Defra project AQ0834 - Identification of Potential "Remedies" for Air Pollution (nitrogen) Impacts on Designated Sites (R.A.P.I.D.S.)

Appendix 5 - Pilot Scenario allocation to UK SACs and A/SSSIs

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Summary

- The approach of assigning initial Scenarios to all UK SACs and A/SSSIs was piloted with source attribution model output at a 5 km grid resolution. These data were combined with an analysis of the spatial distance between designated sites and large pig and poultry farms covered by the Industrial Emissions Directive (IED, formerly IPPC) and major roads.
- Output from the initial scenario allocation shows that most sites are affected by more than one main source type, i.e. many sites are associated with multiple scenarios. In summary, multiple scenarios per designated site are more likely in areas with more diverse land use and hence emission sources. Lowland agricultural areas appear to have less complex source attribution patterns, therefore perhaps making them more suitable for local scale incentive type measures.
- The distribution of the different Scenarios across UK SACs and A/SSSIs, using individual pie charts for each site, illustrates the spatial patterns of the main source types. Areas of major conurbations in south-east England with the associated combustion, shipping and road transport sources can be typified by the combined presence of Sc 3 (non-agricultural (point) sources) and Sc4 (roads), whereas remote upland sites in north-west and northern Scotland are characterised by a combination of Sc5 (long-range transport) and Sc3 (non-agricultural (point) sources). The data derived for each site using this approach provide the basis for further assessment, together with a combination of higher resolution/local data to determine sources and activities contribute to the N threat, thereby enabling the identification of suites of potential measures to reduce N deposition at the sites.
- The current source attribution dataset available for analysis in this project cannot distinguish whether N deposition from any emission source category in a grid square is due to local, medium- or long-range sources. It is expected that a new source attribution dataset developed with a revised approach, as recommended by this project (RAPIDS), would enable a more detailed differentiation whether local targeting of N deposition sources is a viable solution for each site.

1. Introduction

One of the main objectives of project is to develop a framework for identification of the key N threats for each site to guide site-level application of the measures. Having identified the main information sources and a draft framework for conducting an initial top-down national-scale allocation of the five Scenarios to UK SACs and A/SSSIs, testing of the draft N source allocation framework developed was carried out.

2. Input data and methodology

The pilot assessment was carried out using the following data sources:

- The UK source attribution dataset for N deposition (most recent available year 2005) at a 5 km grid resolution; this dataset is the basis of the APIS Source Attribution tool.
- SAC and A/SSSI boundary datasets (GIS, supplied by the conservation agencies)
- IED pig and poultry farm locations in the UK (and pig/bird populations for England, Scotland and Northern Ireland)
- Major roads dataset (GIS) with traffic count data from the Department for Transport (DfT), combined with higher resolution OS data for more accurate spatial location

For each designated site, the detailed source attribution dataset was assessed using the approach shown in **Figure 1**, with N deposition at each site being tested against thresholds for source types. For example, high levels of wet deposition at a site were taken to indicate substantial N deposition through long-range transport, from sources located away from the immediate vicinity of the site. For the purpose of Scenario allocation, the UK source attribution dataset for N deposition was translated from the source categories used in APIS to the five RAPIDS scenarios as shown in **Table 1**. Using this approach, it was possible to distinguish the main scenarios:

- Agriculture (Sc1, Sc2),
- Non-agricultural (point) sources (Sc3),
- Roads (Sc4),
- Remote (mainly upland) sites affected by long-range N input (Sc5) (which may originate from agricultural sources, points sources or roads).

However, it was not possible to distinguish between Sc1 (many diffuse agricultural sources) and Sc2 (agricultural point sources) using the N deposition dataset as the main input, as attempts to use the proportion of dry NH_x deposition to indicate the presence of 'hot spot' intensive farming were not successful, likely due to the spatial resolution of the data (5 km) being too coarse.

Due to the point source nature of large pig and poultry farms[1], a designated site may or may not be substantially affected by intensive farms located in the same or adjacent model 5 km grid square, depending on the actual distance and relative spatial location of the source and the site (see ***Appendix 2*** for a detailed assessment of the uncertainties of the national 5 km grid datasets for Scenario allocation). To test for the presence of large intensive farms that may contribute

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[1] It should be noted that testing could only be carried out for the presence of large pig and poultry farms registered under the Industrial Emissions Directive (IED), which can be viewed on a public register (e.g. the Environment Agency's 'What's in my backyard?' portal (http://apps.environment-agency.gov.uk/wiyby/default.aspx). Any clusters of smaller units below the IED threshold are expected to have similar effects on local N deposition. However, in the absence of local knowledge to support site-level assessments, the detailed datasets required to assess effects from such clusters for the UK (detailed agricultural census/survey) are only available under license, and cannot be used to identify individual farms.

UPDATE 4/11/2014: Under the IPENS-049 project commissioned by Natural England, the agricultural census/survey data for England were analysed under license and summarised at a non-disclosive level to report agricultural emission densities and main sectors for zones surrounding each SAC in England (Dragosits et al. 2014).

substantially to a site and allocate Scenario 2 (agricultural point sources), buffer zones of 2 km radius were used for the initial assessment. This approach should be refined further, using variable buffer distances depending on the emission source strength (calculated using animal populations where available), and with the prevailing wind direction being factored in. This is envisaged to be feasible with an analysis of SCAIL model output used systematically, but is outside the remit of the current project.

