Achieving Water-Sustainable Bioenergy Production

May Wu
Argonne National Laboratory

Session 3–A:

Growing a Water-Smart Bioeconomy

BioEnergy 2015 Conference

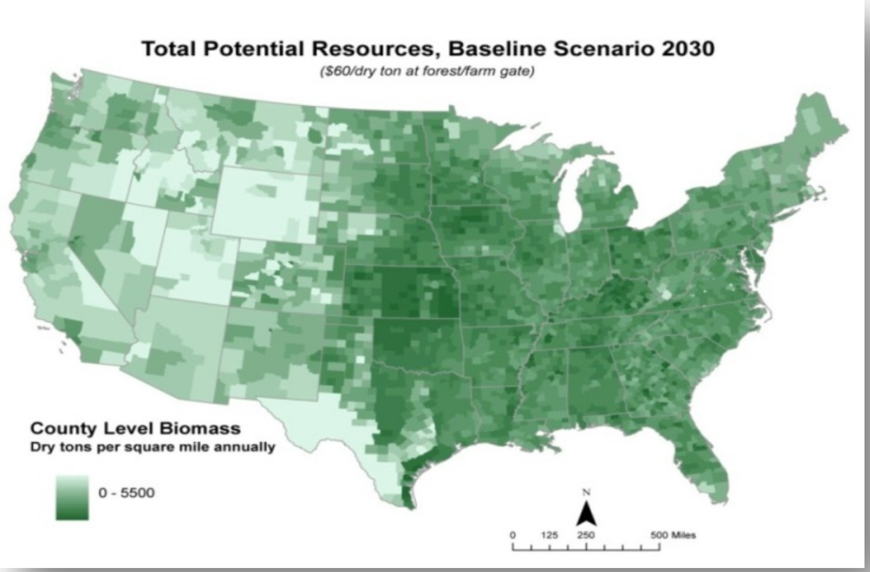
June 23–24, 2015
Washington, DC

Water Energy Nexus

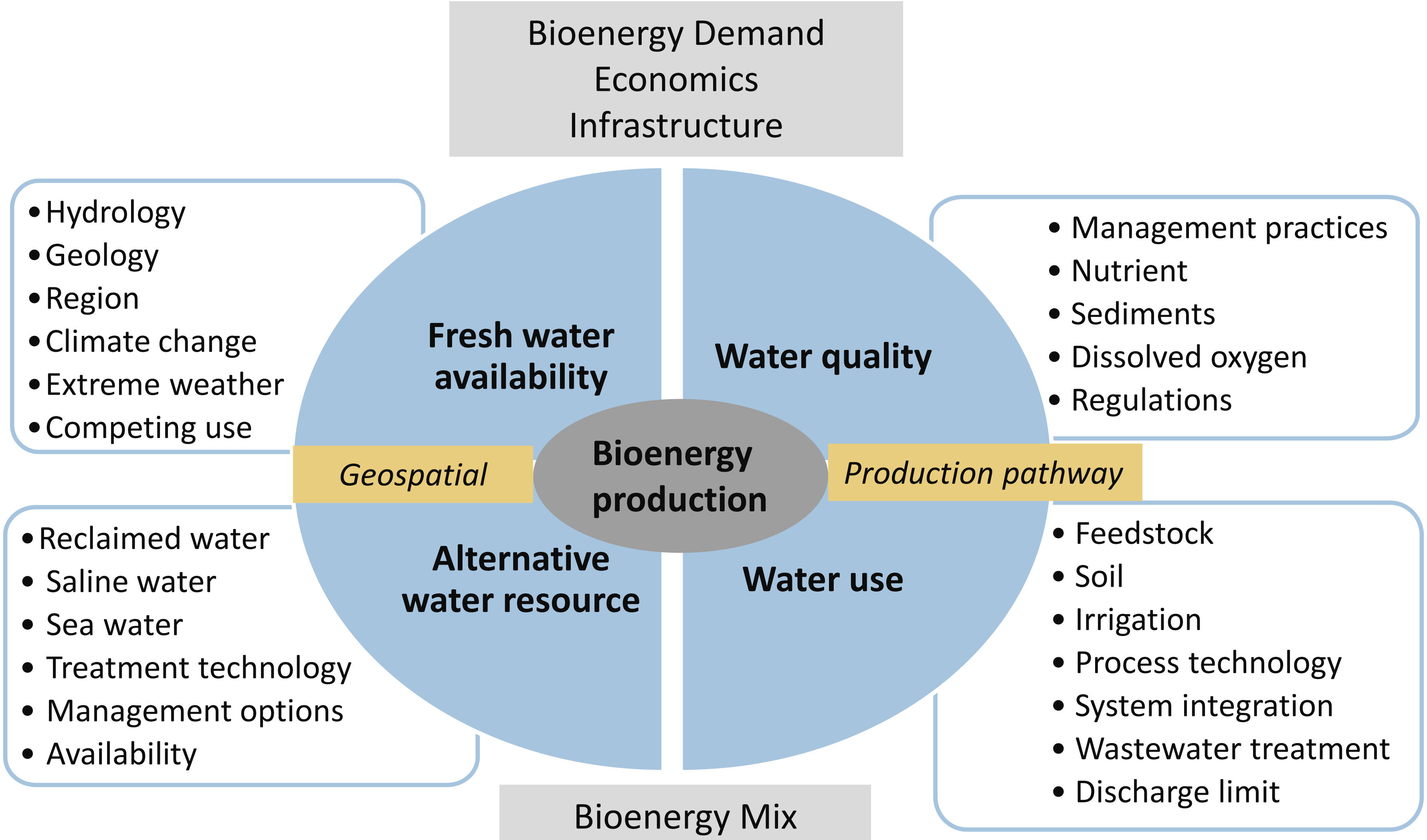
- Water and energy are intertwined. Energy production requires water resource; water supply needs energy. A growing population demands increased supply of water, food, and energy.
- Energy and fuel production and water sustainability have a dynamic relationship. Increased water stress could disrupt their production, and its ripple effect can be felt across various regions in multiple sectors.
- The production of energy and fuels (conventional, unconventional, and renewables) demands water resource withdrawal:
  - Shale gas: Large volume of water required in short period during initial fracking
  - Conventional biofuel feedstock: Irrigation
  - Thermoelectric power plant: Cooling
  - Fuel processing/refining: Process water, steam, cooling

