Future Midwestern Landscapes Study Update

April 8, 2010

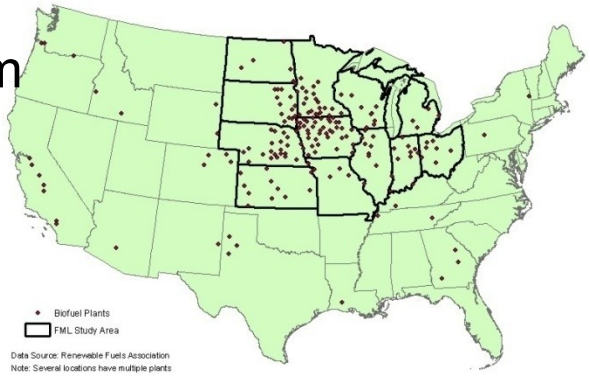
Betsy Smith and Randy Bruins

Transdisciplinary Team

- **Office of Research and Development**
  - Rob Wolcott (policy)
  - **National Exposure Research Laboratory**
    - Randy Bruins (Co-leader) (ecology)
    - Betsy Smith (Co-leader) (ecology)
    - Alex Macpherson (economics)
    - Megan Mehaffey (landscape ecology)
    - Ellen Cooter (atmospheric processes)
    - Yongping Yuan (ag sciences)
    - Jay Christensen (landscape ecology, ag sciences)
    - Charles Lane (wetlands)
    - Vasu Kilaru (spatial analysis)
  - **National Risk Management Research Laboratory**
    - Tim Johnson (energy supply and demand)
    - Rebecca Dodder (energy supply and demand)
    - Ozge Kaplan (energy supply and demand)
    - Curtis Cooper(groundwater)
  - **National Health and Environmental Effects Research Laboratory**
    - Russell Kreis (hydrology)
    - Mark Rowe (aquatic habitat)
  - **National Center for Environmental Assessment**
    - Steve Le Duc (soil biogeochemistry)
- **EPA Region 7 (Kansas City)**
  - Brenda Groskinsky (RO decision needs)
  - Walt Foster (ecology)
- **EPA Region 5 (Chicago)**
  - Mary White (ecology) (RARE)
  - Carole Braverman (RO decision needs)
- **EPA Region 8 (Denver)**
  - Elaine Lai (sustainable development) (RARE)
- **Office of Policy, Economics and Innovation**
  - Andrew Manale (policy, PO needs)
- **Iowa State University/CARD**
  - Ag economics, market projections
- **Experts (Special EPA Employees)**
  - Lisa Wainger, U. of Maryland (spatial economics)
  - Liem Tran, U. of Tennessee (modeling, decision theory)
- **Other Agencies**
  - Rich Iovanna, Farm Services Agency (economics, decision needs)
  - Brad Potter, Diane Granfors, Fish and Wildlife Service (habitat, decision needs)
  - Dale Robertson, USGS (hydrology)

FML Problem Statement: decision-maker's perspective

- How will today's land use **decisions affect trade-offs** of future ecosystem services?
- What **indicators of change communicate** the vulnerabilities and opportunities to decision-makers?
- How can we **facilitate conservation and restoration** of ecosystem services?
- What are the impacts of EISA on ecosystem services?



Presentation Overview

FML – the big picture

- Change drivers and clients
- Services
- Primary product: the FML-EDT
- Research approach

Landscape development – methods and progress

- Base Year
- Biofuel Targets
- Multiple Services

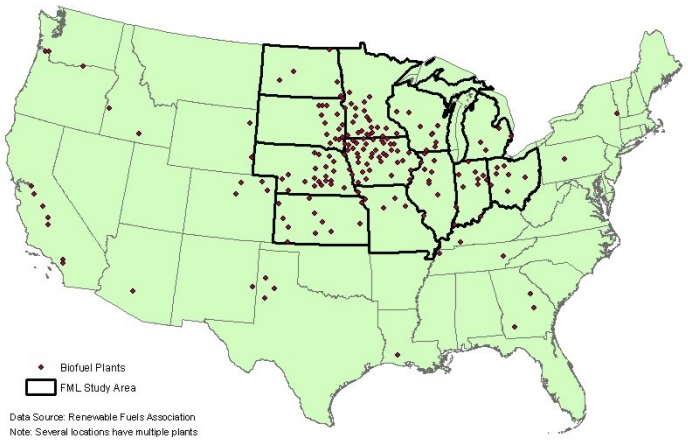
Service estimation – methods and progress

- Scoping of all services
- Soil systems
- Atmospheric systems
- Aquatic systems
- Terrestrial wildlife

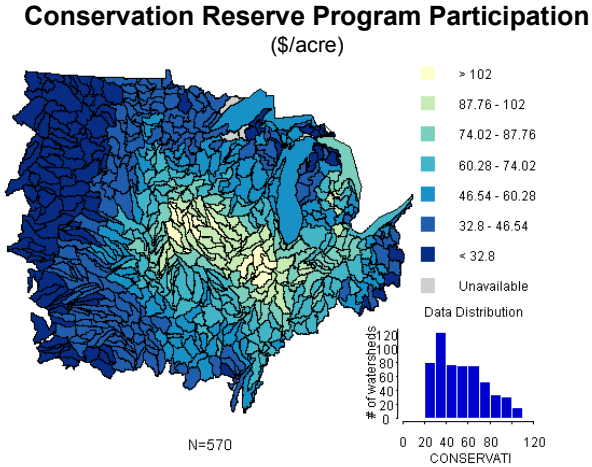
Service metrics and decision support

Change drivers of interest for Midwestern place-based study

- Biofuels
  - Potential for rapid, large-scale changes in land use or land management
  - Implicit trade-offs among ecosystem services
- Agricultural conservation practices
  - Existing area of large investment, uncertain benefit
  - Increasing interest in ecosystem service-based incentives and markets



Locations of ethanol biorefineries and FML boundary



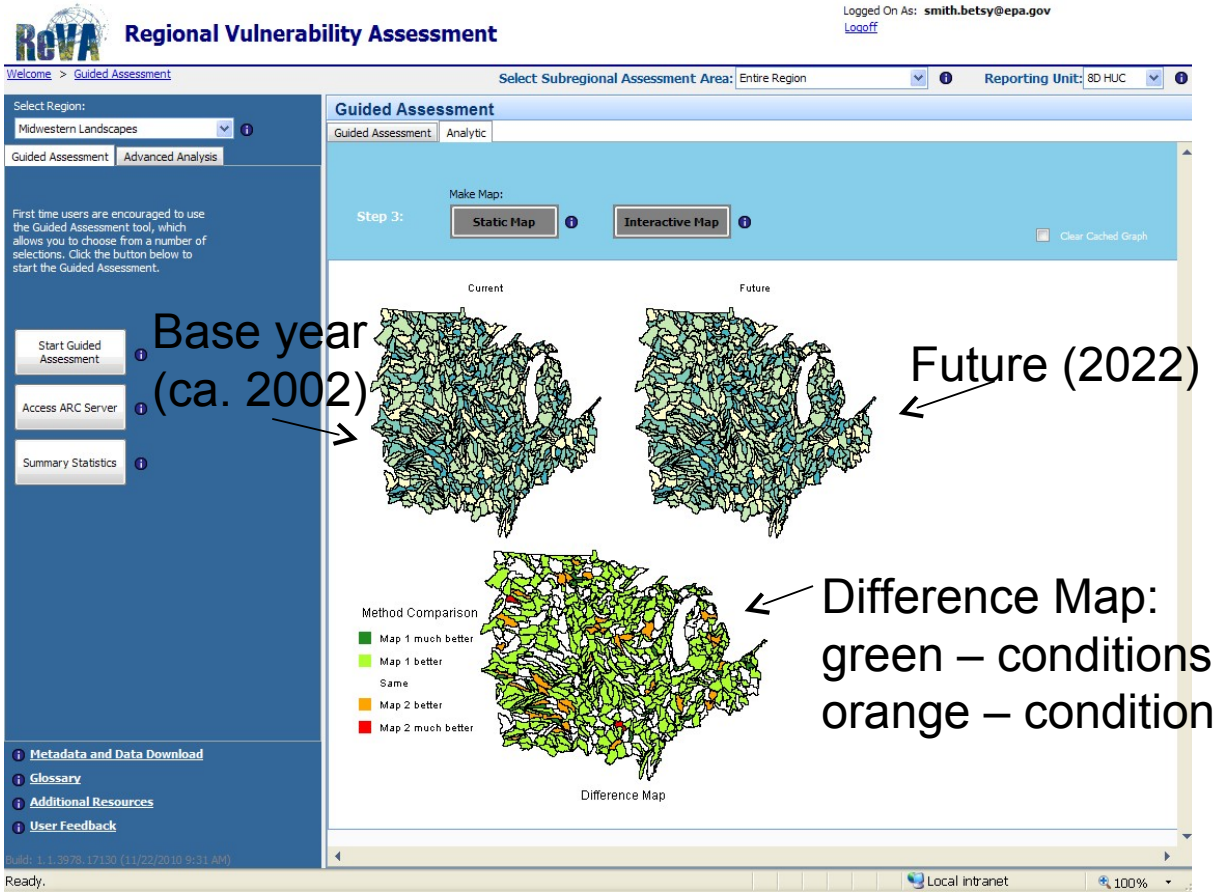
Clients for FML Study

- EPA Regions 5 and 7
- EPA Office of Air and Radiation
- EPA Office of Water
- Great Lakes National Program Office
- Congress – EPA Biofuels Report to Congress
- USDA Farm Service Agency
- USDA Economic Research Service
- USDI Fish and Wildlife Service
- States
- Communities
- NGOs
- Landowners

