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Nitrogen deposition in Northern Ireland and import/export of N deposition across the UK

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Contents

1 Introduction

Atmospheric nitrogen (N) deposition represents a significant threat to sensitive habitats and species in the United Kingdom, with excessive N supply leading to declines in many important species of high conservation value, at the expense of fast growing species that can exploit the additional nitrogen supply. Atmospheric N is produced from emissions of ammonia (NH_3, mainly from agricultural sources) and nitrogen oxides (NO_x, mainly from transport, industry, power generation and other combustion sources).

In Northern Ireland (NI), NH_3 emissions were estimated at 27.9 kt N $year^{-1}$ (33.9 kt NH_3 $year^{-1}$) in 2017, with agriculture contributing 96 % of the total (Jones *et al*., 2019). Overall NH_3 emissions in NI have increased in recent years, with a ~15% increase in ammonia emissions reported between 2013 and 2017. Over 63 % of agricultural NH_3 emissions produced in NI 2018 are associated with cattle farming (Misselbrook and Gilhespy, 2020). Emissions of nitrogen oxides (NO_x) in NI were estimated at 11.2 kt N $year^{-1}$ (36.7 kt NO_x as NO_2 $year^{-1}$) in 2017. This is 4 % of the total NO_x emissions produced in the UK (249 kt NO_x-N or 819.6 kt NO_x expressed as NO_2), with 41 % originating from road transport, 15 % from power generation and the remaining 43 % coming from industrial processing and other sources.

This report aims to quantify and compare N deposition to land in NI from sources within NI and overseas (in the UK, Republic of Ireland, Shipping and the rest of Europe) to the amount of N deposition produced from NI sources that is deposited overseas. Estimating the likely source of N deposition received by NI will allow enable policy makers to assess how effective national N mitigation measures are likely to be.

2 Methodology

The amount of atmospheric nitrogen produced and deposited within Northern Ireland and imported/exported from the rest of the UK has been estimated using source attribution modelling output. Source attribution data were available for this study from an application of the Fine Resolution Atmospheric Multi-pollutant Exchange (FRAME) model (e.g. Dore *et al*. 2007, Dore *et al*. 2015), with deposition estimates made at a 5 x 5 km grid resolution. FRAME is a Lagrangian atmospheric transport model used to assess the annual mean deposition of reduced and oxidised nitrogen and sulphur over the United Kingdom.

Source attribution data using FRAME are estimated by performing multiple model runs, with each source category removed in turn, in order to determine the proportion of N deposition that is attributed to individual emission source categories. Regional land masks were applied to the emission maps to separate sources by each countries of the United Kingdom (i.e. England, Scotland, Wales and Northern Ireland) to quantify the import and export of N deposition to NI from each. The outputs used in this study are based on the most recent source attribution modelling exercise available for the year 2012 (Bealey and Dore 2017).

It should be noted that, for this type of modelling, i.e. the estimation of atmospheric N input to the whole land area of Northern Ireland, a "grid square average" version of the N deposition model output is used. This takes account of the vegetation and land cover types present across each individual grid squares, using the appropriate deposition velocity for each surface type, i.e. summing up the total N deposition in each 5 km by 5 km grid square, depending on vegetation/land surface types (low-growing semi-natural vegetation, woodland, improved grassland, arable, urban, water). This N deposition dataset is distinct from the vegetation-specific versions that are used for assessing atmospheric N input to sensitive semi-natural habitats, where the emphasis is on estimating the amount of N deposition received by individual woodland habitats or low-growing semi-natural habitats (such as bogs).

3 Results

3.1 Total N Deposition

The total amount of atmospheric N deposition that is received in Northern Ireland (NI) is estimated at 16.6 kt N yr^{-1} (Table 1, FRAME model output for 2012, Bealey & Dore 2017).

The data show that NI exports more N deposition to the rest of the UK than it receives (from the UK and elsewhere), in terms of total N (Figure 1). The key missing parameters are import/export between Northern Ireland and the Republic of Ireland, as non-UK deposition is summarised under "rest of Europe" in the raw data. Export flows to the Republic of Ireland and outside of the UK landmass could therefore not be quantified here with the currently available dataset. Separating the import to Northern Ireland from the current "rest of Europe" into contributions from the Republic of Ireland and continental Europe, respectively, and export of NI N deposition beyond the UK boundaries would require additional modelling.

