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ECOSYSTEMS SERVICES RESEARCH PROGRAM
BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Mapping and the National Atlas of Ecosystem Services (NAtl-ES)

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Office of Research and Development
US EPA

Science Advisory Board Presentation
Environmental Processes and Effects Committee

July 14th, 2009
Washington, DC

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Goals of the ESRP Landscape Characterization and Mapping Theme

To collaborate with, and to provide landscape science support to ESRP's, place-based, ecosystem-based, and pollutant-based projects



To develop a publicly accessible and scalable National Atlas of Ecosystem Services in order to inform **decision-making**

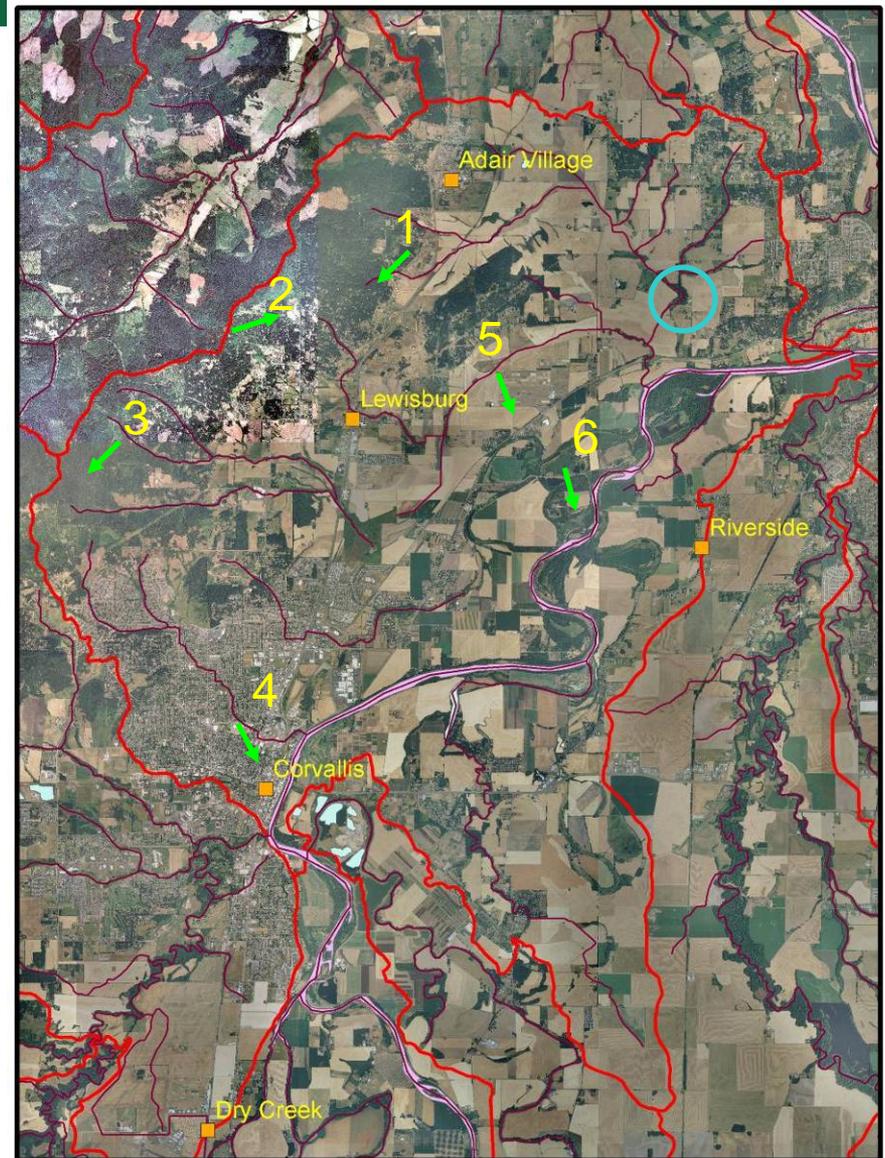
Vision for the National Atlas of Ecosystem Services

How many ecosystem services can you visualize in this image?

Imagine the flow of services into and out of this area

Now, imagine summarizing all of this somehow and mapping for nation!

Location, Location, Location!
(Spatial Pattern Matters)



Implementation Strategy embodies these principals:

- **Reliance on existing data, literature, models and tools while conducting additional research and keeping eye on future developments**
- **Emphasis on interaction with other ESRP projects and themes -- critical for linking functions to services**
- **Reliance on extramural participation**
- **Staged Implementation**

What have we been up to? Presentation Outline

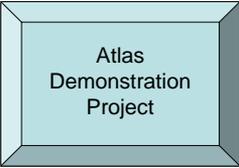
Atlas
Demonstration

Partnership
Development

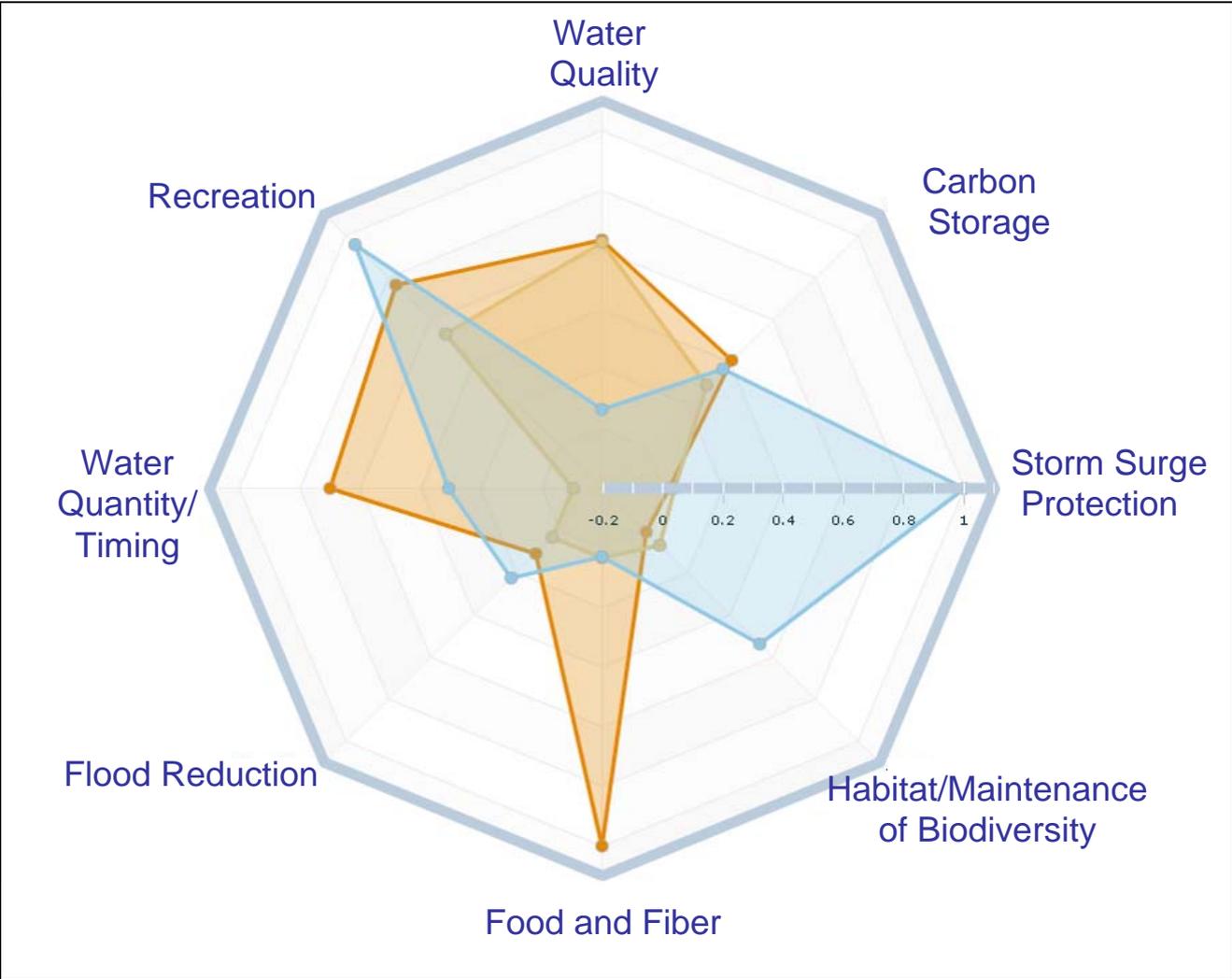
Ecosystems
Services
Indicators
Calculation

National Data
Set
Development

Ecosystem
Services
Mapping
Research

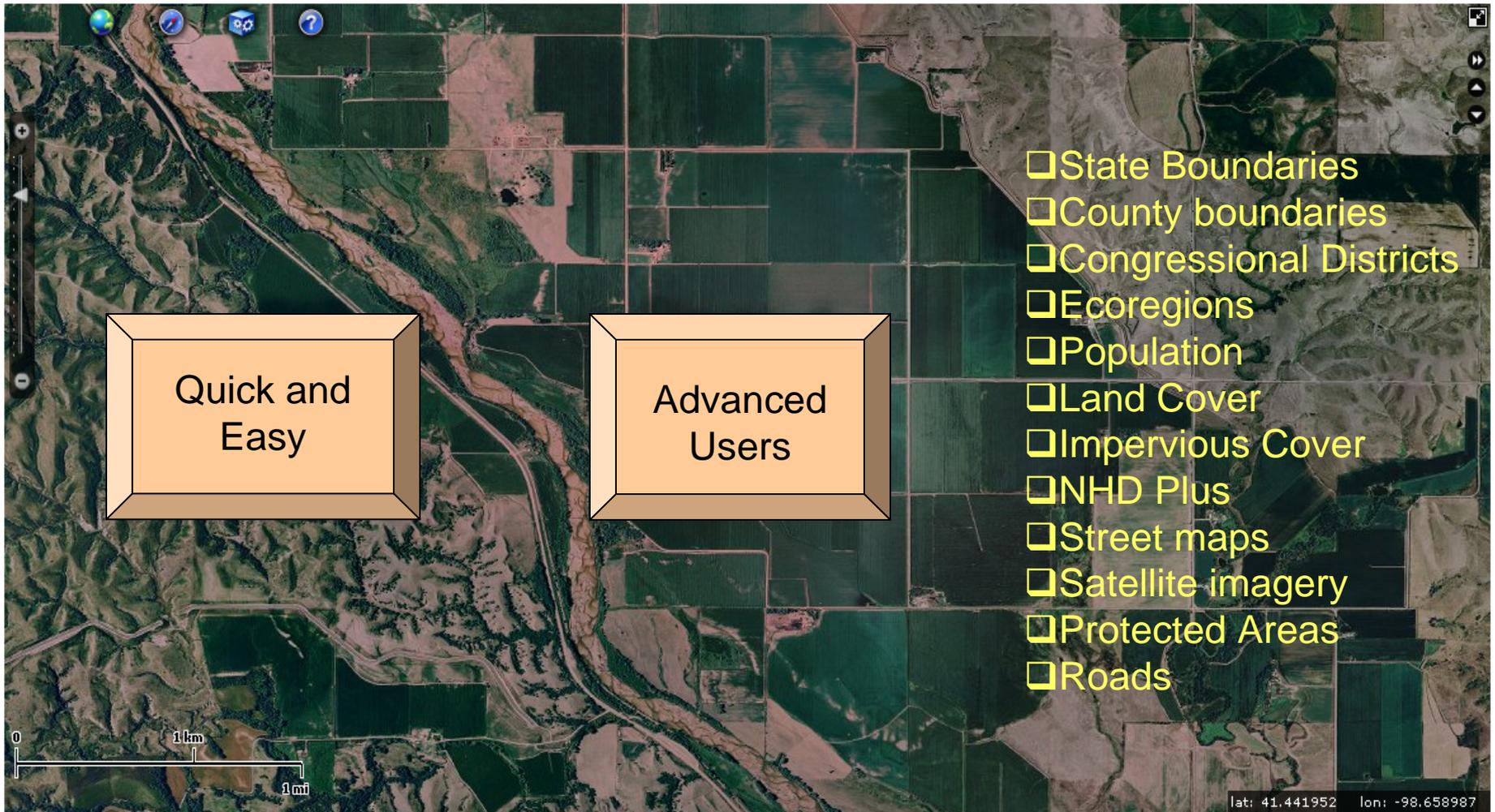


Atlas Demonstration -- Vision



-
- User will zoom to geographic area
 - Contain series of background maps
 - Select ecosystem services from Table of Contents
 - Scalable
 - Include change and future scenarios
 - Allow analysis of multiple services
 - Allow user to place their “area” in context of others

Atlas Demonstration -- Vision



Atlas Demonstration -- Vision

The screenshot displays the VisualSPARROW web application running in a Windows Internet Explorer browser. The browser's address bar shows the URL <http://envext02.rti.org/wlvord/>. The application interface features a search bar at the top left with the text "Enter an address or zipcode" and a "Search" button. Below the search bar, the current location is displayed as Latitude: 35.6997, Longitude: -80.17, and Zoom level: 9. The "Map Controls" section includes buttons for "VisualSPARROW NHDPlus NC", "VisualSPARROW RF1 Potomac", "Catchment Navigation", and "HUC12 Navigation". The "Direction" is set to "Upstream", and the "Travel" mode is set to "Hours". A slider for "Hours" is set to 480. The "Run" button is highlighted, and a "Zoom to last result" button is also visible. The "Raindrop Indexing" section includes a button for "STORET Sites (RTI Copy)". The main map area shows a green catchment area centered on Greensboro, NC, with major roads and cities like Winston-Salem, Durham, and Raleigh visible. The map includes a scale bar for 20 miles and a "Local intranet" status bar at the bottom.