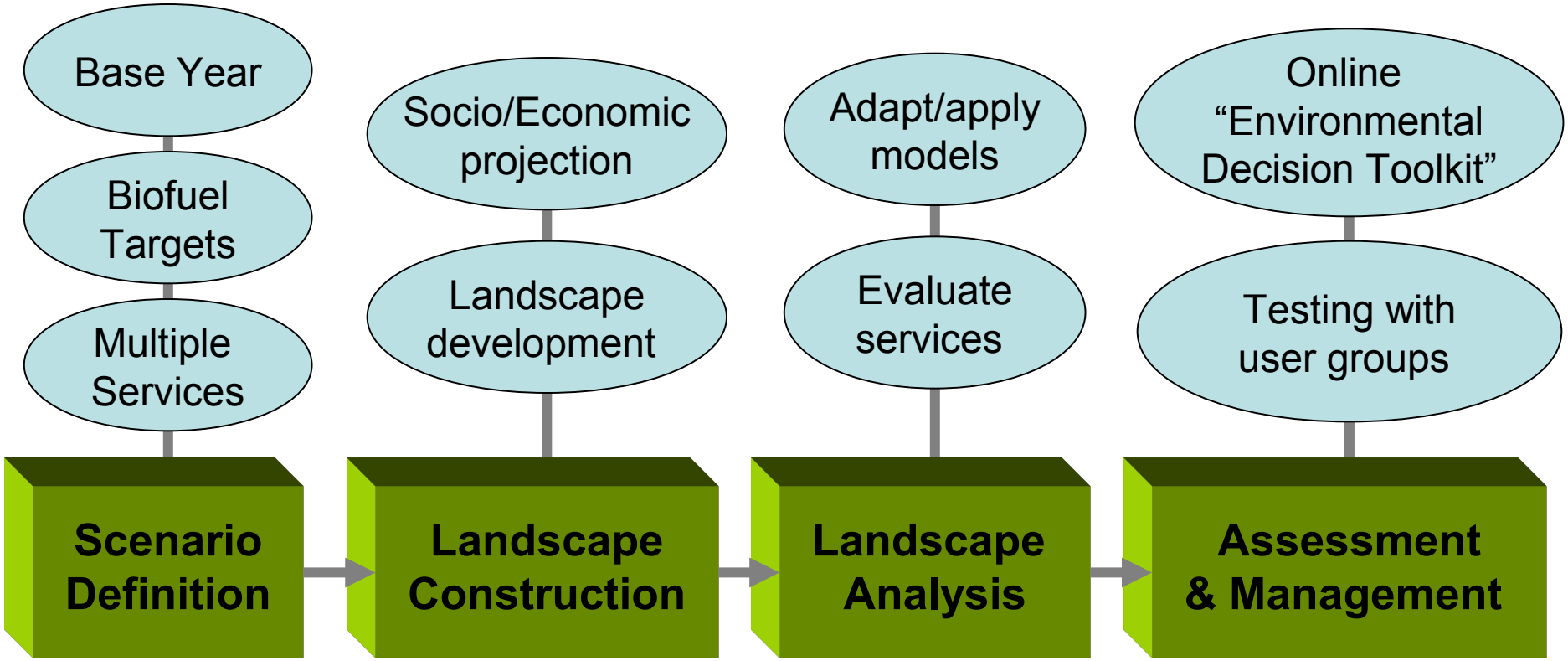
FML ecosystem service categories

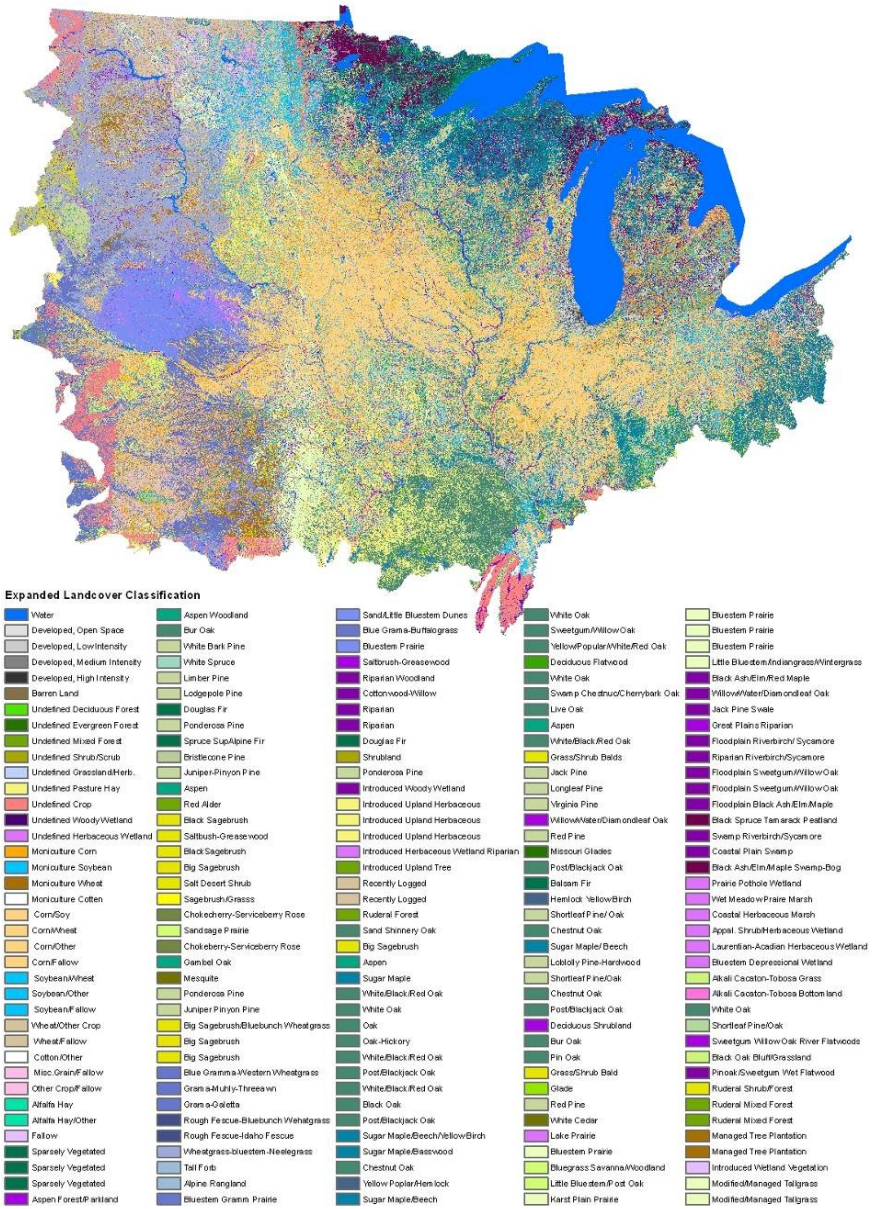
- Production of food and fiber
- Clean air
- Climate moderation (via carbon sequestration)
- Water provision
- Flood moderation
- Aquatic habitat to support wildlife-based recreation
- Terrestrial habitat to support wildlife-based recreation

Evaluating trade-offs using the Environmental Decision Toolkit (EDT)



Overview of FML alternative-futures research approach





FML Base Year Landscape
(Megan Mehaffey)

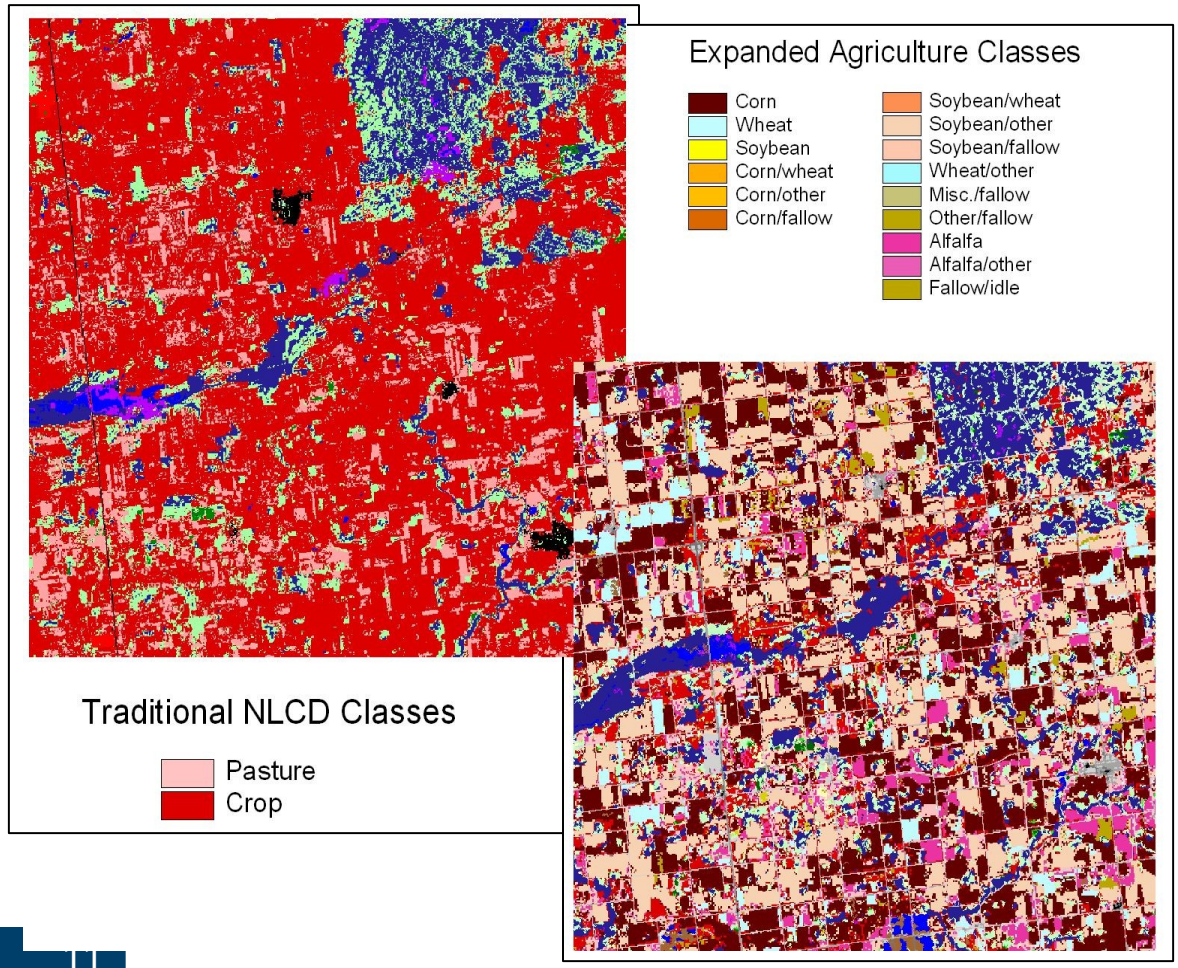
Enhanced Land Cover Data for FML– Combines the best of NLCD, NASS Crop Data Layer, and LANDFIRE using a set of rules

Includes crop type as well as rotation

Implications for better estimation of nutrients and pesticides loads/export

Better assessment of crop yields

FML Base Year Landscape – Enhanced NLCD 2001/2002: Comparison of Traditional and Expanded NLCD Agriculture Classes



Traditional NLCD classes do not distinguish crop types.

Between 2006 and 2007, there was a 19% increase in corn plantings nationwide, mostly from conversion of soybean plantings.

N fertilizer need for corn is ~ 8 times that of soybeans.

Biofuel Targets Scenario (2022)

Tim Johnson
Rebecca Dodder
Ozge Kaplan
& ISU/CARD

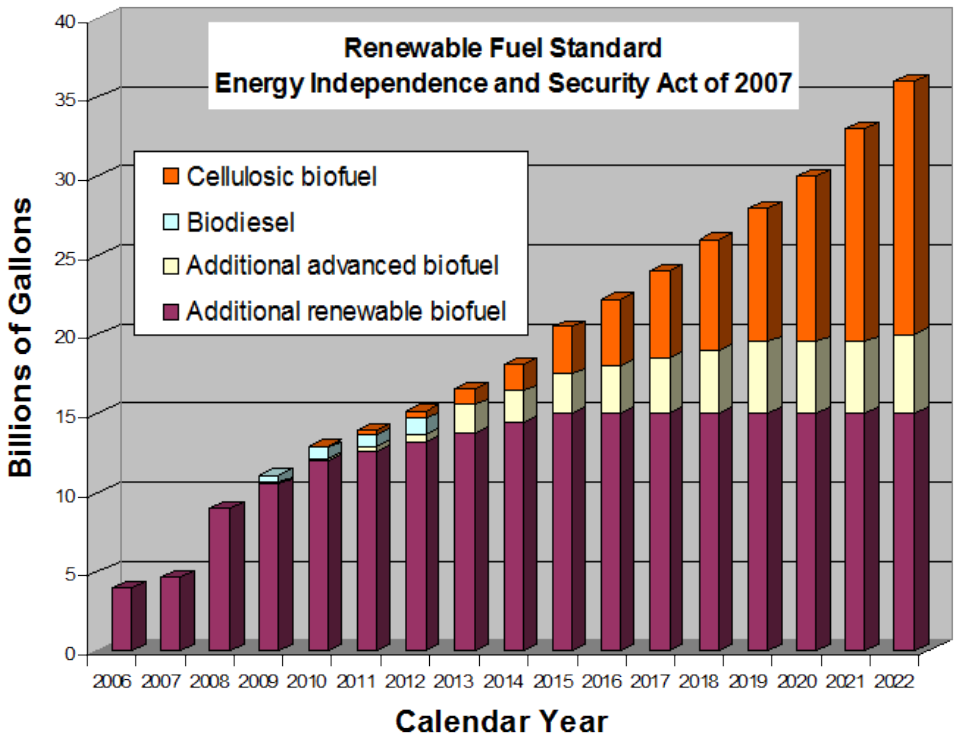
Market Allocation (MARKAL) econometric model

- Energy supply and demand

Sets conditions for:

Food and Agricultural Policy Research Institute (FAPRI) econometric model

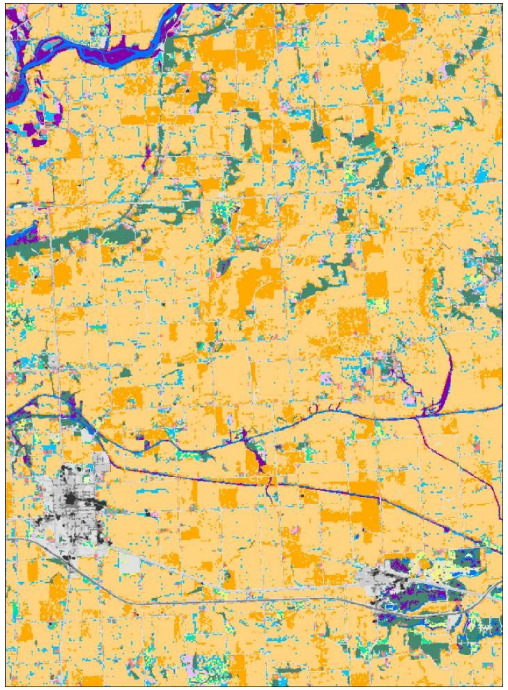
- Agricultural supply and demand
- Projects crop acres / region



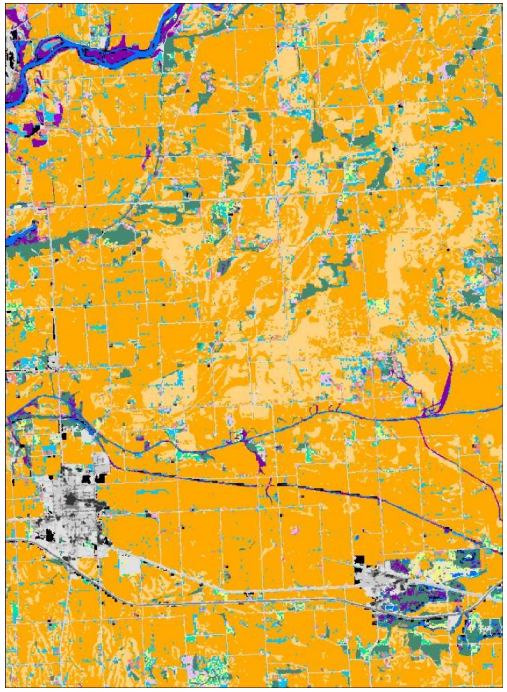
Results disaggregated using soils data, tillage practices, etc.

