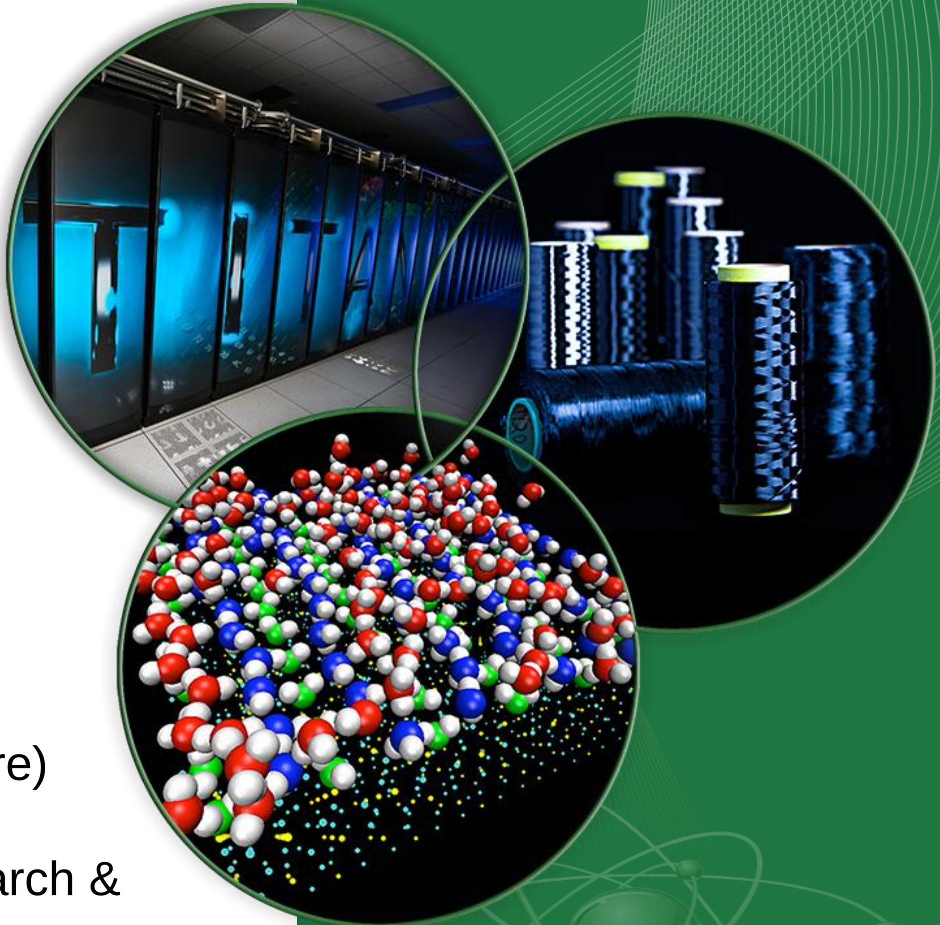
Environmental & Socioeconomic Sustainability of Switchgrass-to-Ethanol Production in East Tennessee



Esther S. Parish (ORNL)
parishes@ornl.gov

Co-Authors:
- **Virginia Dale** (ORNL)
- **Burt English** (UT Institute of Agriculture)
- **Sam Jackson** (Genera Energy)
- **Don Tyler** (UT West Tennessee Research & Education Station, Jackson, TN)

National Bioenergy Day
October 21, 2015

ORNL is managed by UT-Battelle
for the US Department of Energy

CBES
Center for BioEnergy Sustainability
http://web.ornl.gov/sci/ees/cbes/

OAK RIDGE National Laboratory

Sustainability

is the capacity of an activity to continue while maintaining options for future generations.

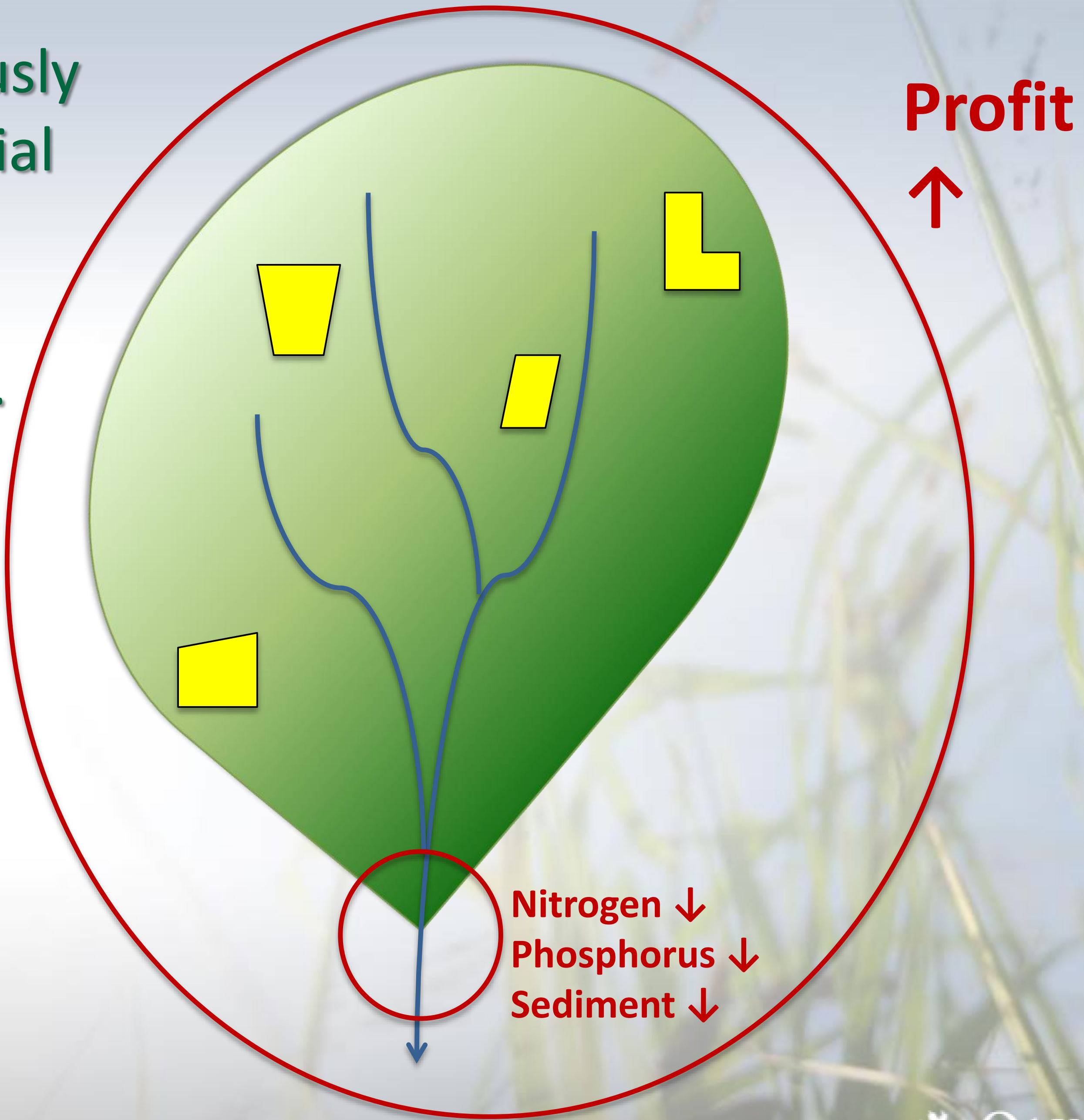
Oak Ridge National Lab's (ORNL's) research agenda includes:

- <u>Defining</u> environmental and socioeconomic costs & benefits of bioenergy systems
- <u>Quantifying</u> opportunities & risks associated with sustainable bioenergy in specific contexts
- <u>Communicating</u> the challenges & paths forward for sustainable bioenergy to a range of stakeholders

To ensure long-term sustainability of bioenergy production, we must consider tradeoffs between multiple stakeholder objectives

Oak Ridge National Laboratory

We have previously modeled potential sustainability tradeoffs at a watershed scale.



<u>Research Question:</u>
Which crop configuration maximizes sustainability objectives while achieving target production?

Schematic based on Parish et al. (2012) Multimetric Spatial Optimization of Switchgrass Plantings Across a Watershed. *Biofuels, Bioproducts & Biorefining* 6(1):58-72

Sustainability Indicators

Measurements that provide information about the effects of human activities on the environment, society or economy.

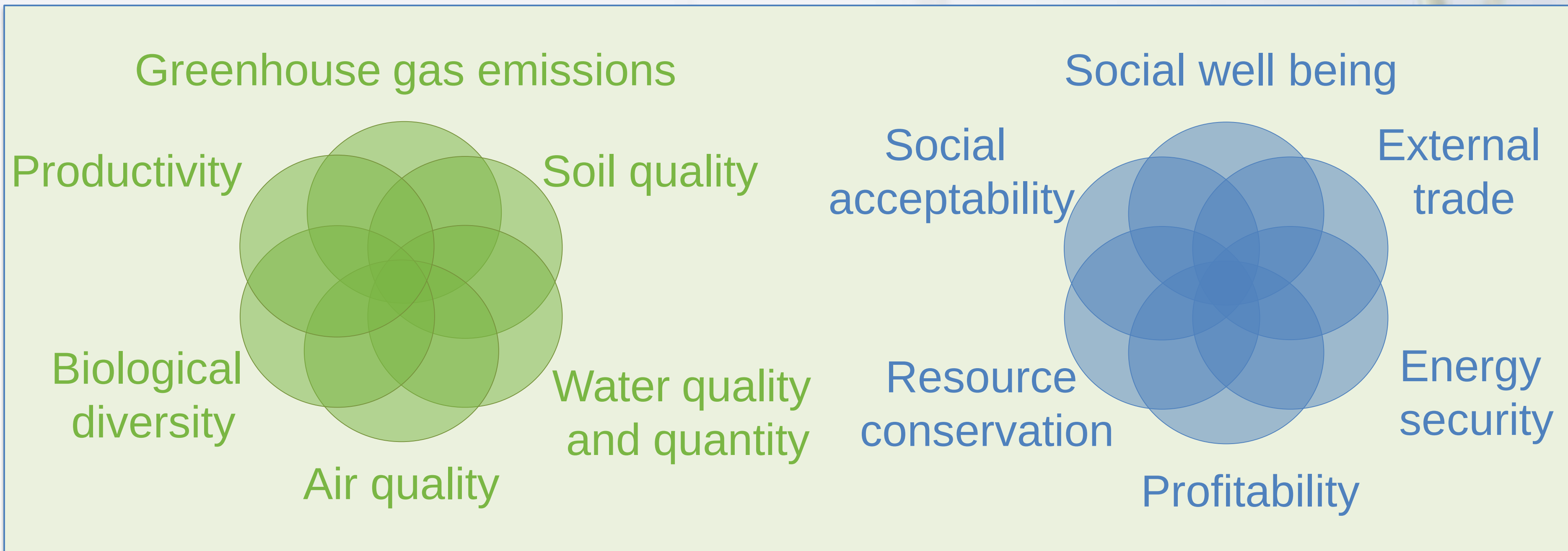
Indicators should be

- Useful
  - Policymakers
  - Producers
- Technically effective
  - Sensitive to stresses on system
  - Anticipatory: signify impending change
  - Have known variability in response
- Practical
  - Easily measured
  - Consider context of measure
  - Broadly applicable
  - Predict changes that can be averted by management actions

Dale and Beyeler. 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators* 1: 3-10.

OAK RIDGE National Laboratory

Recommended Indicator Categories for environmental and socioeconomic sustainability



McBride et al. (2011)
Ecological Indicators
11:1277-1289

Dale et al. (2013)
Ecological Indicators
26:87-102.

All indicator measurements & interpretations will be <u>context</u>-specific.

Efroymson et al. (2013) *Environmental Management* 51:291-306.

OAK RIDGE National Laboratory

Environmental sustainability indicators

Environment	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus (P) concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	7. Suspended sediment concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	8. Herbicide concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	9. storm flow	L/s
	10. Minimum base flow	L/s
	11. Consumptive water use (incorporates base flow)	feedstock production: m^3/ha/day; biorefinery: m^3/day

Environment	Indicator	Units
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)	kgC_{eq}/GJ
Biodiversity	13. Presence of taxa of special concern	Presence
	14. Habitat area of taxa of special concern	ha
Air quality	15. Tropospheric ozone	ppb
	16. Carbon monoxide	ppm
	17. Total particulate matter less than 2.5µm diameter ($PM_{2.5}$)	$\mu g/m^3$
	18. Total particulate matter less than 10µm diameter (PM_{10})	$\mu g/m^3$
Productivity	19. Aboveground net primary productivity (ANPP) / Yield	gC/m^2/year

McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Socioeconomic sustainability indicators

Ten minimum practical measures

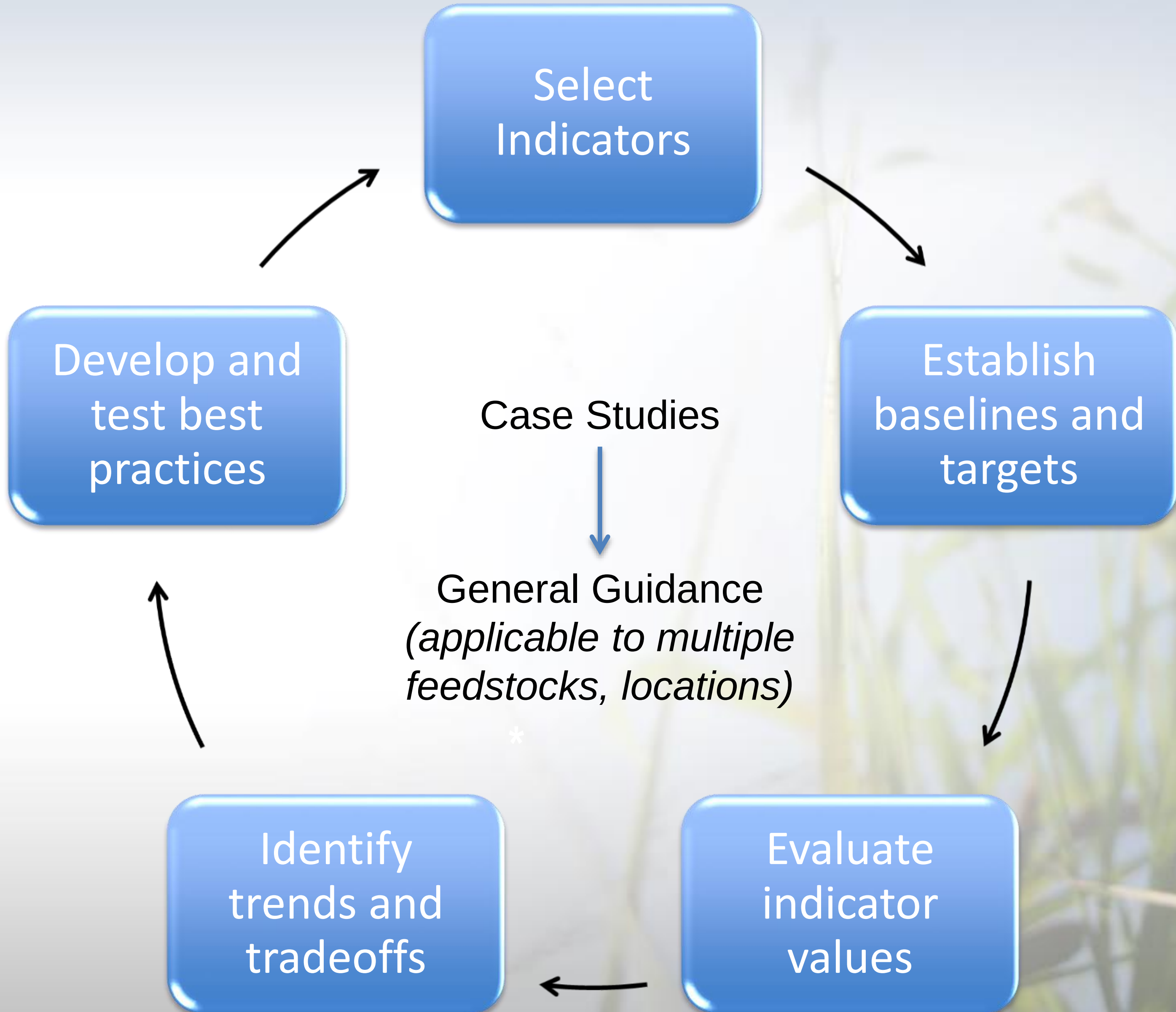
Category	Indicator	Units
Social well-being	Employment	Number of full time equivalent (FTE) jobs
	Household income	Dollars per day
	Work days lost due to injury	Average number of work days lost per worker per year
	Food security	Percent change in food price volatility
Energy security	Energy security premium	Dollars /gallon biofuel
	Fuel price volatility	Standard deviation of monthly percentage price changes over one year
External trade	Terms of trade	Ratio (price of exports/price of imports)
	Trade volume	Dollars (net exports or balance of payments)
Profitability	Return on investment (ROI)	Percent (net investment/ initial investment)
	Net present value (NPV)[2]	Dollars (present value of benefits minus present value of costs)

Category	Indicator	Units
Resource conservation	Depletion of non-renewable energy resources	MT (amount of petroleum extracted per year)
	Fossil Energy Return on Investment (fossil EROI)	MJ (ratio of amount of fossil energy inputs to amount of useful energy outputt
Social acceptability	Public opinion	Percent favorable opinion
	Transparency	Percent of indicators for which timely and relevant performance data are reported
	Effective stakeholder participation	Number of documented responses to stakeholder concerns and suggestions reported on an annual basis
	Risk of catastrophe	Annual probability of catastrophic event

Dale et al. (2013) *Ecological Indicators* 26:87-102.

OAK RIDGE National Laboratory

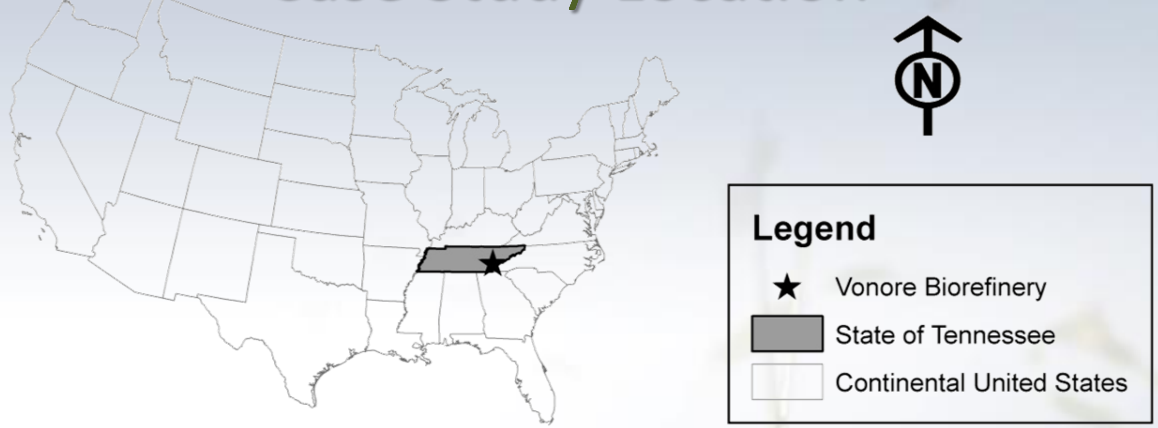
ORNL approach to assessing Bioenergy Sustainability

