Environmental Challenges and Opportunities in the Food-Energy-Water Nexus

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Franklin, TN
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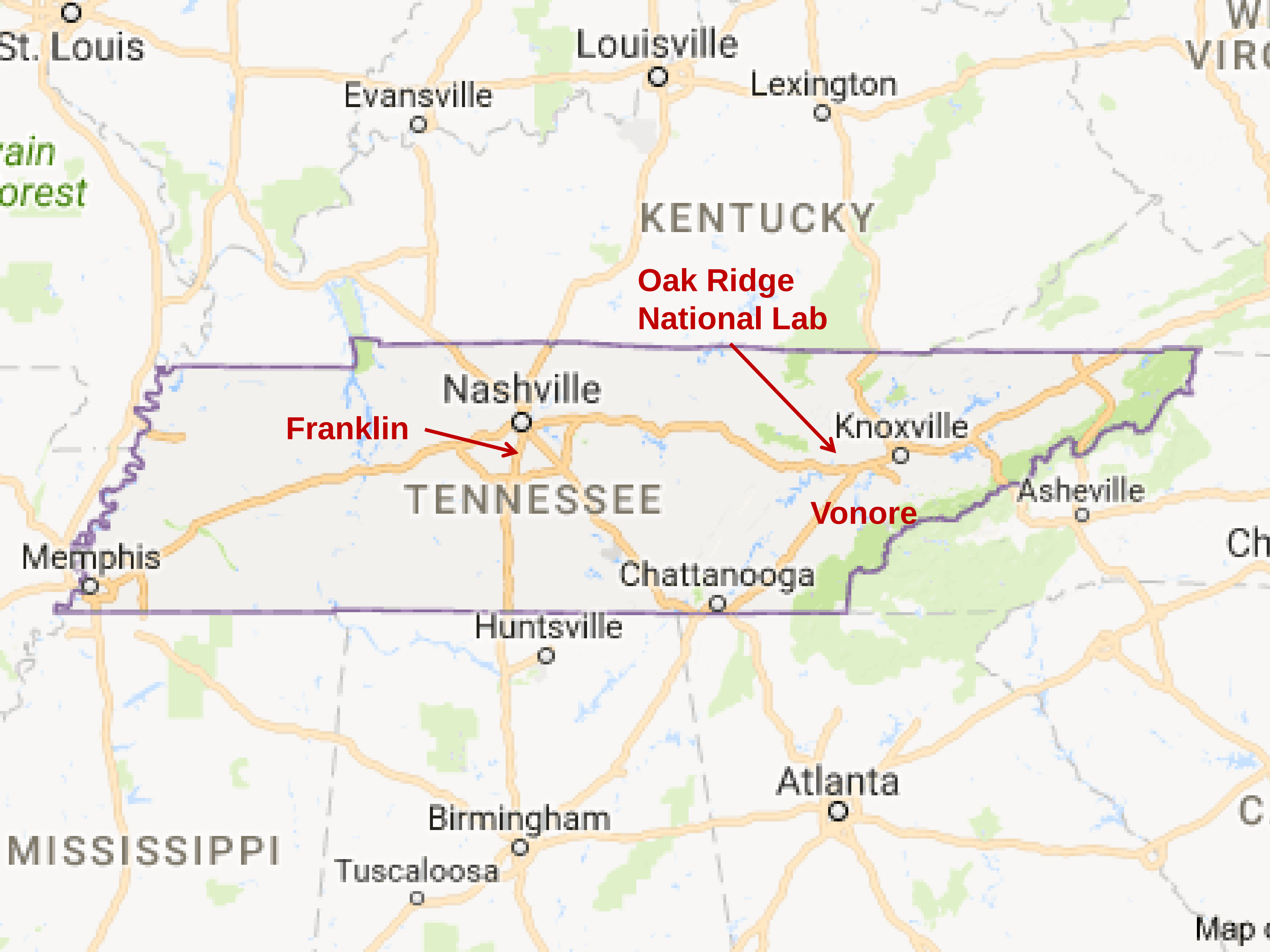
http://www.ornl.gov/sci/ees/cbes/



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Oak Ridge National Laboratory (ORNL)
DOE lab located in the hills of east TN

- 4,500 staff
- 3,000 visitors per year (for more than 2 weeks)
- Focus on energy
- Close ties to the University of Tennessee

- Engineers
  - Nuclear
  - Material
  - Chemical
- Scientists
  - Biology
  - Environmental science
  - Chemistry
  - Computer science
  - Geography
  - Economics
  - Social Science
  - Physics

Sustainability Research

- **Advance common definitions of environmental & socioeconomic costs and benefits of energy systems**

- **Quantify opportunities, risks, & tradeoffs associated with making progress toward sustainability in specific contexts**

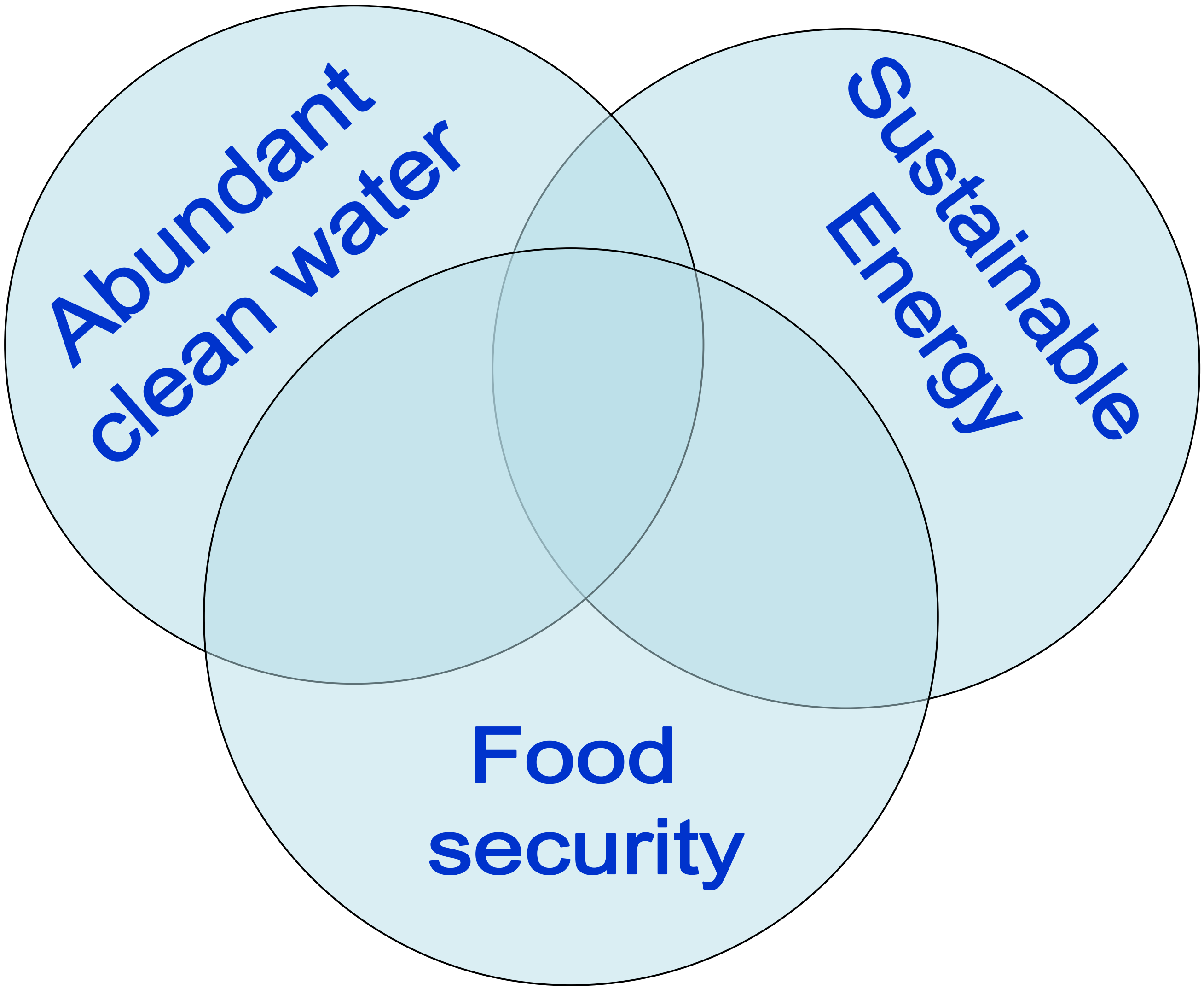
CBES Center for BioEnergy Sustainability

Oak Ridge National Laboratory

U.S. Department of Energy

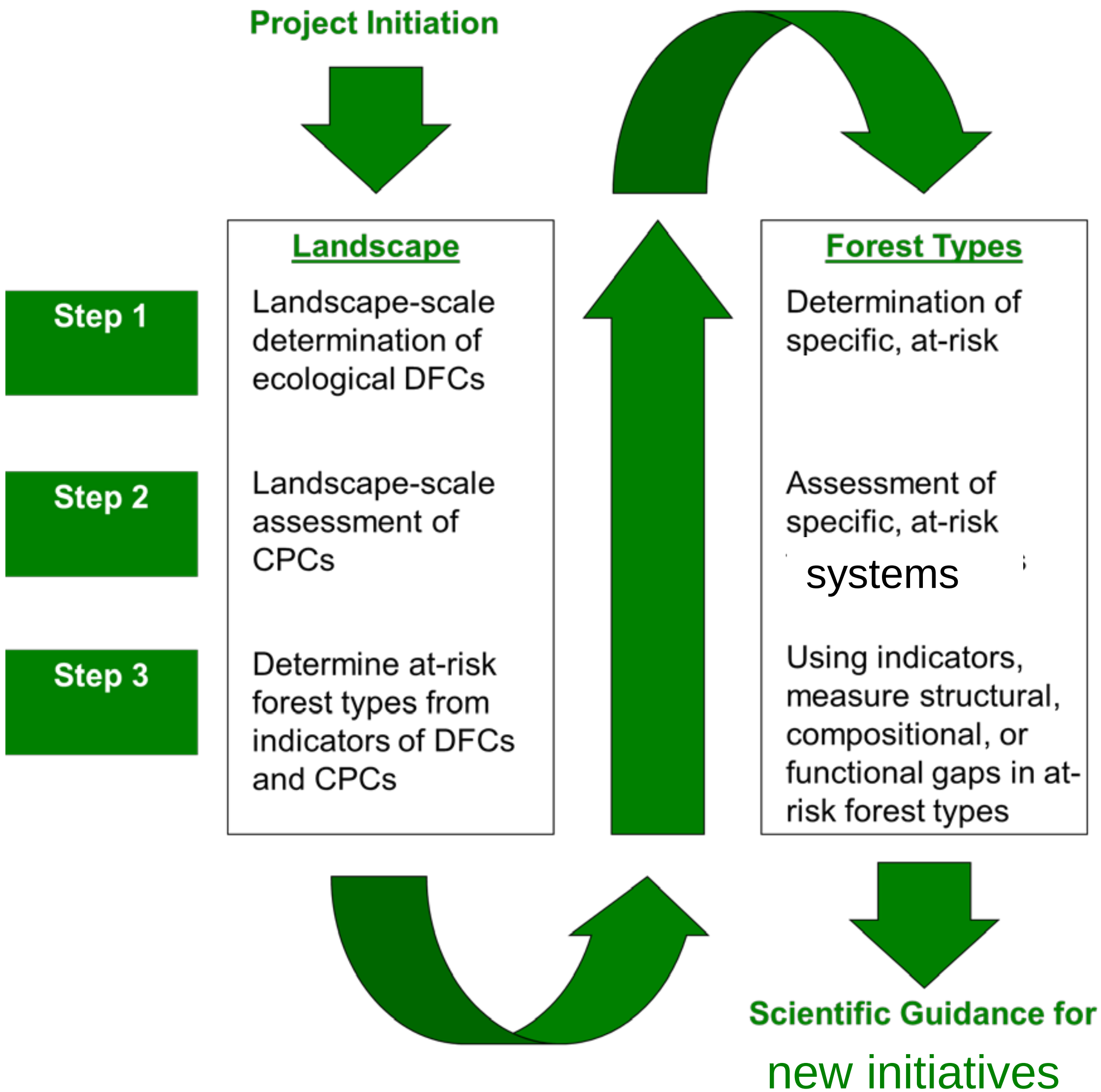
Focusing on sustainability brings together disparate perspectives.