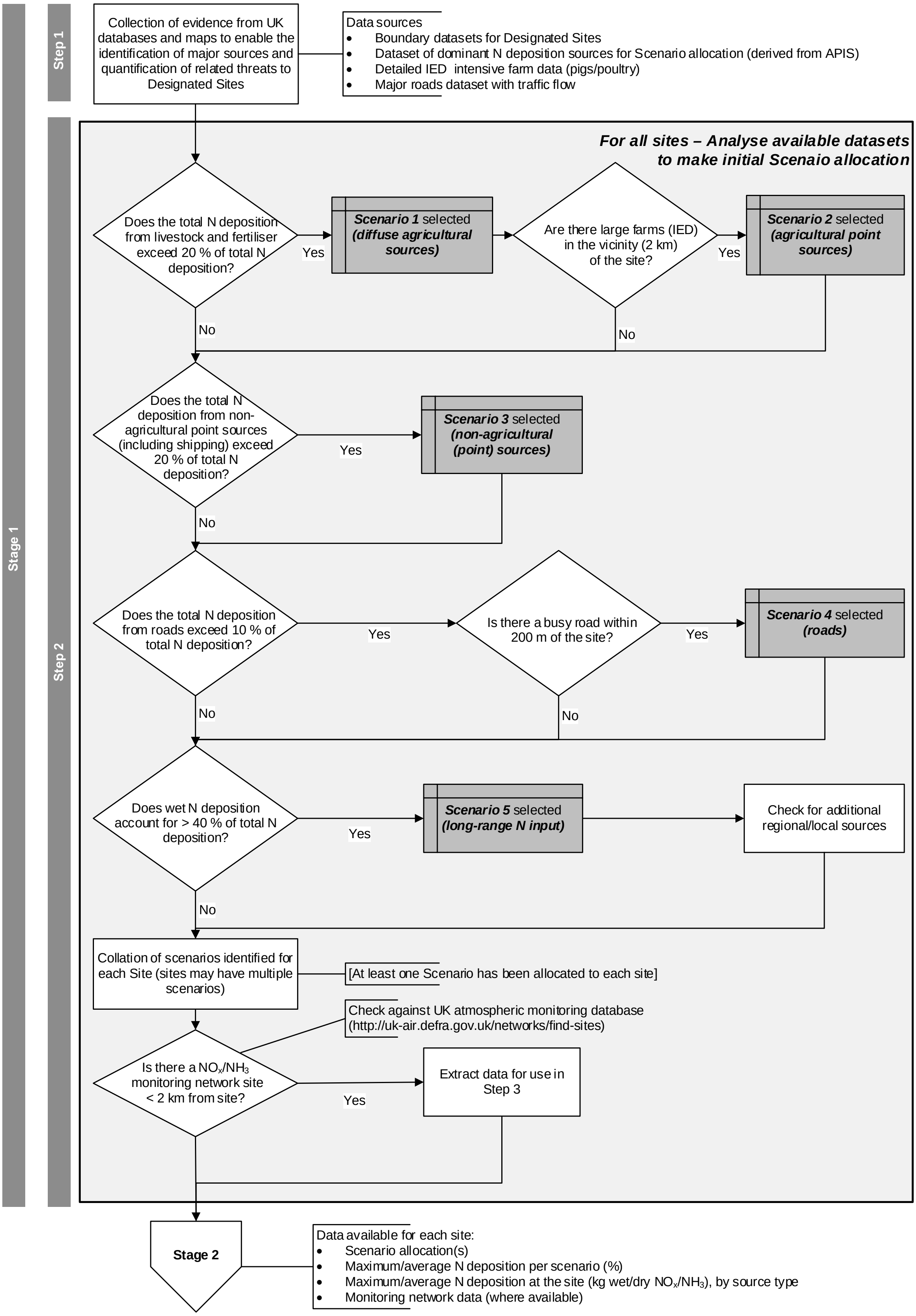

Figure 1- Flow diagram for deriving a dataset/map of dominant N deposition sources (year 2005, to be repeated when new UK source attribution data become available)

Table 1: Definition of the five RAPIDS scenarios using the UK source attribution dataset for N deposition (translation from the source categories used in APIS)

Scenario ID	Scenario name	Sources of N included in Scenario assessment		Criteria for Scenario Assessment
		APIS categories	**Components of N deposition included**	
1	Lowland agriculture (many diffuse sources)	- Ammonia emissions from fertiliser use - Livestock production	Total N deposition (Wet and dry NO_x and NH_3)	Total N deposition from agricultural sources (livestock, fertiliser) > 20 % of total N deposition
2	Agricultural point source(s)	- Ammonia emissions from fertiliser use - Livestock production	Total N deposition (Wet and dry NO_x and NH_3)	Total N deposition from agricultural sources (livestock, fertiliser) > 20 % of total N deposition AND site is within 2 km of an IED intensive farm
3	Non-agricultural (point) source(s)	- International Shipping - Other transport (excl. road transport) - Power stations - Refineries - Combustion plants - Energy production and transformation - NH_3 from non-agricultural sources[1]	Total N deposition (Wet and dry NO_x and NH_3)	Total N deposition from included sources (column APIS categories) > 20 % of total N deposition
4	Roads	Road transport	Total N deposition (Wet and dry NO_x and NH_3)	Total N deposition from road transport > 10 % of total N deposition AND site is within 200 m of a major road (motorway, primary or A-road)
5	Remote (upland) sites affected by long-range N input	All APIS categories [2]	Total Wet N deposition (NO_x and NH_3)	Total wet deposition > 40 % of total N deposition (wet and dry)

[1]Sources include: pets, wild animals, sewage sludge, composting, household products (solvents), humans (breath, sweat, babies nappies), landfill.

[2]Scenario 5 includes additional APIS source categories that were excluded from Scenarios 1-4, i.e. imported emissions and residual background sources (e.g. off-shore installations, crematoria, accidental fires, incineration etc.).

Similar to intensive pig and poultry farms, it is important to test for the distance between designated sites and nearby major roads, if road sources are flagged as a substantial source of N deposition in the source allocation data for a site. Given that concentrations of NO_x and NH_3 from originating from road transport sources deplete to background levels within 200 m from major roads (e.g. Cape *et al.*, 2004), the distance from the site boundary to the nearest major road is an important factor for determining whether to assign Sc4 (roads) to a site. In the pilot data shown, tests on both the road transport contribution to total N deposition and a distance of <200m to a major[2] road had to be positive.

