IMPERIAL

Modelling ammonia and its impacts in the UK

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Introduction

- Introduction to UK context

- Emissions
  - Anaerobic digestion
  - NH_3 as a fuel for shipping
  - Implications of sustainable farming policy and climate-related land use targets for NH_3

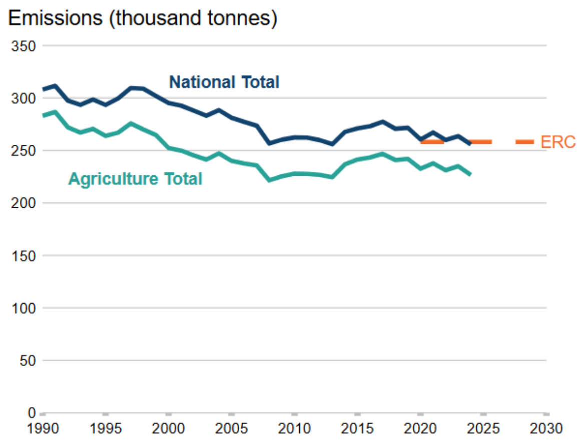
- Modelling impacts
  - Implications of agricultural land use change for CL exceedances
  - Uncertainty in modelling deposition and implications for targets
  - Sensitivity of $PM_{2.5}$ and N deposition to changes in atmospheric chemistry

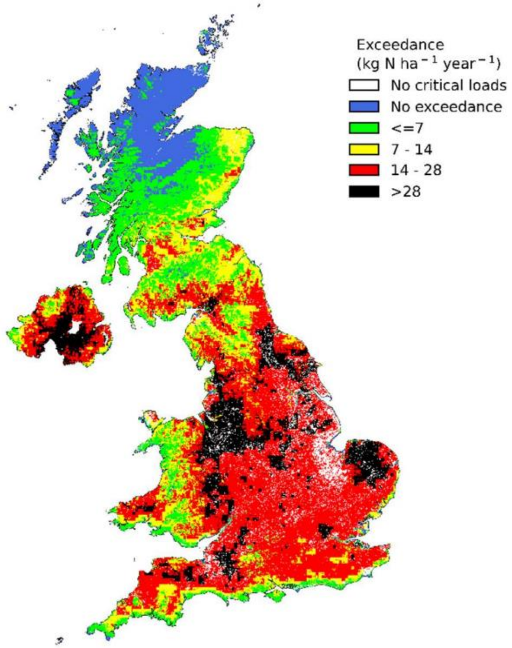
- Summary

Introduction

- **NH_3 an increasing policy priority in the UK**
  - Lack of progress in reducing national total emissions
  - The UK uses an adjustment to remove non-manure digestate in achieving its 2020 ERC
  - Some sources projected to increase significantly and new emerging sources
  - Exceedances of reactive N Critical Loads are high and widespread
  - Priority in Gothenburg Protocol negotiations

- **Modelling the impacts of NH_3 and the future trends of these impacts is a challenge**
  - Scarcity of deposition measurement data
  - Uncertainty in modelling approaches
  - Implications of sustainable agriculture policy and land use change
  - Changes in atmospheric chemistry



