Abstracts - Plenary sessions

The global nitrogen cycle -- past, present and future. **James N. Galloway.** University of Virginia, USA

Abstract: Food and energy production converts N_2 to reactive N species that cascade through environmental reservoirs and in the process impact human and ecosystem health. This presentation will examine the impact of increased N mobilization on the global N cycle by contrasting N distribution in the late-19th century with those of the late-20th century. The presentation will give a general overview of regional differences and will conclude with a projection of the global N cycle for 2050.

Primary findings are: we have a good understanding of the amounts of reactive N created by humans, and the primary points of loss to the environment; we have a fair understanding of the degree of distribution, and the resulting impacts on people and ecosystems; we have a poor understanding of nitrogen's rate of accumulation in environmental reservoirs, which is problematic due to the cascading effects of N in the environment, including enhanced rates of atmospheric reactions, fertilization of terrestrial and aquatic ecosystems, loss of ecosystem biodiversity, and increased emission of greenhouse gases; In addition, we have a good understanding, in general, of what must be done to reduce the amount of Nr created by human action. The challenge is how to minimize reactive N creation while also maximizing food and energy production.

Cascading Costs: An Economic Nitrogen Cycle. **William R. Moomaw.** The Fletcher School, Tufts University, Medford, MA 02155, USA

Abstract: The chemical nitrogen cycle is becoming better characterized in terms of fluxes and reservoirs on a variety of scales. Galloway has demonstrated that reactive nitrogen can cascade through multiple ecosystems causing environmental damage at each stage before being denitrified to N_2. We propose to construct a parallel economic nitrogen cascade (ENC) in which economic impacts of nitrogen fluxes can be estimated by the costs associated with each stage of the chemical cascade. Using economic data for the benefits of damage avoided and costs of mitigation in the Chesapeake Bay basin, we have constructed an economic nitrogen cascade for the region. Since a single ton of nitrogen can cascade through the system, the costs also cascade. Therefore evaluating the benefits of mitigating a ton of reactive nitrogen released needs to consider the damage avoided in all of the ecosystems through which that ton would cascade. The analysis reveals that it is most cost effective to remove a ton of nitrogen coming from combustion since it has the greatest impact on human health and creates cascading damage through the atmospheric, terrestrial and aquatic ecosystems. We will discuss the implications of this analysis for determining the most cost effective policy option for achieving environmental quality goals.

Reactive nitrogen challenges and opportunities: potentials for "win-win alliances" between animal agriculture, municipal waste processing, and forest products industries in various countries. **Ellis B. Cowling.** University Distinguished Professor At-Large and Cari S. Furiness, Research Associate. North Carolina State University, Raleigh, North Carolina 27606, USA

Abstract: Commercial forests in many parts of the world are deficient in nitrogen, phosphorus, and organic matter. These nutrient deficient forests often exist in close proximity to concentrated animal feeding operations (CAFOs), meat packing and other food, textile, or other biomass processing plants,

and in municipal waste treatment facilities in urban centers ranging from small villages to large cities. Many of these facilities produce large surpluses of these same essential nutrient elements in the form of gaseous ammonia, urea, uric acid, phosphorus, bacterial sludges, and partially treated municipal waste waters. These coexisting and substantial nutrient deficiencies and similarly large surpluses of these same essential nutrients, offer ready-made opportunities for discovery, development, and demonstration of science-based, technology-facilitated, environmentally sound, and economically viable "win-win alliances" among these major industries based on the principles of industrial ecology. The principal challenge is to discover practical means by which to capture and transfer the nutrients from the animal rearing barns, food and other biomass-based processing plants, and municipal waste-waters and bacterial-sludge processing facilities in order to put them to work in forest stands from which value-added products can be produced and sold at a profit. This paper will describe how these ideas about mutually beneficial "win-win Alliances" are being pursued in the southern United States and in some other parts of the Americas, Europe, Africa, and Asia. Special attention will be given to intellectual, educational, regulatory, and practical obstacles to overcoming some of these impediments to optimizing nitrogen management in food and fiber production and environmental protection.

Human Health Effects of a Changing Nitrogen Cycle. **Alan R. Townsend.** University of Colorado, Boulder,USA

Abstract: Human changes to the global nitrogen cycle have a diverse set of consequences for human health. The creation and use of fixed nitrogen clearly has benefits for human health, the most obvious example being increased food production. However, while the net public health consequences of a changing N cycle are likely positive at lower levels of change, such benefits will eventually peak, while the negative consequences rapidly worsen as creation and use of fixed N continues to climb. These consequences are remarkably diverse, and some are well recognized, while others remain largely theoretical and require considerable additional research. Fixed nitrogen is a major driver behind several components of air pollution, including ozone and fine particulates, both of which are linked to respiratory ailments, cardiac disease and several cancers. Ecological feedbacks to excess N can inhibit crop growth, increase allergenic pollen production, and potentially affect the dynamics of several important vector-borne diseases, including West Nile virus, malaria and cholera. Finally, the majority of intensively fertilized crops in wealthier nations become animal feed, creating disparities in world food distribution, growing environmental problems associated with modern trends in meat production, and allowing unbalanced diets even in wealthy nations. These and other examples suggest that humankind's intensifying creation and use of fixed nitrogen poses a growing public health risk.

Nitrogen deposition and reduction of terrestrial biodiversity: evidence from temperate grasslands.
Nancy B. Dise,[1,2] and Carly J. Stevens[1,3]. [1] Department of Earth Sciences, The Open University, Milton Keynes MK7 6AA, UK. [2] Department of Biology, Villanova University, Villanova, PA 19085, USA. [3] NERC Centre for Ecology and Hydrology, Monks Wood, Huntingdon PE17 2LS, UK

Abstract: Biodiversity is thought to be essential for ecosystem stability, function and long-term sustainability. Since nitrogen is the limiting nutrient for plant growth in many terrestrial ecosystems, reactive N has the potential to reduce the diversity of terrestrial vegetation and associated biota through favouring species adapted to quickly exploiting available nutrients. Many studies have shown that applications of large quantities of nitrogen, either through intentional fertilization or proximity to a major source, reduce local plant diversity. However, demonstrating the regional effects on biodiversity,

if any, of chronic 'low-level' deposition of nitrogen has proven elusive. One reason for this is that ecological communities are the product of multiple interrelated biological and environmental forces, and detecting the influence of any one of these factors can be a major challenge. Three lines of evidence, taken together, now strongly support the hypothesis that enhanced deposition of reactive nitrogen across Great Britain, and potentially the rest of Europe, has resulted in a significant decline in plant species richness of sensitive grassland communities. First, spatial correlative evidence from a survey of acid grasslands across the island shows that species richness declines as a linear function of the rate of inorganic N deposition, with forbs and nutrient-sensitive shrubs and mosses those most likely to be missing in the low-diversity plots. No other potential driver on biodiversity examined explained as much of the variability in plant species richness as nitrogen deposition. Second, temporal experimental evidence from several N-addition studies in the UK, other parts of Europe, and North America shows the same overall vegetation types affected by increased N, and in some cases the same species, as indicated by the survey. Finally, long-term monitoring of grassland plots across Great Britain shows a reduction in species richness at a rate consistent with that predicted from the other studies. Combining the correlative and experimental evidence, and making the conservative assumption that N deposition has a fully cumulative effect on vegetation, gives a lower limit of approximately 40 years to reach the observed reduction in species richness. This is consistent with the enhanced emission of reactive N beginning around the start of the 20th century, and accelerating in its latter half.

Strategies for farmers and policy makers to control N losses whilst maintaining crop production.

