Earth System Science

Outline

- Where have we been?
- Were are we now?
- Where do we want to go?
- How will we get there?

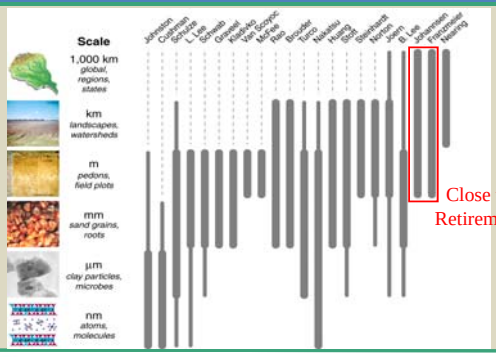
Mission

- The mission of the Earth System Science group is to address significant societal needs by offering innovative and relevant teaching, research, and outreach programs in the soil, hydrologic, atmospheric, earth observation, and environmental sciences, in collaboration with public and private partners.

Where We Were in 2002

- Soil and Environmental Sciences
  - 24 faculty, 4 A/P staff
  - referred to ourselves as the ***Soils Group***
- Areas of activity
  - *Environmental Fate and Transport Processes of Chemicals*
  - *Soil-Plant Interactions*
  - *Land Use and Landscape Processes*

Length Scales that Characterized Our Work in 2002



Where We Wanted to Be in 2002

- Focus Areas:
  1. Develop intellectual resources to address major ecological and environmental concerns
  2. Obtain state-of-the-art equipment and technologies for conducting progressive research
  3. Enhance linkages within the department and across campus
  4. Enhance soils education and outreach

Where We Wanted to Be in 2002

- Develop intellectual resources
  - Evolutionary Geomorphologist (Pedologist)
  - Earth Observation and Landscape Characterization
  - Soil Nutrient Management and Soil-Crop Modeling
  - Watershed Hydrologist
  - Biogeochemist

Where We Are in 2009

- Develop intellectual resources
  - Evolutionary Geomorphologist (Pedologist)
    - Phillip Owens
  - Earth Observation and Landscape Characterization
    - Melba Crawford
  - Soil Nutrient Management and Soil-Crop Modeling
    - Jim Camberato
  - Watershed Hydrologist
    - Laura Bowling
  - Biogeochemist
    - Qianlai Zhuang, Kevin Gurney
  - Climatology
    - Dev Niyogi

Where We Wanted to Be in 2002

- Obtain state-of-the-art equipment

Where We Are in 2009

- Obtain state-of-the-art equipment

Equipment or facility	Year	Cost
PANalytical X'Pert Pro MPD Powder X-ray Diffractometer	2004	$160,000
ICP Mass Spectrometer	2007	140,000
Liquid Chromatography Mass Spectrometer	2004	400,000
SEAL Analytical Autoi		60,000
CN Analyzer (co-purchased with Animal Sciences)		
Mettler-Toledo Thermogravimetric Analyzer	2008	30,000
Mettler-Toledo Differential Scanning Calorimeter	2007	40,000
SeaSpace TeraScan 3.7m L-Band GEO receiving station	2005	
SeaSpace TeraScan 10 node Clust	2005	
SeaSpace TeraScan AXYOM 4.5m with 5.5m radome on 9m tower	2005	
CO2 Eddy Covariance Equipment	2006	25,000
GC/MS QP-20010 EI/PCI	2007	66,000
6 Tuneable Diode Laser Spectrometer s	2007	400,000
Photoacoustic Spectrometer	2007	46,000
3 Instrumented Trailers for gas exchange measurements	2007	240,000
Water Quality Field Station repairs and upgrades	ongoing	120,000

Soil Chemistry and Mineralogy

Satellite Downlink

Air Quality

Where We Wanted to Be in 2002

- Enhance linkages within the department and across campus

Where We Are in 2009

- Enhance linkages within the department and across campus
  - *major strides*
    - *joint appointments in other departments*
      - *Crawford (Civil Engineering)*
      - *Niyogi, Zhuang, Gurney (Earth & Atmospheric Sciences)*
    - *Center for the Environment – Discovery Park*
      - *Linda Lee, Associate Director*
      - *23 faculty affiliates from Agronomy*
    - *Purdue Climate Change Research Center*
      - *8 faculty affiliates from Agronomy*
    - *ongoing discussions within department*

Where We Wanted to Be in 2002

- Enhance soils education and outreach
  - *discussed in education presentation*

Where Are We Now?

