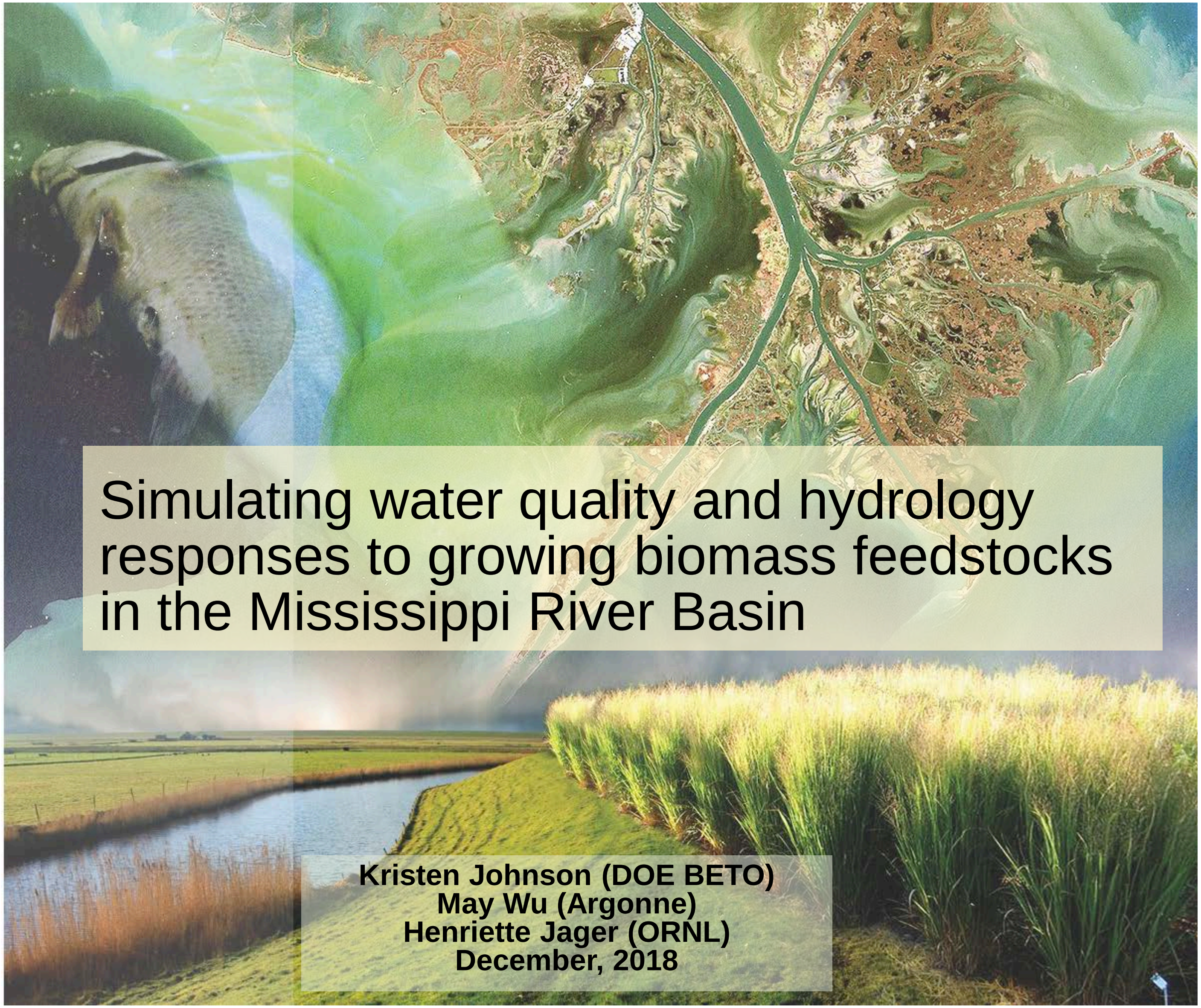

Simulating water quality and hydrology responses to growing biomass feedstocks in the Mississippi River Basin

Kristen Johnson (DOE BETO)
May Wu (Argonne)
Henriette Jager (ORNL)

December, 2018

OAK RIDGE National Laboratory

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Background

- Because of concerns about Gulf hypoxia, a number of government agencies and other entities are working to reduce nutrient loadings to Mississippi River Basin (MRB).
  - USDA ARS developed assessments on contributions of MRB tributary basins and potential reductions in nutrient and sediment loadings that can be achieved through conservation practices.
  - Federal agencies in the Hypoxia Task Force led by the USEPA are working with the twelve MRB states to identify priority watersheds and develop state nutrient reduction strategies.
  - NGOs, stakeholders, and local communities forged partnerships to implement a plan for reducing nutrient losses.

Background – Biomass production and water quality

- **Concerns about corn ethanol and its impacts motivated this DOE funded research.**
- **These two projects evaluated the potential effects of adding future cellulosic biomass production in the Mississippi River Basin.**

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*Received April 15, 2009. Revised man
21, 2009. Accepted August 3, 2009.*

Many studies have compared corn-based
ethanol on a per unit basis and have ge
that cellulosic ethanol will result in fewe
consequences, including nitrate (NO_3^-) c
takes a system-wide approach in consid
and the relative areal extent of hypoxia i
of Mexico (NGOM) due to the introducti
for biofuel production. We stochastically
loading to the NGOM and use these res
the areal extent of hypoxia for scenarios
Independence and Security Act of 2007's
2015 and 2022. Crops for ethanol include
switchgrass; all biodiesel is assumed to b
Our results indicate that moving from corn
ethanol production may result in a 20-perce
on mean values) in NO_3^- output from the M
Atchafalaya River Basin (MARB). This decr
the EPA target for hypoxic zone reduction.
nutrient management strategy will be neede
km² areal extent of hypoxia in the NGOM g
the Mississippi River/Gulf of Mexico Water
Force even in the absence of biofuels, given
to meet food, feed, and other industrial nee

Impacts of biofuel-based land-use change on water quality and sustainability in a Kansas watershed

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RACT

h in ethanol production in the United States has sparked interest in potential land-use change
ssociated environmental impacts that may occur in order to accommodate the increasing
or grain feedstocks. In this study water quality and sustainability indicators are used to eval-
mpacts of land-use change to increase corn and grain sorghum acreage for biofuel production
ry Lake watershed in northeast Kansas. Water quality indicators include sediment loads per
land acreage and the relative increase of total nitrogen, total phosphorus and sediment loads
to the baseline conditions. Sustainability indicators include land-use, water use, and nutrient
ncies. Hay, Conservation Reserve Program (CRP), and winter wheat were selected as targeted
for conversion to biofuel feedstocks. The Soil and Water Assessment Tool (SWAT) was used
e 6 different scenarios, each at 10 land-use change increments, for a total of 60 simulations.
monstrate that increased corn production generates significantly greater sediment loads than
grain sorghum production and larger relative increases in nutrient loads. Expansion of corn
orghum cropland by replacing hay or CRP land-uses resulted in the highest sediment loads
e increases in nutrient loads. Expansion of corn or grain sorghum by replacing winter wheat
produced the lowest relative changes in nutrient and sediment loads and therefore may be a
inable land-use change. Corn had a higher yield potential per km² compared to grain sorghum,
n better land, nutrient and water use efficiencies.

ssessment of large-scale biofuel crops
al regions of Michigan

*ashemi**

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ABSTRACT

The challenges we face in transitioning to a global production of biomass as renewable feedstock sources in a way that is both economical feasible environmentally sustainable are ubiquitous. In this study, the Soil and Water Assessment Tool (SWAT) was used to predict the possible long-term environmental implications, specifically water quality, due to large-scale bioenergy cropping system expansion based on four landuse scenarios and 15 bioenergy crop rotations for four watersheds, totaling 244 model simulations. The study area consists of four watersheds totaling 53,358 km² located in Michigan. The results suggest that perennial grass species are the most suitable for large-scale implementation, whereas traditional intensive row crops should be implemented with caution on such a broad scale. Row crops also had the highest increases of high priority areas for sediment, nitrogen, and phosphorus. Based on the data from this study, it is not recommended that marginal land be converted to any bioenergy rotation in areas with preexisting high nitrogen levels. Statistical analyses demonstrate that perennial grass species significantly reduce sediment on all lands except marginal lands. With the exception of row crops cultivated on marginal lands and all agricultural land, the majority of bioenergy crops significantly reduce total phosphorus loads.

PNAS

Corn-based ethanol production compromises goal of reducing nitrogen export by the Mississippi River

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Edited by Robert Howarth, Cornell University, Ithaca, NY, and accepted by the Editorial Board January 21, 2008 (received for review September 1, 2007)

Corn cultivation in the United States is expected to increase to meet demand for ethanol. Nitrogen leaching from fertilized corn fields to the Mississippi–Atchafalaya River system is a primary cause of the bottom-water hypoxia that develops on the continental shelf of the northern Gulf of Mexico each summer. In this study, we

and water cycling and downstream transport of nitrogen and water across the Mississippi–Atchafalaya River Basin to agricultural land use practices and climate variability (4, 10–16). First, we used USDA data to generate a series of spatially explicit land use scenarios including a control case (based on 2004–2006 mean land

Scientific questions

How can we meet food and bioenergy needs while maintaining or decreasing nitrogen, phosphorus, and suspended sediments run-off in the Mississippi River Basin?

Where are there trade-offs or complementarities between biomass production and water quality?

What are the contributions of tributaries on downstream water quality in the Gulf?

How might nutrient loadings to the Gulf change under assumptions about future biomass production?

Can loadings be minimized by conservation practices in conjunction with biomass production?

Watershed modeling of the Mississippi River Basin

- Joint effort by Argonne National Laboratory (ANL) and Oak Ridge National Laboratory (ORNL) with support of DOE Bioenergy Technologies Office
- Developed watershed models for each river basin in the Mississippi River drainage to assess water quality outcomes for biomass production
  - Historical baseline landscape
  - Potential biomass future scenarios
- Evaluated management practices associated with growing biomass crops
  - Multi-purpose buffers
  - Tillage
  - Cover crops
  - Restricting tile drainage
  - Nitrogen fertilizer management

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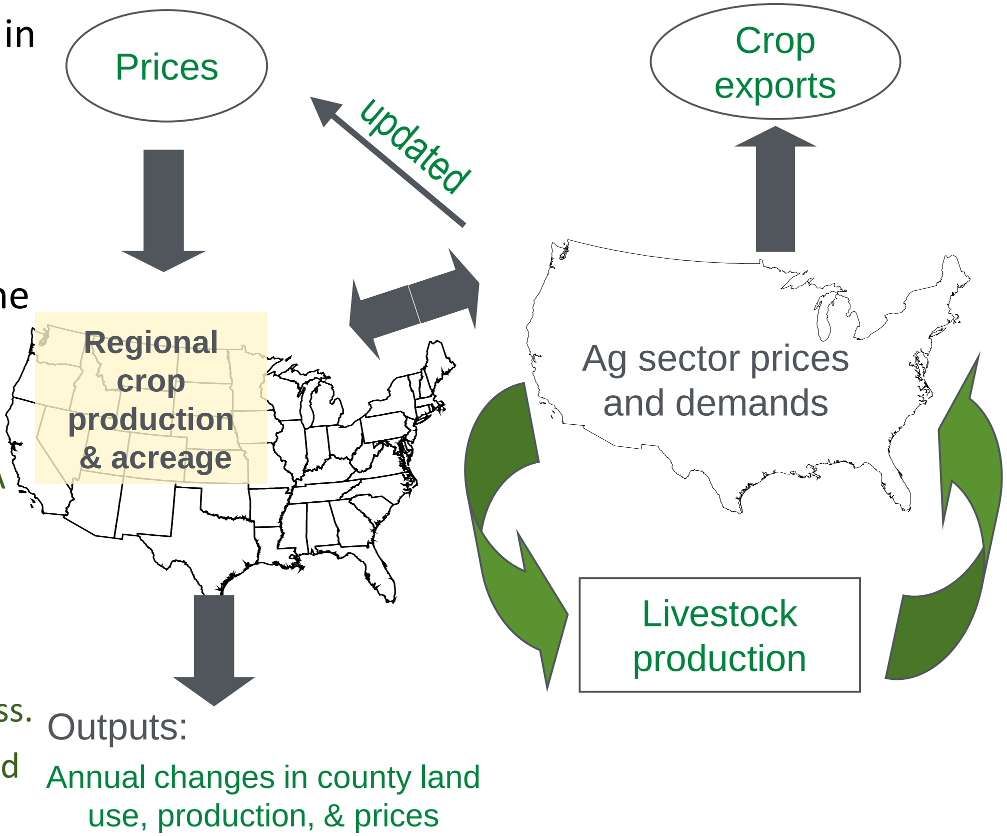
Future biomass production scenarios

- DOE's resource assessments were conducted in 2011 and 2016
- A partial equilibrium model for the US agricultural sector estimated the most profitable allocation of land to crop options, including biomass crops and residues, from the producer's perspective.

Agricultural sector in all 3,110 counties

- Available ag and pasture land is based on the USDA baseline for 10 y and then interpolated linearly.
- Each year, price depends on demand and previous-years supply for food, feed, industry, and export.
- Profitability is estimated from crop budgets and yields, for a range of fixed farmgate prices for biomass.
- Biomass yields are modeled for food, feed, fiber and energy crops
- Represents 8 major crops and hay, livestock, food and feed markets.

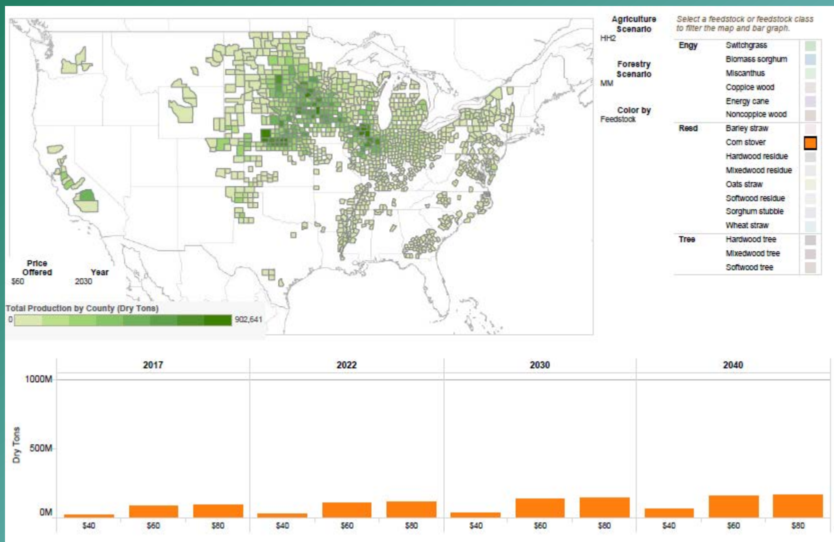


For more information, see the Billion Ton 2016 Report:
www.energy.gov/sites/prod/files/2016/12/f34/2016_billion_ton_report_12.2.16_0.pdf

