EUROPEAN SCIENCE FOUNDATION

SETTING SCIENCE AGENDAS FOR EUROPE

RESEARCH NETWORKING PROGRAMME

NITROGEN IN EUROPE: ASSESSMENT OF CURRENT PROBLEMS AND FUTURE SOLUTIONS (N*in*E)

Standing Committee for Life, Earth and Environmental Sciences (LESC)

www.esf.org

The European Science Foundation (ESF) was established in 1974 to create a common European platform for cross-border cooperation in all aspects of scientific research.

With its emphasis on a multidisciplinary and pan-European approach, the Foundation provides the leadership necessary to open new frontiers in European science.

Its activities include providing science policy advice (Science Strategy); stimulating cooperation between researchers and organisations to explore new directions (Science Synergy); and the administration of externally funded programmes (Science Management). These take place in the following areas: Physical and engineering sciences; Medical sciences; Life, earth and environmental sciences; Humanities; Social sciences; Polar; Marine; Space; Radio astronomy frequencies; Nuclear physics.

Headquartered in Strasbourg with offices in Brussels, the ESF's membership comprises 78 national funding agencies, research performing agencies and academies from 30 European countries.

The Foundation's independence allows the ESF to objectively represent the priorities of all these members.

What is 'Nitrogen in Europe'?

Nitrogen in Europe, or N*in*E, is an ESF Research Networking Programme that runs for five years from March 2006. N*in*E aims to integrate European research and researchers, eventually delivering an assessment report of the state of European nitrogen knowledge, sources, transformations and impacts, as well as establishing a basis for recommending future solutions.

Until now there has never been an assessment of all the interacting problems resulting from excess nitrogen. Previous scientific efforts have focused primarily on the processes of nitrogen turnover and fluxes relevant to individual chemical forms of nitrogen in different environmental compartments or particular environmental problems (see also above). Significant efforts have been made in models that begin to join up the nitrogen cycle and relate it to the carbon cycle, but even these have addressed only a few of the nitrogen problems together. Hence assessments of transboundary air pollution have coupled the issues of acidification, terrestrial eutrophication and ground-level ozone from nitrogen oxides and ammonia (e.g. 1979 UNECE Convention on Long Range Transboundary Air Pollution). Current work is now integrating these issues with atmospheric particles and greenhouse gases, but we are still far from a fully integrated assessment for nitrogen. N*in*E will encourage these linkages to be made, extending the analysis for the first time to cover all nine nitrogen problems. The N*in*E programme is building the European scientific network necessary to quantify these interactions and underpin the development of future solutions.

Cover:
Compilation of pictures taken from www.sxc.hu.
Pictures taken by: T. Rolf, J. Weidema, D. West, A. Cerin, G. Thomson, M. Dobrotka, B. Schneider and I. Spanholi.

Introduction

Nitrogen is essential to the survival of all life forms, yet the natural abundance of useable nitrogen is so low that a massive human alteration of the nitrogen cycle has been required to sustain the feeding of the world's population. The alteration has been made even greater by the release of nitrogen oxides into the atmosphere during fossil fuel combustion.

These changes in the nitrogen cycle have exacerbated a number of environmental issues, including Aquatic, Coastal and Terrestrial eutrophication, Acidification, Climate change, Photochemical smog, Urban air quality, Particles and Stratospheric ozone depletion, all of which have impacts on people and ecosystems on a regional or global scale. The need for food and energy on the one hand and the environmental impacts on the other has caused conflicts between different objectives in society. Resolutions of these conflicts and policy development must be based on high quality, multidisciplinary scientific research and holistic assessments.

The ESF Research Networking Programme ‚Nitrogen in Europe', or in short N*in*E, aims to link together the nine main environmental problems of excess nitrogen for the first time. This challenge of interlinking nine major environmental problems is also reflected in the N*in*E logo, where N*in*E is placed at the centre of the transdisciplinary network, and also provides a mnemonic for the nine problems: 'ACT AS GROUP'. This emphasizes the need to join our efforts in delivering a fully integrated assessment of European nitrogen problems, the state of knowledge, necessary scientific developments and possible future solutions. Next to developing this European Nitrogen Assessment (ENA), N*in*E will operate through a series of workshops, conferences and travel grants, as well as constructing a meta-database containing a description of datasets that are relevant to understanding and explaining the nine main nitrogen problems.