Water for BioEnergy

- Water demand is a regional issue. The extent of water stress varies substantially with geographic regions and is impacted by climate change.
- According to the forecast (IPCC), the world may experience increased flood and draught in various regions currently producing food, feed, and biofuel feedstock.
  - A shift in the frequency and intensity of precipitation and heat waves
  - Changes expected to be spatial and temporal
- Cellulosic biomass feedstock of 1.1 billion dry tons is potentially available for biofuel production by 2030, which would replace 30% of the nation's current petroleum consumption.
  - A majority of current biofuels consists of conventional crops, for which about 11–13% is irrigated.



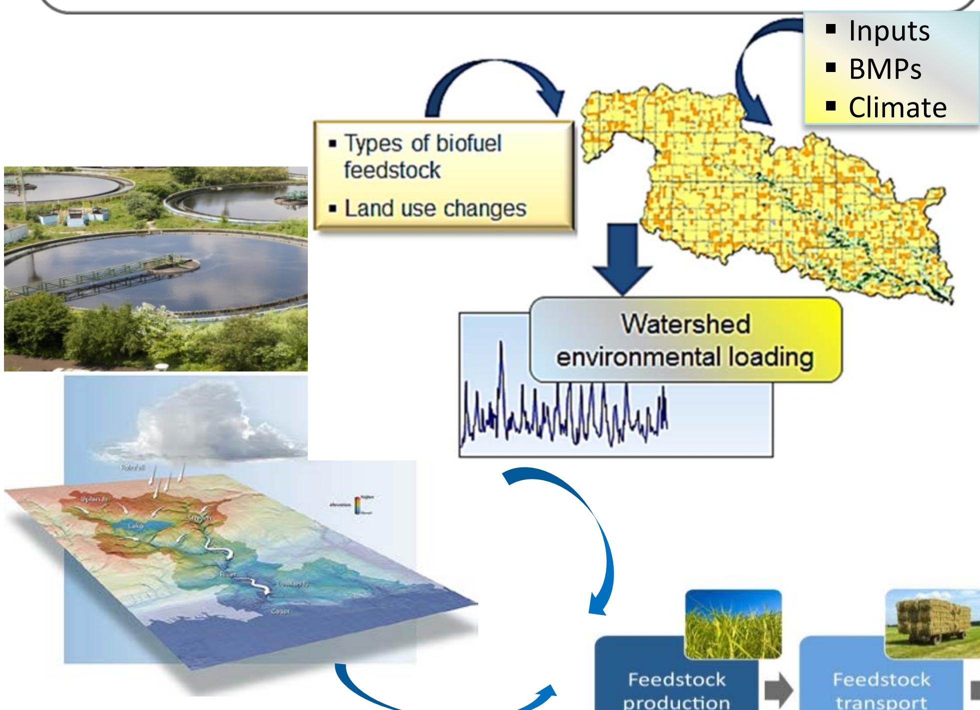
Bioenergy Water Sustainability

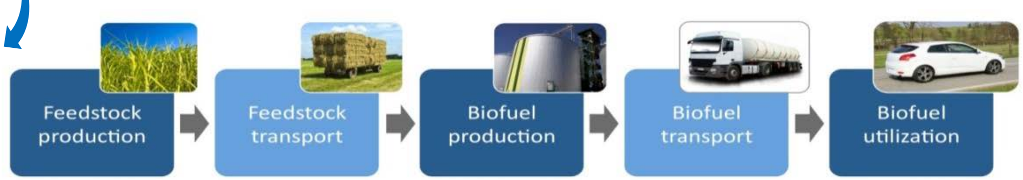


Assessment of Bioenergy Water Sustainability

- Develop analyses on the water use associated with U.S. bioenergy and bio-products production
- Provide tools to quantify impacts on water quality and resources at multiple scales