Maintain
upstream/
downstream
connectivity

Atlas Demonstration

The screenshot displays the LandScope America website interface. At the top, the navigation bar includes 'EXPLORE places', 'UNDERSTAND issues & priorities', 'CONSERVE places you love', 'INTERACTIVE FEATURES', 'CONSERVATION BENEFITS', and 'ABOUT LANDSCOPE'. The main content area is titled 'Find & View Data' and features an article about ecosystem services. The article text includes: 'A vast array of data exists that is relevant to land and waters, but that information is often hard to access. LandScope America will be working to draw data from many sources and present it in ways designed to support protection efforts. We will be striving not just to make the information more accessible to the land protection community, but also to make it visually interesting and even fun ways. Maps are a wonderful way to relate spatial information to the essential component of the land. Recent advances in technology to mapping experience. Building on our industry-leader ESRI, the LandScope America provides a national view to state and local perspectives, able to easily switch among different map views, photography and detailed satellite imagery. In the interface, you can access critical information, highlight your state's information, and zoom in to explore. And of course, no organization is better at providing compelling maps than National Geographic. For viewing the types of richly detailed maps that are acclaimed. This map portrays the national diversity patterns of terrestrial vertebrate species, including all native mammals, reptiles, and amphibians. Each map is based on an analysis of range maps for each of the more than 1,900 species of terrestrial vertebrates. Each of these range maps, in turn, is based on a synthesis of data from various sources, including scientific literature, government records, and field observations. Understanding the distribution of vertebrate species across the United States provides an important context for target areas designed to promote wildlife. One of the most common and straightforward metrics for biological diversity is to count the number of species in an area. This species "richness" metric is helping users understand important centers of biodiversity nationally, and locally. While conservationists have historically taken an interest in protecting ecosystems for their own sake, one of the most persuasive arguments for maintaining the integrity of ecosystems is that they provide essential services. Even if we rarely capture them in our accounting, the value of these resources is hardly inconsequential. Imagine for a moment: would human society be able to sustain itself without the supporting, provisioning, regulating, and cultural services we draw from the natural world? Could we hope to engineer man-made systems that replicate natural processes like air and water purification, crop pollination, aquifer recharge, fisheries, climate and flood regulation, erosion control, seed dispersal, carbon storage, and soil fertilization and renewal? Economists and conservationists are now working together to build models that document, estimate, and assess how changes in natural ecosystem services affect not only environmental conditions of our environment, but also our ability to continue to obtain these goods and services now and into the future. Placing an economic value on these services can help reveal the connections between actions taken by people (whether individually and collectively) and the impact of our actions on those things upon which we fundamentally depend. As we progress through our beta phase, we look forward to sharing examples of how approaches to this promising new area of applied research is changing both the perceptions and the reality of the value of land conservation. Further Reading: Ecological Society of America: Ecosystem Services Fact Sheet; Defenders of Wildlife - Conservation Economics Program; The World Resources Institute: Valuing ecosystem services; The Rand Corporation: Nature's Services; The Millennium Ecosystem Assessment; U.S. Environmental Protection Agency - Ecosystem Services Research Program; Gund Institute for Ecological Economics at the University of Vermont; Gretchen C. Daily and Katherine Ellison, "The New Economy of Nature," Orion Magazine, Spring 2002.



Partnership Development

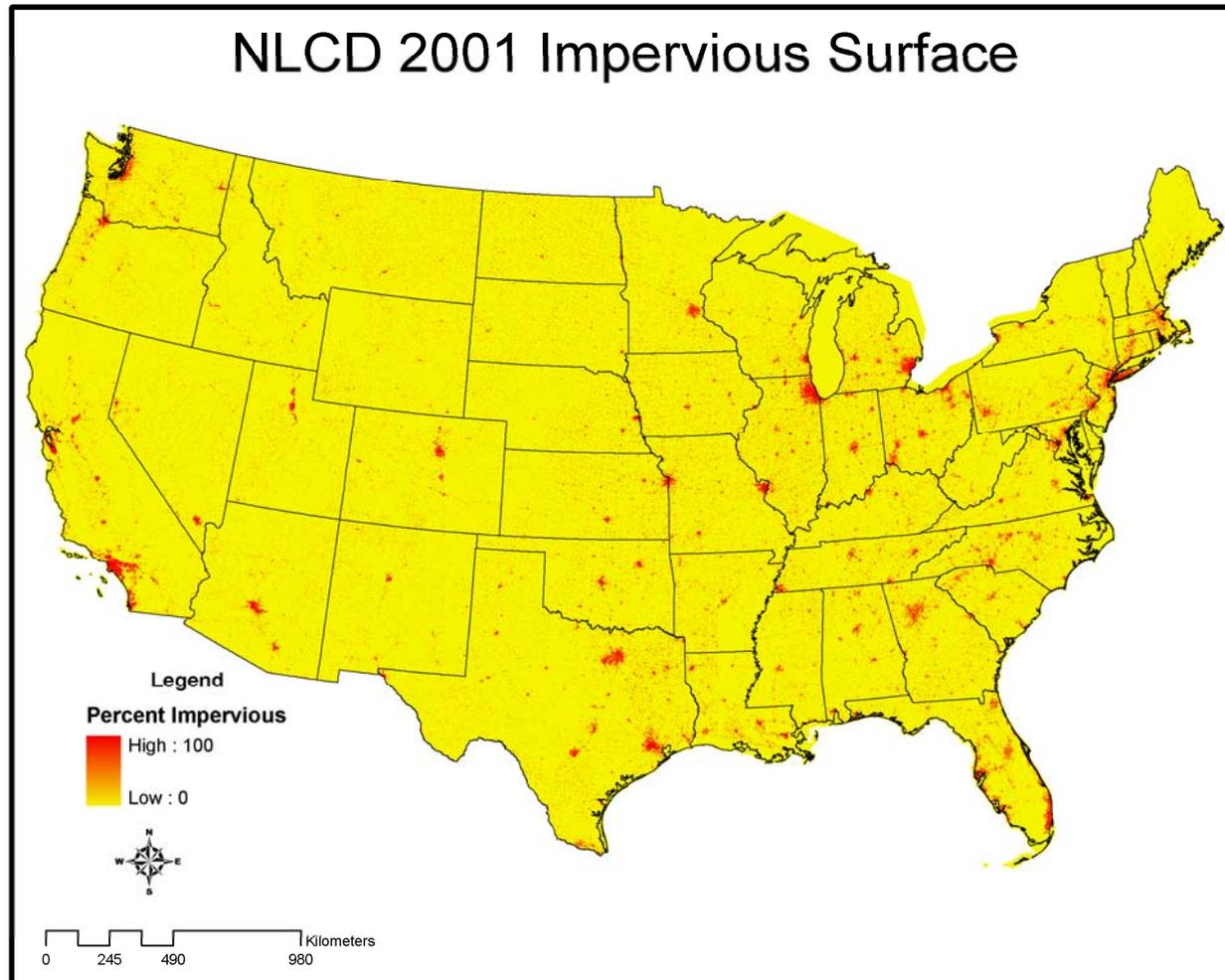
Vision of a National Atlas of Ecosystem Services Consortium

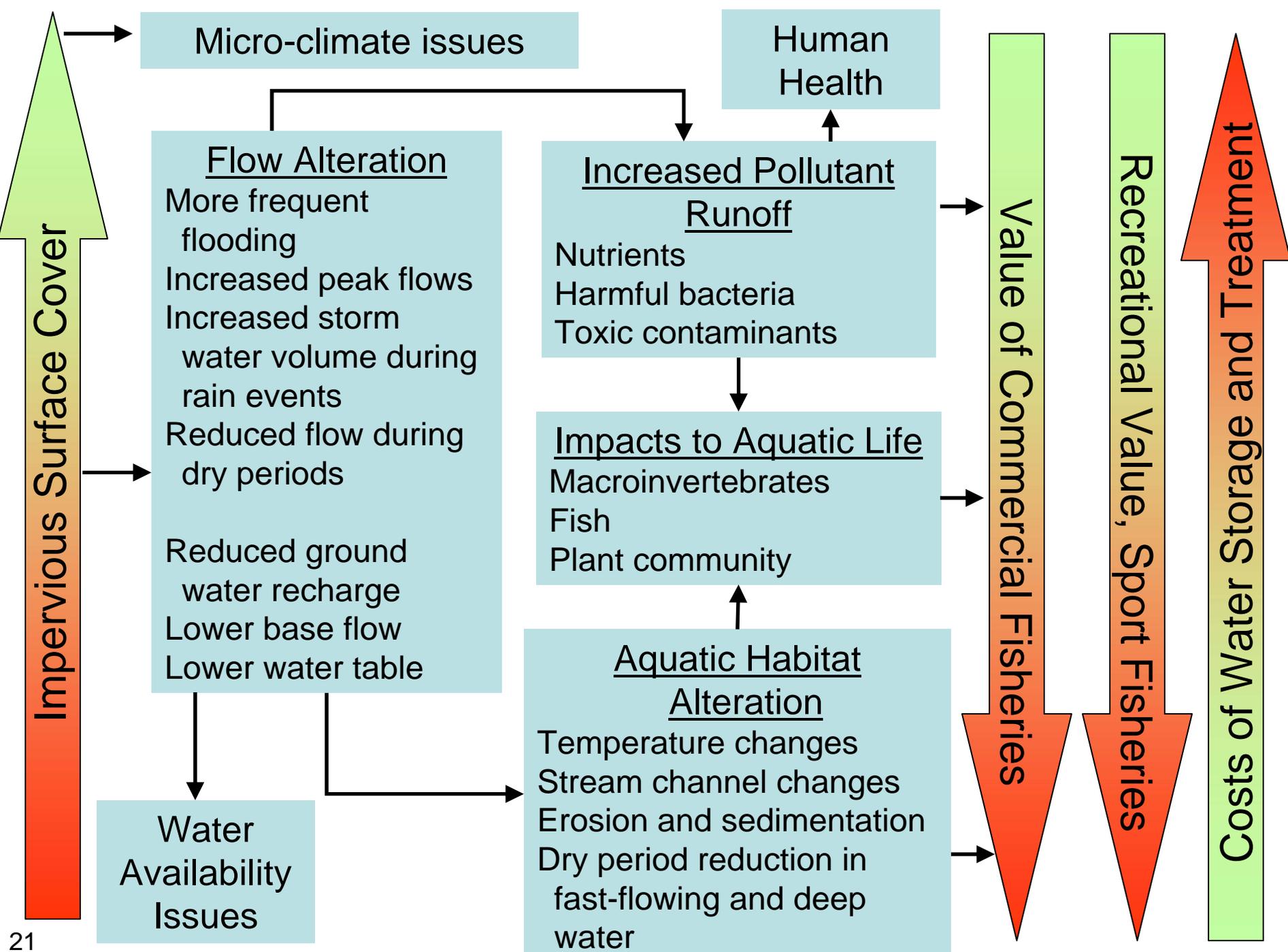
**National Geographic, Frank Biasi
NatureServe, Kyle Kopas
GAP, USGS, Kevin Gergely
USGS, Geography, Roger Sayre
USGS, EROS Data Center
USGS SPARROW Group
USDA, USFS, David Nowak
USDA, USFS, David Wear
USDA, NASS, Rick Mueller
USDA, FSA, Rich Iovanna
Natural Capital Project
NRCS, Sharon Waltman
NCEAS
NOAA CREST**

**CUNY Environmental Cross-Roads Initiative
Iowa State University
UC Santa Barbara, Bren School of the Env.
University of Maryland
Duke University
Arizona State University
Rutgers University
University of Kiel**

Ecosystem Services Indicators Calculation

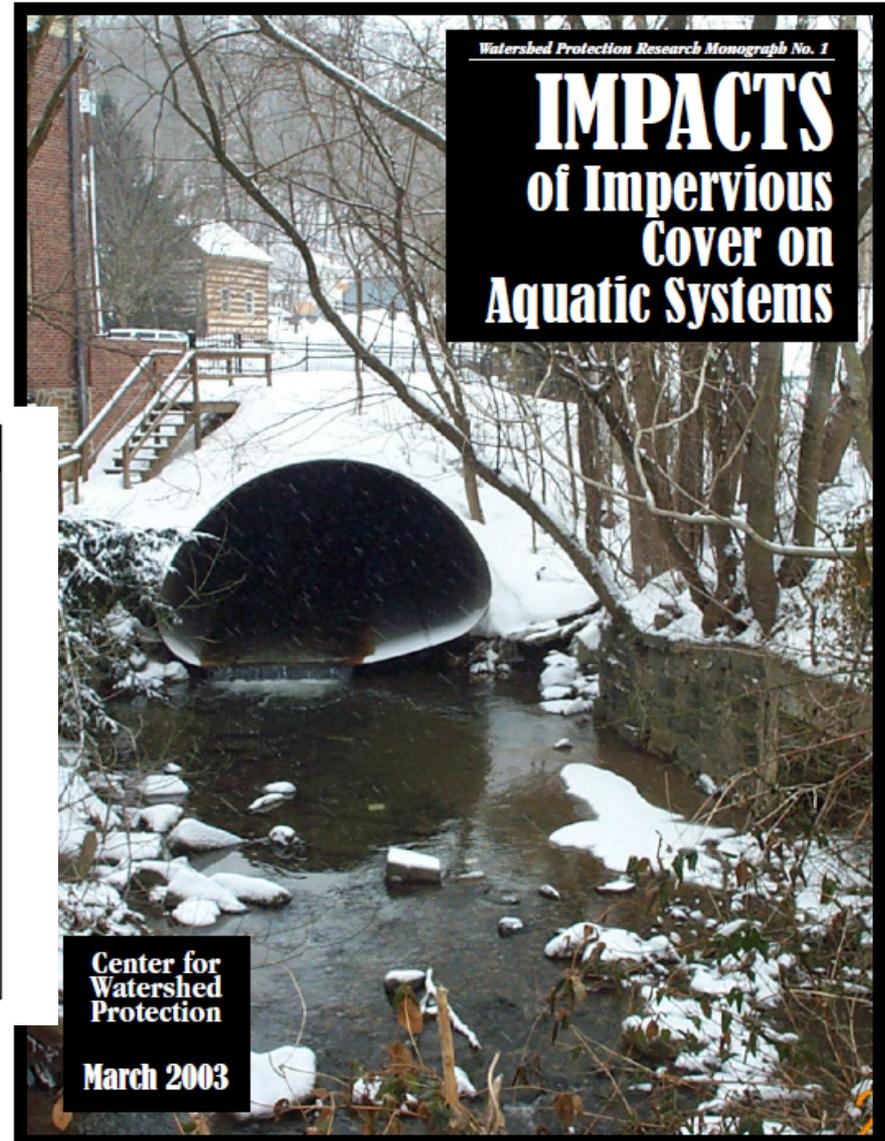
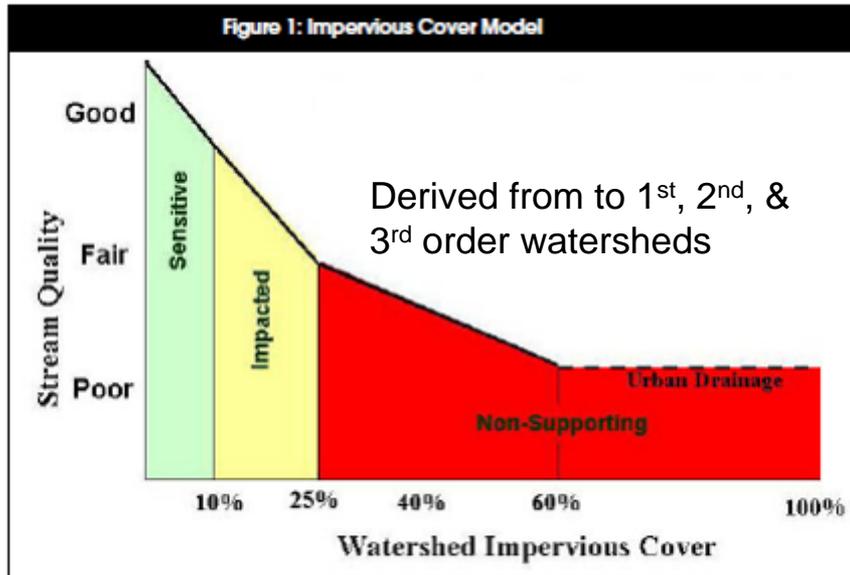
Ecosystems
Services
Indicators
Calculation

