nitrogen 2nd conferNs
14-18 October 2001
Bolger Conference Center
Potomac Maryland, USA

PROGRAM & ABSTRACTS

N2001
The Second International Nitrogen Conference

Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection

BOLGER CONFERENCE CENTER
POTOMAC MARYLAND
OCTOBER 14-18, 2001
http://esa.sdsc.edu/n2001

N2001 – The Second International Nitrogen Conference Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection

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N2001
The Second International Nitrogen Conference

"Optimizing Nitrogen Management in Food and
Energy Production and Environmental Protection."

Bolger Conference Center, Potomac, Maryland, USA
October 14 – 18, 2001

Co-chairs:
Dr. James Galloway
Dr. Ellis Cowling

Sponsors

United States Environmental Protection Agency
    Office of Air and Radiation
    Office of Research and Development
    Office of Wetlands, Oceans, and Watersheds

Ministry of Environment, The Netherlands

The United States National Science Foundation

The Fertilizer Institute (US)

United States Department of Commerce
    National Oceanographic and Atmospheric Administration (US)
        National Ocean Service
        Air Resources Laboratory

United States Department of the Interior
    U.S. Geological Survey

United States Department of Energy
    Office of Biological and Environmental Research

United States Department of Agriculture
    Natural Resources Conservation Service
    Agricultural Research Service
    U.S. Forest Service
    Foreign Assistance Service

National Pork Producers Council (US)

Electric Power Research Institute (US)

Participating and Supporting Organizations and Societies

Board on Environmental Studies and Toxicology, National Research Council

Energy Research Center of the Netherlands

Council for Agricultural Science and Technology

American Society of Agronomy

Crops Science Society of America

Soil Science Society of America

American Dairy Science Association

American Society of Animal Science

Poultry Science Association

American Meat Science Association

WELCOME TO THE MEETING

Dr. James Galloway, Conference Co-Chair, University of Virginia

Dr. Ellis Cowling, Conference Co-Chair, North Carolina State University

Welcome to the Bolger Center and to the Second International Nitrogen Conference!

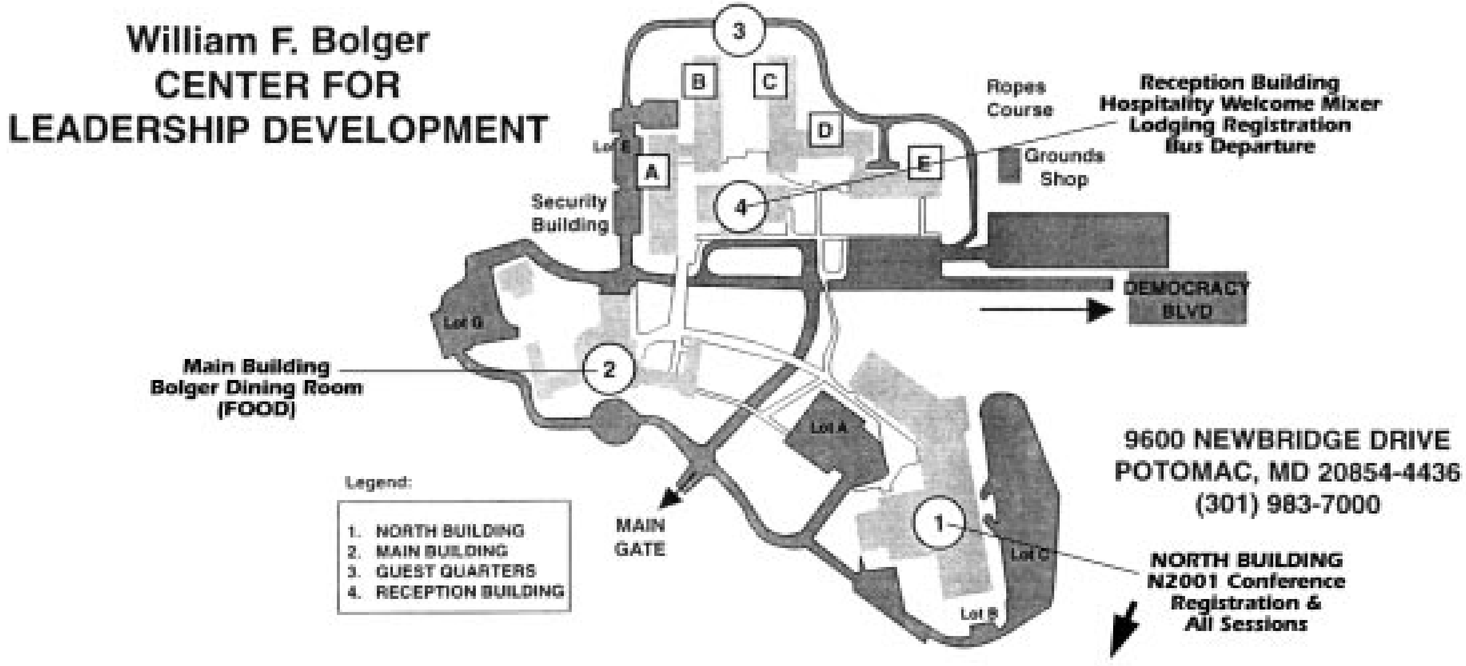
Human efforts to produce food and energy are changing the nitrogen cycle of the Earth. Many of these changes are highly beneficial for humans; others are not. These changes transcend scientific disciplines, geographical boundaries, and political structures. They challenge the creative minds of scientists, engineers, business leaders, and policy makers. This Conference has been designed to facilitate communications among all stakeholders in the "Nitrogen Community" within many countries of the world. Our goal is to help each of our societies make more optimal choices about nitrogen management in food production, energy production and use, and environmental protection.

Cutting-edge science and policy alternatives will be explored during daily Keynote Presentations, Contributed Paper and Poster Presentations, Round-Table Discussions, and by Playing the Nitrogen Game! These varied experiences are designed to help fulfill the three major goals of the Conference:
— Increase scientific knowledge about nitrogen sources and effects,
— Stimulate communication among leaders in nitrogen production and consumption, and
— Explore balanced policy strategies by which to increase food and energy production while decreasing environmental impacts.

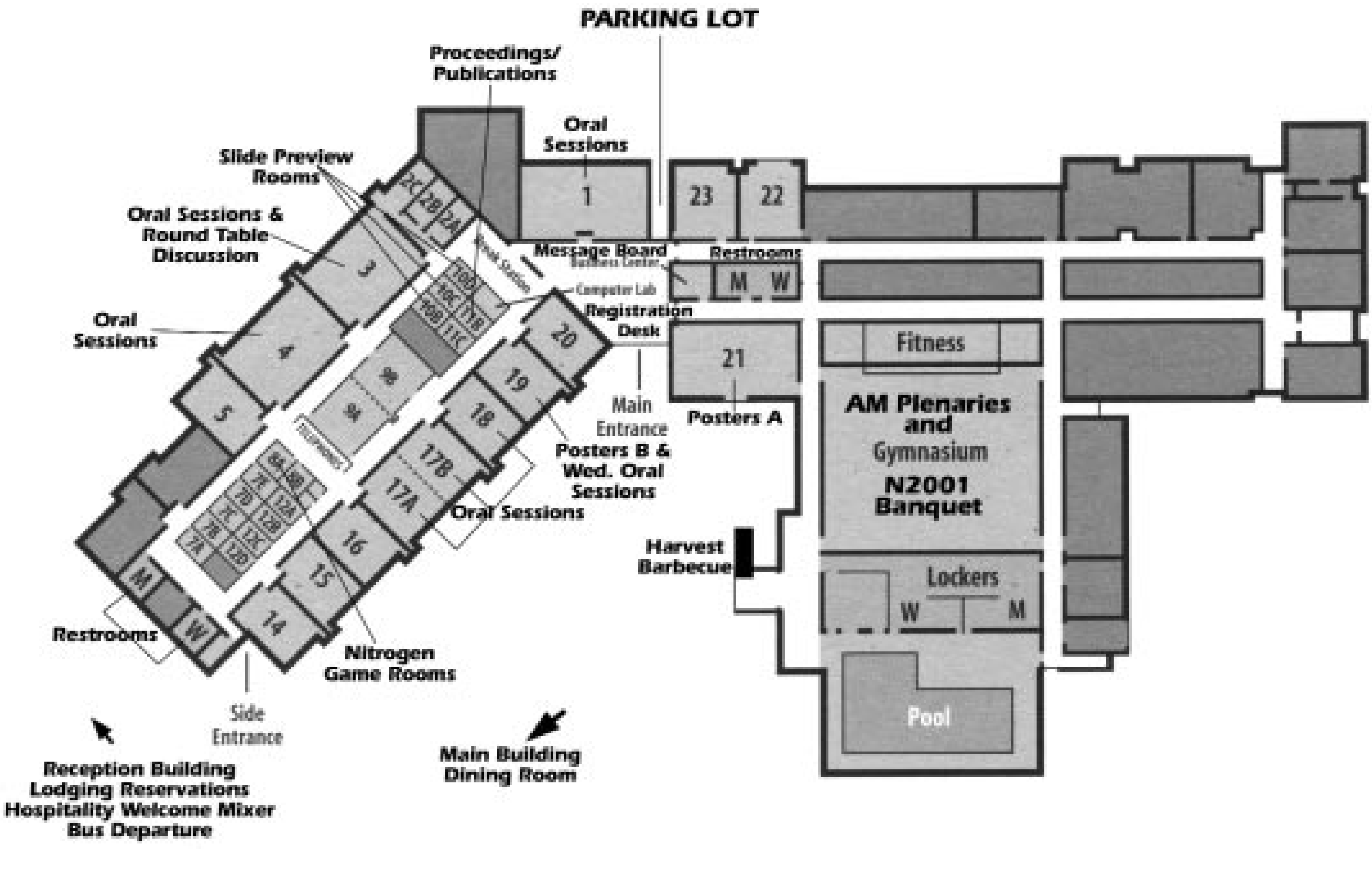
To help ensure that there will be an enduring influence of ideas developed during the Conference, we ask each of you to contribute to the **Conference Summary Statement** and to join in planning **Post-Conference Briefings for Decision Makers** that will help each of our countries and institutions do a better job of understanding nitrogen and its management in the years ahead.

We hope each of you will take full advantage of the Conference by focusing not only on your own specific area of science or policy, but joining in discussions of other areas as well, in order to gain a broader understanding of nitrogen and its management. Such broadened understanding is necessary if we are to do our part to help "Optimize Nitrogen Management in Food and Energy Production and Environmental Protection"!

BOLGER CENTER MAP



North Building



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Sunday October 14

8:00 AM – 6:00 PM	Field Trip #1
12:30 PM – 5:30 PM	Field Trip #2
5:30 – 7:00 PM	Welcome Reception
6:30 – 8:30 PM	Bolger Buffet
7:00 PM	Introduction to the N-Game

Monday October 15

"Nitrogen Production and Movement"

7:00 AM	Continental Breakfast (Gymnasium) or Buffet in Bolger Dining Room
8:30 AM – 12:30 PM	PLENARY (Gymnasium)
8:30 AM	Welcome
9:00 AM	Nitrogen and the World
9:30 AM	Nitrogen and Nature
10:00 AM	BREAK
10:30 AM	Nitrogen and Food
11:00 AM	Energy, Industry and Nitrogen
11:30 AM	Nitrogen Fertilizers…Meeting the Challenge
12:00 PM	Nitrogen and Animals
12:30 – 1:30 PM	BOX LUNCH
12:30 PM	Introduction to the Nitrogen Game (Gymnasium)

CONCURRENT SESSIONS 1:30 – 4:00 PM

Oral Session #1:
Nitrogen Use in Agricultural Fertilization Practices. (Rm 1)
Oral Session #2:
Nitrogen Management in Animal Agriculture. (Rm 17)
Oral Session #3:
Forests and the Nitrogen Cycle. (Rm 4)
Oral Session #4:
Ammonia: Sources, Emissions and Transport. (Rm 9)
Oral Session #5:
Atmosphere-Biosphere Linkages: N_2O and NO Emissions. (Rm 18)
Oral Session #6:
Atmospheric Deposition of Nitrogen. (Rm 3)

4:00 – 4:30 PM	BREAK
4:30 – 5:30 PM	ROUNDTABLE (Rm 3)
5:30 – 7:00 PM	POSTER PUBS (Rm 21 & 19)
7:00 – 9:30 PM	BANQUET (Gymnasium)

Tuesday October 16

"Nitrogen Around the World and its Effects"

7:00 AM	Departure for Tour #2 (Departure from Reception Building)
7:00 AM	Continental Breakfast (Gymnasium) or Buffet in Bolger Dining Room
8:30 AM – 12:30 PM	PLENARY (Gymnasium)
8:30 AM	The European Nitrogen Case
9:00 AM	The North American Nitrogen Story
9:30 AM	The Asian Nitrogen Story
10:00 AM	BREAK
10:30 AM	Nitrogen and Human Health: Direct and Indirect Impacts
11:00 AM	The Globalization of Nitrogen: Consequences for Terrestrial Ecosystems
11:30 AM	Nitrogen and Aquatic Ecosystems
12:00 – 1:30 PM	BOX LUNCH

CONCURRENT SESSIONS 1:30 – 4:00 PM

Oral Session #7:
Agricultural Nitrogen Losses to Ground and Surface Waters. (Rm 17)
Oral Session #8:
Nitrogen Use in Agricultural Crop Production. (Rm 3)
Oral Session #9:
Forest Soils and the Nitrogen Cycle. (Rm 4)
Oral Session #10:
Nitrogen Dynamics in Asia. (Rm 18)
Oral Session #11:
Nitrogen in Surface Waters. (Rm 9)
Oral Session #12:
Effects of Atmospheric Deposition of Nitrogen. (Rm 1)

4:00 – 4:30 PM	BREAK
4:30 – 5:30 PM	ROUNDTABLE (Rm 3)
5:30 – 7:00 PM	POSTER PUBS (Rm 21)
6:30 – 8:30 PM	Dinner at the Bolger Center Dining Room
6:30 – 9:00 PM	Piedmont Winery Tasting and Dinner (Departure from Reception Building)

Wednesday October 17

"Innovation with Nitrogen"

7:00 AM	Continental Breakfast (Gymnasium) or Buffet in Bolger Dining Room
8:30 AM – 12:30 PM	PLENARY (Gymnasium)
8:30 AM	Reduced Reliance on Mineral Nitrogen, Yet More Food
9:00 AM	Reducing Global NO_x Emissions: Encouraging the Development of Advanced Energy and Transportation Technologies
9:30 AM	Agroecosystems, Nitrogen Management, and Economics
10:00 AM	BREAK
10:30 AM	Nitrogen and Public Policies for Environmental Protection
11:00 AM	Perspectives on Decreases in Nitrogen Emissions – Current Efforts and Future Directions
11:30 AM	Nutrient Management in Food Production: Achieving Agronomic and Environmental Targets
12:00 – 1:30 PM	BOX LUNCH

CONCURRENT SESSIONS 1:30 – 4:00 PM

Oral Session #13:
Policy Options to Improve Nitrogen Use in Agriculture. (Rm 17)
Oral Session #14:
Nitrogen Management in Agricultural Systems. (Rm 1)
Oral Session #15:
Forests, Nitrogen and Surface Waters. (Rm 4)
Oral Session #16:
Market Mechanisms and Nitrogen Management. (Rm 18)
Oral Session #17:
Impacts of Anthropogenic Nitrogen on Coastal Ecosystems. (Rm 3)
Oral Session #18:
Policy Responses to Increased Environmental N. (Rm 19)
Oral Session #19:
Interactions of Carbon and Nitrogen at Regional and Global Scales. (Rm 9)

4:00 – 4:30 PM	BREAK
4:30 – 5:30 PM	ROUNDTABLE (Rm 3)
5:30 – 7:00 PM	POSTER PUBS (Rm 21)
7:00 PM	HARVEST BARBEQUE

Thursday October 18

"Futures: Probable, Possible, Preferable"

7:00 AM	Continental Breakfast (Gymnasium) or Buffet in Bolger Dining Room
8:30 AM – 12:30 PM	PLENARY (Gymnasium)
8:30 AM	Future Visions for Optimizing N Management in Agriculture – Point-Counter Point
9:30 AM	Future Visions for Optimizing N Management in Energy –Point-Counter Point
10:30 AM	BREAK
11:00 AM	Challenge to Participants
11:45 AM	Conference Summary Statement and Concluding Remarks
12:30 PM	LUNCH

THE BOLGER CONFERENCE CENTER

Located near Washington, D.C., in the beautiful hunt country of Potomac, Maryland, the William F. Bolger Center for Leadership Development occupies a tranquil 83-acre setting that blends rolling fields, woodlands and pathways lined with colorful gardens and shrubs. The Bolger Center is one of the most spacious and comfortable conference and training facilities in the Washington, D.C. area. The site of a former monastery, the Center is currently owned and operated by the U.S. Postal Service and is made available for meetings such as the Second International Nitrogen Conference.

The Bolger Center's facilities are modern and comprehensive. With attractive guest rooms and meeting space, intimate areas for socializing, dining and breaks, outdoor and indoor sports equipment, scenic paths and trails for walking or jogging, an ATM (automated teller machine), coin-operated washers and dryers, and a business office equipped with for-fee fax, computer and internet services, the Bolger Center will provide attendees at the Conference a premiere conference experience. During the harvest season in October, 2001, the Center's beautiful grounds will be blazing with color from autumn leaves and foliage.

The Bolger Center was formerly owned by The Sisters of Mercy of the Union, a Catholic religious community, who used the Generalate (Main Building) as a residence and school. They then constructed the St. Maurice School (North Building) for disabled children. In 1980 the United States Postal Service purchased the property for training and a conference center.

LODGING AND MEALS AT THE BOLGER CENTER

Unlike a hotel, the Bolger Center is a genuine conference center. As such, the Bolger Center's rates are inclusive of *both* lodging and meals.

The Bolger Center offers standard sleeping rooms and double sleeping rooms. A standard room is equipped with a double bed which can accommodate one person or a couple. Double rooms are, generally, larger than standard rooms and are equipped with queen size beds or trundles. Double rooms can accommodate a couple (or two individuals). There is a limited number of double rooms which will be reserved for couples/significant others or two registrants sharing a room on a first come basis. Bolger Center sleeping rooms cannot be occupied by more than two people. All rooms are equipped with a desk with telephone and port for Internet access, Satellite cable television, hair dryers, coffee makers, iron and ironing board. All rooms are smoke-free. ADA rooms are available for the physically challenged.

By registering for *full registration with lodging* at the Bolger Center, conference attendees receive a package of three meals and two coffee/juice/soda breaks each day during their stay. As part of registration, overnight attendees are invited to the Welcome Reception on Sunday, October 14.

The *Welcome Reception* for the Second International Nitrogen Conference will be held on Sunday, October 14 from 5:30 to 7:00 PM at the Bolger Center's Reception Building – Lounge and Lounge Terrace. An informal gathering with a cash bar and light hors d'oeuvres, the Welcome Reception is your opportunity to get acquainted with other conference attendees, unwind after the field trips and prepare for the upcoming conference activities.

Meals offered to full registration attendees, spouse/significant others, or two individuals occupying the same room include (*tickets are collected upon entering the Dining Hall*):

Breakfast

6:30 – 8:30 AM Full or Continental Breakfast in the Bolger Center Dining Room *or*
7:00 – 8:30 AM Continental Breakfast in the Gymnasium (Mon, Tues, Wed., Thurs.)

Lunch

12:00 PM – 1:30 PM Monday, Tuesday Wednesday – Box Lunch in the Courtyard
12:00 PM – 1:30 PM Saturday, Sunday, Thursday – Bolger Buffet

Dinner

5:00 – 8:00 PM Bolger Buffet Dinner in the Bolger Center Dining Room
Ticketed dinner events are scheduled for Mon, Tues, Wed. Tickets can be purchased at the registration desk

IMPORTANT:

- The value of any missed meals, or meals taken off-site during a field trip, a tour or the off-site evening event at Piedmont Winery will not be credited against the registration fee.
- Those making an Early departure will not be entitled to a refund for meals or lodging.

There are three ticketed social functions. Two are held at the Bolger Center - the Opening Banquet on Monday, October 15 and the Harvest Barbecue on Wednesday, October 17. The price differential between attendees with full, overnight registration and those with local or one-day only registration reflects the dinner meal credit included in full conference registration. Overnight registrants/spouses receive a discount. Tickets are required for admission to ticketed events. The third ticketed social function is the Piedmont Winery tour and dinner. Check with the registration desk to determine if additional event tickets are available for any of these events.

AREA WEATHER AND ATTIRE

In the Washington, D.C. metro area, the October weather can be changeable. In "Indian Summer" the weather can be quite warm during the day (75-80F/20-25C) but possibly chilly (40-50F/5-10C) in the evenings. You will want to have a sweater, light jacket or raincoat for the evenings. You will also want to bring comfortable walking shoes not only for walking around the Bolger Center campus, but for field trips or tours.

The Bolger Center provides an informal working environment. Ties and jackets are not required. If you want to bring something a little more "dressy" for the Opening Banquet or the Wine Tasting Dinner (optional off-site event) please feel welcome to do so. The Bolger Center does have athletic facilities should you wish to bring clothes for jogging or exercise. (Please be aware that shorts, bare midriffs and halter tops are generally considered inappropriate to wear on visits to historic sites or public buildings in the Washington area.)

GETTING FROM THE AIRPORT TO THE BOLGER CENTER

Shuttles:

Airport shuttles are available at Reagan National Airport, at Dulles International Airport, and at Baltimore-Washington International Airport. *Advance reservations are recommended.* Shuttle charges range from $20 - $45 one way.

To arrange for door to door shuttles, contact SUPER SHUTTLE, 1-800-BlueVan *or* 1-800-258-3826, *or* (703) 416-7873. SUPER SHUTTLE operates 24 hours a day, 7 days a week.

Other Airport Shuttles: Montgomery Shuttle Airport Service, 1-800-590-000 *or* (301) 590-0000. Suburban Airport Shuttle, 1-800-996-9393 *or* (301) 279-2222. Affordable Airport Shuttle, (301) 670-0440.

Taxi Service:

Washington Flyer Taxi also operates door to door service. Call (703) 528-4440 for advance reservations or go to www.flyertaxi.com. Taxi rates are generally higher than those on the SUPER SHUTTLE, however there are no intermittent stops and only minimal charges for additional passengers.

Limousine transportation by town car from the airport can be arranged through California Transportation and Limousine Service. Call 1-800-914-2855. Prices range from $40 to $65 per person with $10 extra over the second passenger. Group Rates are also available.

Other Taxi Services to the Bolger Center: Bolger Center's preferred taxi company is Barwood Taxi, (301) 984-1900. Montgomery Taxi (301) 762-2001 and Regency Cab (301) 990-7000 also serve the Bolger Center.

Metro:

For those without much luggage or time pressure, the least expensive way to get to the Bolger Center is to take the DC Area Metro to Bethesda, Maryland and then catch the complimentary Bolger Shuttle. To ensure that there are no changes in the schedule, you should call the Bolger Center from the airport before embarking. The Bolger Center's telephone number is (301) 983-7000.

To get from Reagan National Airport to the Bethesda Metro Station, take the Blue Line from Reagan National to Metro Center and change to the Red Line heading towards Shady Grove. Get off at the Red Line's Bethesda Metro Station and go to the Metro Bus Stop.

Bolger Center pick up schedule-departure from Bethesda:

SATURDAY	SUNDAY	MONDAY – THURSDAY
11:45 am		
1:00 pm	12:30 pm	
3:15 pm	2:40 pm	
4:30 pm	4:00 pm	
5:45 pm	5:15 pm	5:15 pm
7:00 pm	6:25 pm	6:30 pm
9:00 pm		7:45 pm
10:15 pm		9:00 pm
		10:15 pm
		11:30 pm

DRIVING BY CAR TO THE BOLGER CENTER

A scenic 25 minute drive along the George Washington Memorial Parkway from Reagan National Airport or an equally short drive via express lanes from Dulles International Airport assures those coming from out-of-town easy access to the Bolger Center.

Washington area residents will have an equally easy time getting to the Bolger Center. In non-rush hour traffic, the Bolger Center is 35 minutes from downtown Washington, D.C. and considerably less from Bethesda, Maryland or suburban Virginia.

There is no charge for parking at the Bolger Center.

Driving Directions from Northern Cities (Silver Spring, Baltimore, NYC):

1. Take I-95 South towards Washington.
2. Take I-495 West towards Northern Virginia and Silver Spring.
3. Exit Old Georgetown Road (stay right off the exit).
4. At 3rd light, take left onto Democracy Boulevard.
5. Approximately 5 miles, take a left turn onto Newbridge Drive.
6. Take first right onto Main Entrance-9600 Newbridge Drive.

Driving Directions from South (National Airport, Washington D.C.):

1. Take George Washington Memorial Parkway heading North.
2. Where the GW Parkway intersects with I-495 - head North over the Bridge.
3. Take the River Road Exit (EXIT 39 West) off I-495 and stay to the left on the exit.
4. Take River Road (Rt. 190) West.
5. Turn right onto Falls Road.
6. Turn right onto Democracy Boulevard.
7. Turn right onto Newbridge Drive.
8. Take the first right onto Main Entrance – 9600 Newbridge Drive.

Driving Directions from Dulles Airport:

1. Take the Dulles Access Road toward Washington D.C.
2. Take I-495 North to Exit 39 West – River Road (Rt. 190).
3. Follow #4 through #8 above.

REGISTRATION

REGISTRATION CATEGORIES

The formal program of the Second International Nitrogen Conference begins Monday morning, October 15 and concludes after lunch on Thursday, October 18. Pre-Conference Activities including field trips and a Welcome Reception are scheduled on Sunday, October 14.

Registrants in all categories (*EXCEPT* Spouse/Significant Other) receive Conference Materials, Tote Bag, and unrestricted access to the conference sessions. Registrants in all categories *EXCEPT* Local Registration will receive lodging for four nights (Sunday, October 14 through Wednesday, October 17) and food (dinner Sunday through lunch Thursday - plus daily breaks) for the entire conference, as well as discounts on the price of some ticketed social events. All categories (*INCLUDING* Spouse/Significant Other) are eligible to register for Ticketed Social Functions, Scientific Field Trips, Tours, or the Off Site Piedmont Winery Dinner.

(1) **Full Registration -** includes food, lodging as described above. $1,200 US Dollars

(2) **Student Full Registration** - includes food, lodging as described above. Students MUST fax a copy of your valid student identification card to ESA at 202-833-8775 to qualify for the student rate. $870 US Dollars

(3) **Developing Country Full Registration -** includes food, lodging as described above. Developing Countries includes all countries *EXCEPT* the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Korea, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States. *You must be a resident of the country to qualify for this rate.* $870 US Dollars

(4) **Regular Local Registration -** includes conference materials and access to the conference as described above. Food includes lunch and breaks for 4 days, Monday, October 15 through Thursday, October 18, 2001. $450 US Dollars

(5) **Student or Developing Country Local Registration -** as local registration. See (2) and (3) for definitions of student and developing countries. $430 US Dollars

(6) **Spouse/Significant Other Registration -** includes food (as above) and lodging, Sunday, October 14, 2001 through Wednesday, October 17, 2001. $448 US Dollars

(7) **One-Day Registration** will be accepted only on-site at the conference. One Day registration includes Conference materials, lunch and AM and afternoon Breaks. $190 ONE-DAY

Reservations at the Bolger Center may be extended before the conference (Friday, October 12 and/or Saturday, October 13) or after the conference (Thursday, October 18 and/or Friday, October 19). The pre and post conference lodging and meal charge for these reservations is $195 per day for single person occupancy and $95 per day for the spouse/significant other or second person in the same room - based on availability. *PLEASE USE THE CONFERENCE REGISTRATION FORM OR REGISTER AT THE REGISTRATION DESK* to indicate if you want additional reservations before or after the Second International Nitrogen Conference.

PRESS REGISTRATION

All Members of the press with the appropriate credentials are invited to attend the Conference free of charge. Those who wish to stay at the Bolger Center during the meeting will need to pay for housing costs, but will not be required to pay the meeting registration fees.

TICKETED SOCIAL FUNCTIONS

There are two social events held during the Second International Nitrogen Conference at the Bolger Center for which special tickets are required. These events include dining and entertainment costs that exceed the Bolger Center's normal dinner meal calculation. Attendees, spouses, guests are all welcome to purchase tickets to attend these special events. The ticket price will vary based on whether the ticket is for a registrant with overnight lodging at the Bolger Center or a local registrant or area guest without overnight lodging. Both events include cash bars for beer, wine and spirits.

TK #1 *- N2001 Conference Opening Banquet – Monday, October 15, 2001, 7:00-9:30 PM, Bolger Center North Building*
Celebrate the successful start of the Second International Nitrogen Conference with a festive evening of cuisine and music inspired by America's Chesapeake Bay region. Featuring a sumptuous meal of seasonal and area specialties, including vegetarian options, followed by the popular Bill Elliott jazz quartet, this evening will create a stimulating environment for you to renew old friendships and forge new ones. Maximum – 350 people.
Tickets for Overnight Registrants - $25 per person
Tickets for Local Area Registrants or Guests - $45 per person

TK #2 *- Harvest Barbecue – Wednesday, October 17, 2001, 7:00-9:30 PM, Bolger Center North Building and Courtyard*
To conclude the final evening of the Second International Nitrogen Conference, we have planned an informal event showcasing the bounty of the harvest, best savored in a hearty Pennsylvania Dutch and Amish-style barbecue and buffet. The evening will feature cherished musical traditions of early America performed by a prominent local group, a celebrated trio of musicians performing on instruments of the colonial period. This event will keep your memories of the harvest moon shining until the Third International Nitrogen conference. Maximum – 350 people.
Tickets for Overnight Registrant - $20 per person
Tickets for Local Area Registrants or Guests - $40 per person

OFF SITE ACTIVITIES

On Tuesday evening, October 16, 2001, attendees may elect to spend an evening at the Bolger Center or may choose to visit friends or family located in the Washington D.C. Area. An alternative Tuesday evening activity outside of the Bolger Center is the Wine Tasting and Dinner at the Piedmont Winery located in Middleburg, Virginia. Tickets are required and space is limited.

TK #3 *- Piedmont Winery Tasting and Dinner – Tuesday, October 16, 2001, 6:30-9:00 PM (Coach Bus Departure from Bolger Center Reception Building – 6:30 PM)*
Virginia's Piedmont Winery is the second oldest vineyard and winery in Virginia. Nestled in the Northern Virginia hunt country near

Middleburg, the drive from the Bolger Center to the winery will provide you with enchanting scenery of the Blue-Ridge foothills. After you have been greeted by host and Piedmont owner, Gerhard von Finck, you will enjoy a tasting of Piedmonts' prize wining vintages followed by a three course dinner (the entrée is a choice of salmon pasta or vegetarian pasta) catered by the nearby historic Red Fox Tavern and served in the Winery building. Maximum – 60 people.
Tickets for attendees or guests - $45 per person
Ticket price includes coach bus transportation, salmon pasta or vegetarian pasta dinner, wine tasting and tour of Winery.

TOURS

Due to low turn out, tour #1, the Mount Vernon tour, and tour #3, the Antietam Civil War Battlefield Tour, have been cancelled.

Tour #2 *- VIP *White House Tour and US Holocaust Memorial Museum Tour, Tuesday, October 16, 2001, 7 AM departure, 1 PM return (Coach Van departure and return from the Bolger Center Reception Building) * Due to tightened security, the White House portion of the tour may be cancelled. Please check at registration for program changes.*
It is definitely worth getting up early for this specially arranged VIP tour of the White House, including rooms not visited on the public White House tour. After departing the Bolger Center at 7 AM *promptly*, a box continental breakfast will be provided for you on your coach van and you will arrive at the White House, the Executive Residence of the President of the United States, in time for the 8 AM VIP tour we have arranged. Your docent will engage you with history, anecdotes, and a unique view of this famous building and its equally famous residents. After leaving the White House Yyou will head across the Mall to the Holocaust Memorial Museum for an unforgettable visit. Established by a unanimous vote of Congress, this museum is America's only national memorial to the Holocaust. You will be greeted prior to your tour by one of the Museum's directors and you will have 2 hours to travel at your own pace through the museum's Exhibit "The Holocaust" which chronicles the Holocaust from the Nazi rise in power in 1933 to the fall of the Third Reich in 1945 through artifacts, films, photographs, and eyewitness testimonies. Your coach will return you to the Bolger Center in time for lunch, reflection – and, perhaps, an afternoon nap! Minimum 15 people – Maximum 20 people.
Fee - $30 per person
Fee includes transportation, access to White House and the Holocaust Memorial Museum, and a continental breakfast.

STUDENT VOLUNTEERS

There is an opportunity to serve as a *Student Volunteer* during the Second International Nitrogen Conference. A limited number of students will be selected to serve as projectionists during concurrent sessions, and to assist the conference organizers in other capacities (Registration Volunteers, Ticket Takers, Runners). Only undergraduate or graduate students who are registered for the Conference will be eligible for this assignment. Those student volunteers who fulfill their assignment will receive a registration refund of $100 after the conclusion of the conference.

To be considered, you must:
- Be Registered for the Conference as a Student.
- Indicate on the Registration Form that you want to be considered as a Student Volunteer.
- Plan to attend for the duration of the conference.
- Be willing to work 10 hours in segments ranging from 1 hour to 3 hours.
- Document your hours with a timesheet signed by a con ference organizer or staff.

Only a limited number of positions are available and these will be filled on a first registered, first selected basis.

SCIENTIFIC FIELD TRIPS

Field trips will be offered on Sunday October 14. Attendance on all field trips is limited and advanced reservations are required. There is a charge for field trips to cover transportation (and lunch if applicable). Field trip participants will be picked up at the Bolger Center and returned in time for the Sunday evening opening mixer..

FT #1 *- Monitoring of Urban Ecosystem Nitrogen Fluxes in the Baltimore Ecosystem Study. Sunday, October 14, 2001 8:00 AM – 6:00 PM. Organizer: Dr. Richard Pouyat, US Forest Service and Baltimore Ecosystem Study team. Meet at the Bolger Center Registration Desk, 8 AM.*
This all-day field trip will visit study sites of the Baltimore Ecosystem Study (BES); one of two urban Long-Term Ecological Research (LTER) sites in North America. The BES has been monitoring N loads and concentrations on a weekly basis on the main stem and several subwatersheds of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland, USA. We also have established a series of permanent plots on representative land use/cover types to monitor N fluxes. Our monitoring of N fluxes in an urban landscape is one of only a few such efforts in the world. We will begin the field trip at BES's Baltimore facility at the

University of Maryland Baltimore County campus. Here we will provide an overview of the field trip. From the UMBC campus we will work our way from the highly urbanized portions of the Gwynns Falls to the rural countryside. We will make stops at several stream gauging stations, permanent plots (forests, turf areas, and riparian zones) and neighborhoods along the way. We will show data and discuss the importance of infrastructure, human behavior, and urban environments on N ecosystem processes. For lunch we will stop at a local restaurant for Chesapeake Bay Blue Crabs, one of our local delicacies.
Tickets for attendees or guests - $55 per person
Ticket price includes transportation and lunch.
Maximum – 17 people.

FT #2 *- Nutrient Management in Agricultural Systems in Maryland. Sunday, October 14, 2001 12:30 PM – 5:30 PM. Organizer: Dr. Gary Felton, University of Maryland College Park. Meet at the Bolger Center Registration Desk, 12:30 PM.*
This afternoon field trip will be a three stop tour of local agricultural sites where nutrient management practices are being tested. The first stop will be at a poultry research site that, among other practices, includes a mortality composting facility. The next stop will be at Beltsville Agricultural Research Center (USDA) where ammonia fate and transport is being studied and a wetland is used as a component of a dairy waste treatment system. Finally, we will visit the University of Maryland and look at containerized nursery nutrient management. There will be an opportunity to discuss Urban Nutrient Management and some of the programs unique to the Chesapeake Bay.
Tickets for attendees or guests - $25 per person
Ticket price includes transportation. Lunch is not included.
Maximum 15 people.

INFORMATION FOR PRESENTORS

Slide Preview Rooms 11b, c, & d
Three slide preview rooms, each with 3 slide projectors and one overhead projector will be available for presentoers. A sign up sheet will be posted on the door.

Equipment Check Out
Slide carousels and laser pointers can be signed out for use during the day of your presentation. Concurrent session rooms will be equipped with slide projector and overhead projectors. We can not accommodate LCD projectors in the concurrent sessions.

THE CONFERENCE

OVERVIEW

Humans need food. Humans use energy. Production of both food and energy increases the amount of reactive nitrogen that circulates among the world's atmosphere, soils, forests, and waters.

Building on Results
The First International Nitrogen Conference was held in The Netherlands in March 1998. Aquatic and terrestrial ecologists, marine biologists, agricultural scientists, meteorologists, climatologists, atmospheric chemists and physicists, and biogeochemists came to the consensus realization that dealing with oxidized and reduced forms of environmentally reactive nitrogen separately was no longer tenable scientifically.

Conference Title
The Second International Nitrogen Conference on Science and Policy (N2001): Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection

Conference Purpose
To investigate how the benefits of nitrogen use can be maximized and the detrimental aspects can be minimized.

Conference Goals
- Increase scientific knowledge about nitrogen sources and effects,
- Stimulate communication among leaders in nitrogen production and consumption, and
- Explore balanced policy strategies by which to increase food and energy production while decreasing environmental impacts.

Who Should Participate

The conference is designed to draw participants from four distinct science and policy communities:

1. Biogeochemists who investigate the biological and physical processes of N cycling,
2. N producers and users who mobilize and use nitrogen, or distribute synthetic N fertilizers and encourage increased planting of nitrogen-fixing legumes,
3. Ecologists, agricultural and forest scientists, and atmospheric scientists who characterize N exposure/loadings and investigate the response of crop, forest, and aquatic ecosystems to changing N exposure and availability,
4. Decision makers who are the links between scientific understanding of changing energy-, food-, feed-, and fiber-production systems, changing environmental and economic conditions and perspectives, and appropriate policy responses in various countries of the world.

Pre-Conference Plenary Speakers Workshop

One of the special features of the Conference is the pre-Conference Workshop for Plenary Speakers that convened in April 2001. The Workshop consisted of three intensive days of discussions and integration of the plenary papers prior to presentations at the Conference itself in October 2001. A draft Conference Statement was developed by the plenary speakers and Conference organizers and is available for input from all Conference participants. (see "Conference Statement" section)

Conference Schedule

The Second International Nitrogen Conference is organized around the following four general themes:

Nitrogen Production and Movement
Nitrogen Around the World and its Effects
Innovation with Nitrogen
Probable, Possible, and Preferable Futures

The Conference is composed of a mixture of Plenary and crosscutting, Concurrent Paper and Poster Sessions, followed by Round-Table Discussions to ensure maximum learning, discussion and exchange of information about scientific knowledge and policy options. NitoGenius, "The N Game", a set of real world scenarios developed by the Dutch government as a management tool, will be available for testing and play and results will be announced on Thursday morning. These activities are described in detail in the following sections.

THE CONFERENCE STATEMENT

Prior to the Conference, a set of questions designed to provide information for development of the Conference Statement was sent to Conference participants. Each of you has unique observations, conclusions, hypotheses, or other ideas about nitrogen science and/or policy. We hope you will be willing to join with other participants in providing insight into the present state of nitrogen science and policy and in defining the research and policy-development agendas that will be necessary in the years ahead. The Conference Summary Statement will be used in developing plans for Post-Conference Briefings for Decision Makers that we hope will stimulate further progress in "Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection" in various countries around the world.

PUBLICATIONS

Plenary Papers

The plenary papers will be published in a special issue of the journal AMBIO. AMBIO was founded in 1972, the year of the first UN Conference on the Environment which was held in Stockholm, Sweden. The journal is a nonprofit publication of the Royal Swedish Academy of Sciences. AMBIO addresses the scientific, social, economic, and cultural factors that influence the condition of the human environment. It is widely recognized as an important international forum for debate on these issues.

A Chinese language version of AMBIO is now available. The Chinese version can be located at http://www.ambio-chinese.com. AMBIO in Chinese is translated and printed under the auspices of the Chinese Academy of Sciences, Commission for Integrated Survey of Natural Resources, Beijing. The Chinese version of AMBIO is distributed to major scientific institutions, university libraries, and to individual researchers and decision makers in all fields of sciences.

Contributed Papers

Contributed papers are being collected in an exciting new venue, TheScientificWorldJOURNAL. This is a purely digital, Web based, mulltidisciplinary journal for the life and environmental sciences. The Conference Proceedings will also be bound into a printed volume. This volume will be distributed to all Conference attendees and to selected libraries.

TheScientificWorldJOURNAL offers a single unified environment for the publication of all high-quality science drawn from over a hundred scientific domains within the life, biomedical and environmental sciences. Research work submitted for publication is peer-reviewed by prominent Principal and Associate Editors and a network of leading scientists acting as referees. TheScientificWorldJOURNAL accommodates original scientific articles, reviews, methods & protocols, conference proceedings, and databases. The Web address for the journal is www.scientificworld.com.

Accepted papers form the International Nitrogen Conference will be collected as a Conference Proceedings within TheScientificWorld. Delegates attending the meeting will have free access to the Conference Proceedings until the end of 2002. More details about the new journal and instructions about accessing papers will be provided at the Conference.

POST CONFERENCE BRIEFINGS

During the days and months after the Conference, Post-Conference Briefings will be arranged for leaders in federal, state, and provincial agencies, Congressional and Parliamentary leaders, universities, and Science and Agriculture Attachés in various embassies in Washington DC. These briefings will be based on the Plenary Presentations, Conference Summary Statement, and the Contributed Paper and Poster presentations as summarized by the Discussion Leaders and Moderators of the Round-Table Discussions. These briefings will be critical mechanisms of communication with science and policy leaders in industry, government, and public-interest groups concerned with food and energy production and environmental protection.

The organizers hope that many participants in the Second International Nitrogen Conference will take the lead in arranging similar Post-Conference Policy Briefings within their own and related institutions, businesses, agencies, and countries. These efforts will help ensure that a still further increased understanding of nitrogen and its management will be available for the future.

CONFERENCE SCHEDULE

PLAYING THE N-GAME

Hours of play, Rms 8A & 8B:

Sunday	**7:30 PM – 11:00 PM**
Monday	**7:00 AM – 11:00 PM**
Tuesday	**7:00 AM – 11:00 PM**
Wednesday	**7:00 AM – 11:00 PM**

Introduction to the N – Game: NitroGenius

Jan Willem Erisman, Energy Research Foundation (ECN), Petten, The Netherlands

Sunday October 14 7:00 PM, Rm 4

Monday October 15 12:30 PM, Rm 4

With an eye on the conference theme of optimizing nitrogen management while minimizing its detrimental effects, the conference organizers sought creative ways to make use of the range of expertise that will be gathered over the four days of the conference. The Dutch government met the challenge by sponsoring development of an interactive, computer simulation, "the N-game". The N-game will evaluate a series of alternative management and policy options that will be used to inform the real world management dilemma faced in the Netherlands (http://www.alterra-research.nl/).

The Netherlands provides an example of an intensive agricultural and industrial area where the development of activities during the past decades has led to severe over-fertilization. Critical limits of reactive nitrogen have been exceeded, leading to stress in natural areas, groundwater pollution, eutrophication of surface waters and the North Sea, damage to vegetation, contribution to climate change, and other environmental effects. The challenge that the Dutch government faces is how to solve the problems associated with nitrogen in a way that it is cost-effective and provides a series of real-world scienarios to develop solutions to the Dutch nitrogen problem. Players will work in groups each given a role (politician, farmer, industrialist, environmentalist) and a set of parameters and goals. Each player tries to optimize her or his own personal outcome as well as the team outcome. The winners will be awarded a prize at the end of the conference and the outcomes will be collated for use by the Dutch government.

Computers will be set up to play the N-game, so that attendees can play any time during the Conference. Special sessions to introduce and explain the game will take place on Sunday evening following the welcome mixer and during lunch on Monday. *We hope you will participate in this opportunity to test your knowledge and skills, interact with meeting participants, and have fun while providing information about management and policy options to help meet our common goal!*

PLENARY SESSIONS

The plenary sessions will provide the base from which each day's work will begin. The plenary presentations are designed to provide an integrated assessment across the areas of food production, energy production, and environmental protection.

The Thursday morning plenary session will bring the conference to an end with a focus on the future, a dynamic opportunity to discuss and assess alternative visions of how to get there via a set of point counterpoint panel discussions. There will also be a synthesis of what we have learned and will put to use after the conference.

Speaker bios and abstracts are in later sections. See Table of Contents.

Monday October 15

8:30 AM – 9:00 AM	**Opening Addresses** (Gymnasium) Moderators: Stan Smeulders and Rona Birnbaum Jan Pronk, Minister, Ministry of Housing, Spatial Planning, and Environment, Netherlands Linda Fisher, Deputy Administrator, Environmental Protection Agency, USA *(invited)*
9:00 AM – 12:30 PM	**Nitrogen Production and Movement** (Gymnasium) Moderator: Ellis Cowling
9:00 AM	James Galloway, Professor, Department of Environmental Sciences, University of Virginia, USA *Nitrogen and the World*
9:30 AM	Peter Vitousek, Clifford G. Morrison Professor in Population and Resource Studies, Stanford University, USA *Nitrogen and Nature*
10:00 AM	Break
10:30 AM	Vaclav Smil, Distinguished Professor, Department of Geography, University of Manitoba, Canada *Nitrogren and Food*
11:00 AM	William Moomaw, Professor of International Environmental Policy, Fletcher School of Law and Diplomacy, Tufts University, USA *Energy, Industry and Nitrogen*
11:30 AM	Paul Fixen, Senior Vice President, Potash and Phosphate Institute, USA *Nitrogen Fertilizers … Meeting the Challenge*
12:00 PM	Henry Tyrrell, National Program Leader, US Department of Agriculture's Cooperative State Research, Education, and Extension Service *Nitrogen and Animals*

Tuesday October 16

8:30 AM – 12:00 PM	**Nitrogen Around the World and its Effects** (Gymnasium) Moderator: James Galloway
8:30 AM	Klaas van Egmond, Director, National Institute of Public Health and the Environment, The Netherlands *The European Nitrogen Case*
9:00 AM	Bob Howarth, Senior Marine Scientist, Environmental Defense, USA *The North American Nitrogen Story*
9:30 AM	Congbin FU, Director, START Regional Center for Temperate East Institute of Atmospheric Physics, & Professor, Institute of Atmospheric Physics, Chinese Academy of Sciences *The Asian Nitrogen Story*
10:00 AM	Break
10:30 AM	Jonathan Patz, MD, MPH, Assistant Professor, School of Hygiene & Public Health, Johns Hopkins University *Nitrogen and Human Health: Direct and Indirect Impacts*
11:00 AM	Pam Matson, Richard and Rhoda Goldman Professor in Environmental Studies, Stanford University, USA *The Globalization of Nitrogen: Consequences for Terrestrial Ecosystems*
11:30 AM	Nancy Rabalais, Professor, Louisiana Universities Marine Consortium (LUMCON), USA

Nitrogen and Aquatic Ecosystems

Wednesday October 17

8:30 AM – 12:30 PM	**Innovation with Nitrogen** (Gymnasium) Moderator: Jan Willem Erisman
8:30 AM	Rabindra N. Roy, Senior Officer, Food and Agriculture Organization of the United Nations, Rome *Reduced Reliance on Mineral Nitrogen, Yet More Food*
9:00 AM	Michael Bradley, Principle, Senior Consultant, M.J. Bradley & Associates, USA *Reducing Global NO_x Emissions: Encouraging the Development of Advanced Energy and Transportation Technologies*
9:30 AM	Ken Cassman, Department Head, Agronomy, University of Nebraska, USA *Agroecosystems, Nitrogen Management, and Economics*
10:00 AM	Break
10:30 AM	Jerry M. Melillo, Co-Director, The Ecosystems Center of the Marine Biological Laboratory, Woods Hole, USA *Nitrogen and Public Policies for Environmental Protection*
11:00 AM	Robert Brenner, Deputy Assistant Administrator for Air and Radiation, U.S. Environmental Protection Agency *Perspectives on Decreases in Nitrogen Emissions – Current Efforts and Future Directions*
11:30 AM	Oene Oenema, Principal Research Scientist and Manager, Alterra Green World Research,The Netherlands *Nutrient Management in Food Production: Achieving Agronomic and Environmental Targets*

Thursday October 18

8:30 AM - 12:30 PM	**Futures: Probable, Possible, Preferable** (Gymnasium) Moderator: Rona Birnbaum
8:30 AM	*Future Visions for Optimizing N Management in Agriculture – Point-Counter Point* Ronald Follett, Agricultural Research Service, Department of Agriculture, USA Klaas van Egmond, Director, National Institute of Public Health and the Environment, The Netherlands
9:30 AM	*Future Visions for Optimizing Nitrogen Management in Energy – Point-Counter Point* Nancy Kete, Director, Climate, Energy & Pollution Program, World Resources Institute, USA Robert Socolow, Princeton University, USA
10:30 AM	Break
11:00 AM	*Challenge to Participants* (Gymnasium) Marjanne Sint, Secretary General, Ministry of Housing, Spatial Planning, and Environment, Netherlands Paul Stolpman, Director, Office of Atmospheric Programs, Environmental Protection Agency, USA
11:45 AM	*Conference Summary Statement and Concluding Remarks* James Galloway, N2001 Conference Co-Chair Ellis Cowling, N2001 Conference Co-Chair
12:30 PM	Lunch

CONCURRENT ORAL SESSIONS

1:30 PM – 4:00 PM. Monday – Wednesday

Monday, October 15 - Nitrogen Production and Movement

Oral Session #1: **Nitrogen Use in Agricultural Fertilization Practices.** Rm 1
Chair: John Havlin, North Carolina State University.

1:30 SIMARD, R.R., **N. ZIADI**, M.C. NOLIN, and A.N. CAMBOURIS. Prediction of N fertilizer needs for corn by soil N mineralization indicators.
1:45 **OLNESS, A.**, and D. ARCHER. Factors affecting microbial formation of nitrate-N in soil and their effect on fertilizer-N use efficiency.
2:00 **HADERLEIN, L.,** T. JENSEN, and A. BLAYLOCK. Matching nitrogen release to crop needs, controlled release urea.
2:15 **WILLIAMS, P.H.**, C.S. TREGURTHA, R.J. MARTIN, and G.S. FRANCIS. Managing nitrogen fertilizer for winter vegetable production in New Zealand.
2:30 **MESIC, M.**, A. BUTORAC, F. BASIC, and I. KISIC. Influence of nitrogen fertilization on NO_3- N concentration in lysimeter water.
2:45 **ASADI, M.E.**, R.S. CLEMENTE, A.D. GUPTA, R. LOOF, and N. IZUMI. Effect of N fertigationlization on nitrate leaching and corn yield.
3:00 **CHEN, J.**, Y. HUANG, C.A. ROBINSON, and R.D. CALDWELL. Nitrogen, groundwater, containerized plant production.
3:15 **SRIDHAR, M.K.C.**, G.O. ADEOYE, and O.O. ADEOLUWA. Alternate nitrogen amendments for organic fertilizers.
3:30 **BAH, A.R.,** and A.R. ZAHARAH. Gliricidia (*Gliricidia sepium*) green manures as a potential N source for maize production in the tropics.

Oral Session #2: **Nitrogen Management in Animal Agriculture.** Rm 17
Chair: Rick Kohn, University of Maryland-College Park.
1:30 **HONEYCUTT, C.W.**, R.J. WRIGHT, M.D. JAWSON, B.J. WIENHOLD, B. EGHBALL, K.R. SISTANI, G.E. BRINK, T.S. GRIFFIN, S.L. ALBRECHT, J.M. POWELL, R.A. EIGENBERG, R.K. HUBBARD, S.L. McGOWEN, B.L. WOODBURY, and H.A. TORBERT. Nitrogen mineralization from animal manure: USDA-ARS Nationally Coordinated Research.
1:45 **SINGH, U.**, K.E. GILLER, C.A. PALM, J.K. LADHA, and H. BREMAN. Controlling N release from organic residues: Integrated approach to management of N.
2:00 **MARTIN, J.H., JR.**, and K.F. ROOS. Desorption of ammonia from swine waste lagoons: An evaluation of predictive models.
2:15 MILLER, L.R., W.A. HEAD, N.C. HANSEN, and C.R. DAHLEN. Presented by **ALFREDO DICOSTANZO.** The impact of dietary protein manipulation of feedlot nitrogen balance.
2:30 **ERICKSON, G. E.**, and T. J. KLOPFENSTEIN. Nutritional methods to decrease N volatilization from open-dirt feedlots in Nebraska.
2:45 **ERICKSON, G. E.**, and T. J. KLOPFENSTEIN. Managing N imputs and the effect on N volatilization following excretion in open-dirt feedlots in Nebraska.
3:00 **JONKER, J.S.**, R.A. KOHN, A. GROVE, and A. HIGH. Impact of management practices on nitrogen utilization efficiency in lactating dairy cattle.
3:15 **ONDERSTEIJN, C.J.M.**, G.W.J. GIESEN, A.G.J.M. OUDE LANSINK, and R.B.M. HUIRNE. Limitations to the reduction of nitrogen and phosphate surpluses through nutrient efficiency improvement: Evidence from Dutch dairy farms.
3:30 **OVERLOOP, S.M.M.**, D.E.L.J. VAN , and J.F.M. HELMING. Environment scenarios for the future nitrogen policy in Flanders, Belgium.

Oral Session #3: **Forests and the Nitrogen Cycle.** Rm 4
Chair: John Aber, University of New Hampshire.
1:30 **BARON, J.S.**, H.M. RUETH, A.P. WOLFE, K.R. NYDICK, B. MORASKA, and M.PAGANI. Ecosystem responses to nitrogen deposition in the Colorado Rocky Mountains.
1:45 **CURRIE, W. S.**, and K. J. NADELHOFFER. Decadal-scale C/N interactions in temperate forests assessed with 15N tracer redistributions.
2:00 **BEIER, C.,** H. ECKERSTEN, and P. GUNDERSEN. Modelling nitrogen cycling in a Norway spruce plantation in Denmark by the SOILN model.
2:15 **AKSELSSON, C.,** O. WESTLING, and H. SVERDRUP. Nitrogen leakage from clearcuts.
2:30 **BURNS, D.A.**, and P.S. Murdoch. Effects of a clearcut on net nitrification rates and nitrate leaching in a deciduous forest, Catskill Mountains, New York, USA.
2:45 **RING E.**, L. HOGBOM, and H.Ö. NOHRSTEDT. Effects of brash removal after clearfelling on soil and soil-solution chemistry and field-layer biomass along an experimental N-gradient.

3:00 **EICHHORN, J.,** W. VRIES, and T. HAUSSMANN. European wide assessments of nitrogen cycling in beech forests (*Fagus sylvatica*) - Results from the ICP forests programme.
3:15 **GUNDERSON, P.,** H.L. KRISTENSIEN, and I.K. SCHMIDT. Nitrogen input, cycling and leaching in European forests: Differences between conifer and broad leaf stands.
3:30 **VAN MIEGROET, H.,** N.S. NICHOLAS, and I.F. CREED. Spatial variability in N saturation in high-elevation spruce-forests of the southeastern U.S.A.
3:45 **MARTINELLI, L.A.,** P.M. VITOUSEK, and A. KRUSCHE. Nitrogen in the tropics: What are the differences?

Oral Session #4: **Ammonia: Sources, Emissions and Transport.** Rm 9
Chair: Robin Dennis, US Environmental Protection Agency/ National Oceanographic and Atmospheric Administration.
1:30 **DENTENER, F.** Global modeling of NH_3: what do we know?
1:45 **BAEK, B.H.,** and V. P. ANEJA. Measurement, analysis, and modeling of the relationship between ammonia, acid gases, and fine particles.
2:00 **ALEBIC-JURETIC, A**. Airborne Ns (NO_2 and NH_3) in the Rijeka Bay area (Croatia).
2:15 **DENNIS, R.L.** Ammonia deposition and airsheds and their relation to inorganic nitrogen deposition.
2:30 **ANDERSON, N. J.**, R.S. STRADER, and C. I. DAVIDSON. Ammonia emissions and their sources across the United States.
2:45 **GILLILAND**, A.B., R.L. DENNIS, S.J. ROSELLE, and T.E. PIERCE. Inverse modeling to estimate the seasonality of airborne ammonia emissions.
3:00 **HARRIS, D.B.**, R.A. SHORES, C.A. VOGEL, J.A. WALKER, D.F. NATSCHKE, and K. WAGONER. Seasonal emissions of ammonia from tunnel ventilated swine finishing barns.
3:15 **ROBARGE, W.P.**, D. WHITALL, B. HENDRICKSON, H. PAERL, J. WALKER, G. MURRAY, J. CHAUHAN, and T. MANUSZAK. Comparison of atmospheric ammonium at three sites in eastern North Carolina, USA.
3:30 **SKYBOVA, M.** The decreasing of ammonia emission in the Czech Republic.
3:45 **HENSEN, A.**, and J. MOSQUERA. Sources of N: NH_3 & N_2O plume measurements.

Oral Session #5: **Atmosphere-Biosphere: N_2O and NO Emissions.** Rm 18
Co-Chairs: Sybil Seitzinger, Rutgers University, & Carolien Kroeze, Wageningen University.
1:30 **KROEZE, C.**, and S.P.S. SEITZINGER. Future trends in worldwide river nitrogen transport and related nitrous oxide emissions
1:45 **DAVIDSON, E.A.**, M. M. C. BUSTAMANTE, and A. S. PINTO. Updated review of soil emissions of NO and N_2O from forests, savannas, and cattle pastures of Brazil.
2:00 **WICK, B.,** E. VELDKAMP, W. ZAMBONI DE MELLO, and M. KELLER. Linking microbial activities and nitrogen availability to nitrous oxide fluxes in forest-derived pasture sites in the humid tropics of Brazil.
2:15 **HARRISON, J.**, and P. MATSON. Nitrous Oxide (N_2O) emission from drainage waters of an intensively farmed, subtropical valley.
2:30 **KHALIL, M.I.**, A.B. ROSENANI, O. VAN CLEEMPUT, C.I. FAUZIAH, and J. SHAMSHUDDIN. Nitrogen management in a maize-groundnut crop rotation of humid tropics: effect on N_2O emission.
2:45 **BOBBINK, R.**, and M.M. HEFTING. N enrichment and the emission of the greenhouse gas N_2O from wetlands.
3:00 **WALLENSTEIN, M.D.** Environmental and microbial controls on denitrification under elevated nitrogen inputs.
3:15 **TSURUTA, H.**, H. AKIYAMA, Y. NAKAJIMA, W. CHENG, and S. SUDO. Nitrous oxide and nitric oxide emissions from fertilized soils and mitigation options.
3:30 **SMITH, K.A.**, and K.E. DOBBIE. N_2O emissions from temperate agricultural soils: main drivers, possible mitigation procedures, and implications for inventory calculations.
3:45 **YAMULKI, S.** Nitrous oxide emissions from grassland systems: Interactions between soils, management and animals.
4:00 **ROELLE, P.A.**, and V. P. ANEJA. Modeling NO emissions from biosolid amended soils.

Oral Session #6: **Atmospheric Deposition of Nitrogen.** Rm 3
Chair: Richard Artz, National Oceanographic and Atmospheric Administration.
1:30 **LYNCH, J.A.**, and V.C. BOWERSOX. Annual and seasonal trends in nitrate concentration in the USA and their relationship to emissions.
1:45 **NILLES, M.A.**, and B.E. CONLEY. Trends in wet deposition of ammonium and nitrate in the United States, 1985-2000.
2:00 **SICKLES, J. E., II.** Deposition of oxidized nitrogen in the Eastern United States.
2:15 **LEAR, G.G.**, and D.W. SCHMELTZ. Spatial and temporal trends in total nitrogen deposition for the U.S.
2:30 **TARNAY, L. W.**, and A.W. GERTLER. Nitrogen deposition in the Lake Tahoe Basin: Scaling from leaf to landscape using G.I.S.
2:45 **RUSSOW, R.W.B.,** F. BOHME, and H-U. NEUE. A new approach to determine the total airborne N-input into the soil-plant system using the 15N isotope dilution (ITNI): Results for agricultural used areas of central Germany.
3:00 **CAPE, J.N.**, A.P. ROWLAND, and T.D. JICKELLS. Organic nitrogen in precipitation: Real problem or sampling artifact?

3:15 **SUTTON, M.,** S. TANG, D. FOWLER, R.I. SMITH, N. FOURNIER, and K.J. WESTON. Spatial analysis of ammonia and ammonium in the UK: Comparison of model estimates with measurements from the national monitoring network.

3:30 STENSLAND, G.J., **V.C. BOWERSOX**, B. LARSON, and R.D. CLAYBROOKE. Comparison of ammonium in USA wet deposition to ammonia emission estimates.

3:45 **PRYOR, S.C.**, R.J. BARTHELMIE, M. CARREIRO, M.L. DAVIS, A. HARTLEY, B. JENSEN, A. OLIPHANT, J.C. RANDOLPH, and J.T. SCHOOF. Nitrogen deposition to a mid-latitude deciduous forest and ecosystem response.

Tuesday, October 16 – Nitrogen Around the World and its Effects

Oral Session #7: **Agricultural Nitrogen Losses to Ground and Surface Waters.** Rm 17
Chair: Mary Ann Rozum, US Department of Agriculture.

1:30 **BURKART, M.R.**, and J.D. STONER. Effects of agricultural systems on nitrogen in groundwater.

1:45 **DRURY, C.F.**, C.S. TAN, T.O. OLOYA, and J.D. GAYNOR. Reducing tile nitrate loss with watertable management systems.

2:00 OVERBEEK, G.B.J., **A. TIKTAK,** and A.H.W. BEUSEN. Validation of the Dutch model for emission and transport of nutrients (STONE).

2:15 **STAVER, K.W**. Increasing nitrogen and carbon retention in coastal plain agricultural watersheds.

2:30 **STROCK, J.S.**, M.P. RUSSELLE, and P.M. PORTER. Environmental variability and cover crop capacity for reducing nitrate losses from tile drainage.

2:45 **TOTH, J.D.**, Z. DOU, J.D. FERGUSON, and D.T. GALLIGAN. Nitrate leaching losses affected by nutrient inputs and crops.

3:00 **WALTHALL, C. L.**, and T. J. GISH. An innovative approach for locating and evaluating subsurface losses of nitrogen.

3:15 **GRANLUND, K.**, and S. REKOLAINEN. Estimation of nitrogen load on catchment scale- Testing of existing methodologies on a well-instrumented watershed.

Oral Session #8: **Nitrogen Use in Agricultural Crop Production.** Rm 3
Chair: Robert Wright, US Department of Agriculture.

1:30 **USHERWOOD, N.R.**, and W.I. SEGARS. Nitrogen interactions with phosphorus and potassium for optimum crop yield, nitrogen use effectiveness and environmental stewardship.

1:45 **BAKER, J.L.** The potential of improved nitrogen management to reduce nitrate leaching and increase use efficiency.

2:00 SULLIVAN, W.M., and **Z. JIANG**. Nutrient monitoring and management for turfgrass sod farms and golf courses.

2:15 **WIESLER, F.,** T. BEHRENS, and W.J. HORST. The role of nitrogen-efficient cultivars in sustainable agriculture.

2:30 **HASEGAWA, H.** High-yielding rice cultivars perform best even at reduced nitrogen fertilizer rate.

2:45 **YANG, C.M.** Estimation of leaf nitrogen content from spectral characteristics of rice canopy.

3:00 **NÄSHOLM, T.**, J. ÖHLUND, A. NORDIN, and J. PERSSON. Plant uptake and use of organic nitrogen sources.

3:15 **SNAPP, S.**, D. ROHRBACH, and S. SWINTON. Improving nitrogen efficiency: Lessons from Malawi and Michigan.

3:30 PALM, C.A, D.N. MUGENDI, P. MAPFUMO, B. JAMA, and K.E. GILLER. Presented by **PAUL SMITHSON**. Reversing N deficits on African smallholder farms.

Oral Session #9: **Forest Soils and the Nitrogen Cycle.** Rm 4
Chair: Gary Lovett, Institute of Ecosystem Studies.

1:30 **FOSTER, N.**, F. BEALL, P. HAZLETT, R. SEMKIN, S. SCHIFF, I. CREED, and D. JEFFRIES. Sources of exported nitrogen from first-order forested basins at the Turkey Lakes watershed.

1:45 **COMPTON, J.E.**, M.R. CHURCH, and S.T. LARNED. Controls on nutrient losses from a forested basin in the Oregon Coast Range.

2:00 **GILLIAM, F.S.**, B.M. YURISH, and M.B. ADAMS. Temporal and spatial variation of nitrogen transformations in nitrogen-saturated soils of a central Appalachian hardwood forest.

2:15 **AUSTIN, A.T.** and O. E. SALA. Controls on nitrogen cycling along a natural rainfall gradient in Patagonia, Argentina.

2:30 **BALSER, T.C.**, P. MATSON, and P. VITOUSEK. Impact of soil nutrient availability on microbial community composition in Hawaiian tropical soils.

2:45 **LOHSE, K.A.**, and P.A. MATSON. Consequences of experimental nitrogen additions on nitrate soil solution losses from Hawaiian wet tropical forests of different nutrient status: Patterns and regulation.

3:00 KJONAAS, O.J., and **A.O. STUANES**. Ten years of nitrogen addition to an N limited coniferous forest catchment in Sweden: Effects of nitrogen pools and fluxes.

3:15 **MAYER, P.**, JORGENSEN, E., and A. WEST. Effects of exogenous N addition, mammalian exclusion, and detritivore diversity on decomposition in old fields.

3:30 **DAVIDSON, E.A.**, D.B. DAIL and J. CHOROVER. Rapid abiotic immobilization of nitrate in an acid forest soil.

3:45 **GUNDERSEN, P.**, N.B. DISE, W. DE VRIES, B. EMMETT, M. FORSIUS, J. KJØNS, E. MATZNER, K. NADELHOFFER, and A. TIETEMA. Carbon - nitrogen interactions in forest ecosystems (CNTER) – Estimates of soil N and C sequestration based on empirical relationships.

Oral Session #10: ***Nitrogen Dynamics in Asia.*** Rm 18

Chair: Zhao Liang ZHU, Chinese Academy of Sciences.

1:30 **BASHKIN, V.** Critical loads of nitrogen: Eurasian experience and worldwide perspectives.

1:45 **VAN DER HOEK, K.W.** Nitrogen requirements for human food and animal feed production in the European Union and India.

2:00 **XING, G.X.,** and Z.L. ZHU. Nitrogen and environment in China.

2:15 **LARSSEN, T.**, J. MULDER, P.T. YU, J.S. XIAO, and D. ZHAO. Nitrogen leaching from forested catchments in Southwest China - Preliminary data and research needs.

2:30 **DOMAGALSKI, J.L.**, R.J. SHEDLOCK, L. CHAO, and Z. XINQUAN. Comparative ground water quality assessment of the Tangshan Region of the Hai He River basin, People's Republic of China, and similar areas in the United States.

2:45 **ELLIS, E. C.**, R.G. LI, L.Z.YANG, and X. CHENG. Measuring and mediating nitrogen saturation in densely populated Chinese villages.

3:00 **YAGI, K.**, Y. HOSEN, R. ZHANG, Y. ZUO, and Z. LI. Nitrogen flows in agro-ecosystems of Lingxian County, Shandong Province, China.

