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

Case Study E: Atmospheric nitrogen profile for Ingleborough Complex SAC

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Atmospheric nitrogen profile for Ingleborough Complex 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:

- Ingleborough Complex SAC site is located in an extensive upland agricultural landscape in NW England. Its designated habitats are very sensitive to atmospheric nitrogen (N).
- The site has been designated for ten semi-natural features and two woodland features, which are all sensitive to N.
- Current N deposition the wider area is estimated to exceed the critical load of the most sensitive habitat by ~ 37 kg N ha^{-1} yr^{-1}, using the UK 5 km grid data. Diffuse agricultural activities are the main source of atmospheric N input for this site (up to 51%), with a substantial proportion of the total N deposited estimated to originate from long-range N deposition.. The main local agricultural sources are cattle and sheep farming.
- Aerial imagery of the area indicates that the area south west (upwind) of the site has a higher density of agricultural emissions than the north east, which is largely upland grazing for sheep. Implementing mitigation measures should therefore focus on the areas with higher emission density.
- Mitigation measures targeting ammonia (NH_3) emissions from cattle farming are particularly relevant here, given its dominance in the south west 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 following good agricultural practice by accounting for N in manures when calculating mineral fertiliser application rates.
- 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.

1. Site characteristics

Site area: 57.7 km^2

Designated features:

Table 1 - Designated features for Ingleborough Complex SAC

Interest Code	Interest Lay Name	Sensitivity to nitrogen deposition	Expected Exceedance Impact N
H8120	Base-rich scree	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Decline in lichens, bryophytes and evergreen shrubs.
H7130	Blanket 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
H8240	Limestone pavements	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Changes in species composition; increase in plant production
H8210	Plants in crevices in base-rich rocks	Very sensitive (Mapping CL ≤ 10 kg N ha-1 yr-1)	Changes in species composition; increase in plant production
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
H7230	Calcium-rich springwater-fed fens	Less Sensitive (Mapping CL >20-30 kg N ha-1 yr-1)	Increase in tall graminoids, decrease in bryophytes
H6210	Dry grasslands and scrublands on chalk or limestone	Sensitive (Mapping CL > 10-20 kg N ha-1 yr-1)	Increase in tall grasses, decline in diversity, increased mineralization, N leaching; surface acidification
H7220	Hard-water springs depositing lime	Sensitive (Mapping CL >10-20 kg N ha-1 yr-1)	Increase in vascular plants, decrease in bryophytes.
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.
H5130	Juniper on heaths or calcareous grasslands	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
H9180	Mixed woodland on base-rich soils associated with rocky slopes	Sensitive (Mapping CL >10-20 kg N ha-1 yr-1)	Changes in ground vegetation

N.B. - different deposition types should be used to assess each feature; semi-natural features are shown in grey, woodland features are shown in green

***Landscape context*:** The site is located in an upland agricultural landscape abutting a more intensive lowland pastoral landscape of N.W. England and is comprised of four distinct parts, which are separated by distances 250 - 700 m. The area surrounding the SAC is predominantly permanent grassland, with extensive areas of limestone pavement in the upland areas. There is very little woodland currently in the area, with only small patches in the southern-most area. Atmospheric NH_3 is currently being monitored at Ingleborough Complex through Natural England's Long Term Monitoring Network (LTMN) programme, however the data are still being processed at Natural England and are not available yet. Given the varying topography of the area surrounding the site and lack of nearby weather stations, it was not possible to get a reliable quantification of prevailing winds, however a general south-westerly direction may be a reasonable assumption.

