The spatial distribution of ammonia, methane and nitrous oxide emissions from agriculture in the UK 2009

Annual Report to Defra (Project AC0112)

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EXECUTIVE SUMMARY

Modelling and mapping UK ammonia and greenhouse gas emissions from agriculture

Defra project AC0112

- Agricultural emissions of ammonia, methane and nitrous oxide for 2009 were spatially distributed across the UK, and maps produced.
- Agricultural emission sources were spatially distributed using the CEH/University of Edinburgh AENEID model. The model incorporates detailed agricultural census data, landcover data, agricultural practice information (e.g. fertiliser application rates, stocking densities) and emission source strength data from the UK emissions inventories for agriculture 2009 (Misselbrook *et al.* 2010, Cardenas *et al.* 2010).
- All emission maps correspond to the totals reported by North Wyke Research (NWR) for 2009 (Misselbrook *et al*. 2010, Cardenas *et al*. 2010).

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1. INTRODUCTION

1.1. Background

Emissions of ammonia, methane and nitrous oxide for 2009 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 (NWR); 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 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 2009, as collated by NWR and mapped by CEH (in kt yr^{-1}). Totals may not add up exactly due to rounding.

Gas	Source	UK emission (kt) 2009
NH_3	Livestock manure	195.8 kt NH_3
	Fertiliser application	36.0 kt NH_3
	Total agriculture	**231.8 kt NH_3**
CH_4	Enteric fermentation	718.7 kt CH_4
	Livestock manure	133.3 kt CH_4
	Total agriculture	**852.1 kt CH_4**
N_2O	Crops & soils	80.3 kt N_2O
	Livestock manure	6.4 kt N_2O
	Total agriculture	**86.8 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 2009 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 DARD NI (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.

The agricultural emission inventory for NH_3 was mapped using output from the NARSES model at NWR (Misselbrook *et al*. 2010, 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 2009 (BSFP 2010).

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 (19.0 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 2000 (BSFP 2010).
- Grazing and manure spreading (21.2 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 (24.8 kt N_2O): Emissions from this source were spread via the AENEID output for all crops and grassland.
- Crop residues (8.5 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 (4.9 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 (0.9 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 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 2009

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 2009 maps resulting from the spatial modelling of emissions for NH_3, CH_4 and N_2O, respectively (units: kg ha^{-1} $year^{-1}$).