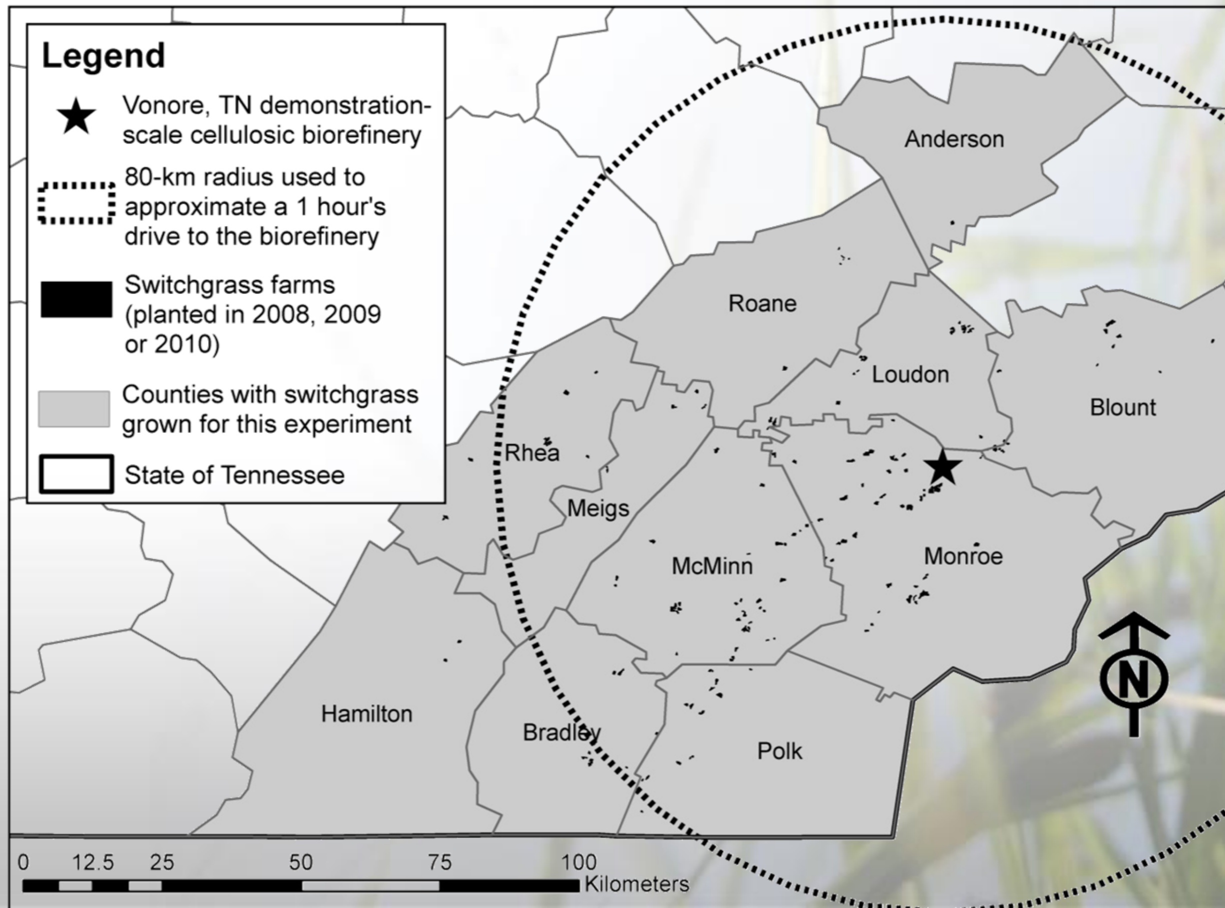


First Case Study:
Cellulosic Biofuel Production in East Tennessee

Oak Ridge National Laboratory

Case Study Location

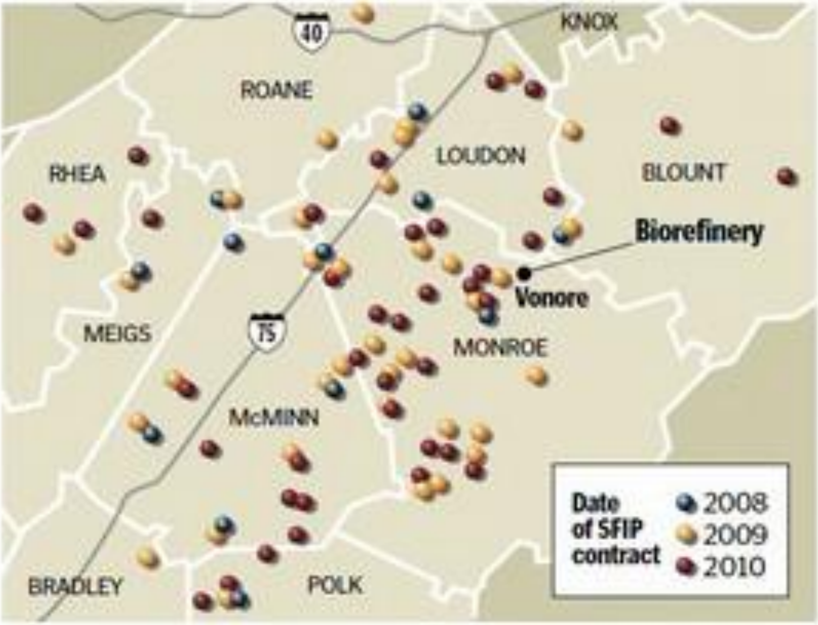




Oak Ridge National Laboratory

5-year Vonore, Tennessee switchgrass-to-ethanol experiment

SWITCHGRASS CONTRACT FARMS



County	Total acres	Farmers
Monroe	2,205.3	26
McMinn	818.1	10
Loudon	553.9	6
Blount	469.5	4
Bradley	354.7	2
Polk	291.9	3
Rhea	258.1	5
Roane	118.8	4
Hamilton	58.6	1
Meigs	33.3	2
Totals	**5,162.2**	**63**

Year	New farmers	Total production in tons
2008	16	1,000
2009	24	6,000
2010	21	*15,000

*Estimated

Farmer type	Farmers
Full time	31
Part time	30

Source: Genera Energy LLC NEWS SENTINEL

Genera energy

Demonstration-scale cellulosic biorefinery (250Mgal/yr) + Switchgrass from 10 counties

Photos from Genera Energy LLC

Ecosphere manuscript (in press)

Assessing Multimetric Aspects of Sustainability: Application to a Bioenergy Crop Production System in East Tennessee

Esther S. Parish[1], Virginia H. Dale[1], Burton C. English[2], Samuel W. Jackson[3], Donald D. Tyler[4]

[1]Center for BioEnergy Sustainability (CBES), Oak Ridge National Laboratory (ORNL), 1 Bethel Valley Road, Oak Ridge, TN 37831;
[2]Agricultural and Resource Economics Department, The University of Tennessee Institute of Agriculture (UTIA), 2621 Morgan Circle, Knoxville, TN 37996;
[3]Genera Energy, 167 Tellico Port Road, Vonore, TN 37885; [4]West Tennessee Research and Agricultural Station, 605 Airways Boulevard, Jackson, TN 38301

CBES Center for BioEnergy Sustainability

Vonore case study objectives:

- Connect the science of sustainability with sustainability deployment
- Explore the following questions:
  - Is it possible to assess a bioenergy system's overall sustainability by integrating multimetric information gathered from across a variety of spatial and temporal scales?
  - Do some sustainability indicators contribute more to the overall sustainability determination than others? If so, how context-specific is this effect?

USDA United States Department of Agriculture National Institute of Food and Agriculture

IBSS Southeastern Partnership for Integrated Biomass Supply Systems

The University of Tennessee Institute of Agriculture

Genera Energy Delivering Sustainable Biomass Solutions

U.S. Department of Energy

Oak Ridge National Laboratory

Sustainability Indicator relevance across Biofuel Supply Chain

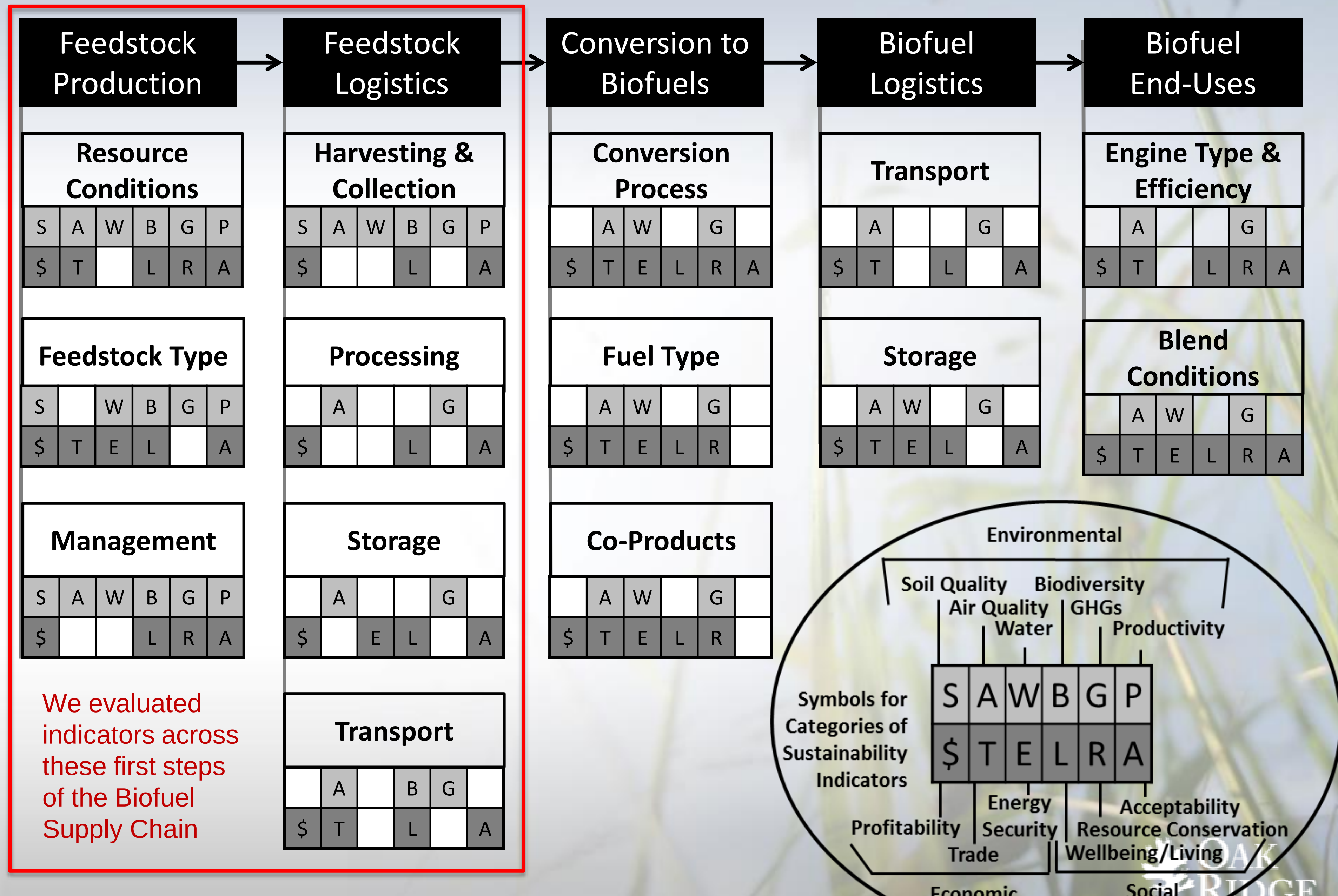
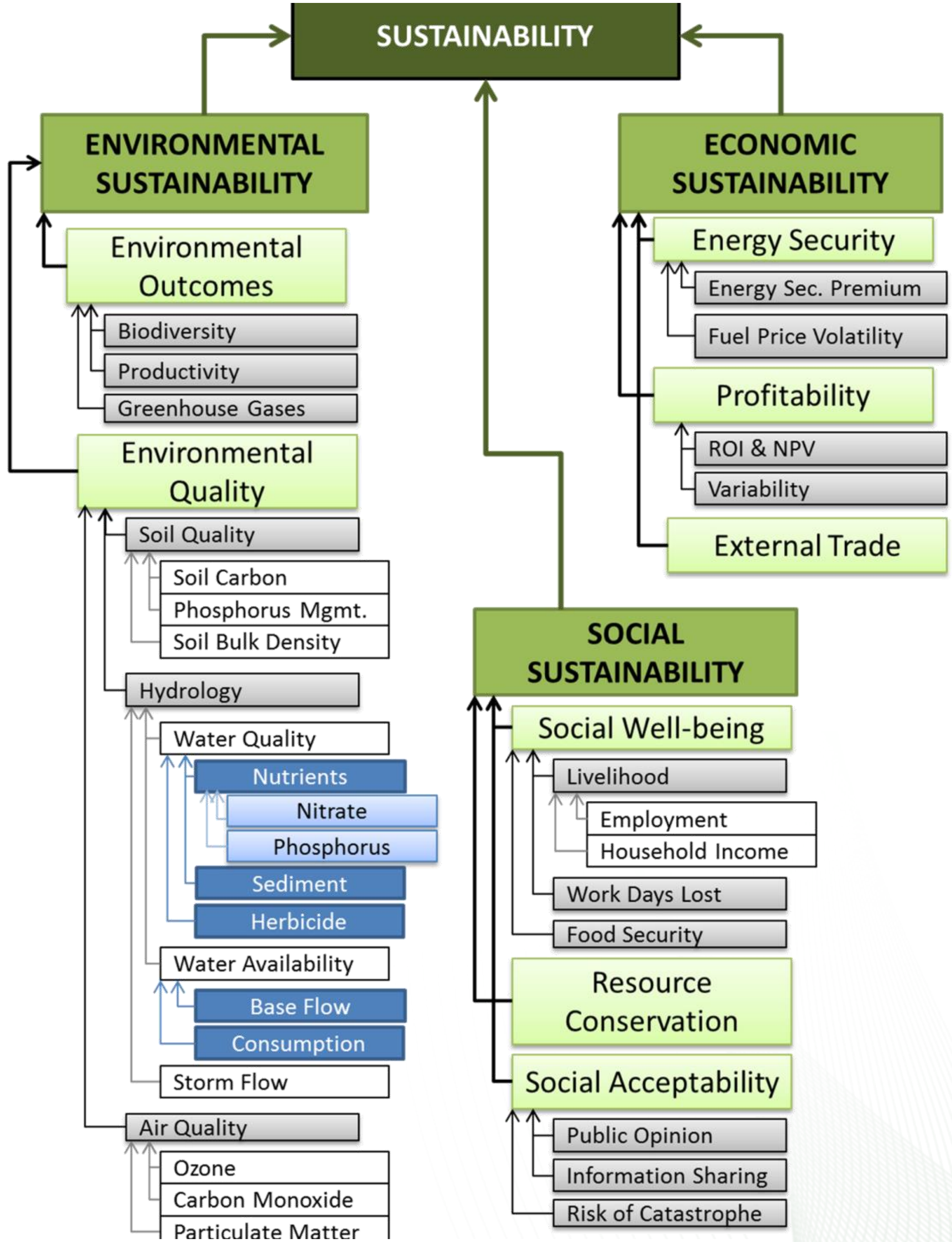


Figure based on Efroymson et al. (2013) & Dale et al. (2013)

We aggregated the indicators within a hierarchical

Multi-Attribute Decision Support System (MADSS)



Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

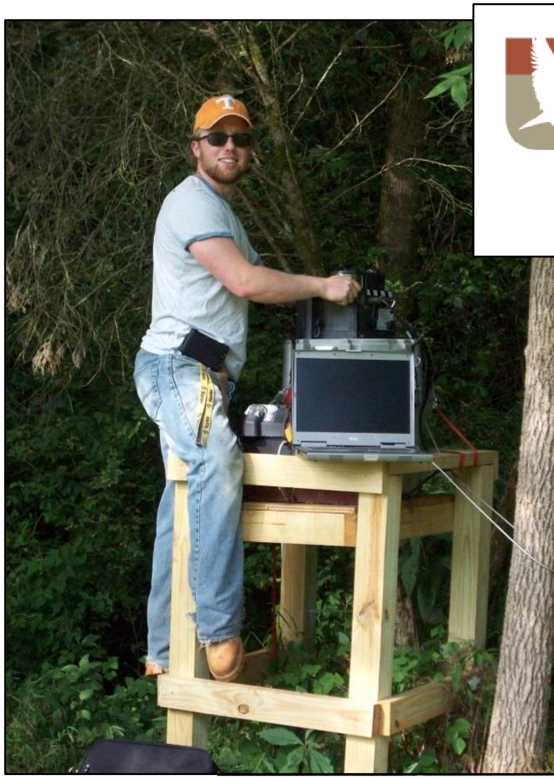
We compared 3 agricultural scenarios

Parameter	NO-TILL SWITCHGRASS	TILLED CORN	UNMANAGED PASTURE
Time of planting	Establish once in spring; no replanting	Plant annually	Already established
Tillage Type	No-till method with a drill is preferred	Planted conventionally	No need for replanting
Harvesting equipment	Conventional hay equipment	Combine	Harvest by cows (1.5 acres/cow)
Harvest Frequency	Once per year (after Nov. 1 or first killing frost)	Once a year (October)	Continuous
Storage	Round bale tarped	Trucked off farm	None
Herbicide Application	1-3 applications of glyphosate herbicide prior to planting	Annual application of glyphosate herbicide	No herbicide used
Fertilizer Application	Apply 40 lbs/acre when soil test is “Low” for P and K	Apply 100-160 lbs/acre when soil test is “Medium”	No fertilizer used
Typical Yield	6-8 tons/year after 3rd year	114.5 bushels/acre (average for 2007-2013)	2.1 tons/acre (estimated as mixed hay)
Price information	$450/acre actual contract price; estimated delivered price= $71.23/ton ($3.25/ton storage)	$5.04/bushel (2007-2013 average)	$90.79/ton (2007-2013 average)
Final Destination	50 million gallon/year Biorefinery within a one-hour’s drive	Multiple uses of corn grain throughout the region	On-site cattle roughage

Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

We combined data gathered from the Vonore switchgrass experiment with modeling results, literature values & expert opinion.

IBSS
Southeastern Partnership for Integrated Biomass Supply Systems



We used this information to develop qualitative ratings for most of the 35 sustainability indicators in all 12 categories.

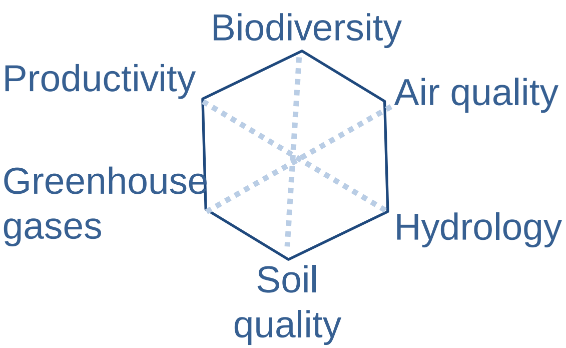
Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

