AMMONIA REGULATIONS IN NORTHERN EUROPE

Summary of policies and practises in France, Germany, the United Kingdom, the Netherlands and Denmark

Scientific Report from DCE – Danish Centre for Environment and Energy No. 321 2019

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Abstract: This report provides a brief summary of ammonia policies and practices related to effects on N-sensitive ecosystems in five European countries: France, Germany, United Kingdom, The Netherlands and Denmark. The study was commissioned by the Danish Government through Aarhus University, Department of Bioscience and consists of five national reports and a synthesis prepared by Wageningen Research.

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Preface

The Danish Environmental Protection Agency has requested DCE/Aarhus University to coordinate a project to compare national methods to measure and model ammonia impacts on sensitive natural habitats in five comparable countries in Northern Europe; Denmark, The Netherlands, Germany, France and the UK. The Danish Agricultural Agency has subsequently granted the financing for the project. The study consist of country reports prepared by research institutions in the five countries, and an overall synthesis prepared by Waageningen Environmental research from the Netherlands.

The effect of ammonia deposition on different habitats varies in a number of ways. Some of the most important factors are the ammonia sensitivity of the natural habitats, the background deposition and the variations in the local ammonia deposition. Measuring and modelling ammonia deposition is tackled differently in the countries, and there are differences in the use of critical loads and in the definition of ammonia-sensitive natural areas.

The purpose of the study is to provide a basis for comparison of these differences between the countries, and the way the differences influences livestock regulation.

Summary

The main findings from the five main topics compared between the countries is summarized here. A more comprehensive summary can be found at the end of each of the main chapters of the summary report.

Monitoring and modelling nitrogen and ammonia deposition

Monitoring of ammonia in air and precipitation is carried out in all five countries, but results are in France and Germany not collated nationally. All countries model national deposition of pollutants including oxidized nitrogen and ammonia with complex models. Often, modelling is combined with measurements to compute the total fluxes. In general, countries use measurements of deposition to calibrate their deposition models. Uncertainties in modelled depositions are reported by four countries and are consistently in the range of 30-50%, but probably higher on local scale.

Ammonia-sensitive areas

Ammonia or nitrogen sensitive areas have been or will be assigned in three countries. In the UK such areas are not defined (yet), but an assessment has been made for the Annex 1 habitats based on their sensitivity. In the Netherlands, nitrogen sensitivity is based on the critical loads assigned to habitats. Natura 2000 areas that are nitrogen sensitive receive extra protection. In Denmark, both Annex 1 habitats and nature types in the Danish Nature Protection Act are used and for both sets nitrogen sensitivity per type have been defined; also about 1/3 of the forest area is considered nitrogen sensitive. In Germany and France, ammonia sensitive areas have not been assigned on national / federal level.

Effect of ammonia regulations

Regulation that effect farm location in relation to N sensitive areas are used in most countries. In UK a distance criteria is used as first step in assessing applications for expanding existing livestock sheds or building new ones. In a second step, assessment is based on critical load exceedances from the project in cumulation with other ammonia sources. A similar procedure is applied in NL were the AERIUS toolkit must be used to assess effects of new activities on N deposition on N-sensitive Natura 2000 areas. In Denmark, restructuring of agriculture has already resulted in a reduction of N deposition to N-sensitive areas reducing the area where critical loads are exceeded. In France, the Industrial Emission Directive is the main driver for ammonia reduction on farm level affecting 3400 farms.

In addition to local regulation, NO_x control and general ammonia regulation e.g. BAT rules have helped controlling emissions. In Germany, deposition of NOx has decreased and deposition of NH3 has remained stable over the period 2000-2015. In the UK total N deposition decreased by 18% between 2004 and 2015. Also in Netherlands and Denmark, emissions of NO_x and NH_3 have been reduced between 2000 and 2015. This is reflected in a decline in NO_x deposition but not in measured ammonia concentrations.

Critical loads and levels

FR and DE use the simple mass balance to calculate critical loads for N and acidity. In Denmark, the SMB model is used for acidity and only for forest. NL uses a slightly different approach with application of a steady state version of the simple soil geochemical model VSD+. The criteria that are being used differ between countries, and often consist of a set of multiple criteria of ecosystem-specific criteria. Management of forest by removal of wood is included in the critical load calculations by all countries. DE, UK and NL also include management of grassland and heathland through e.g. grazing and / or mowing. Denmark and UK use empirical critical loads with different modifying factors

All countries are currently developing and applying methods to compute biodiversity-based critical loads. The approach is generally a geochemical model coupled with an empirical based plan occurrence model. NL is experimenting with VSD+PROPS[1] based methods, which DK is also testing. In France PROPS and EcoPlant are applied, Germany uses the Bern model[2], UK uses Madoc-MultiMove[1] in which empirical critical loads are indirectly used.

Critical levels for NH_3 are used in the UK and in DE within the framework of licensing new installations. In DK critical levels are used in habitat assessment (appropriate assessment) for larger industry.

Mostly the models and procedures follow the Mapping manual and empirical critical loads are mostly derived from reports published with the UNECE convention as well.

Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

In Germany, critical loads are used in the emission control regulation as well as in the nature protection regulation; Different sets of critical loads and different approaches, to include general management such as mowing in the critical load calculations are being used in different federal states. For new emitting activities in Germany, limits are set to the concentration of ammonia at the emitter as well as to the total concentration of ammonia at the Nature area the new emitter affects.

In the UK Environmental permitting is carried out by, and is the responsibility of, separate regulating agencies for England, Wales, Scotland and Northern Ireland. Each Agency has its own procedures, methods and models. If the emissions from a process are judged to result in a likely significant effect on a designated site then a detailed assessment is required. Management practices that may conflict with nitrogen deposition effects are taken into account at the detailed assessment stage.

NL has adopted a Programmatic Approach to Nitrogen (PAN). The PAN guarantees that Natura 2000 objectives will be met, by including effects of

[1] A simple soil geochemical model coupled with an empirical based plan occurrence model

[2] The BERN model describes occurrence probabilities of plant communities, not individual plants.

dedicated management and restoration plans for each N2000 area, as well as effects of extra N deposition.

In DK regulation of effects of ammonia on sensitive nature differentiates between different categories of nature where there for category 1 and 2 is a limit to the total allowable deposition from a single farm. For category 3, requirements can only be made, when e.g. the critical load is exceeded. In DK the Natura 2000 plans do not directly include measures to mitigate effects of too high nitrogen deposition. Normal N removal for managed ecosystems is though included in critical loads.

In UK, NL and DK detailed deposition models are used that use surface roughness to compute deposition fluxes. Local sources (new and existing) and local transport are covered in these models. In Germany, also local deposition should be taken into account in exceedance calculations.

2. Monitoring and modelling nitrogen and ammonia deposition

In this Chapter the following questions are addressed:

- What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas and if a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations (section 1.1)
- Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models (section 1.2)
- An assessment of the uncertainties in estimating nitrogen deposition at different scales (section 1.3)

2.1 Monitoring programs

2.1.1 France

In France, local authorized associations in charge of air quality monitoring are entrusted with the implementation of the air pollution monitoring strategy. The legal framework for air quality monitoring which describes stakeholders and their respective responsibilities and integrates transposition in French laws of the European legislation has been recently revised and is now defined in the so-called “arrêté Surveillance” adopted in 2017 on April, 22.

Ammonia is not mentioned as a regulatory air pollutant which requires routine and mandatory monitoring. Therefore, ammonia measurements, if performed by the local air quality networks, are not reported in the national database.

However, since several years French authorities and local networks are concerned by episodes with high PM (particular matter) concentrations that are influenced by high airborne ammonium nitrate concentrations due to ammonia emissions. Fig. 1 shows the spatial distribution of ammonia emissions in 2012. Large heterogeneity should be highlighted; West and Central regions are higher emitters than the Eastern part of France.

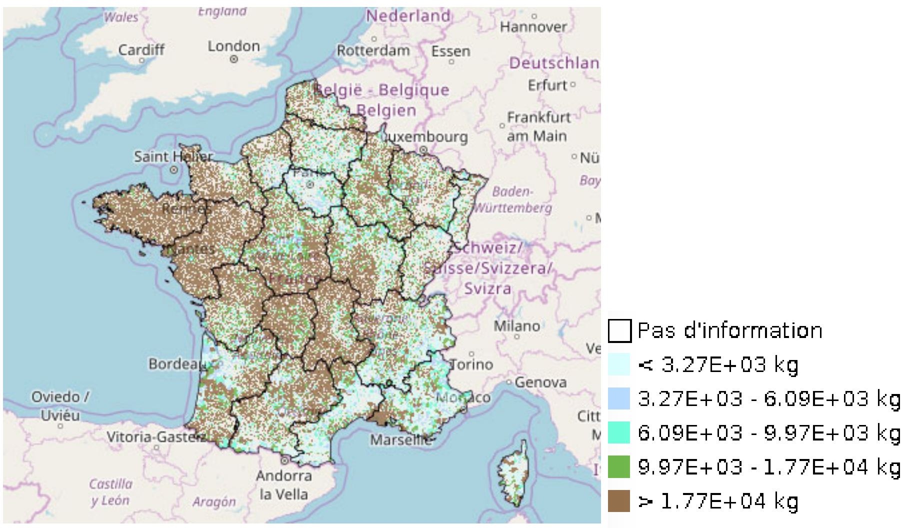


Figure 1. Ammonia emissions in France (metropolitan area) in 2012 (source : http://emissions-air.developpement-durable.gouv.fr)

Occurrence of PM episodes and stagnation of ammonia emissions encouraged French authorities, the reference laboratory and local air quality monitoring networks to increase the number of datasets and evidences likely to qualify and understand the influence of ammonia on air pollution issues. Therefore, even, if not regulated and if there is not standards for its measurement yet, several air quality monitoring networks in France included ammonia monitoring in their regional monitoring strategy3. Details on the monitoring per region can be found in the French National Report. So far, only 4 fixed monitoring stations measure routinely ammonia emissions in the regions Auvergne-Rhone-Alpes and Grand-Est, but several mobile devices are implemented for assessment and field campaigns in almost all French regions. However, the depth of historical dataset of these measurements is not very high and this is difficult to establish trends. But it is important to note that since 2014, the number of field campaigns dedicated to ammonia and nitrogen compounds conducted on a voluntary basis in French region increased significantly.

Finally, it should be reminded that regarding nitrogen compounds as a whole, the French monitoring network includes about 450 stations monitoring NO and NO_2 concentrations for regulatory purposes (implementation of the air quality Directive 2008/50/EC). Moreover, the MERA network, which is the implementation of the EMEP monitoring network[4] in France includes 13 rural stations (see figure below), 9 of which monitoring deposition of inorganic compounds in precipitation (SO_4^{2-}, NO_3^-, NH_4^+).

2.1.2 Germany

In Germany the concentrations of the different components in precipitation are measured by an extensive countrywide measurement network maintained by various national and regional monitoring programs and authorities. The national UBA network consists of 11 background sites, evenly distributed throughout the country. The various regional networks add 249 stations to the database. The UBA network samples on a weekly rhythm, whereas the regional networks may operate at a weekly, two-weekly, four-weekly or monthly basis. The sampling strategies of the regional networks are not synchronised. The data collected contains precipitation amount as well as concentrations of SO42-, NO3-, NH4+, Mg2+, Na+, Ca2+, K+, Cl- as well as pH in rain water.

At the available stations a variety of samplers are used to quantify the wet deposition. Within these samplers two types can be differentiated, wet-only and bulk deposition samplers. Bulk samplers collect precipitation in a bucket, which is open all the time. In contrast, wet-only samplers collect the precipitation in a funnel, which is only open when it rains. A sensor registers whether it is raining and the lid is automatically opened at the beginning of a rain event and closed at the end. Within Germany the majority of the data is obtained with bulk samplers as only 40 out of the 260 stations sample with wet only samplers. Hence, to better compare the concentration of bulk samplers with that of wet only samplers correction factors are available (Gauger et al., 2000, 2008).

[3] Regional air quality monitoring strategies have been revised by the 13 French air quality monitoring networks in 2016-2017

[4] Implementation of the monitoring programme according to the UNECE Convention on Long range Transport of Air pollutants

For the gaseous compounds regulated by the Air Quality Directive the monitoring networks are extensive and the monitoring is obligatory. UBA collects the data from the regional networks, publishes the data on a national map server and reports the data to European authorities. As there are no concentrations limits for NH_3 in the Air Quality Directive, there is no monitoring obligation for NH3 on a national level in Germany. That is why ammonia is not measured regularly in most of the federal states. However there are some federal states measuring ammonia on voluntary basis but the networks are not very extensive.

2.1.3 United Kingdom

In the United Kingdom, the Eutrophying and Acidifying Atmospheric Pollutants (UKEAP) project consists of four rural air pollution monitoring networks and the operation of two UK EMEP Supersites (Chilbolton and Auchencorth) (Table 1).

The UKEAP Networks include (a) the Environmental Change Network[5] which is embedded within the EU eLTER network[6]; and (b) Natural England[7]'s Long Term Monitoring Network (LTMN8:) which has the long-term monitoring of total nitrogen deposition as one of its core aims.

Table 1. UKEAP Monitoring Networks.

Network	In operation since:	No. sites	Measurements	Frequency
NAMN: National Ammonia Monitoring Network#	1996	72#	Concentrations & deposition of NH3 & NH4+	Monthly
AGA-Net: Acid Gases & Aerosol Network	1999	27#	SO2, HNO3, HONO, inorganic composition of PM4	Monthly
Precip-Net: Precipitation chemistry Network	1985	41	Anion & cation concentrations in precipitation	Fortnightly
NO2-Net: Rural NO2 diffusion tube Network	1994	24	NO2 concentrations	Every 4 weeks

#See Figure2.

The UKEAP Networks aim to evaluate policy measures to reduce concentrations and deposition and to estimate secondary formed components of particulate matter.

The UKEAP data are used to produce annual concentrations and wet and dry deposition maps of nitrogen and sulphur pollutants. In addition to UKEAP, the Automatic Urban and Rural Network (AURN) provides hourly high-resolution NO2 and NO measurements (as well as other priority pollutant measurements such as O3) from 140 sites across the UK; this is the main network used for compliance reporting against the EU Ambient Air Quality Directives. The AURN latest measurements and 24 hours summary data are available on UK-AIR9.

[5] http://www.ecn.ac.uk
[6] http://www.lter-europe.net/elter
[7] https://www.gov.uk/government/organisations/natural-england
[8] http://publications.naturalengland.org.uk/publication/4654364897050624
[9] https://uk-air.defra.gov.uk/latest/

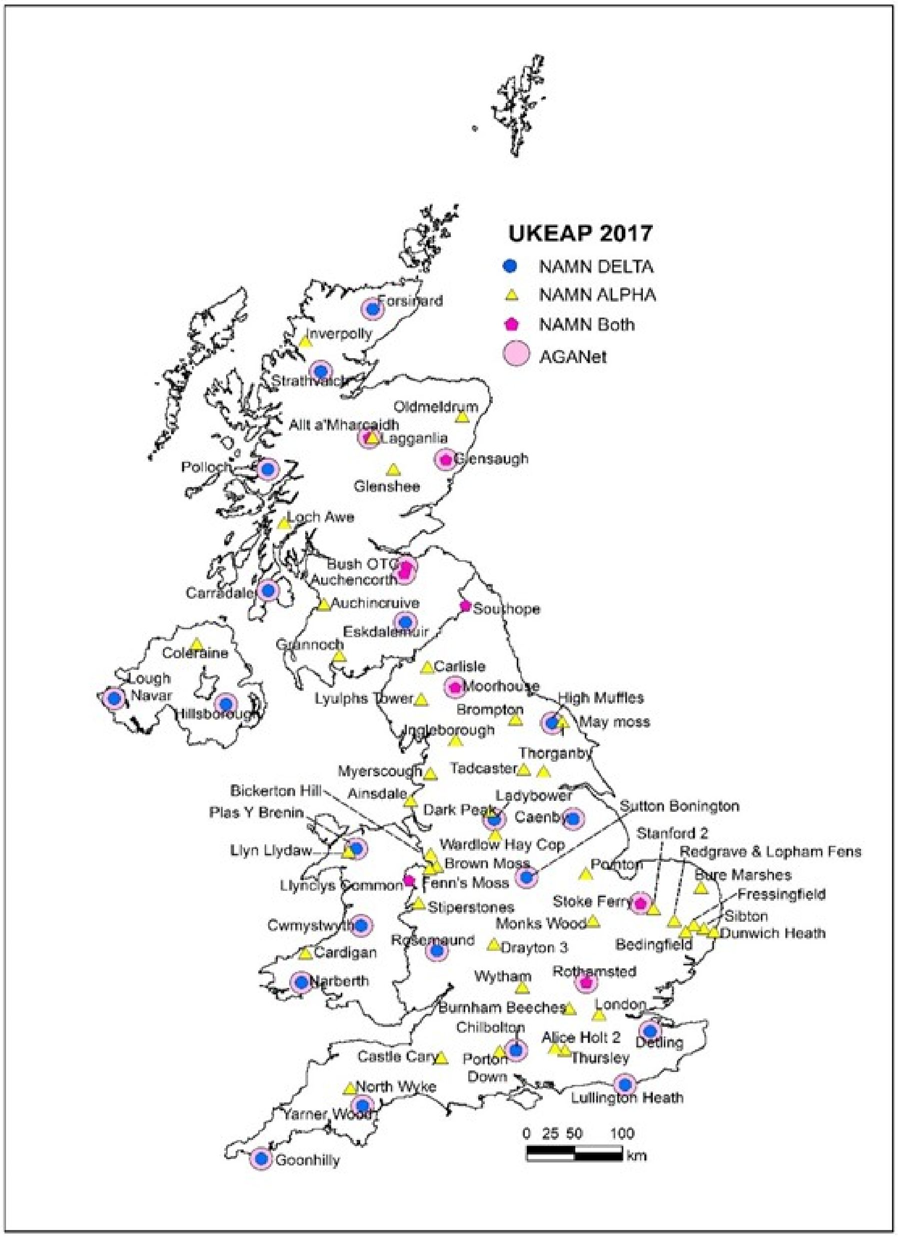


Figure 2. UKEAP ammonia (NAMN) and acid gas and aerosol (AGA-Net) monitoring sites in the UK.

The National Ammonia Monitoring Network (NAMN) was established in 1996 to quantify temporal and spatial changes in air concentrations and deposition of NH_3 (and from 1999 NH_4^+) on a long-term basis. The network currently consists of 72 sites (85 sites pre-2017) across the UK (Figure 1.1) providing monthly data from a mixture of passive badge (ALPHA) samplers and active denuder (DELTA) samplers (Tang et al., 2017). Nine sites have both sampler types and are used for calibration of the passive samplers on an annual basis.

2.1.4 The Netherlands

In the Netherlands two monitoring networks exists:

An hourly based National Air Quality Monitoring Network (LML, Landelijk Meetnet Luchtkwaliteit), consisting of eight monitoring stations, mainly located in agricultural areas, and measuring also other compounds beyond ammonia.

A monthly based Ammonia Monitoring Network in Nature (MAN, Monitoring Ammoniak in Natuur) network, consisting of more than 200 measurements sites, mainly located in Natura 2000 areas, and measuring solely the ammonia concentration.

The LML network

The Dutch National Air Quality Monitoring Network (LML, http://www.lml.rivm.nl) measures various air quality components. Amongst others it measures ammonia concentrations in air, ammonium in aerosol and the wet deposition of ammonium since 1993 (see Figure 3). NH3 in the Netherlands displays a high spatial variability. As a consequence, a representative monitoring network to cover this

variability would be very expensive. Therefore, at its set up, it has been decided to use a limited amount of measurements in combination with modelling of the ammonia concentrations for the Netherlands (Buijsman et al., 1998). The monitoring stations were carefully selected for equal distribution of regions of high, moderate and low emission densities. Since 1993, hourly ammonia concentrations have been measured at 8 monitoring stations which were carefully selected for equal distribution of regions of high, moderate and low emission densities (Buijsman et al., 1998) with a wet-annular denuder system, called ‘AMOR’ (Amanda for MOnitoring RIVM; Wichink Kruit et al., 2007). In the 2014 at two monitoring stations regular measurements have been replaced by a triplet of passive samplers that are measuring ammonia concentrations on a monthly basis.

The MAN network

In 2005 the MAN network was set-up to obtain measurements of ammonia concentrations that are more representative for nature areas (Natura 2000 sites). The MAN network provides monthly mean values of the ammonia concentrations at 235 locations. Measurements are performed with passive samplers (Gradko tubes). The ammonia measurements performed in the LML are used to calibrate the passive sampler measurements. At present the MAN includes approximately 235 measurement sites in nearly 60 Natura 2000 areas and 10 additional sites located in small nature areas (Figure 3).

Deposition measurements

Wet deposition of several components including ammonium have been measured in the Netherlands since 1978 by the Dutch National Precipitation Chemistry Monitoring Network.1 However, the locations of monitoring stations, equipment, and chemical analysis have changed considerably since measurements started. It is generally acknowledged that detailed dry deposition monitoring of ammonia is hardly possible. Therefore, in the Netherlands dry deposition monitoring is based a combination of ammonia aerosol measurements of the LML site and dry deposition monitoring modelling. Where the dry deposition of ammonia and other components is calculated by using the DEPAC-module which is incorporated in the OPS model. The DEPAC-module has been updated in 2009, and this module version is described in detail in Van Zanten et al. (2010).

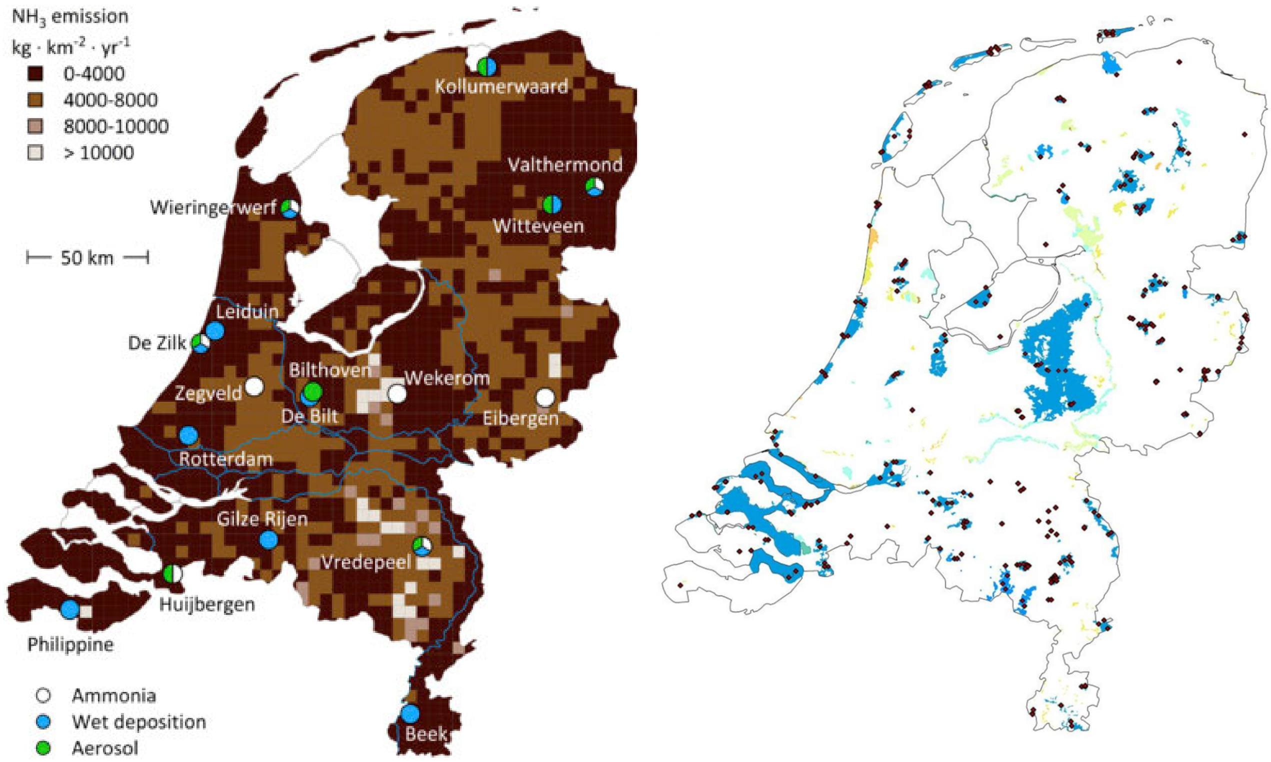


Figure 3. Left: The locations of the monitoring stations of the Dutch National Air Quality Monitoring Network (LML). The map also shows the total ammonia emissions on a 5 by 5 km grid for the year 2014. (source Van Zanten et al., 2017). Right: The locations of the monitoring locations (black dots) of the Monitoring Ammonia in Nature network (MAN). The map shows the nature areas, the Natura 2000 sites are in blue (source: http://man.rivm.nl/).

2.1.5 Denmark

In Denmark, the main national air pollution monitoring network consists of 8 major fixed stations with hourly measurements of:

Wet deposition of nitrogen compounds (ammonium and nitrate), sulfate, phosphate and a number of selected heavy metals.

Concentrations of nitrogen compounds in the gas and particulate phase (ammonia, nitrogen dioxide, particle-bound ammonium and sum of particulate matter bound nitrate and nitric acid) as well as sulfur dioxide and particulate bound sulfate. In addition, select measurements are made at selected measuring stations including nitric acid and particulate bonded nitrate as well as ammonia and particulate bound ammonium.

In addition to the larger measurement stations, the measurement program consists of a number of smaller measurement stations focusing on (monthly mean) concentrations of ammonia and ammonium in relation to the influence of airborne nitrogen on nitrogen-sensitive natural areas. The full set of monitoring stations is given in Figure 4.

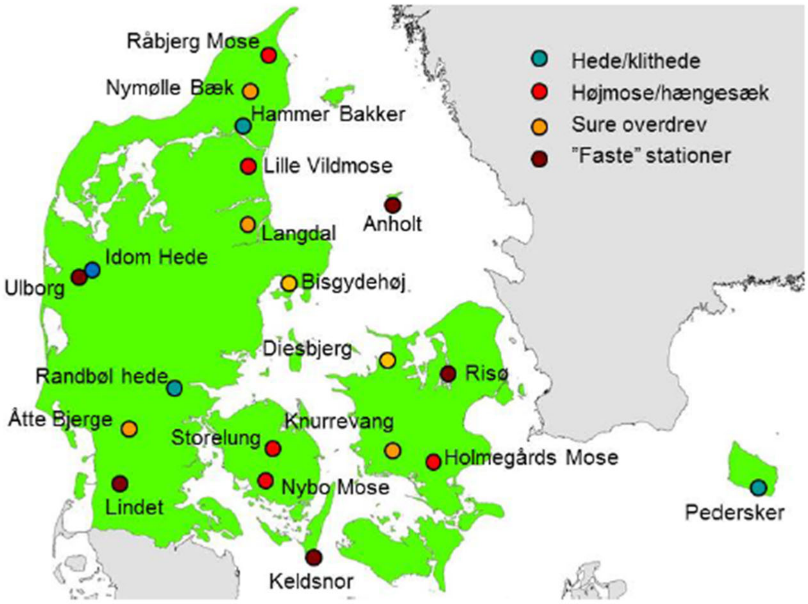


Figure 4. Geographic location of stations in Denmark with ammonia monitoring (Ellermann 2015).

2.2 Deposition models used

2.2.1 France

In France a number of national research projects dedicated to ammonia's behavior and fluxes modeling is currently on-going in France. The reference model is the chemistry-transport model CHIMERE developed by INERIS and the national research center (CNRS). This model is used for air quality forecasting and mapping (see www.prevair.org) at the national and regional scales and for assessing the impact on air pollutant concentrations and deposition of emission reduction strategies. Particulate matter chemistry, and in particular complex processes related to nitrogen compounds are taken into account in the model. Current project aim at analyzing the impact of spatio-temporal variability of ammonia emission on PM formation and transport. In the experiments previously reported, several modelling activities developed. But they are generally focused on assessing the capacities of models to simulate correctly atmospheric PM concentrations (including ammonium nitrate and ammonium sulfate) rather than on deposition of nitrogen compounds to assess eutrophication and acidification.

In 2008, INERIS simulated with CHIMERE nitrogen and sulfur deposition levels in France over the 1999-2008 period and showed that they remained almost constant. Wet and dry deposition processes were distinguished.

Over the 5 past years INERIS coordinated and participated actively to the EURODELTA model intercomparison exercise that aimed at assessing the responses of 6 European chemistry transport models (among which CHIMERE) to emission changes. The final part of the project was dedicated to trends analysis over the 20 past the years, and trends in sulfur and nitrogen depositions were specifically considered. EURODELTA was a part of the EMEP programme (Task force on measurement and modelling) under the Convention on Long Range Transport of Air pollution. (Vivanco et al) showed the systematic underestimation of current models for predicting wet and total deposition of reduced nitrogen, and more generally their difficulties in simulating the deposition processes. Related developments within the CHIMERE model are still going on at INERIS.

2.2.2 Germany

A combination of modelling, observations and empirical relations is used to estimate the total nitrogen deposition in Germany. The chemistry transport model LOTOS-EUROS, a regional 3-D model that simulates emission, transport, chemistry and deposition of air pollutants in the lower troposphere. The LOTOS-EUROS model is state-of-the-art and is one of the few chemistry transport models that uses a description of the bi-directional surface–atmosphere exchange of NH_3 (Wichink Kruit et al., 2010; 2012). The model is used to model the dry deposition distributions for nitrogen and sulphur components at 7x7 km^2 across Germany. For this purpose we use ECMWF meteorology and emission data for the respective years. Long range transport is incorporated by nesting the German study area into a simulation over Europe as a whole. Besides the deposition fluxes also the modelled dry deposition velocities and wet deposition maps are used the deposition assessment.

The LOTOS-EUROS model has a tendency to underestimate the observed wet deposition. Moreover, the variability in wet deposition fluxes is generally underestimated in chemistry transport models. Consequently, it has been decided to use the observed wet deposition as a basis. The density of the observations allow to make an empirical assessment of the wet deposition flux across Germany. The wet deposition data are subjected to a QA / QC procedure and used to correct the modelled rain concentration distribution towards the observed data using residual Kriging. The resulting rain water distribution is combined with a high resolution precipitation distribution (1x1 km) to arrive at the final wet deposition estimates. In this way a highly resolved map based on empirical data is obtained that benefits from the process knowledge incorporated in the LOTOS-EUROS model for nitrogen and sulphur components.

For elevated locations, occult deposition may be a substantial contribution to total deposition. The occult deposition flux is derived by estimating the deposition flux of cloud and fog water which is combined with the pollutant concentration in the cloud water. The cloud water concentrations are deduced from the rain water concentrations under assumption that a pollutant is more concentrated in a cloud droplet than in a rain droplet. The resolution at which this calculation can be performed is not able to capture high resolution variability, which means that the occult deposition reflects background values for larger regions and do not reflect the deposition at very exposed sites.

The total nitrogen deposition calculated at a 1x1 km scale is compared to the critical loads for sensitive areas to calculate the critical load exceedance on a national level. This data is used in national indicators but not for local or regional licensing.

2.2.3 United Kingdom

In the UK, three independent national-scale models are employed to calculate vegetation-specific nitrogen and sulphur deposition at a 5x5 km resolution. These are: (1) Concentration Based Estimated Deposition (CBED) which uses an inferential modelling approach; (2) Atmospheric Chemistry Transport Models (ACTM), the Fine Resolution Atmospheric Multi-pollutant Exchange model (FRAME) which uses average annual meteorology, and (3) EMEP4UK which uses dynamic meteorology. All three models have been applied to estimate nitrogen and sulphur deposition for use in natural ecosystem impact assessments at European, UK and smaller scales.

CBED uses data on precipitation concentrations from the UKEAP monitoring network which are interpolated across the UK and combined with data on annual precipitation from the UK Met Office to generate wet deposition of NH4+, NO3- and SO42-. Dry deposition is calculated using a combination of modelling and interpolation of measurements for gas and particulate concentrations from the UKEAP monitoring network, combined with a big leaf resistance model for deposition velocities (Smith et al., 2000) to generate ecosystem-specific deposition values. Deposition estimates are updated annually and a three-year rolling average national data set is calculated. The CBED data are the official deposition estimates used to calculate national trends in deposition and exceedance of critical loads. CBED calcium and other base cation deposition rates have been used in the derivation of acidity critical loads.

FRAME uses emissions of NH3, NOx and SO2 from the UK NAEI10. The simulation of emissions of gaseous pollutants, vertical diffusion, chemical transformation and wet and dry removal processes takes place within an air column in a Lagrangian framework. The same precipitation data as for CBED are used to drive wet deposition within the model. Model performance is evaluated by comparison with measurements from the UKEAP network (Dore et al., 2015). The model has been used to calculate future (and historic) estimates of deposition according to projected emissions scenarios (Matejko et al., 2009). To generate site-specific scenarios for historic and future deposition, a calibration procedure is adopted whereby CBED provides a recent deposition estimate and FRAME calculates relative temporal changes. Source-receptor data have been generated with FRAME for use (a) in the UK Integrated Assessment Model (UKIAM; Oxley et al., 2013) to test future emissions reductions strategies for reducing the impact of sulphur and nitrogen deposition on natural ecosystems, and (b) for APIS. A high-resolution (1x1 km) version of FRAME, updated annually, is used with data from the NAMN to calculate 3-year annual mean NH3 concentrations for national scale assessments of the exceedance of critical levels (see Sections 2.3 and 4.2).

EMEP4UK is an Eulerian photo-chemistry ACTM that uses dynamic meteorology (Vieno et al., 2014, 2016). The model domain varies in horizontal resolution, with 0.055x0.055 degrees (~5x5 km) typical over the UK. A technical description of the EMEP MSC-W model, from which the EMPE4UK model is derived, is given in Simpson et al. (2012). The physical and chemical processes parameterized in the model are driven by meteorological data calculated by the Weather Research Forecast (WRF) model11. An evaluation of model performance for deposition was undertaken as part of a model inter-comparison exercise (Dore et al., 2015) and an extensive validation was also carried out in Lin et. al., 2017. A transition from the use of FRAME data to EMEP4UK data in the UKIAM is currently underway.

2.2.4 The Netherlands

In the Netherlands, the Operational Priority Substances (OPS) model is used for deposition modelling.

The main purpose of the model is to calculate the concentration and deposition of pollutants (e.g. particulate matter, acidifying compounds such as SO_2, NO_x and NH_3) in the Netherlands using a high spatial resolution, typically 1

[10] http://naei.defra.gov.uk

[11] www.wrf-model.org

× 1 km^2. The OPS model (Van Jaarsveld et al., 2012; Sauter et al., 2015), is a long-term Lagrangian transport and deposition model that describes relations between individual sources or source areas and individual receptors by Gaussian plumes. The model simulates the emission, dispersion, transport, chemical conversion and deposition as a function of meteorological conditions. The model is statistical in the sense that concentration and deposition values are calculated for a number of typical situations (classes) and the long-term value is obtained by summation of these values, weighted with their relative frequencies of occurrence.

The spatial extend is determined by the size of the area for which meteorological parameters are known so the maximum size of the receptor area becomes, in effect, the Netherlands and adjoining regions. The OPS-model obtains land-use type and the roughness length of the receptors from maps. For specific receptor locations the model selects the land-use properties from the 250 m resolution map. OPS calculates concentrations and depositions on a regular grid, with a user defined grid cell size. The model generates multiple sub-receptors inside a grid cell in order to be able to compute a representative grid cell average.

The OPS-model has been updated in 2009 for a new dry deposition of ammonia parameterization using a compensation point (Kruit et al., 2010). Therefore, the dry deposition of acidifying components including ammonia is calculated by the DEPAC (DEPosition of Acidifying Compounds) module (Van Zanten et al., 2010).

Air quality concentrations and deposition maps are produced annually. The maps provide the large-scale contribution to the air quality and deposition from all sources in Europe for the past year and for several years in the future (up to 2030). The output of the model is calibrated using observations from the LML network of NO2, NH_3, PM10 and PM2.5 at rural and urban background locations in the Netherlands. For NH_3, also observations from the MAN network are used.

Beyond the OPS model, the integration modelling system Aerius is used to get a permit related NH_3 and NO_x emission to expand a farm or any other N emitting enterprise.

2.2.5 Denmark

National models for dispersal and deposition of air pollution exist and are used for all scales from hemispheric (DEHM) to local (OML-DEP), urban (UBM) and street canyon (OSPM). DEHM is a nested model with different resolution from hemispheric to European and national scale. For the calculation of national background concentrations and deposition, a resolution of 5.6 x 5.6 km^2 with the DEHM model is used (Christensen, 1996, Ellermann, 2015).

Especially for ammonia deposition, a model system, DAMOS, has been developed which couples the long-range transport model, DEHM, with a local scale (Gausian plume) model, OML-DEP, allowing for local scale resolution of 400 x 400 m^2 in limited areas (16 x 16 km^2) where high resolution emission data needs to be available (Geels, et.al., 2012).

For the assessment of effects around single point sources, deposition curves based on the OML-DEP model have been established for different classes of surface roughness of the receptor area. Deposition calculated with the curves can be adjusted to account for the (local) frequency of different wind-sectors.

2.3 An assessment of the uncertainties in estimating nitrogen deposition at different scales

2.3.1 France

No specific studies have been conducted on this topic in France. However, the results of the EURODELTA exercise (Vivanco et al) gave interesting results at the European scale. The results obtained for CHIMERE demonstrated a complex model behaviour depending also on uncertainties in emissions and mereology inputs. It seems the error of the CHIMERE model generally does not exceed 20-30 % in simulating reduced and oxidised nitrogen deposition.

2.3.2 Germany

The LOTOS-EUROS model has been used in a multitude of model intercomparison studies (REFS). Comparisons specifically aimed at deposition have been performed with the EMEP model and observation data, as well as with wet deposition observations in Germany and its surrounding countries.. Within Germany, a comparison with canopy budget data from the ICP Forest Level II Network is performed. The results of these comparisons are in general satisfactory. More than 50 % of the analysed data lay within +/- 20 %. Comparing the results calculated for Germany to observations and calculated estimates of deposition for other countries, we estimate that the uncertainty is in the order of 30%, although for regions with high variability of orography, emissions and land use, higher local uncertainties should be assumed. While NH_x deposition was in general found to be close to observations and other calculation results (except for local effects that our calculation cannot capture because of its resolution), NO_y deposition was underestimated by up to 30%.

As always with chemistry transport modelling, uncertainties in the emission totals as well as geographical and temporal variability of emissions will be reflected in the uncertainties of the final result.

2.3.3 United Kingdom

National-scale deposition based on CBED is mapped at 5x5 km resolution since many of the underpinning assumptions are not appropriate for generating deposition at a finer resolution (Jones et al., 2016). For the last 20 years, we have produced concentration maps of rainfall ions using kriging, as this method is in many ways optimal and provides an estimate of the uncertainty from the mapping process (Smith and Fowler, 2001). The initial stage in the analysis is to identify the spatial covariance across the dataset, and this is done by fitting a variogram to the pairwise spatial correlations. A subjective assessment (expert opinion) of uncertainties in CBED deposition suggested a normal distribution and a coefficient of variation (CV) of 25%; this equates to an uncertainty range of +/- 50% (Jones et al., 2016). More recently, we have explored the effects of changing measurement network size and measurement locations on mapped means and uncertainties (Smith et al., 2014).

Calculations with a high resolution (1x1 km) process model of the seeder-feeder effect over the mountains of Snowdonia in North Wales (Dore et al., 2006) showed that wet deposition of nitrogen could vary by a factor of up to three within a single 5x5 km grid square, as used for national-scale modelling. Calculations of NH_3 concentrations at a 1x1 km resolution for the UK (Hallsworth et al., 2010) showed significant variation between neighbouring grid squares due to the high local variability of NH_3 emissions within the rural landscape. High-resolution (1x1 km) modelling achieved closer agreement with measurements of NH_3 concentrations at semi-natural sites than 5x5 km resolution model data, due to improved spatial separation of source (agricultural) and sink (natural ecosystem) areas.

Jones et al. (2016) and Vogt et al. (2013) recommended that the national-scale deposition data sets (5x5 km) are complemented with more detailed information (e.g. local scale source-receptor tools and / or local scale atmospheric dispersion models) due to the large variability in nitrogen deposition at a landscape scale, especially with regard to point sources.

2.3.4 The Netherlands

Based on the comparison with observations, RIVM concludes that the uncertainty in the modelled ammonia deposition is 30% on the national scale. Ammonia gap research provided changes in the dry deposition parameterization for grassland and indications that the effectiveness of manure incorporation techniques should be lowered. On the local scale uncertainties in the estimates of the deposition are up to 70%. This is mainly due to the lack of monitoring data to constrain the results and the uncertainty in dry deposition estimates. More measurements in different ecosystems of dry deposition would be needed to improve and test parameterizations. More experiments to evaluate the local scale emission – deposition relationships are needed to determine the uncertainty in emissions and in deposition.

2.3.5 Denmark

The DEHM model has been validated against measured (EMEP) data at European scale and part of intercomparisons between regional models with satisfactory results (Loon et.al., 2004).

The overall uncertainty in deposition calculations with the DAMOS system has been assessed based on experience from the Danish Background Air Quality Monitoring Program where measured and modelled nitrogen components at the five main Danish stations are analysed each year. The estimated uncertainty related to the annual total nitrogen deposition to land areas is in the order of +/–40% for DEHM and up to +/–50% for the coupled system DAMOS. This is the uncertainty for the mean over grid cells, but in the absolute vicinity of large point sources, such as large farms, the uncertainty can exceed 50% in the 400m×400m fields from DAMOS (Geels et.al., 2012).

In a detailed local scale study including measurements and use of bio-monitors, it was shown that the OML-DEP model calculations reflect measured NH_3 concentration and N deposition in the neighborhood of a chicken farm. It was concluded that, within the uncertainties of the measurements, the OML-DEP model gives valid estimates of dispersion and deposition of NH3 emitted from a livestock farm. (Sommer et.al. 2009).

An intercomparison with the ADMS, AERMOD and LADD models showed that all four models performed acceptably according to pre-defined criteria when predictions were compared with NH3 concentration measurements around a livestock farm with ground and building emission sources. For the FAC2 indicator (fraction of model predictions within a factor of two of the observations), the OML scored 76 % (compared to a highest score of 77 %). The model also gave acceptable performance for livestock farms with elevated sources with exit velocities. (Theobald et.al., 2012)

2.4 Summary

Monitoring

The monitoring of ammonia in air and precipitation (wet deposition) is carried out in all 5 countries. In most countries, national programs exists for monitoring, in France and Germany monitoring of ammonia concentrations takes place in several regions but is not part of the national databases. Some countries use multiple networks for measuring air concentrations, combining networks with active samplers and networks with passive samplers (UK, NL, DK).

Modelling

Each of the 5 countries models national deposition of pollutants including oxidized nitrogen and ammonia. Detailed models have been developed that compute both wet and dry deposition fluxes, using detailed data on land use and meteorology. In the UK and DK, several models exist that are being used for different purposes. Often, modelling is combined with measurements to compute the total fluxes; interpolated measurements are used by (at least) UK and NL to estimate the dry deposition flux. Germany uses observations to adjust the computed wet deposition fluxes. In general countries use measurements of deposition to calibrate their deposition models.

Uncertainties

Uncertainties in modelled depositions are reported by four countries. Uncertainty assessments are mostly made by comparing modelled depositions with measurements or by looking at spatial and temporal variability in the modelled outputs. Uncertainties reported are consistently in the range of 30-50%. Some countries (NL, DK) indicate that on the local scale this uncertainty can be (much) higher. Several countries indicate that especially the uncertainty in emission fluxes causes uncertainty in the modelled deposition.

3. Ammonia-sensitive areas

In this Chapter the following questions are addressed:

- Is there a national definition of ammonia sensitive areas?
- Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?
- Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

3.1 France

In France, no specific definition for ammonia sensitive areas is set. A number of habitat types is categorized according to the implementation of the Habitat Directive.

3.2 Germany

As ammonia is not regulated within the EU Air Quality Directive, there is no national obligation to measure ammonia in Germany and in the national legislation there is no definition of ammonia sensitive areas. Outside the Natura 2000 areas the federal states have their own classification systems for all other biotope types. The Federal Agency for Nature Protection publishes a list of the habitat types and describes them qualitatively (BFN, 2014). There are no classifications for ammonia. There is just a verbal classifications with regard to risk through nutrient input. Following this publication a number of habitat types are defined to be threatened by nutrient inputs.

3.3 United Kingdom

Ammonia-sensitive areas have not been defined in the UK, nationally or for Natura 2000 areas. Estimates of ammonia concentration at 1x1 km resolution, derived from FRAME, are used to carry out national-scale assessments of ammonia critical level exceedances (see Section 4.2). Site-specific appropriate or environmental assessments use outputs from APIS[12], which is based on 5x5 km ammonia concentration data. Regulatory agencies in the UK are keen to work towards identifying ammonia-sensitive areas, habitats and species, and implement regular monitoring of site-condition status on sensitive sites, to improve site-specific assessments (*cf.* Pitcairn et al., 2006; Jones et al., 2017).

The Annex 1 habitats present in SACs in the UK have been assessed, based on expert judgement, on their sensitivity to nitrogen deposition. Habitats sensitive to nitrogen are also assumed to be sensitive to ammonia. This process has identified 61 Annex 1 habitats as sensitive to nitrogen (Hall et al., 2015: Table 14.3), and empirical nutrient nitrogen critical loads have been assigned to them based on the EUNIS class that is the closest match to each Annex 1 habitat (Section 4.7; and Hall et al. 2015). Ammonia critical levels have been assigned as described in Section 2.3 below.

[12] (http://www.apis.ac.uk)

Critical levels for ammonia have been assigned to Annex 1 habitats (within SACs), based on whether lichen / bryophyte communities are an integral part of the habitat (in which case the critical level is set to 1 µg m^{-3}) or not (critical level set to 3 µg m^{-3}). The same approach has been applied to designated habitats within A / SSSIs.

3.4 The Netherlands

In the Netherlands, three nature classification systems are used; often a combination of those are used in nature policy, management and management subsidies regarding ammonia-sensitivity. It should be noted that the Netherlands uses N sensitivity of ecosystems rather than ammonia sensitivity. Most of the information in this paragraph is taken from Schmidt and Smidt (2017, in prep) and Smits and Bal (eds, 2014)

In Schmidt and Smidt (2017, in prep) ammonia sensitive areas in The Netherlands are described using three different nature classification systems, namely:

- the nature target types in Dutch 'natuurdoeltypen',
- the nature management types in Dutch 'natuurbeheertypen' and
- the habitat types of Annex I of the Habitat Directive.

The nature target types have been developed right after the establishment of the national ecological network in 1990 for the purpose of setting nature conservation objectives on national and regional scale. This typology has been used for all type of assessments amongst others the exceedance of critical load levels in The Netherlands. This typology is currently replaced by nature management types and habitat types regarding ammonia-sensitivity and critical loads.

Around 2009, the nature target types have been replaced by the nature management types also known as the 'Index Nature and Landscape' (see https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/de-index-natuur-en-landschap/). The subsidies for nature conservation measures are based on this typology (e.g. calculation of management costs per ha) and on the PAN for the ammonia-sensitive areas (see below). The nature management types are used by the (subsidised) nature conservation organisations to set nature conservation objectives on site level.

