Workshop on Needs for Global Nitrogen Integrated Assessment Modelling, Edinburgh, UK 5th & 6th May 2015

Workshop on Needs for Global Nitrogen Integrated Assessment Modelling.

Background Document 1:
Prioritising Nitrogen Threats and Benefits: Which issues need to be linked when developing integrated modelling capability?

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13 April, 2015 (current focus is on food and agriculture and we may need to extend to improve balance with N from energy and transport and from waste water)

1. Objective of BG-document

The purpose of this background document is to inform the INMS Pump Priming workshop on key issues that need to be addressed in globally integrated modeling for nitrogen on both global and regional scales. Before progress can be made in designing appropriate modeling systems, the first requirement must be to develop a scientifically-defensible consensus on which issues need to be linked on which scales. This also opens the question of identifying which issues are of central importance for discussion, which issues can be included alongside other issues, and which issues are not of sufficient priority to be included in globally integrated nitrogen modeling.

Prioritising threats and benefits is a societal issue, while the consequence for the modelling requirements is a scientific issue. Determining societal priorities in principal is a political process, where scientific information is supporting. This means that in principle, policy feedback is needed to test and tune any proposals for priority identification. This process should therefore be seen as iterative between the science and policy communities, including involvement from wider society.

The present document builds on the outcomes of existing science-policy engagement, such as in the European Nitrogen Assessment, incorporating feedback where available from different policy forums relevant to nitrogen. The document takes forward this discussion, bearing in mind recent scientific findings and emerging policy developments. Its aim is to stimulate discussion at the workshop.

In the following paragraphs we will elaborate:

1. The nature and extent of N impacts
2. The quantification of impacts
3. The application of socio-economic approaches to value impacts to support discussion on societal prioritization of impacts (e.g. cost-benefit assessment).

2. A starting point for Nitrogen key threats

In the European Nitrogen Assessment (ENA, Chapter 5), 23 problem areas related to nitrogen were identified initially. These were condensed to 9 major environmental concerns, and finally to 5 key threats. The five key threats were summarized under the acronym WAGES: [1] Water quality and [2] Air quality effects of nitrogen with risks for humans and organisms from an eco-toxicological perspective (dose response relation at level of organisms or humans occurring when threshold concentrations of specific N compounds are exceeded), [3] climate stability by altering the greenhouse gas balance (with both warming and cooling effects) and [4] ecosystems and biodiversity, which can occur at levels below the eco-toxicological thresholds (note: there is overlap between [1, 2 and 4]. Finally, both excess or insufficient N can contribute to [5] threats to soil quality, including soil acidification or soil degradation by accelerating breakdown of organic matter due to excess N, as well as soil mining and subsequent degradation of soil where insufficient N is available. The Our Nutrient World report (ONW) prepared for the United Nations Environment Program (UNEP) also used the WAGES approach, also emphasized the benefits of nitrogen strongly, including enhancements to human food and animal feed security and increased energy security.

3. Nitrogen mitigation

The Towards INMS process conceives of an eventual International Nitrogen Management System (INMS) as an organized process of delivering scientific evidence to support international policy making on the environmental effects of nitrogen. Smart and cost-effective N mitigation schemes must form the basis in such a process. Such schemes demand an integrated approach that takes into account:

- The contribution of N to various environmental, food security and health issues
- The balance of (changes of) cost and benefits of N
- The regional variation of these costs and benefits
- Distinction between global and regional issues, including the global and regional aspects of climate change, marine eutrophication, food and feed security, air pollution, nature quality, with links to income for farmers, manufacturers, services and other parts of the economy, and local health and well-being issues related to air, land, and water quality
- Recognition of social and economic barriers to change, such as linked to global and regional issues of trade, cultural norms, economic development stage, organization structure, institutional assurance, development path dependence,conflict, and political will. These links would change the key mechanisms to model N cycling and their impacts.
- Distinction between issues that create discomfort, morbidity or mortality to humans and issues that threaten the functions of the wider agro-food, energy, and environmental systems as a whole

4. The nature and extent of benefits and negative impacts of N use

While associated with the 5 “key threats”, the global use of reactive nitrogen in fertilizers at the same time is a major factor for improvement of human nutrition, well-being, and financial security, and can contribute substantially to gross national income and export revenues (Figure 1). Just as importantly, the availability of nitrogen inputs (also including the use of crop biological nitrogen fixation) has allowed a major increase in animal feed production and livestock populations, increasing the fraction of livestock products in human diets (with both beneficial and adverse consequences for human health). The impacts of N on the economy of enterprises, regions and countries should be included in an integrated approach, taking into account interaction with water and with other key macro and micro nutrients.

