Assessing and Addressing Atmospheric Nitrogen Impacts on Natura 2000 Sites in Wales (AAANIS)

Project Report

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Action A.9 Evidence Gaps

LIFE Natura 2000 Programme for Wales: Assessing and Addressing Atmospheric Nitrogen Impacts on Natura 2000 Sites in Wales (AAANIS)

Contents

Crynodeb

1. Nod y gwaith hwn yw cynorthwyo i ddatblygu dull i fynd i'r afael ag effaith dyddodiad N ar safleoedd Natura 2000 (N2K) yng Nghymru; mater y tynnwyd sylw ato gan raglen LIFE Natura 2000 ar gyfer Cymru.

2. Mae prosiect AAANIS wedi dilyn fframwaith a ddatblygwyd yn ddiweddar ar gyfer priodoli ffynonellau llygredd nitrogen (N) atmosfferig ac wedi ystyried targedu'n ofodol fesurau lliniaru i safleoedd N2K yng Nghymru. Detholwyd dau safle fel astudiaethau achos i asesu sut y gall dull manylach gyfrannu at fod yn well am dargedu mesurau sy'n effeithiol yn lleol. Dyma'r ddau safle a ddewiswyd; 1. Ardal Cadwraeth Arbennig Ffeniau Ynys Môn a 2. Ardal Cadwraeth Arbennig Fenn's Whixall, Bettisfield, Wem a Cadney Mosses.

3. Cafodd allyriadau NH_3 lleol a'r cyfraniadau tebygol o'r prif sectorau amaethyddol eu hamcangyfrif ar gyfer pob Adran Cadwraeth Arbennig yng Nghymru (gyda nodweddion daearol dynodedig). Roedd y dull hwn, ar y cyd â data ategol ar gyfer y ddau safle a ddewiswyd, yn caniatáu asesu'n llawer mwy manwl yr arferion rheolaeth tebygol sy'n gysylltiedig â phob sector a dethol, gyda mwy o dargedu, fesurau lliniaru sy'n addas yn lleol.

4. Roedd cymharu'r dull manwl ar sail safle, gyda dull cychwynnol (brasach) o ddefnyddio setiau data cenedlaethol, yn darparu cip ar yr ymdrechion sydd eu hangen i gasglu data ar gyfer safleoedd o wahanol feintiau/cymhlethdod a gwerth data manylach ar gyfer targedu mesurau.

5. Ar gyfer y ddau safle astudio, roedd y fethodoleg goeth yn caniatáu **canfod yn ddibynadwy beth yw'r prif fygythiadau** gan N atmosfferig (e.e. amaethyddiaeth wasgaredig, tarddleoedd pwynt, ffyrdd ayyb; lleol vs. pell) i gynefinoedd a rhywogaethau sensitif. Roedd hyn yn galluogi asesu'n gymharol eglur a oedd **mesurau lliniaru lleol** yn debygol o fod yn werth eu hystyried ar gyfer lliniaru drwy dargedu ar safle, a/neu a fyddai **ymdrechion rhanbarthol neu genedlaethol/rhyngwladol ehangach** o fudd i'r safle.

6. Mae **detholiad manwl o fesurau posibl** yn gofyn am **gydweithio lleol gyda rhanddeiliaid a rhannu gwybodaeth** ynghylch systemau ac arferion rheoli cyfredol. Er bod hyn yr un mor berthnasol i bob sector ffynonellau allyriadau, mae'n arbennig o berthnasol i amaethyddiaeth.

7. Mae **crynodiadau amonia'n uchel iawn mewn rhai ardaloedd yng Nghymru** (e.e. ar hyd y ffin rhwng Cymru a Lloegr). Ond mewn ardaloedd, er bod y crynodiadau'n uwch nid ydynt wedi cyrraedd lefelau critigol eto. Dylid anelu ymdrechion yn yr ardaloedd hyn er mwyn atal cynnydd yn yr amonia a fyddai'n achosi iddynt fynd y tu hwnt i lefelau critigol.

8. Wrth ddatblygu'r camau nesaf, byddai mewnbwn gan randdeiliaid lleol yn hollbwysig ar gyfer dyfeisio setiau o fesurau manwl, addas y mae modd eu defnyddio'n lleol.

9. Yn gyffredinol, ar ôl profi'r dull manwl ar ddau safle enghreifftiol, argymhellir y **camau allweddol** a ganlyn pan gaiff y dull ei ymestyn ledled Cymru:

    a) **Dadansoddi dyddodiad N (gan gynnwys priodoli tarddiad, cyfraniadau gan ddyddodiad gwlyb/sych) a chrynodiadau NH_3 ac NO_x**; tarddiadau lleol vs. mewnbwn pell o amaethyddiaeth wasgaredig a tharddleoedd pwynt, ffyrdd, tarddiadau nad ydynt yn amaethyddol.

    b) **Bod yn gyfarwydd â'r safle, lluniau o'r awyr ac allbwn o gamau'r dadansoddi blaenorol**, dwyn ynghyd **broffil drafft o'r safle a mesurau potensial drafft** ar gyfer targedu'n lleol;

c) **Cyfathrebu â rheolwyr y safle leol/rhanddeiliaid** i wirio proffiliau safleoedd a pharatoi **Cynllun Gweithredu Nitrogen Safle (SNAP)** gan gytuno ar **restr o fesurau addas/i'w cymhwyso'n lleol**.

d) Yna, gellir gweithredu'r SNAP hwn i leihau cymaint â phosib yr effeithiau o darddiadau lleol o N atmosfferig ar safleodd N2K (SNAP-**DRAGONS – Delivering Regional Action on the Ground On Nature Sites**)

10. Gallai nifer fechan o astudiaethau peilot brofi gweithrediad y mesurau, ar y cyd â monitro atmosfferig a modelu cyn/ar ôl gweithredu, er mwyn caniatáu mesur y dull a'i gostau/manteision.

11. **Mae CNC mewn sefyllfa ragorol i atal rhagor o effeithiau amonia ar nifer o safleoedd gwarchodedig** drwy ei rôl fel rheoleiddiwr yr unedau mwy ar gyfer da byw ac fel ymgynghorai i geisiadau cynllunio ar gyfer unedau llai ar gyfer da byw dan y system gynllunio. Mae penderfyniadau sgrinio diweddar gan Lywodraeth Cymru yn gofyn am asesiad amgylcheddol o nifer o unedau llai ar gyfer da byw sy'n agos at leoliadau sensitif dan Atodlen 2 o reoliadau Asesiadau Effaith Amgylcheddol. Bydd integreiddio'r darpariaethau hyn yn gymorth i danategu dull **Rheoli Cyfoeth Naturiol (RhCN)** i fynd i'r afael â dyddodiad N yng Nghymru.

Summary

1. The aim of this work is to assist in developing an approach to address the impact of nitrogen deposition on Natura 2000 (N2K) sites in Wales; an issue highlighted by the LIFE Natura 2000 Programme for Wales.

2. The AAANIS project applied a recently developed framework for source attribution of atmospheric nitrogen (N) pollution and considered spatial targeting of mitigation measures to Natura 2000 sites in Wales. Two sites were selected as case studies to assess how a more detailed approach can contribute to better targeting of locally effective measures. The two selected sites were; 1. Anglesey Fens Special Area of Conservation (SAC) and 2. Fenn's Whixall, Bettisfield, Wem and Cadney Mosses SAC.

3. Local NH_3 emissions and the likely contributions from key agricultural sectors were estimated for all Welsh SACs with terrestrial designated features. This approach, combined with auxiliary data for the two selected sites, allowed a much more detailed assessment of likely management practices associated with each sector and a more targeted selection of locally suitable mitigation measures.

4. A comparison of the detailed site-based approach with an initial (coarser) approach using national datasets provided insight into the effort required to compile data for sites of different size/complexity and the value of more detailed data for targeting measures.

5. For the two study sites, the refined methodology 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.

6. **Detailed selection of potential measures** requires **local collaboration with stakeholders and sharing of information** on current management systems and practices. While this applies equally to all emission source sectors, it is particularly relevant for agriculture.

7. **Ammonia concentrations are very high in some areas of Wales** (e.g. along the Wales England border). However, in many areas, although concentrations are elevated they have not yet reached critical levels. Efforts should be targeted in these areas to prevent increases in ammonia that would cause exceedance of critical levels.

8. In developing the next steps, input from local stakeholders would be crucial for devising detailed, suitable and locally applicable sets of measures.

9. Overall, after testing of the detailed approach at two example sites, the following **key steps** are recommended, when the approach is extended across Wales:

   a) **Analysis of N deposition (including source attribution, contributions from wet/dry deposition) and NH_3 and NO_x concentrations**; local sources vs. long-range input from diffuse and point source agriculture, roads, non-agricultural sources.

   b) **Familiarisation with the site, aerial images and output from the previous analysis steps**, pulling together a **draft site profile and draft potential measures** for local targeting;

   c) **Communication with local site managers/stakeholders** to check site profiles and prepare a **Site Nitrogen Action Plan (SNAP)** with an agreed **list of suitable/locally applicable measures**.

d) This SNAP could then be implemented to minimise effects from local sources of atmospheric N on Natura 2000 sites (SNAP-**DRAGONS – Delivering Regional Action on the Ground On Nature Sites**)

10. 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.

11. **NRW is an excellent position to help prevent further ammonia impacts on a number of protected sites** via its role as a regulator of the larger livestock units and as a consultee to planning applications for smaller livestock units falling under the planning system. Recent screening decisions by the Welsh Government require an environmental assessment of a number of smaller livestock units close to sensitive locations under Schedule 2 of the EIA regulations. Integration of these provisions will help underpin a **Natural Resources Management (NRM)** approach to addressing N deposition in Wales.

1. Introduction

Atmospheric nitrogen (N) deposition represents a significant threat to habitats and species in the UK, resulting in declines in many of the key species of high conservation value at the expense of a smaller number of fast growing species that can exploit conditions of increased nitrogen supply (e.g., Dise *et al*., 2011; RoTAP, 2012). These threats are mainly due to emissions of ammonia (NH_3, mainly from agricultural sources) and nitrogen oxides (NO_x, mainly from combustion sources such as transport, industry, and power generation). Substantial efforts in UK and European policies over the last decades have reduced NO_x emissions considerably, whereas, so far, much less has been achieved in reducing NH_3 emissions.

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. The third UK Habitats Directive report[1] published in 2013 reported that, out of a total of 77 annex 1 habitats, 34 had air pollution attributed as a high pressure and a high threat. In addition, data used to produce the UK Biodiversity Indicator on air pollution[2] demonstrates that, at present, 65% of the area of sensitive habitat in the UK exceeds critical loads for N deposition (eutrophication). This is predicted to reduce only slightly by 2020 (RoTAP, 2012) in response to existing measures. Therefore, additional measures are required to protect habitats from air pollution and to restore areas of habitat that are currently impacted.

The identification of dominant emissions sources contributing to N deposition at each site is the first step in targeting mitigation options locally, to achieve the most cost-effective outcome. 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 includes both 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.). A wide range of potential measures exists to reduce emissions from agricultural sources, however, in contrast to other countries, such as the Netherlands and Denmark, where wide-ranging legislation has been implemented to reduce emissions, there has only been limited uptake of NH_3 mitigation measures in the UK.

2. Background

Agriculture is the main source of ammonia emissions to the atmosphere, accounting for about 90% of UK releases. In Wales, NH_3 emissions of ammonia were estimated at 25kt in 2012 (NAEI, 2014), with agriculture contributing 85% of the total, and 52% of agricultural emissions derived from cattle manure management alone. While there has been an overall reduction in animal numbers in the UK (cattle, pigs and sheep) and hence in NH_3 emissions in recent years, this trend has been reversed in Wales with a 5% increase in ammonia emissions reported between 2008 and 2011. Looking at the livestock emissions in more detail, there has been an increase in poultry numbers by 15% 2008-2012 (Misselbrook *et al.*, 2014). Emissions of nitrogen oxides (NO_x) in Wales were estimated at 88kt in 2012 (8% of the UK total), with 42% coming from power generation and 20% originating from road transport (NAEI, 2014).

3. Project Objectives

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

Phase 1 aims to provide an initial assessment of local and regional threats of atmospheric N deposition to every Natura 2000 site situated in Wales. The initial assessment built upon work developed under IPENS-

[1] http://jncc.defra.gov.uk/page-6387

[2] UK Biodiversity Indicators in your pocket: http://jncc.defra.gov.uk/page-4245

049 for England (Dragosits *et al*., 2014b) and used national datasets to assess N threats from local relevant sources (such as agriculture, transport and industry), in addition to long range pollution emitted from sources further afield. Special attention was given to agricultural emission sources, 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). Two SACs were selected for a more detailed analysis and assessment under Phase 2.

Phase 2 focused on the two selected Natura 2000 sites, with the aim of verifying whether spatially targeted mitigation measures identified using national datasets in the initial assessment (Phase 1) are suitable, by drawing on more detailed data and analysis at the local level. Phase 2 drew on additional detailed data such as nitrogen emission, concentration and deposition data, road traffic data, emission factors and calculation tools from the UK inventories, and auxiliary data such as SAC boundary data, Ordnance Survey OpenData, Google Earth etc. This more detailed assessment helped to establish whether the mitigation measures identified in Phase 1 were appropriate for reducing N deposition to the designated sites selected. This analysis informs recommendations on the value of using detailed source attribution data for all Natura 2000 sites in Wales, and how the tools could be used to develop site specific N management plans.

4. Methods

4.1 Background/Source attribution methodology

Previous work funded by Defra and Natural England and carried out by the Centre for Ecology & Hydrology (CEH) and collaborators explored the potential of spatially targeted measures to reduce nitrogen (N) deposition to sensitive habitats (Dragosits et al., 2014a; Dragosits et al., 2014b). 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 atmospheric deposition and source attribution modelling. A draft framework was developed for identifying the most appropriate abatement measures and potential delivery mechanisms to implement these measures at each site, depending on the identified sources, their spatial distribution and other characteristics. This approach was implemented for all SACs in England under the IPENS-049 project, with six sites analysed in more detail as case studies (Dragosits et al., 2014b).

Table 1 – Definition of the five scenarios using the UK source attribution dataset for N deposition (year 2005)

Emission source allocation ID	**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**	
SA1	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
SA2	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

Emission source allocation ID	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	
SA3	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
SA4	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)
SA5	Remote (upland) sites affected by long-range N input	All model 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), and landfill.

[2]SA5 includes additional source categories that were excluded from source allocations1-4, i.e. imported emissions and residual background sources (e.g. off-shore installations, crematoria, accidental fires, incineration etc.).

Under the AAANIS project, the IPENS approach was applied to all SACs with terrestrial designated features in Wales. Initial emission source allocations were assigned to each site, using a combination of the latest available source attribution dataset (for 2005[3]) and the distance of the site's boundaries to large intensive pig and poultry farms (falling under the Industrial Emissions Directive, IED, Figure 4) and major roads (data from the Department for Transport, DfT).

4.2 Phase 1 – Data Sources

The initial Phase 1 source attribution assessment requires the following datasets:

- **UK source attribution dataset** (year 2005) provided estimates of N deposition to each site produced from 160 different point and area emission sources. Emission sources were categorised to provide an initial indication of key potential threats from N deposition (5km grid resolution)
- **IED permit database (2015)** was used to assess whether a designated site was within a zone of influence (2km buffer zone) of an intensive permitted poultry farm.
- **OS OpenData ('Strategi' dataset) road network (2014)** data were 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 Wales (2014)** were 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).

4.3 Phase 1 – Agricultural census summaries

Agricultural sources, likely to play a substantial role in terms of local ammonia sources in the vicinity of Natura 2000 sites, were assessed in a more detailed analysis. This involved the derivation of summary data on likely ammonia emissions in the vicinity of each SAC in Wales, using the methodology developed under the IPENS-049 project (Dragosits *et al.,* 2014b). This method estimates the proportion of the main

[3] N.B. a new model run is currently being carried out for the year 2012

agricultural sectors contributing to NH_3 emissions in a local zone surrounding each SAC (2 km from the boundary) and an average NH_3 emission density for these zones, using average UK emission factors used in the latest available UK agricultural emission inventory (Misselbrook *et al.*, 2014). This use of high-resolution agricultural statistics was possible due to Welsh Government granting a project license. In order to comply with the data licensing agreement, emission estimates from each sector were made non-disclosive, i.e. each data point has to relate to at least 5 agricultural holdings. In extensive agricultural regions, where this requirement was not met, the buffer zone around the site boundary was increased in size to include further agricultural holdings. This methodology was applied to all SACs in Wales, with a non-disclosive dataset produced for the project (Appendix 2).