Projection of 2022 landscape changes due to biofuel targets:

Parcel change from corn/soybean to continuous corn



Base Year (2001)



Biofuel Targets (2022)

Detail for Corn Belt area in Illinois

In the Corn Belt, corn/soybean rotation will change to continuous corn, requiring greater chemical inputs and depleting soil productivity

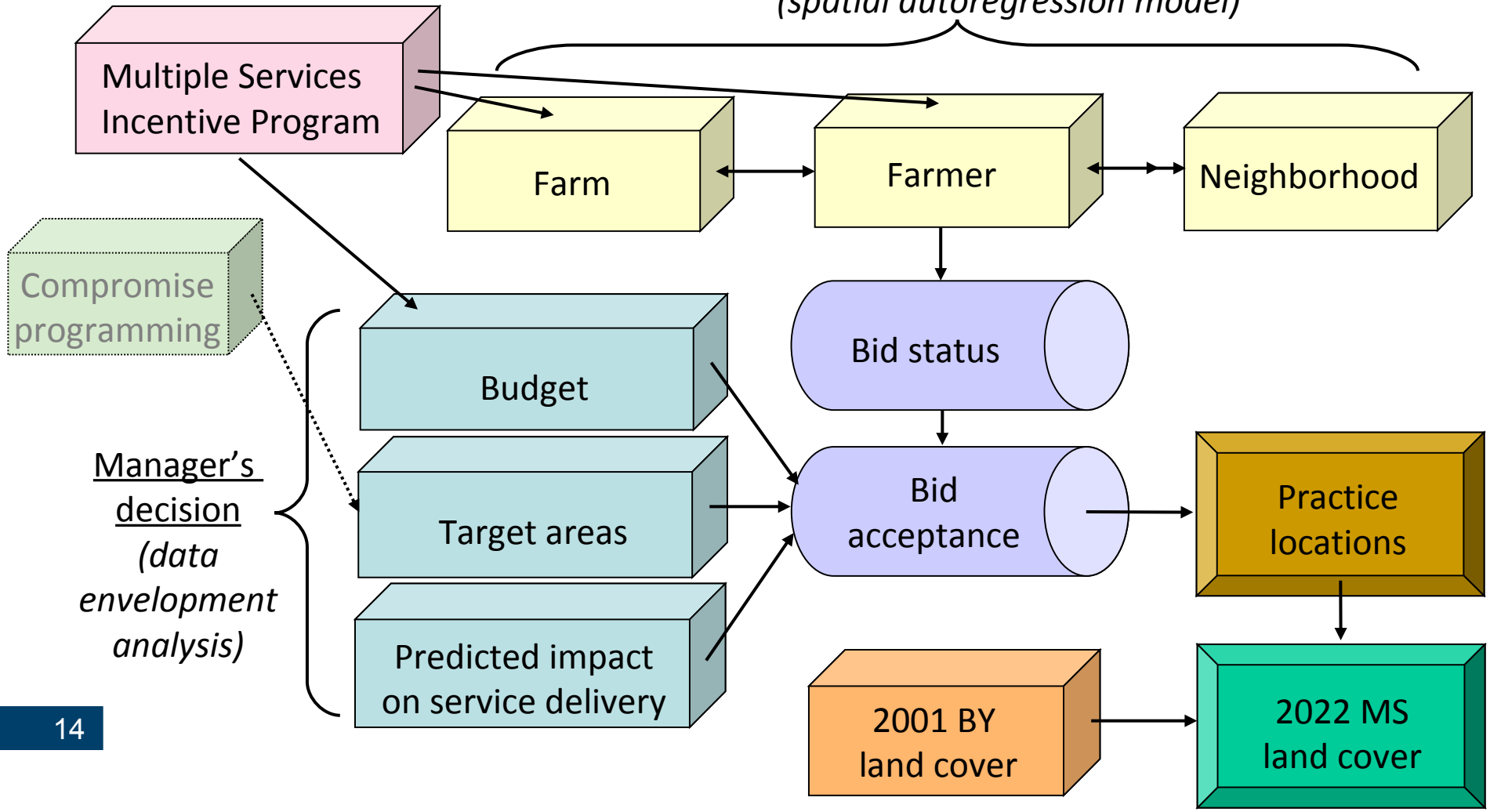
(Megan Mehaffey)

Corn/soybean rotation

Continuous corn

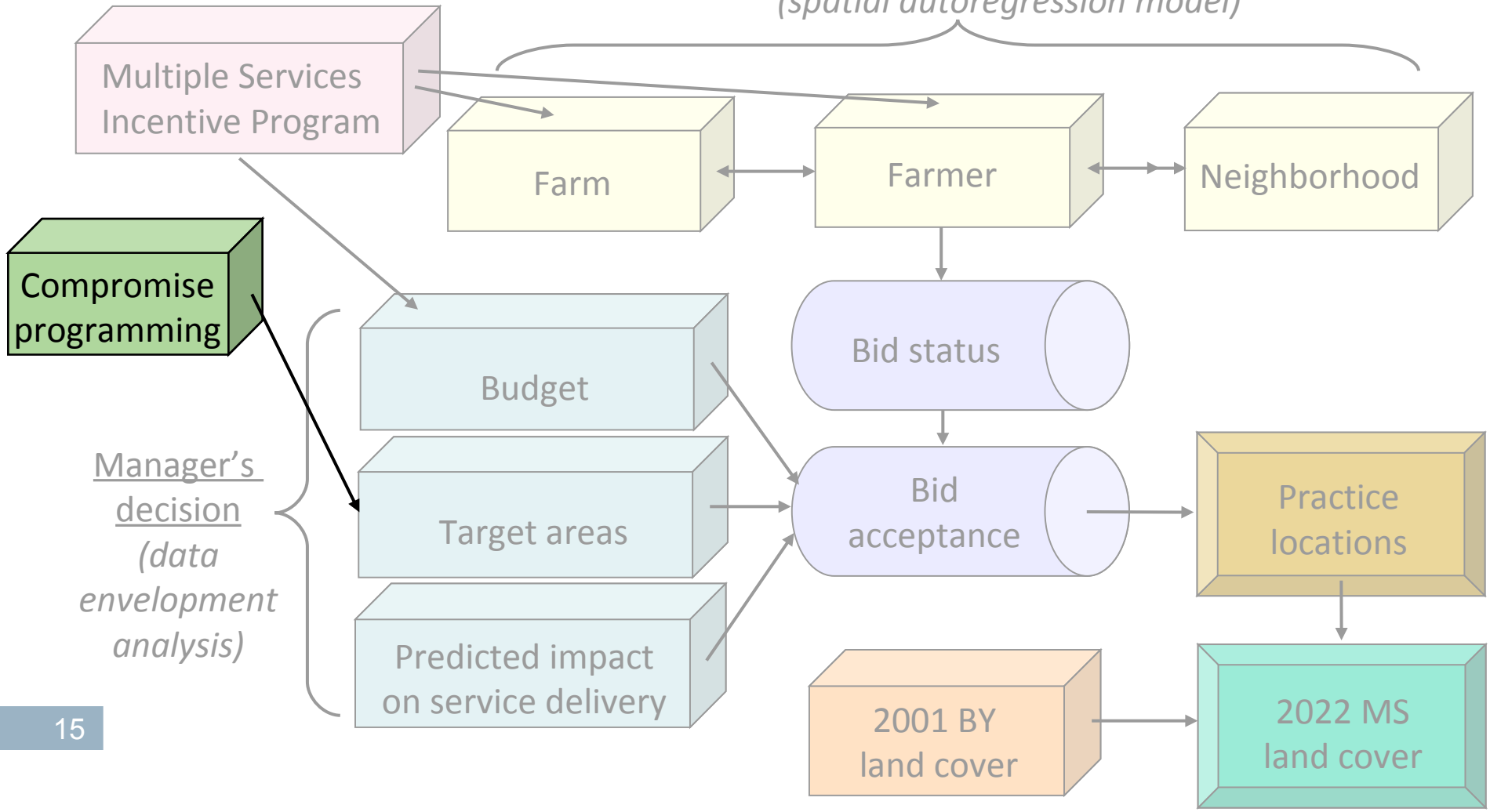
Multiple Services landscape modeling process

(Heather Sander)



Multiple Services landscape modeling process

(Heather Sander)



E-DASH

Environmental Decision Analysis and Support Heuristics

Liem Tran
Mark Ridgley
Robert O'Neill

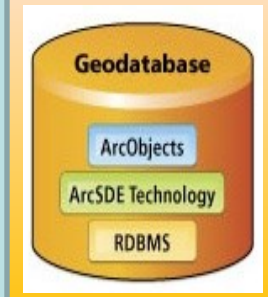
Multi-criteria Decision-Making (MCDM) Module

- SMARTS
- SMARTER
- Analytical Hierarchical Process (AHP)

Multi-Objective Optimization Programming (MOOP) Module

- Goal programming
- Compromise programming
- Adaptive weighted sum

GIS Server



Services

Intra-/Inter-Network

User Interface/Abilities

- Create new or use/modify existing MCDM models
- Apply different MCDM methods (e.g., SMARTS, AHP)
- Connect to MOOP models

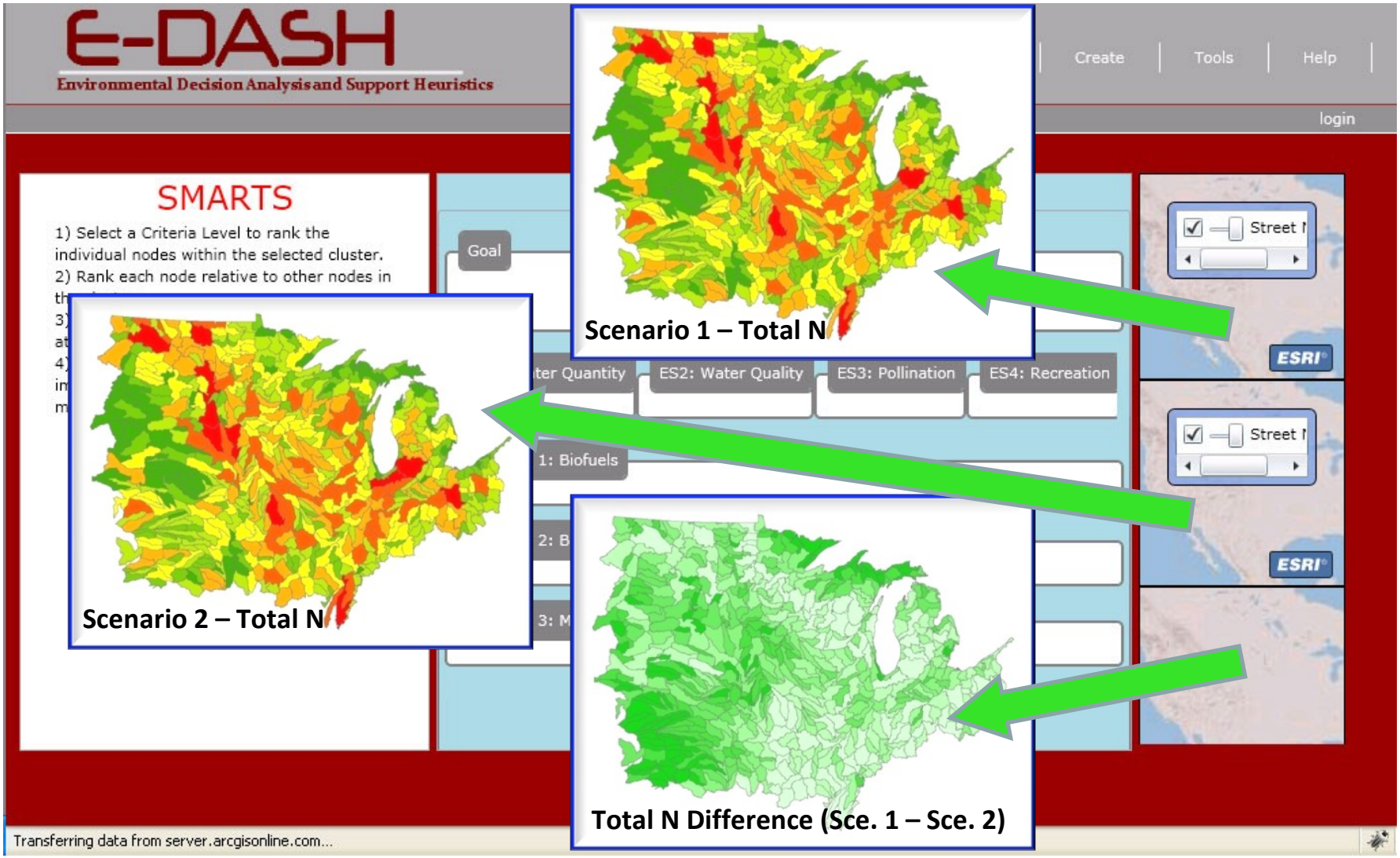
- Run MOOP model in independent mode
- Run MOOP model using weights from MCDM models
- Connect MOOP to GIS Server to explore results

- Interactive map display
- Scenario comparison
- Geospatial analyses
- Multiple-user geodatabase

E-DASH

Environmental Decision Analysis and Support Heuristics

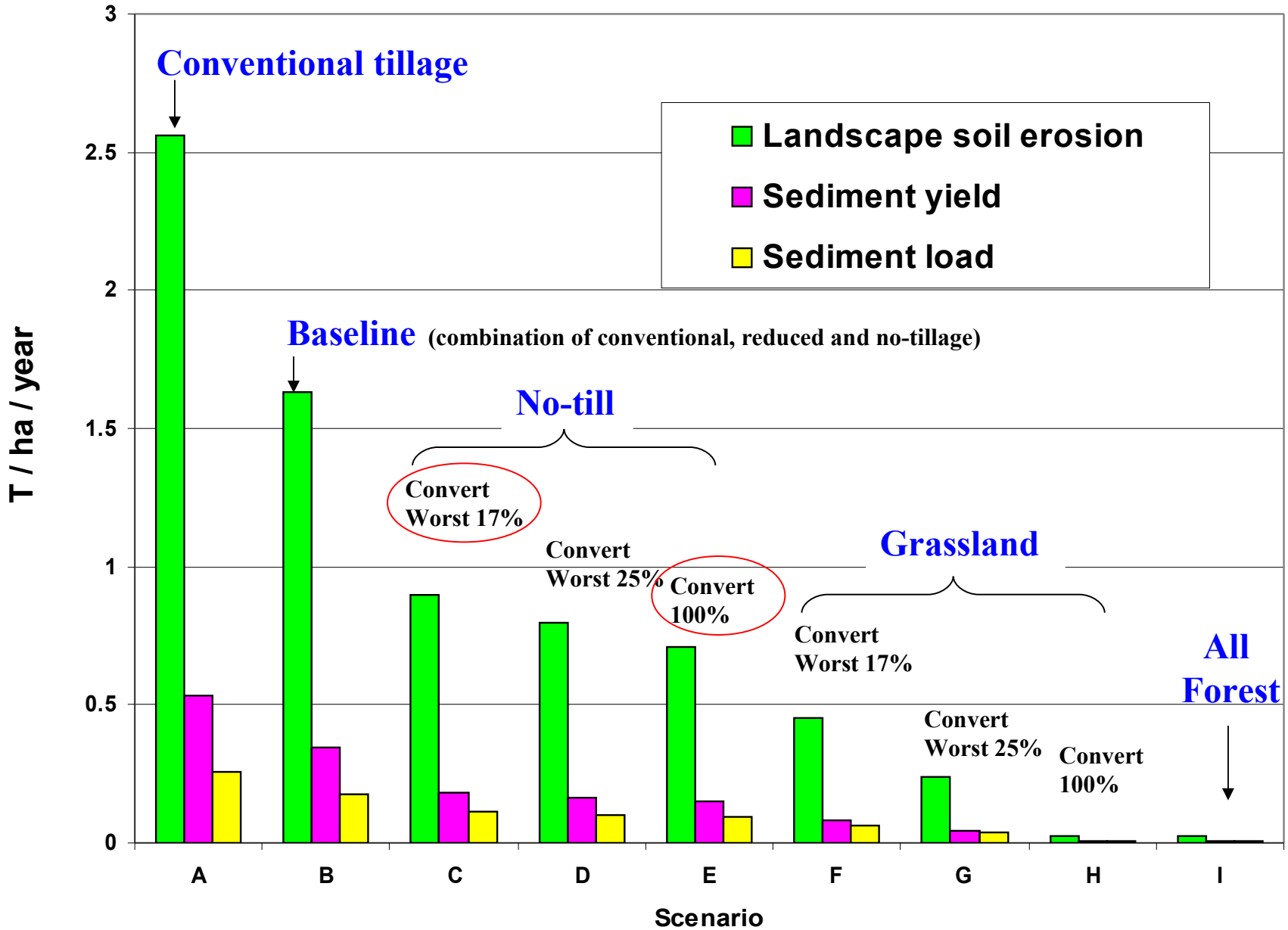
- Viewing interactive GIS maps in E-DASH