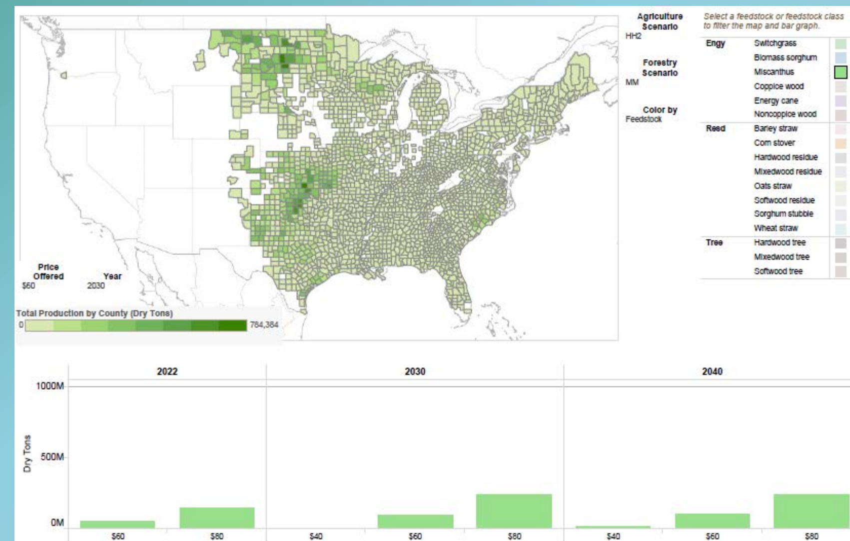
Economic projection of future landscapes ($60/dt, 1%)

https://bioenergykdf.net/map?model=bt16

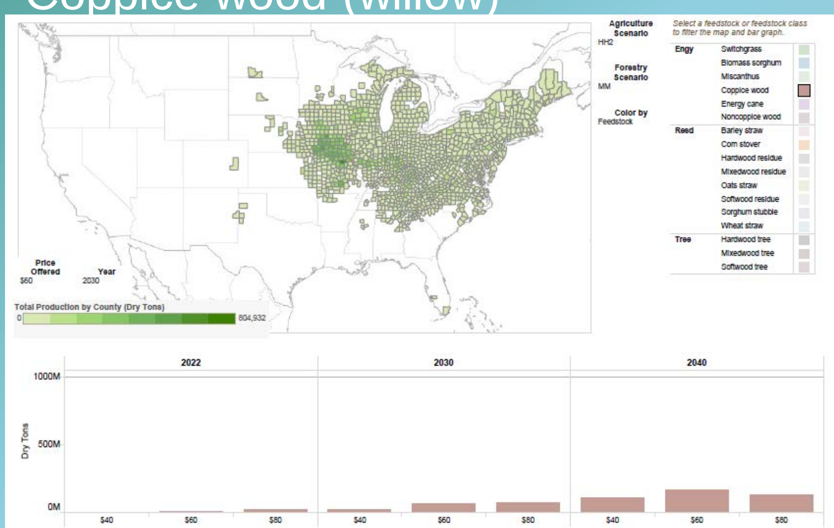
Corn stover



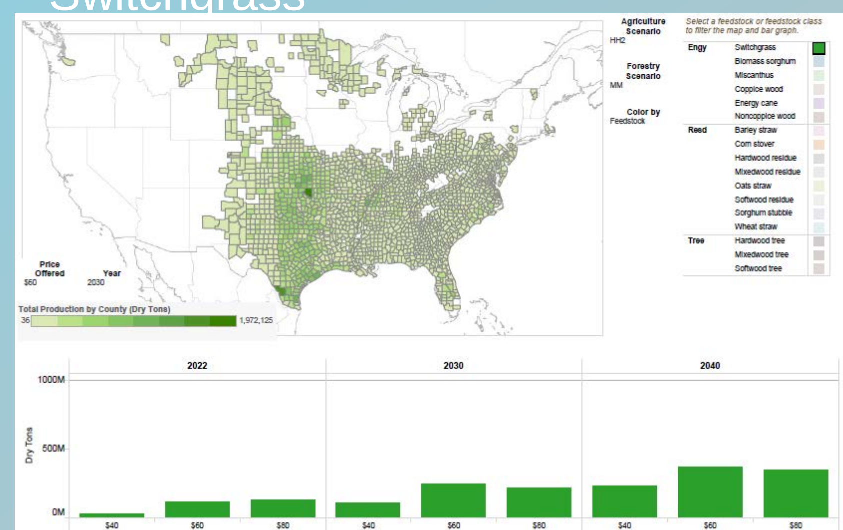
Miscanthus



Coppice wood (willow)



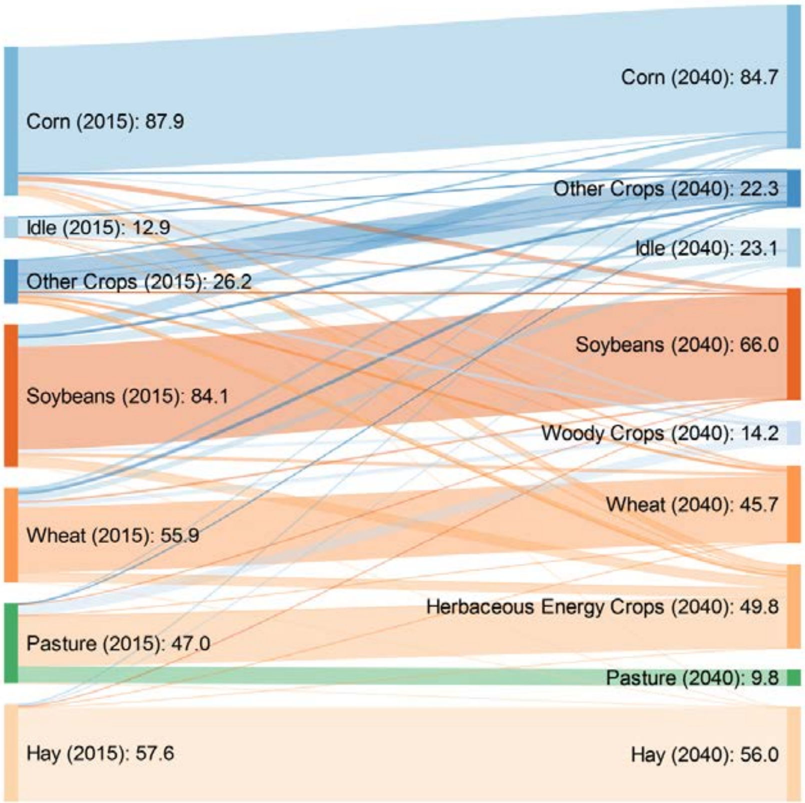
Switchgrass



Composite transitions in land-area 2015 to 2040

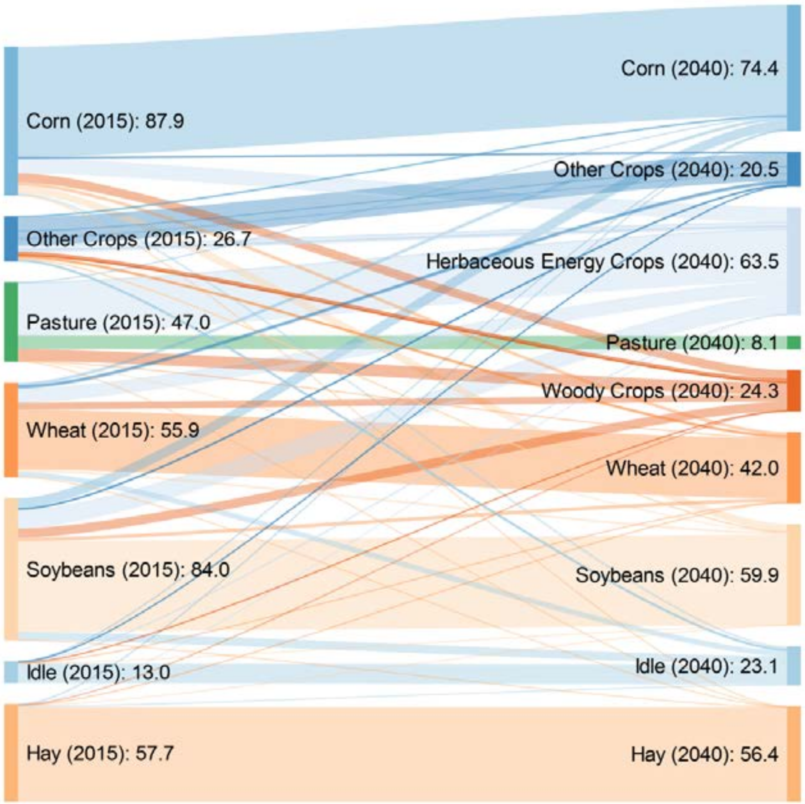
Base-case scenario

- 1% annual yield increases
- $60/dt farmgate price



High-yield scenario

- 3% annual yield increases
- $60/dt farmgate price

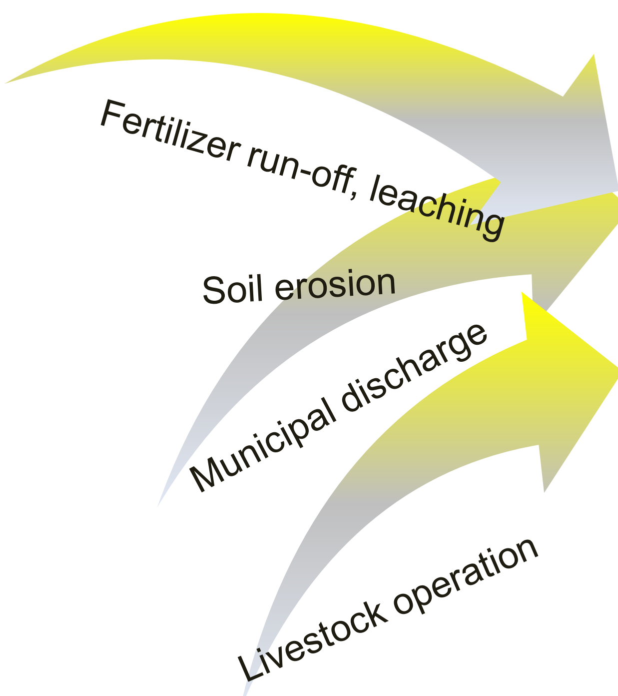


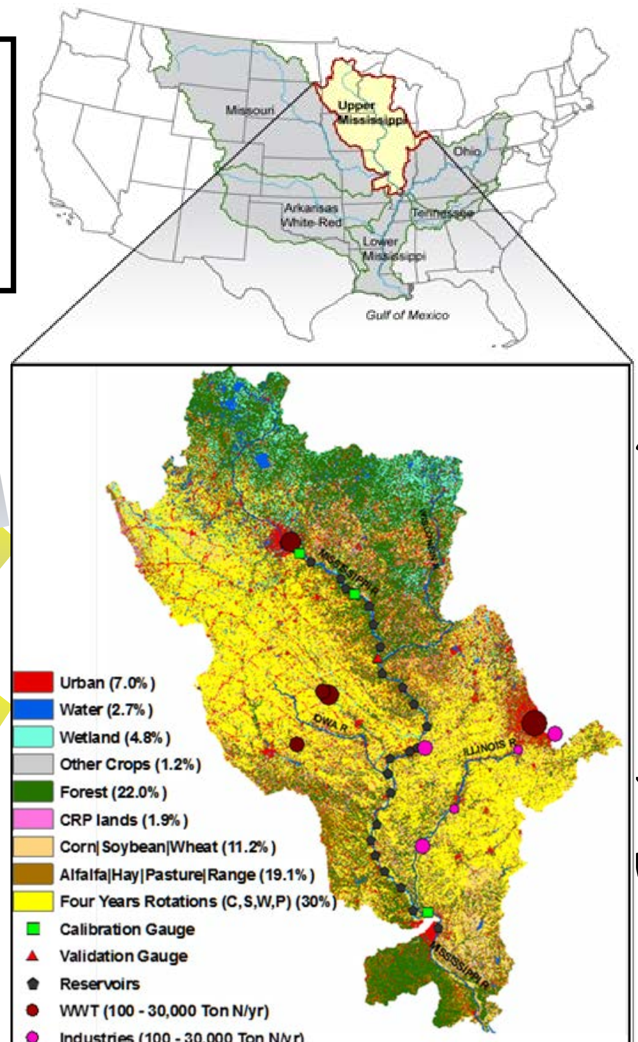
Watershed modeling of the Mississippi River Basin

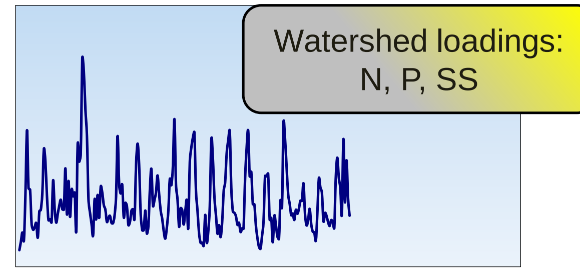
- The Soil Water Assessment Model (SWAT) was used to evaluate current and potential future landscapes.
- MRB tributary basin models
  - Upper Mississippi River Basin (ANL)
  - Ohio / Tennessee River Basin (ANL/ORNL)
  - Missouri River Basin (ANL)
  - Arkansas White-Red River Basin (ORNL)
  - Lower Mississippi River Basin (ANL)

How can we meet sustainability requirements for integrated production of food, feed and fuel?

***W**here might there be hotspots with potential impairments to water quality and **w**hat are opportunities for improvement?*



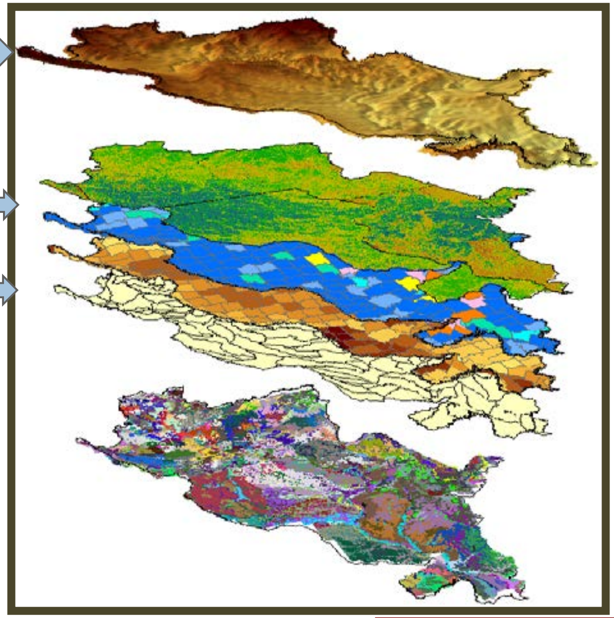




- Biofuel feedstock: grain, residue, perennial, energy crop
- Land use changes
- Agricultural management and practices
- Yield increase
- Future production scenario
- Climate
- Basin and watershed scales