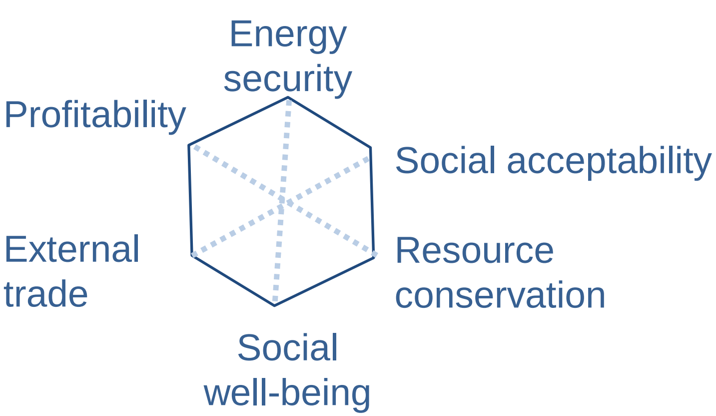
OAK RIDGE National Laboratory

Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

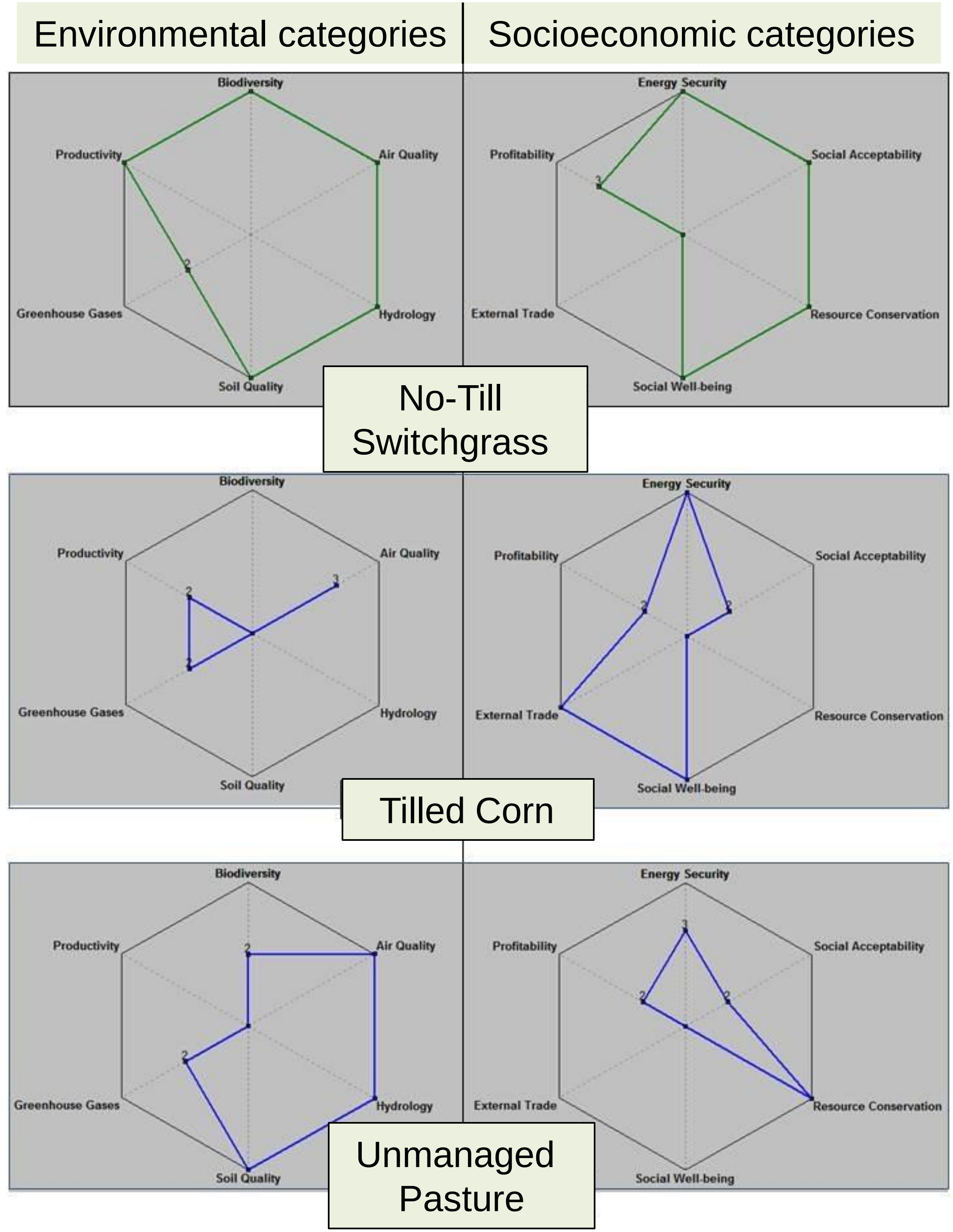
Sustainability ratings* by category

Key to chart





*Ratings are based on Scenario Assumptions shown in earlier slide



Overall Sustainability Ratings*

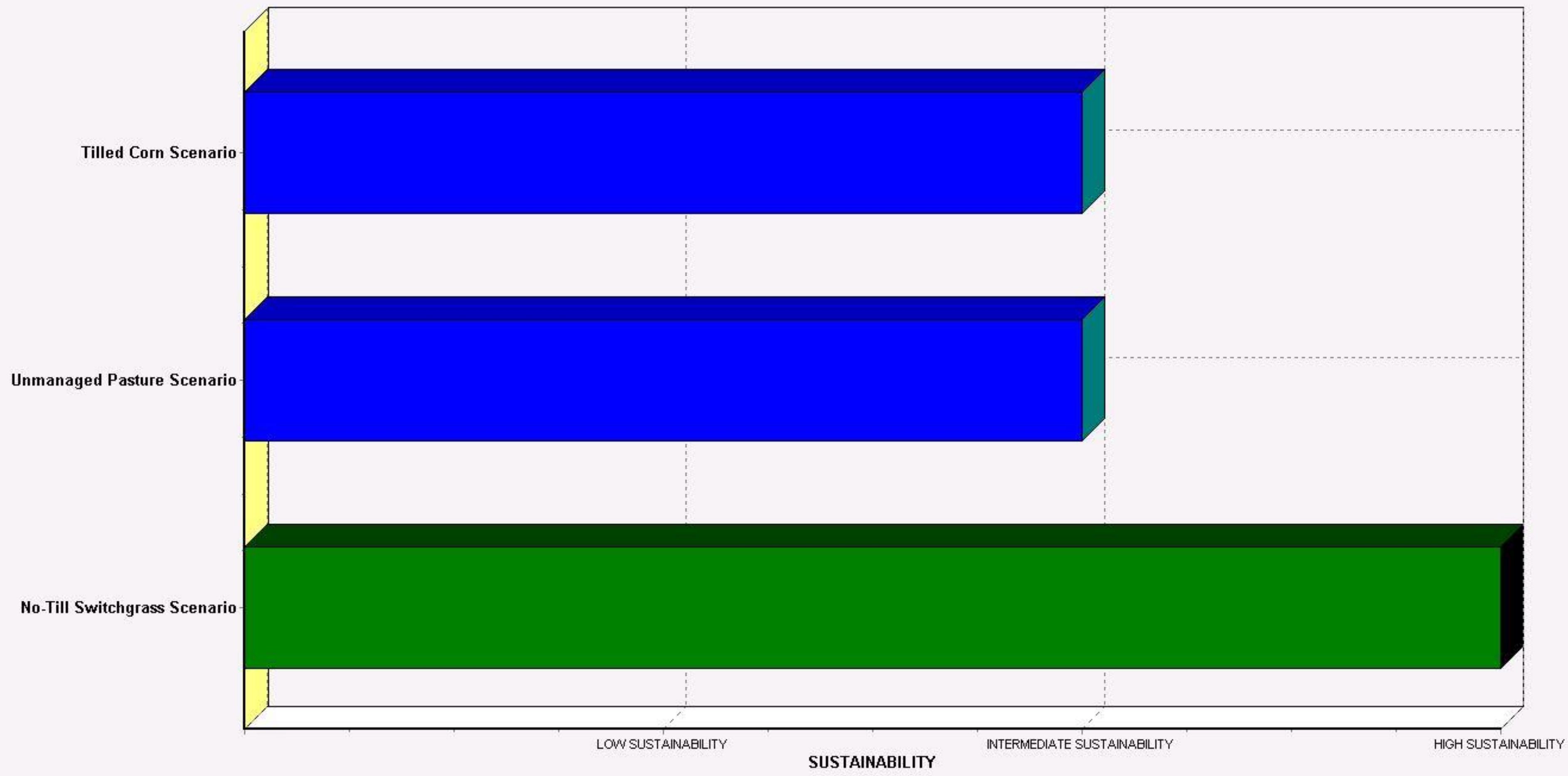
	No-Till Switchgrass Scenario	Unmanaged Pasture Scenario	Tilled Corn Scenario
OVERALL SUSTAINABILITY	**HIGH**	INTERMEDIATE	INTERMEDIATE
ENVIRONMENTAL SUSTAINABILITY	**HIGH**	**HIGH**	**LOW**
ECONOMIC SUSTAINABILITY	INTERMEDIATE	**LOW**	**HIGH**
SOCIAL SUSTAINABILITY	**HIGH**	INTERMEDIATE	INTERMEDIATE

*Ratings are based on Scenario Assumptions shown in earlier slides

Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

OAK RIDGE National Laboratory

Case Study Sustainability Assessment Results*



*Ratings are based on Scenario Assumptions shown in earlier slides

Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (*in press*) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere*

Results of Vonore Case Study

- Within this East Tennessee context, switchgrass production shows potential for improved environmental and social sustainability without adverse economic impacts.
- This case study demonstrates that integration of qualitative sustainability indicator ratings may increase holistic understanding of a bioenergy system in the absence of complete information.

Photo Credit:
Ken Goddard,
UT Extension

OAK RIDGE National Laboratory

<u>Next step</u>: Consider indicators within system as an opportunity to design landscapes that add value

Dale VH, KL Kline, MA Buford, TA Volk, CT Smith, I Stupak (Submitted) Incorporating bioenergy into sustainable landscape designs. *Renewable & Sustainable Energy Review.*

Thank you!

CBES

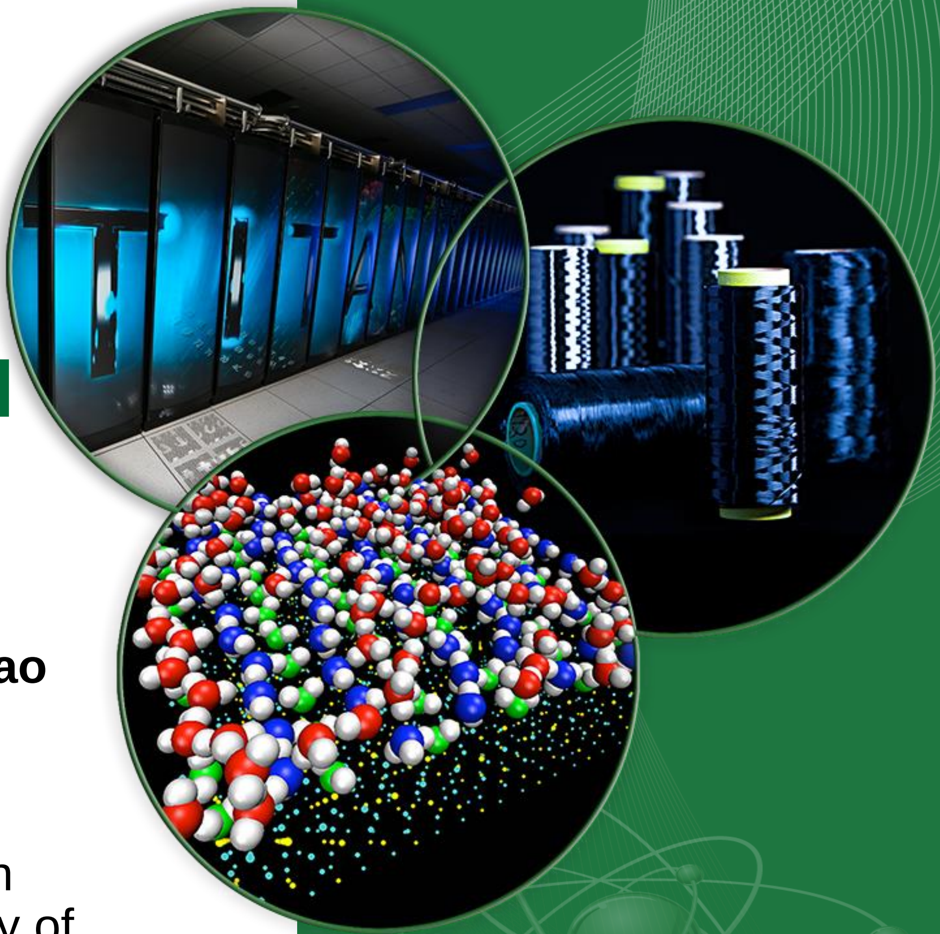
Center for BioEnergy Sustainability

Referenced publications may be accessed freely through our website. → http://www.ornl.gov/sci/ees/cbes/

ACKNOWLEDGMENTS

Funding for this research was provided by the US Department of Energy (DOE) under the Bioenergy Technologies Office (BETO). Oak Ridge National Laboratory (ORNL) is managed by UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725. Support for the Vonore case study was also provided by the Southeastern Partnership for Integrated Biomass Supply Systems (IBSS), which is funded through Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30410 from the USDA National Institute of Food and Agriculture. Thank you to our DOE BETO sponsor, Kristen Johnson, for her support of this project. Thanks to Latha Baskaran of ORNL for her analysis of hydrologic data provided by Zachariah Seiden and John Schwartz of the University of Tennessee (UT). Thanks to Jamey Menard of UT for conducting economic analysis of our case study and alternative scenarios. Thanks to Jessica McCord, Chris Clark and Edward Yu of UT, Jesse Daystar of North Carolina State University, and other IBSS collaborators for the providing their publications and clarification.

Examining the effects of woody biomass production for bioenergy on water quality and hydrology in the southeastern United States



Natalie A. Griffiths, Oak Ridge National Laboratory
C. Rhett Jackson, **Menberu Bitew**, **Enhao Du**, University of Georgia
Kellie Vache, Oregon State University
Jeffrey J. McDonnell, **Natalie Orlowski**, **Julian Klaus**, University of Saskatchewan
Gregory Starr, **Satyra George**, University of Alabama
John I. Blake, **Ben M. Rau**, USDA Forest Service

ORNL is managed by UT-Battelle
for the US Department of Energy

National Bioenergy Day
October 21, 2015

Oak Ridge National Laboratory

Woody feedstocks for bioenergy

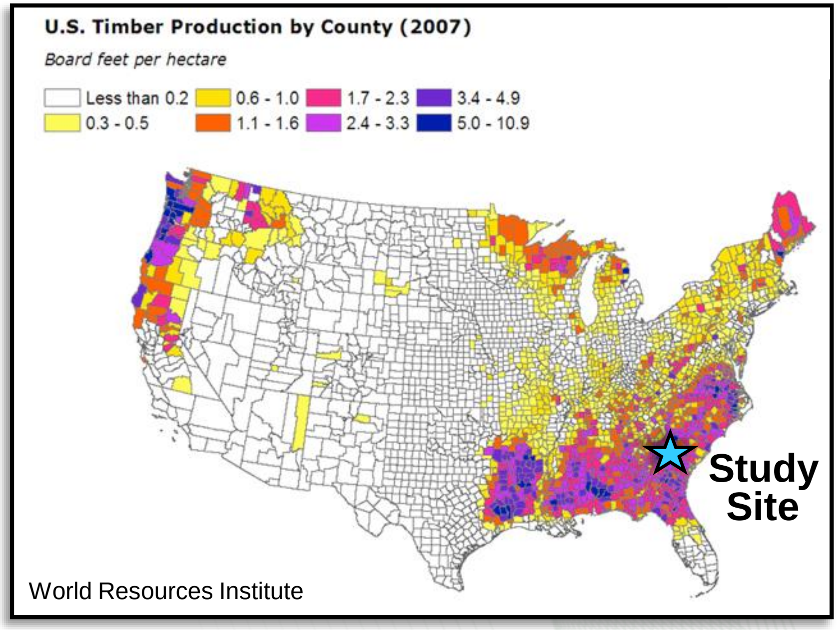
- Forestry dominates in the southeast United States.

- Use of wood for bioenergy:
  - Wood-fired power plants
  - Wood pellets for power/heating
  - Biofuels (EISA, 2007)

- Forest management for bioenergy: shorter rotation (8-12 y), fertilizer and herbicide applications.

- Important to understand and minimize environmental impacts.

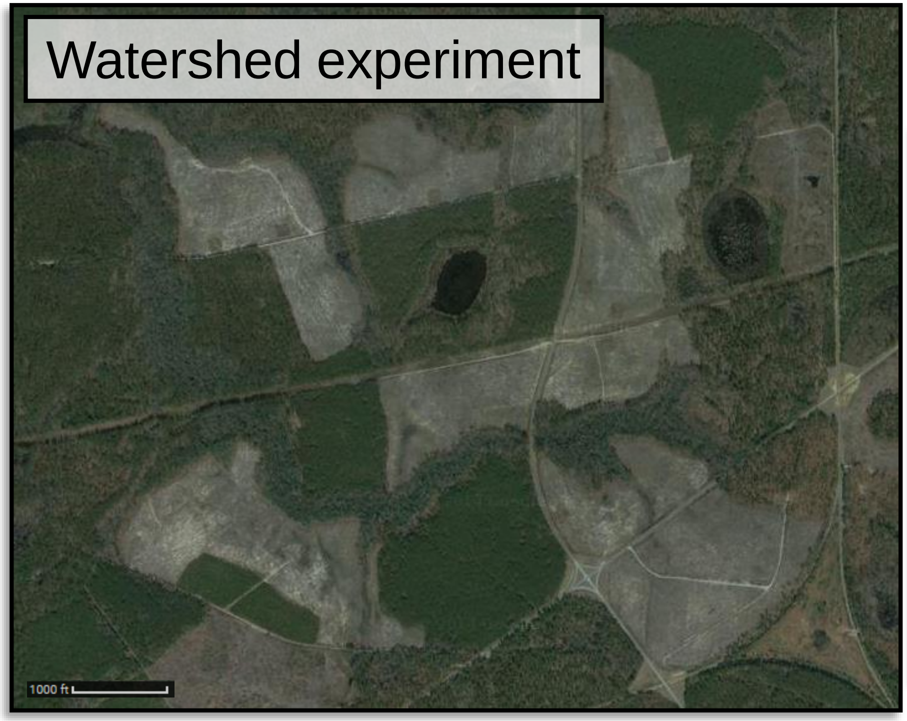

biomassmagazine.com



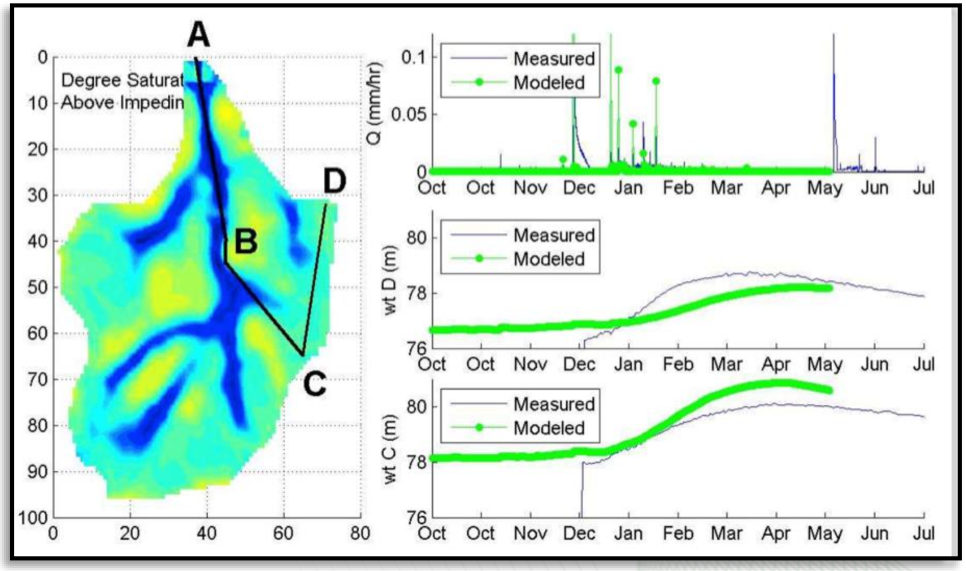
World Resources Institute

Research question and approach

- Research Question: What are the effects of growing loblolly pine for bioenergy on water and soils in the southeastern US?
- Research Approach:
  - Using a watershed-scale experiment to examine effects on environmental sustainability indicators at an operational scale.
  - Using a watershed modeling approach to upscale results spatially and temporally.

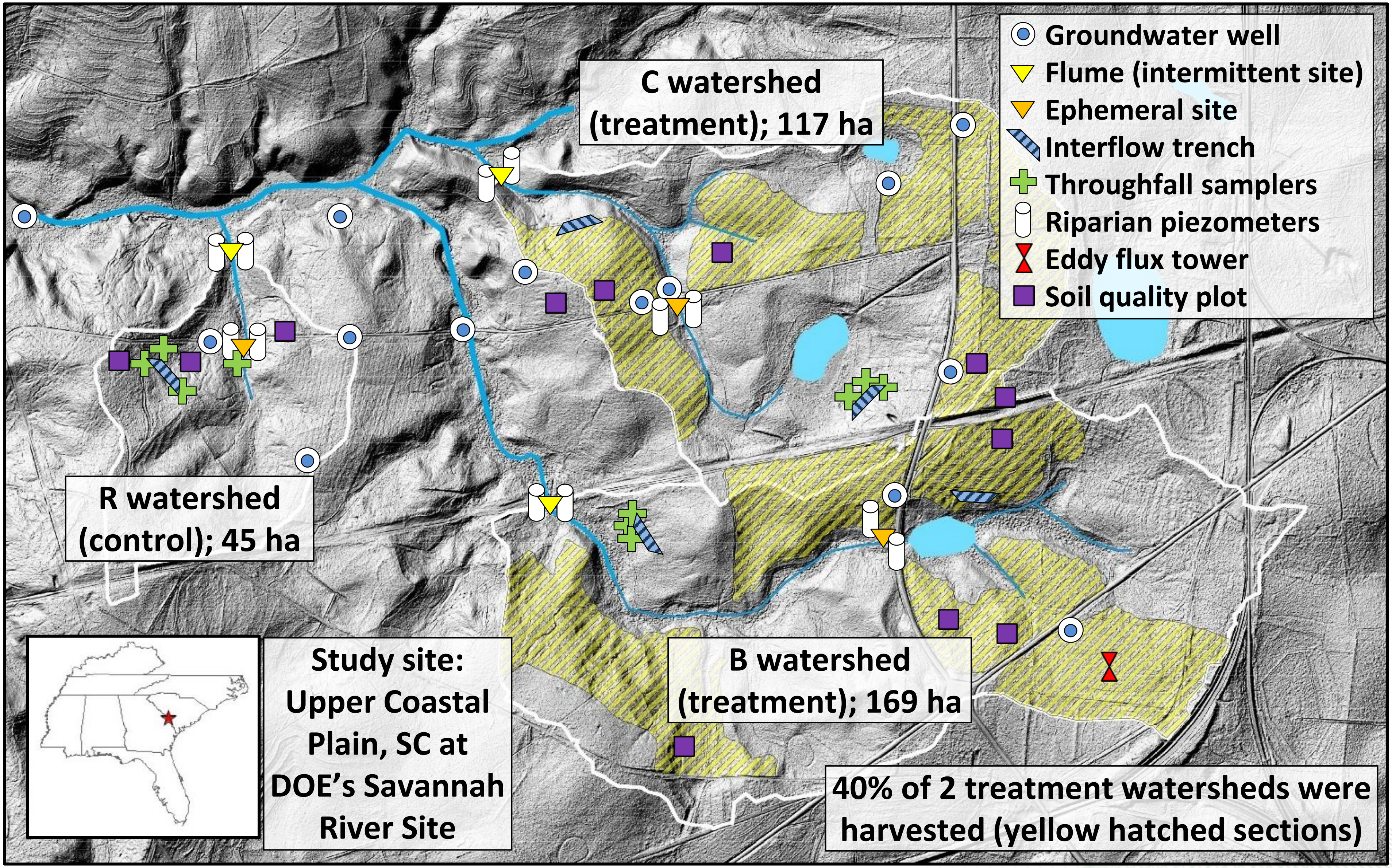


Watershed model

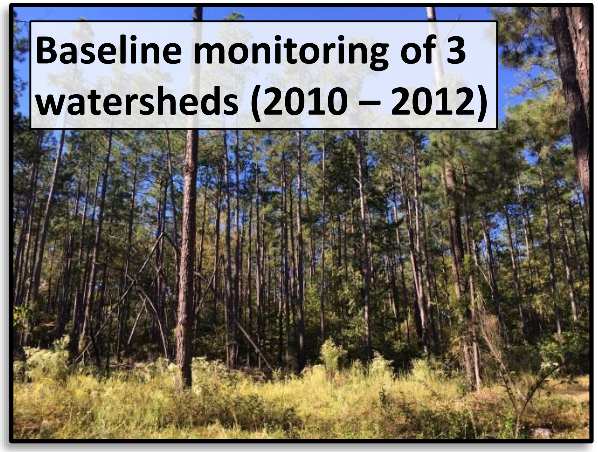


Watershed experimental design

- 3 highly instrumented watersheds: 2 treatment (B, C), 1 control (R).

