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

Background Document 2:
Policy Linkages: What are the priority measures needed for better nitrogen management that should be included in models?

Authors: Clare Howard[1], Will Brownlie[1], Rob Maas[2], Jean Ometto[3] and Mark Sutton[1]

1 Centre for Ecology & Hydrology, UK, inms@ceh.ac.uk
2 National Institute for Public Health and the Environment , RIVM, Netherlands
3 National Institute for Space Research, Brazil

1. Introduction

To manage human perturbation of the nitrogen cycle a wide range of pollutants, sectors and policy measures need to be addressed. The aim of the GEF/UNEP project 'Towards an International Nitrogen Management System' (Towards INMS) is to develop a science evidence process to support global nitrogen policy. Integrated assessment modelling (IAM) provides an important tool in the development of strategies to manage the nitrogen cycle and the interaction with policy mechanisms. The future role of IAM in Towards INMS is therefore crucial. For this reason, IAM has been identified as a central theme of the "INMS pump priming" (INMSpp) project, which is a contributory initiative funded by the UK Natural Environment Research Council (NERC).

The challenge to manage the nitrogen cycle is highly diverse in terms of spatial, temporal environmental and social aspects. In addition, the resources to produce IAM tools are limited, while the need for compatibility between models adds to the challenge (not forgetting the data needs). Therefore, to focus the resources available, it is useful to define and prioritise the technical, societal and other measures which need to be incorporated in models. In this context, we address both measures that are already considered within existing policies, as well as possible future measures.

For the purpose of this discussion, measures represent **actions for change** made by different business sectors or parts of society. These interact with **facilitating actions** to achieve change. Such facilitating actions may include a range of different **policy instruments** (e.g. incentives, levies, regulations, technical support). *To keep the terminology simple, we define a measure as an action that directly changes nitrogen flows, while a policy instrument is an action that can facilitate the uptake of measures.*

In exploring the different options, we need to consider both measures which are known to have reasonable impact on the issues (i.e. with high mitigation potential) and measures which are more aspirational in their nature, but which could drive future innovation in the nitrogen green economy. The latter may be particularly important if the benefits to society can be demonstrated through modelling of future scenarios.

The timescale on which to include measures into IAM is also important. This means that it can be useful to group measures by time horizon, which provides the opportunity to make progress in the present, while planning for the future.

In this background document, we first identify possible measures that could make a difference leading to better management of the nitrogen cycle. As part of this, we consider how criteria may be identified to define priority measures. In the first instance, such identification is made without consideration for the applicability to modelling. In a second stage, the workshop discussion should then consider the extent to which these measures are already incorporated in models, or could be incorporated in models in the future (e.g. 2, 5 and 10 year timescales). This may then feedback to the modelling needs. These outcomes can then be used to encourage reflections from policy makers on key measures that need to be considered by models.

This background document uses the 'Key Actions' identified in *Our Nutrient World* (Sutton et al., 2013) as a framework for considering priority measures in nitrogen integrated assessment modelling. It raises the question of how to set criteria to identify priority measures, and then opens the way to discuss scientific and policy perspectives during the workshop. The document is framed to encourage modellers to consider the extent to which such measures are already included in current models.

The document finishes with questions for discussion at the INMSpp Edinburgh workshop. The aim is to establish during the workshop a first list of priority measures that should be included in models in 2, 5 and 10 years time. The summarized results will then be used to elicit feedback from policy makers in order to ensure that the 'Towards INMS' work plan meets anticipated policy needs.

2. Key intervention points in the nitrogen cycle

To provide a framework on which to examine and prioritise key measures to manage nitrogen, we take as a starting point the 10 Key Actions defined in 'Our Nutrient World' (Sutton et al., 2013). These represent broad areas of intervention by which Nutrient Use Efficiency (NUE) across the full nitrogen supply and use chain can be increased (Figure 1). Although framed in terms of overall nutrients, Figure 1 fits well to the specific discussion for nitrogen.

