Use of the SWAT Model For Water, Pollutant and Food Solutions

Jeff Arnold, Karim Abbaspour,
Phil Gassman, Jaehak Jeong, Virginia Jin,
Hiro Somura, Chehra Aboukinane, Daniel Moriasi
Allan Jones and R. Srinivasan

Presentation Overview

- Current Status
- Water Solutions
  - Blue-Green Water Assessment
  - Irrigation
- Pollution Solutions
  - Local Watershed Issues
  - National Environmental Assessment
- Food and Fuel Solutions
  - Corn for Ethanol in Midwest US
  - Cellulosic Grasses
- Current/Future Developments
- Importance of Collaboration with Korea Institute of Construction Technology

USDA - Grassland, Soil & Water Research Laboratory

Conducting research in Temple since 1927

MISSION

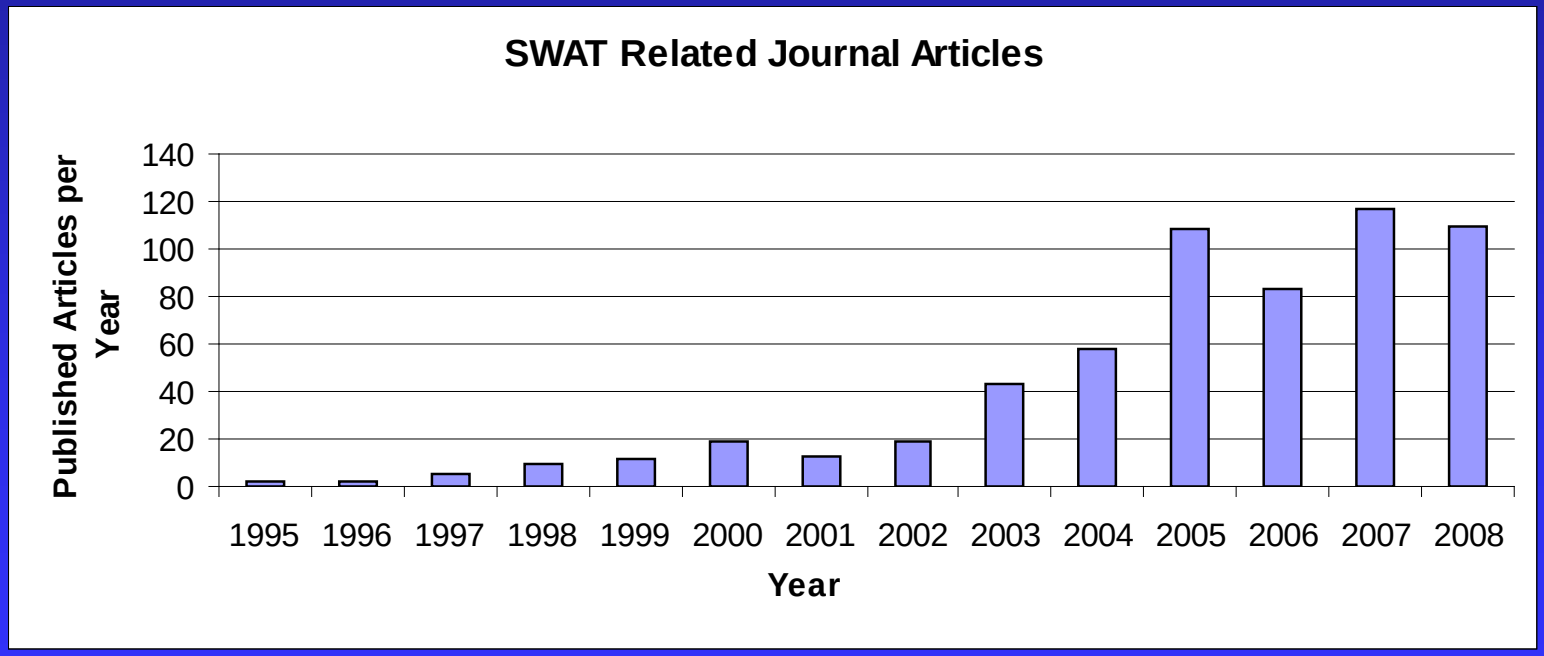
Maximize Crop and Rangeland Production while maintaining a Quality Environment and Healthy Ecosystem

SPECIFIC GOALS

- **Develop Improved Management Practices**
- **Develop Crop Growth and Water Quality Models**
- **Develop and Understanding of Ecosystem Processes of Rangeland Vegetation**
- **Resolve Uncertainty of Rising CO_2 on Ecosystem Processes**
- **Develop Effective Biological Control of Salt cedar**

Current Status - Publications

Over 600 Journal Publications on SWAT development and application



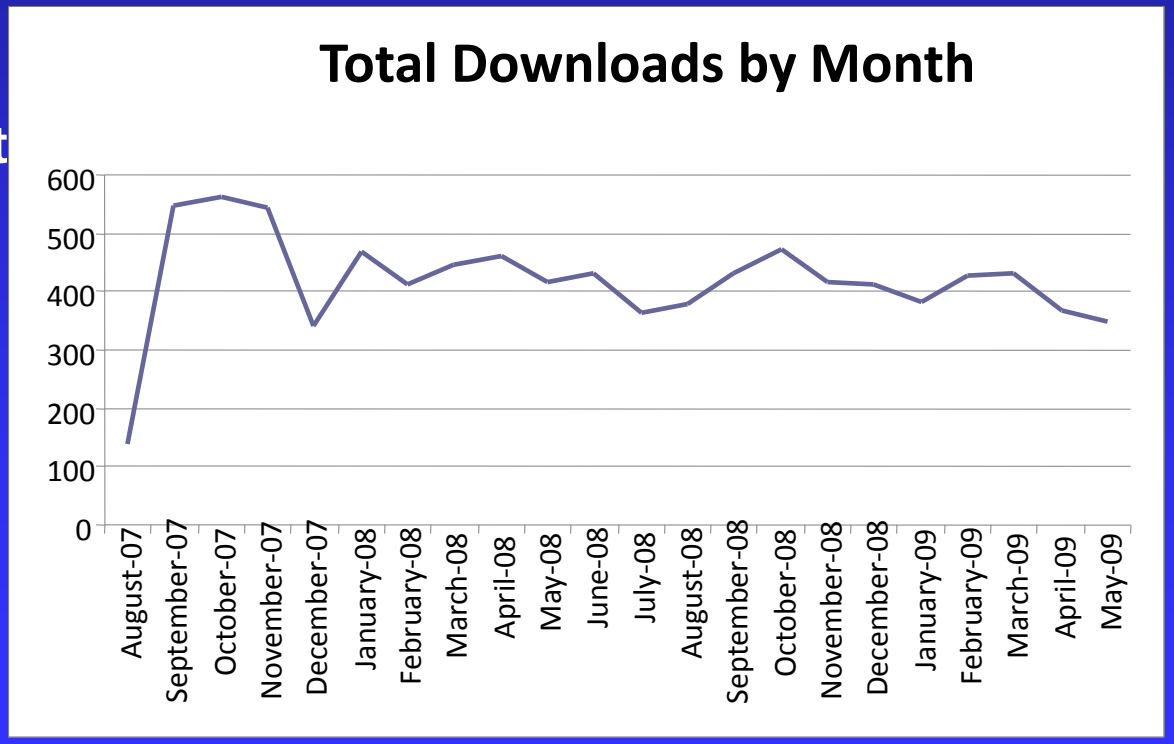
Recent Accomplishments - Publications

Acta Ecologica Sinica
Advances in Engineering Software
Advances in Geosciences
Advances in Water Resources
Agricultural Water Management
Biogeochemistry
Bioresource Technology
Boreal Environment Research
Catena
Chemosphere
Climatic Change
Desalination
Ecological Economics
Ecological Modelling
Environ. Geol.
Environmental Management
Environmental Modelling and Software
Environmental Pollution
Environmental Science & Policy
Global and Planetary Change
Hydrological Processes
Hydrological Sciences Journal
Hydrology and Earth System Sciences

Journal of Archaeol. Sci.
Journal of Environmental Management
Journal of Environmental Quality
Journal of Hydrologic Engineering
Journal of Hydrology
Journal of Soil and Water Conservation
Journal of the American Water Resources Association
Land Use Policy
Nile Water Science and Engineering Magazine
Physics and Chemistry of the Earth
Quaternary International
Review of Agricultural Economics
Science in China Series D: Earth Sciences
Science of the Total Environment
The Open Hydrology Journal
Transactions of the ASABE
Vadose Zone Journal
Water Research
Water Resources Management
Water Resources Research
Water SA
Water Science and Technology
Water, Air, and Soil Pollution

SWAT-MODFLOW paper – Kim, Chung, et al 2008 – Second most downloaded paper of J. of Hydrology

Soil and Water Assessment Tool:
Historical Development, Applications
And Future Research Directions
Gassman et al - ASABE



Current Status

- SWAT Version 2009 was released after the 2009 International Conference in Boulder, Colorado

- New model routines for carbon dynamics, sediment routing, irrigation, filter strips, dynamic land use and conservation structure updates

- User interfaces with ArcGIS and MapWindows and VizSWAT

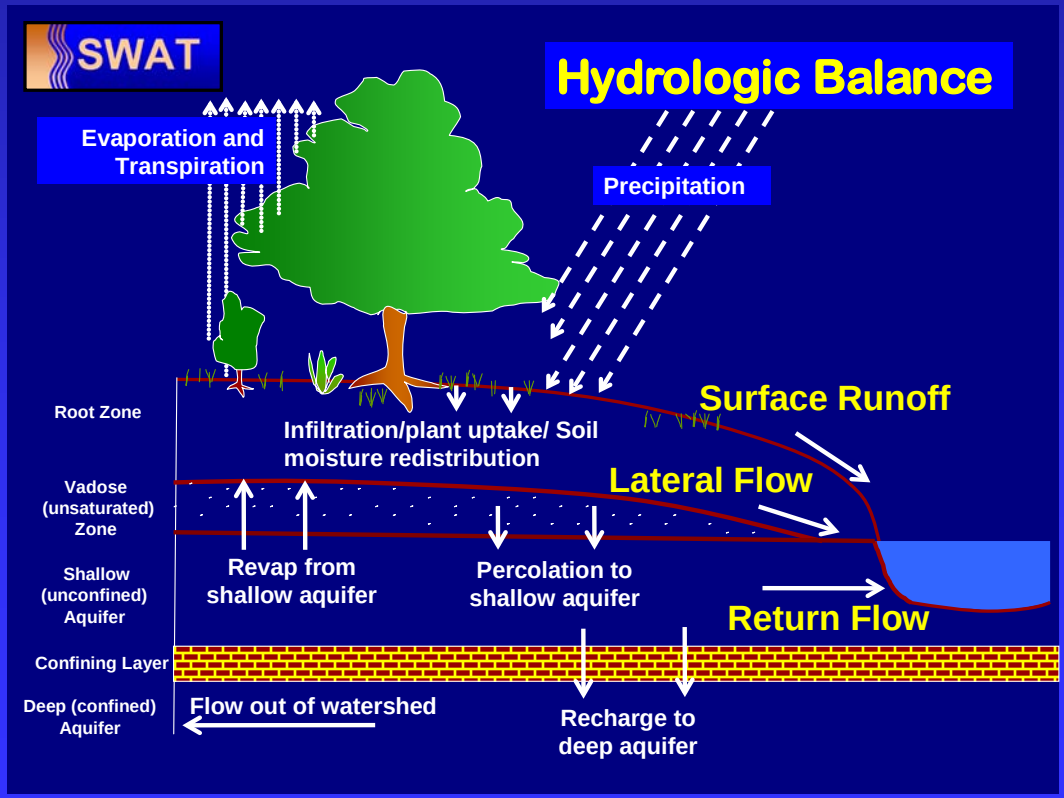
- Version control software and model developer workshops