The nexus between sustainable energy and food security invokes a focus on abundant clean water

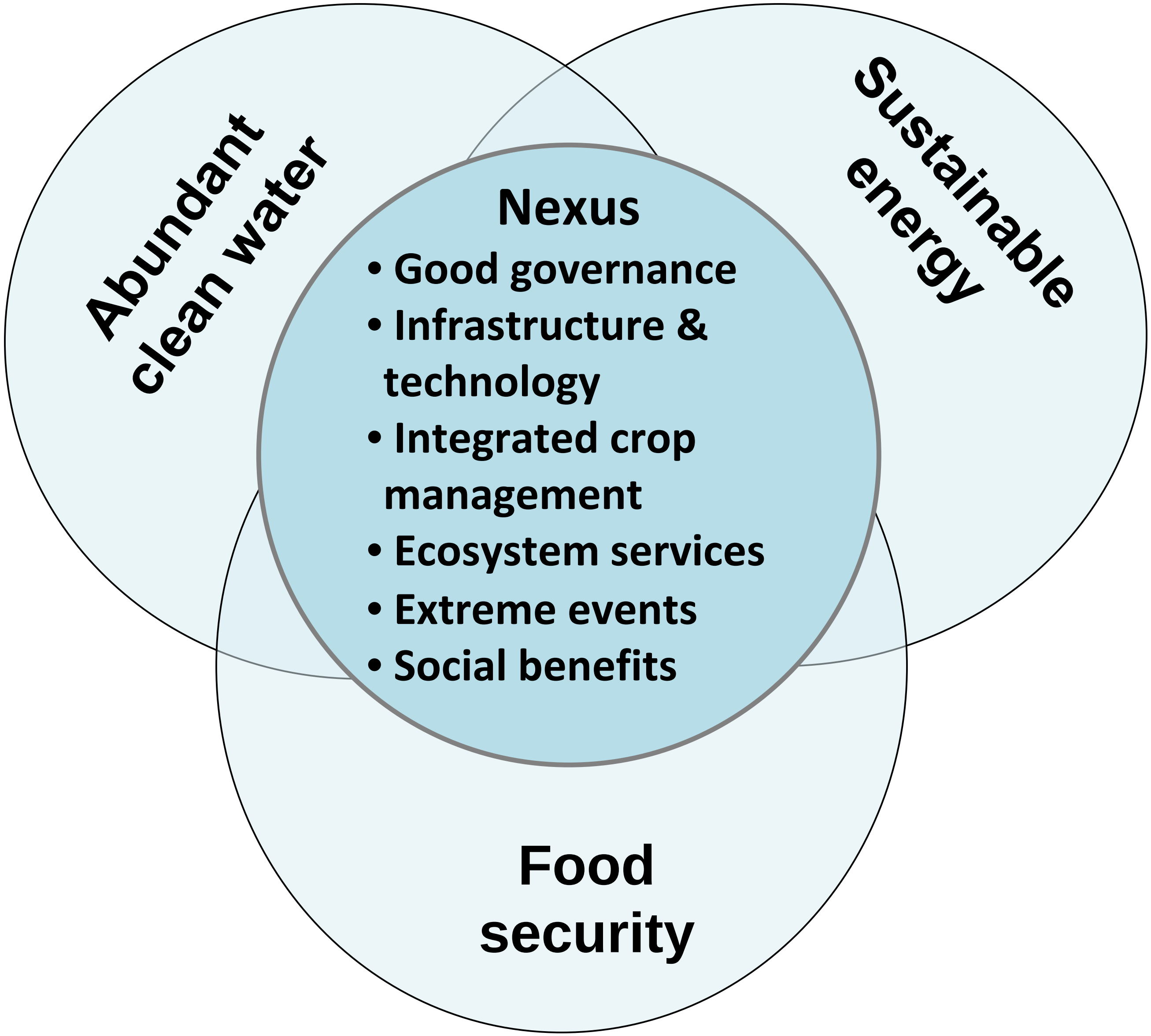


(Kline et al. 2016)

One grand challenge is (1) identifying desired future conditions (DFC) & (2)using current prevailing conditions (CPC) to focus efforts



Key Attributes of the Nexus



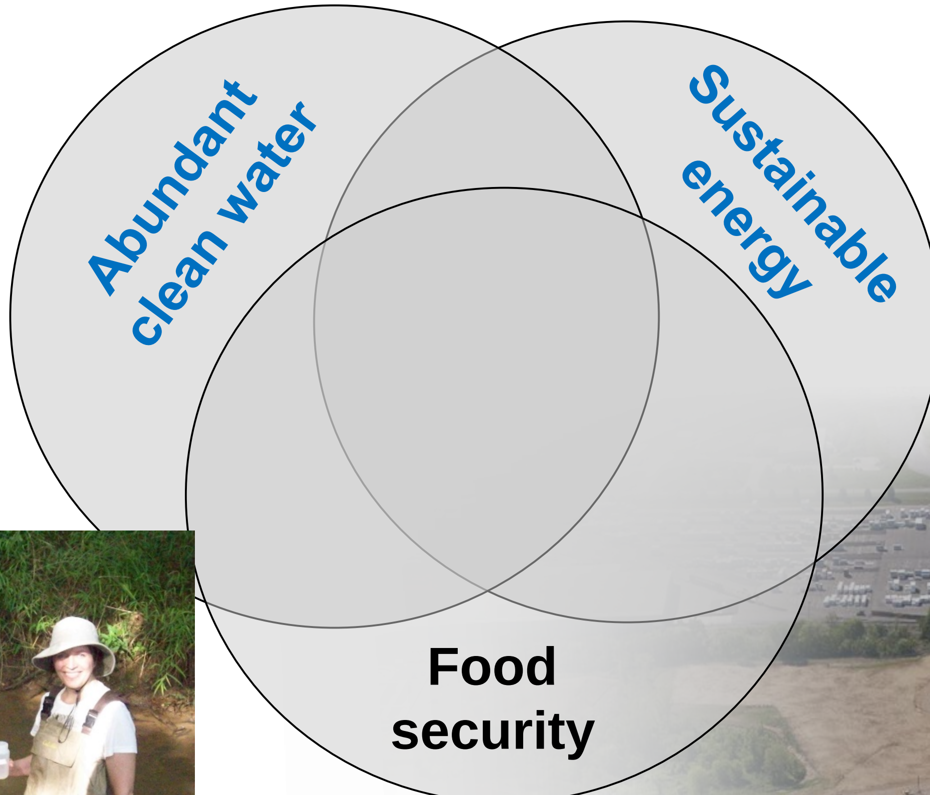
[Kline et al. 2016)

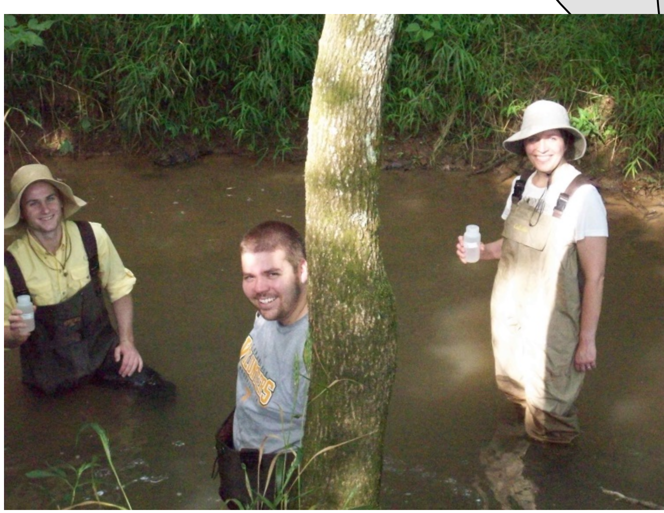
Abundant clean water ➢ Sustainable energy

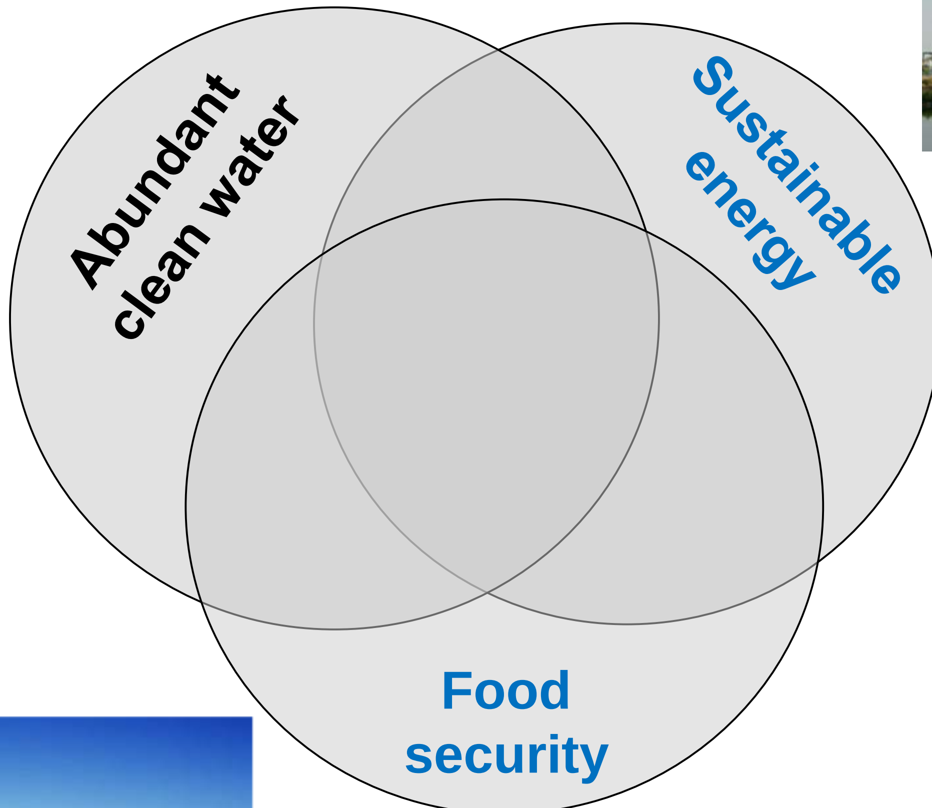
- Increased efficiency & productivity of bioenergy, hydropower, & nuclear energy
- Opportunities & constraints on locations for planting & harvesting biomass for energy

Sustainable energy ➢ Abundant clean water

- Reduced greenhouse gas emissions
- Attention to land-use planning & biodiversity
- Incentives for restoration







