



ECOSYSTEM SERVICES RESEARCH PROGRAM

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)

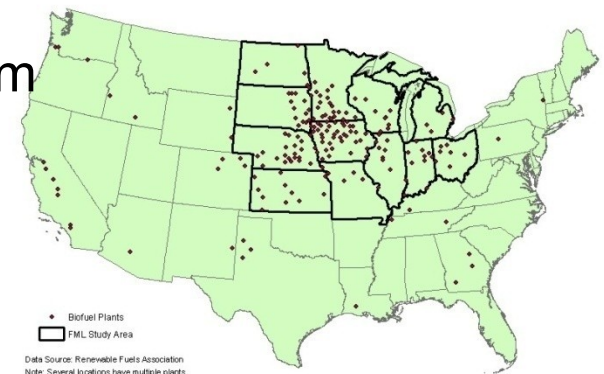
- Lisa Wainger, U. of Maryland (spatial economics)
- Liem Tran, U. of Tennessee (modeling, decision theory)

❑ 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

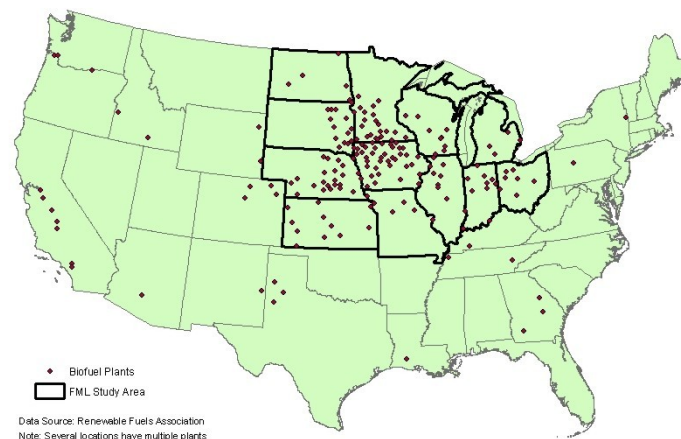
Service estimation – methods and progress

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

Service metrics and decision support

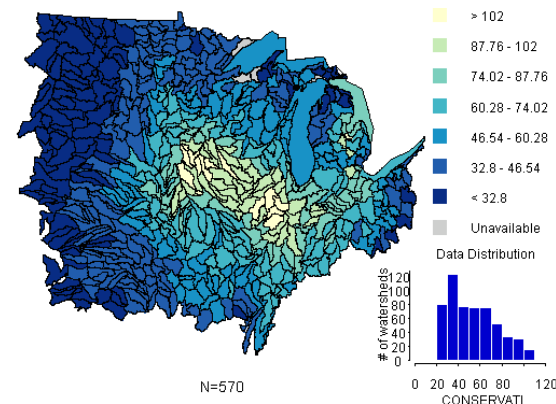
Change drivers of interest for Midwestern place-based study

- 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

Conservation Reserve Program Participation (\$/acre)



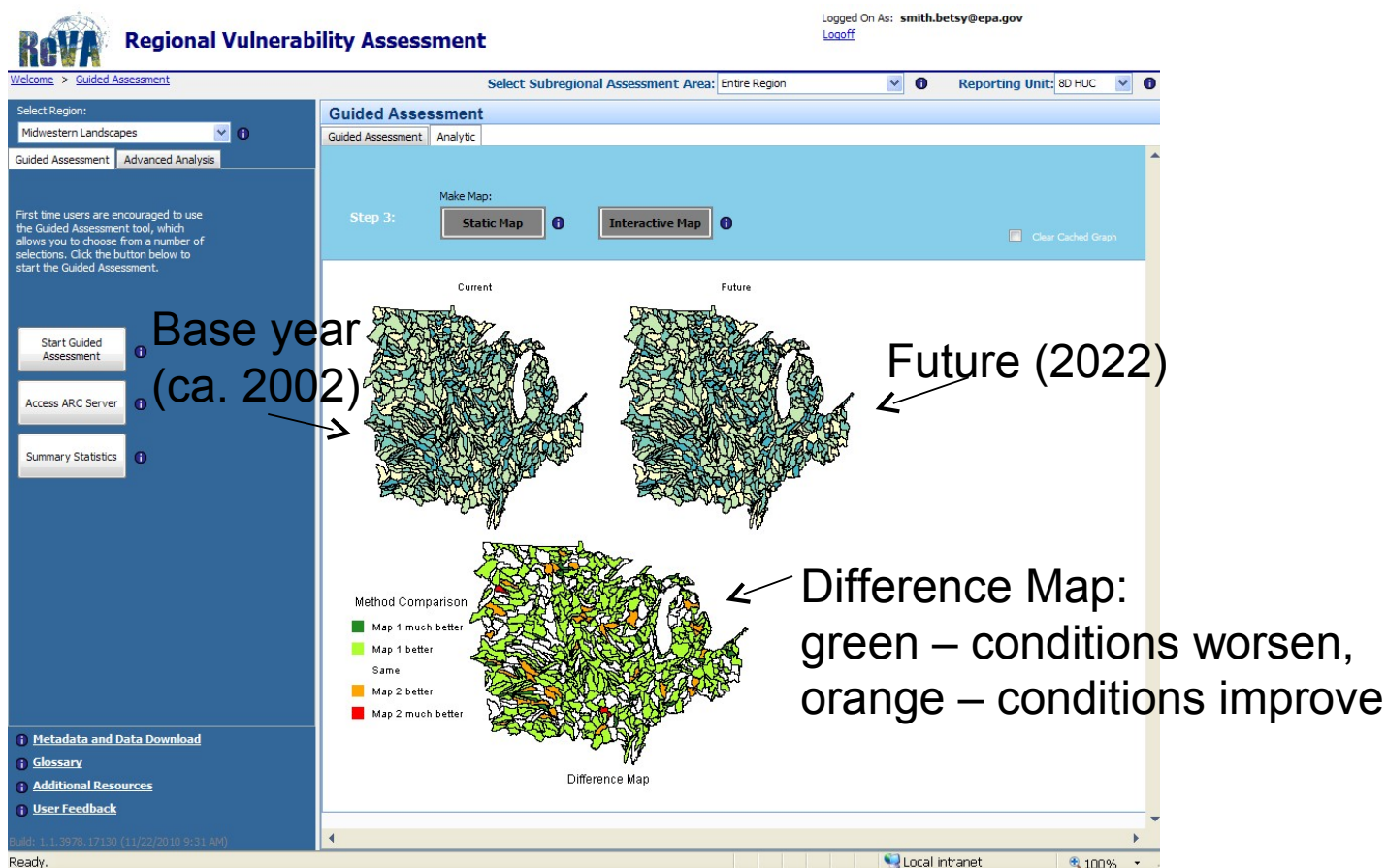
Clients for FML Study

- 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

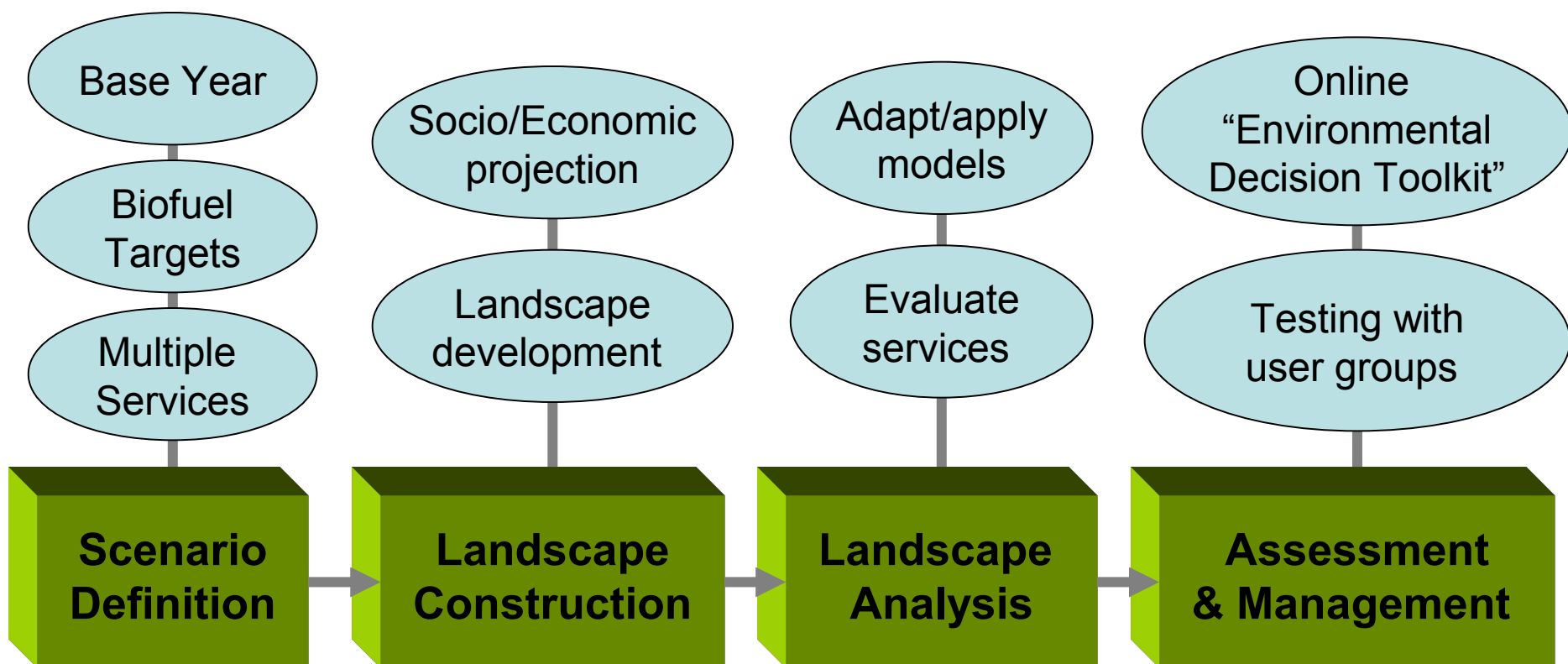
FML ecosystem service categories

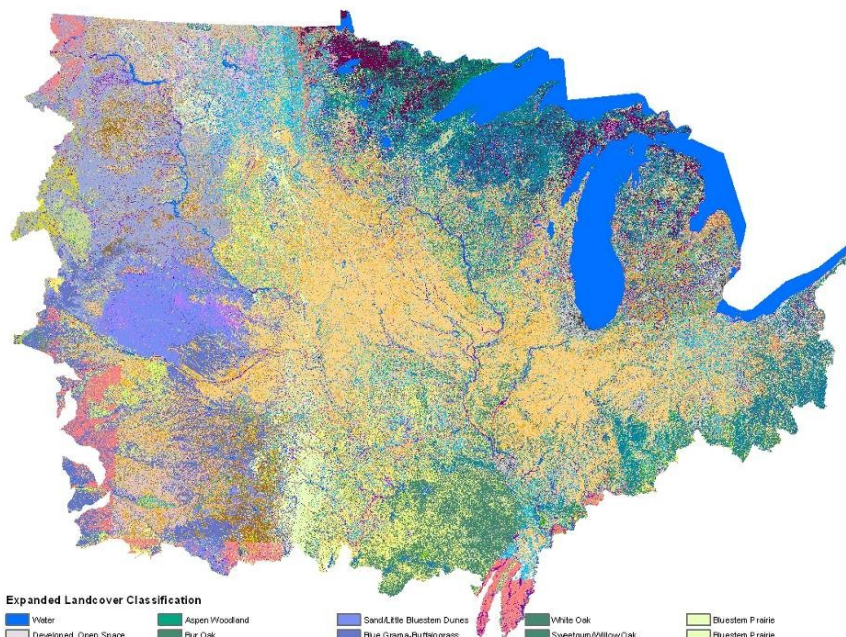
- Production of food and fiber
- Clean air
- Climate moderation (via carbon sequestration)
- Water provision
- Flood moderation
- Aquatic habitat to support wildlife-based recreation
- Terrestrial habitat to support wildlife-based recreation

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

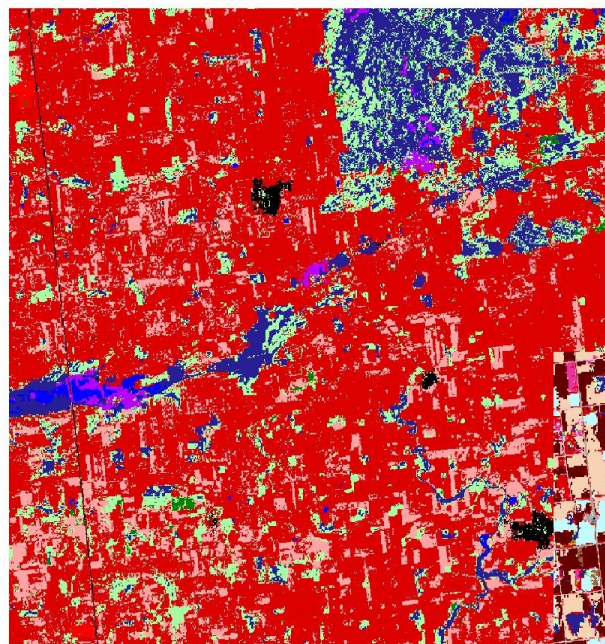
Implications for better estimation of nutrients and pesticides loads/export

