Food Energy Water Nexus: Approaches and Tools

Virginia H. Dale (dalevh@ornl.gov)
Keith Kline (klinekl@orl.gov)

Baltimore, MD
October 7, 2015

Acknowledgements: DOE BETO - Kristen Johnson & Alison Goss-Eng; LM Baskaran, MR Davis, B. Dale, B Davison, ME Downing, LM Eaton, RA Efroymson, C Garten, RL Graham, NA Griffiths, M Hilliard, H Jager, K Kline, PN Leiby, M Langholtz, A McBride, R Middleton, PJ Mulholland, GA Oladosu, ES Parish, RD Perlack, P Schweizer, A Sorokine, J Storey, LL Wright

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

Sustainability Research

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

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

CBES
Center for BioEnergy Sustainability

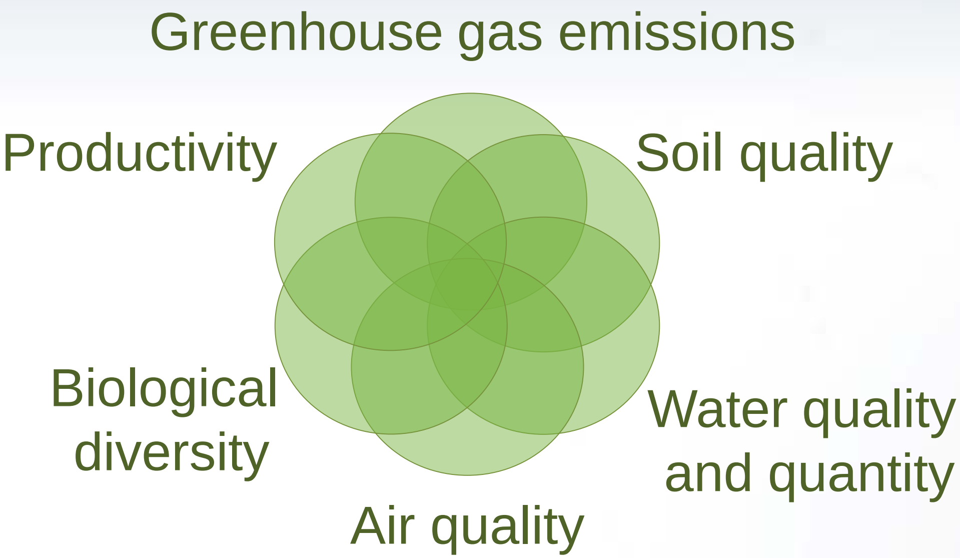
Oak Ridge National Laboratory

U.S. DEPARTMENT OF ENERGY

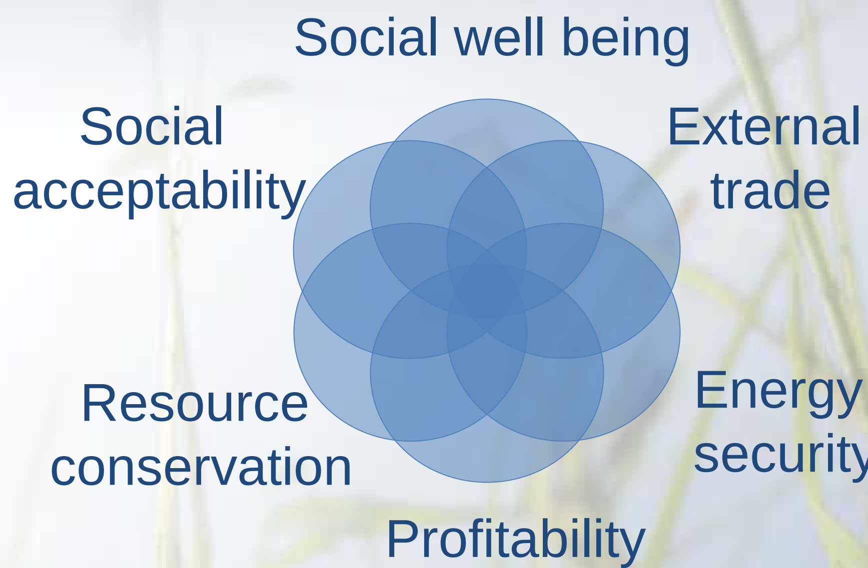
Focusing on sustainability brings together disparate perspectives.

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.

OAK RIDGE National Laboratory

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 ($PM_{2.5}$)	µg/m^3
	18. Total particulate matter less than 10µm diameter (PM_{10})	µg/m^3
Productivity	19. Aboveground net primary productivity (ANPP) / Yield	gC/m^2/year

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

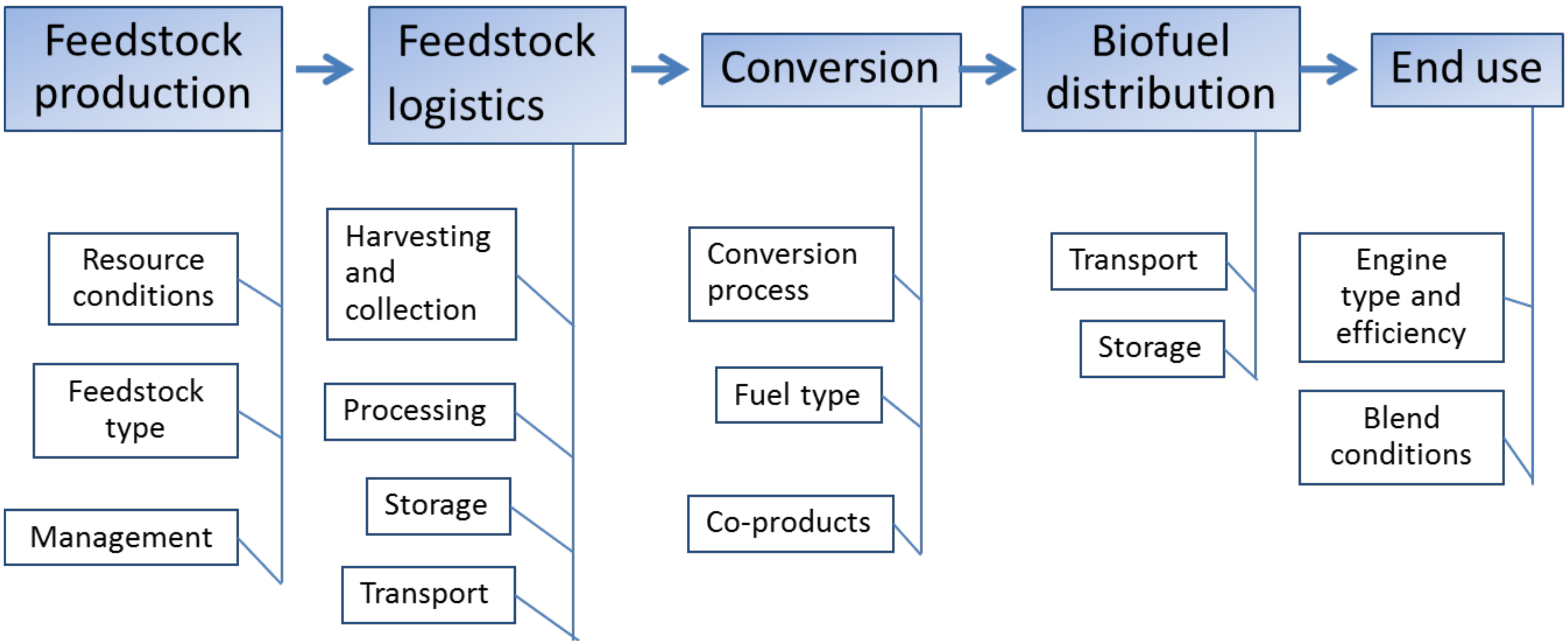
Categories of environmental sustainability indicators