- Continued workshop and support around the world

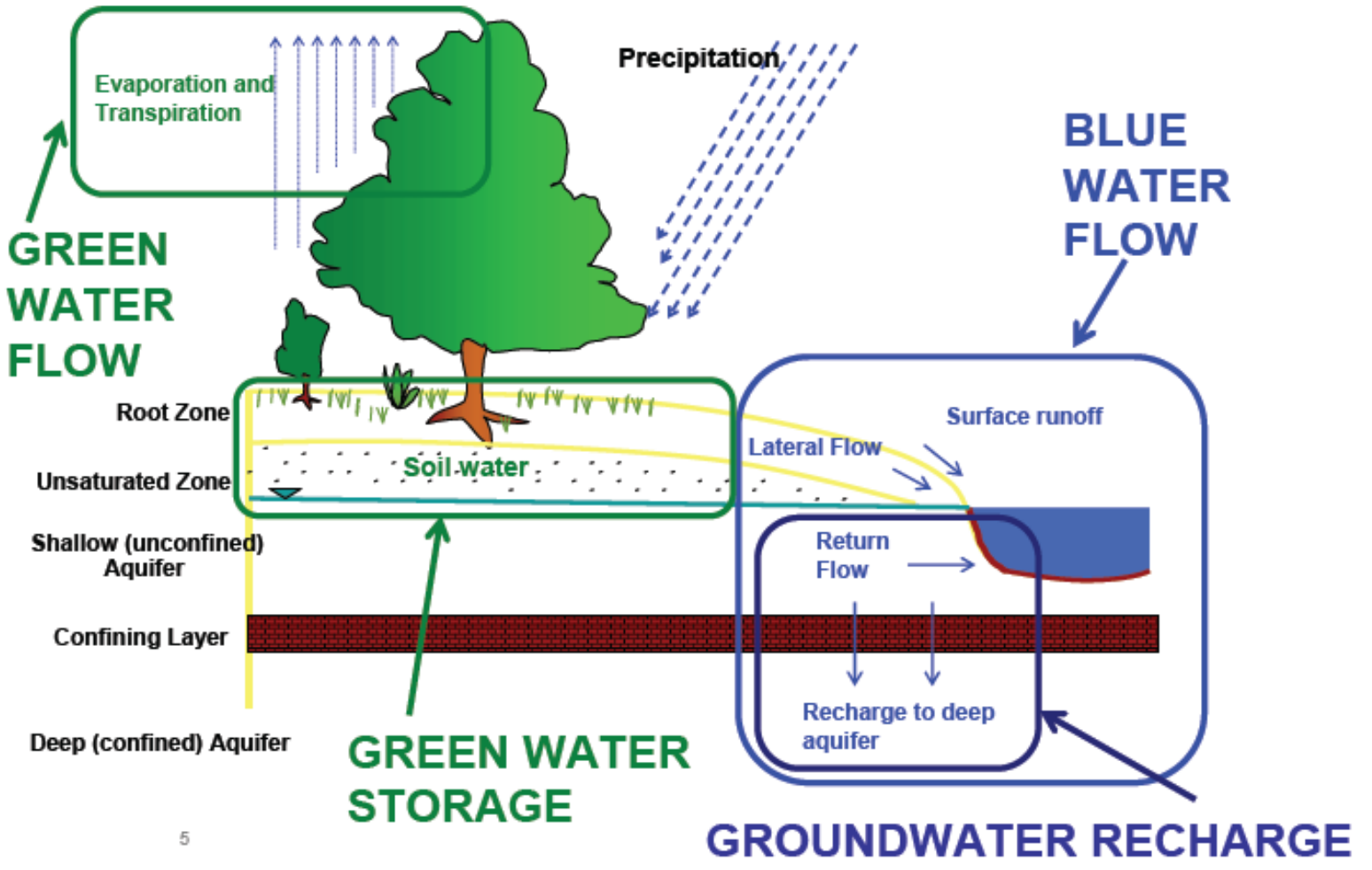
Water Solutions

- SWAT applied to solve water issuess related to sustainability (blue/green water), regional irrigation planning, reservoir management, ground water recharge, climate change and storm water detention

