EMIND - Evaluating and mitigating impacts of N deposition to Natura 2000 sites in Northern Ireland

Project Report

E.J. Carnell and U. Dragosits

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Contents

Introduction

1. Background

Atmospheric nitrogen (N) deposition represents a significant threat to sensitive habitats and species In the United Kingdom, with excessive N supply leading to declines in many important species of high conservation value, at the expense of fast growing species that can exploit the additional nitrogen supply (e.g. Dise *et al*. 2011, RoTAP 2012). The atmospheric N is due to emissions of ammonia (NH_3, mainly from agricultural sources) and nitrogen oxides (NO_x, mainly from transport, industry, power generation and other combustion sources).

Over the last decades, substantial efforts in UK and European policies have reduced NO_x emissions and deposition considerably, while NH_3 has remained relatively constant. Many protected sites in the UK remain under substantial threat with thresholds for atmospheric N pollution effects (Critical Loads for N deposition, Critical Levels for NH_3) exceeded across a large proportion the UK Natura 2000 network designated under the EU Habitats Directive. A first step towards targeting mitigation options locally, with cost-effective outcomes, is to identify key emissions sources contributing to the N deposition received at these sensitive sites. This is particularly important given the high spatial variability of NH_3 concentrations and dry deposition, with rapid decreases in impacts away from sources. Local targeting of measures can be achieved through two main approaches: source-oriented technical measures (e.g. covering slurry stores, catalytic converters for petrol engines) and landscape oriented measures (e.g. adapting local agricultural practice with low-emission buffer zones around sites, tree belts for dispersion and recapture of emissions, etc.).

In Northern Ireland, NH_3 emissions were estimated at 32 kt NH_3 in 2013 (NAEI, 2015), with agriculture contributing 92 % of the total, and 72 % of the agricultural emissions derived from cattle manure management. While there has been an overall reduction in UK NH_3 emissions in recent years, this trend has been reversed in Northern Ireland with a ~3% increase in ammonia emissions reported between 2009 and 2013. Looking at the livestock emissions in more detail, there has also been an increase in poultry numbers by 7% 2009-2013 (Misselbrook *et al.*, 2015). Emissions of nitrogen oxides (NO_x) in Northern Ireland were estimated at 30 kt in 2013 (3% of the UK total), with 36 % originating from road transport, 20% from power generation and the remaining 44 % coming from industrial processing and other sources (NAEI, 2015).

Ammonia concentrations in Northern Ireland are estimated to exceed > 1 µg m^{-3} for most of NI and therefore exceed the critical level for mosses and other lower plants. Approximately 50 % of the area of NI has NH_3 concentrations exceeding 3 µg m^{-3}, which is in exceedance of the critical level for higher-plants. High exceedances of nutrient nitrogen deposition critical loads are widespread across Northern Ireland and parts of southern Ireland, with many areas estimated to exceed critical loads by 14 kg N ha^{-1} $year^{-1}$ (Hall and Smith *et al.* 2015).

The main contributors to N deposition to a given site can be estimated using source attribution data. Source attribution data are derived by performing multiple model runs of an atmospheric transport and deposition model, with each source type removed in turn. N deposition attributed to individual emission source categories (such as agriculture, road transport etc.) or individual large point sources (such as power stations) can then be calculated as a proportion of total deposition to each model grid square.

2. Project Objectives

The aim of this project was to analyse detailed source attribution data on atmospheric N deposition for individual Natura 2000 sites across Northern Ireland, to assess whether this provides a suitable targeting tool for N abatement measures. The project was comprised of two phases:

Phase 1 provides an initial assessment of local and regional threats of atmospheric N deposition to every Natura 2000 site situated in Northern Ireland. The initial assessment built upon work developed under IPENS-049 and AAANIS for England and Wales, respectively (Dragosits et al. 2014, Carnell et al. 2015), and used national scale datasets to assess N threats from relevant local sources (such as agriculture, transport and industry), in addition to long range pollution emitted from sources further afield. The current project utilises a recent source attribution run for 2012 carried out by CEH (unpublished, to become available May 2017 http://eidc.ceh.ac.uk/) to assess the respective contributions from different emission source types, source regions/transport distances and pollutant species. In addition, local sources were investigated further, using detailed datasets for Northern Ireland, with special emphasis on agriculture as the largest N emission source category. This includes sources of both of a diffuse and point source nature, i.e. landspreading of manures and fertilisers and livestock grazing vs. intensive livestock housing operations (such as large poultry or pig farms). Following an initial assessment of all Natura 2000 sites regarding atmospheric N input and the associated threats to designated sensitive features, five sites were selected for a more detailed analysis and assessment under Phase 2.

Phase 2 focused on five selected Natura 2000 sites, with the aim of verifying whether national datasets (initial assessment, Phase 1) are sufficient for identifying suitable spatially targeted mitigation measures or whether more detailed data and analysis at the local level are required. Phase 2 focused on the phase 1 data in more detail (e.g. nitrogen emission, concentration and deposition data) and also drew on additional data such as road traffic data, emission factors and calculation tools from the UK inventories, and auxiliary data such as Ordnance Survey Northern Ireland road network data, Google Earth imagery etc. This more detailed assessment was used to help establish whether the mitigation measures identified in Phase 1 were appropriate for reducing N deposition to the selected designated sites.

3. Methods

3.1 Background/Source attribution methodology

The potential of spatially targeted measures to reduce nitrogen (N) deposition to sensitive habitats has been explored in previous work funded by Defra, Natural England (NE) and Natural Resources Wales (NRW) and carried out by the Centre for Ecology & Hydrology (CEH) and collaborators (Dragosits et al., 2014; Dragosits et al., 2015; Carnell and Dragosits, 2015). This work included allocating emission source categories (e.g. ammonia emissions from livestock farming, road transport, industry, shipping) contributing to N deposition at each Natura 2000 site to a simple set of five 'emission source allocations' (Table 1), depending on the origin of the N deposited, from UK national scale atmospheric deposition and source attribution modelling. A draft framework was developed for identifying the most appropriate abatement measures and potential delivery mechanisms for implementing these measures at each site, depending on the identified sources, their spatial distribution and other characteristics. This modelling approach was implemented for all SACs in England and Wales, with six English sites under IPENS-049 (Dragosits et al., 2014) and two Welsh sites (AAANIS, Carnell et al., 2015) assessed in more detail. The EMIND project builds on this approach, but with the inclusion of a new source attribution dataset for the year 2012 (unpublished, to become available May 2017 http://eidc.ceh.ac.uk/), rather than the old 2005 data that were used in the earlier work in England and Wales. The more recent source attribution dataset also provides additional details on the origin of N deposition sources by separating N species depositing locally (NH_3, NO_2) and regionally (i.e. NH_4, HNO_3). Distinguishing between these chemical species provides an indication of whether the sources of N deposition received by a site are local or regional. The distinction between local and regional sources of N deposition is critical for the selection of suitable N mitigation measures, as it indicates whether targeting local sources is appropriate or whether initiatives to target N regionally are more suitable.

