NITROGEN FUTURES

UNDERSTANDING **IMPACTS OF NITROGEN** ON NATURE

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NITROGEN POLLUTION IS A MAJOR DRIVER OF **BIODIVERSITY LOSS IN THE UK**

OVER 57% OF THE AREA OF UK'S HABITAT IS **THREATENED BY EXCESS NITROGEN DEPOSITION**

EXPLORING WAYS TO PROTECT UK'S NATURE PROTECTED SITES FROM **NITROGEN POLLUTION**

Nitrogen (N) is an important nutrient for plant growth and is used in fertiliser to support food production for a growing global population. However, adding too much nitrogen to the environment can cause air and water pollution, affect ecosystems and soil health as well as contribute to climate change.

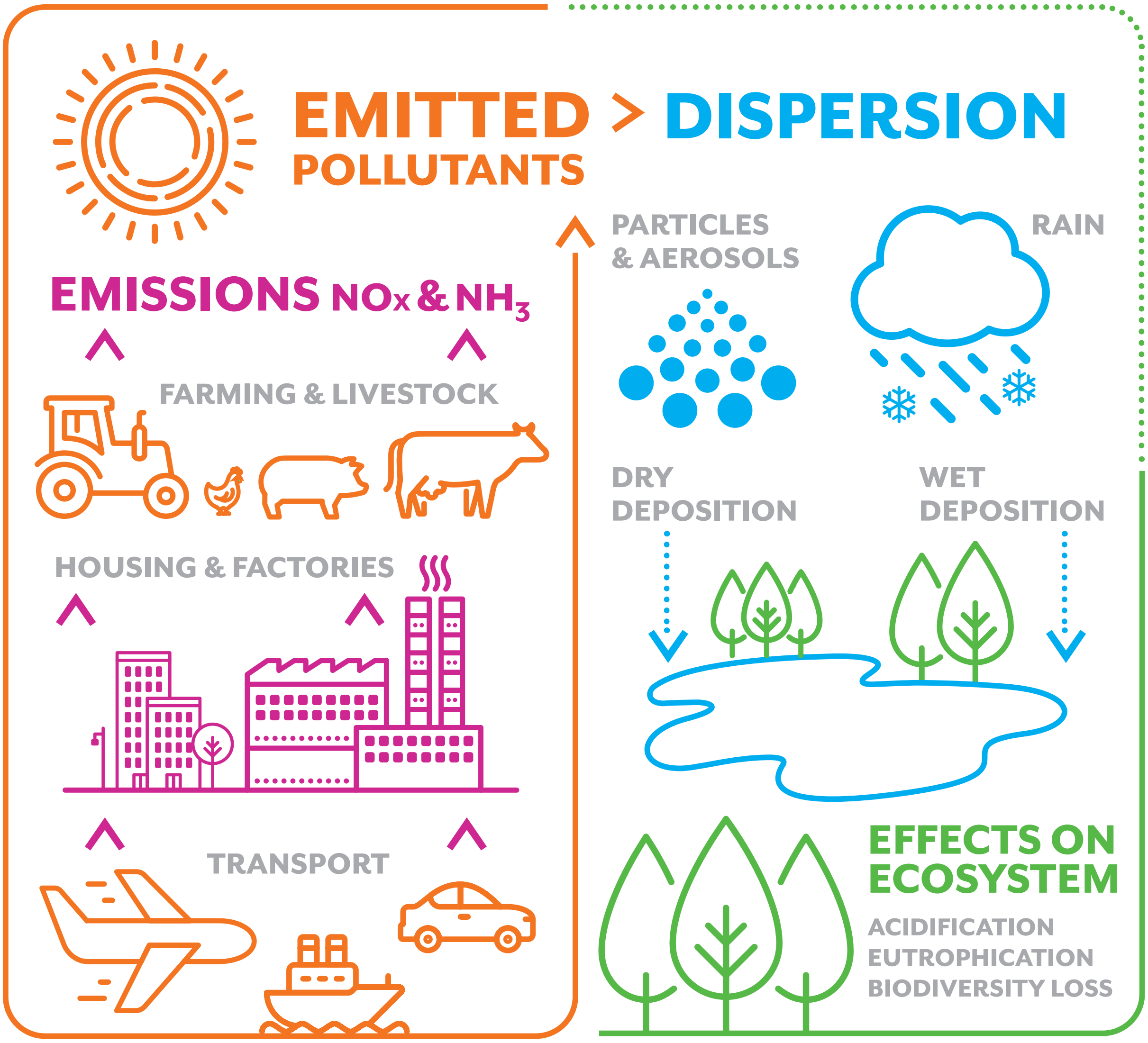
Yellow Stagshorn (*Calocera viscosa*) growing on wood beneath moss on the forest floor. Old Sulehay Forest, England. Image: **Alexandra Cunha, JNCC.**

Impacts of nitrogen pollution are felt across a range of scales, from local, to regional and global. In 2017 over 57% of the area of sensitive habitat in the UK had nitrogen deposition above thresholds where it is harmful to sensitive plants and biodiversity.

