Improvement Programme for England's Natura 2000 Sites (IPENS) – Planning for the Future IPENS049

Case Study F: Atmospheric nitrogen profile for North York Moors SAC

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Atmospheric nitrogen profile for North York Moors Special Area of Conservation (SAC)

> This document has been produced as part of IPENS049. Please read this site profile in conjunction with the report (Dragosits *et al.* 2014) that explains the methods and background. For more information visit - [Improvement Programme for England's Natura 2000 sites (IPENS)]

Conclusions:

- North York Moors SAC site is located in an upland agricultural landscape in NE England. Its designated habitats are very sensitive to atmospheric nitrogen (N).
- The site's designated features are *Wet heathland with cross-leaved heath, Dry heaths, Blanket bog,* which are all sensitive to N.
- Current N deposition in the wider area is estimated to exceed the critical load of the most sensitive habitat by up to 22.2 kg N ha^{-1} yr^{-1}, using the UK 5 km grid data. The level of exceedance may be underestimated locally for some areas of the site, given the proximity of likely local emission sources.
- Measures targeting the wider area are particularly 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 (66-76%), from both agricultural and non-agricultural sources.
- Diffuse agricultural activities are a main source of atmospheric N deposition to this site, from both local and medium/long-range sources. Agricultural sources, in particular cattle farming and intensive pig and poultry farming, are estimated to contribute significantly to the deposition (~50%).
- The estimated agricultural emission density at sub-site C was slightly higher than the other sub-sites, at 11 kg NH_3-N ha^{-1} yr^{-1}. Implementing agricultural mitigation measures at this sub-site may therefore be relevant for reducing local deposition.
- Mitigation measures targeting ammonia (NH_3) emissions from cattle farming would be particularly relevant here, given its dominance in the area (64% of agricultural emissions in an area up to 2 km from the boundary of sub-site C. Potential activities to target are manure spreading and storage, and minimising emissions from cattle housing. Suitable measures include low-emission 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.
- Sub-sites C and D are likely to receive some N deposition from A-roads which intersect the sites. National level incentive schemes such as the promotion of greener technologies and transport choices should be promoted.
- Measures to reduce emissions from non-agricultural sources, such as RAF Fylingdales which is near to the site boundary (< 100 m), and upwind of the site should also be investigated.

1. Site characteristics

Site area: 440 km^2

Designated features:

Table 1 - Designated features for North York Moors SAC

Interest Code	Interest Lay Name	Sensitivity to nitrogen deposition	Expected Exceedance Impact N
H4010	Wet heathland with cross-leaved heath	Very sensitive (Mapping CL ≤ 10 kg N ha^{-1} yr^{-1})	Leaching will cause a decrease in soil base saturation, increasing the availability of Al3+ ions, mobilisation of Al3+ may cause toxicity to plants and mycorrhiza, may have direct effect on lower plants (bryophytes and lichens).
H4030	Dry heaths	Very sensitive (Mapping CL ≤ 10 kg N ha^{-1} yr^{-1})	
H7130	Blanket bog	Very sensitive (Mapping CL ≤ 10 kg N ha^{-1} yr^{-1})	

Landscape Context: The site is located in an upland agricultural landscape of N.E. England. The site is comprised of ten distinct parts, with relatively small distances separating the sites. As emission sources and N deposition are likely to vary over the wide area that North York Moors SAC covers, the site has been split into four sub-sites A-D for the more detailed assessment of N threats and potential mitigation measures.. There are some existing areas of woodland around the site boundary, although there are no existing tree belts suitable for NH3 mitigation around most of the site boundary.

