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A methodology to link national and local information for spatial targeting of ammonia mitigation efforts

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HIGHLIGHTS

- An approach to identify suitable NH_3 mitigation measures is proposed.
- The methodology combines emission, concentration and deposition data.
- Agriculture contributes ~45% of total N deposition received by SACs.

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ABSTRACT

The effects of atmospheric nitrogen (N) deposition are evident in terrestrial ecosystems worldwide, with eutrophication and acidification leading to significant changes in species composition. Substantial reductions in N deposition from nitrogen oxides emissions have been achieved in recent decades. By contrast, ammonia (NH_3) emissions from agriculture have not decreased substantially and are typically highly spatially variable, making efficient mitigation challenging. One solution is to target NH_3 mitigation measures spatially in source landscapes to maximize the benefits for nature conservation. The paper develops an approach to link national scale data and detailed local data to help identify suitable measures for spatial targeting of local sources near designated Special Areas of Conservation (SACs). The methodology combines high-resolution national data on emissions, deposition and source attribution with local data on agricultural management and site conditions.

Application of the methodology for the full set of 240 SACs in England found that agriculture contributes ~45 % of total N deposition. Activities associated with cattle farming represented 54 % of agricultural NH_3 emissions within 2 km of the SACs, making them a major contributor to local N deposition, followed by mineral fertiliser application (21 %). Incorporation of local information on agricultural management practices at seven example SACs provided the means to correct outcomes compared with national-scale emission factors. The outcomes show how national scale datasets can provide information on N deposition threats at landscape to national scales, while local-scale information helps to understand the feasibility of mitigation measures, including the impact of detailed spatial targeting on N deposition rates to designated sites.

1. Introduction

Atmospheric nitrogen (N) deposition is an international issue, with effects of eutrophication and acidification evident worldwide. Throughout Europe, increases in N deposition have resulted in changes to species composition, with declines in N-sensitive species at the expense of a smaller number of fast growing species that favour high N supply (Dise et al., 2011). Thresholds of N deposition are currently exceeded in >50 % of Europe, and will continue to be exceeded under current projections of N emissions (Hettelingh et al., 2008). In the UK, N deposition is estimated to have almost doubled throughout the 20th century (Fowler et al., 2004), with increased emissions of nitrogen oxides (NO_x, mainly from motorised transport, power generation and other combustion sources) and ammonia (NH_3, mainly from agricultural sources). Although substantial efforts in UK and European policies in recent decades have led to a considerable reduction in NO_x emissions (RoTAP,

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2012), much less has been achieved in reducing NH_3 emissions. Around 82 % of UK NH_3 emissions are estimated to derive from agriculture (Misselbrook et al., 2013). As these are typically diffuse sources, it has sometimes been argued that it is much harder to implement emission controls, compared with NO_x, which is often associated with point sources (RoTAP, 2012). However, in the UK there has also been a low political willingness to implement NH_3 control measures in agriculture, compared with other countries, such as the Netherlands and Denmark, which have made more progress in reducing emissions (e.g. Sutton et al., 2003; Bleeker et al., 2009; Jimmink et al., 2014; NERI, 2007).

A wide range of potential mitigation measures exists to reduce NH_3 emissions from agricultural sources. Measures to reduce N deposition include both source-oriented technical measures, which aim to minimise emissions at source (e.g. covering slurry stores; Bittman et al., 2014) and landscape-oriented measures. Landscape-oriented measures aim to optimise spatial relationships between emission sources and sensitive habitats. Such measures include minimising agricultural activity around sites (e.g. controlling spreading within buffer zones close to the sensitive habitat areas) or planting trees to recapture and disperse emissions (e.g. Dragosits et al., 2006; Bealey et al., 2016). Under current rates of N deposition, it is estimated that around 60 % of SACs (European Commission, 2016a) remain under substantial threat, with thresholds for atmospheric N pollution effects exceeded both in the case of critical loads for total nitrogen deposition (Hall and Smith, 2015) and for critical levels for NH_3 concentrations (e.g. Hallsworth et al., 2010; Vogt et al., 2013).

Concentrations of NH_3 (and subsequent deposition of reactive N) from agricultural sources are highly spatially variable (e.g. Vogt et al., 2013; Dragosits et al., 2002; Sutton et al., 1998) making it challenging to avoid critical load and critical level exceedance across all designated sites at a national scale. This highlights the need to interface national level and local level strategies. In particular, to reduce N deposition effectively at designated sites, areas of high NH_3 concentrations need to be reliably identified, which can allow NH_3 mitigation measures to be targeted spatially to the most critical locations (e.g. Dragosits et al., 2002, 2006; Theobald et al., 2004; Hallsworth et al., 2010).

