The Issues of Nitrogen

The Background
Nitrogen, contained in amino acids, proteins, and DNA, is necessary for life. While there is an abundance of nitrogen in nature, almost all is in an unreactive form (gaseous nitrogen, N_2) that is not usable by most organisms. In the absence of human intervention, the supply of reactive nitrogen in the environment is not sufficient to sustain the current abundance of human life. Thus humans learned in the early 20th century how to convert gaseous N_2 into forms that could sustain food production. Over 40% of the world's population is here today because of that capability.

The Problem
There are two major problems with nitrogen: some regions of the world do not have enough reactive nitrogen to sustain human life, resulting in hunger and malnutrition, while other regions have too much nitrogen (due mainly to the burning of fossil fuel and to the inefficient incorporation of nitrogen into food products) resulting in a large number of major human health and ecological effects. The rate of change of the problem is tremendous, probably greater than that for any other major ecological problem. For example, half of the synthetic nitrogen fertilizer ever used on Earth has been used in just the last 15 to 20 years. Opportunities to reduce these problems are plentiful. A prerequisite to reducing these problems is the development of a sound scientific base on which to begin to discuss policy options.

The Challenge
The challenge of nitrogen is how to optimize the use of nitrogen to sustain human life while minimizing the negative impacts on the environment and human health. It is critical to the health of humans and ecosystems that this challenge be met. It is doubly critical because without action, future populations will be more stressed either due to nitrogen limitations or due to nitrogen excesses.

The Opportunities
Numerous opportunities for intervention exist that can increase the availability of nitrogen in deficient regions, and limit the exposure of humans and ecosystems to the problems of excess nitrogen. The opportunities include scientific, engineering, social and political instruments, and when used in an integrated manner, will enable society to meet the challenge.

The Process
The International Nitrogen Initiative proposes a three-pronged, interactive process to meet the challenge of nitrogen. One focus is the assessment of basic knowledge on the creation and distribution of reactive nitrogen: Where is there not enough nitrogen? Where is there too much? What are the effects of the decrease or increase in the abundance of nitrogen, relative to societies' needs? The second focus consists of the development and identification of solutions for regions with an under- or over-abundance of nitrogen. The third focus is the implementation of scientific, engineering and policy tools to solve the identified problems. Policy makers at the governmental level must be involved in these steps, if the problems of nitrogen supply are to be reversed. Towards that end, the Third International Nitrogen Conference and the INI jointly developed the Nanjing Declaration, which lays out the major issues concerning nitrogen and sets the stage for the continued development of an integrated, global approach to meet the challenge of nitrogen.

The International Nitrogen Initiative has a Core Office, a Steering Committee, a Scientific Advisory Committee, and five regional offices. The Core Office is located at the University of Virginia in Charlottesville, VA; James Galloway (Chair). The Steering Committee has nine members and is responsible for International Nitrogen Initiative activities. The Scientific Advisory Committee is composed of experts in the diverse areas of nitrogen and is advisory to the Steering Committee.

The five regional centers are:

African Nitrogen Center:	Coordinator, Mateete Bekunda, Makerere Universit, Uganda
Asian Nitrogen Center:	Director, Cai Zucong, Institute of Soil Science, P. R. China
European Nitrogen Center:	Coordinator, Jan Willem Erisman, Energy Research Center, NL
Latin American Nitrogen Center:	Coordinator, Luiz Martinelli, Universidade de Sao Paulo, Brazil
North American Nitrogen Center:	Director, Alan Townsend, University of Colorado, USA

For further information about the International Nitrogen Initiative, and its regional centers, please visit the INI web site, http://initrogen.org/

Four Central Questions of Nitrogen Distribution and Effects

How has human introduction of reactive nitrogen changed with time relative to natural sources? Reactive N is introduced to the natural terrestrial environment primarily by biological nitrogen fixation in forests and grasslands, particularly in the tropics. Human activity introduces reactive N inadvertently by fossil fuel combustion and purposefully through biological nitrogen fixation associated with agricultural crops and the Haber-Bosch process which allows the manufacture of synthetic fertilizer.