4.4 Phase 2 – Detailed desk based study

The detailed source attribution guidance and selection of measures were applied to two exemplar Natura 2000 sites, which were agreed with the project steering group, following analysis of the outputs from Phase 1:

- Anglesey Fens SAC
- Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC

The results of these desk-based studies are presented in individual site-profiles (see Appendices), which each include a summary of the sites characteristics, graphics of the source contributions and potentially suitable measures, in an easily accessible format.

Anglesey Fens, which consists of a number of **geographically separate units**, was subdivided into three groups of sites that were considered individually, by utilising the complete UK 5 km source attribution dataset (see Site Profile, Appendix 3). This is a significant improvement to Phase 1, where only the 5 km grid square that received the highest N deposition was considered in the simplified source attribution dataset. The following analyses were also carried out for the two study sites, so that recommendations regarding spatially targeted N measures could be made at the site level.

- **High resolution NH_3 concentration data** (1 km grid) were used to identify areas with high NH_3 concentrations. The high spatial resolution of the data means that concentration hotspots can be identified, as well as NH_3 source areas (e.g. dominated by diffuse agriculture) be separated much more successfully from semi-natural NH_3 sink areas than at the 5 km grid resolution, thus allowing a more realistic quantification of NH_3 concentrations across SACs.
- **Intensive poultry farm management data** (permitted under IED) were made available by NRW, for input into the assessment of the two case studies. These data include numbers and types of birds at each installation, as well as the housing/manure storage systems currently implemented. These data were used as input to the SCAIL screening tool, to estimate the contribution of individual IED farms to N deposition and NH_3 concentrations at the sites. In addition, the spatial location of the site relative to a point source was taken into account in the preparation of the site profiles, including the local prevailing wind conditions to give a higher weighting to sources upwind of a designated site. Prevailing wind was determined using information from suitable nearby weather stations on Windfinder.com (free and quick to download data).
- **The National Atmospheric Emission Inventory (NAEI) dataset of non-agricultural point sources** was checked for nearby point sources of NO_x and NH_x emissions. The detailed categories of the UK source attribution dataset were also checked, as the initial scenario allocation combines a multitude of different source types into summary categories (e.g. industry, power generation, shipping, waste processing). Therefore, to enable the identification of potential measures, the individual sub-categories of emission sources from both the source attribution dataset and emission maps from the NAEI were used allow a more detailed identification of sources. Any significant point sources that were within 10 km of a site were considered.

- **Google Earth imagery** was used in conjunction with the national datasets, to identify any potential additional sources and provide further information on the sources already identified, including distance of sources from the site boundary, visual assessment of local conditions etc.
- **NO_x emissions from road transport were calculated using the Defra Emission Factor Toolkit & DfT traffic counts**, used in addition to the N deposition threshold and simple distance-relationship between major roads and SAC boundaries used in Phase 1 (see Table 1). During Phase 1, road transport was assigned as a significant source of N deposition to sites where vehicular emissions contributed > 10 % of the total N deposition in the relevant 5 km grid square, in combination with the presence of a major road within 200 m from site boundaries. The more detailed methodology refines this approach by extracting annual average daily flows (AADF) of traffic (DfT, 2014) for each major road identified by the coarse approach. NO_x emissions are then estimated for each road link, using Defra's freely available Emission Factor Toolkit (v. 6.0.2).

5. Results

5.1 Phase 1 – Initial source allocation

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

The analysis of the UK source attribution dataset for SACs in Wales (Table 2, full dataset see Appendix 1) shows that diffuse agricultural activities pose a significant threat to virtually every SAC in Wales, with local sources likely to contribute to the N deposition at most SACs, except those in extensive upland regions. A number of the larger intensive poultry units (i.e. permitted by NRW under the Industrial Emissions Directive (IED)) are clustered close to protected sites and provide significant point source inputs to some SACs, specifically on Anglesey and the eastern side of Wales (Figures 1, 2 & 3). Increased N deposition due to the vicinity of major roads is relevant to a smaller number of sites, especially in the more populated areas of Wales in the south and north, with the semi-natural features on northern sites less affected by roads when assessed using the habitat-specific deposition estimates than the woodland features (Figures 1, 2). Non-agricultural (point) sources and long-range transport (the latter as indicated by substantial wet deposition) also appear to impact the majority of sites. With regard to N deposition originating from non-agricultural sources, varying proportions may be due to regional to long-range transport, with N being deposited as wet deposition. However, more detailed local information would be needed to distinguish between local and regional sources.

Table 2 – Initial source attribution summary for all SACs in Wales which have terrestrial designated features (90 sites), showing mean N deposition values and initial emission source allocations across all sites, with estimates 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} #	SA 1 (diffuse agriculture)	SA 2 (point source agriculture)	SA 3 (non-agricultural (point) sources)	SA 4 (road transport) *	SA 5 (long-range transport)
Semi-natural features	22.8	100%	7%	83%	4%	64%
Woodland	40.5	98%	17%	95%	35%	25%
Grid Average◊	19.7	98%	7%	98%	27%	90%

The N deposition value at each SAC was selected as the highest estimate 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

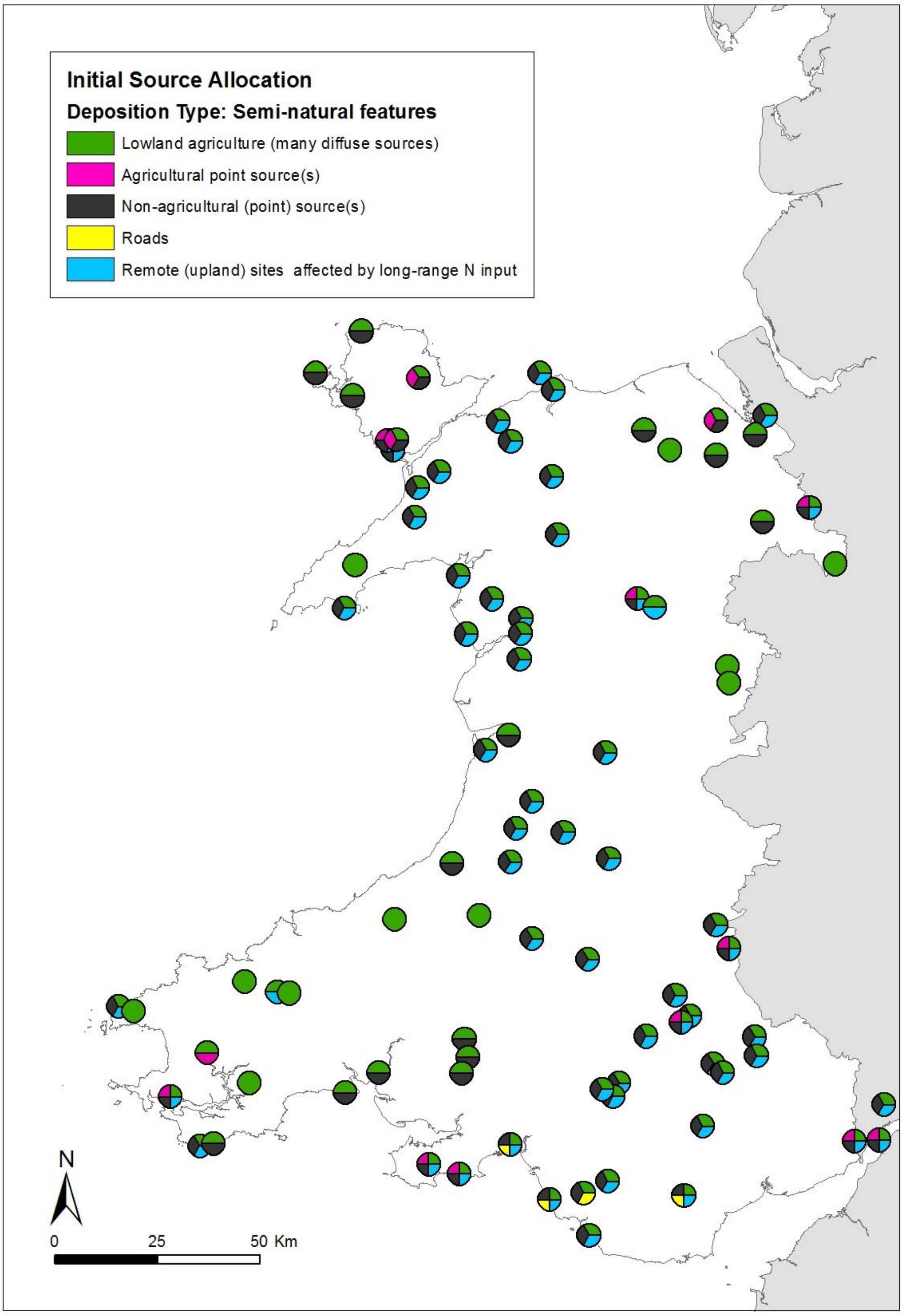


Figure 1 – Estimated source attribution for all SACs in Wales, which have terrestrial designated features (90 sites) from national scale source attribution data (5 km grid) using N deposition estimates to semi-natural features and also drawing on proximity assessment of sites to IED poultry farms data (2 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.

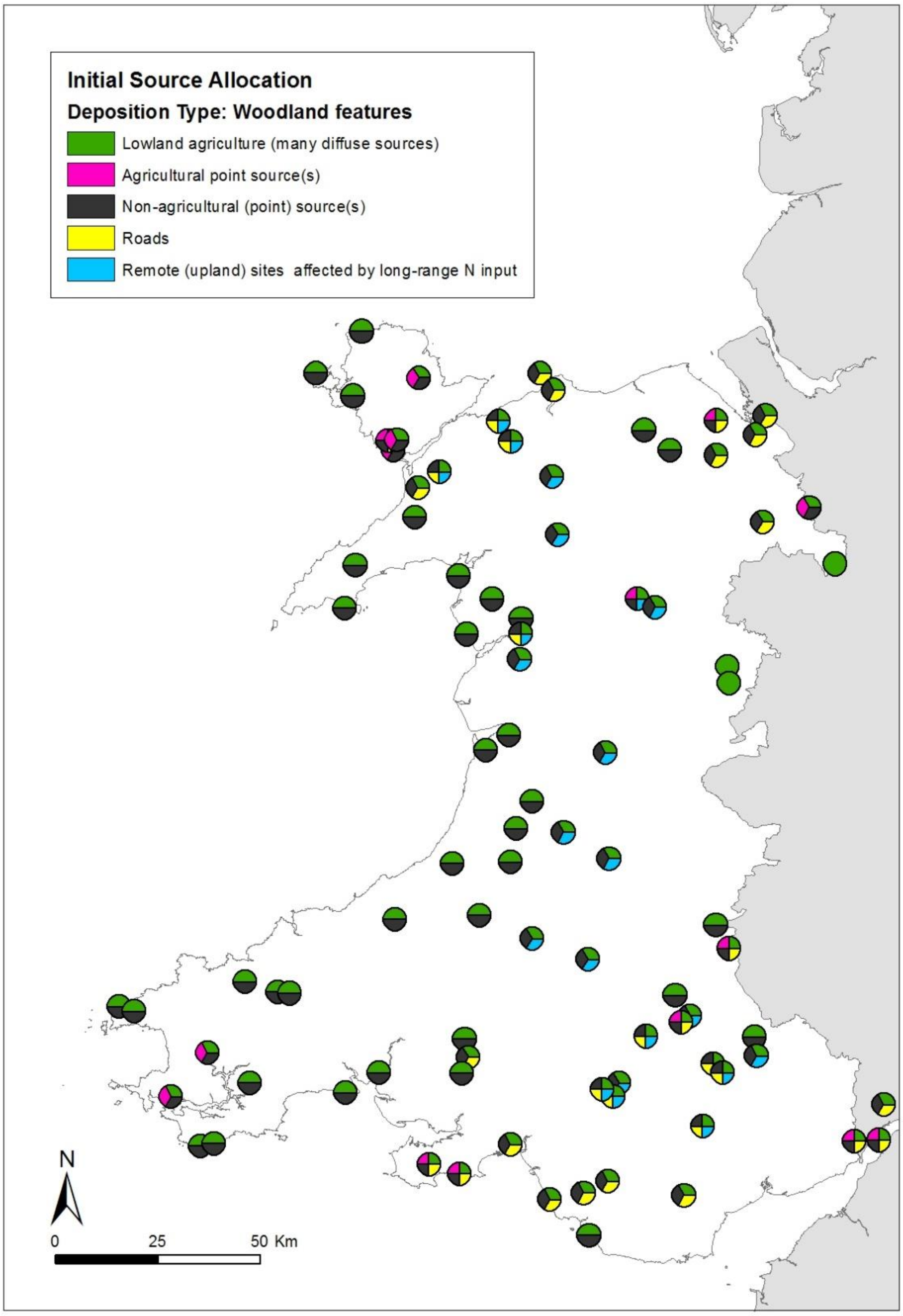


Figure 2 – Estimated source attribution for all SACs in Wales, which have terrestrial designated features (90 sites)from national scale source attribution data (5 km grid) using N deposition estimates to woodland and also drawing on proximity assessment of sites to IED poultry farms data (2 km radius) and major roads (200 m radius). The category 'non-agricultural point source' shown in this map does not include a local distance criterion.

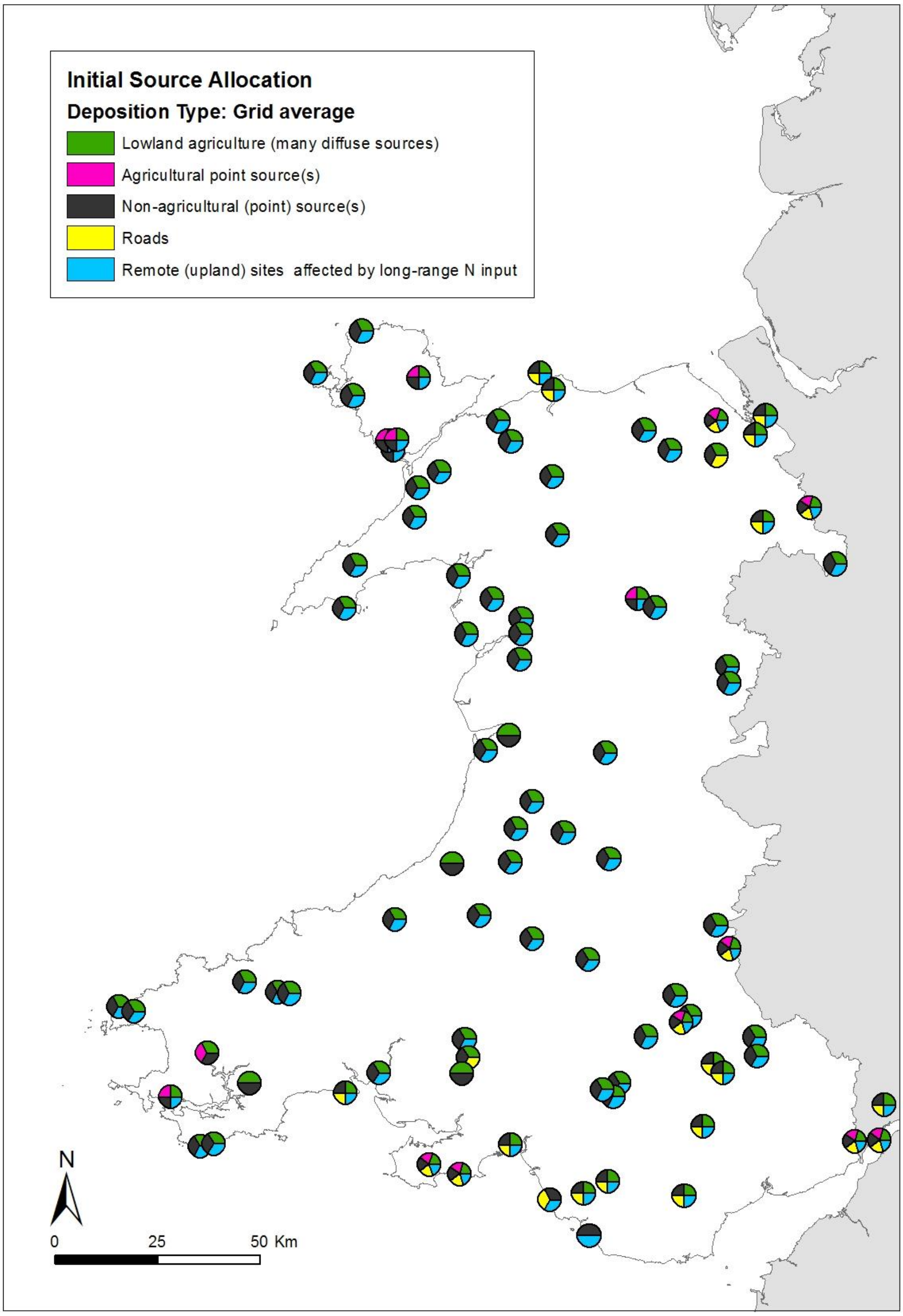


Figure 3 – Estimated source attribution for all SACs in Wales, which have terrestrial designated features (90 sites)from national scale source attribution data (5 km grid) using grid-average estimated (used for estimating effects on freshwater habitats) N deposition and also drawing on proximity assessment of sites to IED poultry farms data (2 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.

