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

Case Study B: Atmospheric nitrogen profile for Culm Grasslands SAC

First published 30 October 2015

www.gov.uk/government/publications/improvement-programme-for-englands-natura-2000-sites-ipens

ISBN 978-1-78354-251-2

Atmospheric nitrogen profile for Culm Grasslands 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:

- Culm Grasslands SAC site is located in an intensive lowland agricultural landscape in SW England. Its designated habitats are very sensitive to atmospheric nitrogen (N), with Critical Loads (CL) ≤ 10 kg N ha^{-1} yr^{-1}.
- The site's designated features are *Marsh fritillary butterfly, wet heathland with cross-leaved heath* and *purple moor-grass meadows*, 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 19.1 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.
- Diffuse agricultural activities are the main source of atmospheric N for this site. Local agricultural sources, in particular cattle farming and intensive pig and poultry farming, contribute significantly to the deposition at the site (60%), but a substantial proportion of the total N deposited is estimated to originate from long-range N deposition and non-agricultural sources.
- Estimated agricultural emission densities at Bradworthy Common (sub-site D) and Dunsdon (sub-site E) are up to six times higher than the other sub-sites. Implementing mitigation measures at these sites are likely to be most effective in reducing emissions.
- Bursdon Moor (sub-site B) and Rackenford (sub-site C) are likely to receive N deposition from A-roads which intersect the sites. Local mitigation measures, such as planting tree belts may help to reduce the impact of the roads, but national level incentive schemes such as the promotion of greener technologies and transport choices should also be promoted.
- Mitigation measures targeting ammonia (NH_3) emissions from cattle farming would be particularly relevant here, 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.
- 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: 7.6 km^2

Designated features:

Table 1 - Designated features at Culm Grasslands 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.
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.

Landscape context: Intensive lowland agricultural landscape in S.W. England, with a south westerly prevailing wind (Figure 1). The site is comprised of multiple, isolated parts, which are separated by distances of up to 60 km. As emission sources and N deposition are likely to vary over the wide area that Culm Grassland covers, the site has been split into five sub-sites comprising 0.14-2.2 km^2 for the assessment of N threats and potential mitigation measures. There are some existing very narrow tree belts around the boundaries of sub-sites A and E, although these are patchy in places. Sub-sites B, C and D have some narrow patches of woodland along boundaries, with some larger areas of woodland (e.g. SW or sib-site C), while there are large areas with no existing tree belts.

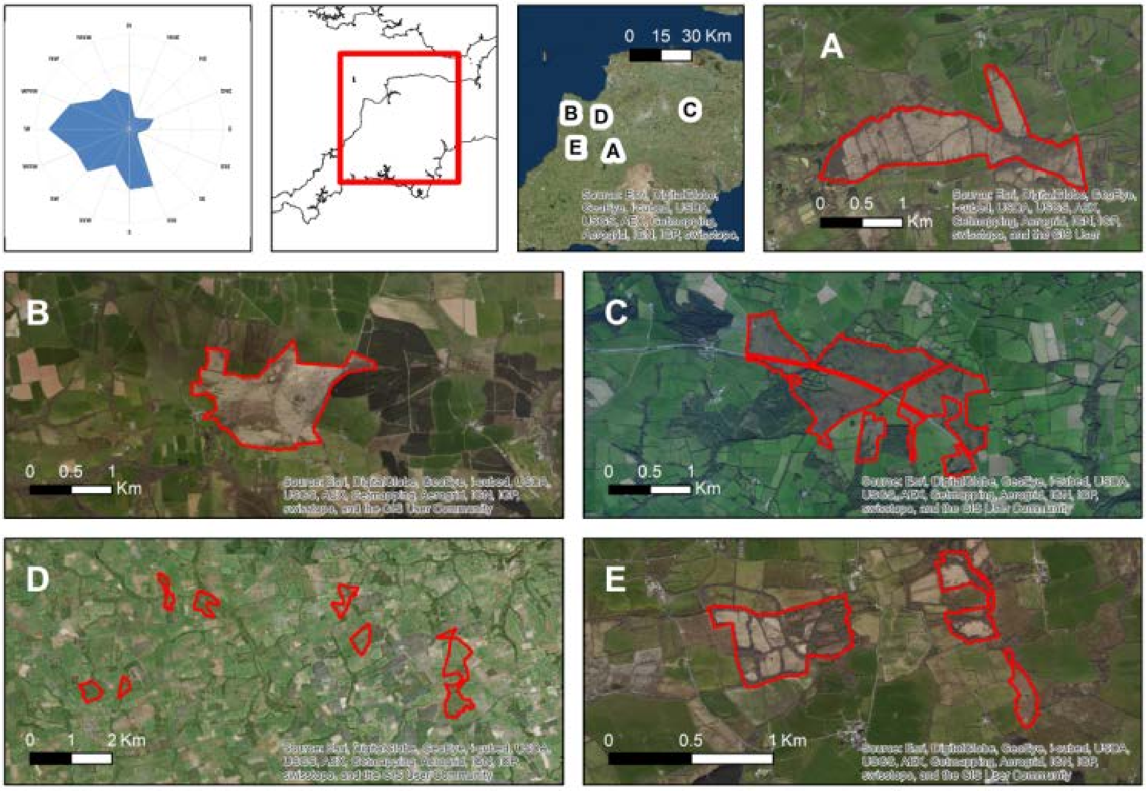

Figure 1 - Location of the sub-sites of Culm Grasslands SAC- A) Hollow Moor; B) Bursdon Moor; C) Rackenford; D) Bradworthy Common; E) Dunsdon. Wind rose shows the annual average (05/13 - 05/14) wind direction (%) in nearby Holsworthy, data from Windfinder (accessed 03/07/14).

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 by up to 19.1 kg N ha^{-1} yr^{-1} (CBED model output for 2012, from APIS), the 2010-2012 estimates of N deposition are marginally higher than those predicted in 2005, the most recent year with source attribution data (FRAME model output, 2005). Therefore the N deposition figures in Table 2 are presented only in reference to source attribution, 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 N sources near the site boundary (such as animal housing and manure spreading).

