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Annex 5
Local Assessment - case studies

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Contents

Glossary

Acronym	Meaning
AAE	Annual Average Exceedance
ASSI	Area of Special Scientific Interest (Northern Ireland), equivalent of SSSI in Great Britain
AENEID	Atmospheric Emissions for National Environmental Impacts Determination. A model to produce high-resolution (1 km grid) maps of agricultural ammonia, methane and nitrous oxide emissions for the UK, annual maps available through the NAEI
BAU	Business As Usual - includes only those policies that have already been adopted or implemented at the time of the project projection compilation. It does not include additional measures set out in the NAPCP which are designed to meet NECD/NECR targets.
CBED	Concentration-Based Estimated Deposition, a model generating maps of deposition of sulphur, oxidised and reduced nitrogen
CCE	Coordination Centre for Effects, of the WGE
CNCBs	Country Nature Conservation Bodies (Natural England, Scottish Natural Heritage, Natural Resources Wales, Council for Nature Conservation and the Countryside)
CL	Critical Load, an amount of deposition per unit area and time. The formal definition is "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson & Grennfelt 1988)
CLe	Critical Level, a concentration in air e.g. of ammonia, below which harmful effects do not occur according to present knowledge
CL_{empN}	Empirical critical load for nutrient-nitrogen, as defined in Bobbink *et al*. (2011) and refined for the UK by Hall *et al*. (2011)
CLRTAP	Convention on Long Range Transboundary Air Pollution
DA	Devolved Administration
Daera	Department of Agriculture, Environment and Rural Affairs
Defra	Department for Environment, Food & Rural Affairs
ECA	Emission Control Area
EDZ	Emission Displacement Zone
ELM	Environmental Land Management
ERC	Emission Reduction Commitments
ERZ	Emission Reduction Zone
EU	European Union
FAPRI	Food and Agricultural Policy Research Institute
FRAME	Fine Resolution Atmospheric Multi-pollutant Exchange (atmospheric chemistry and transport model)
ha	Hectares. One hectare is 100 m x 100 m
ICP-M&M	International Cooperative Programme for Modelling and Mapping critical loads and critical levels.
IED	Industrial Emissions Directive
LEZ	Low Emission Zone (a defined area where access by some polluting vehicles is restricted with the aim of improving air quality)
MCPD	Medium Combustion Plant Directive
N	Nitrogen. Strictly, reactive N, i.e. including oxidised and reduced forms of N but not dinitrogen gas, N_2.
NAEI	UK National Atmospheric Emissions Inventory
NAMN	UK National Ammonia Monitoring Network
NARSES	UK agricultural emission model (spreadsheet based), developed by Rothamsted Research
NAPCP	National Air Pollution Control Programme
NE	Natural England
NECD	EU Directive on the Reduction of National Emissions (2016/2284)
NECR	UK National Emission Ceilings Regulations (2018 No 129) transposing NEC Directive 2016/2284/EU.
NFC	UK National Focal Centre, under ICP-M&M

NFR	Nomenclature for Reporting (Format for reporting of national emission data in accordance with the CLRTAP)
NH_3	Ammonia
NMVOC/VOC	Non-Methane Volatile Organic Compounds/Volatile Organic Compounds
NO_x	Nitrogen Oxides
NRMM	Non-Road Mobile Machinery
NRW	Natural Resources Wales
MCPD	Medium Combustion Plant Directive
PaMs	Policies and Measures
PCM	Pollution Climate Mapping (model)
PM	Particulate Matter
SAC	Special Area of Conservation, designated site protected under the Habitats Directive
SEPA	Scottish Environment Protection Agency
SNAP	Shared Nitrogen Action Plan
SNAP (sectors)	Selected Nomenclature for reporting of Air Pollutants. Pollution sources categorised into sectors for reporting. For example: S3 – Combustion in manufacturing industry, S7 – Road Transport, or S10 Agriculture.
SNCBs	Statutory Nature Conservation Bodies (Joint Nature Conservation Committee, Natural England, Scottish Natural Heritage, Natural Resources Wales, Northern Ireland Natural Environment Division)
SNH	Scottish Natural Heritage
SO_2	Sulphur Dioxide
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
UAN	Urea Ammonium Nitrate (a liquid fertiliser combining urea, nitric acid, and ammonium)
WAM	With Additional Measures. This scenario includes policies that have been adopted and implemented as well as those that are planned.
WGE	Working Group on Effects, within CLRTAP
WM	With Measures. This scenario includes policies that have been adopted and potentially implemented at the time of projection compilation.
WP	Work Package

Summary

This document forms Annex 5 to the main Nitrogen Futures project report. The main purpose of this annex is to document the 15 case studies carried out, to assess a) whether outputs from UK-scale models can help identify and represent atmospheric N issues at designated sites, and b) whether spatial targeting of mitigation measures is a suitable strategy to decrease atmospheric N effects at these sites.

The selected sites from across the UK cover a wide range of habitats, atmospheric N issues and pressures. The case studies used the national scale data together with re-analysis of previous local studies and local knowledge

The local assessment showed that the UK-scale data are useful to identify atmospheric N issues at site level, and to evaluate whether spatial targeting of measures would be effective. While the overall level of threat can be identified, together with likely nearby sources, the 1 km grid resolution may mask acute local gradients in atmospheric N concentrations and deposition, potentially underestimating local enhancement above background and the importance of “hotspots” such as large livestock houses or busy roads next to designated sites.

Designated sites that are subject to high levels of local atmospheric N input, from either farming activities or road transport, could be effectively targeted with locally implemented measures. By contrast, for sites remote from local emission sources, the main drivers for improvement are wide-ranging national and international mitigation efforts, to which the current NECD/NECR targets will contribute.

Insights derived from the local case studies shown in this annex are summarised, in the main report which contains further assessments, discussion and conclusions based on combination with wider project outputs.

1 Introduction

1.1 Background

Local demonstration studies aim to illustrate the spatial targeting concept across a range of sites with different atmospheric nitrogen (N) input characteristics, across the four countries of the UK. This is to help tease out the variation of different policy ambitions at the local scale, and to test the use of this study's output for practical application.

In the original tender, four well-developed case studies with modelling were proposed, to fit within the limited time scale and resources assigned to the related work package. Following discussions with the Steering Group, this approach was changed towards more light-touch assessments, to provide a larger number of case studies as illustrative local assessments of spatial targeting of measures. This approach enabled the case studies to encompass a wider range of situations in terms of geography, emission sources, severity and type of atmospheric N input. For example, it is important to demonstrate that sites that receive mostly long-range N deposition (high proportion of wet deposition) would not benefit directly from spatial targeting, in the absence of local sources. By contrast, sites that have multiple or large local sources would benefit substantially from local measures, compared with a similar amount of mitigation being diluted over a wider area.

The use of UK-scale 1 km grid resolution across the whole modelling chain in this project (see Annex 4) marks a significant improvement to the previous Defra AC0109 project (Ammonia Future Patterns, Dragosits *et al*. 2014). Local scale assessments also demonstrate the importance of more detailed data (beyond the 1 km grid national scale modelling) for quantifying impacts on sensitive habitats/sites. This potential issue has been explored for the selected case study sites and is illustrated in the individual assessments of sites. For some types of sites or types of atmospheric N input, national scale modelling will be appropriate/sufficient, but for other sites, further local scale emission data and modelling would be helpful to sufficiently assess the impacts. This is especially the case at sites where local emissions may be a large contributor to N deposition, so that any spatial targeting can be tailored to maximise benefits.

1.2 Selection of case study sites

The choice of case studies is important in assessing how effective both UK-wide and spatially targeted measures may be, and to evaluate the limitations of national scale modelling, which necessarily operates on less detailed information. Great care was taken in the selection of sites, with the intention to cover a wide range of habitats, across different levels of severity of atmospheric N pollution threats, N pollution source types, and geographically. This includes (in addition to sufficient data/information being available):

- Ammonia vs NO_x sources
- Emission source sectors (agriculture, transport, *etc*.)
- Relatively clean sites vs those very heavily affected by atmospheric N input
- Sites mainly affected by local sources vs those mainly affected by long range N deposition
- Habitat types (e.g. bogs, woodland, heath, grassland types)
- Primary vs secondary mitigation (i.e. emission reduction vs recapture)
- Geography – covering
    - all parts of the UK (England, Wales, Scotland, Northern Ireland)
    - upland and lowland, urban vs rural vs very remote

A large number of potential case study sites were discussed with the Steering Group, with pertinent summary information for the selected sites shown in Table 1.

Table 1. Case study sites for local assessment of spatial targeting.

#	Site	Country	Habitat(s)/designated features	Designation(s)	Main N threat(s)
1	Ashdown Forest	England	Broad-leaved, mixed and yew woodland Dwarf shrub heath Mixed: Lowland heath, woodland	SAC, SSSI, SPA	Transport/ combustion and other sources (NO_x, NH_3)
2 3	Breckland (2 sites, Farmland, Forest)	England	Coniferous woodland Dwarf shrub heath Dry heaths (Breckland Farmland mainly arable land)	SAC, SPA, SSSI	Various agricultural sources (pig, poultry, arable) (mainly NH_3)
4	Epping Forest	England	Acid grassland Broad-leaved, mixed and yew woodland Dwarf shrub heath	SAC, SSSI	Transport/ combustion (NO_x, NH_3)
5	Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses	Wales/ England	Invertebrate assemblage Scirpus cespitosus - Erica tetralix wet heath Erica tetralix - Sphagnum papillosum raised and blanket mire Sphagnum cuspidatum/recurvum (fallax) bog pool community Eriophorum vaginatum blanket and raised mire Juncus effusus/acutiflorus - Galium palustre rush pasture Molinia caerulea - Potentilla erecta mire Eriophorum angustifolium bog pool community Outstanding dragonfly assemblage Rare bird species or feature (wet meadow wader) - Curlew, Numenius arquata Alnus glutinosa - Urtica dioica woodland	SSSI, SAC	Various agricultural sources (mainly NH_3)
6	Dinefwr Estate	Wales	Neutral grassland Upland hay meadows Lowland meadows Lowland beech and yew woodland Upland birchwoods Wet woodland Lowland mixed deciduous woodland Wood-pasture and parkland Upland mixed ashwoods Traditional orchards	SSSI	Local agricultural NH_3 emissions; with elevated concentrations affecting sensitive lichen communities

			Broad-leaved, mixed and yew woodland Improved grassland		
7	Gregynog	Wales	Acid grassland Neutral grassland Native pine woodlands Coniferous woodland Lowland beech and yew woodland Upland oakwood Upland birchwoods Wet woodland Lowland mixed deciduous woodland Wood-pasture and parkland Upland mixed ashwoods Traditional orchards Broad-leaved, mixed and yew woodland	SSSI	Poultry farms (mainly below PPC limit) (mainly NH_3)
8	Beinn Dearg	Scotland	Native pine woodlands Coniferous woodland Upland assemblage	SSSI	One of the cleanest sites in Scotland (NH_3 concentrations and N deposition)
9	Glasgow LEZ	Scotland	N/A	LEZ	Not a designated site, but of interest to Scottish Government as a Low Emission Zone; transport/ combustion sources of NO_x and NH_3
10	Whim Bog	Scotland	Lowland Raised Bog Blanket Bog Bogs	SSSI	Adjacent poultry, beef and sheep farms (mainly NH_3)
11 12	Ballynahone Bog and Curran Bog (2 neighbouring sites)	Northern Ireland	Active raised bog/lowland Raised Bog Invertebrate assemblage	SAC, ASSI, RAMSAR	Intensive mixed farming landscape, with dairy, beef, pig and poultry farming (mainly NH_3)
13	Lough Navar Scarps and Lakes	Northern Ireland	Dry heath Wet heath Inland Rock Blanket bog Purple Moor-grass and rush pastures Upland Flushes, Fens and Swamps Oligotrophic lakes Dystrophic lakes Higher Plant Assemblage Lichen Assemblage	ASSI	Relatively clean site within Lough Navar forest (medium/ long range atmospheric N input)

			Bryophyte Assemblage Marsh fritillary butterfly Invertebrate assemblage		
14	Peatlands Park	Northern Ireland	Lowland raised bog, Fens, Oakwood, Bog woodland Higher plant assemblage, Invertebrate assemblage	SAC, ASSI	Intensive mixed farming landscape, (mainly NH_3)
15	Turmennan	Northern Ireland	Transition mires and quaking bogs/fen Invertebrate assemblage	SAC, ASSI	Intensive mixed farming landscape, at least 1 IED farm <2km (mainly NH_3)

1.3 Scenarios

The derivation of all scenarios (in collaboration with the project Steering Group) and underlying assumptions are described in detail in the parallel Annexes 1 and 2 and summarised in the main report. Tables 2 and 3 provide a summary of the measures across all scenarios and the short names used for the scenarios in this report.

Table 2. Summary description of baseline and mitigation scenarios modelled for 2017, 2030, 2040+. Further details of all scenarios can be found in Annex 2.

Year	Short name	Description	Number of scenarios	Comments on selection
2017	Baseline	Best estimate of present time	1	NAEI 2017 with small updates where available)
2030	BAU (WM)	Business As Usual With Measures (WM) baseline (no spatial targeting)	1	2030 baseline (not meeting NECR); data provided by Defra
2030	NAPCP+DA (NECR NO_x)	UK-wide emission reductions – NAPCP+DA measures for NH_3 & no extra NO_x reduction beyond NECR target (no spatial targeting)	1	NOx: NECR target NH_3: NAPCP central estimate with DA medium ambitions; NAPCP data provided by Defra, modified with DA input for NH_3 as part of this project
2030	NAPCP+DA	UK-wide emission reductions – NAPCP+DA for NH_3 & -10 % for NO_x (targeted across agglomerations)	1	NH_3: as above, non-spatially targeted medium ambition for comparison against targeted scenarios NO_x: -10% across agglomerations, otherwise as NECR target
2030	ERZ SAC 2km ERZ SSSI 1km ERZ SSSI 2km ERZ SSSI 5km	Spatially targeted emission reductions – high ambitions (maximum feasible) for NH_3 in ERZ around sites, outside ERZ: NAPCP+DA. -10 % NO_x reduction on baseline for agglomerations	4	Testing different widths of ERZ, mainly for SSSIs (as preferred by Steering Group), but with 1 SAC-based scenario to enable quantitative efficiency estimates for both types of sites

Year	Short name	Description	Number of scenarios	Comments on selection
2030	High Ambition exc. Cattle	High ambitions for NH_3 everywhere (i.e. as for ERZ above, UK-wide); [excl. the additional more ambitious cattle measures described in the 2040+ scenario below]	1	To enable a fully quantitative comparison across the selected scenarios
2030	EDZ SSSI 1km	Spatially targeted displacement of NH_3 emissions around designated sites, with NAPCP+DA for NH_3, & 10 % reduction in NO_x emissions	1	EDZ can also represent land use de-intensification, but modelled here as moving of slurry/manure spreading away from designated sites
2040+	High Ambition inc cattle	UK-wide emission reductions - high ambitions for NH_3 (*inc higher ambitions for cattle*) & additional 15 % reduction in overall NO_x emissions compared with NAPCP+DA	1	Useful for understanding what overall highest ambition everywhere for 2040+ could achieve, inc. possible additional measures for larger beef (>100 cows) and dairy (>150 cows) farms
2040+	ERZ SSSI 2km inc cattle	Spatially targeted emission reductions – high ambitions (maximum feasible + cattle ambitions) for NH_3 emissions around SSSIs/ASSIs, elsewhere NAPCP+DA; additional 15 % reduction in NO_x emissions compared with NAPCP+DA;	1	2 km zone preferred to other ERZ widths for testing
2040+	Trees SSSI 2km	Tree planting surrounding emission sources in addition to UK-wide NH_3 emission reductions (NAPCP+DA) & additional 15 % reduction in NO_x emissions compared with NAPCP+DA	1	Model shelter belt effect for all livestock housing and manure storage facilities for cattle, pigs & poultry, but not sheep, horses, goats and farmed deer (uptake 75-80%); for 2 km zone around SSSIs
2030	CLe opt. ERZ (no urea) CL opt. ERZ (no urea)	Optimised spatial targeting with efficient combinations of measures (based on 1st round of modelling); optimised minimum ERZ widths, combined with 1 km EDZ and replacing all urea/UAN fertiliser with lower emission alternatives	2	Critical Level (CLe) targets easier to achieve than Critical Loads (CL), as concentrations tail off faster; long-range transport influences N deposition and therefore CL exceedance more;

Table 3. Summary description of baseline and mitigation scenarios modelled for 2017, 2030, 2040+. ERZ are spatially targeted Emission Reduction Zones around designated sites, and EDZ Emission Displacement Zones (see Table 2 for more details and Nitrogen Futures Annex 2 for fully detailed scenario definitions). Cattle reg. refers to additional regulatory measures for larger cattle farms, agglom. refers to agglomerations, i.e. large urban areas used by Defra to report air quality. BAU refers to Business As Usual and NAPCP is the National Air Pollution Control Programme, with modifications by the Devolved Administrations (DA) - see Annex 1 for detailed descriptions of the 2030 baseline scenarios.

Short scenario names	year	NH_3 spatially targeted?	NH3 ambition within ERZ	NH3 ambition outside ERZ	NH_3 EDZ	NH_3 Trees	urea/UAN replacement	NO_x measures
2017 Baseline	2017	UK-wide	-	-	-	-	-	baseline
2030 BAU (WM)	2030	UK-wide	BAU	BAU	-	-	-	BAU (WM)
2030 NAPCP+DA (NECR NOx)	2030	UK-wide	NAPCP+DA	NAPCP+DA	-	-	-	NECR
2030 NAPCP+DA	2030	UK-wide	NAPCP+DA	NAPCP+DA	-	-	-	NECR -10% in agglom.
2030 ERZ SAC 2km	2030	2 km	high scenario	NAPCP+DA	-	-	-	NECR -10% in agglom.
2030 ERZ SSSI 1km	2030	1 km	high scenario	NAPCP+DA	-	-	-	NECR -10% in agglom.
2030 ERZ SSSI 2km	2030	2 km	high scenario	NAPCP+DA	-	-	-	NECR -10% in agglom.
2030 ERZ SSSI 5km	2030	5 km	high scenario	NAPCP+DA	-	-	-	NECR -10% in agglom.
2030 High Amb. exc. cattle	2030	UK-wide	high scenario	high scenario	-	-	-	NECR -10% in agglom.
2030 EDZ SSSI 1km	2030	1 km	NAPCP+DA	NAPCP+DA	y	-	-	NECR -10% in agglom.
2040+ High Amb. inc. cattle	2040+	UK-wide	high + cattle reg.	high + cattle reg.	-	-	-	NECR -10% & addit. -15%
2040+ ERZ SSSI 2km inc. cattle	2040+	2 km	high + cattle reg.	NAPCP+DA	-	-	-	NECR -10% & addit. -15%
2040+ Trees SSSI 2km	2040+	2 km	NAPCP+DA	NAPCP+DA	-	y	-	NECR -10% & addit. -15%
2030 CLe opt. ERZ SSSI (no urea)	2030	variable	high scenario	NAPCP+DA	y	-	y	NECR -10% in agglom.
2030 CL opt. ERZ SSSI (no urea)	2030	variable	high scenario	NAPCP+DA	y	-	y	NECR -10% in agglom.

2 Methodology

2.1 Agricultural emissions density

Holding level agricultural statistics provided by the UK countries and emission factors for each scenario were used to estimate agricultural emission densities (i.e. average NH_3 emissions, as kg N ha^{-1} yr^{-1}) surrounding designated sites (for details of the data sources used for scenario development and associated emission factors, see Annexes 1, 2 and 4). Emission factors represent average estimates for each of the UK countries, based on best available knowledge currently implemented in the UK agricultural emission inventory. Therefore, they do not necessarily reflect site-level conditions. In addition to the overall emission density in each zone, the calculations also provide the proportion of the main agricultural sectors contributing to NH_3 emissions in concentric zones surrounding each site (1 km width zones to a maximum distance of 10 km from the site boundary) was also estimated,. Each zone includes emissions from the site boundary up to the buffer distance (e.g. the 5 km zone includes emissions from 0 - 5 km from the site boundary, rather than 4 - 5 km).

The use of high-resolution agricultural statistics was possible due to project licenses being granted by the UK country authorities (Defra, Daera, Welsh Government, Scottish Government). For Wales, the data (with locations only provided at the parish level rather than for individual holdings) were not suitable for calculating agricultural emission densities for 2017. This was only realised by the team late in the interpretation stage of the data. However, more detailed locational data exist, and earlier versions were used for previous work for Natural Resources Wales (NRW), see Carnell and Dragosits (2015). Therefore, site profiles for Dinefwr Estate and Gregynog do not contain full emission density assessments, with less quantitative descriptions of key agricultural sectors provided instead. This does not affect the UK-wide 1 km grid resolution emission modelling, which uses an area-based approach, rather than individual farm locations, to distribute emissions by land cover weighting, resulting in non-disclosive emission maps.

To comply with the data license agreements, results were aggregated to show only output data that refer to at least five agricultural holdings. For categories where this requirement was not met (i.e. due to fewer than five holdings contributing to a sector total), emissions from that sector were aggregated into a category "Other sources", together with other minor categories, to ensure non-disclosure of all outputs. Therefore, buffer zones with fewer than five agricultural holdings overall cannot be shown but may contain emission sources.

2.2 Assessment of Local Road Traffic

Four of the local case studies are known or expected to be substantially affected by emissions from nearby roads. These are Ashdown Forest (England), Epping Forest (England), Glasgow LEZ (Scotland) and Peatlands Park (Northern Ireland). These four case studies therefore considered the localised effect of road traffic emissions on NO_x, NO_2, and NH_3 concentrations, and N deposition, in addition to the 1 km resolution UK modelling used for all other sites.

Where possible, previously published dispersion modelling was used. The approach taken for assessing the sites depended on available local information. Each case study therefore followed a different method and the results are presented to match the available data sources.

Notwithstanding inter-site differences, the overarching approach taken was to nominally separate concentrations and deposition fluxes into two components: the 'background', i.e. the spatially-averaged conditions which are also representative of location-specific conditions well away from roads, and the location-specific 'local road increment'. In practice, this distinction is artificial but is a convenient way to both conceptualise and calculate roadside conditions. Local roads contribute to both the background and to the local road increment, but in practice double counting will have a negligible effect because the contribution to spatially-averaged conditions from any individual road will be minimal when compared with its contribution close to the road.

Derivation of Current-year 'Background Component'

For Ashdown Forest, published measurements of background conditions made well away from any roads and representing a 2-year period within 2014-2016 were taken from the literature (Marner *et al.* 2018) and assumed to represent conditions in 2017. For the other traffic-related case studies (Epping Forest, Glasgow LEZ and Peatlands Park), the 1 km resolution UK model outputs were taken to represent the background.

NO_x concentrations are not output from FRAME (which only outputs NO_2). Background NO_x concentrations were therefore derived by taking the local study area average ratio of NO to NO_2 from Defra's PCM background maps (Defra 2020) for 2017, and then applying this to background NO_2 concentrations from FRAME. NO_2 in NO_x quotients in these maps are based on well-established relationships and the predicted year-on-year changes in these quotients are relatively small.

Derivation of Future-year 'Background Component'

For Ashdown Forest, the measured background NO_x, NO_2 and NH_3 concentrations were factored to each future-year scenario based on the ratio of the FRAME-modelled future conditions to FRAME-modelled current-year conditions (taking the average ratios across all of the 1 km grid squares covering Ashdown Forest). Similarly, the current-year background nitrogen deposition fluxes were multiplied by the ratio of future to current total deposition fluxes from the FRAME model (applying one set of ratios to woodland and one to short vegetation; averaged across the whole of Ashdown Forest).

For the other local traffic-related case studies (Epping Forest, Glasgow LEZ and Peatlands Park), background concentrations and deposition fluxes on a 1 km resolution across the local demonstration sites were taken directly from FRAME. Background NO_x concentrations were derived by taking the average ratio of NO_x to NO_2 for each study area from Defra's PCM background maps (Defra 2020) for 2030. The FRAME-modelled background NO_2 concentrations were then multiplied by these ratios. In practice, it is reasonable to expect the background NO_x to NO_2 relationship to be different in each future scenario, but the additional uncertainty caused by assuming constant (2030 BAU-specific) ratios is likely to be extremely small.

Derivation of Current-year 'Local Road Component'

For Ashdown Forest, Epping Forest, and Glasgow LEZ, the local road increments of concentrations and, in case of Ashdown Forest, deposition fluxes, were taken directly from published studies. These each used dispersion modelling to predict local roadside effects (Marner *et al.* 2018; Aecom 2019; Malby, A. (SEPA) 2020) with predictions made for 2015, 2017, and 2017 respectively and each was taken to represent the local road increments in 2017. The Epping Forest study includes predictions of ambient concentrations and deposition fluxes, but only the ambient concentration values were used; with deposition fluxes calculated from these concentrations using different deposition velocities than those used in the published study. In the case of Peatlands Park, no such study was available and so project-specific dispersion modelling was carried out.

Derivation of Future-year 'Local Road Component'

NO_x and NO_2

The local road increments of NO_x concentrations (and NO_2 for Ashdown Forest) were assumed to scale linearly with the traffic-related NO_x emissions input to FRAME. Thus, the ratio of traffic-related NO_x in each future scenario to traffic-related NO_x in 2017 was calculated for each 1 km grid square covering all of the roads in each study area. For each study area, these ratios were averaged to give a 'road-NO_x projection factor' which is specific to that study area. The local road increments of NO_x concentrations and NO_2 (for Ashdown Forest) in 2017 were multiplied by these factors to predict concentrations in the future. For Ashdown Forest this assumption of a linear relationship between local traffic-related NO_x emissions and local traffic-related concentrations is valid for NO_x but ignores the non-linearity between NO_x emissions and NO_2 concentrations. In practice, however, the effects of this non-linearity will be relatively trivial when compared with other sources of uncertainty; such as in the emission estimates themselves. For Epping Forest, Glasgow LEZ and Peatlands Park the local road NO_2 concentration was calculated using the NO_x to NO_2 calculator and therefore the relationship between NO_x and NO_2 was taken into account.

NH_3

For all four traffic-related case studies, the current-year local road increments of NH_3 concentrations were multiplied by the ratio of future-year to current-year road NH_3 emissions input to FRAME. These assumptions inform the core sets of model results which are relied upon unless stated otherwise.

There are, however, significant uncertainties in the traffic-related NH_3 emissions factors input to the FRAME model (Marner *et al.* 2020). In the context of 1 km average concentrations and deposition fluxes, these uncertainties are relatively trivial (i.e. the overall effects of other uncertainties will be much greater). However, when considering NH_3 concentrations and nitrogen deposition fluxes alongside roads, the uncertainty in predicting traffic-related NH_3 emissions is more important. For this reason, the predictions for the two sites where traffic-related nitrogen deposition is most significant (Ashdown Forest and Epping Forest) included some additional sensitivity tests regarding traffic-related NH_3 emissions.

For Ashdown Forest, the current-year increment of traffic-related NH_3 concentrations in the published data (Marner *et al.* 2018) was verified against ambient measurements and is thus considered to be robust. The sensitivity tests for Ashdown Forest have thus focused on the future scenarios. For Epping Forest, the published increment of traffic-NH_3 has not been verified against measurements and so, to accompany the results based on the published values, an alternative current-year traffic-related NH_3 increment was calculated by multiplying the current-year traffic-related NO_x increment by 0.022, which is the traffic-NH_3 to traffic-NO_x ratio observed in the ambient measurements made at Ashdown Forest (Marner *et al.* 2018).

Future-year traffic-NH_3 emissions were then calculated using the CREAM model (Marner & Wilkins 2020) which is largely based on the results from recent remote sensing measurements. For each site, a scaling factor was derived by running the CREAM model for a representative vehicle fleet in 2017 and 2030 (using the BAU vehicle fleet assumptions). That scaling factor was then applied to the current-year traffic-NH_3 concentrations in order to predict future-year traffic-NH_3 concentrations assuming the BAU vehicle fleet. For the future-year scenarios which rely upon additional reductions in NO_x emissions, two separate tests were modelled. The first assumes that the reductions in traffic-NO_x emissions will be mirrored by equivalent reductions in traffic-NH_3 emissions. This would be the case if, for example, these reductions were achieved through electrifying the vehicle fleet. The second set of tests assumes that the reductions in traffic-NOx emissions are achieved by encouraging a shift from diesel cars to petrol cars (or petrol hybrid cars). Defra’s Emissions Factors Toolkit (Defra 2020b) was used to calculate the proportion of the car fleet which would need to switch from diesel to petrol in order to achieve the defined NO_x emissions reductions, and these proportions were then used within the CREAM (V1A) model to calculate the commensurate change in traffic-NH_3. While fully electric vehicles have no NH_3 emissions at point of use, petrol vehicles tend, on average, to emit more NH_3 (but less NO_x) than equivalent diesel vehicles. In practice, the same reductions in traffic-NOx might be achieved in many different ways, but these two tests provide an approximate range for the effect that different fleet modifications might have.

All of these sensitivity tests were applied to the local road increment of traffic-NH_3 only; meaning that the background component (from FRAME) is based on the same emissions in the core modelling and in each sensitivity test. The results from these local traffic sensitivity tests are presented separately from the core model results.

Sensitivity tests for traffic-NH_3 were carried out for Glasgow LEZ and Peatlands Park because traffic-NH_3 is not important to the overall findings at either of these sites.

2.3 Source attribution

Source attribution data are derived by performing multiple model runs of an atmospheric transport and deposition model, with each source type removed in turn, to quantify its footprint, compared with the complete deposition dataset. Nitrogen deposition attributed to individual emission source categories (such as agriculture, road transport, *etc*.) or large point sources (such as individual power stations) can then be calculated as a proportion of total deposition to each model grid square. Source attribution modelling requires a very large number of model runs and is therefore not carried out on a regular basis, but updated periodically. The most recent available dataset (for 2012) contains estimates of N deposition to each model grid square at a 5 km grid resolution. From this dataset, the N deposition estimated at a given designed site can be estimated, from 23 major UK point sources, 17 area emission source categories (e.g. agriculture, road transport, *etc.*, separately for each UK country (i.e. Northern Ireland, Scotland, Wales and England) and international emissions (shipping and emissions from Europe). Where there is a local road traffic source, the relative contribution to the site maxima taking into account the local road source is presented. Total N deposition data are further split into N species typically depositing locally (NH_3, NO_2) from those depositing more regionally (i.e. NH_4, HNO_3). Distinguishing between these chemical species provides an indication of whether the sources of N deposition received by a site are local or regional. The distinction between local and regional sources of N deposition is critical for the selection of suitable N mitigation measures, as it indicates whether targeting local sources is appropriate or whether initiatives to target N regionally are more suitable.

2.4 Nitrogen Decision Framework

For three sites: Ashdown forest, Fenn's and Whixall and Turmennan, outcomes of the mitigation scenarios were run through the Factor 1 Exceedance scores of the Nitrogen Decision Framework (Jones *et al.* 2016) to assess how this metric of ecological risk will change under scenarios to reduce emissions. Sites were selected to represent a variety of habitats, and N sources. Results were calculated for selected habitats (including woodland) to illustrate a range of impacts and a range of N sensitivity. Only three emission mitigation scenarios were used for the assessment: 2017 Baseline, 2030 NAPCP + DA (NECR NOx), and 2030 CL OPT ERZ SSSI (no urea), giving a range of future levels of N deposition. Each assessment was run with two different assumptions about uncertainty around the N deposition figures. The standard assessment based on national data is to assume +/- 50% uncertainty (Jones *et al.* 2016). For the purposes of this report, given that detailed deposition modelling was undertaken for the local context, a second assessment was conducted, assuming a lower degree of uncertainty (+/- 20%) in the N deposition estimates. The figure of +/-20% is a rough estimate for the purposes of this analysis, and a more robust estimate of the uncertainty in the local deposition modelling would be useful. All assessments used the 1km site average N deposition data, for woodland or non-wooded habitats, as appropriate.

2.5 Average Annual Exceedance (AAE)

The Average Annual Exceedance (AAE) indicator (also referred to as "excess nitrogen" more recently) has been estimated at all designated sites using the method below:

$$AAE\ (kg\ N\ ha^{-1}\ yr^{-1}) = \frac{exceedance\ (kg\ N\ ha^{-1}\ yr^{-1}) * habitat\ area\ (ha)}{total\ habitat\ area\ (ha)}$$

Estimating AAE provides an exceedance value averaged across the whole habitat area and provides a more intuitive value for comparing the exceedance results under each scenario, i.e. it is a measure of how much deposition has been reduced by, rather than the binary exceedance/non-exceedance indicator, and instead gives the magnitude of the remaining exceedance above the critical load. Further detail on exceedance metrics is given in Annex 3.

2.6 Summary

In summary, the approach taken here utilises the following sources of information:

- Output from the national/country scale modelling at a 1 km by 1 km grid resolution (implementation of scenarios) for the selected sites

- Local scale modelling for transport related atmospheric N input to designated sites where detailed datasets are available. Data rich sites include Epping Forest and Ashdown Forest (England), and further estimates were made for Peatlands Park (Northern Ireland) and Glasgow LEZ (not a designated site)
- Local scale assessments on agriculture-related local sources include information available from previous case studies related to atmospheric N input to designated sites, including Ballynahone Bog (Northern Ireland), Whim Bog (Scotland), or Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses (England). In addition, input from local stakeholders (NRW, Daera, NE, SNH) has been sought.

The following section (Section 3) contains the 15 individual site profiles. The key findings and insights are summarised and discussed in Section 3.2 of the main report.

3 Site profiles

3.1 Ashdown Forest

3.1.1 Site map and location within UK

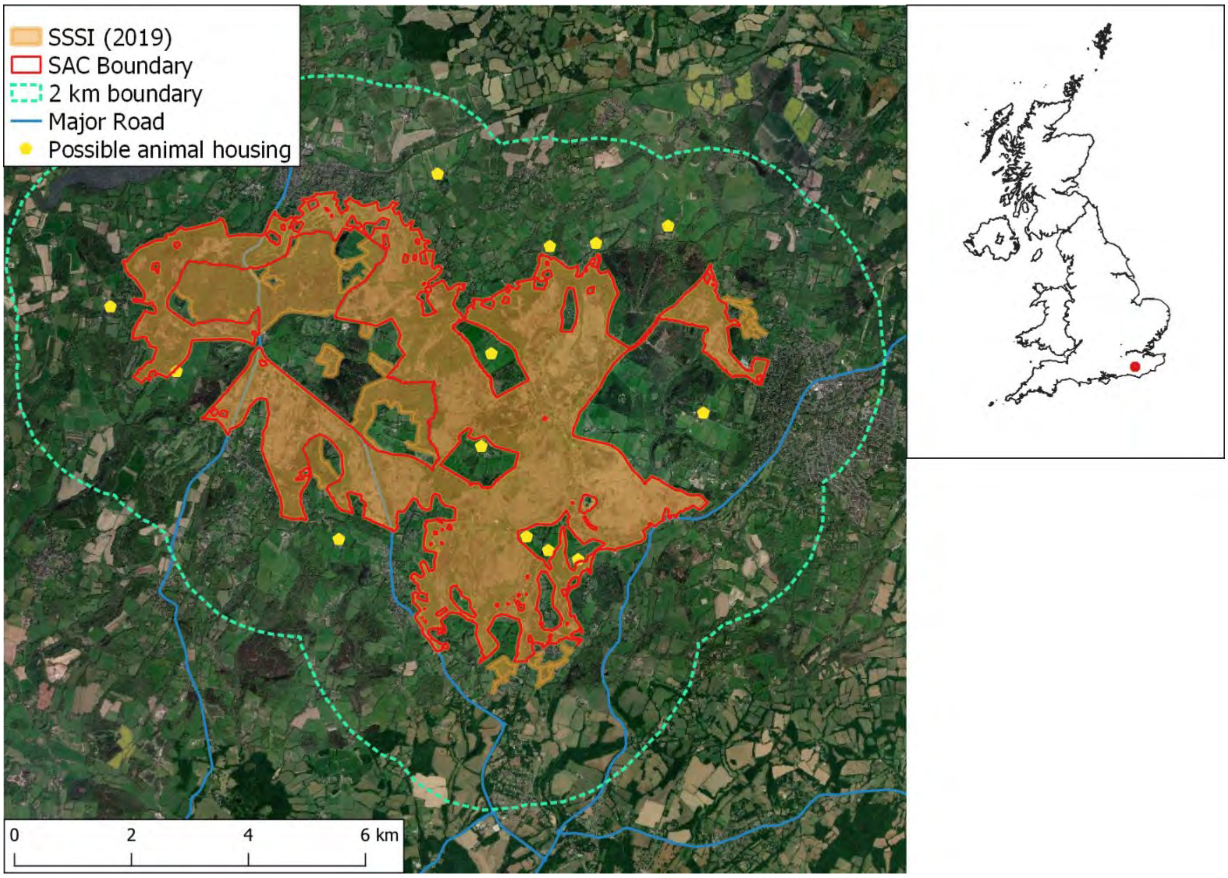


Figure 3.1-1. Site map showing relevant features and boundaries of Ashdown Forest, with location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

The published local road source modelling for Ashdown Forest (Marner *et al.* 2018) covers the SAC boundary rather than the SSSI, therefore the local road traffic analysis relates to the SAC only.

3.1.2 Designated features

Table 1. Nitrogen sensitive interest features at Ashdown Forest SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Broadleaved deciduous woodland Dwarf shrub heath	10 – 20 kg N/ha/yr
Invertebrate assemblage Outstanding dragonfly assemblage	No estimate available

3.1.3 Site characteristics

Ashdown forest (SAC/SSSI/SPA) is a large site (> 3,000 ha) with continuous heath, semi-natural woodland and valley bog. It contains one of the largest single continuous blocks of lowland heath in south-east England. It is of particular interest because it has been the test case in a number of high-profile planning and legal disputes, in relation air quality impacts on sensitive habitats, such as the Judgement of the High Court in case CO/3943/2016 Between Wealden District Council and Secretary of State for Communities and Local Government, Lewes District Council, South Downs National Park Authority, and Natural England; Letter from Planning Inspectorate to Wealden District Council dated 20th December on the Council's Submission Local Plan.

Owing to long-standing debates between the local planning authority (Wealden District Council) and other interested parties regarding the effects of development pressure on the SAC and SPA, Ashdown Forest has become one of the most heavily-studied ecological sites in the UK with respect to ambient air quality. In order to inform local planning policy, Wealden District Council operated a network of 105 air quality monitoring sites, covering all key dry depositing species, as well as classified traffic counts and ecological surveys. The Council used the ambient measurements and traffic surveys to construct a dispersion and deposition model, which covered the SAC area on a 2 m x 2 m grid. Aerial surveys, coupled with ground-truthing, were used to determine the dominant habitat type for each 2 m grid square in order to refine the deposition calculations. The monitoring network operated from 2014 until 2020; although only results for the 2-year period 2014-2016 are used in this current case study.

3.1.4 Agricultural emission density

The average agricultural emission density for the closest 2 km area surrounding the site is low at ~1.2 kg NH_3 ha^{-1} yr^{-1} (compared to the average agricultural emission density in England of ~1.8 kg NH_3 ha^{-1} yr^{-1}). Agricultural emission density in the surrounding 10 km buffer of the site is estimated to decrease with increasing ambition in the selection of mitigation scenarios shown in Figure 3.1-2 below.

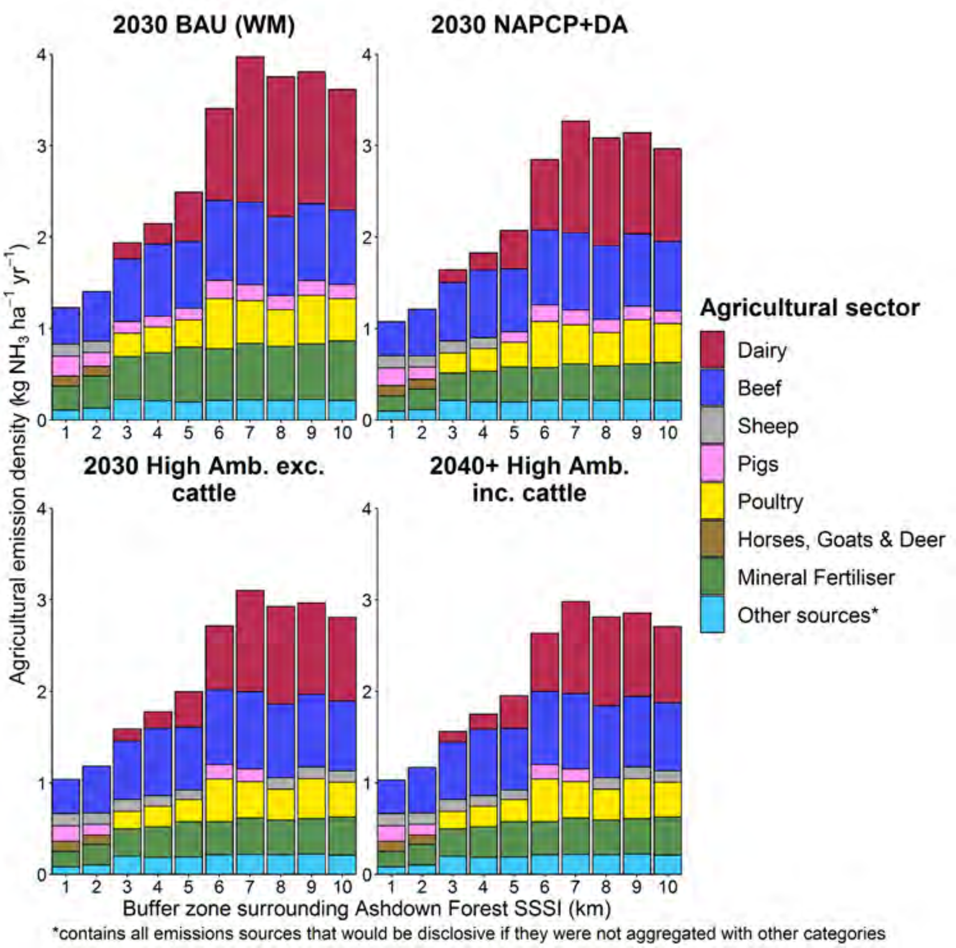


Figure 3.1-2. Estimated agricultural emission densities in concentric buffer zones surrounding Ashdown Forest SSSI.

3.1.5 Source attribution

When considering the total deposition to the site as a whole, local sources of N deposition are estimated to be of roughly similar magnitude at this site as regional sources (Figure 3.1-3 and Figure 3.1-4). Of the locally depositing species, the largest source is livestock emissions and other agricultural sources in England. There are also notable non-agricultural inputs to this site, including transport and non-abatable, non-agricultural emissions (such as those directly related to humans, pets and wild animals).

Woodland features and low-growing semi-natural vegetation are both present at this site, therefore source attribution to both vegetation types is shown here.

Because the effects of individual sources diminish significantly with increasing distance, the source attribution for the site as a whole is very different to the source attribution at the worst-affected locations. Figure 3.1-5 shows the overall contribution of each source to N deposition at these worst-affected points, which are alongside roads. Local road traffic is the single most important source of N deposition by an appreciable margin at the worst-affected locations.

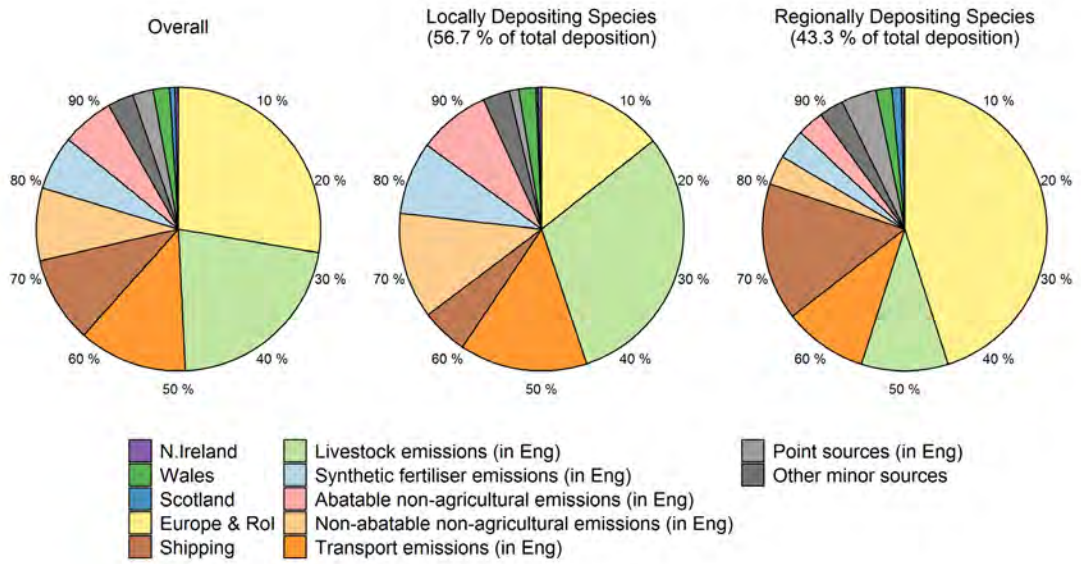


Figure 3.1-3. Relative contribution of emission sources to Site-total N deposition (to woodland features) received by Ashdown Forest SSSI.

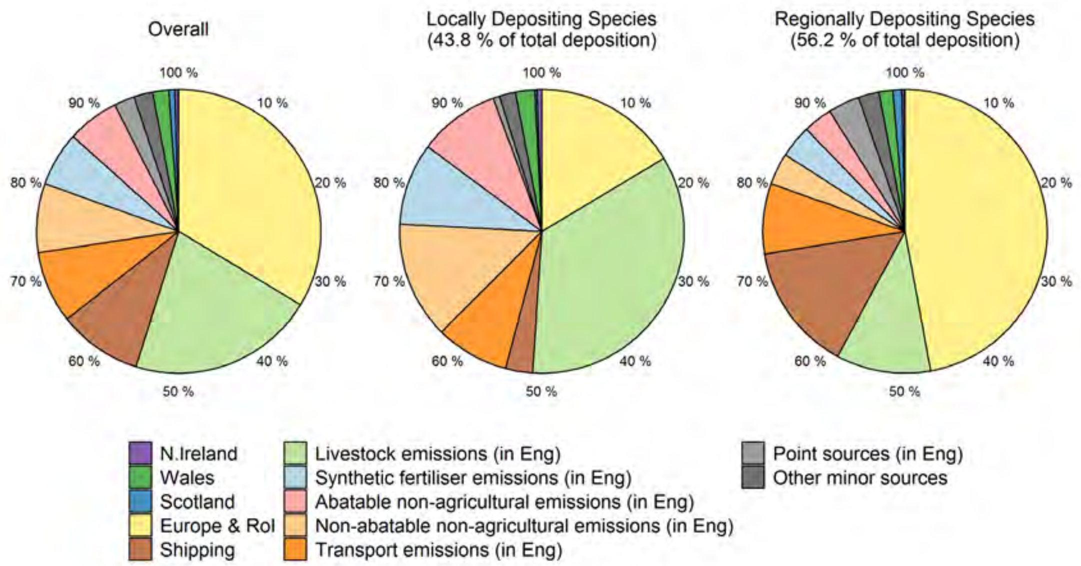


Figure 3.1-4. Relative contribution of emission sources to Site-total N deposition (to low-growing semi-natural vegetation) received by Ashdown Forest SSSI.

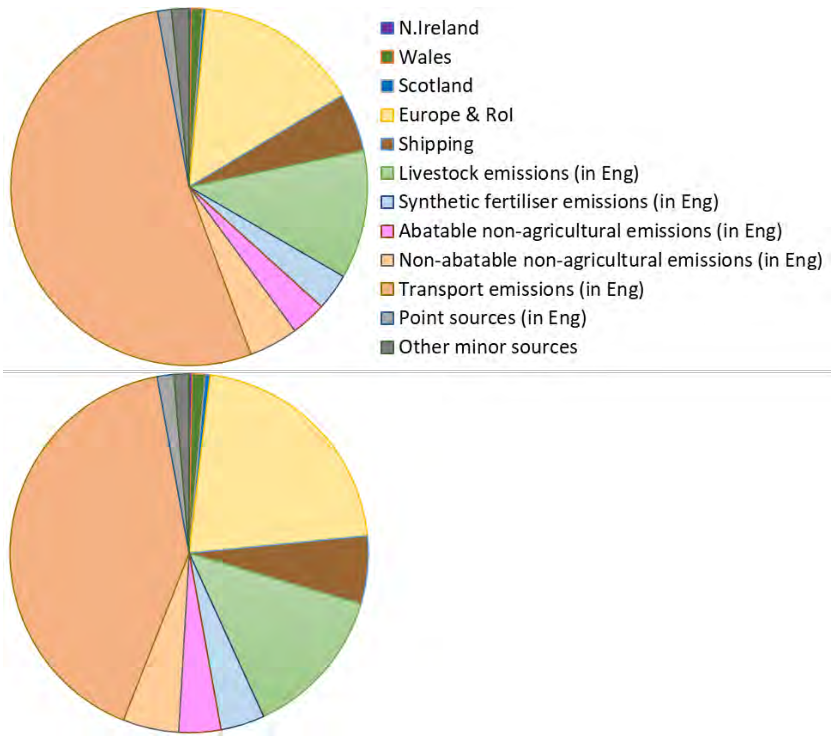


Figure 3.1-5. Relative contribution of emission sources to Site-maximum N deposition (top: to woodland features; and bottom: to low-growing semi-natural vegetation) received by Ashdown Forest SSSI.

3.1.6 NH_3 concentration

Figure 3.1-6 shows the 1 km x 1 km average annual mean NH_3 concentrations predicted by FRAME (calibrated with PCM). When considering 1 km^2 average values, annual mean NH_3 concentrations are below the 1 μg/m^3 critical level across most of the SSSI in 2017 and in every future-year scenario. Figure 3.1-7 shows the maximum 1 km^2 prediction, as well as the SSSI-average prediction in each scenario. The site-average NH_3 concentration is predicted to increase between 2017 and the 2030 BAU scenario, while the highest 1 km^2 average value reduces. The NAPCP scenarios all maintain the SSSI-average NH_3 concentration at approximately the 2017 baseline level, while reducing the 1 km^2 maximum.

Figure 3.1-8 shows the baseline 2 m x 2 m average annual mean NH_3 concentration predicted from local modelling calibrated against local measurements. NH_3 concentrations are less than 0.6 μg m^{-3} across most of the SAC area (the 2 m^2 model does not cover the full SSSI boundary), which agrees with the FRAME modelling. Alongside roads, NH_3 concentrations are predicted to exceed the 1 μg m^{-3} critical level, despite the 1 km^2 average value being below the critical level.

Figure 3.1-9 compares the maximum and SAC-average predictions from the local model with those from FRAME. The differences shown are partly due to spatial resolution in the models, but also differences in model approaches (importantly, the 2 m grid modelling uses a network of NH_3 monitors inside Ashdown Forest while the FRAME modelling does not). The top panel in Figure 3.1-9 shows that FRAME tends to over-predict NH_3 concentrations on average when compared with the locally-calibrated model. Conversely, the bottom panel in Figure 3.1-9 shows the significant difference that model resolution makes when reporting maximum concentrations. While the 1 km^2 maxima in each scenario are all around 1 μg m^{-3}, the 2 m^2 maxima are above 2 μg m^{-3} in every scenario. The relationship between ambient concentrations and distance from emissions sources is such that if a resolution of less than 2 m^2 had been used, even higher concentrations would have been predicted.

While it is informative to consider the site maxima, since they show whether or not the critical level will be achieved within the site, the maxima do not show the amount of the site that will be affected. Figure 3.1-10 thus shows the area of Ashdown Forest SAC predicted to experience different annual mean NH_3 concentrations in each scenario. The black bars in Figure 3.1-10, for the 2017 baseline, relate directly to the map of 2 m^2 concentrations in Figure 3.1-8. They show, for example, that concentrations greater than 2.1 μg m^{-3} are only predicted over 16 m^2 of the SAC in 2017, but that concentrations greater than 1.1 $\mu g/m^3$ are predicted over nearly 17,000 m^2. When comparing the 2017 baseline with the 2030 BAU scenario in Figure 3.1-10, it is interesting that the areas experiencing concentrations >1.9 μg m^{-3} will reduce by 2030, but the areas exceeding 1.5 $\mu g/m^3$ will increase. When compared with 2017, the 2030 NAPCP scenarios are predicted to reduce the areas exceeding each concentration band, with subsequent differences caused by targeted scenarios being relatively small.

As explained in Section 1.4.2, there is significant uncertainty regarding NH_3 emissions from the future vehicle fleet. In particular, the assumed reductions in traffic-related NO_x emissions might be achieved in many different ways; which might cause traffic-NH_3 to either reduce or increase. Figure 3.1-11 thus shows the results from sensitivity tests of different potential outcomes regarding the future-year vehicle fleet. The values in Figures 3.1-6 to 3.1-10, described previously, all assumed that traffic-NH_3 in every future-year scenario would be 4% lower than in 2017. This 4% reduction is also shown by the green bars in Figure 3.1-11 (the green bars in Figure 3.1-11 are the same as the orange bars in Figure 3.1-9). The red-framed bars in Figure 3.1-11 then show the effect (on 2 m^2 average annual mean concentrations) of explicitly modelling the predicted change in the future vehicle fleet (using the method described in Section 1.4.2). The red and white bars assume the BAU vehicle fleet; the red and orange bars assume that the additional 10% reductions in traffic-NOx are achieved via vehicle electrification; and the red and yellow bars assume that the additional 10% reductions in traffic-NOx are achieved by petrolization or petrol-hybridisation of the fleet.

The top panel in Figure 3.1-11 shows that uncertainty regarding traffic-related NH_3 in the future has little effect on the site-average concentrations, but the bottom panel shows that these assumptions are very important for the site maxima. Even assuming the BAU vehicle fleet, the red and white bars show that explicitly modelling the change in fleet composition over time results in much higher concentrations in the future than in 2017. Those scenarios that include an additional 10% reduction in traffic-NOx are then shown to have either much higher, or much lower, NH_3, depending on how these NO_x reductions are achieved. The fact that the red and orange bars are all taller than the green bars shows that even if the additional 10% reduction in traffic-NO_x is achieved by fleet electrification, traffic-NH_3 emissions are still predicted to be higher than those associated with the core (4% reduction) model.

Figure 3.1-6. 1 km x 1 km average NH_3 concentration (FRAME model calibrated with measurements made outside of Ashdown Forest) by scenario at Ashdown Forest SSSI and surrounding area.

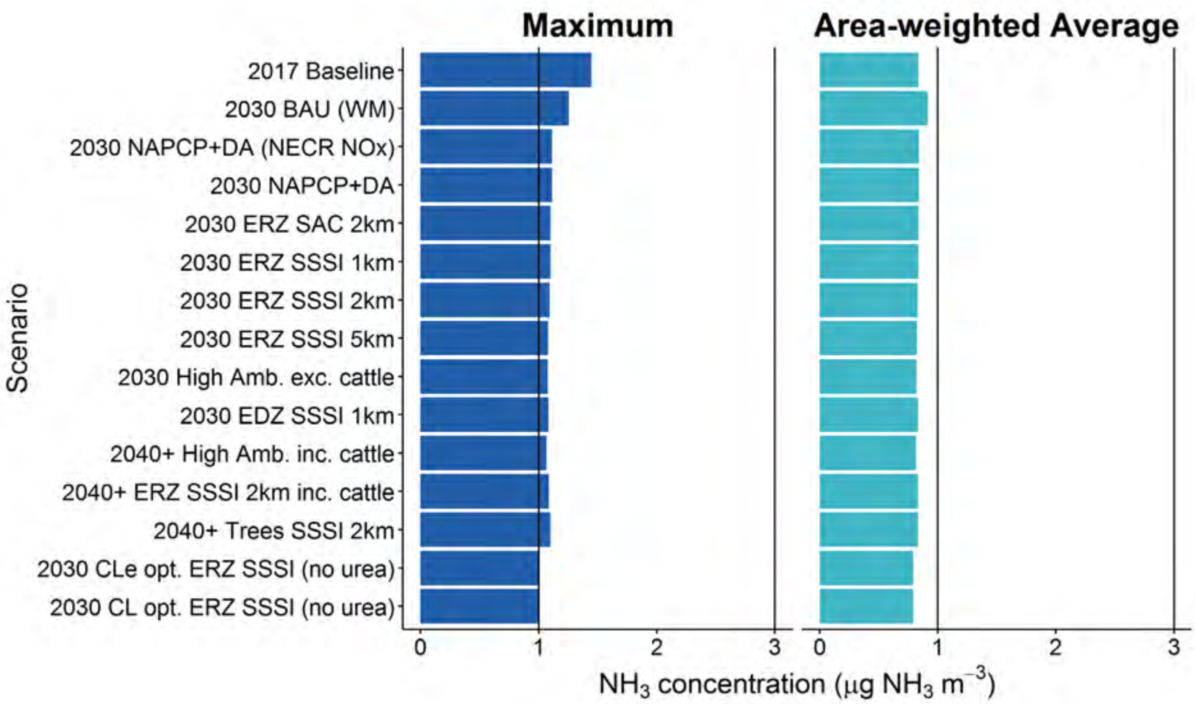


Figure 3.1-7. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at 1 km grid cells overlapping with Ashdown Forest SSSI.

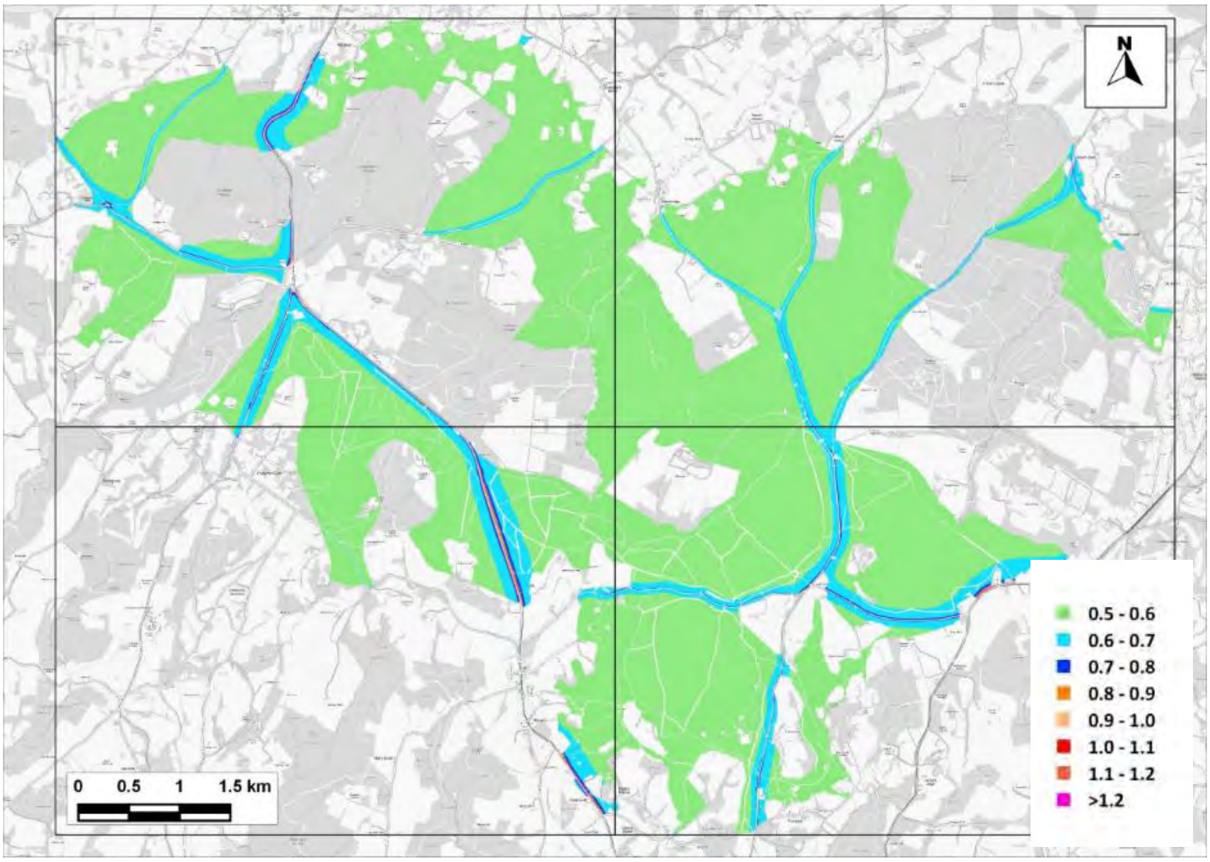


Figure 3.1-8. 2 m x 2 m average annual mean NH_3 concentration in Ashdown Forest SAC in the 2017 Baseline scenario ($\mu g\ m^{-3}$) (local dispersion model calibrated with measurements made inside Ashdown Forest).

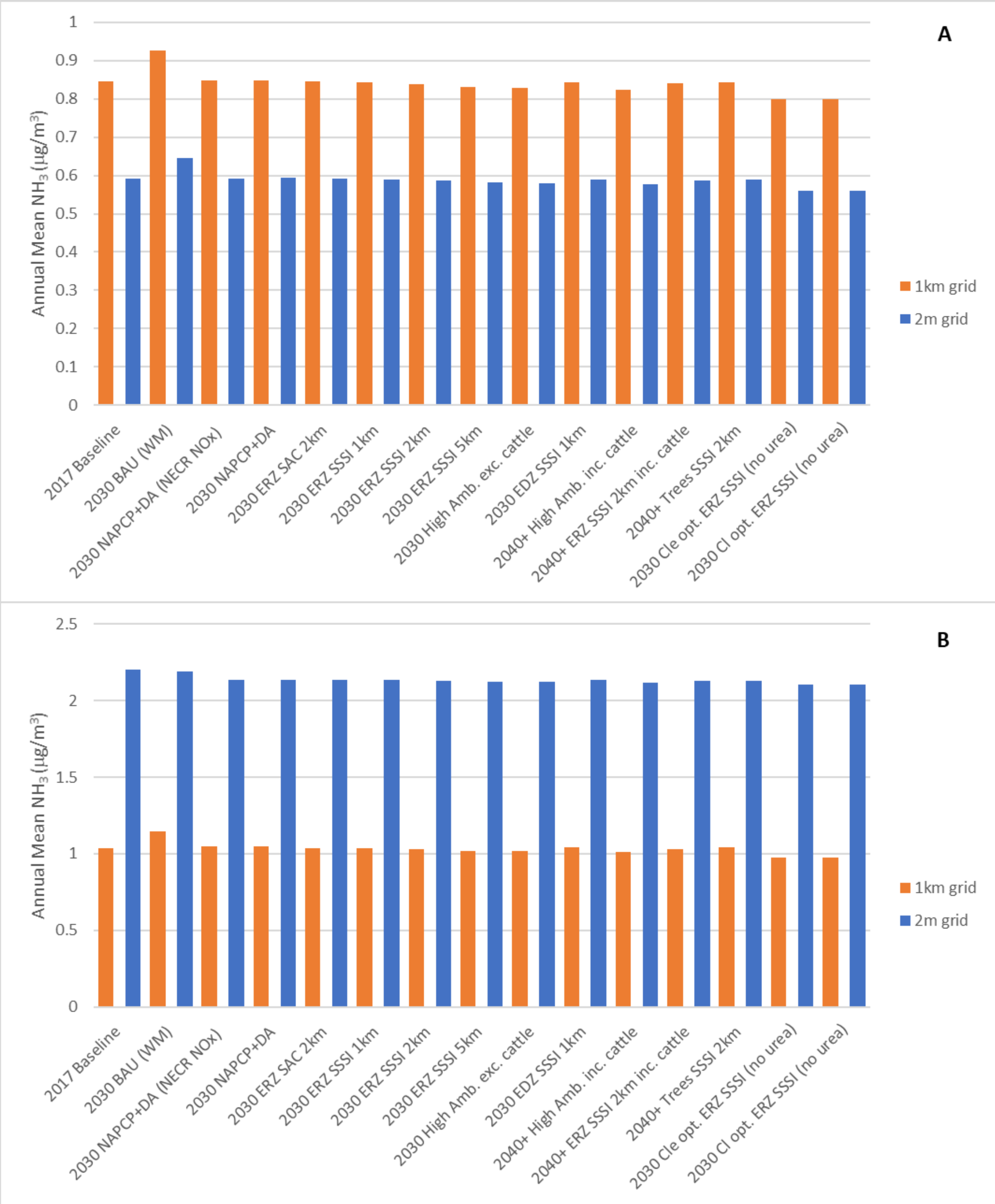


Figure 3.1-9. Comparison of 1 km^2 and 2 m^2 grid predictions – annual mean NH_3: A) mean across all locations in SAC; and B) maximum location in SAC.

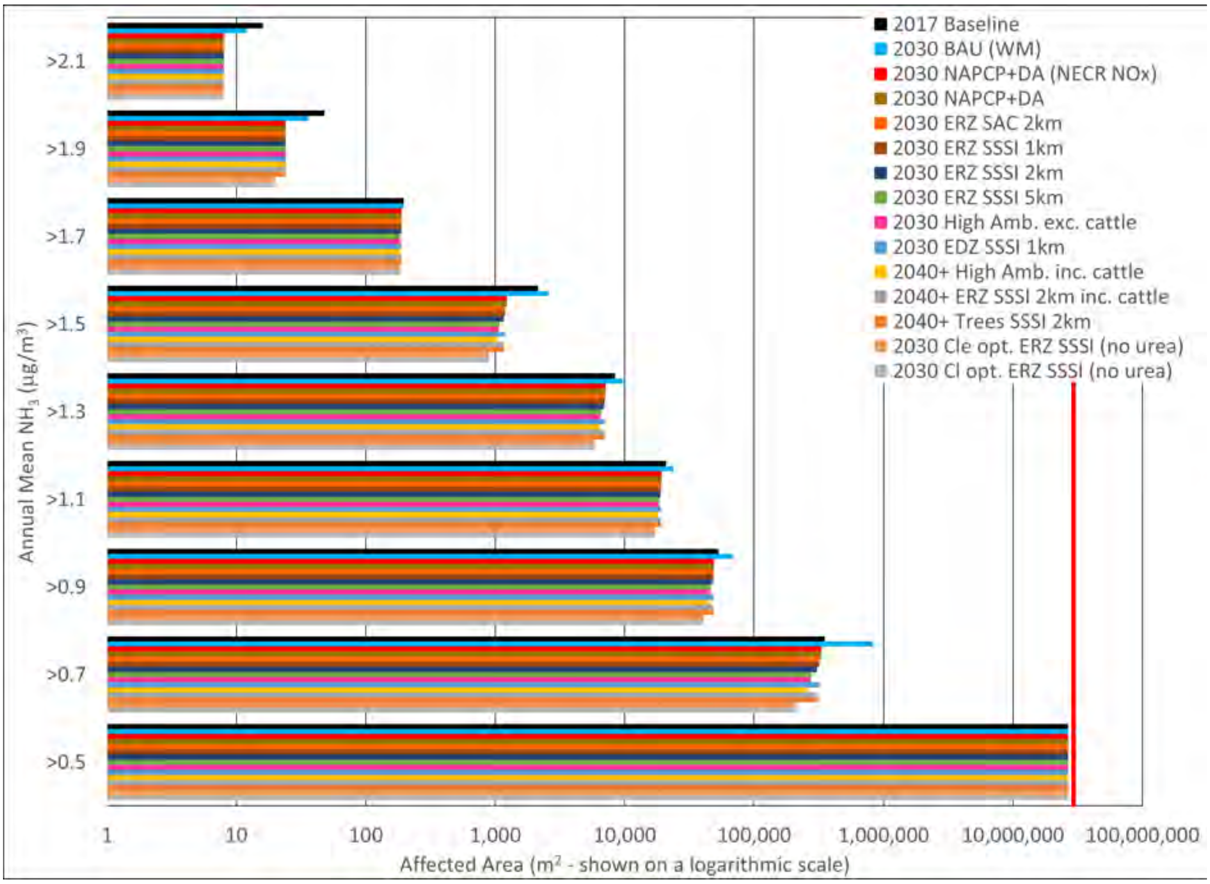


Figure 3.1-10. Area (of SAC) predicted to experience different annual mean NH_3 concentrations (vertical red line shows total area of SAC).

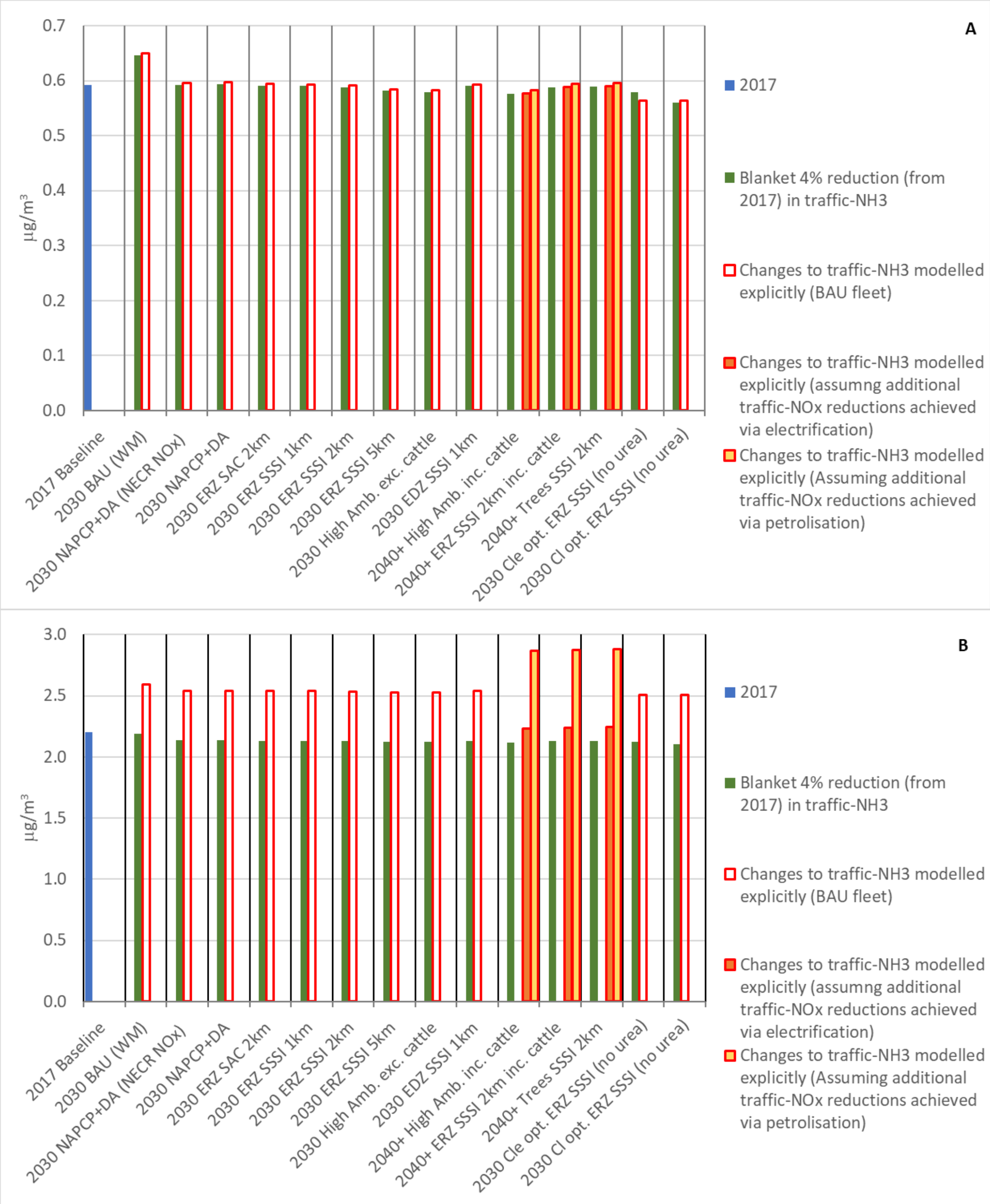


Figure 3.1-11. Effect on 2m-Gridded Annual Mean NH_3 Concentrations of Different Assumptions for NH_3 Emissions from Local Traffic: A) Mean; and B) Maximum (within SAC).

3.1.7 NO_2 and NOx concentration

Figures 3.1-12 and 3.1-13 show the 1 km x 1 km average annual mean NO_2 concentrations predicted by FRAME. While annual mean NO_2 concentrations cannot be directly compared with the 30 $\mu g\ m^{-3}$ critical level for NO_x, they provide an indication of the likely NO_x concentrations ($NO_x = NO_2 + NO$). When considering 1 km^2 average values, annual mean

NO_2 concentrations are mostly below 10 µg m^{-3} in 2017 and are all below 7.5 µg m^{-3} in each future-year scenario.

Figure 3.1-14 shows the baseline 2 m x 2 m average annual mean NO_x concentration predicted from local modelling calibrated against local measurements. NO_x concentrations are below the 30 µg/m^3 critical level across most of the site but exceed the critical level alongside roads.

Figure 3.1-15 shows the maximum and SAC-average annual mean NO_x concentrations based on both the 1 km x 1 km grid, and the 2 m x 2 m grid. For this comparison, the FRAME NO_2 outputs have been used to predict concurrent NO_x concentrations following the approach set out in Section 1.4.2. The fine-resolution grid predicts somewhat higher SAC-average concentrations, and significantly higher maximum concentrations. The maximum predicted NO_x concentration when considered on a 2 m x 2 m grid is 90 µg m^{-3} (three times the critical level) while the maximum from the 1 km x 1 km data is 11 µg m^{-3} (c.a. one third of the critical level). The only future-year scenarios in which the critical level for annual mean NO_x concentrations are predicted to be achieved, when considered on a 2 m x 2 m grid, are those for 2040.

While it is informative to consider the site maxima, since they show whether or not the critical level will be achieved within the site, the maxima do not show the amount of the site that will be affected. Figure 3.1-16 thus shows the area of Ashdown Forest SAC predicted to experience different annual mean NO_x concentrations in each scenario. The black bars in Figure 3.1-16, for the 2017 baseline, relate directly to the map of 2 m^2 concentrations in Figure 3.1-14. They show, for example, that the 30 µg m^{-3} critical level was exceeded over 46,000 m^2 in 2017, but that this will fall to 192 m^2 under the 2030 BAU scenario and just 24 m^2 under the 2030 NAPCP scenarios.

Figure 3.1-12. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Ashdown Forest SSSI and surrounding area.

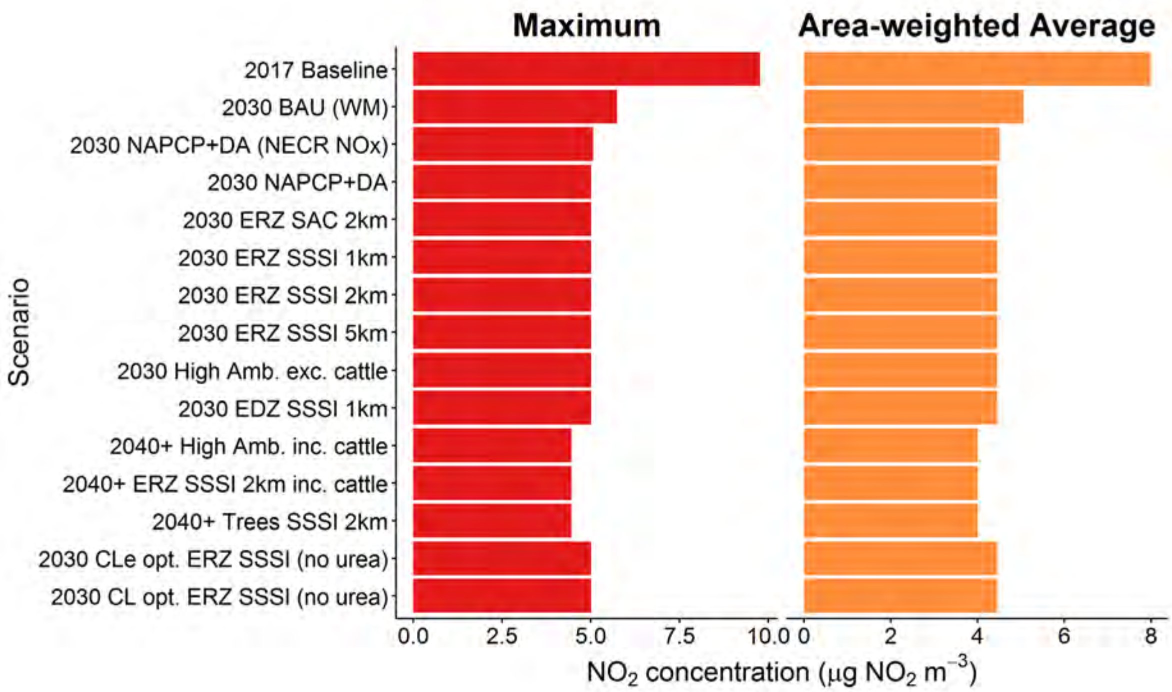


Figure 3.1-13. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Ashdown Forest SSSI.

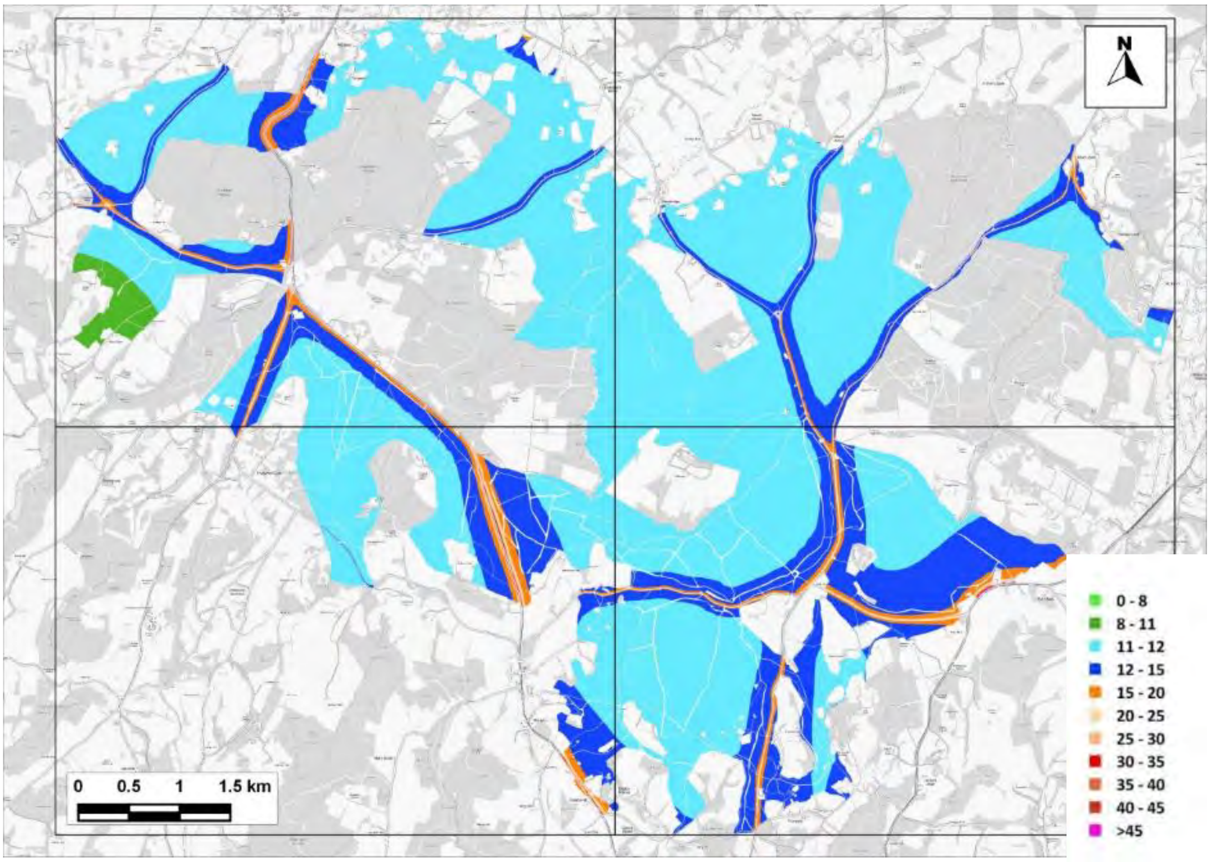


Figure 3.1-14. 2 m x 2 m average annual mean NOx concentration (local dispersion model calibrated with measurements made inside Ashdown Forest) in Ashdown Forest SAC in the 2017 Baseline scenario (µg m^{-3}).