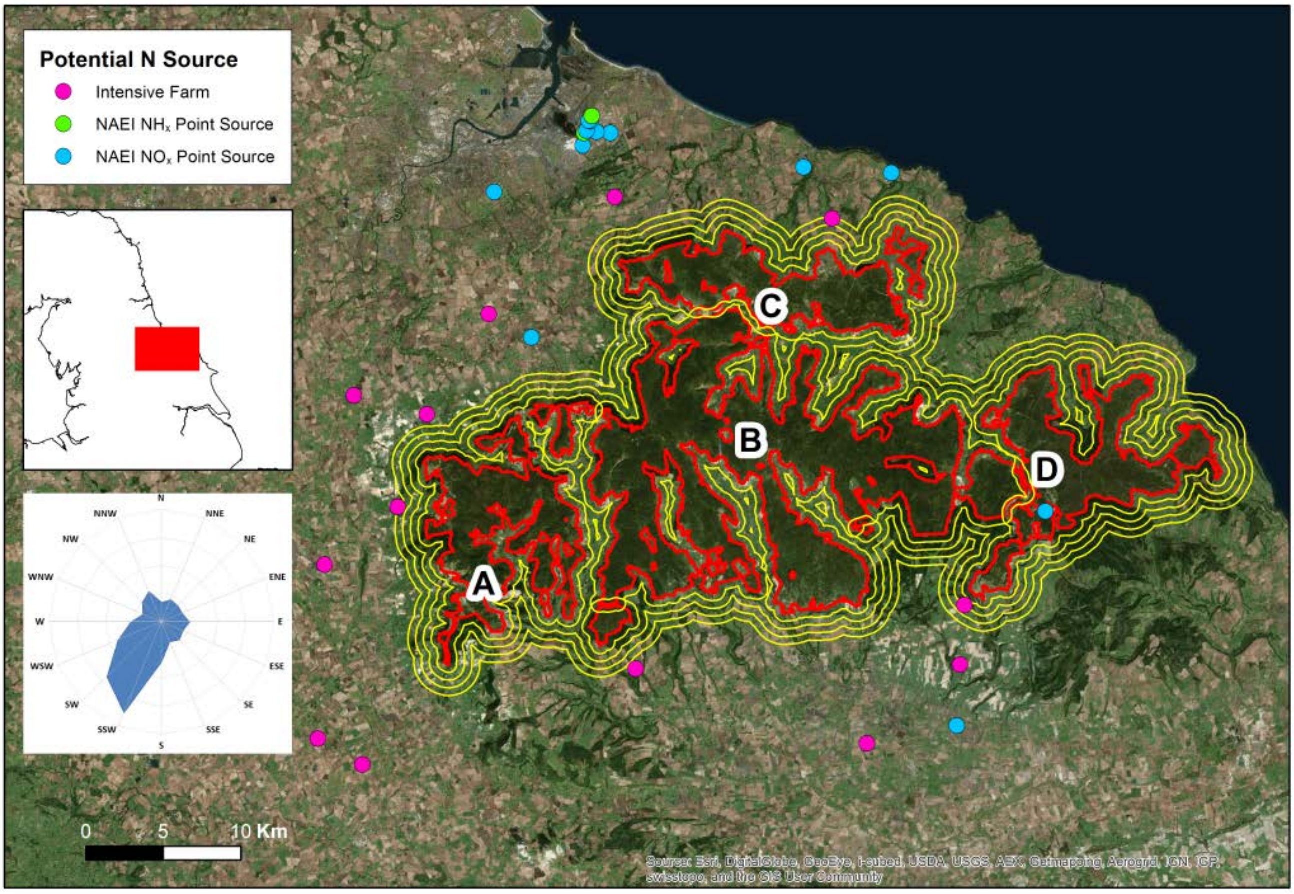

Figure1 - Location of the sub-sites of North York Moors SAC. showing NAEI and point sources and Intensive farms. Wind rose shows the annual average (10/12 - 07/14) wind direction (%) at RAF Fylingdales (near subsite-D), data from Windfinder.com (accessed 09/08/14).

2. Deposition and concentration estimates

5 km grid deposition modelling: The most recent available model estimates of N deposition at the site shows exceedance of the designated features' critical loads by up to 22.2 kg N ha^{-1} yr^{-1} (CBED model output for 2010-2012, also available via APIS). The 2010-2012 estimates of N deposition are fractionally lower than those predicted for 2005, the most recent year with source attribution data. Therefore the N deposition figures in Table 2 refer to the relative contribution from different sources, and the 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 2 are likely to be an underestimate in close proximity to larger N sources near the site boundary (such as animal housing and manure spreading).