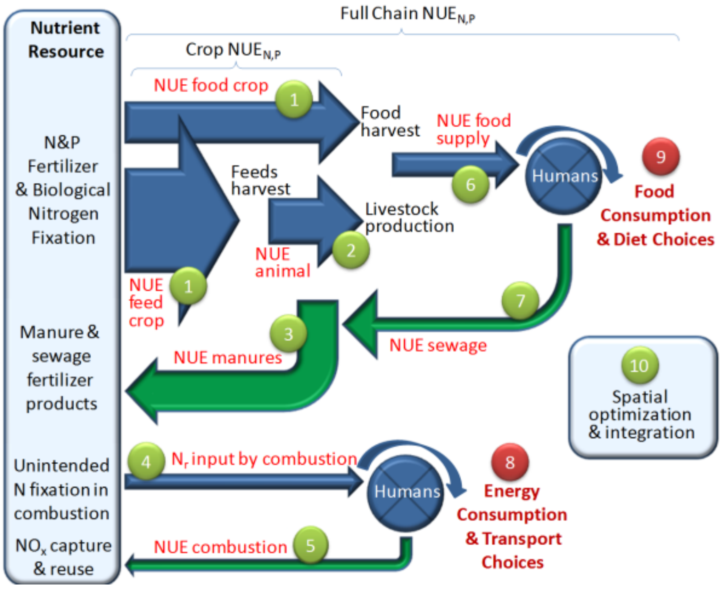

Figure 1: Nitrogen flow depicted as a cycle from resource through the stages of use (blue arrows) with green arrows (recycling). The system is driven by 'motors' of human consumption. Numbered circles highlight ten Key Actions to increase NUE. ('Our Nutrient World' Sutton et al. 2013)

Each of the 'Key Actions' in Figure 1 addresses one or more pollutants (see Table 1), allowing multiple benefits to be realised, as long as any potential trade-offs between pollutants are addressed. To give an indication of the necessary activities supporting these 'Key Actions', a number of 'Overall Measures' have been listed here, each of which would need to be supported by a range of more specific measures (such as improving dietary management in livestock to reduce NH_3 loss, or use of transport emission reduction technologies to reduce NO_x emissions). These specific measures may or may not be related to existing policies.

Table 1: 'Key Actions' from Our Nutrient World, and examples of corresponding 'Overall Measures'

Key actions by sector		**Primary N losses Addressed**	**Overall Measures**
Agriculture			
1	Improving NUE in crop production	NH_3, Nitrate, N_2O, NO_x, N_2	Improvements in fertiliser and manure storage and application (existing and future techniques and technologies).
2	Improving NUE in animal production	NH_3, Nitrate, N_2O, N_2	NUE improvements (existing and future techniques and technologies) in • Farm level N management • Feeding strategies • Animal breeding • Animal Housing
3	Increasing the fertilizer use equivalence value of manure	NH_3, Nitrate, N_2O, NO_x, N_2	Improvements in fertiliser and manure storage and application (existing and future techniques and technologies).

Transport and Industry			
4	Low-emission combustion and energy efficient systems, including renewable resources	NO_x, N_2O, NH_3	• Innovation and regulation in low-emission combustion technologies • Greater use of renewable energy sources
5	Development of NO_x capture and utilization technology	NO_x	Innovation and application of new technology with potential for pre-market green finance support
Waste and Recycling			
6	Improving nitrogen efficiency in fertilizer and food supply (reducing supply chain waste) and reducing food waste	NH_3, Nitrate, N_2O, N_2	• Management systems to reduce post harvest losses. • Reducing waste in the food production sector. • Strategic planning at local/regional level • Technological advances
7	Recycling nitrogen from waste water systems, in cities, agriculture and industry	NH_3, Nitrate, N_2O, N_2	• Technological advances • Strategic planning at local/regional level • Incorporation into waste water investment programmes.
Societal consumption patterns			
8	Energy and transport saving	NO_x, N_2O, NH_3	• Energy saving policies • Alternative transport systems • Technological advances
9	Lowering personal consumption of animal protein among populations consuming high rates (avoiding excess and voluntary reduction)	NH_3, Nitrate, N_2O, NO_x, N_2	• Public awareness of the health, environment and cost co-benefits • Local/national incentives
Integration and optimization			
10	Spatial and temporal optimization of nutrient flows	NH_3, Nitrate, N_2O, NO_x, N_2	• Technological advances • Strategic planning at local/regional level

3. Important Factors

Nitrogen cycle and real world application

A large number of current and potential measures exist which can support the key actions listed above. To prioritise these, however, will require the consideration of a number of factors, which include for example:

- Contribution to improving NUE (which can be measured in a variety of ways)
- Cost-benefit (measured against pollutant)
- Overall (or outlay) costs
- Reproducibility (i.e. in a real world setting or in a variety of settings)
- Possibility of monitoring and measuring the efficiency improvements for general study or policy implementation/enforcement

- Time to market (i.e. is the measure part of existing technology or is significant development still required)?
- Scale of applicability (i.e. wide or specialised)
- Incorporated into a current policy framework
- Co-benefits (or trade-offs) with other pollutants
- Implications/importance of the measures for the different INMS regions

