Good for soil, grim for the air: ammonia emissions from N fertilised soils and their controlling factors

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The limits to agricultural production were busted wide open following……

A Dangerous Fixation

Synthetic nitrogen was born 100 years ago; it's why half of us are alive.

1.1k

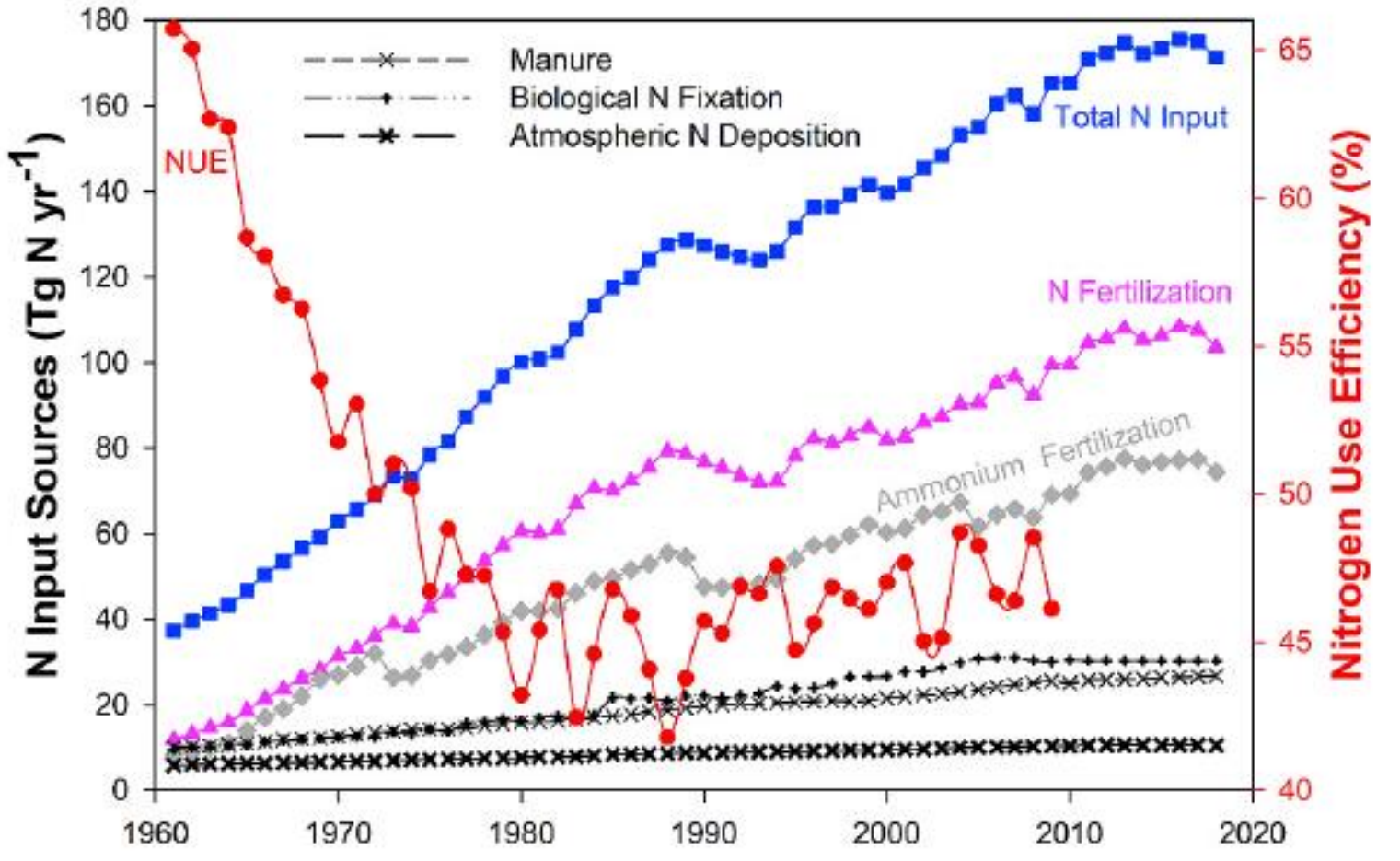
By Jonathan Mingle

A farmer sprinkles fertilizer on his rice field in Burma

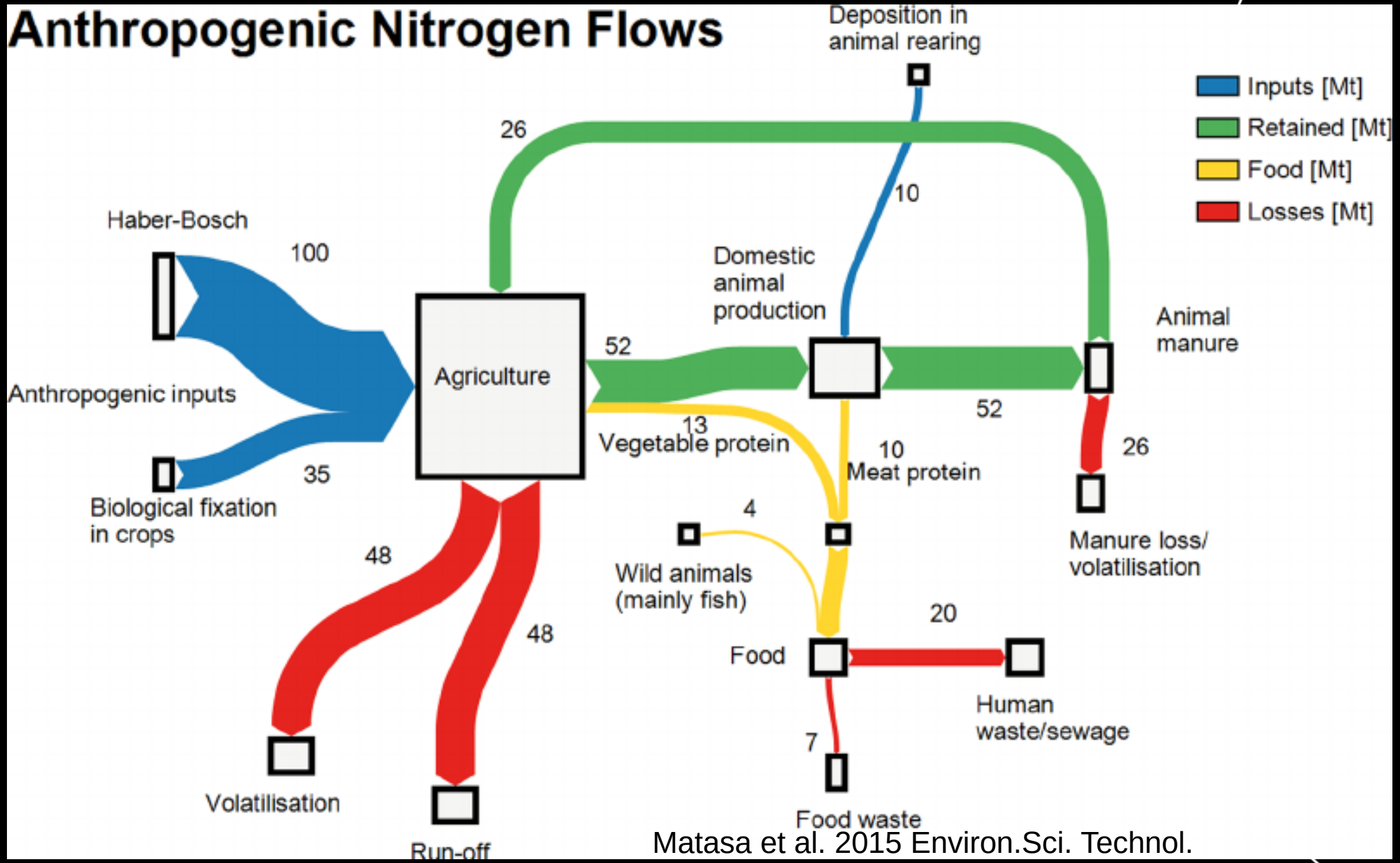
Photo by STR/AFP/Getty Images

Consider Carl Bosch our leading candidate for a modern Prometheus. This year marks a century since Bosch, a chemist, opened the