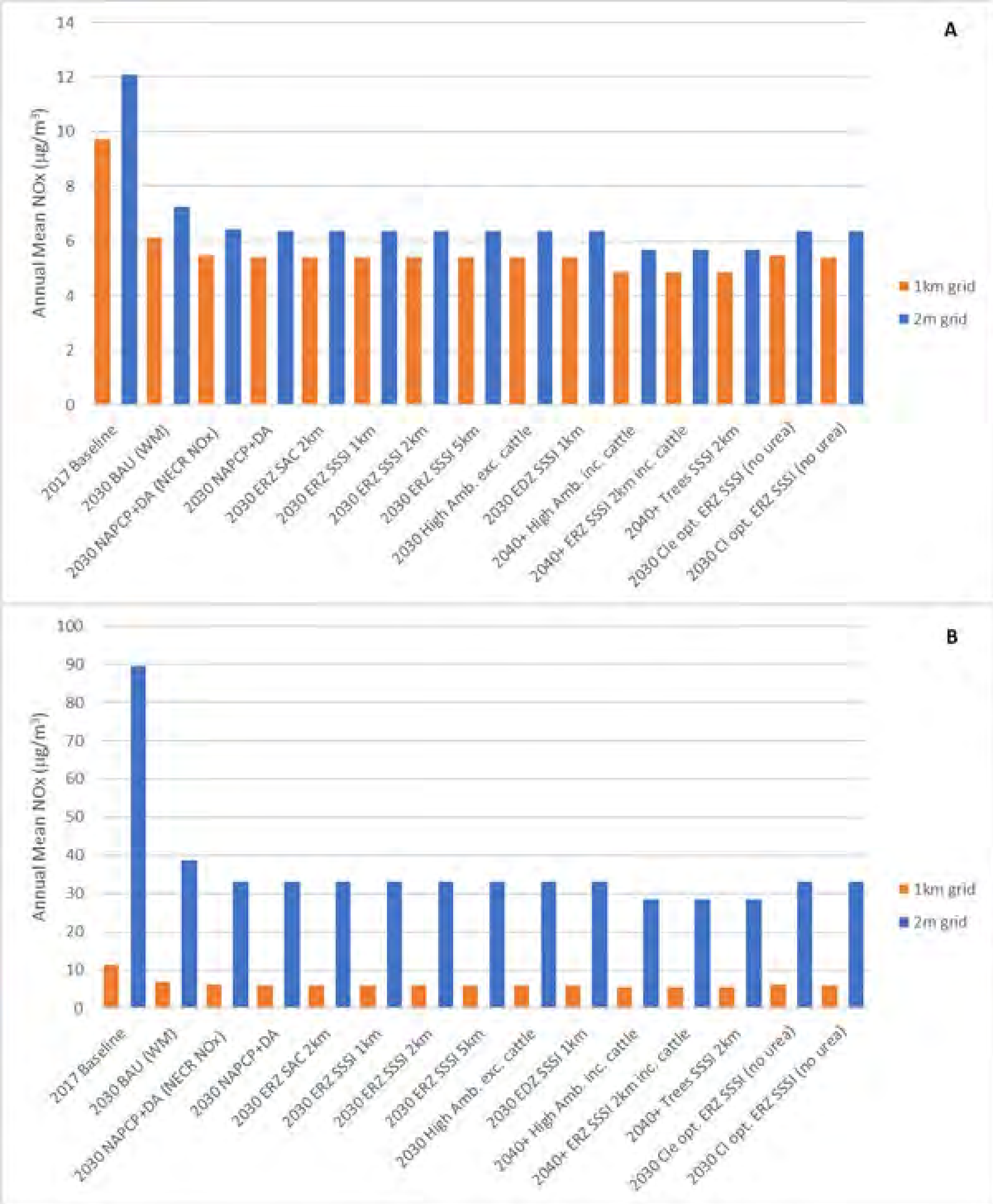


Figure 3.1-15. Comparison of 1 km^2 and 2 m^2 grid predictions – annual mean NO_x: A) mean; and B) maximum (within SAC).

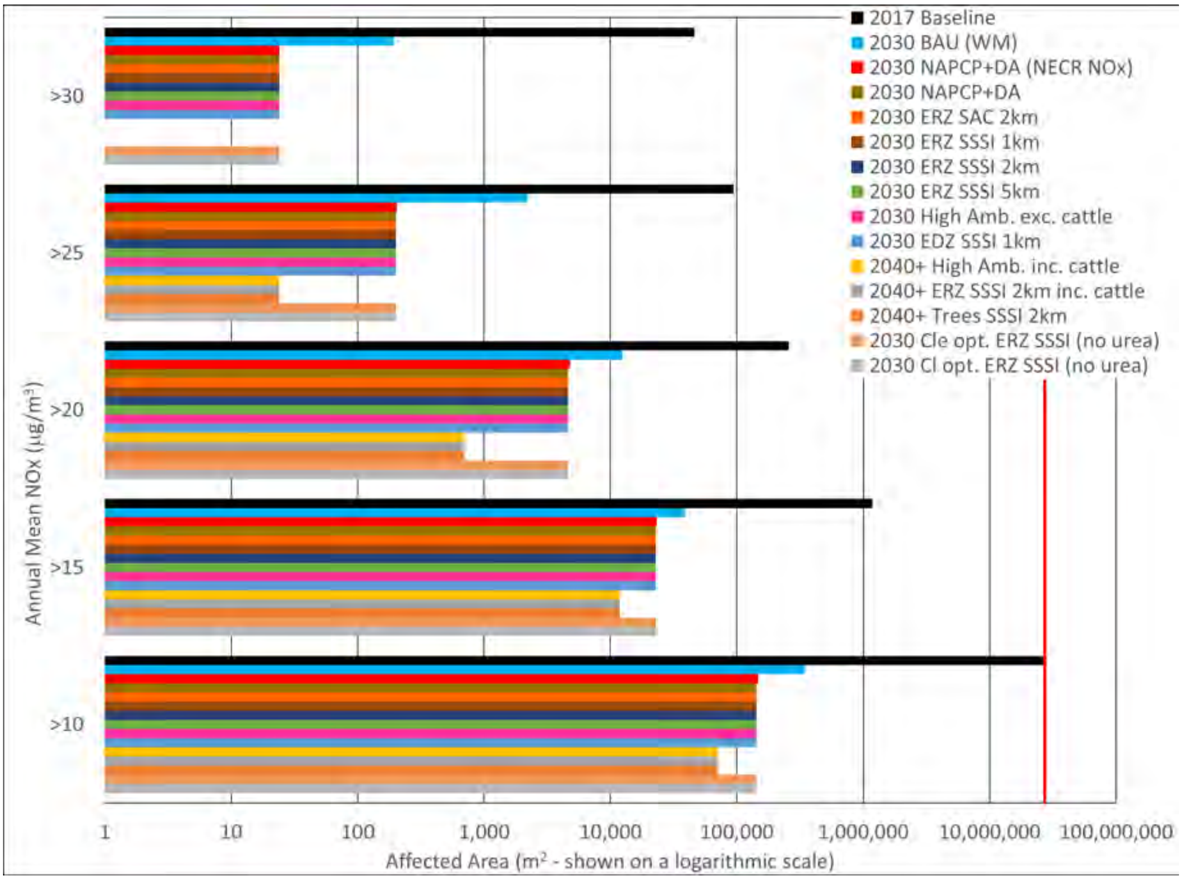


Figure 3.1-16. Area (of SAC) predicted to experience different annual mean NO_x concentrations (vertical red line shows total area of SAC).

3.1.8 N deposition

Figures 3.1-17 and 3.1-18 show the 1 km x 1 km average N deposition fluxes to woodland features predicted by FRAME. Figures 3.1-19 and 3.1-20 show the same results but to low-growing, semi-natural vegetation. When considered on a 1 km^2 average basis, the maximum predicted N deposition flux to woodland in 2017 is 25 kg N ha^{-1} yr^{-1}, while to low-growing vegetation the maximum is 15 kg N ha^{-1} yr^{-1}. Under the 2030 BAU scenario, these values fall to 23 N ha^{-1} yr^{-1} and 14 N ha^{-1} yr^{-1} respectively, with all other scenarios being relatively constant at around 21 N ha^{-1} yr^{-1} and 13 N ha^{-1} yr^{-1} respectively.

Figure 3.1-21 shows the baseline 2 m x 2 m average N deposition fluxes predicted in the local-scale modelling, and calibrated using local measurements. On this finer resolution, deposition fluxes are shown to range from 10 N ha^{-1} yr^{-1} to 56 N ha^{-1} yr^{-1}, with the higher values driven by proximity to roads and by vegetation height (i.e. the 56 N ha^{-1} yr^{-1} maximum occurs to woodland alongside a road).

Figures 3.1-22 and 3.1-23 compare the predictions from the local (2 m x 2 m) model with those from FRAME (1 km x 1 km); first for the entire SAC (taking account of all habitat types) and second for low-growing vegetation only (thus excluding areas of woodland, open water, and bare ground). The area-average results for the entire SAC (top panel of Figure 3.1-22) are much higher using the fine-resolution, locally-calibrated, model than those from FRAME. The biggest difference, however, is seen in the maxima; with the 2 m x 2 m maximum flux being more than double the 1 km x 1 km maximum. The area average results for low-growing vegetation (top panel of Figure 3.1-23) are marginally lower using the fine-resolution model than when using FRAME, but the maxima are still much higher.

Figures 3.1-24 shows the area of Ashdown Forest SAC predicted to experience different deposition fluxes in each scenario. The black bars in Figure 3.1-24, for the 2017 baseline, relate directly to the map of 2 m^2 fluxes in Figure 3.1-21. Figures 3.1-24 shows, for example, that 2,100 m^2 of the SAC is predicted to have received more than 45 N ha^{-1} yr^{-1} in 2017, with this falling to just 16 m^2 in the 2030 BAU scenario and none of the SAC at all in any of the other future scenarios. Figure 3.1-24 also shows that the area of the SAC predicted to exceed 20 N ha^{-1} yr^{-1} (the upper bound of the critical load) is 1,200 ha in all scenarios, with only 640 m^2 moving from above to below this value when comparing 2017 with any future scenario (not discernible from Figure 3.1-24). Figure 3.1-25 repeats Figure 3.1-24 but focuses only on those areas of the SAC covered by low-growing vegetation.

Ammonia emissions$_3$ contribute to N deposition from vehicles and, as explained in Section 1.4.2, there is significant uncertainty regarding NH_3 emissions from the future vehicle fleet. In particular, the assumed reductions in traffic-related NO_x emissions might be achieved in many different ways; which might cause traffic-NH_3 to either reduce, or to increase. Figures 3.1-26 and 3.1-27 thus show the results from sensitivity tests of different assumptions for the composition of the future-year vehicle fleet. The values in Figures 3.1-18 to 3.1-25, described previously, all assumed that traffic-NH_3 in every future-year scenario would be 4% lower than in 2017. The effects of this 4% reduction are also shown by the green bars in Figures 3.1-26 and 3.1-27 (the green bars in Figures 3.1-26 and 3.1-27 are the same as the orange bars in Figures 3.1-22 and 3.1-23). The red-framed bars in Figures 3.1-26 and 3.1-27 then show the effect of explicitly modelling the predicted change in the future vehicle fleet (using the method described in Section 2.2). The red and white bars assume the BAU vehicle fleet; the red and orange bars assume that the additional 10% reductions in traffic-NO_x are achieved via vehicle electrification; and the red and yellow bars assume that the additional 10% reductions in traffic-NO_x are achieved by petrolization or petrol-hybridisation of the fleet.

Both Figure 3.1-22 and 3.1-23 show that uncertainty regarding traffic-NH_3 is relatively unimportant to the area-average values, but potentially significant when considering site-maxima. In particular, if the additional 10% reduction in traffic-NO_x is achieved by petrol/ hybridisation, then the net effect of this change on N deposition could be a disbenefit (i.e. the red and yellow bars are higher than all of the red and white bars in the two bottom panels).

Figure 3.1-17. N deposition (to woodland features) received by Ashdown Forest SSSI and surrounding area.

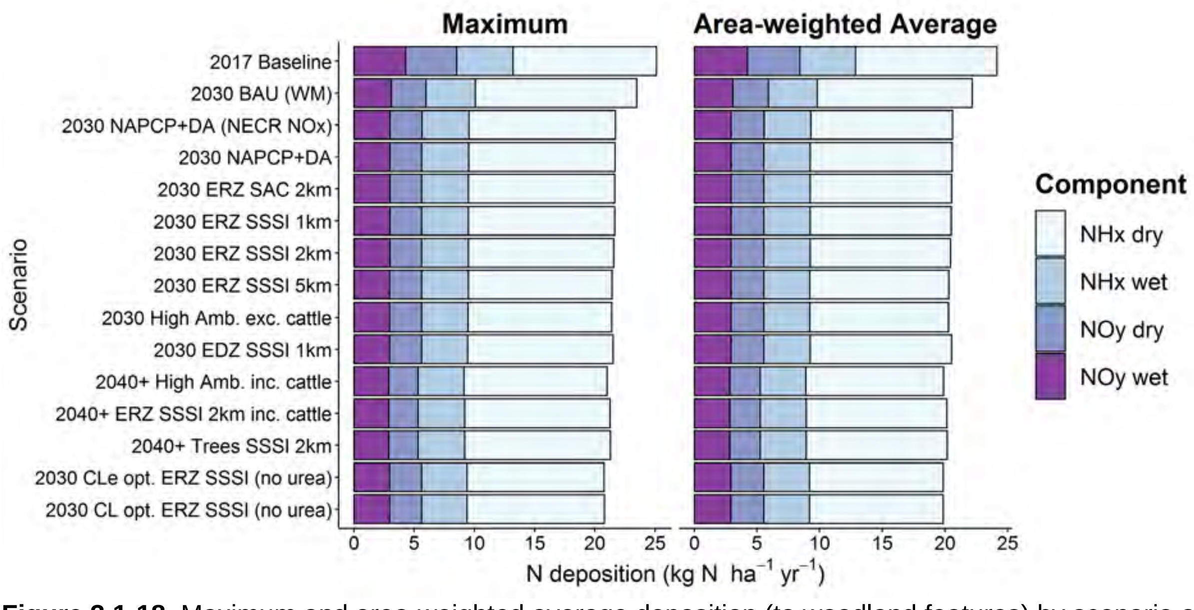


Figure 3.1-18. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Ashdown Forest SSSI.

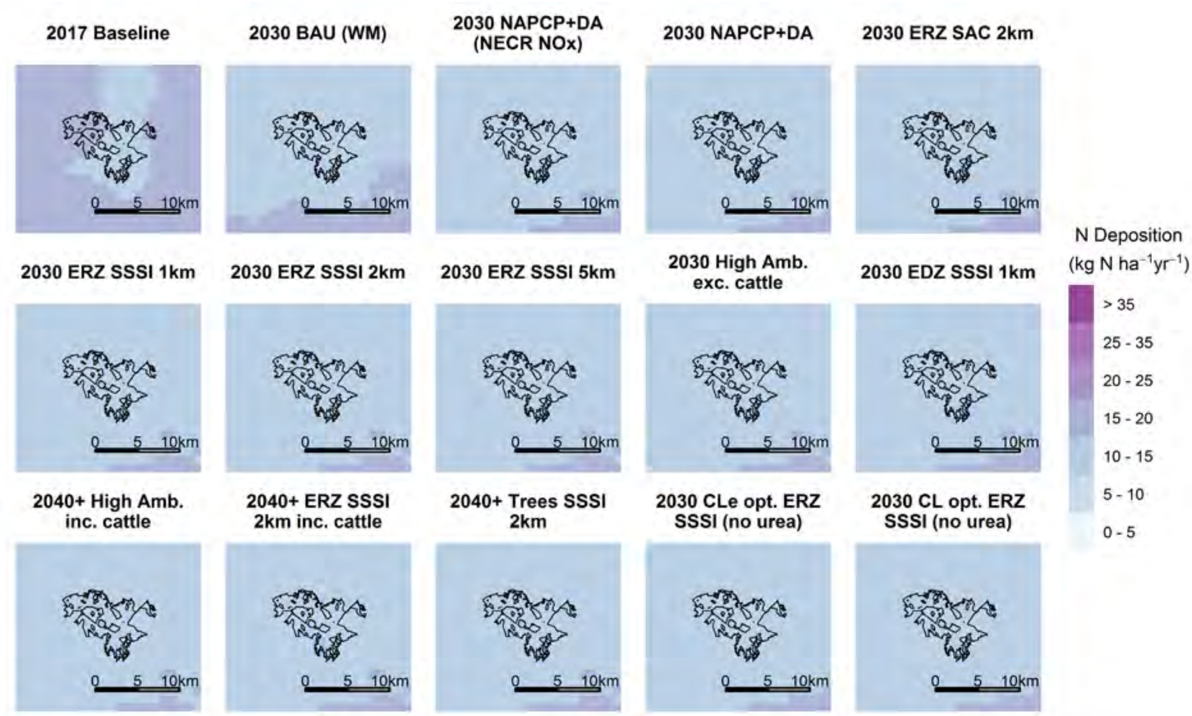


Figure 3.1-19. N deposition (to low-growing semi-natural vegetation) received by Ashdown Forest SSSI and surrounding area.

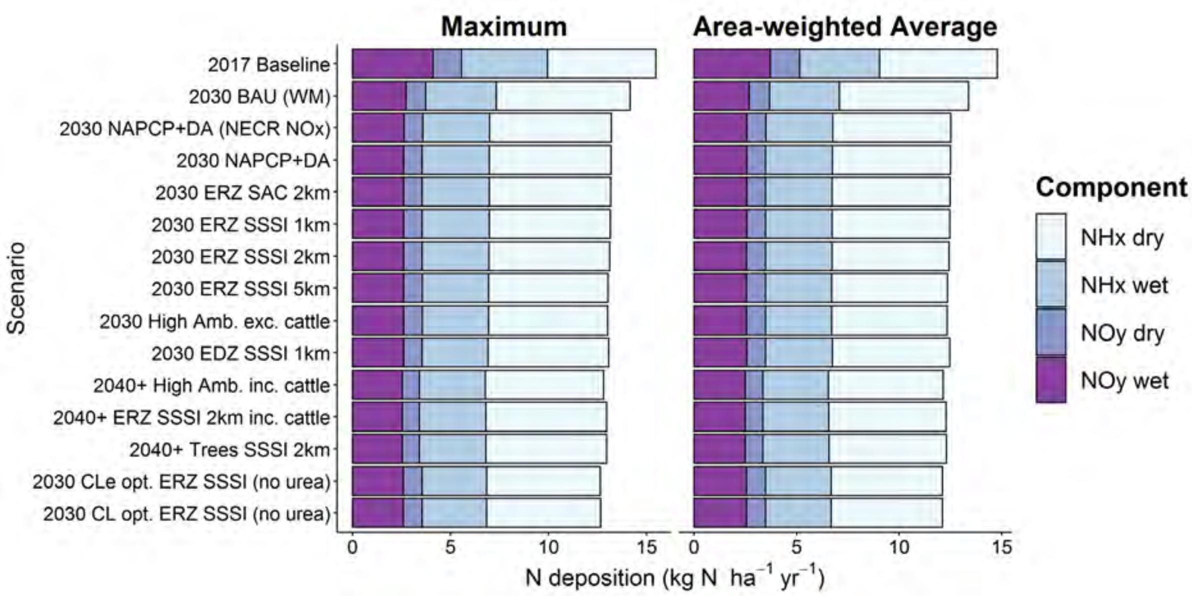


Figure 3.1-20. Maximum and area-weighted average deposition to low-growing semi-natural vegetation by scenario at 1 km grid cells overlapping with Ashdown Forest SSSI.

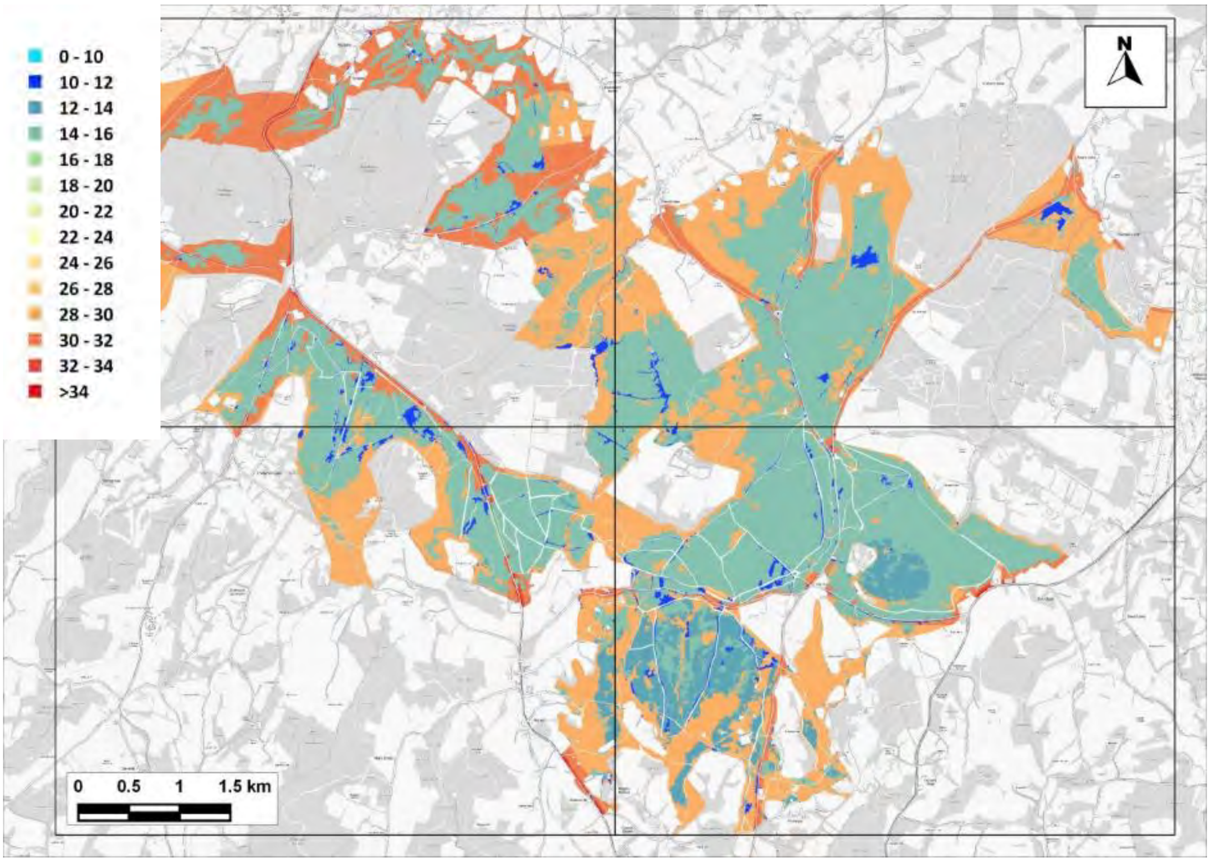


Figure 3.1-21. 2 m x 2 m average N deposition (local dispersion/deposition model calibrated with measurements made inside Ashdown Forest) in Ashdown Forest SAC in the 2017 Baseline scenario (kg-N/ha/yr).

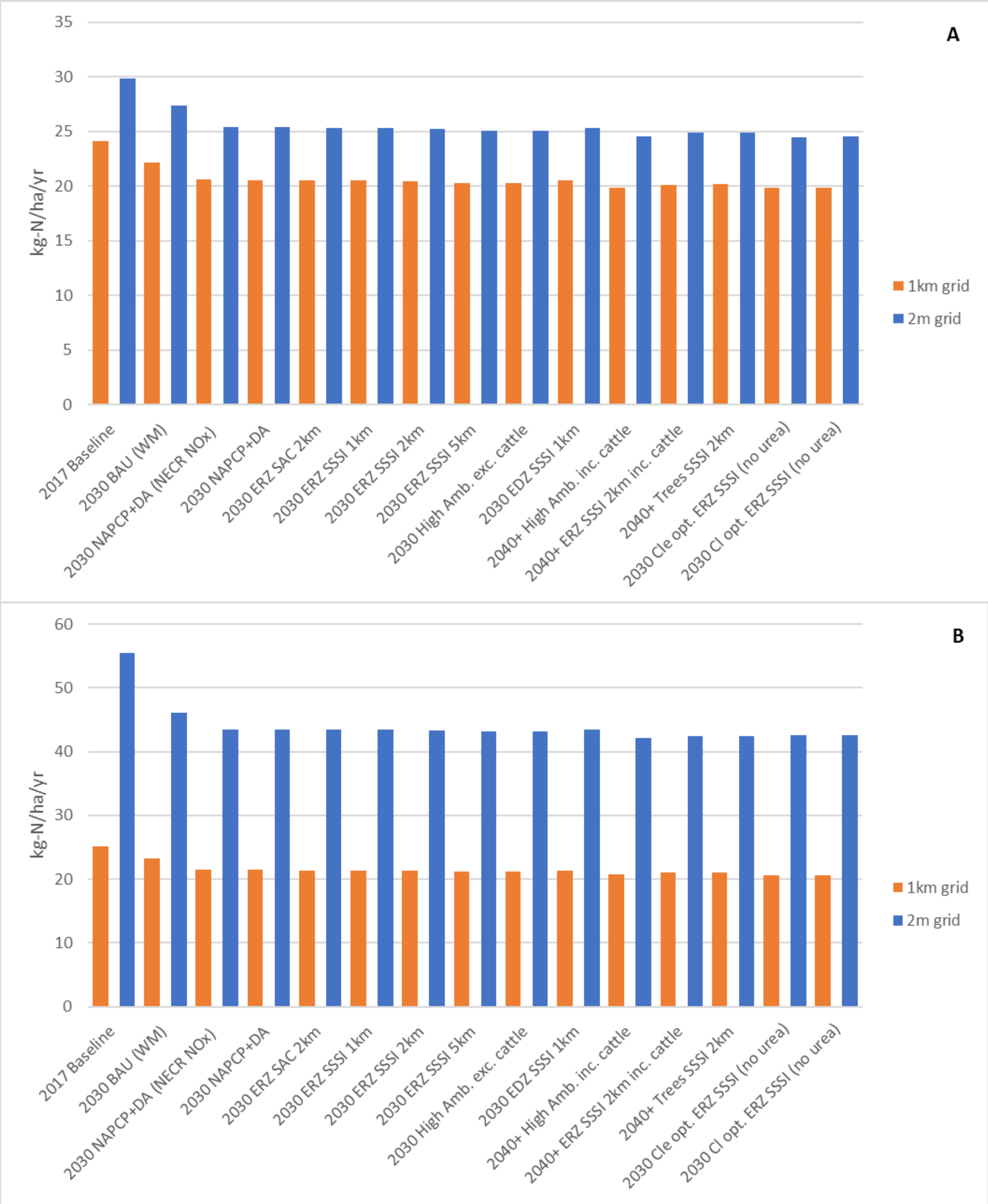


Figure 3.1-22. Comparison 1 km^2 and 2 m^2 grid predictions – N deposition: A) mean; and B) maximum (1 km grid = woodland, 2 m grid = all land cover within SAC).

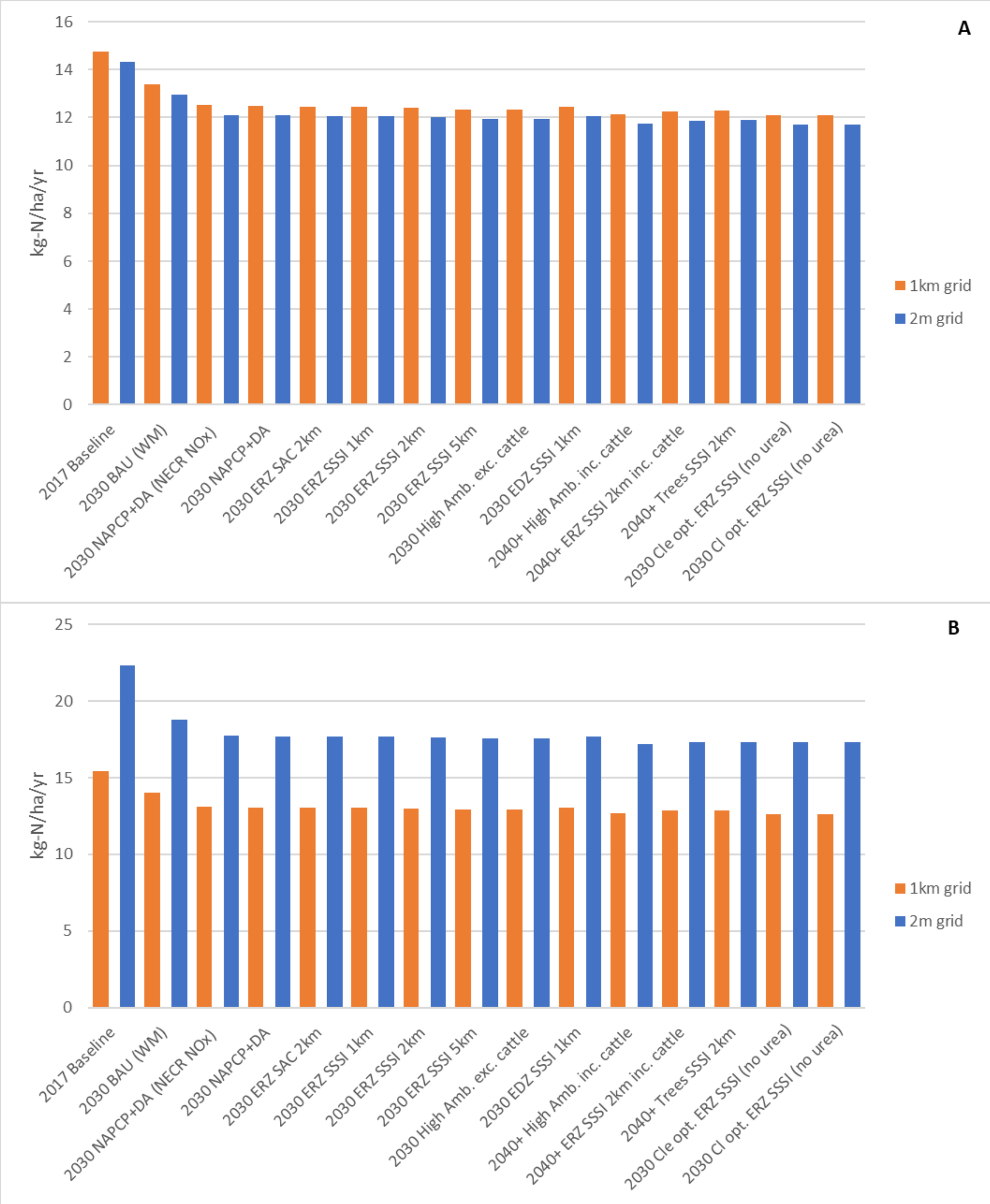


Figure 3.1-23. Comparison 1 km² and 2 m² grid predictions – N deposition to low-growing vegetation within SAC: A) mean; and B) maximum.

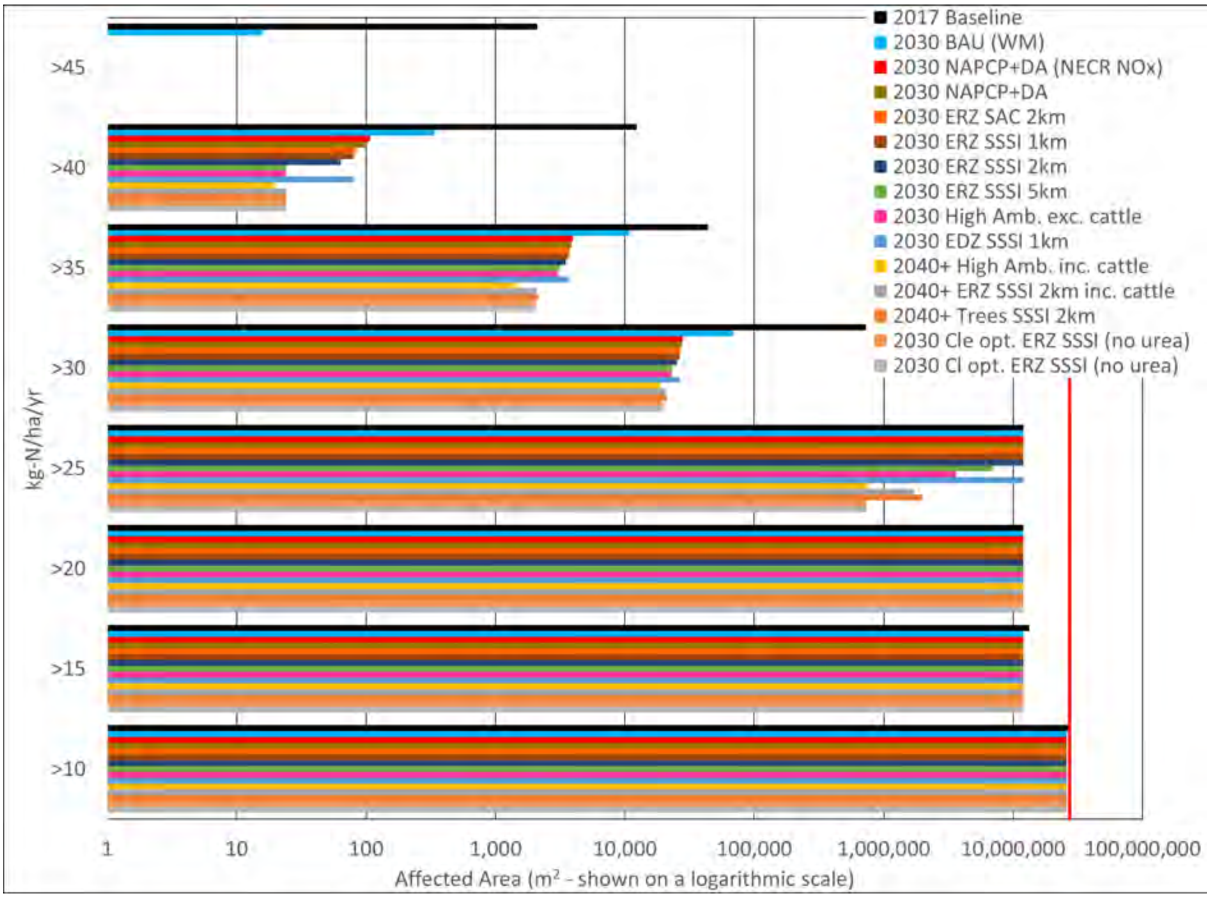


Figure 3.1-24. Area (of SAC) predicted to experience different nitrogen deposition fluxes (vertical red line shows total area of SAC).

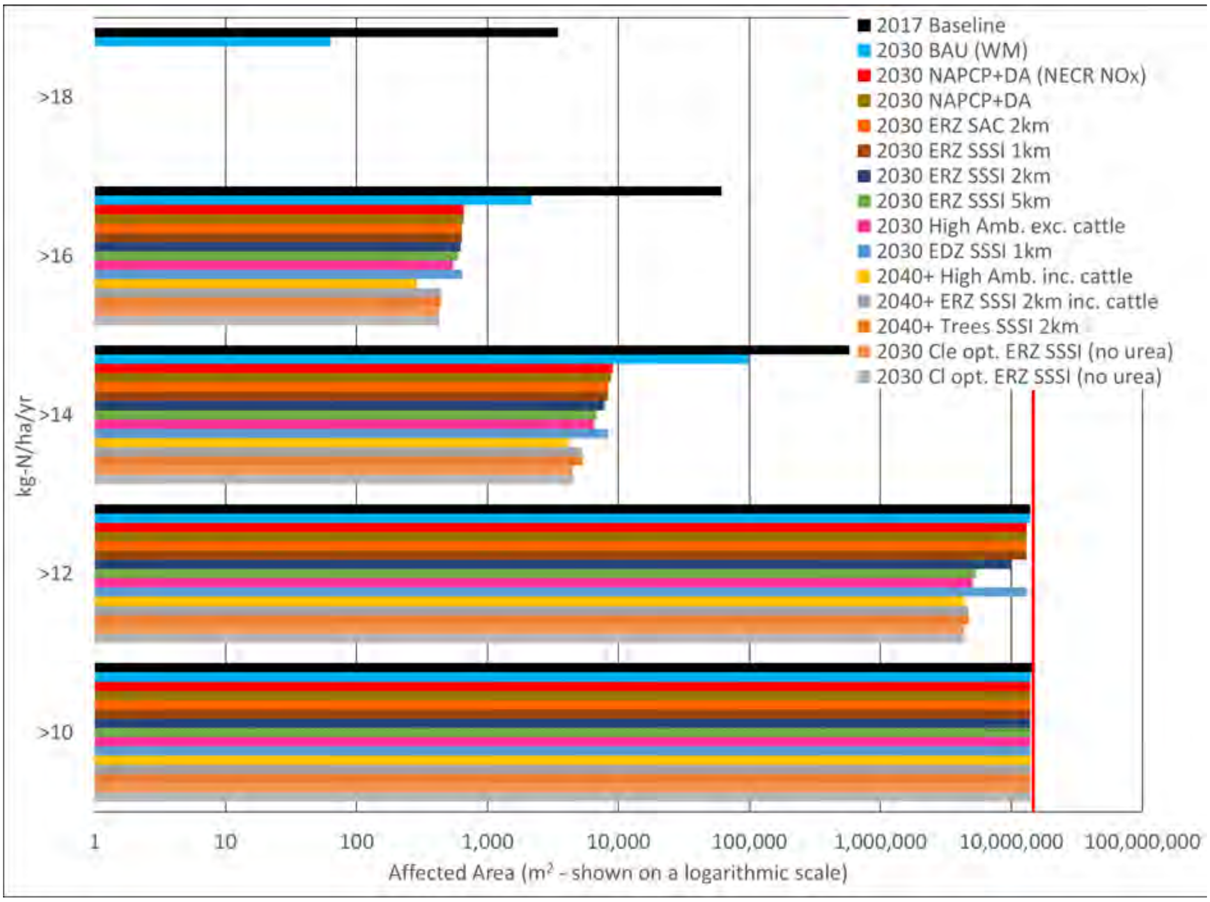


Figure 3.1-25. Area (of SAC) predicted to experience different nitrogen deposition fluxes to short vegetation (vertical red line shows total area of SAC covered by short vegetation).

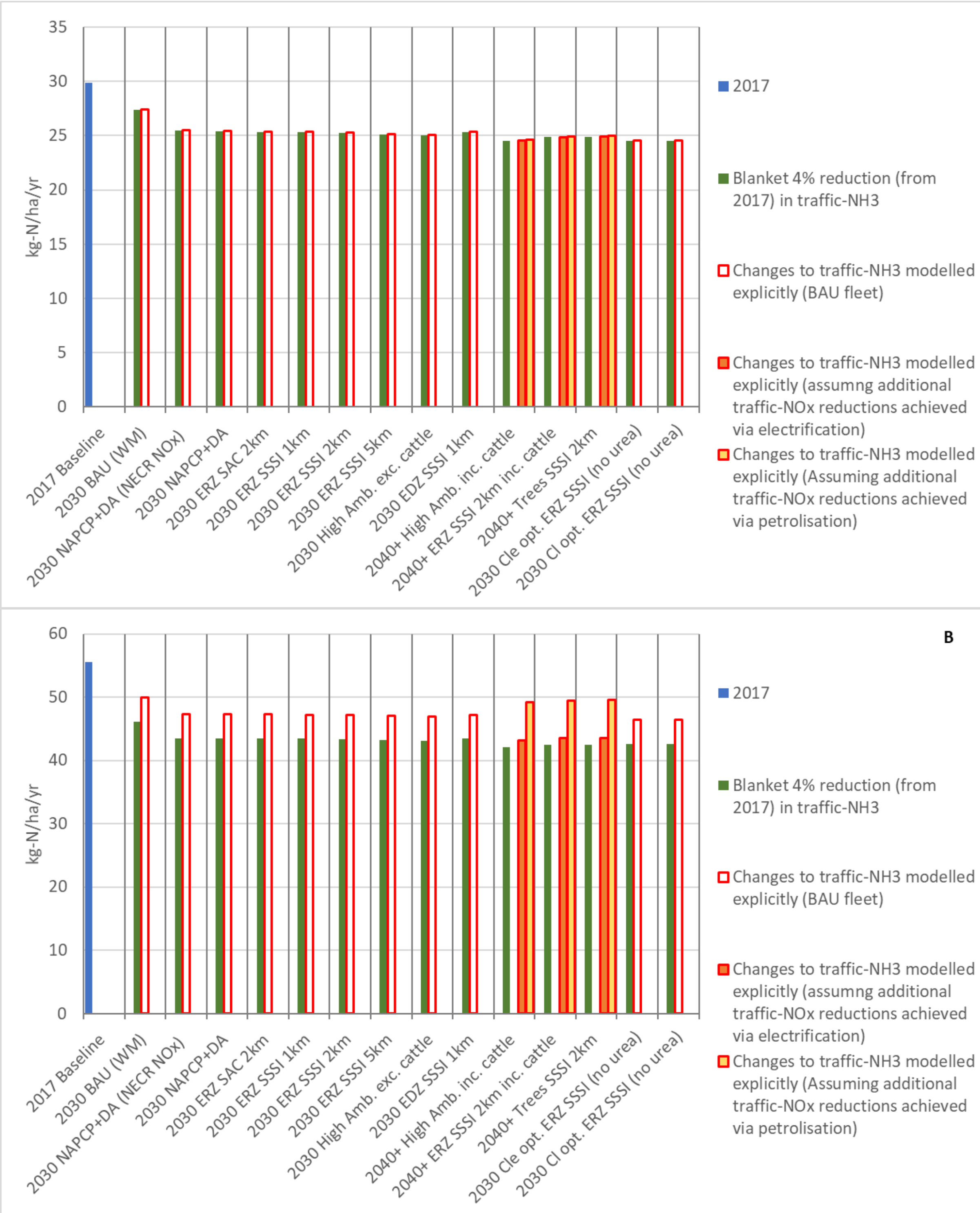


Figure 3.1-26. Effect on 2m-Gridded Nitrogen Deposition Fluxes of Different Assumptions for NH_3 Emissions from Local Traffic: A) Mean; and B) Maximum (all land cover within SAC).

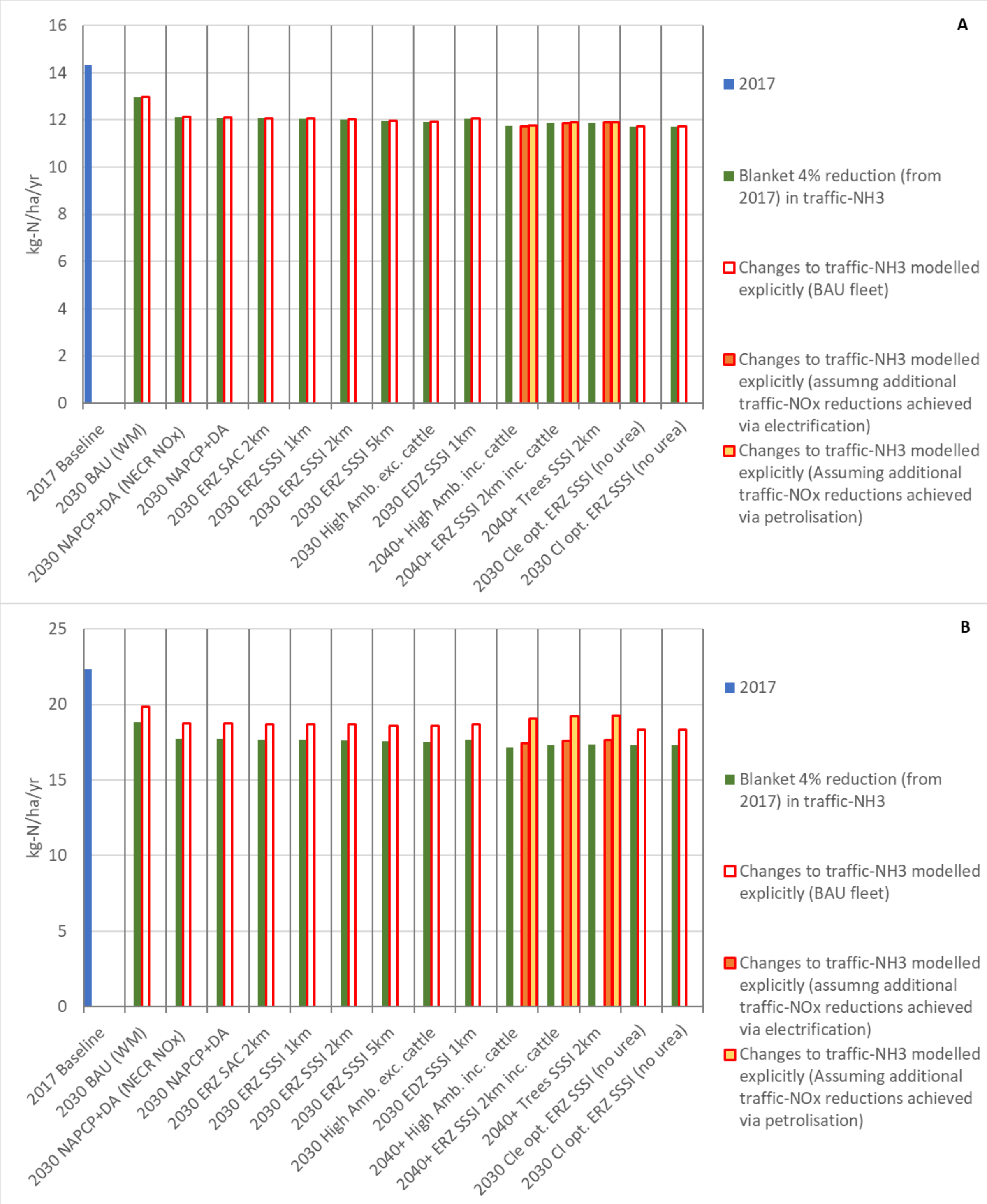


Figure 3.1-27. Effect on 2m-Gridded Nitrogen Deposition Fluxes of Different Assumptions for NH_3 Emissions from Local Traffic: A) Mean; and B) Maximum (all short vegetation within SAC).

3.1.9 Exceedance of critical loads

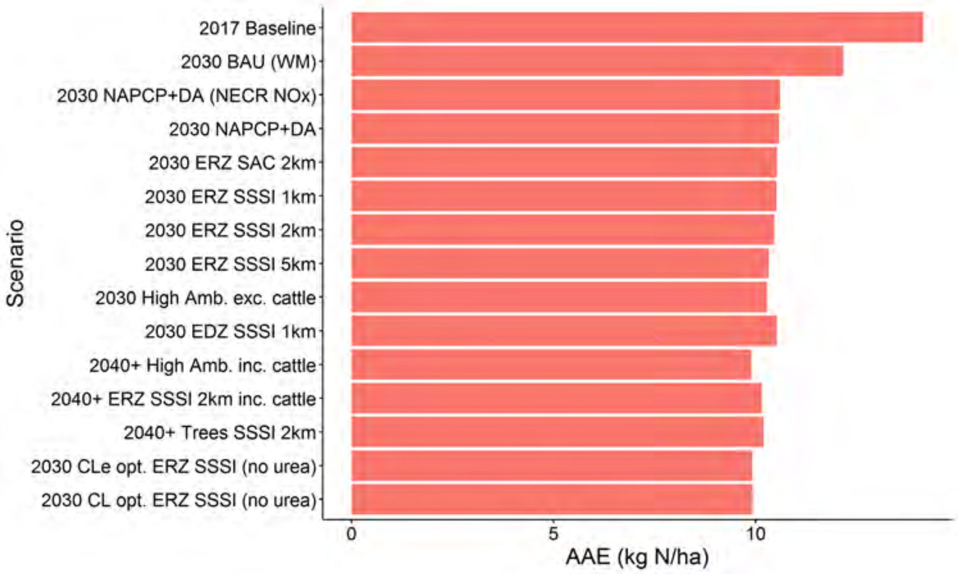


Figure 3.1-28. Exceedance of critical loads by scenario at Ashdown Forest SSSI (1 km grid assessment).

3.1.10 Nitrogen Decision Framework

For the standard assessment with 50% N deposition uncertainty (Table 6), the NDF score dropped a class (from Medium-High to Medium) for Broadleaved deciduous woodland as the N deposition fell within the critical load range in the more ambitious 2030 CL opt ERZ SSSI (no urea) mitigation scenario. For dwarf shrub heath with a similar critical load range, but lower N deposition as it is low-growing vegetation not woodland, the N deposition lies within the critical load range and the exceedance score dropped two categories (from Medium-High to Medium-Low) in both the NAPCP+DA (NECR NO_x) baseline scenario and the 2030 CL opt ERZ SSSI (no urea) mitigation scenario. In the assessment with 20% N deposition uncertainty, the broadleaved deciduous woodland shows a lower NDF score class in the NAPCP+DA scenario (Medium rather than Medium-High), and a lower baseline score for dwarf shrub heath (Medium rather than Medium-High).

Table 6. Nitrogen Decision Framework Factor 1 (Exceedance) score for Ashdown Forest.

			N dep (kg/ha/yr)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 50%)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 20%)		
Case study	Habitats	Critical load range (kg N/ha/yr)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)
Ashdown forest	Broadleaved deciduous woodland	10-20	25.1	20.2	19.6	Medium-High	Medium-High	Medium	Medium-High	Medium	Medium
	Dwarf shrub heath	10-20	14.8	12.4	12.1	Medium-High	Medium-Low	Medium-Low	Medium	Medium-Low	Medium-Low

3.1.11 Local assessment

The degree to which the critical levels and loads are exceeded, and in some cases whether they are exceeded at all, is a direct function of the spatial resolution of the model. Even where the 1 km x 1 km FRAME model outputs are in close agreement with the local-scale modelling when comparing like-for-like resolutions (e.g. area-averages), disaggregating the data into different spatial resolutions gives different conclusions regarding the maximum predicted concentrations and fluxes, and thus the degree to which the critical levels and critical loads are exceeded. This is a well-understood issue when assessing against air quality standards. The critical levels and critical loads specify temporal averaging criteria (e.g. annual means) but they not specify spatial averaging criteria (e.g. they are not restricted to only apply to locations which represent a minimum spatial area, instead relating to the presence and sensitivity of habitat features). If location-specific maxima require assessment, then 1 km x 1 km average values will frequently under-predict close to emissions sources. Statistics regarding exceedances of critical levels or critical loads which are derived from 5 km x 5 km, or 1 km x 1 km resolution modelling are thus specific to that model resolution. Using a finer-resolution model for local-scale assessment will, by definition, give different results unless the site is distant from any concentrated emissions source.

The 2 m x 2 m average data show that the 1 $\mu g\ m^{-3}$ annual mean NH_3 critical level will continue to be exceeded at some locations in Ashdown Forest in all scenarios. Similarly, the 30 $\mu g\ m^{-3}$ NO_x critical level will continue to be exceeded close to roads in all of the 2030 scenarios (but compliant in 2040+ scenarios). Maximum N deposition to woodland is predicted to be greater than 40 kg N $ha^{-1}\ yr^{-1}$ (double the upper-bound critical load) in all future-year scenarios (Figure 3.1-22), while deposition to short vegetation will remain above 17 kg N $ha^{-1}\ yr^{-1}$ (Figure 3.1.2-23). These maximum values do not necessarily represent large areas. By comparison, the 1 km grid resolution assessment of critical loads exceedance also shows continued exceedance of the SSSI, with excess N decreasing from approx. 15 kg N $ha^{-1}\ yr^{-1}$ in 2017 towards 10 kg N $ha^{-1}\ yr^{-1}$ under the most ambitious scenarios.

The key atmospheric N issues vary across different parts of the site. The parts of the site worst-affected by N deposition are close to roads and, in these locations, local road traffic is the single largest contributor. However, this picture changes at greater distance from roads as the localised effects diminish. Well away from roads, where deposition fluxes are much smaller, road traffic contributes significantly less to the total N flux. Because most of Ashdown Forest is not close to roads, this means that the area-average and area-total N deposition fluxes are not dominated by road traffic.

Livestock emissions (originating from England) make up 22% of the current total N inputs to woodland in the SSSI, with road transport only contributing 12% of the total. By contrast, livestock contributes 12% to current N deposition at the worst-affected woodland location, with road transport contributing 55%.

The decreases predicted between the 2017, 2030 BAU (WM), and the 2030 NAPCP+DA (NECR NO_x) baseline scenarios cover a range of sectors, including road transport, and so improvements are predicted over the whole site and also at the worst-affected roadside locations. Similarly, the 2040+ scenarios are predicted to reduce emissions from road transport as well as other sectors; meaning that some improvements are predicted to both area-average and area-maximum deposition fluxes (so long as post-2030 NO_x emission reductions are achieved via fleet electrification). The other targeted measures appear to have very limited effects on either the area-average or the area-maximum fluxes.

The results suggest that the most effective means of reducing the N deposition at the worst-affected locations would be to reduce NO_x and NH_3 emissions from traffic using the roads running through Ashdown Forest. Traffic modelling presented to the Examination in Public of the 2019-submission Wealden Local Plan suggested that a very large proportion of trips on these roads have either their origin or their destination (or both) within the district of Wealden. District-specific measures to target these trips might thus be effective in reducing the maximum deposition fluxes, but the same measures are unlikely to significantly reduce area-total deposition.

The 1 km x 1 km average model results largely agree with the local assessment when the two models are used to compare equivalent spatial resolutions (e.g. comparing predictions of area-averages). However, 1 km x 1 km averages cannot be used to discount the potential for exceedances of the critical levels or critical loads. This is because increasing the spatial resolution of a model close to an emission source will always reveal higher concentrations and fluxes.

3.1.12 Conclusions

The spatially targeted scenarios considered in this current study are unlikely to provide significant benefits to Ashdown Forest, as the main NH_3 sources targeted (agricultural sector) are not a major contributor to local atmospheric N concentrations deposition. Spatial targeting of local (district-level) trips using roads passing through Ashdown Forest may lead to significant improvements to the worst-affected locations but would be less effective at reducing 1 km x 1 km average fluxes. Any measures targeting traffic emissions should take care to consider emissions of both NO_x and NH_3.

3.2 Breckland Farmland

The following sections provide background on Breckland Farmland and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.2.10, which focuses on assessing the information presented in regard to the suitability of this site for spatial targeting of measures.

3.2.1 Site map and location within UK

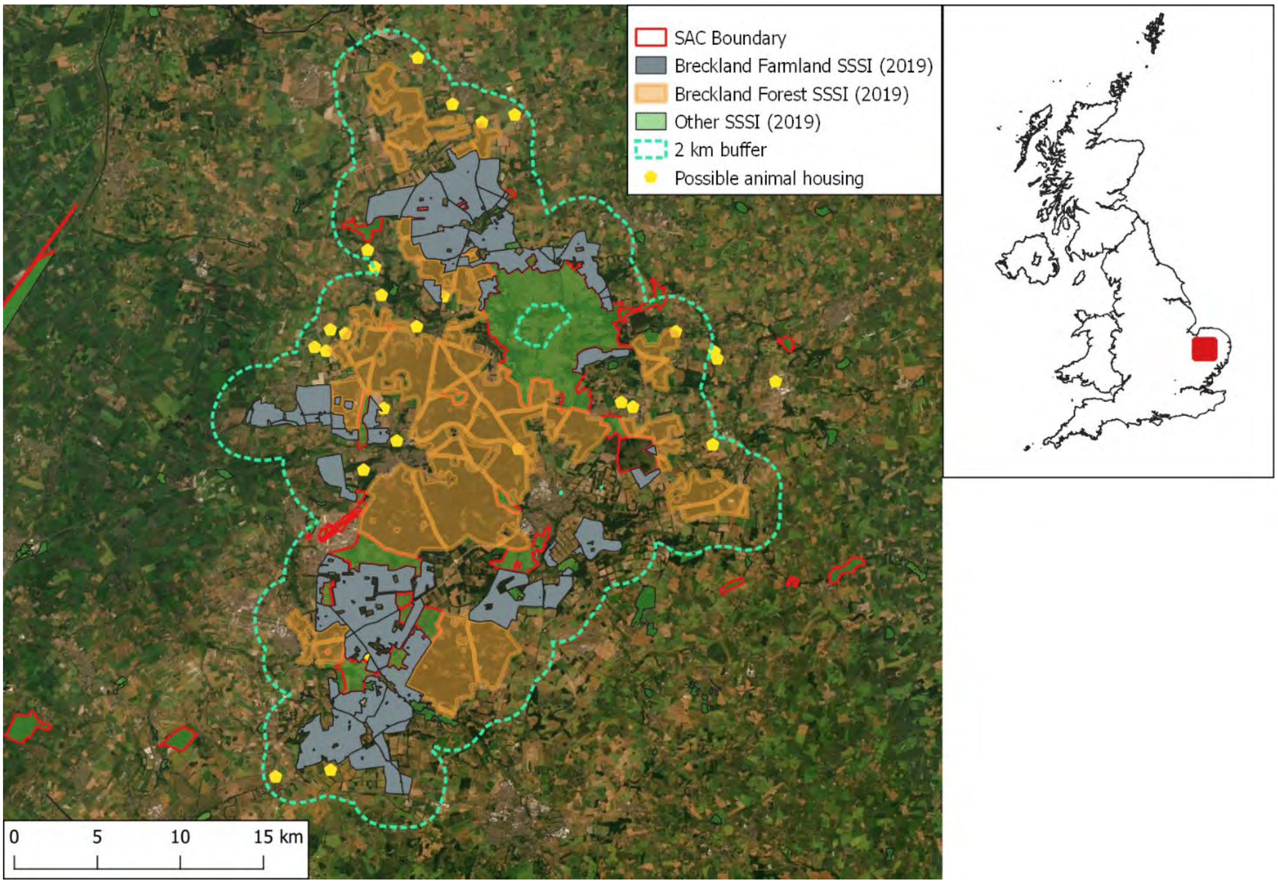


Figure 3.2-1. Site map showing relevant features and boundaries of Breckland Farmland SSSI, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.2.2 Designated features

Table 7. Nitrogen sensitive interest features at Breckland Farmland SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Stone Curlew	No critical load assigned

3.2.3 Site characteristics

Breckland Farmland SSSI (East Anglia, England) covers intensively used agricultural land and is designated to protect biodiversity, in particular the Stone-curlew, one of Britain's rarest birds. The site forms part of an area of multiple SSSIs and SACs, which includes the interlaced N-sensitive Breckland Forest SSSI which is described in Section 3.3. The main source of N input is from intensive pig and poultry farming, with additional input from arable farming.

3.2.4 Agricultural emission density

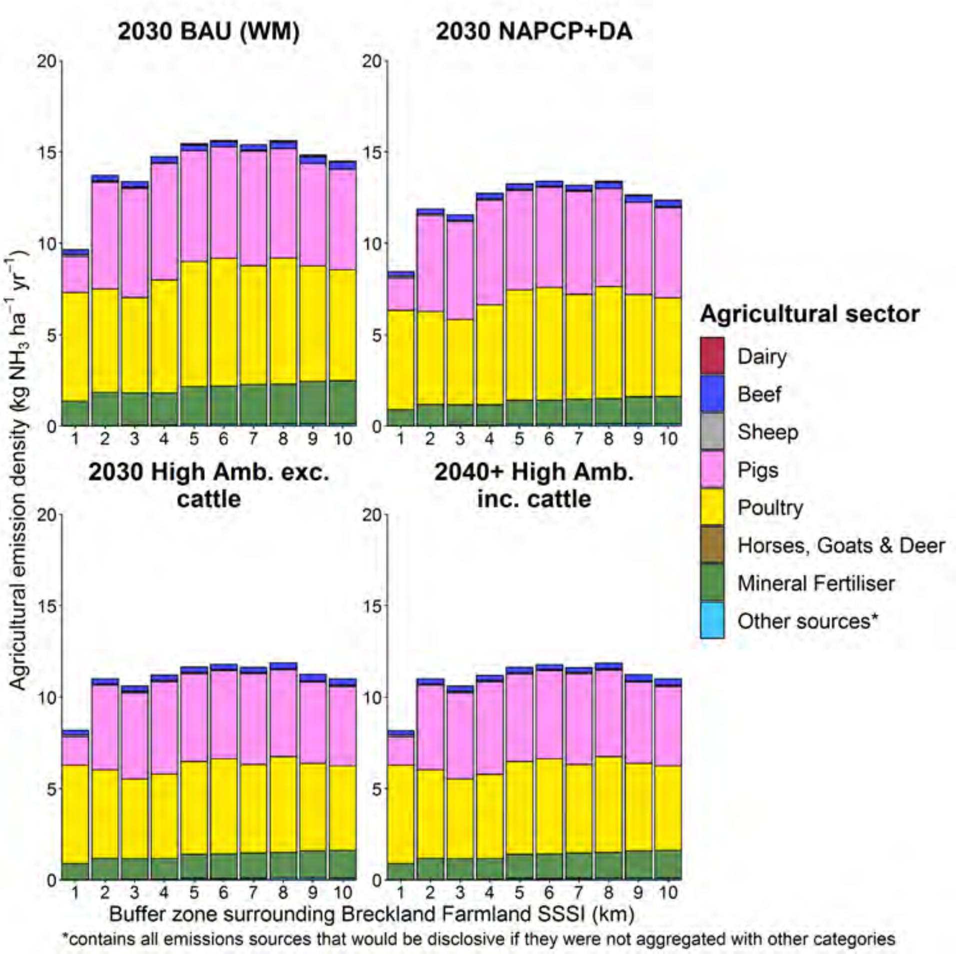


Figure 3.2-2. Estimated agricultural emission densities in concentric buffer zones surrounding Breckland Farmland SSSI.

3.2.5 Source attribution

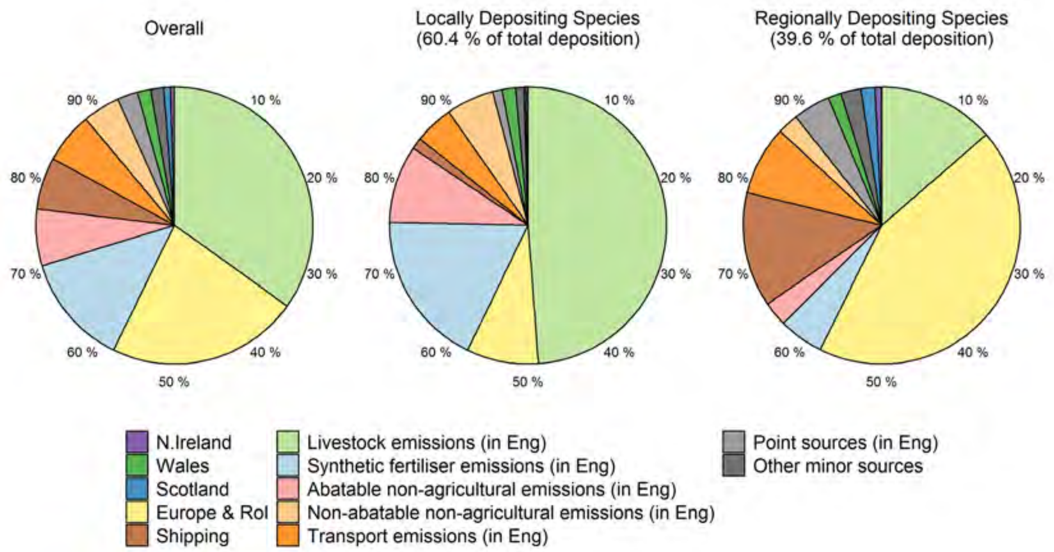


Figure 3.2-3. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Breckland Farmland SSSI.
N.B. Deposition to low-growing semi-natural vegetation is shown here, for information. There are no sensitive designated vegetation features at this site, however the map shows the N deposition estimated for any low-growing semi-natural vegetation within the site boundary.

3.2.6 NH_3 concentration

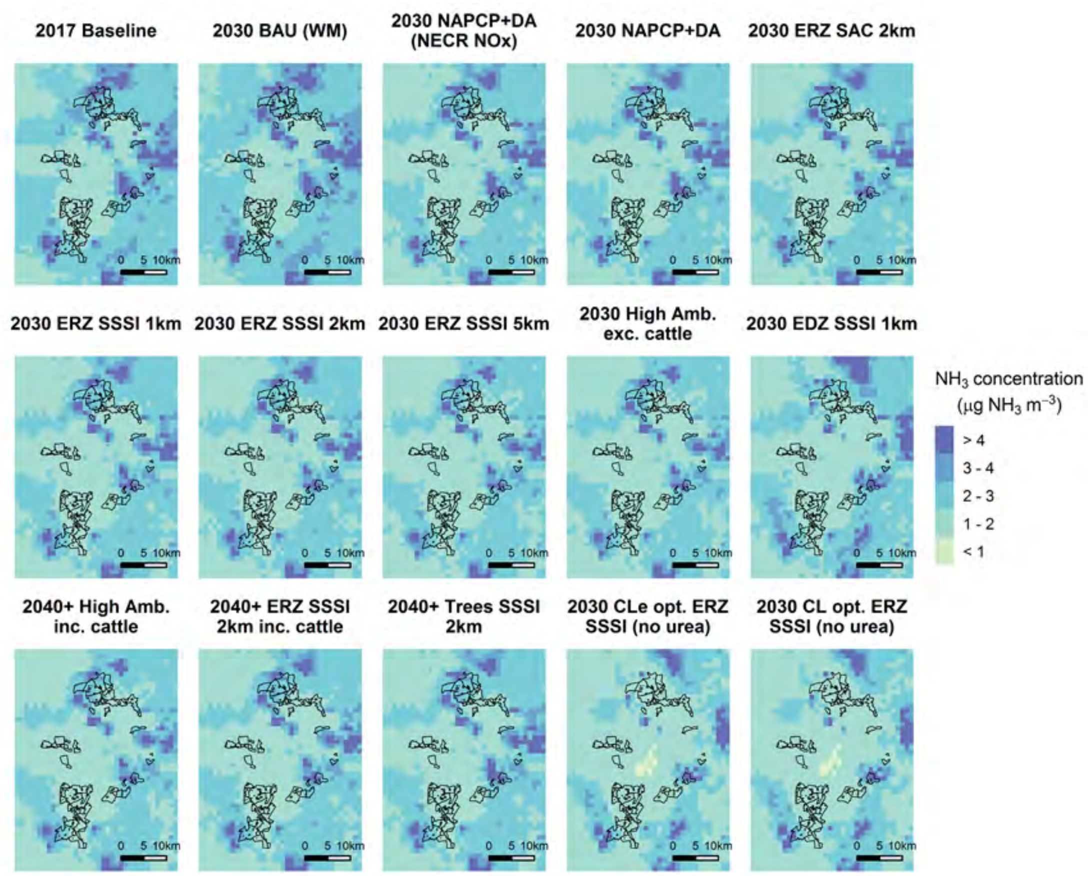


Figure 3.2-4. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Breckland Farmland SSSI and surrounding area.

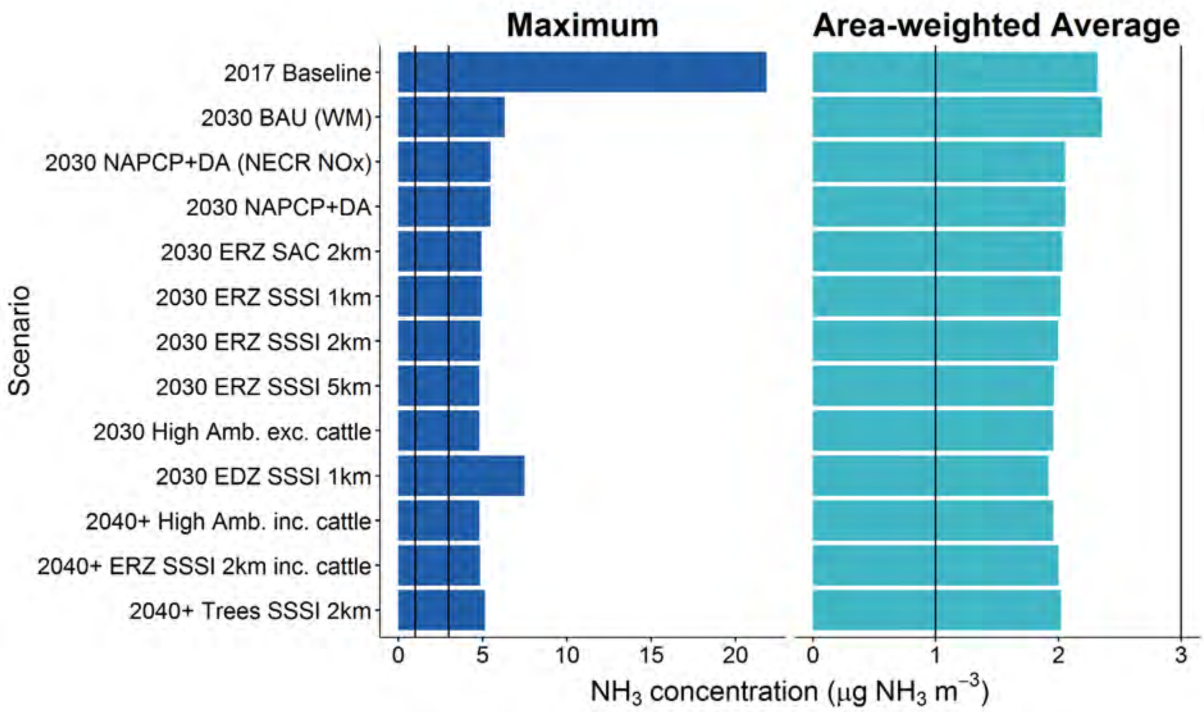


Figure 3.2-5. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Breckland Farmland SSSI. Vertical lines indicate 1µg and 3 µg critical levels.

3.2.7 NO_2 concentration

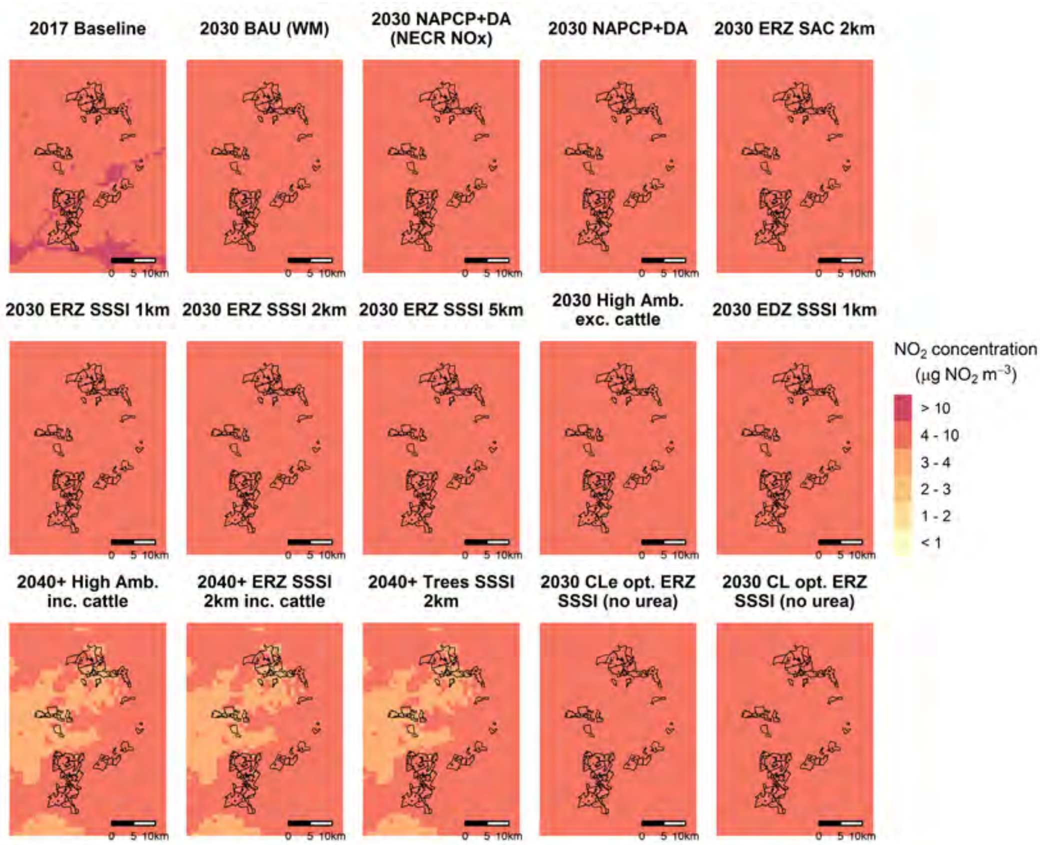


Figure 3.2-6. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Breckland Farmland SSSI and surrounding area.

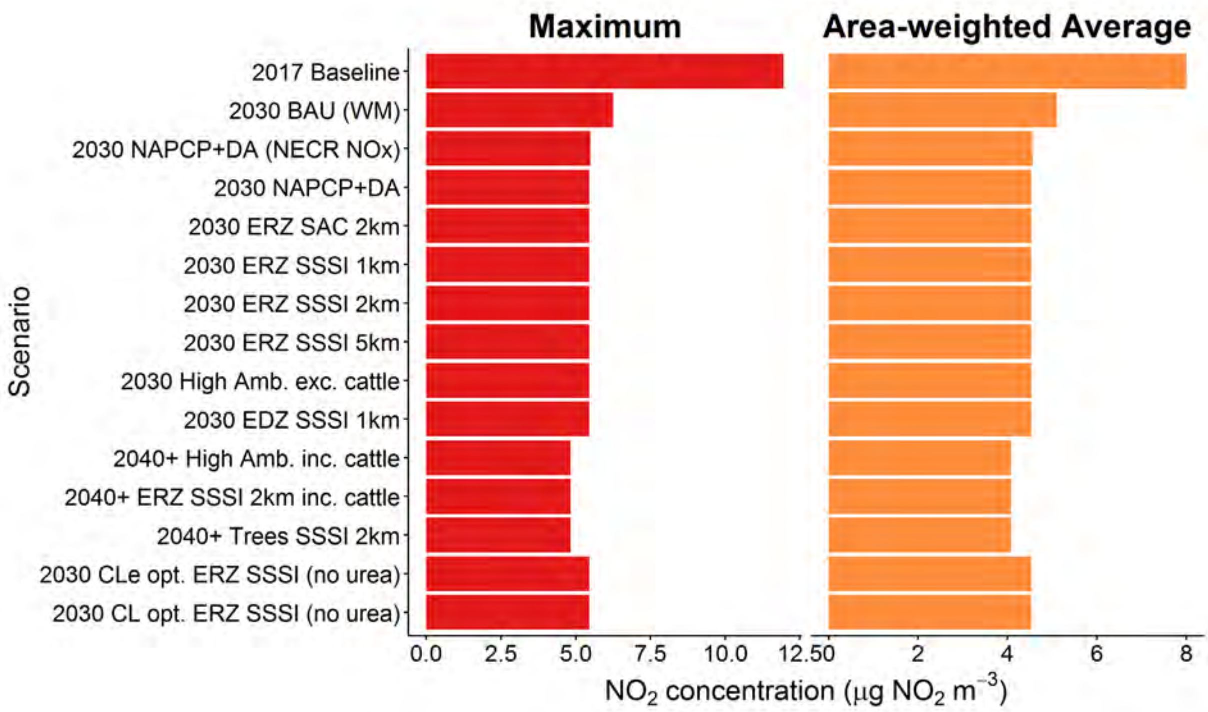


Figure 3.2-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Breckland Farmland SSSI.

3.2.8 N deposition

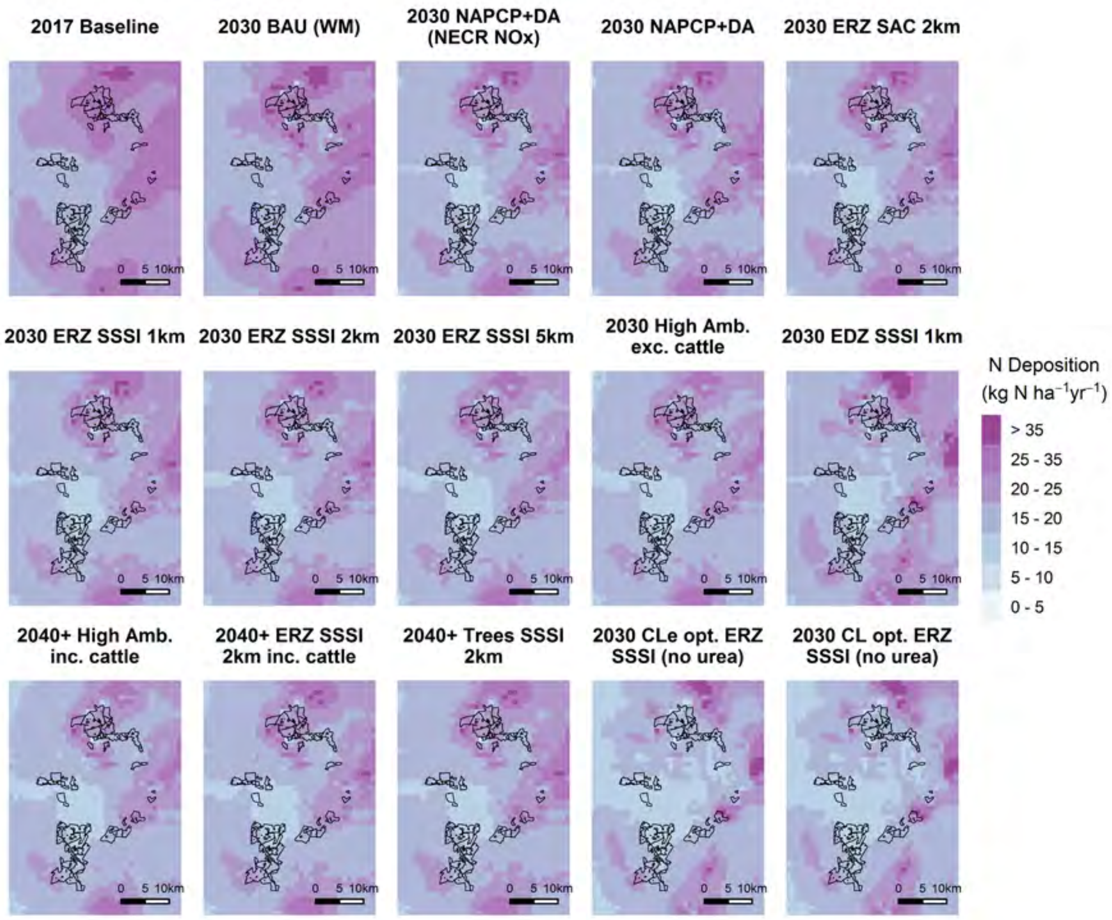


Figure 3.2-8. N deposition (to low-growing semi-natural vegetation) received by Breckland Farmland SSSI and surrounding area.
N.B. Deposition to low-growing semi-natural vegetation is shown here, for information. There are no sensitive designated vegetation features at this site, however the map shows the N deposition estimated for any low-growing semi-natural vegetation within the site boundary.

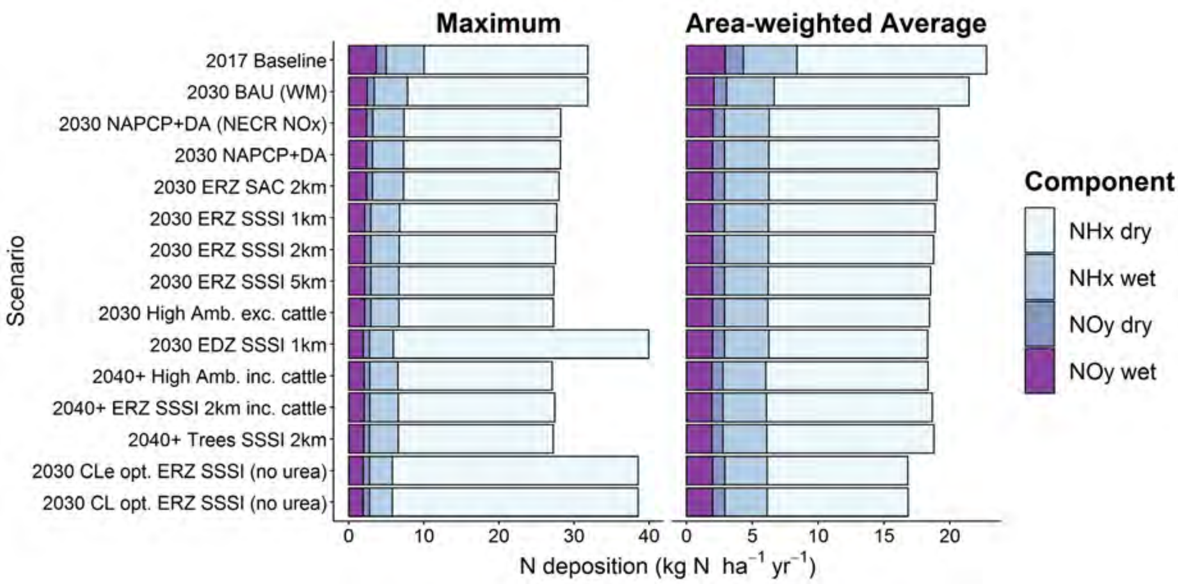


Figure 3.2-9. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Breckland Farmland SSSI.

3.2.9 Exceedance of critical loads

There are no sensitive designated vegetation features at this site, with the feature being a rare bird (stone curlew) nesting in arable crop fields. Therefore, are no critical loads for arable land (which is actively fertilised), and no exceedance calculations could be carried out.

