NitroScape inputs/outputs and field/farm/landscape data regarding units and temporal/spatial resolutions (Drouet *et al.*, 2011).

Data collection for studying landscapes includes consideration of the nitrogen issues to be studied, and balance the size of the study area against the effort of collecting and processing detailed data. To achieve this, a methodology had to be developed that uses generic, re-useable method/tools to be applied over a range of landscapes, collect the appropriate level of detail for the needs of the modellers, provides technical support for data collection from farmers, data cleaning and entry into a common system, checking consistency and respect confidentiality of data where required. The reflections and application to the six NitroEurope landscapes allowed deriving rules for setting-up surveys at landscape scale that might be applicable for other landscapes and other issues (Dragosits *et al.*, 2011).

Another strategic issue at the landscape scale is to verify a model, *e.g. NitroScape*. Faced with the large heterogeneity in flows of reactive nitrogen (N_r) in a landscape, landscape scale analysis requires a more integral approach than at plot scale that combines measurement techniques to characterize the flows of reactive nitrogen. The word 'characterise' is used in recognition that it is not possible to measure all N_r flows at all locations in a landscape, and therefore the measurements provide indicators of characteristic flows rather than a complex set of actual values that could be compared to model outputs. A common strategy was established and applied to all landscapes (Theobald *et al.*, 2011).

More detailed measurements aiming at studying specific landscape processes (*e.g.* atmospheric plumes, transects in the streams) were performed during a common experiment in the Danish landscape where the skills of the different groups involved in the NitroEurope landscape analysis were gathered.

Landscape modelling

Modelling provides a tool to explore and quantify the complexity of interactions in landscapes. This requires modelling a range of natural and anthropogenic processes over a range of space and time scales,

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making sure that all relevant processes and their possible interactions are accounted for. Models exist for the major landscape elements (agricultural land, forestry, wetlands, surface waters, farms) but linking these models into a coherent entity represents a challenge.

The *NitroScape* model couples four existing types of models (atmospheric, farm, agroecosystem and hydrological models) to simulate N_r fluxes within a landscape in a spatially distributed and dynamic way (Duretz *et al.*, 2011). A key-issue was to ensure consistency between models in terms of time and space scales, as well as representation of processes and exchange of variables.

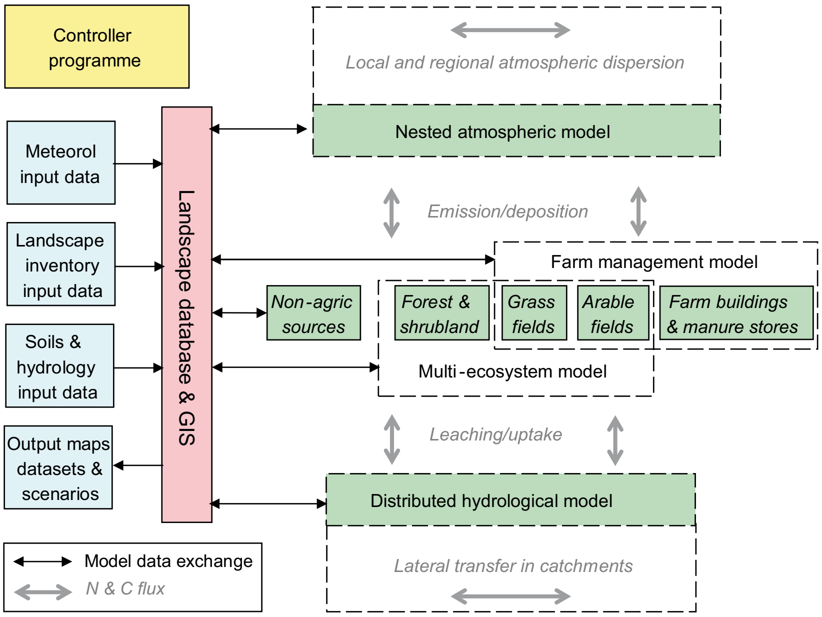

Figure 27 NitroScape modelling framework.

Consequently, the selection of the models was critical. The second stage was to choose the best way to have the selected models work together. The Palm® coupler, developed at *Cerfacs* mostly for atmospheric research and data assimilation, was selected.

In order to highlight the main issues at landscape scale, simulations were carried out on a theoretical landscape with pig farms (large N_r source), crops and fallows (mostly sink for N_r). Simulations showed the effect of spatial interactions between landscape elements and short-range transfers on N_r fluxes and losses to the environment. As expected, the position of ecosystems relative to the farmstead was critical, but *NitroScape* made it possible to quantify the magnitude of deposition and emission fluxes, as well as to analyse their variability in space and time and their dependence on local factors. More than 10% of N_2O emissions were due to indirect emissions caused by either short-range ammonia deposition or nitrate transfer through groundwater. The nitrogen budgets and transformations of the low-nitrogen ecosystems varied considerably, depending on their location within the landscape. *NitroScape* thus represents a new tool for assessing the effect of landscape structure and possible changes in farm management or environmental measures on N_r fluxes.

NitroScape was also used to investigate the importance of natural and anthropogenic processes at landscape scale. First, the spatial interactions and their effects on the additional N_2O emissions were estimated using four configurations of *NitroScape* which considered, or not, different types of transfer within the landscape. Indirect N_2O emissions were shared approximately equally between atmospheric and hydrological transfers. *NitroScape* made it possible to identify the origin and the driving factors (*e.g.* land use, landscape heterogeneity) of these emissions. Second, *NitroScape* was used to compare the N flows of two scenarios: an overall reduction in N inputs of 20% across the entire cereal area, or the establishment of unmanaged buffers along the streams and the semi-natural areas corresponding to taking 20% of the cereal area out of production, but maintaining N total inputs to the cereals at the landscape scale. It showed that some fluxes were significantly affected (*e.g.* ammonia volatilization and deposition, nitrate leaching) while others were not (N_2O emission, N output though the stream). Of course, these results are scenario dependent, but this illustrates the potential of a landscape model to analyse complex situations at landscape scale and derive rules that can be useful for decision-making and environmental protection.

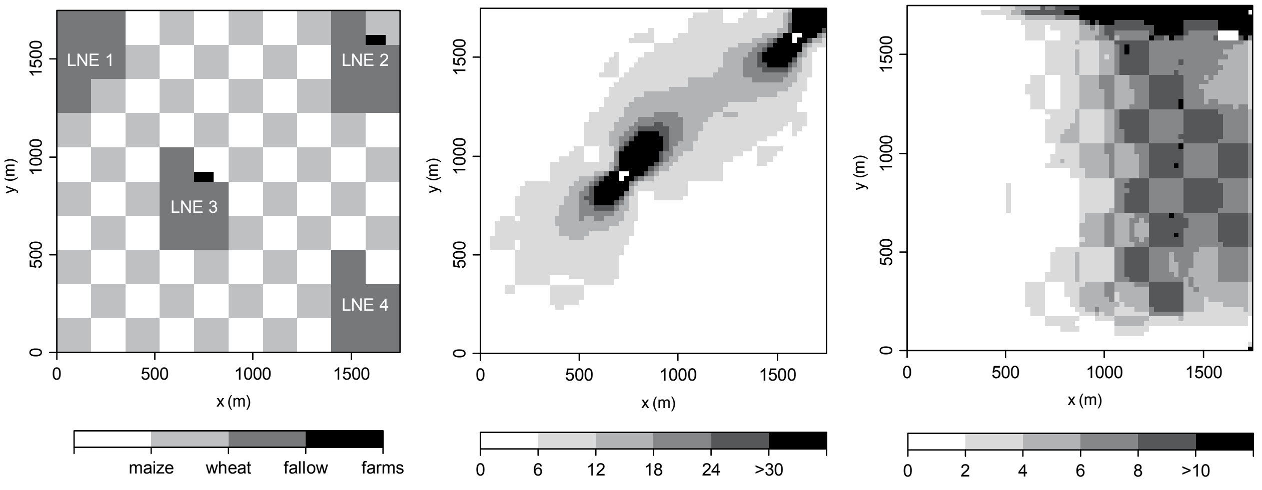

Figure 28 Results from *NitroScape* (Duretz *et al.*, accepted): land use (left), ammonia deposition (kg/ha/y) (centre) and N_2O emissions (kg/ha/y) (right).

