TFRN-4 Background document: Proposed outline for ‘Special report on nitrogen and climate interactions’, requested by EB [ECE/EB.AIR/99 para 83.c].

Outline of the report (20 pages?)

Summary for policymakers
Technical summary

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Summary for policymakers

On a planetary scale, human activities have doubled levels of reactive nitrogen in circulation, largely as a result of fertilizer application and fossil fuel burning. This massive alteration of the nitrogen cycle affects: climate, food security, energy security, human health and ecosystem health. The long-term consequences of this are yet to be fully realized, but the human impact on the nitrogen cycle is largely ignored in international environmental assessments.
In this summary we would like to:

- Provide a short readable summary of the report
- Include some examples where the relations are visible and an issue: mining of nutrients in Africa, estuaries, forest growth, agricultural soils, etc.
- Recommendations about the next steps

1 Introduction

- Climate change as one of the most important threats
- Planetary boundary concept and the role of nitrogen in climate change
- The main drivers for nitrogen and the overlap with those of climate change
- The human impact on the nitrogen cycle is largely ignored in international environmental assessments
- The aim and outline of this report:

An internationally coordinated vision and strategy based on an assessment of the role of nitrogen in climate and global change is required. The objective of this report is to quantify the role of reactive nitrogen production in food production and energy use in both the excess as well as the mining regions of the world and the effect of too little or too much nitrogen on the greenhouse gas balance and climate forcing, the environmental and human health impacts to identify options of N management to increase its use for food and energy production while reducing impacts and increasing carbon storage.

2 Climate change causes and effects in relation to nitrogen:

Climate change and the role of nitrogen

- Introduction climate change
- Similarity between drivers
- Direct and indirect links with nitrogen

The direct link between N and climate change through nitrous oxide (N_2O), ozone, and aerosols.

The most direct effect of Nr on climate is through the formation of N_2O, which is responsible for about 11% of the net anthropogenic radiative forcing (global warming potential). The primary source of increasing N_2O is agriculture, due to expanding use of N fertilizers and animal manure production.
Nitrogen oxides also contribute to positive radiative forcing as a precursor to tropospheric ozone formation. Some forms of nitrogen contribute to aerosol formation, which results in negative forcing (cooling).

The indirect links of N to climate through C-N interactions in ecosystems.

Nitrogen is necessary for plant photosynthesis, which removes carbon dioxide from the atmosphere.

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The impact of N on Blue Carbon, i.e. the capacity of healthy coastal and marine systems to remove and store carbon.
The ability of forests and soils to sequester some of the C emitted to the atmosphere is determined, in part, by the amount of N available in ecosystems. Hence, understanding the C-N linkages is essential for understanding positive and negative feedbacks to climate change and the potential for managing C sequestration in forests and soils. C-N interactions are not yet adequately included in the IPCC assessment process.
A major threat and positive feedback is the role of nitrogen oxides: while increasing the Carbon uptake through fertilizing soils, at the same time NOx forms ozone that can damage the plants and reduce the Carbon uptake. This is an example of interactions that need quantification.

Positive and negative impacts of nitrogen on ecosystem services and human health; regional differences; Cascade effect with N_2O as an end point

3 Nitrogen is essential for life – drivers of the nitrogen cycles

The primary drivers for the nitrogen cycle include population growth, energy, food, feed, fiber and diets, equity, land use, biofuels/bioenergy, carbon, water, Phosphorus, etc.

All plants and animals, including humans, require nitrogen (N) to live.
Nitrogen is essential for producing protein, calories, Megawatts and feedstock for (chemical) industry. For one kg of nitrogen used in agriculture, not limited by light, water, phosphorus or other nutrients, we can produce.. kg protein, .., etc. or food for .. people, MWatts, …. In many cases nitrogen is the limiting factor.
Nitrogen mining has consequences for food production and will affect the water cycle.

Humans depend on the use of N fertilizers in agriculture to support about 50% of the global food production. With growing human population, efforts to reduce malnutrition, increasing prosperity and meat consumption, limited agricultural land, and increasing production of biofuels, it appears inevitable that N fertilizer application will grow substantially. Nitrogen is also emitted during fossil fuel combustion in industry, transportation, and energy production.

