The spatial distribution of ammonia, methane and nitrous oxide emissions from agriculture in the UK 2015

Annual Report to Defra (Project SCF0102)

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Executive Summary

Modelling and mapping UK ammonia and greenhouse gas emissions from agriculture

Defra project SCF0102

- Agricultural emissions of ammonia, methane and nitrous oxide for 2015 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 2015 (Misselbrook *et al.* 2016, Cardenas *et al.* 2016).
- All emission maps correspond to the totals reported by Rothamsted Research North Wyke (RResNW) for 2015 (Misselbrook *et al*. 2016, Cardenas *et al*. 2016).

CONTENTS

1. INTRODUCTION

1.1. Background

Emissions of ammonia, methane and nitrous oxide for 2015 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 SCF0102 (inventories by Misselbrook *et al*. and Cardenas at Rothamstead Research North Wyke (RResNW); see Table 1). The current contract exploits the expertise of CEH in spatially distributing emissions from agricultural sources, and complements the expertise of RResNW 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 2015, as collated by RResNW and mapped by CEH (in kt yr^{-1}).

Gas	Source	UK emission (kt) 2015
NH_3	Livestock manure	193.3 kt NH_3
	Fertiliser application	44.9 kt NH_3
	Total agriculture	**238.2 kt NH_3**
CH_4	Enteric fermentation	962.9 kt CH_4
	Livestock manure	140.7 kt CH_4
	Total agriculture *	**1,103.6 kt CH_4**
N_2O	Crops & soils	48.2 kt N_2O
	Livestock manure	4.9 kt N_2O
	Total agriculture *	**53.1 kt N_2O**

* includes non-agricultural horses (i.e. all horses present in the UK, rather than only those present on farms that are counted as part of the annual agricultural statistics)

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 RResNW. 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 Ricardo-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 2015 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. Emissions from 'non-agricultural' horses (i.e. horses that are not kept on agricultural holdings) are **not included** in ammonia emissions maps and are mapped separately. Emission from these horses are however, **included** in the CH_4 and N_2O emission maps.

The agricultural emission inventory for NH_3 was mapped using output from the NARSES model at RResNW (Misselbrook *et al*. 2016, Defra project SCF0102). 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 2015 (BSFP 2016).

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. The 2007 landcover map (LCM2007) is now used routinely in the model, following implementation for the 2011 inventory.

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. Direct and indirect nitrous oxide emissions from livestock manures (4.9 kt N_2O) 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 and mapped as follows:

- **Fertiliser application**: Direct emissions (15.8 kt N_2O) from this source were spread via the AENEID model for all crops and grassland, combined with detailed data on fertiliser application rates from the British Survey of Fertiliser Practice for 2015 (BSFP 2016). Indirect emissions from this source (leaching (2.9 kt) and the re-emission of N as N_2O from fertiliser use (0.57 kt)) were distributed using the same method.
- **Grazing and manure spreading**: Direct emissions (4.3 kt N_2O) 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. Indirect emissions from this source (leaching (0.7 kt) and the re-emission of N as N_2O (0.37 kt)) were distributed using the same method.
- **Crop residues**: Direct emissions (10.5 kt N_2O) from this source were spread evenly over all NARSES crop categories, excluding grassland, fruit and nursery stock etc. This category now includes biological fixation of nitrogen, which was separated in previous inventories. Indirect emissions of this source through leaching (2.36 kt), were distributed using the same method as the direct emissions.

- **Histosols** (3.6 kt N_2O): Histosols are agricultural soils with a high organic carbon content. A new dataset from Defra project AC0114 (Greenhouse Gas Platform) was combined with the AENEID spatial distribution of crops and grassland to define histosol areas of agriculture. N_2O emissions from this source were distributed over the resulting map.
- **Sewage sludge**: Direct emissions (0.80 kt N_2O) from the spreading of sewage sludge to agricultural land were distributed via the AENEID model across all crops. Indirect emissions from this source were distributed in the same way and were separated into emissions from leaching (0.18 kt) and the re-emission of N as N_2O from fertiliser use (0.16 kt).
- **N Mineralisation**: Direct emissions (1.39 kt) from mineral soils, associated with change in land use of management were distributed via the AENEID model across all crops. Indirect leaching emissions from this source (0.7 kt) were distributed in the same way.