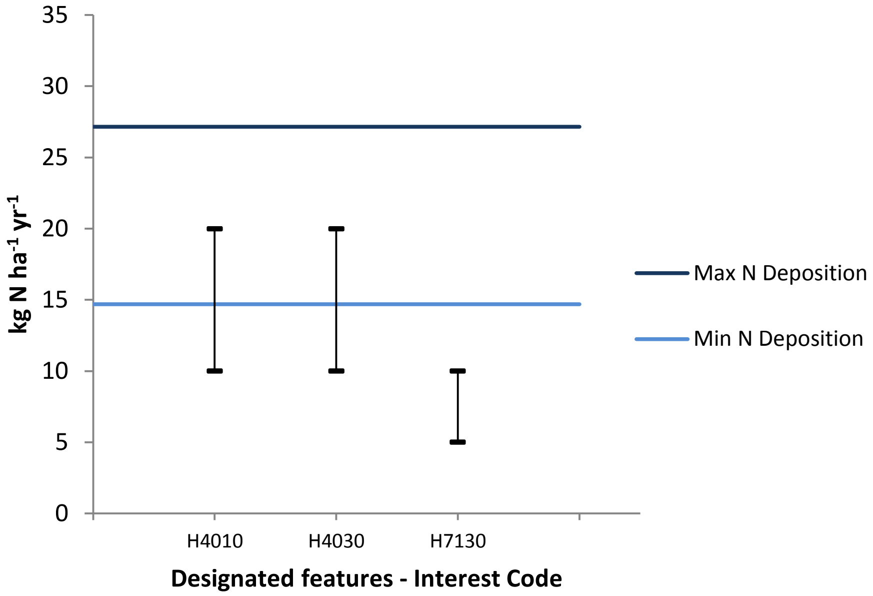

Figure 2: Critical load exceedance for North York Moors SAC designated features (APIS 2012). Designated features: H4010, Wet heathland with cross-leaved heath; H4030, Dry heaths; H7130, Blanket bogs. N.B. Nitrogen deposition values are derived from the 2010-2012 CBED data (available via APIS).

***1 km grid NH_3 concentration modelling*:** The 1 km grid resolution NH_3 dataset (FRAME model output) estimates low NH_3 concentrations (< 1 µg m^{-3}) for the majority of the site area. Concentrations are highest near the SAC boundaries, particularly to the south and east of the site, where higher densities of emission sources (especially agriculture) are present, including a number of intensive livestock farms. Data from the National Ammonia Monitoring Network (NAMN) site (e.g. 2010 data, Defra 2014[1]) located ~10 km east of the SAC at Northallerton[2] are broadly in agreement with the modelled concentrations. It should be noted that there are fluctuations in the NH_3 concentrations with peaks at the beginning of winter and in early spring, potentially linked to land spreading. The site notes show manure applications to fields noted ~0.5 miles away during a number of previous years, with a faint smell of manure sometimes present at the site.

[1] http://uk-air.defra.gov.uk/data/non-auto-data?uka_id=UKA00316&network=namn&s=View+Site
[2] The NAMN Northallerton site suburban site (in private garden) on the edge of Northallerton, so it will be influenced by agricultural activities