Keith W. T. Goulding[1]**.** Agriculture and the Environment Division, Rothamsted Research, Harpenden, Hertfordshire, AL5 2JQ, UK

Abstract: The nitrogen cycle is essentially 'leaky'. The loss of small amounts of nitrate into waters and of ammonia and nitrous oxide to the atmosphere are a part of the global biogeochemical nitrogen (N) cycle. However, intensive agricultural production, industry and vehicle use have doubled the amount of 'reactive' N in the environment, resulting in eutrophication, ecosystem change and health concerns. Farmers are under pressure to reduce losses, including legislation such as the European Union's Nitrate Limit of 50 mg l^{-1} and reductions in ammonia and nitrous oxide emissions required by the UNECE Convention on Long-range Transboundary Air Pollution.

Research has identified practices that cause large losses of N, including the particular problems of livestock farming caused by the inefficiency (<20%) with which animals transfer N in feed into saleable produce. Best Management Practices (BMP) for minimizing losses of N from arable and horticultural crops can be prescribed. These include calculating fertilizer requirements with a recommendation system, allowing for soil mineral N and manures applied, spreading fertilizers evenly with a properly calibrated spreader, minimizing pest and disease infestation, and effective scheduling of irrigation. Livestock production systems can be designed to effectively recycle manures and minimize environmental impact. Computer models of the N cycle have been constructed and used as the core of fertilizer recommendation systems and decision supports. This paper discusses the problems of maintaining productivity while reducing N losses, compares conventional with low input (integrated) and organic systems, and discusses wider options. It also looks at the need to integrate studies on N with other environmental impacts set in the context of the whole farm system.

Impact of population growth and economic development on the N cycle in Asian regions.
Zhaoliang Zhu, Zhengqin Xiong, Guangxi Xing. State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences. Nanjing, 210008, China
Abstract: As one of the most densely populated regions in the world, Asia is characterized by much lower per capita GDP, energy consumption, and protein intake than the world averages. To meet the increased needs for food and energy and the improvement in nutrition, the anthropogenic reactive nitrogen (Nr) will inevitably increase and exert great pressure on the environment. This study estimates total anthropogenic Nr, NOx, nitrous oxide and ammonia emissions, and nitrate leaching and runoff in each country for 1999-2001 and for 2030, and aggregate to the scale of Asian regions, and analyses the major problems existing in the N management and then discusses approaches to reduce the existing N burden. The regional variation in Asia is substantial both at the present and in the near future till 2030 in the creation of total anthropogenic reactive N and the N emissions to the atmosphere and transportation to the aquatic systems. East and South Asia together contribute *ca* 80% of the N fluxes in Asia. Considering the facts that in comparison with the developed countries the lower use efficiency of fertilizer N and energy, as well as the lower recycling rate of N in agriculture, the increase in the consumption of nitrogen fertilizers and energy and their impacts on environment in Asia in the future could be moderated by the implementation of the existing improved technologies both in energy sector and agricultural production.

Sub-regional dimensions of agricultural and environmental nitrogen: the case of Asia.
J. Keith Syers. Naresuan University, Phitsanulok, Thailand
Abstract: The Asia Region embraces several major crop-growing environments, referred to as agroecological zones (AEZs). These range from the cool subtropical areas with summer rainfall of northern China and Japan in the North, to the arid and semi-arid areas of Central Asia in the West, to the warm, humid tropical areas of the Philippines and Indonesia in the South. Thus the potential for food production varies substantially within the region. Widely varying human population densities in the region create associated differences in the demand for food. These result in differing requirements for the nitrogen (N) used in agriculture, particularly synthetic fertilizer N, the input of which accounted for an estimated 69% (or 44.2 Tg N yr^{-1}) of anthropogenic N input in the Asia Region in the mid 1990s. Substantial amounts of this N are lost in some situations (e.g., in intensively-farmed parts of China), giving rise to increasingly serious pollution of the atmosphere and of water resources. In general terms, the pathways of N loss are reasonably well understood and the processes involved can be related to soil, crop, and environmental conditions, in addition to the form (and source) of N. For example, volatilization of ammonia occurs readily when urea is added to warm, calcareous soils with low moisture content (typical of arid and semi-arid areas) and leaching of soil nitrate occurs extensively from well-structured soils in high rainfall areas (typical of humid tropical areas). Given the wide diversity of cropping environments in the Asia Region, it is suggested that a sub-regional approach, based on the AEZ concept (or its further development), could be used to provide meaningful assessments of the N cycle in the context of agriculture and the environment.

Soil Nitrogen Balance Assessment and its application for Sustainable Agriculture and Environment.
R.N. Roy and R.V. Misra. Land and Plant Nutrition Management Service, Room B-703, FAO of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy
Abstract: Nitrogen loss from the agro-ecosystem, besides signifying loss of soil fertility, has its

ecological implications. A quantitative knowledge on soil nitrogen gains or depletion helps to understand the state of soil productivity and could be helpful in devising nitrogen management strategies with the dual objectives of soil resource sustainability and minimizing the escape of nitrogen into the environment. Soil nitrogen balance assessment (SNBA) while serve as an instrument to indicate the sustainability of agricultural systems, as well serve as an important tool for estimating the magnitude of nitrogen loss from the agro-eco systems. Quantitative information relating to nitrogen escape into the environment, through such exercises can be gainfully utilized for identification of causative factors and formulating programs aimed at plugging N leakages. An overview of nitrogen balance approaches and methodologies is presented. Methodologies involve application at macro, meso and micro levels. At macro-level, the nitrogen balance exercises raise awareness of soil fertility problems, and the resultant release of nitrogen into the environment consequent to agricultural practices. Meso-level studies identify specific constraints and reveal the best options to make action plans. Studies at micro-level provide a picture of the variation within a meso-level unit. Methodological constraints in soil N balance assessment relate to uncertainties with regards to nutrient flows, validations, sampling, estimation, and quantification errors besides up-scaling difficulties. Ways to overcome methodological constraints have been deliberated. SNBA exercises provide a deeper understanding and insight into the agro-eco systems and lay the basis for formulation of effective agronomic interventions and policies aimed at promoting sustainable agriculture and benign environment.

Global nitrogen fertilizer supply and demand outlook. **Michel prud'homme.** International Fertilizer Industry Association, France

This paper presents a brief overview of the world nitrogen fertilizer demand, highlights trends in the global and regional developments of production capacity and provides a medium-term perspective of the global nitrogen supply/demand balance. The conditions for world agriculture are improving. In a medium-term perspective, The Processing for Economic Co-operation and Development (OECD) has projected a growth in global grain production by an overall 7 percent during the period from 2003/04 to 2008/09. Cereal prices should remain strong due to low world cereal stocks, thus preserving favorable market conditions. During the period from 2003/04 to 2008/09, world fertilizer demand is projected to grow at an average annual rate of 2.1 per cent to 163.3 million tones (Mt) nutrient. Regionally, high growth rates above or equal to 3 per cent per annum are projected in Eastern Europe & Central Asia (EECA), South America, South Asia and Oceania. The global N fertilizer demand in projected to expand at an annual rate of 1.7 per cent per annum, reaching 94.6 Mt N in 2008. Since 1985, most of the growth in the use of nitrogenous fertilizers has been captured by urea and, to some extent, by ammonium phosphates. The prospect of new nitrogen capacity in the near future is influenced by the firm market conditions that have prevailed in the international scene for the past two years. In the period from 2004 to 2008, new projects and expansion activities will bring on stream more than 25 Mt of urea capacity. With the exception of China, most new projects are located in the gas-rich countries of West Asia and are dedicated to export markets. As regards international trade patterns, the regional supply/demand balances on ammonia and derived products show an increasing deficit in North and South America and Asia. Other net importing regions (West Europe, Africa and Oceania) will show a slightly declining deficit. Imports in East Asia are expected to decline due to the construction of new urea capacity in China and Viet Nam. The main change in exports will occur in West Asian where significant new export capacity will be commissioned, especially in Saudi Arabia, Qatar, Iran and Egypt. Exports from the EECA region are projected to decline in light of the growing domestic requirements, but production from this region will continue to be export-oriented mostly. Global trade will expand for ammonia, urea and ammonium phosphates in the near term.