The resulting spatially distributed N_2O emission estimates were individually checked for consistency with the RResNW 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 2015

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 RResNW (Defra Contract SCF0102) and to Ricardo-AEA (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 2015 maps resulting from the spatial modelling of agricultural emissions (excluding non-agricultural horses) for NH_3, CH_4 and N_2O, respectively (units: kg ha^{-1} year^{-1}).

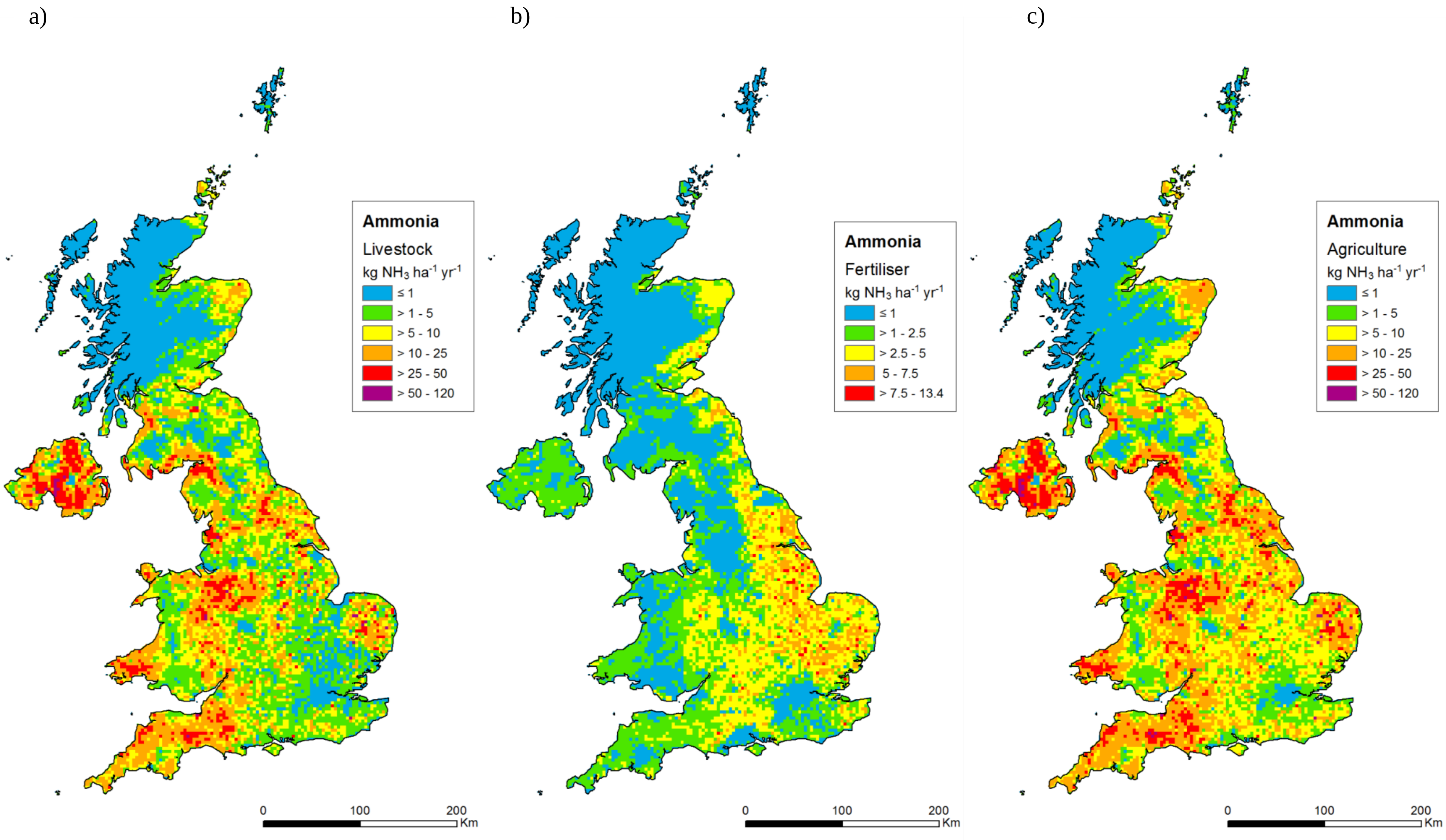

Figure 1: UK ammonia emissions from a) livestock manures, b) fertilisers and c) total agriculture (c = a + b) for 2015 (Units: kg NH_3 ha^{-1} $year^{-1}$).