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

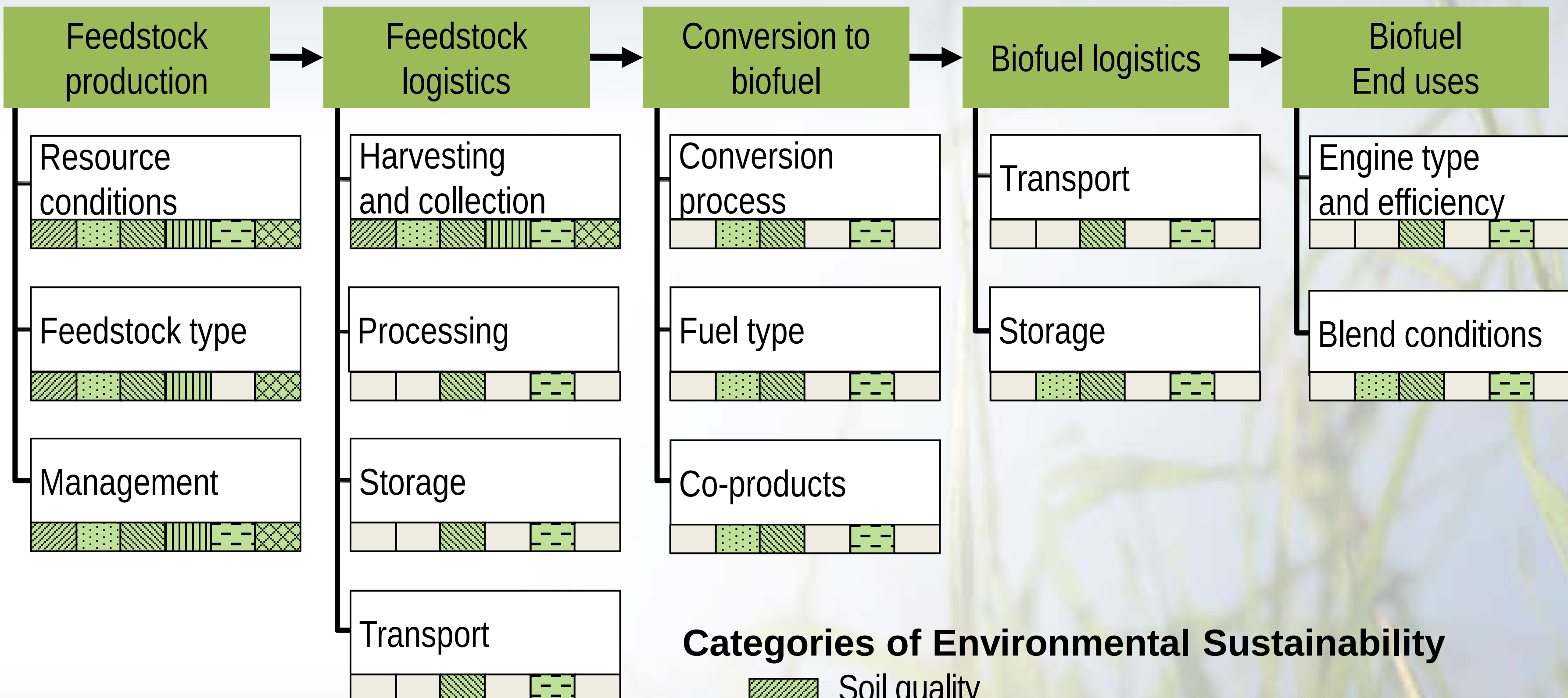
Environment	Indicator	Units
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)	kgC_{eq}/GJ
Biodiversity	13. Presence of taxa of special concern	Presence
	14. Habitat area of taxa of special concern	ha
Air quality	15. Tropospheric ozone	ppb
	16. Carbon monoxide	ppm
	17. Total particulate matter 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

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



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



Categories of Environmental Sustainability

- Soil quality
- Water
- Greenhouse gases
- Biodiversity
- Air quality
- Productivity
- Categories without major effects

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

Oak Ridge National Laboratory

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.

