emission estimates were then aggregated as follows:

- NH_3: emissions from **livestock manures** and **fertilisers**,
- CH_4: emissions from **enteric fermentation** and **livestock manures**
- N_2O: emissions from **livestock manures** and **soils**

All output data were checked for consistency with the NARSES inventory.

3. RESULTS

3.1. Spatially distributed emissions of NH_3, CH_4 and N_2O for 2008

All UK maps were produced on the Ordnance Survey GB Grid at a resolution of 5 km x 5 km. The units for all GIS datasets submitted are kg ammonia (NH_3), methane (CH_4) and nitrous oxide (N_2O), respectively, per grid square. All spatial datasets were submitted to NWR (Defra Contract AC0112) and to AEAT (for use in the National Atmospheric Emission Inventory (NAEI, see www.naei.org.uk) and the Greenhouse Gas Inventory (GHGI, see www.ghgi.org.uk)). Figures 1, 2 and 3 show the 2008 maps resulting from the spatial modelling of emissions for NH_3, CH_4 and N_2O, respectively (units: kg ha^{-1} $year^{-1}$).

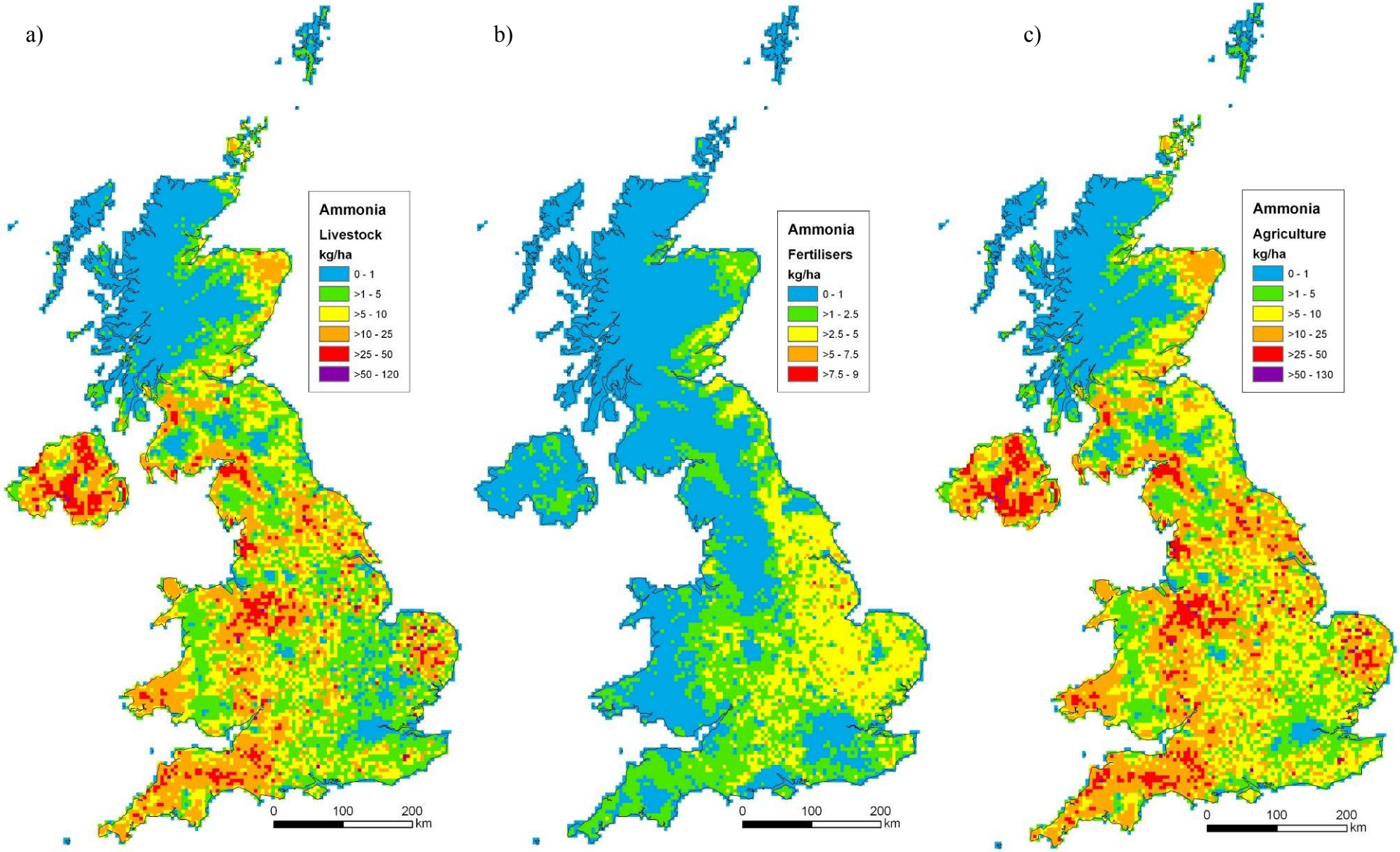

Figure 1: UK ammonia emissions from a) livestock manures, b) fertilisers and c) total agriculture (c = a + b) for 2008 (Units: kg NH_3 ha^{-1} $year^{-1}$).

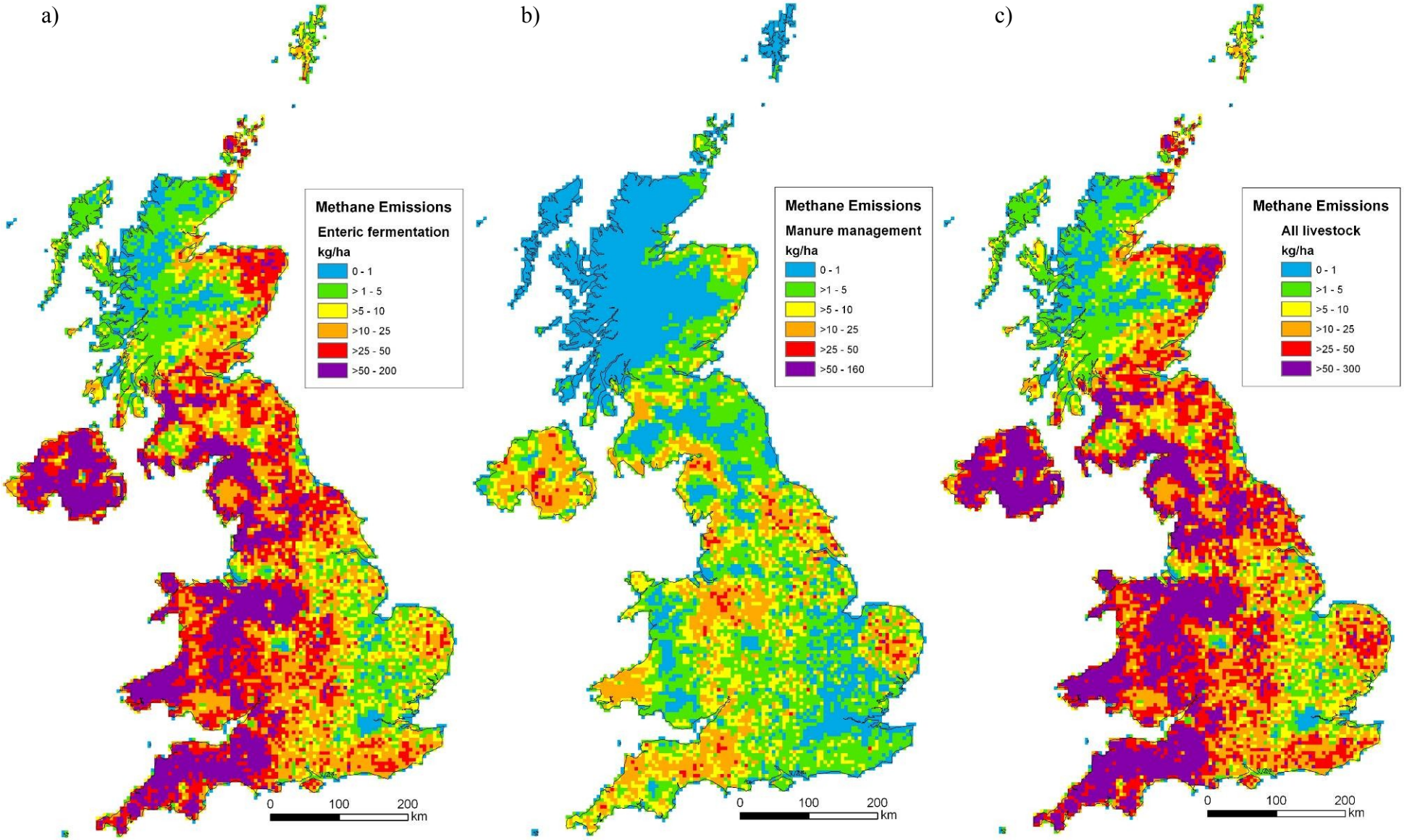

Figure 2: UK methane emissions from a) enteric fermentation, b) livestock manure management and c) total livestock (c = a + b) for 2008 (Units: kg CH_4 ha^{-1} $year^{-1}$).