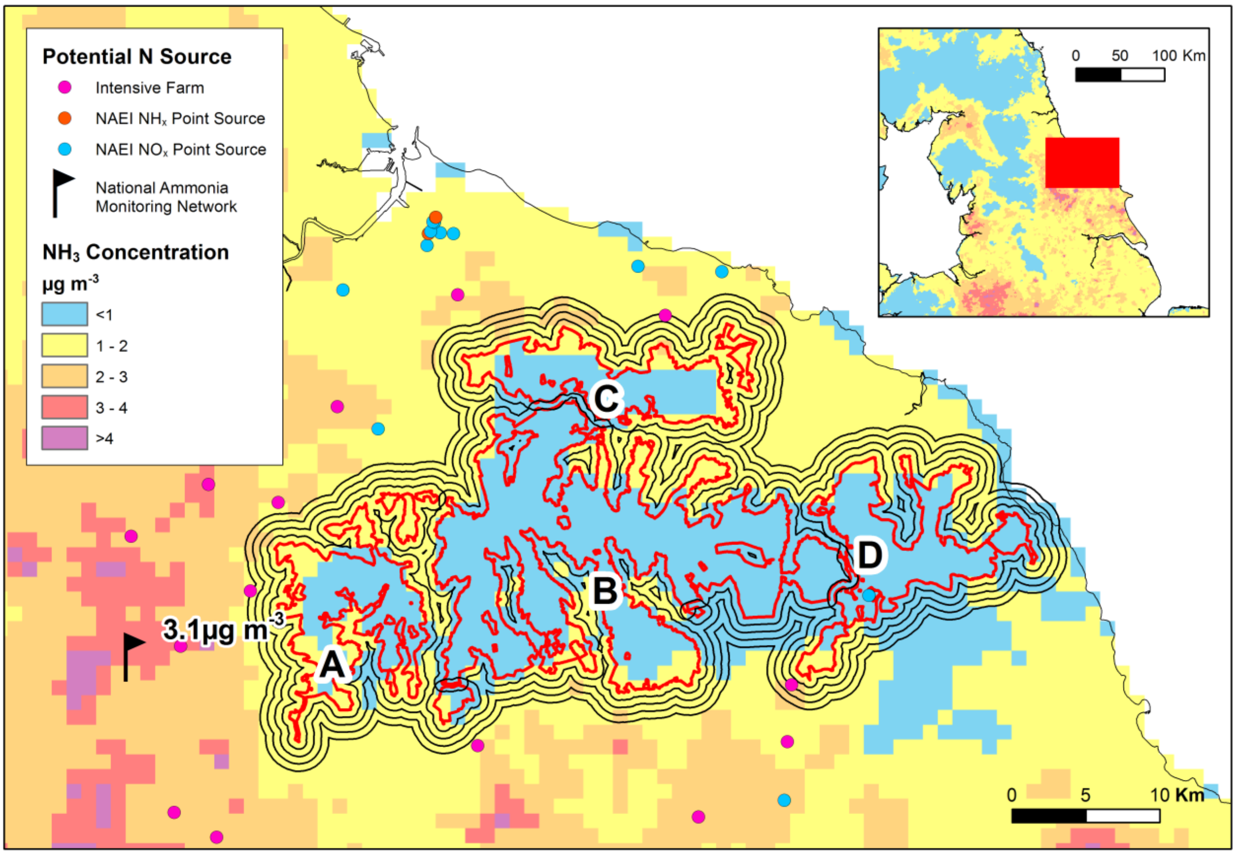

Figure 3 - Ammonia concentrations at North York Moors (FRAME 1 km dataset for 2011), with the locations of N point sources surrounding the site. Measured concentrations from Northallerton NAMN are also shown.

3. Source attribution calculations

5 km grid Source attribution calculations: The initial scenario approach (using the source attribution dataset from 2005) indicates that agricultural activities contribute the largest proportion of the total N deposition, at approx. 46% (Figure 4). A more detailed assessment, checking the relevant 5 km grid square estimates separately for the four sub-sites, shows agricultural sources contributing ~46 - 52 % of the total N deposition, across the forty-seven 5 km grid squares containing the whole site (Figure 5). A significant fraction of the total N deposition across the sub-sites (66-76%) is estimated to be from wet deposition, which is indicative of medium- to long-range N transport, rather than local sources. A smaller proportion (15 - 26 %) of the total N deposition to North York Moors SAC is attributed to non-agricultural (point) sources and the contribution from road transport sources is estimated to be of lesser importance, at 6 % (Figures 4, 5), despite sub-sites C and D being intersected by A roads.

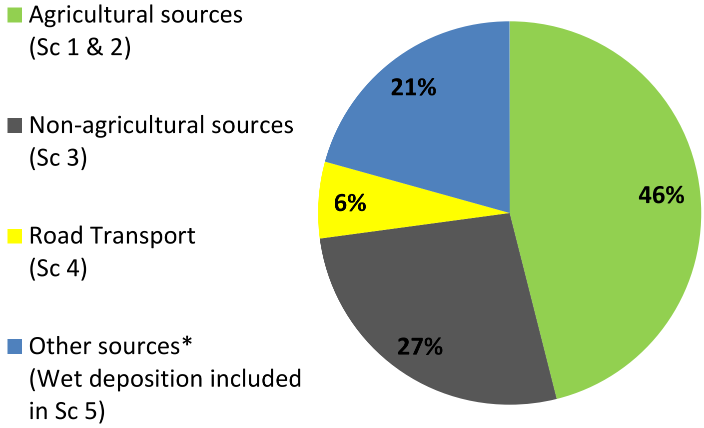

Figure 4 - Source attribution chart, showing the mean contributions to the N deposition across the 5 km grid squares which contain North York Moors SAC.

Table 1 – North York Moors SAC: Scenario allocation derived from the source attribution dataset (2005) using the initial scenario approach

Sub-site	Area (km^2)	Scenarios allocated (number, IDs)	Range in total N deposition for sub-site (kg N ha^{-1} yr^{-1})	Scenario allocations for sub-site (in **bold**) — Source Attribution (% of total N deposition): Agriculture (fertiliser & livestock)	Non- Agricultural sources	Roads	Total wet N deposition: Long Range N deposition	Nearest Features (m): Intensive farm	Major road
A	69.7	4 (Sc1, Sc2, Sc3, Sc5)	20.9 - 25.4	46	26.4	6.4	75.7	2,062	> 200
B	237.3	4 (Sc1, Sc2, Sc3, Sc5)	19.6 - 26.2	52.3	24.5	5.5	65.7	2,521	> 200
C	63	4-5 (Sc1, Sc2, Sc3, Sc4, Sc5)	20.5 - 25.7	46.3	25.8	5.8	75.7	1,926	Intersects
D	70.9	4-5 (Sc1, Sc2, Sc3, Sc4, Sc5)	16.7 - 22.8	45.9	15.2	6.3	68.5	944	Intersects