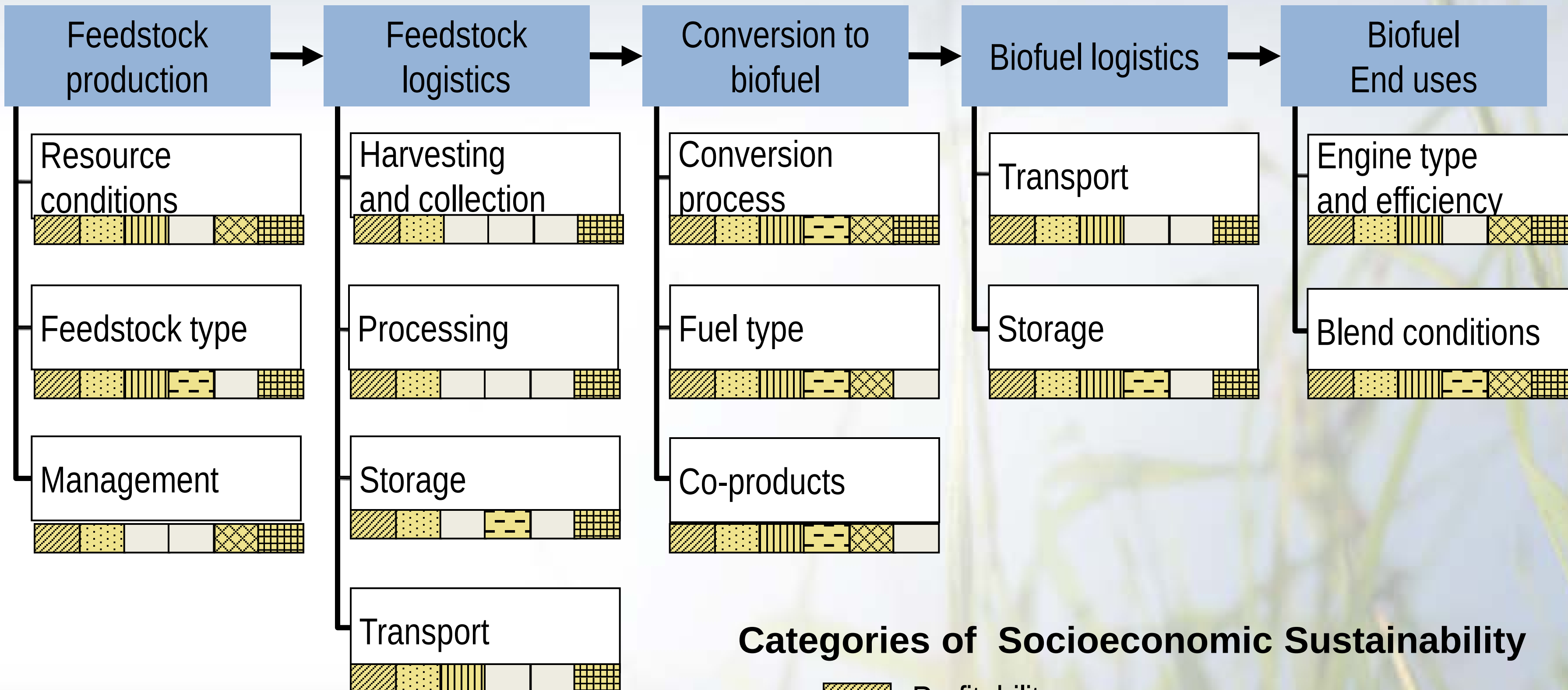
Categories of socioeconomic sustainability indicators

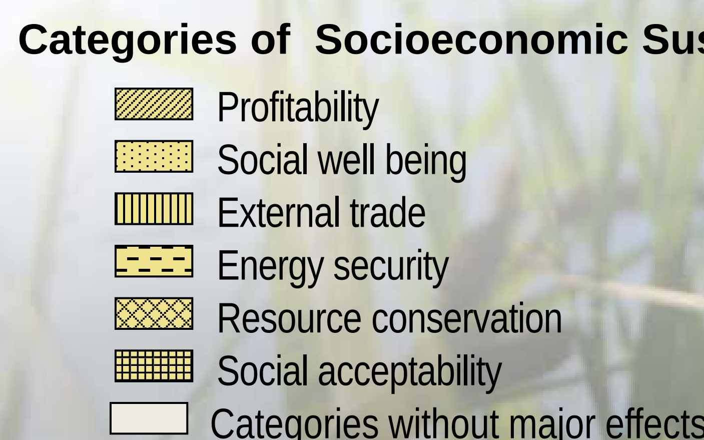
Category	Indicator	Units
Social well-being	Employment	Number of full time equivalent (FTE) jobs
	Household income	Dollars per day
	Work days lost due to injury	Average number of work days lost per worker per year
	Food security	**Percent change in food price volatility**
Energy security	Energy security 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.

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

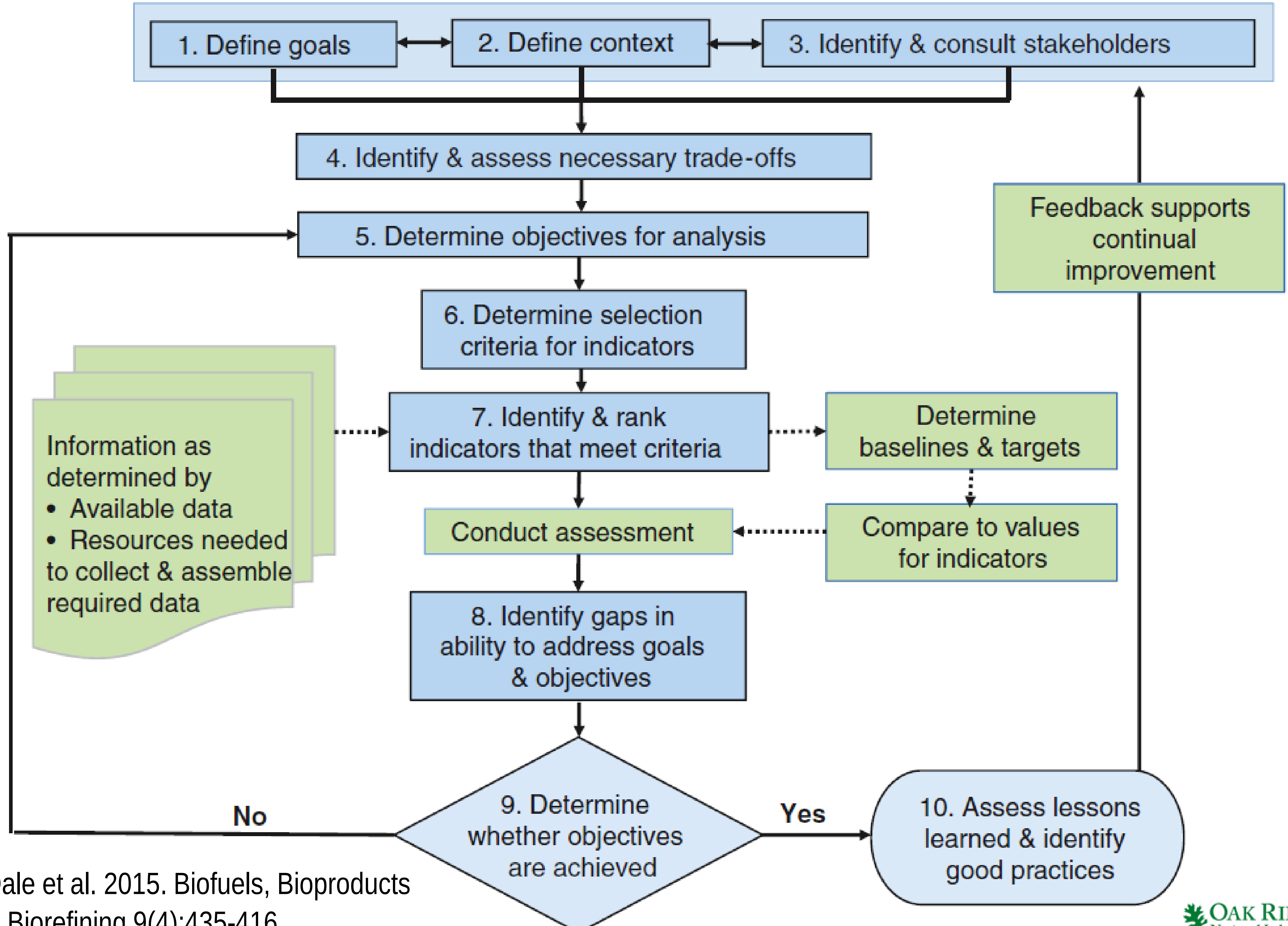




Dale et al. (2013) *Ecological Indicators* 26: 87-102.