SWAT models represent historical landscapes

Topography
Water use
Sub basin

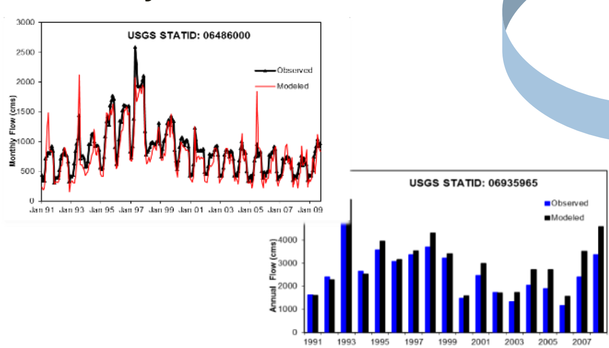


Land use, crop rotation
Fertilizer
Soil type

Other model drivers, inputs

- Climate
- Tile drainage
- Tillage
- Irrigation
- Point source
- Reservoirs

Calibration and validation with 20-years measurements



SWAT

Hydrologic Cycle ↔ Crop Growth
Nutrient Cycle ↔ Routing

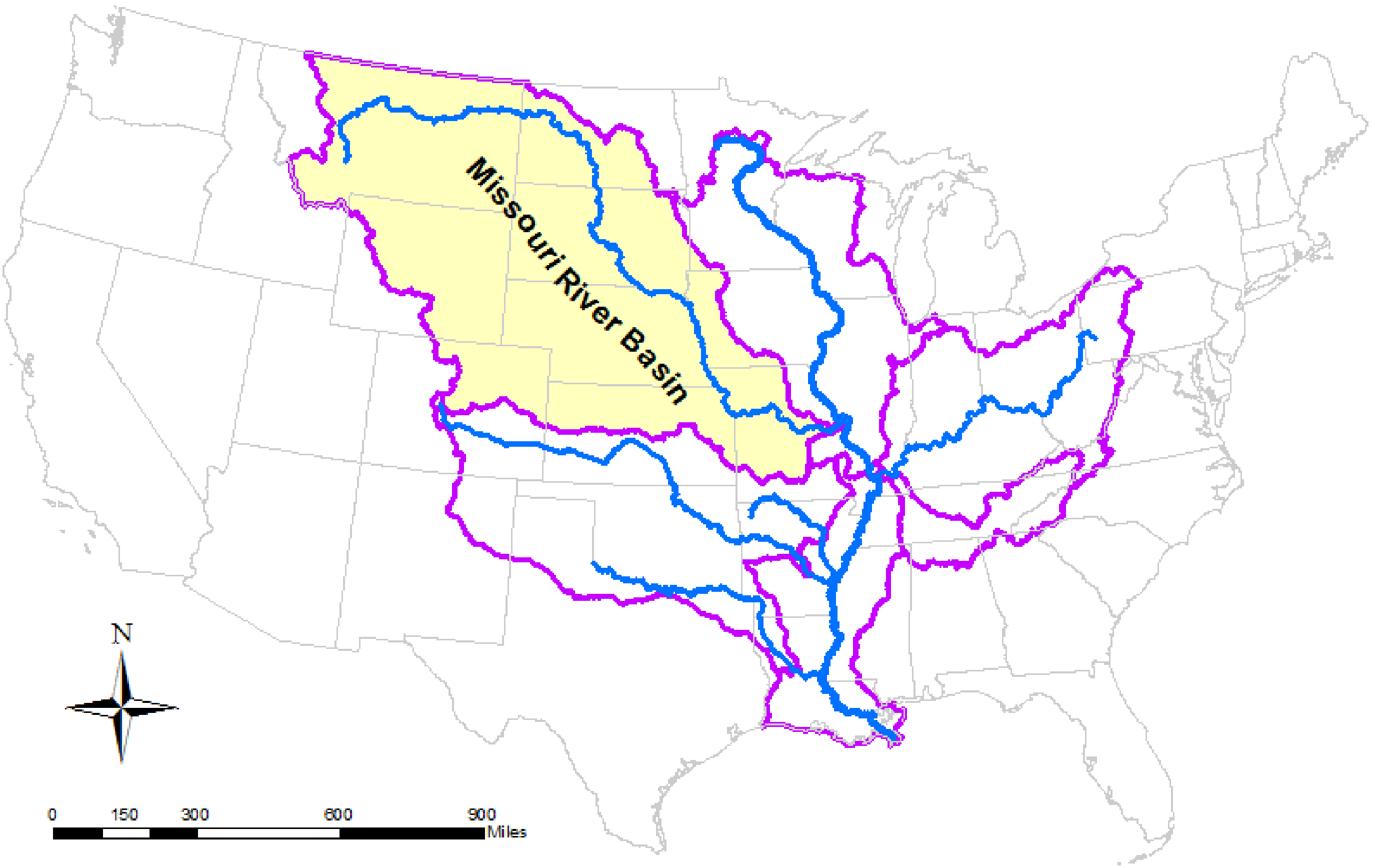
Integrated Simulation

Hydrology:
- Runoff
- Evapotranspiration
- Groundwater
- Soil moisture

Water Quality:
- Nutrients
- Erosion
- Pesticides

Crops:
- Biomass
- Yield

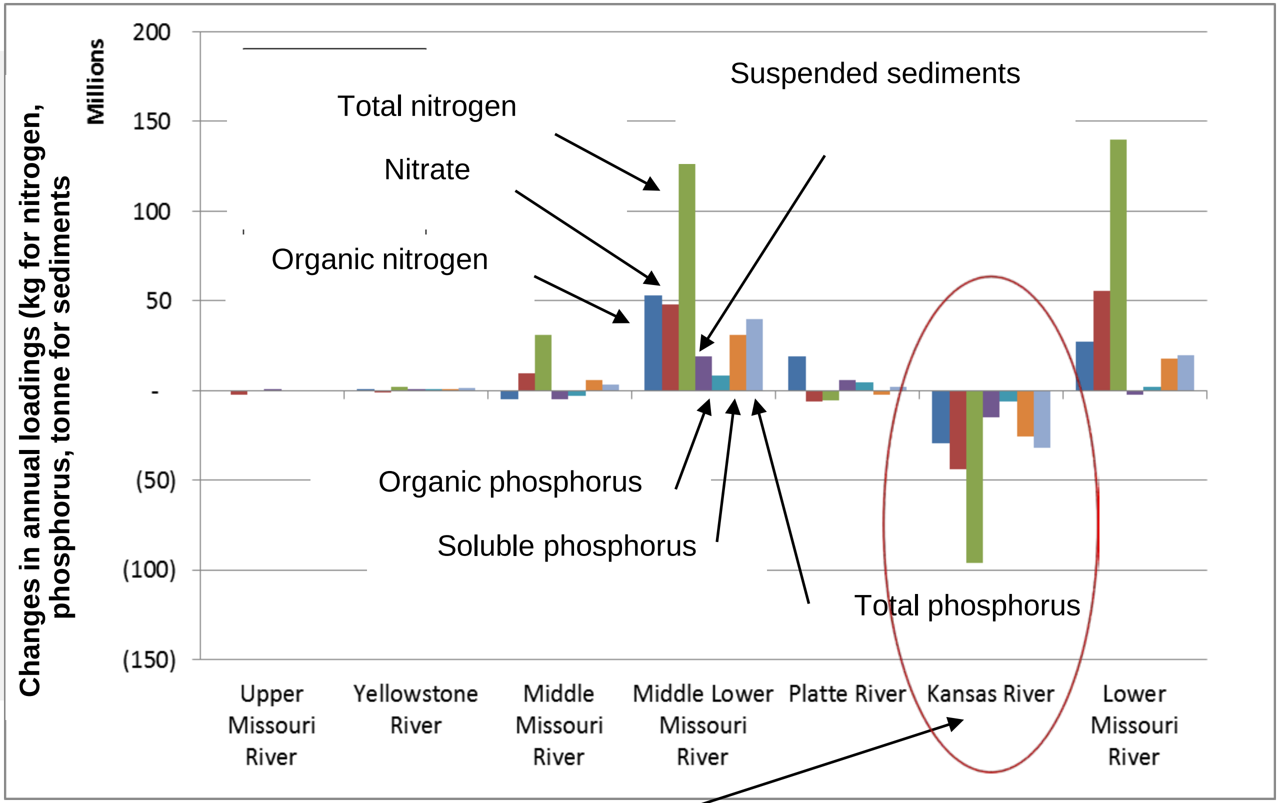
Missouri River Basin (MoRB)

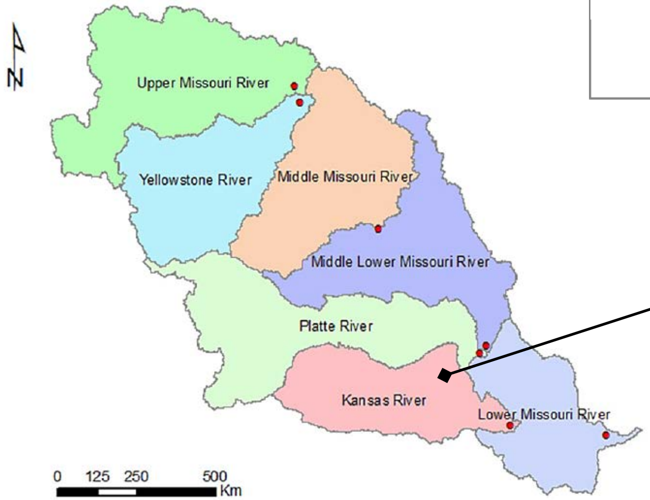


SWAT simulation and regional analysis for a potential scenario

Future scenario

- Soy bean acreages increase by 130 ha.
- Wheat acreages increase by 23 ha.
- Corn acreages remain same.
- Switchgrass grown primarily in pasture land in Kansas River watershed.





Baseline year: 2007

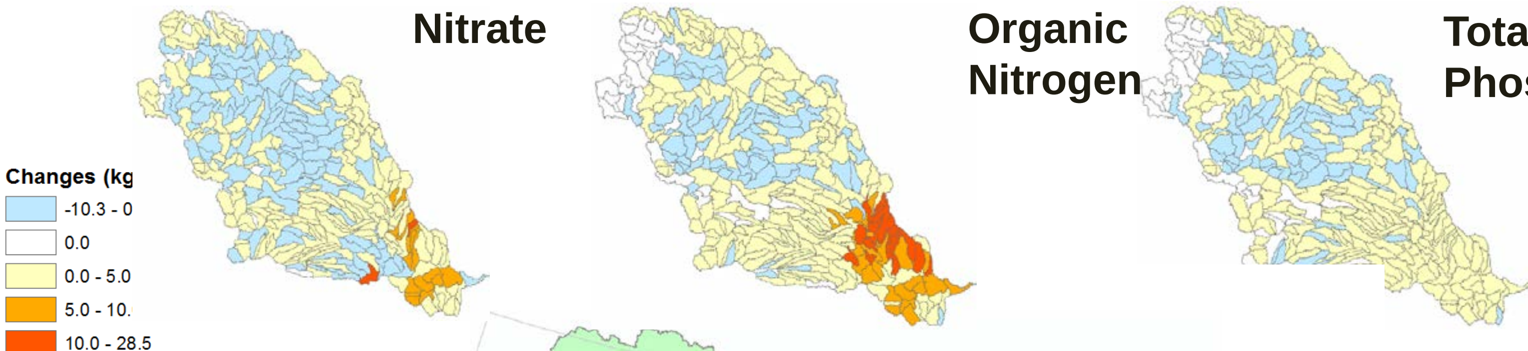
Wu and Zhang, 2015. ANL/ESD-15/13. Argonne National Laboratory.
Zhang and Wu. 2013. ANL/ESD-13/12. Argonne National Laboratory.

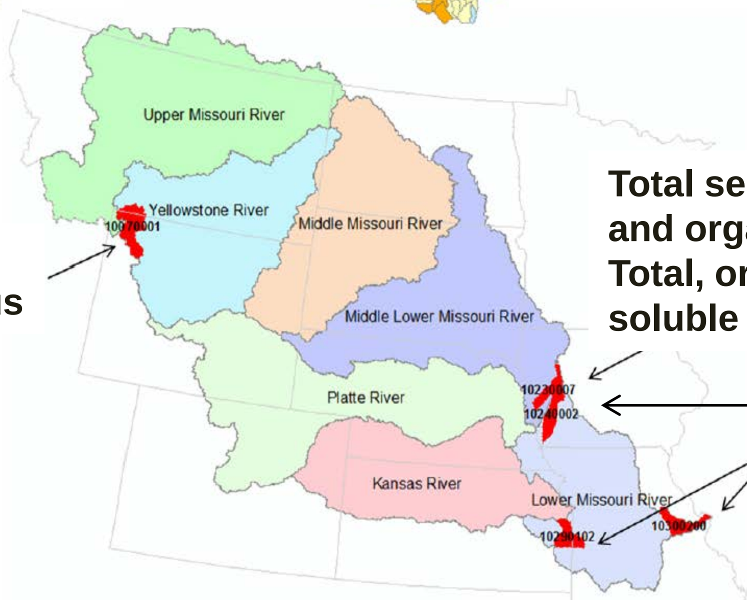
Identify hot spots for nitrogen, phosphorus & sediment loadings in Missouri River Basin under a future scenario

Nitrate

Organic Nitrogen

Total Phosphorus





Soluble phosphorus

Total sediments, Total and organic nitrogen, Total, organic, and soluble phosphorus

Nitrate

Wu and Zhang, 2015. ANL/ESD-15/13. Argonne National Laboratory.
Zhang and Wu. 2013. ANL/ESD-13/12. Argonne National Laboratory.

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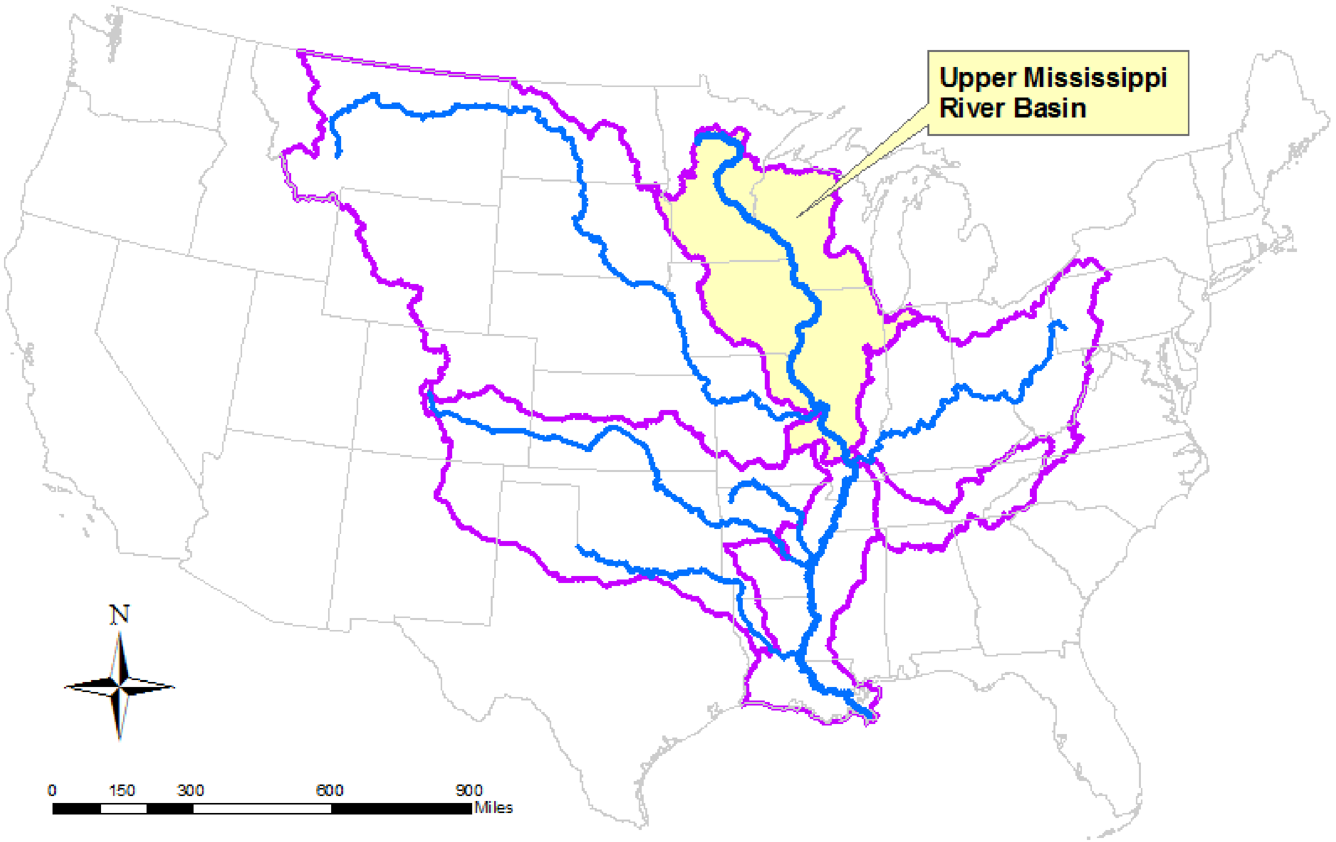
Upper Mississippi River Basin (UMRB)

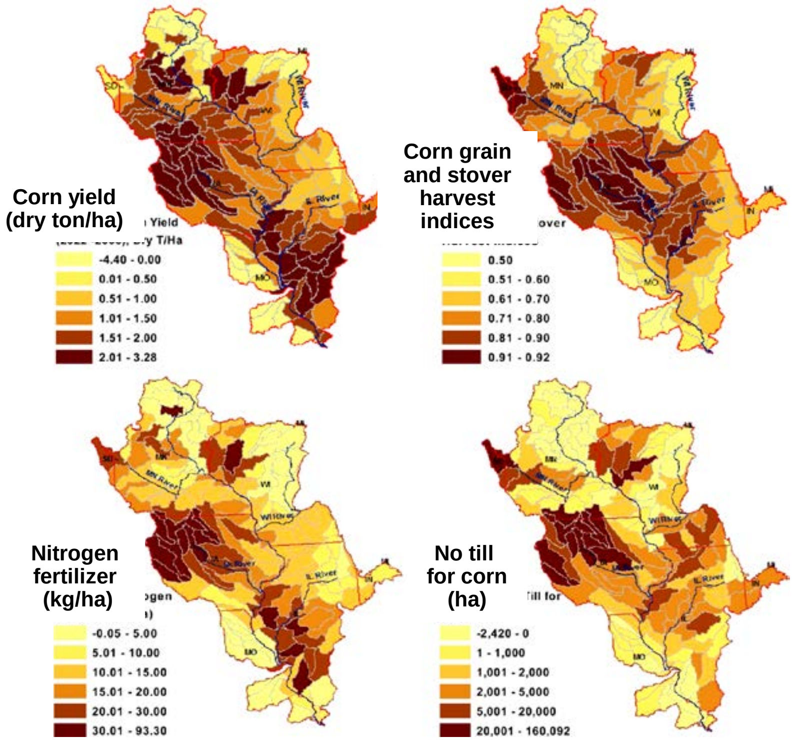


Incorporate land use and management in the Upper Mississippi River basin

Scenario

- Corn increases 3.8 million acres.
- Corn yield increase.
- 1.5 million acre increase in idle land.
- Corn stover is harvested to a total of 48 dry metric tons.
- 4.8 million decrease in pasture and hay.
- No till increases 3.9 million acres; conventional- and reduced-tillage decrease 1.3 million acres.