4.5 European integration and up-scaling

The main aim of the European Integration component within the NitroEurope-IP was to develop and apply GIS-based integrated assessment tools to assess changes in reactive nitrogen fluxes (N_r) and net greenhouse-gas exchange (NGE) for terrestrial ecosystems at European level. Nr fluxes and NGE were derived as a function of changes in land use, livestock intensity, climate and land management practices. Main tasks were: (i) the development of a multi-component European-scale model (INTEGRATOR), (ii) the setup of a consistent European database with basic data and scenario results for use in (detailed) models, (iii) application of various available ecosystem models (e.g. INTEGRATOR, IDEAg/CAPRI-DNDC and Mobile DNDC) to assess the present day situation and (iv) scenario studies, and related uncertainties, including impacts of emission abatement measures, focusing on the period 1970–2030.

Reference Scenario
● Global Economy - Default (A1G1C1E1L1)
○ Regional Communities - Default (B2G3C3E2L2)

Market Support
● G1. Full liberalization of the world market

Income Support
● C1. No income support

Bio-fuels
● E1. No implementation of the Bio-fuel directive

Less Favoured Areas
● L1. Abolishment of LFA policies
○ L2. Continuation of LFA

Scenario
A1, Global Economy

Description
The Global Economy scenario depicts a world with fewer borders and less government intervention compared with today. Trade barriers are removed and there is an open flow of capital, people and goods, leading to a rapid economic growth, of which many (but not all) individuals and countries benefit. There is a strong technological development. The role of the government is very limited. Nature and environmental problems are not seen as a priority of the government.

Assumptions
- Multilateral cooperation on economic issues, including successful WTO negotiations leading to elimination of almost all trade barriers.
- CAP subsidies and cohesion policy are phased out by 2030.
- Societies are predominantly driven by market-based solutions, resulting in high economic growth rates, particularly for poorer countries.
- A strong technological development.
- The role of the government is limited to core responsibilities, such as basic education, security, major infrastructure ensuring conditions for competitive markets, law enforcement.
- Maintenance (and extension) of nature is not seen as a priority for the government and is mainly depending on private initiatives.
- Flexible approach to migration and further extension of the EU.

Simulation #1
Simulation: b2 std
Indicator: Nam (LandUse)
Landuse: Arable land
Scale: NCU
Time: 2030

Simulation #2
Simulation: std A1
Indicator: Nam (LandUse)
Landuse: Arable land
Scale: NCU
Time: 2030

Figure 29 Screenshot of the INTEGRATOR model showing information on the scenario used (top) and results of a run for the year 2030 for two scenarios (below).

The INTEGRATOR model

The INTEGRATOR model integrates modules to compute manure input from animal numbers and excretion, a distribution model to distribute the manure over the various land uses within a region, and various models to estimate N fluxes, including N uptake, NH_3, N_2O, NO_x and N_2 emissions and N leaching and runoff to both ground water and surface water and the emissions of the greenhouse gases CO_2 and CH_4. The model incorporates modified versions of existing modules for estimating N fluxes from agriculture (MITERRA), CO_2 sequestration in forests (EFISCEN and YASSO), meta-models based on results from detailed models (such as DNDC) and regression models based on empirical data (e.g. for CO_2 emission from peat lands and for N_2O emissions from ecosystems). To facilitate the use of INTEGRATOR, a user friendly interface was developed to perform simulations, for different scenarios, evaluate mitigation measures and compare results in terms of graphs, tables and maps (Figure 29).

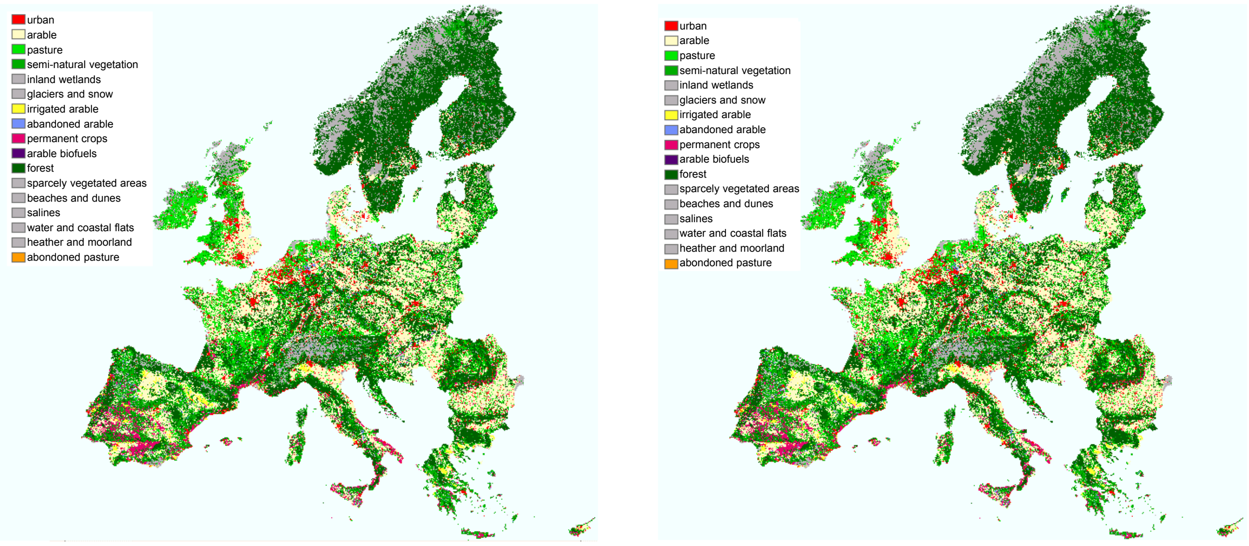

Figure 30 Predictions of land cover by CLUE for 2030 for the A1 (Global Markets) scenario (left) and the B2 (Regional communities) scenario (right).

Establishing a database for European upscaling

Computations by both INTEGRATOR and detailed ecosystem models were made for about 41,000 spatial units in Europe (NCUs), comprising of unique combinations of soil, administrative region, slope and altitude for the period 1970-2030. To do so, a data base (AFOLU) has been set up including all data needed for modelling (http://afoludata.jrc.ec.europa.eu/index.php/public_area/home).