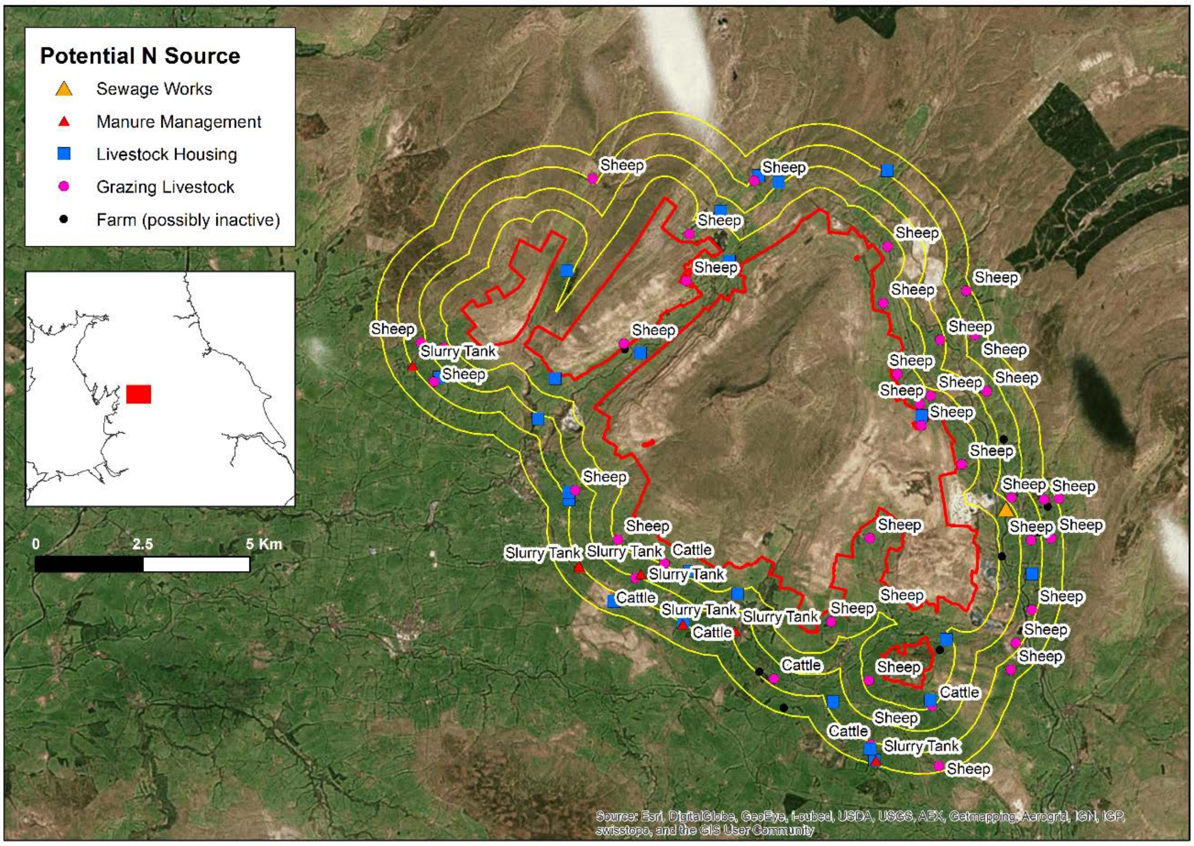

Figure1 - Ingleborough Complex site map, showing N sources identified from Google Earth imagery, during a desk-based study carried out July 2014 (Google imagery date 24/04/2011).

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 37 kg N ha^{-1} yr^{-1} (CBED model output for 2010-2012, from APIS). The 2010-2012 estimates of N deposition are marginally lower than those predicted for 2005, the most recent year where source attribution data are available (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).