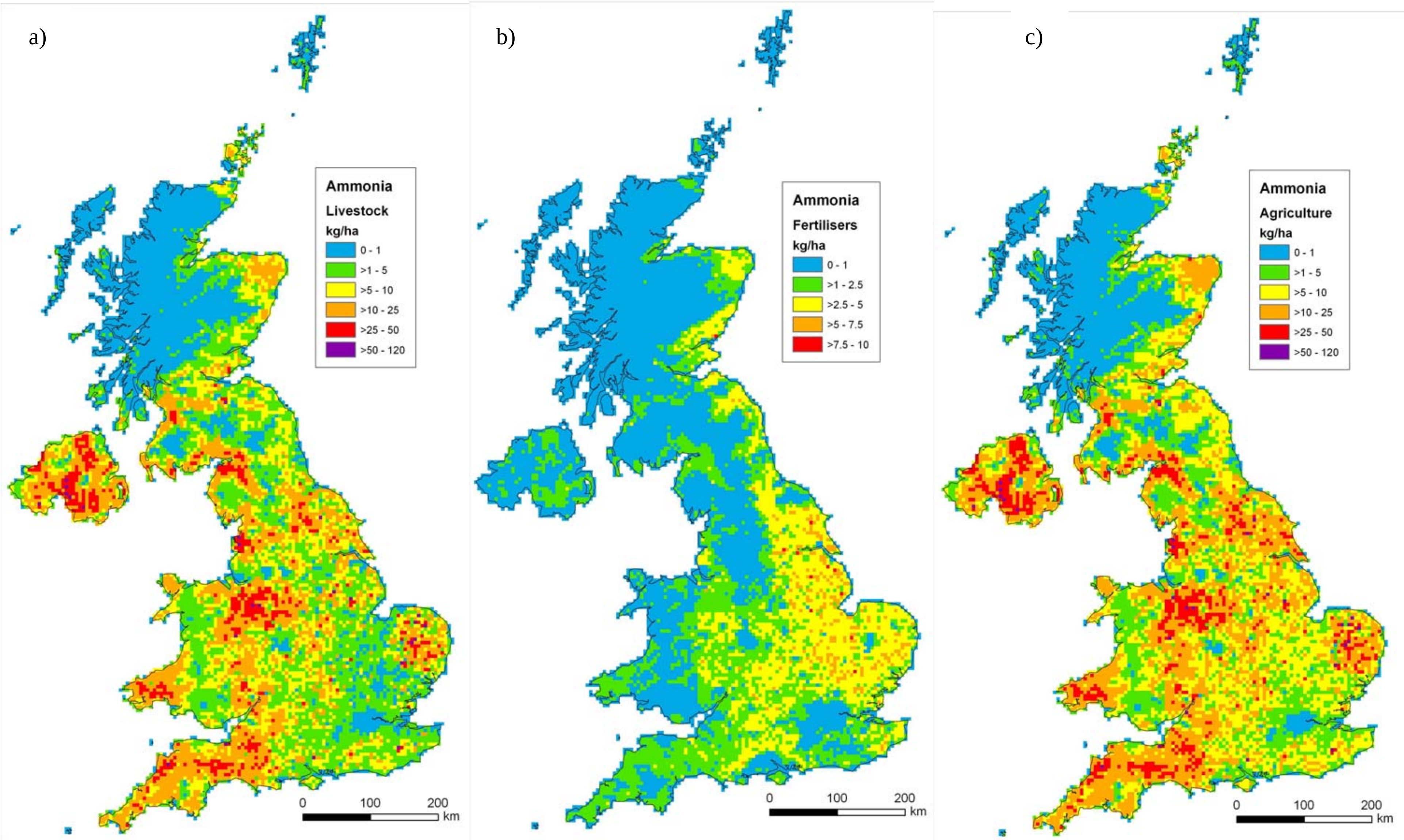

Figure 1: UK ammonia emissions from a) livestock manures, b) fertilisers and c) total agriculture (c = a + b) for 2009 (Units: kg NH_3 ha^{-1} $year^{-1}$).