- Discussions last spring
  - *Soils Group*
  - *Earth Systems Group*
- General consensus for one group
  - *Earth System Science*
- Who are we now?
  - Discipline areas
  - Scales
  - Problem Areas

Discipline Areas

● = primary focus • = secondary focus	Beyrouty	Bowling	Brouder	Camberato	Crawford	Grant	Gravenil	Gumy	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee *	L. Lee	Nakatsu	Nyvgi	Nurton	Owens	Pagnas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
Soil Chemistry	●										•	●	•					●			•			●	●	●			●	•
Soil Biogeochemistry												●			•									●						●
Environmental Chemistry															●															
Soil Mineralogy											•	●		●				•					●					●		
Soil Microbiology							●									●												•	●	
Soil Physics									●	•				●	•				•	•	•									•
Pedology														●				•	●				●			●			•	
Soil Fertility	●		●	●							●							•						●					●	
Soil Remediation / Environmental							●																•							
Soil Erosion							•			●								●		●										
Soil and Water Conservation							•			•										●										
Soil Management / Conservation			●				•							●												●				
Hydrology		●			•					•				•				•	•		•					●				•
Land Surface Modeling							●		•									●												
Remote Sensing		•			●	●				•								•				●				•				•
GIS		•			•					•				•				•				●	•							
Climatology		●			•	•		•										●												
Atmospheric Biogeochemistry			•			●		●																						
Nanotechnology														•																

* left the university

Most of us identify with several discipline areas.

Discipline Areas Summary

Discipline Area	Total Responses
Soil Chemistry	●●●●●●●●•••
Soil Biogeochemistry	●●●●••
Environmental Chemistry	●
Soil Mineralogy	●●●●••
Soil Microbiology	●●●•
Soil Physics	●●•••••
Pedology	●●●●••
Soil Fertility	●●●●●●•
Soil Remediation / Environmental	●•
Soil Erosion	●●●•
Soil and Water Conservation	●••
Soil Management / Conservation	●●●•
Hydrology	●●●•••••••
Land Surface Modeling	●•
Remote Sensing	●●●•••••
GIS	●•••••••
Climatology	●●•••
Atmospheric Biogeochemistry	●●•
Nanotechnology	•

Our disciplinary coverage is both deep and wide.

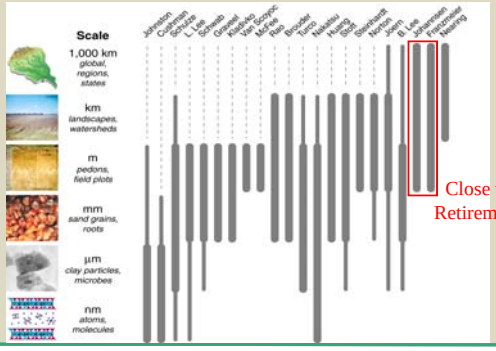
Length Scales that Characterize our Work

● = major focus • = secondary focus	Beyrouty	Bowling	Brouder	Camberato	Crawford	Grant	Gravenil	Gumy	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Nyvgi	Nurton	Owens	Pagnas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
1,000 km global, regions, states		●			●			●	•	•	•						●		•		●	●	•							●
kilometers landscapes, watersheds		●	●	●	●	●		•	●	●	●	•	•	•	•		•	●	●	●	•	•	•		●		●		●	•
meters pedons, field plots	●	•	●	•	•	●			•	●	●	●	●	●	●			•	●	•	•		●	●	●	●	●		●	•
millimeters sand grains, roots	●		●			•				•	•	●		●	•			•	•	•				•	•	•				
micrometers clay particles, microbes							•	●			●	●		●	●	●		•	•				●		•		•		●	●
nanometers atoms, molecules												●			•	•		•					•				•		●	

Scale	Total Responses
1,000 km global, regions, states	●●●●●●●•••••
kilometers landscapes, watersheds	●●●●●●●●●●●●●●●•••••••••
meters pedons, field plots	●●●●●●●●●●●●●●●●●●●●●•••••••••
millimeters sand grains, roots	●●●●•••••••••
micrometers clay particles, microbes	●●●●●●●●●●•••••
nanometers atoms, molecules	●●••••••

New strengths at larger scales.