Table 1: Definition of the five emission source allocations using the UK source attribution dataset for N deposition (year 2012)

Emission source allocation name	**Sources of N included in allocation**		**Criteria for emission source allocation**
	Source attribution model categories included	**Components of N deposition included**	
Lowland agriculture (many diffuse sources)	- Ammonia emissions from mineral 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
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
Non-agricultural (point) source(s)	- International Shipping - Other transport (excl. road transport) - Power stations - Refineries - Combustion plants - Energy production and transformation - Offshore installations - 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
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)
Remote (upland) sites affected by long-range N input	All model categories	Species of N expected to deposit regionally (NH_4, HNO_3)	Total deposition from N species originating regionally > 20 % of total N deposition

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

All SACs with terrestrial designated features in Northern Ireland were assessed using the updated source attribution approach, building on data for the year 2012 (unpublished, to become available May 2017 http://eidc.ceh.ac.uk/). Initial estimates of N deposition from emission source categories were made for each site, using a combination of the 2012 source attribution data and the distance between the site's boundaries and substantial emission sources that may influence local atmospheric N input. Intensive pig and poultry farming in Northern Ireland is permitted under the Industrial Emissions Directive (IED), for farms with > 40,000 places for poultry, > 2,000 places for production pigs (> 30 kg); or > 750 places for sows. Their spatial locations and details of animal places by category are recorded as part of the permit process. Such agricultural 'point sources' were included in the analysis as potential key sources of elevated N deposition for sites where there was an IED farm within 7.5 km of the site boundary and > 20 % of N the total deposition at the site originated from agricultural activities. As most of the N deposition from road transport originates in close proximity to major roads (Cape et al., 2004), this source was only considered a major contributor where it contributed to > 10 % of total N deposition in a model grid square and a major road (motorway, primary or A-road) was within 200 m of a site boundary. N species depositing regionally/nationally/internationally (HNO_3, NH_4^+) are considered a main contributor to deposition at a site where they represent > 20 % of total N deposition (which also includes wet and dry deposition from locally depositing N species, i.e. NH_3 and NO_2).

The emission source allocation and N deposition values for woodland features and low-growing sensitive semi-natural features (e.g. bogs, species-rich grasslands, and dunes) are provided separately, as N deposition estimates differ for different vegetation types. 'Woodland' deposition estimates refer to any woodlands that may be present at the designated site, and 'semi-natural' deposition estimates are the appropriate values to be used for N deposition for other (low-growing) semi-natural vegetation.

3.2 Phase 1 – Data Sources

The initial Phase 1 source attribution assessment of N deposition for SACs in Northern Ireland used the following datasets:

- **UK source attribution dataset** (year 2012, 5 km grid resolution) - estimates of N deposition to each site produced from 23 major UK point sources, 17 area emission source categories (e.g. agriculture, road transport, etc., separately for each UK country (i.e. Northern Ireland, Scotland, Wales and England) and international emissions (shipping and emissions from Eire and EU).
- **IED permit database (2015)** - for assessment whether a designated site was within a zone of influence (7.5 km buffer zone) of an intensive permitted poultry or pig farm.
- **Ordnance Survey Northern Ireland transport network (2014)** - used to establish whether a designated site was with 200 m of a major road (motorway/A road/Primary road).
- **High-resolution agricultural census/survey data for Northern Ireland (2015) -** used to estimate the agricultural emission density and dominant emission sources near each designated site (< 2km from site boundary, or greater where disclosivity clauses in the data agreement were not met).

3.3 Phase 1 – Agricultural census summaries

As agricultural sources are likely to play a substantial role in terms of local ammonia sources in the vicinity of many SAC in Northern Ireland, they were assessed in a more detailed analysis. For this purpose, summary estimates of likely ammonia emissions were derived for the surrounding areas of each SAC in Northern Ireland, using an approach developed for England (Dragosits *et al.,* 2014, IPENS-049 project). This method uses high-resolution agricultural statistics and average UK emission factors from the latest available UK agricultural emission inventory to estimate the proportion of the main agricultural sectors contributing to NH_3 emissions in a local zone around each SAC (2 km from the boundary) and an average NH_3 emission density for these zones (Misselbrook *et al*., 2015). The use of high-resolution agricultural statistics was possible due to the Department of Agriculture, Environment and Rural Affairs (DAERA) granting a project license. To comply with the data licensing agreement, summary emission estimates from each sector had to be non-disclosive, i.e. each data point has to relate to at least 5 agricultural holdings. Across more extensive agricultural regions, where this requirement was not met, the buffer zones around the site boundaries were extended to include further agricultural holdings. This methodology was applied to all SACs in Northern Ireland, with a non-disclosive dataset produced for the project (Appendix 2).

3.4 Phase 2 – Detailed desk based study

Five example SAC were selected for detailed desk-based studies, following the analysis of the outputs from Phase 1, in discussion with the project steering group:

- Ballykilbeg SAC (wetland, designated for Marsh Fritillary butterfly)
- Ballynahone Bog SAC (raised bog)
- Main Valley Bogs SAC (raised bog)
- Peatlands Park SAC (raised bog, oak and bog woodland)
- Turmennan SAC (quaking mire)

For these sites, individual site profiles were prepared (see Appendices), which contain a summary of the characteristics of each site. In addition to the analyses carried out in Phase 1, these sites were assessed in more detail using more detailed, local data. Google Earth imagery was used to identify potential additional sources and provide further information on the sources already identified. Areas with high NH_3 concentrations were identified using 1 km grid resolution NH3 concentration data (1 km grid version of FRAME). Wind statistics taken from weather stations nearby to each of the sites (windfinder.com) were used to assess local wind conditions (where available). Detailed information about IED pig/poultry units nearby to sites (<2 km away) was used to estimate emissions as accurately as possible, using any specific information provided about systems in use at the sites rather than national average emission factors. Road traffic density data (traffic counts) for 2015 were made available (Transport NI, 2017).