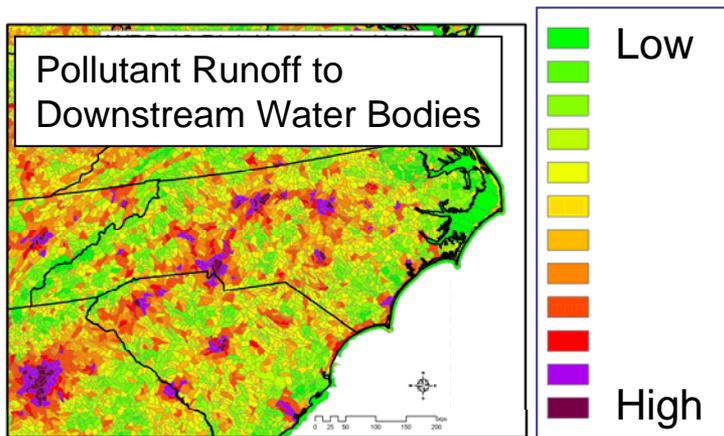
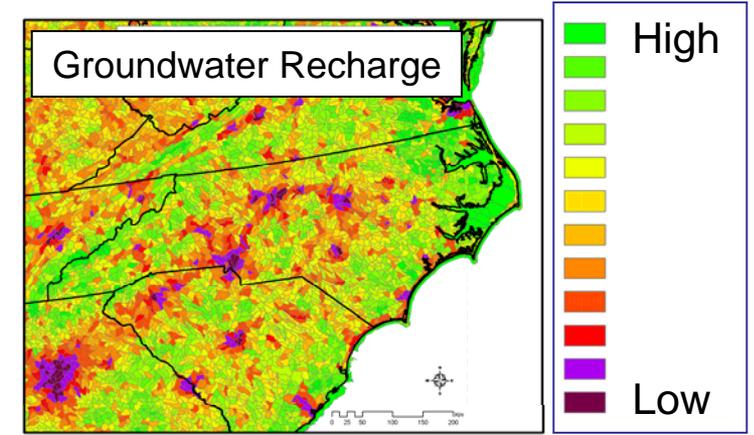
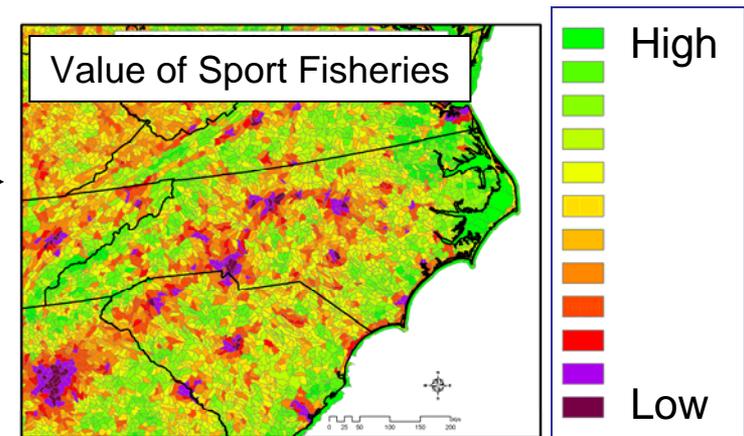
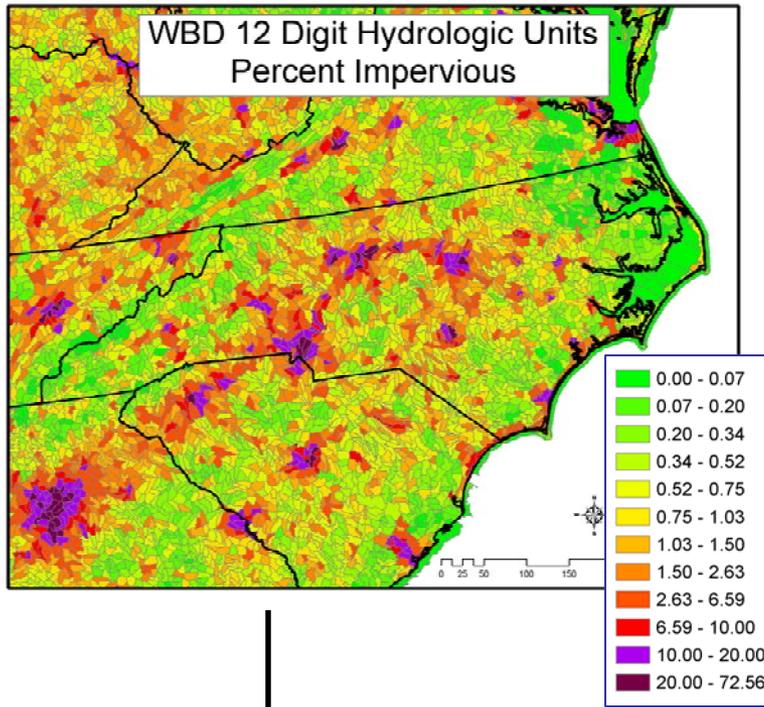




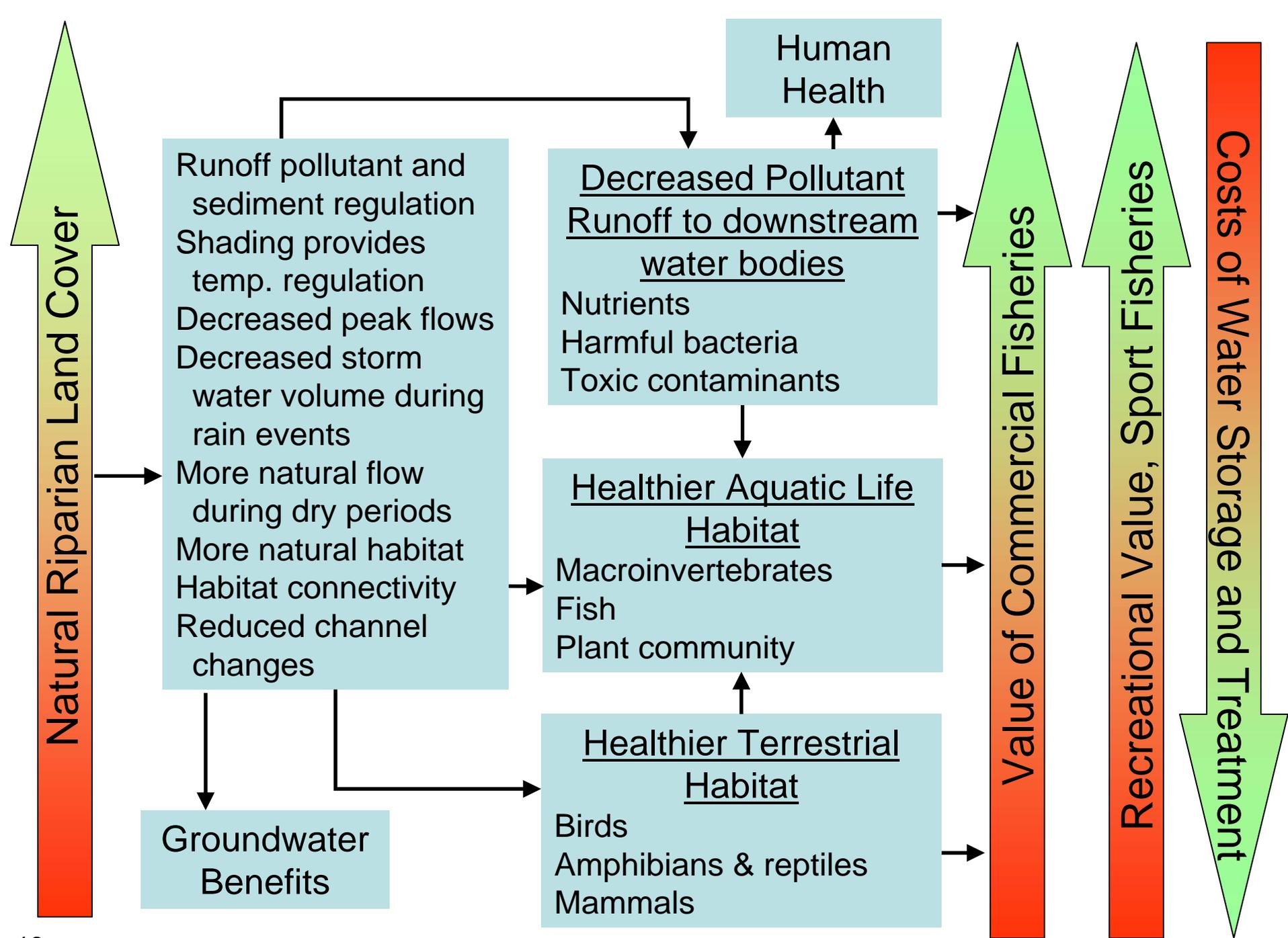
Landmark document published by Center for Watershed Protection in 2003

Reviewed and summarized 225 articles relating **impervious cover** to changes in hydrologic, physical, water quality or biological indicators of stream health

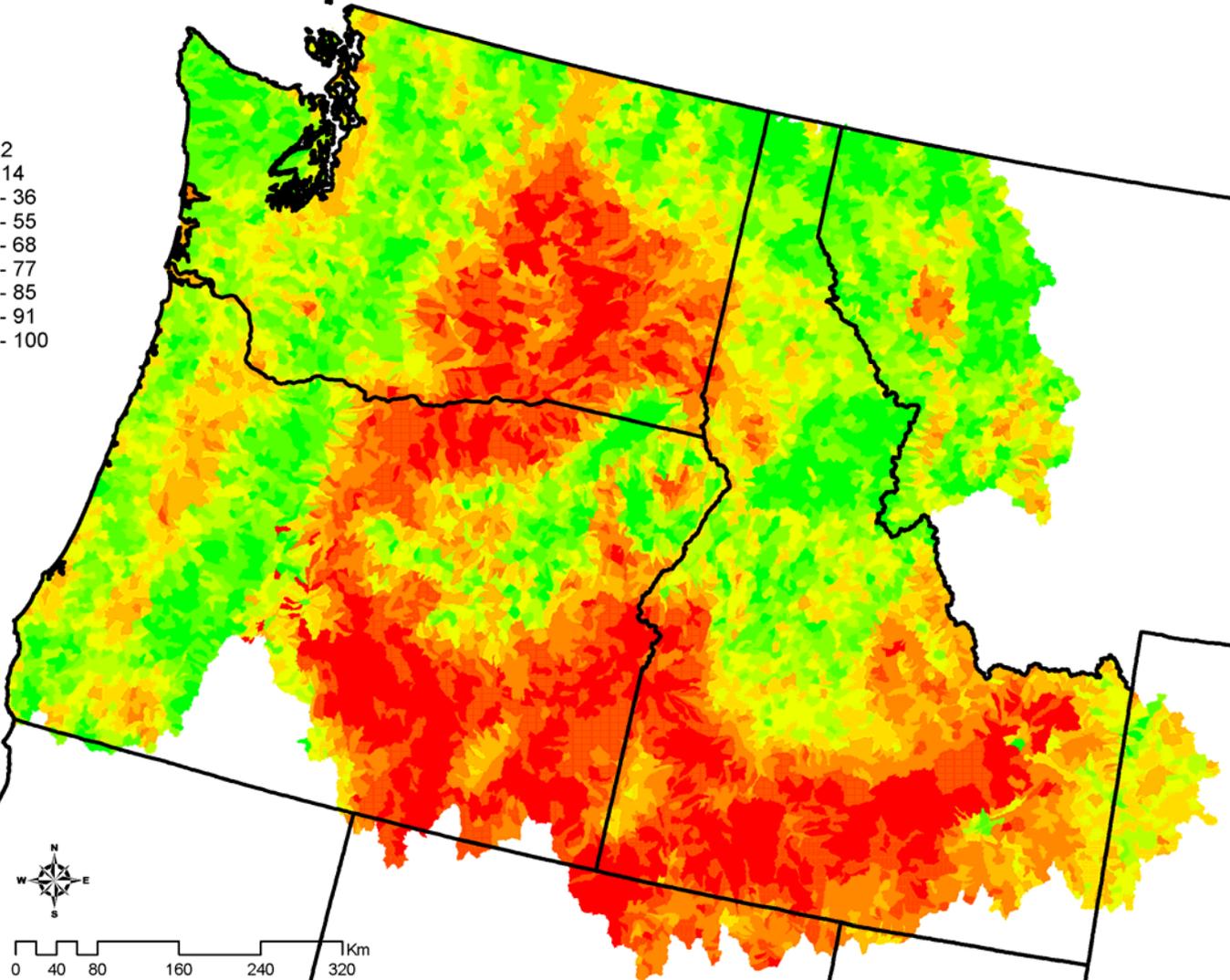
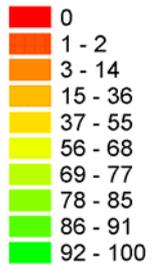




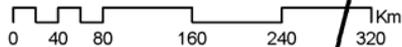
- Mock-up: Actual values for services will vary depending on biogeophysical settings (e.g., Omernik's Ecoregions)