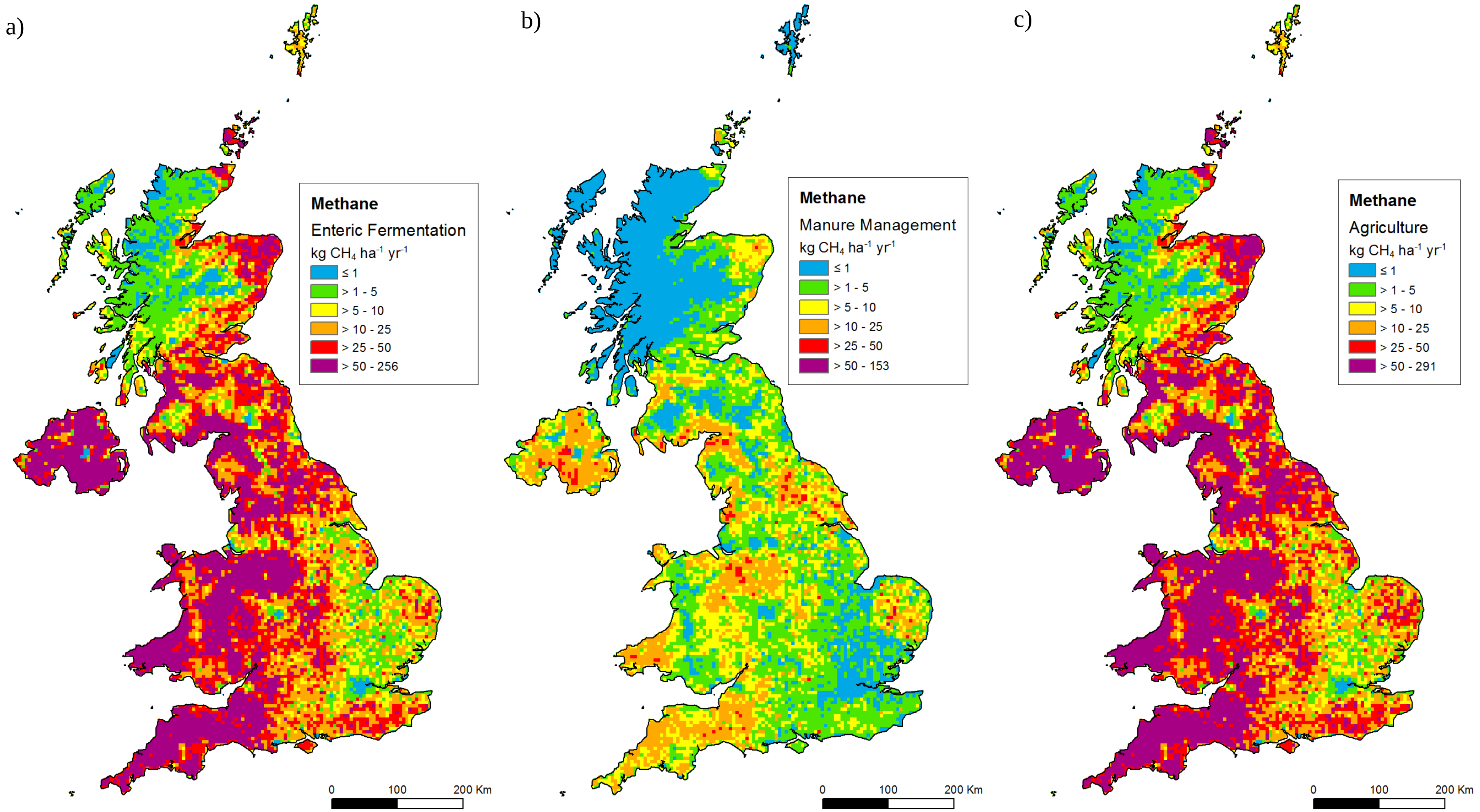

Figure 2: UK methane emissions from a) enteric fermentation, b) livestock manure management and c) total livestock (c = a + b) for 2015 (Units: kg CH_4 ha^{-1} $year^{-1}$).