3:15 **PATEL, K.S.**, K. SHRIVAS, K. AGRAWAL, R.M. PATEL, G.L. MNUDHARA, and M. L. NAIK. Nitrogen production, extent, movement and impact in central India.

3:30 **PUSTE, A.M.**, and D.K. DAS. Optimization of aquatic-terrestrial ecosystem in relation to soil nitrogen status for the cultivation of fish and aquatic food crops of Indian sub-tropics.

3:45 **SHINDO, J.**, N. OURA, T. FUMOTO, H. TODA, and H. KAWASHIMA. Nitrogen cycle in East Asian ecosystems affected by increasing emission of anthropogenic nitrogen compounds.

Oral Session #11: ***Nitrogen in Surface Waters.*** Rm 9

Chair: Jeff Stoner, U.S. Geological Survey.

1:30 **CHAPMAN, P.J.**, and A.C. EDWARDS. The nitrogen and phosphorus content of upland streams in the UK: Form, concentration and biological significance.

1:45 JANSE, J.H., W. LIGTVOET, S. VAN TOL, and **A.H.M. BRESSER**. A Model study: The role of wetland zones in lake eutrophication.

2:00 **WILLIAMS, M.W.**, E. HOOD, and W.H. MCDOWELL. A novel indicator of ecosystem N status: Ratio of DIN to DON in annual riverine flux.

2:15 VALETT, H.M., J.R. WEBSTER, P.J. MULHOLLAND, C.N. DAHM, and C.G. PETERSON. Presented by **STEVEN A. THOMAS**. Nitrate processing and retention in streams (NPARS): Distinguishing benthic and interstitial contributions to energy flow and nutrient retention.

2:30 **DAVID, M.B.**, G.F. McISAAC, T.V. ROYER, J.L. TANK, and L.E. GENTRY. The nitrogen mass balance of an agricultural and artificially drained state: Past and current.

2:45 STONER, J.D., **D.K. MUELLER,** and B.T NOLAN. Nitrogen in streams and shallow aquifers in the United States-The land-use connection.

3:00 **GOOLSBY, D.A.**, and W.A. BATTAGLIN. Nitrogen sources and fate in the Mississippi River Basin.

3:15 **McISAAC, G.F.**, M. B. DAVID, and D. A. GOOLSBY. Net Anthropogenic N Input to the Mississippi River Basin and Nitrate flux in the Lower Mississippi River 1955-1998.

3:30 **ALEXANDER, R.B.**, R.A. SMITH, and G.E. SCHWARZ. The regional transport of nitrogen in streams and reservoirs: Insights from experimental observations and empirical watershed models.

3:45 VAN DRECHT, G., **A.F. BOUWMAN**, J.M. KNOOP, C. MEINARDI, and A. BEUSEN. Global estimation of the N loading of riverine systems from diffuse and point sources.

Oral Session #12: ***Effects of Atmospheric Deposition of Nitrogen.*** Rm 1

Chair: Kathy Tonnessen, National Park Service.

1:30 **BOBBINK, R.** The impacts of air-borne nitrogen pollutants on diversity: An European overview.

1:45 **CAMPBELL, D.H.**, M.A. MAST, D.W. CLOW, L. NANUS, G.P. INGERSOLL, and T. BLETT. Response of aquatic ecosystems to nitrogen deposition in the Rocky Mountains.

2:00 **BYTNEROWICZ, A.**, M. FENN, P. PADGETT, M. ARBAUGH, and M. POTH.. Deposition and effects of nitrogen deposition in California ecosystems.

2:15 **ALLEN, E.B.**, L. EGERTON-WARBURTON, C. SIGUENZA, and A.G. SIRULNIK. Effects of N deposition on plants and soil microorganisms on an urban to rural gradient in southern California.

2:30 **WEISS, S.B.** Mitigation strategies for N-deposition sources in South San Jose, CA: Checkerspot butterflies, powerplants, and the information superhighway.

2:45 **LAWRENCE, G.B.** Accumulation of nitrogen in forest soils continues to cause episodic acidification of streams in calcium-depleted watersheds.

3:00 **BREWER, P.F.**, T. SULLIVAN, B. J. COSBY, and R. K. MUNSON. Responses of forests and streams in Southern Appalachian mountains to changes in S, N, and base cation deposition.

3:15 **PAN, Y.**, J. HOM, K. MCCULLOUGH, and J. ABER. The impacts of increasing atmospheric nitrogen deposition on forest ecosystems and watersheds in the Chesapeake Bay Region.
3:30 SHERWELL, J. Presented by **MARK GARRISON.** Evaluation of the Calpuff model using NADP/NTN and CASTNET data.
3:45 MCCUBBIN, D.R., **B.J. APELBERG**, S. ROE, and F. DIVITA. Animal feeding operations, ammonia, and particulate health effects.

Wednesday, October 17 - Innovation with Nitrogen

Oral Session #13: **Policy Options to Improve Nitrogen Use in Agriculture.** Rm 17
Chair: Teresa Gruber, Council for Agricultural Science and Technology.
1:30 **DABERKOW, S.**, H. TAYLOR, N. GOLLEHON, and M. MORAVEK. Farmer behavioral changes in response to a regulatory and education program to improve nitrogen use and management.
1:45 **DALGAARD, T.**, J.C. KJELDSEN, N.J. HUTCHINGS, and J.F. HANSEN. N-losses and energy consumption in regional scenarios for conversion to organic farming.
2:00 **DINNES, D.L.**, D.B. JAYNES, D.W. MEEK, C.A. CAMBARDELLA, T.S. COLVIN, D.L. KARLEN, and J.L. HATFIELD. Reducing N contamination of surface waters from tile-drained soils at the watershed scale.
2:15 **FRATERS, B.,** L.J.M. BOUMANS, and T.C. VAN LEEUWEN. Monitoring effectiveness of the Dutch mineral policy in agriculture in clay regions by monitoring shallow groundwater nitrogen.
2:30 **OSMOND, D.L.**, L. XU, N.N.RANELLS, S.C. HODGES, R. HANSARD, and S.H. PRATT. Nitrogen loss estimation worksheet (NLEW): An agricultural nitrogen loading reduction tracking tool.
2:45 **SCHARF, P.C.**, N.R. KITCHEN, J.G. DAVIS, K.A. SUDDUTH, and J.A. LORY. Innovative nitrogen management systems for maize: Matching crop needs across variable landscapes.
3:00 **SLAK, M.F.,** L. COMMAGNAC, and P. POINTEREAU. Nitrogen exchanges: Testing the hypothesis of a country without agricultural production.
3:15 **THEOBALD , M.R.,** C. MILFORD, K.J. HARGREAVES, and L.J. SHEPPARD. Assessing the use of woodlands as a novel measure to reduce net ammonia emissions at a farm level.
3:30 **VAN DER PLOEG, R.R.**, and P. SCHWEIGERT. About use and misuse of nitrogen in agriculture: The German story.
3:45 **ASMAN, W.A.H.**, B.E. MÜNIER and J.M. ANDERSEN. A decision tool for local ammonia policy.

Oral Session #14: **Nitrogen Management in Agricultural Systems.** Rm 1
Chair: Thomas Christensen, U.S. Department of Agriculture.
1:30 **POWER, S.A.**, C.G. BARKER, and J.N.B. BELL. Habitat management as a tool to modify ecosystem impacts of nitrogen deposition.
1:45 **SMITHSON, P.C.**, B. JAMA, F. AKINNIFESSI, and P.M. MAFONGOYA. Organic and inorganic integration for nitrogen management in Eastern and Southern Africa.
2:00 **WILSON, E.**, P. J. CHAPMAN, and A. McDONALD. Merging nitrogen management and renewable energy needs.
2:15 **DE VRIES, W.,** H. KROS and O. OENEMA. Impacts of structural agricultural changes and farming practices on nitrogen fluxes in the Netherlands.
2:30 **BRINK, J.C.**, E.C. VAN IERLAND, and L. HORDIJK. Interrelations between abatement of ammonia, nitrous oxide, and methane from European agriculture: A cost-effectiveness analysis.
2:45 **SHAFFER, M.J.**, B. J. NEWTON, and C.M.GROSS. An internet-based simulation model for nitrogen management in agricultural settings.
3:00 **HATFIELD, J. L.**, and J.H. PRUEGER. Increasing nitrogen use efficiency in Midwestern cropping systems.
3:15 HUTMACHER, R. B., R. L. TRAVIS, **R.L. NICHOLS**, W. RAINS, B. ROBERTS, R. VARGAS, W. WEIR, D. MUNK, S. WRIGHT, B. MARSH, and F. FRITSCHI. New guidelines for nitrogen use in California cotton.

Oral Session #15: **Forests, Nitrogen and Surface Waters.** Rm 4
Chair: Bruce Peterson, Woods Hole Marine Biological Laboratory.
1:30 **DISE, N.B.**, and E. MATZNER. Regional patterns in nitrogen dynamics across Europe.
1:45 **SCHLEPPI, P.** Nitrate leaching from forests: Different processes at different time scales?
2:00 **MERILÄ, P.,** A. SMOLANDER, and R. STRÖMMER. Soil nitrogen transformations along a primary succession transect on the land-uplift coast in western Finland.
2:15 **ESHELMAN. K.N.**, D.A. FISCUS, N.M. CASTRO, J.R. WEBB, and F.A. DEVINEY, Jr. Regionalization of disturbance-induced nitrogen leakage from mid-Appalachian forests using a linear systems model.
2:30 **WILLIARD, K.W.J.**, D.R. DEWALLE, and P.J. EDWARDS. Geologic control of stream nitrate concentrations from forested watersheds of the northeastern United States.
2:45 **LOVETT, G.M.**, K.C. WEATHERS, and M.A. ARTHUR. Factors controlling stream water nitrate concentrations in forested watersheds of the Catskill Mountains, New York.

3:00 **HOOD, E.W.**, M.W. WILLIAMS, and D.M. MCKNIGHT. Quality and sources of DON in forested and alpine catchments, Colorado Front Range.
3:15 **DEWALLE, D.**, M.T. GOCKLEY, M. O'DRISCOLL, and J. CHOROVER. Upland versus hyporheic nitrogen losses on an Appalachian forest watershed.
3:30 **PETERSON, B.J.** Nitrogen transformations in stream channels of small watersheds.

Oral Session #16: **Market Mechanisms and Nitrogen Management.** Rm 18
Chair: Rick Haeuber, Clean Air Markets Division, US Environmental Protection Agency; Chris Dekkers, Dutch Ministry of Environment.
1:30 **BENKOVIC, S.R.**, and J. KRUGER. To trade or not to trade? Criteria used in determining the applicability of cap and trade to environmental problems.
1:45 **DUNHAM, S.**, and A. MINGST. NOx Emissions trading in the United States: Lessons from program development and implementation.
2:00 **VAN AMBURG, B.** An enhanced rate-based emission trading program for NOx : The Dutch Model.
2:15 **DEKKERS, C.P.A.** NOX emission trading in an European context: Discussion of the economic, legal and cultural aspects.
2:30 **GREENHALGH, S.**, and P. FAETH. A nitrogen reduction strategy addressing the 'Dead Zone' in the Gulf of Mexico.
2:45 VAN DER LINDEN, J. Presented by **JAN GROENVELD.** Tradeable manure production rights as a tool for tackling the mineral surplus in the Netherlands.
3:00 FAETH, P., and **S. GREENHALGH.** Nutrient trading - The pathway to the future?
3:15 DORING, O.C., R. HEIMLICH, F. HITZHUSEN, R. KAZMIERCZAK, L. LIBBY, W. MILON, A. PRATO, and **M. RIBAUDO**. Economics as a base for large scale nitrogen control decisions.

Oral Session #17: **Impacts of Anthropogenic Nitrogen on Coastal Ecosystems.** Rm 3
Chair: Hans Paerl, Univ. of North Carolina at Chapel Hill.
1:30 **BOYNTON, W. R.** Chesapeake Bay eutrophication: Historical and recent patterns of nutrient inputs, effects on water quality, fate of nutrients, and likely responses to load reductions.
1:45 **ELMGREN, R**, and U. LARSSON. Nitrogen and the Baltic Sea.
2:00 BINTZ, J., B. BUCKLEY, and S. GRANGER. Presented by **S.W. NIXON**. Nutrient enrichment and temperature increases in coastal lagoon ecosystems.
2:15 **HOPKINSON, C.S.,** and R.W. HOWARTH. Predicting estuarine susceptibility to eutrophication from nutrient loading.
2:30 **GREENING, H.S.**, and B.D. DEGROVE. Implementing a nitrogen management strategy in Tampa Bay, Florida: A public/private partnership.
2:45 **PAERL, H.W.**, D.R. WHITALL, and R.L. DENNIS. Integrating atmospheric deposition of nitrogen in estuarine and coastal nutrient cycling and eutrophication dynamics.
3:00 **DETTMANN, E.H.**, and H.A WALKER. Sensitivity of nitrogen concentrations in estuaries to loading and water residence time: Application to the Potomac estuary.
3:15 **DORTCH, Q.**, M.L. PARSONS, R.E. TURNER, and A.F. MAIER. Harmful algal blooms in Louisiana coastal waters clearly linked to N inputs.
3:30 **GLIBERT, P.M.** Organic nitrogen and harmful algal blooms.

Oral Session #18: **Policy Responses to Increased Environmental Nitrogen.** Rm 19
Chair: Wim de Vries, ALTERRA Green World Research
1:30 **POSCH, M.**, J.P. HETTELINGH, and P. MAYERHOFER. Past and future exceedances of nitrogen critical loads in Europe.
1:45 **BULL, K.R.** Beyond the 1999 Gothenburg Protocol - The next step towards future goals.
2:00 **BULL, K.R.** The 1999 Gothenburg Protocol - a step towards effective nitrogen emission controls?
2:15 **DE VRIES, W.**, H. KROS, O. OENEMA, and J.W. ERISMAN. Assessment of nitrogen production ceilings on a regional scale avoiding adverse environmental impacts.
2:30 JONSON, J.E., L. TARRASÓN, and **FAGERLI, H.** Variations in the spatial distribution of present and future levels of nitrogen concentrations and depositions in Europe.
2:45 **FASSBENDER, A.G.** Ammonia recovery process economics.
3:00 **BARTROLI J.**, M.J. MARTIN, and M. RIGOLA. Material flow analysis for nitrogen cycle management at local level: The example of Catalonia (Spain).

Oral Session #19: **Interactions of Carbon and Nitrogen at Regional and Global Scales.** Rm 9
Chair: Arvin Mosier, US Department of Agriculture.
1:30 **LACAUX, J.P.** Nitrogen Deposition In Tropical Africa.
1:45 **WALLMAN, P.**, and H. SVERDRUP. Modeling nitrogen and carbon emissions/sequestrations in a forested area in southern Sweden as a result of management during the period 1450 to 2050.
2:00 **DRINKWATER, L.** Re-coupling carbon, nitrogen and phosphorus cycles in agroecosystems.

2:15 **FOWLER, D.**, M. SUTTON, S. TANG, R. SMITH, and U. DRAGOSTIS. Application of atmospheric mass budgets of fixed nitrogen at the country scale.

2:30 **HICKS, W.K**, P. INESON, and J.C.L. KUYLENSTIERNA. Responses of terrestrial ecosystems to nitrogen enrichment- Impacts and issues at global scale.

2:45 **PARTON, W.J.**, S.J. DEL GROSSO, E.A. HOLLAND, A.R. MOSIER, D.S. SCHIMEL' D.S. OJIMA, R. BRASWELL, OLIVER BOSSDORF, and R. MCKEOWN. Global patterns for nitrogen cycling for terrestrial ecosystems.

3:00 **BAKER, L.A.**, D. HOPE, J. EDMONDS, Y. XU, and L. LAUVER. Factors controlling N cycling in the Central Arizona-Phoenix ecosystem.

3:15 **GROFFMAN, P.M.**, K.T. BELT, L.W. BAND, and G.T. FISHER. Nitrogen fluxes in urban watersheds.

3:30 **BOYER, E.W.**, R.W. HOWARTH, and C.L. GOODALE. Effects of anthropogenic nitrogen loading on riverine nitrogen export.

POSTER SESSIONS

(On display 10:00 AM – 7:00 PM; Poster Pubs 5:30 PM – 7:00 PM)

Posters will be available for viewing throughout the day in Rooms 19 and 21 on Monday and Room 21 on Tuesday and Wednesday. "Poster pubs" will be held from 5:30 – 7:00 Monday through Wednesday to provide an opportunity to view the posters and discuss them with the authors while enjoying light hors d'oeuvres and a cash bar. Posters should be set up between 7:00am and 10:00am and removed between 7:00pm and 9:00 pm.

Monday, October 15 - Nitrogen Production and Movement

Poster Session #1: ***Nitrogen Use in Agricultural Fertilization Practices.***
Chair: John Havlin, North Carolina State University

ARULMOZHISELVAN, K. and M.GOVINDASWAMY. Fitting labeled N recovery parameter in fertilizer prescription model.BRONSON, K.F., T. CHUA, **A.R. MOSIER**, R.J. LASCANO, J.W. KEELING, and J.D. BOOKER. Multi-spectral reflectance in irrigated cotton for reduced nitrogen fertilization and residual soil nitrate.

CLAPP, J.G. Urea-triazone nitrogen characteristics and uses.

EGAMBERDIEVA, D., M. MAMIEV, and S. POBEREJSKAYA . The influence of mineral fertilizers combined with a nitrification inhibitor on microbial populations and activities under cotton cultivation, Uzbekistan.

ISIRIMAH, N.O., C. IGWE, and **S.A. AKELE**. Bioavailable nitrogen content in organic wastes of municipal solid wastes at the dumpsites in Port Harcourt and environs, Rivers state Nigeria.

KOCH, R., J. A. HOUNTIN, and R. ANTICO. Do green manure-managed soils minimize nitrogen leaching over time?

SKARIC, Z., M.MESIC, F. BASIC, and I. KISIC. Influence of nitrogen fertilization on the lettuce yield and on NO3- N concentration in lysimeter water.

SUMMERS, K, **S.B. ROY**, R. MUNSON, R. GOLDSTEIN. Effects of timing of fertilizer use in watersheds on biological impacts in receiving waters.

Poster Session #2: ***Nitrogen Management in Animal Agriculture.***
Chair: Rick Kohn, University of Maryland-College Park.

BOYER, D.G., and D.P. BELESKY. Spatial distribution of nitrogen on grazed karst landscapes.

HUTCHINGS, N.J., B.M. PETERSEN, J. BERNTSEN, and **T. DALGAARD.** Detecting conflicts in nitrogen management policies using the Fasset Farm Model.

LEFCOURT, A., and **J. MEISINGER.** Effect of Adding Alum and Zeolite to Dairy Slurry on Ammonia Volatilization.

SHERWELL, J., D. BROWN, A. CRESSMAN, and G. WALTERS. Full-scale Poultry Litter Test Burn.

SLAK M.-F., L. COMMAGNAC, and P. POINTEREAU. Nitrogen mobilisation by human beings, pets, animals and livestock, environmental impact of nitrogen sources.

STOUT, W.L., J. DELEHOY and L.D. MULLER. Managing N for milk production and water quality.

Poster Session #3: ***Forests and the Nitrogen Cycle.***
Chair: John Aber, University of New Hampshire.

ABER, J., S. OLLINGER, R. FREUDER, C. DRISCOLL, G. LIKENS, R. HOLMES, and C. GOODALE. Temporal changes in nitrate loss from forested ecosystems in response to physical, chemical, biotic, and climatic perturbations.

ARMOLAITIS, K.E., and V.V.STAKNAS. The recovery of damaged forest ecosystems in areas formerly polluted by nitrogen.

CHANG, S.X., and D.J. ROBISON. Genotypic effects on seedling sweetgum nitrogen use efficiency.

ERICSON, L. Vegetation responses upon nitrogen: The effect of natural enemies.

FENN, M.E., and M.A. POTH. A case study of nitrogen saturation in Western U.S. forests.

HERRMANN, M., W.E. SHARPE, and **D.R. DEWALLE**. Nitrogen export from a watershed subjected to partial salvage.

KORORI, S.A.A., M. MOHAGHEGH, A. SALAHI, and M. KHOSHNEVISS. The role of tree as a bio indicator for environmental contaminants.

KUPCINSKIENE, E. Studies on the content of nitrogen and free amino acids in needles of Sots pine growing near the nitrogen fertilizer factory.

MAGILL, A., J. ABER, B. MCDOWELL, and K. NADELHOFFER. Long-term nitrogen additions and nitrogen saturation in two temperate forests at the Harvard Forest, Massachusetts, USA.

MURDOCH, P.S., and D.A. BURNS. Effect of clearcutting on nitrogen export from a watershed in the Catskill Mountains, New York.

PARDO, L.H., S.G. MCNULTY, and J.L. BOGGS. Effects of N deposition on high elevation forests in the Northeastern US: Foliar $^{?15}$N patterns.

SEMENOV, S. M. An approach to balance positive and negative effects of elevated nitrogen oxides in the lower atmosphere on terrestrial plants.

STRENGBOM, J., A. NORDIN, T. NASHOLM, and L. ERICSON. Slow recovery of boreal forest ecosystem following decreased nitrogen input.

VESTGARDEN, L.S., **A.O. STUANES,** G. ABRAHAMSEN, and P. NILSEN. From N limitation to N saturation in a scots pine forest.

WEIS, W., and C. HUBER. Regeneration of mature Norway spruce stands - The Impact of clear cutting and selective cutting on seepage water quality and soil fertility.

WESTLING, O. Impact of harvest of biofuels on nitrogen fluxes in forests in Sweden.

Poster Session #4: ***Ammonia: Sources, Emissions and Transport.***

Chair: Robin Dennis, US Environmental Protection Agency/ National Oceanographic and Atmospheric Administration.

FERGUSON, J.D., Z. DOU, and C.F. RAMBERG. An assessment of ammonia emissions from dairies in Pennsylvania.

ROBARGE, W.P., J. WALKER, G. MURRAY, J. CHAUHAN, and T. MANUSZAK. Atmospheric ammonium in a region with large-scale animal production facilities.

SHARPE, R.R., L.A. HARPER, and F.M. BYERS. Gaseous nitrogen emissions as part of a total system balance in swine production systems.

VAN PUL, A., **J. VAN DAM**, P. HEUBERGER, and J. ABEN. The effect of reallocating ammonia emissions on reducing nitrogen loads to nature areas in the Netherlands.

Poster Session #5: ***Atmosphere-Biosphere Interactions: N_2O and NO Emissions.***

Co-Chairs: Sybil Seitzinger, Rutgers University, & Carolien Kroeze, Wageningen University.

CARDOCH, L. Production of Nitrous Oxide in NC Waterbodies.

DOBBIE, K.E., and **K.A. SMITH**. Impact of different forms of N fertilizer on N_2O emissions from intensive grassland.

ROMANOVSKAYA, A.A, M.L. GYTARSKY, R.T. KARABAN, D.E. KONYUSHKOV, and I.M. NAZAROV. The dynamics of nitrous oxide emission from the use of mineral fertilizers in Russia.

ROYER, T.V., M.B. DAVID, J.L. TANK, and L.C. FITZGERALD. Denitrification in streams, rivers, and reservoirs of Illinois: Its role in the nitrogen mass balance.

SKIBA, U., C.E.R. PITCAIRN, and **D. FOWLER.** Emissions of nitrous oxide and nitric oxide from moorland and grassland soils along gradients of atmospheric N deposition.

VAN BOCHOVE, E., R.J. STEVENS, G. THÉRIAULT, and R.J. LAUGHLIN. Transformation and transport of 15-N labeled fertilizer in soil gaseous, solid, and liquid phases.

WHALEN, S.C., R.L. PHILLIPS, and E.N. FISCHER. Nitrous oxide emission from a spray field fertilized with liquid lagoonal swine effluent in the southeastern United States.

Poster Session #6: ***Atmospheric Deposition of Nitrogen.***

Chair: Richard Artz, National Oceonographic and Atmospheric Administration.

CAMPOS, E.C., N. GARCIA, M. COLINA, G. COLINA, **N. FERNANDEZ**, E. CHACIN, L. SANDOVA, and J. MARIN. Evaluation of the nitrogen forms as macronutrients in atmospheric settleable particles in Maracaibo Lake Strait.

CUESTA-SANTOS, O., A. COLLAZO, A. WALLO, R. LABRADOR, M. GONZALEZ, and P. ORITZ. Atmospheric nitrogen compounds deposition in humid tropic – Cuba.

LOSLEBEN, M., **M. W. WILLIAMS**, and C. SEIBOLD. Four NADP stations along an elevational transect in the Colorado front range: Atmospheric sources of N deposition.

MANTHORNE, D., and **M.W. WILLIAMS.** Class I areas at risk: Event-based nitrogen deposition at a high-elevation, western site.

MORRIS, K. H., and K.A. TONNESSEN. Nitrogen deposition in primenet park units: A comparative analysis.

ROBARGE, W.P., S. JATINDERPAUL, and R.B. MCCULLOCH. An evaluation of alternative absorbent coatings and filter media for gas and aerosol sampling using annular denuder systems.

SALAHI, A., S. GERANFAR, and S.A.A. KORORI. Nitrogen compounds deposition on urban ecosystems.

SINGH, R. K., and M. AGRAWAL. Characterization of wet and dry deposition in the down wind of industrial sources in a dry tropical area.

STENSLAND, G.J., and JACOB MONTGOMERY. Presented by **VAN C. BOWERSOX.** Month-to-month variation in concentration in precipitation of nitrate and ammonium at sites in the USA.

ZAPLETAL, M. Atmospheric deposition of nitrogen and sulphur compounds in the Czech Republic.

Tuesday, October 16 – Nitrogen Around the World and its Effects

Poster Session #7: ***Agricultural Nitrogen Losses to Ground and Surface Waters.***

Chair: Mary Ann Rozum, US Department of Agriculture.

DAUGHTRY, C. S. T., T. J. GISH, W. P. DULANEY, and C. L. WAL. Understanding nitrate surface and subsurface flow pathways on a watershed scale.

FOX, R.H., Y. ZHU, J.D. TOTH, and J.M. JEMISON. Nitrogen fertilizer rate and crop management effects on nitrate leaching from an agricultural field in central Pennsylvania.

LIN, H., R. COOK, and B. SHAW. Nitrate relationships between private well water, stream base flow water, and land use in the Tomorrow-Waupaca Watershed.

MORAN, L.P., and T.E. FENTON. Ecology and landscape variability of carbon and nitrogen in restored wetland complexes in Iowa.
OORTS, K.M., L. SAMMELS, A. EL-SADEK, A. TIMMERMAN, and J. FEYEN. Modeling of nitrate leaching out of the profile during the winter and spring.
TOWNSEND, M.A., S.A. MACKO, and D.P. YOUNG. Distribution and sources of nitrate-nitrogen in Kansas ground water.
TURSIC, I., F. BASIC, A. BUTORAC, M. MESIC, and T. COSIC. Influence of crop rotation on NO3- N leaching in Northern Croatia.
WEBBER, J.A., and K.W.J. WILLIARD. Influences of percent riparian forest cover on stream water quality in southern Illinois agricultural watersheds.

Poster Session #8: **Nitrogen Use in Agricultural Crop Production.**
Chair: Robert Wright, US Department of Agriculture.
HUNT, E.R., JR., C.S.T. DAUGHTRY, and J.E. MCMURTREY, III. Remote sensing methods for estimation of crop nitrogen status.
IBEWIRO, B., M.O. ONUH, B. VANLAUWE, and N. SANGINGA. Symbiotic performance of herbaceous legumes in the derived savanna of West Africa.
KHAN, A.R., S.S. SINGH, A.K. GHORAI, and S.R. SINGH. Nitrogen management for sustainable rice production through organic manure.
KUO, S. Winter cover crop species effects on soil nitrogen availability and nitrate leaching.
MOMEN, B., K.R. ISLAM, C.L. MULCHI, and R. ROWLAND. Temporal changes in soil nitrogen and carbon contents in response to elevated CO_2 and O_3 in agroecosystems.
SHEN, Y., J.C. LO, Y.J. LEE, and K.W. CHANG. Remote sensing techniques to identify nitrogen status of paddy rice.
STEWART, J.C., and **M.A. MCKENNA**. Nodulation and growth of white clover is enhanced by a monoterpene from wild thyme.
STROCK, J.S., and D.R. HUGGINS. Yield variability from long-term nitrogen management in the northern corn belt, USA.

Poster Session #9: **Forest Soils and the Nitrogen Cycle.**
Chair: Gary Lovett, Institute of Ecosystem Studies.
BOECKX, P., H. VERVAET, R. GODOY, C. OYARZÚN, S. LEIVA, and O. VAN CLEEMPUT. $^{?15}$N signatures in soil profiles of polluted and pristine temperate forests: indicators for N turnover rates?
BOOTH, M.S., and J.M. STARK. Relationship of net and gross rates of soil inorganic nitrogen production: Examples from annual- and perennial-dominated ecosystems.
GUNDERSEN, P., and I.K. SCHMIDT. Biogeochemistry in two ammonia affected forests in Denmark.
KOBA, K., G. SHAVER, K.J. NADELHOFFER, J. LAUNDRE, M. SOMMERKORN, A.GIBLIN, E. RASTETTER, and L. KOYAMA. ^{15}N natural abundance of plants and soil N in tundra ecosystems.
KOYAMA, L., N. TOKUCHI, M. HIROBE, and K. KOBA. Soil NO_3^- for plant: Saturated or not? - Estimations of soil NO_3^- availability and plant ability of NO_3^- uptake in Japanese forest.
LAMERSDORF, N.P., M.D. CORRE, R. BRUMME, and M. BREDEMEIER. Sustained reduction of nitrogen deposition in a Norway spruce forest at Solling, central Germany: Impact on gross rates of internal nitrogen cycling.
LEPISTÖ, A., K. RANKINEN, and K. GRANLUND. Integrated nitrogen and flow modeling (INCA): Application to a northern boreal forestry dominated river basin.
NADELHOFFER, K.J., B.P. COLMAN, W.S. CURRIE, A.H. MAGILL, and J.D. ABER. Decadal scale movements of N tracers into vegetation and soil at the Harvard Forest Chronic-N Addition Study: Implications for C sequestration.
OWEN, J.S., H.L. SUN, M.K. WANG, C.H. WANG, H.B. KING, and Y.J. HSIA. Nitrogen cycling in two contrasting forests in Taiwan.
OZAWA, M., H. SHIBATA, F. SATOH, and K. SASA. Effect of surface soil removal on dynamics of dissolved inorganic nitrogen in snow-dominated forest soil.
HUSSEIN, A.H., and M.C. RABENHORST. Modeling of nitrogen sequestration in coastal marsh soils.

Poster Session #10: **Nitrogen Dynamics in Asia.**
Chair: Zhao Liang ZHU, Chinese Academy of Sciences.
ELLIS, E. C., J.D. LACKEY, R.G. LI, and L.Z. YANG. Nitrogen limitation of human nutritional carrying capacity: A Chinese village case study.
PUSTE, A.M., S. BANDYOPADHYAY, and D.K. DAS. Economization of fertilizer nitrogen through organic resources favorably influenced soil health and crop response in Indian sub-continent.
TOKUCHI, N. Soil N cycling pattern in various forest ecosystems in dry tropical and temperate in Asia.

Poster Session #11: **Nitrogen in Surface Waters.**
Chair: Jeff Stoner, US Geological Survey.
DE KLEIN, J.J.M., and PORTIEL, JE. Retention of nitrogen in macrophyte-dominated streams: Measurements and modeling.
JANSE, J.H., **A.H.M. BRESSER,** and R.F.A. HENDRIKS. A model study on eutrophication in polder ditches.
JAWORSKI, N.A. Nitrogen, Phosphorus, and Potassium Inputs and Outputs for the Potomac River Watershed, 1900-2000.
LOS HUERTOS, M.W., G. GENTRY, and C. SHENNAN. Land use and instream nitrogen concentrations in agricultural watersheds along the California coast.

O'BRIEN, J.M., and K.W.J. WILLIARD. Effects of ambient conditions on microbial denitrification in a southern Illinois stream.
WYFFELS, S., P. BOECKX, W. VERSTRAETE, and O. VAN CLEEMPUT. Identification and quantification of N removal in waste water treatment by ^{15}N tracer techniques.

Poster Session #12: ***Effects of Atmospheric Deposition of Nitrogen.***
Chair: Kathy Tonnessen, National Park Service.
BOGGS, J. B., S. G. MCNULTY, and L. H. PARDO. Effects of nitrogen deposition on high elevation spruce-fir and deciduous forests across the Northeastern US.
GILLILAND, A, **T. J. BUTLER,** and G. E. LIKENS. Seasonal and monthly bias in weekly (NADP/NTN) vs daily (AIRMoN) ammonium and nitrogen precipitation chemistry in the Eastern U.S.A.
CORRE, M.D., and F. O. BEESE. Gross rates of internal N cycle in acid, high N deposition forest soil: Changes under long-term N saturated and limed conditions.
KERCHNER, M., J. THOMAS, A. WEBER, and R. HALLORAN. The implications of ammonia emissions to coastal and estuarine areas.
MASTOI, G.M., and M.Y. KHUHAWAR. Effects of fertilizers on the human health of Sindh, Pakistan.
DIXON, L.K., E.D. ESTEVEZ, and **E.M. PORTER.** Water and vegetation sampling to evaluate nitrogen enrichment at Chassahowitzka National Wildlife Refuge 1996-present.
SHERWELL, J., and M. GARRISON. A mitigation strategy for deposition from a new electricity generating facility.

Wednesday, October 17 - Innovation with Nitrogen

Poster Session #13: ***Policy Options to Improve Nitrogen Use in Agriculture.***
Chair: Teresa Gruber, Council for Agricultural Science and Technology.
BIELEK, P. Principles of nitrate vulnerable zones designation.
LUND, E. D., M.C. WOLCOTT G.P., and HANSON. Applying nitrogen site-specifically using soil electrical conductivity maps and precision agriculture technology.
MCARTY, G.W., **T. J. GISH**, C. L. WALTHALL, and C.S.T. DAUGHTRY. Assessment of landscape spatial structure as an indicator of available soil nitrogen for agricultural production.
HERELIXKA, E., L. VANONGEVAL, and M. GEYPENS. Presented by **KATRIEN OORTS.** Mineral nitrogen in the soil as a policy instrument to reduce N-leaching from agricultural soils in Flanders.

Poster Session #14: ***Nitrogen Management in Agricultural Systems.***
Chair: Thomas Christensen, U.S. Department of Agriculture.
ANGIER, J.T., G.W. McCARTY, T.J. GISH, W.P. DULANEY, and C.S.T. DAUGHTRY. Impact of a first-order riparian zone on nitrogen removal and export from an agricultural ecosystem.
CAVIGELLI, M.A., and K. NICHOLS. Soil nitrogen and carbon pools after five years of till, no-till and organic cropping systems management: The USDA-ARS Farming Systems Project.
CRASWELL, E.T., F. PENNING DE VRIES, P. DRECHSEL, and R. LEFROY. Nutrient flows in agroecosystems in the tropics: The rural - urban divide.
DAS, D.K., and A.M. PUSTE. Influence of different organic waste materials on the transformation of nitrogen in soils.
FRANZLUEBBERS, A.J., and J.A. STUEDEMANN. Soil nitrogen pools under Bermuda grass management in the Southern Piedmont USA.
HERDMAN, W.R., and **J.A. HOUNTIN**. Increased microbial biomass C and N in regenerative agro-ecosystems in Southeast Pennsylvania.
PIKUL, J.L., **JR.,** T.E. SCHUMACHER, and M. VIGIL. Nitrogen use and carbon sequestered by corn rotations in the northern Corn Belt, USA.
SUTTON, A.R. Stabilized nitrogen, improving nitrogen efficiency.

Poster Session #15: ***Forests, Nitrogen and Surface Waters.***
Chair: Bruce Peterson, Woods Hole Marine Biological Laboratory.
HIDEHARU, H., T. KAWAKAMI, H. YASUDA, and I. MAEHARA. Nitrate leakage from deciduous forest soils into streams on Kureha Hill, Japan.
ITO, M., M.J. MITCHELL, C.T. DRISCOLL, W. KRETSER, and K. ROY. Nitrogen input and output in the Adirondack Lake-Watersheds.
KAWAKAMI, T., Y. MATSUDA, H. HONOKI, and H. YASUDA. Leaching of nitrate from surface soils into streams on Kureha Hill, Japan.
MEIXNER, T. M.E. FENN, and M.A. POTH. Nitrogen export in polluted semi-arid mountainous catchments.
PETERJOHN, W.T., M.J. CHRIST, J.R. CUMMING, and M.B. ADAMS. Patterns of nitrogen availability in Appalachian forests receiving high inputs of atmospheric nitrogen.

SHIBATA, H., K. KURAJI, H. TODA, and K. SASA. Regional comparative study on nitrogen export to Japanese forested stream.
STOTTLEMYER, R. Ecosystem processes and watershed nitrogen export in U.S. national parks.
SWANK, W.T., J.M. VOSE, and B.L. HAINES. Long-term nitrogen dynamics of Coweeta forested watersheds in the Southeastern USA.
WEBSTER, K.L., I.F. CREED, H. VAN MIEGROET, and N.S. NICHOLAS. Establishing links between deposition, transformation and export of nitrogen in a forested catchment in the southern Appalachians.

Poster Session #18: **Policy Responses to Increased Environmental Nitrogen.**
Chair: Wim de Vries, ALTERRA Green World Research.
AKSELSSON, C. Risks and benefits of nitrogen in forest ecosystems – Research in Sweden.
BULL, K.R. The convention on long-range transboundary air pollution.
FOLLETT, R.F., and J.L. HATFIELD. Nitrogen in the environment: Sources, problems, and management.
LIBLIK, V., and A. RATSEP. Temporal changes in nitrogen pollution in North-Eastern Estonia.
NAGEL, H.-D., and H.-D. GREGOR. Derivation and mapping of critical loads for nitrogen and trends in their exceedance in Germany.

Poster Session #19: **Interactions of Carbon and Nitrogen at Regional and Global Scales.**
Chair: Arvin Mosier, US Department of Agriculture.

RODHE, H., J.C.K. KUYLENSTIERNA, **W.K. HICKS,** H-M. SEIP, F. DENTENER, and M. SHULZ. Global distribution of acidifying deposition and a simple model for terrestrial ecosystem acidification.
SCHMIDT, I.K., C. BEIER, and H.L. KRISTENSEN. Redistribution of N in response to warming.
SVERDRUP, H. The mechanisms included to couple effects of climate change, transboundary air pollution and forest growth on nitrogen cycling in the sustainability assessment model FORSAFE.
WHITALL, D.R., C.T. DRISCOLL, J.D. ABER, C.S. CRONAN, M.S. CASTRO, P.M. GROFFMAN, C.HOPKINSON, G.B. LAWRENCE, and S.V. OLLINGER. Inputs of nitrogen and effects on air, terrestrial, aquatic and coastal resources of the Northeastern US.

ROUND-TABLE DISCUSSIONS

Monday – Wednesday, 4:30 pm – 5:30 pm, Rm 3

A round-table panel discussion will be held each afternoon to synthesize, contrast and address the various ideas brought forth during the morning plenary sessions, lunch time science and policy briefings, and afternoon concurrent sessions.

Monday, October 15 - Nitrogen Production and Movement

Moderator: Stan Smeulders, Ministry of the Environment in the Netherlands
Panel:
John Aber, University of New Hampshire
Robin Dennis, US Environmental Protection Agency/National Oceanographic and Atmospheric Administration
Paul Fixen, Potash and Phosphate Institute
William Moomaw, The Marine Biological Lab
Sybil Seitzinger, Rutgers University
Henry Tyrell, US Dept of Agiculture

Tuesday, October 16 – Nitrogen Around the World and its Effects

Moderator: Pam Matson, Stanford University
Panel:
Klaas van Egmond, National Institute of Public Health and the Environment in the Netherlands
Congbin Fu, Chinese Academy of Sciences
Hans Paerl, University of North Carolina at Chapel Hill
Jonathan Patz, Johns Hopkins University
Mary Ann Rozum, US Department of Agriculture
Peter Vitousek, Stanford University

Wednesday, October 17 - Innovation with Nitrogen

Moderator: Oene Oenema, Alterra Green World Research
Panel:
Rona Birnbaum, US Environmental Protection Agency
Michael Bradley, M.J. Bradley & Associates
Teresa Gruber, Council for Agricultural Science and Technology
Jerry Melillo, The Marine Biological Lab
Arvin Mosier, US Department of Agriculture
Rabindra Roy, Food and Agriculture Organization of the United Nations

INFORMAL MEETINGS

There is ample space in the Bolger Center for informal meetings during lunch and throughout the conference. Informal gatherings of participants who would like to discuss a particular topic or regional issue will be encouraged.

PLENARY SPEAKER BIOGRAPHICAL SKETCHES

Michael Bradley enjoys a national reputation for strategic environmental policy development, use of innovative market systems, and for having an in-depth understanding of environmental regulatory and legislative issues. After 12 years as Executive Director of NESCAUM (Northeast States for Coordinated Air Use Management), Mr. Bradley formed his own firm to assist clients in strategically assessing air quality policy and technical challenges. Mr. Bradley provides clients with strategic assistance in establishing and meeting environmental goals, in the development of business strategies to take advantage of emerging market opportunities, and in effectively working with key stakeholders from the environmental community, private sector, and government to achieve common objectives. Mr. Bradley is also a member of the National Academies' National Research Council Committee on Air Quality Management in the United States.

Ellis Cowling (Conference Co-Chair) is a forest biologist at North Carolina State University who has become a world leader in air pollution research. Cowling is Co-Chairman of the Second International Nitrogen Conference. His doctoral research at the University of Uppsala in Sweden was on conservation of nitrogen in forest trees and the fungi that destroy wood in nature. In 1975-83 he provided leadership for development of the National Atmospheric Deposition Program (NADP) precipitation monitoring program in the US. In 1978-79, Ellis joined three other scientists in developing the original draft plan for the National Acid Precipitation Assessment Program (NAPAP) and was engaged in acid deposition research under NAPAP from 1980-1991. Since 1993, Ellis has served as Director of the Southern Oxidants Study. SOS is an alliance of 40 universities and 42 federal, state, and industrial organizations investigating the chemistry, meteorology, biology, and management of ozone pollution and particulate matter pollution and their effects in 10 southeastern United States. Dr. Cowling was elected to the National Academy of Sciences in 1973.

Jan Willem Erisman obtained his PhD in 1992 at the University of Utrecht on atmospheric deposition in relation to acidification and eutrophication. He is currently the Head of the Department of Integrated Assessments and Programme Manager Environmental Research at the Netherlands Energy Research Foundation. His areas of qualifications include air quality, atmosphere-surface exchange, atmospheric chemistry, monitoring, policy development, and evaluation and instrument development. He was one of the organizers of the First International Nitrogen Confer-N-s in 1998 in the Netherlands.

Paul E. Fixen is Senior Vice President of the Potash and Phosphate Institute. Dr. Fixen grew up on a farm in southwestern Minnesota and received his Ph.D. at Colorado State University. Prior to joining the Potash and Phosphate Institute, where he coordinates the Institute's activities in North America and directs its research program in the U.S. and Canada, he spent nine years in research and teaching in soil fertility at the University of Wisconsin and South Dakota State University. He is a Fellow in the American Society of Agronomy and the Soil Science Society of America.

Congbin Fu is a professor at the Institute of Atmospheric Physics, Chinese Academy of Sciences, the Director of the START Regional Center for Temperate East Asia and now the Chief Scientist of a national fundamental research project *Predicative study on the aridification of Northern China in association with the environmental evolution*. His research interests include atmosphere-ocean and atmosphere-terrestrial interactions, climate-ecosystem interaction, and regional climate modeling. His current research focuses on environmental issues related to aridification and water resources and coupling the climate model with ecological and chemical processes.

James N. Galloway (Conference Co-Chair) earned his BA from Whittier College in 1966 with a double major in Chemistry and Biology. He was awarded his PhD from the University of California, San Diego in Chemistry in 1972 for his research on the fate of trace metals in a coastal ocean. He is currently Professor of Environmental Sciences at the University of Virginia. HIs research is in the area of biogeochemistry and includes works on the natural and anthropogenic controls on chemical cycles at the watershed, regional and global scales. He is the author of over a hundred scientific papers. Jim in internationally recognized for his work on acid deposition effects on soils, waters and forests, watershed biogeochemistry and the influence of Asia on the global environment.

Robert Howarth is Senior Marine Scientist at Environmental Defense (ED). He directs ED's Oceans Program, which examines environmental effects of pollution in coastal oceans, particularly from nutrients and oil pollution, and evaluates sources of nutrients in the landscape from air pollution and from agriculture. Dr. Howarth is also an adjunct Research Scientist at the Ecosystems Center, Marine Biological Labs at Woods Hole and is on leave from Cornell University. His research interests include comparative ecosystem analysis, biogeochemistry, and management of aquatic ecosystems.

Pam Matson is the Richard and Rhoda Goldman Professor in the Department of Geological and Environmental Sciences and the Institute of International Studies, and the Sant Director of the Earth Systems Program at Stanford University. She is an ecologist and biogeochemist, and her research focuses on the effects of human-caused changes on biogeochemical cycling and trace gas exchange in tropical forests and agricultural systems. Together with economists and agronomists, she has analyzed economic drivers and environmental consequences of land use decisions in the developing world agricultural systems, and identified alternative practices that are economically and environmentally viable. She is currently a science advisory committee member for the International Geosphere-Biosphere Programme and serves on the National Research Council Board on Sustainable Development and the US SCOPE Committee. She was elected to the American Academy of Arts and Sciences in 1992 and to the National Academy of Sciences in 1994. In 1995, Dr. Matson was selected as a MacArthur Fellow, and in 1997 was elected a Fellow of the American Association for the Advancement of Science

Jerry M. Melillo is Co-Director of The Ecosystems Center of the Marine Biological Laboratory in Woods Hole, Massachusetts. Dr. Melillo's research on biogeochemistry includes work on global change, the ecological consequences of tropical deforestation, and sustainable management of forest ecosystems. He was a convening lead author on the 1990 and 1995 IPCC assessments of climate change. He has served as a vice-chair of the International Geosphere-Biosphere Programme (IGBP) and is currently President of ICSU's Scientific Committee on Problems of the Environment (SCOPE). He is also a member of the SSC of START (System for Analysis, Research and Training), a joint activity of IGBP, IHDP and WCRP. Dr. Melillo founded the Marine Biological Laboratory's Semester in Environmental Science, an education program for undergraduates from small liberal arts colleges and universities in which students spend a term learning and doing environmental science in Woods Hole. Dr. Melillo also has a strong interest in science policy. He served as the Associate Director for Environment at the Office of Science and Technology Policy in the Executive Office of the President for 15 months in 1996 and 1997.

William Moomaw is Professor of International Environmental Policy at the Fletcher School of Law and diplomacy, Tufts University. He is the only chemist at this school of international relations, receiving his PhD from MIT in physical chemistry. He conducted research in photochemistry and molecular spectroscopy while teaching at Williams College. During the 1970s, he put this background to work as a Congressional Science Fellow working for the US Senate on stratospheric ozone depletion and the ban on CFCs in aerosol cans. In 1988, he became the first Director of the Climate, Energy and Pollution Program at the World Resources Institute in Washington, DC. In 1990, he moved to Tufts where in addition to teaching and research, he is Director of the university wide Tufts Institute of the Environment. He was a lead author for the Second Assessment Report of the IPCC in 1995, and is currently a convening lead author for the Third Assessment Report addressing the Technical and Economic Potential for Emissions Reduction of Greenhouse Gases. He is currently working on economic models of nitrogen impacts.

Oene Oenema is a Principal Research Scientist and Manager in the field of soil science, with special reference to nutrient cycling and greenhouse gas emissions from agro-ecosystems, at Alterra Green World Research, the main Dutch centre of expertise on rural areas. He also has experience in related topics such as developing sustainable agricultural systems and management of heavy metal flows in agro-ecosystems. He has been involved in activities of the Ministries of Agriculture and Environment, Directorates General of the European Union, fertilizer industry, OECD, and IPCC.

Jonathan Patz, MD, MPH, is Assistant Professor in the Department of Environmental Health Sciences and is Director of the Program on Health Effects of Global Environmental Change at the Johns Hopkins Bloomberg School of Public Health. He is also joint faculty in the Departments of Epidemiology, International Health, Microbiology, and Medicine, and holds medical board certification in both Occupational/Environmental Medicine and Family Medicine. Since 1998, he has co-chaired the Health Sector of the US National Assessment on Climate Variability and Change. Since 1994, he has been lead author on four United Nations assessment reports, including the Second and Third Assessment reports of the Intergovernmental Panel on Climate Change (IPCC), and a WHO monograph on climate change. He is also Co-Editor-in-Chief for the journal, *Global Change and Human Health*. From 1996-2000, he was principal investigator for the largest US multi-institutional study on climate change health risks and has briefed the US Congress, Clinton Administration, and federal agency leaders. His areas of research investigation include effects of climate change on air pollution and water- and vector-borne diseases (with >50 publications), as well as the link between deforestation and resurgent diseases in the Amazon.

Nancy Rabalais is a Professor at the Louisiana Universities Marine Consortium. Her research interests include biological oceanography, continental shelf ecosystems influenced by large rivers, benthic ecology, distribution and dynamics of hypoxia, eutrophication, and environmental effects of habitat alterations. Current research focuses on the causes and impacts of the hypoxia in the Gulf of Mexico. She is the recipient of the 1999 NOAA Environmental Heroes Award and the 1999 Blasker Award for Science and Engineering, shared with her husband and research colleague, Gene Turner, of Louisiana State University. In addition, Dr. Rabalais is a AAAS Fellow and an Aldo Leopold Leadership Fellow, and Past-President of the Estuarine Research Federation which publishes the journal *Estuaries*. She is a member of the Ocean Studies Board of the National Research Council.

Rabindra Nath Roy (Robin) is a Senior Officer in the Land and Water Development Division of the Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy. Dr. Roy leads the Integrated Plant Nutrient and Soil Fertility Management Group. He has a unique 35 years of experience in working with research, fertilizer industry and development agencies in the field of soil fertility and plant nutrition management. He has been the architect of Integrated Plant Nutrition Systems (IPNS) and promoter of this approach, which takes into account a holistic and efficient management of organic, biological and mineral sources of plant nutrients that takes care of sustainability issues, environmental concerns, participatory approach, gender bias technology development, indigenous resources and knowledge, and farming systems. He is actively associated with several developmental projects and global initiatives assisting small farmers in the developing countries to achieve food security while sustaining land productivity.

Sybil Seitzinger is Director of Rutgers/NOAA Cooperative Marine Education and Research Program and Visiting Professor at the Rutgers University Institute of Marine and Coastal Sciences. Her research addresses sources, effects and fate of nitrogen in coastal marine ecosystems. Her studies cover a range of spatial scales from measurements at centimeter scales to models at the watershed and global scales. Three major areas of research are: 1) denitrification in rivers, estuaries and continental shelves; 2) dissolved organic nitorgen inputs to, and bioavailability in, aquatic ecosystems; and 3) global modeling of N transport by world rivers.

Vaclav Smil is a Distinguished Professor at the University of Manitoba. His interdisciplinary research encompasses a broad area of environmental, energy, food, population, economic and public policy studies, ranging from quantifications and modeling of global biogeochemical cycles to long-range appraisals of energy and environmental options. Recently, he has been applying these approaches to energy, food and environmental affairs of China. Dr. Smil is an internationally recognized author. His most recent books are *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production* which was published in 2001, and *Understanding the Biosphere* which is in press.

Robert H. Socolow is Professor of Mechanical and Aerospace Engineering and a member of the Center for Energy and Environmental Studies at Princeton University. Dr. Socolow's research interests span energy and environmental technologies and policies. His current research focuses on global carbon management, the hydrogen economy, and fossil-carbon sequestration. He is the co-principal investigator (with ecologist, Stephen Pacala) of Princeton University's new Carbon Mitigation Initiative a coordinated research program in environmental science, energy technology, hydrology, and economics. Dr. Socolow is one of the founders of the new research approach known as industrial ecology and has explored the industrial flows of nitrogen and lead from this perspective.

Henry Tyrrell is an international expert in the field of animal nutrition. He presently serves as National Program Leader in this field for the US Department of Agriculture's Cooperative State Research, Education, and Extension Service (USDA-CSREES). Dr. Tyrrell is an expert scientist and also is an effective advocate for increased awareness and enlightened action by animal scientists and meat, egg, and dairy producers — especially at the interface between animal agriculture, human dietary requirements, and environmental protection.

Prof. ir. N.D. van Egmond is Director of the Environment of the National Institute of Public Health and Environment, The Netherlands. Dr. van Egmond is responsible for the national assessments on the environment and nature, the legislated interface between science, scientific assessment and the political process in the Netherlands. He holds a part-time position as professor of Environmental Science at the University of Utrecht. Prof. Van Egmond serves on many national and international advisory committees and commissions.

Peter Vitousek is the Clifford G. Morrison Professor in Population and Resource Studies at Stanford University. His research focuses on experimental and comparative studies of nutrient cycling in tropical and temperate forests and disturbed ecosystems, greenhouse gases, and biological invasions of exotic species. He focuses on linking biodiversity conservation concerns with the functioning of ecosystems and, ultimately, with the workings of the biosphere and the impacts of invasive species on ecosystem level properties. Dr. Vitousek was selected as a Pew Fellow in Marine Conservation, is a recipient of the Ecological Society of America's MacArthur Award, and in 1992 was elected to the National Academy of Sciences.

ABSTRACTS

PLENARY

MICHAEL BRADLEY. M. J. Bradley & Associates, Inc., Concord, MA 01742.

Reducing Global NO_x Emissions: Encouraging the Development of Advanced Energy and Transportation Technologies.

Globally, energy demand is projected to continue to increase well into the future. As a result, global NOx emissions are projected to continue on an upward trend for the foreseeable future as developing countries increase their standard of living. While the U.S. has experienced improvements in reducing NO_x emissions from stationary and mobile sources to reduce ozone, further progress is needed to reduce the health and ecosystem impacts associated with NO_x emissions. In other parts of the world, (in developing countries in particular) NO_x emissions have been increasing steadily as the growth in electricity demand and transportation needs increases. Advancements in energy and transportation technologies may prove to aid in avoiding this increase if appropriate policies are implemented.

This paper will evaluate the current commercially available energy generation and transportation technologies that produce fewer NO_x emissions than conventional technologies and advanced technologies that are on the 10-year commercialization horizon. Various policy approaches will be evaluated which can be implemented on the regional, national and international levels to promote these advanced technologies and ultimately reduce NO_x emissions.

ROBERT BRENNER. Deputy Assistant Administrator for Air and Radiation, U.S. Environmental Protection Agency, Washington DC 20460.

Perspectives on Decreases in Nitrogen Emissions – Current Efforts and Future Directions.

In 1990, the Clean Air Act Amendments passed Congress with overwhelming support. As a consequence, utility sector NO_x emissions have been reduced by 1.5 million tons from 1990 levels (about 3 million tons lower than projected growth without the Act, particularly the Title IV Acid Rain Program) and nitrogen deposition from utility emissions has held stable (rather than increasing).

Despite this success, NO_x emissions remain a significant problem that is linked to nearly every major environmental and public health threat addressed by air programs at EPA. NO_x is the only criteria pollutant for which emissions have risen since 1970 (albeit declining slightly since 1990). In order to address the problems associated with NO_x emissions, further reductions are needed in sectors that continue to contribute to emissions. Further emissions reductions from both mobile and stationary sources will be achieved by regulatory initiatives already underway, including the NO_x State Implementation Plan (SIP) Call, Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, Heavy-Duty Engine and Vehicle Standards, and the Highway Diesel Fuel Sulfur Control Requirements. Moreover, the recently released National Energy Policy commits the Administration to seek further NO_x emissions reductions from the power generating sector.

However, focusing on NO_x emissions alone is unlikely to address the myriad public health and environmental issues linked to increased levels of nitrogen in the environment. Nitrogen is truly a cross-media and multi-source pollutant, and the complex nature of this pollutant makes it necessary to address pollution in more integrated ways than in the past. At EPA, this means better coordination between media-specific program offices, such as the offices of air and water. In addition, it means acknowledging that there are forms of nitrogen besides NO_x (e.g., ammonia and ammonium) that must be addressed by also focusing on the most significant sources that do not involve fossil fuel combustion. Thus, we must look at entirely new sectors, and work with new partners, to reduce the overall level of nitrogen inputs into the environment from all sources.

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Agroecosystems, Nitrogen Management, and Economics.

Most agricultural scientists and ecologists agree on a number of key issues regarding management and expectations of future agroecosystems. Food production must increase substantially to meet the needs of a much larger and wealthier human population. Nearly all of this increase should come from achieving greater yields on existing agricultural land rather than expanding production to marginal land or at the expense of natural ecosystems. The required yield increases will depend on concomitant increases in crop N uptake. Although a net increase in applied N inputs will be required to meet crop N needs at higher yield levels, farmers must also achieve much greater N use efficiency to improve economic return and to preserve environmental quality. These issues of agreement raise critical questions about the prognosis for meeting the tripartite goals of food security, profitability, and natural resource conservation: (1) How much can N efficiency be increased in the world's major cropping systems using existing technologies? (2) Is this increase in efficiency sufficient to maintain profitability while avoiding environmental degradation caused by N losses? (3) If current technologies are not adequate, what new knowledge is required to ensure adequate food supply, acceptable environmental quality and profit in high-yield cropping systems of the future?

Answers to these questions must come from knowledge of the biophysical controls on N cycling in agroecosystems, the current status of N use efficiency and losses in the world's major cropping systems, and the critical tolerance thresholds of natural ecosystems to reactive N load. On-farm studies indicate that N fertilizer efficiency achieved by farmers is relatively low in most cropping systems. For example, the mean uptake efficiency of N fertilizer applied to irrigated rice in south and southeast Asia is about 30%. Although on-farm research has demonstrated the ability to increase average uptake efficiency to 50% of the applied N by adoption of improved management practices, large losses of N as NH_3 and N_2 still occur in these high-yield systems. In the other major cereal production systems, N losses of a similar magnitude occur from nitrate leaching and denitrification, which have a greater potential for negative environmental consequences than NH_3 and N_2. While significant increases in efficiency can be achieved by adoption of existing technologies, it is not clear that the magnitude of these improvements are sufficient to meet acceptable environmental standards given the need for substantial yield increases to meet global food demand. We therefore believe that achieving a quantum leap in N use efficiency in intensive cropping systems must be a high priority of the agricultural research and extension agenda in both developed and developing countries.

What, then, are the highest priorities for research investment to improve N efficiency? Because the relationship between economic yield and crop N uptake is tightly conserved, we see little scope for improving the physiological efficiency of N utilization once the plant has acquired N from soil. This in turn suggests only marginal gains in N efficiency from molecular engineering of N assimilation and biochemical transformation pathways within the plant. Likewise, N uptake capacity of crop root systems does not appear to be a sensitive factor limiting the efficiency with which most crops acquire soil or fertilizer N. Similarly, we see little, if any, biological or economic advantage of organic N sources over inorganic N fertilizer when both are used following best management practices because the same biophysical factors govern N cycling processes regardless of N source. Instead, we propose that the greatest gains in N use efficiency and environmental protection will accrue from "precision management" in time and space of all production factors to maximize the congruence between crop N demand and the supply of N from native soil reserves and applied N inputs in high-yield systems. Such a precision management approach will be required for both large-scale agriculture in developed countries and small-scale farming in developing countries. To achieve this balance between N demand and supply will require breakthroughs in fundamental understanding of crop and soil ecology and organic geochemistry to allow development of dynamic and cost-effective management tools appropriate for both small- and large-scale cropping systems. In addition, the longer-term cumulative "feedback effects" of N management tactics on soil and environmental quality must also be considered with explicit emphasis on productivity and N use efficiency of the entire agroecosystem. Given the rapid advances in basic plant biology and ecology, we are optimistic that technological solutions can be developed for improved N use efficiency. However, it will require a much larger research investment than presently given to the explicit goals of sustaining increases in crop yields and profitability, while at the same time, ensuring adequate protection of environmental quality and natural resource endowments.

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NitroGenius: A Nitrogen Decision Support System in the Form of a Game to Support the Optimal Policy to Solve the Dutch Nitrogen Problem.

The Netherlands is known as one of the countries with the highest reactive nitrogen emissions density in the world. Especially traffic density and intensive animal husbandry has led to very high oxidized and reduced nitrogen emissions per hectare. In the past decade several measures have been taken to control reactive nitrogen emissions and limit their effects. These measures were directed towards different environmental themes such as acidification, eutrophication, climate change, and dispersion of pollutants. It appears that these measures are not as effective as predicted beforehand, either because effectiveness is lower than expected or because the effect of the measure is compensated for by growth of the activity. Furthermore, it was found that measures taken to decrease emissions have led to a shift in other emissions. The interrelations between the different nitrogen flows are rather complex, involving different equilibria, interactions and dependencies. It appears that there is a serious lack of an instrument that demonstrates the complex interactions and shows the influence of different decisions and measures: a decision support system. A nitrogen decision support system in the form of a game was developed to support scientists and policy makers in finding solutions to solve the Dutch nitrogen problems. The aim of the Nitrogen decision support system is to illustrate in a simple way the complex relations within the nitrogen pollution situation in an extensive agricultural, industrial and transportation area (the Netherlands). The game was developed in order to improve the understanding of the related problems, the search for optimal solutions and policy to prevent pollution and effects, against the lowest costs and with minor societal influences. This paper outlines the game and its relationships, and its use. Furthermore, it describes the outcome of several sessions played by the attendees of the second International Nitrogen Conference.

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Nitrogen Fertilizers … Meeting the Challenge.

Commercial fertilizer nitrogen (N) accounts for approximately half of all N reaching global croplands today and supplies basic food needs for at least 40 percent of the population. Increasing prosperity in developing nations and a population growing at a rate of 1.3 percent per year lead to the prediction that 60 percent of humanity will eventually owe its nutritional survival to N fertilizer. The challenge for N fertilizer producers and N fertilizer users is to help meet the human need for food, fiber and energy while minimizing negative environmental impacts. In other words, the challenge is to increase N use efficiency by minimizing losses of N from agroecosystems while producing the high yields necessary for optimum natural resource efficiency. The immediate steps necessary to meet that challenge differ among the diverse agroecosystems of the world.

World fertilizer N consumption by agriculture in 2000 was 87.5 million tonnes. Western Europe, India and the U.S. consumed 11 to 12 million tonnes each, while China consumed over twice that amount. The most rapid growth in fertilizer N consumption in the next decade is expected in Asia.

Like N consumption, N use efficiency in agriculture varies among regions of the world and among cropping systems. In North America, efficiency has been climbing steadily. For example, fertilizer N efficiency on corn in the U.S., expressed as the amount of grain produced per unit of fertilizer applied, has increased more than 30 percent over the last 20 years while corn yields increased 40 percent. During this same period, USDA estimates that soil carbon increased at a rate of 0.7 percent per year in the central corn belt. This resulted in the immobilization of nearly 20 kg of additional N per ha per year in beneficial soil organic matter. Much additional progress in N efficiency can still be made through improved management of livestock waste, continued improvements in cropping system and nutrient management, improved N fertilizer application timing, site-specific precision agriculture approaches, and possibly through developments in biotechnology and more advanced fertilizer products.

Current N efficiency and productivity are lower in most of Asia than in North America, but they are improving. Factors leading to significant gains include improvement in fertilizer materials, better management practices such as more balanced plant nutrition (use of optimum ratios of N to phosphorus, potassium and other essential nutrients), and general infrastructure improvements.

An exciting part of the challenge to the fertilizer industry in the years ahead is to expand its participation in the capture (to prevent escape into the environment) and reuse of N, not just in agroecosystems, but from other industries as well. The fertilizer industry is currently involved in custom precision application of animal wastes to agricultural land and several supporting service activities. It is pursuing the modification of animal-waste beneficiation processes that may offer a means of economically moving nutrients from areas of surplus around concentrated animal feeding operations to areas that need the nutrients for crop production. In the future, the fertilizer industry may be able to develop partnerships with the energy industry in capturing the N mined from the ground in the form of coal and oil for use in N fertilizer manufacturing.

The fertilizer industry recognizes its crucial role in meeting basic human needs, now and in the future. It stands ready to meet the challenge of adopting new practices and technologies that will allow it to do so with greater efficiency and in a way that not only sustains life, but sustains quality of life as well.

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The Asian Nitrogen Story.

The nitrogen mass balances of agricultural ecosystems for each former Asian country and the whole former Asian region are analyzed on a timeline from 1961 to 2000. The projection for the future 30 years was made based on FAO population scenarios. Nitrogen inputs of the mass balance analysis include crop and animal production, synthetic fertilizer input, biological nitrogen fixation, and NO_y depositions associated with NO_x and NH_3 emissions from energy consumption and agricultural production. Among the output variables, those, which may impose serious influences on environmental safety, are emphasized. They include nitrogen leaching into aquatic systems, deposition on coastal areas, release of gaseous reactive nitrogen, and emission of nitrous oxide. Next to the mass balance analysis, the regional distribution of nitrogen sources are mapped for year 1961, 2000, and 2030. Meanwhile, the most important effects on health and ecosystems in the Asian region, which can be attributed to nitrogen, are discussed. In addition, some anthropogenic activities including synthetic fertilizer application, energy consumption, animal production, and crop residue burning, which are closely related to food security as well as the environmental safety of the Asian region, are discussed in more detail. On the basis of the above analysis, major driving forces for the Asian nitrogen problem are addressed.

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Nitrogen and the World.

The late 18th century—N discovered.
The late 19th century—natural N fixation discovered.
The late 20th century—anthropogenic N fixation exceeded natural N fixation.

This brief historical tour illustrates the impact that humans have had on the creation of reactive N through food and energy production. This paper examines that impact by contrasting the global N cycle in the late 18th century with that of the late 20th century. It pays special attention to what we know of the fate of reactive N created by human action. For example, we have a 'good' estimate (scale of certainty is poor, fair, good, excellent) of the amount of reactive N (Nr) created by humans by the Haber-Bosch process, cultivation, and fossil fuel combustion, ~160 TgN/yr. We have a 'poor' understanding of how much of the anthropogenic N is stored in environmental reservoirs (e.g., forests) and how much is denitrified. This poor understanding limits the determination of the degree of anthropogenic N accumulation in environmental reservoirs. This is problematic for not only is N a component of most biogeochemical processes, but a little bit of it goes a long way. Unlike other elements whose cycles have been altered by human activity (e.g., C, S), an intriguing aspect of N is that as it moves through environmental reservoirs it alters physical and ecological processes along the way. This phenomena, referred to as the N-cascade, means the same N atom in NO_x, formed by fossil fuel combustion, that increases the ozone concentration of the troposphere, also has the potential, in sequence, to cause additional impacts in the atmosphere, in forests and soils, in ground and surface waters, and in coastal ecosystems before being converted back to N_2. Even that process contributes to the cascade due to N_2O formation and resulting changes of tropospheric greenhouse gas and stratospheric O_3 concentrations. The paper concludes with an examination of regional differences in Nr creation and distribution, followed by an assessment of the future regarding N fixation and storage, using 2050 as a target year.

ROBERT W. HOWARTH. The Oceans Program, Environmental Defense, Boston, MA 02109.

The North American Nitrogen Story.