The % thresholds of source contributions for the allocation of Scenarios (**Figure 1**) were derived through expert opinion from the histograms shown in **Figure 2** (SSSIs) and **Figure 3** (SACs), balancing the characteristics of different source types with their spatial distribution across the UK. The histograms illustrate the % contribution of the five main N sources (summarised into the RAPIDS scenarios) at UK designated sites, based on the deposition estimates to woodland in the UK 5 km grid source attribution datasets[3]. Supplementary distance information for major roads and IED farms was taken into account for allocation to the roads and agricultural point source Scenarios.

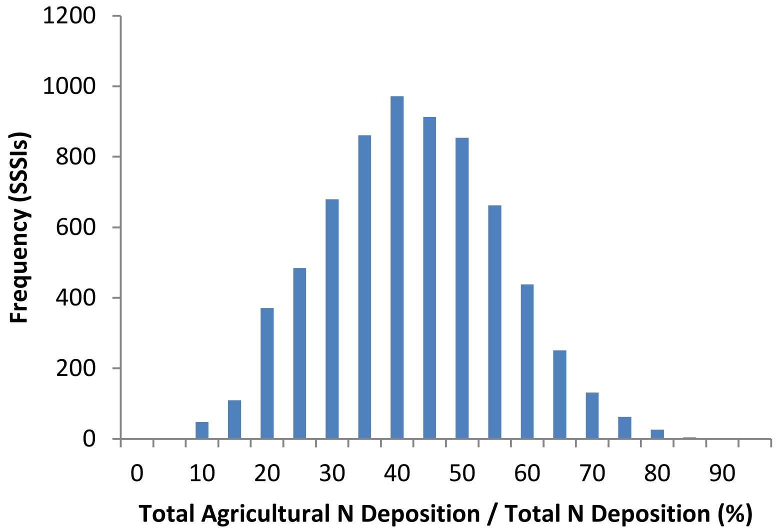

Figure 2.a - Contribution of agricultural sources (livestock and fertiliser) to total N deposition at UK A/SSSIs, for allocation of sites to Scenarios 1 and 2 (diffuse and point source agriculture), derived from UK scale source attribution data for 2005 (5 km grid).

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[2] Major roads are defined here as A roads, primary (trunk) roads and motorways

[3] Generally, the relative difference in % source attribution values between woodland and other (low-growing) semi-natural vegetation is minimal. It should be noted that any such differences at the 5 km grid level are due to a combination of reasons, including differences in deposition velocity between NO_x and NH_3 to different vegetation types, with small differences also due to the calibration approach for the deposition data. Any larger differences in the contribution of wet deposition to total deposition to woodland and other semi-natural vegetation types are due to woodland receiving larger amounts of dry deposition, with similar wet deposition input to both vegetation types, hence the relative differences. When assessing the N deposition threat to designated features within sites in more detail, it is important to use the appropriate deposition type (woodland, low semi-natural vegetation).

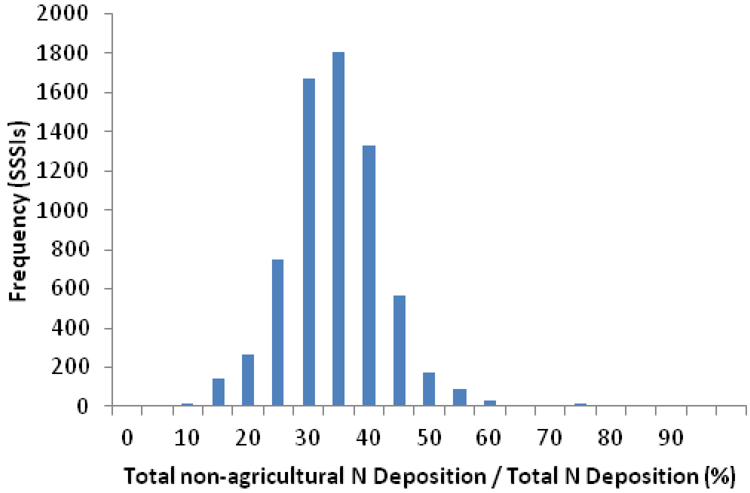

Figure 2.b - Contribution of non-agricultural sources (inc. shipping) to total N deposition at UK A/SSSIs, for allocation of sites to Scenario 3 (non-agricultural (point) sources), derived from UK scale source attribution data for 2005 (5 km grid).

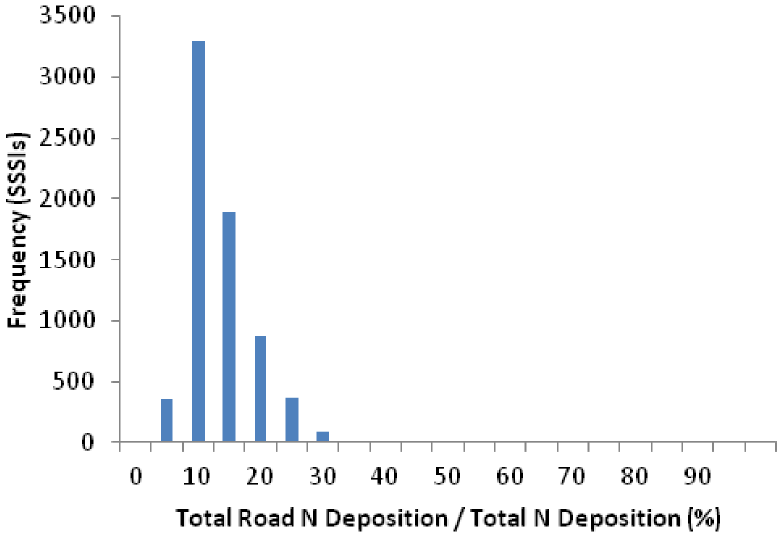

Figure 2.c - Contribution of road transport to total N deposition at UK A/SSSIs, for allocation of sites to Scenario 4 (roads), derived from UK scale source attribution data for 2005 (5 km grid).