The UK's National Air Pollution Control Programme (NAPCP) sets out measures on how the UK can meet targets for emission reduction commitments of five airborne pollutants, including nitrogen, by 2030.

Current projections show the UK is on track to meet its 2030 statutory emission reduction targets. The Clean Air Strategy (2019) and the Clean Air Plan for Wales (2020), sets out the action required to meet these targets in England and Wales respectively. The Cleaner Air for Scotland (revision underway October 2020) and the draft Northern Ireland ammonia strategy expected for consultation soon, will support their country specific strategies to control air pollution as well as contribute to emissions reductions and the national NAPCP 2030 targets.

Meeting these statutory targets will improve air quality for both biodiversity and human health. However, Nitrogen Futures shows the improvements are not fully protective of UK ecosystems, especially in areas with high atmospheric nitrogen input to habitats.



Nitrogen pollution is emitted to the air as nitrogen oxides (NOx) and ammonia (NH_3). Nitrogen oxides are mainly emitted from combustion processes, such as road transport, shipping, rail and air travel, power generation, industry and domestic heating. Ammonia originates mainly from agricultural livestock manures and fertiliser use. Other sources of ammonia, albeit in smaller volumes, include waste management activities, road transport and industry. These pollutants are then dispersed as gases and particles into the air and deposited onto habitats affecting biodiversity and ecosystem function.

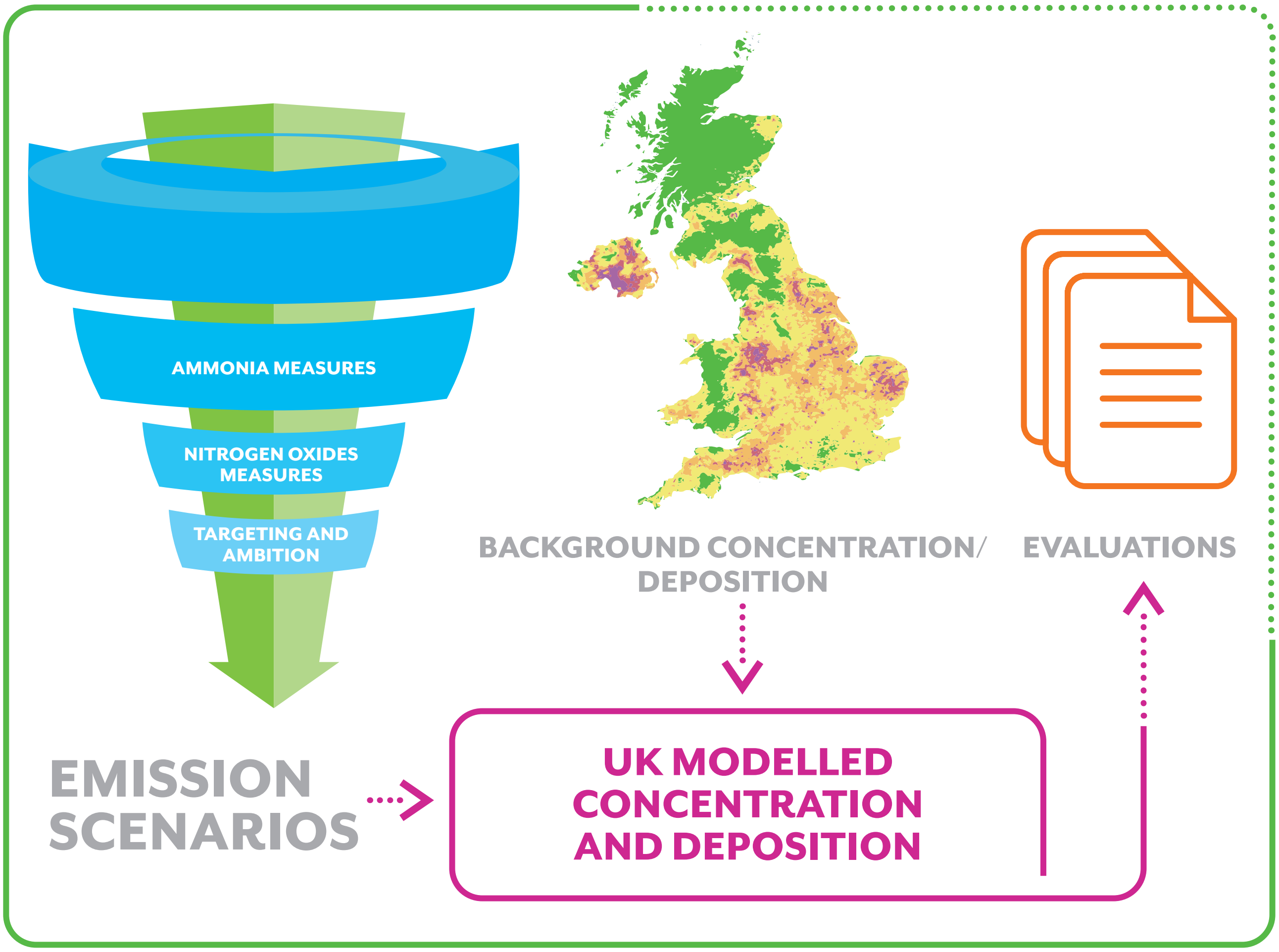
Healthy moss (on the right) and ammonia damaged moss at Ballynahone Bog, Northern Ireland, Images: **Áine O'Reilly, NIEA/DAERA 2019.**