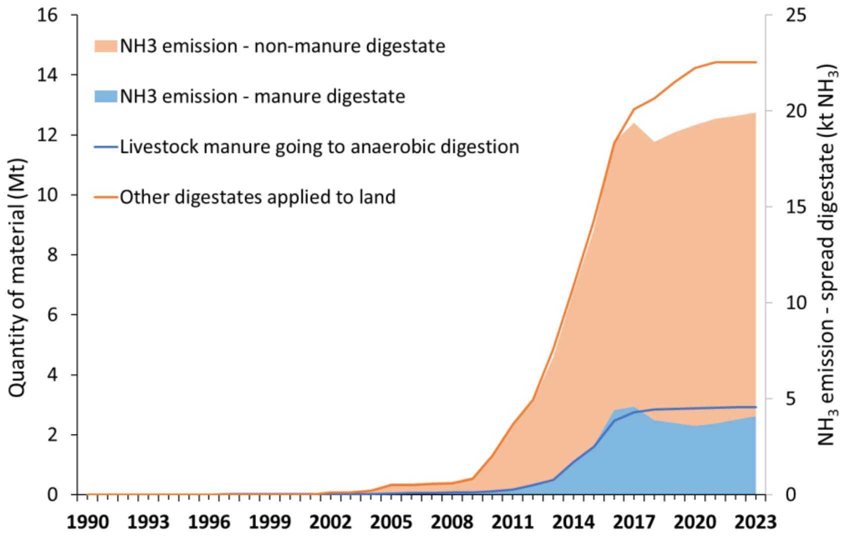


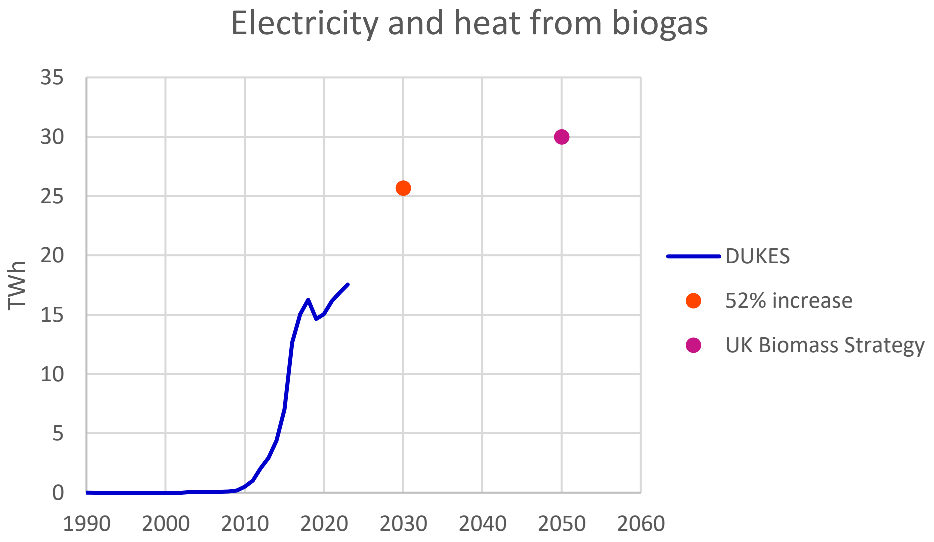
Rowe et al. 2022. https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2208301034_Trends_Report_2022.pdf

NH_3 emission projections

Anaerobic digestion

- NH_3 emissions from digestate spreading have increased from **<1 kt in 2005, to 20 kt in 2022 and 31 kt in 2030**
- The majority (~80%) of these emissions is due to non-manure digestate
- Scaling AD emissions in proportion to biogas production to 2050 = **71% increase relative to 2022 (~14 ktonnes)**
- Emission factor for digestate spreading ~6x greater than chemical fertiliser
- The location of future AD plants is highly uncertain and will have implications for habitat protection
- Best practices for digestate spreading already assumed by inventory so scope for technical abatement is somewhat limited