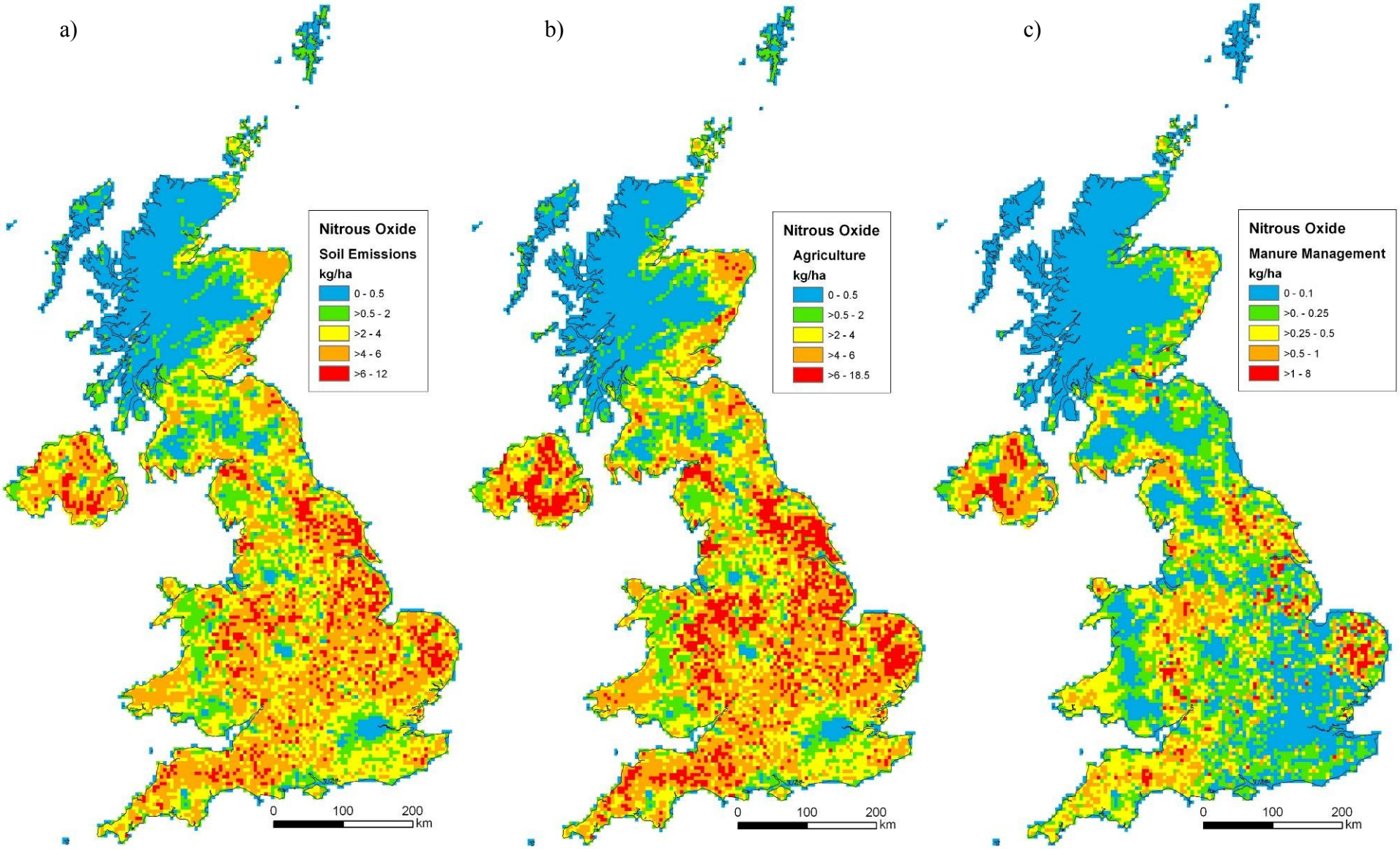

Figure 3: UK nitrous oxide emissions from a) soils, b) livestock manure management and c) total agriculture (c = a + b) for 2008 (Units: kg N_2O ha^{-1} $year^{-1}$).