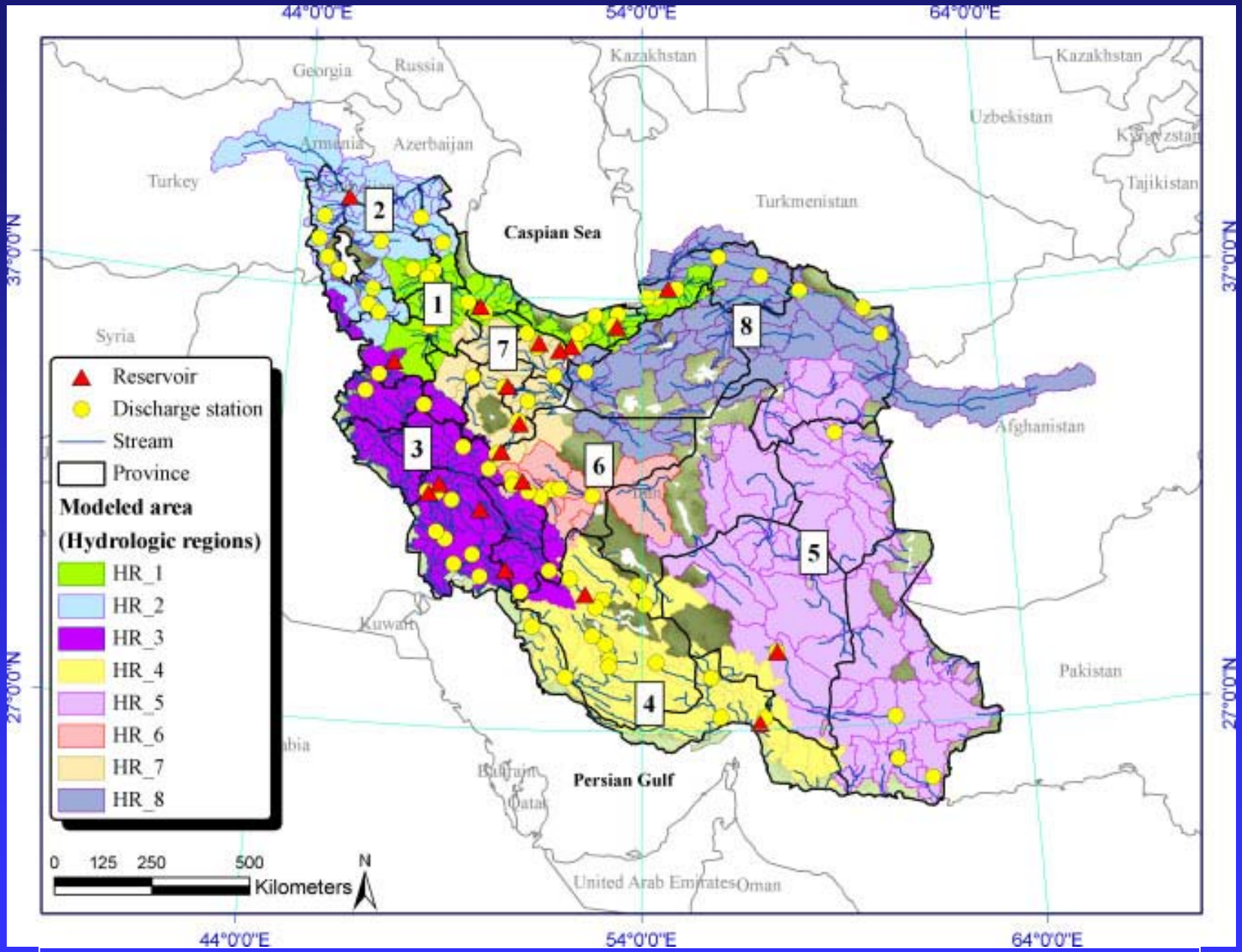
- Karim Abbaspour



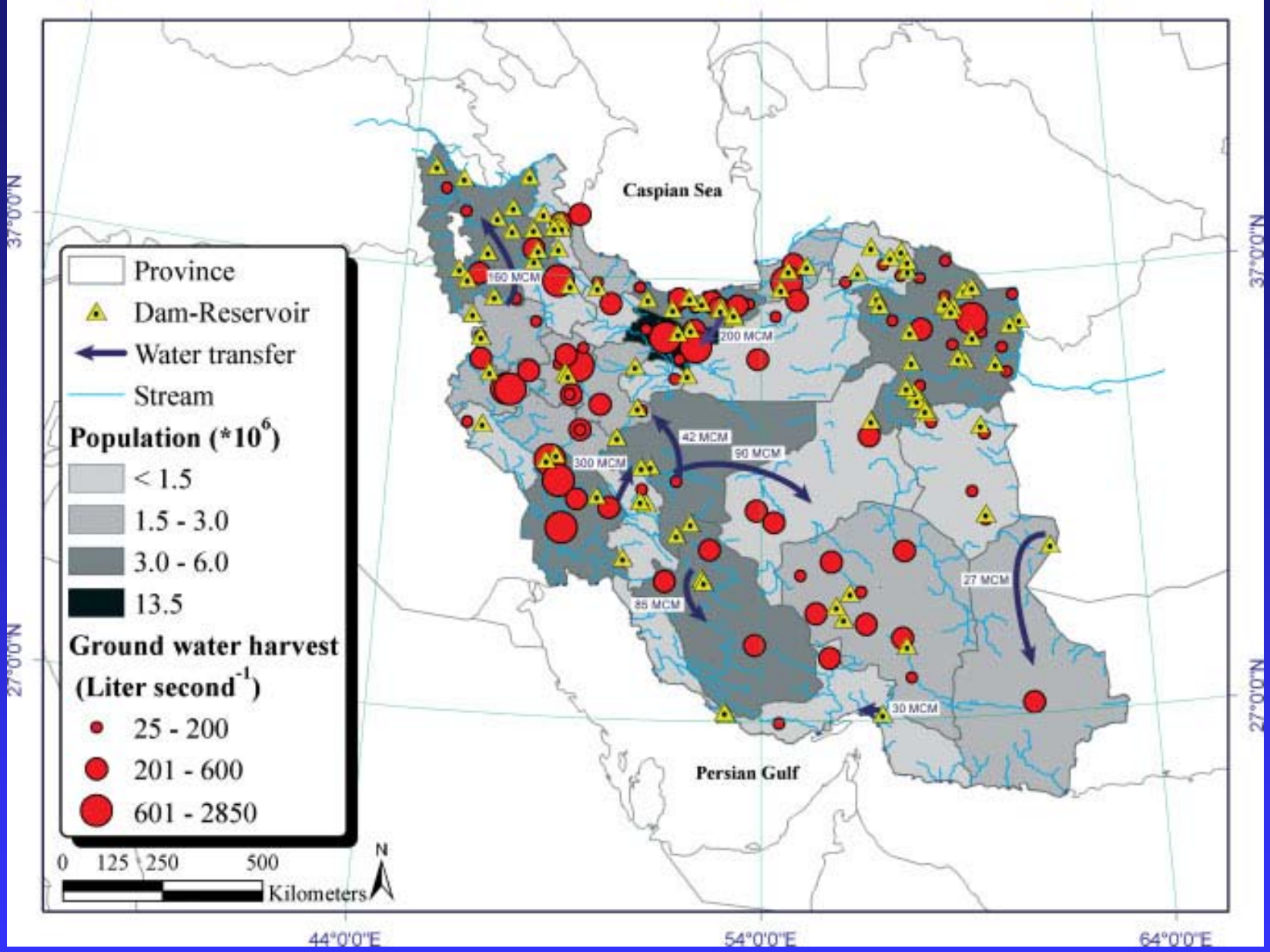
Blue and green water



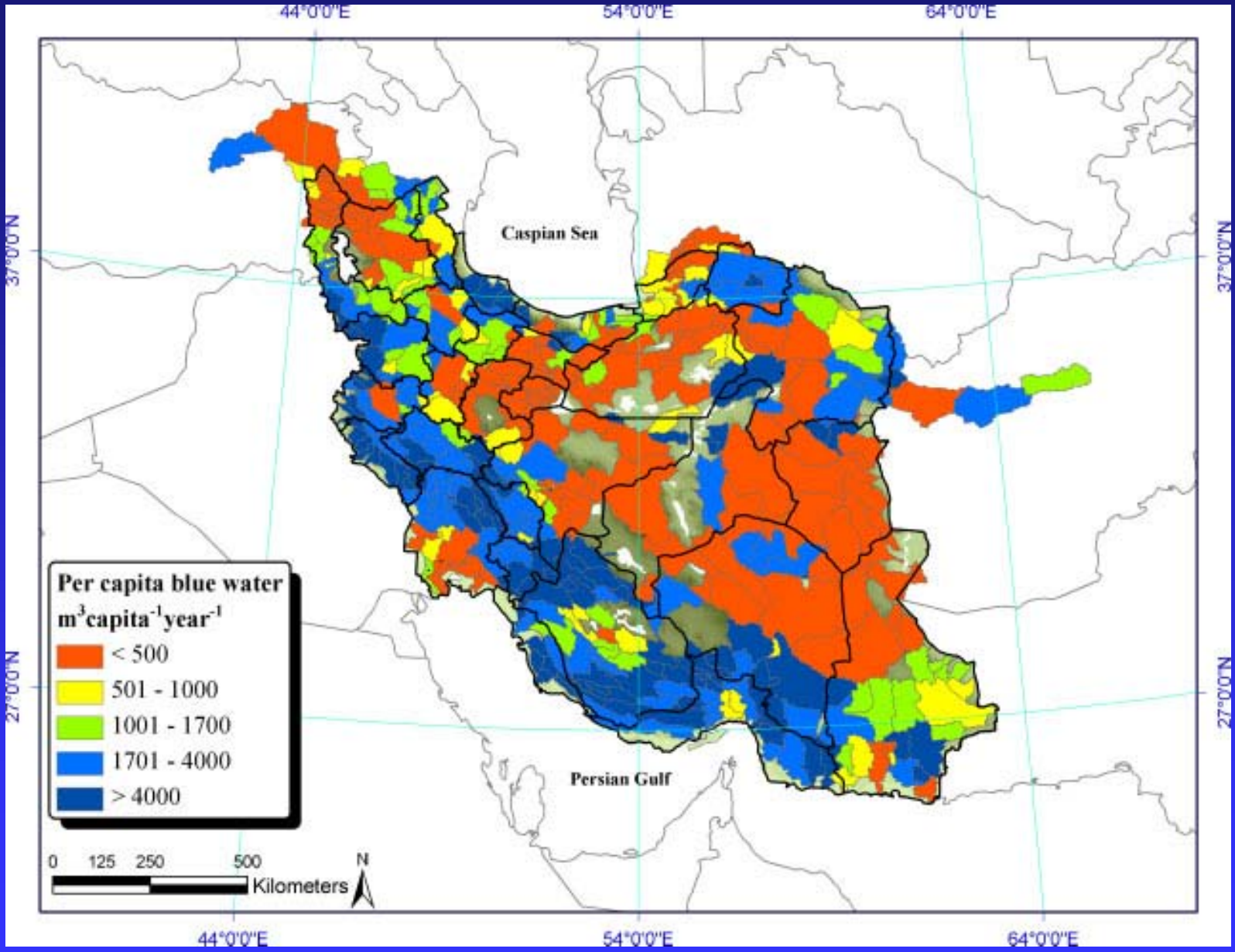
Karim Abbaspour & others; EAWAG, Dubendorf, Switzerland



Faramarzi et al. 2008. Modelling blue and green water resources availability in Iran. *Hydrological Processes* 23(3): 486-501.

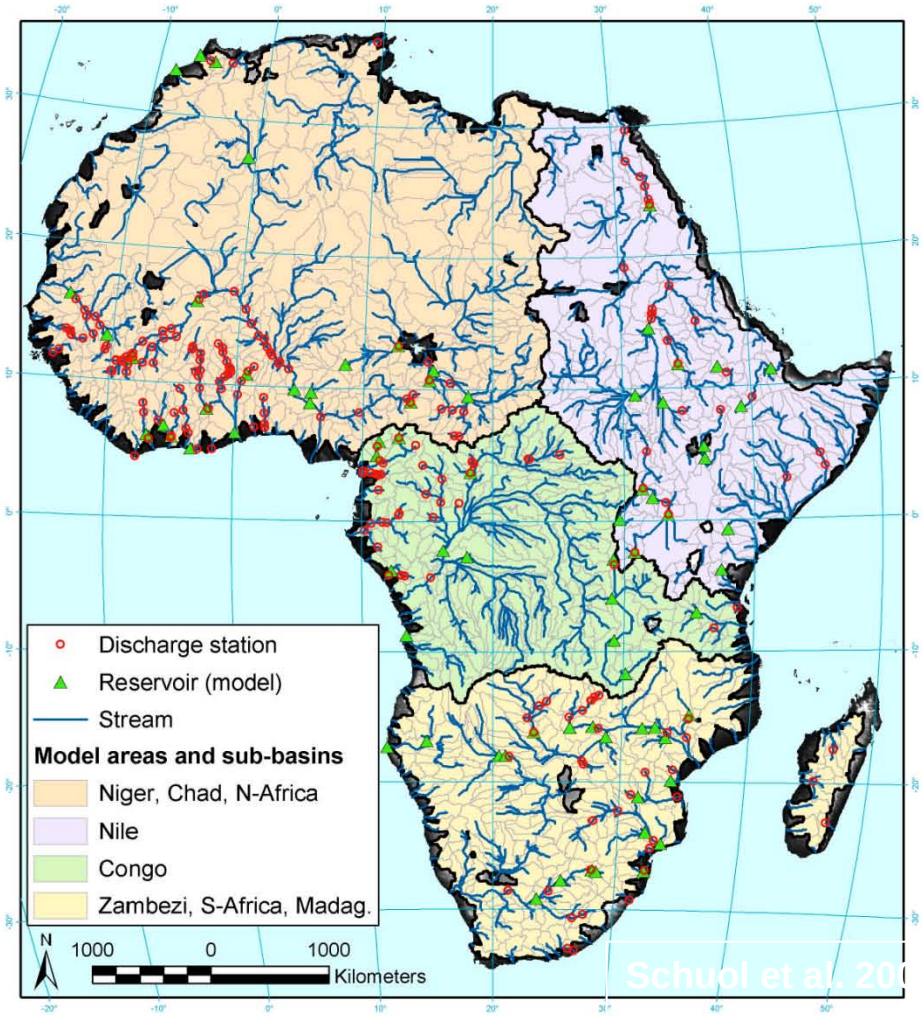


Faramarzi et al. 2008. Modelling blue and green water resources availability in Iran. *Hydrological Processes* 23(3): 486-501.



Faramarzi et al. 2008. Modelling blue and green water resources availability in Iran. *Hydrological Processes* 23(3): 486-501.

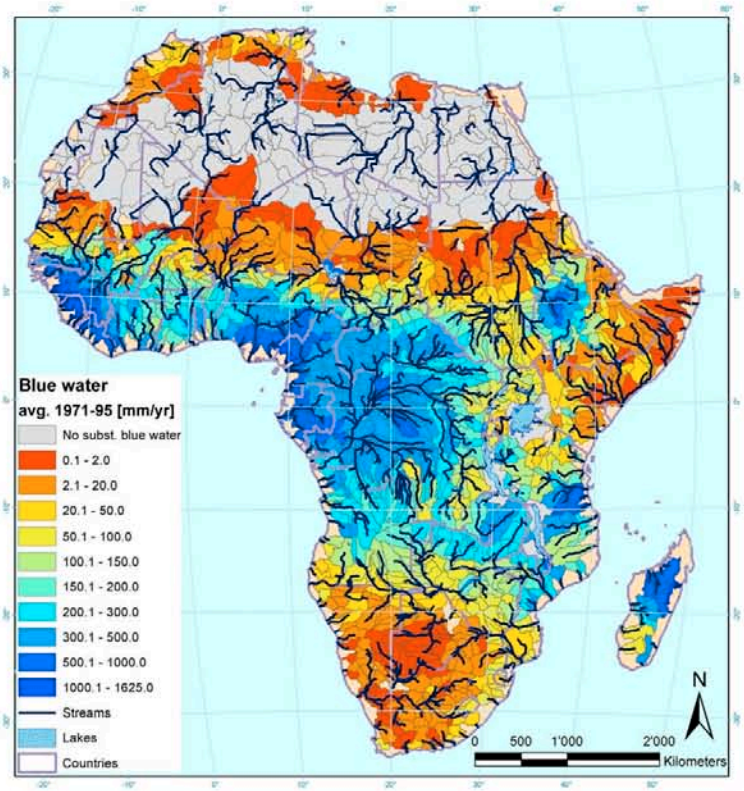
The Africa continental model



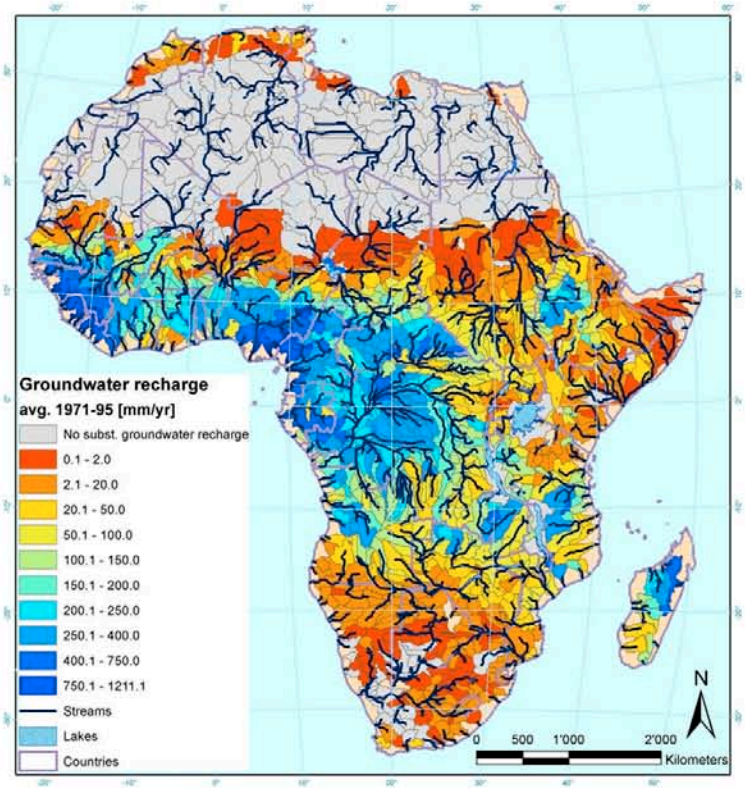
- Delineation of Africa into 1496 sub-basins using the **ArcSWAT interface**
- Use dominant soil, landuse and slope in each subbasin
- 64 reservoirs with a volume >1km^3 are included
- 208 stations with monthly observed river discharge
- Divided the continent into **4 model areas**, which are independently calibrated and validated but within the same model frame