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

A substantial proportion of the SACs in Wales is 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 (in terms of largest contribution to estimated NH_3 emissions within the 2 km (+) buffer zone) for most SACs is cattle farming (~75 %), and in particular activities associated with dairy farming (Figure 5, complete site-specific summary given in Appendix 2). Agricultural NH_3 source categories are identified separately where a category exceeds a 5% contribution to total agricultural emissions in the area surrounding each SAC and where the data are non-disclosive, e.g. from a minimum of 5 holdings. Where the data confidentiality conditions are not met, the emission sources are aggregated into broader categories such as a single combined 'cattle' category, or, especially in agriculturally extensive areas, are further combined into the 'other' category, to comply with the data agreement. Only a small number of SACs required an extension of the buffer zone from 2 km to 3 km to comply with the data agreement.

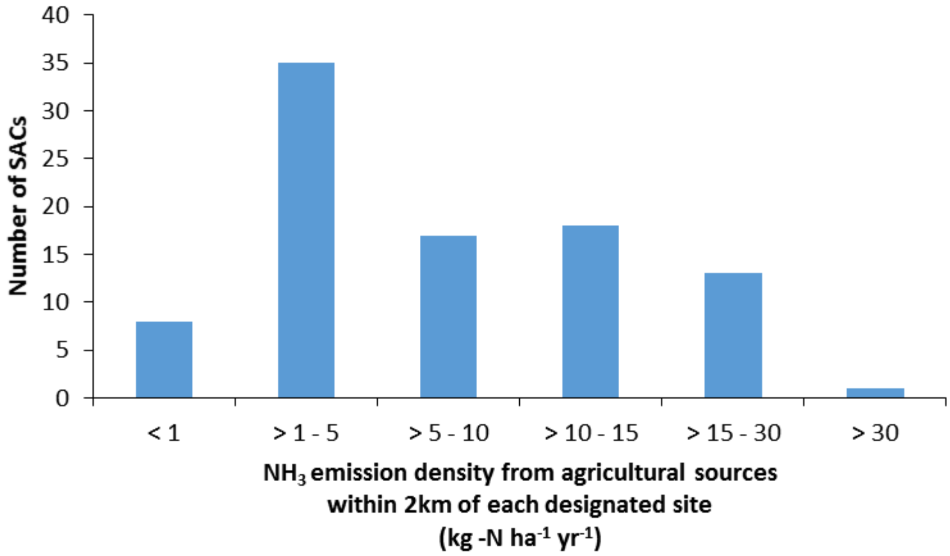
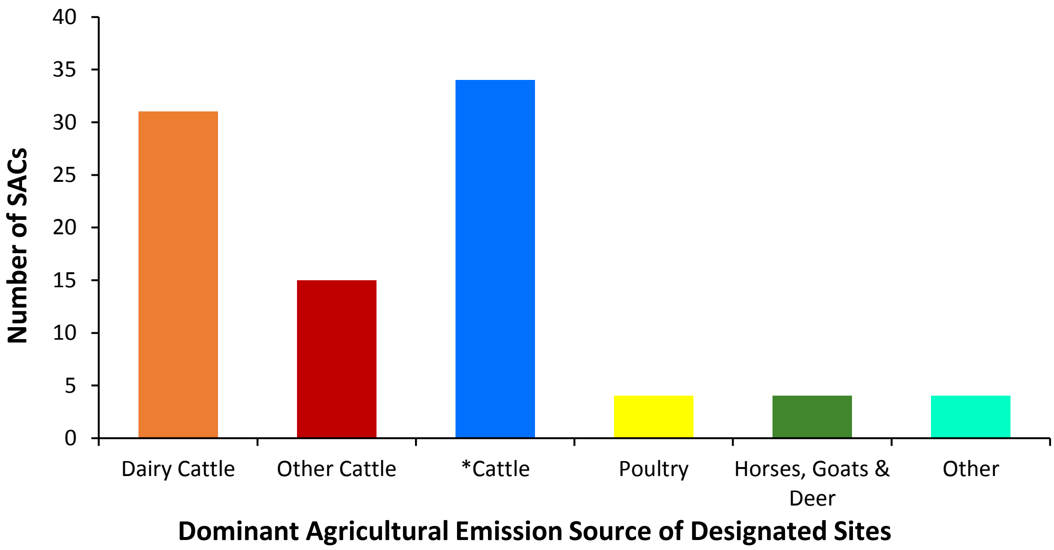


Figure 4 – Estimated agricultural emissions densities within a 2 km buffer zone surrounding each SACs in Wales. In extensive agricultural regions, where the 2 km buffer zone did not contain 5 agricultural holdings, the buffer zone around the site boundary was increased to include further agricultural holdings.



**The category 'Combined Cattle' was used when the 'dairy'/'other cattle' categories were comprised of fewer than five holdings, to satisfy the data agreement for high-resolution agricultural census data.*

Figure 5 – Largest agricultural NH_3 emission source in the 2 km zone surrounding each SACs in Wales. 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 include further agricultural holdings.

The distribution of estimated agricultural emissions surrounding each site is presented in Figure 5 as a series of pie-charts showing the proportion of agricultural NH_3 emissions from each sector. The size of the symbols is indicative of the estimated emission density surrounding each SAC.

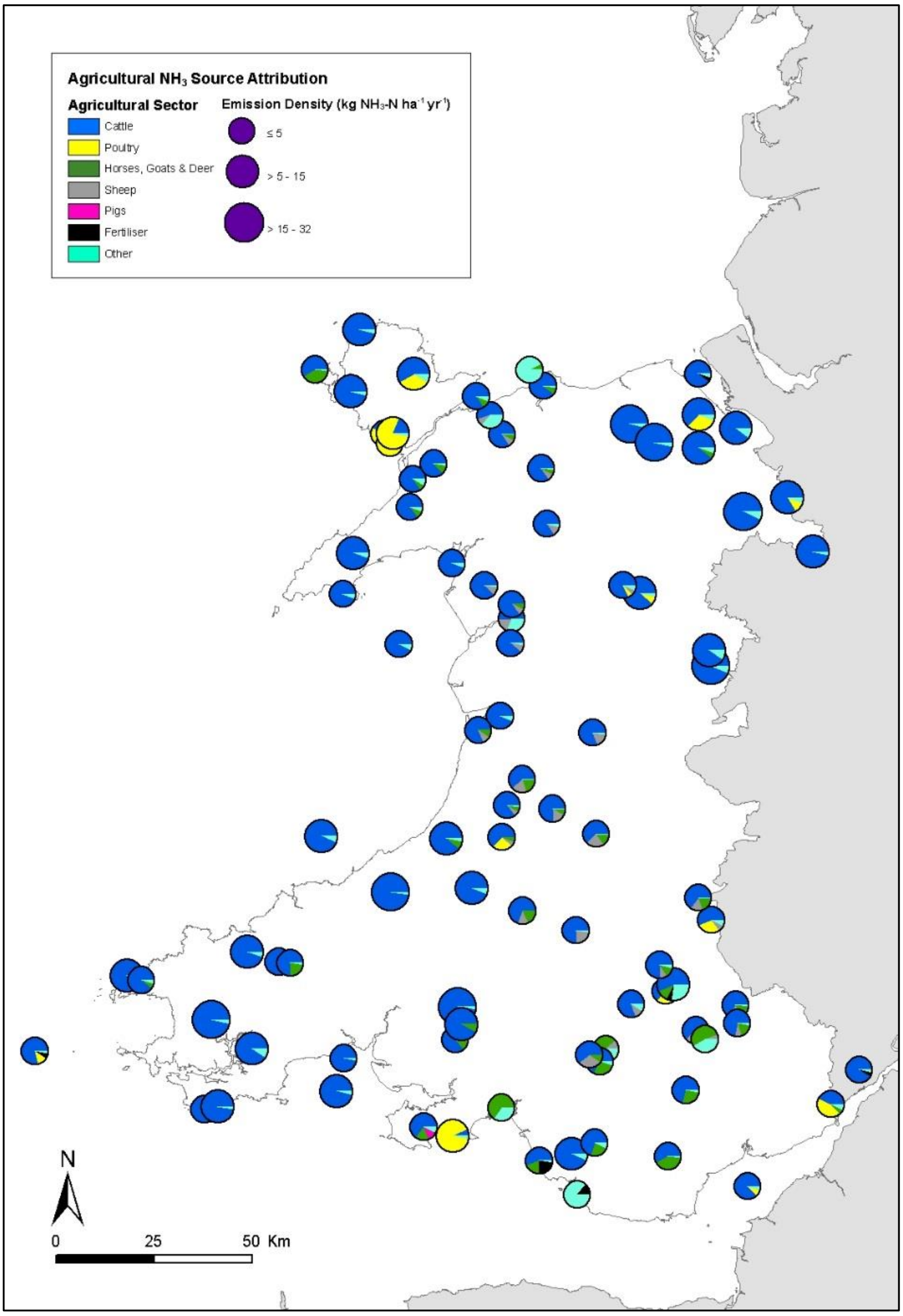


Figure 6 -– Estimated agricultural source attribution for all SACs in Wales, which have terrestrial designated features (90 sites) from national scale source attribution data (5 km grid) using N deposition estimates to semi-natural features, also drawing on proximity assessment of sites to IED poultry farms data (2 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.

5.3 Phase 2 – Detailed site assessment

SACs with geographically separate units and large sites were considered at the 5 km grid scale in Phase 2 by utilising the complete UK 5 km source attribution dataset rather than the summary dataset where each SAC was assessed based on the 5 km grid square from the source attribution dataset (FRAME model output for 2005) with the highest N-deposition. This is a significant improvement to the Phase 1 assessment. An example for Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC (Figure 7) shows individual N deposition estimates and source attribution pie charts for each of the three 5km grid squares that intersect the site.

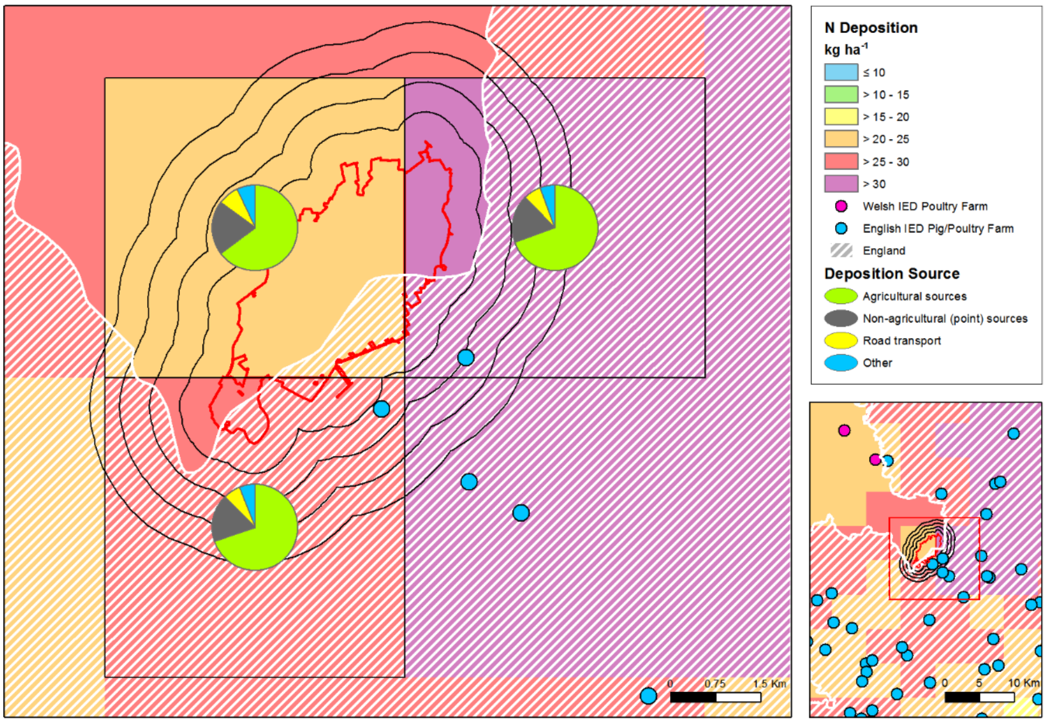


Figure 7 – Estimated N deposition (2010 - 2012) and source attribution (2005) for Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC. 5 km grid squares that are outlined contain portions of the site. Sources are categorised using the initial source categorisation (see main project report for details).

Total N deposition to the north east of the site (30 kg N ha^{-1} yr^{-1}) is estimated to be substantially higher than to the northwest (25 kg N ha^{-1} yr^{-1}). For this SAC on the border of England and Wales, agricultural NH_3 deposition is the dominant source across the wider area, with high N deposition around the cluster of IED pig/poultry farms on the English side. The same pattern is also evident in the 1 km NH_3 grid resolution NH_3 concentration data for the immediate vicinity of the SAC (Figure 8, FRAME model output, year 2011), with concentrations > 3 µg NH_3 m^{-3} in the areas surrounding the IED installations and >1 – 2 µg NH_3 m^{-3} within the SAC boundary. The high spatial resolution of the data means that likely concentration hotspots could be identified, as well as NH_3 source areas (e.g. dominated diffuse agriculture) separated from semi-natural NH_3 sink areas much more successfully than at the 5 km grid resolution.

Emissions from road transport were also assessed in more detail in Phase 2, using detailed traffic flow data (AADF) as input to Defra's Emission Factor Toolkit (EFT). For the Anglesey Fens SAC study, the annual link emissions of the A5025 were calculated as the road is located within 200 m of the SAC. The road is estimated to have a daily traffic flow of 7,000 vehicles, of which ~110 are estimated to be HGVs. Only a small proportion of the road's traffic are HGV and as such the estimated emissions are relatively low at ~ 0.4 t NO_x-N km^{-1} yr^{-1}. This is in agreement initial assessment in Phase 1, which suggested that emissions from road transport did not pose a significant threat.

Google Earth imagery was examined in Phase 2 to determine whether there are any sources in close proximity to the SAC boundary. Identifying emission sources close to the site boundary is useful when considering how to spatially target measures. At Anglesey Fens SAC, for example, it is evident from the Google Earth imagery that there were livestock grazing next to the site boundary on the date when the image was taken. This emission source may therefore become a priority site for any measures relating to livestock grazing (which is normally a lesser source than e.g. livestock houses, manure stores or manure spreading activities). The non-agricultural source allocation category (SA 3) used in Phase 1 included a wide range of emissions sources, making it difficult to establish site relevant mitigation measures. In Phase 2, the NAEI dataset of NH_x and NO_x point sources was used to determine whether there were any local non-agricultural emission sources near the site.