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

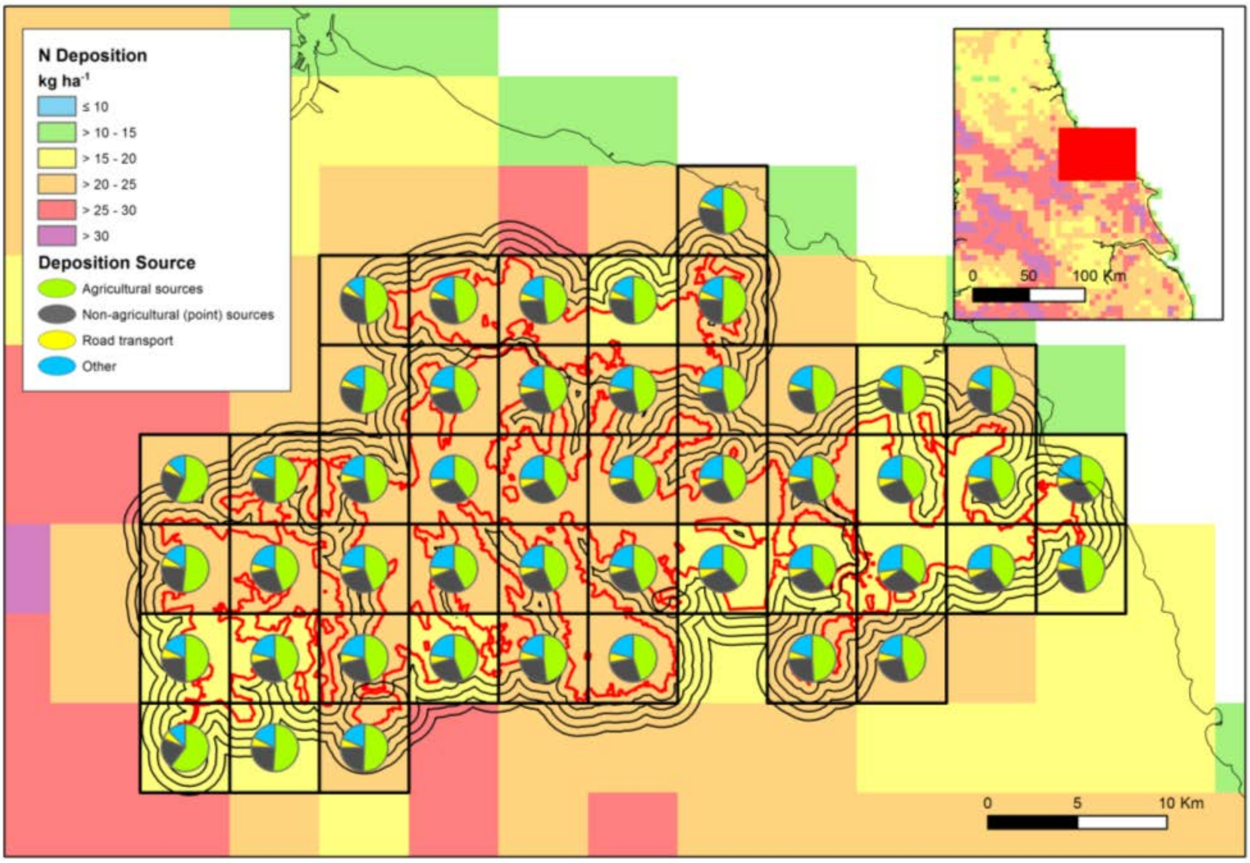

Figure 5 - Estimated N deposition (2010 - 2012) and source attribution (2005) for North York Moors SAC. 5 km grid squares shown in bold contain portions of the site. Sources are categorised using the initial scenario approach.

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

Long range N-sources:

In addition to the local sources already identified, sources further afield are thought to impact the site substantially, given that a large proportion (> 66 - 76 %) of the N deposited to the four sub-sites occurs in the form of wet deposition. A breakdown of the probable origin of N deposition sources in presented in Table 3. About 35 % of N deposition is estimated to originate from sources >10 km away from the site, from sources such as international shipping and imported emissions. The remaining ~65 % of the total N deposition originates from source categories that may potentially be from the surrounding area (< 10 km from site boundary), however a high proportion is also likely to originate from sources further afield, given the high overall proportion of wet deposition.