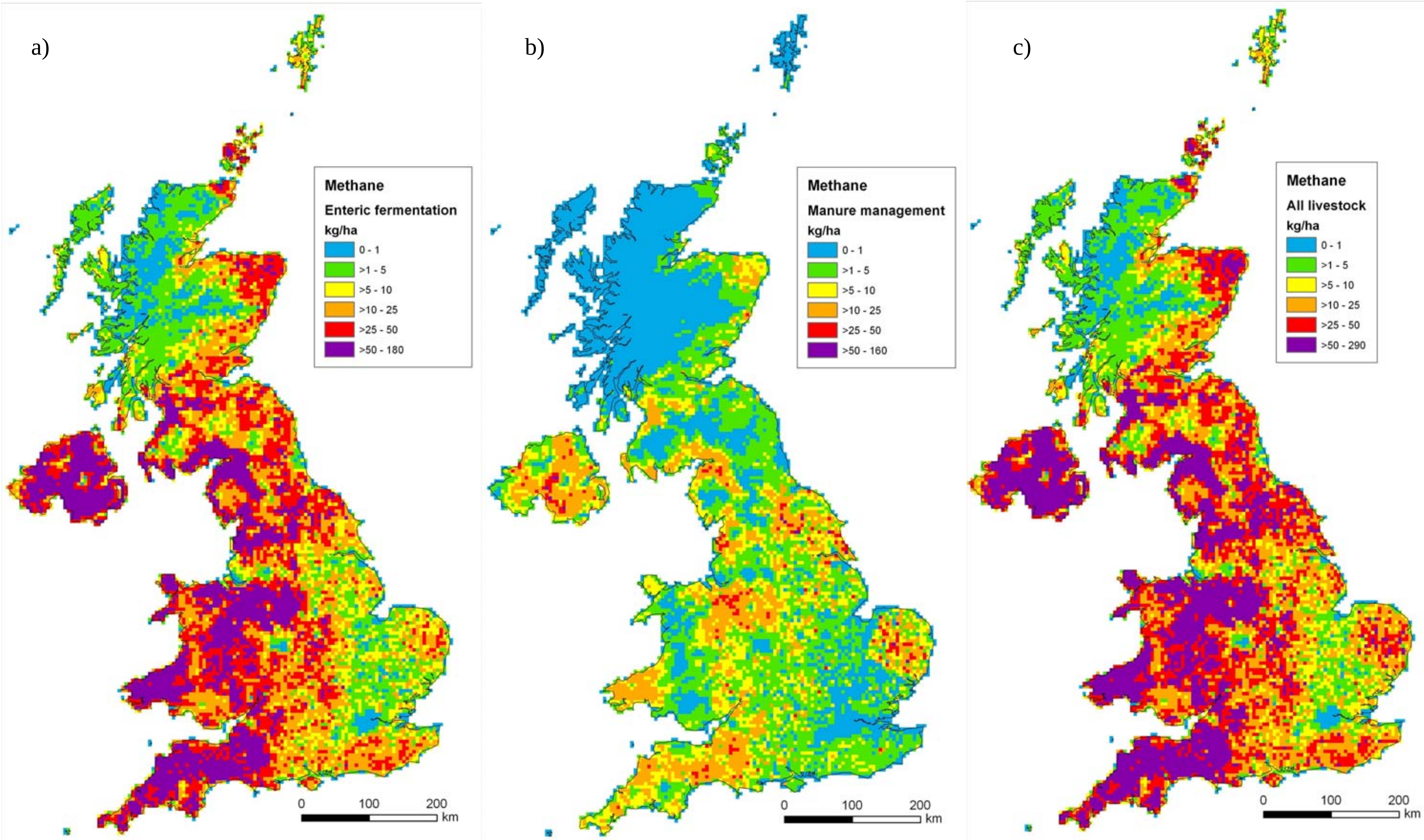

Figure 2: UK methane emissions from a) enteric fermentation, b) livestock manure management and c) total livestock (c = a + b) for 2009 (Units: kg CH_4 ha^{-1} $year^{-1}$).

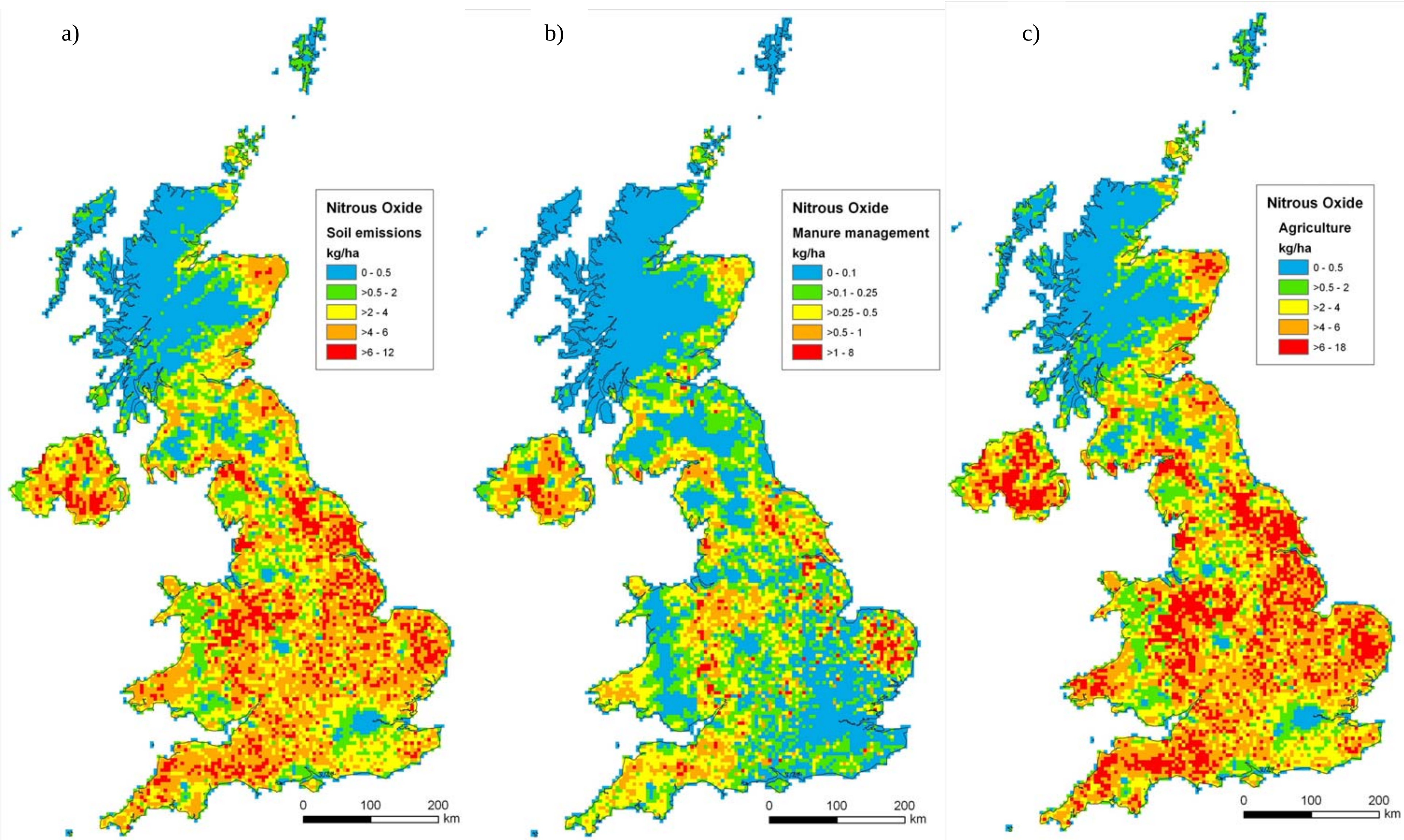

Figure 3: UK nitrous oxide emissions from a) soils, b) livestock manure management and c) total agriculture (c = a + b) for 2009 (Units: kg N_2O ha^{-1} $year^{-1}$).