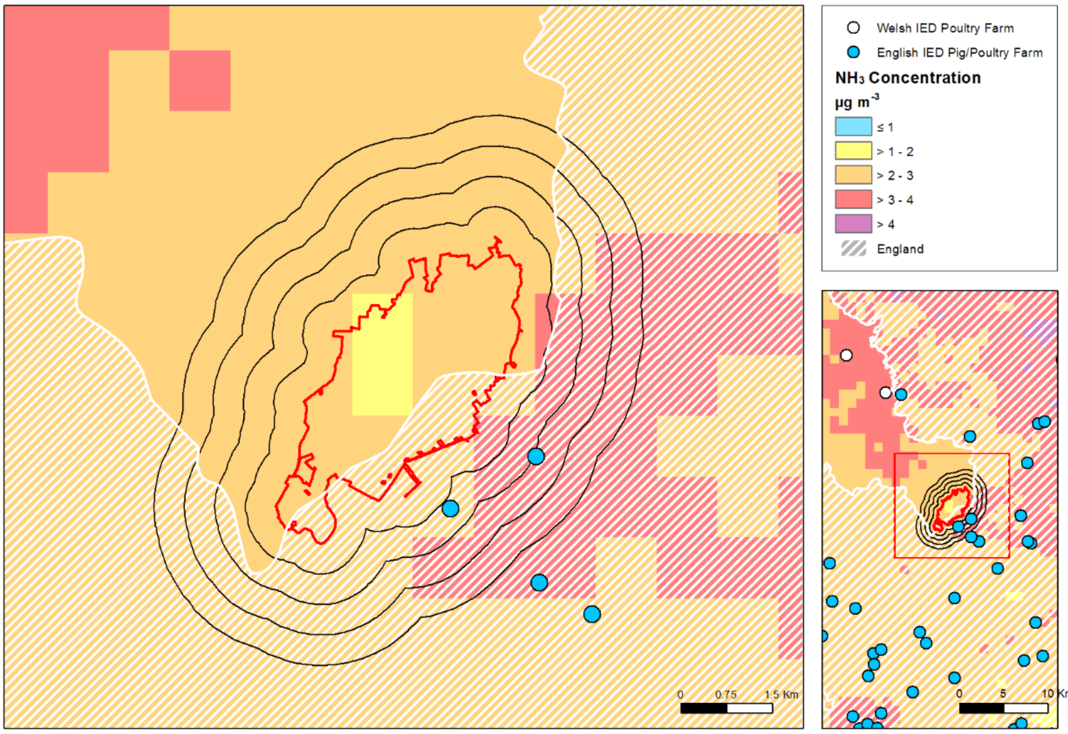


Figure 8 – Ammonia concentrations at Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC (FRAME 1 km dataset for 2011), showing locations of large intensive pig and poultry farms regulated under the Industrial Emissions Directive (IED) farms surrounding the site.

More detailed information about IED poultry installations surrounding the SACs was used in Phase 2, which allowed more accurate estimates to be made of emissions and subsequent N deposition originating from the farms. For example, Anglesey Fens was flagged in Phase 1 as receiving N deposition from agricultural point sources, as the site is situated < 2,000 m from an IED poultry installation. In Phase 2, information about the size of the installation (i.e. number of bird places) and management systems in place were made available, which enabled the calculation of the unit's emissions and subsequent contribution to N deposition at the SAC using the SCAIL model[4]. This IED farm, situated <1,350 m from the boundary of the southern sub-site, has 200,000 broilers places, with housing emissions estimated at ~5,000 kg NH_3-N yr^{-1}, using site-specific emission factors. The farm's housing emissions are estimated to contribute 0.15 µg m^{-3} to NH_3 concentrations /0.8 kg N ha^{-1} yr^{-1} to N deposition at the boundary of the southern sub-site (SCAIL model output, accessed 17/8/2015).

6. Discussion and Conclusions

6.1 General Discussion

In summary, diffuse agriculture is the biggest threat to Welsh Natura 2000 sites away from remote uplands, with point-source agriculture particularly relevant to clusters of SACs located close to a number of large intensive poultry farms (IED). The latter is especially relevant on Anglesey and towards the English border. More densely populated and coastal areas appear to be receiving some N deposition from sources such as roads, industry, shipping etc.

[4] http://www.scail.ceh.ac.uk/

6.2 Phase 1 – Methodology limitations

The initial (Phase 1) methodology assumes N threats are homogenous across the site, however it is important to note that some Welsh SACs have an expansive site area (with some > 250 km^2), and therefore N threats will be highly variable across such sites. For example, agricultural emission densities and dominant agricultural sectors are likely to vary substantially over such large areas. The average N deposition estimates and agricultural emission densities for these sites should therefore be treated with caution, as substantial emissions across parts of the surrounding areas may have been compensated with very low emissions elsewhere.

Similar caution should also be taken with SACs that are designated for linear features such as river networks which span large parts of the country, despite having a relatively small site area. The area of the River Teifi SAC, for example, is >0.3% of a rectangular bounding box in which it is situated (site area ~650 ha, bounding box ~220,000 ha). Similar averaging effects of threats from local sources as described above for larger SACs are therefore likely. To estimate the threat from N deposition more fully, larger SACs and river sites would benefit from being divided into suitable sub-areas (as was suggested under IPENS for the North York Moors in England).

The 5km grid resolution of the source attribution dataset may lead to underestimates of N deposition exceedance at a site, which will vary across the grid square and will be higher closer to emission sources. It is imperative, therefore, that local information is used to evaluate emission sources close to the site boundary, which are considered a priority for spatial targeting of mitigation measures to maximise impacts.

6.3 Phase 2 - Advantages of using more detailed data

For the two sites examined in more details, the sources identified in Phase 2 were comparable to those from Phase 1, with the main N sources identified using national datasets. However, separating the distributed site (Anglesey Fens) into its constituent parts in Phase 2 helped to identify sub-sites under particular threat and to distinguish between local and regional sources. For example, the Phase 1 agricultural summary data for the site suggested that the site as a whole received an agricultural emission density of 14 kg N ha^{-1} yr^{-1}, however the analysis for the constituent parts of the SAC in Phase 2 estimated emission densities of 8 – 13 kg N ha^{-1} yr^{-1}. The greater level of detail is highly advantageous for spatial targeting of measures. The source types of NH_3 emissions were also different between the sub-sites of Anglesey Fens SAC, with poultry farming contributing ~ 37% of the agricultural NH_3 emissions surrounding the Southern sub-site (<2km), while the contribution from poultry at the Eastern sub-site was much lower at 11 % (see Figure 7 of the Anglesey site profile, Appendix 3 to this report).

It cannot be over-emphasised how important local/'on-the-ground' information is compared with relying on national datasets (even detailed ones), especially at any decision making stages. For example, contributions to atmospheric N input, especially for agricultural NH_3, from sources in the vicinity of SACs may vary considerably, depending on some or all of the following issues:

- Correct information on spatial location of sources (agricultural holdings are not located exactly in the census dataset, with locations often based on e.g. post codes which may cover large areas in sparsely populated rural areas; there are no existing datasets on the location of potential sub-sources such as manure storage facilities which may be field heaps separate from e.g. livestock houses; IED farm locations are not always recorded accurately – e.g. Dragosits *et al*. 2014).
- Information on local agricultural management practice/activities/facilities is essential for identifying suitable measures for spatial targeting of mitigation. (For example, if there is much prior implementation of low-emission measures in an area, these need to be a) counted as part of the assessment of the threat of atmospheric N and b) taken into account when optimising mitigation strategies; soil conditions may be unsuitable for injection of slurry; existing systems may or may not allow retro-fitting of measures, which has implications on time scales and costs of their potential suitability).

- Detailed information on IED farms near SACs is essential for determining their potential impact on atmospheric N input to the sites. Such information includes numbers and types of birds (or pigs) and management systems in use. Many of these farms will have been required to implement BAT (at different levels, which may have been due to the timing of their permit applications, and/or estimated impacts during the permitting process). This prior implementation of measures needs to be taken into account for the site profile, as emissions per bird are likely to be lower than standard non-IED poultry units that are often less likely to have implemented measures already.
- Local wind conditions may differ considerably at a site and contrast with wider regional patterns (e.g. due to topography, land-sea circulation patterns and similar, as described by Jones *et al*., 2013 for a sand dune site in Wales).

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

Currently, three quarters of the agricultural NH_3 emissions in 2-km zones surrounding Welsh SACs are derived from activities associated with cattle farming, and in particular dairy farming. While future developments are difficult to predict, given global market fluctuations, the recent abolishment of the EU milk quota may result in increased volatility in this figure. For example, EC (2014) projected that UK milk production may increase by up to 5% by 2023 (no regional estimates were given for the constituent countries) – however this may be achieved by a number of means, including increased milk yields per cow, increased dairy herds or a combination of both. The same source (EC, 2014) states, however, that some experts expect that milk deliveries in the UK could increase by larger proportions, given recent investments in the dairy industry.

The number of IED poultry installations has been increasing in Wales (shown in pink, Figure 10), with currently existing installations also expanding and increasing the number of birds housed (shown in purple). These developments suggest that poultry emissions are becoming more prominent as key sources of atmospheric N input to SACs. The steering group has also indicated that there is at least one pig farm at the IED application stage, which again may be an indication of the increasing importance of more intensive 'point-source' agriculture.

6.5. Wider conclusions/ next steps

For the two study sites, the refined methodology 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, and previous work in England (IPENS projects 049/050) 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.

Given the issues with the IED farm data and the need for strategic planning for wider areas rather than on a case-by-case basis, it would be beneficial if the detailed information on existing IED farms was collated from regional offices into a single database containing details on the location of each IED farm, types and numbers of pig/bird places, management systems in place and any mitigation measures already implemented. Given the relatively small number of IED farms in Wales, this should not be too time consuming, while being a very valuable resource for Wales-wide and more localised assessments of atmospheric nitrogen originating from IED farms (and possibly for other purposes).

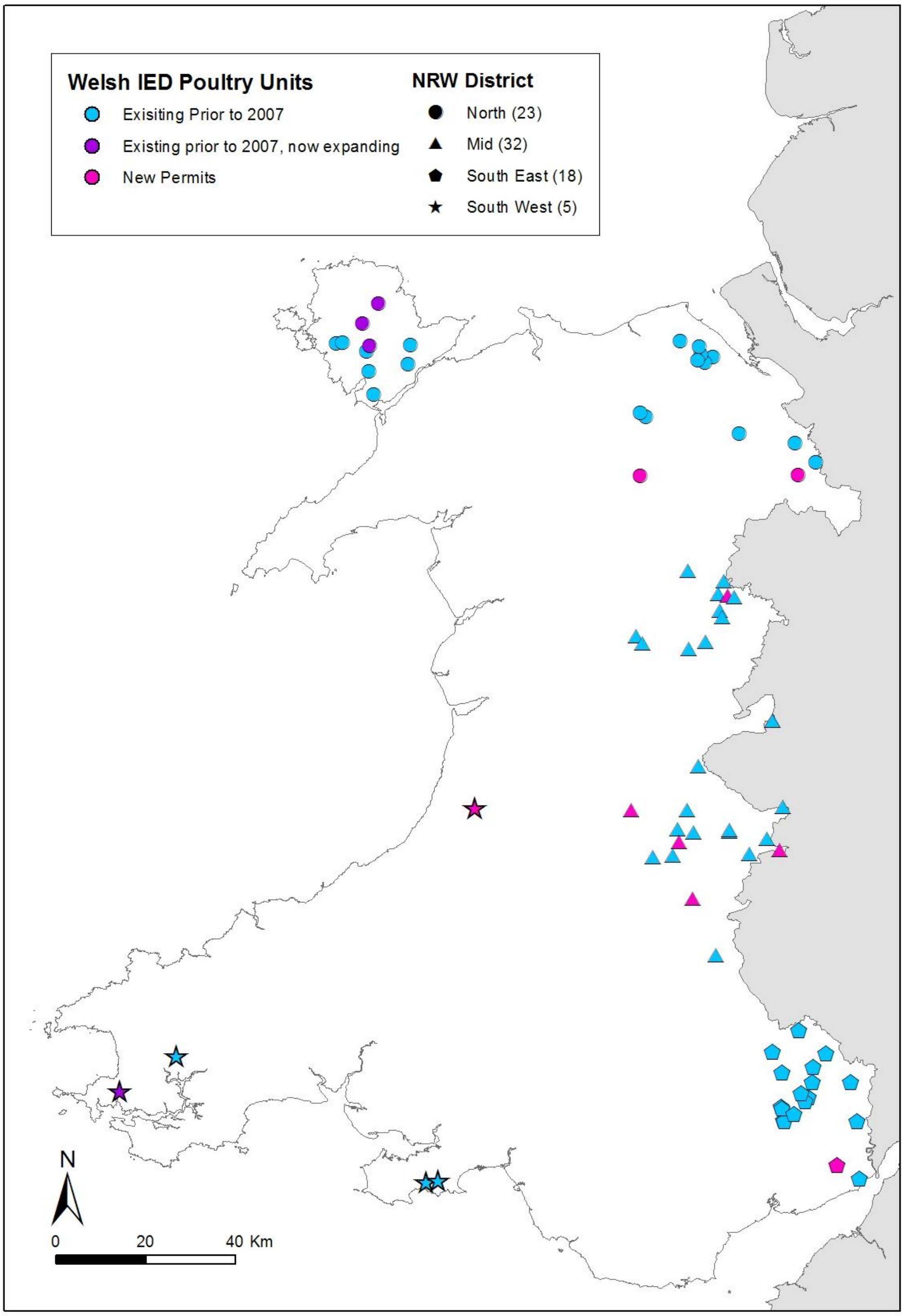


Figure 10 – Location of Welsh IED poultry installations – showing permits granted prior to 2007 in blue; existing permits that are expanding in purple and installations granted from 2007 in pink. The IED farms have been further separated by NRW district.

In developing the next steps, 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).

Overall, after testing of the detailed approach at two example sites, the following **key steps** are recommended, if the approach were to be extended across Wales:

- **Analysis of N deposition (including source attribution, contributions from wet/dry deposition) and NH_3 and NO_x concentrations**; local sources vs. long-range input from diffuse and point source agriculture, roads, non-agricultural sources.
- **Familiarisation with the site, aerial images and output from the previous analysis steps**, pulling together 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)** with an agreed **list of suitable/locally applicable measures**.
- This SNAP could then be implemented to minimise effects from local sources of atmospheric N on Natura 2000 sites (**DRAGONS – Delivering Regional Action on the Ground On Nature 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.

6. References

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Appendix 1: Summary of initial source attribution analysis for all SACs in Wales with terrestrial designated features. Please **click here** to access in an external Excel spreadsheet.

Appendix 2: Agricultural emission densities and main source types for 2 km zones around all SACs in Wales (non-disclosive summary). Please click here to access in an external Excel spreadsheet.

