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What impact could Net Zero agricultural policies have on eutrophication in sensitive habitats across the UK? Can spatially targeting their implementation be more protective?

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How do agricultural policies to address climate change effect eutrophication?

Agricultural land comprises the majority (71%) of all land in the UK and is **responsible for 10% of greenhouse gas (GHG) emissions.**[1] In order to tackle this, the Committee on Climate Change (CCC) have proposed a number of land use policies to reduce GHGs including afforestation, increased bioenergy crops and reducing meat and dairy production.[2]

The agricultural sector is also the main source of ammonia air pollution, accounting for 88% of emissions in the UK, which lead to wet (precipitation) and dry (gas) deposition of reactive forms of nitrogen on habitats which can lead to an excess of nutrients, or eutrophication. This effects biodiversity by promoting the growth of species that thrive in high nitrogen levels and outcompete more sensitive species. The UK Government has set a **17% deposition reduction target on sensitive habitats by 2030**.[3]

The main source of this ammonia is animal manure and its application to land as fertiliser.[3] Measures to reduce meat and dairy production and those to reduce fertiliser use and optimise its application are a part of the CCC's proposed policies. However, some of their policies to reduce GHG emissions, like increasing bioenergy crops, could increase fertiliser application and related ammonia pollution.

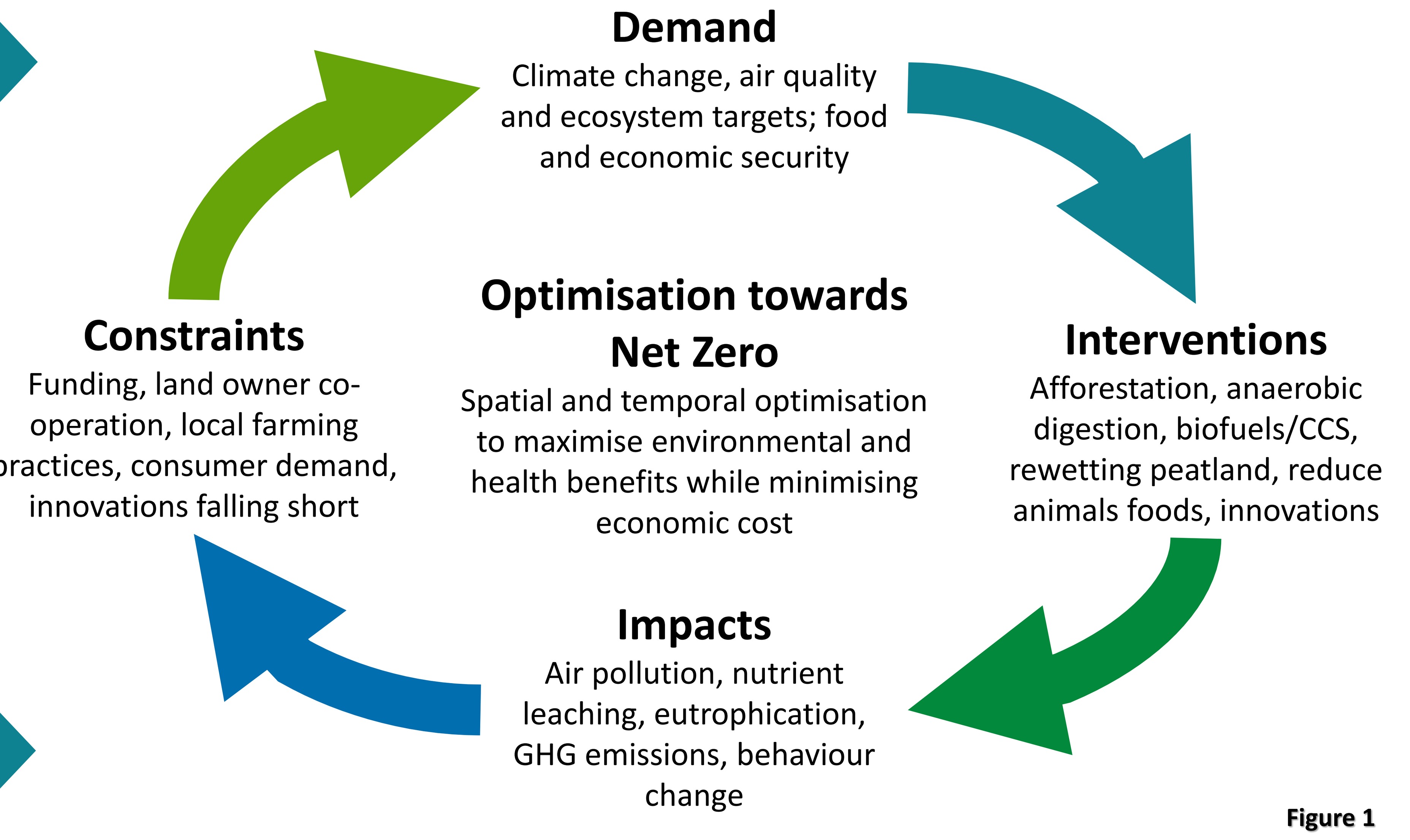


Figure 1

What are some of the wider, integrated impacts of agricultural emissions?

AIR POLLUTION

Ammonia emission react in the atmosphere to form particulate matter which contributes to cardiovascular and respiratory disease. The Clean Air Strategy calls for a **16% decrease in ammonia emissions by 2030** from a 2005 baseline. The interim target of 8% by 2020 was not achieved.[3]

FINITE LAND AREA

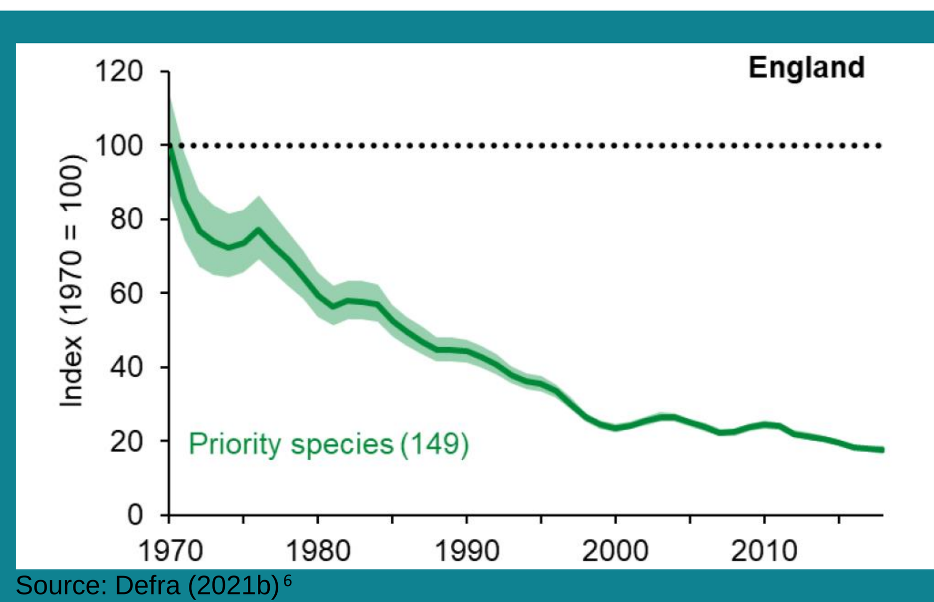
The CCC found that, without changing existing policies and trends, the **UK will require 7% more land by 2035** to accommodate current per capita food production and land needed for settlements.[2]

SHORT TERM CLIMATE EFFECTS

UK agricultural GHG emissions includes **47% of total methane emissions** and **68% of total nitrous oxide emissions**.[1] Both gases have significant temperature impacts.[4] The United Nations Environment Programme (UNEP) are calling for immediate reductions of methane to meet global targets.[5]

Biodiversity and species decline: a wider picture

Excess nitrogen is a key threat to biodiversity on land and in water bodies. A key indicator of biodiversity is species abundance – the number of individuals per species. Since 1970, the **species abundance** index in England has **reduced from 100 to just 17.7** in 2018.[6]



Source: Defra (2021b)[6]

Figure 2

METHODOLOGY | How can we estimate the impact Net Zero agricultural policies can have on sensitive habitats?

