Ecosystem Services Research Program
Pollutant-based studies: Nitrogen

April 29, 2010 Program Update

Our goal: to connect the effects of nitrogen inputs to ecosystem services and human well-being in order to improve policy and management related to nutrients.

Nitrogen Team

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Christine Davis OAQPS
Expert hire: John Harrison Washington State University

Thanks to

Jay Christensen NERL
Tony Olsen, Paul Ringold, John Stoddard, Steve Paulsen, Jim Wigington, Scott Leibowitz NHEERL-WED
Michael Cox EPA R10
Brenda Hoppe, Anna Harding OSU

Outline of talk

Nitrogen and ES: the end goals

Research directions and results

- Connecting Nitrogen and Human Benefits
- Mapping and Monitoring Pressures and Services
- Modeling
- Cross-cut: Demonstration and local ES-N connections

Future work and the end goals

Nitrogen as an integrating theme in ESRP:

nexus between science and decisions

- Clean Air Act: NOxSOx secondary National Ambient Air Quality standards currently under review Link
- Clean Water Act: Nutrient criteria and approach needed for many states; tools need to be tested
- EPA's SAB Integrated Nitrogen Committee Link
- EPA's Water Quality Trading Policy, 2003; Wetland mitigation rule, 2008: EPA & ACE to consider ecosystem services;
- Gulf of Mexico Hypoxia 2007 report Link
- Chesapeake Bay Executive Order – N reduction

Nutrients currently on national stage

An urgent call to action: EPA nutrient innovations task force August 2009 link

- "Current regulations disproportionately address certain sources in a watershed at the exclusion of others contributing substantial loadings of similar pollutants to the same watershed."
- "Establishing a cross-state, enforceable framework of responsibility and accountability for all point and nonpoint pollution sources is central to ensuring balanced and equitable upstream and downstream environmental protection."

Timeline for ESRP-N

FY09 FY10 FY11 FY12

Implementation plan link

Review paper on ES and reactive N – fall 2010

National Nitrogen Inventory For Atlas of ES - 2011

Regional weight-of-evidence modeling – 2012

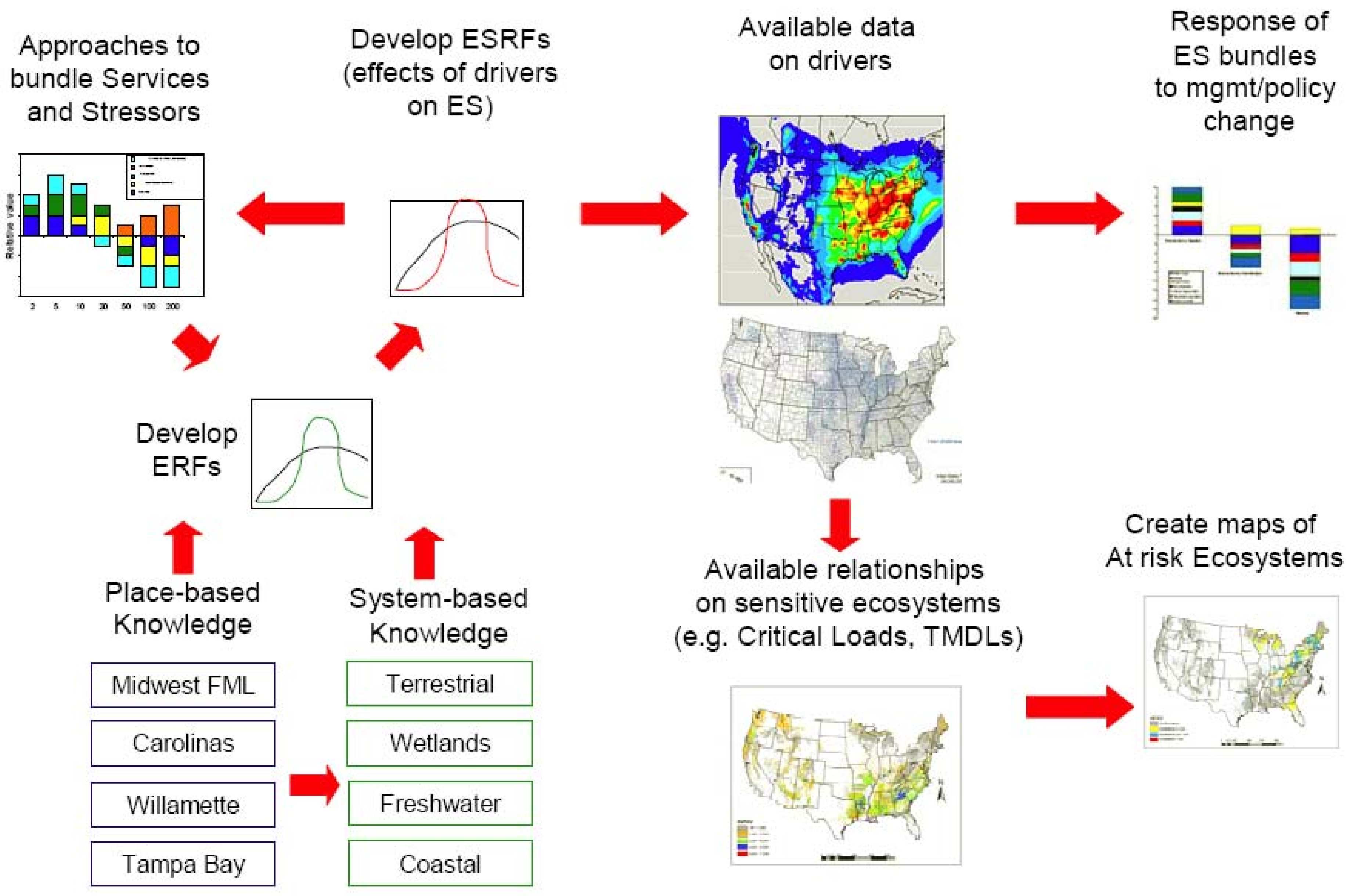
Ecosystem services and nutrient cycling – application work

Sensitive ecosystems and critical loads – 2011

Report on the value of ecological services provided by and affected by Nr - 2012

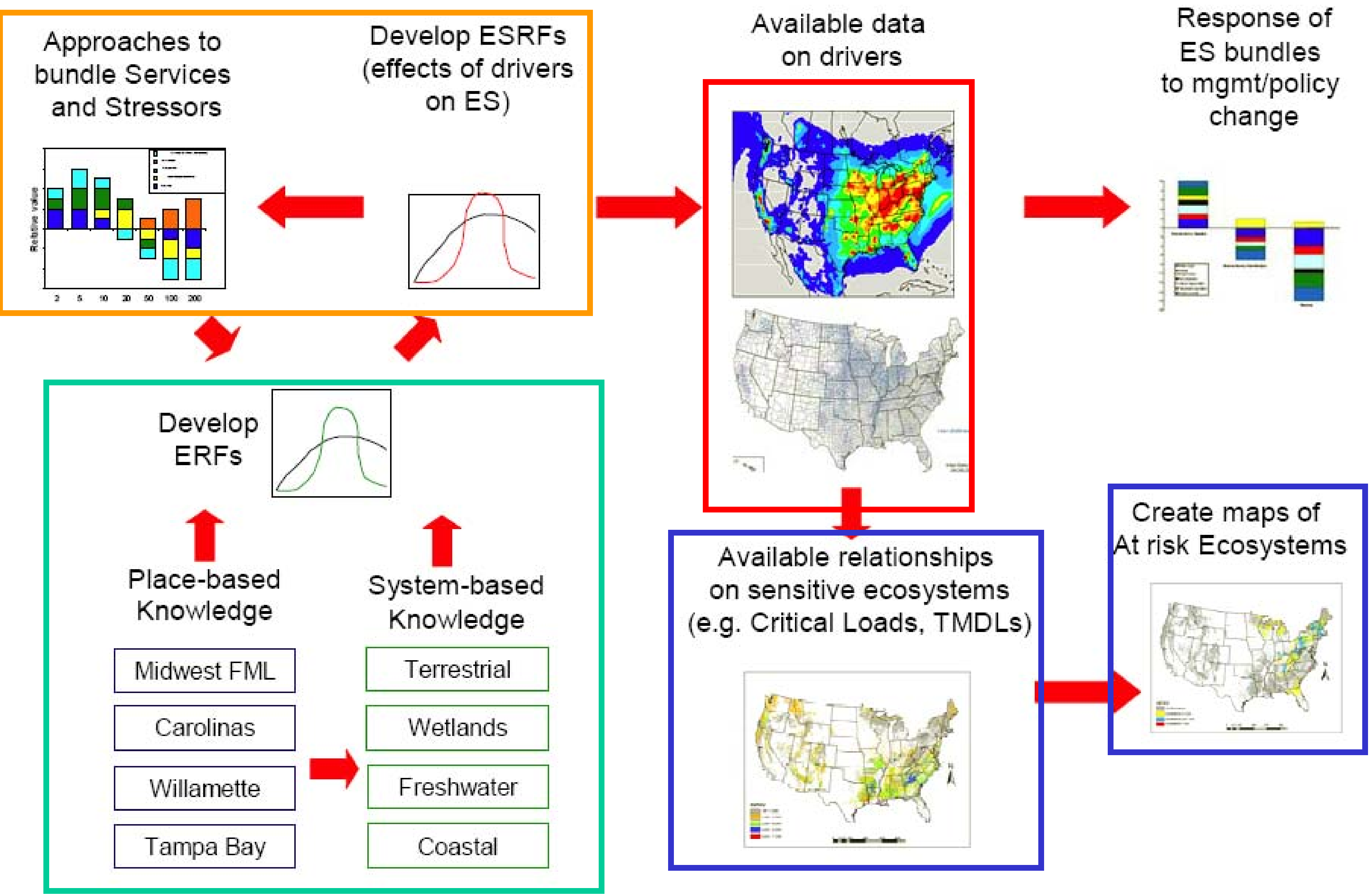
Theme 1
Theme 2
Theme 3
Theme 4

ESRP-Nitrogen Road Map



Boxes represent work underway

ESRP-Nitrogen Road Map



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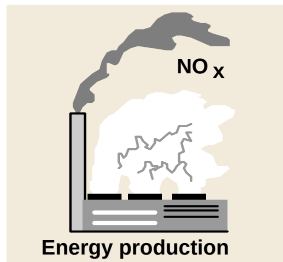
Ecosystem services:

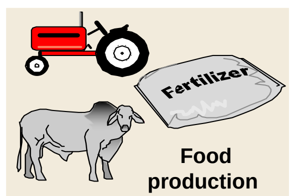
Presenting the effects of decisions so that the public can appreciate the costs and benefits for what is important to them.

- Air – breathing, visibility
- Water – drinking, swimming, fishing
- Food and fiber – productive forests and farms
- Climate regulation
- Quality of life – existence of healthy lakes, forests, coasts, recreation, real estate values

Why Nitrogen and Ecosystem Services?

- Nitrogen is a critical component of energy, food, and fiber production, benefiting humans in many ways.

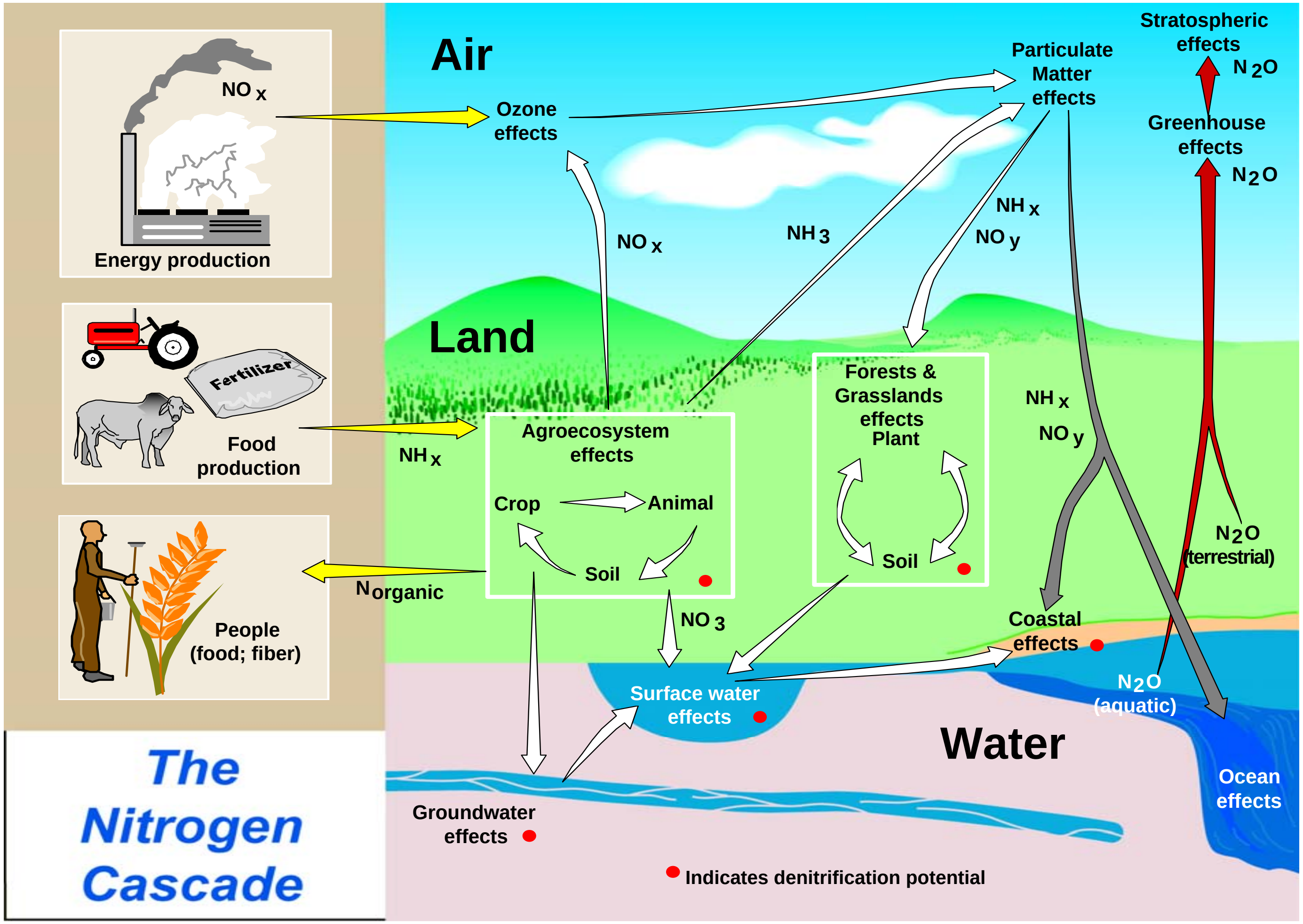




from Galloway et al. (2003)

Why Nitrogen and Ecosystem Services?

- However, N is a major stressor for many ecosystems.



from Galloway et al. (2003)

Valuation vs. complete accounting

Location of impact	Monetized	Valued	Difficult to value
Air	Visibility		Climate change Ozone depletion
Land	Respiratory health	Acid damage Ozone damage	Climate regulation Forest health
Water	Water clarity Drinking water	Recreation Eutrophication	Biodiversity Foodweb

Specific example from NOxSOx policy assessment

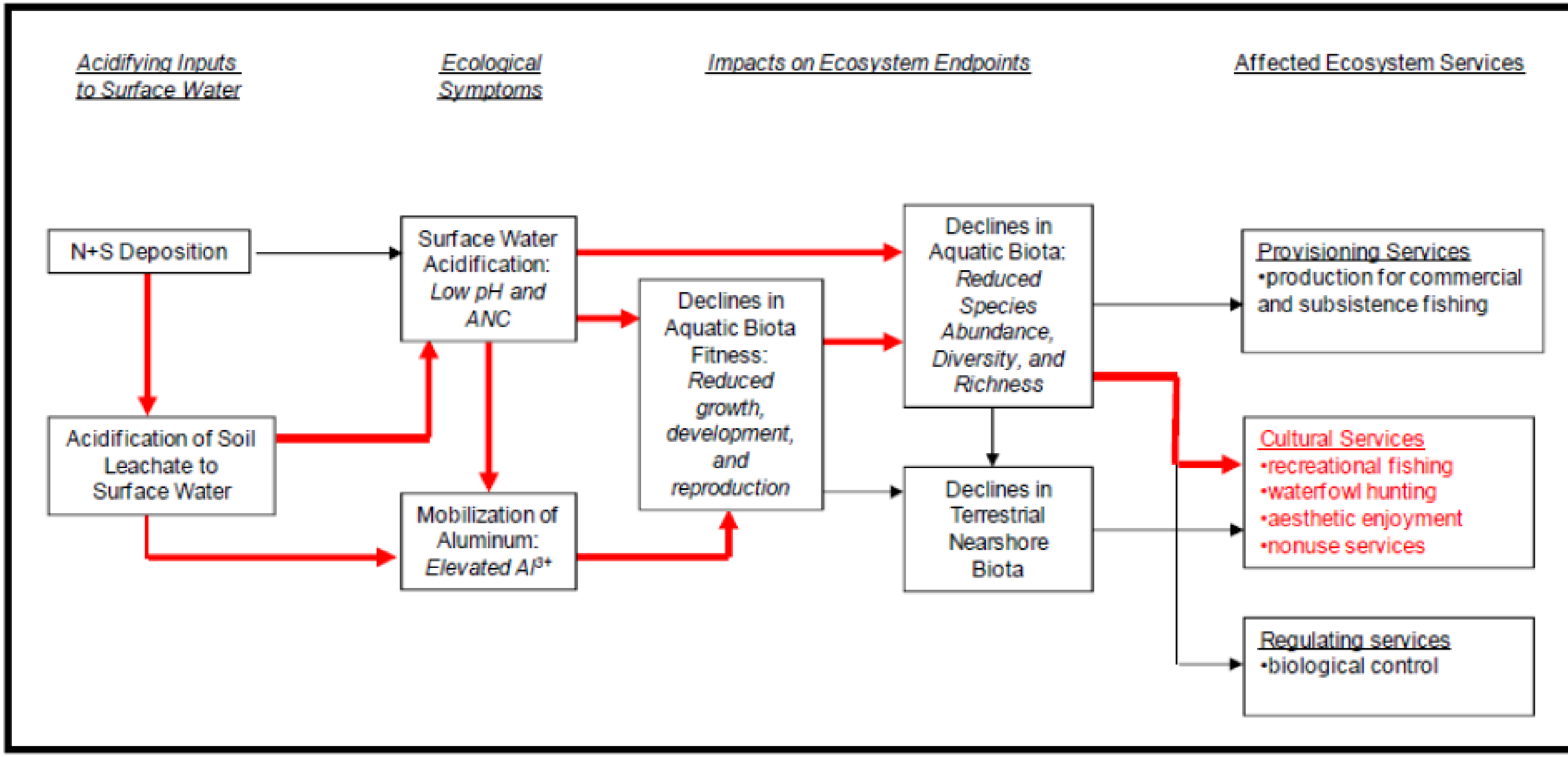
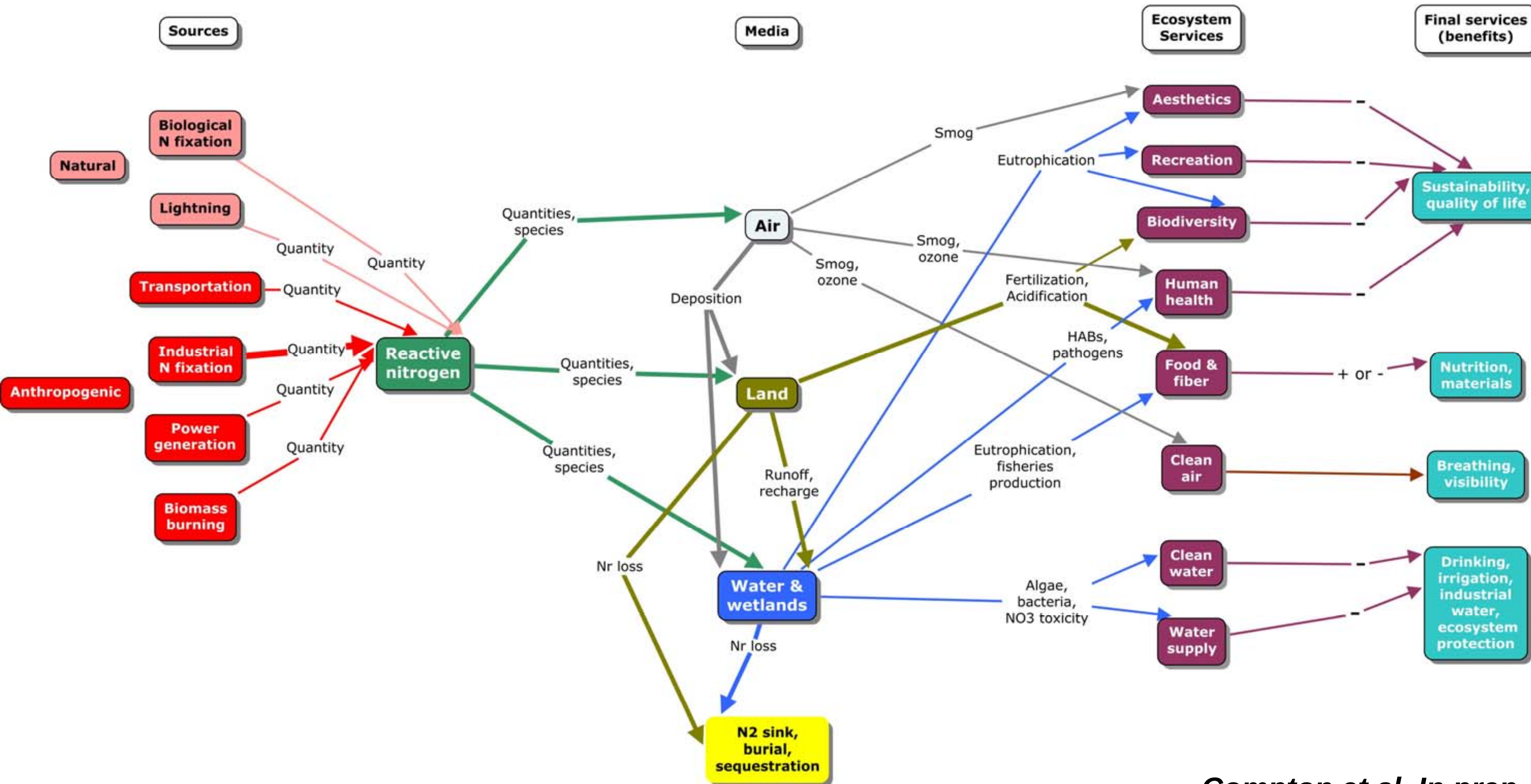


Figure 3-6. Conceptual model linking ecological indicator (ANC) to affected ecosystem services.