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 increased by 2.3 kt NH_3 between 2008 and 2009, with 229.5 and 231.8 kt NH_3 emitted, respectively (Misselbrook *et al.* 2010). This includes decreases in livestock emissions by 1.9 kt NH_3 and increases in fertiliser emissions by 4.2 kt NH_3.

Revisions to the calcuations during the current inventory year include updates to housing data for cattle, pigs and poultry and manure management data for sheep, goats and farmed deer. The decrease in estimated livestock emissions between 2008 and 2009 is mainly due to a decline in livestock numbers for most sectors (apart from pigs and horses). Overall, emissions from cattle showed a small increase due to new housing data, despite a small decrease in the UK cattle population. Conversely, emissions from pigs increased slightly, with housing emissions reduced due to new data, offset by a small increase in the UK pig population.

Fertiliser emissions increased due to an overall increase (by 1.3%) in fertiliser N application (BSFP 2010) as well as an increase in the use of urea (by 28%). As urea is associated with a much larger NH_3 volatilisation rate than other N fertilisers, this resulted in a substantial increase in fertiliser NH_3 emissions between 2008 and 2009.

Table 2: Differences between the 2008 and 2009 inventories for NH_3 emissions from UK agriculture (adapted from Misselbrook *et al.* 2010). Totals may not add up exactly due to rounding.

	2008 kt NH_3	2009 Kt NH_3	difference kt NH_3	difference %
All cattle	132.0	132.5	+0.5	+0.4%
All Sheep, Goats & Deer	10.7	10.1	-0.6	-6%
Pigs	19.8	18.8	-1.0	-5%
All Poultry	30.7	29.5	-1.2	-4%
Horses	4.7	4.8	+0.1	+2%
Livestock total	**197.7**	**195.8**	**-1.9**	**-1%**
N fertilisers	**31.8**	**36.0**	**+4.2**	**+13%**
Agriculture total	**229.5**	**231.8**	**+2.3**	**+1%**

3.2.2. CHANGES IN EMISSIONS FROM AGRICULTURAL CH_4 AND N_2O SOURCES

Between 2008 and 2009, the inventory total for CH_4 emissions from UK livestock has decreased by 14.1 kt CH_4, mainly due to the real general decline in livestock numbers for most sectors. This decrease has been partly offset by new, slightly higher, Tier 2 emission factors for dairy cows in milk.

Table 3: Differences between the 2008 and 2009 inventories for CH_4 emissions from UK agriculture (adapted from Cardenas *et al.* 2008, 2009). Totals may not add up exactly due to rounding.

	2008 kt CH_4	2009 kt CH_4	difference kt CH_4	difference %
Enteric fermentation	731.0	718.7	-12.3	-2%
Livestock manure	135.2	133.3	-1.9	-1%
Total agriculture	**866.2**	**852.1**	**-14.1**	**-2%**

Overall, emissions of N_2O increased by 5 kt between 2008 and 2009, according to the inventories of Cardenas *et al.* (2009, 2010). In the 2009 inventory, land spreading of sewage sludge to agricultural land was included in the calculations for the first time, resulting in an additional 1.4 kt N_2O, split over direct and indirect soil emissions. Further main reasons for the increase in N_2O emissions between 2008 and 2009 are the increase in fertiliser N application rates and a revision in the calculation method of indirect emissions from leaching (previously, volatilised N and N_2O emissions were subtracted before calculating leaching rather than from the total N applied). These increases are partly offset by the continuing decrease in livestock numbers.

Table 3: Differences between the 2008 and 2009 inventories for N_2O emissions from UK agriculture (adapted from Cardenas *et al.* 2009, 2010). Totals may not add up exactly due to rounding.

	2008 kt N_2O	2009 kt N_2O	difference kt N_2O	difference %
Direct soil emissions	50.2	50.7	+0.5	+1%
Indirect soil emissions	25.0	29.7	+4.7	+19%
All crops & soils	75.2	80.3	+5.1	+7%
Manure management	6.6	6.4	-0.2	-3%
Agriculture total	**81.8**	**86.8**	**+5.0**	**+6%**

4. CONCLUSIONS

New ammonia emission maps were derived for the UK (Defra project AC0112), and submitted for inclusion in the 2009 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*. 2010) and the UK greenhouse gas inventory (CH_4 and N_2O; Cardenas *et al.* 2010), 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