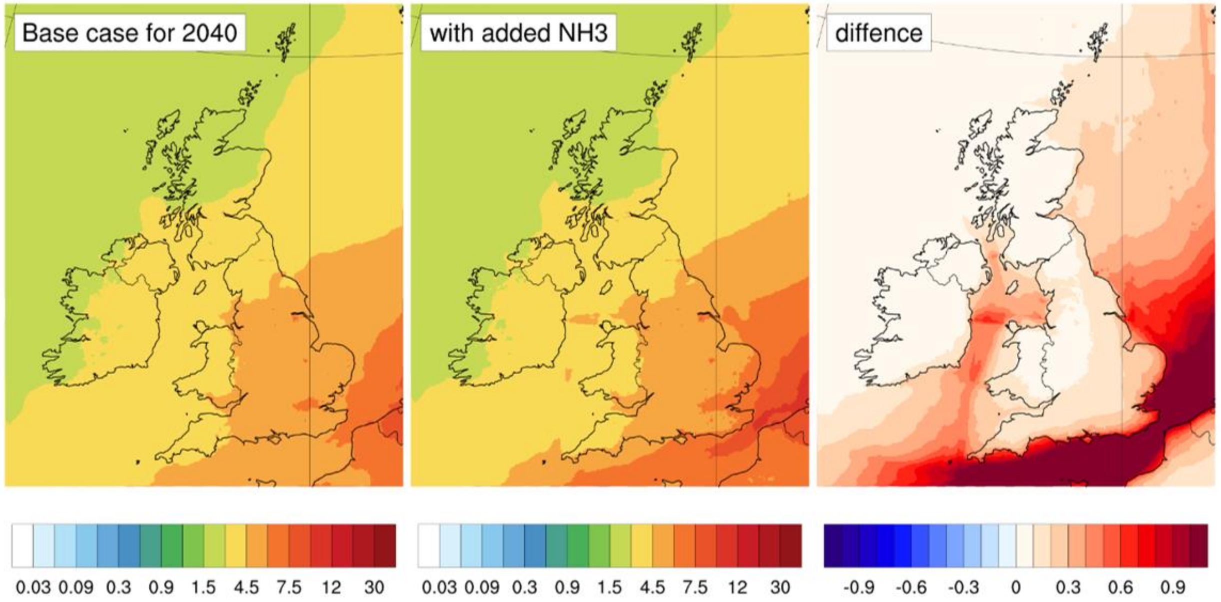




NH_3 as a fuel for shipping

*Credit to Dan Mehlig, Tim Oxley, Helen ApSimon and Massimo Vieno

- NH_3 as a fuel for shipping is projected to be adopted at scale in the UK and surrounding waters
- Emissions of ammonia, through engine slip (unburnt fuel/SCR) or leakage along the supply chain, is very uncertain, but evidence is improving
- Using 1% as an illustrative leakage rate (taking a central value for plausible approximate range of 0.1% to 2.5%), emissions of **NH_3 by 2050 could be ~150 kt in waters surrounding the UK** based upon a projection for low-carbon shipping
- Modelling using EMEP4UK (by Massimo Vieno at UKCEH) suggests that this would result in an **increase in $PM_{2.5}$ concentrations of 0.2 to 0.5 ug.m^{-3} over England and the UK** (all else held equal)
- Increases also seen in N deposition with further work required to assess implications for CL exceedances



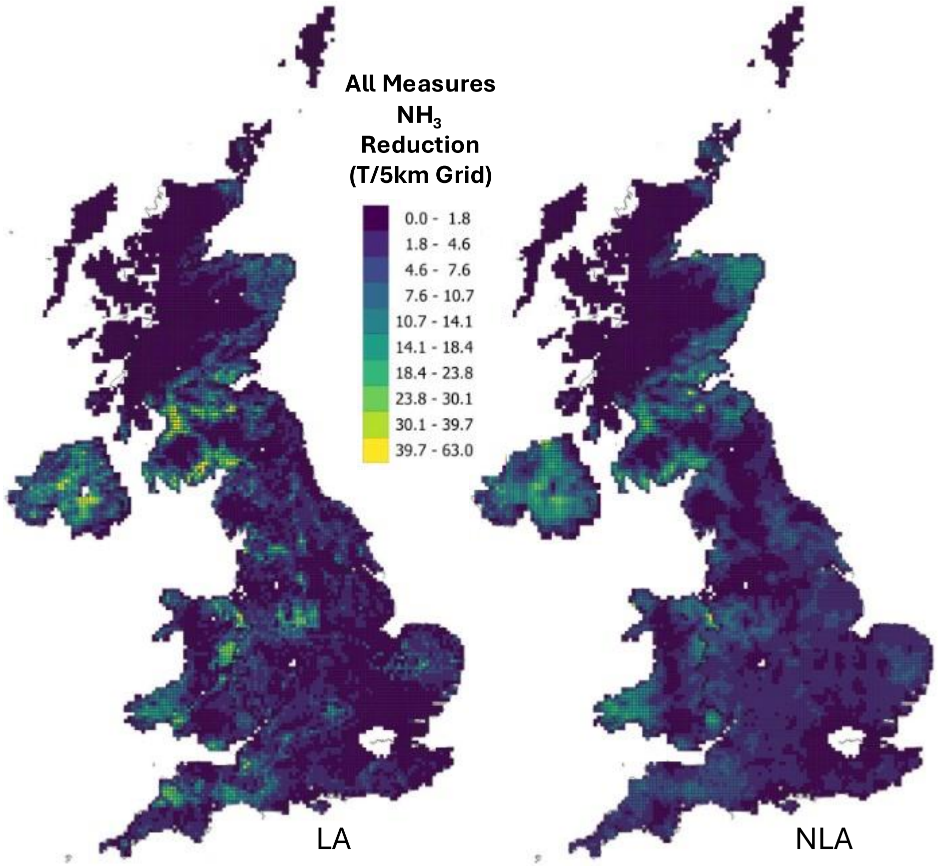
$PM_{2.5}$ concentrations

Implications of sustainable agricultural policy and land use change for NH_3 emissions