The continental picture: Blue water

Blue water flow



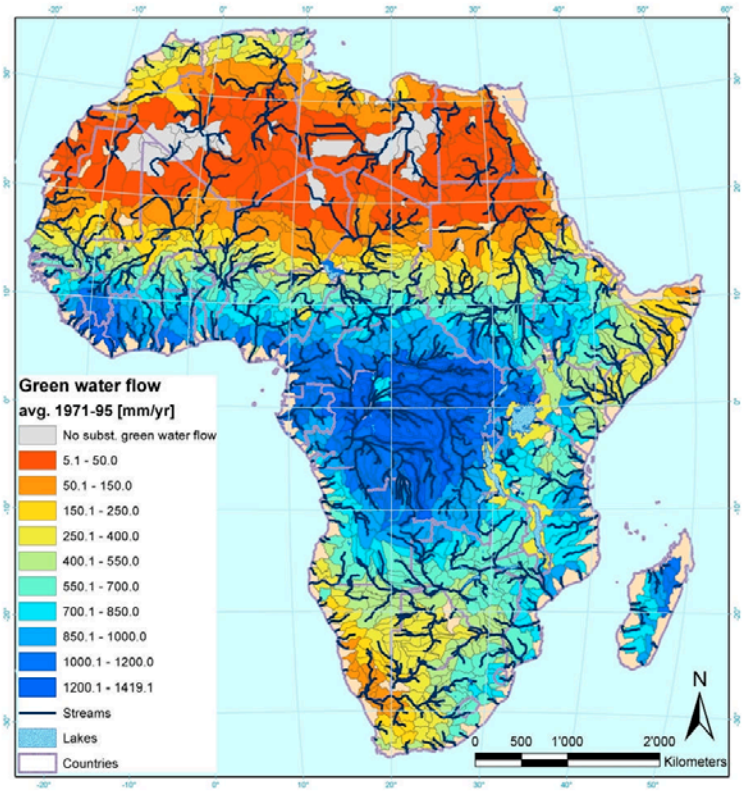
Groundwater recharge



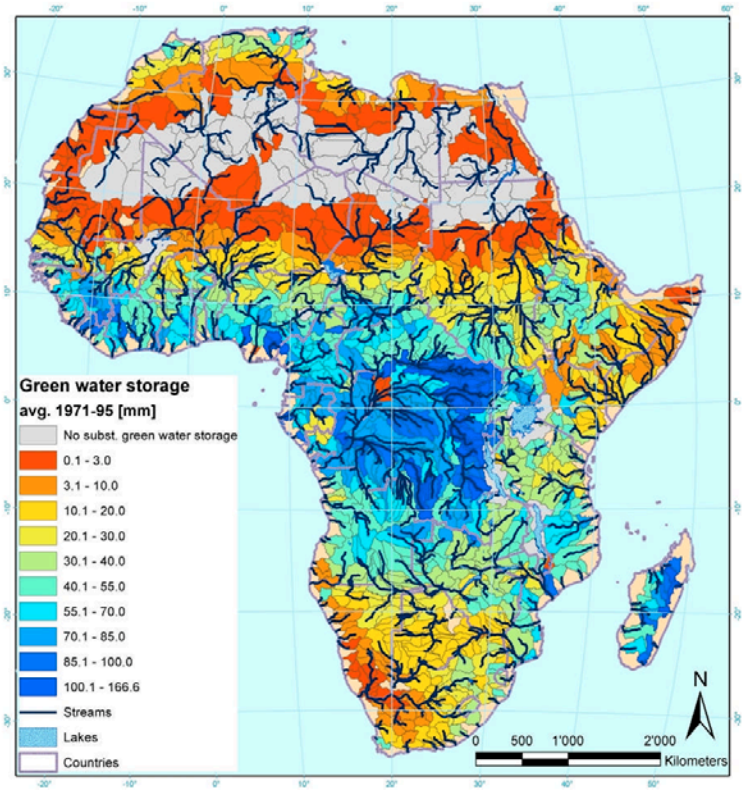
Africa. *Water Resources Research*. 10.1029/2007WR006609.

The continental picture: Green water

Green water flow



Green water storage



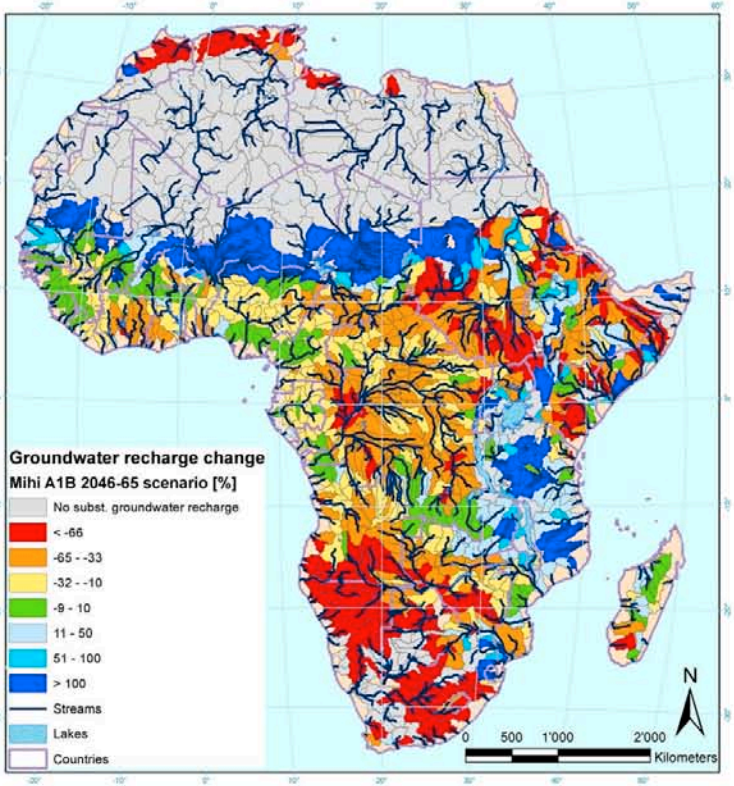
Africa. *Water Resources Research*, 10.1029/2007WR006609.

Changes in groundwater recharge

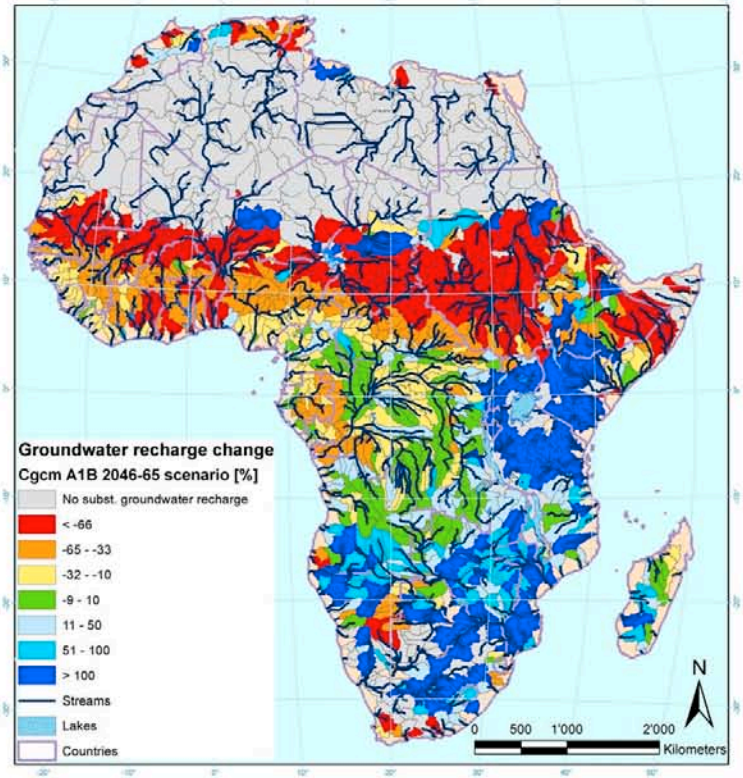
A1B emission scenario

2046-2065

MIROC3.2(hires)



CGCM3.1(T63)



Africa. *Water Resources Research*, 10.1029/2007WR006609.

Pollution Solutions

Major Uses in the U.S.

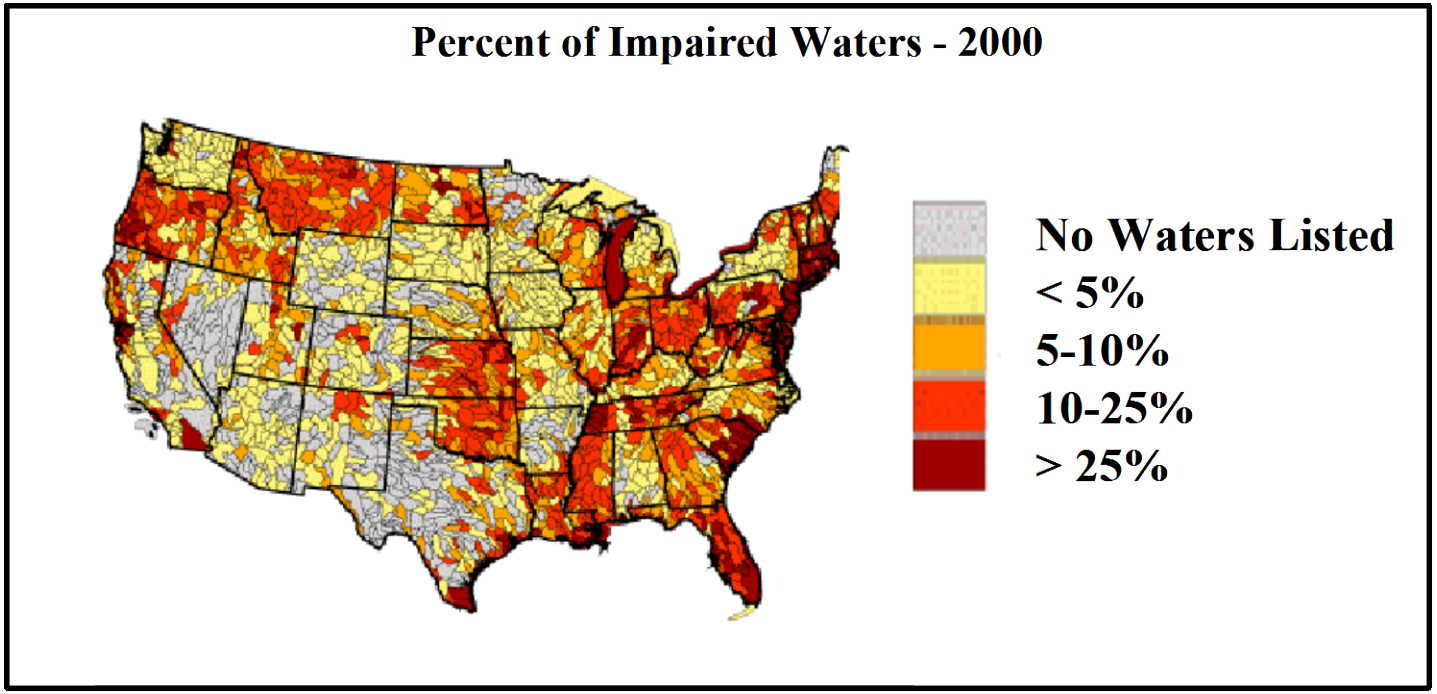
- **US Environmental Protection Agency**
  Local Watershed (100-1000 km^2) water quality concerns. Sediment, nutrients, pesticides, pathogens, DO