Table 1: Modelled estimates of nitrogen deposition received by Northern Ireland (NI) and deposition originating from sources within NI.

Country/area of origin	Total N deposited to land in NI (kt N yr^{-1})	Deposition originating from sources in NI to elsewhere (kt N yr^{-1})
Northern Ireland	9.4	-
England	1.4	2.0
Scotland	0.7	5.0
Wales	0.2	0.5
Europe	3.9	?
Shipping	1.1	?
Total	16.6	Incomplete without additional modelling

"?" refers to information that cannot currently be quantified without additional modelling

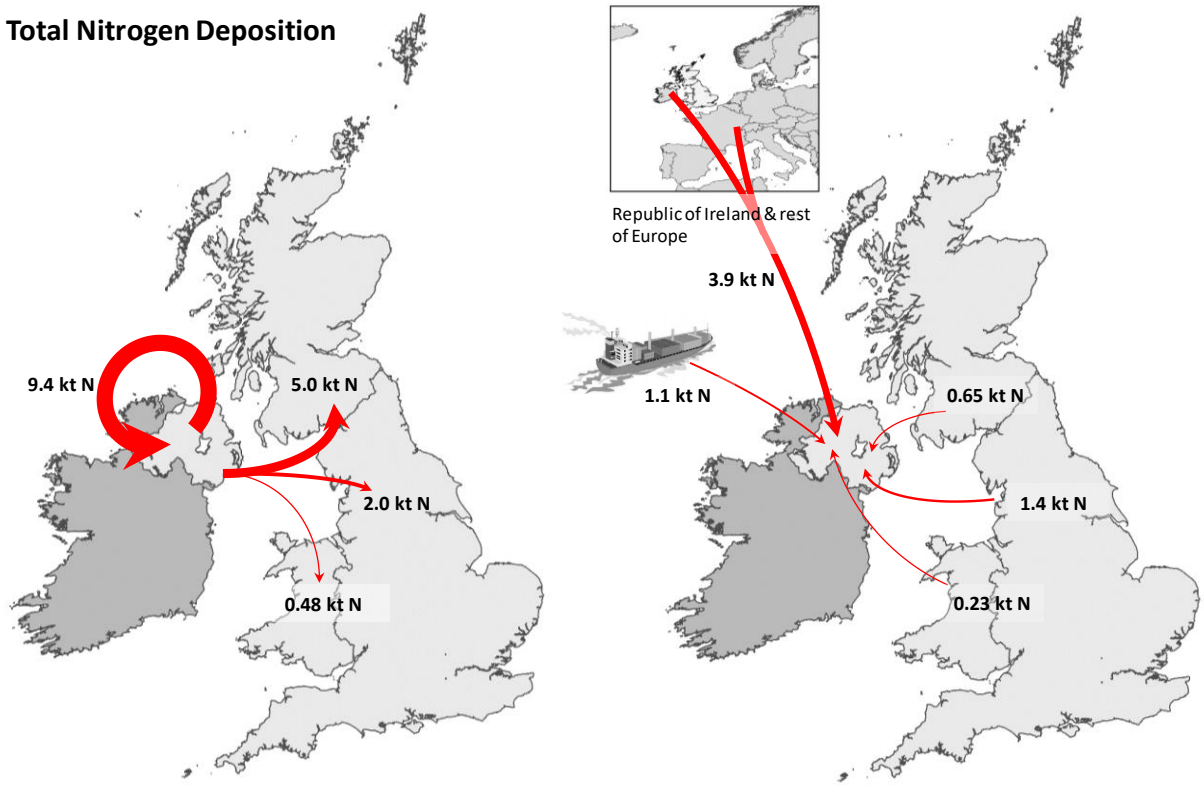

Figure 1: Total N deposition estimates to UK land from emission sources within Northern Ireland (left) and estimated input to NI from sources outside of NI (right). N.B. values may not add up to totals in Table 1 due to rounding.

3.2 Source of N deposition

Northern Ireland exports more reduced N (NH_x) to the rest of the UK than it receives and for oxidised N deposition (NO_y), the import/export terms between Northern Ireland and the rest of the UK roughly cancel each other out (Table 2).