Length Scales that Characterized Our Work in 2002



Programmatic Themes of the Earth System Science Group

- Anthropogenic Contaminants
- Greenhouse Gasses
- Land Use / Sustainability
- N, P, or K in Water and Soils
- Soil Management
- Watershed Hydrology
- Others

Where Are We Now?

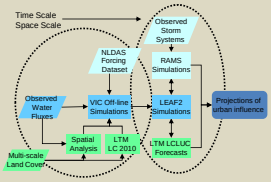
Highlights of a Few Programs

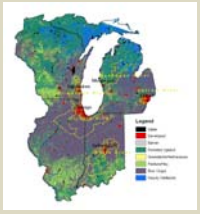
Multisensor / Multiscale Assessment of Urban Impacts in the Great Lakes Region

Laura Bowling and Dev Niyogi

Study the interactions between Land Cover Land Use Change (LCLUC), weather, and surface hydrology, with a focus on the impacts of urbanization within the Upper Great Lakes region.

- spatial analysis
- LCLUC modeling
- historic hydrology modeling experiments
- regional land-atmosphere interaction experiments



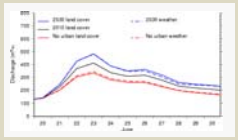


Funding:
NASA Land Cover / Land Use Change Program
Collaborators:
- Dept. of Agronomy: Bowling & Niyogi
- Earth & Atm Science: Niyogi
- Forest. & Nat. Res.: Pijanowski & Ray
- Dept. Ag. and Bio. Eng.: Cherkauer

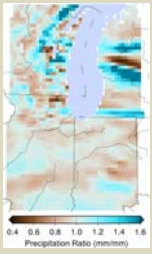
Multisensor / Multiscale Assessment of Urban Impacts in the Great Lakes Region

Major findings based on future projections:

- Residential land use will increase 30% and commercial land use will increase by 91% from 2010 and 2030.
- On average, simulated storm event precipitation is slightly greater in 2030, but spatially varies from 43 to 226% of 2010 values.
- The relative influence of infiltration reduction (through increasing impervious area) and precipitation changes on runoff is spatially variable:
  - Infiltration: -6 to 14 mm
  - Precipitation: -24 to 43 mm



Simulated streamflow in the White River, IN for different land cover and meteorology scenarios



Ratio of 2030 / 2010 storm precipitation simulated using the RAMS model

Students in Training:
Ming Lei (Ph.D., EAS)
Guoxiang Yang (Ph.D. AGRY)
Vimal Mishra (Ph.D., ABE)

National Air Emissions Measurement Study of Open Air Manure Storage Emission Sources

Richard Grant

Efforts to regulate emissions from Concentrated Animal Feeding Operations (CAFOs) by the USEPA have been hampered by the lack of information on actual emissions (NH_3, H_2S, particulates).

- measure emissions of NH_3 and H_2S from manure storage areas at ten farms (6 swine and 4 dairy) across the USA over the course of two years: Summer 2007-Summer 2009.

IMPACT: Results will be used by the USEPA to develop new guidelines for regulations for the animal production industry.

Collaborators :
- Producers
- New Mexico State Univ.
- Washington State Univ.
- Texas A & M
- North Carolina State Univ.
- Univ. Minnesota
- Purdue University (Ag. & Bio. Engineering)

Funding by Swine and Dairy Industry Science overseen by USEPA

Agricultural Drainage and Water Quality

Eileen Kladivko, Jane Frankenberger, Sylvie Brouder, Ron Turco, Laura Bowling, Brad Joern, Linda Lee, Suresh Rao

Goals: To manage tile-drained fields for improved water quality and crop yield

Field sites:

- Southeast Purdue Ag Center (1984)
  - nitrate, pesticides, crop yield
- Water Quality Field Station (1992)
  - nitrate, crop yield, manure, hormones
- Davis-Purdue Ag Center + farmer sites (2004)
  - controlled drainage for nitrate, crop yield

Funding: Purdue Ag. Research Programs; USDA; EPA

Collaborators: ARS and University scientists in IA, IL, OH, MN, WI, NC

Agricultural Drainage and Water Quality

Major findings:

•Nitrate loads are higher with narrower drain spacings - impacts design and mgmt. of systems

•Preferential flow of pesticides is common but short-lived after application

Impacts:

- Impacted subsequent research of other scientists, both in preferential flow and in drainage intensity mgmt.
- Impacted discussions regarding policy: pesticide mgmt.; nitrate and tile drainage - Hypoxia Action Plan
- Contributed to formation of regional groups to reduce nitrate loads
- Increased knowledge of drainage impacts on water quality and potential improvements

Purdue Agronomy

Discharge, Persistence, and Aquatic Impact of Hormones from Tile-drained Fields Receiving Animal Wastes

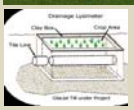
Linda S. Lee et al.