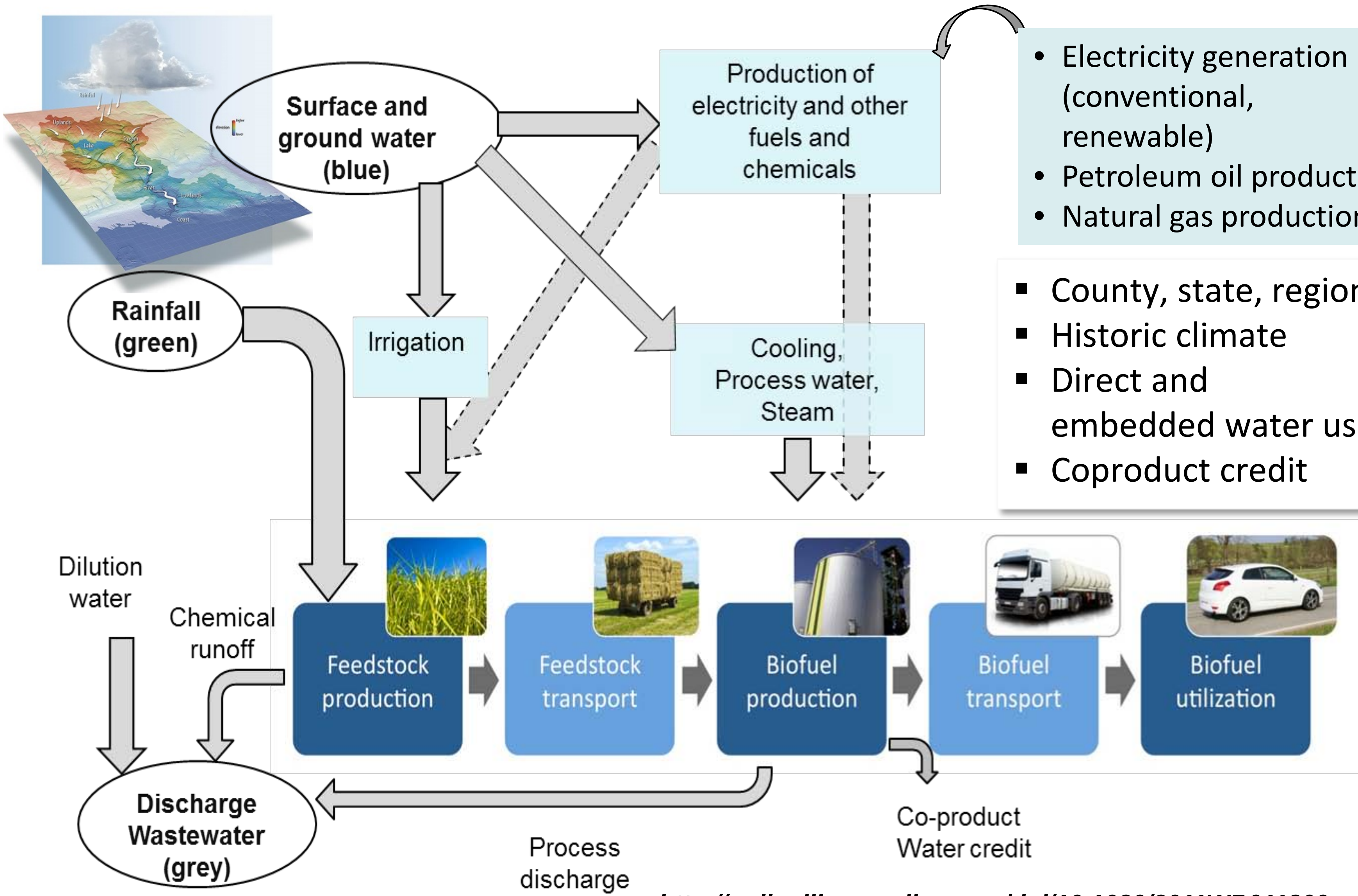
- Evaluate management practices and technologies in bioenergy landscape that protect water resources and increase water-use efficiency
- Identify scenarios that are able to improve water sustainability of advanced bioenergy
- Consider geospatial resolution and production pathways





WATER - Water Analysis Tool for Energy Resources

water.es.anl.gov



- Electricity generation (conventional, renewable)
- Petroleum oil production
- Natural gas production

- County, state, region
- Historic climate
- Direct and embedded water use
- Coproduct credit

http://onlinelibrary.wiley.com/doi/10.1029/2011WR011809

Water Footprint Pathways for Energy Production

- Corn
- Corn stover
- Soybean
- Wheat straw
- Switchgrass and Miscanthus
- Forest wood resource, short-rotation woody crops
- Algae, rapeseeds, camelina, others

Conversion process:
- Biochemical
  - hydrolysis, fermentation
- Thermal chemical
  - gasification, pyrolysis
- Chemical
  - trans-esterification
- Process water
  - management and treatment

- Petroleum gasoline and diesel
  - U.S. on-shore wells
  - Canadian oil sands
  - Oil shale
- Natural gas
  - Conventional
  - Shale
- Electricity
  - Coal, NG, Nuclear
  - Solar, wind, geothermal, biomass
  - Cooling systems
  - Generation technologies

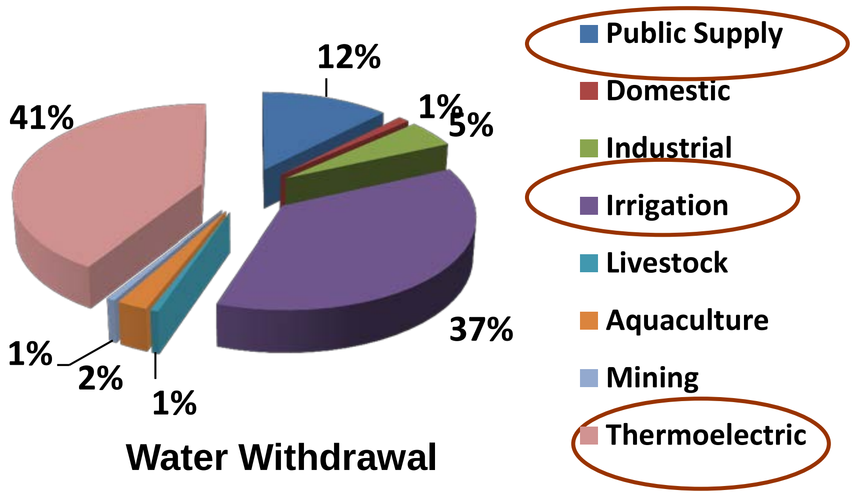
Spatial resolution:
County, state, USDA regions – biofuel
State level – power
PADD, Canadian regions – oil
Play – shale gas