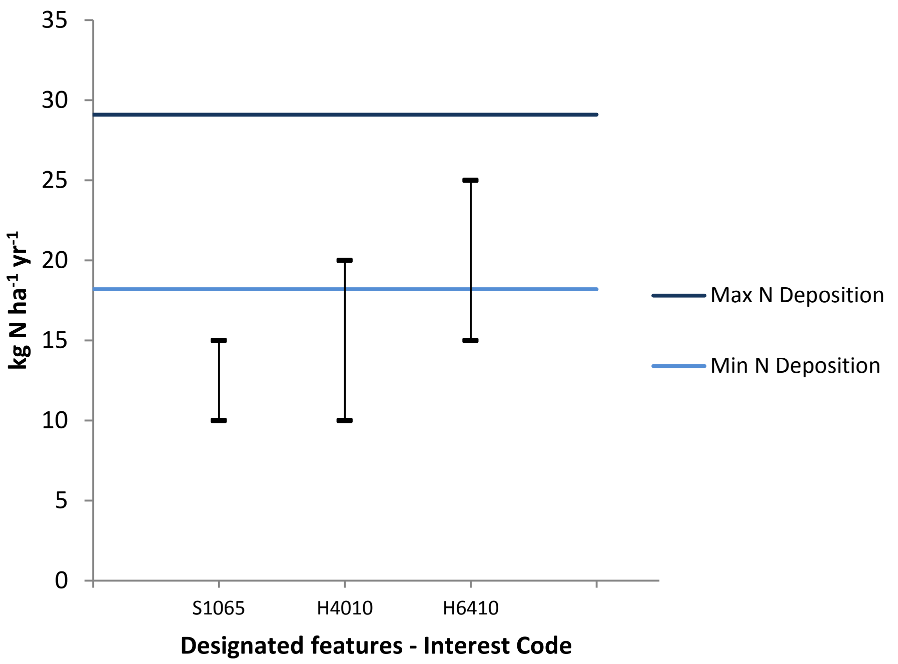

Figure 2 - Critical load exceedance for designated features at Culm Grasslands SAC (APIS 2012). Designated features: S1065 - Marsh fritillary butterfly; H4010 - Wet heathland with cross-leaved heath; H61410 - Purple moor-grass meadows. N.B. Nitrogen deposition values are derived from the 2010-2012 CBED data (from APIS).

***1 km grid NH_3 concentration modelling*:** The 1 km grid resolution NH_3 dataset (FRAME model output) clearly estimates elevated NH_3 concentrations in close proximity the IED intensive farms (Figure 3). According to the EA permitting database, the farms upwind of sub-site D house almost 210,000 layers, 105,000 pullets and 17,000 production pigs (>30 kg). To the south of sub-site C, there is an intensive broiler farm (136,000 birds) less than 1.5 km from the boundary of sub-site C, with further broiler farms located at a greater distance upwind.

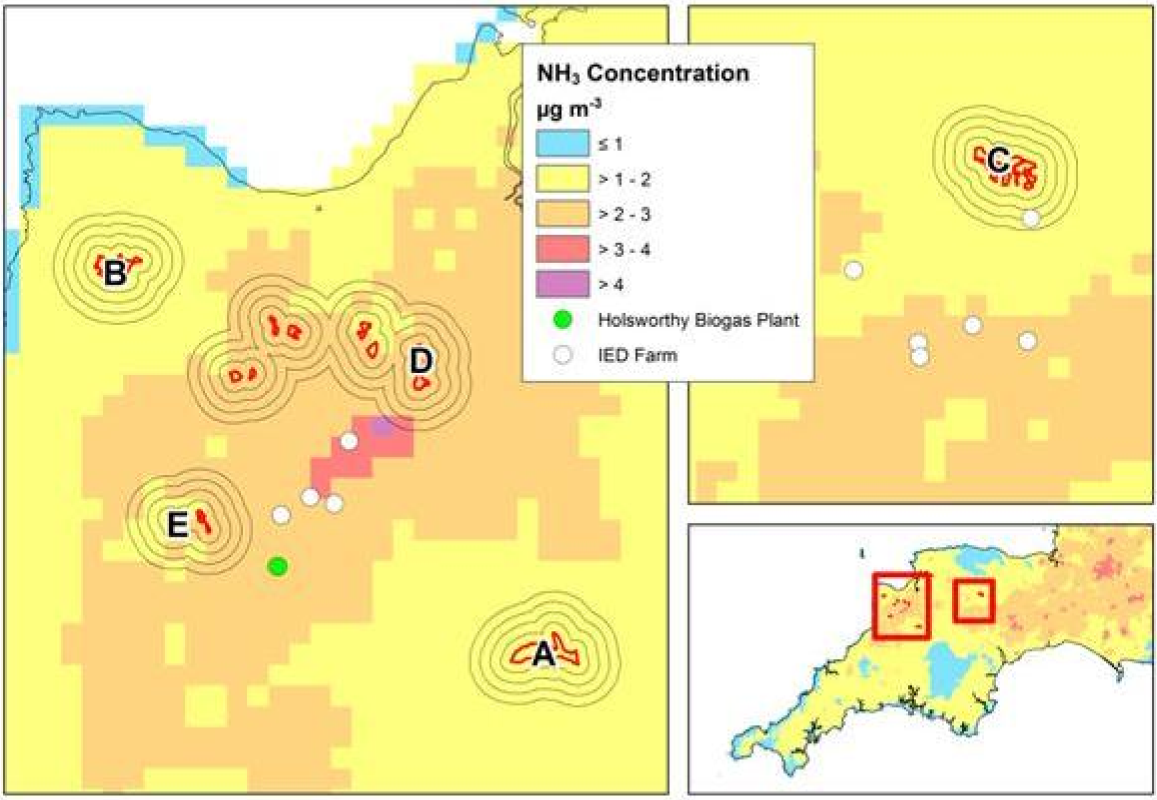

Figure 3 - Ammonia concentrations at Culm Grasslands (FRAME 1 km dataset for 2011), with the location of Industrial Emissions Directive IED farms surrounding the site.

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 majority of total N deposition, at approx. 60% (Figure 4). A more detailed assessment, checking the relevant 5 km grid square estimates separately for the five sub-sites, shows agricultural sources contributing ~51 - 66 % of the total N deposition, across the thirteen 5 km grid squares containing the whole site (Figure 5). A significant fraction of the total N deposition across the sub-sites (37 - 55%) is estimated to be from wet deposition, which is indicative of medium- to long range N sources, rather than local sources. A smaller proportion (15 - 20 %) of the total N deposition to Culm Grasslands is attributed to non-agricultural sources and the contribution from road transport sources is estimated to be of minor importance, at 3 - 6 % (Figures 4, 5).