- **US EPA – National Environmental Assessment**

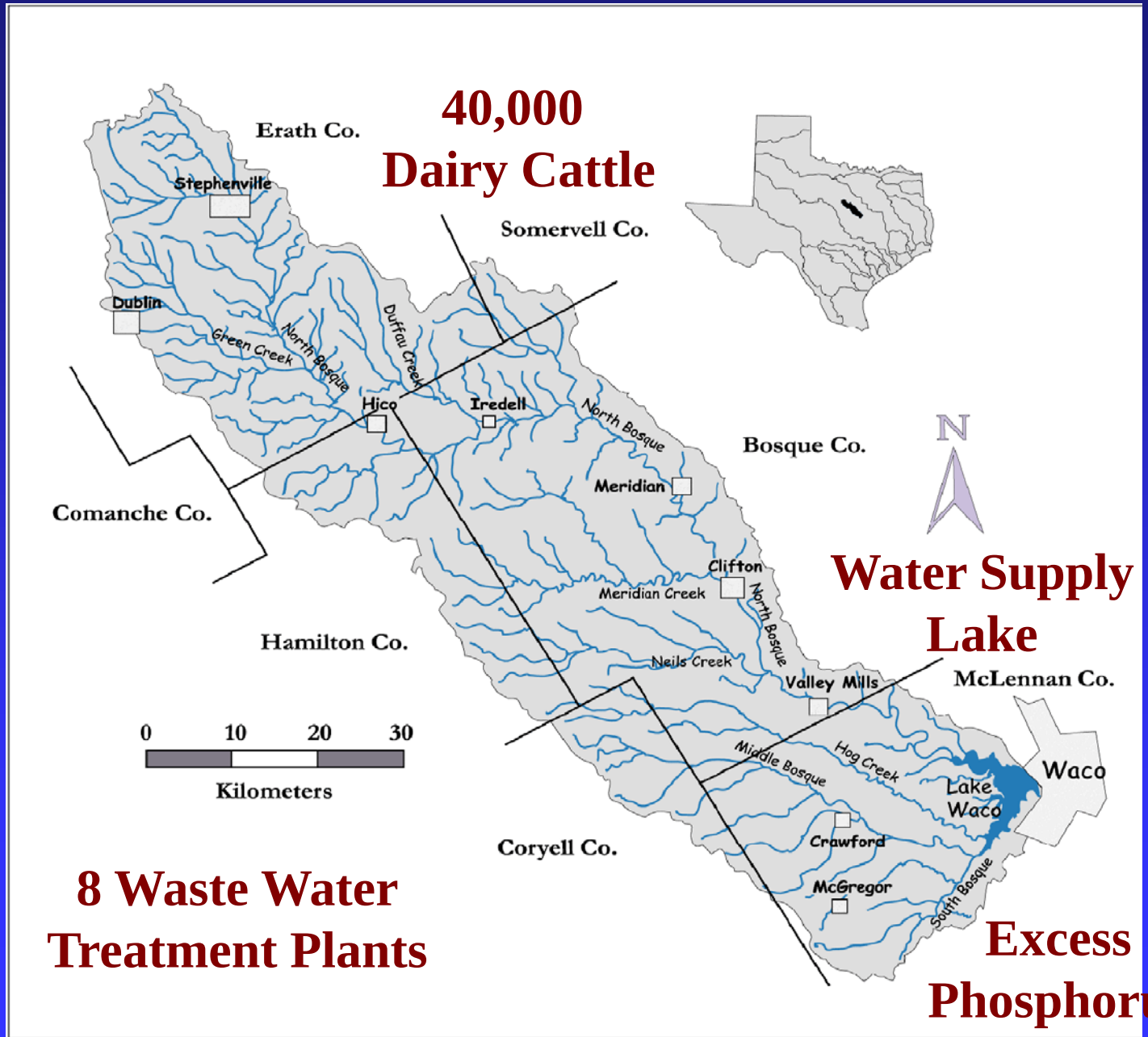
- **US Department of Agriculture**
  National Conservation Effects Assessment Project
  USDA spends $1 B on conservation practices

U.S. Environmental Protection Agency

- 15,000 Water Bodies Identified as Impaired
- Plan to Restore Water Quality Standards
- Models/GIS Tools for Evaluating Management Strategies



Bosque River Watershed, Texas



P Control Measures/Management Scenarios

• Dairy Management Scenarios: Haul Off, manure application at crop P requirement (P rate), reduction of dairy diet P to 0.4% (reduction in manure P content by 29%)

• WWTP Management Scenarios: Concentrations of total P in WWTP effluents were varied to 0.5, 1 and 2 mg/l

Dairy and WWTP Scenarios

- **Dairy Scenarios: Concentrations showed reductions of 1 to 12%; Loadings showed reductions of 7 to 60% along the river**

- **WWTP Scenarios: Concentrations showed reductions of 21 to 78%; Loadings showed reductions of 4 to 50% along the river**

- **Benefits of dairy scenarios are better at reducing sol P loadings than concentration; WWTP scenarios showed greater benefits in reducing the concentration as opposed to total loadings**

CEAP National Assessment of Conservation Programs

Scenarios

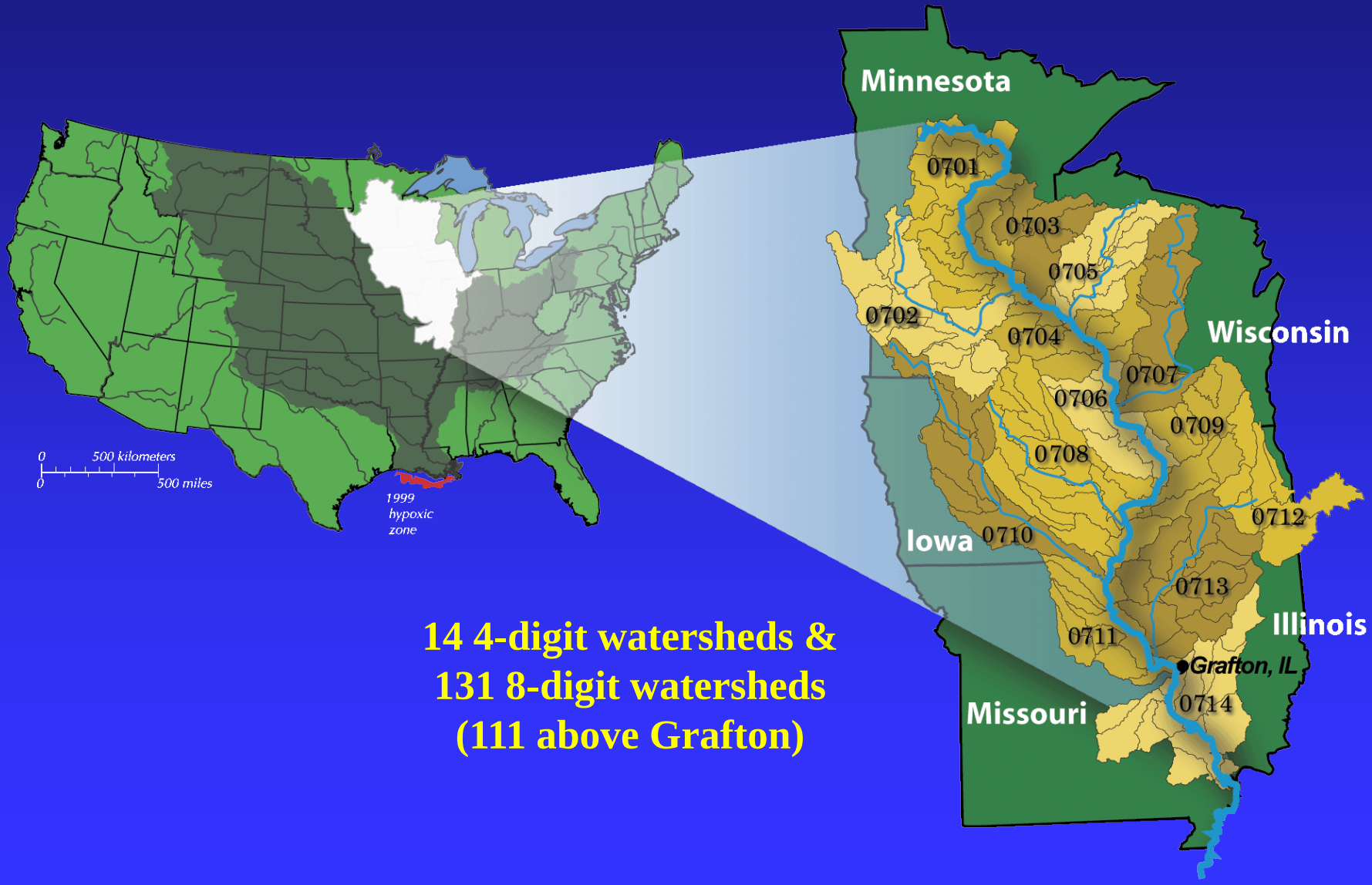
- **No Practices**
- **Current Conditions – Farmer Surveys of Management Practices**
- **Full Treatment**

USDA ARS

USDA NRCS Natural Resources Conservation Service

AgriLIFE RESEARCH Texas A&M System

Upper Mississippi River Basin



14 4-digit watersheds &
131 8-digit watersheds
(111 above Grafton)

Step 1. Retire all land within 100 ft. of a waterway (based on NRI data), place it in perennial uses.

Step 2. Retire additional land to reach a 10% total land retirement, based on the NRI Erosion Index.

Step 3. Terrace remaining cropland with slopes > 5%.

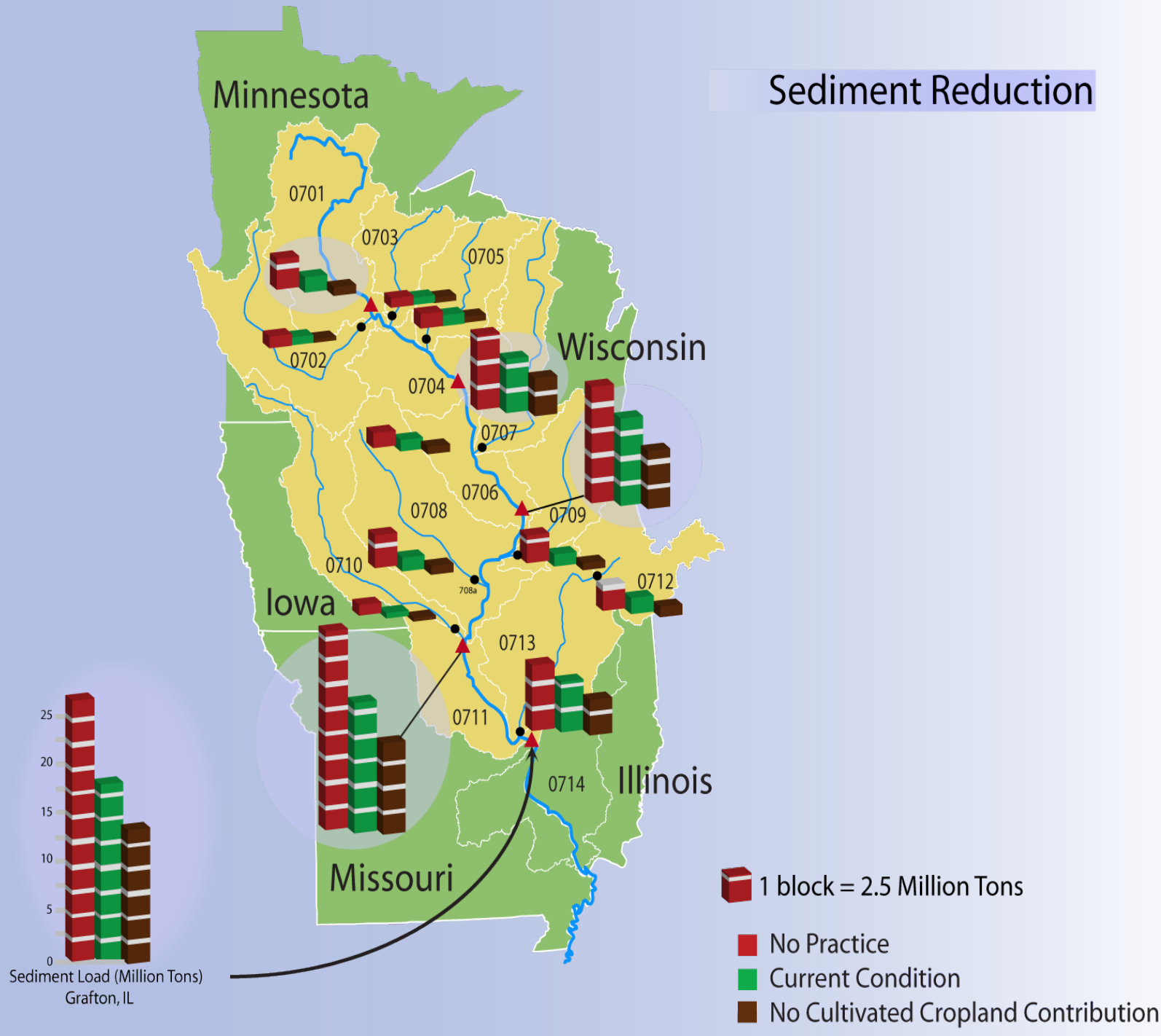
Step 4. Implement contouring on all remaining cropland with slopes > 4%.

