Water Consumption and Water Quality Modeling of Energy Systems

May Wu, Ph.D.

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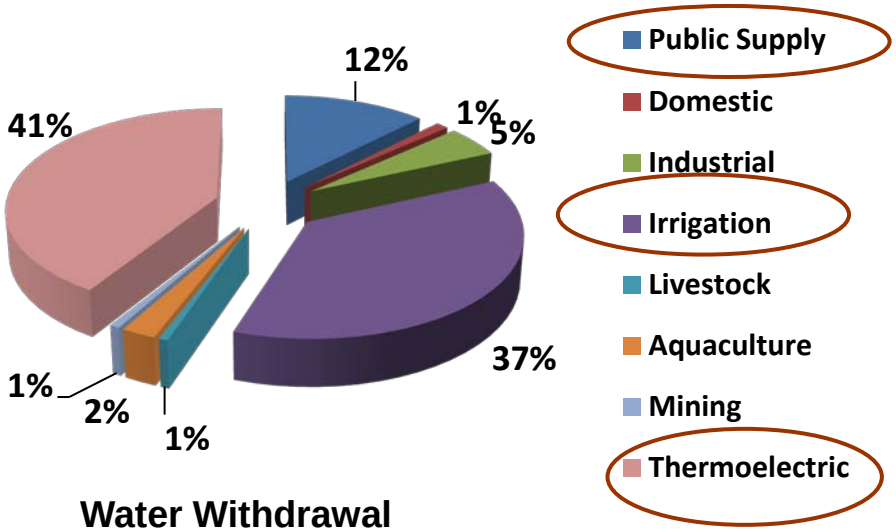
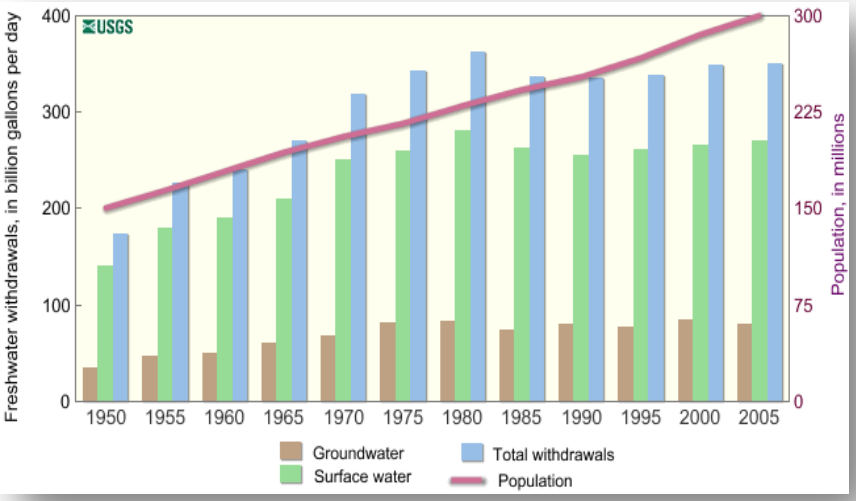
Energy-Water Nexus

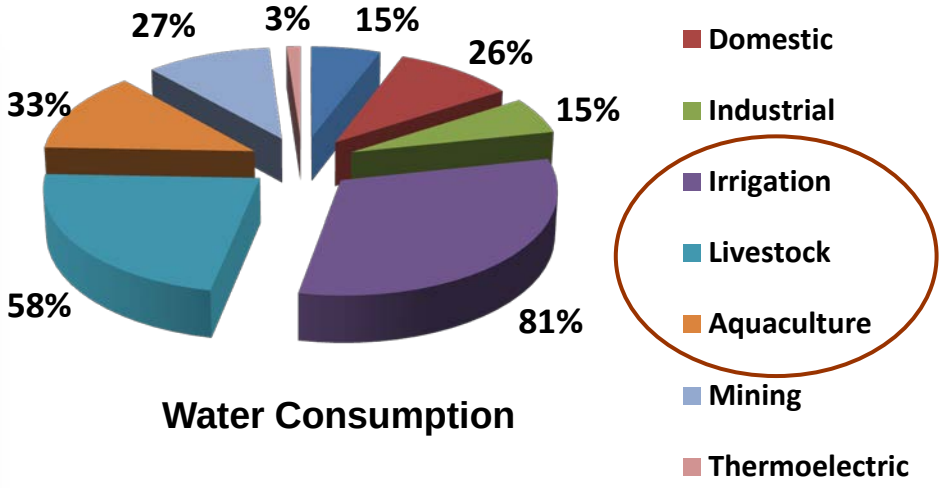
- Energy production requires water (cooling, process water, irrigation for biofuels); water production requires energy (electricity to transport)
- Dynamic relationship between energy security and water sustainability that
  - Crosses different economic sectors
  - Crosses different geographic regions
  - Impacted by climate change

Historical Water Use Overview



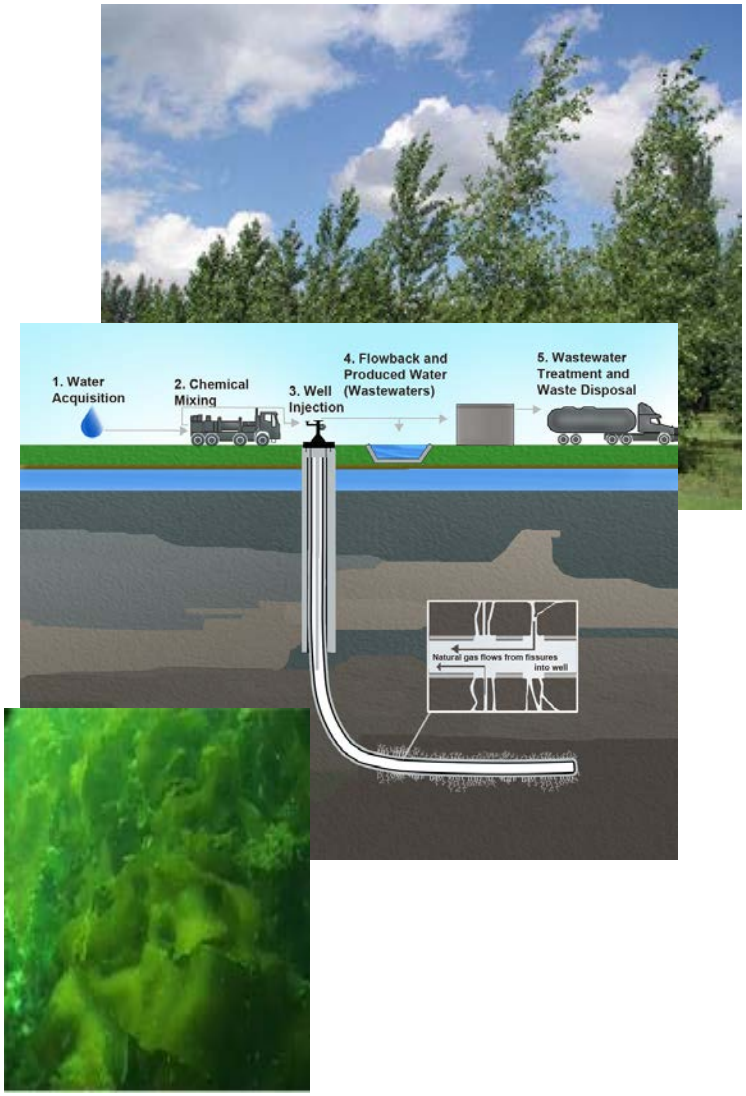
Water Withdrawal





Water Consumption

Increased Demand from New Feedstock and Emerging Resource



- Large volume of water in short period of time in initial injection stage for shale gas – fracking
- Potential ground water resource change impacting hydrology
- Water resource requirement in growing season may compete with demands from other sectors, sometimes in arid regions
- Potential water quality issues: waste fluid contaminants of concern from fracking include
  - Oil and grease
  - NORM (naturally occurring radioactive material): barium and radium.
  - TDS