The total estimated amount of N deposition that both originates in NI and is deposited within NI, at ~9.4 kt N yr^{-1}, is mostly due to NH_3 emissions from within NI (92%), with only 8% due to NO_x emissions from within NI (Table 2). These "home-made" atmospheric N inputs are the fraction that can be tackled with NI-internal policy development. When taking into account atmospheric N input from all sources (NI-internal and beyond), the majority (74 %) of the N deposition received by NI overall originates from reduced N (NH_x) sources (Figure 2), with 70 % of these sources located within NI. However, N deposition from NO_y sources is largely (83 %) produced by sources outside NI (Figure 3). Of the NO_y deposition received by NI, 32 % is from sources located in the rest of the UK and 25 % comes from international sources such as shipping. 25 % is from combined sources in the Republic of Ireland and the rest of Europe (data only available as a total "rest of Europe" sum, without additional modelling being carried out).

Table 2: Modelled estimates of oxidised (NO_y) and reduced (NH_x) nitrogen deposition received by Northern Ireland and deposition originating from sources within Northern Ireland

Country/area of origin	Deposition to land in NI (kt N yr^{-1})			Deposition originating from sources in NI to elsewhere (kt N yr^{-1})		
	NH_x deposition	NO_y deposition	Total N deposition	NH_x deposition	NO_y deposition	Total N deposition
Northern Ireland	8.61	0.74	9.35	-	-	-
England	0.44	1.01	1.45	1.51	0.47	1.98
Scotland	0.43	0.23	0.65	4.28	0.74	5.02
Wales	0.10	0.13	0.23	0.36	0.12	0.48
Europe	2.76	1.09	3.85	n/a	n/a	n/a
Shipping	0.0	1.09	1.09	n/a	n/a	n/a
Total	12.34	4.29	16.63	incomplete	Incomplete	incomplete

"n/a" *refers to information that cannot currently be quantified without additional modelling*