Data in AFOLU include soil data, climate data, fertiliser and manure application data for various crop rotations including timelines for farm management practices. A geostatistical model was developed and applied to predict five basic soil properties (pH, organic carbon, organic

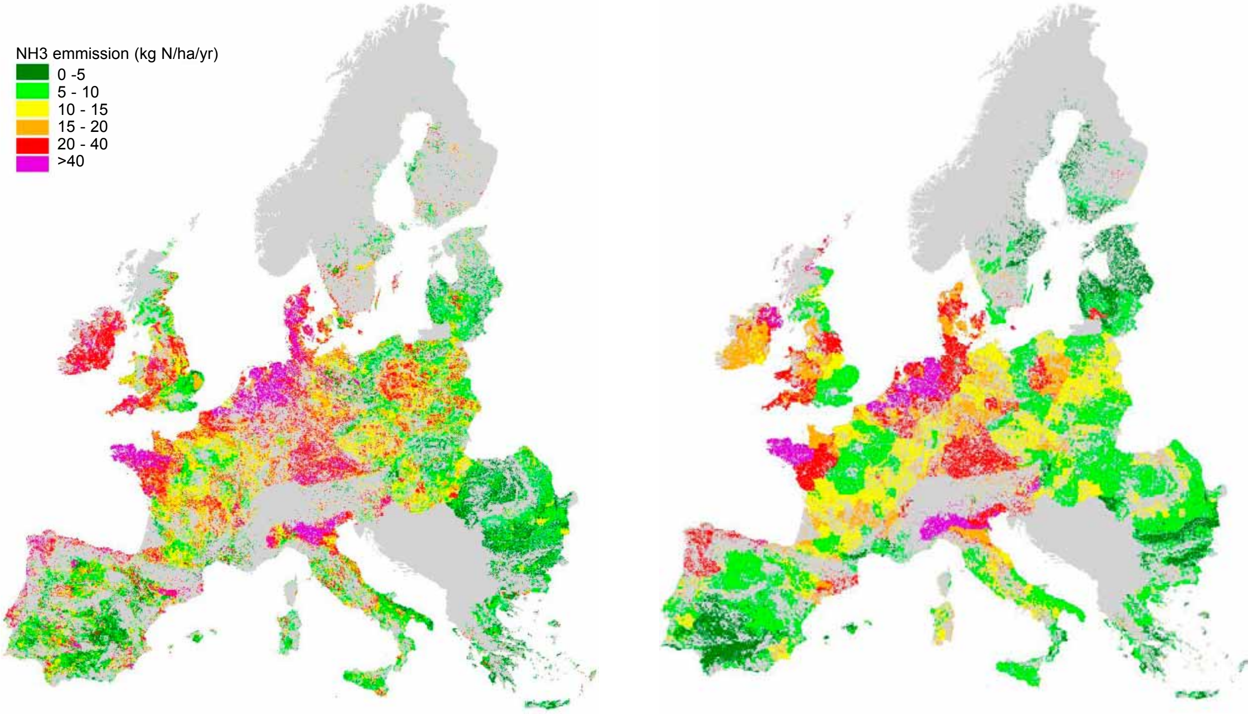

Figure 31 Total NH_3 emissions from agriculture in the year 2000 in EU 27 calculated with IDEAg (left) and INTEGRATOR (right). Gray shading in the EU 27 denote non agricultural areas. Countries outside EU 27 are also included by gray shade.

nitrogen, clay content and bulk density) for three soil horizons at the European scale and quantify the associated prediction uncertainties. A climatic database with daily weather data for the period 1900–2000 was derived by combining the monthly ATEAM/CRU datasets (interpolated monthly climate data at 10'x10' spatial resolution) since 1900 and the daily MARS weather data since 1975. Manure application rates for the period 1970–2030 were based on downscaled agricultural livestock data for the period 1970–2030, making use of data in FAO (Food and Agriculture Organization of the United Nations) statistics (up to 2000) and IMAGE model predictions for Intergovernmental Panel for Climate Change *Special Report on Emissions Scenarios* (IPCC SRES) A1 and B2 scenarios (Neumann *et al.*, 2009). Crop rotations and timelines of farm management practices were derived by a model that simulates the crop rotations and timelines as a function of historical or future daily weather.

Predictions of land use change for various scenarios

High resolution (1 km × 1 km) land-use reconstructions in Europe (EU 27 + Norway, Switzerland and Croatia) between 1970 and 2000 were made by the CLUE model, using a digitized land use map in 1970 as the starting point. Results were validated on the BIOPRESS dataset, which comprises 69 sets of land cover

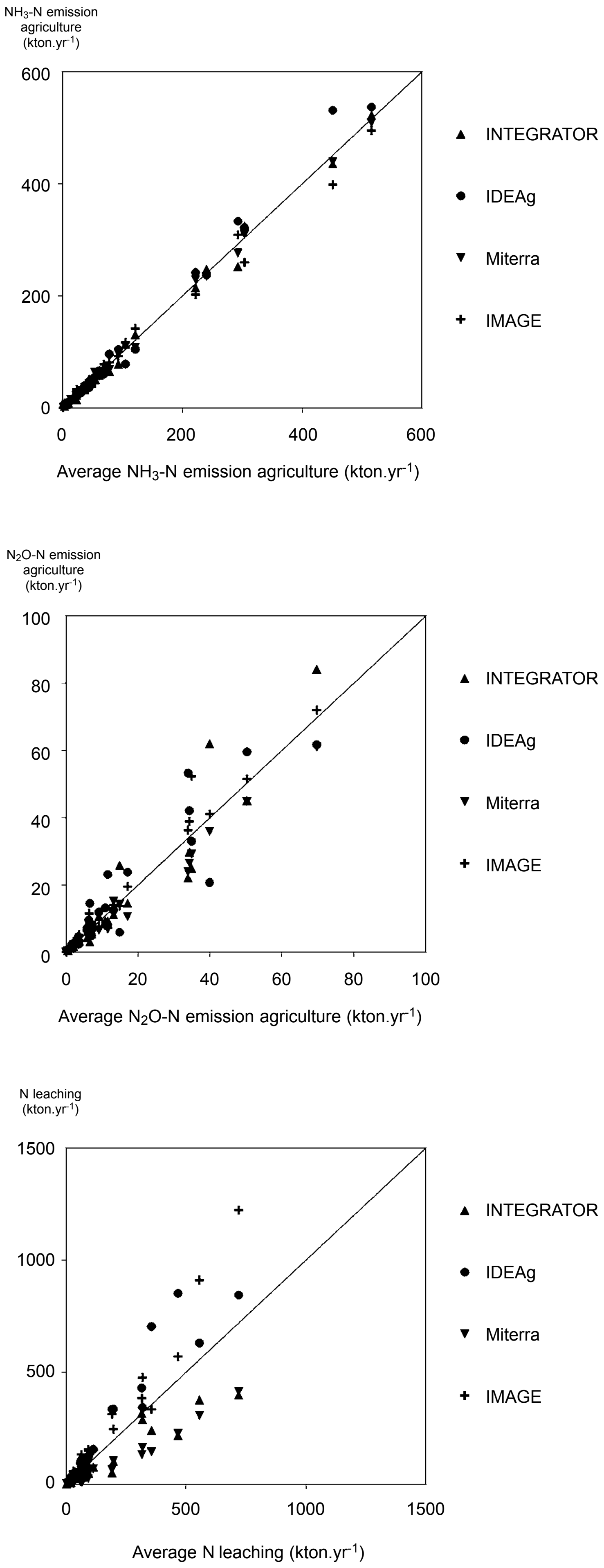

Figure 32 A comparison of total emissions for NH3-N, N_2O-N and sum of N leaching and runoff for the year 2000 at country level within EU27 derived with INTEGRATOR, IDEAg, MITERRA and IMAGE.

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inventories over time in areas of approximately 30×30 km. The validated model was used to make land use predictions for two contrasting future scenarios ('Global Markets' and 'Regional Cooperation'), each subdivided into three different policy settings concerning Common *Agricultural Policy* (CAP) reform, bio-energy production and *Less Favoured Areas*, for the period 2000–2030. The 2030 maps of these two main contrasting scenarios (A1 and B2) are shown in Figure 30.