In the Netherlands, more than 160 nature reserves have been designated under Natura 2000. In more than 130 of these areas there are plants and animals - defined as habitat types and species - which suffer from the effects of the deposition of nitrogen from the air. For the purpose of Natura 2000 (e.g. the Natura 2000 management plans) the habitat types are used. The management plans should include a description of the main characteristics of the Natura 2000 area, an elaboration of the conservation objectives on site level and a description of the measures that are needed (and planned) to reach these objectives. There is a specific paragraph section on the measures needed to solve the pressures related to nitrogen (in Dutch 'stikstofparagraaf').

The pressures related to nitrogen are addressed by the Dutch Integrated Approach to Nitrogen in Dutch 'Programma Aanpak Stikstof' (PAN). Within N2000, nitrogen sensitive habitat types have been identified within the context of the PAN) In addition, nitrogen sensitive habitats for species (not part of Annex I of the Habitat Directive) have been identified. The latter are based on the original nature target types. The identification of sensitive types is based on requirements of these habitat types (and as well habitat for species) in terms of abiotic conditions.

The Netherlands has designated 137 Special Areas of Conservation (SAC's) and 77 Special Protection Areas (SPA's). Combined they form 160 Natura 2000 areas. There is a large overlap in the SAC's and the SPA'S.

In total 60 of the 75 habitat types have a CL lower than 2400 mol of N / ha / year. These habitat types are considered 'sensitive to nitrogen deposition' (Van Dobben et al. 2012) and for all of these types a restoration strategy is outlined. The list of types is given in Annex 1. In addition, 49 protected species have a habitat that is (fully or partially) nitrogen-sensitive. The habitat types largely cover these habitats, but for 14 (additional) nitrogen-sensitive habitats a restoration strategy was prepared (Annex 1).

3.5 Denmark

Two different nature classification systems are used in Danish regulation: i) Annex 1 nature types de-fined in the Habitat directive, but with a Danish interpretation manual, and ii) nature types defined in the Danish Nature Protection Act (§ 3): lakes, streams, bogs, meadows, salt marshes, heathland, and dry grasslands.

The § 3 nature types are nationally defined, but based on CORINE classes. The nature area protected by § 3 is (2016) 444.000 ha (or 10.3 % of the Danish land area). Only the nature types bog, heathland and dry grassland (and two smaller nature types, raised bogs and oligotrophic lakes) are considered nitrogen sensitive in the regulation. The area of these nature types, which are not Annex 1 nature, is 162.000 ha. The major § 3 nature types can be sub-divided into (also nationally defined) sub-types. For heathland, dry grassland and bogs, a total of 16 sub-types are used, which with some overlap and to some degree corresponds to 12 annex 1 nature. In addition to the mentioned nature types, 218,000 ha forest out of the total forest area of 625,000 ha is considered nitrogen sensitive. The part considered not sensitive is mainly production forest.

The Annex 1 types include 10 terrestrial habitats which are not considered nitrogen sensitive in the regulation. Of these, however, only salt meadows, watercourses and tall herb fringe communities constitute a significant area nationally, and only 1330 a significant area inside Natura 2000 areas.

The Annex 1 classification system is used inside the Natura 2000 areas and the § 3 classification outside. The classification systems overlap in the sense that the annex 1 classification is more detailed than the § 3 classification, but also narrower. In the Danish classification, heathland can e.g. be subdivided into Annex 1 dry heath (4030), wet heath (4010), and heathland, which are not considered Annex 1 nature. The total area of Annex 1 nature is 329,000 ha of which 40 % is located inside the SAC areas.

In the latest reporting under the Habitat directive, article 17, it was assessed that the total area of Article 1 nature is 329.000 ha, hereof 40 % (131.000 ha) outside the designated Natura 2000 areas (Fredshavn et.al. 2014). The annex 1 types have, however, not been systematically mapped outside the Natura 2000 areas, and the annex 1 types are not used for the assessment of nitrogen sensitivity outside the Natura 2000 areas.

3.6 Summary

In two countries (NL,DK) ammonia sensitive areas have been assigned. In the UK such areas are not defined (yet), but for the Annex 1 habitats an assessment has been made on their sensitivity to nitrogen that is used to estimate exceedances of critical loads and critical concentrations. In Germany habitats sensitive to nutrient inputs have been defined. In the Netherlands nitrogen sensitivity is based on the critical loads assigned to habitats: if a habitat has a critical load < 2400 eq/ha/yr, it is considered nitrogen sensitive. Within the 'Dutch Approach to Nitrogen' Natura 2000 areas that are nitrogen sensitive receive extra protection. In Denmark, both Annex 1 habitats and nature types in the Danish Nature Protection Act are used and for both sets nitrogen sensitivity per type have been defined; also about 1/3 of the forest is considered nitrogen sensitive.

4. Effect of ammonia regulations

In this Chapter the following questions are addressed:

- The location of husbandry farms in relation to ammonia sensitive areas.
- Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, both 1) due to the general reduction in deposition and 2) due to change in location of husbandry farms and 3) as a result of the national ammonia regulation in relationship to the Habitat Directive.

4.1 The location of husbandry farms in relation to ammonia sensitive areas.

4.1.1 France

The Industrial Emission Directive (IED- 2010/75/EU) is the main driver in France to support ammonia emission reduction strategies for husbandry farms. In this directive, 3400 sites are concerned and half of them are located in Britany. The EU decision 2017/302 establishing best available technologies for the intensive rearing for poultry and pigs will lead to the re-evaluation of the emissions control strategies applied in farms by April 2018 and February 2019. A significant reduction of ammonia emissions is expected but its impact is not quantified or assessed yet. This initiative led to a complete review of emission inventories methodologies in the husbandry activities, thanks to an ambitious project that started two year ago, ELFE, funded by the Ministry of Agriculture and the Ministry in charge of the Environment, that gathered skills from public research institutes (IRSTEA, INRA) together with experts from technical institutes in the agriculture field. A complete review of emission factors has been performed and tools will be made available that will allow simple evaluation of ammonia, methane, nitrogen oxides, volatile organic compounds and nitrous oxide emissions to assess the environmental impact of those sites. It is expected that such information will allow to simulate nitrogen deposition, thanks to chemistry-transport models, but such results are not available yet.

4.1.2 United Kingdom

At a site-specific level, any applications for expanding existing livestock sheds or building new ones are assessed both alone and in combination with other ammonia sources (e.g. other livestock farms), to provide critical load exceedances and process contributions (Section 5). Distance criteria are also applied at an initial stage of the assessment to ascertain whether the plan or project will have an effect on the designated site or not. It is noted in the guidance that emissions can be transported over long distances, and so a level of caution is applied. For ammonia sources, different regulatory agencies for countries within the UK apply different distance criteria ranging from 7.5 to 10 km. If the plan or project falls within the set distance to a designated site, then the assessment passes to the next stage, to test for a 'likely significant' effect on the site and its habitats.

4.1.3 The Netherlands

In the Netherlands policy is focused on both reduction of deposition at the source and mitigation by management in the N2000 areas. For the latter the programmatic approach nitrogen (PAN) was developed. The core of the PAN is to make the preservation and restoration of the nature quality possible without jeopardizing economic development. Within the PAN, binding agreements are made about remedial measures in the Natura 2000 areas and reduction of the nitrogen load. The PAN is an integral program of the government and the joint provinces, which also relies on the cooperation and involvement of many other organizations.

The PAN, supported by the online calculation tool AERIUS (Sterkenburg & van Alphen, 2017), guarantees that Natura 2000 objectives will be met, while creating room for economic development. It uses an inter-governance approach, across all sectors and areas. The PAN includes analysis of scenarios for emission reduction, based on generic measures, an additional national package of measures for the agriculture sector, measures at provincial / regional level and measures at the local level, such as habitat restoration measures. The AERIUS toolkit calculates both emission and deposition levels for Natura 2000 sites, caused by new or expanding economic activity. It provides a validated management approach, defining the risks and options for restoring and maintaining habitat integrity under different nitrogen regimes. It provides information about the requirements for permit applications. By pinpointing areas and sites of high-value habitat, it enables resources to be concentrated for permit requests. Permit requests and assessments are processed automatically, saving a great deal of time and resources, and enabling more-consistent outcomes. Its scenarios allow all parties to reach agreement and it is useful in monitoring those agreements. Initiators of projects will be legally obligated to use AERIUS to calculate the nitrogen impact of their project. This applies to all sectors: agriculture, industry and transport. For more details, and to become a user of AERIUS Calculator see www.aerius.nl / en

4.1.4 Denmark

Danish agriculture has undergone a large structural development from 2005 to 2015. The number of farms with livestock has, in the period, decreased from 51,800 to 22,800, whereas the overall production has been fairly stable. The production has thus been concentrated on a smaller number of larger farms, and a large number of farms have significantly enlarged their production. A statistical analysis between the group of (larger) farms that have been affected by local ammonia regulation and the group that has not, show a significant difference between the groups both in frequency and size of enlargements. Roughly 10 % (500 – 1000) of the larger farms can be shown to have been affected by the specific ammonia regulation in the period. The regulation has affected a total emission of 4.1 kt N in areas close to sensitive nature. The calculated gross effect of the regulation has been a protection of 12,000 ha from exceedance of critical loads, and a 138 t less yearly accumulated exceedance (Bak 2017).

4.2 Reduction in the total deposition (in Natura 2000 areas)

4.2.1 France

No info yet

4.2.2 Germany

The nationwide modelling of ammonia concentration and nitrogen deposition with the LOTOS-EUROS model for the time period 2000 – 2015 allows to document trends with regard to the background deposition or the background concentration of ammonia. Local effects of animal husbandry installations cannot be taken into account in this modelling approach, as the input data of the emissions and the modelling grid are to coarse. A time series of the area-wide modelled critical load exceedance for natural and semi-natural ecosystems in Germany for the period 2000-2015 is shown in Figure 5. This figure shows that there has been some improvement and that less areas receive an excess amount of nitrogen. This is mainly due to a reduction in NOy deposition (because of lower NOx emissions). The deposition of NHx has not decreased in the past two decades. An explicit national assessment of the situation in Natura2000 areas is not possible, as there is no geographical national dataset where the habitats are located within a Natura2000 area.

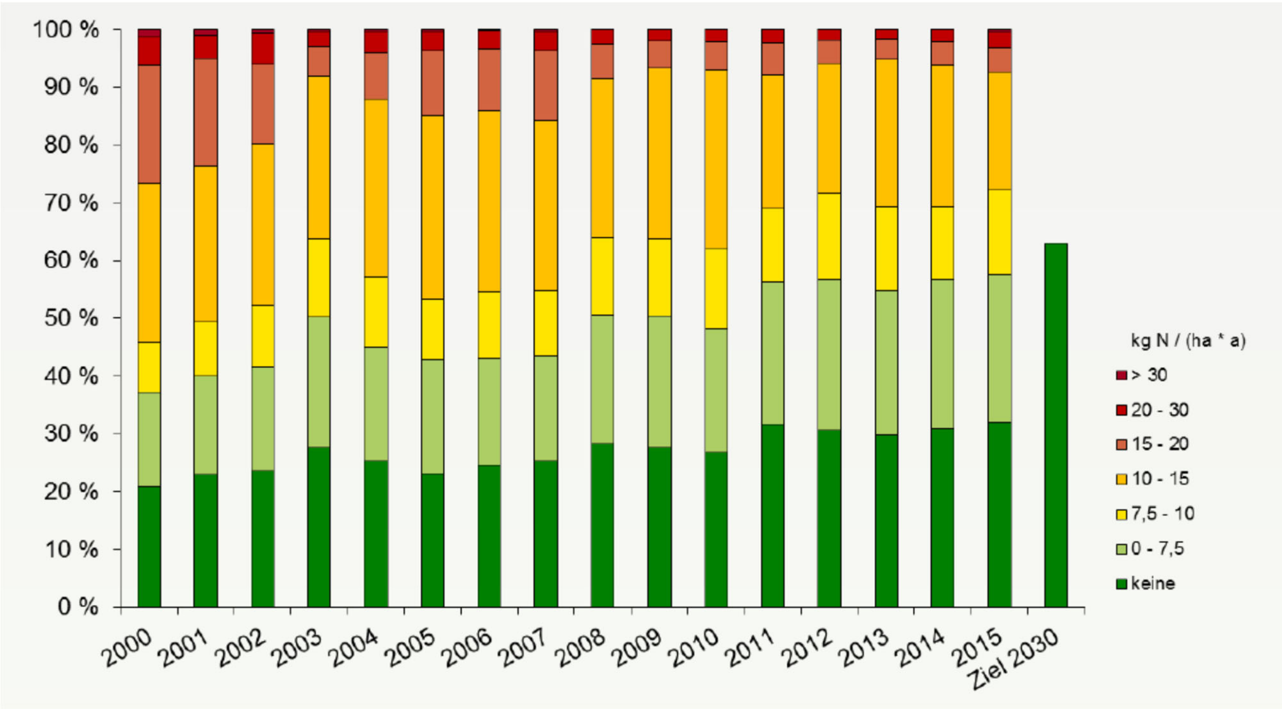


Figure 5. A time series of the area-wide modelled critical load exceedance for natural and semi-natural ecosystems in Germany.

4.2.3 United Kingdom

Based on CBED grid-average (i.e. average deposition to all land cover types) 5x5km data, total nitrogen deposition in the UK has reduced by 18% between 2004 and 2015; this varies spatially and for oxidised and reduced nitrogen deposition. Over the same time period, the area of UK nitrogen-sensitive habitats with exceedance of nitrogen critical loads (Section 4.1) has fallen by 5% (to 63%) and the number of SACs with exceedance of nitrogen critical loads for one or more features (Section 4.7) has fallen by 2% (to 91%).

Trends in nitrogen deposition (and in NH_3, NO_x, SO_2 and acid deposition) from 2004 onwards have been generated for the centroid of each SAC; the data are available by individual site on the APIS website[13]. Source attribution is modelled for each SAC to provide a matrix of source sectors contributing to nitrogen deposition at the site. Deposition is further partitioned by type (i.e. dry / wet, reduced / oxidised), to enable assessment of reduced-nitrogen input, i.e. from ammonia sources across the UK. However, source-attribution modelling is carried out only periodically (e.g. most recently for the years 2005 and 2012) and changes in emissions or in any mitigation measures (i.e. decreases in NH_3 emissions), have not been compared with observed nitrogen deposition at individual sites.

4.2.4 The Netherlands

Observed trends in NH_3 concentrations and deposition are compared with emissions trends and analyzed in view of emission reduction policy. It is, however, not possible to identify the effect of individual ammonia abatement measurements, such as change in location of husbandry farms, on the total deposition in Natura 2000 sites in the period 2004-2015.

In the Netherlands only the relationship between ammonia emissions sources and the observed trends in ammonia concentrations is reported based on monitoring stations outside the Natura 2000 sites (see Figure 6).

For the period 2004-2015 it is difficult to relate the total calculated emissions to the NH_3 concentration. The effects of particular measures on the total ammonia emission, however, has been reported. It is shown that largest decline in ammonia emission occurred between 1990 and 1995, and is mainly due to reduction measures in manure application. The obligation of low-emission manure spreading techniques is the major cause of the emission reduction of 64%. The reductions in ammonia emissions from animal housing contribute 12% of the total ammonia reduction. The remaining 6% is due to reductions in emissions due to grazing, manure storage and fertilizer application. The ammonia emissions from households, traffic and industry remained almost constant over the whole period.

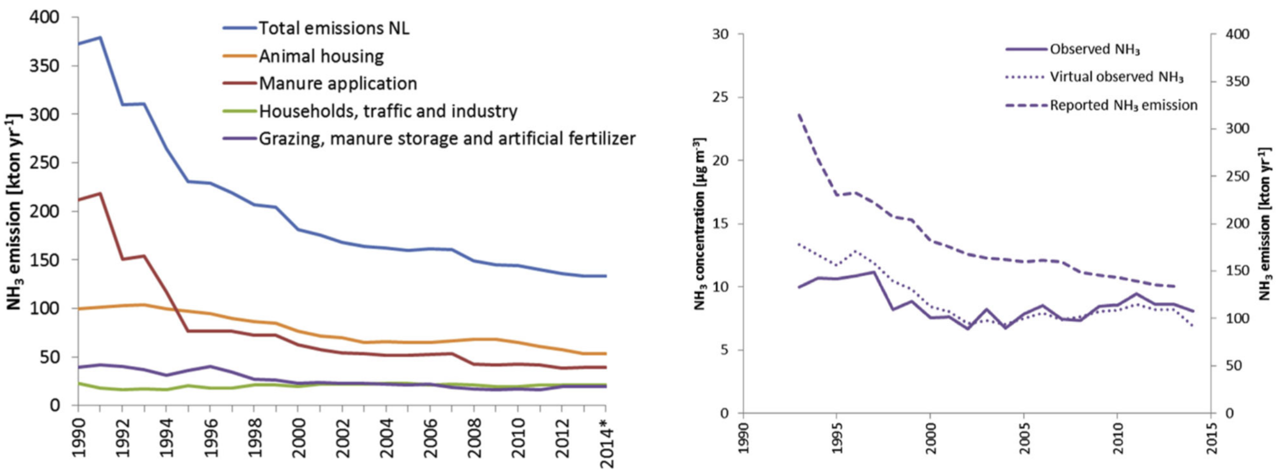
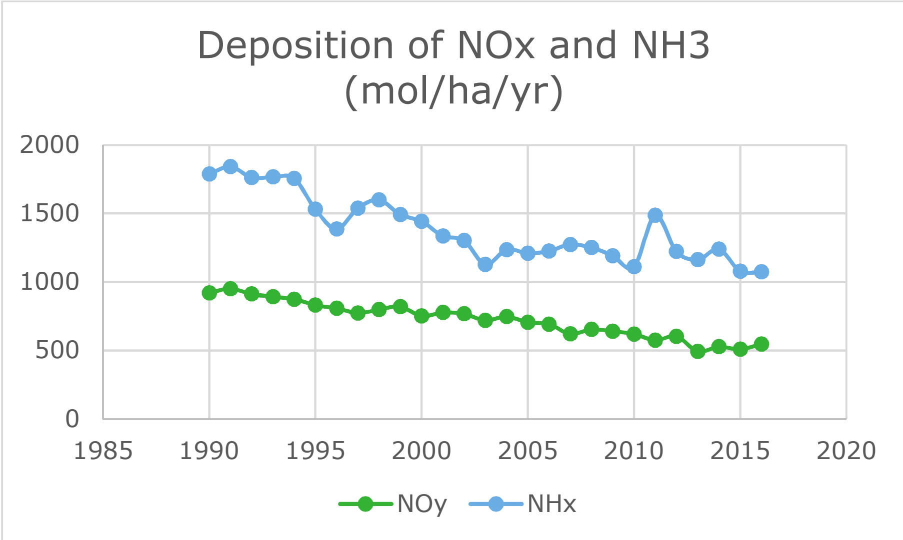


Figure 6. The NH_3 emission of different NH_3 emission sources to the total ammonia emission in the Netherlands from 1990 till 2014 (Van Zanten et al., 2017, left) and the corrected total NH_3 emissions (Virtual observed NH3, dotted line) together with the observed annual average NH3 concentration (solid line) (Wichink Kruit et al., 2007, right). The reported emissions were corrected for changes atmospheric chemistry (interaction with SO_2) and interannual variation in meteorology.

[13] http://www.apis.ac.uk/srcl

Modelled deposition with OPS for the Netherlands shows a decline from 2200 mol/ha/yr in the year 2000 to about 1600 mol/ha/yr in 2015. Most of this decline stems from a (statistically significant) decline in NO_y deposition. Modelled deposition of NH_x over the last ten years is quite stable and does not show a significant change (Figure 7).

Figure 7. Deposition trend 1985 - 2015 for NOy and NHx. Source: RIVM (http://www.clo.nl/indicatoren/nl0189-vermestende-depositie).



4.2.5 Denmark

The present ammonia regulation has been in place since 2006. Danish ammonia emissions have decreased by 16.9 % from 2005 to 2015. 28 % of Danish ammonia emissions are deposited on the Danish land area, where Danish ammonia emissions contribute to 29 % of the total nitrogen deposition. Also emissions in other countries are expected to have declined in this period.

It is, however, not possible to detect a decline in nitrogen deposition in the period 2005 to 2015 based on national deposition calculations (Figure 8 left). This can be due to year to year variation in climate and to other changes in atmospheric chemistry. It is, however, also not possible to detect a decline in measured ammonia concentrations from 2007 to 2015 for 17 monitoring stations placed at nature areas (Ellermann et.al. 2015) (Figure 8, right).

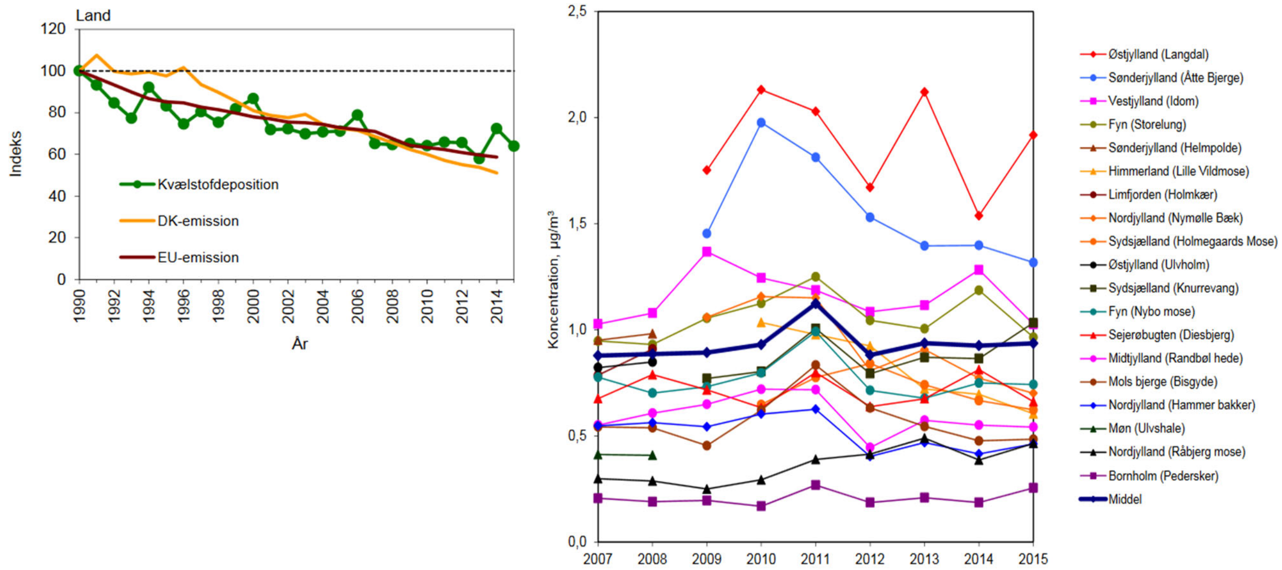


Figure 8. Estimated development of nitrogen deposition to the Danish land area (left) and development in measured annual concentrations of ammonia at a number of natural sites distributed across the country (right). Medium represents a weighted average of the average trend trend for the measurement stations, which has been active from 2007. (Ellermann et al., 2016).

4.3 Summary

Location of husbandry farms in relation to N sensitive areas

In France the Industrial Emission Directive is the main driver in France to support ammonia emission reduction strategies for husbandry farms. In this directive, 3400 sites are concerned. The EU decision 2017/302 establishing best available technologies for the intensive rearing for poultry and pigs will lead to the re-evaluation of the emissions control strategies applied in these farms. In the UK any applications for expanding existing livestock sheds or building new ones are assessed both alone and in combination with other ammonia sources (e.g. other livestock farms), to provide critical load exceedances and process contributions. Distance criteria are also applied at an initial stage of the assessment to ascertain whether the plan or project will have an effect on the designated site or not. A similar procedure is applied in NL were the AERIUS toolkit must be used to assess effects of new activities on N deposition on N-sensitive Natura 2000 areas. Only if this contribution is below a threshold and the total deposition from all sources does not lead to exceedance of critical loads, automatic permits are granted. In Denmark, restructuring of agriculture has already resulted in a reduction of N deposition to N-sensitive areas reducing the area where critical loads are exceeded.

Reduction in total deposition

In Germany deposition of NOx has decreased and deposition of NH3 has remained stable over the period 2000-2015. Exceedances of critical loads for natural and semi-natural ecosystems have decreased. In the UK total N deposition decreased by 18% between 2004 and 2015. The area of exceedance of critical loads in N-sensitive areas has decreased from 68% to 63%. In the Netherlands emissions of NO_x and NH_3 have been reduced between 2000 and 2015. This reflected in a decline in modelled NO_x deposition but not in measured ammonia concentrations (outside N2000 areas) or in modelled national ammonia deposition: neither of these show a significant change between 2000 and 2015. In Denmark national emissions have been lowered by 16.9% between 2005 and 2015, but a decline in national N-deposition has not been observed and ammonia concentrations in air in nature areas remain stable.

5. Critical loads

In this Chapter the following questions are addressed:

- Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?
- Are critical levels used?
- To which extend, and how are calculations based on the Mapping Manual from UNECE?
- Are calculated critical loads based on biodiversity targets used or planned to be used in the future?
- If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?
- Are target loads used for the specific areas; if so, how?
- Is there a reference year in the calculations, and if so, which?
- If model calculations are used: Describe the models and the data included in the calculations
- Are different methods used for setting critical loads for areas inside and outside of Natura 2000 areas, and if so, how?
- How often are the critical loads updated?
- Describe if and how nature management e.g. grazing is taken into account in the model calculations.

5.1 France

Methods and models used

Critical loads are evaluated and calculated in France by ECOLAB research laboratory belonging to the National Research Center. Anne Probst is the National Focal Point for the Coordinating Center on Effects under the Convention on Long Range Transboundary Air Pollution. ECOLAB calculates critical loads that are reported to the CCE according to the Working Group on Effects manuals. An attempt to extrapolate to effects on biodiversity accounting for climate change has recently being performed (Rizetto et al., 2016), but such results are not used for policy decision making

Critical loads for N and S were computed with the SMB model using criteria for either molar Al/Bc or pH (acidity critical loads). For critical load of nutrient N, also empirical critical loads are used, using values from the mapping Manual adapted to the French terrestrial ecosystems (Party et al, 2001).

To which extent, and how are calculations based on the Mapping Manual from UNECE?

In general methods follow the Mapping Manual, empirical critical loads have been derived specifically for the French territory.

Modifying factors

The adaption rules for empirical critical loads of the Mapping manual have been used for temperature, frost periods and base cation availability estimated by expert judgement.

Are calculated critical loads based on biodiversity targets used or planned to be used in the future?

France has computed critical loads for biodiversity using two approaches, PROPS and EcoPlant. PROPS, based on response functions derived from a European data set of plant species and abiotic conditions, was applied to about 39000 ecosystems using expert judgement to select the representative species. The Ecoplant model uses response functions based on French data alone and uses different abiotic variables for predicting plant species occurrence probability than PROPS and has been applied on the same data set. Future developments will include the development and calibration of the new coupled ForSAFE-EcoPlant model.

5.2 Germany

Methods and models used

The percentage of sensitive ecosystem area where SMB-based critical loads for nutrient nitrogen are exceeded (based on a national level assessment) is used as an aggregated indicator in the set of indicators to the German Strategy for Sustainability and the German Strategy for Biodiversity.

Main input data sets to compute the critical loads are long-term climate data (temperature and precipitation; 1981 – 2010), reference soil profiles, seepage rates, Corine land use data and deposition data (PINETI III project). The BERN model (an empirical niche model) was used to derive the receptors from the intersected information of the land use, soil map and climatic data.

For licensing approaches under the federal immission control act 2002 (FIC), federal states use empirical critical loads with modifying factors in conjunction with total nitrogen deposition composed of background deposition and project related deposition. There is a harmonised approach that all federal states shall implement, however they are not obliged to do so (LAI Leitfaden 2012).

For licensing approaches under the nature protection legislation, i.e. Natura 2000 impact assessments, there exist no harmonised approach yet. Different sets of critical loads are being used in different federal states. However there is a harmonised guidance document on a national level for licensing road projects under preparation in in which modelled critical loads are used. This habitat specific set of critical loads for eutrophication and acidification is modelled following SMB and applying the BERN-Model, while taking into account regional soil and climate data (Balla et al, 2013). Once implemented in the road construction regulations, it is foreseen to transfer the approach to all other Natura 2000 assessments with regard to nitrogen and sulphur deposition too.

Critical levels, target loads and modifying factors

Within the national air quality regulation for the good status of air quality (39. Bundes-Immissionsschutz Verordnung – 39. BImSchV) there are no concentration limits defined for ammonia in ambient air quality. Within the current version of the FIC however, where emission and immission limits are defined to protect environment and humans against negative effects of industrial air pollution, concentration limits for ammonia have been defined. These are mainly are binding in the framework of licensing new installations. Currently a project can be realised if a total concentration (background and project related) of 10 µg NH3 m^{-3} at the point of assessment (sensitive ecosystem area) is not exceeded. For the project itself there exist a cut-off criterion of 3 µg NH3 m^{-3}. That means, if the project itself causes additionally less than 3 µg m^{-3} at the point of assessment, the project can be realised. Within the current revision process of the FIC, UBA proposed from a scientific point of view to lower the values to 3 and 1 µg m^{-3} respectively. However the revision is not finalised yet and it remains unclear if there will be new values in a revised version.

As described above the empirical critical loads are the basis of the LAI guideline, which is again rather a policy than an obligation. Instead of modifying factors, a system of additional loading was implemented in this guideline. The allowed additional loading can be derived by a complex matrix of protection category and exposure risk, while the protection category is divided in to three different functions (livestock, regulation and production). Target loads are not used.

To which extend, and how are calculations based on the Mapping Manual from UNECE?
As described above the exceedance of the SMB-critical load is used as aggregated indicator. These critical loads are calculated according to the equations of the Mapping Manual from the UNECE. Even though the equations are very consistent with the Mapping Manual, some variations might be found when it comes to the derivation of the input data. Since there is no data set for receptors on a national scale available yet, several steps were necessary to construct a comprehensive map of valid receptors. Here the information of CORINE land cover, a national soil map and long-term averages of climate data form the basis of the receptors. The descriptions in the Mapping Manual of the calculation is not very specific for certain parameters. In such cases (e.g. for nitrogen immobilisation), other approaches were tested and applied in Germany. All these deviations are well documented in the National Reports published by the CCE.

5.3 United Kingdom

Methods and models used
This section provides an overview of the critical loads and levels used in the UK; more detailed information and detail on the methods can be found in Hall et al. (2015) and the UK National Report. Terrestrial habitats sensitive to acidification and/or eutrophication have been mapped at 1x1 km resolution across the UK. Data for freshwaters are based on the catchment areas of 1752 sites, comprising mainly small upland lakes and streams in acid sensitive regions of the UK.

Critical loads of acidity for non-woodland terrestrial habitats are based on the empirical method; this sets the soil acidity critical load according to the amount of acidity that can be neutralized by the base cations produced by mineral weathering of the dominant soil type in each 1x1 km grid square (Hornung et al., 1995; CLRTAP, 2014+). Acidity critical loads for bog habitats (or peat-dominated areas) are calculated using a critical hydrogen ion concentration equivalent to pH 4.4 (Hall et al., 2015). This method is applied to upland peats only; for lowland or arable peats which are less sensitive to acidity, a high critical load value is applied (4.0 keq ha-1 year-1). Acidity critical loads for woodland habitats (managed / productive broadleaved and coniferous woodland, and unmanaged woodland) are based on the Simple Mass Balance (SMB).

For freshwaters, critical loads are calculated using the First-order Acidity Balance (FAB) model (Henriksen & Posch, 2001; Hall et al., 2015) and water chemistry from the 1752 sites sampled in the 1990s. These data do not include, or represent, all freshwaters (lakes or streams) in the UK, and there are no current plans to extend the data set.

Empirical critical loads of nutrient nitrogen are applied to non-woodland habitats and unmanaged (non-productive) woodland. The critical load values used in the UK are based on (a) the ranges published in the 2010 review and revision of empirical critical loads (Bobbink & Hettelingh, 2011), and (b) a meeting of UK experts to review the evidence of nitrogen impacts and determine where within the ranges to set the UK critical load values (Hall et al., 2011, 2015) (Table 1).

Mass-balance critical loads of nutrient nitrogen are applied to managed (productive) coniferous and broadleaved woodland habitats, to ensure that long-term ecosystem function is protected.

UK critical loads and exceedance data are used in a range of applications, provided in Annex 2

Regarding biodiversity-based critical loads: effects of air pollution on habitat suitability for plant species are simulated using the MADOC-MultiMOVE model (Rowe et al., 2015) (Figure 4.1a). Biogeochemical responses to total N and non-marine S loads are simulated using MADOC (Rowe et al., 2014) to predict changes in soil pH, nitrogen availability and plant productivity. These responses are used to drive MultiMOVE (Henrys et al., 2015), which predicts habitat-suitability for individual plant and lichen species on the basis of niche models defined on seven environmental gradients. Species-level responses are related to biodiversity targets using an indicator-species approach, following a consultation with the habitat specialists to define habitat quality (Rowe et al., 2016). A Habitat Quality Index (HQI) is calculated as the mean habitat-suitability for the set of characteristic species that has been defined for each habitat.

To derive a biodiversity-based critical load function, it is necessary to define a threshold value of HQI below which the habitat is considered to be damaged. For each site, the model is run forward with zero non-marine S deposition and N deposition set to the empirical critical load for nutrient N (using habitat- and site-specific values as calculated in the UK NFC database: Section 4.1), and the resulting value of HQI in 2100 is assumed to represent the damage threshold for the site, HQIcrit. The model is then re-run to 2100 under a range of N and S deposition values to obtain a response surface, and a line or 'contour' where HQI equals HQIcrit is obtained by interpolation. This contour represents the biodiversity-based critical load function. For data submissions to the CCE, the function was simplified to two nodes on the [S load & N load] plane (Posch et al., 2014).

Critical level, target loads and modifying factors

At the national scale, ammonia critical levels have not been assigned to individual habitats or habitat features of designated sites; instead a simple approach has been taken, using ammonia concentration data (Sections 1.3, 2) and ammonia critical levels (Hall et al., 2016) to carry out annual determinations of:

(a) The land area of England, Wales, Scotland, Northern Ireland and the UK where ammonia concentrations exceed critical levels of 1 µg NH3 m-3 to protect lichens & bryophytes, and 3 µg NH3 m-3 to protect higher plants (CLRTAP, 2014+).

(b) The area of nitrogen-sensitive habitats where ammonia concentrations exceed the critical levels of 1 µg NH3 m-3 and 3 µg NH3 m-3.

(c) The percentage of designated sites (SACs, SPAs, A / SSSIs) where ammonia concentrations exceed the critical levels of 1 µg NH3 m-3 and 3 µg NH3 m-3.

For site-specific assessments (Section 2.3, 5), and in the APIS tool14, ammonia critical levels are assigned to the habitat features of designated sites.

The only modifying factor used in the UK is a precipitation modifier for setting the critical load for bog habitats (EUNIS class D1). A simple approach of calculating the rainfall ranges that would give specified median critical load values (8, 9 or 10 kg N ha-1 year-1) was used to enable variable critical loads to be set spatially depending on rainfall (Hall et al., 2015). For site-specific assessments (e.g. SACs, SPAs, A / SSSIs) guidance has been developed for applying the modifying factors of (a) water-table height, and (b) precipitation, in determining the appropriate critical load for individual bog sites. The guidance15 is presented as a three-step approach that considers (in the following order): the condition of the site, the water table and the local annual precipitation.

To which extent, and how are calculations based on the Mapping Manual from UNECE?

The UK calculations are based on the Mapping Manual and the results of international workshops held under CLRTAP, but with some adjustments made for UK conditions, evidence or studies, if appropriate. All methods and data used in the UK are documented in a "Methods Report" (Hall et al., 2015) which is freely available from the project website16.

Are calculated critical loads based on biodiversity targets used or planned to be used in the future?

Biodiversity-based critical loads are being developed in the UK and were included in the data submission to the CCE in May 2017, providing new critical loads for 86% of the 1x1 km squares containing bog habitat in Great Britain (representing ~5000km2 of bog habitat) and sub-sets of other acid-sensitive habitats (acid grassland, dwarf shrub heath). Further development and application of these methods is ongoing under current work funded by Defra.

Inclusion of management in the critical loads

For productive woodlands, the amount of nitrogen, calcium and base cations removed through harvesting is included in the calculations of critical loads (Section 4.1), as is the removal of nitrogen through sheep grazing on calcareous grassland. In general, single values (or separate values for different soils)

[14] http://www.apis.ac.uk/srcl

[15] (http://www.apis.ac.uk/guidance-applying-critical-load-range-atmospheric-nitrogen-deposition-bog-habitats-uk).

[16] http://www.cldm.ceh.ac.uk/content/methods-calculation-critical-loads-and-their-exceedances-uk

are applied in the calculations for all habitat squares, since spatially explicit data on uptake do not exist.

Grazing and other management practices are not taken into account explicitly in the UK-scale dynamic modelling approach. Management (e.g. stocking rate, mowing frequency) effects on vegetation height across different habitats are not well-established, and suitable management data for national-scale modelling are not available. Grazing (or other management practices) can be taken into account in site-specific applications, where observations are available (Rowe et al., 2011).

5.4 The Netherlands

Methods and models used

Critical loads for habitat types were used to define which habitats could be considered as nitrogen-sensitive in the PAN. The critical deposition value for nitrogen was defined as "the limit, beyond which the risk cannot be excluded that the quality of the habitat type is significantly affected as a result of the acidifying and / or fertilizing influence of the atmospheric nitrogen deposition" (Van Dobben & Van Hinsberg 2008).

The critical loads, which are taken as a starting point in the restoration strategies, are established in Van Dobben et al. (2012) specific to habitat types in the Netherlands. In that report, several sources regarding critical deposition values were combined using a fixed protocol (Van Dobben et al. 2012).

Those sources are:

- empirical critical deposition values for nature types according to the EUNIS classification, with a bandwidth, as published in Bobbink & Hettelingh (2011) and adopted by the UN-ECE (of which the Netherlands is also a member);
- model-specific critical deposition values per vegetation type according to Van Dobben et al. (2012);
- expert opinion of the authors.

In short, it means that the CL for a habitat (sub) type must lie within the bandwidth of a comparable EUNIS-type. The CL is (under that precondition) the average of the model-specific critical deposition values of the constituent types of vegetation. The expert opinion was applied for the selection of useful model results (also for those cases in which no empirical values were available) and for adding critical deposition values for habitat types for which no model results were available. Habitats of protected species sometimes also encompass types of nature, which are not covered by habitat types. In order to still be able to determine a CL, the same procedure was used for the determination of critical deposition values for target nature types. The definition of CL therefore applies mutatis mutandis also for (elements of) habitats of species, called 'habitat of the species' in the regulations. Critical loads for N2000 areas have been updated once: in 2012 van Dobben et al updated the earlier critical loads by Van Dobben en van Hinsberg (2008), although the methods remained unchanged. Later on studies have been carried out to investigate if critical loads need to be updated based on e.g. other abiotic thresholds like NO3 concentration, but this has not resulted in updated critical loads.

Critical level, target loads and modifying factors

No modifying factors were used for the empirical critical loads; the value within the range chosen was based on the modelled critical load but only if this values falls within the empirical range. If no reliable model results was available for the habitat type, generally the midpoint of the empirical range was used. For a few habitats, expert judgement was used to select a value that deviates from the midpoint (Van Dobben et al. (2012)). Critical levels for NH3 are not used to set targets or thresholds for nature types or habitat types, nor are target loads.

To which extent, and how are calculations based on the Mapping Manual from UNECE?

The methods used to compute the critical loads are partly in line with the methods described in the mapping manual, for example empirical critical loads are used from in Bobbink & Hettelingh (2011) which is also referred to in the MM. Modelled critical loads deviate from the methods in the mapping manual, as the modelling uses pH and N availability as threshold values and the steady state version of the SMART2[17] model (for critical loads supplied to the UN-ECE recently replaced by the steady state version of VSD+[17]) to compute critical loads for N and S (see Annex 2 for details). The manual, however, describes different methods based on critical N concentrations with SMB[18] as the critical load model.

Are calculated critical loads based on biodiversity targets used or planned to be used in the future?

Using pH and N availability as thresholds provides ‘biodiversity based’ critical loads; in recent years, critical N loads for biodiversity were also computed based on a PROPS-like approach, but only for a number of individual sites.

Inclusion of management in the critical loads

Nature management is included in the calculations in the most simple way possible. A fixed amount of biomass with a fixed content of nitrogen is taken out of the system for the calculations for CL. The amounts vary per vegetation type. The amount and content are based on model calculations with the vegetation succession model SUMO (Wamelink et al. 2009). The SUMO model is a carbon and nitrogen balance model where almost all different types of nature management (including grazing with 17 different species of grazers) is included. The biomass amount taken out of the system calculated with the model was fine-tuned based on expert knowledge. Restoration management is not included in the critical loads.

5.5 Denmark

Methods and models used

A manual to the Danish counties from 2003 recommended the use of mass-balance (SMB) methods for the calculation of critical loads on a site basis, supplemented with the use of empirical critical loads, where data for local calculations were not available (Bak, 2003). There has not been conducted a nationwide mapping of critical loads and exceedances based on local data, and as a consequence, empirical critical loads have been used in different national assessments (Bak & Albrektsen, 2010). In 2013, methods to derive critical loads for

[17] Soil geochemical model

[18] Simple Mass Balance model

biodiversity was developed, and values calculated for selected Annex 1 nature types based on monitoring data from the national monitoring program NOVANA (Bak, 2013). These values have subsequently been used for Annex 1 nature in national assessments of nature consequences of changes in regulation.

The SMB model has been used both for critical loads for acidity and eutrophying N. Weathering rates for different soil types have been calculated with the PROFILE model.

For the calculation of biodiversity based critical loads, the VSD+/MOVE model system has been used for a national assessment for selected annex 1 nature types. In these calculations, the Mean Species Abundance indicator has been used combined with a criterion on 'no loss of biodiversity' compared to a reference year. Calculations have been based on i) plant species observed for the nature types in the national monitoring program, ii) soil data (C/N, pH) from the national monitoring programme, iii) national maps of climatic data, deposition data and soil data. (Bak, 2013). In newer national studies, the VSD+/PROPS has been used with the HSI and BC indicator (Bak, 2016).

Critical level, target loads, modifying factors and reference year

Critical levels have been recommended for use for approval of animal farms since 2003 (Bak, 2003), but is not included in the livestock Act. The use in habitat assessment (appropriate assessment) for larger industry has been recommended since 2016 (Miljøstyrelsen, 2017). The actual use until now has not been systematically recorded but is expected to have been limited. Critical levels are recommended to be used as supplement to critical loads in future approvals for animal farms based on the numbers in the latest update of the Mapping Manual (https://www.umweltbundesamt.de/en/cce-manual; Bak,2017).

The use of empirical critical loads, e.g. in IPC approval, has been recommended as a supplement to computed critical loads since 2003 (Bak, 2003). In addition to the modifying factors described in the mapping manual, it has further been advised to include conservation status, - goals, and other threats in qualifying the critical load within the empirical ranges.

Target loads have so far not been used in Denmark.

The reference years 1950, 1992, and 2010 have been used in national assessment of biodiversity based critical loads for (Danish) annex 1 nature types (Bak, 2013); variation in computed critical loads due to differences in the reference year used, are given in Annex 2

To which extend, and how are calculations based on the Mapping Manual from UNECE?

Denmark participates in the scientific work under the UNECE Air Convention, WGE, but has not submitted national data for the last calls for data. Background data from CCE has therefore been used for Denmark in the development of the revised Gothenburg protocol and NEC directive using methods based on the Mapping manual.

National use of empirical critical loads has followed the updated recommendations after approval of UNECE WGE, with the latest update in 2011. A national translation from EUNIS nature types to Danish § 3 nature types and to annex 1 nature types has been used.

National use of the SMB model has followed recommendations in the mapping manual. The methodology has, however, primarily been used for acidification of forest soils.

Are calculated critical loads based on biodiversity targets used or planned to be used in the future?
Methods and recommendations for the use of biodiversity based critical loads have not yet been included in the Mapping Manual. Development has taken place in the context of the UNECE / WGE / ICP M&M and JEG, and recommendations given for methods and criteria to be used for submission of data under the issued 'call for data' for biodiversity based critical loads under ICP M&M.

5.6 Summary

Critical load methods
FR and DE use the simple mass balance to calculate critical loads for acidity. NL uses a slightly different approach with application of a steady state version of VSD+. The criteria that are being used differ between countries, and often consist of a set of multiple criteria of ecosystem-specific criteria. Denmark and UK use empirical critical loads; UK also submits these critical loads to the UNECE convention, but Denmark does not. In Denmark SMB is uses as well. For critical loads for biodiversity countries use various methods and models. In France PROPS and EcoPlant are applied, Germany uses the Bern model, NL uses VSD+ in conjunction with limits for pH and N availability and constraint by empirical critical loads, UK uses Madoc-MultiMove in which empirical critical loads are indirectly used and DK is testing VSD+-PROPS. In all cases these models are driven by soil characteristics (such as pH and C / N ratio) and climatic variables (such as precipitation and temperature). Mostly the models and procedures follow the Mapping manual and empirical critical loads are mostly derived from reports published with the UNECE convention as well.

Critical level, target loads and modifying factors
Critical levels for NH3 are used in the UK and in DE within the framework of licensing new installations. In DK critical levels are used in hab-itat assessment (appropriate assessment) for larger industry.Target loads are not used in any of the five countries. Modifying factors for empirical critical loads are used by most countries that use empirical critical loads; internationally defined modifying factors are being used as well as nationally defined modifying factors. In NL empirical critical loads are 'modified' using output from critical load models.

Are calculated critical loads based on biodiversity targets used or planned to be used in the future?
All countries are currently developing and applying methods to compute biodiversity-based critical loads (see above). FR, DE and UK have submitted these critical loads to the UNECE. NL submitted critical loads based on VSD+ that are biodiversity based and is experimenting with VSD+PROPS based methods. DK is also testing

Inclusion of management in critical loads
Management of forest by removal of wood is included in the critical load calculations by all countries; DE, UK and NL also include management of grassland and heathland through e.g. grazing and / or mowing. For the other countries, insufficient information is available currently to assess whether or not management has been included for non-woody ecosystems.

6. Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

- Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and I f so: are empirically critical loads or national model calculations and local data used for the specific nature area?
- To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included?
- Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
- Describe briefly if and how local scale transport and deposition is calculated?
- Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how.

6.1 France

No info

6.2 Germany

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance

(1) the Immission Control legislation (no Natura 2000 is affected) uses empirical critical loads in combination with modifying factors (2) in the nature protection legislation different sets of critical loads are applied depending on the federal state, mostly local data is used to set the critical load. However there is a national data set for modelled habitat specific critical loads but its application is not approved finally. No modifying factors are applied.

To what extent and on which geographical scale is local data e.g. data on ammonia deposition, on how sensitive to ammonia the specific nature area is etc, included?

Background data comes from the national area-wide modelling based on a 1*1 km² grid (Gauger et al., 2008), however due to restrictions in resolution of the model it is recommended to additionally take local deposition sources into account for the assessment of the “real” background deposition. The assessment under the nature protection legislation always includes local data on the sensitivity of the assessed habitat. For legal reasons, the scientific substantiation of the sensitivity of the habitat is an essential part of the impact assessment. The assessment under the immission control regulations in most cases can be performed without local assessment data for the sensitivity of the biotope. The modifying factors and cut-off criteria for project applicants are so high that licensing is mostly possible (with restrictions for very large industrial husbandry installation) for smaller installations as long as a Natura 2000 area is not affected.

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
For Natura 2000 impact assessments different (although somewhat similar) approaches are used in the different federal states. The guidance document suggests that principal management measures such as mowing can be used to balance inputs and outputs with regard to the critical load. If this comes into force this regulation would be transferred to all other project assessments under the Nature 2000 impact assessment.