a) b) c)

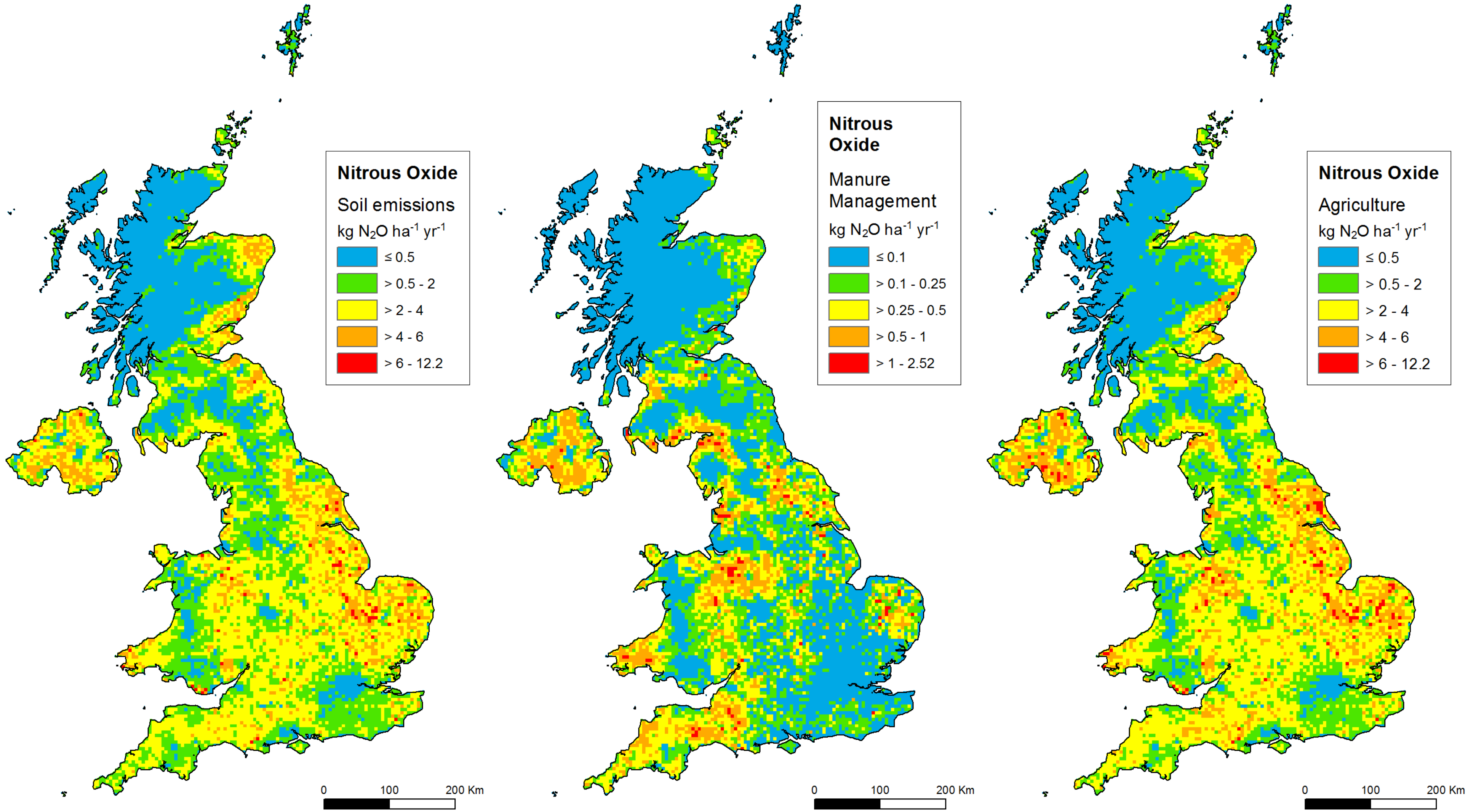

Figure 3: UK nitrous oxide emissions from a) soils, b) livestock manure management and c) total agriculture (c = a + b) for 2015 (Units: kg N_2O ha^{-1} $year^{-1}$).