Assessing current (year 2000) Nr and GHG emissions

A comparison of nitrogen (N) budgets for the year 2000 of agro-ecosystems was made for the EU 27 countries by four models with different complexity and data requirements, i.e. IDEAg, INTEGRATOR, MITERRA and IMAGE. As an example, results are given of the calculated geographic variation in NH_3 emissions by the models IDEAg and INTEGRATOR (Figure 31). In general NH_3 emissions calculated by IDEAg are higher than by INTEGRATOR in Western and Central Europe, but the reverse is true for the Nordic countries. The variation in NH_3 emissions is in general comparable with the geographic variation in N surpluses, which in turn are strongly related to the variation in manure N inputs.

A comparison of country emissions of NH_3, N_2O and of N leaching (including runoff; kton $N.yr^{-1}$) for the EU 27 countries for the year 2000 as derived with INTEGRATOR, IDEAg, MITERRA and IMAGE is given in Figure 32. Results show comparable estimates for NH_3 emissions, due to the use of comparable databases and little differences in model approach. Differences in N_2O emissions are larger, reflecting the larger variation in model approaches, while the sum of N leaching plus runoff is systematically higher for IDEAg and IMAGE than for INTEGRATOR and MITERRA (De Vries *et al.*, 2011).

Scenario analysis

The impact of changes in N inputs, induced by changes in livestock and land management, and climate on nitrogen fluxes from agricultural soils to air and water in the EU 27 during the period 1970–2030 was evaluated using various terrestrial ecosystem models. The models involved include Mobile DNDC, DayCent, CAPRI-DNDC and INTEGRATOR. We evaluated two IPCC-SRES scenarios, i.e. the A1 and B2 scenario. The changes in land use, livestock and national fertilizer N use in response to these scenarios were calculated by the GTAP-IMAGE model. Furthermore, a crop rotation optimizer was developed which translated regional crop share information from CAPRI (http://www.capri-model.org) into a mixture of cropping sequences for all NCUs. Results by INTEGRATOR for NH_3 and N_2O emissions are shown in Figure 33. Results show that the impact of the IPCC scenarios on the change in NH_3 and N_2O emissions at EU 27 scale is limited.

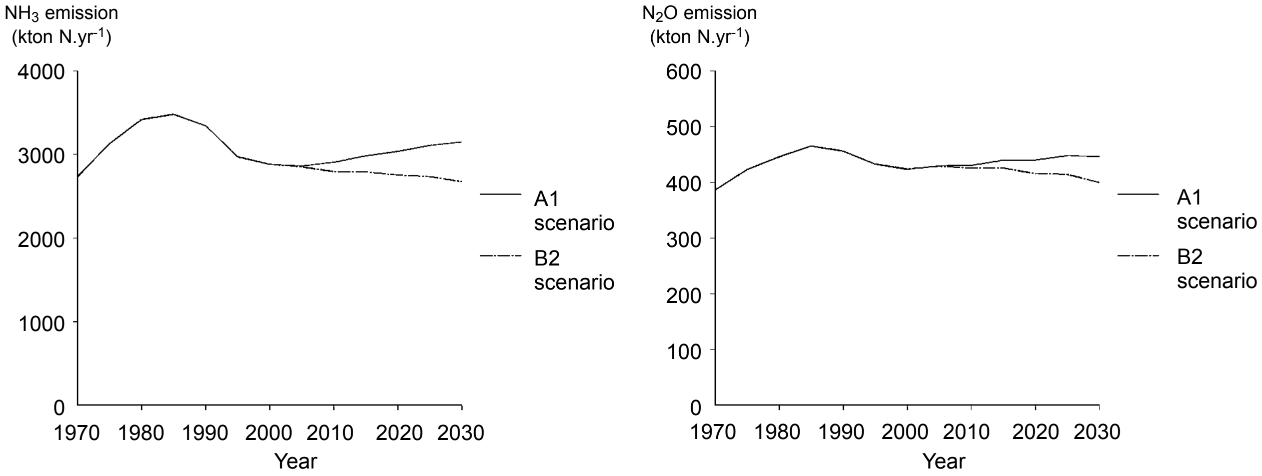

Figure 33 Trends in predicted ammonia emission (left) and nitrous oxide emission (right) by INTEGRATOR for the period 1970–2030 in response to the A1 and B2 scenario.

4.6 Independent verification, uncertainties and policy analysis

Within the framework of NitroEurope it was recognized that independent estimates of nitrogen budgets and greenhouse gas (GHG) emissions were needed for verification of the extensive measurement and modelling efforts, ranging from ecosystem to European scale. A source of independent data is the wet deposition, monitored by national and international organizations across Europe, in support for national or European policy. The data gathered is harmonized and analysed to produce deposition maps of inorganic nitrogen as independent estimate in support of and in addition to NitroEurope results.

Precipitation chemistry data is obtained from EMEP, International Cooperative Programmes on Forests and Integrated Monitoring (ICP-Forest, ICP-IM) programmes under the Convention of Long-Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE). The locations of the monitoring sites are not evenly spread across Europe, causing some serious data gaps in certain regions of this continent. The precipitation chemistry record obtained covers the period 2002–2008 and as such the actual number of locations available depends on the year of observation. The precipitation analysed is collected by a multitude of different sampler designs (wet-only and bulk samplers).

Annual mean concentrations were derived from the data obtained and quality checks as ionic balance and investigating highly correlated elements (van Leeuwen *et al.*, 1996) were carried out. Corrections were applied to the bulk samplers for the contribution of dry deposition onto the collection surface.

The wet deposition fluxes are obtained by multiplication of the derived interpolated annual concentration field with the precipitation field (e.g. Holland *et al.*, 2005 and van Leeuwen *et al.*, 1996) for the respective year on the European scale. The E-OBS dataset provided in the ECA&D project (Haylock *et al.*, 2008) is used as the precipitation field. These products are in itself products of geostatistical analysis for over 2300 precipitation stations across Europe.

The result of this data collection and geostatistical processing, is shown in Figure 34 below. It gives the wet deposition of total nitrogen ($NO_3 + NH_4$) in kg N per hectare per year, based on data for 2007.

Inverse modelling of European N_2O and CH_4 emissions

Atmospheric measurements combined with inverse atmospheric models can provide independent top-down estimates of greenhouse gas (GHG) emissions. This is important in particular for N_2O and CH_4, for which considerable uncertainties of the bottom-up inventories exist. In NitroEurope, European N_2O and CH_4 emissions have been estimated for the years 2006 and 2007 using five independent inverse modelling systems based on different global and regional *Eulerian* and *Lagrangian* atmospheric

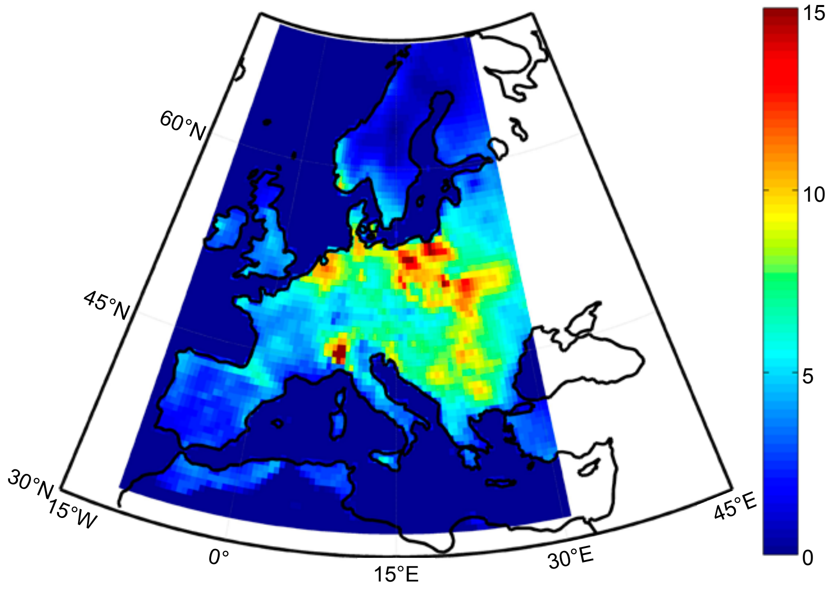

Figure 34 Wet deposition maps of inorganic nitrogen compounds (NH_4^+ and NO_3^-) across Europe derived from site measurements of precipitation chemistry using geostatistical methods.

transport models. The major objective of this model ensemble approach is to provide more realistic estimates of the overall uncertainties in the derived emissions.