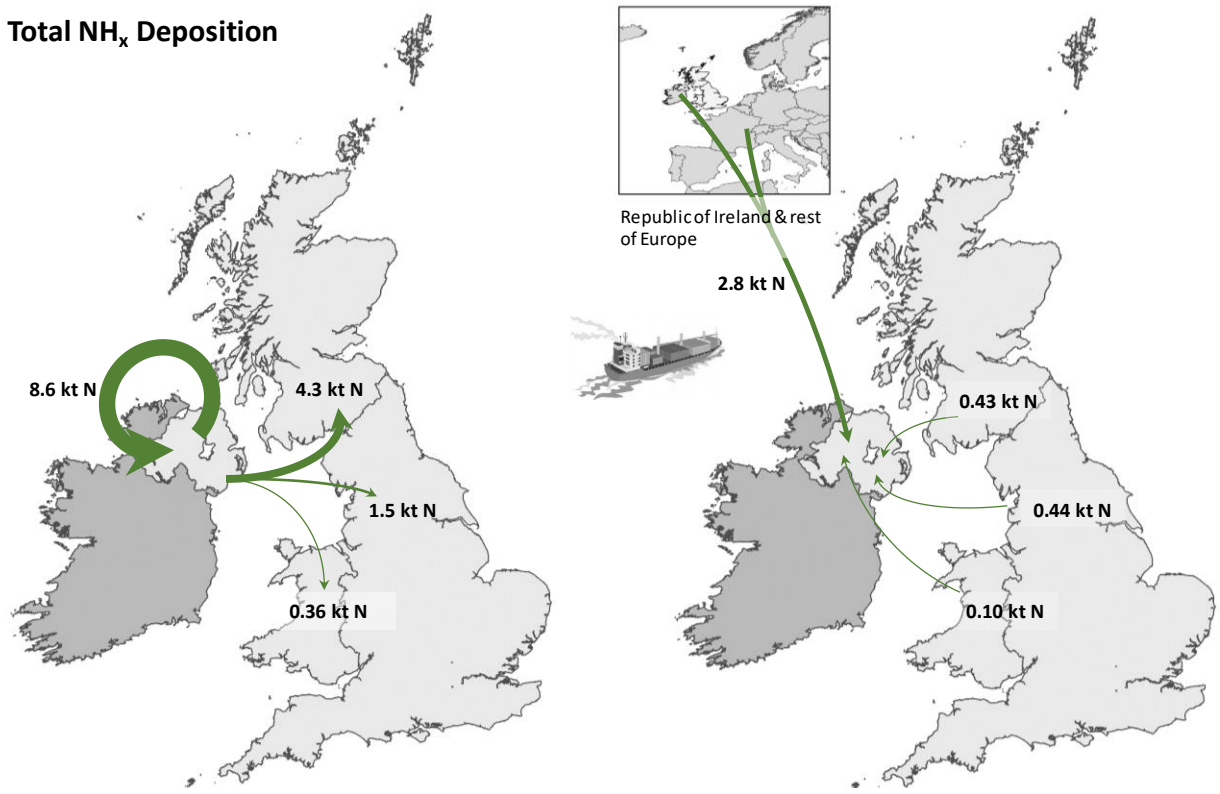

***Figure 2**: N deposition estimates to UK land from reduced nitrogen (NH_x) emission sources within Northern Ireland (left) and estimated input to NI from sources outside of NI (right). N.B. values may not add up to totals in Table 1 due to rounding.*

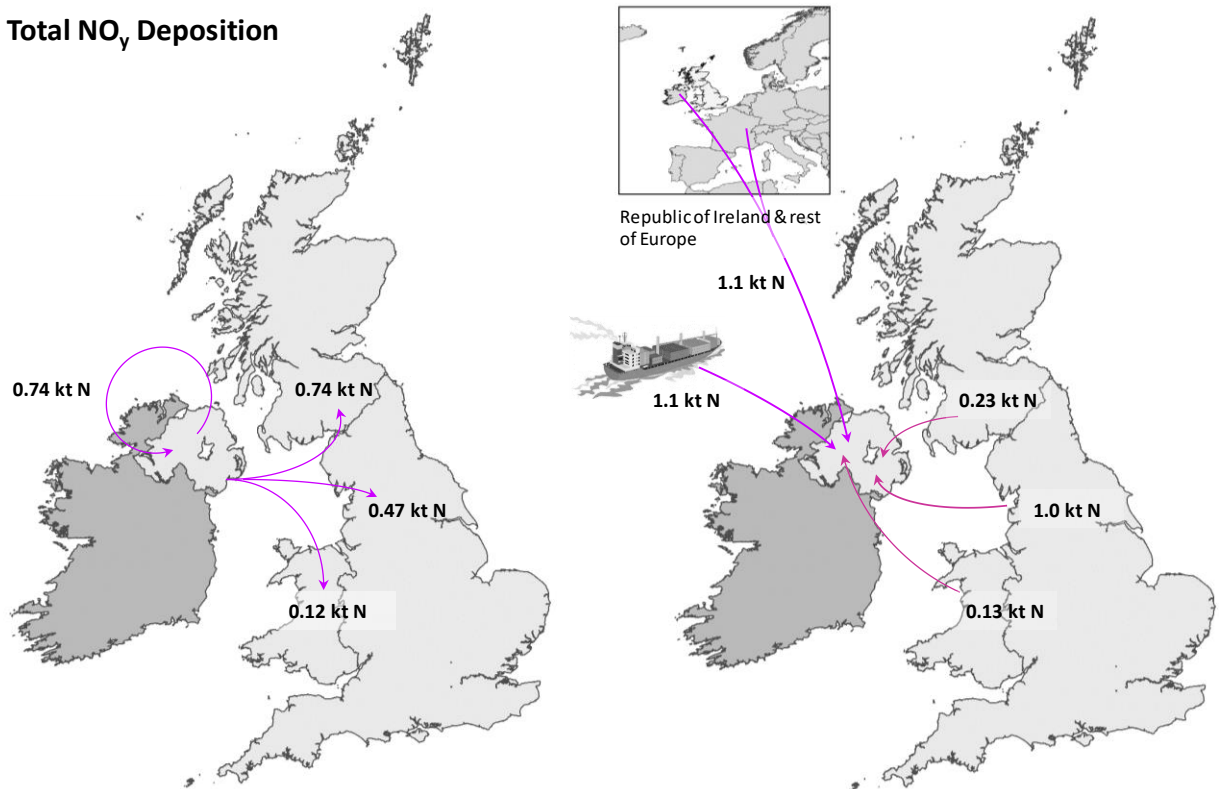

***Figure 3**: N deposition estimates to UK land from oxidised N (NO_y) emission sources within Northern Ireland (left) and estimated input to NI from sources outside of NI (right). N.B. values may not add up to totals in Table 1 due to rounding.*

3.3 Form of N deposition

Most of the dry deposition to land in Northern Ireland is from emission sources within NI (78 %). The vast majority (85 %) of the N deposition received by NI from sources outside of NI is in the form of wet deposition (Table 3). Similarly most of the N deposition originating from NI being deposited in the rest of the UK is in the form of wet deposition (76 %). Figures 4 and 5 present the import/export terms of dry and wet deposition Dry deposition refers to the transfer of gases and aerosols and the gravitational settling of aerosols to the surface, whereas wet deposition occurs when aerosols are washed out and deposited to the surface through precipitation.