My presentation will discuss how the global acceleration of the nitrogen cycle plays itself out in North America, with a particular emphasis on the US. In the US, both inorganic fertilizer use and NO_x emissions increased dramatically from the 1960's through 1985 or so, but have been relatively steady since then. However, future trends in global agricultural production suggest that inorganic N fertilizer use will increase again in the US in the future. And although NO_x emissions have increased little over the past 15 years, NO_x stands out as the only major regulated air pollutant that has not actually decreased during the 1990's.

There is a great deal of regional variability in the N cycle in North America, with different sources dominating in different regions. I will highlight this by contrasting two regions: the Mississippi River Basin and the northeastern US. For the Mississippi, fertilizer is the major input of nitrogen, and the major exports are nitrogen in food exports and nitrogen flowing down the Mississippi River. For the northeastern US, the largest nitrogen input is in NO_y deposition, followed by importation of nitrogen in foods and feedstocks. I will discuss the insights gained by applying mass balance approaches at the regional scale and the scale of large watersheds, with an emphasis on mobility of nitrogen and sinks of nitrogen.

I will also trace the fate of nitrogen applied as inorganic fertilizer to the average field in the US. This will demonstrate that much of the nitrogen is removed from the field in harvested crops, shipped away for the cropland, and fed to animals in feedlots. This industrialization of animal production in North America has resulted in huge amount of animal wastes, with tremendous leakage of nitrogen to surface waters and to the atmosphere. For North America as a whole, these fluxes are comparable to or even larger than the leaching of nitrogen fertilizer from croplands.

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The Globalization of Nitrogen: Consequences for Terrestrial Ecosystems.

Human activities have more than doubled the inputs of nitrogen (N) into terrestrial systems globally. The sources and distribution of anthropogenic N, including N fertilization and N fixed during fossil fuel combustion, are rapidly shifting from the temperate zone to a more global distribution. The consequences of anthropogenic N deposition for ecosystem processes and N losses have been studied primarily in N-limited ecosystems in the temperate zone. In many temperate zone ecosystems, inadvertent N fertilization can lead to increased plant growth and increased storage of carbon (C), thus interacting with global changes in the carbon cycle to increase the terrestrial sink for C. Long term inputs can also result in over-enrichment with N, leading to increased losses of N via solution leaching and trace gas emissions, and forest decline, Experimental and observational studies suggest that chronic N inputs also can lead to changes in species composition, and a reduction in species diversity. While the effects of chronic N additions in tropical ecosystems have received almost no evaluation, there are reasons to expect that these systems, where plant growth is most often limited by some resource other than N, will respond differently to increasing N deposition. Here, I assess the direct and indirect effects of increasing anthropogenic N inputs on temperate ecosystem processes, and compare some of these effects with likely responses in tropical ecosystems. I conclude that anthropogenic inputs of N into tropical forests are unlikely to increase productivity and may even decrease it due to effects on acidity and the availability of phosphorus and cations. I also suggest that, in contrast to temperate ecosystems, anthropogenic N deposition in many tropical systems leads to increased fluxes of N in gas and solution form with little or no time lag. Finally, I discuss the uncertainties inherent in this analysis, and outline future research that is needed to address those uncertainties.

JERRY M. MELILLO. The Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543.

Nitrogen and Public Policies for Environmental Protection.

In this paper I review major aspects of air and water pollution control policies in the United States with respect to nitrogen. I use four questions to organize my discussion - What are the general goals of the major policies as defined in the Clear Air Act, the Clean Water Act, and related legislation? How much progress has been made toward achieving these goals? What factors, if any, have slowed our progress? How might recent advances in ecological and economic thinking lead to revised goals and improved policies?

In dealing with the first question, I briefly summarize the history of air and water pollution control laws and highlight how they deal with nitrogen. For example, with respect to the Clean Air Act, I discuss the 1970 directive from Congress that EPA establish the National Ambient Air Quality Standards (NAAQS) initially for five pollutants including nitrogen oxides. I also consider an amendment to the Act in 1990 that establishes a tradable permit system for sulfur dioxide and nitrogen oxides.

As part of my consideration of the progress made towards the general goals of these major environmental policies, I evaluate the adequacy of the monitoring schemes that are in place to gather data on changes in air and water quality across the nation. One clear conclusion I draw is that existing national water quality statistics are insufficient to show general trends.

Stepping back from the details of the legislation, monitoring networks and air and water quality statistics, I take a “big-picture” look at the factors that have slowed our progress in dealing with the problems created by human disruption of the nitrogen cycle. One factor looms very large - fragmentation. Instead of approaching our nitrogen problems in a systems framework where understanding interrelationships is key, we are approaching these problems in a statutory framework consisting of dozens of unrelated laws passed at different times by different groups dealing with different subjects. What is now a fragmented approach needs to become an integrated approach.

Recent advances in ecological and economic thinking may help us to develop a systems-based approach to our nitrogen problems in the context of other pressing environmental problems including climate change. For example, I think there is promise in making better use of the concepts of ecosystem services and permit trading. Ecological and economic thinking can together guide the evolution of integrated assessments of state of the nation’s and the globe’s ecosystems. The nitrogen problems will be part of these assessments. I expect these assessments will help us to define the “best” ways for managing the nitrogen cycle.

WILLIAM MOOMAW. Tufts University, Medford, MA 02155.

Energy, Industry and Nitrogen.

Nitrogen is released during atmospheric combustion and during the .production of certain chemicals and products. This analysis will suggest how an economic analysis of the nitrogen cycle can identify the most cost effective places to intervene. Nitrogen oxides released during fossil fuel combustion in vehicles, power plants and heating boilers can either be controlled by add-on emission control technology, or can be eliminated by many of the same technical options that accompany carbon dioxide reduction. These integrated strategies also address sustainability, economic development and national security issues. Similarly in industrial production, the most common approach is to focus on pollution elimination rather than on rethinking industrial design. This presentation will suggest how policies might be designed to address multiple benefits rather than focusing on single pollutants.

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Nutrient Management in Food Production: Achieving Agronomic and Environmental Targets.

Nutrient management can be defined as ‘*the management of nutrient inputs and transformations within a defined system to achieve both economic and environmental targets*’. In this concept, nutrient management is termed ‘good’ when all targets have been satisfied, and ‘poor’ when one or more targets have not been satisfied. Evidently, the ‘system’ has to be well-defined, and the ‘targets’ have to be specific, quantitative and controllable. This concept is applicable to essentially all food production systems, though the emphasis will shift somewhat from agronomic to environmental targets when food production increases through an increase in nutrient input. It is applicable at a wide range of scales, from field, farm, region to continent, though targets are most easily defined and controlled at farm and regional levels.

I propose to narrow my presentation on the following three aspects:

What are the differences in nutrient management between farms and between countries
What is effective nutrient management at farm level?
How to implement effective nutrient management in practice?

Re 1. What are the differences in nutrient management between farms and between countries?
Using statistical data and information from African countries, US, Netherlands, and Eastern European countries, I will analyze the differences between farms and between countries in nitrogen (and phosphorus) surpluses per unit of surface area and unit of produce. The background and cause of differences in nitrogen (and phosphorus) surpluses between farms and between countries will be discussed. Current data suggest that 50% or more of the variation in nutrient surpluses between specific farm types (e.g. crop production systems or animal production systems) have to be accounted to 'nutrient management', whilst the remaining 50% (or less) of the variation has to be attributed to differences in soil and climatic conditions, climate, crop and animal varieties, etc. The results of this analysis indicates that the scope for improving nutrient management and decreasing nutrient surpluses is large.

Re 2. Effective nutrient management at farm level.
To become effective, nutrient management has to be implemented at strategic, tactical and operational management levels of the farm enterprise. Economic as well as environmental targets have to be defined quantitatively at the strategic management level (farm level). The management at tactical and operational levels subsequently has to focus on achieving both types of targets. Targets have to be coherent and need to be defined in terms of, for example, yield and quality of farm produce, nutrient transfer efficiencies, maximum nutrient inputs, and nutrient losses. They have to be specific and controllable. All essential plant nutrients and all nutrient stocks and flows in the farm have to be considered properly. Quantitative risk assessment may be an integral step in nutrient management planning, because various external and internal factors have influence on the economic and environmental performance of the farm enterprise. This will be illustrated by some cases.

Re 3. How to implement effective nutrient management in practice?
There is an increasing economic pressure on agriculture, world wide, mainly as a result of the liberalization of the market within the framework of e.g. WTO, improvements in transport and logistics which facilitate the transport of products and nutrients around the world, and because of the inherent structure of most farms, i.e. small family enterprises. The pressure increases further when the environmental costs of agricultural production are taken into account. However, when the market dictates the price of what farms produce, farmers will be reluctant of introducing measures, unless financial incentives force them to do so. I will argue that implementation of effective nutrient management in practice requires from governments a pro-active attitude and a coherent set of policies and measures:

training, management tools, and advice for a license to produce
bans and control measures (do's and don'ts)
financial incentives

The financial incentives must be related to achieving environmental targets at farm level. Targets for N losses or N inputs within a region or country should be related to a fixed N quota for that region, to protect the environment. Quota will depend on the region, and should be the result of (inter)national agreement. This will be illustrated among other topics by discussing the "nutrient accounting system", MINAS, which has been implemented on all farms in The Netherlands from 1998 onwards.

Summarizing, there is large scope for improving nutrient management, thereby improving nutrient use efficiency at the farm level by a factor of up to 2. The need for such improvement will increase concomitant with the increasing quest to produce more food and to protect the wider environment more from nutrient enrichment. Improving nutrient management needs a firm basis in the farm at the strategic management level, and has to be enforced by a coherent combination of governmental measures. Targets at farm level directly follow from quota and production ceilings agreed to and monitored at the (supra)regional level.

AMIR WOLFE, and **JONATHAN PATZ**. Johns Hopkins School of Hygiene and Public Health, Baltimore, MD 21205-2179.

Nitrogen and Human Health: Direct and Indirect Impacts.

Nitrogen can affect human health through numerous pathways, ranging from direct acute impacts, to indirect or long term consequences. This presentation will illustrate nitrogen's diverse effects, from toxic ingestion through to long term sequelae via climate change health outcomes. For example, methemaglobinemia (or infant cyanosis) can occur from ingestion of nitrate contaminated well water in areas with much nitrate fertilizer or livestock operations. Also, persistent pesticides (e.g., aldicarb) in groundwater can convert to carcinogenic nitrosamines when ingested. While nutrient runoff and marine systems will be covered in other presentations, some preliminary data will be discussed regarding the potential link between nitrogen runoff and *Pfiesteria*, a newly recognized toxic dinoflagellate associated with fish kills and possibly human neurological deficits.

Nitrogen release into the air causes several public health problems. First, nitrous oxides (NO_x) combine with volatile organic compounds (VOCs) - in the presence of sunlight and heat - to form tropospheric ozone, better known as ground-level "photochemical smog." Ozone irritates the respiratory system and can exacerbate asthma. Finally, nitrogen can contribute to global climate change which is projected to generate multiple risks to public health such as: heat-related and extreme weather-related mortality; respiratory illness from ozone and biological allergens; changes in water- and vector-borne diseases; and deleterious population migration due to severe droughts and sea level rise. Ironically, one measure to improve urban air pollution (the catalytic converter) has contributed to global warming, thus shifting short term problems to longer term dilemmas. While greatly reducing CO, NO_x, and hydrocarbons, catalytic converters generate N_2O, a greenhouse gas that is presently unregulated and has 310 times the global warming potential of CO_2. Such policy trade-offs will be discussed along with these multiple health outcomes of nitrogen.

NANCY RABALAIS. Louisiana Universities Marine Consortium, Chauvin, LA 70344.

Nitrogen and Aquatic Ecosystems.

Aquatic ecosystems respond in different ways to nitrogen enrichment, along a continuum from freshwater through estuarine, coastal and marine systems. There are differences in freshwater, estuarine and marine systems with regard to which nutrients are limiting or potentially limiting (N, P and Si). These differences become important when resource managers attempt to reduce various nutrient components, especially if nitrogen management is conducted without knowledge of how the other important nutrients influence aquatic ecosystems. Shifts in the ratio of these nutrients can also lead to changes in the biological component of the receiving environment with further effects on phytoplankton communities, food webs, trophodynamics, and ultimately living resources, including commercially important fisheries.

Although phosphorus is considered the limiting nutrient for phytoplankton production in freshwater systems, the effects of atmospheric nitrogen and its contribution to acidification of fresh waters are clear. Within the estuarine to marine continuum, N is considered the primary limiting nutrient, and its overabundance leads to eutrophication. There are well-established positive relationships between dissolved inorganic nitrogen flux and phytoplankton primary production. In addition, data from many marine systems show a relationship between fisheries yield and primary production. There are thresholds, however, where the load of nutrients to estuarine, coastal and marine systems exceeds the capacity for assimilation, and water quality degradation occurs with detrimental effects on components of the ecosystem and on ecosystem functioning. Secondary effects from increased N inputs can include the deleterious effects of noxious and toxic algal blooms, increased turbidity with a subsequent loss of submerged aquatic vegetation, oxygen deficiency in bottom water layers where stratification is present (hypoxia and anoxia), loss of habitat, loss of biodiversity, loss of benthic food webs, shifts in food webs, and loss of harvestable fisheries. N enrichment alone usually enhances marine primary production, but the forms of nitrogen as they enter aquatic ecosystems vary and variably affect phytoplankton growth and community composition. Knowledge of the inputs and forms of nitrogen from watersheds and airsheds and the responses of aquatic ecosystem is essential for eventual management of excess nitrogen.

RABINDRA ROY. Food and Agriculture Organization of the United Nations, 00100 Rome, Italy.

Reduced Reliance on Mineral Nitrogen, Yet More Food.

My presentation will focus on:

i) FAO's projections for the World's food need in 2015 and 2030. This will be based on the incidence of undernourishment in Developing Countries; assessment of world population trends; increase of per capita need for increase of cereal production by almost one billion tons by 2030 from the current level of 1.84 billion tons; amongst the cereals, demand in developing countries for rice will stabilize, demand for wheat will continue to grow, demand for coarse grains (especially maize) will be increasingly driven by their use as animal feed.

ii) Region-wide sources of growth (arable land expansion, yield increases and increases in cropping intensity) will be discussed and consequent need for intensification in eco-regions/major cropping systems will be highlighted.

iii) Present estimates of nitrogen consumption (79 million tons in 1995/97; 103 million tons in 2015; 120 million tons in 2030) with basic assumptions will be elaborated.

iv) Potential and opportunities for further increase in N efficiency, and thus reduced consumption of mineral N fertilizers will be discussed based on field results of an FAO regional project in Asia, and the need for farmers' education/demonstration in integrated nutrient management will be highlighted. Similarly, a review of state of knowledge in Biological Nitrogen Fixation (BNF) will be made, and potential and opportunities for optimizing the use of BNF, with special reference to maize-legume based farming systems will be discussed. Issues relating to enabling policies (pricing, incentives, research, development and training), development of nitrogen applicators, and production/quality control/marketing of BNF inoculants and legume seeds will be discussed.

VACLAV SMIL. University of Manitoba, Winnipeg Mb R3T 2N2 Canada.

Nitrogen and Food.

The history of our understanding of human nitrogen (protein) needs is now more than a century old: it has been marked by many revisions and even the latest findings show a lack of consensus in some areas. Supply and intake of dietary protein remains fundamentally different in rich and poor countries: there is a truly obscene surplus on one hand, and a complex pattern on the other (surprisingly large higher-income segments of people in modernizing countries have more than adequate protein supply, while substantial shares of populations are still experiencing marginal access or undernutrition). In addition, there are some nontrivial problems, and hence appreciable uncertainties, in ways we derive this essential nutritional information.

Consequently, rising use of synthetic fertilizers has played two very different roles in rich and poor countries: in the first instance they have been used to produce excessively meaty diets, to contribute to enormous food waste and to boost agricultural exports — while in the other case they have been assuring the supply of basic nutritional needs and making future population growth possible (the difference being very similar to the use of fossil fuels by these two disparate economic groups).

Gradual adoption of a variety of nutritional changes in both affluent and modernizing countries would moderate the use of nitrogen fertilizers in agriculture without compromising adequate food intakes. As a result, it could be possible to supply adequate nutrition to the world's growing population without any massive increases of nitrogen inputs.

HENRY TYRELL. US Department of Agriculture/Cooperative State Research, Education & Extension Service, Washington, DC 20250.

Nitrogen and Animals.

Animal products play a critical role in providing essential dietary nutrients, primarily essential amino acids and trace minerals, required by the human population. In addition to meeting basic nutritional requirements, the demand for animal products, especially meat, is positively correlated to the economic living status of the population. It is anticipated that the demand for animal products will continue to grow at a rate greater than the growth of the world population. In the United States, like other developed nations, the livestock and poultry industry has responded to increased demand by moving from small, diversified production units to larger and more specialized production units. In addition, the large, intensive production units have tended to concentrate in relatively compact geographic areas to take advantage of capital intensive support segments of the industry such as feed processing plants, slaughter facilities, and product processing and packaging facilities. Associated with the structural change in the livestock sector, which continues to occur, is an uncoupling of livestock production from the land base used to produce the feed to support livestock production. In traditional livestock production systems, waste nutrients from livestock production are recycled to the land as fertilizer for crop production. When livestock production is uncoupled from crop production, disposal of animal waste in an environmentally acceptable manner becomes a major problem. Unfortunately, most animal waste management systems currently in use result in much of the N in animal waste being volatilized and transported away from the production unit in the atmosphere.

Domestic animals, like humans, have a metabolic requirement for amino acids. It is the metabolic requirement for amino acids which determines the flow of N through a livestock production system. Mono-gastric animals like the pig and chicken have an absolute dietary requirement for at least ten of twenty primary amino acids because their tissues lack the ability to synthesize these 'essential' amino acids. Ruminant animals like cattle, sheep and goats do not have an absolute dietary requirement for amino acids, not because their tissues have the ability to synthesize essential amino acids, but because microorganisms contained within the fore-stomach, primarily the rumen and reticulum, synthesize all amino acids from non-protein nitrogen and carbohydrate sources. Microorganisms are then digested and absorbed lower in the digestive tract much the same as in mono-gastric animals. Post-absorptive metabolism of nitrogen and amino acids in mono-gastric and ruminant animals is, in principle, the same.

Metabolism of N by animals is an inefficient process, if efficiency is defined as the ratio of N contained within useful product (meat, milk, egg, etc.) to N contained in feed consumed by the animal. An animal in a non-productive state has an N requirement to maintain life, but operates at zero efficiency because it produces no net useful product. It is estimated that the mammary gland of a dairy cow, for example, converts amino acids extracted from the blood supplying the mammary gland into milk protein with an efficiency of approximately 67%. This efficiency must be defined as the upper limit for that biological process. Efficiency of conversion of dietary N by a lactating dairy cow ranges between near zero when producing very limited amounts of milk up to near 67% at infinitely high milk yield. This example demonstrates a fundamental principle of all animal production systems commonly referred to as the dilution of maintenance. It is the major underlying factor which drives animal production towards higher rates of productivity per animal unit. Another factor contributing to efficiency of N utilization is dietary supply of amino acids, especially essential amino acids, relative to the amino acid composition (requirement) of the animal protein produced. Protein synthesis is limited to the availability of the first limiting amino acid. Amino acids supplied in excess of the animal's ability to synthesize protein will be deaminated, the N converted to urea and excreted in urine. The carbon skeleton of the amino acid is used as an energy substrate for oxidation to carbon dioxide or conversion into fat. One of the major issues restricting optimum N utilization by animals is the ability to predict exact amino acid requirement of the animal and then formulating a diet which will supply the exact amount of each essential amino acid from available feed stocks.

Overall use of dietary N by domestic animals is complex and the subject of much investigation. Practical feeding systems are available and used extensively by livestock producers. Biological availability of N contained in feed stocks is reasonably understood, but can be affected significantly by processing and/or storage of the feed. The undigested fraction of feed excreted in feces is organically bound and relatively stable in the environment until subject to microbial degradation. The digested fraction of feed N enters the blood stream of the animal and is subject to rapid metabolism by animal tissues. The fraction of absorbed N not incorporated into animal tissue or animal product (milk, egg, wool) is ultimately converted to urea (or uric acid in poultry) and excreted in urine. The enzyme urease is ubiquitous in soil, and, especially, in animal feces. Urease is a very efficient enzyme resulting in the rapid conversion of urea N to ammonia N. Ammonia is a very reactive, as well as a volatile form of N. Although quantitative direct measures of ammonia emission from livestock production facilities are inadequate, attempts to trace N through animal production systems using principles of mass balance demonstrate significant loss of N consistent with volatilization of urinary N. This unmanaged loss of N from livestock production systems is undesirable for at least two important reasons: It represents a potential source of biologically active N for sensitive ecosystems; and it represents a significant loss of biologically active N from agroecosystems. A significant research effort is required to develop cost effective methods to eliminate unmanaged loss of N from animal production systems and to develop processes by which N from animal manures can be utilized effectively within agroecosystems.

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The European Nitrogen Case.

In Europe excess nitrogen (N) is a concern for the health of people and ecosystems. The N-budget indicates important losses to the environment through emissions in the European N cycle. Due to the high mobility of N, these losses cause local and regional air and water pollution problems. Various pathways exist: terrestrial systems receive N through atmospheric N deposition; in aquatic ecosystems N inputs stem from seepage, drainage, waste water treatment and untreated effluents; in coastal waters the N load comes from rivers, direct inputs and atmospheric deposition. Ground water receives N mainly from application of fertilizer and animal manure in agriculture, while additional inputs come from deposition.

Vulnerability at the points of effects in the N-cascade is the starting point for the analysis. The vulnerability of people is the same everywhere. Oxidized N is a major health concern in cities. The European situation will be outlined. There is still reason for some concern. Increases in N inputs to terrestrial and aquatic ecosystems can result in shifts in plant species composition with dominance of some (very common) species and loss of biodiversity. The vulnerability of ecosystems to N inputs depends on many factors. Critical loads for N are used to account for these factors for ecosystems in Europe and North America in the framework of the UN-ECE. For ground water quality the drinking water standard of 50 mg/L (as nitrate) is used. Several regions in Europe (and elsewhere) have nitrate levels above this critical load. Coastal zones in Europe differ in reactions to excessive N-input: the Baltic area has hypoxia and anoxia as adverse effects; the North Sea area has algae blooms mainly in the coastal regions; and the Mediterranean has a mixture of effects restricted to the coastal areas. The contribution of Europe to global issues related to nitrogen will also be outlined.

Closing the N cycle must be the objective in order to achieve a more sustainable situation. The cost effectiveness of different policy options will be discussed (Is it more cost effective to reduce NO_x or NH_x? Where is emission reduction most effective in terms of reduced effects in ecosystems and on health? Who pays and who benefits? Are there positive side-effects for other environmental problems?)

European policies on N emission reduction, set up under the UN-ECE protocol for Long Range Transboundary Air Pollution, have led to N-emission reductions between 1990 and 1998 of 10, 14 and 21% for N_2O, NH_3 and NO_x, respectively. The new Gothenburg protocol will lead to projected extra reductions of NO_x and NH_3 of 45 and 12%. N input to the North Sea is subject to the North Sea Action Plan and the OSPAR convention. Reductions of up to 50% have been agreed upon between Rhine and North Sea countries (2000 compared to 1985). Furthermore the EU-Nitrate Directive regulates the protection of waters by means of a ceiling for the N application rate of 170 kg N/ha (50% of current rates in intensive systems). The recent European Framework Directive Water includes all ecologically-based former directives in an attempt to protect aquatic ecosystems (including coastal waters) and ground water resources and to regulate diffuse sources (e.g. agriculture) within river basins. Nutrients receive special attention in this directive.

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Nitrogen and Nature.

We are concerned about anthropogenic changes to the global N cycle in part because added N alters the composition, productivity, and other properties of little-managed ecosystems - "natural" ecosystems - substantially. In this presentation, we ask - why is N in short supply in so many natural ecosystems? For this to happen, N must cycle through ecosystems more slowly than other essential elements and/or be lost more readily - and some process(es) must constrain the biological N fixation.

We identify stoichiometric differences between terrestrial plants and other organisms, the abundance of protein-precipitating plant defenses, and the nature of the C-N bond in soil organic matter as factors that can slow N cycling. In addition, energy-related processes, nutrients other than N, and grazing can constrain the abundance and/or activity of biological N fixers. Together these processes can drive and sustain N limitation in many natural terrestrial ecosystems.

CONCURRENT ORAL SESSIONS

Monday, October 15 - Nitrogen Production and Movement

Oral Session #1: **Nitrogen Use in Agricultural Fertilization Practices.**
Oral Presentation Abstracts

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Effect of N fertigation on nitrate leaching and corn yield.

A study was conducted in an acid sulfate soil in the central region of Thailand, in 1999 and 2000 to assess the influence of N fertilization on corn (*Zea mays* L.) yield and nitrate (NO_3) leaching. Treatments included 3 replications of 0, 100, 150, and 200 kg N/ha as urea arranged in a randomized complete block design. Soil was irrigated to field capacity at 50% available soil moisture depletion regime throughout the season. Nitrate leaching losses were determined from measured daily fluxes of water percolation, soil water NO_3-N concentrations, and seasonal N mass balance. The average maximum corn grain yield of 3.52 ton N/ha was obtained at 200 kg N/ha in 1999 and 5.42 ton N/ha at 150 kg N/ha in 2000. No significant differences in grain yield were observed between 200 and 150 kg N/ha treatments in both years. The lowest yield of 0.55 and 0.98 ton N/ha were obtained at 0 kg N/ha in 1999 and 2000, respectively. The highest NO_3 leaching values of 23 and 5.3 kg N/ha were obtained with 200 kg N/ha in both years in 1999 and 2000, respectively. Throughout 1999, an especially rainy year, the data showed that NO_3-N leached beyond typical maize rooting depth (30 cm). Using N balances as a tool for estimating NO_3 leaching suggests that N balances were not a direct measure for NO_3 leaching in a specific area. Results showed that our fertigation system is an efficient way to provide water and plant nutrients together to the crop.

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Gliricidia (*Gliricidia sepium*) green manures as a potential N source for maize production in the tropics.

Use of N-rich legume green manures to correct N deficiency in infertile soils is a very attractive option in the humid tropics. Understanding the influence of management and climate on their effectiveness, and quantifying their contribution to crop productivity is therefore crucial for technology adaptation. Mineral N buildup and the contribution to N uptake in maize were studied in an ultisol amended with fresh Gliricidia leaves. Net mineral N accumulation was compared in mulched and incorporated treatments in a field incubation study. The ^{15}N isotope dilution technique was used to quantify N supplied to maize by Gliricidia leaves in an alley cropping. Mineral N accumulation was slow, but much greater after incorporation than with mulching. Also N buildup as always higher in the topsoil (0-10cm) than the subsoil (10-20cm). More NO_3-N was leached than NH_4-N, and the effect was greater in the incorporated treatment. Surface applied Gliricidia leaves significantly increased N uptake by maize, and supplied >0% of the total N in the stover and cobs. Thus Gliricidia leaf mulch has immense potential to improve productivity in these soils.

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Nitrogen, groundwater, containerized plant production.

Containerized plant production represents an extremely intensive agricultural practice; 40,000 to 300,000 containers may occupy one acre of surface area to which a large amount of chemical fertilizers will be applied. Currently, recommended fertilizer areas for the production of containerized nursery ornamental plants are far more than plants need wherein up to 50% of the applied fertilizers may be leached or will runoff from containers. Among the nutrients leached or allowed to runoff, nitrogen (N) is the most abundant and is a major concern as a cause of ground and surface water contamination. In this presentation, current fertilizer recommendation rates for different container-grown nursery ornamental plants, the amount of N leaching or runoff from containers and the potential for N contamination of ground and surface water will be discussed. In contrast, our best N management practices that: (1) utilize fertilizer applications based on plant growth need, (2) improve potting medium's nutrient holding capacity using obscure mineral additives, and (3) implement zero runoff irrigation/fertilization delivery systems will encourage revolutionary changes in N management.

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Matching nitrogen release to crop needs, controlled release urea.

Controlled release N products have been commonly used in horticultural applications, such as turf grasses and container grown woody perennials. Agrium, a major N manufacturer in North and South America, is developing a low-cost controlled release urea (CRU) product for use in field crops such as grain corn, canola, wheat and other small grains. Growers can use a CRU designed to release timely and adequate, but not excessive amounts of N to their specific crop. Crop uptake of N will be adequate, while minimizing the amount of N applied and increasing N use efficiency. The grower can eliminate the need for side-dress N applications, as well as potentially reducing the total N applied. Environmentally, the benefits are to minimize N losses from leaching, denitrification, and N use by non-crop plants. Our research over the past four years shows that CRU can be used successfully in field crops.

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Influence of nitrogen fertilization on NO_3- N concentration in lysimeter water.

The objective of our studies was to determine the optimal nitrogen rates for major field crops based on the yield and potential NO_3-N concentration in lysimeter water. A field trial with 10 treatments was set up in Central Croatia. Water leached through the soil to an 80 cm depth was collected by zero tension pan lysimeters. Crops were grown in the following crop sequence: 1996-maize (*Zea mays*),1996/97-winter wheat (*Triticum aestivum*), 1997/98-oil seed rape (*Brassica napus* var oleifera) and 1999-maize (*Zea mays*). NO_3- N concentration in lysimeter water varied application time, temperature, and the quantity and intensity of precipitation. In control treatments, the average NO_3- N concentration was relatively low (3.7 - 5.6 mg/L NO_3- N). Increasing rates (fertilization with 200, 250 and 300 kg N/ha) increased NO_3-N concentration in water (14.3 - 28.7 mg/L/NO_3-N).

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Factors affecting microbial formation of nitrate-N in soil and their effect on fertilizer-N use efficiency.

Mineralization of soil organic matter is governed by predictable factors with nitrate-N as the end product. Crop production, interrupts the natural balance, accelerates mineralization of N, and elevates levels of nitrate-N in soil. Six factors determine nitrate-N levels in soils. These are: soil-clay content, -bulk density, -organic matter content, -pH, -temperature and rainfall. Maximal rates of N mineralization require an optimal level of air filled pore space. Optimal air filled pore space depends on soil clay content, soil organic matter content, soil bulk density and rainfall. Pore space is partitioned into water filled and air space. A maximal rate of nitrate formation occurs at a pH of 6.7 and rather modest mineralization rates at pH 5.0 and pH 8.0. When the components are combined in a computer program, predictions of the soil nitrate-N concentrations with a relative precision of 1 to 2 ug N/g of soil are obtained. Predicting mineralization in this manner allows optimal side-dress N applications to be determined for site-specific soil and weather conditions.

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Prediction of N fertilizer needs for corn by soil N mineralization indicators.

Nitrogen (N) is an important factor influencing corn (*Zea mays* L.) yield, but it can result in water contamination when used in excessive amount. Uniform application of N fertilizer may also result in either under or over-fertilization. The objective of this study was too predict the N fertilizer requirements of corn with different N mineralization indicators. Four indicators were used to determine N mineralization potential: organic matter (OM) content and three equations involving OM and Clay content. The study was conducted on a 15-ha field close to Montreal, Quebec, Canada. In the spring 2000, soil samples (n=150) were collected on a 30 m * 30 m grid and six rates of N fertilizers (0-250 kg N/ha) were applied. Kriged maps of particle size showed areas of clay, clay loam and fine sandy loam soils. The fertilizer rate to reach maximum yield (N_{max}), as estimated by a quadratic model, varied among textural classes and N mineralization indicators and ranged from 159 to 250 kg N/ha. The proportion of variability (R^2) and the standard error of the estimate (SE) varied among groups and N mineralization indicators. The R^2 ranged from 0.53 to 0.91 and the SE from 0.13 to 1.62. Textural classes can be used successfully to determine N max under our conditions. N mineralization indicator may also assist the variable rate fertilizer N application for corn.

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Alternate nitrogen amendments for organic fertilizers.

Organic fertilizers have great demand globally. The use of compost or manure in agriculture as organic source of nutrients is well practiced in many tropical developing countries like Nigeria. One of the drawbacks of such materials is a very low level of nitrogen, 1% or less. Farmers have a tendency of supplementing the soils with chemical nitrogen fertilizers such as urea, CAN and NPK formulations to obtain better crop growth and yield. These chemical supplements have a negative impact on the environment as they leach out nitrates and phosphates into soil and water leading to eutrophication of watercourses, erosion of soil, and also affecting public health. Gliricidia (*Gliricidia sepium*), a tropical fast growing hedge plant, perennial in nature was therefore tested as a source of organic nitrogen which may be effectively supplemented in the Organo-mineral fertilizer formulations. This plant has the composition (%): N, 3.78; P, 0.32; K, 1.83; Ca, 0.80; and Mg, 0.20. Using a sand culture and *Amaranthus caudatus* as a test crop, it was shown that amending the commercial composts with 30% Gliricidia prunings would benefit many farmers and control environmental pollution.

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Managing nitrogen fertilizer for winter vegetable production in New Zealand.

Vegetable growing is a major land use in the Pukekohe region of New Zealand. The area has highly fertile, well-structured soils derived from volcanic ash and a temperate climate, which suits production of fresh vegetables during the winter. Typical crops grown during the winter are potatoes and green vegetables (e.g. cabbages, lettuces, spinach). High rates of N fertilizer (e.g. > 300 kg N/ha) are applied to these crops to compensate for slower plant growth and poor nutrient uptake over winter. However, these practices lead to large losses of N per ha. The growers apply most of the N fertilizer when the winter crops are planted. Our research shows that applying very high N fertilizer rates at planting in May/June (late autumn/early winter) leads to the build up of nitrate concentrations in the soil profile and leaching losses of 180 - 200 kg N/ha over winter. A better option is to apply the N more strategically so that only enough N is applied at planting to get the crop established and most of the N is applied later to match crop uptake. This reduces leaching losses and the amount of fertilizer N required without compromising crop yield or quality.

Oral Session #2: ***Nitrogen Management in Animal Agriculture.***

ERICKSON, G. E., and T. J. KLOPFENSTEIN. University of Nebraska, Lincoln, NE 68583 USA.

Managing N imputs and the effect on N volatilization following excretion in open-dirt feedlots in Nebraska.

Feedlot nutrition will play an important role in meeting environmental challenges of beef cattle feedlots. Nutritionists are continually refining protein requirements and recently adopted a new, metabolizable protein (MP) system to more efficiently use N and allow more accurate diet formulation. Protein requirements are also influenced by whether calves or yearlings are fed and also change as the animal gains weight during the finishing period. Our hypothesis was that formulating diets with the MP system would decrease N inputs leading to decreased excretion and volatilization. Comparing industry average diets (13.5% CP) to phase-fed diets formulated to not exceed MP requirements decreased N inputs by 10 to 20% for calves and yearlings without affecting ADG. Decreasing inputs led to a concomitant decrease in N excretion (12-21%) and volatilization (15 to 33%) in open-dirt feedlot pens. Nitrogen losses are variable with time of year, with averages of 60 to 70% of excreted N lost during the summer months and 4% lost from November to May feeding periods. Protein requirements are continually being refined as more research data are collected. However, formulation to meet and not exceed protein requirements is an important nutritional management option for feedlots to become sustainable.

ERICKSON, G. E., and T. J. KLOPFENSTEIN. University of Nebraska, Lincoln, NE 68583 USA.

Nutritional methods to decrease N volatilization from open-dirt feedlots in Nebraska.

Nitrogen losses from cattle feedlots are a concern due to loss of valuable N and impacts from atmospheric N emissions. Nutritional methods to decrease losses would have economic and environmental benefit. One method to decrease N volatilization is by increasing carbon on the open surface. From a management perspective, feeding a diet that will increase carbon may be the most cost effective. Therefore, three experiments evaluated feeding corn bran (less digestible than corn) at 0, 15, or 30% of the diet. The 15 and 30% bran diets increase organic matter (carbon) excretion by approximately .5 and 1 kgsteer/d, respectively. Compared to no bran, feeding 15 and 30% decreased feed efficiency by 7.8 and 10.4%, respectively. Nutrient balance was assessed for two trials from October through June and one trial from June to September. During the trials from September to June, N losses were decreased by 14.5 and 20.7% for 15 and 30% bran diets compared to no bran. Feeding 15 or 30% bran did not influence N loses in the trial from June to September. Increasing the carbon:nitrogen ratio of manure prior to cleaning open-dirt feedlots has variable results depending on time of year.

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Nitrogen mineralization from animal mnure: USDA-ARS nationally coordinated research.

Increased animal production to feed a growing human population results in more manure to be applied to a shrinking available land base. Management practices must be developed that optimize recycling of manure-derived N to crops, while minimizing adverse environmental consequences of manure application to cropland. Approximately 15 scientists with the USDA-Agricultural Research Service are conducting nationally coordinated research to develop N mineralization predictions across wide ranges in U.S. soils (IL, ME, MS, NE, OR, WI), temperature regimes (11-42 °C), moisture regimes (constant and fluctuating), and manure types (dairy, beef, swine, and poultry). Generalized manure N mineralization predictions are based on laboratory studies conducted at participating laboratories following nationally coordinated protocols. Field studies are then conducted across soils and climatic regimes to validate manure N mineralization predictions under field conditions. The product of this research will be development of a decision support system for predicting manure N mineralization across ranges in soil, climate, and manure composition. This will allow optimal N use efficiency in manure-amended soils, thereby maximizing economic benefits and minimizing deleterious environmental consequences of manure application to cropland.

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Prevention and control of losses of gaseous nitrogen compounds on livestock operations.

Nitrogen losses from livestock houses and manure storage facilities contribute for a larger part to the total loss of nitrogen from livestock farms. Volatilization of NH_3 is the major process responsible for the loss of N in the husbandry systems with slurry (average dry matter content varies between 3 and 13%). Concerning this volatilization of NH_3 the process parameters such as pH and air temperature are crucial. During a period of approximately 10 years systematic measurements were carried out of mainly ammonia (NH_3) losses originating from a large variety of different livestock houses. One of the problems of ammonia emissions is the large variation in the measured data due to the season, the production of the animals, the manure treatment, type of livestock house and the manure storage. Generally speaking, prevention and control of ammonia emission can be done by control of nitrogen content in the manure, moisture content, pH and temperature (Groot Koerkamp, 1994). In houses for growing pigs a combination of simple housing measures can be taken to reduce the ammonia emission remarkably (Aarnink, 1997). In the houses for laying hens the control of the manure drying process determines the emission of ammonia. Monteny (2000) has built an ammonia production model with separate modules for the emission of the manure storage under the dairy house and the floor in the house. Losses via NO, N_2O, and N_2 are important in husbandry systems with solid manure and straw. The number of experimental data is, however, very limited. As N_2O is an intermediate product of complex biochemical processes of nitrification and denitrification, optimal conditions are the key issues in N_2O reduction strategies. We may expect that in the near future the emission of greenhouse gases will get the same attention from policy makers as ammonia. Manure spreading is also an essential source of ammonia emission and is depending on slurry composition, environmental conditions and farm management. The effect of these factors is modeled (Huijsmans, 1998).

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Impact of management practices on nitrogen utilization efficiency in lactating dairy cattle.

Improving the efficiency of feed N utilization by dairy cattle is the most effective means to reduce nutrient losses from dairy farms. The objectives of this study were to quantify the impact of different management strategies on the efficiency of feed N utilization for dairy farms in the Chesapeake Bay Drainage Basin A confidential mail survey was completed in December 1998 by 454 dairy farmers in PA, MD, VA, WV and DE. Nitrogen intake, urinary and fecal N, and efficiency of feed N utilization were predicted from survey data and milk analysis for each herd. Average efficiency of feed N utilization (N in milk/N in feed x 100) was 28.6% (SD=4.5). Efficiency of feed N utilization ranged by 39% between the 83rd and 17th percentile herds. On average, farmers fed about 6% more N than recommended by the National Research Council resulting in a 14% increase in urinary N and a 3% increase in fecal N. Use of monthly milk yield and component testing, administration of bovine somatotropin, and extending photoperiod with artificial light each increased efficiency of feed N utilization by 5.5 to 9.5% while use of a complete feed decreased efficiency by 6.3%. Increased frequency of ration balancing and more frequent forage nutrient testing were associated with higher milk production, but not increased N utilization efficiency. Feeding protein closer to recommendations and increasing production per cow both contributed to improving efficiency of feed N utilization.

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Desorption of ammonia from swine waste lagoons: An evaluation of predictive models.

When excreted, the predominant form of nitrogen in livestock and poultry manures is organic nitrogen. Ammonia and oxidized forms of nitrogen normally are present at most in only trace amounts. However, the organic nitrogen present is rapidly mineralized to ammonia nitrogen under both aerobic and anaerobic conditions. In areas of concentrated livestock or poultry production, this mineralization process creates the potential for the significant release of ammonia to the atmosphere and subsequent negative impacts on water quality following both wet and dry deposition. Lagoons used for the stabilization and storage of livestock and poultry manures have been identified as potentially significant point sources of these emissions. Given the extensive use of lagoons in the swine industry, several mathematical models of ammonia desorption from such sites have been proposed. The significant differences among these models in predicted rates of ammonia desorption indicated the need for the critical review and testing of the validity of each model. The results of this review and testing indicate that the validity of all of these proposed models is questionable. Based on materials balances constructed for two full-scale lagoons used for swine wastes, all of the modes reviewed and tested seriously under predicted rates of ammonia desorption.

MILLER, L.R.[1], W.A. HEAD[2], N.C. HANSEN[2], and C.R. DAHLEN[1]. [1]University of Minnesota, St Paul, MN 55108 USA; [2]West Central Research and Outreach Center, Morris, MN 56267 USA. Presented by **ALFREDO DICOSTANZO**, University of Minnesota, St. Paul, MN 55108.

The impact of dietary protein manipulation of feedlot nitrogen balance.

Increased concerns for the role of nitrogen (N) released into the environment by animal feeding operations (AFO) have led researchers to evaluate feeding and management practices that optimize N output. A strategy to minimize N release into the environment is the reduction of dietary protein in sheep and cattle diets. This has led to reduced N output, thereby reducing N runoff and volatilization. Reducing protein intake can lead to reductions in animal growth and efficiency; therefore, a compromise must be reached between production efficiency and N output. The objectives of this trial were to describe the fate of dietary N (retention by the animal, capture in manure, or volatilization and runoff) in an AFO, and to evaluate a simpler, indirect method of estimating feedlot N balance. A finishing diet containing either 16.5% or 18.1% crude protein was fed to 144 lambs (12/pen) for 133 days. Lambs were housed in pens built to facilitate measurement of N in feedlot soil, manure, run-off and volatilization. Subsets of lambs (12 head) were harvested on days 1, 43, and 125 to measure N retention in the whole body. Equations used to estimate N retention from growth rate were the basis for the indirect method.

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Limitations to the reduction of nitrogen and phosphate surpluses through nutrient efficiency improvement: Evidence from Dutch dairy farms.

Dutch nutrient policy aims at reducing leaching of agricultural nutrients by internalizing the negative externalities associated with inefficient nutrient use. This is done by taxation of nitrogen and phosphate surpluses that exceed a hectare-based threshold of maximum allowed surpluses. One option farmers have to reduce surpluses on their farm is to improve the nutrient efficiency of the agricultural production process. However, it is likely that possibilities for this are limited when farm intensity is high. A higher efficiency will result in a lower surplus per unit of output. However, the intensity of the farming system may cause a farm to exceed the surplus standards after all. This study employs Data Envelopment Analysis (DEA) to calculate nitrogen ad phosphate efficiencies, and an overall nutrient efficiency measure for a three-year panel of 114 Dutch dairy farms. Subsequent analyses show the impact of both farm intensity and nutrient efficiency on the surpluses. It appears that farm intensity has a positive effect on efficiency, but efficiency and intensity exert opposite influences on nutrient surpluses. This is especially the case for nitrogen. The magnitude of a possible reduction of nitrogen surpluses through efficiency improvement is therefore limited by the intensity of the farming system.

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Environment scenarios for the future nitrogen policy in Flanders, Belgium.

The agricultural sector accounts for two thirds of nitrogen losses in Flanders. The government and the farmers have been taking measures since 1991. Initially, the manure policy aimed at distributing the manure surpluses equally across Flanders. At the same time the growth of the livestock was stopped by a strict licensing policy, which required "command and control" measures. In recent years the policy has switched to the use of individual target commitments by farmers. The Flemish manure policy will be even more tightened as a result of international pressures. An *ex ante* evaluation of possible policy options was carried out under three different scenarios till 2010 (Business As Usual, Additional Measures and Sustainable Development). For this purpose a regionalized, environmental, comparative static, partial equilibrium, mathematical programming model of the Flemish agriculture was used. The nitrogen emission into the agricultural soil was calculated by means of a regional soil balance. European targets can only be reached with manure processing, reduced fertilizer usage and a strong reduction of the intensive livestock breeding activities. The atmospheric deposition of nitrogen compounds will strongly decrease in 2010 if additional measures are taken. This will also result in a strong reduction of nitrous oxide emissions.

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Controlling N release from organic residues: Integrated approach to management of N.

The beneficial effects of integrated use of inorganic fertilizers and organic residues and manures have been widely reported. However, there are as many reports indicating negligible benefits or even disadvantages of combining nutrient sources. This is not surprising given the combination of organic residue sources, soils, climatic, crops, and management factors that influence nutrient dynamics. The most widely accepted function of organic materials is improving the nutrient availability to crops by supplying N. The key to both improving efficiency of N use and reducing N losses is synchronization of N supply from soil, BNF, organic sources, and inorganic fertilizers with the crop N demand. Organic materials are not magic, N losses from them occur as well. Controlling N release from organic sources depends on their nutrient content, quality, and the environmental and management factors. Here we *will synthesize the information generated from integrated nutrient management trials in sub-Saharan Africa and the Philippines, an organic resources database, and a dynamic soil-crop simulation model to present N release from organic sources and soils and the management strategies to synchronize with crop N demand.*

Oral Session #3: ***Forests and the Nitrogen Cycle.***

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Nitrogen leakage from clearcuts.

Nitrogen saturation in forest soils in areas with high atmospheric nitrogen deposition, leading to substantial leakage to ground and surface water, has been identified as a potential environmental problem in Sweden. Managed forests usually have a great capacity to utilize nitrogen, which leads to small leakage, except for clearcuts which have increased leakage during 4 to 6 years after cutting. Normally, this increased leakage in the clearcut phase causes a less than 10% increase of the total nitrogen leakage during a forest generation (70-90 years). However, data from clearcuts in regions with intermediate to high nitrogen deposition (> 10 kg/ha/yr) indicate that the leakage during the clearcut phase can cause a considerable increase of the leakage for the whole forest regeneration. Such a contribution has not been observed before in national calculations of nitrogen leakage to surface waters. Calculations of the contribution of nitrogen to surface waters from clearcuts in the southern part of Sweden have been made on a local administrative region level. Leakage from growing forests was based on the average concentration in runoff from small monitored catchments. The contribution from clearcuts was estimated using a function based on empirical data, describing the correlation between nitrogen deposition and leakage. The calculations show a clear gradient from west to east, with higher leakage from clearcuts in the western part, where the deposition is higher due to long-range transport as well as local sources. The results indicate that clearcuts may increase the nitrogen leakage with more than 40% during a whole forest generation in the west coast where the nitrogen deposition exceeds 20 kg/ha/yr. Experiments with shelterwood instead of clearcuts have shown a possibility to reduce nitrogen leakage after cutting.

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Ecosystem responses to nitrogen deposition in the Colorado Rocky Mountains.

Some areas of the Colorado Rocky Mountains receive moderately elevated (3-5 kg/ha/yr) NO_3 and NH_4 deposition. In these areas we have found significant biogeochemical and ecological responses to N in both terrestrial and aquatic ecosystems. Foliage of old-growth Englemann spruce stands have significantly lower C:N and lignin:N ratios, and greater N:Mg and N:P ratios than forest stands in lower N deposition areas. Soil % N is higher, C:N ratios are lower, and potential net N mineralization rates are highest where the deposition is greater. Lake NO_3 concentrations are significantly higher in the high deposition areas, and their phytoplanktons are not N-limited. Paleolimnological investigations show that N-limitation was overcome as much as 50 years ago, in response to rapid increases in post-WWII fertilizer applications, animal feeding operations, and population growth. Algal species have changed from ultra-oligotrophic communities to those that are now representative of increased disturbance or eutrophication. The change in sediment diatom species is coincident with a progressive lightening in bulk sediment N isotope values, most likely from historical shifts in N emissions sources. N deposition to the Colorado Rocky Mountains has caused measurable and significant changes in ecosystem properties.

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Modelling nitrogen cycling in a Norway spruce plantation in Denmark by the SOILN model.

A dynamic C and N circulation model, SOILN, was applied and tested on 7 years of 'control' data and 3 years of 'manipulation' data from an experiment involving monthly N addition in a Norway spruce forest in Denmark. The model was parameterized and applied to the data from the control plot. Subsequently the model performance was tested against data from the N addition experiment by comparing model output with measurements. The model includes uptake of nitrogen directly from soil organic matter as amino acids proposed to mimic N uptake by mycorrhiza as a pathway parallel to mineral N uptake. The model reproduced well the overall trends in C and N pools and the N concentrations in soil solutions in the topsoil layers whereas discrepancies in soil solution concentrations in the deeper soil layers are seen. Also the needle N concentration is slightly underestimated in some years because of drought effects not included in the model. SOILN reproduces well the observed changes in the N addition experiment, especially the changes in needle N concentrations and the overall distribution within the ecosystem of the extra-added 3.5 gN/m^2/yr match well the observations. In the Control plot receiving 1.9 gN/m^2/yr the simulations indicate that organic N uptake in average supply 35% of the total plant N uptake. By addition of extra 35 kg N/ha/yr the organic N uptake is reduced by 46% compared to the control and supplies 16% of the total N uptake.

BURNS, D.A., and P.S. Murdoch. U.S. Geological Survey, Troy, NY 12180 USA.

Effects of a clearcut on net nitrification rates and nitrate leaching in a deciduous forest, Catskill Mountains, New York, USA.

Clearcutting forests can result in a large release of stored nitrogen (N) as nitrate (NO_3^-) and subsequent movement through the soil to surface waters. The release of NO_3- following harvesting has been attributed to the combined effects of (1) increased rates of N-mineralization and nitrification resulting from increased soil temperatures and soil moisture, and (2) decreased uptake of N by vegetation. We studied the effects of a clearcut on the rate of net nitrification and N-mineralization at a Catskill Mountain forest that receives 10 – 15 kg/ha/yr of atmospheric N deposition. Nitrate concentrations in drainage waters rose to values > 1000 mmol/L beginning 4 months after the clearcut, and remained > 200 mmol/L for 2 years. The amount of available NO_3^- and ammonium in the soil increased two- to four-fold after the harvest in parallel with changes in stream NO_3^- concentrations. O-horizon soil temperature was 2 – 4 °C warmer during the growing season following harvest, but was 1 – 2 °C colder during the dormant season, and moisture content did not change significantly. The rates of net N-mineralization and nitrification did not change significantly after harvesting suggesting that the absence of N uptake by vegetation was primarily responsible for the observed increases in NO_3.

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Decadal-scale C/N interactions in temperate forests assessed with ^{15}N tracer redistributions.

Future forest management is likely to have the multiple goals of C sequestration and retention of N deposition. Addressing these goals will require a predictive understanding of the strongly coupled C and N cycles in forests. Rates of initial N retention in and temporal redistribution among soil pools, at low C:N ratios, versus vegetation (especially woody) pools, at high C:N ratios, are especially important features of C/N interactions to predict. We recovered ^{15}N tracers in two temperate forests under ambient and N-amended (+5 g N/m^2/yr) conditions to test model-predicted redistributions of ^{15}N (applied as either $^{15}NH_4$ or $^{15}NO_3$) among woody, non-woody, and soil pools. In 1999, eight years after ^{15}N applications, ^{15}N recovery increased in living wood in both ambient and N-amended treatments relative to tracer recoveries in 1992. In woody detritus, N-amended plots showed slightly greater ^{15}N recoveries relative to ambient, with the mechanism appearing to be tree uptake and production of slightly more N-rich woody litter. Differences in ^{15}N recoveries in tree biomass were related to whole-system patterns of N retention. Differences in woody litter C and N pools were clearly related to differences in management and disturbance histories in the two forests.

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European wide assessments of nitrogen cycling in beech forests (Fagus sylvatica) - Results from the ICP Forests Programme.

The UN/ECE established in 1985 the Internationale Cooperative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). In this context 863 plots for the Intensive Monitoring (Level II) and approx. 5700 permanent plots (Level I) were established in 34 countries, which represent the European forest ecosystems. The assessment of N compounds is an essential part of this monitoring programme. Central and Western European forests are characterized by a high load of atmospheric N deposition. As an example in Germany 80% of N storages in the mineral soil including humus layer vary between 3.400kg and 13.400kg, Nitrate leaching out of the soil (>5 kg N/ha/yr) occurs on 2/3 of the monitoring plots. In a remarkable number of ecosystems N - utilization and storage capacities exceed the nitrogen input. As shown by specific Level II studies, we have to expect long-term processes of increasing nitrogen saturation (watershed system Zierenberg, 1965 - 2000). Litter fall data and changes in ground vegetation indicate adaptation potentials of forest ecosystems. Site history and the hypothesis of humus disintegration (ULRICH, 1981; EICHHORN AND HÜTTERMANN; 1994) will be discussed. A call for cooperation will be made.

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Signs of N saturation of Swiss forest ecosystems.

According to model calculations, N deposition in Swiss forests increased from 11-13kg N/ha/a to up to 30kg N/ha/a on an average during the second half of the past century (sixties to nineties). Growing agricultural activities and traffic has caused the increase. This high deposition rate is promoting N saturation in a large proportion of Swiss forests. Thus, NO_3^- is leached from the soil in rates that are far above acceptable limits; the concentrations sometimes even exceed the Swiss and WHO drinking water standards. Arginine concentration in the foliage of the mature Norway spruce was correlated with modeled N deposition. The mean arginine concentration in current needles of mature *Picea abies* in permanent forest observation plots was comparable to concentrations in young trees which had been fertilized with 200 kg N/ha/a or more during eight years. Ratios of N/P in foliage of beech and Norway spruce in permanent observation plots increased significantly between 1984 and 1999. Today, the ratios are at levels that have to be regarded as seriously imbalanced. With increasing N/P ratios in foliage of *Fagus sylvatica* a decreasing beechnut size and a growing attack of the beechnuts by the moth *Cydia amplana* was observed. Seeds of beech geminated less with increasing N concentration in the leaves.

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Nitrogen in the tropics: What are the differences?

Either in pristine or more impacted regions of the tropics, nitrogen is not so well studied as in developed temperate regions. The tropics are a key region of the world regarding the global N cycle. In more pristine regions of the tropics, large areas of forest are being replaced by pastures, at unprecedented rates in human history, with serious consequences to the environment. In more impacted areas, forests were replaced by crops many years ago. In the last, the single most important threat to the environment is the accelerated process of urbanization, generating a large volume of sewage, which is discarded into water bodies mostly without any previous treatment. In our presentation we would like to discuss the major differences found so far in N biogeochemistry between tropical and temperate regions of the world: (1) tropical forests have a more “open” N cycle than temperate forests, with consequences in the foliar ^{15}N signatures; (2) the legume trees paradox, why are so many legumes in tropical forests; and (3) N inputs to watersheds in the tropics are distinct, N enters rivers mainly from point and not diffusive sources.

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Effects of brash removal after clear felling on soil and soil-solution chemistry and field-layer biomass along an experimental N-gradient.

Biofuels, such as brash from forest fellings, have been proposed as an alternative energy source. Brash removal may affect the sustainability of forest production, e.g. through a change in the availability of cations and N. We report initial effects of brush removal on inorganic N content in humus and mineral soil, soil-solution chemistry and field-layer biomass after clear felling an N-fertilization experiment in central Sweden. The experiment comprised six different fertilizer levels, ranging from 0 to 60kg N/ha. Urea was given every fifth year during 1967-1987 to replicated plots, giving total doses of 0 to 2400kg N/ha. Clear felling took place in 1995, 12 years after the last fertilization. The removal of brash decreased the NO_3^- availability in the humus layer three years after clear felling. No effect of the previous N fertilization was found in the humus layer, but in the mineral soil there was a significant increase in NO_3^- content two years after clear felling. The soil-solution chemistry and the field-layer biomass showed an irregular pattern with no consistent effects of previous fertilization or brash removal.

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Spatial variability in N saturation in high-elevation spruce-forests of the southeastern U.S.A.

The high-elevation red spruce-Fraser fir forests (*Picea rubens* Sarg./*Abies fraseri* (Pursh.) Poir) in the Southeastern U.S. are at an advanced state of N saturation, due to a combination of high atmospheric nitrogen (N) input, low vegetation N retention, and high soil N mineralization. Natural stand dynamics and an exotic insect infestation have created a heterogeneous forest structure with numerous gaps and large variations in stand age, live and dead standing biomass, and coarse woody debris abundance. In such ecosystems, N dynamics and N saturation are expected to show significant spatial heterogeneity. A study was initiated in a small forested catchment (17.4 ha) in the Great Smoky Mountains National Park, Tennessee to assess the spatial variation of factors that control N saturation (N input regime, soil properties, vegetation characteristics); determine relative N source-sink strength in the spruce-fir forest; and link N cycling and hydrology into an integrated watershed N output response. Spatial patterns in N cycling were assessed from forest and coarse woody debris inventories and field measurements of throughfall N, litterfall, in situ N mineralization, NO_3 leaching, and soil properties in 50 20m by 20 m plots located systematically across the watershed. Based on this information, a GIS-based integration of indices of N dynamics was used to delineate relative N source and sink areas and to evaluate their contribution to watershed-level N loss.

Oral Session #4: ***Ammonia: Sources, Emissions and Transport.***

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Airborne Ns (NO_2 and NH_3) in the Rijeka Bay area (Croatia).

Determination of ambient levels of nitrogen dioxide and ammonia started in 1980, as a part of the air quality monitoring programme implemented within Rijeka Bay Area. The results of 15 years survey (1980/81-1994/95) on ambient levels of these pollutants a two sampling sites are given. Site 1 is located in the city, opposite to the old petroleum refinery facilities, while Site 2 is located in the settlement 25km from the city, opposite to the eastern industrial zone. Annual means of NO_2 varied between 3460ug/m^3 at Site 1 and 14-26ug/m3 at Site 2, but do not follow the 40% reduction in industrial emissions of this pollutant, probably due to dominant impact of other minor sources, like traffic. Maximum daily concentrations were mostly above 100ug/m^3 at site 1, and between 40 and 90ug/m^3 at Site 2. After initial increase, since 1985/86 a slow decrease in NO_2 trend is observed until 1992/93 at Site 1, while a steady increase is visible since 1986/87 at Site 2. Yearly averages of ammonia were in the range of 13-26ug/m^3 at Site 1 and 7-16ug/m^3 at Site 2 and are practically constant during the period studied. Occasionally, maximum daily concentrations above 100ug/m^3 were detected at both sites, being more frequent at Site 1.

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Ammonia emissions and their sources across the United States.

Ammonia is a basic gas and one of the most abundant nitrogen-containing compounds in the atmosphere. When emitted, ammonia reacts with oxides of nitrogen and sulfur to form particles, typically in the fine particle size range. Roughly half of the PM2.5 mass in Eastern U.S. is ammonium sulfate, according to the U.S. EPA. Acid neutralization by ammonia varies across the U.S., as emissions of NO_x and SO_2 are characteristically different in the eastern and western parts of the country. Typical sources of ammonia include livestock, fertilizer, soils, biomass burning, industry, vehicles, the oceans, humans, pets, wild animals, and waste disposal and recycling activities. Ammonia emission inventories are usually constructed by multiplying an activity level by an experimentally determined emission factor for each source. These emission factors are generally reported as annual averages. As ammonia emissions from many sources vary significantly during the year, this method introduces considerable uncertainty to an emission inventory. Ammonia emissions also vary across space with geographic variation in source types. Livestock represents the largest source category. As factory farms have large numbers of animals confined in small areas, these farms are hot spots for ammonia emissions. North Carolina, which has seen a huge increase in hog farming in the past decade, and California, with many large dairies and cattle feedlots, show an especially large number of these hot spots.

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Measurement, analysis and modeling of the relationship between ammonia, acid gases and fine particles.

Since 1990, the population of hogs in eastern North Carolina has increased sharply. The commercial hog farms are a major source of ammonia, emitting as much as 90,000 Tons NH_3/year. In this study, an Annular Denuder System (ADS) was used, which consisted of a cyclone separator, two diffusion denuders coated with sodium carbonate and citric acid, respectively, and a filter pack consisting of Teflon and nylon filters in series. The ADS was used to measure ammonia, acid gases, and fine particles in the atmosphere at a commercial hog farm in Eastern North Carolina from April 1998 to March 1999. The sodium carbonate denuders yielded average acid gas concentrations of 0.23 mg/m^3 HCl (± 0.20 mg/m^3); 1.10 mg/m^3 HONO (± 1.17 mg/m^3); 1.14 mg/m^3 HNO_3 (± 0.81 mg/m^3) and 1.61 mg/m^3 SO_2 (± 1.58 mg/m^3). The citric acid denuders yielded an average concentration of 17.89 mg/m^3 NH_3 (± 15.03 mg/m^3). The filters yielded average fine aerosol concentrations of 1.64 mg/m^3 NH_4^+ (± 1.26 mg/m^3); 0.26 mg/m^3 Cl- (± 0.69 mg/m^3); 192 mg/m^3 NO_{3-} (± 1.09 mg/m^3), and 3.18 mg/m^3 SO_4^{2-} (± 3.12 mg/m^3). Using the data collected from the study sites, we evaluated the seasonal variations and the effects of relative humidity on fine particle species, and investigated the relationships between the observed concentration products of ammonia and nitric acid, and theoretical equilibrium constants.

DENNIS, R. L. NOAA Air Resources Laboratory, Research Triangle Park, NC 27711 USA.

Ammonia deposition and airsheds and their relation to inorganic nitrogen deposition.

Ammonia is playing an increasingly important role in the deposition of inorganic nitrogen, especially to the coastal estuaries of the eastern United States. Model and data analyses indicate that for these coastal areas roughly 1/3rd of the inorganic nitrogen deposition is from reduced nitrogen (ammonia/ium), but that for some coastal areas reduced-nitrogen deposition is surpassing that from oxidized nitrogen. Ammonia is involved in fine particle production; the relation of ammonia to sulfate concentrations and how this controls the dry deposition of both reduced and oxidized forms of nitrogen will be noted. A modeling approach has been developed to define a range of influence for reduced and oxidized nitrogen deposition, associated with their lifetime in the lower atmosphere. The ranges of influence from source subregions are used to estimate airsheds associated with reduced and oxidized nitrogen deposition for major endpoints of interest such as coastal watersheds and estuaries. These airsheds are large and multi-state in size. Several pairs of reduced- and oxidized-nitrogen airsheds will be compared and contrasted and some characteristics outlined. While the ranges of influence, and airsheds, for reduced nitrogen are smaller than for oxidized nitrogen, they are still larger than conventional wisdom would anticipate. This apparent disparity will be explored, suggesting that some elements of conventional wisdom are incorrect.

DENTENER, F. *Joint Research Centre, Environment Institute, TP280, I-21020 Ispra (Va), Italy.*

Global modeling of NH_3: What do we know?

NH_3 is the main gas phase neutralizing component in the atmosphere, and plays an important role in aerosol formation, co-determines the acidity and nitrogen content of wet and dry depositions. I will give an overview of the current status of the global modeling, describe the most important processes and evaluate the main uncertainties in the calculation of atmospheric abundances and depositions. I will further illustrate the role of atmospheric NH_x deposition relative to other alkaline and acidic processes.

GILLILAND, A. B., R.L. DENNIS, S.J. ROSELLE, and T.E. PIERCE. NOAA Air Resources Laboratory, Atmospheric Modeling Division, NC 27711 USA.

Inverse modeling to estimate the seasonality of airborne ammonia emissions.

Significant uncertainty exists in both the magnitude and temporal variability of NH_3 emissions, which are needed for air quality modeling of aerosols and deposition of nitrogen compounds. Approximately 85% of ammonia emissions are estimated to come from agricultural non-point sources. We suspect a strong seasonal pattern in NH_3 emissions because of the volatility of ammonia and the seasonality of agricultural practices. However, current NH_3 emission inventories, lack of intra-annual variability, and imprecise magnitude significantly affect model predicted concentrations and wet and dry deposition of nitrogen-containing compounds. To address this, we apply a Kalman filter inverse modeling technique to deduce monthly and seasonal 1990 NH_3 emissions for the Eastern United States domain. The USEPA Community Multiscale Air Quality (CMAQ) model and ammonium wet concentration (NH_4^+) data from the National Atmospheric Deposition Program (NADP) network are used. The inverse modeling technique estimates the emission adjustments that provide optimal modeled results with respect to wet ammonium concentrations, observational data error, and emission uncertainty. Then, independent comparisons are made against the Eulerian Model Evaluation Field Study (EMEFS) data. NH_3 emission adjustments for January, April, May, June, and October 1990 will be presented to illustrate the strong seasonality pattern that is evident in these results.

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Seasonal emissions of ammonia from tunnel ventilated swine finishing barns.

Ammonia emissions from concentrated swine production facilities are of major interest to the state of North Carolina due to the nutrient sensitive estuaries nearby. Tunnel ventilated swine production barns dominate Eastern North Carolina farming operations. Emissions data has been collected directly from the building exhaust fans along with fans flow rates. Seasonal ammonia emissions data are presented for the finishing barns. Effects of size and age of the hogs are examined.

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Sources of N: NH_3 & N_2O plume measurements.

Mobile measurements of NH_3 using a fast wet denuder systems and for N_2O using a tunable diode laser system were performed for various sources of NH_3 and N_2O. For NH_3 a series of experiments was performed to evaluate the emission of farm houses and of manured fields. For this evaluation both static plume measurements (using an array of NH_3 denuder systems) and mobile measurements were combined. An experiment with an artificial source was done to evaluate the validity of the dispersion models used. For N_2O measurements were performed to evaluate the N_2O emission of a nitric acid plant, a waste water treatment facility and a hospital. The presentation will give an overview of these experiments and discuss the main results.

ROBARGE, W.P.[1], D. WHITALL[2], B. HENDRICKSON[2], H. PAERL[2], J. WALKER[3], G. MURRAY[4], J. CHAUHAN[4], and T. MANUSZAK[4]. [1]North Carolina State University, Raleigh, NC 27695 USA; [2]University of North Carolina at Chapel Hill, Morehead City, NC 28557 USA; [3]US EPA, Research Triangle Park, NC 27711 USA; [4]NC DENR, Raleigh, NC 27626 USA.

Comparison of atmospheric ammonia/um at three sites in eastern North Carolina, USA.

Most production of swine in North Carolina (standing herd = 9,100,000 head) occurs within a six-county region located in the eastern portion of the state. Annular denuders have been used to measure the atmospheric concentrations of ammonia (NH_3) and ammonium aerosols in three locations in eastern North Carolina: Sampson Co. where there is a relatively high density of large-scale swine and poultry operations, Lenoir Co. where there are relatively less animal operations, and Carteret Co. which is a coastal site with very few animal operations. From May 1999 to August 2000, mean daily concentration of NH_3 at the Sampson Co. site was 5.3 (+/- 4.1) ug N/m^3 and 0.56 (+/- 0.56) ug N/m^3 at the Carteret Co. site. From May 2000 to August 2000 mean daily concentration of NH_3 was 2.6 (+/- 1.7) ug N/m^3 at the Kinston site. Ammonium aerosols account for 50% of inorganic N at the Carteret Co. site as compared to <25% at the Sampson Co. site. The monitoring of atmospheric ammonia/um in eastern North Carolina will continue and the number of monitoring sites expanded to better understand the fate and transport of ammonia released from large-scale animal production facilities in the region.