We use continuous N_2O observations from 8 European stations (including several tall towers), complemented by further European and global flask sampling sites. A particular challenge is the low signal to noise ratio of the atmospheric N_2O measurements and significant N_2O calibration offsets, which are apparent in measurements from different laboratories. To correct for these calibration offsets, a novel bias correction scheme has been developed and applied (Corazza *et al.*, 2010) and is imperative for the utilization of measurements from heterogeneous networks.

The available observations constrain N_2O (and CH_4) emissions mainly from north-western and eastern Europe (see Figure 35).

The preliminary top-down estimates of European N_2O emissions are consistent with the bottom-up inventories reported to the *United Nations Framework Convention on Climate Change* (UNFCCC). This good agreement is rather surprising, since very large uncertainties are reported for the UNFCCC N_2O inventories (e.g. uncertainties for total N_2O emissions from north-western Europe >160%, mostly due to large uncertainties in emissions from agricultural soils). This illustrates that atmospheric measurements combined with inverse modelling can significantly reduce the overall uncertainty in N_2O emissions.

Uncertainty assessment in model results

Overall, five protocols for uncertainty estimates of model data and model results were written and were disseminated. These protocols were used to determine the uncertainty for different models. This is not straightforward as different approaches have to be used depending on the details of the model, the uncertainty in different parameters and the uncertainty in the data used for evaluation (if any available).

We used three types of models for quantifying Europe-wide N-emissions: ecosystem models, INTEGRATOR and inverse models. These models differed in resolution and in the emission sources they accounted for. The ecosystem models and INTEGRATOR were applied to all ~40 000 NCU's, whereas the inverse models operated at much coarser resolution. The inverse models calculated total emissions from all sources, INTEGRATOR focused on sources and sinks associated with ecosystems and their management, and the ecosystem models quantified the fluxes to and from ecosystem vegetation and soil. To test whether the different modelling results were compatible, results therefore had to be rescaled to a common resolution and set of sources. This was done by aggregating the results from the high-resolution models to form country-totals, and by applying corrections for the contribution from missing sources, derived from the EDGAR database of greenhouse gas fluxes. In the model comparison, the uncertainties associated with the structure and inputs of the models were considered where possible.

Impact on the policy process

Beyond verification of results attained within the project, NitroEurope also touched upon data use in the policy process.

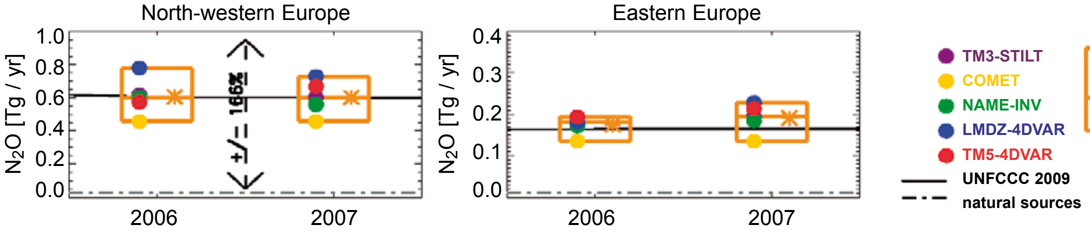

Figure 35 Annual total N_2O emissions for north-western Europe (UK, Ireland, Germany, and BENELUX) and eastern Europe (Poland, Hungary, Czech Republic, and Slovakia). While top-down emission estimates refer to the total emissions, emissions reported to UNFCCC cover only the anthropogenic emissions. For the European countries, however, the contribution of natural N_2O emissions is estimated to be rather small (<10% of total emissions, as estimated from bottom-up inventories).

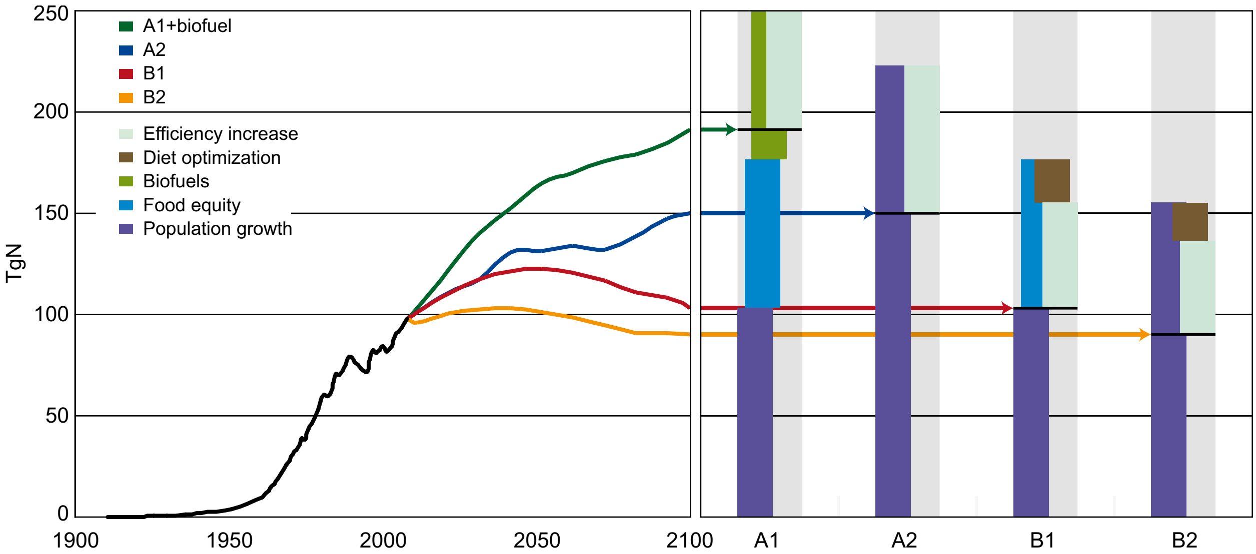

Figure 36 Global nitrogen fertilizer consumption scenarios (left) and the impact of individual drivers on 2100 consumption (right). The A1, B1, A2 and B2 scenarios draw from the assumptions of the IPCC emission scenarios.

For this purpose, a series of structured interviews was held with scientists-turned-policy-makers, in order to understand how to contribute to the quality of the policy process. Specific identified needs referred to the integration of different nitrogen policies and the need to make latest research results on such possible interaction available to the policy process. For that reason NitroEurope developed a strategy paper on 'Interactions of reactive nitrogen with climate change' (Erisman *et al.*, 2011) for the *Task Force on Reactive Nitrogen* (TFRN) under UNECE, which aims to be made available also to UNFCCC. Furthermore, as especially climate issues are strongly forward looking, research focused on the future development of nitrogen related issues and the environment. A publication by Erisman *et al.* (2008) indicates that globally, under very different scenarios, levels of nitrogen pollution may be expected to converge at a level somewhat higher than today, indicating that nitrogen related problems are here to stay independent of assumptions taken (see Figure 36). An assessment focussing specifically on Europe and covering latest projections for Europe (Winiwarter *et al.*, 2011) distinguishes driver-, and effect oriented scenarios, with only the latter ('with policy measures') indicating clear reductions. While technical fixes may be available to abate combustion emissions, reducing agricultural emissions will require integrated approaches that may include behavioural changes (low-meat 'healthy' diets).