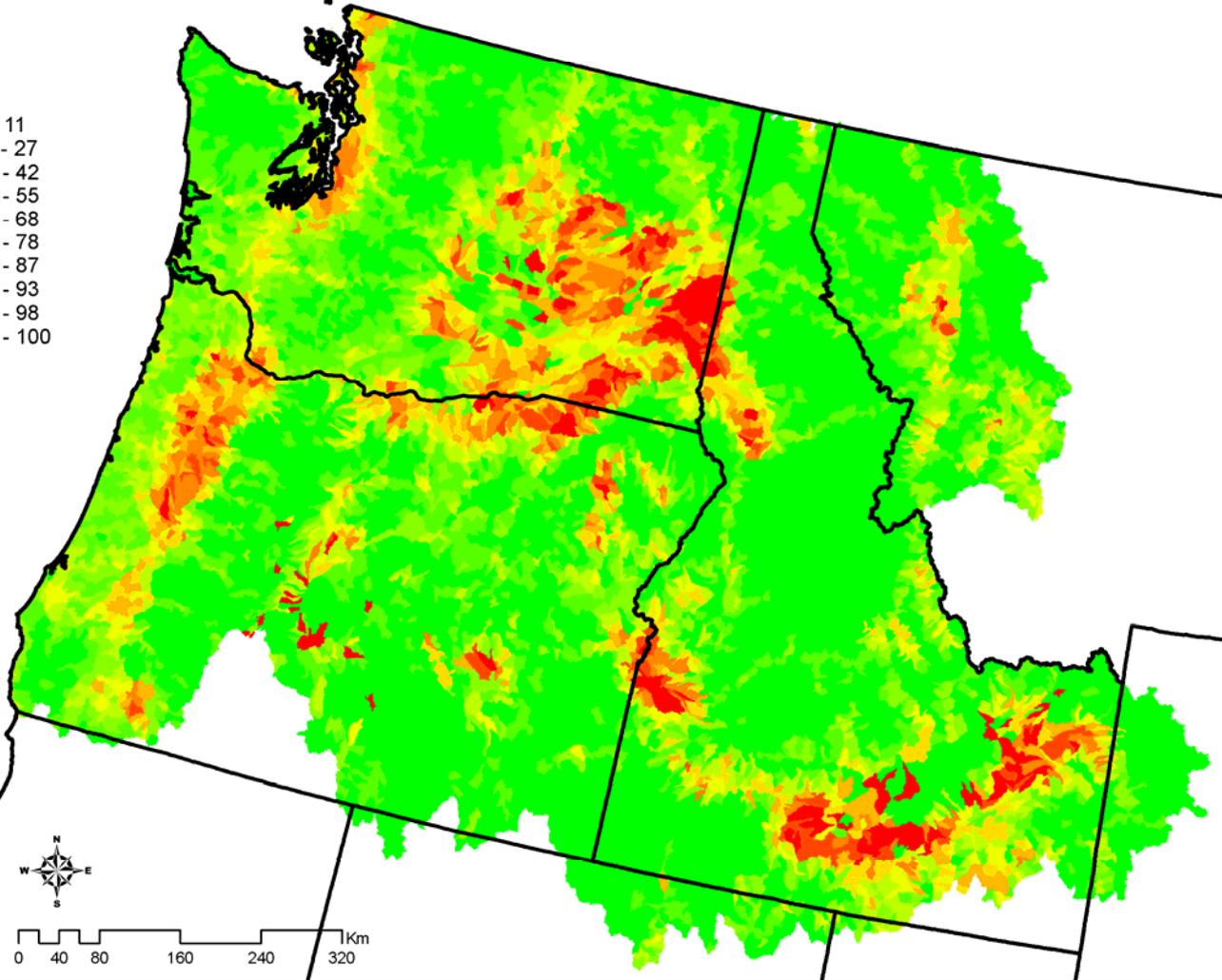
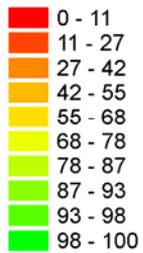
Percentage of Riparian Area that is Forested



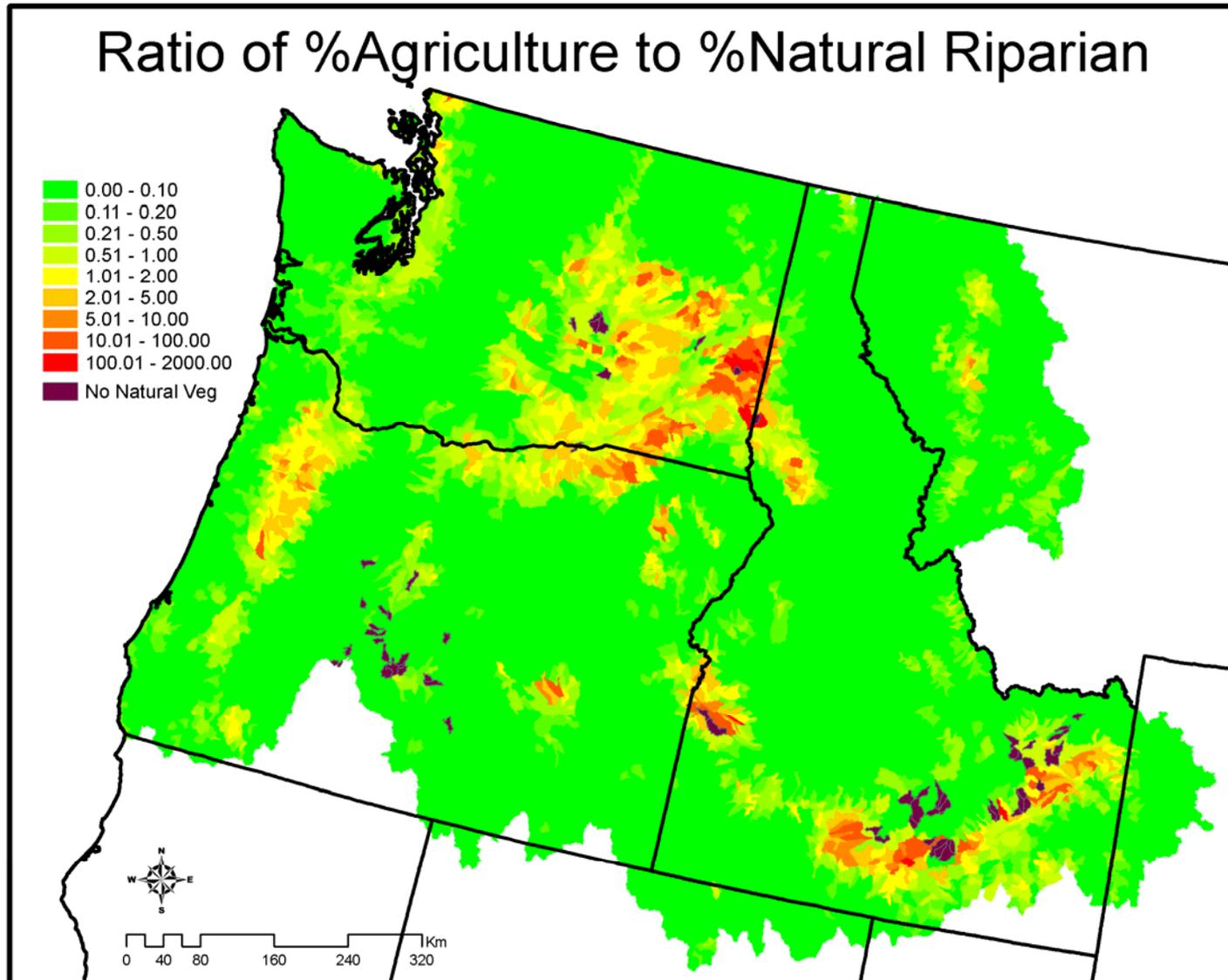
30 m
buffer
size



Percentage of Riparian Area that is Natural



General indicator for multiple ecosystem services



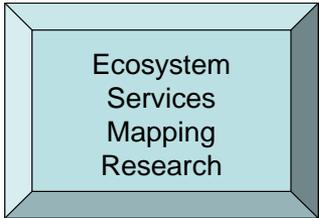


Development Of National Data Sets Key To Mapping Ecosystem Services

- Soils Data – 30 m grids of soils variables for nation, joint effort EPA, NRCS, USGS
- 2009 Cropland Data Layer, 56 m grid of crop type for nation, joint effort, EPA, NASS
- Wetlands Data Layer, Joint venture with USGS EROS Data Center to attempt to develop an enhanced wetlands data layer for nation using predictive variable(s) to improve satellite-based remote sensing data classification accuracy:
 - Identified wetland locations/types (e.g., NWI)
 - Soil type (e.g., hydric soils)
 - Soil moisture
 - Topography (i.e., DEM-based)
 - Climate
 - Vegetation type (e.g., GAP, LANDFIRE)
 - Indices (e.g., Topographic Wetness Index)

Ecosystem Services Mapping Research -- Nutrient Attenuation

- Joint goal of the *nitrogen group* and the *mapping group* to map nutrient attenuation by the landscape nationally.
 - John Harrison's work on nitrogen attenuation by lakes and reservoirs
 - Brian Hill's (and several others) work on nitrogen attenuation by streams, incorporating role of headwater streams
 - Developing new metrics/models to calculate nutrient removal by terrestrial components, e.g., wetlands, buffer strips, stream buffers



Ecosystem
Services
Mapping
Research

In 2005, Paul Mayer, Steven Reynolds, Jr. & Tim Canfield conducted an extensive literature review

- Soils
- Vegetation type
- Surface and subsurface benefits

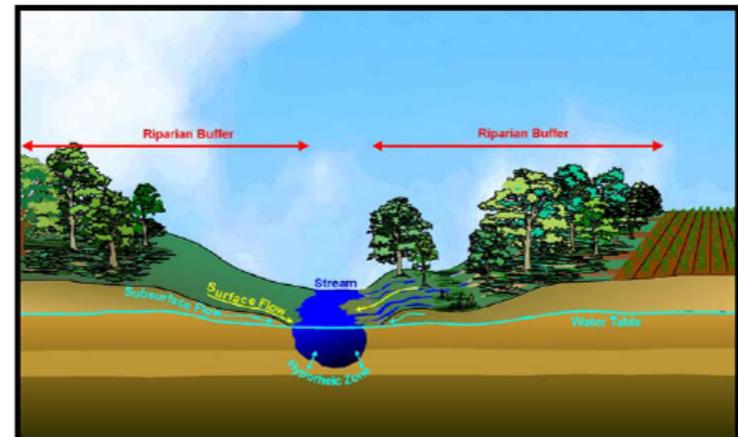
Followed by paper in Journal of Environmental Quality in 2007 by Mayer et al.

Working with Paul Mayer and others to modify and use this effort in mapping nitrogen removal

Steve Jordan is undertaking similar review for nutrient attenuation by wetlands

Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness:

A Review of Current Science and Regulations



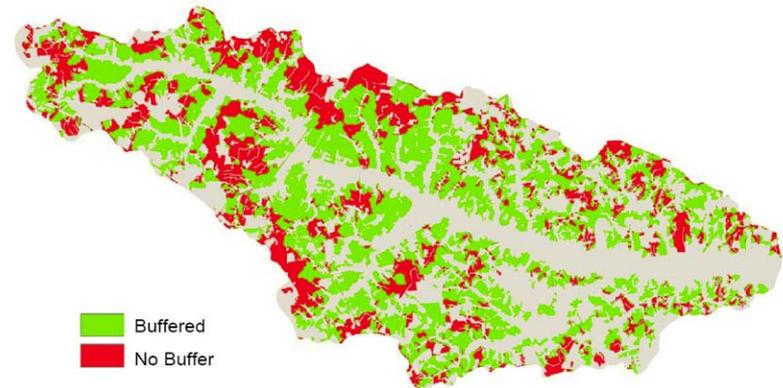
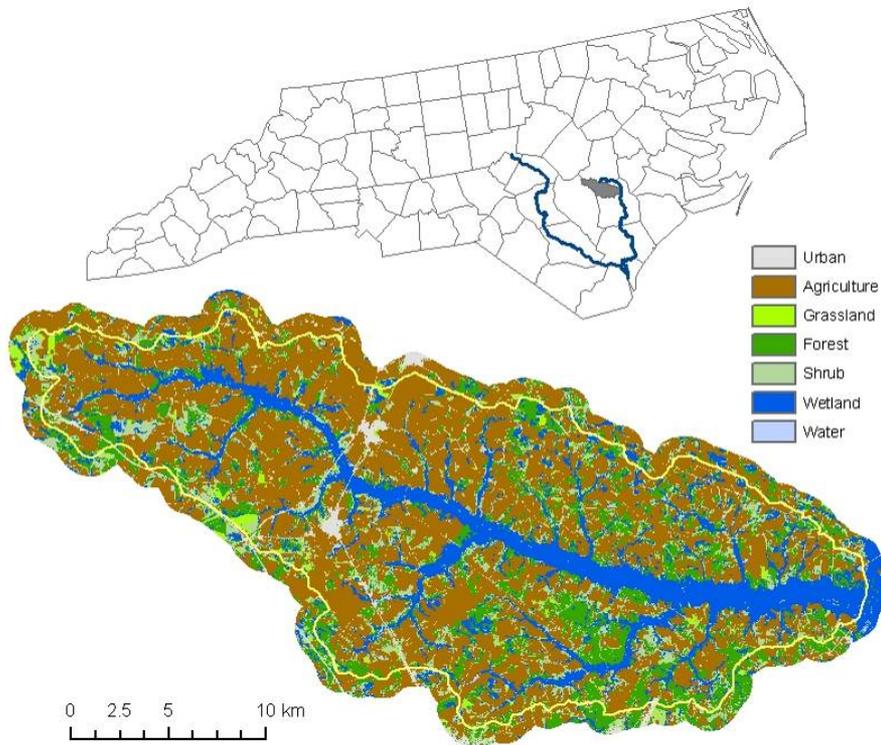
Developing New Metrics to Help Characterize Nutrient Attenuation/Removal by Riparian Buffers

Jay Christensen, Ric Lopez, Annie Neale – Landscape Ecology Branch, ESD

- Metric connecting riparian vegetation to upland sources of nutrients
- Test metric's ability to predict reduced nutrient loads
- Develop landscape model to determine nitrogen removal by riparian buffers
- Test using data of different resolutions
- Possibly test in SPARROW SE model
- Tie this work back to Mayer et al. literature review



Water Quality -- Nutrient Attenuation/Removal by Riparian Buffers Goshen Swamp Tributary of NE Cape Fear River