Describe briefly if and how local scale transport and deposition is calculated?
UBA offers a modelling tool called AUSTAL2000[19]. This tool is generally used to calculate local scale transport and deposition

Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?
For the large scale calculations of the background deposition roughness is included. There are 10 different land use classes with different roughness lengths implemented in LOTOS-EUROS model. For the small scale calculation of project related deposition the AUSTAL2000 model is used in which a selection of different roughness lengths can be implemented.

6.3 United Kingdom

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance
Environmental permitting is carried out by, and is the responsibility of, separate regulating agencies for England (Environment Agency), Wales (Natural Resources Wales), Scotland (Scottish Environment Protection Agency) and Northern Ireland (Department of Environment, Northern Ireland). Each Agency has its own procedures, methods and models.

Critical loads for nutrient nitrogen and critical levels of ammonia are used in appropriate and environmental assessments. Empirical critical loads of nitrogen have been assigned to the features of designated sites, as well as appropriate critical levels. Local air dispersion models are used to calculate depositions and concentrations from a source to a nature area (i.e., designated site). The models used range from screening models (e.g. SCAIL[20]: Simple Calculation of Impact Limits) to more advanced models, e.g. ADMS 5.

If the emissions from a process are judged to result in a likely significant effect on a designated site then a detailed assessment is required. Detailed assessments take into account actual operational practice (including mitigation measures) and site specific data (e.g. any specific critical load value, or whether the sensitive habitat falls within the pollutant footprint).

To what extent and on which geographical scale is local data e.g. data on ammonia deposition, on how sensitive to ammonia the specific nature area is etc, included?
Background depositions and concentrations at 5x5 km resolution are used in assessments. For air-dispersion modelling, local representative meteorology

[19] https://www.umweltbundesamt.de/themen/luft/regelungen-strategien/ausbreitungsmodelle-fuer-anlagenbezogene/uebersicht-kontakt

[20] www.scail.ceh.ac.uk

is recommended and used where possible. The SCAIL screening tool uses regional meteorology from ~40 stations around the UK.

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
Management practices that may conflict with nitrogen deposition effects are taken into account at the detailed assessment stage. Common Standards Monitoring (CSM) under the EU Habitats Directive (Article 17) also allows for recording nitrogen deposition effects and other potentially confounding practices (e.g. grazing). A decision framework has been developed to provide a means of attributing nitrogen deposition as a threat to, or cause of, unfavourable habitat condition on protected sites (Jones et al., 2016).

Describe briefly if and how local scale transport and deposition is calculated?
An assessment of a project or plan that may impact on a designated site is required to use an air dispersion model to predict the potential pollution to a receptor (e.g. habitat or SAC). Models suitable for this type of screening approach are SCAIL or new generation models such as ADMS. The modelling takes into account pre-existing emissions as well as those of the proposed new source(s) to output a maximum predicted pollutant concentration and deposition to the receptor in question. The likely significant effect of a source's pollutant emissions will depend on:

- The contribution of the process (Process Contribution: PC)
- The ambient concentration / deposition (Background: BK)
- The combination of the PC and BK, known as the Predicted Environmental Concentration / Deposition (PEC)
- The relevant critical level / critical load (environmental benchmark) at the site.

Each pollutant emitted from the proposed process is modelled at each receptor boundary (designated site) and combined with the background at each receptor point to give a PEC. Both concentrations and depositions are modelled depending on the pollutant pathway. The percentage of the process contribution to the critical load / level is also calculated: PC as % of benchmark = PC / environmental benchmark * 100

Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?
The models include an appropriate deposition velocity for woodland type habitats and for semi-natural (short-vegetation) habitat types, applied according to the habitat being considered.

6.4 The Netherlands

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance.
The Netherlands has adopted a Programmatic Approach to Nitrogen (PAN, or, in Dutch, Programmatische Aanpak Stikstof). The PAN, supported by the online calculation tool AERIUS (Sterkenburg & van Alphen, 2017), guarantees that Natura 2000 objectives will be met, while creating room for economic development. The PAN includes analysis of scenarios for emission reduction, based on generic measures, an additional national package of measures for the agriculture sector, measures at provincial / regional level and measures at

the local level, such as habitat restoration measures. The AERIUS toolkit calculates both emission and deposition levels for Natura 2000 sites, caused by new or expanding economic activity. This applies to all sectors: agriculture, industry and transport. For more details on the AERIUS Calculator see www.aerius.nl/en. Initiators of projects that will increase N emissions, are legally obliged to use the AERIUS toolkit to compute the extra N deposition to one or more N sensitive Natura 2000 areas that this activity generates. If the additional N deposition is less than a threshold value (currently 1 mol N/ha/yr) and the total N deposition, also computed by AERIUS, does not exceed the critical load for the Natura 2000 area, the foreseen activity is permit free. In all other cases a permit is needed.

To what extent and on which geographical scale is local data e.g. data on ammonia deposition, on how sensitive to ammonia the specific nature area is etc, included?

The sensitivity to N is established per N 2000 area; if the critical load of that area (based on its habitat type) is less than 2400 mol/ha/yr, the area is considered N sensitive. AERIUS computes N deposition for the midpoint of hexagons that have an area of 1 ha each.

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?

For Natura 2000 areas that are subject to the PAN a management plan and a special report about the PAN measures have to be made. In these documents the management and management goals are described in detail including the mitigating measures to be taken. Management as grazing, mowing or sod cutting are described for each area specific including intensity. Note that grazing is normally only used as a measure to influence the structure of the vegetation and not removal of N from the system.

It has been recognised that habitat management measures can be successful in restoring nitrogen affected ecosystems by:

- intensifying nature management in order to preserve nitrogen-sensitive habitats as long as the critical load is exceeded (e.g. by means of introducing or intensifying grazing, mowing, sod cutting);
- mitigating the adverse effects, as long as the critical load is exceeded by means of solving other problems that cause similar effects (such as eutrophication and acidification caused by lowering water tables);
- restoring nitrogen-sensitive habitats when critical load are no longer being exceeded, e.g. by means of the removal of accumulated N in water, soil and/or vegetation.

Furthermore, restoration management can be applied to mitigate the effects of N deposition as long as they are mentioned and approved in the ‘Hersteldocumenten’. This management is site specific, additional to the ‘ usual’ management and the effect on nitrogen availability in the field is estimated and included in the model calculations with AERIUS. The resulting distance to the target (the critical load) is estimated by the model, including these effects of management. Thus restoration management affects the exceedance of the CL calculations.

Describe briefly if and how local scale transport and deposition is calculated?

The core of AERIUS is formed by the OPS model that uses local, national and international emissions. National emissions originate from the national emission inventory that also include detailed point sources. AERIUS computed deposition on hexagons of 1 ha and thus includes ' local transport'.

Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?

The core of AERIUS is formed by the OPS model that takes landscape roughness into account.

6.5 Denmark

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance.

Effects of ammonia on sensitive nature are regulated through the livestock act. The livestock act differentiates between three classes of nature. Category 1 is the Annex 1 types, which are considered sensitive inside Natura 2000 areas, and in addition § 3 heat and dry grassland inside Natura 2000 areas. Category 2 is raised bogs and oligotrophic lakes, and (§ 3) heathland areas larger than 10 ha and § 3 dry grassland areas larger than 2.5 ha outside the Natura 2000 areas. Category 3 is § 3 heath, bogs and dry grasslands outside Natura 2000, which are not category 1 or 2, and ammonia sensitive forest areas. The derivation of the different classes of nature in the ammonia regulation is partly based on critical loads in the sense that the nature types excluded in most cases are type with high critical loads.

For category 1 nature, the allowable total deposition from a single farm is 0.2, 0.4 or 0.7 kg N ha^{-1}, depending on number (0, 1 or> 1) of other farms nearby; for category 2, the allowable total deposition is 1.0 kg N ha^{-1} and for category 3, and acceptable limit for extra deposition can be set based on concrete assessment; however, the limit on extra deposition cannot be lower than 1 kg N ha^{-1} and requirements can only be made, when a number of criteria are met for the affected nature area, e.g. that the critical load is exceeded. Also the requirements for total disposition are subject to some exceptions.

Critical loads and critical load exceedances are hence only used in a limited number of approval cases: where i) there will be an extra deposition on category 3 nature higher than 1 kg, ii) the limits set by category 1 or 2 nature is not more stringent, and iii) the resulting deposition causes critical load exceedance, and iv) several other criteria regarding e.g. conservation value of the area are met. The assessment of critical loads and exceedances has in these cases been based on empirical critical loads.

To what extent and on which geographical scale is local data e.g. data on ammonia deposition, on how sensitive to ammonia the specific nature area is etc, included?

Background deposition of nitrogen is based on national high resolution and high quality data on agricultural point sources, emissions from larger point sources in other sectors, larger roads etc.

Assessment of local scale deposition is based on model calculations on 400 x 400 m^2 resolution or higher for receptor areas in approval cases.

Local differentiated critical loads based on local data have not been used. However, local information on nature values and protection goals are included in approval cases.

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
It is assumed in the Natura 2000 plans that the ammonia regulation will protect the areas against adverse effects of nitrogen deposition, and consequently the Natura 2000 plans do not directly include measures to mitigate effects of too high nitrogen deposition. Nitrogen deposition is, however, mentioned as a pressure in many Natura 2000 plans, and some management actions in the plans will have an effect on the nitrogen balance and in mitigating species changes caused by nitrogen deposition.

For computed critical loads (for biodiversity, see above), an assumed normal removal rate between 1 – 3 kg N ha-1 y-1 is included in the calculations for the managed nature types.

Describe briefly if and how local scale transport and deposition is calculated?
Local scale deposition from the considered project and neighbouring farms considered in cumulation is calculated with deposition curves based on the OML-DEP model (see above). Different deposition curves for three different classes of surface roughness for the receptor area are used. The generic deposition curve is adjusted to account for the (local) frequency of the wind-sector from the emission point to the receptor area. A consequence radius of 1 km is used for sources < 5000 kg N and a radius of 2.5 km for higher emissions. These radii are also used to delimited farms considered in cumulation.

Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?
Yes, for three classes of roughness of the receptor area (see above). Edge effects caused by higher roughness of the surface area compared to surrounding agricultural areas is in general not included, but the outer edge (50 m) of nature areas are in some assessments excluded.

6.6 Summary

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance.
In the DE, UK, DK and NL projects and regulations are in force to establish effects of N emitting activities on N sensitive areas; in NL and DK limits are set on the allowable (extra) N deposition to selected N-sensitive ecosystems. In Germany, critical loads are used in the imission control regulation as well as in the nature protection regulation; critical loads must be scientifically sound to hold in legal procedures. For licensing approaches under the nature protection legislation, i.e. Natura 2000 impact assessments, there exist no harmonised approach yet. Different sets of critical loads are being used in different federal states. For new emitting activities in Germany, limits are set to the concentration of ammonia at the emitter as well as to the total concentration of NH_3 at the Nature area the new emitter affects. In the UK Environmental permitting is carried out by, and is the responsibility of, separate regulating agencies for England Wales , Scotland and Northern Ireland. Each Agency has its own procedures, methods and models. If the emissions from a process are judged to result in a likely significant effect on a designated site then a de-

tailed assessment is required. An assessment of a project or plan that may impact on a designated site is required to use an air dispersion model to predict the potential pollution to a receptor (e.g. habitat or SAC). NL has adopted a Programmatic Approach to Nitrogen (PAN). The PAN guarantees that Natura 2000 objectives will be met, while creating room for economic development by dedicated management and restoration plans for ach N2000 area, as well as a tool to compute the extra N deposition to one or more N sensitive Natura 2000 areas that N emitting activities generate. If the additional N deposition is less than a threshold value and the total N deposition does not exceed the critical load for the Natura 2000 area, the foreseen activity is permit free. In all other cases a permit is needed. In DK effects of ammonia on sensitive nature are regulated through the livestock act. The livestock act differentiates between three classes of nature. For each category the allowable total deposition from a single farm is defined ranging from 0.2 to 1 kg N ha^{-1} for categories 1 and 2 and > 1 for category 3. For category 3, requirements can only be made, when a number of criteria are met for the affected nature area, e.g. that the critical load is exceeded. Critical loads and critical load exceedances are hence only used in a limited number of approval cases.

Inclusion of management

In NL both regular- as well as restoration management is used to mitigate critical load exceedances and to restore habitats where critical loads are no longer exceeded. In the UK management is part of the detailed ecosystem assessments. In DK the Natura 2000 plans do not directly include measures to mitigate effects of too high nitrogen deposition. In Germany different states use different approaches, but the guidance document allows for general management such as mowing to be included in the critical load calculations.

In more detail: in the UK Management practices that may conflict with nitrogen deposition effects are taken into account at the detailed assessment stage. Common Standards Monitoring (CSM) under the EU Habitats Directive (Article 17) also allows for recording nitrogen deposition effects and other potentially confounding practices (e.g. grazing). For Natura 2000 areas in NL that are subject to the PAN a management plan and a special report about the PAN measures have to be made. In these documents the management and management goals are described in detail including the mitigating measures to be taken. Management such as grazing, mowing or sod cutting and its intensity are described for each area. Furthermore, restoration management can be applied to mitigate the effects of N deposition as long as they are mentioned and approved in the 'Hersteldocumenten'. This management is site specific and additional to the ' usual' management. In DK it is assumed in the Natura 2000 plans that the ammonia regulation will protect the areas against adverse effects of nitrogen deposition, and consequently the Natura 2000 plans do not directly include measures to mitigate effects of too high nitrogen deposition. In the critical loads N removal for managed ecosystems is included.

Local transport and surface roughness

In UK,NL and DK detailed deposition models are used that use surface roughness to compute deposition fluxes. Local sources (new and existing) and local transport are covered in these models. In Germany, next to national model calculations also local deposition should be taken into account.

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Annex 1

Empirical critical loads of nutrient nitrogen for habitats mapped for the UK

UK Habitat	EUNIS code	Critical load range# (kg N ha^{-1} $year^{-1}$)	UK Mapping Value## (kg N ha^{-1} $year^{-1}$)
Saltmarsh	A2.53/54/55	20-30	25
Dune grassland	B1.4	8-15	9 for acid dunes 12 for non-acid dunes
Bog	D1	5-10	8, 9, 10 depending on rainfall modifier
Calcareous grassland	E1.26	15-25	15
Dry acid grassland	E1.7	10-15	10
Wet acid grassland	E3.52	10-20	15
Montane habitat	E4.2	5-10	7
Wet dwarf shrub heath	F4.11	10-20	10
Dry dwarf shrub heath	F4.2	10-20	10
Unmanaged beech woodland	G1.6	10-20	15
Unmanaged oak woodland	G1.8	10-15	10
Scots Pine woodland	G3.4	5-15	12
Other unmanaged coniferous or broad-leaved or mixed woodland	G4	G1: 10-20 G3: 5-15	12 (within ranges for broadleaved (G1) and conifer (G3))

#Ranges published in Bobbink & Hettelingh, 2011

##Agreed UK mapping values for the calculation of exceedances (Hall et al., 2011 & 2015)

UK critical loads and exceedance data are used in a range of applications:

- UK critical loads data are submitted to the Coordination Centre for Effects (CCE) for use in mapping and modelling activities at the European scale, and for integrated assessment modelling and the development of abatement strategies under CLRTAP.
- The temporal trends in UK critical load exceedances are used by the UK Government as a biodiversity indicator (B5a) on the pressures from air pollution (see JNCC website[21] and Hall et al., 2016).
- Nitrogen critical-load exceedance data are used by the SNCBs in the assessment of pressures and threats from pollution as part of Article 17 reporting for the EU Habitats Directive.
- Critical load and exceedance data for designated sites (SACs, SPAs, SSSIs) are widely used by the SNCBs for Ministerial submissions, evidence to policymakers and pollution regulators, casework for planning and permitting, informing state of the environment or resources reports, etc..
- Nitrogen critical loads have been used in the development of a decision framework to assess whether nitrogen deposition is a threat to, or cause of, unfavourable habitat condition on protected sites (Jones et al., 2016).
- Critical loads for habitats and designated sites, together with CBED and FRAME data, underpin APIS[22] which provides a resource for SNCBs, Regulators, Local Authorities and other users interested in the impacts of air pollution on ecosystems and designated sites.

[21] http://jncc.defra.gov.uk/page-4245

[22] www.apis.ac.uk

Annex 2

Table 1. Calculated critical nitrogen loads (kg N ha^{-1} y^{-1}) for Denmark with a criterion of 'no net loss of biodiversity compared to 1950, 1992 and 2010 as reference year.

Naturtype		**1950**	**1992**	**2010**
			kg N ha^{-1} $år^{-1}$	
1330	Strandenge	>8.1	>10.5	>12.0
2130	Stabile kystklitter med urteagtig vegetation (grå klit og grønsværklit)	2.6	6.7	8.1
2140	Kystklitter med dværgbuskvegetation (klithede)	6.2	7.5	8.0
2180	Kystklitter med selvsåede bestande af hjemmehørende træarter	9.0	10.4	12.2
2190	Fugtige klitlavninger	5.5	7.2	7.8
2250	Kystklitter med enebær	5.2	6.2	6.8
4010	Våde dværgbusksamfund med klokkelyng	7.3	9.0	9.9
4030	Tørre dværgbusksamfund (heder)	8.8	10.5	11.3
6120	Meget tør overdrevs- eller skræntvegetation på kalkholdigt sand	7.0	8.2	9.1
6210	Overdrev og krat på mere eller mindre kalkholdig bund	4.6	6.6	7.0
6230	Artsrige overdrev eller græsheder på mere eller mindre sur bund	4.5	7.3	7.9
6410	Tidvis våde enge på mager eller kalkrig bund, ofte med blåtop	6.3	7.4	7.9
7230	Rigkær	7.1	7.1	7.5
9110	Bøgeskove på morbund uden kristtorn	8.5	10.5	11.3
9190	Stilkegeskove og -krat på mager sur bund	7.7	9.8	10.6
9198	Skovbevoksede tørvemoser	9.7	11.2	12.4
9199	Elle- og askeskove ved vandløb, søer og væld	7.7	8.3	9.5

Appendix 1. Country report: France

Laurence Rouil, INERIS, France

Monitoring and modelling nitrogen and ammonia deposition

- What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas?
- If a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations?
- Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models?
- An assessment of the uncertainties in estimating nitrogen deposition at different scales.

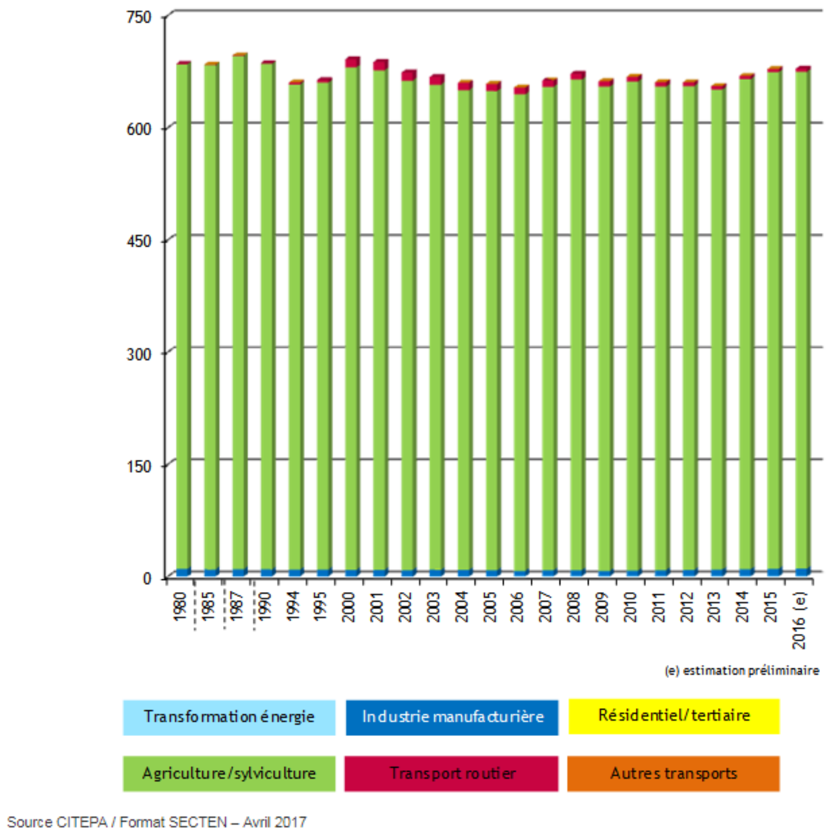
General overview

In France, local authorized associations in charge of air quality monitoring (called AASQA for Associations Agréées de Surveillance de la Qualité de l'Air) are entrusted with the implementation of the air pollution monitoring strategy which is declined in each administrative region. The national reference laboratory (LCSQA for Laboratoire Central de Surveillance de la Qualité de l'Air) coordinates local activities, defines reference methods for measurement and modelling, organizes lab-intercomparison campaigns, and gathers all the observations provided by local networks in the Centralised French air quality database called Geod'air. Geod'air is set-up to fulfill French air quality reporting duties according to the air quality Directives (2004/107/EC and 2008/50/EC) and the decision 2011/850/EU. The legal framework for air quality monitoring which describes stakeholders and their respective responsibilities and integrates transposition in French laws of the European legislation has been recently revised and is now defined in the so-called "arrêté Surveillance" adopted in 2017 on April, 22.

Ammonia is not mentioned as a regulatory air pollutant which requires routine and mandatory monitoring. Therefore, ammonia measurements, if performed by the local air quality networks, are not reported in the Geod'air national database.

However, since several years French authorities and local networks are concerned by PM episodes that are influenced by high airborne ammonium nitrate concentrations due to ammonia emissions, especially in spring and winter periods. Most of ammonia emissions comes from the agricultural sector (fertilizers or manure spreading, manure management, livestock management..). they remain quite stable for almost two decades (679 kt in 2016). 0 shows the spatial distribution of ammonia emissions in 2012. Large heterogeneity is highlighted; West and Central regions, as agricultural regions, are higher emitters than the East part of France.

Figure 1. Ammonia emissions in France (source CITEPA (1990-2016); https://www.citepa.org/en/air-and-climate/pollutants-and-ghg/aep/nh3).



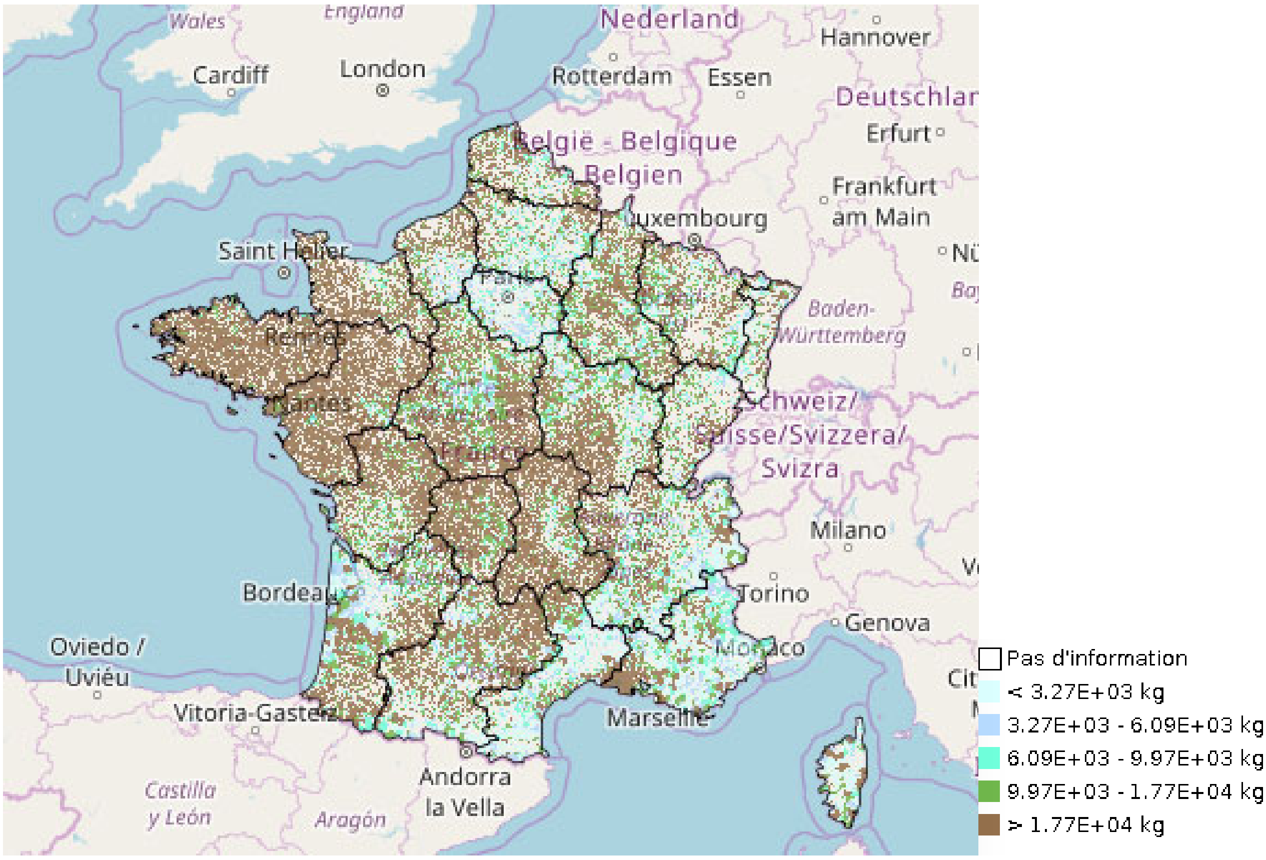
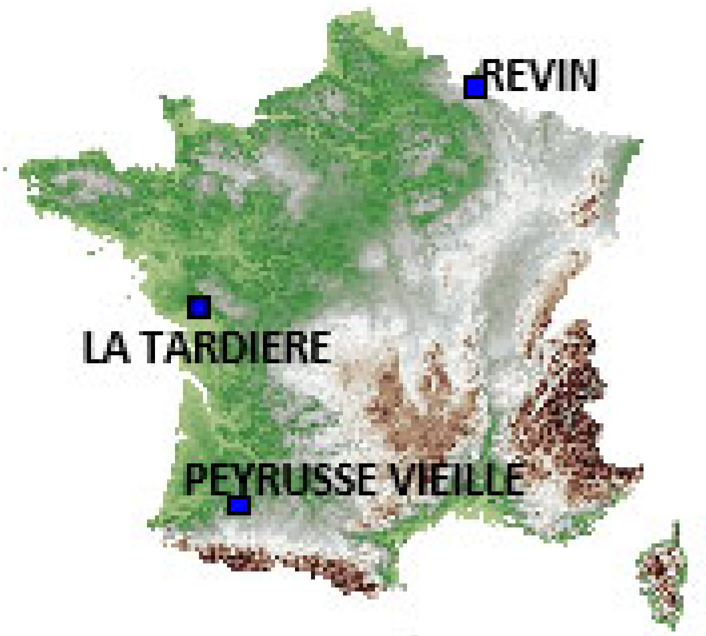


Figure 2. Ammonia emissions in France (metropolitan area) in 2012 (source : http://emissions-air.developpement-durable.gouv.fr).

According to the EMEP[23] monitoring strategy, French authorities developed a monitoring network dedicated to background air concentrations and deposition monitoring in rural areas. It is called the MERA network and includes about 10 monitoring stations. Until 2013, ammonia was monitored in three of them by filterpack devices. The approach was hampered by some uncertainties due to measurement artefacts but comparing the results from a station to another can be instructive. 0 displays the location of the three EMEP stations where ammonia was measured until 2013, and 0 represents the associated time series with annual means from 2005 to 2013. As expected, the station located in the Western part of France (La Tardière) where ammonia emissions are the highest, monitors the highest concentrations which are about 3 times higher than at the other sites. Revin, in the North-East of France, is where the concentrations were the lowest. Interannual variability is not so large except for La Tardière where it is more pronounced. No decreasing or increasing trends can be highlighted. It should be reminded that those measurements are in remote areas supposed to be far away from all local sources.

To conclude the analysis, 0 shows trends for reduced nitrogen concentrations in precipitations as measured by the MERA (EMEP) monitoring stations and by the CATAENAT monitoring network which is managed by the French office for Forests. The measurement sites are displayed on 0. Reduced nitrogen in the atmosphere is partly driven by ammonia emissions and by atmospheric chemistry processes. Therefore, a clear decreasing trend was monitored between 1990 and 1998 when sulfate decreased as well, and it became less pronounced after 2000. However, the reduced nitrogen trends in precipitations slightly decreased between 2002 and 2015 of about 2% per year.

Figure 3. Location of the 3 MERA stations monitoring ammoniac from 2005 to 2013



[23] Cooperative monitoring program of the Convention of Long Range Transboundary air Pollution (CLRTAP) of the United nation Economic Commission for Europe (UNECE)

Figure 4. Annual means of ammonia concentrations at the three EMEP stations run from 2005 to 2013 : Peyrusse-Vieille (PEY), Revin (REV) and La Tardière (TAR). Source: IMT-Douai.

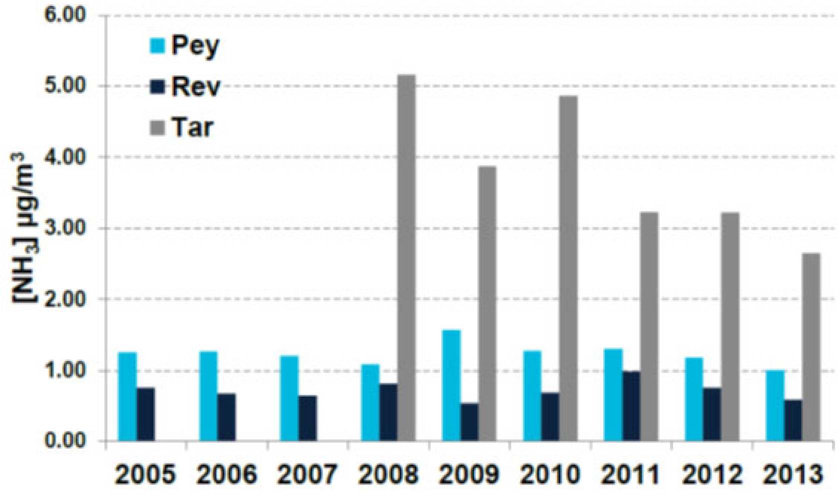


Figure 5. Trends in reduced nitrogen concentrations in precipitations measured at the MERA (EMEP) monitoring stations and the CATAENAT (French forest monitoring network) stations. Source : IMT-Douai and Office National des Forêts.

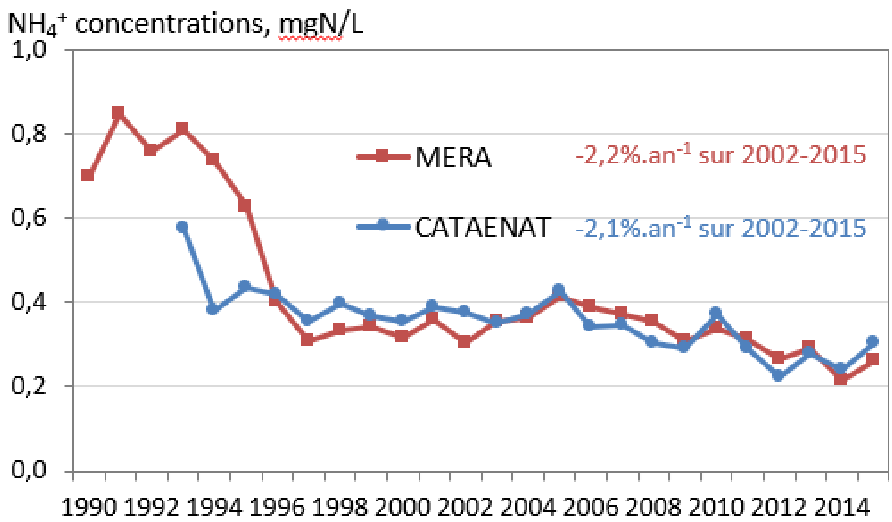


Figure 6. Location of the MERA (in red) and CATAENAT (in blue) monitoring stations.

Occurrence of PM episodes and stagnation of ammonia emissions encouraged French authorities, the reference laboratory and local air quality monitoring networks to increase the number of datasets and evidences likely to qualify and understand the influence of ammonia on air pollution issues. Therefore, even, if not regulated and if there is not standards for its measurement yet, few air quality monitoring networks in France planned to include ammonia monitoring in their regional monitoring strategy[24], as summarized in the table below. Moreover, the reference national laboratory (LCSQA) started in 2018 a study which aimed at assessing the performances of ammonia measurement devices to establish a protocol for monitoring in the future ammonia at the national scale. This work is completed by field campaigns based on both automatic devices and passive samplers that allow to describe ammonia ambient concentrations fields in several French regions. Most of those initiatives are leant to research projects which started recently (in 2017) and results are not available yet. However, some figures regarding ammonia concentrations in French regions can be issued from older field campaigns and are reported below.

Geographical area and AASQA	Type of Device	Device set-up
Air PACA	Picarro model G2103	Mobile Unit
Atmo AuRA (Rhône Alpes)	Picarro model G2103	Fixed station
Atmo Grand Est (Lorraine)	LGR model Ammonia Analyzer (NH3, H2O) rack version	Fixed station
Atmo Grand Est (Champagne Ardenne)	Picarro model G2103	Mobile Unit
Atmo Grand Est (Champagne Ardenne)	Picarro model G2103	Fixed Station
Atmo Nouvelle Aquitaine (Limousin)	Environnement SA AC31M model with rack NH3	Mobile Unit
Atmo Occitanie (Languedoc Roussillon)	Environnement SA AC32M model with avec rack NH3	Mobile Unit

Figure 7. Ammonia monitoring devices currently implemented in France in 2016.

Ammonia monitoring in French regions

Auvergne-Rhone-Alpes (AURA)

Since 2015, the local air quality monitoring network ATMO Auvergne-Rhone-Alpes routinely monitor ammonia concentrations in the South-east of Lyon, near Lyon-Saint Exupéry airport. PICARRO G2103 optical instrumentation has been evaluated and chosen for operations. The measurement site is located very close to large crops areas and farms and theoretically under the influence of agriculture activities.

Available observation data in 2015 demonstrates quite high ammonia concentrations levels and a large temporal variability (0). Highest concentrations were recorded in June and reached 20 µg / m^3 as an average, 12 µg / m^3 in May while they stayed below 5 µg / m^3 the rest of the year. The monitoring station being located in the country side, agricultural work could explain the peak.

[24] Regional air quality monitoring strategies have been revised by the 13 French air quality monitoring networks in 2016-2017

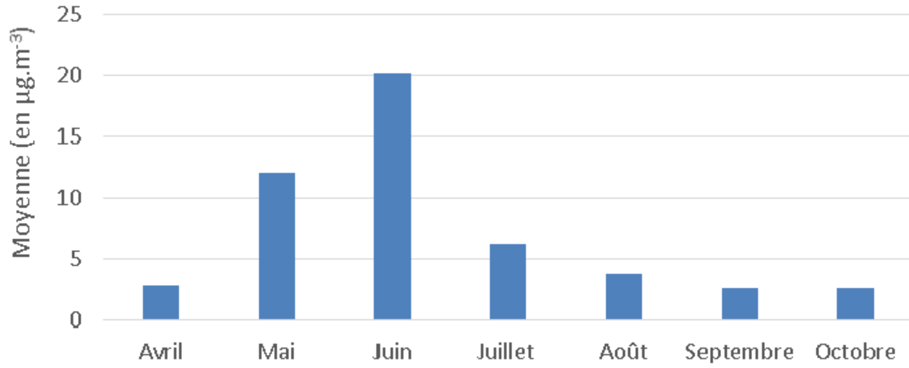


Figure 8. Ammonia concentration measured at Lyon-Saint Exupery site; April-October 2015 (Source : ATMO Auvergne Rhone-Alpes)

Haut de France (HdF)

A field campaign dedicated to the characterization of ammonia concentration levels in the North of France has been set-up my the local air quality monitoring network from April to November 2016. Passive samplers (Radiello) were run at seven monitoring sites, chosen regarding how they were influenced by ammonia emissions from agriculture (ranged from "urban" to "highly exposed"). The results are provided in the table below (0). Ammonia concentrations ranged from 1,8 to 7,8 µg / m³ as an average over the considered period. Highest concentrations were not systematically found in the most exposed areas as expected. In urban areas concentrations were about 3,8 µg / m³, which is significant. Highest concentrations were recorded in August 2016. The most exposed locations show the highest variability.

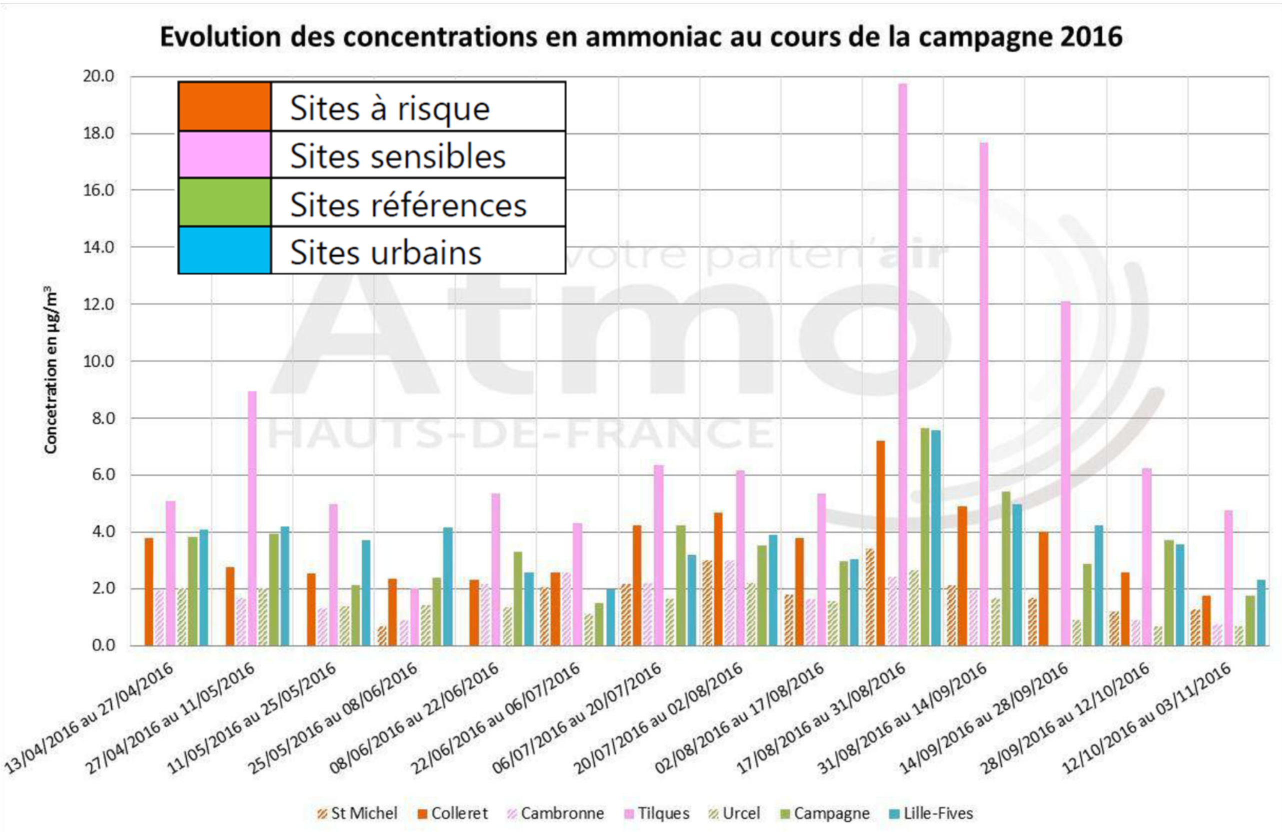


Figure 9. Synthesis of the results of the ammonia field campaign held from April to November 2016 in Haut de France region (source ATMO Haut-de France).

Grand Est (GE)

The AMPAIR project is a French research project funded by the Agency for the environment (ADEME) and the ministry in charge of ecology, which aims at describing accurately the ammonia emissions processes accordingly to knowledge about agricultural practices. It focuses on the East part of France where 5 monitoring sites have been set-up to monitor ammonia concentrations in 2016-2017. The results are not published yet but show an excellent correlation of the time series between the sites, and highest concentrations (that could exceed locally 50 µg / m^3) during spring time . Those results will be used to calibrate inorganic aerosol formation schemes in chemistry transport model and to develop a high resolution (in time) ammonia emission inventory in the region.

Provence-Alpes Côte d'Azur (PACA)

The South-East of France is not characterized by intensive agriculture and is not the most sensitive in terms of influence of ammonia. However, in 2015-2016, Air-PACA, the local air quality monitoring network decided to set-up a field campaign to objectively assess ammonia air concentrations in the region, with a focus on the influence of large point sources (LPS) that may be responsible for a significant part of regional emissions. Passive samplers were used, the quantification limit being 0,3 µg / m^3.

The results show quite homogeneous and low, except in two sites in the South-East of the domain. Investigation showed that concentrations are the highest in summer.

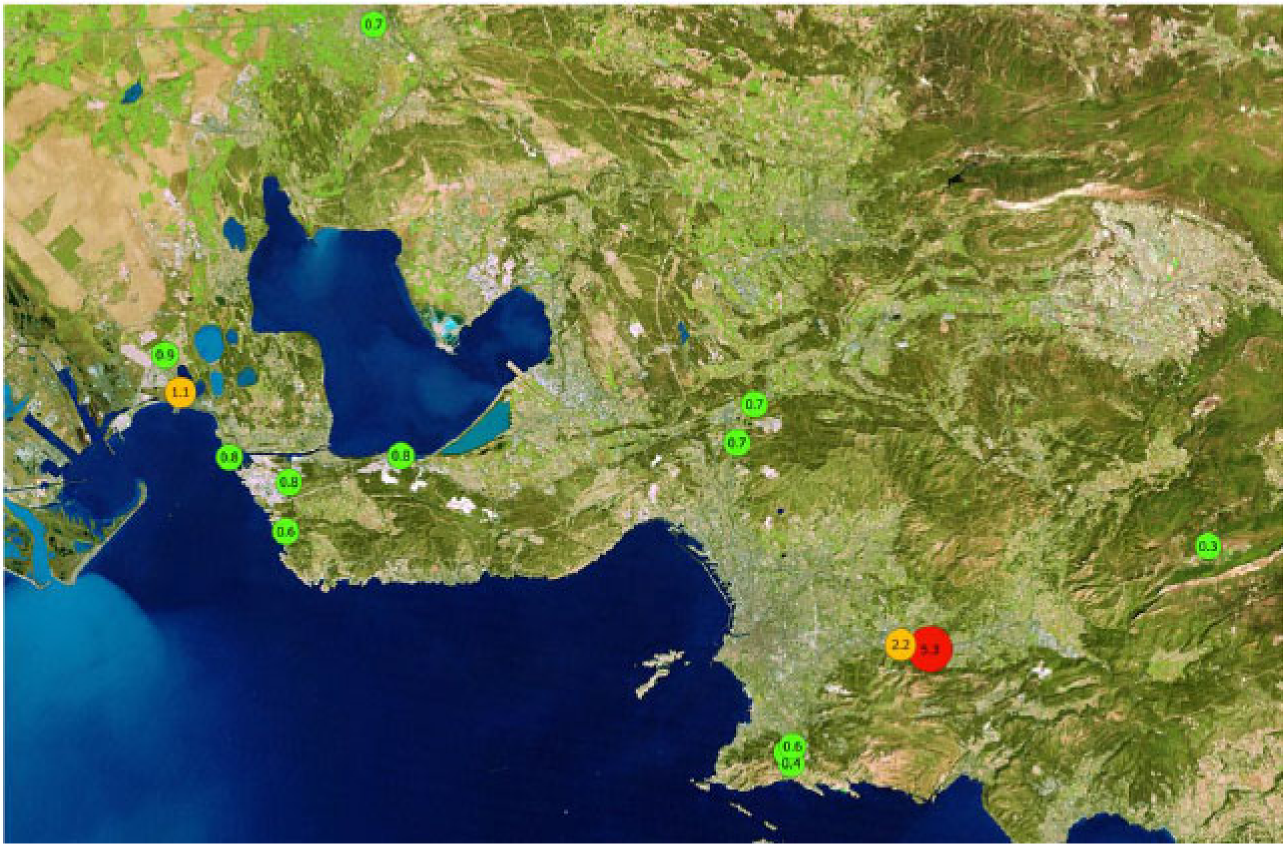


Figure 10. Results of the 2015-2016 ammonia field campaign in Provence-Alpes Cotes d'Azur (Source: Air- PACA).

Ammonia modelling

A number of national research projects dedicated to ammonia's behavior and fluxes modeling is currently on-going in France. The reference model is the chemistry-transport model CHIMERE developed by INERIS and the national research center (CNRS) for more than 15 years now. This model is used for air quality forecasting and mapping (see www.prevair.org) at the national and regional scales and for assessing the impact on air pollutant concentrations and deposition of emission reduction strategies. Particulate matter chemistry, and in particular complex processes related to nitrogen compounds are taken into account in the model. Current project aim at analyzing the impact of spatio-temporal variability of ammonia emission on PM formation and transport. In the experiments previously reported, several modelling activities developed. But they are generally focused on assessing the capacities of models to simulate correctly atmospheric PM concentrations (including ammonium nitrate and ammonium sulfate) rather than on deposition of nitrogen compounds to assess eutrophication and acidification.

In 2008, INERIS simulated with CHIMERE nitrogen and sulfur deposition levels in France over the 1999-2008 period and showed that they remained almost constant. Wet and dry deposition processes were distinguished. 0 and 0 present the results for the year 2007, and highlight the most exposed areas. Wet deposition is strongly correlated with precipitations and mainly impact the East and North-East of the country. Britany appears as the most sensitive areas in the country regarding NHx deposition since it is where ammonia emissions are the highest.

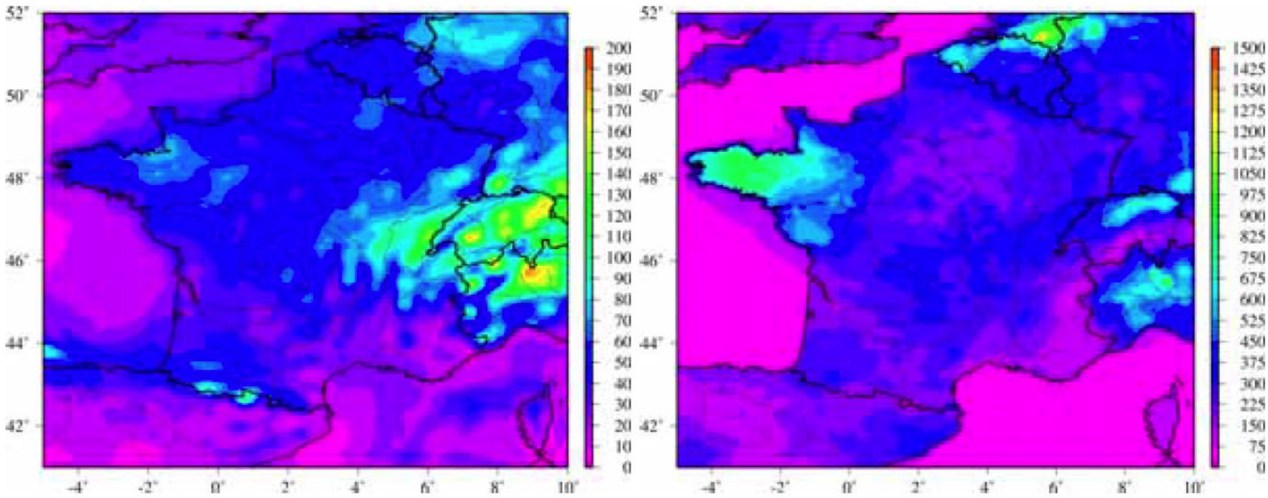


Figure 11. Wet (left) and dry (right) deposition (kg/km²/year) of reduced nitrogen (NHx) computed by the CHIMERE model and averaged over the year 2007 (source INERIS).