Oppau, Germany-based Stickstoffwerke ("nitrogen works")—the first factory to produce synthetic ammonia, the main ingredient of chemical fertilizers.

It was an impressive technical feat that helped **earn Bosch the Nobel Prize** in 1931. His fellow chemist Fritz Haber had pioneered and patented the process for "fixing" inert nitrogen (the gas that makes up 78 percent of the atmosphere) into a usable, reactive form. Bosch figured out how to do it economically and on a large scale.

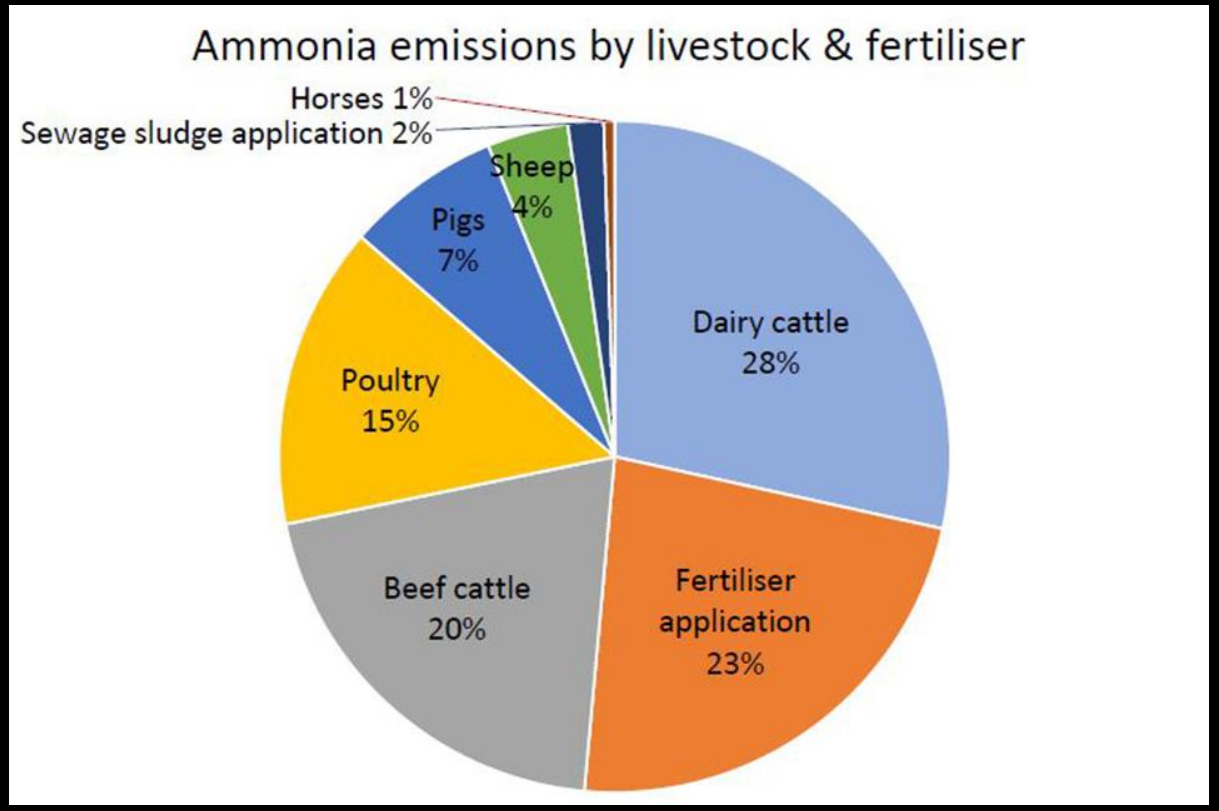


Raza et al. 2021. Journal of Cleaner Production
https://doi.org/10.1016/j.jclepro.2021.128036



Matasa et al. 2015 Environ.Sci. Technol.