Distinctive Attributes

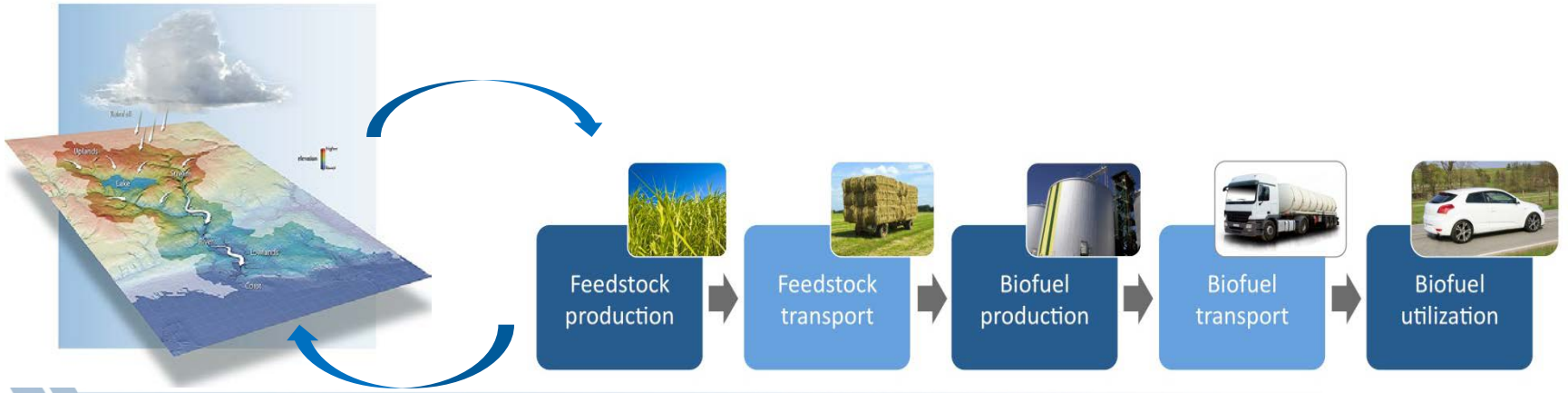
- Water resource varies regionally and locally
- Affected by climate, soil, and land cover
- Governed by hydrologic cycle
- Strained by population growth and new industry project development
- Increased demand could lead to increased wastewater discharge
- Competing water use in a local area could cause compounding effect on water quality

Developing Water Analysis for Biofuel Production

- Examine land availability, climate, soil, and water resource factors.
- Develop a region-specific biofuel feedstock mix for a water-sustainable biofuel production.
- Incorporate local water resource constraints, in addition to economic and infrastructure considerations, in biorefinery siting.

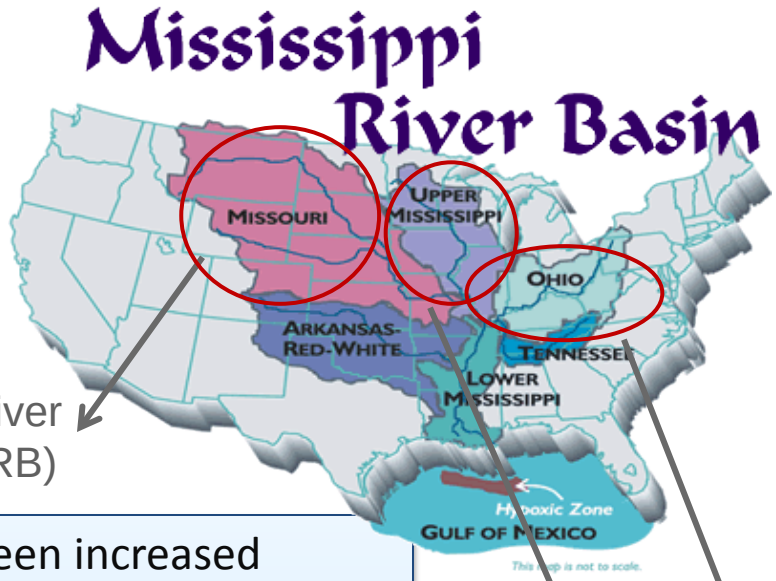
Analytical Framework for Water Analysis

- Develop analytical framework integrating water quality modeling with water use accounting
- Addresses water quality in tributary basins of Mississippi river basin by developing watershed models.
- Considers water consumption across biofuel production supply chain with a focus on feedstock production and refinery
- Characterize spatial-explicit water footprint of biofuels produced from conventional crops, agricultural residue, perennials, and forest resources, algae biofuel.



SWAT (Soil Water Assessment Tool) Modeling

- Large scale river basin modeling to simulate impact of increased production on water quality (nitrogen, phosphorus, suspended sediments)



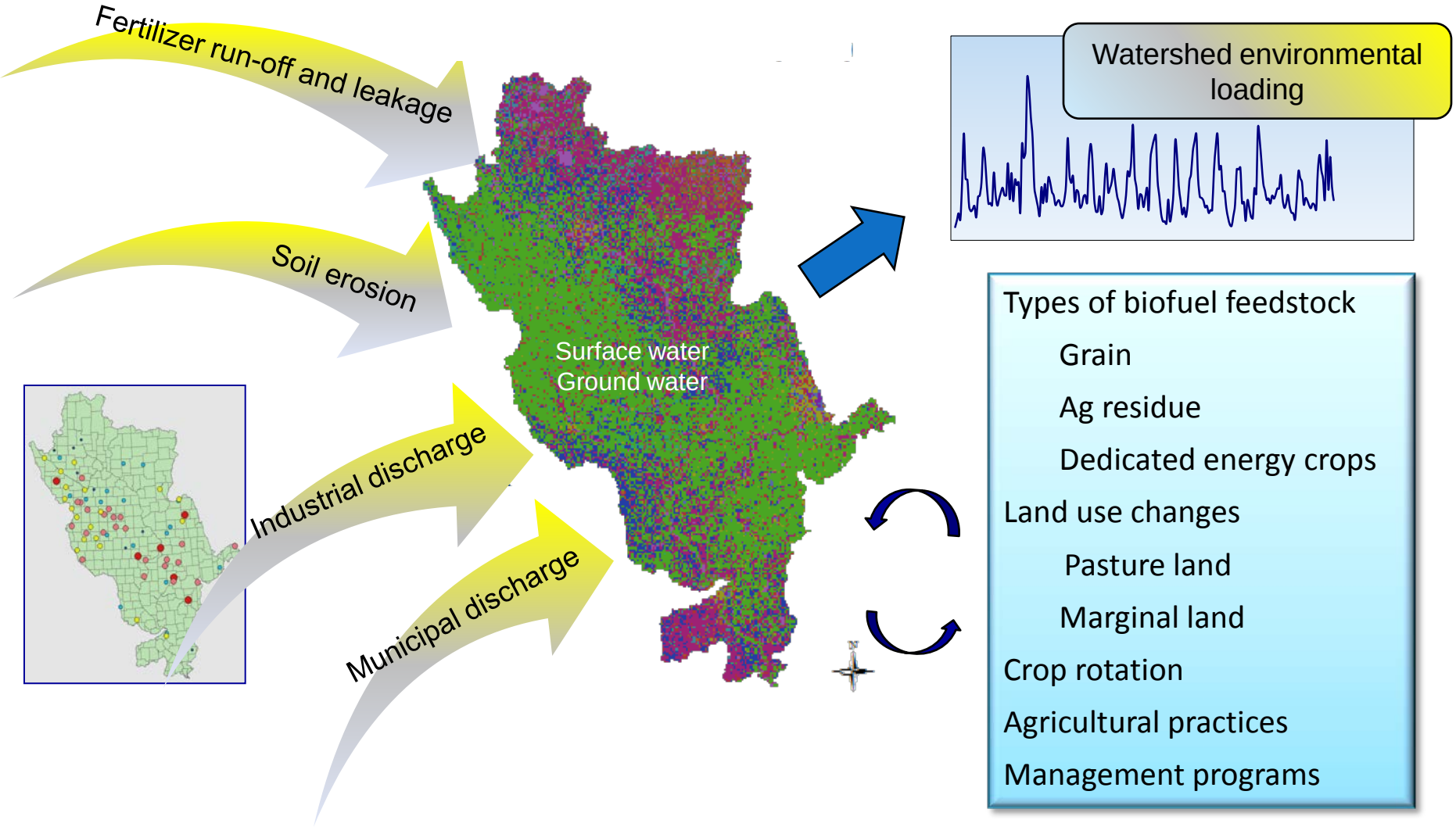
Missouri River Basin (MoRB)

