AQNT Reference: C645_WD01 (WORKING DRAFT)

Project Title: Proposed SoNaRR Case Study for the Air Quality Chapter.

Response Date: 7 March 2025

Air Quality Case Study (draft proposal)

<u>Introduction</u>

The Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015 are legislative frameworks aimed at promoting sustainability, environmental protection, and the well-being of both current and future generations in Wales. Both acts collectively contribute to safeguarding ecosystems and human health by promoting sustainable practices, conservation efforts, and a holistic approach to decision-making that considers the long-term well-being of the environment and future generations in Wales.

As required under the Environment (Wales) Act 2016, the State of Natural Resources Report (SoNaRR) assesses Wales's sustainable management of natural resources (SMNR) and identifies opportunities for action. NRW recognises that to fulfil the goals identified in the Environment (Wales) Act 2016 and the Well-being of Future Generations (Wales) Act 2015, we need to bridge the gap between where we are now and where we need to be to achieve a sustainable future. To help inform this, SoNaRR assesses SMNR against four long-term aims. These are: safeguarded and enhanced natural resources, resilient ecosystems, healthy places for people, and a regenerative economy.

One of the biggest challenges to Wales' SMNR aims for the protection of human health and ecosystems is the emission of pollutants to the atmosphere from anthropogenic sources. While often overlooked, the atmosphere and the earth's ecosystems are two parts of a coupled system and air pollution from anthropogenic sources can have a significant detrimental impact on both ecosystems and human health (as illustrated in Figure 1).

In this context, ammonia (NH_3) is a major atmospheric pollutant in Wales, both harmful to human health and the environment. When combined with other pollutants it forms particulate matter that can cause respiratory and cardiovascular disease. When deposited from the atmosphere, it causes acidification and eutrophication of soils, habitats and fresh waters. Agriculture currently contributes over 85% of the total ammonia emissions in Wales[1] and The Clean Air Plan[2] for Wales, which was passed into law via the Environment (Air Quality and Soundscapes) (Wales) Bill (2024)[3] promotes multiple strategies for improving air quality in Wales and directly links to SMNR by actively working to reduce anthropogenic pollution. Strategies specifically targeted at reducing ammonia emissions from farming include supporting the delivery of the Sustainable Farming Scheme, promoting the uptake of best practice to reduce agricultural ammonia emissions and the development of future regulation "…to tackle

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1) I like footnotes but we will need to check digital accessibility guidance, I suspect that they are not allowed. I can check on this in the New Year if it helps.
2) The rest of SoNaRR uses in line citations (author, date) and makes use of the Zotero reference manager tool to make updating references across different assessments/SoNaRR products more streamlined. We should probably try and use the same approach for any case studies.

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[1] Code of Good Agricultural Practice guidance on reducing ammonia losses from agriculture in Wales
[2] Welsh Government (2020) "The Clean Air Plan for Wales" (https://www.gov.wales/clean-air-plan-wales-healthy-air-healthy-wales)
[3] Bill to tackle air and noise pollution passed in the Senedd, supporting a cleaner, healthier and greener future | GOV.WALES

agricultural pollution, which will contribute to achieving air quality targets including Wales' contribution to a 16% reduction of UK ammonia emissions by 2030."[3].

This case study explores how we might better understand the relationships between the agricultural drivers of NH_3 emission pressures and their impacts in Wales using a Driver-Pressure-State-Impact-Response (DPSIR) model. It shows how this evidence can help better target responses to reduce NH3 emission from agriculture, and highlights potential barriers to widespread adoption of these response measures.

Driver-Pressure-State-Impact-Response (DPSIR) model

The Driver-Pressure-State-Impact-Response (DPSIR) model is a causal framework adopted by SoNaRR to support the analysis of SMNR for different ecosystem and natural resource types. The DPSIR model is a conceptual framework commonly used in environmental management and sustainability studies, which facilitates the organisation and analysis of complex environmental issues by breaking them down into the following key components:

1. **Driver**

   This represents the underlying human activities or processes that lead to environmental changes. Drivers can be social, economic, technological, or political factors influencing the environment.

2. **Pressure**

   The pressures are the specific stressors or forces resulting from human activities that directly affect the state of environment. These could include air pollution emissions, agricultural intensification, or overuse of renewable natural resources.

3. **State**

   This refers to the current condition of the environment, including its physical, chemical, and biological characteristics. It reflects the effect a pressure has on the environment.

4. **Impact**

   Impacts are the changes to human health, ecosystem resilience, or other elements of well-being caused by changes in the state of the environment. These changes can be positive or negative and may have direct or indirect effects.

5. **Response**

   Responses are the measures or actions taken to address or mitigate the impacts on the environment and human-well-being associated with the above drivers, pressures and states. This involves policy decisions, regulations, conservation efforts, or any other interventions aimed at managing environmental and associated impacts on well-being.

The DPSIR framework provides a systematic way to understand and address environmental problems and their impacts on people, facilitating the development of effective strategies for sustainable resource management and environmental protection. It is therefore an appropriate tool to better understand factors currently influencing the rise of NH_3 emissions from agriculture in Wales. Using this framework, we can identify methods or strategies to reduce impacts of agricultural NH_3 emissions in Wales on human well-being and ecosystem resilience.

DPSIR Case Study: Atmospheric ammonia deep dive

Case studies are a useful way in which to explore subjects and concepts that relate to SoNaRR's assessment of natural resources, ecosystems and SMNR. Reflecting that the atmosphere and ecosystems exist as coupled systems, this case study demonstrates the relationship between the DPSIR assessments for air (as a natural resource) and the ecosystems where atmospheric NH_3 deposition is a concern (or pressure). This relationship is shown in Figure 1, which illustrates how changes in atmospheric NH_3 concentrations impact on both human health (Arrow A) and ecosystem resilience (Arrow B). It shows how responses to manage ammonia emissions from agriculture can simultaneously deliver better outcomes for both people (Arrow C) and nature (Arrow D).

Evidence: Drivers and Pressures

The National Atmospheric Emissions Inventory[4] (NAEI) compiles and estimates emissions from sources and activities across the whole of the UK, including agriculture. Despite an encouraging downward trend in atmospheric pollutants from anthropogenic sources over the last twenty years, the NAEI reveals atmospheric emissions of ammonia (NH_3) from agricultural sources remain stubbornly high in Wales.