Table 3 - probable origin of N deposition at North York Moors SAC (based on 2005 source attribution data)

Probable origin	N Source	Proportion of site's N Deposition (%)	Deposition Type (%)	
			Dry	Wet
Potentially local	Agriculture	45.5	72.9	27.1
	Non-Agricultural & background sources	12.9	70.9	29.1
	Transport	8.2	52.5	47.5
Long-range source	N sources outside of England	22.2	15.1	84.9
	Point sources > 10 km away from site	7.4	49.9	50.1
	International Shipping	3.8	22.2	77.8

Agricultural Emissions:

The majority of agricultural NH_3 emissions surrounding the site (<2 km) is estimated to derive from cattle farming, based on an analysis of the 2012 agricultural census (Figure 7). Cattle emissions derive from sources such as animal housing, storage and land spreading of manures/slurry, livestock grazing and mineral fertiliser application. In addition, there are substantial NH_3 emissions from sheep, pig and poultry emissions, but these are less ubiquitous and are more sub-site specific. Emissions deriving from poultry farming, for example, represent almost a quarter of the agricultural emissions from the area surrounding sub-site B. While there are pronounced differences in the agricultural sources for each sub-site, the overall agricultural emission density is fairly constant at a relatively low/medium level across the four sub-sites, ranging from 7.2 kg NH_3-N kg ha^{-1} yr^{-1} (sub-site A) to 11 kg NH_3-N kg ha^{-1} yr^{-1} (sub-site C).

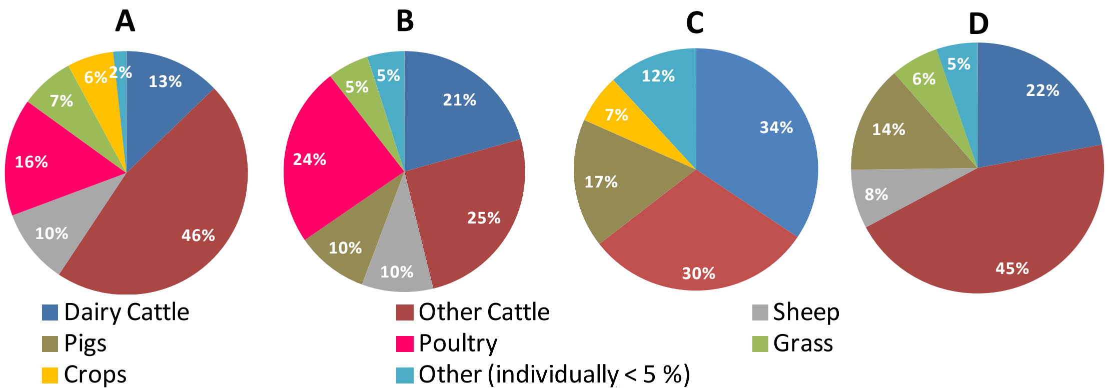

Figure 7 - Agricultural NH_3 emission sources in the 2km zone surrounding the sub-sites of North York Moors derived from 2012 agricultural census.

Non-agricultural Emissions:

According to the NAEI database, the only large N point source within 2 km of the site is RAF Fylingdales, which is situated < 100 m from the site boundary and emits an estimated > 7.5 t NO_x-N yr^{-1}. There are two very large industrial sources which each produce > 200 t NO_x-N yr^{-1} in Middlesbrough, which is located ~8 km to the north west of sub-site C . While these sources are large sources of N, they are located downwind of the site (wind rose in Figure 1), so may not necessarily contribute to the N deposition at the site.

Road Transport:

Estimated NO_x emissions from the roads surrounding North York Moors SAC are presented in Figure 6. Cape *et al.* (2004) found that NO_x concentrations tend to decrease to near background concentrations at around 200 m from the road verge, therefore sites which are < 200m from the road are considered most at risk from local road transport emission sources. Sub-sites C and D are intersected by A-roads with annual emissions of 0.3-0.5 t NO_x-N km^{-1} yr^{-1}. Of the roads which pass through the site, the A171 (which intersects sub-site C) is the largest road NO_x emission source, with sections producing > 0.5 t NO_x-N km^{-1} yr^{-1}. Overall, road transport is not thought to be the main threat to the whole SAC or sub-sites C and D, respectively, with road emissions representing well below 10 % of total N deposition in all 5 km grid squares.