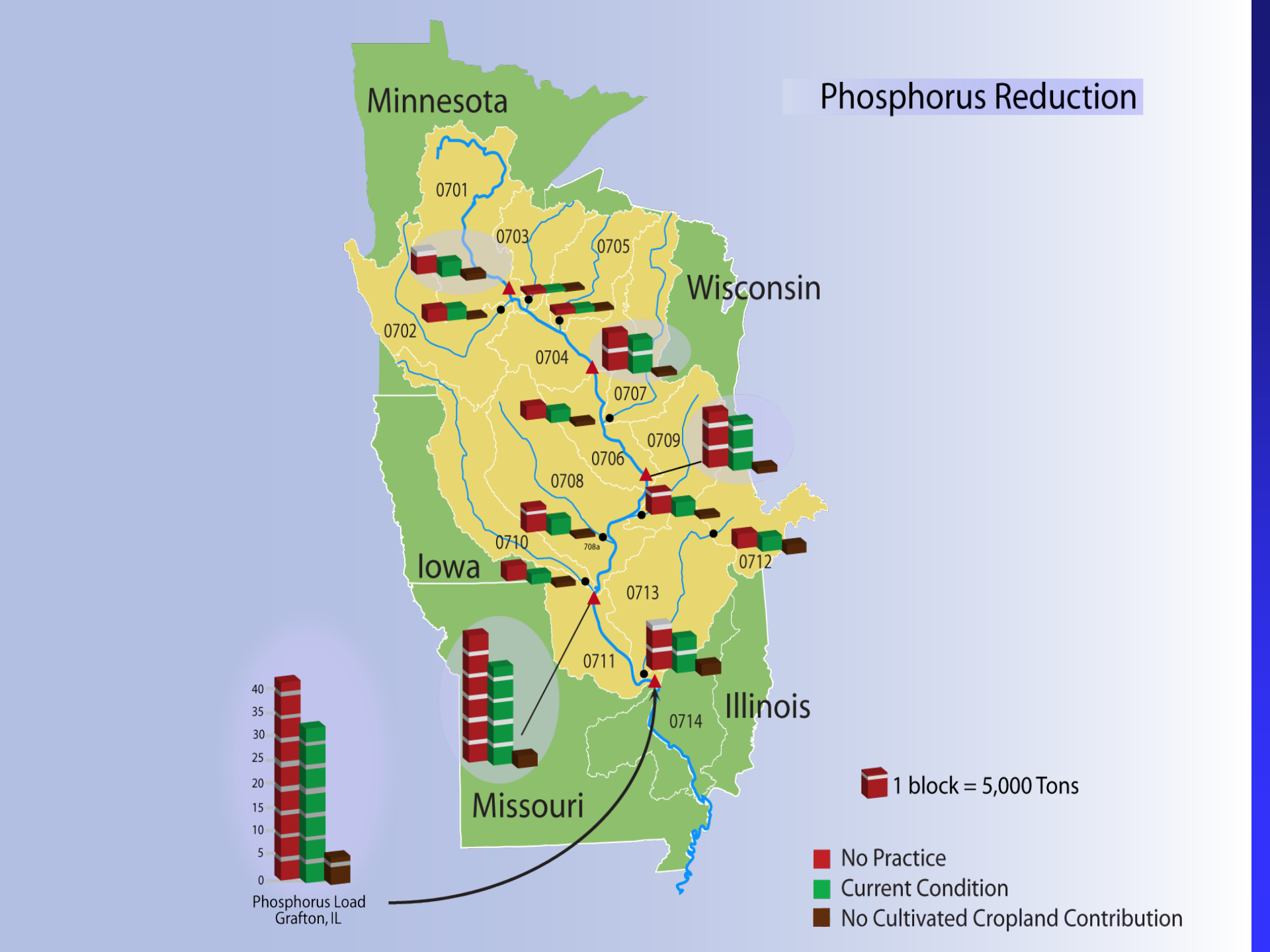
Step 5. Install grassed waterways on remaining cropland with slopes > 2%.

Step 6. For all cropland with slopes ≥ 2% (and not in land set aside), place 20% in no till and 80% in mulch tillage.

- mulch tillage ≥ 30% residue
- no till ≥ 60% residue

Step 7. Nutrient management: 10% reduction in N fertilizer rates on all corn acres.


Sediment Reduction
Minnesota
Wisconsin
Iowa
Illinois
Missouri
0701
0702
0703
0704
0705
0706
0707
0708
0709
0710
708a
0711
0712
0713
0714
25
20
15
10
5
0
Sediment Load (Million Tons)
Grafton, IL
1 block = 2.5 Million Tons
No Practice
Current Condition
No Cultivated Cropland Contribution


Phosphorus Reduction
Minnesota
Wisconsin
Iowa
Illinois
Missouri
0701
0702
0703
0704
0705
0706
0707
0708
708a
0709
0710
0711
0712
0713
0714
40
35
30
25
20
15
10
5
0
Phosphorus Load
Grafton, IL
1 block = 5,000 Tons
No Practice
Current Condition
No Cultivated Cropland Contribution

Food and Fuel Solutions

- The U.S. Departments of Agriculture (USDA) and Energy (DOE) estimate that the U.S. will require the sustained production of one billion tons of biomass annually to displace 30% of current US petroleum demand with biofuels by the target date of 2022

- SWAT – Assess production risks of biofuel production
- Ensure environmental sustainability

Miscanthus

Switchgrass

Food and Fuel Solutions

- Modeling sugar cane production in Brazil and determining the impact on pesticide runoff

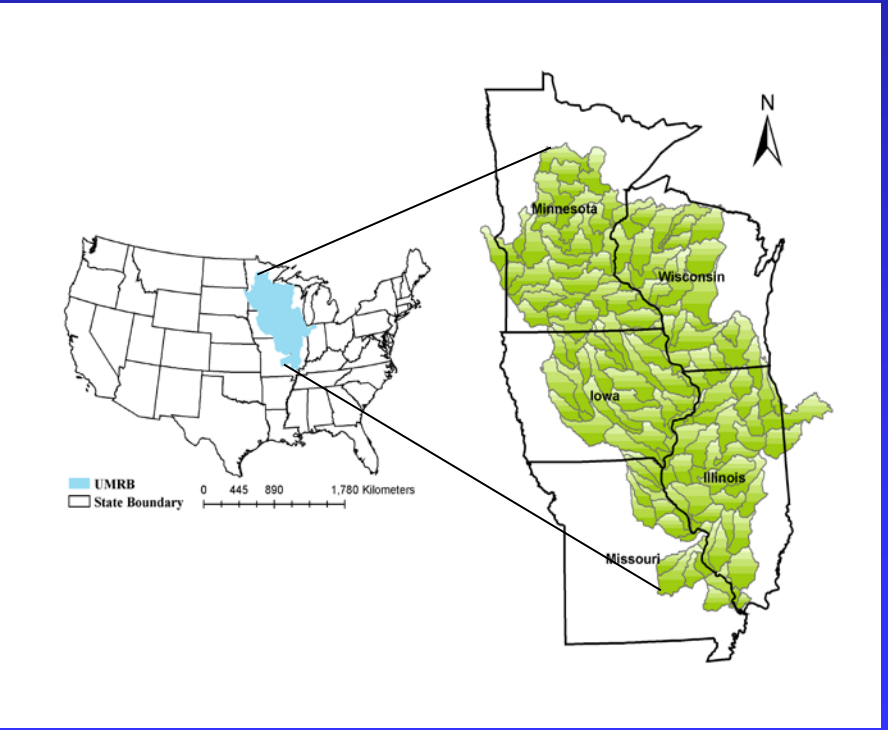
- Bioenergy grasses – switchgrass and miscanthus production across ecoregions of central and south central US

Sugarcane

Sweet Sorghum

Food and Fuel Solutions

- Corn based ethanol production is projected to increase to meet growing demand for alternative fuels
- Rivers are subject to increased sediment, nutrient and pesticide loadings
- SWAT used to estimate effects of increased corn production in the Upper Mississippi River Basin



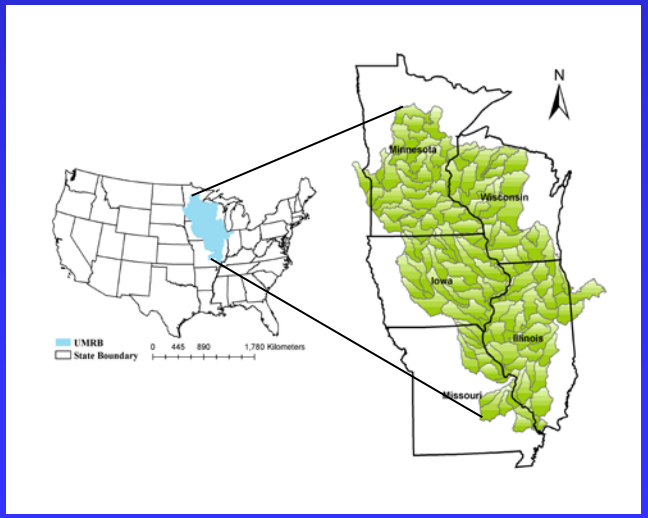
Food and Fuel Solutions

Ethanol Production

	Scenario Average Yield (bu/ac)	(t/ha)	Corn Area (Million Ha)	Ethanol Produced (Billion Liters)
Baseline	140.7	8.2	9.6	-
2010	149.6	8.7	13.5	19.6
2015	159.0	9.3	14.4	24.2
2020	169.0	9.9	14.0	24.2
2022	173.2	10.1	13.9	24.2

Nitrogen Loads in Mississippi River

	Unit Load (kg/ha)	Total Load (Million Kg)	Outflow in River (Million Kg)
Baseline	17.5	860.46	650.22
2010	18.4	904.33	686.19
2015	18.2	896.43	680.52
2020	17.9	879.29	666.55
2022	17.8	873.80	662.06



Current and Future Developments

- Landscape routing
- Urban models
- Subsurface drainage
- Rice paddies
- Emerging contaminants – hormones and antibiotics

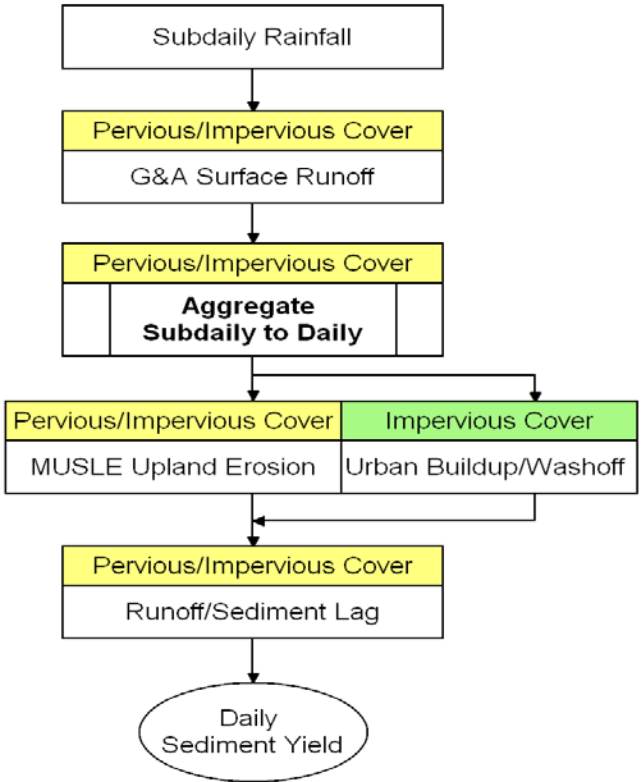
Urban Solutions

- In highly urbanized areas, impervious areas produce instantaneous runoff in response to rainfall
- This sort of quick response has to be controlled to avoid flooding, high erosion and the associated transport of pollutants to the nearby river or lake
- Structural stormwater best management practices can be helpful under these circumstances. They capture some of the instantaneous runoff, attenuate the flood peaks, and remove a portion of the pollutants before they reach the creek