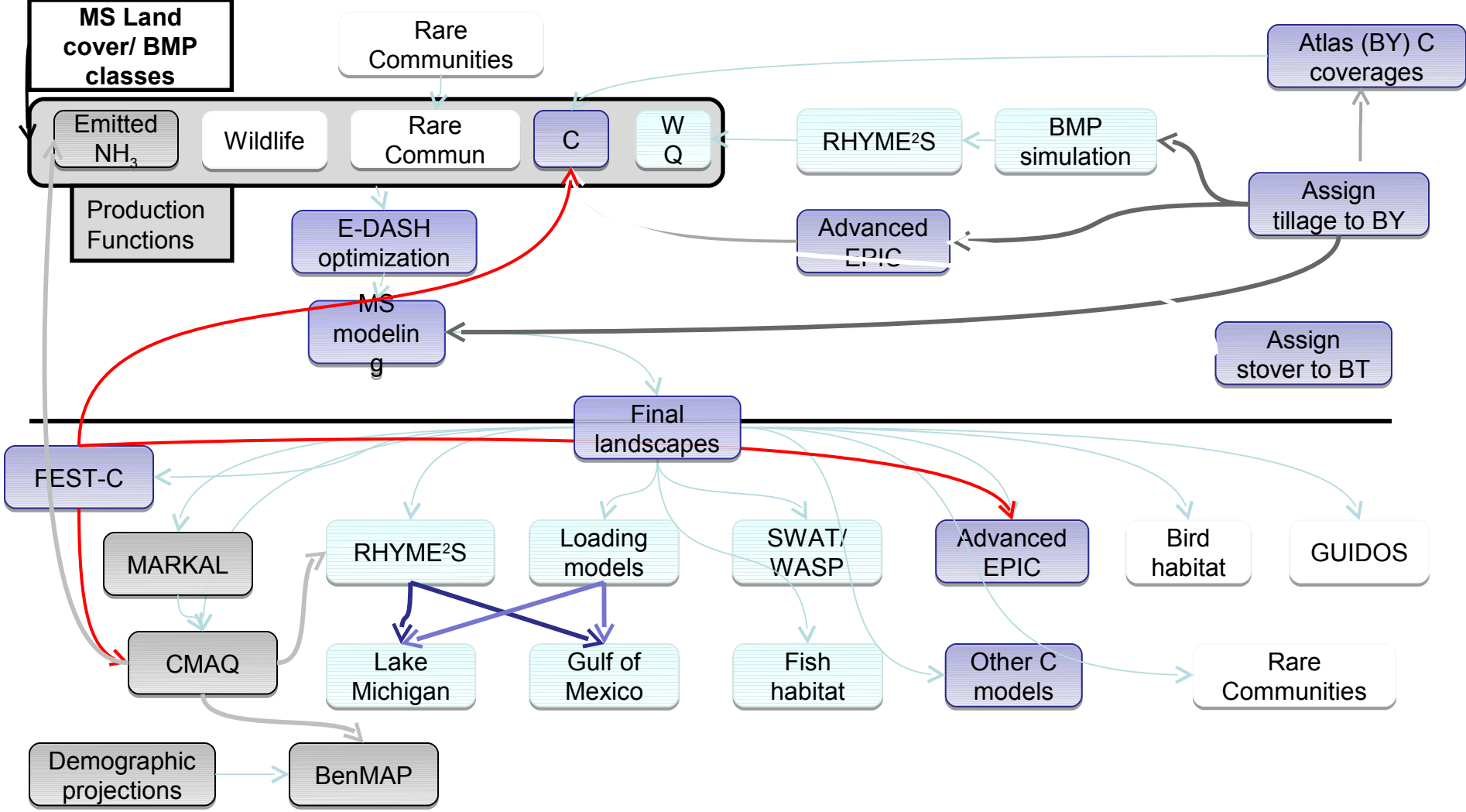


Multiple Services landscape: Potential practices for enhancement

- CRP practices (groupings)
  - land retirement – grasses/legumes
  - land retirement – forest
  - wetland restoration
  - grass filter strip
  - grass contour buffer strips or terraces
- Other conservation practices
  - nutrient management (amount, timing, placement)
  - no-till
  - winter cover

Comparative simulation of targeted conservation practices





- Health/Well-being
  - Clean air
  - Visibility
  - Clean water
    - Nitrate
    - Atrazine

egional income
  - Food, Fiber, Fuel
    - Land use
    - Soil productivity
    - Air quality

- Recreation
  - Natural areas
  - Water qual. (eutroph.)
  - Fish
  - Birds
  - Population access (disadvantaged popns.)

- Water amount
  - Flooding
  - Supply
- Climate
  - C sequestration
  - GHG
- Biodiversity

Fertilizer Emissions Scenario Tool for CMAQ* (FEST-C)

Why Needed?

- NH_3 contributes to PM formation and acid deposition
- >75% of ammonia emissions are from agricultural sources

What Provided?

- estimates of when and how much inorganic fertilizer is applied within a 12-km CMAQ grid cell
- fertilizer use estimates under multiple scenarios

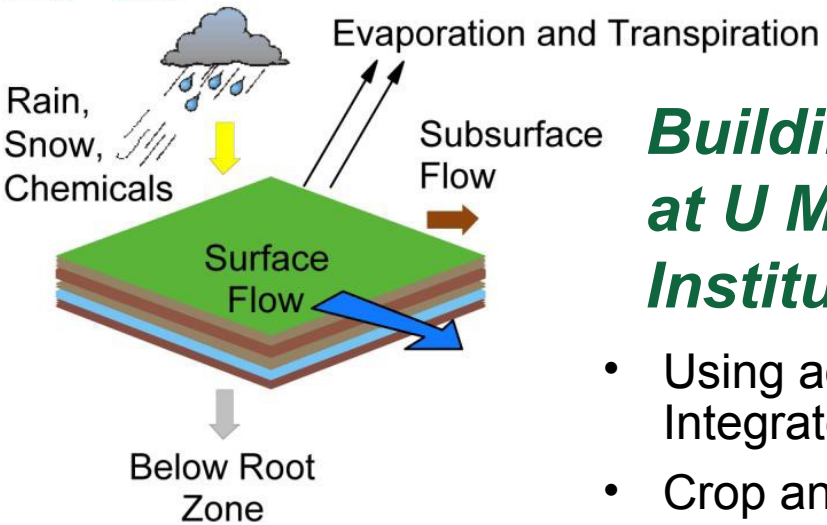
Status: Prototype completed; scenarios expected later in 2011

**CMAQ is the Community Multi-scaled Air Quality Model*

Ellen Cooter, NERL AMAD

Soil Carbon (C) and Nitrogen (N) Storage and Cycling

EPIC



Building on existing modeling efforts at U MD, Joint Global Change Research Institute

- Using advanced version of the Environmental Policy Integrated Climate (EPIC) model
- Crop and soils data at 60-m resolution
- Focus on: Soil organic matter, CO_2 flux, DOC, denitrification, including N_2O, and N leaching and run-off

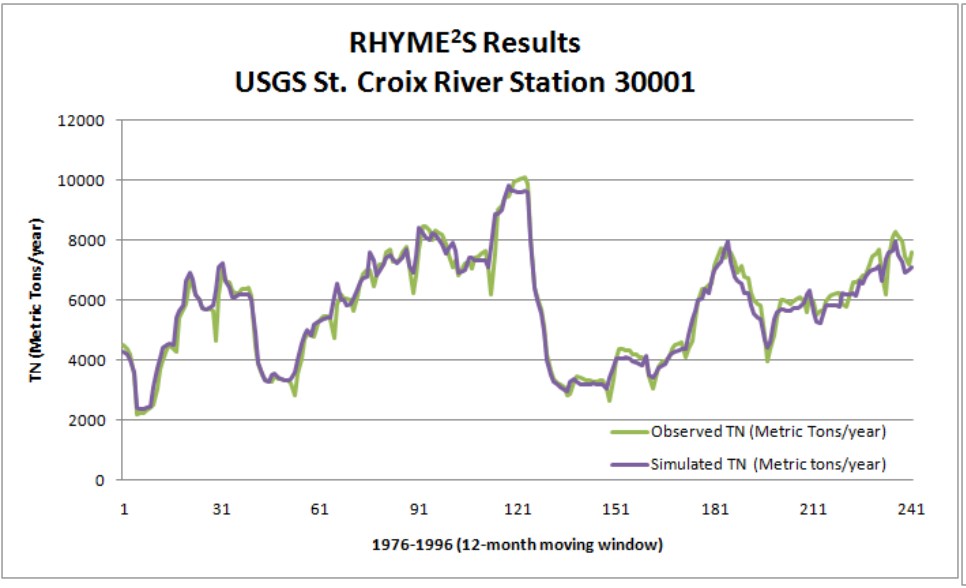
Status: Funding vehicle in progress; work initiated

Stephen LeDuc, NCEA

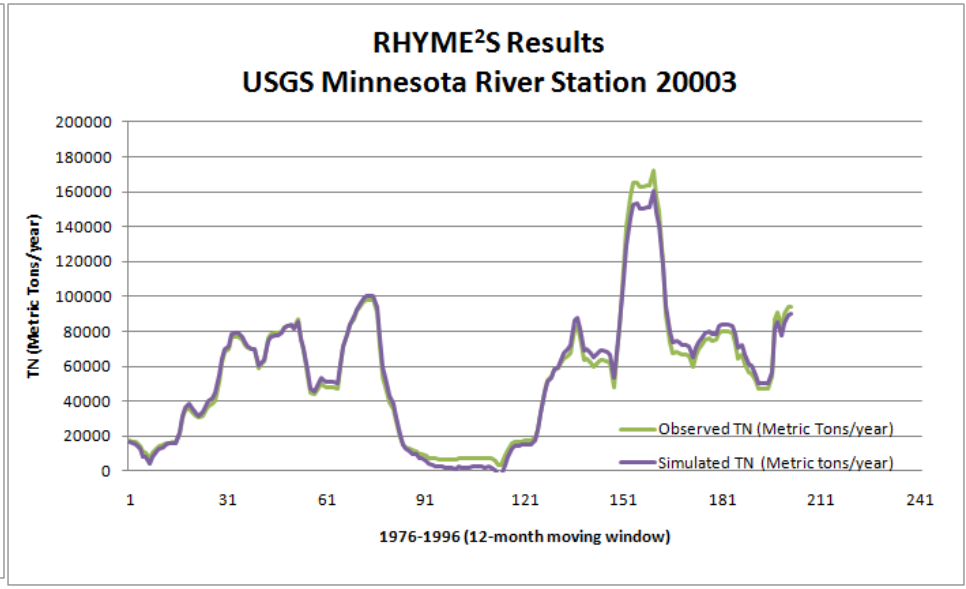
Regional-scale hydrologic modeling for ecosystem services assessment: RHYME²S

Simulated versus observed, annual total N:

R^2 = **0.91**



R^2 = **0.93**



Advantages:

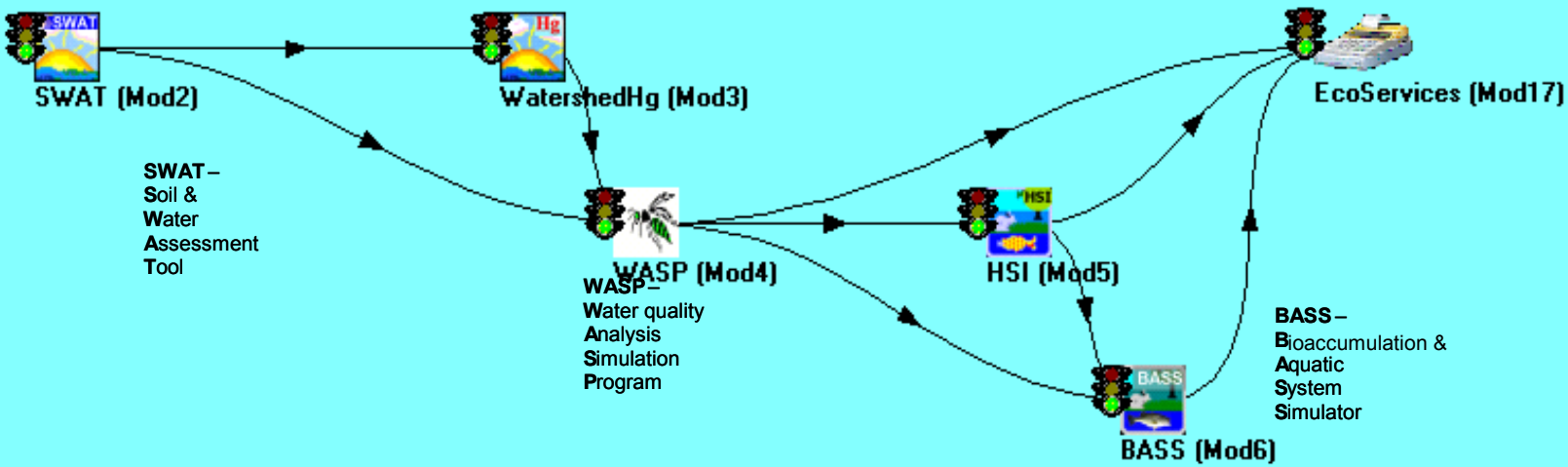
- Better explanation of variability
- Smaller number of parameters
- More consistent results (among watersheds)
- Regional *and* local estimates of loadings