Changes in corn yield, fertilizer application, and tillage, and harvest indices



Compare with baseline year 2006

Demissie, Yan, Wu, 2012. ES&T

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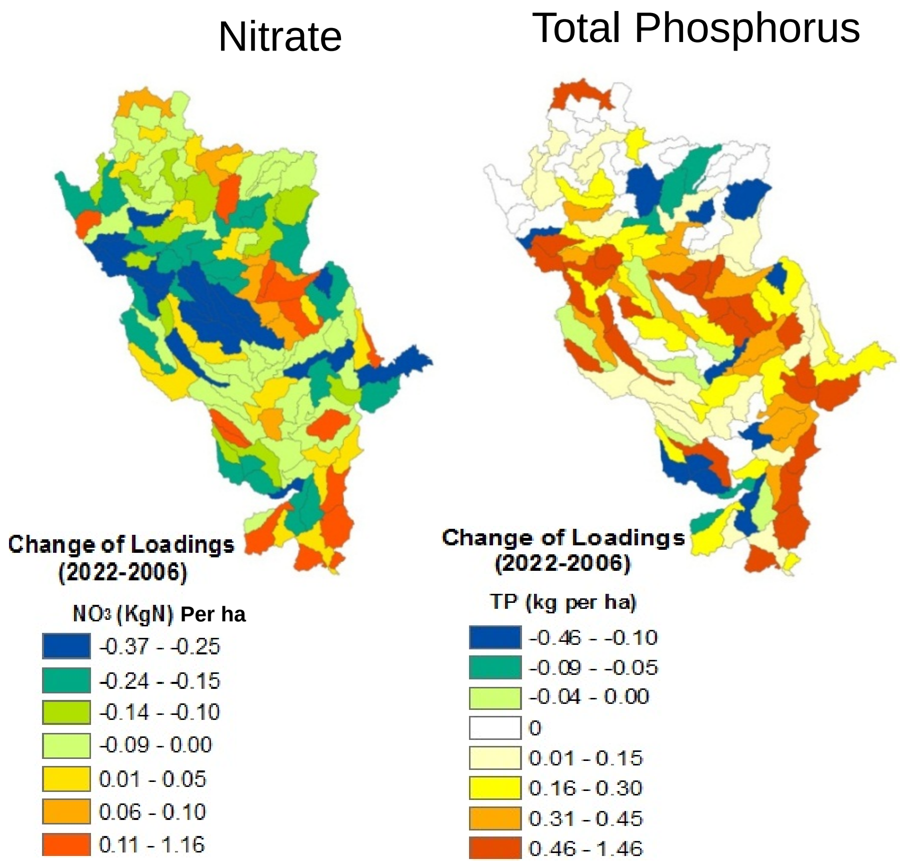
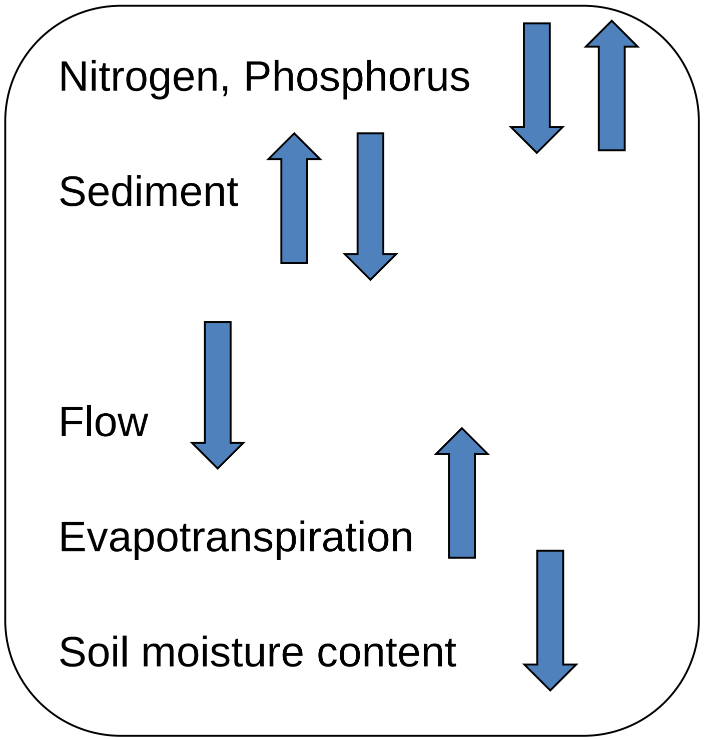
Estimated changes of nutrients, sediments, and hydrology under a potential scenario

Changes relative to baseline year (2006)



Effects associated with biomass production are mixed



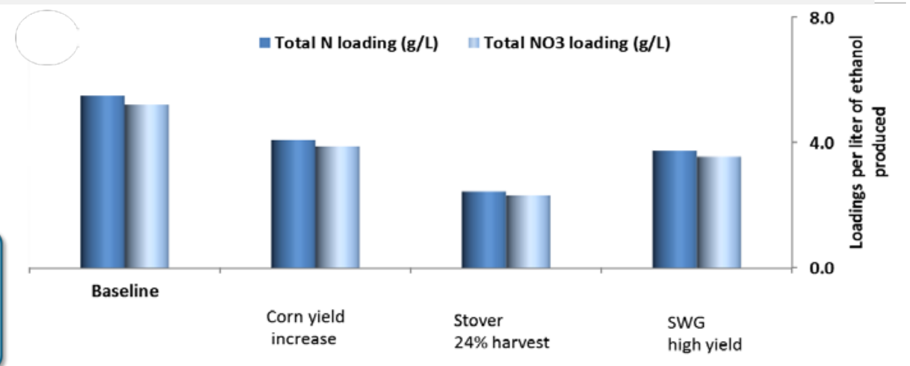
Demissie, Yan, Wu, 2012. ES&T

How do switchgrass, stover harvest, and yield influence water quality and quantity in Upper MRB?

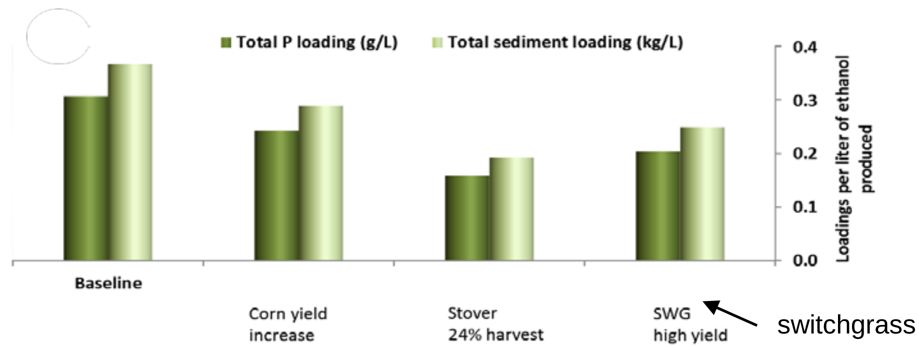
Corn yield increase
- No change in acreages
- Increased yield for corn and ethanol
- Increased fertilizer application

Stover harvest
- 24% stover is collected for biomass
- Supplement fertilizer applied

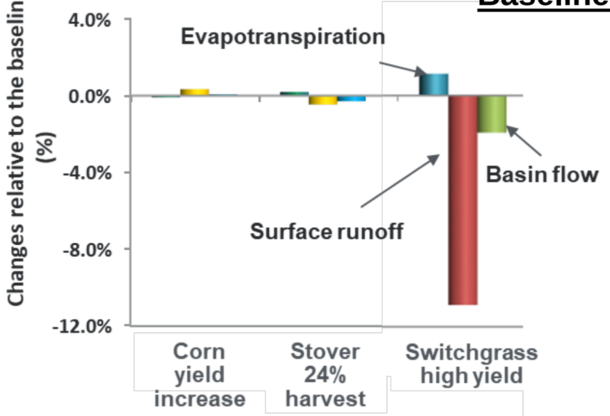
Switchgrass
- Grown on 10% of pasture land
- Fertilizer applied
- High yield range



Biofuel production *(Billion gallons)*		
4.5	6.0	5.3



Baseline year: 2006



- On per volume of fuel production basis, nutrient and sediment loadings decrease when crop yield and cellulosic biomass production from stover and switchgrass increases.
- Evapotranspiration increases whereas surface runoff and flow decreases.

Oak Ridge National Laboratory

Argonne National Laboratory

Wu, Demissie, Yan. 2012. Biomass & Bioenergy.

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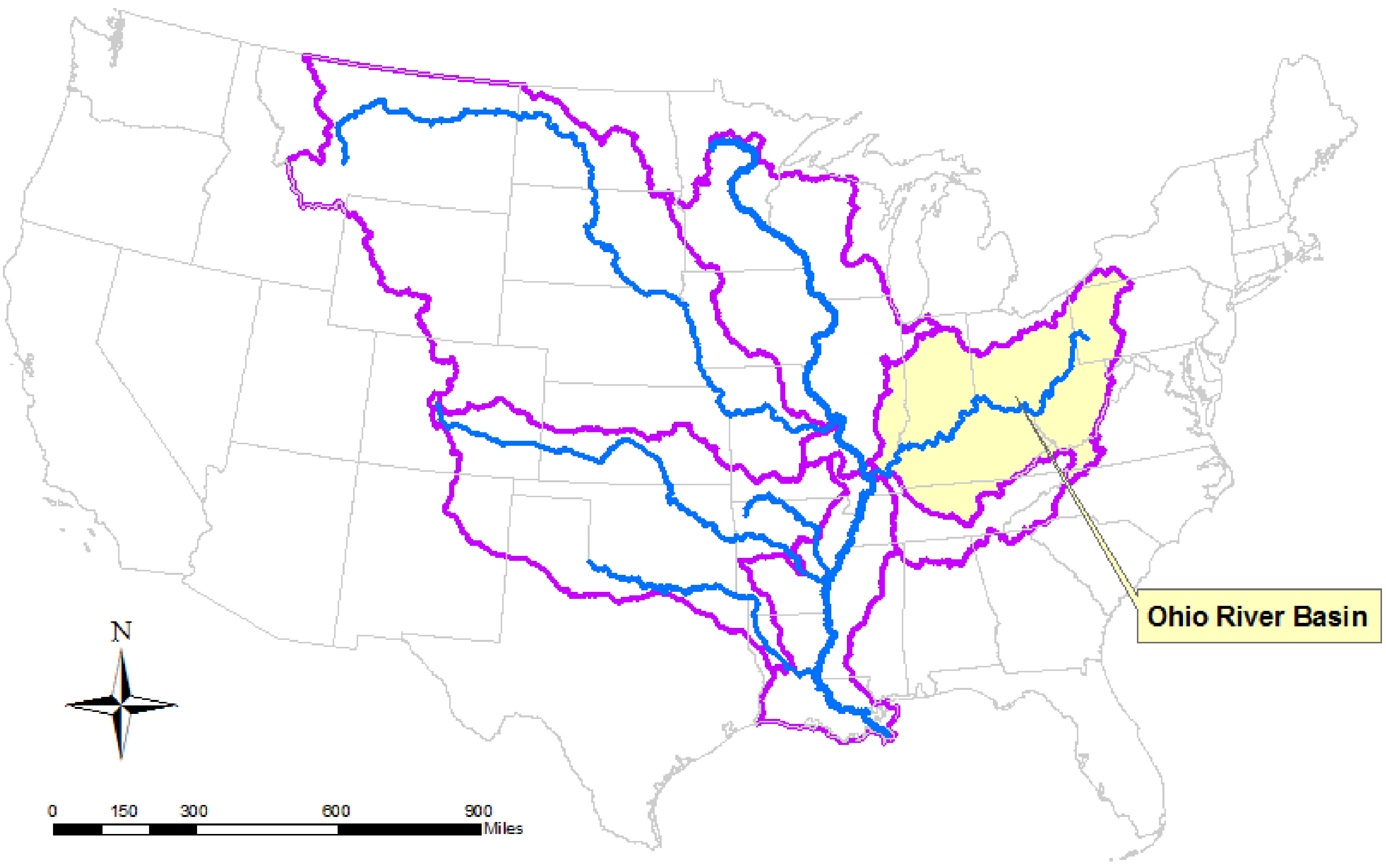
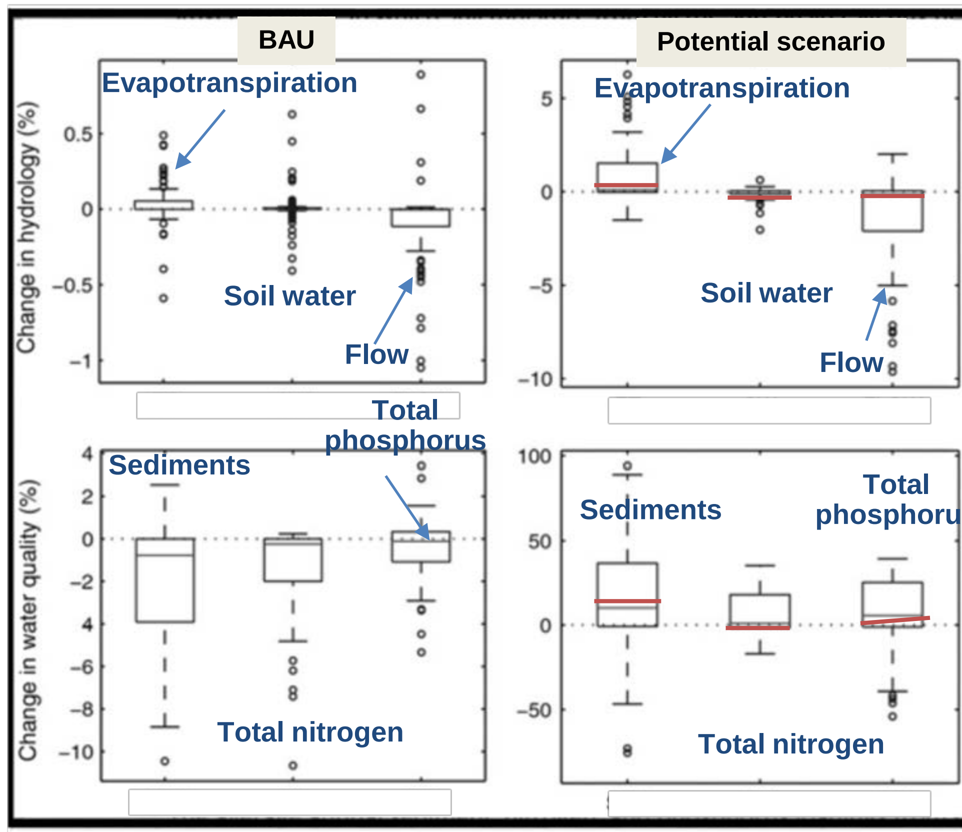
Ohio River Basin (ORB)

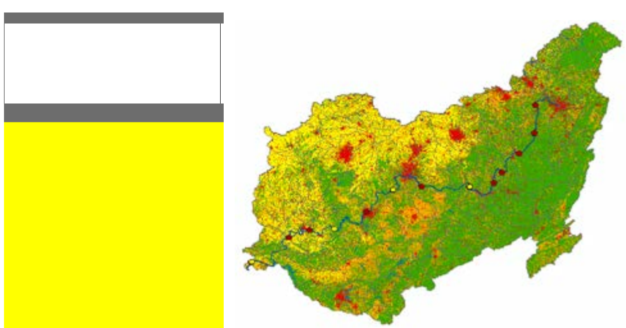


Potential effects of potential biomass production on water quality quantity in Ohio River Basin

Scenarios

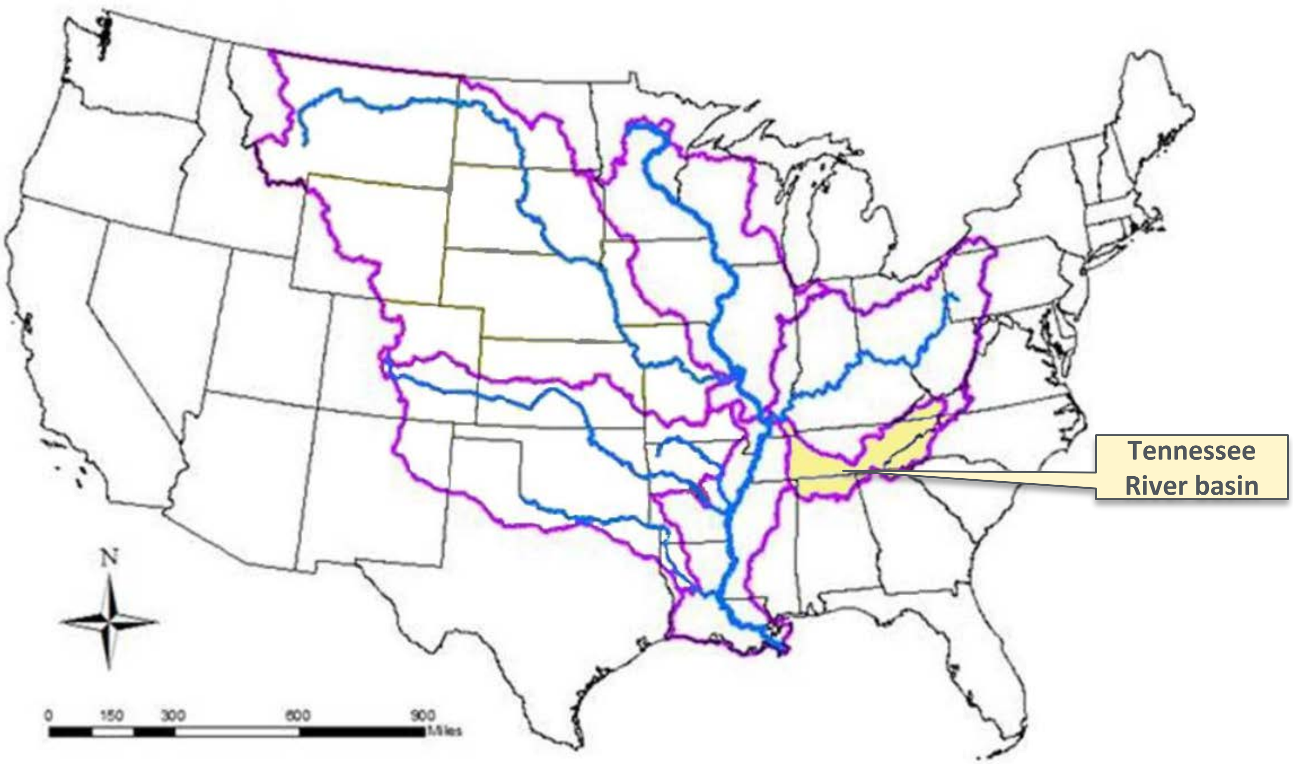
- 1% yield increase, $50/dry ton biomass.
  - Corn, soybean, wheat, and idle land areas to gain 444, 91, 26, and 451 thousand hectares; hay and pasture to decrease 1012 thousand hectares.
  - Stover harvest up to18%, total 7.3 million dry-tons.
  - Increased conservation tillage and decreased conventional tillage.
- Business as usual (BAU): 1% corn yield increase.
- Compare with baseline year 2006.