67 % of Ag buffered
33 % not buffered

Water Quality -- Nutrient Attenuation/Removal by Riparian Buffers

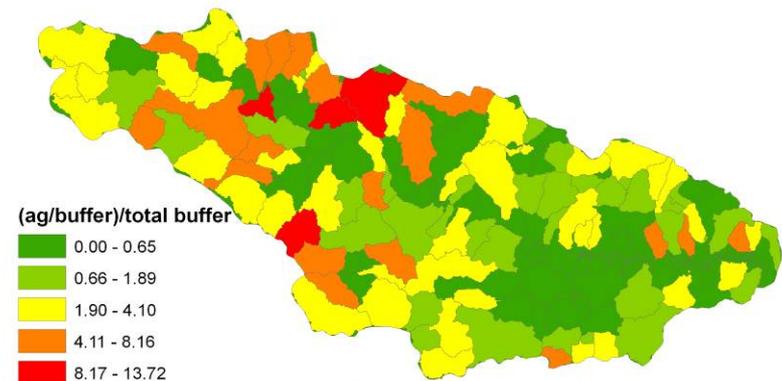
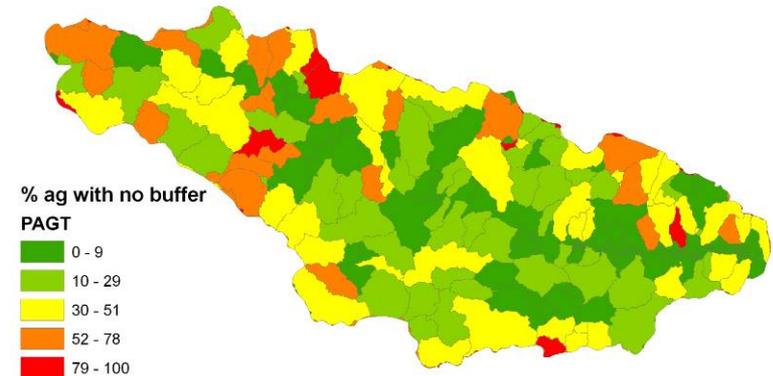
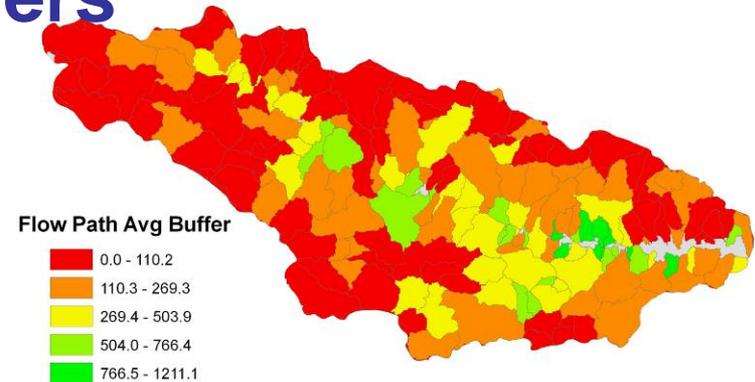
Riparian metrics being tested

- Average Flow Path Buffer Width from Ag Cells (m)

Based on Baker et al 2006

- % Ag draining to stream without passing through naturally vegetated buffer

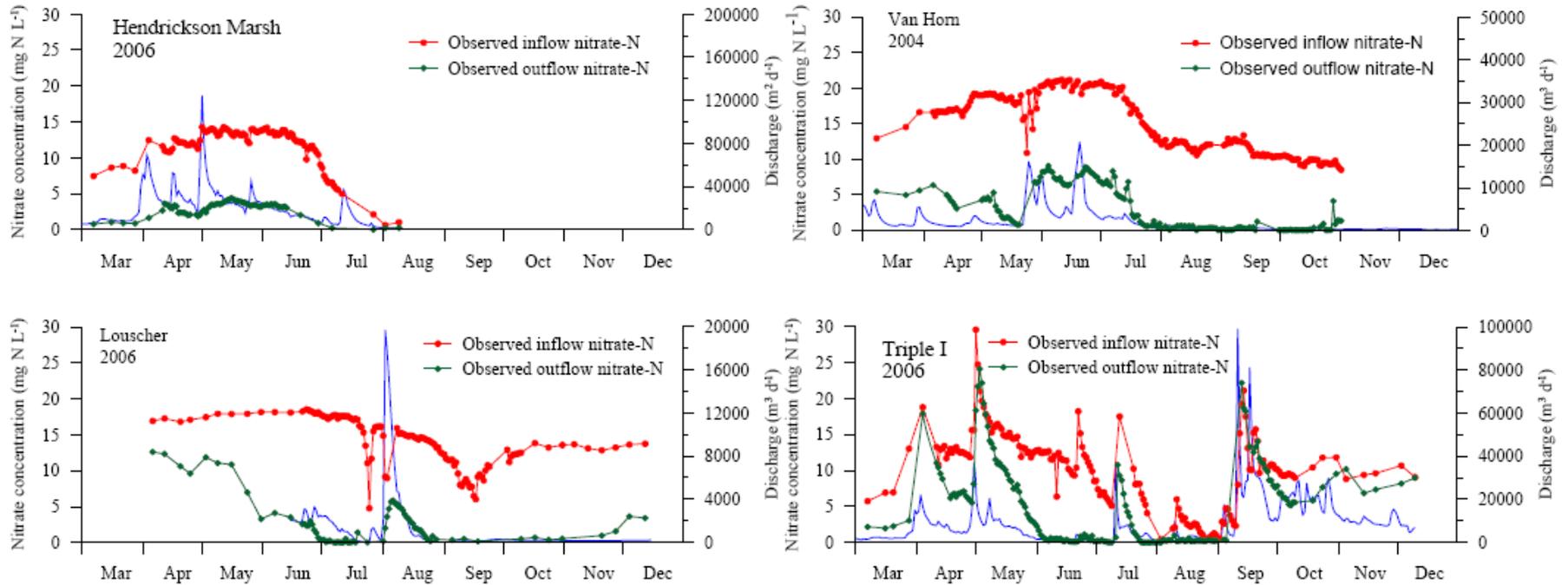
- Sum of Ag/Buffer Ratio / total buffer length



Jay Christensen

Benefits of Constructed Wetland Filters for Tile Drained Systems

0.5% - 2% wetland/watershed area ratio



Their results suggest that a 30% reduction in nitrate load from the UMR and Ohio River basins could be achieved using 210,000-450,000 ha of constructed wetlands

Potential Benefits of Wetland Filters for Tile Drainage Systems: Impact on Nitrate Loads to Mississippi River Sub-basins

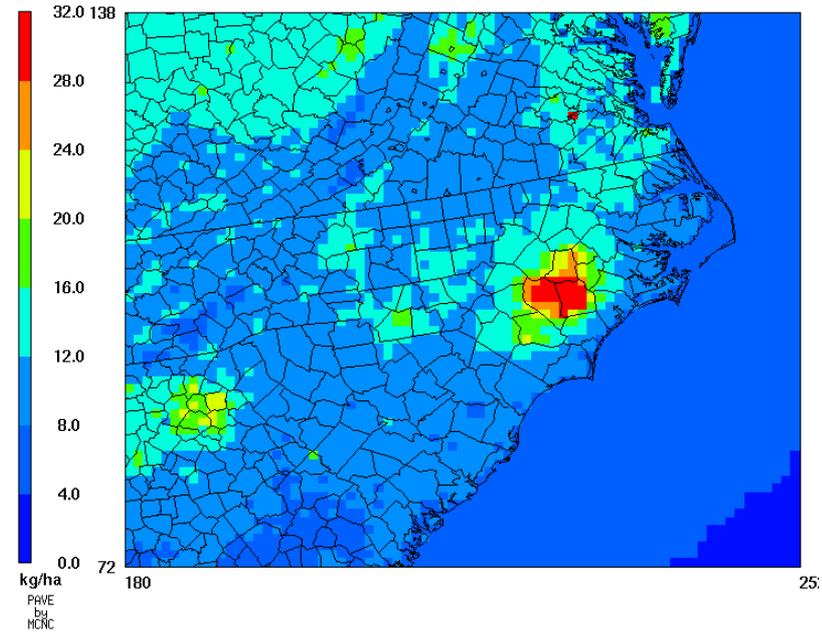
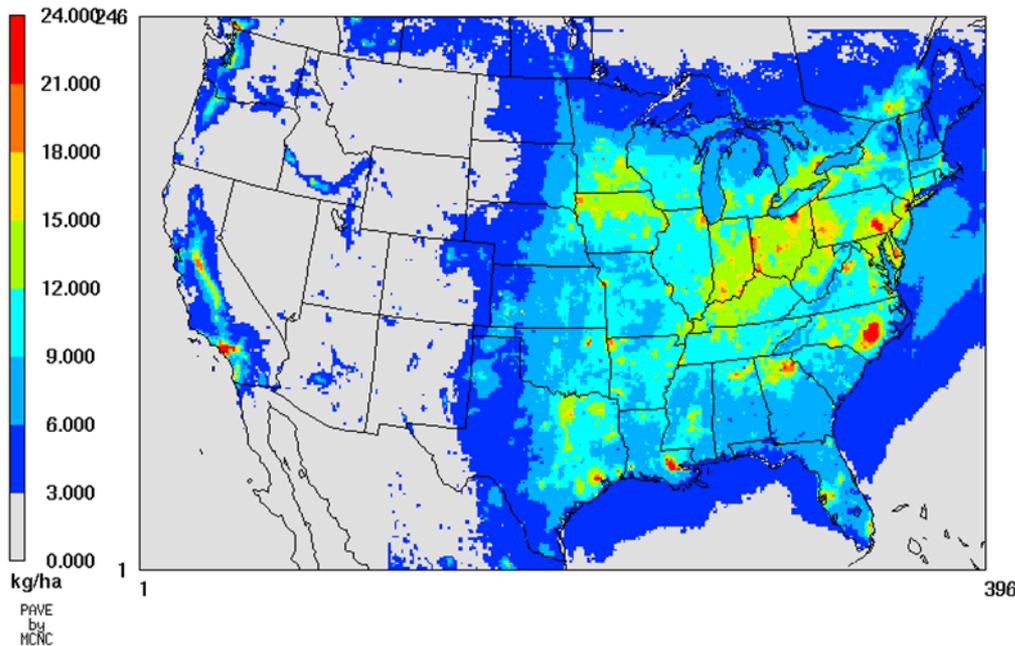
U.S. Department of Agriculture

*Crumpton, W. G., G. A. Stenback, B. A. Miller, and M. J. Helmers

Nutrient Loads

- Joint goal of the nitrogen group and the mapping group to map nutrient loads nationally.
 - Cropland data layer + fertilizer application rates
 - Land use export coefficients and event mean concentrations (e.g., EPA PLOAD Users Manual, USDA MANAGE Data Base,)
 - Developing a CAFO coverage for nation
 - WWTP coverage for nation
 - GlobalNews Model, SPARROW, GWLF, WARMF
 - Atmospheric deposition -- CMAQ

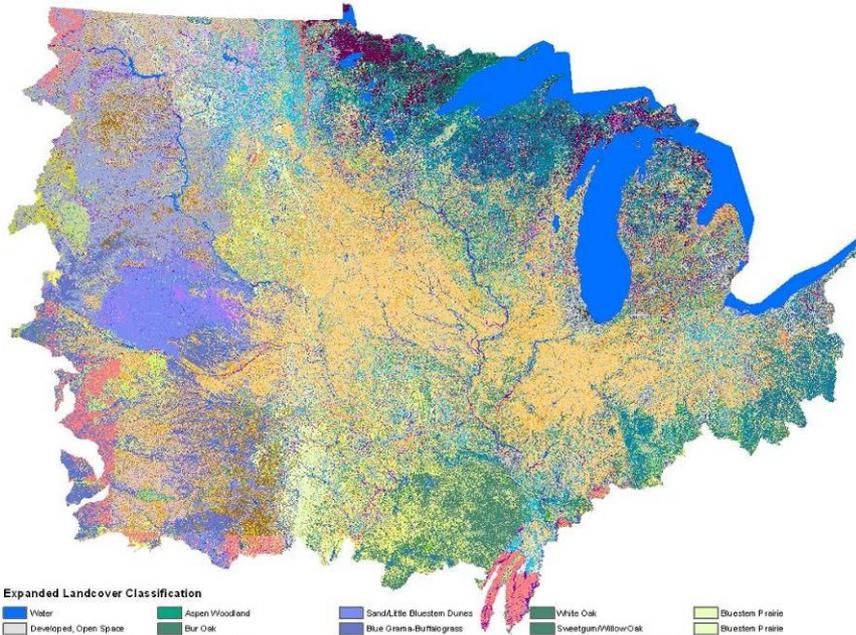
Annual Total Deposition of Nitrogen (kg-N/ha) Community Multiscale Air Quality (CMAQ) model



Models multiple air quality issues including nitrogen
 Uses modeled meteorology data and 2002 National Emissions Inventory data
 Outputs concentrations and deposition on an hourly basis.
 Outputs data on a 12 X 12 Km² or 36 X 36 Km² grid cell basis.
 Watershed Deposition Tool outputs to 8 or 12-digit HUC

Fertilizer Application

Megan Mehaffey – Landscape Ecology Branch, ESD



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

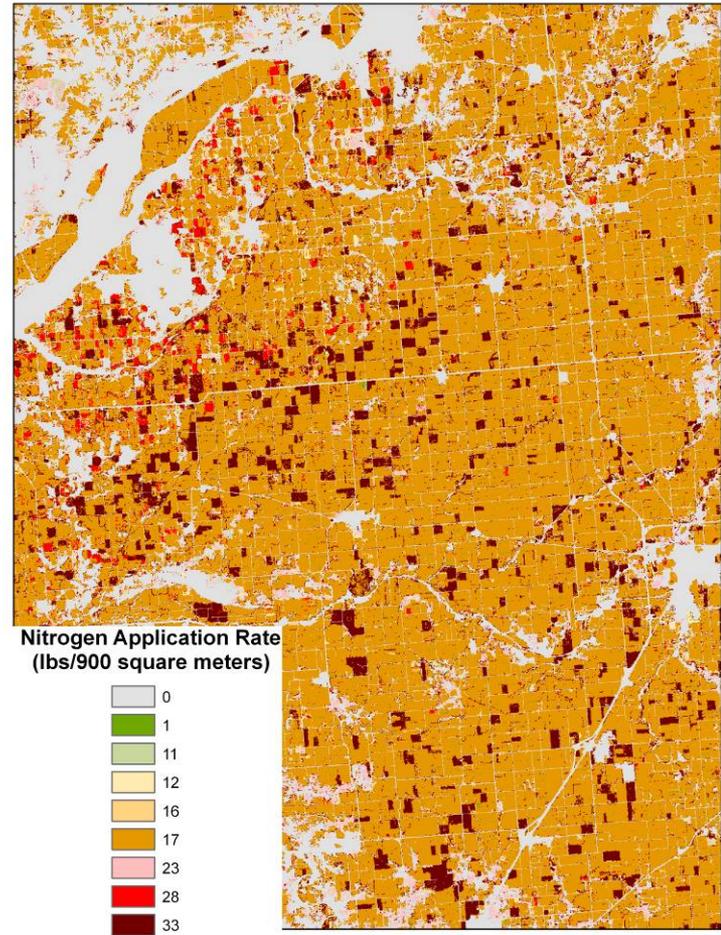
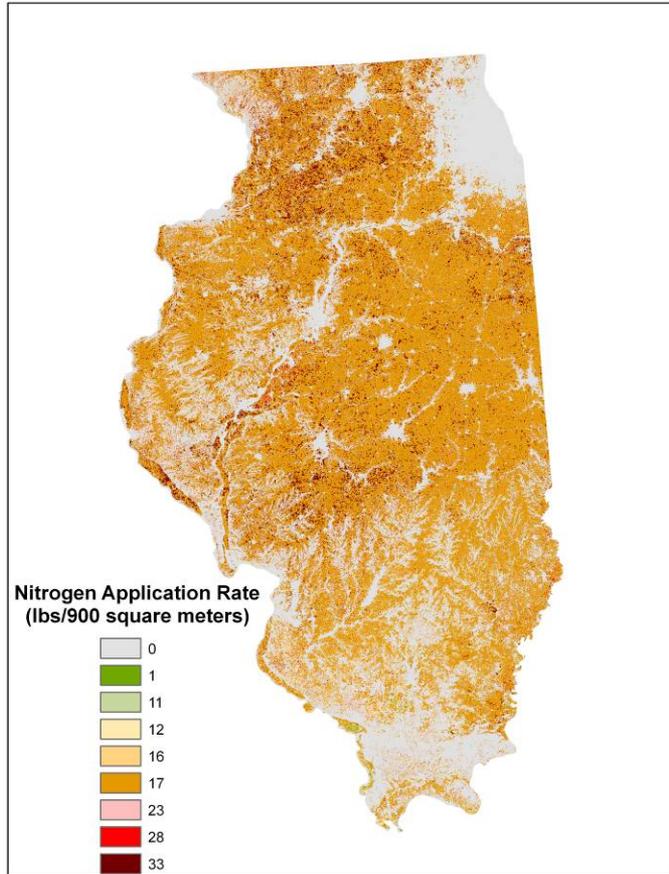
Megan Mehaffey