4. Results

4.1 Phase 1 – Initial source allocation

The analysis of the UK source attribution dataset for SACs in Northern Ireland (Table 2, full dataset see Appendix 1) shows that diffuse agricultural activities pose a significant threat to most sites in Northern Ireland. On average, agriculture contributes to ~59 % of total N deposition (to low-growing semi-natural features) received by SACs, and contributes ~90 % of the N deposition from locally depositing species (wet and dry deposition from NH_3 and NO_2). A number of the larger intensive poultry units (i.e. those permitted under the Industrial Emissions Directive (IED)) are clustered close to protected sites (< 7.5 km from site boundaries) and provide significant atmospheric N input to these sites (Figures 1, 2 & 3). Deposition of N species depositing regionally/nationally/internationally also appear to be a main contributor to a substantial proportion of sites, especially to those close to the border with the Republic of Ireland and near the north east coast, close to Scotland. N deposition originating from road transport and other UK non-agricultural sources appear to be only a minor contributor to N deposition received by Northern Irish SACs, in contrast to England and Wales where these sources were seen to be a main contributor at several sites (Dragosits *et al.* 2015; Carnell *et al.* 2015).

Table 2 – Initial source attribution summary for all Natura 2000 sites in Northern Ireland which have terrestrial designated features (56 sites), showing mean N deposition values and initial emission source allocations across all sites. Estimates are shown separately for low-growing semi-natural features, woodland features (due to different N deposition velocities) and grid average values (taking account of land cover distribution in each model grid square).

Deposition Type	Average N Deposition kg N ha^{-1} yr^{-1}#	Diffuse agriculture	Point source agriculture	Non-agricultural (point) sources	Road transport*	Long-range transport
Semi-natural features	18.0	100%	70%	2%	0%	66%
Woodland	29.1	100%	70%	2%	0%	43%
Grid Average◊	12.0	100%	70%	2%	0%	100%

The N deposition value at each Natura 2000 sites was calculated as the mean N deposition for all model 5km grid squares that intersected each site

* Roads: The 'roads' source allocation is only assigned if both tests (overall N deposition from roads> threshold, <200m distance between site boundary and major road) are passed

◊ Grid average deposition is used for estimating effects on freshwater habitats

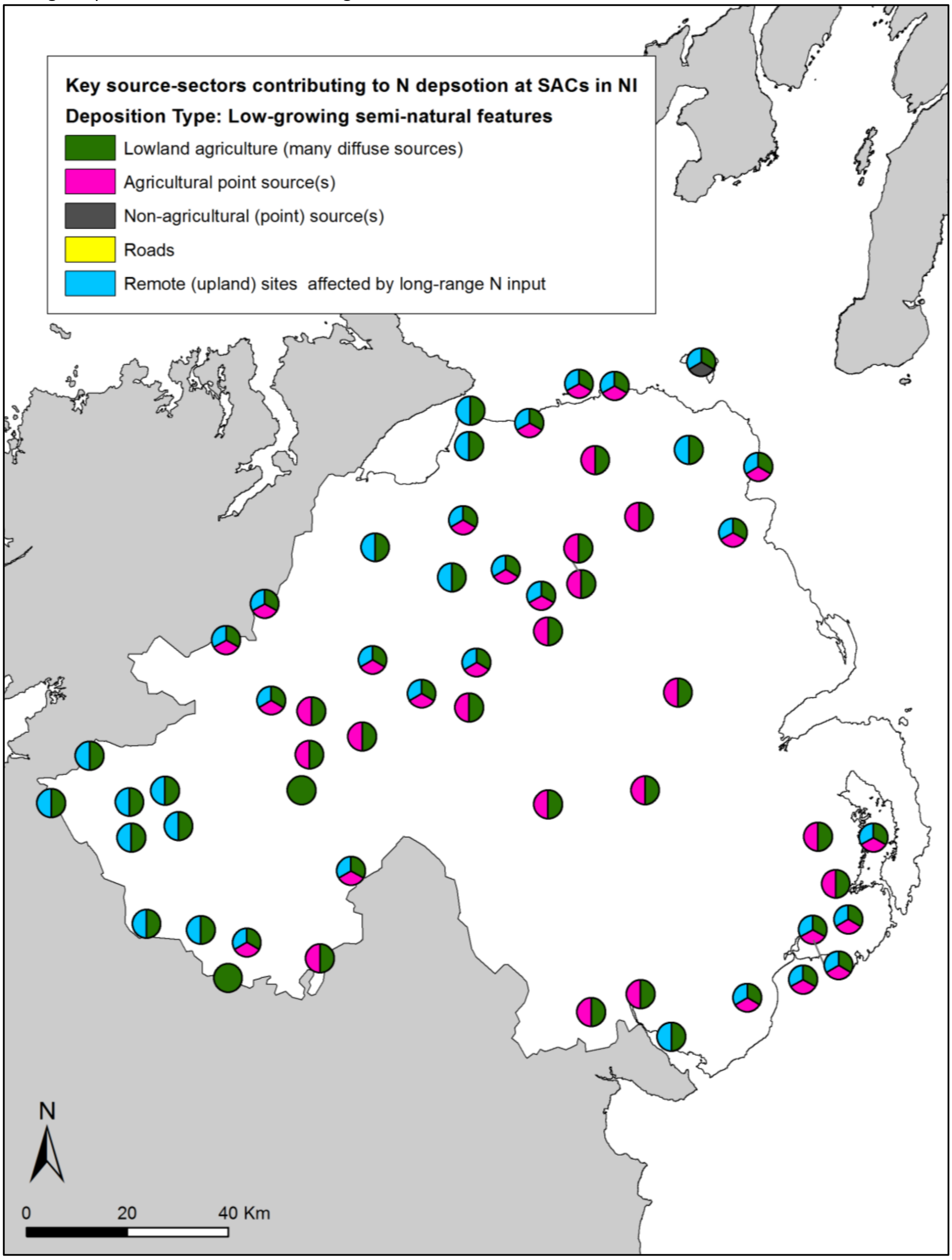

Figure 1 – Estimated source attribution for all SACs in Northern Ireland, which have terrestrial designated features (56 sites) from national scale source attribution data (5 km grid) using N deposition estimates to semi-natural features and also drawing on proximity assessment of sites to IED pig and poultry farms data (7.5 km radius) and major roads (200 m radius). The category 'non-agricultural point source' shown in this map does not include a local distance criterion.