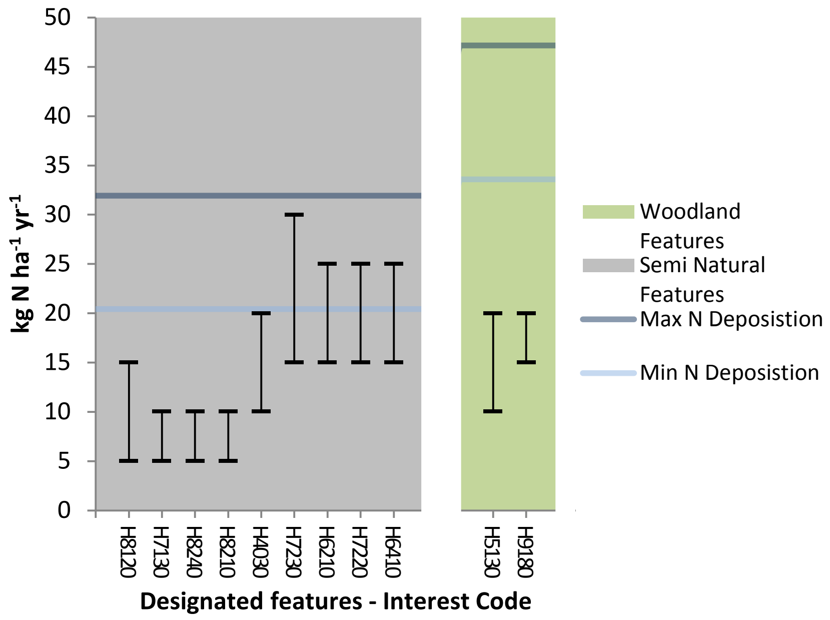

Figure 1 - Critical load exceedance for Ingleborough Complex designated semi natural (grey) and woodland features (green), from APIS 2012. Designated features: H8120,Base-rich scree; H7130, Blanket bog; H8240, Limestone pavements; H8210, Plants in crevices in base-rich rocks ; H4030, Dry heaths ; H7230, Calcium-rich springwater-fed fens; H6210, Dry grasslands and scrublands on chalk or limestone; H7220, Hard-water springs depositing lime; H6410, Purple moor-grass meadows; H5130, Juniper on heaths or calcareous grasslands; H9180, Mixed woodland on base-rich soils associated with rocky slopes. N.B. Nitrogen deposition values are derived from the 2010-2012 CBED data (also 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. Concentrations on the south east of the site are slightly higher at 1-2 µg m^{-3}. With low local concentrations of NH_3 surrounding Ingleborough, this suggests that a larger proportion of the N deposition to the site may originate from medium/long-range sources.

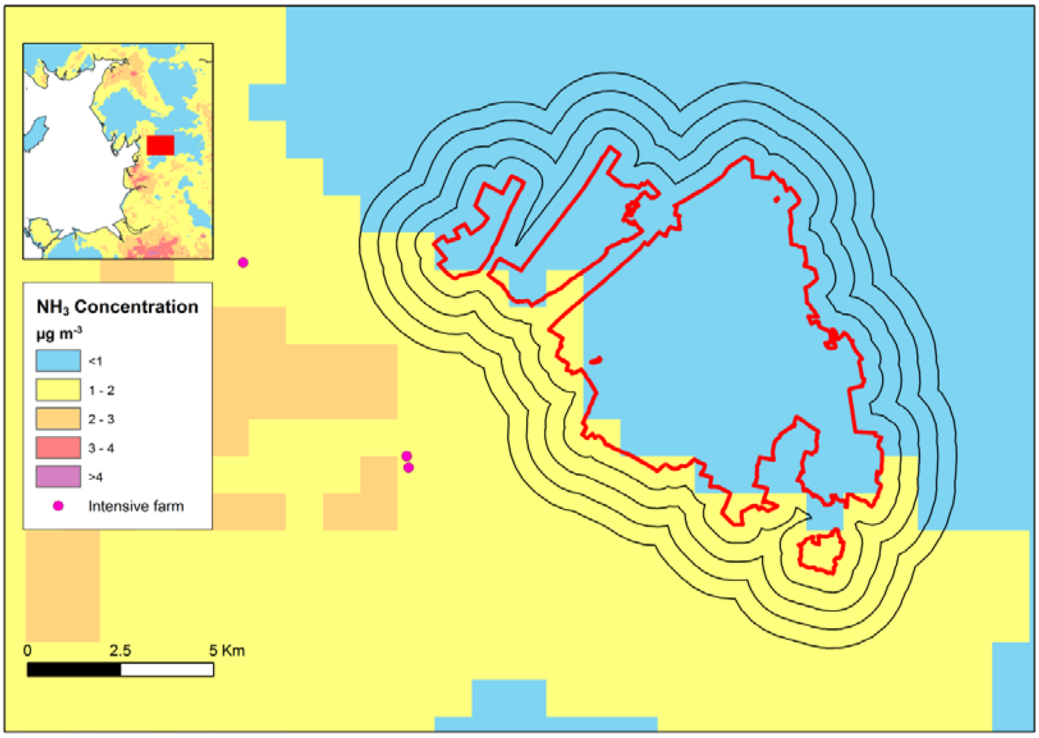

Figure 3 - Ammonia concentrations at Ingleborough Complex (FRAME 1 km dataset for 2011), with the location of IED farms surrounding the site.