Expanded Landcover Classification

Water	Aspen Woodland	Sand/Little Bluestem Dunes	White Oak	Bluestem Prairie
Developed, Open Space	Bur Oak	Blue Grama/Buffalograss	Sweetgum/Willow Oak	Bluestem Prairie
Developed, Low Intensity	White Bark Pine	Bluestem Prairie	Yellow/Poplar/White/Red Oak	Bluestem Prairie
Developed, Medium Intensity	White Spruce	Saltbrush-Oreosewood	Deadkuon Flatwood	Little Bluestem/Indiangrass/Wintergrass
Developed, High Intensity	Lumber Pine	Riparian Woodland	White Oak	Black Ash/Elm/Red Maple
Barren Land	Lodgepole Pine	Cottonwood/Willow	Swamp Chestnut/Cherrybark Oak	Willow/Water/Dian onleaf Oak
Undefined Deciduous Forest	Douglas Fir	Riparian	Live Oak	Jack Pine Swale
Undefined Evergreen Forest	Ponderosa Pine	Riparian	Aspen	Great Plains Riparian
Undefined Mixed Forest	Spruce Sup/Alpine Fir	Douglas Fir	White/Black/Red Oak	Floodplain Riverbch/Sycamore
Undefined Shrub/Scrub	Bristlecone Pine	Shrubland	Grass/Shrub Dicks	Riparian Riverbch/Sycamore
Undefined Grassland/Herb...	Juniper-Pinyon Pine	Ponderosa Pine	Jack Pine	Floodplain Sweetgum/W/lowOak
Undefined Pasture Hay	Aspen	Introduced Woody Wetland	Longleaf Pine	Floodplain Sweetgum/W/lowOak
Undefined Crop	Red Alder	Introduced Upland Herbaceous	Virginia Pine	Floodplain Black Ash/Elm/Maple
Undefined Woody/Wetland	Black Sagebrush	Introduced Upland Herbaceous	Willow/Water/Dian onleaf Oak	Black Spruce/Tamarack/Peatland
Undefined Herbaceous Wetland	Saltbrush-Oreosewood	Introduced Upland Herbaceous	Red Pine	Swamp Riverbch/Sycamore
Monsicature Corn	Black Sagebrush	Introduced Herbaceous Wetland Riparian	Missouri Glades	Coastal Plain Swamp
Monsicature Soybean	Big Sagebrush	Introduced Upland Tree	Post/Blackjack Oak	Black Ash/Elm/Maple Swamp-Dog
Monsicature Wheat	Salt Desert Shrub	Recently Logged	Balsam Fir	Prairie Pothole Wetland
Monsicature Cotton	Sagebrush/Grass	Recently Logged	Heenock Yellow Birch	Viet Meadow/Prairie Marsh
Corn/Soy	Chokecherry-Serviceberry Rose	Ruderal Forest	Shortleaf Pine/Oak	Coastal Herbaceous Marsh
Corn/Wheat	Sand Sage Prairie	Sand Shinnery Oak	Chestnut Oak	Appel Shrub/Herbaceous Wetland
Corn/Other	Chokecherry-Sorckerry Rose	Big Sagebrush	Sugar Maple/Beech	Laurentian-Acadian Herbaceous/Wetland
Corn/Fallow	Gambel Oak	Aspen	Loblolly Pine-Hardwood	Bluestem Depressional Wetland
Soybean/Wheat	Mesquite	Sugar Maple	Shortleaf Pine/Oak	Alkali Cactoon-Tobosa Grass
Soybean/Other	Ponderosa Pine	White/Black/Red Oak	Chestnut Oak	Alkali Cactoon-Tobosa Bottom land
Soybean/Fallow	Juniper-Pinyon Pine	White Oak	Post/Blackjack Oak	White Oak
Wheat/Other Crop	Big Sagebrush/Bluebunch/Wheatgrass	Oak	Deadkuon Shrubland	Shortleaf Pine/Oak
Wheat/Fallow	Big Sagebrush	Oak-Hickory	Bur Oak	Sweetgum/Willow Oak/River Flatwoods
Cotton/Other	Big Sagebrush	White/Black/Red Oak	Pin Oak	Black Oak Bluff/Grassland
Misc Grain/Fallow	Blue Gramma/Western Wheatgrass	Post/Blackjack Oak	Grass/Shrub Bald	Pinoak/Sweetgum/Wet Flatwood
Other Crop/Fallow	Ornan s/Mulry-Threeawn	White/Black/Red Oak	Glade	Ruderal Shrub/Forest
Alfalfa Hay	Ornan s/Oaletta	Black Oak	Red Pine	Ruderal Mixed Forest
Alfalfa Hay/Other	Rough Fescue-Idaho Fescue	Post/Blackjack Oak	White Cedar	Ruderal Mixed Forest
Fallow	Rough Fescue-Idaho Fescue	Sugar Maple/Beech/Yellow Birch	Lake Prairie	Managed Tree Plantation
Sparsely Vegetated	Wheatgrass-buzestem-Nelegrass	Sugar Maple/Baswood	Bluestem Prairie	Managed Tree Plantation
Sparsely Vegetated	Tall Forb	Chestnut Oak	Blugrass Savanna/Woodland	Introduced Wetland Vegetation
Sparsely Vegetated	Alpine Rangeland	Yellow Poplar/Honlock	Little Bluestem/Post Oak	Modified/Managed Tallgrass
Aspen Forest/Parkland	Bluestem Gramin Prairie	Sugar Maple/Beech	Karst Plain Prairie	Modified/Managed Tallgrass

Fertilizer Application

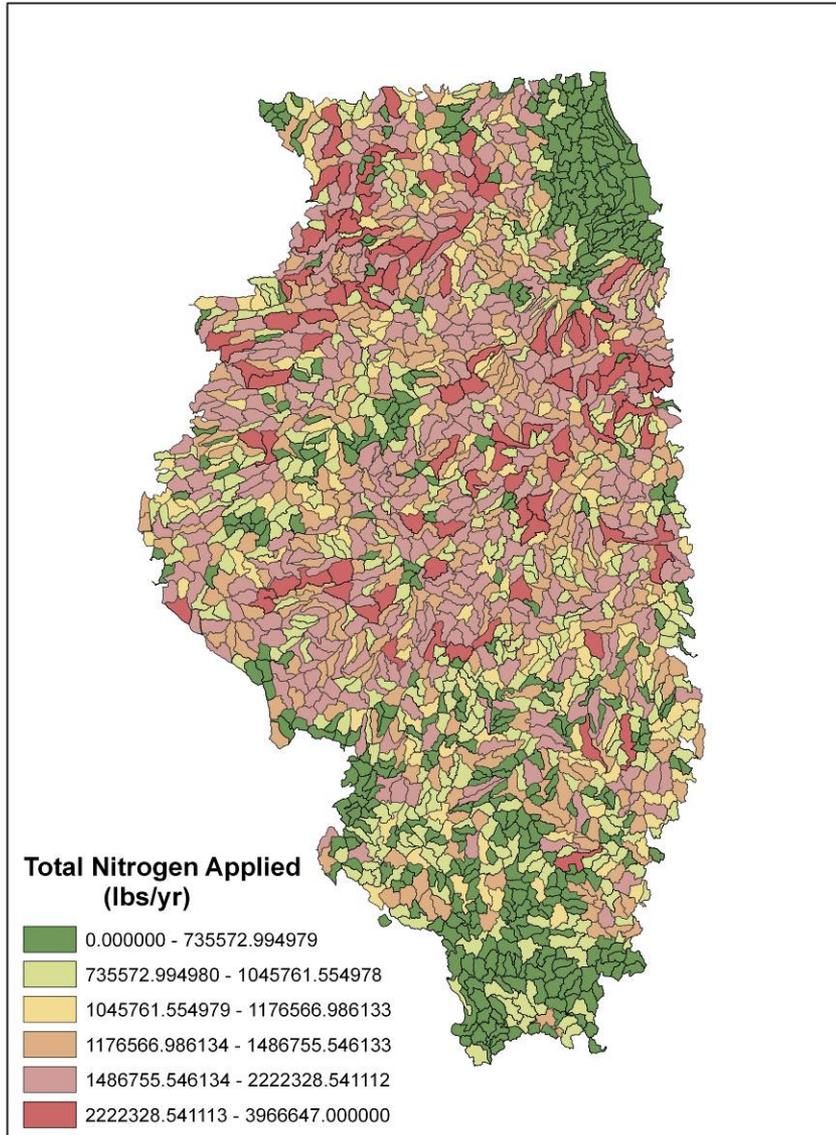
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crop type X fertilizer application rate

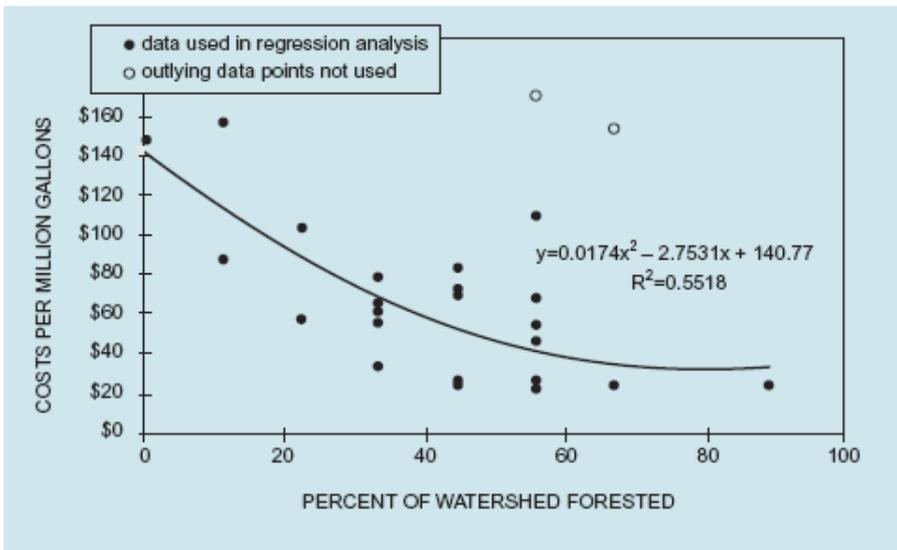
Fertilizer Application

Megan Mehaffey – Landscape Ecology Branch, ESD



Water Quality -- Drinking Water Sustainability

Jim Wickham, Tim Wade



Source: Ernst (2004)

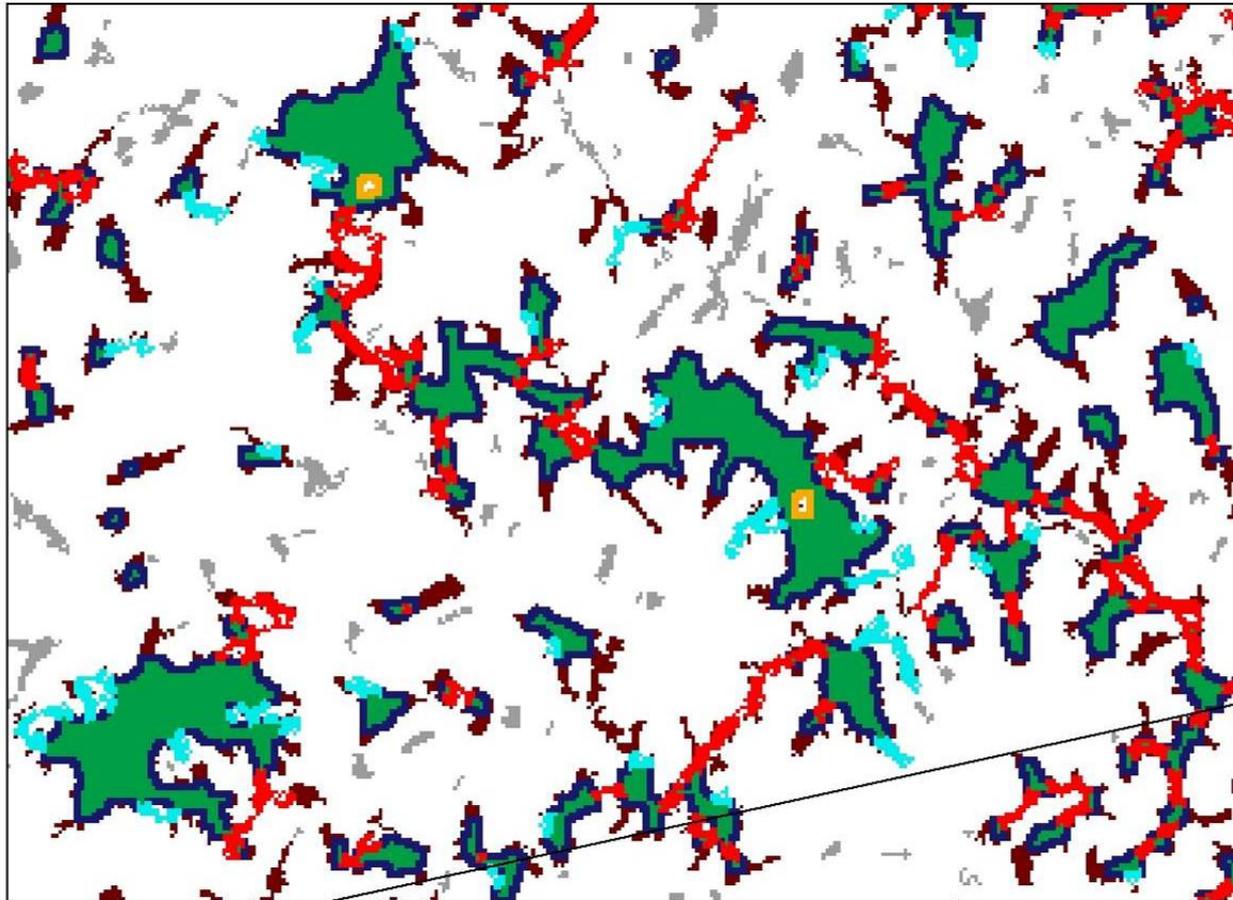
Finding: for every 10% loss of forest, treatment and chemical costs increased by 20%