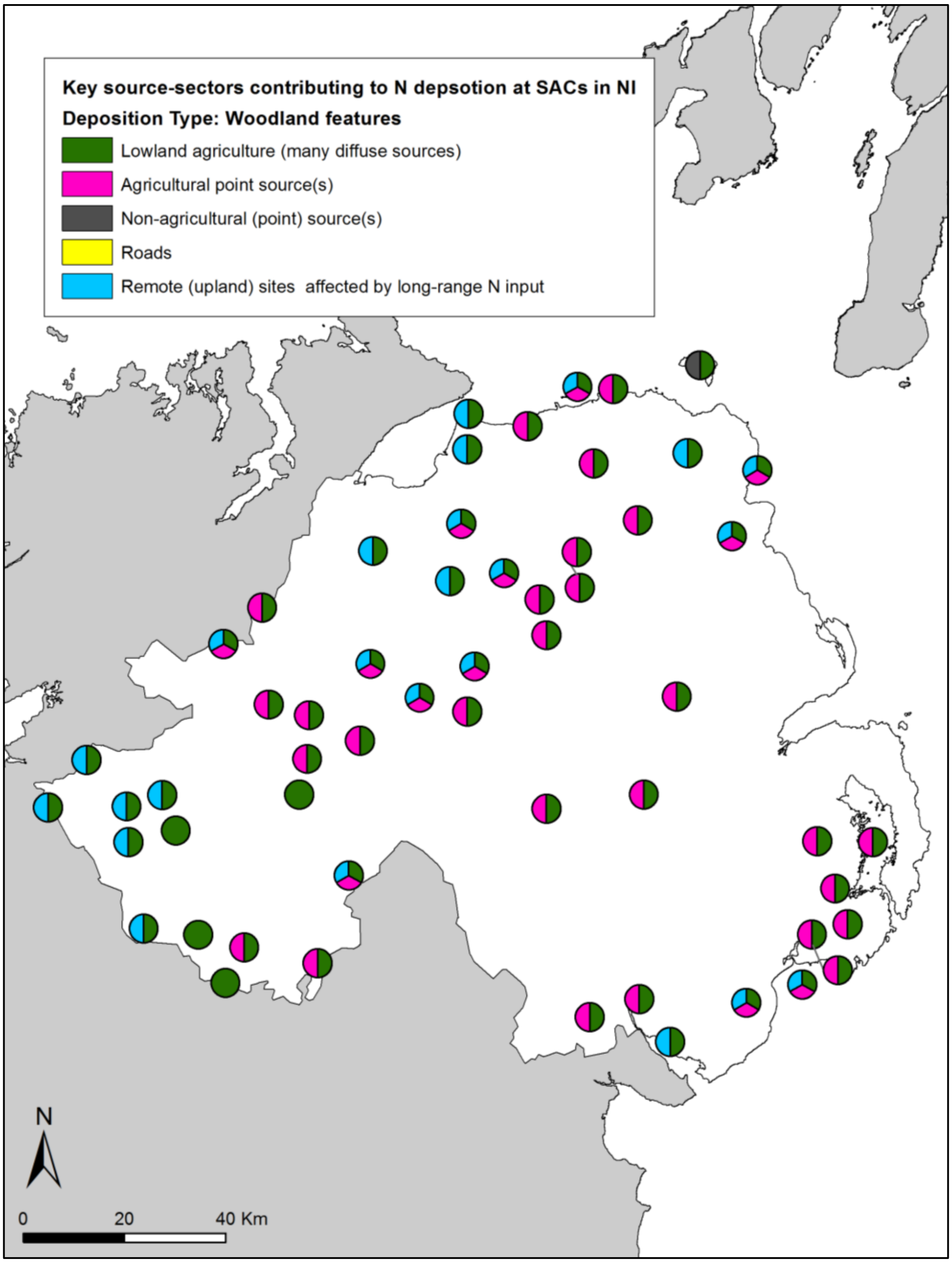

Figure 2 – Estimated source attribution for all SACs in Northern Ireland, which have terrestrial designated features (56 sites) from national scale source attribution data (5 km grid) using N deposition estimates to woodland features and also drawing on proximity assessment of sites IED pig and poultry farms data (7.5 km radius) and major roads (200 m radius). The category 'non-agricultural point source' shown in this map does not include a local distance criterion.