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 received by semi-natural features and woodland features (Figure 4a, b). A more detailed assessment, assessing the relevant 5 km grid square estimates separately for woodland and semi-natural features (Table 2), shows agricultural sources contributing ~38 - 51 % of the total N deposition, across the seven 5 km grid squares containing the whole site (N deposition estimates for semi-natural features presented in Figure 5). A substantial fraction of the total N deposition across the sub-sites (54 - 88 %) is estimated to be from wet deposition, which is indicative of medium- to long range N sources rather than local sources. A smaller proportion (23 - 31 %) of the total N deposition to Ingleborough Complex is attributed to non-agricultural (point) sources and the contribution from road transport sources is estimated to be of lesser importance, at 6 - 10 %.

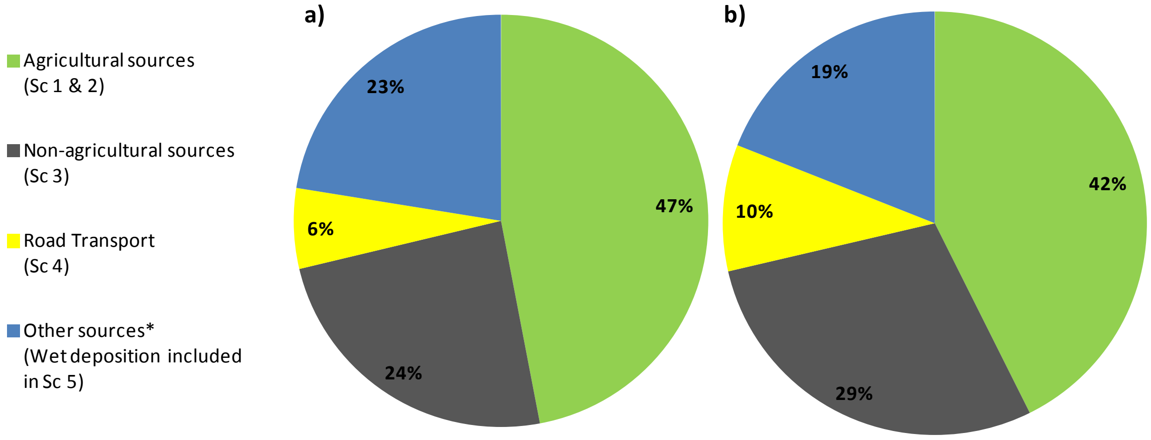

Figure 4 - Source attribution chart, showing the mean contributions to the N deposition estimated for a) semi-natural features, b) woodland features across the 5 km grid squares which contain Ingleborough Complex SAC.

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

Deposition Type	Scenarios allocated (number, IDs)	Range in total N deposition (kg N ha^{-1} yr^{-1})	Scenario allocations for sub-site (in **bold)**				Nearest Features (m)	
			Source Attribution (% of total N deposition)			Total wet N deposition		
			Agriculture (fertiliser & livestock)	Non- Agricultural (point) sources	Roads	Long Range N deposition	Intensive farm	Major road
Semi-natural vegetation	4 (Sc1, Sc2, Sc3, Sc5)	22.7 - 33.3	**43.2 - 51**	**22.9 - 25.7**	**5.9 - 6.7**	**71.1 - 87.9**	4,750	**>200**
Woodland	4 (Sc1, Sc2, Sc3, Sc5)	39.7 - 49.1	**38.4 - 49**	**25.5 - 30.9**	**8.9 - 9.9**	**54.2 - 68**		