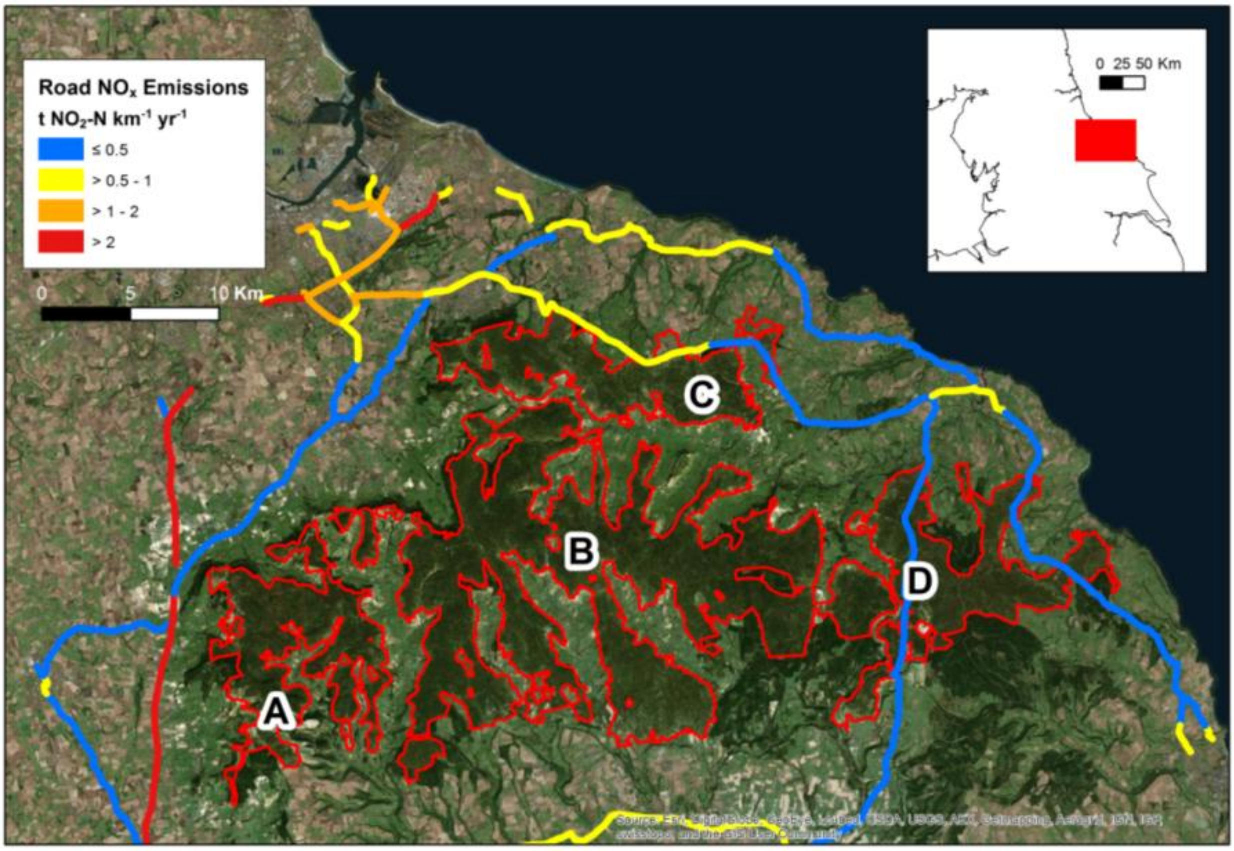

Figure 6 - Estimated annual NO_x emissions (Defra EFT, 2014 and DfT AADF 2012) from road links surrounding North York Moors SAC. Roads buffered to 200 m (following work by Cape et al. 2004).

N.B. Under project IPENS049, resources were only available for one of the four sub-sites to be studied in detail (agreed with the project Steering Group). Sub-site D as chosen because of its proximity to a range of sources including large non-agricultural point sources, a relatively high agricultural emission density and two major roads.

Sub-site D detailed study:

A detailed study of potential local emission sources in the immediate surroundings (<2 km) of the SAC was conducted on sub-site D using Google Imagery. The analysis of the agricultural census data indicated the area surrounding sub-site D is dominated by activities associated with cattle and sheep farming, and a a number of slurry tanks and slurry lagoons associated with cattle farming was found in the aerial images. The survey also identified a small sewage works, which is situated inside the main SAC boundary but is not itself part of the SAC (see insert in Figure 8, top right corner) with a small area surrounding the works excluded from the SAC at a distance of ~30 m. There are a number of tree belts (depth of 80-150 m) downwind of the IED pig farm located ~1 km SW of the site boundary (lower left corner of Figure 8). The tree belts continuous and are downwind of the farm, but are placed about 150 m from the farm, and therefore not nearly as effective as a well-designed tree belt planted immediately next to the livestock buildings. However, there will be a small effect due to enhanced recapture by the existing tree belts.

a) b)