UK NH_3 emission and reduction targets



UK NH_3 emission sources from Agriculture (DEFRA

- Agriculture in the UK contributes ~85% of the total NH_3 emissions.
- UK only achieved 14% reduction in emission since 1980.
- Emission reduction targets of 8% by 2020 of the 2005 levels were not achieved
- And reduction of 16% of 2005 levels by 2030?

- NH_3 in air is a precursor of PM2.5
- Deposition on natural terrestrial and aquatic ecosystems negatively affects ecosystem functions

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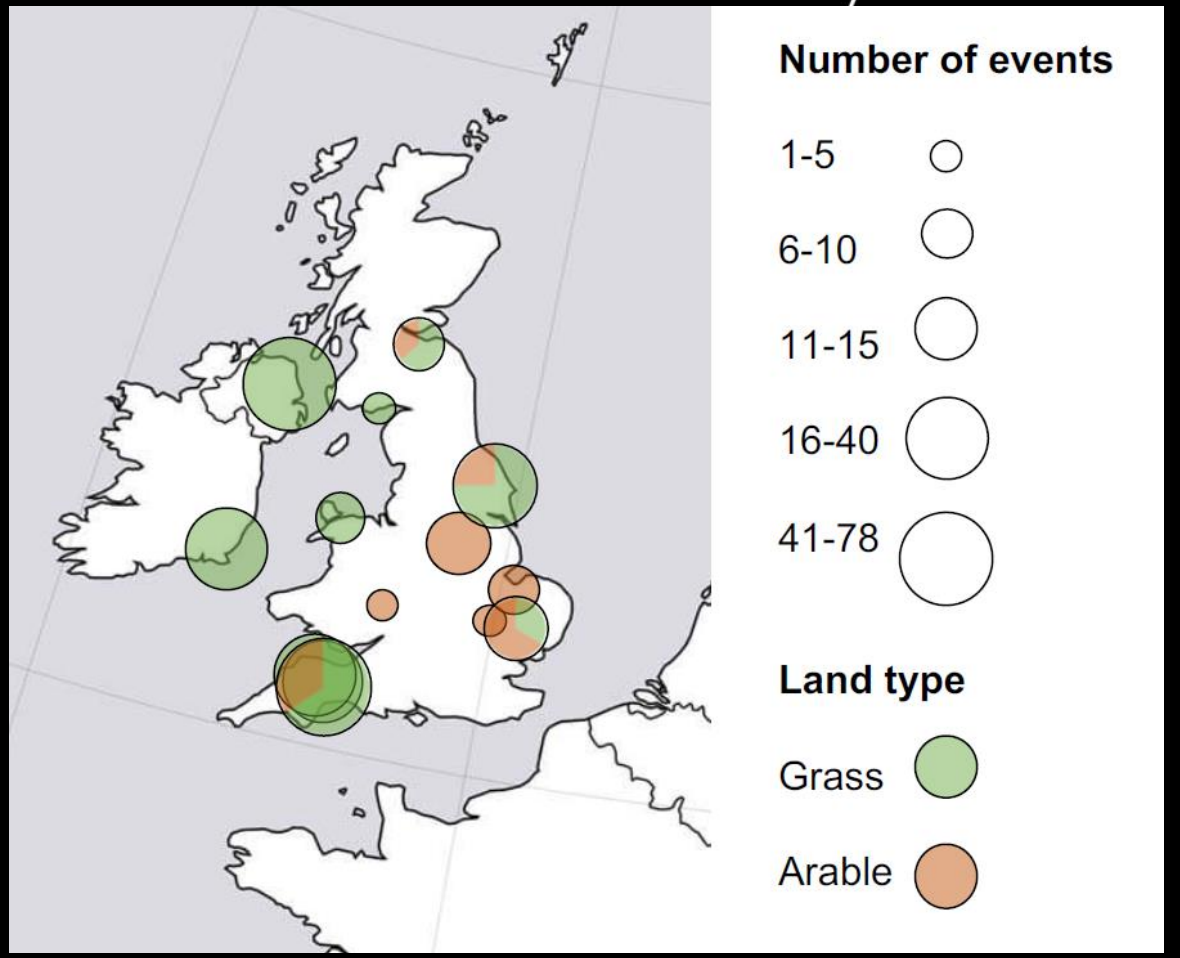
Approach: Meta-analysis

Research led by Catrin Rathbone as her UG thesis in Environmental Sciences at UoB



Field data from 11 studies (298 data points covering arable and grassland soils)

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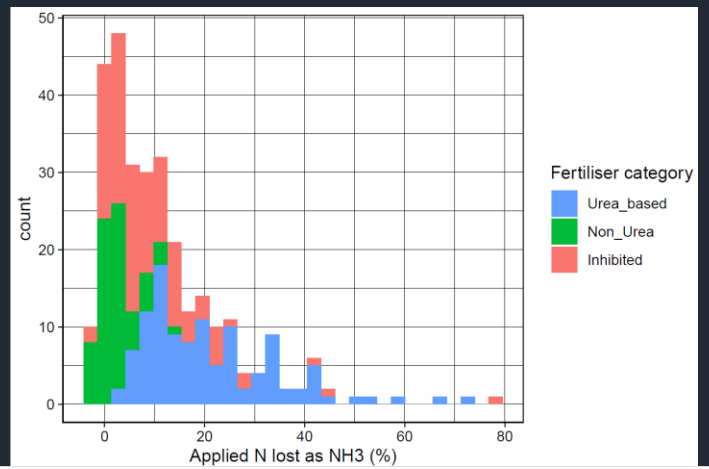
Key variables:
Fertilizer, land use and soil types
N application types, soil properties, pH, SOC, texture etc.