3.2.10 Local assessment

Breckland Farmland is situated in an agricultural area with local N emissions being dominated by pig and poultry farming and forms part of a network of designated sites in this part of eastern England. As this site is designated for protecting a rare bird (stone curlew) and contains mainly managed agricultural crop areas that receive mineral and organic fertilisers, atmospheric N input is not expected to be a threat here. N deposition data (shown in Section 3.2.8 for low-growing semi-natural vegetation) is still a useful indication of key emission sources that contribute to local deposition however, they should not be used quantitatively as they are not representative for the site. The source attribution information for Breckland Farmland indicates that local livestock sources are likely to be a significant source of N input to this site, however longer-range input from nearby continental Europe and international shipping are also contributing.

National scale modelling of mitigation scenarios results in minor changes to NH_3 and NO_x concentrations, as well as N deposition (to low-growing semi-natural vegetation), from a combination of national measures and spatially targeted scenarios at other nearby SSSIs. The notable exception here is the EDZ scenario, where some of the landspreading emissions displaced from the vicinity (1 km zone) of the N-sensitive Breckland Forest SSSI (Section 3.3) were redistributed closer to the non-sensitive Breckland Farmland SSSI. This resulted in increased NH_3 concentrations and related NH_x deposition at Breckland Farmland for this scenario as well as the optimised scenarios which also include the EDZ measures. If such measures were implemented in practice, care would have to be taken to define suitable zones for displacing the additional landspreading materials.

3.2.11 Conclusions

As this site is classified as not sensitive to atmospheric N input, no spatial targeting measures were applied. However, any N sensitive low-growing semi-natural vegetation at the site would benefit from most of the measures applied to the adjacent and spatially intertwined Breckland Forest SSSI. The exception is the EDZ scenario, where the measures designed to protect Breckland Forest result in additional landspreading closer to Breckland Farmland, thereby increasing NH_3 concentrations and related localised N deposition. If both neighbouring sites were designated for N-sensitive vegetation, measures applied to a wider area encompassing both sites would provide additional benefit in terms of reduced atmospheric N input across the wider area.

3.3 Breckland Forest SSSI

The following sections provide background on Breckland Forest and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.3.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.3.1 Site map and location within UK

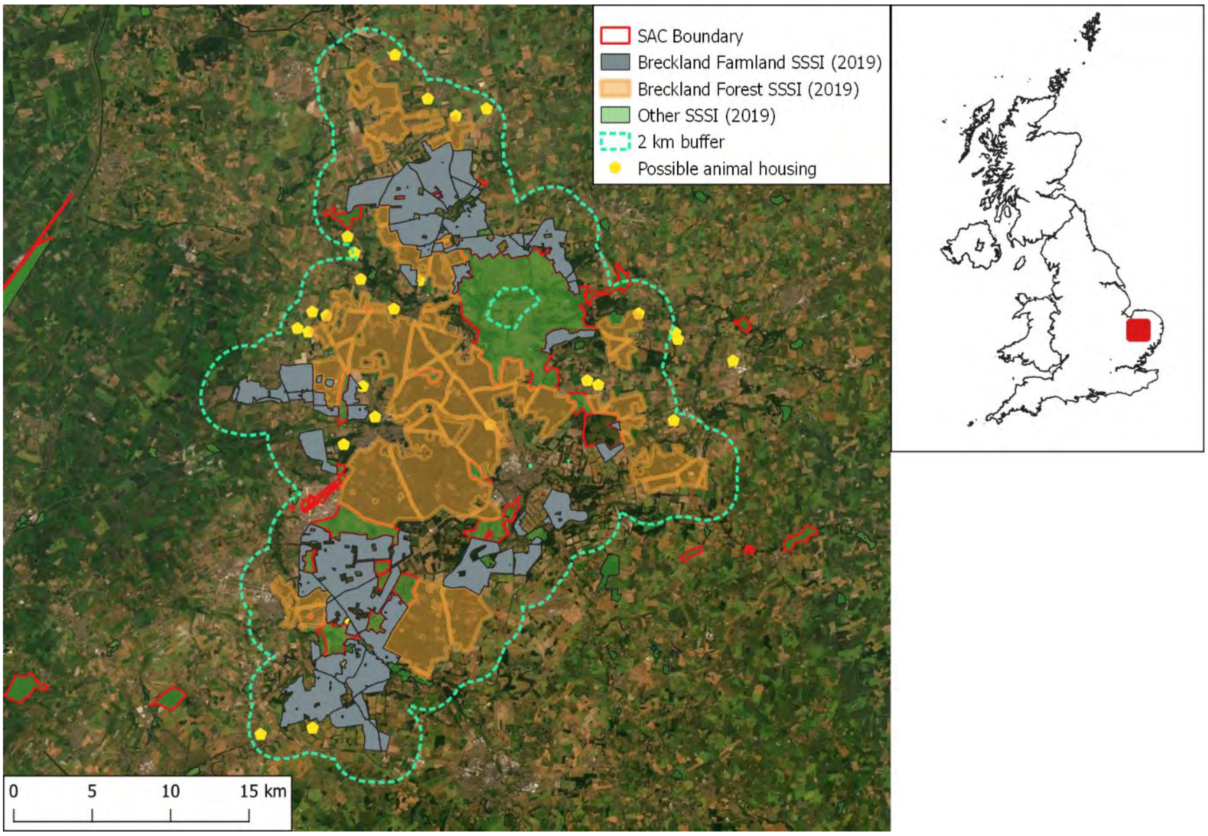


Figure 3.3-1. Site map showing relevant features and boundaries of Breckland Forest, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.3.2 Designated features

Table 8. Nitrogen sensitive interest features at Breckland Forest SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Coniferous woodland	5 – 15 kg N/ha/yr
Dry heaths	10 – 20 kg N/ha/yr
Vascular plant assemblage Invertebrate plant assemblage	No estimate available
Nightjar *Caprimulgus europaeus* Woodlark *Lullula arborea*	5 – 15 kg N/ha/yr (coniferous woodland) 10 – 20 kg N/ha/yr (dry heaths)

The Notification as a SSSI[1] is due to the clear fell areas and young plantations providing breeding habitat for woodlark *Lullula arborea* and nightjar *Caprimulgus europaeus*, which

[1] https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/2000443.pdf.

occur in internationally important numbers. The site has five vascular plants listed on Schedule 8 of the Wildlife and Countryside Act, as well as an important assemblage of nationally rare and scare vascular plant species, which are largely restricted to East Anglia.

3.3.3 Site characteristics

Breckland Forest (East Anglia, England) mostly lies within the commercial forest of Thetford Forest Park. The site undergoes rotation of clear-felled areas and young plantations. The dominant species of the site is Corsican pine (70%). The site forms part of an area of multiple SSSIs and SACs, including the interlaced Breckland Farmland SSSI. The main source of N input is from intensive pig and poultry farming, with additional input from arable farming.

3.3.4 Agricultural emission density

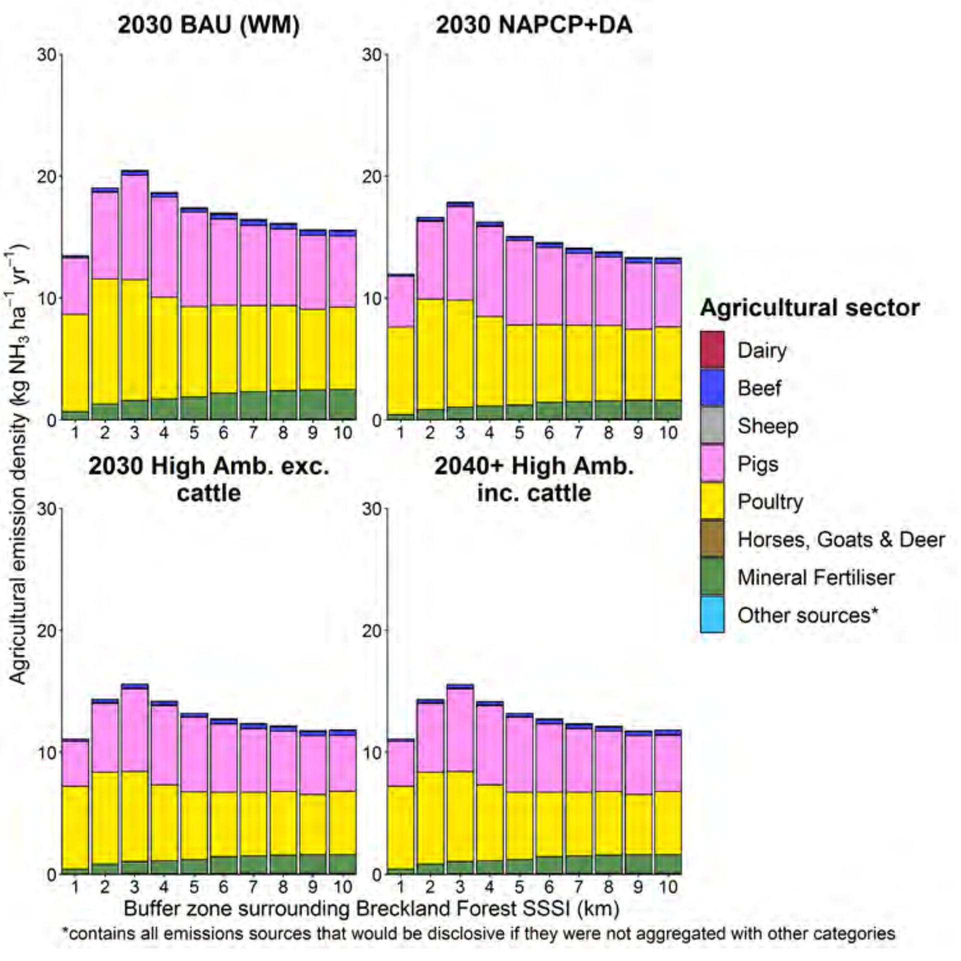


Figure 3.3-2. Estimated agricultural emission densities in concentric buffer zones surrounding Breckland Forest SSSI.

3.3.5 Source attribution

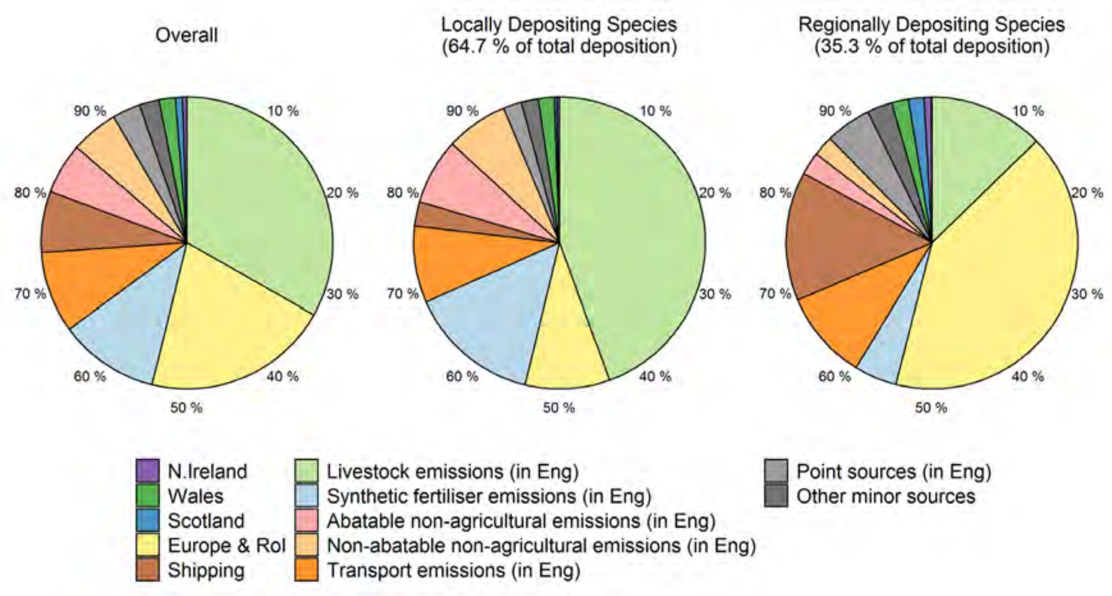


Figure 3.3-3. Relative contribution of emission sources to N deposition (to woodland features) received by Breckland Forest SSSI.

3.3.6 NH_3 concentration

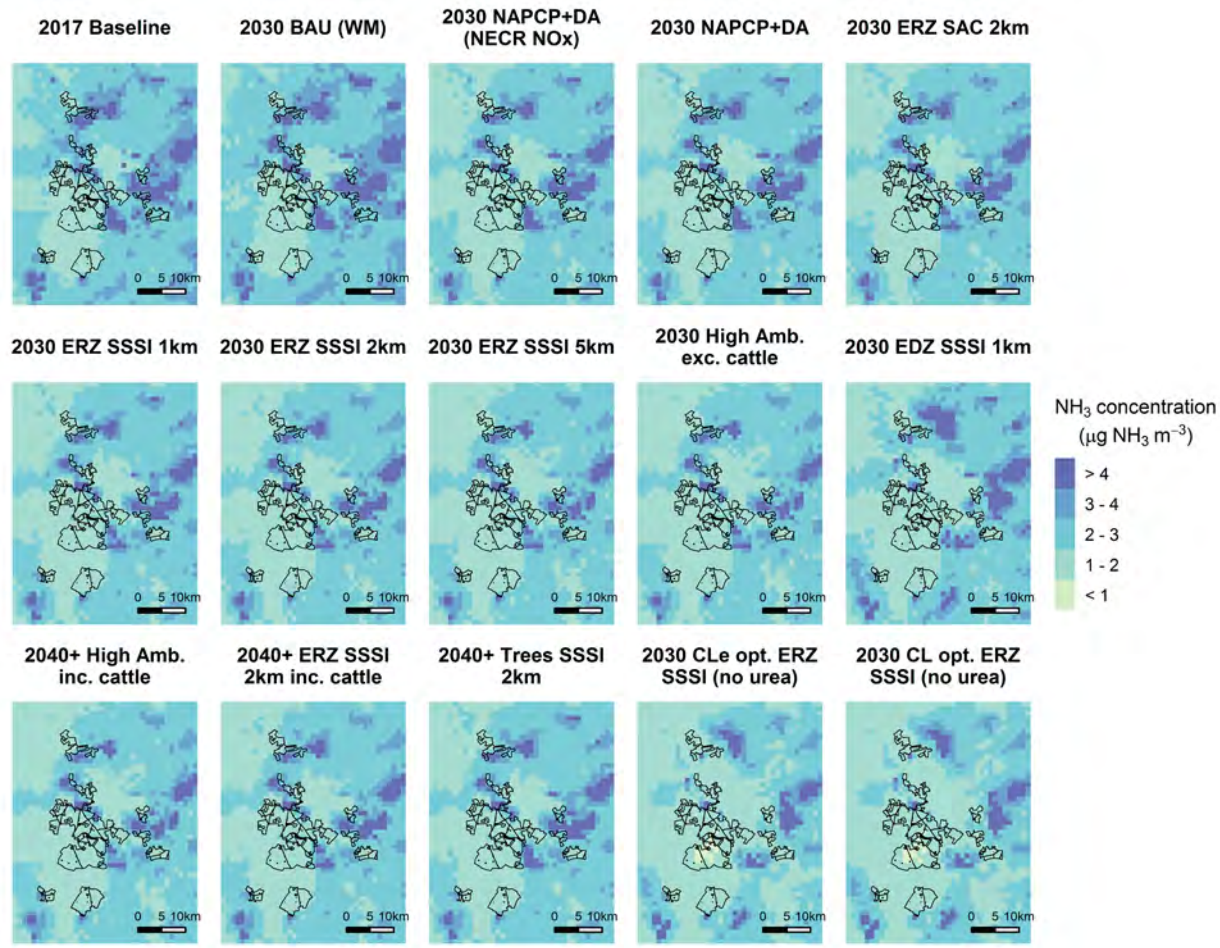


Figure 3.3-4. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Breckland Forest SSSI and surrounding area.

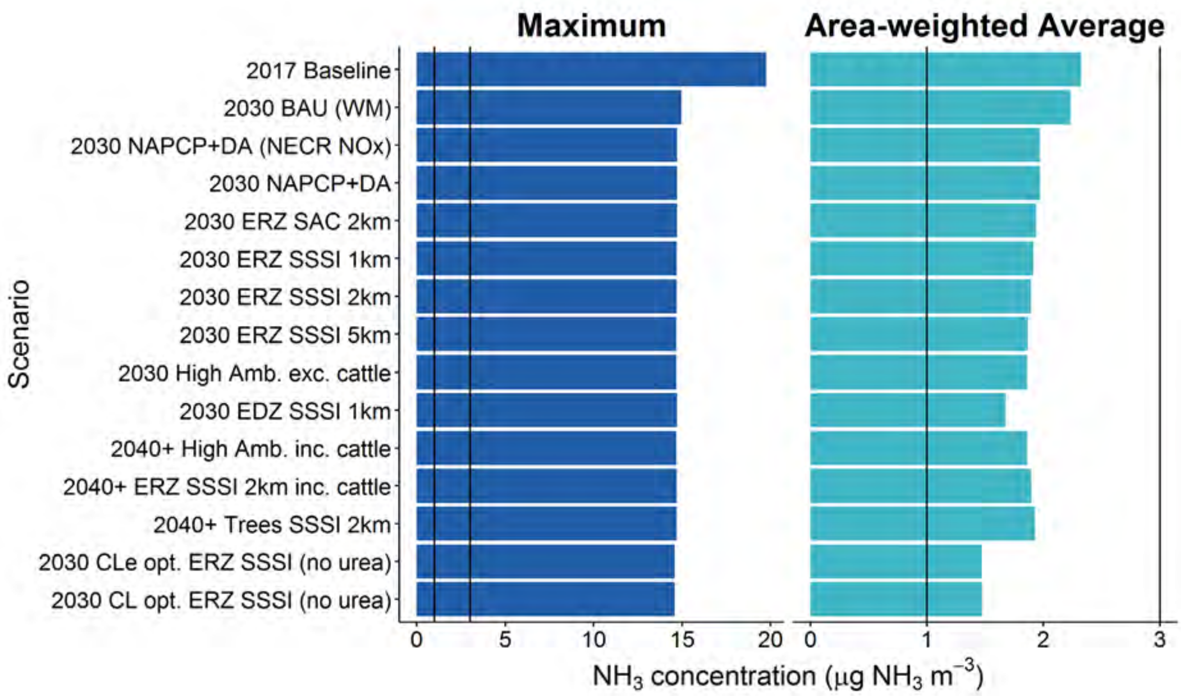


Figure 3.3-5. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Breckland Forest SSSI. Vertical lines indicate 1µg and 3µg critical levels.

3.3.7 NO_2 concentration

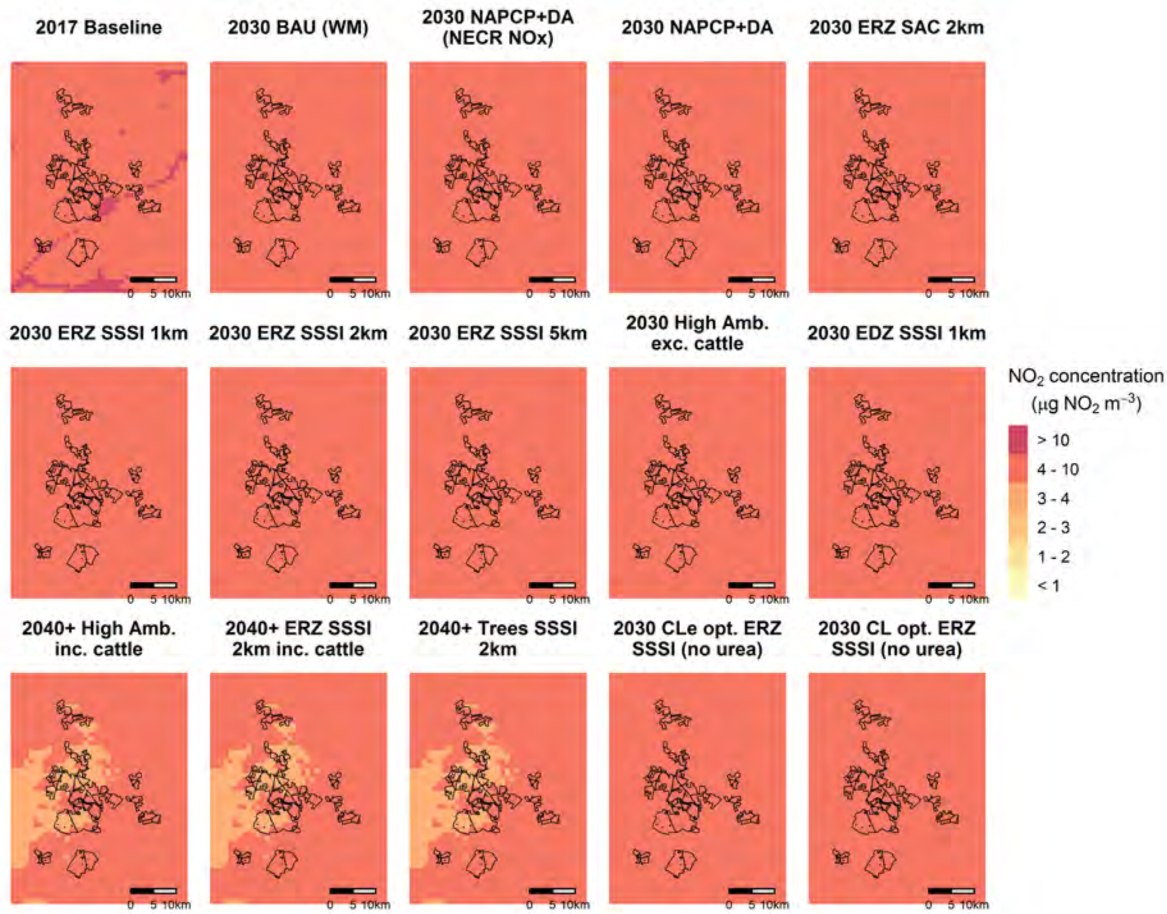


Figure 3.3-6. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Breckland Forest SSSI and surrounding area.

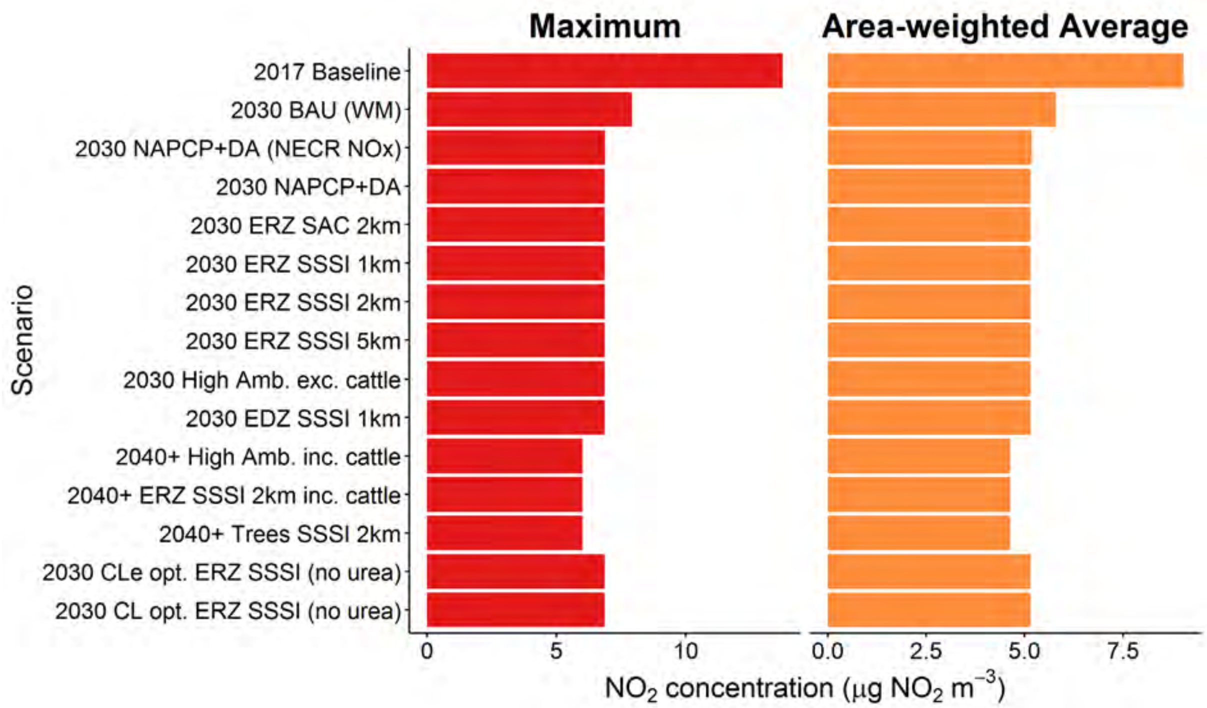


Figure 3.3-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Breckland Forest SSSI.

3.3.8 N deposition

Figure 3.3-8. N deposition (to woodland features) received by Breckland Forest SSSI and surrounding area.

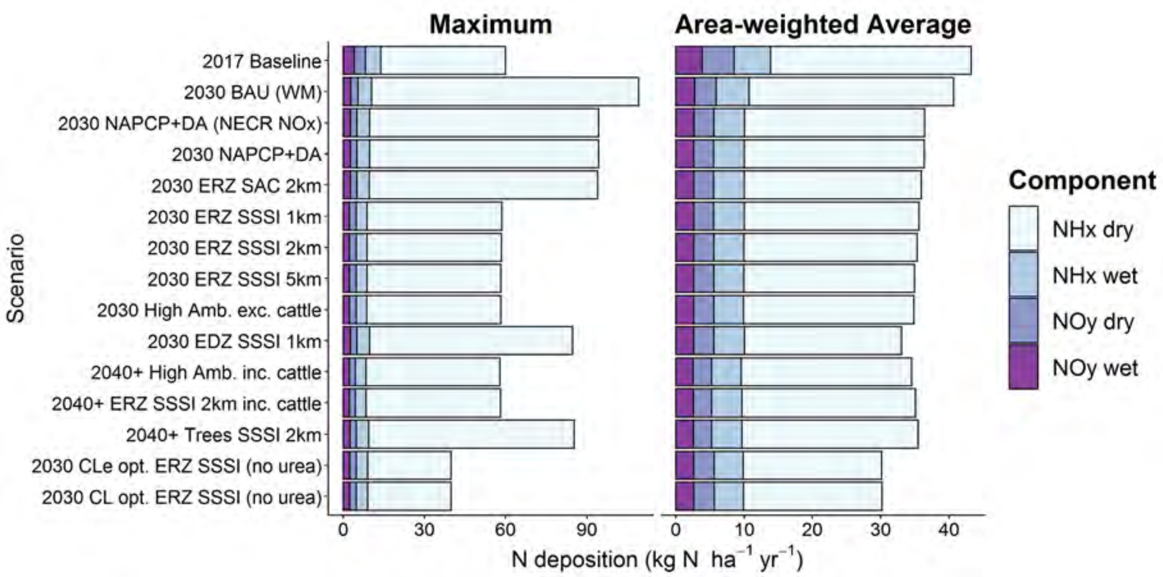


Figure 3.3-9. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Breckland Forest SSSI.

3.3.9 Exceedance of critical loads

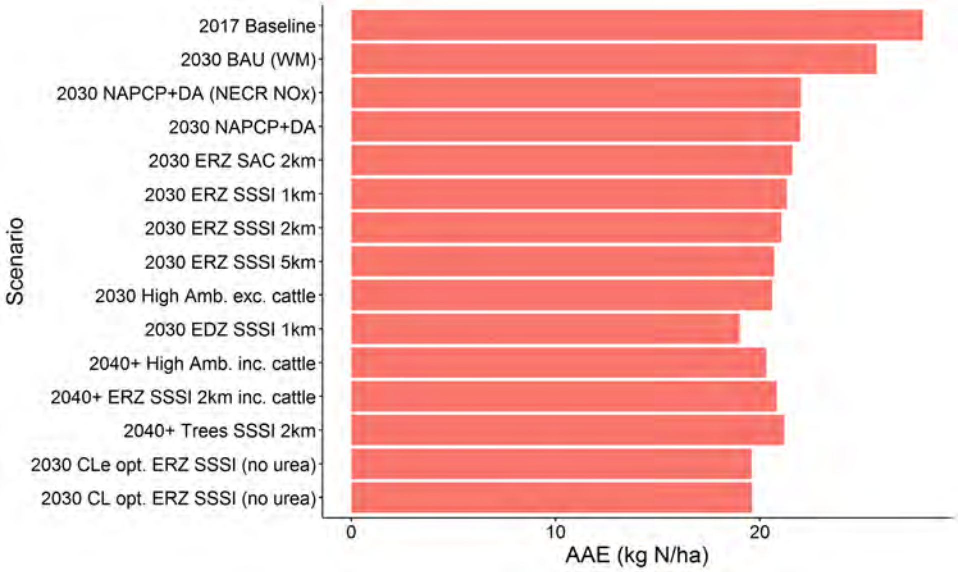


Figure 3.3-10. Exceedance of critical loads by scenario at Breckland Forest SSSI.

3.3.10 Local assessment

Given the location of the site (East Anglia), substantial transboundary influences from mainland Europe and international shipping in the Channel are contributing to the long-range input. More locally, agricultural livestock farming (in particular, pig and poultry – as confirmed with emission density data) provides the largest single source of atmospheric N input. The light, sandy and free draining soils of the area are used to grow high-value crops and are also well suited out outdoor pig rearing.

Overall, national scale modelling is assumed to be representative for the wider conditions across the site, however there may be some uncertainty associated with quantifying the contribution of pig and poultry farming to the local agricultural emission density, depending on the systems in use locally. On a per-pig basis, NH_3 emission factors are estimated to be

30-50% lower for outdoor systems than housed systems (Tom Misselbrook, pers. comm.), and depending on the proportion of outdoor vs housed pigs in the area, there is an uncertainty in the magnitude of emissions from this sector. Unlike traditional pig housing, outdoor pig units are not permanently located, with the rearing areas being moved between fields over time.

Average NH_3 concentrations across the site decrease with the spatial targeting measures but remain above the 1 µg NH_3 critical level. High NH_3 ambition scenarios are estimated to result in decreased N deposition, with the optimised scenarios producing the largest reduction. Overall, the source attribution modelling identified the main contributors to N deposition at the site (using average data across the site). Very local pollution gradients (e.g. from individual livestock houses close to the site boundary or immediate roadside) cannot be captured using this approach. There are substantial numbers of broilers, geese and ducks in the area surrounding the Breckland Forest/Farmland. Although the overall number of broilers is much higher than for ducks/geese, the NH_3 emission factor associated with broilers (0.08 kg NH_3-N head) is lower than for “other poultry” (0.54 kg NH_3-N head) and therefore ducks and geese are likely to be a major contributor to overall emissions.

3.3.11 Conclusions

As the site is surrounded by arable farmland with a widespread presence of pig and poultry farming in the region, it is expected that spatial targeting of measures would provide benefits to Breckland Forest. Given this prevalence of pig and poultry farms nearby, switching all land spreading to low-emission application or creating low/no N-input zones around the site boundary is expected to provide local decreases in N input gradients into the site. For this area, specific points to note are with regard to the location of temporary outdoor pig rearing in relation to the site boundaries and balancing the current high-value crop production with protecting the N-sensitive designated habitats.

As the neighbouring SSSI, Breckland Farmland, is not classified as sensitive to atmospheric N input, no spatial targeting measures were applied there. If both neighbouring sites (and the large number of further designated sites in this area were designated for N-sensitive vegetation, measures applied to a wider area encompassing both sites would provide additional benefit in terms of reduced atmospheric N input across the wider area.

3.4 Epping Forest

3.4.1 Site map and location within UK

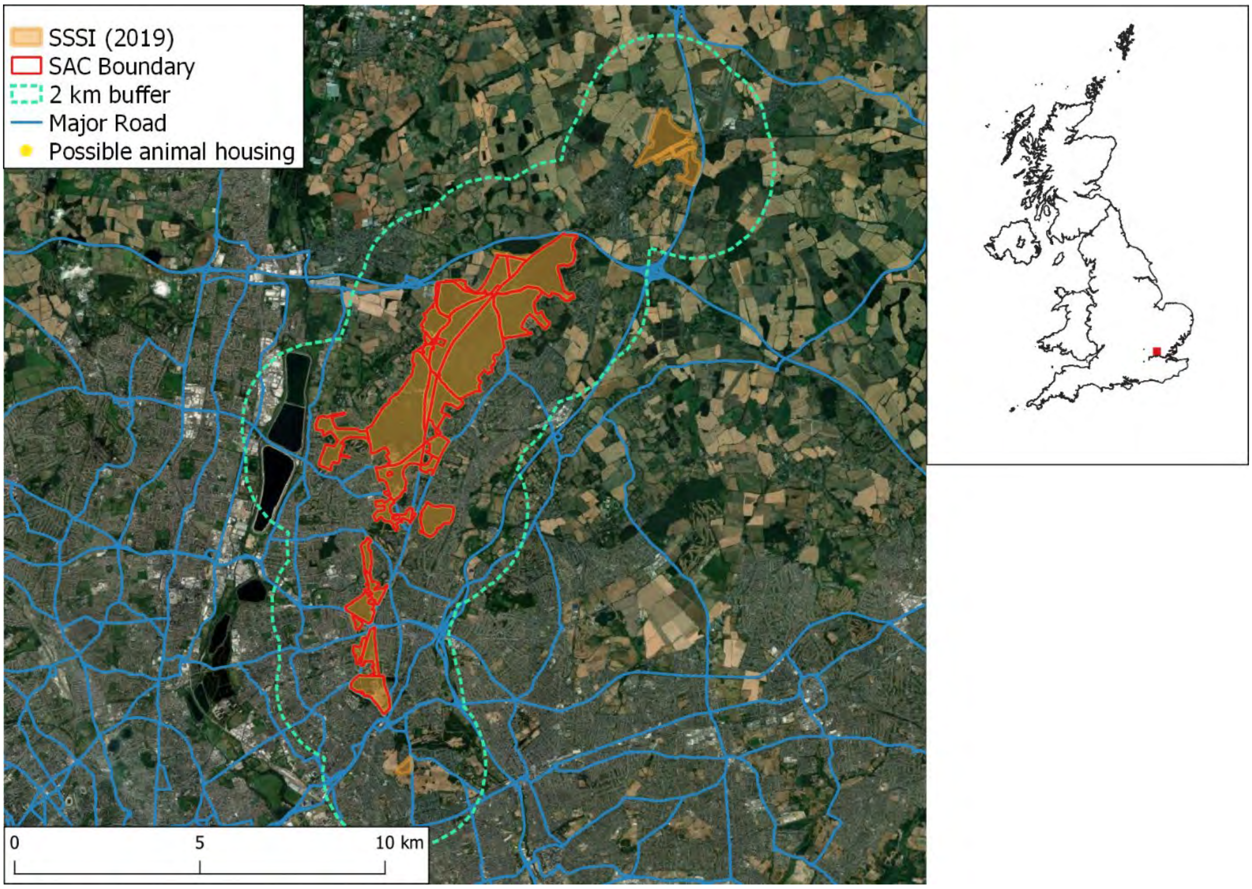


Figure 3.4-1. Site map showing relevant features and boundaries of Epping Forest, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.4.2 Designated features

Table 9. Nitrogen sensitive interest features at Epping Forest SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Acid grassland	8 – 15 kg N/ha/yr
Acidophilous Quercus-dominated woodland	10 – 15 kg N/ha/yr
Dwarf shrub heath Fagus woodland	10 – 20 kg N/ha/yr
Meso- and eutrophic Quercus woodland	15 – 20 kg N/ha/yr
Stag beetle *Lucanus cervus*	10 – 20 kg N/ha/yr (Broadleaved deciduous woodland)
Amphibian assemblage Invertebrate assemblage Outstanding dragonfly assemblage	No estimate available

3.4.3 Site characteristics

The semi-natural woodlands of Epping Forest include important beech *Fagus sylvatica* forests on acid soils. Like Ashdown Forest, there is widespread interest in Epping Forest, since action to protect the SAC designation from development pressures has shaped emerging local planning policy. Epping Forest District Council is currently developing its Local Plan to enable additional housing growth while still protecting Epping Forest.

In developing its Local Plan, Epping Forest District Council has undertaken local scale dispersion modelling of NO_x and NH_3, and nitrogen deposition fluxes, to the SAC. Impacts were predicted along 19 transects, 200 m from the main roads through Epping Forest (Figure 3.4-2). These results were published as part of the evidence base for the Habitats Regulations Assessment (HRA) of the Submission Epping Forest Local Plan (Aecom 2019). The results from this modelling have been used as the basis of this case study following the methodology set out in Section 2.2.

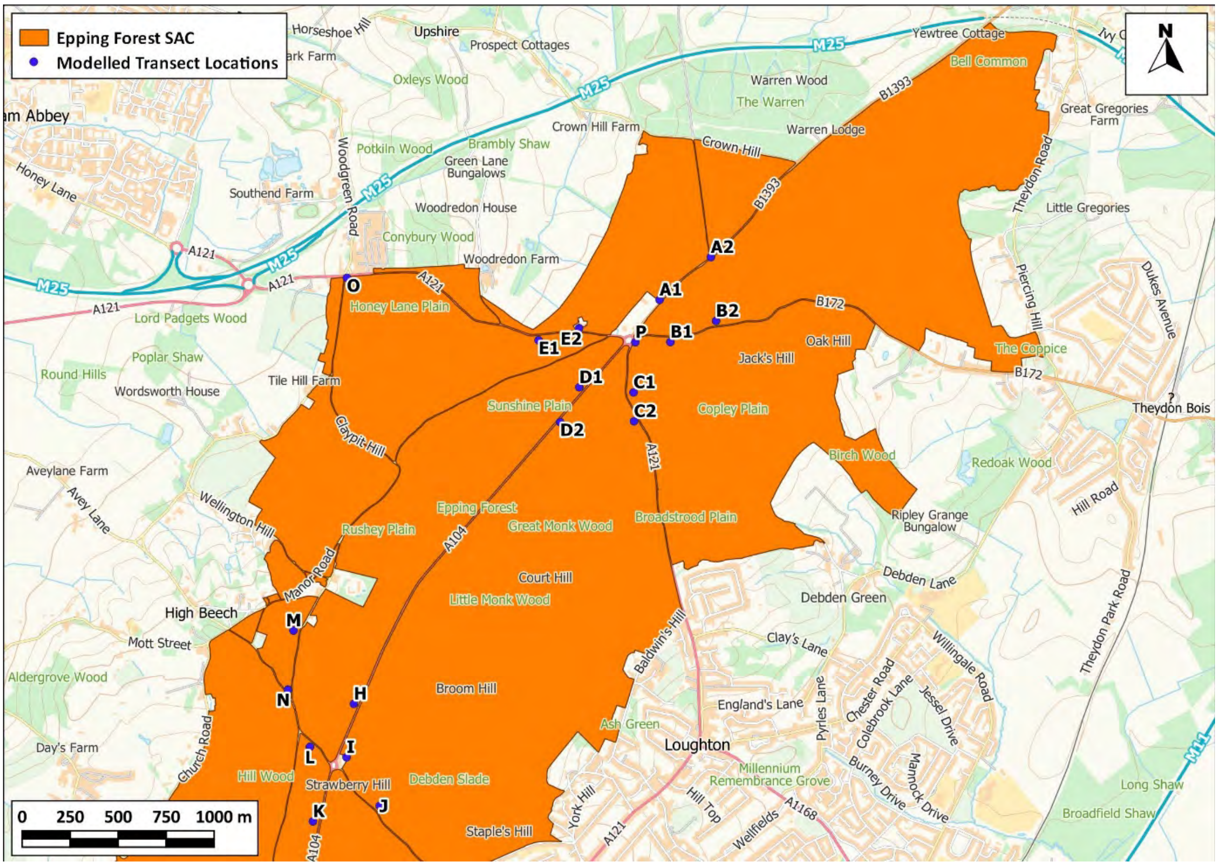


Figure 3.4-2. Location of receptors/transects in Epping Forest model domain.

3.4.4 Agricultural emission density

The average agricultural emission density surrounding the site is low (average of <2 kg NH_3 ha^{-1} yr^{-1}). Agricultural emission density in the surrounding 10 km buffer of the site is expected to decrease with increasing ambition of the selection of mitigation scenarios shown in Figure 3.4-3 below.

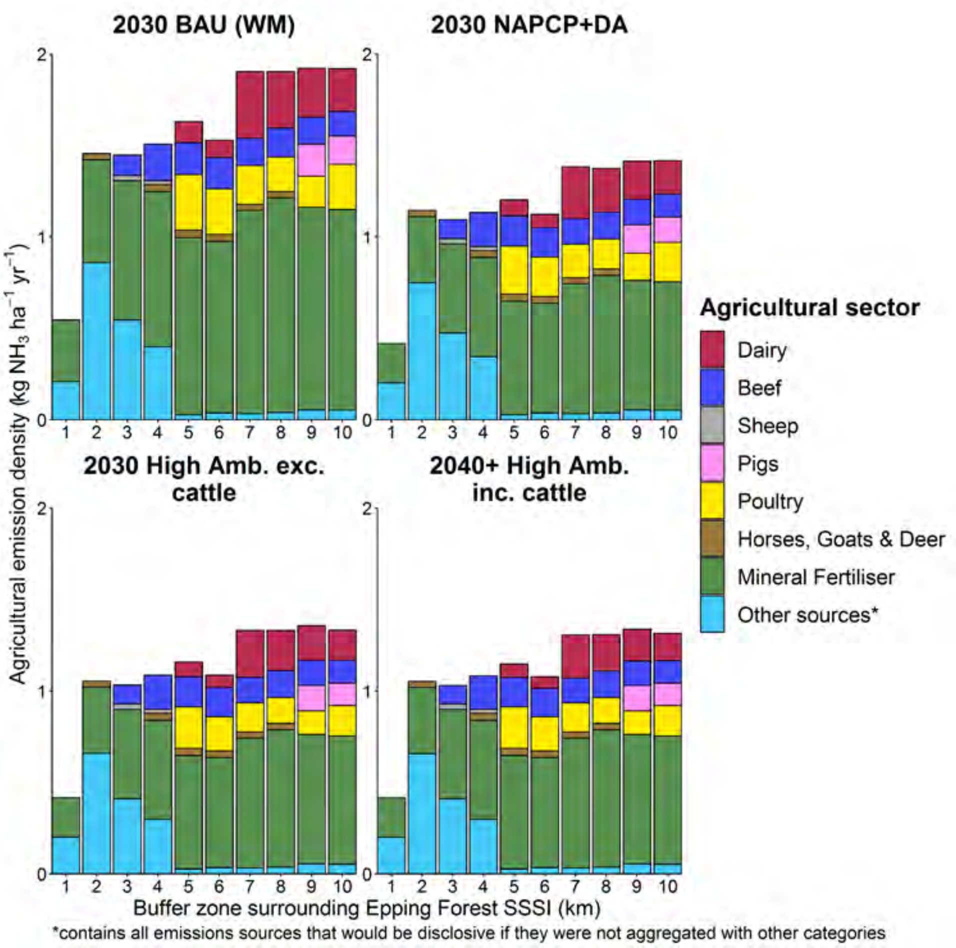


Figure 3.4-3. Estimated agricultural emission densities in concentric buffer zones surrounding Epping Forest SSSI.

3.4.5 Source attribution

When considering the total N deposition to the site as a whole, Figure 3.4-4 shows that local sources of N input are more important to this site (~70%) than regional sources (~30%). In total, road transport (from emissions in England) makes up 20% of the total deposition, with non-agricultural emissions from e.g. waste processing and other process-based sources, referred to as "abatable" emissions making up a further 17% of the total. Livestock emissions contribute only 12%.

Because the effects of individual sources diminish significantly with distance, the source attribution for the site as a whole is very different to the source attribution at the worst-affected locations. Figure 3.4-5 shows the overall contribution of each source to N deposition at this worst-affected point; which is alongside a road. Local road traffic is the single most important source of nitrogen by an appreciable margin at the worst-affected location.

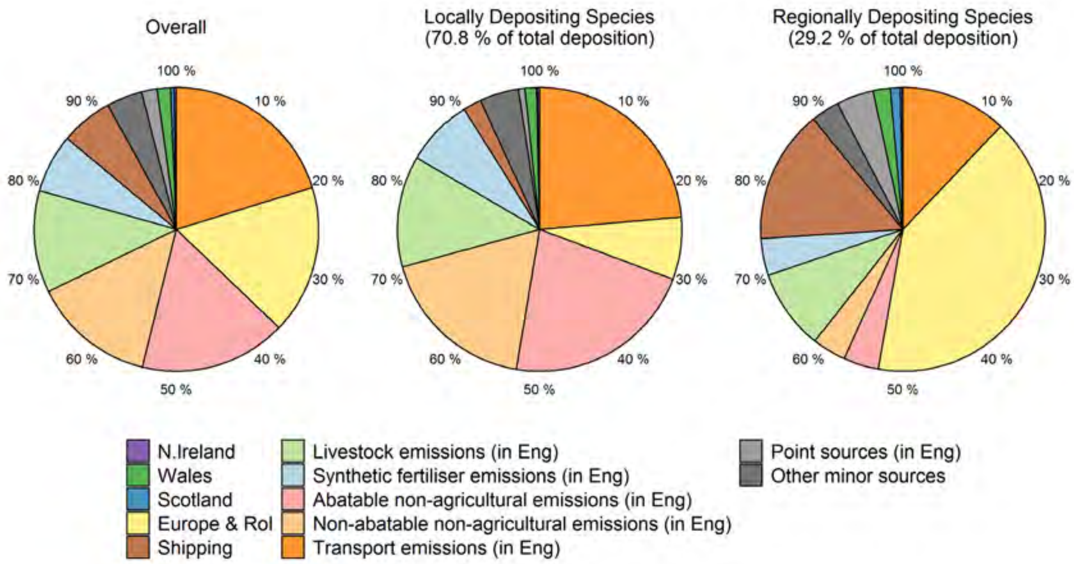


Figure 3.4-4. Relative contribution of emission sources to N deposition (to woodland features) received by Epping Forest SSSI.

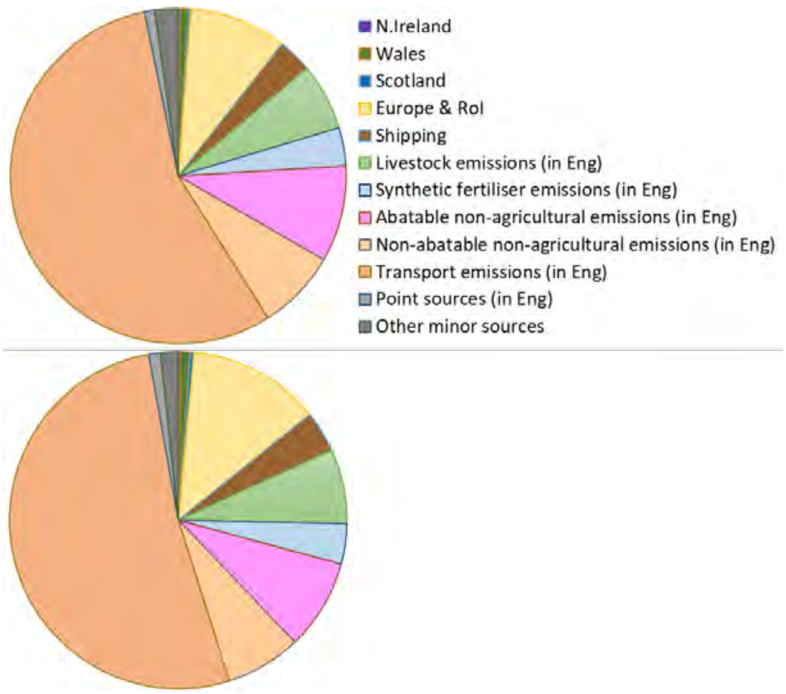


Figure 3.4-5. Relative contribution of emission sources to Site-maximum N deposition (top: to woodland features; and bottom: to low-growing semi-natural vegetation) received by Epping Forest SSSI.

3.4.6 NH_3 concentration

Figure 3.4-6 shows the 1 km x 1 km average annual mean NH_3 concentrations predicted by FRAME. When considering 1 km^2 average values, annual mean NH_3 concentrations are between 1 μg m^{-3} and 2 μg m^{-3} across most of the SSSI in 2017 and in every future-year scenario. Higher 1 km^2 average values only occur toward the south of the site. Figure 3.4-7 shows the maximum 1 km^2 prediction, as well as the SSSI-average prediction in each scenario. Both metrics are predicted to increase between 2017 and both the 2030 BAU and

2030 NAPCP scenarios. The maximum 1 km^2 average concentrations are not predicted to revert back to their 2017 levels in any of the targeted scenarios; thus, remaining higher than at present.

Figure 3.4-8 shows the maximum predicted roadside NH_3 concentrations in each scenario (the maximum roadside concentration across any of the modelled transects). These are lower than the maximum 1 km^2 average values; reflecting the fact that the maximum road increments occur in different locations than the maximum 1 km^2 FRAME predictions (the FRAME predictions are represented by the blue bars in Figure 3.4-8). The local road increment of NH_3 contributes roughly half of the total NH_3 in each scenario, and the maximum NH_3 concentrations remain relatively constant through each scenario considered. Maximum predicted NH_3 concentrations along the other modelled transects are set out in Table 3.

Figures 3.4-9 to 3.4-11 show the predicted NH_3 concentrations along the length of the three transects with the highest predicted concentrations. They show the well-established rate at which annual mean concentrations of primary pollutants reduce with distance from roads; which typically follows a power-law relationship (Laxen & Marner 2008). The differences between the various scenarios are relatively small, with the highest predictions being associated with the 2030 BAU scenario. The 1 $\mu g\ m^{-3}$ critical level is predicted to be exceeded across the entire length of all transects in every scenario.

As explained in Section 1.4.2 there is significant uncertainty regarding NH_3 emissions from road traffic. Unlike in the Ashdown Forest case study, the modelling described above is not informed by any verification against roadside NH_3 measurements. There is also uncertainty regarding whether traffic-NH_3 will increase, or reduce, in the future. In particular, the assumed reductions in traffic-related NO_x emissions might be achieved in different ways; which might cause traffic-NH_3 to either reduce, or to increase. Figure 3.4-12 thus shows the results from sensitivity tests of different assumptions for current and future traffic-NH_3 emissions. They have been carried out following the approach described in Section 1.4.2.

Figure 3.4-12 shows that using a more precautionary set of emissions factors for traffic-NH_3 results in the maximum predicted roadside NH_3 concentration in the 2017 baseline increasing to 4.0 $\mu g\ m^{-3}$ (from 2.6 $\mu g\ m^{-3}$ in Figure 3.4-8). By 2030, expected changes to the BAU fleet increase the predicted maximum concentration to c.a. 4.5 $\mu g\ m^{-3}$ (shown by the red and white bars in Figure 3.4-12). Comparing the red and orange bars, with the red and yellow bars, in Figure 3.4-12 then shows the effect of different technological solutions to achieving the assumed reductions in traffic-NO_x emissions (i.e. 10% reduction beyond NAPCP and 10% + 15% reduction beyond NAPCP). If these reductions are achieved by electrification of the vehicle fleet then NH_3 concentrations will fall, but if they are achieved by swapping diesel cars for petrol cars then concentrations will increase. In any event, maximum NH_3 concentrations are predicted to remain above 3.5 $\mu g\ m^{-3}$ in all scenarios.

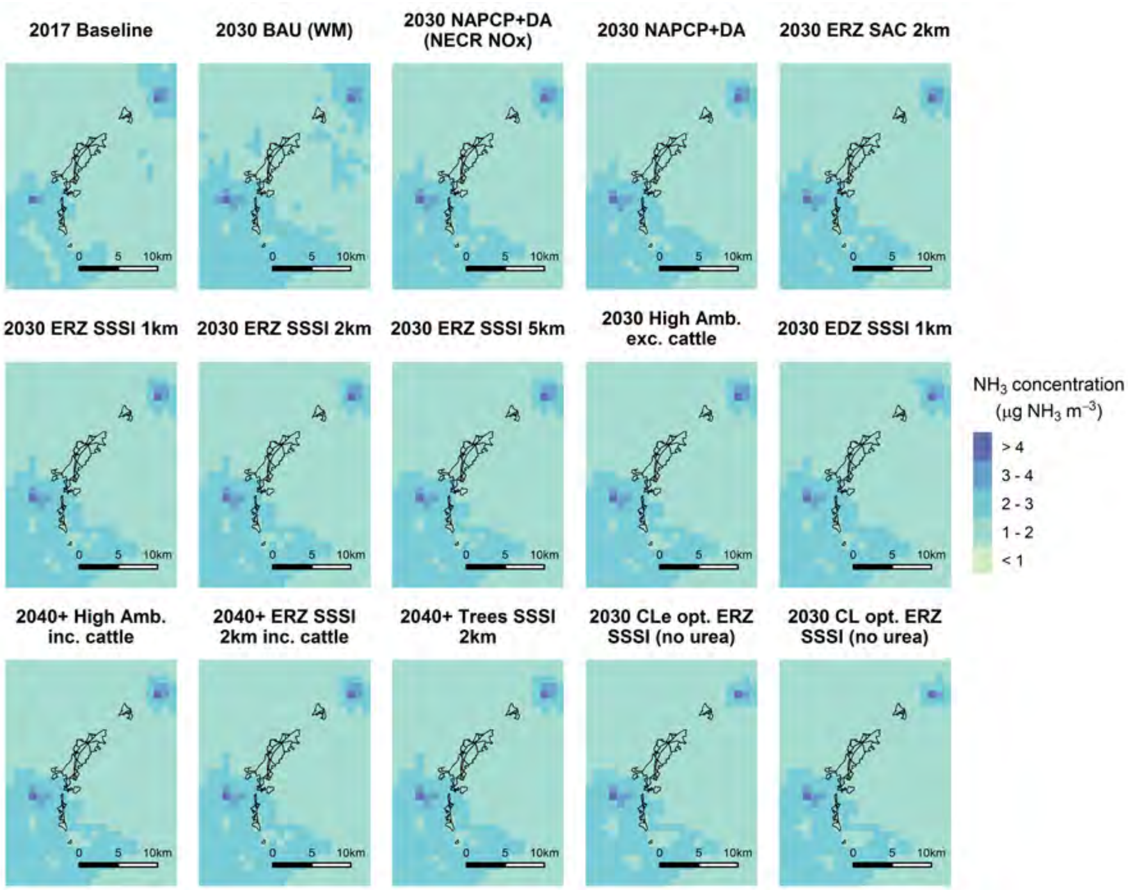


Figure 3.4-6. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Epping Forest SSSI and surrounding area.

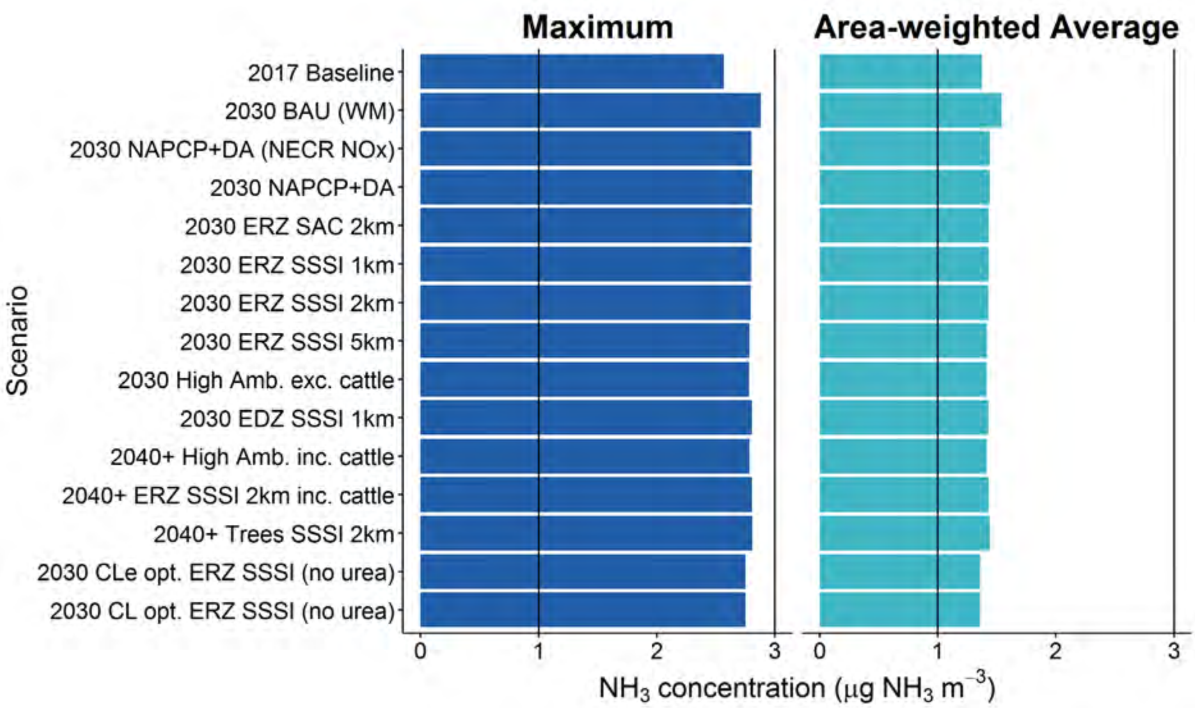


Figure 3.4-7. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Epping Forest SSSI.

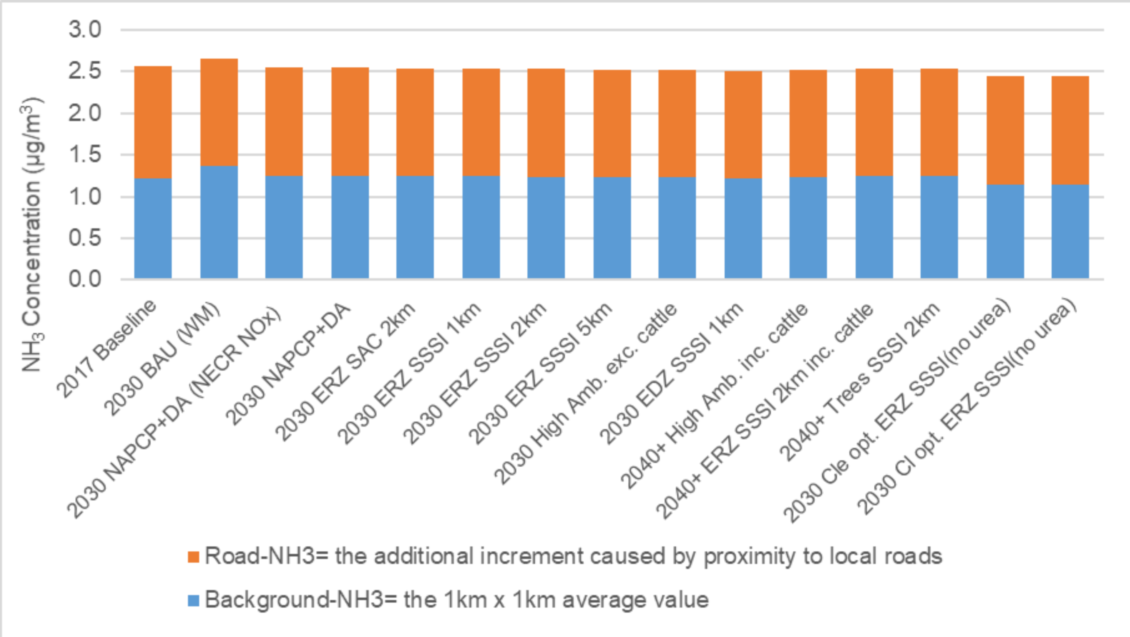


Figure 3.4-8. Maximum predicted roadside NH_3 concentrations in Epping Forest in each scenario (Transect P).

Table 9. Maximum predicted NH_3 by transect and scenario (see Figure 3.4-2 for a map of transect locations).

Transect ID	2017 Baseline	2030 BAU (WM)	2030 NAPCP+DA (NECR NOx)	2030 NAPCP+DA	2030 ERZ SAC 2km	2030 ERZ SSSI 1km	2030 ERZ SSSI 2km	2030 ERZ SSSI 5km	2030 High Amb. exc. cattle	2030 EDZ SSSI 1km	2040+ High Amb. inc. cattle	2040+ ERZ SSSI 2km inc. cattle	2040+ Trees SSSI 2km	2030 Cle opt. ERZ SSSI(no urea)	2030 Cl opt. ERZ SSSI(no urea)
A1	1.7	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6
A2	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
B1	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.7	1.7
B2	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5
C1	2.6	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.6	2.6	2.5	2.5
C2	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8
D1	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.8	1.8	1.7	1.7
D2	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7
E1	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8
E2	2.3	2.4	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.3	2.3	2.2	2.2
H	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5	1.5
I	1.1	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1
J	1.4	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.5	1.4	1.5	1.5	1.4	1.4
K	1.7	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6	1.6
L	1.2	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2
M	1.3	1.5	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.4	1.3	1.3
N	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3
O	2.0	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9
P	2.6	2.7	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4

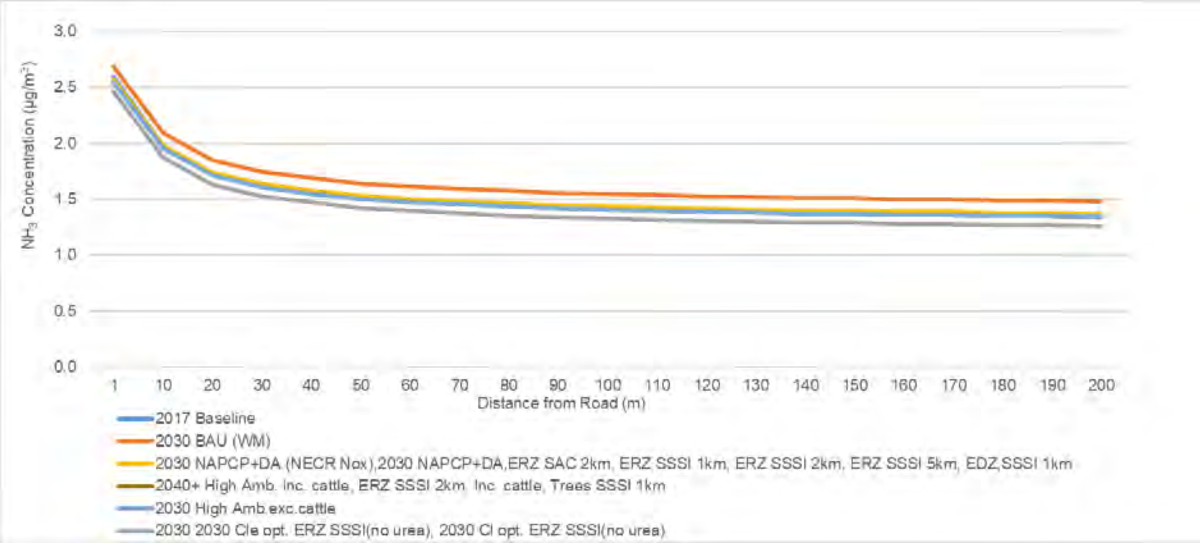


Figure 3.4-9. Transect C1 NH_3 Concentrations with Distance from Road for each scenario.

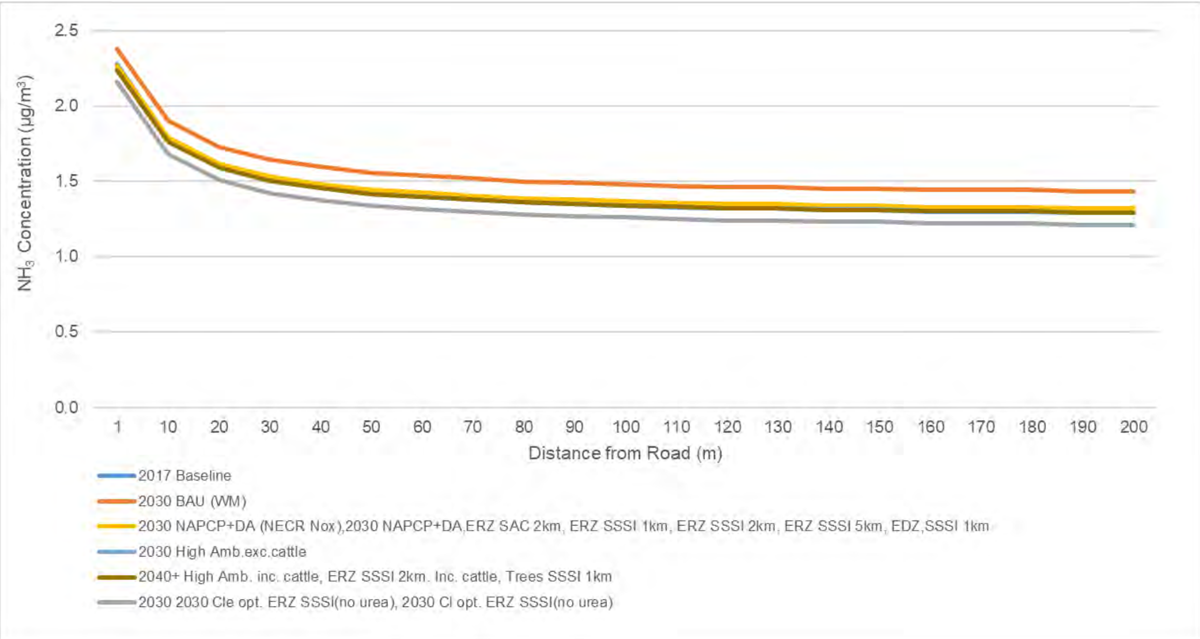


Figure 3.4-10. Transect E2 NH_3 Concentrations with Distance from Road for each scenario.

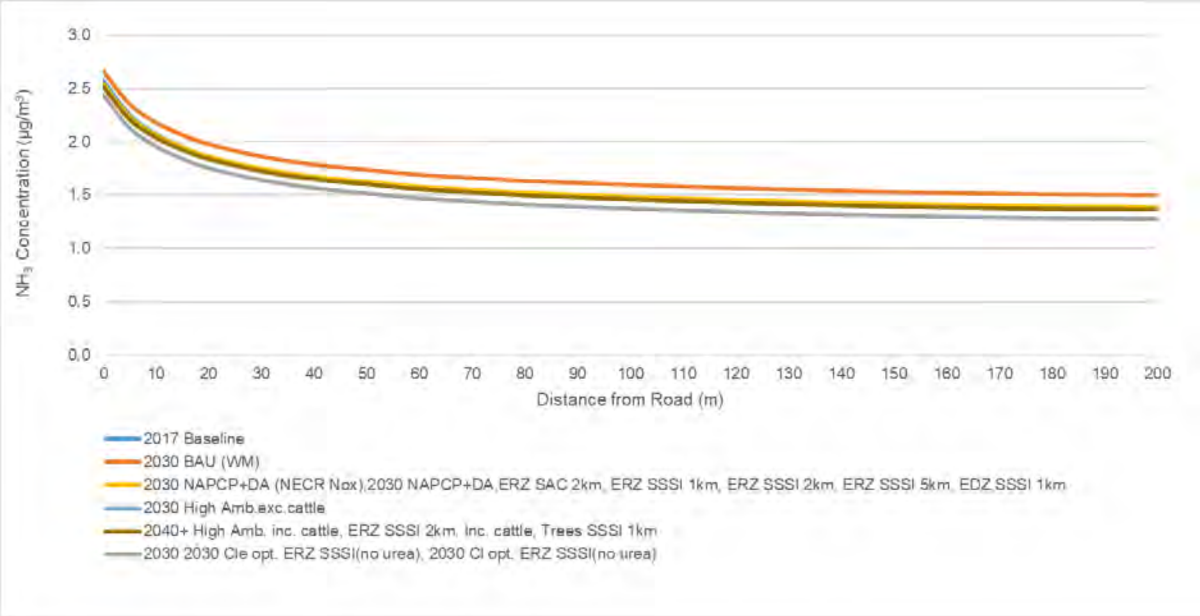


Figure 3.4-11. Transect P NH_3 Concentrations with Distance from Road for each scenario.

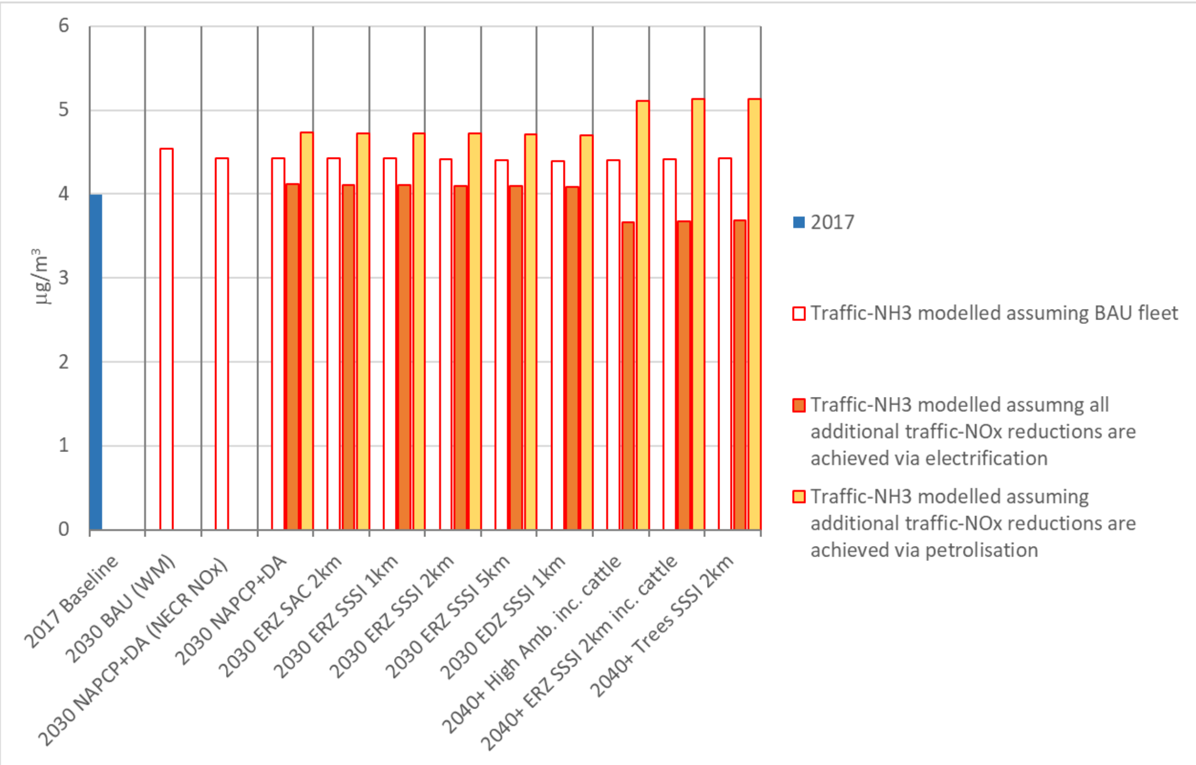


Figure 3.4-12. Effect of Alternative Assumptions for NH_3 Emissions from Local Traffic on Maximum Predicted Annual Mean NH_3 Concentrations (selected scenarios).

3.4.7 NO_2 and NO_x concentration

Figures 3.4-13 and 3.4-14 show the 1 km x 1 km average annual mean NO_2 concentrations predicted by FRAME. While annual mean NO_2 concentrations cannot be directly compared with the 30 μg m^{-3} critical level for NO_x, they provide an indication of the likely NO_x

concentrations ($NO_x = NO_2 + NO$). Figure 3.4-13 shows the 1 km^2 average values in 5 μg m^{-3} increments, showing annual mean NO_2 concentrations mostly greater than 15 μg m^{-3} in 2017. The future-year scenarios show concentrations mostly <10 μg m^{-3}, with higher values toward the south of the study area (i.e. closer to the centre of London).

Figure 3.4-15 shows the maximum predicted roadside NO_x concentrations in each scenario. Unlike the roadside predictions for NH_3 used in this case study, the NO_x concentrations have been verified against roadside measurements. The maximum predicted concentration in 2017 is 152 μg m^{-3}, falling to 62 μg m^{-3} in the 2030 BAU scenario, and to 53 μg m^{-3} in the 2030 NAPCP scenario. As with the Ashdown Forest case study, a large reduction in roadside NO_x concentrations is predicted between 2017 and 2030, reflecting expectations regarding renewal of the vehicle fleet and the effectiveness of the European type-approval emissions standards. The lowest predicted maximum concentration in any scenario is 41 μg m^{-3}, which is still well above the critical level. Maximum predicted NO_x concentrations along the other modelled transects are set out in Table 2.

Figures 3.4-16 to 3.4-18 show the predicted NO_x concentrations along the length of the three transects with the highest predicted concentrations. They show the well-established rate at which annual mean concentrations of primary pollutants reduce on moving away from roads which typically follows a power-law relationship (Laxen & Marner 2008). Large reductions are predicted between the 2017 baseline and 2030 BAU scenarios, after which further reductions are relatively small.

It is clear from these results that the 30 μg m^{-3} critical level is not predicted to be exceeded across the entire length of all transects in every scenario. The evidence base for this threshold is limited, and evidence for interactions with ozone in terms of effects of ecosystems is even more limited and needs to be reviewed and updated. It is therefore difficult to say how appropriate this level is for a particular site. Because the Epping Forest modelling has been carried out for selected transects, rather than across the entire site, it is not possible to determine the total area over which the critical level will be exceeded. It is, however, possible to determine the point along each transect at which the critical level is achieved. Table 3 thus shows how far away from the nearest road the critical level exceedances are predicted to extend in each scenario. This is based on a linear interpolation between the transect points modelled by Epping Forest District Council. For example, for Transect C1, the critical level is predicted to be exceeded over the entire 200 m transect (and beyond) in 2017, falling to 7 m in 2040. At the worst-case transect (transect P) the 2040+ scenarios bring 26 m of the SAC into compliance compared to 2030 BAU (from 35 m down to 9 m).

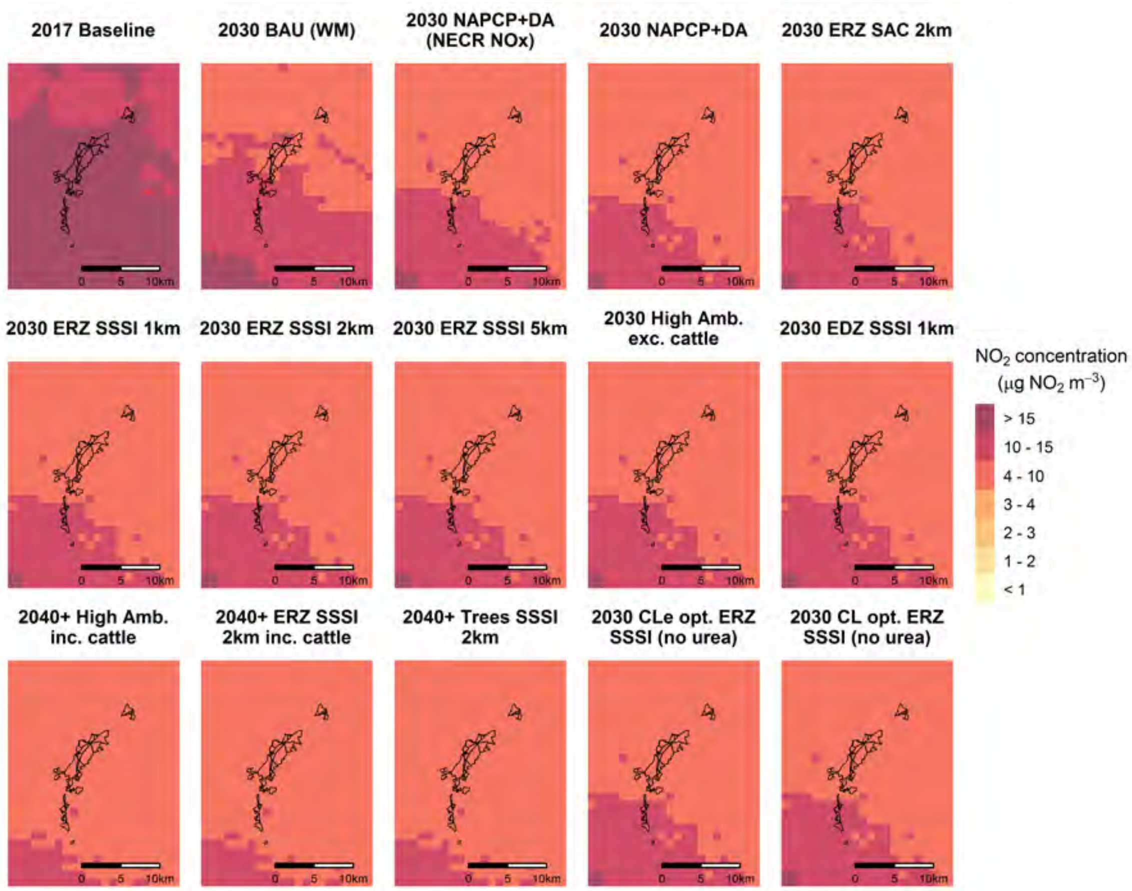


Figure 3.4-13. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Epping Forest SSSI and surrounding area.

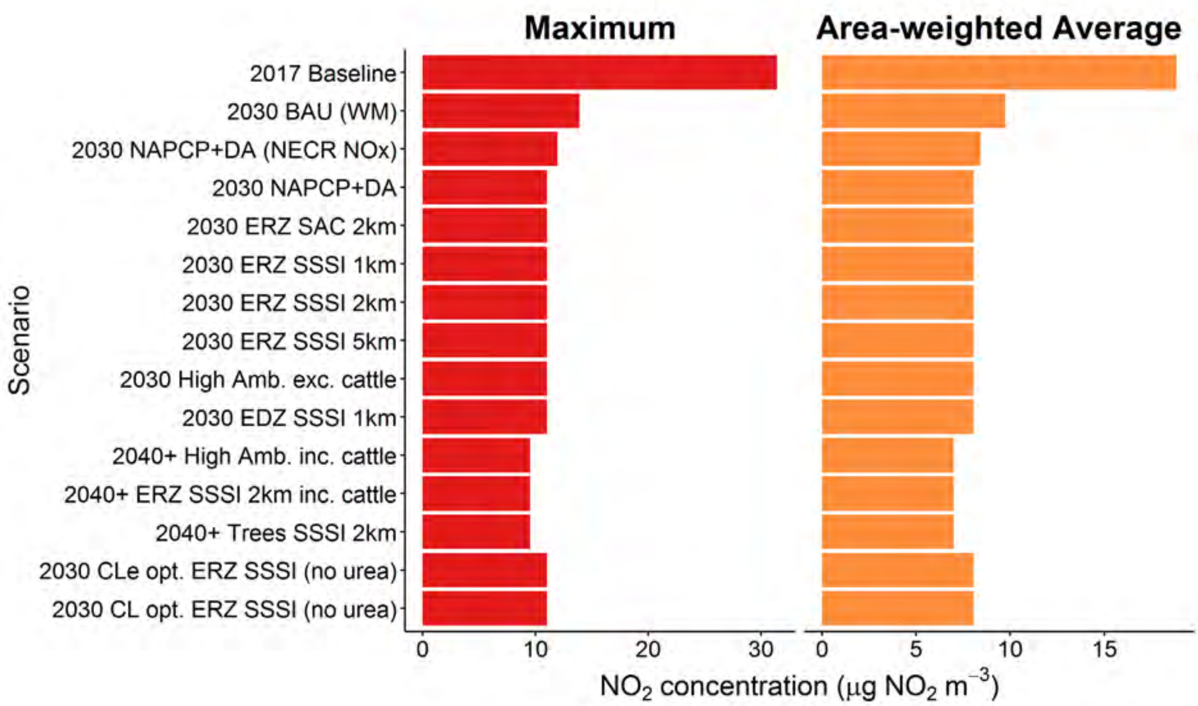


Figure 3.4-14. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Epping Forest SSSI.