The NAEI estimates emissions of ammonia from the agricultural sector in Wales using data collected by Emissions Inventory Reporting from Intensive Farming Installations[5] along with the annual Survey of Agriculture and Horticulture in Wales which provides data on agricultural activity such as livestock numbers, fertiliser use and crop areas etc.

Detailed national data and tailored methodologies show that key sources of NH_3 include livestock manure, particularly from cattle and pigs, and nitrogen-based fertilizer application. Emissions are then estimated using a methodology which incorporates animal populations, manure management, fertilizer usage, and crop production methods.

Since 2005, several updates have been made to emission factors, reflecting changes in scientific understanding and agricultural practices. These include revisions to nitrogen excretion rates, poultry management practices, manure handling, fertilizer use, and the inclusion of new sources such as foliar urea[6] and anaerobic digestion. Despite using this detailed approach, uncertainties remain due to a variety of factors which influence emissions from diffuse sources. Nevertheless, the combined uncertainty for agricultural NH_3 emissions has decreased since 2005, indicating improved accuracy in estimation methods (See Annex I).

[4] NAEI, http://naei.defra.gov.uk
[5] Natural Resources Wales / Emissions Inventory Reporting: Guidance for Intensive Farming
[6] Application of urea fertilisers directly to a plant's leaves rather than application to the soil

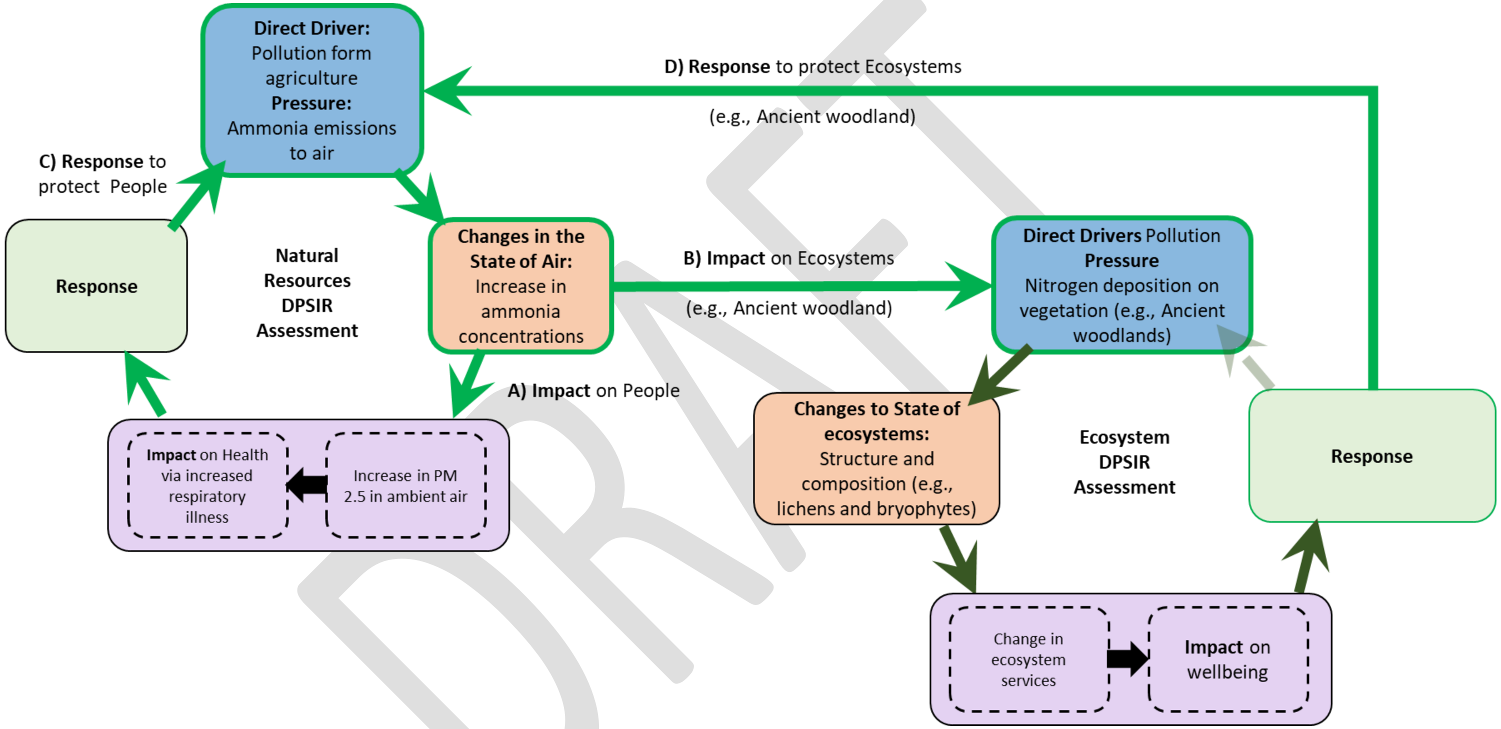

Figure 1: Relationship between DPSIR Assessment for Air and DPSIR Assessments for Ecosystems

According to the NAEI report[7], emissions of NH_3 in Wales were estimated to be 23 kilotonnes (kt) in 2022, with more than 92% of NH_3 emissions originating from agriculture (see Figure 2 and Figure 3:). It should be noted that drivers of recent increases in NH_3 emissions from agricultural practices are primarily driven by increases of livestock numbers (Survey of agriculture and horticulture: June 2024 [HTML] | GOV.WALES) and a move towards more intensive farming practices (particularly poultry), both of which result in increased manure production and application of fertilizers to soil which include the application of fertilizers in the form of digestate from waste-fed anaerobic digesters. While the digestate provides a fertilizer with high nutrient content, both its production and use can result in additional NH_3 emissions which incorporate non-agricultural sources of NH_3 from the digester feedstock which often includes domestic household food and drink waste, and sewage sludge.