Ammonia losses from different fertilizer types

Losses from Urea fertilizers is the highest (~18.5%) and reaching to 70% in certain cases

Rathbone, C. and S. Ullah. 2023. *EVNRIONMENTAL CHEMISTRY,* https://doi.org/10.1071/EN23010



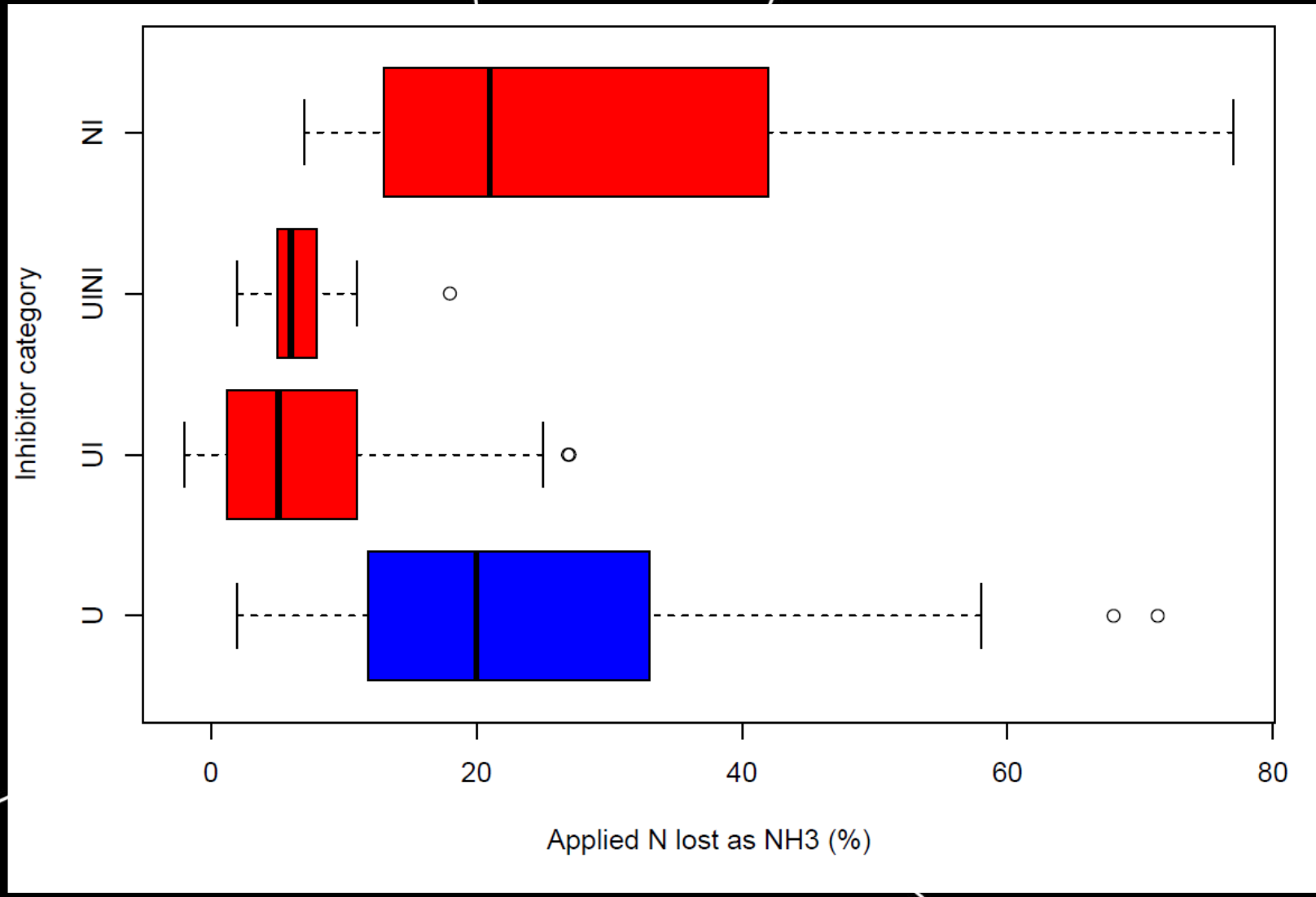
Factor categories	*n*	Median
Fertiliser category		
Non-urea	70	1.85
Urea-based	112	18.50
Inhibited-urea	116	6.00
Soil pH		
$x \leq 7$	258	7.81
$x > 7$	40	10.00
SOM (%)		
$x \leq 7$	37	13.00
$x > 7$	30	8.50

Ammonia emissions from Urea with and without inhibitors

Inhibitor types:

- **UI: Urease inhibitors (blocks hydrolysis of urea into ammonium)**
- **NI: Nitrification inhibitors (blocks nitrification of ammonium to nitrate)**
- **UINI: Urease + nitrification inhibitors**