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The decreasing of ammonia emission in the Czech Republic.

The Czech Republic signed the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone in the year 1999. This Protocol is one of the CLRTAP Protocols - The Convention on Long-range Transboundary Air Pollution. The Protocol sets emission ceilings for 2010 for four pollutants: sulphur, NO_x, VOCs and ammonia. The aim of this Protocol is reducing and decreasing of emissions of sulphur, nitrogen oxides, ammonia, and volatile organic substances resulting from anthropogenic activities and causing adverse effects on health of people, natural ecosystems, materials and crops. The main long-term objectives resulting from the signature of the Protocol are the following: a/ Reducing and decreasing of emissions of ammonia resulting from anthropogenic activities in the most possible degree with synchronous taking into account the level of knowledge and development research, b/ Not to exceed an emission limit for ammonia which was set for the year 2001 and its level is 101 kt/year NH_3. It represents decreasing of 35% compared to year 1990. The most exact quantification of ammonia emission is the basic presumption for discharge of obligations. Most of emitted ammonia in the Czech Republic is produced in breeding of cattle, therefore the problem of solving is primarily determination of emission factors for these kinds of animals whose breeding is the main source of ammonia in respect to their total number, the type of breeding and subsequent disposal with manure. Submitted paper summarizes results of four- year research in this area, emission factors and ways of decreasing emissions from breeding of cattle.

Oral Session #5: ***Atmosphere-Biosphere: N_2O and NO Emissions.***

BOBBINK, R., and M.M. HEFTING. Landscape Ecology, Utrecht University, 3508 TB Utrecht, The Netherlands.

N enrichment and the emission of the greenhouse gas N_2O from wetlands.

Nitrous gas emissions from wet and moist ecosystems may significantly contribute to the enhanced greenhouse effect and to the destruction of stratospheric ozone. These emissions can be seriously influenced by increased inputs of nitrogen compounds, besides by changes in hydrology. Both field and laboratory studies were performed to investigate (1) the effects of nitrogen enrichment on the emissions of nitrous oxide and methane from soils of different moist to wet ecosystems, and, (2) the relationship between abiotic conditions and the emissions of nitrous oxide. It became obvious that differences in water table strongly control the greenhouse gas emissions from the investigated wetlands. In addition, it was also shown that under elevated nitrogen inputs, especially of nitrate, the emissions of nitrous oxide increased significantly from the investigated wetland soils, because of incomplete denitrification processes. N_2O emissions as high as 20 –30 mg N_2O/m^2/day were measured in a forested riparian buffer zone under severe N inputs by groundwater inflow. This has let to an annual emission of 4.3 – 6.9 g N_2O m^2 from this wet forested site. It is concluded that nitrogen enrichment may strongly enhanced the emissions of nitrous oxide from wetlands in a N-saturated environment as the Netherlands.

DAVIDSON, E.A. [1], M. M. C. BUSTAMANTE[2] and A. S. PINTO[2]. [1]The Woods Hole Research Center, Woods Hole, MA 02543 USA; [2]The Universidade de Brasilia, Brasilia, Brazil.

Updated review of soil emissions of NO and N_2O from forests, savannas, and cattle pastures of Brazil.

Recent data from the forested regions of the Brazilian Amazon Basin and from savannas of the Brazilian Cerrado support previous reviews indicating that soil emissions from these regions are important sources of atmospheric NO and N_2O. The humid forests are more important sources of N_2O, while the less humid savannas are more important sources of NO. Unlike early results from previous studies of land-use change in these regions, however, more recent studies indicate that conversion of forest and cerrado ecosystems to cattle pastures results in a long-term decrease in emissions of these nitrogen oxide trace gases from soils. In some cases, there is a brief period, lasting a few months to at most two years, when emissions are elevated after deforestation. However, active and abandoned old pastures and secondary forests generally have lower soil emissions of NO and N_2O than do the mature native ecosystems, so that the net effect of historical land use change has been a decrease in soil emissions of these gases.

HARRISON, J., and P. MATSON. Stanford University, Stanford, CA 94305 USA.

Nitrous oxide (N_2O) emission from drainage waters of an intensively farmed, subtropical valley.

Though agricultural runoff is thought to constitute a globally important source of the greenhouse gas nitrous oxide (N_2O), production of N_2O in polluted, freshwater systems is poorly understood, especially in non-temperate regions where the most rapid agricultural intensification is occurring. We measured N_2O emissions bi-weekly from freshwater drainage systems receiving agricultural and mixed agricultural/urban inputs from the intensively farmed Yaqui Valley of Sonora, Mexico. We also monitored factors likely to control rates of N_2O production. N_2O emissions in both purely agricultural and mixed urban/agricultural drainage systems were high (means: 19.6 and 25.05 ng N_2O –N/c m^2/hr respectively), and isolated measurements of N_2O emissions from the mixed urban/agricultural drainage were extremely high (up to 166.5 ng N_2O -N/ m^2 hr). However, despite high relative fluxes, preliminary calculations of valley-wide N_2O emissions from agricultural drainage indicate that N_2O emissions from drainage waters are not as important as global budgets currently estimate. Under normal, non algae-bloom conditions, N_2O fluxes were strongly correlated with nitrate concentrations (P=0.003). However, the highest N_2O fluxes occurred during green algae blooms, when organic carbon and oxygen were more strongly correlated with N_2O production than nitrate availability.

KHALIL, M.I.[1], A.B. ROSENANI[1], O. VAN CLEEMPUT[2], C.I. FAUZIAH[1], and J. SHAMSHUDDIN[1]. [1]Universiti Putra Malaysia, 43400 Serdang, Malaysia; [2]Ghent University, 9000-Ghent, Belgium.

Nitrogen management in a maize-groundnut crop rotation of humid tropics: Effect on N_2O emission.

Developing appropriate land management technique to attain sustainability and to increase N use efficiency of crops has been gaining momentum in the tropics. Management of nitrogenous fertilizers is an important choice to that effect. However, it may enhance nitrous oxide (N_2O) emission, which causes global warming and ozone layer depletion. Thus, N transformations and N_2O emission during maize-groundnut crop rotation managed with various N sources were studied. Accumulation of nitrate and its reduction were fast immediately after addition of various N sources, showing liming effect. The mineral N retained for 2-4 weeks depending on the type and amount of N application. The chicken manure showed rapid nitrification in the first one week after application during the fallow period, leading to a maximum N_2O flux of 9889 μg N_2O–N/m^2/d. The same plots showed a residual effect by depicting the highest N_2O flux (4053 μg N_2O-N/m^2/d) during maize cultivation supplied with half rate of N fertilizer. Application of N fertilizer only or in combination with crop residues exhibited either lower fluxes or caused a sink during the groundnut and fallow periods due to small availability of substrates and/or low water-filled pore space (<40%). The annual N_2O emission ranged from 1.41 to 3.94 kg N_2O-N/ha, the highest was estimated from the chicken manure plus crop residues and half rate of inorganic N-amended plots. Results indicates a greater influence of chicken manure on the N transformations and thereby N_2O emission.

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Future trends in worldwide river nitrogen transport and related nitrous oxide emissions.

Model calculations indicate that worldwide, rivers transport about 20 Tg of dissolved inorganic nitrogen (DIN) to the oceans (Seitzinger and Kroeze, 1998). Roughly 25% of this amount may be considered natural, indicating that human activities have increased DIN export rates to four times the natural level. The main reasons for this increase are external nitrogen inputs to aquatic systems from agriculture, fuel combustion and point sources. Increased nitrogen availability increases aquatic nitrification and denitrification. Consequently, emissions of the greenhouse gas nitrous oxide (N_2O) from rivers, estuaries and continental shelves are presently higher than in pre-industrial times. Analyses of expected future trends indicate that riverine DIN export and aquatic N_2O emissions may increase considerably in the coming decades (Kroeze and Seitzinger, 1998). Here we present results of model runs in which alternative future developments are considered, along with their effect on DIN export by world rivers and associated N_2O emissions. Our scenarios either assume that current trends continue or that nitrogen to aquatic systems are reduced as a result of changes in agriculture practices and fuel combustion technologies. Global as well as regional results are presented.

ROELLE, P.A., and V. P. ANEJA. North Carolina State University, Raleigh, NC 27695 USA.

Modeling NO emissions from biosolid amended soils.

Fluxes of nitric oxide (NO) were calculated for a field site amended with municipal waste biosolids. An NO flux algorithm, based on soil temperature, was developed for this field site [NO Flux (ng N/m^{-2})=1.07exp (0.1365*Tsoil); R^2=0.81, n=837] and compared to results using the existing Biogenics Emissions Inventory System (BEIS2) model. Results indicate that for this particular field site the BEIS2 model, which provides the NO input data to many air quality models, would have underestimated NO emissions by a factor of 26. This study was then extrapolated to the biosolid amended soils throughout the state of North Carolina to examine the impacts of neglecting this land-use class on existing air quality models. The study revealed that on average, NO emissions from biosolid amended soils in North Carolina represent approximately 1% of the total biogenic budget. However on smaller scales, such as on the county level and smaller (grid cells in model domain are 4 km X 4 km), NO emissions can comprise a more significant fraction of the biogenic budget. For example, in the 5 counties of North Carolina which received the largest application of biosolids, NO emissions would have been underestimated by approximately 12% when using the existing BEIS2 model. Results of a 13-day ozone episode using BEIS2 generated NO input data and modified input data from this study will be presented.

SMITH, K.A., and K.E.DOBBIE. Inst. of Ecol. & Resource Man., Univ. of Edinburgh, Edinburgh EH9 3JU, UK.

N_2O emissions from temperate agricultural soils: Main drivers, possible mitigation procedures, and implications for inventory calculations.

Emissions of N_2O from intensively managed agricultural soils across Great Britain have been measured over several years. Annual emissions varied widely (0.3-27 kg N_2O -N/ha). Crops such as small-grain cereals (winter wheat and spring barley) gave lower emissions (0.2 - 0.7 kg N_2O -N per 100 kg N applied) than those from cut grassland and vegetable crops (0.3-7 kg N_2O -N per 100 kg N). The main drivers for these emissions were soil water-filled pore space, temperature, and soil mineral N content. Fluxes were low when any of these variables was below a critical value. The wet summers of 1997-2000 generated fluxes well above those seen in the earlier years of the study, and well above those predicted by the IPCC methodology for emission inventories, which creates emissions solely to the quantity of N applied. The use of urea fertilizer on grass significantly reduced emissions below those associated with ammonium nitrate; nitrification inhibitors also had a substantial mitigating effect. Control (unfertilized)plots on grassland gave negligible emissions. We discuss the potential for mitigation procedures in normal agricultural management, and the significance of these results for future inventory calculations.

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Nitrous oxide and nitric oxide emissions from fertilized soils and mitigation options.

Nitrous oxide(N_2O) and nitric oxide(NO) are emitted to the atmosphere from soils after the application of nitrogen fertilizers to the agricultural fields. Nitrous oxide in the atmosphere is one of the greenhouse gases, and of the trace gases to destroy the stratospheric ozone. Nitric oxide is a precursor of tropospheric ozone which is a greenhouse gas, and a precursor of nitric acid which contributes to acid deposition. We have measured the flux of N_2O and NO in the upland crop fields by closed chamber method, and have made incubation experiments on the effect of soil moisture and soil types on the emission of N_2O and NO, and have investigated how to reduce the emission of N_2O and NO. In this paper, we present the emission ratio of N_2O -N and NO-N to the applied nitrogen, the flux ratio of NO-N/N_2O -N, major factors controlling the emission of N_2O and NO, and mitigation options for emission of N_2O and NO from upland crop fields.

WALLENSTEIN, M.D. Duke University, Durham, NC 27708 USA.

Environmental and microbial controls on denitrification under elevated nitrogen inputs.

I evaluated the response of denitrification to fertilization and liming in a rapidly aggrading forest at the Fernow Experimental Forest in West Virginia, USA. Increased flux of nitrous oxide in response to increased nitrogen inputs is well documented, though it is unclear whether this response is partly due to a change in the ratio of N_2O to N_2. Using intact soil cores and acetylene inhibition assays, I found no significant differences in the ratio of N_2O to N_2 for fertilized versus unfertilized soils, though total denitrification was greater in fertilized plots. I also found that denitrification enzyme activity was greater in fertilized plots (18728 ug N_2O/kg/h) than in unfertilized plots (11650 ug N_2O/kg/h). These results suggest that denitrification rates are partly controlled by the supply the rate of nitrogen cycling, and environmental conditions at these sites. I am also investigating the effects of chronic nitrogen additions on denitrifier diversity using molecular techniques. Preliminary results suggest that changes in denitrification under elevated nitrogen inputs may be partly due to changes in microbial community structure.

WICK, B[1]. E., VELDKAMP[1], W. ZAMBONI DE MELLO[2], and M. KELLER[3]. [1]University of Goettingen, Institute of Soil Science and Forest Nutrition, Büsgenweg 2, 37077 Germany; [2]Universidade Federal Fluminense, Rio de Janeiro, Brazil; [3]University of New Hampshire, Durham, NH 03824, USA.

Linking microbial activities and nitrogen availability to nitrous oxide fluxes in forest-derived pasture sites in the humid tropics of Brazil.

We studied soil N-cycling, enzyme activities and N_2O fluxes along a chronosequence of pasture sites of 4 months up to 60 years following deforestation near Santarem, Para, Brazil. Microbial biomass-N (CFE-technique), nutrient mineralizing enzymes (protease, ß-glucosidase, acid and alkaline phosphatase), total and inroganic N-pools, net mineralization and nitrification, and N_2O (closed chamber method, ECD chromatography) were measured once during the dry and wet season in 32 pasture sites and 4 primary forest control sites. Average N_2O -fluxes in all pasture sites were lower than in the forest sites. Deforestation and establishment of pasture sites resulted in a decrease of N_2O -emissions during the wet season by about 80 % from 128 mg N_2O-N/m^2/h at the primary forest sites to 29 mg N_2O-N/ m^2/h at the 4 month old pasture sites. N_2O fluxes during the dry season followed the same trend but emissions were negligible by comparison. No apparent age trend in N_2O emissions with both pasture age and total organic nitrogen and carbon could be found. Data on N-cycling rates (microbial biomass, soil nutrient mineralizing enzymes, N-mineralization) will be used to explain the changed emissions of N_2O.

YAMULKI, S., and S.C. JARVIS. IGER, North Wyke, Devon, EX20 2SB, UK.

Nitrous oxide emissions from grassland systems: Interactions between soils, management and animals.

Nitrous oxide has impacts on both the radiative balance of the earth and the depletion of stratospheric ozone molecules. Grassland is a major source of N_2O, contributing more than 10% to the total N_2O flux because of the large carbon and mobile N inputs from the excreta of grazing animals and fertilizer applications. N_2O emissions from soil are also extremely variable in time and space and therefore large uncertainties are associated with current estimations of emission factors. Integrated measurements of N_2O fluxes from different grassland management systems were made over a three-year period in a maritime temperate climate in the south west of England. The results provided comprehensive data sets on effects of grassland management and soil and climatic conditions on N_2O emissions. Discussions will be focused on impacts of excreta from grazing animals, fertilizer applications, sward type and soil conditions as well as their interactions on N_2O fluxes and the extent of diurnal variability on the flux estimates.

Oral Session #6: ***Atmospheric Deposition of Nitrogen.***

CAPE, J.N.[1], A.P ROWLAND[2] and T.D. JICKELLS[3]. [1]Centre for Ecology and Hydrology, Edinburgh, Scotland; [2]Centre for Ecology and Hydrology, Merlewood; [3]University of East Anglia.

Organic nitrogen in precipitation: Real problem or sampling artifact?

Published observations of organic nitrogen compounds in precipitation go back almost a century. Several different methods have been used to measure both the total and ionic concentrations of N. There is therefore some uncertainty as to whether reported 'organic N' is real, or simply the result of uncertainties in chemical analyses, or inadequate sampling methods. We found that the materials from which the collector was made (polypropylene, steel or glass) had no significant effect on the composition of dissolved organic N. The use of a biocide was found to be very important during sampling and storage of samples before analysis. We set up a network of 7 collectors across the UK, from the Cairngorms to Dorset, all operating to the same protocol, and including a biocide. Samples were analyzed centrally, using proven methods. Over 6 months, organic N contributed about 20% to the total N in UK precipitation but with a large variation across the country. This means that current estimates of wet deposited nitrogen to the UK, which are based only on the ammonium and nitrate concentrations, are too small.

LEAR, G.G., and D.W. SCHMELTZ. U.S. Environmental Protection Agency, Washington, DC 20460 USA.

Spatial and temporal trends in total nitrogen deposition for the U.S.

Deposition of biologically active nitrogen species has complex origins and occurs through wet and dry deposition processes. The difficulty in obtaining representative samples from multiple measurement systems over a sustained period has resulted in few studies of total nitrogen deposition for the U.S. Here we used the combined data sets of the Clean Air Status and Trends Network and the National Atmospheric Deposition Program/National Trends Network to estimate the spatial and temporal trends in total deposition of inorganic nitrogen species over the ten-year period, 1990-99. Although the total amount of nitrogen deposited has remained relatively constant over this period, the magnitude and composition of nitrogen deposition varies markedly by region.

LYNCH, J.A.[1], and V.C. BOWERSOX[2]. [1]School of Forest Resources, Penn State University, University Park, PA 16802 USA; [2]Illinois State Water Survey, Champaign, IL 61820, USA.

Annual and seasonal trends in nitrate concentration in the USA and their relationship to emissions.

Nitrogen deposition, which was once thought to be a beneficial bi-product of air pollution, is now viewed as a major environmental threat, contributing not only to the acidification of terrestrial and aquatic ecosystems, but also to the eutrophication of surface and coastal waters as well. Although progress has been made in reducing sulfate deposition in the USA as a result of the Clean Air Act Amendments of 1990, reductions in nitrogen oxides emissions have been relatively small, regionally specific, and often seasonally dependent. This research will examine annual and seasonal trends in nitrate concentrations and wet deposition in the USA in relationship to regional trends in nitrogen oxides emissions. Precipitation chemistry data from the National Atmospheric Deposition Program and emissions data from the AIRS/DATA databases will be used in this analysis. Where possible, trends in wet deposition will be compared to trends in nitrate concentrations in surface waters draining small, headwater streams.

NILLES, M.A., and B.E.CONLEY. U.S. Geological Survey, Denver, CO 80225 USA.

Trends in wet deposition of ammonium and nitrate in the United States, 1985-2000.

In 1998 nearly 27 teragrams of nitrogen oxides and ammonia were emitted to the atmosphere in the United States. Deposition of nitrogen compounds to aquatic and terrestrial ecosystems can account for a significant portion of nitrogen inputs. Trends in wet deposition of oxidized and reduced forms of nitrogen have not followed the well-documented declines in sulfate deposition in the United States. Monthly data from 158 sites in the National Atmospheric Deposition Program/National Trends Network were evaluated for trends over the period 1985-2000 using a parametric model to remove the influence of inter-annual variations in precipitation amount, followed by a non-parametric test for detection of monotonic trends. For ammonium deposition, increases were detected at 61 sites while only 2 sites exhibited declining trends. On a network-wide basis, ammonium deposition increased by 27 percent over the 15-year period of analysis. While the majority of sites did not exhibit any trend in nitrate deposition, a greater number of sites (28) had significant increasing trends versus sites with declining trends (9).

PRYOR, S.C.[1], R.J. BARTHELMIE[1,2], M. CARREIRO[3], M.L. DAVIS[1], A. HARTLEY[1], B. JENSEN[4], A. OLIPHANT[1], J.C. RANDOLPH[5], and J.T. SCHOOF[1]. [1]Atmospheric Science Program, Geography, Indiana University, Bloomington, IN 47405 USA; [2]VEA, Risoe National Laboratory, Roskilde, DK-4000, Denmark; [3]Department of Biology, University of Louisville, Louisville, KY 40292 USA; [4]ATMI, National Environmental Research Institute, Roskilde, DK-4000, Denmark; [5]School of Public and Environmental Affairs, Indiana University, Bloomington, IN 47405 USA.

Nitrogen deposition to a mid-latitude deciduous forest and ecosystem response.

The project described in this presentation seeks to answer questions regarding the role increased nitrogen (N) deposition is playing in enhanced carbon (C) sequestration in temperate mid-latitude forests. We present detailed measurements of N deposition and cycling at an AmeriFlux tower in southern Indiana (MMSF). We describe methods used to determine the atmospheric flux rates which include relaxed eddy accumulation of HNO_3 and fast response NH_3 sensors, document collection of the ecological data and present highlights of sampling conducted to date. The atmospheric measurements indicate an average flux of 4.8 mg-N/m^2/dy during the 2000 growing season with approximately 40% coming from dry deposition of NH_3, HNO_3 and particle bound N. Wet deposition and throughfall measurements indicate significant canopy uptake of N (particularly NH_4^+) at the site, leading to a net canopy exchange (NCE) of -8 kg-N/ha for the growing season. These data are used in combination with data on the above ground C:N ratio, literfall flux and soil net N mineralization rates to indicate the level of potential perturbation of C sequestration at this site.

RUSSOW, R.W.B., F. Böhme, and H.-U. Neue. UFZ Centre for Environmental Research, Department of Soil Sciences, Theodor-Lieser Strasse 4, D-06120 Halle, Germany.

A new approach to determine the total airborne N-input into the soil-plant system using the ^{15}N isotope dilution (ITNI): Results for agricultural used areas of central Germany.

Atmospheric deposition of nitrogen to landscapes raises great concern because of its impact on natural ecosystems with changing vegetation, loss of biodiversity, increasing growth of trees in forest and eutrophication of aquatic systems [1]. The average annual N-emission of Germany into the atmosphere amounts to about 2 mill t N/ha (ammonia/ammonium, NO_x), and assuming a homogeneous distribution over the whole area of Germany an average N-deposition of 45 kg/ha year can be calculated. N-balances from long-term field experiments in Central Germany (e.g. Static Fertilization Experiment Bad Lauchstädt) confirmed such high atmospheric N-deposition. Current estimates generally used to account for a deposition of about 30 kg N/ha year only. These low estimates are derived from measurements using standard methods of wet only and bulk collectors which do not account for organic nitrogen, the gaseous deposition and direct uptake of atmospheric nitrogen by aerial plant parts. Therefore to measure the real total atmospheric N-input into a soil/plant system (Integrated Total Nitrogen Input - ITNI) a new device was developed using the ^{15}N isotope dilution methodology. A soil/plant system is labeled with [^{15}N]ammonium [^{15}N]nitrate and the total input of airborne nitrogen can be calculated from the dilution of this tracer due to nitrogen derived from the atmosphere. During the period 1994-1998 an average annual deposition of 64±12 kg/ha and year was measured with this ITNI system at the research farm Bad Lauchstädt (dry belt of Central Germany). Measurements in 1999/2000 at three other sites in the area of Central Germany revealed deposition rates of about 60 kg/ha year. These data clearly indicate that the total atmospheric N deposition into the soil/plant system determined by the newly developed ITNI-system significantly exceeds those obtained from standard wet only and bulk collectors. The higher atmospheric N-depositions found match well with those postulated from N balances of long-term agricultural field experiments. [1] J.W. Erisman et al., Summary of the First Int. Nitrogen Conference, 23-27. March 1998, Noordwijkerhout, The Netherlands.

SICKLES, J. E., **II**. US EPA, National Exposure Research Laboratory, Research Triangle Park, NC 27711 USA.

Deposition of oxidized nitrogen in the Eastern United States.

Air quality and selected meteorological parameters have been monitored at rural sites in the United States (US) at the Environmental Protection Agency's (EPA) Clean Air Status and Trends Network (CASTNet) sites. The National Atmospheric Deposition Program (NADP) monitors wet deposition of numerous ions in precipitation. The current study examines air quality and both dry and wet deposition of oxidized nitrogen data from the CASTNet and NADP archives for the ten-year period between 1990 and 1999 at rural sites located in the eastern US. Archived weekly determinations of airborne nitric acid and nitrate concentrations, their dry deposition, and wet nitrate deposition are considered. Geographical regions are defined within the eastern US for examination (Midwest, South, and Northeast). Both the regional (spatial) distribution and the seasonal behavior of concentration and deposition are emphasized. Notice: The US EPA through its Office of Research and Development funded this research and approved this abstract as a basis for an oral presentation. The actual presentation has not been peer reviewed by EPA.

STENSLAND, G.J., **V.C. BOWERSOX**, B. LARSON, and R.D. CLAYBROOKE. Illinois State Water Survey, Champaign, IL 61820 USA.

Comparison of ammonium in USA wet deposition to ammonia emission estimates.

For the USA a substantial database exists for ammonium in precipitation. This paper presents spatial and temporal patterns in the precipitation ammonium record and compares these patterns to those for ammonia emission estimates. We use NADP National Trends Network (NTN) data to examine 5-year average ammonium concentrations in precipitation for two time periods: 1985-89 and 1995-99. For each of the time periods the area of highest ammonium concentration extends from northwestern Texas to North Dakota and eastward through Minnesota and Iowa. To examine changes in these two time periods, we subtract the objectively-analyzed 1985-89 concentrations from the objectively-analyzed 1995-99 concentrations. Ammonium concentrations generally increased over this10-year interval (mean difference: +3.0 [s.d. 2.9] meq/L or +25.6% [s.d. 23.5%] median difference: +2.5 meq/L or +22.5%, range: -2.8 meq/L to +17.6 meq/L or -24.9% to +121%). We also examine sources of airborne ammonia in the two 5-year periods in an effort to identify potential explanations for the spatial distributions and temporal changes of ammonium concentrations. Among the sources of airborne ammonia that we examine are livestock manure (beef cattle, dairy cows, pigs, laying hens, broiler chickens, and turkeys), fertilizer applications, and automobile exhaust.

SUTTON, M.[1], S. TANG[1], D. FOWLER[1], R.I. SMITH[1], N. FOURNIER[2], and K.J. WESTON[2]. [1]Centre for Ecology and Hydrology Edinburgh, Bush Estate, Penicuik, Midlothian, EH26 0QB, UK; [2]University of Edinburgh, Department of Meteorology, Edinburgh, UK.

Spatial analysis of ammonia and ammonium in the UK: Comparison of model estimates with measurements from the national monitoring network.

As As measures are implemented in Europe to reduce SO_2 and NO_x emissions, attention is falling on the contribution of NH_3 emissions to acidification, nitrogen eutrophication and aerosol formation. In the UK, an atmospheric transport and chemistry model, FRAM, has been developed, with a focus on predicting the patterns of reduced nitrogen (NH_x) concentrations and deposition. At the same time, a national network has been established to measure gaseous NH_3 and aerosol NH_4^+, with sampling at many locations to address questions of regional and local variability, and the extent to which different source categories contribute to concentrations. The paper summarizes the sampling strategy underpinning the national network, including new low cost methods for sampling N_3 and NH_4^+ concentrations (<0.05 - >50 mg/m^3). As expected for a pollutant with ground level emissions in the rural environment, the measurements, made at 80 sites, show that NH_3 concentrations vary spatially at a local level. In contrast, NH_4^+ concentrations measured at 50 locations show regional differences, but little local variation. These features are reproduced in FRAME, which provides concentration estimates at a 5 km level. Analysis of the underlying NH_3 emission inventory shows that pig, poultry and sheep emissions may have been underestimated relative to emissions from cattle. The combination of model and measurements is applied to estimate patterns of NH_3 dry deposition to different vegetation types. The combined approach provides the basis to assess NH_x responses across the UK to European emission control policies.

TARNAY, L. W., and A.W. GERTLER. Desert Research Institute/DAS, Reno, NV 89512 USA.

Nitrogen deposition in the Lake Tahoe Basin: Scaling from leaf to landscape using G.I.S.

As urban areas encroach on forest ecosystems, monitoring atmospheric nitrogen (N) fluxes is becoming increasingly important. A necessary component of any flux estimate is a deposition velocity (m/s), which when multiplied by pollutant concentration yields a flux (nmol/m^2/sec). Leaf-scale deposition velocities (Vg) are relatively well characterized for the principal components of nitrogen deposition (i.e., nitric acid, nitrogen dioxide, and ammonia, ammonium nitrate) in semi-arid forests like those in the Lake Tahoe Basin (located on the California-Nevada border). The factors needed to scale those Vg values to the landscape level (cm to km) vary nonlinearly both due to leaf area index in the vertical plane, and heterogeneous canopy distribution in the horizontal plane. Inferential resistance models are commonly used to account for this nonlinear variation, however they assume a homogeneous canopy distribution. A GIS (Geographic Information System) has the ability to map the heterogeneous variability in parameters for such inferential models. This study reports the results of a 'bigleaf' inferential model applied within a GIS framework to address nonlinear scaling issues, and compares the results with less complex N deposition estimates for the Lake Tahoe Basin.

Tuesday, October 16 – Nitrogen Around the World and its Effects

Oral Session #7: ***Agricultural Nitrogen Losses to Ground and Surface Waters.***

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Effects of agricultural systems on nitrogen in groundwater.

Research from several regions of the world provide spatially anecdotal information to hypothesize the hydrologic and agricultural factors affecting groundwater vulnerability to nitrate contamination. Analysis of nationally consistent data from the U.S. Geological Survey NAWQA program confirm these hypotheses for a range of agricultural systems. Shallow unconfined aquifers are most susceptible to nitrate contamination associated with agricultural systems. Alluvial and other unconsolidated aquifers are the most vulnerable followed by shallow carbonate aquifers. Where overlain by permeable soils the risk of contamination is larger. Corn, soybeans, and hogs had larger concentrations of nitrate than all other agricultural systems. If fertilizer and groundwater nitrate trends in the U. S. are repeated elsewhere, Asia may experience increasing groundwater problems because of recent dramatic increases in fertilizer use. Groundwater monitoring in Western and Eastern Europe and Russia over the next decade may help determine if nitrate contamination can be reversed. In these regions fertilizer use has dropped since the early 1990s. If the concentrated livestock trend in the United States is global, it may be accompanied by increasing nitrogen contamination in groundwater. Irrigation was found to have larger groundwater-nitrate concentrations many parts of the world. This practice is expanding throughout the world, but particularly in Asia.

DRURY, C.F., C.S. TAN, T.O. OLOYA, and J.D. GAYNOR. Agriculture & AgriFood Canada, Harrow, ON, Canada, N0R 1G0.

Reducing tile nitrate loss with water table management systems.

A water table management system was designed to alleviate uneven water distribution in the growing season and to reduce tile nitrate leaching losses on soybean rotation. Treatments included tile drainage (TD), controlled drainage (CD) and controlled drainage/subirrigation (CDS). N was applied at two rates (150 and 200 kg N/ha for corn and 0 and 50 kgN/ha for soybeans).

Surface and tile water samples were collected over 3 years. When the low N rate was used, the total tile nitrate loss was 51 kgN/ha for the TD treatment, 27 kg N/ha for the CD treatment and 16 kgN/ha for the CDS treatment. Nitrate loss was reduced by 47% with CD and by 69% with CDS compared to TD. At the higher N rate, CD and CDS reduced nitrate loss by 31% and 73%, respectively. The higher N rate increased nitrate loss by 29% and increased corn and soybean yields by 10% to 11%. CD increased soybean and corn yields by 3 to 6% whereas the CDS treatment increased yields by 3% at the higher N rate. Water table management systems were found to dramatically reduce nitrate losses.

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Estimation of nitrogen load on catchment scale- Testing of existing methodologies on a well-instrumented watershed.

Today, environmental pollution control is focusing on controlling nonpoint source pollution and watersheds have emerged as the environmental unit for assessing, controlling and reducing pollution. Harmonized Quantification and Reporting Procedures for Nutrients (HARP) have been developed to help implementation of OSPAR's (Convention for the Protection of the Marine Environment of the North-East Atlantic) strategy in controlling eutrophication and reducing input to marine ecosystems. HARP guidelines #6 and 9 related to quantification and reporting of nutrient losses in river systems will be evaluated in a co-operation project coordinated by the Environment Institute of the Joint Research Centre. In Finland, nutrient losses associated with the different landuse, management practices and pathways are evaluated using different existing methodologies. Three types of methodologies for estimating losses to watercourses will be tested on a well-instrumented micro-watershed (15 km^2) in southern Finland. Simple loading models are based on loading functions. Mid-range models, based on the nutrient cycle of the soil, are applied to simulate the nutrient cycle in a simplified manner in relation to climate, soil properties, land-use and management practices. Physical models (SWAT, ICECREAM) describe in detail the water and nutrient cycle within the watershed. Our paper presents the selected methodologies used for estimating nitrogen load and discusses the preliminary results of the calculated nitrogen load at the selected watershed. The studies will provide valuable insights about the most appropriate methodologies to be used at larger scale.

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Validation of the Dutch model for emission and transport of nutrients (STONE).

The Netherlands face large losses of N and P to the ground- and surface water. Agriculture is the dominant source for these nutrients, particularly nutrient excretion by intensive animal husbandry in combination with fertilizer use. Recently, the Dutch government has set-up a stricter eutrophication abatement policy to comply with the EC nitrate directive. To evaluate this and future abatement plans, the Dutch model for nitrogen and phosphorus emission to the ground- and surface water (STONE) has been developed. Due to the large economical and social impacts of eutrophication abatement plans, it is important that the model is validated. Because STONE is applied on a nation-wide scale, the model validation has been carried out at this scale. The model output were compared with results from monitoring networks of nitrate in the shallow groundwater and surface waters. About 13000 recent point observations of nitrogen in the shallow groundwater were available. Before comparison with STONE outputs, the observations were interpolated onto the model grid (resolution 500 x 500 m^2). Statistical and geo-statistical methods were used for this purpose. Approximately 5000 observations of nitrate and phosphate in local surface water systems were available. We compared the monthly and yearly average concentrations.

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Increasing nitrogen and carbon retention in coastal plain agricultural watersheds.

Historically N availability has limited agricultural production as well as primary production in coastal waters. Prior to the middle of the last century N available for grain production generally was limited to that supplied by previous legume crops, relapsed from soil organic matter, or returned to the soil in animal wastes. The development of infrastructure to produce relatively low cost inorganic N fertilizers eliminated the need to focus farm management on balancing internal N sources with crop N needs. Increased N availability has contributed to dramatic increases in agricultural production but also has led to increased losses of both N and C from agricultural systems. N losses from cropland have been linked to excessive algal production in Chesapeake Bay with N loss from cropland estimated to be the primary N input to the Bay from Coastal Plain regions of the watershed. The decade long effort to reduce these losses initially focused on reducing agricultural N use and more recently on using winter cover crops. Results from long-term field experiments and watershed monitoring will be used to assess the effectiveness of various N reduction strategies in the context of achieving local water quality goals, maintaining agricultural productivity, and enhancing soil C storage.

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Environmental variability and cover crop capacity for reducing nitrate losses from tile drainage.

Nitrate contamination impairs surface and ground water quality. Surface water is affected in areas where surface and ground waters are hydrologically connected, and this is especially the case were artificial drainage is necessary for crop production. An experiment was initiated in 1998 to determine whether a fall-seeded winter rye (*Secale cereale*) cover crop following corn (*Zea mays*) might be an option for controlling nitrate-nitrogen losses through subsurface drainage in a corn-soybean (*Glycine max*) rotation. This experiment was conducted in southwest Minnesota on a Webster clay loam (Typic Endoaquoll) soil. The cover crop was planted annually in the fall following corn from the period 1998 to 2000. Considerable variation in climatic conditions from year-to-year during the project resulted in uneven water flow and nitrate-nitrogen losses from subsurface tile discharge. Variation in environmental conditions also impacted rye biomass, nitrogen uptake by the rye, and residual soil nitrate levels. During the project, the rye cover crop reduced water loss from subsurface tile lines with cover crop treatments by up to 23% and lowered nitrate-nitrogen loss by 40 to 50% compared with the corn-soybean rotation without the cover crop. Presence or absence of the cover crop did not affect subsequent soybean yield.

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Nitrate leaching losses affected by nutrient inputs and crops.

Nitrate losses from cropland to groundwater are largely affected by the fertilization program and the characteristics of the crop-soil-water system. We initiated a field experiment in southeastern Pennsylvania, USA, to investigate NO_3 leaching losses from three agronomic crops receiving differing nutrient source applications. Replicated plots of corn, alfalfa and orchard grass received nutrient inputs either as chemical fertilizer (to meet crop N requirements), N-based dairy manure (fulfilling crop N requirements) or P-based dairy manure (to meet crop P needs, with supplemental N fertilizer), plus no-nutrient input control plots. Passive capillary wick lysimeters, installed beneath the crop plots, provide soil water samples for estimation of nitrate leaching losses. Two-year (April 1998-March 2000) flow-weighted leachate NO_3-N concentrations averaged 8-9 mg/L from the control plots, 8-19 mg/L from the N-based manure plots and 11-16 mg/L from the commercial fertilizer plots. Data on P leaching losses, crop yields and nutrient uptake, soil residual NO_3 and soil P accumulation are also being recorded.

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An innovative approach for locating and evaluating subsurface losses of nitrogen.

Fundamental watershed-scale processes governing chemical flux to neighboring ecosystems are so poorly understood that effective strategies for mitigating chemical contamination cannot be formulated. Characterization of evapotranspiration, surface runoff, plant uptake, subsurface preferential flow, behavior of the chemicals in neighboring ecosystems and an understanding of how crop management practices influence the processes are needed. Adequate characterization of subsurface flow has been especially difficult because conventional sampling methods are ineffective for measuring preferential flow of water and solutes. A sampling strategy based on ground penetrating radar mapping of subsurface structures coupled with near-real time soil moisture data, surface topography, remotely sensed imagery and a geographic information system appear to offer a means of accurately identifying subsurface preferential flow pathways. Four small adjacent watersheds draining into a riparian wetland and first order stream at the UDA ARS Beltsville Agricultural Research Center, Beltsville, Maryland are being studied with this protocol. The spatial location of some of the preferential flow pathways for chemicals exiting these agricultural watersheds to the neighboring ecosystems have been identified. These results will be presented with a description of the broader objectives of the experiments at the site.

Oral Session #8: ***Nitrogen Use in Agricultural Crop Production.***

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The potential of improved nitrogen management to reduce nitrate leaching and increase use efficiency.

Management of nitrogen in row-crop agriculture has considerable impact on its fate. Nitrogen uptake is critical in crop production; e.g., corn needs to take up over 300 kg/ha to produce an economic yield. However, if sufficient N is available to meet crop needs, the potential for loss by nitrate leaching can be significant. Leaching loss is a product of a source term (concentration) and a transport term (drainage volume). Improved management in terms of optimum rate and timing, as well as additives, can reduce the source term. Use of the soil nitrate test and/or plant sampling can help determine the optimum rate for specific sites and conditions. Avoidance of fall or early spring application improves timing. The use of a nitrification inhibitor with ammonium-nitrogen reduces the potential for nitrate leaching. Reducing the transport term (drainage volume) is harder. With the exception of nitrate leaching, maintaining high infiltration rates generally has large water quality benefits because of delayed and reduced surface runoff. Therefore, the current approach is to improve nitrogen management by placing it in zones that have been altered to reduce excess water movement through them. Quantitative information will be summarized on the potential benefits of these improved practices.

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High-yielding rice cultivars perform best even at reduced nitrogen fertilizer rate.

The production package consisting of high-yielding cereal crop cultivars, together with high inputs of fertilizers, chemicals, and irrigation contributed to great yield increases in developed and developing countries during the past decades. This has led many to believe that high-yielding cereal cultivars would perform well only in the presence of sufficient amounts of those inputs. I was one who believed that, and began my research with the hypothesis that high-yielding rice (*Oryza sativa*, L) cultivars don't perform well when they receive reduced amounts of N fertilizer. My 2-yr field experiment was conducted at Hokuriku National Agricultural Experiment Station, Japan, on soil classified as clayey montmorillonitic, mesic typic endoaquepts. Thirteen rice cultivars released between 1893 and 1995 and one line were grown at conventional (120 kg/ha) and reduced (40 kg/ha) N fertilizer rates, with a sufficient supply of other nutrients and water. Insects, diseases and weeds were controlled by agrochemicals. In spite of contrasting weather between 1993 and 1994, there were highly positive correlations in grain yield of the rice cultivars between conventional and reduced N rates. In the reduced N rate, high-yielding cultivars, Hokuriku 153, Fukuhibiki, Habataki and Xin Ging Ai 1, consistently surpassed others not only in grain yield ($P < 0.01$) but also aboveground dry matter, harvest index, N use efficiency and sink capacity ($P < 0.01$), with two exceptions. Thus, my conclusion is directly opposite of my hypothesis; there are significant advantages to the use of high yielding rice cultivars at reduced N fertilizer rates, giving such cultivars potential benefits in alternative cropping systems.

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Plant uptake and use of organic nitrogen sources.

Research and development within the area of plant nitrogen nutrition has traditionally focused on the two inorganic nitrogen forms ammonium and nitrate. Both these nitrogen forms can, however, cause problems in particular when used for growth of plants with low capacities for nitrate uptake and assimilation as e.g. conifer seedlings. Firstly, a low rate of plant uptake of nitrate is accompanied with a risk for nitrogen losses when nitrate predominates in the fertilizer. Secondly, a high fraction of ammonium in the fertilizer is followed by risks for unbalanced nutrition of plants. A number of studies have shown that several plant species can take up organic nitrogen sources as well as inorganic. Uptake of amino acids has been demonstrated in the field for plants growing in natural as well as agricultural systems. The extent to which these nitrogen forms can sustain growth of terrestrial plants is, however, largely unknown. In this presentation, uptake of amino acids by terrestrial plants in natural as well as in agricultural settings is discussed and plant growth on organic nitrogen sources is exemplified.

PALM, C.A.[1], D.N. MUGENDI[2], P. MAPFUMO[3], B. JAMA[4], and K.E. GILLER[3]. [1]TSBF, Nairobi, Kenya; [2]Kenyatta University, Nairobi , Kenya; [3]University of Zimbabwe, Harare, Zimbabwe; [4]ICRAF, Nairobi, Kenya. Presented by **Paul Smithson,** Tropical Soil Biology and Fertilty Program, Kenya.

Reversing N deficits on African smallholder farms.

Nitrogen deficits of up to 60 kg N/ha/y are found in most cropping systems in Sub-Saharan Africa, in stark contrast to the N saturated systems in northern latitudes. To alleviate the current and projected food insecurity in the region, this trend must be reversed and N must be put into these agroecosystems. Accepting that several barriers exist to use of substantial amounts of mineral fertilizers by smallholder farmers in Africa, biological nitrogen fixation by leguminous crops, green manures and tree has enormous potential to improve productivity. Rates of N_2-fixation can attain 5 kg N/ha/d under optimal conditions but are less than 5 kg N/ha/y in typical smallholder systems. The primary reasons are the small proportion of legumes in the system and environmental constraints that prevent the optimal functioning of the symbiosis. A number of promising approaches including improved management of grain legumes and leguminous fallows have been developed that increase the N input to these systems up to 200 kg N/ha/y. None of these systems can function optimally without addressing the problem of P deficiency in the majority of African soils.

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N balance of effluent irrigated cropping systems in Southern Australia.

The nitrogen (N) balance in a double-cropped, effluent spray, irrigation system was examined for several years in southern Australia. The amount of N added by irrigation, removed in the crop and lost by ammonia volatilization, denitrification and leaching were measured. Results from the project provide producers with the knowledge necessary to evaluate the efficiency of such systems for managing N, and enable sustainable effluent reuse practices to be developed. Oats were grown through the winter (May – Nov) without irrigation, whereas irrigated maize was grown during the summer/autumn (December – April). Effluent was the only source of water for the summer crop and 18 mm was applied every three days. The effluent was alkaline (pH 8.3) and had an average of ammoniacal-N (NH_4+ + NH_3) concentration of 430 mgN/L (range: 320 – 679 mgN/L). Mineral N in the 0-1.7 m layer tended to increase during the irrigation season and decreased during the winter/spring. About 2000 kgN/ha was found in the profile in October 2000. N removed in the aboveground biomass (oats + maize) was 590 and 570 kgN/ha/yr, equivalent to »25% of the applied N. Average NH_3 volatilization during the daytime (6:00 to 19:00) was 2.73 kg NH_3-N/ha, while volatilization at night (19:00 to 6:00) was 0.36 kg NH_3-N/ha, giving a total of 3.09 kg NH_3-N/ha/d. This represents »12% of the N loading, assuming that these rates apply throughout the season.

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Improving nitrogen efficiency: Lessons from Malawi and Michigan.

Farmers from developing and developed countries are pursuing improved nitrogen efficiency. The majority of Malawi smallholder farmers surveyed were at the margins of survival, and efficient use of nitrogen was key to achieving food security. We conducted input and output budgets on selected Malawi smallholder farms. Nitrogen availability, not phosphorus, appeared to regulate cropping system productivity in case study sites, at least over the short-term. The data suggested that nitrogen influenced net carbon balance as well. Malawi farm surveys documented deep concern about efficient use of small amounts of nitrogen fertilizer and residue management; whereas interest was minimal in new legumes as a nitrogen source. In Michigan, formal and semi-formal survey of potato producers documented that, similarly, farmers primarily focused on application practices to improve nitrogen fertilizer efficiency. Michigan farmers were widely dissatisfied with the tools available to predict crop nitrogen response. Some growers were experimenting with different cover crops, primarily to ameliorate erosion and pest problems. There was limited interest in legume cover crops as nitrogen sources. Our nitrogen monitoring on-farm and economic budgets implicated nitrogen fertilization of fall-seeded cover crops as, potentially, a critical nitrogen loss factor in Michigan.

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Nutrient monitoring and management for turfgrass sod farms and golf courses.

Knowledge of seasonal soil nitrate flux can be helpful to farmers in applying fertilizers at the right times of the year and avoiding nutrient loss from unnecessary or ill-timed applications, which can lead to nitrate pollution of ground and surface water. An ion exchange resin capsule system has been used to monitor seasonal variation in soil nitrate levels under turfgrass sod production and golf course management. In this research, resin capsules were installed at 12 sites in southern Rhode Island, USA, and were retrieved and replaced periodically based on rainfall, irrigation application, and other management events. Our results were in agreement with multi-year federal and state supported studies involving regional monitoring and residential wells sampling, indicating a possible link between agricultural production and ground water contamination in those areas. Turf sites that were composed primarily of Kentucky bluegrass, along with some fine fescue, had higher levels of nitrate at the beginning of the year, but, throughout the rest of the year, soil nitrate remained relatively low at these sites, compared to turf sites that comprised creeping bentgrass. These differences could also be attributable to management practices associated with the grass species and use. The role of soil nitrate monitoring in turfgrass management will be discussed.

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Nitrogen interactions with phosphorus and potassium for optimum crop yield, nitrogen use effectiveness and environmental stewardship.

The development of best management practices (BMPs) for optimum nitrogen (N) use by crops contribute to farm profitability, increased food and fiber production and best stewardship of the environment and its resources. Such BMPs are both site and crop specific. Optimum N use by plants is influenced not only by climate and certain soil characteristics but also by management practices such as tillage, time and method of N application, or positive interactions with nutrients and supporting cropping practice. Phosphorus (P) and potassium (K) are two of the nutrients essential for efficient use of N by plants. Nitrogen interactions with P and/or K help to improve root systems, disease resistance, dry matter production, protein formation, and other plant functions regulating crop yield and quality. The need for P and K in balance with N allows optimum N use by the plant, increased dry matter production and earlier crop canopy coverage of the soil for optimum crop yield and stewardship of soil and water resources.

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The role of nitrogen-efficient cultivars in sustainable agriculture.

Breeding and growing of nitrogen-efficient genotypes may play an important role in both low-input (improving crop productivity) and high-input (reduction of environmental pollution) agriculture (Lynch, J. of Crop Production 1, 1998). We are working with winter rape, an oil crop being characterized by high nitrogen uptake (i.e. high N fertilizer demand) but low N export with harvested seeds resulting in large N balance surpluses and nitrogen losses to the environment. N surpluses and environmental pollution might be reduced by reduced fertilizer N application in combination with the cultivation of N-efficient cultivars. In 4-years field experiments we found significant differences between the 12 cultivars tested in agronomic N efficiency (i.e. seed yield at educed N supply). Seed yield formation with limited N supply was closely correlated with N uptake-efficiency, leaf area duration and photosynthetic activity of leaves during the reproductive growth phase. N utilization-efficiency and N losses with dropping leaves were of minor importance. Based on the results of these studies an N-efficient oilseed rape ideotype will be characterized and the role of N-efficient cultivars for integrated nutrient management strategies will be discussed.

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Estimation of leaf nitrogen content from spectral characteristics of rice canopy.

Ground-based remotely sensed spectral data of rice canopy were acquired to study spectral characteristics in response to various nitrogen levels applied to paddy soil during the cropping seasons of 1999 and 2000. Changes of reflectance spectrum over the growing periods were monitored and 15 band regions were identified as characteristic wavebands from major peaks and valleys of spectral waves. The simplified features connecting the centered wavelengths of these characteristic wavebands were named spectral signatures, which varied between nitrogen levels both qualitatively and quantitatively. Reflectance of some wavelengths was found significantly correlated with nitrogen levels. A number of approaches were adopted to determine spectral parameter(s) suitable for estimating leaf nitrogen content. Results indicated that vegetation indices were not a good parameter if a precise estimation in required.

Oral Session #9: **Forest Soils and the Nitrogen Cycle.**

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Controls on nitrogen cycling along a natural rainfall gradient in Patagonia, Argentina.

Precipitation acts as one of the major abiotic controls on ecosystem processes, and can be viewed both directly through the effects of water availability on organisms, and indirectly, as mediated through effects on nutrient availability and turnover. We explored the control of precipitation on nitrogen cycling along a natural rainfall gradient (100mm to 800mm mean annual precipitation) in the southern region of Patagonia, Argentina, with shifts in natural vegetation from a dwarf desert scrub to closed-campy southern beech forest. We measured inorganic nitrogen concentrations in soil, and rates of net nitrogen mineralization for two consecutive years (1998-2000) in representative ecosystems along the rainfall gradient. Total inorganic nitrogen concentrations were highly positively correlated with annual rainfall of site across all seasons, where $[N_{soil}]=0.175*(MAP) -29.65$, $r^2= 0.82$, $p < 0.0001$. However, rates of net nitrogen mineralization during the growing season (October-December) were most highly correlated with initial concentrations of ammonium rather than soil moisture where $N_{min}=-0.0063*NH_4 +0.2078$, $r^2 = 0.66$, $p < 0.0001$. These results suggest that while nitrogen availability is directly affected by water availability in these sites, other factors such as spatial heterogeneity of soil resources and plant-microbial interactions also play an important role in determining rates of nitrogen cycling.

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Impact of soil nutrient availability on microbial community composition in Hawaiian tropical soils.

We measured soil properties (nitrogen and phosphorus availability, pH, carbon content), and microbial community composition and metabolic activity (phospholipid fatty acid analysis, genetic ITS fingerprints, potential nitrification, substrate utilization profile), at several natural and fertilized forest sites along an age sequence in the Hawaiian Islands. We asked whether fertilization with nitrogen (N) and phosphorus (P) affects microbial community composition and metabolic activity in the same way that natural gradient in N and P availability does. The sites show a distinct patterns in soil properties with age, and have distinguishable microbial communities. Soils at the natural sites range in age from 300 to 4.1 million years old. Intermediate aged sites have maximal soil N and P content, and also have the highest microbial metabolic activity. Diversity and evenness of substrate utilization (BiOLOG® assay) varied, with the highest diversity at the oldest site. Microbial community metabolic profiles fro the youngest (300 year old), intermediate (20,000 year old), and oldest (4.1 million year old) sites differ significantly (principal components analysis). Long-term application of nitrogen and phosphorus fertilizer reduced the diversity of substrates used by the microbial communities. Nitrogen containing substrates were the most affected. Nitrification potential increased from youngest to oldest sites, and in nitrogen fertilized sites. Changes in N availability (both natural and fertilizer) appear to be related to changes in microbial community parameters, whereas changes in P availability had less impact.

COMPTON, J.E., M.R. CHURCH and S.T. LARNED. US Environmental Protection Agency, National Health and Environmental Effects Laboratory, Western Ecology Division, Corvallis, OR 97333 USA.

Controls on nutrient losses from a forested basin in the Oregon Coast Range.

Although conceptual models of watershed biogeochemistry emphasize the movement of materials from the land to the sea, important transfers occur in the reverse direction in coastal watersheds through salt spray deposition and returning anadromous fish. To understand the connections between land and sea in the Pacific Northwest, we examined 45 small forested watersheds in coastal Oregon's Salmon River basin. The Oregon Coast Range has very low atmospheric N deposition, but high soil N content and widespread distribution of red alder, an early successional N_2-fixing tree. Stream nitrate concentrations ranged from nearly zero to over 3 ppm nitrate-N, and were positively related to proximity to the coast and proportion of the watershed in broadleaf cover (dominated by red alder). Dissolved organic nitrogen concentrations were generally much lower and less spatially variable than nitrate. For watersheds with less than ten percent alder cover, we found a correlation between nitrate and chloride in stream water, suggesting that chloride deposited in salt spray may displace nitrate and promote leaching. Our work indicates that these watersheds are subject to high N losses, possibly driven by atmospheric deposition of sea salt and maintained by the shifting presence of N_2-fixing red alder.

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Rapid abiotic immobilization of nitrate in an acid forest soil.

Nitrate immobilization into organic matter is thought to require catalysis by the enzymes of soil microorganisms. However, recent studies showing rapid immobilization of added nitrate suggest that abiotic pathways may be important. We amended living and sterilized soil from a hardwood stand at the Harvard Forest, Massachusetts, with ^{15}N -labeled nitrate. Approximately 30, 40, and 60% of the ^{15}N -labeled nitrate added to live, irradiated, or autoclaved organic horizon soil, respectively, disappeared from the extractable inorganic-N pool in less than 15 minutes. About 5% or less of the nitrate was recovered as insoluble organic N, and the remainder was determined to be soluble organic N. Nitrate added to live A-horizon soil was largely recovered as nitrate, suggesting that rapid conversion of nitrate to soluble organic-N may be limited to C-rich organic horizons. The processes by which nitrate is transformed to soluble organic-N cannot be explained by established mechanisms, but appear to be due to abiotic reactions in the organic horizon. If abiotic soil processes similarly immobilize nitrate from atmospheric deposition, then the additional N may not greatly enhance primary productivity, and less carbon sequestration may occur than has been predicted by some biogeochemical models.

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Sources of exported nitrogen from first-order forested basins at the Turkey Lakes Watershed.

Topographic regulation of nitrogen dynamics was examined in order to elucidate the role of within-catchment processes in determining nitrogen (N) export from forested basins on the Canadian Shield. Interdisciplinary studies were carried out over a ten-year-period within small (5 to 60 ha) calibrated catchments to trace the pathways of N from the atmosphere through the forest and soil to the outlet of forest streams. Atmospheric N inputs, biological N production/retention in soil and trees and N transport processes in sub-soil and groundwater and streams were examined in four basins with mature hardwood forest in the Turkey Lakes Watershed in central Ontario. Water and N moved laterally downslope through surficial soil layers rich in soluble inorganic and organic N during spring snowmelt and after periods of soil recharge. Intensive plot-scale studies revealed that nitrate leaching from well-drained soils was very high, exceeding 750 mol/ha/yr, and was attributable largely to the high mineralization / nitrification potential of the soil. Examination of ^{15}N /^{14}N and ^{18}O/^{16}O isotopic ratios of nitrate in precipitation and surface waters confirmed that the majority of the nitrate leached from the catchments originated from nitrification in soil. Mineralization of N was less and conversion to nitrate more complete in soils in riparian zones. Topographically regulated heterogeneity in N pools and hydrologic processes was assessed in order to scale N processes from the plot to hillslope to catchment levels.

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Temporal and spatial variation of nitrogen transformations in nitrogen-saturated soils of a central Appalachian hardwood forest.

We studied temporal and spatial patterns of soil N dynamics from 1993 to 1995 in mineral soil of three watersheds of Fernow Experimental Forest, West Virginia: WS3 (24 yr-old/treated); WS4 (mature/untreated); WS7 (24 yr-old/untreated). WS3 has received aerial applications of ammonium sulfate since 1989 (35 kg N/ha/yr). Net N mineralization was 134.5, 123.8, and 126.2 kg N/ha/yr for WS3, WS4, and WS7, respectively. Net nitrification was 141.1, 114.3, and 114.9 kg N/ha/yr, respectively. Extractable ammonium and nitrate pools were higher on WS3 than on untreated watersheds. Temporal (monthly) patterns of nitrification were significantly related to soil moisture and ambient temperature in untreated watersheds, but not in WS3. Although WS4 shows signs of saturation, spatial patterns of soil water nitrate suggest that microenvironmental variability may limit rates of N processing in some areas of WS4, with low rates possibly being maintained by presence of ericaceous species (*Vaccinium spp.*) in the herbaceous layer. Spatial patterns of soil water nitrate in WS3 suggest that later stages of N saturation may result in less spatial variability in soil water nitrate, net nitrification, and extractable N pools. Biotic processes responsible for regulating N dynamics appear altered in N-saturated forests.

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Carbon - nitrogen interactions in forest ecosystems (CNTER) – Estimates of soil N and C sequestration based on empirical relationships.

In terrestrial ecosystems the largest pools of carbon (C) and nitrogen (N) are bound in soil organic matter. The fate of deposition N in forests is to large extent regulated by C availability in this soil pool. Then again C sequestration in plants and soil may be stimulated by N deposition. This interdependence of the C and N cycles is the basis for a new project 'Carbon – Nitrogen inTERactions in forest ecosystems' (CNTER). In CNTER we use data from several hundred European study and monitoring sites (e.g. UN-ECE ICP Forest sites), and results from long-term nitrogen addition and labeling experiments (European NITREX and similar experiments in N. America) to gain new insights in C and N interactions in forest soils. Based on analyses of parts of the data sets we already found: (1) Strong relationships between nitrate leaching/soil water concentrations and the C/N ratio of the forest floor. (2) A quantitative separation of N-limited and N-saturated forest ecosystems by their flux and concentration characteristics. (3) Differences in N cycling between conifer and broadleaf stands. (4) Preliminary estimates of C-sequestration in forest soils Europe wide (including a spatial image) calculated by combining knowledge on the fate of N and N budgets from numerous monitoring sites. In the presentation we will take these results a step further refining and validating the empirical relationships and calculations.

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Effects of exogenous N addition, mammalian exclusion, and detritivore diversity on decomposition in old fields.

Plant litter decomposition strongly controls C and N flux in terrestrial ecosystems. Anthropogenic inputs of N may influence decomposition by changing N supply to microbes or by changing litter quality and quantity. Detritivore diversity also may influence decomposition rates when diverse functional groups process litter more efficiently, whereas, mammalian consumers may, in turn, affect detritivore diversity. This study was designed to test the effects on litter decomposition of 1) exogenous N inputs, 2) detritivore diversity, and 3) mammal diversity. N and mammals were manipulated in 16 plots in a factorial experiment where 4 plots each were treated with fertilizer only (48 kg/ha/yr), mammal exclusion only, a combination of fertilizer and exclusion, or no treatment. A mixture of grass and forbs litter of known quantity was contained in either fine (0.33 mm) nylon mesh intended to exclude macro-detritivores (e.g. macroarthropods, isopods, annelids, gastropods) or in coarse (6.35 mm) mesh bags intended to allow access by all detritivores. Litter bags were placed randomly in each plot and collected every two months for one year. Loss of litter mass, C, and N were quantified as response variables. Mammal exclusion had no significant main effects on any of the response variables. However, a significant interaction between exclusion and N addition was observed ($P < 0.02$) with respect to mass loss and N loss. Exogenous N addition had significant main effects on litter N loss ($P < 0.001$), but not on other response variables. Detritivore exclusion had the greatest influence on litter dynamics. Mass loss and C loss of litter were lower in bags without macro-detritivores and N eventually began to accumulate in litter ($P < 0.001$). These results suggest that, for terrestrial ecosystems, limits exist for the processing of exogenous N and that relatively low levels of excess N disrupt natural flux processes. Results also indicate that macro-detritivores have a large effect on litter decomposition likely by physically processing recalcitrant fragments of litter and/or by grazing on microbes. Therefore, environmental stressors, such as pesticides that remove larger detritivores from the decomposer community may affect nutrient flux patterns in terrestrial ecosystems. (Disclaimer: The views expressed in this manuscript are those of the authors and do not necessarily reflect the views and policies of the U.S. Environmental Protection Agency.)

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Ten years of nitrogen addition to an N limited coniferous forest catchment in Sweden: Effects of nitrogen pools and fluxes.

In spite of nitrogen (N) being a major limiting factor for forest growth in most parts of Scandinavia, increased nitrate levels in surface waters and soil water have been coupled to questions of increased input and decreasing immobilization of N in watersheds. To study an ecosystem response to elevated chronic N deposition, NH_4NO_3 was added to a 0.52 ha forested headwater catchment in weekly portions by means of sprinklers below the canopy. Total N input as throughfall was increased from the ambient 13 kg/ha/yr to a total of about 50 kg/ha/yr. ^{15}N was added to the whole catchment over one year in 1992 to study the stability of the added N in soil, vegetation and runoff water. The major part of the added N is being retained within the terrestrial system. Here we present data on changes in N content in needle and litter, tree growth, soil pools, N transformation rates and soil water along with data from the ^{15}N study. The data indicate the fate of the incoming N, and the possible longer-term effects of N input on N dynamics and N leaching.

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Consequences of experimental nitrogen additions on nitrate soil solution losses from Hawaiian wet tropical forests of different nutrient status: patterns and regulation.

The consequences of anthropogenic nitrogen (N) additions on the patterns and regulation of nitrate soil solution losses from wet tropical forests are poorly understood. Many studies in N-limited temperate forest ecosystems suggest that biotic demand for delays the onset of nitrate losses in response to anthropogenic N inputs. Preliminary hydrological and nitrate leaching data from two Hawaiian wet tropical forests differing in soil age and nutrient status suggest that soil physical processes may dominate over biological processes in controlling transport and retention of anthropogenic N. To evaluate the relative importance of these different soil processes in regulating nitrate losses, we conducted a simulated rainfall experiment at each site and trace the fate of isotopically enriched nitrate and water. Breakthrough of nitrate was rapid, and losses accounted for 84% of the applied nitrate in the N-limited site growing on a 300 year old soil. Breakthrough was delayed and only 38% was lost from the P-limited forest growing on a 4.1 million year old soil. While biotic demand for N appears to be the primary mechanism retaining nitrate in the N-limited site, hydrological flow processes and anion exchange appear to control nitrate losses from wet tropical forests growing on highly weathered soil.

Oral Session #10: **Nitrogen Dynamics in Asia.**

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Critical loads of nitrogen: Eurasian experience and worldwide perspectives.

This paper deals with the application of biogeochemical concept of critical loads forwarding the impact-oriented reduction of pollutant inputs to the terrestrial and aquatic ecosystems. Within the defined areas, critical loads are calculated for all major combinations of tree species and soil types (receptors) in the case of terrestrial ecosystems, or water biota (including fish species) and water types in case of freshwater ecosystems. These combinations include the great variety of different ecosystems, the sensitivity of which to both acidification and eutrophication inputs by atmospheric pollutants differs greatly, determining the necessary reduction needs when CLs are exceeded by modern deposition levels. The areas of “exceedance” indicate where present levels of pollutant deposition increase the risk of damage to ecosystems and human health. Until now critical loads for acidifying and eutrophication nitrogen have been calculated for all European countries as well as for China, Korea, Thailand and Japan. The initiative CL calculations are in progress for some states and provinces in Eastern Coast of USA and Canada. These results will be presented. Using relevant maps and DBs, worldwide CL calculations and mapping will also be discussed. Innovation with nitrogen, through changes in N management policies and processes, and implementation of regional biogeochemical standards might be based on these critical loads. For instance, the whole area of North-East American lakes is one of the regional challenges where biogeochemical mapping of CLs will be useful for predicting effects on human and ecosystems health.

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Comparative ground water quality assessment of the Tangshan Region of the Hai He River Basin, People’s Republic of China, and similar areas in the United States.

Ground water quality with respect to nitrate, pesticides, and other constituents was assessed in the agricultural Tangshan region of the People’s Republic of China and compared with similar areas in the United States. Median nitrate concentrations (less than 5 mg/L as N) were found to be generally similar in both countries and were below the U.S. nitrate drinking water standard of ten milligrams per liter. However, higher concentrations at individual wells, and a greater range of concentrations, were apparent for the Tangshan region. Whereas nitrate concentrations exceeded the Chinese standard of 20 milligrams per liter at various locations in water samples collected from a shallow aquifer, few comparative samples collected in the United States exceeded that standard. Elevated concentrations of total dissolved solids and levels of coliform bacteria also have affected the agricultural areas of the Tangshan region. Pesticides were not detected in the groundwater of the Tangshan region.

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Measuring and mediating nitrogen saturation in densely populated Chinese villages.

China’s densely populated agricultural villages are characterized by highly heterogeneous landscapes and a high diversity of farming practices. To measure and mediate the long-term impacts of synthetic nitrogen in village ecosystems, researchers must stratify village landscapes into measurable components, measure agricultural management by households, determine the pre-industrial state of village ecosystems, and combine these data to make village-scale estimates. This presentation will demonstrate statistically robust methods to accomplish these tasks by measuring the effects of farmer variability in fertilizer N loading on N loss *in paddy fields, and by measuring the long-term impacts of synthetic N on soil and sediment N sequestration across village landscapes. These methods give a 70% probability that total village soil nitrogen sequestration has increased over this period, as a result of sediment accumulation and increased N concentration in agricultural soils moderated by changes in village landscape structure. These and other results prove that synthetic N has impacts across entire village landscapes, even in areas where they are not applied. Methods described here are generally useful for studies of long-term biogeochemical changes in densely populated landscapes, and can help in mediating the long-term negative impacts of synthetic nitrogen.*

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Nitrogen leaching from forested catchments in Southwest China - Preliminary data and research needs.

Increased nitrogen deposition has resulted in increased nitrogen pools and nitrogen leaching in European and North American forest soils. The development in Asia in general, and China in particular, suggests increased deposition of reduced nitrogen from changes in agricultural practices and of oxidized nitrogen from fast increase in the transportation sector. Hence, it has been suggested that nitrogen mobilization from forested areas will become an increasing acidification as well as eutrophication problem in the future. The differences in climate, ecosystems, land use and deposition history makes direct application of knowledge based on studies from Europe and North-America difficult. In Southwest China the potential for nitrogen mobilization from forest oils may be high because of warm and humid climate, fast degradation rates and low organic pools in the soils. However, there are very few data available confirming and quantifying the suspected potential for increased nitrogen mobilization from these forests. Here we present data from two forested research and monitoring sites outside Guiyang and Chongqing in Southwest China. The present nitrogen deposition is moderate, estimated in the range 1 - 4 $gN/m^2/yr$. The C/N ratios of the soils are for most samples below 15. High nitrate concentrations, being several hundred μeq/L, are commonly observed and nitrate leaching is also observed in stream water. Based on the presented field data we discuss further research needs for better being able to predict future nitrogen leaching from subtropical Asian coniferous forests.

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Nitrogen production, movement and impact in central India.