Better assessment of crop yields

Expanded Landcover Classification

Water	Aspen Woodland	Sand/Little Bluestem Dunes	White Oak	Bluestem Prairie
Developed, Open Space	Bur Oak	Blue Grass/Buffalograss	Sweetgum/Willow Oak	Bluestem Prairie
Developed, Low Intensity	White Bark Pine	Bluestem Prairie	Yellow Poplar/White Red Oak	Little Bluestem/Indiangrass/Vintergrass
Developed, Medium Intensity	White Spruce	Saltmarsh/Greenwood	Deciduous Flatwood	Black Ash/Elm/Red Maple
Developed, High Intensity	Lumber Pine	Riparian Woodland	White Oak	Willow/Water/Dian onleaf Oak
Barren Land	Lodgepole Pine	Cottonwood/Willow	Swamp Chestnut/Cherrybark Oak	Jack Pine Swale
Undefined Deciduous Forest	Douglas Fir	Riparian	Live Oak	Great Plains Riparian
Undefined Evergreen Forest	Ponderosa Pine	Riparian	Aspen	Floodplain Riverbri/Sycamore
Undefined Mixed Forest	Spruce Sup/Alpine Fir	Douglas Fir	White Black/Red Oak	Riparian Riverbri/Sycamore
Undefined Shrub/Scrub	Bristlecone Pine	Shrubland	Grass/Shrub Belds	Floodplain Sweetgum/Willow Oak
Undefined Grassland/Herb.	Juniper/Plinyon Pine	Ponderosa Pine	Jack Pine	Floodplain Black Ash/Elm/Maple
Undefined Pasture Hay	Aspen	Introduced Woody Wetland	Longleaf Pine	Floodplain Black Ash/Elm/Maple
Undefined Crop	Red Alder	Introduced Upland Herbaceous	Virginia Pine	Black Spruce/Tamarack Peatland
Undefined Woody Wetland	Black Sagebrush	Introduced Upland Herbaceous	Willow/Water/Dian onleaf Oak	Swamp Riverbri/Sycamore
Undefined Herbaceous Wetland	Saltmarsh/Greenwood	Introduced Upland Herbaceous	Red Pine	Coastal Plain Swamp
Moniculture Corn	Black Sagebrush	Introduced Herbaceous Wetland Riparian	Missouri Glades	Black Ash/Elm/Maple Swamp-Bog
Moniculture Soybean	Big Sagebrush	Introduced Upland Tree	Post/Blackjack Oak	Prairie Pothole Wetland
Moniculture Wheat	Salt Desert Shrub	Recently Logged	Balsam Fir	Wet Meadow/Prairie Marsh
Moniculture Cotton	Sagebrush/Grass	Recently Logged	Hemlock/Yellow Birch	Coastal Herbaceous Marsh
Corn/Soy	Chokeberry-Serviceberry Rose	Ruderal Forest	Shortleaf Pine/Oak	Appal. Shrub/Herbaceous Wetland
Corn/Wheat	Sand Sage Prairie	Sand Shinnery Oak	Chestnut Oak	Laurentian-Acadian Herbaceous Wetland
Corn/Other	Chokeberry-Serviceberry Rose	Big Sagebrush	Sugar Maple/Beech	Bluestem Depressional Wetland
Corn/Fallow	Gambel Oak	Aspen	Loblolly Pine-Hardwood	Alkali/Cocaton-Tobosa Grass
Soybean/Wheat	Nesque	Sugar Maple	Shortleaf Pine/Oak	Alkali/Cocaton-Tobosa Bottomland
Soybean/Other	Ponderosa Pine	White Black/Red Oak	Chestnut Oak	White Oak
Soybean/Fallow	Juniper/Plinyon Pine	White Oak	Post/Blackjack Oak	Shortleaf Pine/Oak
Wheat/Other Crop	Big Sagebrush/Bluebunch Wheatgrass	Oak Hickory	Deciduous Shrubland	Sweetgum/Willow Oak River Flatwoods
Wheat/Fallow	Big Sagebrush	White Black/Red Oak	Bur Oak	Black Oak/Buff/Grassland
Cotton/Other	Big Sagebrush	Post/Blackjack Oak	Pin Oak	Pin oak/Sweetgum Wet Flatwood
Misc Grain/Fallow	Blue Grass/Western Wheatgrass	White Black/Red Oak	Grass/Shrub Bald	Ruderal Shrub/Forest
Other Crop/Fallow	Gram s-Mulit-Threes w/n	Black Oak	Grass/Shrub Bald	Ruderal Mixed Forest
Alfalfa Hay	Gram s-Oaletta	Post/Blackjack Oak	Red Pine	Ruderal Mixed Forest
Alfalfa Hay/Other	Rough Fescue-Bluebunch Wheatgrass	Super Maple/Beech/Yellow Birch	White Cedar	Managed Tree Plantation
Fallow	Rough Fescue-Idaho Fescue	Sugar Maple/Basswood	Lake Prairie	Managed Tree Plantation
Sparsely Vegetated	Wheatgrass-Bluestem-Heslegrass	Chestnut Oak	Bluestem Prairie	Introduced Wetland Vegetation
Sparsely Vegetated	Tall Foli	Yellow Poplar/Hemlock	Blugrass Savanna/Woodland	Modified/Managed Tallgrass
Sparsely Vegetated	Alpine Rangeland	Sugar Maple/Beech	Little Bluestem/Pot Oak	Modified/Managed Tallgrass
Aspen Forest/Parkland	Bluestem Grass/Prairie		Karst Plain Prairie	

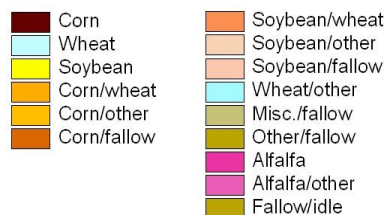
FML Base Year Landscape – Enhanced NLCD 2001/2002: Comparison of Traditional and Expanded NLCD Agriculture Classes



Traditional NLCD Classes



Expanded 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

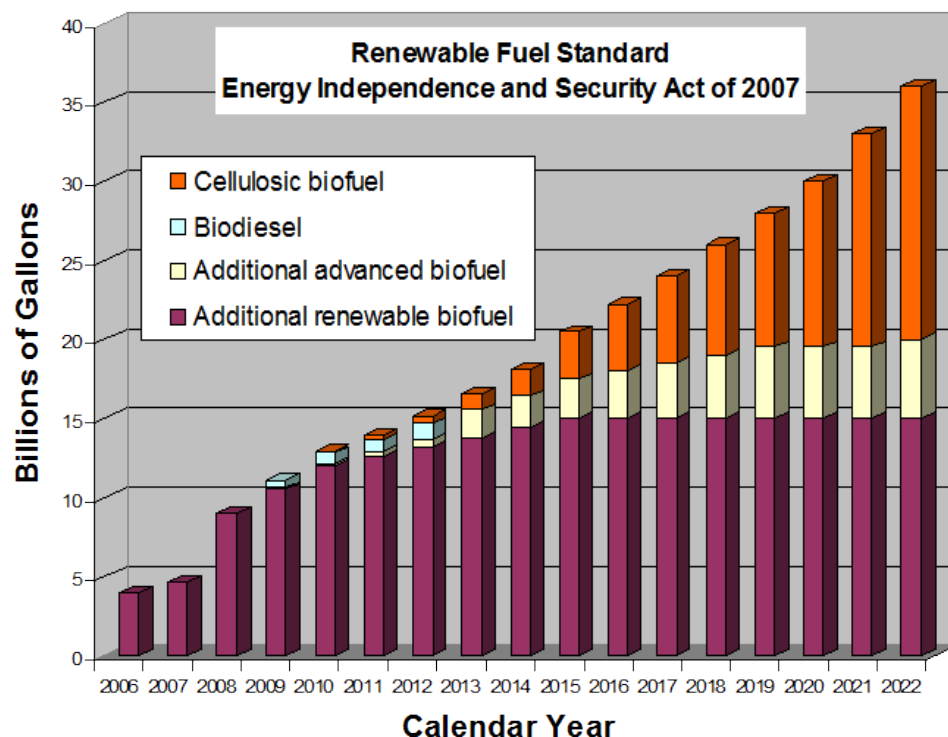
Market Allocation (MARKAL) econometric model

- Energy supply and demand

Sets conditions for:

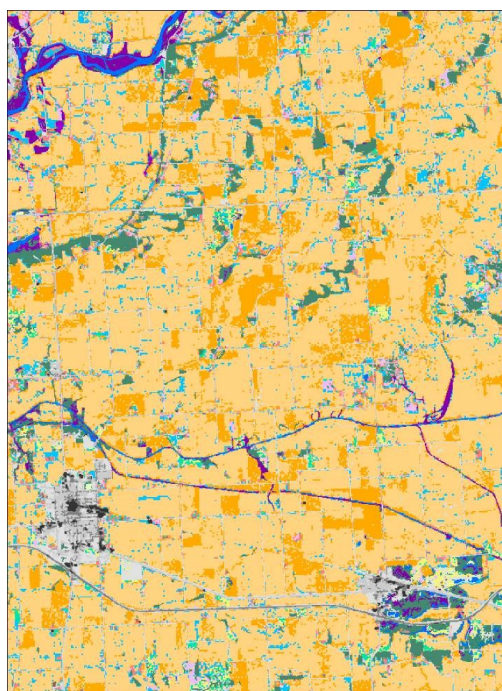
Food and Agricultural Policy Research Institute (FAPRI) econometric model

- Agricultural supply and demand
- Projects crop acres / region

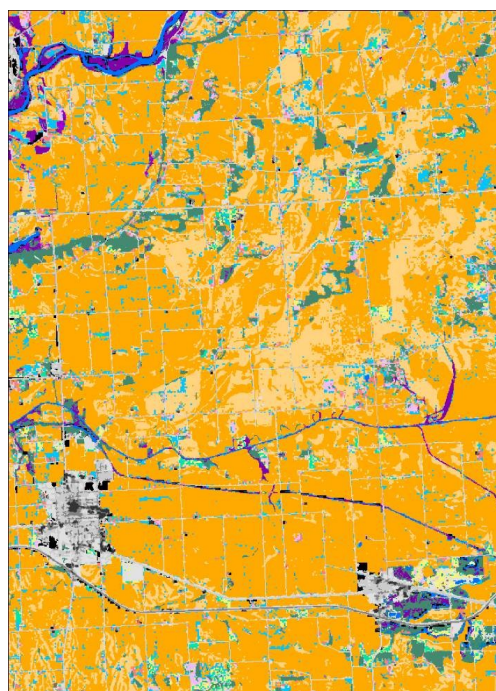


Results disaggregated using soils data, tillage practices, etc.