Use of NI for N_2O reduction alone increases NH_3 losses



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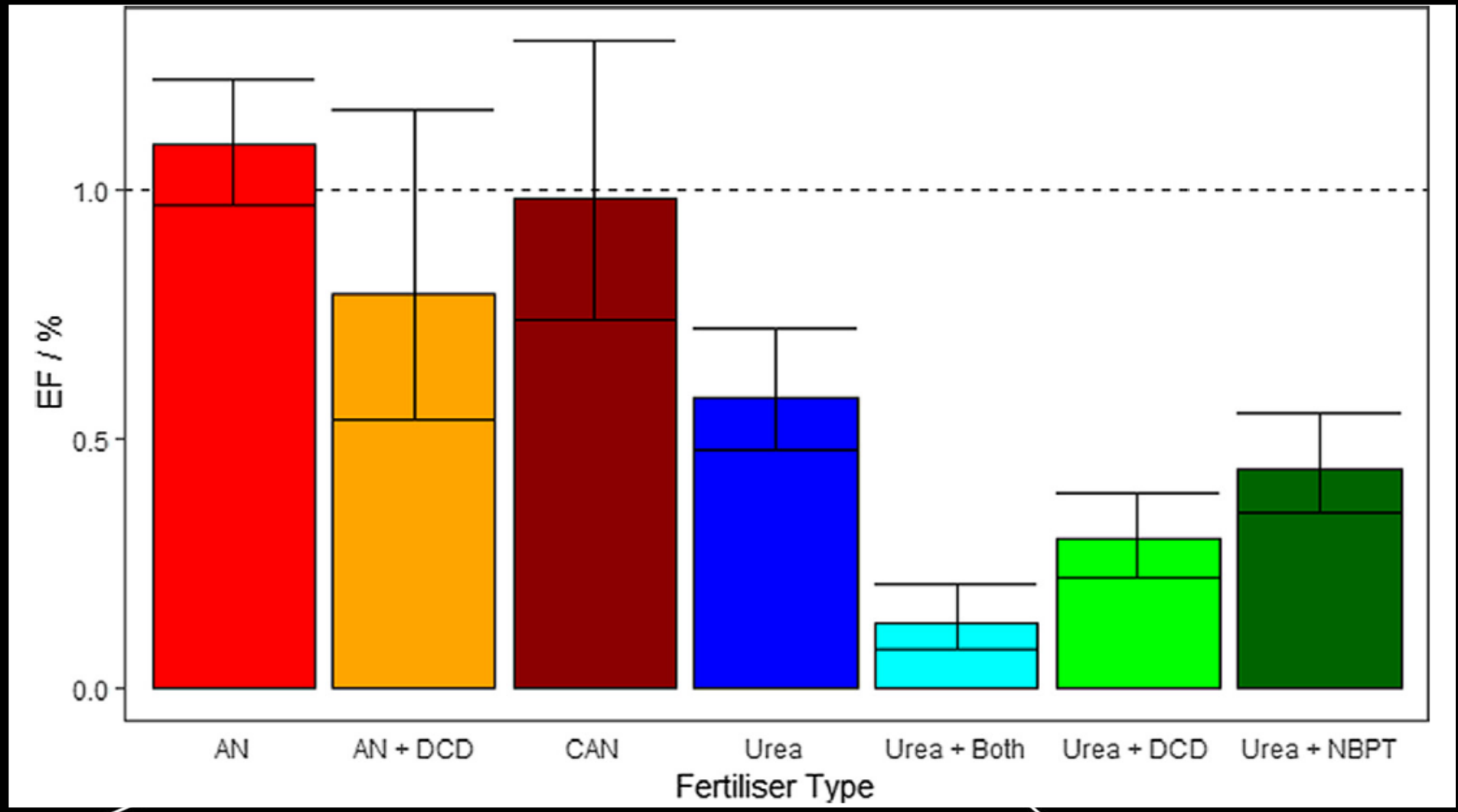
- UK emission of Nitrous Oxide (N_2O) as a fraction of applied N fertilizers
- Trade-offs between N_2O vs NH_3 emissions

Use of both nitrification and urease inhibitors can reduce both ammonia and nitrous oxide emissions.

Health implication of NI across the food chain?



(from Cowan et al. 2021 Science of Total Environment).