Status: First half of development completed, preliminary results available

Liem Tran, EPA expert hire, NERL ESD

Water quality and aquatic habitat assessment using FRAMES

Linked Models for Scenario Analysis



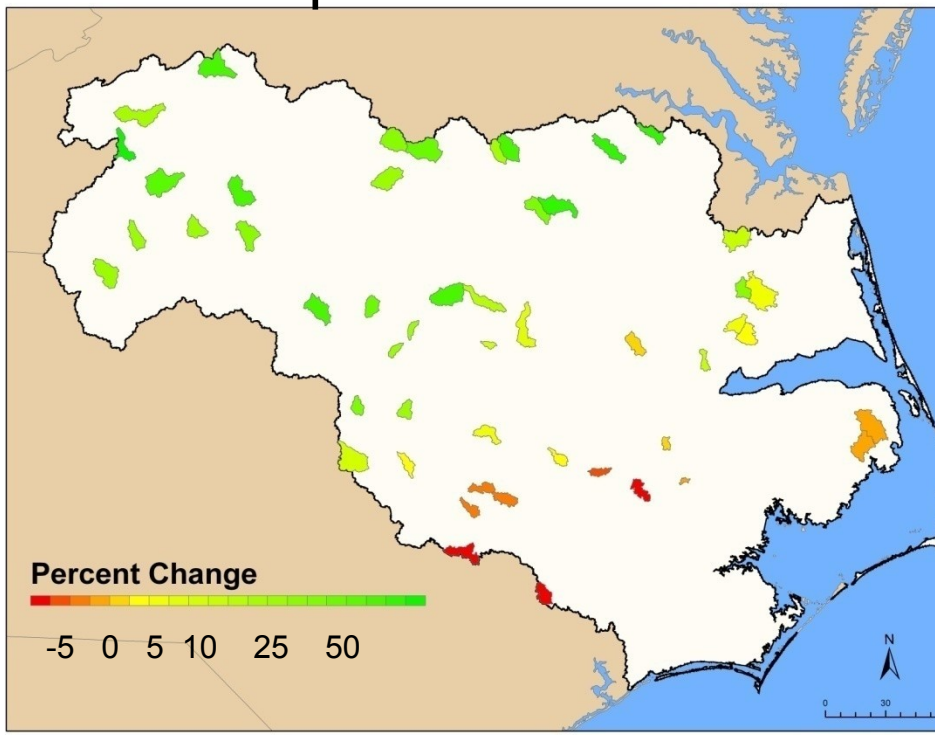
Models are dynamic and process-based

* Framework for Risk Analysis of Multi-Media Environmental Systems

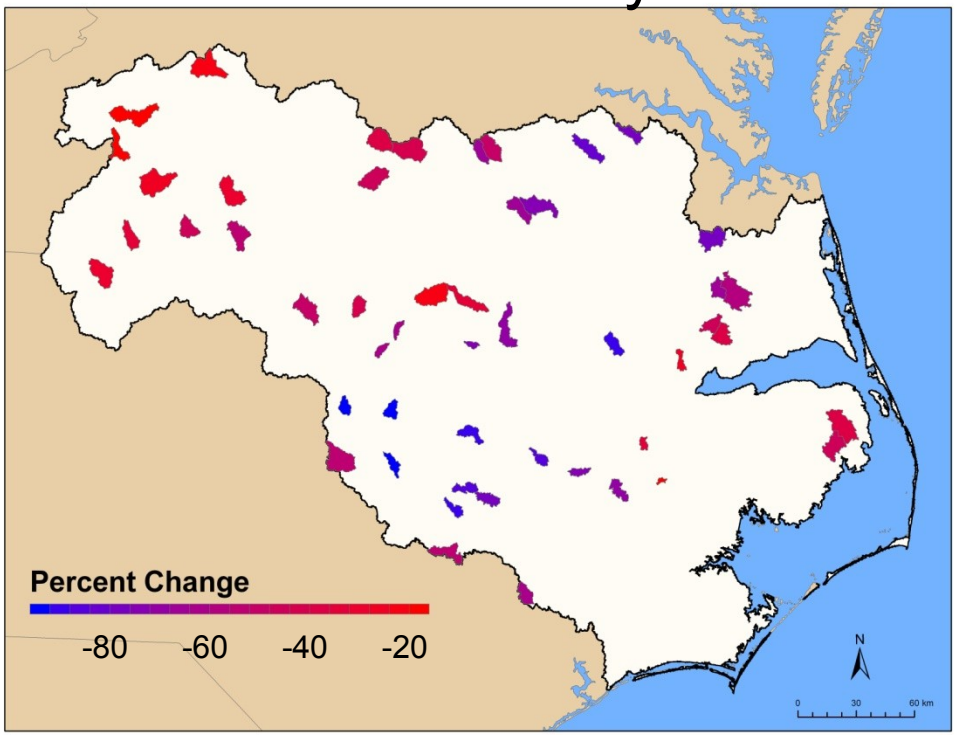
Courtesy Brenda Rashleigh, EPA

Service Response to 1.5 °C Temperature Increase (predicted for 2020-2029)

Sport fish



Biodiversity

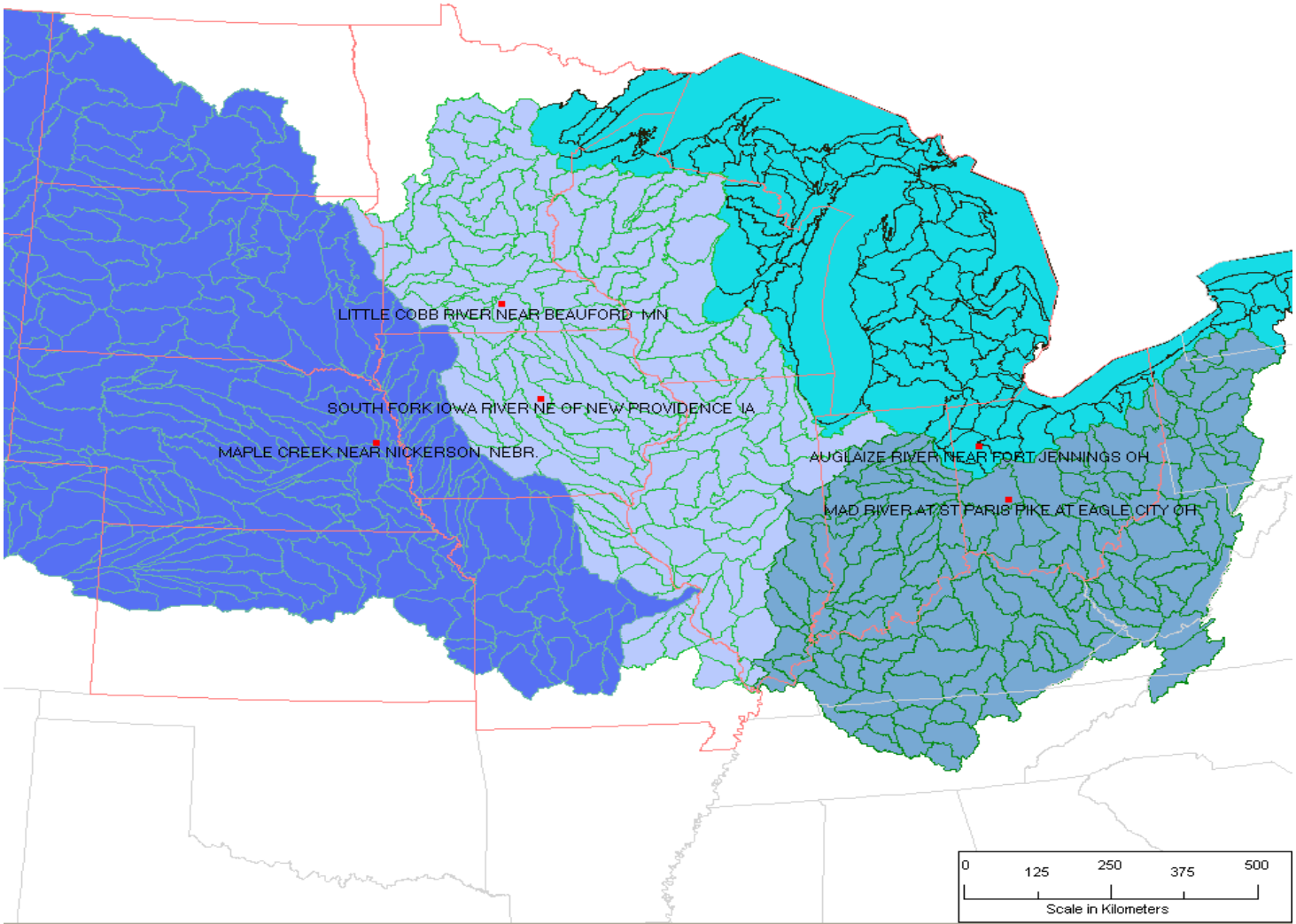


Example from Albemarle Pamlico Watershed Study

Courtesy Brenda Rashleigh, EPA

Locations for initial trials of FRAMES in FML Study

(Mark Rowe, NHEERL; Gerry Laniak)