While nitrogen oxides (NOx) emissions have decreased substantially over recent decades the same trend has not been observed for ammonia (NH_3) and further mitigation efforts are needed to meet policy objectives for air quality and nature.

The main objective of Nitrogen Futures was to explore how different emission mitigation measures could improve the long term status of habitats and nature protected sites in the UK.

The project developed scenarios for nitrogen oxide (NOx) and ammonia (NH_3) emission reductions to 2030 and beyond (2040+). Scenarios included bundles of mitigation measures with different levels of ambition for reducing emissions.

MODELLING METHODS



These scenarios were used to predict atmospheric emissions, concentrations and deposition of nitrogen at UK nature protected sites, at a 1 km^2 grid resolution. The predictions were analysed for the UK as a whole and for England, Scotland, Wales and Northern Ireland separately.

Specific case studies for each country were further explored to illustrate how the national results can be applied in practice at local level. The analysis included indicative costs of the measures, wider environmental benefits and possible trade-offs resulting from each scenario.

Nitrogen Futures used updated models with increased resolution, accounted for both NOx and NH_3, at UK and international level to produce an innovative piece of evidence.

THE RIGHT REDUCTIONS MADE IN THE RIGHT PLACES

Reducing emission levels near sensitive habitats is the most effective way to decrease nitrogen deposition and damage to habitats. In contrast to applying reductions across the nation, the focussed approach is referred to as "spatial targeting". Nitrogen Futures shows that in many cases supplementing national measures with spatial targeting measures can produce the greatest cost-benefit option.

Nitrogen Futures provides new evidence to support strategic local actions that improve habitat and species condition at the UK's nature protected sites.

The project used the best available N emission data, policy target information and each country level of ambitions. This was the basis for scenarios that explored different mitigation measures to reduce the impacts of atmospheric N on nature protected sites.

For the UK-wide scenarios, the tools, models and datasets used for annual UK Government reporting were applied at a 1 km^2 grid square resolution. This included detailed modelling to determine the magnitude and spatial patterns of atmospheric emissions.

Chemical transport modelling was used to estimate atmospheric concentrations and deposition to habitats. This was used to calculate benefit to habitat including exceedance of thresholds for damage to habitats, using critical loads (for N deposition) and critical levels (for air concentrations).

Nitrogen Futures starts with a 2017 baseline. Then, a 2030 baseline accounts for the effects of national and international emission reductions across all UK habitats and nature protected sites. It is on top of these national measures that additional benefit from the various scenarios was tested.

UK-WIDE BASELINE SCENARIOS

The baseline scenarios accounted for current policy ambitions in each UK country, including:

- Country-specific air pollution strategy/plans and commitments;
- NAPCP to use low emission fertiliser and manure application. It also includes improved livestock management waste handling with modifications across the UK countries to suit agricultural practices in use;
- Reduction of fugitive industrial emissions and installation of Best Available Technology; and
- Pollution reduction and alternative fuels in shipping, aviation and housing.

UK-WIDE MITIGATION SCENARIOS

The UK-wide mitigation scenarios were added on top of the 2030 baseline that meets the UK's emission reduction targets. These additional measures included:

- Higher implementation rates of measures already included in the 2030 baseline; and
- Additional measures; for example, testing the impact of potential requirements for low-emission cattle housing for large dairy and beef farms. These measures were similar to "Best Available Technique" as seen in controls for large pig and poultry farms.