Sustainable energy
➢ Food security

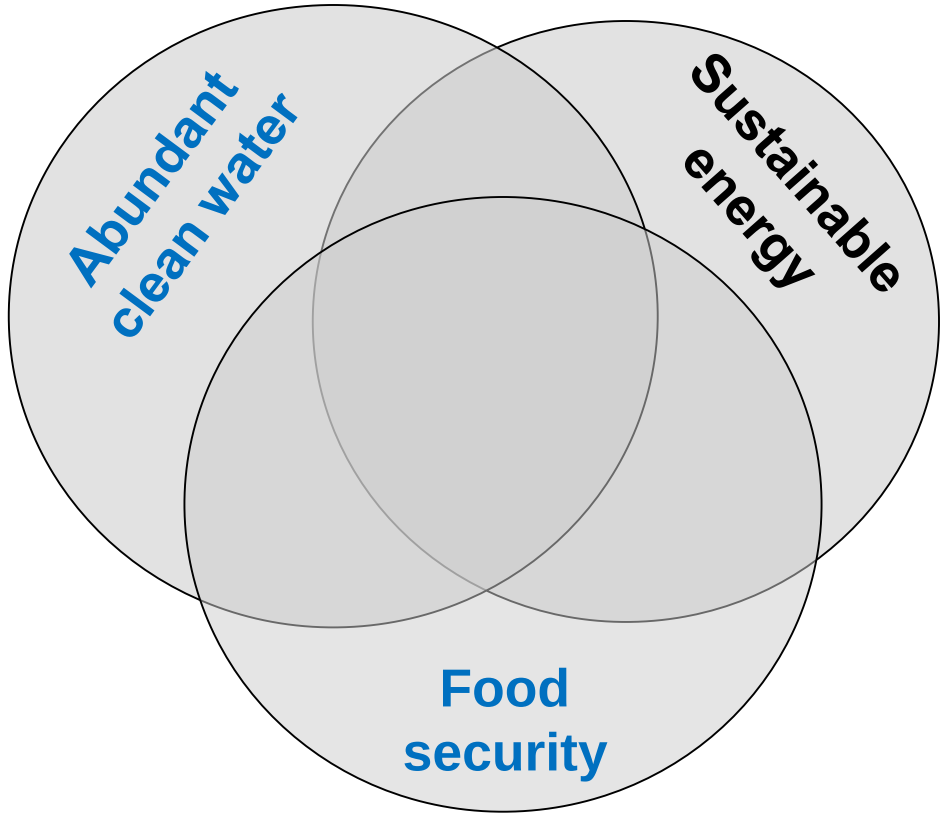
- Income enhancement & diversification
- Energy for food production, processing, & transportation
- Reduced volatility in market prices
- Enhanced sustainability of food crops

Food security ➢
Sustainable energy

- Oversupply cushion required for food security
- Healthy workforce underpins energy markets

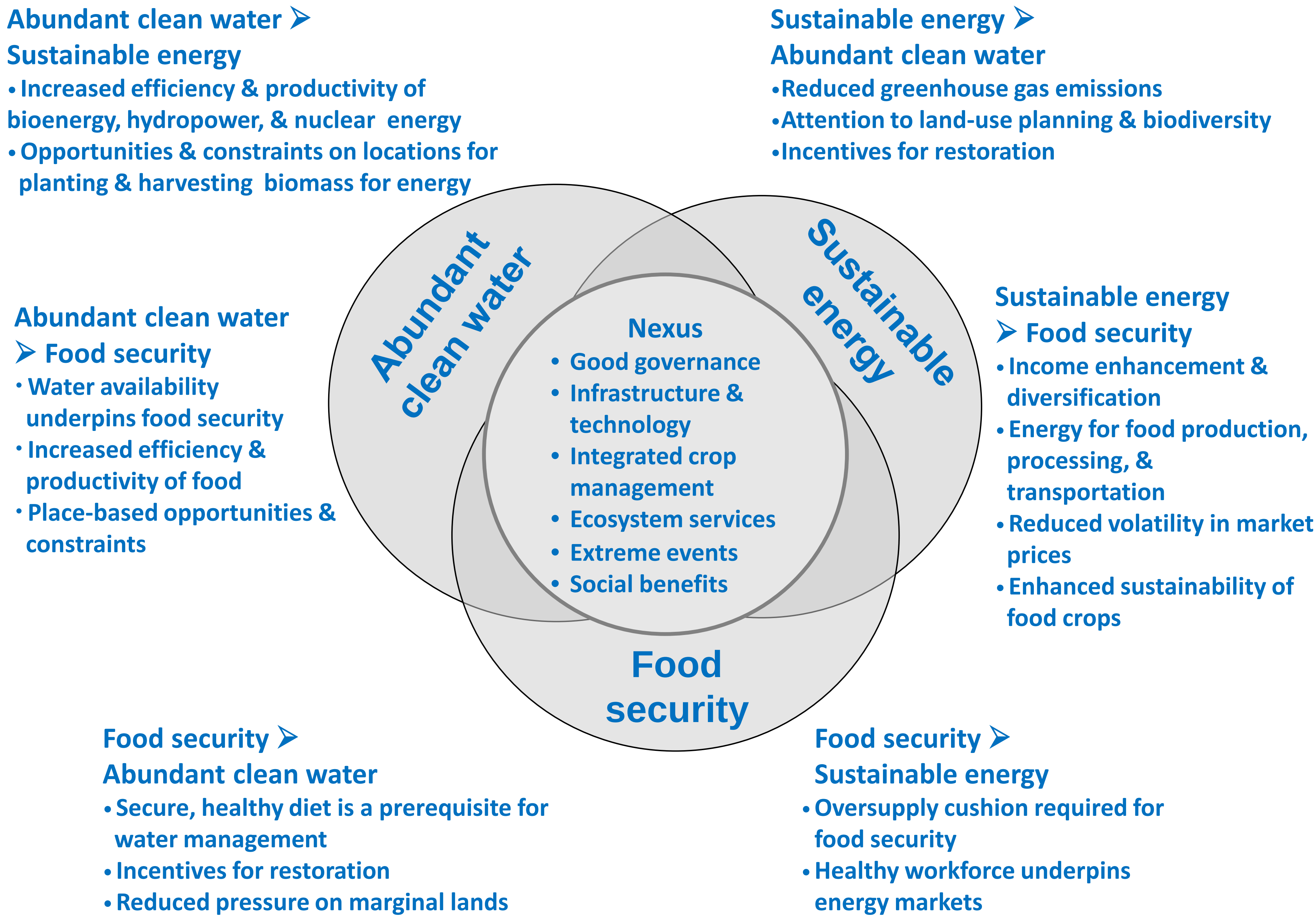
Abundant clean water ➢ Food security

- Water availability underpins food security
- Increased efficiency & productivity of food
- Place-based opportunities & constraints



Food security ➢ Abundant clean water

- Secure, healthy diet is a prerequisite for water management
- Incentives for restoration
- Reduced pressure on marginal lands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Abundant clean water
Sustainable energy
Nexus
• Good governance
• Infrastructure & technology
• Integrated crop management
• Ecosystem services
• Extreme events
• Social benefits
Food security
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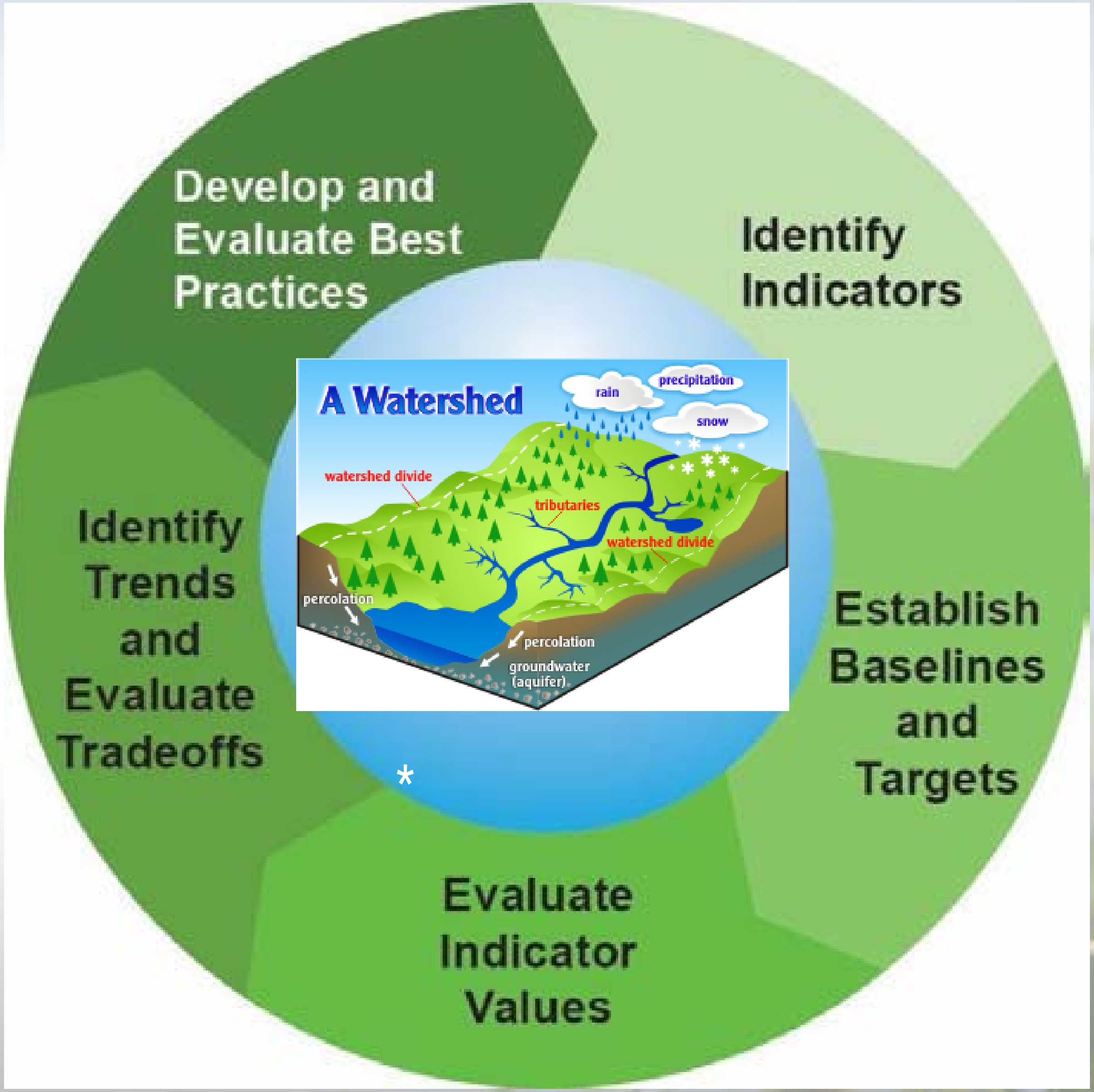
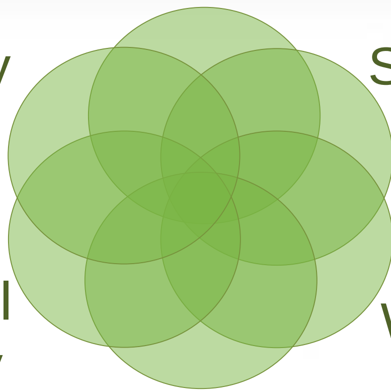
Overall Approach



Common categories for environmental & socioeconomic sustainability



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

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

Recognize that measures and interpretations are <u>context</u> specific

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

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Categories of 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