Connecting N and final services



Compton et al. In prep

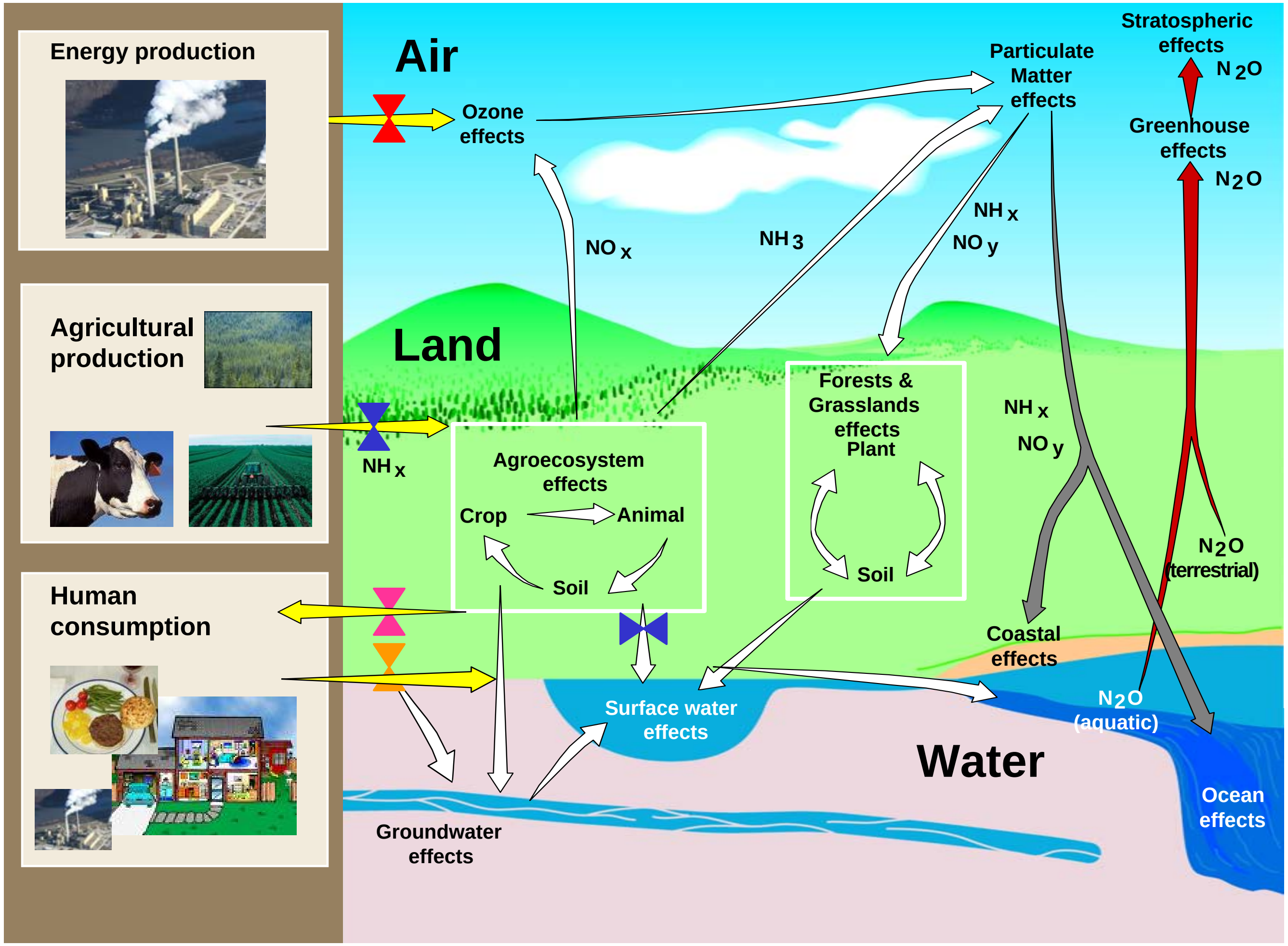
What are the most effective intervention points along the nitrogen cascade, maximizing ES?

Reducing air emissions (power plants and cars)

Land use choices (nutrient management, wetland restoration)

Reducing water point source loads

Individual decisions (diet, vehicles, lawn fertilizer)



Modified from Galloway et al. (2003)

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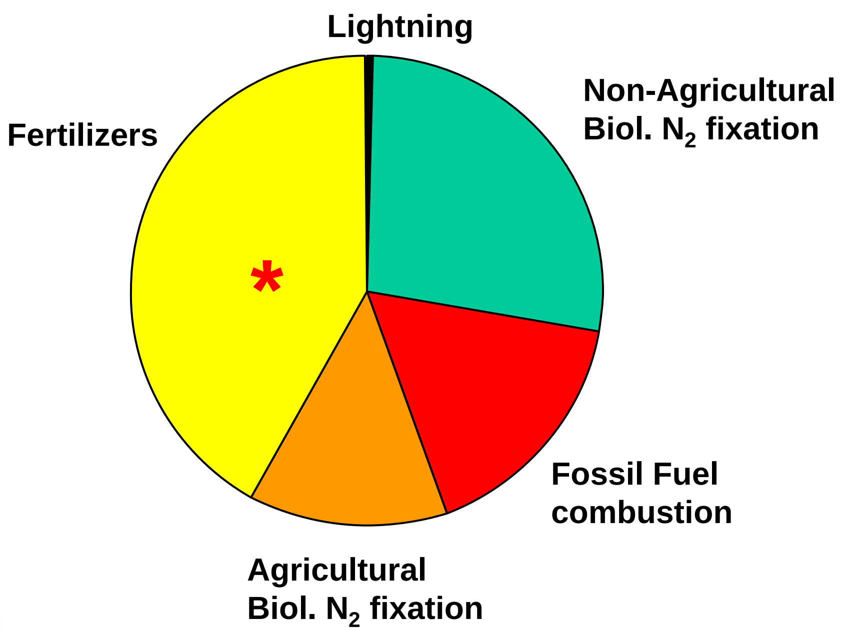
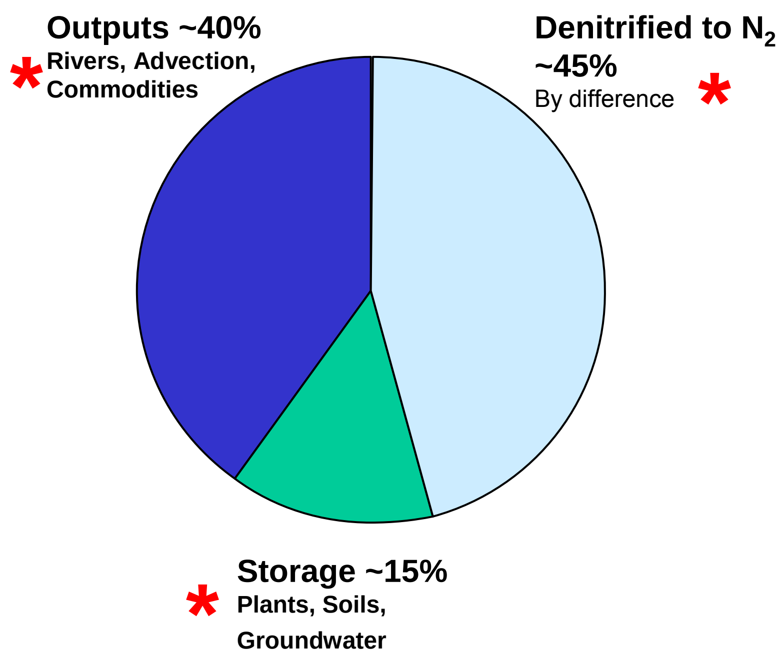
Human activities accelerated transfer of N from the atmosphere to biosphere

*Uncertainties and poorly understood spatial/temporal variability

Nitrogen fixed from atmosphere
North America early 1990s
25 Tg N yr^{-1}



Fate of fixed N



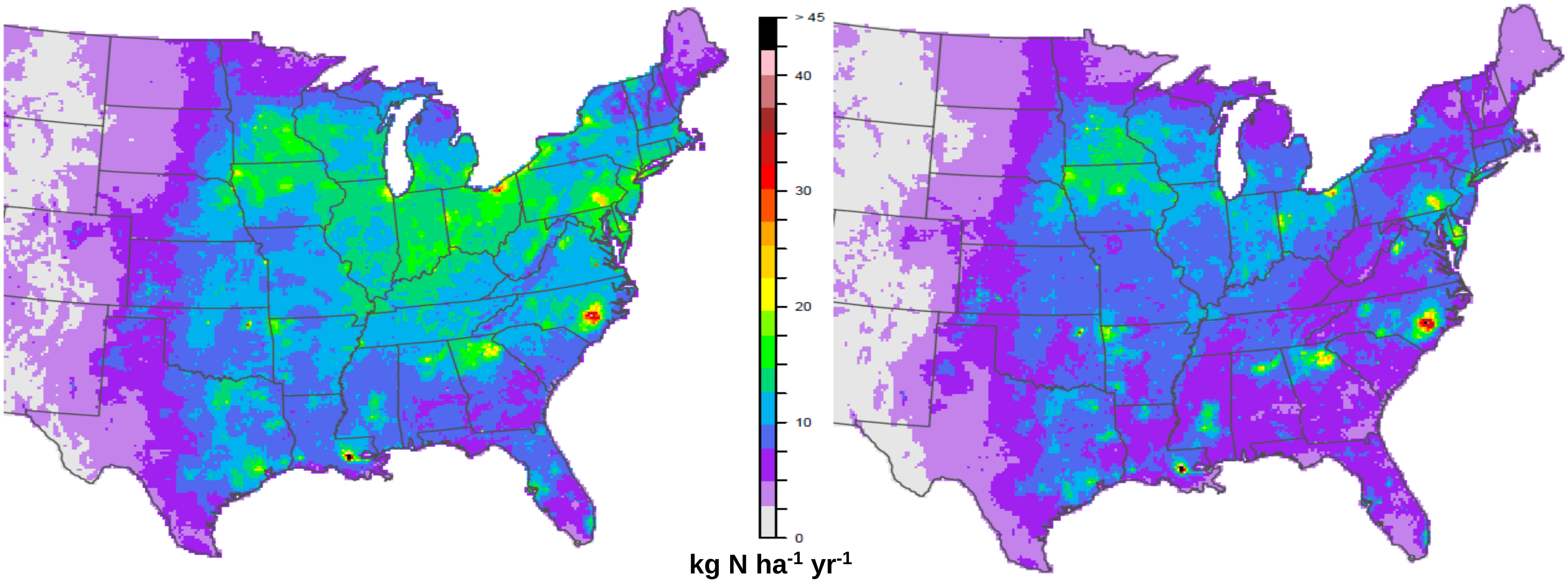
Galloway et al. 2004 Biogeochemistry

Mapping Pressures and Services

- N sources at National Scale
  - Deposition - total inorganic N (CMAQ)
  - Confined Animal Feedlots - Mapping
  - Fertilizers - FML, N and Mapping
  - Sewage Treatment Plants - Mapping
  - Soil N - with Mapping
- Modeling tools to estimate N removal
  - SPARROW (regional & national)
  - Global NEWS (with expert John Harrison)
  - Wetland work

CMAQ total N deposition 2002, 2020

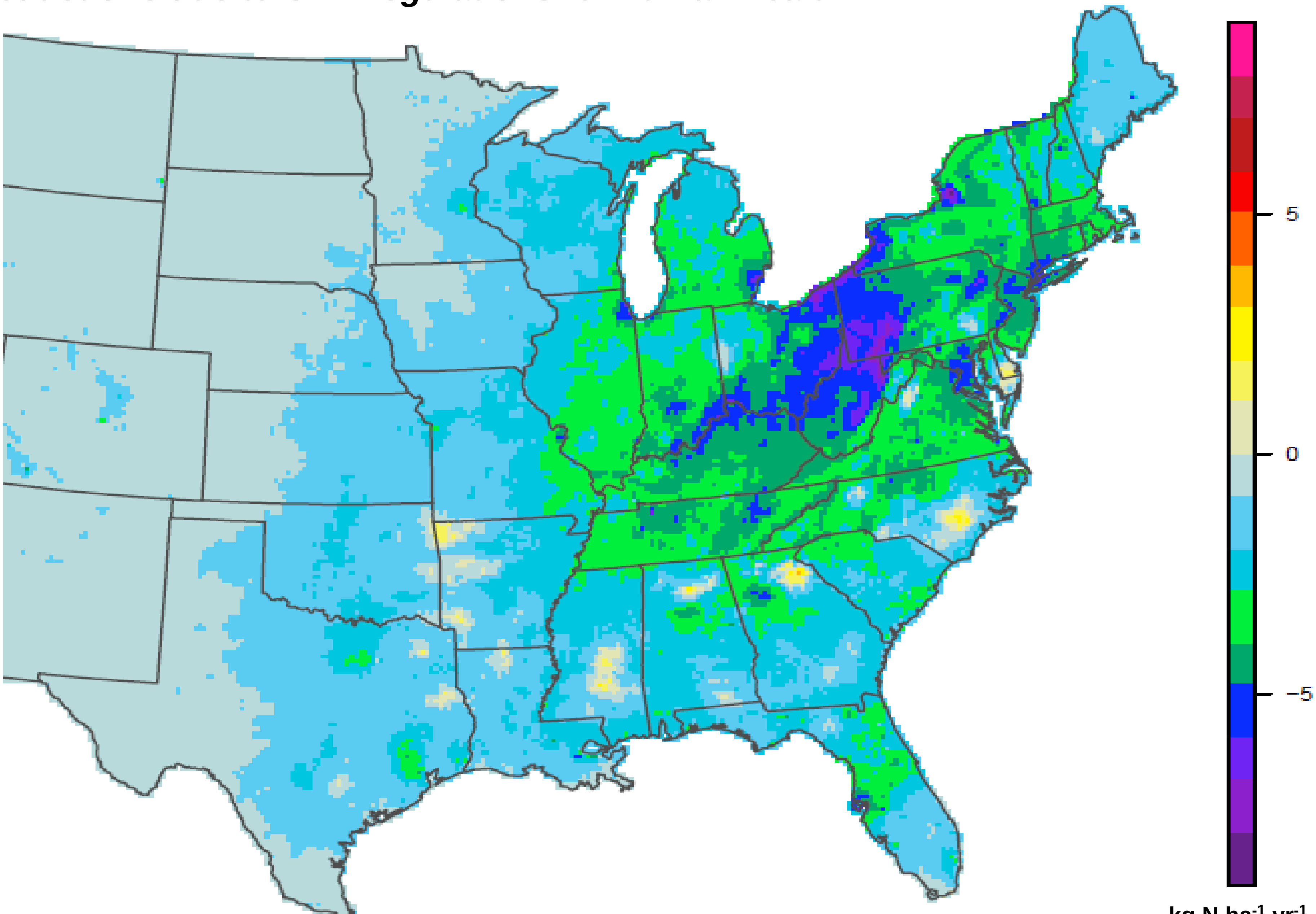
2002 **2020**



Robin Dennis, EPA NERL

Difference map

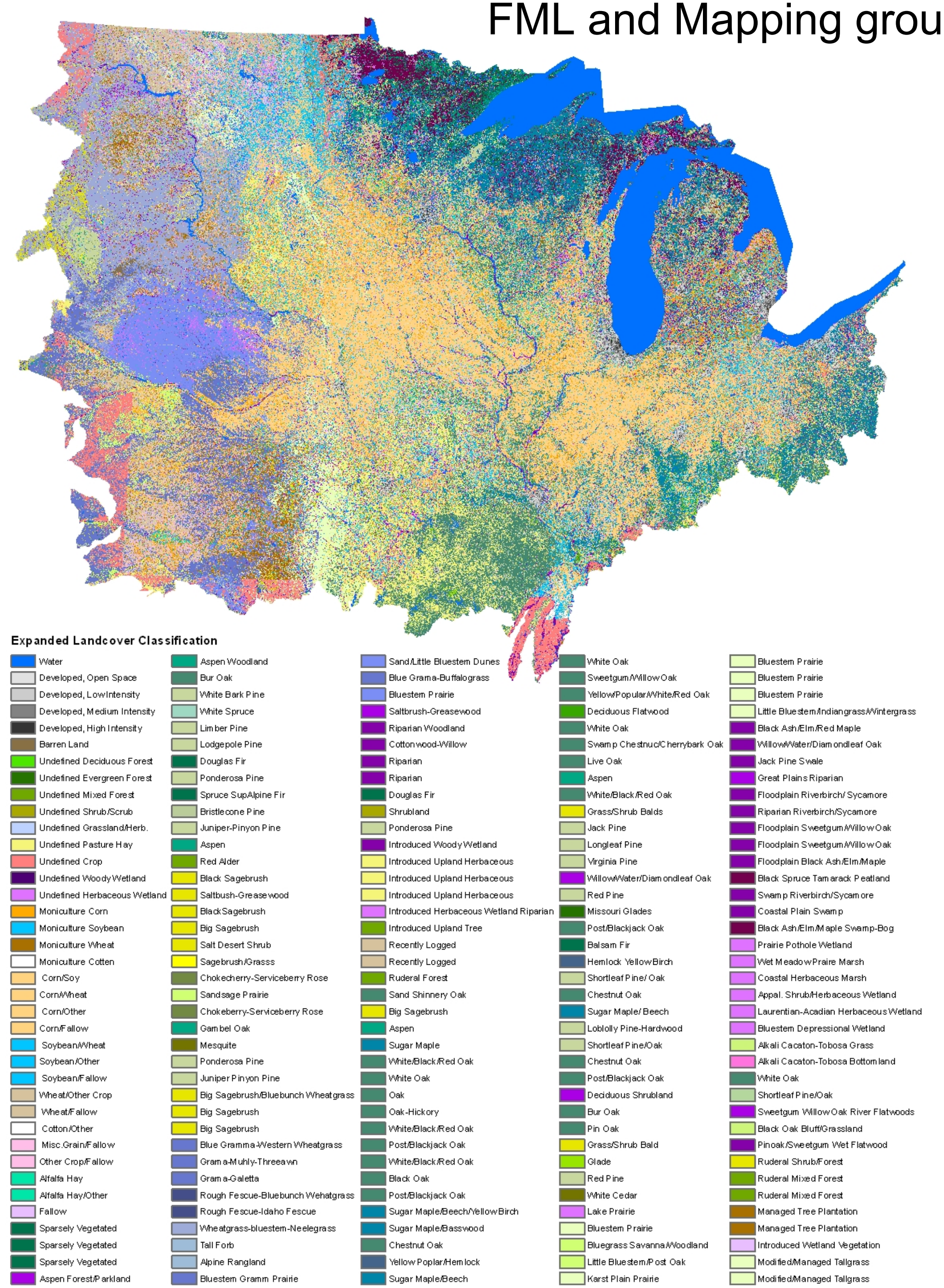
- reductions due to CAA regulations for human health