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

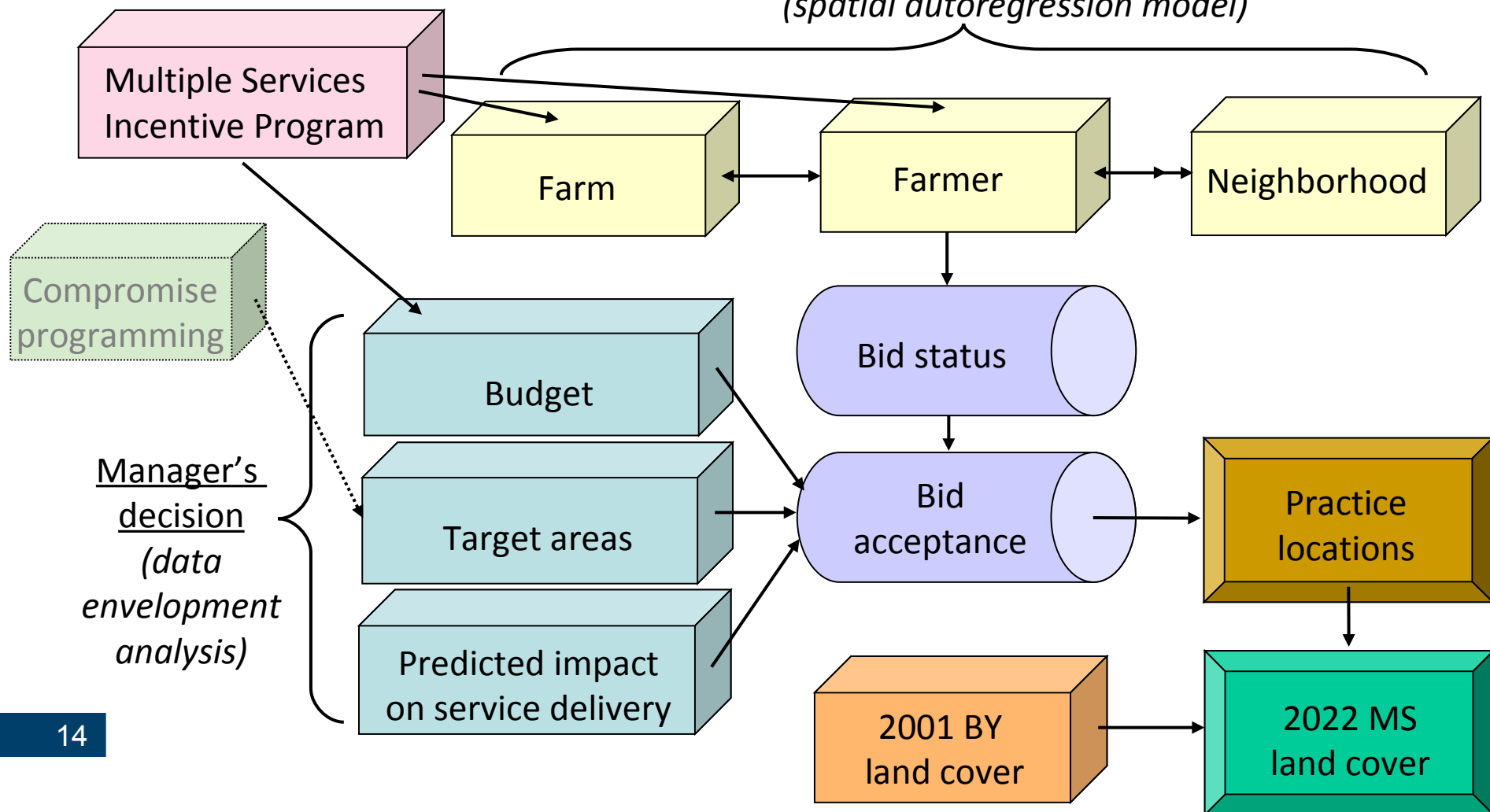


Continuous
corn

Multiple Services landscape modeling process

(Heather Sander)

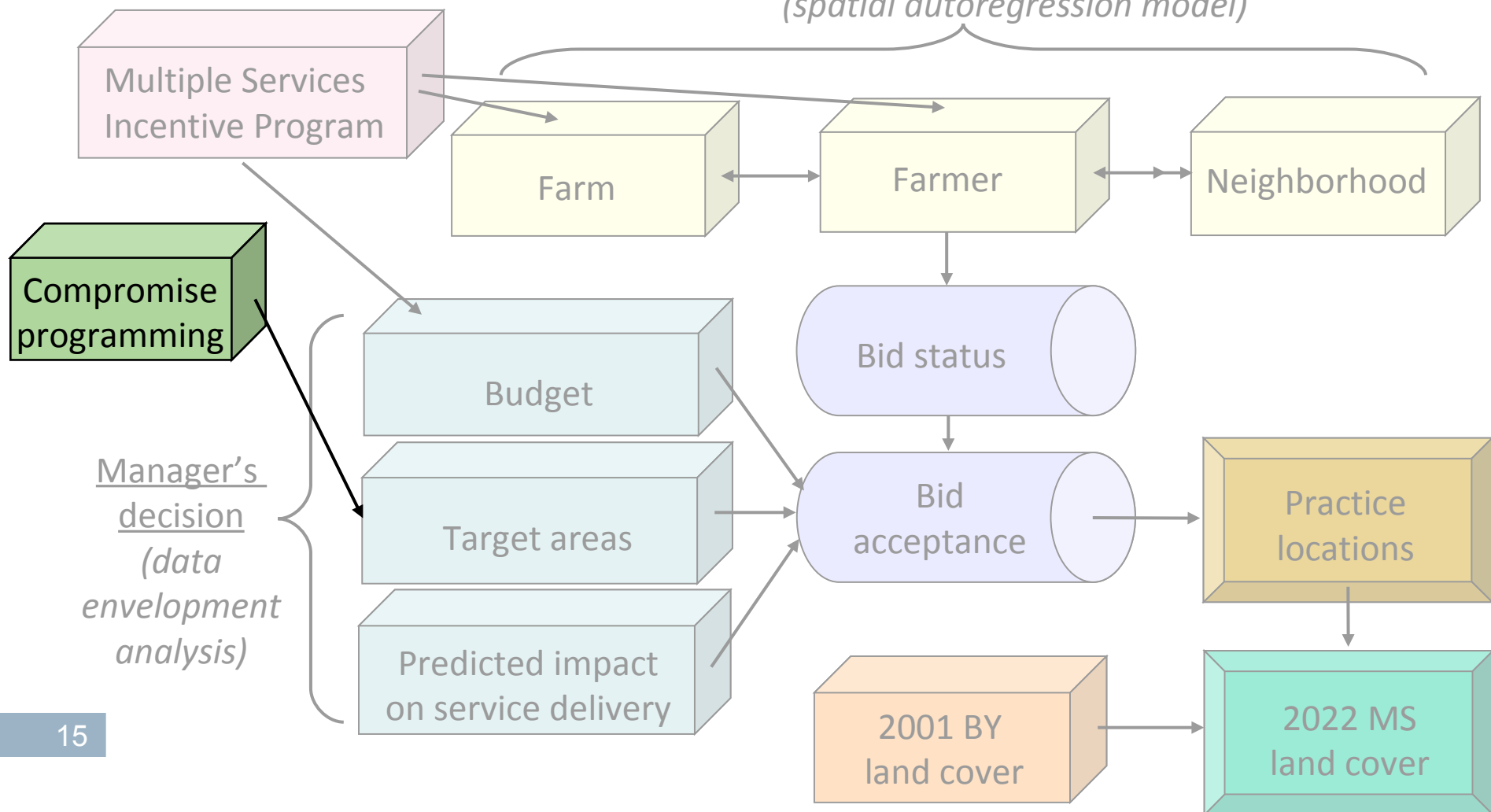
Farmer's decision
(spatial autoregression model)



Multiple Services landscape modeling process

(Heather Sander)

Farmer's decision
(spatial autoregression model)



E-DASH

Environmental Decision Analysis and Support Heuristics

Liem Tran
Mark Ridgley
Robert O'Neill

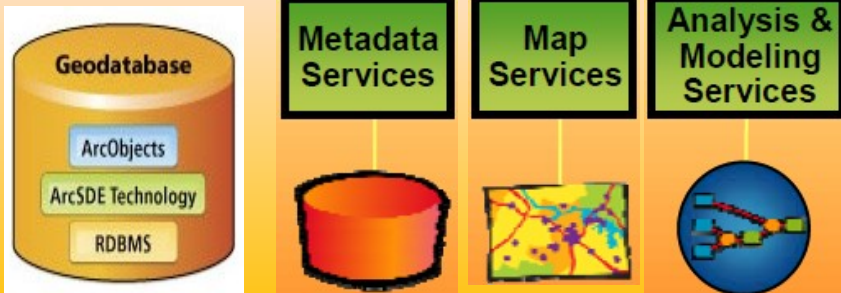
Multi-criteria Decision-Making (MCDM) Module

- SMARTS
- SMARTER
- Analytical Hierarchical Process (AHP)

Multi-Objective Optimization Programming (MOOP) Module

- Goal programming
- Compromise programming
- Adaptive weighted sum

GIS Server



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

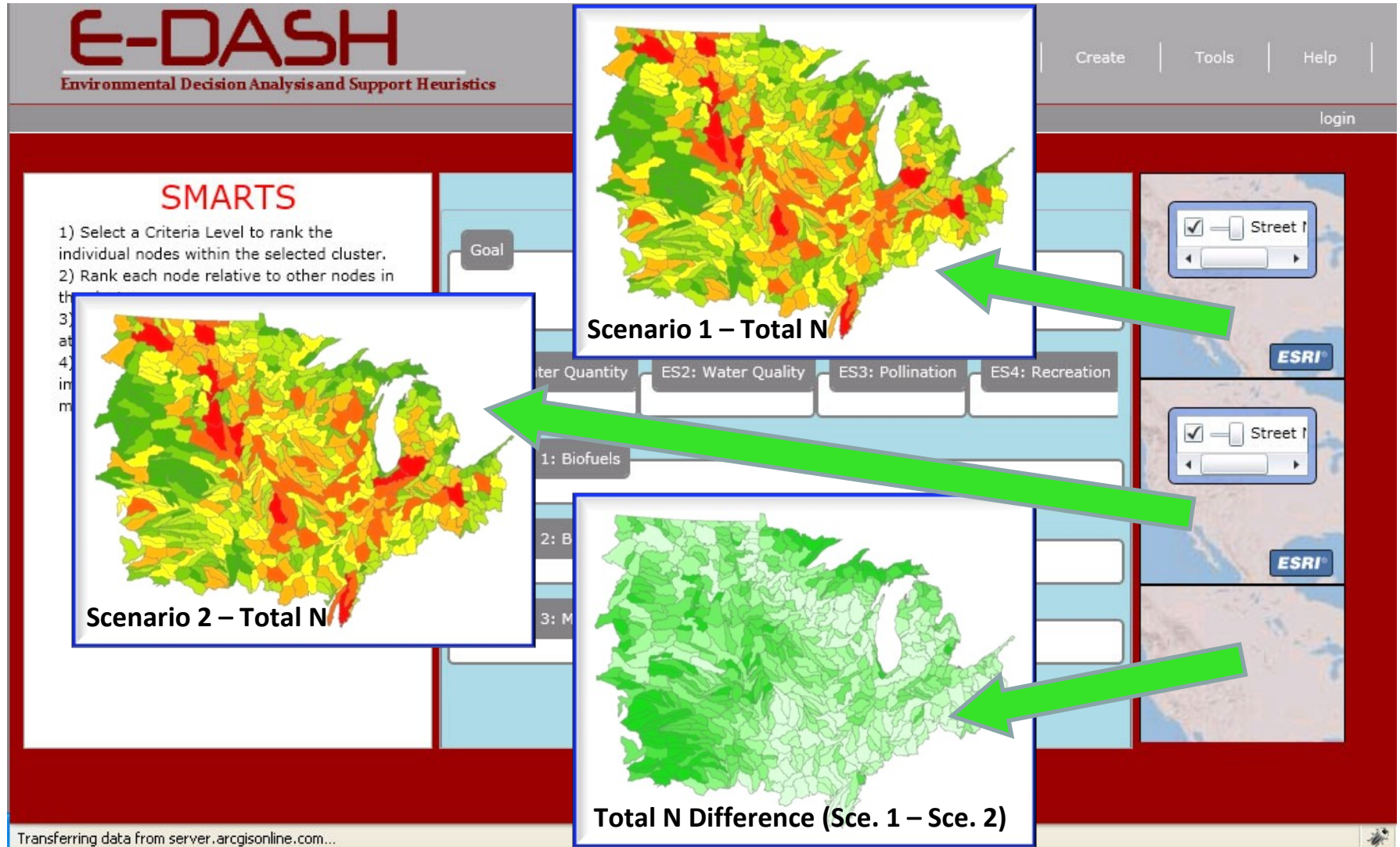
- Run MOOP model in independent mode
- Run MOOP model using weights from MCDM models
- Connect MOOP to GIS Server to explore results