The running period of the ESF N*in*E Research Networking Programme is for five years from March 2006 to March 2011.

The N*in*E Logo

The N*in*E logo reflects the challenge to interlink nine major environmental problems. European scientists and stakeholders from all relevant disciplines with a vision to address this challenge are invited to contribute.

The logo places N*in*E at the centre of the transdisciplinary network, and also provides a mnemonic: 'ACT AS GROUP', for the nine problems. This emphasizes the need to join our efforts into delivering a fully integrated assessment of European nitrogen problems and their future solutions.

Scientific Background

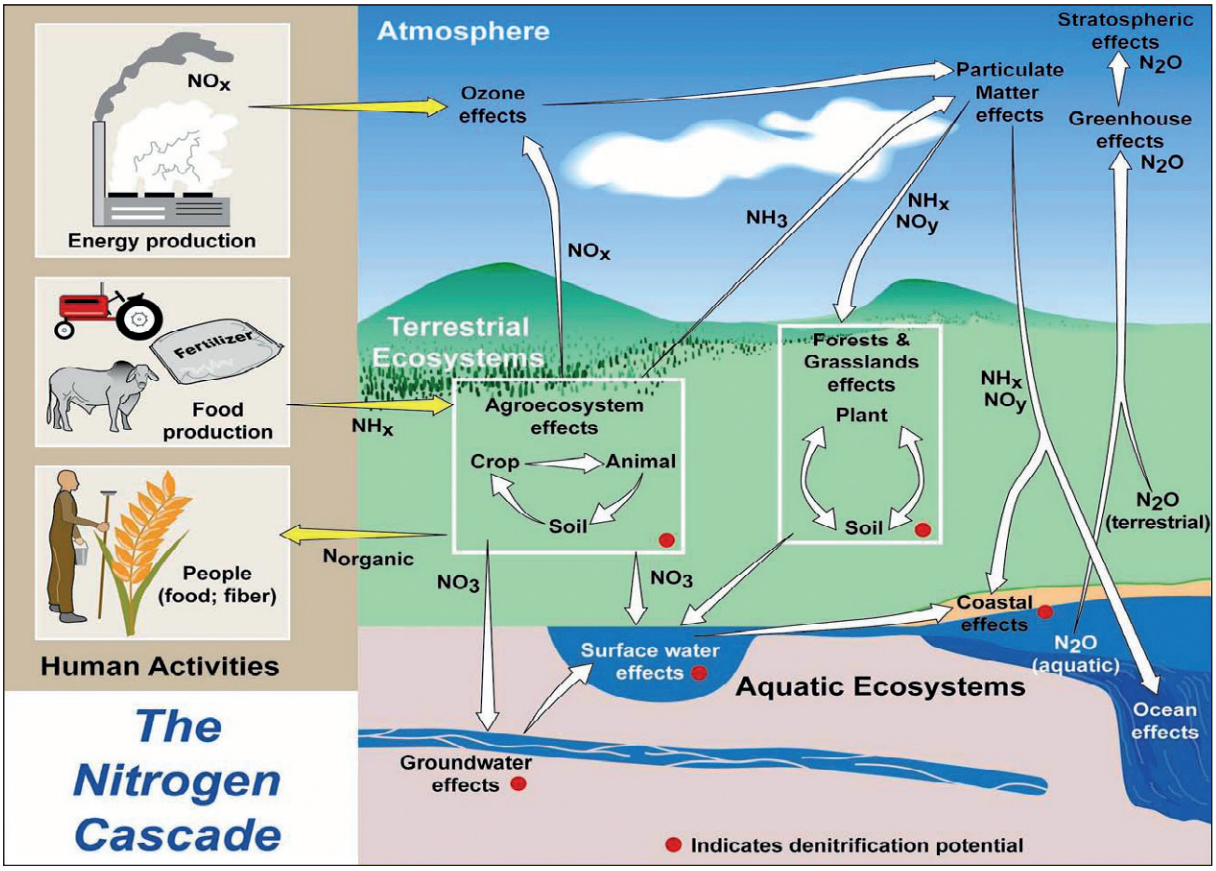
European ecosystems are threatened by many pressures, including changes in land use, atmospheric composition and climate. These anthropogenic disturbances lead to major changes in water and nutrient cycles. Globally, one of the most perturbed nutrient cycles is the nitrogen cycle: it has been estimated that the present nitrogen cycle is perturbed to more than 80%, whereas the carbon cycle is by comparison perturbed by less than 10%. Intensified agriculture and combustion of fossil fuels increase the amounts of reactive nitrogen and these compounds will, when released into the environment, have a cascade of effects on human health and ecosystems. Agricultural activities release ammonia (NH_3), nitrous oxide (N_2O) and nitric oxide (NO) into the atmosphere, while nitrate (NO_3^-) and ammonium (NH_4^+) are released into aquatic systems. Fossil fuel combustion from stationary and mobile sources is well known for emitting nitrogen monoxide (NO) and nitrogen dioxide (NO_2) (collectively termed NO_x). Equipment installed in order to reduce emissions of nitrogen oxides, e.g. catalytic converters in cars, cause emissions of small but significant amounts of NH_3 and N_2O.