Predicting global N fertilizer requirements from trends in N efficiency of major crops, countries, and regions. **Achim Dobermann** and Kenneth G. Cassman.Department of Agronomy and Horticulture, University of Nebraska-Lincoln, P.O. Box 830915, Lincoln, NE 68583-0915, USA;

Abstract: At a global scale, cereal yields and fertilizer N consumption have increased in a near-linear fashion during the past 40 years and are highly correlated with one another. However, large differences exist in historical trends of N fertilizer usage and nitrogen use efficiency (NUE) among regions, countries, and crops. These differences must be understood and disaggregated to estimate future N fertilizer requirements and for developing and implementing improved N management strategies at different scales. Examination of trends at different scales leads to the following conclusions (i) aggregate global data do not provide a sound basis for assessing future fertilizer-N needs, (ii) interventions to increase N efficiency and reduce N losses to the environment must be accomplished at the farm or field scale through a combination of improved technologies and carefully crafted local policies that contribute to the adoption of improved N management, and (iii) studies that do not account for the interactive effects of changes in cropped area, yields and NUE typically overestimate future N needs by a substantial margin. We describe an approach for predicting future global and regional N fertilizer requirements that is based on expected trends in food demand, cereal harvest area, and cereal yields as well as current and future levels in NUE on a crop-specific basis. Our analysis demonstrates that future yield increases can be achieved with relatively little or no increase in N fertilizer use if NUE can be increased by 0.5 to 1.0 % per year—a rate of increase that has been achieved in USA maize for the past 25 years. In irrigated rice, for example, global average yield must rise from 5.3 Mg ha^{-1} at present to about 6.7 Mg ha^{-1} by 2020 (+26%), and this increase could be achieved with a 15% increase in N fertilizer (from 8.7 to 10 Tg N yr^{-1}) if crop recovery efficiency of applied N can be increased from 30% today to 45% by 2020. Achieving this rate of increase in NUE is feasible in different environments and cropping systems if adequate investments are made in research and extension to assure continued development and adoption of new technologies. We believe, however, that current levels of investment are woefully inadequate. Failing to improve NUE in the world's most important agricultural systems will likely cause severe damage to environmental services at local, regional, and global levels due to a large increase in the the global reactive N load.

Global Assessment of Nitrogen Fertilizer: The SCOPE Nitrogen Fertilizer Rapid Assessment Project (NFRAP). **A.R. Mosier,** USDA – ARS, Fort Collins, CO, USA, J.K. Syers, Naresuan University, Phitsanulok, Thailand, and J.R. Freney, CSIRO, Canberra, ACT, Australia

Abstract: Nitrogen (N) availability is a key factor in food and fibre production. Providing plant-available N through synthetic fertilizer in the 20th and early 21st century has been a major contributor to the increased production required to feed and clothe the growing human population. To continue to meet the global demands and to minimize environmental problems, significant improvements are needed in the efficiency with which fertilizer N is utilized within production systems. There are still major uncertainties regarding the fate of fertilizer N added to agricultural soils and the potential for reducing emissions to the environment. Enhancing the technical and economic efficiency of fertilizer N is seen to promote a favorable situation for both agricultural production and the environment, and this has provided much of the impetus for a new N Fertilizer project. To address this important issue, a rapid

assessment project on N fertilizer (NFRAP) was conducted by the Scientific Committee on Problems of the Environment (SCOPE) during late 2003 and early 2004. This was the first formal project of the International Nitrogen Initiative (INI). As part of this assessment, a successful international workshop was held in Kampala, Uganda on 12-16 January, 2004. This workshop brought together scientists from around the world to assess the fate of synthetic fertilizer N in the context of overall N inputs to agricultural systems, with a view to enhancing the efficiency of N use and reducing negative impacts on the environment. Regionalization of the assessment highlighted the problems of too little N for crop production to meet the nutrient requirements of sub-Saharan Africa and the oversupply of N in the major rice-growing areas of China. The results of the assessment will be presented in a book which will be available at the Conference to provide a basis for further discussions on N fertilizer.

Capitalizing on multi-element interactions through balanced nutrition — a pathway to reduce environmental impacts of nitrogen in China, India and the U.S. **P.E. Fixen**, J. Jin, K.N. Tiwari, and M. D. Stauffer. Potash & Phosphate Institute/Potash & Phosphate Institute of Canada.

Abstract: A viable option for mitigation of negative impacts of nitrogen (N) on the environment is to capitalize on multi-element interactions through implementation of nutrient management programs that provide balanced nutrition. Numerous studies have been conducted that clearly demonstrate the immediate efficacy of this approach in developing regions like China and India as well as developed countries such as the U.S. Though specific practices differ among these countries, the opportunity for improving N efficiency and reducing N loss potential through increased adoption of this proven best management practice is very real for all three. A major advantage to this approach of reducing N losses is that it results in a simultaneous increase in productivity and profitability because all inputs and resources are used more efficiently. To be successfully utilized, information must exist on which elements are potentially limiting growth in the local area. Studies will be reviewed that illustrate the magnitude of multi-element interactions and the associated impact on N use efficiency or N loss potential. Steps needed to increase adoption will also be discussed.

Managing spatially and temporally variable N fertilization needs of crops. W.R. Raun, J.B. Solie, M.L. Stone, K.L. Martin, K.W. Freeman, R.W. Mullen, H. Zhang*, J.S. Schepers, and **G.V. Johnson**. [1]Department of Plant and Soil Sciences, [2]Department of Biosystems and Agricultural Engineering, Oklahoma State University, Stillwater, OK 74078.USA *Corresponding author

Abstract: Cereal grains are commonly produced using fertilizer-N inputs based on average yields or traditional practices, without accounting for varying crop N requirements across the landscape and from season-to-season. Consequently, average N use efficiency is only about 34 percent. By delaying most fertilizer-N inputs, except of a non-limiting strip, until after the crop is growing and experiencing the current season conditions, N management can take into account spatial and temporally variable crop needs. Crop conditions and N status are indexed using active sensors that determine normalized difference vegetative index (NDVI) as inputs for predicting yield, responsiveness to N fertilizer, and N fertilizer rate. By positioning sensors every 0.4 m across the fertilizer applicator, spatial variability is treated at a resolution of 0.4 m^2.

Global Perspective on Denitrification in Terrestrial and Aquatic Ecosystems: Past, Present and Future. **Sybil P. Seitzinger.** Institute of Marine and Coastal Sciences, Rutgers University, 71 Dudley Rd. New Brunswick, NJ 08901. USA

Abstract: Nitrogen inputs to terrestrial and aquatic ecosystems around the world are increasing due to the increased mobilization of N associated with the production and consumption of food and energy. Denitrification, the microbial transformation of fixed nitrogen to N_2, is the major removal process for reactive N in the environment and occurs in almost all terrestrial and aquatic (both freshwater and marine) ecosystems. As N cascades along the terrestrial to aquatic continuum, at each step there is the potential for N removal by denitrification. The magnitude of N removal varies greatly in time and space and among ecosystems. Therefore, identify major sites and quantifying rates of denitrification within a watershed, or at regional and global scales is challenging. One limitation is measuring N_2 production rates with existing analytical instrumentation. A recent workshop (May 2004) associated with the International Nitrogen Initiative (INI) brought together the terrestrial and aquatic scientific communities to advance quantification of denitrification around the world.

Denitrification has likely increased in terrestrial, freshwater and near shore aquatic ecosystems during the past 150 years as N inputs to those ecosystems have increased. Since 1850 denitrification is estimated to have increased from 270 to 310 Tg N/yr. Globally, hotspots for denitrification are estimated to occur in the same regions where anthropogenic N inputs are high. By 2050 denitrification rates are estimated to increase to 370 Tg N/y. Denitrification can not maintain pace along the terrestrial aquatic continuum with the increased N inputs, and thus the environmental effects of increased N inputs, while decreased by denitrification, still persist. Managing physical and biological properties of certain ecosystems (e.g., buffer strips, river channelization) may help to increase denitrification. However, the most effective solution to minimizing negative environmental effects of increased N mobilization, is to decrease N use/emissions and N losses at the point of application/deposition.