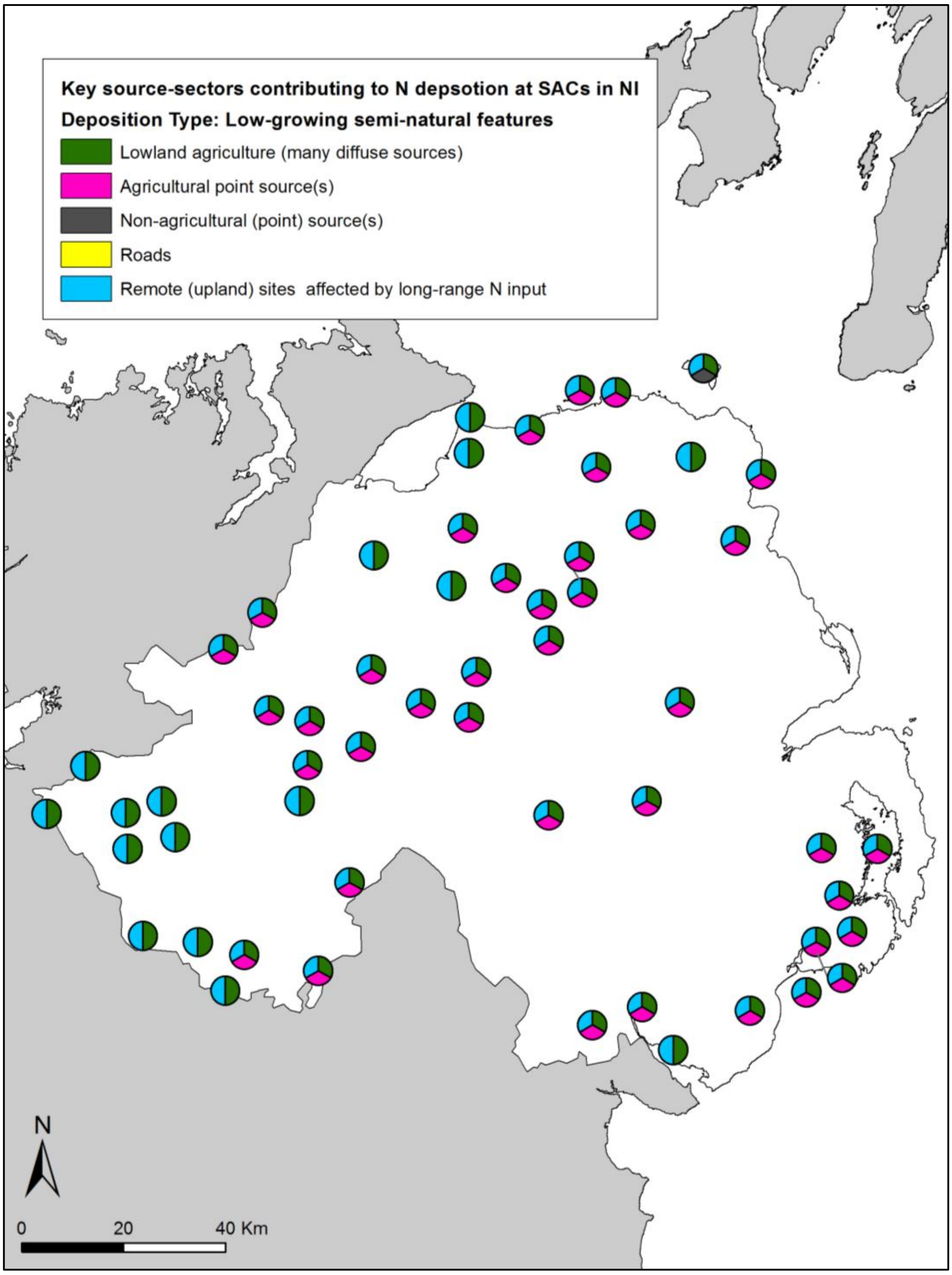

Figure 3 – Estimated source attribution for all SACs in Northern Ireland, which have terrestrial designated features (56 sites) from national scale source attribution data (5 km grid) using grid average N deposition and also drawing on proximity assessment of sites to IED pig and poultry farms data (7.5 km radius) and major roads (200 m radius). The category 'non-agricultural point source' shown in this map does not include a local distance criterion.

4.2 Phase 1 – Agricultural NH_3 emissions (diffuse and point sources)

A substantial proportion of SACs in Northern Ireland are estimated to be subject to high concentrations of agricultural NH_3 from emission sources close to their site boundary (Figure 4). The dominant emission source of NH_3 (i.e. the largest contribution to estimated NH_3 emissions within the

2 km (or larger) buffer zone) for most SACs is cattle farming (~73 %), and in particular activities associated with beef farming (Figure 5, complete site-specific summary given in Appendix 2).

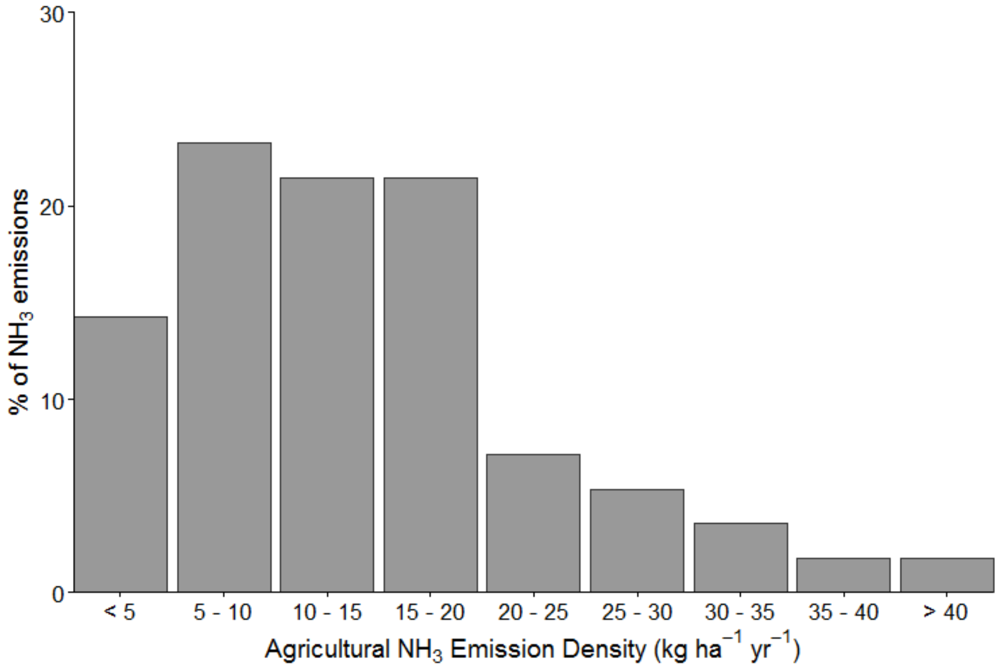

Figure 4 - Estimated agricultural emissions densities within a 2 km buffer zone surrounding each Natura 2000 in Northern Ireland. In extensive agricultural regions, where the 2 km buffer zone did not contain 5 agricultural holdings, the buffer zone around the site boundary was increased (to a maximum of 5 km) to include further agricultural holdings.

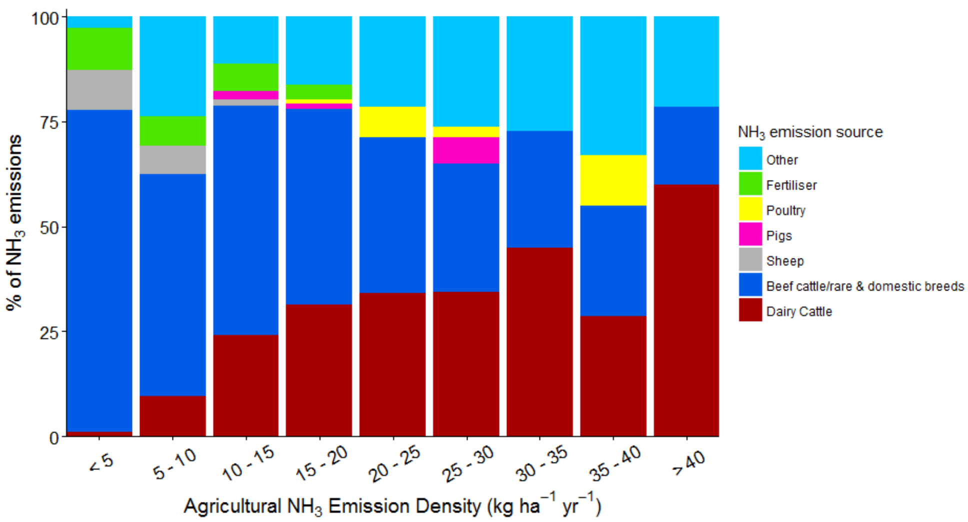

Figure 5 – Proportion of agricultural NH_3 emissions attributed to each sector, by estimated agricultural emission density within a 2 km buffer zone surrounding Natura 2000 sites with terrestrial features in Northern Ireland.