LOCAL SCALE SCENARIOS

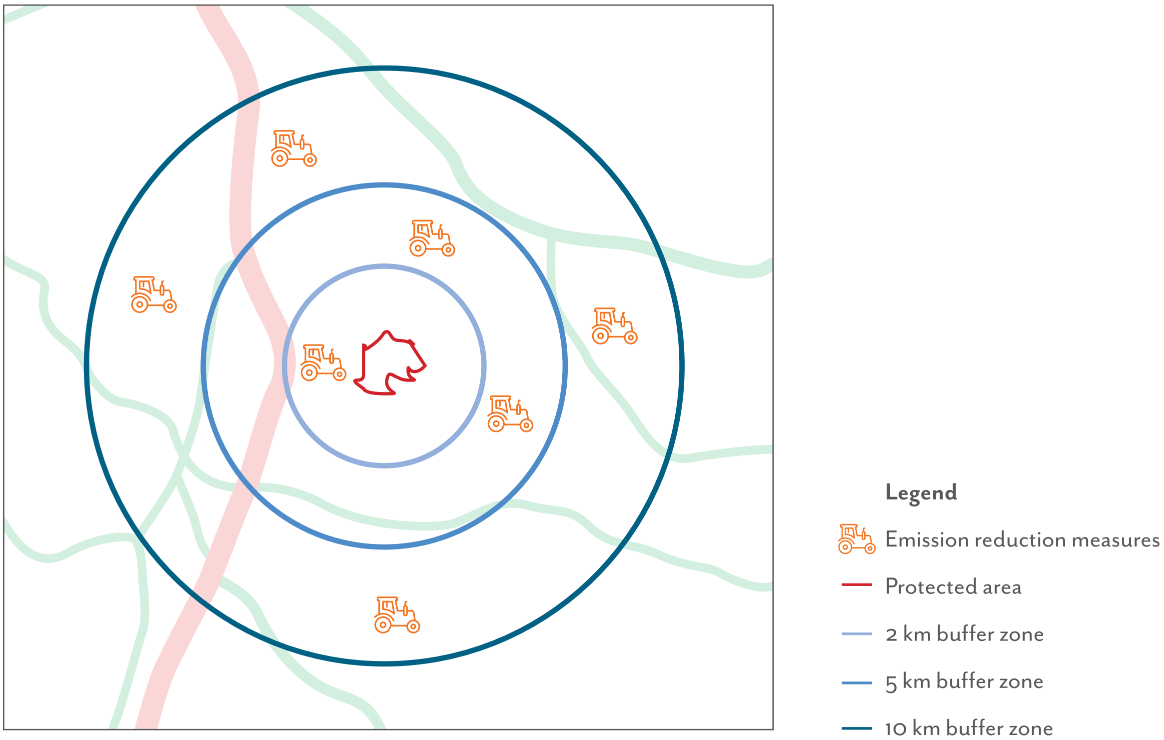
Other scenarios tested spatial targeting of measures specifically around nature protected sites. These focused specifically on Sites of Special Scientific Interest (SSSIs) for Great Britain and the equivalent Areas of Special Scientific Interest (ASSIs) for Northern Ireland.

Measures were applied in concentric buffer zones around the sites' boundaries

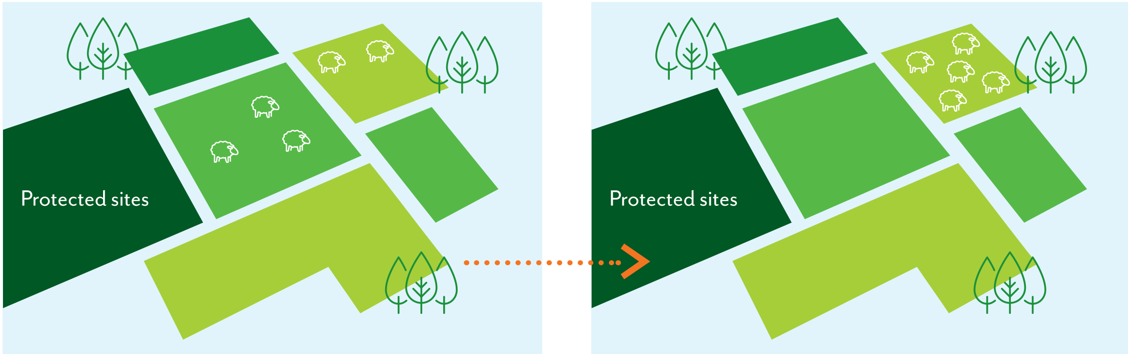
These scenarios grouped measures by their effect on air quality around areas of habitat:

- Emission Reduction Zones (ERZ) – where emission reduction measures are applied, e.g. low emission slurry spreading, covering of slurry tanks;
- Emission Displacement Zones (EDZ) – where activities associated with emissions are moved further away, e.g. slurry spreading exclusion zones, with the slurry spread elsewhere instead; and
- Optimised scenarios – where the most effective measures from previous analyses were combined to maximise reductions in concentration or deposition.

SPATIAL TARGETING OF MITIGATION



LIVESTOCK EXCLUSION



Likely to displace NH_3 emissions

FERTILISER EXCLUSION

Potential reduction of NH_3 emissions

Potential displacement of NH_3 emissions

> While meeting these targets will improve air quality for both biodiversity and human health, it is still not fully protective of UK ecosystems, especially in areas with high atmospheric nitrogen input to habitats.