Nitrogen is a very important plant nutrient but in certain respects it also becomes an environmental problem. In developing countries like India, the use of NPK fertilizers and emission of NO_x by high thermal processes sharply increased. The various complex environmental issues i.e. health hazard due to presence of excess nitrate in drinking water, eutrophication of surface water, blooms of toxic algae, increased production of ozone, effect on biodiversity, intensification of green house effect, incipient nitrogen saturation and declining productivity of forest land, etc., are arisen due to over loading of nitrogen in the environment. In the proposed work, the concentration level of nitrate in various environmental compartments i.e. rain, fog, particulate, water and soil of central India, are investigated. Its sources, movement and correlation with other ions are discussed. The effect of nitrate in physical and chemical composition of various environmental compartments i.e. rain, fog, particulate, ground water, surface water and soil, eutrophication of surface water, in yields various crops, change in biodiversity, bacterial population, etc., are discussed.

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Optimization of aquatic-terrestrial ecosystem in relation to soil nitrogen status for the cultivation of fish and aquatic food crops of Indian sub-tropics.

A case study was undertaken during rainy and post rainy season to improve the perennial and alternate submerged saucer shaped ponded lands ('tal' and 'semi-tal lands') in the coasts and North-Eastern plains of Indian sub-tropics through pisci-culture and cultivation of starch and protein rich aquatic food crops like water chestnut (*Trapa bispinosa* Roxb.) and makhana or gorgon nut (*Euryale ferox* Salisb.). The results revealed that the physico-chemical properties of soils (pH, organic carbon, organic matter, available nitrogen, phosphorus and potassium) as well as quality of water (pH, EC, BOD, COD, CO_3, HCO_3-, NO_3-N, SO_4-S and Cl-) growing fish, makhana and water chestnut under different moisture regimes exhibited a significant improvement of soil health. The amount of organic carbon, available nitrogen, phosphorus and potassium content were found significantly highest in the treatment where makhana was grown under alternate flooding and drying situation with a depth of > 2 m as compared to other treatments. Such enrichment of soil fertility particularly in available nitrogen and phosphorus content might be due to accumulation of considerable amount of bio-mass and fish excreta and their subsequent decomposition in situ in the soils. Therefore, the present study suggested that the nitrogen enriched soil may effectively be utilized further for growing subsequent arable crops surroundings during summer season. This not only saves the amount of applied nitrogen fertilizer but also increases the apparent nitrogen efficiency with simultaneous increase in yieldand would benefit the farmers in this region.

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Nitrogen cycle in East Asian ecosystems affected by increasing emission of anthropogenic nitrogen compounds.

Consumption of nitrogen fertilizer in Asia has been increasing rapidly to feed the increasing population. The amount of nitrogen fertilizer used in Asia increased from 18.3% of the world in 1961 to 57.8% in 1998. Nitrogen emission from fossil fuel combustion has been also increasing due to the rapid economic growth in this area. The estimation of the nitrogen cycle, which should be affected by these changes, will provide valuable information to make rational development strategies. We have conducted the field survey to estimate the effect of changing nitrogen deposition on the nitrogen cycle in two forests located in the central part of Japan. Nitrogen deposition rates via throughfall were 15 to 30 kg N/ha/y. Throughfall water was enriched in nitrogen by passing through the litter layer and nitrate concentration was high in surface soil water. From the 100 cm depth, 25% to 40% of the nitrogen deposited via throughfall has discharged to underground and to stream, and about 1.3% was emitted as N_2O from forest floor. Results of field experiment of N removal and enrichment showed that the response of nitrogen concentration in soil water to the change of deposition rates was slower than that of sulfate.

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Nitrogen requirements for human food and animal feed production in the European Union and India.

On a global scale human food consumption contains about 24 Tg of nitrogen (one-third animal products and two-third vegetable products). Animal feed consumption contains about 22 Tg of nitrogen for pigs and poultry and about 92 Tg of nitrogen for cattle and sheep. The diet for cattle and sheep contains about 83 Tg of nitrogen originating from grassland products. These products are unsuitable for human consumption and are very often grown on land unsuitable for arable crops. This article analyses the situation in the European Union and in India. They have in common an equal land size of about 300 million hectares and an average consumption of about 65 kg of nitrogen fertilizer per hectare of agricultural land. They differ in population density and animal density. Starting with calculation of nitrogen balance sheets for animal production, crop production and the national agricultural sector in both continents, it is argued how to improve the nitrogen efficiencies in the animal and crop sectors and at the same time increase the productivity of both sectors. Global trade of feed crops and oilseeds and an increasing ratio of animal products to vegetable products in human nutrition play an important role in this analysis.

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Nitrogen and environment in China.

The amounts of chemical N fertilizer consumption has reached up to 24.45 million t N, about 1/3 of the total chemical N fertilizer consumption in the world. Nitrogen has become one of the important issues related to agriculture and environment in China. This paper presents the alteration of N in China over the past five decades, for instance, anthropogenic reactive N such as synthetic nitrogen fertilizers, fixed N by legume crops and NO_x formed during fossil combustion, and the recycling N, i.e. the excrements N of raised animals and populations. The N flux on land, N transported into water bodies and escaped to atmosphere and dry/wet deposition N was estimated in China. The regional characters of N leaching in the different regions were discussed. The present state of N pollution in water bodies of typical developed regions in China was also addressed as well as its pollution source of N.

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Nitrogen flows in agro-ecosystems of Lingxian County, Shandong Province, China.

Regional nitrogen flows in the agro-ecosystems of Lingxian County, which is a typical maize-wheat production area of northern China, were analyzed by collecting statistical data, interviewing, and chemical analysis of collected samples. The results showed a remarkable trend of the increase of nitrogen input to arable land, due to increasing consumption of chemical fertilizer and organic manure. The average application rate of chemical nitrogen fertilizer amounted to about 300 kg N/ha in 1990's, which is about two times that in the early 1980's. The amount of nitrogen input as organic manure also showed a significant increase during this period, from 72 kg N/ha in 1981 to 246 kg N/ha in 1997, resulting from a significant increase in the number of livestock in this region. Total input of nitrogen to arable land in this area was estimated to be 268 and 584 kg N/ha in 1981 and 1997, respectively. On the other hand, total output from arable lands in this area was estimated to be 109 and 296 kg N/ha in 1981and 1997, respectively. The results indicate an increasing trend in the annual load of nitrogen to arable land of this area since the early 1980's.

Oral Session #11: **Nitrogen in Surface Waters.**

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The regional transport of nitrogen in streams and reservoirs: Insights from experimental observations and empirical watershed models.

Although the major cultural sources responsible for the increased inputs of reactive N to terrestrial ecosystems over past decades are generally known, the fate of this nitrogen in the surface waters of large regional watersheds is less clear. River networks and reservoirs influence the delivery of N to downstream coastal waters-yet limited knowledge of the factors governing the rates of removal from the water column has made it difficult to predict N movements over a range of stream and reservoir sizes. Recent information from empirical spatially referenced watershed models (SPARROW) and experimental observations from the literature provide insights into N processing in streams and reservoirs over multiple spatial scales. Nitrogen loss rates in streams (per unit of water travel time) decline substantially from small streams to large rivers, reflecting the effects of channel size (depth, water volume) on particulate N settling times and denitrification. The rates of loss in lakes and reservoirs are also related to physical and hydraulic properties that influence the contact and exchange of water with the benthic sediment. Spatially referenced models provide an effective method to relate the regional-scale transport of N in streams and reservoirs to information from experimental observations of small catchments.

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The nitrogen and phosphorus content of upland streams in the UK: Form, concentration and biological significance.

Within estuarine and coastal waters N is considered to limit biological productivity, while P is widely regarded to be limiting for freshwaters. However, recent studies in North America and Northwestern Europe suggest that this is an oversimplification especially for oligotrophic waters where N limitation or a co-limitation of both N and P has been shown to exist. In addition, being able to demonstrate that N and P concentrations and loads in rivers and to estuaries have increased is not sufficient to predict the nature or extent of a consequential biological impact. The variety of chemical forms in which both N and P may exist together with seasonal changes in the timing of N and P inputs also requires consideration.

DAVID, M.B.[1], G.F. MCISAAC[1], T.V. ROYER[1], J.L. TANK[2], and L.E. GENTRY. [1]University of Illinois, Urbana, IL 61801 USA; [2]University of Notre Dame, Notre Dame, IN 46556 USA.

The nitrogen mass balance of an agricultural and artificially drained state: Past and current.

The agricultural Midwest has large riverine exports of N, and the largest flux to the Mississippi River system comes from Iowa and Illinois. Exports are a direct result of large N inputs to this agricultural landscape. We used historic and current data to construct mass balances of N inputs, outputs, and transformations for Illinois. About 64% of Illinois is in intensive row crop (corn and soybean) agriculture, and half of this area tile drained. Presently each year, ~800,000 metric tons of N is added as fertilizer and another 500,000 in N-fixation. Inputs are not balanced by exports in grain, and lead to large surpluses of N on the landscape. Rivers of the state export approximately 50% of this surplus N, mostly as nitrate, and large amounts appear to be denitrified. Directly linking surplus N to riverine export is difficult due to variable hydrologic factors. We contrast the current N mass balance to estimates for periods prior to modern agriculture, demonstrating factors affecting N loss and the magnitude of changes that have occurred through time (such as net flux of N to, or from, large soil pools). Human activity, principally agriculture, has had profound impacts on N riverine export from Illinois.

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Nitrogen sources and fate in the Mississippi River Basin.

Nitrogen from the Mississippi River Basin is believed to be one of the principal causes for the expanding hypoxic zone that develops each spring and summer on the Louisiana shelf of the Gulf of Mexico. Fresh water from the Mississippi River causes the Gulf to stratify and nitrogen in the water fuels the growth of algae. Bacterial consumption of algal material that settles to the bottom consumes oxygen and results in hypoxia. The concentrations and flux of nitrogen in the Mississippi River have increased significantly during the past 100 years, and especially since the 1970's. The current average annual nitrogen (N) flux from the Mississippi Basin to the Gulf is nearly 1.6 million metric tons, almost 3 times larger than it was during 1955-70. The increased annual nitrate flux to the Gulf can be largely explained by three factors: increased fertilizer use, annual variability in precipitation and increased stream flow, and the year-to-year variability in the amount of nitrogen available in the soil-ground water system for leaching to streams. The predominant source areas for the nitrogen are basins draining southern Minnesota, Iowa, Illinois, Indiana, and Ohio. Basins in this region yield 1,800 to 3,050 kg N/km^2/year to streams, several times the N yield .

JANSE, J.H.[1], **A.H.M. BRESSER1**, and R.F.A. HENDRIKS[2]. [1]National Institute of Public Health and Environment (RIVM), Laboratory for Water and Drinking Water Research, 3720 BA Bilthoven, The Netherlands; [2]Alterra Green World Research, 6700 AA Wageningen, The Netherlands.

A model study on eutrophication in polder ditches.

Polder areas are lowland areas drained by canals and ditches. These surface waters are affected by eutrophication with nitrogen and phosphorus, mostly from agriculture. Instead of the original submerged vegetation, dense layers of duckweed (Lemnidae) occur. This causes anoxic conditions in the water and loss of aquatic life. Management questions are: what level of manure application causes this shift; which quality standards can be applied; what is the influence of physical and management factors. This problem is addressed by means of an integrated model study, in which a soil-groundwater model (SWAP-ANIMO), a surface water model (DUFLOW, NUSWA) and an ecological model (PCDitch) were combined. The PCDitch model describes the competition between several vegetation classes (submerged, floating, emergent, algae), within the context of the nutrient cycling in the system. The model was calibrated on data from experimental ditches (mesocosms) with different nutrient treatments. Sensitivity analysis suggested non-linear response of the vegetation to nutrient loading. The joint model tool was then applied in Dutch polder areas (mainly dairy farming) using a schematization of the water network in the area and actual data on soil, land use, manure application, precipitation and ground water flow. The average measured nutrient concentrations and vegetation data were reasonably reproduced, although the variability of local factors could not be fully appreciated. The simulations suggest that nitrogen and phosphorus drainage are the main factors determining the vegetation's response, but at an intermediate level, management options like dredging were quite effective. In many cases, it took tens of years for the soil-water-system to fully respond to land use changes.

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Net anthropogenic N input to the Mississippi River Basin and nitrate flux in the Lower Mississippi River 1955-1998.

We analyzed the 1955-1998 time series of annual nitrate flux in the Lower Mississippi River using a regional net anthropogenic N input approach. A simple model was developed that accounts for 94% of the variation in observed nitrate transport in the Mississippi River at St. Francisville, Louisiana between 1960-1998. Nitrate concentrations and fluxes have increased exponentially as N inputs to the watershed have increased. Our model, which includes water yield, suggests that a 33% reduction in nitrate transport to the Gulf of Mexico, which would represent a 20% reduction in total N flux, could be accomplished during a period of 9 years by reducing net N inputs to the basin by 14.2%. A 12% reduction in fertilizer inputs would be needed to accomplish this reduction, if N harvested in agricultural crops were not reduced. Our estimate of the reduction in N fertilizer use required to achieve a 20% reduction in total N flux to the Gulf is little more than half of a recent estimate that was based on model simulations of N losses from the edge of farm fields.

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Nitrogen in streams and shallow aquifers in the United States-The land-use connection.

Total nitrogen loads (nitrate, nitrite, ammonia, and organic nitrogen) in streams and nitrate concentrations in ground water are related to primary nonpoint sources of nitrogen, such as fertilizer and animal manure applied to agricultural land, fertilizer applied to suburban areas, and atmospheric deposition in general. More than one-half of the 370 streams sampled in 36 study areas nationwide indicated over enrichment by nitrogen, which can lead to eutrophication of surface waters. Nitrate concentrations generally were less than the 10 milligram per liter drinking-water standard for the United States in most streams and major aquifers sampled. The most severe nitrate contamination of ground water occurred in aquifers located less than 30 meters beneath agricultural land, where the water is potentially used for domestic supplies. Significant spatial and seasonal differences in nitrogen conditions can be explained largely by the amounts of fertilizer, including animal manure, applied during growing seasons and by the variety of soils, geology, climate, and land- and water-management practices across the Nation. Systematic analysis of these differences through statistically-based models has value for more efficient protection of aquatic ecosystems and ground-water resources needed for drinking supplies.

VALETT, H.M.[1], J.R. WEBSTER[1], P.J. MULHOLLAND[2], C.N. DAHM[3], and C.G. PETERSON[4]. [1]Virginia Tech, Blacksburg, VA 24061 USA; [2]Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA; [3]University of New Mexico, Albuquerque, NM 87131 USA; Presented by **STEVEN A. THOMAS,** Virginia Tech, USA.

Nitrate processing and retention in streams (NPARS): Distinguishing benthic and interstitial contributions to energy flow and nutrient retention.

In a collaborative research effort to understand Nitrate Processing and Retention in Streams (NPARS), we have applied hydrologic, metabolic, and biogeochemical techniques to determine the fate of nitrate in headwater streams. The NPARS program is designed to compare semi-arid (NM) and mesic (NC and TN) catchments with differing extent of riparian-stream interaction. Within each landscape setting, streams with extensive hyporheic zones were compared with those having less groundwater-surface water interaction. Comparisons of metabolism rates derived from whole-system and benthic chamber methods were used to determine the extent of respiration attributed to surface and interstitial subsystems. All streams were heterotrophic with P/R ratios ranging from ~0 to 0.78. Benthic (~3cm deep) respiration was only 20-33% of total ecosystem respiration indicating high oxygen demand in subsurface habitats. By coupling hydrologic models and isotope (i.e. ^{15}N) tracer injections, we found that subsurface zones accounted for nearly half (41- 47%) of total nitrate retention. Seasonal variation in nitrate uptake was promoted by autumnal leaf fall in mesic catchments where total N uptake increased 4 - 40 fold from Summer to Fall. Together, these data suggest that subsurface habitats of these montane streams are metabolically dominant and constitute an important sink for water column nitrate.

VAN DRECHT, G., **A.F. BOUWMAN**, J.M. KNOOP, C. MEINARDI, and A. BEUSEN. National Institute of Public Health and the Environment, 3720 BA Bilthoven, The Netherlands.

Global estimation of the N loading of riverine systems from diffuse and point sources.

Global estimates are presented of the fate of N stemming from diffuse and point sources, including plant uptake, denitrification, leaching, runoff, and N flow to deeper groundwater and riverine systems via aquifers and runoff. The various N flows are described on a 0.5 degree resolution on the basis of local hydrology and terrain conditions. For diffuse N sources (agricultural and natural ecosystems) calculations are based on geographical soil information, land use, crop production and climate data for 1995 combined with data on the N inputs from mineral N fertilizers and animal manure (corrected for NH_3 volatilization), biological N fixation and N deposition. For point sources estimates are based on the N inputs from human and industrial wastes. Historical N inputs are estimated to describe the N flows in ground water reservoirs with long residence times. The results provide a first insight in the magnitude of the N losses from soil-plant systems and point sources in various parts of the world, and the fate of N during transport in atmosphere, groundwater and surface water. The problem areas identified can be used to select watersheds where detailed analyses are needed to determine the fate of N on a more local scale.

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A novel indicator of ecosystem N status: Ratio of DIN to DON in annual riverine flux.

We propose that the ratio of the annual flux of DIN to DON in stream waters provides a robust and sensitive method of determining the N-status of ecosystems from a variety of biomes. Effects of N deposition are generally decoupled from N deposition because of the large variety of N species found in air, deposition, watersheds, and surface waters, as well as the myriad of pathways through which N can be cycled in terrestrial and aquatic ecosystems Moreover, the amount of N in biomass and soils and resident time within these reservoirs varies widely among biomes. Consequently, developing robust indicators of the N-status of ecosystems is difficult. Our results from many biomes suggest that N-limited ecosystems have DIN:DON ratios less than 0.5 and that ecosystems where N is no longer limiting have DIN:DON ratios greater than 2.0. The DIN:DON ratio in annual riverine yields is independent of ecosystem N storage, rates of N cycling, magnitude of N yield in surface waters, and hence a robust indicator of the N-status of ecosystems. We hypothesize that DON export from terrestrial ecosystems is controlled primarily by the standing stock of C and N in soils and hence will change only slowly in response to anthropogenic additions of N. In contrast, atmospheric deposition of N stimulates net nitrification and nitrate export in soil solution and stream waters. Therefore export of dissolved inorganic N responds directly and quickly to increases in anthropogenic deposition of N.

Oral Session #12: ***Effects of Atmospheric Deposition of Nitrogen.***

ALLEN, E.B., L. EGERTON-WARBURTON, C. SIGUENZA, and A.G. SIRULNIK. University of California, Riverside, CA 92521 USA.

Effects of N deposition on plants and soil microorganisms on an urban to rural gradient in southern California.

Southern California has up to 45 kg/ha/yr N deposition, the highest in the nation. We measured the effects of N deposition on vegetation and soil microorganisms on a gradient from the Riverside area southward 50 km. Most of the atmospheric N that is plant-available is in the form of nitrate, originating from automobile exhaust. Extractable N in soil along the gradient was 87 to 15 µg/g. To test the hypothesis that N is increasing the productivity of exotic annuals, we fertilized plots following a 1993 wildfire in a rural site with 60 kg/ha/yr of ammonium nitrate. Grass productivity increased with N during wet years but not during dry years. Shrub cover increased after the fire but was lower in the fertilized plots by the forth year. The species richness of arbuscular mycorrhizal fungi decreased with elevated soil N along the gradient and in fertilized plots, and large-spored species dropped out. Fatty acid methyl ester soil profiles indicated changes in soil bacteria and fungi that were similar for soils with N deposition or fertilization. Soil microorganisms were consistent indicators of elevated soil N, while there was variability in the plant community along the gradient dependent on other local factors.

BOBBINK, R. Landscape Ecology, Utrecht University, 3508 TB Utrecht, The Netherlands.

The impacts of air-borne nitrogen pollutants on diversity: an European overview.

The effects of increased atmospheric nitrogen inputs, from both NO_y & NH_x on diversity in semi-natural and natural ecosystems of conservational value are reviewed. The severity of their impacts depends on the abiotic conditions in the particular ecosystem. The sensitivity of various vegetation types is presented in detail. Long-term nitrogen enrichment may gradually increase the availability of nitrogen in several of the reviewed vegetation types leading to competitive exclusion of characteristic species by more nitrophilic plants, especially under oligotrophic to mesotrophic soil conditions. Soil acidification is especially important after nitrification of ammonium in weakly buffered environments when acid-resistant plant species became dominant while several endangered plants typical of intermediate pHs disappear. In addition, the related change in the balance between ammonium and nitrate may also affect the performance of several plant species. The susceptibility of plant species to secondary stress factors (pathogens; frost & drought) may be seriously affected by air-borne nitrogen pollutants but the relevant data are absent for most plant communities. It is thus crucial to control emissions of nitrogenous compounds to the atmosphere, in order to reduce or prevent effects on diversity.

BREWER, P.F.[1], T. SULLIVAN[2], B. J. COSBY[3], and R. K. MUNSON[4]. [1]SAMI Technical Coordinator, Interchange Building, 59 Woodfin Place, Asheville, NC 28801 USA; [2]E&S Environmental Chemistry, Inc., Corvallis, OR 97339 USA; [3]University of Virginia, Charlottesville, VA 22903 USA; [4]Tetra Tech, Inc., Pittsburgh, PA, USA.

Responses of forests and streams in Southern Appalachian mountains to changes in S, N, and base cation deposition.

As part of a comprehensive regional environmental assessment, the Southern Appalachian Mountains Initiative (SAMI) is evaluating the responses of streams and forests in the Southern Appalachian Mountains to changes in future deposition levels of sulfate, nitrate, ammonium, and base cations. The current sensitivity of streams and forests in the Southern Appalachian Mountains to acidification has been characterized using physio-geographic province, stream water acid neutralizing capacity, and forest community type as classification variables. The Model of Acidification of Groundwater in Catchments (MAGIC) and the Nutrient Cycling Model (NuCM) are being used to evaluate the responses of 155 representative streams and 15 forest stands, respectively, to changes in deposition over the period 1995 to 2040. The annual average deposition for 1991-1995 for the 180 sites was characterized using spatially interpolated wet deposition data from the National Atmospheric Deposition Program and factors for dry and cloud deposition derived from the ASTRAP atmospheric transport model. Changes in future wet and dry deposition were projected using the Urban to Regional Multi-scale (URM) atmospheric model and emissions inventories representing SAMI emissions reduction strategies. MAGIC results will be used to interpret regional changes in stream water quality and trout survival. NuCM results will be used to interpret changes in acidification risk for the modeled forest stands.

BYTNEROWICZ, A., M. FENN, P. PADGETT, M. ARBAUGH, and M. POTH. USFS, Pacific Southwest Research Station, Albany, CA 94710-1105 USA.

Deposition and effects of nitrogen deposition in California ecosystems.

Atmospheric deposition of nitrogen (N) in California is ecologically significant and highly variable, ranging from about 1 to 45 kg/ha/year. The lowest ambient concentrations and deposition values are found in remote locations of the eastern Sierra Nevada Mountains and the highest in parts of the San Bernardino and San Gabriel Mountains exposed to urban photochemical smog and agricultural emissions. In the Sierra Nevada Mountains, N is deposited mostly in precipitation (rain, snow, and fog) although, especially in the southern part of that range, dry deposition may also provide substantial amounts of N. On the western slopes of the Sierra Nevada, the majority of airborne N is in reduced forms as ammonia (NH_3) and particulate ammonium (NH_{4+}) resulting from agricultural activities in the California Central Valley. In southern California, most of the N air pollution is in oxidized forms of nitrogen oxides (NO_x), nitric acid (HNO_3), and particulate nitrate (NO_{3-}) resulting from gasoline and diesel fuel combustion and complex photochemical reactions. Consequently, in southern California dry deposition of gases and particles provides most (up to 90%) of the atmospheric N to forests and other ecosystems, with the exception of areas where fog occurrence is frequent. In the mixed conifer forest zone, elevated deposition of N may initially benefit growth of trees and other plants. However, chronic N deposition and ozone (O_3) exposure tend to affect forest health and cause other detrimental effects such as reduction of biomass and carbohydrate levels of roots. In addition to growth disturbances, changes in vegetation composition and contamination of ground and stream water are some of the observed consequences. Other ecosystems have also been affected - in coastal sage ecosystems of southern California, non-native nitrophilous grasses have suppressed native plant species. Long-term, complex interactions of N deposition with other environmental stresses such as elevated O_3 concentrations; drought, insect infestations, fire suppression or intensive land management practices may affect water quality and sustainability of California forests and other ecosystems. Long-term studies of N air chemistry, deposition, cycling, and biological and ecological changes in mixed conifer forests will be conducted on a network of 18 sites along O_3 and N air pollution gradients in the San Bernardino Mountains. The network will encompass 12 sites in which air pollution effects on mixed conifer forest have been studied for nearly 40 years. Similar long-term studies on N deposition and effects are planned for desert, coastal sage and chaparral ecosystems of southern California. These studies will be done in collaboration with researchers of the University of California, Riverside.

CAMPBELL, D.H., M.A. MAST, D.W. CLOW, L. NANUS, G.P. INGERSOLL, and T. BLETT. U.S. Geological Survey, Denver, CO 80225 USA.

Response of aquatic ecosystems to nitrogen deposition in the Rocky Mountains.

In the Rocky Mountain region of the United States, nitrogen deposition rates are affected by population growth, agricultural activities, and energy development. Regional plus local emissions result in annual atmospheric deposition rates of 3-5 kg N /ha in the Front Range of Colorado, causing symptoms of advanced watershed nitrogen saturation in sensitive alpine/subalpine ecosystems. Research there has provided significant insight into nitrogen sources, cycling, and effects on terrestrial and aquatic ecosystems. Here we examine spatial and temporal patterns of nitrogen deposition and surface-water nitrate concentrations from other parts of Colorado and Wyoming to (1) assess the potential for nitrogen saturation in watersheds with moderate rates of nitrogen deposition; and (2) determine if the aquatic response in other areas is consistent with conceptual models of nitrogen cycling developed for Front Range sites. Early to advanced symptoms of nitrogen saturation were evident in sensitive ecosystems from southwest Colorado to north central Wyoming. As in the Front Range, sensitivity to nitrogen deposition was determined by the presence of steep slopes and sparse soil and vegetation. Future changes in nitrogen deposition or climate are likely to affect biogeochemcal cycling in sensitive ecosystems that are scattered over much of the Rocky Mountain region.

LAWRENCE, G.B. U.S. Geological Survey, Troy, NY 12180 USA.

Accumulation of nitrogen in forest soils continues to cause episodic acidification of streams in calcium-depleted watersheds.

In forest soils of geologically sensitive regions of the northeastern United States, atmospheric deposition of sulfur and nitrogen has led to decreased concentrations of exchangeable calcium (and other bases), the form readily available for neutralization of acidic soil water and uptake by roots. Although, leaching of cations by sulfate has decreased over the past three decades as a result of decreasing sulfur emissions, neither emissions of nitrogen nor leaching by nitrate have shown consistent trends. Analysis of northeastern soils suggests that atmospheric deposition has increased the accumulation of nitrogen in the O horizon, and that soils with high organic matter content tend to retain a larger fraction of nitrogen inputs than soils with low organic matter content. Organic rich soils also tend to release higher amounts of nitrate to streams during storms that follow extended dry periods than soils with relatively low organic matter content; a response that results in severe episodic stream acidification in calcium depleted watersheds.

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Animal feeding operations, ammonia, and particulate health effects.

Nitrogen from livestock can have wide-ranging effects. Federal regulators recently proposed new regulations on livestock producers designed to control nitrogen in surface and ground water. Changes in livestock management practices can affect ammonia emissions, as agricultural operations are the largest source of ammonia emissions in the U.S. These emissions contribute to the formation of fine particulate matter in the atmosphere. Epidemiologists have found an association between particulate matter and adverse health effects, including premature mortality. Management practices that reduce ammonia emissions may decrease adverse health effects, resulting in significant economic benefits. We estimated the impact of a variety of emission controls, including diet optimization, alum, storage tank covers, and the incorporation of manure into the land. To the extent that ammonium nitrate and ammonium sulfate contribute to adverse health effects, ammonia management could have significant health implications. Our results suggest that a 10 percent reduction in livestock ammonia emissions can lead to over $4 billion annually in benefits. Because of the heterogeneous nature of particulate matter, a key question is to what extent the composition and size of particulate matter contribute to adverse effects. Comprehensive cost-benefit analyses of animal waste management practices should consider including these impacts.

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The impacts of increasing atmospheric nitrogen deposition on forest ecosystems and watersheds in the Chesapeake Bay Region.

Forests cover about 56% of the total land area of the Chesapeake Bay Watershed. It is important to evaluate the potential effects of long-term atmospheric N deposition on forest productivity, nitrogen retention and water quality. In this study, we applied a process-based forest ecosystem model, PnET-CN, to estimate forest productivity, N leaching losses and forest N retention under a chronic increase of atmospheric N deposition. Wet nitrogen deposition data from 1992 to 1998 were used in this study. The high-resolution deposition maps were generated by Penn State University using interpolation algorithms based on concentration data collected at National Atmospheric Deposition Project/ National Trends Network monitoring sites and precipitation from a larger network of sampling sites. The model showed that the average N leaching loss from forested lands is 1.26 kg/ha/y at current N deposition levels, suggesting about 87% retention of N by forest ecosystems. Total dissolved inorganic N exported from the forested watersheds is 25,337 Mg. If N deposition were twice current values, N retention by forests would drop to 76%. Total N leaching loss to streams would then increase four fold. The model simulations also indicated that the N deposition provided additional N availability to trees, increasing the foliage N concentration, which had a positive effect on regional forest productivity. However, it is unclear what is the threshold in which additional nitrogen may degrade forest ecosystem function in terms of reducing net photosynthesis, N use efficiency and forest growth.

SHERWELL, J. Department of Natural Resources, Annapolis, MD 21403 USA. Presented by **MARK GARRISON,** Maryland Department of Natural Resources, USA.

Evaluation of the Calpuff model using NADP/NTN and CASTNET data.

The Maryland Department of Natural Resources Power Plant Research Program (PPRP) has undertaken efforts to investigate the contribution of atmospheric nitrogen to excess nutrient loading in the Bay. These investigations have focused on the use of the CAMET/CALPUFF modeling system to estimate nitrogen deposition attributable to NO_x emissions from both local Maryland and regional sources onto the surface of the Bay and onto land areas in the Bay watershed. PPRP's work on atmospheric nitrogen deposition has resulted in the development of an approach to using CALMET/CALPUFF that allows for estimates of nitrogen deposition due to sources of NO_x in the Eastern U.S. The work also involves evaluations of the estimates produced by CALPUFF, by comparing model predictions to measured deposition rates and concentrations. PPRP has used NADP/NTN data on nitrogen deposition to perform evaluations of wet deposition rates and has used CASTNET data to perform evaluations of HNO3 and particulate nitrate concentrations. The proposed paper focuses on the evaluation of model vs. measured deposition and concentrations, presenting comparisons for stations in the eastern U.S. and providing insights into the potential uses of CALMET/CALPUFF for investigating the effect of air pollution emissions control strategies on acidic deposition.

WEISS, S.B. Creekside Center for Earth Observations, Menlo Park, CA 94025 USA.

Mitigation strategies for N-deposition sources in South San Jose, CA: Checkerspot butterflies, powerplants, and the information superhighway.

Nitrogen deposition from urban smog sources can greatly affect downwind ecosystems. In south San Jose, CA, grasslands on thousands of hectares of nutrient-poor serpentinitic soils are being invaded by nutrient-demanding introduced annual grasses, driven by dry N-deposition loads around 10 kg/ha/yr. These grass invasions threaten the native biodiversity of the serpentinitic grasslands, including the federally listed threatened Bay checkerspot butterfly. Surprisingly, moderate and well-managed cattle gazing is necessary to combat the grass invasions. Additional NO_x and NH_3 sources planned for the region include a 600 MW natural gas fired powerplant and industrial parks that may eventually draw 20,000 to 50,000 additional cars per day, producing hundreds of tons of NO_x. The US Fish and Wildlife Service and California Energy Commission oversaw the development of a mitigation formula for the powerplant that addressed incremental increases in N-deposition over already stressful background levels. The formula may lead to the dedication of 52 hectares of serpentinitic grassland habitat along with a management endowment for maintaining a suitable grazing regime. Application of the mitigation formula to other projects in the region may lead to several hundred hectares of this unique habitat being protected and managed in perpetuity.

Wednesday, October 17 - Innovation with Nitrogen

Oral Session #13: ***Policy Options to Improve Nitrogen Use in Agriculture.***

ASMAN, W.A.H., B.E. MÜNIER and J.M. ANDERSEN. National Environmental Research Institute (NERI), Frederiksborgvej 399, 4000 Roskilde, Denmark.

A decision tool for local ammonia policy.

In large parts of Europe many relative small nature areas are embedded in agricultural areas as small patches (from 2500m^2 upward). The nitrogen deposition to these areas can exceed the critical load for nitrogen. The EU Habitat Directive requires conservation of biodiversity by protecting valuable nature areas. In Denmark this directive is about to be implemented by the county authorities. Moreover, the counties are responsible for environmental impact assessments, among that permission of larger husbandry producing farms. One of NERI's research activities is developing tools for environmental impact assessment and regional planning. Part of this work has been to develop a high-resolution nitrogen deposition model at county level. The contribution from Ny and the contribution from NH_x from other counties and countries were modeled on a 5x5 km^2 grid, whereas the contribution from sources within the county was modeled on a resolution 100x100 m^2. A GIS has been used to model ammonia emission and deposition on a 100x100 m^2 grid using country specific emission factors and information from the Central Husbandry Register and information on crops grown from the General Agricultural Register linked to a map of agricultural fields. The GIS-based tool can be used to study the impact of emission reductions and removal of sources close to nature areas.

DABERKOW, S., H. TAYLOR, N. GOLLEHON, and M. MORAVEK. Economic Research Service, U.S. Dept. of Agriculture, Washington, DC 20036 USA.

Farmer behavioral changes in response to a regulatory and education program to improve nitrogen use and management.

Given the societal concern about groundwater pollution from agricultural sources, localized programs have been proposed or implemented to change farmer behavior with respect to nutrient use and management. The Central Platte Natural Resources District (CPRD) in Nebraska has identified an intensively cultivated, irrigated area with average groundwater nitrate-nitrogen levels nearly double EPA’s safe drinking water standard. The CPNRD implemented a joint education and regulatory nitrogen management program in the mid-1980’s to reduce groundwater nitrate-nitrogen. Farmers in the CPNRD face limits on the timing of nitrogen fertilizer application but no limits on amounts. In addition, CPNRD’s nitrogen management program requires farmers to annually report field-level production and production practice data, creating a unique geo-referenced, time-series data-base. This analysis utilizes data on farmer’s commercial nitrogen use, farm size, deviations from the CPNRD guidelines for commercial nitrogen applications, nitrogen BMP adoption, irrigation practices and systems, residual soil nitrogen, expected and actual yields, and groundwater nitrate levels in the CPNRD for nearly 3000 continuous-corn fields from 1989 to 1998. Geo-spatial statistical methods, which control for the varied soil and aquifer characteristics in the area, are used to analyze how these variables and their inter-relationships have changed over the first 10-years of the CPNRD nitrogen management program. During 1989-98, farmers demonstrated an increasing willingness to more closely follow CPNRD recommendations and increased their use of side-dress nitrogen applications, an indication of improved synchrony between nitrogen availability and crop uptake.

DALGAARD, T., J.C. KJELDSEN, N.J. HUTCHINGS, and J.F. HANSEN. Danish Institute of Agricultural Sciences, DK-8830 Tjele, Denmark.

N-losses and energy consumption in regional scenarios for conversion to organic farming.

The aims of organic farming include the recycling of nutrients and organic matter and the minimization of the environmental impact of agriculture. Reduced N-losses and energy consumption is therefore a fundamental objective of conversion to organic farming. However, the case is not straightforward and different scenarios for conversion to organic farming might lead to reduced or increased N-losses and energy consumption. This paper presents the use of a scenario tool that uses a Geographical Information System in association with a number of dynamic models. The scenario tool has been developed within the multidisciplinary research project “Land use and landscape development, illustrated with scenarios (ARLAS)”. Different strategies for conversion to organic farming are compared to the present situation for an area in Denmark, and predicted changes in N-losses and energy consumption are evaluated.

DINNES, D.L., D.B. JAYNES, D.W. MEEK, C.A. CAMBARDELLA, T.S. COLVIN, D.L. KARLEN, and J.L. HATFIELD. USDA-ARS National Soil Tilth Lab, Ames, IA 50011 USA.

Reducing N contamination of surface waters from tile-drained soils at the watershed scale.

Agricultural field drainage systems have a significant impact on water quality because they behave like shallow direct conduits to surface waters. Nitrogen (N) is often transported with agricultural drainage water and has been implicated as contributing to hypoxia in the Gulf of Mexico. In 1997, we implemented a N fertilizer best management practice (BMP) on corn production fields in a Midwestern tile-drained agricultural watershed to determine its impact on water quality. The N fertilizer BMP is designed to better match N rates and timing of application to crop needs than conventional practices. This is the first project ever to examine a N fertilizer BMP at the watershed scale. At the time of project termination in December 2000, the treatment watershed had a significantly lower nitrate-N concentration (7.3 ppm, or 41.5%, reduction) than the control at the 95% confidence level. These results suggest that by implementing N BMPs on tile-drained agricultural landscapes, we should expect improved water quality. Also, applied N rates and timing of application are important factors to consider in regard to improved water quality. Attempting to manage one of these factors without the other will likely produce diminished environmental returns compared to those found from this research.

FRATERS, B.[1], L.J.M. BOUMANS[1], and T.C. VAN LEEUWEN[2]. [1]National Institute of Public Health and the Environment, 3720 BA Bilthoven, The Netherlands; [2]Agricultural Economics Research Institute, The Netherlands.

Monitoring effectiveness of the Dutch mineral policy in agriculture in clay regions by monitoring shallow groundwater nitrogen.

The European Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (Nitrate Directive) sets goals for preventing pollution and reducing existing nitrate levels in groundwater. By implementing action plans member states are required to reduce nitrate leaching and run off. In 1998 the Dutch government introduced a Mineral Accounting System (MINAS) as a part of the mineral policy for agriculture. To evaluate the effectiveness of the mineral policy, among others, groundwater quality should be monitored regularly. Short-term effects of the Dutch policy are monitored with the National Monitoring Programme for Effectiveness of the Mineral Policy (LMM). At the first N-conference methodology and results for the sandy regions were presented. In this paper the methodology and results for nitrogen surpluses and nitrogen concentration in shallow groundwater - of the second phase (1996-2001) of the subprogram for the clay regions, will be discussed. Results will be compared with those of the first phase (1993-1995). A blue print for the third and final phase (2001 onwards) is presented.

OSMOND, D.L.[1], L. XU[2], N.N.RANELLS[1], S.C. HODGES[1], R. HANSARD[3], and S.H. PRATT[4]. [1]NC State University, Raleigh, NC 27695 USA; [2]NC Division of Water Quality, Raleigh, NC 27601 USA; [3]Natural Resources Conservation Service, Raleigh, NC 27609 USA; [4]Understanding Systems, Inc., Raleigh, NC 27695 USA.

Nitrogen loss estimation worksheet (NLEW): An agricultural nitrogen loading reduction tracking tool.

Excessive nitrogen (N) loading from the Neuse River into its estuary has caused a large perturbation in the environment of the Albemarle-Pamlico Sound. In 1995, massive fish kills in the Neuse Estuary prompted North Carolina to adopt nitrogen reduction rules that apply to point sources, agriculture, and urban storm water. Each source of N loading must be reduced by 30%. The agriculture community was given the option to adopt one of two strategies: either implement the approved mandatory best management practices (BMP) on all fields or form decision-making groups at the local level to implement these reductions on selected fields. Most agricultural producers have chosen the local-level strategy. Reductions in N loading must be tracked, however, only for the local-level option. In response to this accounting need, a multi-agency committee developed a tracking tool to provide quantitative estimates of nitrogen dynamics that occur following the installation of a BMP or BMP system. The nitrogen loss estimation worksheet (NLEW) developed is both a basin- and field-based procedure. It is currently being used in the Neuse River Basin to track the reduction of N from the implementation of agricultural BMPs. The concept of the tool and its current implementation will be presented.

SCHARF, P.C.[1], N.R. KITCHEN[2], J.G. DAVIS[1], K.A. SUDDUTH[2], and J.A. LORY[1]. [1]University of Missouri, Columbia, MO 65211 USA; [2]USDA-ARS, Columbia, MO 65211 USA.

Innovative nitrogen management systems for maize: Matching crop needs across variable landscapes.

Nitrogen (N) fertilizer need of maize can vary widely across landscapes. The dominant practice is to apply uniform and relatively high N rates, leading to many areas with more N than the crop can use. Unused N may be subject to movement to ground and/or surface waters. Matching N fertilizer rates more closely to crop needs could produce both economic and environmental benefits. Our objective is to develop and evaluate innovative systems for supplying maize N needs in a spatially precise manner at a fixed scale. Systems being developed/evaluated include soil nitrate tests by zone, variable yield goal based on soil electrical conductivity, and sidedress applications based on corn color measured either in aerial photographs or with a ground-based spectralradiometer. Sidedress nitrogen applications based on corn color (either method) or sidedress soil nitrate reduced average N rate by 35 to 90 kg N/ha (relative to current University of Missouri recommendations) in two 1999 experiments; slight yield losses were more than compensated by N savings.

SLAK M.-F.[1], L. COMMAGNAC[1], and P. POINTEREAU[2]. [1]Laboratoire Sols et Paysages, ENITA de Bordeaux, BP 201, 33175 Gradignan Cedex, France; [2]Solagro, Muret, France.

Nitrogen exchanges: Testing the hypothesis of a country without agricultural production.

We previously proposed a model allowing measurement of nitrogen exchange resulting from international trade (Nitrogen ConferNs, 1998). This paper proposes a comparison of nitrogen exchanges when food is nationally obtained by agricultural production and when, conversely, it is obtained through importation. Agricultural production has environmental impacts, especially as concern water quality, which is degraded by nitrogen surpluses. To reduce this impact, and thereby obtain environmental improvement one could think that agricultural production should be limited. Our model estimates what the effects on nitrogen balance would be if an entire country suppressed its agricultural production. The model uses nutritional data (needs, but also habits, which are something quite different) to estimate nitrogen importation required by the human population and by its pets: most importantly horses, dogs and cats (canine and feline contribution to pet food imports should be considered, these animals being carnivorous). Results of this model for France are proposed as an example. The balance obtained is discussed and compared to other ways of environmental improvement while maintaining agricultural production. Food and feed production contributes through agriculture to landscape production, the maintenance of specific wildlife biotopes and the recycling of sewage and wastes of organic compounds.

THEOBALD , M.R., C. MILFORD, K.J. HARGREAVES, and L.J. SHEPPARD. Centre for Ecology and Hydrology, EH26 0QB Edinburgh UK.

Assessing the use of woodlands as a novel measure to reduce net ammonia emissions at a farm level.

There have been increasing pressure on farmers in Europe to reduce the emissions of ammonia from their land. Due to the current financial climate that farmers have to operate in, it is important to identify ammonia control measures that can be adopted with the minimum cost. The planting of trees around farmland and buildings has been identified as a potentially effective and low cost measure to enhance ammonia recapture at a farm level and reduce long-range atmospheric transport. This work assesses experimentally what fraction of ammonia farm woodlands could potentially remove from the atmosphere. We constructed an experimental facility in southern Scotland to simulate a woodland shelterbelt planted in proximity to a small poultry unit. By measuring horizontal and vertical ammonia concentration profiles within the woodland and comparing this to the concentration of an inert tracer (SF6) we estimate the depletion of ammonia due to dry deposition to the woodland canopy. Together with measurements of mean ammonia concentrations and throughfall fluxes of nitrogen, this information is used to provide a first estimate of the fraction of emitted ammonia that is recaptured by the woodland canopy. Analysis of these data show that the planting of woodlands adjacent to agricultural sources of ammonia can recapture a significant fraction of that emitted.

VAN DER PLOEG, R.R., and P. SCHWEIGERT. Institute of Soil Science, University of Hannover, 30419 Hannover, Germany.

About use and misuse of nitrogen in agriculture: The German story.

The usefulness of N-fertilization in agriculture has been discussed controversially in Germany for almost two centuries. The agronomist Carl Sprengel, who published his theory on the mineral nutrition of plants in 1828, advocated the use of mineral N-fertilizers. The chemist Justus von Liebig, on the other hand, denied around 1850 vehemently the need of N-fertilization. Although it soon became evident that Sprengel was right and Liebig was wrong, not much synthetic N-fertilizer was used in German agriculture until the Haber-Bosch technique enabled the commercial production of ammonia around 1920. We will show, how the use of N-fertilizers since then has grown, especially since 1950. To increase agricultural productivity, the German government has promoted, directly and indirectly, the use of N in agriculture, also in animal production. Unfortunately, it was overlooked that N-surpluses in the German agricultural production system increased rapidly; around 1980 they amounted yearly to more than 100 kg/ha. These surpluses have put a heavy burden on the environment, especially on the country's ground and surface waters. Additionally, the high consumption of animal proteins and fats has adversely affected the health of its population. It appears that postwar farm policy in Germany urgently needs fundamental corrections.

Oral Session #14: ***Nitrogen Management in Agricultural Systems.***

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Interrelations between abatement of ammonia, nitrous oxide, and methane from European agriculture: A cost-effectiveness analysis.

Agriculture is an important source of ammonia (NH_3), which contributes to acidification and eutrophication, as well as emissions of the greenhouse gases nitrous oxide (N_2O) and methane (CH_4). Controlling emissions of one of these pollutants through application of technical measures might have an impact (either beneficial or adverse) on emissions of the others. These side effects are usually ignored in policy making. This study analyses cost-effectiveness of measures to reduce acidification and eutrophication as well as agricultural emissions of N_2O and CH_4 in Europe, taking into account interrelations between abatement of NH_3, N_2O, and CH_4 in agriculture. The model used is based on the RAINS model for air pollution in Europe, which includes emissions, abatement options, and atmospheric source-receptor relationships for pollutants contributing to acidification and eutrophication. We extended the RAINS model to include emissions of N_2O and CH_4 from agriculture and technical measures to reduce these emissions. For all abatement options included we estimated the side effects on other emissions. The model determines abatement strategies to meet restrictions on emission and/or deposition levels at least cost. We found that NH_3 abatement may cause an increase in N_2 emissions whereas several options to reduce agricultural N_2O emissions simultaneously reduce NH_3 emissions. Moreover, taking into account interrelations may change the cost-effective allocation of abatement considerably.

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N-management of European grasslands: To what extent can the exchange of gaseous N-species be influenced "actively"?

Managed grasslands can be regarded as biochemical reactors in which large amounts of organic N are converted into inorganic N, and vice versa. These systems are open to the atmosphere. The exchange of various gaseous N-species (NH_3, NO, NO_2, N_2O and N_2) between grasslands and the atmosphere is regulated by a cascade of production, transport and consumption processes. Agricultural systems managed in a sustainable manner should operate in a "quasi steady-state" in which the net N-output from the system is balanced by the total N-input. Therefore, the net flux of gaseous N-species is very small compared to the total N-turnover. Nevertheless it may have an important influence on the chemistry of the atmosphere. Process-oriented grassland models integrate the various aspects of gaseous N-exchange and are well-suited to study the response of the system to changes in the boundary conditions (e.g. climatic change, mitigation measures, etc.). Here, the Pasture Simulation Model (PASIM) is used to investigate to which extent different model formulations (e.g. single layer model versus multi-layer model) determine the net exchange rate of gaseous N-species and the partitioning among the N-species. The results are discussed in relation to total system N-balances.

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Impacts of structural agricultural changes and farming practices on nitrogen fluxes in the Netherlands.

In the Netherlands, intensive animal husbandry has contributed largely to decreased species diversity in (semi) natural terrestrial ecosystems, eutrophication of surface waters, pollution of ground water due to nitrate leaching and global warming due to N_2O emissions. Structural measures to reduce N inputs include the reduction of live stock intensity, specifically with respect to pigs and poultry, and the use of low emission animal housing systems. Furthermore, a Mineral Accounting System (MINAS) has been introduced to stimulate farming practices aiming at a more efficient nutrient use. Examples are the coverage of manure storage systems, slurry injection, reduction of the grazing time, precision fertilization, optimizing of animal feed, improvement of drainage or irrigation, fertilizer reduction and the use of cover crops. To determine the effectiveness of policies aimed at the reduction of the ammonia emission, nitrate leaching and nitrogen runoff, it is essential to have information on the fate of nitrogen in agricultural soils on a regional and national scale. This paper presents the results of a modeling study presenting the impacts of both structural measures and improved farming practices on major nitrogen fluxes, including NH_3 and N_2O emission, uptake, leaching and runoff, in the Netherlands, using input data for the year 2000. Results showed that at present inputs, nitrate concentrations in groundwater often exceed the target of 50 mg/l, specifically in sandy well drained soils, and the ammonia emissions cause strong exceedances of critical N loads for non-agricultural land in view of biodiversity. Only strong structural measures clearly improves the situation, whereas improved farming practices are useful in addition to those measures.

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Increasing nitrogen use efficiency in Midwestern cropping systems.

Management of nitrogen in Midwestern farming systems to achieve both environmental and production goals are often contradictory to each other. To address this question we have been conducting a series of experiments to quantify the interactions among nitrogen rate, crop growth and yield, soil water use, and soil type within a field. These studies have been conducted in field scale experiments in central Iowa. The experimental protocol has been to observe the soil water use patterns and crop growth patterns in different soils across a range of nitrogen rates. These studies have been conducted since 1997 on a 65 ha corn-soybean production field. Corn yields show a large variation among years and nitrogen application rates. There are seasonal differences in the soil water use patterns that are influenced by nitrogen management. In the lower organic matter soils, applying a large amount of nitrogen early in the season does not increase the yield because these areas of the field are often water limited in the late summer. The residual nitrogen within the profile is then available for leaching to subsurface drains. We have developed a decision support approach to nitrogen management that enhances both environmental quality and nitrogen use efficiency by the crop.

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New guidelines for nitrogen use in California cotton.

San Joaquin Valley cotton growers often can achieve yields of 1500 kg lint/ha or greater. In the early 1990's the average rate of nitrogen (N) applied to cotton was 204 kg N/ha. In a five-year project, 39 uniform N-rate experiments were done in six counties. Soil nitrate was estimated in fall and spring to the 240-cm depth. The experimental rates were adjusted, as the sum of estimated soil nitrate-N plus applied fertilizer N, as required. Thus, the test rates were 56 kg N/ha or total soil nitrate N, whichever was greater, and 112, 168 and 224 kg N/ha. In 26 of 39 location-years, cotton yields were not increased with use of rates above the lowest rate, i.e., nominally 56 kg/ha N, but often with no fertilizer N applied ($P < 0.05$). Lint yield responses were found in 4, 6, and 3 of 39 location-years with rates of 112, 168, and 224 kg N/ha, respectively ($P < 0.05$). Lack of response to applied N may have been because 56-90 kg N/ha generally was present already in the cotton root-zone. Nitrate in irrigation water was only low to moderate. New guidelines will call for estimation of soil nitrate N before fertilizer N application, and a reduction in N use rates.

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Habitat management as a tool to modify ecosystem impacts of nitrogen deposition.

Nitrogen deposition is one of the primary drivers of ecosystem change in semi-natural communities such as heathlands and grasslands. However, since semi-natural ecosystems are subjected to the regular management removal of above-ground plant material, the rate of increase in nitrogen status, and thus of nitrogen-mediated effects, can be expected to depend on the precise form of habitat management. We present results from manipulation experiments at a lowland heathland in southern England, aimed at investigating interactions between nitrogen deposition and habitat management. *Calluna* regeneration and seedling invasion by other species were affected by both nitrogen addition (0 or 30 kg/ha/yr/) and management regime. Significant effects of both treatments were also seen on the rate of litter decomposition, suggesting that habitat management can modify the effect of nitrogen deposition on ecosystem nutrient cycling. Ecosystem recovery following a reduction in nitrogen deposition has also been investigated at this site. Whilst some effects of earlier nitrogen addition (0-15.4 kg/ha/yr from 1989-1996) were still apparent four years after cessation of additions, the most intensive management (i.e. greatest organic material removal) was more effective at restoring *Calluna* growth in previously enriched plots, although invasion by grass seedlings was promoted.

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An internet-based simulation model for nitrogen management in agricultural settings.

Numerous chemical, physical, and biological processes mediate nitrogen transformation and movement during agricultural crop production. The complexity of these processes makes optimizing the management of fertilizer and other N sources for crop production and environmental protection exceedingly difficult. Various computer simulation models have been developed to simulate the site-specific fate and transport of nitrogen resulting from different crop production scenarios, but these models are too complex and difficult to use for most farmers, consultants, and conservationists. In an effort to facilitate access and simplify the use of sophisticated models, the USDA has developed an Internet-based nitrogen analysis tool. Based on the Nitrate Leaching and Economic Analysis Package (NLEAP), the web site allows a user to conduct multi-year nitrogen simulation modeling specific to a crop field. Servers handle much of the required data assembly and formatting thus sparing the user. Model runs are executed and the results are transmitted to the user. This new tool is presented along with early implementation results.

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Organic and inorganic integration for nitrogen management in Eastern and Southern Africa.

Per capita food production continues to decline in sub-Saharan Africa, and food insecurity is reaching crisis proportions. Staple cereal crops respond to N fertilization, but farm-gate prices of fertilizer in most of Africa are 2 to 4 times world market prices. Affordable, economically viable and environmentally sustainable N technologies are essential for food security and economic development in sub-Saharan Africa. In this paper we summarize research on integrated N management approaches in western and central Kenya, eastern Zambia and southern Malawi. Some approaches include agroforestry options such as leguminous fallows and intercrops, which add N from biological fixation as well as from recapture of leached N, possible due to the deep rooting architecture of perennial shrubs and trees. Biomass transfer of organic materials from nutrient scavenging shrubs in hedgerows and field borders redistributes N in the landscape for better utilization. In areas where livestock ownership is common, manure and residue management is important, and in addition shows promise for slowing the loss of carbon from forest soils converted to agriculture. With any of these organic options, integration with judicious applications of inorganic fertilizer is often the most promising option.

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Merging nitrogen management and renewable energy needs.

Project ARBRE, the UK's first wood fueled electricity generating plant, represents a significant development in realizing British and European policy objectives on renewable energy. The plant is fuelled by a mix of wood from short rotation coppice (SRC) and forest residues. Where feasible, composted sewage sludge is applied to coppice sites to increase yields. In the Yorkshire Water region typical N:P:K composition of composted sludge cake is 100:134:9 respectively. Sludge cake application is calculated on the basis of N content to achieve 750 kg N ha-1 assuming 20% mineralization annually. Willow coppice forms a dense, widely spaced root network, which, with its long growing season, make it an effective user of nutrients. This, in combination with willows use as a non-food, non-fodder crop, make it an attractive route for the disposal of biosolids in the absence of sea disposal banned under the Urban Waste Water Treatment Directive (UWWTD). Further work is required on the nutritional requirements of SRC in order to understand better the quantities of sludge that can be disposed of in this way. This paper suggests the source of N re-routing under the UWWTD and suggests the likely expansion of SRC as an alternative disposal pathway.

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Use of different crop nitrogen models to simulate nitrogen cycling at regional and ecological levels in Canada.

Recent research to develop an Indicator of Risk of Water Contamination by Nitrogen (IROWC-N) was based on an annual nitrogen and water balance approach. Application of the IROWC-N model with 1996 data predicted that nearly 69% and 17% of total farmland in British Columbia and Ontario generated sufficient surplus to raise nitrogen levels in water above the upper limit of drinking water guideline of 14.1 mg N/L. With results of such importance it is imperative that we are confident in our numbers. We have adopted the approach of using nitrogen simulation models in local, data-rich areas to provide independent assessments of IROWC-N results. We are currently integrating dynamic models with a regional GIS database so that nitrogen cycling in farmland can be simulated in both temporal and spatial scales; in each soil polygon monthly, for example. Three field level models, DSSAT3.5 (USA), EPIC (USA) and N_ABLE (UK) are being used and evaluated using local measured data. This presentation will address the work from the perspective of: (1) crop and animal husbandry input data from agricultural census databases of 1981, 1991, 1996 and 2001; (2) soil and weather inputs from regional soil and weather databases; (3) validation data from local field experiments; (4) simulation carried out using a graphic user interface; and (5) mapping of the nitrogen distribution using GIS. Aggregated results are compared with IROWC-N outputs.

Oral Session #15: ***Forests, Nitrogen and Surface Waters.***

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Upland versus hyporheic nitrogen losses on an Appalachian forest watershed.

The relative importance of nitrogen losses due to assimilation by upland vegetation and soil organisms versus losses in the hyporheic zone was studied on a small forest basin in the mid-Appalachian region of the United States. Measurements of total dissolved nitrogen fluxes showed that of the estimated 11 kg/ha/yr inputs from atmospheric wet plus dry deposition, only about 3.5 kg/ha/yr were exported in stream flow. The difference of 7.5 kg/ha/yr has been traditionally interpreted as largely a loss due to upland nitrogen assimilation. Recent evaluation of nitrogen delivered by groundwater to the hyporheic zone during low flows on this basin changed this interpretation. Over half of nitrogen losses appeared to be occurring in the hyporheic zone. Upwelling hyporheic groundwater was dominated by dissolved ammonium and organic nitrogen, while nitrate dominated in stream water. Stream water nitrate concentrations varied diurnally with water temperature during low flows. Diurnal variations were not related to differences in amount of stream macrophytes in this and four other forest streams. Results suggest that rapid nitrification/denitrification in the hyporheic zone was an important control on nitrogen loss in this headwater catchment.

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Regional patterns in nitrogen dynamics across Europe.

In comparison to North America, there is very wide gradient of nitrogen deposition in throughfall across Europe, from 2-3 kg N/ha/yr in parts of Scandinavia to over 70 kg N/ha/yr in parts of the Netherlands and northern Germany. The IFEF (Indicators of Forest Ecosystem Functioning) database has been developed over the last 10 years to determine significant regional trends in nitrogen leaching. It now contains information on over 240 forested plots and catchments across Europe. Past analyses have shown that output fluxes of nitrogen are strongly related to the amount of nitrogen deposited in throughfall and the C:N ratio of the organic horizon. Here we present new relationships between nitrate leaching and N deposition, and variables such as aluminum leaching, latitude and mean annual temperature and precipitation from the most recent compilation of the database. Among other significant relationships, the analysis shows that fluxes of dissolved aluminum from forested plots and catchments across Europe are more strongly related to the deposition of nitrogen than to any other input ion.

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Regionalization of disturbance-induced nitrogen leakage from mid-Appalachian forests using a linear systems model.

Long-term watershed research conducted in Shenandoah National Park (SNP) in Virginia and elsewhere in the eastern United States indicates that annual export of dissolved nitrogen (N) from gauged forested watersheds to surface waters increases dramatically in response to vegetation disturbances. Dissolved N export is a common, well-documented response of small forested watersheds to logging in the larger region, while recent defoliation outbreaks of the gypsy moth (*Lymantria dispar*) larva in the deciduous forests of SNP have been shown to generate similar biogeochemical responses. A recent modeling analysis further suggests that a parsimonious, empirical, unit N export response function (UNERF) model can explain large percentages of the temporal variation in annual N export from a group of small gauged forested watersheds in the years following disturbance. The empirical UNERF modeling approach is completely analogous to the unit hydrograph technique for describing storm runoff, with the model representing annual N export as a linear deterministic process both in space and in time. The purposes of this analysis is to: (1) test the applicability of the UNERF model using quarterly stream water nitrate data from a group of ungauged watersheds in SNP; (2) demonstrate a park-wide application of a regional UNERF model that references the geographic distributions of bedrock geology, forest vegetation, and the timing of gypsy moth defoliation over the entire SNP area; and (3) visualize the temporal and spatial patterns in vegetation disturbance and annual dissolved N export through the use of computer animation software.

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Quality and sources of DON in forested and alpine catchments, Colorado Front Range.

We are attempting to better understand ecosystem controls on dissolved organic nitrogen (DON) export in surface waters using a variety of innovative techniques in forested and alpine catchments on North Boulder Creek in the Colorado Front Range. Chromatographic fractionation shows that the fulvic acid content of dissolved organic matter (DOM) increases moving downstream from alpine to forested sites. The C:N ratios of fulvic acids ranged from 18.1-45.3%, whereas the C:N ratios of the non-fulvic fractions were lower, between 11.9-29.4%. These differences indicate that, in surface waters, DOM quality and N-content change both spatially and temporally in our study catchment. Use of a novel fluorescence technique has shown that the source of fulvic acid in surface waters varies seasonally, with N-rich algal sources making important contributions in the spring and fall and N-depleted terrestrial sources dominating during snowmelt. Additionally, *13$_C$ values from organic material isolated at two sites show a relative enrichment both in space (moving downstream) and in time (later in the snowmelt season). Further, *13$_C$ values appear to be correlated with changes in the C:N ratio of DOM, and could therefore reflect changing sources of dissolved organic material and DON in North Boulder Creek. We believe these insights will prove useful for understanding the role of DON in the nitrogen cycle of other catchments being affected by anthropogenic N deposition.

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Factors controlling stream water nitrate concentrations in forested watersheds of the Catskill Mountains, New York.

Stream water nitrate concentrations vary 18-fold in small, forested watersheds in the Catskill Mountains of southeastern New York State. This variation does not appear to be due to differences in atmospheric deposition rates or watershed topography. The amount of deep groundwater entering the stream through seeps may alter the seasonal pattern of nitrate concentrations, but does not explain the among-watershed differences in mean annual concentration. Variation in the severity of beech bark disease among watersheds also cannot explain the variation in nitrate concentrations. Very low nitrate concentrations are observed year-round in streams with a significant component of oak in the watershed vegetation. This pattern may result from direct effects of the oaks themselves on N retention. However, oaks are also symptomatic of historical cutting and /or burning of watersheds, consequently it is difficult to separate the role of forest history from the role of species composition in controlling N retention. Single-species plot studies indicate that soils under oak stands have very low nitrification rates compared to other species, suggesting a direct effect of oak litter quality on nitrification and nitrate leaching.

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Soil nitrogen transformations along a primary succession transect on the land-uplift coast in western Finland.

We monitored net and gross N transformations and their relationship to certain soil properties in the organic layer along a primary successional transect (alder/rowan, birch, birch/spruce, spruce I and spruce II) typical for the land-uplift coast of Western Finland. Net N mineralization rates in the organic layer were estimated in 5-week incubation experiments in situ using intact soil cores, and in the laboratory on sieved, fresh organic layer samples. Microbial biomass N and gross N mineralization were determined once in the laboratory using the ^{15}N-isotope dilution method. Net N mineralization in the organic layer decreased along the succession transect, while gross N mineralization showed no significant differences between the forest stages. The decrease in net N mineralization therefore resulted from an increase in microbial immobilization of N rather than from a decrease in gross mineralization. The combined results of four field incubations (period 3 June - 21 Oct 1997) showed significantly lower net mineralization on an areal basis in the late successional spruce forests (2.8 - 3.6 g m-2) in comparison to the preceding alder/rowan (7.4 g m-2), birch (7.4 g m-2) and birch/spruce (7.0 g m-2) stages. The alder/rowan stage differed from the other stages in having a higher $\mathrm{pH(C_aCl_2)}$ (range 3.32-4.84) and greater N availability, and was the only stage to show net nitrification.

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Nitrogen transformations in stream channels of small watersheds.

Nitrogen exports from watersheds are assessed in part by measurements of nitrogen export in streams. These fluxes are known to be affected by nitrogen deposition, forest management practices, insect defoliation, agriculture, and urbanization. The fluxes are strongly affected by forest soil processes but may also be modified by stream channel N transformations. If we could quantify the impact of stream processes on nitrogen concentrations in stream water, we could more fully understand the role of forest processes on N cycling. Over the past 10 years we have been using ^{15}N -NH_4 tracer additions to small streams to assess NH_4 uptake, nitrification, NO_3 uptake and nitrogen export downstream. Thus far mainly undisturbed headwater streams with low N concentrations have been studied. In most cases we find that during spring, summer and fall NH_4 and NO_3 concentrations in these streams are several fold less than the waters seeping from the upland portion of the catchment. This change is due to uptake of nitrogen by stream channel microbes and plants and to a poorly known extent to denitrification. These studies must be extended to catchments that export much higher N concentrations to determine the limits of the capacity of stream processes to affect inorganic N exports.

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Nitrate leaching from forests: Different processes at different time scales?

Nitrogen was chronically added (27 kgN/ha/year as NH_4-NO_3) to a small subalpine forest catchment for 6 years. Within weeks, and compared to an untreated catchment, this resulted in increased nitrate leaching from the Gleysol. In a replicated experiment in small plots, nitrate concentrations were also elevated in the solution from the topsoil, but not in the soil solution below 10 cm. Together with short travel times of hydrological tracers, this indicated the dominance of near-surface and/or preferential flow. ^{17}N labeling, an end-member mixing analysis and an experiment with micro-suction cups all confirmed that nitrate leaching was mainly hydrologically driven, originating directly from the deposition and not from an N saturation of the ecosystem. Compared to this short-time reaction, the difference between N-addition and control tends to increase slowly after several years. In this longer time scale, it is likely that the ecosystem is slowly evolving towards true N saturation. Because most of the added N is still retained in the soil, the long-term effect of N deposition depends on this immobilization processes and the resulting binding forms of N in the soil. Beside the ongoing addition experiment, new ^{15}N tracer experiments have therefore been initiated to answer this question.

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Assessment of trends and leaching in Nitrogen at ICP Waters Sites (Europe And North America).

The International Cooperative Programme on Acidification of River and Lakes currently holds data for almost 200 surface water sites free from local disturbance, in Europe and North America. About 50% of the sites currently have nitrate concentrations indicative of nitrogen saturation, that is, elevated level of nitrate above that expected in undisturbed systems not receiving significant amounts of N deposition. The relative importance of nitrate as an acid anion has increased at the ICP sites since the early 1990s, mostly due to the decrease in sulphate concentrations (due in turn to reduced sulphate deposition). The data indicate no major change in N saturation at the ICP sites during the 1990s. Very few sites have changed status with respect to Stage of N saturation. Nitrate concentrations show significant trends over time at only a few sites. Overall the data indicate that progression to increased N saturation is a slow process of time scale of decades.

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Geologic control of stream nitrate concentrations from forested watersheds of the northeastern United States.

Stream nitrate concentrations during summer and winter baseflow were measured on 49 mid-Appalachian forested watersheds with different bedrock geology, soil characteristics, stand age, and past land disturbances to explain the significant variation in stream nitrate export. Pottsville/Allegheny sandstone (PVA), Catskill/Chemung/Pocono shale and sandstone (CCP), and Mauch Chunk/Greenbrier shale/limestone (MCG) exhibited low, mid, and high mean summer and winter stream nitrate concentrations, respectively. Stream nitrate variation was not related to past land disturbances (fire, farming, and logging) or stand age (old-growth). The basal area of black locust, a nitrogen-fixing species, showed a moderate, positive correlation with stream nitrate concentrations. Stream nitrate concentrations were correlated positively with the soil chemistry parameters pH, Ca, and %N and negatively correlated with C/N ratios. Soil chemistry differences were the most likely proximate cause of stream nitrate differences, since they have a more direct control on soil nitrate production. Bedrock geology was the most likely ultimate cause of stream nitrate differences, because of its primary influence on soil chemistry characteristics in this unglaciated region. Bedrock geology explained the most variation in winter (49%) and summer (32%) stream nitrate concentrations. This study suggests that regional bedrock geology could be used to help predict nitrate leaching from forestland.