OAK RIDGE National Laboratory

Framework for Selecting Indicators in Context



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

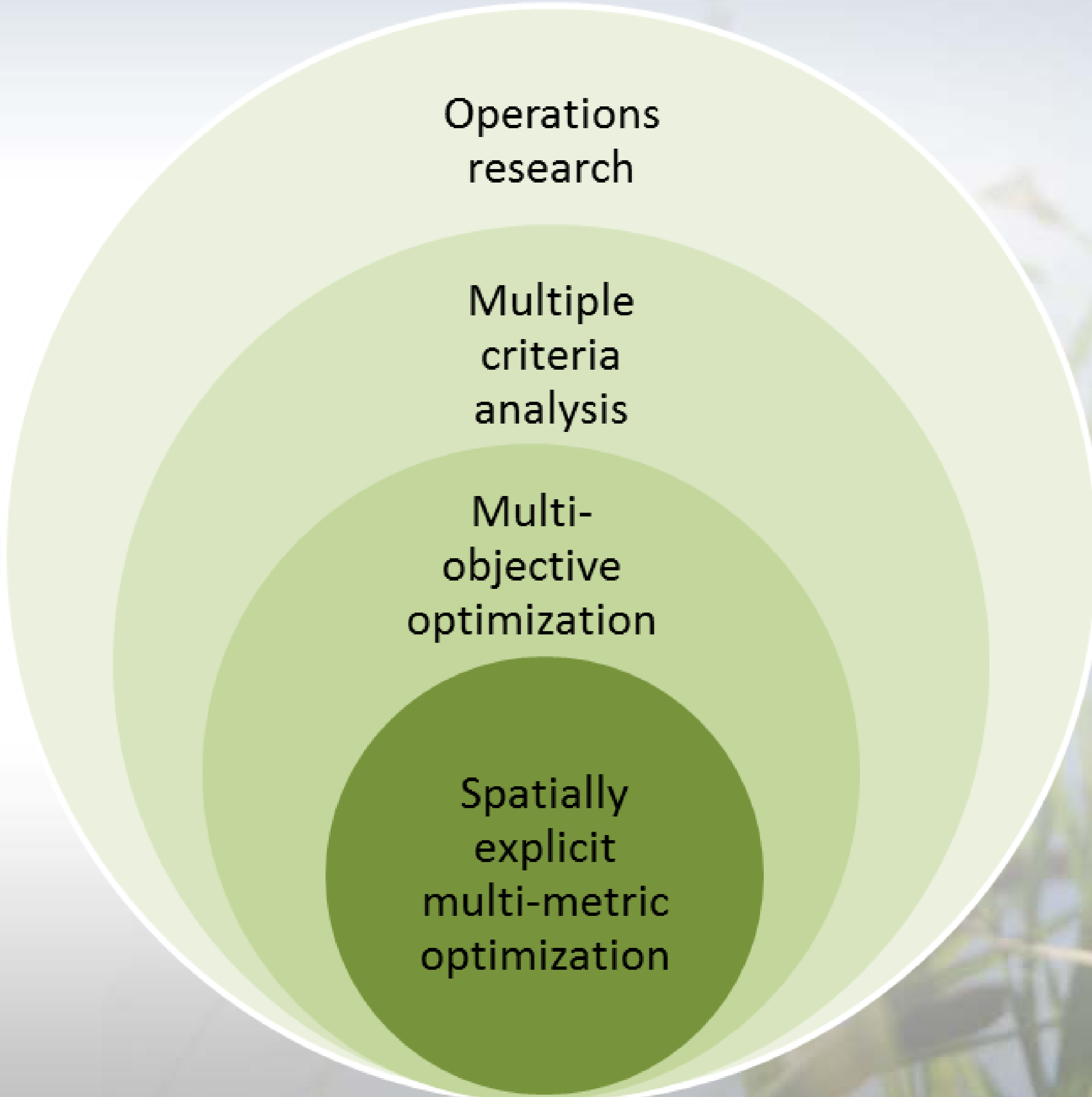
OAK RIDGE National Laboratory

Consider indicators within system as an opportunity to design landscapes that add value