Appendix 3: Atmospheric nitrogen profile for Anglesey Fens Special Area of Conservation (SAC)

Summary & conclusions:

- Anglesey Fens SAC is located in an intensive lowland agricultural landscape, in the eastern part of the Isle of Anglesey, and consists of a number of discontinuous parts. These sub-sites were analysed separately in three groups (northern, southern and eastern) for generating the detailed site nitrogen (N) profile.
- The site's designated plant features are *wet heathland with cross-leaved heath, dry heaths, purple moor-grass meadows,* which are all very sensitive to atmospheric N, whereas *calcium-rich fen dominated by great fen sedge (saw sedge), calcium-rich springwater-fed fens* are less N-sensitive. *The site's other designated features: marsh fritillary butterfly, southern damselfly and Geyer's whorl snail are highly dependent on N sensitive habitats.*
- Current N deposition across the site and in the wider surrounding area is estimated to exceed the critical load of the most sensitive habitat by up to 8.2 kg N ha^{-1} yr^{-1}, using the UK national scale data (5 km grid resolution). The level of exceedance may be underestimated locally for some areas of the site, given the proximity of likely local emission sources.
- Diffuse agricultural activities have been shown to be the main source of atmospheric N for this site, using source attribution modelling. Local agricultural sources, in particular cattle farming and intensive poultry farming, are estimated to contribute approximately half of the N deposition at the site, with the remainder originating from long-range N deposition and non-agricultural sources.
- The estimated agricultural emission densities (14 kg N ha^{-1} yr^{-1}) at the Southern and Northern sub-sites are higher than the Eastern sub-site. Implementing mitigation measures near these two sub-site is therefore likely to be most effective in reducing atmospheric N input.
- Mitigation measures targeting ammonia (NH_3) emissions from cattle farming are particularly relevant for the wider site, given its dominance in the area. Potential activities to target are manure spreading and storage, and minimising emissions from cattle housing. Suitable measures include efficient application of slurries and manures to grassland, as well as following good agricultural practice by accounting for N in manures when calculating mineral fertiliser application rates.
- At the Southern sub-site, 37%of the agricultural emissions are estimated to originate from poultry farming, with > 12 % of this source category thought to originate from an intensive broiler farm < 1,500 m from the sub-site boundary. Given the relatively high density of existing poultry farming in this area, further developments of the poultry industry in the area would need to be assessed carefully with regard to their potential impact to the site.
- Measures targeting the wider area are also relevant here and should be considered, given the large proportion of N deposited to the site as wet deposition from medium- to long-range N sources.

1. Site characteristics

Total site area: 467 ha

Designated features:

Table 3-1 – Designated features at Anglesey Fens SAC

Interest Code	Interest Lay Name	Sensitivity to nitrogen deposition	Expected Exceedance Impact N
S1065	Marsh fritillary butterfly	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Increase in graminoids, decline of typical species, decrease in total species richness
H4010	Wet heathland with cross-leaved heath	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Transition heather to grass. Ericaceous species susceptible to frost and drought.
H4030	Dry heaths	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Transition from heather to grass dominance, decline in lichens, changes in plant biochemistry, increased sensitivity to abiotic stress
S1044	Southern damselfly	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Transition heather to grass. Ericaceous species susceptible to frost and drought.
H6410	Purple moor-grass meadows	Sensitive (Mapping CL > 10-20 kg N ha-1 yr-1)	Increase in tall graminoids, decreased diversity, decrease of bryophytes.
H7210	Calcium-rich fen dominated by great fen sedge (saw sedge)	Less Sensitive (Mapping CL > 20 kg N ha-1 yr-1)	Increase in tall graminoids, decrease in bryophytes
H7230	Calcium-rich springwater-fed fens	Less Sensitive (Mapping CL > 20 kg N ha-1 yr-1)	Increase in tall graminoids, decrease in bryophytes
S1013	Geyer`s whorl snail	Less Sensitive (Mapping CL > 20 kg N ha-1 yr-1)	Increase in tall graminoids, decrease in bryophytes

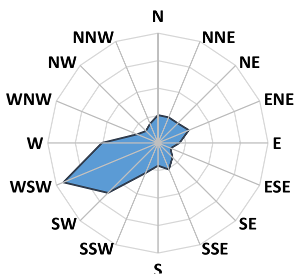


Figure 3-1 – Wind rose showing the annual average (04/14 - 07/15) wind direction (%) in nearby Pentraeth, data from Windfinder (accessed 23/07/15).

Landscape context: Intensive lowland agricultural landscape, situated in the eastern part of Anglesey, with a prevailing wind from the west-south-west. The site is comprised of multiple isolated parts that are separated by distances of up to ~5 km. Recent prevailing wind directions (Figure 3-1) show a predominance of WSW winds (with shorter periods of ENE and SSE winds during the last year) which emphasise the importance of more detailed local assessments for prioritising mitigation measures appropriately, rather than simple distance relationships (see main report for further details). As emission sources and N deposition are likely to vary over the wider area that Anglesey Fens SAC covers, the site has been split into three sub-sites (comprising 74 – 295 ha) for a more detailed assessment of N threats and potential mitigation measures. There are some existing areas of woodland around parts of the site boundary (Southern sub-site, Figure 3-2), although there are no existing tree belts suitable for NH_3 mitigation around most of the site boundary.

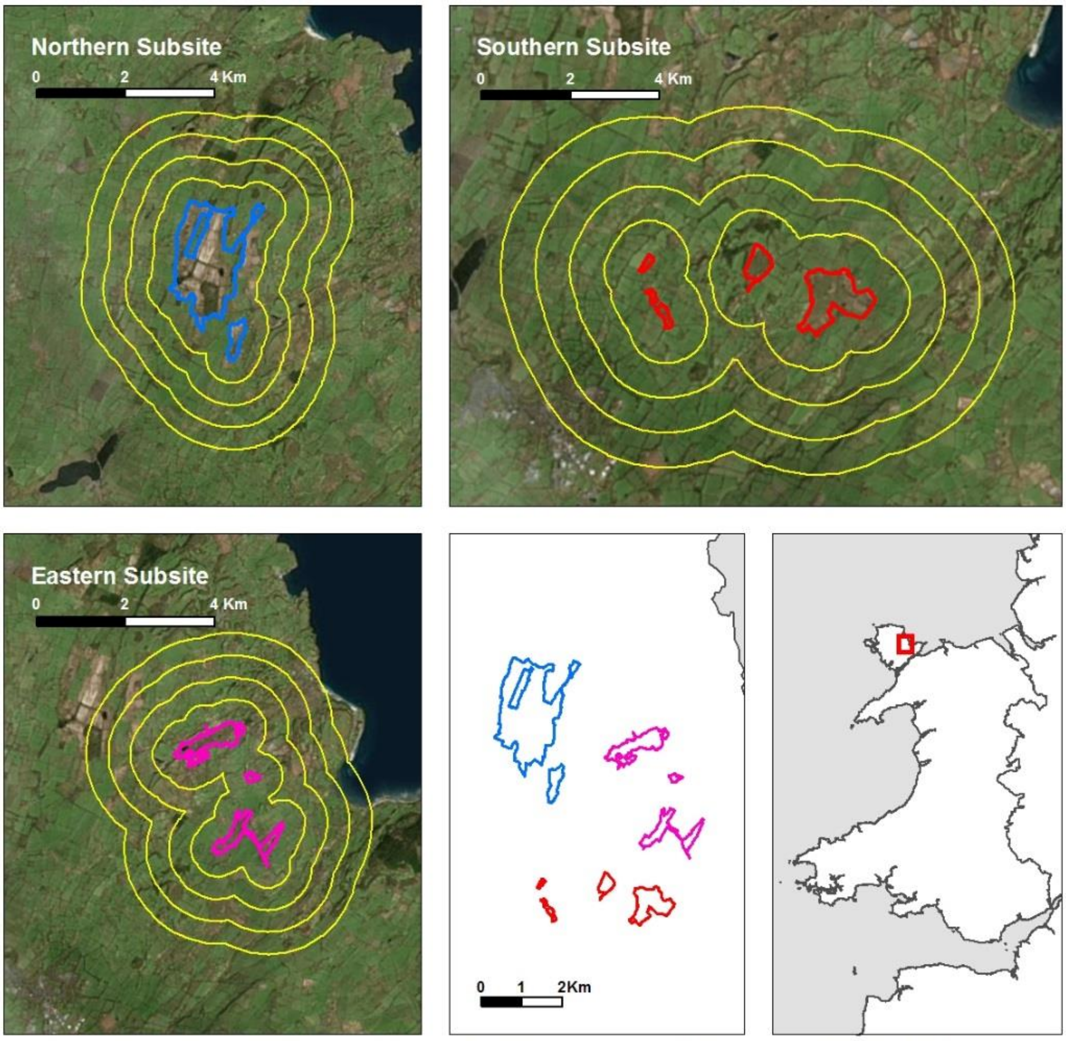


Figure 3-2 – Location of the sub-sites of Anglesey Fens SAC, with concentric 500 m buffer zones surrounding each sub site (up to 2 km) distance from the site boundaries.

2. Deposition and concentration estimates

5 km grid deposition modelling: The most recent available model estimate of N deposition at the site is in exceedance of the designated features' critical loads, with the minimum critical load for dry heath (10 kg N ha^{-1} yr^{-1}) exceeded by up to 8.2 kg N ha^{-1} yr^{-1} (max deposition 18.2 kg N ha^{-1} yr^{-1}, CBED model output for 2012, from APIS). The 2010-2012 estimates of N deposition for this SAC are very similar to those predicted in 2005 (15 – 18 kg N ha^{-1} yr^{-1}), the most recent year with source attribution data (FRAME model output, 2005). The N deposition figures in Table 3-2 refer to source attribution for distinguishing different N sources impacting on the site, however the newer 2010-2012 estimates should be used to estimate critical loads exceedance at the site. Given the large spatial variability of N at the landscape scale, the exceedance values presented in Figure 3-3 are likely to be an underestimate in close proximity to N sources near the site boundary (such as animal housing and manure spreading).

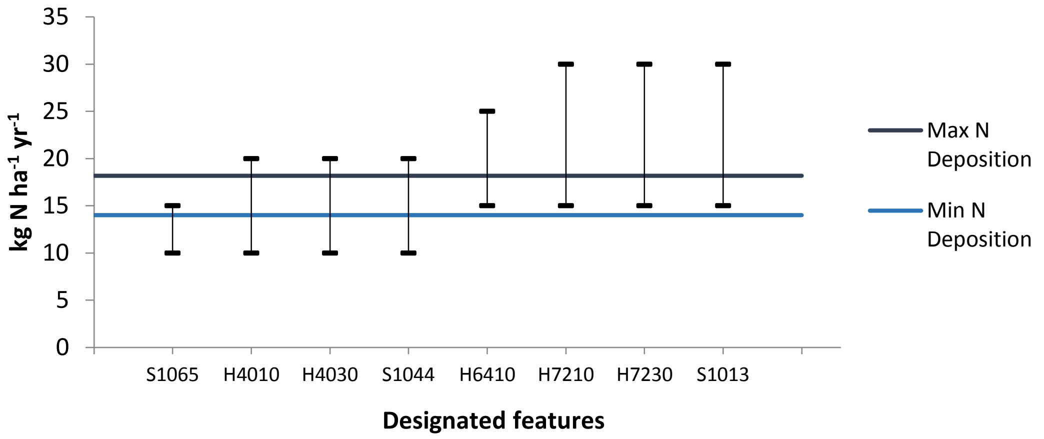


Figure 3-3 – Critical load exceedance for designated features at Corsydd Mon/Anglesey Fens SAC (APIS 2012). Designated features: S1065 - Marsh fritillary butterfly; H4010 - Wet heathland with cross-leaved heath; H4030 - Dry heaths; S1044 - Southern damselfly; H6410 - Purple moor-grass meadows; H7210 - Calcium-rich fen dominated by great fen sedge (saw sedge); H7230 - Calcium-rich springwater-fed fens; and S1013 - Geyer`s whorl snail

N.B. Nitrogen deposition values are derived from the 2010-2012 CBED data (from APIS).

1 km grid NH_3 concentration modelling: Ammonia concentrations of 1 - 2 µg m^{-3} are estimated for all three sub-sites, using the 1 km grid resolution NH_3 dataset (FRAME model output, 2012). This implies that the critical level for higher plants (3 µg m^{-3}) is not generally expected to be exceeded at a 1 km grid resolution, however the critical level for mosses and other lower plants (1 µg m^{-3}) is exceeded across the site, and the IED poultry installations and other 'hot spot' sources may generate more elevated concentrations for some parts of the site. More detailed knowledge of the exact location of NH_3 sources (such as livestock houses or manure spreading close to the site boundaries) would be required to investigate this further, with local expertise. In summary, it is encouraging that the site's average atmospheric NH_3 concentrations are estimated to not exceed 2 µg m^{-3}, and future developments/expansions across all emission sectors should be screened carefully to avoid increasing NH_3 emissions.

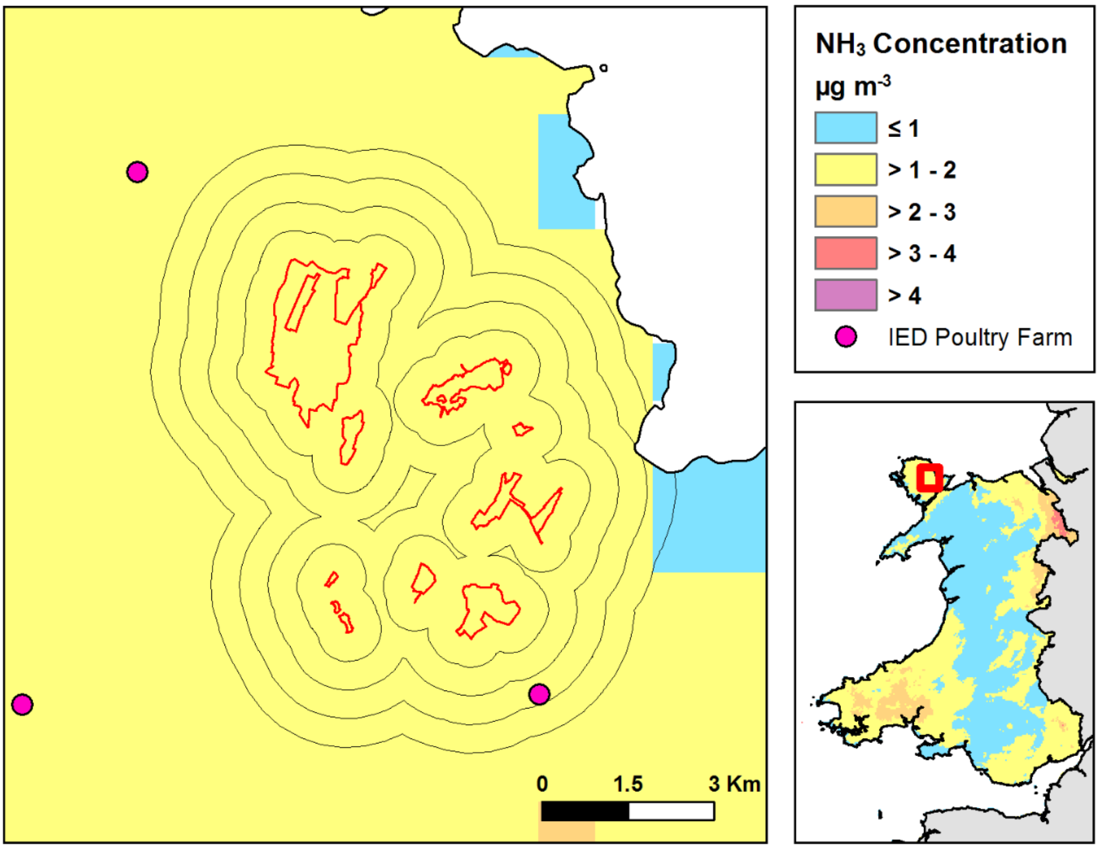


Figure 3-4 – Agricultural NH_3 emission sources in the 2km zone surrounding the sub-sites of Anglesey Fens SAC derived from 2014 agricultural census (with emission factors from the 2013 agricultural NH_3 inventory) and their corresponding emission densities.

3. Source attribution calculations

5 km grid Source attribution calculations: The initial source allocation (using the source attribution dataset from 2005) indicates that agricultural activities are the largest source of total N deposition in the area, at approx. 50% (Figure 3-5). A more detailed assessment, checking the relevant 5 km grid square estimates separately for the three sub-sites, shows agricultural sources contributing ~44 - 56 % of the total N deposition across the four 5 km grid squares containing the whole site (Figure 3-6). Non-agricultural sources represent a smaller proportion (20 - 28 %) of the total N deposition to Anglesey Fens, and the contribution from road transport sources is estimated to be of minor importance, at 4 - 5 % (Figures 3-5, 3-6). A significant fraction of the total N deposition across the sub-sites (23 - 25%) is estimated to be from wet deposition, which is indicative of medium- to long range N sources, rather than local sources. This also ties in with the estimated NH_3 concentrations from the immediate surrounding areas being at around 2 µg m^{-3}.