This paper presents an approach for identifying the main sources of N deposition at Natura 2000 sites and ascertain the most effective measures to target local decreases of deposition at each site. It focuses on where to apply NH_3 mitigation measures rather than an analysis of the different abatement measures themselves. This paper's focus is on the case of protecting Special Areas of Conservation (SACs), but the approach is generally applicable to other regions and natural habitat designations. The methodology is first applied to all 240 SACs in England by applying national datasets. It is then applied by combining national and local datasets for seven example SACs to provide insights on how local information can help refine the assessment.

2. Methods

The main emission sources contributing to N deposition were identified for each SAC in England, which are part of the European Union's Natura 2000 network. NH_3 emissions were also estimated in areas up to 2 km surrounding each site, for agricultural sources, which are the largest contributor of NH_3 emissions. In addition, seven sites were assessed in more detail, to establish whether supplementary local data (e.g. the direction of prevailing winds) and refinements to the methodology could lead to improved targeting of measures. Fig. 1 illustrates the draft framework devised to assess designated sites for N threats.

The datasets used to determine the threat of atmospheric N input to sensitive protected features at SACs include: i) modelled atmospheric concentration and deposition data; ii) high-resolution agricultural statistics for livestock numbers and crop areas; iii) farm management and practice information; iv) aerial images; and v) meteorological data. A draft framework for the approach used is summarised in Fig. 1. The following sub-sections outline how this framework may be applied and how national and local information sources have been used to assess N deposition threats to designated sites in England.

2.1. Data sources

2.1.1. National data sets

The main emission sources contributing to N deposition at each SAC were estimated using modelled source attribution data. Source attribution data are derived by performing multiple model runs of an atmospheric transport and deposition model, with each source type removed in turn. N deposition attributed to individual emission source categories (such as agriculture, road transport etc.) or individual large point sources (such as power stations) can then be calculated as a proportion of total deposition to each model grid square.

In this study, N deposition estimates for the year 2005 were produced at a 5 km grid resolution using the Fine Resolution Atmospheric Multi-pollutant Exchange model (FRAME, e.g. Dore et al., 2014; Bealey et al., 2014). FRAME is a Lagrangian atmospheric chemistry transport model with the relevant atmospheric processes (vertical diffusion, chemical transformation, wet and dry deposition) calculated in a moving vertical column of air comprising 33 layers with a variable layer depth from 1 m at the surface to 200 m for the upper layer. The model utilises emission estimates of NH_3, NO_x and SO_2, to calculate atmospheric concentrations of gases. Chemical reactions include both aqueous and dry phase oxidation and the conversion of gases to form particulate matter (ammonium sulphate and ammonium nitrate). Long range transport is driven by year specific wind direction and wind speed frequency roses (Dore et al., 2006) The model uses a resistance analogy within a 'big leaf model' to calculate the dry deposition velocity of gases and particulates to vegetation (Smith et al., 2000). Wet deposition is calculated using scavenging coefficients combined with annual precipitation estimates based on the UK Met Office national precipitation monitoring network. Deposition estimates are calculated for different vegetation types including forest, moorland, grassland, arable, urban and water. The boundary conditions for the concentrations of pollutants in air used to initialise a UK simulation were calculated with a larger scale European simulation using a 50 km grid resolution and emissions from the EMEP database (http://www.ceip.at). The model has been used to calculate historical and future trends in sulphur and nitrogen deposition as well as the exceedance of critical loads (Matejko et al., 2009). Source-receptor relationships generated by the model were used in integrated assessment modelling to determine cost-effective emission abatement strategies to protect natural ecosystems and human health (Oxley et al., 2013).

Comparison of the modelled concentrations of gases and particulates in air and of sulphur and nitrogen compounds in precipitation with measurements from the national monitoring networks demonstrated that the model was 'fit for purpose' and performed well in comparison with other atmospheric chemical transport models (Dore et al., 2015). These data incorporate UK estimates of NO_x and NH_3 emissions (National Atmospheric Emission Inventory (NAEI), www.naei.org.uk), with agricultural emissions distributed using the AENEID model (e.g. Dragosits et al., 1998). N deposition estimates from 160 source categories (e.g. agriculture, road transport, shipping, industry) were used in this study.