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

Oak Ridge National Laboratory

Tools for Analysis



Assessing multiple effects of bioenergy choices

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

Spatial optimization model

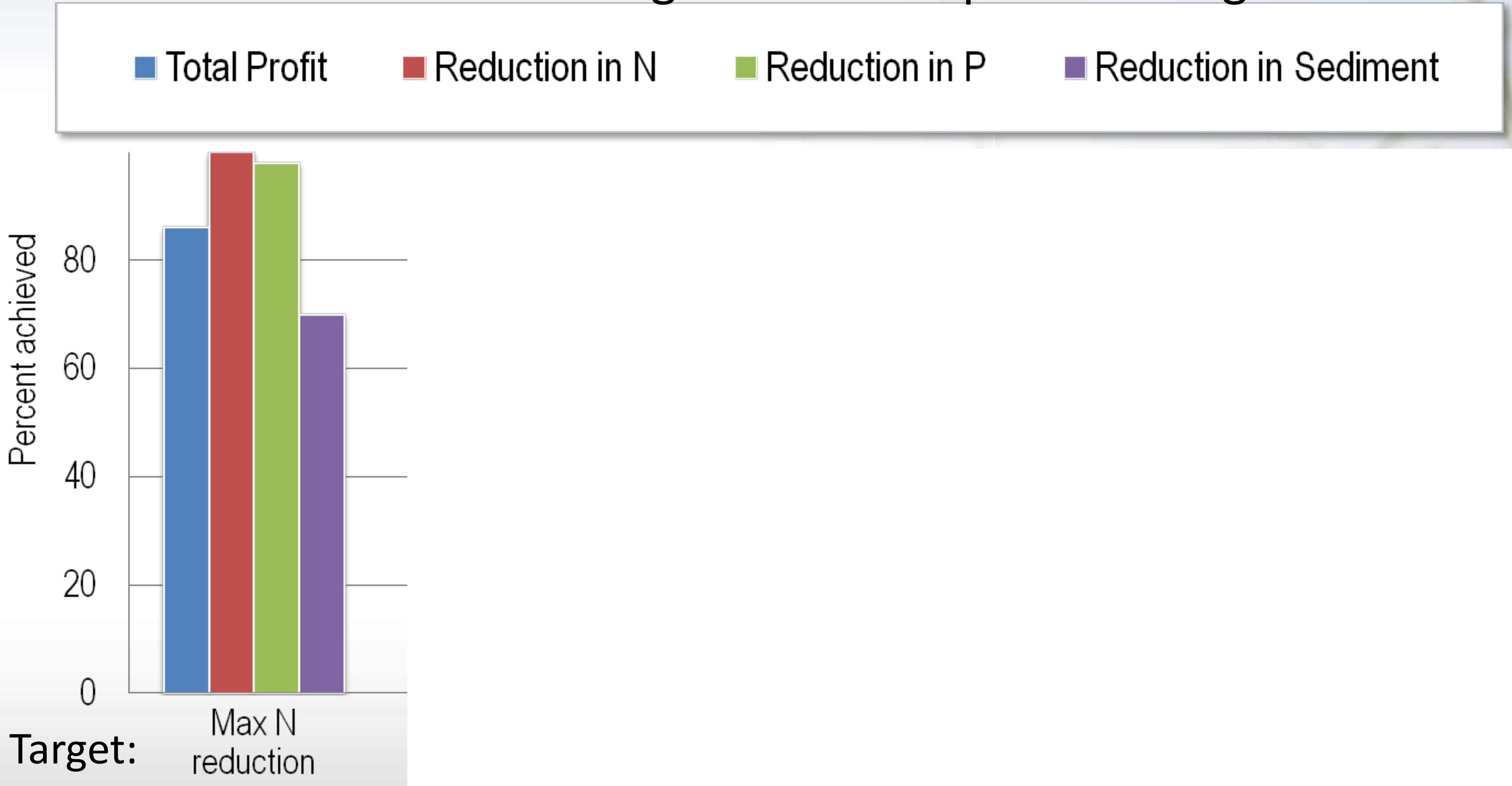
- Identifies where to locate plantings of bioenergy crops given feedstock needs for Vonore refinery
- Considering
  - Farm profit
  - Water quality constraints

Southeastern Partnership for Integrated Biomass Supply Systems

Oak Ridge National Laboratory

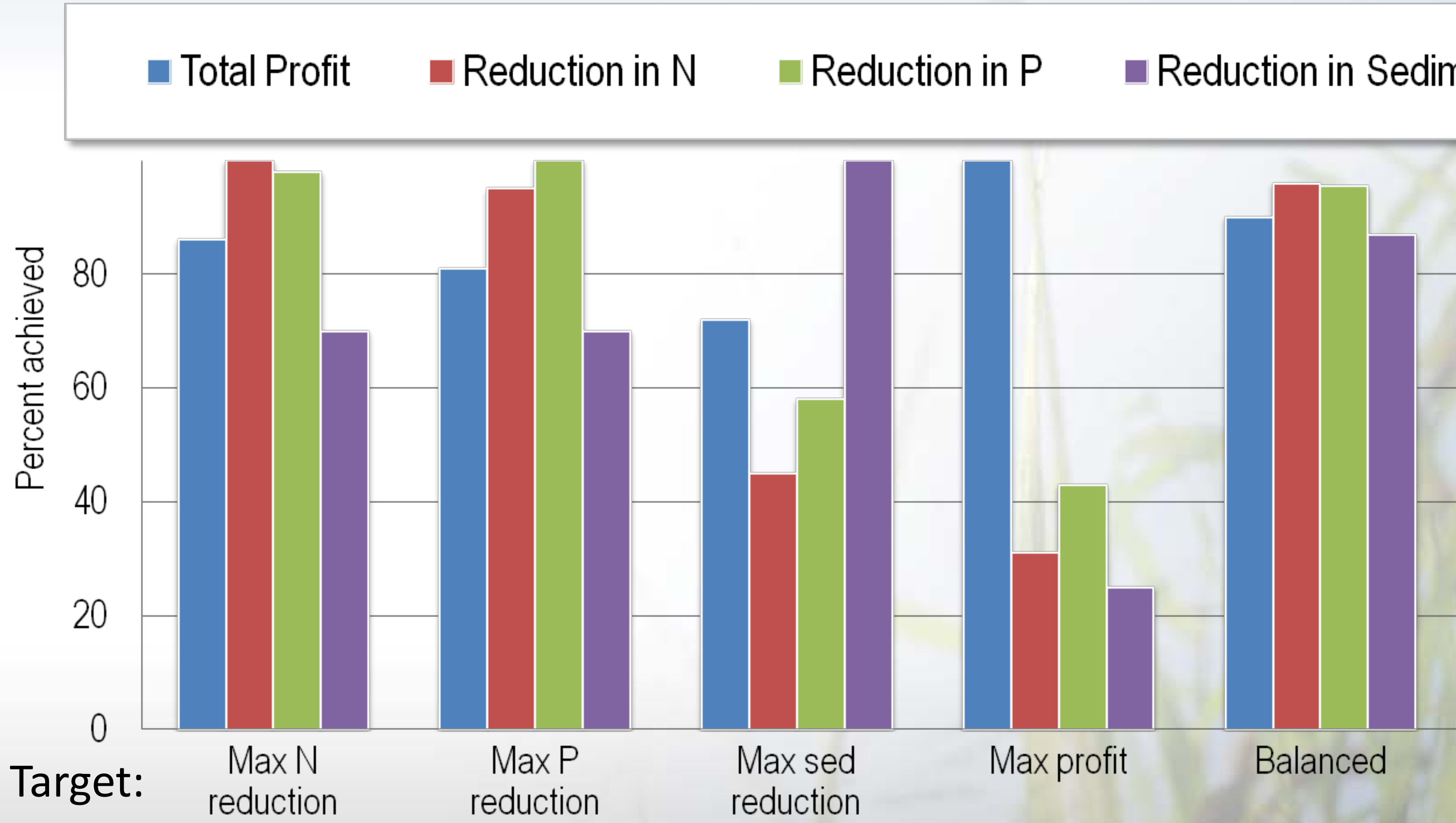
Parish et al. (2012) *Biofuels, Bioprod. Bioref*. 6:58–72.