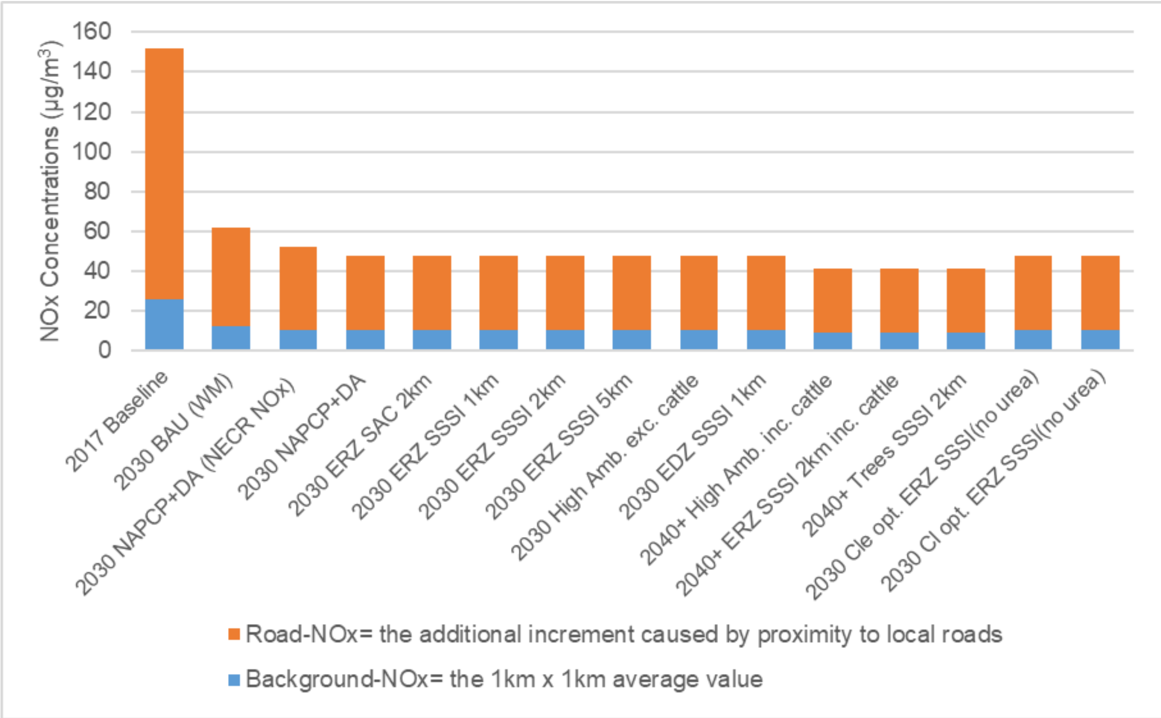


Figure 3.4-15. Maximum predicted annual mean NO_x concentration in Epping Forest in each scenario.

Table 10. Maximum predicted annual mean NO_x ($\mu g\ m^{-3}$) by transect and scenario[a].

Transect ID	2017 Baseline	2030 BAU (WM)	2030 NAPCP+DA (NECR NOx)	2030 NAPCP+DA	2030 ERZ SAC 2km	2030 ERZ SSSI 1km	2030 ERZ SSSI 2km	2030 ERZ SSSI 5km	2030 High Amb. exc. cattle	2030 EDZ SSSI 1km	2040+ High Amb. inc. cattle	2040+ ERZ SSSI 2km inc. cattle	2040+ Trees SSSI 2km	2030 Cle opt. ERZ SSSI(no urea)	2030 Cl opt. ERZ SSSI(no urea)
A1	**63.3**	27.0	23.1	21.5	21.5	21.5	21.5	21.5	21.5	21.5	18.5	18.5	18.5	21.5	21.5
A2	**70.8**	**30.1**	25.7	23.8	23.8	23.8	23.8	23.8	23.8	23.8	20.4	20.4	20.4	23.8	23.8
B1	**79.0**	**33.1**	28.3	26.2	26.2	26.2	26.2	26.2	26.2	26.2	22.5	22.5	22.5	26.2	26.2
B2	**55.6**	24.1	20.7	19.2	19.2	19.2	19.2	19.2	19.2	19.2	16.6	16.6	16.6	19.2	19.2
C1	147	**59.9**	**51.0**	**46.7**	**46.7**	**46.7**	**46.7**	**46.7**	**46.7**	**46.7**	**39.9**	**39.9**	**39.9**	**46.7**	**46.7**
C2	**84.5**	**35.6**	**30.4**	28.0	28.0	28.0	28.0	28.0	28.0	28.0	24.0	24.0	24.0	28.0	28.0
D1	**64.8**	27.5	23.6	22.0	22.0	22.0	22.0	22.0	22.0	22.0	18.9	18.9	18.9	22.0	22.0
D2	**71.2**	**30.4**	26.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	20.6	20.6	20.6	24.0	24.0
E1	**81.5**	**34.1**	29.2	27.0	27.0	27.0	27.0	27.0	27.0	27.0	23.2	23.2	23.2	27.0	27.0
E2	112	**46.0**	**39.2**	**36.0**	**36.0**	**36.0**	**36.0**	**36.0**	**36.0**	**36.0**	**30.8**	**30.8**	**30.8**	**36.0**	**36.0**
H	**55.6**	24.5	21.0	19.6	19.6	19.6	19.6	19.6	19.6	19.6	16.9	16.9	16.9	19.6	19.6

I	**99.0**	**41.5**	**35.5**	**32.6**	**32.6**	**32.6**	**32.6**	**32.6**	**32.6**	**32.6**	27.9	27.9	27.9	**32.6**	**32.6**
J	**35.8**	17.1	14.7	13.8	13.8	13.8	13.8	13.8	13.8	13.8	12.0	12.0	12.0	13.8	13.8
K	**53.5**	24.0	20.6	19.1	19.1	19.1	19.1	19.1	19.1	19.1	16.5	16.5	16.5	19.1	19.1
L	**30.4**	14.7	12.7	12.0	12.0	12.0	12.0	12.0	12.0	12.0	10.5	10.5	10.5	12.0	12.0
M	27.2	13.8	11.9	11.4	11.4	11.4	11.4	11.4	11.4	11.4	9.9	9.9	9.9	11.4	11.4
N	**31.9**	15.6	13.5	12.8	12.8	12.8	12.8	12.8	12.8	12.8	11.1	11.1	11.1	12.8	12.8
O	**99.6**	**40.9**	**34.9**	**32.2**	**32.2**	**32.2**	**32.2**	**32.2**	**32.2**	**32.2**	27.6	27.6	27.6	**32.2**	**32.2**
P	**152**	**61.6**	**52.5**	**48.0**	**48.0**	**48.0**	**48.0**	**48.0**	**48.0**	**48.0**	**41.0**	**41.0**	**41.0**	**48.0**	**48.0**

[a] Exceedances of the critical level are highlighted in bold.

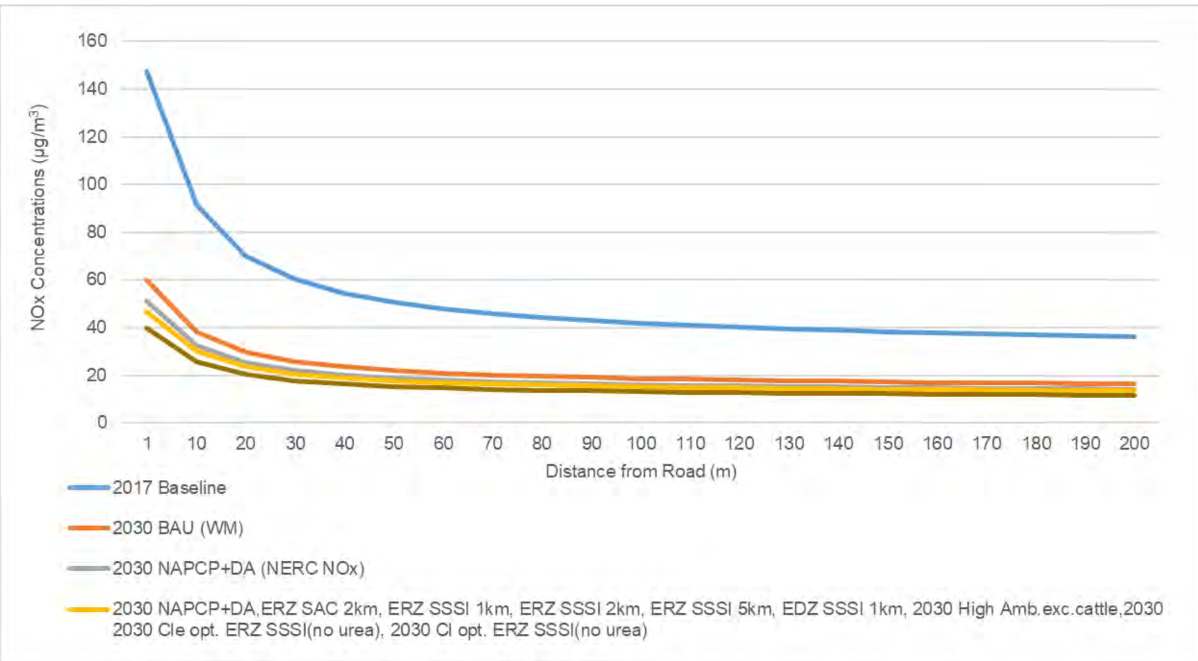


Figure 3.4-16. Transect C1 NOx concentrations with distance from road for each scenario.

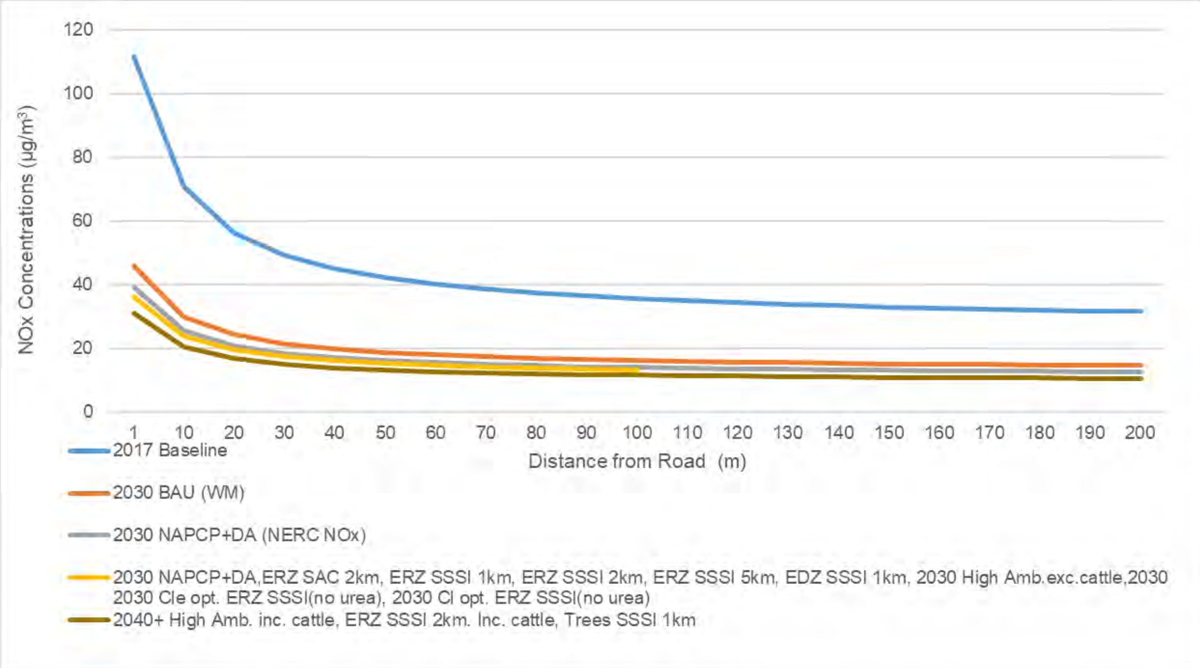


Figure 3.4-17. Transect E2 NO_x concentrations with distance from road per scenario.

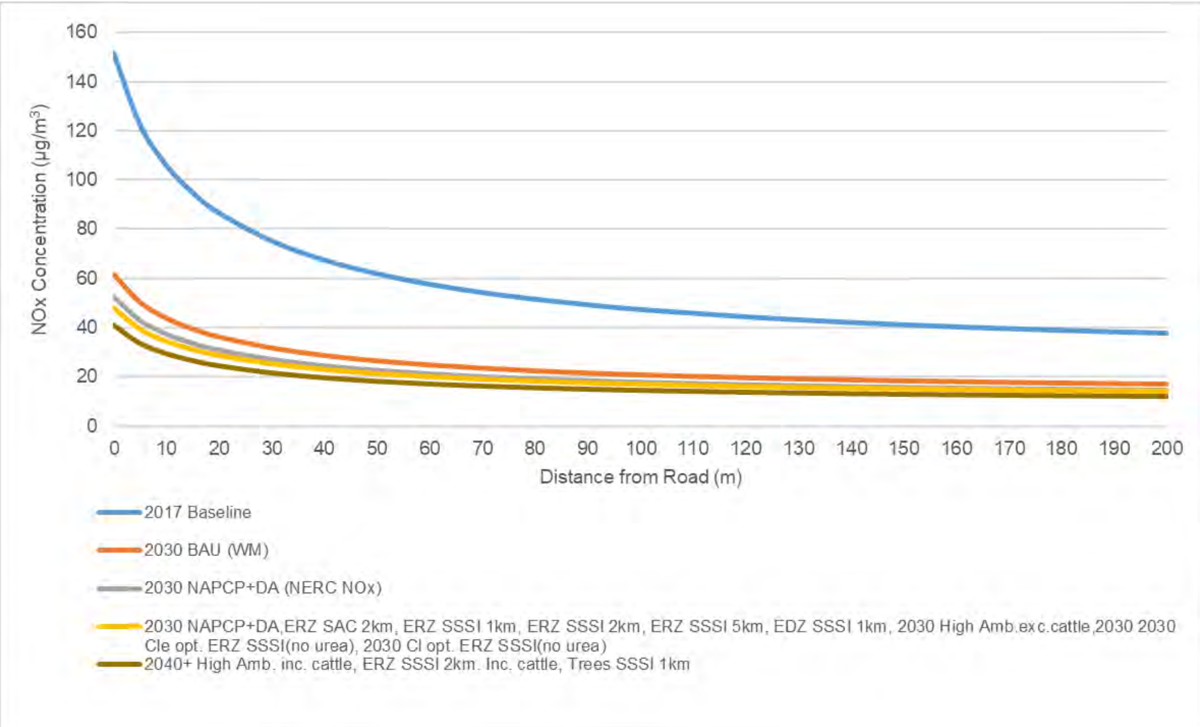


Figure 3.4-18. Transect P NOx concentrations with distance from road for each scenario.

Table 10. Maximum Distance from Road where Critical Level is exceeded[a].

Transect ID	2017 Baseline	2030 BAU (WM)	2030 NAPCP+DA (NECR NOx)	2030 NAPCP+DA	2030 ERZ SAC 2km	2030 ERZ SSSI 1km	2030 ERZ SSSI 2km	2030 ERZ SSSI 5km	2030 High Amb. exc. cattle	2030 EDZ SSSI 1km	2040+ High Amb. inc. cattle	2040+ ERZ SSSI 2km inc. cattle	2040+ Trees SSSI 2km	2030 Cle opt. ERZ SSSI(no urea)	2030 CI opt. ERZ SSSI(no urea)
A1	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A2	129	1	-	-	-	-	-	-	-	-	-	-	-	-	-
B1	200	3	-	-	-	-	-	-	-	-	-	-	-	-	-
B2	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C1	200	19	13	9	9	9	9	9	9	9	7	7	7	9	9
C2	79	4	1	-	-	-	-	-	-	-	-	-	-	-	-
D1	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D2	200	1	-	-	-	-	-	-	-	-	-	-	-	-	-
E1	200	4	-	-	-	-	-	-	-	-	-	-	-	-	-
E2	200	9	7	5	5	5	5	5	5	5	1	1	1	5	5
H	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I	123	8	4	2	2	2	2	2	2	2	-	-	-	2	2
J	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	200	8	3	1	1	1	1	1	1	1	-	-	-	1	1
P	200	35	22	17	17	17	17	17	17	17	9	9	9	17	17

[a] Where the distance from road is 200m, this is the maximum distance from road considered by the Council. The actual distance from the road where exceedances are predicted may therefore be greater than this.

3.4.8 N deposition

Figures 3.4-19 and 3.4-20 show the 1 km x 1 km average N deposition fluxes to woodland features predicted by FRAME. When considered on a 1 km^2 average basis, the maximum predicted N deposition flux to woodland in 2017 is c.a. 40 kg N ha^{-1} yr^{-1}. Under the 2030 BAU scenario, this value falls below 40 kg N ha^{-1} yr^{-1} but remains above 30 kg N ha^{-1} yr^{-1} in all future-year scenarios. The highest 1 km x 1 km average values are all predicted toward the southwest of the study area, which is well away from any of the ecological transects considered in the modelling which underpins this case study.

Figure 3.4-21 shows the maximum predicted roadside N deposition flux in each scenario, focusing on the woodland habitats only. The lower part (in blue) of each bar gives the 1 km^2 value taken from FRAME, and the upper part (in orange) gives the increment caused by proximity to local roads. The maximum predicted deposition flux in 2017 is 53 kg N ha^{-1} yr^{-1}, which like the similar value of 56 kg N ha^{-1} yr^{-1} predicted for Ashdown Forest, occurs to woodland alongside a road. This is predicted to decrease to 44 kg N ha^{-1} yr^{-1} in the 2030 BAU scenario, and to around 40 kg N ha^{-1} yr^{-1} in all of the other future scenarios. When comparing the 2030 NAPCP+DA (NECR NO_x) and 2040+ High Amb.inc.cattle scenarios, N deposition is predicted to reduce by around 2 kg N ha^{-1} yr^{-1}. Maximum predicted N deposition fluxes along the other modelled transects are set out in Table 3, all of which exceed the critical loads in every scenario.

Figures 3.4-22 to 3.4-24 show the predicted N deposition values (to woodland) along the length of the three transects with the highest predicted fluxes. As with the ambient pollutant concentrations which drive them, fluxes are substantially elevated above the 1 km^2 average FRAME values close to the roads, with this local increment declining on moving away from the road. The lower bounds of the critical loads are predicted to be exceeded over the full length (200m) of all of the modelled transects in all of the scenarios.

As explained in Section 1.4.2 there is significant uncertainty regarding NH_3 emissions from road traffic. Unlike in the Ashdown Forest case study, the modelling described above is not informed by any verification against roadside NH_3 measurements. There is also uncertainty regarding whether traffic-NH_3 will increase, or reduce, in the future. In particular, the assumed reductions in traffic-related NO_x emissions might be achieved in different ways which might cause traffic-NH_3 to either reduce, or to increase. Figure 3.4-25 thus shows the results from sensitivity tests of different assumptions for current and future traffic-NH_3 emissions. They were carried out following the approach described in Section 1.4.2. Figure 3.4-25 shows that using a more precautionary set of emissions factors for traffic-NH_3 (taking account of verification against measurements) results in the maximum predicted N deposition flux in 2017 increasing to 65 kg N ha^{-1} yr^{-1} (from 53 kg N ha^{-1} yr^{-1} in Figure 3.4-21). Assuming the 2030 BAU vehicle fleet, maximum deposition fluxes to Epping Forest will fall to between 53 and 55 kg N ha^{-1} yr^{-1} in each scenario (shown by the red and white bars in Figure 3.4-25). Comparing the red and orange bars with the red and yellow bars in Figure 3.4-25 then shows the effect of different technological solutions to achieving the assumed reductions in traffic-NO_x emissions (i.e. 10% reduction beyond NAPCP and 10% + 15% further reduction beyond NAPCP). If these reductions are achieved by electrification of the vehicle fleet then N deposition will decrease, but if they are achieved by swapping diesel cars for petrol cars then deposition fluxes are predicted to increase. Maximum deposition fluxes will, however, remain lower than those in 2017 in each future scenario regardless of how the additional NO_x reductions are achieved; albeit that only an 8% reduction in total N deposition is predicted between 2017 and 2040+ when using the more pessimistic assumptions.

Figure 3.4-19. N deposition (to woodland features) received by Epping Forest SSSI and surrounding area.

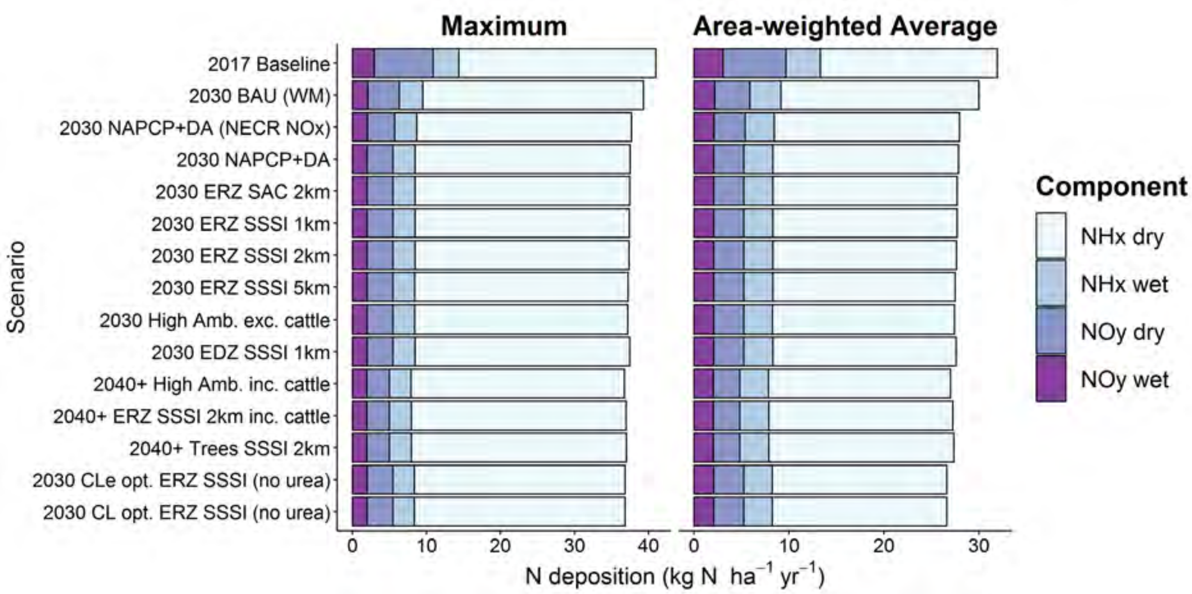


Figure 3.4-20. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Epping Forest SSSI.

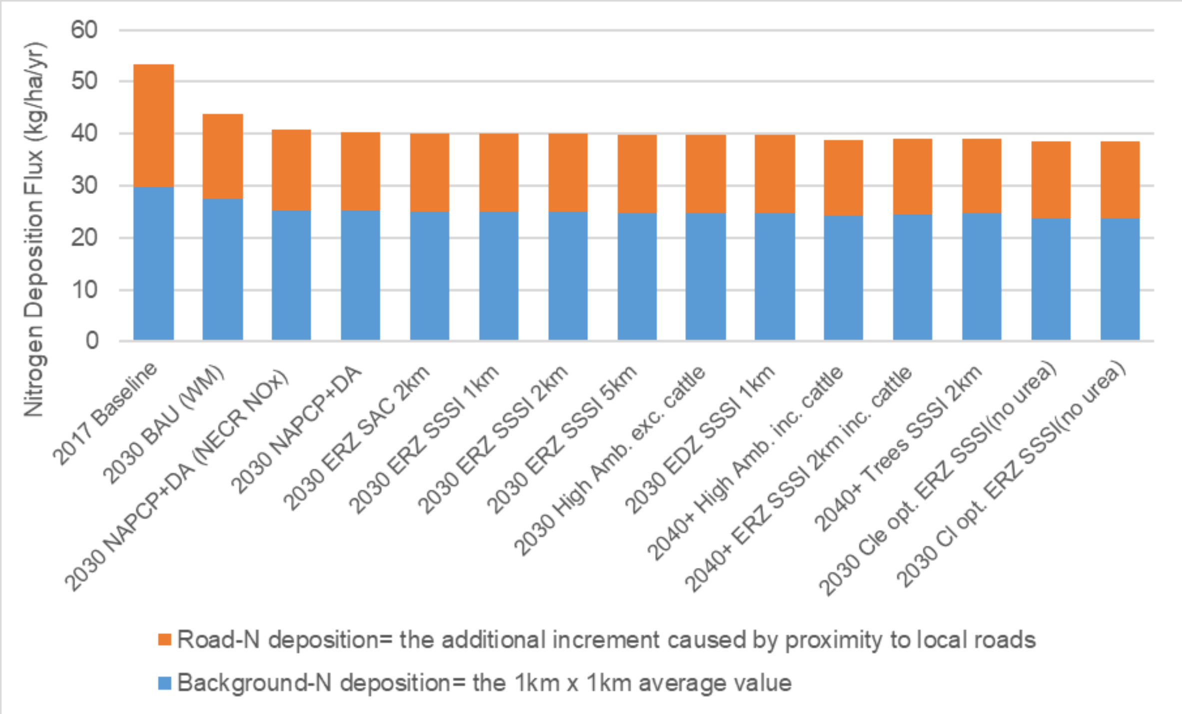


Figure 3.4-21. Maximum predicted N deposition in Epping Forest in each scenario.

Table 12. Maximum predicted deposition by transect and scenario (kg N ha^{-1} yr^{-1}).

Transect ID	2017 Baseline	2030 BAU (WM)	2030 NAPCP+DA (NECR NOx)	2030 NAPCP+DA	2030 ERZ SAC 2km	2030 ERZ SSSI 1km	2030 ERZ SSSI 2km	2030 ERZ SSSI 5km	2030 High Amb. exc. cattle	2030 EDZ SSSI 1km	2040+ High Amb. inc. cattle	2040+ ERZ SSSI 2km inc. cattle	2040+ Trees SSSI 2km	2030 Cle opt. ERZ SSSI(no urea)	2030 Cl opt. ERZ SSSI(no urea)
A1	38.2	33.0	30.5	30.2	30.1	30.1	30.0	29.9	29.8	29.8	29.2	29.4	29.6	28.7	28.7
A2	41.4	35.7	33.2	32.9	32.8	32.8	32.7	32.5	32.4	32.7	31.8	32.1	32.2	31.6	31.6
B1	40.5	34.3	31.7	31.4	31.3	31.3	31.2	31.1	30.9	31.0	30.3	30.5	30.6	29.9	29.9
B2	37.7	33.0	30.6	30.4	30.3	30.3	30.2	30.1	30.0	30.2	29.4	29.6	29.7	29.1	29.1
C1	53.3	43.7	40.8	40.2	40.1	40.1	40.0	39.9	39.8	39.8	38.8	39.0	39.1	38.7	38.7
C2	42.7	36.1	33.6	33.3	33.1	33.1	33.1	32.9	32.8	33.1	32.1	32.3	32.5	32.1	32.1
D1	38.9	33.6	31.1	30.8	30.7	30.7	30.6	30.5	30.4	30.4	29.8	30.0	30.1	29.3	29.3
D2	40.7	34.8	32.5	32.2	32.0	32.0	31.9	31.8	31.7	32.0	31.0	31.3	31.4	31.0	31.0
E1	41.9	35.5	32.9	32.6	32.5	32.5	32.4	32.3	32.2	32.2	31.5	31.7	31.8	31.1	31.1
E2	47.7	39.8	37.0	36.6	36.4	36.4	36.3	36.2	36.1	36.1	35.3	35.5	35.6	35.0	35.0
H	37.8	33.0	30.7	30.5	30.3	30.3	30.2	30.1	30.0	30.2	29.4	29.6	29.8	29.2	29.2

I	**38.9**	**31.8**	**29.3**	**28.9**	**28.7**	**28.7**	**28.6**	**28.5**	**28.4**	**28.6**	**27.6**	**27.8**	**27.9**	**27.6**	**27.6**
J	**33.6**	**30.6**	**28.5**	**28.4**	**28.1**	**28.1**	**28.0**	**27.9**	**27.8**	**28.1**	**27.3**	**27.6**	**27.8**	**27.1**	**27.1**
K	**37.7**	**33.3**	**31.2**	**30.9**	**30.7**	**30.7**	**30.6**	**30.5**	**30.4**	**30.7**	**29.8**	**30.0**	**30.2**	**29.6**	**29.7**
L	**31.8**	**29.0**	**26.9**	**26.8**	**26.6**	**26.6**	**26.6**	**26.4**	**26.3**	**26.5**	**25.9**	**26.1**	**26.2**	**25.5**	**25.5**
M	**31.0**	**28.9**	**26.7**	**26.6**	**26.4**	**26.4**	**26.3**	**26.2**	**26.1**	**26.0**	**25.7**	**25.9**	**26.1**	**24.9**	**24.9**
N	**32.2**	**29.7**	**27.4**	**27.2**	**27.1**	**27.1**	**27.0**	**26.9**	**26.7**	**26.6**	**26.3**	**26.6**	**26.7**	**25.5**	**25.6**
O	**43.8**	**36.8**	**34.1**	**33.7**	**33.5**	**33.6**	**33.5**	**33.3**	**33.3**	**33.2**	**32.4**	**32.7**	**32.9**	**32.0**	**32.0**
P	**53.4**	**43.7**	**40.7**	**40.2**	**40.0**	**40.0**	**40.0**	**39.8**	**39.7**	**39.7**	**38.7**	**39.0**	**39.1**	**38.7**	**38.7**

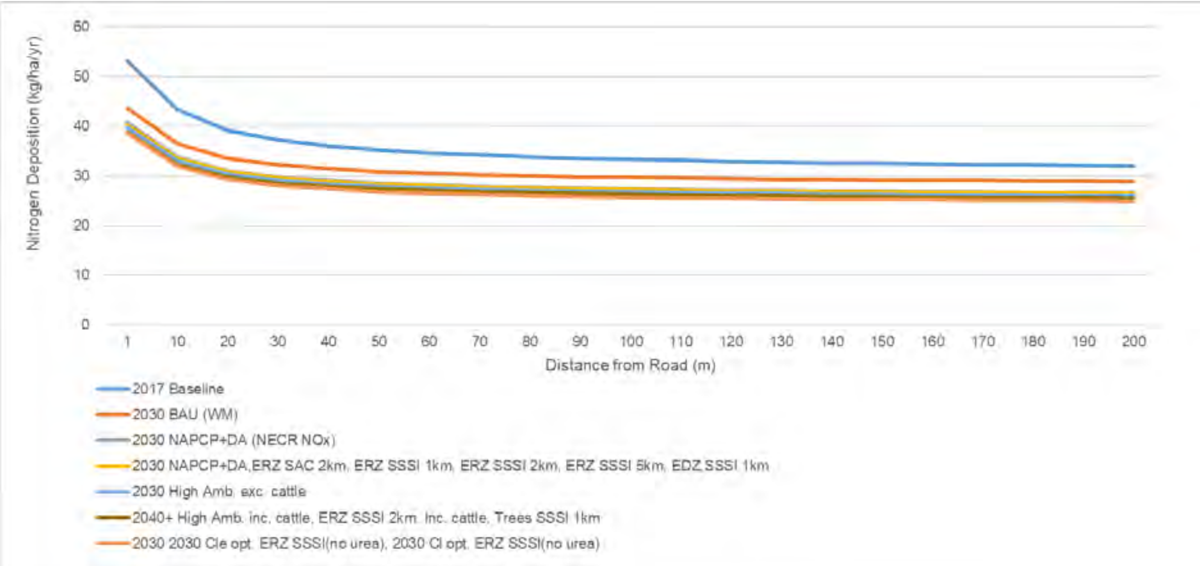


Figure 3.4-22. Transect C1 N deposition with distance from road for each scenario.

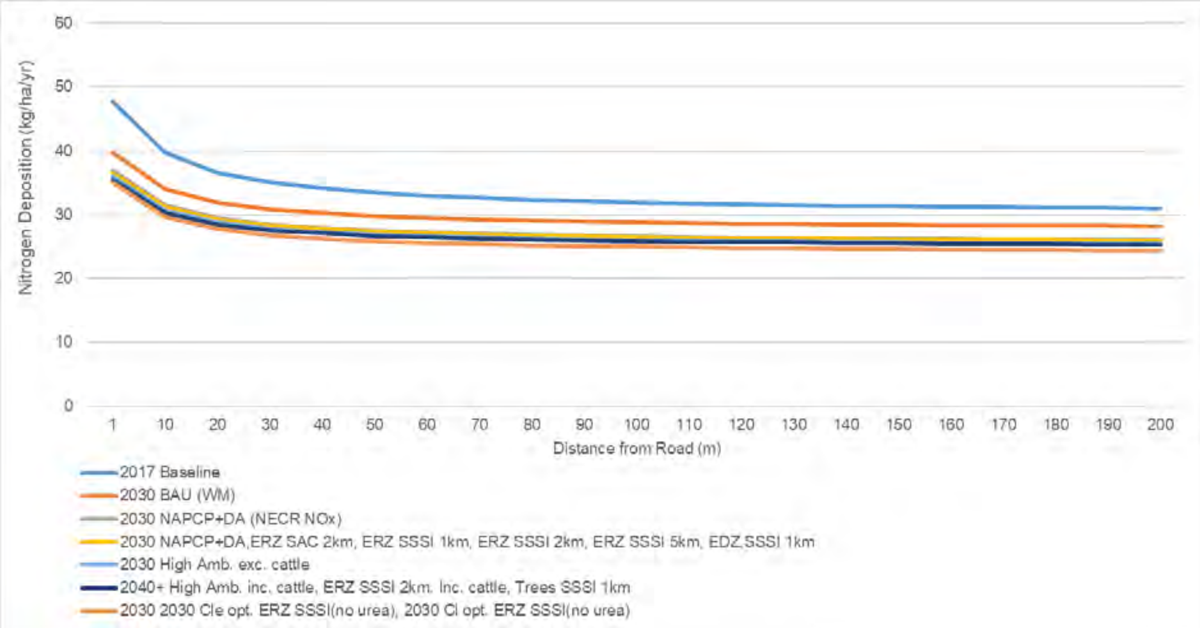


Figure 3.4-23. Transect E2 N deposition with distance from road for each scenario.

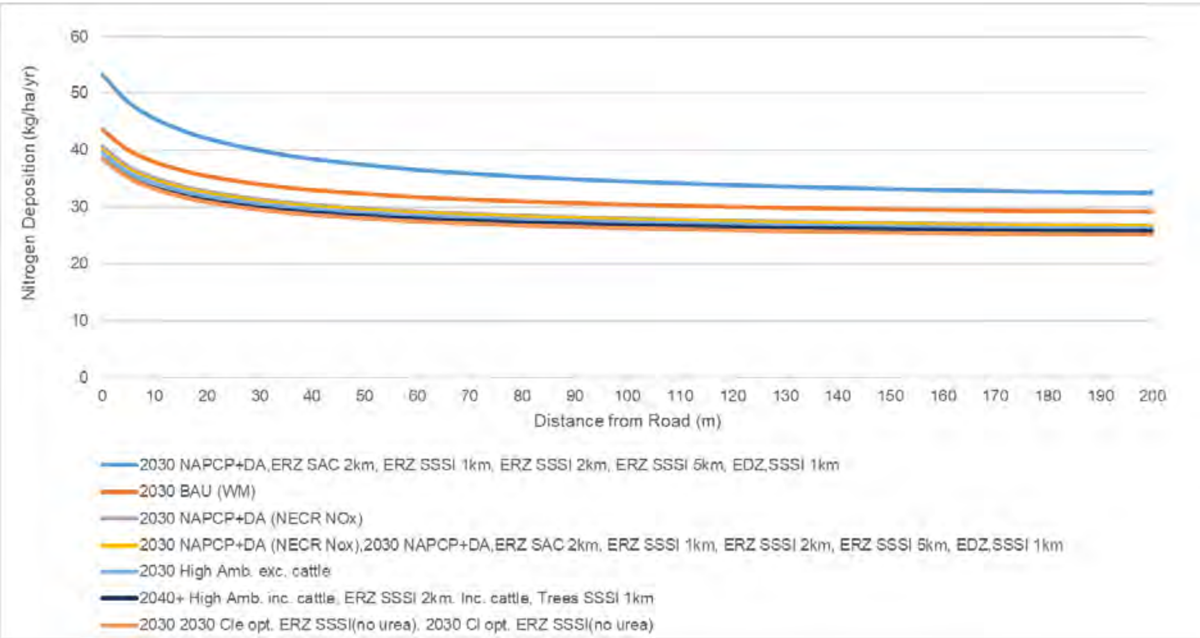


Figure 3.4-24. Transect P N deposition with distance from road for each scenario.

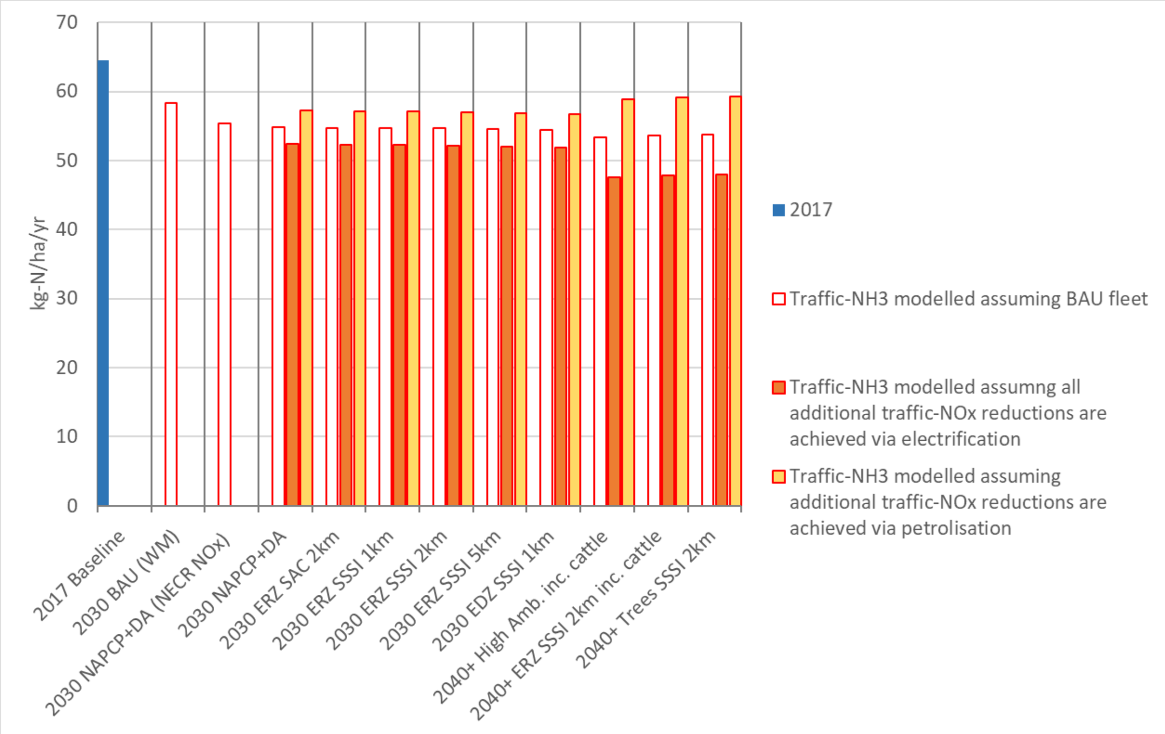


Figure 3.4-25. Effect of alternative assumptions for NH_3 emissions from local traffic on maximum predicted N deposition to woodland (selected scenarios only).

3.4.9 Exceedance of critical levels and loads

The 1 μg m^{-3} critical level for annual mean NH_3 concentrations is predicted to be exceeded across the whole of Epping Forest SSSI in every scenario. Similarly, all the upper and lower bounds of critical loads are predicted to be exceeded in all scenarios. The 30 μg m^{-3} critical level for annual mean NO_x concentrations is predicted to be exceeded in all scenarios at some, but not all, locations within the site.

The degree to which the critical levels and loads are reported as exceeded is a direct function of the spatial resolution used in the model. Disaggregating the data into different spatial resolutions thus gives different conclusions regarding the maximum predicted concentrations and fluxes, and thus the degree to which the critical levels and loads are exceeded. This is a well-understood issue when assessing against air quality standards. The critical levels and critical loads specify temporal averaging criteria (e.g. annual means) but they do not specify spatial averaging criteria (e.g. they are not restricted to only apply to locations which represent a minimum spatial area; instead relating to the presence and sensitivity of habitat features). If location-specific maxima require assessment, then 1 km x 1 km average values will frequently under-predict close to emissions sources (e.g. Laxen & Marner 2008; Marner *et a*l. 2018; Aecom 2019). Statistics regarding exceedances of critical levels or critical loads which are derived from 5 km x 5 km, or 1 km x 1 km resolution modelling are thus specific to that model resolution. Using a finer-resolution model for local-scale assessment will, by definition, give different results unless the site is distant from any concentrated emissions source.

The local-scale modelling predicts NH_3 concentrations of 2.6 μg m^{-3} in the core scenario and as high as 4 μg m^{-3} in 2017 in the sensitivity test (see Figure 3.4-12); potentially increasing to above 5 μg m^{-3} by 2040; although different assumptions for road traffic emissions result in lower NH_3 concentrations. This means that it is very difficult to predict the current scale and future trajectory of roadside NH_3 concentrations in locations where there is no roadside NH_3

monitoring. Maximum NO_x concentrations are predicted to decrease from 152 $\mu g\ m^{-3}$ in 2017 to 41 $\mu g\ m^{-3}$ by 2040. Maximum N deposition fluxes are predicted to decrease from 53 kg N $ha^{-1}\ yr^{-1}$ in 2017 to 39 kg N $ha^{-1}\ yr^{-1}$ by 2040; although with alternative assumptions for traffic-NH_3 these values change to 64 kg N $ha^{-1}\ yr^{-1}$ and 59 kg N $ha^{-1}\ yr^{-1}$ for 2017 and 2040+ respectively. These maxima do not represent large areas of exceedance.

3.4.10 Local assessment

The key atmospheric N issues are different in different parts of the site. In general, the parts of the site worst-affected by N deposition are close to roads and, in these locations, local road traffic is the single largest contributor to deposition. However, this situation may change at locations within the site that are a greater distance from roads and localised effects have diminished. Well away from roads, where deposition fluxes are much smaller, road traffic makes a much smaller contribution to the total N deposition. Epping Forest is a relatively long and narrow site that is fragmented by numerous roads including many with a high traffic volume and the SAC features may be very close to the roadside. Compared with other equivalent SAC sites the proportion of SAC habitat significantly affected by road traffic emissions is high. However, there may be locations within the Forest that are a sufficient distance from roads where the area-average and area-total N deposition fluxes are not dominated by road traffic; with European long-range transboundary import, English non-transport and non-agricultural emissions, and English livestock emissions also being an important consideration.

The decreases in emissions predicted between the 2017 baseline, the 2030 BAU, and the 2030 NAPCP scenarios cover a range of sectors, including road transport, and so improvements are predicted over the whole site and at the worst-affected roadside locations. Similarly, the 2040+ scenarios are predicted to decrease emissions from road transport as well as other sectors; meaning that some improvements are predicted to both area-average and area-maximum deposition fluxes (so long as post-2030 NO_x reductions are achieved via fleet electrification). The other targeted measures considered appear to have very limited effects on either the area-average or the area-maximum N deposition fluxes.

The results suggest that the most effective means of reducing N deposition at the worst-affected locations would be to mitigate NO_x and NH_3 emissions from the roads running through Epping Forest.

The 1 km x 1 km average model results agree with the local assessment in that both models predict continued exceedances of the NH_3 critical level and the N deposition critical loads. However, the values predicted through the local assessment are much higher than the spatially-averaged FRAME outputs. This is because increasing the spatial resolution of a model close to an emission source will always reveal higher concentrations and fluxes.

3.4.11 Conclusions

The spatially targeted scenarios considered in this current study relate mostly to agricultural NH_3 sources and are unlikely to provide significant benefits to Epping Forest. Spatial targeting of traffic using individual roads passing through Epping Forest may lead to significant improvements to the worst-affected locations but would be less effective at reducing 1 km x 1 km average fluxes. Any measures targeting traffic emissions should take care to consider emissions of both NO_x and NH_3.

3.5 Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses

The following sections provide background on Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.5.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.5.1 Site map and location within UK

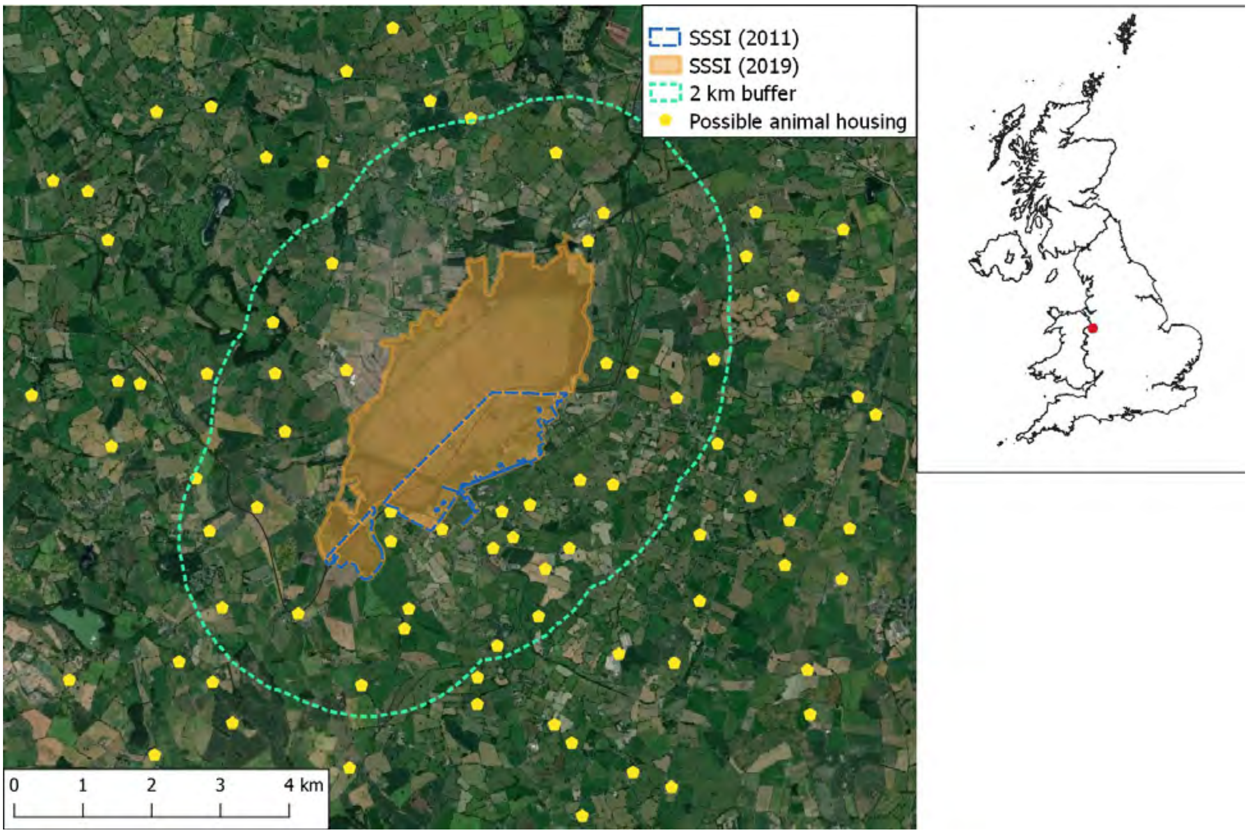


Figure 3.5-1. Site map showing relevant features and boundaries of Fenn's, Whixall, Bettisfield and Cadney Mosses, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.5.2 Designated features

Table 13. Nitrogen sensitive interest features at Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI from the Designated Sites Viewer[2].

Features
Invertebrate assemblage
Scirpus cespitosus - Erica tetralix wet heath
Erica tetralix - Sphagnum papillosum raised and blanket mire
Sphagnum cuspidatum/recurvum (fallax) bog pool community
Eriophorum vaginatum blanket and raised mire
Juncus effusus/acutiflorus - *Galium palustre* rush pasture
Molinia caerulea - *Potentilla erecta* mire

[2]https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1007134&SiteName=Fenn&countyCode=&responsiblePerson=&SeaArea=&IFCAArea= (accessed August 2020).

Eriophorum angustifolium bog pool community Outstanding dragonfly assemblage Rare bird species or feature (wet meadow wader) - Curlew, *Numenius arquata* *Alnus glutinosa - Urtica dioica* woodland

3.5.3 Site characteristics

This large lowland raised bog straddles the English/Welsh border and is amongst the largest and most southerly raised bogs in the UK. The proximity of intensive livestock farming in the wider Shropshire/Cheshire area is of relevance regarding atmospheric N input, especially of NH_3. Local ammonia pressures have been assessed (e.g. Carnell & Dragosits 2015), and the site has been identified as a pilot for Natural England's Shared Nitrogen Action Plans (SNAPs), as part of the Marches Mosses BogLIFE Project funded by the EU. There are long-term atmospheric NH_3 concentration monitoring data available for the site, as part of the UK National Ammonia Monitoring Network (NAMN, Fenn's Moss A (UKA00291: from September 1996[3]). The monitoring location is near the centre of the reserve. Average concentrations over the last 22 years (1997–2018) are 2.56 µg NH_3 m^{-3}, with seasonal variability between 1.7 and 3.9 µg NH_3 (highest during February to April, which is typical in cattle dominated areas, due to manure/slurry spreading in these months). Two additional monitoring locations were re-established in mid-2018 (Marches Mosses BogLIFE project[4]), positioned at the edge of the reserve to capture the highest NH_3 concentrations from surrounding activity and providing a measured gradient towards the centre of the site.

[3] https://uk-air.defra.gov.uk/networks/site-info?uka_id=UKA00291 (accessed April 2020).
[4] https://themeresandmosses.co.uk/2018/12/05/fenns-whixall-nnr-shared-nitrogen-action-plan/ (accessed April 2020).

3.5.4 Agricultural emission density

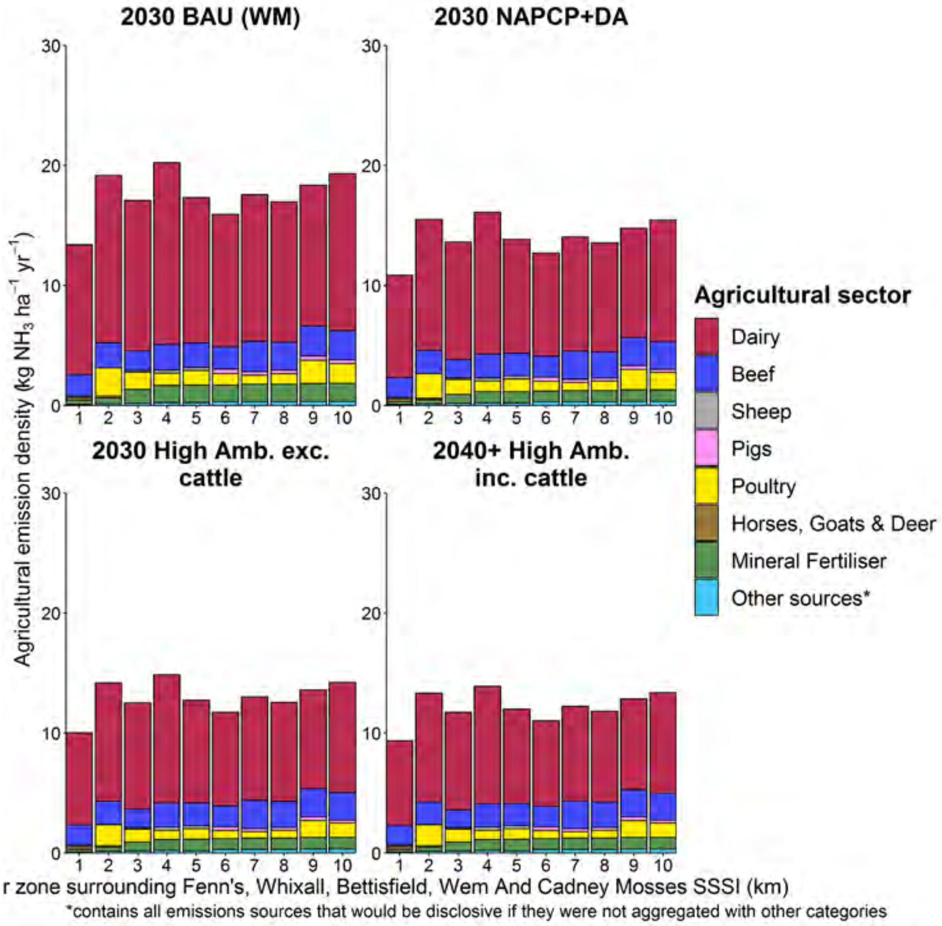


Figure 3.5-2. Average estimated agricultural emission densities in concentric buffer zones surrounding Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.5 Source attribution

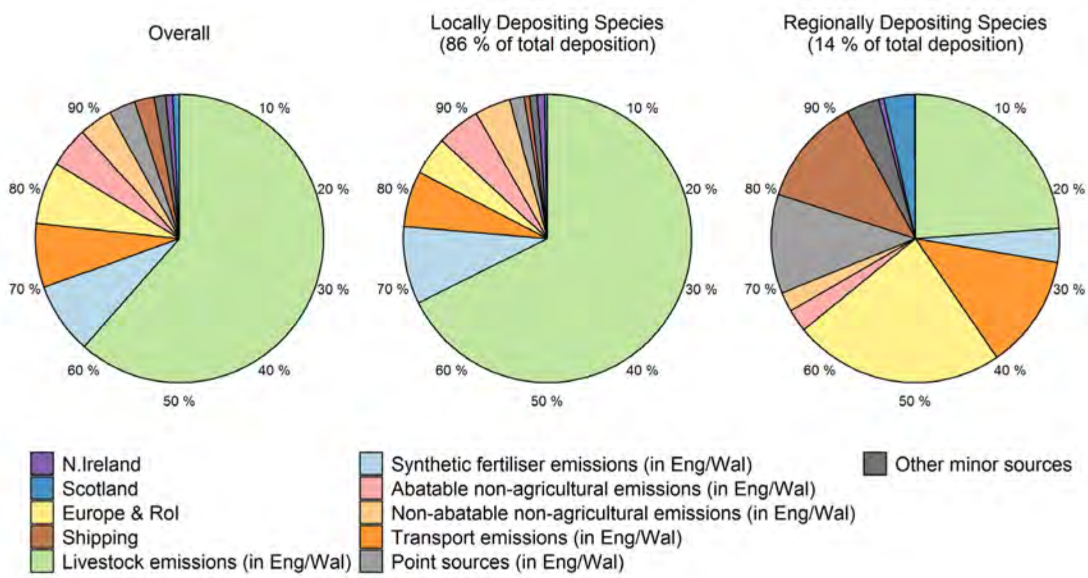


Figure 3.5-3. Relative contribution of emission sources to N deposition (to woodland features) received by Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

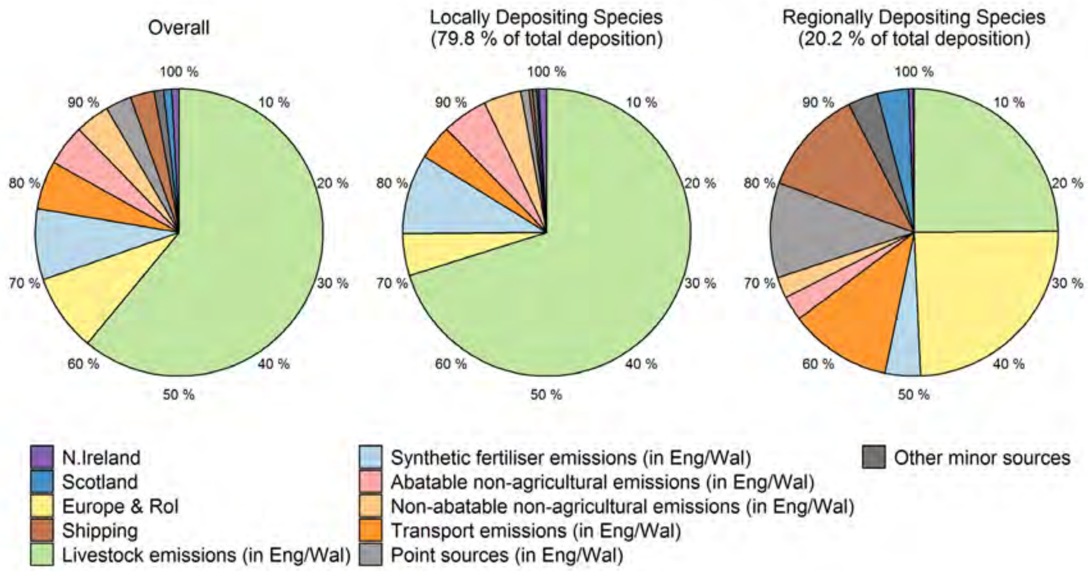


Figure 3.5-4. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.6 NH_3 concentration

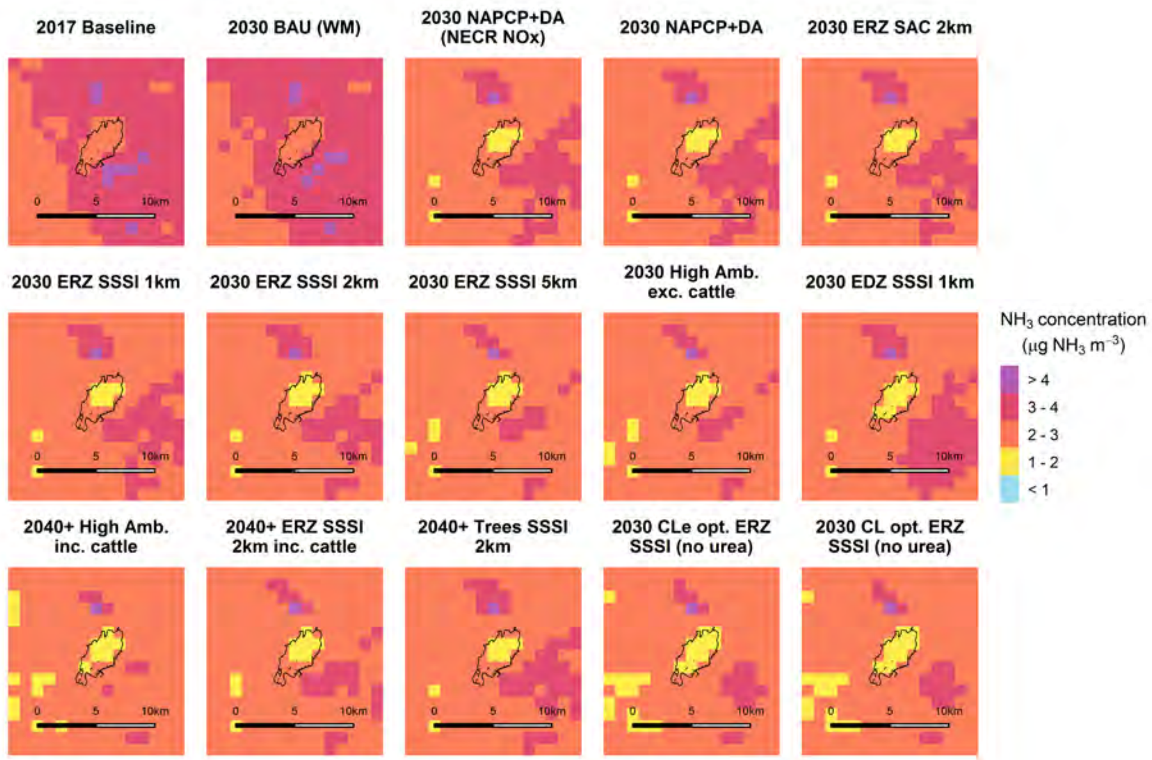


Figure 3.5-5. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI and surrounding area.

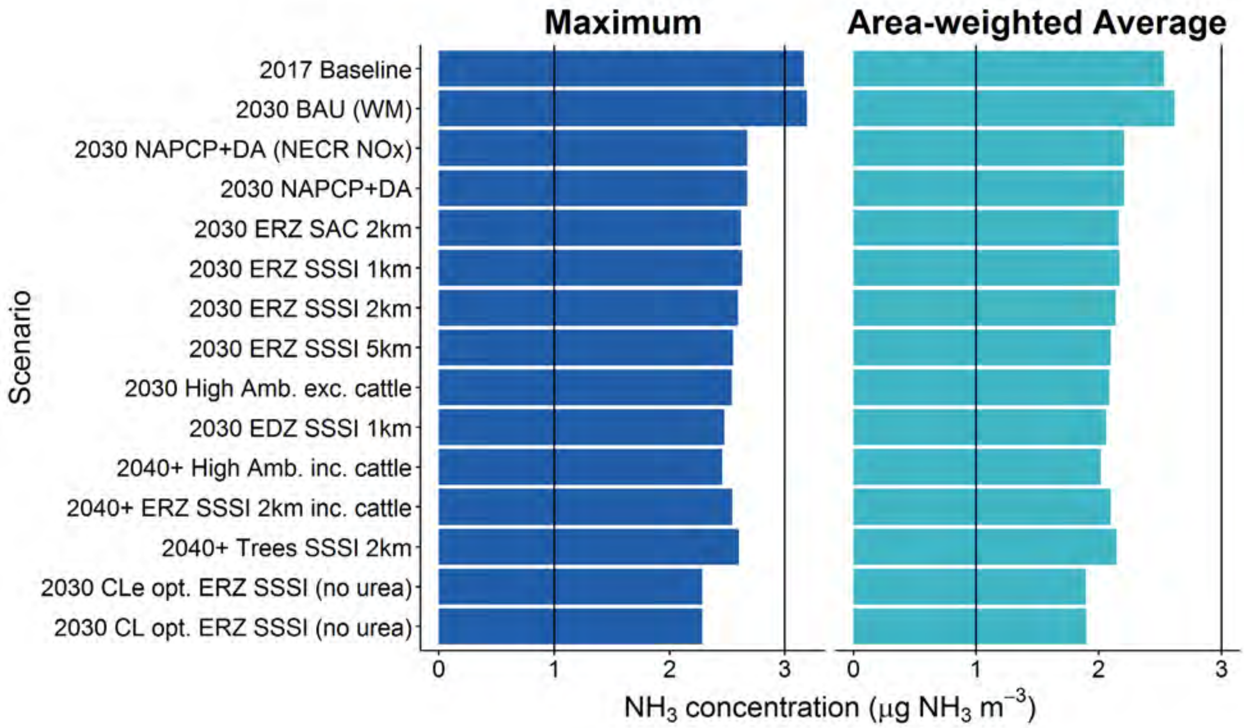


Figure 3.5-6. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.7 NO_2 concentration

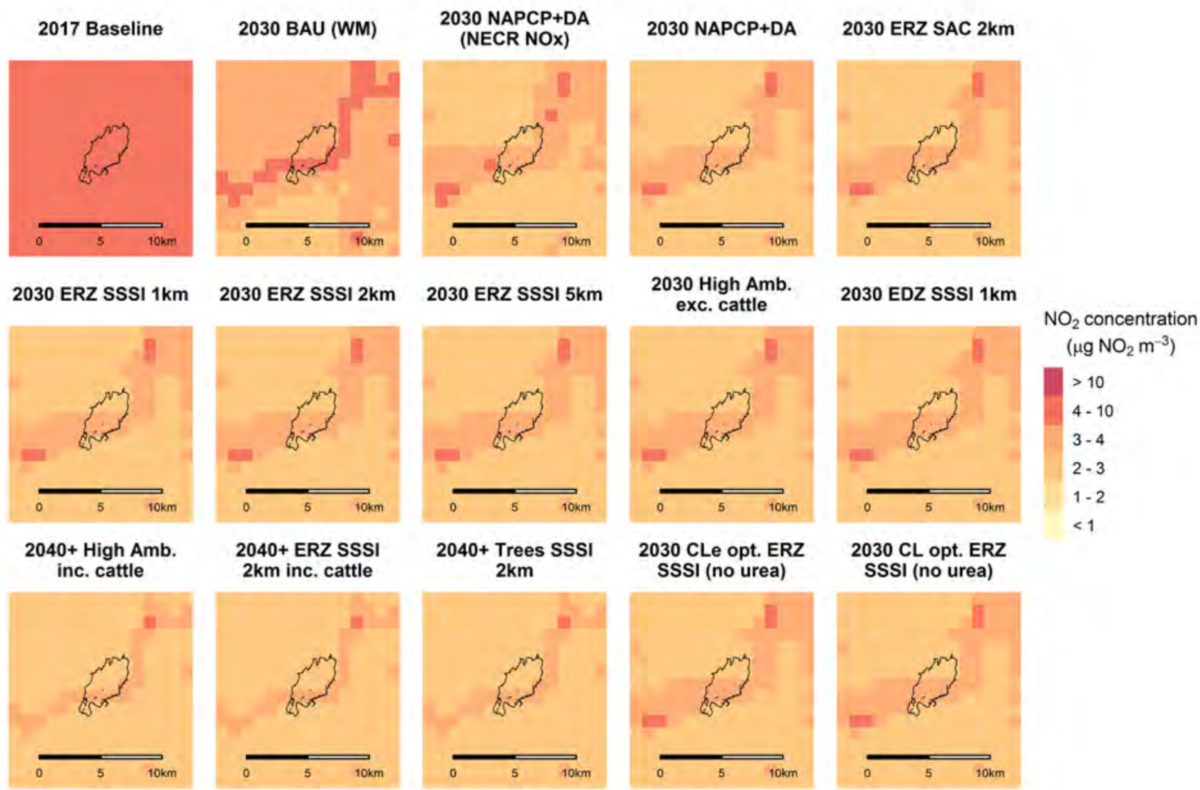


Figure 3.5-7. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI and surrounding area.

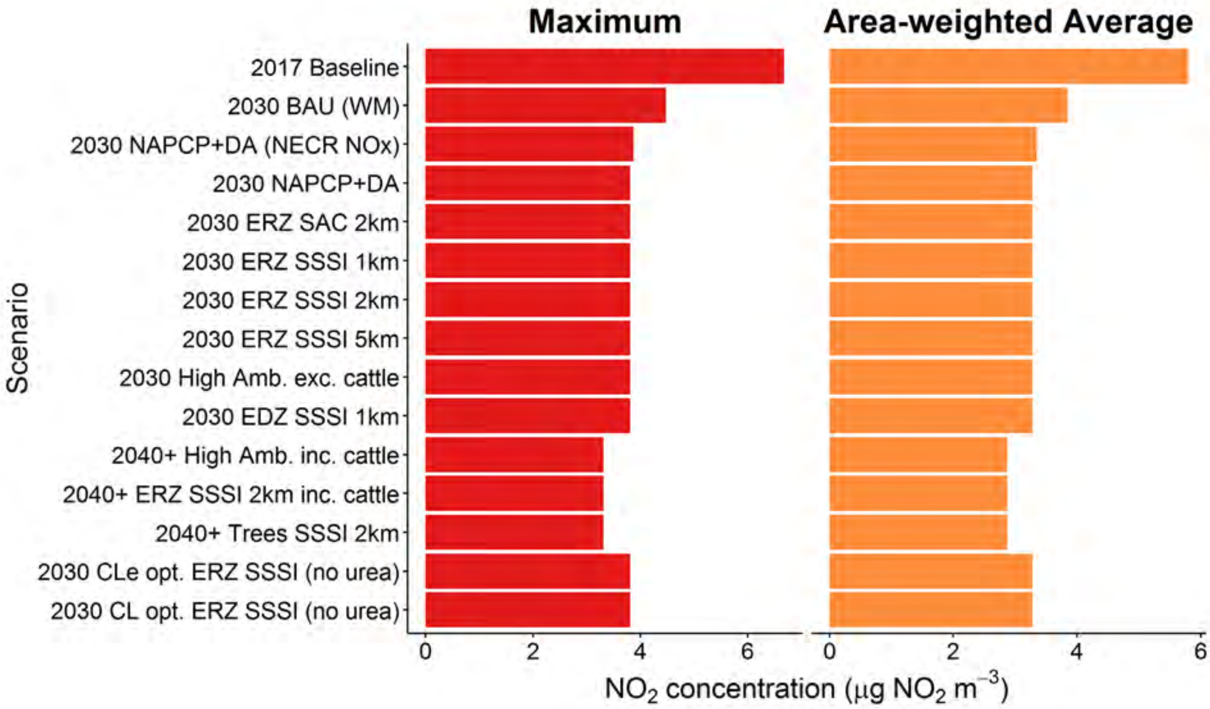


Figure 3.5-8. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.8 N deposition

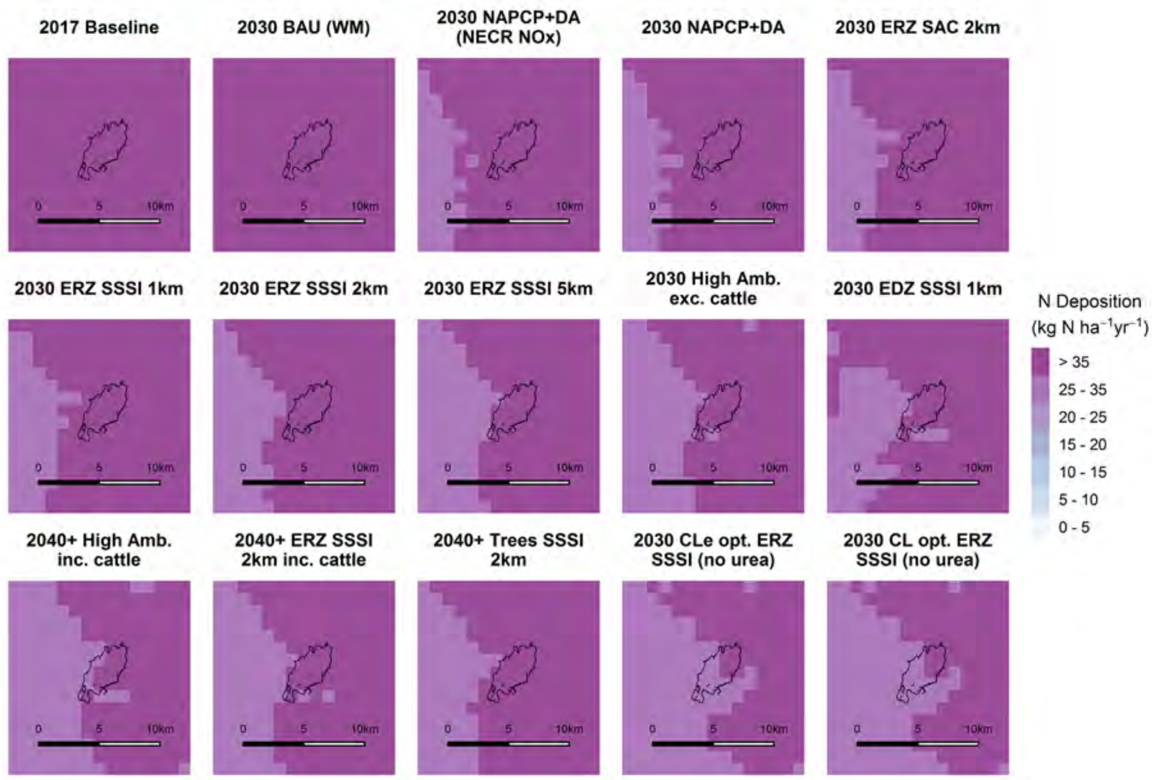


Figure 3.5-9. N deposition (to woodland features) received by Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI and surrounding area.

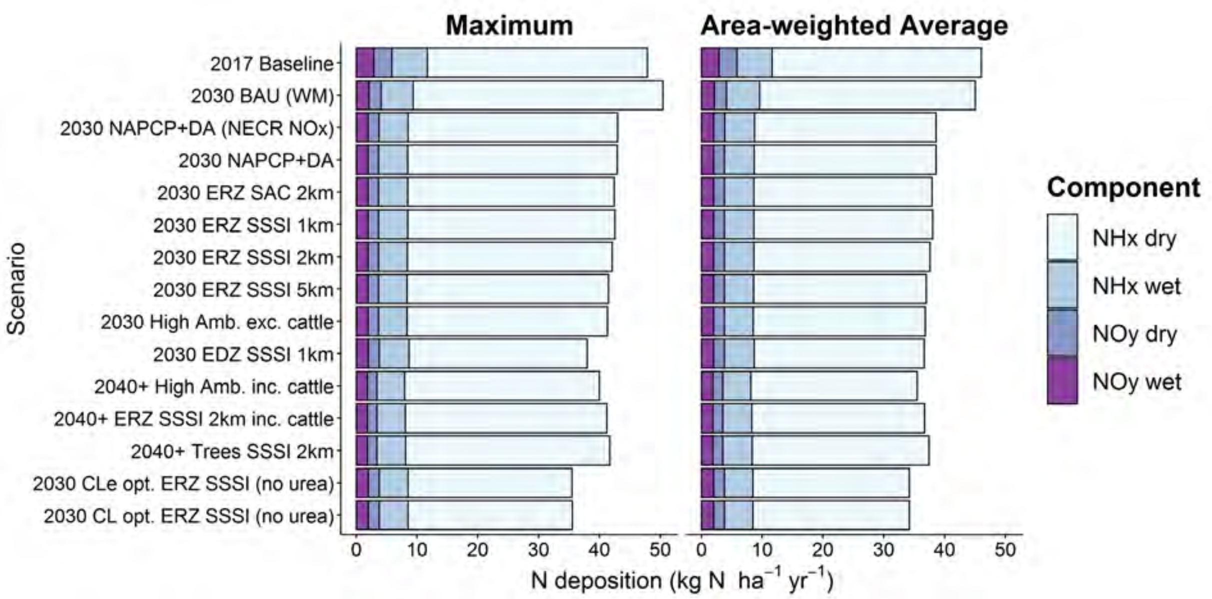


Figure 3.5-10. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

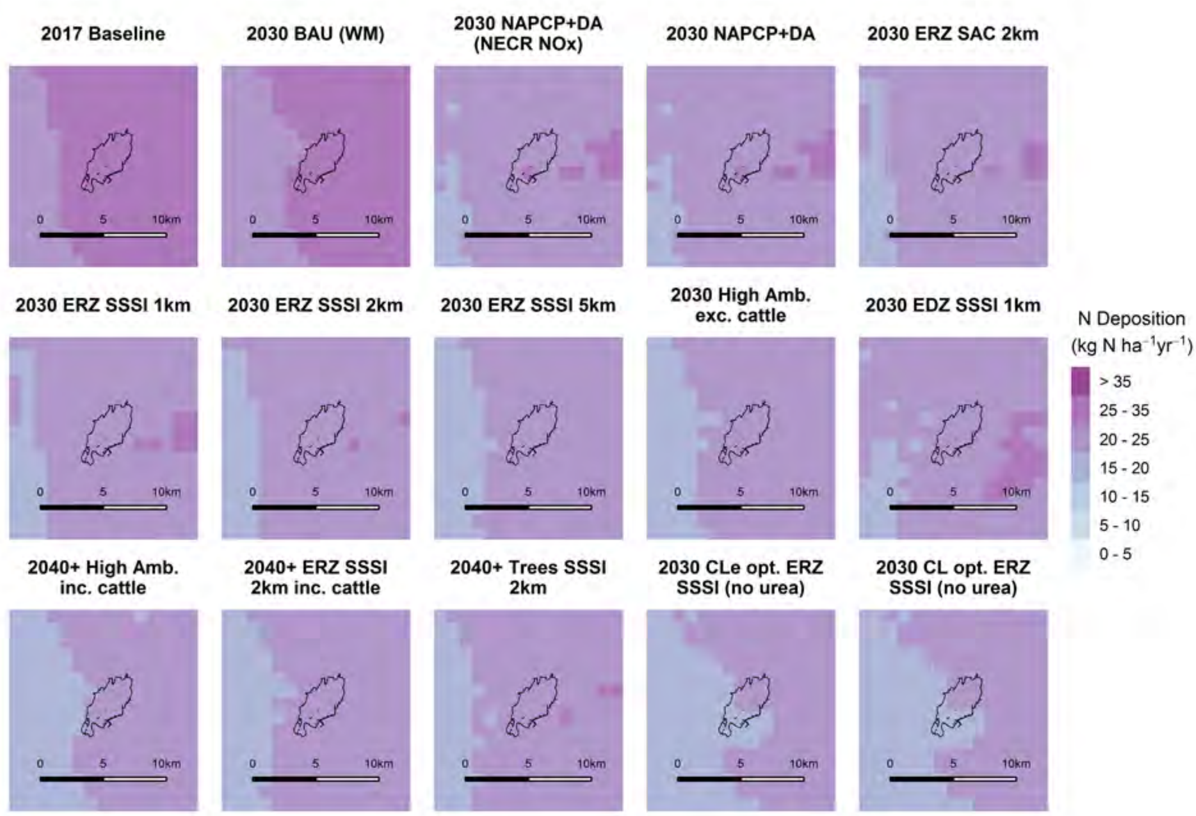


Figure 3.5-11. N deposition (to low-growing semi-natural vegetation) received by Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI and surrounding area.

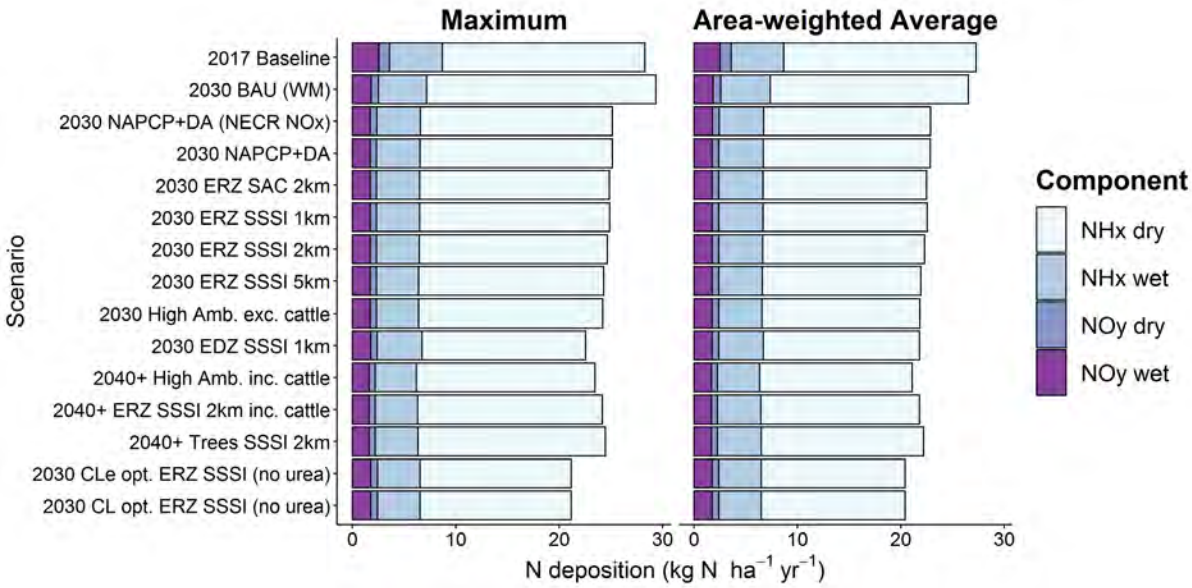


Figure 3.5-12. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.9 Exceedance of critical loads

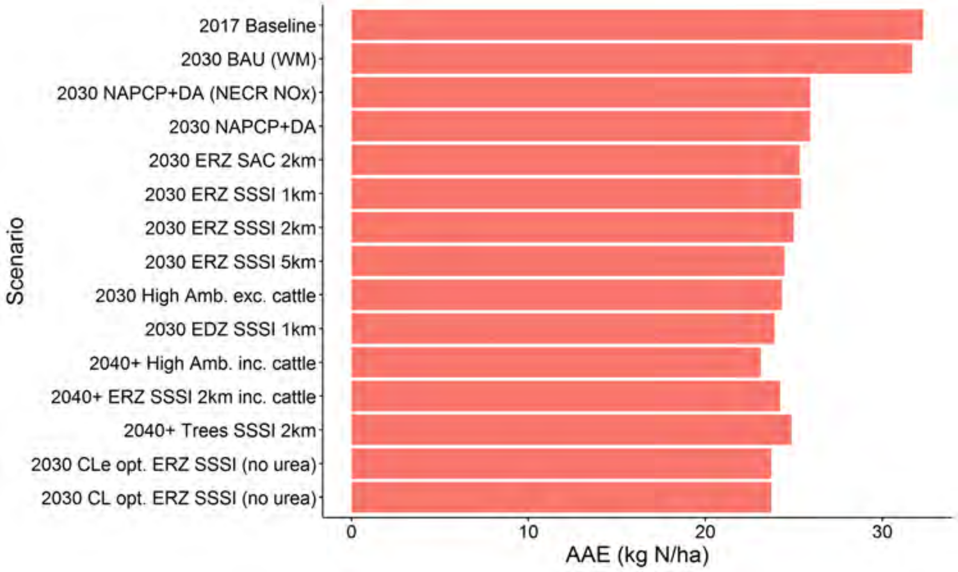


Figure 3.5-13. Exceedance of critical loads by scenario at Fenn's, Whixall, Bettisfield and Cadney Mosses SSSI.

3.5.10 Nitrogen Decision Framework

In the 50% N deposition uncertainty assessment, the NDF score did not change for any of the habitats (Table 14). This is because the critical load range remained exceeded for all three habitat types, even in the more ambitious 2030 CL opt ERZ SSSI (no urea) mitigation scenario. However, when the lower 20% uncertainty assessment was applied, there was some differentiation in the NDF scores. The broadleaved deciduous woodland started at Very High (compared with only High when using 50% uncertainty) and dropped a class (to High) in the most ambitious 2030 CL opt. ERZ SSSI (no urea) scenario, while the dwarf shrub heath dropped a class (from Very High to High) in both the 2030 NAPCP+DA (NECR NOx) baseline and the 2030 CL opt ERZ SSSI (no urea) scenarios compared with 2017 baseline. This improved characterisation of the outcomes reflects the reduced uncertainty around the deposition estimates even though all habitats remain exceeded for critical loads.