Ohio River Basin (ORB)

Upper Mississippi River Basin (UMRB)

- Advance understanding of the relationship between increased feedstock production through land use change and water quality impact at watershed scale.
- Examine projected future biofuel production and simulate its impact.
- Identify region-specific scenarios that are able to increase water-use efficiency and reduce potential negative impacts.
- Assist in a variety of management decisions and protection strategies to meet regulatory limit and sustainability criteria

Examine Options to Meet Sustainability Requirement for the Biofuel Production System



- Types of biofuel feedstock
  - Grain
  - Ag residue
  - Dedicated energy crops
- Land use changes
  - Pasture land
  - Marginal land
- Crop rotation
- Agricultural practices
- Management programs

Biofuel Feedstock Specific Application

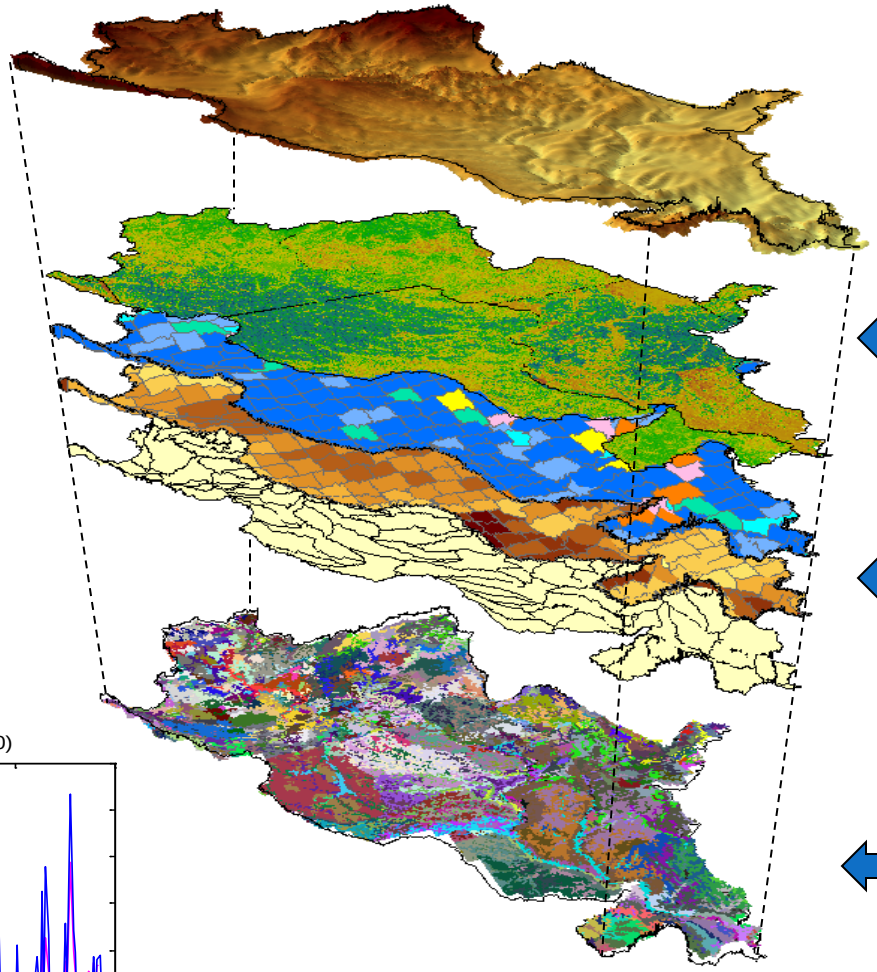
Ground surface topography

Water use

Sub basin

Others:

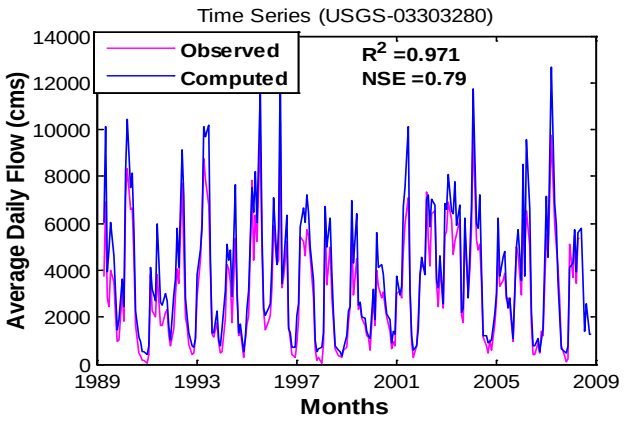
Climate, Tile drainage, Tillage, Point source, and Reservoirs



Land use, crop rotation

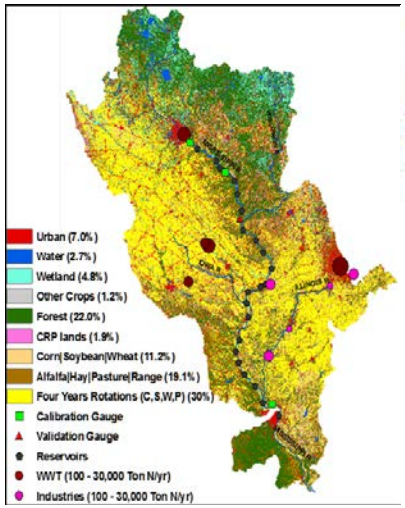
Fertilizer

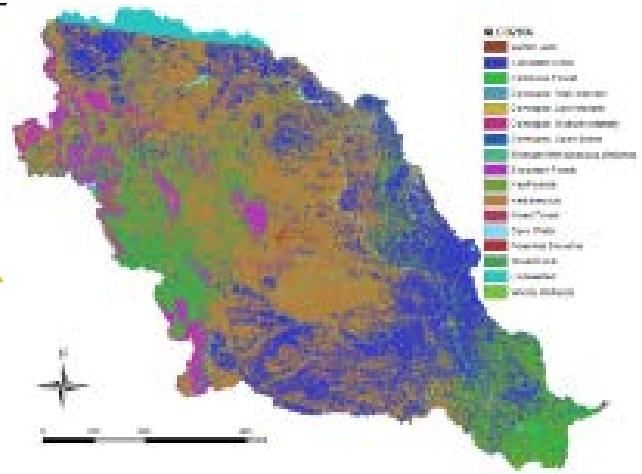
Soil type



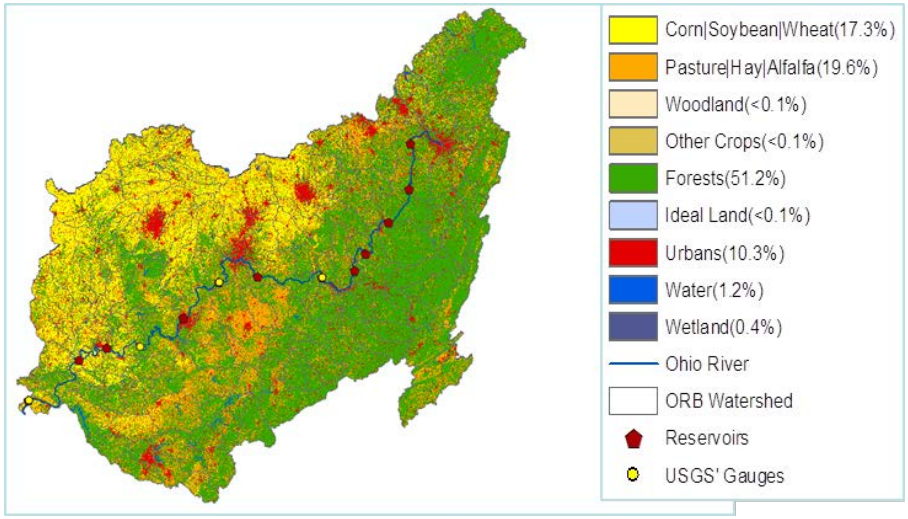
Model calibration and validation with 20 years hydrologic data