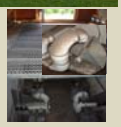
Goals

- Quantify contribution of tile-drain discharges to hormone loads to streams from manure and effluent amended agricultural fields
- Evaluate seasonal variations on hormone persistence
- Evaluate hormone loads (relevant levels and mixtures) to aquatic organisms

This research is funded by US EPA - Science To Achieve Results (STAR) Program
Grant # RD833417

Water Quality Field Station





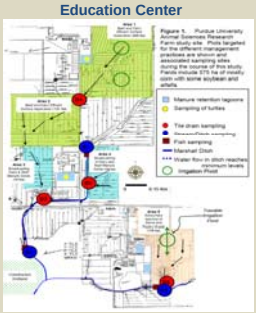
Contributors & Collaborators

Agronomy (8); Animal Science (2); Civil Engineering (2); Forestry & Natural Resources (4); USEPA Molecular Indicators Research Branch (Cincinnati, OH); USEPA ORD, NHEERL (Research Triangle Park, NC); USEPA Mid-Continent Ecology Division (Duluth, MN); USEPA NRMRL; and Clarkson University ; Jenkins Environmental

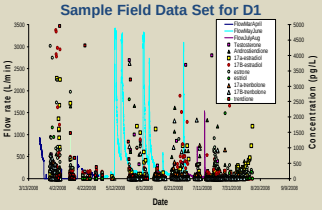
Purdue Agronomy

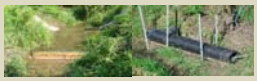
Discharge, Persistence, and Aquatic Impact of Hormones from Tile-drained Fields Receiving Animal Wastes

Animal Science Research and Education Center



Sample Field Data Set for D1



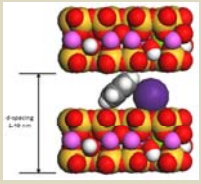


Purdue Agronomy

Geochemical Controls on the Adsorption, Bioavailability, and Long-term Environmental Fate of Pesticides, Nitroaromatics, Carbamates, Dioxins, PCBs and PAHs

Cliff Johnston

- Surface chemistry of soil and environmental particles in the broader context of biosphere science
  - optical, laser-based, and structural methods
  - fundamental studies of clay minerals and hydrous oxides
- environmental fate and transport of antibiotics, dioxins, pesticides, PCBs, PAHs, and explosives
- earthworms, carbon sequestration, and emission



Funding:
NIEHS Superfund Project (2006-2011)
4 USDA NRI Grants (funding since 1999)
New proposals funded by:
National Science Foundation
Shell Oil Company

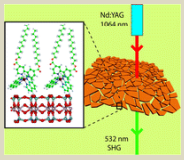
Collaborators (# of scientists):
- Michigan State University (12)
  Stephen Boyd, Brian Teppen, Hui Li, Thomas Pinnavaia
- USDA/ARS National Soil Tilth Lab (4)
  David Laird
- Purdue University (6)

Purdue Agronomy

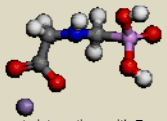
Geochemical Controls on the Adsorption, Bioavailability, and Long-term Environmental Fate of Pesticides, Nitroaromatics, Carbamates, Dioxins, PCBs and PAHs

Major findings:

- Clay minerals are important but overlooked sorptive phases for many important solutes including many pesticides, nitroaromatics, carbamates, antibiotics, PAHs, PCBs and dioxins



Currently working with toxicologists to study the bioavailability of compounds sorbed to clays



Glyphosate interactions with Fe- and Al-oxides (E. Johnston 2009)

Productivity: 52 refereed journal articles and book chapters published since 2002.