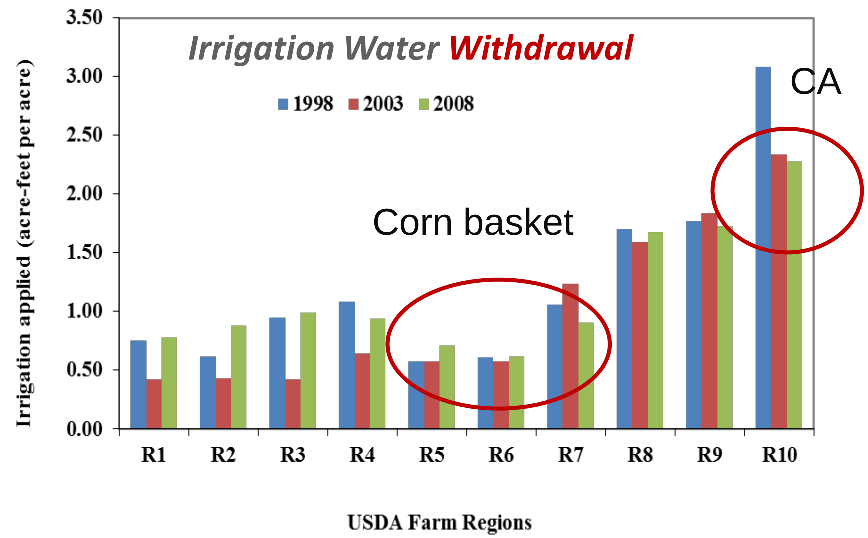
Alternative water resources, Resource use index

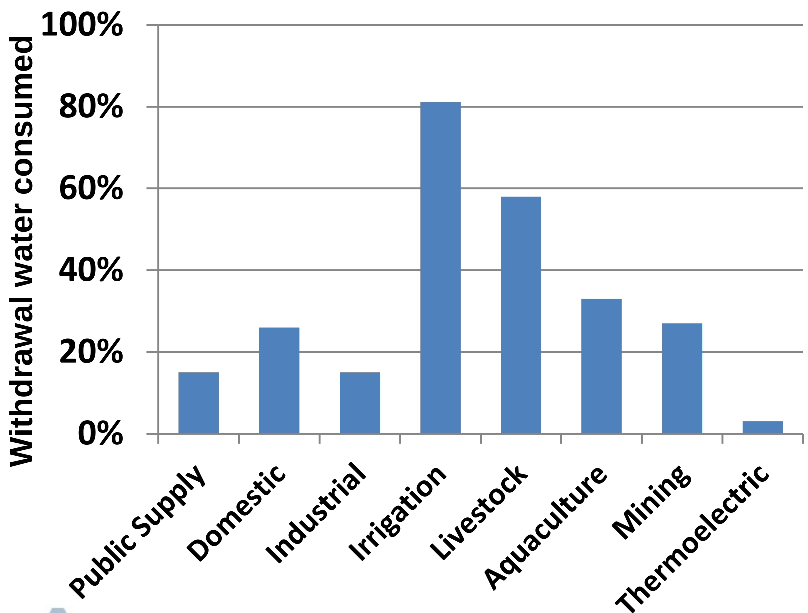
Improve Water Management and Efficiency in BioEnergy Production

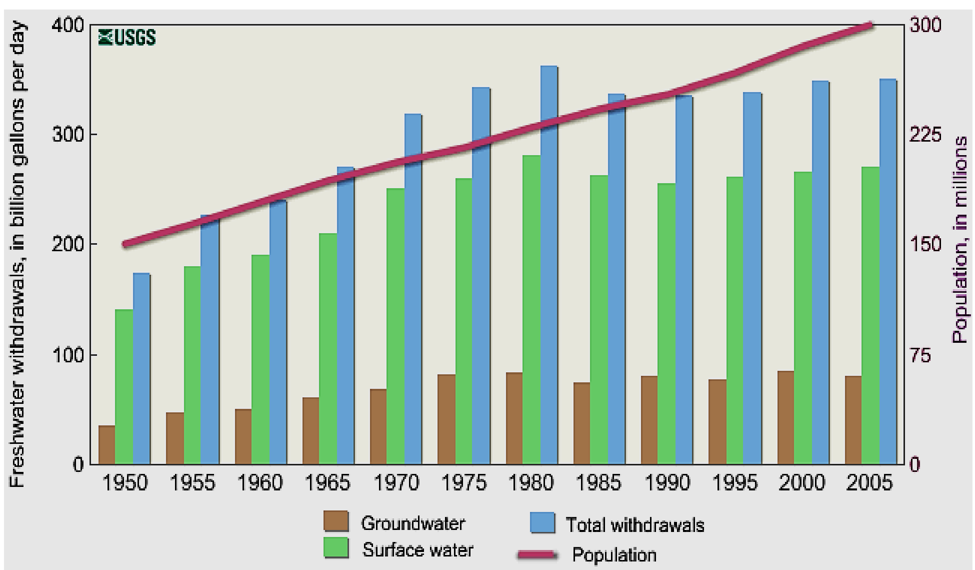
- Advance irrigation management and technology
- Integrate conservation practice into feedstock production
- Improve system integration and apply advanced technology in biorefinery
- Consider water stress in biorefinery siting
- Adopt alternative water resource use
- Analyze bioenergy feedstock mix