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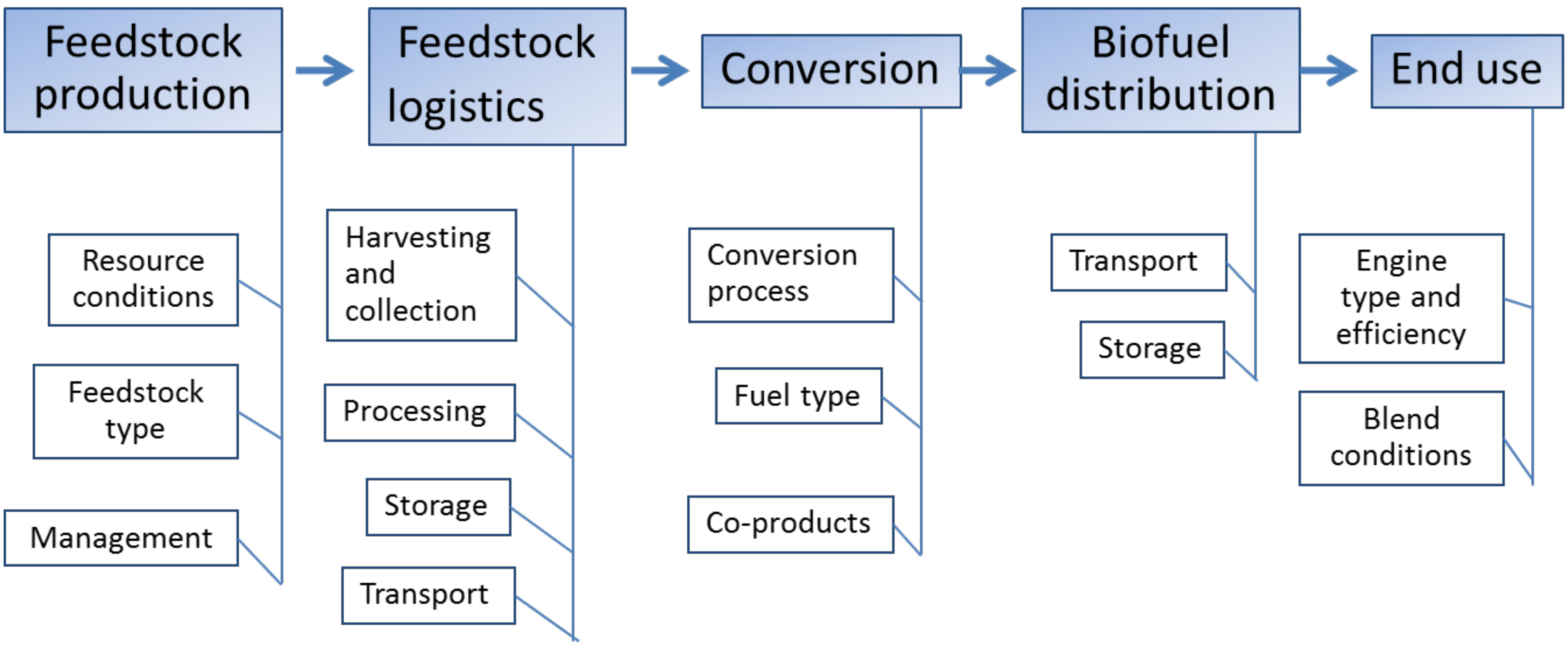
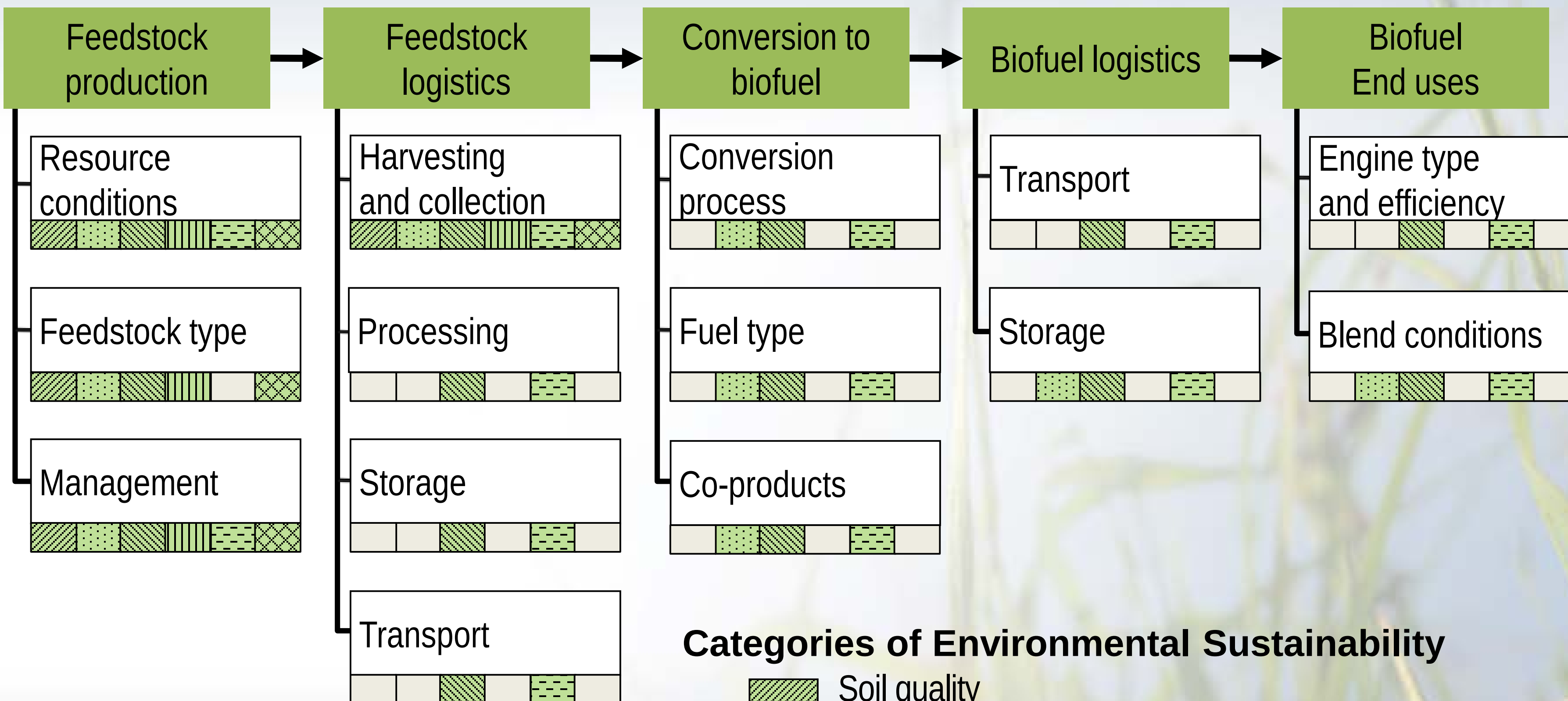
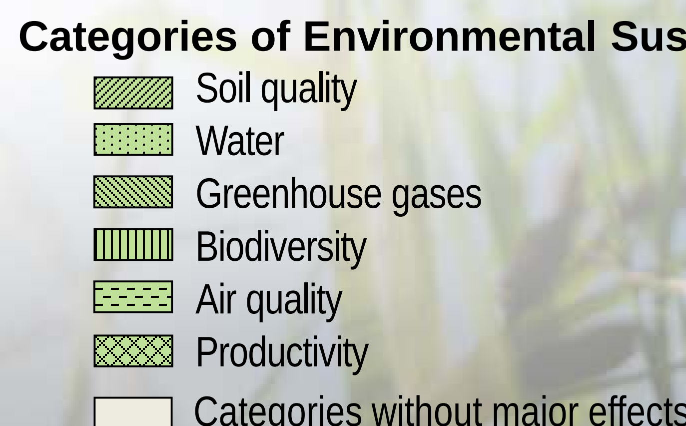
Indicator approach should apply across supply chain (example is biofuel supply chain)



Source: Dale VH, KL Kline, D Perla, A Lucier. 2013. Communicating about bioenergy sustainability. Environmental Management 51(2): 279-290.

Environmental sustainability indicators occur at all steps of the biofuel supply chain





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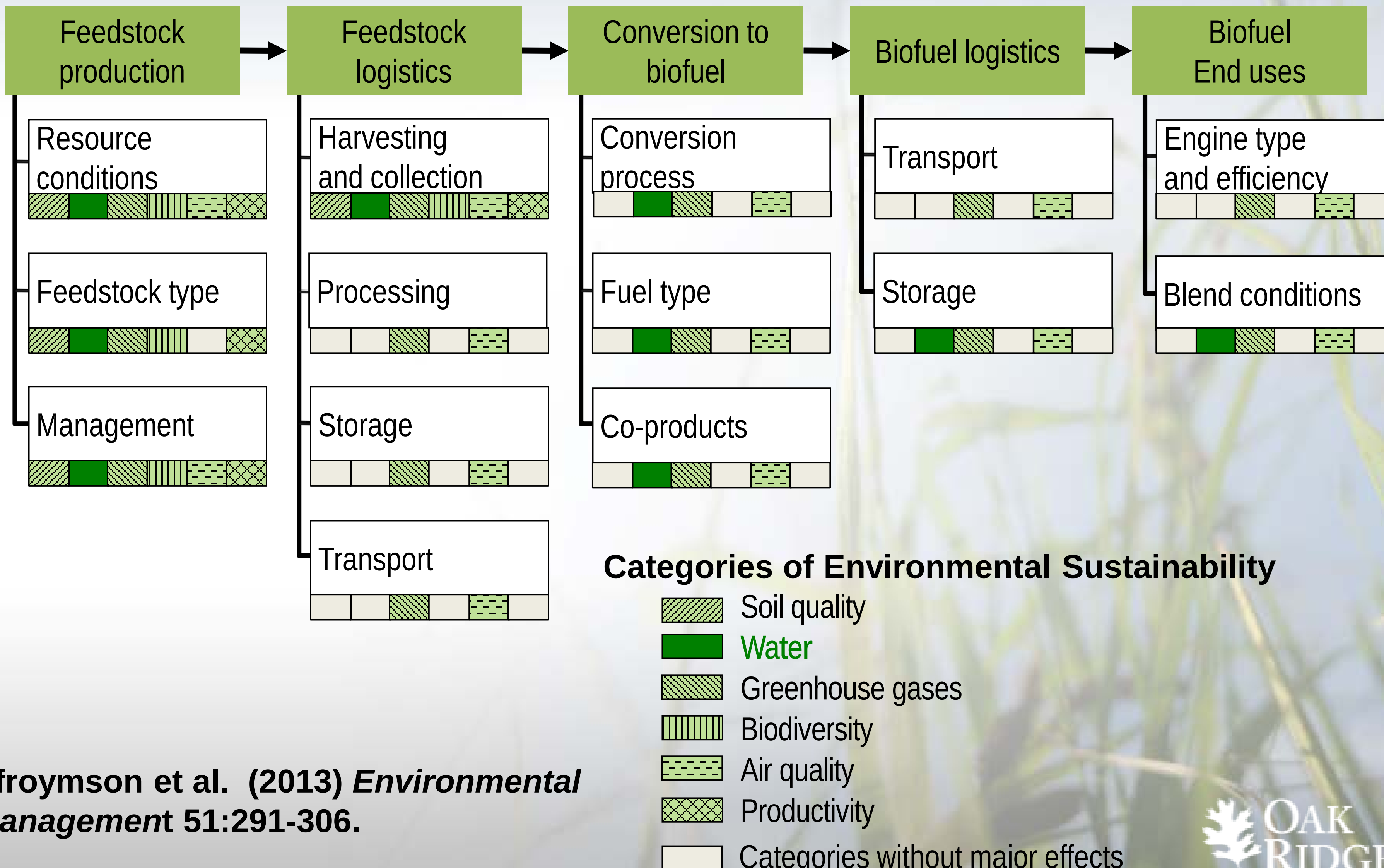

Efroymson et al. (2013) *Environmental Management* 51:291-306.

Categories of socioeconomic sustainability indicators

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.