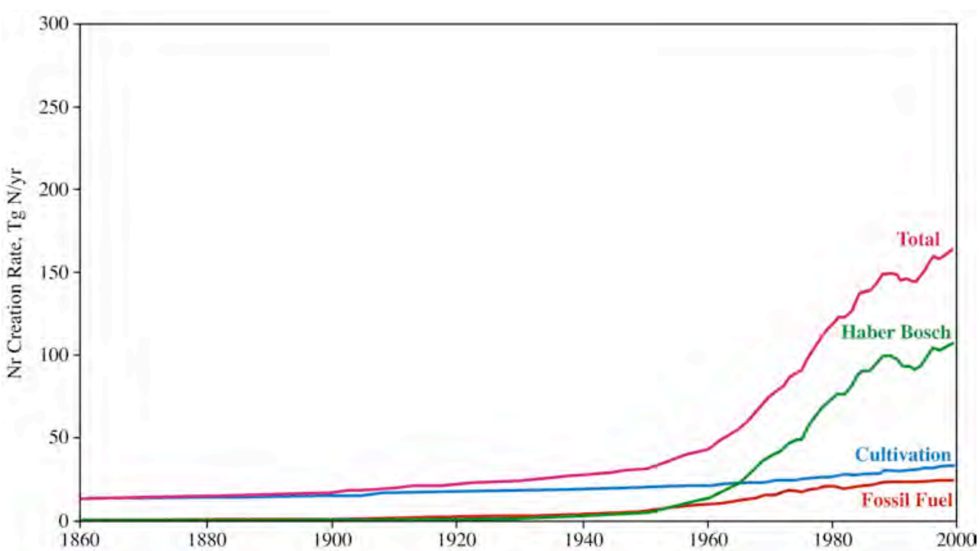

Figure 1: Anthropogenic creation rates of reactive nitrogen by the Haber-Bosch process, biological nitrogen fixation associated with cultivation of agricultural crops, and combustion of fossil fuels. The units are Tg nitrogen per year (or millions of metric tons per year) over the entire planet.

In 1860, natural nitrogen fixation on the land masses of the planet introduced between 100 to 200 million metric tons per year of reactive nitrogen into the terrestrial environment. Within the last few decades, human activities have roughly matched this supply. The rate of human creation continues to grow, particularly from the manufacture of synthetic nitrogen fertilizer.

How much have atmospheric deposition rates of reactive nitrogen changed relative to historical conditions? Once introduced into the environment, reactive nitrogen can be chemically transformed to different nitrogen species, many of them in gaseous forms (NH_3 and NO) and thus become available for emission to the atmosphere. Once emitted these gases can be transported to environments thousands of kilometers from the point of emission and deposited to ecosystems.

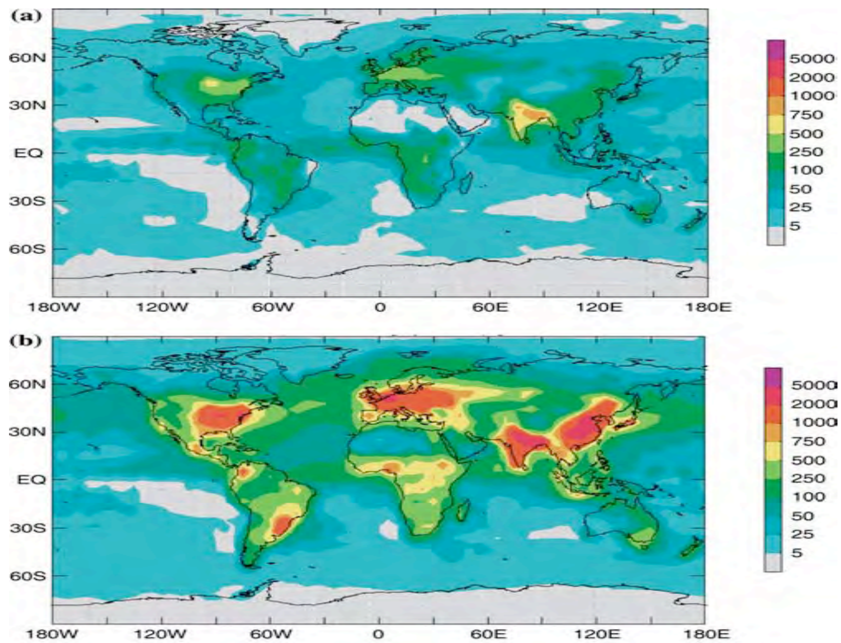

Figure 2: Spatial patterns of total inorganic nitrogen deposition in 1860 (top) and early 1990 (bottom) in units of kg nitrogen per square kilometer per year.

Note the large increases in many parts of the world, but note also that in some regions deposition of nitrogen pollution from the atmosphere remains low.

How much has human activity changed the flow of reactive nitrogen into coastal waters? In addition to atmospheric emission and transport, much nitrogen is transported to coastal marine waters.