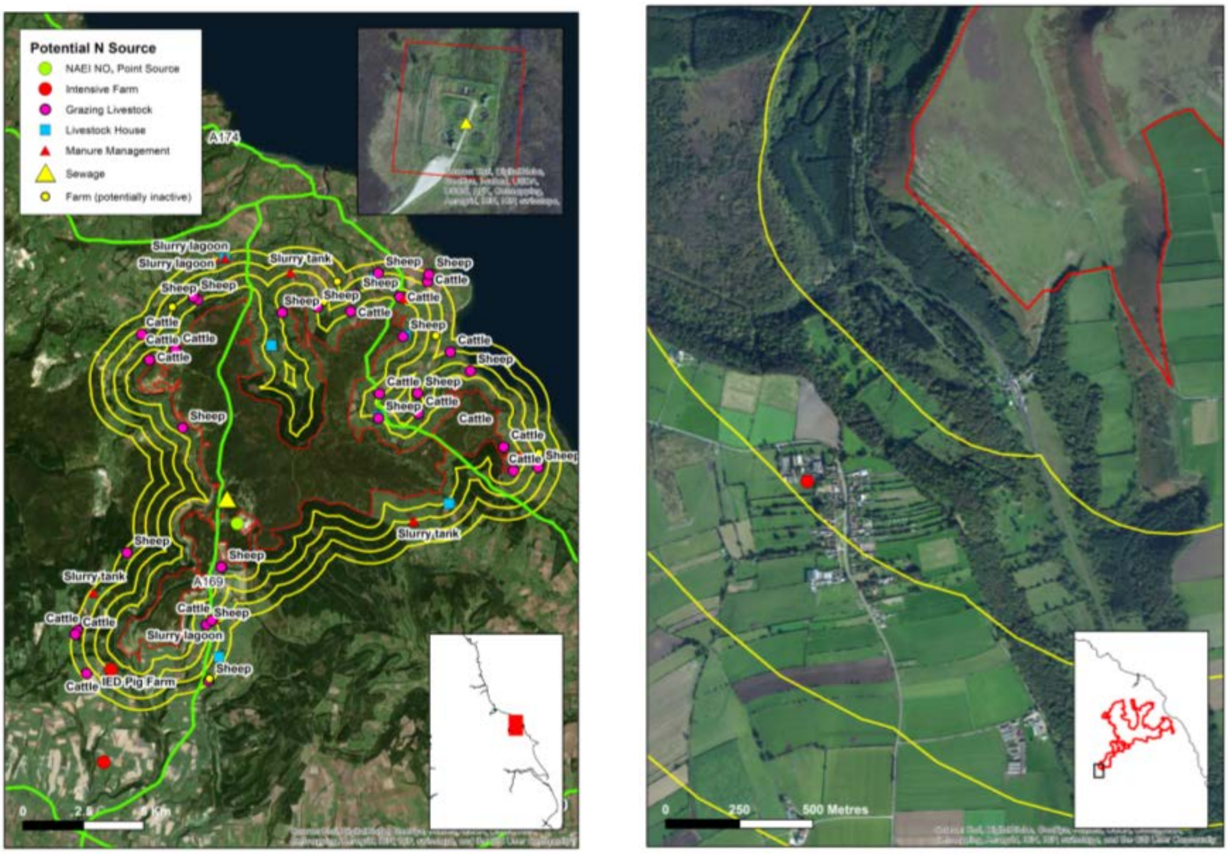

Figure 8 - North York Moors sub-site D, a) potential N sources identified from Google Earth imagery, during the desk-based study carried out August 2014 with the insert map in Fig 8a showing the location of the sewage works in relation to the site boundary. b) location of the intensive pig farm and tree-belts upwind of sub-site D (Google imagery date 13/05/2009).

5. Selection of potential measures

Potential measures for sub-site D

Measures targeting NH_3 emissions from cattle farming are likely to be the main options relevant to sub-site D for local emission reduction, 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. It may also be relevant to explore options for reducing combustion emissions produced by RAF Fylingdales, considering it is surrounded by the site boundary at a distance of < 100 m.

General site measures for North York Moors SAC

Some of the measures identified for sub-site D are also likely to be relevant to the wider SAC. In particular, activities associated with cattle farming are estimated to represent at least 45 % of agricultural NH_3 emissions for the areas surrounding every sub-site (< 2km from site boundary). Measures targeting poultry units may also be relevant at sub-sites A and B, considering that they represent almost a quarter of agricultural NH_3 emissions at sub-site B (16 % at sub-site A), however the current set of measures already implemented to achieve BAT under the IED would need to be confirmed. Measures for reducing emissions over a wider surrounding area should also be considered, 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 large-scale incentive schemes or country-wide regulatory approaches, as well as through international agreements.

It should be noted that Table 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. 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 sources.

Table 4 - Potential local measures for decreasing local concentrations and deposition of nitrogen to sub-site D at North York Moors SAC for the main local sources, selected from a list of potential measures.

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%

N source	Measure	Mitigation effect
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 SW 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., Misselbrook T. and Sutton M. (2014a) Site categorisation for nitrogen measures. Final report to Natural England for project IPENS049. 20 pp. http://publications.naturalengland.org.uk/publication/5802656649969664