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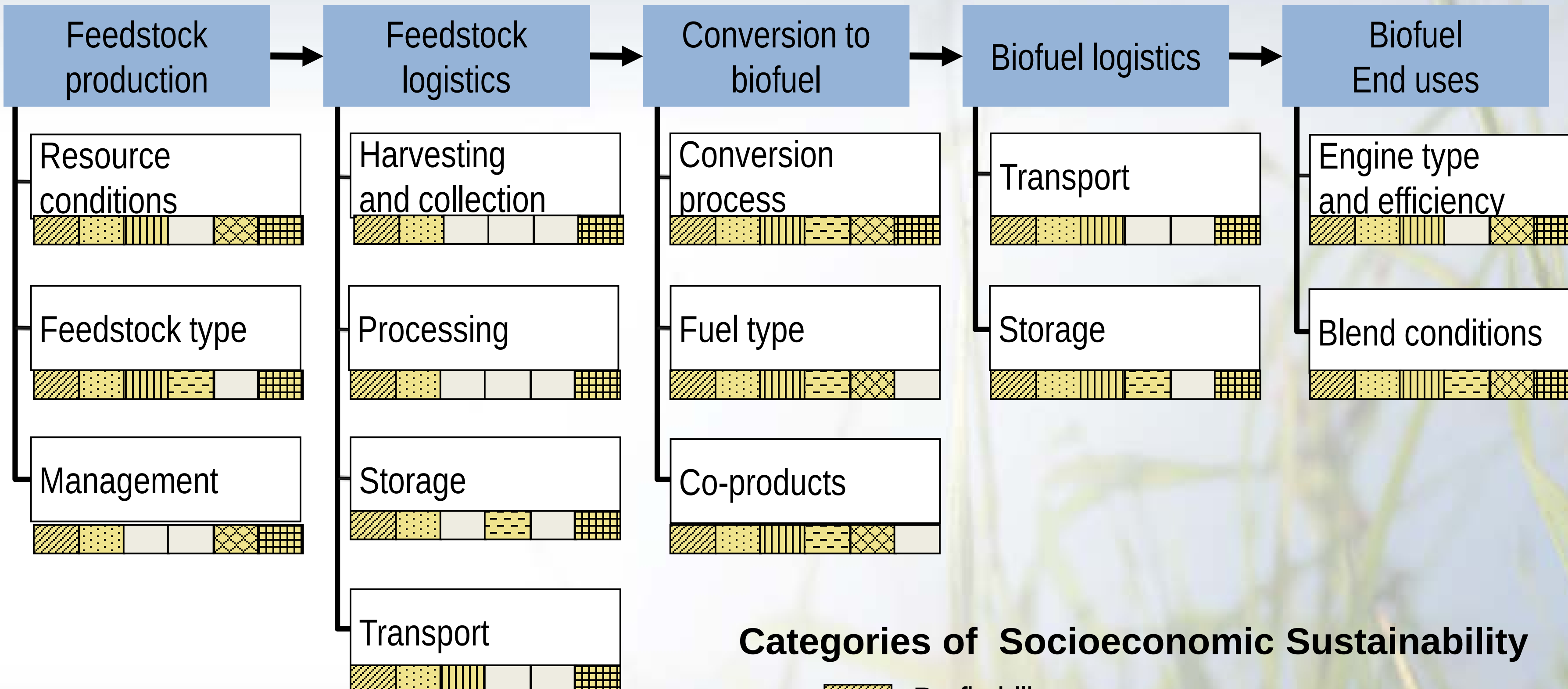
Socioeconomic sustainability indicators occur at all steps of the biofuel supply chain



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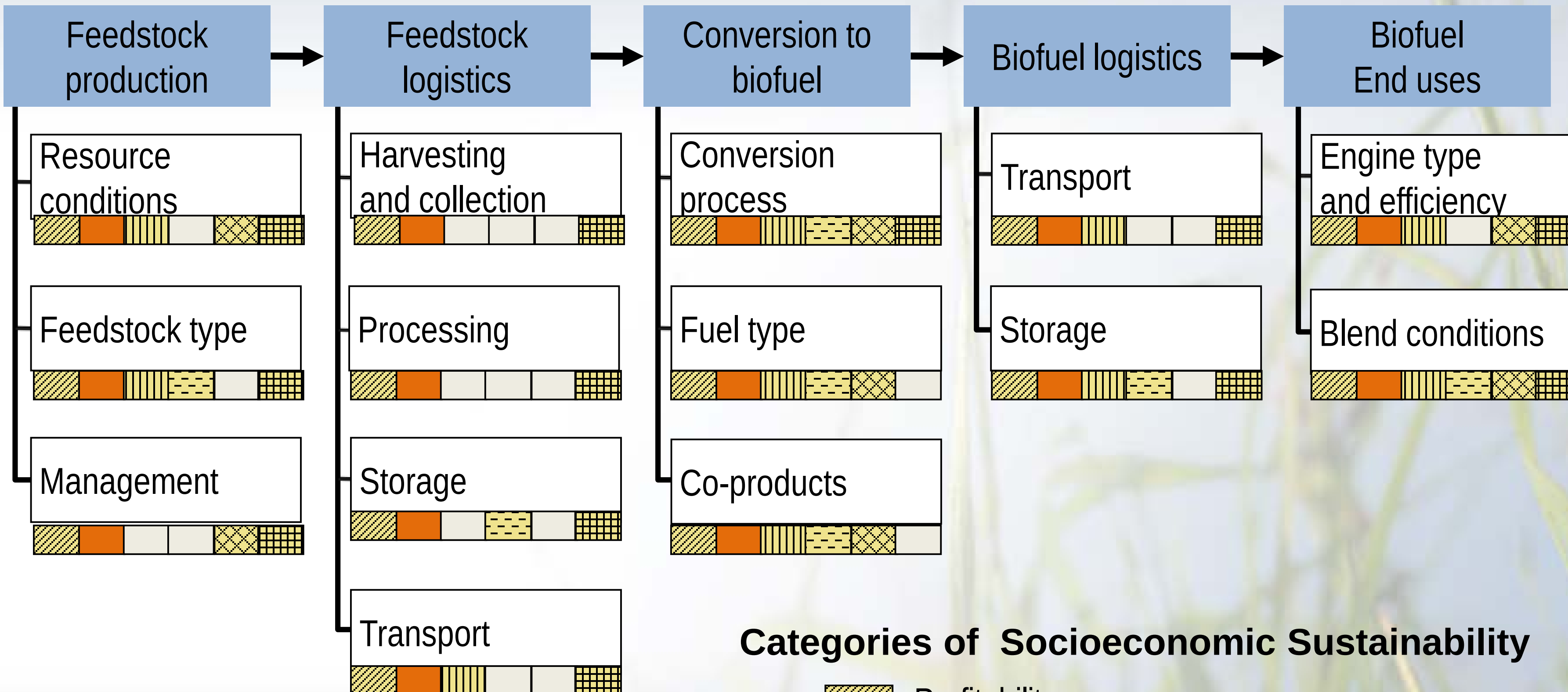

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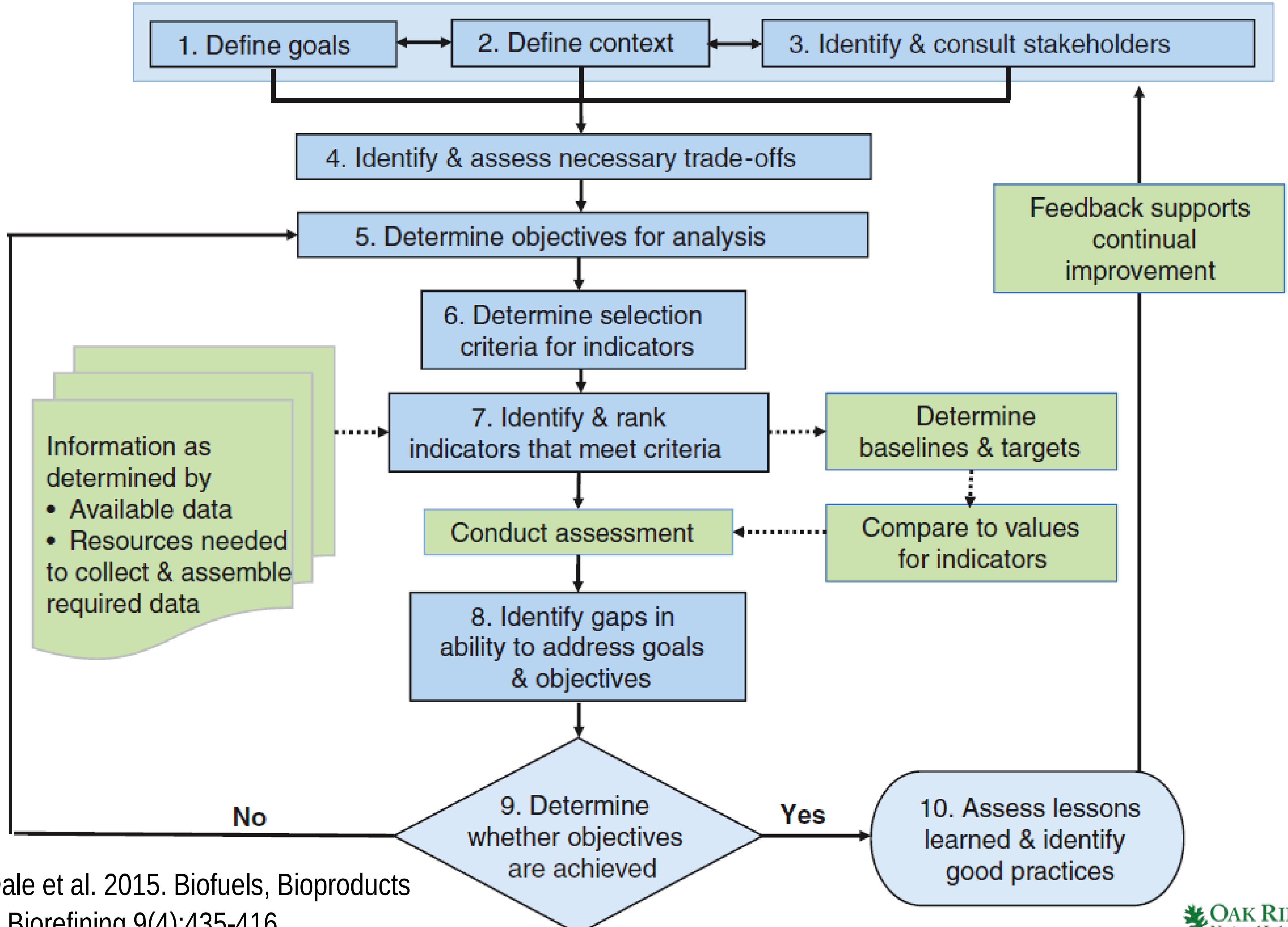
Framework for Selecting Indicators in Context



Dale et al. 2015. Biofuels, Bioproducts & Biorefining 9(4):435-416.

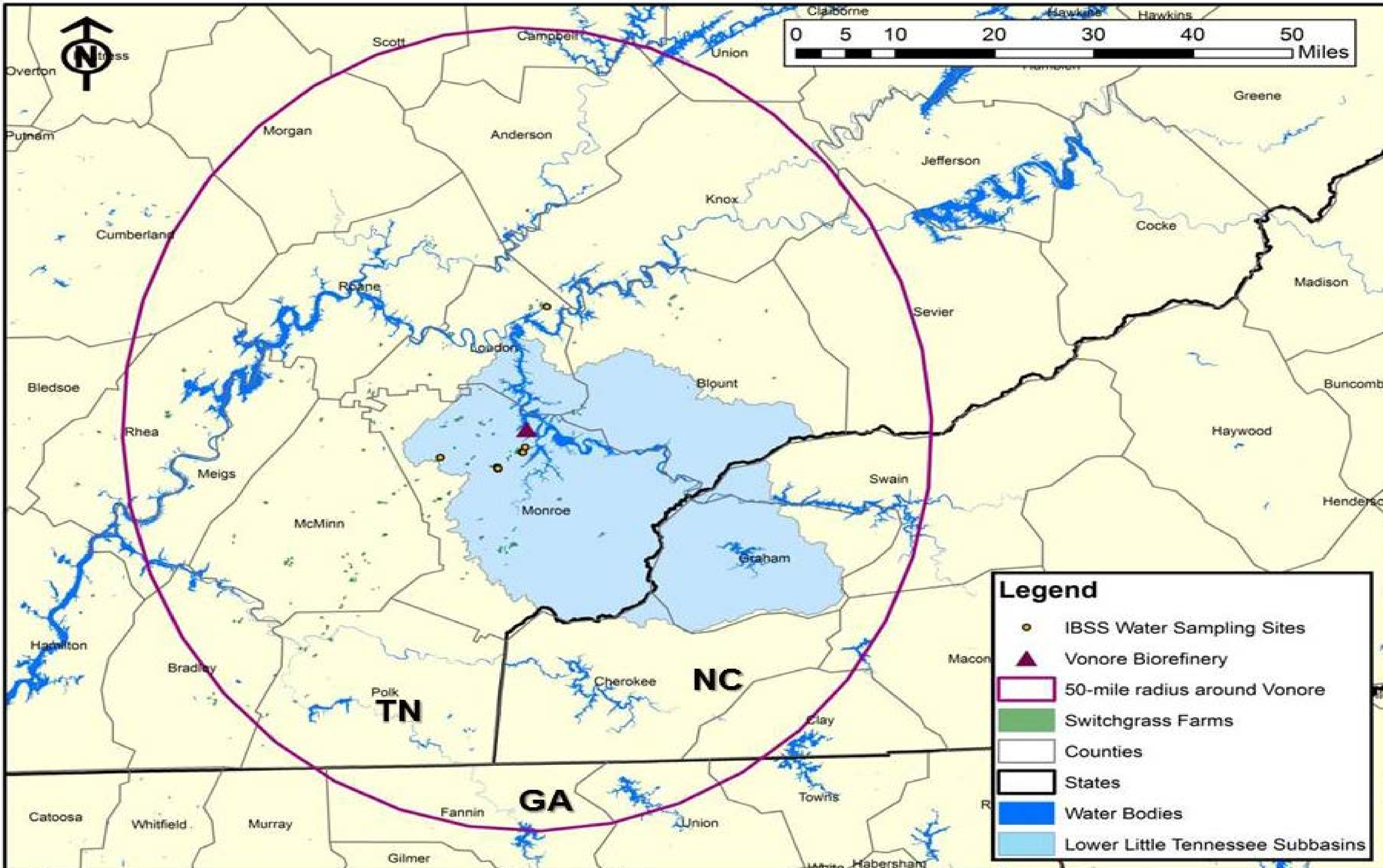
Consider indicators within system as an opportunity to <u>design landscapes</u> that add value

Dale et al. (2016) Incorporating Bioenergy into Sustainable Landscape Designs. Renewable & Sustainable Energy Reviews

What can we do better moving forward?