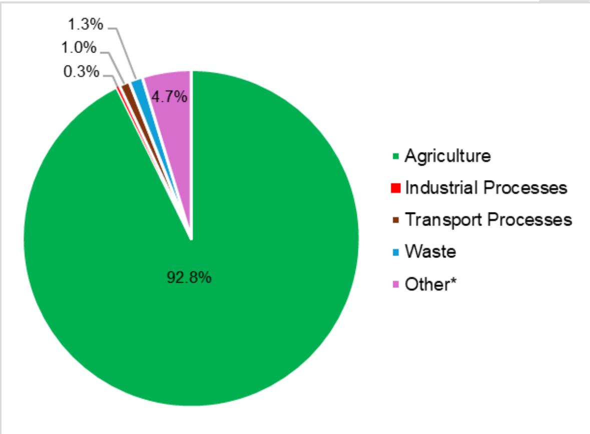

Figure 2: NH3 Emission Contributions in Wales Ranked by Sector, 2022

[7] NAEI, Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 2005-2022, 2024

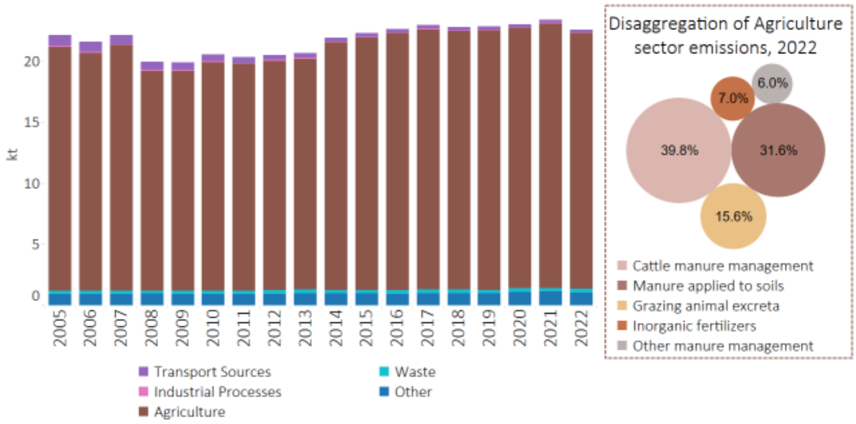

Figure 3: Agricultural NH3 Emission Sources in Wales[8]

Analysis of emissions of NH_3 from agricultural sources[1] clearly shows a significant proportion of land area in Wales where the long term trend is one of increasing NH_3 emissions (see Figure 4a). As Figure 4 shows, approximately 35.4% of land area in Wales was subject to a persistent increasing trend in local agricultural NH_3 emissions between 2005 and 2021, whilst only 17.8% of the land area was subject to reductions in local NH_3 emissions. Of the terrestrial Sites of Special Scientific Interest (SSSIs) whose designation includes biological features, 33% intersect with areas showing an increasing trend in agricultural NH_3 emissions (see figure 4b).

In fact, the proportion of areas where trends show decreasing NH_3 emissions is significantly lower in the decade leading up to the most recent data year available (2013 to 2022) relative to the ten-year period spanning 2005 to 2014 (see Figure 5). In short, NH_3 emission pressures from agriculture have generally increased across much of Wales in recent years. This is particularly noticeable across larger contiguous areas in the southwest and north east of Wales, with patches also observed in the south, east and north west (see Figure 5).