Modelling Considerations

The following considerations may also come into play when deciding which measures should be prioritised in IAM:

- Availability of data to assess the measure
- Spatial resolution of the measure
- Temporal resolution
- Model type - i.e. process based or empirical
- Model compatibility (either technically or due to original model type or construction)

4. Developing Selection Criteria for Priority Measures

Information on these issues can provide evidence to support the identification of priority measures for inclusion in integrated assessment models. However, such an identification of priorities for modelling capability also depends on policy considerations. Scientists may identify options based on quantitative analysis of the potential of a measure, its practicality and cost, while policy makers also include the acceptability of different measures. It is therefore important to develop a dialogue between different views, also incorporating the latest experience from stakeholder communities (business, civil society etc).

For transparency, it is also important to make clear the criteria for selection of certain measures as "priorities". As far as possible this should allow distinction between scientific, policy, business and other social factors.

Box 1: Example of priority identification when considering nitrogen mitigation measures. The following is an excerpt from the report of the UNECE Task Force on Reactive Nitrogen to the LRTAP Convention. It illustrates the identification of potential mandatory measures for agricultural ammonia mitigation during revision of the Gothenburg Protocol (UNECE, 2011) as specified in the draft annex IX of the protocol.

"Para. 16. Considering the request from the Working Group [on Strategies and Review] for flexibility in annex IX, the Task Force agreed a ranked list of priority measures for ammonia emission reduction. The priorities were established on the basis of: (a) availability and applicability of the measures across the UNECE region; (b) being cost neutral or have a low cost to farmers, especially when taking account of their co-benefits; (c) focusing on sectors where the application of measures provided a significant contribution to ammonia emissions reduction; and (d) the need for long-term capacity-building. The priorities were as follows (with the highest priority first):

1. Low-emission application of manures and fertilizers to land, including:

(a) Low emission application of slurry and solid manure from cattle, pigs and poultry. Available measures included immediate or fast incorporation into the soil, trailing hose, trailing shoe and other band spreading and injection methods, and slurry dilution via irrigation;

(b) Low-emission application of urea fertilizers. Available measures included immediate or fast incorporation into the soil, coated pellets, urease inhibitors and fertilizer substitution;

2. Animal feeding strategies to reduce nitrogen excretion. Available measures included: (a) low-protein phase feeding on pig and poultry farms; and (b) low-protein supplement feeding of cattle during housing, and improved nitrogen and grazing management of grazed grassland targeted to improve nitrogen use efficiency;

3. Low emission techniques for all new stores for cattle and pig slurries and poultry manure. Available measures included covers on all new slurry tanks, use of floating covers or slurry bags, prohibition of the building of new open slurry lagoons and keeping stored poultry manure dry;

4. Strategies to improve nitrogen use efficiencies and reduce nitrogen surpluses. The priority target was to establish nitrogen balances on demonstration farms or through on-farm demonstration, as a basis to monitor improvements in nitrogen use efficiency. That priority would develop capacity across the UNECE region for wider use of nitrogen budgeting approaches after 2020;

5. Low emission techniques in new and largely rebuilt pig and poultry housing. Available measures included improved building designs, reducing the area of manure exposed to the air, keeping poultry litter dry and chemical scrubbing of exhaust air.

Para. 17. The Task Force noted that, for each of those priorities, the options for annex IX allowed flexibility by: (a) specifying a range of possible quantitative targets for which several techniques were available; (b) specifying exemptions for small farms through the use of farm-size and equipment-size thresholds with varying degrees of ambition; and (c) allowing relaxation in the implementation date for countries with economies in transition.

Para. 18. The Task Force noted that packages of priority measures might be more cost-effective than selecting one or two of the priority measures. For example, covering manure storages made little sense if the manure was applied subsequently without low-emission manure application techniques."

An example of setting criteria to identify priority measures is the work by the UNECE Task Force on Reactive Nitrogen to identify the five most important actions needed to reduce ammonia emissions in Europe – as reported in Box 1 (UNECE, 2011, Para. 16.). This represents the stage of "identification by scientists", and would imply that integrated assessment models should be able to address each of the measures outlined. This list of priorities was then presented to c. 40 national governments in the Working Group on Strategies and Review (WGSR) of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP), who provided the "review and decision by policy makers". Under this process, it was the task of the policy makers to amend the priorities in their deliberations to revise the Gothenburg Protocol. In practice the approach was iterative, as 6 monthly feedback from WGSR policy makers during a 4 year period allowed the TFRN to refine a range of measures and options that provided the countries with suitable negotiating space. In parallel, work on the GAINS integrated assessment model allowed the updating of mitigation costs estimates which formed the basis of scenario development across the UNECE region.