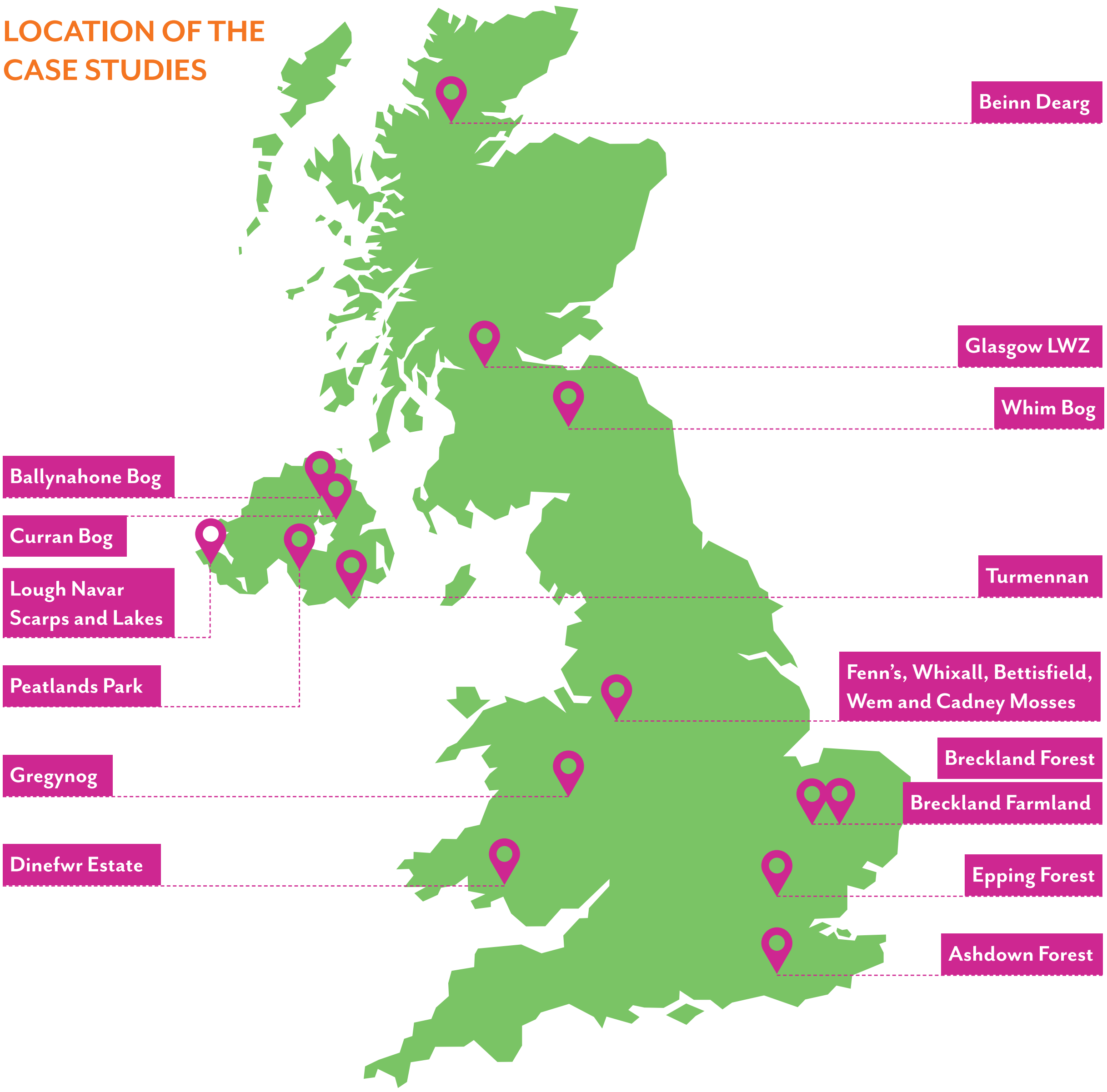
CASE STUDIES

Fifteen nature protected sites across the UK were chosen as case studies to explore how well the national modelling could be used at local level. They also demonstrate which circumstances will benefit most from strategies like spatial targeting to decrease atmospheric N at a site.

The case studies included sites with a variety of:

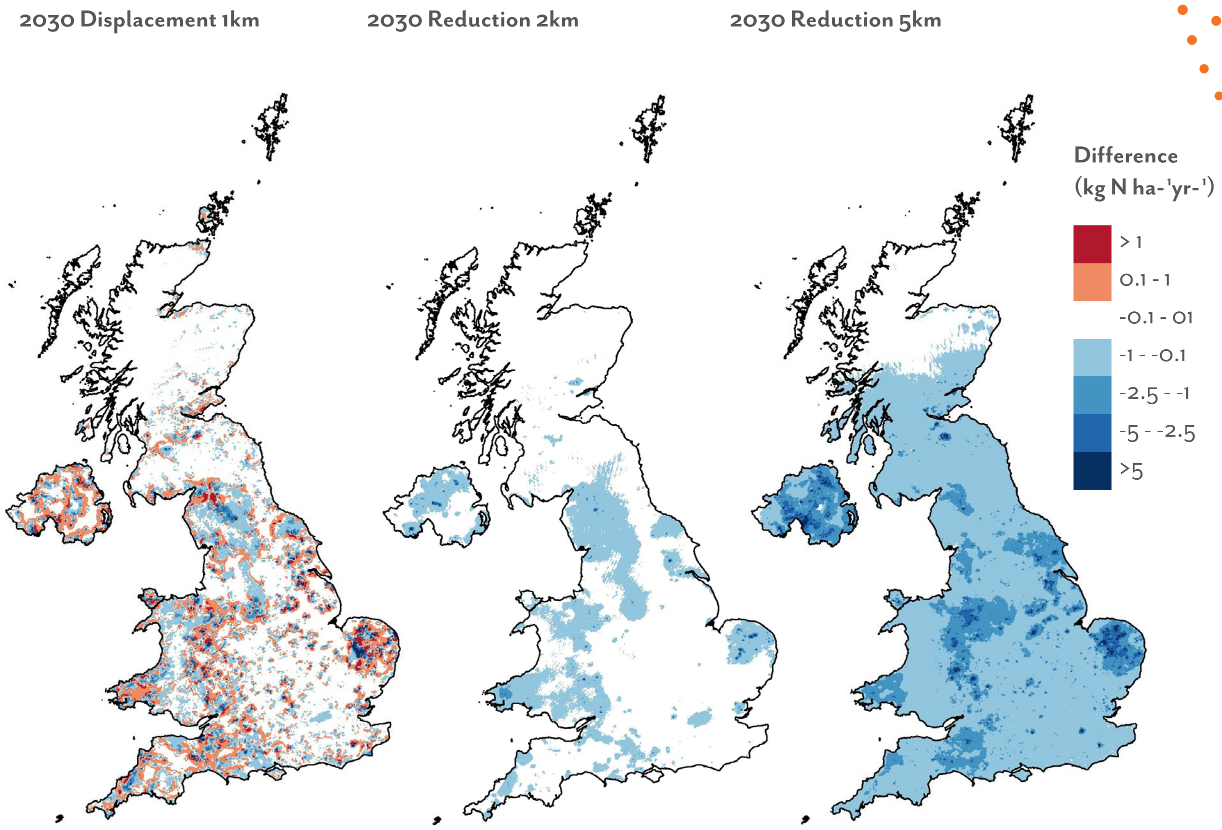
- Emission source sectors (e.g. agriculture, transport, energy production)
- Distance to emission sources
- Habitat types (e.g. bogs, woodland, heath, grassland)
- Geography – covering all parts of the UK (England, Wales, Scotland, Northern Ireland), upland vs lowland, urban vs rural vs very remote areas.