Modified from Dale et al. (2016) Renewable & Sustainable Energy Reviews 56:1158-1171

Identifying bioenergy opportunities for east Tennessee



Assessing multiple effects of bioenergy choices

An optimization model identifies "ideal" sustainability conditions for using switchgrass for bioenergy in east Tennessee

Spatial multiple objective optimization model

- Identifies where to locate plantings of bioenergy crops given feedstock needs for Vonore refinery
- Considering
  - Farm profit
  - Water quality constraints

USDA

IBSS
Southeastern Partnership for Integrated Biomass Supply Systems

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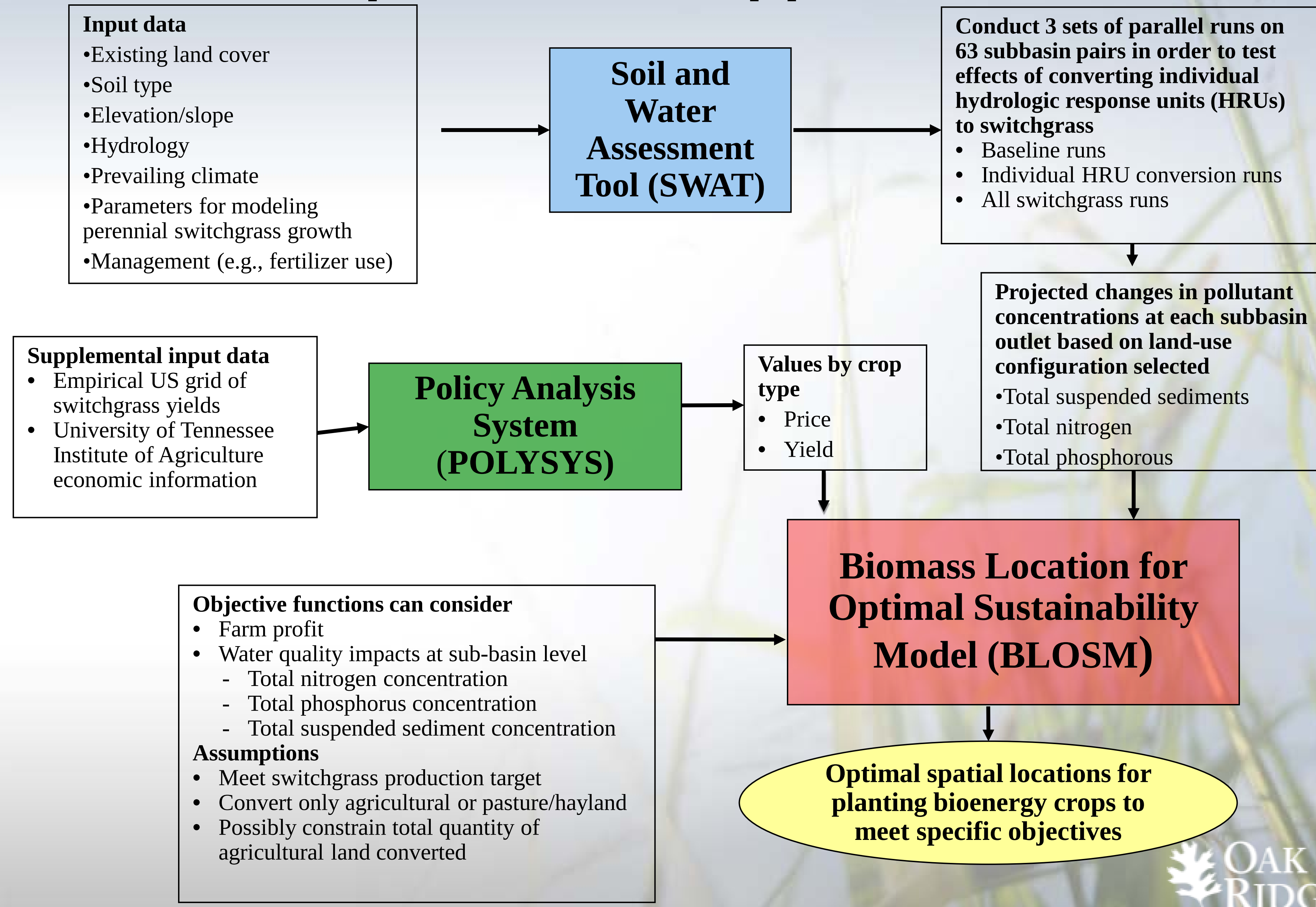
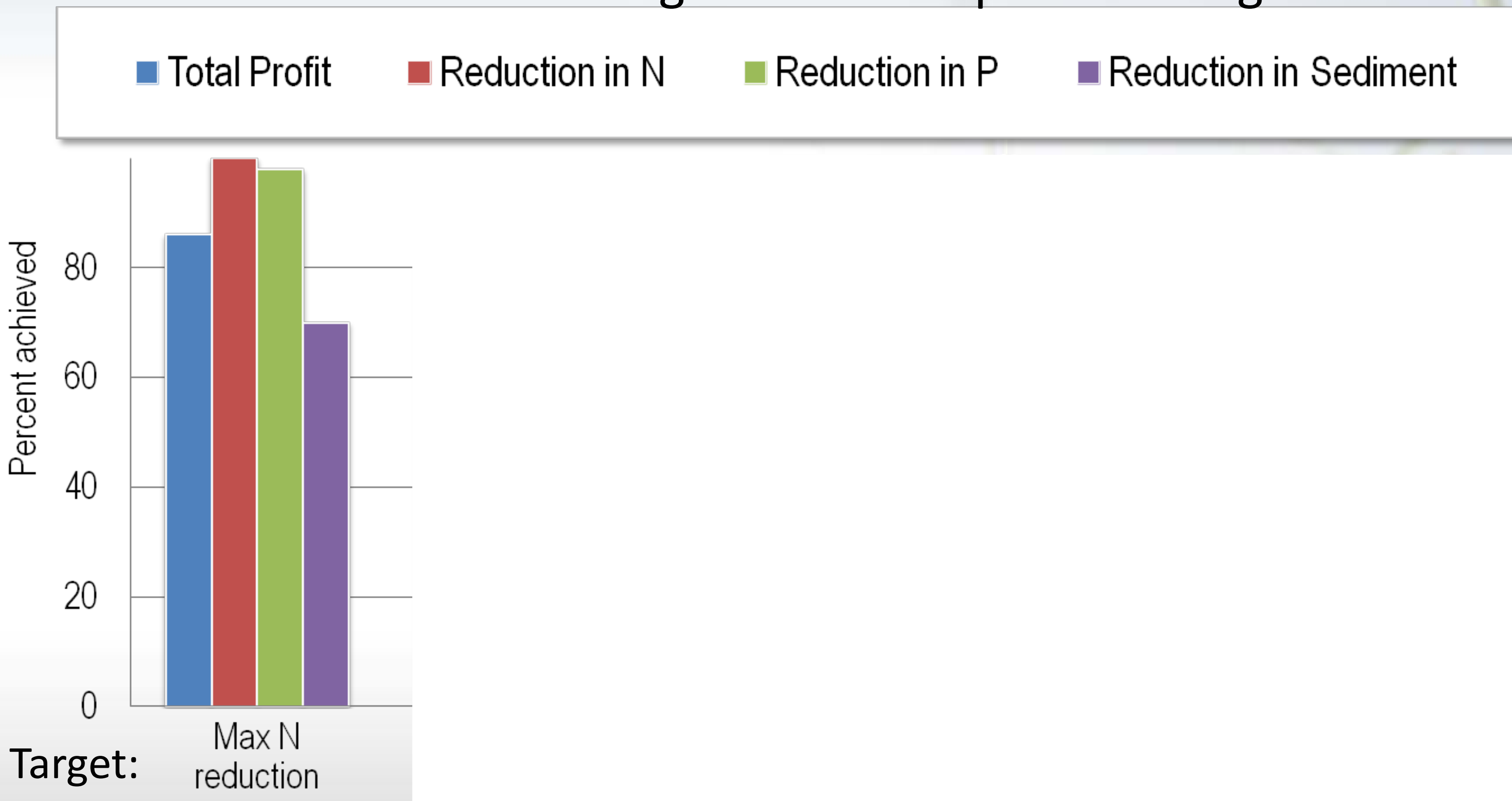
Parish et al. (2012) *Biofuels, Bioprod. Bioref*. 6:58–72.

Optimization Approach



Balancing objectives: Design of cellulosic bioenergy crop plantings may both improve water quality and increase profits while achieving a feedstock-production goal