Future Net Zero agricultural policy scenarios can be used to estimate associated changes in ammonia emissions from sources across the UK. These emissions can then be used to model and map the resulting deposition of reactive nitrogen. This mapped data can be overlayed with sensitive habitat maps and corresponding **Critical Loads** to assess the impacts of the policy scenarios.

Ammonia Emissions Data

The National Atmospheric Emission Inventory (NAEI), provided by Defra, are annual emissions, including NH_3, across the UK. It provides a breakdown by source sectors including industrial, transport waste treatment along with the largest sector, agriculture, broken into individual categories (**cows (beef, & dairy), pigs, laying hens, other poultry, sheep, other livestock, and fertiliser**) and provided in a 1-5km grid.

↓ Input

Modelling Framework

The UK Integrated Assessment Model (**UKIAM**)[7] framework uses physically-based models into which NAEI data or future emissions projections can be inputted to approximate ambient concentrations and deposition.

↓ Output

Reactive Nitrogen Deposition Maps

↑ Overlay

Sensitive Habitats

These are ecosystems that are sensitive to reactive nitrogen deposition. The UK Centre for Ecology & Hydrology (UKCEH) provide maps with the spatial extent of these habitats across the UK in a 1km grid. They include **acid and calcareous grasslands, montane, bogs, managed & unmanaged woodlands and dwarf shrub heath**.