Table 14. Nitrogen Decision Framework Factor 1 (Exceedance) score for Fenn's and Whixall.

			N dep (kg/ha/yr)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 50%)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 20%)		
Case study	Habitats	Critical load range (kg N/ha/yr)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)
Fenns & Whixall	Broadleaved deciduous woodland	10-20	46.2	37.8	34.1	High	High	High	Very high	Very high	High
	Lowland raised bog	5-10	27.3	23.4	20.5	Very high	Very high	Very high	Very high	Very high	Very high
	Dwarf shrub heath	10-20				High	High	High	Very high	High	High

3.5.11 Local assessment

This site is located in an area of intense agricultural activity and emissions from agriculture are known to be the key atmospheric N issue at the site. The wider region of Cheshire/Shropshire has very high densities of agricultural emissions, and this is reflected in the dominance of the livestock sector which is estimated to account for >2/3 of local atmospheric N deposition input (source attribution data). Local atmospheric N input, in turn, dominates N deposition to the site overall, with locally depositing N species estimated to contribute ca. 80% or more of the total N deposition, depending on the vegetation type.

The high average NH_3 concentrations (>3 µg NH_3 m^{-3}) estimated in the area surrounding the site in the UK-scale 1 km modelling reflect the density of local agricultural activities, with concentrations on the site estimated between 2-3 µg NH_3 m^{-3}, and small areas exceeding 3 µg NH_3 m^{-3}. The model estimates (Section 3.5.6) are in close agreement with the long-term monitoring in the centre of the bog (Section 3.5.3), away from any immediate sources. Given the close proximity of diffuse and point source agricultural emissions to the boundary of the site, the level of Critical Level exceedance may be underestimated locally for some areas of the site.

All scenarios beyond the less ambitious 2030 BAU (WM) baseline are expected to result in substantially decreased atmospheric N input at the site itself, with the optimised scenarios bringing most of the site area (i.e. average NH_3 concentrations) below 2 µg NH_3 m^{-3}. Given the high density of local agricultural enterprises, with some located relatively close to the site boundary, local gradients of NH_3 concentrations (and related locally enhanced deposition) are expected. However, recent monitoring at the site identified a period of higher concentrations in the centre of the SSSI, indicative of the complexity of fine-scale NH_3 emissions and the importance of local sources. Gradients across the site are diluted over a wider area by the UK-scale 1km grid modelling approach, i.e. within individual 1 km grid squares but also between neighbouring squares. This dilution occurs as the underlying agricultural statistics are spatially distributed across local zones, using land cover as a proxy, due to a) lack of information on individual livestock houses at the national scale and b) disclosive agreements for the use of the dataset in the UK National Agricultural Emission Inventory (NAEI), which require information from at least five holdings to contribute to each data point (i.e. model grid square).

Given the site's location across the border between Wales and England (with the larger part of the SSSI in Wales), close collaboration between NRW and NE would be required for spatial targeting of measures at this site, with the emission source density being higher on the English side of the border (Carnell & Dragosits 2015).

3.5.12 Conclusions

As the site is surrounded by a high density of dairy and beef farming, with some large poultry farms also present in the region, it is expected that spatial targeting of measures would provide substantial benefits to the site. Given the prevalence of cattle farms and poultry manure nearby, switching land spreading techniques to low-emission application and/or creating low/no N-input zones around the site boundary is expected to provide local decreases in N input gradients into the site.

3.6 Dinefwr Estate

The following sections provide background on Dinefwr Estate and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.6.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.6.1 Site map and location within UK

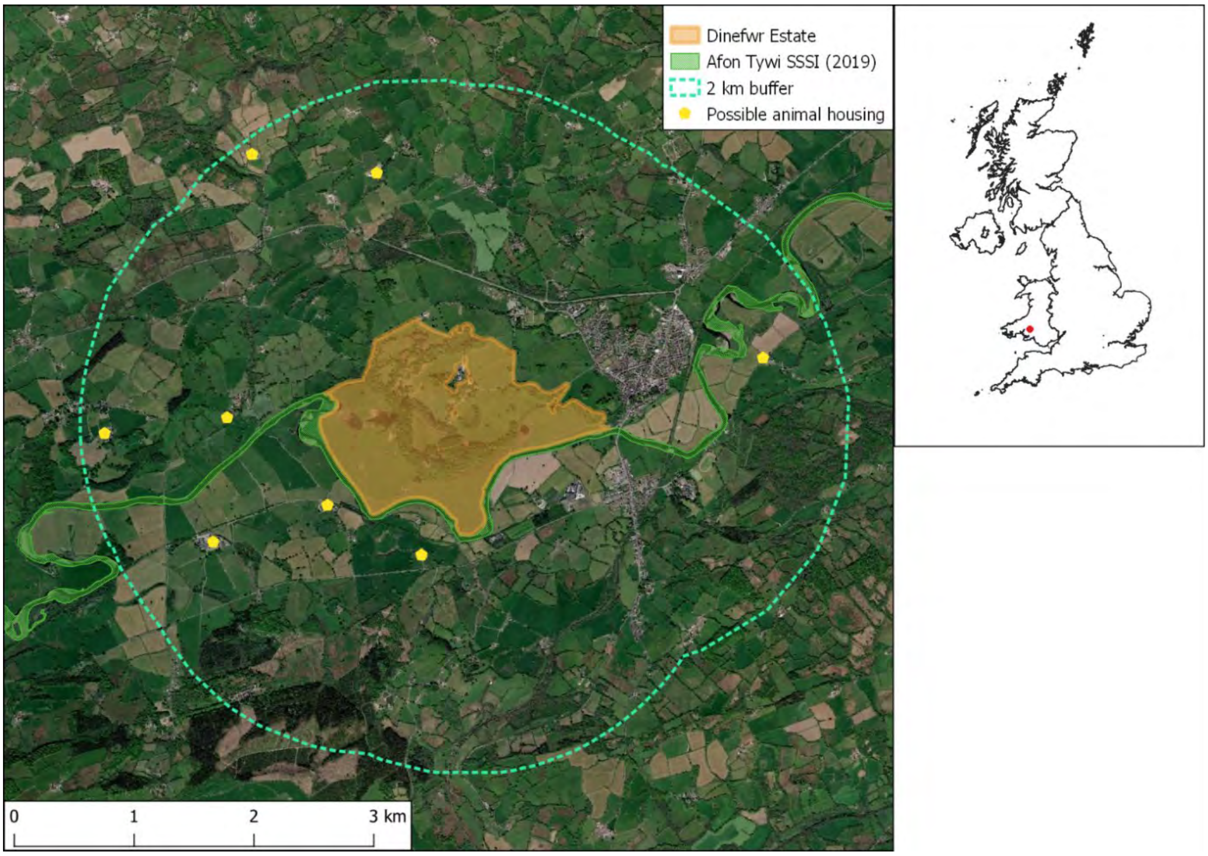


Figure 3.6-1. Site map showing relevant features and boundaries of Dinefwr Estate, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.6.2 Designated features

Table 15. Nitrogen sensitive interest features at Dinefwr Estate SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Upland hay meadows Lowland meadows	10 – 20 kg N/ha/yr
Lowland Beech and Yew Woodland Broadleaved, Mixed and Yew Woodland	5 – 15 kg N/ha/yr
Wet Woodland Lowland Mixed Deciduous Woodland Wood-Pasture and Parkland	10 – 20 kg N/ha/yr
Upland Oakwood Upland Birchwoods	10 –15 kg N/ha/yr
Upland Mixed Ashwoods	15 – 20 kg N/ha/yr

3.6.3 Site characteristics

Dinefwr Estate SSSI (South Wales) is a site containing parkland and woodland trees, designated for a number of sensitive features (Table 7). The southern boundary of the site backs onto the Afon Tywi SSSI. Dinefwr Estate is of special interest for the lichen communities, of which there are over 160 species present, including several known to be very sensitive to atmospheric pollution. Additionally, the site is of national importance for its community of saproxylic invertebrates. The main sources of atmospheric N input to the site are local agricultural emissions, with dairy farming activity prominent.

3.6.4 Source attribution

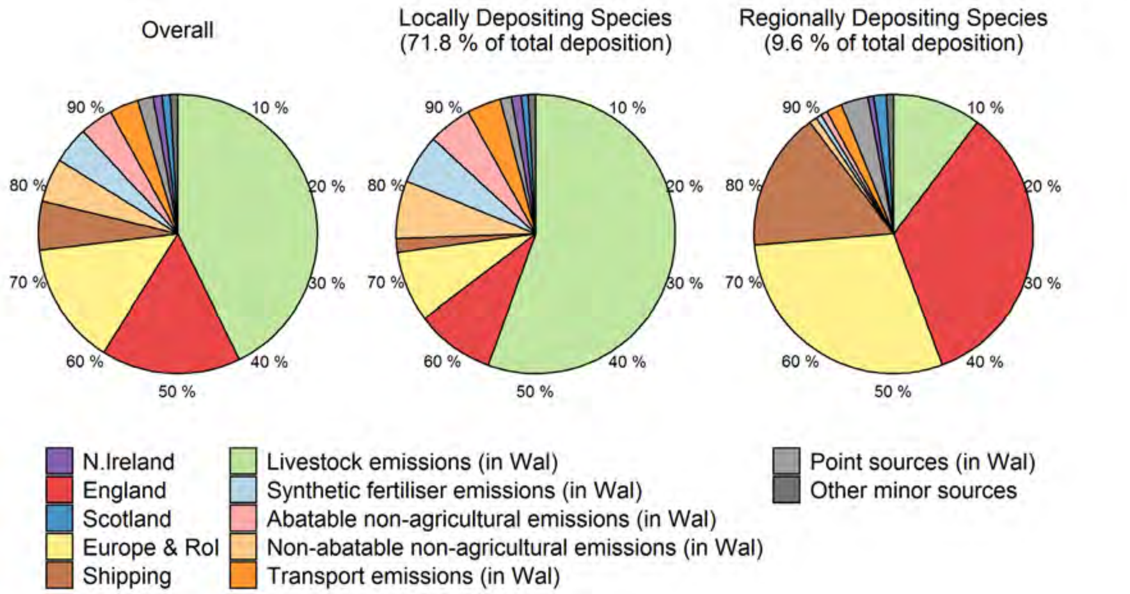


Figure 3.6-2. Relative contribution of emission sources to N deposition (to woodland features) received by Dinefwr Estate SSSI.

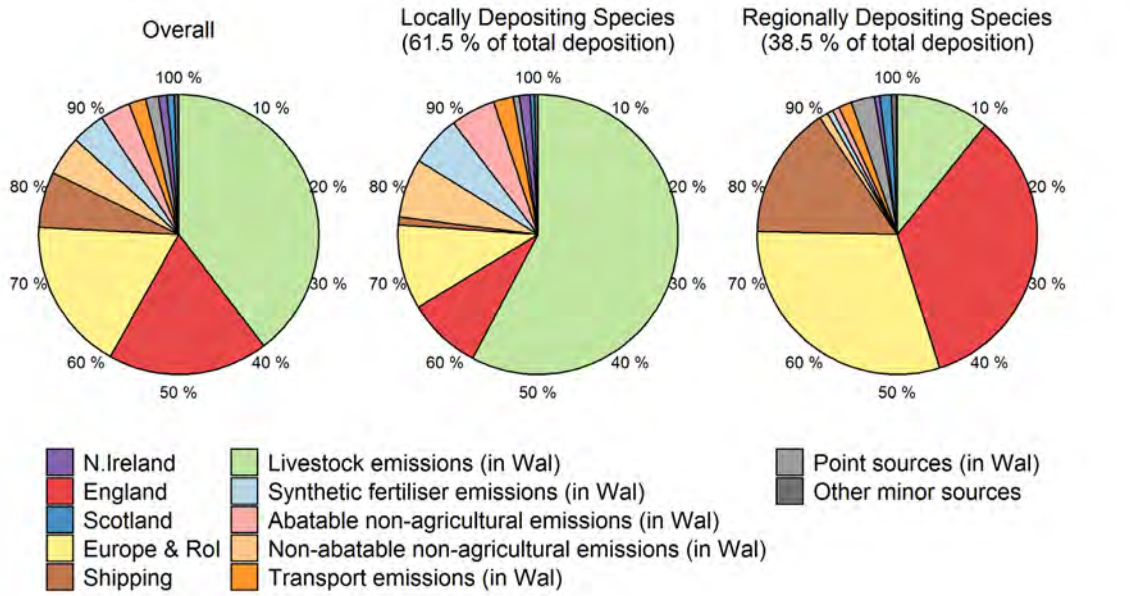


Figure 3.6-3. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Dinefwr Estate SSSI.

3.6.5 NH_3 concentration

Figure 3.6-4. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Dinefwr Estate SSSI and surrounding area.

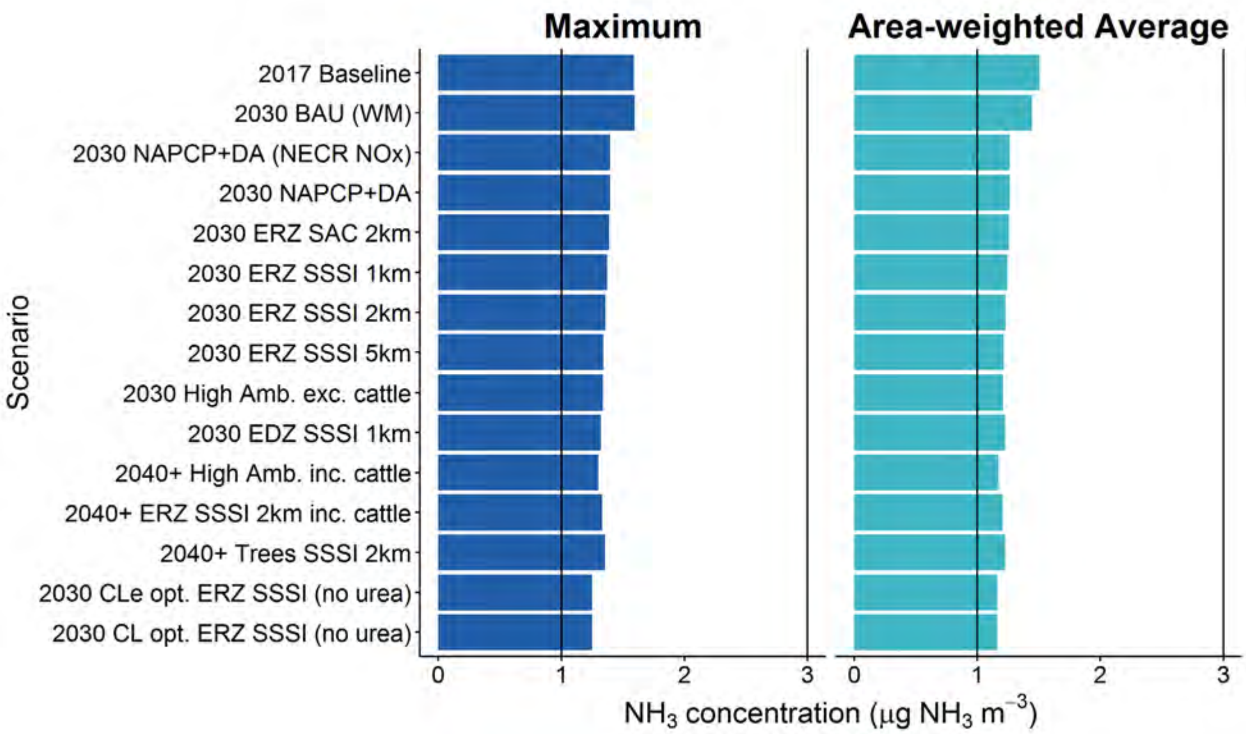


Figure 3.6-5. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Dinefwr Estate SSSI. Vertical lines indicate 1µg and 3µg critical levels.

3.6.6 NO_2 concentration

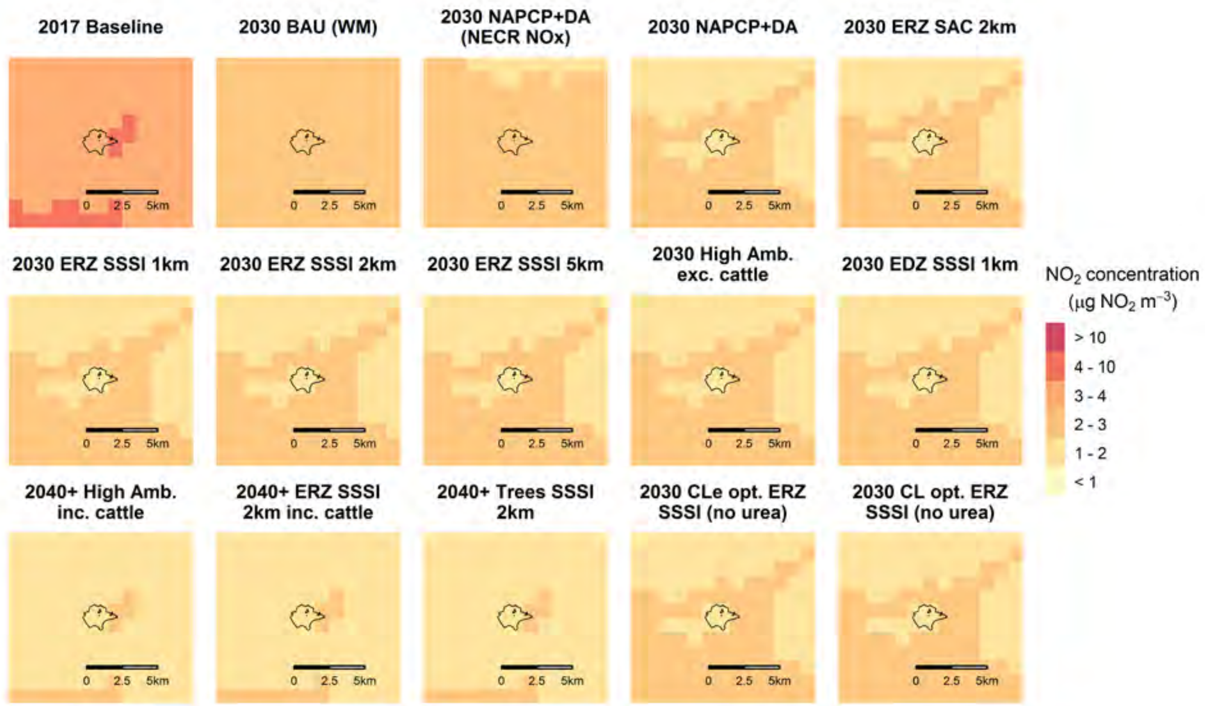


Figure 3.6-6. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Dinefwr Estate SSSI and surrounding area.

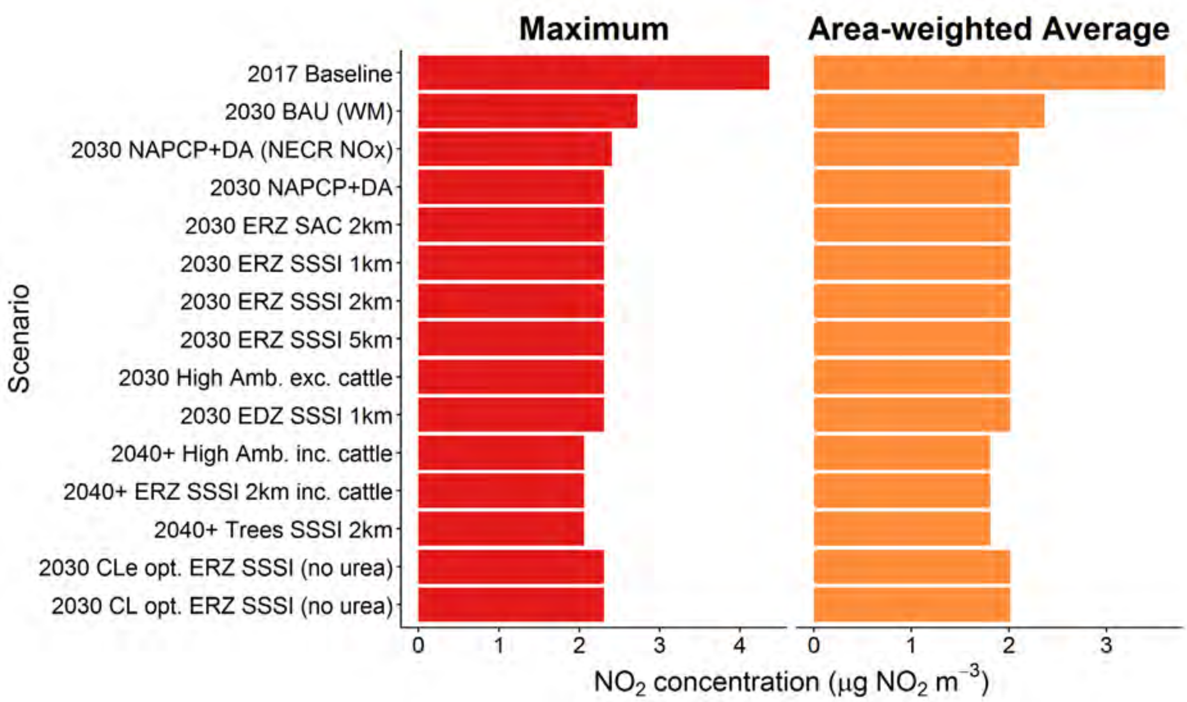


Figure 3.6-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Dinefwr Estate SSSI.

3.6.7 N deposition

Figure 3.6-8. N deposition (to woodland features) received by Dinefwr Estate SSSI and surrounding area.

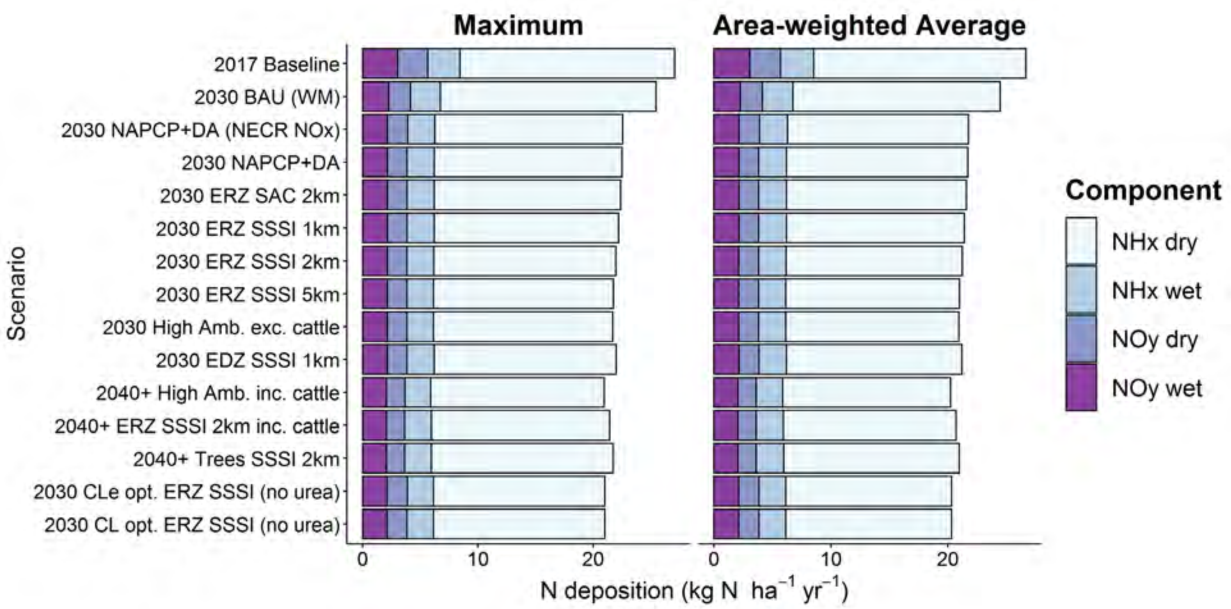


Figure 3.6-9. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Dinefwr Estate SSSI.

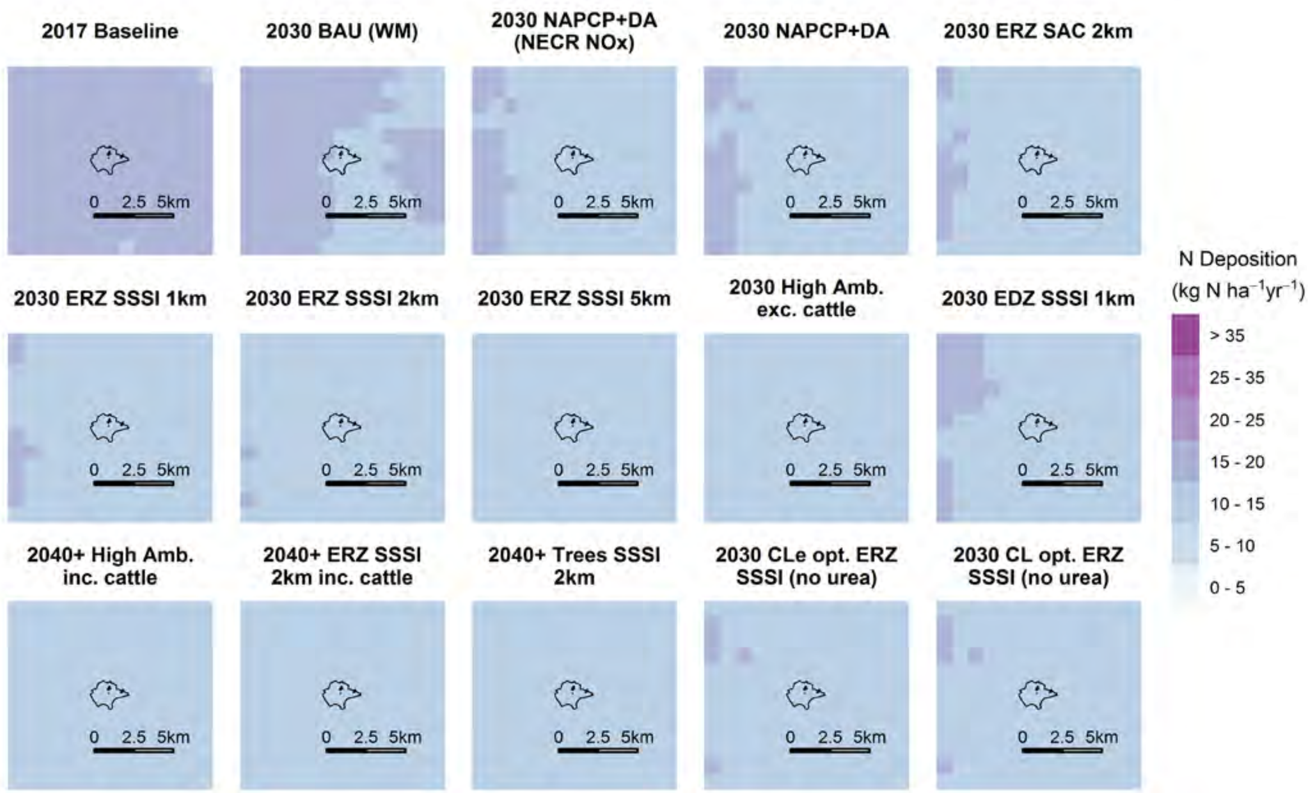


Figure 3.6-10. N deposition (to low-growing semi-natural vegetation) received by Dinefwr Estate SSSI and surrounding area.

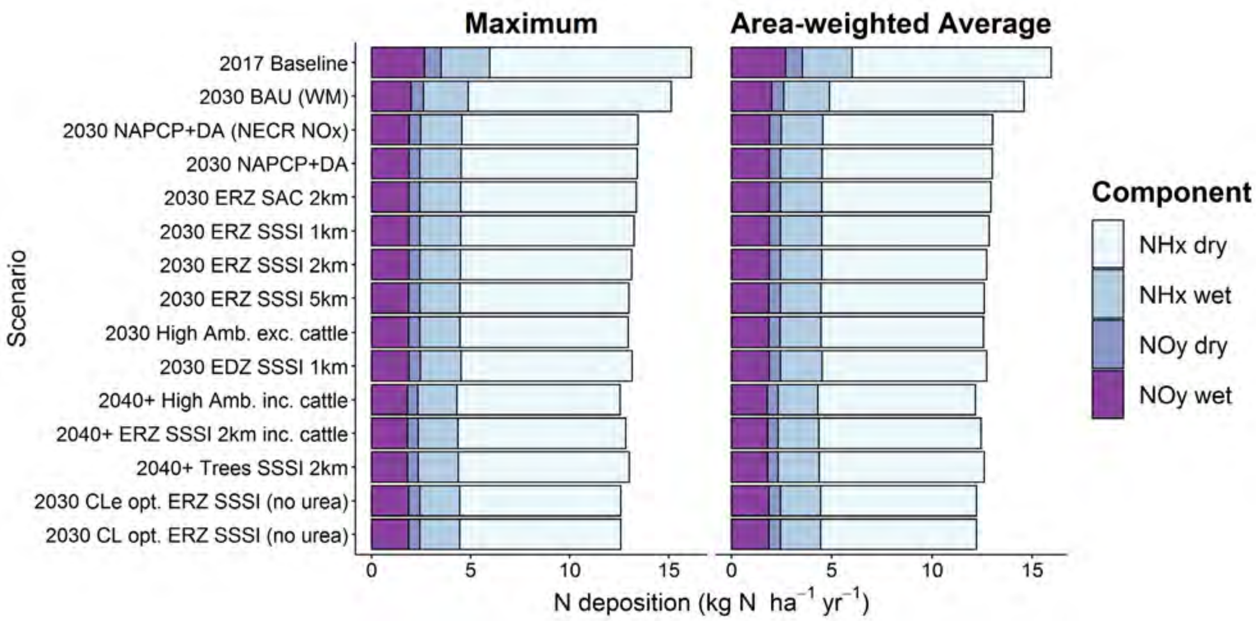


Figure 3.6-11. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Dinefwr Estate SSSI.

3.6.8 Exceedance of critical loads

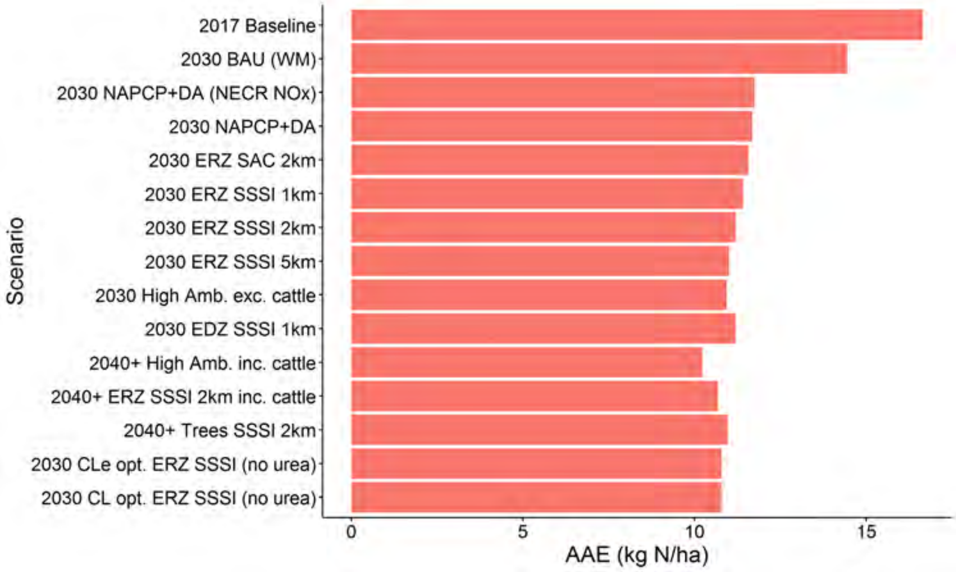


Figure 3.6-12. Exceedance of critical loads by scenario at Dinefwr Estate SSSI.

3.6.9 Local assessment

The source attribution assessment (5 km grid resolution), is appropriate for the grid square it relates to, and higher deposition to the North-west in several modelling scenarios reflects the estimated locations of animal housing (Section 3.6.4). The data identifies the main contributors to N deposition at the site (using average data across the site), with local knowledge supporting the importance of agricultural emissions sources in this area. The emission density dataset cannot be shown for sites in Wales, as the spatial detail on holding locations available is not sufficiently detailed (see Section 2.1 for details). However, it can be confirmed from the data available that the key agricultural sectors in the area are dairy, beef and sheep farming. Aerial photography confirms that there are several cattle farms located within 1-2 km from the site.

The results of UK-scale modelling show concentrations for most of the surrounding area at 1-2 µg NH_3 m^{-3}. These modelled concentrations appear to be on the low side, given local data on lichen (Bosanquet 2019) and reports of strong slurry smells across the site on numerous occasions. With the local sources (at the 1 km scale) relatively close to the site boundary, such as cattle houses and related manure/slurry storage and spreading, spatial targeting scenarios should result in overall decreases of maximum and average NH_3 concentrations. However, modelled values remain above the 1 µg critical level for NH_3 with a very flat concentration surface in Figure 3.6-5. It is very likely that local concentration gradients are smoothed out across the wider area at the 1 km grid resolution, and local concentration monitoring at several points on the boundary and towards the centre of the site would provide further insights. The relative importance of cattle emissions to atmospheric N input at this site is emphasised, with the highest ambition cattle scenarios producing the greatest decreases at this site.

3.6.10 Conclusions

Spatial targeting of measures, especially those relevant for cattle farming, is expected to decrease local concentration gradients. From the modelling results, it would be important to include sources within the wider area due to higher agricultural emission density 3-10 km from the site boundary. Without inclusion of broader measures, the regional background is likely to continue to affect the designated features.

3.7 Gregynog

The following sections provide background on Gregynog and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.7.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.7.1 Site map and location within UK

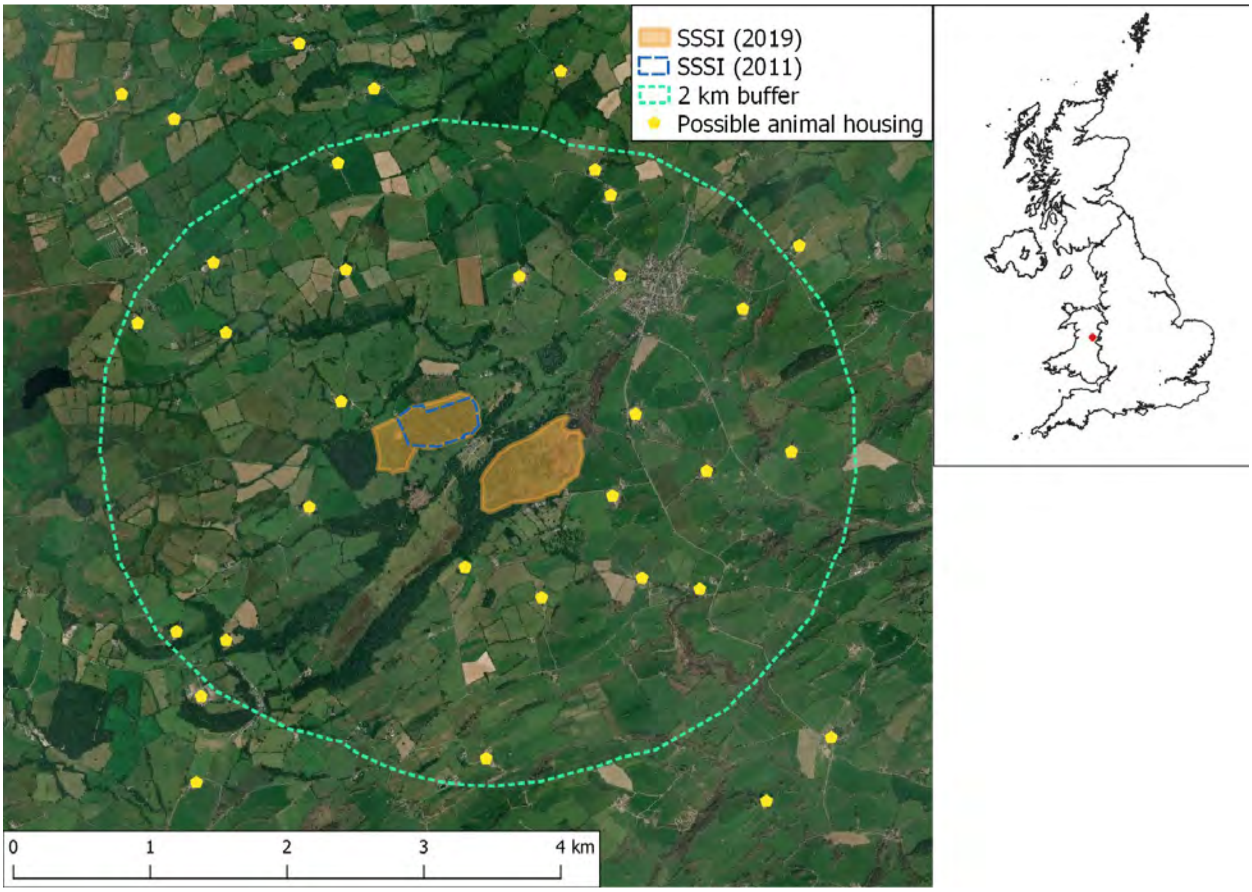


Figure 3.7-1. Site map showing relevant features and boundaries of Gregynog, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.7.2 Designated features

Table 16. Nitrogen sensitive interest features at Gregynog SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Upland Birchwoods Upland Oakwood	10 – 15 kg N/ha/yr
Lowland Beech and Yew Woodland Native Pine Woodlands	5 – 15 kg N/ha/yr
Lowland Mixed Deciduous Woodland Wood-Pasture and Parkland Wet Woodland	10 – 20 kg N/ha/yr
Upland Mixed Ashwoods	15 – 20 kg N/ha/yr

3.7.3 Site characteristics

Gregynog SSSI (approximately 5km north of Newtown, Powys, Wales) is a 55 ha area of wood-pasture/parkland habitat and ancient trees. The site is part of a wider 300 ha estate and is of special interest for the communities of diverse epiphytic lichens and specialist invertebrate fauna it supports. The main local sources of atmospheric nitrogen input to the site are agricultural emissions, primarily from large numbers of poultry farms below the PPC limit, as well as beef cattle.

3.7.4 Source attribution

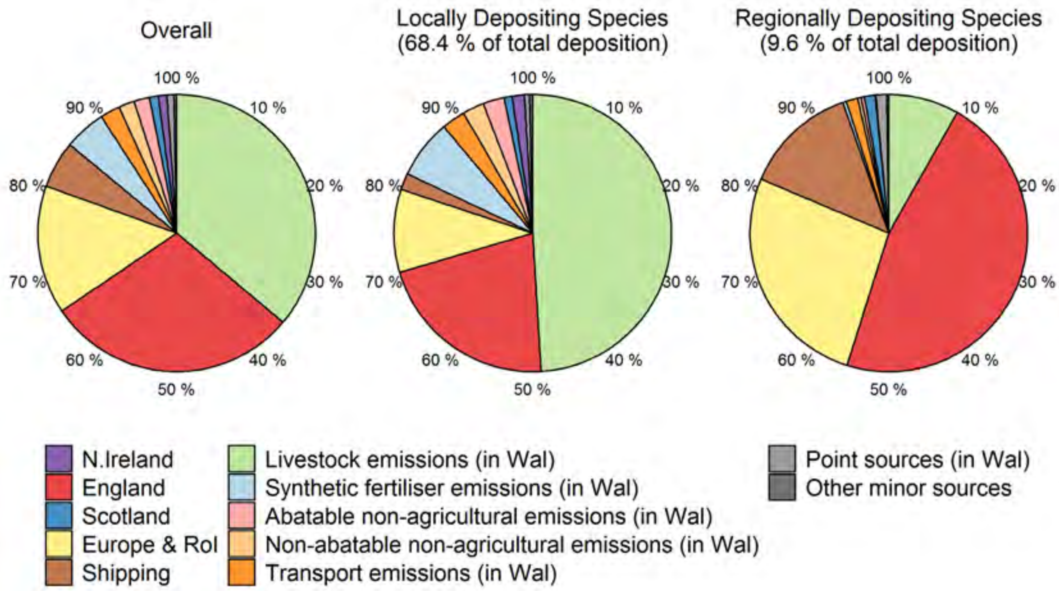


Figure 3.7-2. Relative contribution of emission sources to N deposition (to woodland features) received by Gregynog SSSI.

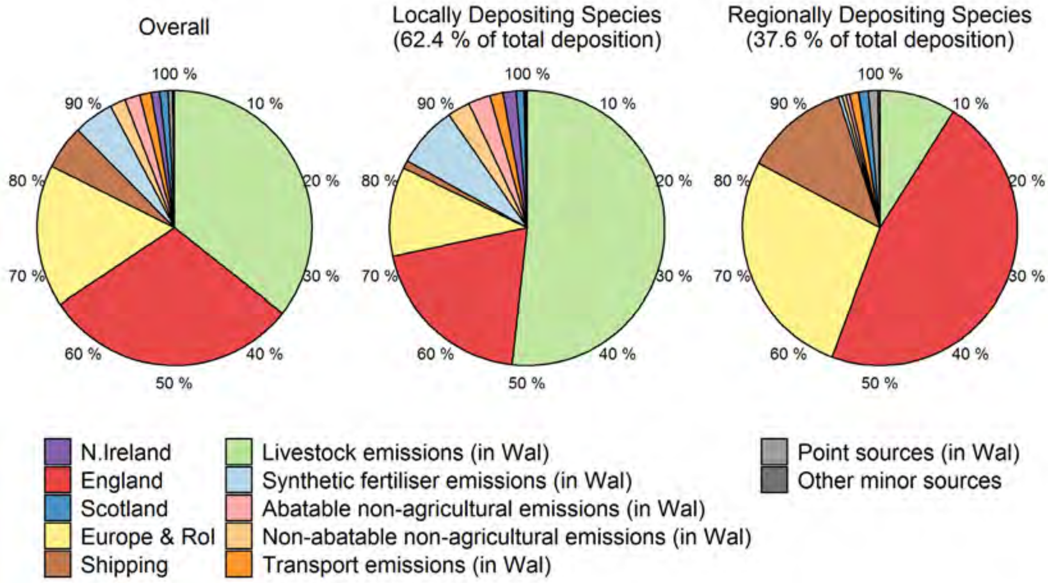


Figure 3.7-3. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Gregynog SSSI.

3.7.5 NH3 concentration

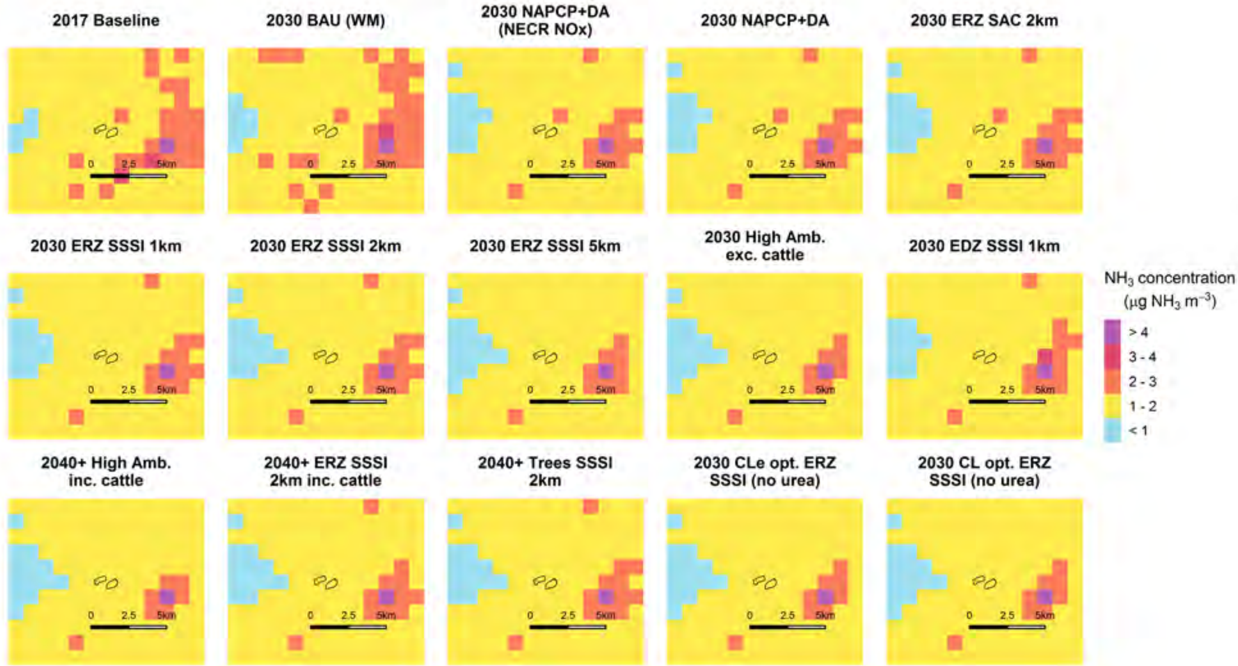


Figure 3.7-4. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Gregynog SSSI and surrounding area.

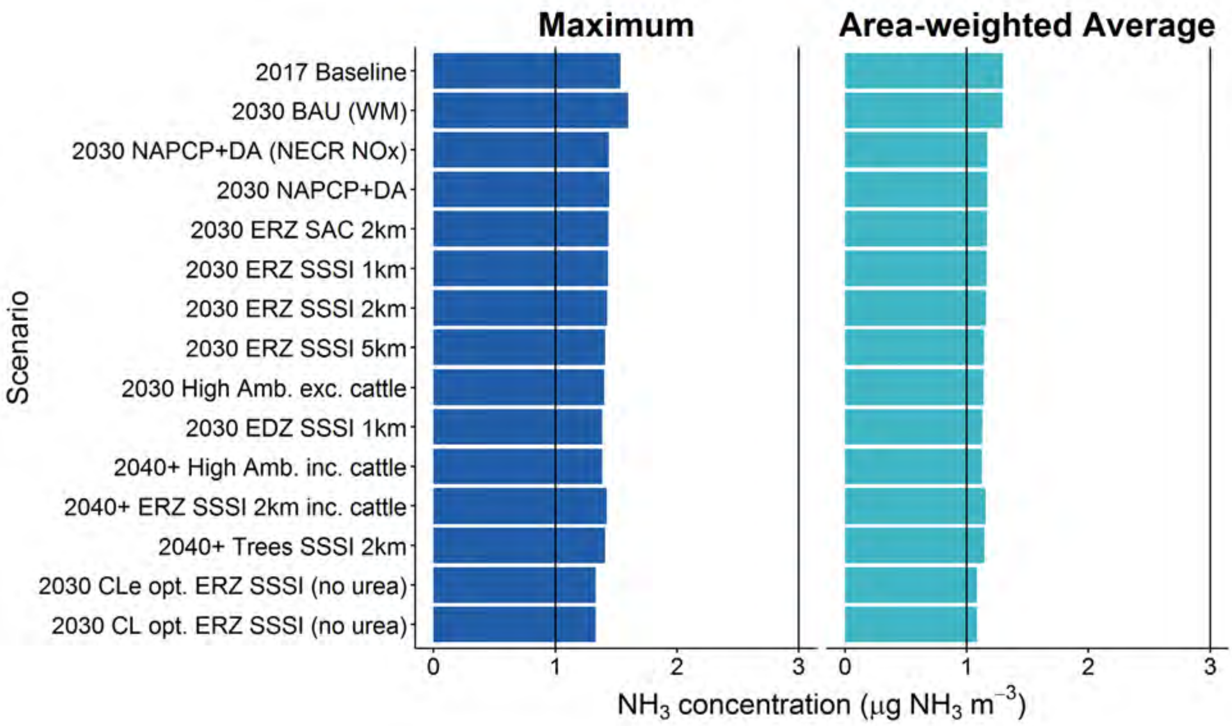


Figure 3.7-5. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Gregynog SSSI. Vertical lines indicate 1µg and 3µg critical levels. Vertical lines indicate 1µg and 3µg critical levels.

3.7.6 NO_2 concentration

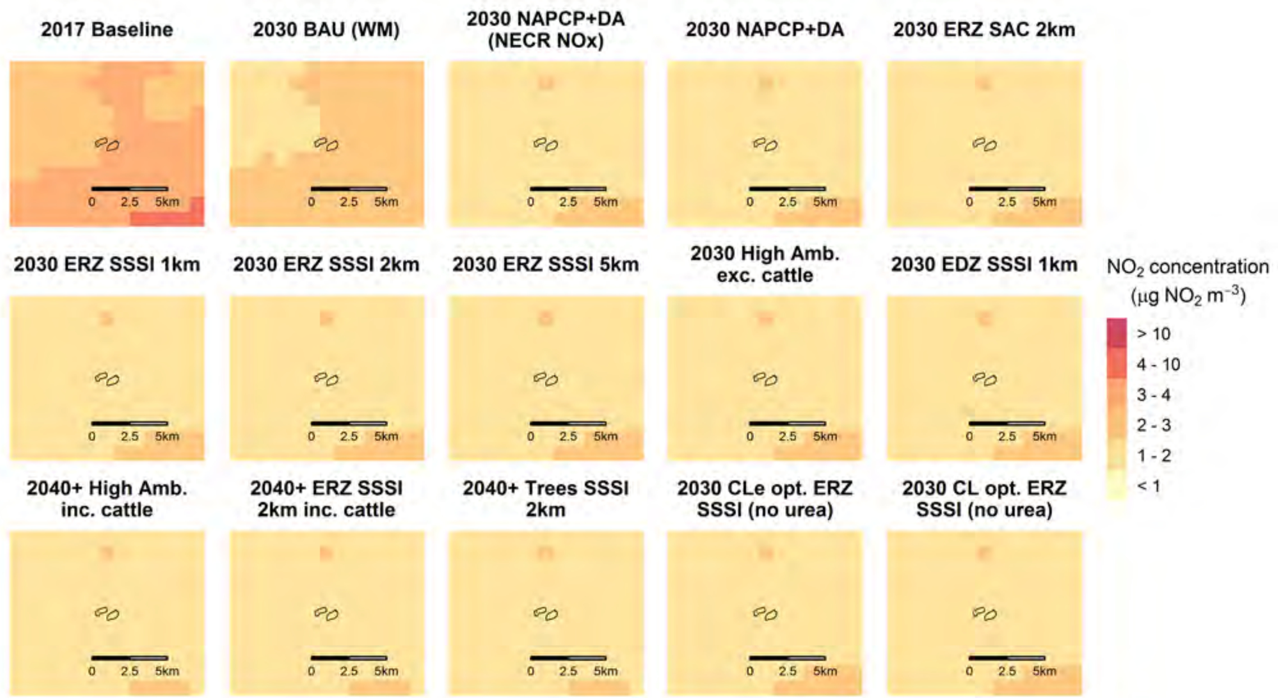


Figure 3.7-6. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Gregynog SSSI and surrounding area.

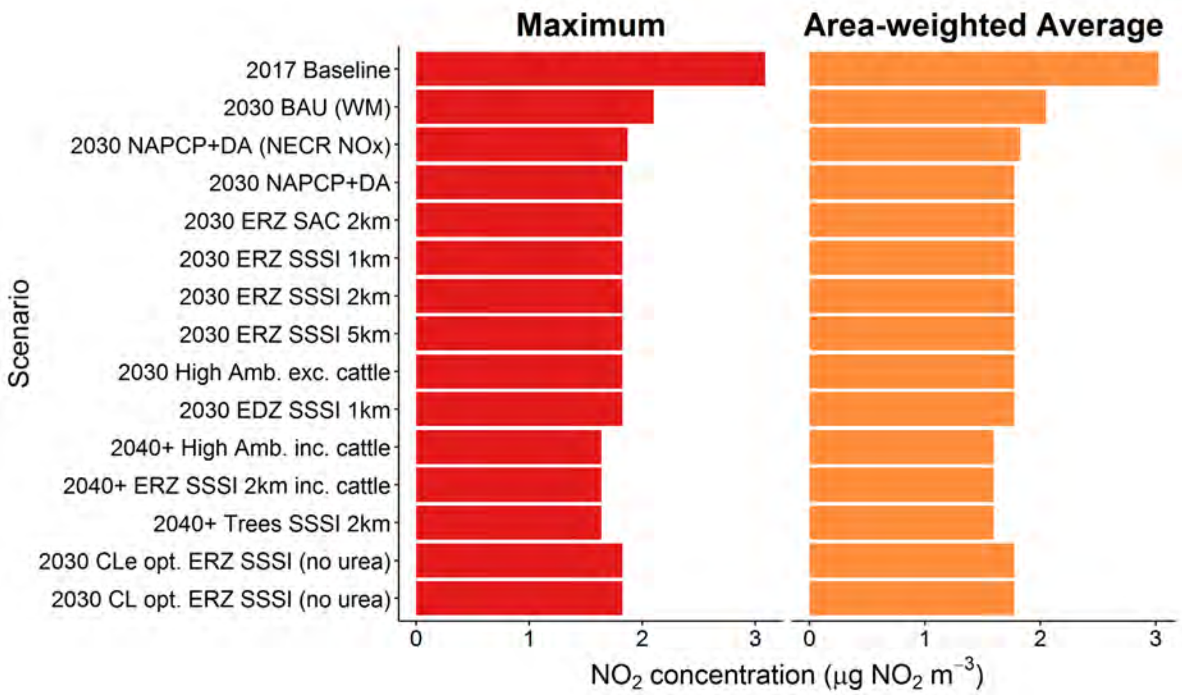


Figure 3.7-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Gregynog SSSI.

3.7.7 N deposition

Figure 3.7-8. N deposition (to woodland features) received by Gregynog SSSI and surrounding area.

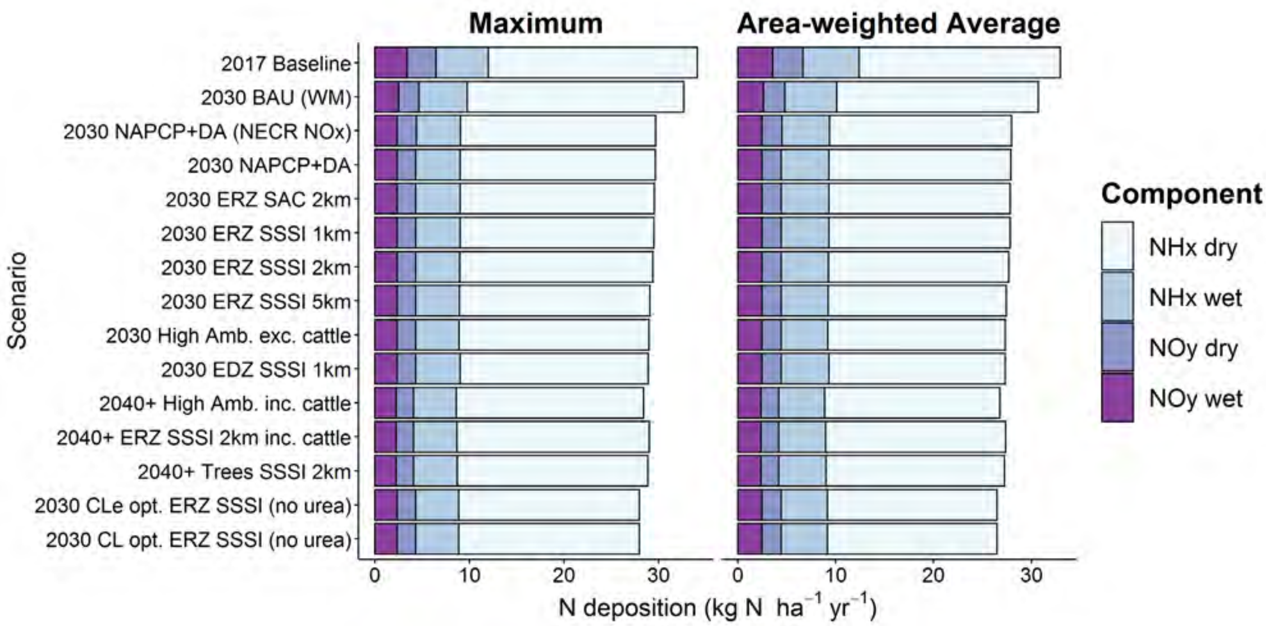


Figure 3.7-9. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Gregynog SSSI.

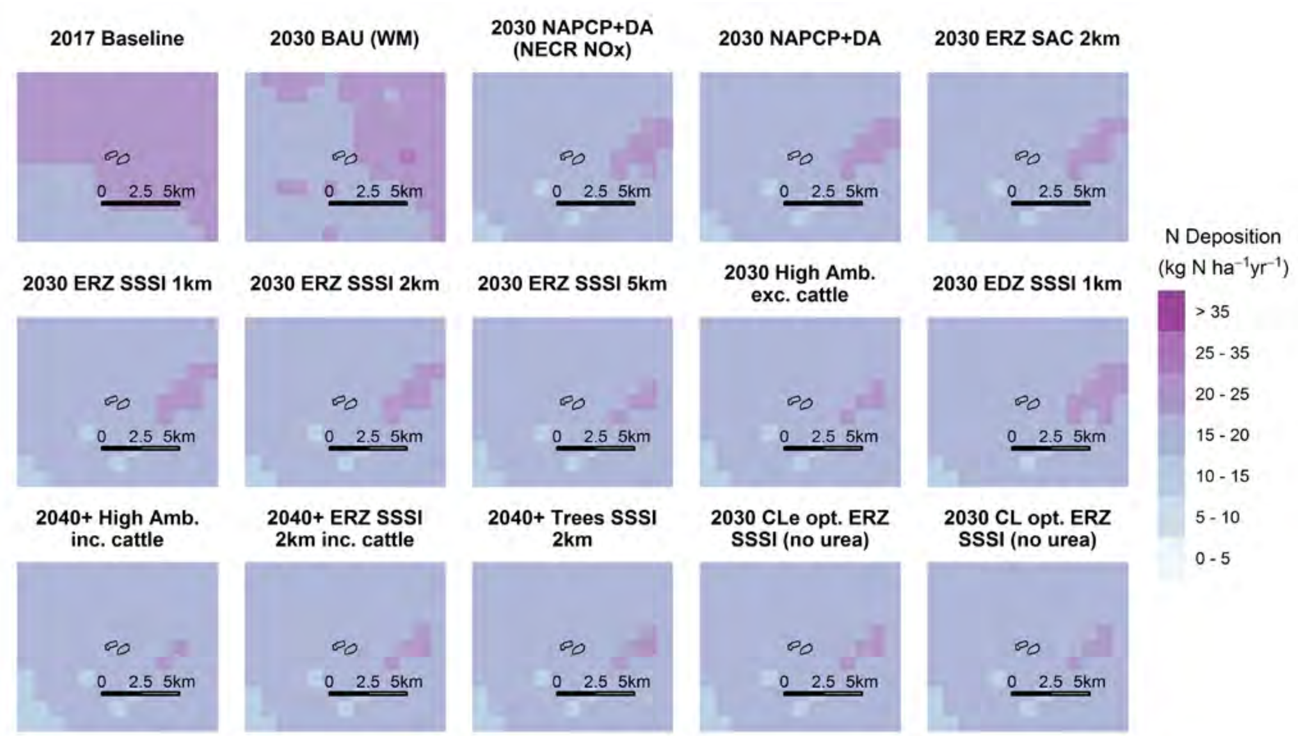


Figure 3.7-10. N deposition (to low-growing semi-natural vegetation) received by Gregynog SSSI and surrounding area.

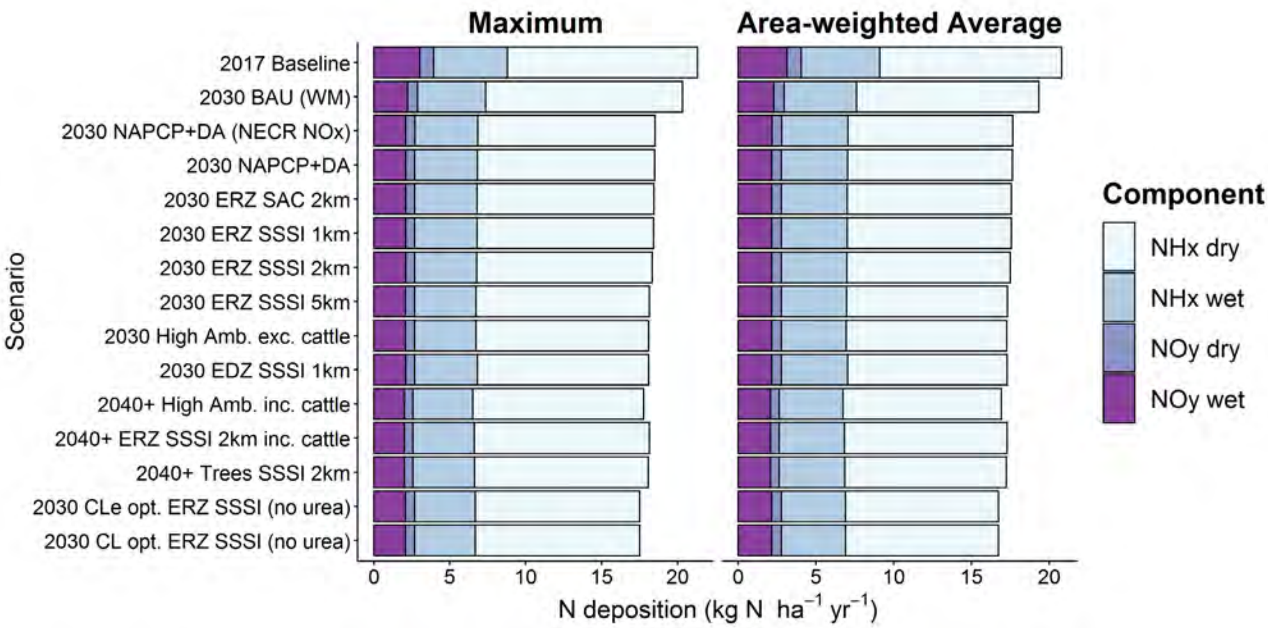


Figure 3.7-11. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Gregynog SSSI.

3.7.8 Exceedance of critical loads

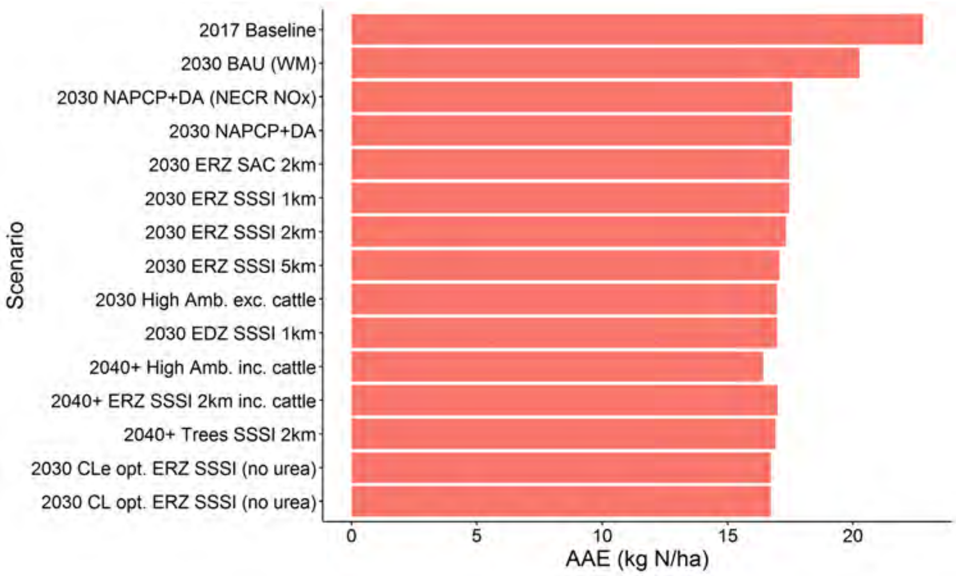


Figure 3.7-12. Exceedance of critical loads by scenario at Gregynog SSSI.

3.7.9 Local assessment

This site is located in an area of intensive agricultural activity, and emissions from this sector are known to be the key atmospheric N issue at the site. Activities such as slurry spreading are evidenced from site visits where cattle slurry was found to present on trees from adjacent spreading in 2017 (Bosanquet 2019). The 5 km grid resolution source attribution assessment identifies the main contributors to N deposition at the site, with the primary input being livestock emissions and > 60% of atmospheric N input attributed to local sources. For the site's specific situation and the sensitive lichen community, the accurate assessment of local NH_3 concentrations may be more important than atmospheric N input through deposition. The emission density dataset cannot be shown for sites in Wales, as the spatial detail on holding locations available is not sufficiently detailed (see Section 2.1 for details). However, it can be confirmed from the data available that the key agricultural sectors in the area are beef, poultry and sheep farming. The area is well known for large numbers of smaller poultry farms that together form a substantial source of NH_3 emissions. Given the relatively recent establishment of many of these farms, it is possible that their emissions are not yet fully represented in the national agricultural emission inventory, due to time lags involved with various sequential data collection and inventory preparation stages.

Nevertheless, national scale modelling overall reflects this local knowledge of an intensive agricultural area, with relatively high NH_3 concentrations observed to the east of the site. All the scenarios beyond the less ambitious 2030 BAU (WM) baseline are expected to result in additional decreases in atmospheric N input at the site itself, however average NH_3 concentrations remain above the 1 µg critical level.

3.7.10 Conclusions

Local concentration gradients at this site may be mitigated with spatial targeting measures, which are expected to produce declines in NH_3 concentrations and N deposition. However, if the sources in the wider area are not included in efforts to reduce NH_3 emissions, the regional background is likely to continue to affect the designated features.

3.8 Beinn Dearg

The following sections provide background on Beinn Dearg and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.8.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.8.1 Site map and location within UK

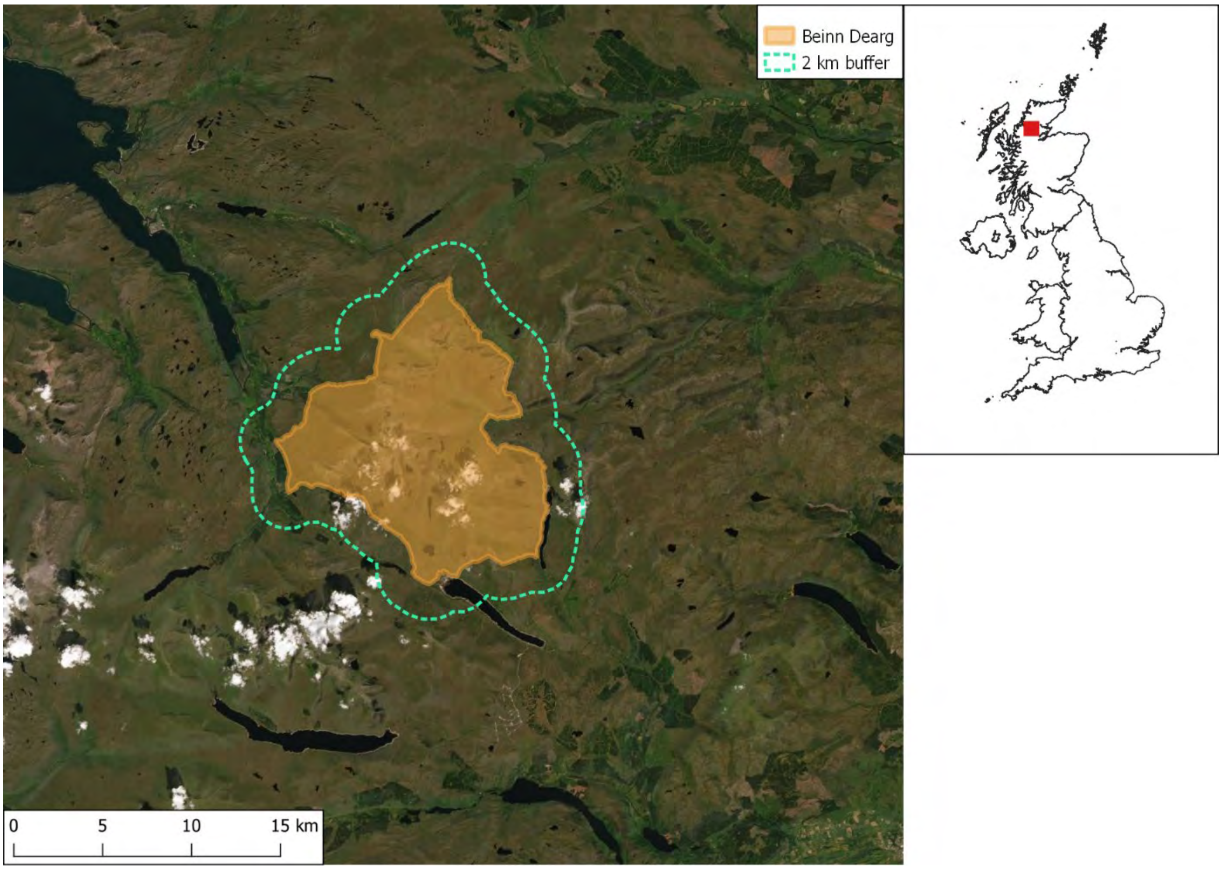


Figure 3.8-1. Site map showing relevant features and boundaries of Beinn Dearg, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.8.2 Designated features

Table 17. Nitrogen sensitive interest features at Beinn Dearg SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Native pinewood	5 – 15 kg N/ha/yr
Moss and lichen dominated mountain summits	5 – 10 kg N/ha/yr

3.8.3 Site characteristics

Beinn Dearg (North-west Scotland) is a large site of > 13,000 ha, covering the highest and most diverse mountain range in the northern Highlands. The site is also designated as a SAC, and parts of the SSSI form part of the River Oykel SAC and Beinn Dearg SPA. As the site is relatively remote and far from centres of agricultural activity and population, there are no major local nitrogen sources, and low background levels of NH_3 concentrations and dry N deposition would be expected.

3.8.4 Agricultural emission density

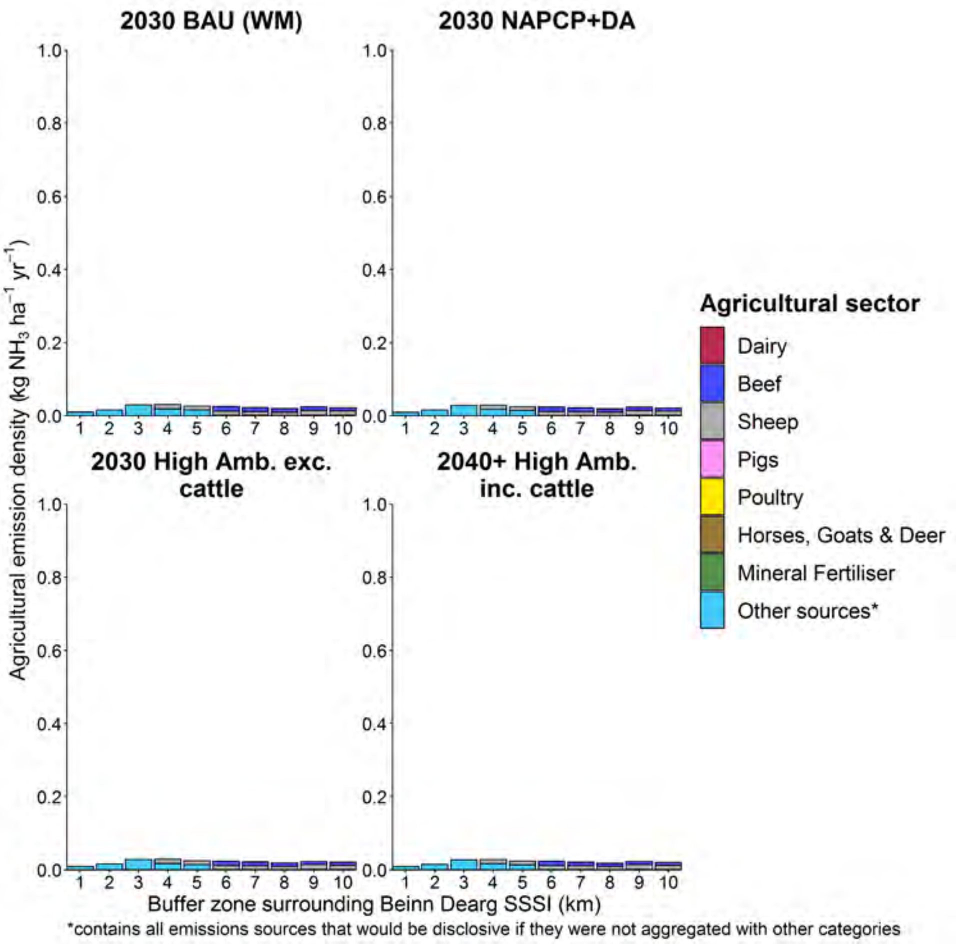


Figure 3.8-2. Estimated agricultural emission densities in concentric buffer zones surrounding Beinn Dearg SSSI.

3.8.5 Source attribution

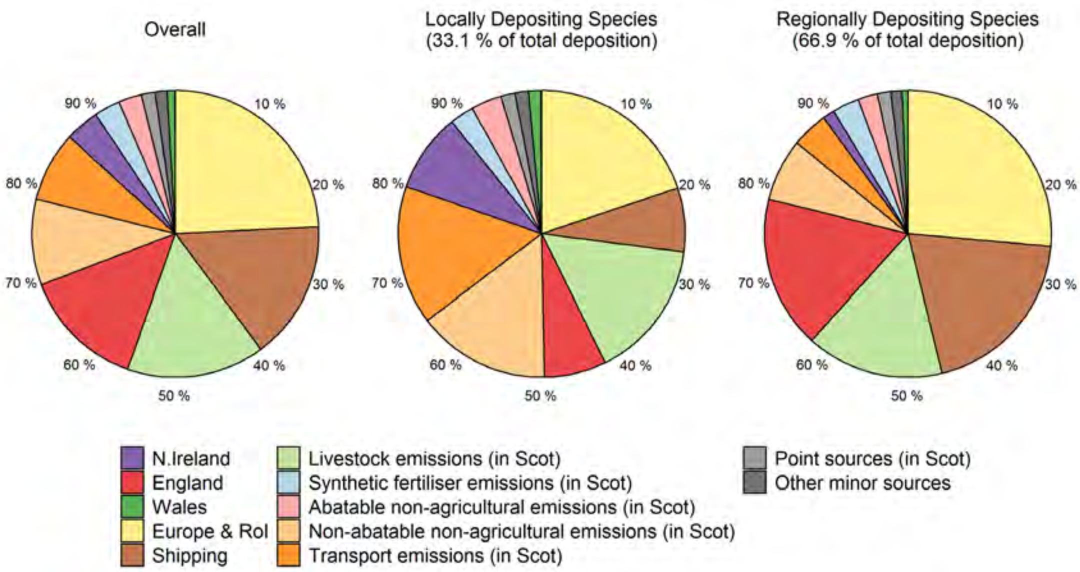


Figure 3.8-3. Relative contribution of emission sources to N deposition (to woodland features) received by Beinn Dearg SSSI.

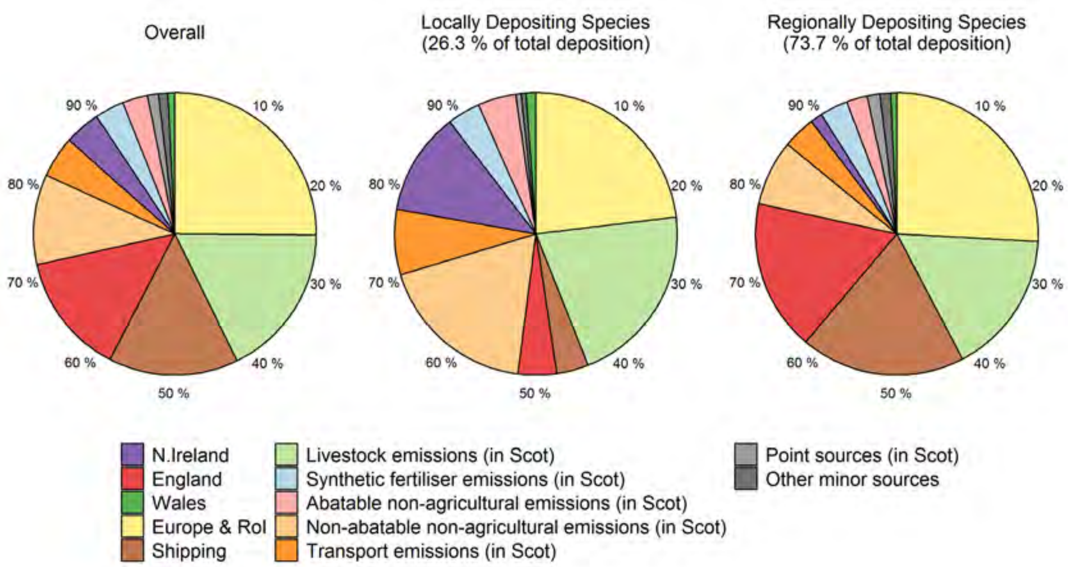


Figure 3.8-4. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Beinn Dearg SSSI.

3.8.6 NH_3 concentration

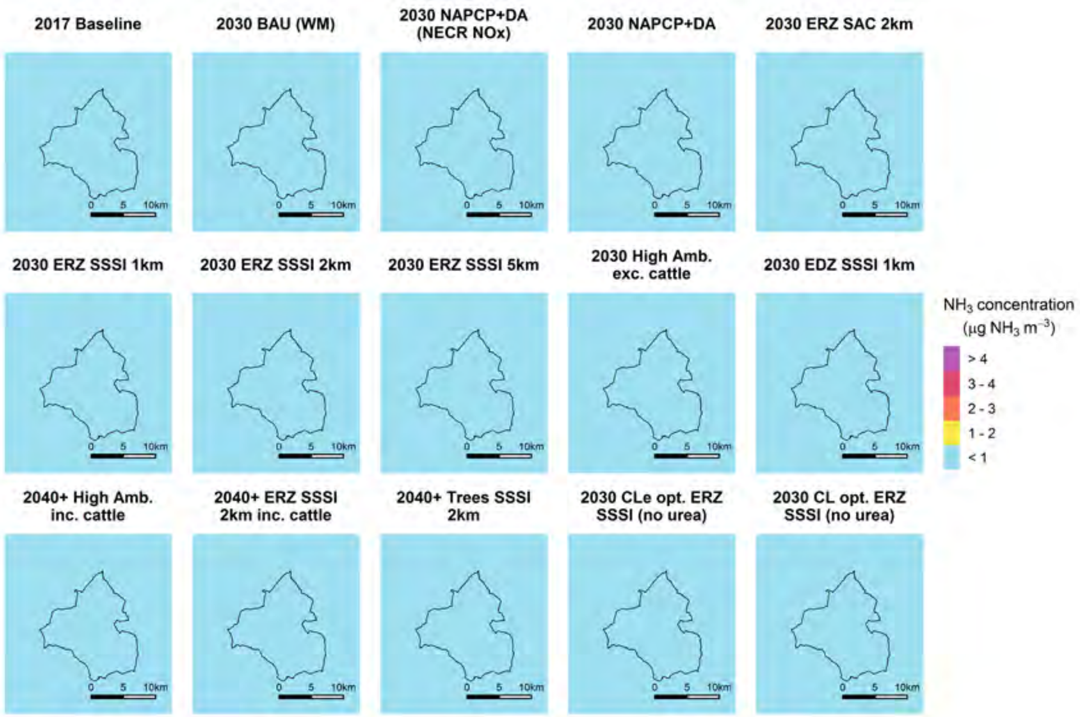


Figure 3.8-5. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Beinn Dearg SSSI and surrounding area.

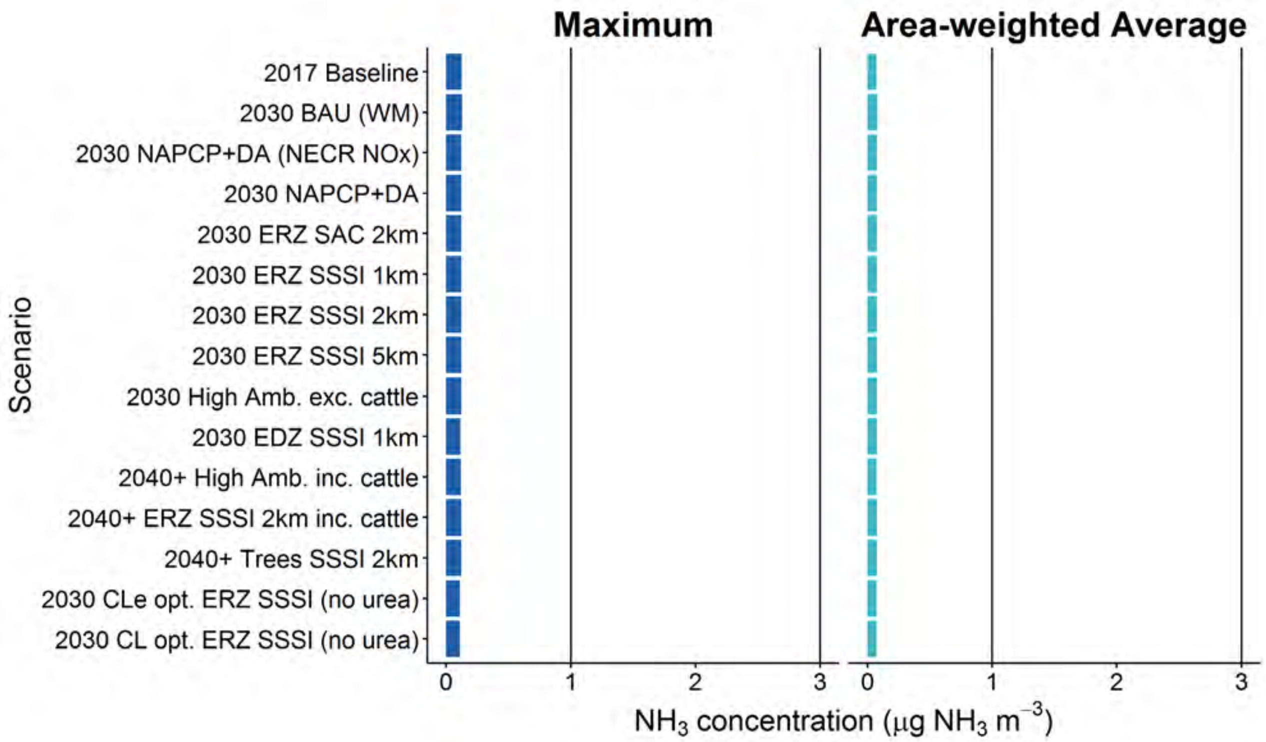


Figure 3.8-6. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Beinn Dearg SSSI. Vertical lines indicate 1µg and 3µg critical levels.