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4.7 Long-term curation and integration management of data

To address the challenge of managing the wide diversity of data generated by NitroEurope activities, including data access and managing Intellectual Property Rights (IPR) issues, the Data Management Committee (DMC) developed and implemented a Data Management Policy and Plan for the project duration and beyond. The DMC organised the operation of three NitroEurope data centres, each maintaining a database specific to different aspects of NitroEurope. The 'C1-C3 database' provides user-friendly storage and data retrieval facilities for field and manipulated plot measurements and plot-scale model output, the 'C4 database' caters for field measurements, farm data and spatial data for landscape modelling and verification, and the 'C5-C6 database' for European scale modelling and validation data. The databases are currently available to all NitroEurope scientists via log-in through the NitroEurope web portal (http://www.nitroeurope.eu). Additional registration for each of the databases provides additional security and detailed user rights management.

The databases will be maintained beyond the end of NitroEurope, with provision for optional access to non-NitroEurope scientists on a case-by-case basis. Such access rights are fully controlled by data owners. The NitroEurope databases will be integrated into a new project *Environment and Climate interactions—Observations and Responses in Ecosystems* (ENCORE), which is currently being developed. ENCORE will coordinate access to high-quality climate-change related data throughout Europe.

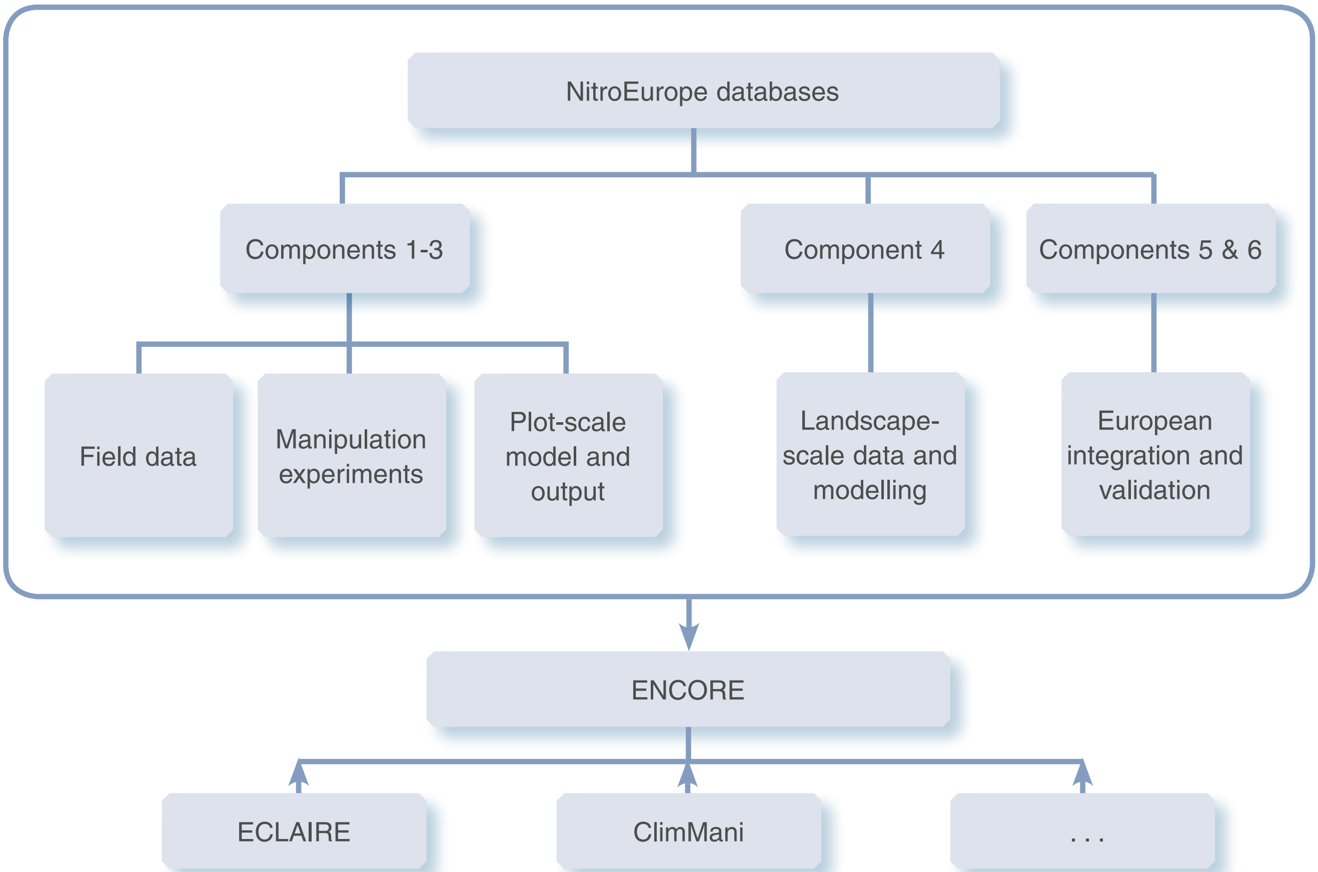

Figure 37 Overview of data management and storage in NitroEurope.

5 Synthesis and integration

Synthesis and integration activities within NitroEurope have worked to establish the links between the component activities and with issues beyond the scope of NitroEurope. This has focused especially on contributing to the European Nitrogen Assessment (Sutton *et al.,* 2011a), as well as to the establishment and development of the UNECE Task Force on Reactive Nitrogen (www.clrtap-tfrn.org). These activities have been conducted in partnership with other European programmes, which have significantly extended the scope of NitroEurope, including the Nitrogen in Europe (NinE) programme of the European Science Foundation, the COST Action 729 and the Network of Excellence ACCENT. At the same time, NitroEurope has contributed actively to the European Centre of the International Nitrogen Initiative (INI), with the NitroEurope coordinator acting as the European INI Centre Director, setting the work of NitroEurope clearly in a global context (e.g. Galloway et al., 2008).

European Nitrogen Assessment

The European Nitrogen Assessment—or ENA—has been established through the coordinated efforts of the NitroEurope team, working in partnership with the NinE and COST 729 partners. The ENA represents the first major continental assessment of all the linked threats and benefits of reactive nitrogen in the environment. As such it sets the work of NitroEurope on nitrogen and climate in context in relation to other threats, including air quality, water quality, soil quality and biodiversity. NitroEurope authors have contributed to all 26 chapters of the ENA, showing the importance of this linking approach.