Comparison of different approaches to developing spatially explicit emission inventories for NH_3, N_2O and NO. **A.F. Bouwman**[1], J. Van Aardenne[2] and K.W. van der Hoek[1]. [1]National Institute for Public Health and the Environment, Bilthoven, The Netherlands. [2]Max Planck Institute for Chemistry, Air Chemistry Department, mainz, Germany

Abstract: In this paper we will present global and regional estimates of emissions of ammonia (NH_3), nitrous oxide (N_2O) and nitric oxide (NO) based on different approaches applied to spatial information with 0.5 by 0.5 degree resolution. We will compare emission factor approaches with more "sophisticated" methods (such as statistical and mechanistic models for the soil-related emissions) and assess the causes of the observed differences. As it is difficult to judge the reliability of an estimate, we will discuss the possibilities for verifying emission estimates using independent measurements (for example in combination with chemistry-transport models) at different spatial and temporal scales. The advantages and disadvantages of each of the methods will be discussed, and recommendations will be given on the use of each of these methods for a specific spatial and temporal scale.

The Dutch N-cascade in the European perspective. **Jan Willem Erisman**, Hein de Wilde (ECN), Wim de Vries, Hans Kros (Alterra), Bronno de Haan (RIVM) and Kaj Sanders (VROM). The Netherland

Abstract: The Netherlands is 'well known' for its nitrogen problems, it has one of the highest reactive nitrogen (Nr) emissions densities in the world. It is a small country at the delta of several large European rivers. It has a large effect on nitrogen levels in Europe and at the same time imports different forms of reactive nitrogen. The Netherlands has always been a country that imported raw materials from

outside Europe to be manufactured into products for export within Europe. In addition, agriculture has always been an important economic factor. Ever since the industrial revolution, there has been a growing excess of nutrients and related emissions into the atmosphere (NH_3, NO_x and N_2O) and groundwater and surface water (NO_3). The Netherlands is both recieving and accepting Nr from other European countries. Vehicular traffic and animal husbandry are the principal sources of oxidized and reduced forms of Nr. The impacts of these emissions in the Netherlands as well as many other countries include eutrophication of nature areas and surface waters, soil acidification, and nitrate pollution of groundwater, particle formation leading to impacts on human health and influencing the earth's radiation balance, ozone formation leading to effects on humans and vegetation, and to climate change when it is transformed into nitrous oxide. One molecule of Nr can thus contribute to a cascade of effects, e.g. by first contributing to direct effects, then, when deposited, to eutrophication and groundwater pollution and eventually to N_2O emissions after denitrification. The Dutch 'nitrogen case' within a European perspective provides relevant experience and information for comparable regions in the world where nitrogen is or becomes a serious issue. This paper provides an overview of the origin and fate of nitrogen in the Netherlands, the various reported impacts of nitrogen, the Dutch and European policies to reduce nitrogen emissions and related impacts and the innovative ways to go forward to potentially solve the problems in a European perspective.

For holistic control of reactive N: regional, national and global perspectives. **Makoto Kimura.** Nagoya University, Japan

Abstract: Reactive N is closely related to the global issues of Earth warming and regional pollutions. Nitrous oxide (N_2O), the fourth important gas among greenhouse gases, is produced as an intermediate in nitrification and denitrification processes. As methane (CH_4) is the end product in the anoxic decomposition of organic materials, mitigation options of N_2O emission are different from those of CH_4 emission. Nitrate is another reactive N bringing about the eutrification of aqueous environments and the hazard of drinking water. Mitigation of NO_3 problem also relates closely to the N_2O emission. Therefore, holistic approaches are necessary for solving the problems of Earth warming and environmental eutrification by reactive N at the same time. In the presentation, the deforestation in the tropics and the present situations of food supply and sustainable agriculture in Japan are re-evaluated in terms of N_2O emission and NO_3 discharge from agricultural sector. The magnitude of N_2O emission by deforestation in the tropics may fall within the similar order of magnitude by N fertilization. As more N is imported as foods and fodder than fertilized N in Japan, more attention should be paid to the phases of their consumption and waste treatment. Sole attention to the productive phase is not enough for the total mitigation of various environmental problems by reactive N in relation to agriculture. Parameters holistically evaluating the impact of reactive N on the Earth and respective regions are urgently necessary.

Options for Reducing the Environmental Effects of Nitrogen in Agriculture. **J.R. Freney.** CSIRO, Canberra, ACT, Australia

Abstract: After addition of nitrogen to farmers' fields as animal excreta, fertilizer, crop residues or biological fixation, it can be lost by gaseous emissions to the atmosphere as ammonia, nitrous and other nitrogen oxides, by runoff or leaching of nitrate, and by soil erosion. The predominant loss process and the amounts lost are influenced by the ecosystem, soil characteristics, farming practice, fertilizer techniques, and prevailing weather conditions. The lost nitrogen can acidify soils and water bodies,

deplete stratospheric ozone, change climate, produce blooms of toxic algae, eutrophy coastal ecosystems, and produce respiratory and cardiac disease in humans.

Many approaches have been suggested for increasing the efficiency of fertilizer nitrogen and reducing losses, including optimal use of fertilizer form, rate and method of application, matching supply with crop demand, optimizing split application schemes, supplying fertilizer in the irrigation water, applying fertilizer to the plant rather than the soil, changing the fertilizer type to suit the conditions, and use of slow-release fertilizers and nitrification inhibitors. In addition, agronomic practices such as higher plant densities, weed and pest control and balanced fertilization with other nutrients can increase efficiency of nitrogen use and result in reduced loss of nitrogen. The efficiency of nitrogen use by animals can also be increased by manipulating the diet. Feeding dairy cattle low degradable protein and high starch diets, and grazing sheep and cattle on grasses high in water soluble carbohydrate resulted in less nitrogen being excreted in the urine and reduced ammonia volatilization.

If the options proposed for reducing emissions from fertilizer use were implemented, they would not only reduce impacts on the environment, but they would increase farmer's income.

Nitrogen cycling in paddy ecosystem and friendship for the environment. Guangxi Xing and **Zhengqin Xiong**. State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences. Nanjing, China

Abstract: Rice is the most important food crop of the developing world and the staple food for Asia. The crop was planted to 153 million hectares of land, producing 603 million tons. About 91% of rice grains were produced in Asia, amounting to 548 million tons for average 1999-2001. About 10.7 Tg N/y, 22% of fertilizer N was applied to rice crops in Asia. Research results of nitrogen cycling in paddy ecosystem and its effects on the environment were reported in this paper. Partly due to the denitrification occurring at both plough layer and sub-soil saturated layer, both nitrous oxide emissions and nitrate leaching in rice paddy region were less than that in the upland farmland; moreover, both nitrous oxide emissions and nitrate leaching during rice-growing season were less than that during upland crop growing season in rice paddy region. Though with higher volatilization rate in paddy region, emitted ammonia could be used as one source of N nutrition from atmospheric deposition. Considering the fact that the success of high-yield rice hybrida was bred and the environmental impacts were caused mainly by the upland crop in the rice-upland double cropping system, a radical change of cropping system from rice-wheat to rice-legume green manure was suggested as a potential solution for sustainable development.