While the above example relates to agricultural ammonia, it is equally relevant to ask: what would be the priority measures for controlling leaching and run off of nitrogen compounds or of nitrous oxide emissions listed by UNEP, 2013), or to minimize denitrification emissions as N_2? For example

UNEP (2013, 2014) have identified measures suitable to reduce nitrate leaching and nitrous oxide emissions. For each N form a different set of priority measures could be identified. From a joined up perspective of the nitrogen cycle, an additional criteria for a priority measures may be that it delivered significant co-benefits between N forms, threats and benefits. Measures with a justifiable trade-off (major gain in return for small trade-off) might still be considered a priority, but this would imply the availability of significant supporting evidence.

The example in Box 1 therefore provides a starting point. We should ask if the approach can be improved when identifying priority measures for integrated nitrogen assessment modelling. To what extent can global measures be identified versus specific options for different regions?

5. Specific measures by sector and key action

In this section each of the 'Key Actions' is considered and a short-list of more specific measures is identified. This starting point is summarized from Chapter 6 of 'Our Nutrient World'. At this point modelling considerations, such as listed above, are NOT taken into account, to avoid adding any bias. It will be a task for discussion at the workshop to consider the more specific measures that are easy or hard to include into regional and global models. Similarly, this list can form a starting point to reflect at the workshop on the criteria for selection of priorities for more specific measures to be treated in models.

Agriculture

1. *Improving NUE in crop production*

- Implementation of the '4R Nutrient Management Stewardship' approach (i.e. Right fertiliser, Right amount, Right time, Right Approach)
- Use of precision farming and fertiliser placement technologies.
- Site specific nutrient loss mitigation (and full soil health sustainability) measures such as erosion control and tillage management
- Optimization of all critical crop growth factors such as micronutrients, water, and removal of weeds, pests and disease.
- Improved site specific integrated management supported by targeted research and training of farmers and advisors to apply measures.

2. *Improving NUE in animal production*

- Improved dietary management of livestock to avoid over-feeding of nutrients and unnecessarily enriching manures with feed N.
- Development of low emission housing systems to decrease NH_3.
- Increased animal welfare to improve efficient production of animal products.
- Utilising genetic advances through breeding that improve overall productivity of livestock (such as improving efficient use of ingested feeds and better partitioning of nutrients into animal products as opposed to excreted wastes).

3. Increasing the fertilizer use equivalence value of manure

- Improved dietary management of livestock to control the N content of manure.
- Implementation of storage, handling and spreading practices of manures that reduce N losses via ammonia (NH_3) volatilization, and denitrification.
- Ensure the '4R Nutrient Stewardship' approach to better manage animal manure (as with fertilizers; see Key Action 1).

Transport and Industry

4. Low-emission combustion and energy efficient systems, including renewable resources

- Develop primary measures to reduce NO_x and other N_r emissions per unit of combustion, such as low-NO_x burners reducing NO_x formation.
- Develop secondary measures to de-nitrify NO_x and N_r compounds to N_2 per unit of combustion, prior to their release to the environment.
- Increasing fuel efficiency and reducing energy requirements for the fuel used (such as better aerodynamic performance of vehicles, and improved insulation of buildings)
- Migrating to re-generative sources of energy (hydro, geothermal, solar, wind, wave and tidal) or renewable such as biofuels (where potential trade-offs have been minimised) to not only reduce emissions but also provide further environmental benefits.

5. Development of NO_x capture and utilization technology

- Develop NO_x Capture and Utilization (NCU) technology, (i.e. economic ways to capture and reuse NO_x that has already been produced in existing processes).

Waste and Recycling

6. Improving nutrient efficiency in fertilizer and food supply and reducing food waste

- Reducing food wastage during production, distribution, processing and consumption (halving losses and waste in the food supply chain would equate to a *c.*15% global reduction in the nutrients needed for food production).
- In developing countries, reduction of losses following harvest and during distribution and processing, resulting from poor storage facilities and lack of infrastructure.
- In developed countries, reduction in food wasted by consumers and public facing food industries (i.e. supermarkets, restaurants etc.).

7. Recycling nitrogen from waste water systems, in cities, agriculture and industry

- Improved recycling of nutrients from wastewaters by implementing existing technologies, and/or redesigning or upgrading existing sewage systems to perform the role efficiently.
- Focus on conserving the N_r already present in sewage and treating for direct use as a fertilizer in a cost-effective manner, whilst addressing barriers to its usage such as disease risk perception and resultant blanket prohibition policies.