Historical Water Use Overview — Dominant Sector and Regional Variations





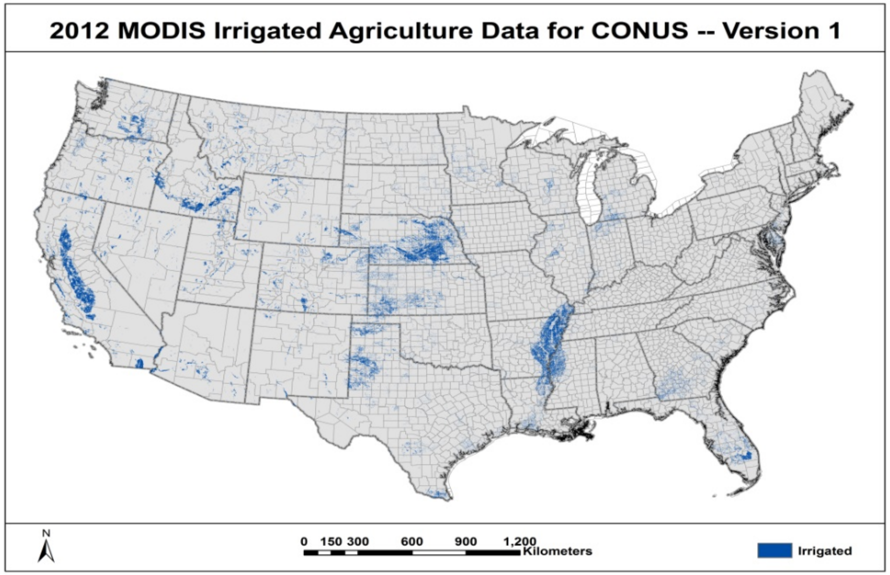


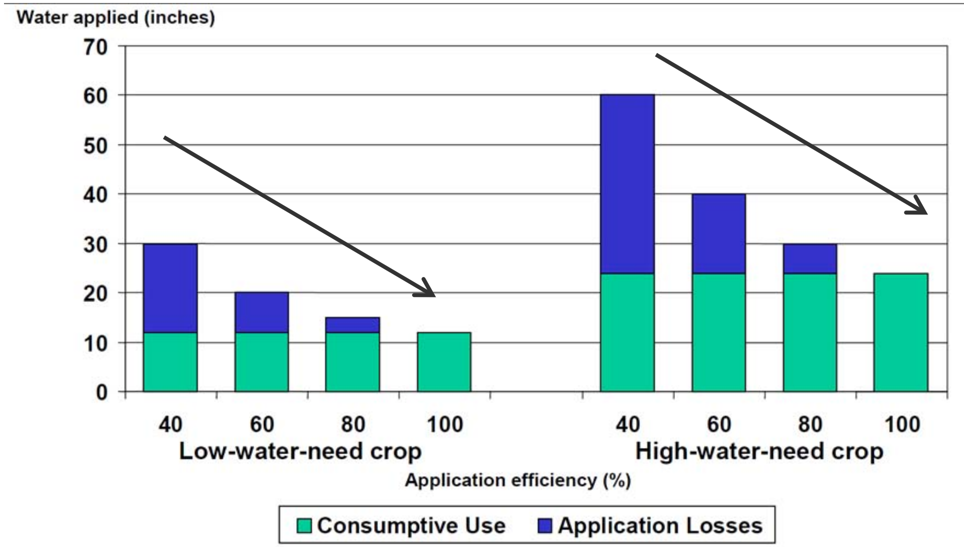


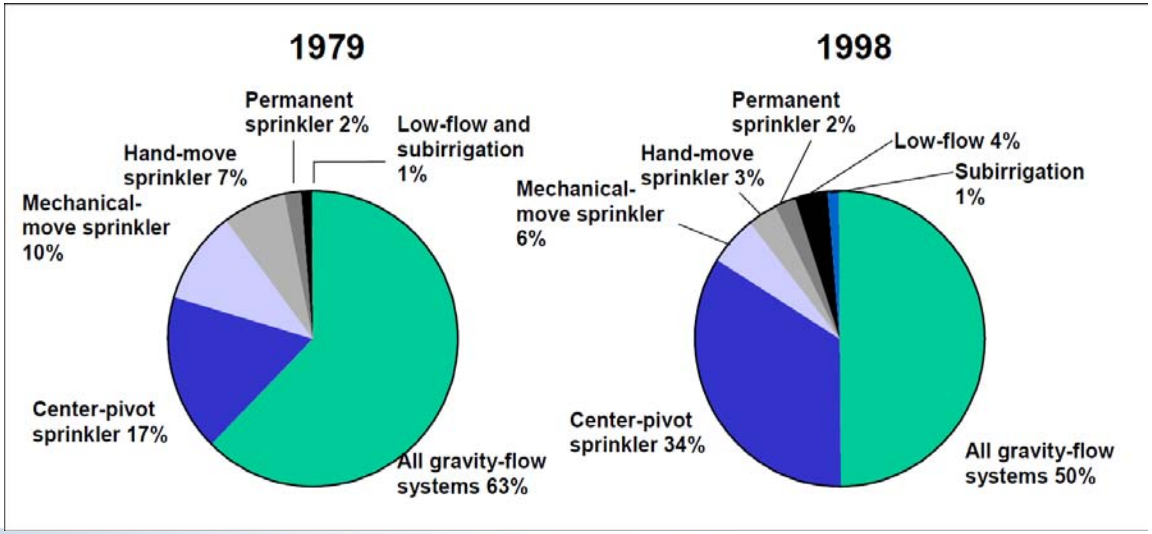
Source: USGS, USDA FRIS

Wu, M, M. Mintz, M. Wang, S. Arora, Y. Chiu. ANL/ESD/09-1 – Update, Aug. 2011.