Nitrogen management in animal production systems. **Oenema[1]** & Seerp Tamminga[2]. [1]Environmental Sciences, Wageningen University & Research Center, P.O.Box 47, NL-6700 AA Wageningen, the Netherlands

Abstract: Basically, animal production systems convert plant protein into animal protein. Usually between 5 and 35 % of the nitrogen (N) in plant protein is converted into animal protein. The other 65 to 95% is excreted via urine and dung, and can be used as nutrient source for plant (animal feed) production, to make the circle round. The estimated global amount of N voided by animals ranges between 80 and 130 Tg N per year, and is as large as or larger than the global annual N fertilizer consumption. Cattle (60%), sheep (12%) and pigs (6%) have the largest share in animal waste N production. The conversion of plant N into animal N is on average more efficient in poultry and pork production than in dairy production, which is higher than in beef and sheep production. However,

differences within a type of animal production system can be as large as differences between types of animal production systems, due to large effects of the genetic potential of animals, animal feed and management. The management of animals and animal feed, together with the genetic potential of the animals, is key to a high efficiency of conversion of plant protein into animal protein. The efficiency of the conversion of N from animal wastes, following application to land, into plant protein ranges between 0 and 40%, while the estimated global mean is about 15%. The other 60-100% is lost to the wider environment via NH_3 volatilization, denitrification and leaching in pastures or during storage and/or following application of the animal wastes to land. On a global scale, only about 50% of the amount of N voided is collected in barns, stables and paddocks, and only half of this amount is recycled to crop land. The N losses from animal wastes collected in barns, stables and paddocks depend on the animal waste management system. Relative large losses occur in confined animal feeding operations, as these often lack the land base to utilize the N from animal manure effectively. Losses will be relatively low when all wastes are collected rapidly in water-tight and covered basins, and when they are applied subsequently to the land in proper amounts and at the proper time, and using the proper method (low-emission technique). In this paper we discuss the efficiencies of N conversion in animal production, using a whole-systems approach. We analyze the impact of management factors on the conversion of N from plant protein into animal protein, and on that from animal waste into plant protein again, for the major animal production systems in the world. We conclude that there is scope for improving the N conversion in animal production systems, by improving the genetic production potential of the herd, the composition of the animal feed, and the management of the animal wastes. Coupling of crop and animal production systems, at least at regional scale, is prerequisite to a high N use efficiency in the whole system.

Symbiosome-like intracellular colonization of cereals and other crop plants by nitrogen fixing bacteria for reduced inputs of synthetic nitrogen fertilizers. **Edward C. Cocking,** Philip J. Stone and Michael R. Davey. University of Nottingham, Centre for Crop Nitrogen Fixation, University Park, Nottingham, NG7 2RD, UK.

Abstract: It has been forecast that the challenge of meeting increased food demand and protecting environmental quality will be won or lost in maize, rice and wheat cropping systems, and that the problem of environmental nitrogen enrichment is most likely to be solved by substituting synthetic nitrogen fertilizers by the creation of cereal crops that are able to fix nitrogen symbiotically as legumes do. In legumes, rhizobia present intracellularly in membrane-bound vesicular compartments in the cytoplasm of nodule cells fix nitrogen endosymbiotically. Within these symbiosomes, membrane-bound vesicular compartments, rhizobia are supplied with energy derived from plant photosynthates and in return supply the plant with biologically fixed nitrogen, usually as ammonia. This minimises or eliminates the need for inputs of synthetic nitrogen fertilizers. Recently we have demonstrated, using novel inoculation conditions with very low numbers of bacteria, that cells of root meristems of maize, rice, wheat and other major non-legume crops, such as oilseed rape and tomato, can be intracellularly colonized by the non-rhizobial, non-nodulating, nitrogen fixing bacterium, *Gluconacetobacter diazotrophicus* that naturally occurs in sugarcane. *G. diazotrophicus* expressing nitrogen fixing (*nif*H) genes is present in symbiosome-like compartments in the cytoplasm of cells of the root meristems of the target cereals and non-legume crop species, somewhat similar to the intracellular symbiosome colonization of legume nodule cells by rhizobia. To obtain an indication of the likelihood of adequate growth and yield, of maize for example, with reduced inputs of synthetic nitrogen fertilizers, we are

currently determining the extent to which nitrogen fixation, as assessed using various methods, is correlated with the extent of systemic intracellular colonization by *G. diazotrophicus*, with minimal or zero inputs.

The role of vegetation in ammonia exchange between terrestrial ecosystems and the atmosphere.
Jan K. Schjoerring. Plant and Soil Science Laboratory, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Copenhagen, Denmark
Abstract: Vegetation is under some circumstances a source of NH_3, and under others a sink for NH_3; the bi-directional fluxes are an implication of the existence of an NH_3 compensation point in plant tissues which differs in positive or a negative direction from the naturally occurring atmospheric NH_3 concentrations. Plant communities on arable cropland in most cases represent a net source of NH_3 to the atmosphere, with NH_3 emissions on a seasonal basis of up to 5 kg NH_3-N ha^{-1}. The amount of NH_3 lost represents between 1 and 5% of the applied nitrogen and between 1 and 5% of the actual amount of nitrogen present in the shoots of agricultural crops, i.e. a significant proportion of the total crop N budget. The actual size of the volatile NH_3 losses depend on seasonal variations in climatic conditions affecting crop nitrogen economy. The losses may increase under conditions with excessive N absorption by roots and under conditions unfavourable for nitrogen remobilization from vegetative plant parts.
Physiological regulation of plant-atmosphere NH_3 fluxes is mediated *via* processes involved in nitrogen uptake, transport and metabolism. A rapid turnover of NH_4^+ in plant leaves leads to the establishment of a finite NH_4^+ concentration in the leaf apoplastic solution. This concentration determines, together with that of H^+, the size of the stomatal NH_3 compensation point, which under natural growing conditions ranges from 0.1 to 15 nmol NH_3 mol^{-1} air. NH_4^+ is constantly added to the apoplastic NH_4^+ pool *via* NH_3 efflux from the mesophyll cells. The NH_4^+ is retrieved by various transport proteins which are able to respond very rapidly to perturbations in apoplastic [NH_4^+], thereby maintaining apoplastic NH_4^+ homeostasis. Steady state apoplastic [NH_4^+] increases with the level of root N supply and plant N status and may vary from a few μM to well above 1 mM in various crop, grassland and tree species. During leaf senescence, apoplastic and bulk tissue [NH_4^+] increases, particularly in leaves with a high N/C ratio. Replacement of NO_3^- with NH_4^+ in the root medium leads to a rapid increase in xylem and apoplastic [NH_4^+]. Inhibition of glutamine synthetase, the central NH_4^+ assimilating enzyme in all plants, causes a rapid and substantial increase in apoplastic NH_4^+ and barley mutants with reduced GS activity have higher apoplastic NH_4^+ than wild type plants. Increasing rates of photorespiration do not affect the steady state [NH_4^+] or [H^+] in tissue or apoplast of oilseed rape, indicating that the NH_4^+ produced is assimilated efficiently. In agreement, apoplastic [NH_4^+] in field grown oilseed rape plants seems on a diurnal basis to be relatively constant. The NH_3 exchange, nevertheless, shows a diurnal pattern due to a temperature-mediated displacement of the chemical equilibrium between gaseous and aqueous NH_3 in the apoplast. Increasing temperature may, within a short time frame, cause a given plant to switch from being an NH_3 sink to becoming an NH_3 source.

Innovative use of controlled availability fertilizers with high performance for intensive agriculture and environmental conservation.
Sadao SHOJI. Agriculture and Environmental Conservation, 5-13-27 Nishitaga, Taihaku-ku, Sendai, 982-0034, Japan
Abstract: Of the essential nutrient elements for agricultural crops, nitrogen is a fertilizer element that most strongly determines the crop production while it contributes most intensely to the environmental

degradation. Thus, the present paper deals with controlled availability (release) fertilizers (CAFs) that are resin-coated nitrogen fertilizers.

Thermoplastic polyolefin coated fertilizers show the highest accuracy of release control and have a variety of linear and sigmoid formulations. Using these high-performance CAFs, programmed fertilization and best site placement have been developed. Various agro-technologies also have been innovated. For example, they include no-till transplanting rice culture with single basal nursery application, no-till direct seeding rice culture with single basal co-situs application, multi-plantings by one-time application and controlling plant root distributions.