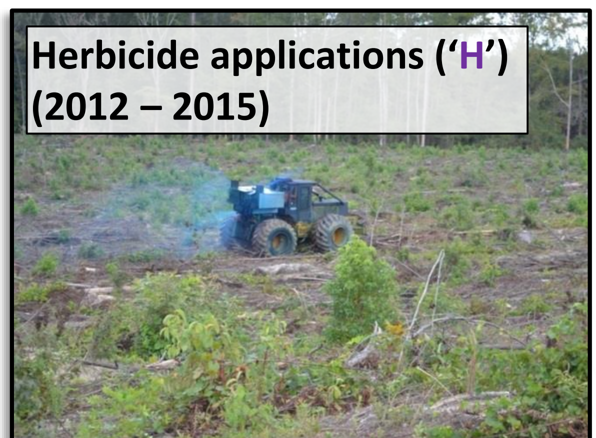


Experiment timeline



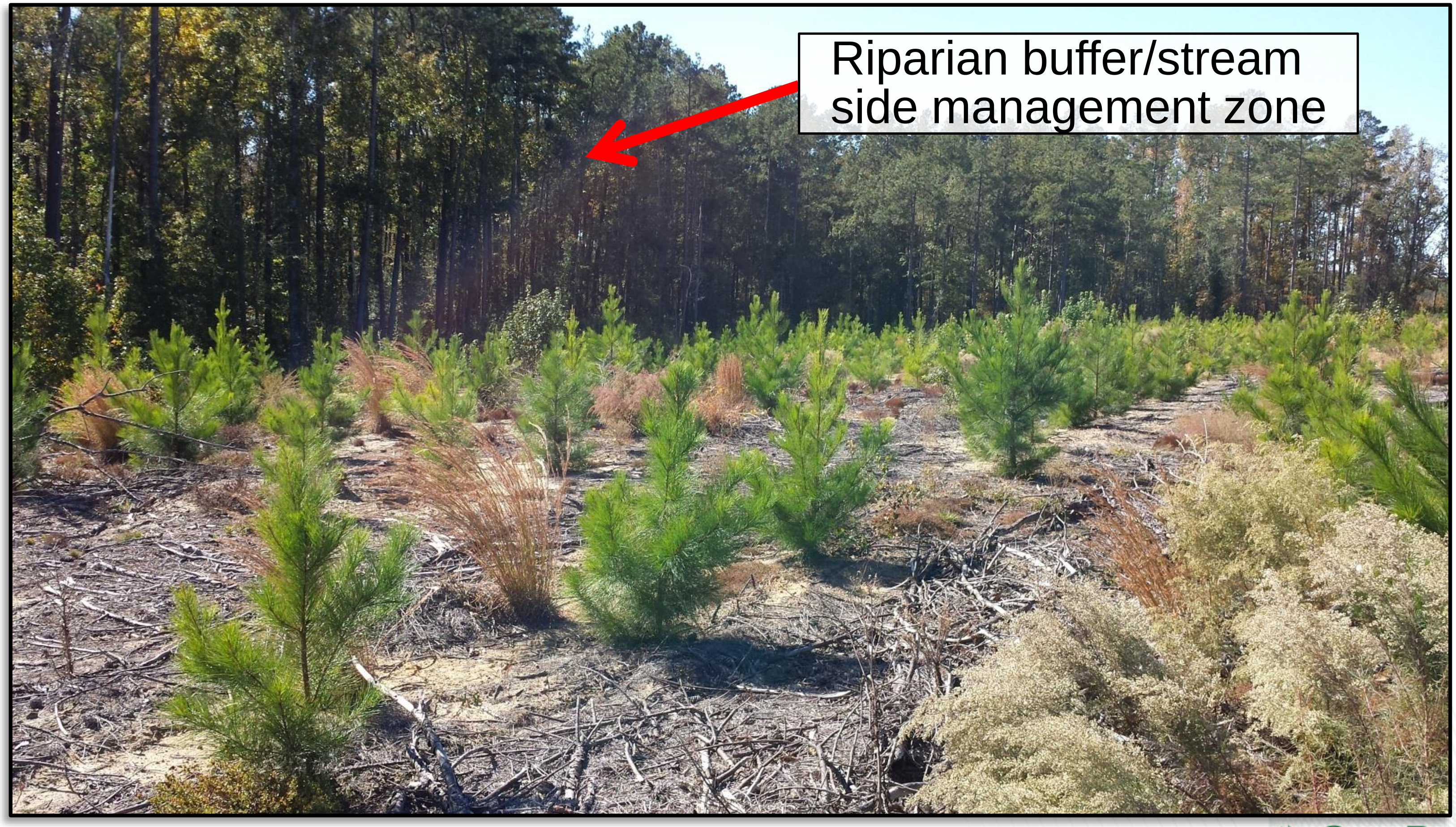
Progress to date

2010 2012 H H F 2014 H F F H 2016 F 2018 F



Applying current forestry BMPs

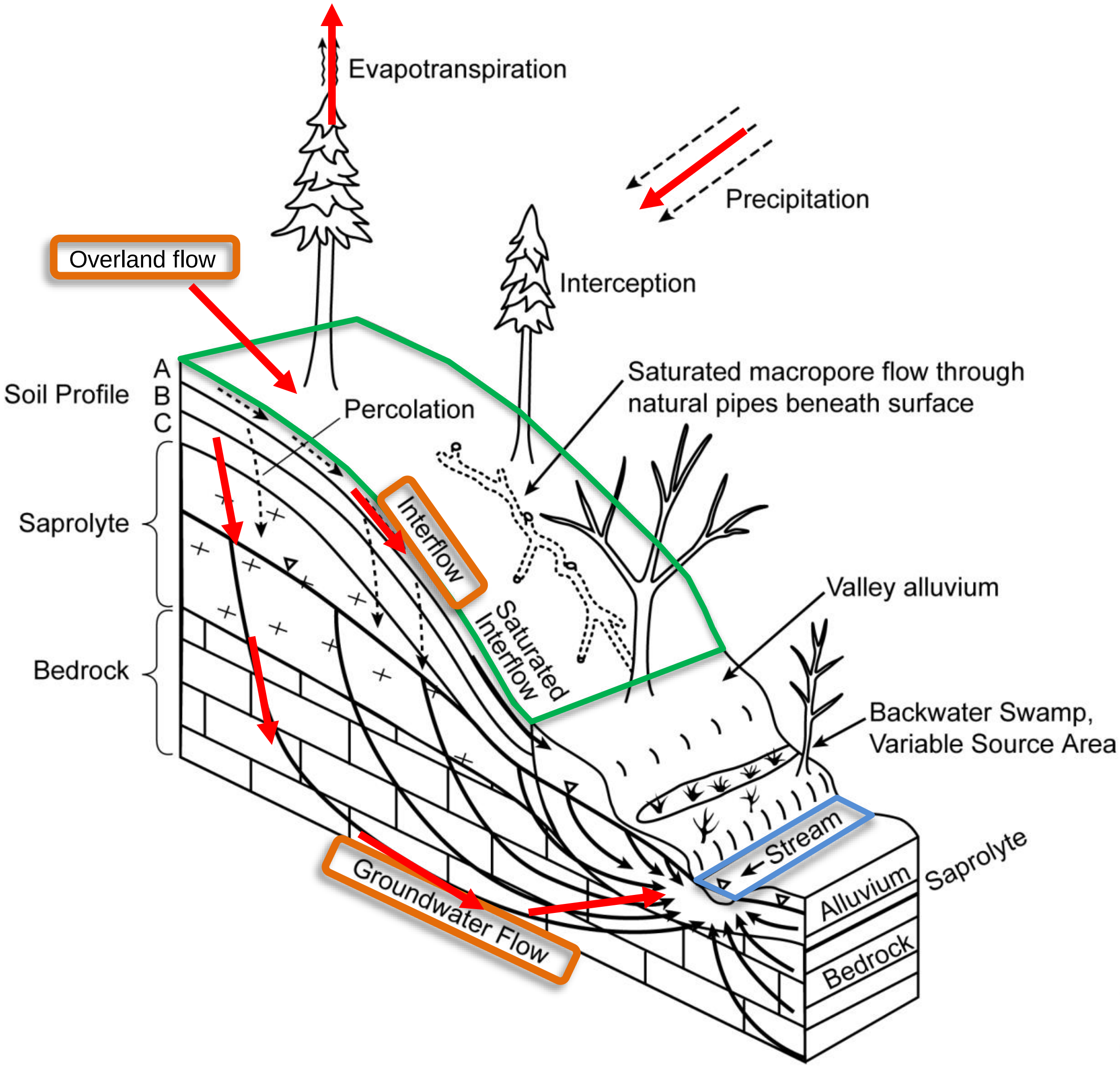
- Implemented forestry Best Management Practices (BMPs) for South Carolina to assess whether current BMPs will protect water resources.
  - BMPs include: minimizing bare ground and soil compaction, keeping an in-tact riparian buffer (50 ft) on either side of the stream/wetland.



- Planted old fields (pine/hardwood)
- Minimally managed (by USFS)
- Low-gradient, Coastal Plain watersheds
- Sandy soils overlay clay

• Low-gradient streams
• Dense vegetation
• Organic-rich soils
• Intermittent, blackwater streams with indistinct channels

Detailed research questions



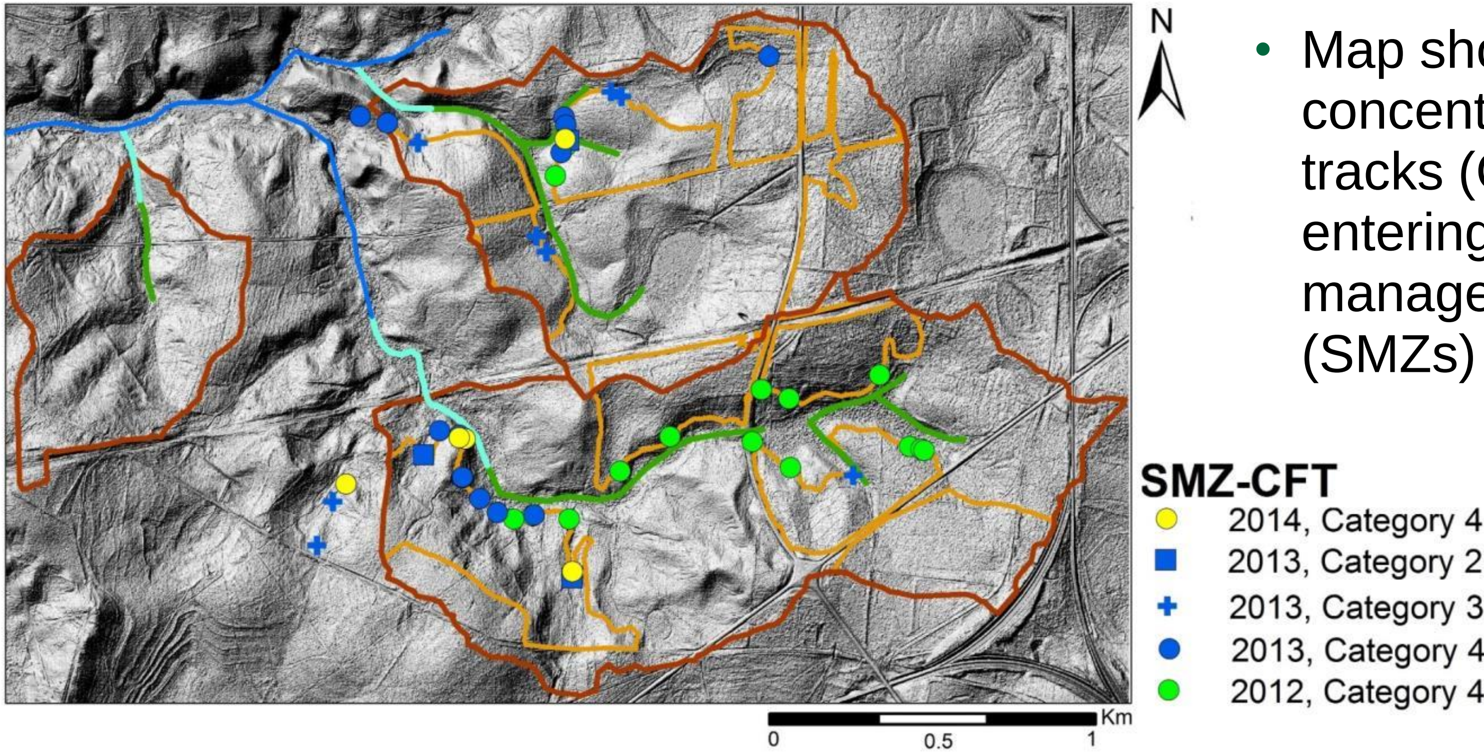
1) What are the dominant water flowpaths?

   How and when are hillslopes connected to the stream?

2) What are the initial effects of pine management on water and soil quality and productivity?

OAK RIDGE National Laboratory

Overland flow is rare

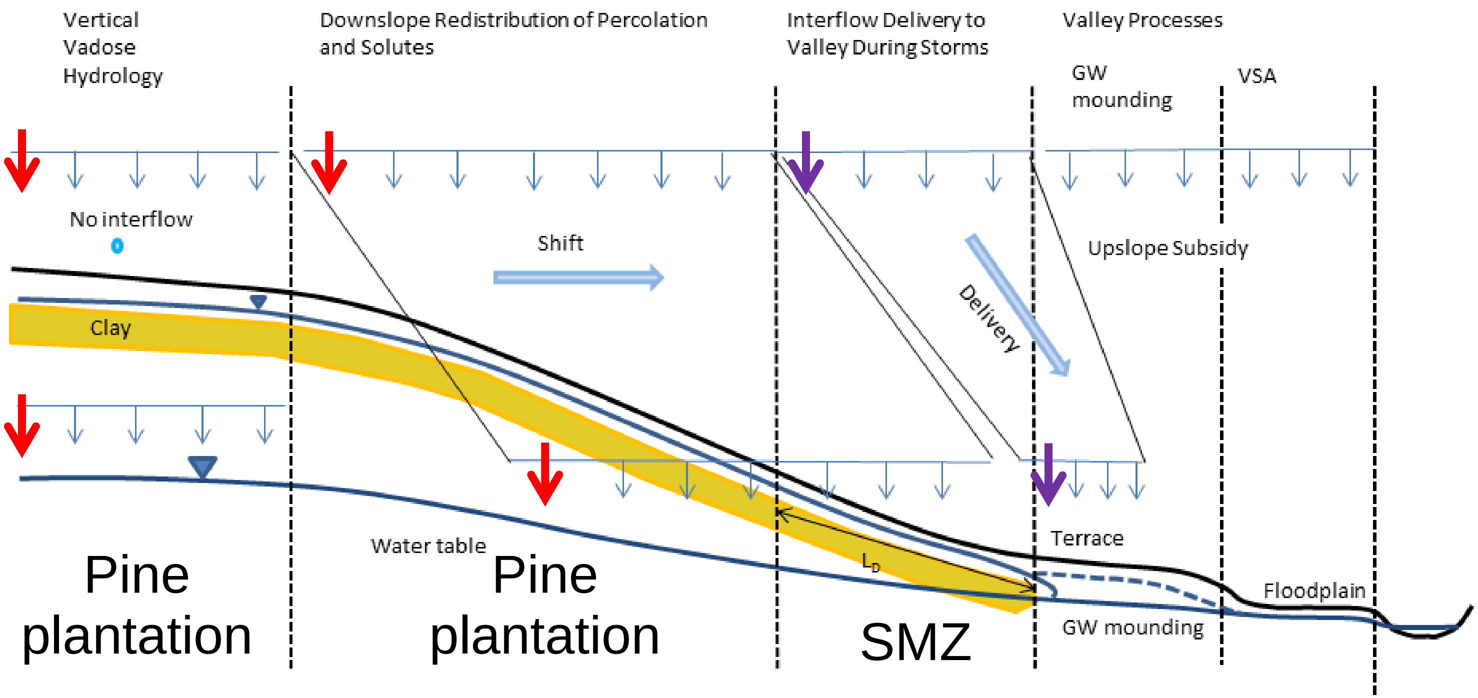


- Map showing concentrated flow tracks (CFTs) entering streamside management zones (SMZs) in 2012-2014.

- SMZ-CFTs:
  Cat. 2: water and fine sediments reach water bodies.
  Cat. 3: water without sediment reaches water bodies.
  Cat. 4: water reinfiltrates in the SMZ.
- **Main finding:** Overland flow is rare. SMZs are working. During wet periods, water table rises into flat, planted areas, forming seasonal seeps.

OAK RIDGE National Laboratory

Interflow distances are short

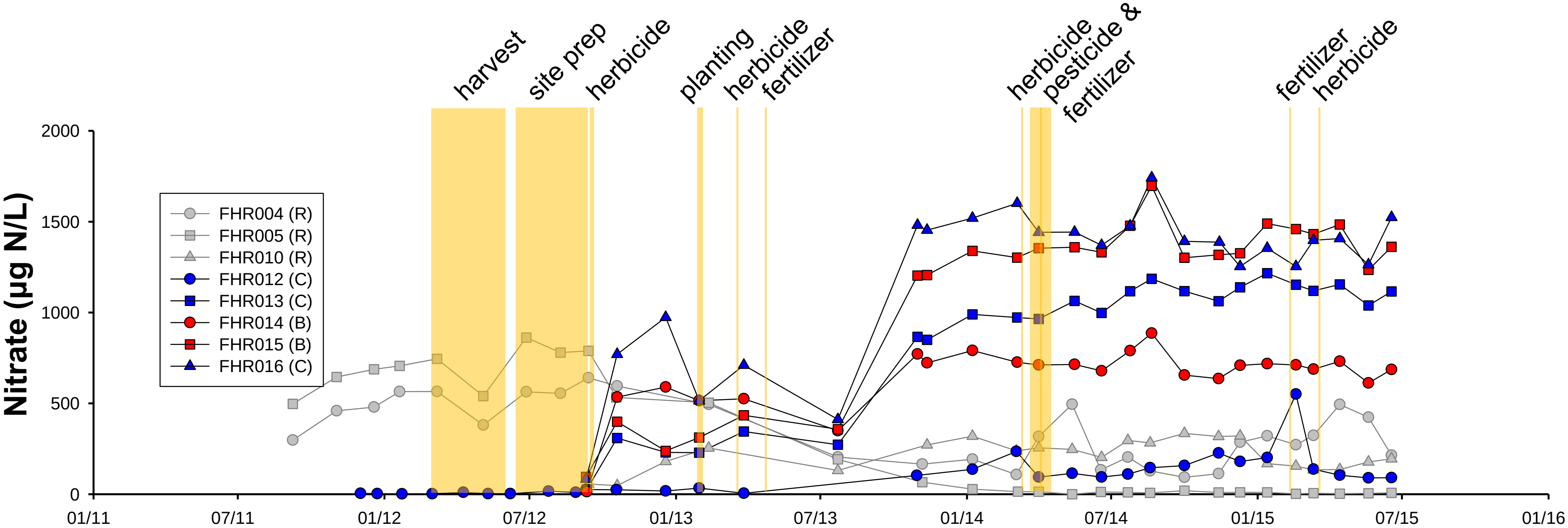


(Jackson et al. 2014. Hydrological Processes)

- All hydrometric, isotope, and water quality data show that interflow delivers water to the valleys only from the immediately adjacent steeper-slope segments.
- **Main finding:** The most likely stream water quality effects will be via a groundwater pathway.

OAK RIDGE National Laboratory

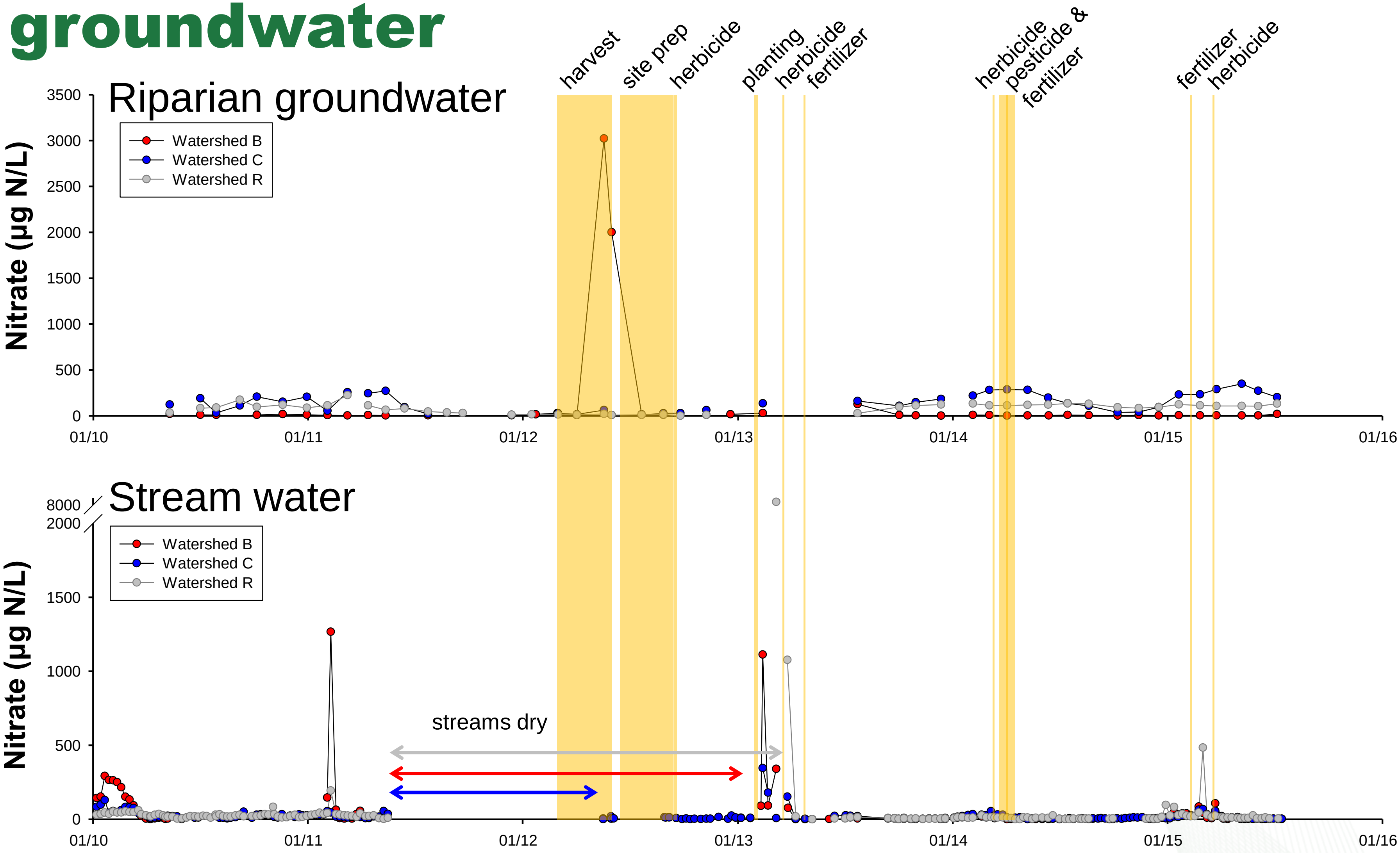
Nitrate increased in groundwater post-treatment



- **Main finding:** Nitrate is the nutrient of greatest water quality concern. Nutrient uptake is inefficient early due to low pine growth rates and complete weed control. Results in elevated nitrate in groundwater, but concentrations are <2 mg N/L (drinking water limit = 10 mg N/L).