Progress in Irrigation Technology and Management



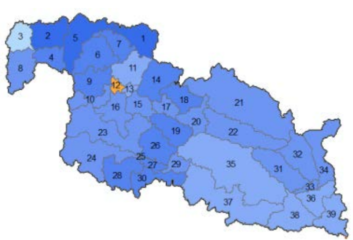




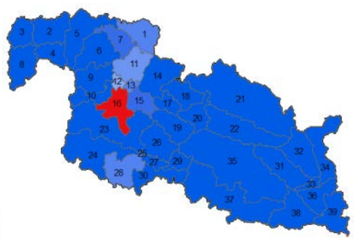
Sources:
USDA ERS
http://www.ers.usda.gov/media/873628/irrigationwater.pdf;
MODIS
http://earlywarning.usgs.gov/images/usewem/2012_MIrAD_CONUS.png

Water Quality Improvement with Integrated Landscape Management

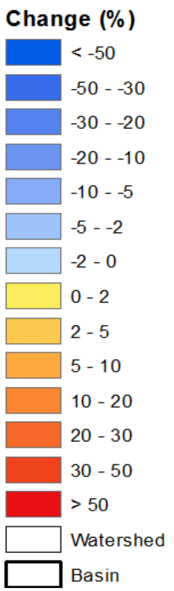
- Watershed Modeling
  - Applied a scenario that converts a portion of low-productivity land to grow switchgrass (SWG)
  - Converting a portion of cropland to SWG brings substantial reduction – 69% for sediments, 55% for total nitrogen, and 46% for total phosphorus – on weighted average



Nitrate (NO_3)

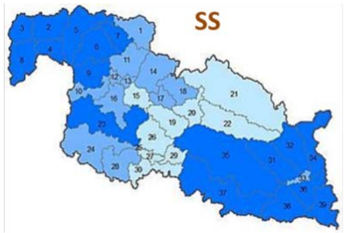


Sediments (SS)



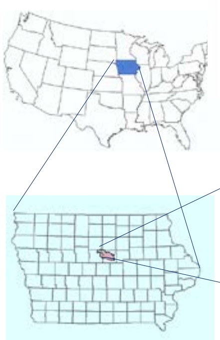
Changes under land conversion

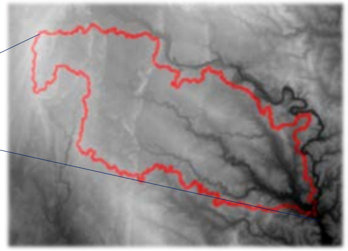
NO_3

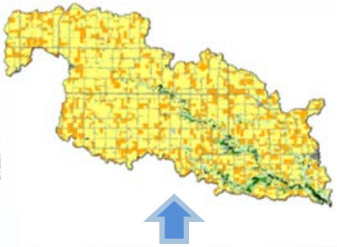


SS

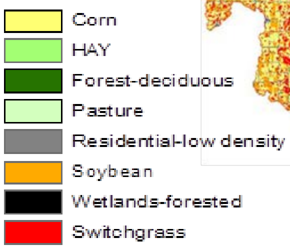
Changes under land conversion and projected climate