High yielding of field crops needs high nitrogen supply meeting the crop demand. Thus, multi-split application using conventional fertilizers is commonly employed for this purpose. However, high concentration of nitrogen from the split-applications can have harmful effects on plant roots. In contrast, high-performance CAFs can supply continuously nitrogen to the crops in a suitable concentration, contributing greatly to the high yielding.

There is a rapidly growing interest on the quality and safety of farm products in relation to human nutrition and health. For example, chemical attributes such as the concentrations of minerals, nitrate, oxalic acid and vitamins in vegetables are often disscussed. Quality and safety of farm products can be enhanced by nitrogen application. It has been shown that high performance CAFs are successfully utilized for the programmed fertilization and best site placement that can supply fertilizer ammonium or nitrate to the agricultural plants, improving the quality and safety of farm products.

High performance CAFs can efficiently control the adverse effects of intensive agriculture on the environment. The principles of minimizing N fertilizer pollution are to maximize fertilizer N use efficiency (NUE) and to reduce the N rate according to the highest NUE and natural N supply. These principles can be achieved by use of suitable formulations of high performance CAFs. Agro-technologies innovated using high performance CAFs also can contribute to improving the upland and paddy field environments.

Policy Approaches for Reducing Nitrogen Pollution in the USA. **Robert W. Howarth.** Department of Ecology & Evolutionary Biology, Cornell University, Ithaca, NY 14853, USA

Abstract: Nitrogen pollution has grown steadily as a problem in the USA over the past several decades. On a per capita basis, more synthetic nitrogen fertilizer is used and more NOx are emitted to the atmosphere than in any other country. Technical solutions exist to greatly alleviate many of the problems from this nitrogen pollution, often at relatively low cost. Despite this, progress in reducing nitrogen pollution in the USA has been slow. In this talk, I will review what policy approaches have been tried and discuss failures and successes. I will also present the beginnings of a blueprint for new policies for solving the nitrogen problem in the USA.

The nitrogen cycle and policy relevant science. **David Norse**. China Office, University College London, WCIH 0BT, UK

Abstract: Much of the research on nitrogen cycling is focused on improving scientific understanding rather than helping policy makers to formulate appropriate responses to old or emerging environmental problems. Policy makers, for example, commonly find it difficult to assess the spatial or temporal importance of the various risks to human and ecosystem health that stem from man's interference with the natural N cycle. This paper will endeavour to support this contention by reference to the perceived risks of groundwater nitrate to human health, the uncertainties about critical NOx levels and interactions

with other pollutants, and various other dimensions of man's impact on the N cycle. The paper will go on to suggest a more systematic process by which scientists can select and design their research in a manner that could give more effective support to policy makers.

Nitrogen use in Asian agriculture: balancing the implications on food supplies and the environment. **Virendra Pal Singh**. Regional Representative for South Asia, International Center for Research In Agroforesty, New Delhi, India.

Abstract: The threat to crop failure and famine in Asia during the last four decades has been kept away by the expansion of fully or partially irrigated agriculture environments. In these environments, the use of improved varieties, and eight fold increase in chemical fertilizer (primarily nitrogen) use, more effective control of weeds, insects and diseases and optimal use of soil moisture from rainfall and irrigation have played a key role in pushing the yielding of cereal crops, mainly wheat, rice and maize to win the race between population growth and food grain production. In order to encourage adoption by farmers, nitrogen responsive varieties were developed and governments made additional investments in irrigation and drainage and in supply and distribution of chemical fertilizers. With the transfer of lands from traditional to modern varieties, the consumption of chemical nitrogen and total cereal grain production continue to increase with very little addition to cropped land. For example since 1996, when IR 8, the first green revolution rice variety was released, the rice production doubled and the fertilizer consumption increased by 8 folds, while rice harvested area in Asia increased only by 13%.

Over the last decade however, there has been a significant change in policies regarding the government involvement in the fertilizer sector due to the fiscal burden of fertilizer subsidize and concerns about the efficient use of this input. There has also been a fundamental change in the importance attached to chemical fertilizers in general and to the nitrogen in particular due to environment concerns. At the same time, expansion of irrigation has slowed down due to a decline in donor support and the dampening of private sector investment for water control. As a result nutrient consumption growth rate started to slow down. However the food grain production growth must be sustained to address the food insecurity concerns and at the same time the environments have to be made habitable.

This paper attempts to review the role of nitrogen fertilizer in sustaining food grain production growth in the major agriculture based countries of Asia. While section II reports past trends in N-fertilizer consumption and the intensity of fertilizer use in major food crops, section III assesses yield response policy change in the fertilizer sector and there impact on fertilizer prices. Section IV analyses the implications of sustaining food security on fertilizer use, and suggests some areas of research needed to achieve the targets. The main conclusions are drawn in section V of this paper.

Nitrogen use sceinario in India. **A.P. Gupta.** Department of Soil Science, CCS Haryana Agricultural University, Hisar, 125 004 India

Abstract: Nitrogen is one of the major plant nutrient without which the agricultural production is not possible. Nitrogen is very dynamic and is readily discharged into the atmosphere as NH_3 and NO_x and also leached down the soil profile and join the aquifers. Nitrogen use in Indian Agriculture was nearly 55,000 tons in 1950-51 that increased to 11.31 million tons in 2001-02. The total food production of the country has also experienced the similar increase from 50.83 to 222 million tons in the respective years. Interestingly the N fertilizer consumption of India remained almost constant during the last six years varying between 10.3 to 11.59 million tons. The change in N consumption and increase in productivity is also related to the introduction of high yielding and fertilizer responsive crop cultivars. The N

consumption scenario has been compared within four different zones of India. The highest N consumption has been observed in North zone that is evident by the introduction of rice-wheat cropping system followed by West, South and East. The increase in N consumption in North was linear and curvilinear in rest of the zones. The N consumption is also related with increase in production and productivity.

The N use efficiency has been reported to be varying between 30 to 60% depending on the crops and the management. But in all these cases, the N use efficiency has been calculated based on the total N removed by the crops (above ground part only) forgetting the N content in the roots. It has been observed in controlled experiments that the total N uptake varied from 18 to 44% of the total N removed by the above ground part i.e. grain and straw. If this N is also accounted in calculating the N use efficiency then the N use efficiency will be higher. Another concern is the N released in the atmosphere by burning of the organic wastes. In this review all these issues will be covered to reach to some tangible conclusions to decide the next course of research and maintain the environment healthy.

Challenges of reducing excess nitrogen in Japanese agroecosystems. **Kazuyuki Yagi** and Katsuyuki Minami. National Institute for Agro-Environmental Sciences (NIAES), Tsukuba, Japan

Abstract: Fertilizer N use in Japan has decreased by about 30% from 1960 to 2000, while keeping a little increase in cereal yields. This results in significant increase in apparent nitrogen use efficiency, in particular for rice. On the other hand, national N load on the environment associated with the production and consumption of domestic and imported agricultural products has almost tripled during this period, mainly due to the dramatic increase of imports of food and feed. The environmental problems, including water and air pollution, caused by the excessive load of N are serious public concerns and there is an urgent need to minimize N losses from agricultural production. In order to meet the necessity of reducing environmental impacts by excess N, political and technological measures have been taking at regional and country levels. In recent years, the Japanese government has embarked on a series of policies to encourage transition to an environmentally conscious agriculture. Promoting proper material circulation with reducing fertilizer impact and utilizing biomass and animal wastes is emphasized in these policies. Implementation of environmentally friendly technology and management, such as use of controlled release fertilizers and pellets of animal wastes, is investigated and extended. The effectiveness of environmental assessment and planning for reducing regional and national N load has been discussed. In this talk, we would like to introduce these recent challenges of reducing environmental N impacts in Japanese agroecosystems.