To make the somewhat fuzzy concept of sustainability operational for the agro-food system, Westhoek et al. (2013) (drawing among others on Lang and Heasmann, 2004) grouped all issues where the agro-food system can have negative and positive effects. Based on this, in Figure 1 (which only covers the food system), we show a wide range of issues where nitrogen is important. In this figure, we distinguish between impacts where nitrogen has a major role (**N** in bold type font) or is simply relevant (N in normal type). This approach is somewhat different from the WAGES approach as it includes economy and health impacts through food, and distinguishes the different relevant scales for impacts. A similar scheme can be developed for the energy&transport, industry&households and waste systems.

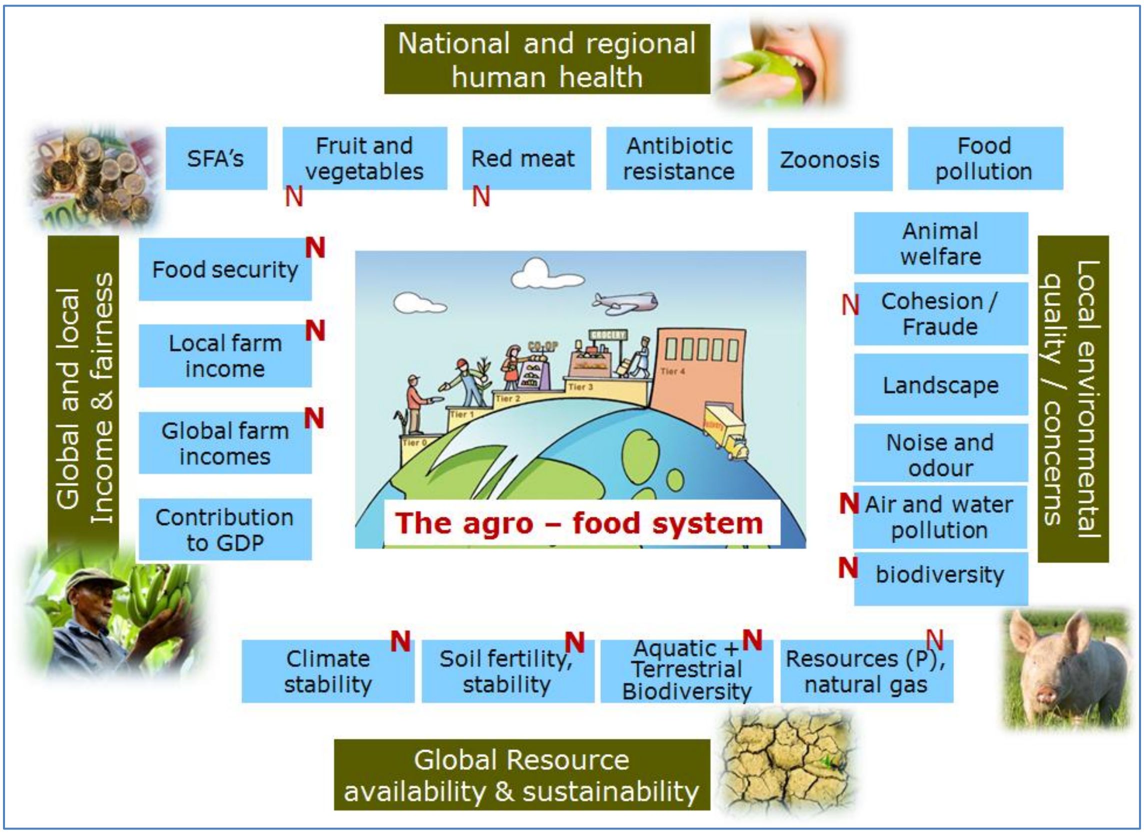

Figure 1: A sustainable agro-food system should deliver safe and healthy food, sufficient food, adequate farm incomes, and a clean and livable local environment; it should not deplete vital global resources. N indicates a relationship with nitrogen while bold type ***N*** *indicates a major relationship with nitrogen (Modified from Westhoek et al., 2013). SFA's are saturated fatty acids. Natural gas refers to fossil methane which is a key ingredient for the clean production of N fertilizer*

5. Assessment of impacts and the role of modelling

A fully integrated assessment of the impact of N use and N emissions and the suitability of mitigation options would involve all categories of impacts. Prioritizing N issues as presented in Figure 1 may be region and stakeholder dependent and thus differ for the respective INMS regional demonstrations. Also the commonly used units of impacts in the four categories in Figure 1 may differ. Three levels of impact quantification can be distinguished:

1. Quantification of impact of the N budget: N inputs, emissions, surpluses etc.;
2. Quantification of impacts relevant for society according to the proper units of indicators for each impact;
3. Quantification of impacts in in the same units; e.g. in case of human health impacts in loss of life years or health life years, or ultimately in preferences of societies to prevent these impacts (which on its turn can be expressed in monetary units).