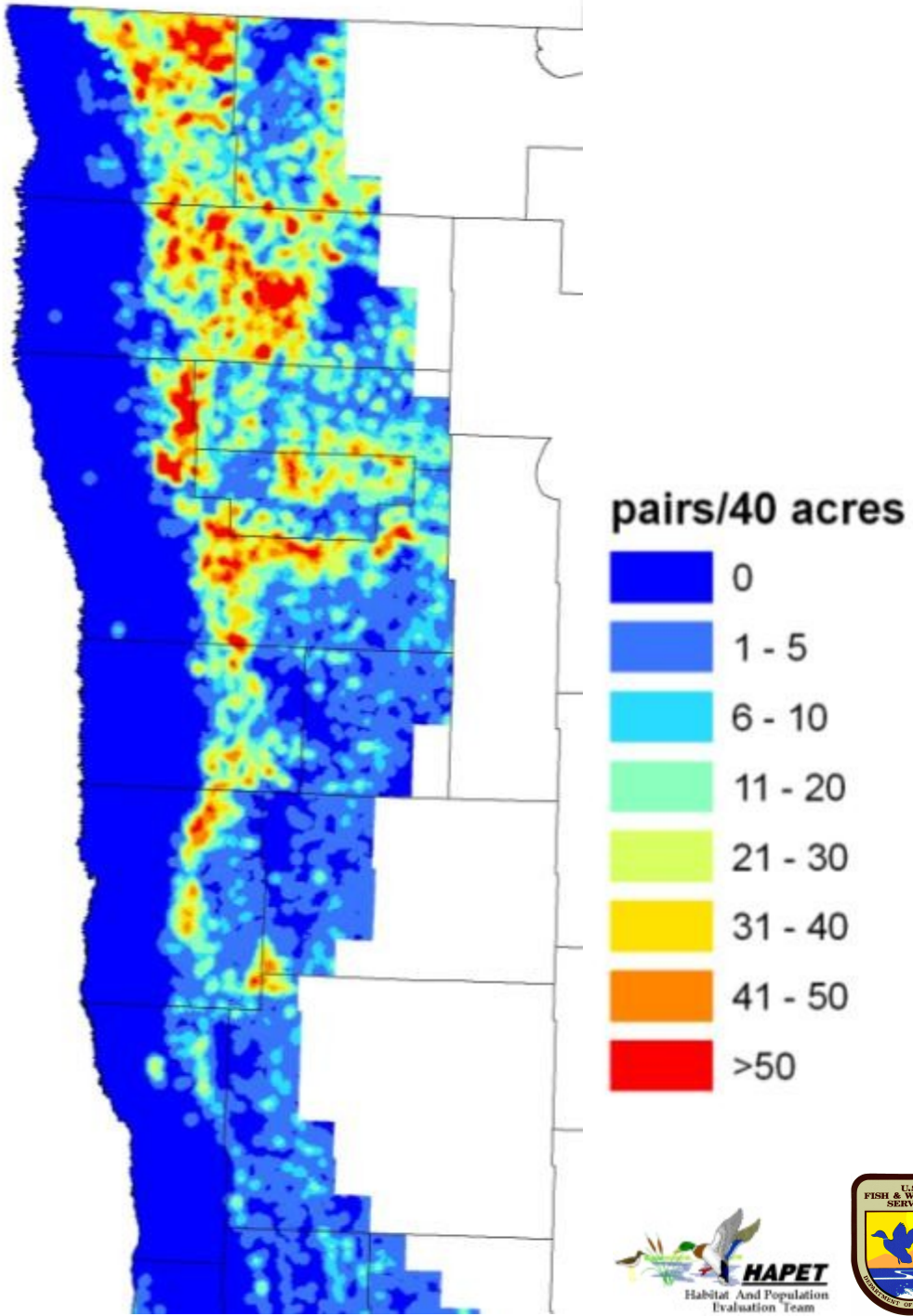


Example of habitat modeling

Migratory Grassland Birds

Predicted number of pairs *with* the Conservation Reserve Program

Courtesy Diane Granfors, FWS Joint Ventures Program

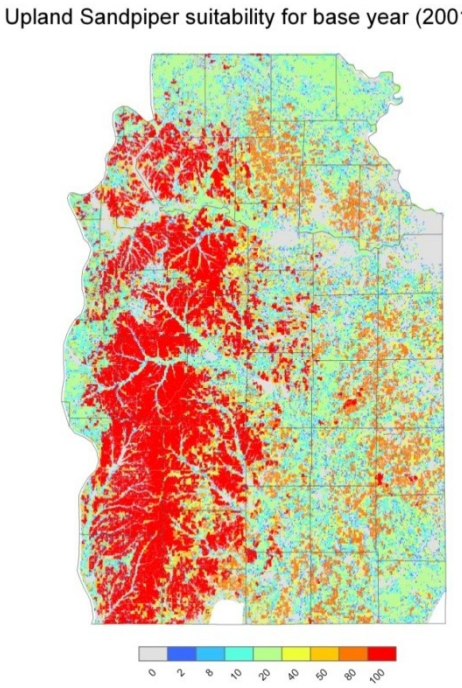


Effects of Conservation Set-asides (CRP) on Grassland Bird Populations

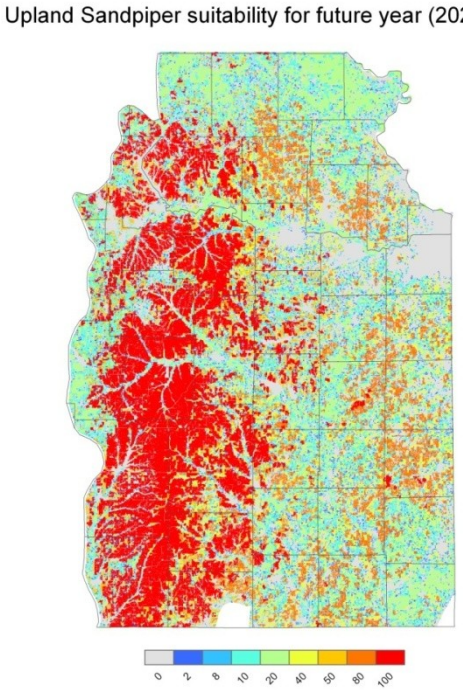
	With CRP	Without CRP	% loss
Grass >1 ha *(total ha)*	863,263	711,846	17.5
Bobolink *(# breeding pairs)*	888,863	626,152	29.6
Clay-colored Sparrow	247,717	153,462	38.1
Grasshopper Sparrow	198,298	128,308	35.3
Savannah Sparrow	559,044	366,324	34.5
Sedge Wren	730,540	502,674	31.2
Le Conte's Sparrow	261,169	123,973	52.5

Courtesy Diane Granfors, FWS Joint Ventures Program

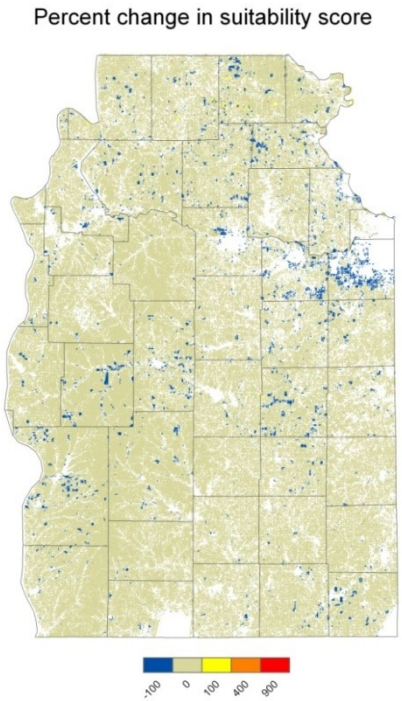
Preliminary analyses of individual species' habitat changes



Base Year



Biofuel Targets

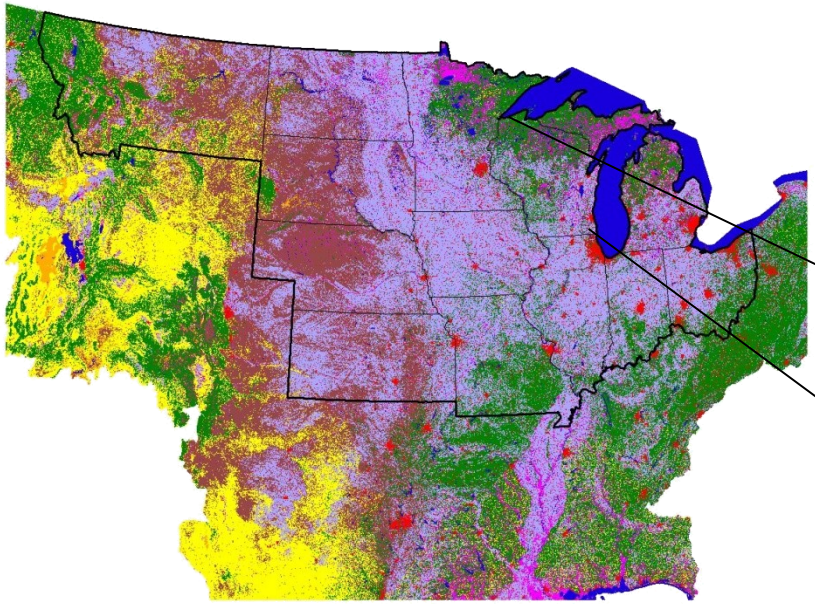


Percent change

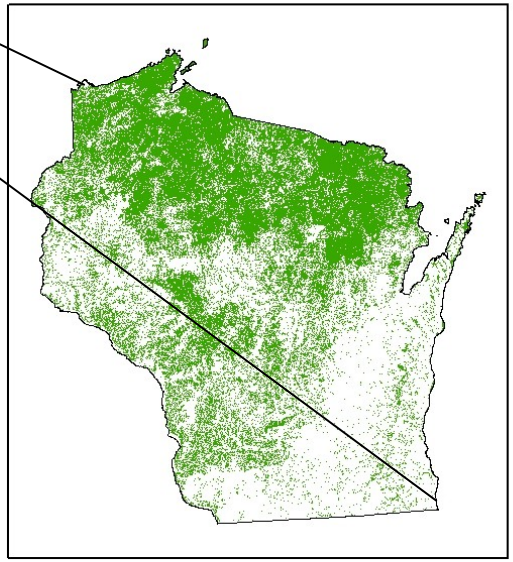
Goal is to integrate models across species

Analysis provided by Brad Potter, FWS Joint Ventures Pgm

Mapping Habitat from Land Use/Land Cover Maps

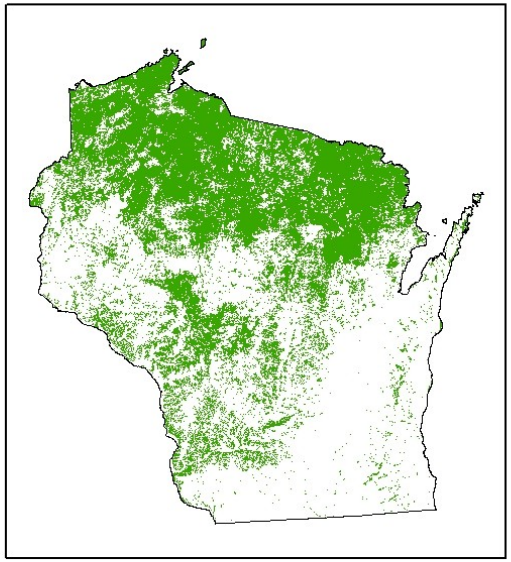


Habitat for small mammals, forest bird species



10 acre window (small range)

Habitat for large migratory species, black bear



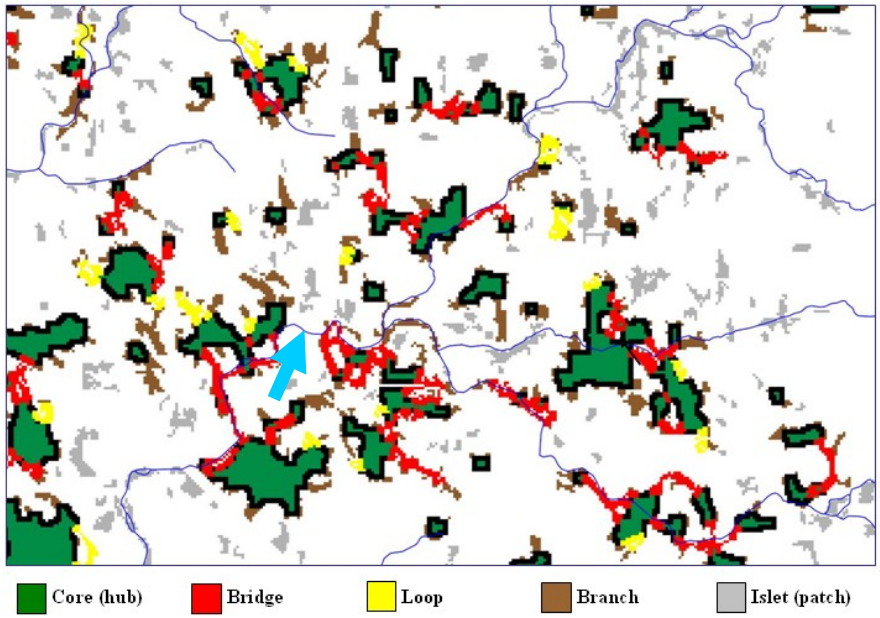
160 acre window (large range)

One input map (the finer resolution, the better) can produce a variety of habitat maps

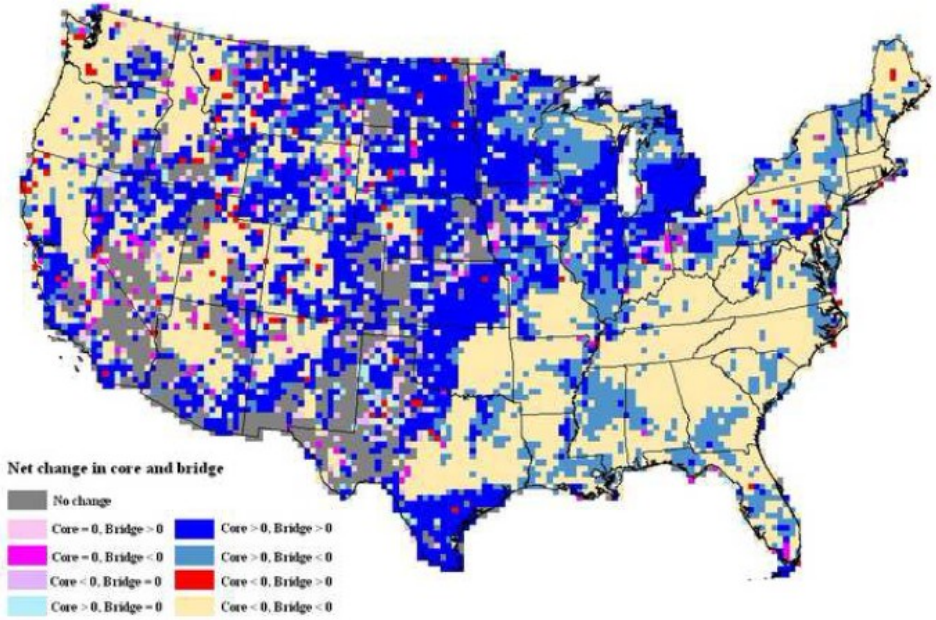
Habitat can be any type of land cover….

Habitat/Green Infrastructure

GUIDOS to identify map elements of green infrastructure, networks, and fragmentation for conservation and landscape planning



(to be included on LandScope website…)



Wickham et al. (2009)

Source: NLCD 30 m, forest and wetland as land-cover of interest

Potential uses:

- identify areas for wildlife habitat, restoration/protection, water quality
- MSPA and GIS analysis: maximize benefits (improve water quality/connectivity)
- evaluate projected urban growth, impervious surface,
- land trusts in guiding land purchase
- MSPA habitat information for Data Envelopment Analysis

forest.jrc.ec.europa.eu/download/software/guidos

EPA ESRP

In progress:

Using *Level of Service* to communicate priorities for conservation/protection of ecosystem services *(Lisa Wainger)*

- Comparative metric of scarcity
- Similar metrics used by local governments to prioritize investments to service shortfalls

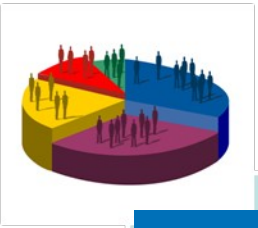
Supply (e.g. suitable acres) / **Demand (e.g. user day demanded – unconstrained)** = **Level of Service (e.g. acres per user day demanded)**

- New application to natural resource investments

Level of Service
Examples of Submetrics

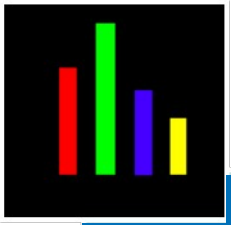
Supply

- Acres suitable for specific use (huntable acres, remote public lands, species-rich bird habitat)
- Quality "inflators" for superlative elements (rare species), regional connections (attracts migrants), public access, etc.