Several researches on N-balance in Korea. Youn Lee and **Mun-Hwan Koh.** Nat'l Institute of Agri. Sci. & Tech., Rep. of Korea

Abstract: Research on nutrient balance in Korea started after Korea became an OECD member country (1996). When we calculated gross N balance in national scale by the request of agricultural indicator working group in OECD, it was shown one of the highest N balance among OECD member countries. Nitrogen balance in Korea was the highest in 1998 (296 kg N $ha^{-1}yr^{-1}$), and had been decreased to 251 kg N $ha^{-1}yr^{-1}$ in 2001. Reduced consumption of chemical fertilizer in recent years contributed to the reduction of N balance. Also, the change of N balance from 1985 to 2001 well represented the change in agricultural policy, economic and social situation during the period. In regional scale N balance study of 150 districts, the numbers of livestock in the districts were positively correlated to N balance of those regions. But, uncertainty of the calculation came from the lack of information on the sales of composted

manure, since statistic data of the districts did not cover such information. Rice cropping system, which covers 60% of agricultural land in Korea, showed relatively low N balance (80 kg N $ha^{-1}yr^{-1}$), compared with the national average of N balance. On the contrary, plastic film house system for vegetable production showed relatively high N balance. Farm-gate N balance in national scale showed that how 15 million tons of imported concentrated feeding materials could affect nitrogen flow in agricultural systems of Korea. When we estimated target N balance by recommended N consumption for crop production, about 180 kg N $ha^{-1}yr^{-1}$ was appropriate in year 2001. In Korea, nutrient balance became an important agricultural environmental indicator for monitoring and implementing agricultural policy. But, in order to be a good indicator, much effort is necessary in the area of research, agricultural statistic and database construction in regional scale.

Environmental friendly systems of N application. **Avi Shaviv.** Dept. Of Environmental, Water and Agricultural Engineering, Faculty of CEE, Technion, IIT, Israel

Abstract: Increasing attention is being paid to "environmentally friendly" N-fertilization techniques/systems due to demands to maintain a cleaner environment and focus on sustainable agriculture. The effectiveness of such techniques strongly depends on their ability to synchronize nutrient demand by plants with its supply and the possibility to apply favored or optimal nutrient compositions. Controlling the rates of N transformations (e.g., nitrification, urea hydrolysis) and the control over nitrogen supply (e.g., controlled release nitrogen – CRN, fertigation) offer solutions for increasing N use-efficiency (NUE) and reducing environmental pollution by fertilizer N. This is a result of reducing excess mineral nitrogen in the root zone, thus diminishing N gaseous and leaching losses. In addition, plant exposure to ammonium rich nutrition results in higher NUE and a reduction of rhizosphere pH, which in turn can increase availability of pH sensitive nutrients (e.g., P, microelements) in arid and semi-arid soils. Control over ammonium and nitrate formation/consumption and release in soil can be achieved via several main application techniques or sophisticated fertilizers: i. by applying ammonium rich sources in nests, bands or super-granules ("depot" or "localized" application) thus inducing conditions that reduce the rate of nitrification; ii. by using bio-amendments (e.g., nitrification inhibitors – NIs, or Urease Inhibitors - UIs) incorporated in N-fertilizers and by combing their application with the "localized" application; and iii. by controlling the supply of N via fertigation or by applying controlled release nitrogen (CRN) fertilizers. This presentation focuses on: laboratory, greenhouse, and lysimeter experiments demonstrating the potential advantages of the techniques mentioned above.

The possibility to model N-dynamics under several environmentally friendly N-fertilization techniques is demonstrated on the basis of a comprehensive N-dynamics model accounting for major N processes in soils that utilizes sub-models obtained in laboratory studies.

The cost-effectiveness of the techniques and their impact on the environment depend on the farming scale and sophistication, type of crops grown as well as soil types and agro-techniques used by the growers. The adaptation of the different techniques to different farming practices is discussed and analyzed.

Analysis of eutrophication state and trend for lakes in China. Xiangcan Jin* and **Qiujin Xu**. Chinese Research Academy of Environmental Sciences, Beijing, 100012, China *Corresponding author

Abstract: Present state and eutrophicate trend of lakes in China were analyzed in this paper. All data show that the lakes are all commonly undergoing the process of eutrophication, water quality is

deteriorating and lake ecosystem is destroyed. Most of urban lakes are facing hypertrophication. Many medium-sized lakes are of eutrophic state, some of them even approaching to hypertrophic level. The famous five large freshwater lakes have the condition to be eutrophicate, especially Lake Caohu and Lake Taihu are already in the state of eutrophication. Eutrophicate lakes mainly distribute in the middle and lower reaches of Yangzi River, Yungui Altiplano. The trend of the Eutrophic Lakes in China is quite rapid. 34 lakes were investigated in the end of 70's. At that time most of lakes were of in mesotrophic state, the area accounted to 91.8%. Eutrophic lake area was only 5.0 %. During ten years, oligotrophic lakes changed to be mesotrophic lakes. The oligotrophic lake percent decreased from 3.2 to 0.53. mesotrophic lakes changed to be eutrophic lakes, area percent increased from 5.0 to 55.01. In 1996 eutrophic and hypertrophic lakes accounted for 85%. Lake eutrophication became a serious environmental problem in China. According to domestic and foreign experiences of the eutrophication control technology, the theory of combining source control with lake ecological restoration was put forward, which could be the guidance for eutrophication control of lakes in China.

Status, causes and prediction of red tides along Chinese coast. **Mingjiang Zhou.** Institute of Oceanology, Chinese Academy of Sciences, China

Abstract: This paper summarized historical main events and present status of Red Tides (or HAB, Harmful Algal Blooms) along Chinese coast. It showed that red tides in China increased in frequency and scale, in number of causing species, in percentage of toxic events and in the degree of damages to marine environment and economy. The potential cause of frequent red tides occurrence in China was discussed both on ecological and oceanographic bases. We also reviewed research progress made recently in the population dynamics of red tides formation, taxonomy of causative species, physiology, ecology and life cycle of essential species, algal toxin distribution and production, and modeling for red tides prediction.

Estimation of NOx emission induced by China's energy production and consumption and options for its mitigation. **Xiulian HU,** Shengmin YU and Huaqing XU. Energy Research Institute, National Development and Reform Commission, Beijing 100038, China

Abstract: China is the second largest energy producer in the world, next to the United States. In 2002, the primary energy production was totally 1.48 billion tce in China, ranked the second in the world list, which accounted for about 12 per cent of world energy production. Output of coal was 1.38 billion tons, power generation was 1654 TWh and output of crude oil was 167 million tons, all of which taken up the first, second and fifth place respectively in the world. The percentage of coal shared in total primary energy production and its use still remained at about 70 per cent from 1978 to 2002. Coal-based power generation accounted for about 95 per cent in thermal power generators. Energy use by transportation has increased very rapidly. Therefore, this makes power generation and transportation sectors become the main NOx emission sources in China' energy production and consumption activities. According to estimation, NOx emission reached over 6.5 million tons in 2000, taken up about 60 per cent of total NOx emission in China. This article applies IPAC-AIM/China Energy Emission Model to simulate and analyze NOx emission from different energy activities under the different scenarios from 2000 to 2030. It analyzes and evaluates the effects of NOx emission mitigation through adopting the various emission mitigation technologies and policy options.