Working at regional, continental, or global scales, [1] generally requires the use of models with some level of determinism. Models may operate at the local, regional, national to even global scale. As environmental impacts of nitrogen depend on the environmental and management conditions, often spatially and temporally explicit models are required. In addition, because the nitrogen cycling through our environment is related to many different processes that interact across different scales in soil, air and water, models should integrate many different components of the environment and our society where nitrogen is processed, transferred, accumulated or leaked to the environment. Level [2] needs a combination of monitoring / data collection and extrapolation towards impacts, but often involves also models (e.g. emission-deposition models to determine critical limit exceedance). The nature of a common term for point [3] typically would be economic or human well-being, and involve more assumptions.

Focusing on N, as in INMS, would require that [2] and [3] are linked to [1] in the sense that the effect contribution of emissions or concentrations of N to the impacts is quantified. This step also is hardly possible without models. In short: models from the regional to global scale, were the processes are described spatially explicit, are essential to link human development to N emitting activities, to N emissions and to N-pollution and impacts. Regional scale and larger scale models linking N use to economic benefits are rare (see Birch et al. 2010; Van Grinsven et al. 2013; and Sobota et al. 2015 for exceptions). Further discussion of integrated assessment models for nitrogen is made in the accompanying background document by De Vries et al. (2015).

6. Scenarios

Another important distinction is between quantification of the current situation and the quantification of projected future situations (scenarios). If the INMS process will investigate mitigation options it will be essential to be able to analyze future scenarios.

Scenario analysis starts with establishing a baseline (Business As Usual, BAU) scenario which is driven by future demands for food, feed, non-food goods and energy, based on population growth curves, development of GDP and assumptions on resource efficiency and recycling, emission reduction and behavioral change. Such scenarios are to some extent available for the global and regional (supra national) scale, e.g. from IPCC or FAO, although they will often have been designed with a different purpose in mind, implying that modification is needed to suit nitrogen scenario assessment. Examples are the application of the IPCC Special Report on Emissions Scenarios (SRES) approach to future nitrogen fertilizer use, which compared different strategic views of the future (Erisman et al.,

2008) and the revision of these estimates using the Representative Concentration Pathways (RCP for CO_2) scenarios more recently used by IPCC, where future fertilizer use scenarios were linked to scenarios matched to different levels of global radiative forcing (Winiwarter et al., 2013; Figure 2).

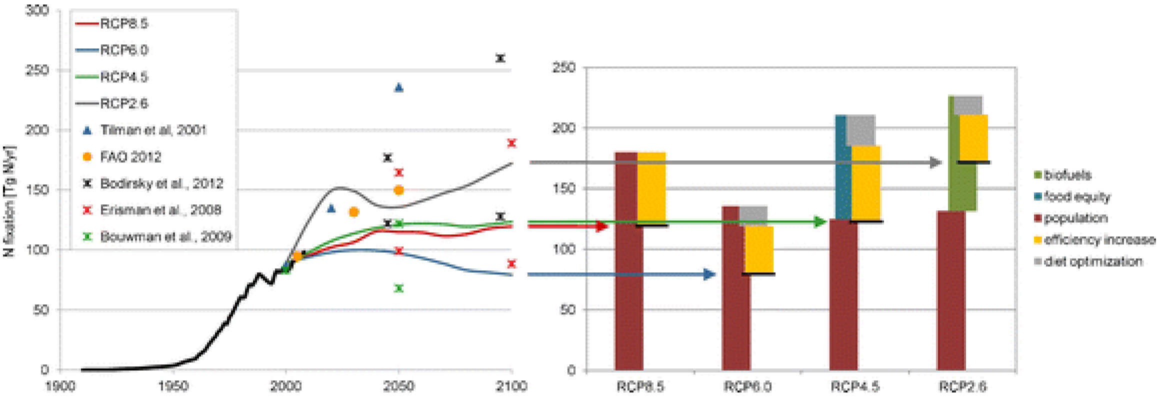

Figure 2 Global agricultural demand for industrial N fixation (Tg N/yr), projected till 2100 (from Winiwarter et al 2013). Lines in the left panel reflect trends attributed in this paper to the respective RCP scenarios, while dots and asterisks show other assessments. The asterisks express the ranges (maximum and minimum) out of several scenarios based on storylines, with Erisman et al. (2008) using a methodology very similar to the one applied here for RCPs. Global population numbers used for 2100 are 12.4 billion, 9.34 billion, 8.6 billion and 9.06 billion (RCP8.5, RCP6.0, RCP4.5 and RCP2.6, respectively)