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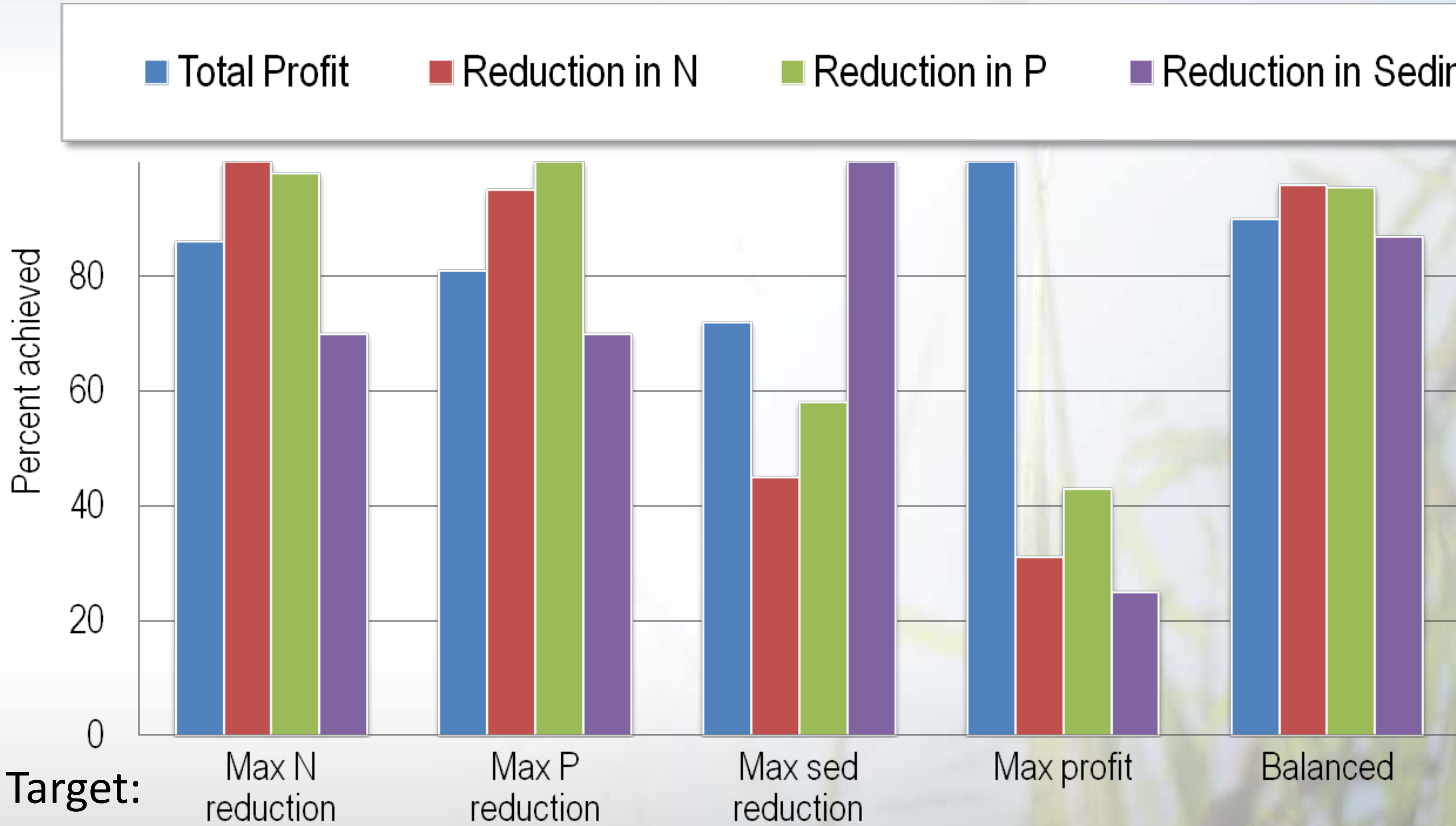

Land area recommended for switchgrass in this watershed: 1.3% of the total area (3,546 ha of 272,750 ha)

Parish et al. (2012) *Biofuels, Bioprod. Bioref*. 6:58–72

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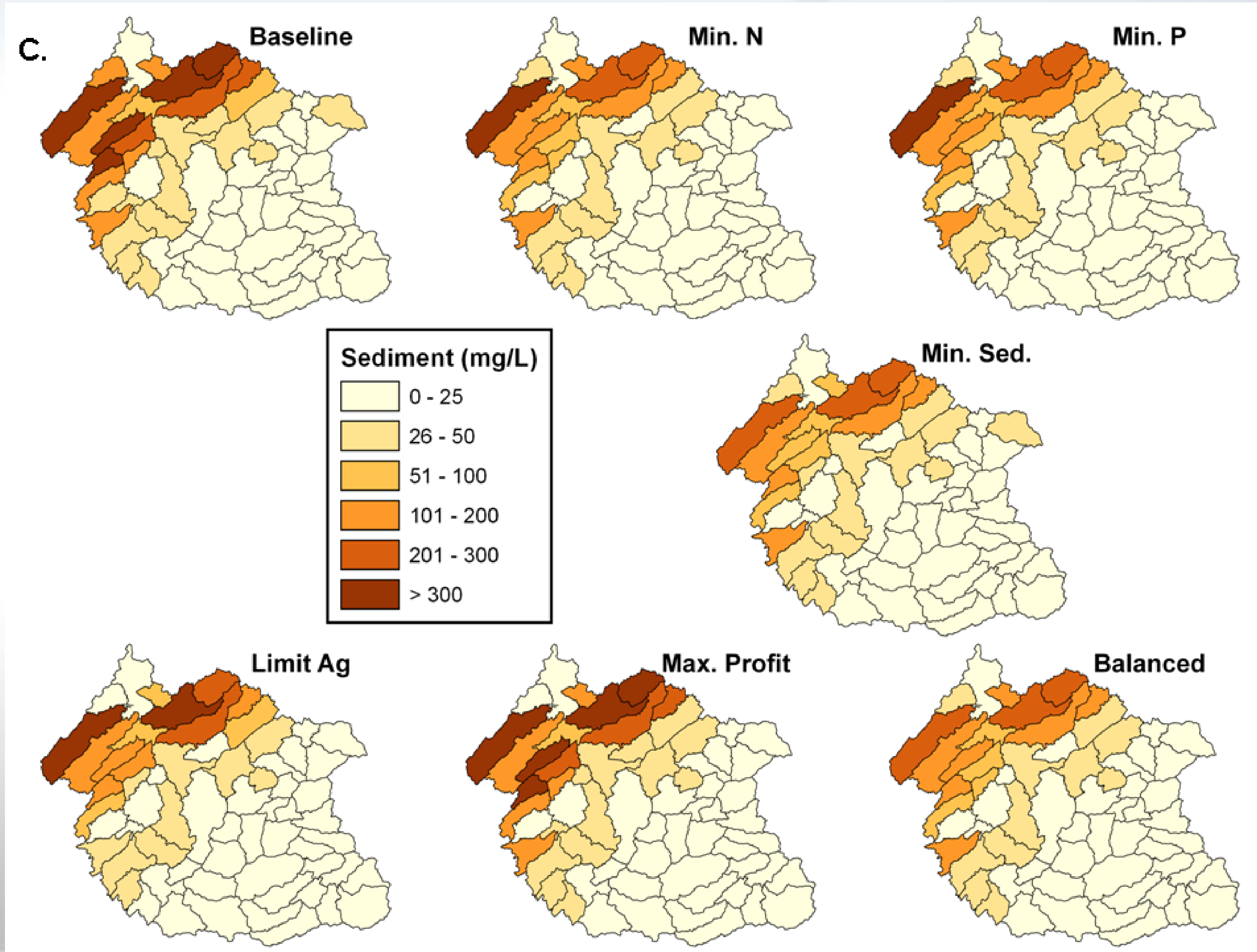
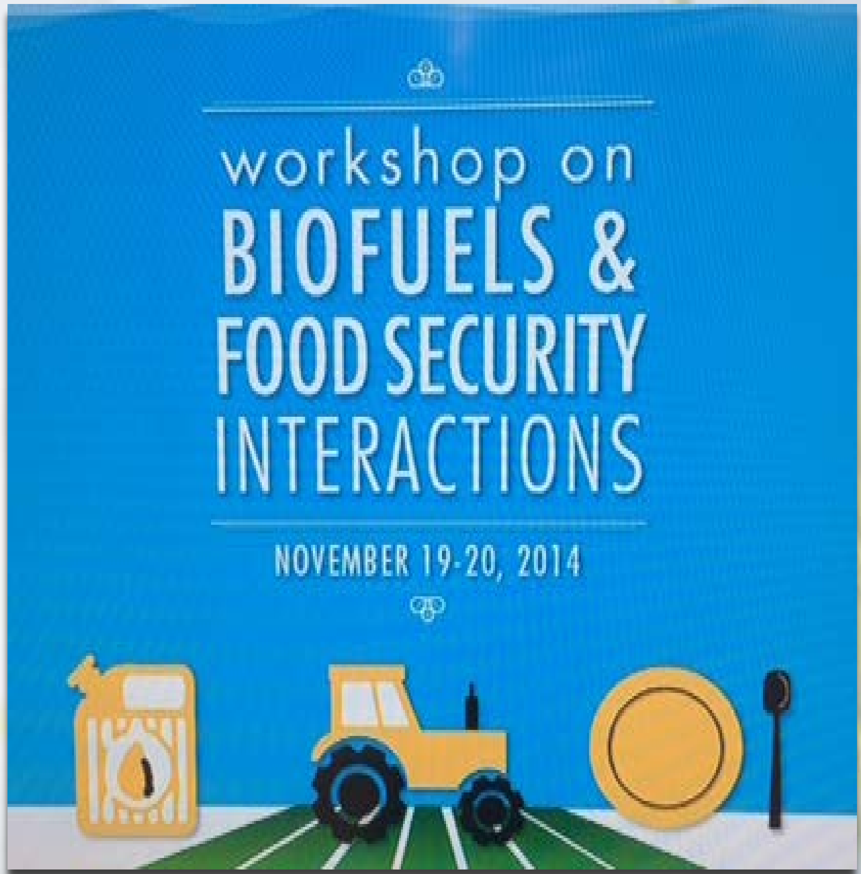
Projected sediment concentrations under 6 BLOSM scenarios



Food security

International workshop set forth key issues*

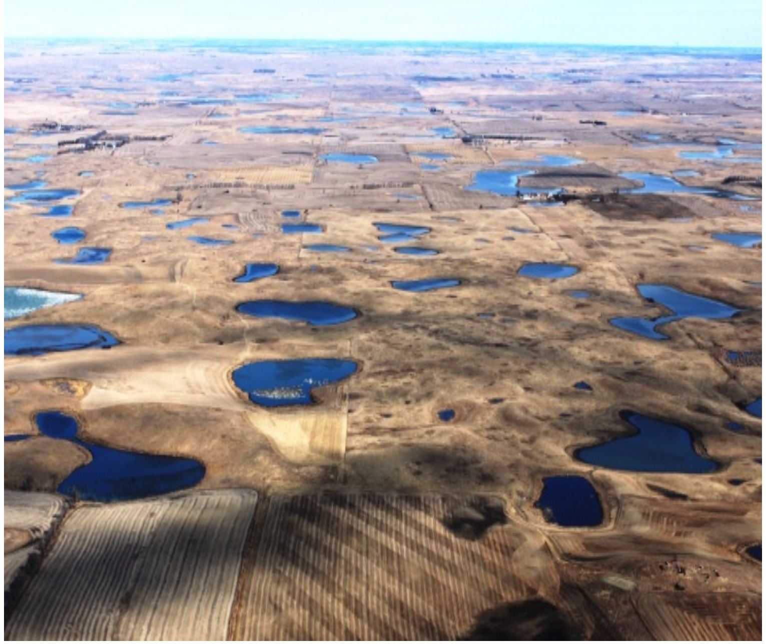
- **Identify synergies – for example**
  - Flex crops (can be used for food or fuel)
  - Infrastructure in rural areas supports food & fuel
  - Sustainability is key to both
- **Ask questions that matter**
- **Use clear terminology**