- Acquired OW Drinking Water Source Water Intake points and wells for U.S. – Done
- Delineating watershed area contributing to those points – ~ 3500/6000 delineated
- Conduct landscape assessment of drinking water source areas
- Confidentiality issue
- Relate landscape metrics to intake water quality/degree of treatment required
- Relate to populations served & multiple benefits

Examples of Ongoing Atlas Work

Terrestrial Habitat -- Green Infrastructure Approach (i.e., Hubs and Corridors)

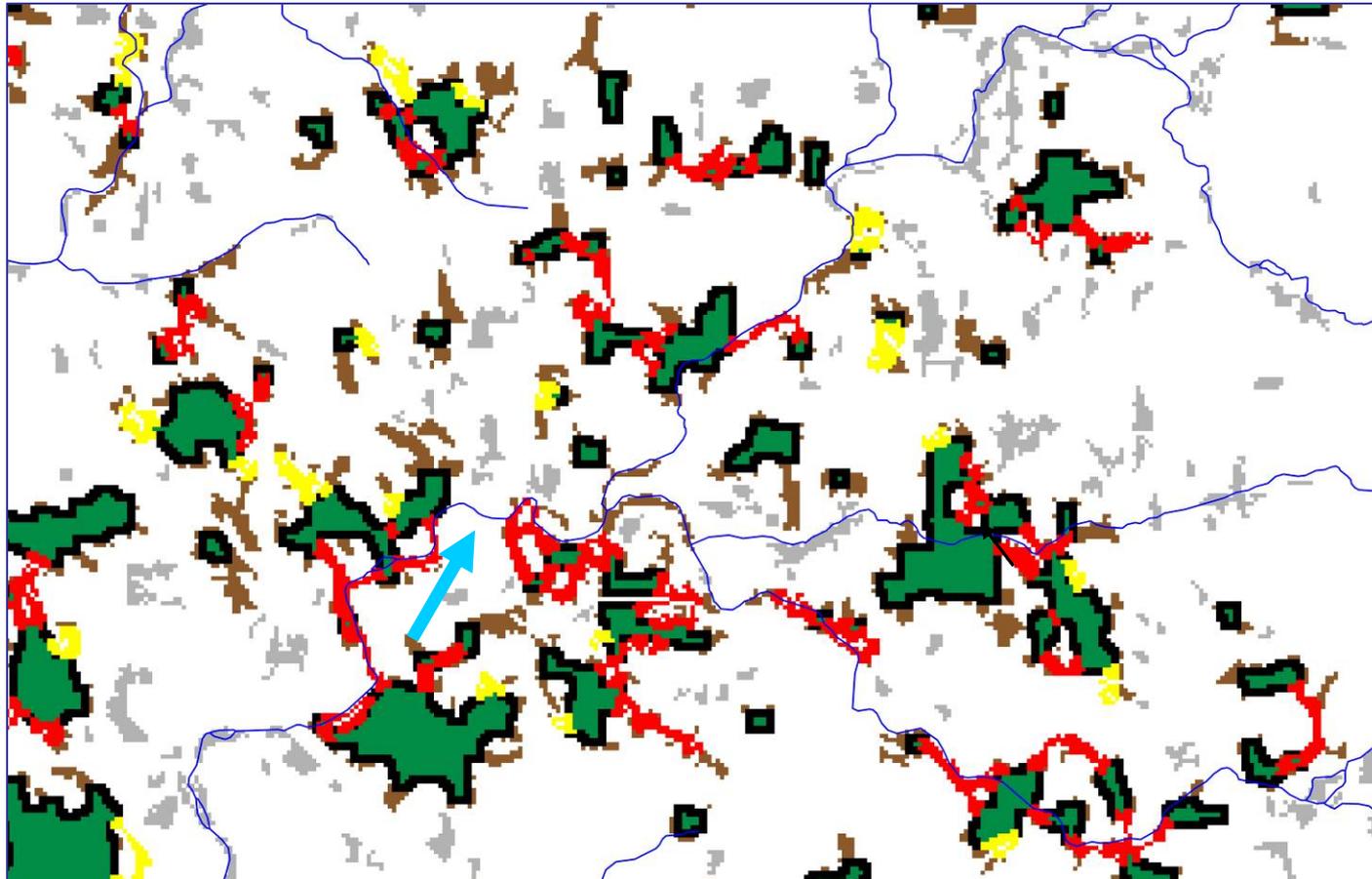
Jim Wickham, Tim Wade, Landscape Ecology Branch, ESD



- 7 green infrastructure classes mapped for entire US based on NLCD 30 m data
- Used NLCD forest and wetland classes only
- Identifies potentially important wildlife habitat
- Identifies areas for restoration/protection
- Will soon be included on LandScope web site

Branch Edge Islet Core Bridge Loop Perforation

Developed from: Vogt P, Riitters KH, Iwanoski M, et al. 2007. Mapping landscape corridors. Ecol. Indic. 7:481-488. <http://forest.jrc.ec.europa.eu/biodiversity/GUIDOS/>

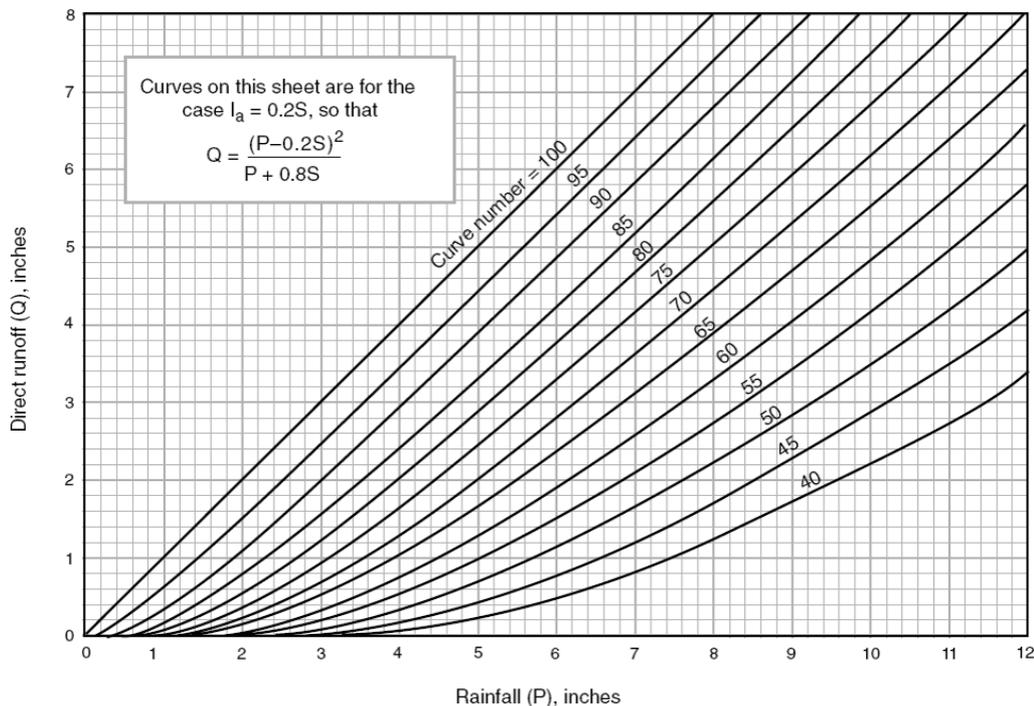


Can also add projected urban growth, impervious surface, etc.

Useful for land trusts in guiding land purchase

Examples of Ongoing Atlas Work Water Quantity, Timing, Groundwater Recharge -- SCS Curve Number Approach

Jim Wickham, Tim Wade, Landscape Ecology Branch, ESD

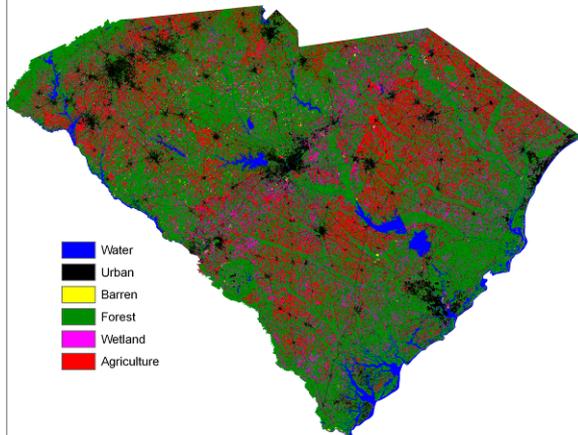


Generalized Curve Numbers				
	<u>Hydrologic Soil Group</u>			
LC Class	A	B	C	D
Imp. Surf	98	98	98	98
Cropland	64	75	85	89
Pasture	39	61	74	80
Forest	30	55	70	77
Pin-jun		41	61	71
Wetlands			0-100	

Where $S = \frac{1000}{CN} - 10$

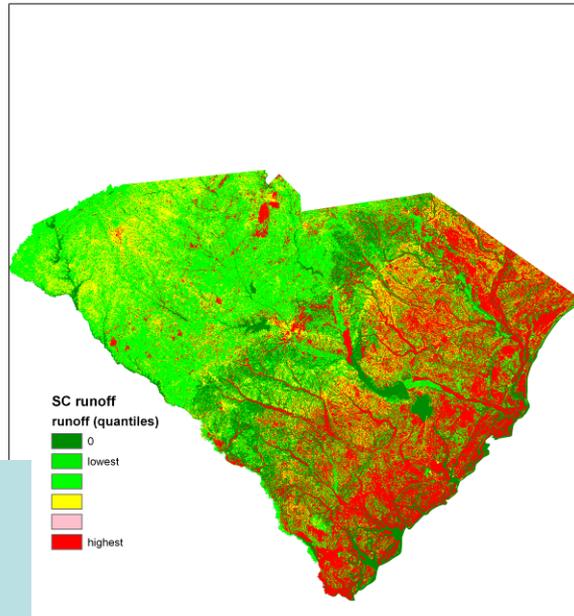
Water Yield using SCS Curve Number Approach

South Carolina Land Cover

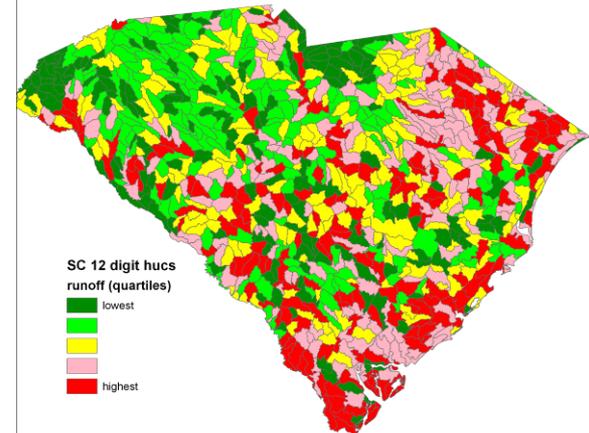


Calculations of CN based on NLCD land cover and SSURGO soils data

Discharge from 10 yr storm event (2 in) calculated for each 30 m pixel

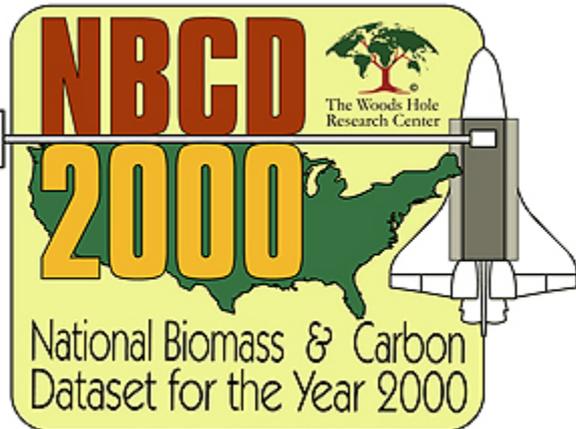
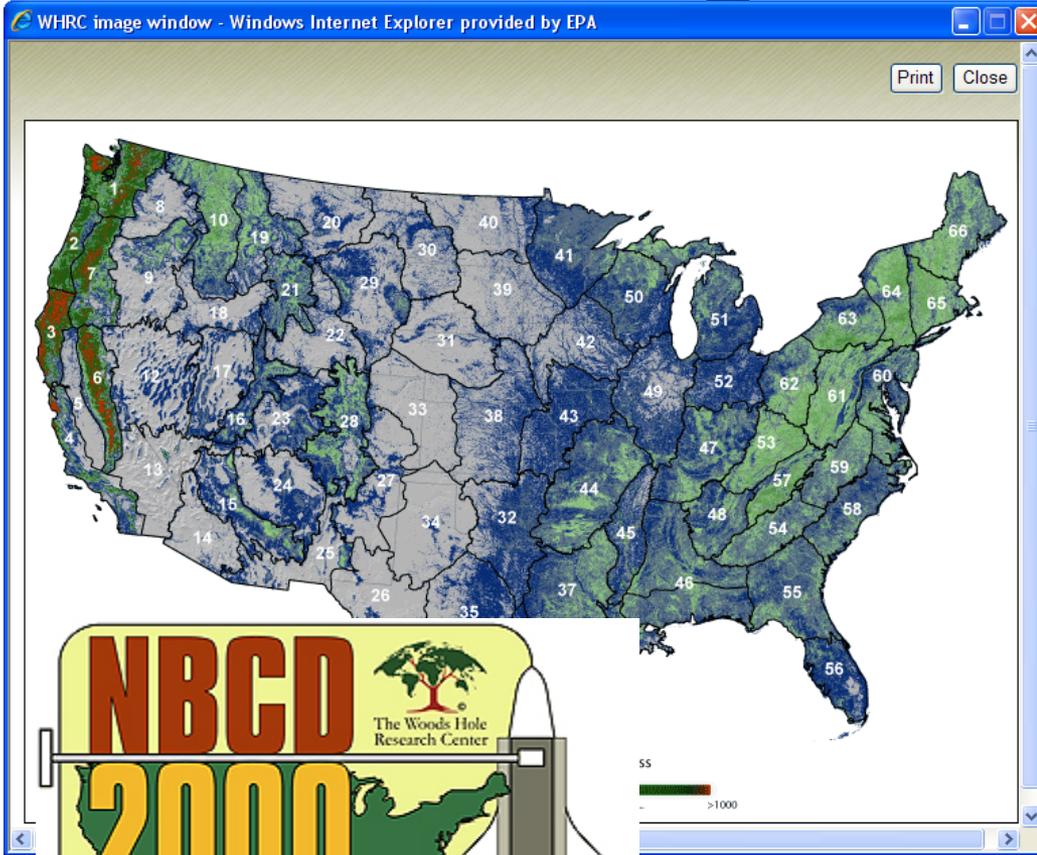