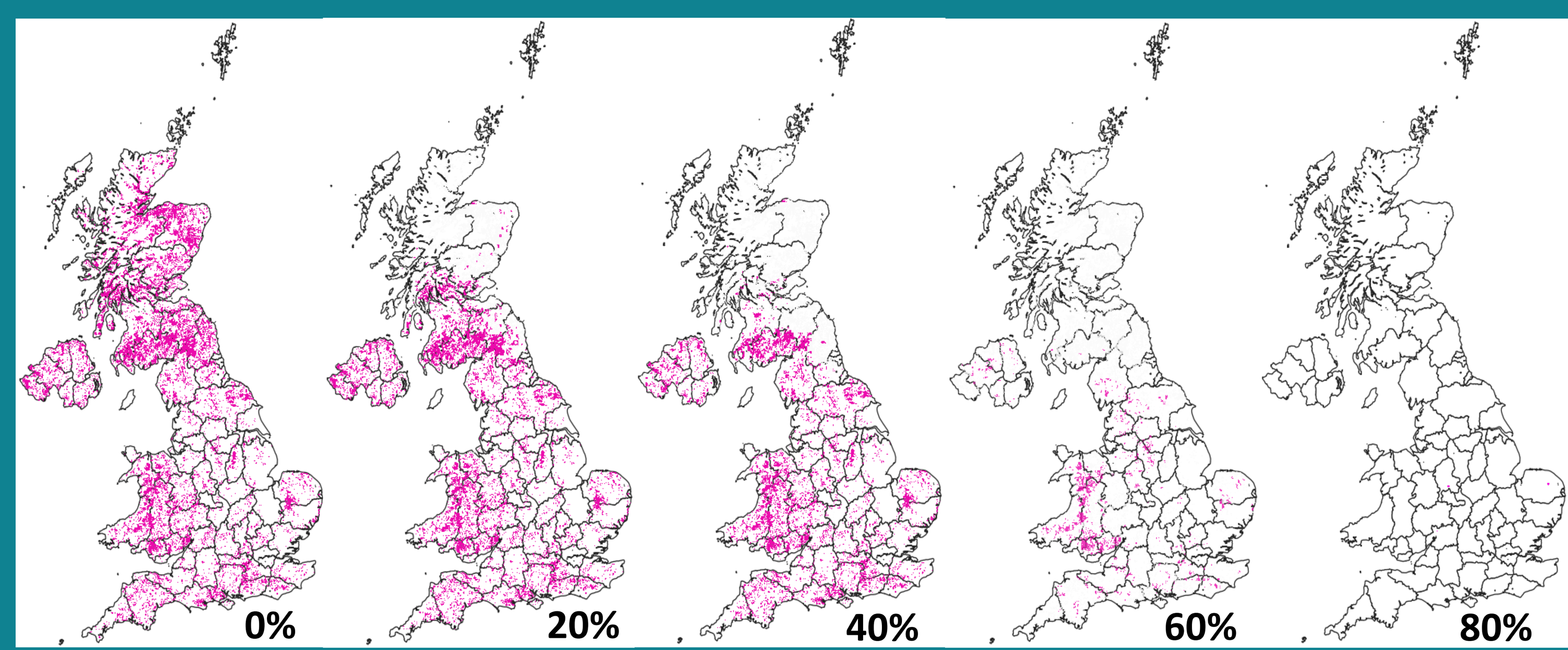
↑ Compare

Critical Loads (CL)

This is the estimated exposure to reactive nitrogen calculated for sensitive habitats, above which it is considered damaging to biodiversity. CL are mapped and provided by UKCEH using UNECE protocols.[8]

RESULTS | Output example – Reductions in reactive nitrogen deposition needed to meet Critical Load values for eutrophication:

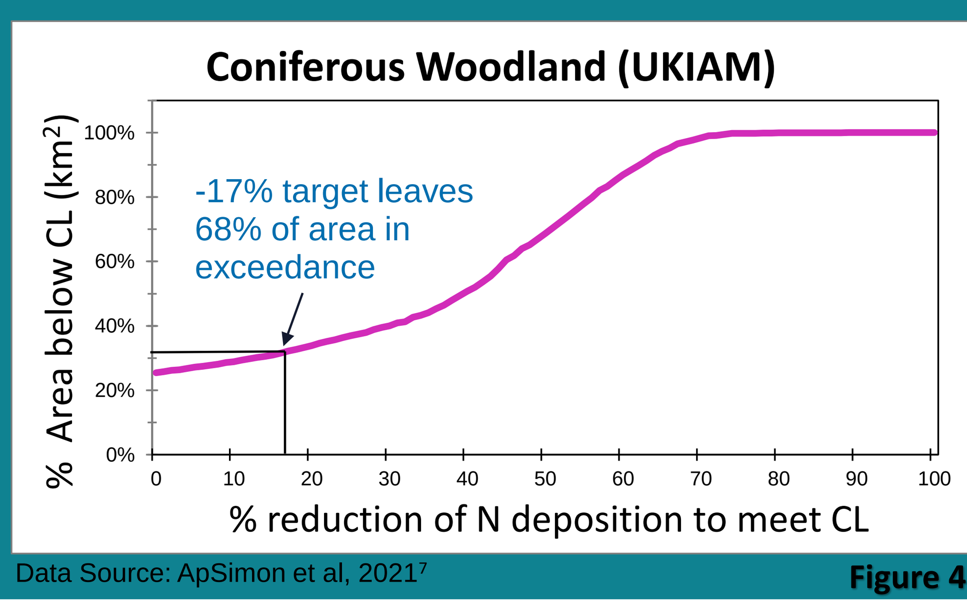
The pink shading on the UK maps in **Figure 3** below denote 1km² areas of Coniferous Woodland where Critical Load (CL) values for nutrient nitrogen are exceeded. The first map on the left shows this area with no reductions in nitrogen deposition, with the subsequent maps representing **20%, 40%, 60% and 80% deposition reductions**.



Data Source: ApSimon et al, 2021[7]

Figure 3

Figure 4 below is a graphical representation of the spatial CL exceedance outputs showing the area of Coniferous Woodland with deposition concentrations below the CL, plotted against percentage reductions in reactive nitrogen deposition needed to meet the CL. These show **that greater than 40% reductions are needed to see meaningful improvements** to this habitat.



Data Source: ApSimon et al, 2021[7]

Figure 4

References

[1]Defra (2021a). *Agriculture in the United Kingdom 2020*.

[2]Committee on Climate Change. (2020). *Sixth Carbon Budget: Agriculture and land use, land use change and forestry*.

[3]Defra. 2019. *Clean Air Strategy 2019*.