3.8.7 NO_2 concentration

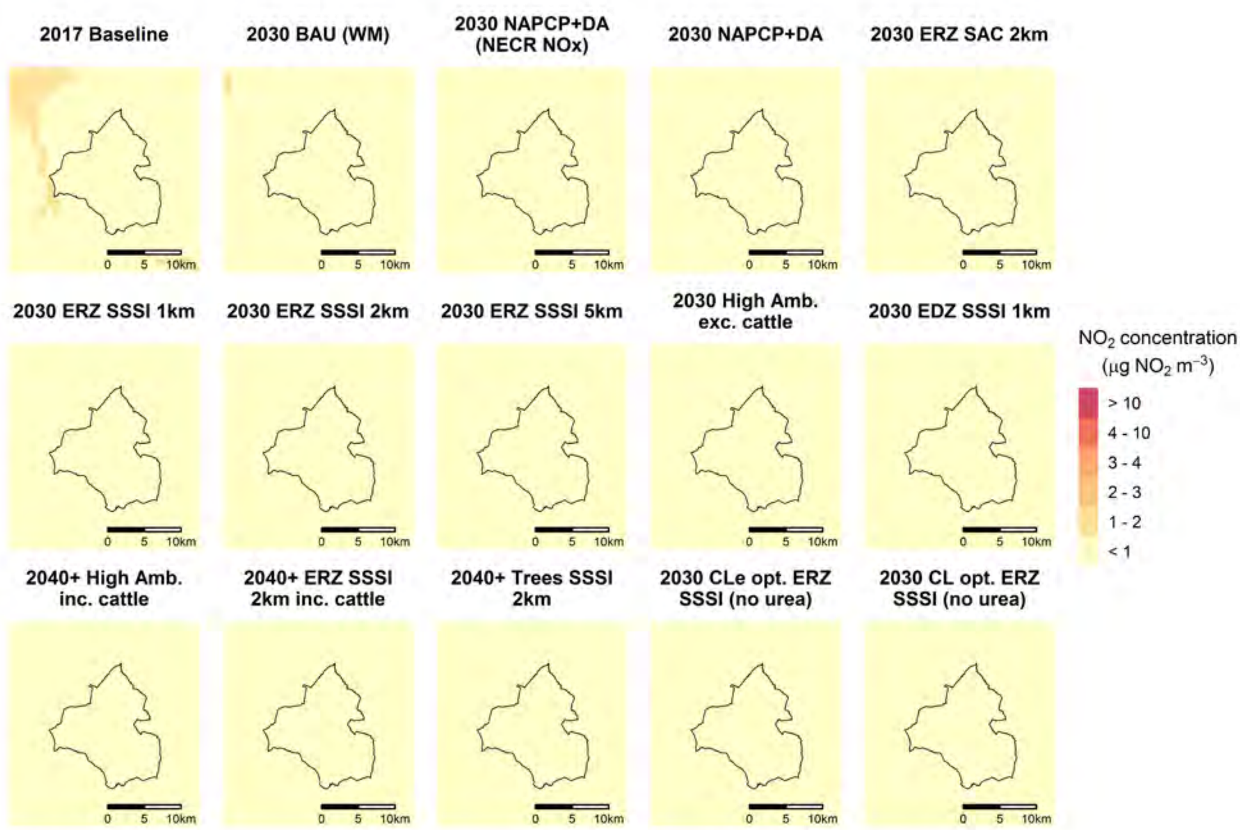


Figure 3.8-7. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Beinn Dearg SSSI and surrounding area.

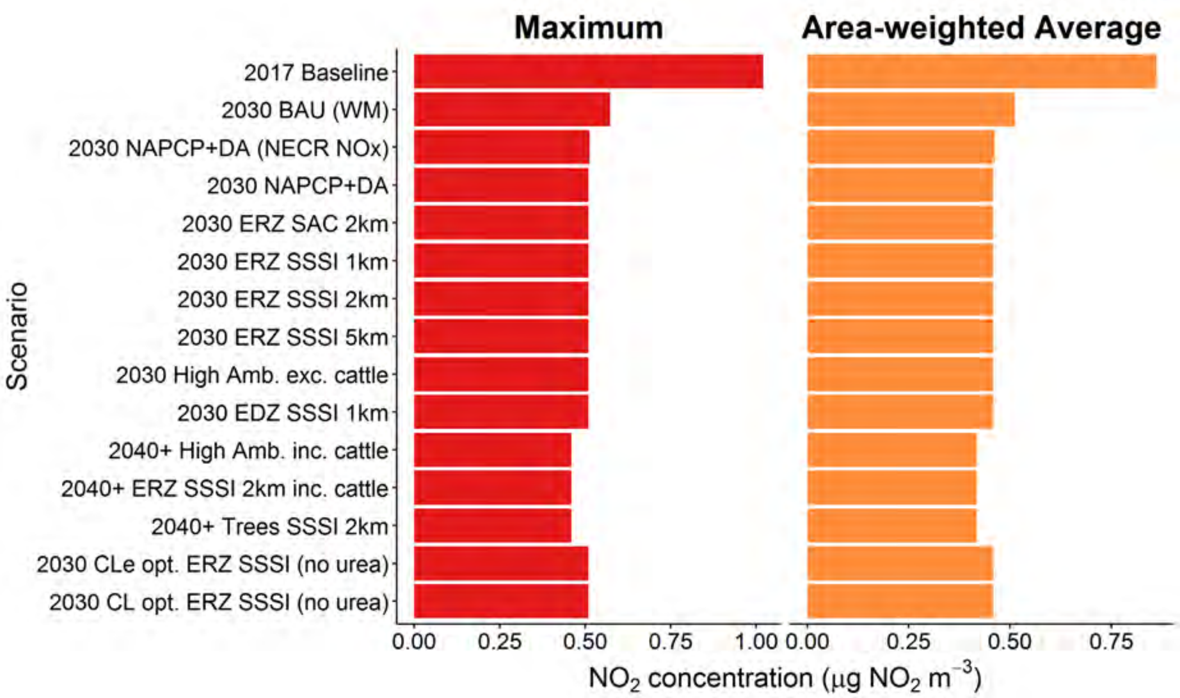


Figure 3.8-8. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Beinn Dearg SSSI.

3.8.8 N deposition

Figure 3.8-9. N deposition (to woodland features) received by Beinn Dearg SSSI and surrounding area.

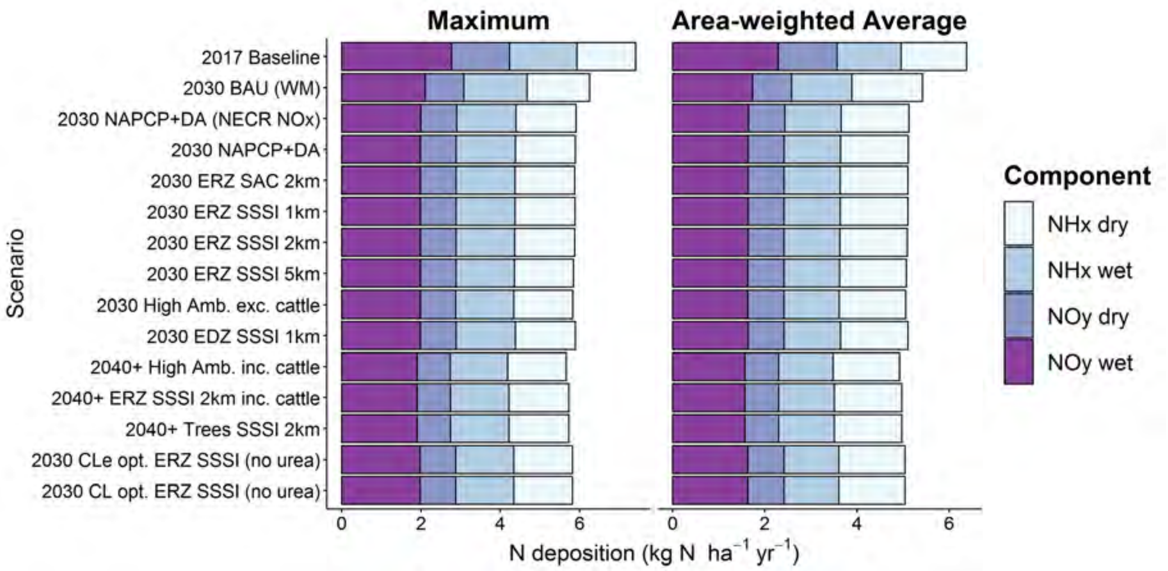


Figure 3.8-10. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Beinn Dearg SSSI.

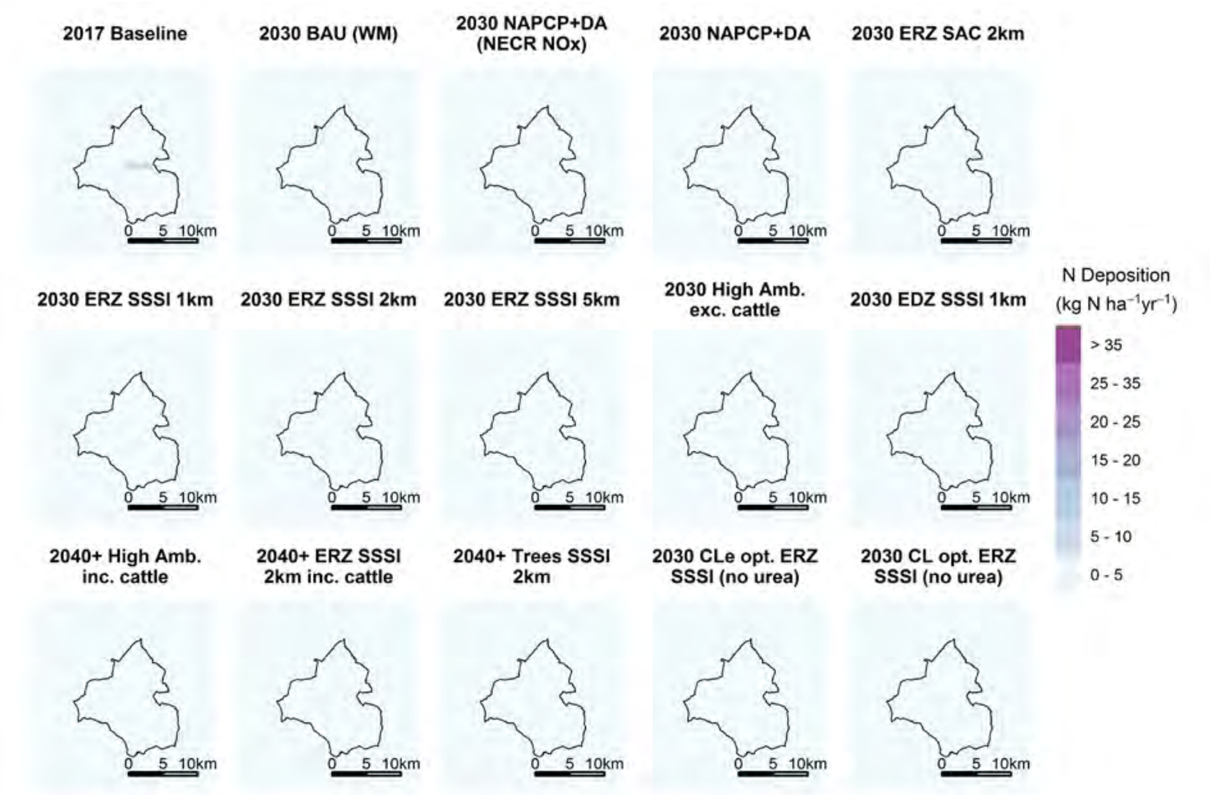


Figure 3.8-11. N deposition (to low-growing semi-natural vegetation) received by Beinn Dearg SSSI and surrounding area.

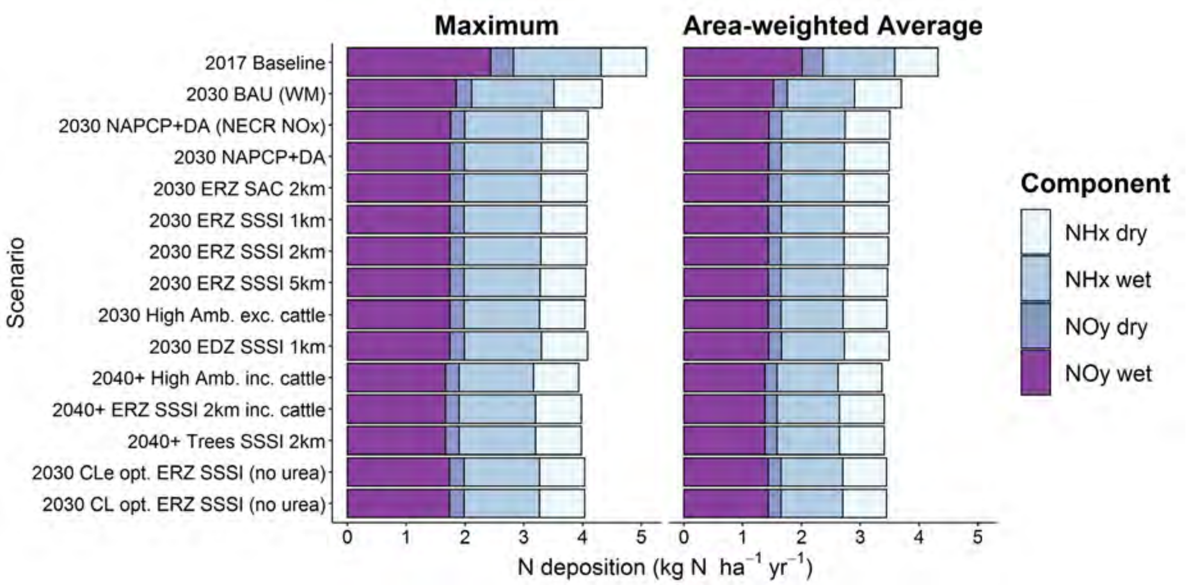


Figure 3.8-12. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Beinn Dearg SSSI.

3.8.9 Exceedance of critical loads

Beinn Dearg is only in minor exceedance of critical loads under the 2017 baseline emissions and moves out of exceedance with all subsequent scenarios for 2030 and beyond.

3.8.10 Local assessment

Beinn Dearg is situated in a relatively remote area of Scotland with few emissions sources identified nearby and a very low agricultural emissions density. It is therefore estimated to receive much less atmospheric N input than the other case study sites considered in this project. This is also supported by the 5 km source attribution assessment indicating that N input to the site primarily comes from regional or long-range sources (nearly 75%), as well as by the low (background) levels of NH_3 and NO_2 concentration, and relatively low N deposition established from national scale (1 km grid) modelling.

3.8.11 Conclusions

Spatially targeting mitigation measures at this site does not achieve any reduction in local atmospheric NH_3 emissions or concentrations, as agricultural emission density is very low (< 0.1 kg NH_3 ha^{-1} yr^{-1} for the surrounding 10 km). Minor reductions in NO_2 concentrations and N deposition, the latter largely associated with decreases in long-range transport of oxidised N, are estimated for the site towards 2030. The site is expected to no longer exceed the minimum critical load associated with the woodland features through UK-wide decreases in NO_x emissions projected for the 2030 baseline scenarios (Figure 3.8-9).

3.9 Glasgow Low Emission Zone (LEZ)

The following sections provide background on Glasgow LEZ and contain extracts of the UK scale model outputs centred on the site and a re-analysis of modelling carried out by SEPA for road transport, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.8.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.9.1 Site map and location within UK

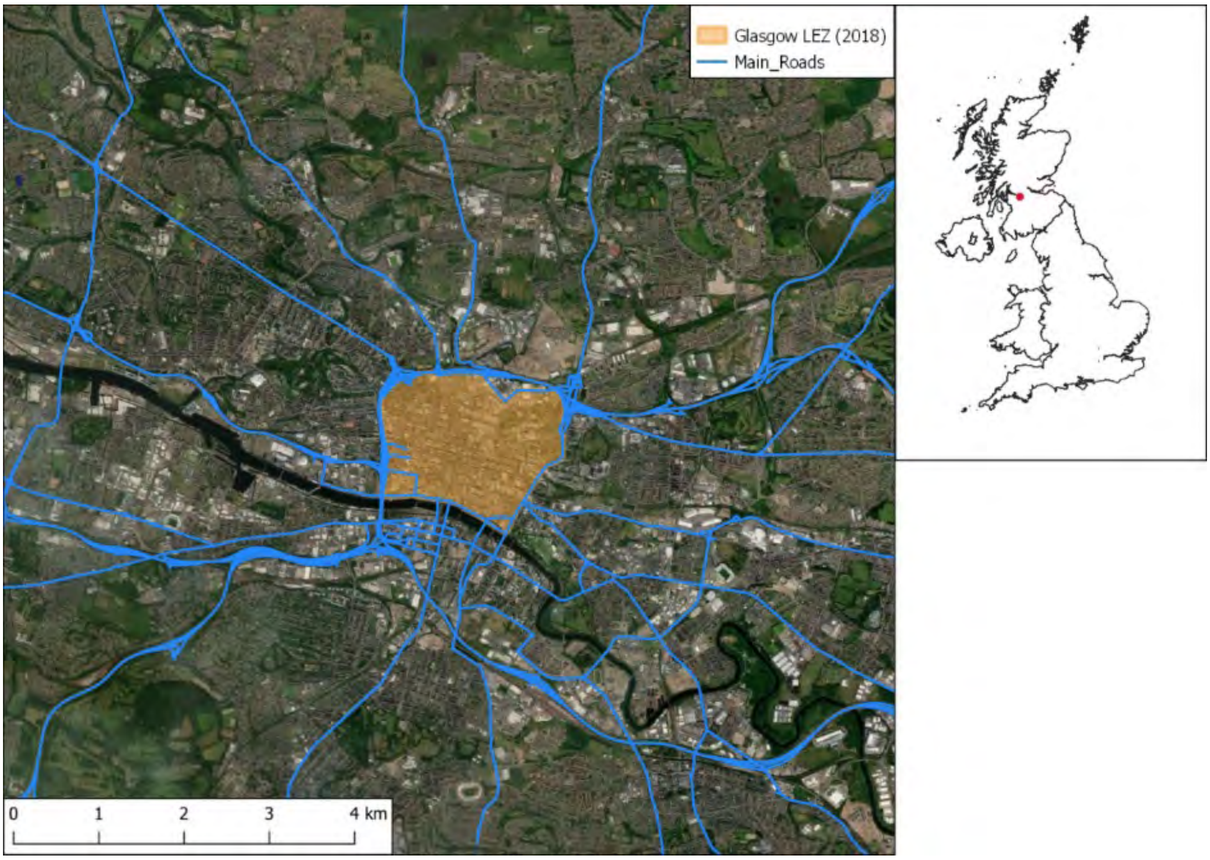


Figure 3.9-1. Site map showing relevant features and boundaries of Glasgow LEZ, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.9.2 Designated features

There are no designated habitats or features within this site.

3.9.3 Site characteristics

Glasgow City Council has declared an Air Quality Management Area (AQMA) covering the city centre for exceedances of the annual mean and 1-hour mean nitrogen dioxide objectives as well as the annual mean PM_{10} objective. These are objectives set by the Scottish Government to protect the health of particularly vulnerable members of the public. They do not relate to ecosystem protection. As a result of continued exceedances of these objectives, Glasgow City Council has implemented a Low Emission Zone (LEZ). This was Scotland's first LEZ and came into effect in Glasgow city centre on 31 December 2018. Initially the LEZ covers buses and is to be extended to cover all vehicles in 2022.

SEPA has undertaken detailed dispersion modelling of NO_x and NO_2 in Glasgow City Centre to provide evidence to support proposals for the LEZ (Malby, A (SEPA) 2020). The locations for which SEPA predicted roadside NO_x and NO_2 concentrations are shown in Figure 3.9-2. SEPA's modelling included all of the roads alongside these receptors, as well as other roads outside of the LEZ and was not restricted to the main roads shown in Figure 3.9.2. This modelling underpins the case study.

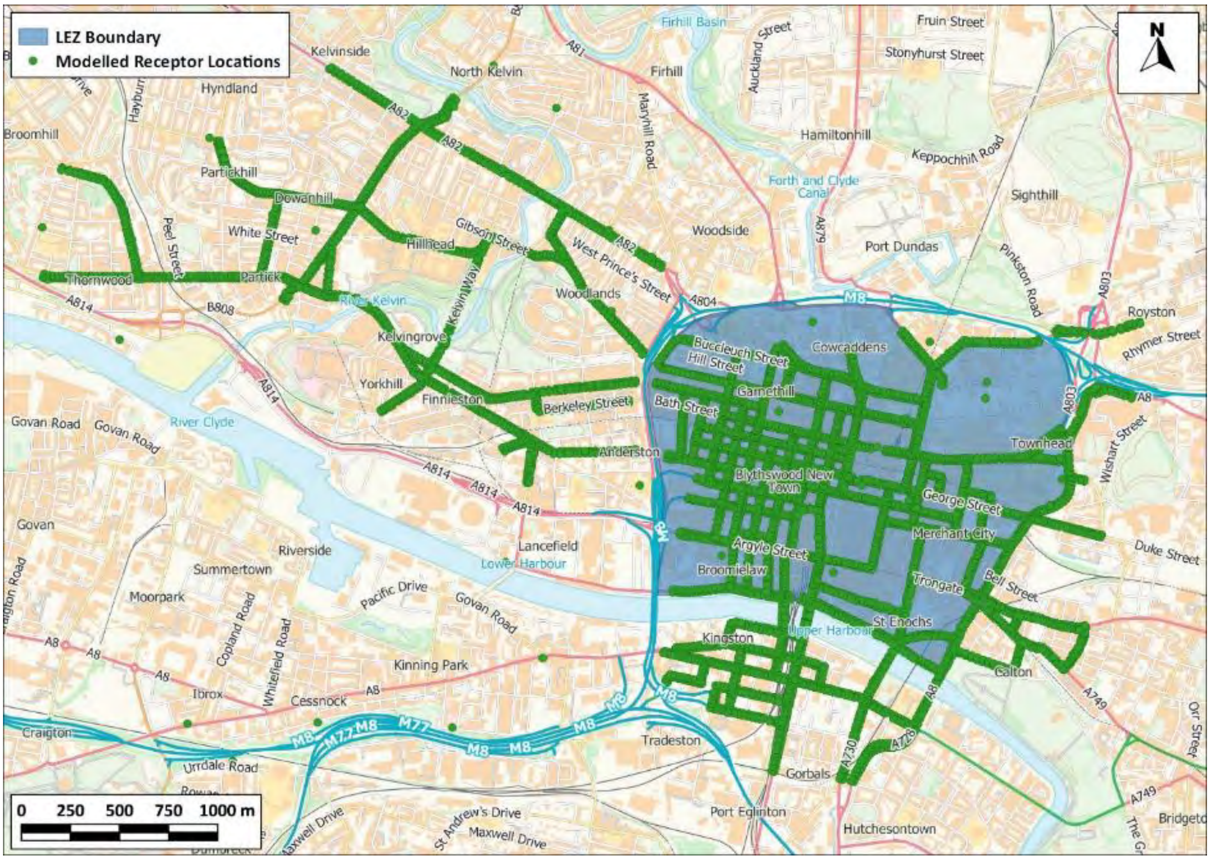


Figure 3.9-2. Modelled Receptor Locations for Glasgow LEZ.

3.9.4 Agricultural emission density

Agricultural emissions density is not relevant for this site.

3.9.5 Source attribution

Nitrogen deposition is of relevance when assessing impacts to sensitive habitats but not in respect of human health, where atmospheric pollutant concentrations are the key metrics. Therefore, the source attribution data (which refer to N deposition) are not relevant for this site.

3.9.6 NH_3 concentration

At typical ambient concentrations, NH_3 is not usually considered to be of direct concern to human health. NH_3 is of interest as a precursor to airborne particulate matter, but since this typically forms over large distances, localised concentrations are of less concern. Nevertheless, Figures 3.9-3 and 3.9-4 shows the 1 km x 1 km average annual mean NH_3

concentrations across the LEZ predicted by FRAME. Predicted concentrations are between 1 and 2 µg m^{-3} in the LEZ in all scenarios, with very little variation.

Figure 3.9-5 shows the spatial variation in receptor-specific roadside annual mean NH_3 concentrations in the 2017 baseline. The maximum concentrations are confined to the centre of the LEZ. Figure 3.9-6 shows the maximum predicted NH_3 concentrations at the roadside in each scenario. Local traffic emissions are predicted to elevate the roadside values to be well above those in the 1 km^2 average FRAME outputs, to be around 5 µgm^{-3} in all scenarios with very little variation. Because traffic-NH_3 is not a principal concern in relation to direct local effects on human health, no sensitivity testing of alternative future projections for traffic-NH_3 has been carried out.

Figure 3.9-3. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Glasgow LEZ and surrounding area.

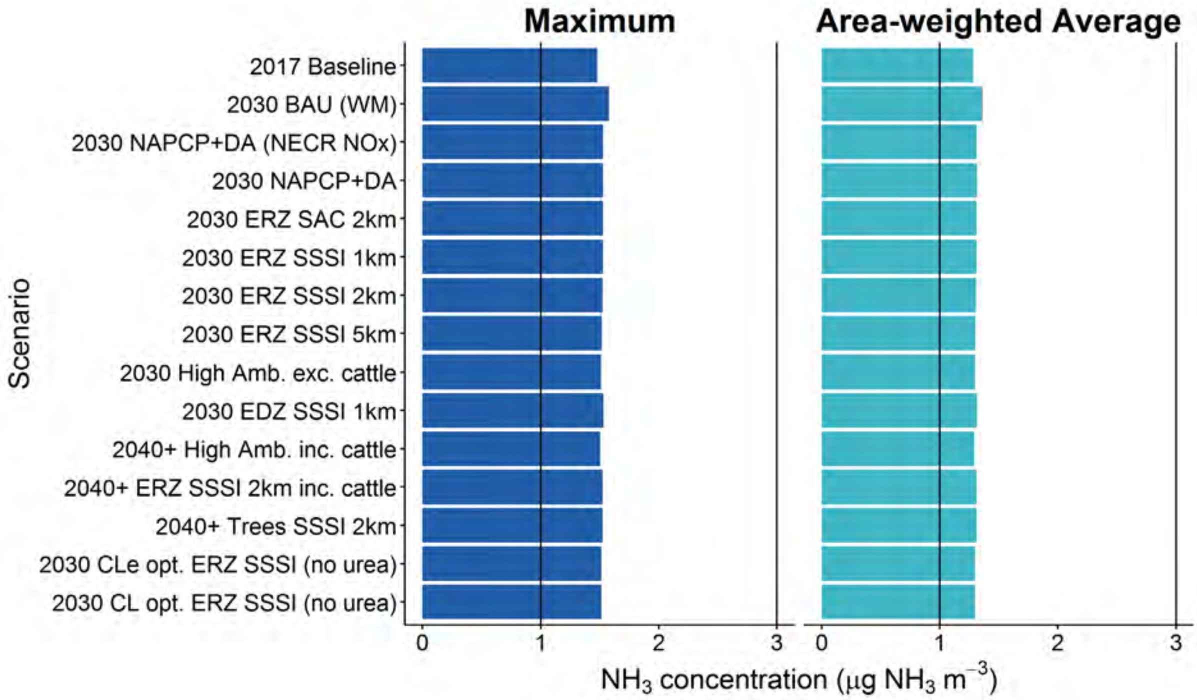


Figure 3.9-4. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Glasgow LEZ.

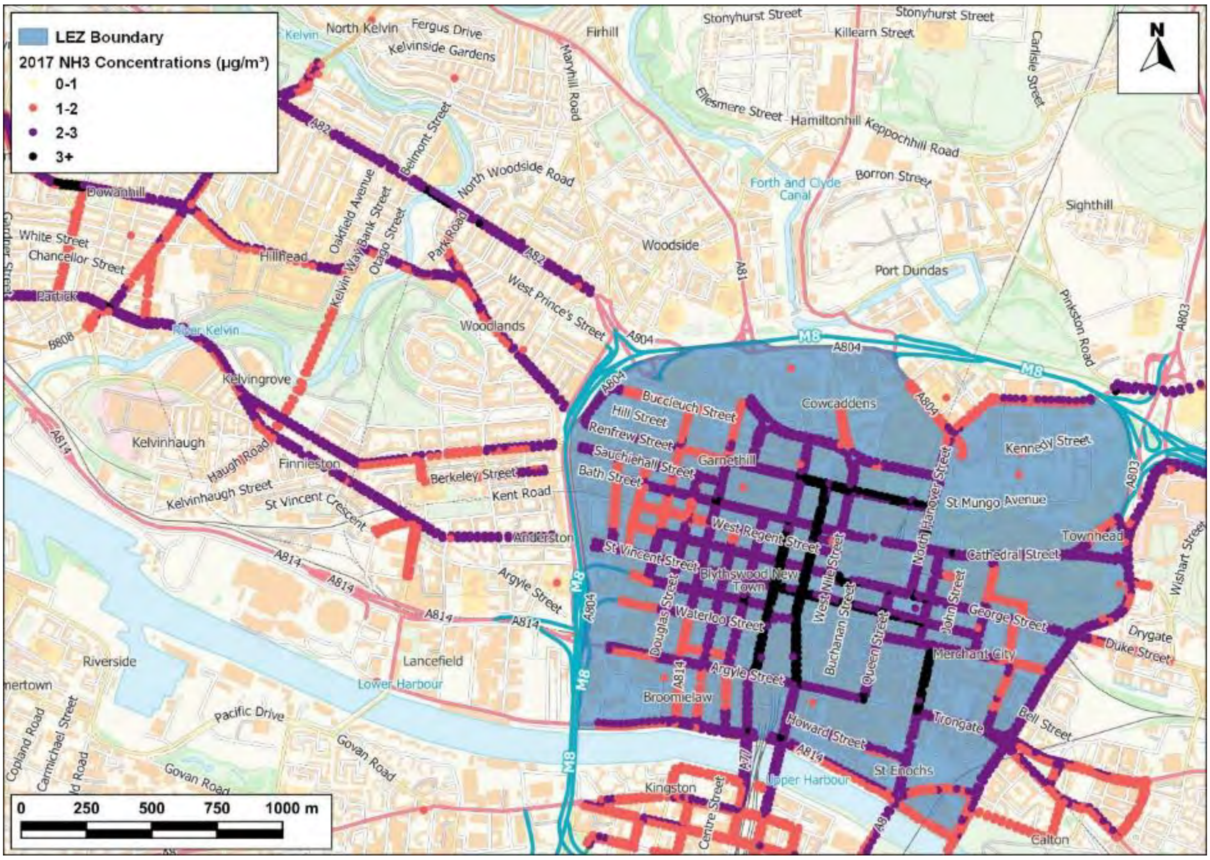


Figure 3.9-5. Location-specific 2017 baseline annual mean NH_3 concentrations within Glasgow LEZ.

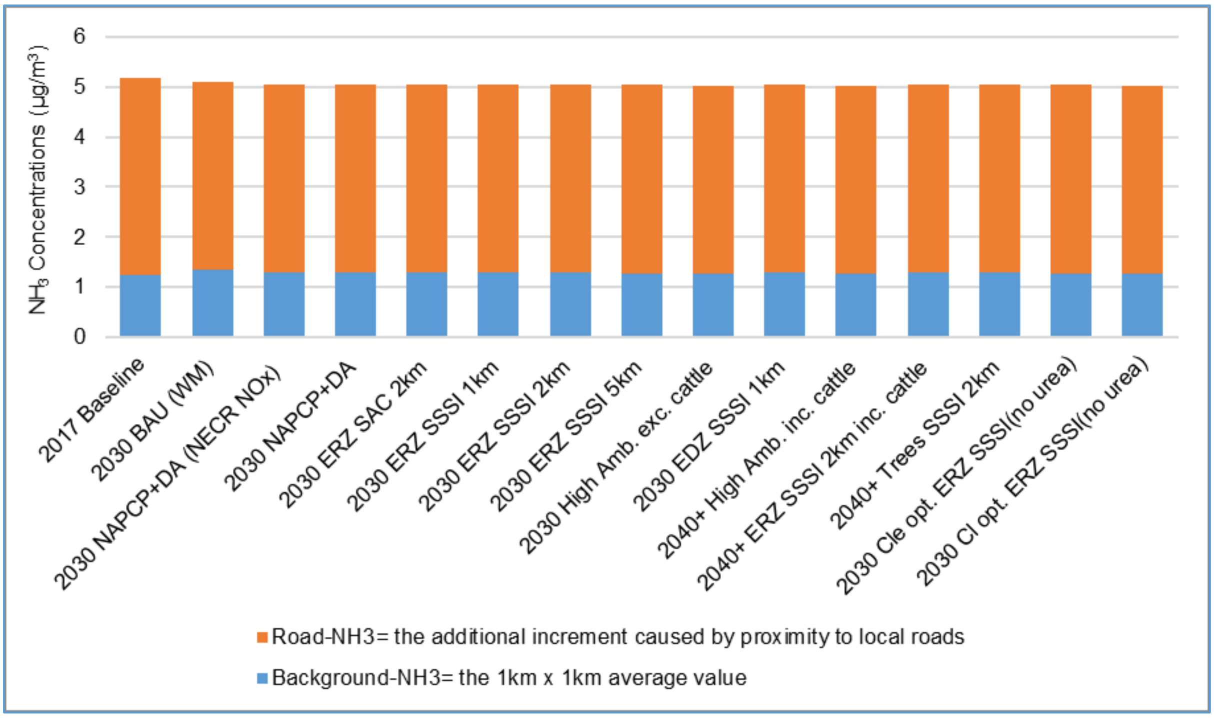


Figure 3.9-6. Maximum predicted annual mean NH_3 concentrations in Glasgow LEZ in each scenario.

3.9.7 NO_2 concentration

Results are presented for NO_2 concentrations as NO_2, rather than NO_x as the principal pollutant of concern for Glasgow LEZ. Figures 3.9-7 and 3.9-8 show the 1 km x 1 km average annual mean NO_2 concentrations predicted by FRAME. Significant decreases are predicted between the 2017 baseline and the 2030 BAU (WM) baseline, with smaller changes thereafter. None of the predicted 1 km^2 average concentrations are above the 40 µg m^{-3} objective for annual mean NO_2 concentrations.

The receptor-specific predicted NO_2 concentrations for the 2017 and 2030 BAU (WM) baselines are shown in Figure 3.9-9. The highest concentrations are confined to the centre of the LEZ, with exceedances of the 40 µg m^{-3} objective alongside roads in both scenarios. The area of exceedance of the human health air quality objectives is predicted to decrease significantly by 2030.

Figure 3.9-10 shows the change in predicted annual mean NO_2 concentrations when comparing the 2030 NAPCP+DA and 2040+ High Amb.inc.cattle scenarios with the 2030 BAU scenario. The largest decreases are in the centre of the LEZ where baseline concentrations are also highest, with up to a 9.1 µg m^{-3} reduction with 2030 NAPCP+DA compared to 2030 BAU (WM) and 13.8 µg m^{-3} reduction to 2040+ HighAmb.inc.cattle compared to 2030 BAU (WM).

The influence of each scenario on the maximum predicted NO_2 concentrations is shown in Figure 3.9-11. Maximum concentrations are predicted to reduce from more than 70 µgcm^{-3} in 2017 to less than 40 µg m^{-3} in all of the future-year scenarios except for 2030 BAU.

As explained in Section 1.4.2, this modelling is based on relatively simplistic scaling from current baseline modelling and will necessarily be less precise and accurate than scenario-specific dispersion modelling would be. It is also important to note that the modelling does not take any account of local measures introduced, for example, the implementation of the LEZ itself. However, in the 2030 BAU scenario, a large proportion of the vehicle fleet is assumed to conform with the latest (at the time of writing) European type-approval emissions standards; meaning that the effect of any LEZ-measures which promote the uptake of these vehicles will have been largely exhausted by 2030.

Figure 3.9-7. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Glasgow LEZ and surrounding area.

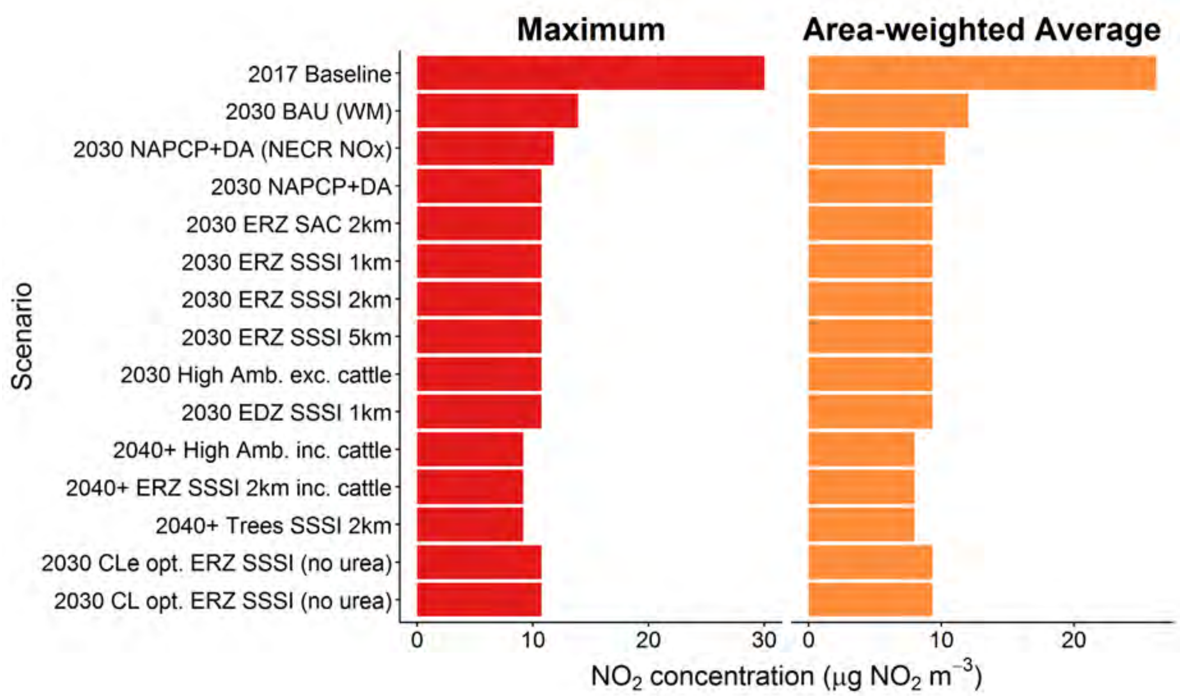


Figure 3.9-8. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Glasgow LEZ.

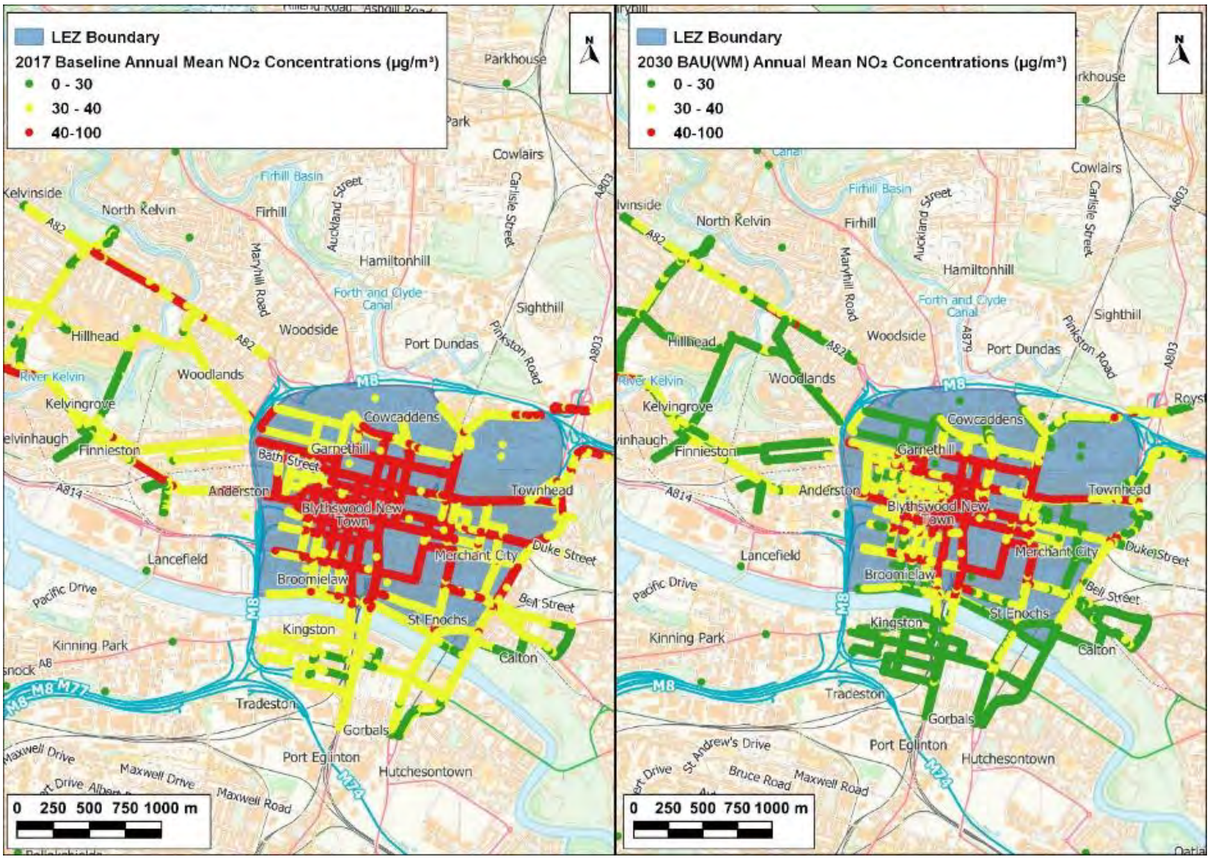


Figure 3.9-9. 2017 Baseline and 2030 BAU (WM) NO_2 Concentrations.
Contains Ordnance Survey data © Crown copyright and database right 2020. Ordnance Survey licence number 100046099. Additional data sourced from third parties, including public sector information licensed under the Open Government Licence v1.0.

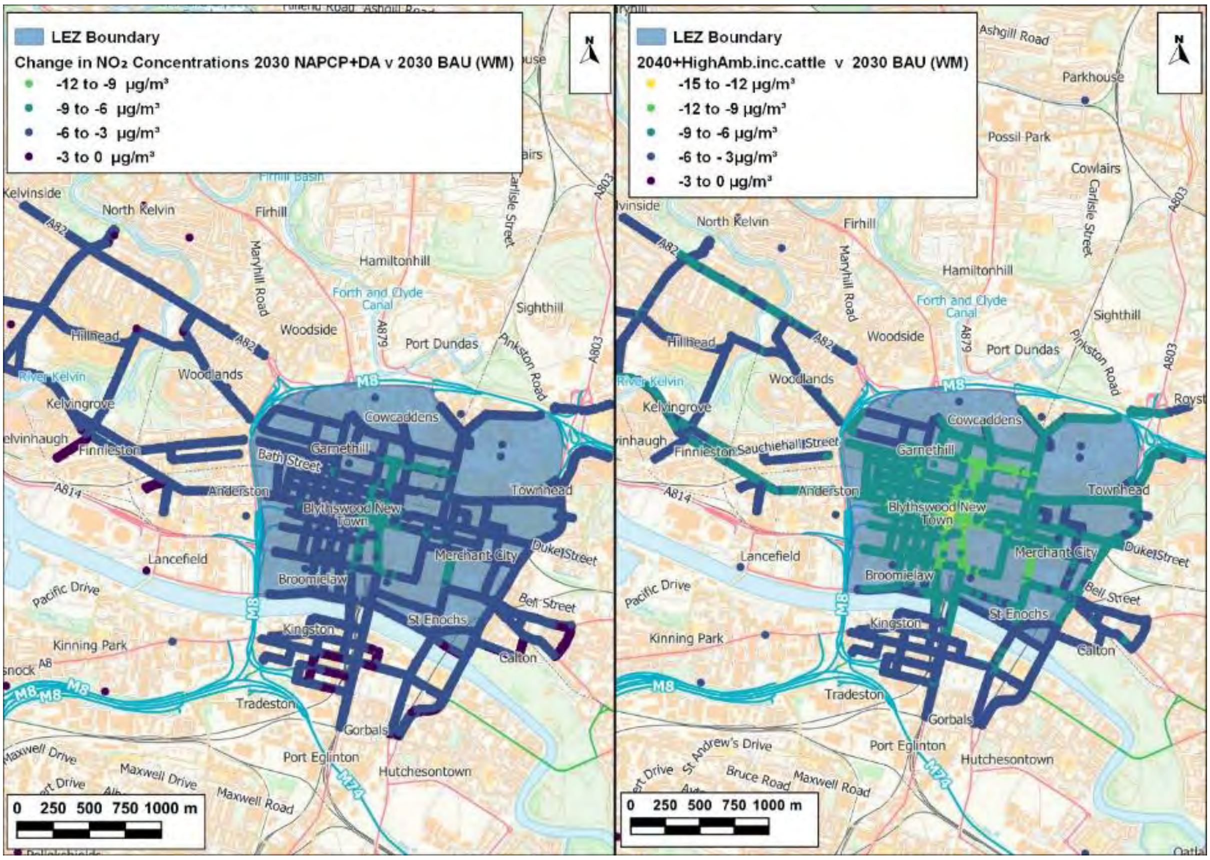


Figure 3.9-10. Change in annual mean NO_2 concentrations for 2030 NAPCP+DA and 2040+ High Amb.inc.cattle relative to 2030 BAU (WM).

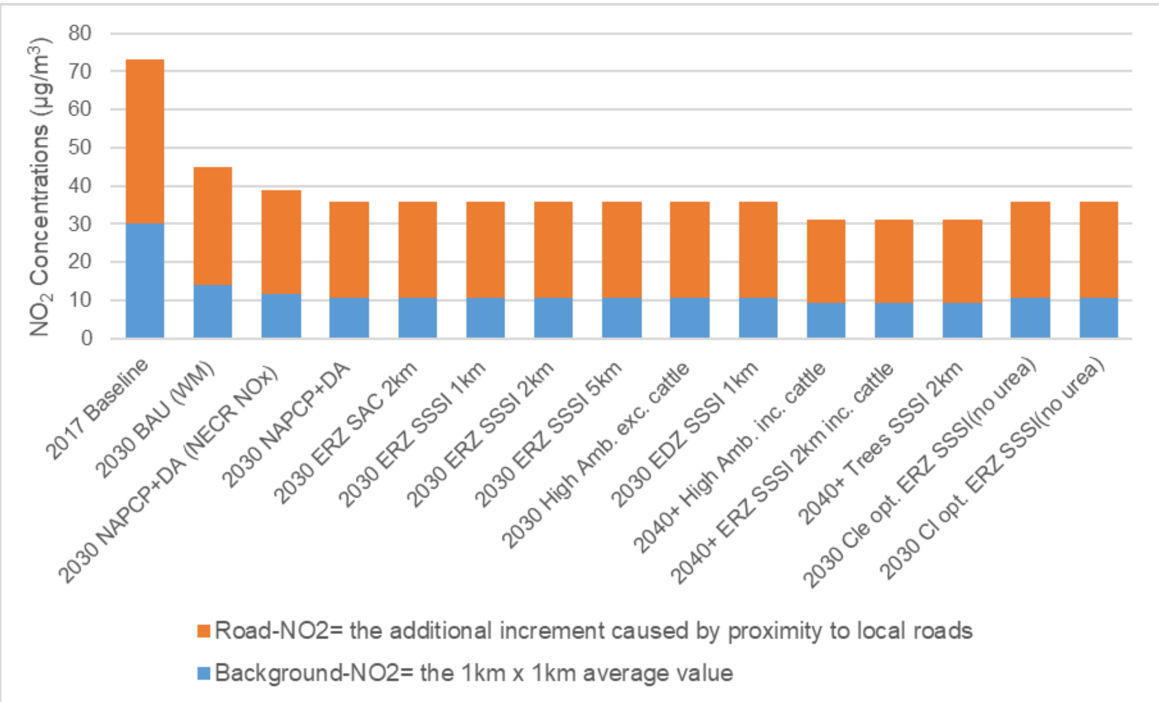


Figure 3.9-11 Maximum predicted annual mean NO_2 concentrations in Glasgow LEZ for each Scenario.

3.9.8 Exceedance of critical levels and loads

There are no critical levels or critical loads which are relevant to Glasgow LEZ. The modelling suggests that the annual mean NO_2 objective for human health will not be achieved in 2030 under the BAU scenario but will be achieved under the 2030 NAPCP+DA scenarios and each other future-year scenario tested.

3.9.9 Local assessment

Local emissions, from road traffic and other urban sources, are very important to air quality in Glasgow LEZ. Thus, those measures which assume blanket reductions in NO_x emissions, including from road transport, clearly have a positive effect on predicted annual mean NO_2 concentrations. Location-specific air quality predictions cannot, however, be made directly from 1 km x 1 km resolution model outputs.

3.9.10 Conclusions

Spatial targeting is likely to work for this site so long as the measures considered are urban-specific emissions-reduction strategies. The main spatially targeted scenarios tested in the current project focused on agricultural NH_3 emissions rather than sources close to or within the LEZ.

3.10 Whim Bog

The following sections provide background on Whim Bog and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.10.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.10.1 Site map and location within UK

Figure 3.10-1. Site map showing relevant features and boundaries of Whim Bog, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.10.2 Designated features

Table 18. Nitrogen sensitive interest features at Whim Bog SSSI from the APIS database (www.apis.ac.uk).

Feature	Critical Load
Lowland Raised Bog Blanket Bog	5 – 10 kg N/ha/yr

3.10.3 Site characteristics

Whim Bog SSSI[5] (southern Scotland) is one of the best examples of raised bog habitat in the Scottish Borders. This is despite the bog been subject to drainage and peat cutting in the past. It is one of just six lowland raised bogs in the Borders which remain intact to any

[5] https://sitelink.nature.scot/site/1625 (accessed April 2020)

degree. Plants typical of lowland raised bog occurring in the co-dominant heather-cotton grass vegetation include crowberry *Empetrum nigrum*, bog asphodel *Narthecium ossifragum*, round-leaved sundew *Drosera rotundifolia* and cranberry *Vaccinium oxycoccus*. Nine species of bog moss *Sphagnum* are also known to be present, including the rare *S.fuscum*. Birch woodland has colonised from peripheral areas of wet woodland at the east end of the site and Scots pine is naturally colonising the southern edge. The pine area includes juniper *Juniperus communis* which is extremely local in the area.

Ammonia emissions are highly spatially variable in the area surrounding Whim Bog, with intensive poultry farming intermixed with extensive beef cattle and other areas with more extensive sheep grazing, such as to the west and northwest of the site (i.e. the area known as Auchencorth Moss). UKCEH carried out an intensive measurement and modelling study at this site in 2007-2008 (Vogt *et al.* 2013).

3.10.4 Agricultural emission density

Emission density data for this site are not shown here, due to the highly unusual local constellation of very large poultry emission point sources, which are a) disclosive for the innermost concentric zones (i.e. contain information from less than 5 farms and can therefore not be shown) and b) an issue with the post code allocation of several holding locations not resulting in a realistic distribution.

3.10.5 Source attribution

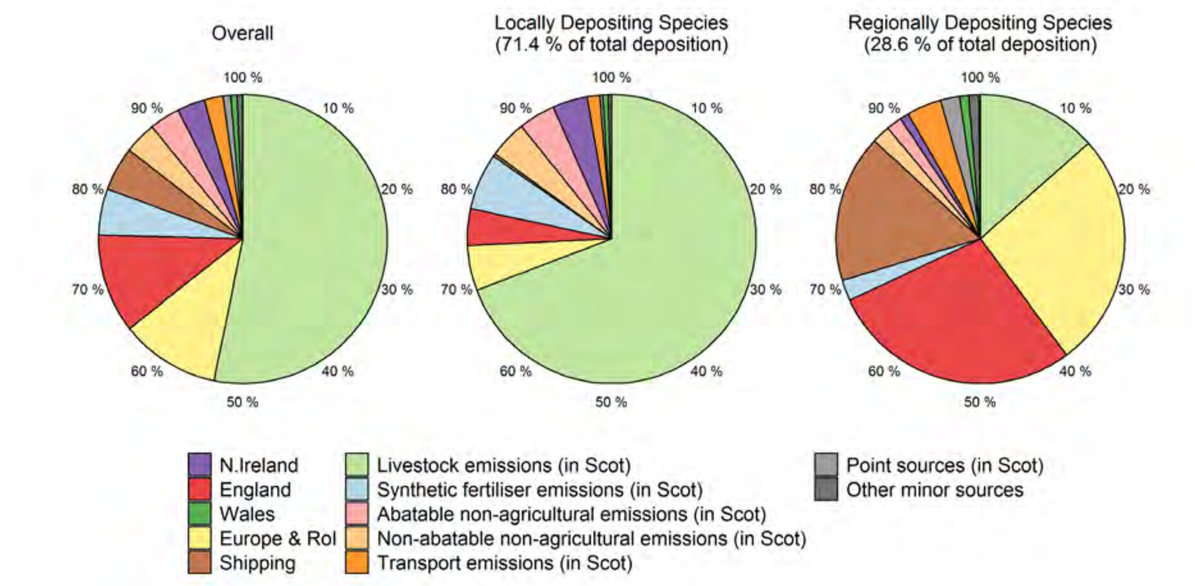


Figure 3.10-2. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Whim Bog SSSI.

3.10.6 NH3 concentration

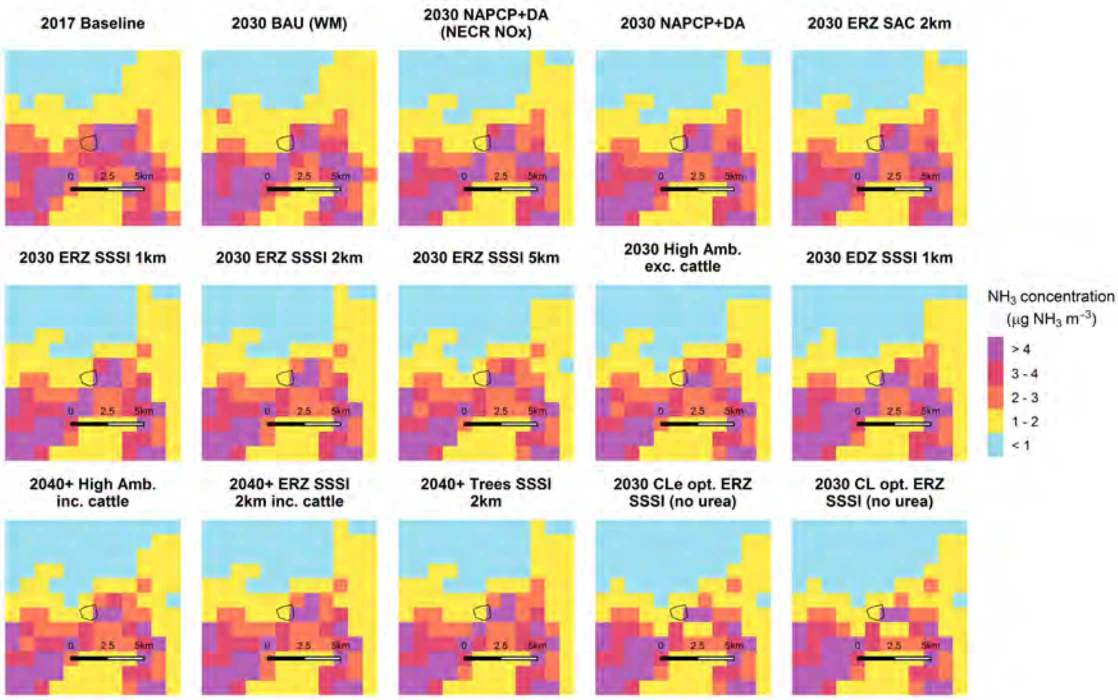


Figure 3.10-3. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Whim Bog SSSI and surrounding area.

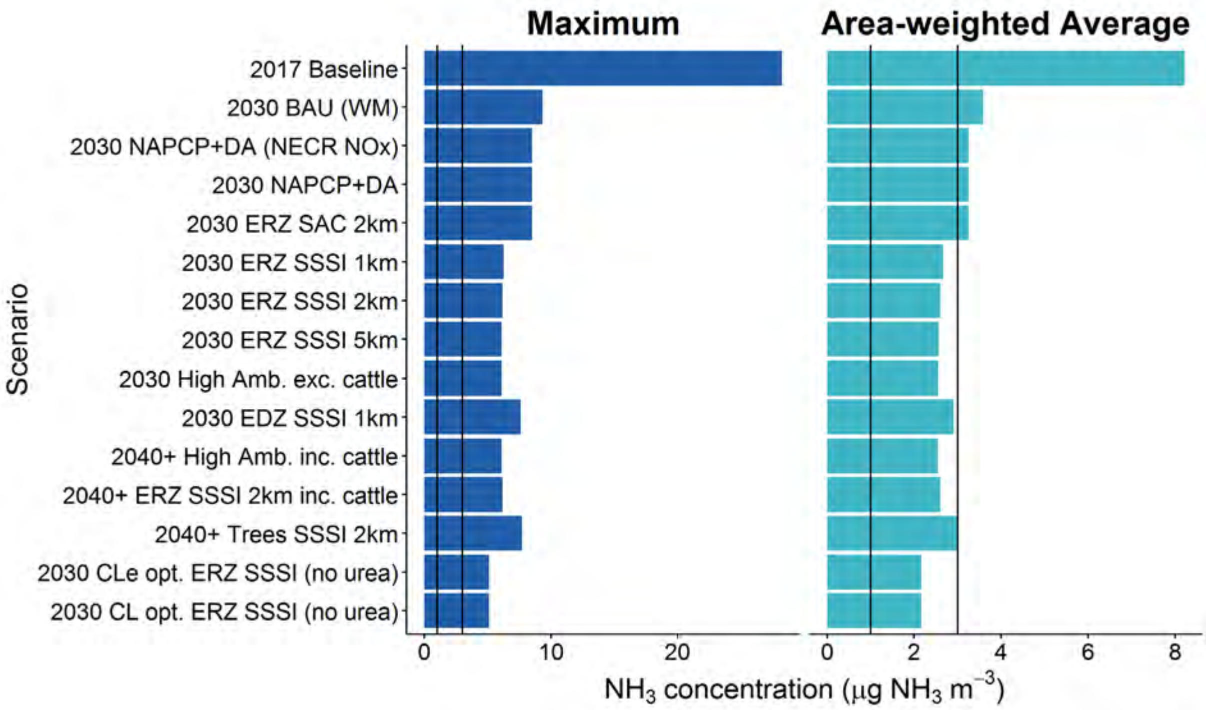


Figure 3.10-4. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Whim Bog SSSI. Vertical lines indicate 1µg and 3µg critical levels.

3.10.7 NO_2 concentration

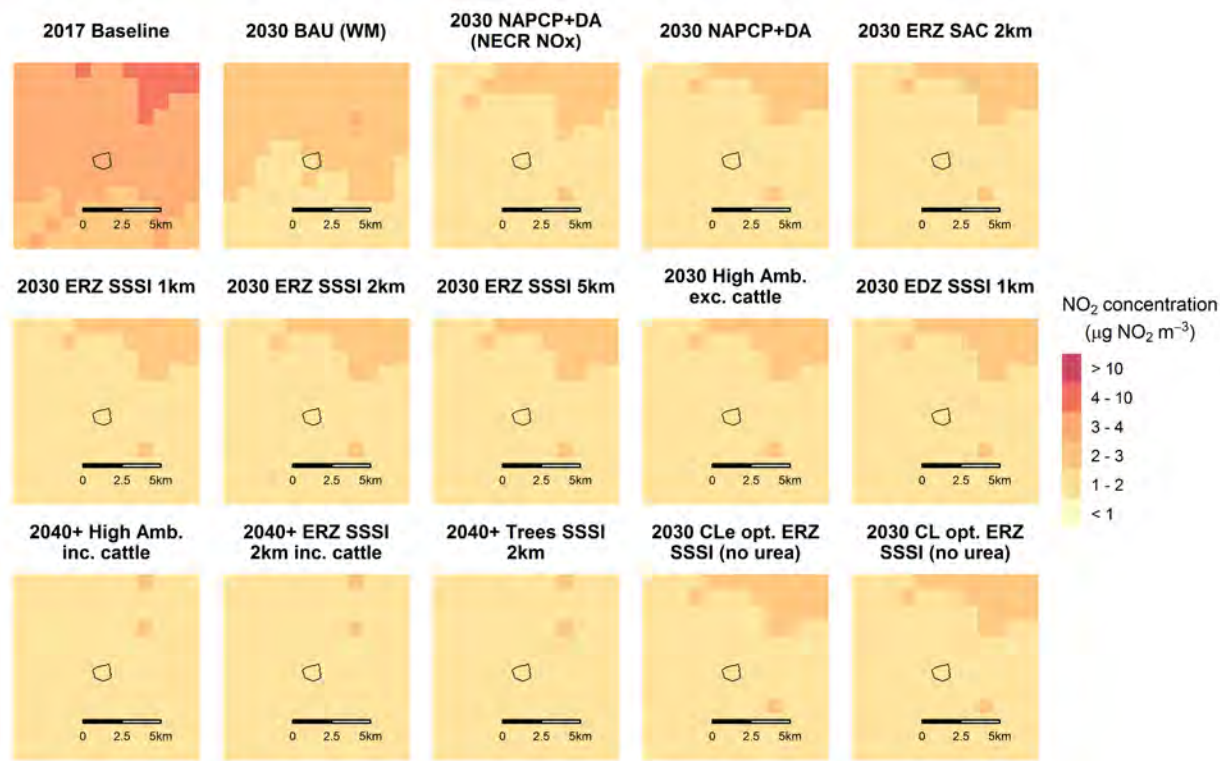


Figure 3.10-5. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Whim Bog SSSI and surrounding area.

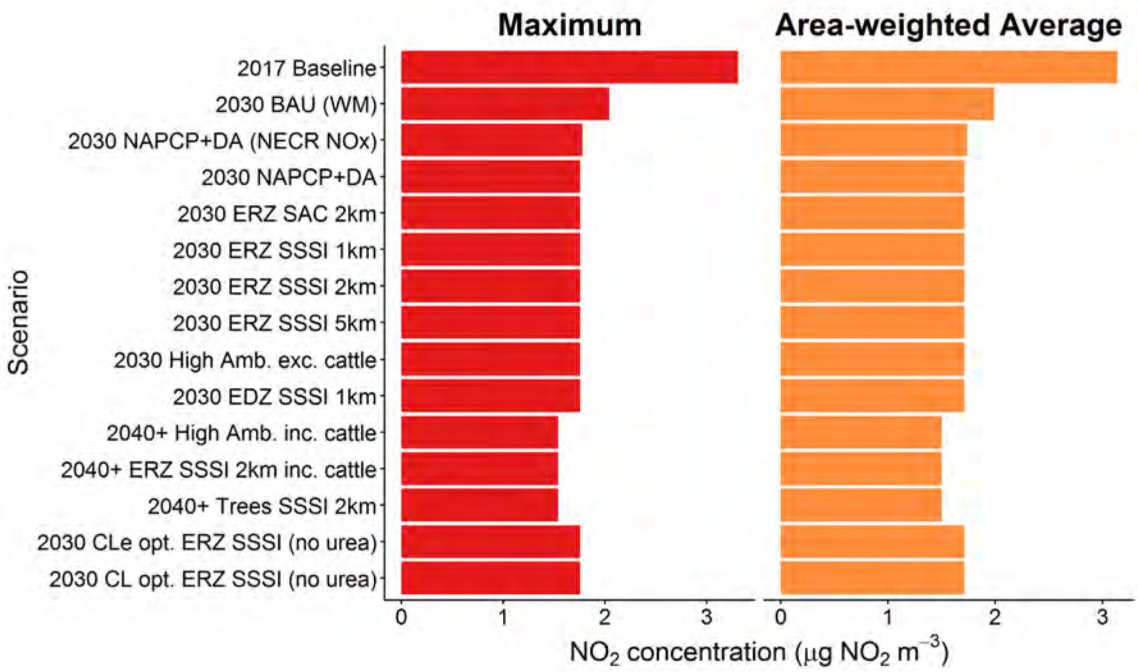


Figure 3.10-6. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Whim Bog SSSI.

3.10.8 N deposition

Figure 3.10-7. N deposition (to low-growing semi-natural vegetation) received by Whim Bog SSSI and surrounding area.

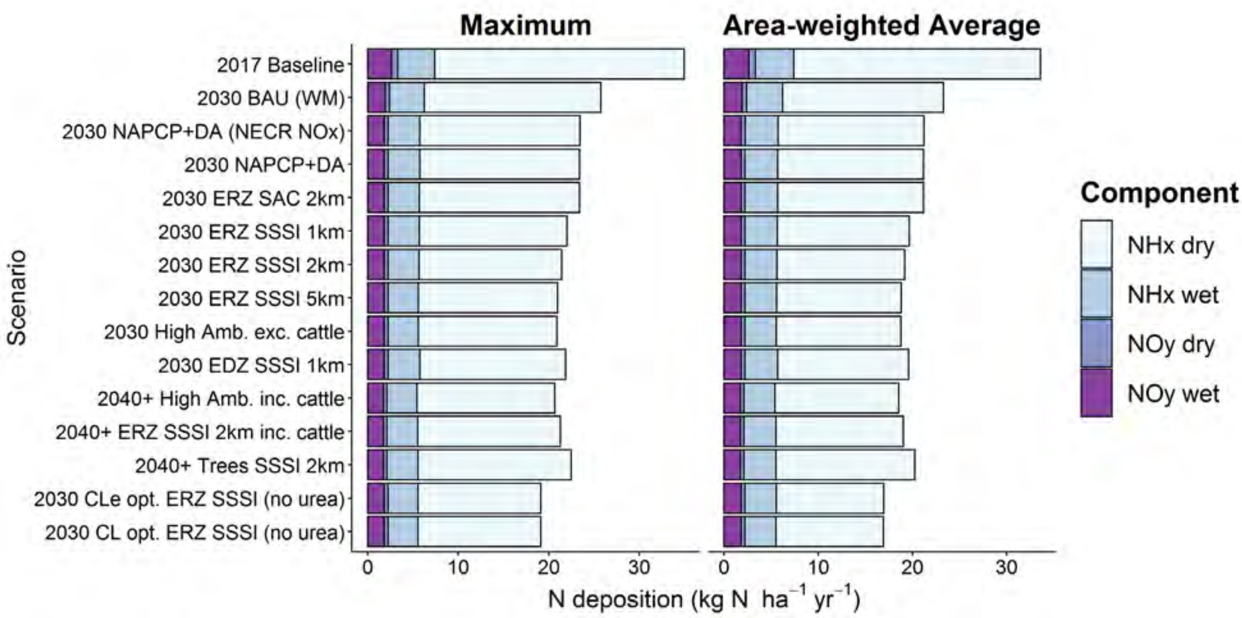


Figure 3.10-8. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Whim Bog SSSI.

3.10.9 Exceedance of critical loads

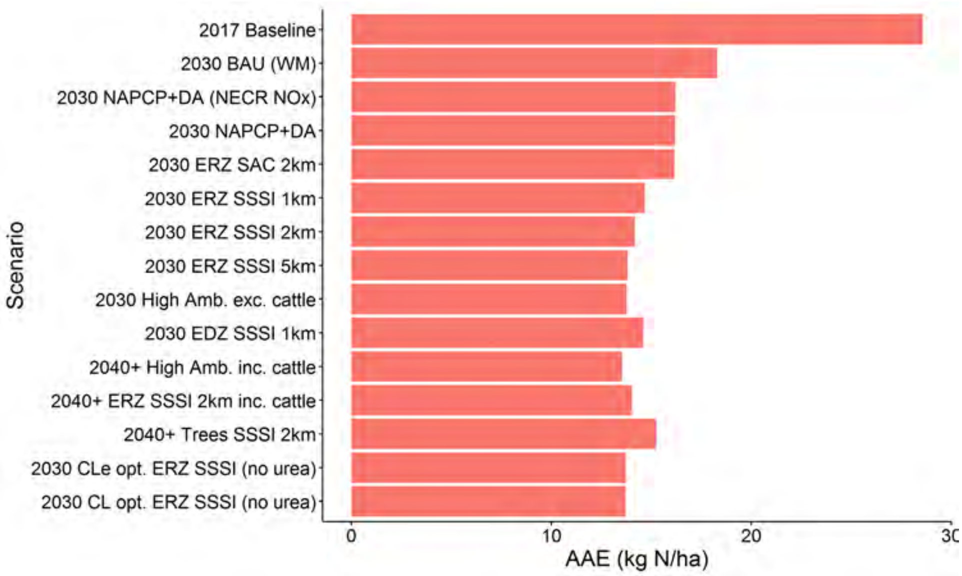


Figure 3.10-9. Exceedance of critical loads by scenario at Whim Bog SSSI.

3.10.10 Local assessment

Whim Bog is situated in an area with intensive local agricultural activity, due to the presence of several large poultry enterprises (above the IED threshold). There are large numbers of poultry houses within the local area, and the estimated resulting agricultural emission densities in the adjacent buffer zones are high (however, details cannot be shown here due to issues with the detailed data as detailed in Section 3.10.4).

The high density of poultry farms around Whim Bog provides an extreme example to illustrate several limitations of the UK-scale modelling approach, some of which are currently being addressed, whereas others are genuine limitations that cannot be resolved given the current information and data availabilities for this type of modelling in the UK. The main points are:

- The poultry farms in the study area are applying advanced mitigation measures, as required under the IED, i.e. Best Available Technology. Many of the poultry houses are, for example, equipped with belt systems for manure removal that are frequently cleaned, and much of the manure is exported from the area to further afield (loaded directly from the belts in a clean operation). Therefore, the emissions predicted by the model, from local operations, are assumed a very large overestimate, given current practice at the farms.

- Poultry emission factors – current emission factors for laying hen housing are not representative of more modern housing systems (enriched and colony cage systems, single-tier and multi-tier free range systems). New emission factors for these housing types have been derived and will be applied in the 1990-2019 emission inventory. The new emission factors are based on more recent measurements (Defra AC0123[6]) and a revised emission reduction factor for in-house poultry litter drying systems, of 60%, compared to the previous 30% reduction. The new housing emission factors are lower than those representing the older laying hen systems (by 30 – 70%). Therefore, the currently used emission factors in this project are very likely resulting in further

[6] Unpublished.

overestimation of emissions from the local farms, in addition to the BAT already known to be in place for the majority of the poultry housing in the study area.

- The high-resolution emission model used to create the 1 km by 1 km grid data (AENEID, see Annex 4 for detailed description) uses a statistical approach to estimate local emissions, by combining high-resolution agricultural statistics (at a parish level) with land cover and agricultural practice information and emission factors. This approach generally works well for diffuse emission sources, such as landspreading of manures, mineral fertiliser applications and livestock grazing. For livestock housing and associated manure storage emissions, this approach necessarily dilutes and smooths out what are often local “hotspots” in the landscape, but is the best available, given the limitation of spatial location data across the UK. This is mostly an issue for larger pig and poultry farms where emissions are concentrated on large hotspots of animal housing and manure storage facilities, more so than for cattle, where emissions are more land-based and diffuse, by comparison. A further important point here is the data licensing agreements for using these detailed data, which require information from at least five holdings to be combined to protect the confidentiality of these datasets, to meet the non-disclosive requirements for any output.

For the Whim Bog case study in particular, the limitations of the 1 km grid national modelling approach can be detailed further:

- Although overall emissions under 2030 High Amb. exc. cattle (and the ERZ scenarios) are lower than NAPCP+DA for the area, the measures to reduce poultry emissions are mainly aimed at housing systems. This decrease in housing emissions may translate to increased N content in poultry manure, which in turn may increase storage/spreading emissions (depending on the systems in place). The AENEID methodology uses land cover data to spatially distribute emissions across the local zones (civil parishes), based on the association of land cover types with activities such as livestock housing and manure storage, manure spreading and livestock grazing (e.g. stocking density of grazing livestock is weighted for extensive/rough grazing). At the national scale, this is useful as emissions are mainly distributed to good agricultural land (arable and improved grassland), with only low-density cattle and sheep grazing emissions in the uplands. Any emission increases associated with increased N content of manure will be more noticeable in areas with a wide range of land cover types which are associated with the different emission activities (such as the area around Whim Bog). This is particularly noticeable in unusual areas such as around Whim Bog, where a single livestock sector dominates, at high emission densities, rather than the more complex interplay in more mixed farming areas, with more diffuse sources. When comparing different emission scenarios, this may result in local emission increases in individual 1 km grid squares in more ambitious scenarios, compared with the baseline, despite overall emission decreases over the wider area. This is due to the local allocation of emissions to particular land cover types in the statistical approach of AENEID. The detailed spatial patterns of emissions should therefore be assessed with caution in highly unusual areas such as around Whim Bog.

- A previous landscape scale case study included both detailed monitoring of atmospheric NH_3 concentrations over 18 months (2007-2008) and modelling of emission sources, concentrations and N deposition for a 6 km by 6 km area including Whim Bog (Vogt *et al.* 2013). This study illustrated very clearly how the UK-scale modelling aggregates and smooths out the individual emission sources located across the fields and farms in each 1 km grid cell, with a large number of poultry houses (layers) and extensive upland sheep and cattle farming. This example illustrates both the potential for very high spatial variability of NH_3 emissions and concentrations over a short distance, and the associated opportunity for local spatial targeting to make a difference. Since the case study was carried out, further local NH_3 emission sources have been established, therefore Figure 3.10-10 for 2007/8 cannot be directly compared with Figure 3.10-3 for 2017.

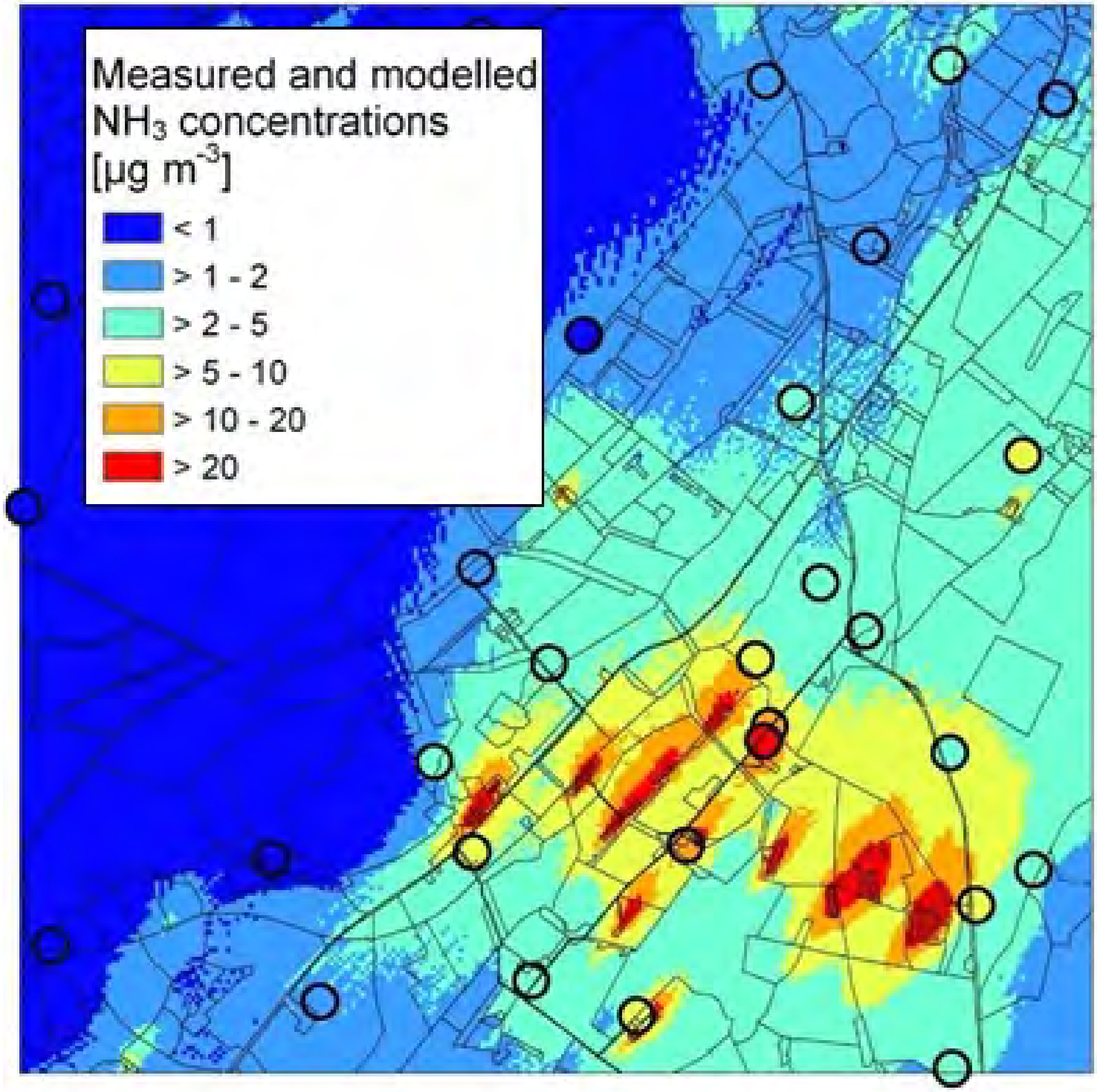


Figure 3.10-10. Annual average modelled (grid) and measured (circles) ammonia concentrations in a landscape in southern Scotland (6 km by 6 km). After Vogt *et al.* 2013.

3.10.11 Conclusions

Notwithstanding the limitations and caveats associated with the various derived national datasets applied here for the very unusual case of the emission sources surrounding Whim Bog, this case study has provided a good example of why and how spatial targeting of measures is an appropriate strategy for N-sensitive designated sites in high-density emission areas. The assessment illustrates how important it is to take account of local concentration gradients above the wider regional background at a landscape scale, to include detailed information on local practice in use and mitigation measures already in place.