Table 3: *Modelled estimates of dry and wet nitrogen deposition received by Northern Ireland and deposition originating from sources within Northern Ireland*

Country/area of origin	Deposition to land in NI (kt N yr^{-1})			Deposition originating from sources in NI to elsewhere (kt N yr^{-1})		
	Dry deposition	Wet deposition	Total N deposition	Dry deposition	Wet deposition	Total N deposition
Northern Ireland	4.94	4.42	9.35	-	-	-
England	0.21	1.23	1.45	0.49	1.48	1.98
Scotland	0.09	0.56	0.65	1.09	3.93	5.02
Wales	0.03	0.20	0.23	0.16	0.32	0.48
Europe	0.82	3.03	3.85	?	?	?
Shipping	0.21	0.88	1.09	?	?	?
Total	6.30	10.33	16.63	Incomplete	Incomplete	incomplete

"?" *refers to information that cannot currently be quantified without additional modelling*

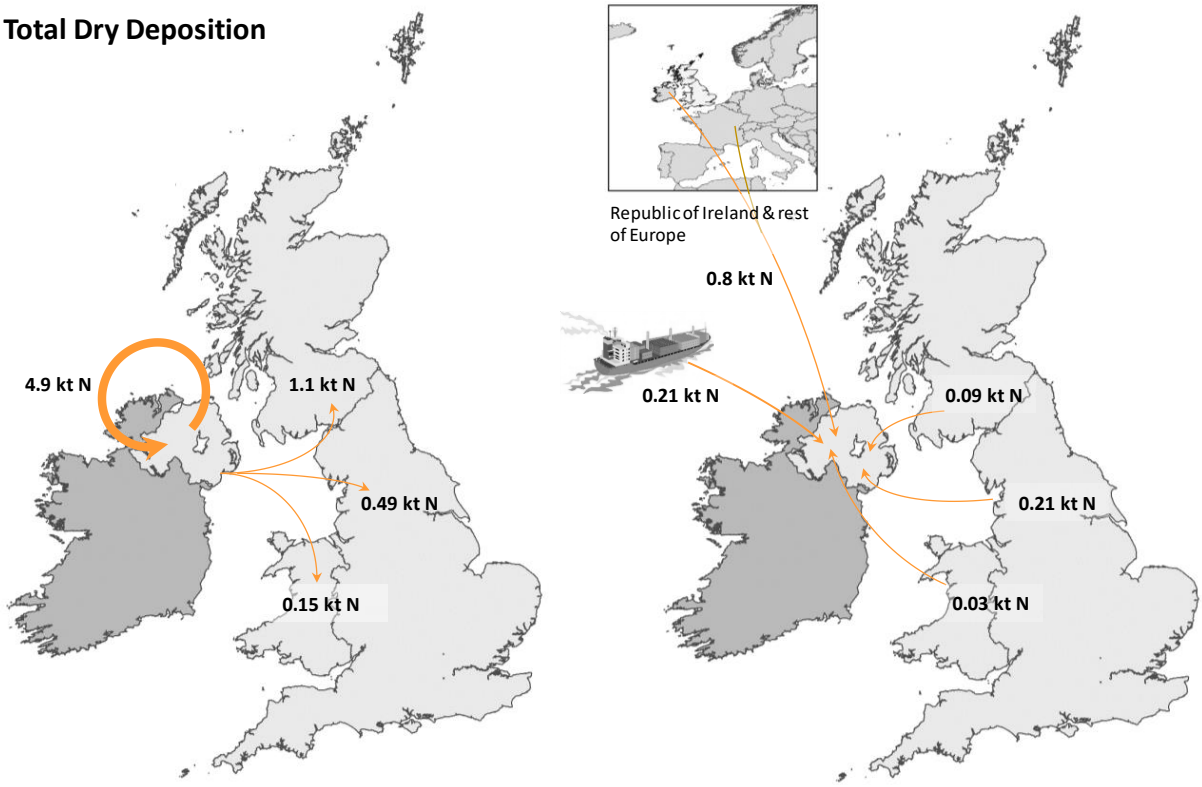

Figure 4: Dry N deposition estimates to UK land from emission sources within Northern Ireland (left) and estimated input to NI from sources outside of NI (right). N.B. values may not add up to totals in Table 1 due to rounding.