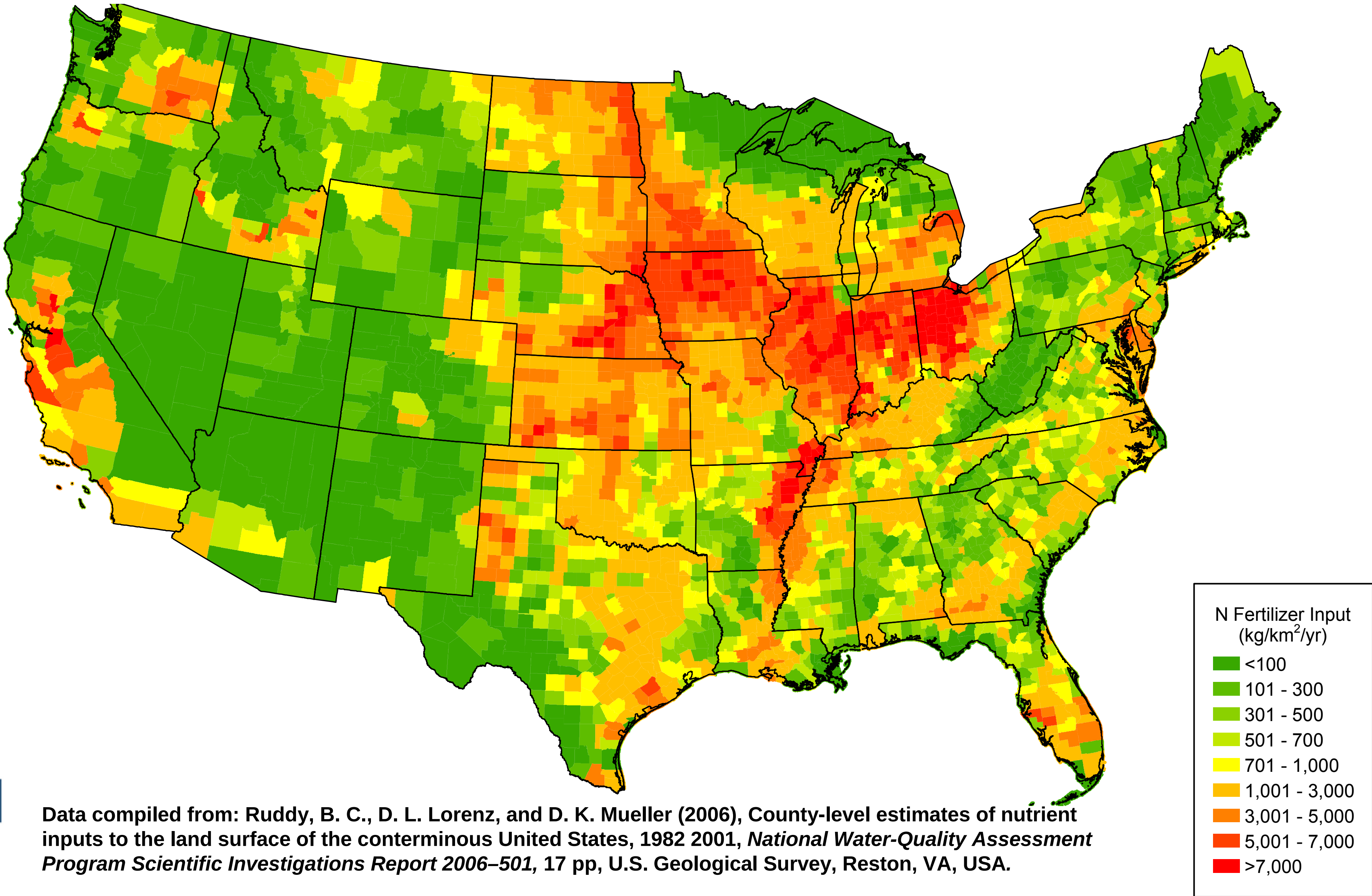
FML and Mapping group

Land use and N

- **Better land use information and spatial resolution → better N accounting.**
- **Partition county-level (or state-level) fertilizer sales by crop type.**

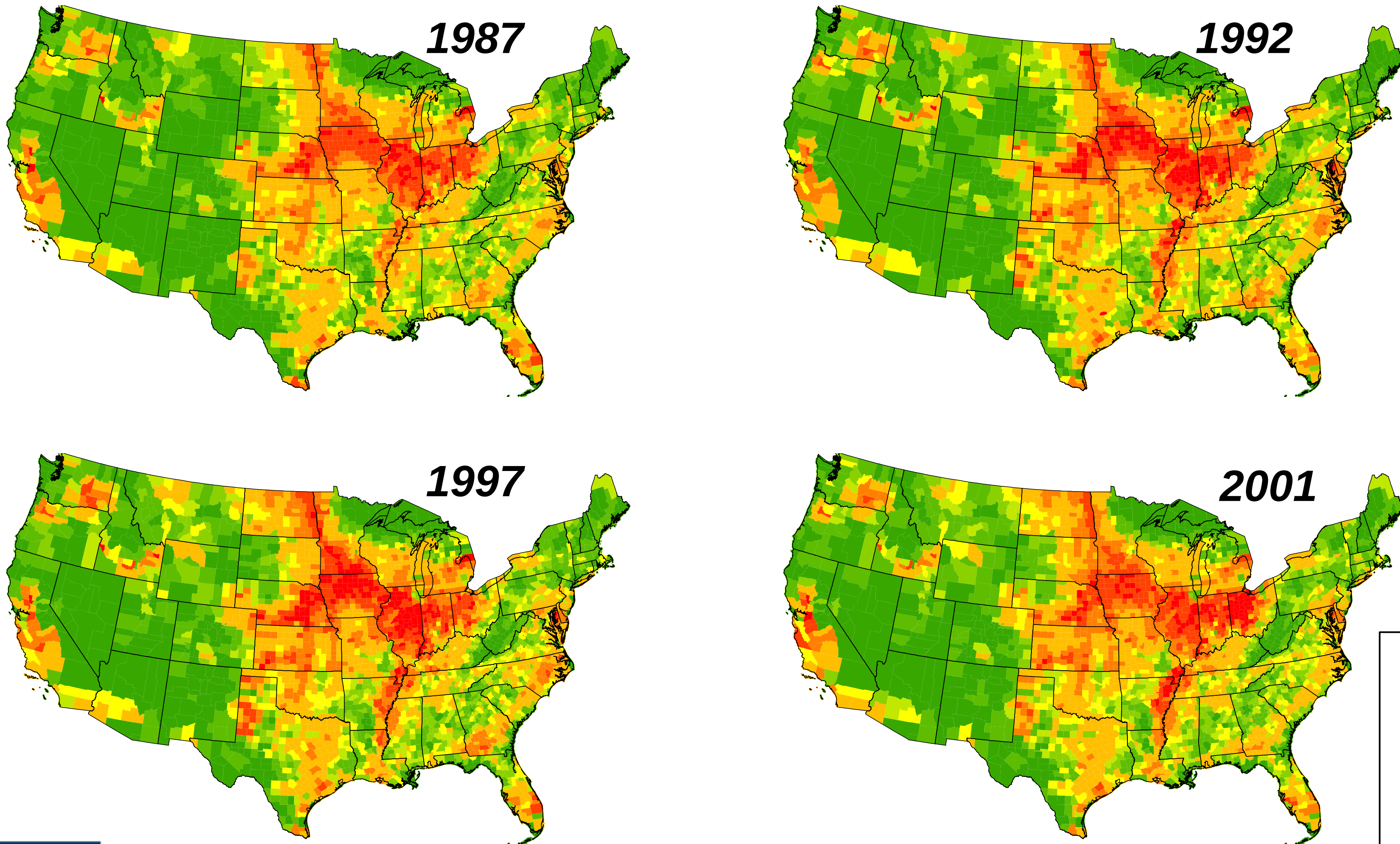


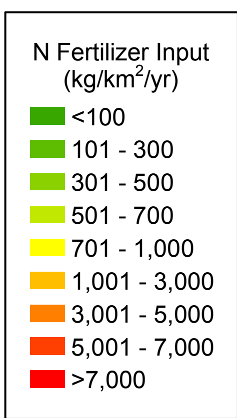
Example nutrient inventory: Agricultural N fertilizer use by county



Data compiled from: Ruddy, B. C., D. L. Lorenz, and D. K. Mueller (2006), County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982 2001, *National Water-Quality Assessment Program Scientific Investigations Report 2006–501,* 17 pp, U.S. Geological Survey, Reston, VA, USA.

Nutrient inventory over time





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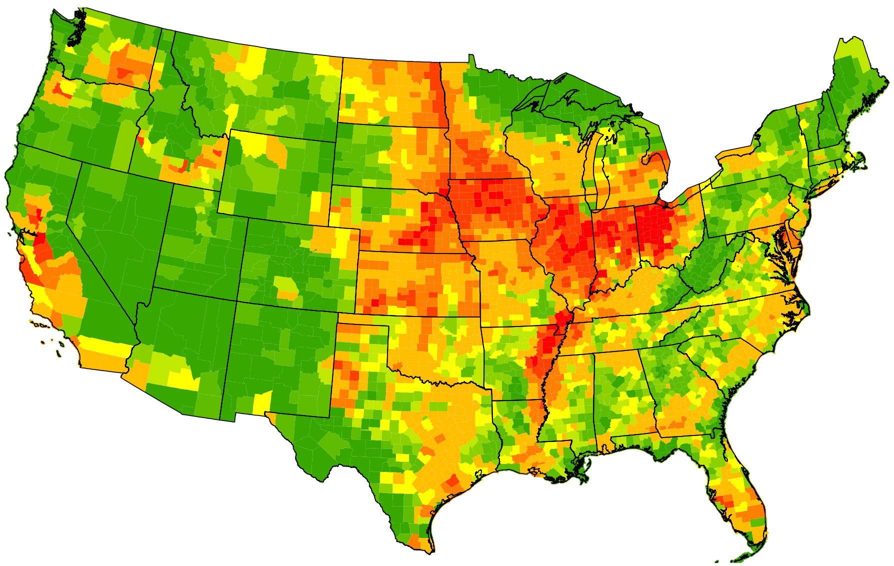
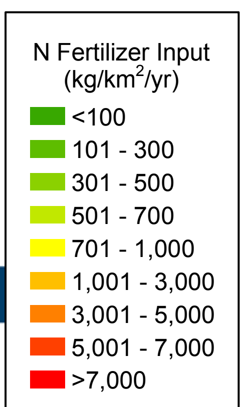
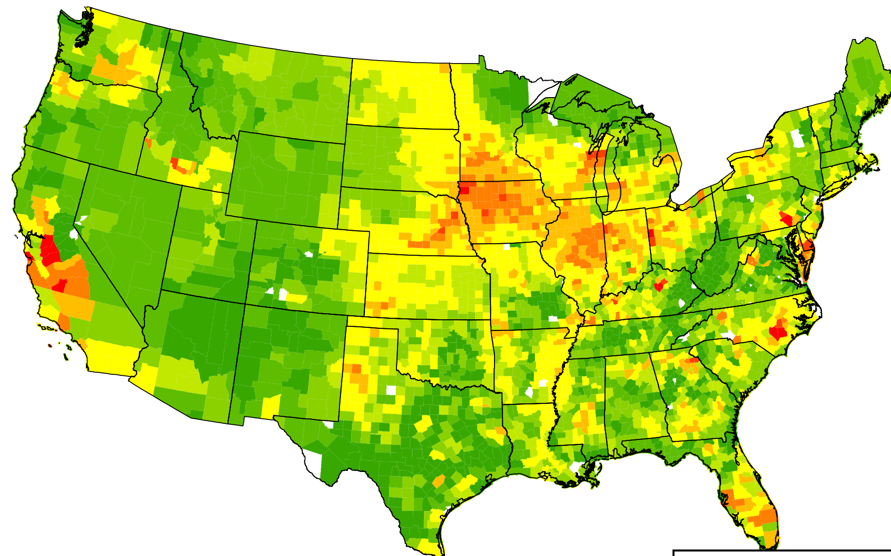
Linking Nitrogen Fertilizer to Net Farm Income: County- level

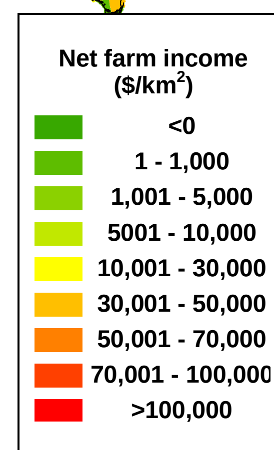
N fertilizer 2001





Net farm income 2002

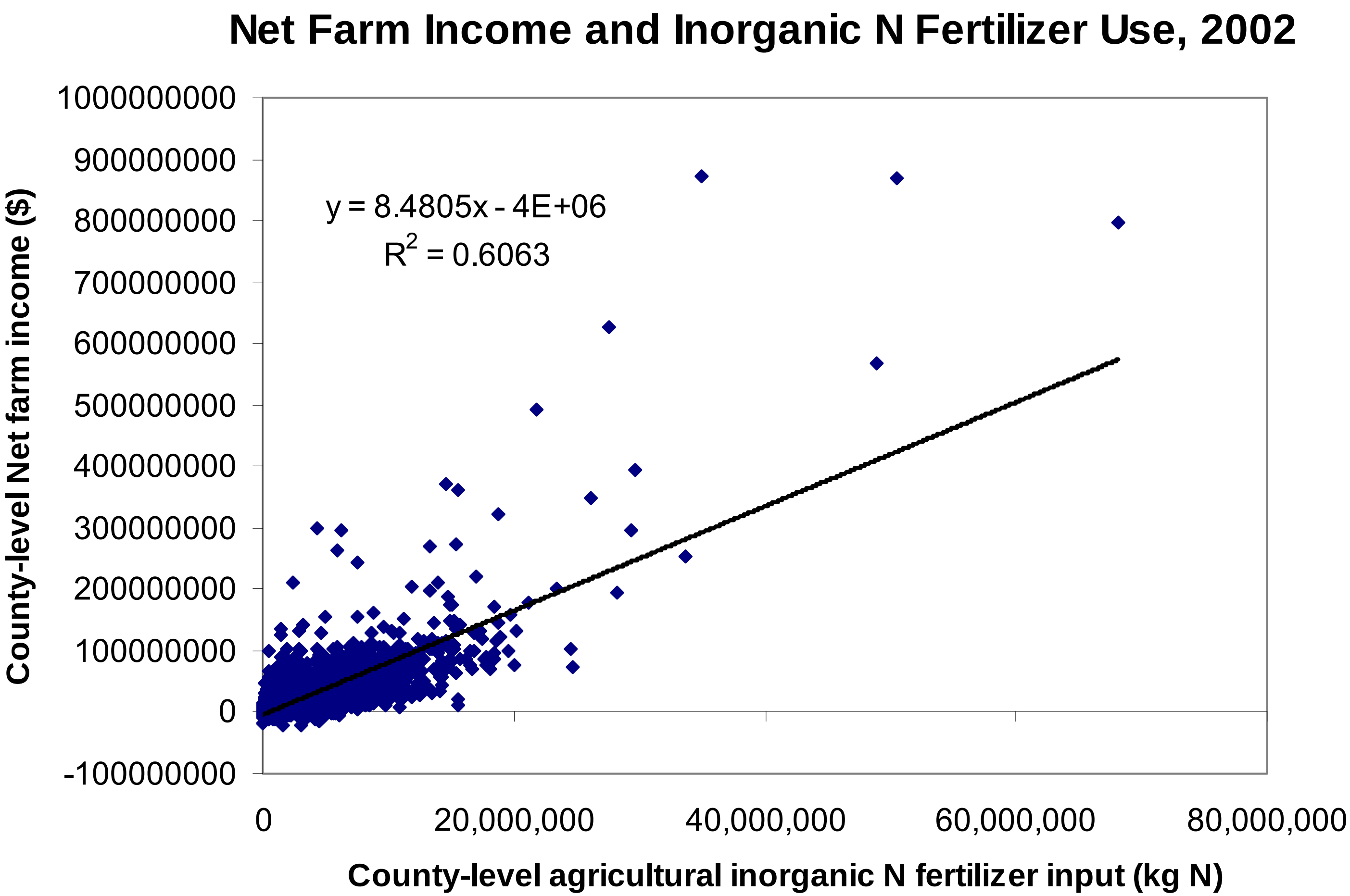




Fertilizer data compiled from:Ruddy, B. C., D. L. Lorenz, and D. K. Mueller (2006), County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001, *National* Water-Quality Assessment Program Scientific Investigations Report 2006–501, 17 pp, U.S. Geological Survey, Reston, VA, USA.

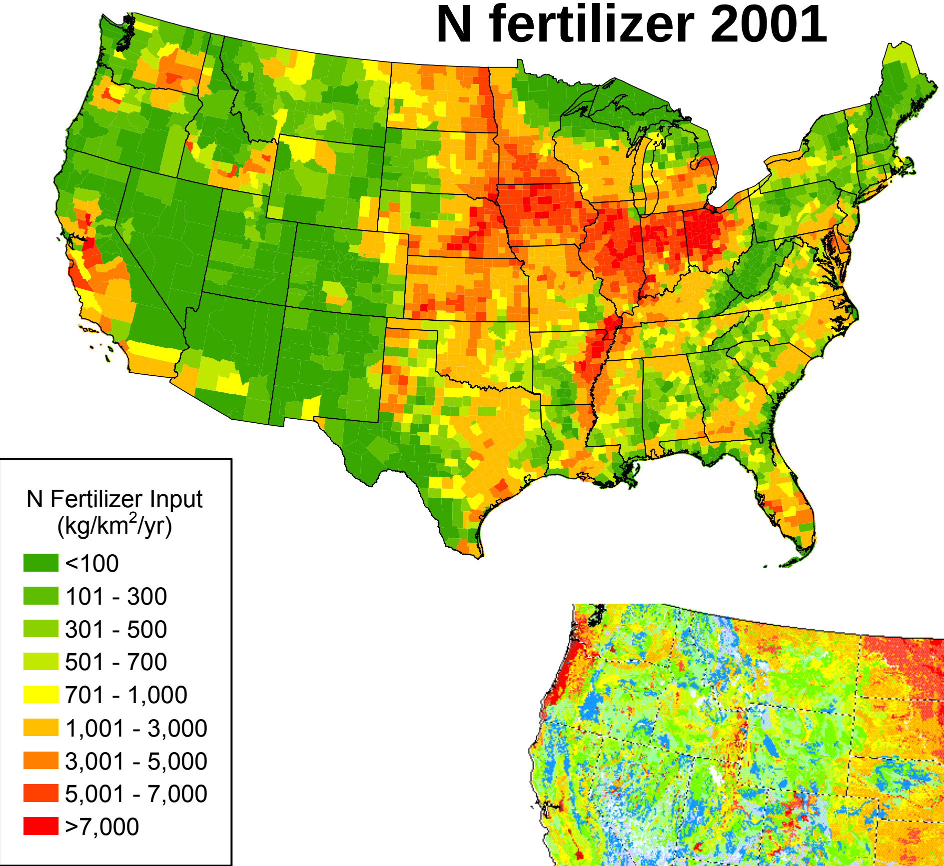
Farm income downloaded from the USDA/NASS QuickStats Ad-hoc Query Tool (http://151.121.3.59/).