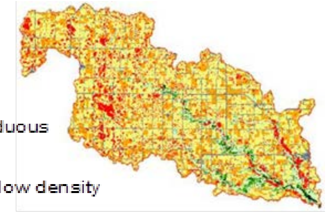






Land conversion to SWG

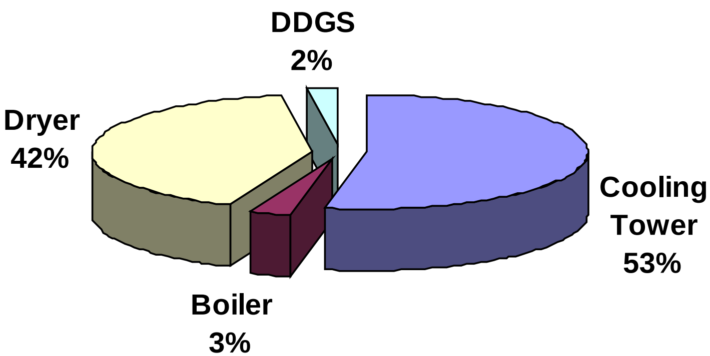


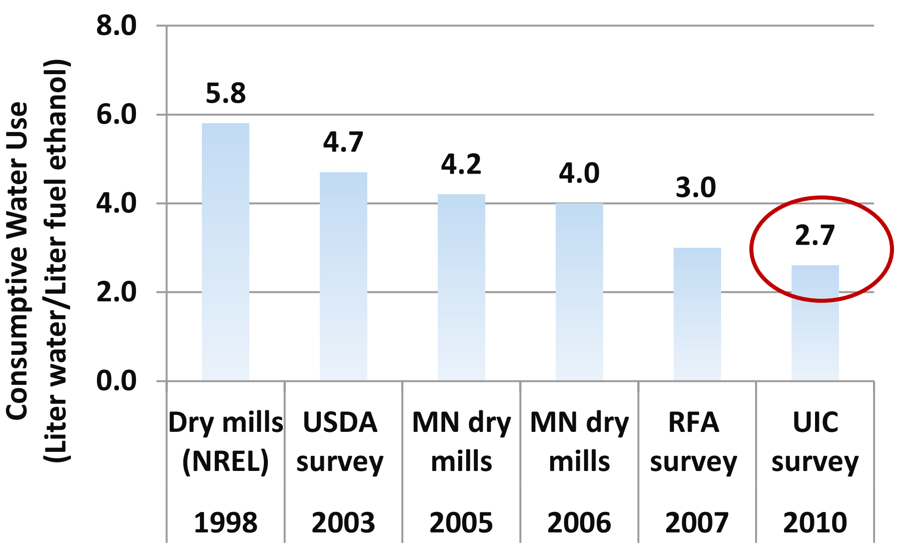


Red - SWG

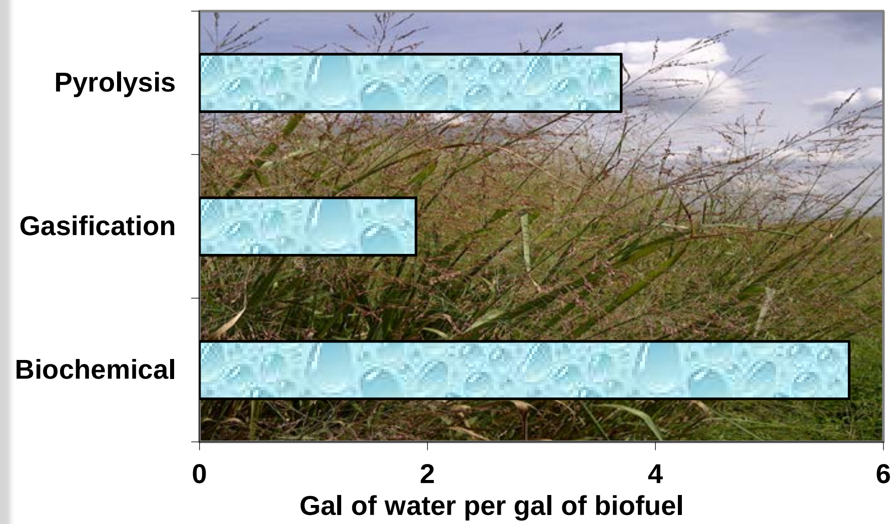
Improve Biorefinery Technology and Water Management