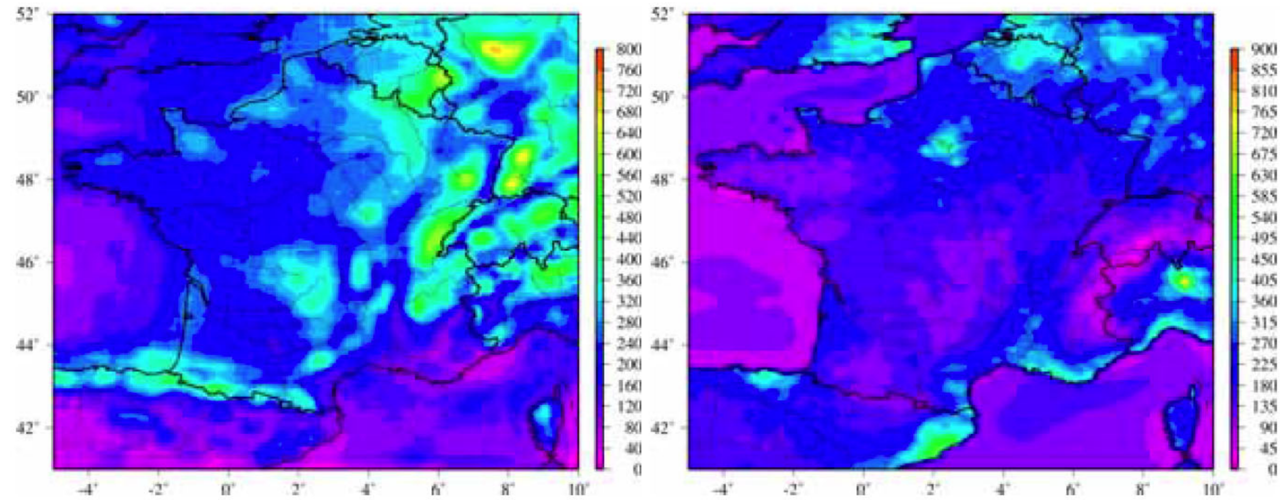


Figure 12. Wet (left) and dry (right) deposition (kg/km^2/year) of oxidized nitrogen (NOx) computed by the CHIMERE model and averaged over the year 2007 (source INERIS)

Ammonia-sensitive areas

- Is there a national definition of ammonia sensitive areas?
- Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?
- Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

In France, no specific definition for ammonia sensitive areas is set. A number of habitat types is categorized according to the implementation of the Habitat Directive.

Effect of ammonia regulations

- The location of husbandry farms in relation to ammonia sensitive areas.
- Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, both 1) due to the general reduction in deposition and 2) due to change in location of husbandry farms and 3) as a result of the national ammonia regulation in relationship to the Habitat Directive?

The Industrial Emission Directive (IED- 2010/75/EU) is the main driver in France to support ammonia emission reduction strategies for husbandry farms. 3400 sites are concerned and half of them are located in Britany. The Eu decision 2017/302 establishing best available technologies conclusions for the intensive rearing for poultry and pigs will lead to the re-evaluation of the emissions control strategies applied in farms by April 2018 and February 2019. A significant reduction of ammonia emissions is expected but its impact is not quantified or assessed yet. This initiative led to a complete review of emission inventories methodologies in the husbandry activities, thanks to an ambitious project that started two year ago, ELFE, funded by the Ministry of Agriculture and the Ministry in charge of the Environment, that gathered skills from public research institutes (IRSTEA, INRA) together with expert from technical institutes in the agriculture field. A complete review of emission factors has been performed and tools that will allow simple evaluation of ammonia, methane, nitrogen oxides, volatile organic compounds and nitrous oxide emissions will be made available to assess the environmental impact of those sites.

It is expected that such information will allow to simulate nitrogen deposition, thanks to chemistry-transport models, but such results are not available yet.

Critical loads

- Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?
- Are critical levels used?
- To which extend, and how are calculations based on the Mapping Manual from UNECE?
- Are calculated critical loads based on biodiversity targets used or planned to be used in the future?
- If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?

Critical loads are evaluated and calculated in France by ECOLAB research laboratory belonging to the National Research Center. Anne Probst is the National Focal Point for the Coordinating Center on Effects (CCE) under the Convention on Long Range Transboundary Air Pollution (CLRTAP). ECOLAB calculates critical loads that are reported to the CCE according to the methodologies described in the Working Group on Effects Mapping Manual. Therefore, critical loads (CL) for acidification and for eutrophication were recently (2017) updated by using the SMB model for French forest ecosystems. The French Critical Loads database has been updated by computing and using the new 0.10° x 0.05° EMEP grid from the CLRTAP.

An attempt to extrapolate to effects on biodiversity accounting for climate change has recently being performed (Rizetto et al., 2016), but such results are not used for policy decision making.

- If model calculations are used:
    - Describe the models and the data included in the calculations
    - Are target loads used for the specific areas; if so, how?
    - Is there a reference year in the calculations, and if so, which?
- Are different methods used for setting critical loads for areas inside and outside of Natura 2000 areas, and if so, how?
- How often are the critical loads updated?
- Describe if and how nature management e.g. grazing is taken into account in the model calculations.

Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

- Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and I f so: are empirically critical loads or national model calculations and local data used for the specific nature area?
- To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included?
- Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
- Describe briefly if and how local scale transport and deposition is calculated?

- Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?

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Appendix 2. Country report: Germany

Thomas Scheuschner, UBA, Germany; Markus Geupel, UBA, Germany; Martijn Schaap, TNO, The Netherlands; Carlijn Hendriks, TNO, The Netherlands

Preface

The German administration of the nitrogen and ammonia related with respect to the protection issues is rather diverse. Indeed, on the federal level the Ministry for the Environment and Nature Protection is setting the overarching frame but with regard to the execution and implementation of the legislation in responsibility of the federal government there are two independent agencies: One for Nature Protection (BfN) and one for the Environment (UBA) including Immission Control issues. Furthermore the legislation for licensing installations such as housing, roads or combustion plants lies in the responsibility of the federal states. Indeed, there are a federal immission control and an independent nature protection act; however, the implementation within these frameworks is in the hand of the federal states. This leads to the fact that with regards to some aspects in different federal states different assessment levels are in force. The following text is written by UBA and colleagues and does not refer to all deviating approaches within the federal states.

Monitoring and modelling nitrogen and ammonia deposition

What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas?

If a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations?

The concentrations of the different components in precipitation in Germany are measured by an extensive countrywide measurement network maintained by various national and regional monitoring programs and authorities. The national UBA network consists of 11 background sites, evenly distributed throughout the country. The various regional networks in the authority of the federal states add 249 stations to the database. The UBA network samples on a weekly rhythm, whereas the regional networks may operate at a weekly, two-weekly, four-weekly or monthly basis. The sampling strategies of the regional networks are not synchronised. The data collected contains precipitation amount as well as concentrations of SO_4^{2-}, NO_3^-, NH_4^+, Mg^{2+}, Na^+, Ca^{2+}, K^+, Cl^- as well as pH in rain water.

At the available stations a variety of samplers are used to quantify the wet deposition. Within these samplers two types can be differentiated, wet-only and bulk deposition samplers. Bulk samplers collect precipitation in a bucket, which is open all the time. This sampling method has a slight tendency to cause an overestimation of the wet deposition, because it is susceptible to dry deposition during dry conditions. In contrast, wet-only samplers collect the precipitation in a funnel, which is only open when it rains. A sensor registers whether it is raining and the lid is automatically opened at the beginning of a rain event and closed at the end. Within Germany the majority of the data is obtained with bulk samplers as only 40 out of the 260 stations sample with wet only samplers. Hence, to better compare the concentration of bulk samplers with that of wet only samplers correction factors are available based on earlier investigations in which measurements with wet-only samplers and bulk samplers were performed simultaneously (Gauger et al., 2000, 2008).

Concentrations of gaseous and particulate compounds (NO_x, NH_3, NH_4, NO_3) in air are also monitored in national and regional networks, on an hourly, daily, or multi-day basis. For the gaseous compounds regulated by the Air Quality Directive the monitoring networks are extensive and the monitoring is obligatory. UBA collects the data from the regional networks, publish the data on a national map server (link) and reports the data to European authorities. As for NH_3 there are no concentrations limits in the Air Quality Directive, there is no monitoring obligation for NH3 on a national level. That's why ammonia is not measured regularly in most of the federal states. However there are some federal states measuring ammonia on voluntary basis but the networks are not very extensive[25].

Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models?

A combination of modelling, observations and empirical relations is used to estimate the total nitrogen background deposition in Germany. The chemistry transport model LOTOS-EUROS, a regional 3-D model that simulates emission, transport, chemistry and deposition of air pollutants in the lower troposphere. The LOTOS-EUROS model is state-of-the-art and is one of the few chemistry transport models that uses a description of the bi-directional surface–atmosphere exchange of NH_3 (Wichink Kruit et al., 2010; 2012). The model is used to model the dry deposition distributions for nitrogen and sulphur components at 7x7 km^2 across Germany. For this purpose we use ECMWF meteorology and emission data for the respective years. Long range transport is incorporated by nesting the German study area into a simulation over Europe as a whole. Besides the deposition fluxes also the modelled dry deposition velocities and wet deposition maps are used the deposition assessment.

The LOTOS-EUROS model has a tendency to underestimate the observed wet deposition. Moreover, the variability in wet deposition fluxes is generally underestimated in chemistry transport models. Consequently, it has been decided to use the observed wet deposition as a basis. The density of the observations allow to make an empirical assessment of the wet deposition flux across Germany. The wet deposition data are subjected to a QA / QC procedure and used to correct the modelled rain concentration distribution towards the observed data using residual Kriging. The resulting rain water distribution is combined with a high resolution precipitation distribution (1x1 km) to arrive at the final wet deposition estimates. In this way a highly resolved map based on empirical data is obtained that benefits from the process knowledge incorporated in the LOTOS-EUROS model for nitrogen and sulphur components.

[25] https://www.lfu.bayern.de/luft/schadstoffe_luft/eutrophierung_versauerung/ergebnisse/index.htm

https://www.umwelt.niedersachsen.de/download/71268

For elevated locations, occult deposition may be a substantial contribution to total deposition. The occult deposition flux is derived by estimating the deposition flux of cloud and fog water which is combined with the pollutant concentration in the cloud water. The cloud water concentrations are deduced from the rain water concentrations under assumption that a pollutant is more concentrated in a cloud droplet than in a rain droplet. The resolution at which this calculation can be performed is not able to capture high resolution variability, which means that the occult deposition reflects background values for larger regions and do not reflect the deposition at very exposed sites.

The total nitrogen deposition calculated at a 1x1 km scale is compared to the critical loads for sensitive areas to calculate the critical load exceedance on a national level. This data is used in national indicators but not for local or regional licensing.

An assessment of the uncertainties in estimating nitrogen deposition at different scales

The LOTOS-EUROS model has been used in a multitude of model inter-comparison studies (REFS). Comparisons specifically aimed at deposition have been performed with the EMEP model and observation data, as well as with wet deposition observations in Germany and its surrounding countries. The final estimate of nitrogen deposition, combining modelled and measured values, has undergone the same comparison with observation data from the EMEP and national networks. Within Germany, a comparison with canopy budget data from the ICP Forest Level II Network is performed. The results of these comparisons are in general satisfactory. More than 50 % of the analysed data lay within + / - 20 %. Comparing the results calculated for Germany to observations and calculated estimates of deposition for other countries, we estimate that the uncertainty is in the order of 30%, although for regions with high variability of orography, emissions and land use, higher local uncertainties should be assumed. While NH_x deposition was in general found to be close to observations and other calculation results (except for local effects that our calculation cannot capture because of its resolution), NO_y deposition was underestimated by up to 30%.

As always with chemistry transport modelling, uncertainties in the emission totals as well as geographical and temporal variability of emissions will be reflected in the uncertainties of the final result.

Ammonia-sensitive areas

Is there a national definition of ammonia sensitive areas?

No. As ammonia is not regulated within the EU Air Quality Directive, there is no national obligation to measure ammonia and in legislation there don’t exist any definitions of ammonia sensitive areas

Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?

The Federal Agency for Nature Protection publishes a list of the habitat types and describes them qualitatively[26]. There are no classifications for ammonia. There is just a verbal classifications with regard to risk through nutrient input. Following this publication the following habitat types are threatened by nutrient inputs: 2180, 2310, 2320, 2330, 4010, 4030, 5130, 6110, 6120, 6210, 7110, 7140, 7140, 7150, 7150, 8230, 9110, 9190, 91T0, 91U0.

Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

Outside the Natura 2000 areas the federal states have their own classification systems for all other biotope types.

Effect of ammonia regulations

The location of husbandry farms in relation to ammonia sensitive areas.

Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, due to

1) *the general reduction in deposition*

The nationwide modelling of ammonia concentration and nitrogen deposition with the LOTOS-EUROS model for the time period 2000 – 2015 allows to document trends with regard to the background deposition or the background concentration of ammonia. Local effects of animal husbandry installations cannot be taken into account in this modelling approach, as the input data of the emissions and the modelling grid are to coarse.

2) *change in location of husbandry farms and*

If there is knowledge about it this knowledge lies at the regional authorities within the federal states.

3) *the national ammonia regulation in relationship to the Habitat Directive*

A time series of the area-wide modelled critical load exceedance for natural and semi-natural ecosystems in Germany for the period 2000-2015 is shown below. This figure (fig 1) shows that there has been some improvement and that less areas receive an excess amount of nitrogen. This is mainly due to a reduction in NO_y deposition (because of lower NO_x emissions). The deposition of NH_x has not decreased in the past two decades. An explicit national assessment of the situation in Natura2000 areas is not possible, as there is no geographical national dataset where the habitats are located within a Natura2000 area.

[26] https://www.bfn.de/themen/natura-2000/lebensraumtypen-arten/lebensraumtypen.html

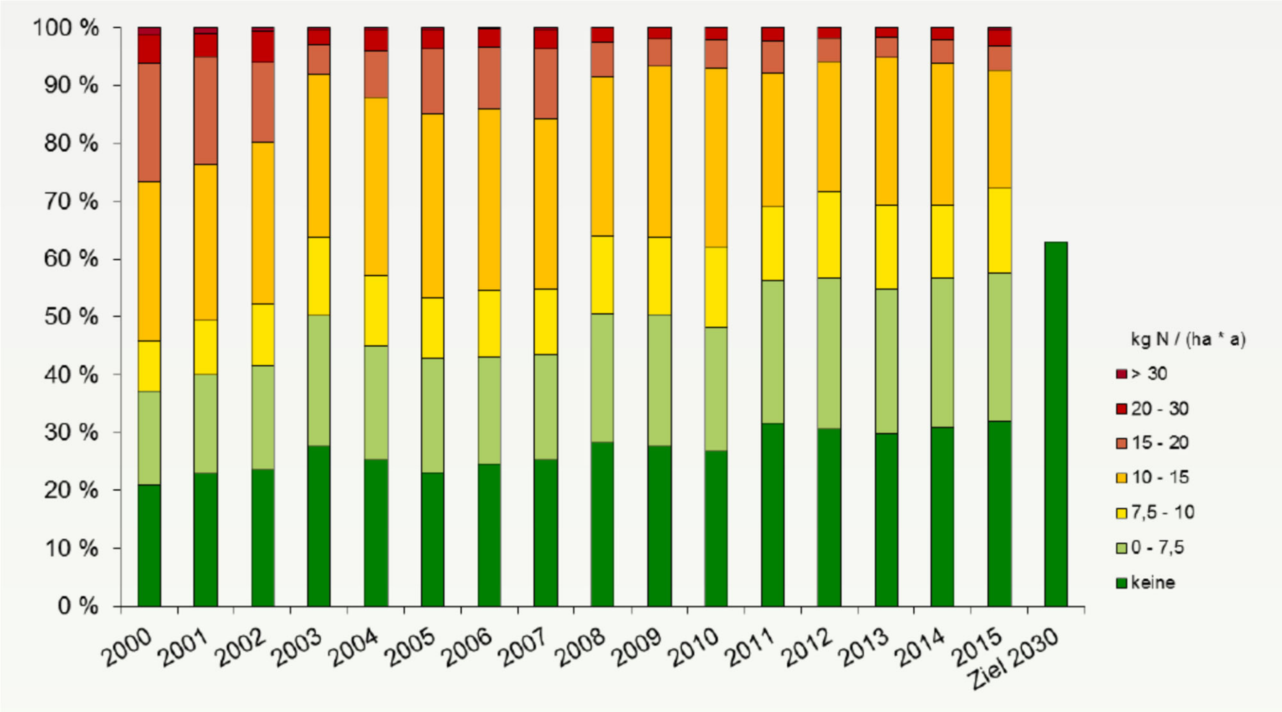

Figure 1. Time series of the area-wide modelled critical load exceedance for natural and semi-natural ecosystems in Germany for the period 2000-2015

Critical loads

Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?

Percentage of sensitive ecosystem area where Critical Loads for nutrient nitrogen are exceeded on a national level assessment is used as an aggregated indicator in the set of indicator to German Strategy for Sustainability and the German Strategy for Biodiversity. In this context SMB-modelled Critical Loads are applied.

For licensing approaches under the federal Immission control federal states use empirical Critical Loads in combination with modifying factors to assess total nitrogen deposition composed of background deposition and project related deposition. There is harmonised approach that all federal states shall implemented, however they are not obliged[27]

For licensing approaches under the nature protection legislation, i.e. Natura 2000 impact assessment there exist no harmonised approach yet. Different sets of Critical Loads are used in different federal states. However there is a harmonised guidance document on a national level for licensing road projects under preparation where modelled Critical Loads are applied. This habitat specific set of Critical Loads for eutrophication and acidification is modelled

[27] LAI_N-Leitfaden_Langfassung_März_2012

following the SMB approach applying the BERN-Model and taking into account regional soil and climate data[28]. Once implemented in the road construction regulations, it is foreseen to transfer the approach to all other Natura 2000 assessments with regard to nitrogen and sulphur deposition, too (i.e. husbandry installations or combustion plants).

Are critical levels used?

Within the national air quality regulation for the good status of air quality (39. Bundes-Immissionsschutz Verordnung – 39. BImSchV) there are no concentration limits defined for ammonia in ambient air quality. The above mentioned 39. BImSchV-regulation is inter alia an implementation of the EU Air Quality Directive.

In contrary to that within the current version of the federal Immission control act (2002), where emission and Immission limits are defined to protect environment and humans against negative effects of industrial air pollution, there are concentration limits for ammonia defined. The definitions mainly are binding in the framework of licensing new installation. Currently a project can be realised if a total concentration (background and project related) of 10 µg NH3 m^{-3} at the point of assessment (sensitive ecosystem area) is not exceeded. For the project itself there exist a cut-off criterion of 3 µg NH3 m^{-3}. That means, if the project itself causes additionally less than 3 µg m^{-3} at the point of assessment, the project can be realised. Within the current revision process of the federal Immission control act UBA proposed from a scientific point of view to lower the values to 3 and 1 µg m^{-3} respectively. However the revision is not finalised yet and it remains unclear if there will be new values in a revise version.

To which extend, and how are calculations based on the Mapping Manual from UNECE?

As described above the exceedance of the SMB-Critical Load is used as aggregated indicator to validate the success of the German Strategy for Sustainability and the German Strategy for Biodiversity. The SMB-Critical Loads used for this purpose are calculated according to the equations of the Mapping Manual from the UNECE. Even if the equations are very consistent with the Mapping Manual, some variations might be found when it comes to the derivation of the input data. Since there is no data set for receptors on a national scale available yet, several steps of derivations are necessary to receive a comprehensive map of valid receptors. Here the information of CORINE Landcover, a National Soil map and long-term averages of climate data form the basis of the derivation of the receptors.

The descriptions in the Mapping Manual of the calculation for several parameters is not very specific for certain parameters. In such cases (e.g. Nitrogen Immobilisation), individual approaches were tested and applied in Germany.

[28] Balla, S., et al. (2013). Untersuchung und Bewertung von straßenverkehrsbedingten Nährstoffeinträgen in empfindliche Biotope - Bericht zum FE□Vorhaben 84.0102/2009 der Bundesanstalt für Straßenwesen, Forschung Straßenbau und Straßenverkehrstechnik Band 1099. BMVBS. Bonn, BMVBS, Abteilung Straßenbau. 1099. http://www.bast.de/DE/Publikationen/Download-Berichte/unterseiten/naehrstoffeintrag-bericht.html.

All these deviations are well documented in the National Reports published by the CCE.

If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?

As described above the empirical critical loads are the basis of the LAI guideline, which is again rather a policy than an obligation. Instead of modifying factors, a system of additional loading was implemented in this guideline. The allowed additional loading can be derived by a complex matrix of protection category and exposure risk, while the protection category is divided in to three different functions (livestock, regulation and production).

Describe the models and the data included in model calculations

Main input data sets are:
- Climate data (temperature and precipitation) using the long-term mean values, timeframe 1981 – 2010,
- Soil data (reference soil profile),
- Seepage rate,
- Land use data (CORINE 2012) and
- Deposition data (PINETI III project)

The BERN model was used to derive the receptors from the intersected information of the Landuse, soil map and climatic data. The BERN model is an empirical niche model developed by the private company ÖKO-DATA GmbH.

Are target loads used for the specific areas; if so, how?

No.

Is there a reference year in the calculations, and if so, which?

Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

- Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and if so: are empirical critical loads or national model calculations and local data used for the specific nature area?
    - Yes
    - Immission Control legislation (no Natura 2000 is affected): Empirical Critical Loads in combination with large modifying factors
    - Nature protection legislation: Different sets of Critical Loads are applied depending on the federal state, mostly to always local data is used to define / to assess the Critical Load. However there is a national data set for modelled habitat specific critical loads but its application is not approved finally. No modifying factors are applied.
- To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included?

- Background data comes from the national area-wide modelling based on a 1*1 km² grid[29], however due to restrictions in resolution of the model it is recommended to additionally take local deposition sources into account for the assessment of the “real” background deposition.
- The assessment under the nature protection legislation always includes local data on the sensitivity of the assessed habitat. A lot of cases are taken to court, so the scientific substantiation of the sensitivity of the habitat is an essential part of the impact assessment.
- The assessment under the immission control regulations (when no Natura 2000 habitats are affected) in most cases can be performed without local assessment data for the sensitivity of the biotope. The modifying factors and ruling cut-off criteria for project applicants are so high that a licensing is mostly possible (with restriction in very large industrial husbandry installation) for smaller installations as long as a Natura 200 area is not affected.

- Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
  - Under the Natura 2000 impact assessment there are different (but similar) approaches in the different federal states.
  - The guidance document for assessments of road construction projects suggests that in principal management measures such as mowing can be used to balance inputs and outputs with regard to the Critical Load. If this comes into force this regulation would be transferred to all other project assessments under the Nature 2000 impact assessment.
  - As far as known grazing and resulting ammonia emissions and nitrogen deposition or other area-related agricultural activities causing Nitrogen emissions (such as spreading of manure) don’t have to be assessed with respect to sensitive areas.
- Describe briefly if and how local scale transport and deposition is calculated?
  - UBA offers a modelling tool called AUSTAL2000[30]. This tool is generally used to calculate local scale transport and deposition
- Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?
  - For the large scale calculations of the background deposition, yes. There 10 different landuse classes with different roughness lengths implemented in LOTOS-EUROS model. For the small scale calculation of project related deposition the AUSTAL2000 is model is used, there too, a selection of different roughness lengths can be implemented as an average value for the whole modelling domain.

[29] LOTOS-EUROS modelling (see above) published by UBA: http://gis.uba.de/website/depo1/

[30] https://www.umweltbundesamt.de/themen/luft/regelungen-strategien/ausbreitungsmodelle-fuer-anlagenbezogene/uebersicht-kontakt

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Appendix 3. Country report: United Kingdom

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Introduction

To get an overview of how factors affecting impacts of ammonia deposition on different habitats are addressed in the ammonia regulation in comparable countries in Northern Europe, the Danish Environmental Protection Agency commissioned a project to compare national methods for measuring and modelling impacts on ammonia-sensitive natural habitats. This report describes methods applied in the UK.

The UK National Focal Centre (NFC) for Critical Loads Mapping and Modelling is responsible for (a) national-scale critical load and exceedance data for acid- and nitrogen-sensitive habitats and designated sites, including the development of biodiversity-based critical loads; (b) the submission of UK data in response to "Calls for Data" under the Convention on Long-Range Transboundary Air Pollution (CLRTAP); (c) representing the UK at meetings of the CLRTAP International Cooperative Programme on Modelling and Mapping. This work is funded by the UK Department for the Environment, Food and Rural Affairs (Defra) and the current contract is carried out by CEH. Defra also funds the National Atmospheric Emissions Inventory (NAEI) which provides mapped data on pollutant emissions including NOx and ammonia. Under separate funding from the Environment Agency, CEH is responsible for the operation, running and reporting of data from four national pollutant monitoring networks funded by the UK Department for the Environment, Food and Rural Affairs (Defra) and administered by the Environment Agency. The NAEI and monitoring data are used for emission and transport modelling using the CBED, FRAME and EMEP4UK models, to generate pollutant concentration and deposition maps for the UK.

Designated sites in the UK consist of Special Areas of Conservation (SACs) and Special Protected Areas (SPAs), which together comprise the Natura 2000 sites, and Areas / Sites of Special Scientific Interest (A / SSSIs[31]). SACs may contain one or more A / SSSIs, and there may be overlap between the SAC and SPA areas. The sites are managed by the Statutory Nature Conservation Bodies (SNCBs), and permit applications for development within specified distances of a designated site are assessed by the relevant regulatory body with input from the SNCBs (Table 1).

[31] SSSI in England, Wales and Scotland, ASSI in Northern Ireland

Table 1. SNCBs and Regulatory Agencies for different countries within the UK.

UK country	Statutory Nature conservation agency (SNCB)	Regulatory agency
England	Natural England (NE)	Environment Agency (EA)
Wales	Natural Resources Wales (NRW)	Natural Resources Wales (NRW)
Scotland	Scottish Natural Heritage (SNH)	Scottish Environment Protection Agency (SEPA)
Northern Ireland	Council for Nature Conservation and the Countryside (CNCC)	Northern Ireland Environment Agency (NIEA)

Analysis Framework

1. Monitoring and modelling nitrogen and ammonia deposition

1.1 What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas?

The UK Eutrophying and Acidifying Atmospheric Pollutants (UKEAP) project (funded by Defra) consists of four rural air pollution monitoring networks (Table 1.1), the operation of two UK EMEP Supersites (Chilbolton and Auchencorth) and provides support for EMEP science in the UK.

The UKEAP Networks include (a) the Environmental Change Network[32] which is embedded within the EU eLTER network[33]; and (b) Natural England[34]'s Long Term Monitoring Network (LTMN[35]:) which has the long-term monitoring of total nitrogen deposition as one of its core aims.

Table 1.1. UKEAP Monitoring Networks

Network	In operation since:	No. sites	Measurements	Frequency
NAMN: National Ammonia Monitoring Network[#]	1996	72[##]	Concentrations & deposition of NH_3 & NH_4^+	Monthly
AGA-Net: Acid Gases & Aerosol Network	1999	27[##]	SO_2, HNO_3, HONO, inorganic composition of PM_4	Monthly
Precip-Net: Precipitation chemistry Network	1985	41	Anion & cation concentrations in precipitation	Fortnightly
NO_2-Net: Rural NO_2 diffusion tube Network	1994	24	NO_2 concentrations	Every 4 weeks

[#]See Section 1.2 for further information on this network.

[##]See Figure 1.1

The UKEAP Networks aim to:

- Evaluate policy measures to reduce concentrations and deposition;
- Estimate secondary formed components of particulate matter.

Measurements from these networks are:

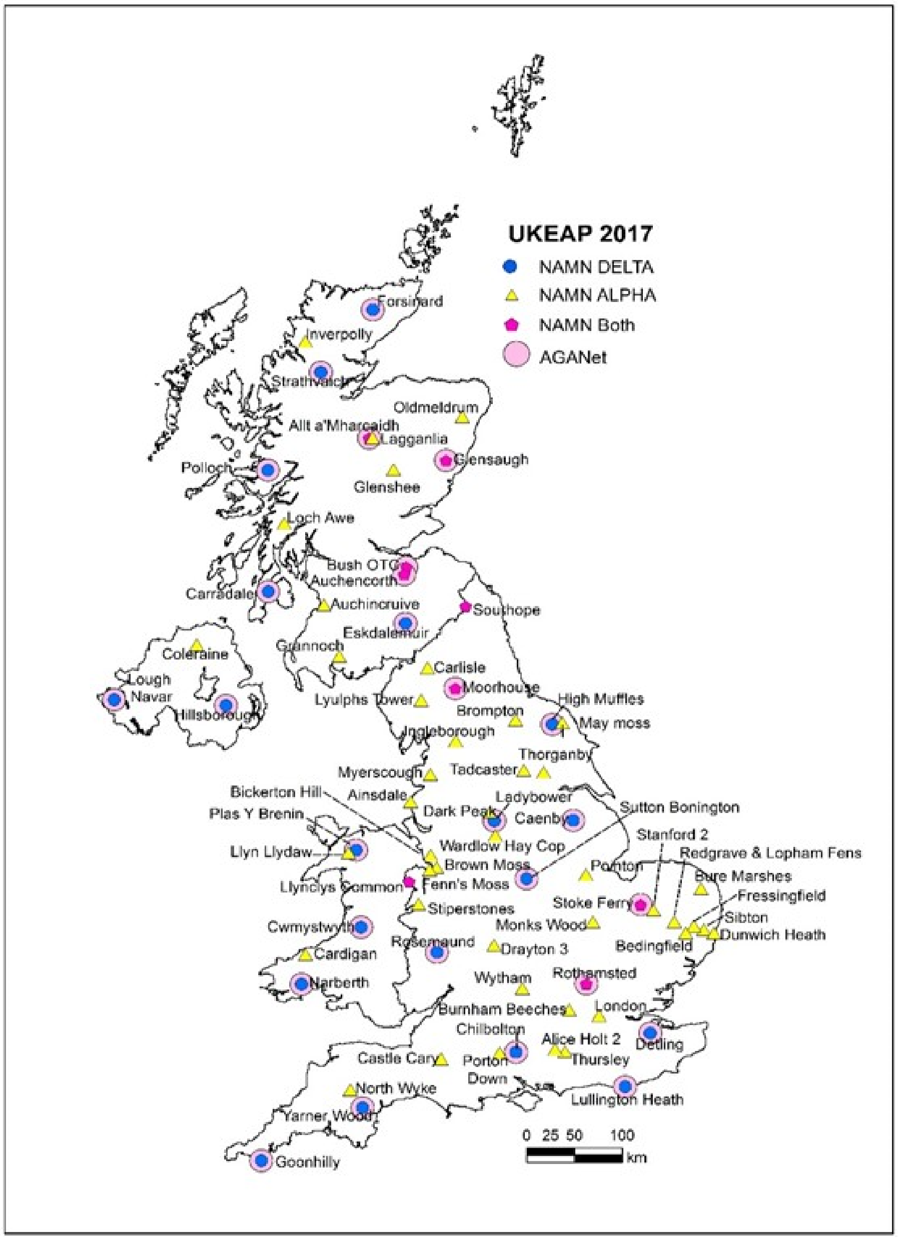
- Traceable to the point of collection and in a format that is INSPIRE compliant;
- Provided to the Defra Data Dissemination Unit (DDU) in a format consistent with all other sampling networks;

32 http://www.ecn.ac.uk
33 http://www.lter-europe.net/elter
34 https://www.gov.uk/government/organisations/natural-england
35 http://publications.naturalengland.org.uk/publication/4654364897050624

- Flagged with both a validity flag (IPR requirement) and an EMEP flag (in respect of concentration measurements). The flags indicate data validity status and any known issues (local source effects, high variability in the sampling etc.).

Quarterly unratified data followed by annual ratified data are available via the UK-Air website[36] from June in the year following collection, and disseminated in an appropriate format to atmospheric and ecosystem impact modellers.

Figure 1.1. UKEAP ammonia (NAMN) and acid gas and aerosol (AGA-Net) monitoring sites in the UK.



The UKEAP data are used to produce annual concentrations and wet and dry deposition maps of nitrogen and sulphur pollutants (see Section 1.3). The UKEAP project is led by CEH scientists, who are embedded in the ACTRIS

[36] https://uk-air.defra.gov.uk/

programme[37], CEN Working Groups[38] and on the Task Force for Measurement and Modelling (TFMM[39]) to represent and adopt standards and best practice approaches to the measurement of background air quality on behalf of the UK Environment Agency and the Department of Environment, Food & Rural Affairs (Defra). Figure 1.2 summarises the dissemination and use of UKEAP data.

Sampling at the EMEP Supersites is coordinated with EMEP. Data on speciation of $PM_{2.5}$ at rural background locations provide input to Article 6 and Annex IV of the EC Directive on Ambient Air Control and Clean Air for Europe, and allow long-term source apportionment and back-trajectory analysis.

In addition to UKEAP, the Automatic Urban and Rural Network (AURN) provides hourly high-resolution NO_2 and NO measurements (as well as other priority pollutant measurements such as O_3) from 140 sites across the UK; this is the main network used for compliance reporting against the EU Ambient Air Quality Directives. The AURN latest measurements and 24 hours summary data are available on UK-AIR[40].

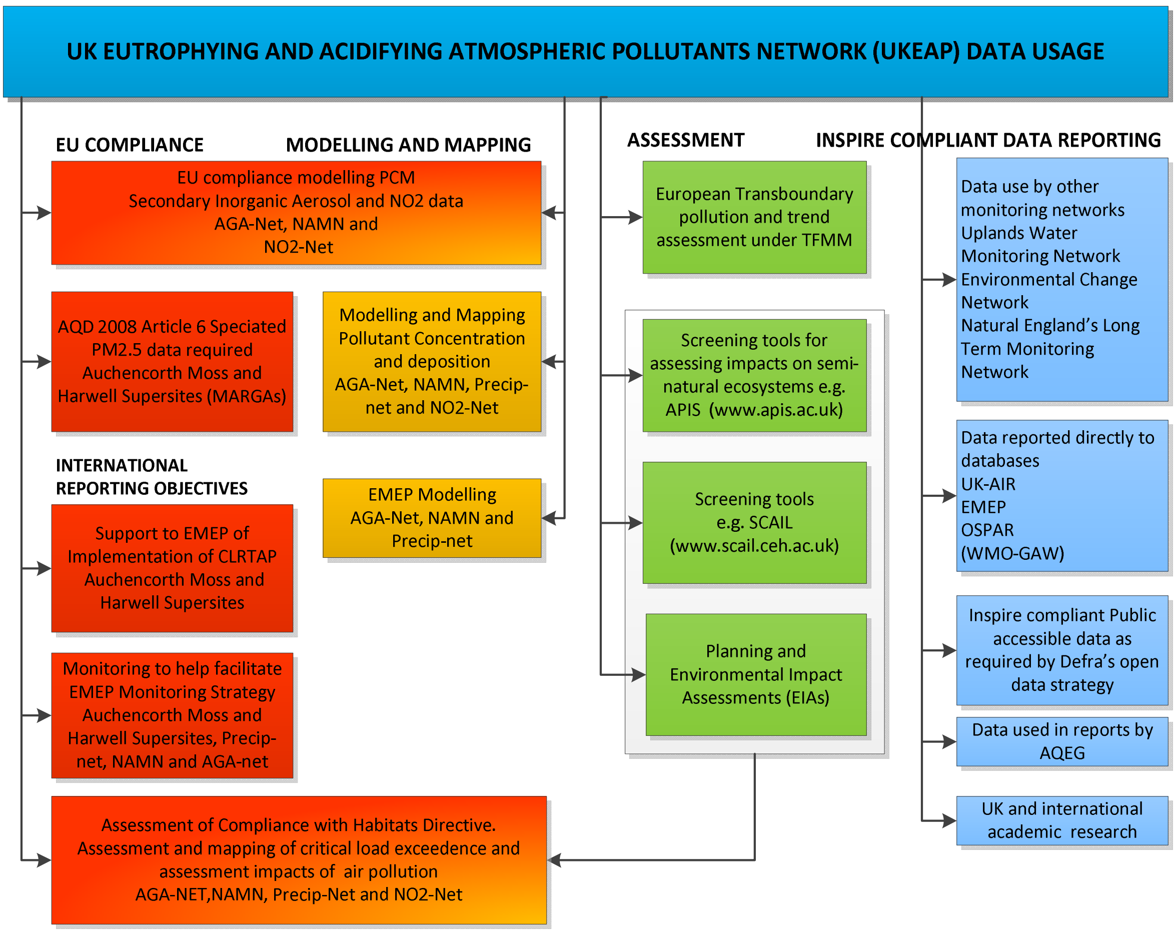


Figure 1.2. Summary of the dissemination and use of UKEAP data.

[37] http://www.actris.eu/
[38] https://www.cen.eu/work/areas/Pages/default.aspx
[39] http://www.unece.org/env/lrtap/taskforce/tfmm/welcome.html
[40] https://uk-air.defra.gov.uk/latest/

1.2 If a national monitoring program for ammonia deposition exists, describe briefly the density / geographical coverage and location of measurement stations

The National Ammonia Monitoring Network (NAMN) was established in 1996 to quantify temporal and spatial changes in air concentrations and deposition of NH_3 (and from 1999 NH_4^+) on a long-term basis. The network currently consists of 72 sites (85 sites pre-2017) across the UK (Figure 1.1) providing monthly data from a mixture of passive badge (ALPHA) samplers and active denuder (DELTA) samplers (Tang et al., 2017). Nine sites have both sampler types and are used for calibration of the passive samplers on an annual basis.

1.3 Which transport and deposition models are used for different purposes and scales? Are national models used and/or is the calculation of total nitrogen deposition based on internationally adopted models?

Three independent national-scale models are employed in the UK to calculate vegetation-specific nitrogen and sulphur deposition at a 5x5 km resolution. These are: Concentration Based Estimated Deposition (CBED) which uses an inferential modelling approach; and two Atmospheric Chemistry Transport Models (ACTM), the Fine Resolution Atmospheric Multi-pollutant Exchange model (FRAME) which uses average annual meteorology, and EMEP4UK which uses dynamic meteorology. All three models have been applied to estimate nitrogen and sulphur deposition for use in natural ecosystem impact assessments at European, UK and smaller scales and provide evidence to support environmental policy decisions.

CBED uses data on precipitation concentrations from the UKEAP monitoring network (Section 1.1), which are interpolated across the UK and combined with data on annual precipitation from the UK Met Office national precipitation monitoring network to generate wet deposition of NH_4^+, NO_3^- and SO_4^{2-}. Dry deposition is calculated using a combination of modelling and interpolation of measurements for gas and particulate concentrations from the UKEAP monitoring network, combined with a big leaf resistance model for deposition velocities (Smith et al., 2000) to generate ecosystem-specific deposition values. Deposition estimates are updated annually and a three-year rolling average national data set is calculated. This allows some smoothing of the inter-annual variability in annual N deposition due to meteorology. The CBED data are the official deposition estimates used to calculate national trends in deposition and exceedance of critical loads. CBED calcium and other base cation deposition rates have been used in the derivation of acidity critical loads (Section 3.1). The CBED UK 5x5 km data are available via the CEH Pollutant Deposition website[41] and are also to be made available via Defra's UK-AIR website[42]. The UK Air Pollution Information System (APIS[43]) enables users to search for CBED deposition values for designated sites (including Natura 2000 sites) or for any UK location(s) specified by the user.

FRAME uses emissions of NH_3, NO_x and SO_2 from the UK NAEI[44]. The simulation of emissions of gaseous pollutants, vertical diffusion, chemical transformation and wet and dry removal processes takes place within an air column in a Lagrangian framework. The same precipitation data as for CBED are

[41] http://www.pollutantdeposition.ceh.ac.uk/

[42] https://uk-air.defra.gov.uk/

[43] www.apis.ac.uk

[44] http://naei.defra.gov.uk

used to drive wet deposition within the model. Model performance is evaluated by comparison with measurements from the UKEAP network (Dore et al., 2015). The model has been used to calculate future (and historic) estimates of deposition according to projected emissions scenarios (Matejko et al., 2009). To generate site-specific scenarios for historic and future deposition, a calibration procedure is adopted whereby CBED provides a recent deposition estimate and FRAME calculates relative temporal changes. Source-receptor data have been generated with FRAME for use (a) in the UK Integrated Assessment Model (UKIAM; Oxley et al., 2013) to test future emissions reductions strategies for reducing the impact of sulphur and nitrogen deposition on natural ecosystems, and (b) for APIS. A high-resolution (1x1 km) version of FRAME, updated annually, is used with data from the NAMN (Section 1.1) to calculate 3-year annual mean NH_3 concentrations for national scale assessments of the exceedance of critical levels (see Sections 2.3 and 4.2).

EMEP4UK is an Eulerian photo-chemistry ACTM that uses dynamic meteorology (Vieno et al., 2014, 2016). The model domain varies in horizontal resolution, with 0.055x0.055 degrees (~5x5 km) typical over the UK. A technical description of the EMEP MSC-W model, from which the EMPE4UK model is derived, is given in Simpson et al. (2012). The physical and chemical processes parameterized in the model are driven by meteorological data calculated by the Weather Research Forecast (WRF) model[45]. An evaluation of model performance for deposition was undertaken as part of a model inter-comparison exercise (Dore et al., 2015) and an extensive validation was also carried out in Lin et. al., 2017. A transition from the use of FRAME data to EMEP4UK data in the UKIAM is currently underway.

For the dynamic modelling of biodiversity-based critical loads (Section 4.4), deposition sequences covering the time period 1880-2010 have been derived using EMEP modelled data (50x50 km) for nitrogen and sulphur deposition and for temporal changes (2008 as reference year, background scenario and Gothenburg Protocol scenario), together with base-cation deposition data modelled using CBED. The EMEP data were provided in the databases circulated to NFCs as part of the "Call for Data" under CLRTAP in 2014. However, EMEP deposition data are not used directly in UK assessments of critical load exceedances, since higher-resolution data are available (e.g. CBED at 5x5 km resolution), and because of concerns as to the accuracy of EMEP predictions for the UK, in particular for wet, mountainous regions. The EMEP model has been shown to generate spatial patterns of sulphur and nitrogen deposition for the UK that differ from UK models, leading to under-estimates of the areas of UK habitats with exceedance of critical loads (RoTAP, 2012). This issue will be kept under review and may improve with future developments and higher resolution versions of the EMEP model.

1.4 An assessment of the uncertainties in estimating nitrogen deposition at different scales

National-scale deposition based on CBED is mapped at 5x5 km resolution since many of the underpinning assumptions are not appropriate for generating deposition at a finer resolution (Jones et al., 2016). For the last 20 years, we have produced concentration maps of rainfall ions using kriging, as this method is in many ways optimal and provides an estimate of the uncertainty from the mapping process (Smith and Fowler, 2001). The initial stage in the analysis is to identify the spatial covariance across the dataset, and this is done

[45] www.wrf-model.org

by fitting a variogram to the pairwise spatial correlations. The underlying assumption is that locations which are close together will be more correlated than locations which are further apart. The second stage uses this spatial covariance structure to provide weightings in a regression-type interpolation, namely kriging, which predicts values everywhere in the map domain from the observed values at the measurement sites. A subjective assessment (expert opinion) of uncertainties in CBED deposition suggested a normal distribution and a coefficient of variation (CV) of 25%; this equates to an uncertainty range of +/- 50% (Jones et al., 2016). More recently, we have explored the effects of changing measurement network size and measurement locations on mapped means and uncertainties (Smith et al., 2014).

Calculations with a high resolution (1x1 km) process model of the seeder-feeder effect over the mountains of Snowdonia in North Wales (Dore et al., 2006) showed that wet deposition of nitrogen could vary by a factor of up to three within a single 5x5 km grid square, as used for national-scale modelling (e.g. CBED deposition; Section 1.3). Calculations of NH_3 concentrations at a 1x1 km resolution for the UK (Hallsworth et al., 2010) showed significant variation between neighbouring grid squares due to the high local variability of NH_3 emissions within the rural landscape. High-resolution (1x1 km) modelling achieved closer agreement with measurements of NH_3 concentrations at semi-natural sites than 5x5 km resolution model data, due to improved spatial separation of source (agricultural) and sink (natural ecosystem) areas. Whilst the modelled high-resolution data gave lower values for national statistics on the exceedance of the critical level for NH_3 than 5x5 km resolution data, Dore et al. (2012) found that the national summary statistics for the exceedance of critical loads were relatively insensitive to spatial resolution.

Jones et al. (2016) and Vogt et al. (2013) recommended that the national-scale deposition data sets (5x5 km) are complemented with more detailed information (e.g. local scale source-receptor tools and/or local scale atmospheric dispersion models) due to the large variability in nitrogen deposition at a landscape scale, especially with regard to point sources.

2. Ammonia-sensitive areas

2.1 Is there a national definition of ammonia sensitive areas?

Ammonia-sensitive areas have not been defined, nationally or for Natura 2000 areas. Estimates of ammonia concentration at 1x1 km resolution, derived from FRAME, are used to carry out national-scale assessments of ammonia critical level exceedances (see Section 4.2). Site-specific appropriate or environmental assessments use outputs from APIS[46], which is based on 5x5 km ammonia concentration data. Regulatory agencies in the UK are keen to work towards identifying ammonia-sensitive areas, habitats and species, and implement regular monitoring of site-condition status on sensitive sites, to improve site-specific assessments (*cf.* Pitcairn et al., 2006; Jones et al., 2017).

2.2 Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SACs)?

The Annex 1 habitats present in SACs in the UK have been assessed, based on expert judgement, on their sensitivity to nitrogen deposition. Habitats sensitive to nitrogen are also assumed to be sensitive to ammonia. This process has identified 61 Annex 1 habitats as sensitive to nitrogen (Hall et al., 2015a: Table

46 (http://www.apis.ac.uk)

14.3), and empirical nutrient nitrogen critical loads have been assigned to them based on the EUNIS class that is the closest match to each Annex 1 habitat (Section 4.7; and Hall et al. 2015a). Ammonia critical levels have been assigned as described in Section 2.3 below.

2.3 Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

Critical levels for ammonia have been assigned to Annex 1 habitats (within SACs), based on whether lichen / bryophyte communities are an integral part of the habitat (in which case the critical level is set to 1 µg m^{-3}) or not (critical level set to 3 µg m^{-3}). The same approach has been applied to designated habitats within A / SSSIs. For information on the application of ammonia critical levels and assessments of exceedances at the national scale, see Section 4.2.

3. Effect of ammonia regulations

3.1 The location of husbandry farms in relation to ammonia sensitive areas

At a site-specific level, any applications for expanding existing livestock sheds or building new ones are assessed both alone and in combination with other ammonia sources (e.g. other livestock farms), to provide critical load exceedances and process contributions (Section 5). Distance criteria are also applied at an initial stage of the assessment to ascertain whether the plan or project will have an effect on the designated site or not. It is noted in the guidance that emissions can be transported over long distances, and so a level of caution is applied. For ammonia sources, different regulatory agencies for countries within the UK apply different distance criteria ranging from 7.5 to 10 km. If the plan or project falls within the set distance to a designated site, then the assessment passes to the next stage, to test for a 'likely significant' effect on the site and its habitats.