3.2. Major changes and Consequences

3.2.1. CHANGES IN EMISSIONS FROM AGRICULTURAL NH_3 SOURCES

Overall, the estimate of NH_3 emissions from UK agriculture decreased by 12.6 kt NH_3 between 2007 and 2008, with 242.1 and 229.5 kt NH_3 emitted, respectively (Misselbrook et al. 2009). This includes decreases in livestock emissions by 4.8 kt NH_3 and decreases in fertiliser emissions by 7.9 kt NH_3.

Revisions to the NARSES model during the current inventory year include a revision of historical livestock numbers. The decrease in estimated emissions between 2007 and 2008 is mainly due to a decline in livestock numbers for all sectors, apart from broilers, with an increase in the UK population by 1%. Fertiliser emissions decreased due to a 10% reduction in fertiliser N application (BSFP 2009), and a large reduction (-48%) in the use of urea. As urea is associated with a much larger NH_3 volatilisation rate than other N fertilisers, this resulted in a substantial decrease in fertiliser NH_3 emissions between 2007 and 2008.

Table 2: Differences between the 2007 and 2008 inventories for NH_3 emissions from UK agriculture (adapted from Misselbrook *et al.* 2009)

	2007 kt NH_3	2008 Kt NH_3	difference kt NH_3	difference %
All cattle	134.0	132.0	-2.0	-2%
All Sheep, Goats & Deer	11.0	10.7	-0.3	-3%
Pigs	20.9	19.8	-1.1	-5%
All Poultry	31.7	30.7	-1.0	-3%
Horses	4.9	4.7	-0.2	-4%
Livestock total	**202.4**	**197.7**	**-4.7**	**-2%**
N fertilisers	39.7	31.8	-7.9	-20%
Agriculture total	**242.1**	**229.5**	**-12.6**	**-5%**

3.2.2. CHANGES IN EMISSIONS FROM AGRICULTURAL CH_4 AND N_2O SOURCES

Between 2007 and 2008, the inventory total for CH_4 emissions from UK livestock has decreased slightly, mainly due to the real general decline in livestock numbers for all sectors. This decrease has been partly offset by new, slightly higher, Tier 2 emission factors for dairy cows in milk and beef cows.

Table 3: Differences between the 2007 and 2008 inventories for CH_4 emissions from UK agriculture (adapted from Cardenas *et al.* 2007 and 2008)

	2007 kt CH_4	2008 kt CH_4	difference kt CH_4	difference %
Enteric fermentation	733.1	731.0	-2.1	-0.3%
Livestock manure	136.0	135.2	-0.8	-0.6%
Total agriculture	**869.1**	**966.2**	**-3.9**	**-0.4%**

Overall, emissions of N_2O increased slightly between 2007 and 2008, according to the inventories of Cardenas et al. (2008 and 2009), mainly due to an increase in emissions from manure management, due to revised N excretion data. This is partly offset by the decrease in livestock numbers.

Table 3: Differences between the 2007 and 2008 inventories for N_2O emissions from UK agriculture (adapted from Cardenas *et al.* 2008 and 2009)

	2007 kt N_2O	2008 kt N_2O	difference kt N_2O	difference %
Direct soil emissions	49.4	50.2	+0.8	+2%
Indirect soil emissions	25.7	25.0	-0.7	-3%
All crops & soils	75.1	75.2	+0.1	+0.1%
Manure management	5.4	6.6	+ 1.2	+22%
Agriculture total	**80.6**	**81.8**	**+1.2**	**+1.5%**

4. CONCLUSIONS

New ammonia emission maps were derived for the UK (Defra project AC0112), and submitted for inclusion in the 2008 version of the NAEI and GHGI for agriculture for the UK.

Agricultural emission sources 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). The latest source strength estimates from the UK NH_3 Emissions Inventory (Misselbrook *et al*. 2009) and the UK greenhouse gas inventory (CH_4 and N_2O; Cardenas *et al.* 2009), produced at NWR, were also applied in AENEID.

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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