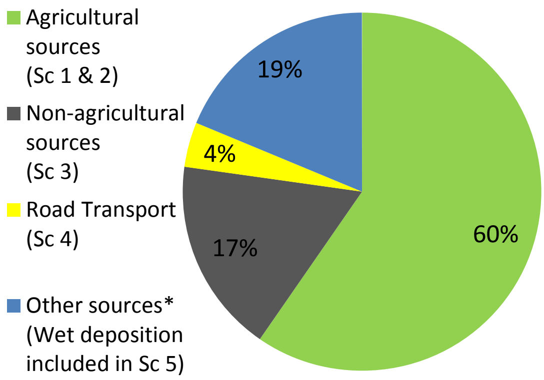

Figure 4 - Source attribution chart, showing the mean contributions to the N deposition across the 5 km grid squares which contain Culm Grasslands SAC.

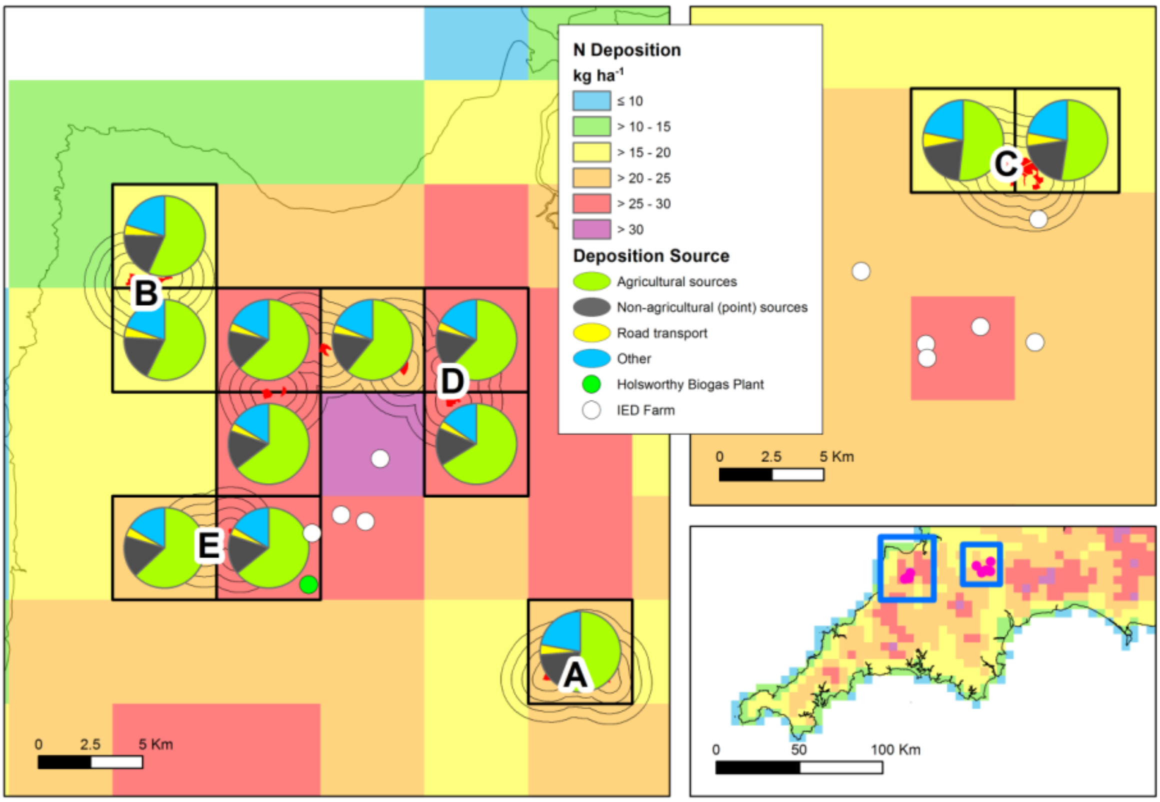

Figure 5 - Estimated N deposition (2010 - 2012) and source attribution (2005) for Culm Grasslands. 5 km grids highlighted in bold contain portions of the site. Sources are categorised using the initial scenario approach.

Table 2 - Culm Grasslands SAC: sub-site Scenario allocation - derived from the source attribution dataset (2005) using the initial scenario approach

				Scenario allocations for sub-site (in **bold)**					
			Range in total N deposition for sub-site (kg N ha^{-1} yr^{-1})	Source Attribution (% of total N deposition)			Total wet N deposition	Nearest Features (m)	
Sub-site	Area (km^2)	Scenarios allocated (number, IDs)		Agriculture (fertiliser & livestock)	Non-Agricultural sources	Roads	Long Range N deposition	Intensive farm	Major road
A	1.83	3 (Sc1, Sc3, Sc5)	21.8	53.7	20	4.21	53	> 10,000	> 200
B	1.47	3 (Sc1, Sc3, Sc5)	21.1 - 22	56.6	18.7	4.25	46	> 10,000	Intersects
C	2.21	4 (Sc1, Sc2, Sc3, Sc5)	21 - 21.9	52.4	20.3	5.29	53.6	1,400	Intersects
D	1.74	2 (Sc1, Sc2)	26.6 - 28.4	66.1	15.2	3.19	38.9	4,075	> 200
E	0.43	2 (Sc1, Sc2)	21.3 - 24.4	64.1	15.9	3.34	39.7	3,485	> 200