Oral Session #16: **Market Mechanisms and Nitrogen Management.**

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To trade or not to trade? Criteria used in determining the applicability of cap and trade to environmental problems.

The use of emissions trading (cap and trade) is gaining worldwide recognition as an extremely effective policy tool. The environmental and economic results of the US SO_2 emissions trading program has led domestic and foreign governments to consider application of cap and trade to address other environmental challenges. Certain analyses are particularly important in determining whether cap and trade is an appropriate policy tool. This paper briefly discusses the results of the US SO_2 and NO_x emissions trading programs in the US and offers a set of questions that can be used as criteria for determining whether cap and trade is the preferred policy approach to an environmental problem.

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NO_x emission trading in an European context: Discussion of the economic, legal and cultural aspects.

Emission trading is a new instrument in environmental policy. It is an alien notion in most European countries and it is often viewed with suspicion. The paper discusses the economic, legal and perhaps more importantly, the cultural aspects to consider when one tries to explore the prospects for trading emissions of NO_x and other substances in Europe. Issues to be addressed are the present legal framework in Europe in relation to the national emission ceilings on NO_x and other substances on the basis of relevant EU directives and UN-ECE protocols. The paper will discuss the extent to which the legal framework within the EU imposes constraints on the design of a national emission trading scheme, and what options are available to fit emission trading into that legislative structure. The NO_x emission trading programme developed in the Netherlands will be used to demonstrate the various aspects in a European context.

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Economics as a base for large scale nitrogen control decisions.

The biophysical science of nitrogen control, especially from non-point sources such as agriculture, is not very certain. Widespread precise data does not exist coupling management practices for non-point nitrogen flows with specific outcomes for river basins. Other drivers of nitrogen flows such as weather further complicate the picture. In addition, economics has its own sets of uncertainties and simplifying assumptions. The economic analysis of the National Hypoxia Assessment provides an example of combining less than complete scientific information with economic analysis (a soft social science) to inform policy makers about alternative approaches and their economic consequences. The potential value to decision makers comes primarily from bounding the magnitude of alternative options and their consequences. What such analysis provides is answers to concerns about the impact of different degrees of control on actors within the nitrogen loss system, indirect impacts outside of the system, and an approach to determine some policy and level of control that reduces environmental risk cost effectively while considering those suffering the impact of nitrogen loss controls.

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NO_x emissions trading in the United States: Lessons from program development and implementation.

The Ozone Transport Commission (OTC) NO_x Budget Program and the NO_x SIP call NO_x Budget Trading Program use market forces to facilitate cost-effective compliance with the cap on aggregate NO_x emissions from large electric and industrial combustion units. This paper explores the development of these programs and then focuses on market development for NO_x allowances during the first two years of the trading program. After presenting the structure of the NO_x SIP call and its emission trading component, observed trends in the market price index and trading volume are analyzed with respect to market forces and program requirements. The paper also examines whether the NO_x cap and trade system designed for purposes of achieving NO_x reductions from large stationary sources in the eastern half of the United States is an appropriate model for other air emission reduction goals.

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Nutrient trading- The pathway to the future?

Since the introduction of the Clean Water Act in 1972, there have been significant improvements in water quality in the US. A majority of these improvements have resulted from regulating point sources- industrial and municipal facilities. However, water quality, in particular nutrient pollution, still remains a problem, and non-point sources like agriculture are the predominant source. Innovative solutions are needed to provide incentives for non-point sources, whose nutrient discharges are difficult to regulate, to reduce their nutrient contributions. One such solution is nutrient trading. Trading involves setting a goal for the total amount of nutrients entering streams and rivers within a watershed and allowing sources, both point and non-point, to trade nutrient reduction credits in order to meet the local and regional water quality goals. Nutrient trading is being explored and implemented as a viable mechanism to reduce nutrient pollution in a number of areas in the US and internationally. To facilitate the establishment of these markets, WRI has been developing an e-market place, NutrientNet, for farmers and point sources to determine their nutrient loads and achievable reductions, provide a market place for trades to occur and a registry that allows trades to be tracked.

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A nitrogen reduction strategy addressing the 'dead zone' in the Gulf of Mexico.

Nutrient pollution, now the leading cause of water quality impairment in the United States, has had significant impact on the nation's waterways. The hypoxic 'dead zone' in the Gulf of Mexico is a striking illustration of what can happen when excess nutrients (nitrogen) from inland watersheds reach coastal areas. Despite the efforts of municipal building programs, industrial wastewater requirements and agricultural programs designed to reduce sediment loads in waterways, water quality and nutrient pollution continues to be a problem. We undertook a policy analysis to assess how the agricultural community could better reduce its nitrogen contribution to the 'dead zone'. Using a sectoral model of U.S. agriculture, we compared policies including conservation subsidies, nutrient trading, Conservation Reserve Program extension and fertilizer reduction. This economic and environmental analysis is watershed based, focusing on nitrogen in the Mississippi Basin, allows us to assess the distribution of nitrogen reduction, environmental co-benefits and impact on agricultural cash flows within the Basin from various options. The model incorporates natural resource accounts and alternative production practices, giving a more complete picture of the costs and co-benefits of nitrogen reduction. These elements also help to identify those policy options that minimize the costs to the farmers and maximize benefits to society.

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An enhanced rate-based emission trading program for NO_x : The Dutch Model.

Since 1997 government and industry in the Netherlands have been engaged in intensive policy discussions on how to design an emission trading program that would satisfy the Government's policy objectives within the national regulatory framework and accommodate industry's need for a flexible and cost-effective approach. Early on in the discussions the most promising solution was a rate-based approach, which dynamically allocated saleable emission credits based on a performance standard rate and actual energy used by facilities. All industrial facilities above a threshold of 20 MWth would be judged on their ability to meet this performance rate. Those "cleaner" than the standard can sell excess credits to others with an allocation that is less than their actual NO_x emission. Such a design fits well into the national and EU legislative framework while at the same time uniquely meeting industry's requirement of flexibility towards economic growth and facility expansion. However, the environmental outcome of such a system is not as certain as under an absolute emission cap. At the request of the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM), Automated Credit Exchange, in close cooperation with the working group of government and industry representatives introduced a number of features into the Dutch NO_x program allowing full exploitation of market mechanisms while allowing intermediate adjustments in the performance standard rates. The design is geared towards meeting environmental targets without jeopardizing the trading market the program intends to create. The paper discusses the genesis of the two-tier credit system ACE helped to design, explains the differences between primary (fixed) and secondary (variable) credits, and outlines how the Dutch system is expected to function once implemented in 2003. The paper discusses the market trading simulation held in early 2001 to assess and test the trading program, and reviews also the current status of the market program development.

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Tradeable manure production rights as a tool for tackling the mineral surplus in the Netherlands.

There is far more manure produced by livestock in the Netherlands than there is land on which to deposit the manure. The Dutch government first introduced policy to combat the problem of mineral surpluses in the 1980's. Over the years several instruments have been implemented, first to stabilize manure production and later on to reduce it. The paper will discuss the political and economic impact of the instruments which have been deployed, such as manure production rights based on the number of animals held during a reference period, the mineral accounting system and manure disposal contracts.

Oral Session #17: **_Impacts of Anthropogenic Nitrogen on Coastal Ecosystems._**

BINTZ, J., B. BUCKLEY and S. GRANGER. Graduate School of Oceanography, Narragansett, RI 02882-1197 USA. Presented by **S.W. Nixon**, Graduate School of Oceanography, Narragansett, RI, USA.

Nutrient enrichment and temperature increases in coastal lagoon ecosystems.

During recent decades, coastal marine waters of the northeastern United States have commonly been subjected to increasing inputs of inorganic nitrogen and to increasing temperatures. During the summer of 1999, we carried out a lagoon mesocosm experiment to determine if there were interactive effects of these two factors. We used ten well-mixed tanks (4 m^2, 1.1 m deep) with a water residence time of ten days. Four systems were cooled approximately 4°C below the ten-year mean for nearby natural lagoons, four were warmed about 4°C above the mean, and two were maintained near the mean temperature of the natural systems. Two of the cooled and two of the warmed mesocosms also received continuous nutrient enrichment of 6 mm $N/m^2/d$ and 0.5 mmol $P/m^2/d$. Both warm temperatures and nutrient enrichment increased the standing crop of phytoplankton and macroalgae and decreased the survival of eelgrass. There was also a strong interactive effect that resulted in much lower eelgrass growth rate, shoot biomass, root and rhizome biomass, and plant density in the warmed and enriched systems. We suggest that the rapid and steep declines in eelgrass frequently and recently observed in the northeast may result from the interactive effects of nutrient enrichment and warmer summer temperatures.

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Chesapeake Bay eutrophication: Historical and recent patterns of nutrient inputs, effects on water quality, fate of nutrients, and likely responses to load reductions.

Estimates indicate nutrient loads (TN, total nitrogen, and TP, total phosphorus) to Chesapeake Bay have increased by factors of 7 and 17, respectively, since colonial times. Detailed examination of load changes during the last half century indicates increases of about a factor of 2 for TN loading in one tributary (Potomac) and 4 in another (Patuxent). The relative amounts of TN and TP (N:P ratio) have also been substantially modified by land use changes and management actions. Changes in characteristics of estuarine community production, development of hypoxic/anoxic bottom waters, and loss of seagrass communities are common features of estuarine eutrophication and all have been evident in Chesapeake Bay and sub-estuaries. Several Chesapeake Bay data sets were examined for relationships between these features and nutrient loading rates. In one case (Patuxent) monthly nutrient loading rates were reconstructed back to 1960 and compared with estuarine production measurements made in each decade since 1960. Rates increased markedly in proportion to TN loads, the pattern of production shifted from bi-modal to unimodal and P/R ratios increased. Annual hypoxic (dissolved oxygen < 1 mg/l) volumes were computed for the Chesapeake Bay mainstem for most years since 1950. There were clear indications of increases in hypoxic volume since the mid-1960's. The volume of anoxic (dissolved oxygen ~0 mg/l) water was very small (or not detected) prior to the late 1960's but has increased sharply to the present. There are large differences in hypoxic volumes before and after the mid-1960's in years of similar hydrologic conditions (i.e., drought years). The decline in seagrass distribution and abundance was also first noted during the mid-1960's. The decline involved multiple species, was initiated in the upper bay and upper tributary regions and eventually included most mesohaline regions of the bay. It appears that increased water column turbidity, coupled with enhanced epiphytic fouling of seagrass leaves, were major causes of the decline. While there has been seagrass recovery in some areas, total seagrass coverage is still a small fraction of pre-1960's coverage. Estimates of nutrient inputs from point, diffuse and atmospheric sources have improved markedly, especially since the mid-1980's when large-scale monitoring and modeling activities were established. However, the final fate of nutrients in the bay has received less attention. Present estimates for the mainstem and several large tributaries indicate that burial in sediments, denitrification and export to the coastal ocean are all important for TN (each about 30% of TN inputs from the land plus atmosphere). About 10% of TN is removed as commercial and recreational fish harvest. All terrestrial and atmospheric TP inputs appear to be buried and TP is imported to the bay from the coastal ocean. Most of the TN and TP in the bay is contained in sediments as detrital particulate material. Despite a large sediment pool of nutrients, decade-scale field measurements and short-term laboratory experiments suggest that the "nutrient memory" of these coastal plain systems is relatively short, on the time scale of several years rather than several decades.

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Sensitivity of nitrogen concentrations in estuaries to loading and water residence time: Application to the Potomac estuary.

We use a simple nitrogen budget model to analyze concentrations of total nitrogen (TN) in estuaries for which both nitrogen inputs and water residence time are correlated with freshwater inflow rates. While the nitrogen concentration of an estuary varies linearly with TN loading rate, its dependence on residence time is more complex. For a fixed mass-loading rate of nitrogen, the concentration of TN in estuaries with residence time less than a month increases nearly linearly with residence time. Concentrations increase more slowly as residence time grows further, and are essentially constant for residence times greater than approximately 10 months. This nonlinear behavior affects the relative sensitivities to TN loading of estuaries with different residence times, and year-to-year variation in the sensitivity of a single estuary with fluctuating freshwater inputs. We examine the effects of interannual changes in water and nitrogen inputs to the Potomac Estuary. Analysis with the model shows that although reduced residence time lessens the effect of larger nitrogen inputs in wet years, the net effect on the estuary is still an increase in the concentration of total nitrogen.

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Harmful algal blooms in Louisiana coastal waters clearly linked to N inputs.

Evidence to support the hypothesis linking Harmful Algal Blooms (HABs) to increasing N inputs is sparse, except for several well known examples like the Inland Seto Sea, Japan, and Tolo Harbor, Hong Kong. Two HABS in Louisiana coastal waters have been clearly linked to increasing N inputs. 1) *Pseudo-nitzschia* spp. are extremely abundant and sometimes toxic in Louisiana coastal waters in the outflow region of the Mississippi River. Spatial and temporal distributions and microcosm experiments suggest a link to riverine nutrient inputs. These inputs have doubled since the 1950's and coincident historical and sediment core data show that *Pseudo-nitzschia* spp. abundance has increased four fold over the same period. 2) In 1997 Mississippi River water was diverted in Lake Pontchartrain for flood control, tripling in one month the annual nitrogen loading to this normally oligotrophic, oligohaline estuary. A massive bloom of heptatotoxic, colonial cyanobacteria, comprised primarily of *Anabaena cf. circinalis*, resulted. Heterocysts, indicating N fixation, did not develop until the nutrients were depleted at the end of the bloom, suggesting that N limited the bloom. Since blooms have not developed in non-diversion years it is concluded that nutrient inputs from the diversion caused the bloom.

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Nitrogen and the Baltic Sea.

The Baltic is the World's second largest brackish sea, 377 000 km^2, with a drainage area of 1.6x10^6 km^2 (population 8 x 10^7). It extends from 54°N, where ice is short-lived, to ~66°N, with several months of ice. Surface salinity is 3-8, and biodiversity low. Last century, annual N inputs increased 4X, to 10^6 metric tons, and P inputs rose 8X, to 50x10^3 tons. Each summer, cyanobacteria fix 2-4x10^5 tons N. Eutrophication is worst in the N-limited south, where Secchi depths have been halved, and bottom water oxygen deficiency greatly increased, while the north is P-limited and low-productive. Eutrophication is severe in many coastal areas, with blooms of plankton (sometimes toxic) and filamentous algae reducing amenity value. Baltic countries try to reduce nutrient inputs, with some success for P, but only little, locally, for N. Since Baltic N limitation is natural, reducing only P-inputs might create a quite different, artifically P-limited Baltic. Reduction is needed of both N, to reduce production, and of P, to avoid blooms of nitrogen-fixing cyanobacteria. The political goal of halving anthropogenic N and P loads requires both reduced emissions to air, soil and water, and wetland construction and mussel farming, to remove circulating nutrients.

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Organic nitrogen and harmful algal blooms.

In recent years, there has been a growing recognition of the link between eutrophication and the development of harmful algal blooms in coastal and estuarine waters. The sources of nutrients potentially stimulating algae are many, and there is no question that many high biomass algal blooms are related to increases in nutrient loading. There is also an increasing awareness that the composition of the nutrient pool, in addition to the total nutrient loading may play a role in the development of those alga that cause harm to the environment. Furthermore, the organic component of the nutrient pool, particularly organic nitrogen, may contribute disproportionately to the development of harmful blooms. Urea has been associated with the outbreaks of blooms in fish ponds, and elevations in the ratio of dissolved organic nitrogen to carbon has been related to other blooms along the eastern seaboard of the US. Many harmful bloom species have a diversity of mechanisms whereby nitrogen is acquired by the cells, and this may impart an advantage to these cells under both nitrogen limiting and nitrogen sufficient conditions.

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Implementing a nitrogen management strategy in Tampa Bay, Florida: A public/private partnership.

Participants in the Tampa Bay Estuary Program have agreed to adopt nitrogen loading targets for Tampa Bay based on the water quality and related light requirements of underwater seagrasses. Based on modeling results, it appears that light levels can be maintained at necessary levels by holding the line at existing nitrogen loadings. However, this goal may be difficult to achieve given the 20% increase in the watershed's human population and associated 7% increase in nitrogen loading that are projected to occur over the next 20 years. To address the long-term management of nitrogen sources, a Nitrogen Management Consortium of local electric utilities, industries and agricultural interests, as well as local governments and regulatory agency representatives, have developed a Consortium Action Plan to address the target load reduction needed to hold the line at 1992-1994 levels. To date, implemented and planned projects collated in the Consortium Action Plan meet and exceed the agreed-upon nitrogen loading reduction goal. Three phosphate fertilizer mining and manufacturing companies located on Tampa Bay are participants in the Estuary Program and the Nitrogen Management Consortium in order to provide input into, and support, a program that advocates voluntary cooperation to reach environmental goals.

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Predicting estuarine susceptibility to eutrophication from nutrient loading.

Do all estuaries respond similarly to equivalent nutrient loads? Or are some types of estuaries, such as those dominated by seagrasses, more susceptible than others, such as those dominated by intertidal salt marshes? To address these questions, we require a classification system that will enable us to balance the various processes and factors that enhance and inhibit eutrophication. Scientists and resource managers have used classification systems for decades to organize information about ecological systems. Yet the classification of estuarine and coastal systems remains a difficult topic because they exhibit such dynamic changes with time and space. Each estuary or coastal system has unique characteristics (e.g., morphology, river flow, tidal range, circulation, productivity and so forth) that change in response to the local climate, geology, and disturbance regime. A classification system is needed to help predict estuarine susceptibility to nutrient over enrichment. Such a system should have the ability to encompass broad spatial and temporal scales, to integrate structural and functional characteristics under different disturbance regimes, to convey information about mechanisms controlling estuarine or coastal features, and to accomplish the goal at low cost and at a high level of uniform understanding among resource managers. A useful classification scheme should allow classification of relatively unknown systems on the basis of a minimum suite of measurements. We will review a variety of estuarine classification schemes that have been used to classify hydrodynamics, geomorphology, habitats, and eutrophication potential.

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Integrating atmospheric deposition of nitrogen in estuarine and coastal nutrient cycling and eutrophication dynamics.

Atmospheric deposition of nitrogen (AD-N) represents 10 to >40% of external, or new, N loading to N-limited coastal waters. This growing N source has been linked to eutrophication and algal bloom expansion. Regionally and globally, AD-N from urbanization (NO_x) and agricultural expansion (NH_4^+, organic N) has increased in coastal airsheds. Intensification of animal (swine, poultry) operations in the U.S. and Western Europe have caused increased NH_4^+ deposition. Changes in chemical composition of AD-N may alter primary production and algal composition in receiving waters. AD-N combined with other atmospherically-derived nutrients (e.g. Fe) is particularly stimulatory to marine primary production. Extension of the regional acid deposition model (RADM) to coastal waters indicates that 11, 5.6, and 5.6 kg-N/ha may be deposited on the Northeast, Southeast and Eastern Gulf of Mexico continental shelves, respectively, exceeding riverine inputs in many coastal regions. Spatially, AD-N is a unique new N source to coastal waters because airsheds may exceed watersheds by 10-20 fold or greater and AD-N inputs often occur far downstream of terrigenous N inputs. Because of its overall biogeochemical and ecological importance, AD-N should be integrated in air/watershed nutrient budgeting and management strategies aimed at reducing N pollution of coastal waters.

Oral Session #18: *Policy responses to increased environmental N.*

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Material flow analysis for nitrogen cycle management at local level: The example of Catalonia (Spain).

The great complexity of the nitrogen cycle, including anthropogenic contributions, makes it necessary to carry out local studies that allow identifying the specific cause-effect links of a particular society. The modeling of local societies by methods like Material Flow Accounting (MFA) (which study and characterize the performance of metabolic exchanges between human society and environment) is a useful tool to direct local policy towards a sustainable management of nitrogen cycle. In this oral presentation, a model for Catalonia (the northeast region of Spain next to the Mediterranean Sea) is presented. The experience obtained in the construction of this model is used to draw attention to the difficulties found in local studies, related to data gaps and to the quantification of input-output flows at this level.

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Soil acidification in Switzerland and its ecological consequences.

In Switzerland, about 80% of acid deposition is formed by nitrogen compounds. The critical loads for acid deposition are exceeded in large areas with till soils or on granitic bedrock. There are several indicators for progressing soil acidification within the last 15 years. First, the manganese concentration in beech leaves has been increasing continuously between 1984 and 1999. Second, in permanent forest observation plots sampled in 1984/85 and 1996/97, soil base saturation has decreased by 7% on an average and by up to 40% where acid deposition loads are high. Third, the BC/Al ratio in the soil water of several plots shows a marked decrease within a few years. One possible ecological consequence of this soil acidification is a decreased tree stability: during a heavy storm in December 1999, the proportion of uprooted *Fagus sylvatica* and *Picea abies* was significantly enhanced on soils with a base saturation of less than 40%.

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Beyond the 1999 Gothenburg Protocol - The next step towards future goals.

Over the last decade, the Convention on Long-range Transboundary Air Pollution has developed effects-based mechanisms for emission controls using critical loads and levels, pollutant transport models, abatement cost information and integrated assessment models. In December 1999, a protocol to the Convention was adopted in Gothenburg, Sweden. This addresses the environmental effects of nitrogen pollutants through a multi-pollutant, multi-effect approach aimed at abating acidification, eutrophication and the effects of ground-level ozone. In addition to setting basic obligations, the protocol defines agreements for exchange of technology; strategies, policies and measures to ensure implementation; reporting; research, development and monitoring; compliance and reviews. Protocol annexes define critical loads and levels for Europe and North America, and emission ceilings for each Party for sulphur, nitrogen oxides, ammonia and VOCs in 2010. Further annexes specify limit values for sulphur, nitrogen oxides and VOCs from stationary sources, and for fuels and new mobile sources, as well as control measures for emissions of ammonia from agricultural sources. The protocol aims to set realistic targets with associated environmental benefits and has a well-structured mechanisms for achieving its objectives. It is the first international agreement of its type and sets an important precedent for future instruments for emission controls.

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The 1999 Gothenburg Protocol - A step towards effective nitrogen emission controls?

The 1999 Gothenburg Protocol is just one step towards protecting man and his environment from harmful emissions of nitrogen pollutants. While negotiators of the protocol would not accept more costly measures, they did recognize that further steps were needed to prevent damage in sensitive areas. Already the Convention is considering the next steps and how these might be achieved. Future deliberations will still be based upon scientific knowledge of effects, atmospheric transport models and costs of abatement measures. However, there will be more emphasis on certain new or previously poorly addressed effects. Human health issues, especially from the effects of fine particulates, are being considered in collaboration with WHO. Ammonia emissions and controls, for long an area of uncertainty, are being investigated by an expert group. Ozone effects on vegetation, dealt with very simply in previous models, will be predicted using improved atmospheric modeling and exposure-response relationships. In addition, it is now recognized that soils and freshwaters take time to recover from acidification and eutrophication. Dynamic models will lead to better predictions of environmental benefits (recovery). The review of the Protocol is required within 12 months of its entry into force, possibly in 2004. The review should show further steps needed for future emission controls.

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Assessment of nitrogen production ceilings on a regional scale avoiding adverse environmental impacts.

In the Netherlands, high traffic density and intensive animal husbandry has led to very high emissions of reactive nitrogen into the environment. This does lead to a series of environmental impacts, including: (i) nitrate contamination of drinking water inducing illness in infants, (ii) eutrophication of freshwater lakes inducing blooms of toxic algae, (iii) acidification of soils, lakes, streams, and ground waters, (iv) biodiversity impacts on terrestrial ecosystems and (v) global climate change induced by emissions of N_2O. Measures that have been taken to control the reactive nitrogen emissions and limit their effects were up to now directed towards different environmental themes such as acidification, eutrophication, climate change and dispersion. This approach led to measures with varying, and in several cases limited, success. Here we summarize the results of a study to analyze the nitrogen problem in the Netherlands in an integrated way, which means that all relevant aspects are taken into account simultaneously. A simple N balance model was developed, in which the maximum nitrogen application in the field (organic manure and/or fertilizer) under different soil types was calculated on the basis of critical limits for nitrate concentrations in groundwater and nitrogen concentrations in surface water. The N balance model is based on simple empirical relationships between the different N fluxes as a function of land use, soil type and groundwater level. The model accounts for the N removal through products (net uptake), N immobilization and denitrification in both soil and surface water and the corresponding ammonia emission. The acceptable ammonia emission related to the protection of biodiversity of natural areas was calculated on 5x5 km grid cells over the Netherlands by using source – receptor relationships and an optimization routine. The maximum N application in the field was re-estimated when the acceptable ammonia emission related to protection of biodiversity of natural areas was lower than the ammonia emission related to protection of ground water and surface water quality. The maximum N production or N-ceilings were thus calculated, being equal to the N input in feed products and fertilizer and the N deposition. Calculations were done for the Netherlands on a 5km x 5 km scale. Results show that in most parts of the Netherlands, except the west and the north, the ammonia emissions derived from critical N loads for nature areas are more restrictive than those based on limits for both ground and surface water. On the country scale the maximum allowable N import ranges between 350 and 540 kton per year depending on the choice of critical limits. The current N import is 922 kton per year. A reduction of 50 to 70% is therefore needed to reach the ceilings necessary to protect the environment against all adverse impacts of nitrogen pollution from agriculture. The limitations and uncertainties of this quantification are described in a separate article. It is shown that for agriculture, nitrogen ceilings provide a good basis for regulating nitrogen through fertilizer use and feed import.

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Ammonia recovery process economics.

The ARP process is an award winning, low cost, environmentally responsible method of recovering nitrogen, in the form of ammonia, from various dilute waste streams and converting it into ammonium sulfate. The ARP process uses reversible chemisorption and double salt crystal precipitation to recover and concentrate the ammonia. The process was successfully proven in a recent large-scale field demonstration at New York City's Oakwood Beach Wastewater Treatment Plant, located on Staten Island. This project was a joint effort with Foster Wheeler Environmental Corporation, the Civil Engineering Research Foundation and New York City Department of Environmental Protection. Independent validated plant data show that the ARP process consistently recovers up to 9.9% of the ammonia from the City's central waste stream (derived from dewatering of sewage sludge), as ammonium sulfate. ARP technology can reduce the nitrogen (ammonia) discharged daily into local bodies of water by municipalities, concentrated animal farming operations, and industry. Recent advances to the ARP process enhance its performance and economic competitiveness in comparison to stripping or ammonia destruction technologies. ThermoEnergy and joint venture partner, Foster Wheeler Environmental Corporation, are providing the ARP process.

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Progress in the EU Nitrate Directive.

From 1991 onwards, the European Union (EU) member states (MS) have to comply with the Nitrate Directive (ND). The aim of this directive is to protect ground and surface waters in a sustainable way against pollution with nitrogen (nitrate) originating from agriculture. Agriculture is the largest single source of nitrate (runoff, leaching) pollution for the EU, although households and industries also contribute to some extent. An important element in this ND is the monitoring of ground and surface water quality every four years. Furthermore, all 15 EU-member states are enforced to designate so called Vulnerable Zones (VZ). These are regions where the nitrate concentrations in the ground water amounts to 50 mg/l or more. Besides Codes of Good Agricultural Practice (GAP), valid on a countrywide basis and often consisting of voluntary based measures to reduce nitrate pollution, specific Action Programmes (AP) have to be developed for the VZ. The first monitoring period ended in 1994. This paper describes the progress in MS compliance with the ND during the second period (1994-1998), with a focus on the GAP and AP. The MS reports form the basis of this evaluation. According to the reporting guidelines by the EU, the MS reports have to deal with the following issues: (1) designation of VZ; (2) GAP implementation; (3) AP; and (4) prediction of water quality. By the end of the second monitoring period all MS had delivered their progress reports. This is a dramatic improvement when compared to the first period. Furthermore, most MS have formulated and implemented AP, besides codes of GAP. These AP often consist of law enforced: (1) limited periods for application of animal manures (mainly during winter time); (2) restrictions for manure application on sloping, snow-covered or frozen soils; (3) buffer zones near water courses; and (4) maximum amounts of 170 kg N per ha per year from organic manure.

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Past and future exceedances of nitrogen critical loads in Europe.

Critical loads of acidity and nutrient nitrogen - simple measures of the sensitivity of ecosystems to deposition - have been widely used for setting emission reduction targets in Europe. In contrast to sulfur, the emissions of nitrogen compounds remain high in the future. This is also true for the exceedances of these critical loads until 2010. Looking further into the future, climate change is likely to influence ecosystem sensitivity, and thus critical loads. It is shown that higher temperatures, changed precipitation patterns and modified net primary production mainly increase critical loads, except in mountainous and arid regions. Using consistent scenarios of climate change and air pollution from a recently completed European study (AIR-CLIM), it is shown that the exceedances in 2100 of the critical loads are declining in comparison to 2010. However, exceedances of critical loads of nutrient nitrogen remain substantial, even under the most stringent scenario. This confirms the increasing role nitrogen plays in environmental problems in comparison to sulfur. Thus research should focus on the effects of nitrogen in the environment, especially under conditions of climate change to support N-emission mitigating policies. This not only reduces acidification and eutrophication, but also helps curb the formation of tropospheric ozone.

Oral Session #19: ***Interactions of Carbon and Nitrogen at Regional and Global Scales.***

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Factors controlling N cycling in the Central Arizona-Phoenix ecosystem.

A detailed fixed N mass balance was constructed for the Central Arizona-Phoenix (CAP) ecosystem. Fluxes and storage were examined in 10 subsystems: wastewater, human food, combustion, pet food, natural desert, cropland, dairies, urban landscapes, landfills, and the subsurface. Input of fixed N input to the ecosystem was 94 Gg/yr. Humans deliberately import or mediate the fixation of 49 Gg N/yr (commercial fertilizer, animal and plant food, and alfalfa); combustion processes added another 34 $G_g/_y$. Fixation by desert plants, wet deposition, and surface water input combined accounted for 12% of total N input. Total fixed N output was 76 Gg N/yr, mostly gaseous N products of combustion and denitrification. Computed accumulation of N was 18.0 Gg/yr (total input minus total output) or alternatively, 16.6 Gg/yr (summing individual accumulation fluxes). Inputs to the urban and agricultural components of the ecosystem were an order of magnitude higher than inputs to the desert. Human hydrologic modifications in this ecosystem promote accumulation and volatilization of N while keeping riverine export low (3% of input). Interplay among the form and amount of N inputs, edaphic and climatic characteristics of the system, hydrologic modifications, and deliberate efforts to reduce N pollution controls the fate of N in human-dominated ecosystems.

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Effects of anthropogenic nitrogen loading on riverine nitrogen export.

Human activities have greatly altered the nitrogen (N) cycle, accelerating the rate of N fixation in landscapes and delivery of N to water bodies. To examine the effects of anthropogenic N inputs on riverine N export, we quantified N inputs to large watersheds and the associated riverine N losses. We focus on watersheds in the eastern United States, Western Europe, and in Eastern Asia — regions that are heavily impacted by human populations. We quantified inputs of N to each basin from atmospheric deposition, fertilizer application, agricultural and forest biological N fixation, and the net import of N in food and feed. We compared these inputs with N losses from the system in riverine export. Despite significant differences between these regions, patterns relating human controlled N inputs to riverine exports are similar. Climate and runoff have important influences on this relationship. The greatest N inputs were observed in regions of EA, which receive the highest deposition rates globally and have intensive agricultural practices.

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Nitrogen losses from anthropogenic sources and their effects on Canadian ecosystems: A national assessment.

A national assessment was recently undertaken in Canada to identify the extent to which nutrient losses from anthropogenic sources were impairing environmental quality and affecting the quality of life for Canadians. As part of this assessment, nitrogen (N) losses from major anthropogenic sources were estimated and their impacts on aquatic and forest ecosystems and on the atmosphere were documented. We estimated that > 300x10^3 t/yr N entered surface or ground waters from anthropogenic sources (primarily from sewage, industrial and agricultural sources and long-range atmospheric deposition), approximately 1471x10^3 t/yr N was emitted to the atmosphere (primarily from agricultural, industrial and transportation emissions) and > 795 x10^3 t/yr N was added to forested land (from long-range atmospheric deposition of ammonia and nitrate). Our review showed N losses from anthropogenic sources have caused environmental and human health concerns in Canada including the development of toxic marine algal blooms; fish kills in streams; a decline in amphibian numbers in southern Ontario; an increase in the frequency and spatial extent to which the drinking-water guideline for nitrate has been exceeded in ground waters; and an increase in the production of the greenhouse gas N_2O and nitrate in acid rain. Environmental problems caused by excessive nutrients are less severe and tend to be more localized in Canada than in countries with a longer history of settlement and agricultural production. However, it is critical that gains achieved by improved wastewater treatment, agricultural best management practices and other control measures not be reversed by relaxation of standards or by failure to keep pace with population growth or agricultural intensification.

DRINKWATER, L. Department of Horticulture, Cornell University, Ithaca, NY 14853 USA.

Re-coupling carbon, nitrogen and phosphorus cycles in agroecosystems.

Carbon and N cycling are linked through net primary production, decomposition and storage as plant biomass and soil organic matter pools. In agricultural systems, these linkages can be manipulated by management practices that can either promote or interfere with the biological cycling processes. Typical management practices disengage energy flows from the cycling of biologically limiting nutrients such as N. Long-term use of management practices that disconnect nutrient cycling processes has led to the depletion of soil organic matter pools and reduced the biomass of primary and secondary consumers in the soil. As a result, the overall capacity of the ecosystem to supply nutrients through mineralization is reduced, increasing the dependency on fertilizer inputs that are difficult to retain in the system. As ecosystem function deteriorates, fertilizer requirements increase and the imbalance between inputs and exports grows. The majority of lands under agricultural production in industrialized countries are N-saturated and some are also P-saturated. The most effective way to reduce the need for surplus nutrient additions that lead to saturation and subsequent loss of nutrients is to restore biological linkages between these cycles. Re-coupling the C, N and P cycles will increase the retention of N and P as biomass and as soil organic matter creating positive feedbacks that will increase the internal cycling of nutrients and reduce the need for surplus nutrient additions.

FOWLER, D., M. SUTTON, S. TANG, R. SMITH, and U. DRAGOSTIS. Centre for Ecology and Hydrology Edinburgh, Penicuik, Midlothian, EH26 0QB, UK.

Application of atmospheric mass budgets of fixed nitrogen at the country scale.

Monitoring networks have been established for gas and aerosol phase nitrogen compounds in the boundary layer over the UK (NH_3, NH_4, NO_2, HNO_3 and NO_3). These networks provide the necessary data to quantify the wet and dry deposition budgets and the spatial distribution for both oxidized and reduced nitrogen directly from measurements. In addition, for the first time the aerosols advected out of the country by wind, as NO_3 and NH_4 have been calculated directly. Thus, it is possible to compare the atmospheric mass balance over the country, with the official inventory. The measurements show that UK emission of NH_3-N required to satisfy the mass balance are approximately 350 k tonne N annually, approximately 20% larger than official emission estimates. For oxidized nitrogen, the mass balance based emissions are in reasonable accord with official estimates. The deposition of fixed nitrogen in the UK is dominated by reduced nitrogen, especially for the ecologically sensitive semi-natural land, and the deposition data have been used to quantify exceedance of critical loads of oxidized and reduced nitrogen for the different ecosystems.

GROFFMAN, P.M.[1], K.T. BELT[2], L.W. BAND[3], and G.T. FISHER[4]. [1]Institute of Ecosystem Studies, Millbrook, NY 12545 USA; [2]U.S. Forest Service; [3]University of North Carolina; [4]U.S. Geological Survey.

Nitrogen fluxes in urban watersheds.

Urban ecosystems are among the most heavily human dominated ecosystems on earth. However there have been relatively few studies of N fluxes in these ecosystems compared to agricultural or forest ecosystems. The Baltimore Ecosystem Study (BES, www.ecostudies.org/bes) is an urban component of the U.S. National Science Foundation Long-Term Ecological Network. BES research is centered on the Gwynns Falls watershed, a 17,150 ha catchment that traverses a gradient from the urban core of Baltimore, through older urban residential and suburban zones, rapidly suburbanizing areas and a rural/suburban fringe. Our long-term sampling network includes four longitudinal sampling sites along the Gwynns Falls as well as four small (40-100 ha) watersheds (forest, agriculture, rural/suburban, urban) located within or near the Gwynns Falls. Each of the gauging sites is continuously monitored for discharge and is sampled weekly for chemistry. The long-term monitoring is linked to studies of internal watershed dynamics and modeling efforts. Concentrations and loads of N are surprisingly high in some suburban catchments relative to urban and forested reference catchments. High N in suburban catchments may be linked to home lawns, leaking sanitary sewers and septic systems, old agricultural nitrate and/or loss of riparian and in-stream sinks for N.

HICKS, W.K, P. INESON and J.C.L. KUYLENSTIERNA. Stockholm Environment Institute - York, University of York, York, YO10 5YW, UK.

Responses of terrestrial ecosystems to nitrogen enrichment- Impacts and issues at global scale.

Impacts of increased nitrogen enrichment on terrestrial ecosystems have been particularly well documented in Europe and the negotiations within the UN/ECE Convention on LRTAP provided a framework for the coordinated research activity that led to the development of protocols using the effects-based critical loads approach. As global emissions of oxidized and reduced forms of nitrogen continue to increase, nitrogen deposition rates to terrestrial ecosystems in developing countries are reaching those found in Europe and North America. It is, therefore, important to compare the response of terrestrial ecosystems in different regions to nitrogen enrichment and to determine the transferability of methods, tools and approaches between regions. In the spring of 2001, researchers from Asia, Africa, Australasia, Europe and North and South America met at the Stockholm Environment Institute -York, K, to discuss the implications for terrestrial ecosystems of nitrogen enrichment. The outcome of this meeting is discussed in terms of: (i) terrestrial ecosystems that are most sensitive to nitrogen mediated changes and what value the changes have for the countries in question; (ii) the applicability of critical load concepts in different ecosystem types; (iii) interactions of nitrogen enrichment mediated effects with other global environmental change concerns.

LACAUX, J.P. Medias, Toulouse Cedex4, France.

Nitrogen deposition In tropical Africa.

In the framework of the IGBP core project: IGAC (International Global Atmospheric Chemistry), DEBITS (Deposition of Biogeochemically Important Trace Species) has been created to encourage existing and new activities in the final step of the biogeochemcal cycles: the atmospheric deposition of the chemical species to the Earth's surface. The deposition chemical content, signature of numerous physical and chemical mechanisms, allows one to trace temporal and spatial evolution of atmospheric chemistry and is a pertinent indicator to evaluate natural and anthropogenic influences. The DEBITS scientific activities are mainly based on measurements of controlled quality of precipitation chemistry to quantify wet deposition and aerosol (bulk sampling) and gases (passive sampling) concentrations to estimate dry deposition. DEBITS has been expanded in 1994 to Africa, with the launch of the IDAF (IGAC DEBITS AFRICA) program and ten sites representative of the great African ecosystems (dry and wet savanna, equatorial forest) are active in 2001. Here we present wet and dry depositional fluxes of nitrogenous compounds, from six stations located in a transect of ecosystems, from the Sahelian savanna to the Congolese equatorial forest. Seasonal sources (marine, terrigenous, biogenic, and biomass burning) and heterogeneous or multiphase chemical processes are taken into account to explain the characteristics and the relative contribution of dry versus wet deposition.

PARTON, W.J.[1], S.J. DEL GROSSO[1], E.A. HOLLAND[2], A.R. MOSIER[3], D.S. SCHIMEL[2], D.S. OJIMA[1], R. BRASWELL[4], O. BOSSDORF[2], and R. MCKEOWN[1]. [1]Colorado State University, Ft. Collins, CO 80523 USA; [2]MPI für Biogeochemie, 07701 Jena, Germany; [3]USDA-ARS, Ft. Collins, CO 80522 USA; [4]University of New Hampshire, Durham, NH 03824 USA.

Global patterns for nitrogen cycling for terrestrial ecosystems.

The spatial grid version of the Century model was used to simulate global patterns of nitrogen mineralization, soil organic matter and plant production for terrestrial ecosystems. The results show that nitrogen mineralization rates are one of the primary controls of plant production. The simulated impact of increased anthropogenic nitrogen inputs during the last 100 years show substantial increases in plant production and carbon storage. Conifer forest systems show the highest increases in carbon storage followed by mixed and deciduous forest systems, savanna and grassland systems. Most of the increase in carbon storage was in the large wood component and soil carbon. The ecosystem retention of added nitrogen was highest for the forest systems (85%) and lowest for the grassland systems (70%). Agricultural fertilizer studies show that N fertilizer additions result in increased plant production and plant N uptake. Approximately 40% of the fertilizer N is removed in plant biomass, 40% is stabilized in the soil organic matter, and the remainder is lost due to leaching or gaseous N losses. Adding N in an organic form results in lower N losses, higher N stabilization in the soil organic matter and similar N uptake by the crop.

WALLMAN, P., and H. SVERDRUP. Chemical Engineering II, Lund University, SE-22100 Lund, Sweden.

Modeling nitrogen and carbon emissions/sequestrations in a forested area in southern Sweden as a result of management during the period 1450 to 2050.

The well-established models PnET and SAFE have been merged together with a recently developed decomposition model into a new model system. This model system is used as a tool for analyzing the profound impact of climate change and management strategy in aforested area in Southern Sweden. The strong feedback relationships between carbon and nitrogen in a forest ecosystem make nitrogen management, to a certain extent, possible through forest management. Land-use history and species composition changes for the period 1450-2000 have been reconstructed and calculations of nitrogen and carbon mass balances during the period have been done. These calculations show that the loss of carbon in the managed forest is substantial and that the nitrogen cycle processes are widely influenced. It is shown that these changes are mainly due to management strategies, to the greatest extent plantation of Norway spruce instead of replanting of deciduous trees. The period 2000-2050 is simulated with a climate change scenario for the Nordic countries made by the Swedish Meteorological and Hydrological Institute. These simulations show that forest management in order to release nitrogen also emits large amounts of carbon to the atmosphere, and that the forest is actually a net source of carbon.

POSTER SESSION

Monday, October 15 - Nitrogen Production and Movement

Poster Session #1: **Nitrogen Use in Agricultural Fertilization Practices.**

ARULMOZHISELVAN, K., and M. GOVINDASWAMY. Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore - 641003, INDIA.

Fitting labeled N recovery parameter in fertilizer prescription model.

In many targeted-yield N prescription models, the coefficients for soil, fertilizer and other N contributing sources are interrelated and derived by unlabeled methods. Further, the soil efficiency is computed based on the yield of the control plot, which excludes the effect of Added N Interaction (ANI). Due to this, the fertilizer N efficiency becomes apparent, leading to inaccuracy in N prescription. In Tropical soils, ANI is considerably active. Hence, to refine the model, a field experiment was conducted under four N fertility gradients in *Vertic Ustropept* soil. Labeled N was used to assess N fertilizer efficiency for cotton (*Gossypium hirsutum* L.). By the accuracy of labeled N assay, subsequently the coefficients for all other N contributing sources acted in Integrated N Management, viz. soil, farm yard manure (FYM) and *Azospirillum* were refined. The prescribed N dose/ha as urea for achieving a target of 30 q/ha seed cotton yield by labeled N approach was 169 kg for managing with urea alone, 115 kg with urea and FYM, and 105 kg with urea, FYM and *Azospirillum*, showing a saving of 24, 12 and 6 kg respectively relative to unlabeled method. Thus, this conservatory labeled N approach would be a promise for its practice.

BRONSON, K.F.[1], T. CHUA[1], **A.R. MOSIER**[2], R.J. LASCANO[1], J.W. KEELING[1], and J.D. BOOKER[1]. [1]Texas A&M University, Texas Agricultural Experiment Station, Lubbock, TX 79401 USA; [2]USDA-ARS, Fort Collins, CO 80523 USA.

Multi-spectral reflectance in irrigated cotton for reduced nitrogen fertilization and residual soil nitrate.

Spring soil NO_3 tests have traditionally tailored N fertilizer recommendations for cotton in western USA. In-season monitoring of plant N status can, however, produce improved N recommendations because soil NO_3 tests do not account for NO_3 loss between soil sampling and planting. In-season monitoring of plant N status can produce N recommendations. We tested multi-spectral reflectance and chlorophyll meter measurements as in-season N decision aids for two irrigated cotton sites in TX. Zero-N, soil-test-based, chlorophyll meter-based, reflectance-based, well-fertilized N treatments were tested. Multi-spectral reflectance measurements were made using CropScan® MSR16R at 0.5 m and chlorophyll meter (Minolta® SPAD 502) readings were taken on the leaf. In-season N of 34 kg N/ha was applied to reflectance and chlorophyll meter plots when the sufficiency index (relative to well-fertilized) < 0.95 at early squaring, first bloom, and peak bloom. Lint yield responded to N at Lubbock, up to 34 to 68 kg N/ha, however, there was no N response at Ropesville. The green vegetative index was the reflectance index that most highly correlated with N rate at both sites and with lint yield at Lubbock. Chlorophyll meter measurements were positively related with N rate at both sites. This study demonstrated that with in-season monitoring, N applied and residual soil NO_3 at harvest was less than with soil test-based N applications.

CLAPP, J.G. Tessenderlo Kerley, Inc, Greensboro, NC 27405 USA.

Urea-triazone nitrogen characteristics and uses.

Urea-triazone nitrogen is defined by the Association of America Plant Food Control Officials as a stable solution resulting from controlled reaction in aqueous medium of urea, formaldehyde and ammonia that contains at least 25% total nitrogen. The solution shall contain no more than 40% nor less than 5% of total nitrogen from unreacted urea and not less than 40% from triazone. All the nitrogen shall be derived from water-soluble dissolved reaction products of the above reactants. It is a source of slowly available nitrogen. Initially developed by the Arcadian Corporation for use on turf, this nitrogen source has proven to be a safer and effective material for direct application on plant foliage alone or in combination with other nutrients. Results from field trials on turf, vegetable, fruit and field crops indicate that urea-triazone nitrogen is effective for increasing yields and, or quality when used to supplement a sound soil fertility program. The stability of this nitrogen source from potential losses via ammonia volatilization and nitrate leaching when soil applied is also documented by results from university trials

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The influence of mineral fertilizers combined with a nitrification inhibitor on microbial populations and activities under cotton cultivation Uzbekistan.

Application of fertilizers combined with nitrification inhibitors affects the soil microbial biomass and activity. The objective of the research was to determine the effects of fertilizer combined with a nitrification inhibitor, potassium oxalate (PO), on soil microbial population and activities in low N soils under cotton cultivation. Fertilizer treatments were N as urea, P as ammophos and K as potassium chloride. Inhibitor of nitrification PO was added to urea and ammophos at the rate of 2%. Three treatments: $N_{200}P_{140}K_{60}$(T1), $N_{200\ PO}P_{140}K_{60}$ (T2), $N_{200}P_{140\ PO}K_{60}$ (T3) mg kg^{-1} soil were applied for this study. The control $N_0P_0K_0$ were without fertilizer and PO. The populations of oligotroph bacteria, actinomycets, spora forming bacteria, ammonifying bacteria, nitrifying bacteria, denitrifying bacteria, mineral assimilating bacteria, oligonitrophil bacteria, bacteria group Azotobacter and Clostridium were determined by the most probable number method. Treatments T2 and T3 increased the number of N fixing microorganisms and utilization of mineral N on the background of reducing quantity of ammonifying bacteria, decreased the number of nitrifying and denitrifying bacteria. Our experiments showed that PO combined with mineral fertilizers is one of the promising compounds for inhibiting nitrification rate, which was reflected in increased availability and efficiency of fertilizer N to the cotton and increased N fixation by N-fixing microorganisms.

ISIRIMAH, N.O., C. IGWE, and **S.A. AKELE**. Institute of Geoscience and Space Technology, University of Science and Technology, Port Harcourt, Rivers State, Nigeria.

Bioavailable nitrogen content in organic wastes of municipal solid wastes at the dumpsites in Port Harcourt and environs, Rivers State Nigeria.

Organic wastes were collected from many dumpsites, sorted and incubated. The content of nitrogen and rate of mineralization and nitrification of Nitrogen was studied. Significant content of nitrogen was reported.

KOCH, R., J.A. HOUNTIN, and R. ANTICO. The Rodale Institute, Kutztown, PA 19530 USA.

Do green manure-managed soils minimize nitrogen leaching over time?

A study was conducted in Rodale Institute's Farming Systems Trial in Pennsylvania to evaluate the contribution of three cropping systems to nitrate (NO_3) leaching in organically and conventionally managed soils. The specific objective of this study was to show the NO_3 pollution of ground water from green manure incorporation into soils. Intact soil core lysimeters were installed in the three systems to monitor nitrogen losses from raw manure, green manure and mineral fertilizer over a period of 10 years. Leachate samples were collected bi-weekly, depending on rainfall events. Nitrogen losses were dependent on cropping system and seasons. During the first five years the NO_3 loss in the conventional system (100 kg NO_3-N/ha) was significantly greater than in the organic systems (60 kg NO_3-N/ha). Conversely, the results obtained the following years showed greater increase in NO_3 leaching in the legume system probably due to large biomass production of green manure. As a result the cumulative amounts of NO_3 lost from the legume system were 8 and 27% higher than from the conventional and manure system, respectively. To minimize the downward movement of nitrate in legume systems more in-depth research is needed for a holistic management of organic agriculture.

SKARIC, Z.[1], M. MESIC[2], F. BASIC[2], and I. KISIC[2]. [1]Institute for Adriatic Crops and Karst Reclamation, 21000 Split, Croatia; [2]Faculty of Agriculture, University of Zagreb, 10 000 Zagreb, Croatia.

Influence of nitrogen fertilization on the lettuce yield and on NO_3^- N concentration in lysimeter water.

With the aim of determining the optimal mineral nitrogen fertilization for lettuce (*Lactuca sativa* L.) according to the yield and nitrate concentration in lysimeter water a stationary field trial with 6 treatments was set up in Southern Croatia. The trial included different rates of nitrogen fertilization from 0 to 450 kg/ha N. Water leached through the soil to an 80 cm depth was caught by the installed lysimeters. The lysimeters applied were without lateral sides (after Ebermayer). According to the lettuce yield best results were obtained with 100 kg/ha N. Highest nitrogen content in lettuce was recorded in the treatment with 300 kg/ha N. Average NO_3- N concentrations in lysimeter water varied from 113 to 350 mg/L NO_3- N. Depending on the trial treatment average quantity of leached NO_3- nitrogen varied from 29.9 to 85.0 kg/ha.

SUMMERS, K.[1], **S.B. ROY**[1], R. MUNSON[1], and R. GOLDSTEIN[2]. [1]Tetra Tech, Inc., Lafayette, CA USA; [2]EPRI, Palo Alto, CA , USA.

Effects of timing of fertilizer use in watersheds on biological impacts in receiving waters.

Agricultural fertilizer use is a major component of nutrient loads delivered to water bodies. The biological consequences of the nutrient loads, such as algal blooms and anoxia in deeper waters, are observed at certain times of the year, typically summer and fall. This study examines the role of timing of fertilizer addition on the biological effects of nutrient enrichment. The nutrient supply in receiving water can also originate in the sediments, which are largely uncontrollable over short time periods. We identify water body types where modified timing of fertilizer use, consistent with agricultural needs, is likely to ameliorate the harmful effects of nutrient enrichment.

Poster Session #2: **Nitrogen Management in Animal Agriculture.**

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Spatial distribution of nitrogen on grazed karst landscape.

The impact on water quality by agricultural activity in karst terrain is an important consideration for resource management within the Appalachian Region. Karst areas comprise about eighteen percent of the Region's land area. An estimated one-third of the Region's farms, cattle, and agricultural market value are located on karst terrain. Mean nitrate concentrations in several karst springs in Southeastern West Virginia exhibit a strong linear relationship with percent agricultural land cover. Development of best management practices for efficient nitrogen use and reduction of outflow of N to water from karst areas requires a knowledge about nitrogen dynamics on those landscapes. We studied the terrestrial distribution of nitrogen on a grazed karst sinkhole landscape and the associated export of nitrogen in internal drainage water. Accumulation of mineralized nitrogen and carbon in the surface soil layer near sinkhole drains may be a result of transport of animal manures by hydrologic processes and by the animals themselves. Best management practices that control delivery of those by-products to sinkhole drain areas may be the most effective strategy for protecting groundwater quality in karst areas.

HUTCHINGS, N.J., B.M. PETERSEN, J. BERNTSEN, and **T. DALGAARD.** Danish Institute of Agricultural Sciences, DK-8830 Tjele, Denmark.

Detecting conflicts in nitrogen management policies using the Fasset Farm Model.

Nitrogen is lost from farming systems to the environment via nitrate leaching and the gaseous emission of ammonia, nitrous oxide and dinitrogen. Nitrate leaching contributes to pollution of surface and drinking waters, ammonia contributes to eutrophication and acidification and nitrous oxide contributes to global warming. Within farming systems there is often an interaction between the losses of the different forms of nitrogen. For example, reducing ammonia emission from animal housing and manure storage increases the amount of labile nitrogen added to the soil when the manure is utilized as a fertilizer for cropping. Unless crop management practices are changed, this will tend to increase the subsequent loss of nitrogen via nitrate leaching. The FASSET farm model dynamically simulates production and nutrient flows through the farm plus logs fossil energy use. In this poster, we present the FASSET model and show how it can be used to detect conflicts between policies designed to reduce farm-scale ammonia emissions and the losses of other forms of nitrogen to the environment.

LEFCOURT, A., and **J. MEISINGER.** USDA-ARS, Animal and Natural Resource Institute, Beltsville, MD 20705 USA.

Effect of adding alum and zeolite to dairy slurry on ammonia volatilization.

Ammonia volatilization is a major N cycle process for manures. Ammonia losses impact both agricultural and non-agricultural ecosystems by being a direct loss of plant available N to the farmer and by contributing to eutrophication in neighboring ecosystem through atmospheric transport and deposition. The effect of adding alum or zeolite to dairy slurry was studied to determine their usefulness in reducing ammonia emissions and the resulting chemical changes in the slurry. Ammonia volatilization over 96 hours was measured using six small wind tunnels with gas scrubbing bottles at the inlets and outlets. Manure samples from the start and end of trials were analyzed for total N, and were extracted with KCl solution and water with extracts analyzed for ammonium N and pH. The addition of 6.25% zeolite or 2.5% alum (percent by weight)to dairy slurry reduced ammonia emissions by nearly 50% and nearly 60%, respectively. Alum treatment retained ammonia by reducing the slurry pH to 5 or less. In contrast, zeolite, being a cation exchange medium, adsorbed ammonium and reduced dissolved ammonia gas. Both alum and zeolite offer the potential for reducing ammonia losses from dairy slurries, conserving N for crop production, and reducing eutrophication in neighboring ecosystems.

SHERWELL, J.[1], D. BROWN[1], A. CRESSMAN[2], and G. WALTERS[2]. [1]Maryland Dept. Natural Resources, Annapolis, MD 21403 USA; [2]Environmental Resources Management, Exton, PA, USA.

Full-scale poultry litter test burn.

The results of a test burn using poultry litter in a normally wood-fired stoker boiler are reported. Current management practice is to apply poultry litter to land; however, this can result in an excess of nitrogen phosphorus being applied. This practice can contribute to groundwater contamination and may be linked to outbreaks of the toxic microorganism Pfisteria piscicida. Use as a boiler fuel was viewed as possible alternate use for the litter. The unit selected had an 80MMBtu/hr heat input that would consume an estimated 54,000 tons of litter annually. Engineering and economic feasibility studies indicated that liter use was viable, and a test burn was recommended. Pelletized fuel was prepared to be compatible with in-place fuel handling equipment. In addition to boiler operations monitoring, extensive stack testing was performed, along with fuel and ash analyses to assess any environmental impacts. Fuel performance was adequate for full boiler performance, but ash characteristics were incompatible with the boiler grate. A saleable ash is produced, and a fuel-nitrogen mass balance indicates complete destruction of TKN compounds. All criteria air pollutants were within expected ranges.

SLAK M.-F.[1], L. COMMAGNAC[1], and P. POINTEREAU[2]. [1]Laboratoire Sols et Paysages, ENITA de Bordeaux, BP 201, 33175 Gradignan Cedex, France; [2]Solagro, Muret, France.

Nitrogen mobilisation by human beings, pets, animals, and livestock, environmental impact of nitrogen sources.

This paper compares yearly nitrogen mobilization required in a country for the feeding of human populations, pets and livestock (all of which are defined by human activities). Every animal requires protein nutriments. The nitrogen contained in food resources mainly returns to the environment as wastes, sewage and sludge. Hence, every animal will engender environmental impacts. Results of the model for France are proposed as an example. Results obtained are discussed especially in relationship to the ESB disease context. The link between nitrogen sources for the feeding of humans and animals and the environmental impacts is discussed using farm-gate nitrogen balances. Depending on the nitrogen resource used to feed livestock, impacts on environment are found to be quite different. If the nitrogen sources used in feeding are locally produced, the impact should be limited; conversely, if nitrogen sources are imported, the nitrogen balance is degraded. As a consequence, water resource degradation could increase. Results estimate what the effects would be on the nitrogen balance if an entire nation suppressed protein importation for livestock production. Results for France are proposed as an example. The balance obtained is discussed.

STOUT, W.L., J. DELEHOY, and L.D. MULLER. USDA/ARS and The Pennsylvania State University, USA.

Managing N for milk production and water quality.

Many small- to medium-sized dairy farms in the northeast U.S. have adopted management intensive grazing (MIG) to reduce costs and improve farm profitability. It has been assumed that MIG was by nature an environmentally friendly practice that would have minimal or even positive impact on water quality. In MIG, however, nitrate leaching loss is increased because of high stocking rates and the concentration of N in urine patches. Dietary supplementation with energy can be used to improve N utilization by the animal, improve milk production and subsequently reduce urinary N loss. This paper uses output from N leaching and animal nutrition models to explore management options to reduce N leaching loss and improve milk production.

Poster Session #3: ***Forests and the Nitrogen Cycle.***

ABER, J.[1], S. OLLINGER[1], R. FREUDER[1], C. DRISCOLL[2], G. LIKENS[3], R. HOLMES[4], and C. GOODALE[5]. [1]Complex Systems Research Center, University of New Hampshire, Durham, NH 03824 USA; [2]Department of Chemical and Environmental Engineering, Syracuse University, Syracuse, NY 13244 USA; [3]Institute of Ecosystem Studies, Millbrook, NY 12545 USA; [4]Department of Biology, Dartmouth College, Hanover, NH 03755 USA; [5]Department of Plant Biology, Carnegie Institute of Washington, Stanford, CA 94305 USA.

Temporal changes in nitrate loss from forested ecosystems in response to physical, chemical, biotic and climatic perturbations.

Nitrate leaching to streams is a sensitive indicator of the biogeochemical status of forest ecosystems, and has been used as a primary response variable in studies of both forest management and atmospheric deposition. Two theories (N saturation and nutrient retention) predict that maturing forests in the northeastern U.S. should exhibit increasing nitrate leaching. Long-term stream chemistry data from Hubbard Brook, New Hampshire, USA, and elsewhere show decreasing stream nitrate from the 1970s through the mid-1990s. In this paper we present a model (PnET-CN)-based analysis of the individual and combined effects of: (1) climate variability (ambient internannual and a severe drought); (2) chemical disturbance (N deposition, and increases in global CO_2 and tropospheric ozone); (3) physical disturbance (harvesting, hurricane and ice storm damage); and (4) biotic disturbance (defoliation) on nitrate loss rates from watershed 6 at Hubbard Brook using data for actual disturbance events on the watershed. Long-term N deposition is the largest contributor to long-term increases in nitrate losses, but considerable temporal variability is induced by ambient climatic variation. The relevance of results to nutrient cycling theory and water quality policy will be presented.

CHANG, S.X.[1], and D.J. ROBISON[2]. [1]University of Alberta, Edmonton AB T6G 2E3 Canada; [2]North Carolina State University, Raleigh, NC 27695 USA.

Genotypic effects on seedling sweetgum nitrogen use efficiency.

Screening and selecting tree genotypes that are responsive to nitrogen additions and show high nutrient use efficiencies can provide better genetic material for short-rotation plantation establishment. A pot experiment was conducted to test the hypothesis that sweetgum (*Liquidambar styraciflua* L.) families that are more responsive to N additions will also have greater nutrient use efficiencies. Seedlings from two half-sib families that were known to have contrasting responses to fertility and other stress treatments were used for an experiment with two levels of N (0 vs. 100 kg N/ha equivalent) and two levels of P (0 vs. 50 kg P/ha equivalent). Sweetgum seedlings responded to N and P treatments rapidly, in both size and biomass production, and those responses were different between the two families tested. Nitrogen use efficiency was significantly improved by N addition, and was different between the two families when nutrient supply was limiting. A better understanding of genotype by fertility interactions is important in selecting genotypes for specific site conditions, and for optimizing nutrient use in forestry production.

ERICSON, L. Department of Ecology and Environmental Science, Umeå University, SE-901 87 UMEÅ, Sweden.

Vegetation responses upon nitrogen: The effect of natural enemies.

Present knowledge of vegetation responses upon increased nitrogen rely upon correlative data and small-scale experiments focusing upon interspecific interactions between plants. Nitrogen also affects various natural enemies (e.g. parasitic fungi and insect herbivores) that may respond showing dramatic population changes subsequently affecting both community structure and species composition. Such changes are unlikely to be included in small-scale and short-term experiments. This implies that effects following increased nitrogen deposition are likely to be underestimated. I will give some examples from boreal nitrogen-limited forest ecosystems and point out: (1) the danger of excluding the effect of natural enemies; (2) the importance of running experiments at adequate scales; (3) the interaction between nitrogen and global warming.

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A case study of nitrogen saturation in Western U.S. forests.

Forests within the urban airsheds of Mexico City and greater Los Angeles, California represent case studies of urban air pollution induced N saturation. Nitrate concentrations in streamwater in chaparral and forested watersheds in the San Gabriel and San Bernardino Mountains in southern California reach levels in excess of 350 µmoles/L during peak runoff events. Annual fluxes of nitric oxide (NO) from soil are similar to levels reported from agricultural fields, further evidencing levels of excess N in soil. In situ soil incubations suggest that mineralized N is rapidly nitrified, resulting in high rates of NO and nitrate production. Data on gross N transformation rates will also be presented. Notwithstanding the high levels of nitrate in soil and soil solution, bole growth of ponderosa pine and California black oak trees responded positively to long-term N fertilization treatments. Study results will be summarized in order to present a conceptual model of forest responses to chronic N deposition under a Mediterranean climate. Key differences between this Western N Saturation Model and the model based on northern mesic forests will be discussed. These differences include: active nitrification at all stages of N saturation, high NO fluxes, temporal asynchrony between peak hydrologic fluxes of nitrate (winter) and the period of peak biotic N demand (spring), relatively large pools of base cations in soil, and relatively high soil pH.

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Nitrogen input, cycling and leaching in European forests: Differences between conifer and broadleaf stands.

Three data sets were analyzed for relationships between nitrogen (N) input, forest ecosystem characteristics and nitrate leaching (or nitrate concentration in soil water). The European data sources were (i) a literature compilation including 80 studies from the period 1985-95, (ii) the forest monitoring network (UN-ECE ICP Forest, Level II, 1996-98), and (iii) a regional survey at 111 Danish forests sites. Most sites were from central and northwestern Europe where N deposition in throughfall is 5-60 kg N/ha/yr. Nitrogen input (throughfall N) explains approx. 50% of the variation in nitrate leaching (or nitrate concentrations in soil water). For conifers output was also related to measures of ecosystem N status: N concentration in foliage, litterfall N flux and forest floor C/N ratio. Especially C/N ratio of the forest floor was strongly related to nitrate leaching. In broadleaf N input and pH of the top mineral soil were the parameters, which best explained nitrate leaching. Further N output in broadleaf stands seems to respond more to changes in N input than conifer stands. Based on the analysis of these European scale data and recent experimental projects the presentation will review the current understanding of the forest N cycle in conifer vs. broadleaf stands.

HERRMANN, M., W.E. SHARPE, and **D.R. DEWALLE**. The Pennsylvania State University, University Park, PA 16802 USA.

Nitrogen export from a watershed subjected to partial salvage.

Logging has been shown to induce nitrogen (N) leaching. We hypothesized that logging a watershed that previously exhibited forest decline symptoms would place additional stress on the ecosystem and result in greater N loss than from harvesting vigorous forests. To test this hypothesis we conducted a 10-year (1988-1998) assessment of N export from Baldwin Creek watershed in southwestern Pennsylvania that was partially clearcut to salvage dead and dying northern hardwoods. N export from the watershed increased significantly following salvage logging operations and did not completely return to pre-logging levels by the end of the study period. The largest annual nitrate-nitrogen (NO_3-N) export, 13 kg/ha, was observed during the first year after harvesting, an increase of approximately 10 kg/ha. Compared to data from other watersheds in North Carolina, West Virginia, and Pennsylvania, calculated N loss from Baldwin Creek was considerably greater. Longer periods of reduced N uptake due to slow revegetation of salvage logged areas coupled with increased amounts of N available to leaching could have accounted for the large N losses observed for Baldwin Creek watershed. Thus, salvaging of dead and dying trees from forested watersheds in this region has the potential to result in much larger N losses than previously reported for harvesting activities involving more vigorously growing trees.

KORORI, S.A.A., M. MOHAGHEGH, A. SALAHI, and M. KHOSHNEVISS. Research Institute of Forests & Rangelands (RIFR), Alborz Research Center, Karaj, IRAN.

The role of tree as a bio indicator for environmental contaminants.

Following the Iraq-Kuwait war, southern and southwestern Iran, especially the mangrove ecosystem, was damaged severely. In order to study these damages, laboratory works have been carried out in addition to field study. In this study we used 30cm long branches from 5 stands of mangroves of similiar size growing under natural conditions. In the laboratory, treatments included a food treatment respectively on food treatment without pollutants, food treatment with HNO_3, food treatment with H_2SO_4, food treatment with salt containing lead (Pb), food treatment with crude oil and food treatment with mixtures of contaminants. With quantitative and qualitative enzyme studies, changes in peroxidase enzyme in the period of 4, 24, 48 hours were studied and checked with control. peroxidase enzyme was introduced as a most important indicator for environmental stresses. Results showed that, increase in Peroxidase enzyme originates from effects of different contaminants. All kinds of contaminants caused increase in Peroxidase. Maximum activity of peroxidase enzyme was observed in mixed treatment and treatment containing HNO_3. Iso-enzyme patterns related to branches and leaves changed due to contaminants effect. This damage in leave samples was more than branches. Qualitative studies of enzymes using Gel-Electrophoreze (PAGE) were made along with quantitative studies of enzyme carried out using a spectrophotometer.

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Studies on the content of nitrogen and free amino acids in needles of Scots pine growing near the nitrogen fertilizer factory.

Near the nitrogen fertilizer factory, sites on podzols with 15-25-year-old *Pinus sylvestris* on a 0.5-17 km interval in the direction of prevailing wind were chosen. In the period 1995-2000 the concentration of NH_3 in the air was found to vary (1.8-45.2 $\mu g/m^3$) across the transect, and the most contrasting concentrations differed 7.2-25.1 times. The scale of variations for NO_2 was lower. Nitrogen content in current-year needles was higher than in one-year-old needles and ranged between 13000-20000 µg/g d.w. The needles taken from sites near the factory had higher nitrogen concentrations (109-129%). No significant differences in N content were found between the needles collected in 1995 and 2000. Content of proteins and amino acids determined in winter 2000 revealed similar to nitrogen concentration differences among sites. According to the amount of spearate free amino acid needles of sites near the factory differed only in content of blutamic acid (162-141% commpared to 100% in 17th km site), threonine (232%), serine (233%), lysine (234%) and arginine (771-276%). There were significant correlations between amino acid concentration in the needles and other needle and tree parameters as well as with pollutant concentrations in the air.