Farm income and N fertilization

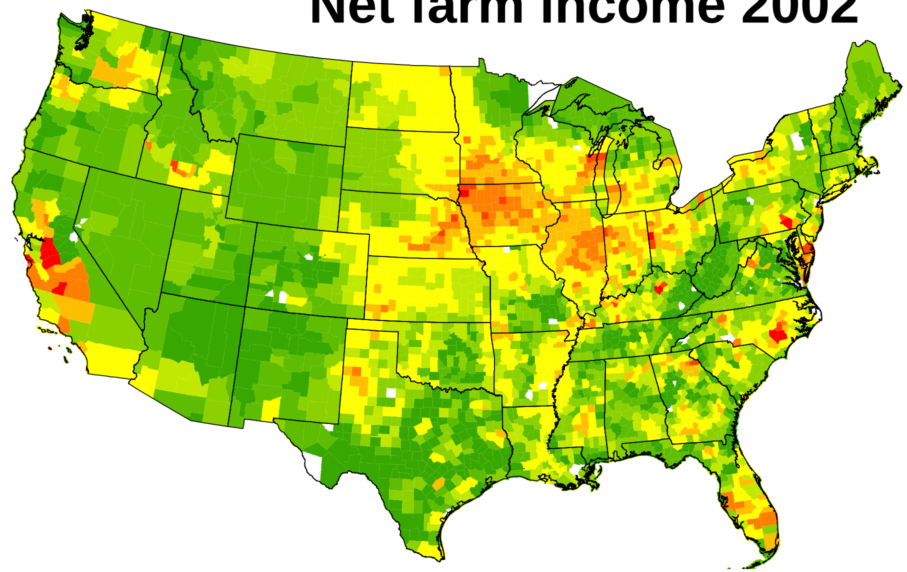


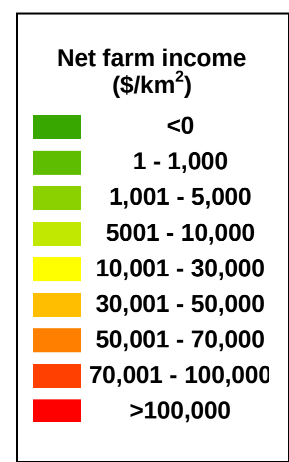
Capitalizing on supporting service: Soil fertility

N fertilizer 2001

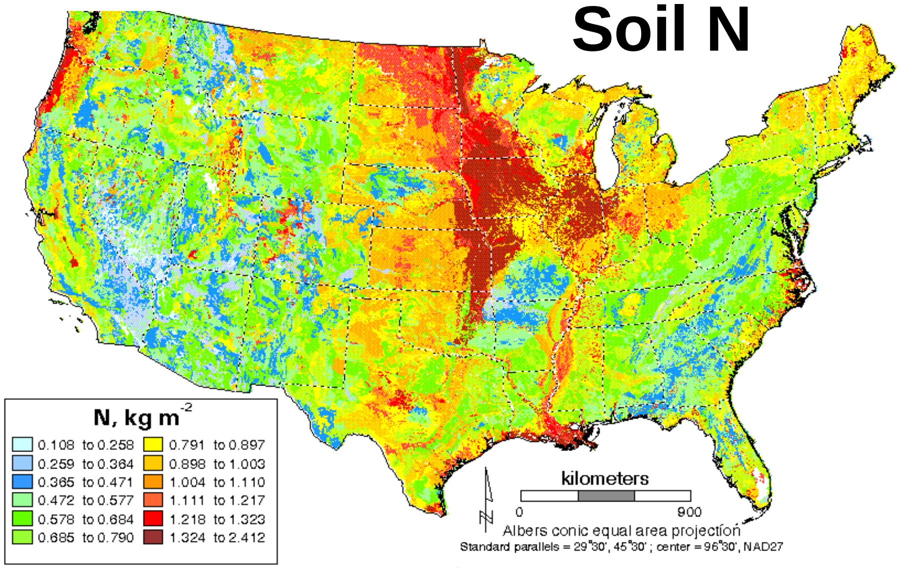


Net farm income 2002





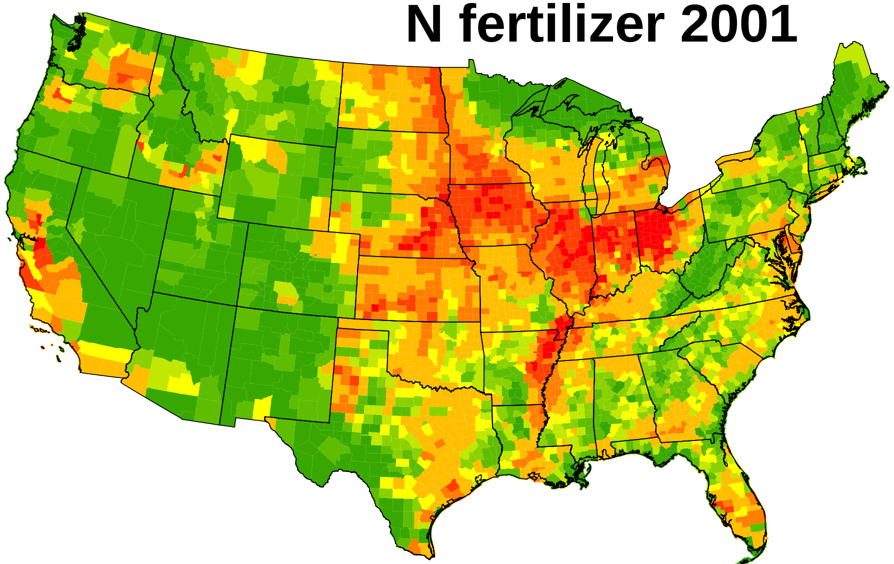
Soil N



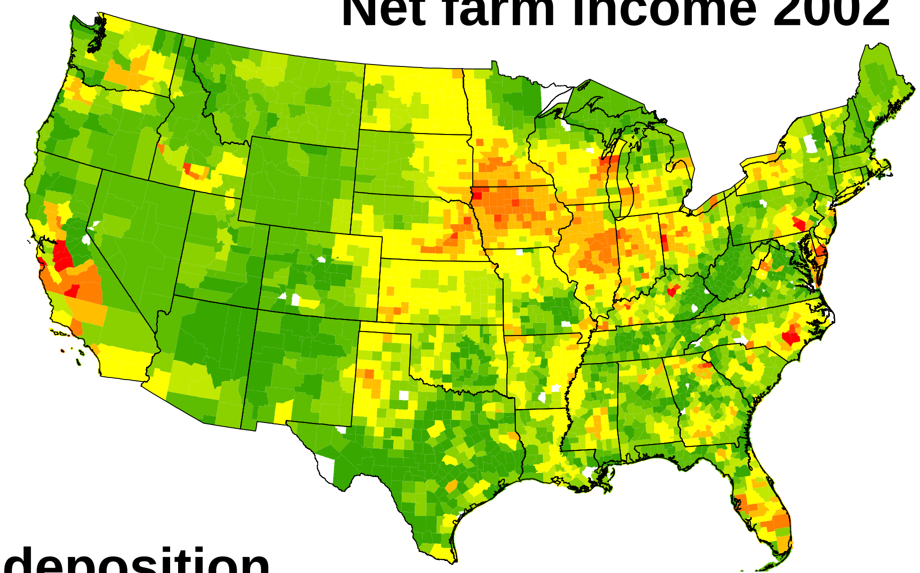
EPA - Johnson, Kern et al. In prep.

Links between N use and other services

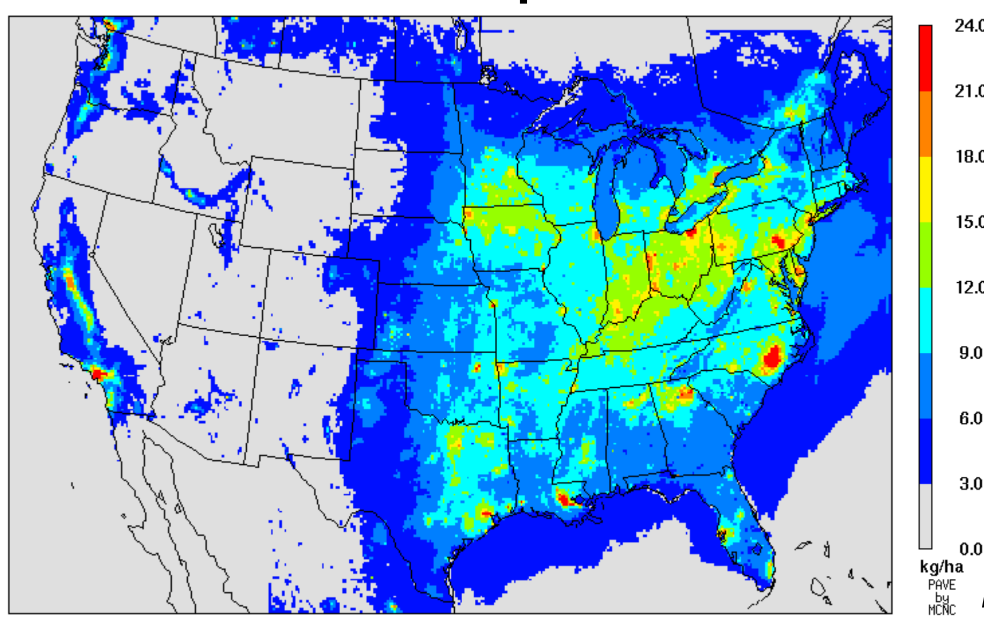
N fertilizer 2001



Net farm income 2002



N deposition



Robin Dennis, EPA NERL

Links between N use and other services

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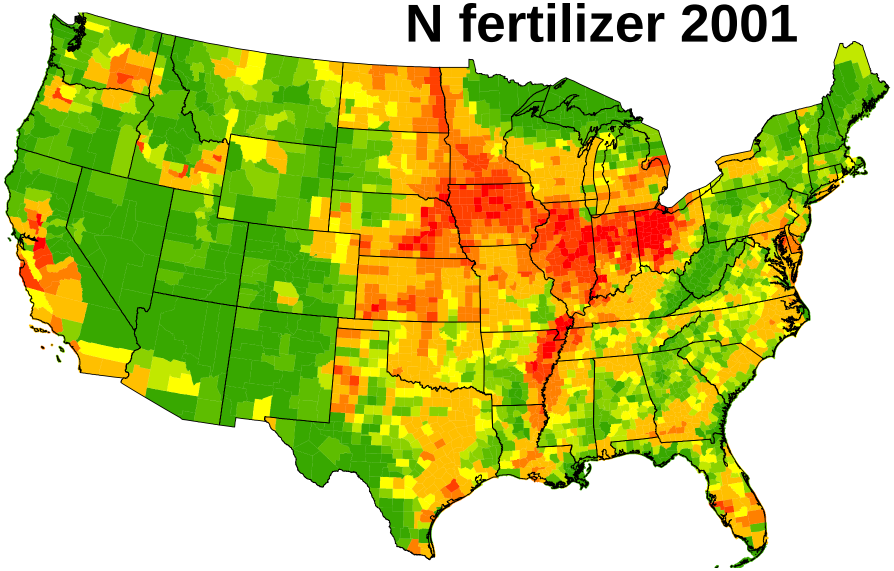
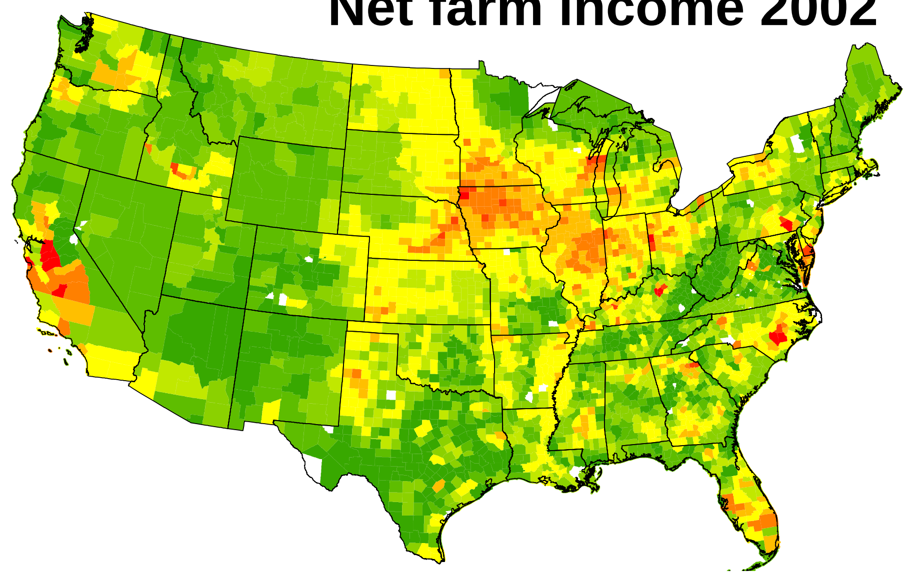
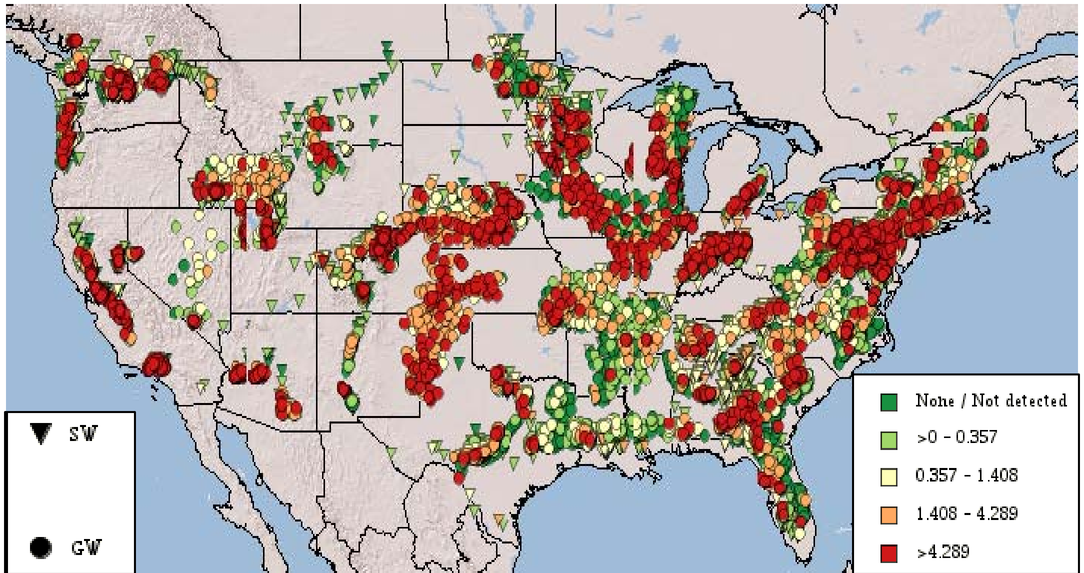


Net farm income 2002



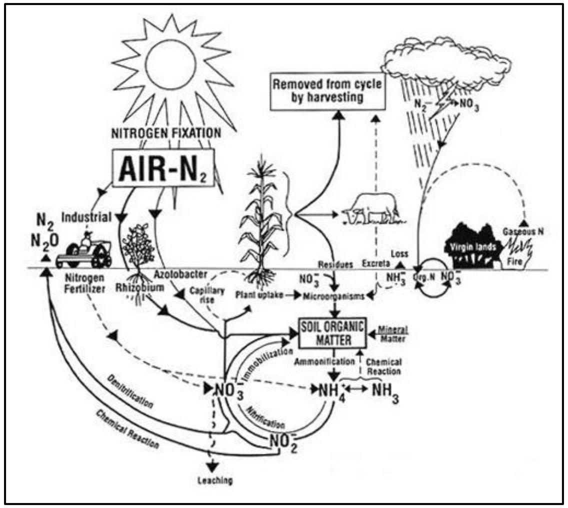
NAQWA nitrate in SW & GW



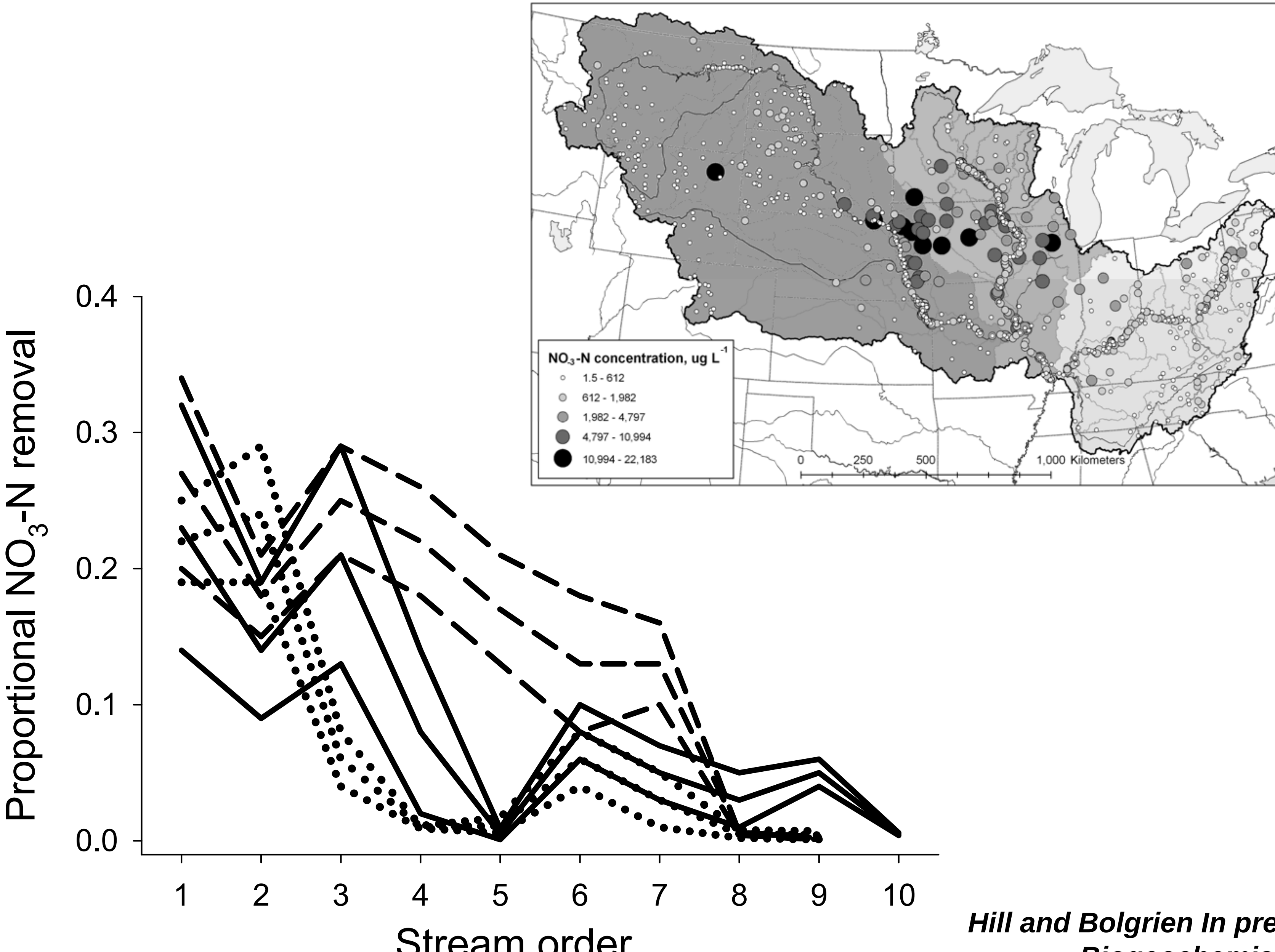
National N Inventory

- Compile and provide current information on anthropogenic N inputs to the US – include in Atlas
- Assess variability of this information
  - Compare estimation methods and data origins
  - Identify current limitations and suggest improvements
  - Examine uncertainty of input estimates and explore what it means for biogeochemical modeling and ecosystem services