- Ammonium and phosphate concentrations are low and similar in all 3 watersheds. Herbicides and pesticides below detection.

Nitrate low in stream and riparian groundwater



- To date, elevated nitrate in groundwater has not reached the riparian areas/stream or has been taken up/transformed.

Soil quality and productivity study

- Examining the effect of different fertilizer and herbicide levels on soil quality and productivity.

- 5 fertilizer/herbicide treatments. 4 replicates in each treatment watershed. 4 reference plots in the control watershed.

- Measuring soil nutrients, N mineralization, nitrification, nitrate leaching, pine growth & mortality.

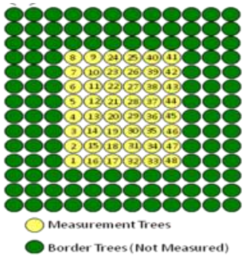
TRT1
Elite genetics
No nutrients
No herbicides
Op. density

TRT2
Elite genetics
No nutrients
Op. herbicides
Op. density

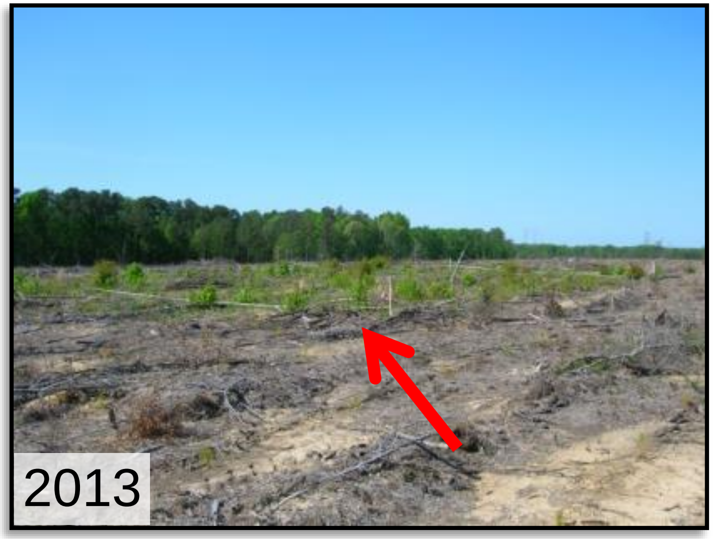
TRT3
Elite genetics
1/2 nutrients
Op. herbicides
Op. density

TRT4
Elite genetics
Op. nutrients
Op. herbicides
Op. density

TRT5
Elite genetics
Op. nutrients
Op. herbicides
High density



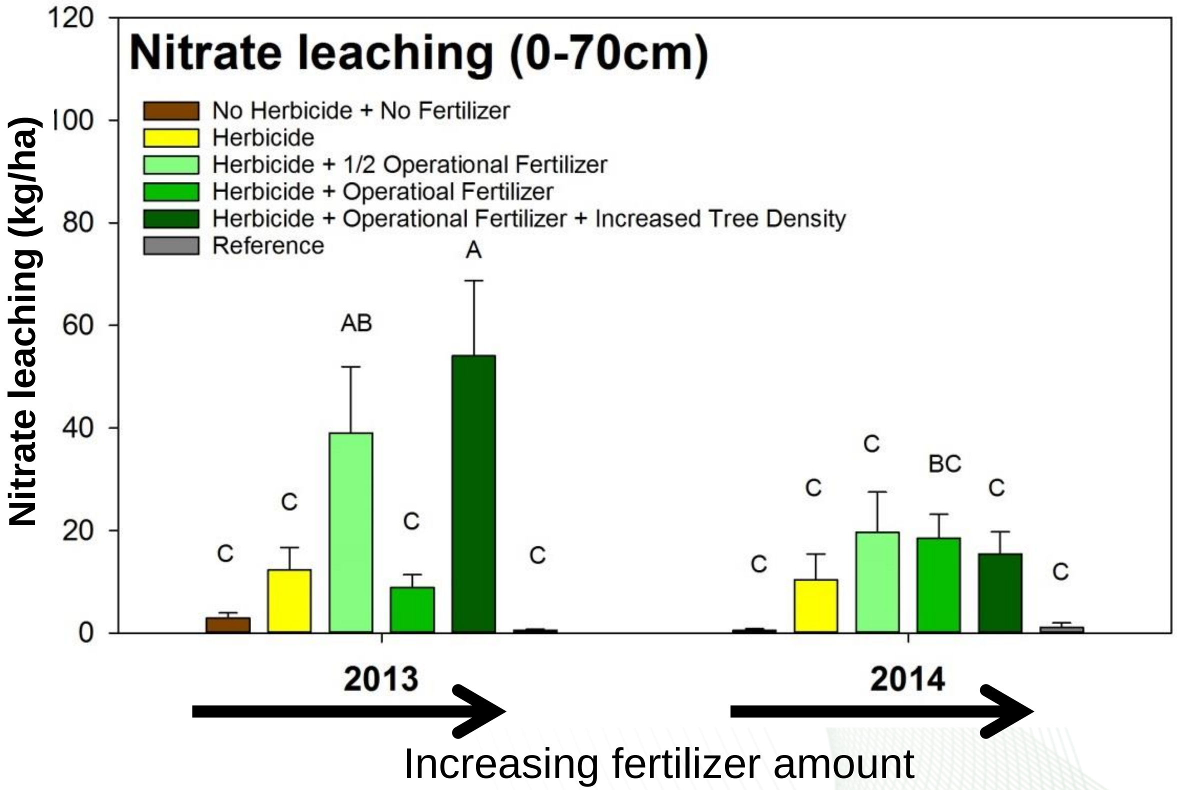
No herbicide treatment plot



TRTs affect productivity and N leaching

- Productivity:
  - **Main finding:** Herbicide effective at increasing pine growth after 2 years. However, competing vegetation using 10 times more N than loblolly pine, even with herbicide application.

- Soil quality:
  - Nitrate leaching high in 2013, and lower and similar to control plots in 2014.
  - **Main finding:** Nutrient uptake by pine is not 100% efficient. During early growth, excess nitrate may leach from plantations to the groundwater and affect groundwater quality.



OAK RIDGE National Laboratory

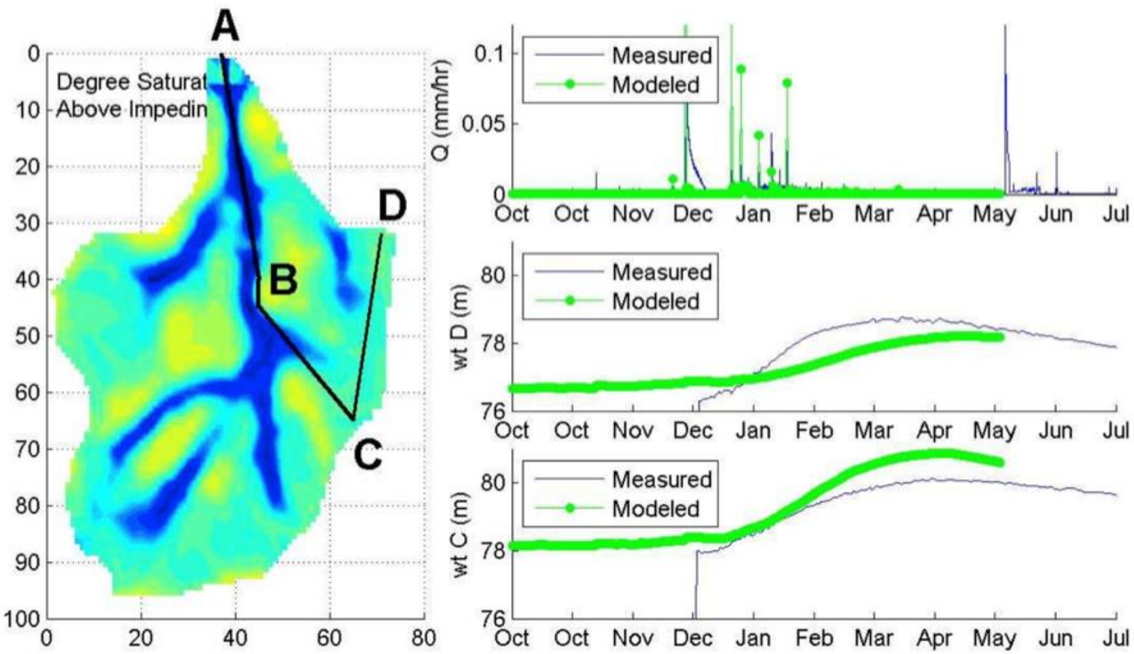
Evapotranspiration measurements initiated in 2015

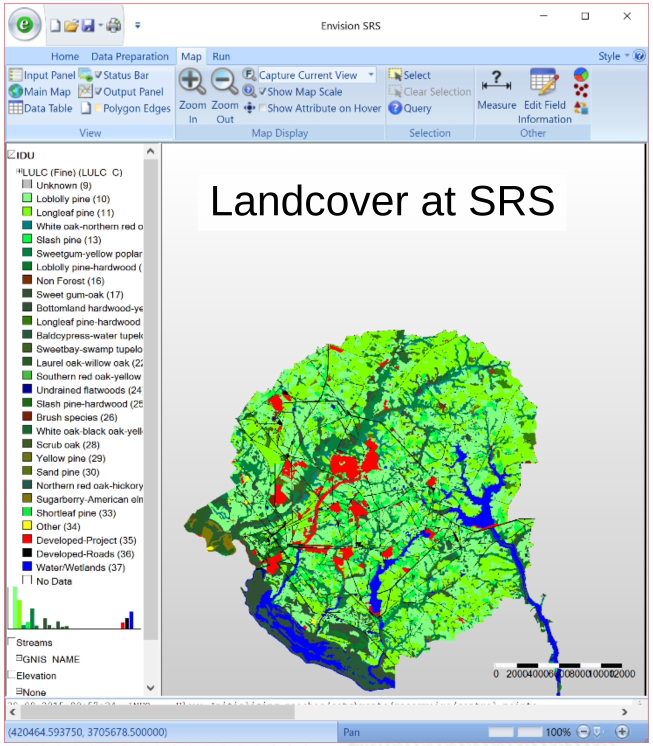
- Investigating the water use efficiency of loblolly pine for bioenergy.
- Eddy flux measurements will provide stand scale estimate of evapotranspiration (ET) to be used in model parameterization. ET will be compared to ET of native long-leaf pine from the SRS Ameriflux site.
- Results from 2015 growing season show increased ET, leaf area index, and canopy development in spring to summer period.

Fisheye photos showing tree growth from May to July, 2015

Developing a watershed model for upscaling results

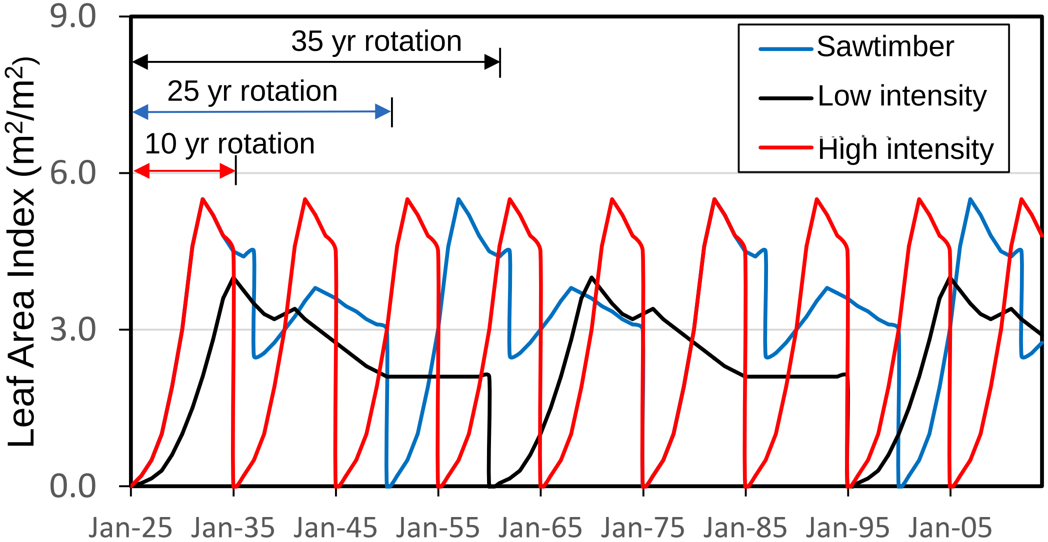
- Watershed-scale model developed based on field observations.
- Upscaling to broader spatial and temporal scales.
  - Scale to Fourmile watershed (encompasses the 3 study watershed) and the Savannah River Site (SRS).
  - Run model over multiple rotations and management scenarios to explore long-term impacts.

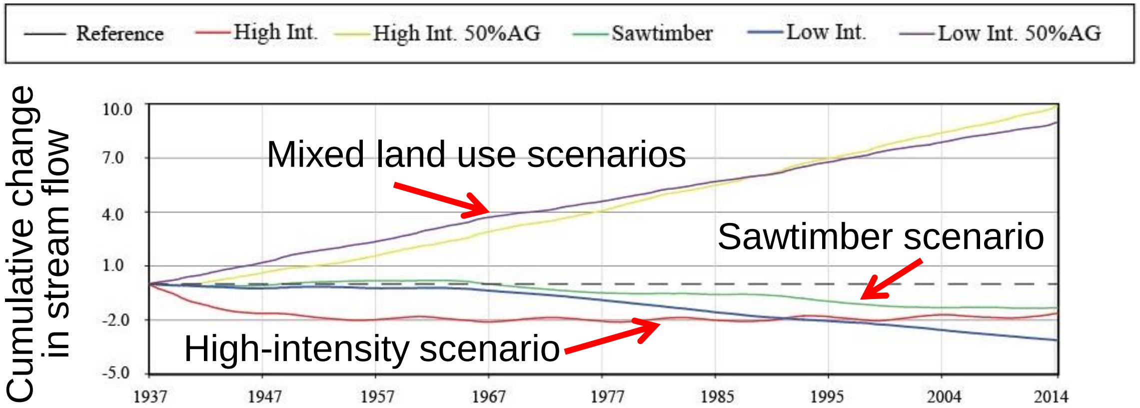




Forest management scenario modeling

- Parameterizing standard models (MIKE-SHE, SWAT) for comparison to watershed model. Running forest management scenarios.





Preliminary results:

- Small decrease (1%) in stream flow under high-intensity (10 yr) pine production for bioenergy relative to a minimally managed forest (based on vegetation condition in the control watershed).
- Larger changes with mixed land use (50% ag with no irrigation, 50% forest).

OAK RIDGE National Laboratory

Summary

- Quick flowpaths rarely important in delivering solutes to the stream.
- Route of excess fertilizers to streams mainly via groundwater.
- Nitrate leaching was high initially, and nitrate increased in groundwater suggesting nutrient uptake is inefficient during early growth.
- No increases in stream water nitrate. BMPs appear effective at maintaining stream water quality thus far.
- Watershed-scale model will be used to upscale water quality and hydrology results.

Acknowledgments

- Field sampling: Kevin Foust, Ben Morris.
- Lab analysis: Allison Fortner, Kitty McCracken, Jana Phillips, Deanne Brice.
- Funding: Department of Energy, Office of Energy Efficiency and Renewable Energy, Bioenergy Technologies Office.

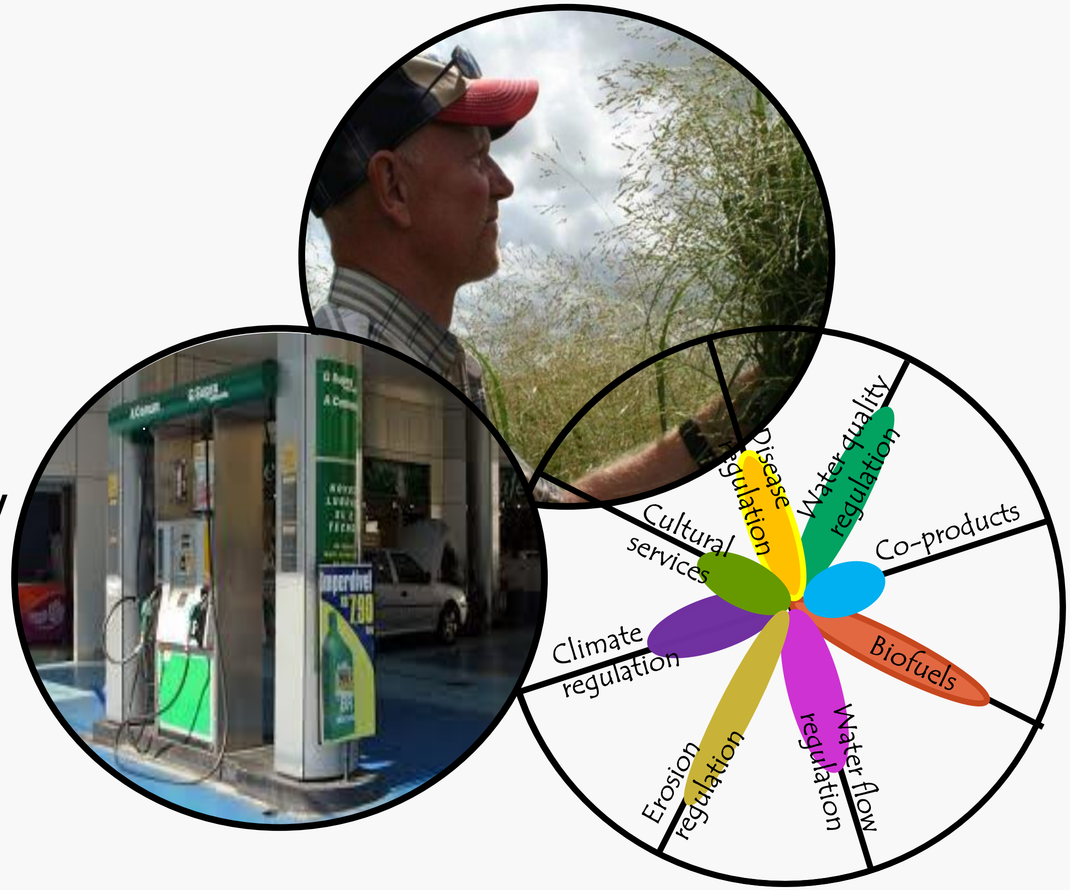
Contact: griffithsna@ornl.gov

OAK RIDGE National Laboratory

Future bioenergy production in two southern tributary basins of the Mississippi River Basin is projected to improve water quality

Henriette Jager
Latha Baskaran
Gangsheng Wang
Jasmine Kreig
Mike Hilliard

Oak Ridge National Laboratory



Bioenergy Day Webinar
October 21, 2015
University of Tennessee

Funding provided by the USDOE
Biomass Energy Technology Office (Sustainability)

U.S. DEPARTMENT OF ENERGY

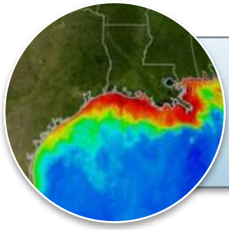
http://www.esd.ornl.gov/~zij/

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview

- The emerging bio-economy is largely viewed favorably, but public concerns remain.
- In particular, how will adding bioenergy crops and harvesting residues influence biodiversity and water quality?
- We used SWAT modeling at a large regional scale, combined with economic future projections for changes in landuse and management to project future water quality.

OAK RIDGE
National Laboratory



Problem: Gulf Hypoxia

Upstream Causes

Bioenergy Crops

Conservation Practices

Recover Ecosystem Services

Will corn-ethanol compromise nutrient-reduction goals?