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.***

4. Sub-site specific Inventory of most likely local emissions sources (desk based study)

Sub-site A - Hollow Moor

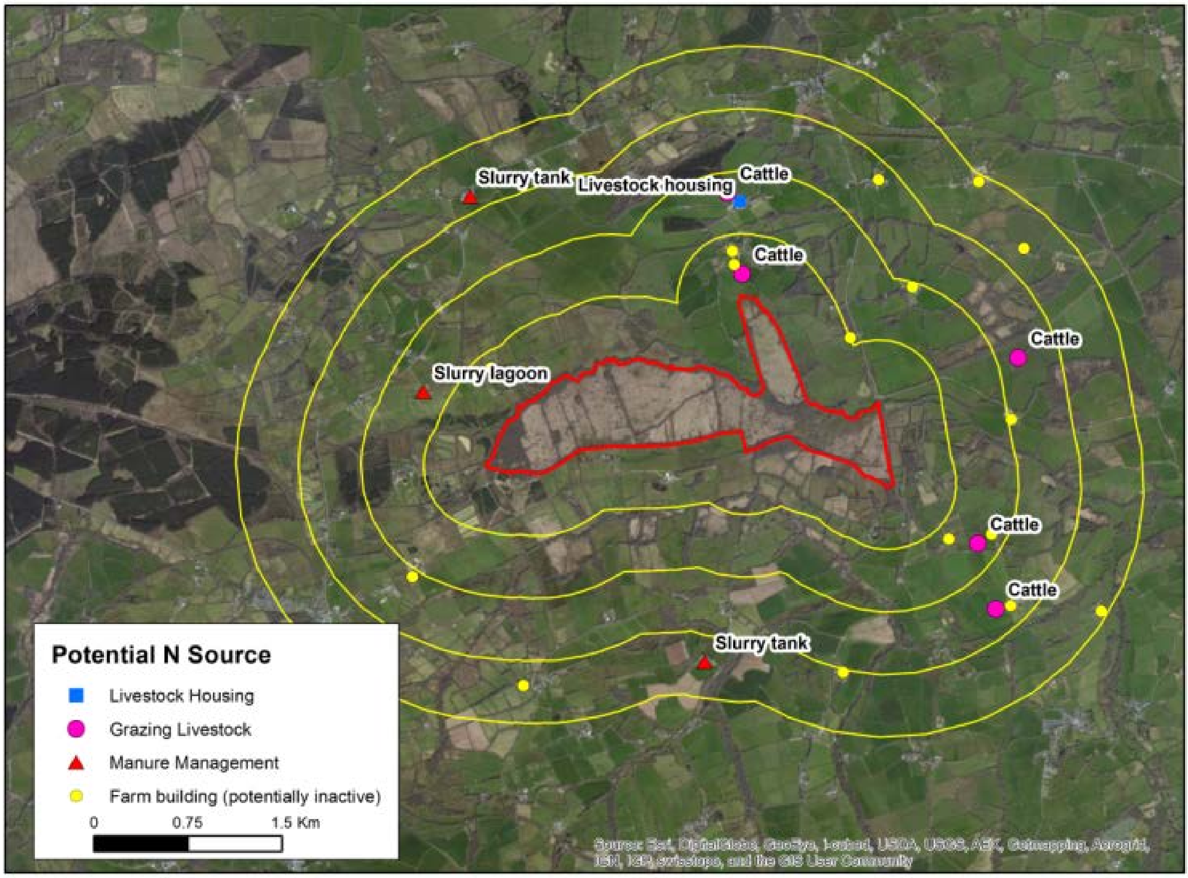

Figure 6 - Culm Grassland sub-site A: Hollow Moor, with potential N sources identified from Google Earth Earth imagery, during the desk-based study carried out July 2014 (Google imagery date 01/01/2010).

Area: 1.8 km²

Scenario allocations:

1 - Lowland agriculture (many diffuse sources)
3 - Non-agricultural (point) sources
5 - Long range N deposition

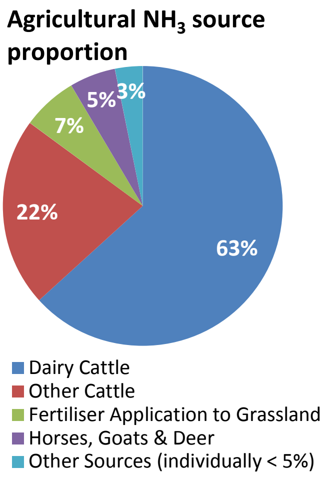

Figure 7 - Agricultural NH_3 emission sources in the 2km are surrounding Hollow Moor derived from 2012 agricultural census.

Dairy farming is prevalent in the surrounding Hollow Moor (Figures 6 and 7); cattle farming can be associated with high NH_3 emissions from activities such as animal housing, storage and land spreading of manures, livestock grazing and fertiliser application.

Based on the 2012 Agricultural Census[1] , it is estimated that cattle farming contributes to about 85 % of the approx. 13 kg NH_3-N ha^{-1} yr^{-1} agricultural emissions in the 2 km area surrounding Hollow Moor. Approximately three quarters of these cattle emissions are associated with dairy farming.

Hollow Moor is situated > 15 km from the nearest large intensive pig and poultry farm and non-agricultural point source and is > 1.5 km from the nearest major road. Measures targeting diffuse agricultural emissions, in particular from dairy farming, are therefore likely to be the most effective at reducing local N deposition and NH_3 concentration. There are a number of uncovered farm yard manure heaps and slurry lagoons within close proximity to the site boundary that may be good candidates for cost-effective N mitigation to the site. Additionally there grazing cattle near the northern site boundary , which is often a good indication of heavily-fertilised improved grassland, and buffer zones of low-emission agriculture around the site boundary could be introduced to minimise N input to the site.

[1] By assigning farms as data points to a 2-km concentric local emission zone around the area of each sub-site.