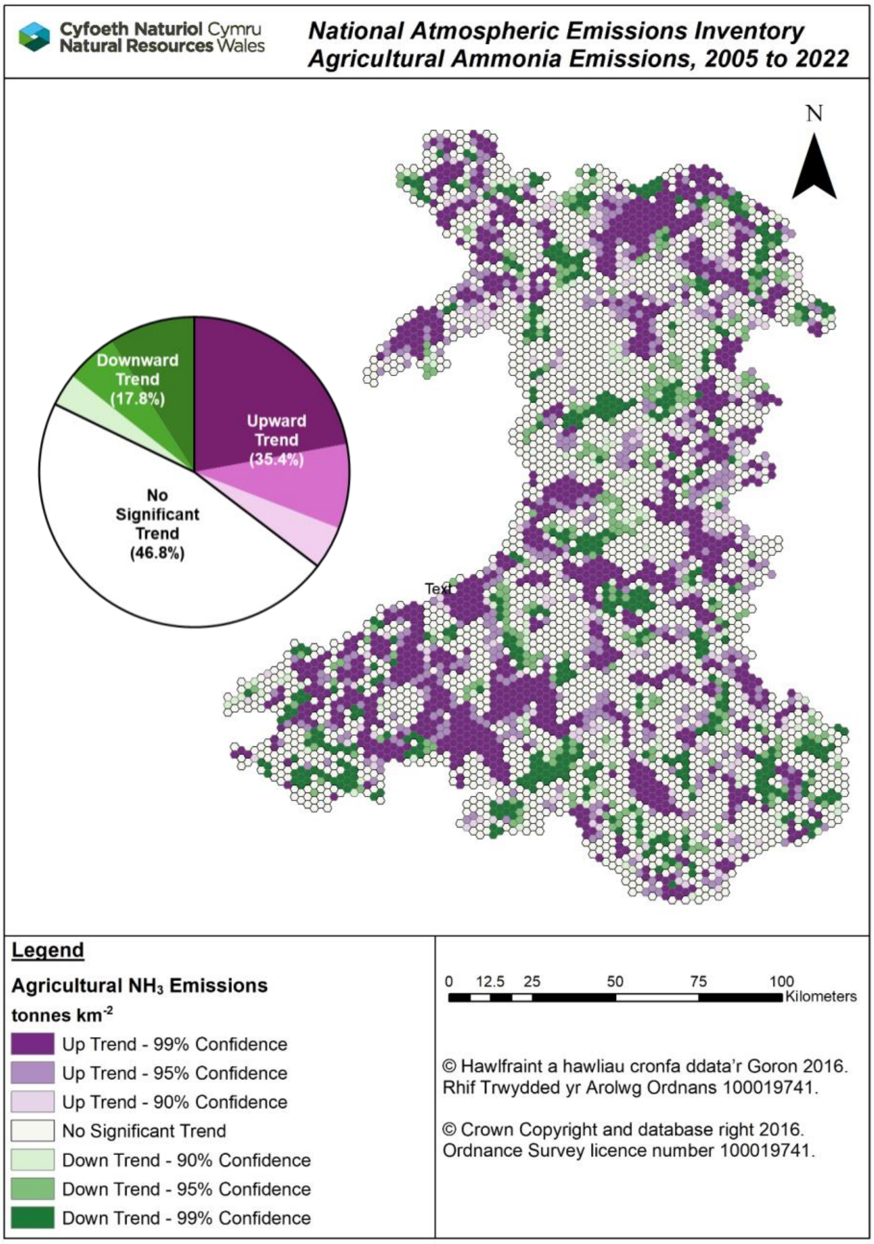

Figure 4a: Agricultural NH_3 Emissions Trends in Wales between 2005 and 2022

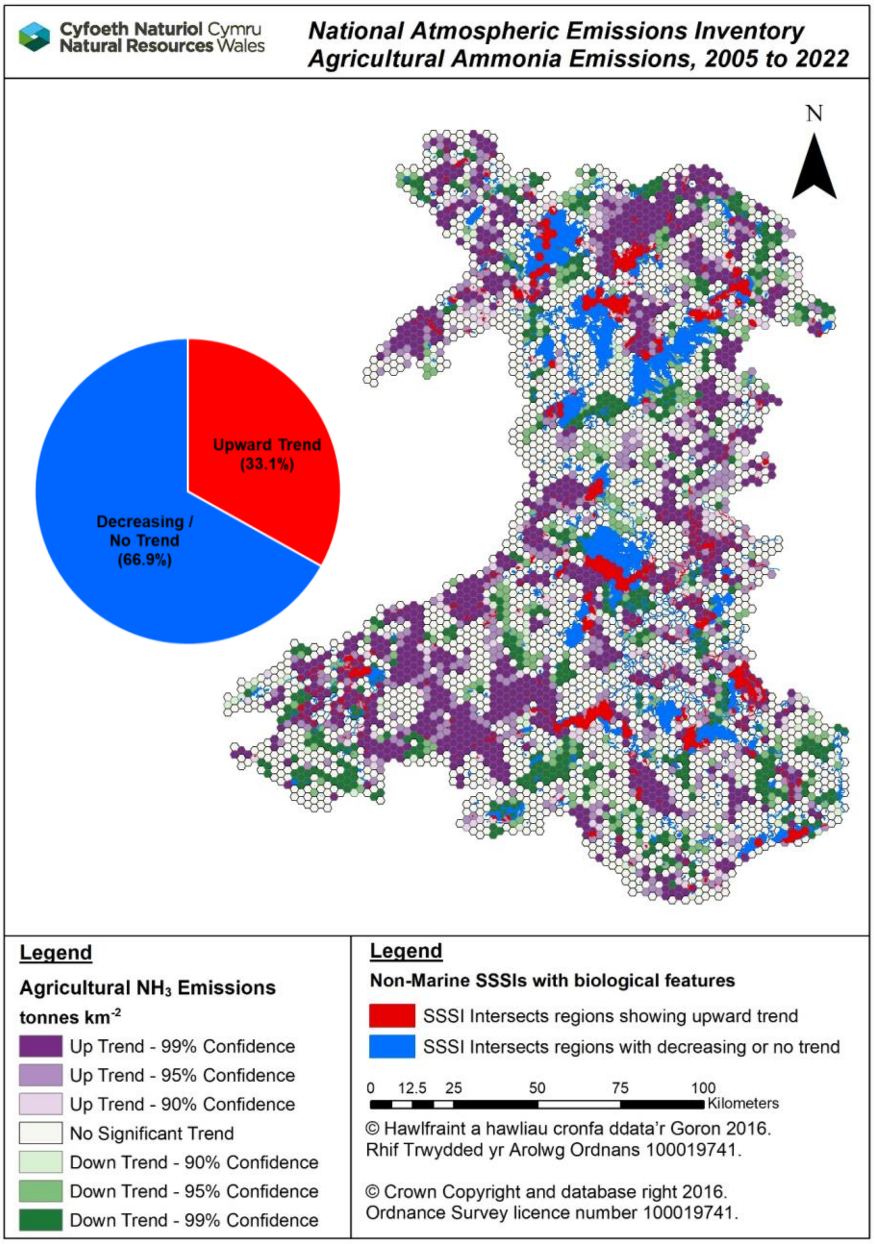

Figure 4b: SSSIs intersecting areas showing upward trends of NH_3 emissions

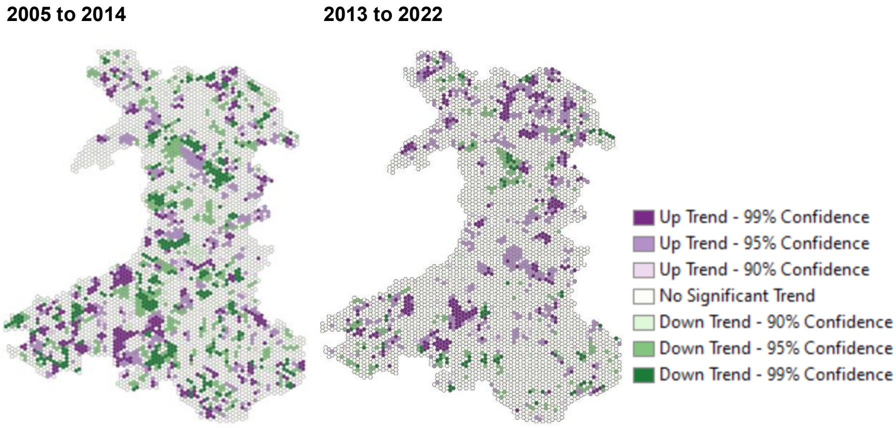

Figure 5: Reduction in areas showing downward trends of NH3 emissions in Wales

Evidence: State

Whilst there are several sites for monitoring local ambient ammonia concentrations in Wales, there are no overall national monitoring programmes for ammonia concentrations at the national scales. In order to understand where ambient ammonia concentrations may be a potential concern, modelling approaches are employed based on the atmospheric emissions described in the Drivers and Pressures section above. Figure 7 provides an example with respect to potential impacts on ecosystem health associated with exceedance of critical thresholds for ammonia deposition.

Evidence: Impacts on Human Health

NH_3 released from agricultural sources also contributes significantly to the generation of fine particulate matter ($PM_{2.5}$).[8] As Figure 6 shows, the formation of $PM_{2.5}$ from NH_3 is influenced by the availability of other gases like NOx and SO_2. Meteorological conditions, particularly temperature and relative humidity, also affect rates of formation.