3.11 Ballynahone Bog and Curran Bog

The following sections provide background on Ballynahone Bog and Curran Bog and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.11.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.11.1 Site map and location within UK

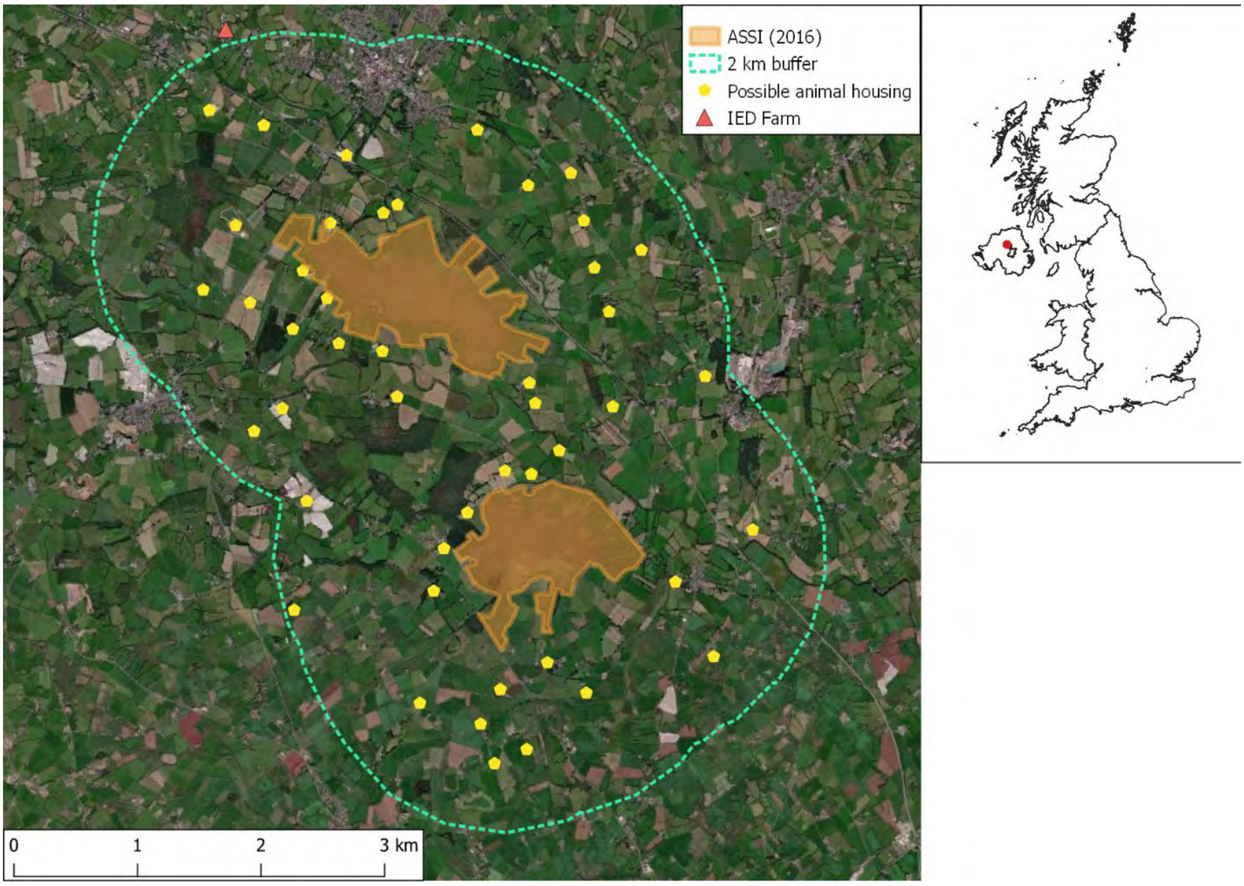


Figure 3.11-1. Site map showing relevant features and boundaries of Ballynahone Bog (northern site) and Curran Bog (southern site), and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.11.2 Designated features

Table 19. Nitrogen sensitive interest features at Ballynahone Bog ASSI and Curran Bog ASSI from the NIEA database (provided by Aine O'Reilly, pers. comm.).

Feature	Critical Load
Active raised Bog/Lowland Raised Bog	5 – 10 kg N/ha/yr
Invertebrate assemblage	

3.11.3 Site characteristics

Ballynahone Bog is one of the two largest intact active raised bogs/lowland raised bog in Northern Ireland, with hummock and hollow pool complexes. A current NIEA project by UKCEH is modelling and measuring NH_3 concentrations on and around the bog, to determine the levels of atmospheric N input and advise on potential mitigation strategies. This project is embedded in wider DAERA-funded work where separate spatially targeted mitigation scenario modelling across Northern Ireland is ongoing (unpublished).

Curran Bog is an example of lowland raised bog, which despite extensive turf cutting around its edge supports a high cover of *Sphagnum (*indicating active peat growth) and well-developed surface patterning (i.e. pool, hummock and hollow complexes).

The two ASSIs are embedded in an intensive lowland agricultural landscape with cattle, pig and poultry farming very close to the sites, and associated NH_3 emissions.

3.11.4 Agricultural emission density

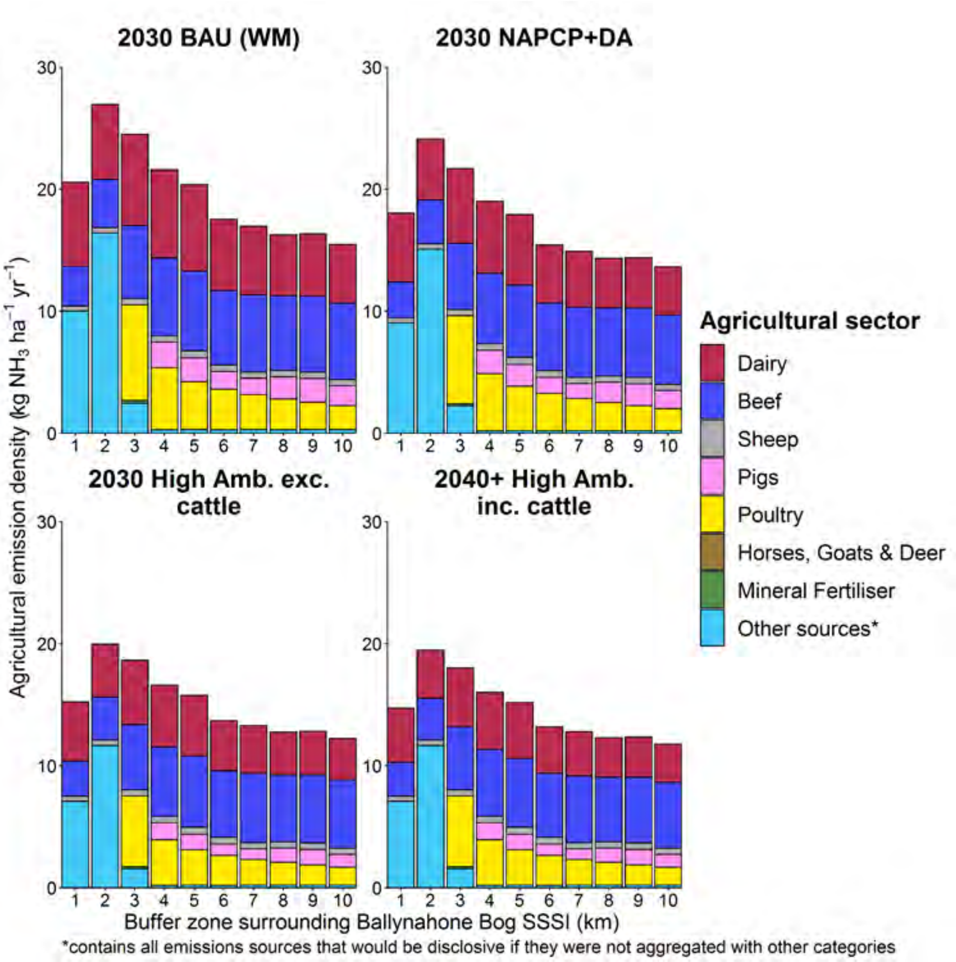


Figure 3.11-2. Estimated agricultural emission densities in concentric buffer zones surrounding Ballynahone Bog ASSI.

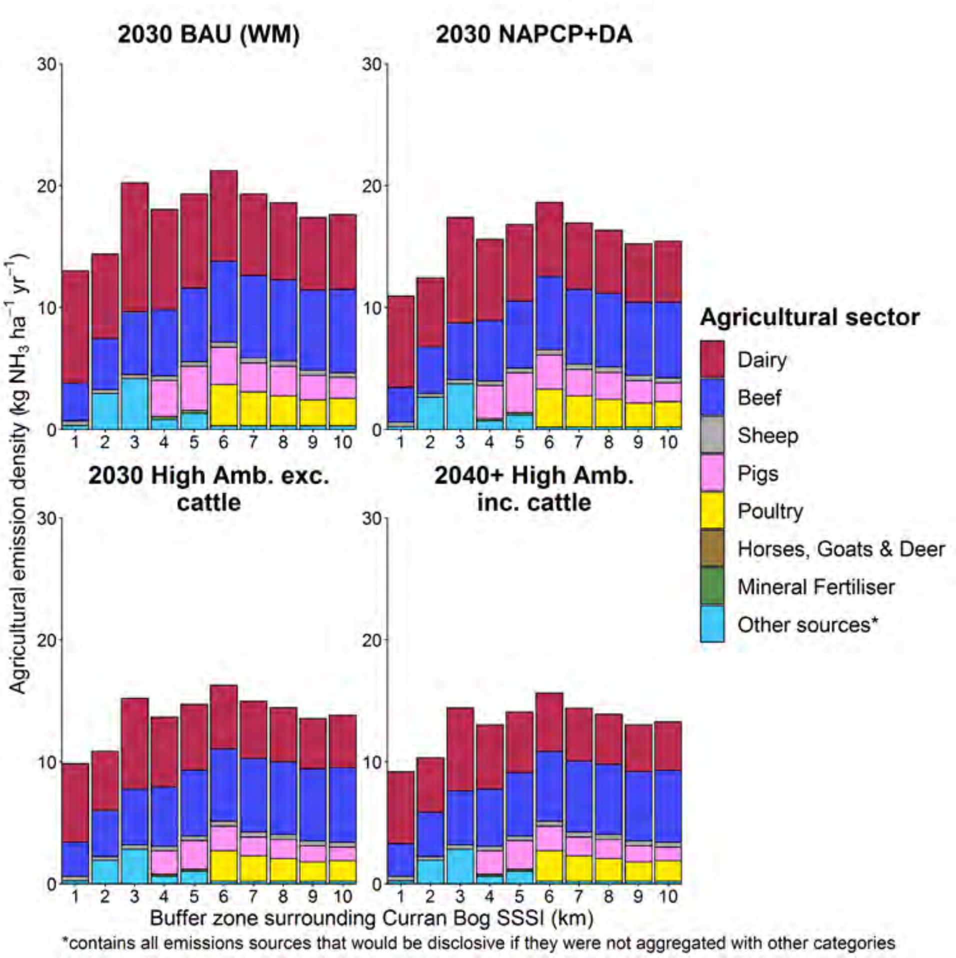


Figure 3.11-3. Estimated agricultural emission densities in concentric buffer zones surrounding Curran Bog ASSI.

3.11.5 Source attribution

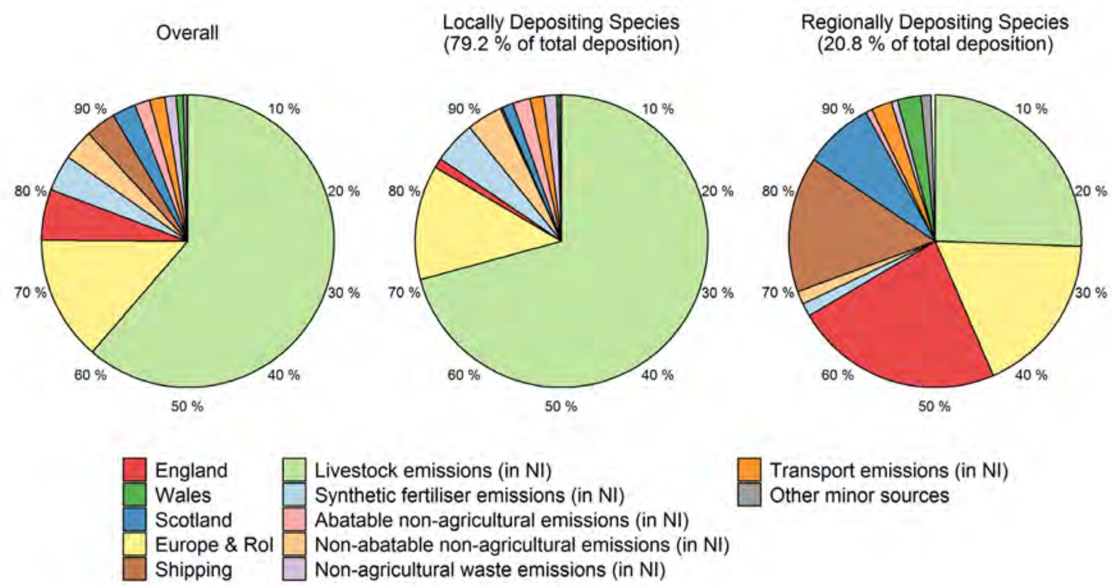


Figure 3.11-4. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Ballynahone Bog ASSI and Curran Bog ASSI.

3.11.6 NH_3 concentration

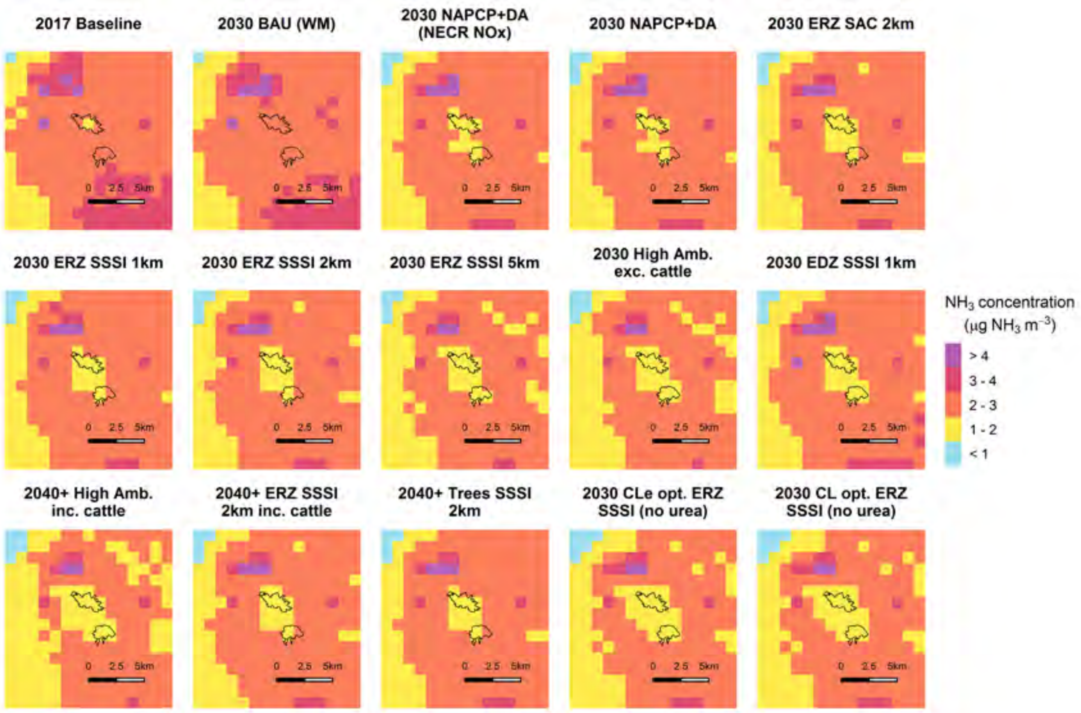


Figure 3.11-5. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Ballynahone Bog ASSI and Curran Bog ASSI and surrounding area.

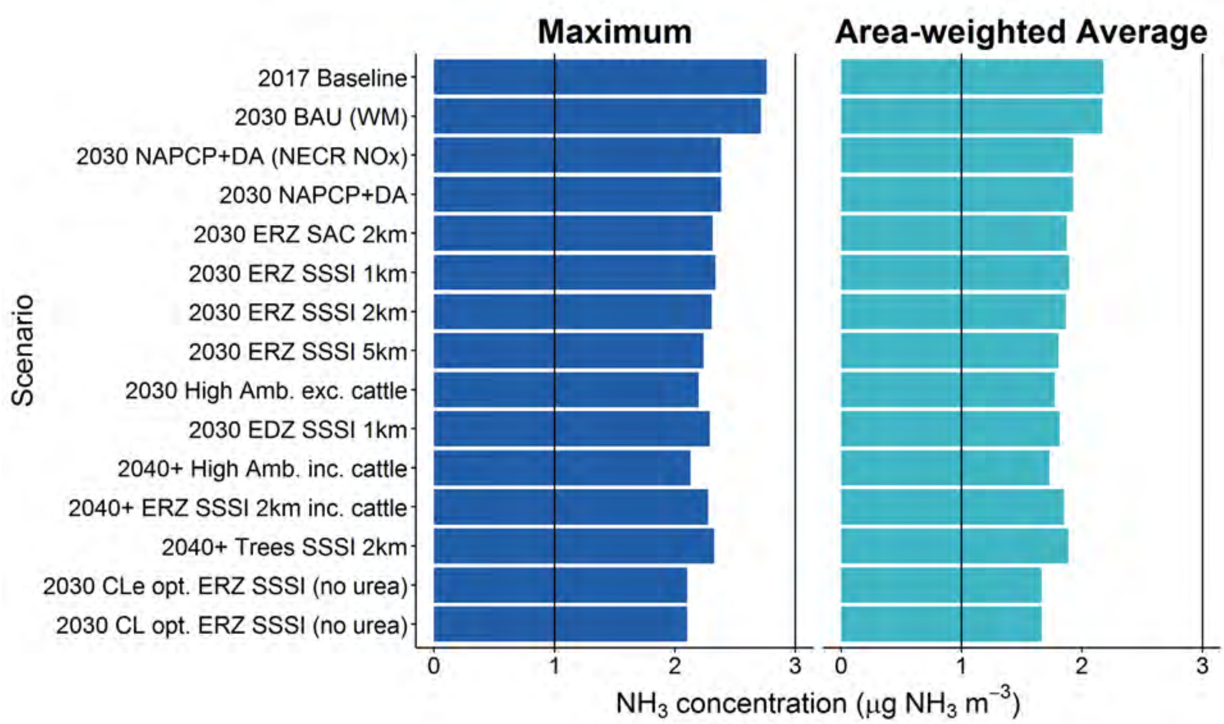
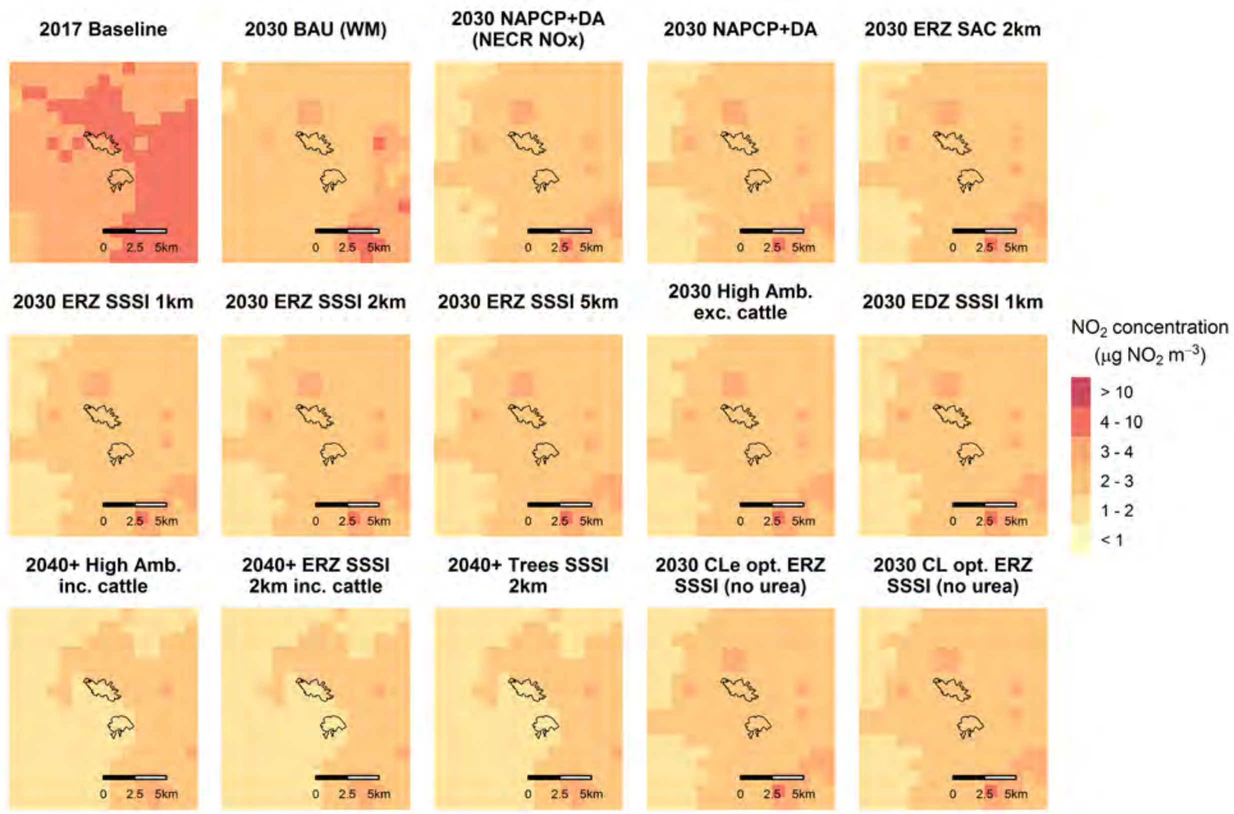


Figure 3.11-6. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Ballynahone Bog ASSI and Curran Bog ASSI. Vertical lines indicate 1µg and 3µg critical levels.

3.11.7 NO_2 concentration



3.11-7. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Ballynahone Bog ASSI and Curran Bog ASSI and surrounding area.

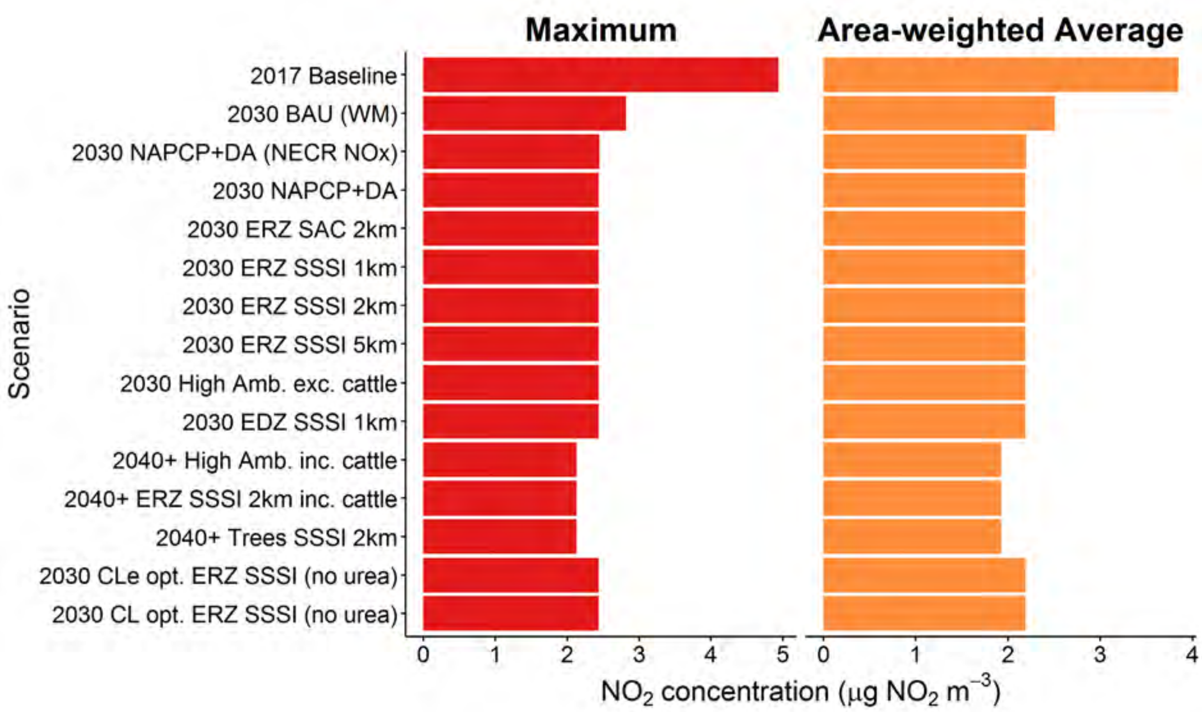


Figure 3.11-8. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Ballynahone Bog ASSI and Curran Bog ASSI.

3.11.8 N deposition

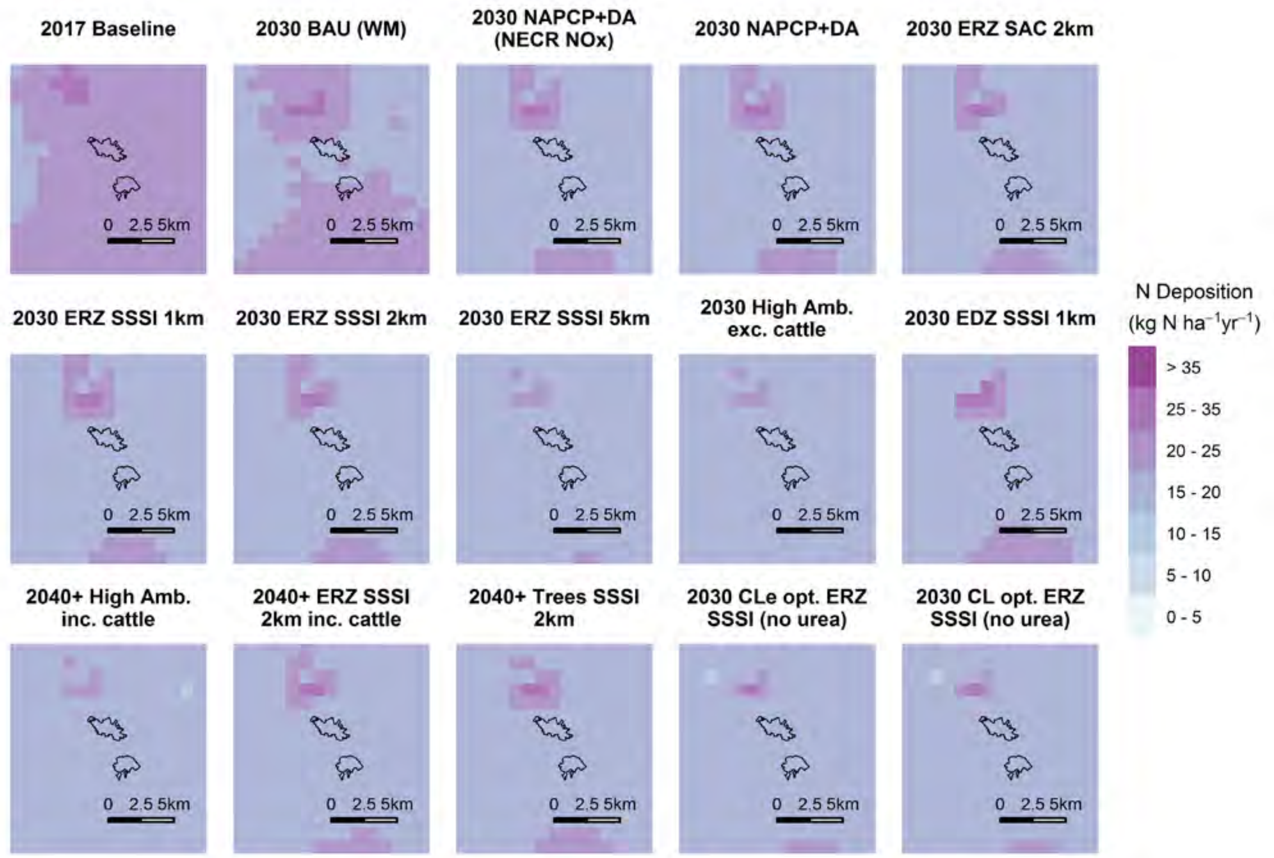


Figure 3.11-9. N deposition (to low-growing semi-natural vegetation) received by Ballynahone Bog ASSI and Curran Bog ASSI and surrounding area.

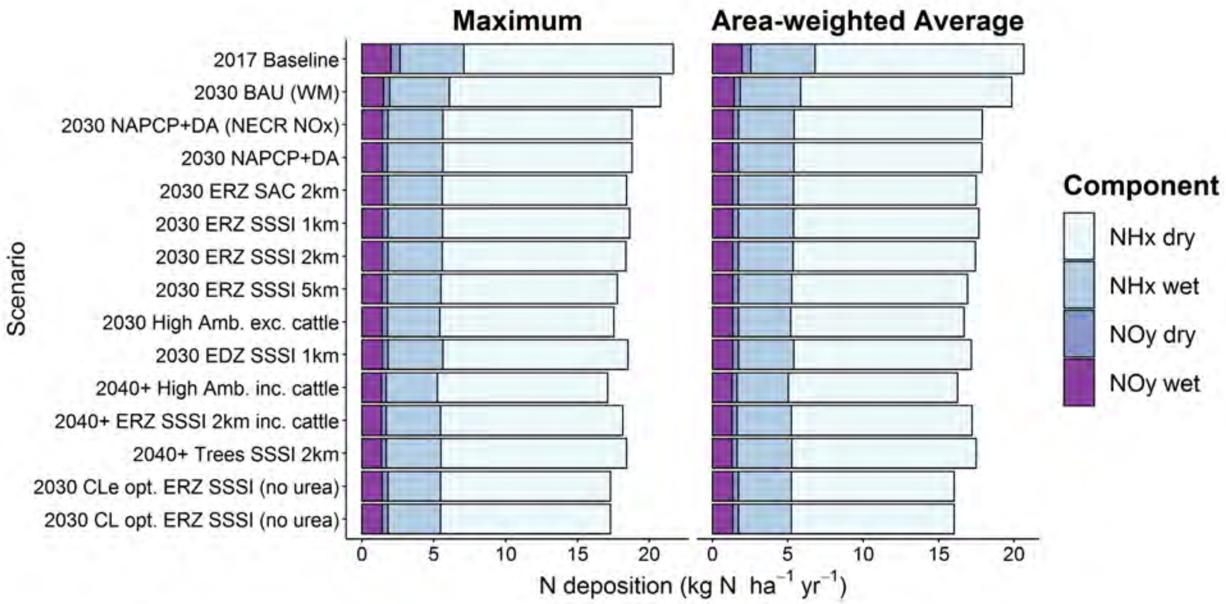


Figure 3.11-10. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Ballynahone Bog ASSI and Curran Bog ASSI.

3.11.9 Exceedance of critical loads

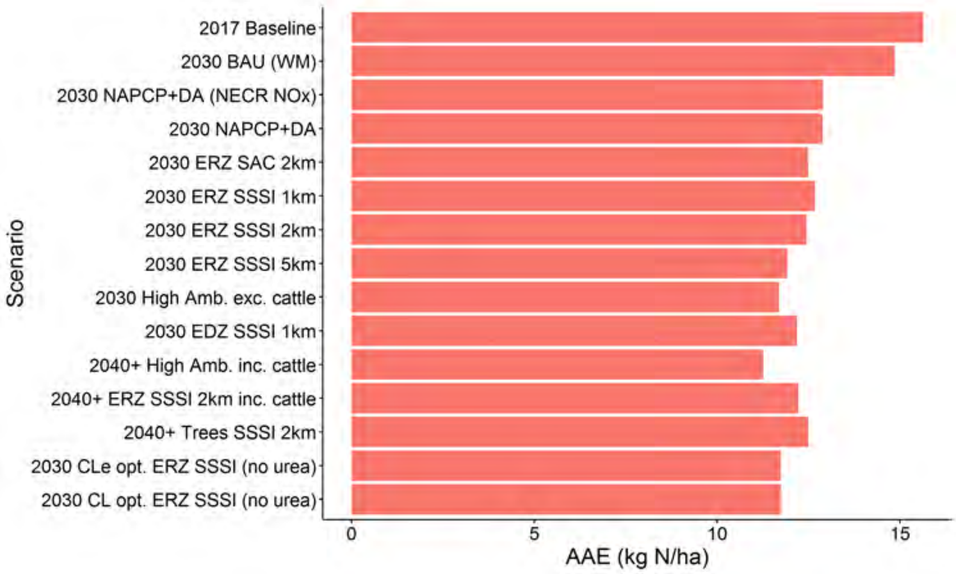


Figure 3.11-11. Exceedance of critical loads by scenario at Ballynahone Bog ASSI.

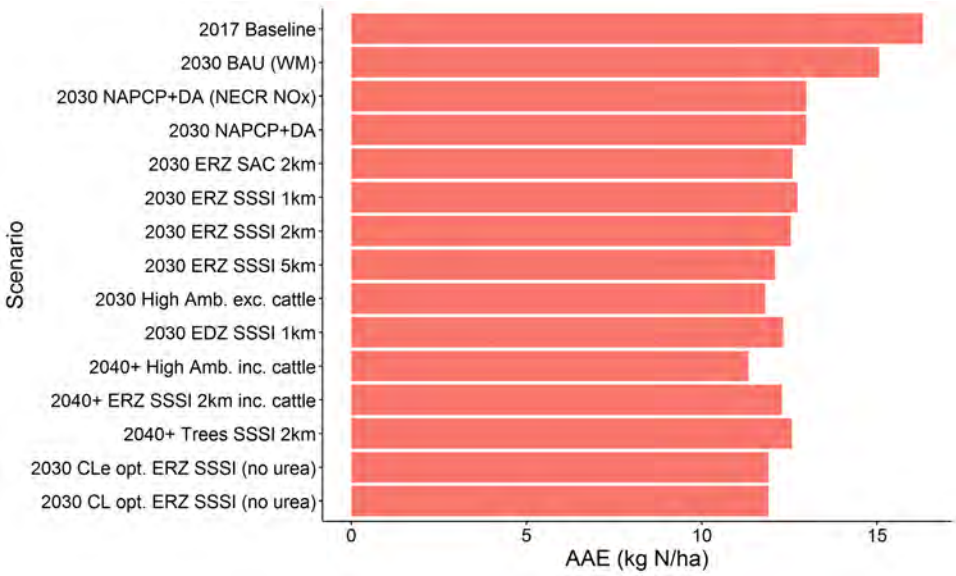


Figure 3.11-12. Exceedance of critical loads by scenario at Curran Bog ASSI.

3.11.10 Local assessment

Ballynahone Bog and Curran Bog are located in an area of high agricultural emission densities, dominated by beef and dairy cattle farming, with pig and poultry also present. The most recent source attribution assessment (for 2012, 5 km grid resolution) indicates that both Ballynahone Bog and Curran Bog are mostly influenced by local agricultural sources. This is in agreement with both local knowledge and the results of previous and ongoing monitoring on Ballynahone Bog. The results of several years of NH_3 concentration measurement at Ballynahone Bog show spatial variability in NH_3 concentration across the ~2 km^2 area of the SSSI (Figure 3.11-13). Measurement sites in the western part (Sites 1-7 in Figure 3.11-13), which are close to known local emission sources, frequently display high monthly NH_3 concentrations. In contrast, Site 8, located near the eastern edge of Ballynahone Bog and approximately 1-2 km further away of the main local sources, shows, on average the lowest concentration across the bog. No current NH_3 concentration measurements are available for Curran Bog, however there are plans to establish several sites following the current lock-down due to COVID-19.

The measured concentrations on Ballynahone Bog (Figure 3.11-13) are much higher than those estimated by the 1 km grid modelling (Section 3.11.6) at the UK scale. This is due to the following main reasons:

- Two farms are located very close to the site boundary, with local concentration gradients from livestock housing and manure storage extending into the bog. This is shown by the measurements at Sites 1-7, with Site 1 being closest to one of the sources (Figure 3.11-13). There is a clear gradient showing decreasing concentrations with distance, across sites 2, 3, 4, 5. Site 6 is not part of this gradient and closer to the other local source. The processes of dispersion and dilution of emission plumes from very local sources cannot be captured by the 1 km grid resolution modelling approach. Local scale modelling is in progress under a different project, but full results are not expected to be published until 2021.

- The UK-scale spatial modelling carried out under this project, at a 1 km grid resolution, uses the best available high-resolution agricultural emission maps (see also Annex 4 for a more detailed description of the methodology). These are derived from aggregated zonal statistics (approx. 5 km grid areas), using a statistical approach that spatially distributes emissions calculated for the livestock population and crop/grass areas present based on land cover data. This approach was designed to meet the strict disclosive criteria for use of the high-resolution June agricultural survey statistics and has been shown to work well, on average[7]. This is especially the case for distributing diffuse emission sources, such as land spreading of manures, mineral fertiliser application and livestock grazing, across the wider landscape (in the absence of more detailed data that could be used for modelling). However, for livestock housing and associated manure storage emissions, larger farms would, in reality be individual emission “hot spots” in the landscape - these are necessarily more diluted and dispersed across the wider area, due to the restrictions on how the input data can be used.

Therefore, in the case of Ballynahone Bog, and for similar small sites with emission sources close to the boundaries, the modelled UK-scale 1 km grid emissions are resulting in smoother concentration and dry deposition patterns, for the combined reasons of input data resolution and model grid cell size. It should also be noted that the modelling approach does not consider the inter-annual variability of NH_3 concentrations, which are evident from long-term monitoring at this site (Figures 3.11-13, 3.11-14).

Spatial targeting of measures, as modelled in the current project (and with the limitations described above), are estimated to achieve reductions in NH_3 concentrations, with the higher ambition and optimised scenarios being the most effective. The modelled concentration decreases are not estimated to be sufficient to bring the two sites below the 1 µg critical level for NH_3 and their critical loads thresholds, due to the continued high agricultural emissions densities in the wider surrounding area (Figure 3.11-2). A separate modelling exercise, carried out for DAERA (unpublished), applied high-ambition Northern Ireland-wide measures (25% agricultural NH_3 emission reduction, with additional smaller spatially targeted measures close to sites). A key message from the DAERA work is that the 25%

[7] A new Northern Ireland-wide monitoring network across Northern Ireland (25 monthly samplers) funded by Daera was set up in early 2019, with the first year of measurements due to be fully analysed in the near future (delayed due to temporary laboratory closure following COVID-19 outbreak). The first 9 months of NH_3 concentrations have been compared with modelled data (using the same approach as in the current project), showing that average concentrations match well between modelled and measured estimates.

emission reduction achieved through NI-wide measures reduces NH_3 concentrations and N deposition considerably from a very high baseline, but is by itself not sufficient to achieve widespread decreases in the number of sites exceeding critical levels and loads across Northern Ireland. This 25 % overall reduction in NI agricultural NH_3 emissions is more ambitious than the 2030 NAPCP+DA (NECR NO_x) scenario modelled here in terms of agricultural NH_3 emissions. The DAERA report does however suggest that targeted local measures, especially for situations such as Ballynahone Bog, with very local sources, could make a substantial difference, in combination with country-wide measures to decrease wider background concentrations and deposition. For such spatial targeting to work, the measures need to be suitable for the specific emission sources and operations present.

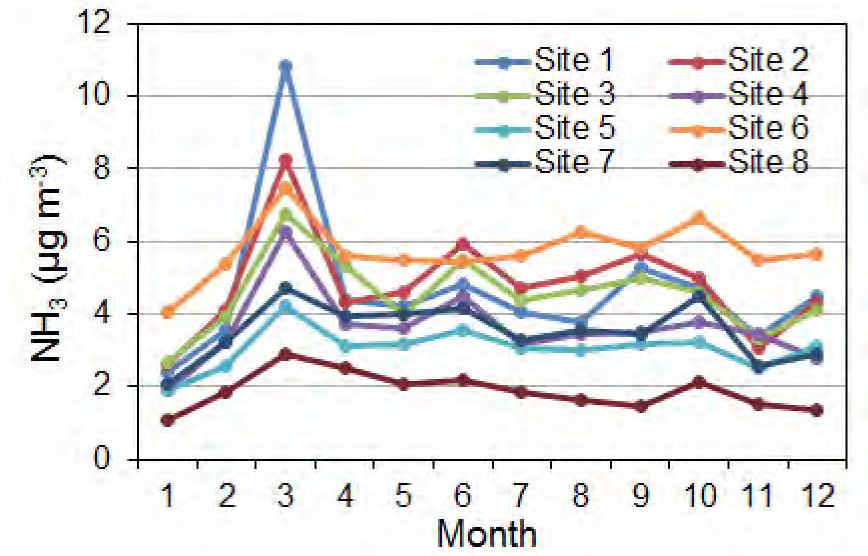


Figure 3.11-13. Monthly NH3 concentration at 8 measurement sites on Ballynahone Bog (average of 2014-2019).

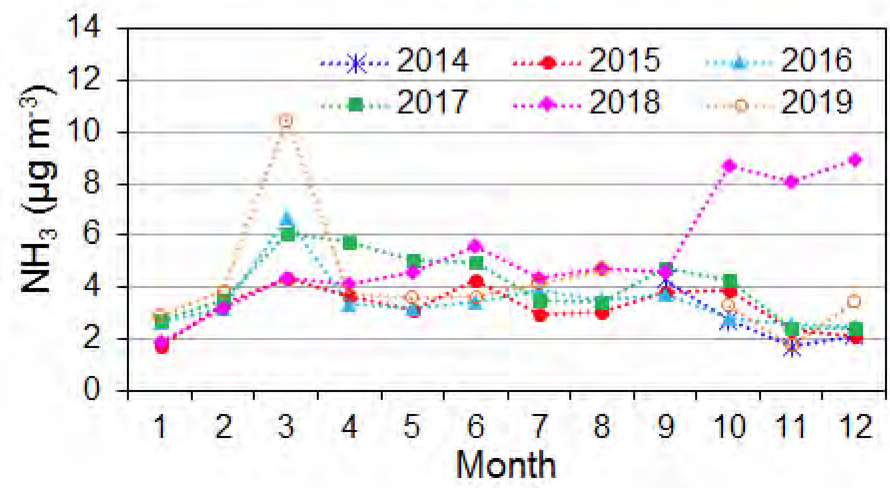


Figure 3.11-14. Monthly NH3 concentration by year on Ballynahone Bog (average of all 8 measurement sites).

3.11.11 Conclusions

Spatial targeting measures could produce substantial reductions to N input to these sites through reduction of the strength of local sources. The greatest impact would be produced in combination with national measures to decrease wider background concentrations and deposition.

3.12 Lough Navar Scarps and Lakes

The following sections provide background on Lough Navar Scarps and Lakes and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.12.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.12.1 Site map and location within UK

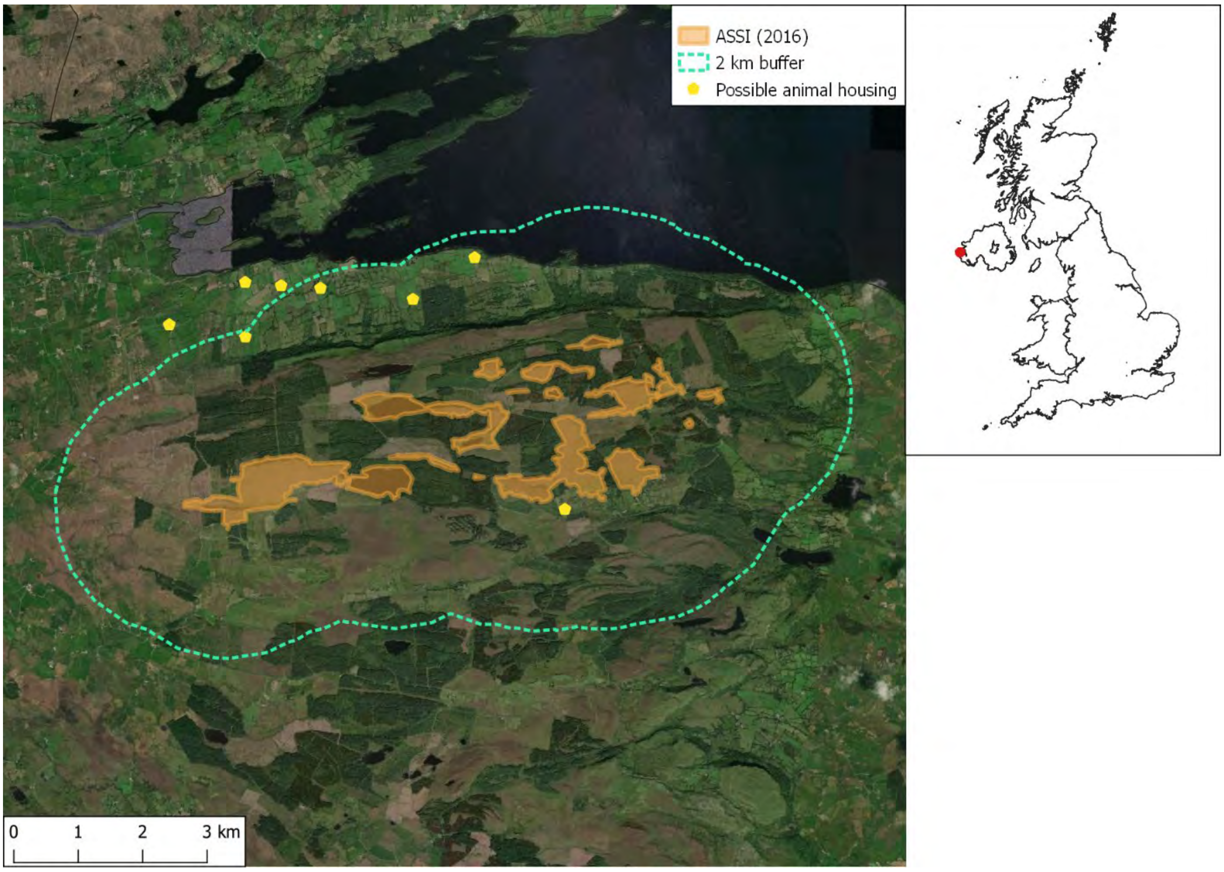


Figure 3.12-1. Site map showing relevant features and boundaries of Lough Navar Scarps and Lakes, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.12.2 Designated features

Table 20. Nitrogen sensitive interest features at Lough Navar Scarps and Lakes ASSI from the NIEA database (provided by Aine O'Reilly, pers. comm.).

Features
Dry heath
Wet heath
Inland Rock
Blanket bog
Purple Moor-grass and rush pastures
Upland Flushes, Fens and Swamps
Oligotrophic lakes
Dystrophic lakes
Higher Plant Assemblage

Lichen Assemblage Bryophyte Assemblage Marsh fritillary butterfly Invertebrate assemblage

3.12.3 Site characteristics

Lough Navar Scarps and Lakes ASSI is largely located within Lough Navar Forest to the south-west of Lough Erne. It is of interest because of its range of upland habitats. The site is known to be relatively clean with regard to nitrogen pollution, and with few local sources.

Lough Navar has one of three active long-term national monitoring network sites under the UKEAP (UK Eutrophying and Acidifying Atmospheric Pollutants) network[8]. NH_3 concentrations at the site are monitored as part of the National Atmospheric Monitoring Network (NAMN, Lough Navar UKA00166: operational since October 1996[2]) and acid gases and aerosols are monitored as part of the UK Acid Gas and Aerosol network, at both Hillsborough and Lough Navar (AGANet[9]). Average concentrations over the last 22 years (1997–2018) are 0.48 µg NH_3 m^{-3}, with seasonal variability between 0.25 and 0.83 µg NH_3.

3.12.4 Agricultural emission density

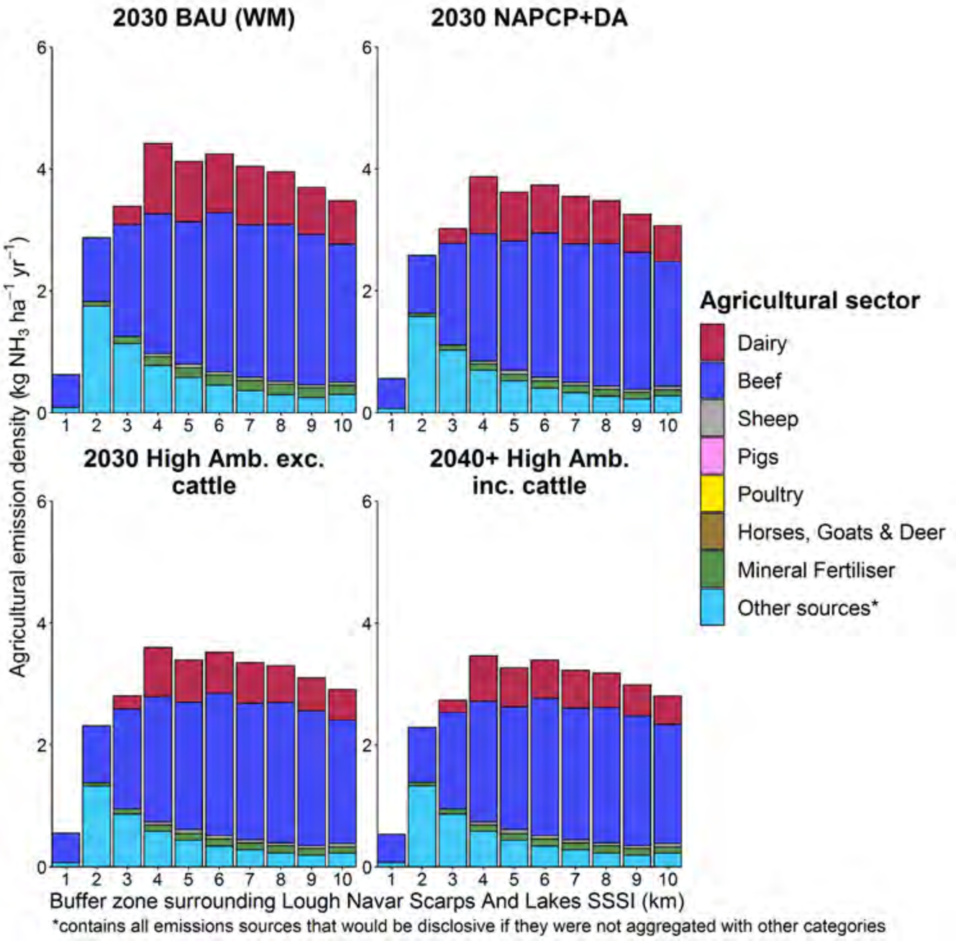


Figure 3.12-2. Estimated agricultural emission densities in concentric buffer zones surrounding Lough Navar Scarps and Lakes ASSI.

[8] https://uk-air.defra.gov.uk/networks/network-info?view=ukeap
[9] https://uk-air.defra.gov.uk/networks/network-info?view=aganet

3.12.5 Source attribution

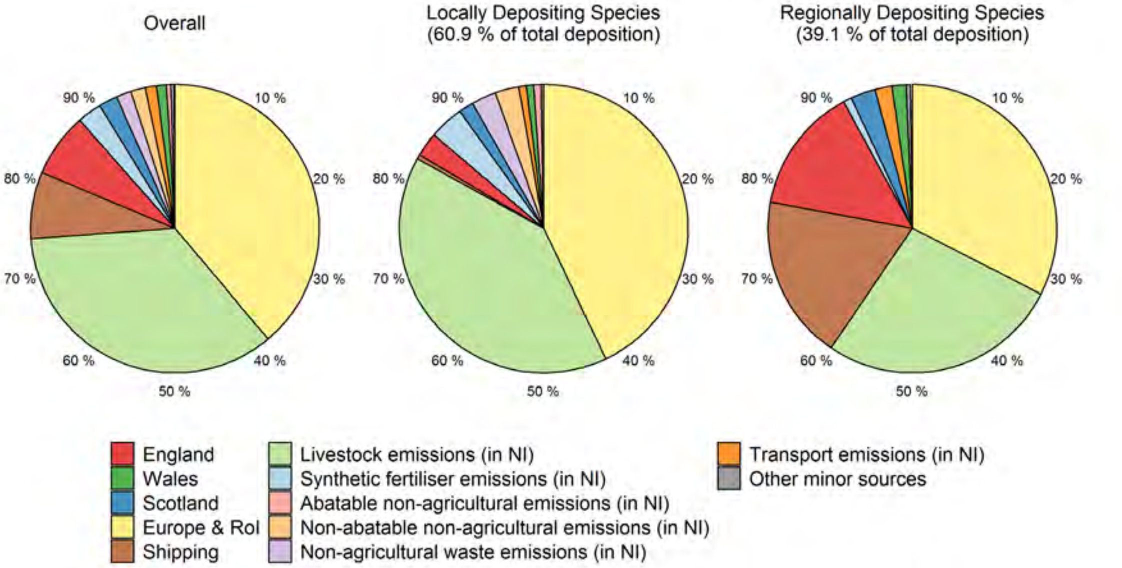


Figure 3.12-3. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Lough Navar Scarps and Lakes ASSI.

3.12.6 NH_3 concentration

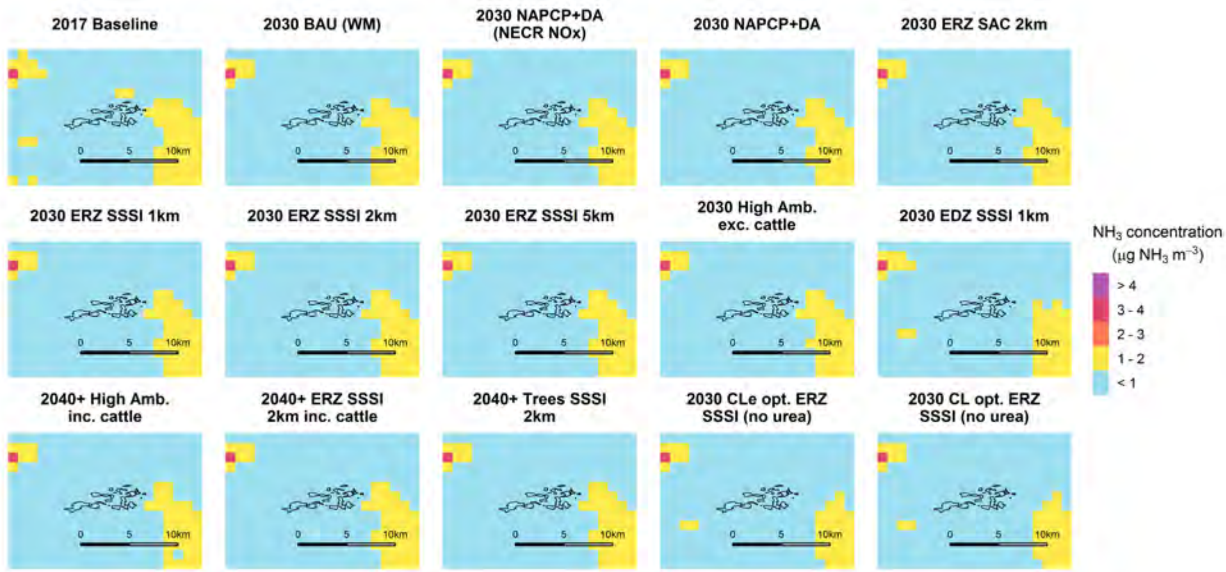


Figure 3.12-4. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Lough Navar Scarps and Lakes ASSI and surrounding area.

3.12.7 NO_2 concentration

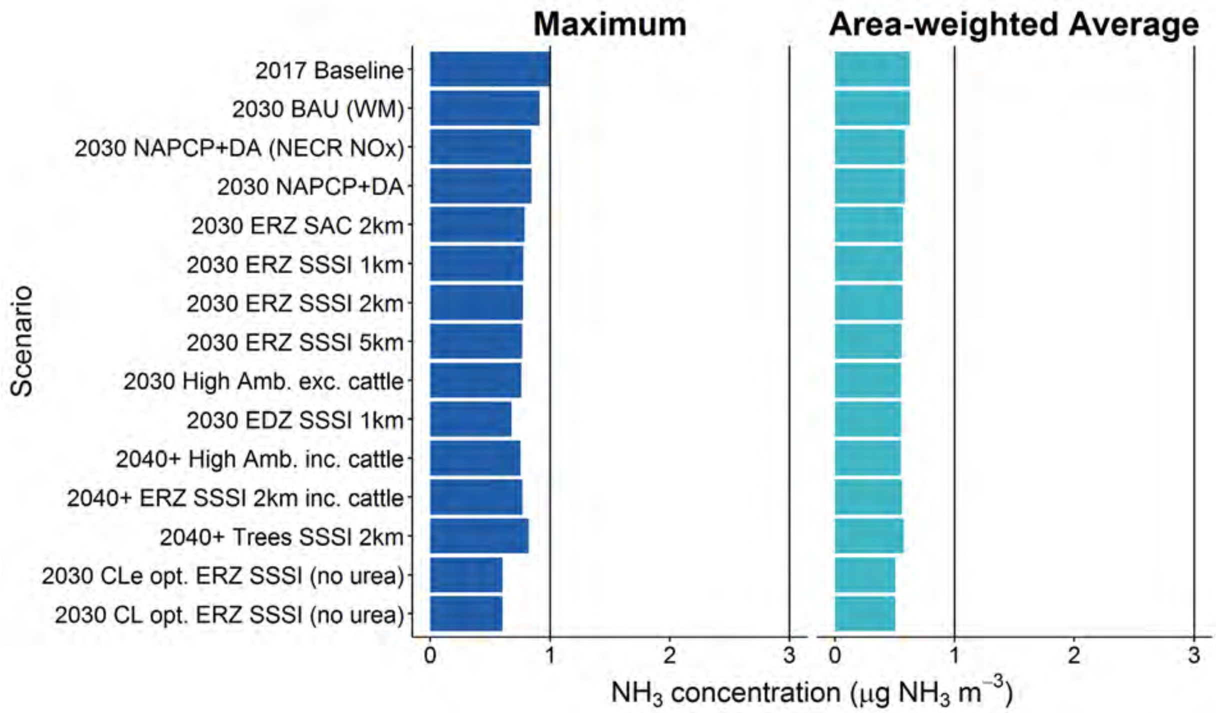
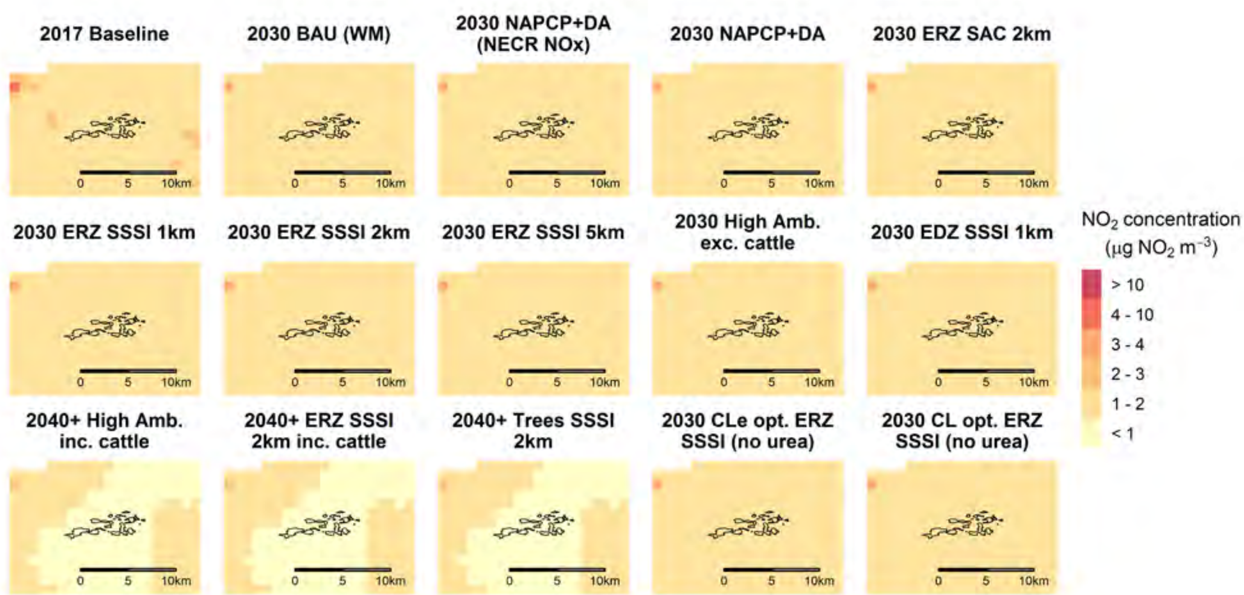


Figure 3.12-5. Maximum and area-weighted average NH_3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Lough Navar Scarps and Lakes ASSI.



3.12-6. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Lough Navar Scarps and Lakes ASSI and surrounding area.

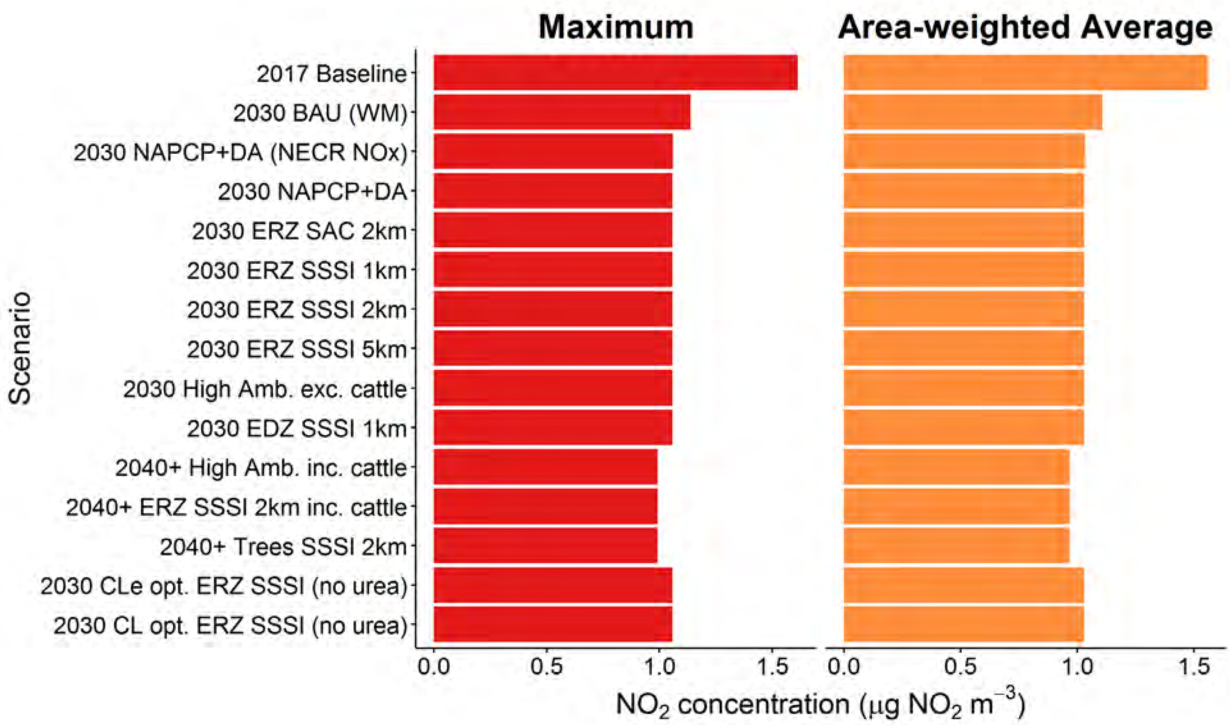


Figure 3.12-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Lough Navar Scarps and Lakes ASSI.

3.12.8 N deposition

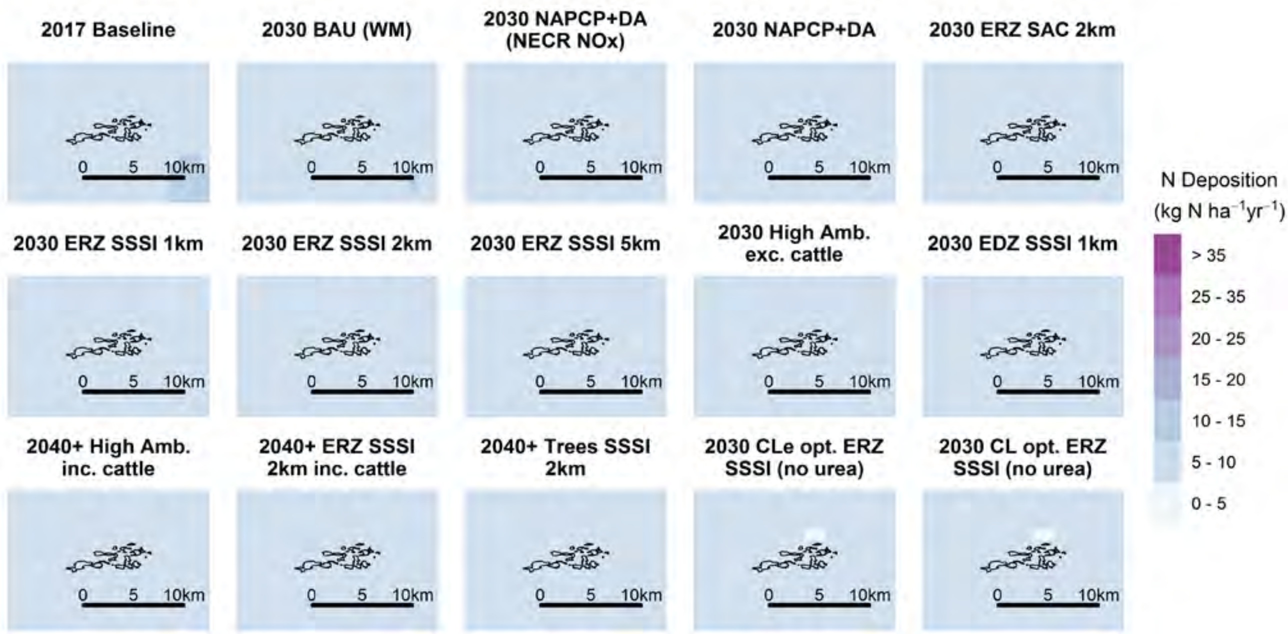


Figure 3.12-8. N deposition (to low-growing semi-natural vegetation) received by Lough Navar Scarps and Lakes ASSI and surrounding area.

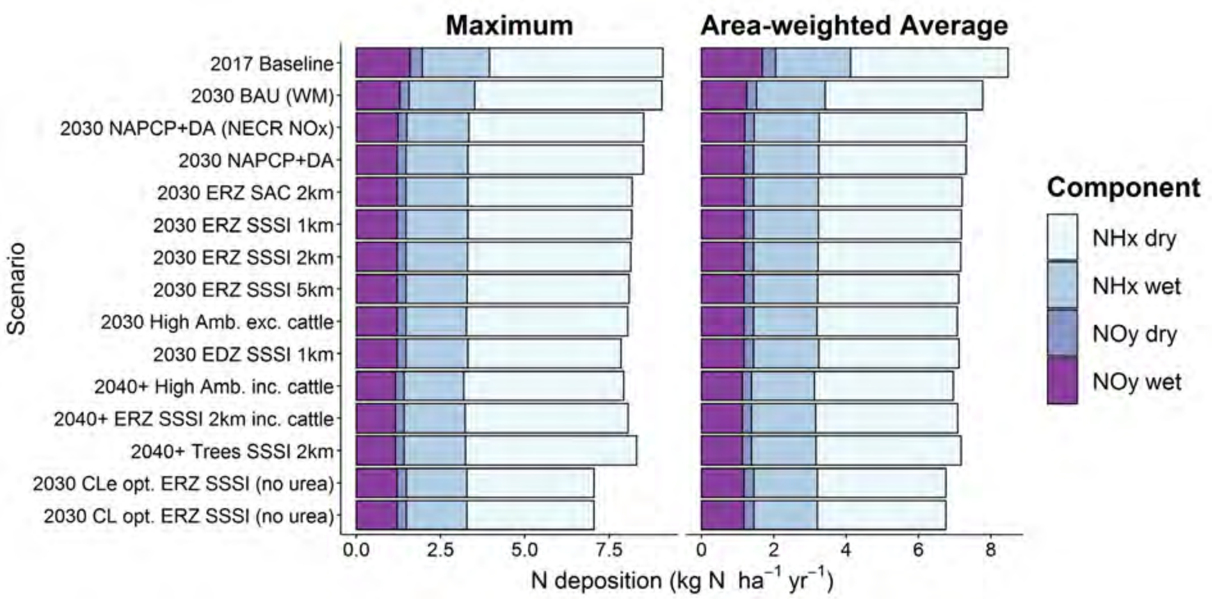


Figure 3.12-9. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Lough Navar Scarps and Lakes ASSI.SSI.

3.12.9 Exceedance of critical loads

Critical loads exceedance data are not available for this site, which is one of the 127 SSSIs in the UK for which critical load information is unknown in the database used for modelling. However, the lower critical load for lowland raised bog and blanket bog (5 kg N ha^{-1} yr^{-1}, Section 3.12.2) is exceeded, as shown in Figure 3.12-9, with most of the deposited N originating from NH_3 emissions (NH_x).

3.12.10 Local assessment

Locally depositing species account for most of the total N input to this site (Figure 3.12-3), at approx. 60% of deposited N. Approximately 40% of this local N deposition is attributed to livestock emissions and input from wider European sources, in particular the Republic of Ireland (RoI), and a similar amount from livestock emissions originating in NI. With NH_3 concentrations at the site already at low levels in 2017 and relatively low emission densities across the wider region, only small decreases in atmospheric N input are achieved through the higher ambition scenarios. Optimised scenarios are estimated to result in further decreases in the wider landscape to the south-east of the site, with some 1 km^2 cells brought below 1 µg m^{-3} NH_3, however the actual area of the site is expected to undergo more minor decreases, on average. The 1 km grid UK-scale modelling reflects the known conditions of the area, with few local nitrogen sources resulting in relatively low background level NH_3 and NO_2 concentrations and N deposition. The relatively high importance of emissions from Europe (i.e. mainly from the RoI for this site) illustrated in the 5 km source attribution assessment is indicative of the ASSI's location in the south-west of Northern Ireland close to the Irish border. Combined with almost 40% of atmospheric N input attributable to regional sources, this indicates the importance of wider-scale measures for this ASSI, including collaboration across the border with the RoI.

3.12.11 Conclusions

Atmospheric N concentrations and deposition at this site are already relatively low due to the low number and magnitude of nearby emissions sources, but with the critical load for the most sensitive designated features exceeded. Due to the relatively small number and magnitude of local sources, spatial targeting measures are expected to produce little effect, and wider regional scale efforts would be required to decrease N deposition further. National scale scenarios are estimated to achieve some decreases in atmospheric N input by reducing regional N deposition contributions. Regional/national mitigation efforts in the RoI would likely further decrease N input.

3.13 Peatlands Park

The following sections provide background on Peatlands Park and contain extracts of the UK scale model outputs centred on the site as well as specific local modelling of road transport impacts, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.133.10, which focuses on assessing the information presented in regard to the suitability of this site for spatial targeting of measures.

3.13.1 Site map and location within UK

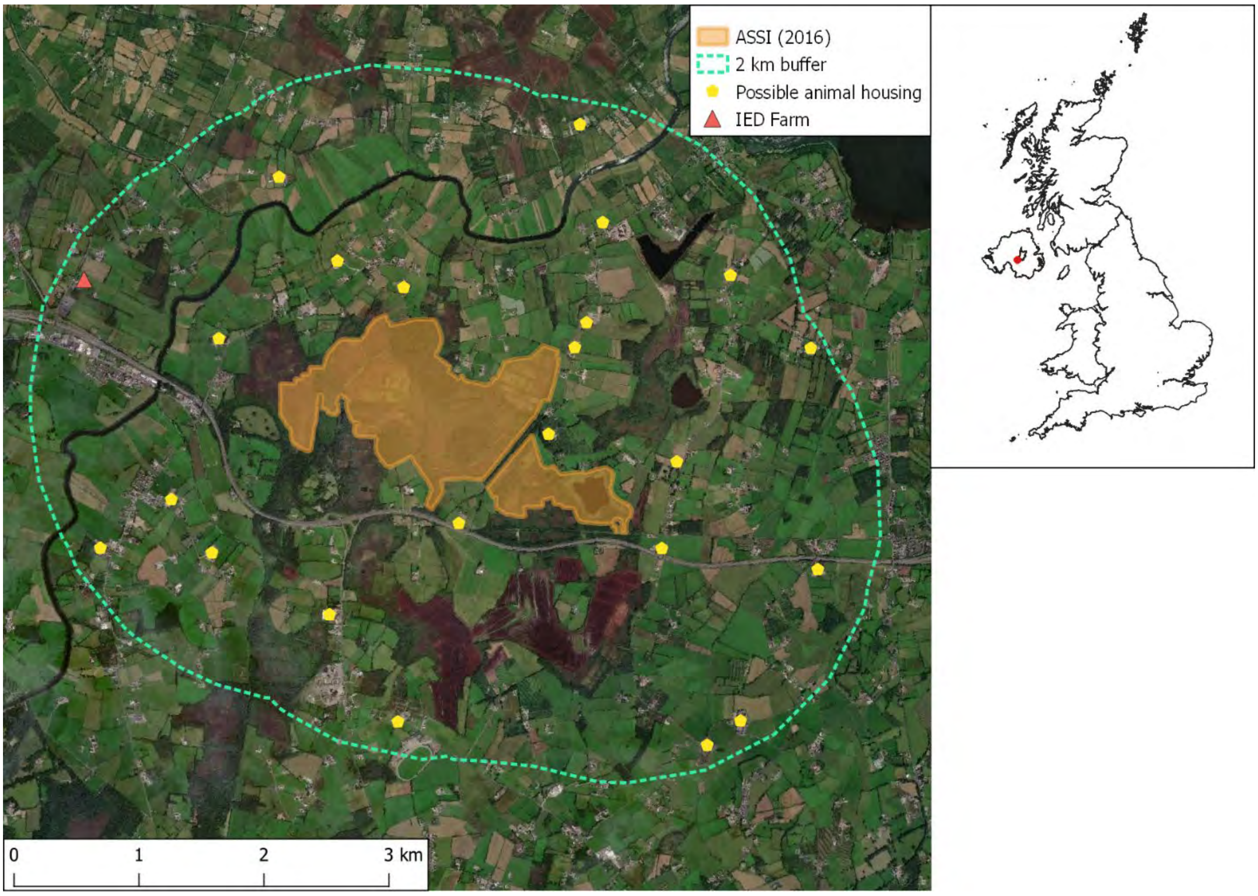


Figure 3.13-1. Site map showing relevant features and boundaries of Peatlands Park, and location within the UK. Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.13.2 Designated features

Table 21. Nitrogen sensitive interest features at Peatlands Park SSSI from the NIEA database (provided by Aine O'Reilly, pers. comm.).

Features
Lowland raised bog
Fens
Oakwood
Bog woodland
Higher plant assemblage
Invertebrate assemblage

3.13.3 Site characteristics

Peatlands Park represents a large area of cutover bog and woodland, remnant of an extensive lowland raised bog complex, lying just south of Washing Bay in the south-western corner of Lough Neagh. It is located between the M1 motorway and the village of Maghery. Peatlands Park is a complex site with a wide range of habitats and associated flora and fauna that includes a number of rare and notable species. The site consists of a number of low wooded drumlins covered by mature Oak Woodland interspersed by a series of flat plains covered by both intact and cutover raised bog and bog woodland. Derryadd Lough, situated in the south-eastern corner of the site, provides additional interest with its marginal swamp and poor acid fen. The range of habitats displayed throughout Peatlands Park supports a rich flora and fauna, including a number of rare species. Due to the proximity of the main M1 motorway 70 m from the closest part of Peatlands Park, the effect of national road measures on this local scale study have been assessed.

Measurements of NH_3 concentrations at several points are due to start at this site in the near future (post COVID-19 lockdown), to determine the level of atmospheric N input and advise on potential mitigation strategies.

3.13.4 Agricultural emission density

The agricultural emission density for this site is shown in Figure 3.13-2. Agricultural emission density in the surrounding 10 km zone is estimated to decrease with increasing ambitions of the scenarios.

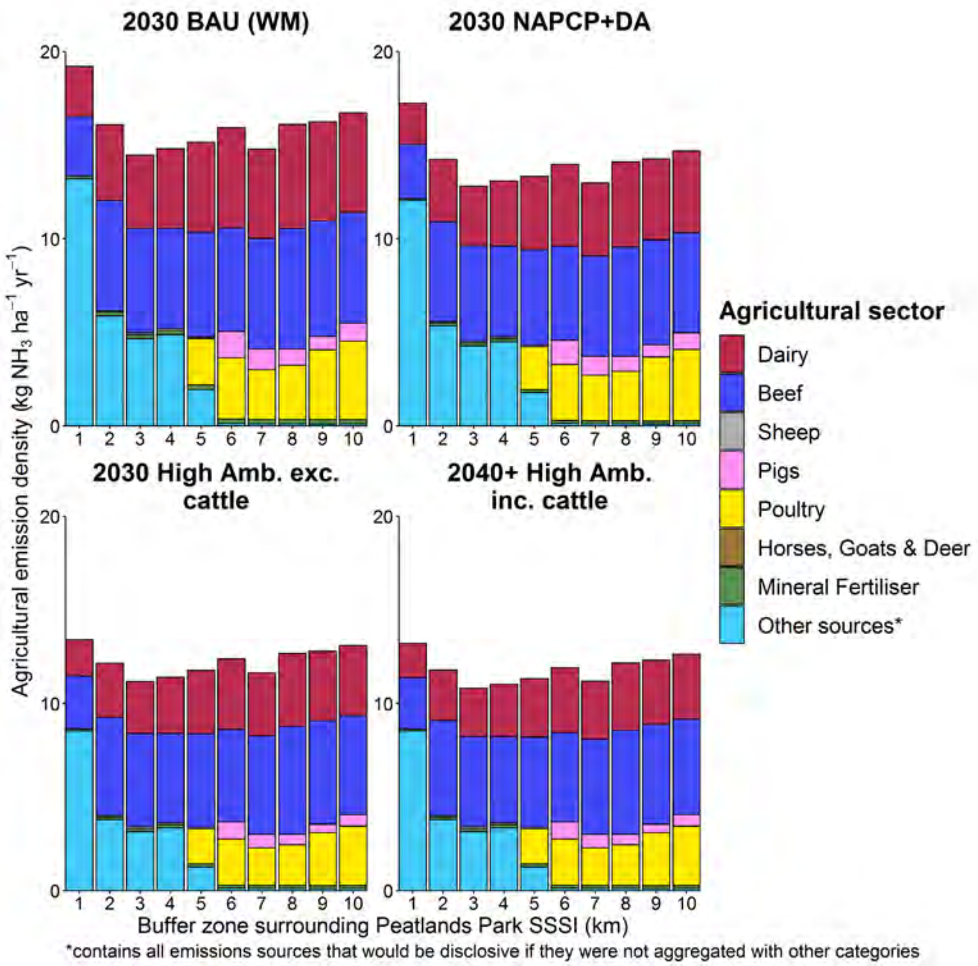


Figure 3.13-2. Estimated agricultural emission densities in concentric buffer zones surrounding Peatlands Park ASSI.

3.13.5 Source attribution

When considering the total deposition to the site, as a whole, Figures 3.13-3 and 3.13-4 show that local sources of N input are significantly more important to this site than regional sources, with the majority coming from NI livestock emissions. Figure 3.13-5 shows the location-specific source attribution for the point of the site where the road impact is greatest. Because the M1 is not directly adjacent to the site (70 m away from the boundary), it contributes relatively little and so the source attribution at the roadside edge of the site is very similar to that shown in Figures 3.13-3 and 3.13-4.

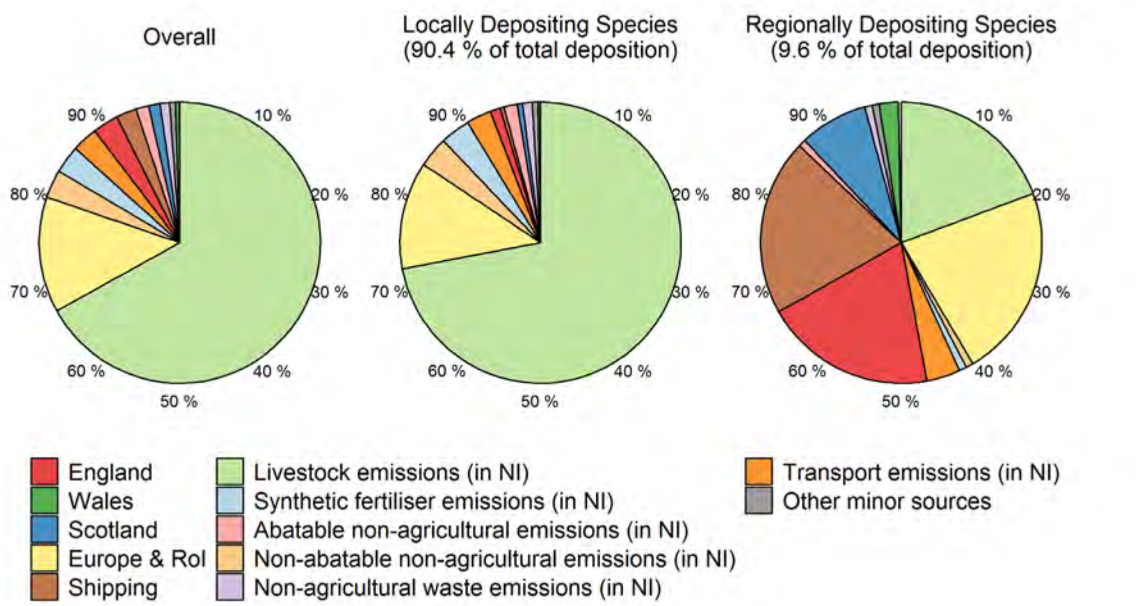


Figure 3.13-3. Relative contribution of emission sources to N deposition (to woodland features) received by Peatlands Park ASSI.