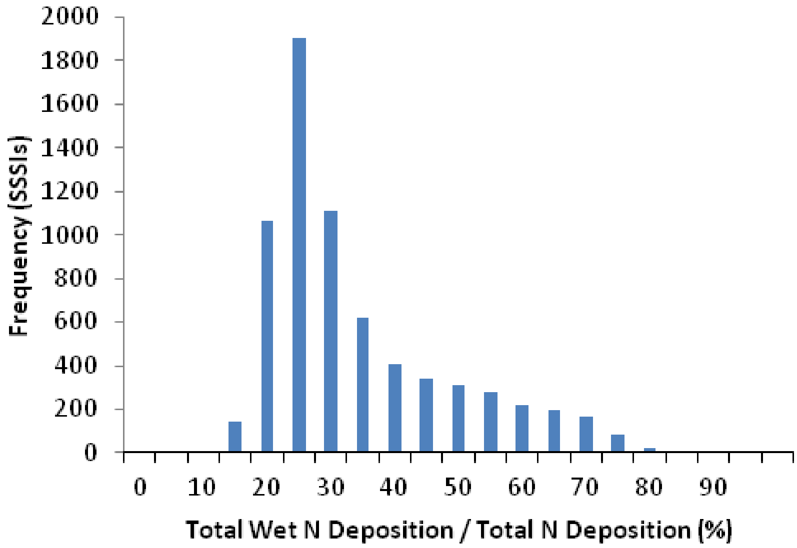

Figure 2.d - Contribution of wet deposition to total N deposition at UK A/SSSIs, for allocation of sites to Scenario 5 (remote sites affected by long range N deposition), derived from UK scale source attribution data for 2005 (5 km grid).

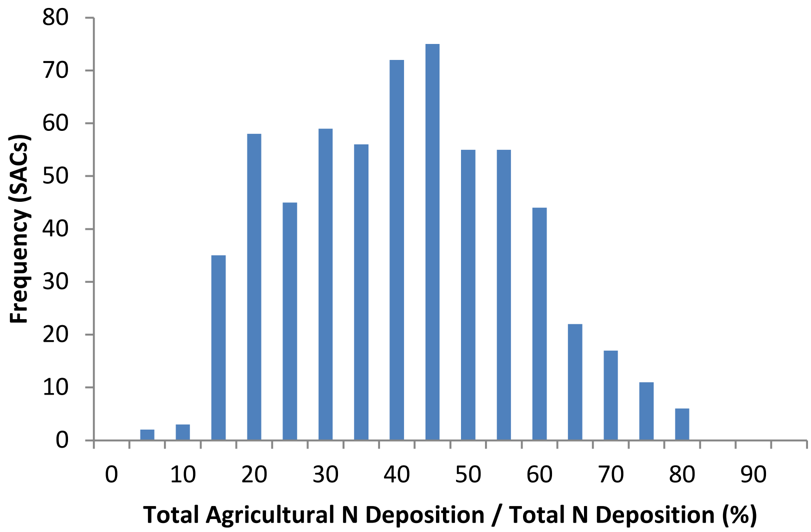

Figure 3.a - Contribution of agricultural sources (livestock and fertiliser) to total N deposition at UK SACs, for allocation of sites to Scenarios 1 and 2 (diffuse and point source agriculture), derived from UK scale source attribution data for 2005 (5 km grid).

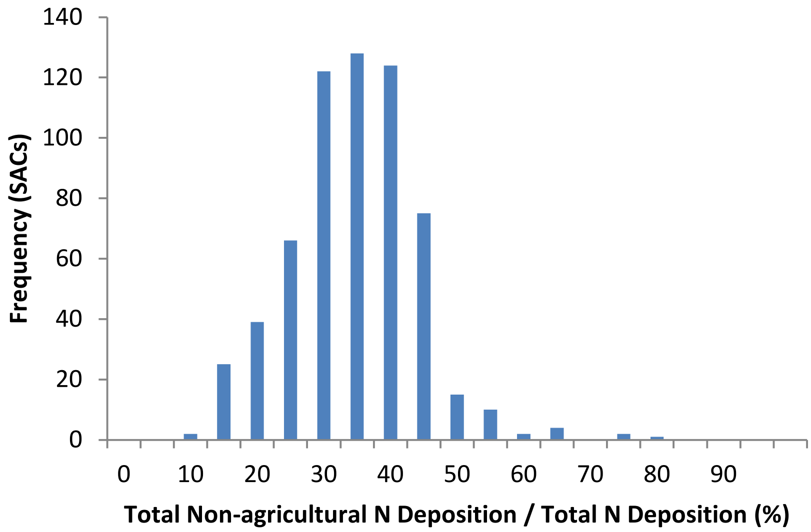

Figure 3.b – Contribution of non-agricultural sources (inc. shipping) to total N deposition at UK SACs, for allocation of sites to Scenario 3 (non-agricultural (point) sources), derived from UK scale source attribution data for 2005 (5 km grid).

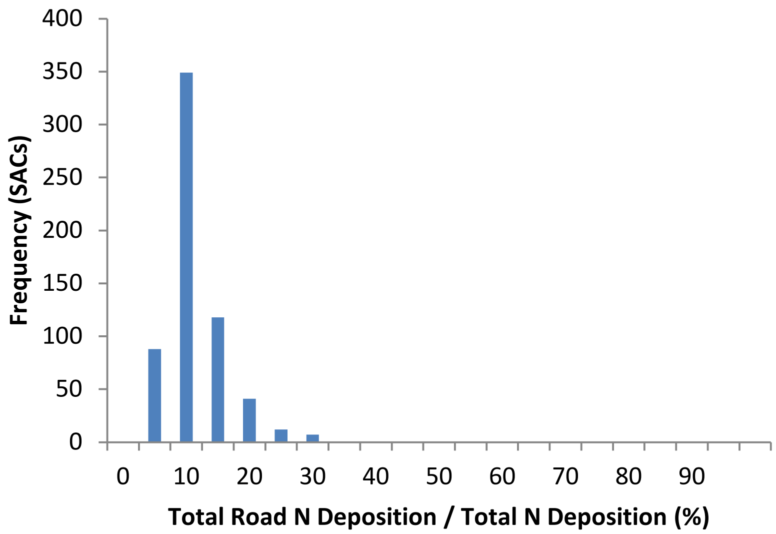

Figure 3.c – Contribution of road transport to total N deposition at UK SACs, for allocation of sites to Scenario 4 (roads), derived from UK scale source attribution data for 2005 (5 km grid).