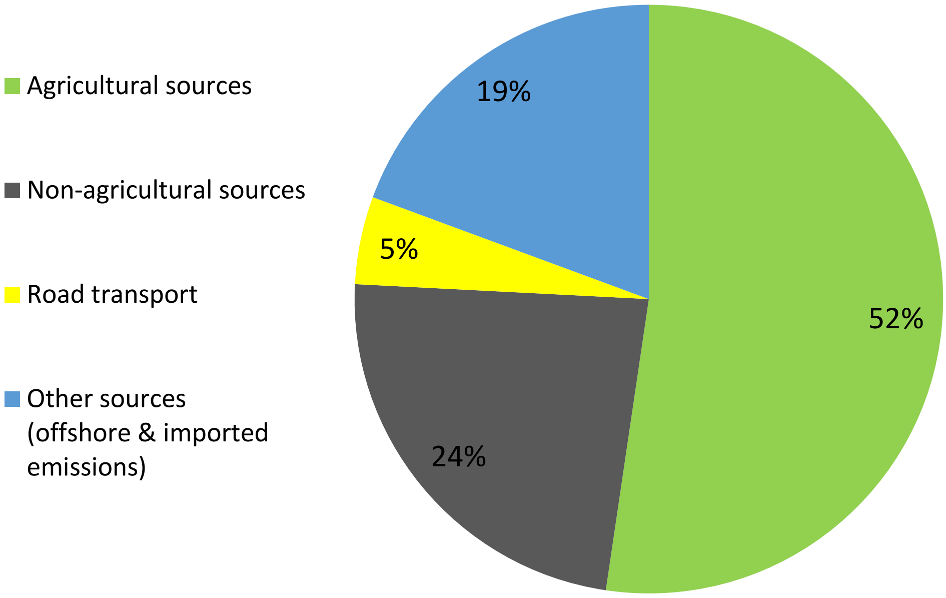


Figure 3-5 – Source attribution chart, showing the mean contributions to the N deposition across the 5 km grid squares which contain Anglesey Fens SAC. Agricultural sources (green) include both regulated (IED) and non-regulated agricultural emission sources, i.e. point sources and diffuse sources.

Table 3-3 – Anglesey Fens SAC: Source allocations derived from the source attribution dataset (2005)

Sub-site	Area (ha)	Source allocations (# assigned, IDs)	Range in total N deposition for sub-site (kg N ha^{-1} yr^{-1})	Source allocations for sub-site (in **bold**)					Nearest point/line sources (m)	
				Source Attribution (% of total N deposition)				Total wet N deposition		
				Agriculture (fertiliser & livestock)	Non-Agricultural sources	Roads	Other*	Long Range N deposition (kg N ha^{-1} yr^{-1})	Intensive farm	Major road
North	295	2 (SA 1, SA 3)	29	**56**	**20**	4	20	4	< 3,500 m	< 3,500 m
East	98	2 (SA 1, SA 3)	25	**44**	**28**	6	22	4	~ 2,500 m	~ 500 m
South	74	3 (SA 1, SA2, SA 3)	28 - 30	**54**	**23**	5	18	4	**< 1,500 m**	< 2,000 m

*Sources which are not included in source allocations, except as wet deposition for the assessment of contributions from long-range transport

N.B. *the source attribution data refers to the 5 km grid square with higher estimated N deposition at each sub-site. Source allocation totals will not add up to 100%, due to rounding and other small source categories, which are not included in the source allocation definitions (e.g. dry deposition from imported emissions and offshore installations). The colour coding shows source allocations in red and emission sources below the threshold un-shaded.*

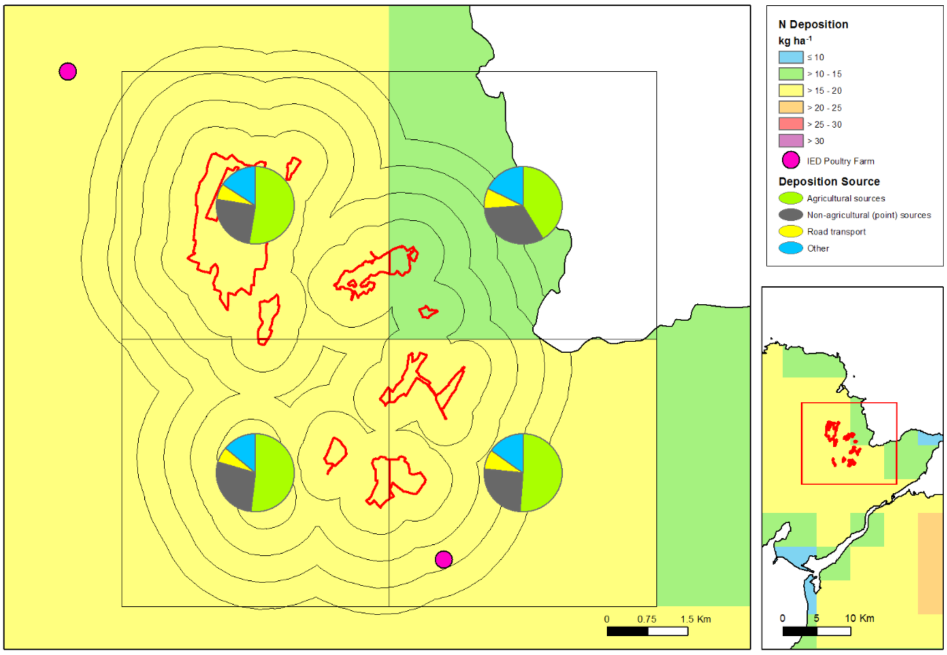


Figure 3-6 – Estimated N deposition (2010 - 2012) and source attribution (2005) for Anglesey Fens SAC. 5 km grids that are outlined contain portions of the site. Sources are categorised using the initial source categorisation (see main project report for details).

4. Inventory of most likely local emissions sources (desk based study) using national datasets

Agricultural Emissions:

The majority of agricultural NH_3 emissions surrounding Anglesey Fens SAC (<2 km) are estimated to derive from cattle farming (Figure 3-6), based on an analysis of the 2014 agricultural census/survey data and using the latest published UK emission factors (Misselbrook *et al.*, 2014; see main report for details). The Southern sub-site has a higher proportion of poultry emissions and a slightly higher emission density of 14 kg NH_3-N ha^{-1} yr^{-1}, compared to the other two sub-sites, at 8 and 13 kg NH_3-N ha^{-1} yr^{-1}, respectively(site average 12 kg NH_3-N ha^{-1} yr^{-1}; see Figure 3-2 for location of the three sub sites). The dominant emission source at the Southern sub-site is thought to be an IED poultry unit <1,350 m from the site boundary. The IED poultry installation has ~200,000 broiler places, with housing emissions estimated at ~5,000 kg NH_3-N yr^{-1}, using site-specific emission factors. The site-specific housing emission factor used in SCAIL is virtually identical (to 3 decimal places) to that used in the UK emission inventory, at 0.025 kg NH_3-N $head^{-1}$ yr^{-1}. The farm's housing emissions are estimated to contribute 0.15 µg m^{-3} of NH_3/0.8 kg N ha^{-1} yr^{-1} at the boundary of the Southern sub-site (SCAIL model[5] output, accessed 17/8/2015). The IED poultry installation northwest of the Northern sub-site also houses broilers and has annual estimated housing emissions of ~5,000 kg N yr^{-1}. Given that the site is > 3 km from this farm and that it is perpendicular to the prevailing wind, this farm is thought to contribute marginally (0.2 kg N ha^{-1} yr^{-1}) to the N deposition and 0.04 µg NH_3 m^{-3} to the NH_3 concentrations received by the boundary of the Northern sub-site.

The dominant cattle emissions at the other sub-sites are likely due to sources such as animal housing, storage and land spreading of manures/slurry, livestock grazing and mineral fertiliser application.

[5] http://www.scail.ceh.ac.uk/

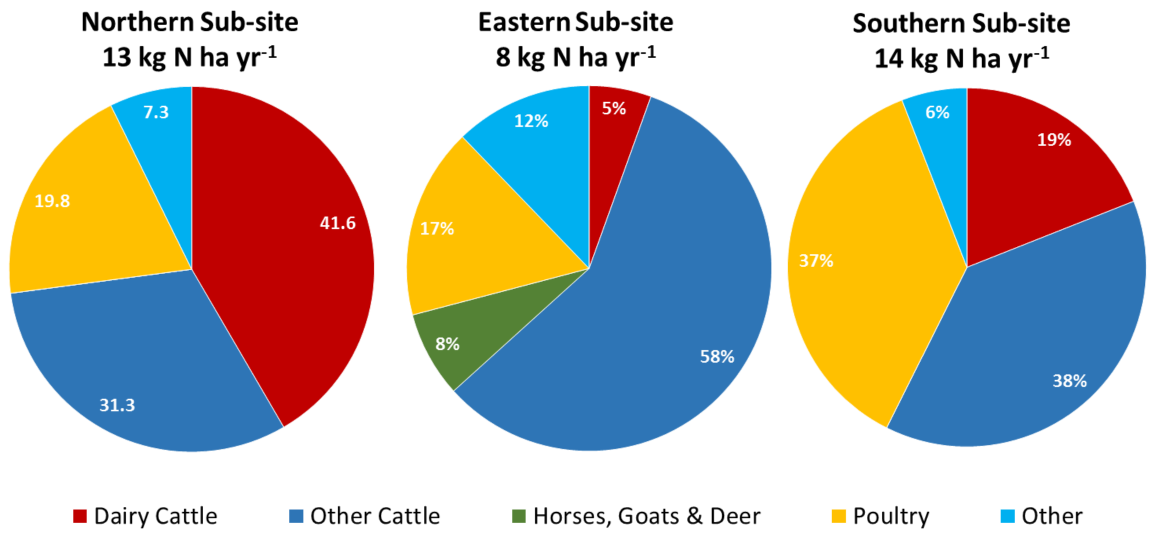


Figure 3-7 – Agricultural NH_3 emission sources in the 2km zone surrounding the sub-sites of Anglesey Fens SAC derived from 2014 agricultural census returns.

Non-agricultural Emissions:

Only one point source of atmospheric N emissions is listed in the NAEI database (naei.org.uk), Penhesgyn Landfill, which is situated ~ 4.5 km to the south-east of the Southern sub-site. The combustion of waste at the landfill site is a relatively minor point-source of NO_x, contributing ~ 5 t-N yr^{-1}.

The A5025 is located ~ 200 m from the Eastern sub-site. The road is estimated to have a daily traffic flow of 7,000 vehicles, of which ~110 are thought to be HGVs. It is estimated that the road produces ~ 0.4 t NO_x-N km^{-1} yr^{-1}. Road transport is therefore not thought to be a significant threat to the SAC as a whole, with road emissions representing well below 10 % of total N deposition in all 5 km grid squares.

N.B. Under project AAANIS, resources were only available for one of the three sub-sites to be studied in detail (agreed with the project Steering Group). The Southern sub-site was selected because of its proximity to a range of sources including an IED poultry farm and due to its relatively higher agricultural emission density.

Southern sub-site - detailed study:

The area surrounding the Southern sub-site is dominated by activities associated with poultry and cattle farming at just below 50% of total emissions for these categories in the surrounding 2 km zone, using agricultural census/survey data and the national emission inventory methodology. There is some evidence of grazing cattle in fields adjoining the SAC from Google Earth (imagery date 20/4/2009), however there are no obvious signs of livestock housing or manure storage within the immediate vicinity of the SAC boundary. There are a patches of woodland between the IED poultry farm (Figure 3-7) and the SAC, however these are discontinuous and narrow (~10 m wide) and are unlikely to contribute substantially to dispersion or recapture of NH_3 emissions from the installation.

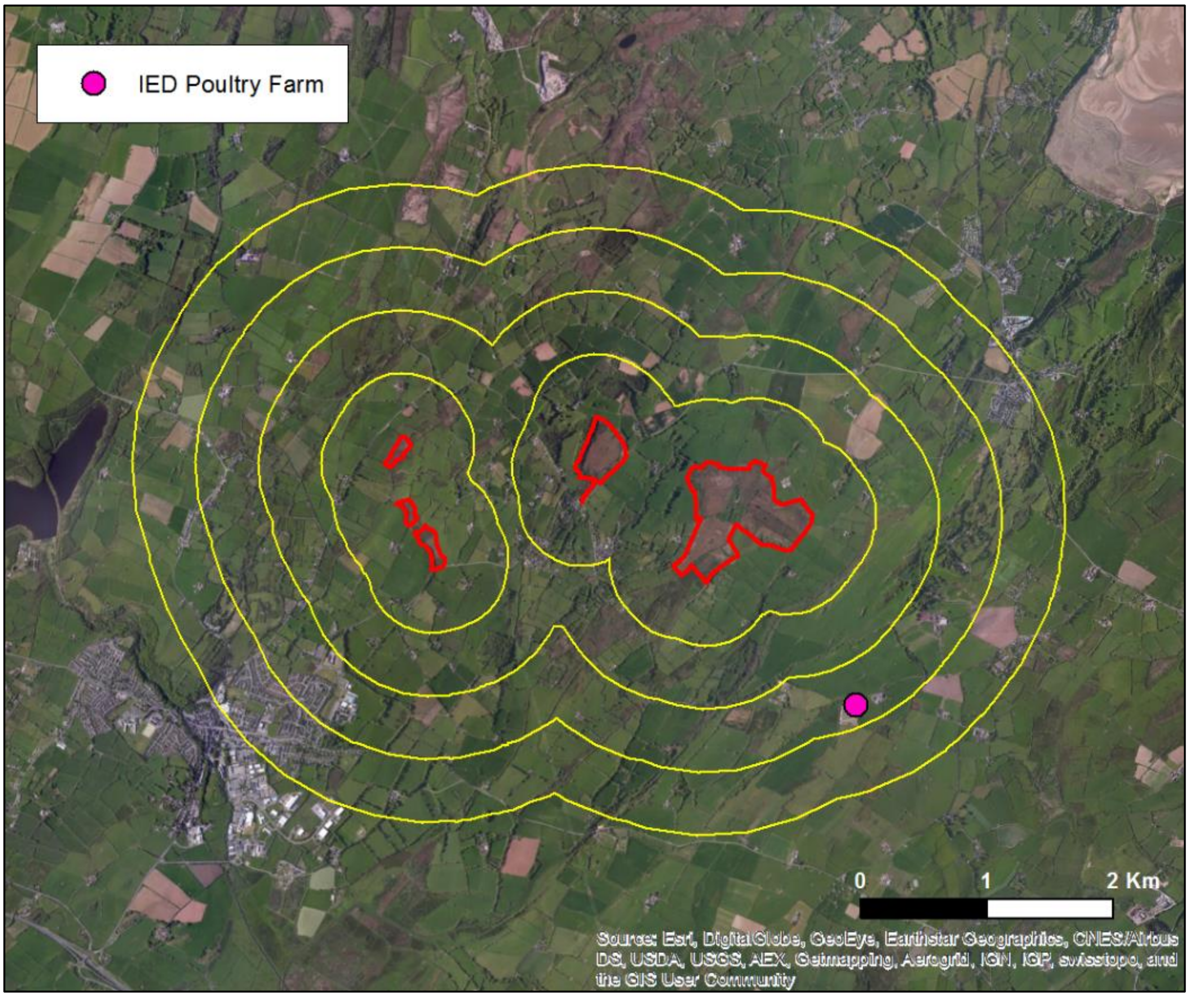


Figure 3-8 – Location of the Southern sub-site of Anglesey Fens SAC, with concentric 500 m buffer zones surrounding the site (up to 2 km).

5. Selection of potential measures

Potential measures for the southern sub-site

Measures targeting emissions from cattle farming are likely to be particularly relevant to the sub-site, given that activities associated with cattle farming contribute to a large fraction of NH_3 emissions within 2 km of the site. Potential activities to target are manure spreading and storage, and minimising emissions from cattle housing. Suitable measures include efficient application of slurries and manures to grassland, as well as generally following good agricultural practice by accounting for N in manures when calculating mineral fertiliser application rates. As the Southern sub-site is not situated immediately downwind from the IED farm and given that the farm is likely to be implementing mitigation measures already, additional measures were not considered here.