Discharge is routed from each 30 m pixel to the next until reaching HUC outlet



Discharge summarized for each 12 digit HUC for 10-yr storm event – investigating routing from one HUC to another to maintain hydrological network

Carbon Storage and Sequestration



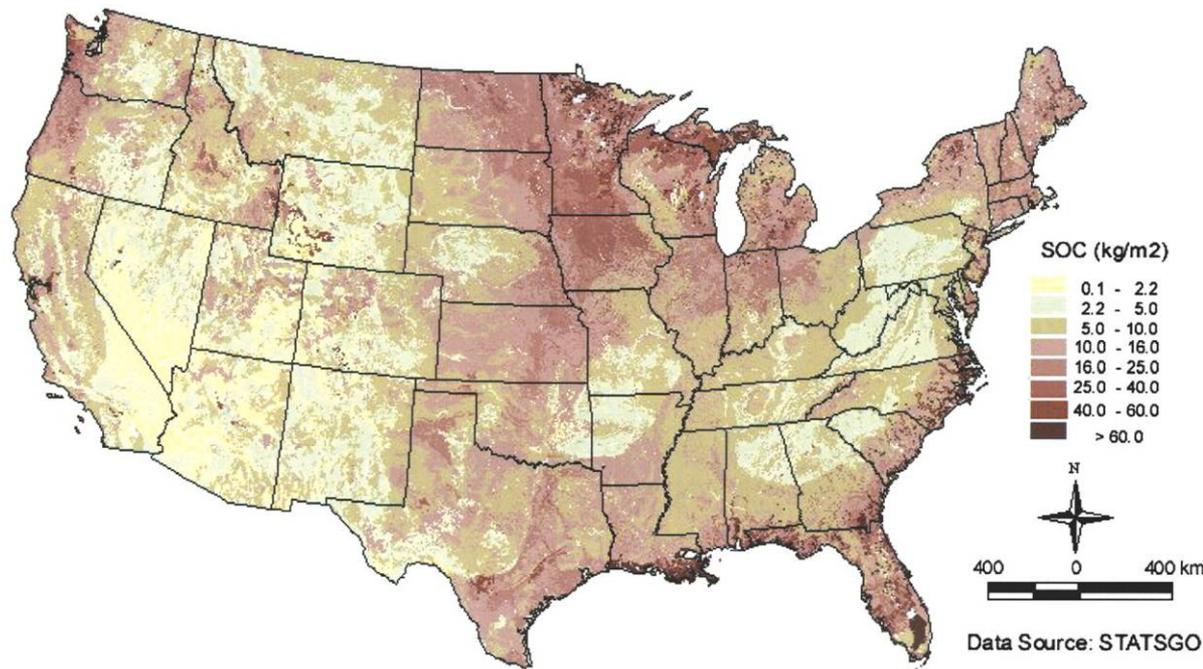
Empirical modeling effort using:

- USDA Forest Service Forest Inventory and Analysis
- High-resolution InSAR data (2000 Shuttle Radar Topography Mission)
- Optical remote sensing data acquired from the Landsat ETM+ sensor.
- National Land Cover Dataset 2001
- LANDFIRE
- National Elevation Dataset (NED)



Carbon Cycling – Carbon Storage

Spatial distribution of soil organic carbon (SOC) content to 2-m soil depths



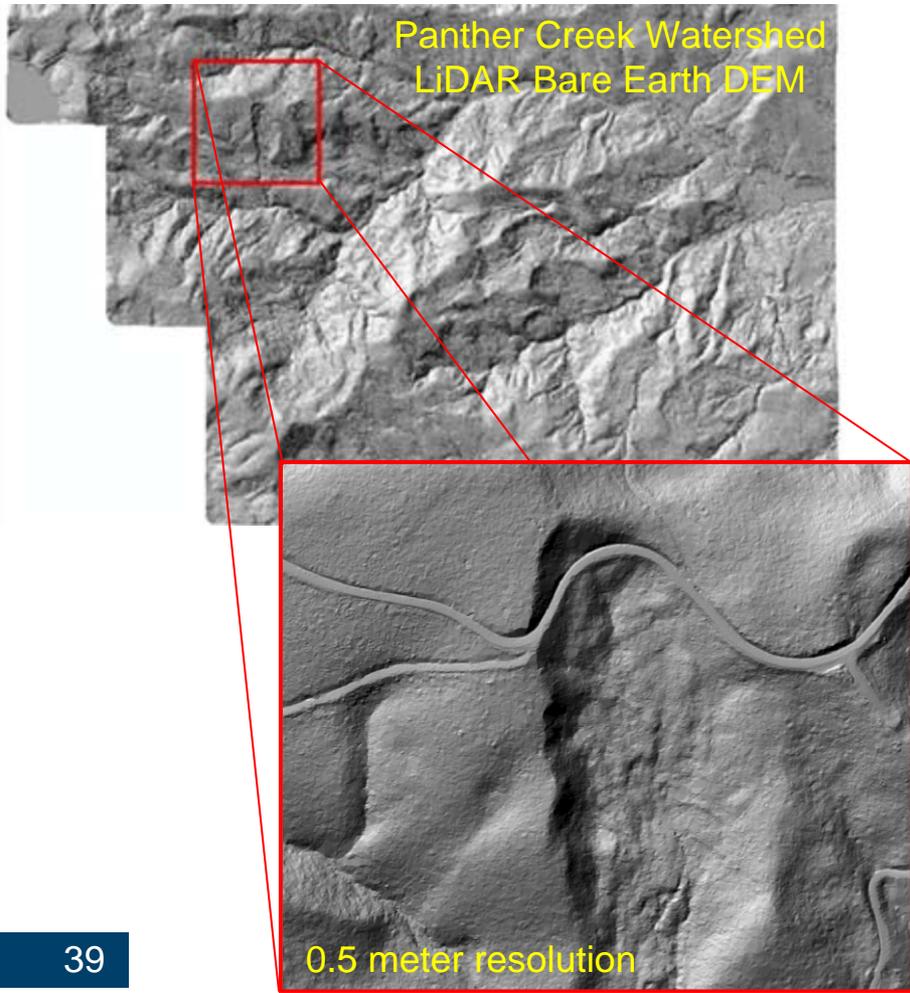
Developing similar
using SSURGO

Source: Guo, Yinyan, Amundson, Ronald, Gong, Peng, Yu, Qian
Quantity and Spatial Variability of Soil Carbon in the Conterminous
United States Soil Science Society of America Journal. 2006 70: 590-600

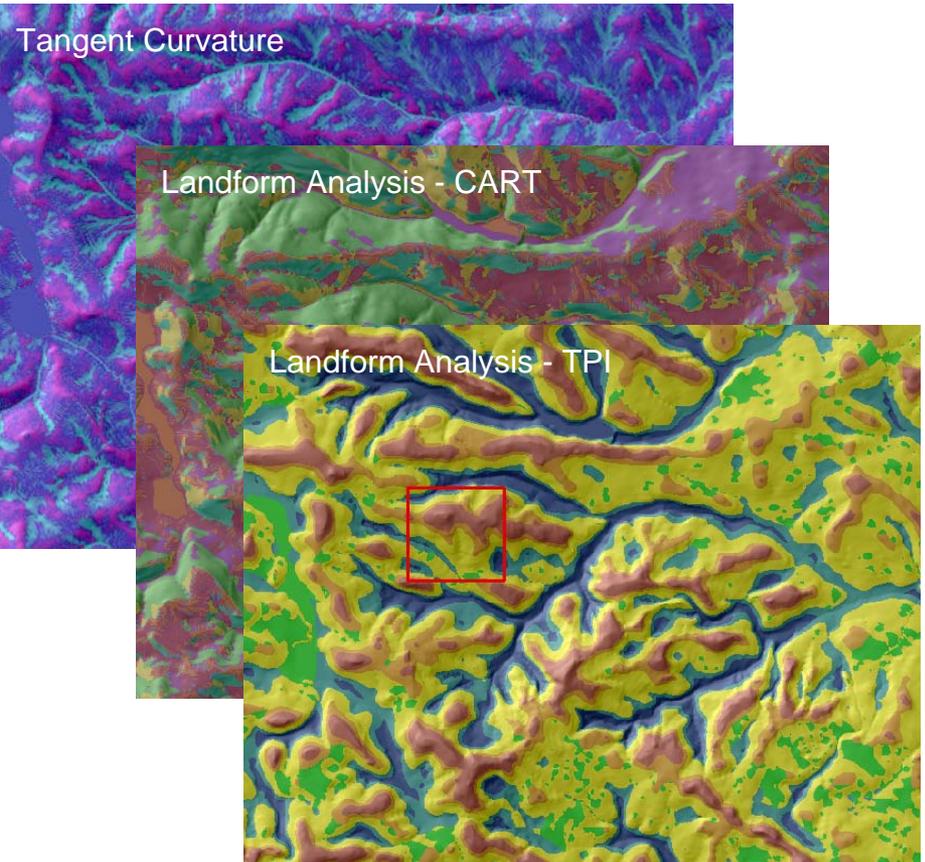
WESP – Quantifying Soil Carbon Stocks

Approach: Use quantitative terrain analysis to characterize topographic and environmental features that control soil carbon distribution across the landscape.

Panther Creek Watershed
LiDAR Bare Earth DEM

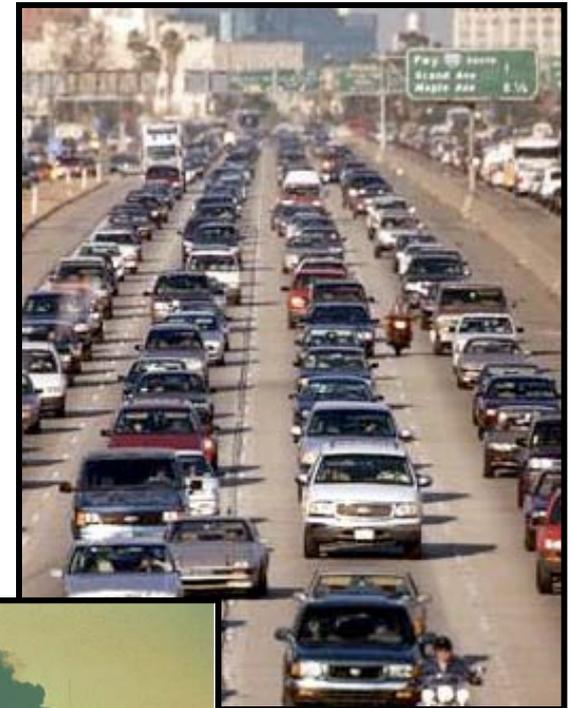


0.5 meter resolution



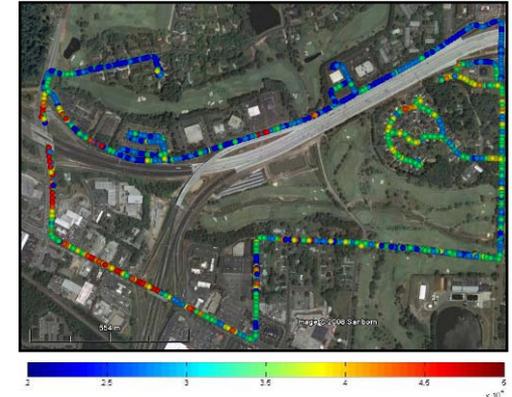
Ecosystem Services provided by Urban Ecosystems

- In-depth analysis of urban areas with population \sim 100,000 using Urban Forest Effects Model (UFORE) and UFORE-Hydro in collaboration with USFS
 - Air pollutants removed by vegetation
 - Energy savings due to shading of buildings
 - Carbon storage benefits
 - Storm water runoff benefits
 - Water Quality benefits
- Near-roadway removal of pollutants by vegetation
- Developing other metrics
 - Heat Island Index
 - Indices of green places (parks)
 - Number of days exceeding air quality standards
 - Nighttime lights index
- Relate metrics to human health and possibly EJ
 - Bird diversity – West Nile Virus
 - $PM^{2.5}$ removal - Asthma



Mapping and human well-being

Monitoring and modeling to quantify pollutant filtration by near-roadway vegetative buffers



- Stationary and mobile monitoring completed at two field sites in RTP, NC (n = 50 rush-hour periods).
- Data analysis begun on ambient concentrations of PM, CO, and black carbon downwind of roadside vegetation.
- Computational fluid dynamics modeling underway to simulate pollutant flow through various vegetation forms.

Ecosystem service will be valued in ambient pollutant concentrations reduced and days of life extended.

Technical Challenges

- Computing resources, technologically feasible but requires \$\$ investment
- Data accuracy –large national data sets are imperfect, will sometimes get it wrong. How do we convey that? How do we avoid, “my pixel is bad, the product is no good”
- Linking the services to beneficiaries ---how do we map this or is it enough to show the ontology?
- What can we do to best provide the foundational data for valuation?
- Data privacy issues – feasible to provide publicly available, fine-scale data, will there be privacy issues?
- Preferred modeling approach
 - Simple model applied fine-scale across the landscape vs.
 - Complex model applied to subset (by ecoregion), then extrapolated across landscape