Water Purification:
Quantifying this ecosystem service

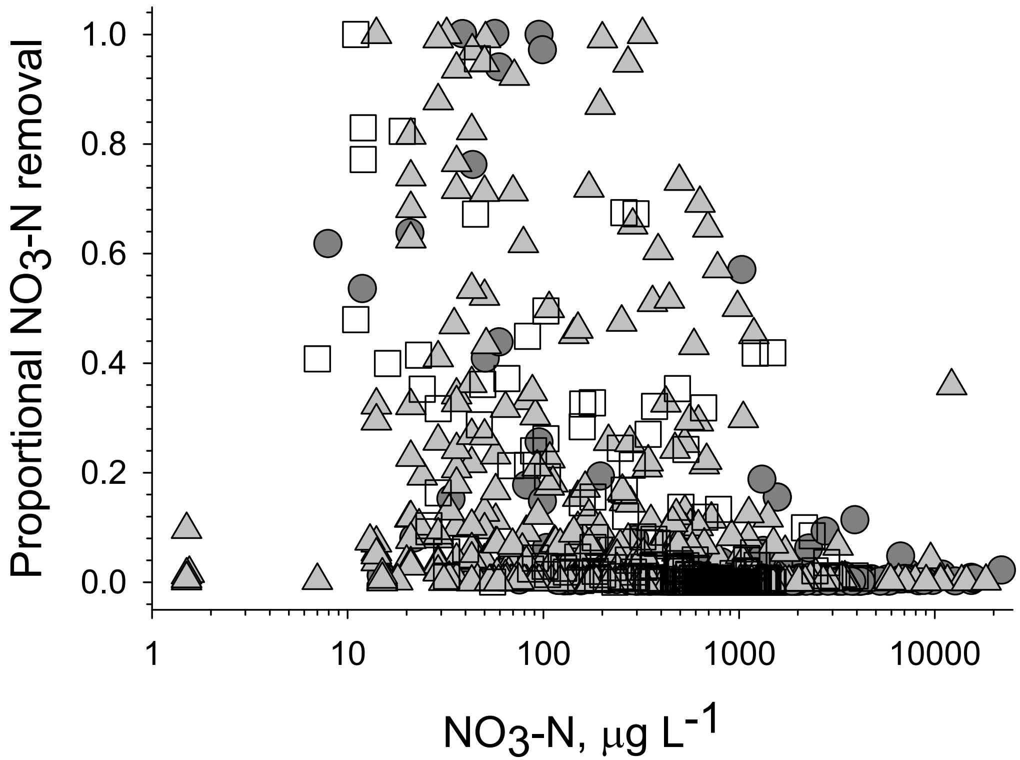


Nitrate removal in a river network



Hill and Bolgrien In press Biogeochemistry

Removal efficiency declines with increasing nitrate



Hill and Bolgrien In press Biogeochemistry

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Future work and the end goals

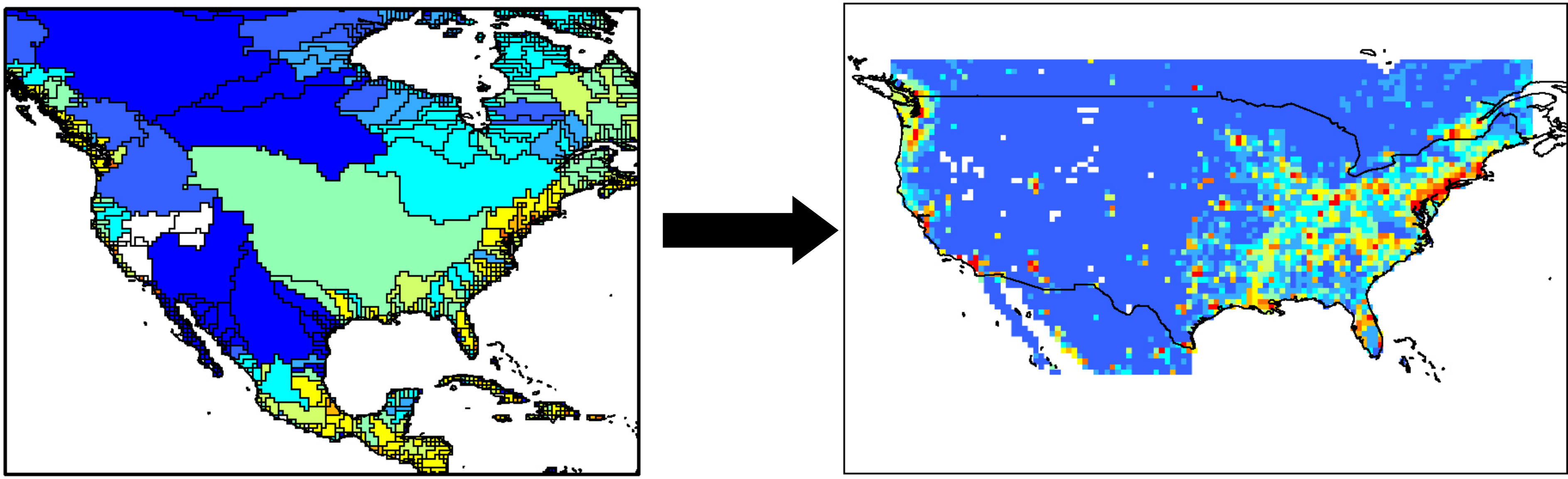
ESRP-N Modeling

- **Review of existing models - spreadsheet form by Heather Golden (NERL) et al.**
- **“Weight of evidence” modeling approach**
  - How different are estimates and predictions of N loading from land to water for SPARROW, SWAT and NEWS?
  - How do we combine/compare model estimates to better understand N flux uncertainties?
- **Developing models that link N load and Ecosystem Services, because few exist**

NEWS models

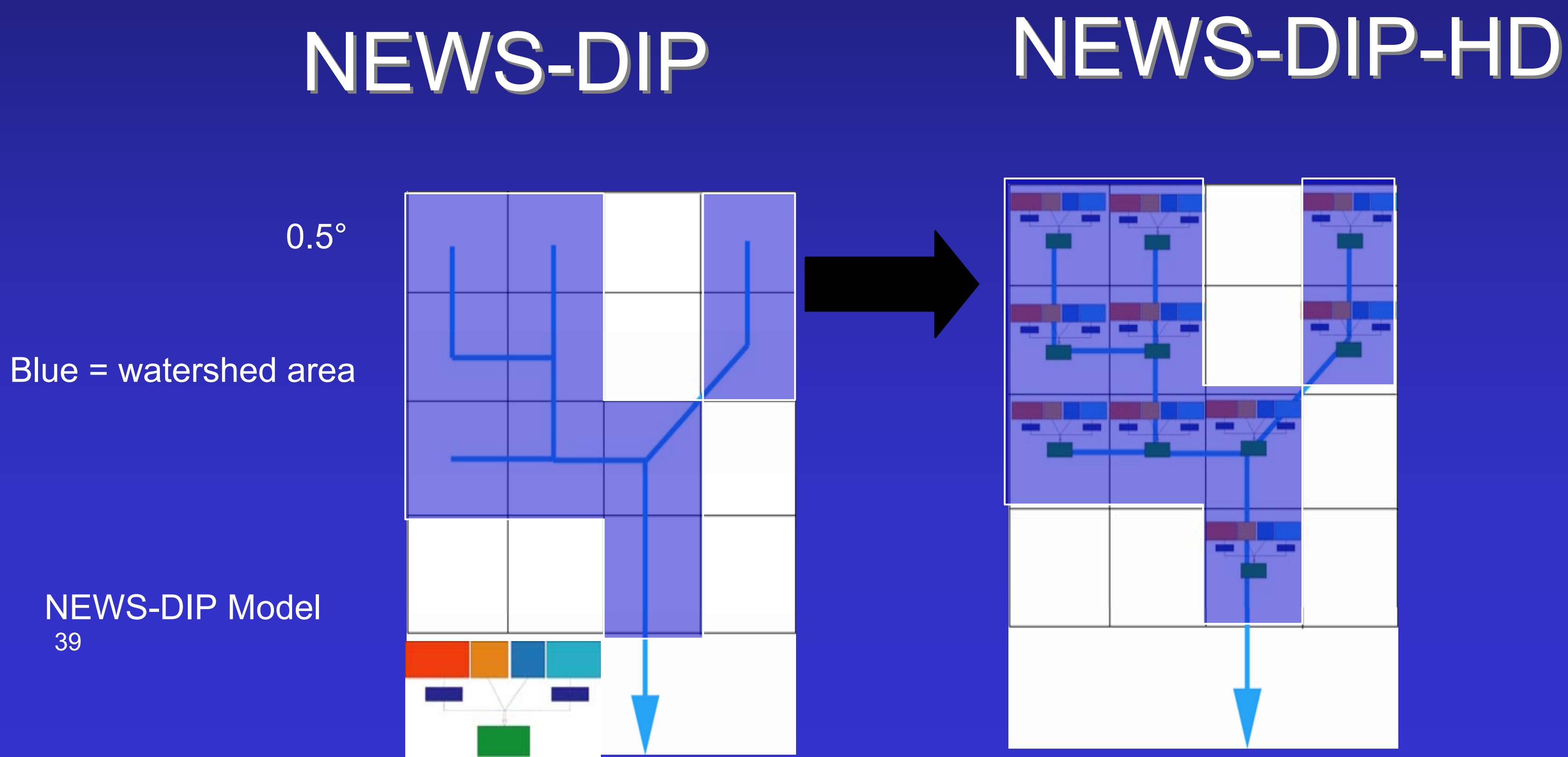
- UNESCO Intergovernmental Oceanographic Commission Workgroup
- Goal: construct and apply the next generation of spatially explicit, nutrient export models, linking the resulting river loads to quantitative assessments of coastal ecosystem health.
- Similar in some ways to SPARROW
- Less data intensive than other nutrient models
- Designed for scenario assessment
- In addition to N also models P, C, and Si (dissolved/particulate, organic/inorganic forms)

Question of scale:
Can we zoom in with NEWS modeling?



NEWS-DIP-HD Improvements

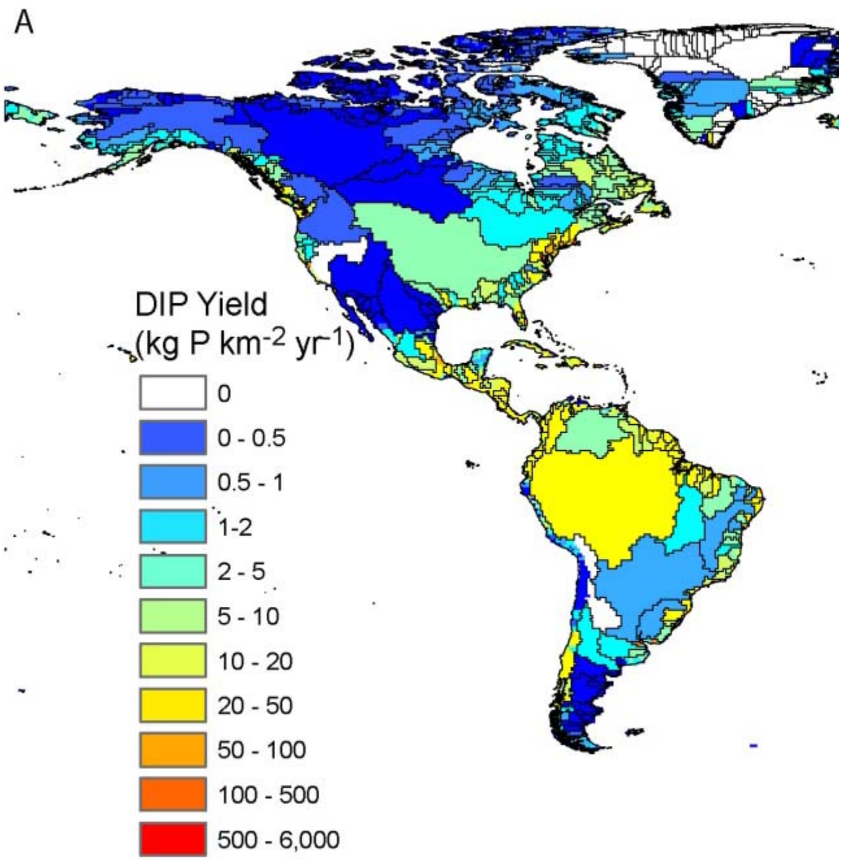
- Preserves 0.5 degree resolution
- Explicit downstream routing of water and DIP



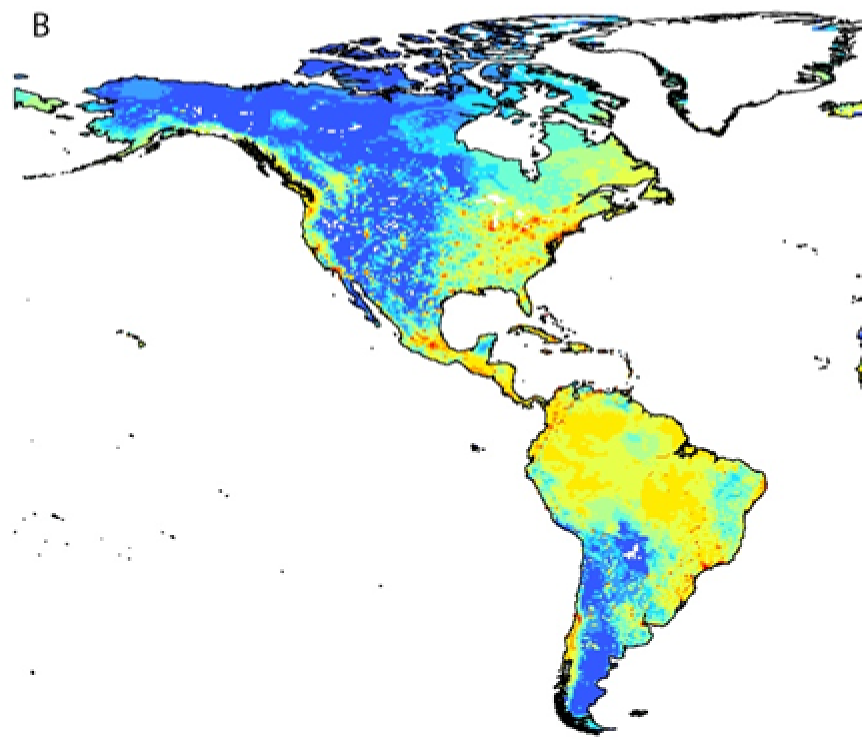
NEWS-Predicted DIP Yield

(kg P / km^2 / yr)

NEWS-DIP-2005



NEWS-DIP-HD-2009



John Harrison et al. 2010
Global Biogeochemical Cycles

Modeling and ESRP-N

- National run of NEWS-DIN: proposed HUC-12, connect to GOM services and climate
- Comparisons of SPARROW, NEWS, SWAT (& other models) for “weight of evidence” approach

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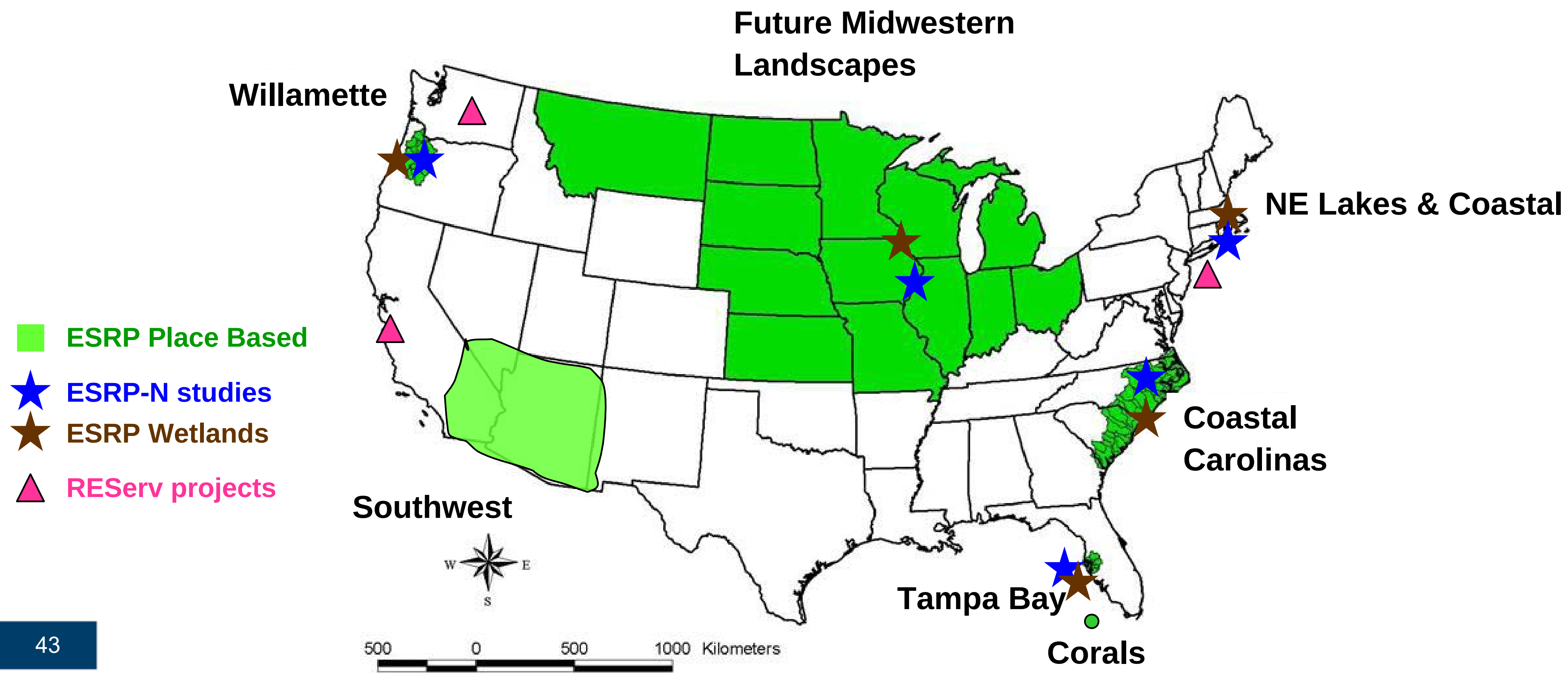
Future work and the end goals

Place-based, corals and REServ projects: Demonstration projects with close connection to decision-makers.

Wetlands project: Combining mapping and monitoring to examine wetland ecosystem services.



Wetlands

What ESRP-N asks of ESRP Wetlands:

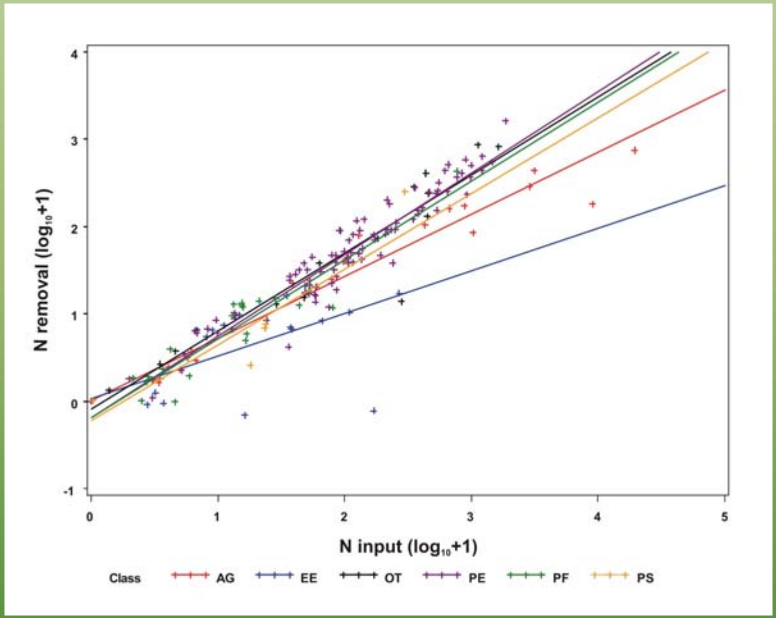
- Develop ESRFs of different N reduction interventions for multiple ecosystem services in wetlands
- Compare site-level estimates with national assessments of N sources, loading and removal
- Create spatially explicit maps of wetlands on the landscape by wetland type and hydrogeomorphic position
- Use and validate local tools for estimating N removal

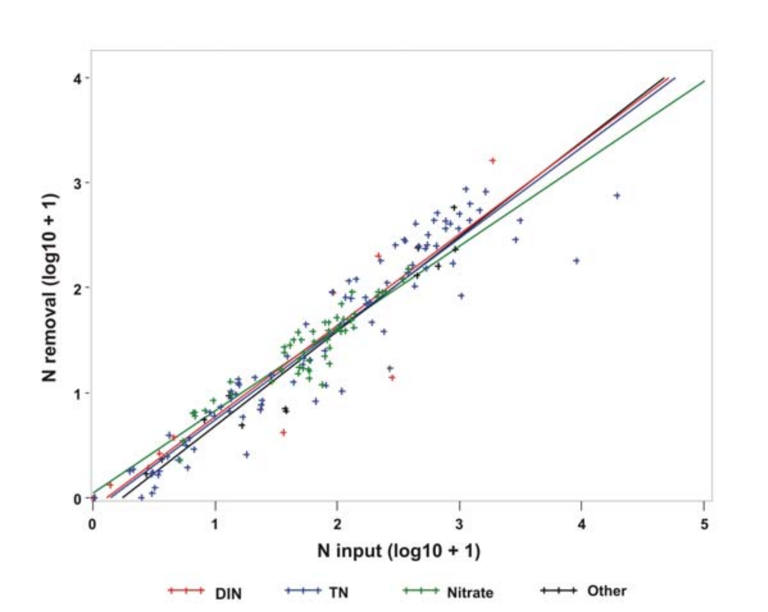
Removal of Reactive Nitrogen by Wetlands