Pathways to the environment.
Once a reactive nitrogen (Nr) molecule has been created the chance that it escapes to the environment is almost 100% for nitrogen oxides from fossil fuels and 70% for agricultural nitrogen. It can be emitted to the air as ammonia, nitrogen oxides or nitrogen dioxide and as nitrate to (ground)water. Furthermore, together with Phosphorus it enhances the nutrient availability in estuaries and coastal areas. Reactive nitrogen cascades through the different compartments and can be transported over long distances. During the cascade it contributes to different effects in space and time. The endpoint of the cascade is at some place and time the emission of N2 or N_2O, which has a long lifetime and contributes to climate change and stratospheric ozone destruction (IPCC, 2007).

4 Co-benefits, in addition to climate mitigation, of improved N management; Costs and benefits.

Climate change is one of five “pillars” of opportunities and threats due to massive human alteration of the nitrogen cycle. The other four include:

- Food Security – N management can improve agricultural productivity
- Energy Security and Industry – N is needed for biofuel production; technologies exist to reduce N emisions from combustion of fossil fuels
- Human Health – N in water and air pollution causes human health problems; too little N for agriculture results in malnutrition
- Ecosystem Health and Biodiversity – Harmful algal blooms, reduced fisheries, and loss of biodiversity on land and in water are among the many environmental consequences of excess N in the environment. (Albert Bleeker: N deposition and biodiversity risk areas)

These five pillars are not only nitrogen related but encompass many other issues and biogeochemical cycles. The nitrogen issue has to be regarded in relation to these other areas. This section needs a multi-disciplinary approach involving expertise from different fields.

Cost and benefits: in the European Nitrogen Assessment a chapter on cost and benefits is drafted, which can serve as a basis.

5 Options for N management

Multiple direct and indirect impacts of N on the climate system are known, but they are not sufficiently represented in the scientific and policy discussions on climate change mitigation strategies. N management and its consequences span disciplines and ministerial responsibilities, including agriculture, energy, human health, and the environment. A few examples of opportunities for improved N management include (Galloway et al. 2008):

- Using best available technologies, N release during fossil fuel combustion can be decreased by about one third, from about 24 to about 16 billion kilograms N per year.
- Improving fertilizer use efficiency and animal waste management in agriculture may be a cost-effective way of mitigating climate change through reduced N_2O emissions, while also allowing agricultural productivity to improve in both developed and developing countries. By increasing the efficiency of fertilizer use, the projected 38% increase in global cereal demand by 2025 could be met with a 25% decrease in N fertilizer application, which would reduce fertilizer used by about 15 billion kilograms N per year.
- Improved animal feeding strategies and manure management (e.g., low-protein animal feed, barn adaptations, covered manure storage, air purification and efficient manure applications to crop land and grassland) could decrease N release to the environment by about 17 billion kilograms N per year.
- Dietary changes that decrease portions and frequency of eating meat in developed countries would substantially decrease N losses to the environment while also providing salutary human health benefits.
- Globally, humans produce about 20 billion kilograms N per year in human waste, of which less than 1% undergoes tertiary sewage treatment that converts the N to a harmless form. If this type of sewage treatment were implemented for half of the 3.2 billion people who live in urban areas, releases would decrease by about 5 billion kilograms N per year, which

would improve water quality and fisheries and help avoid harmful algal blooms in coastal zones. Alternatives could be the recovery and agricultural use of excreted nutrients.

- In areas where nitrogen is mined, such as Africa, N management could improve food production while increasing carbon sequestration.

These interventions could reduce N releases to the environment by about 50 billion kilograms N per year, which is about one-third of human-induced increases of reactive N in the environment. These reductions would have direct effects on climate via reduced emissions of nitrous oxide from soils and water bodies, in addition to multiple co-benefits to society. Less well quantified are the potential indirect effects of improved N management on climate, such as carbon sequestration and feedbacks to climate change, but which could be systematically addressed in regional and global nitrogen assessments. Also the impacts of N in adaptation strategies, such as food production, ecosystem resilience are not well quantified. A Global Nitrogen Assessment for identifying innovative N management strategies for global climate change mitigations and associated co-benefits to society is required.

6 Scenarios for future Nr, climate, environment and human impacts

Future predictions of major drivers that influence the nitrogen and carbon cycle are available from IPCC, IAASTD, … The translation of these into scenarios for Nr, climate, environment and human impacts including options for Nr management is essential to provide directions of optimally use Nr. Basic work has been done within the Millennium Ecosystem Assessment and in the GlobalNews and IMAGE model

7 References

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Annex on selected key variables (“indicators”) for the effectiveness of N management