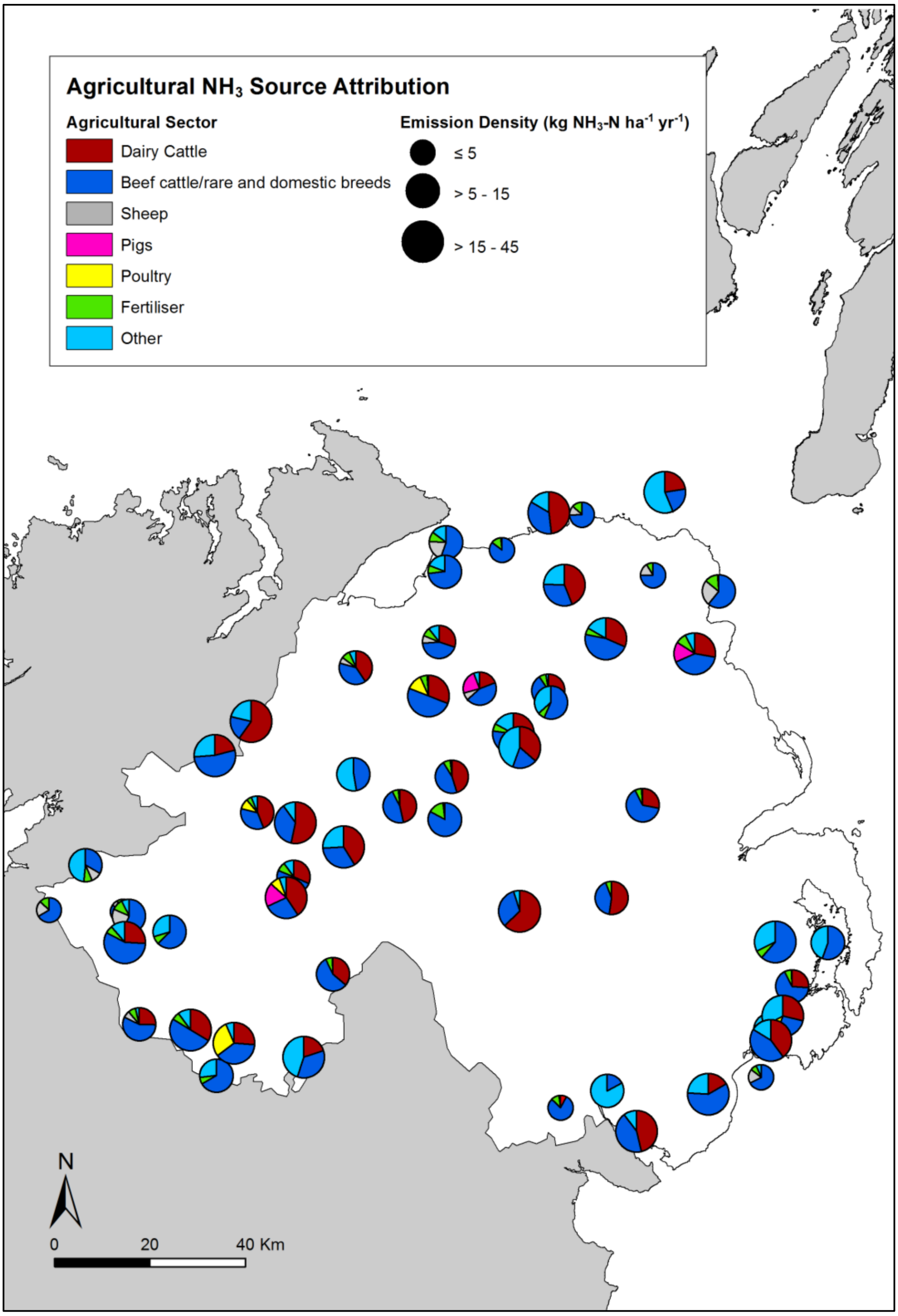

Figure 6 -– Estimated contributions from main agricultural sectors to emissions in areas immediately surrounding SACs in Northern Ireland, which have terrestrial designated features (56 sites). The size of each pie chart is proportional to the estimated local NH_3 emission density surrounding each site (< 2 km where data licensing conditions are met, and up to 5 km in extensive agricultural regions). The category 'other' refers to fertiliser emissions and all livestock sectors which are disclosive (i.e. data points from less than five agricultural holdings) or a category that contributes less than 5% of the total.

4.3. Phase 2 – Detailed assessment of selected sites

Sub-site variation in N deposition was assessed in Phase 2 for sites that intersect multiple 5 km grid squares. This is a significant improvement when compared with the results from Phase 1, as it allows spatial targeting of N mitigation measures. An example for Main Valley Bogs (SAC) shows that the southern areas of the site have higher rates of N deposition compared to the northern areas (Figure 7). Targeting N sources around the southern part of the site may be more effective, given that a high proportion (85 %) of N deposition received is from locally depositing N species (NH_3, NO_2). High-resolution (1 km) NH_3 concentration data for Main Valley Bogs (see Site Profile in Appendix) also shows NH_3 concentration hotspots surrounding the south of the site (near to the IED farms). The high spatial resolution of the data means that likely concentration hotspots can be more easily identified. In addition, the higher resolution allows main NH_3 source areas (e.g. dominated by diffuse agriculture) to be separated from semi-natural NH_3 sink areas much more successfully than at a 5 km grid resolution.