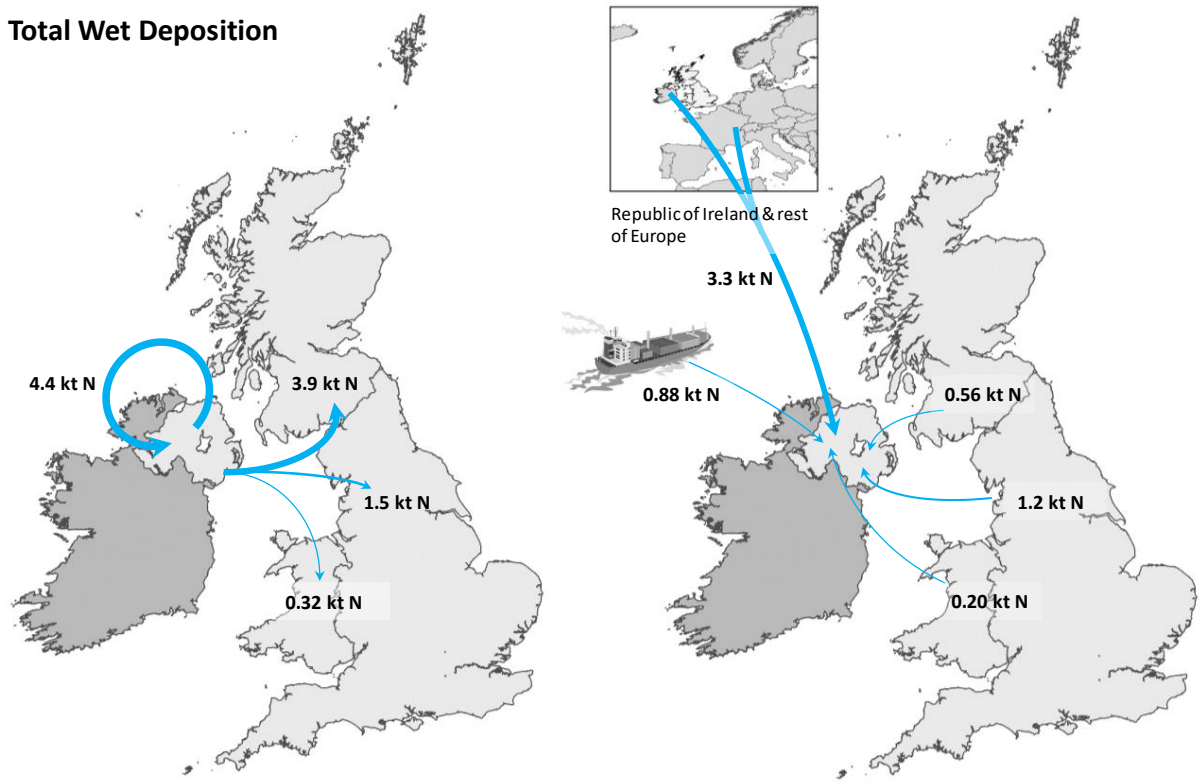

Figure 5: Wet N deposition estimates to UK land from emission sources within Northern Ireland (left) and estimated input to NI from sources outside of NI (right). N.B. values may not add up to totals in Table 1 due to rounding.

4 Conclusion

This study shows that Northern Ireland exports more atmospheric N deposition to the rest of the UK than it receives (from the UK and elsewhere). The amount of N originating from sources within NI and deposited within NI is mostly from NH_3 emission sources (92%), with only 8% due to NO_x emissions. These atmospheric N inputs produced within the country are the fraction that can be tackled with NI-internal policy development. When taking into account atmospheric N input from all sources (NI-internal and beyond), a substantial proportion of the NH_x deposition is from sources within NI, while NO_x deposition may be harder to tackle with a substantial proportion coming from the UK, Republic of Ireland and the rest of Europe, including shipping.

5 References

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