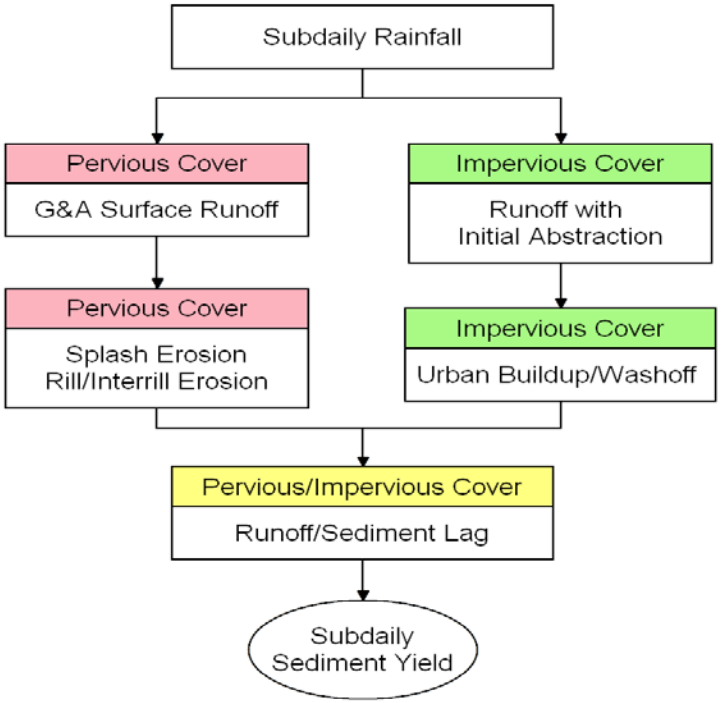
Urban Solutions

- Jaehak Jeong is developing new routines for subdaily runoff and sediment transport
- Allan Jones and Jaehak are developing urban stormwater best management practices that capture some of the instantaneous runoff, attenuate the flood peaks, and remove a portion of the pollutants before they reach the creek

SWAT 2005



Urban SWAT

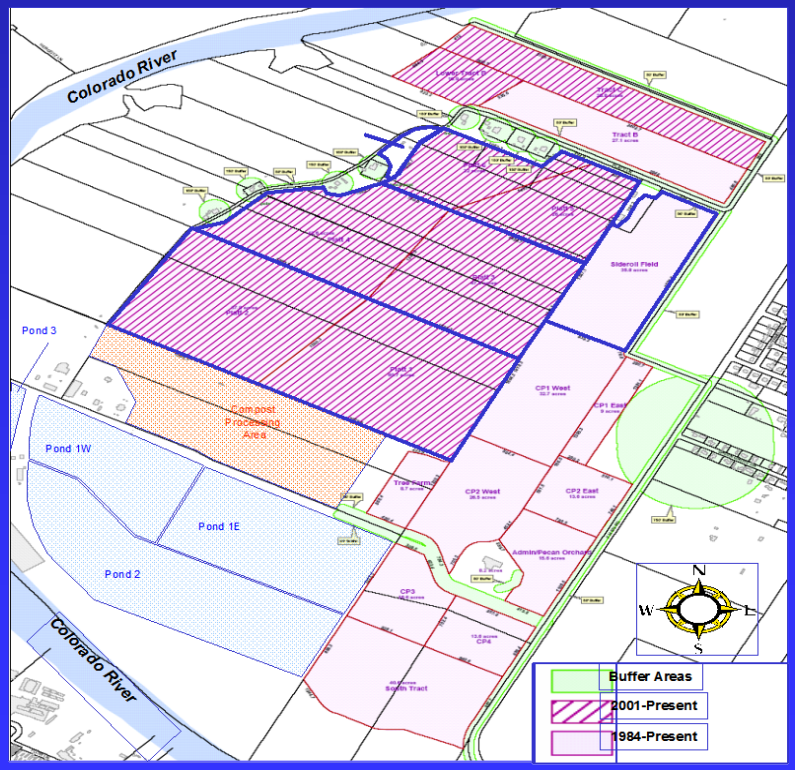


Rice Paddy Simulation

- Hiro Somura is developing new routines for rice paddy water balance, sediment and nutrient release
- Management includes irrigation and ponded water depth, puddling impacts on sediment concentrations and conductivity of the soil, planting and harvest, nutrient and pesticide applications, and wildlife nutrient inputs
- Validation on monitored rice paddies near Matsue, Japan

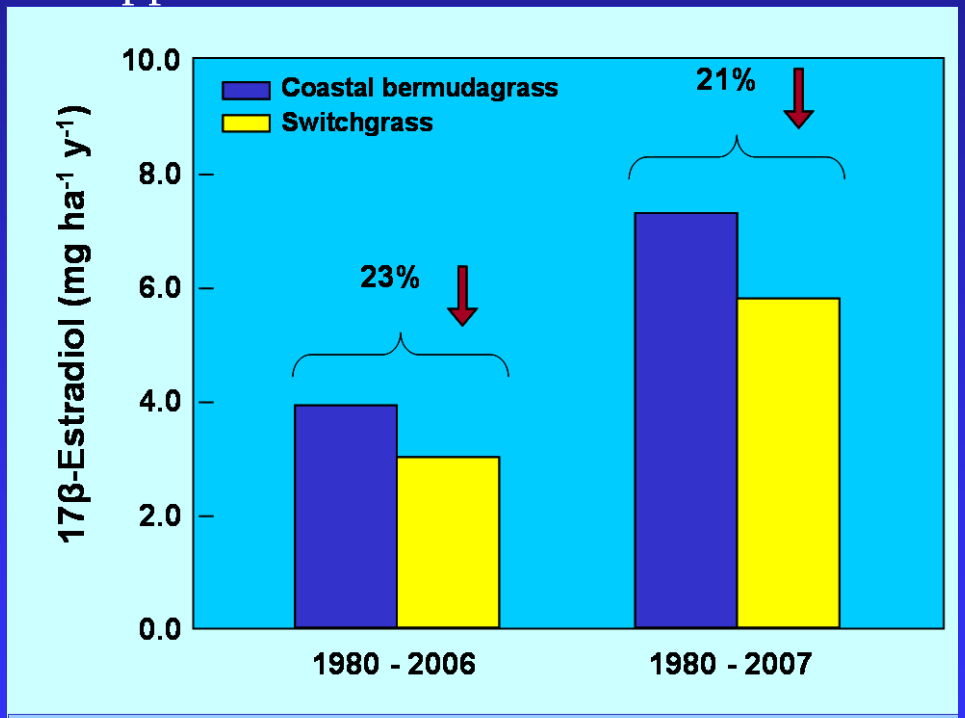
Municipal Biosolids Applications
Fate of Hormones and Antibiotics

- City of Austin, Texas biosolids facility
- Applied to pasture over the last 25 years at differing rates
- Monitoring nutrients, metals, hormones and antibiotics in pasture soils, Colorado River, wetlands, and biota (earthworms)
- Virginia Jin (ARS-Lincoln, NE) and Mari-Vaughn Johnson



Municipal Biosolids Applications
Fate of Hormones and Antibiotics

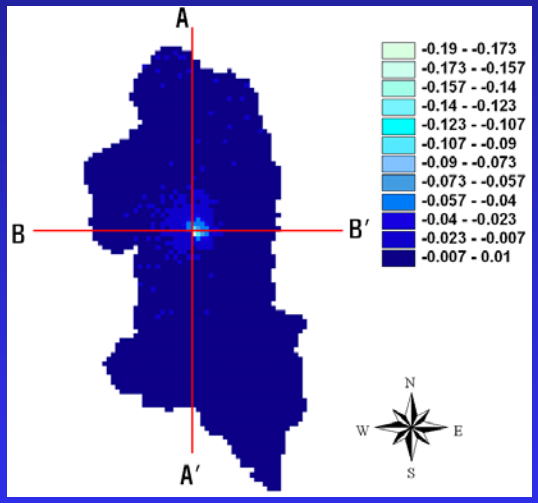
- SWAT used to simulate the amount of estradiol that leaches into the groundwater under different management and climate
- Fate emerging contaminants in rivers at the watershed scale at the Shell River in Nebraska from animal manure applications – (Chehra Aboukinane)

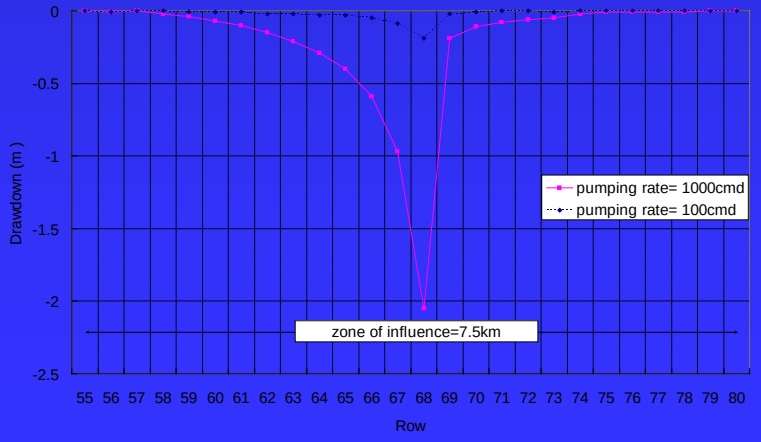


SWAT simulation of 17β-Estradiol leached from the A horizon in Bergstrom silt loam (0-23 cm depth). Note less hormone leaches from deeper rooted switchgrass than from currently cultivated coastal bermudagrass. Also, note the inclusion of the high-rainfall year, 2007, increased soil leaching by almost 90% under current forage-production management.

Korea Institute of Construction Technology

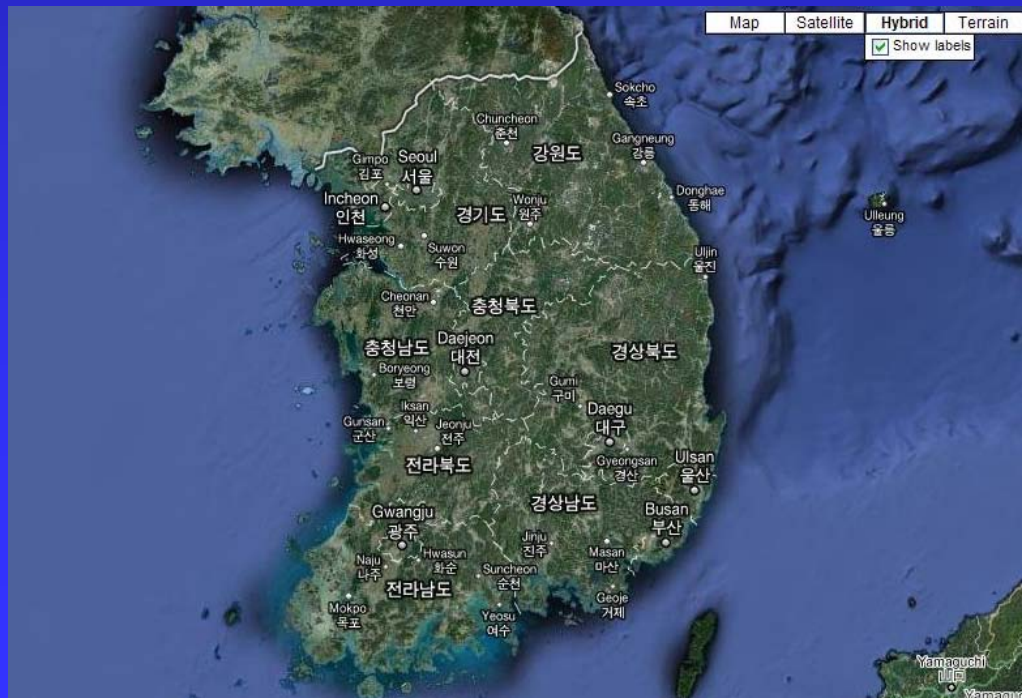
- SWAT-K - Excellent development of SWAT-MODLFOW that allows integrated assessment of surface and groundwater resources
- Numerous improvements to SWAT development and application
- Reservoir operation, forests, rice paddies, SWAT-SWMM, pre and post processors