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Long-term nitrogen additions and nitrogen saturation in two temperate forests at the Harvard Forest, Massachusetts, USA.

In order to determine the long-term impact of N deposition to forest ecosystems, key indicators of nitrogen saturation, such as forest productivity, foliar chemistry, soil net mineralization rates and soil solution chemistry, have been measured on plots receiving NH_4-NO_3 additions at the rate of 0, 50 and 150 kg N/ha/yr since 1988. Plots were established in two forest stands, a red pine plantation and a mixed hardwood stand, located at the Harvard Forest LTER site. Increased soil water nitrate concentrations have been measured in the pine high N plot since 1989 and in the hardwood high N plot since 1995. In 1999, pine high N mean annual nitrate concentration was 20-fold greater than pine control; hardwood high N mean annual nitrate concentration was nearly 10-fold greater than control. Green foliage N content of the dominant species has increased dramatically with nitrogen treatments. Percent N in foliage from the high treatment plots has been measured at 80% and 25% greater than control foliage for red pine (pine stand) and black oak (hardwood stand), respectively. Above ground woody biomass accumulation has decreased with N additions in the pine stand, and foliar biomass is now declining as well in the highest N treatment plot in the pine stand.

MURDOCH, P.S., and D.A. BURNS. U.S. Geological Survey, Troy, NY 12180 USA.

Effect of clearcutting on nitrogen export from a watershed in the Catskill Mountains, New York.

The Catskill Mountains of New York receive high rates of nitrate deposition (10-12 kg/ha/yr), and many streams have measurable nitrate concentrations throughout the growing season. Approximately 16 hectares of a 22-hectare watershed in the Catskills was clearcut during the winter of 1996-97. Soil- and surface-water quality was monitored for 4 years prior to the cut, and monitoring has continued since. Nitrate concentrations in stream samples peaked at 1400 umoles/liter during the first summer following cutting. Patterns of stream nitrate concentrations in the 4 years following the cut are strongly similar to concentrations observed in the 4-year postcut period at Watershed 5 in the Hubbard Brook Experimental Forest. Nitrate concentrations in the Catskill clearcut appear to be rising to pre-cut levels during year 5 of the postcut period, while the 5th-year concentrations at Watershed 5 were at or near detection. Nitrification rates in Catskill watersheds are high relative to those reported from other areas of the Northeast (5-7 g N/m^2/yr), and showed little change as a result of the cut. The comparison of the two logging studies in watersheds receiving differing rates of N deposition suggests both short-term similarities and long-term differences in rates of nitrogen export following clearcutting.

PARDO, L.H.[1], S.G. MCNULTY[2], and J.L. BOGGS[2]. [1]USDA Forest Service, Burlington, VT 05402 USA; [2]USDA Forest Service, Raleigh, NC 27606 USA.

Effects of N deposition on high elevation forests in the Northeastern US: Foliar ^{15}N patterns.

Recent studies have demonstrated that natural abundance of ^{15}N can be a useful tool for assessing N saturation, because as nitrification and nitrate loss increase, ^{15}N of foliage and soil also increases. In this 1999 study, we measured foliar ^{15}N at seven high elevation sites along a N deposition gradient from Maine to New York. Foliar samples were collected from paired northern hardwood and spruce-fir stands. Foliar ^{15}N in the spruce-fir stands increased from –5.2 to –0.7‰ while foliar C:N decreased from 47 to 30 with increasing N deposition from Maine to NY. Foliar ^{15}N in the hardwood stands was on average 1‰ higher than the spruce-fir foliage, and ranged from –4.2 to –0.5‰ with increasing deposition. Foliar C:N decreased from 28 to 16 along the gradient. The spruce-fir foliar ^{15}N values at the upper end of the deposition gradient approach values observed at a site (Mt Ascutney, VT) where foliar ^{15}N went from –3.5 to +0.5‰ as the site reached N saturation. Additional measurements included soil C:N and base cations, net mineralization and nitrification potential, basal area, and seedling regeneration. This study allowed us to evaluate ecosystem response to different levels of N deposition.

SEMENOV, S. M. Institute of Global Climate and Ecology, 107258 Moscow, Russia.

An approach to balance positive and negative effects of elevated nitrogen oxides in the lower atmosphere on terrestrial plants.

Elevated NO_x in the lower atmosphere has the following major effects on terrestrial plants. On one hand, it causes an increase in surface ozone concentration. This reduces plant growth rate. On the other hand, elevated NO_x causes an increase in a flow of oxidized N-compounds from the atmosphere to the land surface. This plays a dual role in the life of plants. Additional N in soils stimulates plant growth (N-fertilization effect), whereas soil acidification may negatively affect it. We have developed a simple model for calculating the overall effect of an increase in NO_x level. This empirical model is based directly on experimental "cause-response" data presented in world scientific literature. Calculations showed that O_3 plays a large and negative role. Its negative effect on plants is partly compensated by N-fertilization in unmanaged ecosystems, especially, in boreal forests. Such compensation appears to be negligible in agricultural lands.

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Slow recovery of boreal forest ecosystem following decreased nitrogen input.

Ecosystem recovery after decreased input of nitrogen was examined in two different fertilization experiments where the fertilization have been terminated for 9 and 47 years, respectively. The species composition of the understory vegetation showed no sins of recovery 9 years after the fertilization was terminated. There were, however, no differences in amino acid concentrations in plant tissues between controls and formerly fertilized plots. An increased sporocarp production of mycorrhizal fungi was seen on formerly fertilized plots compared to plots still nitrogen fertilized, but the species composition showed large differences compared to control plots. In the second experiment, examined 47 years after termination of the fertilization, the bryophyte community, sporocarp production of mycorrhizal fungi, and the abundance of the leaf parasitic fungus *Valdensia heterodoxa* showed signs characteristic of increased nitrogen availability. No differences in either plant species composition or tissue concentrations of amino acids were noticed for vascular plants. Our result contrasts to other studies that have interpreted reduced nitrogen leakage and nutrient levels in trees after decreased nitrogen input as a rapid ecosystem recovery. This study suggests that the time needed for re-establishment of the ecosystem biota may be substantial in originally nitrogen-limited ecosystems.

VESTGARDEN, L.S.[1], **A.O. STUANES**[1], G. ABRAHAMSEN[1], and P. NILSEN[2]. [1]Agricultural University of Norway, N-1432 Ås, Norway; [2]Norwegian Forest Research Institute, Ås, Norway.

From N limitation to N saturation in a Scots pine forest.

The objectives of the present study were to show how different processes of the N cycle of a Scots pine forest in southern Norway respond on increased N input and to see how these processes could indicate N saturation and exceedance of the critical load for N (CLN). The CLN was estimated to 20 kg N/ha/yr. In the control plots (only receiving 10 kg N/ha/yr as atmospheric deposition) the N cycle was tight. Addition of 30 and 90 kg N for nine years (yearly dose of NH_4-NO_3) decreased the N retention to 83 and 63%, respectively. Where the pine stand has been exposed to a total input of 900 kg N/ha, the forest has changed from a N-limited to a N-saturated system. Even though the inputs of high doses of N over a ten-year span are not directly comparable to chronic additions of lower inputs, the changes observed indicated how the system will respond when the CLN is exceeded. Effects on N uptake, tree growth, litter decomposition, net N transformation, net N storage and leaching of N (inorganic and organic) in the N-limited (CLN not exceeded) and N-saturated (CLN exceeded) plots are discussed.

WEIS, W., and C. HUBER. Section for Forest Nutrition and Water Budget, TU Munich, D-85354 Fresing, Germany.

Regeneration of mature Norway spruce stands - The Impact of clear cutting and selective cutting on seepage water quality and soil fertility.

The cutting of trees as introductory measure when regenerating mature Norway spruce stands influences the elemental turnover in the forest ecosystem. The lack of plant uptake as well as an increased mineralization and nitrification due to higher soil temperature and soil moisture can lead to remarkable losses of nutrients from the main rooting zone. This may result in reduced soil fertility and a decrease in drinking water quality due to high nitrate concentrations in the seepage water. In Bavaria (Germany) selective cutting is preferred to clear cutting when initiating regeneration. The poster presentation summarizes the impact of both forest management practices on soil fertility and seepage water quality for three different sites. The changes in microcimatic conditions and nutrient input are shown. The development of the nitrate concentrations in 40 cm soil depth before tree cutting and for two vegetation periods after cutting is presented. The role of the ground vegetation as competitor and nutrient store is estimated. The project results shall help officials in forestry to evaluate different forest management practices not only due to economical aspects but also with regard to their ecological consequences.

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Impact of harvest of biofuels on nitrogen fluxes in forests in Sweden.

Sweden is planning to increase the use of biofuels to improve the sustainability of the energy system. Slash from clearcuts represents a substantial potential of renewable fuels for energy production (50-90 TWh/yr depending on different restrictions). The production potential of forests, including biofuels, is mainly limited by the supply of N, and the use of slash, as biofuels will increase the intensity in forestry. Large parts of Sweden have experienced an enhanced atmospheric deposition of N during several decades and the forest is an effective sink. Intensive harvest of slash including green parts has also been mentioned as a measure to counteract accumulation of N in areas with a high atmospheric load. In other areas with low or moderate deposition whole tree utilization can lead to impoverishment of N in soil and decreased productivity. Interactions between air pollutants and forest management are studied in the ASTA programme (International and National Abatement Strategies for Transboundary Air Pollution). Calculations of the fluxes of N in different parts of managed forests in Sweden with different scenarios of slash removal have been conducted. The calculations comprise N input from deposition and output from leakage and harvest of biomass in forests with different productivity. The results of the study can be used to assess the possibilities to control the fluxes of N in sustainable forestry, including harvest of biofuels.

Poster Session #4: ***Ammonia: Sources, Emissions and Transport.***

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An assessment of ammonia emissions from dairies in Pennsylvania.

A survey of 747 dairy farms in Pennsylvania was used to construct demographics for the average Holstein dairy farm: 69 lactating cows, 11 nonlactating pregnant cows, and 52 nonlactating (heifers) animals. Milk production averaged 27.4 kg (60.2 lb). Average crop acres was 71.6 h per farm. Milk production, crop type and average county yields, and herd animal groups were used to construct a typical feeding program. Rations were constructed for 6 feeding groups (3 milk production groups, 1 nonlactating group, 2 heifer groups) to meet milk production, pregnancy and growth requirements. Rations were constructed based on three forage qualities (excellent, average, and poor) typically observed on PA dairy farms. Data for animal description (milk production, body weight, growth, and pregnancy status) and ration components and amounts consumed for each animal group were input into the excretion model of the Dairy Nutrient Planner computer program (DNP). Excretion of fecal N, urinary N, total P and K, and fecal dry matter were for each animal group was output and used to assess potential volatile losses of N. Based on observations at the Marshak Dairy, New Bolton Center, ammonia losses were based on urinary N. The losses of N as ammonia were estimated to be 4.63, 4.62 and 4.28 metric tons per year for the farms with excellent, average, and poor quality forages. Volatile losses of N may be reduced by controlling levels of urea excreted in urine. This may be reduced through dietary manipulation of protein and carbohydrate sources. Post excretion conversion of urea to ammonia may be reduced by altering the pH of barn floors and gutters. Entrapment of ammonia may be accomplished by acidification of manure slurry.

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Atmospheric ammonia/um in a region with large-scale animal production facilities.

Fate and transport of ammonia (NH_3) emitted from lagoons, housing units, or land application of animal wastes is dictated in part by partitioning between NH_3 and ammonium aerosols (NH_4NO_3, NH_4HSO_4, NH_4Cl) in the atmosphere. Annular denuders were used to measure the atmospheric concentrations (height = 2.6 m) of NH_3 and ammonium aerosols in Sampson County, NC, USA where there is a high density of large-scale animal production facilities. From October 1998 to December 1999, the mean daytime

(12-hr) concentration of NH_3 was 5.6 (+/- 5.4) ug N/m^3. Highest NH_3 concentrations occurred in summer with readings often exceeding 20 ug N/m^3. Ammonia increased exponentially with atmospheric temperature, which explains 54% of the variation in 12-hr concentrations. Sulfate aerosols and SO_2 exhibited inverse seasonal cycles with highest SO_2 in the winter. Aerosols account for less than 25% of the inorganic N species in the atmosphere. Aerosol ammonium is associated primarily with sulfate, except during winter when nitrate becomes more prevalent. The high atmospheric concentrations of NH_3 at this location are consistent with the increase in ammonium concentrations in rainwater (and the fraction of ammonium-N in wet deposition) that have been recorded at a nearby National Atmospheric Deposition Program/National Trends Network site.

SHARPE, R.R.[1], L.A. HARPER[1], and F.M. BYERS[2]. [1]Southern Piedmont Conservation Research Unit, JPCSNRCC-USDA-Agricultural Research Service, Watkinsville, GA 30677 USA; [2]Beltsville Agricultural Research Center, USDA-Agricultural Research Service, Beltsville, MD.

Gaseous nitrogen emissions as part of a total system balance in swine production systems.

About 65% of atmospheric ammonia (NH_3) is from animals, their wastes, and synthetic fertilizers. Atmospheric NH_3 can result in excess N loading in natural ecosystems and combine with sulfur and nitrogen oxides to form particulates (PM2.5). Our objective was to determine NH_3 emission factors for swine production in the U.S. Coastal Plains. Micrometeorological techniques were used to measure NH_3 fluxes from two lagoons and a soybean field. Mass balance techniques were used to measure NH_3 fluxes from houses. Gas collectors were also tethered below the lagoon surface to capture mass-flux gases emitted from the sludge layer. Ammonia emissions from lagoons varied diurnally and seasonally and were related to lagoon NH_4^+ concentration, acidity, temperature, and wind turbulence. Conversion of significant quantities of NH_4 to N_2 gas was measured in all lagoons with the rate dependent upon NH_4^+ concentration. Ammonium conversion to N_2 (43%) and N retention in the animals (30%) were the largest components (compared to N fed) of N transport from the farm systems. Ammonia emissions from land application of waste effluent accounted for about 2% on N input to the farm; but a nearby soybean field could also absorb significant quantities of NH_3 emitted from the lagoon/houses complex. Small amounts of N_2O were emitted from the lagoon (0.1%) and from field applications (0.05%). In disagreement with previous and current estimates of NH_3 emissions from confined animal feeding operation (CAFO) systems, we found much smaller NH_3 emissions from animal housing (10%), lagoons (5%), and fields (2%) using independent measurements. With these independent measurements we were able to account for approximately 95% of the N entering the farm operation.

VAN PUL, A., **J. VAN DAM**, P. HEUBERGER, and J. ABEN. Air Research Laboratory, RIVM, 3720 BA Bilthoven, The Netherlands.

The effect of reallocating ammonia emissions on reducing nitrogen loads to nature areas in the Netherlands.

Atmospheric deposition of nitrogen is one of the most important threats to nature areas in the Netherlands. At a large scale the critical loads for nitrogen are exceeded to a great extend. Ammonia emissions from agricultural activities contribute over 50% to the nitrogen deposition in the Netherlands. For nature areas, this contribution can be even higher because agricultural and nature areas are often situated close to each other. This offers special opportunities for (sub) national policy makers to reduce the large nitrogen loads at a local scale by reallocating ammonia emissions. Also, the effect of these local measures can be compared to generic measures for reducing agricultural ammonia emissions for the Netherlands as a whole. In this study we will present a method with which ammonia emissions are reallocated in such a way that nature areas are optimally protected given a national emission ceiling. This is carried out by minimizing the exceedences of the critical loads for nitrogen for the nature areas and taken into account the atmospheric deposition of nitrogen from other sources and countries. The optimization is carried out at a spatial scale of 1x1 km^2. Results of the calculations for 2010 will be presented assuming emission ceilings according to the UN-ECE Göteborg protocol. Results for 2030 will be presented where it is assumed that much stronger emission reductions have taken place.

Poster Session #5: ***Atmosphere-Biosphere Interactions: N_2O and NO Emissions.***

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Production of nitrous oxide in NC waterbodies.

This poster would present preliminary results of emissions of nitrous oxide off the Neuse river basin. Measurements of nitrous oxide emissions are being taken at 12 sites from April 2001 to April 2002. Most activity is expected during the summer months, the period of highest denitrification. This poster would present 6 months of sampling with possible explanations of trends.

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Impact of different forms of N fertilizer on N_2O emissions from intensive grassland.

Nitrous oxide emissions from soils arise from the microbial processes of nitrification and denitrification. If nitrification of ammonium N to nitrate is inhibited, this potentially reduces N_2O formation during nitrification and production of N_2O via subsequent denitrification of the nitrate formed. We compared N_2O emissions from a ryegrass ley fertilized on three occasions variously with ammonium nitrate, urea with and without a nitrification inhibitor, urea plus a urease inhibitor with and without nitrification inhibitor, and a controlled-release urea fertilizer. Emissions from the ordinary urea treatment (5.3±2.7 kg N_2O-N/ha) were significantly lower than those from ammonium nitrate over the season (14.2±3.9 kg). The reduction occurred in the periods following the first two N applications, in spring and early summer respectively. Emissions from the urea plus nitrification inhibitor showed a further significant reduction (1.4±0.6 kg), and those from the controlled release material were lower still. However, the materials with the urease inhibitor gave emissions not significantly different from the unmodified urea. The results indicate that substantial reductions in N_2O emissions from intensively managed grassland are possible by avoiding the use of N fertilizer containing nitrate, and by using an effective nitrification inhibitor with urea/ammonium N.

ROMANOVSKAYA, A.A.[1], M.L. GYTARSKY[1], R.T. KARABAN[1], D.E. KONYUSHKOV[2], and I.M. NAZAROV[1]. [1]Institute of Global Climate & Ecology, 20-B, Glebovskaya Str., Moscow, 107258, Russia; [2]Dokuchaev Soil Science Institute, 7, Pyzhevskii per., Moscow, 109017, Russia.

The dynamics of nitrous oxide emission from the use of mineral fertilizers in Russia.

The intensity of nitrous oxide (N_2O) emission was considered based on literature data on the single input of mineral nitric fertilizers into different types of soils used in agriculture of Russia. Ambient environmental factors exert a combined effect on the process of gaseous nitrogen formation from fertilizers applied. To reduce the uncertainty of estimates as much as possible, only experimental results obtained under conditions similar to natural were selected for the assessments. If 40 to 75 kg/ha of mineral nitric fertilizers were applied to soil, the N_2O emission was identified approximately for 140 days, and its daily average value varied from 0.08 to 0.45% of fertilizer nitrogen. Correspondingly 1.26 and 2.38% of fertilizer nitrogen were emitted as N_2O from chernozems and soddy podzols. In 1990, the use of fertilizers in agriculture of Russia caused anthropogenic emission of 53 Gg N- N_2O. That was almost 6.1% of global nitrous oxide emission. Later on, the emission dropped because of decrease in the input of nitric fertilizers to agricultural crops, and in 1998, it constituted just 20.5% of the 1990 level. In 2008- 2012, the nitrous oxide emission is expected to vary from 0.5 to 65.0 Gg N_2O -N with regard to possible alternatives in national agriculture development. The most reliable scenario of N_2O emission from the use of mineral fertilizers in Russia may contribute to 34 and 40 Gg N- N_2O in 2008 and 2012 respectively.

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Denitrification in streams, rivers, and reservoirs of Illinois: Its role in the nitrogen mass balance.

Mass balances for N in the midwestern US and other intensively agricultural landscapes are generally not balanced, with inputs substantially exceeding outputs. A current N mass balance for Illinois suggests large losses of N through denitrification, either in-field or in-stream. We evaluated denitrification in streams, rivers, and reservoirs in Illinois using direct measurements, input/output budgets, and historic data to estimate the contribution of denitrification to the overall N balance of the state. Despite dissolved concentrations of >10 mg N/L, direct measurements of denitrification in streams suggested denitrification was not a major sink for nitrate in the surface waters of Illinois. We believe denitrification in stream sediments was often limited by the availability of anoxic microsites and the diffusion of nitrate into the sediments during certain seasons. Furthermore, much of the annual export of N occurs during floods when contact between water-column nitrate and the streambed is minimal. Conversely, input/output budgets indicated that a large amount of N was denitrified in reservoirs, particularly in central Illinois where riverine inputs to reservoirs were large. Our estimates provide an important step in resolving the “missing” N for the mass balance of an agricultural state.

SKIBA, U., C.E.R. PITCAIRN, and **D. FOWLER**. Centre for Ecology and Hydrology (CEH), Bush Estate, Penicuik, Midlothian EH26 0QB, UK.

Emissions of nitrous oxide and nitric oxide from moorland and grassland soils along gradients of atmospheric N deposition.

In the UK and many other north European countries total annual atmospheric N deposition rates range from < 10 to > 30 kg N/ha/y. Large deposition rates are measured in close vicinity to cities, in rural areas in close proximity of intensive livestock farms and in upland areas, receiving high rates of cloud droplet deposition. Export of atmospheric N to non- agricultural ecosystems can present an important source of N and has been shown to lead to increased N cycling in the soil and increased emissions of the atmospheric pollutants nitrous oxide (N_2O) and nitric oxide (NO). In order to quantify this effect, we collected soils along gradients of atmospheric N deposition in several regions of the UK. Information on N deposition gradients were obtained from published maps. In the laboratory rates of soil NO and N_2O emissions were measured and soils were analyzed for available NH_4 and NO_3 concentrations. Invariably linear relationships were established between N deposition rates, soil available N and gaseous emissions of NO and N_2O.

VAN BOCHOVE, E.[1], R.J. STEVENS[2], G. THÉRIAULT[1], and R.J. LAUGHLIN[2]. [1]Agriculture and Agri-Food Canada, Sainte-Foy, Quebec, G1V 2J3, Canada; [2]Department of Agriculture and Rural Development, Belfast, UK.

Transformation and transport of ^{15}N labeled fertilizer in soil gaseous, solid, and liquid phases.

We have often measured peak concentrations of N_2O at 35 cm below the soil surface although the denitrification potential tends to decrease with depth. A majority of studies examining N_2O distribution with depth have shown a similar pattern and some indicated large losses of soluble N_2O to the groundwater. The flux of N_2O from the soil profile to the atmosphere and the groundwater is a function of the rate of production within the soil (N, C, O_2 availability), the changes in solubility (redox potential, WC,Temp.) and the rate of transport from the site of production to the surface (gas diffusivity). The ratio of end products of denitrification, N_2/ N_2O, increases when reductants are abundant relative to oxidants and N_2 may be 100% of the end product in extreme environmental conditions. The N_2/ N_2O ratio varies with depth as a function of the environmental parameters controlling both the production and the solubility of N_2O and N_2. Our objective was to understand and quantify the mechanisms of solubility and diffusivity of gaseous N products from denitrification in the soil profile to evaluate the impact of agriculture on environmental pollution and to optimize the availability of N for agricultural production.

WHALEN, S.C., R.L. PHILLIPS, and E.N. FISCHER. University of North Carolina, Chapel Hill, NC 27599-7400, USA.

Nitrous oxide emission from a spray field fertilized with liquid lagoonal swine effluent in the southeastern United States.

Increasingly, livestock is produced in confined facilities and stored waste is land-applied. Emission of N_2O from receiving soils is a poorly constrained term in the atmospheric N_2O budget. Few data exist for N_2O emissions from spray fields on industrial scale swine production facilities that proliferate throughout the Southeastern U.S. In a 24 d investigation over three spray cycles, we followed the time-course for changes in N_2O emission and soil physicochemical variables for a North Carolina agricultural field irrigated with liquid swine effluent. The total-N (535 mg/L) of the waste was almost entirely NH_4^+ (>90%) and thus had a low mineralization potential. Application of liquid fertilizer in a form that is both rapidly volatilized and immediately utilizable by the endogenous N-cycling microbial community resulted in a sharp decline in soil NH_4^+ and supported a transient (days) burst of N_2O emission. Nitrous oxide fluxes as high as 9200 mg N_2O-N/g dry soil/h were observed shortly after fertilization. The fractional loss of applied N to N_2O was 1.4%, agreeing with the mean of 1.25% for synthetic fertilizers. The direct effects of fertilization are more immediate and short-lived for liquid swine waste than for manures and slurries that show slower nutrient release.

Poster Session #6: *Atmospheric Deposition of Nitrogen.*

CAMPOS, E.C., N. GARCIA, M. COLINA, G. COLINA, **N. FERNANDEZ**, E. CHACIN, L. SANDOVA and J. MARIN. Laboratorio de Ingeniería, Sanitaria y Ambiental, Facultad de Ingeniería, La Universidad del Zulia, Maracaibo 4011, Zulia, Venezuela.

Evaluation of the nitrogen forms as macronutrients in atmospheric settleable particles in Maracaibo Lake Strait.

The aim of this study is to determine the nutrients levels in dustfall over Maracaibo Lake strait. Results on ambient particle fallout measurement, as well as the contribution of $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2$, $S\text{-}SO_4^{-2}$, and $P\text{–}PO_4^{-3}$ (macronutrients), are given for three different monitoring sites, located in the northern and in the southern area of the channel. Samples were collected and analyzed using Standard Methods procedures together with instrumental analysis by high-resolution liquid chromatography. The results showed that settleable particles exhibit the higher deposition at “Los Higuitos” (site 1) with $N\text{-}NO_2^- > N\text{-}NH_4^+ > N\text{-}NO_3^- > S - SO_4^{-2} > P - PO_4^{-3}$; “Isla de Pájaros” (site 2)) $N\text{-}NO_2^- > N\text{-}NH_4^+ > N\text{-}NO_3^- > S - SO_4^{-2} > P - PO_4^{-3}$; “San Francisco” (site 3) $S - SO_4^{-2} > N\text{-}NH_4^+ > N\text{-}NO_2^- > N\text{-}NO_3^- > P - PO_4^{-3}$. Results on atmospheric fallout particles mensurent as well as nutrients levels were higher than those reported in previous studies. The possible sources for the observed atmospheric levels together with the incidence of local conditions are discussed.

CUESTA-SANTOS, O., A. COLLAZO, A. WALLO, R. LABRADOR, M. GONZALEZ, and P. ORITZ. Atmospheric Environment Research Centre, Meteorological Institute of Cuba, 11700 Havana, Cuba.

Atmospheric nitrogen compounds deposition in the humid tropics – Cuba.

N mobilized by human and natural activities have caused atmospheric and ecosystem acidification. Acid deposition, as well as direct effect of gaseous air pollutants is causing widespread damage to terrestrial and aquatic ecosystems. Also, the pollutants are responsible for corrosion of building materials and pieces of art and also have an impact on human health. Emissions of ammonia are also a cause of concern regarding the acidification of soils and waters. Actually NH_3 emissions are the same magnitude as NO_x and SO_2 emissions and potentially even more acidifying. In Cuba, main atmospheric nitrogen deposition compounds vary approximately from 12.0 to 65.0 kgN/ha/year in rural places. The oxidized nitrogen forms being provided more 20% and wet deposition depends on our tropical rain climate features. The NH_3 and ammonium are the most important elements in our tropical conditions. Some N compounds have a trend of increasing concentrations.

INDRIKSONE, I., **I. LYULKO**, and M. FROLOVA. Environmental Quality Observation Department, Latvian Hydrometeorological Agency 165, Maskavas str., Riga, LV-1019, Latvia.

Nitrogen deposition in Latvia.

A wide network of long-running environmental stations covers the territory of Latvia. The network consists of regional GAW/EMEP (Global Atmosphere Watch and Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutan in Europe) stations, ICP-IM (International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems) stations and national stations that are performing deposition and snow cover measurements. Deposition can be divided into dry deposition and wet deposition. Dry and wet nitrogen depositions are measured at the regional GAW/EMEP stations in Rucava and Zoseni. Wet deposition is measured at the ICP-IM background stations in Rucava and Zoseni in open forested area, and at the national stations in 10 towns of Latvia in regions with different anthropogenic impact. An analysis of nitrogen deposition measurement results for 1994-2000 shows that total nitrogen deposition at a background level has decreased by 62% in Rucava and by 39% in Zoseni. In regions under minor anthropogenic impact, wet nitrogen deposition was 2 to 3 times as low as in the regions under anthropogenic impact. The measurement results have been employed in carrying out the ICP-IM, EMEP and ICP-Waters (International Cooperative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes) programmes.

LOSLEBEN, M., **M. W. WILLIAMS**, and C. SEIBOLD. University of Colorado, Boulder, CO 80309 USA.

Four NADP stations along an elevational transect in the Colorado front range: Atmospheric sources of N deposition.

NADP results have shown that atmospheric deposition of N in wetfall to the Colorado Front Range is now at a critical threshold where irreversible ecosystem damage may occur. Nitrogen deposition to the Front Range is influenced by easterly and westerly weather patterns that can bring air from either the Denver metropolitan area to the east or well mixed tropospheric air to the west. Thus there is potential for a steep depositional gradient, and very different depositional regimes along the Front Range. To help determine source-receptor relationships, we have supplemented two existing NADP sites (Sugarloaf, 2530 m; Niwot Ridge, 3,529 m) with two additional sites at C1 (3032 m) and Soddie (3,400 m). These four sites along North Boulder Creek span an elevation range of 1 kilometer and permit better resolution of storm tracks and N source areas. For this presentation, circulation conditions will be characterized by indices of vorticity, flow force, and vector component of flow direction, at multiple elevations, as well as by synoptic weather type.

MANTHORNE, D., and **M. W. WILLIAMS.** University of Colorado, Boulder, CO 80309 USA.

Class I areas at risk: Event-based nitrogen deposition to a high-elevation, western site.

Here we report on atmospheric deposition of inorganic nitrogen from the only AIRMoN type-site operated west of the Mississippi River. Our site was not part of the official AIRMoN program but was operated and maintained according to AIRMoN protocols, except for sample analysis. Thirty-two precipitation events were sampled between 1 June and 30 September, 2000, near Telluride Colorado at an elevation of 3,200 m. Inorganic nitrogen deposition at the AIRMoN site of 1.41 kg/ha during the study period was 25% to 50% higher than nearby NADP sites. In turn, nitrogen deposition at these NADP sites was similar to high-elevation sites in and near the Colorado Front Range that have been shown to be impacted by atmospheric deposition of inorganic nitrogen in wetfall. Power plant emissions are the likely source of this elevated inorganic nitrogen in wetfall to the San Juan Mountains. PCA analysis shows that solutes that are emitted from power plants were clustered tightly together, including nitrate, ammonium, sulfate, and chloride. Trajectory analysis, including both backward trajectories and forward trajectories, shows that the airmasses that contributed to the precipitation events with high amounts of nitrogen deposition at the AIRMoN site passed directly over or near power plants. Our results suggest that Class I Wilderness Areas in and near the San Juan Mountains are at risk to ecosystem impairment at present rates of atmospheric deposition of inorganic nitrogen in wetfall.

MORRIS, K. H.[1], and K. A. TONNESSEN[2]. [1]U.S. Fish and Wildlife Service, Denver, CO 80225 USA; [2]National Park Service, Cooperative Ecosystem Studies Unit, Missoula, MT 59812 USA.

Nitrogen deposition in primenet park units: A comparative analysis.

Wet deposition is being monitored in fourteen National Parks (NPs) as part of the NPS/EPA PRIMENet (Park Research and Intensive Monitoring of Ecosystems Network), including Acadia, Shenandoah, Great Smoky Mountains, Everglades, Virgin Islands, Big Bend, Theodore Roosevelt, Canyonlands, Glacier, Rocky Mountain, Olympic, Denali, Sequoia-Kings Canyon, and Hawaii Volcanoes NPs. PRIMENet park sites are part of the National Atmospheric Deposition Program, monitoring weekly concentrations and deposition of inorganic nitrogen species, nitrate and ammonium. A comparison of the 1999 NADP data for these fourteen sites shows a gradient of concentration of inorganic nitrogen (N) from highs in the eastern parks, to lows in Olympic, Virgin Islands and Denali NPs. When we compare N deposition in kg/ha/yr the patterns are somewhat different due to precipitation amount and seasonality. In these "Class 1" parks the ecosystem indicators that are most likely to be affected by nitrogen inputs are stream water quality in the upend parks in the East and high-elevation lakes in the West. Soils and surface waters in western mountain parks are also at risk to pulses of N released from melting seasonal snowpacks. A case study comparing an eastern park (Shenandoah) with a western park (Sequoia-Kings) shows the temporal variability of inorganic N concentrations at these two different locations, influenced by different sources of emissions.

ROBARGE, W.P.[1], S. JATINDERPAUL[2], and R.B. MCCULLOCH[3]. [1]North Carolina State University, Raleigh, NC 27695 USA; [2]Chauhan, North Carolina Department of Environment and Natural Resources, Raleigh, NC 27626 USA; [3]URS-Radian International.

An evaluation of alternative absorbent coatings and filter media for gas and aerosol sampling using annular denuder systems.

Over the past few years, ambient atmospheric measurements via annular denuder systems have increased in popularity in areas such as eastern North Carolina, where both crop and animal agriculture play prominent roles in the regional economy. Annular denude systems offer the advantage of simultaneously providing data on several trace gases (ammonia and acid gases) and aerosol species. However, recent developments reported in the literature indicate that acidic coatings that have been traditionally used in enuders for ammonia measurements may suffer from certain deficiencies. Furthermore, the customary serial arrangement of multiple membrane filters to capture the aerosol fraction of samples adds to the complexity and expense of long-term measurement programs that deploy multiple samplers. This study details certain options in terms of both coating matrices and filter media. Data collected using different acidic coatings illustrate reported differences in collection efficiency and stability. Ammonia data collected using these different coatings are further compared to a collocated chemiluminescent analyzer to illustrate relative differences in accuracy associated with different coatings. Data from filter media comparisons illustrate options that offer more operational and analytical simplicity, and lower cost while maintaining the integrity of collected aerosol samples and measurement accuracy.

SALAHI, A., S. GERANFAR, and S.A.A. KORORI. Research Institute of Forests and Rangelands (RIFR), Alborz Research Center, Karaj, IRAN.

Nitrogen compounds deposition on urban ecosystems.

This investigation was carried out to determine air pollution and acid rain impacts in Tehran metropolitan area during the period 1992- 2000. Nitrate ion (NO_3^-) amount as wet deposition in a number of sampling stations of Tehran was over 30kg/ha/yr, and 13 kg/ha/yr for Chitgar Parkland,15 kilometer west of Tehran metropolitan area. Amount of NO_3^- in warm seasons was more than 2 fold compared with cold seasons. Seasonal sampling of NO_3^- showed that, there was significant difference ($p= 0.01$) between cold and warm seasons. In cold period production of NO_3^- is not parallel with increased consumption of fossil fuels. It means that conditions for photochemical reaction does not occur during winter and cold season. Ammonia (NH_3) is formed as a result of the decomposition of most nitrogenous organic materials, used as fertilizer and as a chemical intermediate. Annual wet deposition of NH_3 was 9 kg/ha/yr. Acidity (PH) of precipitation is neutralized by Suspended Particulate Matter (S.P.M), however many samples of precipitation showed acid rain(pH= 4) in Tehran. The regression equation for independent variable of NO_3^- and dependent variable of acidity(pH) was computed as [$Y= 6.048 + 0.071X$]. Coefficient of determination was 0.34 ($r= 0.34$)

SINGH, R. K., and M. AGRAWAL. Banaras Hindu University, Varanasi-221005, India;

Characterization of wet and dry deposition in the down wind of industrial sources in a dry tropical area.

An atmospheric deposition study was conducted in the downwind of Shaktinagar Thermal Power Plant (STPP), Renusagar Thermal Power Plant (RTPP), and Anpara Thermal Power Plant (ATPP), at Singrauli region, U.P., in India to characterize the dry and wet deposition in relation to different pollution loading. During the study period dry and wet depositions and levels of gaseous pollutants (SO_2 and NO) have been estimated across the sites. Dry deposition was collected on a fortnight basis and wet deposition on event basis. Depositions were analyzed for pH, conductivity, nitrate, ammonium, and sulphate. Dry deposition rate both collected as clearfall and throughfall varied between 0.36 - 2.65 and 0.50 - 2.91 g/m^2/day, respectively at control and maximally polluted sites. The pH of dry deposition varied from 5.9 to 7.2 during winter and 6.7 to 7.4 during summer across the sites. In rainy season, the mean pH of clear wet deposition varied from 6.8 to 7.2 and throughfall varied from 6.8 to 7.8. The concentrations of NO_2 and SO_2 pollutants were maximum in winter season. Mean SO_2 concentrations varied from 17 to 70 $\mu g/m^3$ at control and differently polluted sites during winter season. The variation in NO_2 concentrations did not show a pattern similar to that of SO_2. Maximum NO_2 concentration in winter season was 42 $\mu g/m^3$ observed near RTPP, whereas in summer maximum was observed near STPP. NO_2 concentration did not show much variation among different sites, suggesting that the sources of NO_2 emission are evenly distributed along the sites. The concentrations of NH_4^+, NO_3^- and SO_4^{2-} ions in dry deposition were found higher in summer as compared to winter season. In dry deposition (clear fall) the concentrations of NH_4^+, NO_3^- and SO_4^{2-} varied from 0.13-1.0, 0.81-2.15 and 0.67-3.76 mg/l respectively. In wet deposition (clear fall) the above varied from 0.14-0.74, 0.81-1.82 and 0.67-2.90 mg/l respectively. The study clearly showed that the dry deposition was maximum near the power plants. Both dry and wet depositions varied between the sites and season, which suggests significant impact of industrial activities in modifying the atmospheric input.

STENSLAND, G.J., and J. MONTGOMERY. Illinois State Water Survey, Champaign,IL 61820 USA. Presented by **Van C. Bowersox,** Illinois State Water Survey.

Month-to-month variation in concentration in precipitation of nitrate and ammonium at sites in the USA.

This paper summarizes the monthly concentration of ammonium and nitrate in precipitation for sites across the 48 contiguous states of the USA. The data are from the National Trends Network (NTN) of the National Atmospheric Deposition Program (NADP).

About 200 sites are analyzed, with some of the site data records exceeding 20 years. The fine temporal and spatial coverage by NTN allows for a more comprehensive examination of seasonal concentration patterns than has been possible in the past. Because of the long temporal record the data are grouped and analyzed by month instead of some longer averaging period. Maps of the month at each site of the highest median concentration show considerable variation across the 48 states and between different ion group. For example ammonium concentrations are highest for eastern sites during months 4,5, and 6; for central plains sites during months 2,3 and 4; for southwestern sites during month 6; and for northwestern sites during month 8. Ammonium concentrations will be examined in detail and discussed in relation to the expected variation in potential ammonia emission sources: livestock, fertilizer losses and emission from crops.

ZAPLETAL, M. Centre for Environment and Land Assessment - Ekotoxa, Opava, Czech Republic.

Atmospheric deposition of nitrogen and sulphur compounds in the Czech Republic.

In this paper estimates of dry and wet deposition of nitrogen and sulphur compounds in the Czech Republic for the years 1994 and 1998 are presented. Deposition has been estimated from monitored and modeled concentrations in the atmosphere and in precipitation, where the most important acidifying compounds are sulphur dioxide, nitrogen oxides and ammonia, and their reaction products. Measured atmospheric concentrations of SO_2, NO_x, NH_3 and aerosol particles (SO_4^{2-}, NO_3^- and NH_4^+), along with measured concentrations of SO_4^{2}-, NO_3^- and NH_4^+ in precipitations, weighted by precipitation amounts, were interpolated with a properly used Kriging technique on a 10 x 10 km grid covering the whole Czech Republic. Wet deposition was derived from concentration values for SO_4^{2}-, NO_3^- and NH_4^+ in precipitations and from precipitation amounts. Dry deposition was derived from concentrations of gaseous components and aerosol in the air, and from their deposition velocities. It was estimated that the annual average deposition of SO_x in the Czech Republic decreased from 1384 to 1027 mol H+ /ha/a between 1994 and 1998. The annual average NO_y deposition was estimated to be 972 and 919 mol H^+/ha/a in 1994 and 1998 respectively. The annual average NH_x deposition was estimated to be 887 mol H^+/ha/a and 779 mol H^+/ha/a in 1994 and 1998 respectively. Sulphur compounds (SO_x) contributed about 36%, oxidized nitrogen species (NO_y) 37%, and reduced nitrogen species (NH_x) 27% to the total deposition in the Czech Republic in 1998. The wet deposition contributes 42% to the total deposition in the Czech Republic in 1998.

Tuesday, October 16 – Nitrogen Around the World and its Effects

Poster Session #7: ***Agricultural Nitrogen Losses to Ground and Surface Waters.***

DAUGHTRY, C. S. T., T. J. GISH, W. P. DULANEY, and C. L. WAL. USDA-ARS Hydrology and Remote Sensing Lab., Beltsville, MD 20705 USA.

Understanding nitrate surface and subsurface flow pathways on a watershed scale.

Understanding the interaction and impact of surface runoff and subsurface flow on nutrient export from agricultural ecosystems has been hindered by our inability to characterize subsurface soil structures at a watershed scale. Extensive ground-penetrating radar (GPR) data of four small watersheds with similar soil textures, organic matter, and yield distributions at the Beltsville Agricultural Research Center, Beltsville, Maryland were evaluated for subsurface structure. The subsurface hydrology was characterized by combining subsurface structure and surface topography in a geographic information system (GIS). Discrete subsurface flow pathways were confirmed with aerial color infrared imagery, real-time soil moisture monitoring, and yield maps. Significantly greater nitrate flux from one of the watersheds was best explained with a knowledge of the GPR-GIS identified subsurface flow pathways. These discrete subsurface flow patterns were also useful in understanding observed nitrate levels entering an adjacent riparian wetland and first order stream. This study demonstrates how strongly subsurface stratigraphy can impact nitrate flux exiting agricultural lands and raises questions on how to effectively approach nitrate flux characterization.

FOX, R.H.[1], Y. ZHU[1], J.D. TOTH[2], and J.M. JEMISON[3]. [1]Penn State University, University Park, PA 16802 USA; [2]University of Pennsylvania, Kennett Square, PA 19348 USA; [3]University of Maine, Orono, ME 04469 USA.

Nitrogen fertilizer rate and crop management effects on nitrate leaching from an agricultural field in Central Pennsylvania.

Eighteen pan lysimeters were installed at a depth of 1.2 m in a Hagerstown silt loam soil in a corn field in central Pennsylvania in 1988. In 1995, wick lysimeters were also installed at 1.2 m depth from the same access pits. Treatments have included N fertilizer rates, use of manure, crop rotation (continuous corn, corn-soybean, alfalfa-corn), and tillage (chisel plow-disk, no-till). The leachate data were used to evaluate a number of nitrate leaching models. Some of the highlights of the 11 yr of results are: 1) Growing corn at the economic optimum N rate (EON) results in NO_3^-N concentrations of 15-20 mg/L in leachate. 2) Use of manure or previous alfalfa crop as partial source of N also results in 15-20 mg/L of NO3-N in leachate below corn at EON. 3) NO3-N concentration in leachate below alfalfa is approximately 4 mg/L. 4) NO3-N concentration in leachate below soybeans following corn is influenced by fertilizer N rate applied to corn. 5) The mass of NO3-N leached below corn at the EON rate averaged 93 kg N/ha (approx. 40% of fertilizer N applied at EON). 6) Wick lysimeters collected approximately 100% of leachate vs. 40-50% with pan lysimeters. CV's for both types were similar. 7) Tillage did not markedly affect nitrate leaching losses. 8) Nitrate leaching models required a large number of detailed parameters as inputs. They could be calibrated to match observed leachate volumes and nitrate losses, but did poorly with validation data. Apparent problems were with estimating sizes of organic N pools and their transformation rates, and the models not handling macropore flow well. 9) It can be speculated that the average NO3-N concentration in leachate leaving a well-managed corn-alfalfa dairy farm is less than 10 mg/L.

LIN, H., R. COOK, and B. SHAW. College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI 54481 USA.
Nitrate relationships between private well water, stream base flow water, and land use in the Tomorrow-Waupaca Watershed.
This study examines the potential of using stream base flow water quality as a representative measure of mean ground water quality in the Tomorrow-Waupaca Watershed located in Central Wisconsin and the relationship between land use and watershed water quality. From 1997 to 1999 thirty-eight stream sites were sampled during summer and winter base flow conditions. Some sites have been sampled during winter base flow conditions since 1994. The land area contributing ground water to each stream sampling sit was delineated, resulting in thirty-eight sub-basins. In addition, over 3,500 test results from private wells in the watershed have been compiled and mapped using a Geographic Information System (GIS). The nitrate-N relationship between well water and stream base flow water was found to have a strong positive correlation when the sub-basins were second order or higher, indicating that stream base flow may be valid for monitoring ground water quality in the watershed for sub-basins greater than first order. Analysis of seasonal variation in the stream data showed that winter nitrate-N concentrations were higher than summer concentrations, implying that winter stream monitoring may be more critical for the assessment of ground water quality in the watershed. This study also found that as the amount of agricultural land increased in each sub-basin, average nitrate-N concentration in the sub-basin's well water also increased, suggesting a connection between agricultural land use and ground water nitrate contamination in the watershed.

MORAN, L.P., and T.E. FENTON. Soil Survey, Department of Agronomy, Iowa State University, Ames, IA 50011 USA.
Ecology and landscape variability of carbon and nitrogen in restored wetland complexes in Iowa.
Wetlands are regarded as valuable sinks of global C and N. Wetlands are important in water and soil quality maintenance because they trap sediments and sorb contaminants, such as NO_3^-. This study documents the landscape and ecology variability of total, total N, and NO_3^-N in restored wetland complexes on the Des Moines Lobe, Iowa. The Des Moines Lobe is a physiographic region of till deposits hosting numerous soils, dominantly Mollisols, differing in parent material, topographic position, and drainage Recharge in topographic highs, throughflow in midslopes, and discharge in topographic lows characterizes the hydrology of the landscapes. Soils from 0-15, 15-30, 30-45 cm were sampled along landscapes of three wetland complexes under distinct restoratin periods (1yr, 5yrs, 15yrs, and natural). Vegetative zones and landscape positions were integrated into 4 distinct classes: upland prairie (summit to backslopes), wet prairie (backslopes), cattail/sedge wetlands (footslopes), and pond depression wetland (toeslopes). In each wetland complex, total soil C, total soil N and soil NO_3^-N increased from the upland prairie to the pond depression wetland. The least amount and landscape change in total soil C, total N and soil NO_3^-N were in the natural and 1-year restored wetland complexes. The greatest amount and landscape change in total soil C, total N and soil NO_3^-N was in the 15-year restored wetland complex. After 15 years of restoration, soils in upland prairies exhibited minimal increases in total C and total N and minimal decreases in NO_3^-N. Soils in the wet prairies exhibited gradual increases in total C and N, but relative decrease in NO_3^-N after 15 years of restoration. The soils in the cattail/sedge wetlands and pond depression wetlands showed proinent increases in total C, total N, and NO_3^-N after 15 years of restoration. Restored wetland soils interact efficiently with surrounding landscape by sorbing and trapping sediments containing NO_3^-N. Restoration time shows restored wetlands are reachin ecological and soil steady-state properties distinct from a natural equilibrium state.

OORTS, K.M.[1], E. HERELIXKA[2], F. COPPENS[3], A. EL-SADEK[1], and J. FEYEN[1]. [1]K.U.Leuven, Institute for Land and Water Management, Vital, Decosterstraat 102, B-3000 Leuven, Belgium; [2]Belgian Soil Service, W. de Croylaan 48, B-3001 Heverlee, Belgium; [3]K.U.Leuven, Laboratory of Soil Fertility and Biology, Kasteelpark, Arenberg 20, B-3001 Heverlee, Belgium.
Modeling of nitrate leaching out of the profile during the winter and spring.
In the winter period significant N losses can occur due to leaching of nitrate remaining in the soil after harvest. Liberalization of organic N in soil organic material, plant residue or manure increase in this period the leachable portion of NO_3^-N. In order that agriculture meets the EU-norm of 11.3 mg N/ l in surface water and groundwater the Flemish Government (Belgium) states that the residual mineral nitrogen, measured in the soil profile of cropland (0-90 cm), may not exceed 90 kg N/ha between 1 October and 15 November. In the N-(eco)2 project experimental and field data, and mathematical models are used to study the relationship between residual mineral N in the soil after harvest and the NO_3-N leached out of the profile in the winter and spring. Research is focused on modeling the transport and fate of nitrogen for various management-crop-soil-groundwater conditions. Use is being made of the WAVE- and the DRAINMOD-model. The holistic WAVE-model allows a detailed simulation of the N-processes in the unsaturated zone of the soil profile, while the DRAINMOD-model is used for describing the fate of nitrogen in the saturated zone. Preliminary results of both models are presented.

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Distribution and sources of nitrate-nitrogen in Kansas ground water.

Kansas is primarily an agricultural state. Evaluation of irrigation water and fertilizer use shows a long-term increasing trend. Similarly nitrate-nitrogen concentrations in ground water show long-term increases and exceed the drinking water standard of 10 mg/L in many areas. A statistical analysis of nitrate-N data collected for local and regional studies in Kansas from 1990 to 1998 (707 samples) found significant relationships between nitrate-N concentration with depth, age, and geographic location of wells. Sources of nitrate-N have been identified for 277 water samples using nitrogen stable isotopes. Of these samples, 44% showed fertilizer sources (+2 to +8) and 37% showed either animal waste sources (+10 to +15 with nitrate-N greater than 10 mg/L) and/or indication that enrichment processes had occurred (+10 or above with variable nitrate-N). Ultimate sources for nitrate include non-point sources such as past farming and fertilization practices, and point sources such as animal feed lots, septic systems, and commercial fertilizer storage units. Detection of nitrate from various sources in aquifers of different depths in geographically varied areas of the state indicates that non-point and point sources currently impact and will continue to impact ground water in the future under current land uses.

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Influence of crop rotation on NO_3^-N leaching in Northern Croatia.

A field trial was setup on experimental field of the Tobacco Institute Zagreb with tobacco monocropping (fertilized and unfertilized tobacco) and with tobacco in crop rotations with maize, soybean, wheat and oil rape. Water leached through the soil to a 5 cm depth was caught by the installed zero tension pan lysimeters. Nitrogen fertilizer rates amounted to 30 kg/ha for tobacco, 160 kg/ha for wheat, 180 kg/ha for maize, 50 kg/ha for soybean and 150 kg/ha for oil seed rape. Nitrate leaching from fertilizers applied to test crops amounted to 7 — 9.5% while total quantities ranged from 10.8 kg/ha in tobacco monocropping to 27.5 kg/ha of nitrate nitrogen in maize growing in crop rotation. Total amounts of nitrate nitrogen leached depended on the amount and distribution of rainfall during the growing season, soil conditions, crop type, and on the applied mineral fertilizer rate.

WEBBER, J.A., and K.W.J. WILLIARD. Southern Illinois University at Carbondale, Carbondale, IL 62901-4411 USA.

Influences of percent riparian forest cover on stream water quality in southern Illinois agricultural watersheds.

State and Federal land management agencies have been promoting forest and grass riparian zones to combat non-point source nutrient and sediment pollution of our nations' waters. The vast majority of research determining riparian zone effectiveness of reducing nutrient and sediment inputs to streams has been conducted at the field scale. This study takes a broader watershed approach to determine the water quality benefits of forested riparian zones. Specifically, annual loads of nitrate, ammonium, orthophosphate, and sediment will be compared among three agriculturally impacted watersheds with varying percents of riparian cover (7, 32, 70). The study catchments are located in the Sugar Creek watershed and contain similar soil types and land use (row crop agriculture). The Global Information System software, ArcView 3.2, was used to delineate the percent forest riparian cover across the length of the 1st and 2nd order streams. Stream water samples are being collected biweekly during base flow periods and significant storm events (>0.25 in) for nutrient and sediment analysis. Preliminary water quality results will be available at the time of the meeting in October 2001.

Poster Session #8: **Nitrogen Use in Agricultural Crop Production.**

HUNT, E.R., JR., C.S.T. DAUGHTRY, and J. E. MCMURTREY, III. USDA-ARS Hydrology and Remote Sensing Lab., Beltsville, MD 20705 USA.

Remote sensing methods for estimation of crop nitrogen status.

Mapping the spatial variability of within-field crop nitrogen status is essential for better nitrogen management using site-specific variable-rate application technology. Reflectances from multispectral and hyperspectral remotely sensed images are correlated with expressions of crop nitrogen status such as leaf chlorophyll content, leaf nitrogen content, leaf area index, and percent crop cover. Multispectral approaches emphasize linear combinations of broad spectral bands (known as vegetation indices) and hyperspectral approaches analyze reflectance signatures from narrow spectral bands. Active system approaches with laser-induced fluorescence imaging spectrometers have also yielded data that are highly correlated with leaf nitrogen and leaf chlorophyll. Impediments to adoption of these remote sensing approaches include sensitivity of passive reflectance data to other characteristics of the crop and the low signal to noise of fluorescence data in daylight. If used as a basis for nitrogen management, erroneous information can lead to applications of excess nitrogen fertilizer, thus contributing to non-point-source pollution. Additionally, information on crop nitrogen status from remote sensing may be available only after the window of time when sidedress nitrogen treatments can be applied. Thus, remote sensing solutions to mapping crop nitrogen status clearly require attention to issues of optimization before application.

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Symbiotic performance of herbaceous legumes in the derived savanna of West Africa.

The increasing use of herbaceous legumes like mucuna (*Mucuna pruriens* var. utilis) and lablab (*Lablab purpureus*) in the derived savannas of West Africa can be attributed to their potential to fix atmosphere nitrogen (N_2). The effects of management practices on N_2 fixation by mucuna and lablab was examined using ^{15}N isotope dilution technique. Dry matter yield of both legumes at 12 weeks was 2 to 5 times more in in-situ mulch (IM) than live-mulch (LM) systems. Land Equivalent Ratios however showed 8 to 30% more efficient utilization of resources required for biomass production under LM than IM systems. Live-mulching reduced nodule numbers in the legumes by one third compared to values in the IM systems. Similarly, nodule mass was reduced by 34 to 58% under LM compared to the IM systems. The proportion of fixed N_2 in the legumes was 18% higher in LM than IM systems. Except for inoculated mucuna, the amounts of N fixed by both legumes were greater in IM than LM systems. Rhizobia inoculation of the legumes did not significantly increase N_2 fixation compared to uninoculated plots. Application of N-fertilizer reduced N_2 fixed in the legumes by 36 to 51% compared to inoculated or uninoculated systems. The implications of management systems on N contributions of the legumes into tropical low-input systems are discussed.

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Nitrogen management for sustainable rice production through organic manure.

Marginal and poor farmers in India are unable to use inorganic fertilizers for the crop production. There is a need to introduce an effective management of internal resources, i.e., nitrogen management by leguminosae green manure (organic manure) in the rained rice based ecosystem of India. Few experiments were conducted for sustainable and reliable rice production season after season in eastern India through using the organic manure of locally produced green manure like *Sesbania aculeata* in the field or by using the green leaves of Ipomea sp. and other greeny plants. The introduction of green manure (organic manure) increased the rice yield by 7-10 q/ha without the use of nitrogenous fertilizers. It is felt that there is enough scope to substitute the nitrogenous fertilizers partially or fully for sustainable and reliable rice yields. It will not only reduce the dependence on inorganic fertilizers but also will sustain soil health and reduce the cost of input for resource poor farmers.

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Winter cover crop species effects on soil nitrogen availability and nitrate leaching.

While winter cover cropping is often practiced to protect soil from erosion and to enhance soil quality in regions with high precipitation, cover crop species have an important bearing on nitrogen availability to the succeeding summer crop and nitrate leaching during the winter. This study examined the influence of mono-cultured cereal rye, annual ryegrass, and hairy vetch, and bi-cultured rye/vetch and ryegrass/vetch on N utilization by corn over a range of N fertilizer rates applied to corn, and nitrate leaching during the winter. While mono-cultured vetch promoted soil N availability, corn yield and N uptake at low N rates, it aggravated nitrate leaching during the winter even with zero N fertilizer application to the corn. This implies that a portion of N in the legume incorporated into the soil in the spring was continuously mineralized well into the winter. In contrast, mono-cultured rye or ryegrass was not beneficial to soil N availability, but they minimized nitrate leaching in the soil. Bi-cultured rye/vetch or ryegrass/vetch possessed the characteristic of enhancing N availability during the growing season and minimizing nitrate leaching during the winter. This unique characteristic makes the bi-cultures the kind of winter cover crop to use for protecting soil and water quality.

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Temporal changes in soil nitrogen and carbon contents in response to elevated CO_2 and O_3 in agroecosystems.

Effects of elevated CO_2 and O_3 have been studied extensively on plants, but the impacts on stoichiometric changes in C and N of soil organic matter (SOM) remains largely unexplored. In this study, the C and N contents of soils were examined under wheat-soybean rotations in open-top field chambers exposed to a 22 factorial combinations of two CO_2 (360 vs. 500 mmol mol^{-1}) and two O_3 (25 vs. 70 nmol mol^{-1}) levels over five growing seasons (1995 to 1999). Plants were grown at ambient light and temperature conditions and exposed to treatments daily from April to October. Soil samples were collected annually and analyzed for C and N contents using the LECO dry combustion method. The soil N content significantly decreased over time under both levels of the CO_2 and O_3 treatments. The rate of N decrease was higher under elevated CO_2 (-216 kg N/ha/y) as compared to ambient CO_2 (-152 kg N/ha/y), and smaller under elevated O_3 (-172 kg N/ha/y) as compared to low O_3 treatment (-197 kg N/ha/y). A significant temporal increase in C content of SOM was found under elevated CO_2 (585 kg C/ha/y) compared to ambient CO_2 (18 kg C/ha/y). The C:N ratios of soil were significantly increased over time under both levels of CO_2 and O_3 treatment. Increased sequestration of C in SOM at elevated CO_2 in the long run implies future soil N deficiency. Whereas, elevated O_3 may decrease the rate of soil N depletion compensating the effect of elevated CO_2.

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Biological nitrogen fixation as a source of nitrogen for improving crop productivity in Ethiopian agriculture.

Nitrogen is the first and most serious production-limiting nutrient in Ethiopian agriculture, which probably is the major reason for the recurrent food shortage and hunger in the country. With a long history of settled agriculture and mismanagement of soils, most of the cultivated soils are currently nutrient depleted and the organic matter content is very low. In spite of continuous cultivation of cropped lands, the annual average input of chemical fertilizers is as low as 15 kg/ha. This is mainly due to the poverty of most of the farmers for purchasing fertilizers and the limited supply of such an essential input as a result of high price of fertilizer that the country cannot afford to allocate sufficient funds for importing adequate quantity. In order to come out of this vicious circle by developing supplemental and less expensive sources of natural supply of nitrogen, Rhizobia inoculation experiments, with and without NPK chemical fertilizers, were conducted on fababean at Holetta Agricultural Research Center on Alfisols. Results showed that yield response to both chemical and biological supply of nitrogen were highly significant (increases of two to three folds), particularly for interactions with phospahte fertilizer. These findings are indicative of the high limitation of nutrients in the cultivated soils, particularly nitrogen, and the potential of the not yet exploited biological nitrogen supply of nitrogen through artificial inoculation technique, which is currently not practiced by any farmers in the country. If the currently started research undertakings on development of biological nitrogen fixing inocula is strengthened and the technique could be widely adopted by the farmers, it could be one of the important solutions for improving the supply of nitrogen to crops, hence for increasing crop productivity and attaining food self-sufficiency by the country.

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Remote sensing techniques to identify nitrogen status of paddy rice.

Nitrogen is the most important fertilizer to increase and stabilize yield of paddy rice. However, it is very difficult to identify nitrogen status of rice plants by visual inspection. In this study, 3 rates of nitrogen fertilizer, 0, 90 and 180 kgN ha^{-1}, were applied to paddy rice (TNG 67). Reflectance spectra of the rice canopies were measured by a portable spectroradiometer (LI-1800) at regular basis. Remote sensing techniques, such as band ratio, vegetation index, and spectrum differentiation, were used to identify the characteristic indices for nitrogen status of rice plants. Results indicated that SRVI, NDVI and dR/d;735 can all be used as the nitrogen status indicator. Though SRVI and NDVI can identify only severely nitrogen deficient rice plants, dR/d;735 index can distinguish the concentration of nitrogen status within rice plants. Therefore, dR/d;735 is a much better indicator for delineating nitrogen status of rice plants. This remote sensing technique can provide information regarding the spatial distribution of the nitrogen status of rice plants within the field and constitutes the basis of precision management of nitrogen fertilizer.

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Nodulation and growth of white clover is enhanced by a monoterpene from wild thyme.

White clover(*Trifolium repens*) and wild thyme(*Thymus serpyllum*) inhabit similar meadow habitats in the eastern United States. This study explores the effects of thyme essential oil on the white clover/Rhizobium symbiosis. Thyme essential oil contains the terpene, thymol. Many terpenes are phytotoxic and antimicrobial. We compared the effects of wild thyme seedlings, thyme essential oil and pure thymol on root nodulation and growth in white clover. Sterilized, inoculated clover seeds were sown in a fertilized mixture of sand and vermiculite (pH 5.3). There were 4 treatments: (1) clover (control), (2) clover with 6 ng pure thymol (3) clover with 6 ng thymol in thyme essential oil and (4) clover with 6 thyme seedlings. We used concentrations of thymol and thyme essential oil that simulate natural production levels. Plants were grown for four weeks in an environmental chamber (10L: 14D; 25°C (day): 18°C (night)). Greater numbers of nodules per plant were found in all thyme treatments compared to the control. Greater mean nodule weight was seen in pots with thyme essential oil or thyme seedlings, and greater clover shoot dry weight was found in pots with thymol or thyme seedlings.

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Yield variability from long-term nitrogen management in the northern corn belt, USA.

Long-term experiments, where management and climatic interactions are expressed over time, provide an opportunity for evaluating sources of yield variation. This project was conducted to evaluate the factors influencing corn yield variability. An experiment to evaluate nitrogen source, time of application, and rate for continuous corn was initiated in 1960 at the Southwest Research and Outreach Center, Lamberton, MN on a Normania loam soil (fine-loamy, mixed, mesic Aquic Haplustoll). Preliminary results suggest that nitrogen treatments accounted for less than 20% of corn yield variability while soil and climatic variables accounted for more than 80% of corn yield variation. The more important variables included temperature, precipitation, available soil moisture, date of planting, nitrogen rate, and nitrogen timing. Year-to-year variation due to climatic factors appears to be the major source of yield variability at this site. Nitrogen rate and timing were the more important treatment factors. Yield variability over the past 40 years of continuous corn of contrasting environmental conditions will be presented in the context of the historical weather record.

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^{15}N signatures in soil profiles of polluted and pristine temperate forests: indicators for N turnover rates?

The unique and pristine temperate forest ecosystem of southern Chile might be under threat by an increasing N deposition trend. It is suggested that increased N mineralization rates, as observed in polluted temperate forests of North America and Europe, may be a direct consequence of enhanced regional N deposition. Thus, an increased N deposition on pristine forests might increase the turnover of the organic N pool, leading to increased N losses and influencing biodiversity. Both in polluted and pristine forest ecosystems an increasing abundance of the heavy N isotope (^{15}N) versus the lighter N isotope (^{14}N) (expressed as ^{15}N values) has been observed with increasing soil depth. This gradual enrichment in ^{15}N is caused by microbial fractionation during mineralization of soil organic N or a loss of depleted nitrate. The ^{15}N profiles of 5 pristine forest ecosystems in southern Chile were compared with ^{15}N profiles of 5 polluted (30-50 kg N/ha/yr) forest ecosystems in Belgium. In Chilean forests ^{15}N signatures gradually increased from –2percent - +1.5 (litter) to +6.5 percent at 60 cm depth. In the Belgian forests, ^{15}N signatures were highly depleted in the litter layer (–12 to –5 percent) and gradually increased to 0 - +4 percent at 60 cm depth. At the same time a correlation between the ^{15}N enrichment and N mineralization rates has been found. Thus, the assessment of variations of natural abundance of ^{15}N offers perspectives to evaluate long-term effects of N deposition on forest ecosystems.

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Relationship of net and gross rates of soil inorganic nitrogen production: Examples from annual- and perennial-dominated ecosystems.

Measures of net mineralization and nitrification are frequently used to evaluate inorganic N production in soils. However, net rates may actually provide little information about the amount of inorganic N made available to plants and soil organisms in undisturbed systems, since microbial consumption may remove mineralized N as fast as it is produced in incubated cores, leading to negligible or even negative rates of net production. The use of isotope dilution techniques is increasingly being used to measure gross mineralization and nitrification rates, as well as providing estimates of microbial consumption. Here, gross and net inorganic N production data collected in annual grass-dominated and perennial-dominated ecosystems are evaluated to highlight discrepancies between the two types of data, and to hypothesize some general rules for when net rates may be a reliable proxy for gross rates.

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Biogeochemistry in two ammonia affected forests in Denmark.

In a national survey focused on agricultural impacts on water quality, dormant season soil solution nitrate concentrations were measured 1986-92. The survey was based on a systematic grid including also forest soils. Some 10% of these forest soils had high nitrate concentration (>10 mg N/l) indicating nitrogen saturation. From this group two sites with mature coniferous stands where chosen for element cycling studies. Through fall and litterfall fluxes, soil water chemistry, foliage chemistry and soil characteristics were measured in 1996-1999. The sites were situated within areas with intensive agricultural activity. Throughfall supplied >40 kg N/ha/yr with c. 70% being ammonium. Nitrogen concentrations in needles were 1.7% in *Picea abies* and 1.5% in *Abies alba*. Concentrations of K and P were low and below critical values relative to nitrogen. Nitrate concentrations in soil water varied between 10 and 30 mg N/l at both sites over the whole monitoring period 1986-92, 96-99. The paper will discuss the effect of nitrogen input on element cycling and the future nutrient supply in the stands. Data on the effect of clear felling/windthrow on nitrate leaching at such nitrogen-saturated sites will be presented as well.

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Modeling of nitrogen sequestration in coastal marsh soils.

Extensive field-based data from two representative submerged upland tidal marsh soils in the Chesapeake Bay area were gathered to develop a predictive model for N sequestration. The data covered the range in physiographic position and variation in marsh habitat. Sampling protocol and model validation assure the validity of the model and placed 80% confidence, and 10% accuracy on the rate of N sequestration and the predictive model. In coastal marsh ecosystems, N sequestration continues to occur over time by accumulation in the organic horizons and sea level rise is the driving force. The predictive model was two-step linear function indicating accelerated sequestration of N in the past two centuries. During the last 150 years the rate of N sequestration averaged 4.2±1.15 g/m^2/yr, while over the last one or two millennia the rate of N sequestration averaged 1.47±0.3 g/m^2/yr. In the next century modeled prediction of N sequestration averaged 20± 7.9 g/m^2/yr.

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^{15}N natural abundance of plants and soil N in tundra ecosystems.