Demissie, Yan, and Wu, 2017. GCB Bioenergy, doi: 10.1111/gcbb.12466

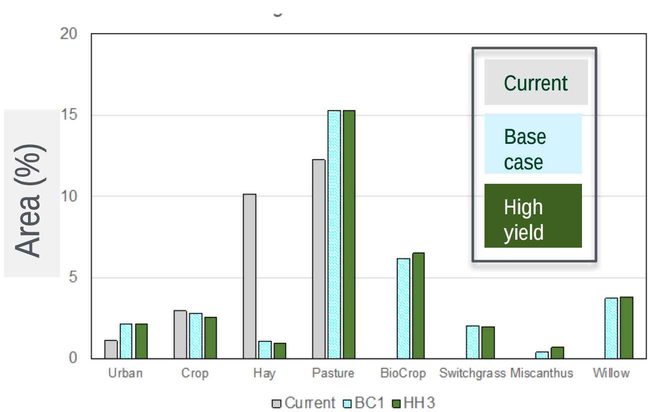
Tennessee River Basin (TRB)

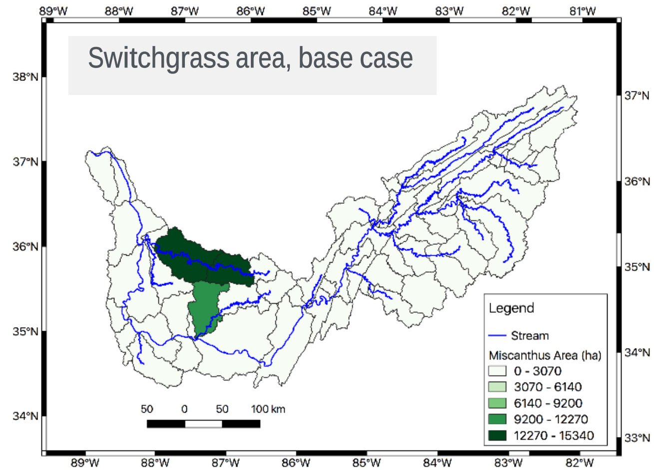


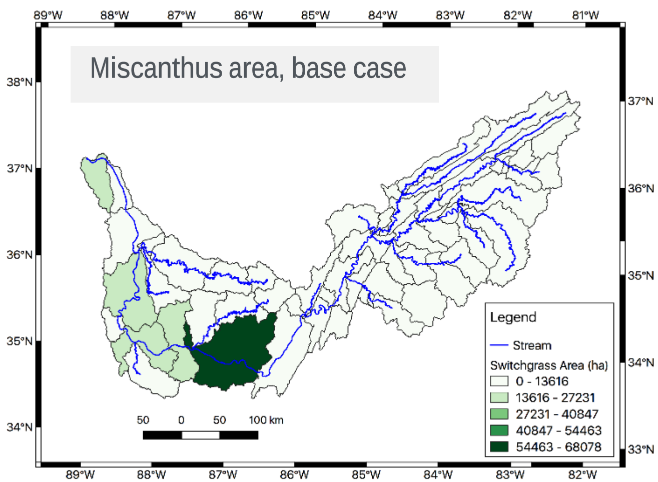
SWAT simulation of biomass crops in the Tennessee River Basin

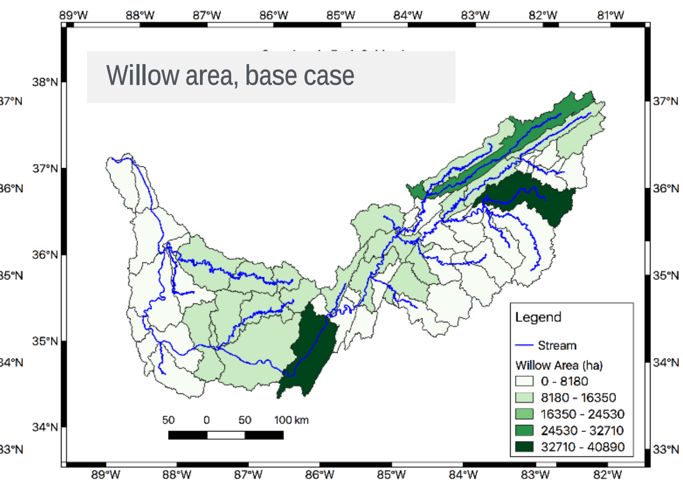
- We compared two potential future scenarios, a base case and high-yield scenario with the current landscape.
- Dominant biomass crops included willow, miscanthus, and switchgrass.
- SWAT model calibration and comparisons against data were challenging because of the influence of dams and the sparse availability of field measurements for this river basin.
- We developed solutions including comparison against synthetic, intermediate response variables derived from gage-derived measurements. This required the development of a new calibration methodology, SWATopt.
- SWAT model performance was reasonably good (median model efficiencies = 0.83 and 0.72 for runoff calibration and validation; percent biases generally within ±25% for runoff and ±70% for water quality) for most subbasins.

Future biomass crops in the Tennessee River Basin







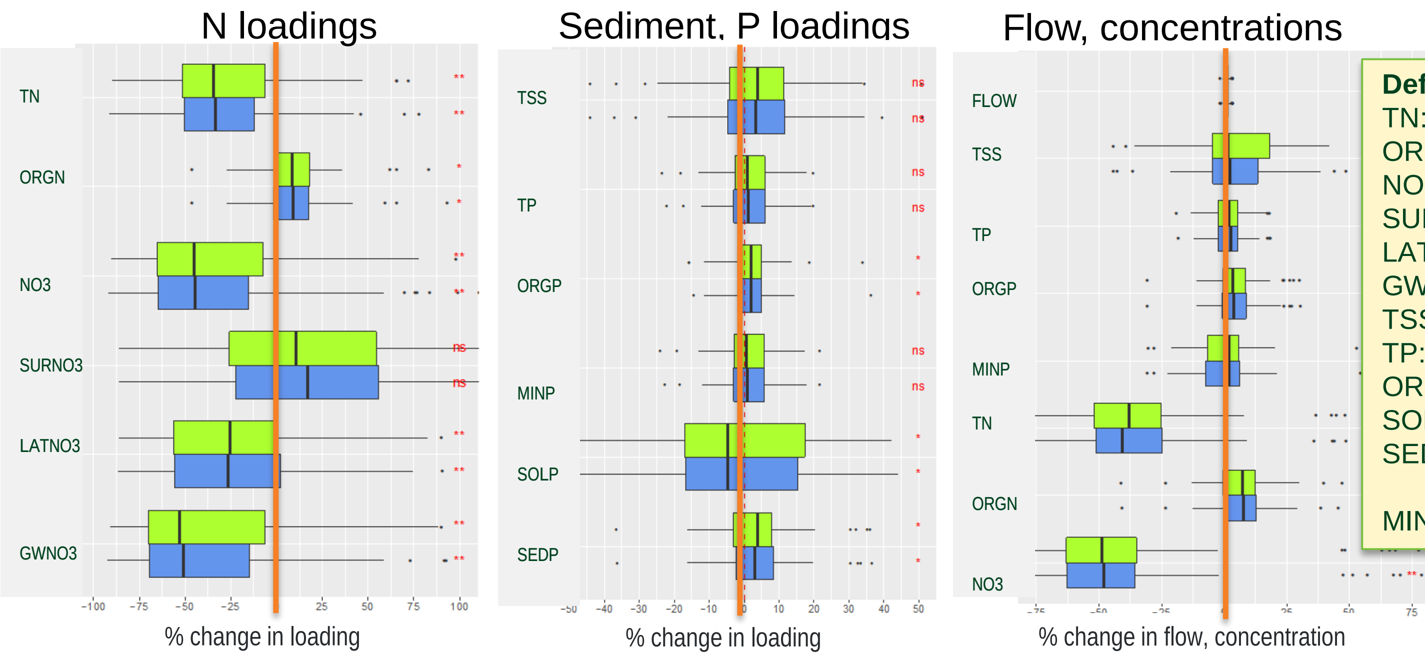


Hay was converted to miscanthus and willow, whereas pasture converted to switchgrass (overall pasture increased).

Simulated water quality in the Tennessee River Basin

Key findings:

- Large decreases in median total N loadings and concentrations…
- … because less fertilizer was required to grow miscanthus and willow than hay.
- No significant change in sediment or total P (opposite sig. responses of soluble and sediment-bound components).

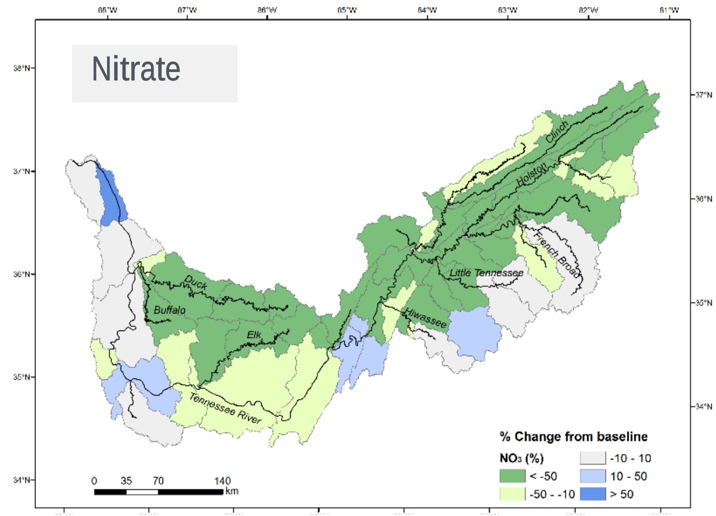


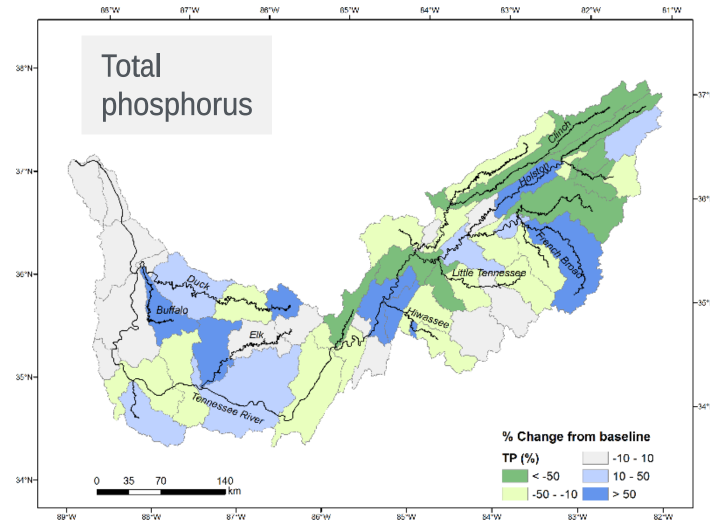
Definitions
TN: total N
ORGN: organic N
NO3: nitrate
SURNO3: nitrate in surface runoff
LATNO3: nitrate in lateral flow
GWNO3: nitrate in groundwater flow
TSS: total suspended sediment
TP: total P
ORGP: organic P
SOLP: soluble P
SEDP: mineral P attached to sediment
MINP = SOLP+SEDP

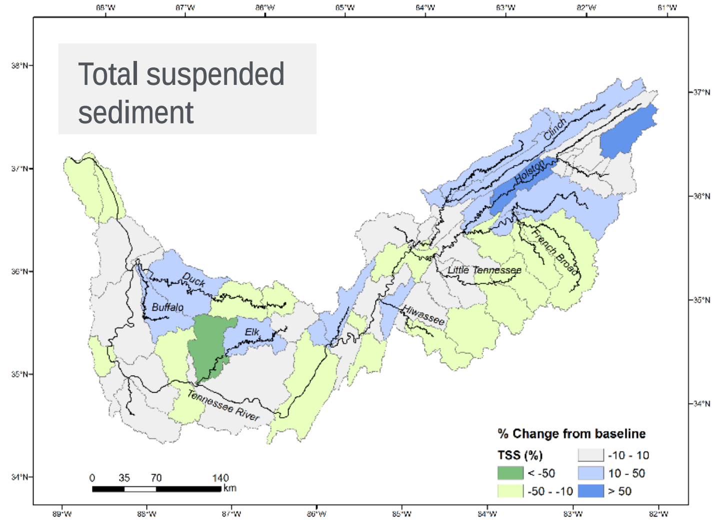
High yield - Current

Base case - Current

SWAT-simulated changes in water quality from a 2015 baseline in the Tennessee River Basin

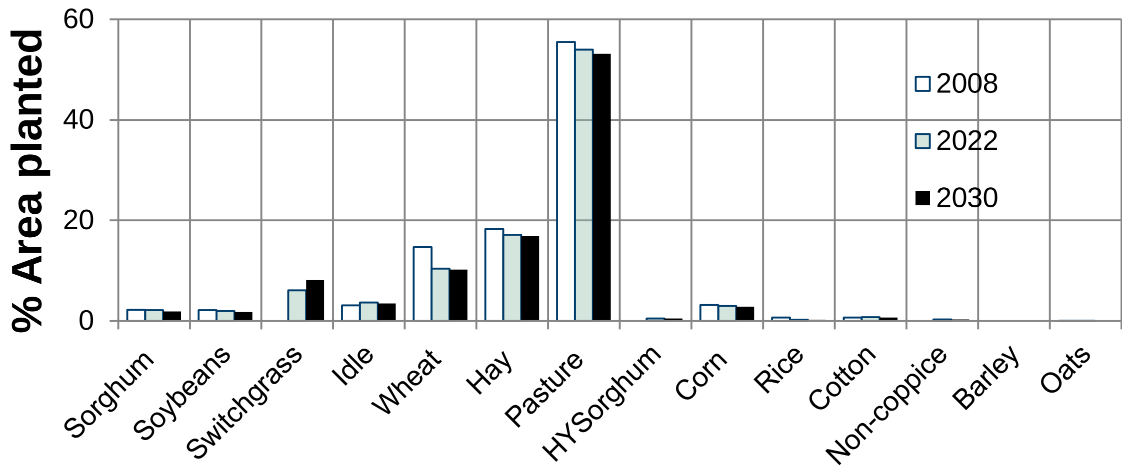




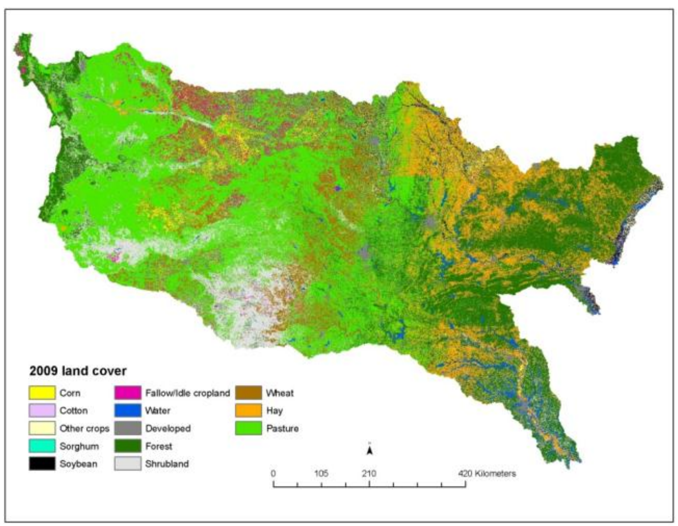


Arkansas White-Red River Basin (AWRRB)

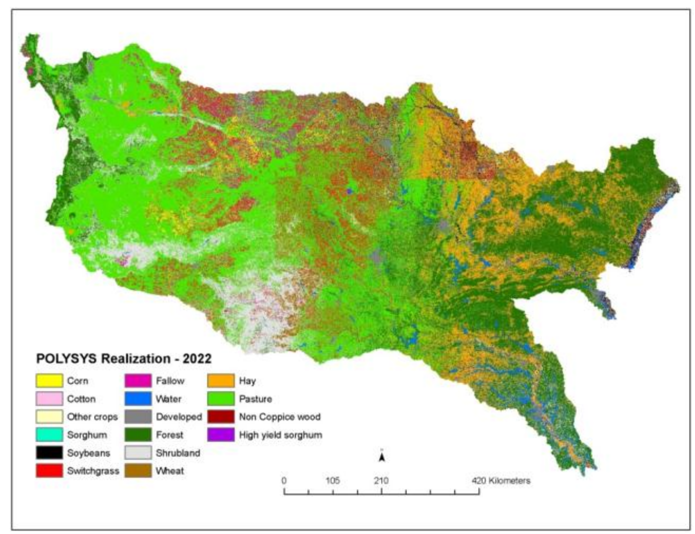
Future biomass crops in the Arkansas-White-Red River Basin