Other standard sets of scenarios include relationship to meeting the Millennium Development Goals (MDGs) or the Shared Socioeconomic Pathways (SSPs) approach of IPCC. SSPs are sets of alternative plausible trajectories of future global development that incorporate alternative strategic views of the future. The ambition of the SSPs process is to better inform and involve communities in choosing between different adaptation and mitigation strategies (Figure 3; Van Vuuren et al., 2014). Modification of such scenarios and zooming to smaller scales requires additional assumptions on relation between food and energy demand, N-use and N-emissions.

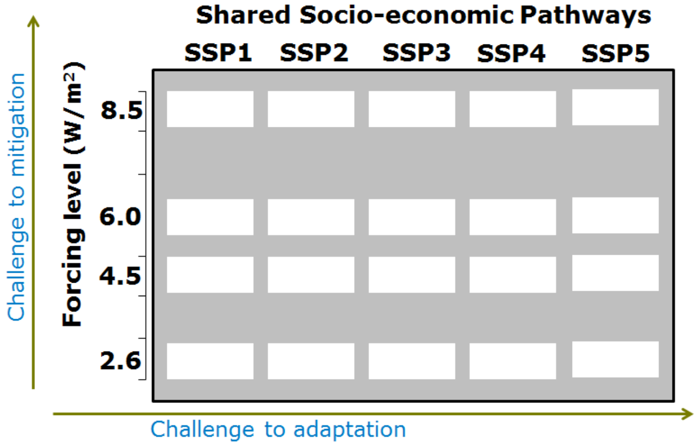

Figure 3. The linkage between the SRES-RCP approach and the SSP approach highlighting the societal choice between adaptation and mitigation strategies for climate change policies (Van Vuuren et al, 2014).

7. Cost-benefits analysis is a supporting tool for prioritisation of N-issues

Economic aspects may serve to differentiate between individual impacts and to prioritize measures. Cost benefit analysis may be an adequate tool here. A first assessment of costs and benefits for the EU (for year 2008), seems to indicate that damage costs by N pollution to human health and ecosystem health are of similar magnitude, while the net N costs for climate instability are small (See Figure 2; based on Brink et al., 2011; van Grinsven et al., 2013). A recent damage cost assessment in the United States showed somewhat similar results, although damage to aquatic environments exceeded human health-related costs (Sobota et al. 2015). Currently in the US, damages of N leakages from agriculture and other non-point sources are considered externalities not captured in the cost of doing business.

It should be stressed that these results are not undisputed: assessment of cost to aquatic ecosystems is based on surveys of Willingness to Pay (WTP) for the Baltic region, while cost to terrestrial systems is based on a model study of restoration costs. This difference in approach may explain the full difference in the damage costs for aquatic and terrestrial ecosystems. Moreover, climate-related costs are based on a market carbon price of moderate mitigation levels and thus may not be fully stringent, explaining the low priority of climate instability.

The methods and data underlying the estimate of societal cost of N pollution for human health are better established than for ecosystems, both regarding the WTP (even if based on a disputable value of life year) and region specific dose-response relationships. Effects of air pollution (NO_x and NH_3) on human health are larger than those of water pollution. The largest health impacts of N pollution by N_r are caused by secondary particulate matter (PM; aerosols of ammonium and nitrate salts). Although clinical studies have not been able to distinguish health effects specifically attributable to water-soluble secondary PM, epidemiological data conclude no difference in health impacts of primary and secondary PM (EU, 2014).