Steve Jordan, Jonathan Stoffer and Janet Nestlerode
USEPA Gulf Ecology Division
Gulf Breeze, FL

Manuscript In preparation

Results





Nr removal is a linear function of Nr load for several wetland classes and various forms of Nr

United States Environmental Protection Agency

Nitrogen Removal in Riparian Zones

- Water Quality for Drinking Water & Ecosystem Health
  - Gulf of Mexico
  - Chesapeake Bay
  - Albemarle-Pamlico Estuary
  - Regional component of national atlas

- Riparian Zones:
  - Often effective at reducing nitrogen loads
  - Efficacy influenced by SPATIAL location of:
    - Riparian zone (carbon), farm practices (N loads & transport), soil drainage (anaerobic conditions), and hydrologic flows (degree of interaction)

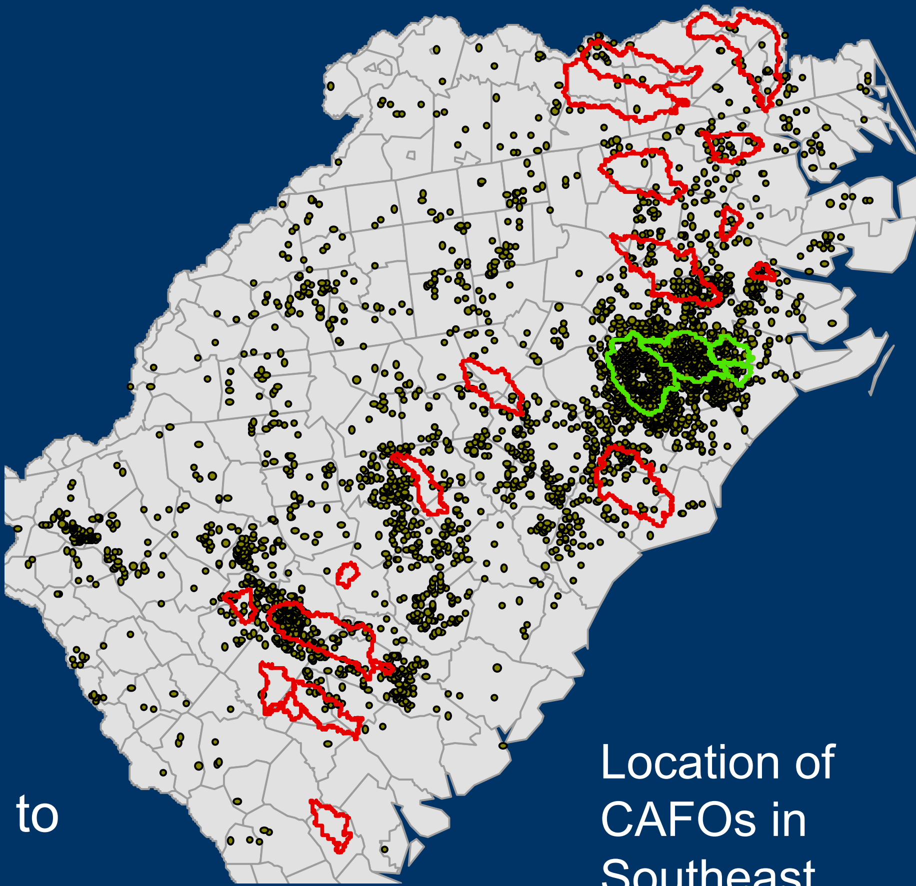
Jay Christensen et al. EPA NERL

EPA United States Environmental Protection Agency

Nitrogen Removal in Riparian Zones

Where are likely areas of nitrogen removal?

- Subwatersheds in Cape Fear
- Combine:
- Reducing Conditions
  - Riparian flow analysis
  - Soil drainage
  - Subsurface GW proxy
- N Inputs
  - High N crops
  - & CAFOs



Location of CAFOs in Southeast

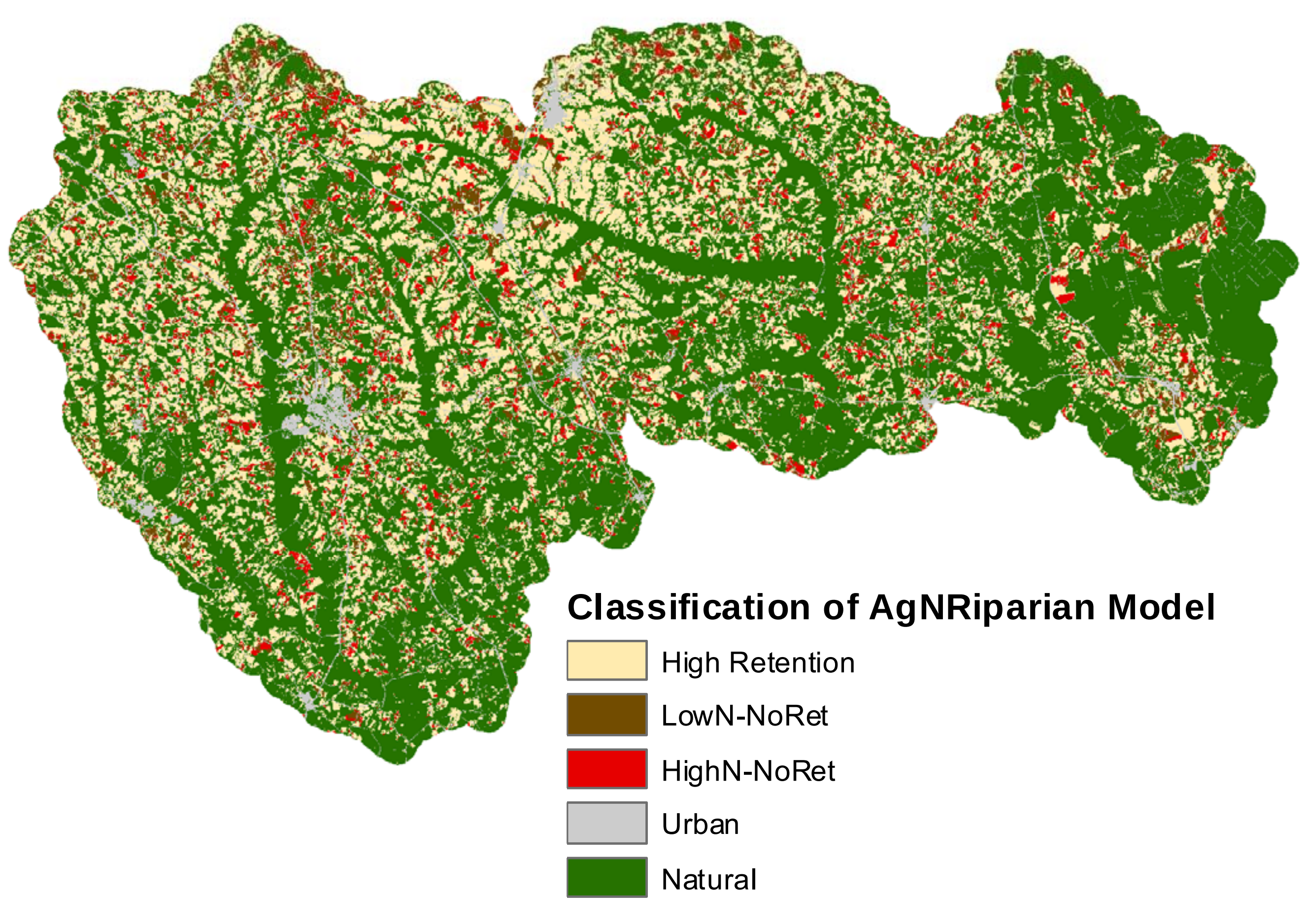
Statistical relationship of metrics to SE SPARROW N loads

EPA
United States
Environmental Protection
Agency

Nitrogen Removal in Riparian Zones

Where are likely areas of nitrogen removal?

– Subwatersheds in Cape Fear



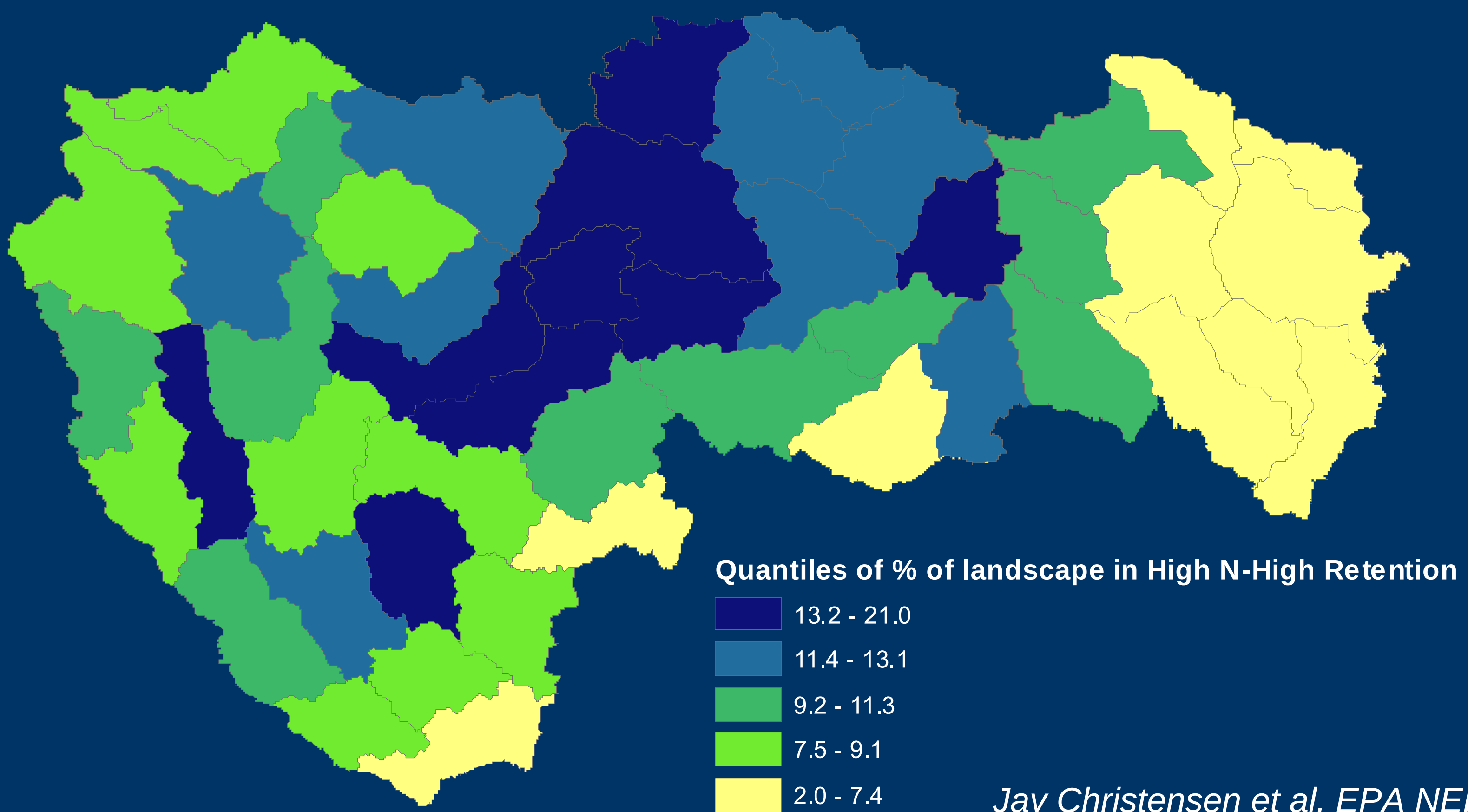
Ecosystem Services Research Program

United States Environmental Protection Agency

Nitrogen Removal in Riparian Zones

Where are likely areas of nitrogen removal?

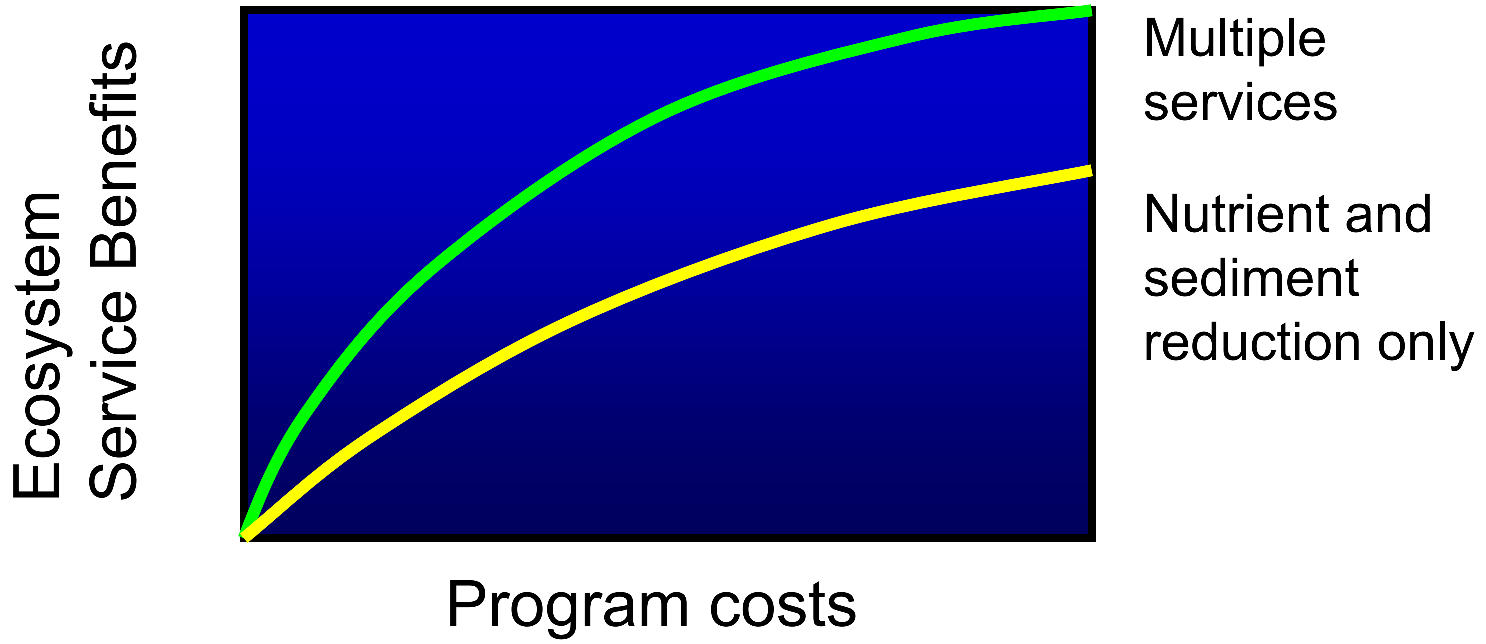
Subwatersheds in Cape Fear – 12 digit HUCs



Jay Christensen et al. EPA NERL

ESRP Chesapeake Bay Pilot

- The ESRP pilot project will explore the extent to which some mix of green and gray infrastructure could meet target loads, while delivering substantially more ecosystem services valued by Bay residents.



Groundwater and drinking water provision

- REServ project in Region 10: groundwater nitrate
  - *ORD, Region and USGS*
- Private wells in Oregon: Nitrate and coliforms
  - *Brenda Hoppe and Anna Harding, Oregon State University*
  - *Laura Jackson EPA NERL, ESRP Human Well-being lead*
- ESRP-N will collaborate, providing N source information

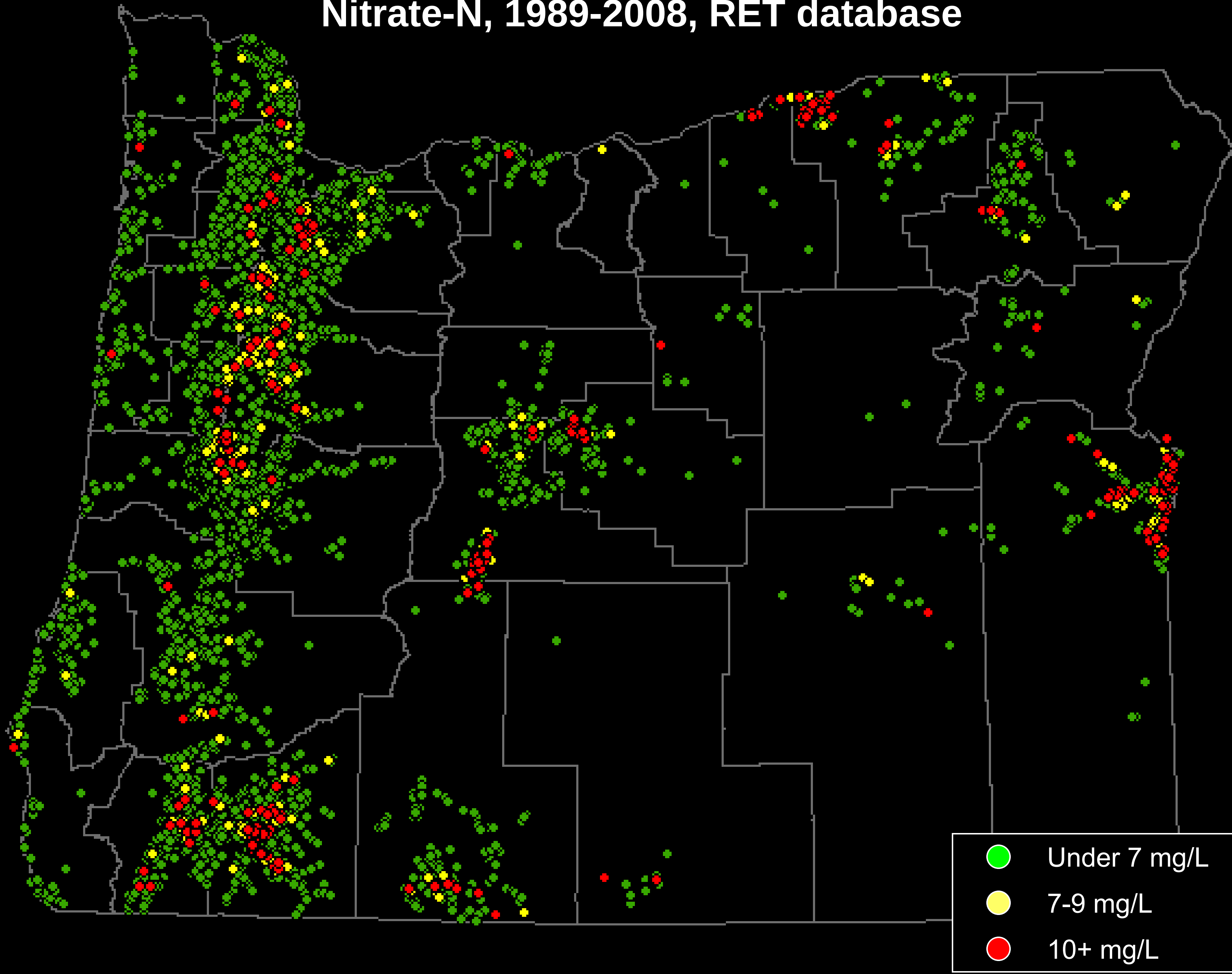
GIS Analysis of Nitrate in Oregon Domestic Wells: Capturing Exposure through Innovative Drinking Water Policy

Brenda Hoppe
Oregon State University and
Office of Environmental Public Health
Oregon Department of Human Services