Current landscape



Future scenario

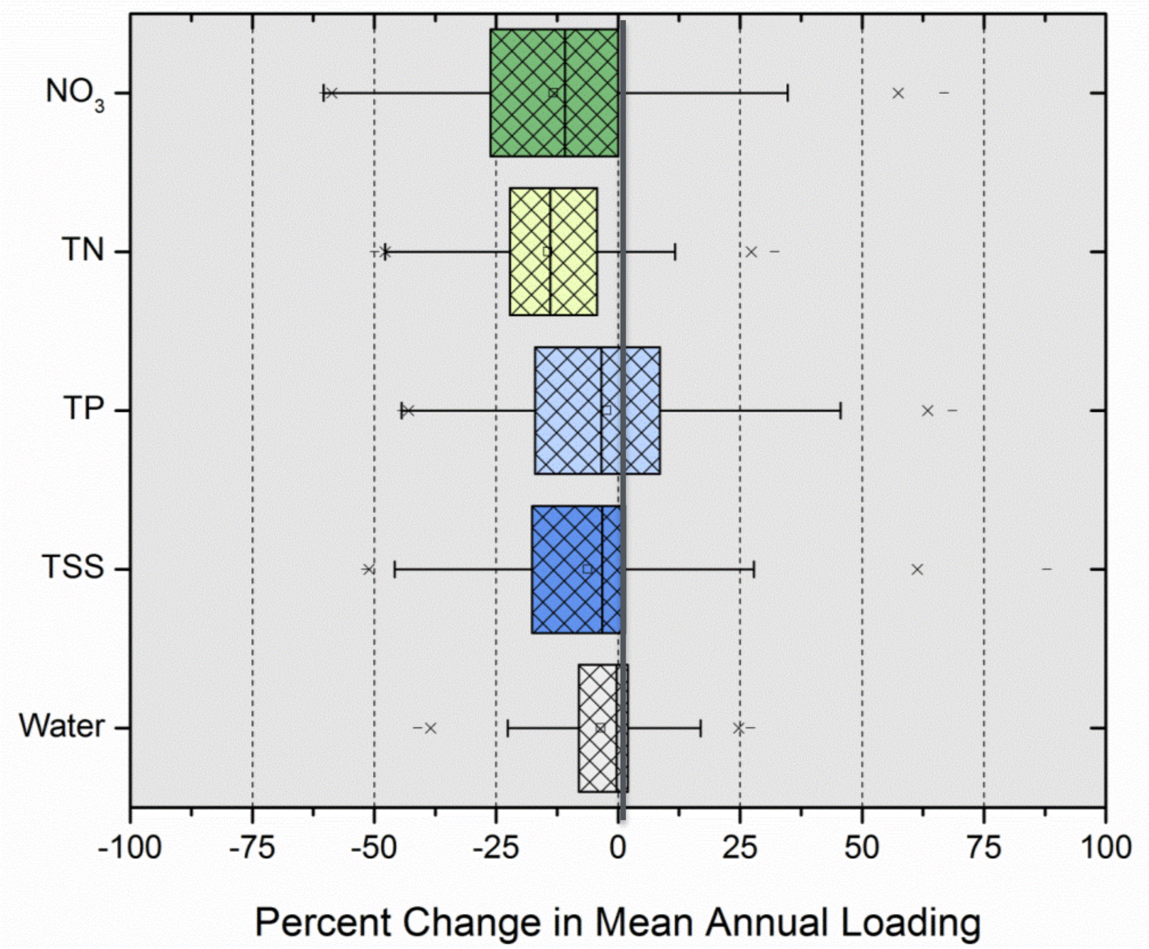


$50 farmgate price for switchgrass
1% annual yield increase

Results for Arkansas-White-Red River basins

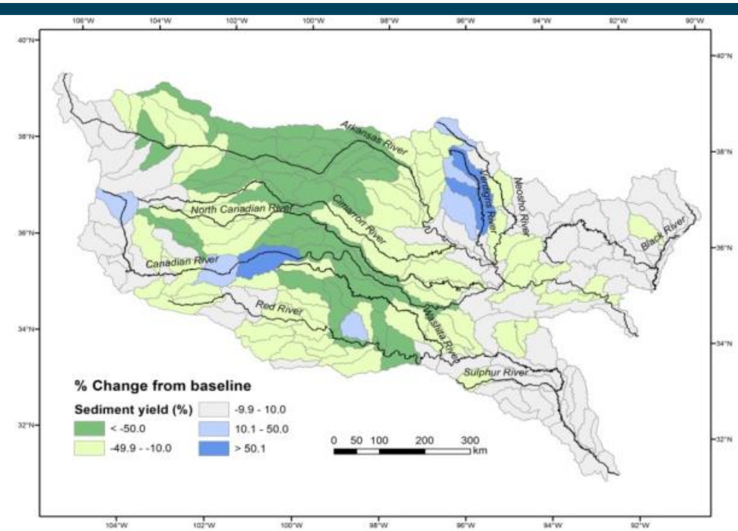
Key findings:

- Substantial decrease in simulated median nitrate loadings and TN loadings
- Smaller decrease in median total phosphorus (TP) and sediment (TSS)
- Smaller decrease in water yield

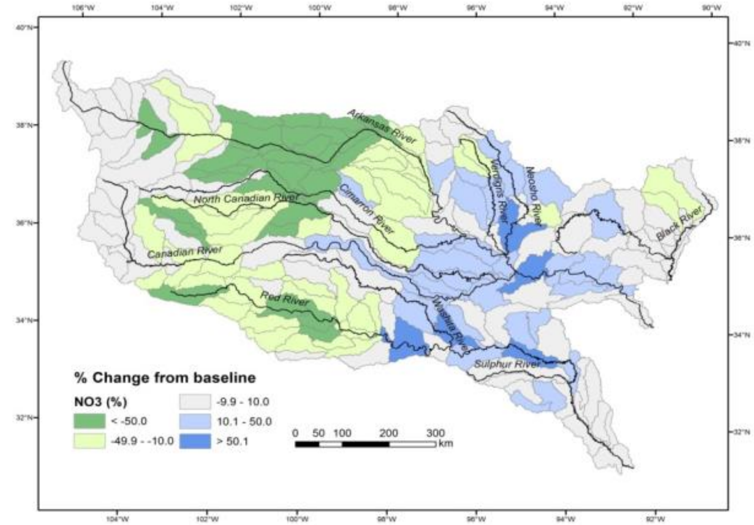


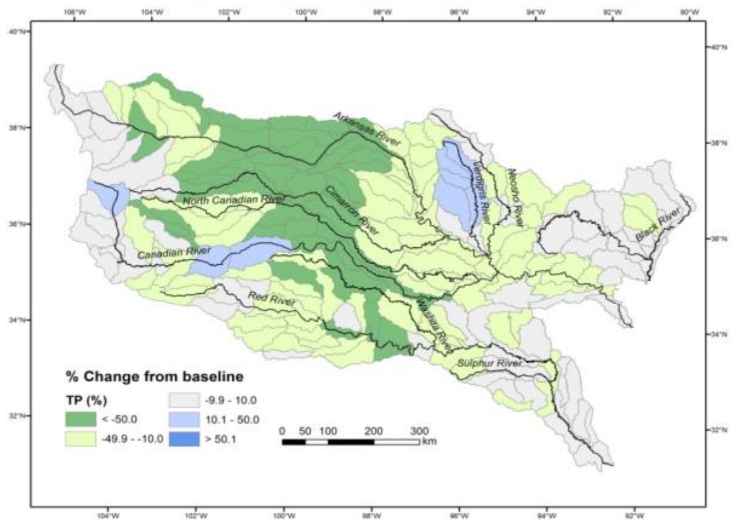
Bioenergy future (1% annual yield increase, $50/dt)

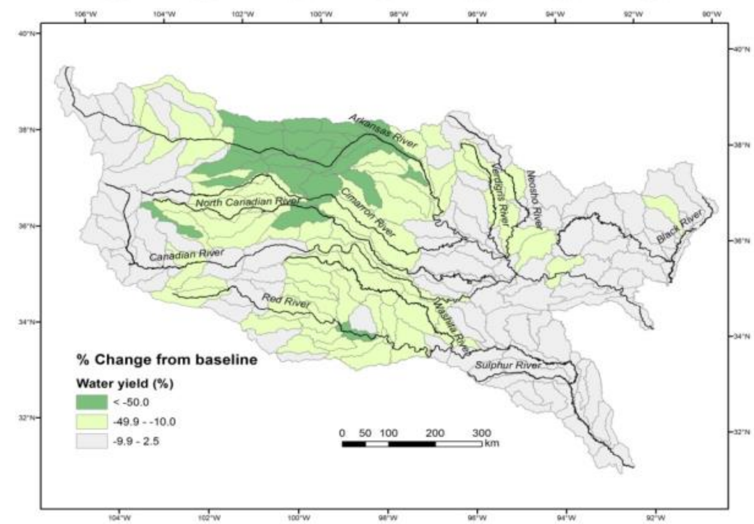
SWAT-simulated changes in water quality for the Arkansas-White-Red River basin



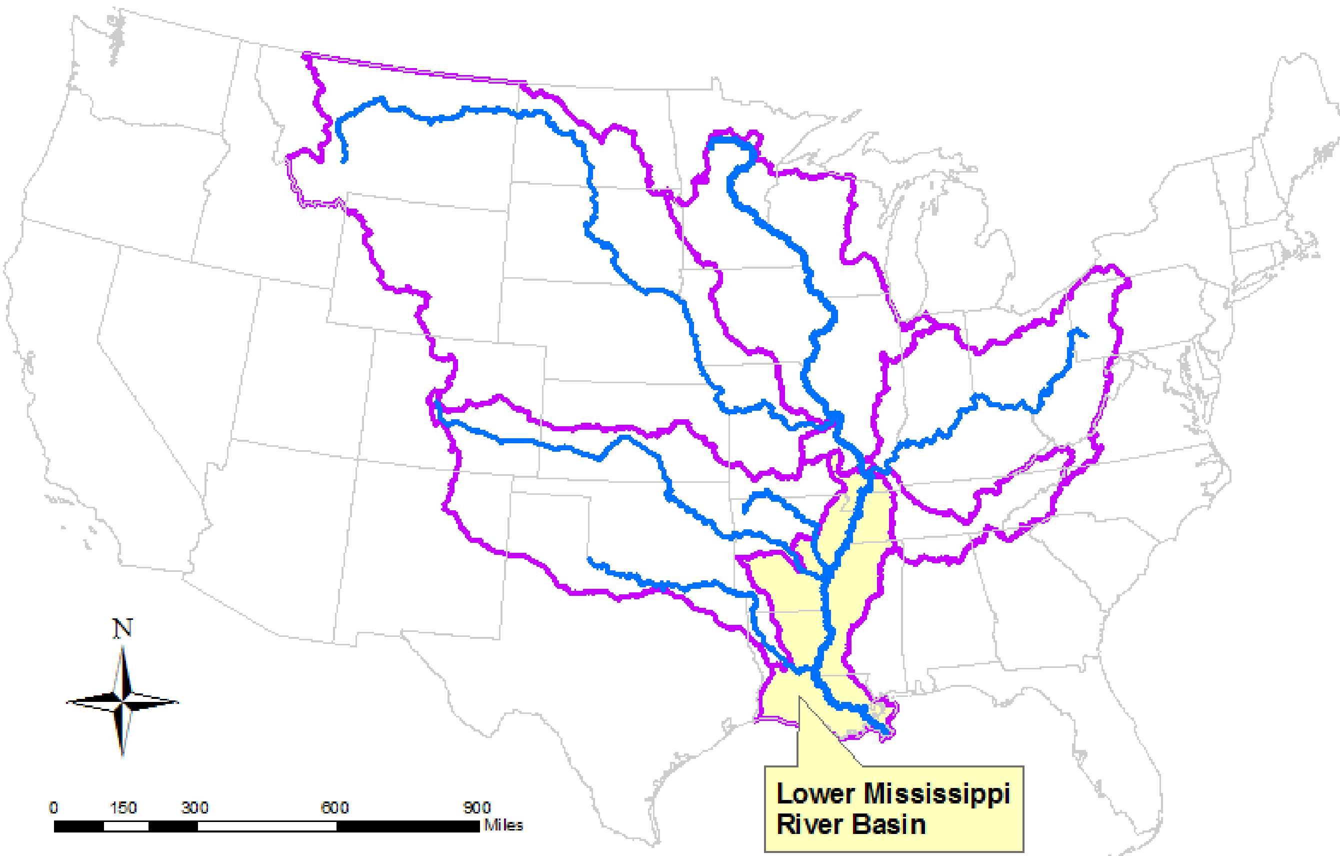
precipitation gradient



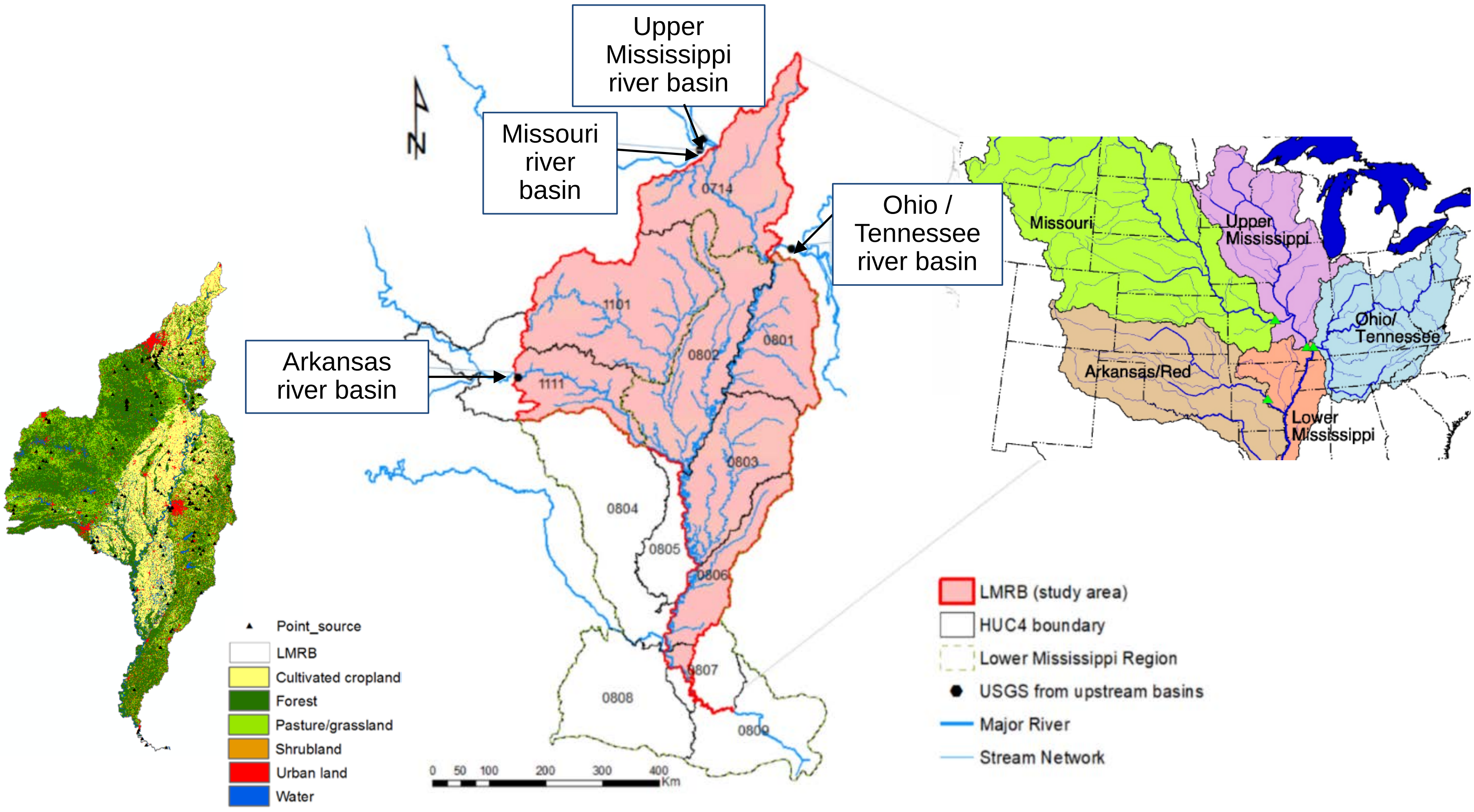




Lower Mississippi River Basin (LMRB)



Four major basins contribute to Lower Mississippi River basin



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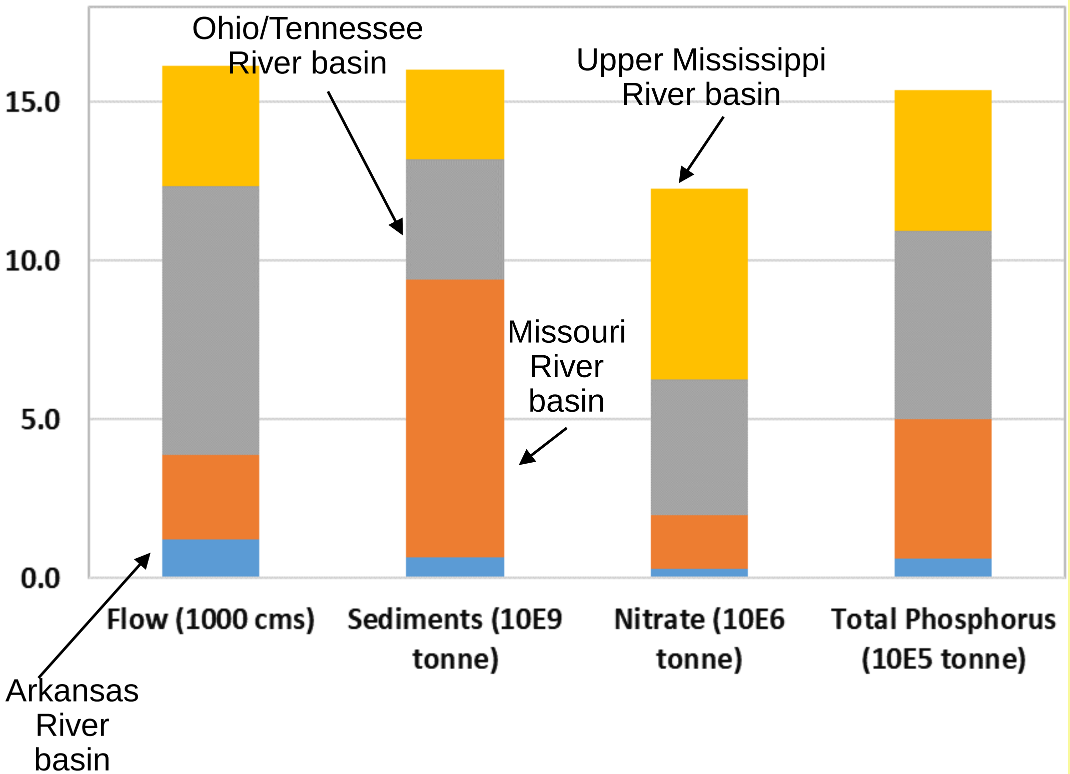
Spatial distribution of nutrients and sediments from MRB to the Gulf of Mexico



- Upper Mississippi River basin accounts for ~50% of nitrogen loadings to Lower Mississippi river basin.
- Ohio/Tennessee river basin contributes to a majority of flow and phosphorus.
- Missouri River basin is responsible to most of the sediments.
- Lower Mississippi River basin contributes 17% of the streamflow, 42% of the sediments, 10% of the nitrate, and 16% of the phosphorus into Gulf of Mexico.