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



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

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



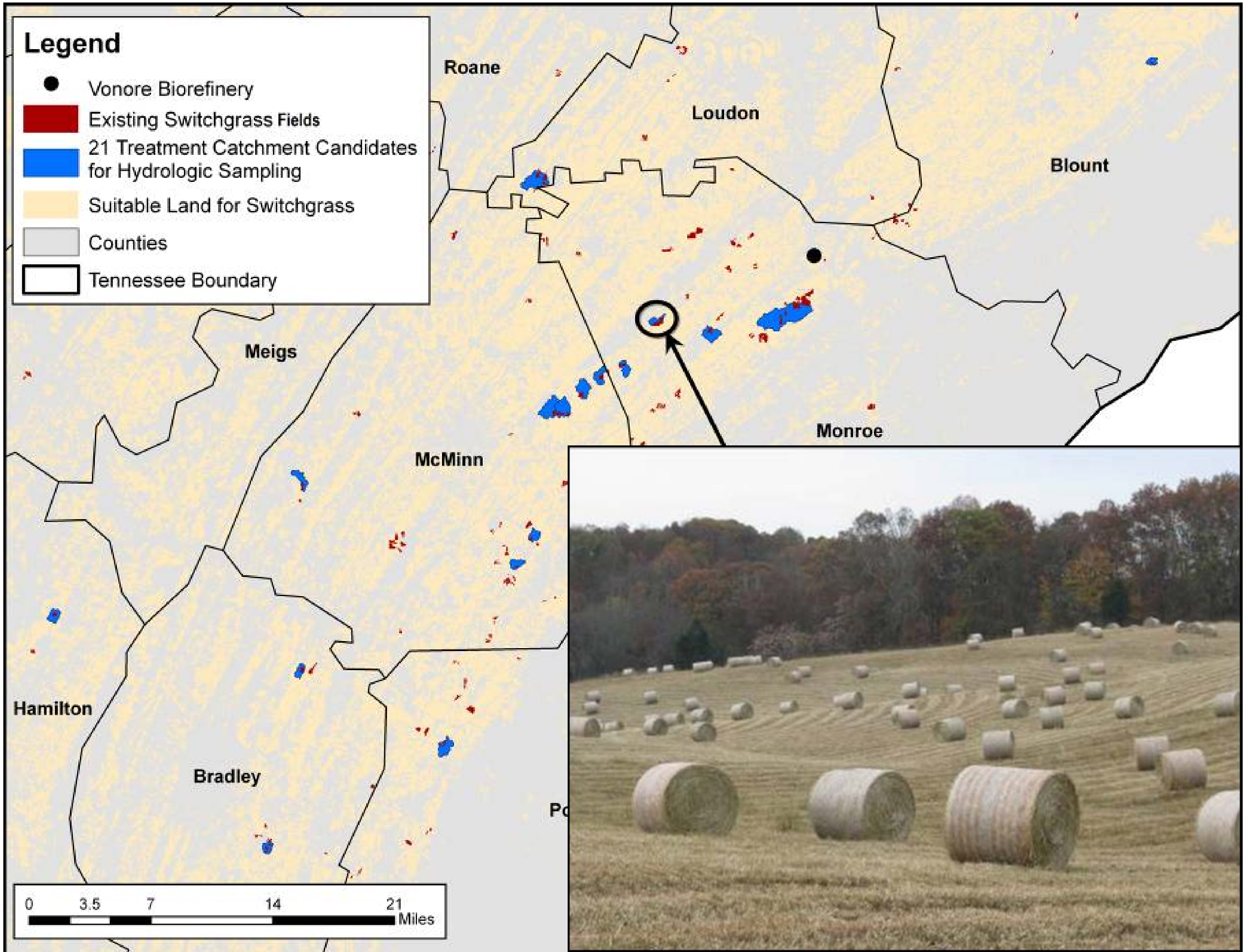
Land area recommended for switchgrass in this watershed: 1.3% of the total area (3,546 ha of 272,750 ha)

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

Oak Ridge National Laboratory

Using Multi-Attribute Decision Support System (MADSS): to compare sustainability of 3 scenarios in east Tennessee

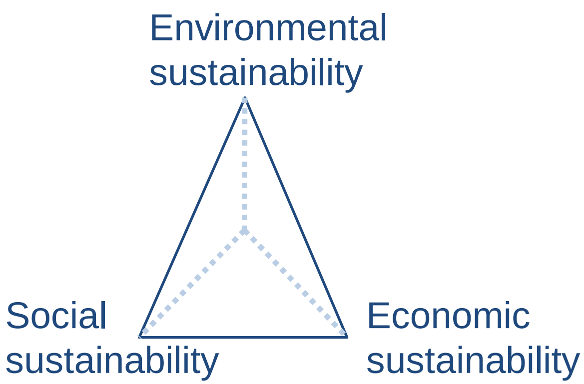
Leverages data from SE Partnership for Integrated Biomass Supply Systems (IBSS)



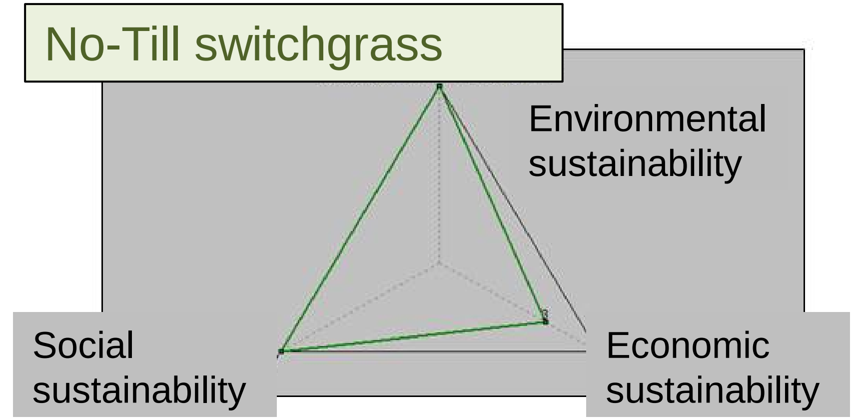
Case Study of MADSS Applied to East TN:

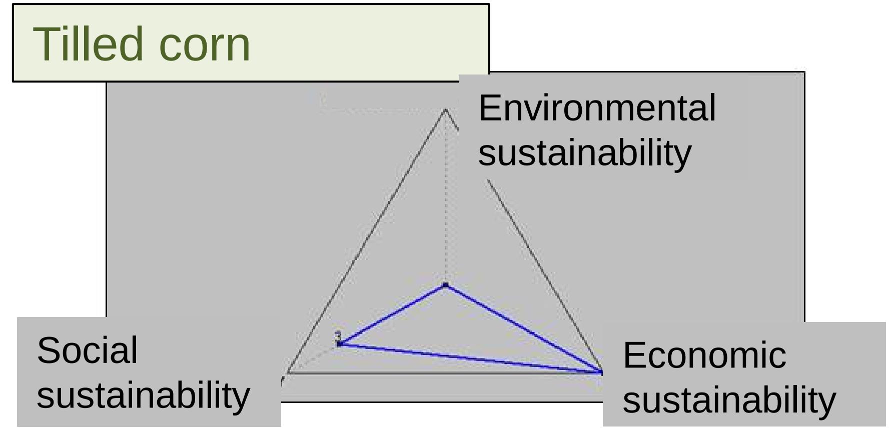
Determines relative contributions of three "pillars" to overall sustainability

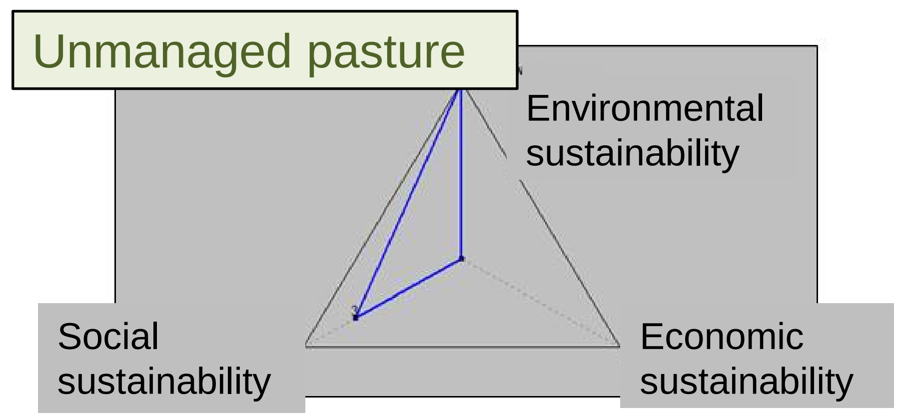
Key to chart



[Parish et al. (In press) Assessing multimetric aspects of sustainability. Ecosphere]



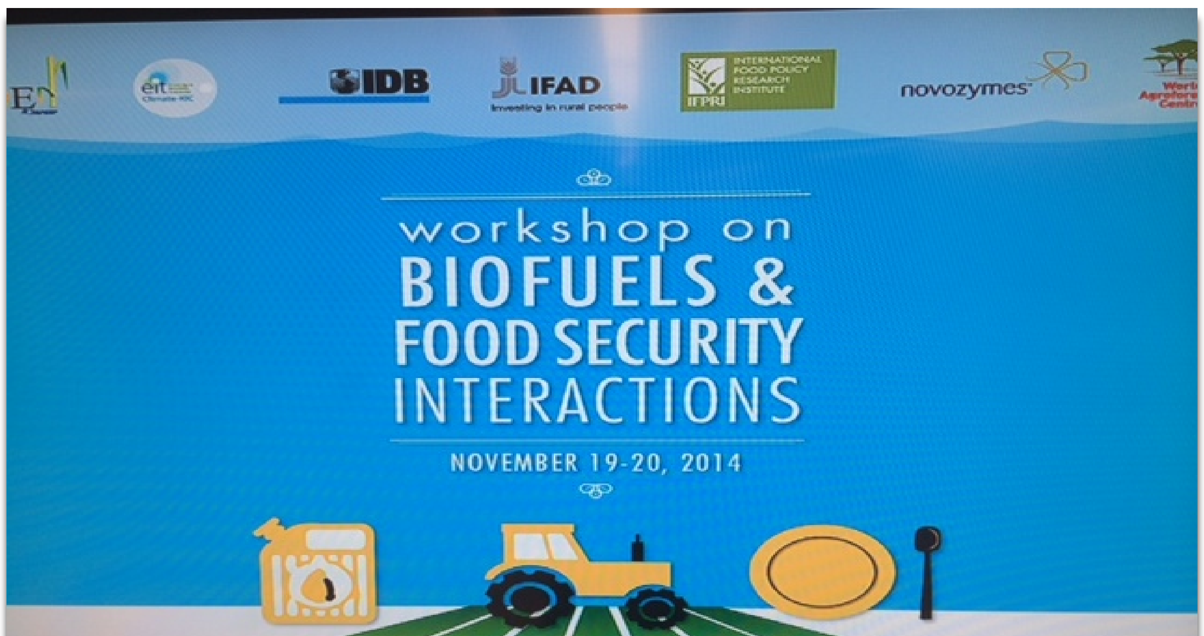




Food security issues

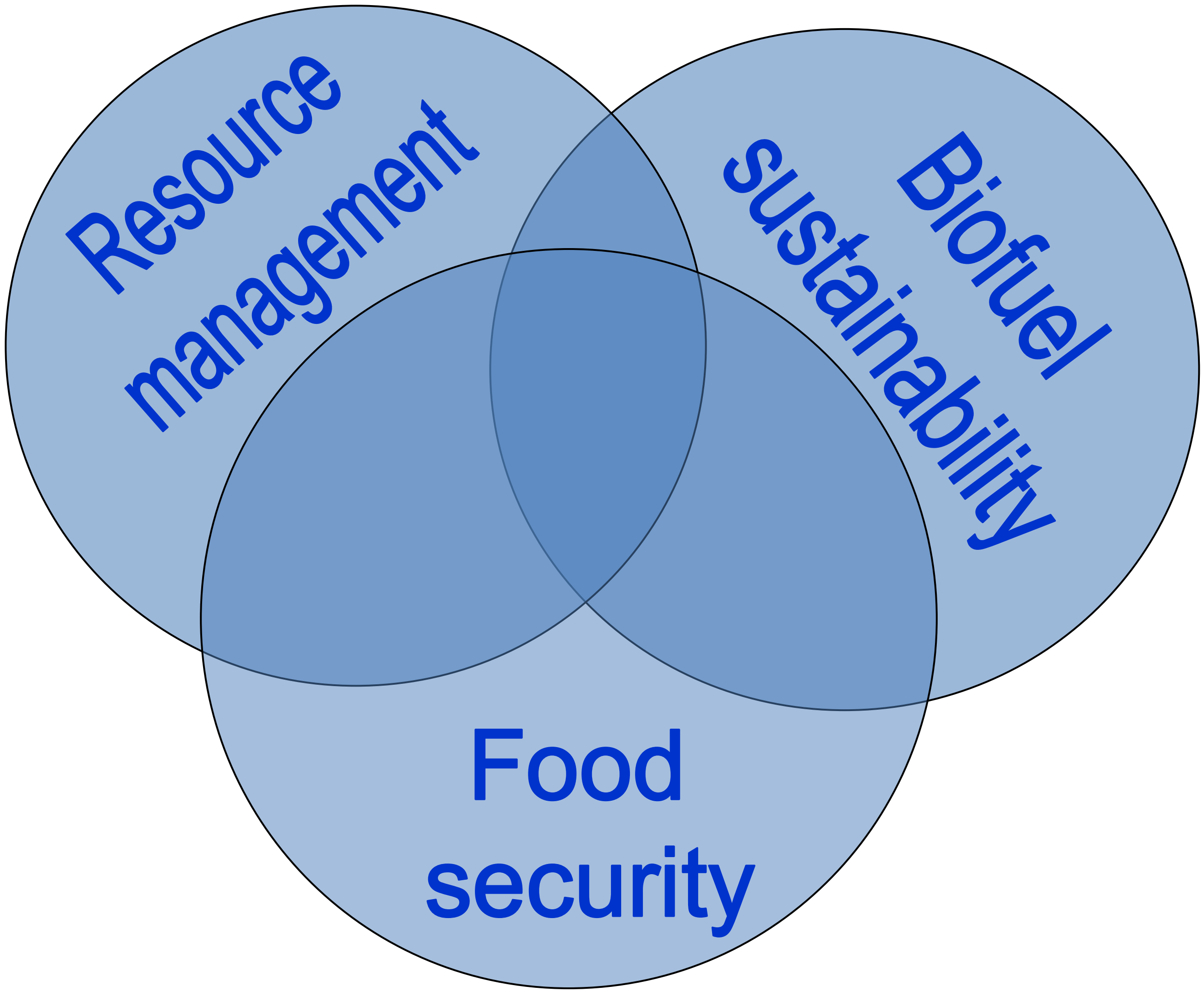
International workshop* helped frame key issues