The main drivers of change in the European nitrogen budget are the anthropogenic fixation of nitrogen by agriculture, leading to releases of NH_3, N_2O, NO and NO_3^-; the import of nutrients from other parts in the world through concentrates and food; and high temperature combustion processes, which oxidize a fraction of the atmospheric N_2 to NO_x. The presence of excess N in these reactive forms leads to an extremely wide range of environmental problems:

- NO and NO_2 react with volatile organic compounds (VOCs) to produce enhanced ground level ozone (O_3) concentrations, with impacts on crops, natural vegetation and human health. Increased tropospheric formation of ozone also makes a substantial contribution to the greenhouse effect.
- NH_3 reacts with atmospheric acids, including HNO_3 from NO_x emissions, to produce fine aerosol, such as ammonium nitrate (NH_4NO_3) and ammonium sulphates (e.g. NH_4HSO_4, $(NH_4)_2SO_4$). These undergo long-range transport in the atmosphere, depositing reactive N many thousands of kilometres from the sources.
- N–containing aerosols enhance light scattering, which reduces visibility and has a direct negative effect on global radiative balance. In addition, N-containing aerosols act as 'cloud condensation nuclei', providing an often indirect global cooling effect.
- N–containing aerosols are respirable and may be associated with both coronary and respiratory diseases.
- Deposition of oxidized–N (NO_y) and reduced–N (NH_x) leads to eutrophication of nutrient-poor aquatic and terrestrial ecosystems decreasing biodiversity. In particular, the local inputs of NH_x may be very large, leading to biodiversity loss in vulnerable habitats.
- Deposition of NO_y and NH_x to terrestrial ecosystems can result in soil acidification, with consequent changes in species composition and water quality. At a European level, the potential acidifying contribution from N is now larger than that from sulphur.
- Run-off and leaching of agricultural N lead to enhanced NO_3^- concentrations in ground and surface waters, with potential human health risks from drinking-water and changes in aquatic ecosystems.
- Excess N–flow in rivers and atmospheric deposition into coastal waters lead to eutrophication of marine areas, resulting in increased risks of algae blooms and hypoxia. Atmospheric deposition is also an important source of nitrogen in marine ecosystems.
- N_2O is a powerful greenhouse gas, which contributes ~12% of the anthropogenic global warming potential, while it also plays a role in stratospheric atmospheric chemistry leading to destruction of high-altitude O_3.
- The additional N supply from atmospheric deposition also affects CO_2 and CH_4 fluxes between ecosystems and the atmosphere in a positive (sink) and negative (source) way, leading to knock-on effects on the global radiative balance. Nitrogen deposition is important for the sequestration of carbon in terrestrial ecosystems, a highly considered method to counteract the increasing concentrations of carbon dioxide. Present fertilization of forests through balanced deposition of N leads both to increased growth and to an increased capacity for carbon sequestration.

Once released into the environment, nitrogen compounds may contribute to a cascade of effects before getting into a final sink as N_2 molecules or immobilized in soils or sediments. The nitrogen cascade (see figure on next page) may be illustrated by the fate of nitrogen applied as synthetic fertilizer to agricultural soils or emitted into the atmosphere because of the burning of fossil fuels. A significant part is emitted to the air as NH_3, NO, N_2O or NO_2; another part is leached as NO_3^- into ground- or surface waters; a third part is converted into plant biomass, used for human or livestock nutrition. The part eaten by humans (possibly after long-distance transport and transformation by the food industry) is released in waste water and discharged into surface waters after some degree of treatment. The part consumed by livestock is returned to agricultural soils, with a significant fraction excreted by livestock and emitted as NH_3, with additional losses as N_2O, NO and NO_3^-. Subsequent atmospheric deposition of the NH_3 leads to further N_2O and NO emissions and NO_3^- leaching. The atmosphere provides a means

Source: Galloway *et al* - nitrogen *et all* (made by UNEP for the GEO2003 yearbook)



to disperse the N widely, resulting in perturbation of the nitrogen cycle in areas remote from direct human intervention.