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

E-DASH

Environmental Decision Analysis and Support Heuristics

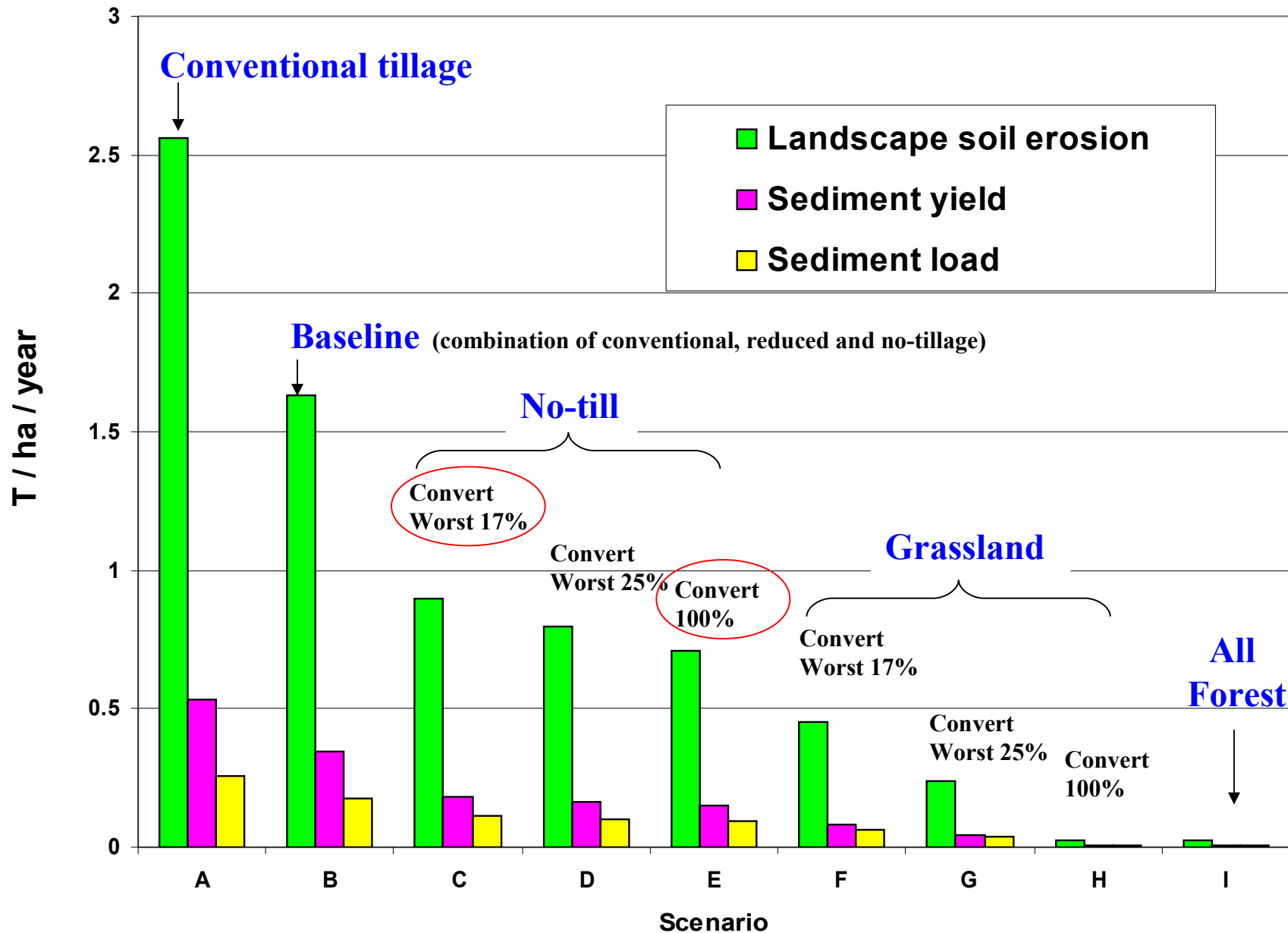
- Viewing interactive GIS maps in E-DASH

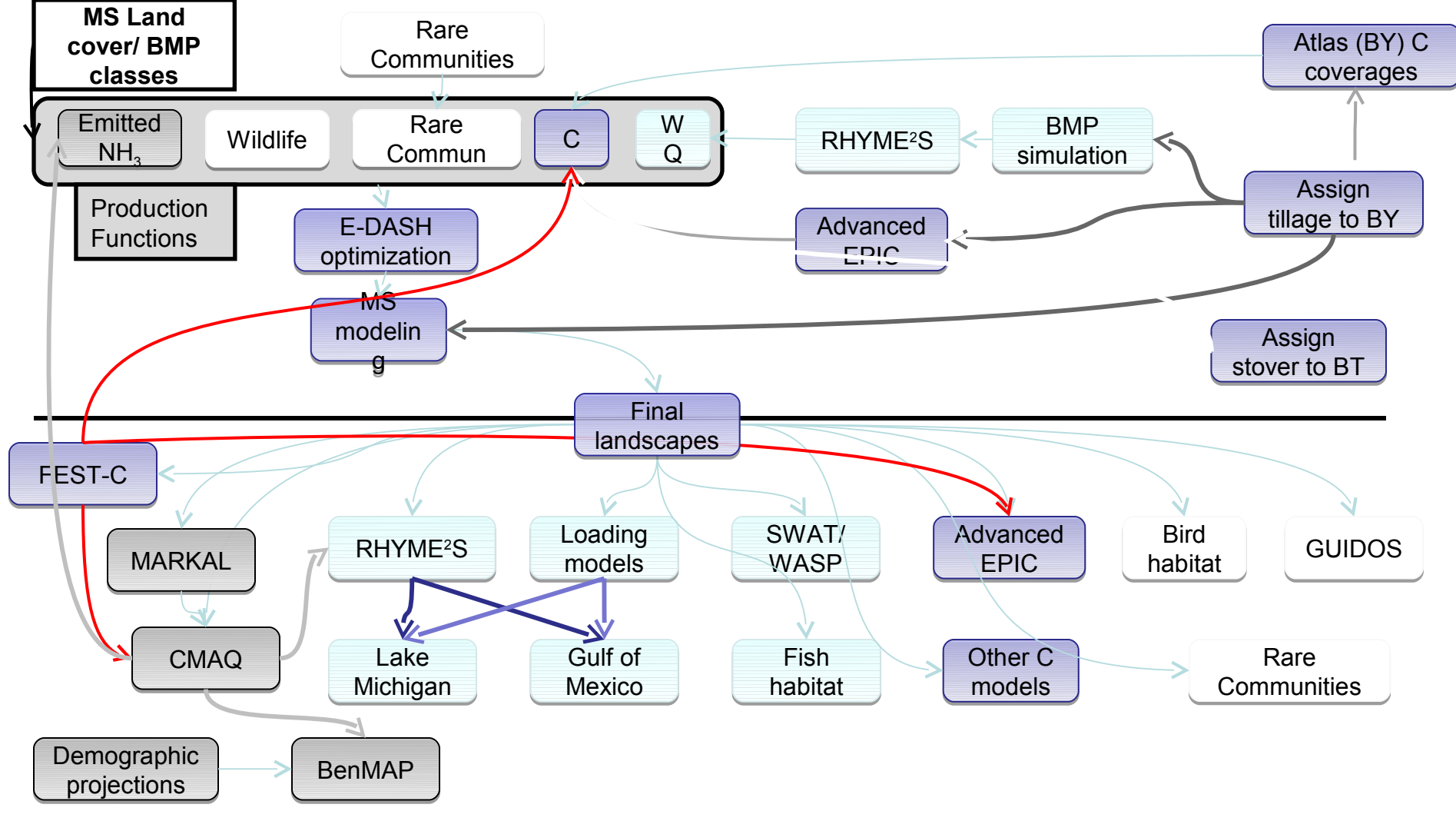


Multiple Services landscape: Potential practices for enhancement

- **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

regional 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

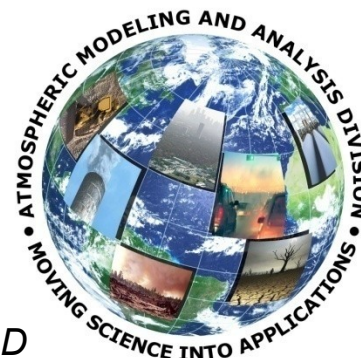


What Provided?

- 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

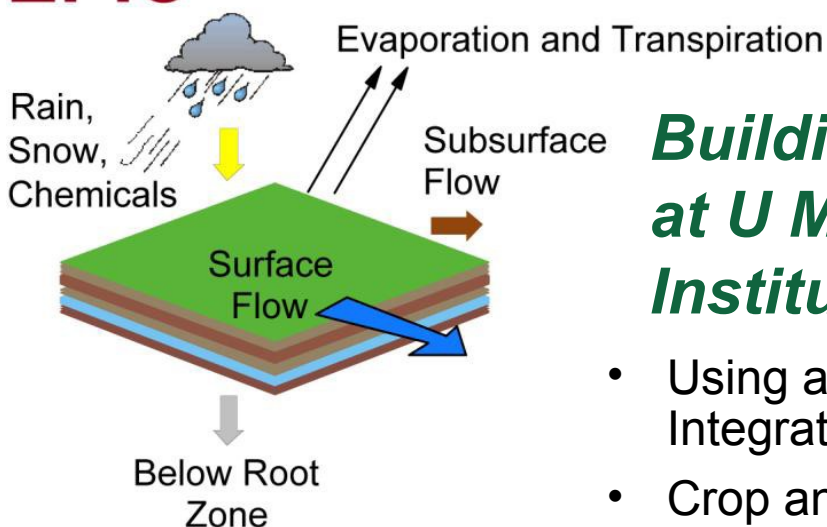
**CMAQ is the Community Multi-scaled Air Quality Model*



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, CO₂ flux, DOC, denitrification, including N₂O, and N leaching and run-off

Status: Funding vehicle in progress; work initiated

Stephen LeDuc, NCEA

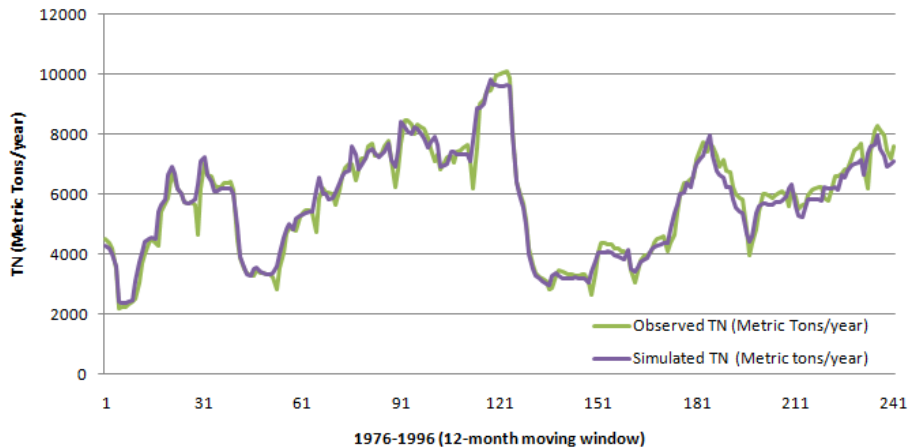
Regional-scale hydrologic modeling for ecosystem services assessment: RHYME²S

Simulated versus observed, annual total N:

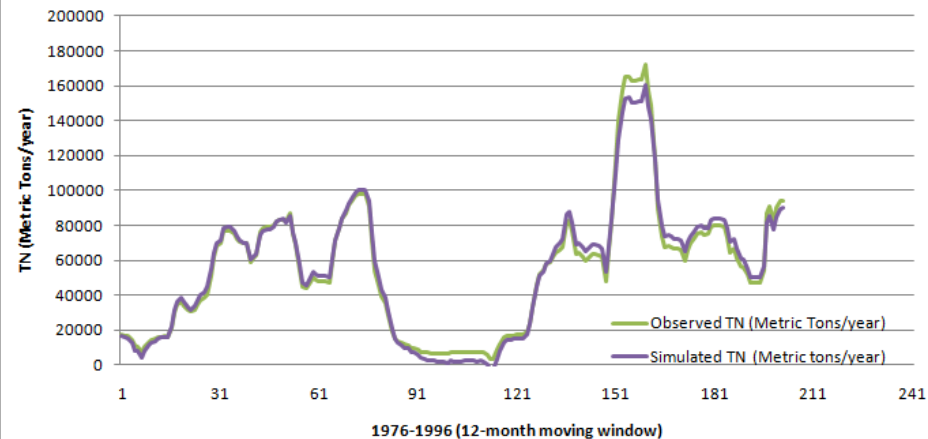
$$R^2 = 0.91$$

$$R^2 = 0.93$$

RHYME²S Results
USGS St. Croix River Station 30001



RHYME²S Results
USGS Minnesota River Station 20003



Advantages:

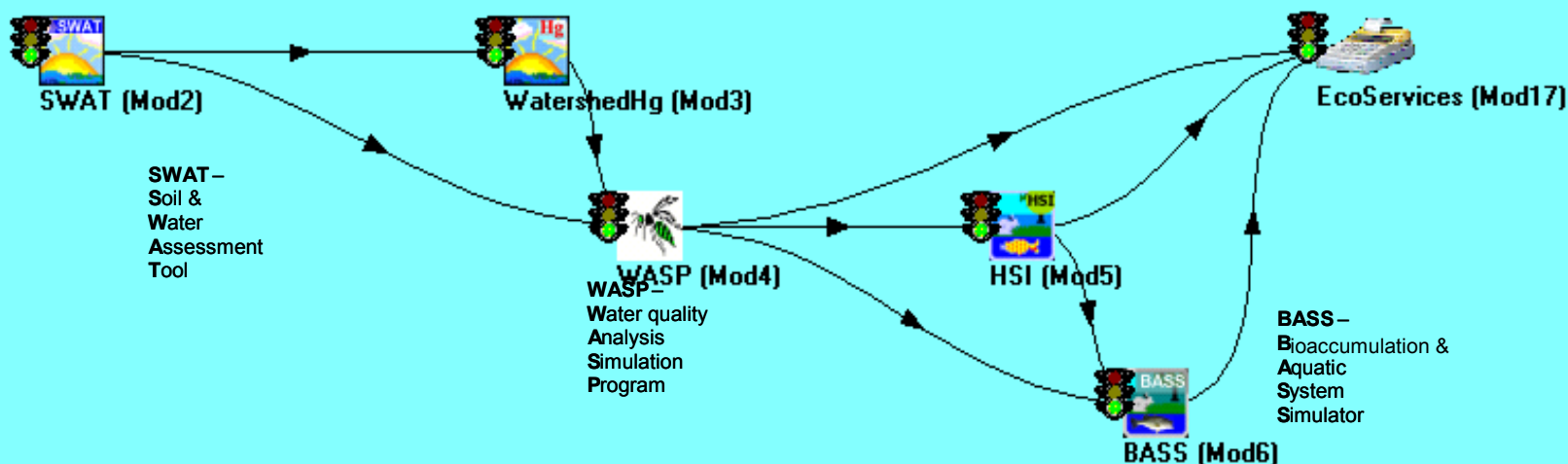
- Better explanation of variability
- Smaller number of parameters
- More consistent results (among watersheds)
- Regional *and* local estimates of loadings