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



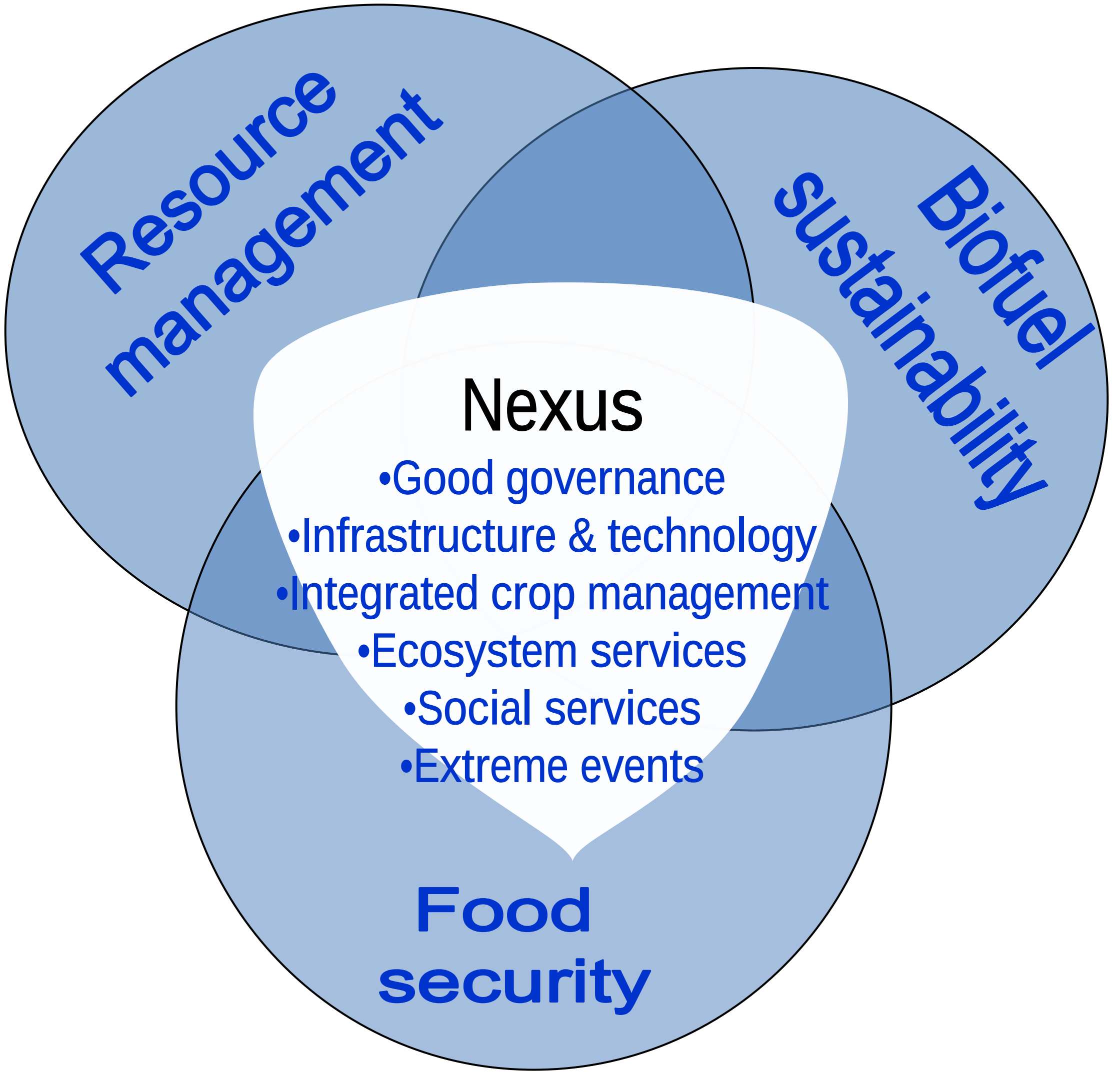
* http://www.ifpri.org/event/workshop-biofuels-and-food-security-interactions

The nexus between biofuel sustainability and food security invokes a focus on resource management



(Kline et al. In prep)

Key attributes of the nexus



(Kline et al. In prep)

Recommended practices

- **Apply systems to support continual improvement**
  - Monitor, assess & report on key measures of sustainability
  - Attend to what is "doable"
- **Enhance ecosystem services**
  - Identify & conserve priority biodiversity areas
  - Reduce waste
- **Focus on local needs**
- **Communicate opportunities and concerns to the stakeholders and get their feedback**
- **Employ adaptive management**

OAK RIDGE
National Laboratory

Thank you!

CBES

Center for BioEnergy Sustainability

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

Oak Ridge National Laboratory

This research is supported by the U.S. Department of Energy (DOE) Bio-Energy Technologies Office and performed at Oak Ridge National Laboratory (ORNL). Oak Ridge National Laboratory is managed by the UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725.