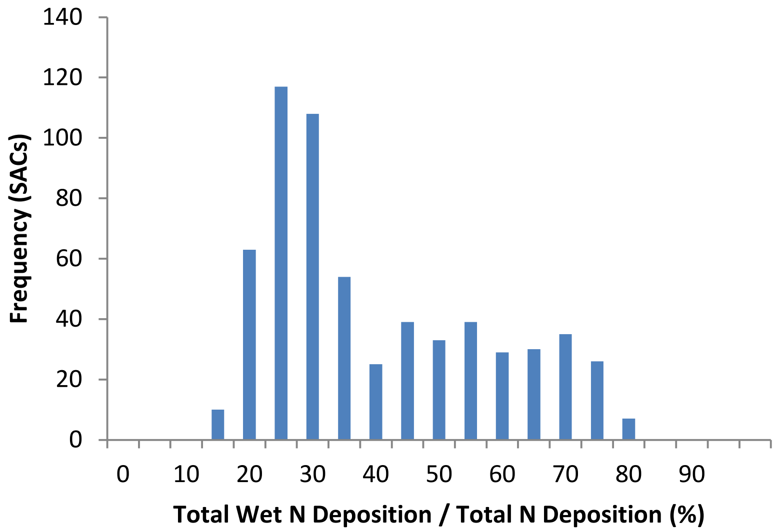

Figure 3.d – Contribution of wet deposition to total N deposition at UK SACs, for allocation of sites to Scenario 5 (remote sites affected by long range N deposition), derived from UK scale source attribution data for 2005 (5 km grid).

3. Results – Scenario Allocation

All sites are allocated to at least one Scenario with the thresholds used, with most sites being assigned to at least two or three main N threats, with similar patterns emerging for both SACs and A/SSSIs (**Figure 4**). The spatial distribution of the number of Scenarios assigned to each site is shown in **Figure 5**, which may be summarised as showing higher numbers in areas with more diverse land use and hence emission sources. Lowland agricultural areas appear to have less complex source attribution patterns, therefore perhaps making them more suitable for local scale incentive type measures.

The distribution of the different Scenarios across UK SACs and A/SSSIs in **Figure 6**, using individual pie charts for each site, illustrates the spatial patterns of the main source types. Areas of major conurbations in south-east England with the associated combustion, shipping and road transport sources can be identified from the combined presence of Sc 3 (non-agricultural (point) sources) and Sc4 (roads), whereas remote upland sites in north-west and northern Scotland are characterised by a combination of Sc5 (long-range transport) and Sc3 (non-agricultural (point) sources). The data derived for each site using the approach described above provide the basis for further assessment, together with a combination of higher resolution/local data to determine sources and activities contribute to the N threat, thereby enabling the identification of suites of potential measures to reduce N deposition at the sites.

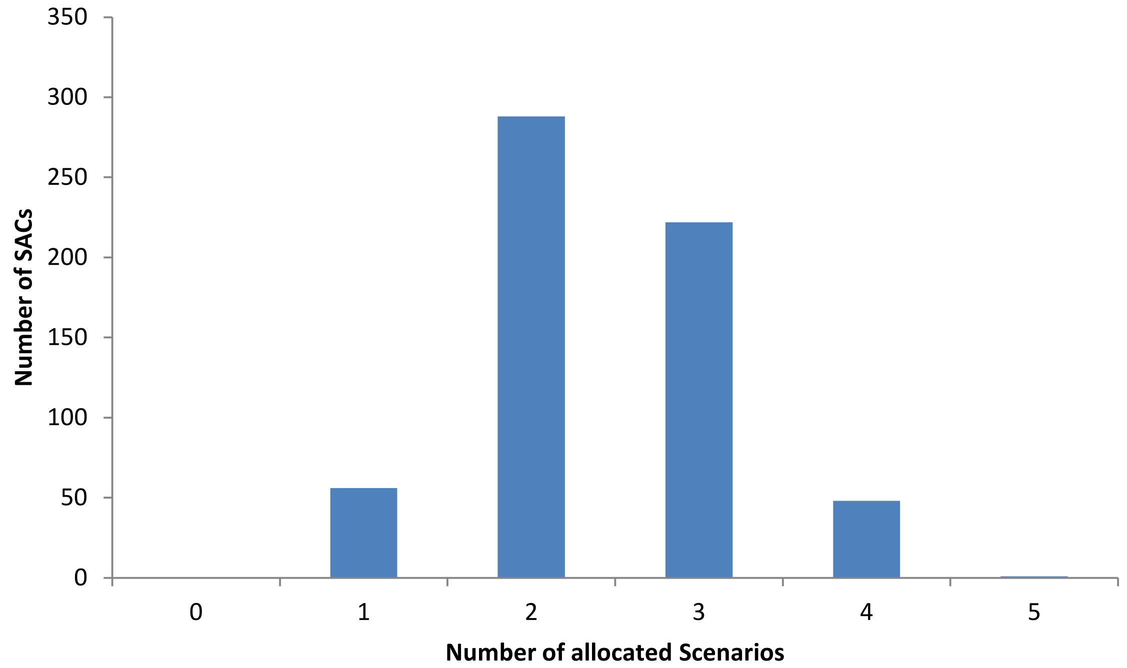

Figure 4.a - Number of Scenarios allocated to UK SACs from 5 km source attribution data, IED farm points and major roads. IED and road data are used to screen for proximity to designated sites, at 2 km and 200 m distance, respectively.