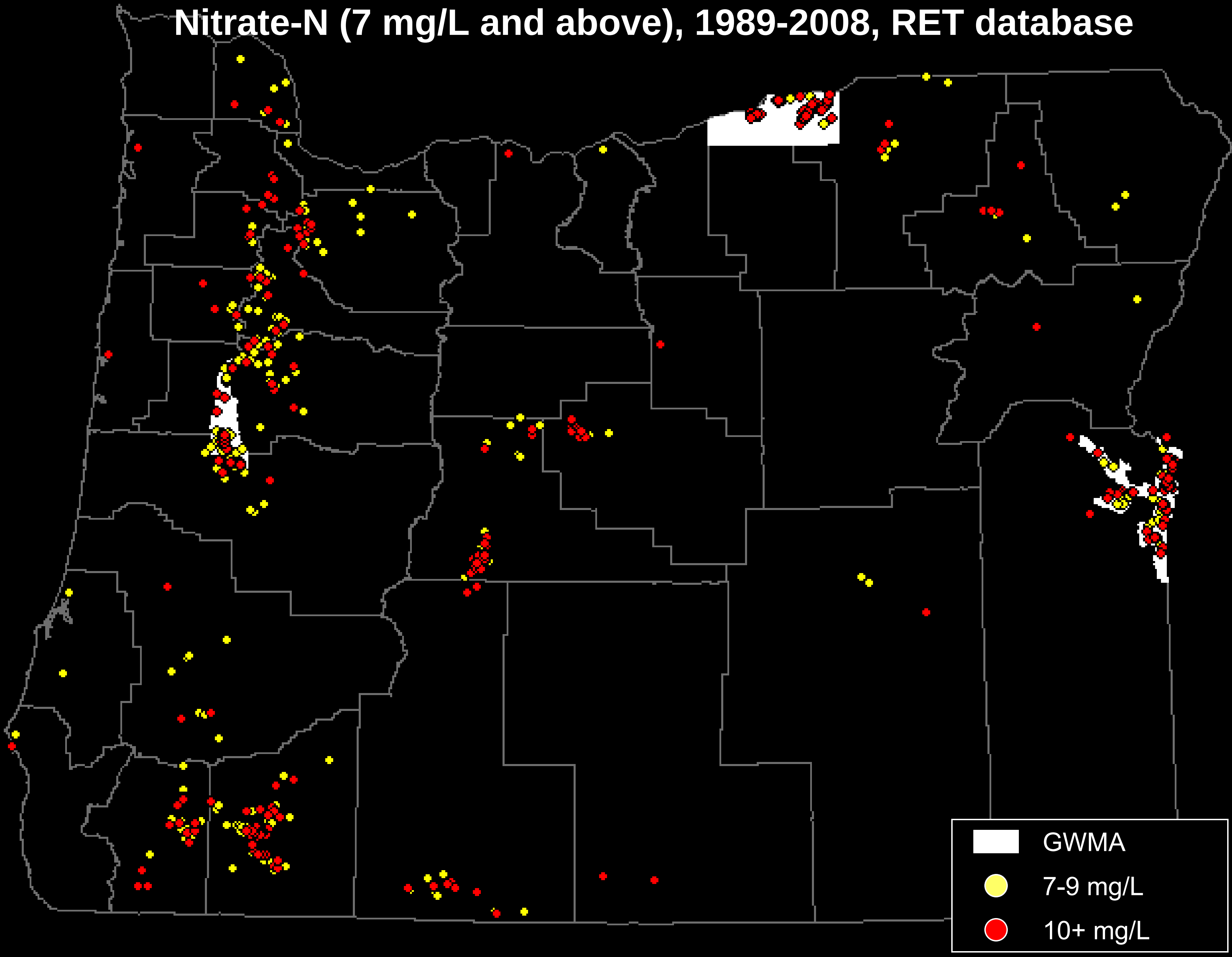
Private Wells in Oregon

- Over 350,000 private wells in Oregon (DEQ, 2009 Report to the Legislature)
- 23% of Oregon’s population
- Given population growth forecasts, will likely increase

Nitrate-N, 1989-2008, RET database

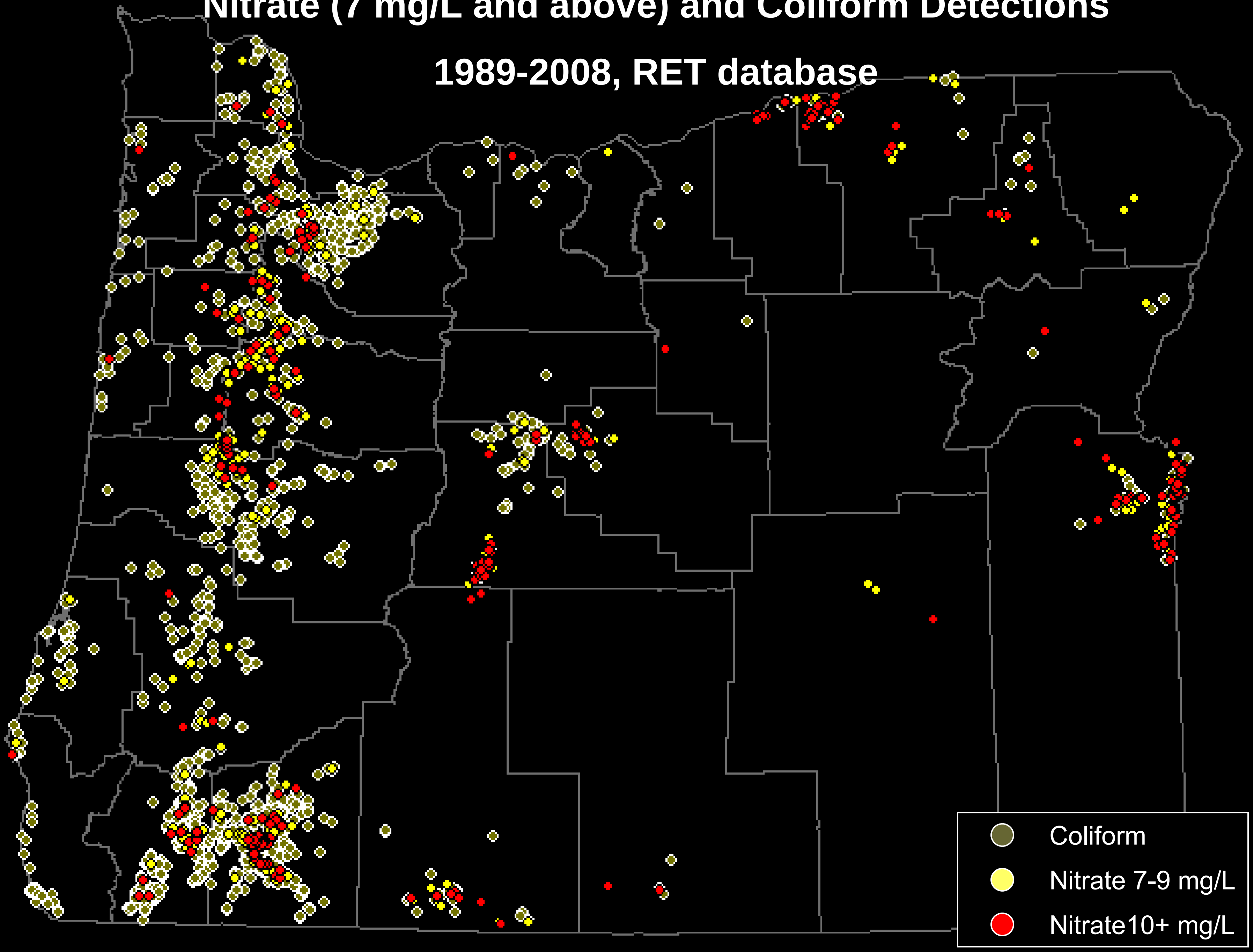


Nitrate-N (7 mg/L and above), 1989-2008, RET database



Nitrate (7 mg/L and above) and Coliform Detections

1989-2008, RET database



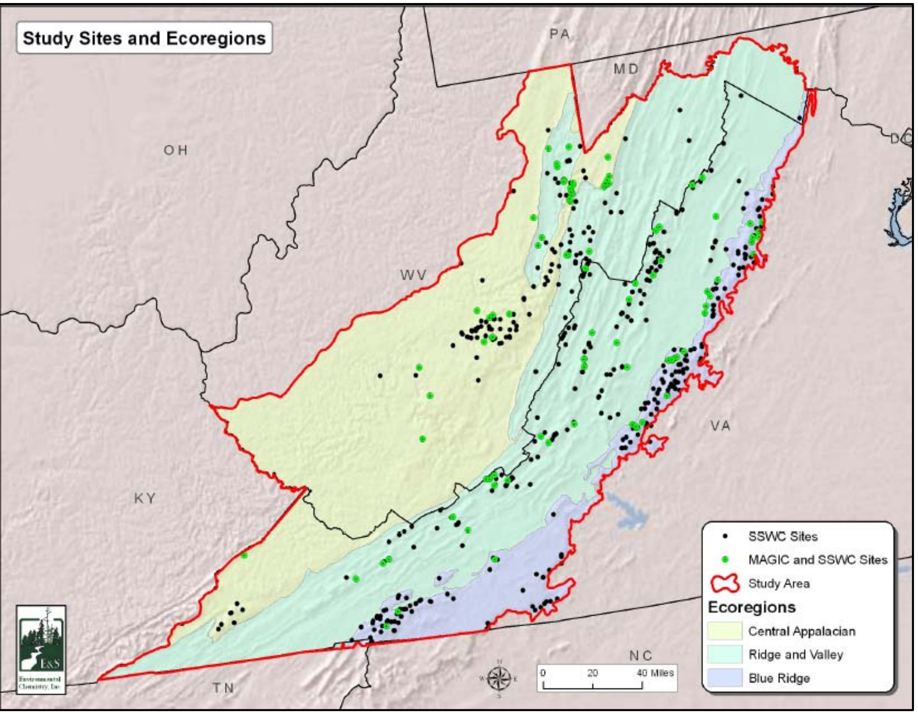
Theme 4: Tipping Points in Ecosystem Condition and Services

- Blue Ridge Mountains Aquatic Systems
- Adirondacks Terrestrial Systems
- Rocky Mountain Aquatic Systems

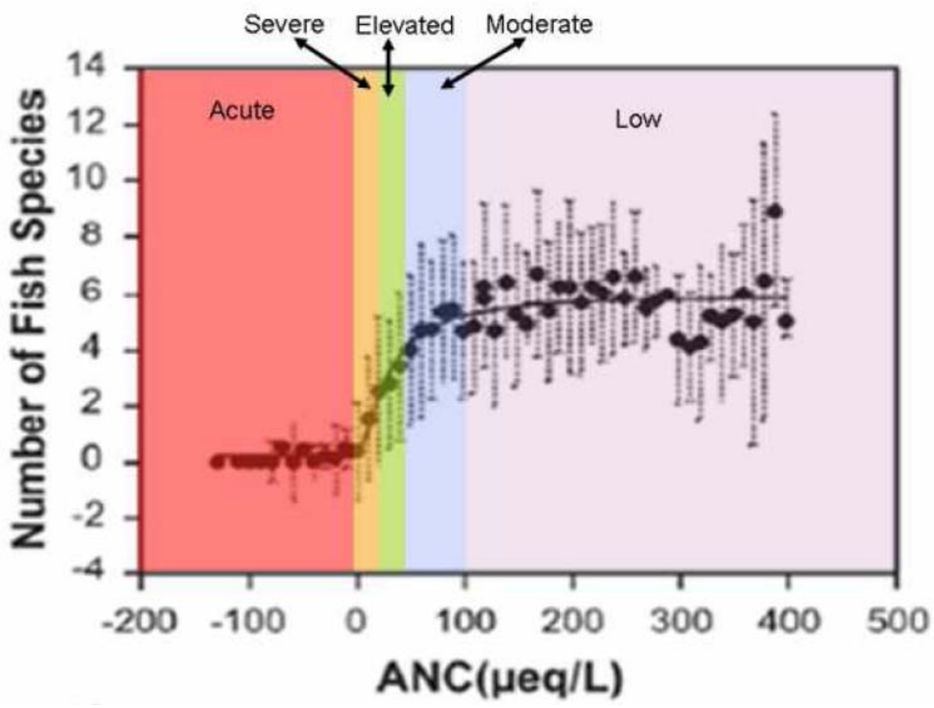
Connecting Critical Loads Modeling to ES

Sensitivity to acid inputs in Blue Ridge Streams

Modeled sites: MAGIC (n=92) and Steady State Water Chemistry model (n>500)



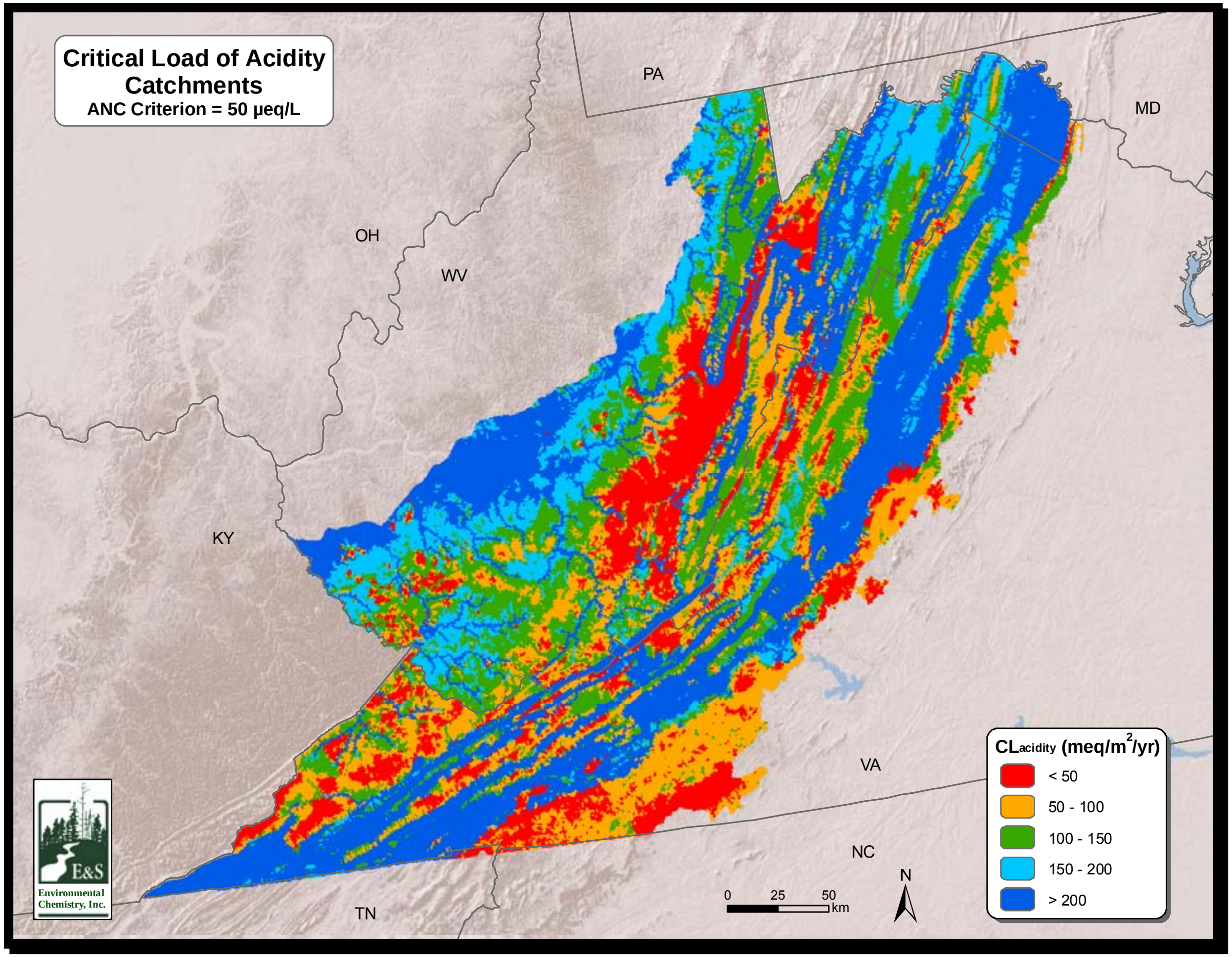
Link between ANC and fish species



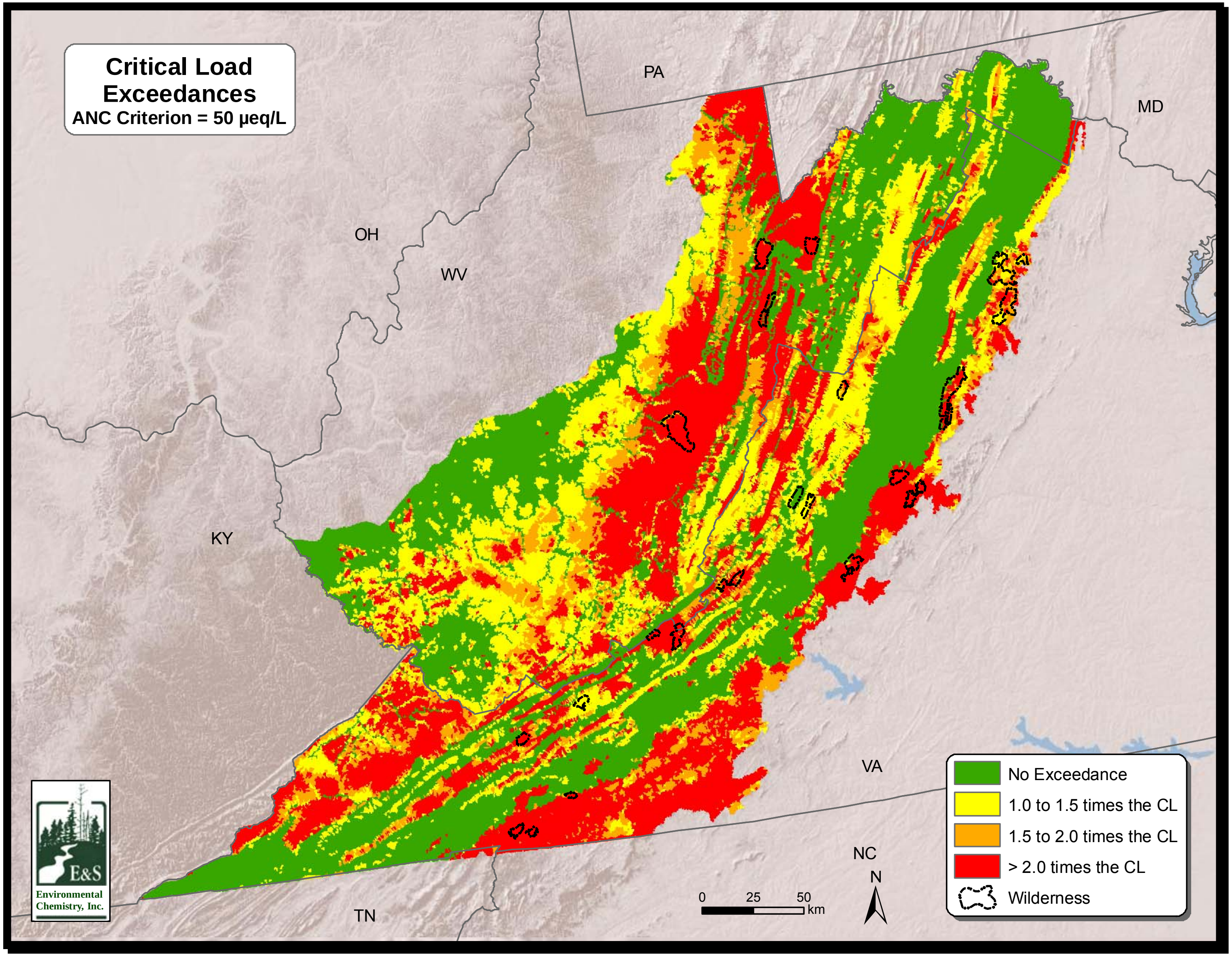
Critical loads of acidity:

Weathering is most important component of the critical load.

Locations with low weathering will have low CL, and vice versa.