Conventional biofuel: Corn dry mill



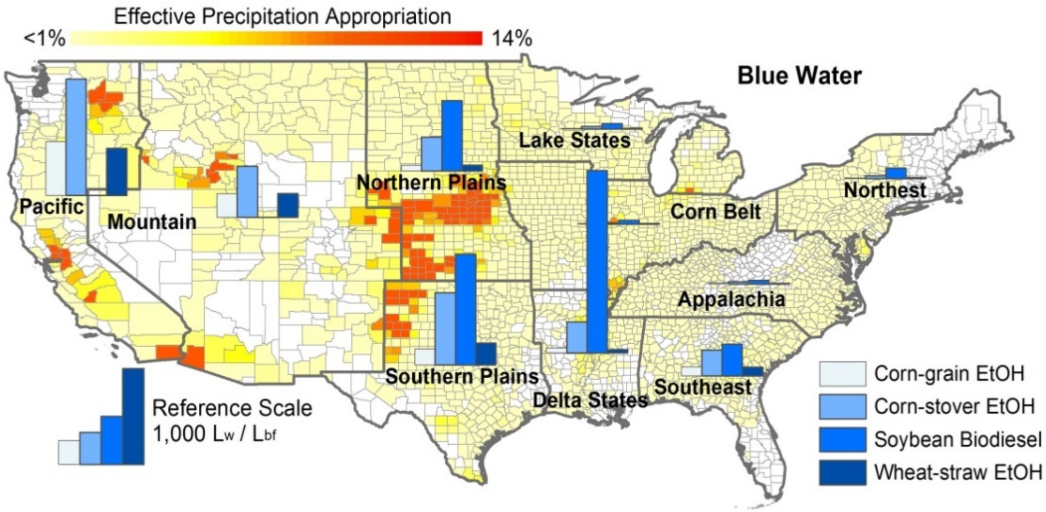


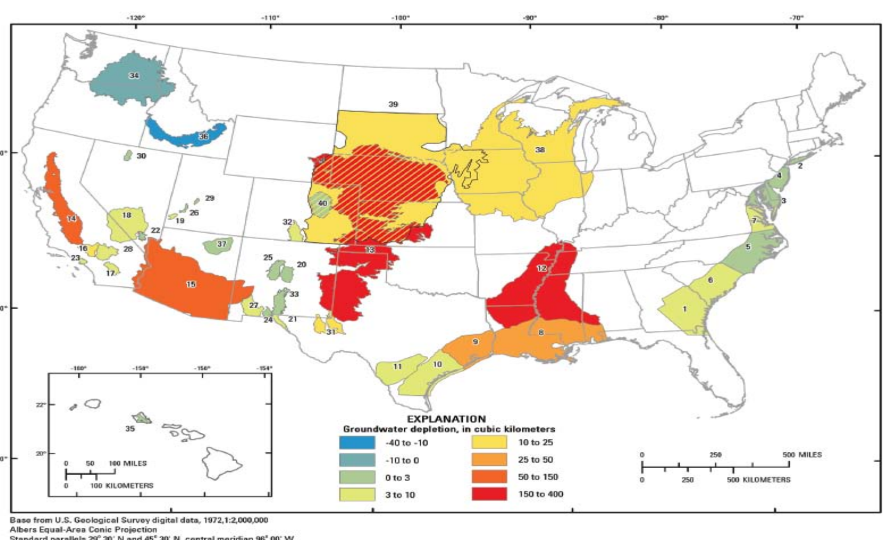
Cellulosic biofuel: Biorefinery



http://link.springer.com/article/10.1007%2Fs00267-009-9370-0

Consider Water Footprint in Biorefinery Siting





http://water.usgs.gov/edu/gwdepletion.html

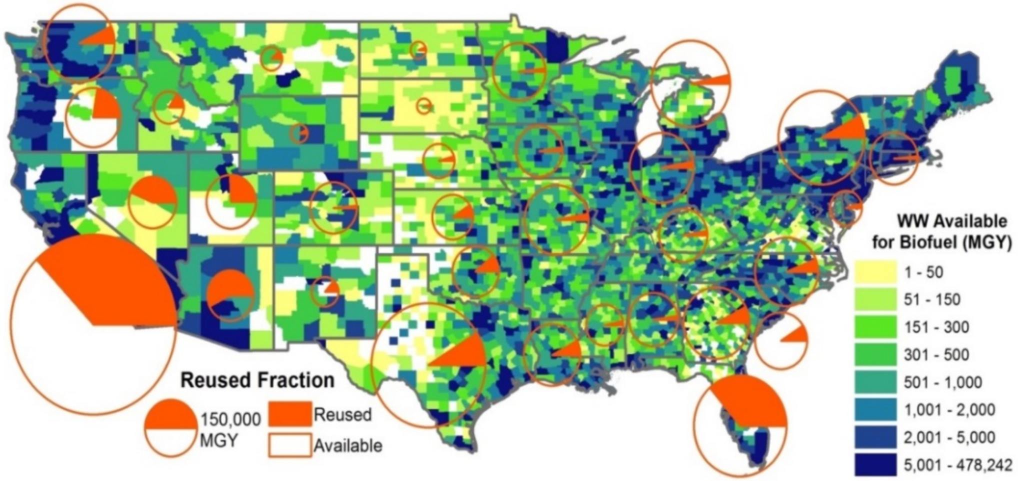
overlaps with other aquifers having different values of depletion.

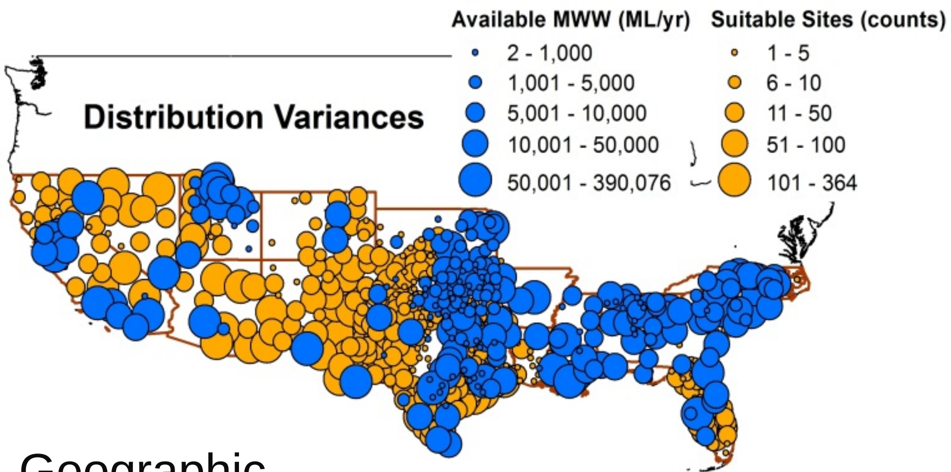
- Water footprint of biofuels varies with feedstock and regions.
- Impacts of biorefinery water use are largely local.
- A majority of biorefineries using ground water, which could add stress in areas where ground water table is decreasing.
- Local water resource constraints should be incorporated, in addition to economic and infrastructure considerations.

http://dx.doi.org/10.1021/es3002162

Reclaimed Water for Bioenergy

Degree of reclaimed water reuse in the U.S.





Geographic disparity

Significant amount of irrigation volumes can be replaced by reclaimed water

Biofpr 2013. doi: 10.1002/bbb.1397

Broader Perspective: Bioenergy Feedstock Mix

In BGY

RFS2	Total biofuels	Corn starch-derived ethanol	Portion to be from advanced biofuels		
			Cellulosic	Biomass-derived diesel	Others
2008	9	9	0	0	0
2022	36	15	16	1.28	4.0

- U.S. Department of Energy's current R&D focuses on cellulosic and advanced bioenergy produced from non-irrigated feedstock.
- Changing of energy feedstock mix can significantly affect water use in bioenergy production.
- According to RFS2, about 46% of biofuels can be produced from conventional feedstock by 2022; remaining is from cellulosic.

Bioenergy Water Mix

	2008	2022	
	Corn starch-derived ethanol	Corn starch-derived ethanol	Biomass-derived diesel
Percent of fuel in total biofuels	100	42	4
Percent of irrigated acreage in total acreages	13	13	8
Relative irrigation share*(%)	13	5.4	0.3
		5.7	

- Bioenergy feedstock mix has impact on water-mix. The changing of bioenergy feedstock-mix from starch to cellulosic starch/oil seeds-mix reduces relative irrigation share by more than a half.
- Projected bioenergy production is not expected to demand additional irrigation, given the same land acreage and yield.

**Relative Irrigation Share: % of total biofuel production that receives irrigation on acre basis.*

Source: irrigated acreages – USDA FRIS 2008

Concluding Remarks

- Water footprint of biofuels varies by type of feedstock, by regional soil and climate, and by refining process. Its assessment provides geospatial water information to support water-informed decision making.
- Technology advancement in irrigation and in biorefining increases water-use efficiency of the bioenergy production system.
- Increased bioenergy production could impact water quality. The impact could be mitigated by incorporating conservation principles and integrated landscape design and management.
- A substantial portion of the irrigation needs from bioenergy feedstock can be met by using reclaimed water.
- Transitioning from conventional biofuel to a feedstock mix with increased cellulosic can reduce irrigation share and improve the future bioenergy water mix.

Acknowledgment

Department of Energy, EERE, Bioenergy Technologies Office

Water footprint of biofuels
http://water.es.anl.gov/

Contact
mwu@anl.gov