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 increase by 3.9 kt NH_3 between 2014 and 2015, with 234.3 and 238.2 kt NH_3 emitted, respectively (Misselbrook *et al.* 2015, 2016). This includes increases in livestock emissions by 0.8 kt NH_3, but is primarily due to increased fertiliser emissions of 2.5 kt NH_3.

Taking into account methodological differences, the minor estimated increase in livestock emissions between 2014 and 2015 is primarily due to increased populations of dairy cattle (3 %), which has been offset to some extent by decreases total pig, poultry and sheep populations of 1.6 %, 1.2 and 1.2 % respectively.

Total fertiliser N has increased by 2.5 % between 2014 and 2015 (Misselbrook et al., 2016), caused by increased total fertiliser N use and proportion applied as urea (BSFP, 2016). The proportion applied as urea-based fertiliser increased from 23% in 2014 to 28% in 2015.

Table 2: Differences between the 2014 and 2015 inventories for NH_3 emissions from UK agriculture (adapted from Misselbrook *et al*. 2015, 2016). Totals may not add up exactly due to rounding.

	2014 kt NH3	2015 kt NH3	difference kt NH_3	difference %
All cattle	*128.2*	*129.6*	+1.4	1%
All Sheep, Goats & Deer	*10.1*	*9.9*	-0.2	-2%
Pigs	*18.5*	*18.2*	-0.3	-2%
All Poultry	*31.8*	*31.8*	+0	0%
Horses (agricultural only)	*3.9*	*3.6*	-0.3	-8%
Livestock total	192.5	193.3	0.8	+0.4%
N fertilisers	41.8	44.3	2.5	+6%
Total agriculture	**234.3**	**238.2**	3.9	+2%

3.2.2. CHANGES IN EMISSIONS FROM AGRICULTURAL CH_4 AND N_2O SOURCES

Total agricultural CH_4 emissions are estimated to have increased (+2.2 %) between the 2014 and 2015 inventories. Taking into account the methodological differences between the inventories, CH_4 emissions are estimated to have increased by 0.4 %. These increases, as with ammonia emissions, are a result of increased dairy cattle populations, which have been somewhat offset by decreased pig, poultry and sheep cattle populations (Cardenas et al. 2016).

Table 3: Differences between the 2014 and 2015 inventories for CH_4 emissions from UK agriculture (adapted from Cardenas *et al*. (2015, 2016). Totals may not add up exactly due to rounding.

	2014 kt CH_4	2015 kt CH_4	difference kt CH_4	difference %
Enteric fermentation	941.5	962.9	21.4	2.3%
Livestock manure	138.4	140.68	2.28	1.6%
Total agriculture	**1079.9**	**1103.6**	23.7	2.2%

Overall, emissions of N_2O increased marginally (0.6 %) between 2014 and 2015, according to the inventories of Cardenas *et al.* (2015, 2016). Taking into account the methodological differences between the inventories, N_2O emissions are actually estimated to have decreased by 0.8 kt (1.5%). N_2O emission estimates from livestock manure are in line with those made for 2014, with only a minor increase in emissions associated with increased dairy cattle. Emissions from agricultural soils have decreased marginally, primarily associated with decreased emissions from fertiliser application.

Table 3: Differences between the 2014 and 2015 inventories for N_2O emissions from UK agriculture (adapted from Cardenas *et al.* 2015, 2016). Totals may not add up exactly due to rounding.

	2014 kt N_2O	2015 kt N_2O	difference kt N_2O	difference %
Direct soil emissions	*38.8*	*38.8*	0	0.0%
Indirect soil emissions	*9.0*	*9.4*	0.4	4.4%
Total soil emissions	**47.9**	**48.2**	0.3	0.6%
Total manure management emissions	**4.9**	**4.9**	0	0.0%
Total agriculture	**52.8**	**53.1**	0.3	0.6%

4. Conclusions

New ammonia, methane and nitrous oxide emission maps were derived for the UK (Defra project SCF0102), and submitted for inclusion in the 2015 version of the NAEI and GHGI for agriculture in 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 2015 UK NH_3 Emissions Inventory (Misselbrook *et al*. 2016) and the UK greenhouse gas inventory (CH_4 and N_2O; Cardenas *et al.* 2016), produced at RResNW, were also applied in AENEID.

Acknowledgements

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