SWAT Model Application for MRB Tributary Basins

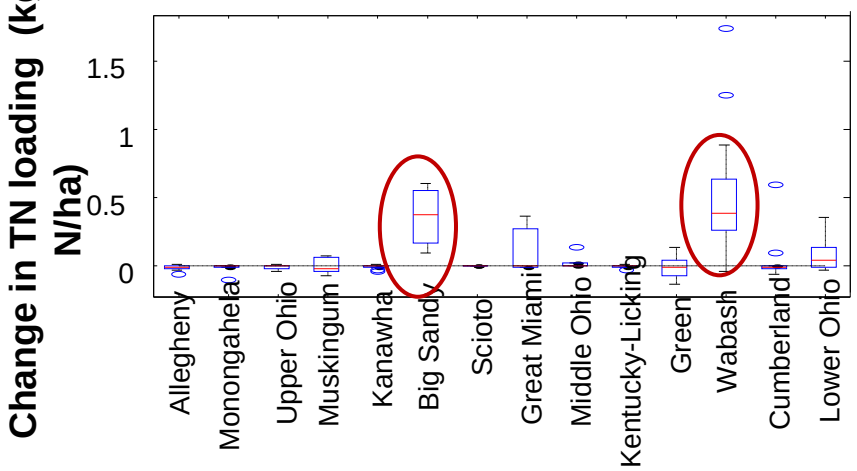




- Simulating several management schemes and comparing their impacts on **N, P, and SS loadings**
- Identify sub basins that have shown strong response to a change in stover harvest, crop rotation, and fertilizer application rate.



Response to stover removal

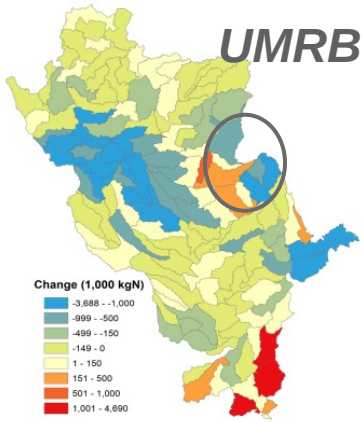


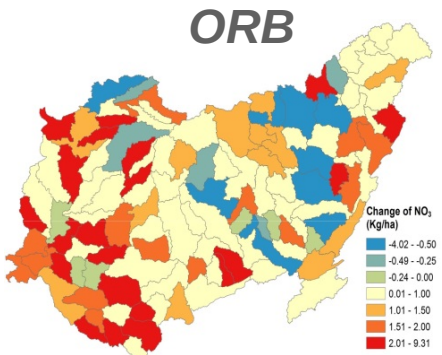
SWAT Enables Analysis of Future Production and Climate Impacts

- Increased production
- Increased production with climate change
- Results mixed
  - Evapotranspiration ↑ Runoff ↓
  - N, P ↓↑ Sediment ↑↓

Change of Nitrate Loadings

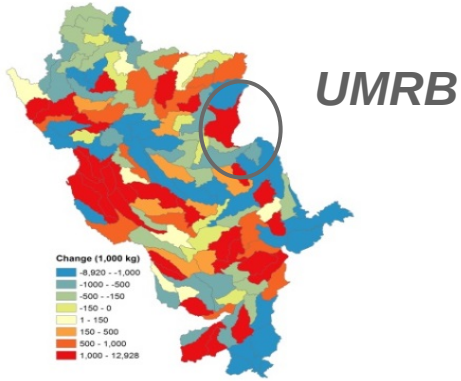
Increased production from 2006-2022



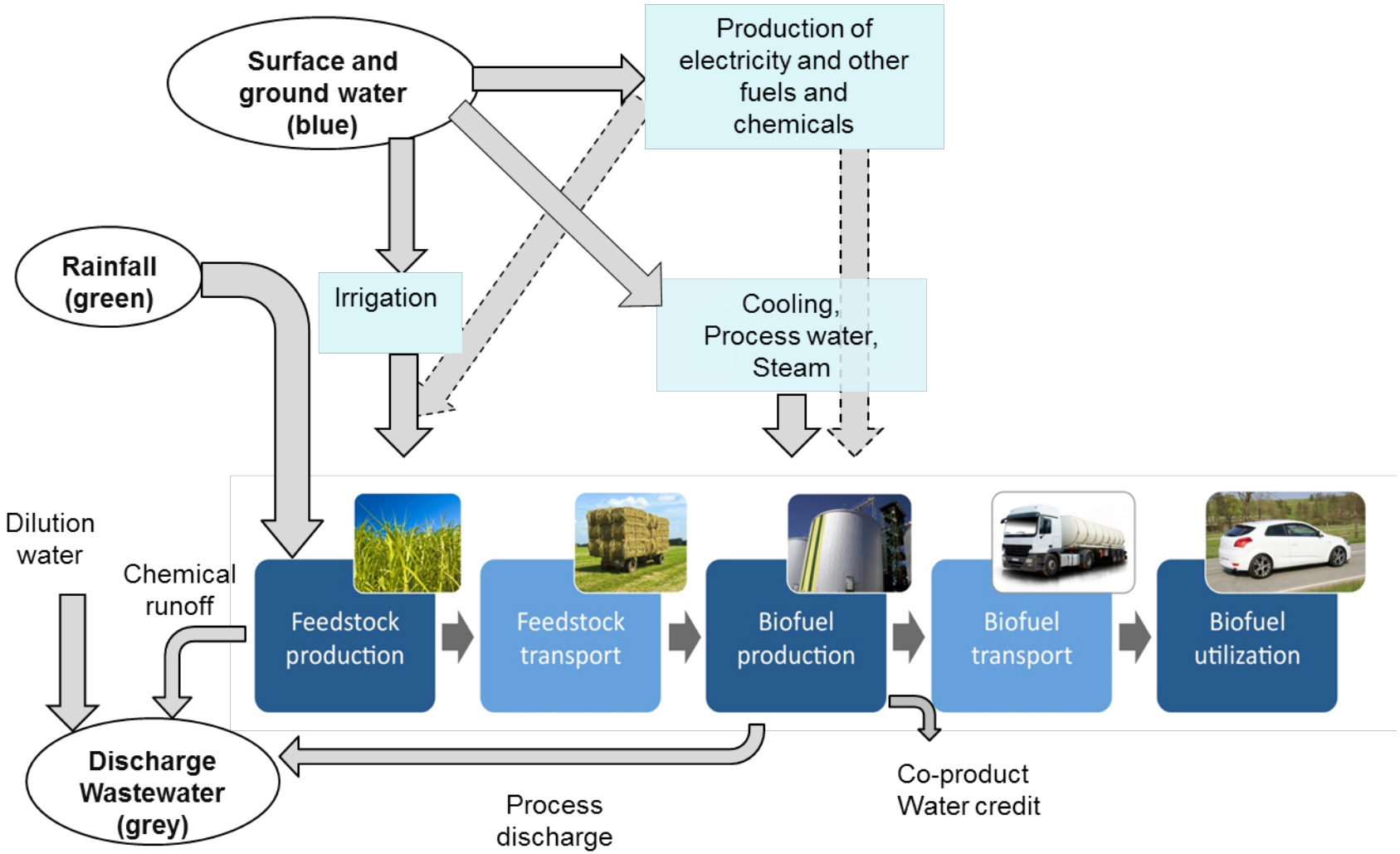


Increased production with response to climate change

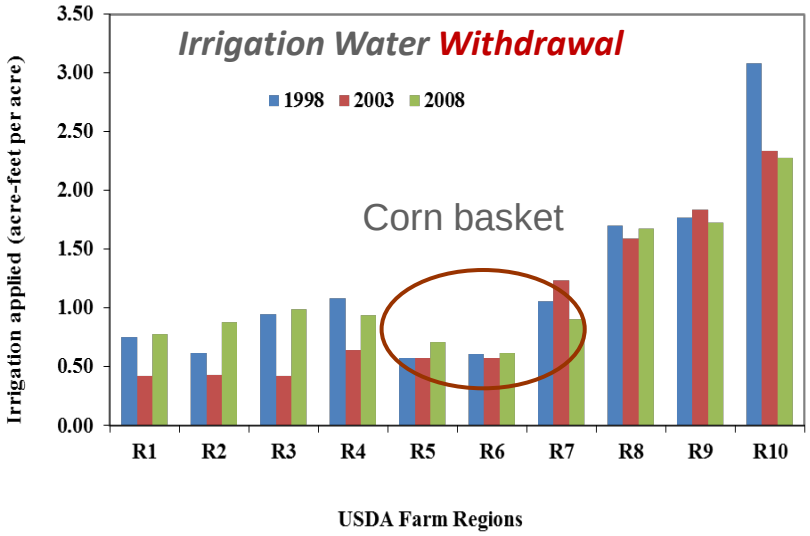
- Identify potential hot spot and assist evaluating mitigation program that could reduce negative impact