PNAS

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

Simon D. Donner*† and Christopher J. Kucharik‡

*Department of Geography, University of British Columbia, 1984 West Mall, Vancouver, BC, Canada V6T 1Z2; and ‡Center for Sustainability and the Global Environment, Nelson Institute for Environmental Studies, University of Wisconsin, 1710 University Avenue, Madison, WI 53726

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 combine agricultural land use scenarios with physically based models of terrestrial and aquatic nitrogen to examine the effect of present and future expansion of corn-based ethanol production on nitrogen export by the Mississippi and Atchafalaya Rivers to the Gulf of Mexico. The results show that the increase in corn cultivation required to meet the goal of 15–36 billion gallons of renewable fuels by the year 2022 suggested by a recent U.S. Senate energy policy would increase the annual average flux of dissolved inorganic nitrogen (DIN) export by the Mississippi and Atchafalaya Rivers by 10–34%. Generating 15 billion gallons of corn-based ethanol by the year 2022 will increase the odds that annual DIN export exceeds the target set for reducing hypoxia in the Gulf of Mexico to >95%. Examination of extreme mitigation options shows that expanding corn-based ethanol production would make the already difficult challenges of reducing nitrogen export to the Gulf of Mexico and the extent of hypoxia practically impossibl- ...ithout large shifts in food production and agricultural m...

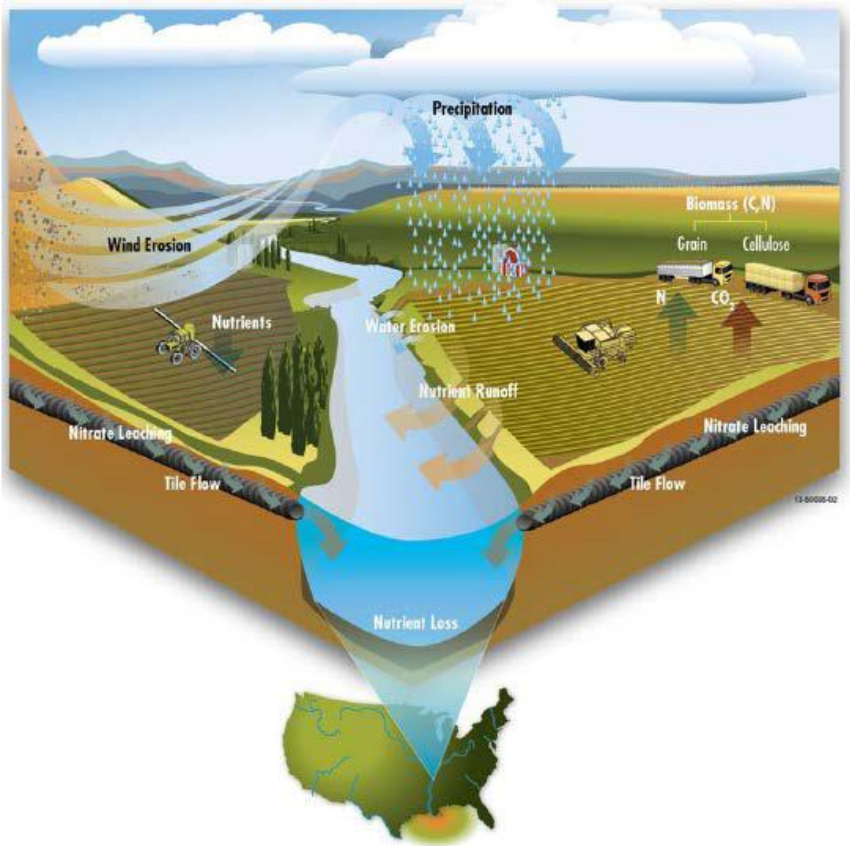
and water cycling and downstream transport of nitrogen and water across the Mississippi–Atchafalaya River Basin to agricultural land use practices and climate variability (4, 10–16). First, we used USDA data to generate a series of spatially explicit land use scenarios including a control case (based on 2004–2006 mean land use and land cover); a representation of 2007 land management based on the projected plantings from the spring (1); three scenarios designed to meet the ethanol production goals in the recent Energy Bill (3); and an extreme mitigation scenario (Table 1). Second, we used the control scenario to validate the ability of the models to simulate nitrogen cycling across the Mississippi–Atchafalaya River Basin and nitrogen export to the Gulf of Mexico. Third, we evaluated the effect of the alternative land cover scenarios on nitrogen export to the Gulf of Mexico and the goal of reducing the extent of the seasonal hypoxic zone.

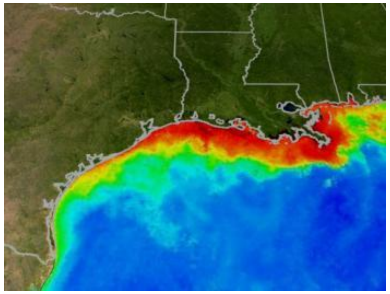
Results

The study focuses o... River Basi...

Déjà vu all over again?

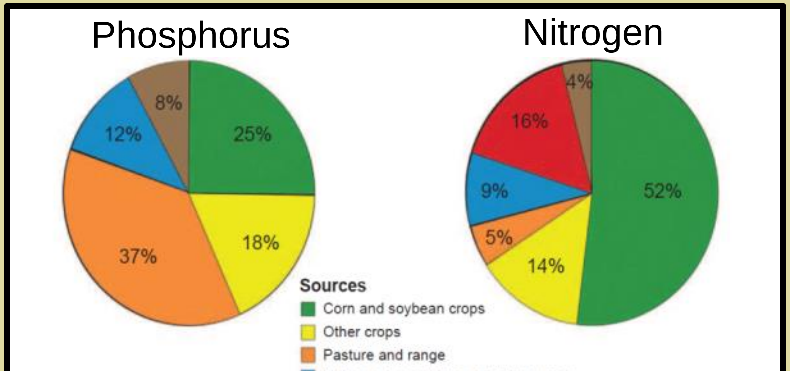
- Agriculture enriched runoff from fertilizer since the 1970's
- http://oceantoday.noaa.gov/happnowdeadzone/ (2.5 min.)
- Area of dead zone doubled since 1980 to 5,052 in 2012; target area <1,900 sq. miles
- Fisheries collapsed





Hypoxia Effects on the Gulf of Mexico ‘Dead Zone’

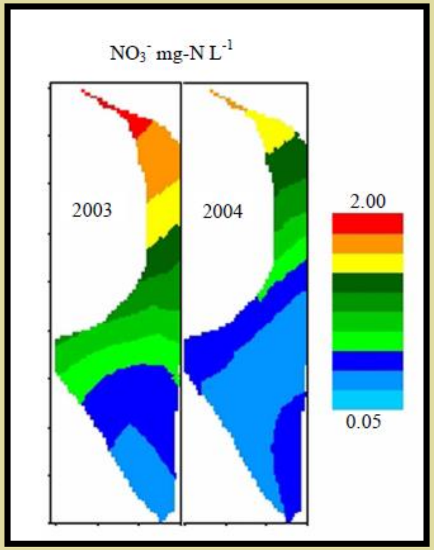
More nutrients upstream….



Alexander et al. 2008

Fink & Mitsch 2004

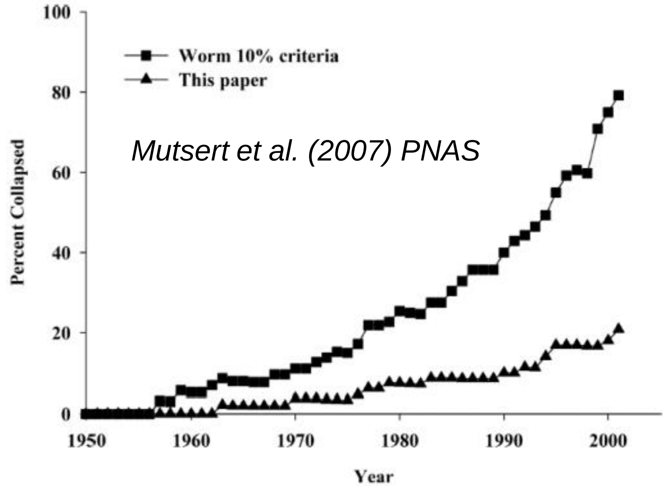
Fewer filters downstream….



Economic consequences to GOM fisheries

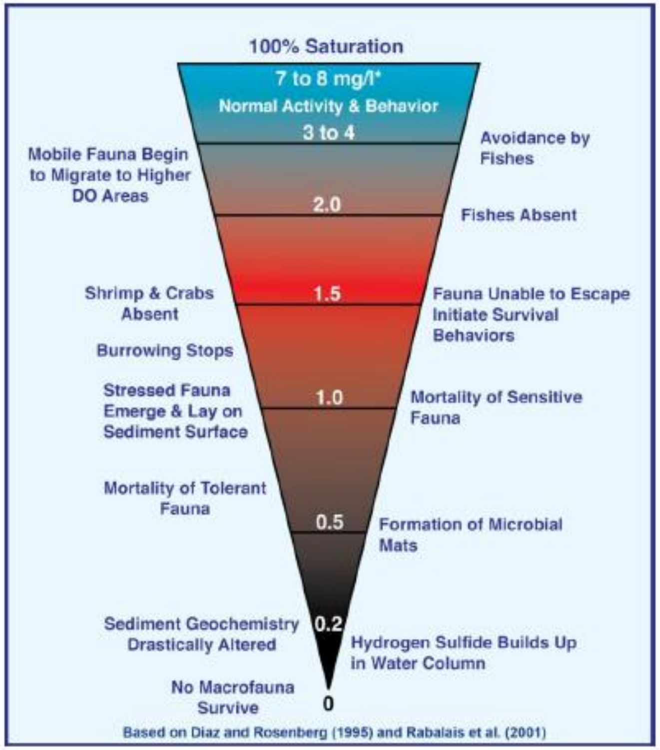
- The northern Gulf of Mexico (GOM) is the most productive fishery in the US with over 60% of landings.
- Example: Brown shrimp fishery worth $200 million in 2012.

The closed squares show the cumulative percentage of fisheries that collapsed in the Gulf of Mexico between 1950 and 2001 based upon the criterion used by Worm et al.

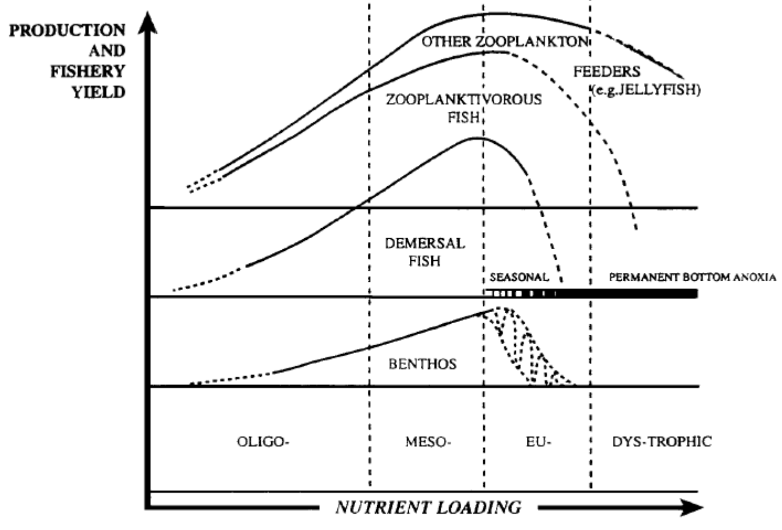


Kim de Mutsert et al. PNAS 2008;105:2740-2744

Figure 2. Cone of faunal response to declining oxygen concentration

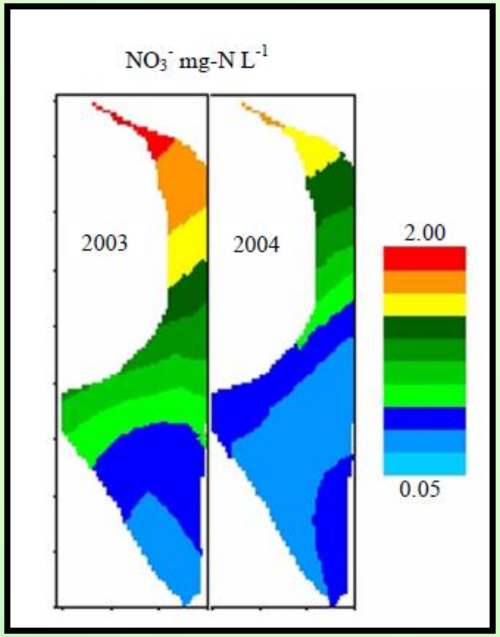


Based on Diaz and Rosenberg (1995) and Rabalais et al. (2001)

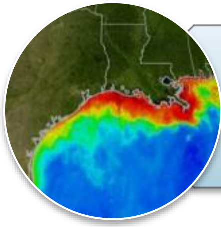


Upstream solutions

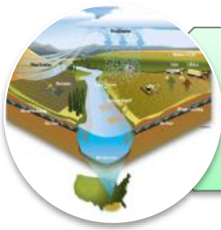
- EPA's Hypoxia taskforce includes states in the MARB
- About half have set nutrient standards (not Tennessee).
- Some states (e.g., Iowa) have implemented nutrient reduction goals
- Conservation practices include tile drain mitigation, restoration of wetlands, cover crops, etc.



Oak Ridge National Laboratory



Problem: Gulf Hypoxia



Upstream Causes

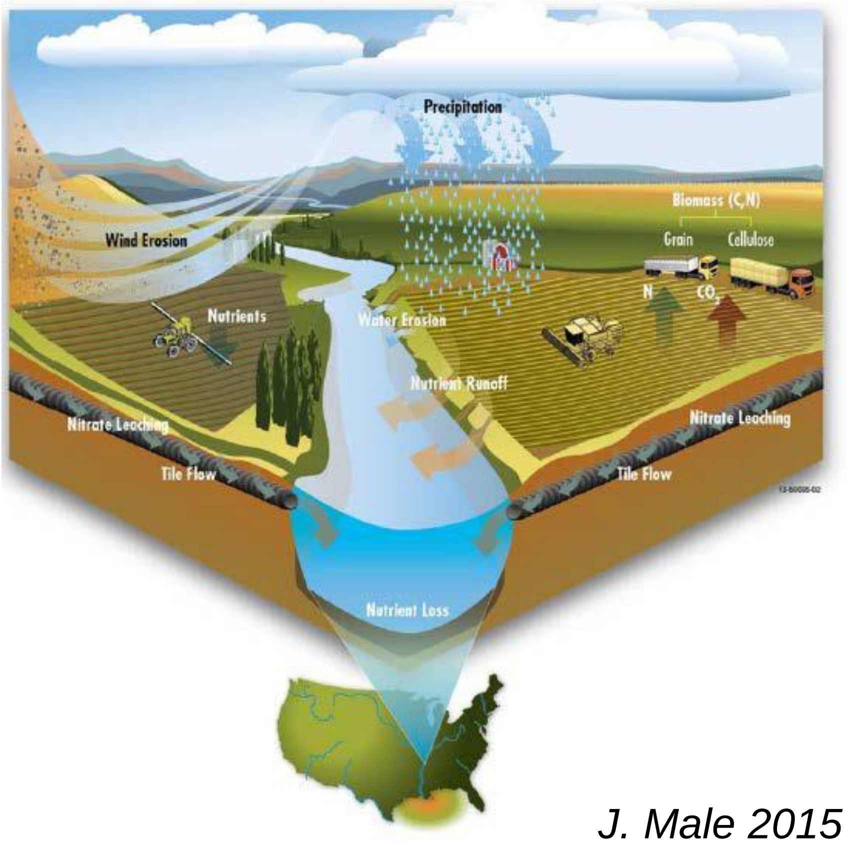
Bioenergy Crops

Conservation Practices

Recover Ecosystem Services

First, do no harm: Manage 2nd generation bioenergy production to meet GOM nutrient targets

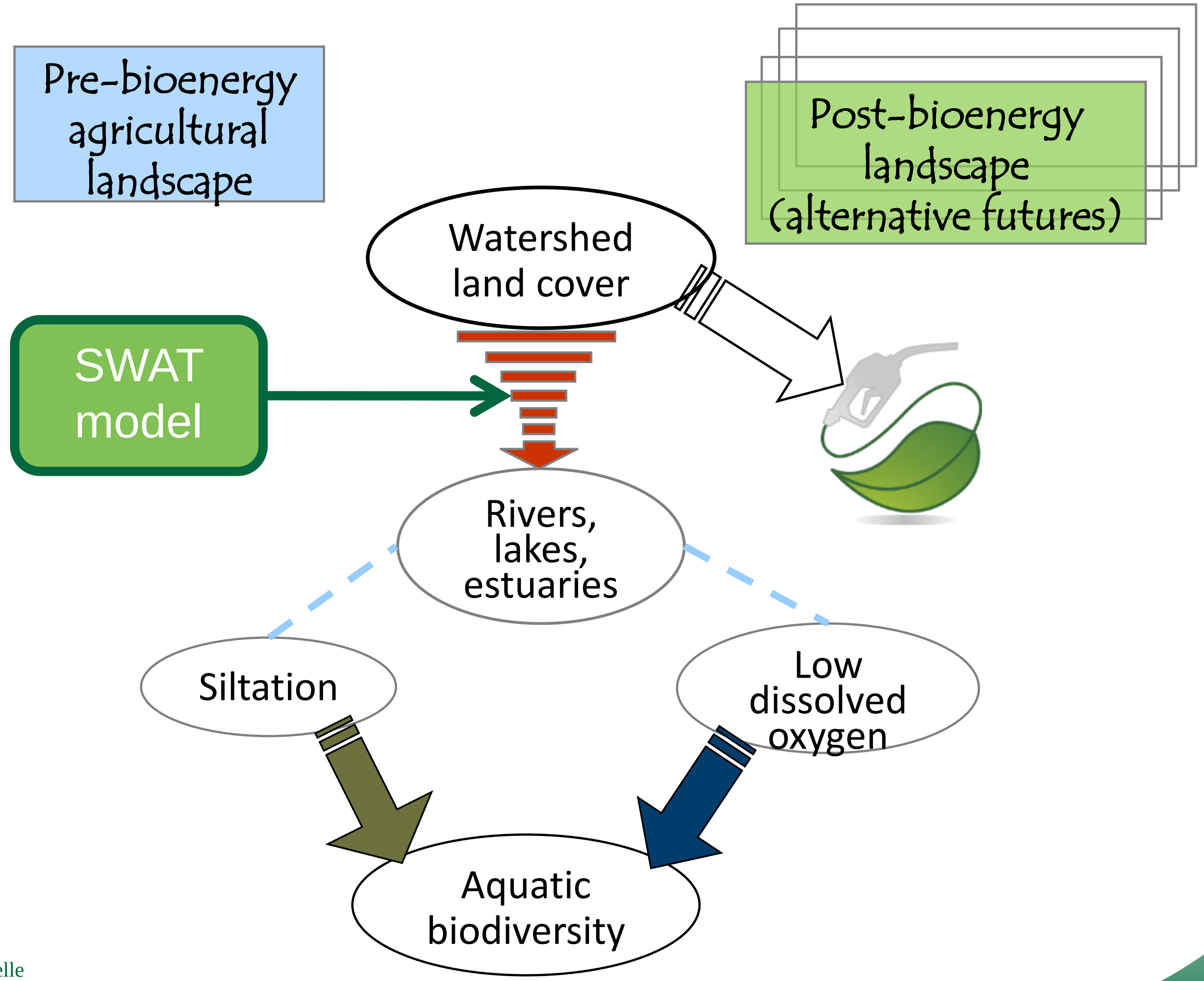
- Multi-LCC (Landscape Conservation Cooperative) Gulf Hypoxia Initiative
- Involves stakeholders and experts in 31 states, including DOE BETO and ORNL.
- Develop a decision support system to design and deliver wildlife conservation practices in watersheds

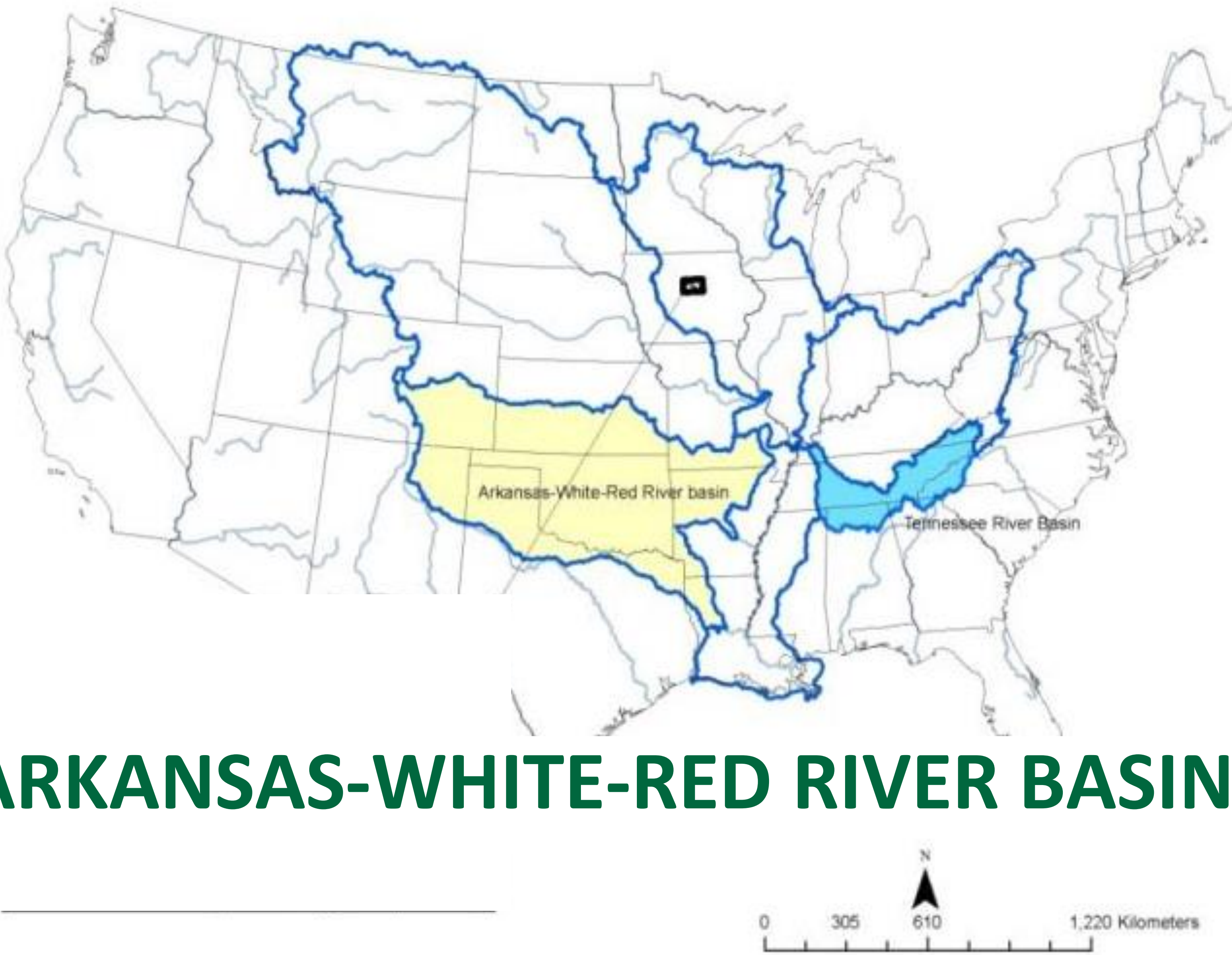


J. Male 2015

Bioenergy feedstock production can be incorporated into the landscape to help accomplish N-reduction strategies while keeping ag producers' business models solvent.