3.2 Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, both 1) due to the general reduction in deposition, and 2) due to change in location of husbandry farms, and 3) as a result of the national ammonia regulations in relation to the Habitats Directive

Based on CBED grid-average (i.e. average deposition to all land cover types) 5x5km data, total nitrogen deposition in the UK has reduced by 18% between 2004 and 2015; this varies spatially and for oxidised and reduced nitrogen deposition. Over the same time period, the area of UK nitrogen-sensitive habitats with exceedance of nitrogen critical loads (Section 4.1) has fallen by 5% (to 63%) and the number of SACs with exceedance of nitrogen critical loads for one or more features (Section 4.7) has fallen by 2% (to 91%).

Trends in nitrogen deposition (and in NH_3, NO_x, SO_2 and acid deposition) from 2004 onwards have been generated for the centroid of each SAC; the data are available by individual site on the APIS website[47]. Source attribution is modelled for each SAC to provide a matrix of source sectors contributing to nitrogen deposition at the site. Deposition is further partitioned by type (i.e. dry / wet, reduced / oxidised), to enable assessment of reduced-nitrogen input, i.e. from ammonia sources across the UK. However, source-attribution modelling is carried out only periodically (e.g. most recently for the years 2005 and 2012) and changes in emissions or in any mitigation measures (i.e. decreases

[47] http://www.apis.ac.uk/srcl

in NH_3 emissions), have not been compared with observed nitrogen deposition at individual sites.

4. Critical loads

4.1 Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?

This section provides an overview of the critical loads and levels used in the UK; more detailed information and detail on the methods can be found in Hall et al. (2015a). Terrestrial habitats sensitive to acidification and / or eutrophication have been mapped at 1x1 km resolution across the UK, based on the CEH Land Cover Map 2000 (Fuller et al., 2002a & b) and ancillary data sets on species distributions, soil hydrology and altitude (Hall et al., 2015a). The maps also provide the area of each habitat within each 1x1 km grid square. Data for freshwaters are based on the catchment areas of 1752 sites, comprising mainly small upland lakes and streams in acid sensitive regions of the UK.

Critical loads of acidity for non-woodland terrestrial habitats (acid grassland, calcareous grassland, dwarf shrub heath, montane) are based on the empirical method; this sets the soil acidity critical load according to the amount of acidity that can be neutralized by the base cations produced by mineral weathering of the dominant soil type in each 1x1 km grid square (Hornung et al., 1995; CLRTAP, 2014+). As this method is inappropriate for peat soils, on which bog habitats occur, acidity critical loads for bog habitats (or peat-dominated areas) are calculated using a critical hydrogen ion concentration equivalent to pH 4.4 (Hall et al., 2015a). This method is applied to upland peats only; for lowland or arable peats which are less sensitive to acidity, a high critical load value is applied (4.0 keq ha^{-1} $year^{-1}$) taken as an upper value of the range of empirical values (Hornung et al., 1995; Calver 2003; Calver et al., 2004). Acidity critical loads for woodland habitats (managed / productive broadleaved and coniferous woodland, and unmanaged woodland) are based on the Simple Mass Balance (SMB) equation using a critical chemical criterion of Ca:Al = 1 eq eq^{-1} to protect the fine roots of trees. These acidity critical loads are used together with habitat-specific parameters to generate the acidity critical load values $CL_{max}S$, $CL_{min}N$ and $CL_{max}N$ (CLRTAP, 2014+). CBED calcium, base cation and chloride deposition (Section 1.3) are used in the derivation of the SMB acidity critical loads and $CL_{max}S$ calculations. $CL_{min}N$ requires values for nitrogen immobilization (N_i), denitrification (N_{de}) and nitrogen uptake (N_u) by vegetation (harvesting or removal). N_i and N_{de} are assigned according to the dominant soil type in each 1x1 km square; N_i = 1 or 3 kg N ha^{-1} $year^{-1}$ and N_{de} = 1, 2 or 4 kg N ha^{-1} $year^{-1}$. For dwarf shrub heath, nitrogen removal by fire is included in the calculation of $CL_{min}N$ (4.5 kg N ha^{-1} $year^{-1}$ for wet heaths, 10 kg N ha^{-1} $year^{-1}$ for dry heaths). Values for nitrogen uptake are taken from the literature; uptake is set to zero for unmanaged (non-productive) woodland. Base cation uptake (BC_u used in the derivation of $CL_{max}S$) is also habitat-specific: zero for acid grassland, dwarf shrub heath, bog, montane and unmanaged woodland, and 0.222 keq ha^{-1} $year^{-1}$ for calcareous grassland, based on removal by sheep grazing. BC_u figures for managed woodland are derived from site-specific measurements for the 10 UK Level II ICP Forest monitoring sites and are set at 0.27 keq ha^{-1} $year^{-1}$ for managed conifers, 0.315 keq ha^{-1} $year^{-1}$ for managed broadleaved on Ca-poor soils and 0.41 keq ha^{-1} $year^{-1}$ for managed woodland on Ca-rich soils. BC_u is set to zero for managed woodland on peat soils. In addition, in the SMB equation the application of phosphate and potassium fertilizers is taken into account as a contribution to the base cation budget to managed woodlands on organomineral and peat soils.

For freshwaters, $CL_{max}S$, $CL_{min}N$, $CL_{max}N$ are calculated using the First-order Acidity Balance (FAB) model (Henriksen & Posch, 2001; Hall et al., 2015a) and water chemistry from the 1752 sites sampled in the 1990s. These data do not include, or represent, all freshwaters (lakes or streams) in the UK, and there are no current plans to extend the data set. The critical loads are based on the chemical criterion of a critical Acid Neutralising Capacity (ANC) of 20 µeq L^{-1}, representing a 10% probability of damage to brown trout populations. This critical value was applied to all sites except those where there was evidence suggesting an ANC value of 0 µeq L^{-1} was more appropriate (Hall et al., 2015).

Empirical critical loads of nutrient nitrogen are applied to non-woodland habitats and unmanaged (non-productive) woodland. The critical load values used in the UK are based on (a) the ranges published in the 2010 review and revision of empirical critical loads (Bobbink & Hettelingh, 2011), and (b) a meeting of UK experts to review the evidence of nitrogen impacts and determine where within the ranges to set the UK critical load values (Hall et al., 2011, 2015a) (Table 1). The published critical loads (Bobbink & Hettelingh, 2011) are assigned to habitat classes of the European Nature Information System (EUNIS) to enable consistency of habitat terminology and understanding across Europe. For applications in the UK, the nearest most appropriate EUNIS class(es) have been assigned to the different UK habitats (Table 4.1).

Table 4.1. Empirical critical loads of nutrient nitrogen for habitats mapped for the UK

UK Habitat	EUNIS code	Critical load range# (kg N ha^{-1} $year^{-1}$)	UK Mapping Value## (kg N ha^{-1} $year^{-1}$)
Saltmarsh	A2.53/54/55	20-30	25
Dune grassland	B1.4	8-15	9 for acid dunes 12 for non-acid dunes
Bog	D1	5-10	8, 9, 10 depending on rainfall modifier
Calcareous grassland	E1.26	15-25	15
Dry acid grassland	E1.7	10-15	10
Wet acid grassland	E3.52	10-20	15
Montane habitat	E4.2	5-10	7
Wet dwarf shrub heath	F4.11	10-20	10
Dry dwarf shrub heath	F4.2	10-20	10
Unmanaged beech woodland	G1.6	10-20	15
Unmanaged oak woodland	G1.8	10-15	10
Scots Pine woodland	G3.4	5-15	12
Other unmanaged coniferous or broad-leaved or mixed woodland	G4	G1: 10-20 G3: 5-15	12 (within ranges for broadleaved (G1) and conifer (G3))

#Ranges published in Bobbink & Hettelingh, 2011

##Agreed UK mapping values for the calculation of exceedances (Hall et al., 2011 & 2015a)

Mass-balance critical loads of nutrient nitrogen are applied to managed (productive) coniferous and broadleaved woodland habitats, to ensure that long-term ecosystem function (e.g. soils, soil biological resources, trees & linked aquatic ecosystems) is protected. Inputs for N_u, N_i, N_{de} are as defined for $CL_{min}N$. The acceptable concentration of N in the leaching flux, $[N]_{acc}$, has not been defined for UK woodlands (or other habitats). Instead, fixed values of the acceptable nitrogen leaching flux ($N_{le(acc)}$) have been defined by woodland type, based on data from UK studies or the literature: 4 kg N ha^{-1} $year^{-1}$ for managed coniferous woodland and 3 kg N ha^{-1} $year^{-1}$ for managed broad-leaved woodland.

The application of critical loads to UK designated sites (Natura 2000 areas: SACs and SPAs; and A / SSSIs) is described in Section 4.7.

UK critical loads and exceedance data are used in a range of applications:

- UK critical loads data are submitted to the Coordination Centre for Effects (CCE) for use in mapping and modelling activities at the European scale, and for integrated assessment modelling and the development of abatement strategies under CLRTAP.
- The temporal trends in UK critical load exceedances are used by the UK Government as a biodiversity indicator (B5a) on the pressures from air pollution (see JNCC website[48] and Hall et al., 2016).
- Nitrogen critical-load exceedance data are used by the SNCBs in the assessment of pressures and threats from pollution as part of Article 17 reporting for the EU Habitats Directive.
- Critical load and exceedance data for designated sites (SACs, SPAs, SSSIs) are widely used by the SNCBs for Ministerial submissions, evidence to policymakers and pollution regulators, casework for planning and permitting, informing state of the environment or resources reports, etc..
- Nitrogen critical loads have been used in the development of a decision framework to assess whether nitrogen deposition is a threat to, or cause of, unfavourable habitat condition on protected sites (Jones et al., 2016).
- Critical loads for habitats and designated sites, together with CBED and FRAME data, underpin APIS[49] which provides a resource for SNCBs, Regulators, Local Authorities and other users interested in the impacts of air pollution on ecosystems and designated sites.

4.2 Are critical levels used?

At the national scale, ammonia critical levels have not been assigned to individual habitats or habitat features of designated sites; instead a simple approach has been taken, using ammonia concentration data (Sections 1.3, 2) and ammonia critical levels (Hall et al., 2016) to carry out annual determinations of:

(a) The land area of England, Wales, Scotland, Northern Ireland and the UK where ammonia concentrations exceed critical levels of 1 µg NH_3 m^{-3} to protect lichens & bryophytes, and 3 µg NH_3 m^{-3} to protect higher plants (CLRTAP, 2014+).

(b) The area of nitrogen-sensitive habitats where ammonia concentrations exceed the critical levels of 1 µg NH_3 m^{-3} and 3 µg NH_3 m^{-3}. This analysis uses the nitrogen-sensitive habitat distribution maps created for mapping critical loads of nutrient nitrogen (see Section 3.1).

(c) The percentage of designated sites (SACs, SPAs, A / SSSIs) where ammonia concentrations exceed the critical levels of 1 µg NH_3 m^{-3} and 3 µg NH_3 m^{-3}. A

[48] http://jncc.defra.gov.uk/page-4245
[49] www.apis.ac.uk

site is counted as exceeded if the ammonia concentration exceeds the critical level anywhere across the site, i.e. a precautionary approach is used.

For site-specific assessments (Section 2.3, 5), and in the APIS tool[50], ammonia critical levels are assigned to the habitat features of designated sites.

4.3 To which extent, and how are calculations based on the Mapping Manual from UNECE?

The UK calculations are based on the Mapping Manual and the results of international workshops held under CLRTAP, but with some adjustments made for UK conditions, evidence or studies, if appropriate. All methods and data used in the UK are documented in a "Methods Report" (Hall et al., 2015a) which is freely available from the project website[51].

4.4 Are calculated critical loads based on biodiversity targets used or planned to be used in the future?

Biodiversity-based critical loads are being developed in the UK and were included in the data submission to the CCE in May 2017, providing new critical loads for 86% of the 1x1 km squares containing bog habitat in Great Britain (representing ~5000km^2 of bog habitat) and sub-sets of other acid-sensitive habitats (acid grassland, dwarf shrub heath). Further development and application of these methods is ongoing under current work funded by Defra; see Section 4.5.

4.5 If model calculations are used:

- *Describe the models and the data included in the calculations*
- *Are target loads used for the specific areas; if so, how?*
- *Is there a reference year in the calculations, and if so, which?*

Effects of air pollution on habitat suitability for plant species are simulated using the MADOC-MultiMOVE model (Rowe et al., 2015) (Figure 4.1a). Biogeochemical responses to total N and non-marine S loads (as calculated using the deposition sequences described in Section 1.3) are simulated using MADOC (Rowe et al., 2014) to predict changes in soil pH, nitrogen availability and plant productivity. These responses are used to drive MultiMOVE (Henrys et al., 2015), which predicts habitat-suitability for individual plant and lichen species on the basis of niche models defined on seven environmental gradients. These are: mean January minimum and mean July maximum temperatures; annual precipitation; and mean values for four floristic traits: 'Ellenberg' Fertility (N), Wetness (F) and Alkalinity (R), and cover-weighted Grime score for species height. 'Ellenberg' scores are not cover-weighted, and values adjusted for the UK are used (Hill et al., 2000). Abiotic outputs from MADOC are converted into mean trait responses using a set of transfer functions (Hall et al., 2015b). The MultiMOVE outputs represent the suitability of the habitat for each individual species. Probabilities are adjusted to allow for prevalence in the training datasets using the method of Real et al. (2006), so are comparable among species without further rescaling.

[50] http://www.apis.ac.uk/srcl

[51] http://www.cldm.ceh.ac.uk/content/methods-calculation-critical-loads-and-their-exceedances-uk

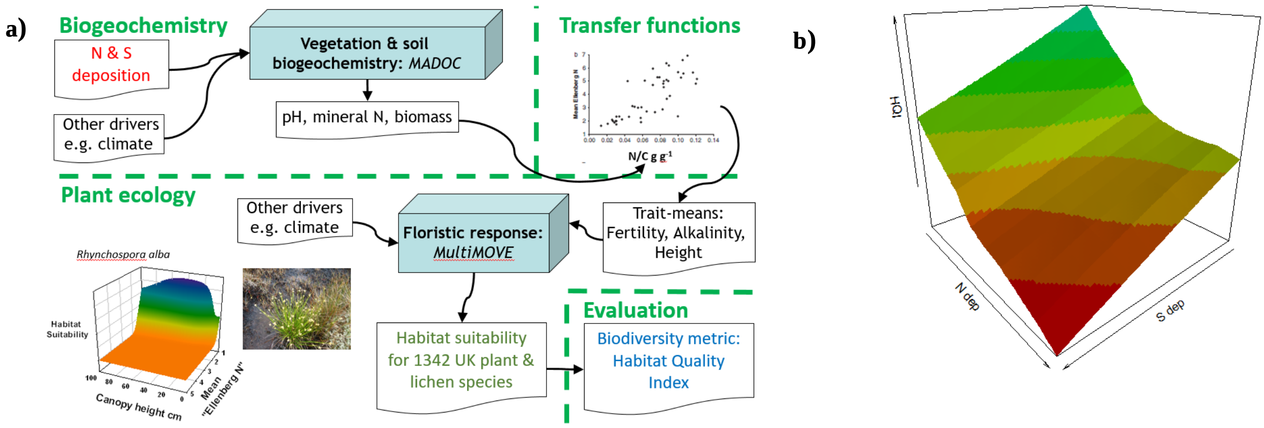


Figure 4.1. a) Schematic diagram of MADOC-MultiMOVE-HQI; b) example response of Habitat Quality Index to nitrogen and sulphur deposition load, showing a decrease when either pollutant increases above zero anthropogenic deposition.

Species-level responses are related to biodiversity targets using an indicator-species approach, following a consultation with the habitat specialists with statutory responsibility to define habitat quality (Rowe et al., 2016). A *Habitat Quality Index* (*HQI*) is calculated as the mean habitat-suitability for the set of characteristic species that has been defined for each habitat. To avoid effects of low habitat-suitability due to unfavourable climate, species which have never been recorded within the 10x10 km grid-square where the site is situated are excluded. Species previously recorded but currently absent (e.g. due to N pollution) are included.

To derive a biodiversity-based critical load function, it is necessary to define a threshold value of *HQI* below which the habitat is considered to be damaged. However, the value of this threshold is inevitably a matter of judgement, and it would be difficult for habitat specialists to make such judgements about *HQI* values that are not easy to relate to their experience. We therefore drew on the data review and expert judgement embodied in the definitions of empirical critical loads for nitrogen (Bobbink et al., 2011). These are set at a level where damage is just avoided even in the long term, so logically if the model is run for an extended period with N deposition set to exactly the empirical critical load, the resulting value of *HQI* will correspond to a damage threshold. For each site, the model is run forward with zero non-marine S deposition and N deposition set to the empirical critical load for nutrient N (using habitat- and site-specific values as calculated in the UK NFC database: Section 4.1), and the resulting value of *HQI* in 2100 is assumed to represent the damage threshold for the site, HQI_{crit}. The model is then re-run to 2100 under a range of N and S deposition values to obtain a response surface, and a line or 'contour' where *HQI* equals HQI_{crit} is obtained by interpolation (*cf.* the transition from yellow to pale green in Figure 4.1b). This contour represents the biodiversity-based critical load function. For data submissions to the CCE, the function was simplified to two nodes on the [S load & N load] plane (Posch et al., 2014), by minimising squared differences from the $HQI = HQI_{crit}$ contour.

The reference date of 2100 used to calculate HQI_{crit} was required in the CCE data submission instructions, and probably represents a good compromise, taking into account long-term processes but not over an impractical timescale. Target loads have not yet been explored but could be developed using a similar approach, i.e. as the loads of N and / or S required to bring *HQI* above the HQI_{crit} threshold by a specified date.

4.6 If empirical critical loads are used: to what extent and based on which modifying factors are values adjusted to local conditions?

The application of empirical critical loads for nitrogen to UK habitats is described in Section 4.1. The only modifying factor used in the UK is a precipitation modifier for setting the critical load for bog habitats (EUNIS class D1). The modifier proposed by the CCE (Slootweg et al., 2008) to take account of the variability in precipitation across the geographic range for each habitat was considered, but rejected by UK experts as it implied greater knowledge of the spatial variability in habitat sensitivity to nitrogen than actually exists. Instead, a simpler approach of calculating the rainfall ranges that would give specified median critical load values (8, 9 or 10 kg N ha^{-1} $year^{-1}$) was used to enable variable critical loads to be set spatially depending on rainfall (Hall et al., 2015a).

For site-specific assessments (e.g. SACs, SPAs, A / SSSIs) guidance has been developed for applying the modifying factors of (a) water-table height, and (b) precipitation, in determining the appropriate critical load for individual bog sites. The guidance[52] is presented as a three-step approach that considers (in the following order): the condition of the site, the water table and the local annual precipitation.

4.7 Are different methods used for setting critical loads for areas inside and outside of Natura 2000 areas?

Separate UK databases are maintained of (a) critical loads for UK habitats mapped at 1x1 km resolution (see Section 4.1) and (b) critical loads for feature habitats of Natura 2000 sites (SACs and SPAs) and A / SSSIs. The areas covered by (b) may overlap with (a), but critical load exceedance assessments are performed and reported separately for (a) and (b). In submitting UK data for work under CLRTAP, areas within (a) that are also Natura 2000 areas are identified, but any areas in (b) that are not within (a) have not been included.

For acidity, the same critical load methods are applied to habitats within Natura 2000 areas (and A / SSSIs) as are applied outside, with the exception of freshwaters. Critical loads of acidity for six broad habitats (acid grassland, calcareous grassland, dwarf shrub heath, bog, montane, unmanaged coniferous and broadleaved woodland) are mapped at 1x1 km resolution and have been assigned to the relevant habitat features (i.e. Annex I habitats for SACs, Annex II habitats for SPAs, A / SSSI habitat features) of the designated sites using habitat correspondence tables. Critical loads of acidity for freshwaters are only available for a subset of UK freshwaters (Section 4.1) and cannot be extrapolated and applied to other freshwaters, either within or outside Natura 2000 sites.

For nutrient nitrogen, empirical critical loads are applied to the "feature" habitats (i.e. habitats of particular conservation interest) within Natura 2000 sites (SACs, SPAs) and A / SSSIs, using correspondence tables that reflect the relationship between the interest features and EUNIS class. For some nitrogen-sensitive features, no corresponding or appropriate EUNIS class and / or critical loads are available. Experts from the SNCBs agreed a set of "recommended" critical load values (see APIS website[53] and JNCC, 2013) from within the published ranges (Bobbink & Hettelingh, 2011). Where no recommended value was set for a feature, the minimum of the range was applied. The recommended values may be the same as the UK mapping values (Table 1), but

[52] (http://www.apis.ac.uk/guidance-applying-critical-load-range-atmospheric-nitrogen-deposition-bog-habitats-uk).

[53] http://www.apis.ac.uk.indicative-critical-load-values

for some habitats, particularly those where there is a lack of UK evidence of nitrogen impacts, a precautionary principle is applied and the critical load at the lower end of the published ranges is used. The modifying factors applied in site-specific assessments are described in Section 4.6 above.

4.8 How often are the critical loads updated?

In the UK critical loads research is carried out by CEH under funding won through competitive tender from the UK Department of Environment, Food & Rural Affairs (Defra). There is therefore no schedule for updating UK critical loads data in future, but critical loads have generally been updated in the following circumstances:

- Improved input data becoming available, either for the calculation of critical loads and / or for habitat mapping. The last major update of this kind was completed in 2003-04 (Hall et al., 2003, 2004), with further minor updates in 2008 (Hall, 2008) and 2009 (Hall, 2009).
- Following international workshops held under CLRTAP that reviewed or updated methods; the last update of this kind was in 2011 following the 2010 CLRTAP review of empirical critical loads of nitrogen and a follow-up meeting of UK experts (Hall et al., 2011).
- Following UK developments in the calculation and application of critical loads; for example, the work on the development and application of biodiversity-based critical loads under the current Defra contract (AQ0843).

In each case, support from Defra is required to fund the update. Some updates have been proposed in recent years for which funding has not been available, for example:

(i) The habitat distribution maps currently in use are based on the CEH Land Cover Map 2000 (LCM2000; Fuller et al., 2002a & b) and ancillary data on species, altitude etc. Newer land cover maps (2007, 2015) are available. A study of the impacts of updating the critical loads habitat distribution maps to LCM2007 was carried out (Evans et al., 2012) but funding has not been available to update the habitat distribution maps and associated critical load databases.

(ii) A new method was proposed in 2016 (Hall et al., 2016) for calculating acidity critical loads for peat soils; funding was sought to further develop and apply this method, but to date this has not been funded.

4.9 Describe if and how nature management, e.g. grazing is taken into account in the model calculations

For productive woodlands, the amount of nitrogen, calcium and base cations removed through harvesting is included in the calculations of critical loads (Section 4.1), as is the removal of nitrogen through sheep grazing on calcareous grassland. In general, single values (or separate values for different soils) are applied in the calculations for all habitat squares, since spatially explicit data on uptake do not exist.

Grazing and other management practices are not taken into account explicitly in the UK-scale dynamic modelling approach. Management (e.g. stocking rate, mowing frequency) effects on vegetation height across different habitats are not well-established, and suitable management data for national-scale modelling are not available. Grazing (or other management practices) can be taken into account in site-specific applications, where observations are available (Rowe et al., 2011).

5. Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

5.1 Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and if so: are empirical critical loads or national model calculations and local data used for the specific nature area?

Environmental permitting is carried out by, and is the responsibility of, separate regulating agencies for England (Environment Agency), Wales (Natural Resources Wales), Scotland (Scottish Environment Protection Agency) and Northern Ireland (Department of Environment, Northern Ireland). Each Agency has its own procedures, methods and models.

Critical loads for nutrient nitrogen and critical levels of ammonia are used in appropriate and environmental assessments. As described in Section 4.7 empirical critical loads of nitrogen have been assigned to the features of designated sites, as well as appropriate critical levels (Sections 2.3 and 4.2). Local air dispersion models are used to calculate depositions and concentrations from a source to a nature area (i.e., designated site). The models used range from screening models (e.g. SCAIL[54]: Simple Calculation of Impact Limits) to more advanced models, e.g. ADMS 5.

If the emissions from a process are judged to result in a likely significant effect on a designated site (Section 5.4) then a detailed assessment is required. Detailed assessments take into account actual operational practice (including mitigation measures) and site specific data (e.g. any specific critical load value, or whether the sensitive habitat falls within the pollutant footprint).

5.2: To what extent and on which geographical scale is local data e.g. data on ammonia deposition, on how sensitive to ammonia the specific nature area is etc, included?

Background depositions and concentrations at 5x5 km resolution are used in assessments. For air-dispersion modelling, local representative meteorology is recommended and used where possible. The SCAIL screening tool uses regional meteorology from ~40 stations around the UK.

5.3 Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?

Management practices that may conflict with nitrogen deposition effects are taken into account at the detailed assessment stage. Common Standards Monitoring (CSM) under the EU Habitats Directive (Article 17) also allows for recording nitrogen deposition effects and other potentially confounding practices (e.g. grazing). A decision framework has been developed to provide a means of attributing nitrogen deposition as a threat to, or cause of, unfavourable habitat condition on protected sites (Jones et al., 2016).

5.4 Describe briefly if and how local scale transport and deposition is calculated?

An assessment of a project or plan that may impact on a designated site is required to use an air dispersion model to predict the potential pollution to a receptor (e.g. habitat or SAC). Models suitable for this type of screening approach are SCAIL or new generation models such as ADMS; the latter is often

[54] www.scail.ceh.ac.uk

used in detailed assessments. The modelling takes into account pre-existing emissions as well as those of the proposed new source(s) to output a maximum predicted pollutant concentration and deposition to the receptor in question. The likely significant effect of a source's pollutant emissions will depend on:

- The contribution of the process (Process Contribution: PC)
- The ambient concentration / deposition (Background: BK)
- The combination of the PC and BK, known as the Predicted Environmental Concentration / Deposition (PEC)
- The relevant critical level / critical load (environmental benchmark) at the site.

Each pollutant emitted from the proposed process is modelled at each receptor boundary (designated site) and combined with the background at each receptor point to give a PEC (i.e. PEC = PC + PK). Both concentrations and depositions are modelled depending on the pollutant pathway. The percentage of the process contribution to the critical load / level is also calculated: PC as % of benchmark = PC / environmental benchmark * 100

5.5 Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?
The models include an appropriate deposition velocity for woodland type habitats and for semi-natural (short-vegetation) habitat types, applied according to the habitat being considered.

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Appendix4. Country report: The Netherlands

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TNO, Netherlands

Monitoring and modelling nitrogen and ammonia deposition

- In this Chapter the following questions are addressed:
- What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas?
- If a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations?
- Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models?
- An assessment of the uncertainties in estimating nitrogen deposition at different scales.

Monitoring programs

In the Netherlands two monitoring networks exists:

- An hourly based National Air Quality Monitoring Network (LML, Landelijk Meetnet Luchtkwaliteit), consisting of eight monitoring stations, mainly located in agricultural areas, and measuring also other compounds beyond ammonia.
- A monthly based Ammonia Monitoring Network in Nature (MAN, Monitoring Ammoniak in Natuur) network, consisting of more than 200 measurements sites, mainly located in Natura 2000 areas, and measuring solely the ammonia concentration.

National Air Quality Measurement Network

Ammonia monitoring

The Dutch National Air Quality Monitoring Network (LML, http://www.lml.rivm.nl) measures various air quality components. Amongst others it measures ammonia concentrations in air, ammonium in aerosol and the wet deposition of ammonium since 1993 at eight and since 2014 at six locations.

Since 1993, hourly ammonia concentrations have been measured with a wet-annular denuder system, called ‘AMOR’ (Amanda for MOnitoring RIVM; Wichink Kruit et al., 2007). Ammonia is measured at 8 monitoring stations, which were carefully selected for equal distribution of regions of high, moderate and low emission densities (Buijsman et al., 1998).

Since 2014, the hourly concentration measurements at two monitoring stations have been replaced by a triplet of passive samplers that are measuring ammonia concentrations on a monthly basis. The number of monitoring stations has varied over the years, i.e., in 1993: n = 5, from 1994 to 1999: n = 7, from 2000: n = 8. To account for missing data, the time series were gapfilled (Van Zanten et al., 2017).

Recently, a new ammonia monitoring instrument, the mini-DOAS, has been developed at RIVM (Volten et al., 2012). The mini-DOAS is based on the DOAS (Differential Optical Absorption Spectroscopy) principle. The instrument measures spectral absorption of UV light over an open path of 14 to 20 m. The great advantage of the instrument is that it does not require sampling lines or filters to which ammonia molecules or ammonium aerosols may stick. Therefore, the instrument is free from interference of ammonia-generating aerosols, and free from delays and memory-effects.

We have introduced the miniDOAS instruments at six locations in LML in 2013/2014. They measure in parallel with AMOR instruments. In time they will replace the AMOR instruments. The miniDOAS is as sensitive, accurate, and stable as an AMOR, but has a faster reaction time and is less expensive in purchase and maintenance.

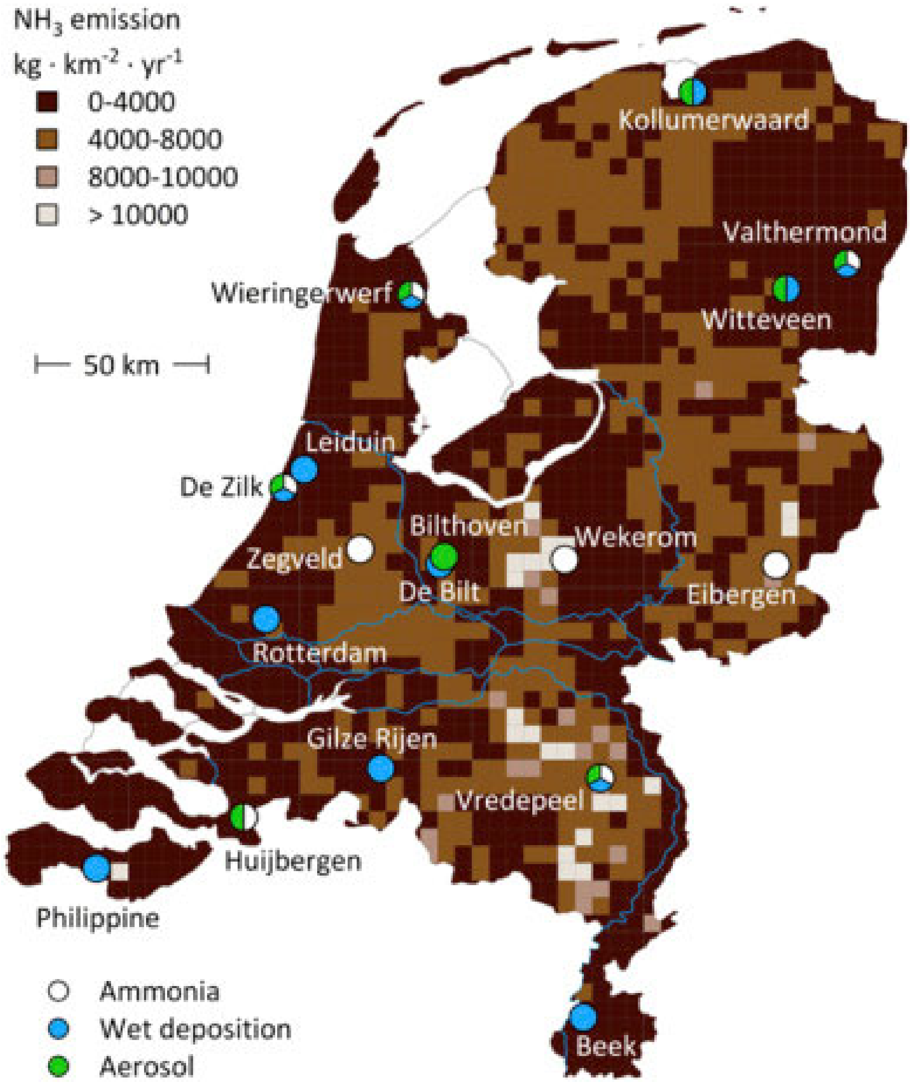


Figure 1. The locations of the monitoring stations of the Dutch National Air Quality Monitoring Network (LML). The map shows the total ammonia emissions on a 5 by 5 km grid for the year 2014. (source Van Zanten et al., 2017).

An extensive overview and discussion of the measured trends in ammonia measurements in the Netherlands over the period 1993 to 2014 is given in Van Zanten et al. (2017).

Other ammonia-related monitoring
From the early 1990s onwards, concentrations of nitrate, sulphate and ammonium in aerosol have been measured. Up until 2009 a Low-Volume Sampler

was used for this. Wet deposition has been monitored since 1978, with the time series starting in 1990 being used here. Although the current wet-only samplers replaced the older type in 2006, this hardly affected the continuity of the measurements for ammonium deposition (van der Swaluw et al., 2011). Data before 1992 was revalidated according to the current validation rules (Somhorst et al., 1994). Due to changes in monitoring stations, a selection was made of 10 time-series with good coverage over the full period. Due to the constriction of annual mean values being based on a data availability of at least 75%, the number of monitoring stations meeting the quality criteria varied between 5 and 10 over the years.

Monitoring strategy of LML

NH_3 in the Netherlands displays a high spatial variability. As a consequence, a representative monitoring network to cover this variability would be very expensive. Therefore, at its set up, it has been decided to use a limited amount of measurements in combination with modelling of the ammonia concentrations for the Netherlands (Buijsman et al., 1998). The monitoring stations were carefully selected for equal distribution of regions of high, moderate and low emission densities. Van Pul et al. (2004) demonstrated the eight monitoring stations (although representing somewhat higher emission areas) to show a similar agreement with model calculations as was obtained with a vast network of 159 measurements over the Netherlands. Ammonia concentrations calculated with the OPS model are then compared with the measurements at these locations for calibrating the Operational Priority Substances OPS-model (see section Models used). Because NH3 is influenced by the effects of meteorology and physicochemical processes, model calculations are necessary to account for all these processes. Therefore, the OPS was used to quantify these effects on the monitored atmospheric ammonia concentrations (Wichink Kruit et al., 2007). Results show that the general performance of the OPS model for ammonia concentration, ammonium concentration and wet deposition of ammonia/ammonium is quite good when evaluated with observations over the whole period.

The MAN network

In 2005 the MAN network was started to obtain measurements of ammonia concentrations that are more representative for nature areas (Natura 2000 sites). The MAN network provides monthly mean values of the ammonia concentrations at 235 locations, see **Figure 2**. Measurements are performed with passive samplers (Gradko tubes). Each month, the passive samplers are replaced by local volunteers in the field, mostly nature rangers. The passive sampler technique is widely used to monitor various air pollution components (nitrogen dioxide, ammonia).

The MAN network is one of the monitoring activities of the PAS (Programma Aanpak Stikstof; Integrated Approach to Nitrogen,) with the following goals:

- To monitor the national and regional trends of the ammonia concentration in nature areas (mostly Natura 2000 sites);
- To validate calculated ammonia concentrations for nature areas.

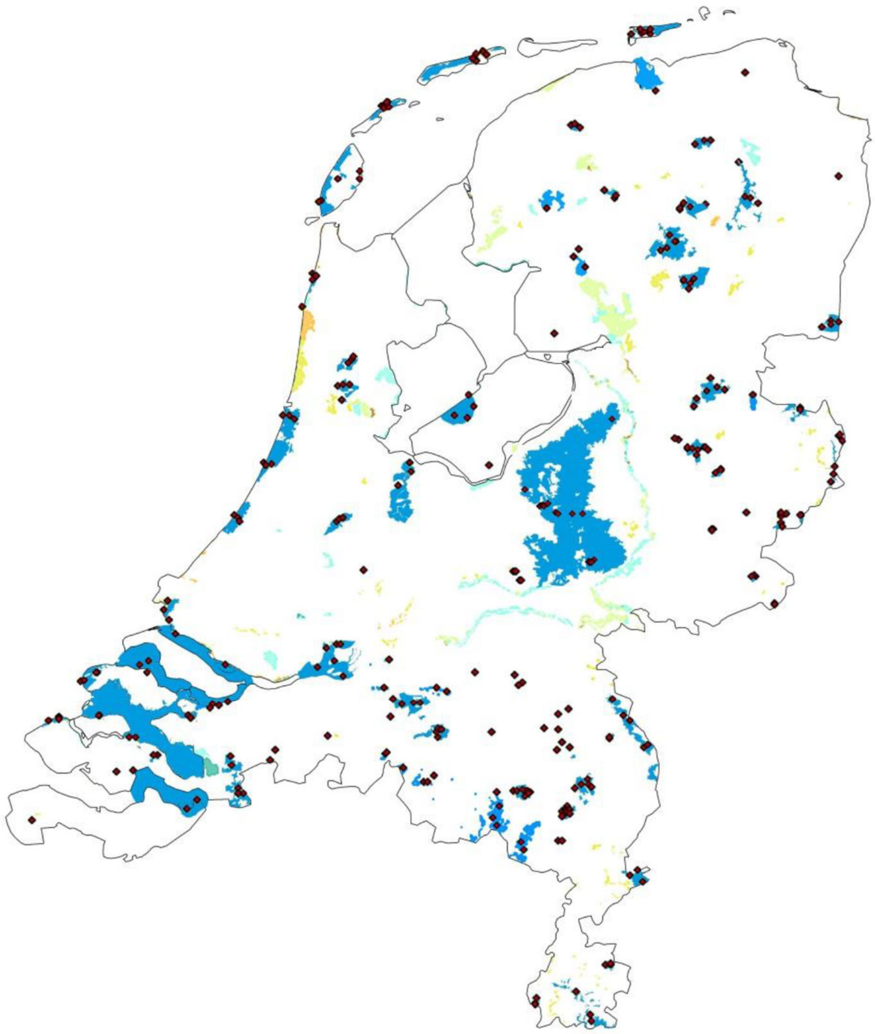
The ammonia measurements performed in the LML are used to calibrate the passive sampler measurements. Each month sets of three passive samplers (triplets) are placed at five, and from January 2009 onwards at six LML-stations that represent a wide range (1 to 16 µg m^{-3}) of annual mean atmospheric ammonia concentrations. To determine the calibration parameters, the ratio between the LML-concentration and the mean of the triplet is determined for each LML-station. A linear regression is performed on the five/six ratios against the triplet means. Subsequently, the determined calibration parameters are applied to the remaining passive samplers at non-LML locations. The calibration parameters are not constant, but determined for each month.

Monitoring strategy of MAN

At present the MAN includes approximately 235 measurement sites in nearly 60 Natura 2000 areas and 10 additional sites located in small nature areas. The Natura 2000 areas where measurements are performed are selected based on their regional representativeness, emission characteristics of the surrounding, vulnerability for nitrogen deposition, and representativeness for several other spatial characteristics.

Usually there are 3-5 sites operational for each selected Natura 2000 area. The locations need to be representative for ambient ammonia concentrations in that nature reserve. In general, the sites are located in an open environment, with woods or bushes at a distance of usually at least 100 m and a measurement height of usually 1.5 to 1.8 m above the ground.

Figure 2. The locations of the monitoring locations (black dots) of the Monitoring Ammonia in Nature network (MAN). The map shows the nature areas, the Natura 2000 sites are in blue (source: http://man.rivm.nl/).



Deposition monitoring

Wet deposition

Wet deposition of several components including ammonium have been measured since 1978 by the Dutch National Precipitation Chemistry Monitoring Network.1 However, the locations of monitoring stations, equipment, and chemical analysis have changed considerably since measurements started. The current wet-only sampler replaced an older type in 2006 and before 1988 bulk deposition was measured (van der Swaluw et al., 2011). According to Blank (2001) wet deposition measurements have an uncertainty of about 6%. The data have been corrected for the effect of replacing bulk samplers with wet-only samplers. Data before 1992 were revalidated according to the current validation rules (Somhorst et al., 1994), to obtain consistent time series.

Dry deposition

It is generally acknowledged that detailed dry deposition monitoring of ammonia is hardly possible. Therefore, in the Netherlands dry deposition monitoring is based a combination of ammonia aerosol measurements of the LML site and dry deposition monitoring modelling. Where the dry deposition of ammonia and other components is calculated by using the DEPAC-module which is incorporated in the OPS model. The DEPAC-module has been updated in 2009, and this module version is described in detail in Van Zanten et al. (2010). The OPS-model and the DEPAC-module are briefly described in the next section.

Models used

Introduction

In the Netherlands The Operational Priority Substances (OPS) model is used for deposition modelling.

The main purpose of the model is to calculate the concentration and deposition of pollutants (e.g. particulate matter, acidifying compounds such as SO_2, NO_x and NH_3) in the Netherlands using a high spatial resolution, typically 1 × 1 km^2. These air quality concentrations and deposition maps are produced annually, based on a combination of model calculations and measurements (so called GCN and GDN maps, Grootschalige Concentratie- en Depositiekaarten Nederland: Large scale concentration and deposition maps of The Netherlands). The maps provide the large-scale contribution to the air quality and deposition from all sources in Europe for the past year and for several years in the future (up to 2030). Maps are produced of the annual mean concentrations of e.g., NO_2, PM10, PM2.5, and the annual mean deposition of oxidized and reduced nitrogen. The OPS dispersion and deposition model is used for the calculations. The output of the model is calibrated using observations from the LML network of NO2, NH_3, PM10 and PM2.5 at rural and urban background locations in the Netherlands. For NH_3, also observations from the MAN network are used.

The maps are used by the Dutch government to assess the air quality and deposition levels and have a legal status. Results are presented in reports and published on the internet for further use by local authorities in their air quality reporting and in decision making on infrastructural projects (Velders et al., 2015 and www.rivm.nl/gcn).

Beyond the OPS model , the integration modelling system Aerius is used to get a permit related NH_3 and NO_x emission to expand a farm or any other N emitting enterprise.

The OPS model

The OPS model (Van Jaarsveld et al., 2012; Sauter et al., 2015), is a long-term Lagrangian transport and deposition model that describes relations between individual sources or source areas and individual receptors by Gaussian plumes. The model simulates the emission, dispersion, transport, chemical conversion and deposition as a function of meteorological conditions. Because chemical conversion rates and dry deposition velocities depend on background concentrations taken from a series of concentration maps, one may call it a pseudo non-linear model. The model is statistical in the sense that concentration and deposition values are calculated for a number of typical situations (classes) and the long-term value is obtained by summation of these values, weighted with their relative frequencies of occurrence. The OPS model includes three groups of substances (i) acidifying and eutrophying substances (SO_2, NO_x, NH_3 and secondary products), (ii) non-acidifying (gaseous) substances (e.g. heavy metals) and (iii) particle-bounded substances. Model input data consists of wind speed and wind direction at two heights, temperature, global radiation, precipitation, snow cover and relative humidity from standard and routinely-available meteorological data.

The spatial extend is determined by the size of the area for which meteorological parameters are known. Since the standard climatological data set used for this model is based on observations from the Royal Netherlands Meteorological Institute (KNMI), the maximum size of the receptor area becomes, in effect, the Netherlands and adjoining regions. The land-use and terrain roughness data maps, covering only the Netherlands in great detail, also impose limitations. Receptor parameters that need to be specified are coordinates, roughness length and land use. The receptor height is fixed within the OPS model. In terms of the vertical dispersion, the receptor height is set to 0 m. In terms of the influence of dry deposition on the vertical concentration profile, the receptor height is 3.8 m, being equal to the measuring height of the LML network.

The OPS-model reads the land-use type and the roughness length of the receptor location from maps. For specific receptor locations the model selects the land-use properties from the 250 m resolution map. In the case of gridded receptor points, the model selects a corresponding spatial resolution (250, 500, 1000, 5000 m). It is important to note here that the calculation of a grid-cell representative roughness length is based on a logarithmic weighing of roughness elements, while the grid cell representative land-use type is defined as the most abundant land-use type within that grid cell.

As output OPS calculates concentrations and depositions on a regular grid, with a user defined grid cell size. The model generates multiple sub-receptors inside a grid cell in order to be able to compute a representative grid cell average.

In addition to the regular long term version of OPS a short version exists (OPS-ST). This expert version is used on an hourly basis and computes hourly concentrations and depositions at local scale (~ 0 - 50 km) only, using steady-state Gaussian plumes (Van Jaarsveld et al., 2000). In addition many processes are modelled in OPS-ST in the same way as in the long term version. The OPS-ST model played an important role in studies that were performed in view of the discussion over a decade ago about the “ammonia gap” in the Netherlands, i.e., a systematic difference between the calculated and measured ammonia concentrations of 25% (van Pul et al., 2008).

The OPS-model has been updated in 2009 for this new dry deposition of ammonia parameterization using a compensation point (Kruit et al., 2010). Therefore, the dry deposition of acidifying components including ammonia is calculated by the DEPAC (DEPosition of Acidifying Compounds) module (Van Zanten et al., 2010). DEPAC is fully incorporated in the OPS model and includes compensation points for ammonia as described by. The process of co-deposition, i.e., enhanced NH_3 deposition in the presence of SO_2 due to a higher surface acidity, is not included in the long term model yet.

Various model validation exercises are described in Van Jaarsveld (2004) and a An intercomparison of measured and modelled ammonia concentrations in nature areas can be found in (Stolk et al., 2009). A comparison between modelled and measured wet deposition levels of ammonium, nitrate and sulphate over the period 1992–2008 was reported in Van der (van der Swaluw et al., 2011). A recent comparison between OPS and LOTOS-EUROS, i.e., a more complex Eulerian Chemical Transport Model, showed that both models have a very similar non-linear response to emission changes that are representative for the early Nineties (Manders-Groot et al., 2015).

The ammonia emissions highly determine the ammonia concentration in the air. Agricultural emissions contribute about 85% of the total ammonia emissions in the Netherlands. In general, agricultural emissions are quantified by following the total N flow in the agricultural system and applying NH_3 emission factors. However, the NEMA model calculates the ammonia emissions based on the direct dependency between NH_3 volatilization and TAN (Velthof et al., 2012). TAN consists of ammonium and nitrogen compounds that are readily broken down to ammonium. The TAN content of excreted nitrogen is calculated from feed composition and nitrogen digestibility of the components. For the NEMA model, TAN-based emission factors were derived for housing systems, manure application techniques, outside manure storage, N fertilizer types, and grazing.

Uncertainty assessment

Based on comparison with observations RIVM concludes that the uncertainty in the estimated ammonia deposition is 30% on the national scale. Ammonia gap research provided changes in the dry deposition parameterization for grassland and indications that the effectiveness of manure incorporation techniques should be lowered. On the local scale uncertainties in the estimates of the deposition are up to 70%. This is mainly due to the lack of monitoring data to constrain the results and the uncertainty in dry deposition estimates. More measurements in different ecosystems of dry deposition would be needed to improve and test parameterizations. More experiments to evaluate the local scale emission – deposition relationships are needed to determine the uncertainty in emissions and in deposition.

Ammonia-sensitive areas

- Is there a national definition of ammonia sensitive areas?
- Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?

- Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

Different nature classification systems

In the Netherlands, three nature classification systems are used. Often, a combination of those are used in nature policy, management and management subsidies regarding ammonia-sensitivity. It should be noted that the Netherlands uses N sensitivity of ecosystems rather than ammonia sensitivity. Parts of the mentioned information is taken from Schmidt and Smidt (2017, in prep) and Smits and Bal (eds, 2014)

In Schmidt and Smidt (2017, in prep) ammonia sensitive areas in The Netherlands are described using three different nature classification systems, namely:

- the nature target types in Dutch 'natuurdoeltypen',
- the nature management types in Dutch 'natuurbeheertypen' and
- the habitat types of Annex I of the Habitat Directive.