[8] Wyer, K.E., Kelleghan, D.B., Blanes-Vidal, V., Schauberger, G. & Curran, T.P., 2021. Ammonia emissions from agriculture and their contribution to fine particulate matter: A review of implications for human health. Journal of Environmental Management 2022 Dec 1:323:116285. doi: 10.1016/j.jenvman.2022.116285

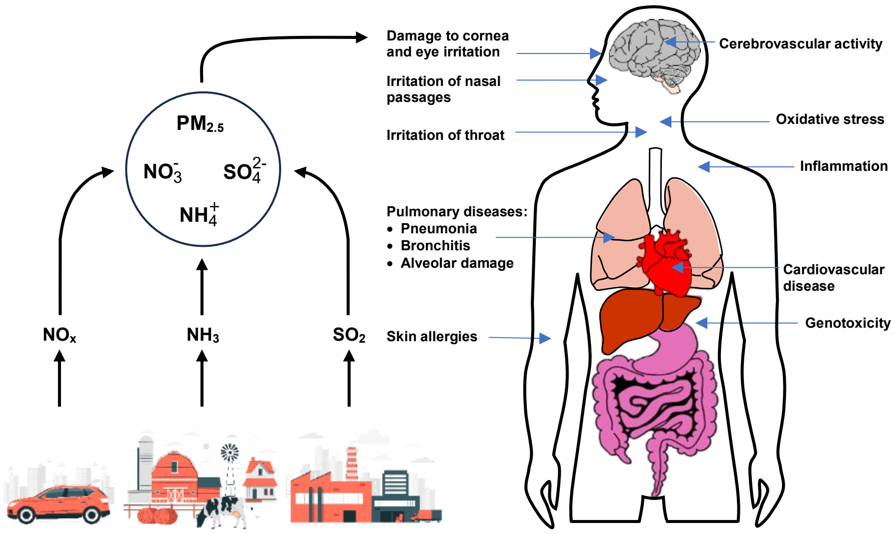

Figure 6: NH_3 reacts with other gases in the atmosphere, primarily nitrogen oxides (NOx) and sulphur dioxide (SO_2), to form secondary particulate matter ($PM2._5$).

It's important to note that while NH_3 itself has a short atmospheric lifetime, the particulate matter formed through these reactions can persist for several days and be transported over long distances. This makes NH_3 emissions a significant contributor to $PM_{2.5}$ pollution, As Figure 6 shows, exposure to $PM_{2.5}$ pollution has significant implications for human health, including aggravating asthma symptoms and increased risk of death due to cardiopulmonary disease. While it is not possible to separate out effects of multiple air pollutants, based on analysis by the UK expert Committee on the Medical Effects of Air Pollution (COMEAP), Public Health Wales estimated the burden of long-term air pollution exposure (including $PM_{2.5}$) in 2017 to be the equivalent of 1,000 to 1,400 deaths each year[9]. Data[10,11] available from the Stats Wales website indicates that air quality indicators for $PM_{2.5}$ in 2022 remain at the same levels identified for 2017.

The Clean Air Plan for Wales[3] outlines several strategies to mitigate the health impacts of PM2.5 with the Key measures identified as

- **Enhancing Air Quality Monitoring**: Developing a new Air Pollution Monitoring Network to better assess and manage PM2.5 levels, particularly in areas with vulnerable populations.
- **Develop Evidence Based Targets**: Welsh Government is working closely with the Clean Air Advisory Panel to receive independent and expert advice on the

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@Kuznets, Alison S. - we will need to check copyright and we are OK to re-publish this too.

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[9] Public Health Wales (February 2020), "Air Pollution and Health in Wales". phw.nhs.wales/services-and-teams/environmental-public-health/air-quality/air-pollution-and-health-fact-sheet/ accessed January 2025.
[10] https://statswales.gov.wales/Catalogue/Environment-and-Countryside/Air-Quality/airqualityindicators
[11] http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

development of evidence-based and effective air quality targets to reduce impacts on both current and future generations in Wales.

- **Promoting Active Travel and Public Transport**: Investing in infrastructure to encourage walking, cycling, and the use of public transport, thereby reducing emissions from private vehicles.
- **Regulating Domestic Combustion**: Reviewing local authority powers to address emissions from domestic burning of solid fuels, such as wood and coal, which are significant sources of PM2.5.
- **Implementing Clean Air Zones**: Investigating measures like Clean Air Zones or Low Emission Zones to reduce personal vehicle use and lower PM2.5 emissions in urban areas

Evidence: Impacts on Ecosystems

In terrestrial habitats, NH3 deposition from the atmosphere is a significant pressure on ecosystems. It can alter soil nutrient levels, with the increased availability of nitrogen favouring certain plant species that are adapted to high-nitrogen conditions. This can lead to a shift in plant communities, with nitrogen-loving species outcompeting those adapted to lower-nitrogen environments. As a result, sensitive habitats, including those hosting protected species, may experience a decline in biodiversity due to this species succession. Most Welsh habitats have evolved in naturally low-nitrogen environments, so NH3 enrichment causes widespread deterioration of semi-natural habitats. In addition, NH3 has direct toxic effects on many mosses, liverworts, lichens and fungi, causing species death and significant loss of biomass in bryophyte- and lichen-rich ecosystems including woodland, bog and heathland. A Critical Level of 1µg/m3 NH3 has been set to protect these lichen- and bryophyte-rich ecosystems from direct damage. NH3 has also been shown to reduce the survival of common grassland lepidoptera* (* Kurze, S, T Heinken, T Fartmann. 2018. Nitrogen enrichment in host plants increases the mortality of common Lepidoptera species. *Oecologia* 188: 1227–1237), providing direct impacts on animal species as well as indirect impacts through habitat change.

As Figure 4 shows, approximately 35.6% of land area in Wales was subject to a persistent increasing trend in agricultural NH_3 emissions between 2005 and 2021, with 25.5% of Sites of Special Scientific Interest (SSSI) and 20.3% of Special Areas of Conservation (SAC) land area exposed to increasing trends in NH_3 emissions from agricultural sources. In 2021, 45.2% of land area in Wales exceeded the 1mug/m^3 critical level of NH3 concentration which has been set to protect bryophytes and lichens (see Figure 7).[12]. This also applied for the area of SSSIs designated for biological features[13], with 45% of SSSI land area exposed to NH_3 concentrations greater than 1 $\mu g/m^3$. The geographical areas of impact concern mainly in the southwest and the east of Wales, plus Anglesey.