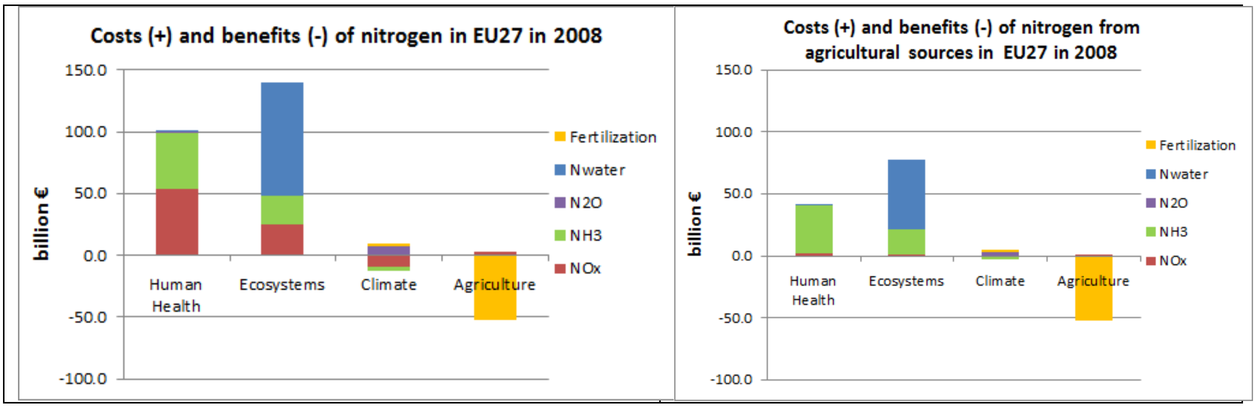

Figure 2: Cost of N pollution for all sources (left) and agricultural sources (right), for different impacts, as compared with benefits of N for agricultural production (based on N response of cereals, which is a low value crop group, thereby providing a conservative estimate). (Cf. Van Grinsven et al. 2013).

The benefits of N fertilization for society are obvious. The yield gap between agriculture with and without synthetic N fertilization is around 20-30% (de Ponti et al., 2012), and some authors assume it to be even higher. The economic return on farmers investment (providing the basis to establish the Economic Optimum Nitrogen fertilization Rate, EONR) in synthetic N fertilizer depends on: (a) prices of fertilizer and crops and (b) the N response curve. In various European countries and N. America, the recommended amounts of N fertilizer are based on the EONR concept, and therefore recommendations can vary significantly between countries and years because of different prices. E.g. in arid regions, with no cheap access to irrigation water, EONR-based N recommendations will be much lower than in temperate regions with adequate rainfall.

In developing countries, with often very low N rates compared to NW Europe and N America, yield response to increasing N rates is much higher, but in view of very high local prices of synthetic N (compared to the prices that agricultural products can achieve) EONR based N rates still will be very low. In transition countries the situation is reverse. While N rates can be much higher, yield are relatively lower compared to developed countries with a low local prices of synthetic N by strong subsides.

Another important point is that further use of primary crops in the food chain (e.g. cereal for animal feed, pasta, bread) will create additional added value. Typically, an average multiplier of three on the value of the crop value is needed to express this added value for national western economies (Grinsven et al., 2013). A final point is that the N benefit in Figure 3 is based on the mean N response of cereals in the EU. A recent study by Lassaletta et al. (2015), building on the ENA (Brink et al., 2011, Grinsven et al., 2013) estimated the total crop benefits for some EU regions and compared these to the cost of N_r pollution in agriculture. These crop benefits are considerably higher than in the EU cost-benefits budget, and exceed the N pollution costs in all regions examined. The most important reason for this is that these new estimates of the crop benefits include high value crops like vegetables or permanent crops (Figure 3).

Although N application rates in horticulture are notoriously high, they only constitute a minor proportion of total fertilizer use in most countries (perhaps not in developing economies) or continents and N surplus expressed in absolute amounts of N. Therefore N mitigation schemes in agriculture at regional or higher scale would often tend to exclude measures in horticulture, and therefore would not lower the benefits for these crops. However, for assessments in smaller regions with a large acreage of high N input – high value crops, including N mitigation in horticulture cannot be ignored. It could be argued that for large scale application (e.g. at a global level), inclusion of major arable crops, meat and dairy production would be sufficient to characterize agriculture in relation to other N sources such as transport and industry.