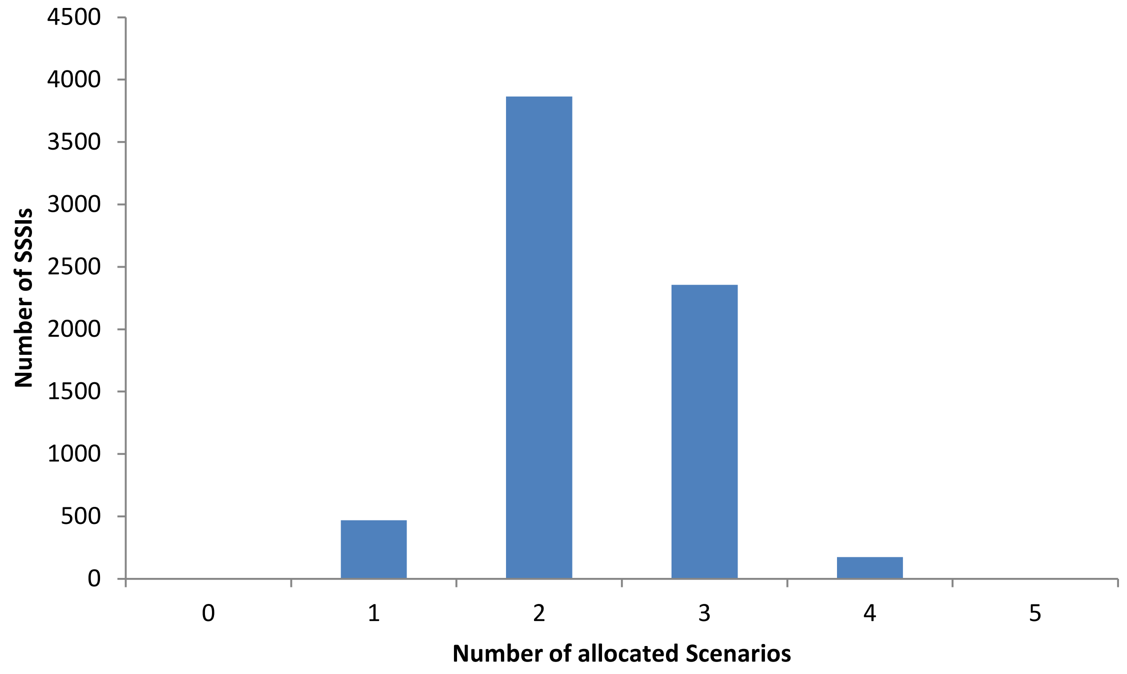

Figure 4.b – Number of Scenarios allocated to UK A/SSSIs from 5 km source attribution data, IED farm points and major roads. IED and road data are used to screen for proximity to designated sites, at 2 km and 200 m distance, respectively.

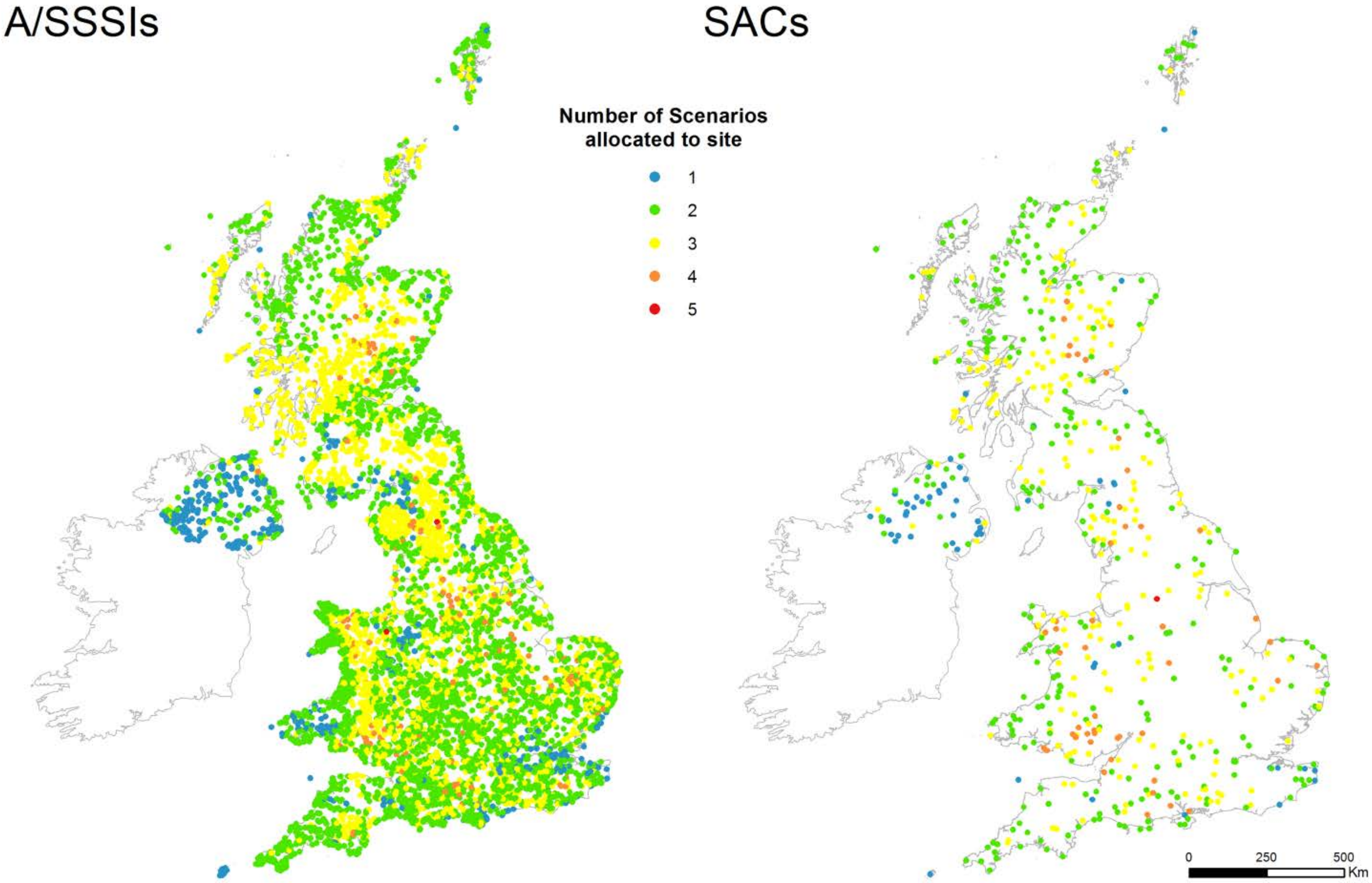

Figure 5 – Number of Scenarios allocated to each designated site (left: A/SSSIs, right: SACs), using 2005 national scale source attribution data (5 km grid resolution), supplemented with IED farm and road data to screen for proximity to designated sites, at 2 km and 200 m distance, respectively.