Map of at-risk areas



Outline of talk

Nitrogen and ES: the end goals

Research directions and results

- Connecting Nitrogen and Human Benefits
- Mapping and Monitoring Pressures and Services
- Modeling
- Cross-cut: Demonstration and local N-ES connections

Future work and the end goals

Research needs at local-regional scale

- Demonstration of the advantages of assessing the multiple ecosystem services benefits of nutrient-related decisions
  - NAAQS standards (recreation, fisheries)
  - Chesapeake
  - Wetlands (nutrients, flood protection, C)
- Climate change impacts on C-N interactions, N fluxes
- Connecting Nitrogen and ES in ways that are useful to decision-makers

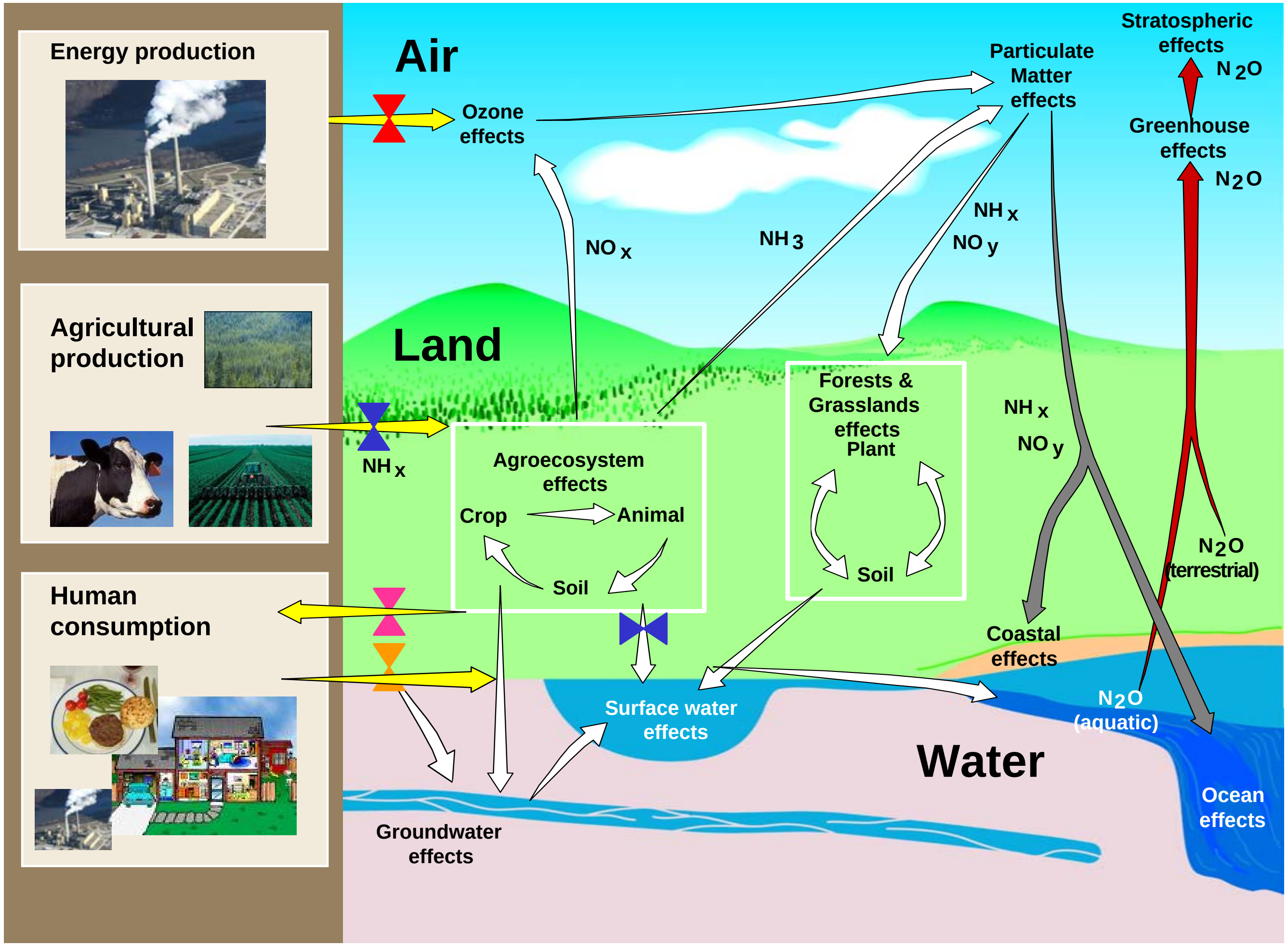
What are the most effective intervention points along the nitrogen cascade?

Reducing air emissions (power plants and cars)

Land use choices (nutrient management, wetland restoration)

Reducing water point source loads

Individual decisions (diet, vehicles, lawn fertilizer)



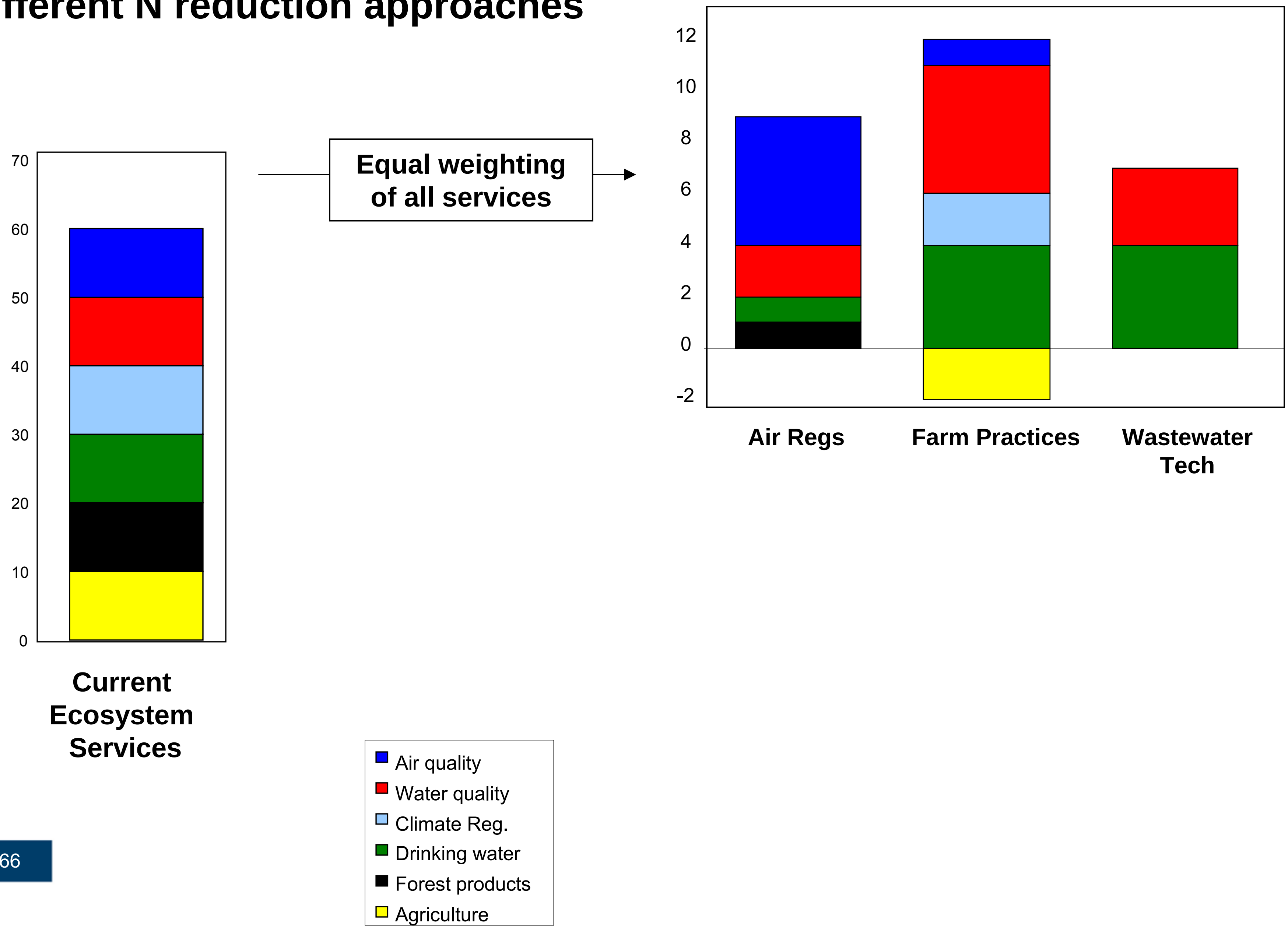
Modified from Galloway et al. (2003)

Positive and negative implications of ways to reduce N loads

Intervention	Benefit	Downside
Air deposition	Forest health, biodiversity, acidity, fisheries, human respiratory health, visibility, recreation	Cost to industry and consumers
Waste treatment	Water clarity, pathogens, chemicals, fisheries, recreation, air quality improvements, jobs	Cost to industry and consumers
Farm conservation practices & BMPs	Carbon storage, minimize erosion and sedimentation, biodiversity, water clarity, fisheries, recreation, flood protection	Cost to farmer (in part offset by USDA), possible ↑ GHG

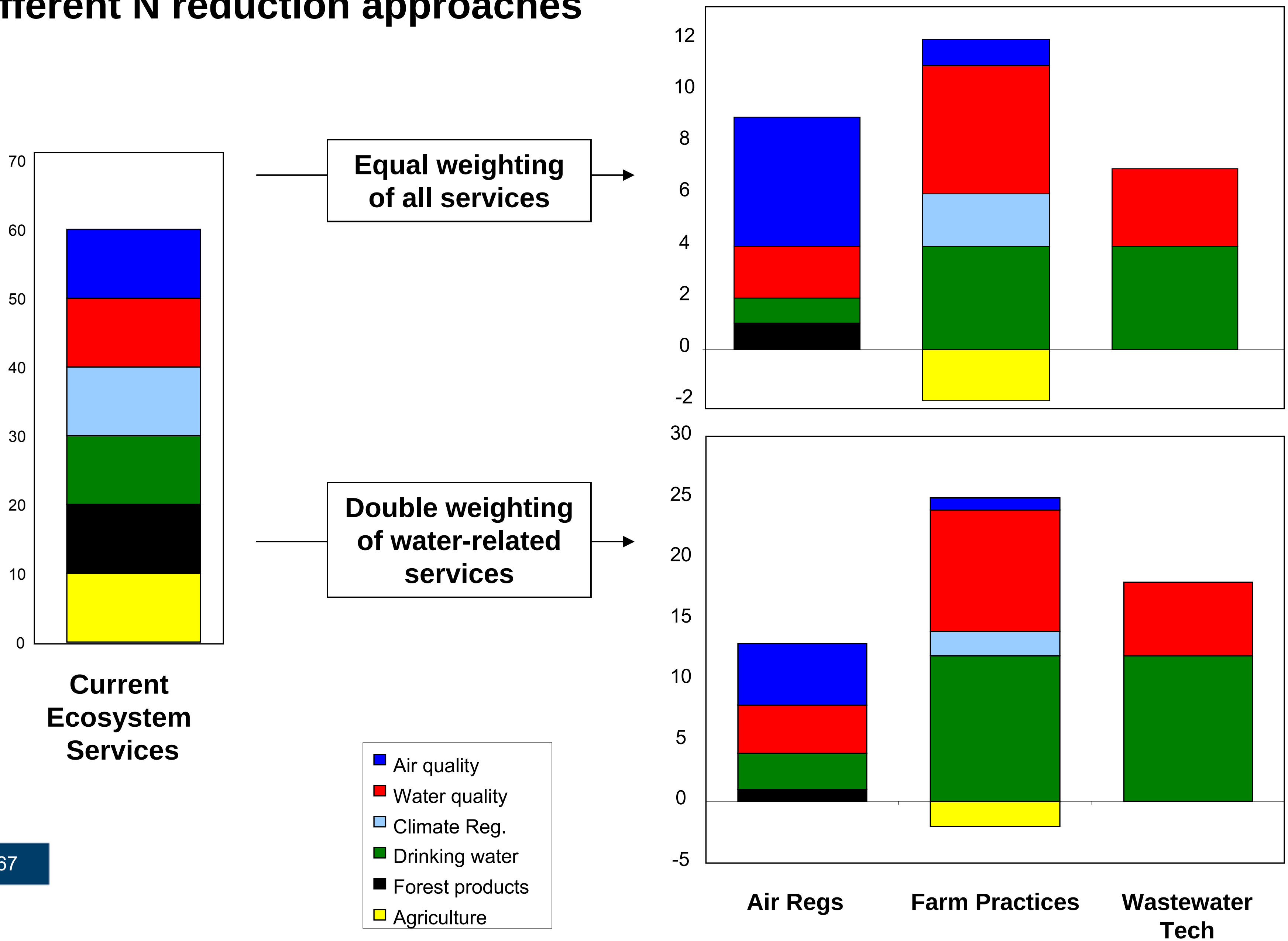
Potential benefits of different N reduction approaches

Change in services



Potential benefits of different N reduction approaches

Change in services



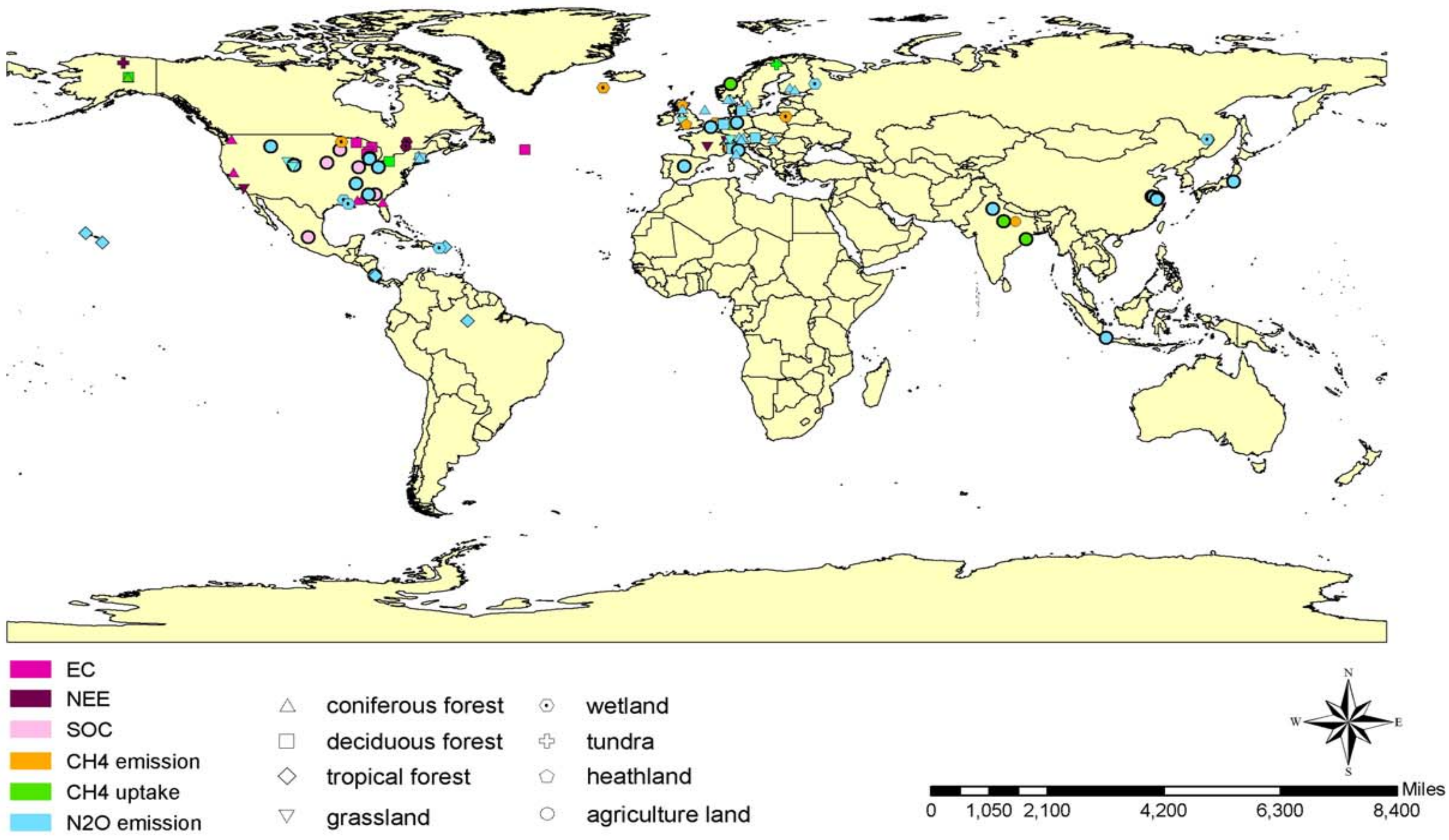
Nutrient Management: Literature Review of Interventions and Policies

- Will review nutrient management approaches around the globe, focusing on United States and European approaches
- Suggested during SAB review
- Holly Campbell and Jana Compton
  EPA Student Contractor and Mentor

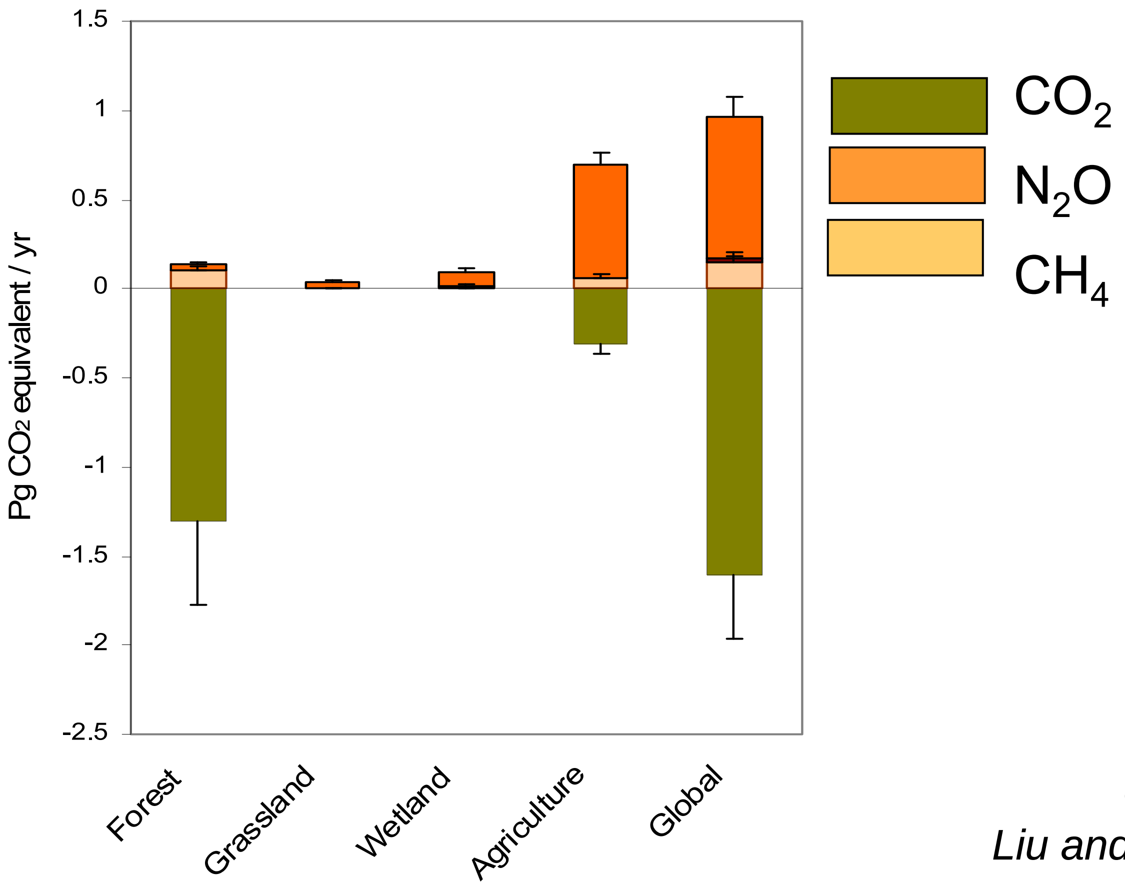
Interactions with Climate change

- Climate-air quality modeling
- Literature review and meta-analysis of N addition effects on
  - C, N_2O and CH_4 flux (Liu and Greaver 2009)
  - Belowground C (Liu and Greaver 2010 in press)
- Workshop on Ecological Effects of N x Climate Interactions planned for fall 2010
  - NCEA, ESRP, OAR

Global map of N addition experiments on GHG flux



Estimates of net changes in global GHG flux caused by N enrichment, results from meta-analysis



Calculated from Liu and Greaver (2009) Ecology Letters

Timeline for ESRP-N

FY09 FY10 FY11 FY12

Implementation plan link

Review paper on ES and reactive N – fall 2010

National Nitrogen Inventory For Atlas of ES - 2011

Regional weight-of-evidence modeling – 2012

Ecosystem services and nutrient cycling – application work

Sensitive ecosystems and critical loads – 2011

Report on the value of ecological services provided by and affected by Nr - 2012

Theme 1
Theme 2
Theme 3
Theme 4

The end result of this work will be the development of credible, scientifically-based methods to:

- Inventory, measure and map nitrogen pressures and ecosystem services that are useful at multiple scales;

- Improve understanding of the effects of reactive nitrogen on ecosystem services;

- *Provide the regulatory community with data and tools that are scientifically sound and represent the appropriate uncertainties in order to understand N impacts on ecological and human systems.*

Thank you!

For more information →

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