Status: First half of development completed, preliminary results available

Liem Tran, EPA expert hire, NERL ESD

Water quality and aquatic habitat assessment using FRAMES

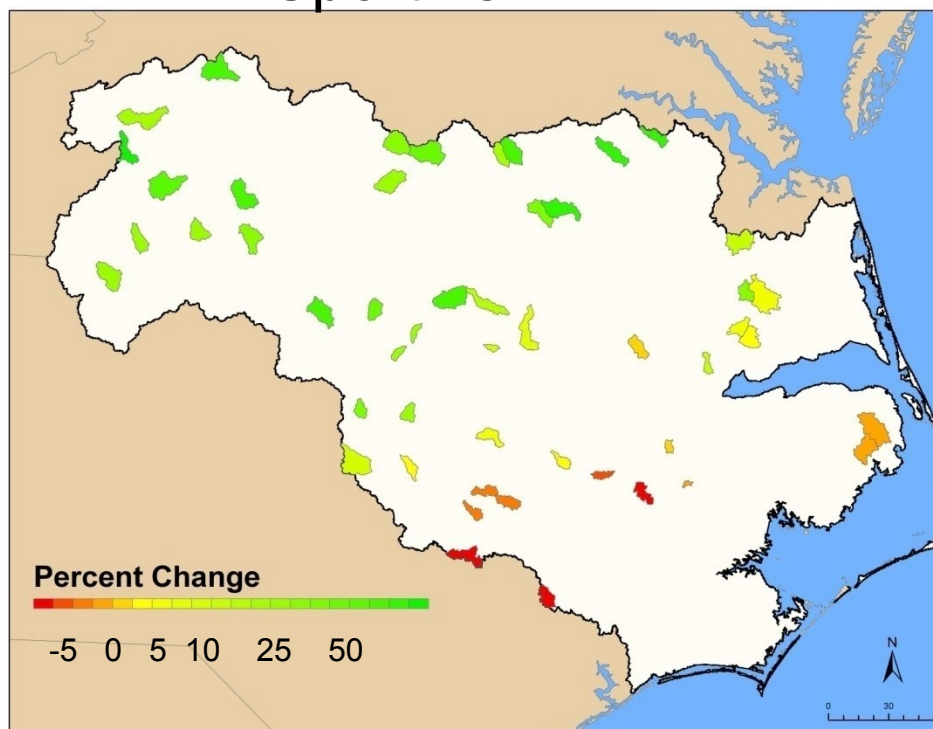
Linked Models for Scenario Analysis



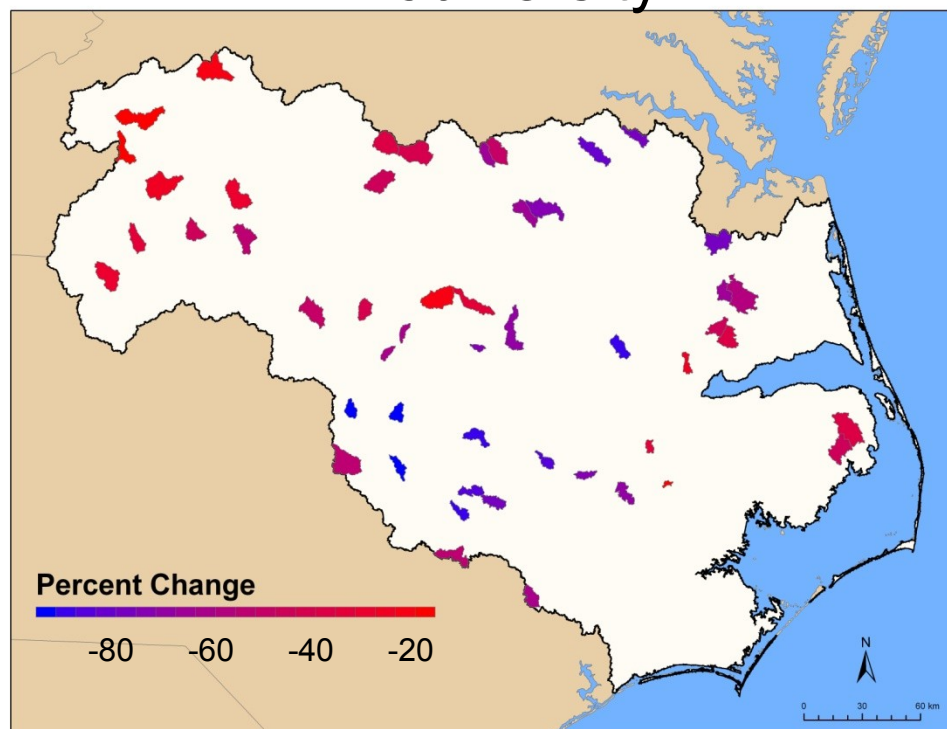
Models are dynamic and process-based

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

Sport fish

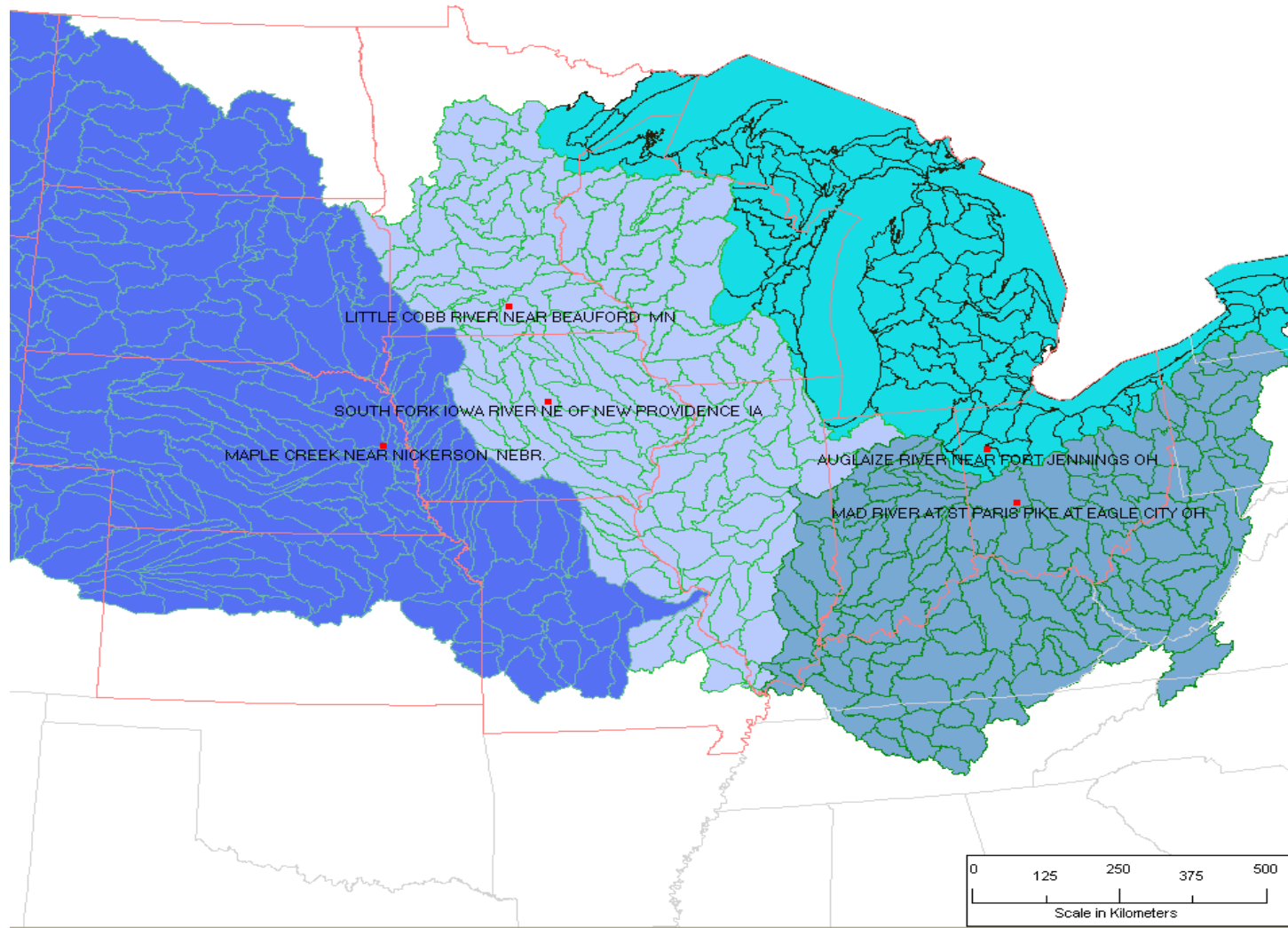


Biodiversity



Locations for initial trials of FRAMES in FML Study

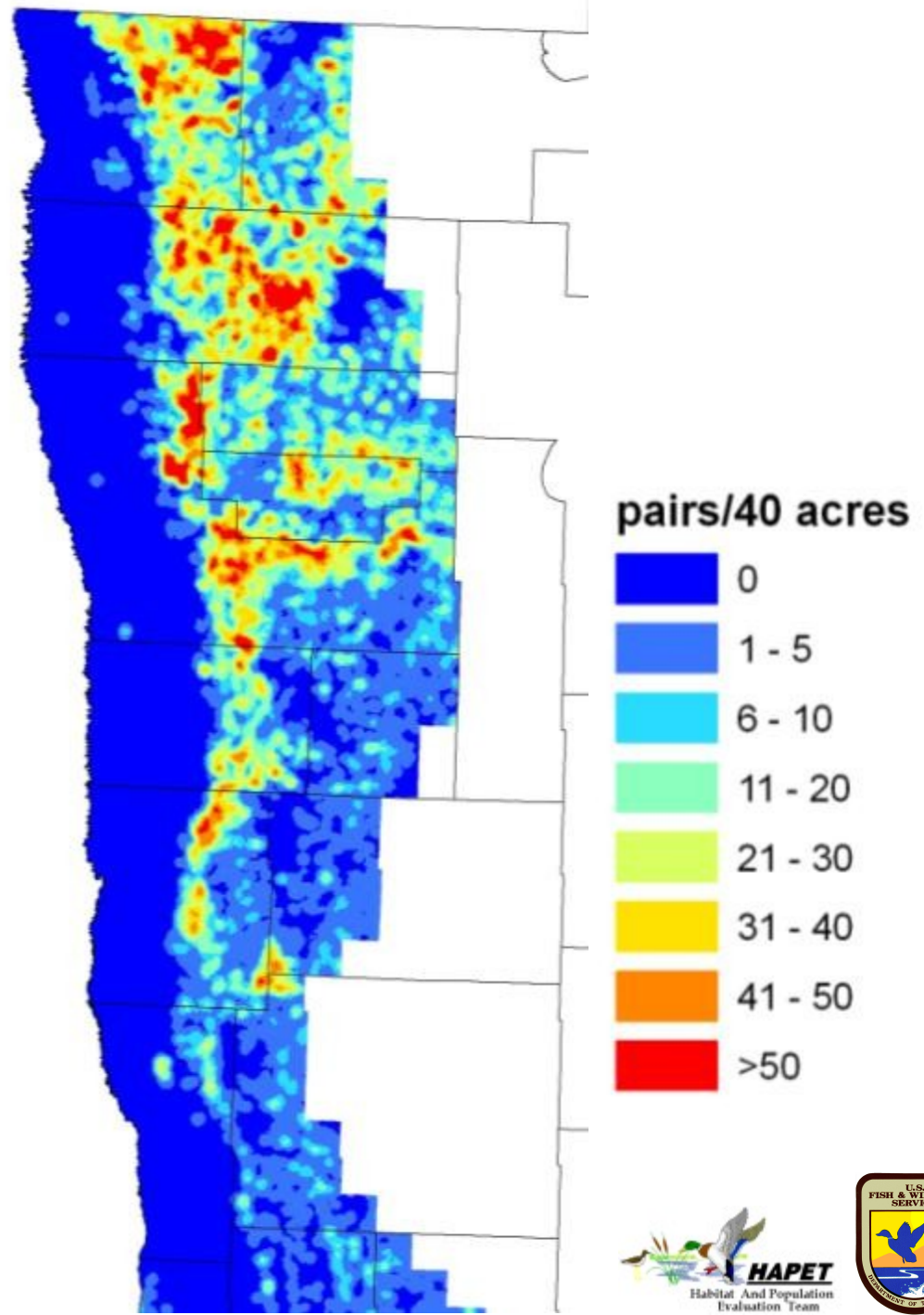
(Mark Rowe, NHEERL; Gerry Laniak)