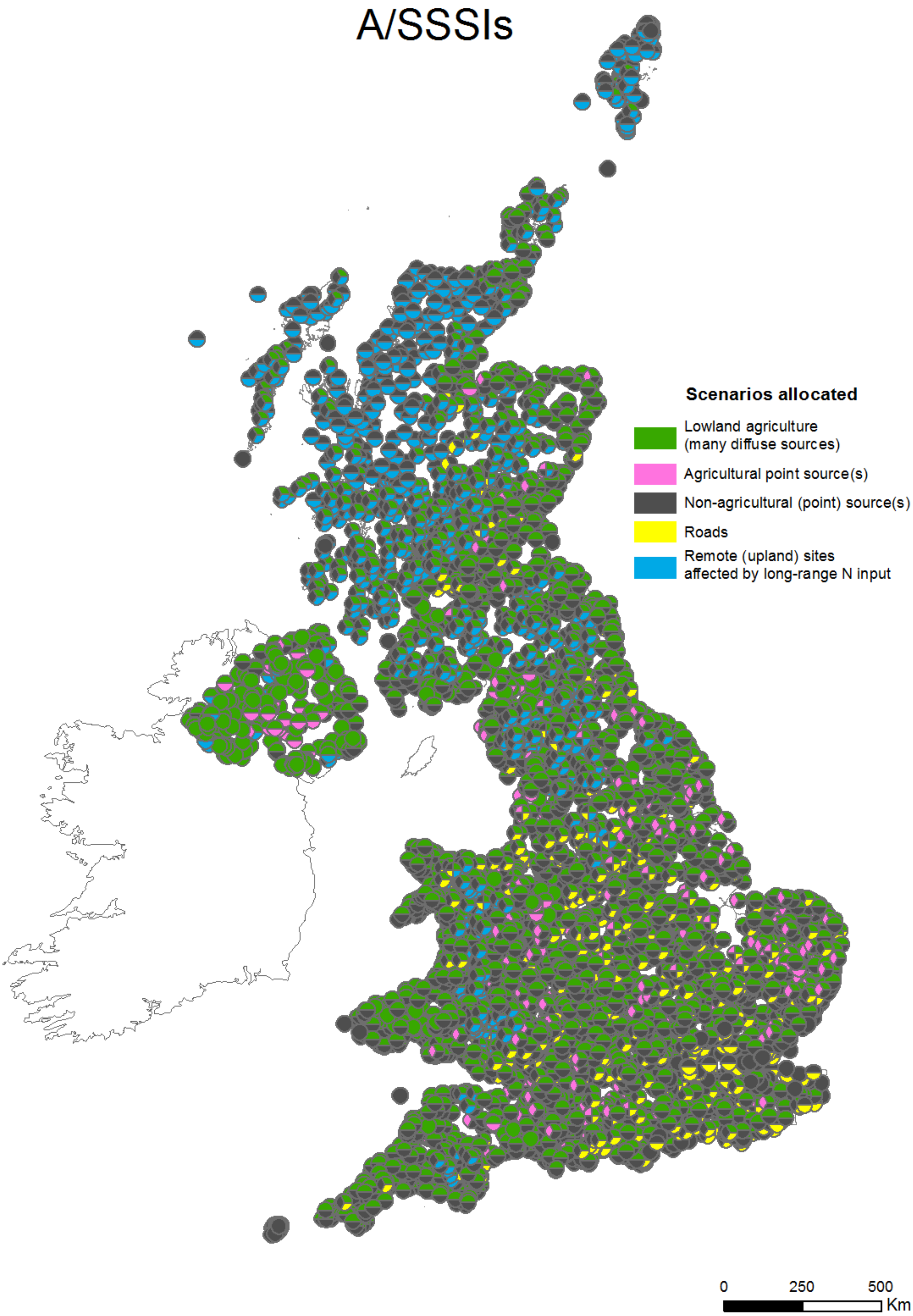

Figure 6.a - Scenario allocation at each A/SSSI, using 2005 national scale source attribution data (5 km grid resolution), supplemented with IED and road data to screen for proximity to designated sites, at 2 km and 200 m distance, respectively.