Societal consumption patterns

8. Energy and transport saving

- Greater provision of fuel efficient (e.g. hybrid-electric) passenger cars and public mass transportation in urban areas to reduce emissions.
- Migration towards less carbon-intensive fuels (e.g. from coal to natural gas) in stationary combustion sources (i.e. industry) as a short-term measure to reduce N_r emissions.
- Develop technologies for widespread use that apply re-generative energy sources (hydro, geothermal, solar, wind, wave and tidal), in conjunction with intelligent technologies for demand-side management of energy use.

9. Lowering personal consumption of animal protein among populations consuming high rates (avoiding excess and voluntary reduction)

- In developed regions the lowering of total protein intake is required, in conjunction with a shift from animal to plant based protein. [In developing regions improvement of the diet to optimum protein levels should be made with protein-rich plant-based products where possible].

Integration and optimization

10. Spatial and temporal optimization of nitrogen flows

- Optimising the placement of nitrogen pollution sources, i.e. increasing distance from sensitive areas for example using the critical loads concept in spatial planning policies and buffer zones
- Decreasing receptor vulnerability to pollution by avoiding high pollution emissions during the most sensitive times for adverse impacts.
- Integration of different nutrient flows to foster more effective use, such as adopting spatial integration of livestock and arable agriculture (including potential export of excess manure to replace damaged topsoils).
- Optimization of nutrient production to be close to consumers (reduction of losses associated with poor transport infrastructure).
- Optimize solutions to relavant farm scale

6. Questions for the workshop

The following questions are intended to stimulate discussion during the workshop.

Intermediate questions

- What criteria should we use to help identify priority measures for better nitrogen management?
- Could a short proposal of such common criteria be developed as a basis for reaction by policy makers?

- Should we use ranking based on threats and benefits/co-benefits of pollutants or is relative cost-benefit needed?
- What importance should current policy frameworks/targets have on the measures we choose or should the approach be equally open to future aspirational measures?
- Is there a particular target number of priority measures to which we limit ourselves in modelling capability for each time period, 2, 5, 10 years?
- Should we consider different groups of measures for the different INMS demonstration regions?
- If you were to make a "Nitrogen Top 10" of measures to manage nitrogen better. What criteria would you set, and what would be on your list?

Overarching questions

In the context of providing global food security, without adverse nutrient related impacts; What would be the priority measures to be incorporated into nitrogen IAM over different timescales?

- Suggested priority measures to include in the short-term (2 years)
- Suggested priority measures to include in the medium term (5 years)
- Suggested measures to include in the long term (10 years)

Summary Table

One of the outputs of the workshop will be to populate the following table.

What are the priority measures needed for better nitrogen management that should be included in models?

'Key Actions' by sector		Primary Pollutants Addressed*	Priority measures	Included now (or soon)	Relevance to INMS regions ###*	Priority measures short-term (2yr)	Technical difficulty & Cost ???, $$$**	Priority measures long-term (5yr)	Technical difficulty & Cost ???, $$$**	Model systems
Agriculture										
1	Improving NUE in crop production	NH_3, Nitrate, N_2O, NO_x, N_2								
2	Improving NUE in animal production	NH_3, Nitrate, N_2O, N_2								
3	Increasing the fertilizer use equivalence value of manure	NH_3, Nitrate, N_2O, NO_x, N_2								
Transport and Industry										
4	Low-emission combustion and energy efficient systems, including renewable resources	NO_x, N_2O, NH_3								

5	Development of NO_x capture and utilization technology	NO_x								
Waste and Recycling										
6	Improving nutrient efficiency in fertilizer and food supply and reducing food waste	NH_3, Nitrate, N_2O, N_2								
7	Recycling nitrogen and phosphorous from waste water systems, in cities, agriculture and industry	NH_3, Nitrate, N_2O, N_2								
Societal consumption patterns										
8	Energy and transport saving	NO_x, N_2O, NH_3								

9	Lowering personal consumption of animal protein among populations consuming high rates (avoiding excess and voluntary reduction)	NH_3, Nitrate, N_2O, NO_x, N_2									
Integration and optimization											
10	Spatial and temporal optimization of nutrient flows	NH_3, Nitrate, N_2O, NO_x, N_2									

*### indicates relevance to the INMS demonstration regions, # less relevant, ### most relevant, () not at all relevant:
East Africa EA
East Asia EA
Eastern Europe EE
Latin America LA
South Asia SA
Western Europe WE

**??? Indicates potential difficulty - ? least difficult, ??? most difficult; $$$ indicates potential cost (person hours and/or capital costs), $ least difficult, $$$ most difficult

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