Korea Institute of Construction Technology

- National Water Resource Assessment of Korea
- Dr. Kim, Dr. Chung and colleagues at KICT are international leaders in water resource assessment and SWAT development
- We encourage KICT to continue regional and global leadership in water resource technology and spread the SWAT-K improvements around the world
- We look forward to continued close collaboration with KICT

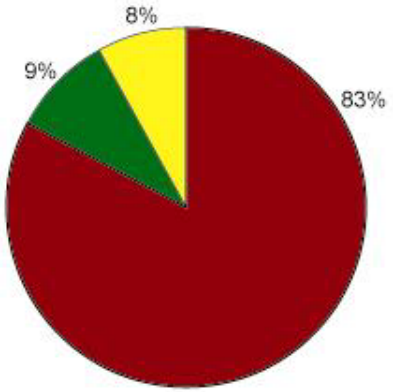


Thank You

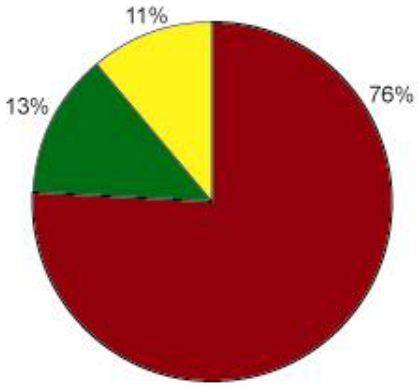

Home
Team
Contact
Links
Soil & Water Assessment Tool
SWAT
Software
Documentation
Publications
Education
Conferences
Applications
Support
Jobs
Welcome to the Official SWAT Web Site
SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds.
SWAT is a public domain model actively supported by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas, USA.
Visit our user groups
SWAT fact sheet
Disclaimer
SOFTWARE UPDATES
ArcSWAT (9/21/2009)
Version 2.3.4 for ArcGIS 9.3 SP1,
Version 2.1.6 for ArcGIS 9.2 SP6
SWATeditor (6/18/2009)
Version 2.1.5 for ArcGIS 9.2; Companion to ArcSWAT
SWAT-CUP
MapWindow-SWAT
VizSWAT Software
SWAT2005 available for download
UPCOMING EVENTS
SWAT Workshops (2/8-2/12/2010) Beginner, Advanced, and Advanced Data Processing for ArcSWAT
2010 International SWAT Conference (8/2-8/6/2010)
Ilsan, Korea
2nd International SWAT-SEA (1/4-1/7/2011)
Ho Chi Minh City, Vietnam
PUBLICATIONS AND PRESENTATIONS
SWAT: Global Applications Book
SWAT Literature Database
MANAGE Database
Comprehensive review of SWAT model paper
2009 5TH INTERNATIONAL SWAT CONFERENCE
Conference information, videos, and presentations
Compact with Texans | Privacy Statement | Accessibility Policy | State Link Policy | Statewide Search | Equal Opportunity for Educational Programs Statement
Risk, Fraud & Misconduct Hotline | Texas Homeland Security | Open Records/Public Information
© 2009 All rights reserved | Web Site Maintenance: twri-webmaster@tamu.edu

NITROGEN SOURCE LOAD

NO PRACTICE



CURRENT CONDITIONS



FULL TREATMENT

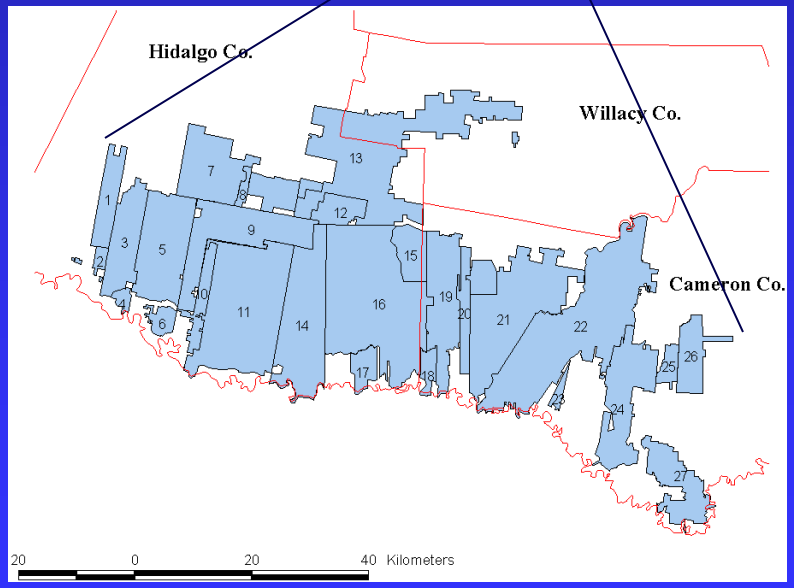
Irrigation Solutions

- SWAT is used as a regional planning tool for determining irrigation demand and water savings from water metering systems, drip and sprinkler systems, canal conveyance efficiency, and crop diversification.

- SWAT was applied in the Rio Grande River in the US, the Indus Basin in Pakistan and several irrigation systems in China

Irrigation Solutions

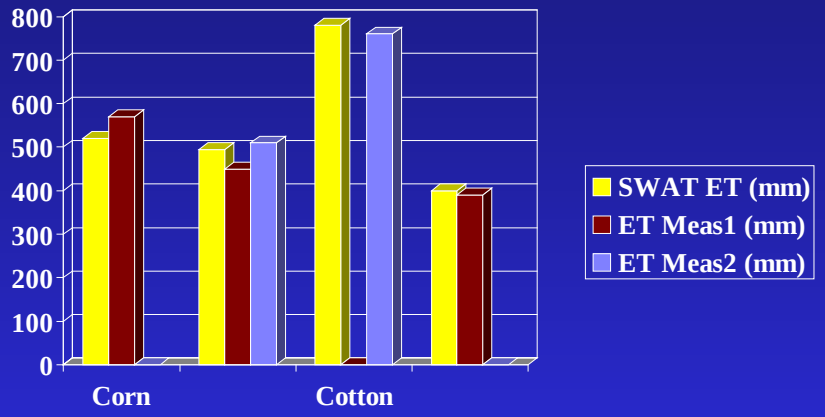
- Lower Rio Grande River – US Mexico border – 27 irrigation districts
- Major crops include corn, grain sorghum, cotton, vegetables, citrus and sugarcane
- 625 mm precipitation
- Water rights – 7,600 m^3 per ha
- Water from Falcon and Armistad Reservoirs on the Rio Grande River



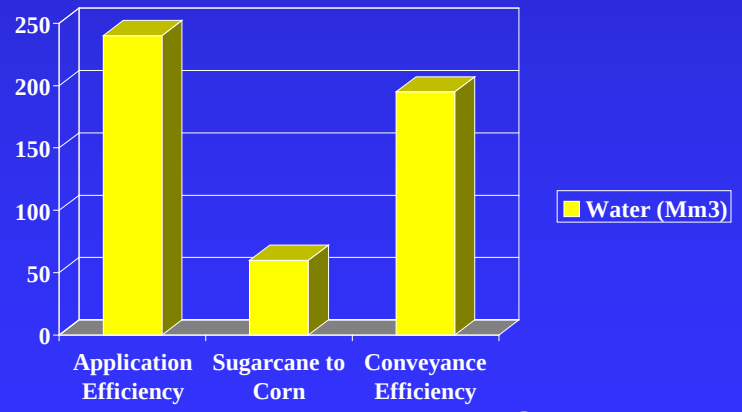
Irrigation Districts

Irrigation Solutions

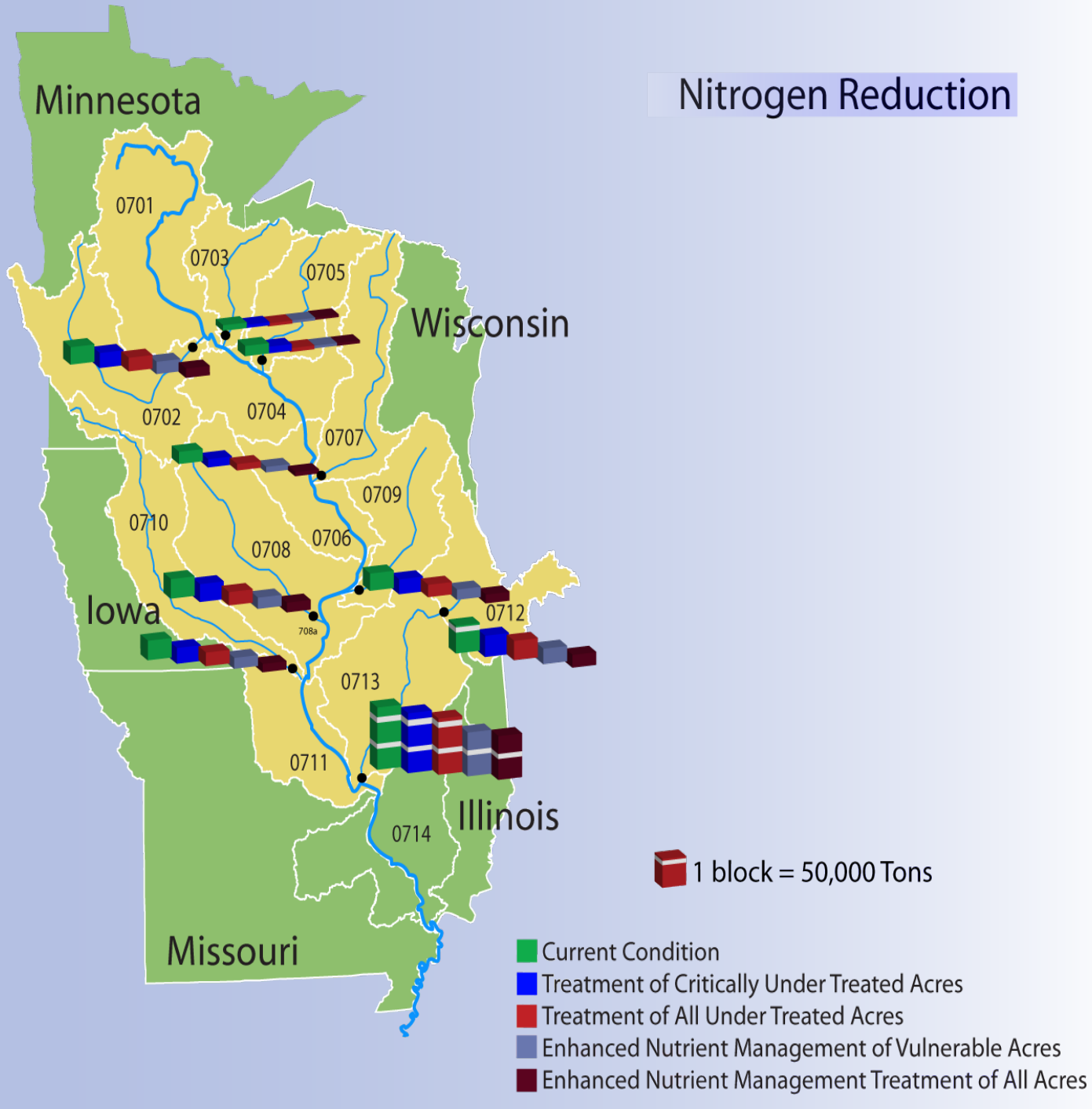
Model Validation
- **Crop Yields**
- **Canal conveyance efficiency**
- **Evapotranspiration**



Management Scenarios
- **On-farm efficiency (metering, poly pipelines, drip and sprinkler systems)**
- **Conveyance efficiency (canal losses-5-10%)**
- **Replacing sugarcane with corn**



Water savings – millions m^3 per year


Nitrogen Reduction
Minnesota
Wisconsin
Iowa
Illinois
Missouri
0701
0703
0705
0702
0704
0707
0709
0710
0708
0706
708a
0712
0713
0711
0714
1 block = 50,000 Tons
Current Condition
Treatment of Critically Under Treated Acres
Treatment of All Under Treated Acres
Enhanced Nutrient Management of Vulnerable Acres
Enhanced Nutrient Management Treatment of All Acres