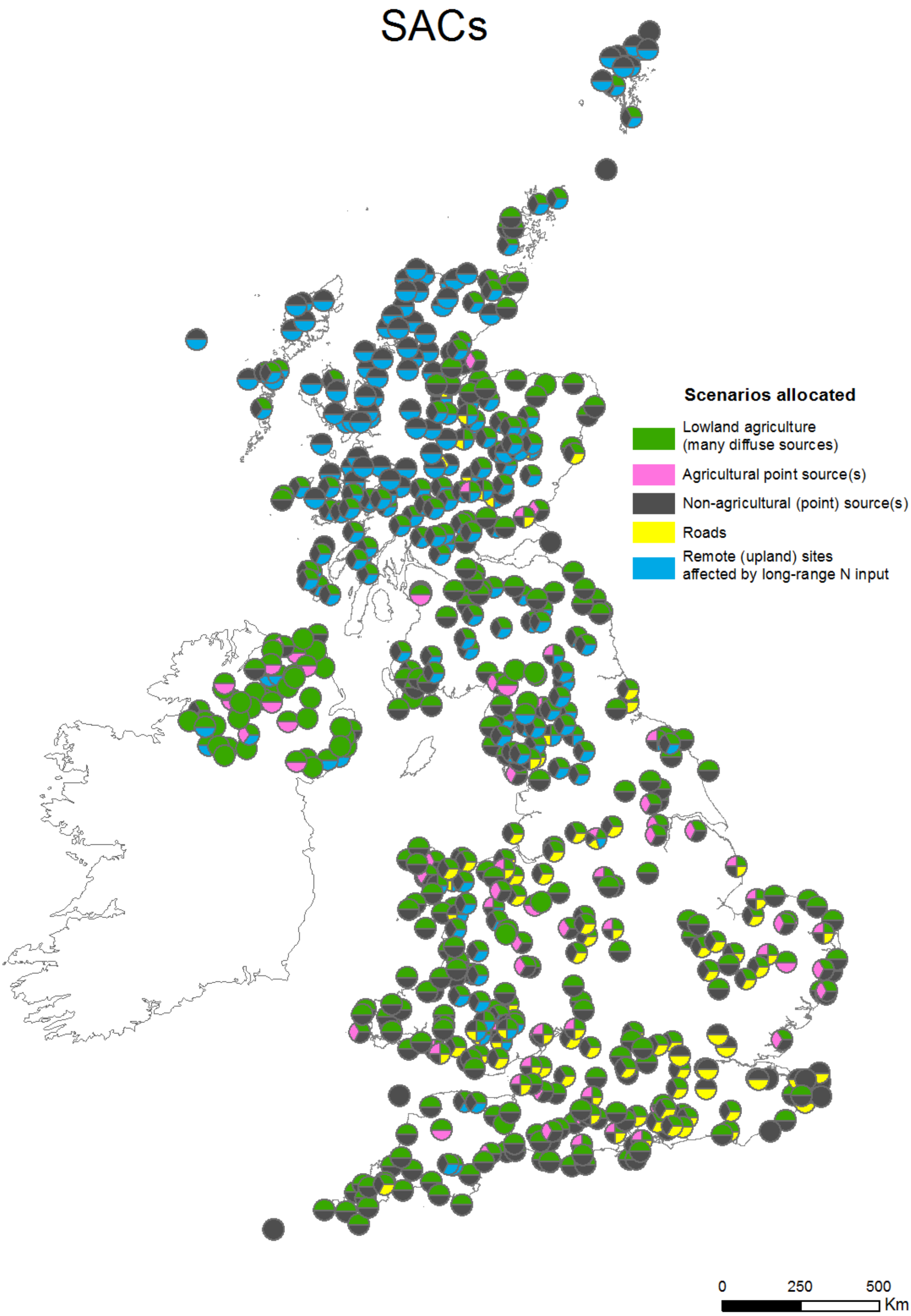

Figure 6.b - Scenario allocation at each SAC, using 2005 national scale source attribution data (5 km grid resolution), supplemented with IED and road data to screen for proximity to designated sites, at 2 km and 200 m distance, respectively.

4. Recommendations for future work

The current source attribution dataset available for analysis in this project cannot distinguish whether N deposition from any emission source category in a grid square is due to local, medium- or long-range sources. This results in, e.g., large numbers of sites in remote upland areas such as the Highlands of Scotland, being allocated to a combination of Scenario 5 (long-range input) and Scenario 3 (non-agricultural (point) sources. While it is correct that most of the N deposition at such sites is due to long-range input, and especially large point sources such as the big power stations, it does not help in the identification of local sources. It is therefore not helpful in the RAPIDS context of trying to determine local sources (or source categories) where targeted emission reduction would be of substantial benefit to the SAC/SSSI.

This lack of suitable national datasets can be tackled in two ways:

a) Derivation of a new source attribution dataset using a revised approach enabling a more detailed differentiation of the likely transport distance of N deposited at an SAC/SSSI. The proposed approach is described in detail below.
b) Use of more detailed local information knowledge of potential sources to build a more complete picture. Local information and validation/cross-checking of any automated national-scale calculations and classification for each site are required in any case, for detailed selection of measures where spatial targeting could decrease N input to sites substantially, as well as for identifying any anomalies in the automated data analysis steps.

Proposed improvement of source attribution approach to allow distinction between short/medium and long-distance origin of emission source categories

It is not straightforward to calculate the proportion of N deposition in a FRAME/CBED grid square that is due to local emission sources, i.e. from within the same grid square, without separate model runs being carried out for each individual 5 km grid square, for all source attribution categories. However, an approximation of the contribution from short (~0-10 km), medium (~10-100 km) or long (> 100 km) range sources could be calculated by producing additional output from FRAME for a larger number of individual gases and particulates in combination with dry/wet deposition.

At the moment, N deposition is split into the following categories in FRAME and CBED:

- wet N total
- dry N total
- NH_x total
- NO_x total

Splitting the FRAME output data into more detailed chemical species (than is done currently) could provide an approximation of how much of each source attribution type (e.g. livestock, fertiliser, shipping, etc) is from short, medium or longer distance sources, as follows:

- Wet NH_3 deposition (short range)
- Wet NH_4^+ deposition (medium/long range)
- Dry NH_3 deposition (short range)
- Dry NH_4^+ deposition (medium/long range)
- Wet nitric acid deposition (medium range)
- Wet nitrate deposition (long range)
- Dry NO_2 deposition (short range)
- Dry nitric acid deposition (medium range)
- Dry nitrate aerosol deposition (long range)

This would then allow the allocation of proportions of N deposited for each source attribution (emission) category into short/medium/long range origins.

This could be done by introducing a modification to the FRAME code to output these components separately and is expected to be reasonably straight-forward, however the format would be incompatible with current plotting and post-processing routines. The same approach would be possible in CBED, but only for dry deposition. Splitting wet deposition into further components in CBED is not possible, due to the bulk collection of precipitation samples for chemical analysis.

References

Cape J.N., Tang Y.S., van Dijk N., Love L., Sutton M.A. and Palmer S.C.F. (2004) Concentrations of ammonia and nitrogen dioxide at roadside verges, and their contribution to nitrogen deposition. *Environmental Pollution* **132**(3), 469-478.

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