[12] Rowe EC, Sawicka K, Carnell E, Bealey B, Martín Hernandez C, Vieno M, Vigier A, Scheffler J, Tomlinson S & Jones L (2024) Air Pollution Trends Report 2024: Critical load and critical level exceedances in the UK. Report to Defra under Contract AQ0849, UKCEH project 07617

[13] Excluding offshore areas.

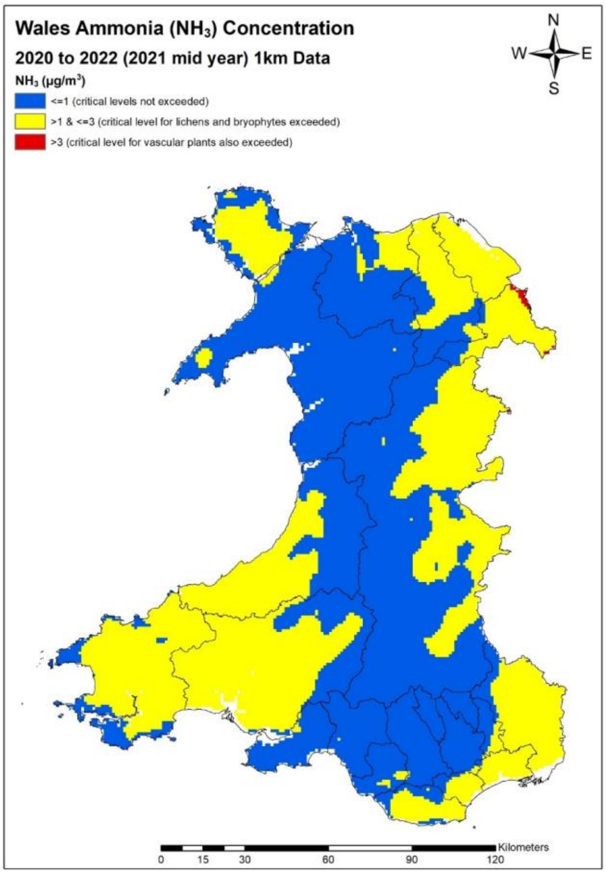

Figure 7: Distribution of areas exceeding critical levels of NH_3 concentration for the protection of lichens/bryophytes (1 mg/m^3) and higher plants (3 mg/m^3).

Comparison between Figure 4 and Figure 7 reveals that the areas of concern for increasing emissions between 2013 and 2022 are largely coincidental with areas of concern for exceedance of critical levels in Wales. This confirms local NH_3 emissions from agriculture as an increasing pressure on ecosystem resilience over the last decade. Indeed, The Clean Air Plan for Wales identifies a number of actions[14] to specifically tackle pollution from agriculture and land use, specifically aimed at reducing NH_3 emissions.

The changes in species composition that result from NH_3 deposition can have a cascade effect on entire ecosystems, affecting food webs, nutrient cycling, ecosystem functioning and the delivery of ecosystem services[15]. Protected species that rely on

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[14] See "Agriculture and Landuse" chapter of the Clean Air Plan for Wales[3].

[15] Guthrie, Susan, Sarah Giles, Fay Dunkerley, Hadeel Tabaqchali, Amelia Harshfield, Becky Ioppolo, and Catriona Manville, (2018). "Impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis." Santa Monica, CA: RAND Corporation, 2018. https://www.rand.org/pubs/research_reports/RR2695.html.

specific plant communities or environmental conditions will also face increasingly challenging conditions as their suitable habitat declines, driving species change[16]. Consequently, any exceedance of critical levels is an indication that the ecosystem or habitat is at risk from potentially harmful effects, with knock on impacts for biodiversity and people (via reductions in ecosystem services supply). This effect of ammonia deposition on ancient woodland ecosystems is a particular concern. Table 1 presents the percentage of each woodland type in Wales that experiences ammonia concentrations above the critical levels for bryophyte- and lichen-rich woodlands.[17] As reveals, approximately the extent of ancient woodland exposed to levels of ammonia above the critical threshold of 1 to 3 μg/m3 NH3 has increased by over 10,000ha between 2015/17 and 2020/2022.

Table 1: Area (hectares, ha) of each category of Ancient Woodland (from Ancient Woodland Inventory (NRW, 2011)) in Wales exposed to three bands of ammonia concentrations (the proportion, %, within each band across each category is shown in brackets) within the time periods 2015-2017 and 2020-2022

Category of Ancient Woodland	**Period**	**Below Critical Level for Lichens and Bryophytes (<1 $\mu g/m^3$ NH_3)**	**Above Critical Level for Lichens and Bryophytes and Below Critical level for Vascular Plants (1 to 3 $\mu g/m^3$ NH_3)**	**Above Critical Level for Vascular Plants (>3 $\mu g/m^3$ NH_3)**	**Total (hectares)**
Ancient Semi Natural Woodland (hectares)	2015-2017	19451.07 (46.80%)	22103.42 (53.18%)	7.48 (0.02%)	41561.97 (100%)
Ancient Woodland Site of Unknown Category (hectares)	2015-2017	1236.87 (44.51%)	1541.86 (55.49%)	0.00 (0.00%)	2778.73 (100%)
Plantation on Ancient Woodland Site (hectares)	2015-2017	12747.73 (47.54%)	14060.95 (52.44%)	3.36 (0.01%)	26812.04 (100%)
Restored Ancient Woodland Site (hectares)	2015-2017	8873.65 (38.30%)	14295.39 (61.70%)	0.00 (0.00%)	23169.03 (100%)

[16] Sheppard, LJ, Leith, ID, Mizunuma, T, Cape, JN, Crossley, A, S., L, Sutton, MA, Fowler, D, van Dijk, N, (2011). "Dry deposition of ammonia gas drives species change faster than wet deposition of ammonium ions: evidence from a long-term field manipulation", Global Change Biology, 17(12), pp 3589 - 3607

[17] SoNaRR (2020) included a table of the percentage of each woodland type in Wales that experiences ammonia concentrations above the critical levels for bryophyte- and lichen-rich woodlands. Those data were based on modelling using the FRAME model (Dore *et al.*, 2007), but since then this model has been replaced by the EMEP4UK model (Rowe *et al.*, 2023). To allow comparison between reports, 2020 data were recalculated using EMEP4UK (UKCEH, 2024), and the changes apparent in Table 1 are therefore the result of genuine changes in ammonia concentrations rather than a change of approach. This means that the data presented in SoNaRR (2020) should no longer be referred to or compared with Table 1.