Work by Elizabeth Fonseca

- There is ongoing transformational change in UK agriculture policy, with an emphasis on climate, nature restoration and resilience
- Large scale land use change occurring in the UK to meet climate, nature restoration and resilience targets
- Scenario based on the scale of change recommended by the UK Climate Change Committee (CCC) – land use change due to woodland creation, peatland restoration, agroforestry, hedgerow expansion and bioenergy crops
- We found that:
  - **Emission reductions by 2050 (39 ktonnes or 17%) were comparable to ambitious tech measure scenario**, and sufficient to achieve 2030 NECR target
  - **Spatial land allocation analysis resulted in significantly different spatial distribution in emission reductions**, with onward implications for CL exceedance assessments

- **Key assumption** – agricultural activity reduced where land was changed, and was not intensified on remaining land
  - ➢ However, intensification on remaining land may occur and there an increasing focus self sufficiency could lead to increased production and increased NH_3 emissions



Spatial land allocation

No spatial land allocation

Fonseca et al. 2025. https://doi.org/10.1016/j.envadv.2025.100640

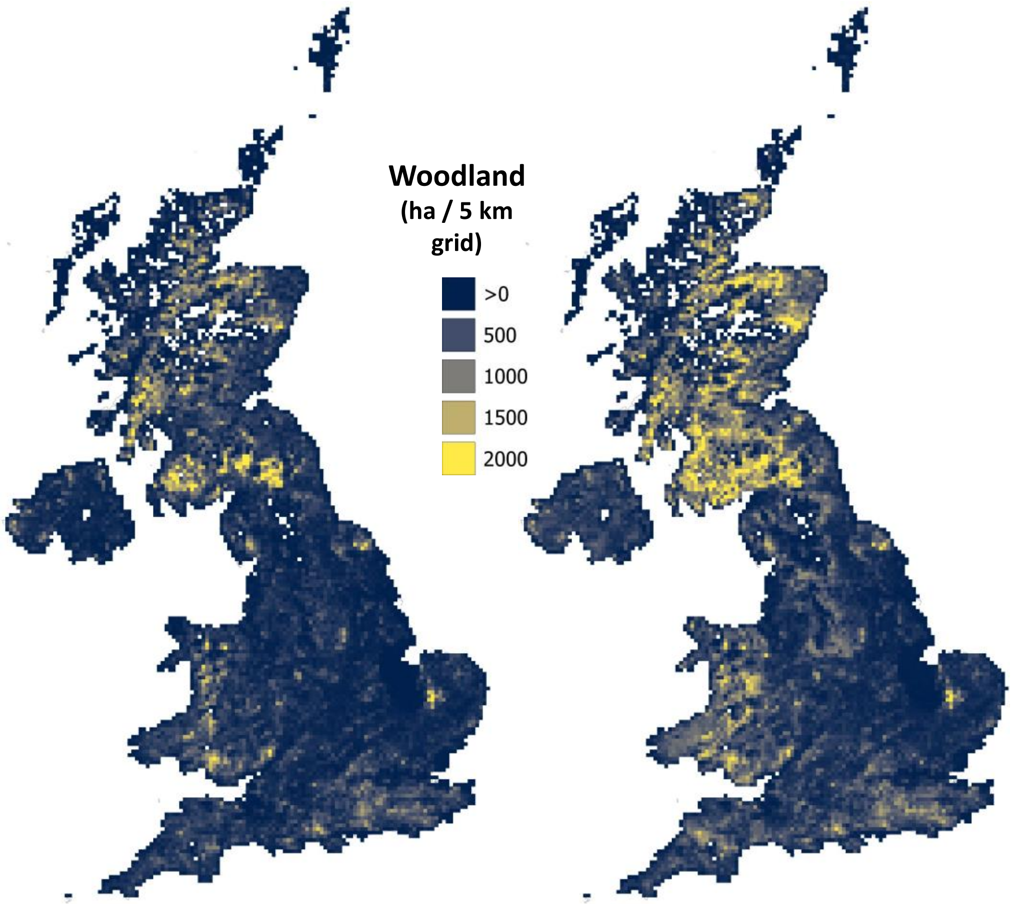
Modelling NH_3 impacts