^{15}N natural abundance (^{15}N) of plants has been studied as an indicator for intact N cycling. So far now, it has been proved that plants in tundra ecosystems have wide ^{15}N range, as well as low d^{15}N, which suggests strong niche differentiations of plants in N use under strong N-limited conditions. We report here some results from ^{15}N survey in several tundra ecosystems in a single hillslope, emphasizing on N biogeochemistry. Nitrogen fixation measured by acetylene reduction method and ^{15}N, showed that considerable amount of N was fixed and provided into ecosystems. Denitrification, on the other hand, didn't occur in any ecosystems even under water-saturated conditions of soils. DON was dominated as N sources in soils, and no nitrate was detected. ^{15}N of DON and ammonium in soils, however, had higher ^{15}N than plants. Since isotopic fractionations do not seem to occur during plant N uptake under such N-limited conditions, this inconsistency between plants and two potential N sources for plants proposed that there might be other N sources which have low ^{15}N and can explain low ^{15}N of tundra plants. The possible explanations about this inconsistency will be discussed.

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Soil NO$_3^-$ for plant: Saturated or Not? - Estimations of soil NO$_3^-$ availability and plant ability of NO$_3^-$ uptake in Japanese forest.

Plant nitrate (NO$_3^-$) uptake is an important process in N cycle in forest ecosystem, since it is one of the possible factors reducing the NO$_3^-$ loss from forest ecosystems. Thus, it is required to evaluate the role of plant in N cycle in forest ecosystems by estimating ability of plant NO$_3^-$ uptake and soil NO$_3^-$ availability that has an effect on plant NO$_3^-$ uptake. Responses of shrub species grown in perlite culture medium to NO$_3^-$ supply were investigated to estimate the saturating point of available NO$_3^-$ for plant uptake. Nitrate reductase activity (NRA) was applied as an indicator of plant NO$_3^-$ uptake. Retained NO$_3^-$ in perlite was compared with NO$_3^-$ pool sizes in soils from some forests to estimate the level of NO$_3^-$ availability to plant in forest soil. Discussion will include if NO$_3^-$ in forest soil is saturated for plant in Japan or not, by comparing the maximum ability of plant NO$_3^-$ uptake and NO$_3^-$ pool sizes in some forest soils.

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Sustained reduction of nitrogen deposition in a Norway spruce forest at Solling, central Germany: Impact on gross rates of internal nitrogen cycling.

Employing a permanent roof construction below the canopy of a Norway spruce plantation at Solling, central Germany, throughfall water was continuously collected, partly de-ionized and re-sprinkled below the roof since 1991. Compared to the control deposition rates, the "clean rain" plot were reduced to: [kg/ha/a; (% of control)] H$^+$ = 0.15 (22%); SO$_4^-$S = 15.6 (51%); NH$_4$+ = 2.1 (14%); NO$_3^-$N = 8.3 (57%). The flux budget of nitrogen remained positive (net accumulation) at the "clean rain" plot decreased from +13.6 (mean of 1990-1991) to +2.8 (mean of 1992-1997) kg/ha/a. 10 years after sustained reduction of the nitrogen input our objective was to assess changes of internal N cycling by measuring rates of gross nitrogen mineralization, immobilization, and nitrification. We applied the ^{15}N dilution technique, integrated measures of microbial N, and compared our results to ambient conditions, where, following clean air legislation of the early nineties, drastic reductions of the atmospheric input of sulphur and acidity are obvious but no trend for nitrogen input can be observed so far. Our results give insight into processes of N storage and the capability to restore the N cycling in forests under a changing chemical environment.

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Integrated nitrogen and flow modeling (INCA): Application to a northern boreal forestry dominated river basin.

The integrated nitrogen model (INCA) has been designed (Whitehead et al. 1998) to investigate the fate and distribution of nitrogen in the terrestrial and aquatic environment. The model simulates flow pathways and tracks fluxes of both nitrate-N and ammonium-N in the land and riverine phase. Day-to-day variations in flow, N fluxes and concentrations can be investigated following a change in N inputs. The N input change may be due to land use change, deposition or climate change. There are five components included; the GIS interface, the N deposition model, the hydrological model, the catchment process model and the river process model. The model is being applied to the Simojoki river basin (3160 km^2) in the Northern Boreal zone in Finland, in the context of an EU 5th framework project. The main emphasis is to study the model behavior in areas where major human impacts to N fluxes are forest management and N deposition. The model application will utilize detailed spatial forest change information - cut areas based on remote sensing. Further, the model application will utilize the available empirical data of N transformation processes, the river basin hydrological model and N-deposition estimated by the DAIQUIRI model. Measured hydrological and N time-series are available for calibration and verification. Preliminary model runs of dynamics of flow, N concentrations and fluxes are presented and discussed.

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Decadal scale movements of N tracers into vegetation and soil at the Harvard Forest Chronic-N Addition Study: Implications for C sequestration.

Some global scale analyses have suggested that elevated N deposition in north temperate regions could contribute to C storage by stimulating wood production in temperate forests. At the Harvard Forest LTER Chronic N Addition Study, ^{15}N -tracers were added to control (ambient deposition) and fertilized (50kg N/ha/yr since 1988) plots in 1991 and 1992. In both oak and red pine stands, ambient (deposition = 8 kg N/ha/y) and fertilized plots (fertilized with 50 kg NH_4NO_3-N/ha/y) received $NH_4{}^{15}NO_3$ tracer on one half and $^{15}NH_4NO_3$ on the other. Previous work showed that ^{15}N tracer recovery in bolewood at the end of the two-year tracer addition ranged from 0.2% to 4.4% when averaged across tracer forms. Recoveries varied with forest type, N-input rate, and ionic form of the ^{15}N tracer. Overall, more ^{15}N accumulated in wood when $^{15}NO_3$ was applied, oaks accumulated more tracer than pines, and the percent recoveries increased with N input rate. In 1999, seven years after the end of tracer application, recoveries were larger in bolewood than at the end of the two-year tracer addition, ranging from 1.4% to 5.1% averaged across tracer forms. As in 1992, tracer recovery depended on forest type, rate of N-input, and form of tracer addition. Although tracers continued to accumulate in wood for almost a decade after being added to plots, low recoveries suggest N deposition is not stimulating C sequestration in woody tissues at these forests.

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Nitrogen cycling in two contrasting forests in Taiwan.

We compared temporal and spatial patterns in inorganic nitrogen cycling in two forested ecosystems in Taiwan. One site, Fu-shan Experimental Forest, has a mean annual temperature of 18.2 °C. At Fu-shan, the extractable nitrate concentration in the mineral soil varied from about 1 to 4 mg N/kg dry soil. Extractable ammonium concentrations had nearly the same range (1 to 5 mg N/kg dry soil). The second study site, Ta-Ta Chia, is located within the central mountain range in Taiwan and is characterized by a mosaic of grassland and forest species vegetation. Ta-Ta Chia has a mean annual temperature of 12.3 C. Soil nitrate concentration in a grassland area (10-20 cm depth) soil ranged from less than 1 to 4 mg N/kg dry soil and less than 1 to 2.5 mg N/kg dry soil in an adjacent forested area. Extractable ammonium concentrations ranged from 2 to 13 mg N/kg dry soil and between 3 and 25 mg N/kg dry soil in the grassland and forest, respectively. Both sites are part of the Taiwan's LTER program and these results highlight the need for future studies to better understand spatial and temporal patterns in nitrogen cycling and export from forested watersheds in Taiwan.

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Effect of surface soil removal on dynamics of dissolved inorganic nitrogen in snow-dominated forest soil.

To clarify the effect of surface soil removal on dissolved inorganic nitrogen dynamics in a snow-dominated forest soil in northern Japan, the seasonal fluctuation of nitrogen concentration in soil solution and the annual flux of nitrogen in soil were investigated at treated (surface soil removal including understory vegetation and organic and A horizon) and control sites from July 1998 to June 2000. We also observed a temporal change of water-soluble nitrogen contents in soil at six sites passed 1-7 years after treatment. Nitrate concentration in soil solution at treated site was significantly higher than those at the control site, probably affected by the increase of soil temperature due to the removal of understory. The annual net output of nitrate from soil at the treated and the control sites was 258 and 12 mmol/m^2/yr , respectively and about 56% of net output at the treated site occurred during the snowmelt period. The nitrate content in soil tended to decrease year by year after the treatment, and reached the same level as the untreated soil in six years after the treatment. Our results suggested that the snowmelt strongly affected the nitrate leaching and restoration at the treated site.

Poster Session #10: **Nitrogen Dynamics in Asia.**

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Nitrogen limitation of human nutritional carrying capacity: A Chinese village case study.

In the past fifty years, human populations have doubled over their traditional maxima in the ancient and densely populated agricultural villages of China's Tai Lake Region. To feed these populations, rice yields have doubled and nitrogen inputs have increased by 500%. Based on village household surveys from the 1930's and 1994, we measure long-term changes in dietary nitrogen demand by human populations resulting from changes in population and diet, and compare these with productive capacity to determine whether it would be possible to sustain current human populations without the use of synthetic nitrogen. Using a statistically robust village scale analysis of a typical village in the region, we demonstrate that the nutritional demands of current populations could not be supported without the use of synthetic nitrogen. This provides a proven case where human nutritional carrying capacity of a village ecosystem is limited by nitrogen, and where industrial nitrogen synthesis is necessary in supporting currant human populations under a subsistence agriculture model. The extent of the regions in China subject to these conditions, and the local and global impacts of this development will be discussed.

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Economization of fertilizer nitrogen through organic resources favorably influenced soil health and crop response in Indian sub-continent.

Field experiments were conducted at the farmers' plot adjacent to Regional Research Station, Red and Laterite Zone, sub-center Sekhampur (Birbhum district) of West Bengal situated 23°24′ N latitude, 87°24′ E longitude to visualize the effect of different bio and organic sources of nutrients instead of total fertilizer nitrogen in terms of crop productivity in the sequence and building up of soil fertility. During the wet season, 12 combinations of bio and organic sources (crop residues, well decomposed cowdung, green manure) were substituted by 25-50% of nitrogen fertilizer applied on transplanted rice (cv. IR 36) and subsequently during winter, leguminous pulse crops like lentil (*Lens culinaris* (L.) Medic), gram (*Cicer arietinum* L.) and lathyrus (*Lathyrus sativus* L.) were grown with and without Rhizobium culture. Results revealed that a combination of inorganic nitrogen in combination with organic sources exhibited a significant rice grain yield (3.84 t/ha) in comparison with nitrogen fertilizer alone even when 100% of the recommended dose of nitrogen was applied on this crop (3.26 t/ha). This achievement saved a considerable amount of fertilizer nitrogen without significant yield reduction as well as remarkably improved the physico-properties of the soils (pH, organic carbon, organic matter and all other related nutrients of the soil). Seed yield of pulses (lentil, gram and lathyrus) were more pronounced when these were sown with Rhizobium culture that could save to the tune of 42.6 to 48.4 kg N for the succeeding crops per hectare, stored in the soil which is a costly input in this sub-tropics. Therefore, the present investigation suggested that an ideal combination of inorganic along with bio and organic sources effectively be imperative in respect to uphold the nutrient status of the soil as well as for gaining total productivity of the crop sequence.

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Soil N cycling pattern in various forest ecosystems in dry tropical and temperate areas in Asia.

Deposition of inorganic N to natural ecosystems has increased accordingly. Inputs of ammonium (NH_4^+) and nitrate (NO_3^-) can induce eutrophication of previously N-limited systems and cause their "nitrogen saturation". There are many studies in North America and Europe, however, little is known about dry tropical forest ecosystems, especially in East Asia. In Asia, including Japan, the situation is quite different from North America and Europe, because of its geography and climate. We need to describe the cycling in forest ecosystems quantitatively. In this study we determined the spatial and temporal pattern of N cycling in forest ecosystems and discuss the influences of N deposition and climate changes.

Poster Session #11: **Nitrogen in Surface Waters.**

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Retention of nitrogen in macrophyte-dominated streams: Measurements and modeling.

Understanding nutrient cycling in catchments is vital for the implementation of measures to reduce diffuse nutrient loading to surface waters. Generally retention of nitrogen in surface waters is defined as the difference in N-input and output at the system boundaries, due to denitrification, biomass production and burial. Many studies indicate that these permanent (and temporal) losses of nitrogen in surface waters are unknown terms in the nutrient budgets at catchment scale. We studied the retention of nitrogen in a small river catchment in the Netherlands. During 2 periods of 14 days, in June and September, the actual retention of nitrogen was measured in 4 macrophyte-dominated sections of the stream, by frequent sampling and analysis of nutrients. We found reductions of 15-40% of both inorganic and total nitrogen content in the sections that were monitored. Additional process-oriented research in experimental ditches was performed to determine to which extent denitrification contributes to the total retention in this type of stream sections. N-retention fractions were incorporated in a 1-D dynamic surface water model to calibrate the nitrogen concentrations in several section of the model. With this procedure it was possible to study N-retention in a dynamic way and extrapolate the loss of nitrogen to the whole catchment. We found both spatial and temporal variation in N-retention fractions over the catchment over one year.

JANSE, J.H., W. LIGTVOET, S. VAN TOL, and A.H.M. BRESSER. National Institute of Public Health and Environment (RIVM), Laboratory of Water and Drinking Water Research, 3720 BA Bilthoven, The Netherlands.

A model study: The role of wetland zones in lake eutrophication.

Shallow lakes respond in different ways to changes in nutrient loading (nitrogen, phosphorus). These lakes may be in two different states: turbid, dominated by phytoplankton, and clear, dominated by submerged macrophytes. Both states are self-stabilizing; a shift from turbid to clear occurs at much lower nutrient loading than the opposite. These 'critical' loading levels vary among lakes and are dependent on morphological, biological and lake management factors. This paper focuses on the role of wetland zones. Several processes are important: transport and settling of suspended solids, denitrification, nutrient uptake by marsh vegetation (increasing nutrient retention), and improvement of habitat conditions for predatory fish. A conceptual model of a lake with surrounding reed marsh was made, including these relations (fig.1). The lake-part of this model consists of an existing lake model PCLake [Janse, 1997]. The relative area of lake and marsh can be varied. Model calculations for a number of situations revealed that the marsh area should be relatively large to effectively decrease nutrient concentrations to the level where a shift to clear water occurs. Export of nutrients can be enhanced by harvesting of reed vegetation; then the relative marsh area can be smaller. Optimal predatory fish stock contributes to water quality improvement, but only if combined with favorable loading and physical conditions. Within limits, the presence of a wetland zone around lakes may thus increase 'critical nutrient loading' and thus increase the ability of lakes to cope with nutrients. Validation of the conclusions in real lakes is recommended, a task hampered by the fact that in The Netherlands, many wetland zones have disappeared in the past.

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Nitrogen, phosphorus, and potassium inputs and outputs for the Potomac River Watershed, 1900-2000.

Estimates of annual nitrogen, phosphorus, and potassium inputs and outputs for the Potomac River Watershed are presented for the period 1900-2000. These estimates were based on historic air emissions and air deposition data, fertilizer sales, crop and animal census, population census and wastewater data, and riverine water quality data. Mass balances for four, five-year periods 1980-84, 1985-90, 1990-95, and 2000 are also presented. Agriculture practices dominate the inputs. Climate dominates year-to-year variability of riverine outputs.

LOS HUERTOS, M.W., G. GENTRY, and C. SHENNAN. University of California, Santa Cruz, CA 95064 USA.

Land use and instream nitrogen concentrations in agricultural watersheds along the California coast.

In coastal California, runoff from urban and agricultural land is suspected to contribute to reduced water quality and adversely impact threatened and endangered species. However, few quantitative data have been presented regarding the impacts of land use activities on water quality within central California agricultural watersheds. We report on the spatial and temporal patterns of instream nitrogen concentrations for several coastal creeks. Specifically, nitrate-N concentrations were <1 mg N/L in grazing lands, oak woodlands, and forests but increased to a range of 3 to 5 mg N/L as surface waters passed through agricultural lands. Very high concentrations of nitrate (in excess of 50 mg N/L) were found in selected agricultural ditches, especially those receiving tile drainage. Surprisingly, a subset of agricultural ditches remained high in nitrate concentrations during and after rain events, which indicated nitrate was not being flushed out of the soil profile. We hypothesize that the shallow groundwater is nitrate saturated in the tile-drained fields due to long-term nitrogen loading from agricultural practices. Results are being used to help landowners and resource managers understand the relationship between land use activities and local water quality.

O'BRIEN, J.M., and K.W.J. WILLIARD. Southern Illinois University, Carbondale, IL 62901 USA.

Effects of ambient conditions on microbial denitrification in a southern Illinois stream.

Transport of nitrogen compounds in urban and agricultural runoff can lead to significant environmental impacts, including eutrophication of downstream water bodies and health risks in drinking water. While in transit within the stream channel, these compounds may be retained or removed entirely through a variety of biological activities. This study investigated the effects of ambient stream characteristics on denitrification in Big Creek, an agricultural watershed in southern Illinois. Comparisons were made between denitrification rates in a 'natural' gravel dominated stream segment and a channelized sand-silt dominated segment. Samples were collected on a biweekly basis for one year in addition to measurements of ambient nitrate concentration, oxygen concentration, temperature, stream flow and sediment characteristics such as pH, organic matter content, and C:N ratio. Potential denitrification rates were estimated using the acetylene block technique. Laboratory incubations of sediment cores were used to determine actual nitrate loss from overlying stream water and to determine the effects of other microbial processes, such as nitrification, on denitrification rates. Preliminary data indicates a higher rate of denitrification within the channelized stream segment which is likely to be due to the prevalence of organic matter as well as reduced oxygen concentrations in the sediments.

WYFFELS, S., P. BOECKX, W. VERSTRAETE, and O. VAN CLEEMPUT. Ghent University, B-9000 Gent, Belgium.

Identification and quantification of N removal in waste water treatment by ^{15}N tracer techniques.

EU legislation on N discharge into the aquatic environment as stringent as 10 mg N/L has forced waste water treatment plants to upgrade their facilities. Recently, some promising processes, such as SHARON, ANAMMOX and OLAND have been developed for the treatment of ammonium-rich effluents. All these innovative processes for biological N removal are an alternative approach of the classical sequence of nitrification and denitrification. In these new processes, nitrification is blocked at the stage of nitrite, followed by further reduction to gaseous nitrogen. Conventional analysis techniques of N species do not allow an unambiguous identification and quantification of N removal pathways and N transformation rates. However, one can assess biological N transformations in waste water accurately by ^{15}N tracer techniques and ^{15}N analysis via Isotope Ratio Mass Spectrometry (IRMS). The labeling and measurement of ^{15}N in different chemical N species, such as ammonium, nitrite, nitrate and dinitrogen gas allows the precise calculation of N mass balances and N gas fluxes. Isotope dilution and isotope redistribution provide a powerful tool to assess N transformation rates and to identify pathways for N removal. This enabled us to evaluate - both qualitatively and quantitatively - N removal via anoxic ammonium oxidation.

Poster Session #12: **Effects of Atmospheric Deposition of Nitrogen.**

BOGGS, J. B.[1], S. G. MCNULTY[1], and L. H. PARDO[2]. [1]USDA Forest Service, Raleigh, NC 27606 USA; [2]USDA Forest Service, Burlington, VT 05402 USA.

Effects of nitrogen deposition on high elevation spruce-fir and deciduous forests across the Northeastern US.

Concern about the effects of nitrogen deposition on high elevation spruce-fir forests has continued for several decades throughout Europe and the US. Recent studies have suggested that nitrogen deposition may also have negative impacts on forest health in deciduous forests. To test this hypothesis, in 1999, a series of deciduous plots were sampled adjacent to spruce-fir plots originally established in 1987/88 across a nitrogen deposition gradient in the northeastern US. A subset of the spruce-fir plots was also re-sampled. Foliar, forest floor and tree core samples were collected from 70 spruce-fir and 60 deciduous plots at several elevations and aspects to evaluate how these forests respond to nitrogen deposition, and to determine if the ecological state of the previously sampled spruce-fir plots has changed during the past 12 years. Results indicated that forest floor chemistry (C:N ratios, pH and net mineralization and nitrification potential) from deciduous and spruce-fir plots were positively correlated at $p < 0.05$. Nitrogen deposition was negatively correlated with forest floor C:N ratios within both forest types. Additionally, spruce-fir forest floor C:N ratios decreased by 10% from 1987 to 1999. These relationships provide useful information about the chronic impacts of nitrogen deposition on spruce-fir and deciduous forests.

GILLILAND, A[1], **T. J. BUTLER[2],** and G. E. LIKENS[3]. [1]Atmospheric Sciences Modeling Division. NOAA Air Resources Laboratory, Research Triangle Park, N.C. 27711 (on assignment to the USEPA National Exposure Research Laboratory, RTP N.C.); [2] Institute of Ecosystem Studies, Millbrook NY 12545 and Center for the Environment, Cornell University, Ithaca NY; [3] Institute of Ecosystem Studies, Millbrook NY 12545.

Seasonal and monthly bias in weekly (NADP/NTN) vs daily (AIRMoN) ammonium and nitrogen precipitation chemistry in the eastern U.S.A.

Previous research has suggested that there is an annual bias for ammonium concentration, but not for nitrate, sulfate and hydrogen ion, between the weekly and daily precipitation chemistry collected at collocated sites (Oxford OH, Bondville IL, Penn State PA, and Oak Ridge TN). For the period 1992 to 1995, a relative bias of about 15% was found for ammonium, the mean concentration and standard error (s.e.) being 14.3 (0.7) ueq/l for the NADP data and 16.4 (0.8) ueq/l for the AIRMoN data. For nitrate concentrations there was only a slight relative bias (-3.3%), the mean and standard errors for concentrations being 21.3 (0.7) ueq/l for NADP and 20.6 (0.7) for AIRMoN. In this study, with significantly more data (1992-2000), we assess the bias on a seasonal and monthly basis for these two networks, and also evaluate changes in bias on a year by year basis. For ammonium the greatest differences (AIRMoN > NADP) are from July through September (21.3% relative bias). Nitrate concentrations show a low bias throughout the year, without a strong seasonal signal. Sulfate shows a greater bias in the winter months (NADP> AIRMoN), and H^+ shows an increased biased compared with our earlier work, the largest bias(13.2%, AIRMoN > NADP) is from May to September . Data for other ions will also be presented.

CORRE, M.D., and F.O. BEESE. Institute of Soil Science and Forest Nutrition, University of Goettingen, Buesgenweg 2, Goettingen 37077 Germany.

Gross rates of internal N cycle in acid, high N deposition forest soil: Changes under long-term N saturated and limed conditions.

The effects of N saturation and liming on the microbial internal N cycling in acid, high N deposition beech forest soils, common in Germany, has received little attention. Our study site in Solling, Germany received ambient N deposition from 35 kg N/ha/y during 1969-1989 to 25 kg N/ha/y beginning the last decade. It is largely unknown whether the internal N cycle and microbial biomass in such a system could be improved by liming and would reverse from N saturation (attained by 11-y N fertilization on top of the ambient N deposition) after 7 years of reduced N input (no fertilizer application and reduced N deposition). Our objectives were: 1) to assess quantitatively the changes of internal N cycling and of microbial biomass under control, N saturation, and lime amelioration, and 2) to determine the factors controlling the differences in internal N cycling from these systems. Gross rates of internal N cycle were measured using ^{15}N pool dilution technique. Our results give insights on the importance of integrating measures of microbial N cycling activity, as a sensitive and long-term soil N status indicator, in the development of parameters for assessing N status of forest ecosystems.

KERCHNER, M., J. THOMAS, A. WEBER, and R. HALLORAN. NOAA Air Resources Laboratory, Chesapeake Bay Program Office, Annapolis, MD 21403 USA.

The implications of ammonia emissions to coastal and estuarine areas.

Considerable attention continues to focus on nutrient over-enrichment of U.S. coastal and estuarine waters. In recent years, a growing number of people have begun to define the importance of ammonia emissions and subsequent nitrogen deposition on the declining health of these areas. To effectively deal with ammonia emissions, and the attendant effects on air, land and water quality, attention must be focused on strengthening our abilities to identify the primary sources and magnitude of emissions, understand the transport and fate of these emissions, and assess the ecological implications created by those emissions. This poster presentation provides insights into the sources and relative magnitude of ammonia emissions, the nature and distribution of ammonia/ammonium deposition, and the ecological implications. Explicit examples used to support the presentation come from an array of science-based assessments.

MASTOI, G.M., and M.Y.KHUHAWAR. University of Sindh Jamshoro, Sindh, Pakistan.

Effects of fertilizers on the human health of Sindh, Pakistan.

Lake and canal water were collected and monitored for 6 years for the contents of nitrogen. It was found that the sources of nitrogen were the agricultural fertilizers. Attempts were made to correlate diseases of humans with nitrogen. Various parameters are correlated with each other and with the diseases.

DIXON, L.K.[1], E.D. ESTEVEZ[1], and **E.M. PORTER**[2]. [1]Mote Marine Laboratory, Sarasota, FL, USA; [2]U.S. Fish and Wildlife Service, Denver, CO, USA.

Water and vegetation sampling to evaluate nitrogen enrichment at Chassahowitzka National Wildlife Refuge 1996-present.

The U.S. Fish and Wildlife Service (FWS) and Mote Marine Laboratory (MML) have been conducting water and vegetation sampling in the riverine and offshore waters of Chassahowitzka National Wildlife Refuge (NWR) since 1996 to evaluate nutrients and eutrophication related parameters. Chassahowitzka NWR is located on the Gulf of Mexico approximately 100 km north of Tampa, Florida. Portions of the refuge are a nationally designated wilderness and a Class I air quality area. The study was initiated in response to FWS concerns that the Chassahowitzka ecosystem might be experiencing similar increased nitrogen loadings and eutrophication as observed in nearby Tampa Bay. Nitrogen inputs from groundwater discharges to Chassahowitzka have increased; in addition, nitrogen inputs from wet deposition from the atmosphere have increased. The shallow nature of the area provides comparatively little dilution capacity of the region to “buffer” additional nutrient loads. Approximately 20 stations are sampled quarterly for water quality parameters, including nutrients, chlorophyll, and physical parameters. Submerged aquatic vegetation (SAV) is sampled yearly at 30 sites to determine species-specific frequency and abundance. During most sampling periods, water quality has been generally good in Chassahowitzka. However, in 1998, a persistent phytoplankton bloom occurred, apparently stimulated by an increase in offshore nutrients following an unusual discharge event from a nearby watershed river. The severe increases of chlorophyll and reductions in water clarity were coincident with the reduction in abundance or total exclusion of several SAV species from the refuge. Subsequent vegetation samplings have identified recovery of at least some of the species, with others still at depressed levels. FWS is concerned that any increases in nitrogen to the area will further compromise the ecological health and wilderness values of Chassahowitzka NWR.

SHERWELL, J.[1], and M. GARRISON[2]. [1]Department of Natural Resources, Annapolis, MD 21403 USA; [2]Environmental Resources Management, Exton, PA. USA.

A mitigation strategy for deposition from a new electricity generating facility.

It has been estimated that about a quarter of the total nitrogen load in the Chesapeake Bay may be attributed to atmospheric deposition. Policy coordinating the restoration of the Bay has been developed through a series of Chesapeake Bay Agreements, negotiated and agreed to by the affected jurisdictions. The current Agreement recognizes the contribution from atmospheric deposition and is anticipating that the implementation of the Clean Air Act Amendments of 1990 will provide collateral reductions in deposition. This paper discusses a deposition mitigation strategy developed for a new electricity generating facility located close to the Bay. For the majority of the Bay watershed, new major sources are required to offset NO_x emissions, generally at a greater than 1:1 ratio. However, these offsets may not be in the same region, so that local deposition effects are not addressed. An estimate of 2.4 tons per year in incremental deposition in the vicinity of the new facility was made using the CALPUFF model. Nonpoint source loading mitigation studies have shown that vegetative buffers in riparian zones play an important role in intercepting nitrogen before it can run off into the receiving waterway. A forest planting plan that included riparian forest buffer was included as a part of the new facilities permit to construct.

Wednesday, October 17 - Innovation with Nitrogen

Poster Session #13: ***Policy Options to Improve Nitrogen Use in Agriculture.***

BIELEK, P. Soil Science and Conservation Research Institute, Gagarinova 10, 827 13 Bratislava, Slovak Republic.

Principles of nitrate vulnerable zones designation.

Specific farming systems must be implemented into areas where ground and surface water pollution from agriculture can be expected. Mainly pollution by nitrates is dangerous because of its many negative environmental and human health impacts. Until now no standardized approaches were adopted when we want to determine concrete size and borders of nitrate vulnerable zones. Comprehensive data collection must be used and data assessments must be done for it. Relevant GIS have to be available as well. Using both these tools and procedures we defined most significant parameters (indicators) which must be taken into account to designate vulnerable zones. The following are proposed by us: (1) nitrate production potentials in soils (we have specific software for it connected with comprehensive soil GIS); (2) assessment of existing farming systems; mainly inputs of nitrogen into the soils by fertilizers (organic, mineral), deposition, fixation, etc.; (3) water quality data assessment; mainly nitrate contents in ground and surface water (data from water quality monitoring); (4) soil erosion potentials from slopes located near by natural and artificial lakes (using USLE or RUSLE models connected to soil GIS). All mentioned indicators were used for nitrate vulnerable zones identification inside of 2.4 mill. ha of agricultural land of Slovakia. About 1.7 mill. ha from that were proposed as vulnerable zones. All procedures, principles and territorial interpretations will be presented during the presentation.

LUND, E. D.[1], G. P. HANSON[2], and M. C. WOLCOTT[3]. [1]Veris Technologies, Salina, KS 67401 USA; [2]Lousiana State University Ag Center, 8105 East Campus Ave., Alexandria LA 71301 USA; [3]MZB Technologies, LLC 519 20th St. SW, Jamestown, ND 58401 USA.

Applying nitrogen site-specifically using soil EC maps and precision agriculture technology.

Within most production agriculture fields, there is a significant variability in soil textures. Soil physical properties such as soil texture have a direct effect on water-holding capacity, cation-exchange-capacity, crop yield, production capability, and nitrogen loss variations within a field. In short, mobile nutrients are used, lost, and stored differently as soil textures vary. A uniform application of nitrogen to varying soils results in a wide range of nitrogen availability to the crop. Nitrogen applied in excess of the crop usage results in a waste of the grower's input expense, a potential negative effect on the environment, and in some crops a reduction of crop quality, yield, and harvest ability. Inadequate nitrogen levels represent a lost opportunity for crop yield and profit. The GPS-referenced mapping of bulk soil electrical conductivity (EC) has been shown to serve as an effective proxy for soil texture, due to the fact that small grain-sized soils such as clay conduct more electricity than larger-grained silt or sand. This poster will describe the EC mapping process and provide case studies of site-specific nitrogen applications based on EC maps.

MCARTY, G.W.[1], T. J. GISH[2], C. L. WALTHALL[1], and C.S.T. DAUGHTRY[2]. [1]USDA-ARS Hydrology and Remote Sensing Lab., Beltsville, MD 20705 USA; [2]USDA-ARS Hydrology and Remote Sensing Lab., Beltsville, MD 20705 USA.

Assessment of landscape spatial structure as an indicator of available soil nitrogen for agricultural production.

The ability to predict available soil nitrogen for crop production has been the elusive "holy grail" of nitrogen management for the past half century. Efforts to develop laboratory soil tests to predict nitrogen with mineralization potential as an indicator of available nitrogen for crop growth have largely failed. While the pre-sidedress nitrate test (PSNT) has shown some promise, it has substantial logistical difficulties that hinders implementation by farmers. The importance of landscape-level parameters as drivers of nitrogen availability may explain why random point-sample methods fail. An assessment of how landscape influences the spatial distribution of processes governing the nitrogen cycle was conducted at the Beltsville Agricultural Research Center Beltsville, Maryland. Physical, chemical and biological parameters as well as surface and subsurface topographic features were evaluated in assessing nitrogen behavior on a watershed scale. The spatial structure of various nitrogen cycling processes was found to be closely linked to surface features such as topographical curvature and subsurface structures. These findings suggest that landscape parameters will be a critical driving force in developing nitrogen management models. Such models when used with remotely sensed data for crop nitrogen status could facilitate site specific management of nitrogen for crop production, thus leading to reduced nitrogen loss from agricultural ecosystems.

HERELIXKA, E., L. VANONGEVAL, and M. GEYPENS. Soil Service of Belgium, B-3001 Heverlee, Belgium. Presented by **KATRIEN OORTS.** Soil Service of Belgium.

Mineral nitrogen in the soil as a policy instrument to reduce N-leaching from agricultural soils in Flanders.

In order not to exceed the Nitrate Directive, which defines a maximum admissible concentration of 11.3 mg NO_3-N/l in surface water and groundwater, agriculture in Flanders is under severe pressure. The aim of this study is to investigate the relationship between the residual mineral nitrogen in the soil after harvest and N leaching through field experimentation in combination with simulation models. After the calibration and validation of the models, a scenario-analysis for a period of 30 years will be performed to predict the nitrogen dynamics in the soil and the leaching of nitrate in response to changes in management or weather patterns. The model output will be validated with field measurements during two successive winter periods on twenty fields, representative for the most frequent combinations of agricultural crops, soil textures and hydrological situations in Flanders. In order to get a better quantification of N-leaching, the mineralization rate and denitrification capacity of these soils are determined and related, if possible, to easily measurable soil characteristics.

Poster Session #14: ***Nitrogen Management in Agricultural Systems.***

ANGIER, J.T., G.W. MCCARTY, T.J. GISH, W.P. DULANEY, and C.S.T. DAUGHTRY. USDA-ARS EQL, Beltsville, MD 20705 USA.

Impact of a first-order riparian zone on nitrogen removal and export from an agricultural ecosystem.

Riparian zones are reputed to be effective at preventing export of agricultural groundwater nitrogen from local ecosystems. This is one impetus behind riparian zone regulations and initiatives. However, riparian zone function can vary under different conditions, with varying impacts on the regional (and ultimately global) environment. Rates of groundwater delivery to the surface appear to have significant effects on the nitrogen-removing capabilities of a riparian zone. Research conducted at this site, a first-order agricultural watershed with a well-defined riparian zone in the Maryland coastal plain, indicates that significant amounts of nitrogen can be exported under moderate-to-high stream baseflow conditions. The total nitrogen load that exits the system increases with increasing flow not simply because of the greater volume of water export. Stream water nitrate-N concentrations also increase as flow increases, at least during baseflow. This appears to be largely the result of changes in dominant groundwater delivery mechanisms. Higher rates of groundwater exfiltration lessen the contact time between nitrogen-carrying groundwater and potentially reducing riparian soils. Subsurface preferential flow paths, in the wetland and adjacent field, also strongly influence nitrogen removal. Simple assumptions regarding riparian zone function may be inadequate because of complexities observed in response to changing hydrologic conditions.

CAVIGELLI, M.A., and K. NICHOLS. USDA-ARS, Beltsville, MD 20705 USA.

Soil nitrogen and carbon pools after five years of till, no-till and organic cropping systems management: The USDA-ARS Farming Systems Project.

Recent reports from long-term cropping systems studies in the USA have shown that relying on legume forms of N can increase N and C retention and reduce the global warming potential of cropping systems relative to conventional tillage systems that rely on synthetic N fertilizer. Further improving legume cover crop management may provide even greater reductions in N losses from agricultural systems. We are using innovative cover crop management at the USDA-ARS Farming Systems Project in Beltsville, Maryland, a long-term study designed to assess the sustainability of cropping systems appropriate to the Mid-Atlantic region. At the FSP, seven field cropping systems were established in 1996, including till, no-till and organic systems that use various combinations of synthetic fertilizer, chicken manure, and legume sources of N. The cover crops (legumes and non-legumes) in the organic systems are not incorporated into the soil prior to planting the cash crop; instead, the cover crops are killed either by crushing or mowing. We hypothesize that these reduced tillage organic systems increase C and N retention relative to the synthetic till and no-till systems. We will present data collected to test this hypothesis and to begin investigating mechanisms responsible for soil N and C changes.

CRASWELL, E. T.[1], F. PENNING DE VRIES[1], P. DRECHSEL[2], and R. LEFROY[1]. [1]IBSRAM, PO Box 9-109, Jatujak, Bangkok 10900, Thailand; [2]IBSRAM African Regional Office, UST, Kumasi, Ghana.

Nutrient flows in agroecosystems in the tropics: The rural - urban divide.

In many developing countries, there is increasing nutrient mining in rural and peri-urban food production areas to feed the growing populations in urban centres, where at the other end of the spectrum, large amounts of nutrient accumulate. Reducing the treated disposal problems and environmental impact on one hand, and to re-cycle nutrients through composting on the other could result in a win-win situation for both municipal authorities and farmers, especially in urban and peri-urban areas. The paper reviews recent data from IBSRAM research in Asia and Africa that illustrate the scope of these problems: (a) nutrient overload in Bangkok indicated by re-cycling of only 7% of the N; (b) soil nutrient decline in rice farms of Northeast Thailand at the annual rate of 50 kg N/ha on some farms and; (c) the potential of co-composting for diverting N fluxes to peri-urban agriculture in Kumasi, Ghana. A framework for the economic assessment of nutrient decline is also reviewed. The framework shows that in the countries of Sub-Saharan Africa the costs of nutrient replacement in arable lands is an average of 7% of the agricultural gross domestic product (AGDP) for all countries, but ranges to as high as 18-25% for Niger.

DAS, D.K.[1], and A.M. PUSTE[2]. [1]Soil Science, B.C.K.V., Mohanpur-741252, Nadia, WB, India; [2]Agronomy, B.C.K.V., Mohanpur-741252, Nadia, WB, India.

Influence of different organic waste materials on the transformation of nitrogen in soils.

Various kinds of organic resource materials like crop residues, well decomposed cowdung, composts and other wastes of rural and urban areas are considered as immensely useful in enhancing soil fertility with simultaneous increase in crop productivity. It is evident that organic matter helps in building up plant nutrient status in soil, which depends upon the nature of the organic residues, because through various mineralization processes the plant nutrients like nitrogen, phosphorus etc. are added to the soil. Keeping these in view, the present investigation was undertaken to study the transformation of nitrogen as affected by the application of different organic waste materials to soils of the Indian Sub-tropics. The results showed that the amount of NH_4^+-N, NO_3-N, hydrolysable N (HLN) and non-hydrolysable (NHLN) were increased up to 60 days of soil submergence, being higher with the higher rate (1% by weight of soil) of organic residues application. Considering the effect of various organic waste materials, it was found that the amount of NH_4^+-N, NO_3-N, HLN and NHLN content were higher with the application of groundnut hull as compared to wheat straw and potato skin which may be due to narrow C:N ratio of groundnut (22.43) than that of wheat straw (62.84) and potato skin (71.32). However, the results showed that the release of NH_4^+-N, NO_3-N, HLN and NHLN were in the order of groundnut hull > wheat straw > potato skin.

FRANZLUEBBERS, A.J., and J.A. STUEDEMANN. USDA-ARS, Watkinsville, GA 30677 USA.

Soil nitrogen pools under bermudagrass management in the Southern Piedmont USA.

An appropriate and economic supply of N is essential for developing and maintaining the productivity of grasslands on the weathered soils of the warm, humid southeastern USA. We evaluated the factorial combination of three N fertilization sources (i.e., inorganic only, crimson clover cover crop + inorganic, and broiler litter all applied at an equivalent of 200 kg N/ha/yr) and four harvest strategies (i.e., unharvested, low and high cattle grazing pressure, and haying) on total, particulate, and potentially mineralizable soil organic N accumulation and soil inorganic N depth distribution during the first five years of Coastal bermudagrass [*Cynodon dactylon* (L.) Pers.] management. With cattle grazing of forage, fertilizer applications contributed to forage and animal production and 30-50% of the total N applied was subsequently stored as soil organic N. Increases in particulate organic N indicate the development of a large pool of biologically active soil organic N. Inorganic soil N was primarily limited to the surface soil where grass roots are most active with little indication of leaching beyond 1 m soil depth. Consequences of N fertilization and harvest strategies on plant and animal productivity and environmental quality will be discussed.

HERDMAN, W.R., and **J.A. HOUNTIN**. The Rodale Institute, Kutztown, PA 19530 USA.

Increased microbial biomass C and N in regenerative agro-ecosystems in Southeast Pennsylvania.

Microbial biomass carbon (MBC) and nitrogen (MBN) constitute a large part of active soil organic matter and the nutrient sink in agro-ecosystems. An experiment was carried out in Rodale Institute's Compost Utilization Trial (CUT) to evaluate changes in MBC and MBN as affected by rotation, crop and fertilizer types. Since 1993, several composts, fresh manure and chemical fertilizer were applied to corn, peppers and wheat in rotation. In 1997 and 1998, twenty soil cores (0-20cm) were taken from these experimental plots. The MBC and MBN were measured using the CHC_{13}-fumigation-extraction method. Over this one year period, MBC increased by 1.75 gC/kg. Fertilizer source and crop type significantly affected MBC and MBN ($p<0.0001$) whereas rotation only affected MBC ($p<0.001$). In compost treated plots, the level of MBC was 12.83 gC/kg and that of MBN was 2.38 gN/kg, compared to levels of 11.27 gC/kg and 2.08 gN/kgfor manure and 10.72 gC/kg and 1.87 gN/kg for chemical fertilizer. Increases in MBC and MBN in legume/corn were consistently greater than other crops. Results from this study suggest that compost application and use of cover crops can increase C and N sequestration into microbial biomass of low put agriculture systems on short-term basis.

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Nitrogen use and carbon sequestered by corn rotations in the northern Corn Belt, USA.

Diversified crop rotation may improve production efficiency and reduce fertilizer N requirements for corn (*Zea mays*_L.). Objectives were to determine effect of rotation and fertilizer N on soil carbon sequestration and N use efficiency. Experiments started in 1990 on a clay loam soil near Brookings, SD. Rotations were: corn (CC), corn-soybean [*Glycine max* (L.) Merr.] (CS), and corn-soybean-wheat (*Triticum aestivum* L.) companion seeded with alfalfa (*Medicago sativa* L.)-alfalfa hay (CSWA). N treatment for corn were: corn fertilized for a grain yield of 8.5 Mg/ha (highN), 5.3 Mg/ha (midN), and no N fertilizer (noN). Total (1990-2000) corn yield was not different among rotations at 80.8 Mg/ha under highN. Total inorganic N used by corn was 2 Mg/ha under high N.

Production differences among rotations increased with decreased fertilizer N. Total corn yield under no N fertilizer was 69 Mg/ha under CSWA, 53 Mg/ha under CS, and 35 Mg/ha under CC. Total N attributed to rotation (noN treatments) was 0.68 Mg/ha under CSWA, 0.61 Mg/ha under CS, and 0.28 Mg/ha under CC. After 10 years, 6% of 30 Mg/ha plant carbon under CC (highN) was retained in soil. Diversified rotations have potential to increase N use efficiency and reduce fertilizer N input for corn.

SUTTON, A.R. Agrotain International LLC, Corydon, KY 42406 USA.
Stabilized nitrogen, improving nitrogen efficiency.
Nitrogen is the element that most often limits crop yields and profits. The benefits of nitrogen fertilization in pounds, bushels and dollars over the past 50 years have been most impressive. However a challenge remains to manage nitrogen fertilizer to achieve greater efficiency. A crop's nitrogen utilization can be improved by the use of "Best Management Practices" including nitrification and urease inhibitors. Research indicates that first-year crop uptake efficiencies can be significantly increased. This translates to higher yields and profits per pound of nitrogen applied. It also means an environmentally safer use of nitrogen fertilizer because less nitrogen is exposed to loss. No other nutrient offers greater benefits from wise use and management than nitrogen. Two methods are available to achieve this goal, enhanced nitrogen feeding and minimizing nitrogen loss.

Poster Session #15: ***Forests, Nitrogen and Surface Waters.***

HIDEHARU, H.[1], T. KAWAKAMI[2], H. YASUDA[3], and I. MAEHARA[4]. [1]Toyama Science Museum, Toyama-city 939-8084, Japan; [2]Toyama Prefectural University, Toyama 939-0398, Japan; [3]Toyama Forestry & Forest Products Research Center, Toyama 930-1362, Japan; [4]Toyama University, Toyama 930-8555, Japan.
Nitrate leakage from deciduous forest soils into streams on Kureha Hill, Japan.
Nitrate leakage from deciduous forest soils into streams was investigated for two adjacent hills. Many of the streams on Kureha Hill, located in Toyama City, Japan, have extremely high nitrate concentrations. The nitrate concentration of Hyakumakidani, one of the streams on Kureha Hill, averaged 154 meq/l and reached 470 meq/l during an episodic event. In contrast, the streams on Imizu Hill, adjacent to Kureha Hill, had low concentrations, below 10 meq/l. Even during an episode, the nitrate concentrations increased to no more than 75 meq/l. Both areas have similar brown forest soils, C/N ratios ranging from 16 to 20, and vegetation consisting primarily of deciduous trees. However, soil incubation experiments, which lasted for four weeks, revealed that the nitrification rates in the surface soils of Kureha Hill were much higher than in the soils of Imizu Hill.

ITO, M.[1], M. J. MITCHELL[1], C. T. DRISCOLL[2], W. KRETSER[3], and K. ROY[3]. [1]State University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210 USA; [2]Syracuse University, Syracuse, NY 13210 USA; [3]Adirondack Lakes Survey Corporation
Nitrogen input and output in the Adirondack Lake-Watershed.
In the Adirondack region of New York, soils and surface waters have been found to be highly sensitive to acidic deposition. The emissions of sulfur dioxide have been decreased since 1973 after the 1970 Amendments to the Clean Air Act, while the emissions of nitrogen oxide have essentially remained unchanged since 1980. Our estimation over the Adirondack region suggested an increasing pattern of wet deposition of nitrate from the northeast to the southwest and with elevation. Assessment of N deposition and the N input and N drainage loss from lake-watersheds as the N output in this region quantifies the extent of the impact of N deposition in the region. In the present analysis, the N input and output in Adirondack Long-Term Monitoring (ALTM) lakes were estimated, using the empirical models developed to predict precipitation quantity and the concentrations of nitrate and ammonium, the estimated discharge S from the ALTM lake-watersheds, and the lake concentrations of nitrate, ammonium, and dissolved organic nitrogen. Nitrogen retention was calculated as the difference between the N input and output. These results will be used to describe the spatial patterns of N loss and retention in the Adirondacks.

KAWAKAMI, T., Y. MATSUDA, H. HONOKI, and H. YASUDA. Toyama Prefectural University, Toyama 939-0398, Japan.
Leaching of nitrate from surface soils into streams on Kureha Hill, Japan.
Many streams on Kureha Hill, Toyama, Japan, are believed to suffer from nitrogen saturation because of their extremely high nitrate concentrations. Some streams contain average nitrate concentrations of more than 150 meq/l. Soil cores of the A horizon and the B horizon taken from a deciduous forest watershed on Kureha Hill were incubated for 232 days and 101 days, respectively. To simulate rainfalls containing enhanced nitrogen concentrations, NH_4Cl solutions with 5- or 10-fold nitrogen concentrations of rainwater were dropped into the cores during incubation. All the nitrogen in the drainage water from both cores was found to be in nitrate forms, indicating that the nitrifiers oxidized nitrate compounds to nitrates under pH levels as low as 4.2. The nitrate concentrations of drainage water (900 meq/l) from the A horizon core were much higher than those of the NH_4Cl solution (162 meq/l), while the nitrate concentrations of drainage water from the B horizon core were nearly equal to those of the NH_4Cl solution. These results indicate that most of the nitrate contained in the stream water originated in the A horizon and was not absorbed in the lower layer. The results were consistent with those of model calculations simulating the flow-path in the watershed.

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Nitrogen export in polluted semi-arid mountainous catchments.

The mountains of southern California receive among the highest rates of N deposition in the world (~40 kg/ha/yr). These high rates of deposition have translated into consistently high levels of inorganic nitrogen export in some streams of the San Bernadino Mountains. However, not all streams are exhibiting these high levels of export. Perennial streams have high inorganic export while ephemeral streams do not. This difference points to groundwater as the source of the nitrate observed in streams. Furthermore the evidence indicates a decoupling of the impact of N deposition on terrestrial and aquatic systems in Mediterranean climates. The primary reason for the decoupling involves the asynchrony between when atmospheric deposition occurs (summer), the time period of maximum soil nitrate availability and leaching (winter), and the time of maximum plant N demand (spring). Our results indicate that semi-arid Mediterranean climate systems behave differently from more humid systems because of this asynchrony. These differences lead us to the conclusion that the extrapolation of impacts from humid to Mediterranean climates is hazardous and the concept of N saturation may need to be revisited for semi-arid systems.

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Patterns of nitrogen availability in Appalachian forests receiving high inputs of atmospheric nitrogen.

Forested watersheds receiving high inputs of atmospheric nitrogen exhibit variable losses of nitrogen in stream water at both coarse and fine spatial scales. Many factors may contribute to this variability in nitrogen retention. These factors include land-use history, stand age, climate, geology, soils, insect defoliation, and species composition. Forested watersheds in the Fernow Experimental Forest allow us to examine the importance of a narrower range of variables because the watersheds differ significantly in stream-water nitrogen losses despite their close proximity to each other, the lack of significant insect defoliation, and their similarity in land-use history, stand age, and geology. In the watersheds examined, higher rates of nitrate leaching were associated with greater rates of potential net nitrate production (NNP). NNP, in turn, was associated with the pH (r=0.75), C:N ratio (r=-0.70), and exchangeable Ca (r=0.63) in surface soils. Significant correlations also existed between NNP an the importance values of sugar maple (r=0.64) and chestnut oak (r=-0.45). Our results are consistent with the idea that tree species may indirectly account for variable N retention through their affect on soil properties. If true, then forests containing certain species may be more resistant than others to nitrogen saturation.

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Regional comparative study on nitrogen export to Japanese forested streams.

Nitrogen emission in Asian countries will grow during this decade. The assessment of the mechanisms of temporal and spatial gradient of nitrogen export to forested streams was very important in quantifying not only the critical load of nitrogen saturation and soil acidification but also to estimate the carbon dynamics in forested watersheds. The lack of comparable regional studies of stream nitrogen chemistry makes the current status of the nitrogen cycling and budget in Japanese forested watersheds still under debate. We measured the stream nitrogen chemistry at 18 experimental forests belonging to the Japanese Union of University Forests, broadly distributed from Hokkaido to Kyushu Islands in the Japanese archipelago. Nitrogen concentration in stream water at the base and high flow period was observed on an annual basis and nitrogen mineralization potential in soil was measured using the batch incubation experiments. We will present the current regional pattern of nitrogen concentration in Japanese stream water and discuss the cause of the spatial gradient, especially for the higher nitrate concentrations in the central mountainous region in Japan.

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Ecosystem processes and watershed nitrogen export in U.S. National Parks.

There is much interest in the relationship of atmospheric nitrogen (N) inputs to ecosystem outputs as an indicator of possible "nitrogen saturation" by human activity. Longer-term, ecosystem-level mass balance studies in the U.S. suggest the relationship is not clear, and that other ecosystem processes may dominate variation in outputs. We have been studying small-forested watershed ecosystems in seven U.S. National Parks for up to 20+ years. Wet precipitation N inputs to this network of sites ranges from <0.3 to 30 kg N/ha/yr. The sites are paired: high precipitation amounts with low and high N inputs, cold (Arctic treeline) and warm desert, east and west slope of Central Rocky Mountains. In general, sites with the lowest N inputs have the highest output/input ratios. The ratio of mean monthly headwater nitrate concentration to precipitation nitrate concentration declines with increased precipitation concentration. We have studied a series of ecosystem processes and related them to seasonal N outputs. The most important appear to be seasonal change in hydrologic flowpath, soil freezing, seasonal inorganic N pools resulting from over-winter mineralization beneath the snowpack, spatial variation in inorganic N pools, the degree to which snowmelt percolates soils, and gross soil N cycling rates.

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Long-term nitrogen dynamics of Coweeta forested watersheds in the Southeastern USA.

Long term data (25 yrs) were analyzed for trends and dynamics of NO_3 and NH_4 deposition and loss for mature mixed hardwood forest stands. Watershed N saturation was evaluated in the context of altered N cycles and stream inorganic N responses associated with management practices (cutting prescriptions, species replacement and prescribed burning) and with natural disturbances (drought and wet years, insect infestation, hurricane damage, and ozone episodes). Reference watersheds were highly retentive of inorganic N with deposition of < 9.9 kg/ha/yr and stream water exports below 0.25 kg/ha/yr. Reference watersheds were in transition between stage 0 and stage 1 of watershed N saturation as evidenced by significant time trend increases in annual flow-weighted concentrations of NO_3 in stream water and increases in the seasonal amplitude and duration of NO_3 concentrations during 1972-1994. These stream water chemistry trends were partially attributed to significant increases in NO_3 and NH_4 concentrations in bulk precipitation over the same period and/ or reduced biological demand due to forest maturation. Evidence for stage 3 of N saturation (the watershed is a net source of N rather than a N sink) was found for the most disturbed watershed at Coweeta.

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Establishing links between deposition, transformation and export of nitrogen in a forested catchment in the southern Appalachians.

The high-elevation red spruce-Fraser fir forest (*Picea rubens* Sarg./ *Abies fraseri* (Pursh.) Poir] of the southern Appalachians is nitrogen (N) saturated as a result of high N atmospheric deposition (~27 kg/ha/yr) and low N retention within the ecosystem. In the Noland Divide Watershed, a headwater catchment in the Great Smoky Mountains National Park, N saturation is indicated by high stream export of nitrate-N (~40 kg/ha/yr), where base flow concentrations of nitrate-N remain constant at 2.5 mg/L and park concentrations are variable, reaching 4.5 mg/L in the autumn. The imbalance in the annual N budget requires examination of the factors regulating N source areas and their spatial and temporal variability within the catchment. N source areas are dynamic and the proximity of these areas to either surface or near surface hydrologic pathways that are connected to the outlet will influence stream N export. Using a distributed model, we simulate the formation of N source areas from input, output and internal N dynamics (net soil mineralization and nitrification rates; fine and coarse woody debris N retention/release rates; plant N uptake) and the mobilization of these N sources by coupling biogeochemical and hydrologic processes at daily to decadal time scales.

Poster Session #18: **Policy responses to increased environmental N.**

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Risks and benefits of nitrogen in forest ecosystems - Research in Sweden.

ASTA and SUFOR are two research programmes in Sweden dealing with “International and National Abatement Strategies for Transboundary Air Pollution” (ASTA) and “Sustainable Forestry in Southern Sweden” (SUFOR). Parts of the programmes are overlapping, which has lead to extensive cooperation. Nitrogen processes in forest soils is a field that fits into both ASTA and SUFOR. However, the aims for the programmes are somewhat different. Within ASTA, the aim is to develop new methods to set critical loads of nitrogen in Sweden. The aim for SUFOR is more related to forestry management methods that lead to a sustainable forestry, without nitrogen leakage and other environmental disturbances. At this conference, ASTA and SUFOR have presentations on the following issues: (1) Development of a new model, FORSAFE, that connects carbon, nitrogen and soil chemistry. The model can be used to predict carbon and nitrogen cycling as well as forest growth with different climate and air pollution scenarios. (2) Using the FORSAFE model to model carbon and nitrogen cycling between 1450 and 2050. (3) Predicting effects of harvest of biofuels in managed forests. (4) Calculations of nitrogen leakage from clearcuts on a local administrative region level. (5)Recovery of a boreal forest ecosystem when the nitrogen input is decreased. (6) The need to include trophic interactions when assessing the impact of nitrogen input. (7)Plant uptake and use of organic nitrogen.

BULL, K.R. UN/ECE, Palais des Nations, CH-1211 Geneva 10, Switzerland.

The Convention on Long-Range Transboundary Air Pollution.

The Convention on Long-range Transboundary Air Pollution was adopted in Geneva in 1979. It lays down general principles for international cooperation on air pollution abatement, and sets up an institutional framework associating research and policy. The Convention has been extended by eight specific protocols; five have already entered into force. Two protocols specifically address the problems of atmospheric nitrogen pollutants. Recent protocols have focused increasingly upon effects and used effects-based mechanisms for defining national emission ceilings. The bodies of the Convention reflect this with scientific groups and negotiating bodies creating the necessary science-policy link. Science is based upon the output of national centers, collated and analyzed by international coordinating centers, as directed by scientific task forces. The Convention now has 48 Parties including the European Community, the United States and Canada, and there are few countries in the ECE region that are not Parties or Signatories. The success of the Convention is evident through the decreases of emissions of sulphur throughout Europe and North America, and the halt in the increase of nitrogen oxide emissions despite large increases in the numbers of motor vehicles. Future challenges will be for instruments with more ambitious pollution controls but still linked to sound science.

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Nitrogen in the environment: Sources, problems, and management.

Nitrogen is applied Worldwide to produce food. It is in the atmosphere, soil, and water and is essential to all life. Nitrogen can be transformed into soluble and/or gaseous forms that pollute water resources, cause greenhouse effects, and are transported immense distances. Nitrogen for agriculture includes fertilizer-, biologically fixed-, manure-, recycling crop residue-, and soil mineralized-N. Presently fertilizer N is a major source of N and animal manure N is inefficiently used. Potential environmental impacts of N excreted by humans are increasing rapidly with increasing World Populations. Where needed, N must be efficiently used. Unfortunately, increased amounts of gaseous N enter the environment as N_2O to cause greenhouse warming and as NH_3 results in shifts in ecological balances of natural ecosystems. Huge amounts of soluble N, as runoff or leachate, enter streams, rivers, and groundwater and include large amounts of N displaced with eroded sediments. High-nitrate drinking water can cause methemoglobinemia, while nitrosamines are associated with various human cancers. Nitrogen is ubiquitous, it has numerous essential benefits, and it is essential to life. We describe the benefits and how N in the wrong form or place results in harmful effects on humans and animals and to ecological and environmental systems.

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Variations in the spatial distribution of present and future levels of nitrogen concentrations and depositions in Europe.

Levels of nitrogen pollution in the atmosphere and its deposition are calculated for future (2010 and 2020) emission scenarios based on Current Reduction Plans (CRP) and Maximum Feasible Reductions (MFR). The calculations have been made with the EMEP Eulerian model, using emission data officially submitted by European countries. From 1990 to 1998 emissions of sulphur were reduced in Europe by approximately 50%, while the reductions for NO_x and NH_3 were 21% and 14% respectively (Vestreng and Støren 2000). Because the magnitude of the emission reductions varies considerably between countries, changes in the deposition and concentration patterns have been found. Future reductions in these emission values are also expected to show considerable spatial variations, mainly between eastern and western European countries. In addition, the different emission reduction rates for sulphur and nitrogen influence the chemical composition of the European atmosphere. In particular, the relative formation of ammonium sulphate and bisulphate versus ammonium nitrate will be altered. This paper presents a separate analysis of (a) the spatial differences in emission reductions and (b) the changes in the chemical composition of the atmosphere, and how these affect the future deposition levels of nitrogen in Europe. An evaluation of the predicted distribution of ecosystem areas affected by eutrophication and also acidification in Europe will also be presented.

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Temporal changes in nitrogen pollution in North-Eastern Estonia.

During the last five decades since 1950, the area of north-eastern Estonia (the main region of local oil shale and chemical industry) has been affected by acidic pollutants. In 1960–1988 a yearly mean N deposition load within the ranges of 6.6–11 kg ha-1 (up to 44 kg ha-1 near chemical plants) was registered. This nitrogen pollution level combined with a simultaneous load of sulphur (20–200 kg ha-1yr-1) can seriously endanger nature. For NE Estonia the following critical pollution loads have been established (kg ha-1yr-1): $CL_{min}(N)=4.9$; $CL_{max}(N)=67$ and $CL_{max}(S)=33$. Only the simultaneous presence of a strongly alkaline oil shale fly ash in emissions and atmospheric air has prevented acidification processes and sheer alkalisation in NE Estonia. Since 1989 the general pollution situation has changed. Since 1994–1996 the N load in Kohtla-Jarve and Johvi region remained within the range of 2.6–6.6 kg ha-1yr-1 and S 2–50 kg ha-1yr-1. Because the fly ash deposition has also shown a tendency to decrease, more sensitive plants can be subjected to critical N+S loads in future. The share of north-eastern region in total emission of NO_x in Estonia equals approximately 75–77%. During 1990–1999 the yearly mean concentration of NO2 in the air of towns increased from 9–15 µg m-3 to 18–28 µg m-3 and the short-term maximum values reached 70–800 µg m-3. The ratio of NO_2/NO in the air was approximately 1:1-1.2. The emission of N-compounds was mainly caused by NO_x in fly gasses from power plants, as well as ammonia and carbamide discharges from chemical plants. In 1990–1991 the yearly emission of NO_x about 16–18 thousand tons and in 1994–1999 about 9.7–11 thousand tons were determined.

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Derivation and mapping of critical loads for nitrogen and trends in their exceedance in Germany.

Critical loads define the thresholds of deposited pollutants which lead to harmful effects on sensitive elements of the environment. Both oxidised and reduced nitrogen compounds contribute to the total deposition of acidity which exceeds critical loads in many forest ecosystems and have negative effects caused by eutrophication. Critical loads of nitrogen were derived for forest soils (deciduous and coniferous forest), natural grassland, acid fens, heathland and mesotrophic peat bogs. In Germany, a decrease in sulphur emissions over the past 15 years resulted in a reduced exceedance of critical loads for acid deposition. Mapping indicated that reduced emissions of nitrogen oxides and ammonia remained insignificant. Emissions of nitrogen compounds become relatively more important as sulphur emissions decreased. This decrease in the extent of exceedance is mainly due to a substantial reduction in sulphur emissions. However, emissions of nitrogen oxides and ammonia will continue to threaten ecosystem function and stability. The risk for environmental damage remains at an unacceptable level. Critical load exceedance maps for Germany present current developments and the expected future trend. Dynamic modeling is capable of demonstrating trends over *10 years* or more. Our models show that recovery from pollutant stress occurs only gradually.

Poster Session #19: *Interactions of Carbon and Nitrogen at Regional and Global Scales.*

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Global distribution of acidifying deposition and a simple model for terrestrial ecosystem acidification.

Emissions of SO_x, NO_y and NH_x are increasing in many regions of the world and in several areas little is known about the current deposition of acidic or alkaline compounds and their effects. The work presented describes the use of current chemistry/transport models of the atmospheric cycles of S, N and Ca to estimate the global distribution of oxidised S, oxidised and reduced N and calcium deposition, together with precipitation pH. A simple model linking deposition and soil data to estimate the time development of soil acidification in terrestrial ecosystems is also presented. The model incorporated three scenarios for the fate of deposited N: a) no nitrate leaches; b) 33% of N-input leaches; and c) all N-input leaches. In agreement with observations, the results show that currently, outside of Europe and North America, the most acidic deposition occurs in SW China. According to the model, high ammonium deposition in parts of Asia (e.g. northeastern India) has the potential to contribute to soil acidification if ecosystems are N saturated and leach nitrate. It is estimated that if the current rates of deposition remain then sensitive soils in China, India and Malaysia may lose base cations down to 15% base saturation in as little as 25 to 100 years.

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Redistribution of N in response to warming.

Nitrogen cycling was studied in a heath-land ecosystem in Denmark, which has been subjected to nighttime warming by reducing the loss of IR radiation at night. Carbon and nitrogen pools in plants, microbes and soil, throughfall, net mineralization, microbial immobilization and soil water chemistry were monitored in control and heated plots. Responses in net N mineralization and allocation of C and N by plants and microbes were compared with similar data sets from other European climate change experiments in shrub communities. In general it showed that net mineralization measured by the buried bag method was low and far from plant uptake requirements. During the incubation in buried bags, but not outside in the field, the microorganisms immobilize substantial amount of nutrients. The results indicate that plants compete well with microorganisms for nutrients. The poster will present a nitrogen budget for the heath ecosystem and discuss how enhanced temperature affects nitrogen cycling. Furthermore, the poster will discuss the resource partitioning between plants and microbes in response to warming.

SVERDRUP, H. Lund University, 221 00 Lund, Sweden.

The mechanisms included to couple effects of climate change, transboundary air pollution and forest growth on nitrogen cycling in the sustainability assessment model FORSAFE.

A new model tool for joint assessment of climate change and transboundary pollution effects has been developed. The FORSAFE model combines a mechanistic carbon cycle model (DECOMP) with a nitrogen model (PnET) and a soil chemistry model (SAFE). Strong feedback links between soil solution pH, cation concentrations, nitrogen concentrations and the soil organic matter decomposition rate, affect the cycling of carbon, nitrogen and forest growth in the model. The feedbacks incorporated into DECOMP were parameterized on laboratory data and field data taken from a transect going from Northern Sweden to Portugal, spanning a variation in climate and pollution. The feedback from soil water and temperature has been carried to all carbon, nitrogen and acidity transformation processes. The new model shows dynamic patterns that cannot be reproduced with conventional single-problem-models for C-, N- or acidity cycling. The carbon cycle as described by the model affects nitrogen cycling, in turn affecting carbon sequestration and forest growth, as well as the rate of cycling is affected by the future hydrological, climatic and sulphur and nitrogen deposition change scenario adopted. The model yields predictions for evolution of soil chemistry, carbon sequestration, nitrogen immobilization, denitrification, climate gas emissions and forest growth.

WHITALL, D.R.[1], C.T. DRISCOLL[2], J.D. ABER[3], C.S. CRONAN[4], M.S. CASTRO[5,] P.M. GROFFMAN[6], C.HOPKINSON[7], G.B. LAWRENCE[8], and S.V. OLLINGER[3]. [1]Hubbard Brook Research Foundation, Hanover, NH 03755 USA; [2]Syracuse University, Syracuse, NY 13244 USA; [3]University of New Hampshire, Durham, NH 03824 USA; [4]University of Maine, Orono, ME 04469 USA; [5]Appalachian Laboratory, Frostburg, MD 21532 USA; [6]Institute of Ecosystem Studies, Millbrook, NY 12545 USA; [7]Marine Biological Laboratory, Woods Hole, MA 02543 USA; [8]U.S. Geological Survey, Troy, NY 12180 USA.

Inputs of nitrogen and effects on air, terrestrial, aquatic and coastal resources of the northeastern US.

In this study we present a synthesis of inputs, effects and management of nitrogen for the northeastern U.S. For this analysis we utilize many data sets compiled from across the region. The northeastern U.S. generally receives anthropogenically-elevated inputs of nitrogen largely from net imports of food and atmospheric deposition. Other inputs of nitrogen such as net feed imports, nitrogen fixation associated with legumous crops and fertilization generally are lower for the region. Emissions of nitrogen oxides to the source area for the Northeast have remained essentially constant since 1980. Atmospheric deposition of nitrate is similarly elevated and has been constant since the 1970s. Likewise, there are no trends in atmospheric ammonium deposition. Elevated inputs of nitrogen from net food import is readily transported to surface waters via wastewater discharge, and exported from northeastern watersheds. Consequences of elevated nitrogen inputs to the Northeast include: enrichment of nitrogen pools in forest soils and increases in nitrogen cycling, impacts on forest vegetation, increases in nitrous oxide production and decreases in methane consumption from forest soils, elevated leaching losses of nitrate in streams and rivers, and eutrophication of coastal areas. Biogeochemical models are used to evaluate options for nitrogen management.

ACKNOWLEDGEMENTS

No major gathering is possible without the dedication and hard work of scores of people – often behind the scenes – whose individual contributions and efforts combine to make the meeting happen. The Second International Nitrogen Conference is no exception. We are indebted to many individuals and organizations. The Organizers and Sponsors are listed in the front of this Meeting Program. Those who are acknowledged on this page have also shared in the work of conference organization or implementation and have brought their unique talents and their professionalism and enthusiasm to this important project. We thank you all!

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Dr. Martyn Goldman
US Holocaust Museum

N2001 Banquet Entertainment
The Bill Elliott Trio
Walkersville, Maryland

Harvest Barbecue Entertainment
Alexander's Reel-Time Band
Alexander Mitchell – fiddle, mandolin, guitar
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