N_2O emissions from the agriculture of China. **Xunhua Zheng**[1], Shenghui Han[1], Yuesi Wang[1], Yao Huang[1], Yue Li[2]. [1] Institute of Atmospheric Physics, CAS, China. [2] Institute of Sustainable Agriculture Development, CAAS, China **Abstract:** Agricultural activities, especially those in association with nitrogen application and management, are important to contribute to the current rise of atmospheric N_2O, which is one of climatically/environmentally important trace gases. Accurate quantification of regional/national or global N_2O emission is one of current key research issues in the field of global change. Our study shows that the direct emission from agricultural soils accounts for about 60% of the total N_2O released from the agriculture of China. There is a huge uncertainty (ranging from -80% to 130%) in the current estimate of the direct N_2O emission from agricultural soils, which is mainly due to the uncertainties in emission factors. Of the 54 available direct N_2O emission factors obtained in China, about 2/3 were underestimated by 29%, and 1/3 overestimated by 50%, due to inevitable shortages in field observations. This suggests that the biases due to inevitable observational shortages needs to be corrected before these emission factors are used in estimation of N_2O emission. Our results also suggest that the uneven development in economy most likely accounts for the high spatial variability (up to 94%) in direct N_2O emission on area basis of croplands. Consumption of synthetic N fertilizers, which is driven by the increase in population, is thought to be the principal contribution of N_2O emission from the agriculture of China. Enlargement of population may exclusively be the root driving force for the quick increase in N_2O emission from the agriculture of China during 1978 and 2000, as the former can entirely explain the later. Population-based projection gives that N_2O emission from the agriculture of China will likely increase by 30 - 90% in 2020 - 2040, as compared to that in 2000, provided that no effective mitigation measures are adopted.

Utilization and management of organic manures in China. **Fusuo Zhang,** Xiaotang Ju, Xuemei Bao, Guoxue Li. Key Laboratory of Plant-Soil Interactions, Ministry of Education; College of Agricultural Resources and Environmental Sciences, China Agricultural University, Beijing 100094, China

Abstract: Composting and recycling of organic waste such as animal waste and crop residuals have a long tradition in China. In the past, the application of organic manures has guaranteed a high return of organic substances and plant mineral nutrients and thus, soil fertility. In addition, application of composted organic waste materials can have a distinct effect on suppression of soil born plant pathogens. As a result of rapid economic development companied with the increased urbanisation and labour costs, the recycling of organic waste materials in Chinese agriculture has dramatically declined during the last two decades, in particular in the more developed eastern and south-eastern provinces of China. Because more and more farmers use the mineral fertilizer, only 47% of the cropping lands is still using organic fertilizers, which bring 18% of N, 28% of P and 75% of K into field. Even though the organic manures are important nutrient sources and soil conditioners for Chinese agriculture.

In China, one of the major problems is the de-coupling of animal and plant production which is increasingly taking place, thereby interrupting formerly closed nutrient cycles. This is occurring in a time when “re-coupling” is increasingly being considered in Western countries as a means to improve soil fertility and reduce pollution from animal husbandry. In addition, as consequence of enhanced industrialization and intensified animal husbandry with excessive feeding with micronutrients such as Zn and Cu (especially for piglets) and use of other heavy metal containing products organic waste materials can be polluted by heavy metals and toxic organic compounds, which become the main pathways leading to heavy metal contamination of soils and subsequently vegetables in China.

As a consequence of a general stronger consideration of ecological aspects in agriculture, various legal initiatives, and different new techniques have been developed recently. Composting of organic wastes to produce commercial organic fertilizers or various growth mediums is particularly addressed. The newly developed techniques for co-fermentation of agricultural, industrial and municipal wastes could be of interest for production of alternative energy. Furthermore, the re-coupling of modern animal and plant production is urgently needed.

Estimation of agricultural non-point source pollution in China in early 21 century. **Wei-li Zhang**[1], Shu-xia WU[1], Hong-jie JI[1], H. KOLBE[1]. [1]Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China. [2] Sächsische Landesanstalt für Landwirtschaft，Gustav-Kühn-Str. 8，D-04159 Leipzig

Abstract: Since 1970s, the N and P eutrophication of major Chinese lakes and water systems has been getting worse rapidly. Investigation revealed that non-point source pollution from agriculture and rural region is the leading source of water pollution. The contribution of non-point source pollutants from fertilization of crop land, rural animal husbandry and living sewage of transition region between rural and urban area is much greater than that of point-source from wastes of civil domestic and industry in urban area with developed wastewater pipe nets. Since 1980s, the acreage of vegetables, fruits and flowers has been increased by 4.4 times. Due to high profit, it is common using very high rates of N and P fertilizers on these crops. The average fertilizer application rate is 569-2000 kg (pure nutrient)/hm2 in single crop, about 10 times as that for grain crops. The increasing vegetable area with high fertilizer input is one of the biggest potential problems for eutrophication of water bodies in watersheds. At the same time, animal breeding farmers in rural region intended to be developed in a pattern that certain townships with very high concentration of animal breeding farmers. N and P amount from animal husbandry in such concentrated region has reached very high level, as much as 1721 kg N and 639 kg P_2O_5 per hectare agricultural land area, far more surpassing the acceptance capacity of soil to these organic nutrients. In almost all of the important watersheds in China, non-point source N- and P-discharge to aquatic ecosystem from animal husbandry is becoming a crucial pollution source. Fast expansion of new city zones without wastewater pipe nets in transition region between rural and urban area makes such zones the main non-point source pollution. The research results also showed: although the non-point source pollution is already serious in the country, the growing influence factors will lead to even worse situation in the early 21 century. The non-point source pollution from agriculture and rural area will become one the of biggest challenges to sustainable development of China.

Balanced nitrogen economy as a flexible strategy on yield stabilizing and quality of aquatic food crops. **A. M. Puste**[1], P. K. Sarkar[2] and D. K. Das[3]. [1 & 2]Department of Agronomy. [3]Department of Agricultural Chemistry and Soil Science, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya (Agricultural University), Mohanpur - 741 252, Nadia, West Bengal, India

Abstract: In wetland ecosystem, nitrogen along with other elements and its management is most imperative for the production of so many aquatic food, non-food and beneficial medicinal plants and for the improvement of soil and water characteristics. With great significant importance of INM (integrated nutrient management) as sources and its divergence, a case study was undertaken on such aquatic food crops (starch and protein-rich, which are most popular and remunerative) in the farmers' field of low-lying *Tal* situation of New Alluvial Zone of Indian subtropics (23º5/ N latitude and 89º E longitude and elevated at 8.50 MSL). The study was designed in split-plot, where, three important aquatic food crops [water chestnut (*Trapa bispinosa* Roxb.), makhana (*Euryale ferox* Salisb.) and water lily (*Nymphaea* spp.) as major factor and eleven combinations of organic and inorganic sources of nutrients as sub-factor was considered in the experiment. It revealed from the results that the production of fresh kernels or nuts of water chestnut (8.57 t ha^{-1}), matured nut yield of makhana (3.06 t ha^{-1}) and flower stalks of water-lily as vegetables (6.38 t ha^{-1}) including its nutritional quality (starch, protein, sugar and minerals) was remarkably influenced with the application of both organic (neem oilcake @ 0.2 t ha^{-1})

and inorganic sources (NPK @ 30:20:20 kg ha^{-1} along with spraying of N @ 0.5% thrice at 20, 40 and 60 DAT) than the other INM combinations applied to the crops. Among the crops, highest WCYE (water chestnut yield equivalence) exhibited in makhana due to its high price of popped-form in the country which is being exported to other countries at now. Sole application of both (organic and inorganic sources) with lower range did not produce any significant outcome from the study and exhibited lower value for all the crops. Besides production of food crops, INM also greatly influenced the soil and water characterization as aquatic ecosystem play an important criterion for habitats of thousands of flora and fauna and it was favourably reflected in this study. The physico-chemical characteristics of soil (textural class, pH, organic carbon, organic matter, ammoniacal nitrogen, nitrate nitrogen, available nitrogen, phosphorus and potassium) are most important and contributed a significant improvement due to cultivation of these aquatic crops. Analysis of such wet bodies represented the water characteristics (pH, BOD, COD, CO^{-}_{3}, HCO^{-}_{3}, $NO^{-}_{3}N$, $SO^{-}_{4}S$ and Cl^{-}) were most responsive, adaptable and quite favourable for the cultivation of these crops in this vast waste unused wetlands for the mankind's without any environmental degradation.