Example of habitat modeling

Migratory Grassland Birds

Predicted number of
pairs *with* the
Conservation
Reserve Program



Courtesy Diane Granfors, FWS Joint
Ventures Program

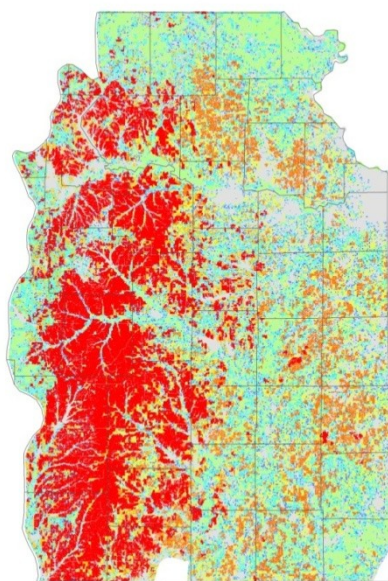
Effects of Conservation Set-asides (CRP) on Grassland Bird Populations

	With CRP	Without CRP	% loss
Grass >1 ha (<i>total ha</i>)	863,263	711,846	17.5
Bobolink (<i># breeding pairs</i>)	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

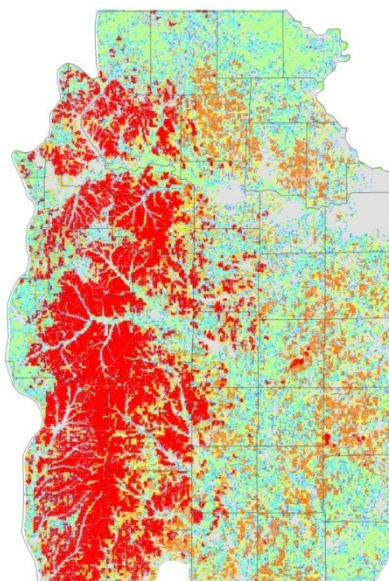
Preliminary analyses of individual species' habitat changes

Upland Sandpiper suitability for base year (2001)

Upland Sandpiper suitability for future year (2020)

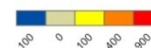
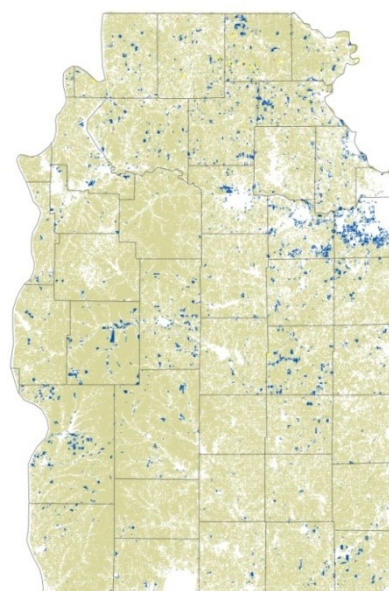


Base Year



Biofuel Targets

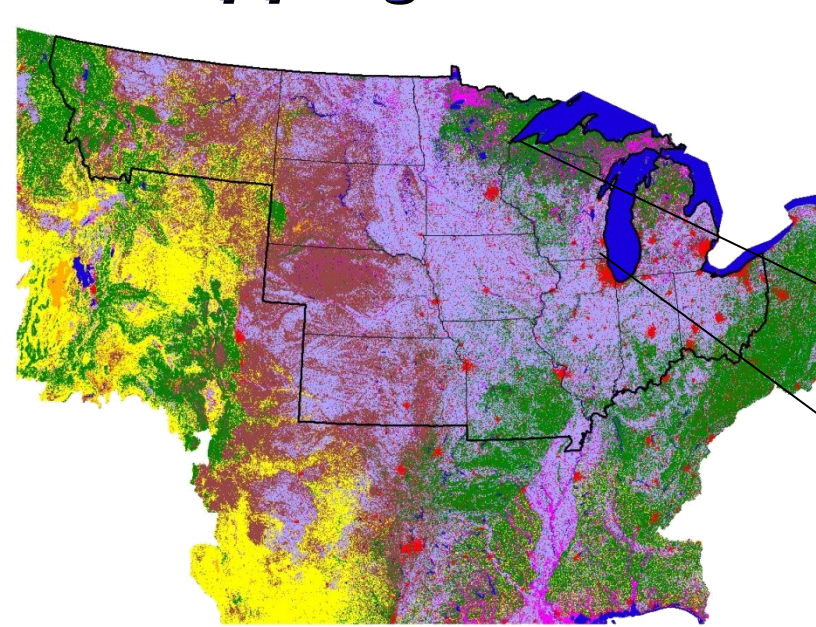
Percent change in suitability score



Percent change

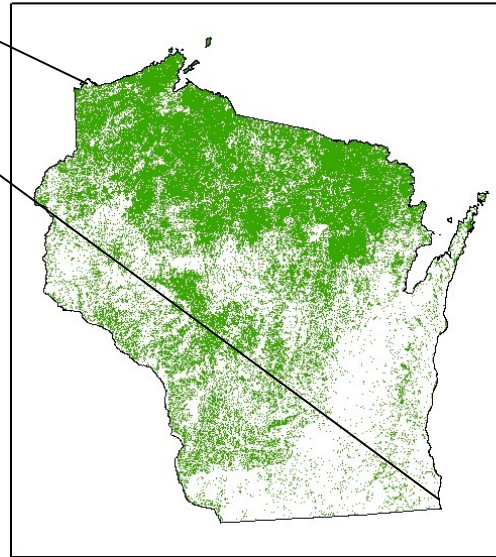


Mapping Habitat from Land Use/Land Cover Maps



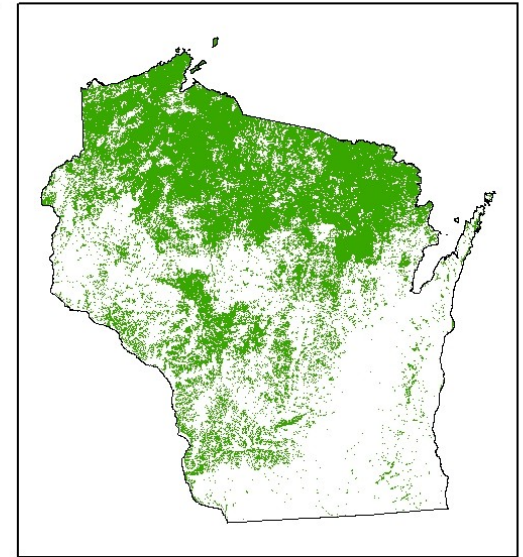
One input map (the finer resolution, the better) can produce a variety of habitat maps

Habitat for small mammals, forest bird species



10 acre window
(small range)

Habitat for large migratory species, black bear



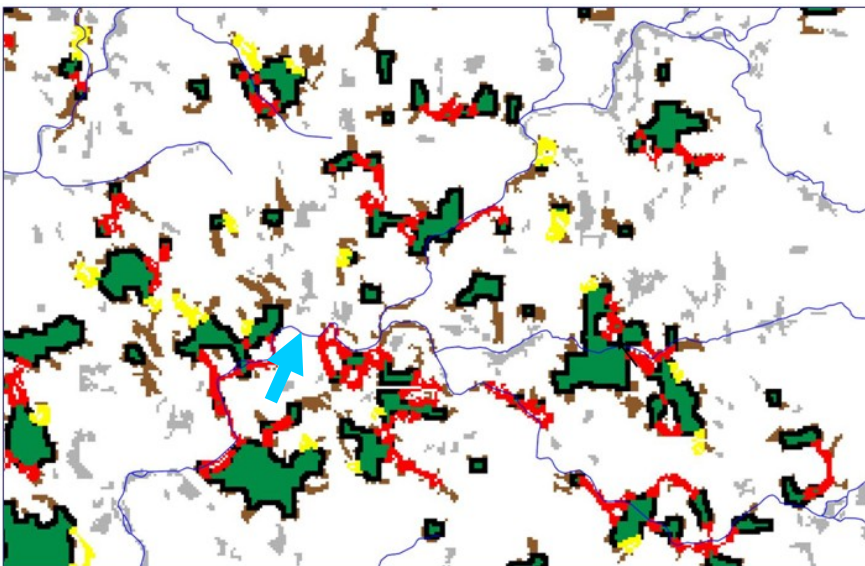
160 acre window
(large range)

Habitat can be any type of land cover....



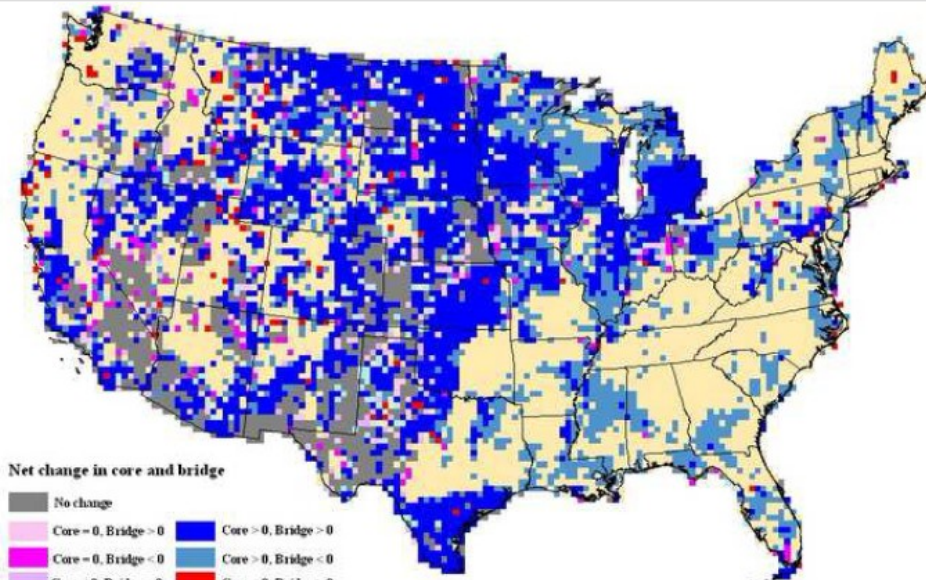
Habitat/Green Infrastructure

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



Core (hub) Bridge Loop Branch Islet (patch)

(to be included on LandScape website...)



Net change in core and bridge

No change
Core = 0, Bridge > 0
Core > 0, Bridge > 0
Core > 0, Bridge < 0
Core < 0, Bridge < 0
Core < 0, Bridge = 0
Core < 0, Bridge > 0
Core > 0, Bridge = 0
Core < 0, Bridge = 0

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

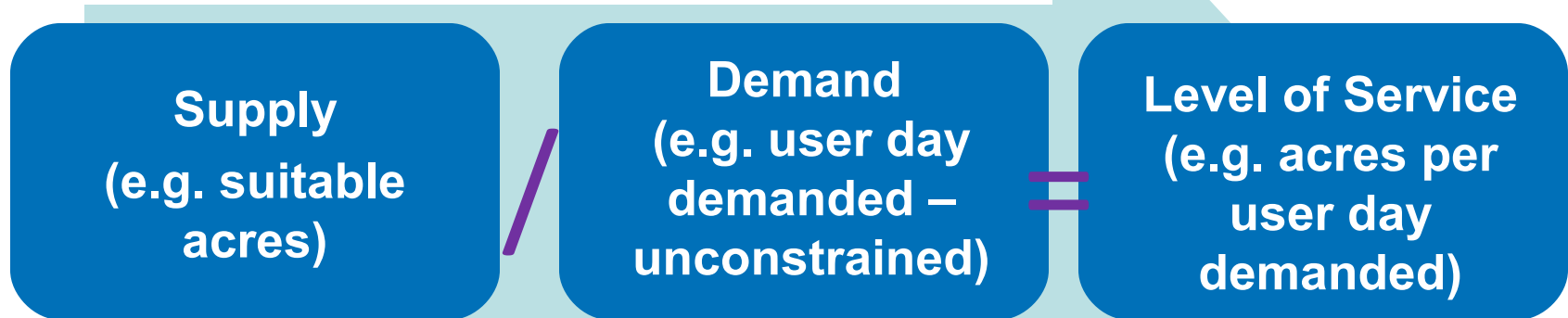
forest.jrc.ec.europa.eu/download/software/guidos



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



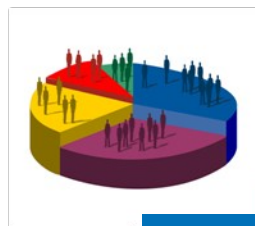
Level of Service Examples of Submetrics



Supply

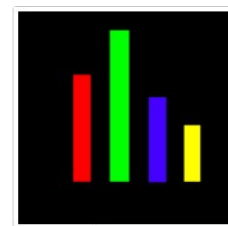
Acres suitable for specific use (hunnable acres, remote public lands, species-rich bird habitat)