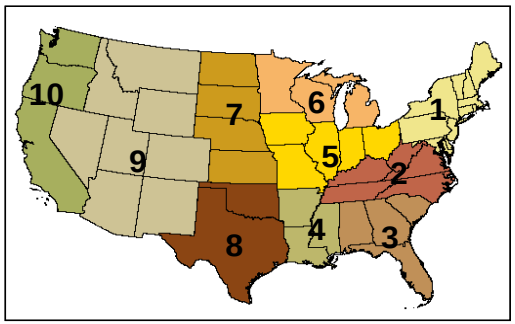


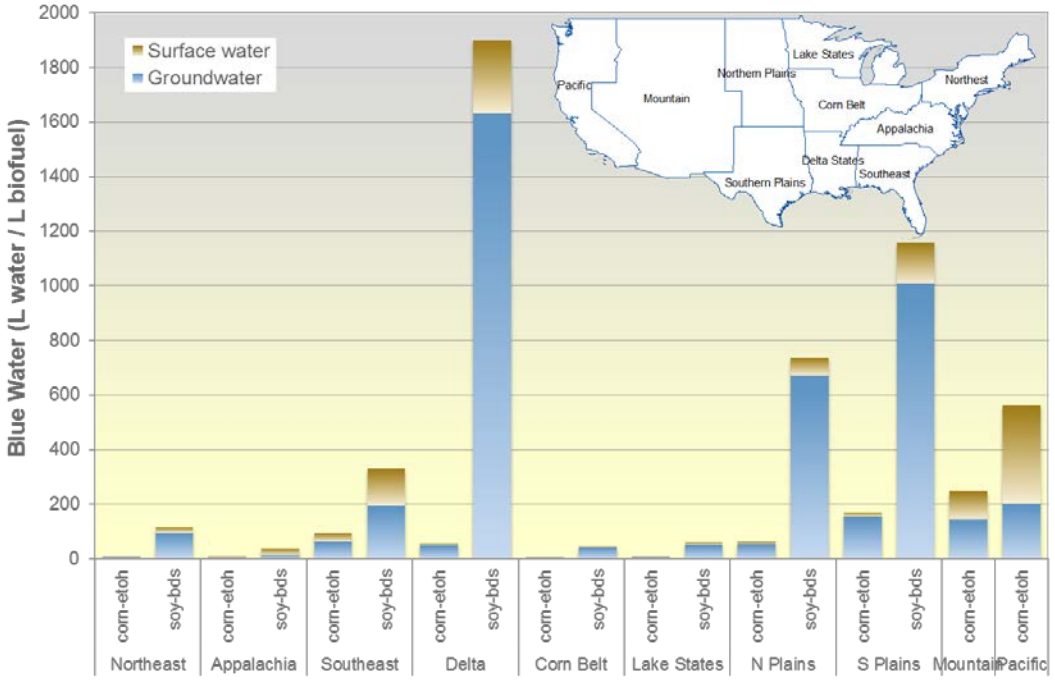
Water Footprint Accounting



Substantial Spatial and Temporal Variability

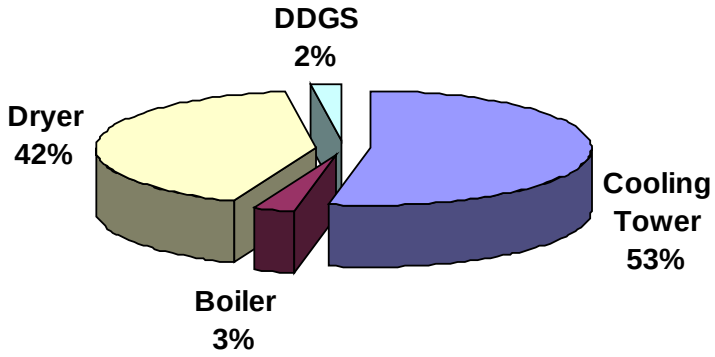


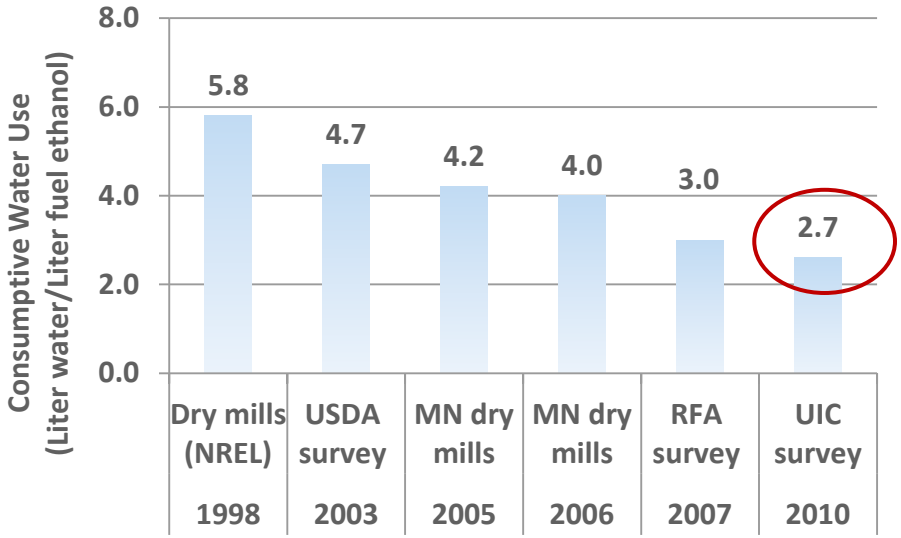




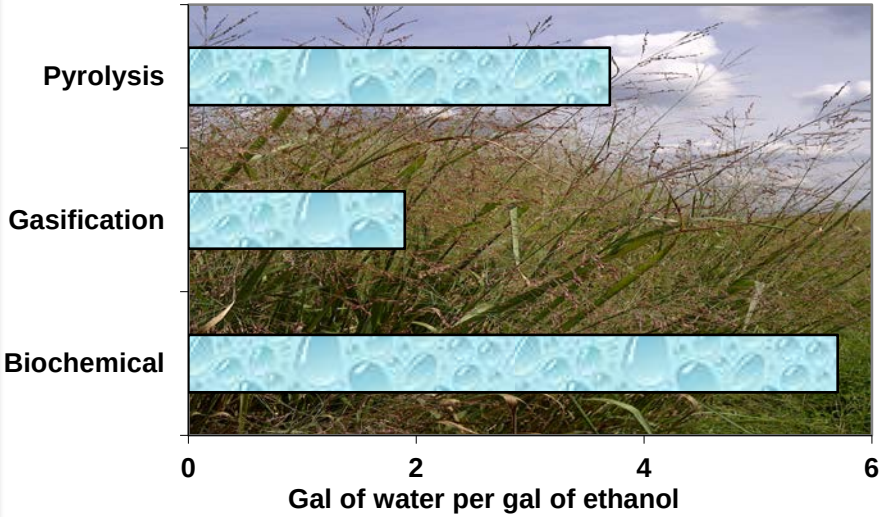
Water Use in Biorefinery Varies with Feedstock and Conversion Process