LOCATION OF THE CASE STUDIES

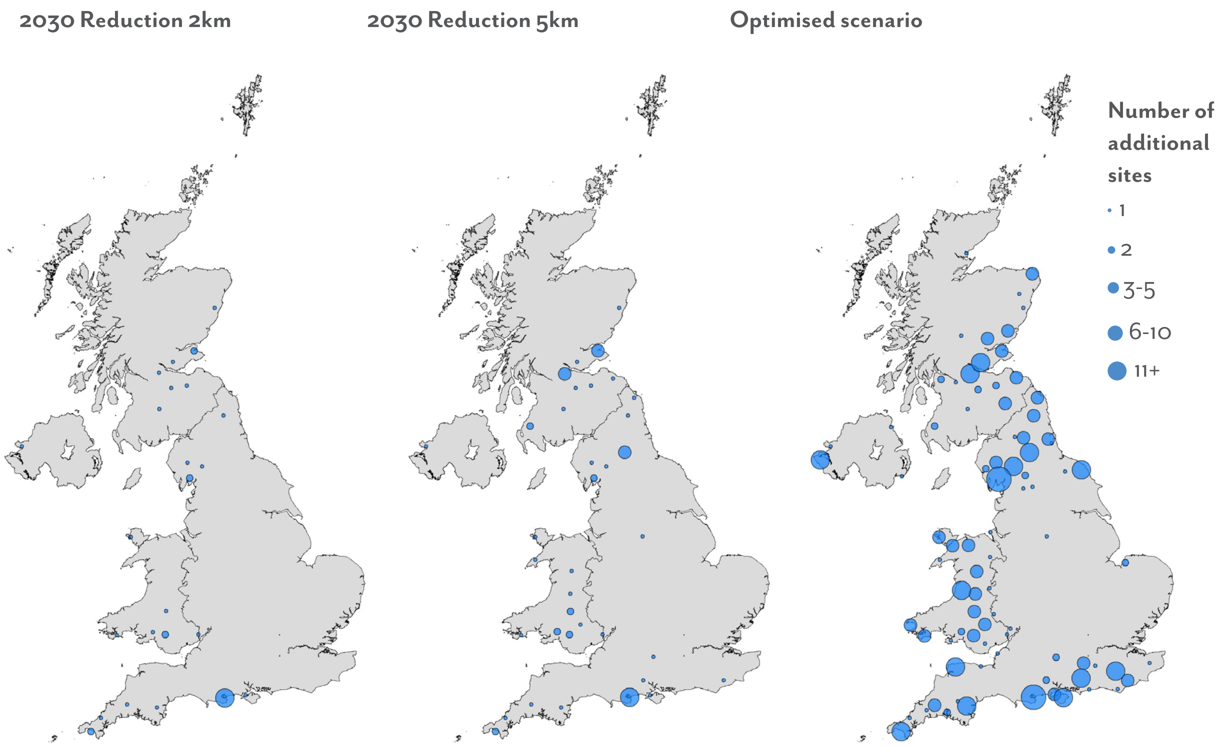


HOW MUCH OF A DIFFERENCE DOES SPATIAL TARGETING MAKE?

The modelling results show that not all areas of the UK will experience the same reductions in atmospheric N under the same set of emission reduction measures. This highlights the importance of using local and regional information when developing policy and mitigation strategies.



In this example of the project results, the maps show the difference in nitrogen deposition to woodland habitats, where these exist, when different spatial targeting measures are applied on top of national commitments for 2030. This example looks at Emission Displacement Zones (EDZ) and Emission Reduction Zones (ERZ) of different buffer widths around protected areas. The results show that implementing Emission Reduction Zones with a 5km buffer around a woodland will be the most efficient way of decreasing N deposition into this habitat. The results also show that using Emission Displacement Zones will contribute to the increase of nitrogen in other areas (areas in red). This is most visible in Northern Ireland and near the border between England and Wales and in Norfolk. For this reason, we need to be very careful when thinking about using displacement alone as a strategy.

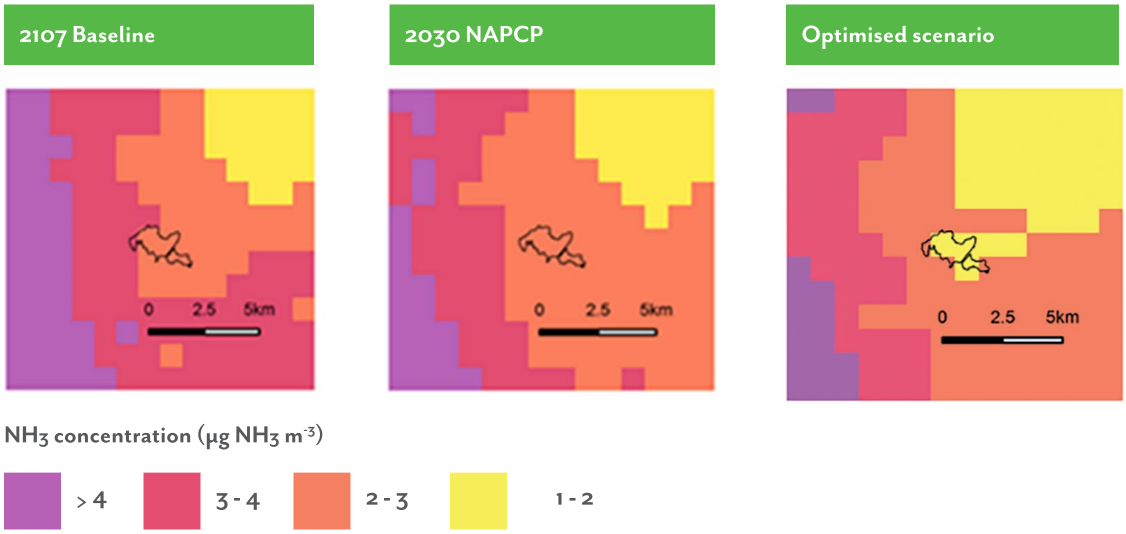


Number of additional nature protected sites not in exceedance of the 1 µg m^{-3} ammonia critical level. To note: 1 µg m^{-3} ammonia critical level is the ammonia concentration levels in the air below which lichen and bryophytes do not suffer an impact.

In this example of the project results, the maps show the additional number of protected areas with ammonia concentration no longer exceeding critical level for lower plants, i.e. lichen/bryophytes. The scenarios are Emission Reduction Zones of 2 km and 5 km buffer widths and the optimized scenario. Each of these scenarios are compared with the 2030 baseline, i.e. assuming the UK meets the NAPCP emission reduction targets.

The optimised scenarios achieve the largest benefits at UK protected areas. This scenario combines a bundle of measures such as optimised minimum Emission Reduction Zones buffer widths, combined with 1 km Emission Displacement Zone and replacing all urea fertiliser with lower emission alternatives.