Implications of agricultural land use change for NH_3

Work by Elizabeth Fonseca

- Land use change policies are expected to change the area of N sensitive habitats, with implications for CL exceedances
- For our CCC scenario, the change in habitat area resulted in:
  - **15% increase in N sensitive habitat area**
  - **% area in exceedance increased by 4.8%**
  - **AAE increased by 12.8%**
- These changes are **due to the change in habitat area only**, not changes in NH_3 emissions which also has an impact

	Acid Grassland	Dwarf Shrub Heath	Bog	All Woodland	All changed habitats
Δ Area, %	-12.2%	-24.1%	53.4%	49.3%	15.0%
Δ % area in exceedance, %	-1.8%	2.2%	14.8%	2.2%	4.8%
Δ Area in exceedance, %	-13.8%	-22.5%	76.0%	52.6%	20.5%
Δ AAE, %	-4.3%	-0.8%	11.1%	-0.2%	12.8%



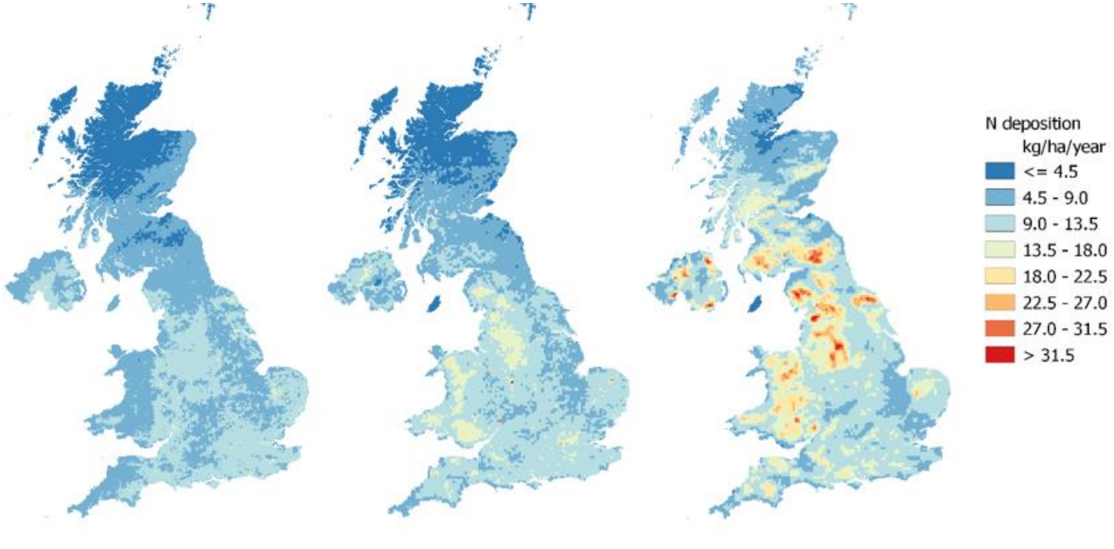
Woodland Baseline (3,209 kha)

Woodland with land use change (4,789kha)

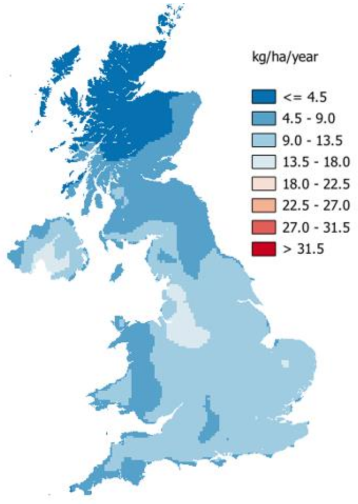
Uncertainty in modelling deposition and implications for targets

- Significant difference in wet deposition estimates between different UK models – due to differences in modelling of orographic enhancement effects, lack of data and bias in bulk measurements
- There is also large uncertainty in dry deposition – complex process, need for more measurement data
- Improvement programme ongoing in the UK led by UKCEH