Conventional biofuel - Corn dry mill

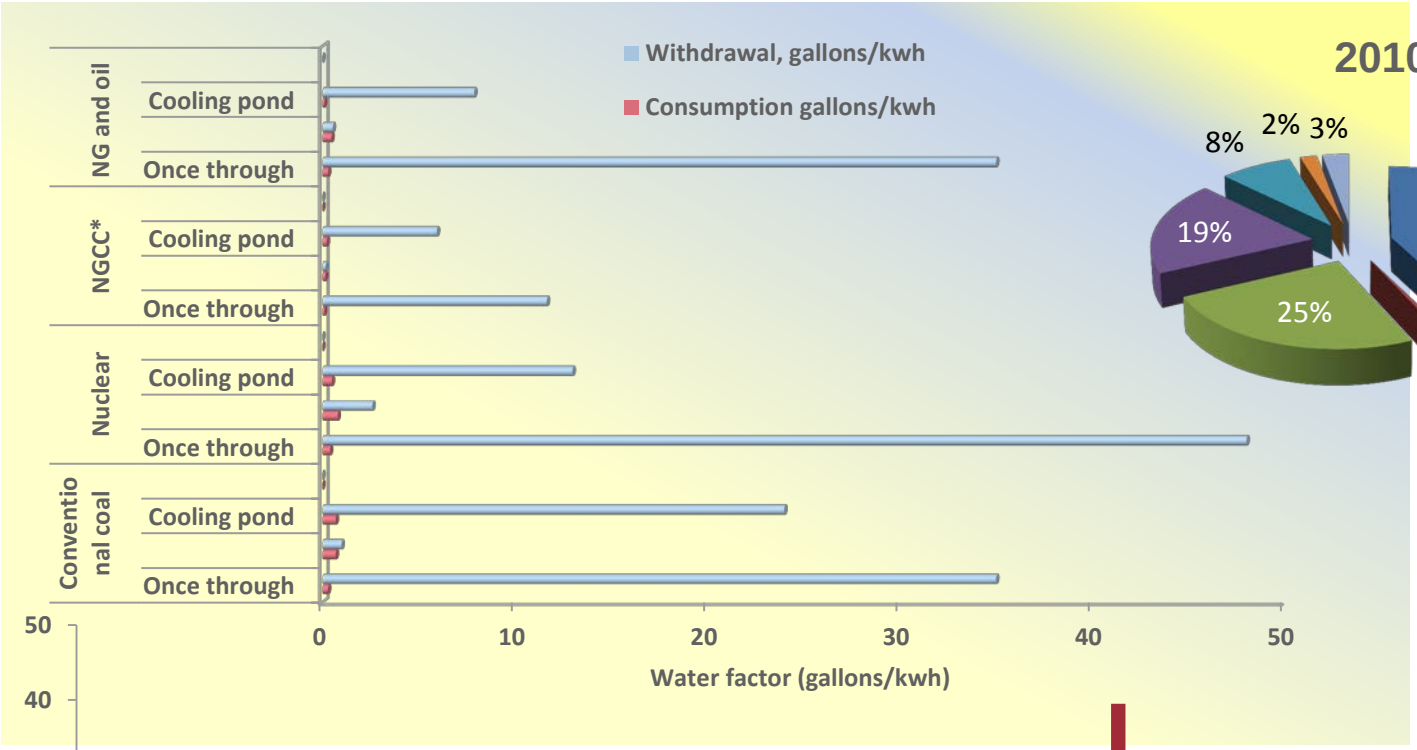


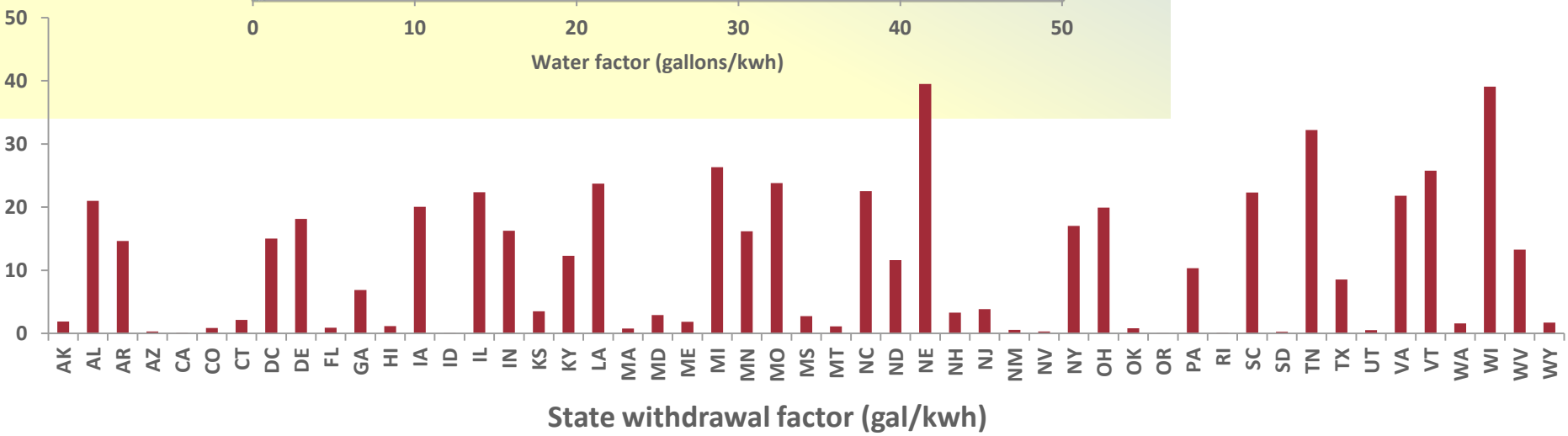


Cellulosic biofuel - Biorefinery



Water Intensity in Electricity Generation





Power-Water Tool

Water Use in Electricity Generation Model (WEGM)

This spreadsheet-based tool has
for the 50 states in the United S
technology, and cooling system
the inventory. It also incorporat
data inventory and the tool cov
such, the tool allows decision m
future water use in electricity g
examine how changes in fuel sc
fuel sources and technologies fr
water resources associated with

Developed by Center for Transportation
97000 S. Cass Avenue, Argonne, IL 6043

State Selection

AK	IL	ND	TN
AL	IN	NE	TX
AR	KS	NH	UT
AZ	KY	NJ	VA
CA	LA	NM	VT
CO	MA	NV	WA
CT	MD	NY	WI
DC	ME	OH	WV
DE	MI	OK	WY
FL	MN	OR	
GA	MO	PA	
HI	MS	RI	
IA	MT	SC	
ID	NC	SD	

US (All states in charts)

Reset

Scenario

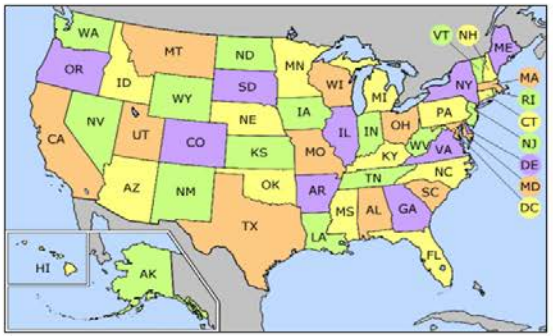
- Current (2005)
- Current (2005) + Historic (2000) *
- Future Prediction

Click Here To Enter Future Predictions

* Historical data are presented in tables.