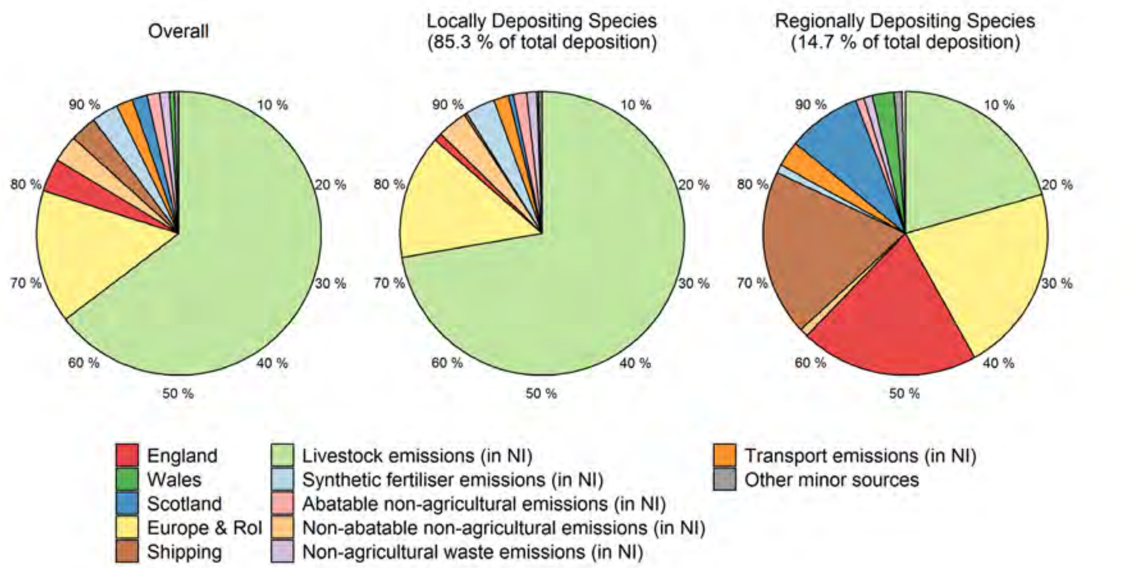


Figure 3.13-4. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Peatlands Park ASSI.

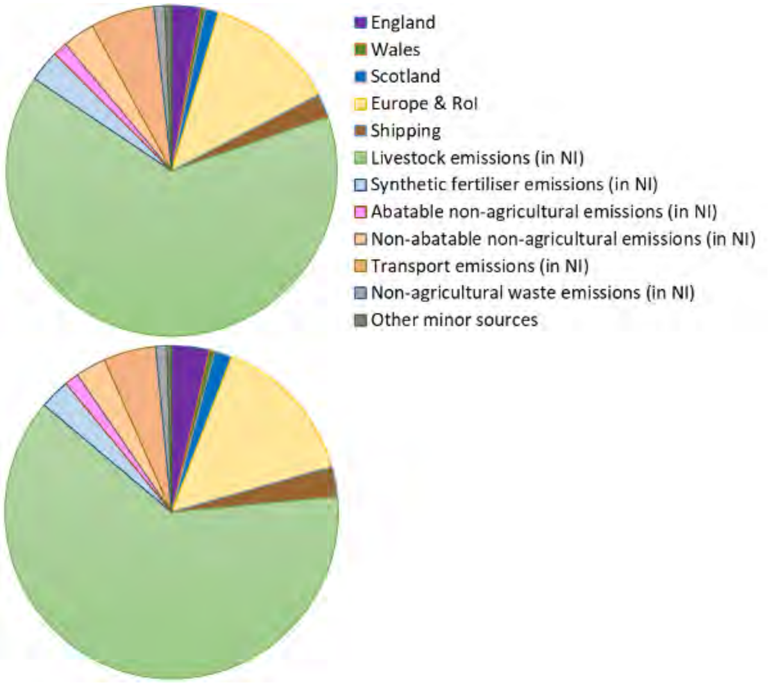


Figure 3.13-5. Relative contribution of emission sources to roadside-maximum (i.e. roadside edge of receptor transect) N deposition (top: to woodland features; and bottom: to low-growing semi-natural vegetation) received by Peatlands Park ASSI.

3.13.6 NH_3 concentration

Figures 3.13-6 and 3.13-7 show the 1 km x 1 km average annual mean NH_3 concentrations predicted by FRAME. The highest concentrations are predicted toward the western edge of the site in the 2017 Baseline and are predicted to decrease between 2017 and both the 2030 BAU and 2030 NAPCP baseline scenarios. Further decreases to below 2 µg m^{-3} NH_3 are predicted to require higher ambition measures, either through the 2030 or 2040+ High ambition measures implemented country-wide, or the optimised spatially targeted scenarios.

Figure 3.13-8 shows the predicted concentrations along a transect of receptors from 70m (the closest point of the site to the M1) to 310m (the furthest point on the transect) from the road where the road increment is greatest (which is at the eastern side of the site). Because the site is some 70 m from the road, the local increment of road traffic, over and above that already shown in the 1 km x 1 km average values, is relatively small. It should also be noted that this is at the far eastern edge of the site, where the 1 km x 1 km FRAME predictions (which form the background to which the road increments have been added) are lowest. Thus, the maximum concentrations predicted in Figure 3.13-8 are all smaller than the maximum predictions shown in Figure 3.13-7.

The influence of each scenario on the maximum concentration from the transect shown in Figure 3.13-8 is shown in Figure 3.13-9. The total results are not materially different from the 1 km x 1 km FRAME outputs (which comprise the blue sections of the bars in Figure 3.13-9), owing to the distance of the site from the road.

Because the local influence of traffic-related NH_3 is relatively unimportant for this site, compared to other atmospheric N input, no sensitivity testing using alternative traffic-NH_3 emissions assumptions has been carried out. Sensitivity testing for other traffic-related case studies shows that the effects would be too small to significantly alter the results in Figure 3.13-9 (e.g. the local road contribution in Figure 3.13-9 is so small that the uncertainty range for NH_3 shown in Figure 3.1.11 (for Ashdown Forest) would not have a significant effect).

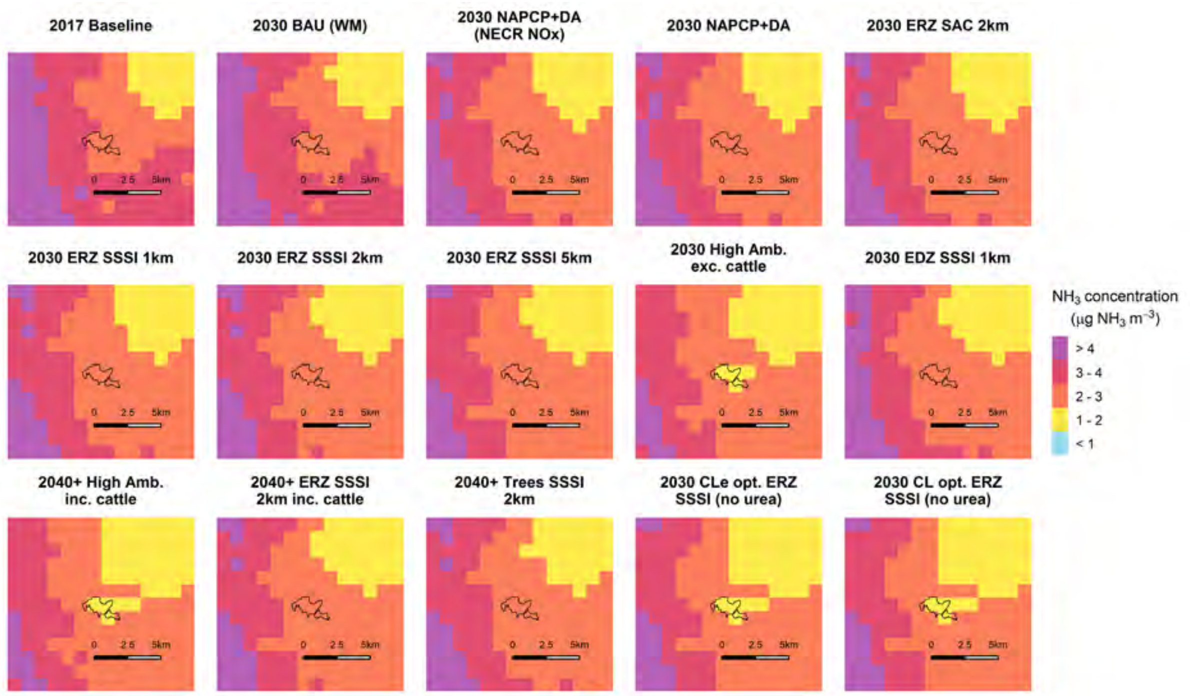


Figure 3.13-6. NH_3 concentration (FRAME model calibrated with measurements) by scenario at Peatlands Park ASSI and surrounding area.

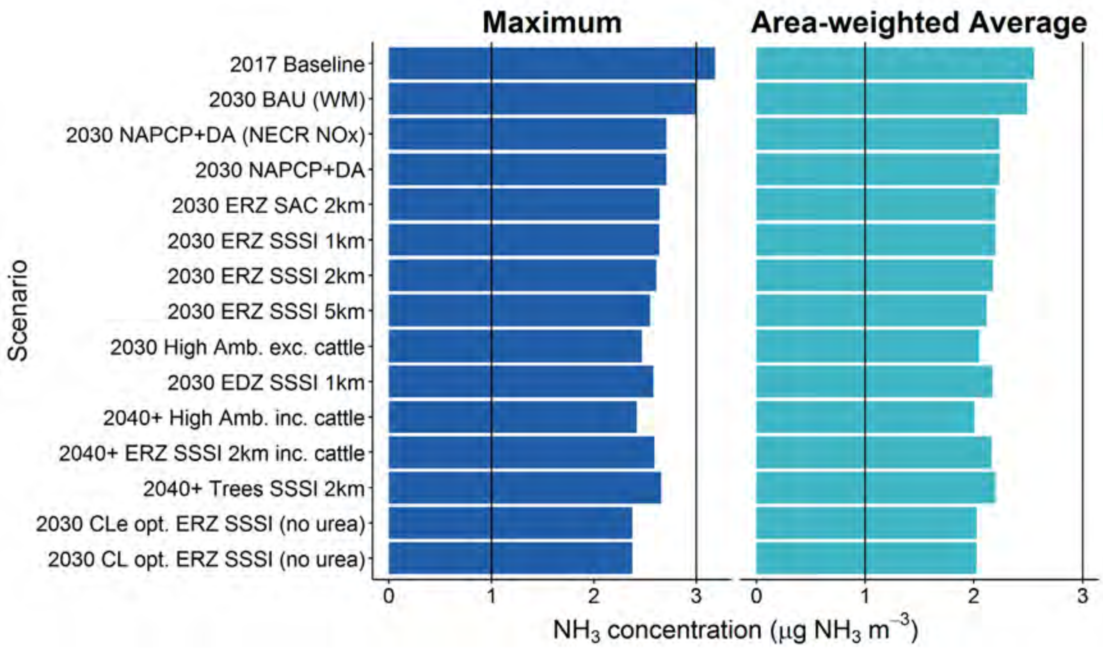


Figure 3.13-7. Maximum and area-weighted average NH3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Peatlands Park ASSI.

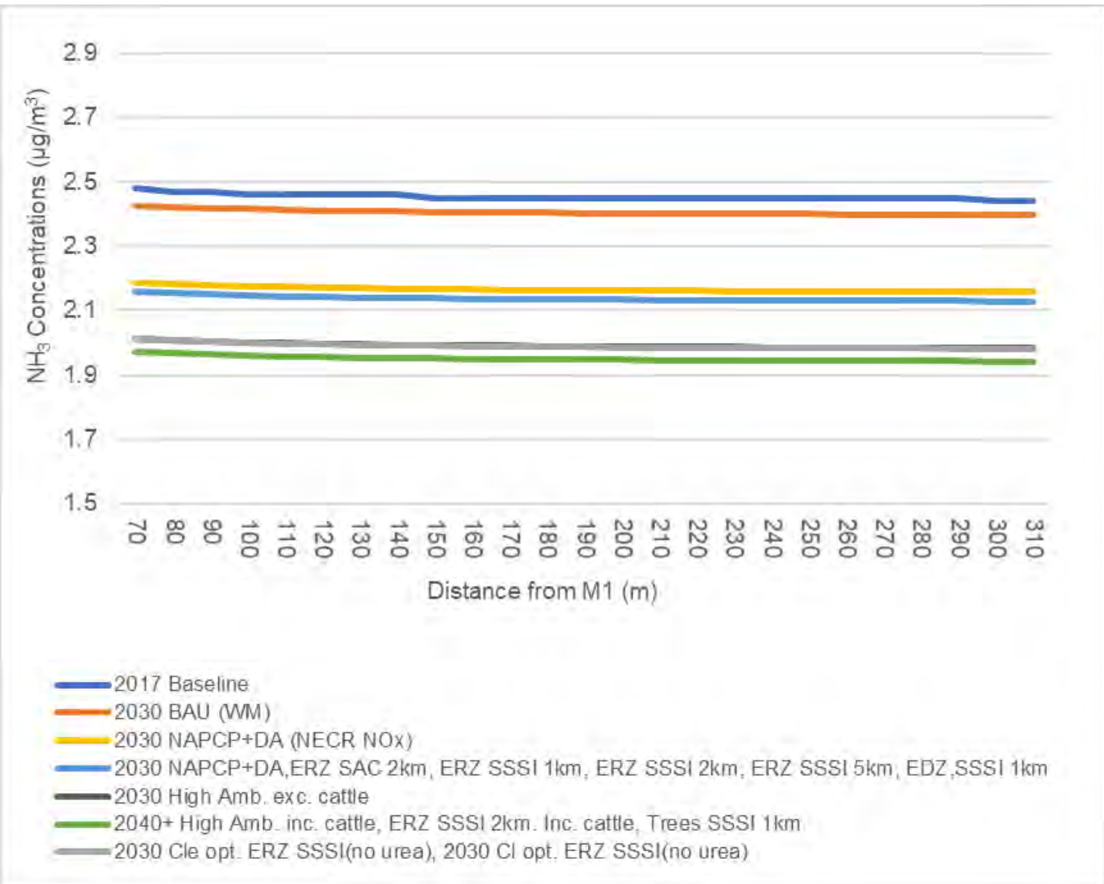


Figure 3.13-8. Annual mean NH_3 concentrations with distance from M1 (for location of maximum road contribution).

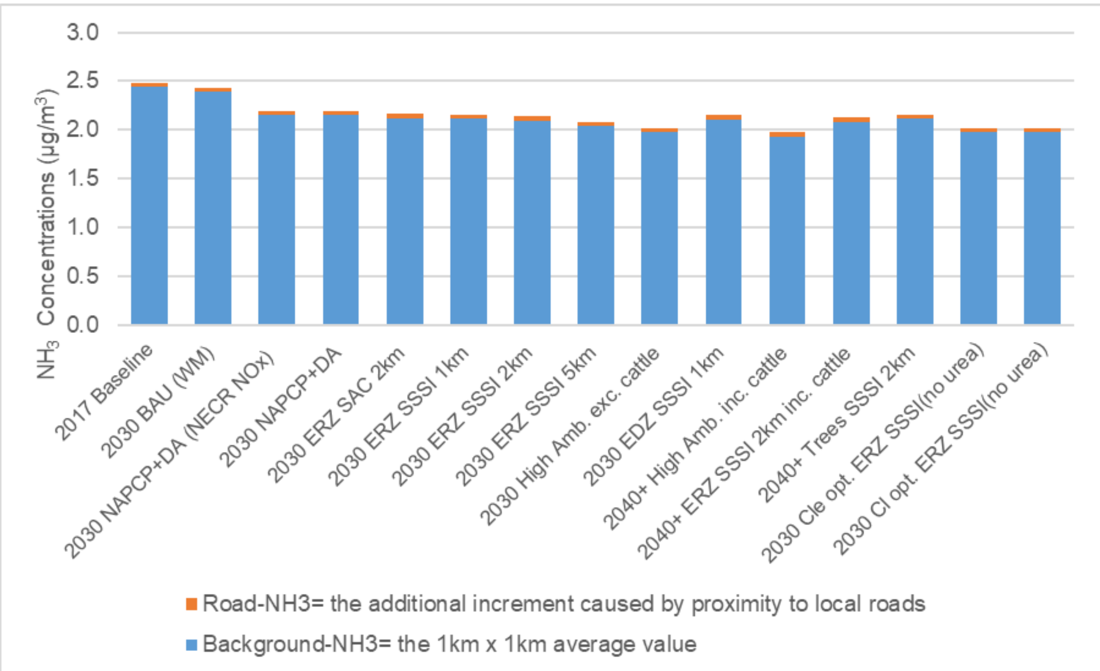


Figure 3.13-9. Maximum predicted annual mean NH_3 concentration (where road component is greatest) in Peatlands Park ASSI in each scenario.

3.13.7 NO_2 and NO_x concentration

Figures 3.13-10 and 3.13-11 show the 1 km x 1 km average annual mean NO_2 concentrations predicted by FRAME. While annual mean NO_2 concentrations cannot be directly compared with the 30 µg m^{-3} critical level for NO_x, they provide an indication of the likely NO_x concentrations (NOx = NO_2 + NO). All of the 1 km^2 average annual mean concentrations are less than 10 µg m^{-3} in each scenario, and less than 4 µg m^{-3} in each future-year scenario.

Figure 3.13-12 shows the predicted NO_x concentrations along a transect of receptors from 70m to 310m from the road where the road increment is greatest (which is at the eastern side of the site). Because the site is some 70 m from the road, the local increment of road traffic, over and above that already represented in the 1 km x 1 km average values, is relatively small.

The influence of each scenario on the maximum concentration from the transect shown in Figure 3.13-12 is shown in Figure 3.13-13. The blue bars in Figure 3.13-13 represent the 1 km^2 average FRAME outputs (adjusted to represent NOx instead of NO_2), while the orange sections show the additional increment caused by proximity to the road. Predicted concentrations are less than half of the 30 µg m^{-3} critical level in every scenario.

Figure 3.13-10. NO_2 concentration (FRAME model calibrated with PCM) by scenario at Peatlands Park ASSI and surrounding area.

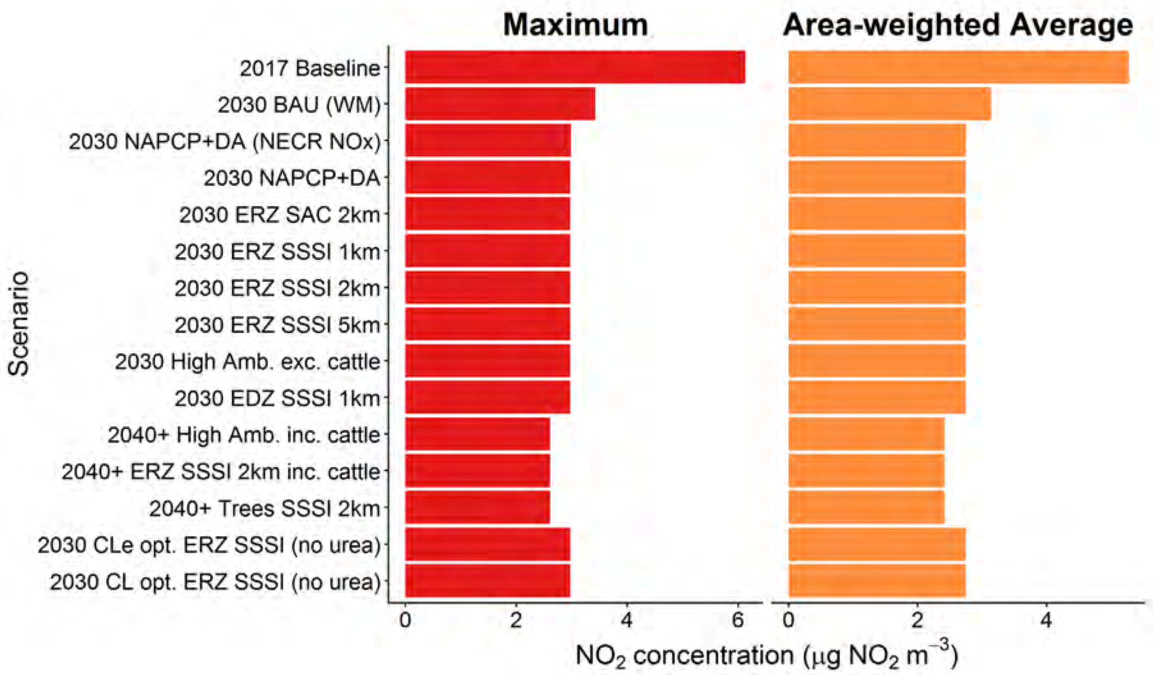


Figure 3.13-11. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Peatlands Park ASSI.

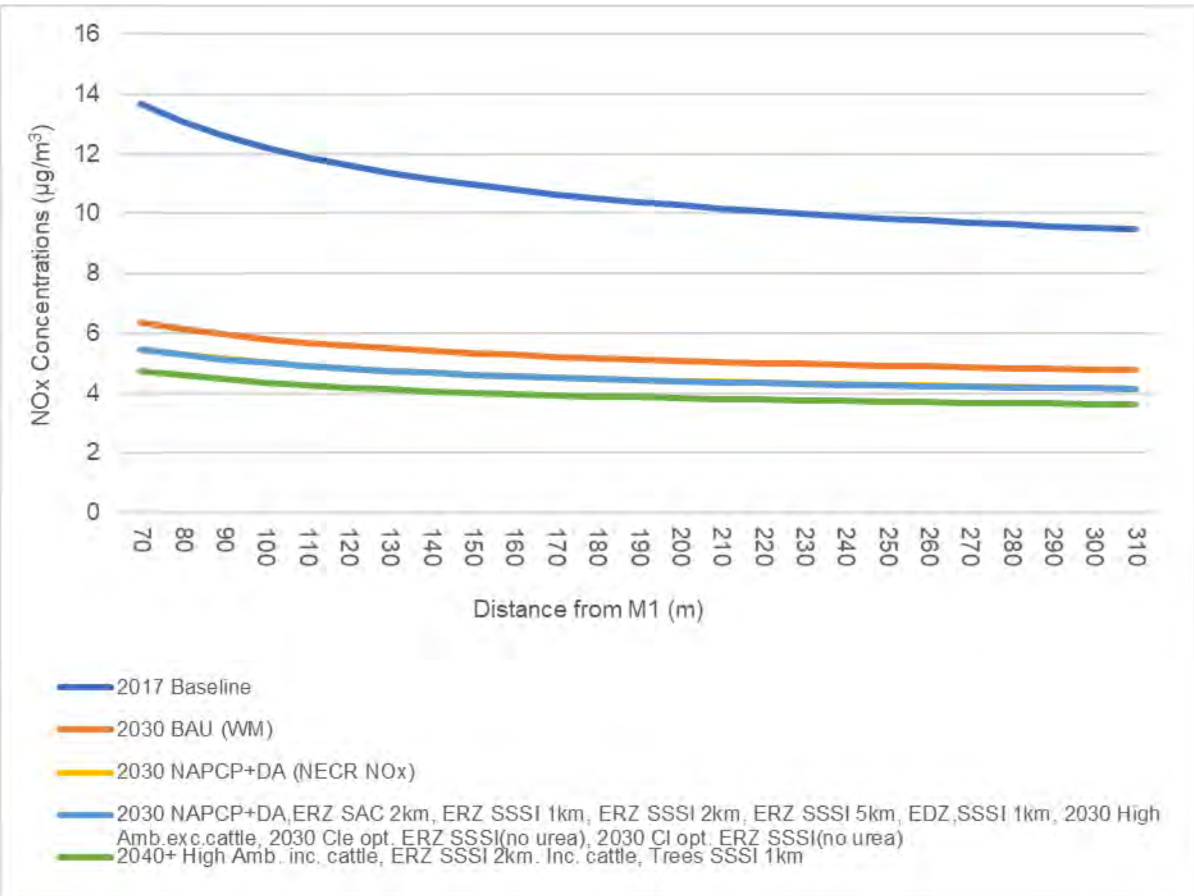


Figure 3.13-12. Annual mean NO_x concentrations with distance from M1 (for location of maximum road contribution).

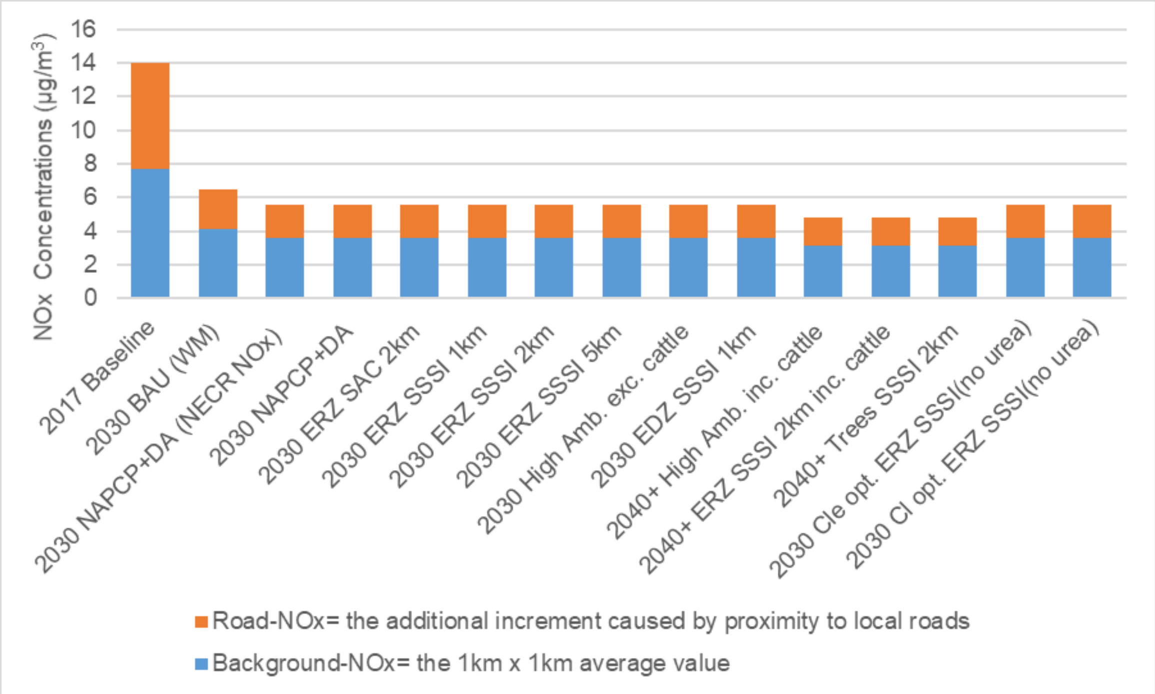


Figure 3.13-13. Maximum predicted annual mean NO_x concentration (where road component is greatest) in Peatlands Park ASSI in each scenario.

3.13.8 N deposition

Figures 3.13-14 to 3.13-17 show the 1 km x 1 km average N deposition fluxes predicted by FRAME to woodland features and low-growing semi-natural vegetation. Maximum 1 km^2 average fluxes are predicted to be 40 kg N ha^{-1} yr^{-1} to woodland in 2017; remaining greater than 30 kg N ha^{-1} yr^{-1} in each future-year scenario. Figures 3.13-18 and 3.13-19 show the worst-case increment to nitrogen deposition caused by proximity to the M1, which, owing principally to the 70 m separating the site from the road, is relatively small; meaning that the total fluxes are driven by the spatially-averaged FRAME outputs. It is also noted that the maximum road contribution is not collocated with the maximum 1km^2 prediction and so the total in Figure 3.13-19 is less than that shown in Figure 3.13-15. Because this section of the site is wooded, fluxes are shown to woodland only.

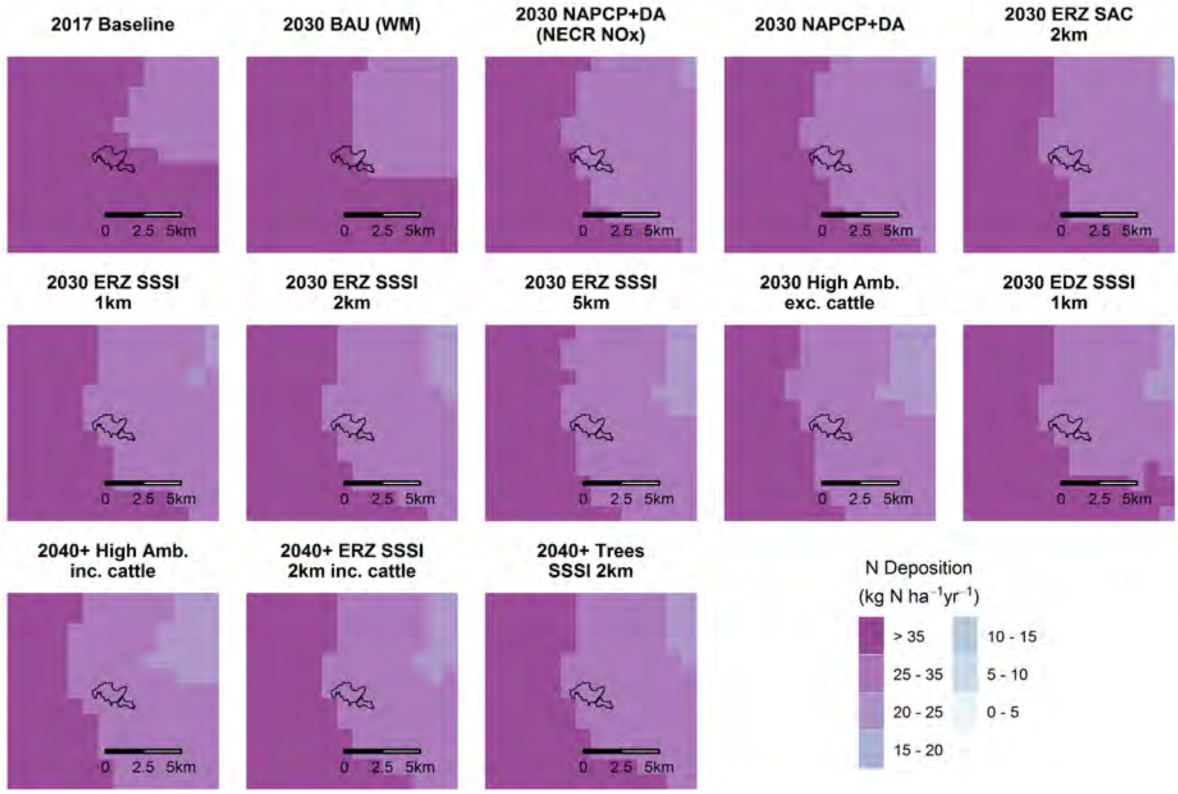


Figure 3.13-14. N deposition (to woodland features) received by Peatlands Park ASSI and surrounding area.

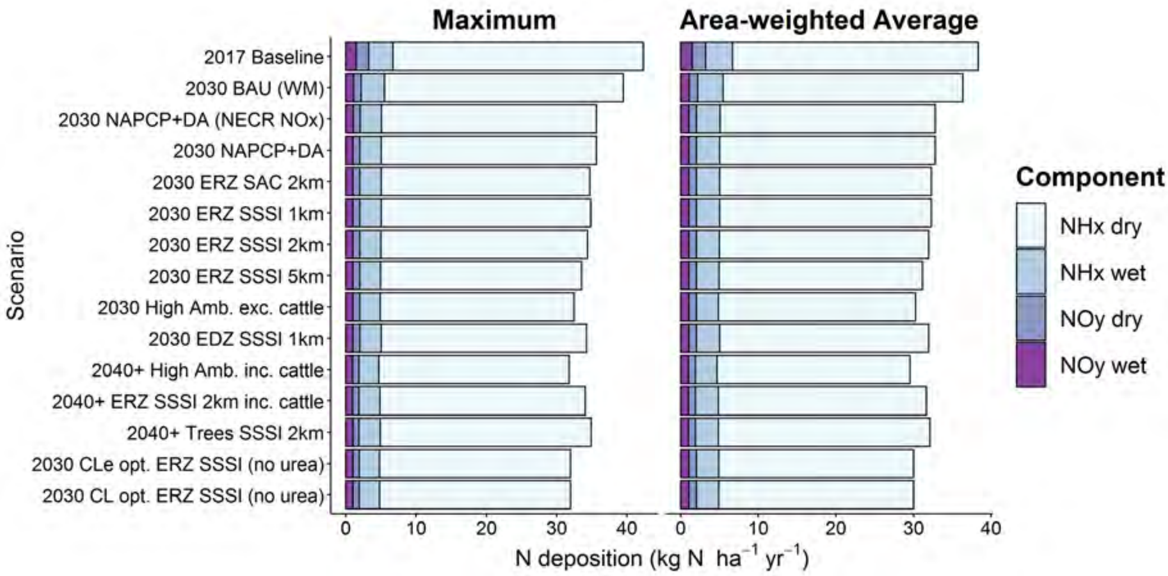


Figure 3.13-15. Maximum and area-weighted average deposition (to woodland features) by scenario at 1 km grid cells overlapping with Peatlands Park ASSI.

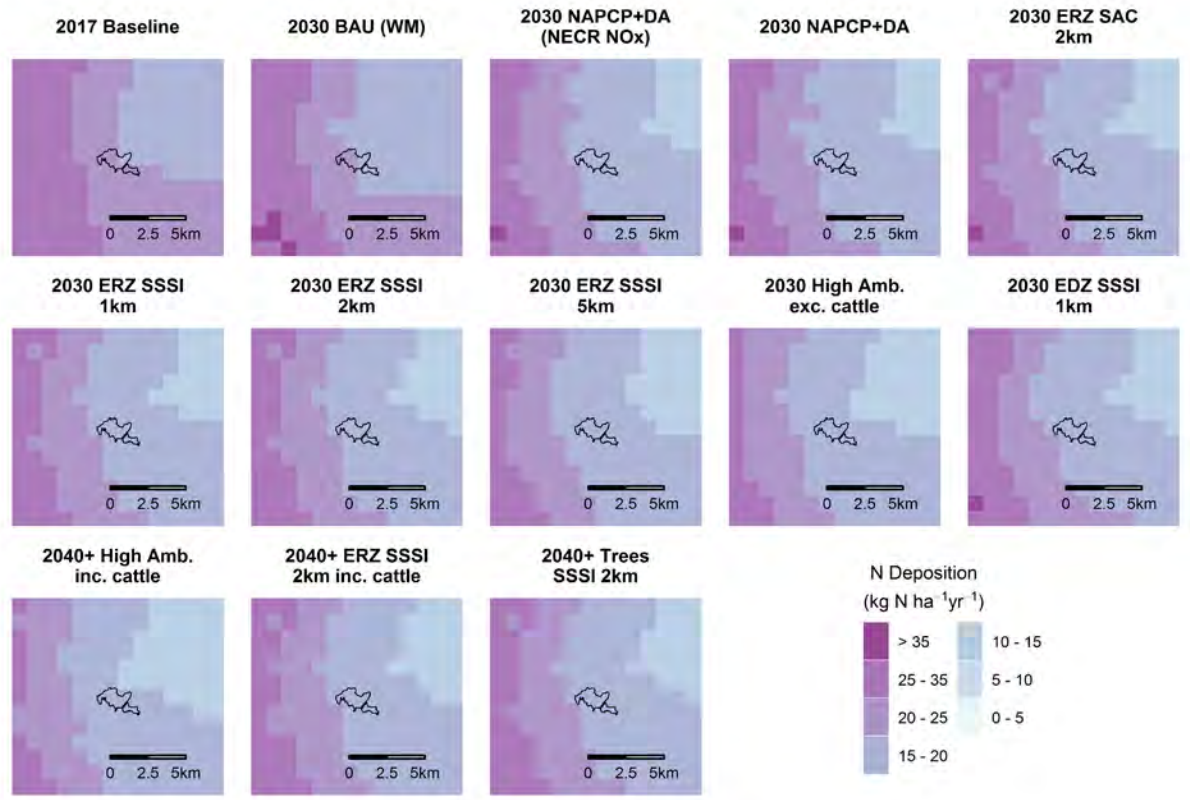


Figure 3.13-16. N deposition (to low-growing semi-natural vegetation) received by Peatlands Park ASSI and surrounding area.

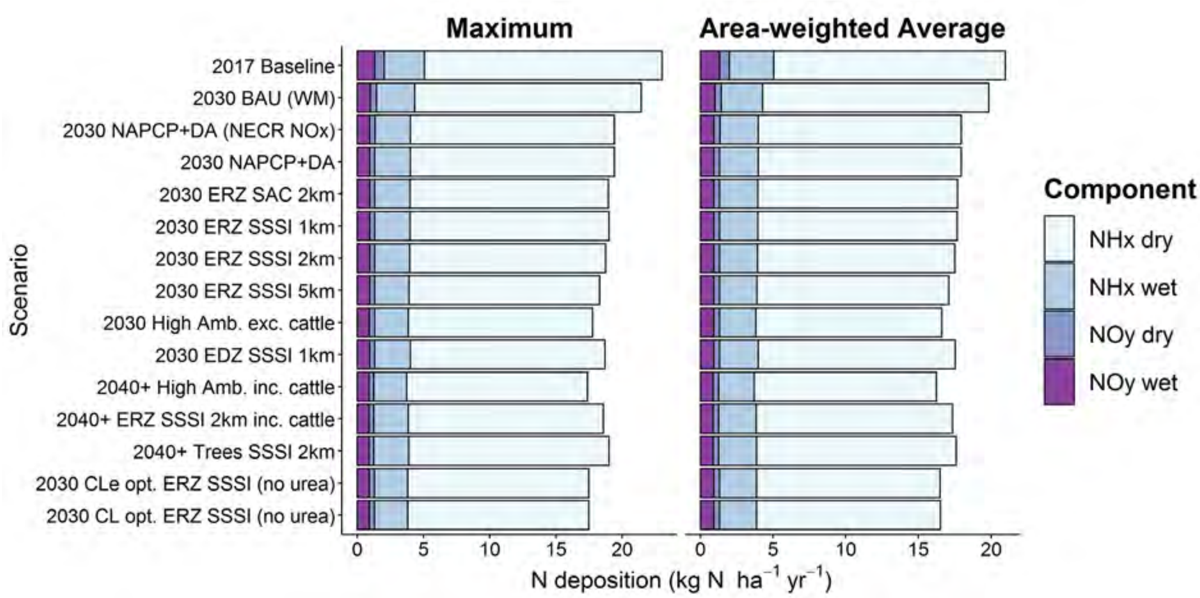


Figure 3.13-17. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Peatlands Park ASSI.

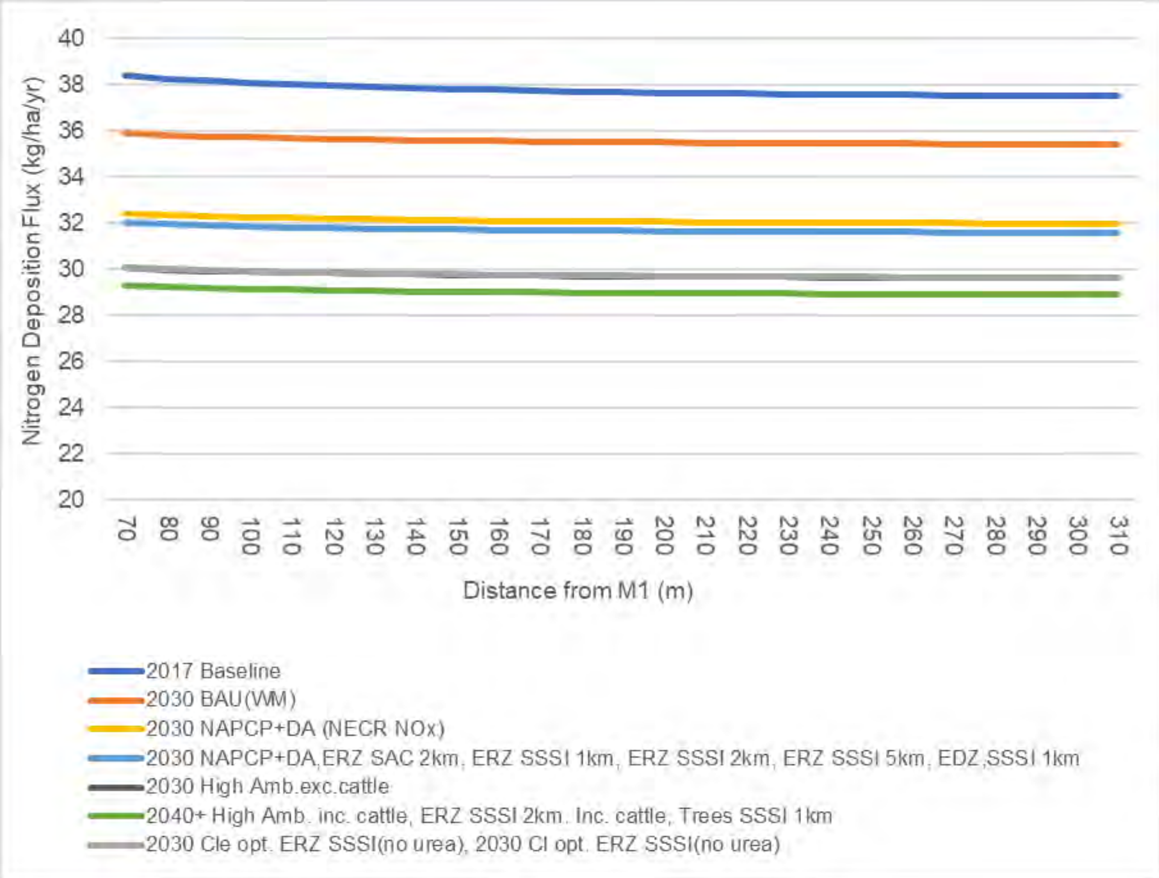


Figure 3.13-18. N Deposition to woodland with distance from M1 (for location of maximum road contribution).

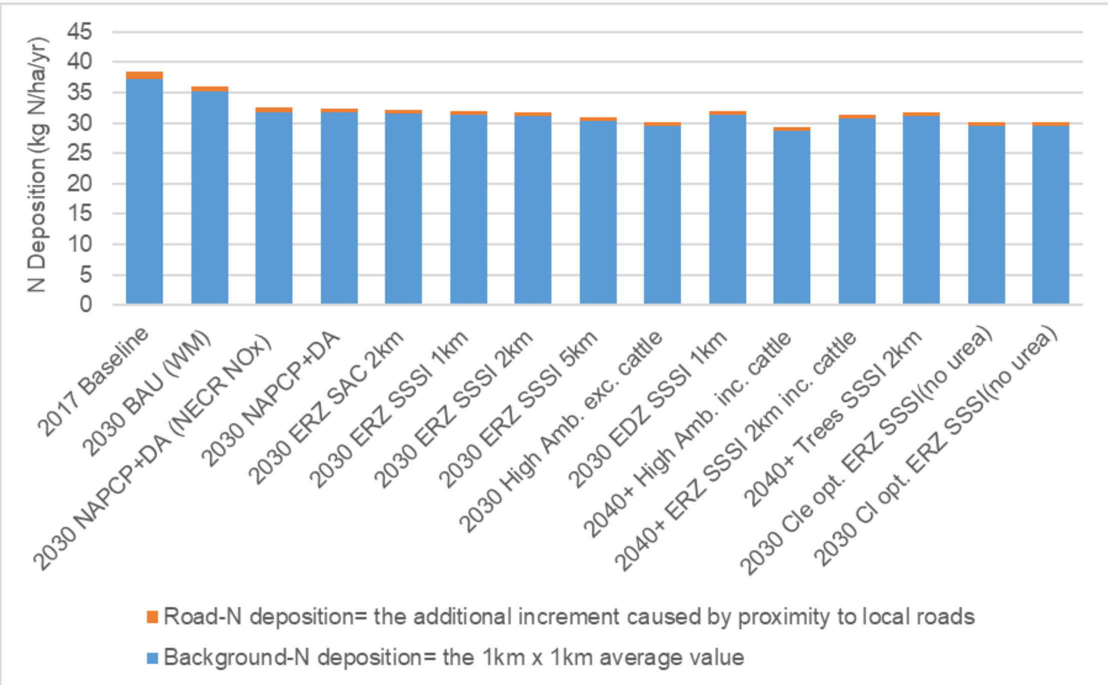


Figure 3.13-19. Maximum predicted N deposition to woodland (where road component is greatest) in Peatlands Park ASSI in each scenario.

3.13.9 Exceedance of critical levels and loads

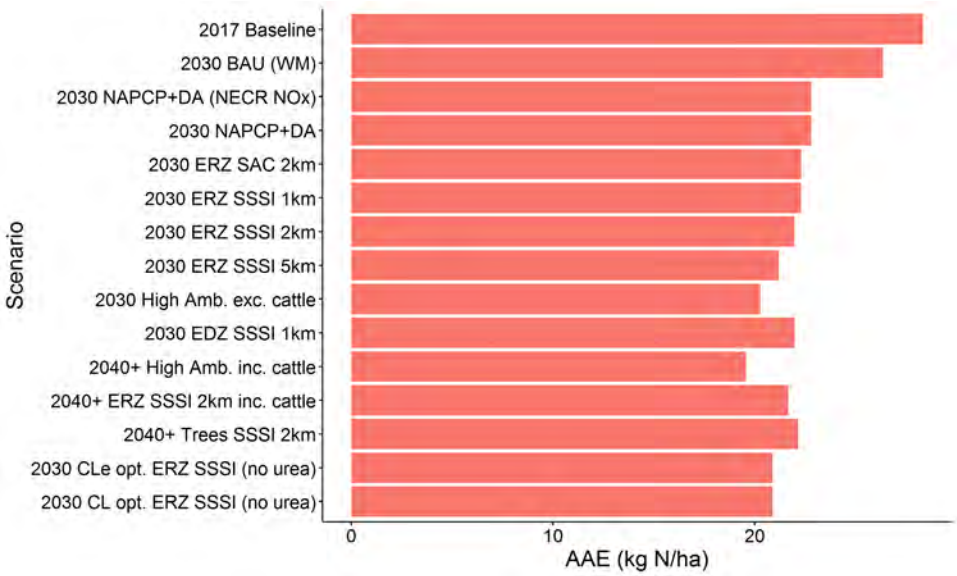


Figure 3.13-20. Exceedance of critical loads by scenario at Peatlands Park ASSI.

Annual mean NO_x concentrations are predicted to be well below the 30 µg m^{-3} critical level across Peatlands Park ASSI in all scenarios across the whole site. Annual mean NH_3 concentrations are predicted to be above the 3 µg m^{-3} critical level in 2017 only, and remain well above the 1 µg m^{-3} critical level in all scenarios across the whole site. N deposition fluxes are also predicted to be above the critical load in all scenarios across the whole site. The location-specific modelling only considers road traffic, and the nearest road is some 70 m from the site. If location-specific modelling had taken account of agricultural emissions, then it is possible that higher on-site maximum NH_3 concentrations and N deposition fluxes would have been predicted.

3.13.10 Local assessment

Peatlands Park is located in an intensive agricultural area with cattle and poultry farming, and modelled NH_3 concentrations in the surrounding area are high, in keeping with local knowledge. Current ongoing work by UKCEH to establish a new network of NH_3 measurement across the site has estimated gradients of high concentrations from potential sources close to the site boundary in the west, north and east and lower concentrations towards more central locations. Indeed, the 5 km source attribution data indicate that local sources provide most (>90%) of the atmospheric N input to Peatlands Park ASSI, with emissions from NI livestock accounting for > 70% of locally depositing species. The mitigation scenarios modelled in this project are expected to bring the maximum 1 km grid square NH_3 concentration at the site below the 3 µg m^{-3} NH_3 critical level following a reduction in agricultural emissions density, but concentrations remain above the 1 µg m^{-3} NH_3 critical level in all scenarios. Scenarios with high ambitions for NH_3, i.e. UK-wide 2030 and 2040 High Amb. inc./exc. cattle achieve the greatest decreases across the ASSI, for both NH_3 concentrations and N deposition, indicating the need for broader national measures. However, the optimised spatially targeted scenarios are as effective for decreasing NH_3 concentrations as the UK-wide mitigation scenarios.

As Peatlands Park contains both woodland and low-growing semi-natural vegetation, both vegetation types are considered for N deposition. N deposition to the site is estimated to decrease by several kg N ha^{-1} yr^{-1} under the most ambitious scenarios. It is, however, expected that spatial variability within the 1 km grid cells of the UK-scale modelling hides larger potential improvements to areas closer to the centre of the site, with the site's outer perimeters acting as a buffer zone for the core area.

The new monitoring assessment due to start in the near future is expected to bring further clarity on the finer gradients and magnitude in NH_3 concentrations at the site. This should shed light on the complex spatial variability across the site which contains some potentially sheltered areas contrasting with areas closely bordering emission sources. This information can then be assessed against the 1 km grid baseline modelling for further conclusions to be drawn.

The nearest road is 70 m from the ASSI and so the localised effect of this road, over and above that accounted for in the 1 km^2 average concentrations, is very small. Including this localised effect thus has very little effect on the overall conclusions for the site.

3.13.11 Conclusions

From the UK-scale 1 km grid modelling and local assessment, the level of exceedance may be underestimated locally for some areas of the site, given the proximity of likely local emission sources. While the spatially targeted scenarios are likely to benefit N-sensitive vegetation across Peatlands Park, they are, on average not estimated to achieve non-exceedance of the 1 µg m^3 critical levels for NH_3 or the critical loads at the 1 km grid resolution. The higher critical level of 3 µg m^3, which is exceeded at the 1 km grid resolution in the 2017 baseline for parts of the site, is estimated to be no longer exceeded under any of the future mitigation scenarios. Locally implemented measures are expected to further decrease the strong local NH_3 concentration and deposition gradients into the site, especially given the very high estimated local N deposition input at >90%, which is predominantly due to local livestock farming. In combination with wider regional improvements, local measures can be expected to make a considerable difference in terms of atmospheric N input to the site.

3.14 Turmennan

The following sections provide background on Turmennan and contain extracts of the UK scale model outputs centred on the site, to illustrate the effects of the UK-wide and spatially targeted mitigation scenarios at different levels of ambition. Additional specific analysis for the site can be found in Section 3.14.10, which focuses on assessing the information presented with regard to the suitability of this site for spatial targeting of measures.

3.14.1 Site map and location within UK

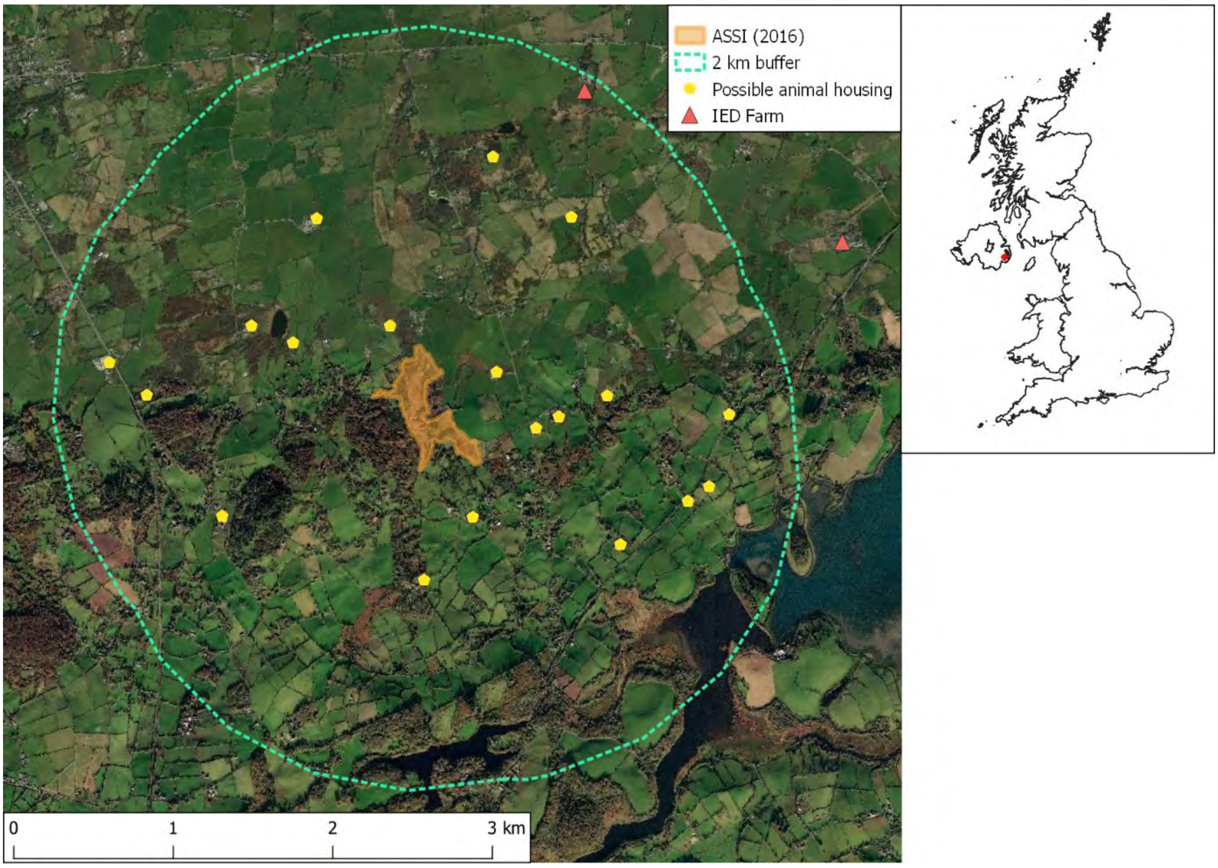


Figure 3.14-1. Site map showing relevant features and boundaries of Turmennan, and location within the UK.
Satellite imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

3.14.2 Designated features

Table 22. Nitrogen sensitive interest features at Turmennan ASSI from the NIEA database (provided by Aine O'Reilly, pers. comm.).

Features
Transition mires and quaking bogs/fen
Invertebrate assemblage

3.14.3 Site characteristics

Turmennan ASSI is a small site, which is one of the best examples in Northern Ireland of a transition mire. The main sources of atmospheric N input to Turmennan are agricultural emissions. The site located in an intensive farming landscape, with at least one IED farm within 2 km of the ASSI boundary and eastern parts of the site bordering farmland directly.

Measurements of NH_3 concentrations at several points are due to start at this site in the near future (post COVID-19 lockdown), to determine the level of atmospheric N input at different locations on the site and for developing potential options for mitigation.

3.14.4 Agricultural emission density

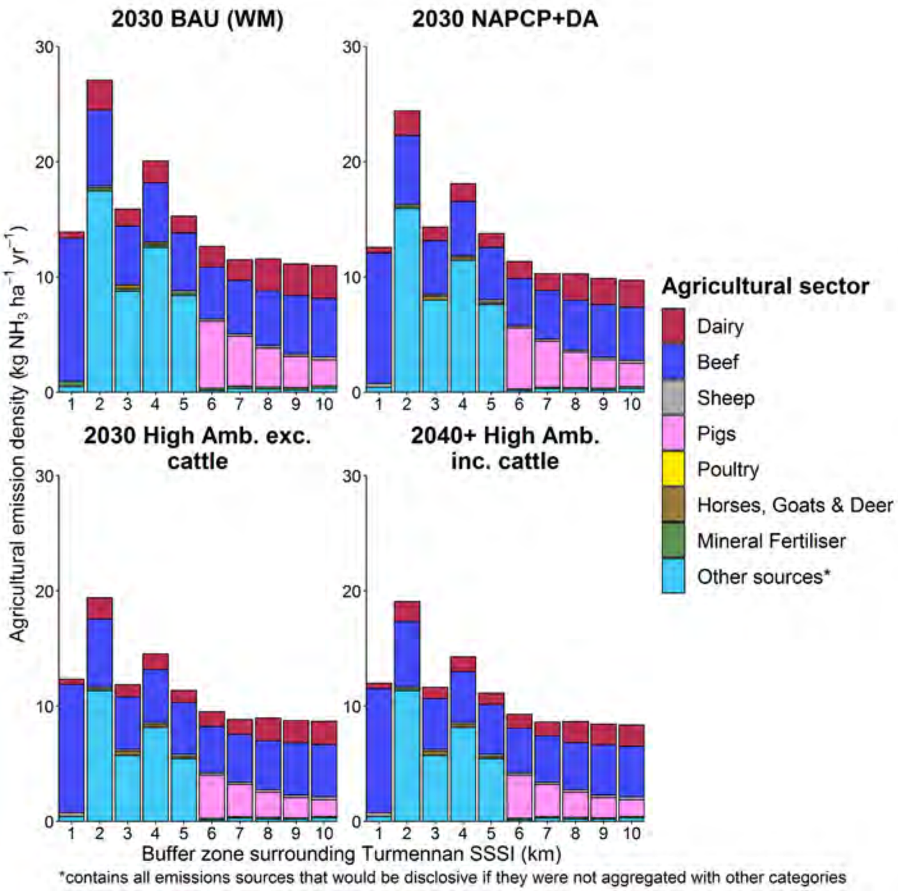


Figure 3.14-2. Estimated agricultural emission densities in concentric buffer zones surrounding Turmennan ASSI.

3.14.5 Source attribution

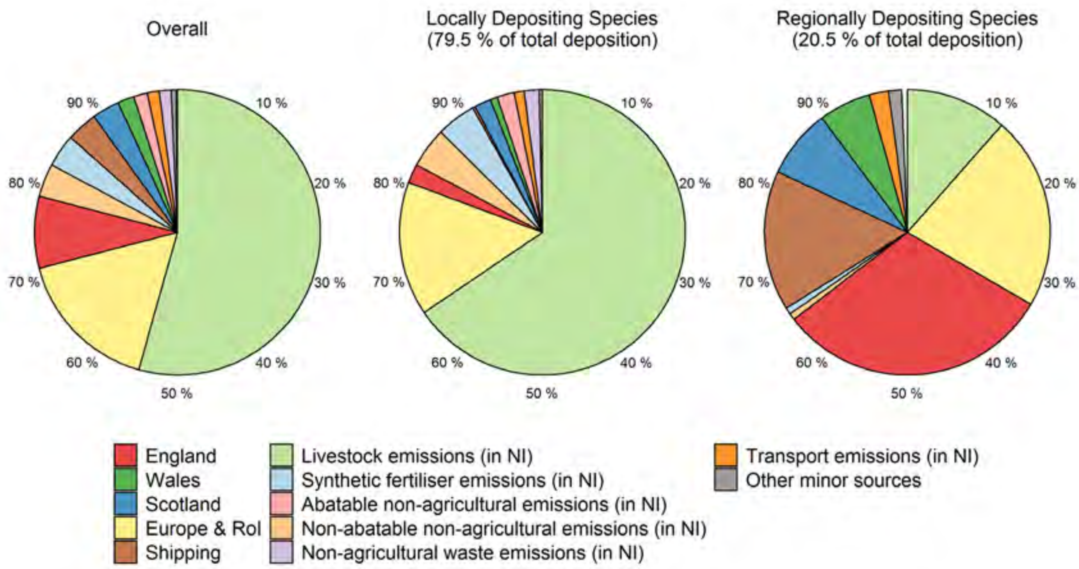


Figure 3.14-3. Relative contribution of emission sources to N deposition (to low-growing semi-natural vegetation) received by Turmennan ASSI.

3.14.6 NH3 concentration

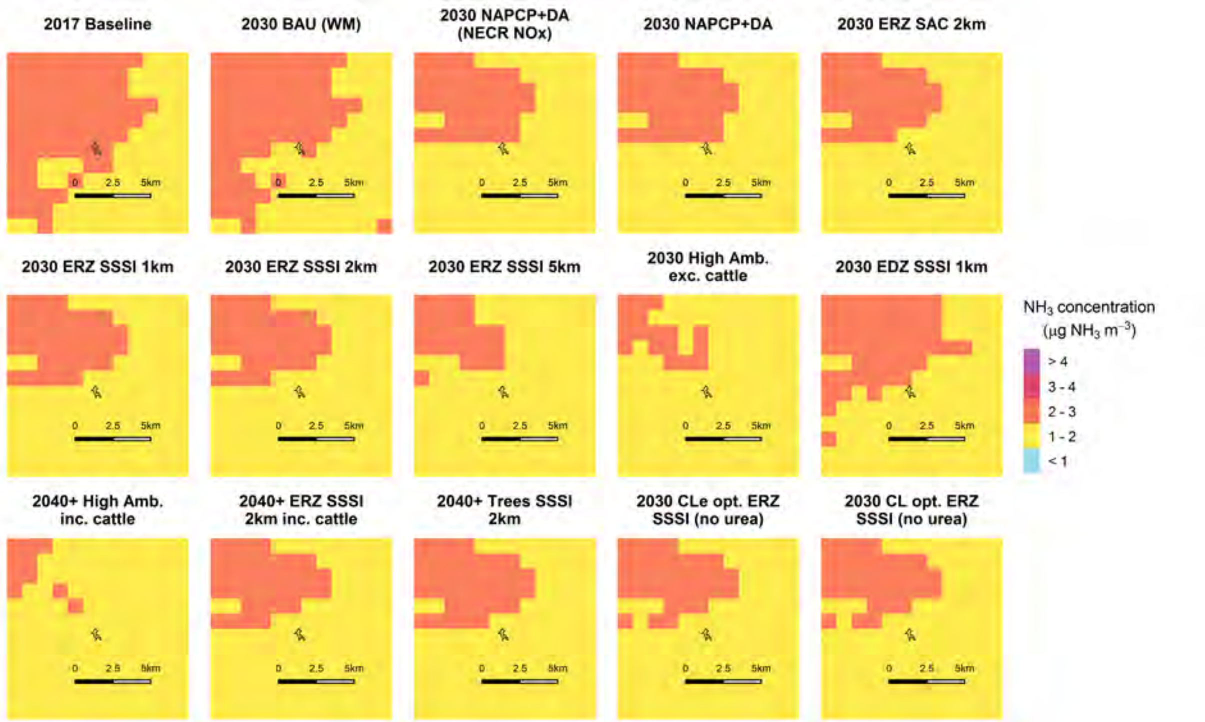


Figure 3.14-4. NH_3 concentrations (FRAME model calibrated with measurements) by scenario at Turmennan ASSI and surrounding area.

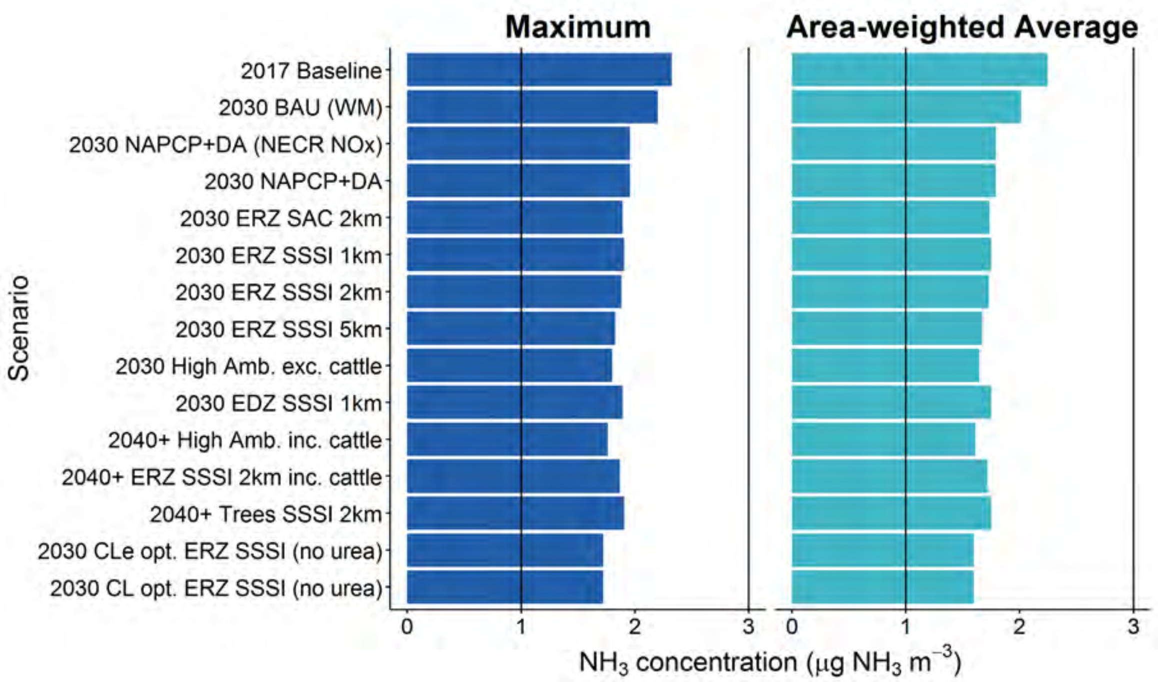


Figure 3.14-5. Maximum and area-weighted average NH3 concentration (FRAME model calibrated with measurements) by scenario at grid cells overlapping with Turmennan ASSI. Vertical lines indicate 1µg and 3µg critical levels.

3.14.7 NO_2 concentration

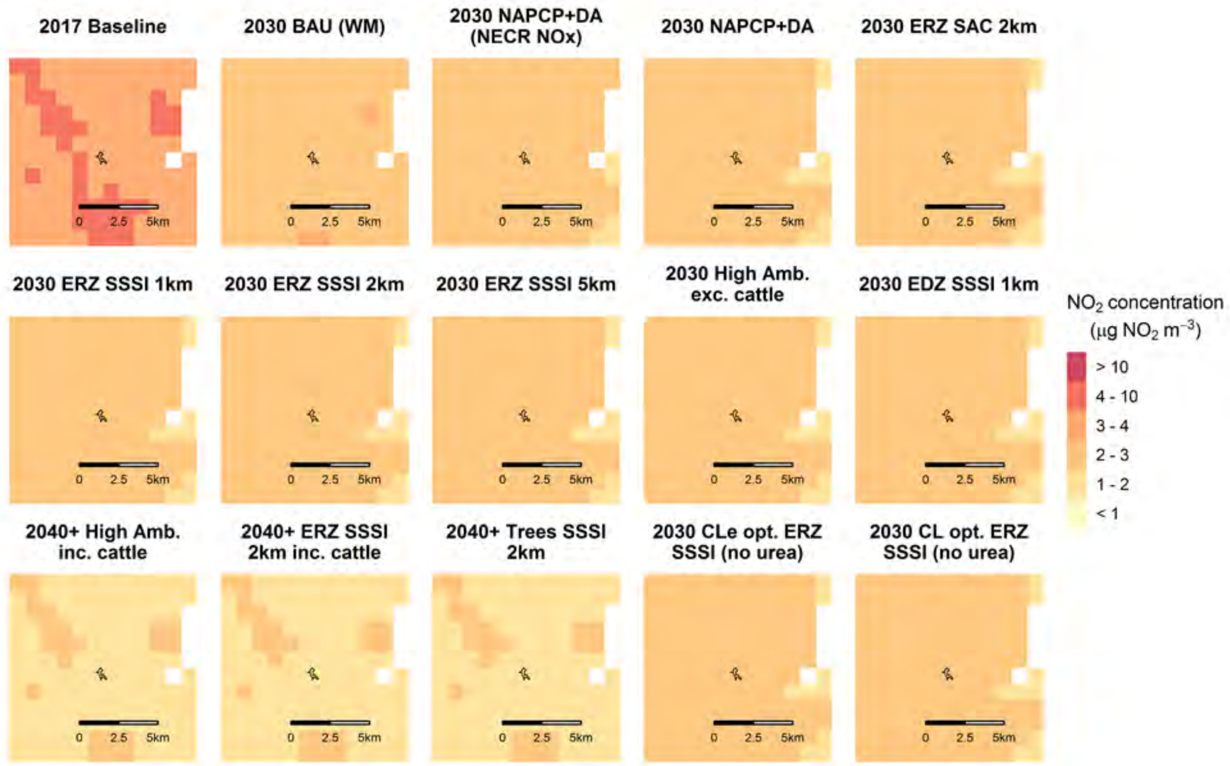


Figure 3.14-6. NO2 concentration (FRAME model calibrated with PCM) by scenario at Turmennan ASSI and surrounding area.

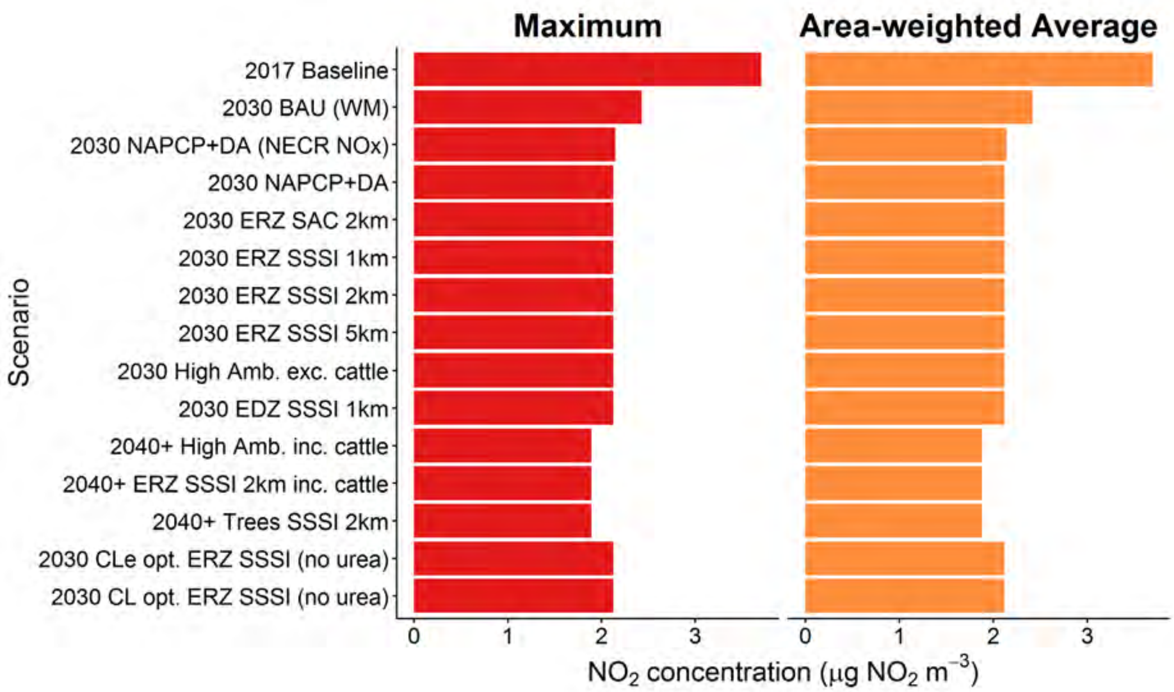
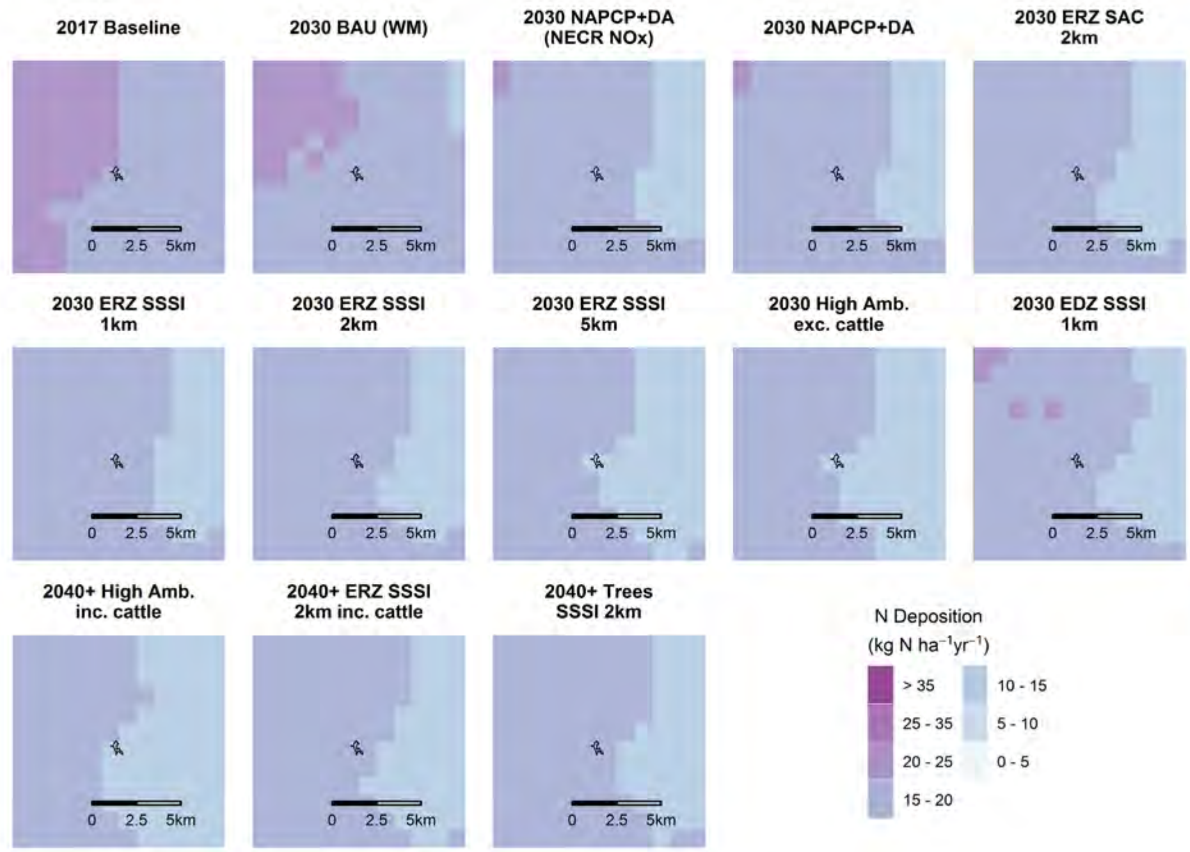


Figure 3.14-7. Maximum and area-weighted average NO_2 concentration (FRAME model calibrated with PCM) by scenario at 1 km grid cells overlapping with Turmennan ASSI.

3.14.8 N deposition



3.14-8. N deposition (to low-growing semi-natural vegetation) received by Turmennan ASSI and surrounding area.

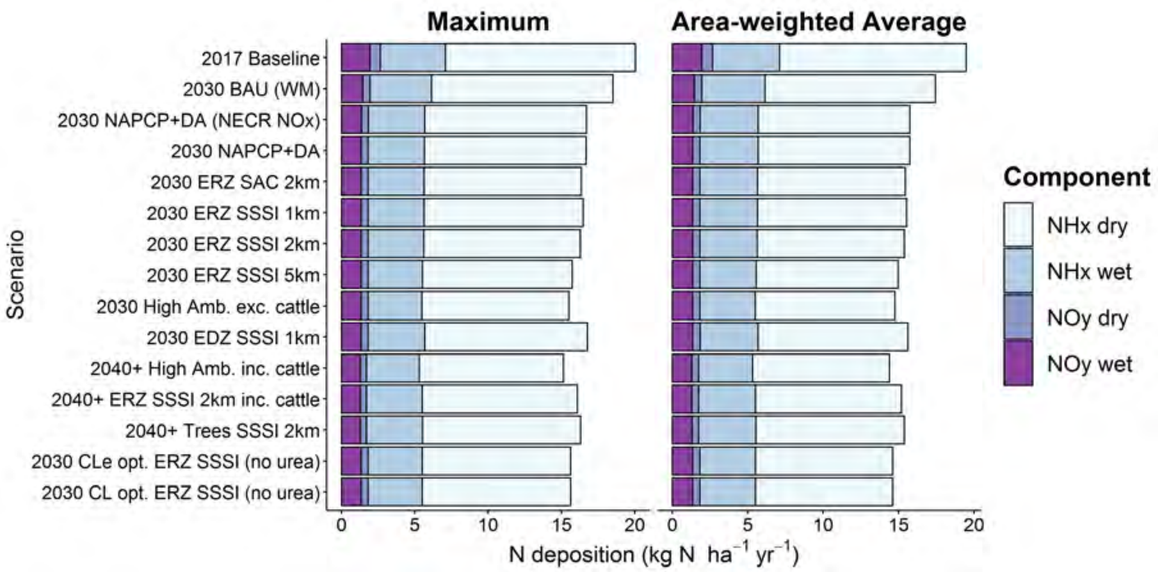


Figure 3.14-9. Maximum and area-weighted average deposition (to low-growing semi-natural vegetation) by scenario at 1 km grid cells overlapping with Turmennan ASSI.

3.14.9 Exceedance of critical loads

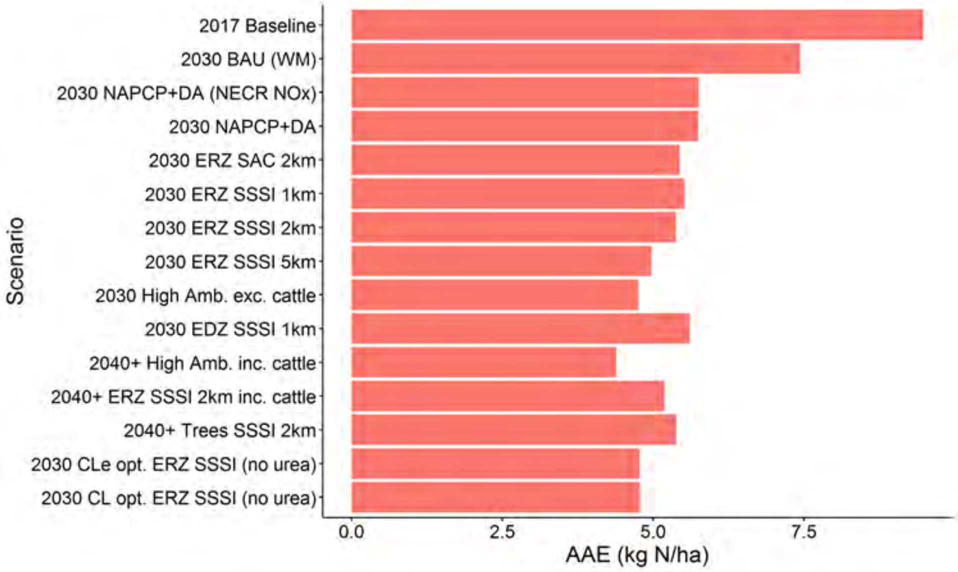


Figure 3.14-10. Exceedance of critical loads by scenario at Turmennan ASSI.

3.14.10 Nitrogen Decision Framework

For the 50% N deposition uncertainty assessment, the NDF score did not change (Table 23). However, in the 20% N deposition uncertainty assessment, the NDF score for Transition mire and quaking bog dropped from Very high to High for both the 2030 NAPCP+DA (NECR NOx) baseline and the most ambitious 2030 CL opt. ERZ SSSI (no urea) scenario, reflecting the N deposition dropping to closer to the upper end of the critical load range. The NDF score class changed because the uncertainty in the N deposition estimates is factored into the exceedance score calculation.

Table 23. Nitrogen Decision Framework Factor 1 (Exceedance) score for Turmennan.

			N dep (kg/ha/yr)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 50%)			Nitrogen Decision Framework Factor 1 (Exceedance) score (Uncertainty +/- 20%)		
Case study	Habitats	Critical load range (kg N/ha/yr)	2017 Baseline	NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)	2017 Baseline	2030 NAPCP + DA (NECR NOx)	2030 CL OPT ERZ SSSI (no urea)
Turmennan	Transition mire, and quaking bog	10-15	19.3	15.4	15.4	High	High	High	Very high	High	High

3.14.11 Local assessment

Turmennan is located in an agriculturally intensive region which contains many cattle and pig farms, and a high number of agricultural sources within several kilometres' distance to what is a relatively small designated site. Source attribution assessment reflects local knowledge that the main atmospheric N inputs to the site are local input from livestock emissions (~70% of local N input, which accounts for almost 80% of total input). Turmennan is bordered to the east by a large intensively fertilised field, with the high nitrogen status both visible on the ground and from aerial images (such as Google or Bing). Notably for Turmennan, and in contrast to many other sites considered in these local scale assessments, NH_3 concentrations are not expected to decrease substantially from the 2017 baselines towards the 2030 NAPCP+DA scenario. Subsequent scenarios with spatial targeting measures do result in a small decrease in NH_3 concentrations and N deposition to semi-natural low-growing vegetation. NH_3 concentrations remain above the 1 µg NH_3 critical level for all scenarios.

Given the large spatial variability of N at the landscape scale, the 1 km grid exceedance estimates, especially for critical levels, are likely to be an underestimate. This is due to the close proximity to N sources near the site boundary, such as animal housing and slurry/manure spreading. The critical level for mosses and other lower plants (1 µg NH_3 m^{-3}) is exceeded across the site at a 1 km grid resolution. Depending on the local concentration gradients into this very small site, the critical level for higher plants (3 µg NH_3 m^{-3}) may also be exceeded close to the boundary, at a higher resolution assessment than is possible with the UK-scale 1 km grid modelling.

3.14.12 Conclusions

The spatially targeted scenarios considered in this current study indicate the likely benefit spatial targeting could provide to Turmennan ASSI, given the high agricultural density in the surrounding area and the close proximity of agricultural activities, especially on the eastern side. Measures targeting the specific sectors relevant and in close proximity to this very small site and acting in the wider region surrounding the ASSI, particularly those including high-ambition measures for cattle, would be most effective in this case. The model results suggest that a zone of at least 5 km with spatial targeting would be required to decrease N deposition to below 15 kg N ha^{-1} yr^{-1}.

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