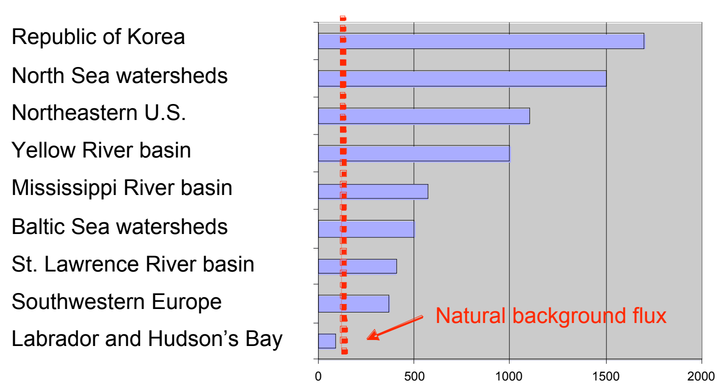

Figure 3: Flux of reactive nitrogen from the landscape to coastal oceans in rivers for key contrasting regions of the world in the temperate zone, in units of kg nitrogen per square kilometer of watershed area per year.

Human activity has had an incredible influence on nitrogen fluxes to coastal oceans in some parts of the world, and very little effect elsewhere. The nitrogen cycle is most altered where farming and industrial activity is greatest.

What are the consequences on ecosystem and human health? The increased introduction of reactive nitrogen to the environment by human action, and the increased dispersion of this nitrogen via the atmosphere and rivers has both positive and negative impacts on human and ecosystem health.

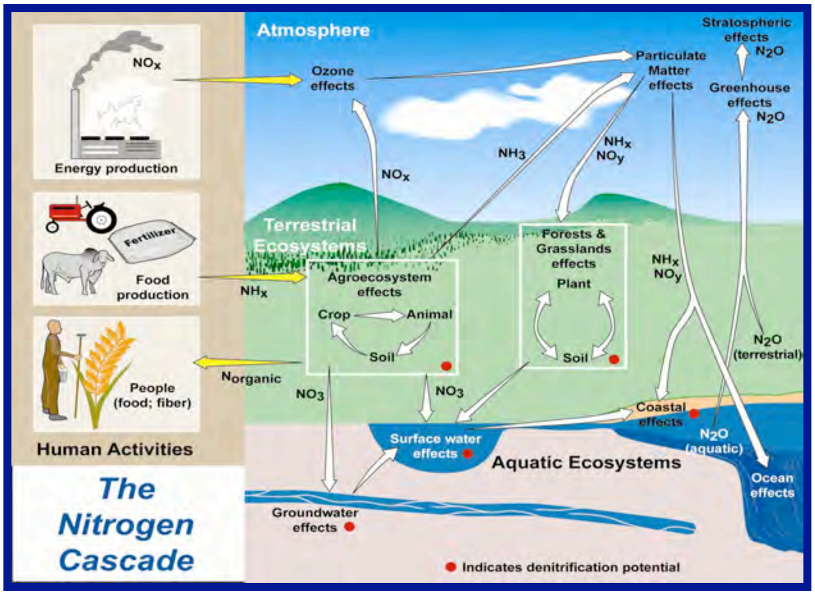

Figure 4: The movement of nitrogen through the environment and the associated environmental effects

Nitrogen is now known to be unusual among the elements that have had their cycles significantly perturbed by human action. As nitrogen moves along its biogeochemical pathway, the same atom can contribute to many different negative impacts in sequence: as NO_x it can increase ozone concentration in the atmosphere, decrease atmospheric visibility, and increase acidity of precipitation; following deposition it can increase soil acidity, decrease biodiversity, lead to coastal eutrophication, and then emitted back to the atmosphere as nitrous oxide it can increase greenhouse warming, and decrease stratospheric ozone. Nitrogen can be transported to any part of the Earth system, no matter where it was introduced. This sequence of effects has been termed the nitrogen cascade. The concept of the cascade, and the extensive research that underlies it, has allowed us not only to determine the linkages among the various aspects of the nitrogen cycle, but also to begin to assess how changes in one part of the cycle can delay or enhance the transfer of nitrogen to other parts of the cycle. The cascade continues as long as the nitrogen remains active in the environment, and it ceases only when reactive nitrogen is stored for a very long time, or is converted back to non-reactive N_2. The enormous significance of nitrogen is that it is linked to so many of the major global and regional environmental challenges that policymakers face today: ozone layer depletion, acidification of soils and surface waters, global warming, surface and groundwater pollution, biodiversity loss, and human health and vulnerability.

Summary

Nitrogen is needed to grow food, but many regions have too much nitrogen, other regions do not have enough. Both situations lead to negative impacts on people and ecosystems. The International Nitrogen Initiative was formed to assess the extent of our scientific understanding on nitrogen-related issues, how they are related, and from that foundation work with the policy community to maximize the benefits of nitrogen, and minimize the problems associated with its use.