Demand

- Population
- Demographics
- Spillover demand from urban areas
- Vulnerability

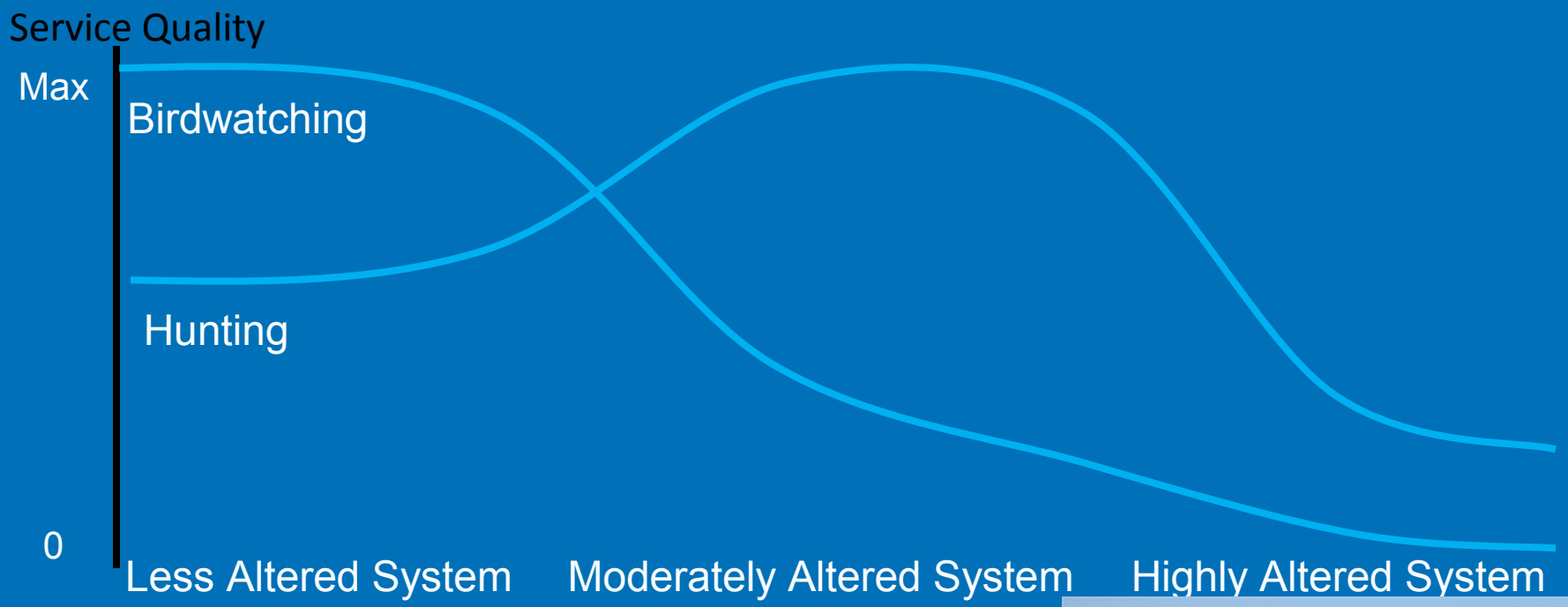


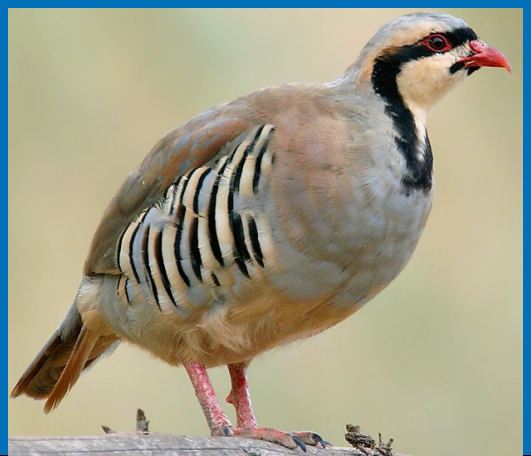
LOS

- Outdoor recreation acres per likely user
- Unimpaired stream/lake area per boat
- Groundwater yield per crop acre
- Wetland acres per $ million economic output generated by businesses in coastal zone communities

Damage Functions:

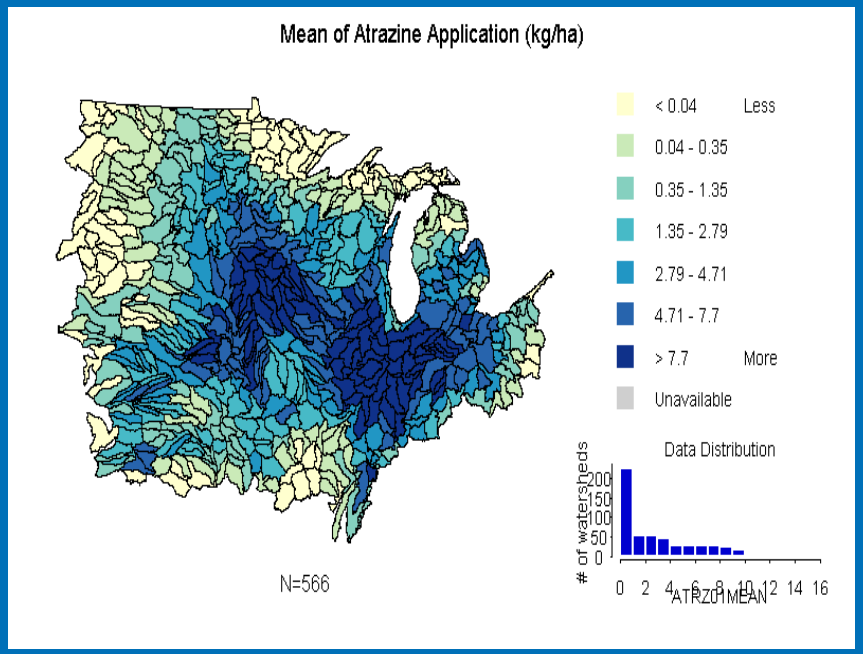
Service quality and potential value of a change varies along the land alteration spectrum





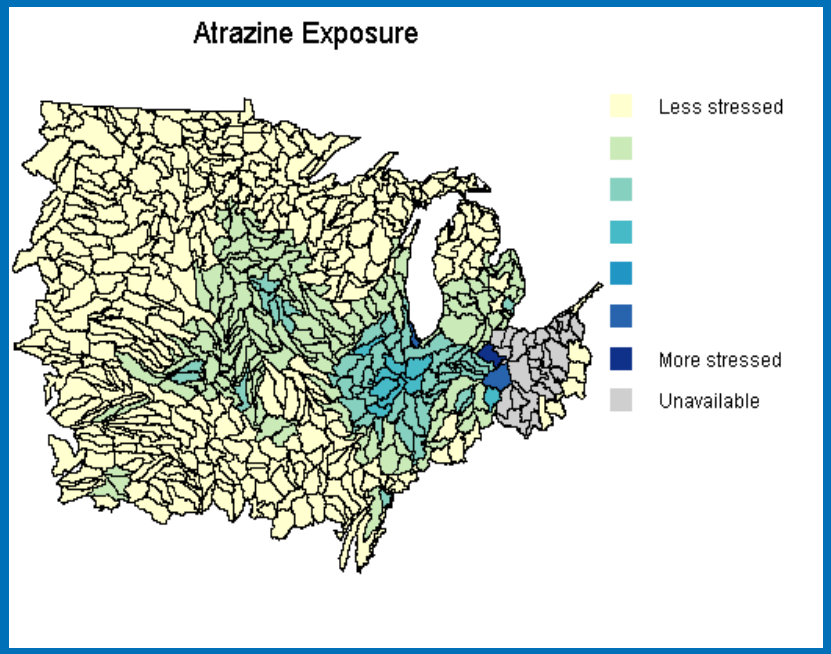
Exposure: Service value is related to the ability to mitigate or reduce risk

Estimated Atrazine application for Base Year landscape



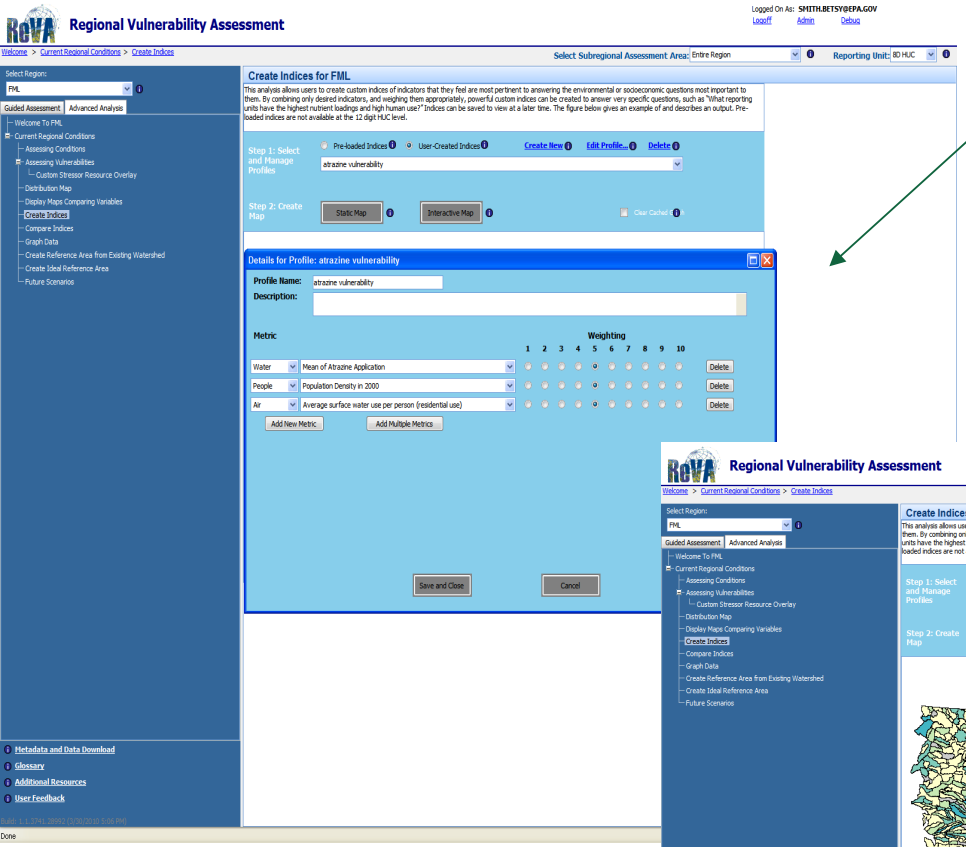
Potential risk only – incomplete endpoint

Combined index: Atrazine application and population using surface water supplies

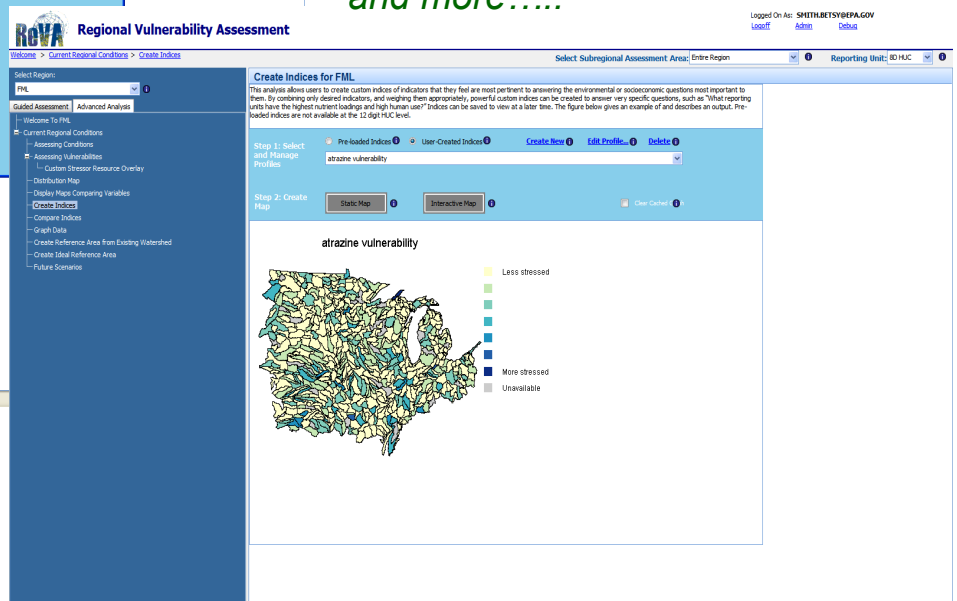


Risk + Exposure – a better endpoint

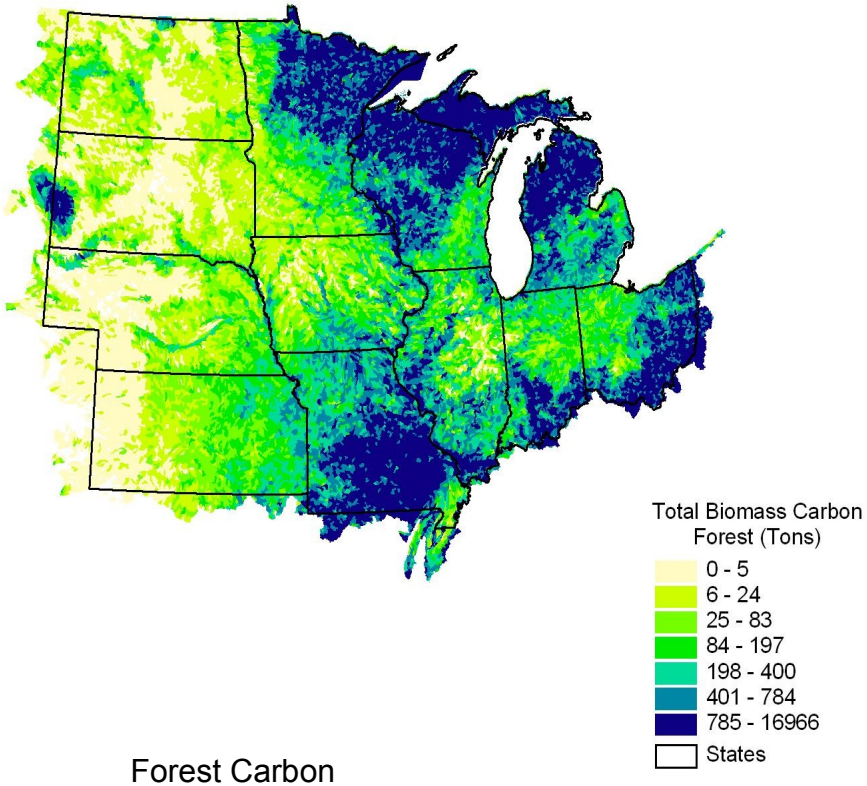
Expanded Capabilities in web-based Environmental Decision Tool