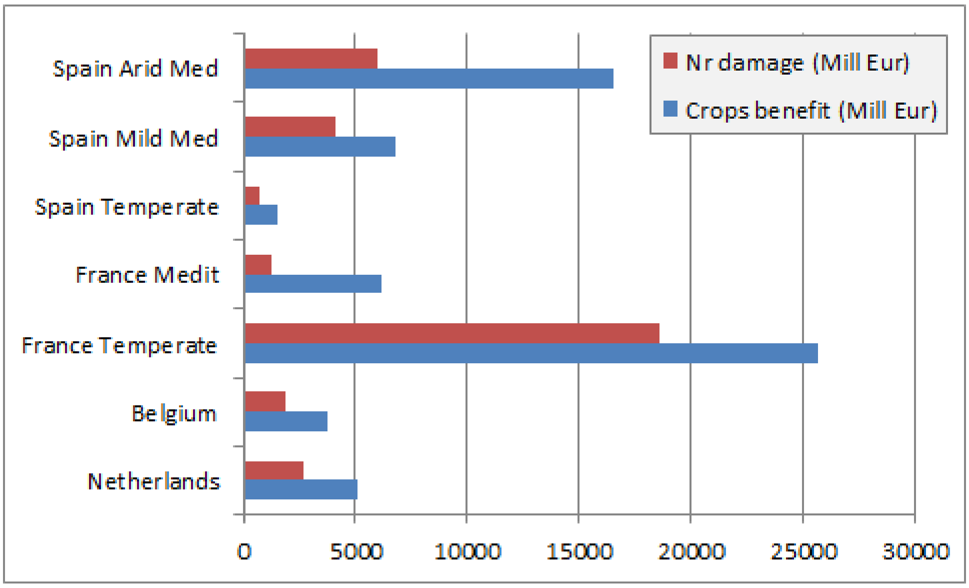

Figure 3. Total N costs and crop benefits for some EU regions in 2008 (Lassaletta et al, Poster and in prep. 2015).

Nitrogen is released into the environment from many sources, including industry, transport, agriculture and waste water. However, farming is a special case because the practice distributes Nr in excess over large areas and is a major source of non-point N_r pollution. This makes individual farms a key places of mitigation. There are also major challenges as the farmer is one of the most important actors for mitigation and also the receptors of mitigation costs. Typically, the farmer cannot transfer these costs to the consumer. The extent of this problem depends strongly on the region, and the current level of mitigation. At low levels of mitigation, measures can also generate benefits both for society and the farmer. When considering the different key benefits and threats, it is relevant that management responses explore the options that could overcome such barriers to change.

8. For discussion in Edinburgh: Which issues need to be linked when developing integrated modelling capability

- Is it useful to define common criteria for what constitutes a "priority nitrogen issue" to help standardize the identification of nitrogen priorities in INMS regions? Could a short proposal of such common criteria be developed as a basis for reaction by policy makers?
- To what extent should INMS focus its efforts on certain environmental impacts (Water, Air, Greenhouse balance, Ecosystems and Soils of the WAGES paradigm)? Have some key impacts been neglected? What is the relative effort appropriate to quantify benefits (e.g. for food, energy, etc.)?
- Should all major economic sectors generating N_r be included: agriculture, animal feed and human food, combustion sources, industrial manufacturing (e.g., plastics and nylon), solid waste, residential non-point sources, waste water? What is the relevant role of action by source sectors versus by wider society in managing N_r impacts?
- What is the relative priority to quantify impacts of nitrogen and its better management on national income versus income of particular business sectors (e.g. in case of the food system, on farm income)?
- What level of detail of source and activity information needs to be considered at global and regional scales to capture the main damages and benefits of nitrogen? For example, when should specific small sectors (e.g. horticultural and permanent crops, and aquaculture) not be excluded from analyses?
- To what level of detail interactions between nitrogen on the one hand, and water, other pollutants, and other nutrients, on the other hand, need be taken into account or quantified?
- How should interactions between regions be addressed when considering key benefits and threats? For example in agriculture, this is particularly relevant when feed production and livestock production are spatially disconnected. This may create a loss of nitrogen use efficiency when observed at the whole system scale, N pollution swapping (and export) issues and income and unequal distribution of N benefits.
- How can cost-benefit approaches be advanced for developing and transitional economies? Apart from lacking data, this may raise some ethical discussion (e.g. differences between value of a life year, when monetizing impacts of N_r on human health or the advantage of externalizing environmental costs of production to countries with no strict environmental legislations).

- Based on possible criteria for prioritization, can an initial ranking of key nitrogen issues be assembled, that can be used to inform discussion with policy makers?
- What are the main barriers to make the N use more sustainable in different countries? What are the pathways to realize these potentials in different scenarios? For example, the policy, technology, economic development stages, or institutional design? Whether the main barriers can evolve in different development stages or interact with the N fluxes changes? If so, do we have to change our models with these mechanism evolutions? Or we need different approaches to links N science with social science?

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