The nature target types have been developed right after the establishment of the national ecological network in 1990 for the purpose of setting nature conservation objectives on national and regional scale. This typology has been used for all type of assessments amongst others the exceedance of critical load levels in The Netherlands. This typology is currently replaced by nature management types and habitat types regarding ammonia-sensitivity and critical loads.

Around 2009, the nature target types have been replaced by the nature management types also known as the 'Index Nature and Landscape' (see https://www.bij12.nl/onderwerpen/natuur-en-landschap/index-natuur-en-landschap/de-index-natuur-en-landschap/). The subsidies for nature conservation measures are based on this typology (e.g. calculation of management costs per ha) and on the PAS for the ammonia-sensitive areas. The nature management types are used by the (subsidised) nature conservation organisations to set nature conservation objectives on site level.

Natura 2000 is the European network of valuable habitats and is also the name of the European policy protecting the nature in those areas. In the Netherlands, more than 160 nature reserves have been designated under Natura 2000. In more than 130 of these areas there are plants and animals - defined as habitat types and species - which suffer from the effects of the deposition of nitrogen from the air. For the purpose of Natura 2000 (e.g. the Natura 2000 management plans) the habitat types are used. The management plans should include a description of the main characteristics of the Natura 2000 area, an elaboration of the conservation objectives on site level and a description of the measures that are needed (and planned) to reach these objectives. There is a specific paragraph section on the measures needed to solve the pressures related to nitrogen (in Dutch 'stikstofparagraaf').

N-sensitivity in N2000

The pressures related to nitrogen are addressed by the Dutch Integrated Approach to Nitrogen in Dutch 'Programma Aanpak Stikstof' (PAS). Within N2000, nitrogen sensitive habitat types have been identified within the context of the PAS) In addition, nitrogen sensitive habitats for species (not part of

Annex I of the Habitat Directive) have been identified. The latter are based on the original nature target types. The identification of sensitive types is based on requirements of these habitat types (and as well habitat for species) in terms of abiotic conditions.

The Netherlands has designated 137 Special Areas of Conservation (SAC's) and 77 Special Protection Areas (SPA's). Combined they form 160 Natura 2000 areas. There is a large overlap in the SAC's and the SPA'S. There are 20 sites of which the borders of the SAC's and SPA's exactly coincide (site type C in the Standard Data Form).

In total 60 of the 75 habitat types have a CL lower than 2400 mol of N / ha / year. These habitat types are considered 'sensitive to nitrogen deposition' (Van Dobben et al. 2012) and for all of these types a restoration strategy is outlined. The list of types is given in Annex 1. The list is expanded with CL for nitrogen-sensitive habitats of species from the Birds and Habitats Directive.). In addition, 49 protected species have a habitat that is (fully or partially) nitrogen-sensitive. The habitat types largely cover these habitats, but for 14 (additional) nitrogen-sensitive habitats a restoration strategy was prepared (Annex 1).

Effect of ammonia regulations

- The location of husbandry farms in relation to ammonia sensitive areas.
- Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, both 1) due to the general reduction in deposition and 2) due to change in location of husbandry farms and 3) as a result of the national ammonia regulation in relationship to the Habitat Directive

In the Netherlands policy is focused on both reduction of deposition at the source and mitigation by management in the N2000 areas. For the latter the programmatic approach nitrogen (PAS) was developed.

The Programmatic Approach Nitrogen (PAS)

The core of the PAS is to make the preservation and restoration of the nature quality possible without jeopardizing economic development. Within the PAS, binding agreements are made about remedial measures in the Natura 2000 areas and reduction of the nitrogen load. The PAS is an integral program of the government and the joint provinces, which also relies on the cooperation and involvement of many, such as the Association of Dutch Municipalities, the Association of Water Boards, the agricultural and horticultural organisations, the employers' organisation VNO-NCW and the various land management organisations. In 2009, the government at that time decided that the Programmatic Approach Nitrogen had to be developed (Advisory group Huys (Parliamentary document 31700 XIV 160) & the Trojan Commission (Parliamentary document 30654, No. 51) and in 2012 the PAS will enter into force.

Part of the PAS approach is moving from the one-sided emphasis on lowering the deposition to the realisation of a widely supported range of measures for the conservation and restoration of habitats. This involves the quality and the surface of these habitats. If a certain effect of nitrogen on this quality can be (temporarily) reduced by measures that are themselves not focused on nitrogen deposition, then such a measure can be characterised as a mitigation measure. Mitigation measures are, as long as the deposition is still too high, often of great importance. For this reason, measures aimed at hydrological restoration have, amongst others, gotten a prominent place within the restoration strategies.

Application of the restoration strategies

The restoration strategies have been prepared for the habitat types and species based on the best available knowledge and form the ecological foundations of the measures, which need to be taken in practice. From the available recovery measures, a package of (local, field level) management measures need to be compiled for a specific Natura 2000 area, where nitrogen-sensitive nature occurs. The area-specific information needs to be added. Information on the location, differences in space and time and environmental factors (e.g. air and groundwater quality) are, in addition to, for example, historical analyses with which the trend can be determined, the basis for an area-specific landscape ecological analysis (LESA; Van der Molen 2010). The information from the current project must help the writers of the management plans to get to an optimal package of management measures against the effects of atmospheric nitrogen deposition. In addition, this information forms the foundation for a possible authorization of new economic activities.

The strategies therefore offer guidance in achieving concrete measures to protect vulnerable habitats in specific areas. This can involve measures at the location where the habitat types are present, such as removing the present nitrogen supply by mowing, turf cutting or digging, or adjusting the water level locally. But there may also be measures under discussion relating to an entire landscape, both inside and outside the Natura 2000 area concerned. Think of, for example, the improvement of the groundwater quality in the catchment area, the increase of the local groundwater level and of interventions in the landscape that contribute to sand drift.

The knowledge is made available through a computer application (web tool), whereby the user sees the nitrogen problem on the spot from a specific Natura 2000 area. Everts & De Vries (2011) have developed an application for this use. Through a roadmap the user gets the right information at his disposal and the relevant measures will become visible.

Preconditions of the project

Definition habitat types

The Dutch habitat types (as defined in the profile documents) are the Dutch interpretation of the European definitions. They are a used for the reports to the EU. The definitions have been accepted by both the European Commission and the Dutch Council of State.

Critical Loads

In this report the CL as defined for the Netherlands (Van Dobben et al. 2012) is used. They were subjected to an international review (Bobbink & Hettelingh 2011).

Impact-oriented measures vs source-based measures

The ecological underpinnings only address the impact-oriented measures. Source-based measures are not included in this assignment for the ecological underpinnings.

Abiotic conditions

The abiotic conditions (acidity, nutrient-richness and moisture levels) are adopted from Runhaar et al (2009). Conditions are calculated for the vegetation types in the profile documents (definition of habitat types).

Critical loads

- Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?
- Are critical levels used?
- To which extend, and how are calculations based on the Mapping Manual from UNECE?
- Are calculated critical loads based on biodiversity targets used or planned to be used in the future?
- If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?
- If model calculations are used:
- Describe the models and the data included in the calculations
- Are target loads used for the specific areas; if so, how?
- Is there a reference year in the calculations, and if so, which?
- Are different methods used for setting critical loads for areas inside and outside of Natura 2000 areas, and if so, how?
- How often are the critical loads updated?
- Describe if and how nature management e.g. grazing is taken into account in the model calculations.

Methods to compute critical loads

Critical loads for habitat types were used to define which habitats could be considered as nitrogen-sensitive in the PAS. The critical deposition value for nitrogen was defined as "the limit, beyond which the risk can not be excluded that the quality of the habitat type is significantly affected as a result of the acidifying and / or fertilizing influence of the atmospheric nitrogen deposition" (Van Dobben & Van Hinsberg 2008).

The critical loads, which are taken as a starting point in the restoration strategies, are established in Van Dobben et al. (2012) specific to habitat types in the Netherlands. In that report, several sources regarding critical deposition values were combined using a fixed protocol (Van Dobben et al. 2012).

Those sources are:

- empirical critical deposition values for nature types according to the EUNIS classification, with a bandwidth, as published in Bobbink & Hettelingh (2011) and adopted by the UN-ECE (of which the Netherlands is also a member);
- model-specific critical deposition values per vegetation type according to Van Dobben et al. (2012);
- expert opinion of the authors.

In short, it means that the CL for a habitat (sub) type must lie within the bandwidth of a comparable EUNIS-type. The CL is (under that precondition) the average of the model-specific critical deposition values of the constituent types of vegetation. The expert opinion was applied for the selection of useful model results (also for those cases in which no empirical values were available) and for adding critical deposition values for habitat types for which no model results were available. Habitats of protected species sometimes also encompass types of nature, which are not covered by habitat types. In order to still be able to determine a CL, the same procedure was used for the determination of critical deposition values for target nature types. The definition of CL therefore applies mutatis mutandis also for (elements of) habitats of species, called 'habitat of the species' in the regulations. Critical loads for N2000 areas have been updated once: in 2012 van Dobben et al updated the earlier critical loads by Van Dobben en van Hinsebrg (2008), although the methods remained unchanged. Later on studies have been carried out to investigate if critical loads need to be updated based on e.g. other abiotic thresholds like NO3 concentration, but this has not resulted in updated critical loads.

Critical level, target loads and modifying factors

No modifying factors were used for the empirical critical loads; the value within the range chosen was based on the modelled critical load but only if this values falls within the empirical range. If no reliable model results was available for the habitat type, generally the midpoint of the empirical range was used. For a few habitats, expert judgement was used to select a value that deviates from the midpoint (Van Dobben et al. (2012)). Critical levels for NH3 are not used to set targets or thresholds for nature types or habitat types, nor are target loads.

Agreement with methods from the mapping manual

The methods used to compute the critical loads are partly in line with the methods described in the mapping manual, for example empirical critical loads are used from in Bobbink & Hettelingh (2011) which is also referred to in the MM. Modelled critical loads deviate from the methods in the mapping manual, as the modelling uses pH and N availability as threshold values and the steady state version of the SMART2 model (for critical loads supplied to the UN-ECE recently replaced by the steady state version of VSD+) to compute critical loads for N and S (see Annex 2 for details). The manual, however, describes methods based on critical N concentrations with SMB as the critical load model.

Inclusion of management in the critical loads

Nature management is included in the calculations in the most simples way possible. A fixed amount of biomass with a fixed content of nitrogen is taken out of the system when doing the calculations for CL. The amounts vary per vegetation type. The amount and content are based on model calculations with the vegetation succession model SUMO (Wamelink et al. 2009). The SUMO model is a carbon and nitrogen balance model where almost all different types of nature management (including grazing with 17 different species of grazers) is included. The biomass amount taken out of the system calculated with the model was fine-tuned based on expert knowledge. Restoration management is not included in the critical loads.

Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

- Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and I f so: are empirically critical loads or national model calculations and local data used for the specific nature area?
- To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included?
- Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
- Describe briefly if and how local scale transport and deposition is calculated?
- Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how

Permissions to increase ammonia emissions from existing livestock farms: The Aerius model

The Netherlands has adopted a Programmatic Approach to Nitrogen (PAS, or, in Dutch, Programmatische Aanpak Stikstof). The PAS, supported by the online calculation tool AERIUS (Sterkenburg & van Alphen, 2017), guarantees that Natura 2000 objectives will be met, while creating room for economic development. It uses an inter-governance approach, across all sectors and areas. The PAS includes analysis of scenarios for emission reduction, based on generic measures, an additional national package of measures for the agriculture sector, measures at provincial/regional level and measures at the local level, such as habitat restoration measures. The AERIUS toolkit calculates both emission and deposition levels for Natura 2000 sites, caused by new or expanding economic activity. It provides a validated management approach, defining the risks and options for restoring and maintaining habitat integrity under different nitrogen regimes. It provides information about the requirements for permit applications. By pinpointing areas and sites of high-value habitat, it enables resources to be concentrated for permit requests. Permit requests and assessments are processed automatically, saving a great deal of time and resources, and enabling more-consistent outcomes. Its scenarios allow all parties to reach agreement and it is useful in monitoring those agreements. Initiators of projects will be legally obligated to use AERIUS to calculate the nitrogen impact of their project. This applies to all sectors: agriculture, industry and transport. For more details, and to become a user of AERIUS Calculator see www.aerius.nl/en

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?

For Natura 2000 areas that are subject to the PAS a management plan and a special report about the PAS measures have to be made. In the documents the management and management goals are described in detail including the mitigating measures to be taken. Management as grazing, mowing or sod cutting are described for each area specific including intensity. Note that grazing is normally only used as a measure to influence the structure of the vegetation and not removal of N from the system.

From Smits and Bal (eds 2012).

It has been recognised that habitat management measures can be successful in restoring nitrogen affected ecosystems by:

(i) intensifying nature management in order to preserve nitrogen-sensitive habitats as long as the critical load is exceeded (e.g. by means of introducing or intensifying grazing, mowing, sod cutting);
(ii) mitigating the adverse effects, as long as the critical load is exceeded by means of solving other problems that cause similar effects (such as eutrophication and acidification caused by lowering water tables);
(iii) restoring nitrogen-sensitive habitats when critical load are no longer being exceeded, e.g. by means of the removal of accumulated N in water, soil and/or vegetation.

Restoration management can be applied to mitigate the effects of Ndep as long as they are mentioned and approved in the 'Hersteldocumenten'. The management is site specific and the effect on nitrogen availability in the field is estimated and included in the model calculations with Aerius. The resulting distance to the target (CL) is estimated by the model, including the effects of management. Thus restoration management affects the exceedance of the CL calculations.

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Annex 1 Overview of the N-sensitive habitat types and N-sensitive habitats for species within the PAS

Within the PAS 2400 mol / ha / yr is regarded to be the threshold value for nitrogen-sensitivity. Therefore the list below consists of habitat types and added habitats for species with a CL smaller than 2400 mol / ha / yr. For most types, the conservation objectives are conservation, improvement and expansion. For the types Grasslands on soils rich in heavy metals (6130) and Woodrush-beech forests (9110) only improvement and expansion apply. The Critical Load (CL) is presented in mol / ha / yr and is derived from Van Dobben et al. (2012).

Name	Critical load
1. Nitrogen-sensitive habitat types	
Silty pioneer vegetation, glasswort (H1310A)	1643
Silty pioneer vegetation, sea pearlwort (H1310B)	1500
Spartina fields (H1320)	1643
Salt marshes and silty grass fields, outside the dyke (H1330A)	1571
Salt marshes and silty grass fields, inside the dyke (H1330B)	1571
Embryonic dunes (H2110)	1429
White dunes (H2120)	1429
Grey dunes, lime-rich (H2130A)	1071
Grey dunes, lime-deficient (H2130B)	714
Grey dunes, nutrient-poor soil (H2130C)	714
Dune heath with crowberry, humid (H2140A)	1071
Dune heath with crowberry, dry (H2140B)	1071
Dune heath with crowberry (H2150)	1100
Dunes with thorny scrub (H2160)	2000
Creepy willow thickets (H2170)	2286
Wooded dunes, dry (H2180A)	1071 en 1429
Wooded dunes, wet (H2180B)	2214
Wooded dunes, inside dune edge (H2180C)	1786
Humid dune slacks, open water (H2190A)	2143 en 1000
Humid dune slacks, lime-rich (H2190B)	1429
Humid dune slacks, decalcified (H2190C)	1071
Driftsand heathland (H2310)	1071
Inland crowberry heathland (H2320)	1071
Driftsand (H2330)	714
Oligotrophic waters containing very few minerals of sandy plains (H3110)	429
Oligotrophic to mesotrophic peat bogs (H3130)	571
Hard oligo-mesotrophic waters with benthic vegetation of Chara spp. (H3140)	571, 2143 en 2400
Lakes with crab's claw and Potamogeton (H3150)	2143 en 2400
Acid fens (H3160)	714
Humid heathland, elevated sandy soils (H4010A)	1214
Humid heathland, fenland (H4010B)	786
Dry heathland (H4030)	1071
Juniper thickets (H5130)	1071
Pioneer vegetation on rocky soil (H6110)	1429

Brook valley grasslands (H6120)	1286
Grasslands on soils rich in heavy metals (H6130)	1071
Calcareous grassland (H6210)	1500
Xeric sand calcareous grasslands (H6230)	714 en 857
Nutrient-poor grassland with carnation sedge (H6410)	1071
Tall herb fringe communities, dry forest fringes (H6430C)	1857
False oat-grass and Alopecurus hay meadows, false oat-grass (H6510A)	1429
False oat-grass and Alopecurus hay meadows, meadow foxtail (H6510B)	1571
Active raised bogs, high raised bogs (H7110A)	500
Active raised bogs, small heathland moors (H7110B)	786
Recovering raised bogs (H7120)	500, 1214 en 1786
Transitional and quaking bogs, quaking bogs (H7140A)	1214
Transitional and quaking bogs, sphagnum reed beds (H7140B)	714
Pioneer vegetations with white beak-sedge (H7150)	1429
Cladium mariscus marshes (H7210)	1571
Petrifying springs with tufa formation (H7220)	<2400?
Calcium-rich springwater-fed fens (H7230)	1143
Woodrush-beech forests (H9110)	1429
Beech-oak forests with Ilex (H9120)	1429
Oak-hornbeam forests, higher arenaceous soils (H9160A)	1429
Oak-hornbeam forests, undulating landscape (H9160B)	1429
Old oak forests (H9190)	1071
Bog woodland (H91D0)	1786
Humid alluvial forests, ash-elm forests (H91E0B)	2000
Humid alluvial forests, riparian forests (H91E0C)	1857
Dry riparian hardwood forests (H91F0)	2071
2 Nitrogen-sensitive habitats of species from the Birds and Habitats Directive	
Permanent spring & slowly-flowing upper course	<2400
Isolated meander and peat trench	2143
Poorly buffered ditch	1786
Acid fen	1214
Large-sedge swamps	1714
Marsh-marigold meadow of stream valleys	1429
Marsh-marigold meadow of turf and clay	1429
Wet, moderately nutrient-rich grassland	1571
Dry agrostis field	1000
Dog's-tail grass & multifloral meadow-bird grassland of the sand and fen area	1429
Dog's-tail grass & multifloral meadow-bird grassland of the riverine and marine clay area	1429
Edge, mantle and dry thicket of the dunes	1643
Forest on poor sandy soils	1071
Oak and beech forest on loamy arenaceous soils	1429

Annex 2

Description of the models

SMART2-SUMO2 is a soil-vegetation model, which has been developed to calculate the long-term effects of, among other things, atmospheric deposition and management on soil and vegetation on a regional and national scale. SMART2 is the soil module and SUMO2 the vegetation module. They are fully integrated with an annual feedback. SMART2 (Kros 2002) consists of a set of equations, which describe the chemical processes in the soil. The model contains all the macro-ions and also describes the dynamics of organic compounds. The soil chemistry in SMART2 depends on the input from the atmosphere (deposition) and the ground water (seepage), chemical tree crown interactions (uptake or release of ions), nutrient cycle processes, and the geochemical interactions in the soil and soil solution (CO2-equilibria, carbonate weathering, silicate weathering, solution of Al-hydroxides and cation exchange). The uptake and litter production are calculated by SUMO2.

In SMART2, the organic compounds dynamics is only present in the litter layer. The litter is formed by leaf drop and root mortality. Decomposition of organic compounds is described by a first order reaction dependent on pH and moisture condition (GVG). Decomposition slows down at lower pH values and shallower groundwater levels.

The model covers one year; seasonal variability is not taken into account. The simulation is based on a rooting depth of 60 cm.

SUMO2 (Wamelink et al. 2009a, b) is a model that describes the vegetation development, particularly succession and related processes. This makes it possible to simulate the influence of management on vegetation and enables feedback from the vegetation development to the soil. For the current application SUMO2 is directly linked to SMART2.

The biomass development is the driving force in SUMO2. Biomass growth is simulated based on the availability of nutrients, light and moisture, the temperature, CO_2 concentration and management. In SUMO2 five functional types compete for nutrients and light. Management is implemented as a discharge term of biomass (and possibly litter).

The five functional types are: climax trees, pioneer trees, shrubs, dwarf shrubs and herbs (including grasses). For each type, three organs are simulated: roots, woody non-photosynthetic parts and leaves. The functional types differentiate from each other in the way new biomass is distributed between the organs and which part of the organs dies a year. Between the types, the competition for nutrients is carried out on the basis of the root biomass present (the more root biomass, the more nutrients are absorbed). The nutrient uptake is, however, bound to a maximum, which is determined by the quotient of the maximum growth rate and the maximum nutrient standard.

Competition for light between the types occurs based on the length (the highest captures light first) and the leaf biomass (the more leaf biomass, the more light is intercepted). In order to make this possible, the length of each functional type is simulated. For trees, this is done by species, which are selected based on either planting or succession. For succession, the tree species are determined by the soil conditions (soil type and the fluctuation and depth of the groundwater). The annual linear growth is dependent on the newly formed biomass. For the other functional types no distinction is made between species. For the linear growth of bushes a growth curve of the same type as for the trees was used, whereby a maximum length of about seven meters can be reached The length of the dwarf shrubs and herbs is dependent on the biomass in the functional type concerned.

The amount of biomass, which is present per functional type, determines the predicted vegetation structure type. This will predict. Possible succession By SUMO2 12 structure types are distinguished. The five functional types are present in each structure type, although the amount of biomass can be small (eg shrubs in grassland).

Starting points for the calculations

The following preconditions were used for the calculations:

- for the hydrology generic water balances:
- national average precipitation (757 mm.y^{-1})
- evaporation dependent on the soil (see Kros 2002);
- for the total deposition of alkaline cations and chloride the national average was used (BC^{2+}: 540, K^{+}: 45, Na^{+}: 1068 en Cl^{-}: 1270 $mol_c.ha^{-1}.y^{-1}$);
- for the SO_2-deposition a constant value of 400 mol $ha^{-1}.y^{-1}$ was used;
- the calculations are based on a fixed ratio of 2:1 between NH_3-deposition and NO_x-deposition.
- vegetation growth is exclusively limited by N; P and alkaline cations therefore do not play a part.

In addition, the following combinations of soil type, vegetation type, average spring groundwater level (GVG), seepage flux, seepage quality and N-deposition were used:

Soil types:	poor sand and loam-rich sandsoils
Vegetation types:	grassland, heath and broad-leaved forest
GVG:	0.20 m-mv (wet) and 1.60 m-mv (dry)
Seepage:	3 mm day^{-1} if the GVG is 0.20 m-mv and 0 mm day^{-1} if the GVG is 1.60 m-mv.
Seepage quality:	Ground water or rainwater quality. For the composition see Table 1.
N-deposition:	700, 1500 en 3000 mol ha^{-1} y^{-1}.

Table 1. Seepage quality.

Element (mol_c l^{-1})	Water type: Ground water	Water type: Rain water
Na	0.522	0.070
K	0.051	0.007
Ca + Mg	6.417	0.037
SO4	0.271	0.119
NO3	0.021	0.095
NH4	0.043	0.055
Cl	0.31	0.084

Starting point is standard SUMO2 management. This means that grass is mowed once a year if the aboveground biomass is higher than 1 t/ha. The heath's turf is cut once every 30 years, whereby all vegetation and 90% of the plant litter layer is removed. Forest management is 'natural', which means that nothing is done unless the biomass ends up above 25 t / ha, in which case 10% is thinned once a decade.

The initialization is done with standard SMART2-SUMO2 start conditions. The initial age of the vegetation is 10 years for grassland and heath and 60 years for broad-leaved forests. The initial thickness of the waste layer is calculated using the age of the vegetation and the average leaf fall for the type of vegetation. An initialization period of 10 years is used. The model thus starts at t = -10, but the output starts at t = 0. Because the initial age is set at 10 years, heath's turf is cut at t = -20 and then every 30 years, thus at t = 10 and t = 40. An output covering a period of 60 years is generated each year. This output is reproduced graphically.

Results

The diagrams below show the results of the runs for the period t = 0 to t = 60. Per model output (Table 2) three diagrams are shown with 6 soil-vegetation combinations each. The three diagrams per model output are the three hydrological situations, one dry and two wet:

Dry: GVG 1.6 m below ground level, no seepage
Nat: GVG 0.2 m below ground level, seepage 3 mm / day with groundwater
GVG 0.2 m below ground level, seepage 3 mm / day with rain.

Output was generated each year and these points were connected with a 'smooth' curve. Please note that the Y-axes in all plots are scaled in such a way that they run between the minimum and the maximum value in that plot. The scale can therefore differ per plot. Moreover, the difference between minimum and maximum values can be very small. The plot therefore sometimes gives the impression that a development occurs, while the variable concerned is actually almost constant.

Table 2. Meaning of the abbreviations in the diagrams.

Abbreviation	Meaning (English)	unit
pH	pH	-
Strooisel	plant litter production	$t.ha^{-1}.y^{-1}$
N_uitsp	N leaching	$kg.ha^{-1}.y^{-1}$
Nupt	N uptake	$kg.ha^{-1}.y^{-1}$
Biomassa	biomass	$t.ha^{-1}$
Nbiom	N in biomass	$t.ha^{-1}$
N_besch	N availability[1])	$kg.ha^{-1}.y^{-1}$
Diktestr	thickness of the waste layer	cm

[1]) the availability is the sum of deposition and mineralisation.

The three lines show three deposition levels:
green = 700 mol ha^{-1} y^{-1} = 9.8 kg N ha^{-1} y^{-1}
black = 1500 mol ha^{-1} y^{-1}= 21 kg N ha^{-1} y^{-1}
red = 3000 mol ha^{-1} y^{-1}= 42 kg N ha^{-1} y^{-1}.

In the development over time the turf cutting cycle in heath (1x per 30 years) and the thinning cycle in forest (1x per 10 years) are clearly visible. In general, the effect of the deposition level is greatest in grassland.

The pH in loamy or groundwater-fed situations is mainly determined by buffering and is therefore independent of the deposition and constant after about t = 50. In the dry, poor situation the pH slowly rises in grassland and is almost constant in the forest. In heath, at the highest deposition level, a drop in pH to below 4 occurs in the period shortly after turf cutting.

The waste production for grassland is constant, as it is cut annually, whereby a fixed amount of biomass (1 t/ha) remains, of which then a fixed percentage becomes waste (please note that the three lines for the deposition levels coincide, leaving only the red one visible). For other types of vegetation the waste production increases along with the deposition.

The N leaching is under all conditions significantly higher under the high deposition scenario than under the other two scenarios.

Particularly in grassland, the biomass is strongly dependent on the deposition. Note that in grassland the biomass is determined before mowing (peak standing crop), but the amount of waste is determined after mowing (and is therefore constant). In grassland, in the course of time, a slight decrease in biomass takes place, even under the highest deposition scenario. The leaps in biomass in wet grasslands (especially when rain-fed) are inexplicable. The N in biomass roughly follows the biomass itself. The N availability is strongly dependent on deposition (please note that the N availability can be calculated as mineralisation + deposition - immobilization - denitrification). The in time increasing N availability in forests is the result of the build-up of the waste layer.

The thickness of the waste layer is little dependent on deposition. In grassland a decrease of the thickness occurs, except in the rain-fed situations. In forests an increase takes place. It should be realized that only annually mowed grassland was calculated, of which the waste production is constant and independent of the deposition.
A priori it is difficult to state something about the relationship between deposition and waste thickness, because:
more deposition > higher production > more waste > thicker waste layer
more deposition > lower pH > less litter decomposition > thicker waste layer
but:
more deposition > more N in waste > lower C / N ratio > faster waste decomposition> thinner waste layer.
Which mechanism will dominate will probably depend on the other circumstances. Generic statements are therefore difficult and a national, location-specific calculation is actually needed here.

The C/N ratio almost always has a downward trend, in other words, an accumulation of N occurs, also under the low deposition scenario. But this is perhaps, because the initial C/N ratio is always very high (around 30, for grassland this is unrealistically high!). For this reason, the C/N ratio is not plotted here.

Determining the 'critical levels' in Diagrams 1.X and 1.Y

The critical levels, shown as dotted lines in Diagrams 1.X and 1.Y, are derived from the simulation by Van Dobben et al. (2006), on which the used CDV's of Van Dobben & Van Hinsberg (2008) are based.

To this end, the average and standard deviation of the critical N availabilities and pH's from the input files of the simulation for the respective vegetation structure type (in this case grassland) are determined. Then, generalized critical levels are determined per vegetation structure type: for N availability as (average + 2 * standard deviation) and for pH as (average - standard deviation). These levels are therefore levels above which (for N availability) or under which (for pH) associations of this structure type practically do not occur. The figures can be found in Annex 4.

Annex 3 CL of nature management types

The nature management types do work with the CL concept though in a slightly different way than the habitat types. The management types have three categories, good, moderate and bad. Good is when the deposition is below the CL of the most critical vegetation association that make up the management types, moderate is when the deposition is above that CL but below the CL of the most tolerant association of the management type, bad is when the deposition is above the CL of the most tolerant association. Values are in kg/ha/y. The list is adopted from Wamelink et al. in prep.

code	Name	Description	good	mode-rate	bad
N01.01	See	Northsee and Waddensee			
N01.02	Dune and salt Marsh	Large scale landscape of the Dune and flooded by the sea land. It contains several of the types mentioned here below.			
N01.03	River and swamp landscape	Large scale landscape with floodplains , swamps and small lakes. It contains several of the types mentioned here below			
N.01.04	Sand landscape	More or less undisturbed areas on the sandy soils. It contains several of the types mentioned here below.	< 10	10 - 18	> 18
N04.02	Fresh water lakes	Lakes of major size			
N04.03	Brakish water	Waterbodies between the salt sea and the freshwater rivers			
N04.04	Former sea inlets	Lakes that were isolated from the sea due to the Deltaworks.			
N05.01	Marshland	The marshes are situated at the transition of salt water to fresh water or are fresh water fen marches. They were once present in about 40% of the Netherlands on peaty and clayey soils. The optimal nutrient status is high and the optimal soil pH is slightly acid till neutral. Typical species are tall grasses (reed, reedmace) and sedges, rushes, fish, dragon flies, otter and beaver. Marshland contains parts of open water, bushes and trees.	< 15	15 - 35	> 35
N05.02	Mown Reed Marshland	This type is normally mown once a year, preferably in winter. Reed harvest for commercial practices is normal. Unmown reed, bushes and trees may be present in small areas. Most of the mown marshlands occur on peaty soils often together with other wet marsh types.			
N06.01	Reed with Sphagnum and Marsh Heath	These marshlands are normally relative nutrient poor and only occur in fens. Marsh heath is a transition state to raised bog. The vegetation has a minor coverage of reed and a dominance of Sphagna, common sundew, orchids and small ferns, typical species of Sphagno palustis-Ericetum. The vegetation height is low and very open, tall growing species are mostly absent.	< 10	10 - 18	>18
N06.02	Quaking Bog	Floating raft of organic material of plants of mostly 20-70 cm thick. The water quality is very important and has to be modest nutrient rich and base rich and with a stable groundwater table. Originally it occurred in floodplains of streams, but nowadays mostly in fens. The vegetation consist mostly of low sedges, brown mosses and herbs, and some very rare species of Scorpidio-Caricetum diandrae.	< 10	10 - 16	> 16
N06.03	Raised Bog	Raised bog has a hummock-hollow pattern with raised Sphagna and Erica hummocks and water hollows with submerged Sphagna like Sphagnum cuspidatum. Locally, at the borders of the raised bog, spontaneous occurring shrubs and trees may be	< 5	5 - 10	> 10

		present. The pH is low and the bogs are mostly rainwater dependent. Besides rare plants as cotton-grass and bog asphodel, many rare butterflies and other insects occur in raised bogs.			
N06.04	Moist Heath	This wet heathland time often includes small raised bog like situations shrub land, small waters and fens and bare soil. Normally the soil is sandy or loamy, acidic, wet and nutrient poor. Dominant are the dwarf shrubs, with the most prominent species *Erica tetralix.* This species poor type is sometimes overgrown by grasses, especially purple moor grass and sometimes parts are dominated by bog myrtle.	< 11	11 - 18	> 18
N06.05	Mire	This type has very clear water with vegetation dominated by rushes. In the summer the fens may partly or totally dry out. They often occur in heathlands with moist heath. The water is nutrient poor and buffered. The buffering in an acid surrounding may originate from loamy soil, streaming base cations rich water, or base cation rich seepage.	< 5	5 - 10	> 10
N06.06	Bog or Raised Bog	These wetlands occur on sandy soils in the Netherlands. They are often the result of wind erosion, blowing the top soil layer away. The water stagnates because of an impermeable soil layer. The bogs are rainwater fed, the water is acidic and nutrient poor. Sometimes the water colours brown by DOC. The borders of the bogs can be wetland, but also can consist of sedges or moist loving heather species.	< 5	5 - 10	> 10
N07.01	Dry Heath	Dry heath consist, besides heathland, of shrub land, small places with bare sand and grassy places. It occurs on base cations poor sand and loam. The vegetation is dominated by dwarf shrubs, mainly Calluna. Open spots are often dominated by (rare) lichens, sometimes the vegetation is dominated by grasses, juniper, broom or blackberries.	< 15	15 - 30	> 30
N07.02	Inland Dunes	Inland dunes consist mostly of free blown sand, the vegetation cover is low. Pioneer species as lichens and mosses may be present. Inland dunes occur on dry acidic very nutrient poor soils. Late successional stages contain vegetation of bunt grass or sheep's fescue, heathers and small shrubs. Late successional stages contain normally pine forest. Sometimes sand is blown away till the groundwater level and then species belonging to wet heathland may occur.	< 10	10 - 15	> 15
N08.01	Beach and Young Dunes	This type contains the seashore and the small young ' living' dunes at the seaside. Many of the young dunes and even the beaches have a short lifespan, they disappear when a very high tide or a storm changes the distribution of sand. The vegetation is scarce and consist mostly of band wheat grass and in late succession stadia marram grass. The presence of a high salt concentration dominates the soil circumstances resulting in a high soil pH.	< 10	10 - 20	> 20
N08.02	Open Dune	Open dune has a structure rich vegetation and includes bare soil as well, as a result of wind, grazing and salt spray. Mosses and lichens can be dominant, together with marram grass. More inland herb rich grasslands occur together with shrubs and forest.	< 10	10 - 20	> 20
N08.03	Moist Dune Valley	Open water, low pioneer vegetation, sedges dominated vegetation and *Salix repens* vegetation make up the Moist Dune Valley type. The Valleys are mostly fed with fresh groundwater.	< 15	15 - 20	> 20
N08.04	Dune Heath	Both dry and wet dune heath are represented in Dune Heath. Besides different types of heathers it can also consist of *Salix repens*. The variation in this type is high, it contains more wet	< 15	15 - 35	> 35

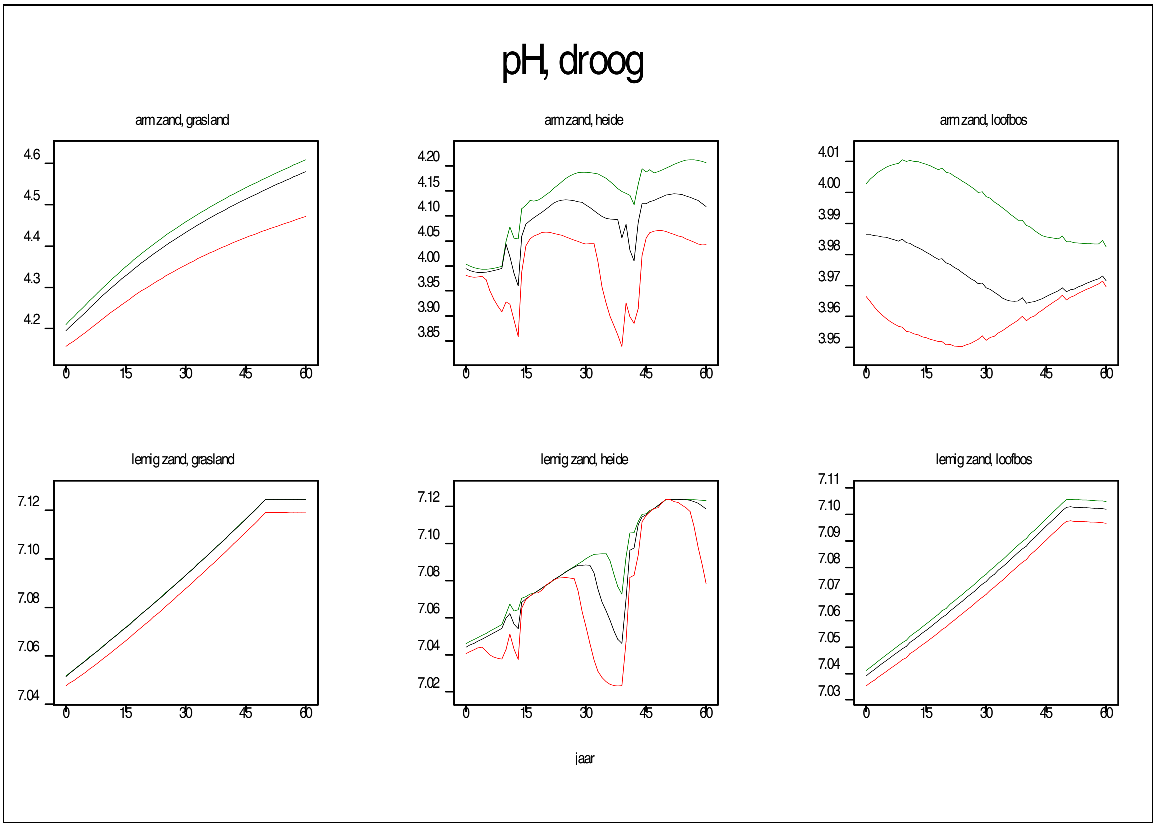
		north slopes with mosses and lichens or polypody and dry south slopes also dominated by mosses and lichens and areas dominated totally by heather species. Although more buffered than inland heathers, the heathers are acidifying the soil due to the build-up of organic matter and especially the breakdown of the organic matter, releasing organic acids.			
N09.01	Salt marsh	The Salt marshes are under direct influence of the sea and are flooded from twice a day till occasionally. Clay particles brought in by the sea build up the grassland. Salt concentrations can be very high, also giving in a high soil pH. The presence of small creeks is normal in this highly dynamic landscape and gives rise together with the flooding and salt to a large variation in vegetation.	< 30	30 - 40	> 40
N10.01	Wet Nutrient Poor Grassland	Old grassland type, due to the wet circumstances difficult to manage. In winter they can be submerged. Yearly haymaking is necessary to maintain these grasslands. The variation in vegetation types is rather large, from *Cirsio dissecti-Molinietum,* short sedges vegetation, and vegetation of Sharp-flowered Rush as *Crepido-Juncetum acutiflori.* Many rare grassland plant species occur in these hay fields. Normally these grasslands are not manured, though this may have happened occasionally in the past.	< 11	11 - 15	> 15
N10.02	Moist Hayfield	These hayfields are a result of long year hay making of former swamps or forests. It occurs on wet peat or clayish soils and are better manageable than the Wet Nutrient Poor Grasslands. These flower rich grassland are normally rich in half parasite plants, keeping the biomass production relative low. Also present are clover species, buttercup species and marsh-marigold. Especially important are abiotic gradients within the fields, e.g. along rivers and streams. The grasslands are also important for meadow birds.	< 11	11 - 23	> 23
N11.01	Dry Nutrient Poor Grassland	These Dry Grasslands occur on loamy sandy soils, river dunes and loess in the hilly parts of the Netherlands. They include grasslands along streams, chalk rich grasslands, zinc grasslands and *Nardetea* grasslands. For this type transitions to shrub and forest at the borders are important. Base richness is a necessity, this can originate from the soil, but also from flooding with base rich water.	< 12	12 - 30	> 30
N12.01	Flower-rich Dyke	Typical for the province of Zeeland and sometimes Groningen and Friesland in the Netherlands. Often these are old none functional dykes made of chalk rich sandy clay. They are grazed in low densities or used for hay making.	< 20	20 - 30	> 30
N12.02	Species-rich Grassland	A vegetation type of 'left over' grasslands. They have to be herb-species-rich and offer opportunities for insects and other animals. The typical Holcus grasslands belong to this type. The grasslands are more nutrient rich than the other inland grassland types and situated on moist till dry soils. Most of the grasslands are gone due to excessive manuring and spraying of herbicides against dicots.			
N12.03	Flower-rich Meadows	Meadows that belong to the phytosociological class *Arrhenaterion elatioris.* They occur on moist till frequently flooded parts of the floodplains on sea clay and loess. Tall grasses are dominant present, as well as members of the carrot family. Often these grasslands have two vegetation layers, one with the taller grasses and one with the lower herbs.	< 20	20 - 30	> 30

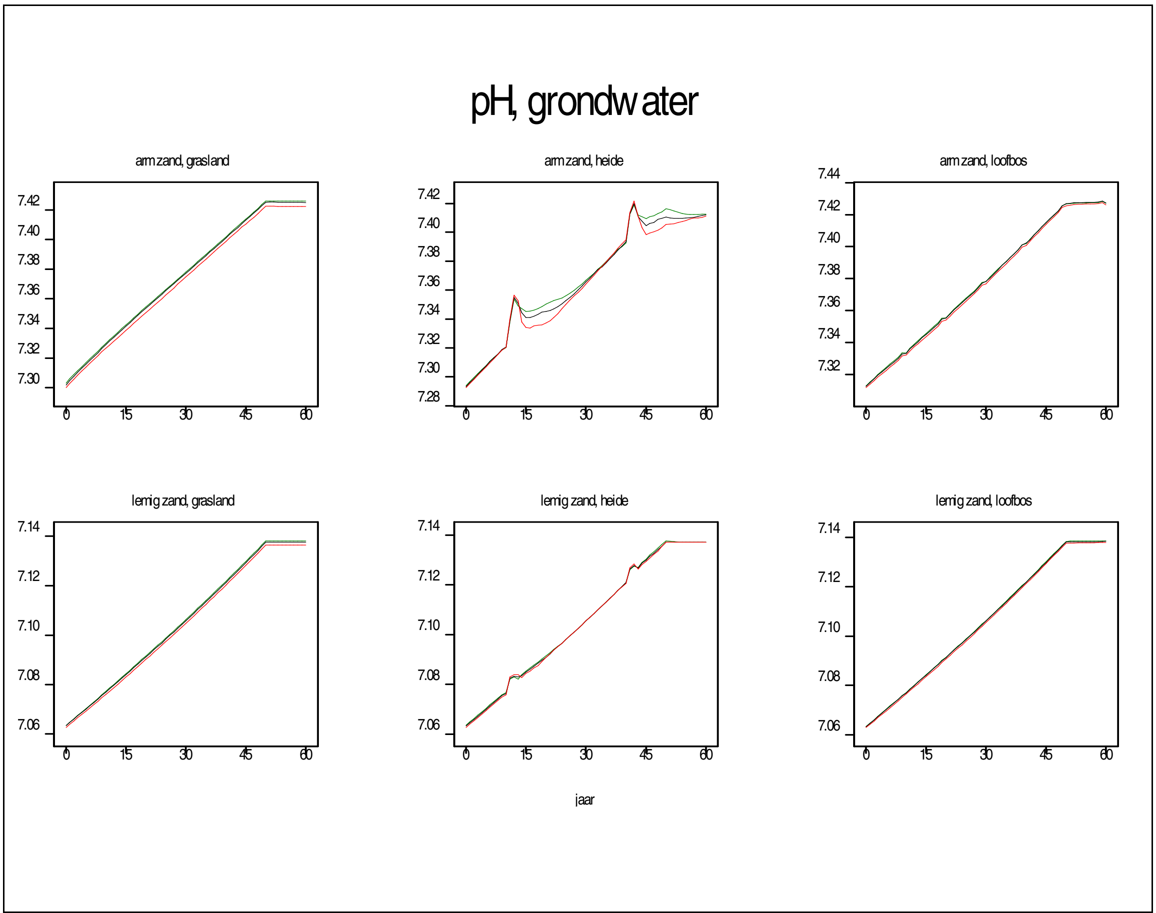
N12.04	(salt) Floodplains	The type consists of vegetation with grasses, sedges and herbs on moist sand, peat or clay soils. The vegetation is almost yearly flooded, the salt vegetation type by salt or brackish water.	< 20	20 - 35	> 35
N12.05	Species-rich Arable Land	Arable land with within the crop a layer of herbs and or grasses. The coverage of grasses is limited and the crop is sawn not to dense. This gives rise to a typical pioneer vegetation with opportunities for insects and birds.			
N12.06	Tall Forbs and Grasses	This dense and rough vegetation type occurs often after large scale changes, e.g. land reclamation or change from intense agriculture to extensive vegetation management. Due to the dense vegetation cover succession towards forest can be blocked for a long period. Several herbs may be found here, but the vegetation is especially rich in insects and important for several bird species as Blue throat, Common grasshopper warbler and Short-eared owl.			
N13.01	Moist Bird-rich Meadows	Moist and wet grasslands primarily managed for their bird population. The soils are light acidic till neutral and they are minimal moderate nutrient rich. Species like Black-tailed godwit, Lapwing, Oyster catcher and Redshank are important. Most of the grasslands occur on peat and clayish soils in the west of the Netherlands, but they also occur in floodplains and on dry sandy soils in the east of the Netherlands.			
N13.02	Wintering Birds Meadow	Often plant species poor nutrient rich agricultural production grassland used by swans, geese and ducks during winter time. The grasslands are intensively managed and mown and have a short vegetation at the beginning of winter. Part of the grasslands are submerged during winter or have (small) lakes in the neighbourhood.			
N14.01	Forest of Rivers and Streams	These type forests are regularly flooded by surface water. The forests mostly occur in floodplains and along streams but also in constant water giving wells. The forest is dominated by broad leafed trees and has normally a rich understory of grasses and herbs.	< 26	26 - 40	> 40
N14.02	Forest of Quacking and Raised Bogs	These forests grow on peat and are dominated by species as common alder, moor birch and large grey willow. The forest may be structure rich but also dominated by just one tree species. Rainwater and rainwater quality are important for the occurrence of typical bog species in the understory, including varies types of Sphagna and dwarf shrubs.	< 12	12 - 25	> 25
N14.03	Hornbeam and Ash Forest	This forest type is dominated by, besides hornbeam and ash, maple and field elm. The forests occur on nutrient rich loamy or clayish soils or on soils with a permanent high groundwater table with base-rich water. Especially the spring flora is of interest.	< 20	20 - 28	> 28
N15.01	Dune Forest	All forests in the dune area belong to this vegetation type, including oak, ash and needle forest and including tall shrub vegetation. The forests are rich in fungi and bird species.	< 18	18 - 28	> 28
N15.02	Pine, Oak and Beech forest	Forests of sandy acidic dry soils. Often these forest are planted and some kind of forestry takes place. In some cases the management has stopped totally and these forests slowly turn to their more natural existence. Mostly these forest are structure poor and only consist of one or two dominant tree species. In general the understory is also species poor, except for the more loamy soils.	< 10	10 - 20	> 20
N16.01	Dry Production Forest	Production forests have two goals, wood production and nature conservation. This is reflected in the tree species, mostly one	< 20	20 - 29	> 29

		dominant tree species, often an exotic species as Douglas. Nowadays, there is a trend to more mixed stands with native tree species present as well and more variation in age class. Trees are normally planted when gaps occur and no saplings of the desired species occurs. The planted trees may not necessary fit to the local circumstances.			
N16.02	Moist Production Forest	Moist production forest consist of species as poplar, ash, hornbeam, maple, beech, alder and field elm. It occurs on wet till moist clayey till sandy soils and is rather nutrient rich. As for Dry Production Forest, the major purpose is wood production.	< 20	20 - 30	> 30
N17.01	Moist Coppice Forest	Managed forest type where trees are cut from once every year till once every twenty to thirty years and a stump is left behind to re-sprout. It is a traditionally way of forestry in existence for ages. The diversity in forest types is large, caused by both the cut tree species, the frequency of management and the soil and groundwater table circumstances.	< 20	20 - 34	> 34
N17.02	Dry Coppice Forest	Dry coppice forest is comparable with the moist variant except the groundwater table (lower), the management intensity (less) and the soil type (mostly sandy soils).	< 20	20 - 29	> 29
N17.03	Forest in Parks	Park forest are often relative old, with old trees and they occur either in towns or cities or as gardens at large manors. Especially the parks at manors can be botanically interesting. Many parks have also isolated exotic tree species and shrubs for decoration purposes.	< 15	15 - 34	> 34
N17.04	Decoy	A decoy minimal consist of a pond and a set up for catching birds (ducks). Often the pond is surrounded by trees, e.g. willow that is maintained as coppice. Decoys date back to the middle ages.			