__Sub-site B - Bursdon Moor__

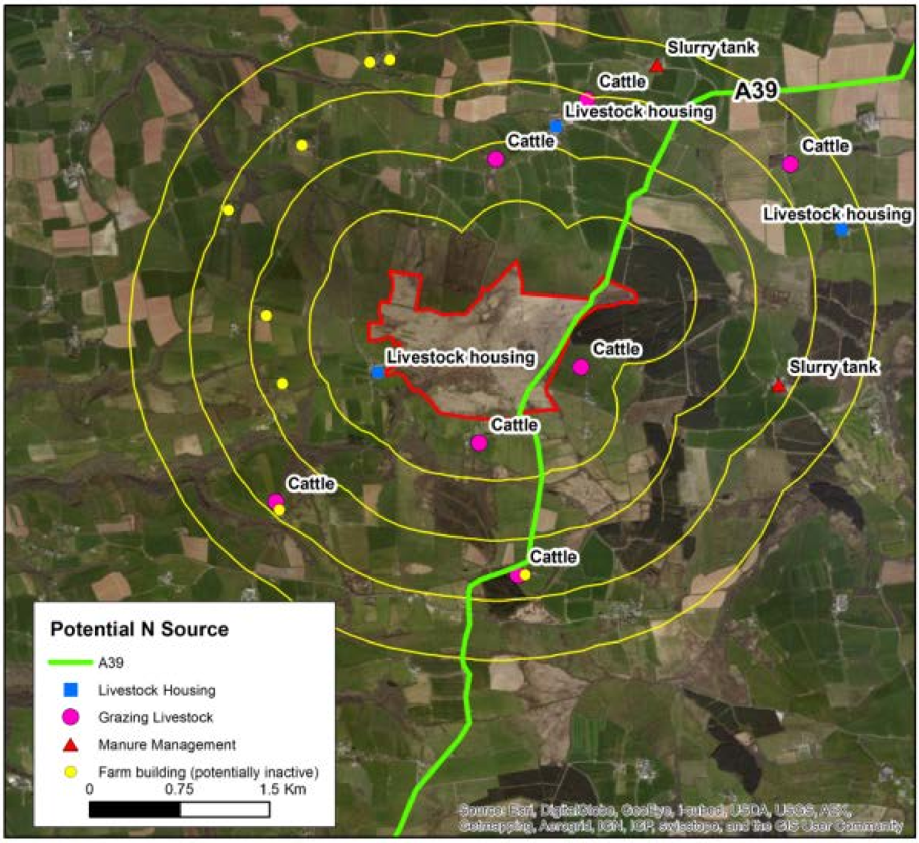

Figure 8 - Culm Grassland sub-site B: Bursdon Moor, with potential N sources identified from Google Earth imagery, during the desk-based study carried out July 2014 (Google imagery date 01/01/2010)

Area: 1.5 km^2

Scenario allocations:

1 - Lowland agriculture (many diffuse sources)

5 - Long range N deposition

The area surrounding Bursdon Moor is similar to that of Hollow Moor (sub-site A), in terms of the dominance of cattle farming (Figure 9a) and estimated agricultural NH_3 emission density (12 kg NH_3-N ha^{-1} yr^{-1}). Unlike Hollow Moor, however, there are a number of potential N sources bordering the

site boundary (Figure 8). There is livestock housing <100 m from the site boundary, with evidence of FYM stored in uncovered heaps adjacent to the buildings. There are also a number of fields with grazing cattle located upwind of the prevailing wind.

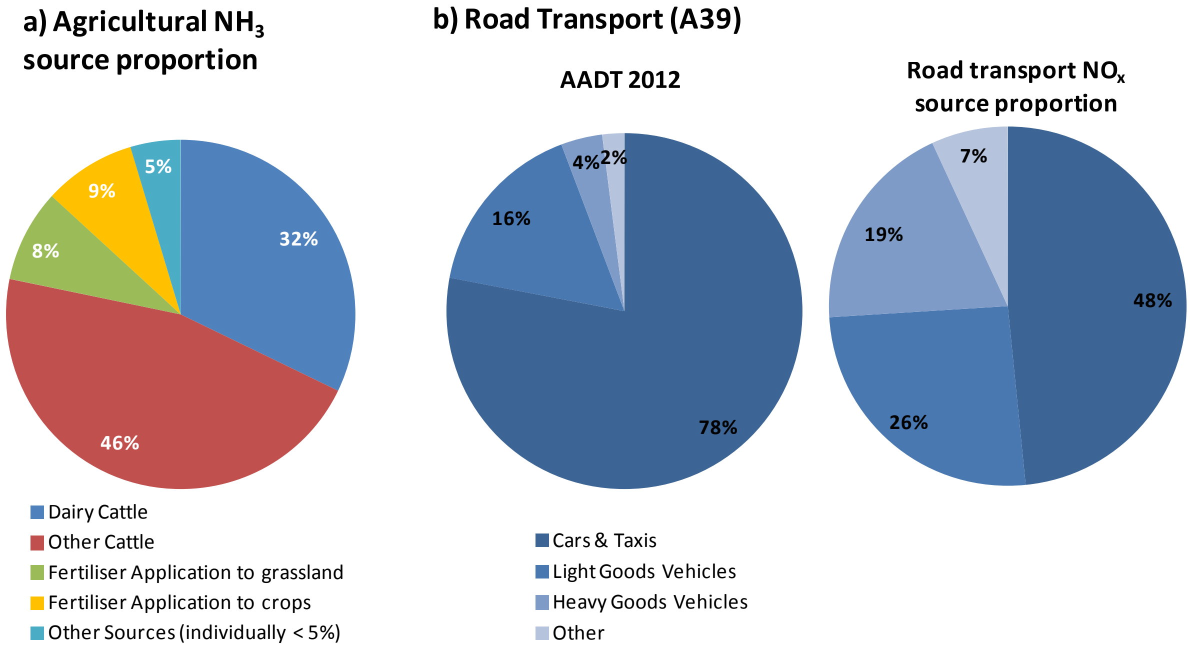

Figure 9 - a) Agricultural NH_3 emission sources in the 2km is surrounding Bursdon Moor derived from 2012 agricultural census. B) 2012 annual average daily traffic flow (DfT, 2013) for A39 and estimated NOx source apportionment (using the Emission Factor Toolkit v.6.0.1, Defra, 2014).

The site is located away from any large intensive pig or poultry farms (> 10 km), but is intersected by the A39, which has an average traffic flow of almost 6,000 vehicles daily (for vehicle type breakdown see Figure 9b). The road is estimated to produce emissions of just over 0.3 t NO_X-N km^{-1} yr^{-1}.