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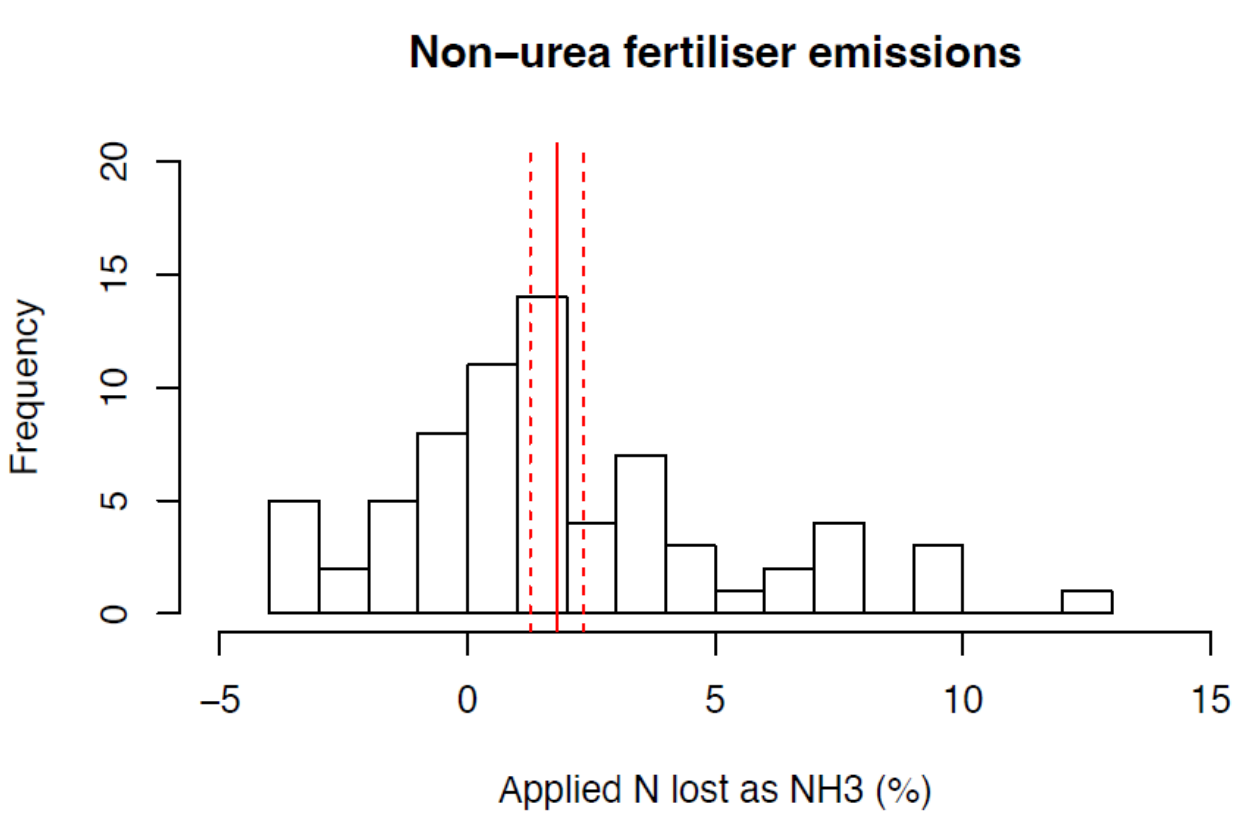
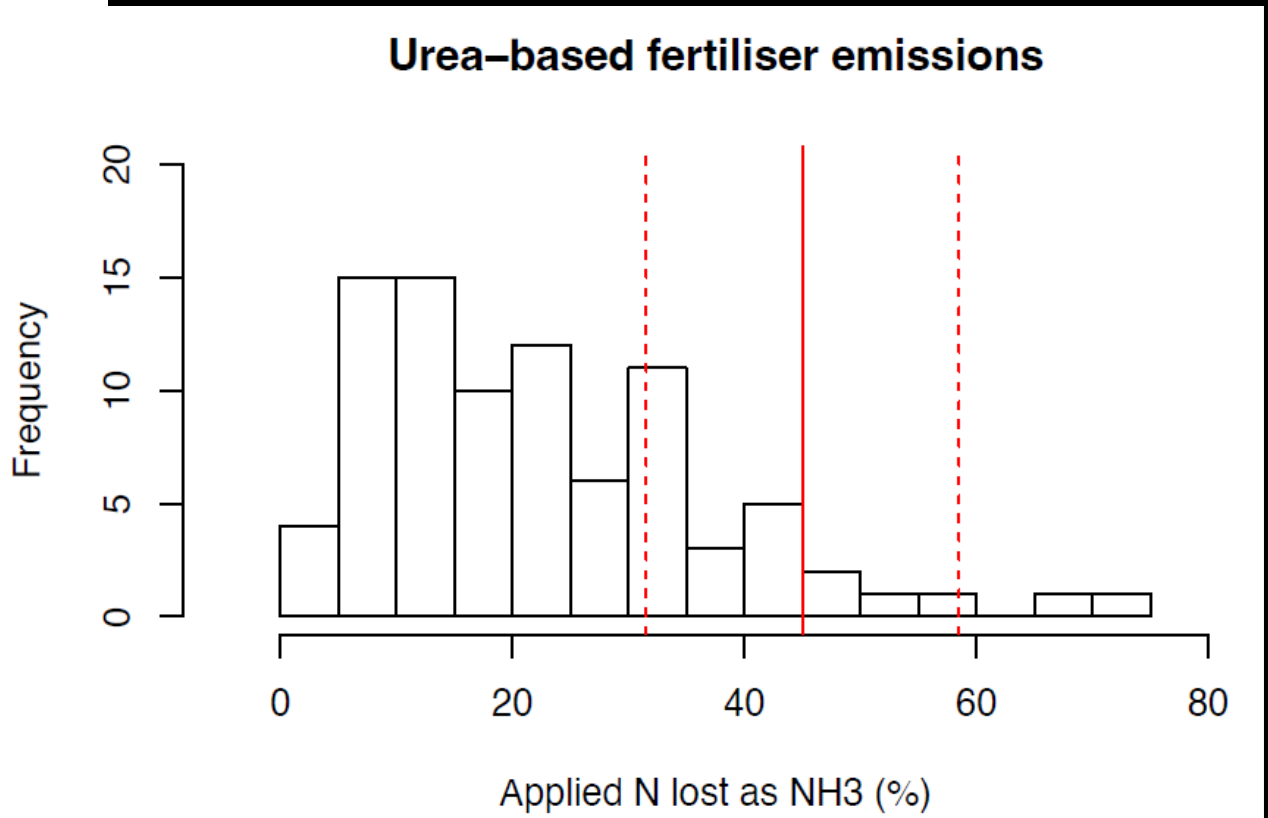
DEFRA'S ammonia Max Emission Factor (EFmax) for non-urea and urea fertilizers with uncertainty bands

1/3rd of the NH_3 loss observations greater than EFmax

Only ~2% observation > EFmax in case of urea, though mean losses are way higher than non-urea fertilizers