Annex 4 Figures

droog = dry
grondwater = groundwater
regenwater = rainwater
jaar = year
armzand, grassland = poor sand, grassland
armzand, heide = poor sand, heath
armzand, loofbos = poor sand, broad-leaved forest
lemigzand, grassland = loam-rich sand, grassland
lemig zand, heide = loam-rich sand, heath
lemig zand, loofbos = loam-rich sand, broad-leaved forest

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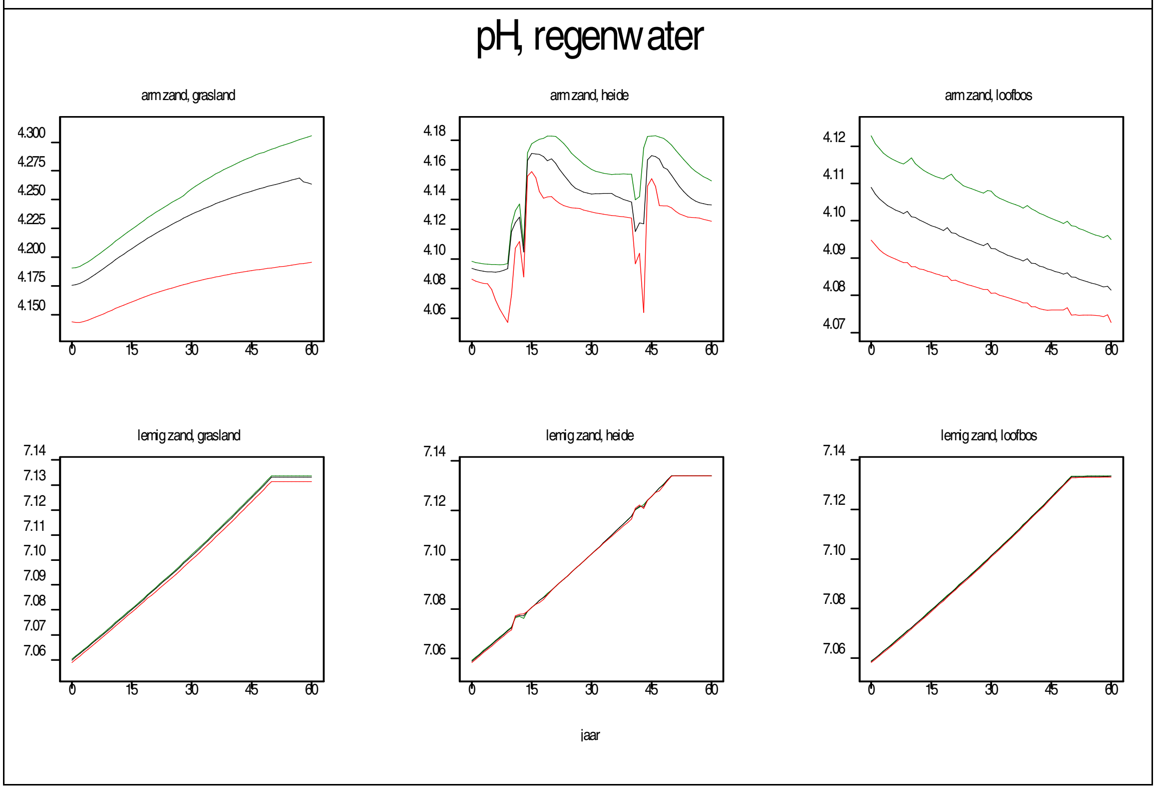
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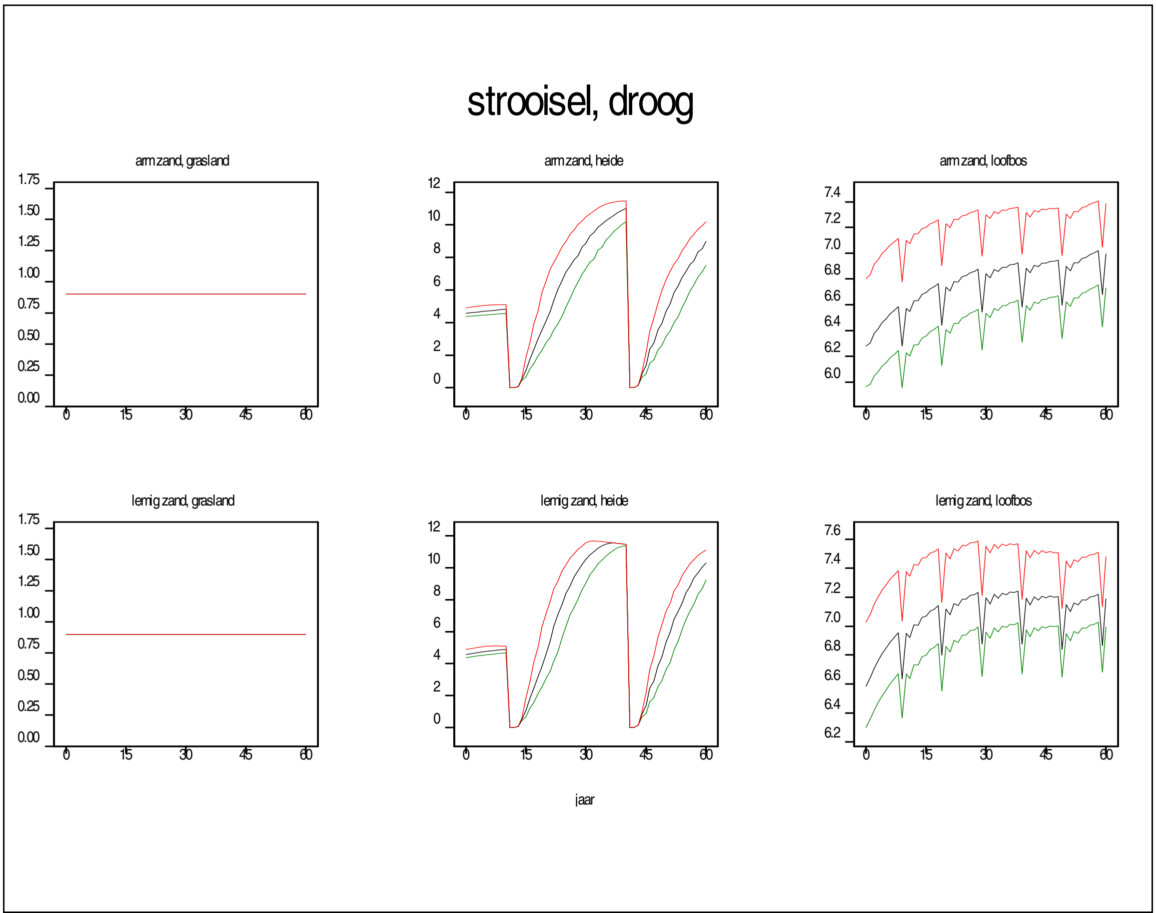
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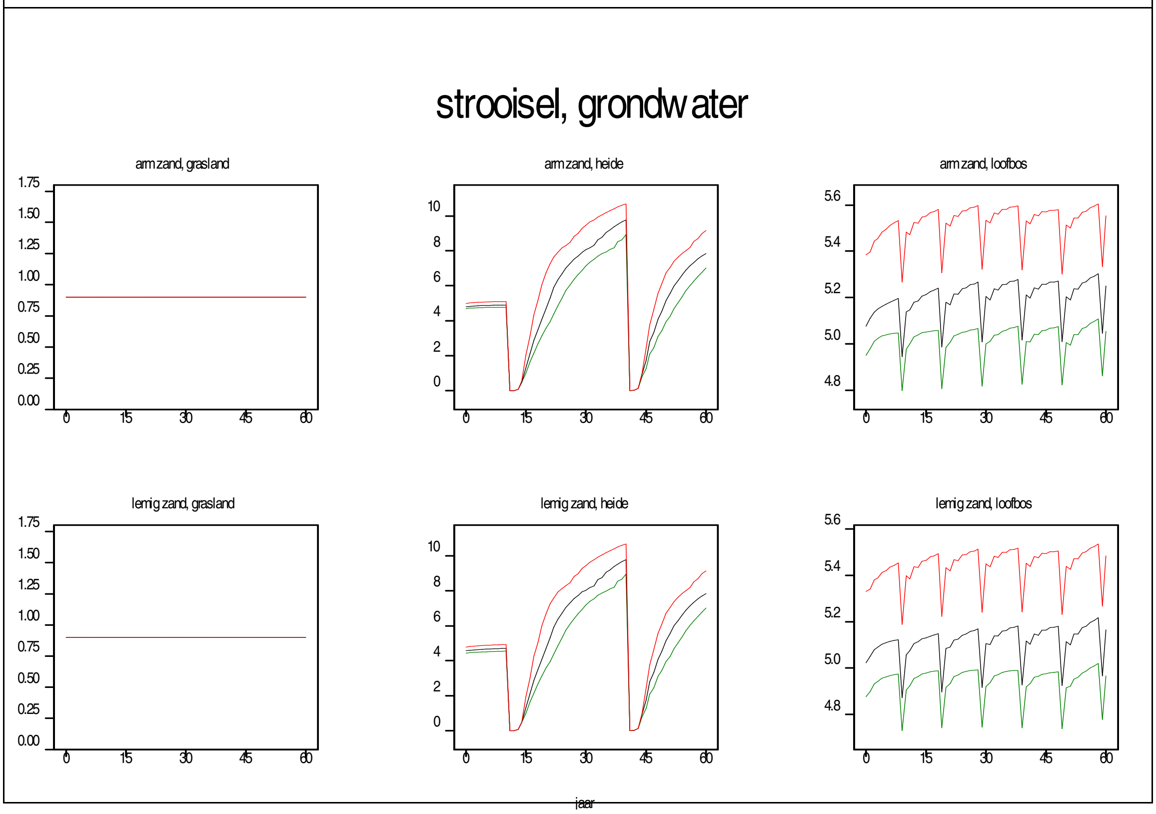
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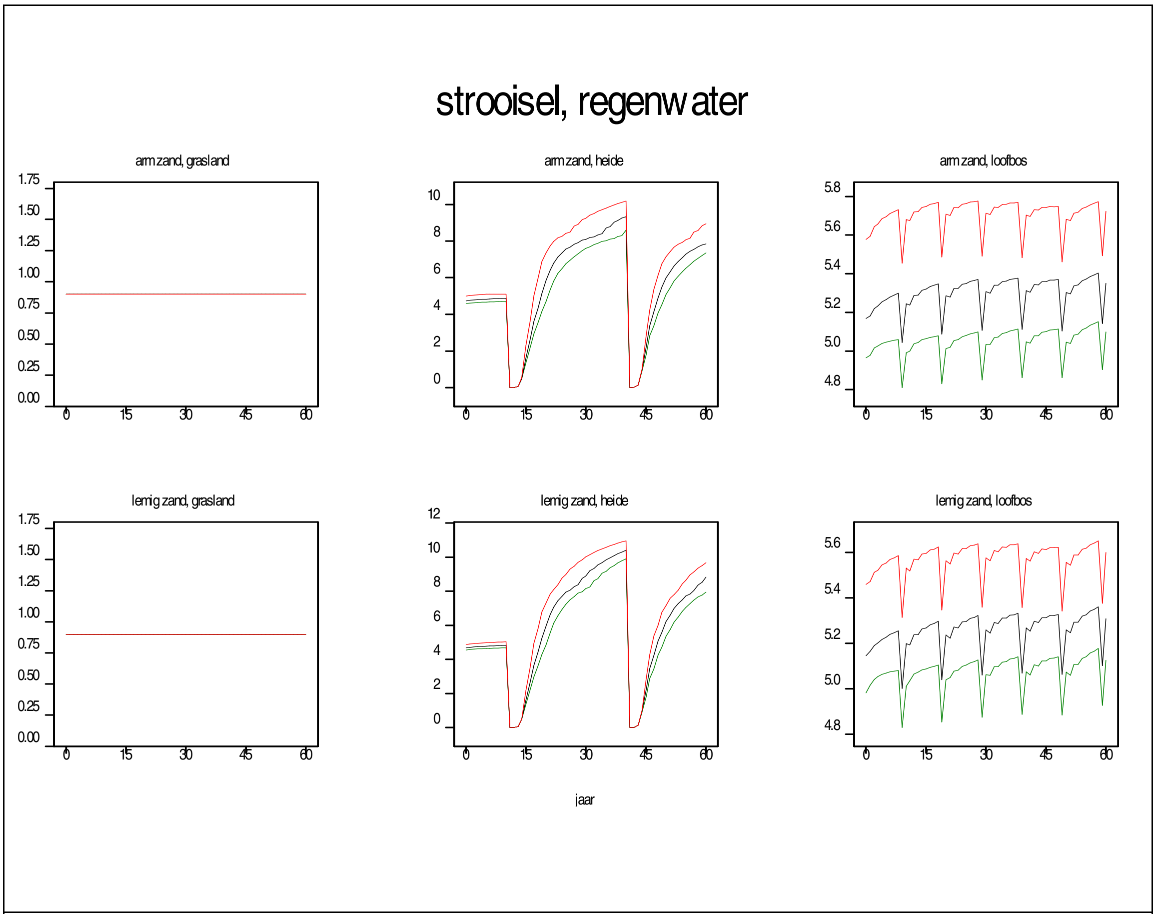
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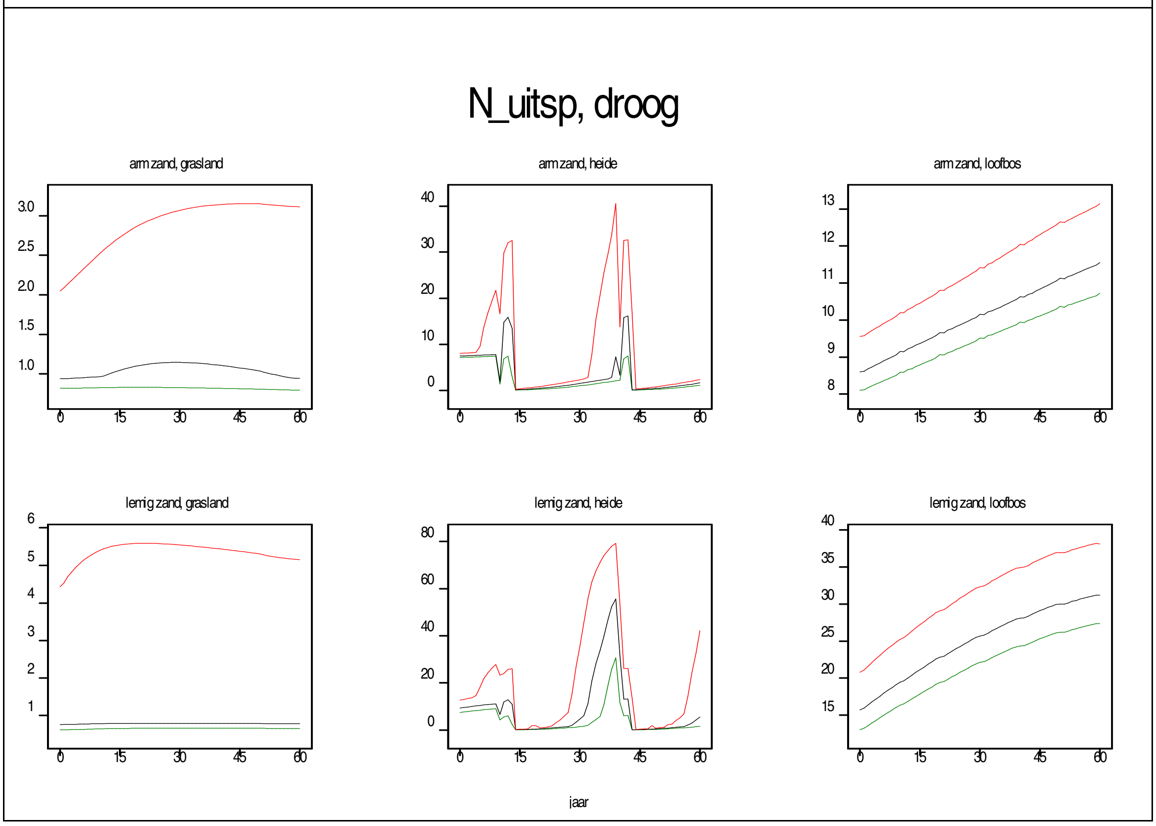
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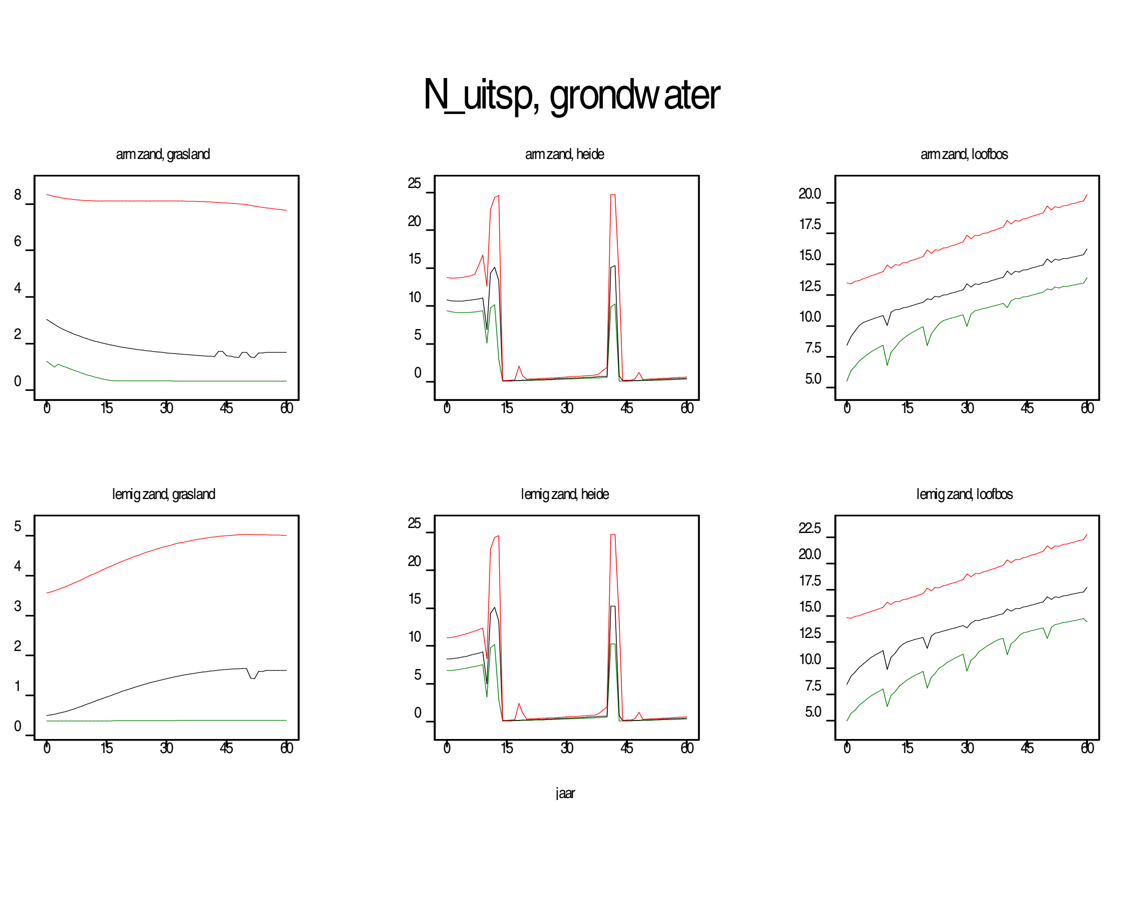
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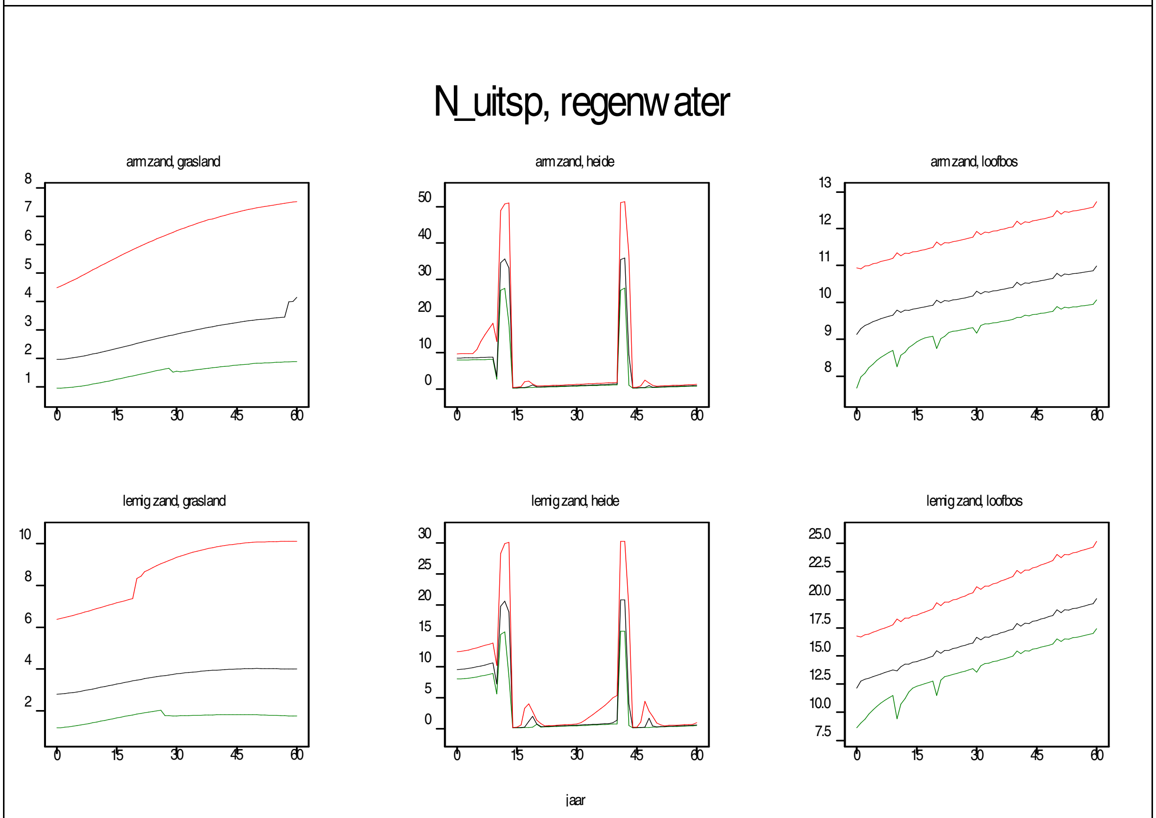
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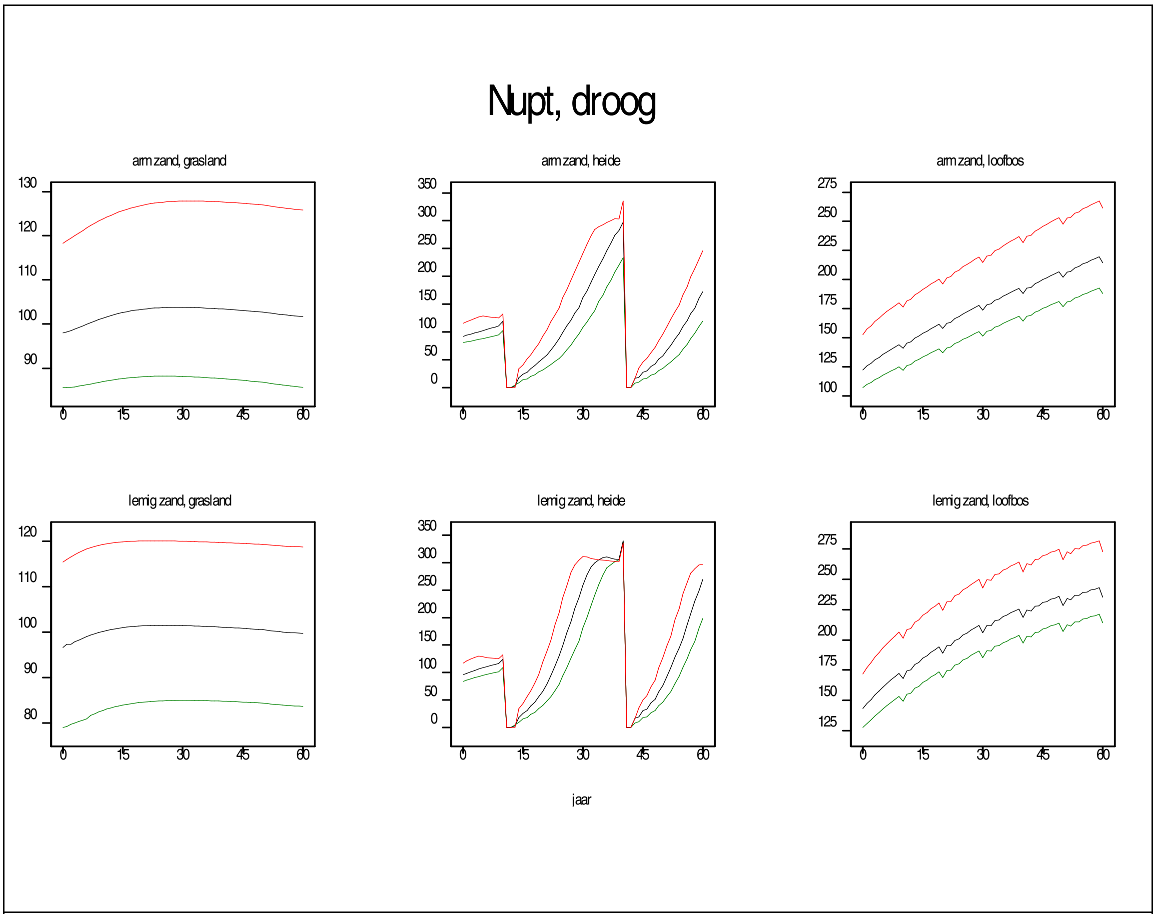
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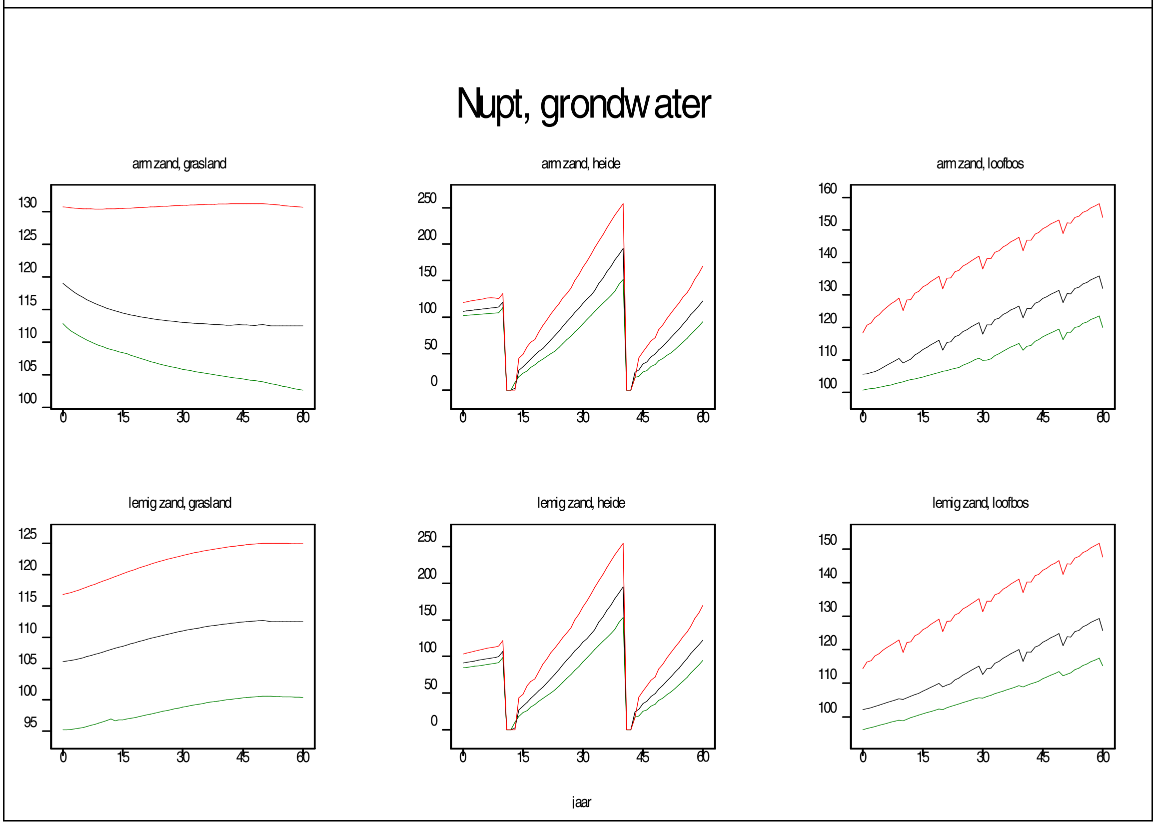
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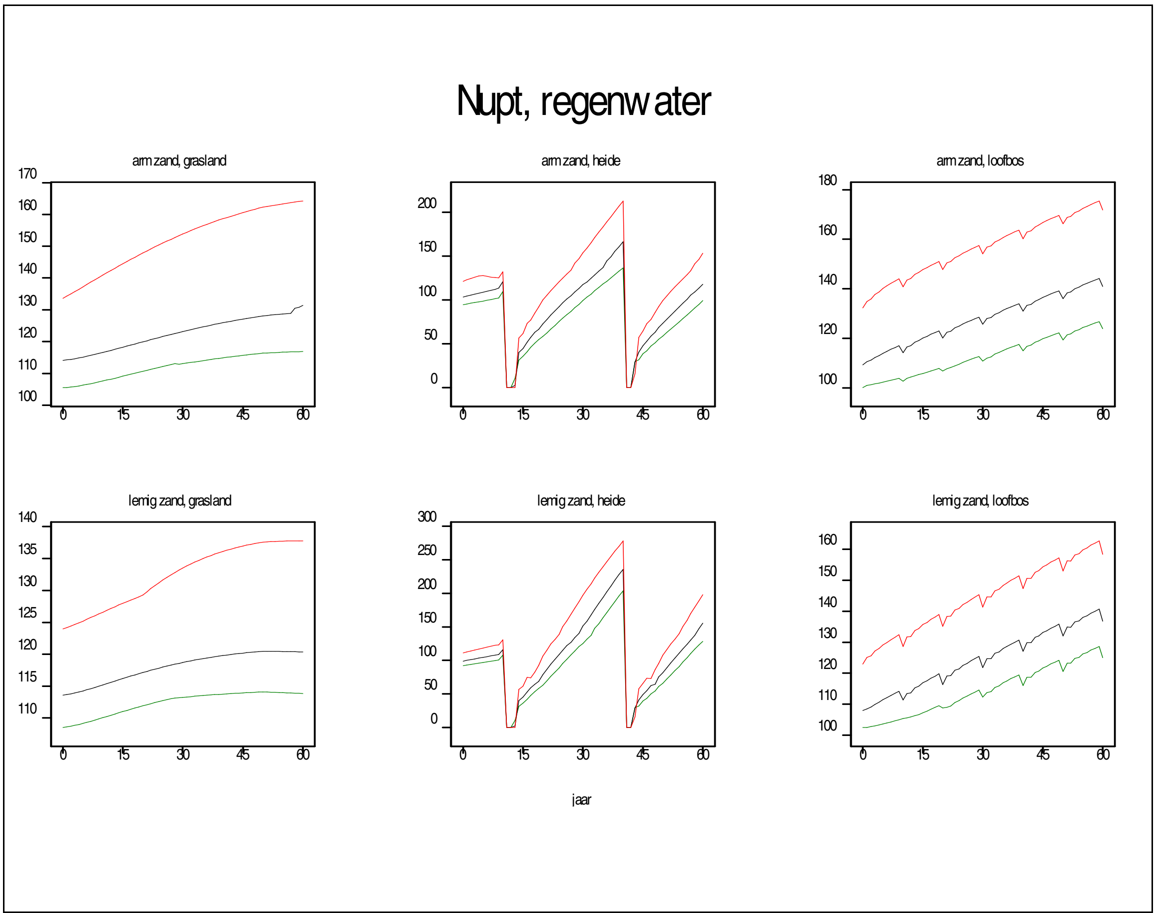
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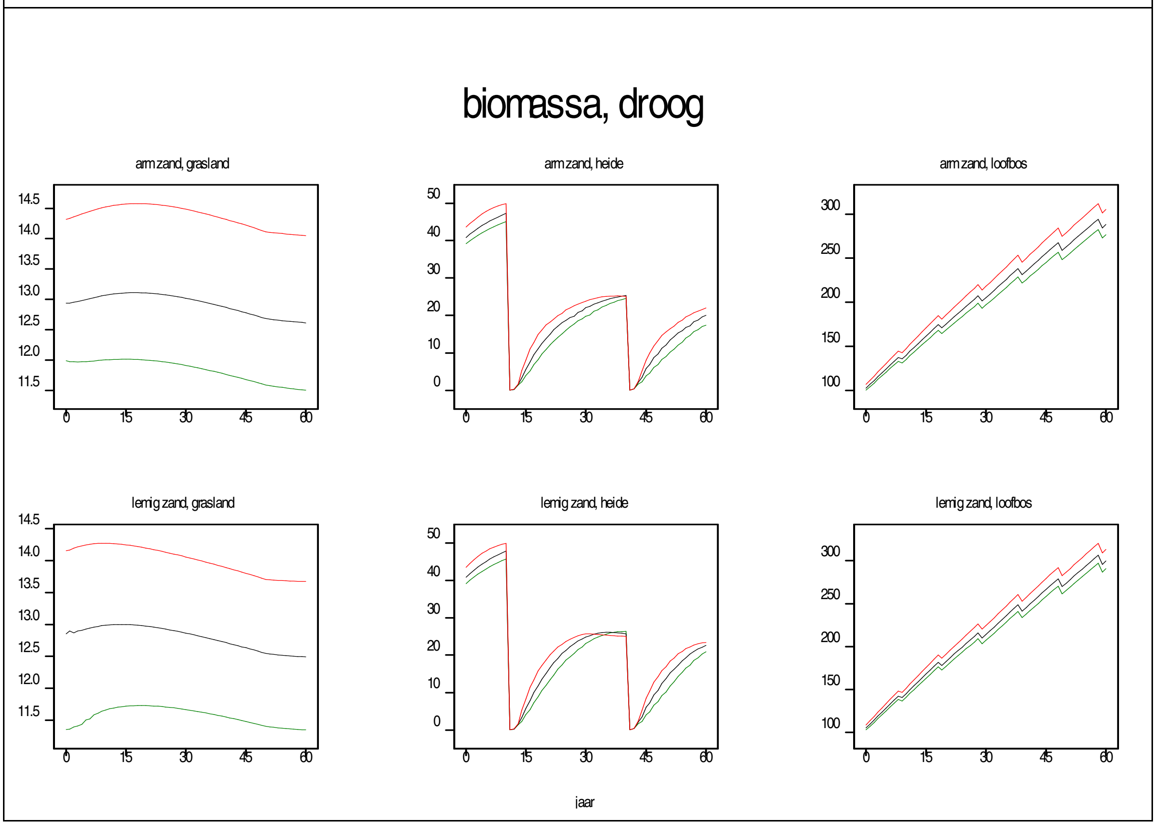
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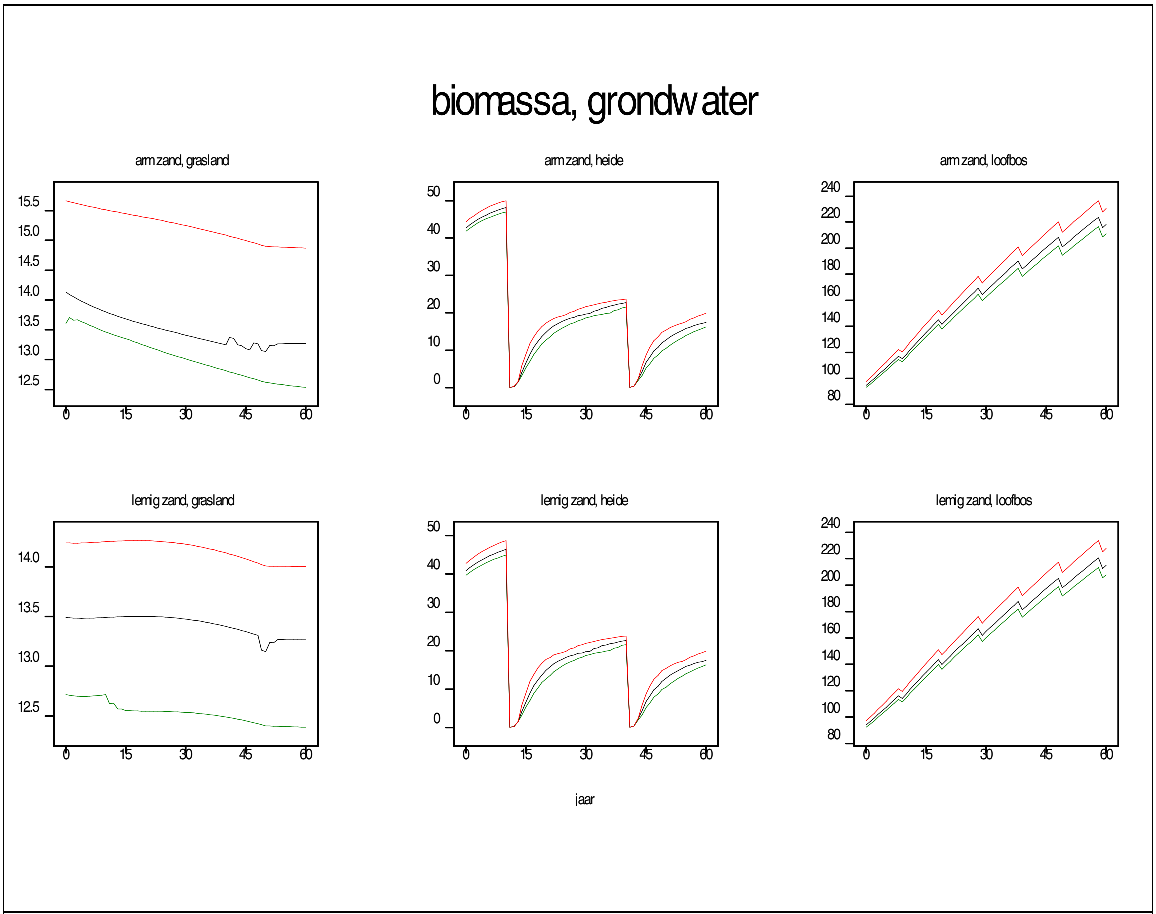
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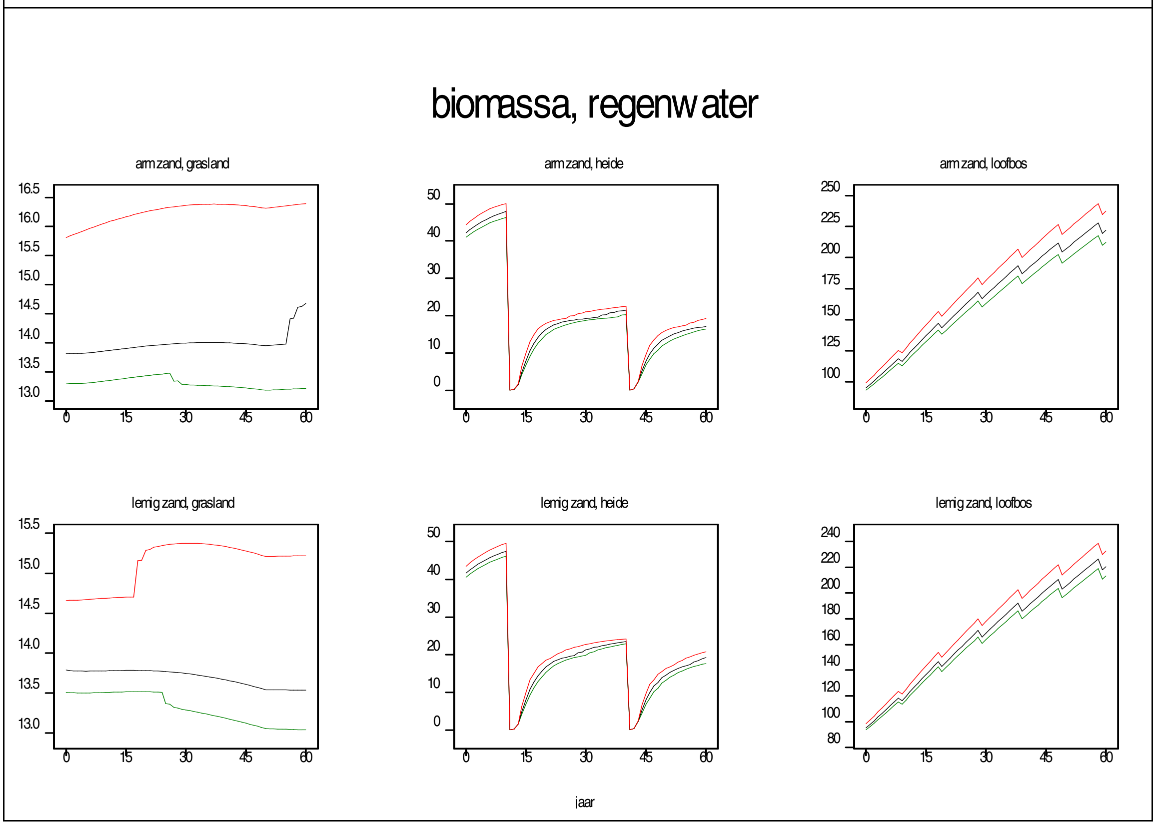
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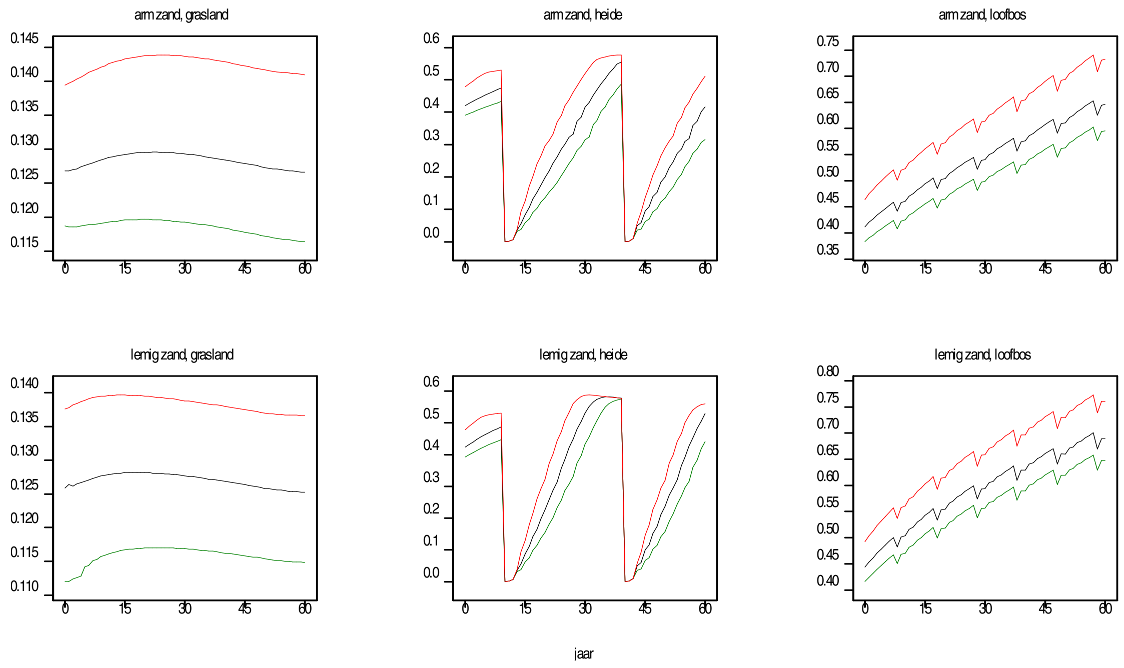

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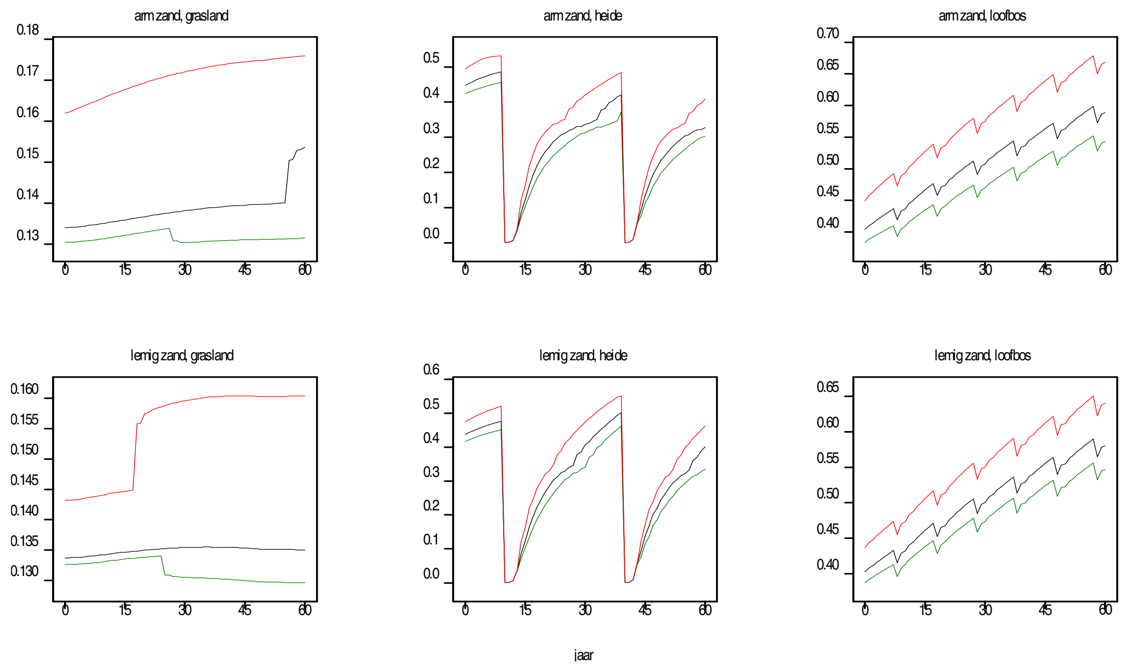