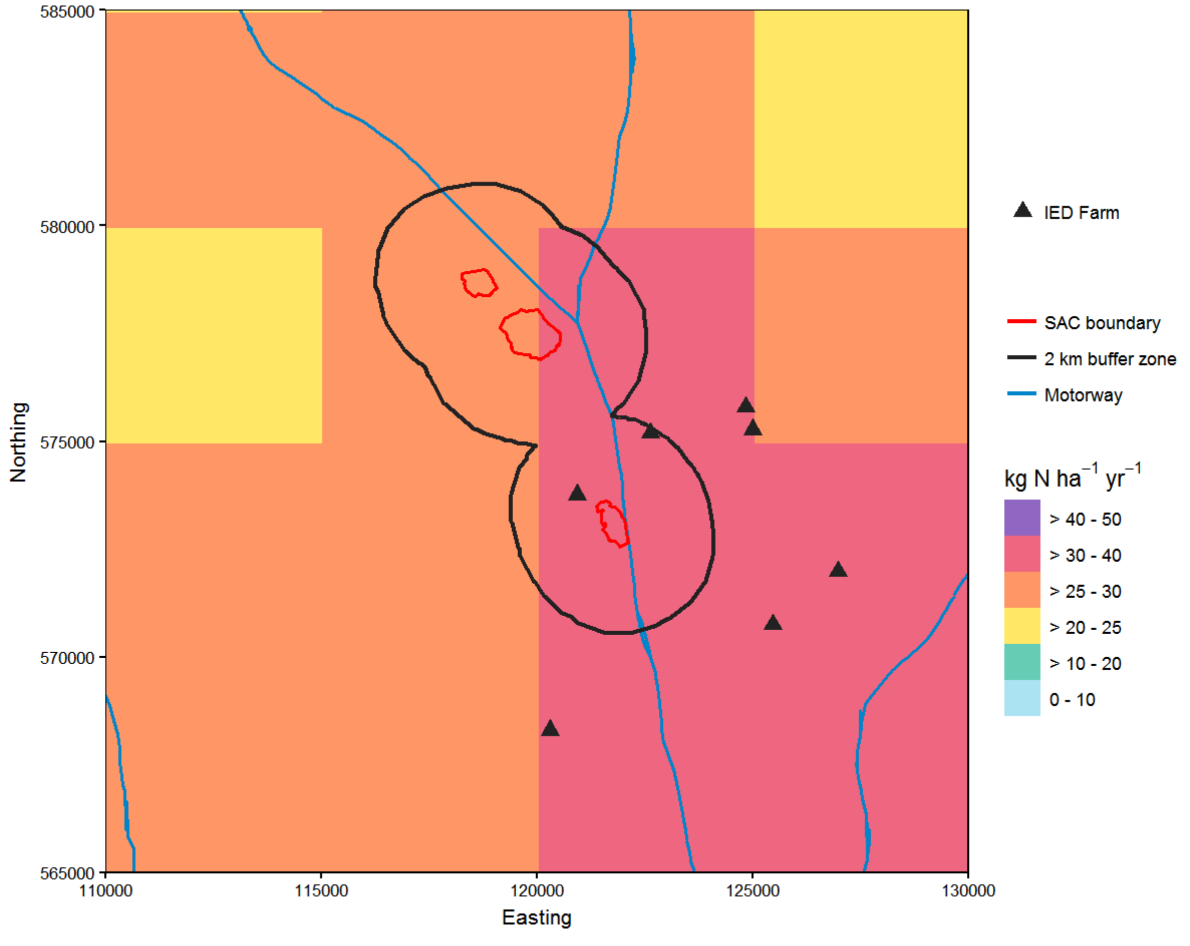

Figure 7 – Total N deposition to lowing growing semi-natural features at Main Valley Bogs SAC (FRAME model output for 2012), showing the location of IED poultry installations and 2 km buffer zone surrounding the site boundary (dataset from 10/5/2016).

Distinguishing between N species estimated to be depositing locally (NH_3, NO_2) and regionally (i.e. NH_4, HNO_3) at sites indicates that there are clear differences in the origin of the related emissions. Unsurprisingly, a high proportion of N deposition from locally depositing species is estimated to originate from agriculture.

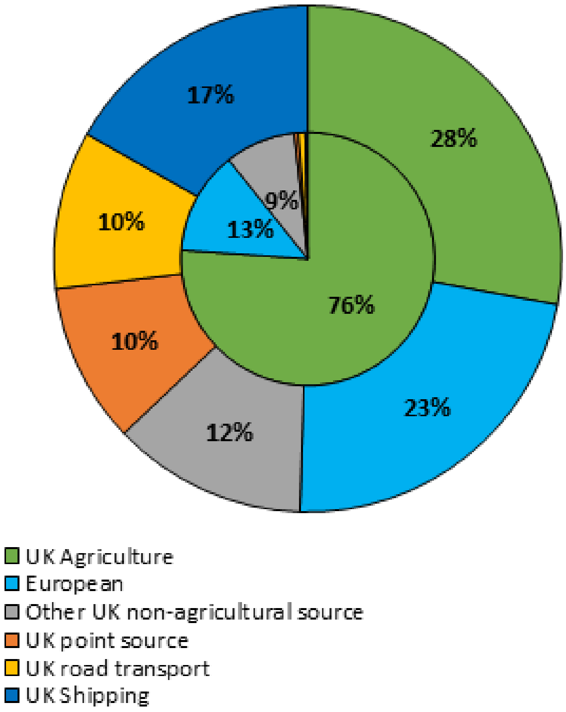

Figure 8 – Source attribution chart, showing the mean contributions to N deposition from locally depositing N species (i.e. NH_3 and NO_2, inner pie) and regionally depositing N species (i.e. NH_{4+}, HNO_3, outer pie) across the 5 km grid squares which contain Turmennan SAC. Agricultural sources (green) include both regulated (IED) and non-regulated agricultural emission sources,

An example for Turmennan SAC shows that over three quarters of the locally depositing N species is estimated to derive from local/regional agriculture, mostly in the form of ammonia (details shown in the site profile, see Appendix).

Conversely, ~1 % of N deposition from locally depositing species is estimated to derive from road transport, while this source contributes ~10 % of deposition from regionally depositing species. Therefore reducing N deposition from road transport at the site may be best achieved through national level incentive schemes such as the promotion of greener technologies and transport choices should be promoted. At sites situated immediately next to major roads, more detailed emissions from road transport were calculated using traffic flow data (AADT) as input to Defra's Emission Factor Toolkit (EFT). An example for such calculations is shown in the Site Profile for Ballynahone Bog SAC (see Appendix).