* http://www.ifpri.org/event/workshop-biofuels-and-food-security-interactions

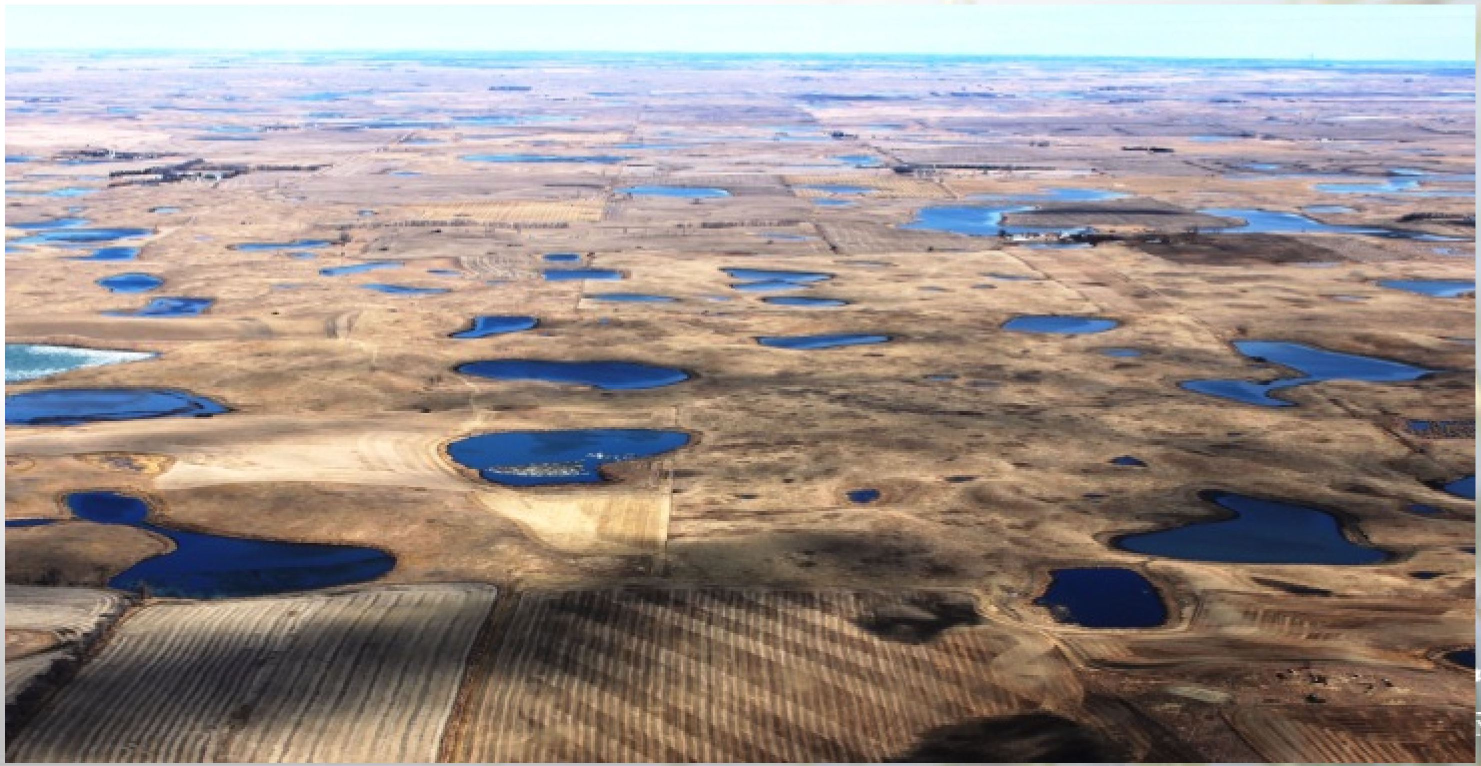
Opportunities Bioenergy Offers to more Sustainable FEW Systems

- Better management of renewable resources
  - Reducing wastes and inefficiencies
  - Existing infrastructure, know-how and technologies
  - Retaining land in agriculture or forest
- Improve environmental conditions
  - Soils & water
  - Biodiversity
  - Carbon and GHG
- Enhance food & energy security
  - Conserving fossil energy resources
  - Reducing risk of catastrophes
- Increase rates and stability of employment



Path Forward

1. Adopt systems approach
2. Involve team of investigators
3. Address appropriate scale
4. Engage stakeholders to develop collective understanding and resolution of issues



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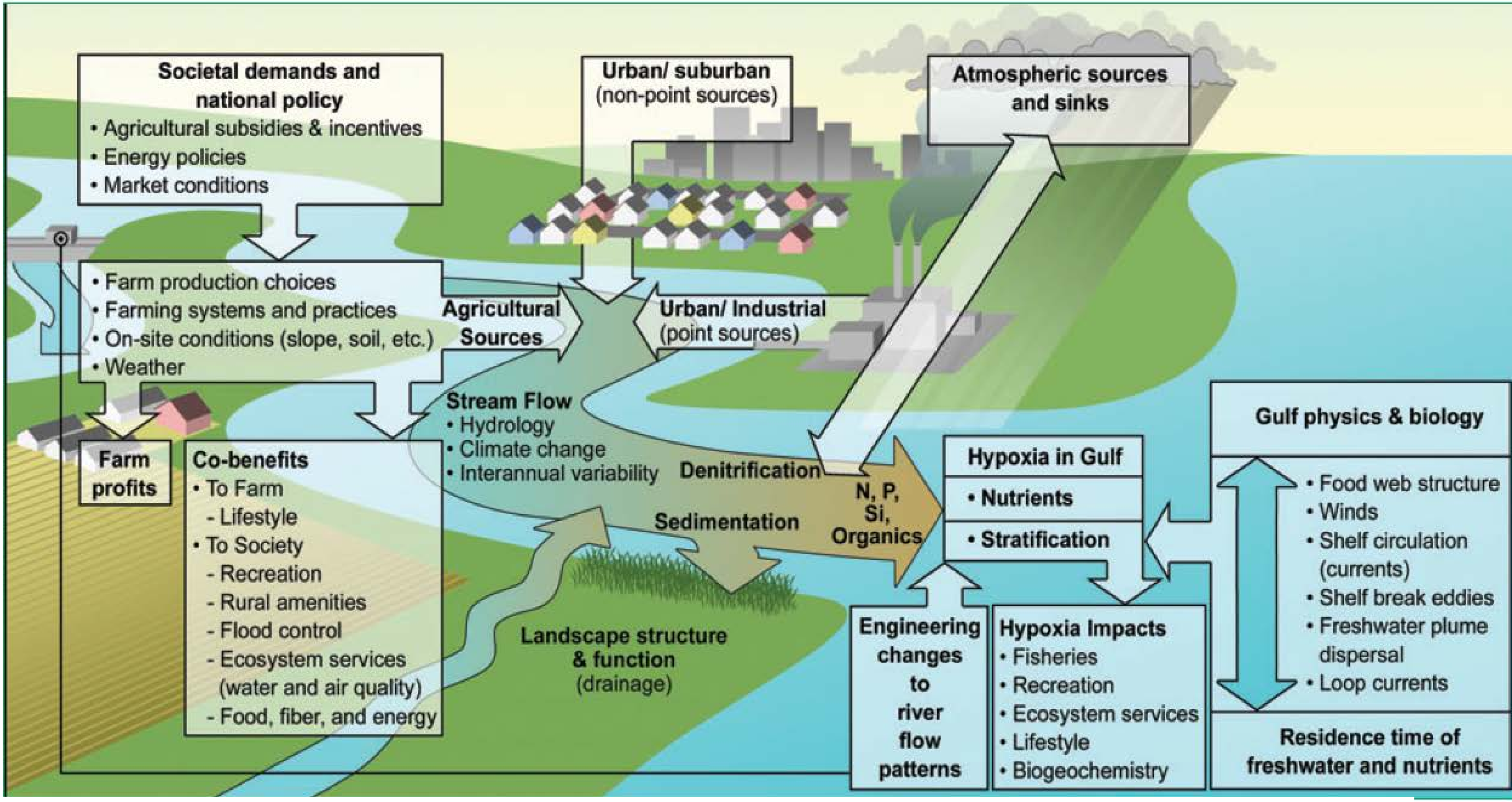
1. Systems approach



Example: systems perspective of hypoxia in Gulf of Mexico (Dale et al. 2010)

2. Team approach

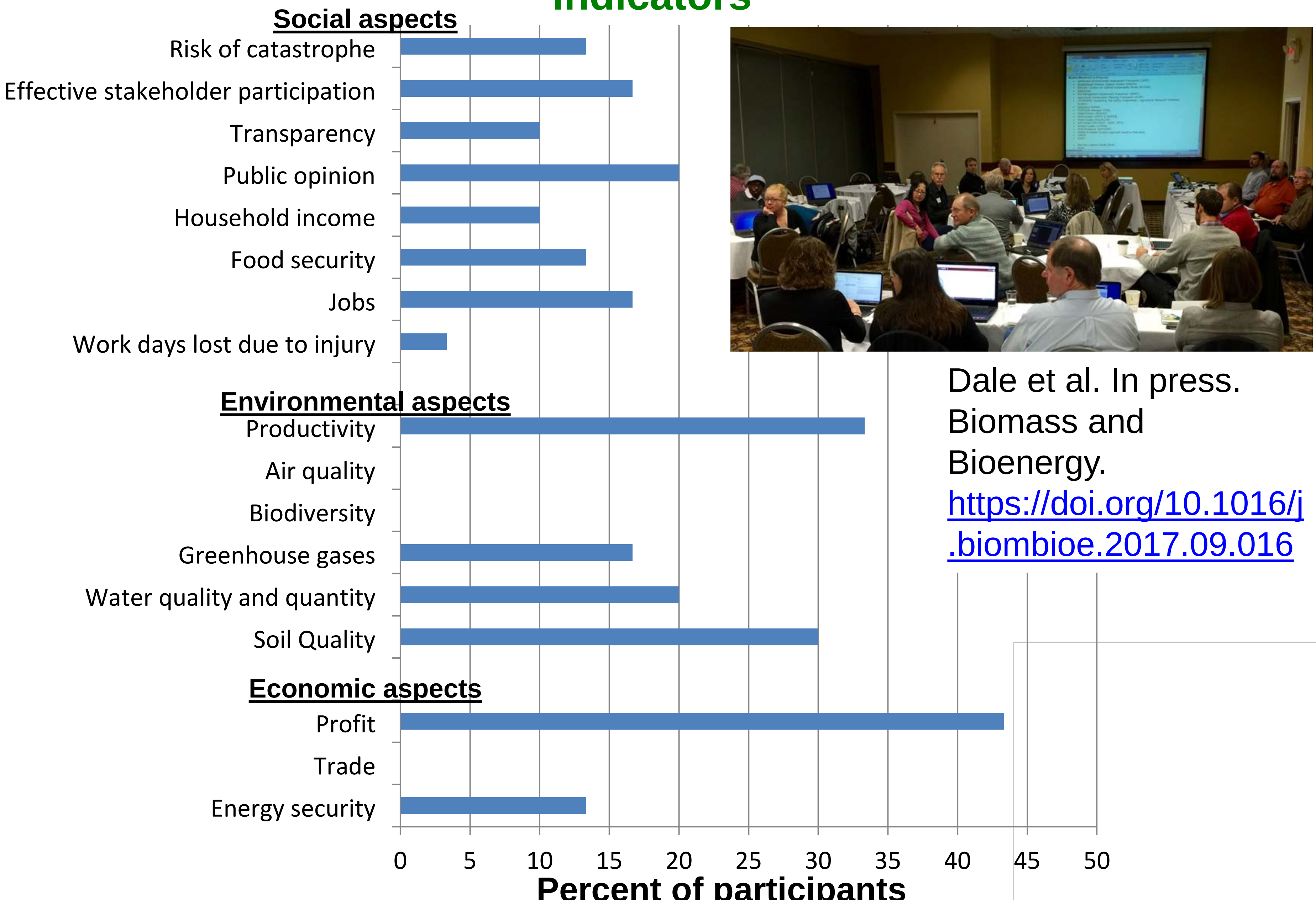
Authors and Members of the Hypoxia Advisory Committee of the Science Advisory Board (SAB) of the Environmental Protection Agency (EPA)			
Virginia Dale	David Wangsness	Mark David	Hans Paerl
Catherine L. Kling	Thomas Bianchi	Denis Gilbert	Kenneth Reckhow
Judith L. Meyer	Alan Blumberg	Robert W. Howarth	Andrew N. Sharpley
James Sanders	Walter Boynton	Richard Lowrance	Thomas W. Simpson
Holly Stallworth	Daniel J. Conley	Kyle Mankin	Clifford S. Snyder
Thomas Armitage	William Crumpton	James Opaluch	Donelson Wright

3. Address appropriate scale of issue

4. Engage stakeholders to develop collective understanding and resolution of issues

Intense discussion during Bioenergy Study Tour:
http://web.ornl.gov/sci/ees/cbes/workshop.shtml

Stakeholder consensus derived by having participants prioritize indicators



Dale et al. In press. Biomass and Bioenergy. https://doi.org/10.1016/j.biombioe.2017.09.016

A poem that summarizes the challenges in these difficult times – a haiku by John Cooper Clark

“To convey one’s mood
in seventeen syllables
is very diffic”

*

Thank you!

CBES

Center for BioEnergy Sustainability

http://www.ornl.gov/sci/ees/cbes/

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