From all the issues described above, it is clear that 'nitrogen' is an important crosscutting theme covering most of the important societal sectors and their direct and indirect influence on environmental problems for Europe: climate change, biodiversity, ecosystem health, human health, ground water pollution, etc. This ESF Research Networking Programme on Nitrogen in Europe assesses the current state of knowledge on problems related to nitrogen that will be relevant for solutions for the future, while looking at the European nitrogen cycle as a whole.

Objectives and Activities

The detailed scientific objectives of N*in*E are listed in the programme proposal (which can be found on the N*in*E website *www.nine-esf.org*). The N*in*E Steering Committee has summarized these objectives as follows:

i. To develop the underpinning science that links different forms of nitrogen;
ii. To develop the science linking nitrogen interactions between environmental compartments;
iii. To establish approaches on a range of scales;
iv. To refine methodologies for relating information between different spatial and temporal scales;
v. To apply the analyses of N*in*E in selected case studies across Europe;
vi. To establish a meta-database of nitrogen research activities and assessments that integrate different nitrogen forms, interactions and scales;
vii. To prepare a major assessment report covering the state of knowledge on interlinked problems of Nitrogen in Europe.

How will N*in*E deliver?

As an ESF Research Networking Programme, N*in*E will operate through:

- **Grants for short visits**, of up to two weeks for activities that address one or more of the above objectives.
- **Exchange grants**, of up to 6 months for activities that address one or more of the above objectives.
- **Summer schools**, providing training to young scientists on nitrogen interlinkages, building the capacity for integrated assessment of nitrogen.
- **Targeted workshops** (10-40 people), relating to specific issues of the N*in*E programme.
- **Science conferences**, bringing together analyses of all nine nitrogen problems.
- **Meta-database,** that brings together access to published studies and datasets on all nine aspects of the European nitrogen challenge.

Workshops focusing on topics addressed by N*in*E might be eligible to receive financial support from N*in*E. This also holds for short visits or exchange grants. If you are interested in organising a workshop co-funded by N*in*E, please follow the application instructions on the N*in*E website (*www.nine-esf.org*). At the website you can also find more information about how to apply for a N*in*E exchange grant.

European Nitrogen Assessment (ENA)

A major outcome of the N*in*E programme will be the European Nitrogen Assessment (ENA). This ENA will be a joint effort of many European experts from different disciplines in the field of nitrogen-related issues. The specific objectives for the ENA are:

- specify the data bases needed to determine human alteration of the N cycle
- determine the extent and availability of the data bases and their degree of spatial and temporal definition
- identify gaps in data availability that can set the stage for assessments on the regional scale
- produce an annotated listing of existing research programmes focused on N assessment
- produce a review of existing assessments of the N cycle on regional and global scales
- highlight research priorities and future needs for assessments

In the coming years the ENA will evolve based on different background documents for specific topics, using a review process in which many experts are invited to contribute. In 2009 this will then result in an assessment based on the current knowledge on nitrogen issues in Europe, together with a policy-relevant summary on this assessment.

N*in*E website

The N*in*E website (*www.nine-esf.org*) will be the place where you can find information about the progress of N*in*E and about N*in*E topics. We hope that this website will evolve to become a meeting place for people interested in nitrogen-related work in Europe and beyond. A special topic on the N*in*E website will be a database on Who-is-Who in Nitrogen. Once established, this searchable database will enable interested fellow researchers and/or other parties to find the right person in the field of nitrogen-related activities. The database will not only contain information about names, addresses of people and institutes, but also on fields of expertise and participation in relevant networks. To find out more about Who-is-Who in the world of nitrogen, go to the N*in*E website, register and you will be taken to a database of people involved in the European N-world.

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For the latest information on this Research Networking Programme consult the N*in*E websites:
www.nine-esf.org and
www.esf.org/nine

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