- We use a scaling approach that takes the difference between the models in 2018 as a proxy for the uncertainty in deposition
- Despite this uncertainty, it is clear that **an increase in policy ambition is needed to eliminate CL exceedances for the majority of N sensitive habitat area**

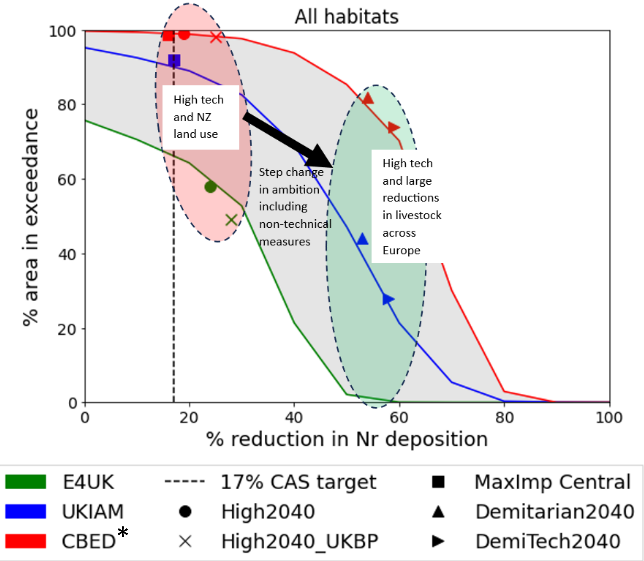


EMEP4UK Met2018 UKIAM CBED 2018-20



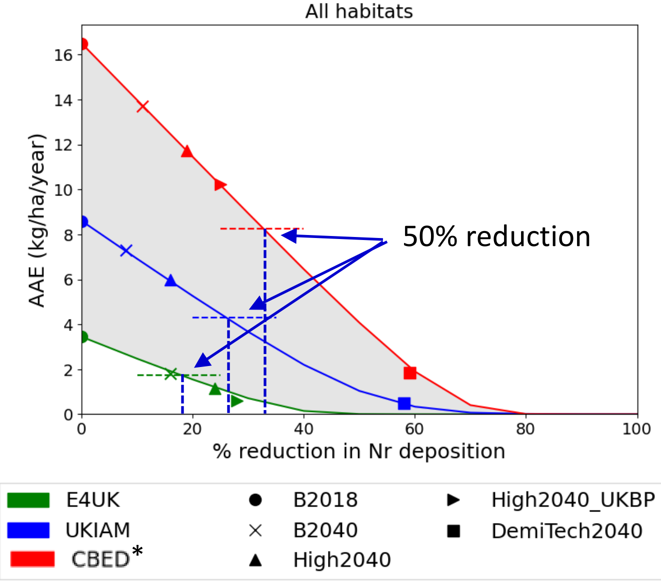
GAINS

England % area in exceedance vs % reduction in deposition



*CBED value derived using scaled approach for future projections

England AAE vs % reduction in deposition



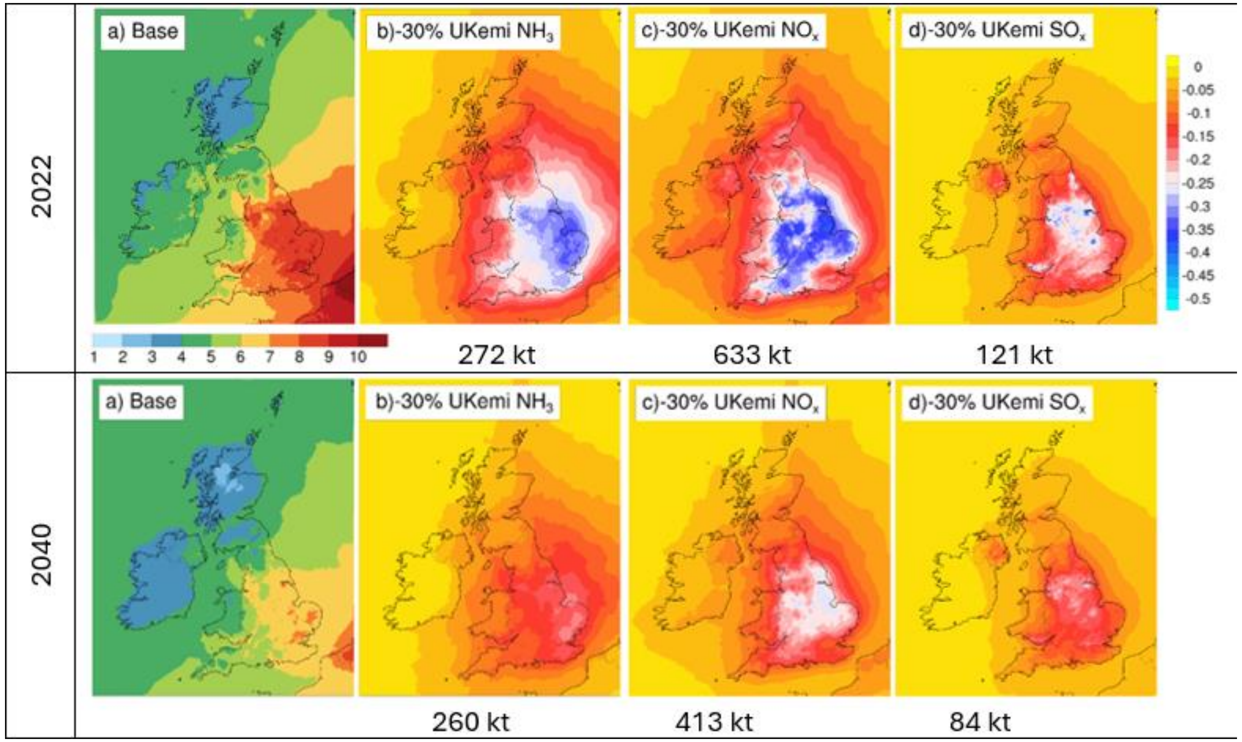
 Woodward et al. 2025 https://doi.org/10.1016/j.envres.2025.121519

Implications of changes in atmospheric chemistry

*Credit to Eiko Nemitz and Massimo Vieno, UKCEH

- In the **UK NO_x emissions have fallen from 1700 ktonnes in 2005 to 641 ktonnes in 2022**. The baseline projection for 2040 is 392 ktonnes
- Meanwhile, **the change in NH_3 is comparably small** (291 ktonnes in 2005, 261 ktonnes in 2022 and projected 268 ktonnes in 2030)
- The change in the proportion of NO_x (and SO_2) to NH_3 has **implications for atmospheric processes including the formation of $PM_{2.5}$**
- Modelling using EMEP4UK suggests that the response of $PM_{2.5}$ to a reduction in NH_3 emissions will be smaller in 2040 than it is currently
- The response of N deposition to NH_3 emissions is less sensitive to these changes in emissions

- Despite the expected reduction in sensitivity, **NH_3 emission reductions will still result in meaningful reductions in $PM_{2.5}$ concentrations**