Commented [MM6]: Dore, AJ, Vieno, M, Tang, YS, Dragosits, U, Dosio, A, Weston, KJ, Sutton, MA (2007) Modelling the atmospheric transport and deposition of sulphur and nitrogen over the United Kingdom and assessment of the influence of SO2 emissions from international shipping. Atmospheric Environment 41, 2355-2367.

Liu, M, Huang, X, Song, Y, Xu, T, Wang, S, Wu, Z, Hu, M, Zhang, L, Zhang, Q, Pan, Y, Liu, X, Zhu, T (2018) Rapid SO2 emission reductions significantly increase tropospheric ammonia concentrations over the North China Plain, Atmos. Chem. Phys., 18, 17933–17943, https://doi.org/10.5194/acp-18-17933-2018.

Rowe EC, Sawicka K, Hina NS, Carnell E, Martín Hernandez C, Vieno M, Tomlinson S, & Jones L (2023) Air Pollution Trends Report 2023: Critical load and critical level exceedances in the UK. Report to Defra under Contract AQ0849, UKCEH project 07617.

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Grand Total (hectares)	**2015 - 2017**	**42309.31 (44.86%)**	**52001.62 (55.13%)**	**10.84 (0.01%)**	**94321.77 (100%)**
Ancient Semi Natural Woodland (hectares)	2020-2022	14282.19 (34.36%)	27199.21 (65.44%)	80.57 (0.19%)	41561.97 (100%)
Ancient Woodland Site of Unknown Category (hectares)	2020-2022	831.34 (29.92%)	1946.06 (70.03%)	1.33 (0.05%)	2778.73 (100%)
Plantation on Ancient Woodland Site (hectares)	2020-2022	10239.32 (38.19%)	16555.52 (61.75%)	17.19 (0.06%)	26812.04 (100%)
Restored Ancient Woodland Site (hectares)	2020-2022	6369.00 (27.49%)	16742.88 (72.26%)	57.16 (0.25%)	23169.03 (100%)
Grand Total (hectares)	**2020 – 2-22**	**31721.85 (33.63%)**	**62443.67 (66.20%)**	**156.25 (0.17%)**	**94321.77 (100%)**

Exploring Responses

Increasing trends in agricultural NH_3 emissions are a clear indication that significant challenges remain to meet our obligations under the Environment (Air Quality and Soundscapes) (Wales) Bill (2024) and the Well-being of Future Generations (Wales) Act 2015. This increase in NH_3 emissions is impacting on human health via its contribution towards secondary $PM_{2.5}$ production and impacting on ecosystem resilience via deposition. This highlights the ongoing need to carefully manage the conflicting pressures between agricultural production and protecting human health and ecosystems.

Using the DPSIR framework, we can systematically analyse the issues associated with NH_3 emissions from agriculture, understand the various components, and design targeted responses to mitigate impacts on human health and ecosystem resilience in Wales. The most tractable way of limiting the impact of atmospheric NH_3 on people and ecosystems is by reducing emissions at source. Possible responses to achieve a reduction in NH_3 emissions from the agricultural sector include:

- Sustainable agriculture responses to reduce the NH_3 emissions pressures from agriculture (see Figure 3)
    1. Promote best practices such as soil testing, slurry management improvements, and collaborative farming approaches to reduce high emissions associated with manure management and grazing animals from by the sector.
    2. Align reducing agricultural NH_3 emissions with broader goals linked to climate change mitigation and biodiversity objectives, securing co-benefits via improved air and soil quality.

- Pollution management responses
    1. Promote adoption of technologies like covered slurry storage, anaerobic digestion, and precision fertilizer application equipment to reduce NH_3 volatilization associated with manure storage, the main source of NH_3 emissions from the sector.
    2. Implement innovative housing designs that enhance air circulation and reduce NH_3 build-up in conjunction with the use of scrubbers to reduce NH_3 emissions from intensive agricultural production facilities.
    3. Targeted crude protein diets for livestock to reduce nitrogen intake by livestock and associated concentrations in manure and excreta, the main sources of NH_3 emissions from the agricultural sector in Wales.
    4. Enable shared investments in technologies or infrastructure, like anaerobic digestion systems, that can lower emissions efficiently.
- Nature based Solution responses
    1. Introducing buffer zones or green infrastructure to absorb and mitigate NH_3 emissions. This would also have the co-benefit of reducing agricultural runoff associated with washout.
- Education and awareness responses
    1. Educating farmers through advisory programs can fill knowledge gaps and improve uptake of mitigation strategies.
    2. Co-design and collaborative approaches enable farmer-driven solutions.
    3. Targeted soil testing to support improved nutrient management and better use of fertilizers. This could reduce excess nitrogen application, decrease NH_3 volatilization and optimize costs.

Case Study Summary

The DPSIR Assessment deep dive for ammonia presents the evidence that the agricultural sector is the main source of NH3 emissions in Wales by a substantial margin. The NAEI identifies agricultural emissions of ammonia comprise 92% of all ammonia emissions in Wales, mainly associated manure management and grazing livestock excreta. Increasing trends in emissions between 2012 and 2021 are particularly notable across larger areas in the southwest and north east of Wales, with patches also observed in the south, east and north west. Overall,

The evidence is clear that, as a precursor to PM 2.5, ammonia has documented ill health effects. It also has established effects on ecosystem resilience, with approximately 45% of the land area Wales exposed to concentrations above critical thresholds for sensitive species. These ecosystem impacts are mainly anticipated in the southwest and eastern areas of the country, as well as Anglesey.

Implementing a combination of the identified responses to manage agricultural NH_3 emission pressures based on where they are of particular concern, local conditions and farming systems is needed to achieve more sustainable and environmentally friendly agriculture. Regular assessments can help refine the responses over time, based on the effectiveness of implemented responses and changes in environmental conditions. This would support a comprehensive and structured approach to mitigating the impacts from NH_3 emissions, protecting the resilience of ecosystems and the well-being of current and future generations by reducing health impacts from $PM_{2.5}$ inhalation. This is one of the ambitions of the Welsh Sustainable Farming Scheme (SFS), proposed to launch in 2025, which integrates measures aimed at reducing NH_3 emissions as part of a broader set of environmental and agricultural sustainability goals.