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.***

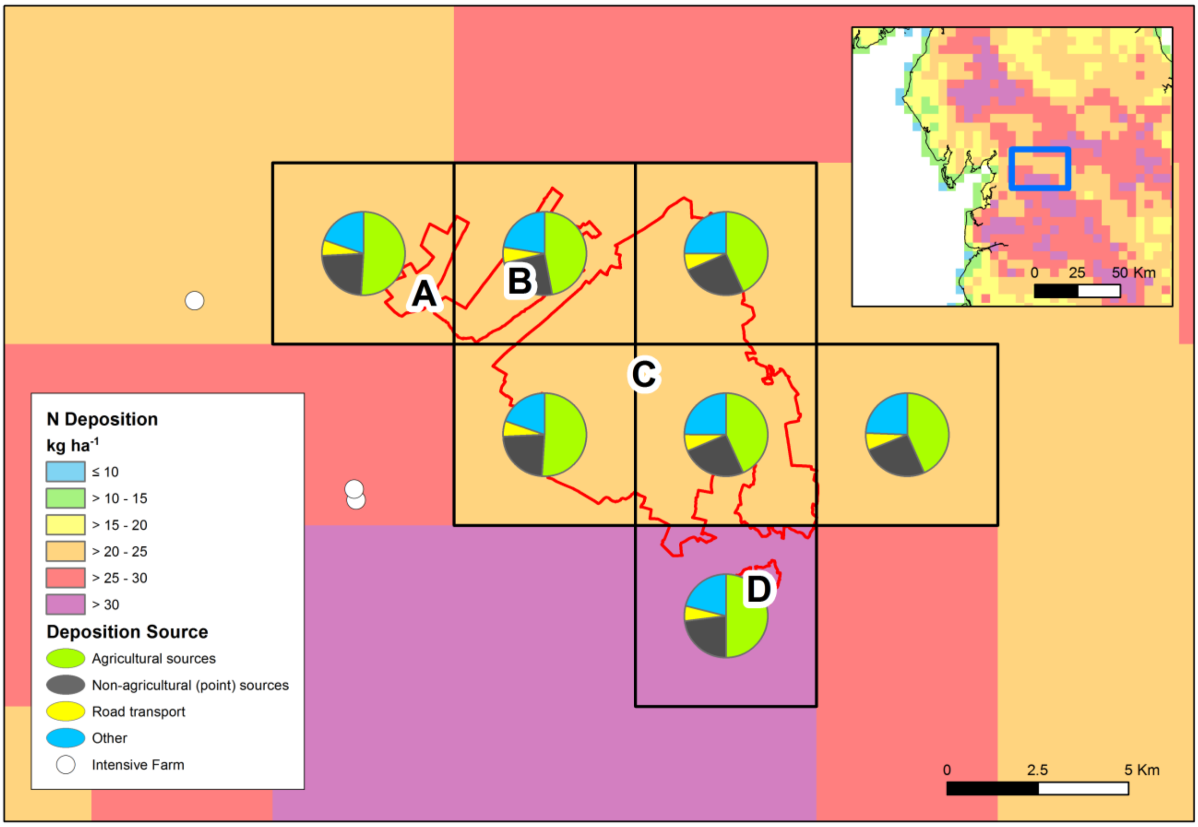

Figure 5 - Estimated N deposition (2010 - 2012) for semi-natural features and source attribution (2005) for Ingleborough Complex. 5 km grid square outlines shown contain portions of the site. Sources are categorised using the initial scenario approach.

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

Agricultural emissions:

The area surrounding the site is dominated by grazing livestock, the majority of which are sheep (Figure 1). There are an estimated >80,000 sheep in the 2km zone surrounding the site boundary, based on the 2012 Agricultural Census. In this area it is estimated that 22 % of agricultural NH_3 emissions derive from activities associated with sheep farming (Figure 6).

Cattle farming is also widespread throughout the region, with > 1,000 dairy cattle and >4,300 other cattle estimated in the area surrounding the site (< 2km from site boundary). While there are considerably fewer cattle compared with sheep, the NH_3 emissions produced are estimated to represent > 60 % of agricultural emissions (of which 28 % are estimated from dairy farming).

The remaining agricultural emissions in the area derive from mineral fertiliser application to grassland (10 %) and other smaller sources, such as mineral fertiliser application to arable crops and other livestock types. The agricultural NH_3 emission density surrounding the site is estimated at 8.3 kg NH_3-N ha^{-1} yr^{-1}.