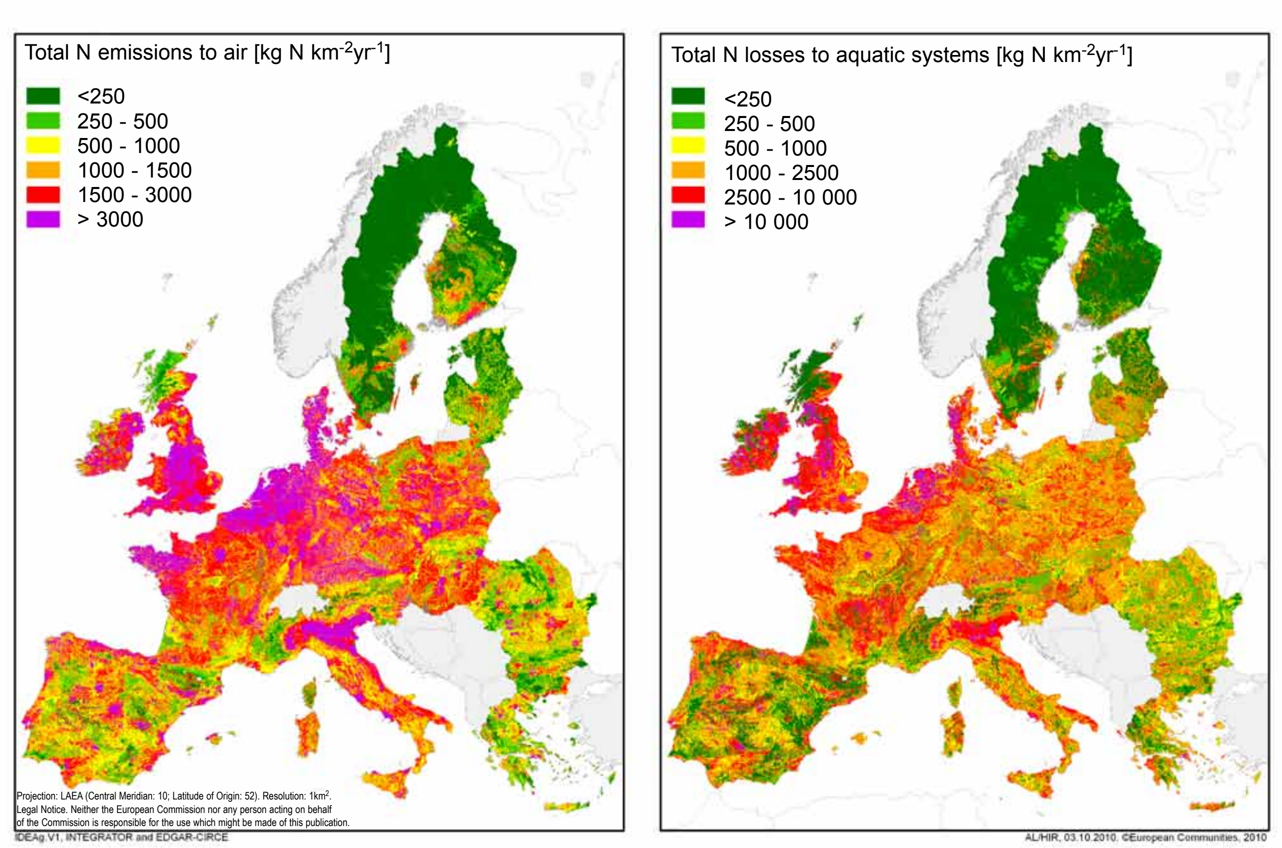

Figure 38 Distribution of reactive nitrogen emissions across Europe (kg N per km^2 for 2000) including emissions to air as NO_x , NH_3 and N_2O, and total losses to aquatic systems, including nitrate and other Nr leaching and wastewaters (taken from the European Nitrogen Assessment—Sutton *et al.,* 2011a).

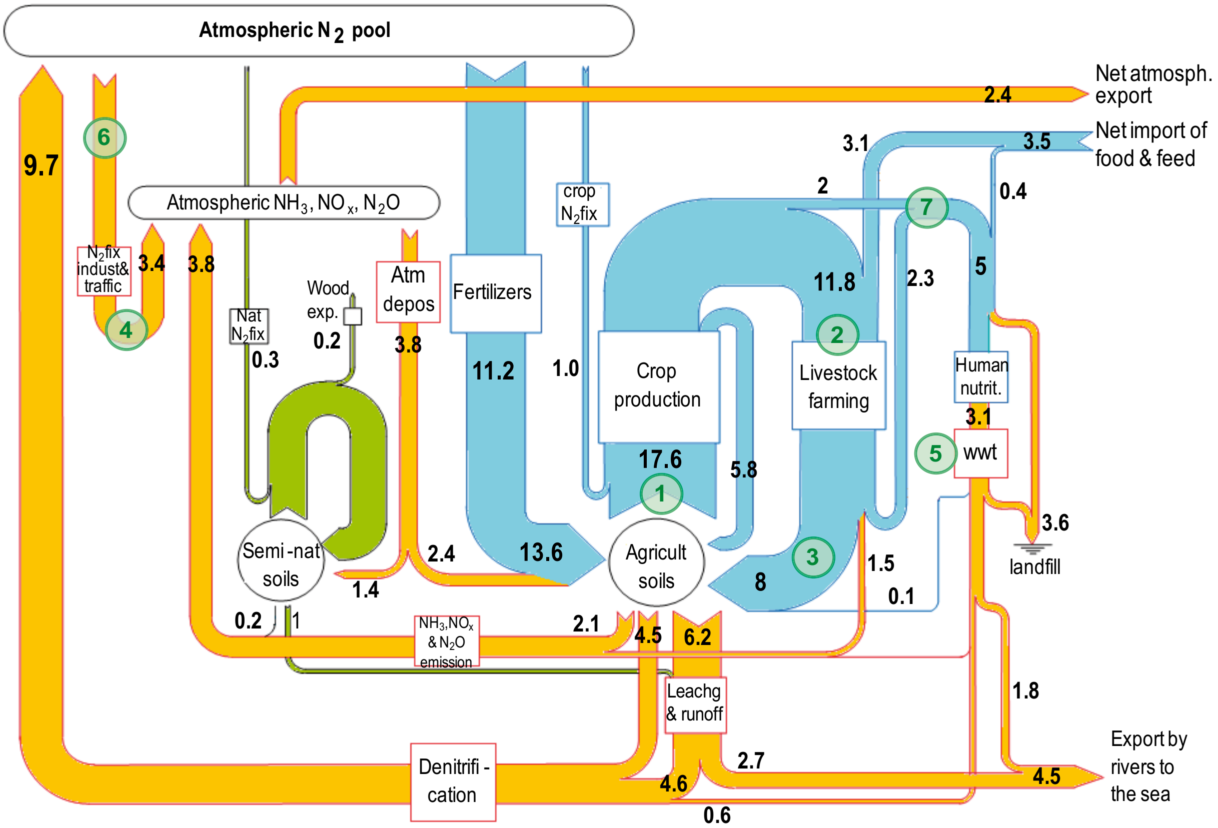

Figure 39 The nitrogen cycle at the scale of EU-27. Fluxes in green refer to 'natural' fluxes (to some extent altered by atmospheric N_r deposition), those in blue are intentional anthropogenic fluxes, those in orange are unintentional anthropogenic fluxes. The numbered green circles indicate a package of seven key actions for overall integrated management of the European nitrogen cycle (taken from the European Nitrogen Assessment—Sutton *et al.*, 2011a).

A key element of the ENA has been the establishment of Europe wide maps of nitrogen emissions, combining the NitroEurope outcomes (e.g. from INTEGRATOR) to provide the state of the art in locating European N emissions (see Figure 38 and Leip *et al.*, 2011). These maps and the underpinning models have allowed the establishment of a new nitrogen budget for Europe, showing all of the major flows (Leip *et al.*, 2011; Sutton *et al.*, 2011a, Figure 39). The European Nitrogen Budget shows several interesting features of high policy relevance. For example, as emphasized by Sutton *et al.* (2011b), 85% of European reactive nitrogen harvested in crops or imported into the EU (including grass) goes to feed livestock with only 15% feeding people directly. Given that the average European citizen eats 70% more animal products than is necessary for a healthy diet, this shows how nitrogen use in Europe is not primarily an issue of food security, but one of luxury consumption of animal products (mainly meat and milk products, see as well Reay *et al.*, 2011).