Quality “inflaters” 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

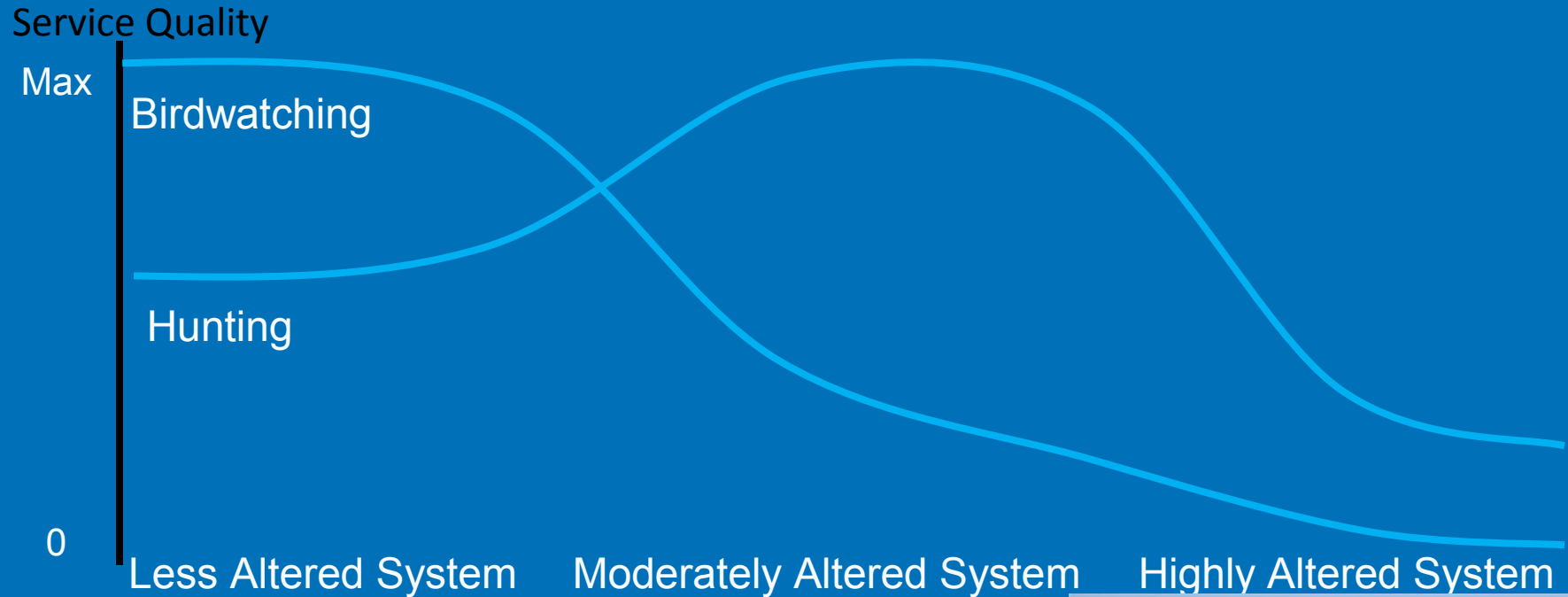
Unimpaired stream/lake area per boat

Groundwater yield per crop acre

Wetland acres per \$ million economic output generated by businesses in coastal zone communities

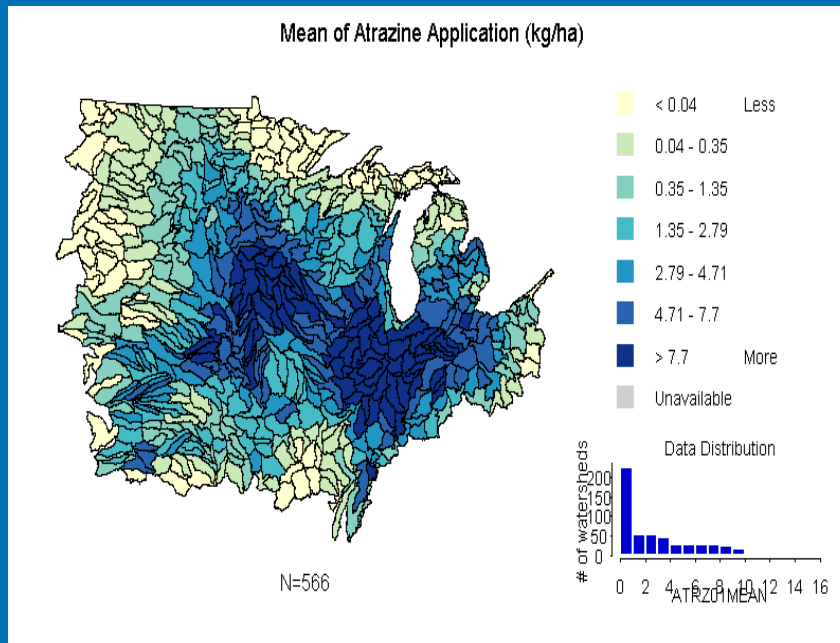
Damage Functions:

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



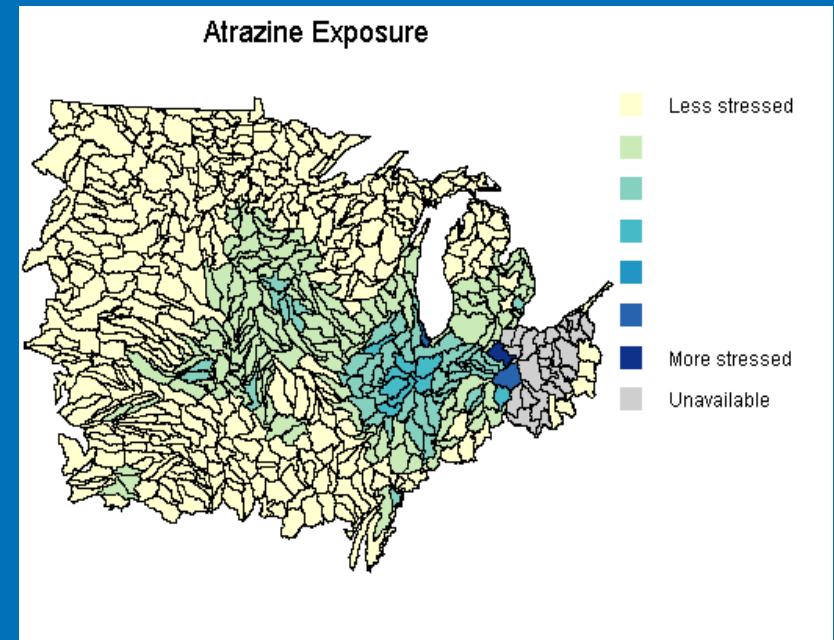
Exposure: Service value is related to the ability to mitigate or reduce risk

Estimated Atrazine application for Base Year landscape



Potential risk only –
incomplete endpoint

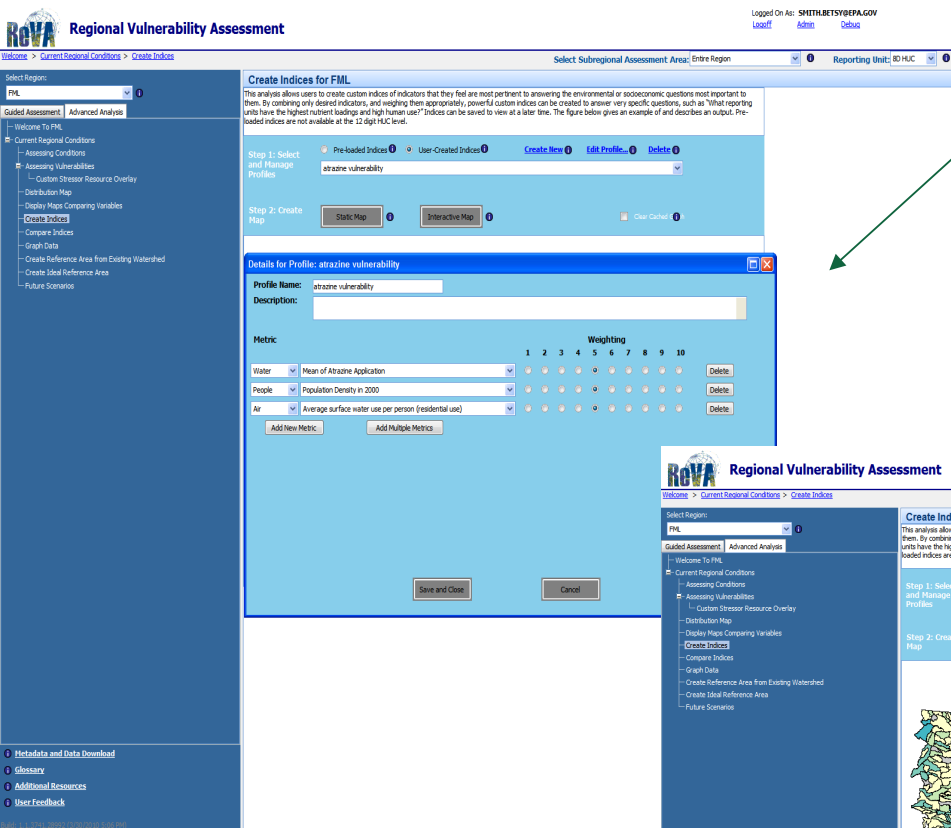
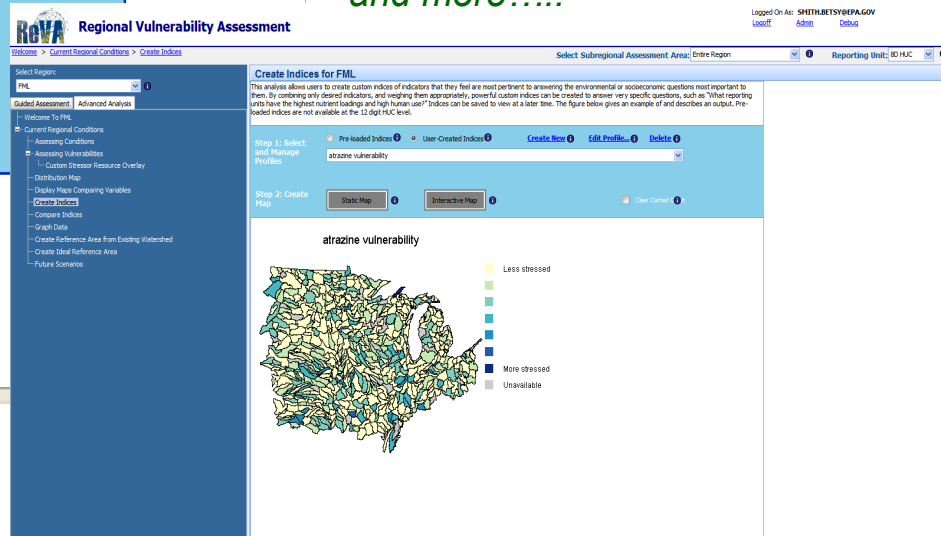
Combined index: Atrazine application
and population using surface water
supplies



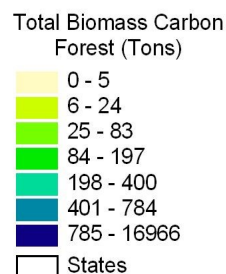
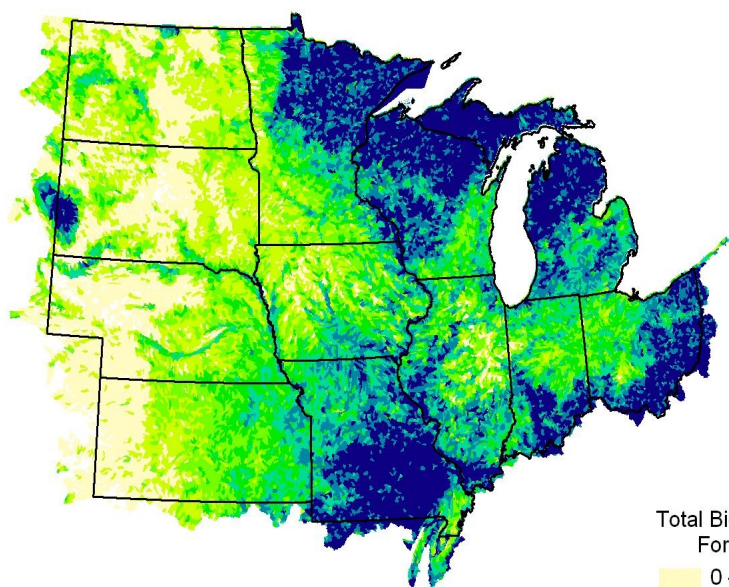
Risk + Exposure –
a better endpoint