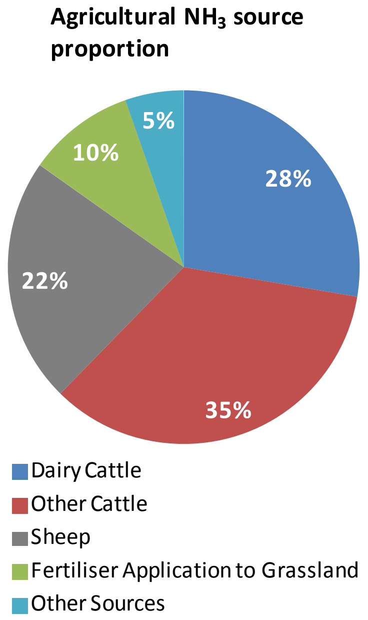

Figure 6 - Agricultural NH_3 emission sources in the 2km area surrounding Ingleborough Complex derived from 2012 agricultural census.

Using Google imagery, it appears that there is a higher density of livestock housing (and manure management) to the south west of the site, when compared to the north and east of the site which is primarily dominated by grazing sheep. There are numerous smaller sources that are within metres of the site, the most common of which is grazing sheep and small farms. Sheep grazing within the site boundary were also identified during the desk top survey (Figure 1).

In addition to the sources already identified, there are three large intensive poultry farms within 10 km of the site (with IED permits). All three sites are located > 4 km from the site and house a modest number of birds (< 75,000 birds each) and are therefore likely to only have a marginal impact on the N deposition of the site.

Other local N sources:

There are no NH_x or NO_x point emission sources within 2 km of the site according to the NAEI database. The only point source located within 10 km of the site boundary is Settle Creamery, which is located > 5km south of the site and is only a minor NO_x emission source, producing >5 kg NO_x-N yr^{-1}. Google imagery revealed that there is however a sewage works located ~800 m northeast of the site boundary, which could be a potential source of N.

The nearest major road is the A65, which at its closest point is ~ 500 m from the site boundary and is therefore unlikely to be a significant source of N deposition to the site.

Discussions with the site officer revealed that steam trains operate in the summer months on the railway line to the north east of the site. Considering this source is located downwind of the site and only runs intermittently during the summer months, it is not considered to be a major threat to the site. The site officer also identified a number of sewage works, which were not identified by the Google Imagery, given the size and distance from the SAC boundary, they are unlikely to pose a significant threat.

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 (> 50 %) of the N deposited to the site is as wet deposition. A breakdown of the probable origin of the N deposition at Ingleborough Complex in presented in Table 3. Almost 40 % of N deposition comes from sources which are well over 10 km away from the site boundary, such as international shipping and emissions imported from outside England. The remaining 60 % of N deposition is estimated to come from source categories that could potentially be local, however a high proportion of these is also likely to originate from sources further afield, given the high proportion of wet deposition.

Table 3 - probable origin of N deposition at Ingleborough Complex SAC (based on 2005 source attribution data)

Probable origin	N Source	N Deposition %	Deposition Type (%)	
			Dry	Wet
Potentially local	Agriculture	44.0	60.0	40.0
	Non-Agricultural & background sources	8.7	45.4	54.6
	Transport	7.6	46.9	53.1
Long-range source	N sources outside of England	28.9	11.8	88.2
	Point sources > 10 km away from site	6.3	38.4	61.6
	International Shipping	4.4	20.0	80.0

5. Selection of potential measures

Measures targeting NH_3 emissions from sheep and cattle farming are likely to be the main options relevant here for local emission reduction, given their 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.

However, given the relatively low local emission density and NH_3 concentrations, and that a large proportion of the N deposition received by the site arrives as wet deposition, measures for reducing emissions in a wider area should be considered. Potential measures across a wider area would need to be delivered through large-scale incentive scheme or country-wide regulatory approaches, as well as through international agreements.

Table 4 - Potential local measures for decreasing local concentrations and deposition of nitrogen to Ingleborough Complex SAC selected 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 %
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 %

N source	Measure	Mitigation effect
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 %

It should be noted that Table 4 summarises potential measures to target only the most significant local sources. Therefore measures targeting the wider-area (inc. medium/long range transport) and those which target local minor sources are not listed here.

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