Sub-site C - Rackenford

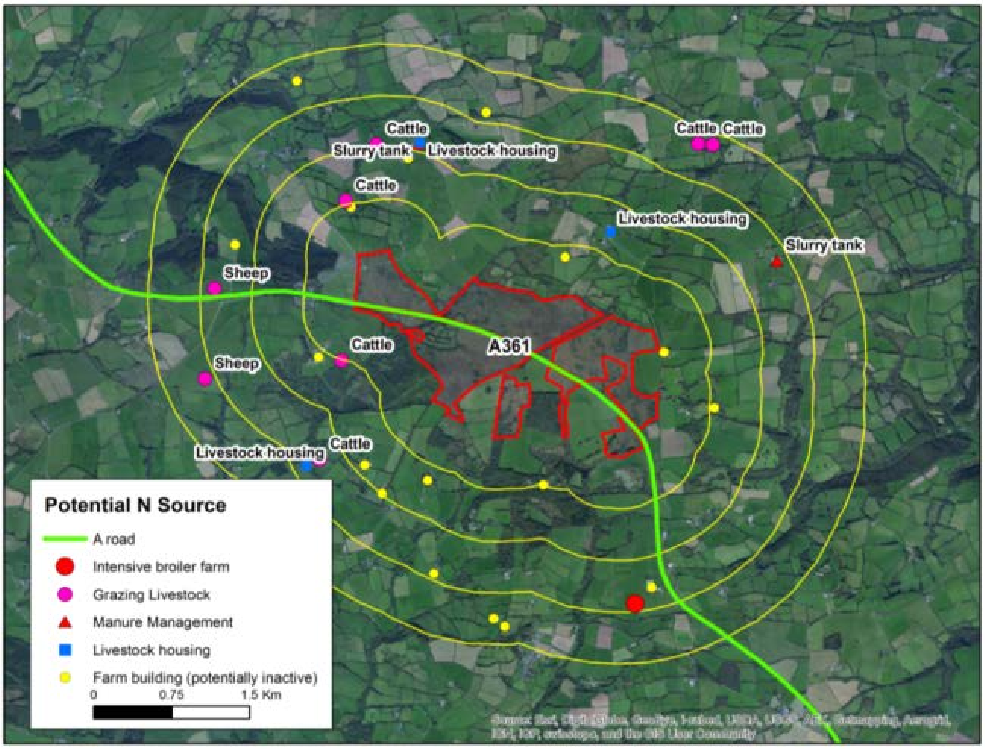

Figure 10 - Culm Grassland sub-site C: Rackenford, with potential N sources identified from Google Earth imagery, during the desk-based study carried out July 2014 (Google imagery date 01/01/2010) and the A361 also shown.

Area: 2.2 km^2

Scenario allocations:

1 - Lowland agriculture (many diffuse sources)
2 - Agricultural point sources
3 - Non-agricultural (point) sources
5 - Long Range N deposition

The site at Rackenford is situated less than 1.5 km from an intensive broiler farm (Figure 10), which houses around 135,000 broilers that contribute ~30% of the agricultural emissions in the 2 km zone surrounding Sub-site C (Figure 11a). Using the SCAIL screening tool (Theobald *et al.* 2006), it is estimated that the IED farm contributes to ~ 4 % of the N deposition at the site boundary. It is estimated that four other large intensive pig and poultry farms in the vicinity (< 10 km from site boundary) contribute approximately 1 % of the total N deposition to the sub-site.

The site is also intersected by the A361, which has an average traffic flow of almost 12,000 vehicles daily (vehicle breakdown presented in Figure 11b). The road is estimated to produce emissions of ~ 0.8 t NO_X-N km^{-1} yr^{-1}.

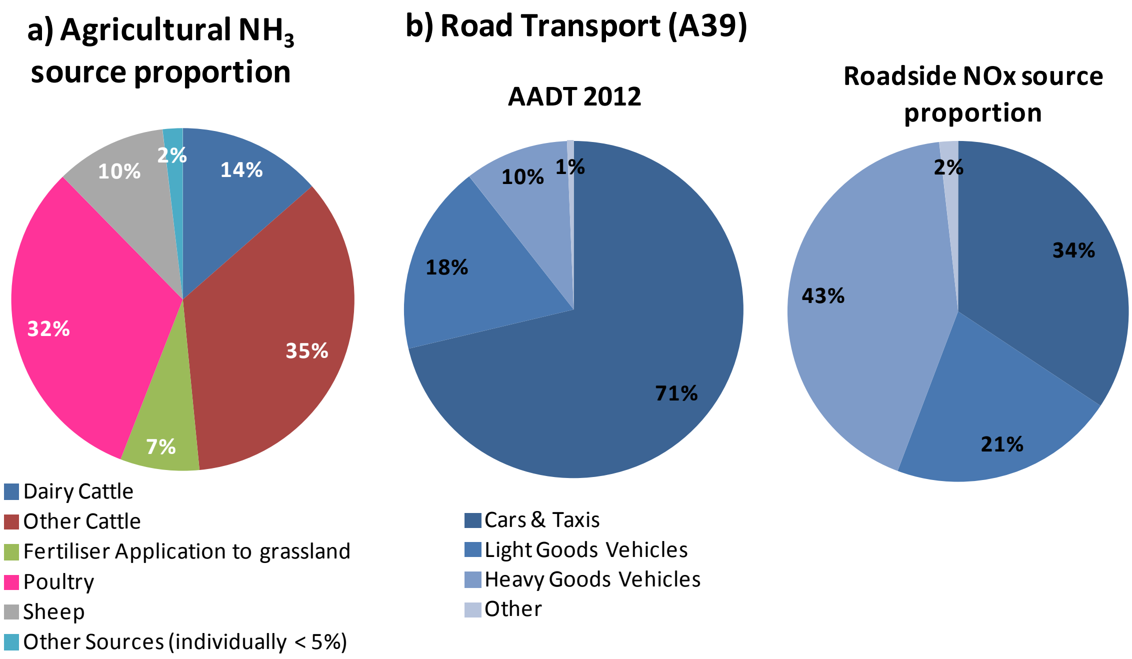

Figure 11 - a) Agricultural NH_3 emission sources in the 2km is surrounding Rackenford derived from 2012 agricultural census. B) 2012 annual average daily traffic flow (DfT, 2013) for A361 and estimated NOx source apportionment (using the Emission Factor Toolkit v.6.0.1, Defra, 2014).