Cooling Type Selection

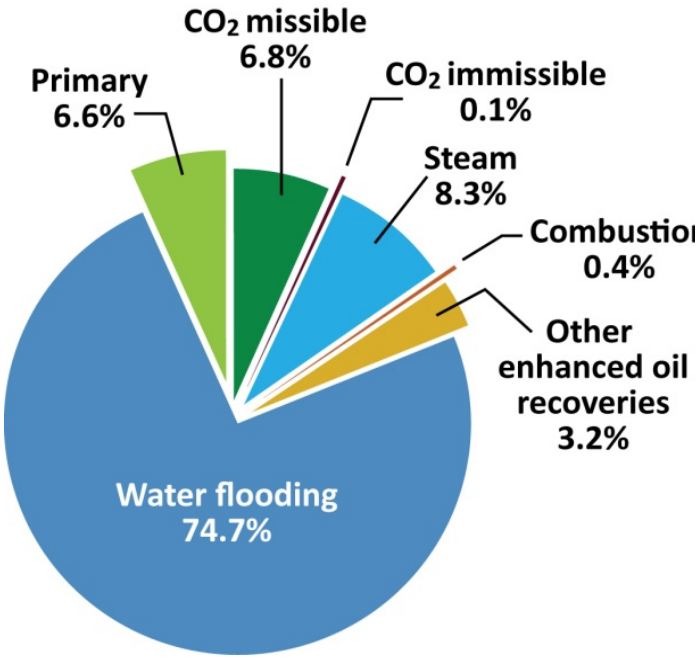
- Once Through
- Recirculating
- Cooling Pond
- Dry Cooling
- All Type

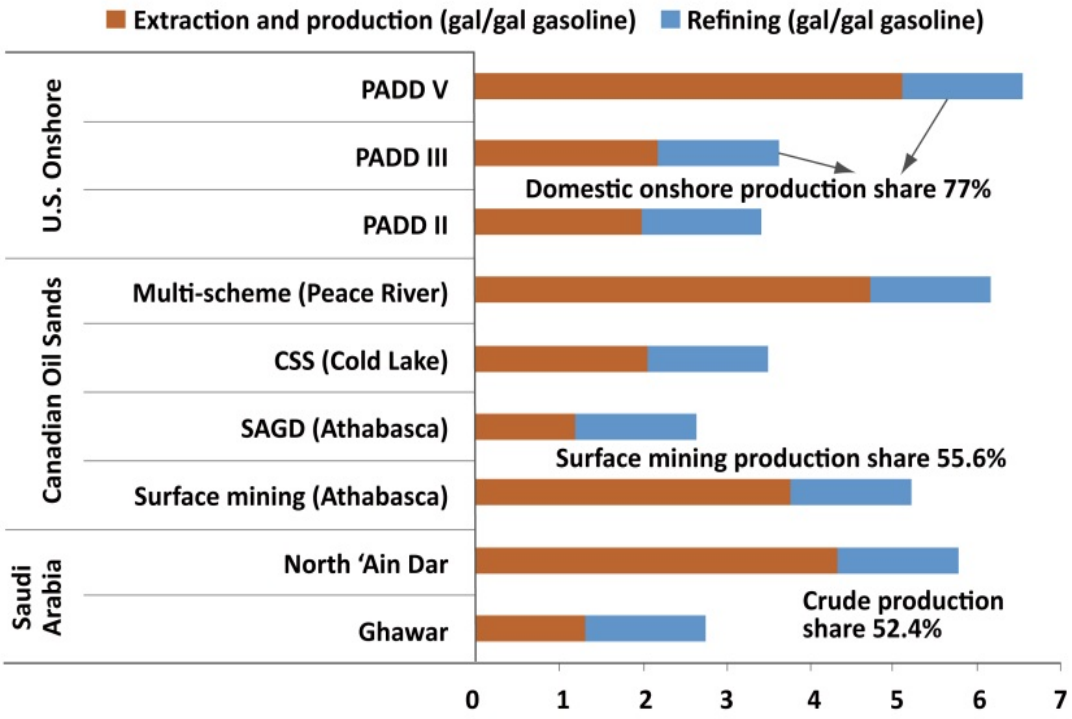


States: None
Cooling Type: All Type Cooling
Scenario: Current and Historic
Future Prediction:

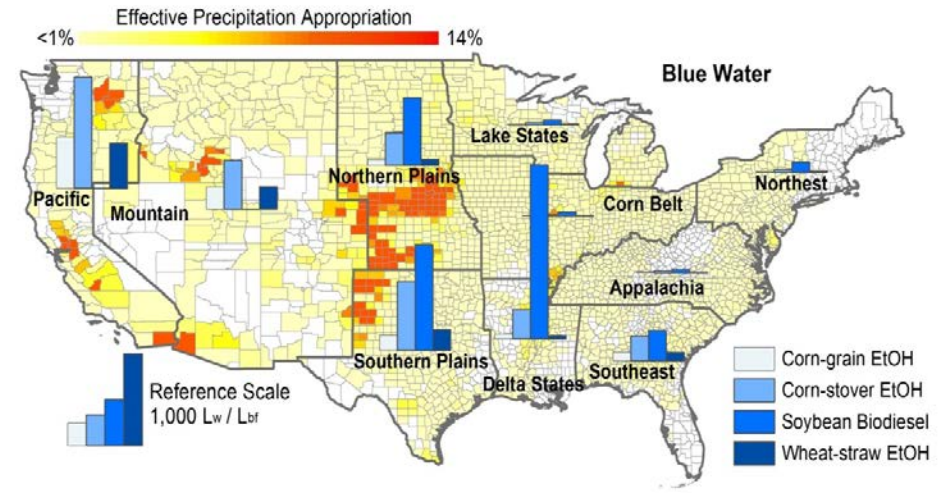
http://greet.es.anl.gov/publication-watertool