Students Trained: Kiran Rana (Ph.D)
Eric Johnson (M.Sc)

Postdocs Trained: Don Zhu
Maurilio Fernandes de Oliveira

Purdue Agronomy

A New Approach for Improving Phosphorus Acquisition and Aluminum Tolerance of Plants in Marginal Soils

Darrell Schulze and Cliff Johnston

Increase yield of sorghum and maize grown on nutrient-poor acid soils by increasing P uptake efficiency and Al tolerance.

- conventional plant breeding (Brazil → Africa)
- introduce citrate synthase gene into maize and sorghum
- plant physiology
- soil fertility, soil characterization

Funding: McKnight Foundation Collaborative Crop Improvement Program

Collaborators (# of scientists):
- Embrapa Maize and Sorghum, Brazil (15)
- Moi University, Kenya (4)
- Kenya Agricultural Research Center (KARI) (1)
- Purdue University (4)
- USDA ARS / Cornell University (1)

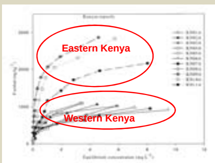
Purdue Agronomy

A New Approach for Improving Phosphorus Acquisition and Aluminum Tolerance of Plants in Marginal Soils

Our role: soil chemistry and mineralogy

Major findings:

- Soils in western Kenya are similar physically, chemically, and mineralogically to soils in central Brazil
- Soils in eastern Kenya (Mt Kenya) are:
  - considerably more acid
  - have higher Al saturation
  - higher P sorption capacities
- 2 μm citrate increases P release by ~3×



Field Sampling, Kenya, Jan. 2003

Students Trained:
Kirin Rana (M.S.)
Pamela Obura (Ph.D.)

Field Sampling, Tanzania, July 2008

Where Do We Want to Go?

Interest in Grand Challenge Areas

● = major interest or focus • = secondary interest or focus	Beyrouty	Bowling	Brouder	Camberato	Crawford	Grant	Graveel	Gurney	Heathman	Huang	Joern	Johnston	Kladivko	B. Lee	L. Lee	Nakatsu	Niyogi	Norton	Owens	Pappas	Rao	Rochon	Schulze	Schwab	Smith	Steinhardt	Stott	Turco	Van Scoyoc	Zhuang
Landscape Mgmt. & Systems	●	●	●	●	●	•	•	•	●	●	●	●	●	●	•		•	•	●	•	●	●	●	•	●	●	●	•	●	●
International Agriculture	•		•		•			•			•	●		•			●	•					●						•	
Chemicals in the Environment	•	•	•			●	●		•	•	●	●	•	●	●	•	•	●		●	•		•	●	•			●	●	
Bioenergy		•	●		•			•			•	●	•				•				•						•	●		●
Plant Breeding & Genetics																														
Climate Change		●	•		●	●		●	•			●	•				●		•		•	●			•		●			●

Grand Challenge	Total Responses
Landscape Mgmt. & Systems	●●●●●●●●●●●●●●●●●●●●•••••••••
International Agriculture	●●●••••••••
Chemicals in the Environment	●●●●●●●●●●●•••••••••••
Bioenergy	●●●●••••••••
Plant Breeding & Genetics	
Climate Change	●●●●●●●●●••••••

How Will We Get There?

How Will We Get There?

- Develop a new corporate identity for the Earth System Science Group
  - *Earth System Science* – for now
  - distinguish ourselves from other departments
  - how we present ourselves impacts our ability to attract students

How Will We Get There?

- Develop a conceptual research framework for the Earth System Group
  - Grand Challenge White Papers a good start
  - Can we develop a research framework for the group?
    - will not dictate what we must work on as individuals
    - guide and focus new projects
    - engage strategic collaborators
      - within the university
      - external collaborators and stakeholders

How Will We Get There?

- Enhance our undergraduate and graduate education program
  - Graduate education
    - new Earth System Science disciplinary area
      - incorporate and integrate soil science, cropping systems, spatial technologies, land-atmosphere interactions
  - Undergraduate education
    - Soil and Hydrologic Sciences degree option
      - emphasize course in soil physical sciences, pedology, water movement at landscape and watershed scales, hydrologic modeling and observation

How Will We Get There?

- Additional faculty expertise needed over next five years
  - Environmental Soil Physics
  - Environmental Soil Microbiology
  - Soils and Land Use Planning

Earth System Science