Expanded Capabilities in web-based Environmental Decision Tool

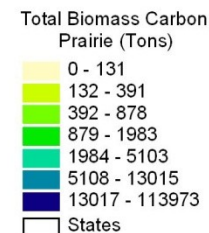
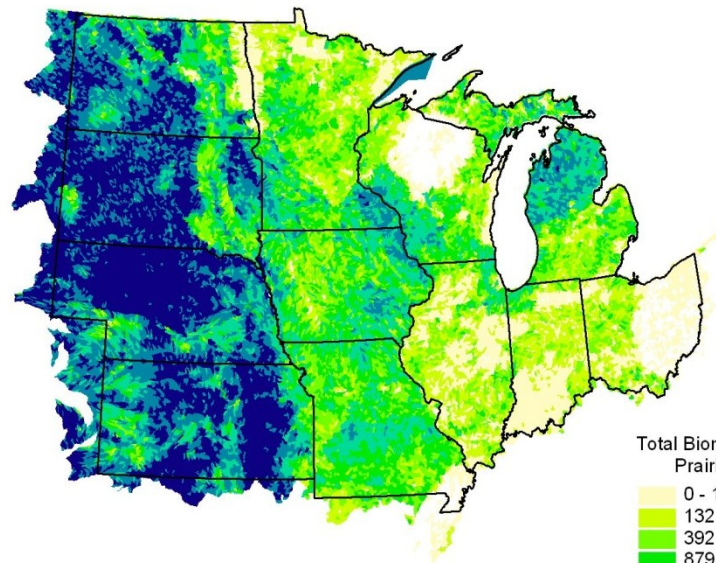
- *Menu-driven assessment guide (wizard)*
- *Mash-up between S-PLUS and Arc GIS Server*
- *Assess within subregions (e.g. states)*
- *Create, save, reuse customized indices*
- *Identify a reference watershed (or other reporting unit) and compare to others*
- *Assess spatial patterns using linked micro-maps*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

Preliminary estimates of Carbon sequestration – Base Year Landscape



Forest Carbon

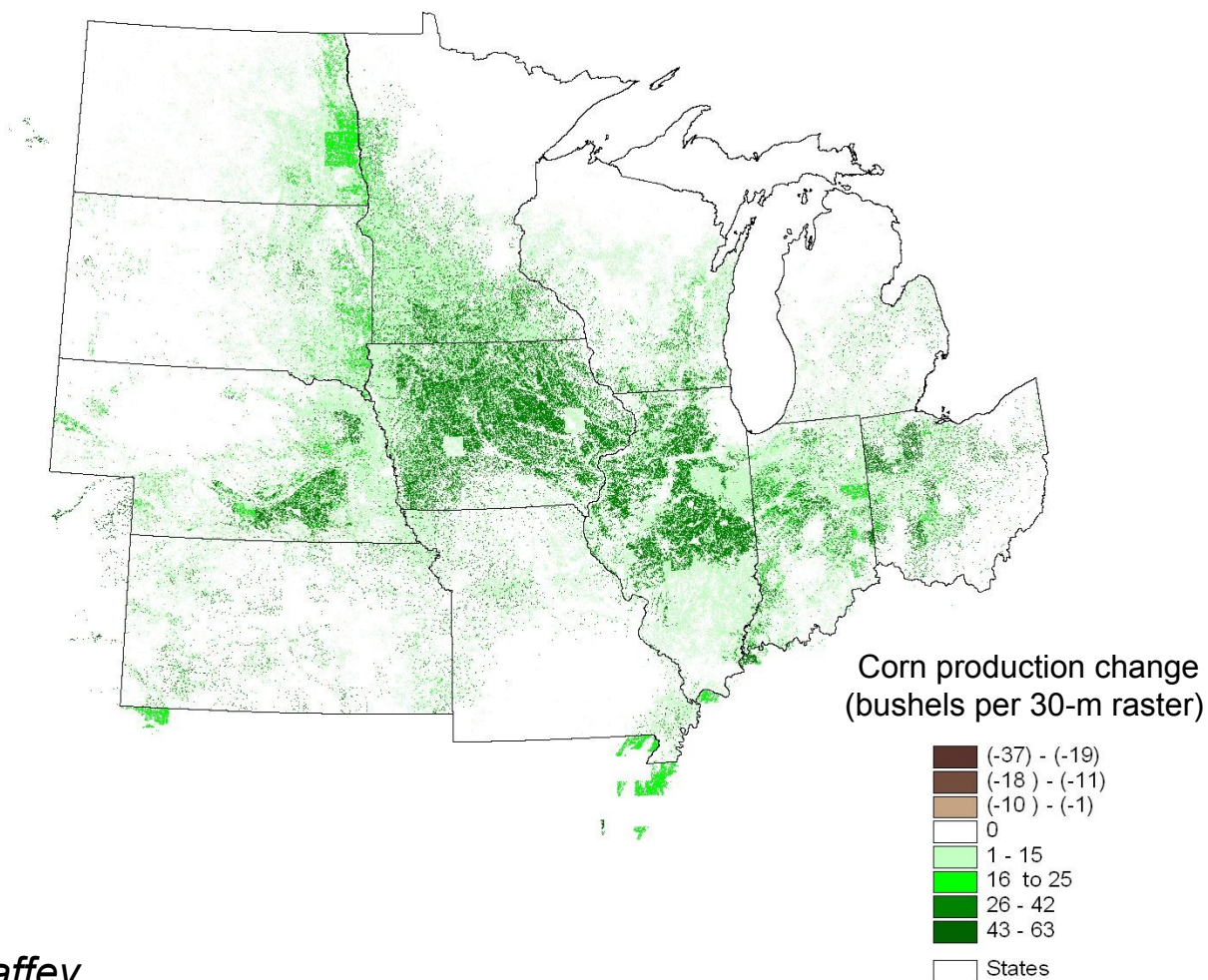


ABD = from National Biomass Carbon Database (NBCD2000)

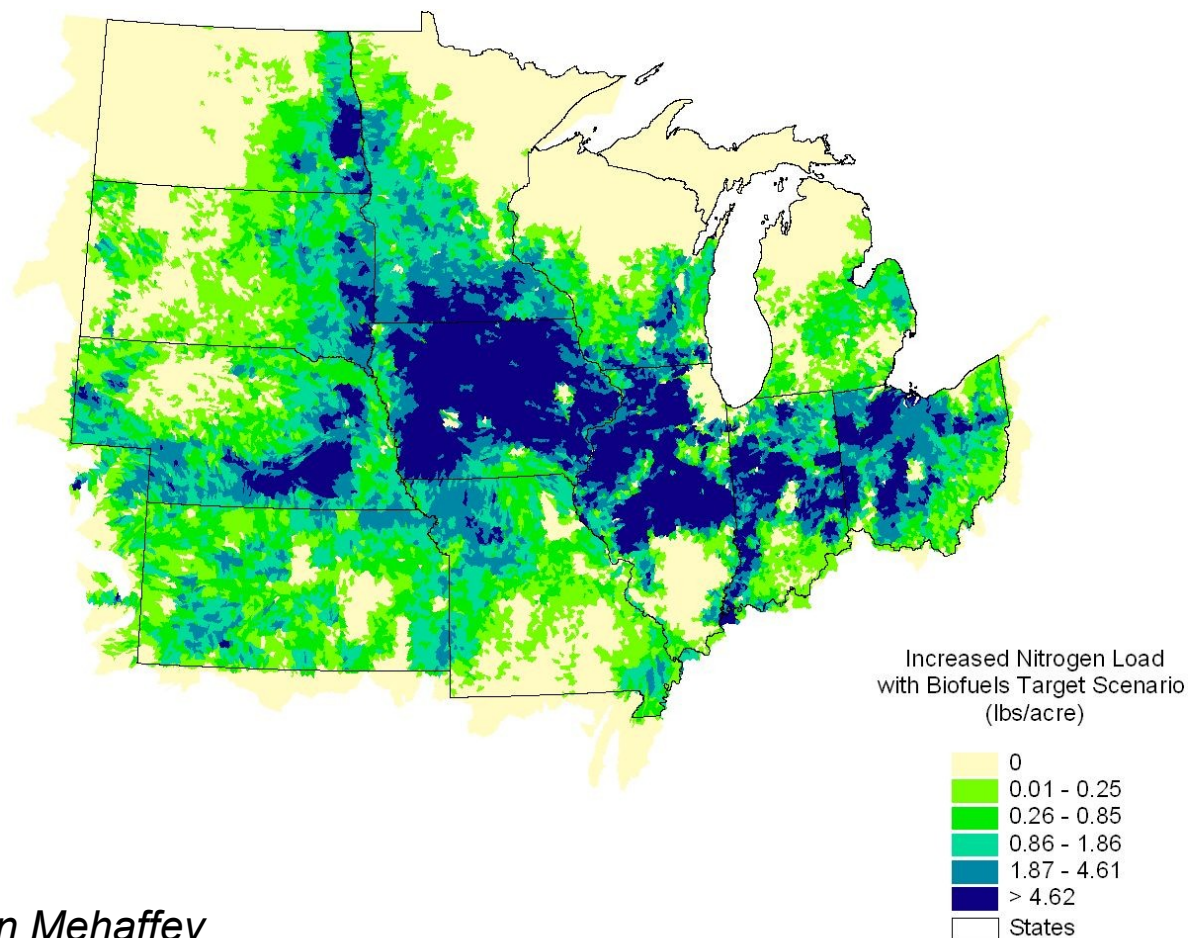
+ $BGB = \exp(-1.0587) + (0.8836 * \ln ABD) + 0.1874$

from USDA General Technical Report NRS-18

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

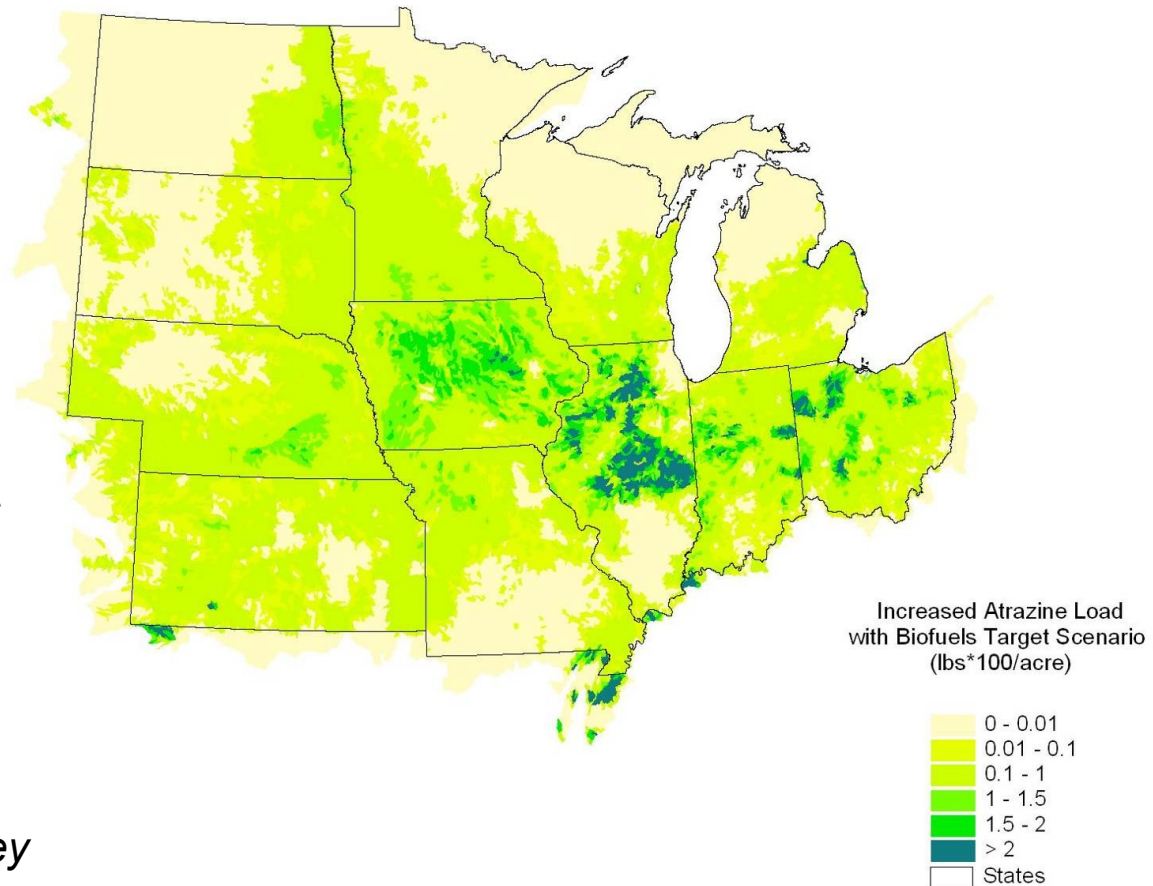


Clean Water: change in Nitrogen application rate projected with shift in cropping practices to reach Biofuel Targets



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*





Questions?