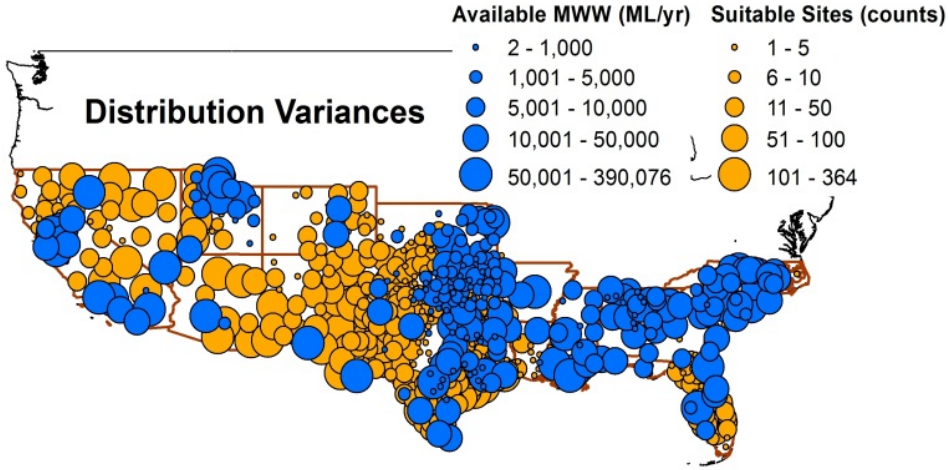
Water Use for Petroleum Oil Production





Water Intensity of Biofuel Produced from Corn, Soybean, Wheat Straw, and Algae

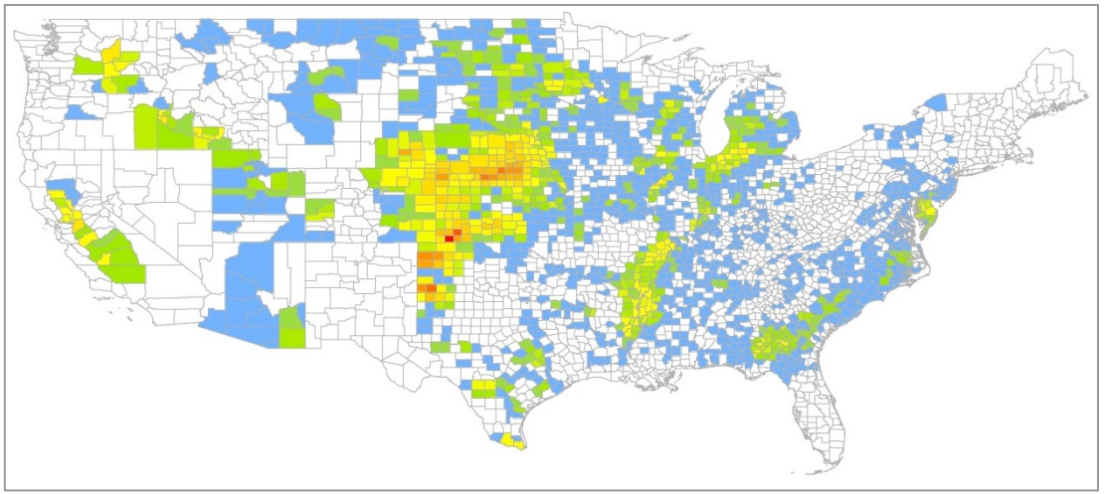




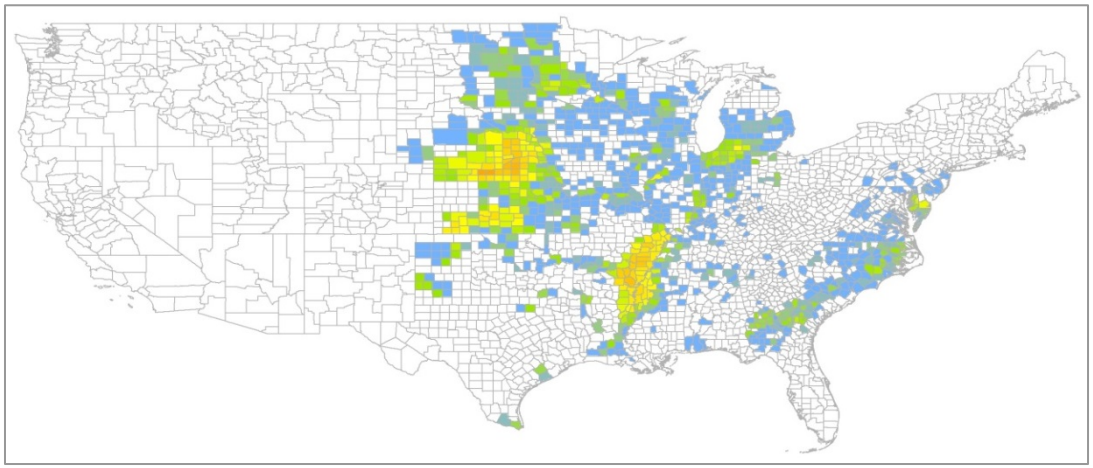
- Substantial variability in water footprint across feedstock and regions
- Identify water stress hot spot to address water availability issue
- Geographic mismatch between the alternative water source (MMTW effluent) and potential refinery location
- Availability of wastewater from WWTP lessened by increasing use for cooling in thermoelectric power plant

Evaluating Impacts on Water Resources

About 30% of US corn and 12% of soybean went to biofuel production



Corn



Soy bean

Percent of Annual Precipitation used for Irrigation (2008)

Blue Water Consumption in the Production of Energy and Fuels

Surface and ground water consumed to drive a passenger car for a mile

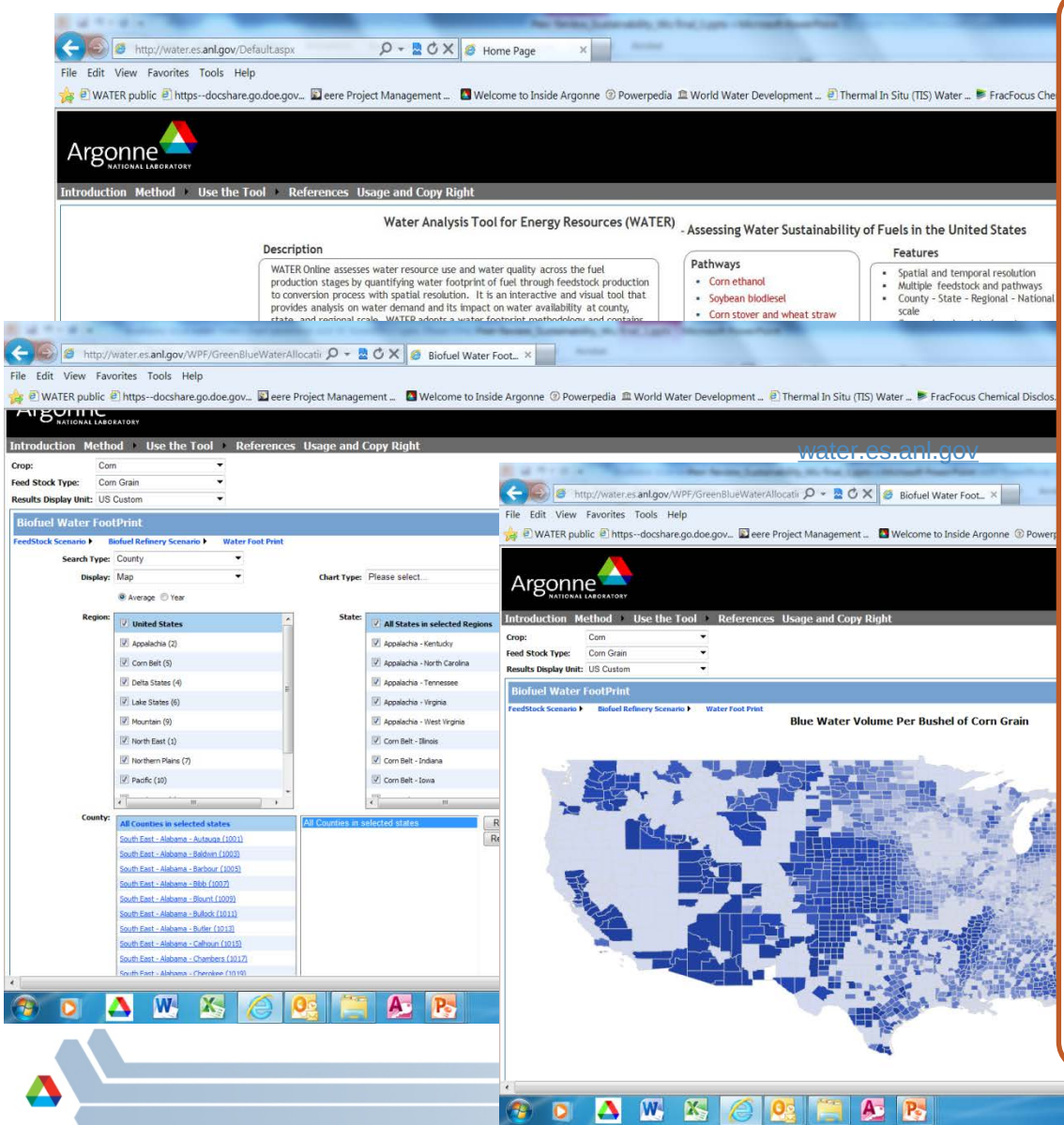
Corn ethanol:	0.7–10.4 gal	Midwest regions
Cellulosic ethanol:	0.1–0.3 gal	Non-irrigated perennial/wood residue
Petroleum gasoline:	0.1–0.3 gal	Onshore United States, Saudi Arabia, oil sand

Water consumed to generate one million btu of electricity in power plant *(gallons)*

U.S. Average Mix	**164**
Wind	0
• Geothermal	3 – 214
• Natural gas	6 – 202
• Biomass	12 – 179
• Nuclear	41– 249
• Solar	9 – 310
• Coal	18 – 439
• Hydroelectric	586

WATER (Water Assessment Tool for Energy Resources)

water.es.anl.gov



Production pathways

- Corn ethanol
- Soybean biodiesel
- Corn stover
- Wheat straw ethanol
- Perennial ethanol*
- Forest resource biofuel*

Features

- Interactive web model
- County, state, region
- Blue, green, grey water
- Land use and fuel production metrics
- Map, table, chart display

Project team members

Y. Chiu, Natural Resources

S. Yalamanchili, Engineering

D. Lampert, Engineering

Y. Demissie, Hydrology

E. Yan, Geology

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- NREL: Eric Tan, Abhijit Dutta
- PNNL: Lesley Snowden-Swan
- SI: Amy Schwab, Andrew Argo

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