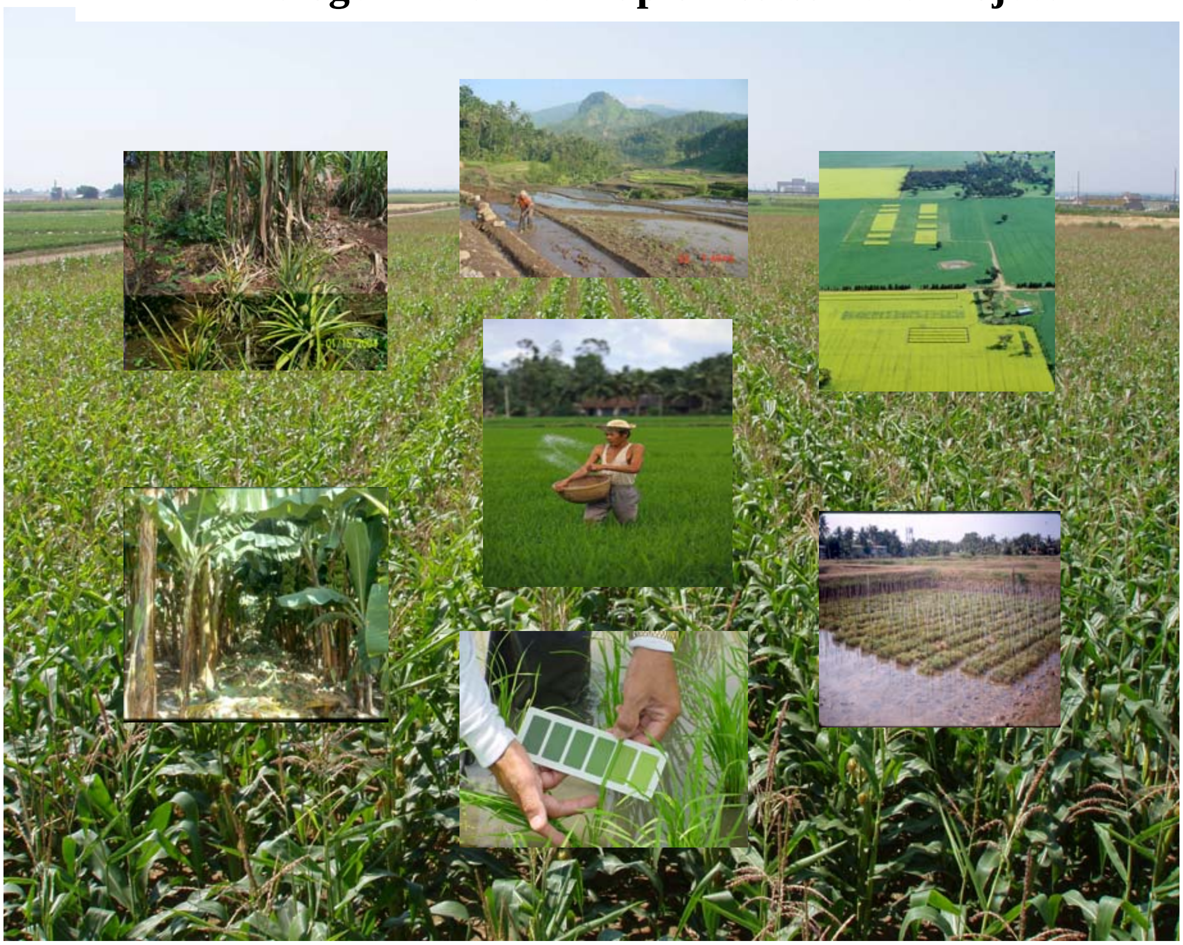
Executive Summary for the SCOPE/IGBP Nitrogen Fertilizer Rapid Assessment Project



Arvin R. Mosier, J. Keith Syers and John R. Freney, ***USDA – ARS, Ft. Collins, CO, USA; Naresuan Univ., Phitsanulok, Thailand; CSIRO, Canberra, Australia***[1]

[1] Information presented represents views of authors and not their institutions.

Background

Nitrogen (N) availability is a key factor in the production of food, feed, and fiber. The provision of plant-available N through synthetic fertilizer in the 20th and 21st centuries has contributed substantially to feeding and clothing an ever-increasing human population. However, the increased use of N fertilizer has not come without cost to the environment as its use, along with other human activities, has caused major changes in the cycling of N at a range of scales, from the very local to the global.