General site measures for Anglesey Fens SAC

Some of the measures identified for the Southern sub-site are likely to be relevant to reducing atmospheric N input to the wider SAC. In particular, activities associated with cattle farming are estimated to represent at least 68 % of agricultural NH_3 emissions for the other sub-sites (< 2km from site boundary). Measures for reducing emissions over a wider surrounding area/regionally should be considered for this site, given the high proportion of N deposition falling as wet deposition across all sub-sites. Potential measures across a wider area would need to be delivered through larger-scale incentive schemes or country-wide regulatory approaches, as well as through international agreements.

It should be noted that Table 3-4 summarises potential measures to target only the most significant local sources. Therefore further measures which target minor sources, such as mineral fertiliser application to arable fields, are not listed here, but information on their mitigation effect etc. can be found in the RAPIDS report (Appendix 3 of Dragosits *et al*., 2014b). In addition, as the IED farm close to the SAC is likely to be already implementing all or many of the most cost-effective measures, these are not listed here.

Table 3-4 – Potential local measures for decreasing local concentrations and deposition of nitrogen to the south sub-site of Anglesey Fens SAC for the main local sources, selected from the RAPIDS measures table (Appendix 3 of Dragosits *et al*., 2014)

N source	Measure	Mitigation effect
Arable and grassland	Apply slurry to land via open-slot shallow injection instead of surface broadcast application	Open-slot injection -70 % Closed-slot injection -90 %
Arable and grassland	Surface applied slurry is incorporated into the soil shortly after application by either plough, disc or tine	< 4 hrs (Plough - 65%; Disc/tine - 50%) < 24 hrs - 30%
Arable and grassland	Surface applied FYM is incorporated into the soil shortly after application by either plough, disc or tine	< 4 hrs (Plough - 70%; Disc/tine - 45%) < 24 hrs - 30%
Cattle farms	Farm yard manure heaps are covered with an impermeable sheet for the duration of storage	60%
Dairy farms	Formulating dairy cattle diets such that protein content does not greatly exceed requirement	10%
Dairy farms	Increased frequency of removing manure from the floor of dairy cow cubicle housing	15%
Dairy farms	Installation of grooved floors allowing faster drainage of urine to storage, thus lowering the potential for NH_3 emission from dairy house floors.	35%
Dairy farms	Pressure washing (or hosing and brushing) of dairy cow collecting yards immediately following each milking event	70%
Existing un-covered slurry lagoons and tanks	Use of slurry bags instead of existing un-covered slurry storage facilities	95%
Manure heaps	Siting of temporary manure heaps in fields away from the vicinity of Designated Sites (at least 500m), also taking account of local topography and prevailing winds	Reduction in NH_3 concentration and deposition at the site, 0 % reduction in emissions
Manure heaps	Cover farm yard manure heaps with an impermeable sheet for the duration of storage	60%
Slurry lagoons	Addition of floating clay granules (or similar material) to reduce gaseous NH_3 transfer from slurry surface to the atmosphere	50%
Slurry lagoons	Tree belt shelters air flow across the lagoon and also re-captures ammonia downwind of the slurry store (note modelling included the increase in T associated with the sheltering of the slurry	20%
Slurry tanks	Fitting a tent-like structure to above-ground slurry tanks to reduce gaseous transfer from the slurry to the atmosphere	80%

N source	Measure	Mitigation effect
Sources located to the WSW of the site (upwind)	Consider suitable sites for planting tree belts downwind of NH_3 sources (e.g. livestock houses) close to the designated site, or upwind of the designated site (in relation to the prevailing wind direction)	20%

References:

Dragosits U., Carnell E.J., Jones L., Rowe E., Hall J.R., Dise N., Dore A.J., Tomlinson S.J., Sheppard L., Reis S., Bealey W., Braban C.F., Misselbrook T.H., Stevens C., O'Shea L., Smyntek P. and Sutton M.A. (2014b) Identification of Potential "Remedies" for Air Pollution (nitrogen) Impacts on Designated Sites (R.A.P.I.D.S.). Defra project AQ0834, Draft final report. 59pp (main report) + 11 appendices (November 2014).

Misselbrook T.H., Gilhespy S.L., Cardenas L.M., Chambers B.J., Williams J. and Dragosits U. (2014) Inventory of Ammonia Emissions from UK Agriculture 2012. Inventory submission report. Defra Contract SCF0102. Rothamsted Research, North Wyke, Okehampton, Devon EX20 2SB. 34 pp (Jan. 2014)

Appendix 4: Atmospheric nitrogen profile for Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses Special Area of Conservation (SAC)

Summary & conclusions:

- Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC is located in an intensive lowland agricultural landscape on the border between England and Wales.
- The site's designated features are *Active raised bogs, Degraded raised bogs which are very sensitive to N and Dry heaths*, which are all sensitive to N.
- Current N deposition across the site and in the wider surrounding area is estimated to exceed the critical load of the most sensitive habitat by up to 25.5 kg N ha^{-1} yr^{-1}, using the UK national scale data (5 km grid resolution). The level of exceedance may be underestimated locally for some areas of the site, given the proximity of likely local emission sources.
- Diffuse agricultural activities have been shown to be the main source of atmospheric N for this site, using source attribution modelling. Regional and local agricultural sources contribute to approximately 70 % of the deposition at the site, with ~17 -22 % of the total N deposited estimated to originate from long-range N deposition.
- Given the dominance of dairy farming in the area surrounding the SAC, mitigation measures targeting ammonia (NH_3) emissions from cattle would be particularly relevant here,. Potential activities to target are manure spreading and storage, and minimising emissions from cattle housing. Suitable measures include efficient application of slurries and manures to grassland, as well as following good agricultural practice by accounting for N in manures when calculating mineral fertiliser application rates.
- Measures targeting the wider area are also relevant here and should be considered, given the large proportion of N deposited to the site as wet deposition from medium- to long-range N sources. This is especially relevant for this site, which straddles the border between England and Wales.
- Close collaboration between NRW and NE would be required for spatial targeting of measures at this site, with emission source density being higher on the English side of the border. (N.B. English emission sources were considered using data from the IPENS-049 project (Dragosits *et al*., 2014) but not been assessed in detail in the detailed analysis).

1. Site characteristics

Total site area: 728 ha

Designated features:

Table 4-1 – Designated features at Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC –

Interest code	Interest lay name	Sensitivity to nitrogen deposition	Expected exceedance impact N
H7110	Active raised bogs	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Increase in vascular plants, altered growth and species composition of bryophytes, increased N in peat and peat water
H7120	Degraded raised bog	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Increase in vascular plants, altered growth and species composition of bryophytes, increased N in peat and peat water
H4030	Dry heaths	Sensitive (Mapping CL > 10-20 kg N ha-1 yr-1)	Transition from heather to grass dominance, decline in lichens, changes in plant biochemistry, increased sensitivity to abiotic stress

Landscape context: Intensive lowland agricultural landscape on the border between England and Wales. Recent prevailing winds were variable, with predominant WSW directions but substantial NW and SE elements (Figure 4-1). Local variability in wind directions emphasises the importance of more detailed local assessments for prioritising mitigation measures appropriately, rather than simple distance relationships (see main report for further details).

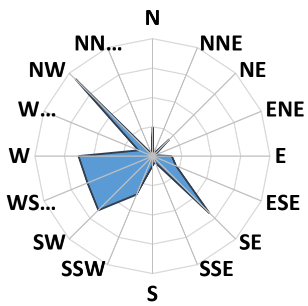
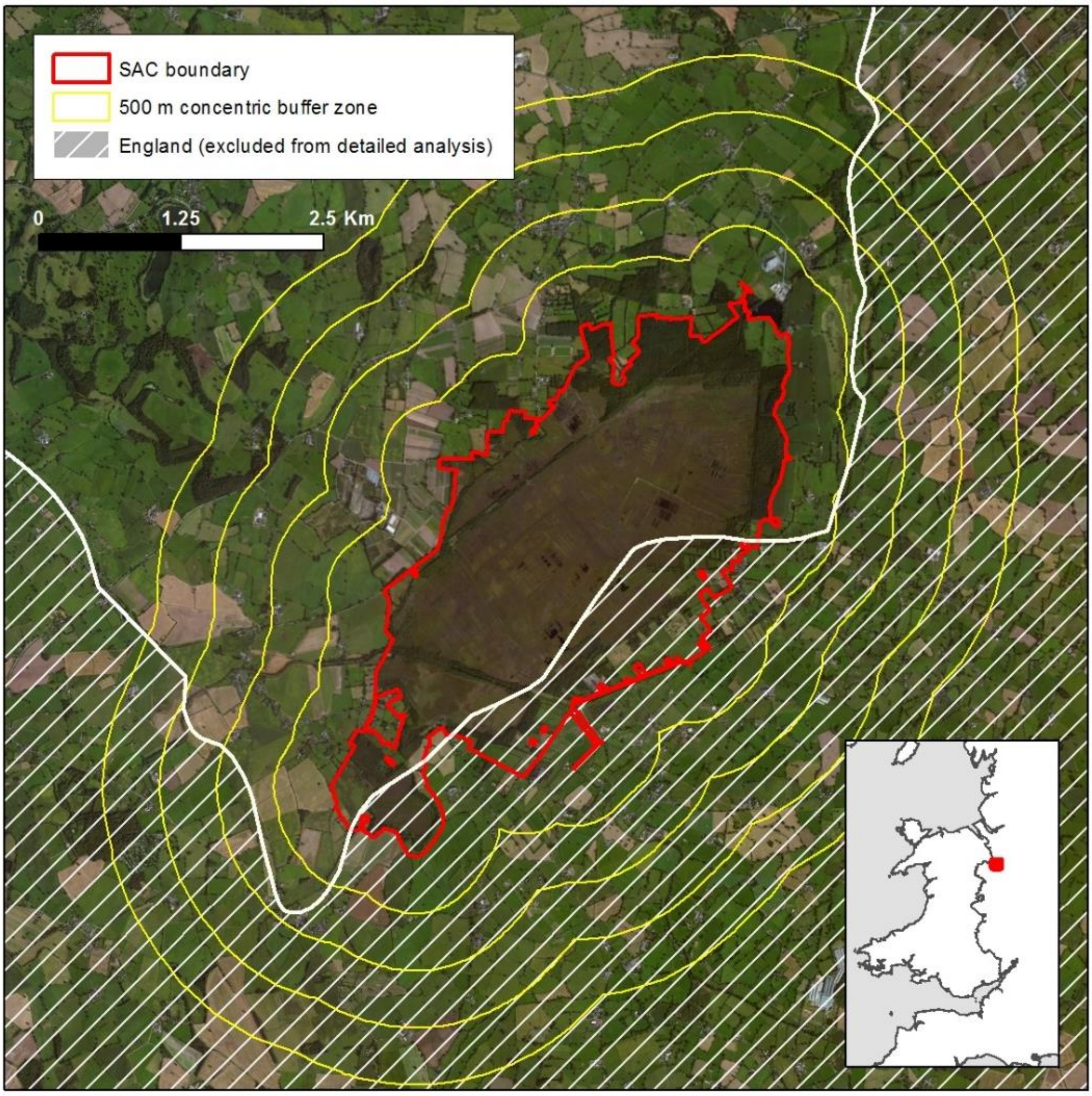


Figure 4-2 – Wind rose showing the annual average (09/09 - 07/15) wind direction (%) in nearby Whixall, data from Windfinder.com (accessed 06/08/15).

There are some existing tree belts surrounding the site of varying widths, with sections to the north of the site up to ~200 m. However, there are large sections in the south west which are unsheltered and given the direction of the prevailing wind, these existing tree belts are not well placed to capture nitrogen from sources upwind of the site. English emission sources have not been assessed in detail in the detailed analysis but have considered using data from the IPENS-049 project (Dragosits *et al.*, 2014). Data derived from the source attribution dataset considers deposition at the 5 km grid resolution, irrespective of the devolved authority from which the N originates.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4-2 – Location of Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC, with concentric 500 m buffer zones surrounding the site (up to 2 km).

2. Deposition and concentration estimates

5 km grid deposition modelling: The most recent available model estimate of N deposition at the site is in exceedance of the designated features' critical loads, with the 5 kg N ha^{-1} yr^{-1} minimum critical load of the site's active and degraded bogs exceeded by up to 25.5 kg N ha^{-1} yr^{-1} (max. deposition 30.5 kg N ha^{-1} yr^{-1}, CBED model output for 2012, from APIS).The 2010-2012 estimates of N deposition for this SAC are very similar to those predicted in 2005 (~25 - 30 kg N ha^{-1} yr^{-1}), the most recent year with source attribution data (FRAME model output, 2005). The N deposition figures in Table 4-2 refer to the source attribution data for distinguishing different N sources impacting on the site, however the newer 2010-2012 estimates should be used to estimate critical loads exceedance at the site. Given the large spatial variability of N at the landscape scale, the exceedance values presented in Figure 3 are likely to be an underestimate in close proximity to N sources near the site boundary (such as animal housing and manure spreading).

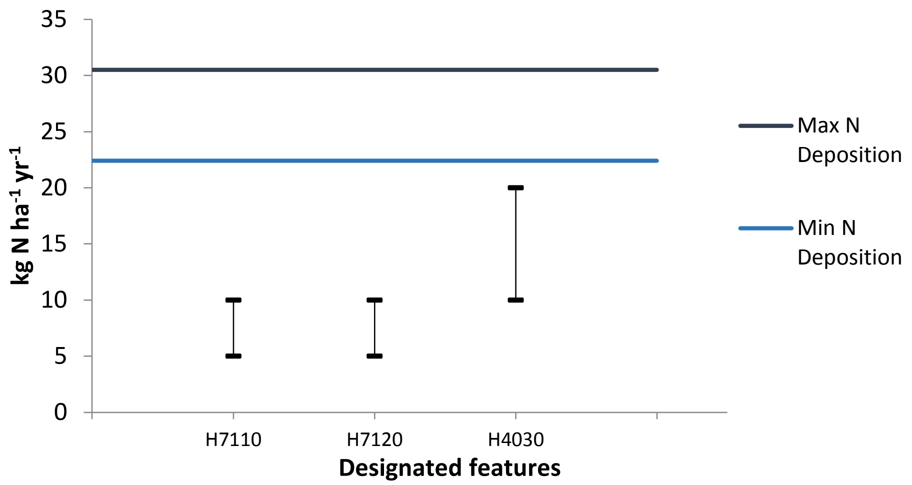


Figure 4-3 – Critical load exceedance for designated features at Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC (APIS 2012). Designated features: H7110 Active raised bogs, H7120 Degraded raised bog; H4030 Dry heaths
N.B. Nitrogen deposition values are derived from the 2010-2012 CBED data (from APIS).

Ammonia concentrations are estimated at 2 - 3 µg m^{-3} across most of the SAC, using a 1 km grid resolution NH_3 dataset (FRAME model output, 2012). Concentrations of 3 - 4 µg m^{-3} are estimated for areas to the south east of the site, likely due to several large intensive pig/poultry farms (IED) in the area, in addition to the diffuse sources from dairy farming in the wider area. Most of the nearby IED farms are located to the south and southeast of the site, in England (Figure 4-4). This points to the specific need for cross-border collaboration for devising a site nitrogen action plan (SNAP) for this site and for stakeholder engagement to deliver on site measures to minimise effects (DRAGONS - Delivering Regional Action on the Ground On Nature Sites).