ORNL is modeling implications of adding bioenergy crops and harvesting residues in the Mississippi River Basin

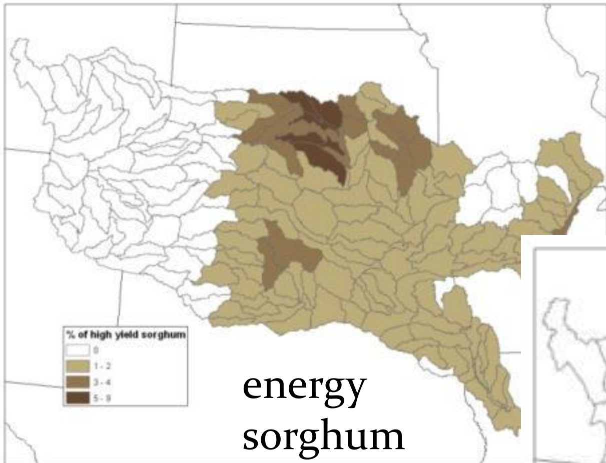




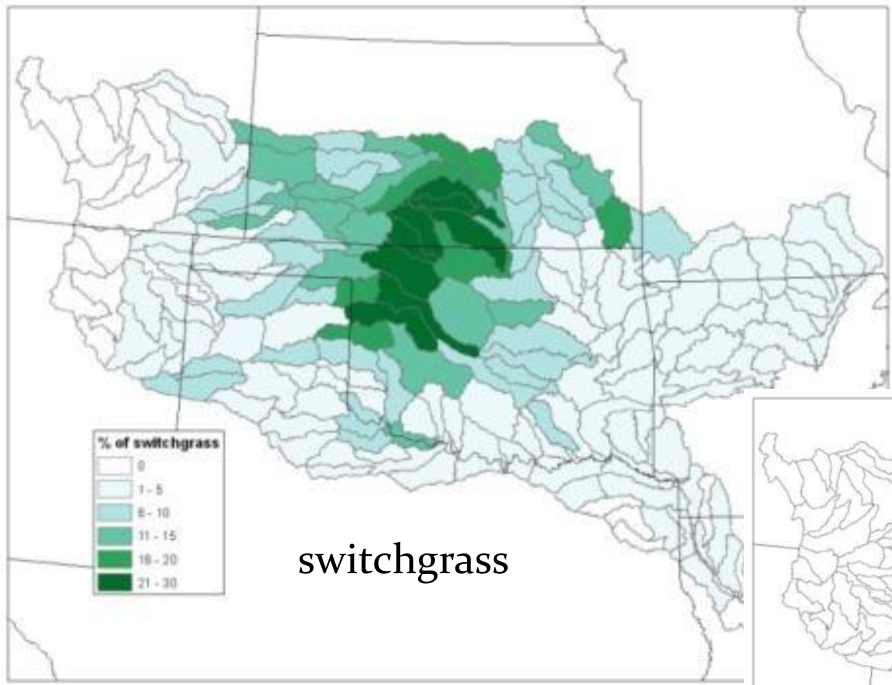
ARKANSAS-WHITE-RED RIVER BASIN

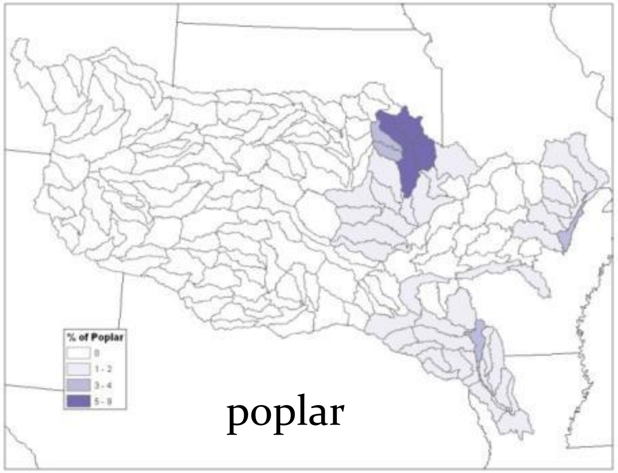
Oak Ridge National Laboratory

Billion Ton-2 2030 future landscape



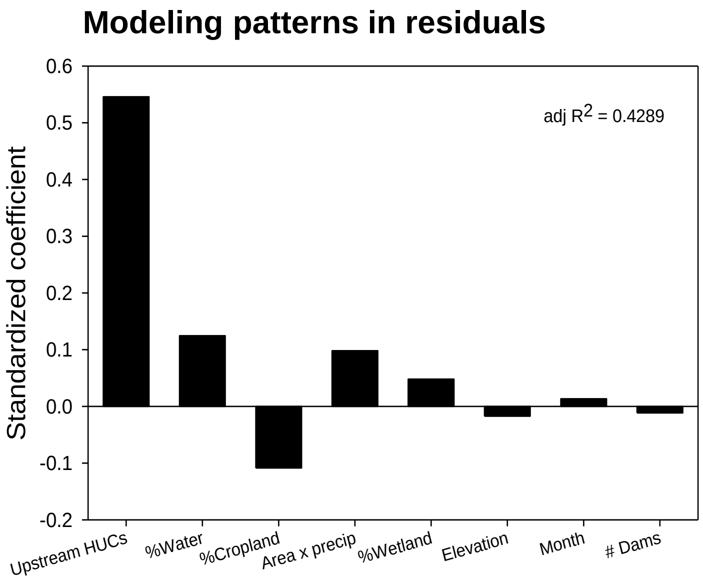
Precipitation gradient

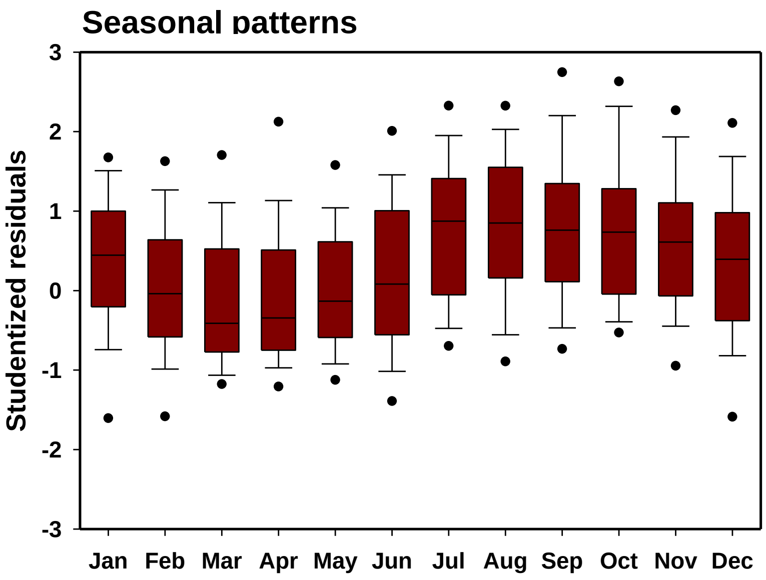




Precipitation gradient

Functional validation of flow

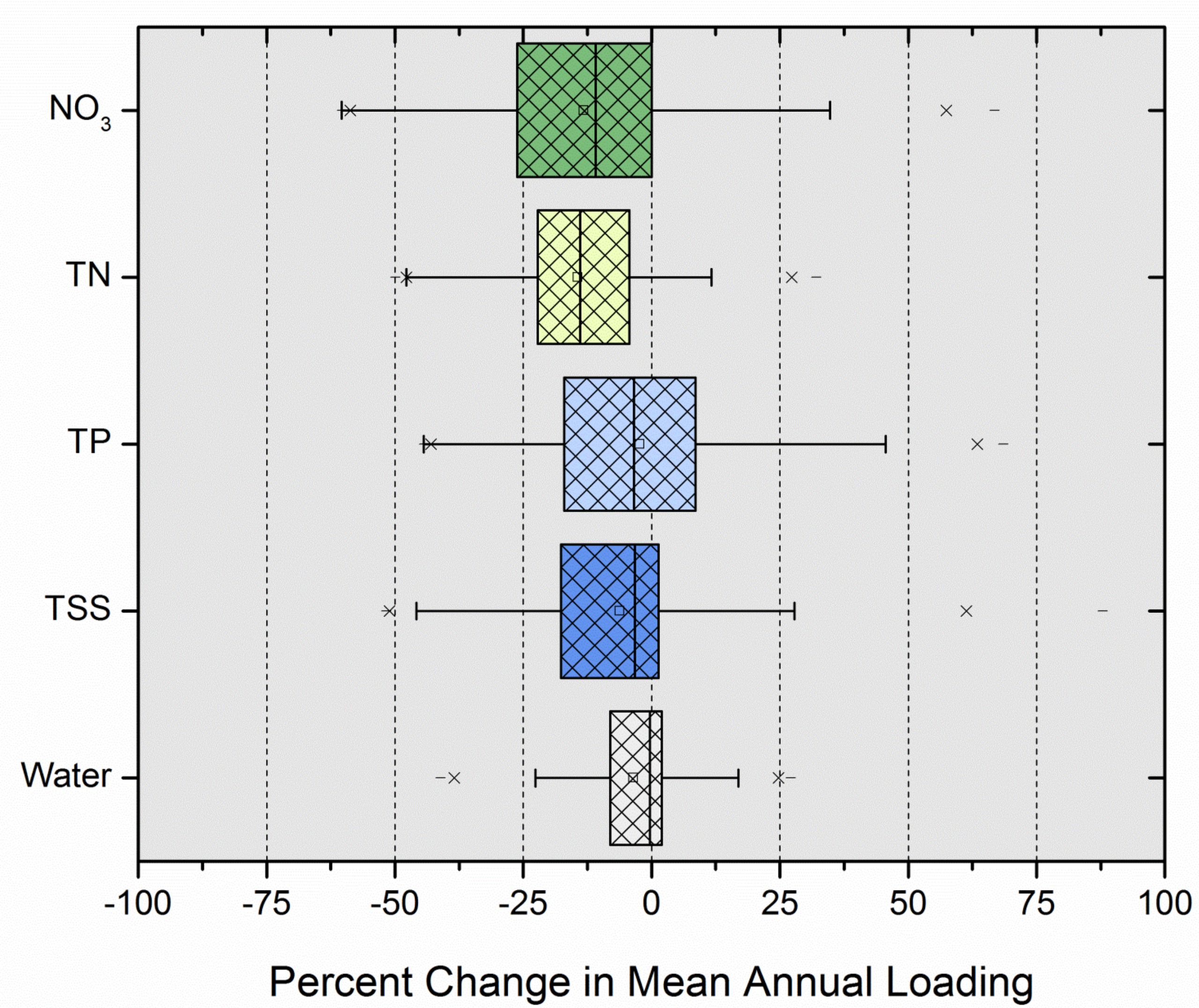




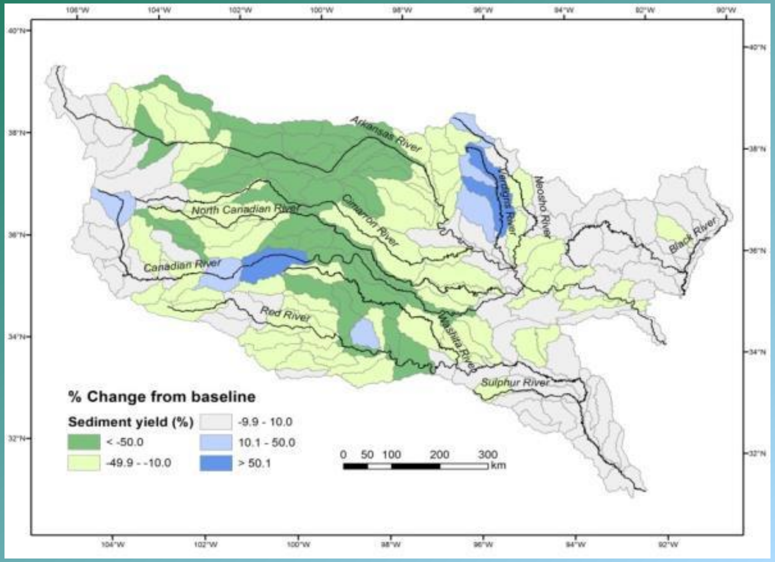
- **Confidence in SWAT-predicted water quality changes will depend on validation.**
- **Functional validation analyzes patterns in residuals to identify areas for model improvement (Jager et al. 2000).**
- **Good agreement between SWAT-predicted and observed USGS monthly flows for 86 of 173 subbasins in the AWR with flow data, adj R^2 = 0.823.**