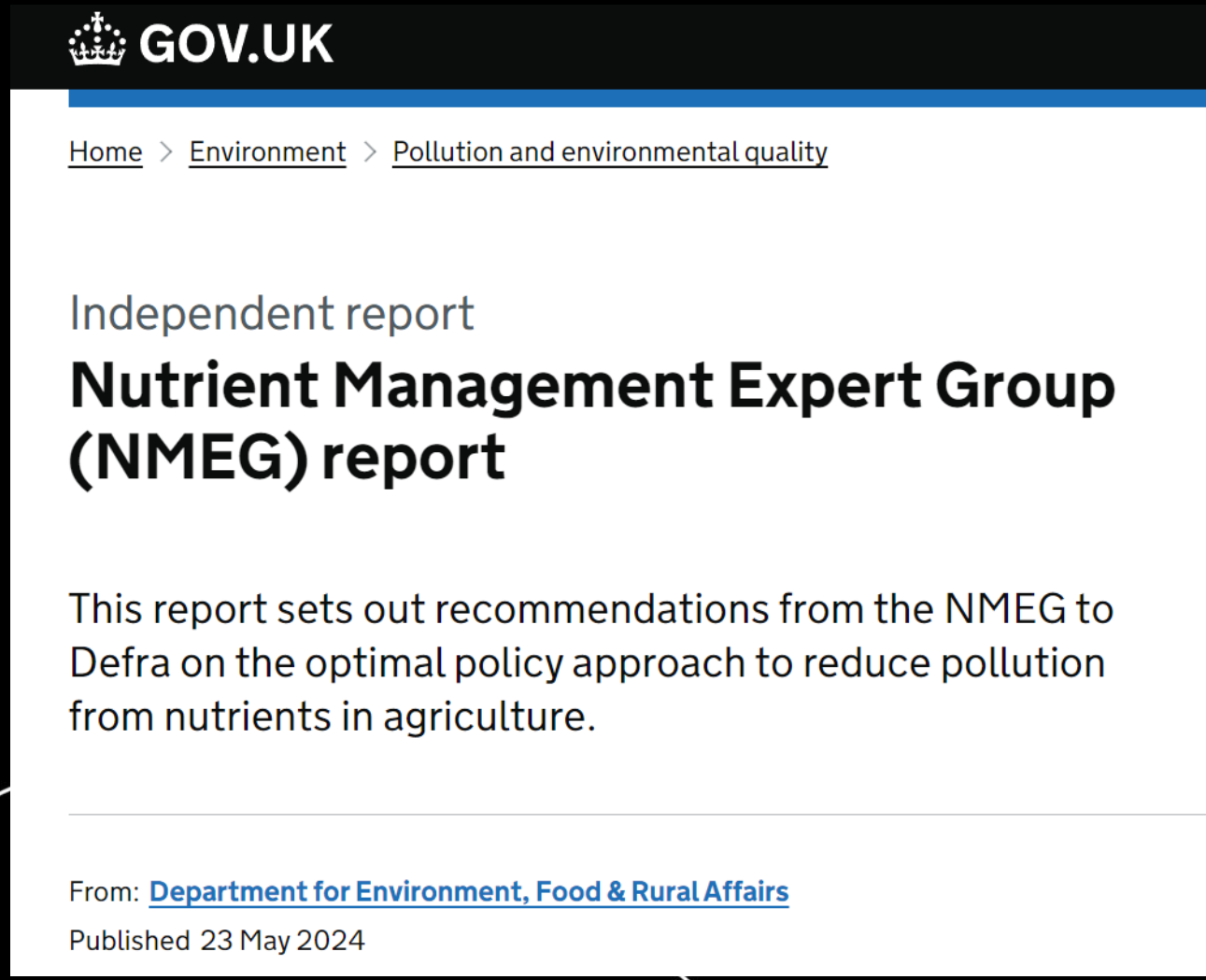


Future ammonia emission reduction directions…

A serious air quality and ecosystem health concern but poorly studied (11 field studies)….

The DEFRA's Nutrient Management Expert Group's report published in 2024 recommended:

1. Soil testing before fertilization to match crop N needs
2. Improve land application rates and time
3. Use of inhibitors, though research on health impacts recommended
4. Measures for improving N use efficiency of crops
5. Scope for use of non-urea fertilizers to reduce ammonia losses
6. Encourages use of bio-derived fertilizers



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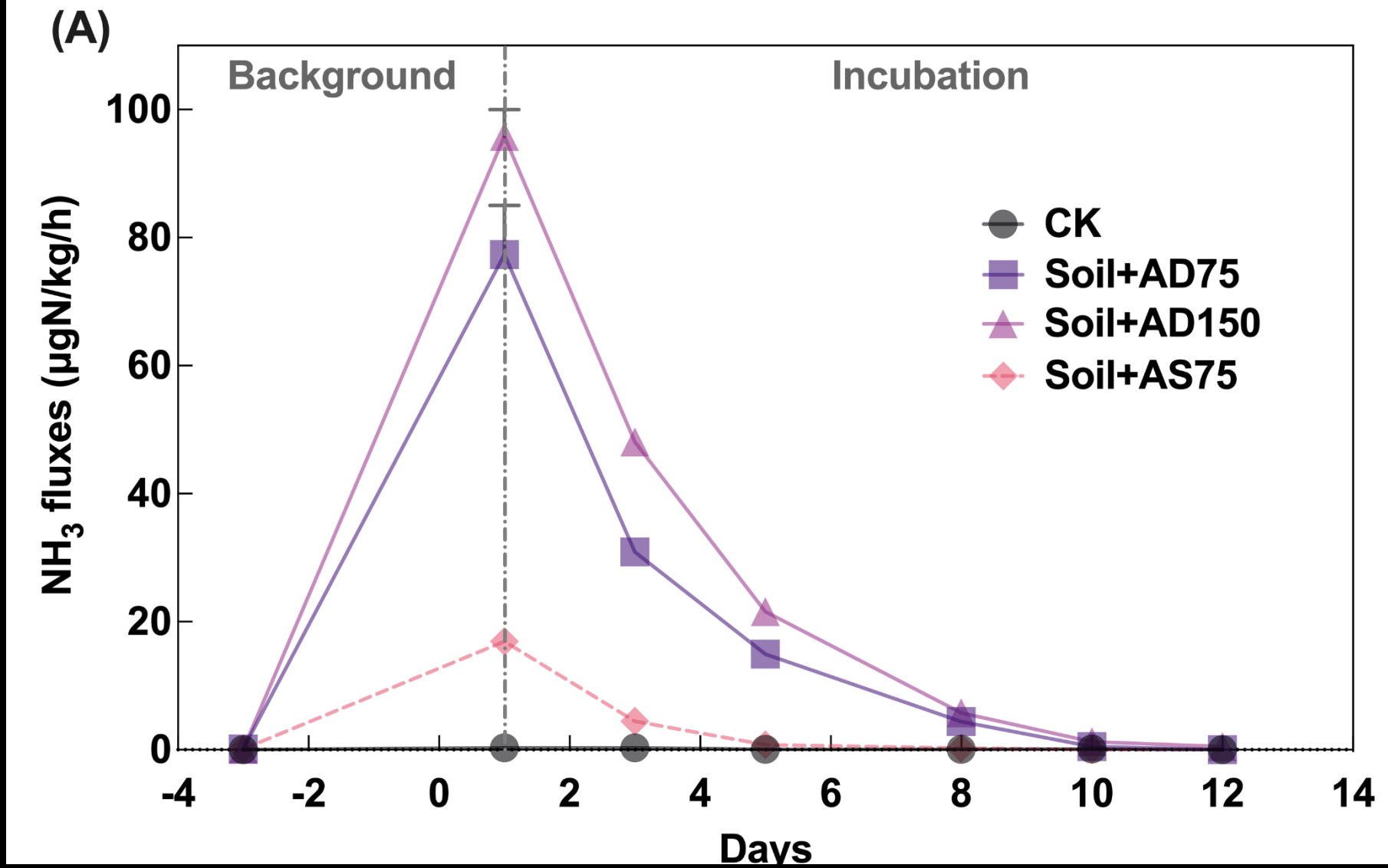
More research on smart application needed before switching to bioderived fertilizers!