Ha, M., Z. Zhang, & M. Wu. 2018. *Science of the Total Environment*, 10.1016/j.scitotenv.2018.03.184.

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Cross-cutting insights

- The Upper Mississippi, Ohio River, and Missouri River basins have been identified as major sources of nitrogen, phosphorus, and suspended sediments to the Gulf of Mexico.
- Our results suggest that loadings in these and other basins can be reduced by growing biomass such as switchgrass, short rotation woody crops and the degree of reductions can vary across tributary basins.
- Assumptions regarding biomass crop replacement and associated management (fertilizer, tillage, and others) were important to the outcomes.
- In watersheds and economic scenarios where annual crops, hay, or pasture were replaced by perennial biomass crops, SWAT predicted improvements in water quality. Harvesting annual crop residues also had beneficial effects on reducing nitrogen.
- Evapotranspiration increased, surface runoff and soil water decreased under the potential scenarios examined in most basins.
- In all basins, geographic variation in water quality outcomes occurred, with some areas serving as nutrient or sediment sources and others as sinks relative to that simulated from a current landscape.

Lessons learned

- As DOE labs, our expertise is in modeling management of biomass crops, economic assumptions, projected land management, and simulating water quality implications.
- Model fitting at large regional scales was challenging, and approaches such as functional validation and use of synthetic data such as USGS regional loading models were helpful.
- Watershed modeling requires attention to many variables not of immediate interest (conventional crops, tile drainage, point sources, dams and reservoirs). Therefore collaborations, e.g., SWAT developers, USGS, USACE, TVA were important.

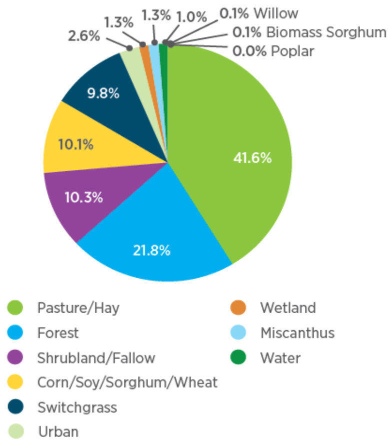
Conservation practices

- Biomass feedstock specific
- For short-rotation woody crops, filter strips
- For perennial grasses, fertilization
- For conventional crops:
  - Stover removal rates
  - Fertilizer management (type, timing)
  - Riparian buffers
  - Tile drain mitigation

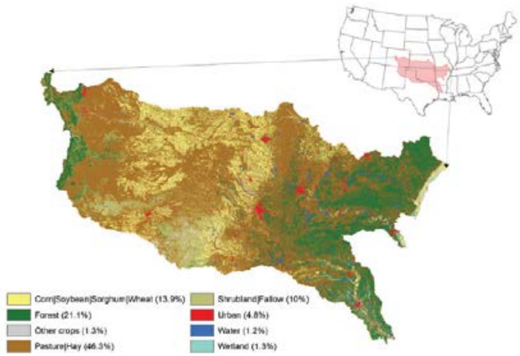
https://energy.gov/eere/bioenergy/articles/volume-2-2016-billion-ton-report-analyzes-potential-environmental-effects

Two river basins with different feedstock profiles

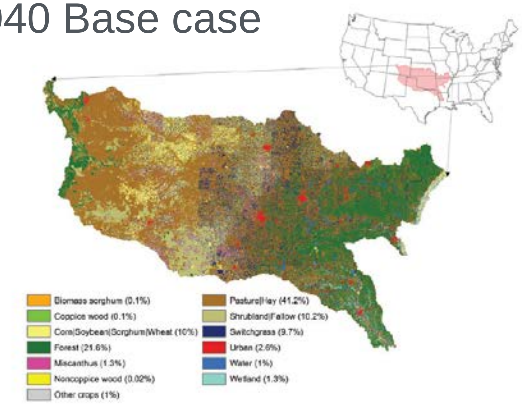
Arkansas-White-Red River Basin



2014

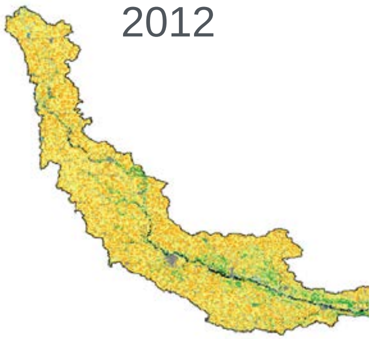


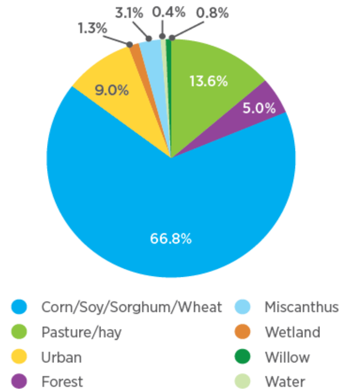
2040 Base case



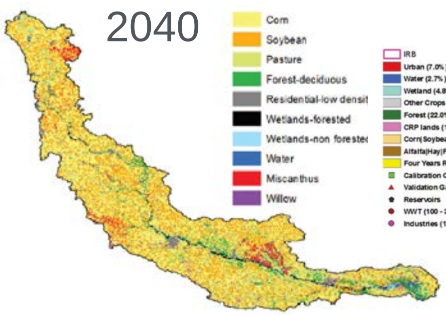
Iowa River Basin

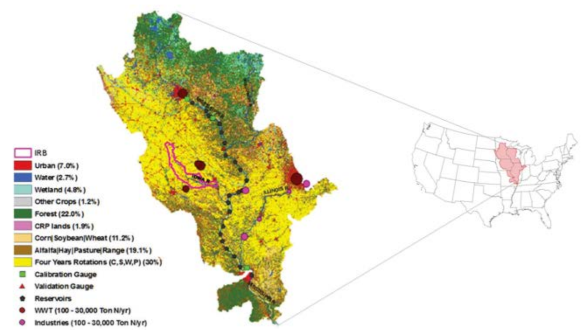
2012



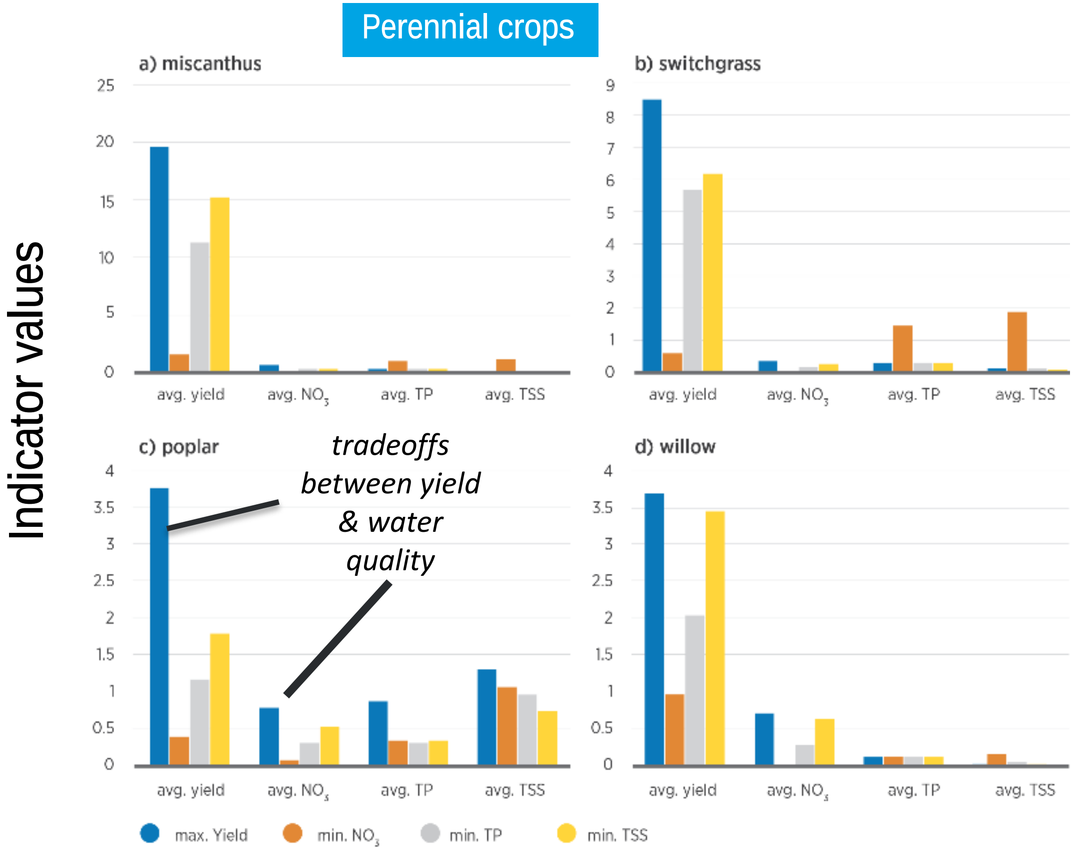


2040





‘Best’ practices revealed trade-offs between indicators

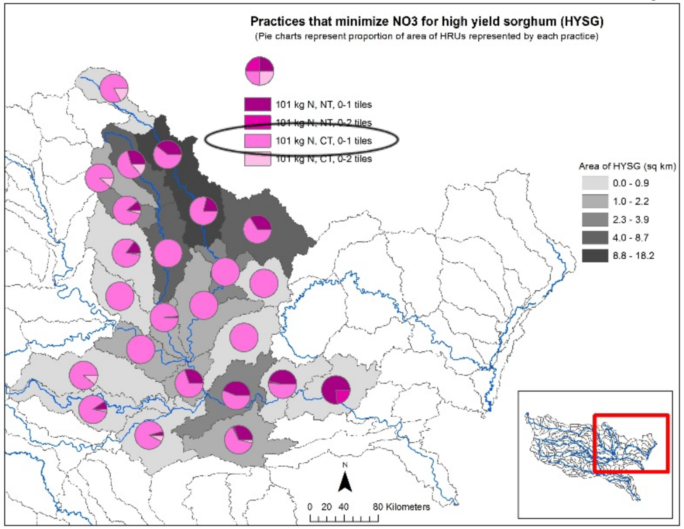


- Tile drains on lands steeper than 1% slope rarely benefited residue yield or water quality.
- No-till favored higher yields, and reduced sediment and TP (but not nitrate) loadings.
- Filter strips improved water quality for willow and poplar, with some cost to yield. Harvest of strips can be considered in future.
- Residue removal from annual crops increased sediment but decreased nutrient loadings. This assumed fixed fertilizer input.

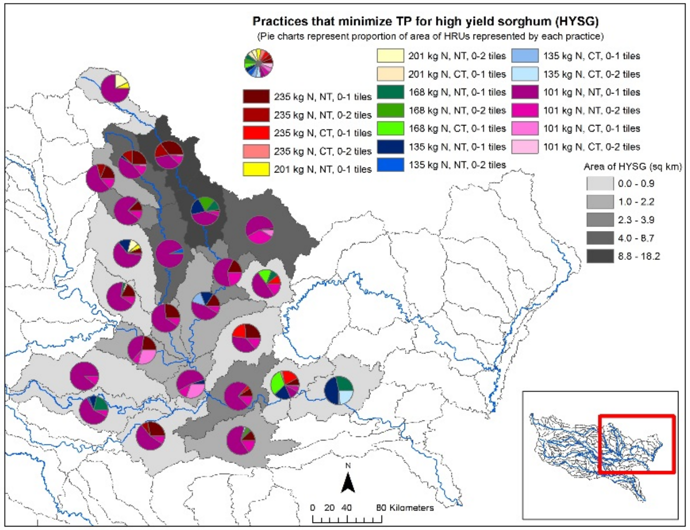
Larger trade-offs between yield and nitrate than yield and TSS or TP, primarily caused by variation in fertilizer amounts.

Trade-offs: Locally ‘best’ practice depends on indicator

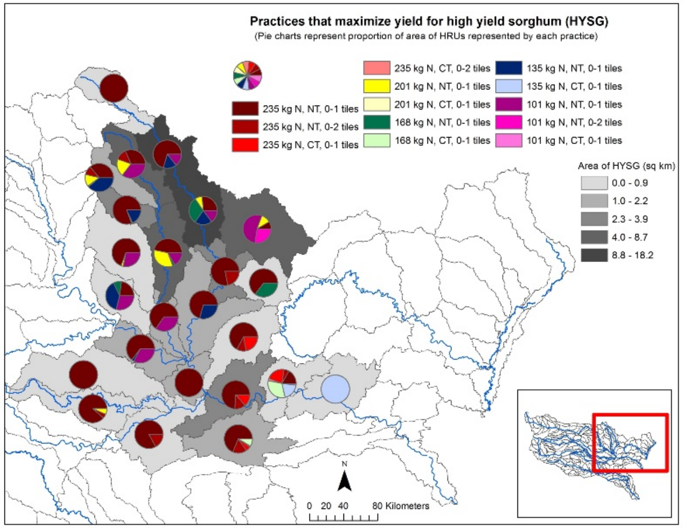
NO3: Conventional till, least fertilizer, tiles only on flat land



TP: Mostly no till, least fertilizer, tiles only on flat land



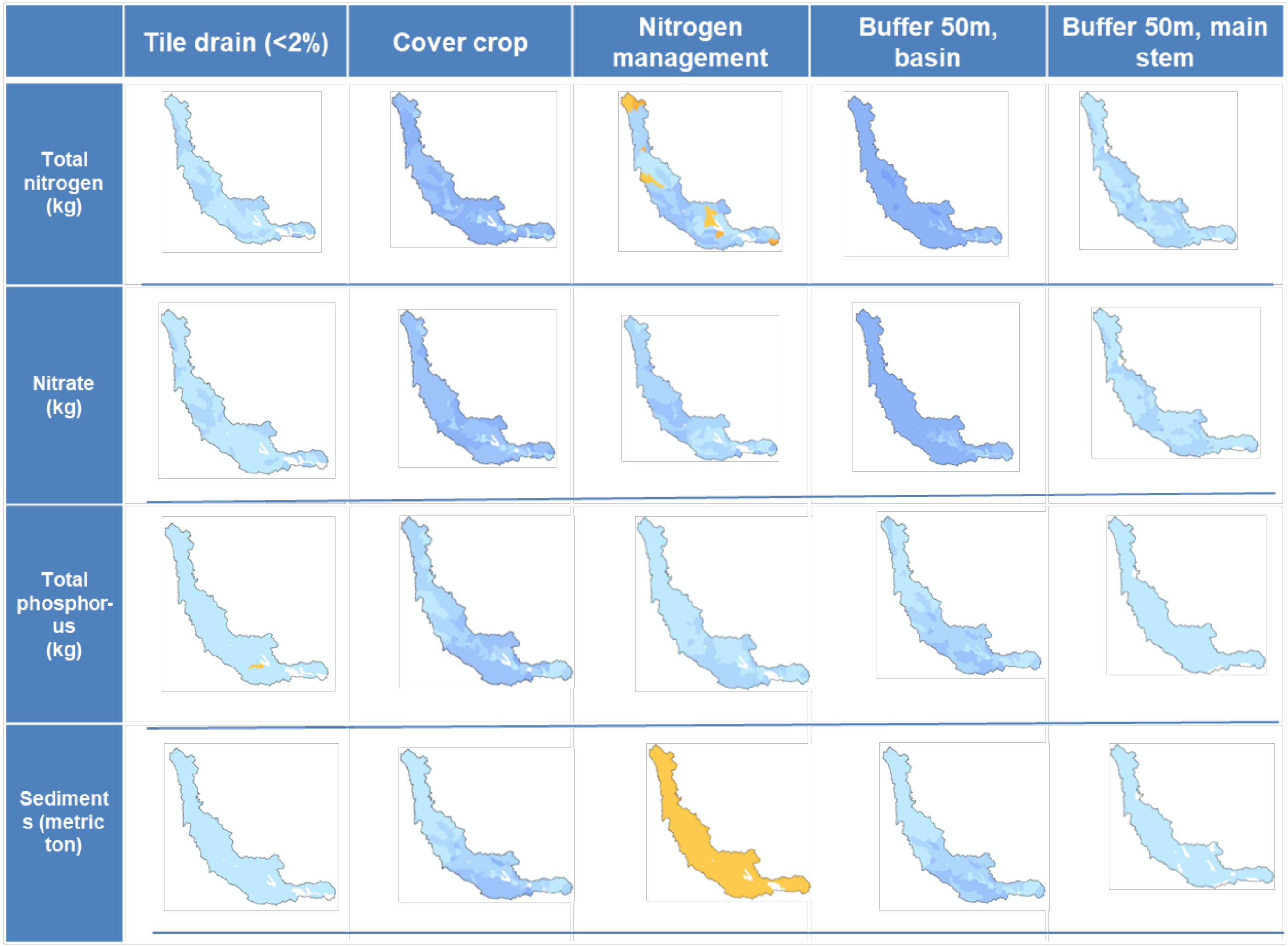
Yield: Mostly no till, high fertilizer, tiles only on flat land



Fertilizer	**Tillage**
101 kg N/ha (pink)	NT = no till
135 kg N/ha (blue)	CT = conventional till
168 kg N/ha (green)	
201 kg N/ha (yellow)	**Tile drains**
235 kg N/ha (red)	0% to 1% slope
	0% to 2% slope

Win-win opportunities occur where the same practice benefits yield and water quality indicators

Geospatial results – Iowa River Basin



- Loadings of nutrients and sediments exhibit strong heterogeneity across the landscape.
- Removal of sediments and phosphorus is correlated with the size of flow and stream network when buffer is installed.