Information on components of the N cycle has accumulated rapidly in the last decade, particularly with regard to the processes of its transfer in different terrestrial, aquatic, and atmospheric environments. There is now a need to synthesize this information and to assess the impacts of continuing to supply additional N to natural and agricultural ecosystems. In particular, the efficiency with which fertilizer N is used in production systems is usually low and improvements are urgently required if the global demands for food are to be met and environmental problems minimized. However, there are still major uncertainties regarding the fate of fertilizer N added to agricultural soils and the potential for reducing losses to the environment. Improving the technical and economic efficiency of fertilizer N is essential for both enhanced agricultural production and protection of the environment, thus creating a win-win situation.

The Project

SCOPE (the Scientific Committee on Problems of the Environment) joined forces with IGBP (the International Geosphere-Biosphere Programme) to develop the International Nitrogen Initiative (INI) following the World Summit on Sustainable Development in Johannesburg in August, 2002 with a view of addressing these and other issues relating to environmental N. The Nitrogen Fertilizer Rapid Assessment Project (NFRAP) is the first INI project to be conducted and is seen to be the first step in the development of a science base for the INI.

The assessment was conducted at an International Workshop held in Kampala, Uganda, on January 12-16, 2004. Prior to the workshop, a series of background papers on various aspects of N fertilizer use were prepared by leading experts from around the world. Four cross-cutting issues, relating to the efficiency of fertilizer N use, the role of emerging technologies in influencing the efficiency of fertilizer N use, impacts of N loss on human health and the environment, and societal responses to meeting N needs in different regions, were identified in advance of the workshop. The ensuing discussions in Kampala resulted in four synthesis papers on these topics, which along with the background papers and an overview paper that are published in a project synthesis volume (see below).

Project Outcomes

Importance and consumption of nitrogen fertilizer

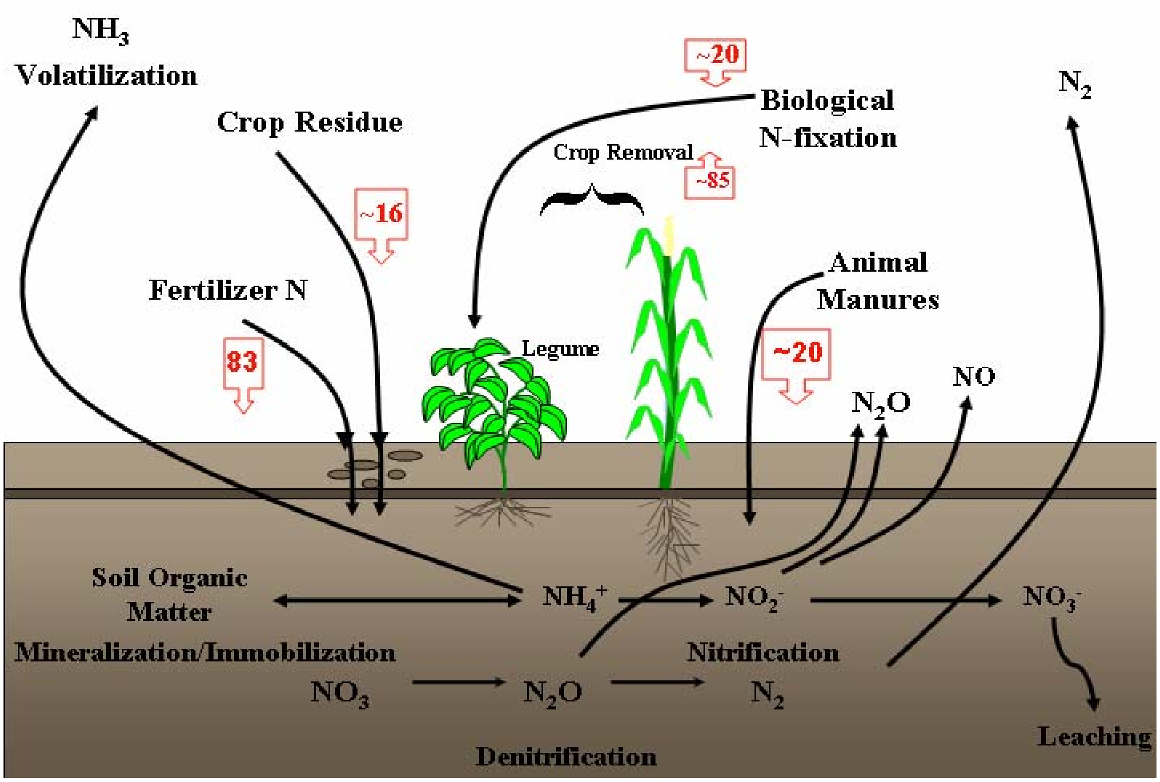
The assessment has highlighted the importance of N fertilizer(estimated to be 40%) in contributing to the tripling of global food production over the last 50 years but pointed to the non-uniform distribution of N fertilizer use globally. There are several reasons for the inequities in N fertilizer use, including supply and cost. Under-use of N fertilizer is characteristic of sub-Saharan Africa whereas excessive N fertilizer is sometimes used in Europe and the USA (and more recently in China). This can potentially lead to a number of problems related to human health and ecosystem vulnerability, including land degradation and the eutrophication of coastal systems.