- **NH_3 emission reduction will remain vital for reducing the impact of N deposition on sensitive habitats**



Summary

- **Future NH_3 emissions in the UK and surrounding sea area are highly uncertain**, both in terms of magnitude and spatial distribution. This uncertainty is due to:
  - Alternative possible policy directions
  - Lack of data on emerging technologies
  - Difficulty in predicting the impacts of agricultural policy
  - A current lack of spatial analysis
- **There is also uncertainty in our modelling of the impacts**, both on health and on N sensitive habitats due to:
  - Paucity of N deposition measurement studies, the complexity of deposition processes and differences in modelling approaches
  - Need to understand implications of agricultural transition towards sustainable land management and climate land use measures for N sensitive habitat areas (in addition to UK nature restoration/protection targets)
  - The sensitivity of $PM_{2.5}$ to reductions in NH_3 emissions is changing as atmospheric composition changes with reduced NO_x and SO_x
- **These uncertainties pose a challenge for target setting and assessing progress**
- **Despite these uncertainties it is clear that:**
  - **NH_3 abatement is critical to reduce the risk posed to N sensitive habitats** and an increase in ambition is needed to protect the majority of habitat areas
  - **NH_3 reductions will also still deliver meaningful reductions in population exposure to $PM_{2.5}$**

Thank you

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