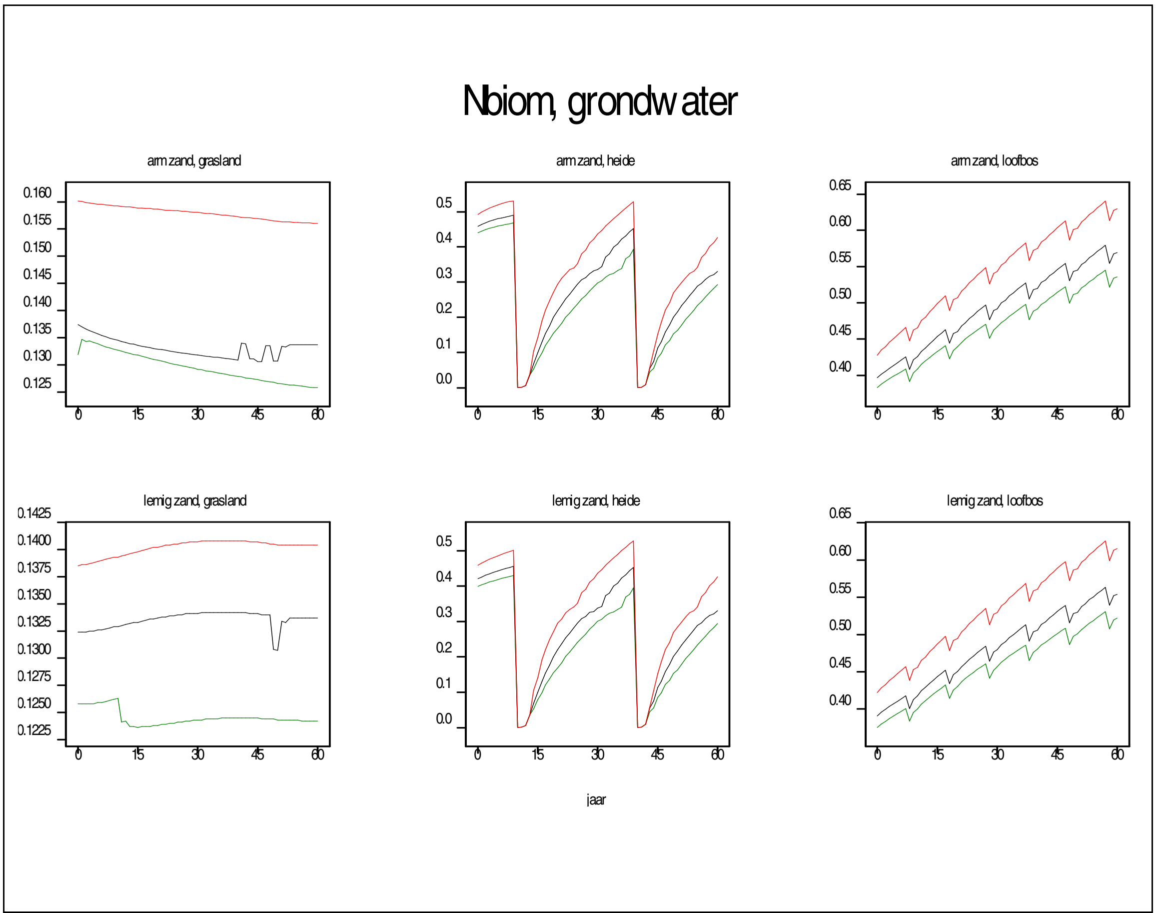
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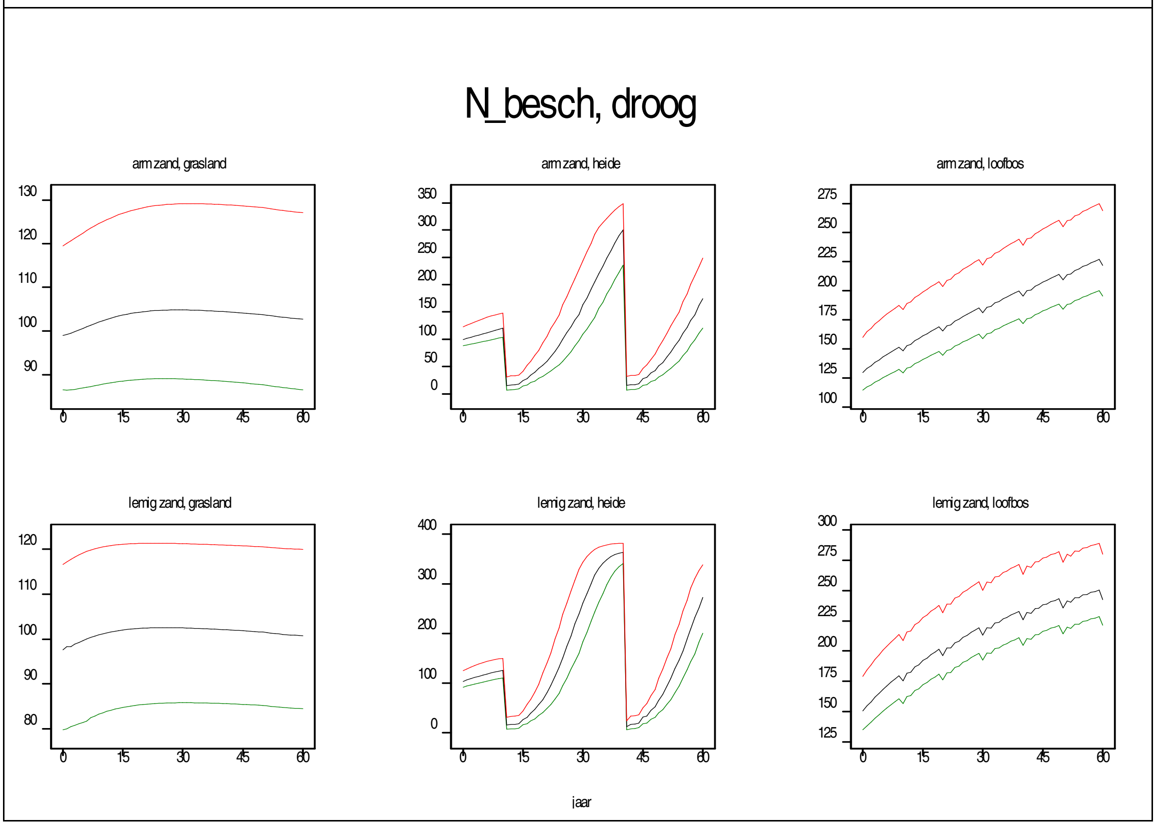
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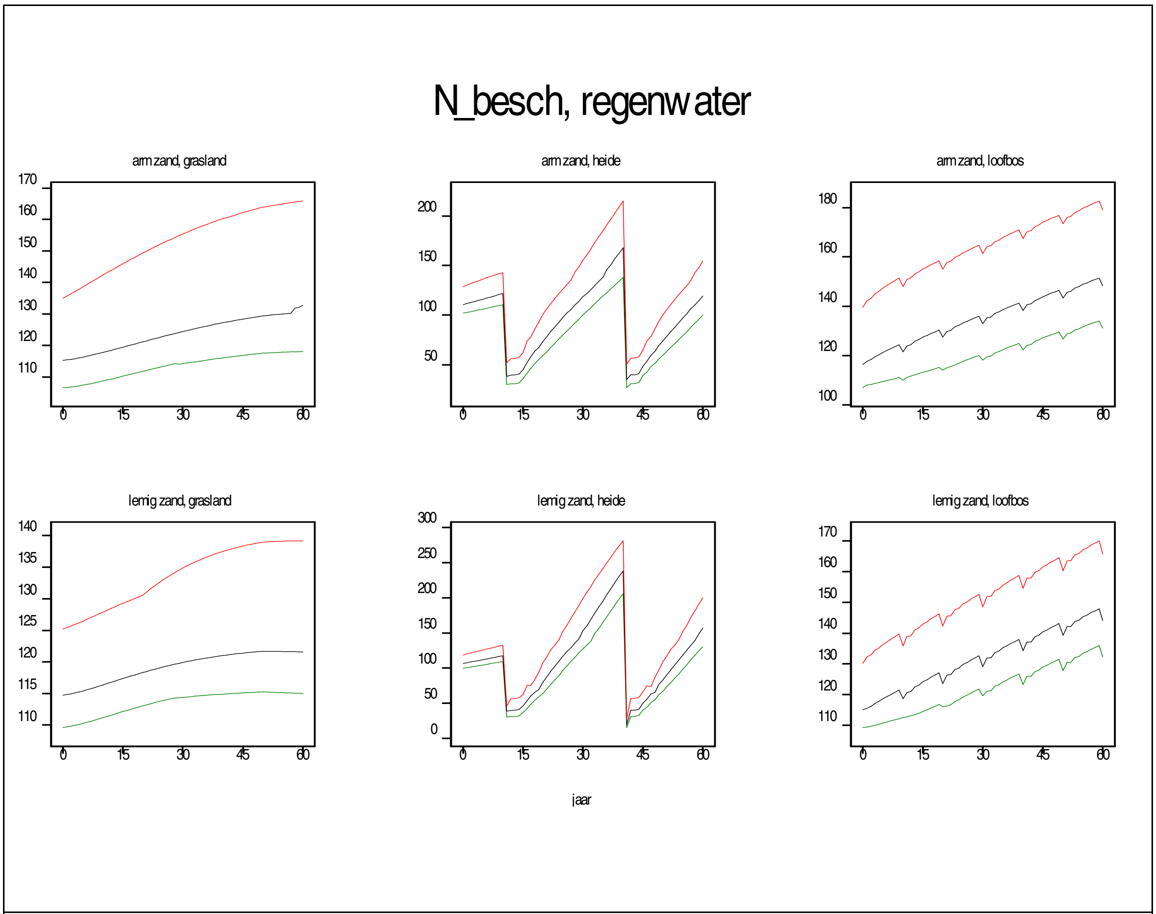
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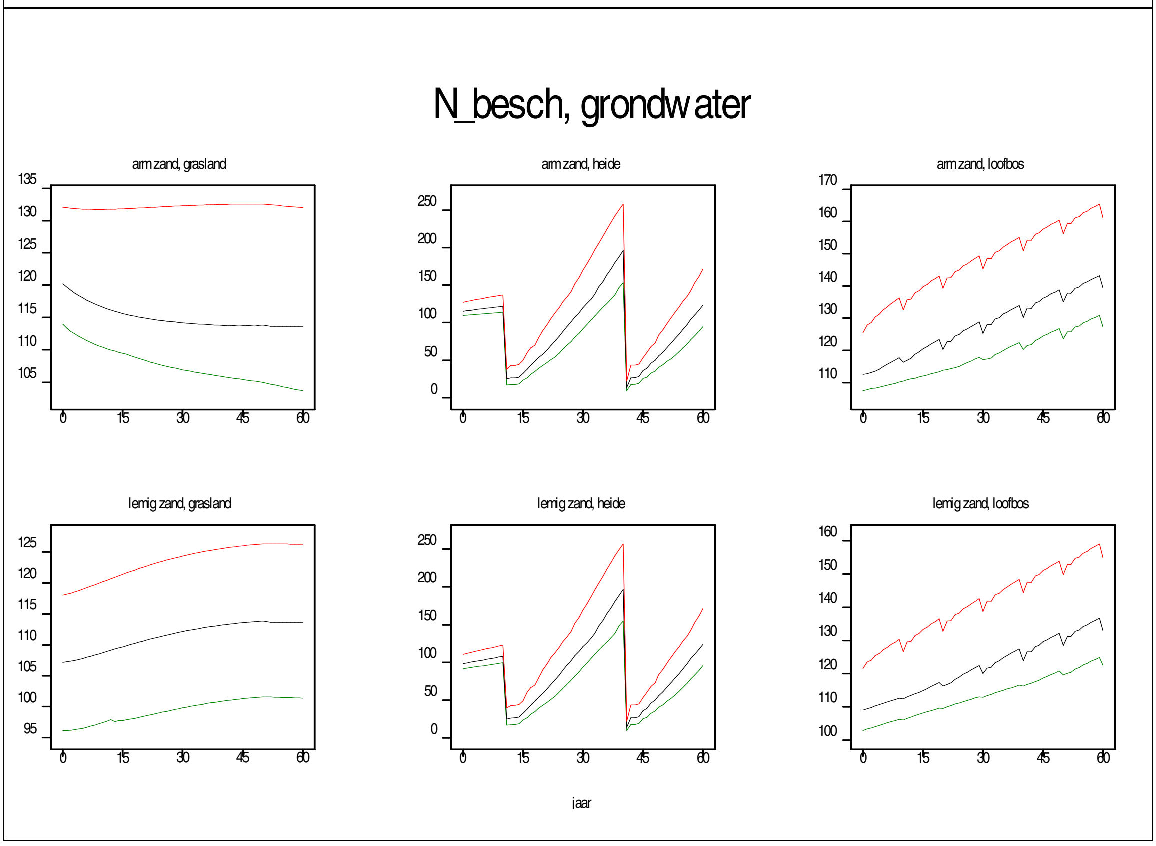
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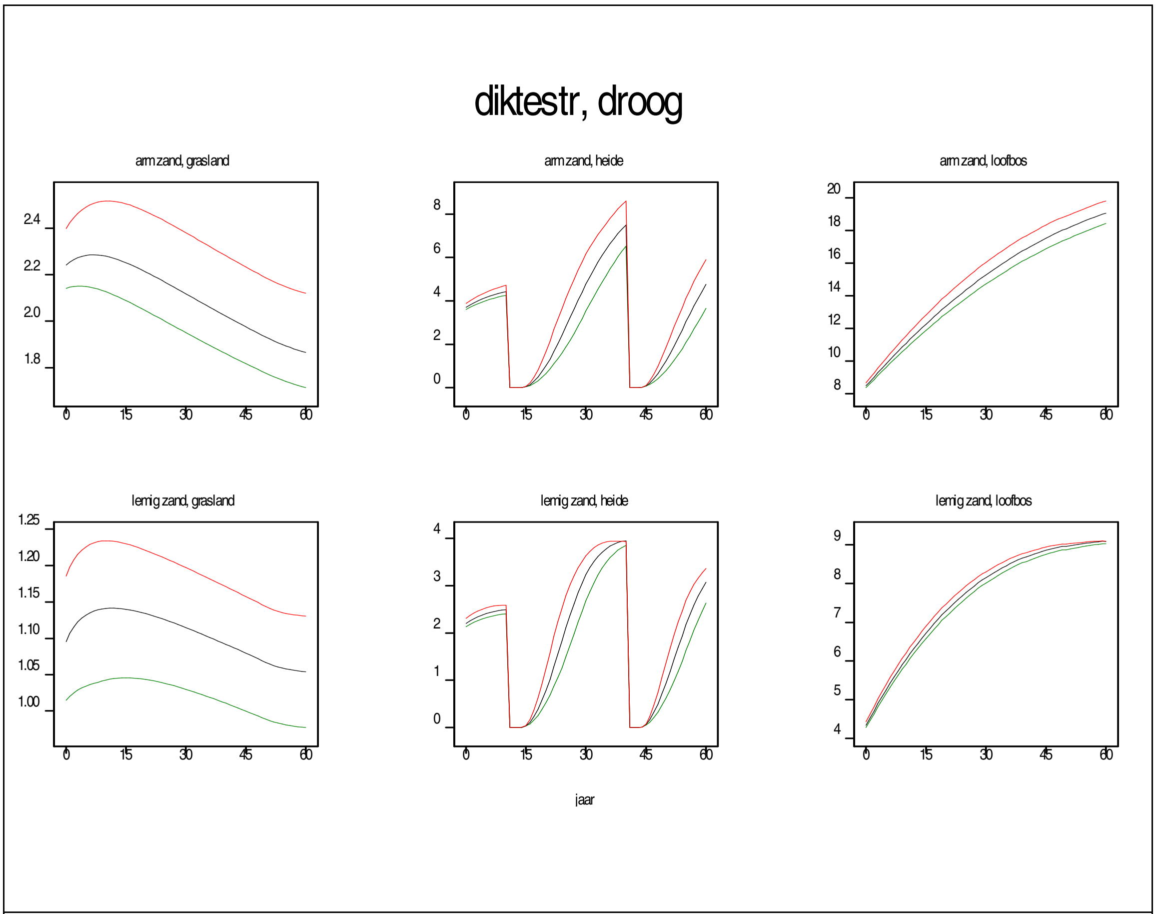
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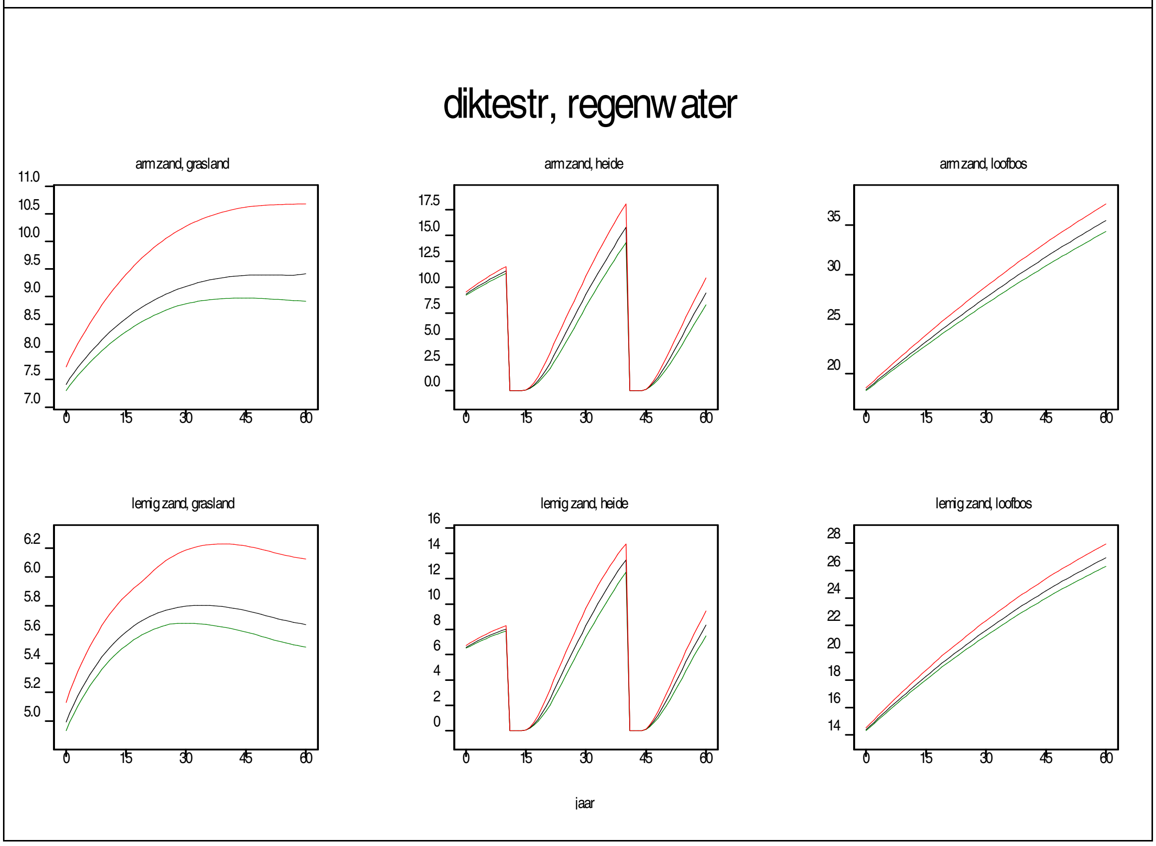
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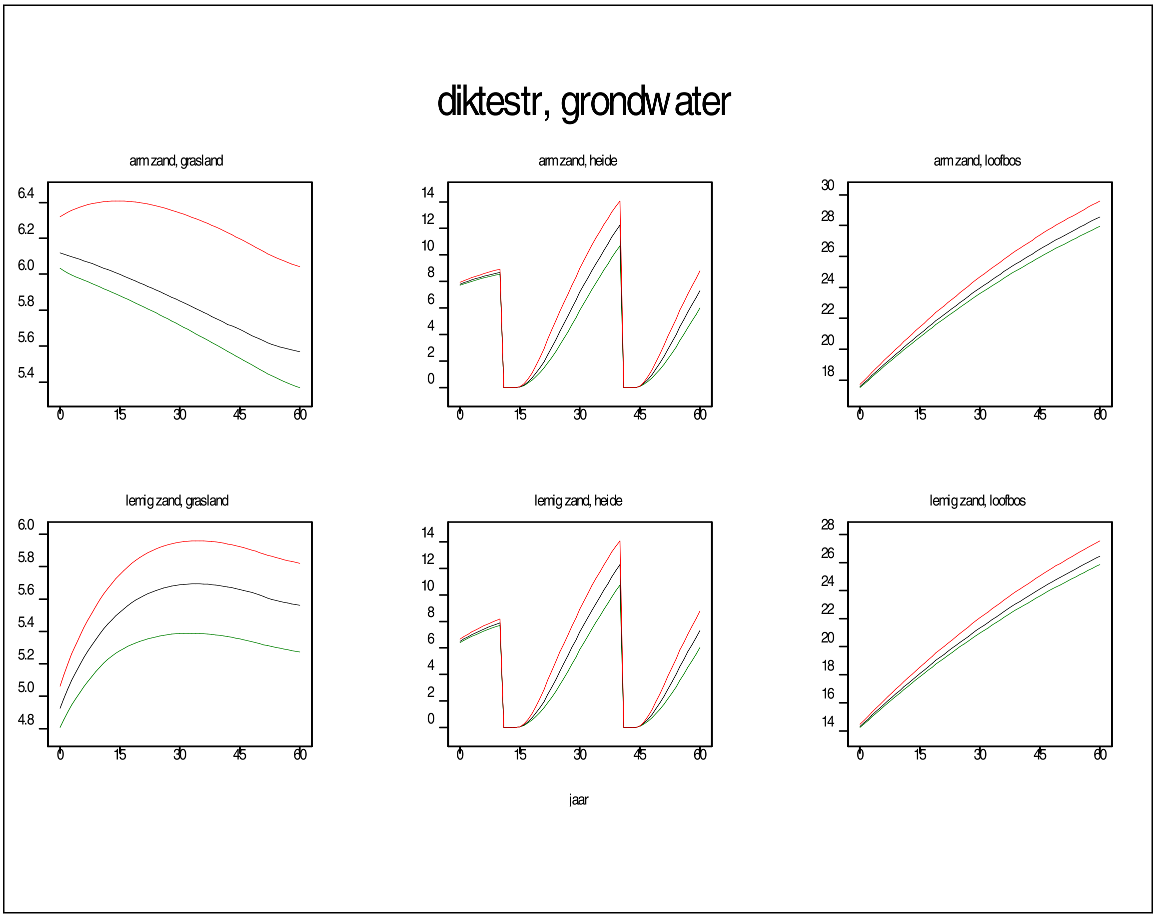

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Appendix 5. Country report: Denmark

Jesper Bak

Aarhus University, Department of Bioscience

Monitoring and modelling nitrogen and ammonia deposition

- What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas?
- If a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations?
- Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models?
- An assessment of the uncertainties in estimating nitrogen deposition at different scales

What monitoring programs exist, and what is the frequency of measuring and reporting on total atmospheric nitrogen deposition in the rural areas? If a national monitoring program for ammonia deposition exist, describe briefly the density / geographical coverage and location of measurement stations?

The main national air pollution monitoring network consists of 8 major fixed stations with hourly measurements of:

- Wet deposition of nitrogen compounds (ammonium and nitrate), sulfate, phosphate and a number of selected heavy metals.
- Concentrations of nitrogen compounds in the gas and particulate phase (ammonia, nitrogen dioxide, particle-bound ammonium and sum of particulate matter bound nitrate and nitric acid) as well as sulfur dioxide and particulate bound sulfate. In addition, select measurements are made at selected measuring stations including nitric acid and particulate bonded nitrate as well as ammonia and particulate bound ammonium.

In addition to the larger measurement stations, the measurement program consists of a number of smaller measurement stations focusing on measurements of the (monthly mean) concentrations of ammonia and ammonium in relation to the influence of airborne nitrogen on nitrogen-sensitive natural areas.

The primary stations in this network are located on Idom Hede (heath) and Lille Vildmose (high mountain), with additional stations at 15 nature stations distributed on nitrogen-sensitive natural areas around in the country.

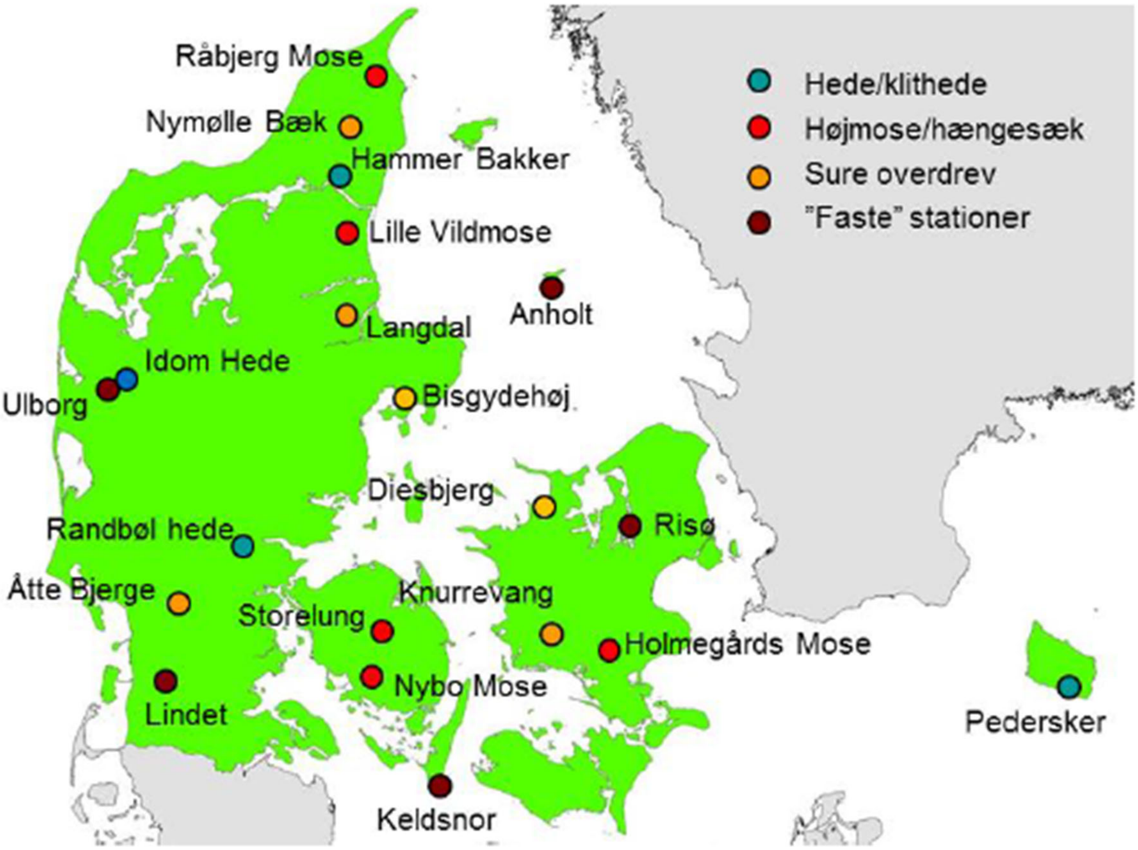

Figure 1. Geographic location of stations with ammonia monitoring (Ellermann 2015).

Which transport and deposition models are used for different purposes and scales? Are national models used and / or is the calculation of total nitrogen deposition based on internationally adopted models?

National models for dispersal and deposition of air pollution exist and are used for all scales from hemispheric (DEHM) to local (OML-DEP), urban (UBM) and street canyon (OSPM). DEHM is a nested model with different resolution from hemispheric to European and national scale. For the calculation of national background concentrations and deposition, a resolution of 5.6 x 5.6 km^2 with the DEHM model is used (Christensen, 1996, Ellermann, 2015).

Especially for ammonia deposition, a model system, DAMOS, has been developed which couples the long-range transport model, DEHM, with a local scale (Gausian plume) model, OML-DEP, allowing for local scale resolution of 400 x 400 m^2 in limited areas (16 x 16 km^2) where high resolution emission data needs to be available (Geels, et.al., 2012).

For the assessment of effects around single point sources, deposition curves based on the OML-DEP model have been established for different classes of surface roughness of the receptor area. Deposition calculated with the curves can be adjusted to account for the (local) frequency of different wind-sectors.

An assessment of the uncertainties in estimating nitrogen deposition at different scales

The DEHM model has been validated against measured (EMEP) data at European scale and part of intercomparisons between regional models with satisfactory results (Loon et.al., 2004).

The overall uncertainty in deposition calculations with the DAMOS system (going down to 400 x 400 m^2 resolution has been assessed based on experience from the Danish Background Air Quality Monitoring Program where measured and modelled nitrogen components at the five main Danish stations are analysed each year. The estimated uncertainty related to the annual total nitrogen deposition to land areas is in the order of +/–40% for DEHM and up to +/–50% for the coupled system DAMOS. This is the uncertainty for the mean over grid cells, but in the absolute vicinity of large point sources, such as large farms, the uncertainty can exceed 50% in the 400m×400m fields from DAMOS (Geels et.al., 2012).

The OML-DEP model has been tested and validated for use in describing dispersal and deposition around animal farms both individually and in comparison with other similar models ('advanced' Gaussian dispersion models, e.g. ADMS, AERMOD, LADD).

In a detailed local scale study including measurements and use of bio-monitors, it was shown that the OML-DEP model calculations reflect measured NH_3 concentration and N deposition in the neighbourhood of a chicken farm. It was concluded that, within the uncertainties of the measurements, the OML-DEP model gives valid estimates of dispersion and deposition of NH3 emitted from a livestock farm. (Sommer et.al. 2009).

An intercomparison with the ADMS, AERMOD andLADD models showed that all four models performed acceptably according to pre-defined criteria when predictions were compared with NH3 concentration measurements around a livestock farm with ground and building emission sources. For the FAC2 indicator (fraction of model predictions within a factor of two of the observations), the OML scored 76 % (compared to a highest score of 77 %). The model also gave acceptable performance for livestock farms with elevated sources with exit velocities. (Theobald et.al., 2012)

Ammonia-sensitive areas

- Is there a national definition of ammonia sensitive areas?
- Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?
- Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?

Is there a national definition of ammonia sensitive areas?

Two different nature classification systems are used in Danish regulation: i) Annex 1 nature types de-fined in the Habitat directive, but with a Danish interpretation manual, and ii) nature types defined in the Danish Nature Protection Act (§ 3): lakes, streams, bogs, meadows, salt marshes, heathland, and dry grasslands.

The § 3 nature types are nationally defined, but based on CORINE classes. The nature area protected by § 3 is (2016) 444.000 ha (or 10.3 % of the Danish land area). Only the nature types bog, heathland and dry grassland (and two smaller nature types, raised bogs and oligotrophic lakes) are considered nitrogen sensitive in the regulation. The area of these nature types, which are not Annex 1 nature, is 162.000 ha. The major § 3 nature types can be sub-divided into (also nationally defined) sub-types. For heathland, dry grassland

and bogs, a total of 16 sub-types are used, which with some overlap and to some degree corresponds to 12 annex 1 nature-types (heath: 4010, 4030, 5130, dry grassland: 6210, 6230, 6120, bog: 7110, 7120, 7230, 7150, 2190, 6430).

In addition to the mentioned nature types, 218,000 ha forest out of the total forest area of 625,000 ha is considered nitrogen sensitive. The part considered not sensitive is mainly production forest.

Which habitat types are categorized as ammonia sensitive in the Habitats Directive Sites (SAC)?
The Annex 1 types include 10 terrestrial habitats (1220, 1310, 1320, 1330, 1340, 3260, 3270 and 6430), which are not considered nitrogen sensitive in the regulation. Of these, however, only 1330 (salt meadows), 3260 (watercourses) and 6430 (tall herb fringe communities) constitute a significant area nationally, and only 1330 a significant area inside Natura 2000 areas.

Is there a separate definition of ammonia sensitive habitat types used in Natura 2000 areas (SAC) or is the same definition used outside the Natura 2000 areas?
The Annex 1 classification system is used inside the Natura 2000 areas and the § 3 classification outside. The classification systems overlap in the sense that the annex 1 classification is more detailed than the § 3 classification, but also narrower. In the Danish classification, (§ 3) heathland can e.g. be subdivided into Annex 1 dry heath (4030), wet heath (4010), and heathland which are not considered Annex 1 na-ture. The total area of Annex 1 nature is 329,000 ha of which 40 % is located inside the SAC areas.

In the latest reporting under the Habitat directive, article 17, it was assessed that the total area of Article 1 nature is 329.000 ha, hereof 40 % (131.000 ha) outside the designated Natura 2000 areas (Fredshavn et.al. 2014). The annex 1 types have, however, not been systematically mapped outside the Natura 2000 areas, and the annex 1 types are not used for the assessment of nitrogen sensitivity outside the Natura 2000 areas.

Effect of ammonia regulations

- The location of husbandry farms in relation to ammonia sensitive areas.
- Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, both 1) due to the general reduction in deposition and 2) due to change in location of husbandry farms and 3) as a result of the national ammonia regulation in relationship to the Habitat Directive

The location of husbandry farms in relation to ammonia sensitive areas.
Danish agriculture has undergone a large structural development from 2005 to 2015. The number of farms with livestock has, in the period, decreased from 51,800 to 22,800, whereas the overall production has been fairly stable. The production has thus been concentrated on a smaller number of larger farms, and a large number of farms have significantly enlarged their production. A statistical analysis between the group of (larger) farms that have been affected by local ammonia regulation and the group that has not, show a significant difference between the groups both in frequency and size of enlargements. Roughly 10 % (500 – 1000) of the larger farms can be shown to have been affected by the specific ammonia regulation in the period. The regulation has affected a total emission of 4.1 kt N in areas close to sensitive nature. The

calculated gross effect of the regulation has been a protection of 12,000 ha from exceedance of critical loads, and a 138 t less yearly accumulated exceedance (Bak 2017).

Is it possible to document a reduction in the total deposition in Natura 2000 areas in the period 2004-2015, due to
1) the general reduction in deposition and
2) change in location of husbandry farms and
3) the national ammonia regulation in relationship to the Habitat Directive

The present ammonia regulation has been in place since 2006. Danish ammonia emissions have decreased by 16.9 % from 2005 to 2015. 28 % of Danish ammonia emissions are deposited on the Danish land area, where Danish ammonia emissions contribute to 29 % of the total nitrogen deposition. Also emissions in other countries are expected to have declined in the period.

It is, however, not possible to detect a decline in nitrogen deposition in the period 2005 to 2015 based on national deposition calculations. This can be due to year to year variation in climate and to other changes in atmospheric chemistry. It is, however, also not possible to detect a decline in measured ammonia concentrations from 2007 to 2015 for 17 monitoring stations placed at nature areas (Ellermann et.al. 2015).

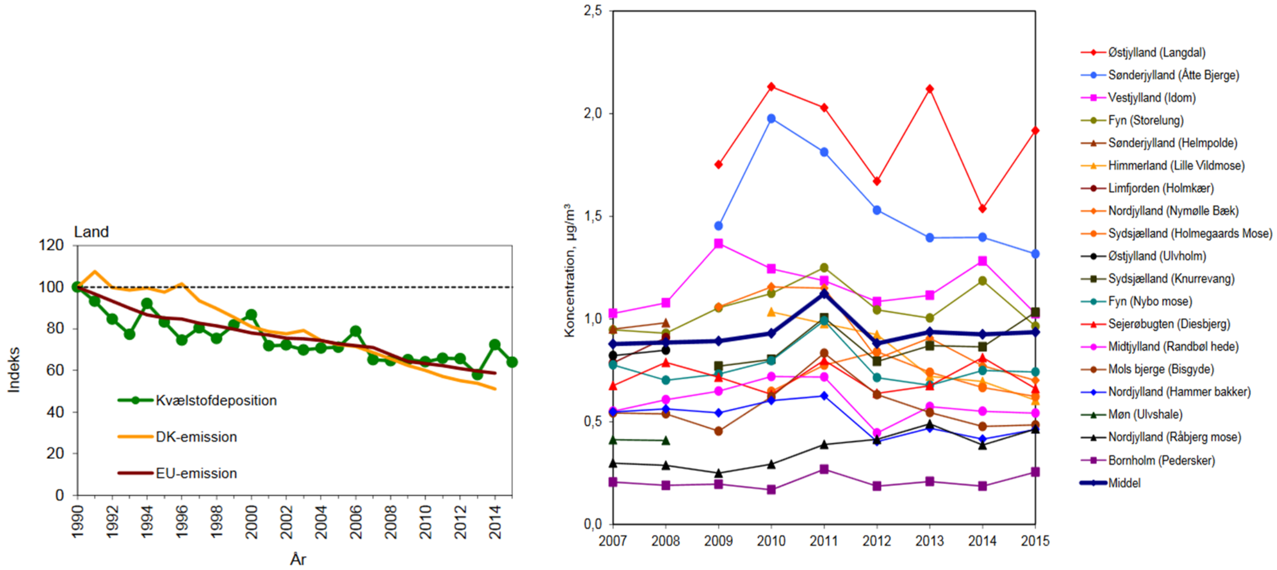

Figure 2. Estimated development of nitrogen deposition to the Danish land area (left) and development in measured annual concentrations of ammonia at a number of natural sites distributed across the country (right). Medium represents a weighted average of the average trend trend for the measurement stations, which has been active from 2007. (Ellermann et al., 2016)

Critical loads

- Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?
- Are critical levels used?
- To which extend, and how are calculations based on the Mapping Manual from UNECE?
- Are calculated critical loads based on biodiversity targets used or planned to be used in the future?

- If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?
- If model calculations are used:
    - Describe the models and the data included in the calculations
    - Are target loads used for the specific areas; if so, how?
    - Is there a reference year in the calculations, and if so, which?
- Are different methods used for setting critical loads for areas inside and outside of Natura 2000 areas, and if so, how?
- How often are the critical loads updated?
- Describe if and how nature management e.g. grazing is taken into account in the model calculations.

Which methods are used to establish critical loads / target loads for individual areas, and for which pollutants and effects (are different methods used for eutrophication and acidification, for forest stability, freshwater and biodiversity)?
A manual to the Danish counties from 2003 recommended the use of mass-balance (SMB) methods for the calculation of critical loads on a site basis, supplemented with the use of empirical critical loads, where data for local calculations were not available (Bak, 2003). There has not been conducted a nationwide mapping of critical loads and exceedances based on local data, and as a consequence, empirical critical loads have been used in different national assessments (Bak & Albrektsen, 2010). In 2013, methods to derive critical loads for biodiversity was developed, and values calculated for selected Annex 1 nature types based on monitoring data from the national monitoring program NOVANA (Bak, 2013). These values have subsequently been used for Annex 1 nature in national assessments of nature consequences of changes in regulation.

Are critical levels used?
Critical levels have been recommended for use for approval of animal farms since 2003 (Bak, 2003), and in habitat assessment (appropriate assessment) for larger industry since 2016. [ref Bak, 2017]. The actual use until now has not been systematically recorded but is expected to have been limited. Critical levels are recommended to be used in future approvals for animal farms based on the numbers in the latest update of the Mapping Manual [ref], Bak (2017).

To which extend, and how are calculations based on the Mapping Manual from UNECE?
Denmark participates in the scientific work under the UNECE Air Convention, WGE, but has not submitted national data for the last calls for data. Background data from CCE has therefore been used for Denmark in the development of the revised Gothenburg protocol and NEC directive.

National use of empirical critical loads has followed the updated recommendations after approval of UNECE WGE, with the latest update in 2011. A national translation from EUNIS nature types to Danish § 3 nature types and to annex 1 nature types has been used.

National use of the SMB model has followed recommendations in the mapping manual. The methodology has, however, primarily been used for acidification of forest soils.

Methods and recommendations for the use of biodiversity based critical loads have not yet been included in the Mapping Manual. Development has taken

Methods and recommendations for the use of biodiversity based critical loads have not yet been included in the Mapping Manual. Development has taken place in the context of the UNECE / WGE / ICP M&M and JEG, and recommendations given for methods and criteria to be used for submission of data under the issued 'call for data' for biodiversity based critical loads under ICP M&M. The Danish development has been part of this process, and the use of models and criteria updated following the UNECE process.

If empirical critical loads are used: to what extend and based on which modifying factors are values adjusted to local conditions?

The use of empirical critical loads, e.g. in IPC approval, has been recommended as a supplement to computed critical loads since 2003 (Bak, 2003). In addition to the modifying factors described in the mapping manual, it has further been advised to include conservation status, - goals, and other threats in qualifying the critical load within the empirical ranges.

Describe the models and the data included in model calculations

The SMB model has been used both for critical loads for acidity and eutrophying N. Weathering rates for different soil types have been calculated with the PROFILE model.

For the calculation of biodiversity based critical loads, the VSD+ / MOVE model system has been used for a national assessment for selected annex 1 nature types. In these calculations, the MSA indicator has been used combined with a criterion on 'no loss of biodiversity' compared to a reference year. Calculations have been based on i) plant species observed for the nature types in the national monitoring program, ii) soil data (C / N, pH) from the national monitoring programme, iii) national maps of climatic data, deposition data and soil data. (Bak, 2013). In newer national studies, the VSD+ / PROPS has been used with the HSI and BC indicator (Bak, 2016).

Table 1. Calculated critical nitrogen loads (kg N ha^{-1} y^{-1}) with a criterion of 'no net loss of biodiversity compared to 1950, 1992 og 2010 as reference year.

Naturtype		1950	1992	2010
			kg N ha^{-1} $år^{-1}$	
1330	Strandenge	>8.1	>10.5	>12.0
2130	Stabile kystklitter med urteagtig vegetation (grå klit og grønsværklit)	2.6	6.7	8.1
2140	Kystklitter med dværgbuskvegetation (klithede)	6.2	7.5	8.0
2180	Kystklitter med selvsåede bestande af hjemmehørende træarter	9.0	10.4	12.2
2190	Fugtige klitlavninger	5.5	7.2	7.8
2250	Kystklitter med enebær	5.2	6.2	6.8
4010	Våde dværgbusksamfund med klokkelyng	7.3	9.0	9.9
4030	Tørre dværgbusksamfund (heder)	8.8	10.5	11.3
6120	Meget tør overdrevs- eller skræntvegetation på kalkholdigt sand	7.0	8.2	9.1
6210	Overdrev og krat på mere eller mindre kalkholdig bund	4.6	6.6	7.0
6230	Artsrige overdrev eller græsheder på mere eller mindre sur bund	4.5	7.3	7.9
6410	Tidvis våde enge på mager eller kalkrig bund, ofte med blåtop	6.3	7.4	7.9
7230	Rigkær	7.1	7.1	7.5
9110	Bøgeskove på morbund uden kristtorn	8.5	10.5	11.3
9190	Stilkegeskove og -krat på mager sur bund	7.7	9.8	10.6
9198	Skovbevoksede tørvemoser	9.7	11.2	12.4
9199	Elle- og askeskove ved vandløb, søer og væld	7.7	8.3	9.5

Are target loads used for the specific areas; if so, how?
Target loads have so far not been used in Denmark.

Is there a reference year in the calculations, and if so, which?
The reference years 1950, 1992, and 2010 have been used in national assessment of biodiversity based critical loads for (Danish) annex 1 nature types (Bak, 2013)

Concrete projects and the assessment of when and if critical loads for a certain ammonia sensitive area is exceeded

- Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and I f so: are empirically critical loads or national model calculations and local data used for the specific nature area?
- To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included?
- Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?
- Describe briefly if and how local scale transport and deposition is calculated?
- Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?

Are permissions to increase ammonia emissions from existing livestock farms based on assessment of critical load exceedance; and I f so: are empirically critical loads or national model calculations and local data used for the specific nature area?
Effects of ammonia on sensitive nature are regulated through the livestock act. The livestock act differentiates between three classes of nature. Category 1 is the Annex 1 types, which are considered sensitive (described above), inside Natura 2000 areas, and in addition § 3 heat and dry grassland inside Natura 2000 areas. Category 2 is raised bogs and oligotrophic lakes, and (§ 3) heathland areas larger than 10 ha and § 3 dry grassland areas larger than 2.5 ha outside the Natura 2000 areas. Category 3 is § 3 heat, bogs and dry grasslands outside Natura 2000, which are not category 1 or 2, and ammonia sensitive forest areas. The derivation of the different classes of nature in the ammonia regulation is partly based on critical loads in the sense that the nature types excluded in most cases are type with high critical loads.

For category 1 nature, the allowable total deposition from a single farm is 0.2, 0.4 or 0.7 kg N ha^{-1}, depending on number (0, 1 or> 1) of other farms nearby; for category 2, the allowable total deposition is 1.0 kg N ha^{-1} and for category 3, and acceptable limit for extra deposition can be set based on concrete assessment; however, the limit on extra deposition cannot be lower than 1 kg N ha^{-1} and requirements can only be made, when a number of criteria are met for the affected nature area, e.g. that the critical load is exceeded. Also the requirements for total disposition are subject to some exceptions.

Critical loads and critical load exceedances are hence only used in a limited number of approval cases: where i) there will be an extra deposition on category 3 nature higher than 1 kg, ii) the limits set by category 1 or 2 nature is not more stringent, and iii) the resulting deposition causes critical load exceedance, and iv) several other criteria regarding e.g. conservation value of the area are met. The assessment of critical loads and exceedances has in these cases been based on empirical critical loads.

To what extent and on which geographical scale is local data e.g. data on ammonia deposition, data on how sensitive to ammonia the specific nature area is etc. included

Background deposition of nitrogen is based on national high resolution and high quality data on agricultural point sources, emissions from larger point sources in other sectors, larger roads etc.

Assessment of local scale deposition is based on model calculations on 400 x 400 m^2 resolution or higher for receptor areas in approval cases.

Local differentiated critical loads based on local data have not been used. However, local information on nature values and protection goals are included in approval cases.

Is nature management e.g. grazing, taken into account when the impact of ammonia deposition from a concrete project is assessed, and if so, how?

It is assumed in the Natura 2000 plans that the ammonia regulation will protect the areas against adverse effects of nitrogen deposition, and consequently the Natura 2000 plans do not directly include measures to mitigate effects of too high nitrogen deposition. Nitrogen deposition is, however, mentioned as a pressure in many Natura 2000 plans, and some management actions in the plans will have an effect on the nitrogen balance and in mitigating species changes caused by nitrogen deposition.

For computed critical loads (for biodiversity, see above), an assumed normal removal rate between 1 – 3 kg N ha^{-1} y^{-1} is included in the calculations for the managed nature types.

Describe briefly if and how local scale transport and deposition is calculated?

Local scale deposition from the considered project and neighbouring farms considered in cumulation is calculated with deposition curves based on the OML-DEP model (see above). Different deposition curves for three different classes of surface roughness for the receptor area are used. The generic deposition curve is adjusted to account for the (local) frequency of the wind-sector from the emission point to the receptor area. A consequence radius of 1 km is used for sources < 5000 kg N and a radius of 2.5 km for higher emissions. These radii are also used to delimited farms considered in cumulation.

Is the landscape roughness taken into account in the calculations of ammonia deposition, and if so, how?

Yes, for three classes of roughness of the receptor area (see above). Edge effects caused by higher roughness of the surface area compared to surrounding agricultural areas is in general not included, but the outer edge (50 m) of nature areas are in some assessments excluded.

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AMMONIA REGULATIONS IN NORTHERN EUROPE

Summary of policies and practises in France, Germany, the United Kingdom, the Netherlands and Denmark

This report provides a brief summary of ammonia policies and practices related to effects on N-sensitive ecosystems in five European countries: France, Germany, United Kingdom, The Netherlands and Denmark. The study was commissioned by the Danish Government through Aarhus University, Department of Bioscience and consists of five national reports and a synthesis prepared by Wageningen Research.

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