The most important chapter of the ENA related to NitroEurope is that on the threat of nitrogen on European greenhouse gas balance (Butterbach-Bahl *et al.*, 2011). This synthesis activity extended the scope of NitroEurope to consider not just greenhouse balance, but also the effects of particulate matter on European climate balance. The outcome of this synthesis is summarized in Figure 40, which shows that the component warming effects of N_r emimssions (N_2O emission, and tropospheric ozone effects) are at least balanced by the component cooling effects (including effect of N_r deposition on forest growth, altered methane atmospheric lifetime and increased aerosol loading). Overall, the Assessment estimates a net cooling of 15.7 mWm^{-2} with ranges from -46.7 to +15.4 mW m^{-2}.

However these coolling effects cannot be taken for granted. An economic analysis conducted as part of the Assessment, shows that the social damage costs of

particulate matter emissions on human health and of nitrogen deposition on ecosystems are about an order of magnitude larger than their potential climate benefits (expressed in billion Euro per year). Overall the total damage cost of N in the environment is estimated at 70 to 320 billion Euro per year across the EU. The message is that efforts must minimize particulate loading and nitrogen deposition, while putting effort on reducing N_2O emissions. To achieve the N_2O emission reductions needed will require a significant improvement in *Nitrogen Use Efficiency* in agriculture, which will also depend centrally on implementing measures to reduce NH_3 emissions, N_2 emissions and nitrate leaching (Brink *et al.*, 2011; Sutton *et al.* 2011a,b).

Task Force on Reactive Nitrogen (TFRN)

This Task Force was established during the life of NitroEurope, in large part due to the efforts of the project partners engaging with policy stakeholders of the UNECE Air Convention (Convention on Long-range Transboundary Air Pollution, CLRTAP). The TFRN is now chaired by two NitroEurope scientists, Mark Sutton and Oene Oenema, and is making use of the results of NitroEurope to develop the wider vision of future nitrogen management, linking climate with other threats (Sutton *et al.*, 2011b). Specific tasks where NitroEurope partners and results are feeding in to the work of the Task Force include:

- Developing a special report on nitrogen and climate (Erisman et al., 2011)
- Establishment of the European Nitrogen Budget and methods for further development of budgets *(Expert Panel on Nitrogen Budgets chaired by Wilfried Winiwarter, IIASA, and Albert Bleeker, ECN)*.
- Updating of the UNECE guidance document for control of ammonia emissions.
- Development of options for Annex IX of the Gothenburg Protocol on ammonia emissions, in support of revision of the protocol.
- Estimation of ammonia damage costs, and revison of the abatement costs.
- Assessment of the relationships between nitrogen and food, including the development of future scenarios, in support of different UN conventions.

Through the work of the TFRN and involvement of NitroEurope partners directly, the results will in parallel be incorporated within the forthcoming 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

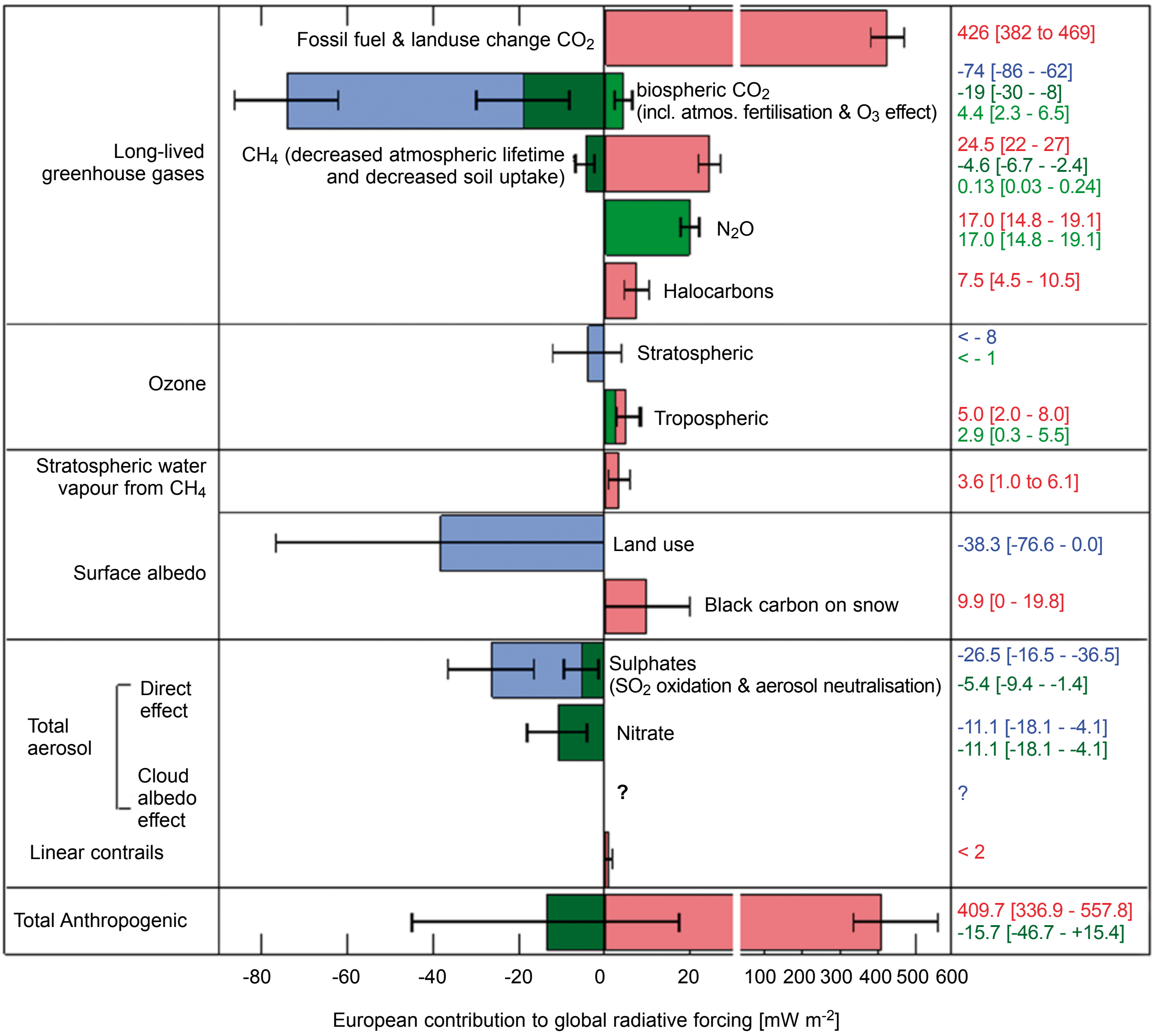

Figure 40 Estimate of the change in global radiative forcing (RF) due to European anthropogenic reactive nitrogen (N_r) emissions to the atmosphere. Red bars: positive radiative forcing (warming effects); light green bars: positive radiative forcing due to direct/ indirect effects of N_r; blue bars: negative radiative forcing (cooling effects); dark green bars: negative radiative forcing due to direct/indirect effects of N_r. For biospheric CO_2, the dark green bar represents the additional CO_2 sequestered by forests and grasslands due to N_r deposition, while the light green bar represents the decrease in productivity due to effects of enhanced O_3 caused by NO_x emissions. For CH_4 the positive (not visible) and negative contributions represent the effects of N_r in reducing CH_4 uptakes by soil and the decreased atmospheric lifetime, respectively. Other contributions include the positive effect of tropospheric ozone from NO_x and the direct and indirect cooling effects of ammonium nitrate and sulphate containing aerosols. (taken from the European Nitrogen Assessment—Sutton *et al.*, 2011a).

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