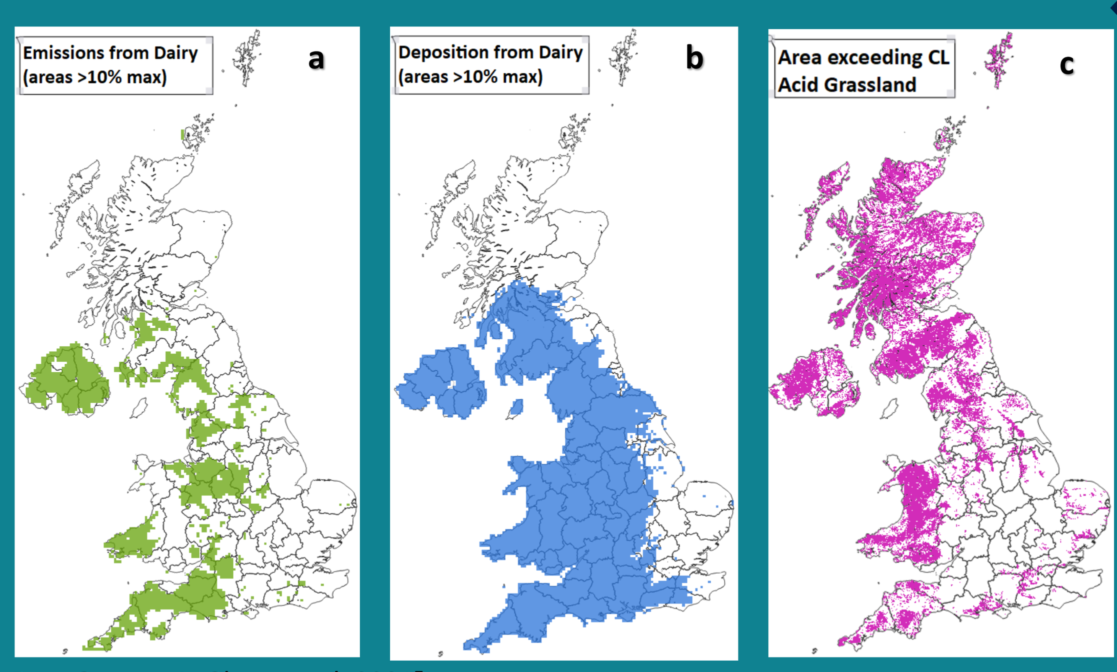
[4]Methane has 81 times and nitrous oxide has 273 times more global warming potential than CO_2 (Source: IPCC (2021). *Climate Change 2021, The Physical Science Basis: Working Group 1 contribution to the sixth assessment report of the IPCC*).

[5]UNEP (2022). *Global Methane Assessment: Benefits and Costs of Mitigation Measures.*

[6]Defra (2021b). *England Biodiversity Indicators: A strategy for England's wildlife and ecosystem services, biodiversity indicators: 2021 Assessment.*

[7]ApSimon, H., Oxley, T., Woodward, H., Mehlig, D., Dore, A., Holland, M. (2021). The UKIAM model for source apportionment and air pollution policy applications to PM2.5. Environ. Int. 153, 106515.

[8]UNECE: United Nations Economic Commission for Europe



Data Source: ApSimon et al, 2021[7]

Figure 5

DISCUSSION & FUTURE WORK | How can we use our models to optimise Net Zero measures?

Some Net Zero agricultural policies have been proposed by government bodies and others will be developed as a part of this research. Emissions changes resulting from these policies can be used to estimate their impact. Because of the spatial nature of the policies (i.e. afforestation on suitable land) the modelling can look at where policies changes would have the greatest impact on ecosystems and air quality.

For example, The CCC have proposed a **20% reduction in dairy production**. **Figure 5a** shows emissions from dairy cows, and **5b** shows the modelled area of deposition. Figure **5c** shows the extent of Acid Grassland, a sensitive habitat, in exceedance of CL values. Future modelling and spatial comparison will quantify the impact of concentrating reduction measures on emissions (**a**) where corresponding deposition (**b**) effects sensitive habitats exceeding the CL (**c**).