There remain several barriers to successfully implementing responses to reduce NH3 emissions from the agricultural sector. These include: High initial costs associated with NH_3-reducing measures; Knowledge gaps; and, Tenancy-related constraints. For instance, smaller farms and tenants may find it harder to participate in NH_3 reducing measures due to restrictive tenancy agreements that impede changes, as well their relatively limited resources. Clearly, some of the responses suggested also come with trade-offs that need to be considered. For example, limiting fertilizer application could reduce crop yields, creating economic risks for farmers.

Annex I

National Atmospheric Emissions Inventory

The National Atmospheric Emissions Inventory (NAEI) compiles and estimates ammonia (NH_3) emissions from agriculture in the UK using a mix of detailed national data and methodologies tailored for specific emission sources. Key sources of agricultural NH_3 emissions include livestock manure, particularly from cattle and pigs, as well as the application of nitrogen-based fertilizers to soils.

Wales livestock numbers at agricultural holding level are obtained from the annual returns to the June Agricultural and Horticultural Survey (Survey of agriculture and horticulture | GOV.WALES) and, for the years from 2005 onwards, additional details on all types of cattle is provided by data from the Cattle Tracing Service database (About us - British Cattle Movement Service - GOV.UK). Each agricultural holding is categorised according to Robust Farm Type (RFT)[18], and is spatially located within a 10 x 10 km grid square for association with soil type and climate allowing for differences in management practices and/or environmental factors to be reflected in the emission estimates.

These surveys are considered the most complete and robust data sources for UK livestock numbers and have remained relatively consistent over a long timescale. They are structured to be representative of the UK agricultural sectors and are associated with low uncertainties (actual values depending on year and livestock category).

The emissions are categorized and estimated using a Tier 3 methodology[19], which incorporates farm animal population data, manure management practices, fertilizer usage, and crop production specifics (https://naei.energysecurity.gov.uk/air-pollutants/ammonia) (https://naei.energysecurity.gov.uk/reports/uk-informative-inventory-report-1990-2022).

Since 2005, the estimation of NH_3 emissions from agricultural sources in the UK has undergone several updates, with changes to emission factors (EFs) reflecting revised scientific understanding and agricultural practices:

1. **Revisions to Nitrogen Excretion Rates**: Updates have been made for various livestock categories, including cattle, pigs, and poultry. These revisions account for changes in milk yield, slaughter weight, and feed composition. For example, nitrogen excretion rates for cattle were adjusted in response to changing milk production levels and updated manure management practices.

[18] A classification used across different UK surveys (e.g. Farm Business Survey), enabling linking of input or output datasets where appropriate.

[19] Tier 3 methods typically apply more complex modelling approaches that are developed to generate more accurate estimates than Tier 1 and 2, often through research to better understand high-emitting emission sources (see also Section 1.4.2. of UK Informative Inventory Report (1990 to 2022) UK IIR 2024 Submission).

(https://naei.energysecurity.gov.uk/sites/default/files/cat09/2307061001_UK_Agriculture_Ammonia_Emission_Report_1990-2021_Final.pdf)

(https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

2. **Poultry Management**: Recent changes include a revision of the time outdoor poultry spends outside, reducing the outdoor ratio from 20% to 10%. This reflects updated activity data based on studies commissioned by environmental agencies

   (https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

   (https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

3. **Manure Management**: Changes include increased adoption of Low Emission Slurry Spreading Equipment (LESSE) and revisions to the proportions of manure managed in slurry versus solid forms. These adjustments affect NH_3 emissions from storage, land spreading, and housing systems.

   (https://naei.energysecurity.gov.uk/sites/default/files/cat09/2307061001_UK_Agriculture_Ammonia_Emission_Report_1990-2021_Final.pdf)

   (https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

4. **Fertiliser Use**: The proportion of urea-based fertilisers, which have a high NH_3 EF, has increased. However, the introduction of urease inhibitors with these fertilisers has been shown to reduce emissions significantly. Updates to fertiliser practices also include improved data on application rates and timings.

   (https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

   (https://naei.energysecurity.gov.uk/reports/inventory-ammonia-emissions-uk-agriculture-2020)

5. **Inclusion of New Sources**: Foliar urea and manure diverted to anaerobic digestion have been incorporated into the inventory, reflecting new practices and technologies in agricultural management.

   (https://naei.energysecurity.gov.uk/sites/default/files/2024-09/UK_Agriculture_Ammonia_Emission_Report_1990-2022_23072024.pdf)

6. **Regional Adjustments**: Changes were also made for specific devolved administrations, such as adjustments to manure storage systems and slurry applications in Northern Ireland, reflecting local practices.

(https://naei.energysecurity.gov.uk/sites/default/files/cat09/2307061001_UK_Agriculture_Ammonia_Emission_Report_1990-2021_Final.pdf)

(https://naei.energysecurity.gov.uk/reports/inventory-ammonia-emissions-uk-agriculture-2022)

These methodological refinements, often informed by new surveys and research, aim to provide more accurate emissions estimates and support mitigation strategies.

NH_3 emission estimates are dominated by uncertainties in the estimates of emissions from agricultural sources, which represent the majority of the national total NH_3 emissions. Although the UK uses a detailed (largely Tier 3) approach to estimating emissions from agriculture, which accounts for different animal sub-categories and management systems, it is not possible to fully represent the many factors influencing emissions from what are often diffuse emission sources including, for example, animal stocking densities, daily weather, soil type and conditions, etc. These are therefore reflected in the uncertainties associated with individual emission factors, the parameters of which are continually updated to reflect the latest understanding for the latest submissions.

Combined uncertainty as % of total national emissions has dropped from 24.6% in 2005 to 13.1% in 2022 for NH_3 emissions associated with agriculture (manure management and application of fertilisers to soil, see also Table 1-8 in “Assessment of NH_3 uncertainty, UK Informative Inventory Report” (1990 to 2022)).

https://naei.energysecurity.gov.uk/reports/uk-informative-inventory-report-1990-2022