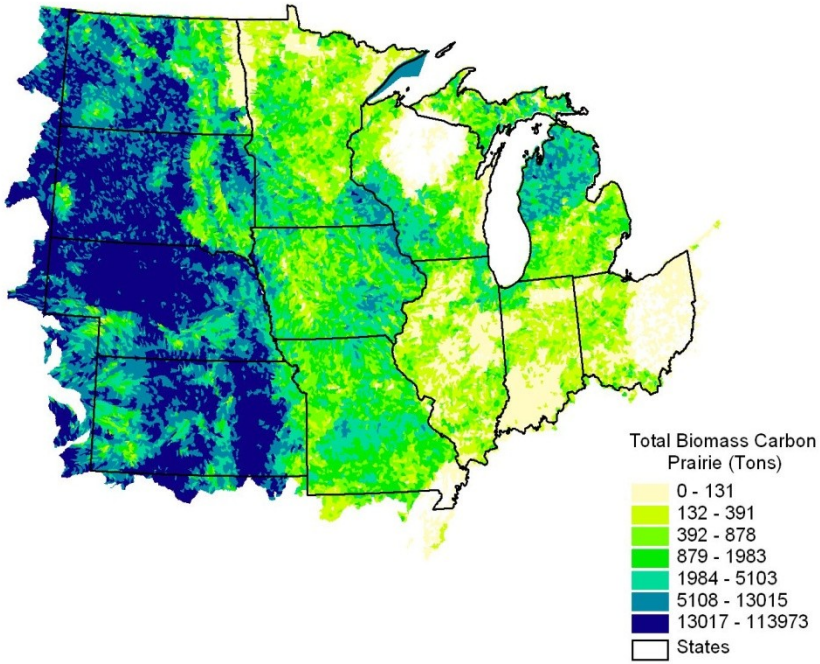


- *Menu-driven assessment guide (wizard)*
- *Mash-up between S-PLUS and Arc GIS Server*
- *Assess within subregions (e.g. states)*
- *Create, save, reuse customized indices*
- *Identify a reference watershed (or other reporting unit) and compare to others*
- *Assess spatial patterns using linked micro-maps*
- *Drill down to original data, access Google Earth, Digital Watershed*
- *and more…..*



Preliminary estimates of Carbon sequestration – Base Year Landscape





Forest Carbon

ABD = from National Biomass Carbon Database (NBCD2000)

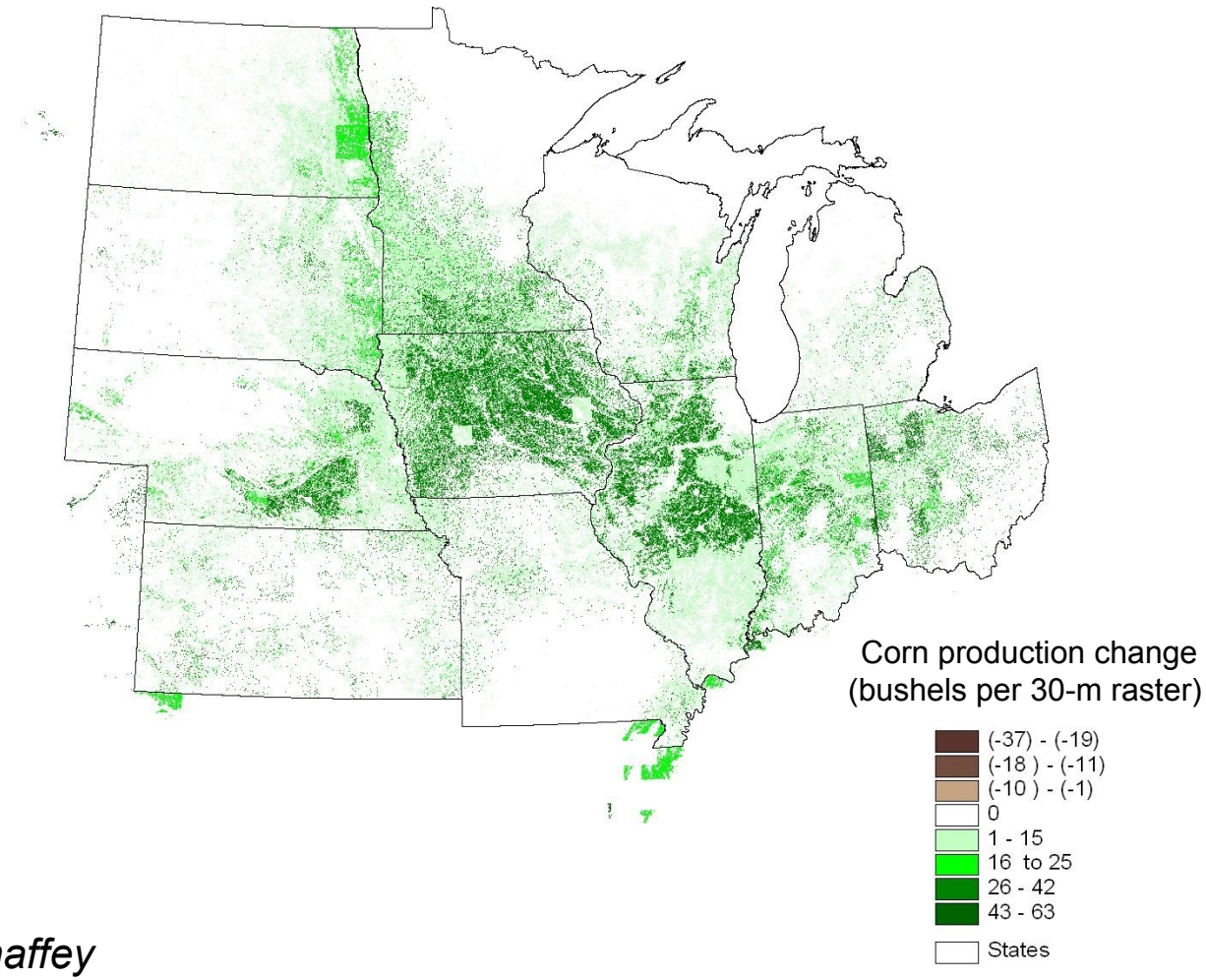
\+ BGB = exp (-1.0587)+(0.8836 * ln ABD) + 0.1874

from USDA General Technical Report NRS-18

Total Forest Carbon

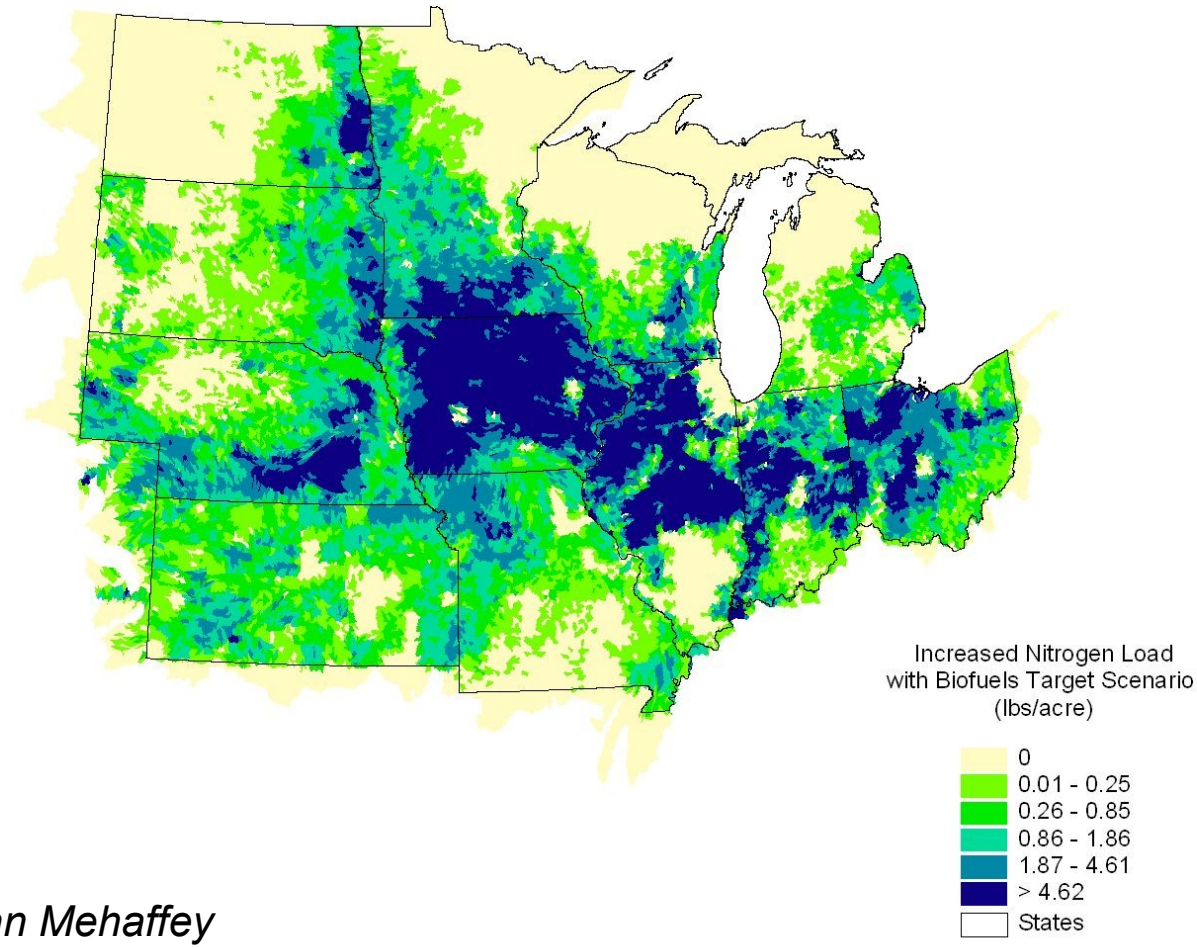
Megan Mehaffey

Food and Fiber production: change in corn production from Base Year to projected Biofuel Targets landscape



Megan Mehaffey

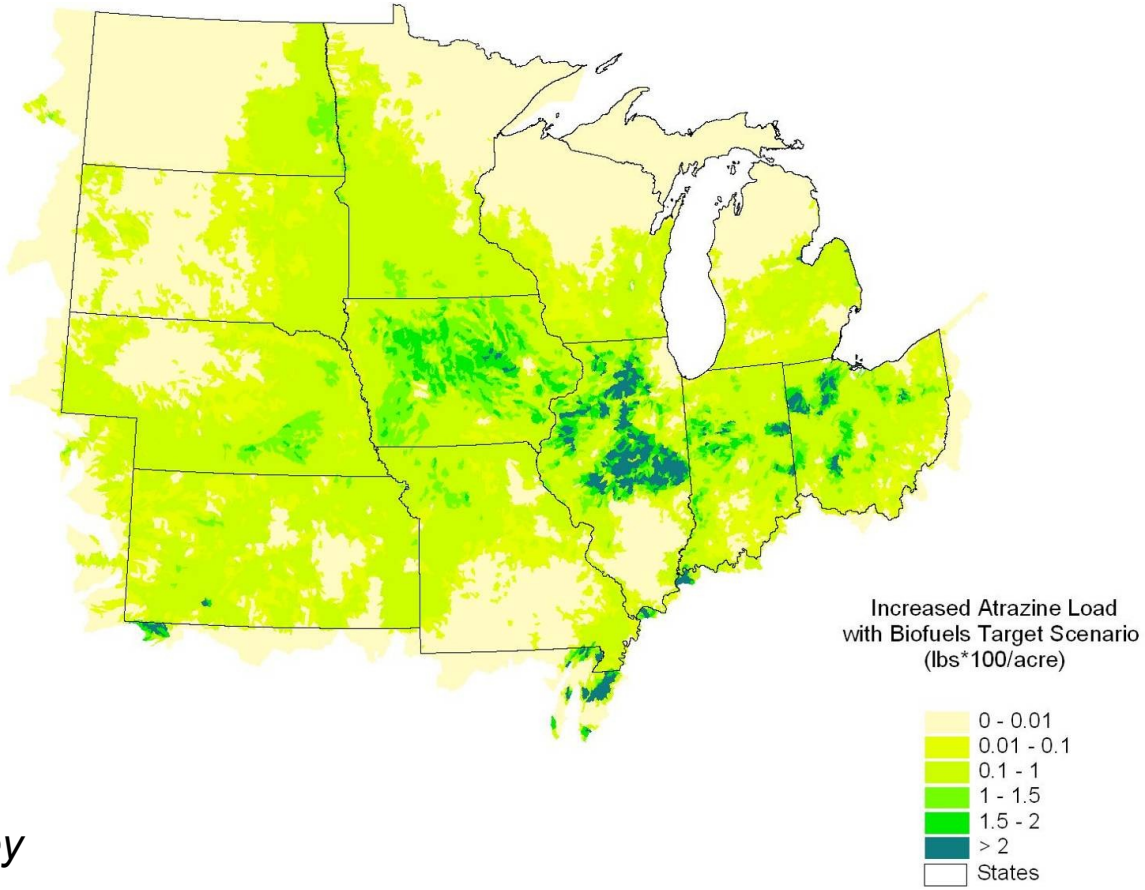
Clean Water: change in Nitrogen application rate projected with shift in cropping practices to reach Biofuel Targets



Megan Mehaffey

Clean Water: change in Atrazine loadings projected with shift in cropping practices to reach Biofuel Targets

- *Atrazine is linked to human health, particularly hormone-related cancers.*
- *Combination of atrazine and nitrate has been shown to impact sexual development in amphibians.*
- *Change in atrazine loadings may push levels of pesticides in surface water beyond current MCLs*



Megan Mehaffey


Questions?