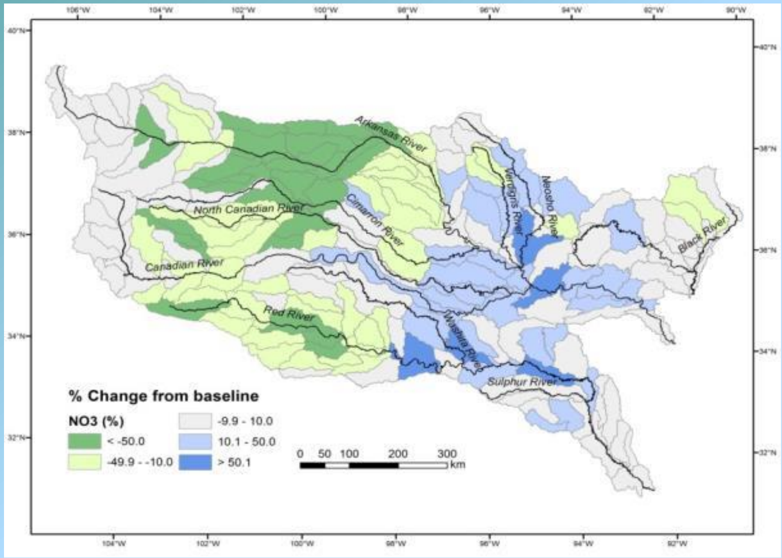
Oak Ridge National Laboratory

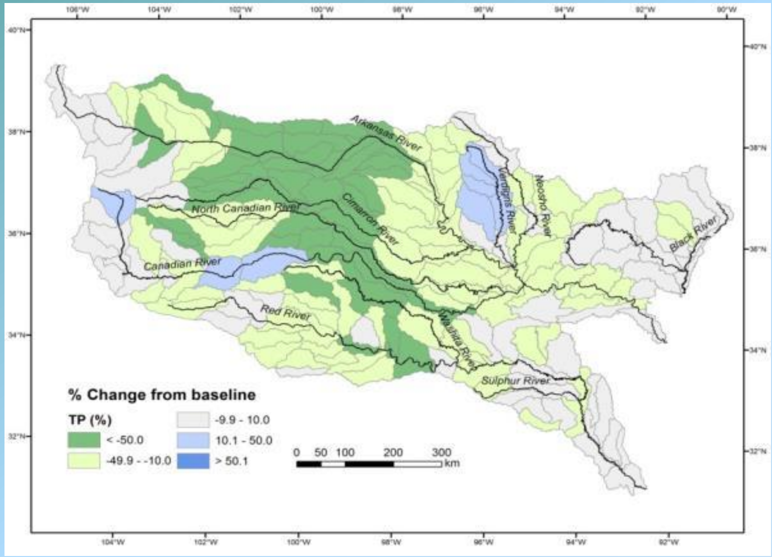
Projected changes in Arkansas-White-Red

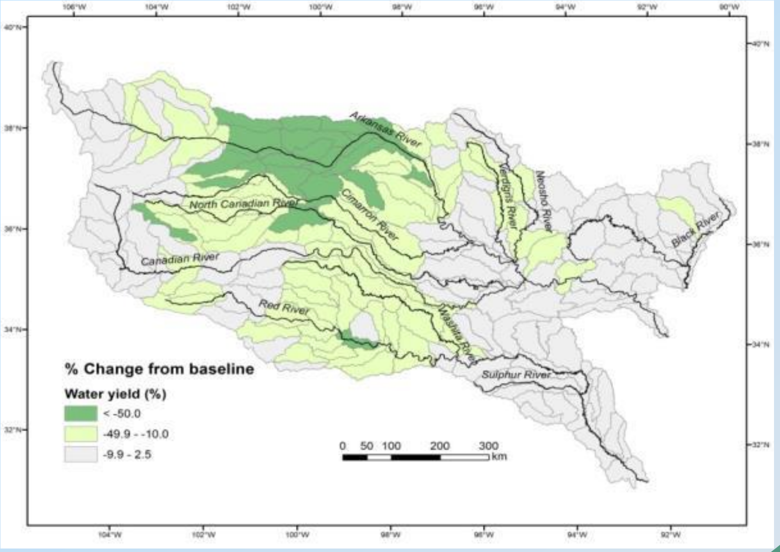


Projections Arkansas-White-Red River Basin









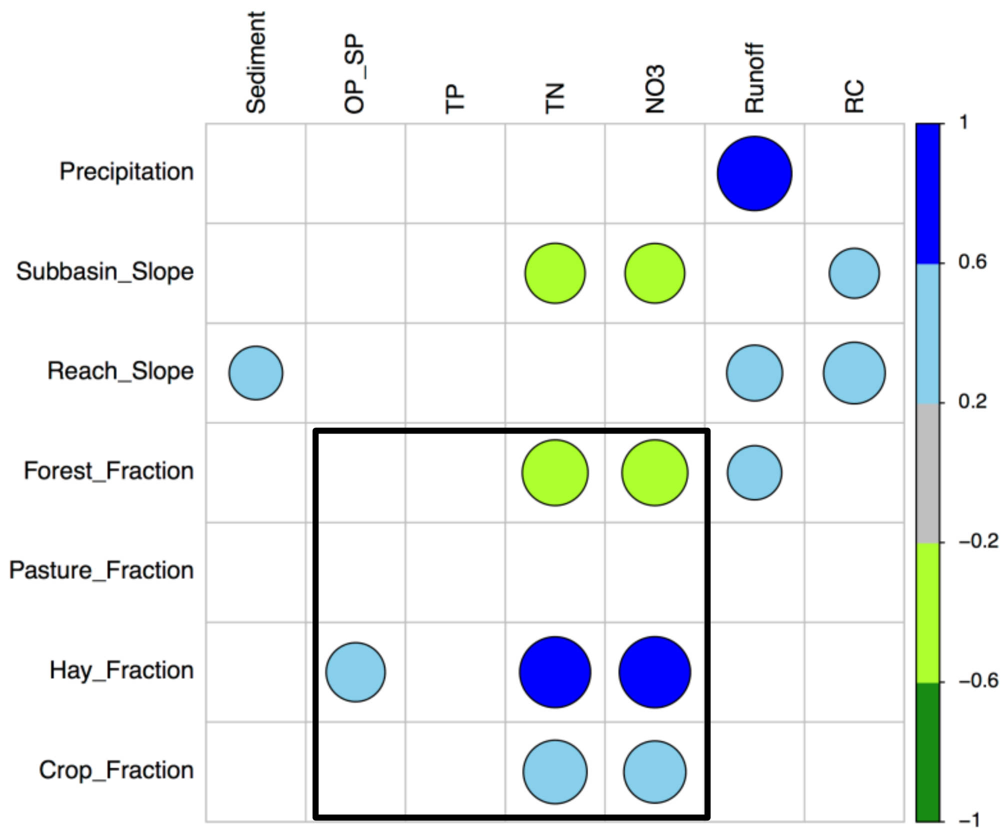
OAK RIDGE National Laboratory

TENNESSEE RIVER BASIN

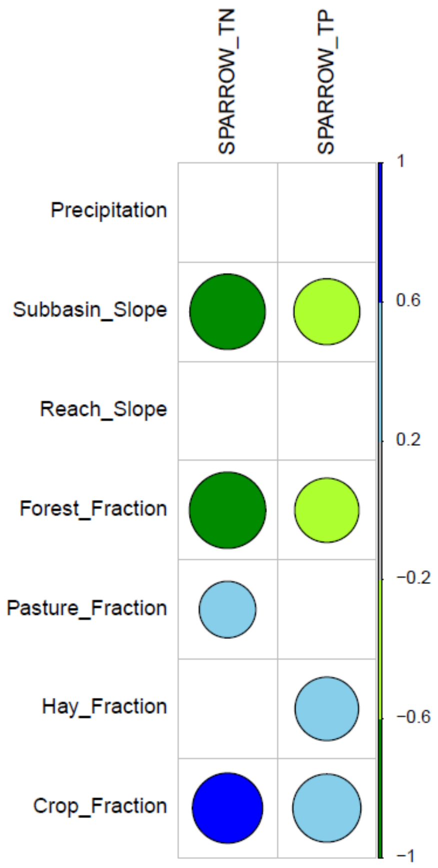
OAK RIDGE
National Laboratory

Functional validation of runoff, water quality

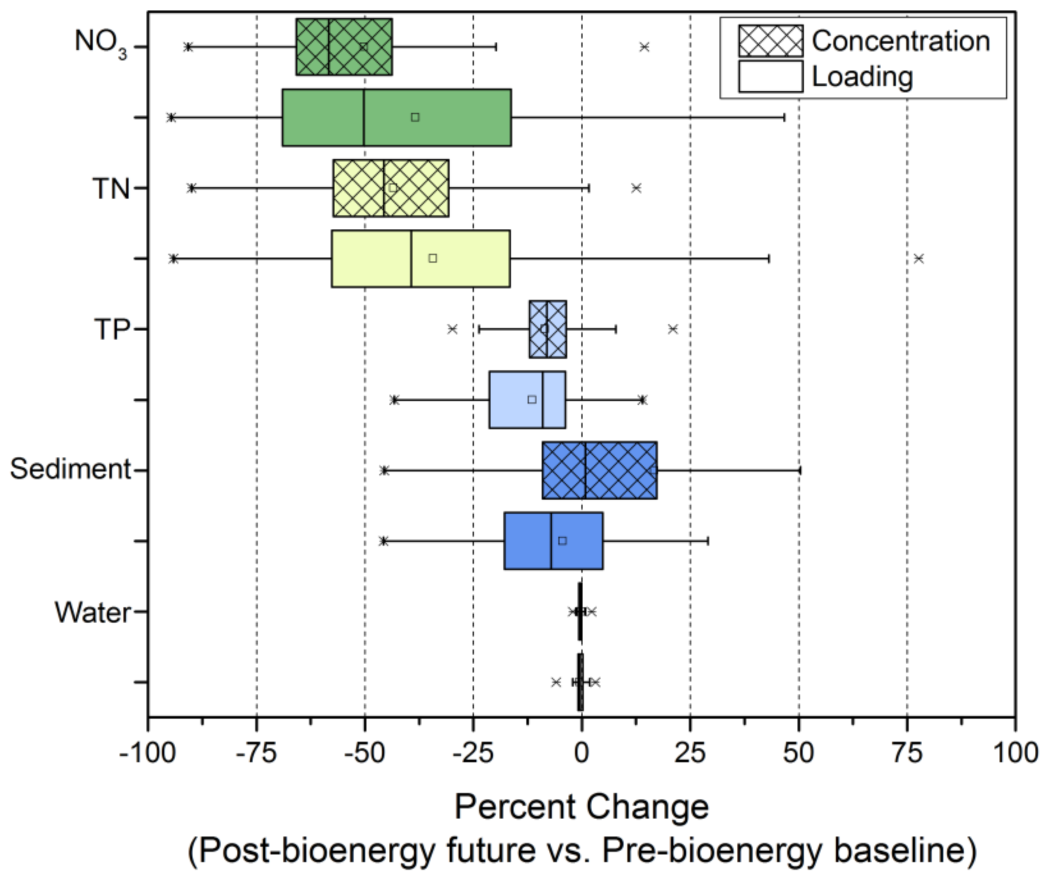
SWAT
(process-based)



SPARROW
(empirical)

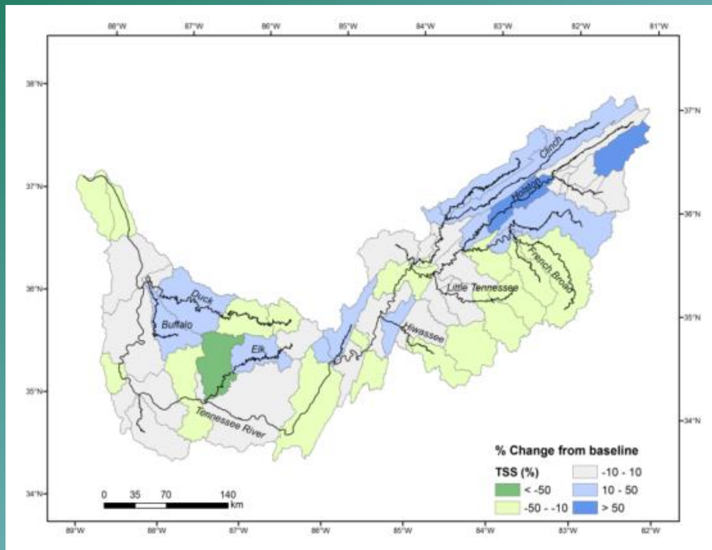


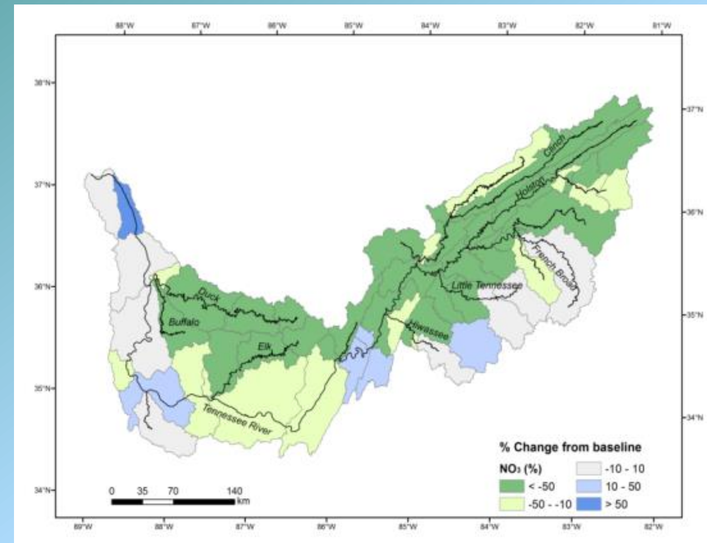
Reduced nutrient and sediment Tennessee River Basin

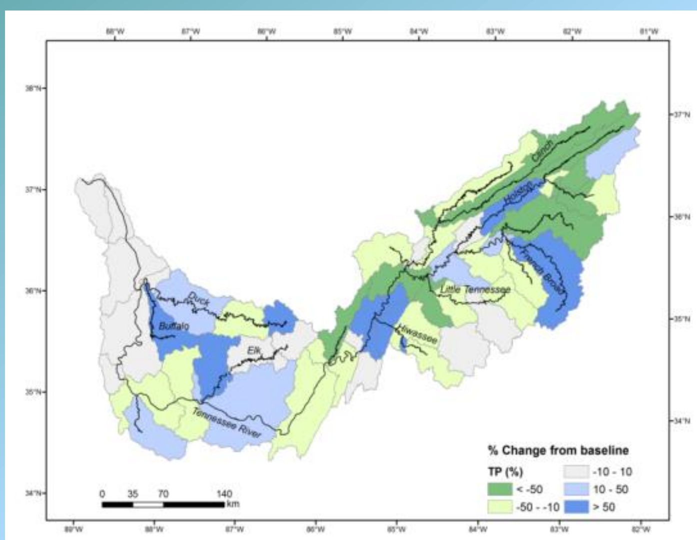


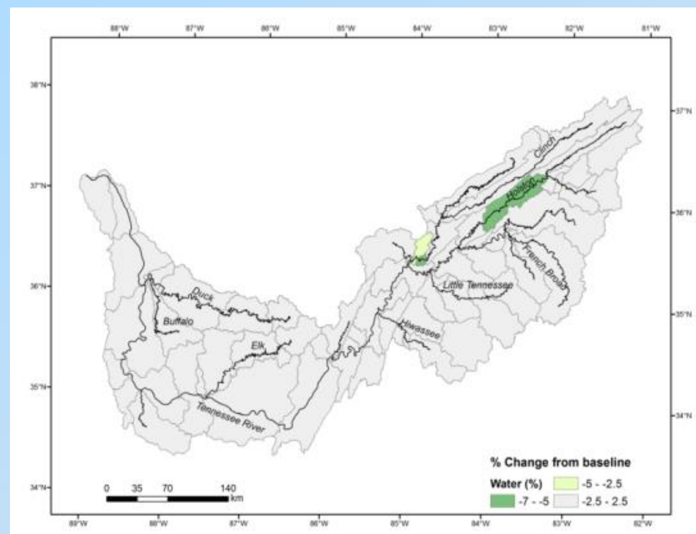
Bioenergy future ($50/dt)

Preliminary projections – Tenn. River Basin

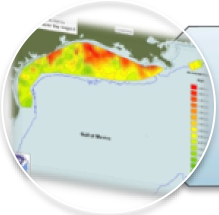








Oak Ridge National Laboratory



Problem: Gulf Hypoxia

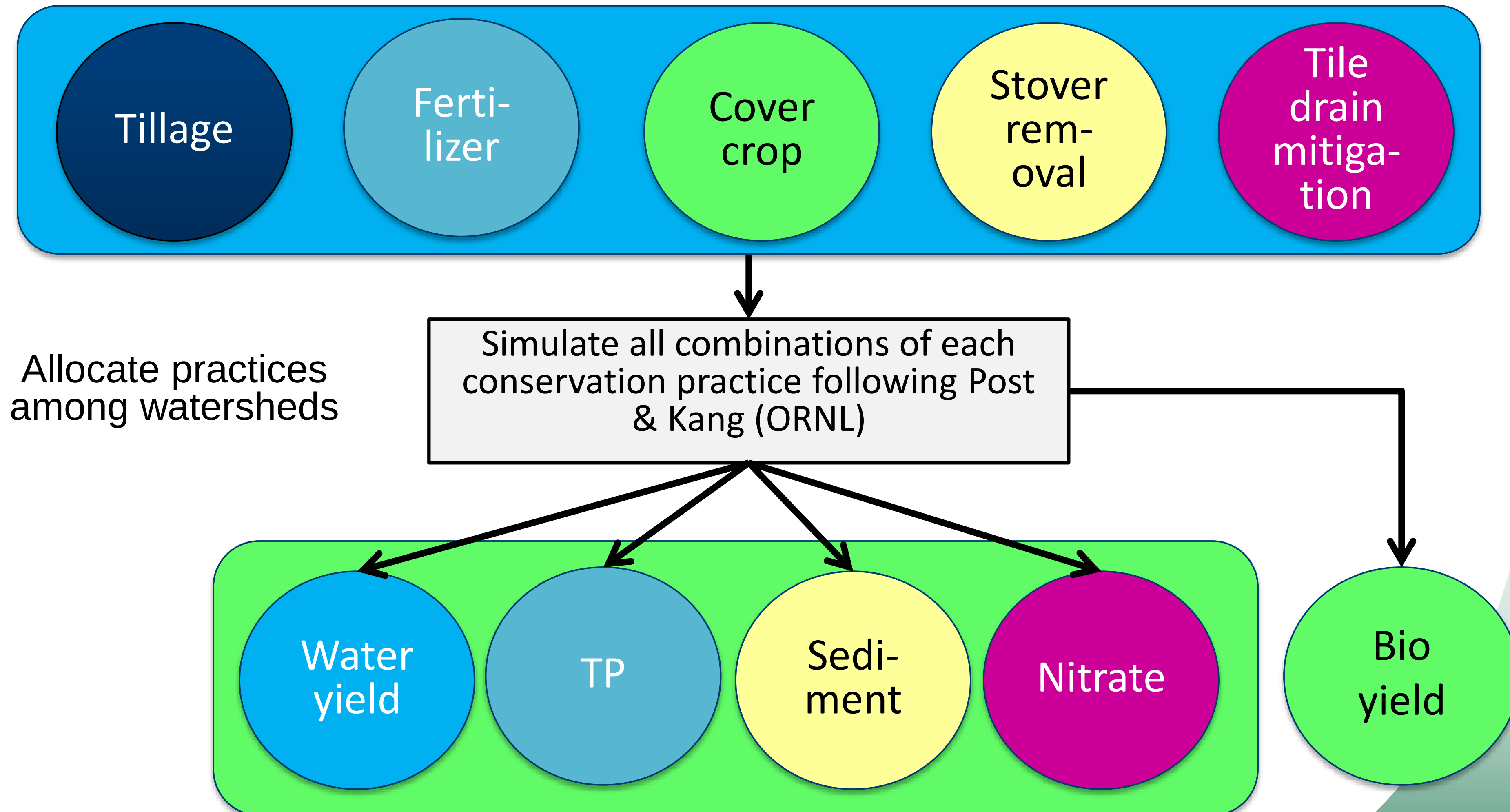
Upstream Causes

Bioenergy Crops

Conservation Practices

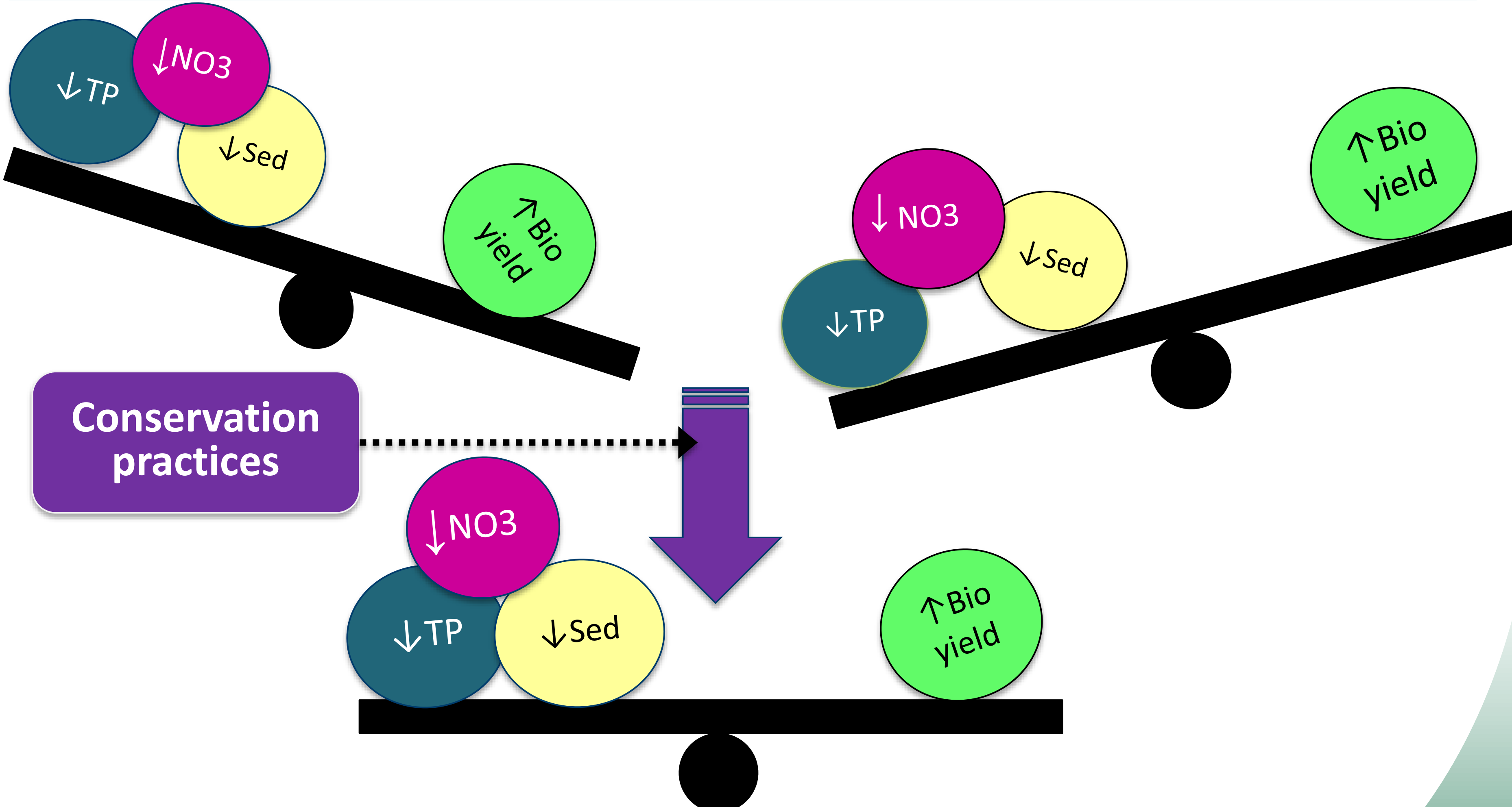
Recover Ecosystem Services

How can we improve water quality and increase bioenergy yields?



Oak Ridge National Laboratory

How can we improve water quality and increase bioenergy yields?



https://public.tableau.com/profile/michael.hilliard#!/vizhome/ParetoAnalysisHYSGTopPractices/Whiskers

Summary and Future

- 2nd generation perennial crops improved water quality in two southeast river basins
- Combine results for whole Mississippi River basin
- Evaluate change in the size of the Dead Zone
- Quantify economic gain or loss to fishery

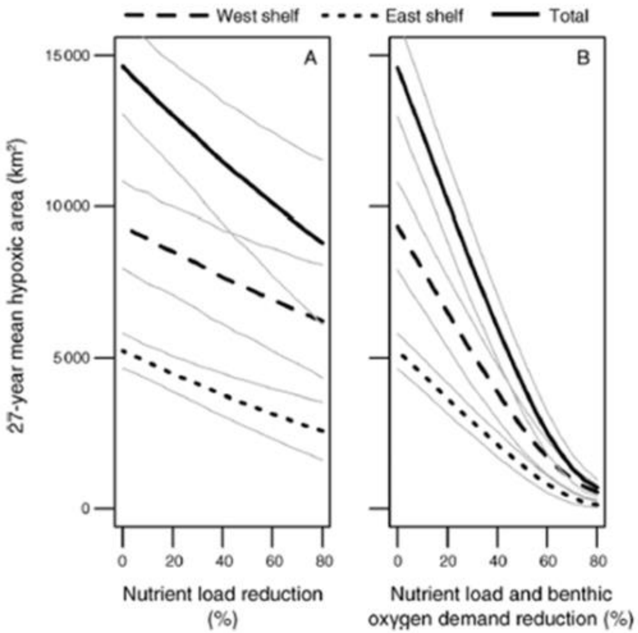


FIG. 8. Mean (over 27 years) hypoxic areas (with 95% credible intervals shown in gray) for west shelf, east shelf, and total shelf under (A) spring nutrient load reductions alone and (B) nutrient load reductions with proportional benthic oxygen demand reductions.

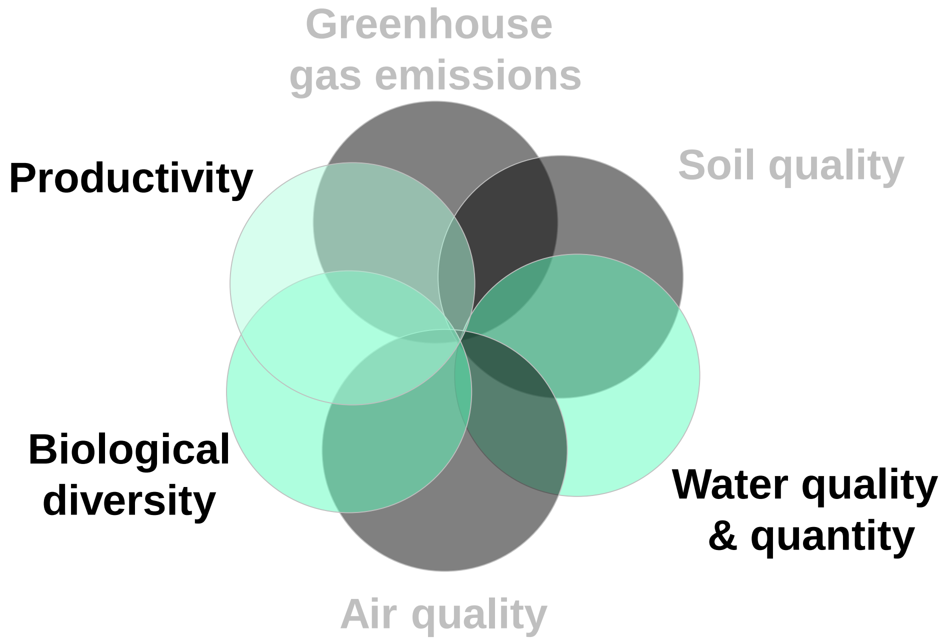
Obenouer et al. 2015

Corn ethanol – local history

The Moonshine Capital – Cosby, TN
(two displays in Maggie Valley)

References

- 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
- 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



Questions?

Bioenergy Garden UTK

jagerhi@ornl.gov
http://www.esd.ornl.gov/~zij/