Subsite D - *Bradworthy Common*

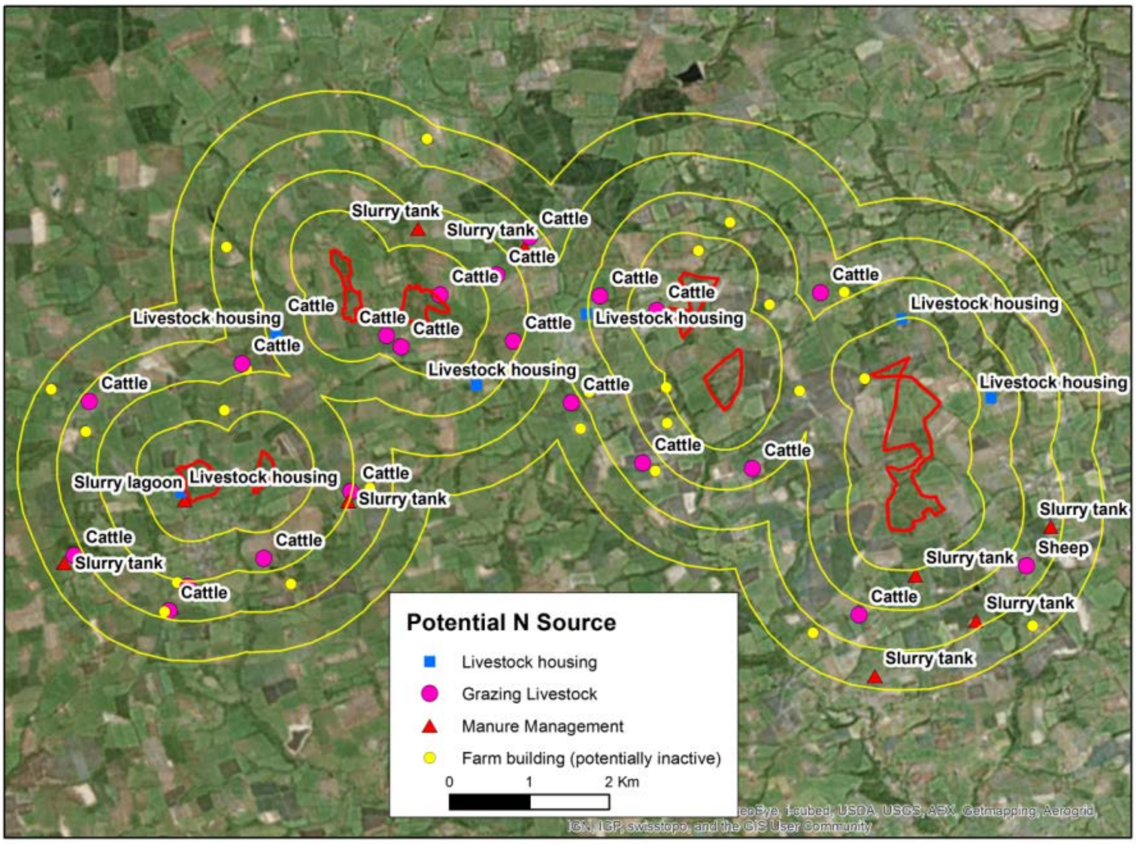

Figure 12 - Culm Grassland sub-site D: Bradworthy Common, with potential N sources identified from Google Earth imagery, during the desk-based study carried out July 2014 (Google imagery date 31/12/2010).

Area: 1.7 km^2

Scenario allocations:

1 - Lowland agriculture (many diffuse sources)
2 - Agricultural point sources

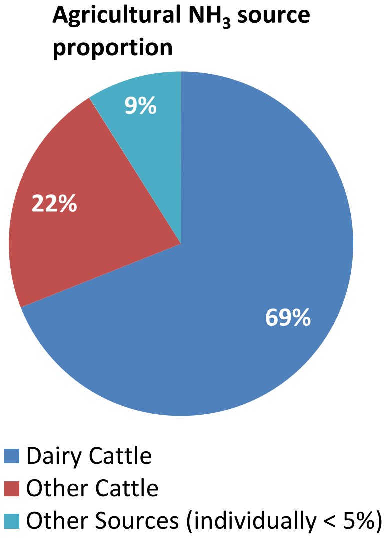

Figure 13 - Agricultural NH_3 emission sources in the 2km is surrounding Bradworthy Common derived from 2012 agricultural census.

It is estimated that the agricultural NH_3 emission density of the surrounding area (< 2km from site boundary) is almost three times as high as that of sub-sites A-C, at ~35 kg NH_3-N ha^{-1} yr^{-1}. The area is dominated by dairy farming (Figures 12 and 13), with cattle grazing right up to the site boundary. At one of the farms an uncovered slurry lagoon can be seen in the aerial images, which lies < 20 m from the site boundary. However local information gathered as part of the IPENS-050 project revealed that a new slurry tank was built and covered (local Catchment Sensitive Farming Officer, *pers. comm*.).

The closest large intensive farm, a poultry unit, is ~ 4 km from the site and only contributes a small fraction of the N deposited to the site (0.2 %). However, an intensive pig unit, ~8.5 km from the site boundary contributes approximately 2.6 % of the N deposited (assessed using the SCAIL[2] screening tool). This is primarily due to the higher total emissions estimated for the pig farm, but may in part also be attributed to the modern low-emission manure management systems installed in the poultry unit (manure belt, removing manure twice a week).

There are no major roads or large non-agricultural point sources near to the sub-site (they are located at > 200 m and > 10 km respectively), and these sources are estimated to contribute very little to the N deposited.

[2] SCAIL Screening Tool (Simple Calculation of Atmospheric Impact Limits): http://www.scail.ceh.ac.uk/