Nature protected sites currently in exceedance that would benefit most from the optimised scenario are in Scotland, Wales and North West England as well as the South coast of England and the West of Northern Ireland. Compared with the 2030 baseline, which assumes that the UK meets its emission reduction targets, approximately 280 additional nature protected sites would become protective of the most sensitive plant species.



Ammonia concentration maps for different scenarios for Peatlands Park, an Area of Special Scientific Interest (ASSI) in Northern Ireland.

The highest NH_3 concentrations, shown in purple and red, represent levels which endanger all sensitive habitats. Concentrations above 1 µg m^{-3} are harmful to the most sensitive plants without roots, such as lichens and mosses – to note that none of the scenarios modelled achieve protection for these species in this case study. Under the NAPCP 2030 baseline scenario, significant wider decreases in NH_3 concentrations around the site are expected. In the case of Peatlands Park ASSI, the implementation of the 2030 optimised scenario was most likely to alleviate pressure on lichen and mosses.

CASE STUDY RESULTS:

The case studies results show that nature protected sites close to large or clustered emissions sources benefit most from the implementation of local measures. This is when compared with similar mitigation measures applied regionally or at a UK scale.

Conversely, nature protected sites that receive atmospheric N primarily through long-range transport, benefit more from wider national and international reductions than from spatial targeting.

This highlights the importance of UK-wide and international transboundary policies as well as local mitigation in decreasing effects of N pollution on protected areas. Current national policies, as represented by the 2030 baseline, will help reduce pressure on protected areas across the UK. However, in many cases, specific locally targeted measures are required to bring nitrogen pollution to levels that do not damage habitats.

COST-BENEFIT ANALYSES

Cost-benefit was measured by comparing the additional cost of a specific scenario with the additional benefit, e.g. protection for habitats and species, emission reduction.

Targeting mitigation around nature protected sites is the most efficient and cost-effective option method for decreasing atmospheric N input in areas with higher risk to habitat. This is particularly true for sites in areas with high emission density from farming activities or road transport.

Cost-effectiveness of spatially targeted mitigation scenarios for NH_3 Critical Levels exceedance (Cle) for UK nitrogen sensitive SSSIs. All comparisons are made to the baseline scenario 2030 NAPCP.

Scenarios by 2030	Additional SSSIs out of exceedance	Reduction in excess nitrogen deposition (tonnes N)	Difference in cost to NAPCP(£M)
Emission Reduction Zone of 2km	34	354	41.5
Emission Reduction Zone of 5km	56	607	93.8
Emission Displacement Zones of 1km	94	455	3.7
Optimised scenario (Cle)	268	1519	94.3

The optimised scenario was the most cost-effective option for reducing nitrogen critical load exceedance at local level. This scenario combines a bundle of measures such as optimised minimum Emission Reduction Zones buffer widths, combined with 1 km Emission Displacement Zone and replacing all urea fertiliser with lower emission alternatives

The least costly scenario for reducing ammonia (NH_3) critical level exceedance was Emission Displacement Zone (EDZ), i.e. displacing the emission source further away from the protected site. For example, an EDZ may require spreading of manure in a field at least 1km away from the protected site boundary. Equipment investment is low, hence the greater cost-benefit ratio when damage costs of displacement are not accounted for.

Although this is the least cost scenario, the implementation of this scenario is only recommended for use as an initial and simple measure to be introduced at the highest risk nature protected sites. This is because implementing EDZ scenarios will increase levels of N emissions in other areas without decreasing the overall contribution of N emissions at UK level. In some cases, this may even push areas over acceptable limits that were not previously in this state. Displacing a pollutant activity does not contribute to national targets and thus may require additional reductions elsewhere.

MAIN MESSAGES FROM THE PROJECT

There is no single “one size fits all” solution that will be the most effective approach across all parts of the UK.

A combined approach of UK-wide strategy with spatially targeted measures around nature protected sites boundaries is the most beneficial approach to enhance benefits for sensitive habitats and species.

In summary, the project recommendations are the following:

- Develop ambitious UK-wide measures to decrease emissions, adapted regionally to each UK country. This will benefit both, nature protected sites near emission source areas and remote nature protected sites subject to nitrogen long-range transport atmospheric emissions.
- Implement spatially targeted mitigation measures near nature protected sites by selecting relevant and ambitious measures from a “tool kit” and implementing these to tackle local emissions around the site’s boundaries.
- Work with stakeholders to develop a clear nitrogen emission reduction framework for identifying priority actions in each locale.

Nitrogen Futures is a research project undertaken to understand where additional action would be most beneficial and cost-effective for protection of ecosystems.

Nitrogen Futures is a partnership project between Defra, the devolved administrations, JNCC and each of the country's statutory nature conservation bodies. Funded by Defra, the project was undertaken by a consortium led by the UK Centre for Ecology & Hydrology (UKCEH) which brought together leading expertise from Rothamsted Research, Aether, Air Quality Consultants, Lancaster University and Manchester Metropolitan University.

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