There are also varying efficiencies of fertilizer N use in agricultural production both locally and across regions. On average, only 20-50 % of the N added in cereal production is taken up by the crop. An insufficiency of other nutrients (e.g., phosphorus and potassium) typically causes low efficiency of N. Even with high efficiency (approaching 70% in intensive maize production) losses of N occur and these can contribute to environmental problems.

The agricultural nitrogen cycle

Fertilizer supplies approximately 50% (83 Tg of N in 1996) of the total N required for global food production. Other annual inputs into crop production are biological N fixation, recycling from crop residues, animal manure, and atmospheric deposition and irrigation water. The N not removed by the crop is incorporated into soil organic matter or is lost to the environment (atmosphere and water bodies) by leaching, runoff, erosion, ammonia volatilization, and denitrification. But the quantities lost via individual pathways are highly uncertain and are very much situation dependent. Reducing these losses to the environment is a priority research issue.

The inefficiency of N use is exacerbated by the relative inefficiencies of animal protein production. With the anticipated increases in demand for animal protein, even larger losses of N can be expected in the future. Intensification of livestock production



A simplified view of the N cycle in crop production (Tg N yr^{-1})

systems, particularly in North America, to some extent in Europe, and increasingly in China, and their centralization in regions that produce relatively small amounts of animal feed are creating major problems with waste disposal because the land area is not sufficient to carry the animal waste input load.

Environmental and human health impacts

Nitrogen can have several impacts on the environment. Inadequate N supply can limit plant growth which can result in increased soil loss. This affects water quality through increased sedimentation and the release of N and P, causing excessive growth of aquatic plants in N and P limiting situations. Inputs of soil and fertilizer N from agricultural land can contribute to N-induced eutrophication in estuaries. The excessive growth of algae and the resulting depletion of oxygen, and the production of a range of substances toxic to fish, cattle, and humans, can be a major pollution problem.

The human health-related effects of environmental N have attracted much attention. Air pollutants (primarily nitrogen oxides) and dietary nitrate have been issues of concern. In the case of nitrate in drinking waters, which for many years was implicated in the incidence of infantile methaemoglobinaemia there has been a change in thinking in some quarters and the ingestion of pathogen-contaminated water and the associated gastroenteritis may be a more likely cause of this condition.

Similarly, there have been changing views on the situation with regard to dietary nitrate and gastrointestinal cancer. Early thinking favored restrictions on nitrate levels in foods, particularly in leafy vegetables, but some studies now suggest that dietary nitrate may have beneficial effects against gastrointestinal pathogens, cancer, and cardiovascular disease. This remains a controversial area and one where further research is urgently warranted

Increasing nitrogen use efficiency

The NFRAP assessment has confirmed the vital importance of increasing the efficiency of fertilizer N use, with benefits to agricultural production and the environment. In attempts to achieve this, it is important to know the forms and pathways of N loss and the factors controlling them. For example, losses can vary over small differences within a field (due to soil variability), from region to region (because of changing cropping practices), and over time during a growing season (due to weather changes).

Several approaches have been suggested for increasing fertilizer N use efficiency, including the optimal use of fertilizer form, rate, and method of application, using improved agronomic practices (such as reducing weeds and pests), and plant selection to increase both acquisition and internal-use efficiencies.

The fact that current efficiencies on cereal cropping farms (20-50%) are well below those obtained in well-managed, research plots (60-90%) points to the opportunities for enhancing N use efficiency through better management.

Stakeholders in the food production chain

Production agriculture is part of the food production chain in which several major stakeholders participate and influence each other. The food production chain of any country does not exist in isolation from other parts of the socio-economic system and so it is not surprising that contributors outside the production chain also exert their influence. This is particularly the case for agricultural and environmental policies, which influence the use of N fertilizer. The interplay of stakeholders requires different balance and interpretation among production, environmental, economic, and social functions in different regions.

There are major tradeoffs in agricultural and environmental policies when determining N fertilizer use in a given country and the effect that N fertilizer use has on food production and the environment. The impacts of N fertilizer determine whether priority should be given to increasing N fertilizer use to enhance food production and rural livelihoods or whether environmental and health issues drive the agenda and lead to a reduction in N fertilizer use.