Subsite E - *Dunsdon*

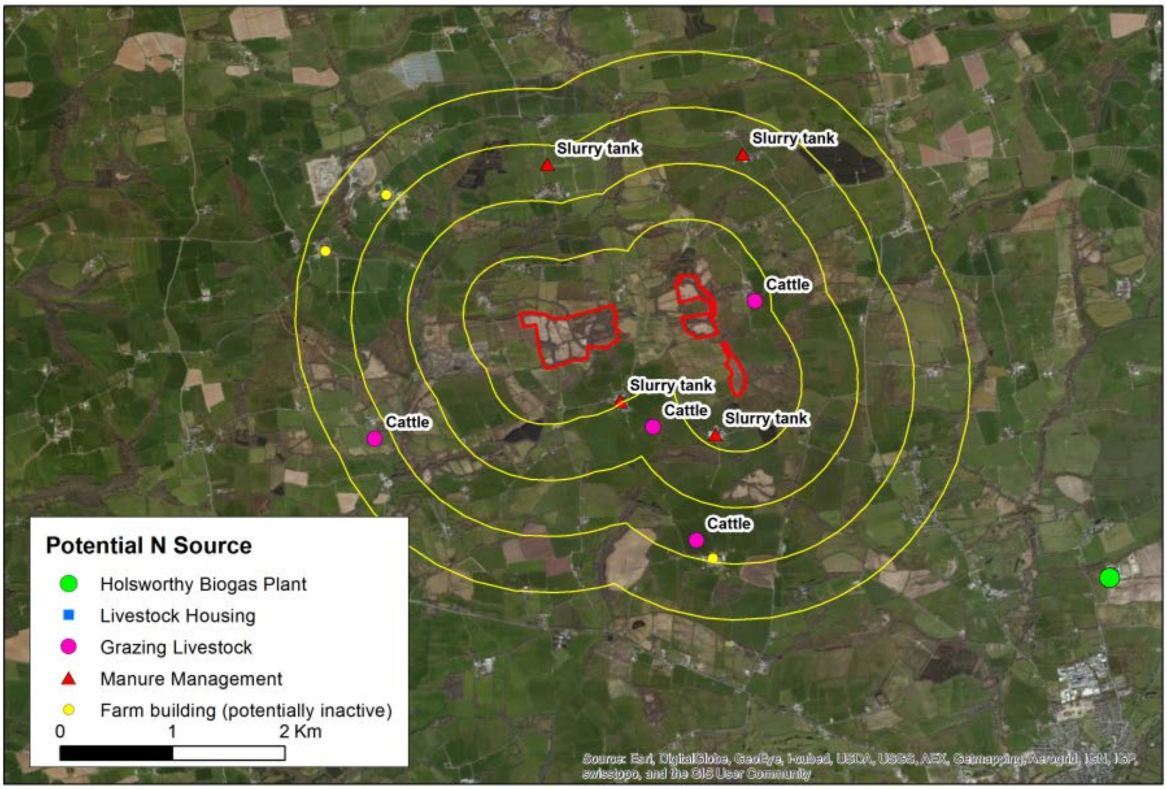

Figure 14 - Culm Grassland sub-site E: Dunsdon, with potential N sources identified from Google Earth imagery, during the desk-based study carried out July 2014 (Google imagery date 31/12/2010).

Area: 0.4 km^2

Scenario allocations:
1 - Lowland agriculture (many diffuse sources)
2 - Agricultural point sources

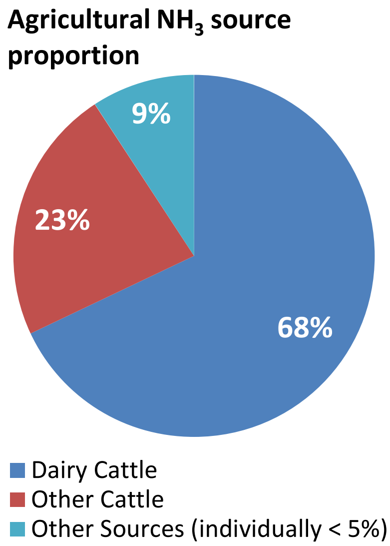

Figure 15 - Agricultural NH_3 emission sources in the 2km is surrounding Dunsdon derived from 2012 agricultural census.

Based on the agricultural census data, the NH_3 emission density of the area surrounding sub-site E is the highest of all the sub-sites with > 65 kg NH_3-N ha^{-1} yr^{-1}. Dairy farming is predominant in the area (Figures 14 and 15), similar to the area surrounding Bradworthy Common (sub-site D), with large areas of grassland for grazing cattle. It is estimated that about a third of the N deposited to the site comes from the nearby large intensive pig/poultry farms, with one pig farm (~ 5km NE of the site boundary) estimated to contribute > 4 kg NH_3-N ha^{-1} yr^{-1} (SCAIL estimate).

In addition to the agricultural sources identified, there is an anaerobic digestion (AD) plant located ~3.6 km from the site. The site is estimated to produce > 40 t NH_3 - N yr^{-1} in storage and fugitive emissions (equivalent to housing emissions of ~3,000 dairy cows) and further emissions from land spreading of digestate of > 45 t NH_3 - N yr^{-1}. Personal communications with the local Catchment Sensitive Farming Officer suggest that the site now only processes material of non-farm origin (food waste).

5. Selection of potential measures

Measures targeting emissions from cattle farming are particularly relevant here, 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.

While the majority of large intensive pig and poultry (Industrial Emissions Directive - IED) farms close to the site boundary are likely already implementing many effective measures, there may be potential to reduce the N deposition at the SAC originating from these farms by implementing secondary measures. For instance, as several IED farms are positioned upwind to the western part of the site, planting tree belts downwind of the farms or at a suitable distance upwind of the SAC boundary, i.e. between the farm and the SAC.

Table 2 summarises potential measures to target the most significant local sources affecting most sub-sites of the Culm Grasslands SAC. It should be noted that measures targeting minor agricultural sources at some of the sub-sites, such as mineral fertiliser application to arable fields, are not listed here, despite their potential to achieve further emission reductions. Similarly, measures targeting deposition from road transport to sub-sites B and C are not listed here, as the most effective measures for road transport are likely to stem from national level measures such as the promotion of greener technologies (alternative fuels and end of pipe technologies) or personal transport choices. High-cost measures such as the alignment of links do not seem to be proportional to the risk, given the relatively low emissions from the A39 and A361, compared with other major UK roads. In summary, targeting agricultural emissions is thought to be most cost-effective way to decrease N input to the SAC through atmospheric N deposition.

Table 3 - Potential N mitigation measures for Culm Grasslands

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%

N source	Measure	Mitigation effect
Dairy farms	Installation of grooved floors allowing faster drainage of urine to storage, thus lowering the potential for NH3 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%
FYM/poultry manure storage	Cover farm yard manure heaps with an impermeable sheet for the duration of storage.	60%
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
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 NH3 sources (e.g. livestock houses) close to the designated site, or upwind of the designated site (in relation to the prevailing wind direction)	20%
Manure and fertiliser application	Change land use from intensive agriculture to unfertilised grass or semi-natural land cover, with no fertiliser of manure applied.	90% 80% with grazing to manage the sward
Fertiliser application	reduce mineral fertiliser N application rates to below the economic optimum.	20

References:

Defra (2014) Emission Factor Toolkit v6.0.1, [Online], Available: http://laqm.defra.gov.uk/review-and-assessment/tools/emissions-factors-toolkit.html

DfT (2013) Annual Average Daily Flows, [Online], Available: http://www.dft.gov.uk/matrix/

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

Misselbrook T.H., Gilhespy S.L., Cardenas L.M., Chambers B.J., Williams J. and Dragosits U. (2013) Inventory of ammonia emissions from UK agriculture 2012. Defra Contract Report (AC0112). Rothamsted Research, North Wyke, Devon. 34 pp.

National Atmospheric Emission Inventory (NAEI), Available: http://www.naei.org.uk

Theobald M.R., Bealey W.J., and Sutton M.A. (2006) Refining the Simple Calculation of Ammonia Impact Limits (SCAIL) model for application in Scotland. http://www.scail.ceh.ac.uk/