Key findings – Iowa River Basin

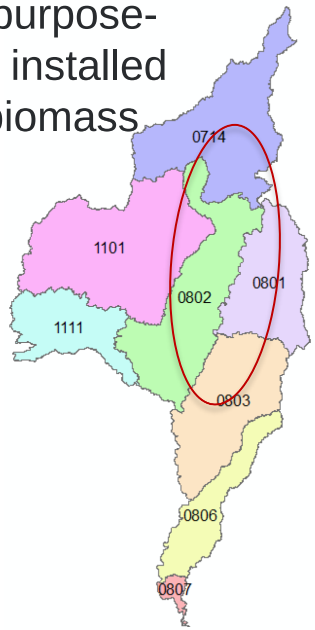
	Removals Relative to a Potential Scenario (%)			
Conservation Practice Scenarios	Suspended Sediments	Total Phosphorus	Total Nitrogen	Nitrate
Buffer 30m, main stem of Iowa River	70.5%	7.9%	8.2%	6.2%
Buffer 50m, main stem of Iowa River	70.8%	8.6%	8.9%	6.9%
Buffer, 50m, entire Iowa River stream network	80.3%	22.7%	22.7%	10.8%
Cover crop	37.0%	27.4%	18.5%	19.0%
Nitrogen fertilizer management (scheduling)	5.6%	9.9%	10.9%	11.4%
Tile drain (<2% slope)	1.8%	1.7%	27.5%	28.6%

- Riparian buffer is most effective in reducing suspended sediments. Degree of reduction increases with buffer coverage.
- Limiting tile drainage to the land with less than 2% slope could significantly reduce nitrate loadings to downstream communities.

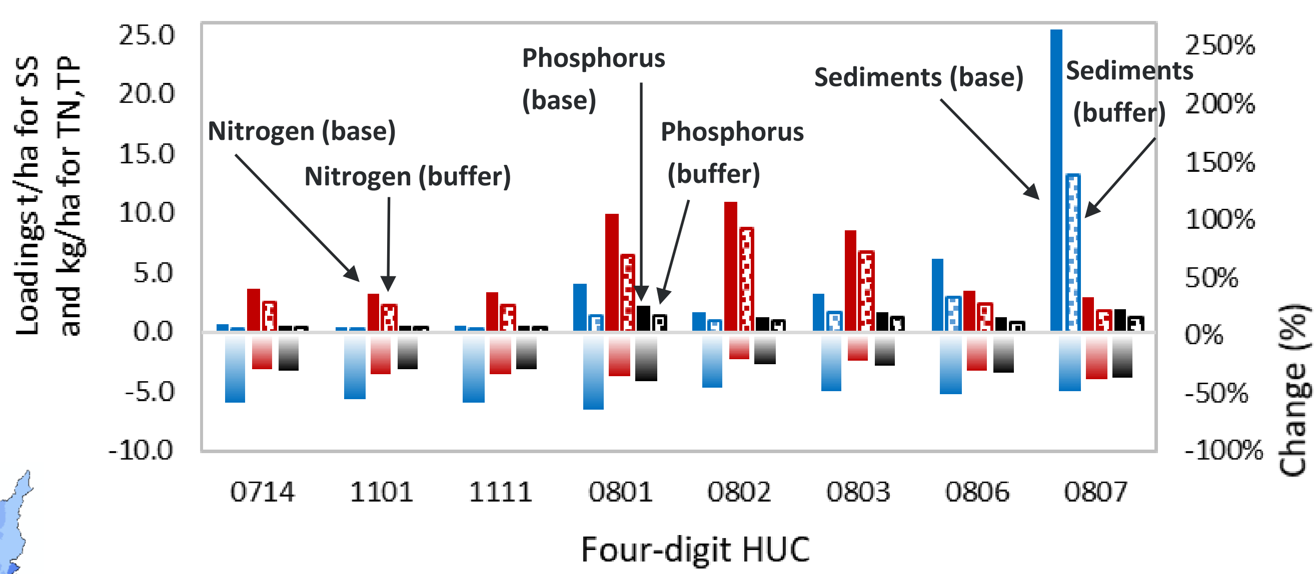
- A combination of the four conservation practices could result in substantial improvement in this region.
- Results may be applicable to regions with similar soil, climate, landscape, and crop systems.

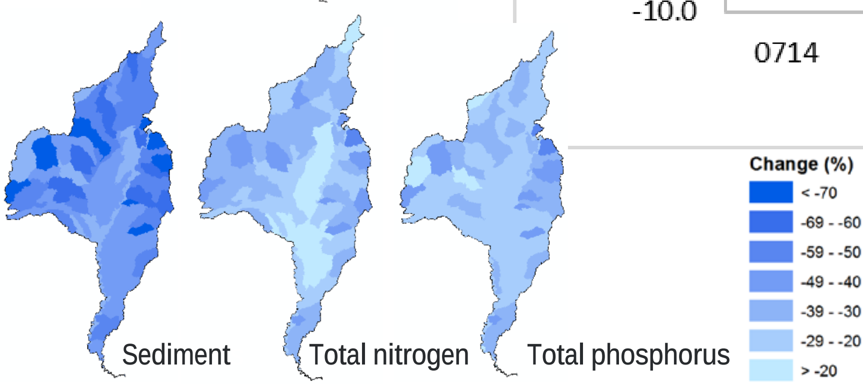
Simulation of riparian buffers in Lower Mississippi River basin

Multipurpose-buffer installed for biomass



Changes of nutrients and sediments in regional watersheds relative to baseline year 2012





Ha, M., Z. Zhang, M. Wu, 2018. *Science of the Total Environment*, DOI: 10.1016/j.scitotenv.2018.03.184

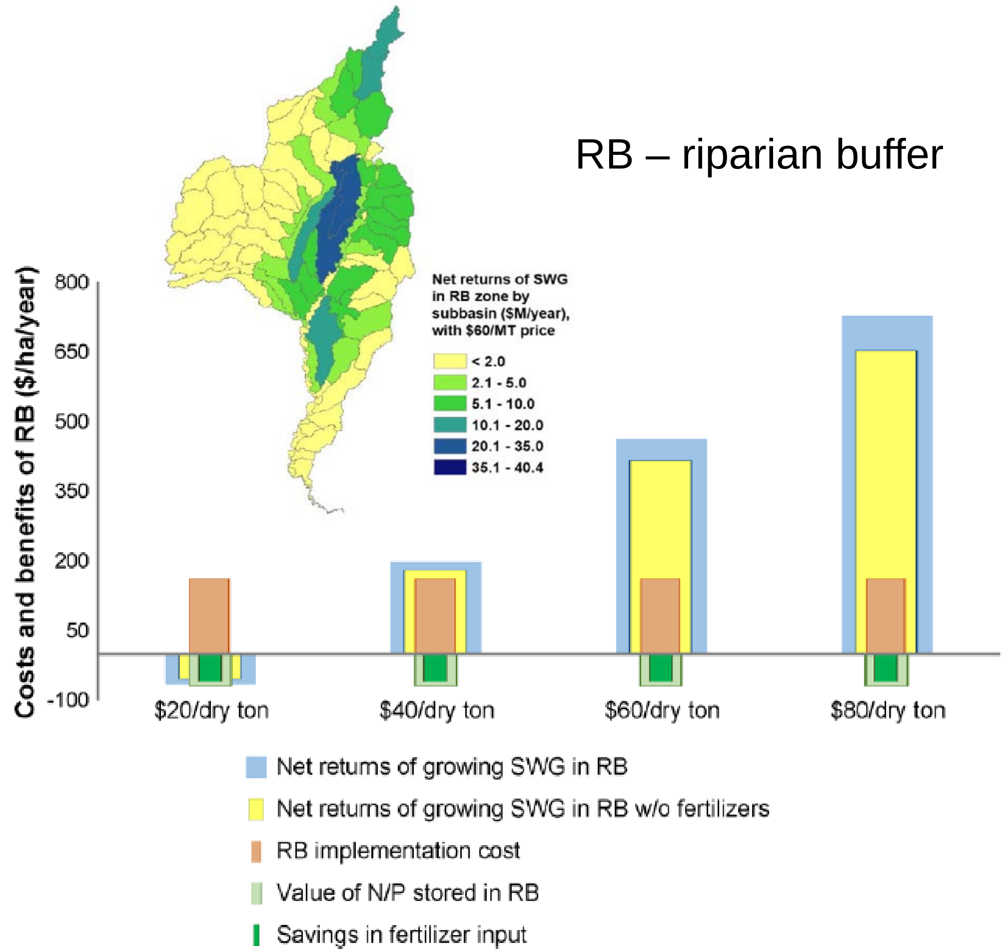
Benefit analysis of riparian buffer in agriculture land in Lower Mississippi River Basin

- Buffer can be harvested as biomass.
- Use nutrients trapped in the soil to grow switchgrass as buffer.
- Factors considered: buffer installation, fertilizer savings, biomass value, crop production.

Findings:

- Net returns increase with increase of switchgrass yield, switchgrass market price, and fertilizer prices; and decrease with an increase of buffer installation cost and crop land loss to buffer.
- Results vary from state to state in the lower MRB.

RB – riparian buffer



Xu, H., M. Wu, and M. Ha, 2018. *BioFPR*.

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Summary – Management practices and water quality

- Riparian buffers were highly effective at reducing loadings of sediment and phosphorus in lands growing annual crops and residues (IRB and LMRB).
- Filter strips for short-rotation woody crops and corn/soy bean were effective in reducing all loadings with no significant effect on willow yield (AWR and IRB).
- Cover crops were effective in reducing nutrients and sediments runoff from annual crop land with residual harvest (IRB).
- Avoiding tile-drains on >1% slope was effective in reducing nitrogen loadings and still provided a yield benefit (AWR and IRB).
- Scheduling of nitrogen fertilizer reduced nitrogen loadings comparable to that associated with planting a riparian buffer (IRB).
- Compared with conventional till, no-till production of annuals was associated with lower phosphorus and sediment loadings, but not lower nitrate loadings (AWR and UMRB)
- Integrating multi-purpose riparian buffer planted in switchgrass is an attractive strategy to effectively trap nutrient loss from agricultural land while producing biomass for energy production (LMRB).
- The profitability of implementing buffers is constrained by switchgrass price, the cost of installation of buffer, and loss of conventional crop acreage (LMRB).

References

- Jager, HI & RA Efroymson. 2018. Biomass production mediates the flow of ecosystem goods and services downstream to the Gulf of Mexico. Biomass and Bioenergy 114: 125-131. Special Issue on Biomass and Ecosystem Services.
- Wang, G., HI Jager, LM Baskaran, and CC Brandt. 2018. Hydrology and Water Quality Responses to Biomass Production in the Tennessee River Basin. *Global Change Biology: Bioenergy* 10: 877-893.
- Xu, H., M. Wu, and M. Ha, 2018. The value proposition of reducing nutrient loss from agricultural fields by growing riparian buffers as bioenergy feedstock in the Lower Mississippi Basin. BioFPR. https://onlinelibrary.wiley.com/doi/abs/10.1002/bbb.1930
- Ha, M., Z. Zhang, M. Wu, 2018. Biomass production in the Lower Mississippi River Basin: Mitigating associated nutrient and sediment discharge to the Gulf of Mexico. Science of the Total Environment, DOI: 10.1016/j.scitotenv.2018.03.184.
- Lampert, D. and M. Wu, 2018. Automated Approach for Construction of Long-Term, Data-Intensive Watershed Models, J. Comput. Civ. Eng., 2018, 32(4): 06018001. DOI: 10.1061/(ASCE)CP.1943-5487.0000762.
- Demissie, Y.; E. Yan, and M. M. Wu. 2017. Hydrologic and Water Quality Impacts of Biofuel Feedstock Production in the Ohio River Basin, GCB Bioenergy (2017) 9, 1736–1750, doi: 10.1111/gcbb.12466.
- Wu, M. and M. Ha, Incorporating Conservation Practices into the Future Bioenergy Landscape: Water Quality and Hydrology. In: Bioenergy and Land Use Change (Eds Qin Z, Mishra U, Hastings A), John Wiley & Sons, Inc, Hoboken, NJ. 2017, 125-139. Print ISBN: 9781119297345; Online ISBN: 9781119297376; DOI: 10.1002/9781119297376.
- Ha, M., M. Wu. 2017. Land management strategies for improving water quality in biomass production under changing climate. Environ. Res. Lett. 12(3):034015. http://iopscience.iop.org/article/10.1088/1748-9326/aa5f32
- Jager, HI, LM Baskaran et al. 2015. Forecasting changes in water quality in rivers associated with growing biofuels in the Arkansas-White-Red river drainage, USA. Global Change Biology: Bioenergy. 7(4): 774-784
- Negri, C., Nair, S., L. Ovard, and H. Jager. Bioenergy solutions to Gulf hypoxia. Multi-lab report on a workshop.

References

- Wu, M. and Z.L. Zhang, 2015. Identifying and mitigating potential nutrient and sediment hot spots under a future scenario in the Missouri River Basin, ANL/ESD-15/13, Argonne National Laboratory, Lemont IL, Sept. http://www.ipd.anl.gov/anlpubs/2015/09/121150.pdf.
- Zhang, Z.L and M. Wu, 2015. Progress and challenges in quantifying water quality and ecosystem responses from agricultural, forestry, and bioenergy landscapes, Current Sustainable/Renewable Energy Reports, DOI 10.1007/s40518-015-0041-x.
- Ha, M. and M. Wu, 2015. Simulating riparian buffer in integrated landscape management scenarios for biofuel feedstock production, BioFPR. DOI: 10.1002/bbb.1579
- Zhang, ZL, M. Wu. 2013. Evaluating the Transport and Fate of Nutrients in Large Scale River Basins Using an Integrated Modeling System, in Landscape Ecology for Sustainable Environment and Culture, Ed. Bojie Fu, K. Bruce Jones, Springer Netherlands. ISBN: 978-94-007-6529-0. 2013.
- Demissie, Y., E. Yan, M. Wu. 2012. Assessing Regional Hydrology and Water Quality Implications of Large-Scale Biofuel Feedstock Production in the Upper Mississippi River Basin, Environ. Sci. Technol., 2012, 46, 9174−9182. DOI: 10.1021/es300769k.
- Wu, M., Demissie, Y., Yan, E. 2012. Assessing the Impact of Future Biofuel Scenario on Water Quality and Water Cycle Dynamics, Biomass & Bioenergy, 41(2012)44-56. doi:10.1016/j.biombioe.2012.01.030.
- Demissie Y, Yan E, Wu M, Zhang Z (2012) Watershed Modeling of Potential Impacts of Biofuel Feedstock Production in the Upper Mississippi River Basin. Argonne National Laboratory, ANL/EVS/AGEM/TR-12-07, Argonne, IL.
- Baskaran, L.M., H.I. Jager, P. E. Schweizer, R. Srinivasan. 2010. Progress toward evaluating the sustainability of switchgrass production at a regional scale. American Society of Agricultural and Biological Engineers 53(5): 1547-1556
- Jager, H.I., L. M. Baskaran, C. C. Brandt, E. B. Davis, C. A. Gunderson, S. D. Wullschleger. 2010. Empirical geographic modeling of switchgrass yields in the United States. Global Change Biology: Bioenergy 2: 248-257

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