A range of options is available in the context of policies and strategies to improve fertilizer N use efficiency. The NFRAP assessment has emphasized the fact that any policies relating to N fertilizer use should be formulated jointly by contributors both within and outside the food production chain.

Paying for protecting the environment

The problems of too little or too much N fertilizer are complex and not amenable to single solutions; they also come at high economic costs. Who pays for these costs and how should the costs of conserving natural resources be shared between the interested parties, which include governments, agricultural producers, and conservationists?

Governments have a role in ensuring long-term agricultural production and the supply of adequate food, and in developing and maintaining sustainable production systems. Their concerns about protecting the environment have not always been translated into action and financing in individual countries. Farmers need to increase production on a sustainable basis, maximize profits on their investment, and conserve the resource base for future generations, while conservationists are interested in preserving natural resources and the environment. The scientific community also has stake in conducting appropriate research and development work and seeing, as far as practicable, that the results are put to good use.

A complicating factor is that N fertilizer can also impact on more than one part of an ecosystem at the same time while government policies are typically piecemeal, being directed at one problem at a time. It would be more appropriate to consider the problems in an integrated way to better address human nutritional and environmental needs.

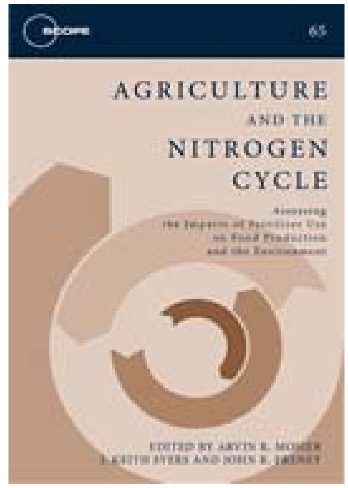
Who should pay the real costs of too little N fertilizer for food, feed, and fiber production and too much N fertilizer for environmental quality and human health? The NFRAP assessment has highlighted the fact that the answer is likely to vary with the situation. Scientific and technical expertise has a role to play in helping decision-makers to resolve these issues on a case by case basis, taking into account the biophysical as well as the social, economic, and political dimensions involved.

Conclusions

The NFRAP assessment highlights six factors:

- the importance of N fertilizer for the global production of food for the rapidly increasing human and animal populations,
- the non-uniform distribution and use of N fertilizer globally,
- the inefficiency of use and sometimes large losses of fertilizer N,
- the lack of sufficient knowledge of the fate of the N lost,
- the environmental and human-health related effects of the lost N, and
- the question of who should pay for the real costs of too little or too much N fertilizer.

It also identifies methods for reducing N losses and increasing the efficiency of fertilizer N, and points to the need for further research on the pathways of N loss and on controversies regarding possible detrimental as well as beneficial effects of dietary nitrate.



Project Output

'Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment,' edited by Arvin R. Mosier, J. Keith Syers, and John R. Freney, will be published in October 2004 by Island Press (www.islandpress.org/scope) as SCOPE volume 65, in time for the 3rd International Nitrogen Conference, to be held in Nanjing, People's Republic of China, October 12-16, 2004.

Financial Support

International Fertilizer Industry Association (IFA), United States Department of Agriculture-Foreign Agricultural Service (USDA-FAS), USDA-Agricultural Research Service (USDA-ARS), Global Change SysTem for Analysis, Research and Training (START)/United States National Science Foundation (NSF), International Geosphere Biosphere Programme (IGBP), International Nitrogen Initiative (INI), International Council for Science (ICSU) and the UN Education, Science and Culture Organization (UNESCO), USAID-Agricultural Productivity Enhancement Program-Uganda, Australian Centre for International Agricultural Research (ACIAR), and A.W. Mellon Foundation.

SCOPE (http:// www.icsu-scope.org): The Scientific Committee on Problems of the Environment (SCOPE) was established by the International Council for Science (ICSU) in 1969. It brings together natural and social scientists to identify emerging or potential environmental issues and to address jointly the nature and solution of environmental problems on a global basis. SCOPE operates at an interface between the science and decision-making sectors, and its members include forty national science academies and research councils and twenty-two international scientific unions, committees, and societies, which guide and develop its scientific program.

IGBP (http:// www.igbp.kva.se): The International Geosphere- Biosphere Program (IGBP) is a program of global change research, sponsored by the International Council for Science (ICSU). IGBP is an international scientific research program built on interdisciplinary, networking and integration that aims to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth System, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions. IGBP works in close collaboration with the International Human Dimensions Program on Global Environmental Change (IHDP), the World Climate Research Program (WCRP), and DIVERSITAS, an international program of biodiversity science. These four international programs have formed an Earth System Science Partnership.