Additional local information about nearby agricultural emission sources was supplied by DAERA, for the sites selected for detailed analysis in Phase 2, to help with short-listing of likely suitable measures for local spatial targeting of measures. For example, at Ballynahone Bog, site officers noted that there are two uncovered slurry stores very close to the site boundary (also visible in aerial imagery). As the agricultural NH_3 emission density at the site is estimated to be relatively high (29 kg N ha^{-1} yr^{-1}), covering these lagoons may be a cost-effective way of lowering NH3 concentrations and localised N deposition received at the site. Information about pending IED applications was also used to assess their potential impact to N deposition at sites. At Main Valley Bogs SAC, there are seven pending IED permits for poultry farms (as of 2/11/2016). It was estimated that emissions from intensive poultry farms in a 7.5 km buffer zone (distance used for IED permits) surrounding Main Valley Bogs SAC could potentially increase by ~62 % if all seven permits were approved (using NI specific average emission factors – N.B. this may be an overestimate, and detailed calculations would require site-specific parameters for proposed systems to be used).

4. Discussion and Conclusions

5.1. General Discussion

It is estimated that the biggest threat to Northern Irish SACs comes from diffuse agriculture and in particular activities associated with cattle farming. Sites with high agricultural emission densities of > 30 kg N ha^{-1} yr^{-1} across the surrounding area had a high proportion of emissions from dairy, beef and poultry farming.

5.2. Phase 1 – Methodology limitations

The national scale analysis (Phase 1) relates to the grid square with the highest N deposition that intersects each site and therefore implies that N threats are homogenous across sites. However, some of Northern Ireland's SACs are expansive (and in some cases being comprised of multiple geographically distinct areas), and deposition estimates are likely to vary substantially across such larger sites. At sites that cover multiple 5 km grid cells, the range in N deposition should be taken into account (which is accounted for in Phase 2). Similarly, the average agricultural emission densities calculated in Phase 1 are also likely to vary more substantially over the surroundings of such larger sites. In Northern Ireland there are a number of SACs related to river features (such as Cladagh River SAC), where the site area is a small proportion of the buffer area used to calculate emission densities and to assess N deposition. For example, the buffer zone used to calculate agricultural NH_3 emission densities at Cladagh (Swanlinbar) river SAC is 166 % greater than the site area (4,737 ha vs ~28 ha) and therefore spans areas with many different agricultural characteristics. Caution should therefore be taken at such sites when deciding on appropriate mitigation measures, and spatial variability and local information should always be used for any considerations.

It is also important to note that N deposition varies at the sub-grid level, depending on local sources and sinks and their spatial distribution, as well as long-range transport of longer lived N species. The 5km grid resolution of the source attribution dataset may therefore under- or overestimate the influence of N sources at a site, however the data give a good characterisation of key N threats at each site. For spatial targeting of mitigation measures, it is crucial that any local information on emission sources and their properties is considered/utilised, to evaluate potential impacts of sources close to the site boundary.

5.3. Phase 2 - Advantages of using more detailed data

For the five SACs assessed in more detail, the sources identified in Phase 1 corresponded well with the results in Phase 2, with key threats identified successfully. Assessing the full source attribution dataset rather just the values of one 5 km grid square (the most precautionary estimate) allows for improved spatial targeting of measures at a site. This was particularly relevant to sites such as Main Valley Bogs SAC where IED farms are clustered around a particular area of a site (i.e. the southernmost sub-site in the case of Main Valley Bogs SAC, see Site Profile for details, Appendix). As agricultural NH_3 sources are often highly spatially variable as well as in the management practice and systems used, it is imperative that local information is used in combination with national datasets at any decision-making stages for N mitigation.

Wind data were also an important factor to the detailed assessment of N threats. The location of an emission source relative to prevailing wind sector(s) substantially impacts the amount of N received by a site.

5.4. Potential future challenges to reducing threats from atmospheric N to Natura 2000 sites

Approximately 70 % of the agricultural NH_3 emissions in 2-km zones surrounding Northern Ireland's SACs are derived from activities associated with cattle farming, and in particular beef farming. The number of IED poultry installations has been increasing in Northern Ireland, and there are a number of proposed IED installations (mainly poultry) surrounding the SACs assessed in greater detail, which may suggest that poultry emissions are set to become a more prominent source of atmospheric N input to SACs. These developments suggest that poultry emissions are becoming more prominent as key sources of atmospheric N input to SACs.

Several Northern Irish SACs are in close proximity to the land border with the Republic of Ireland (RoI) and the general prevailing wind patterns over the British Isles are dominated by Atlantic systems (SW winds). Current atmospheric transport of N from the RoI is contributing substantially to deposition at sites in Northern Ireland (as shown with the source attribution data), and any current and future agricultural policies (such as potential expansion of dairy farming or intensive pig or poultry farming) would have cross-border impacts.

5.5. Wider conclusions/ next steps

The refined methodology applied at the five example sites allowed a reliable distinction of the main threats from atmospheric N (e.g. diffuse agriculture, point sources, roads, etc.; local vs. long-range) to sensitive habitats and species. This enabled a relatively clear assessment of whether local mitigation measures were likely to be worth considering for targeted mitigation at a site, and/or whether wider regional or national/international efforts would benefit the site.

Detailed selection of potential measures requires local collaborations and sharing of information on current management systems and practices, prior implementation of low-N systems and measures, etc. While this applies equally to all emission source sectors, it is particularly relevant for agriculture. Previous work in England (IPENS projects 049/050, Dragosits et al. 2014, Misselbrook et al. 2014) and Wales (AAANIS project, Carnell et al. 2015) showed the value of engaging with local stakeholders, knowledge exchange on atmospheric N, its sources and effects on the SAC as essential for constructive targeting of measures.

In developing the spatial targeting concept further, e.g. for an example pilot site, input from local stakeholders would be crucial for devising detailed, suitable and locally applicable sets of measures, as local management information cannot be derived from other data sources, apart from some insight from recent aerial images (e.g. Google Earth). The following key steps are recommended, if the approach were to be adopted in Northern Ireland:

- Analysis of N deposition (including source attribution, contributions from wet/dry deposition) and NH_3 and NO_x concentrations for all SACs under threat: local sources vs. long-range input from diffuse and point source agriculture, roads, non-agricultural sources.
- Familiarisation with each site, aerial images and output from the previous analysis steps, preparation of a draft site profile and draft potential measures for local targeting
- Communication with local site managers/stakeholders to check site profiles and preparation of a "Site Nitrogen Action Plan" (SNAP; term developed by Natural England) with an agreed list of suitable/locally applicable measures.
- These SNAPs could then be implemented (e.g. via agri-environment schemes) to minimise effects from local sources of atmospheric N on Natura 2000 sites.

A small number of pilot studies could test the implementation of measures, combined with atmospheric monitoring and modelling before/after implementation, to allow thorough quantification of the approach and its costs/benefits, for review before potential wider application, if successful.

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