Ammonia emissions from soils treated with Anaerobic digestate (AD) and conventional fertilizer (Ammonium Sulphate)
AD75 and AD150: Anaerobic digestate applied at 75 and 150 kg N h^{-1}

Hou and Ullah, 2024 (in prep)

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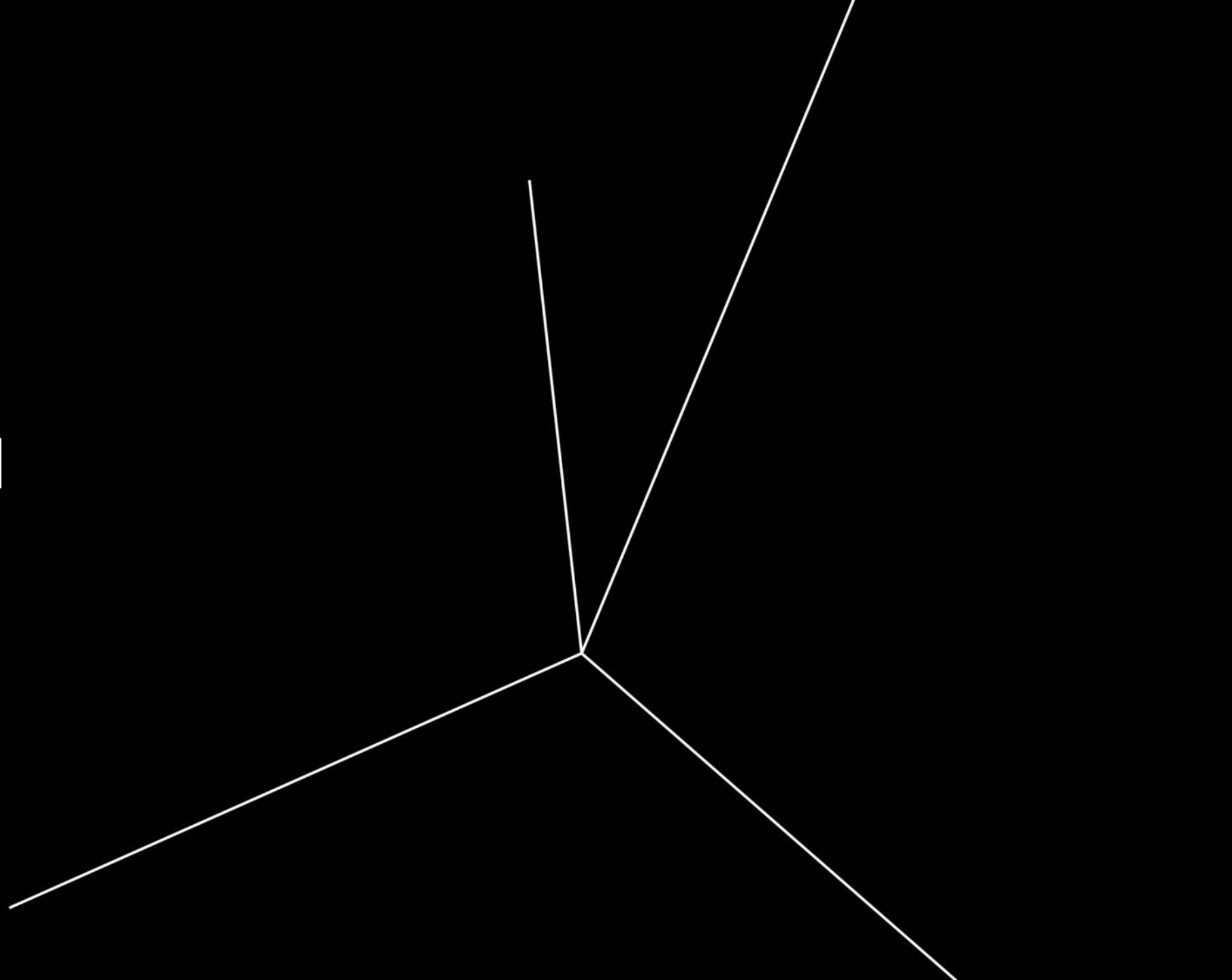
Thank you



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