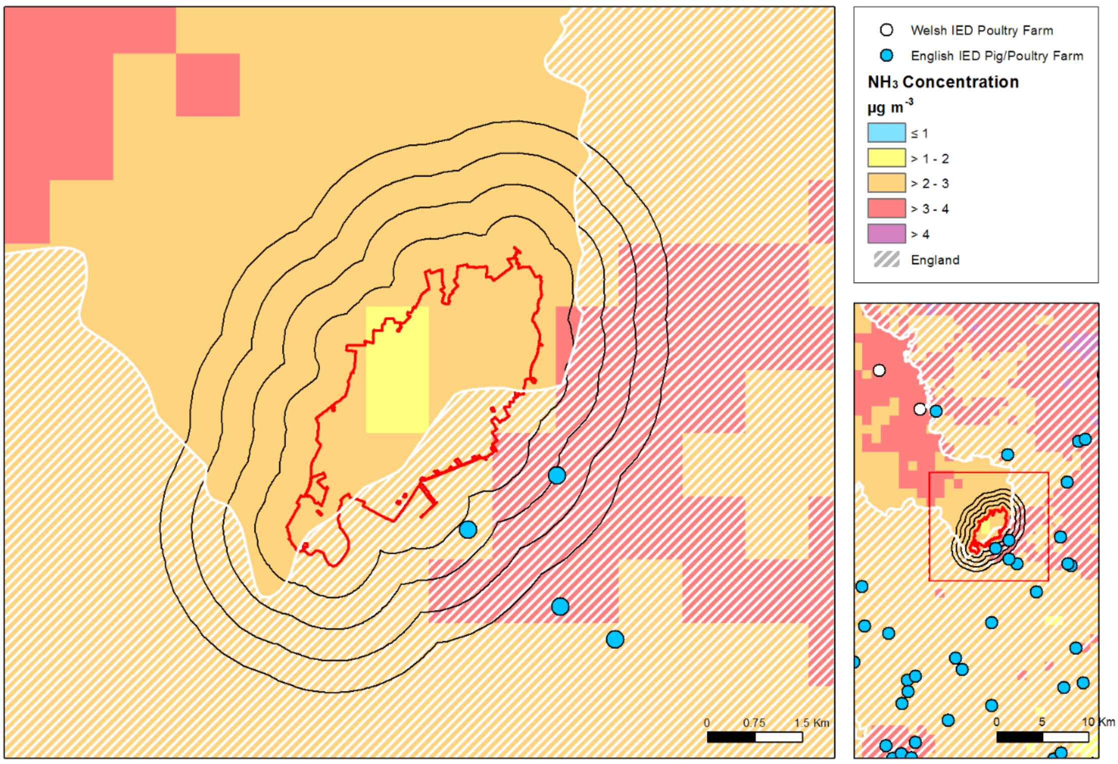


Figure 4-4 – Ammonia concentrations at Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC (FRAME 1 km dataset for 2011), showing locations of large intensive pig and poultry farms regulated under the Industrial Emissions Directive (IED) farms surrounding the site.

3. Source attribution calculations

5 km grid Source attribution calculations: The initial source allocation (using the source attribution dataset from 2005) indicates that agricultural activities contribute the majority of total N deposition, at approx. 68% (Figure 4-5). A more detailed assessment, checking the three 5 km grid square estimates that cover the SAC, shows agricultural sources contributing up to 73% of the total N deposition in the south eastern part of the SAC (Figure 4-6). A smaller proportion (15 - 18 %) of the total N deposition to the site is attributed to non-agricultural sources and the contribution from road transport sources is estimated to be of minor importance, at 4 - 5 % (Figures 4-5, 4-6). A significant fraction of the total N deposition across the sub-sites (5 kg N ha^{-1} yr^{-1}, 17 - 21%) is estimated to be from wet deposition, which is indicative of medium- to long range N sources, rather than local sources.

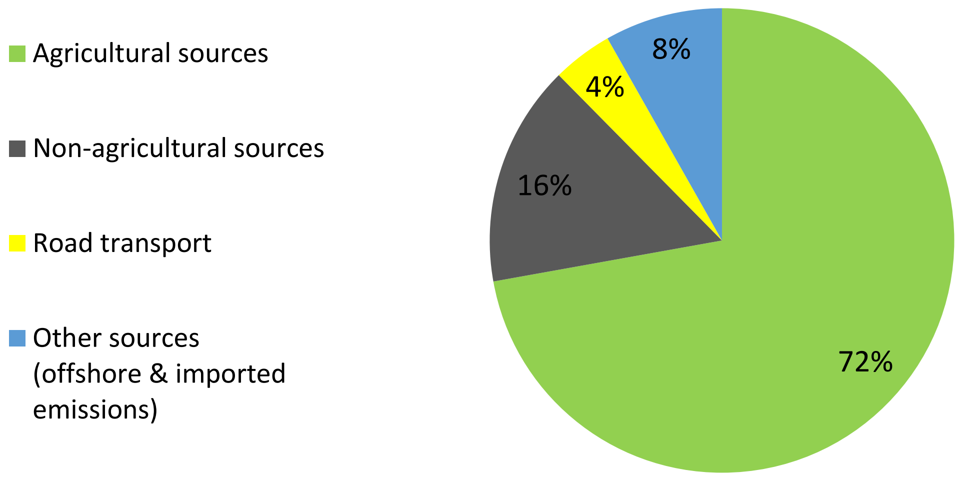


Figure 4-5 – Source attribution chart, showing the mean contributions to the N deposition across the 5 km grid squares which contain Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC. Agricultural sources (green) include both regulated (IED) and non-regulated agricultural emission sources, i.e. point sources and diffuse sources.

Table 4-3 – Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC: Source allocations derived from the source attribution dataset (2005)

Source allocations (# assigned, IDs)	Range in total N deposition for site (kg N ha^{-1} yr^{-1})	Source allocations for sub-site (in **bold**) Source Attribution (% of total N deposition): Agriculture (fertiliser & livestock)	Non- Agricultural sources	Roads	Other	Total wet N deposition: Long Range N deposition (kg N ha^{-1} yr^{-1})	Nearest point/line sources (m): Welsh Intensive farm*	Major road
2 (SA 1, SA 3)	25 - 30	**68 - 70**	**15 - 18**	4-5	8-10	5	< 10,00 m	< 700 m

*There are two pig/poultry IED farms located < 1km from the SAC, in England.

N.B. *the source attribution data refers to the 5 km grid square with the highest estimated N deposition. Source allocation totals will not add up to 100%, due to rounding and other small source categories, which are not included in the source allocation definitions (e.g. dry deposition from imported emissions and offshore installations). The colour coding shows source allocations in red and emission sources below the threshold un-shaded.*

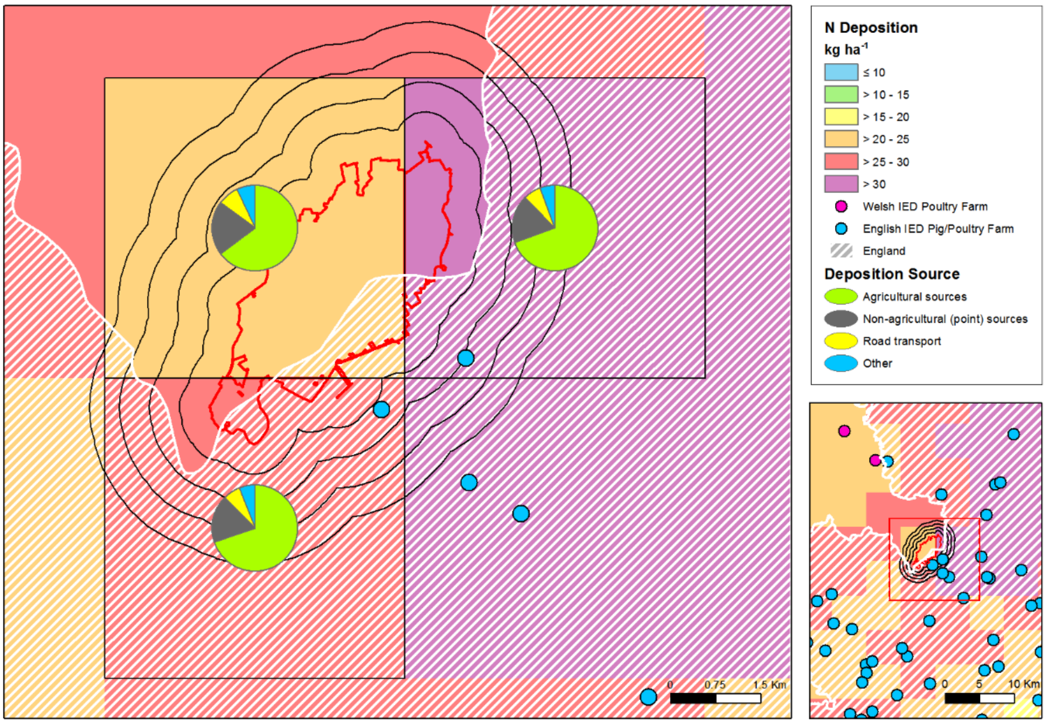


Figure 4-6 – Estimated N deposition (2010 - 2012) and source attribution (2005) for Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC. 5 km grid squares that are outlined contain portions of the site. Sources are categorised using the initial source categorisation (see main project report for details).

4. Inventory of most likely local emissions sources using national datasets (desk based study)

Agricultural Emissions:

The majority (65 %) of agricultural NH_3 emissions surrounding the SAC (<2 km) on the Welsh side are estimated to derive from dairy farming, based on an analysis of agricultural census/survey data for 2014 (Figure 4-7). The emission density for the surrounding area (Wales only) is estimated at 20 kg NH_3-N ha^{-1} yr^{-1}, using the latest data from the UK agricultural emission inventory (Misselbrook *et al.,* 2014) The dominant dairy cattle emissions derive from sources such as animal housing, storage and land spreading of manures/slurry, livestock grazing and mineral fertiliser application. Cattle grazing appears to occur within the northern part of the SAC, and there are a number of fields surrounding the site where livestock are grazing, in addition to arable fields bordering the SAC (Google Earth imagery, accessed 6/8/2015, images dated 20/04/2009). On the English side of the SAC, the estimated emission density is higher at 38 kg NH_3-N ha^{-1} yr^{-1} and poultry farming represents 28 % of agricultural NH_3 emissions from the English 2 km buffer zone.

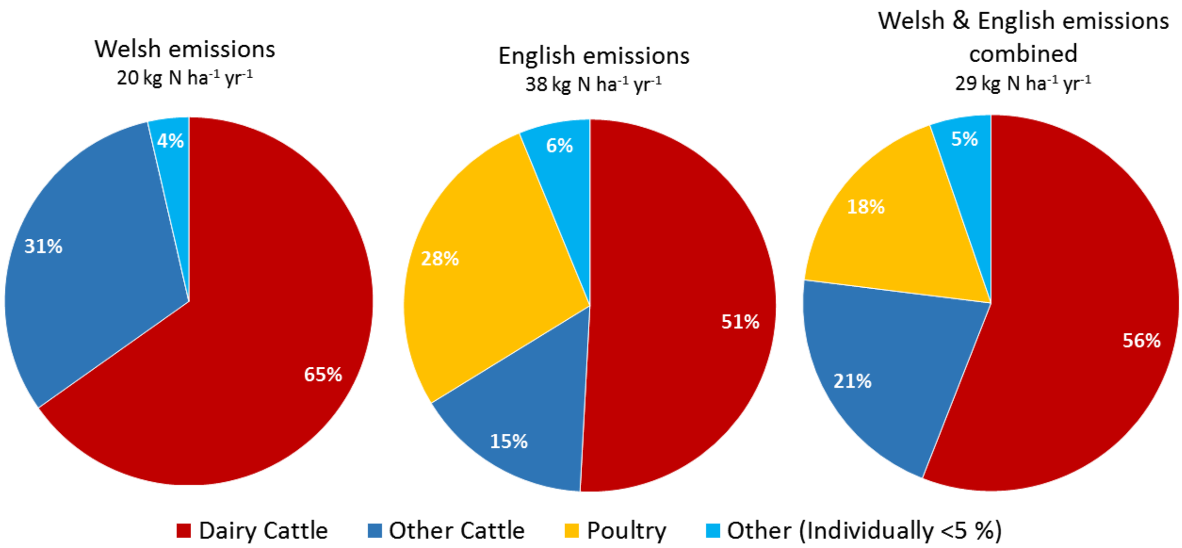


Figure 4-7 – Agricultural NH_3 emission sources in the 2km zone surrounding the sub-sites of Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC. With Welsh emissions derived from 2014 agricultural census/survey returns and English emissions derived from the 2012 agricultural census/survey returns (IPENS-049 project, Dragosits *et al.,* 2014).

Non-agricultural Emissions:

There are no large point sources of NH_x or NO_x emissions within 10 km of the SAC, according to the NAEI database (http://naei.defra.gov.uk/), There are no major roads within the 200 m threshold used for the source allocation, the nearest major road is the A495 ~700 m north-west of the site boundary.

6. Selection of potential measures

Local agricultural sources are estimated to contribute significantly to the local N deposition and elevated NH_3 concentrations at Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC. Therefore agricultural sources are the most promising for reducing N deposition to the site through spatially targeted mitigation measures (Table 4-3). Measures targeting emissions from cattle farming are particularly relevant here, given its dominance in the area. Key activities to target are manure/slurry spreading and storage, and minimising emissions from cattle housing. Suitable measures include efficient low-emission application of slurries and manures to grassland, in addition to following good agricultural practice by accounting for N in manures when calculating mineral fertiliser application rates. In order to address the threat from long-range N deposition, measures for reducing emissions in a wider area should also be considered. Potential measures across a wider area could be delivered through a large-scale incentive scheme or regulatory approaches.

It should be noted that Table 4-4 summarises potential measures to target only the most significant local sources. Therefore further measures which target minor sources, such as mineral fertiliser application to arable fields, are not listed here, but information on their mitigation effect etc. can be found in the RAPIDS report (Appendix 3 of Dragosits et al., 2014b). In addition, as the majority of IED farms close to SACs are likely already implementing all or many of the most cost-effective measures, therefore these are not listed here. However, there may be the potential for further emission reductions from these large intensive pig and poultry farms.

Table 4-4 – Potential local measures for decreasing local concentrations and deposition of nitrogen to for Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC for the main local sources, selected from the RAPIDS measures table (Appendix 3 of Dragosits et al., 2014b)

N source	Measure	Mitigation effect
Arable and grassland	Apply slurry to land via open-slot shallow injection instead of surface broadcast application	Open-slot injection -70 % Closed-slot injection -90 %
Arable and grassland	Surface applied slurry is incorporated into the soil shortly after application by either plough, disc or tine	< 4 hrs (Plough - 65%; Disc/tine - 50%) < 24 hrs - 30%
Arable and grassland	Surface applied FYM is incorporated into the soil shortly after application by either plough, disc or tine	< 4 hrs (Plough - 70%; Disc/tine - 45%) < 24 hrs - 30%
Cattle farms	Farm yard manure heaps are covered with an impermeable sheet for the duration of storage	60%
Dairy farms	Formulating dairy cattle diets such that protein content does not greatly exceed requirement	10%
Dairy farms	Increased frequency of removing manure from the floor of dairy cow cubicle housing	15%
Dairy farms	Installation of grooved floors allowing faster drainage of urine to storage, thus lowering the potential for NH_3 emission from dairy house floors.	35%
Dairy farms	Pressure washing (or hosing and brushing) of dairy cow collecting yards immediately following each milking event	70%
Existing un-covered slurry lagoons and tanks	Use of slurry bags instead of existing un-covered slurry storage facilities	95%
Manure heaps	Siting of temporary manure heaps in fields away from the vicinity of Designated Sites (at least 500m), also taking account of local topography and prevailing winds	Reduction in NH_3 concentration and deposition at the site, 0 % reduction in emissions
Manure heaps	Cover farm yard manure heaps with an impermeable sheet for the duration of storage	60%
Slurry lagoons	Addition of floating clay granules (or similar material) to reduce gaseous NH_3 transfer from slurry surface to the atmosphere	50%
Slurry lagoons	Tree belt shelters air flow across the lagoon and also re-captures ammonia downwind of the slurry store (note modelling included the increase in T associated with the sheltering of the slurry	20%
Slurry tanks	Fitting a tent-like structure to above-ground slurry tanks to reduce gaseous transfer from the slurry to the atmosphere	80%
Sources located to the west and south of the site (upwind)	Consider suitable sites for planting tree belts downwind of NH_3 sources (e.g. livestock houses) close to the designated site, or upwind of the designated site (in relation to the prevailing wind direction)	20%

References:

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Dragosits U., Carnell E.J., Misselbrook T.H. and Sutton M.A. (2014) Site categorisation for nitrogen measures. Final report to Natural England on project IPENS-049. 20pp. + appendix (October 2014).

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