IEA Bioenergy InterTask Workshop: Sustainability of Bioenergy Supply Chains

Bridging ecosystem services and sustainable bioenergy indicators on agricultural landscapes with stakeholders

IEA Bioenergy Sustainability Intertask
Governance Case Study
Gothenburg, Sweden
May 18-19, 2017

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Oak Ridge National Laboratory

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

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

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Background - governance status

- Systems in place for
  - monitoring, reporting, and regulating
  - stewardship of public lands, reserves
- Examples
  - Conservation easements
  - U.S. Farm Bill programs:
    - Conservation Stewardship Program, Environmental Quality Incentives Program, Agricultural Conservation Easement Program (and the former Wetlands Reserve Program), Regional Conservation Partnership Program, Continuous Conservation Reserve Program and Rural Energy for America Program among others
    - Most under Natural Resources Conservation Service (NRCS) www.nrcs.usda.gov
  - State-driven programs
    - “best management practices”
    - "State Forest Action Plans“
- Forestry and Agriculture
  - Laws and regulations related to air, water, and endangered species
  - Applicable to public and privately owned land
  - Complexity due to multiple layers of authorities: federal, state, local, tribal

Examples of laws and regulations

Endangered Species Act (ESA)

- ESA is a program for conservation of threatened & endangered plants and animals & habitats
- ESA applies to all private forest land
- Landowners must "avoid" threatened, endangered and proposed species
- If known species present, consult with FWS

http://www2.epa.gov/laws-regulations/summary-endangered-species-act

Clean Water Act (CWA)

- **CWA is the primary federal law** governing discharge of pollutants into waters and quality standards for surface waters
- **Compliance & Monitoring** - EPA works with federal, state & tribal regulatory partners to monitor compliance with CWA
- **Forestry pollution prevention** programs in Southern U.S. vary by State as regulatory, quasi-regulatory & non-regulatory

http://www2.epa.gov/laws-regulations/summary-clean-water-act

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Private Landowner Incentives

- Forest Service **Stewardship Program**
  - Focused on private forest land management assistance
  - Provided more than 330,000 forest management plans covering more than 38 million acres nationwide.
- NRCS **Incentive Program**
  - Environmental Quality Incentive Program (EQIP)
- **Tax Incentives**
  - States assess lower property taxes on forest land than other properties

Examples of laws and regulations

Coastal Zone Management Act

- The U.S. Congress passed the Coastal Zone Management Act in 1972
- Goal is to "preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone"
- Established "Management Measures" must be addressed for forestry operations

http://coast.noaa.gov/czm/act/sections/#1455

Farm Bill

- Recent Farm Bill enacted in 2014
- It includes provisions on forestry, farming, renewable energy
  - Forest Service was granted the permanent authority to conduct Stewardship Contracting
  - Allows State Foresters to conduct restoration services on National Forest System Lands
  - Established Energy Title Programs for rural energy, biomass crop assistance, markets, biofuels & community wood energy

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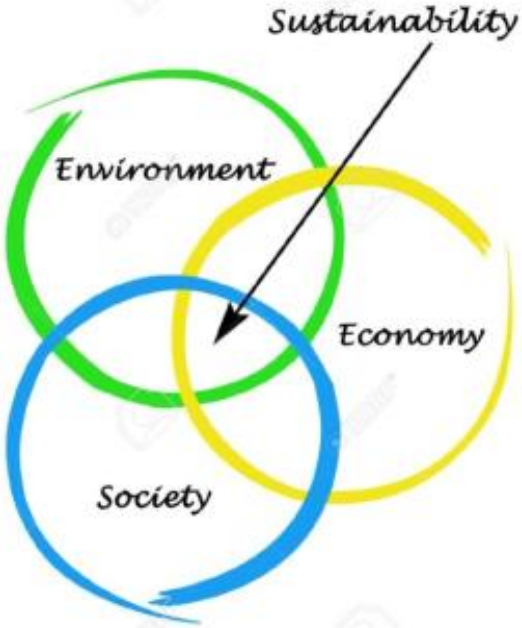
Sustainability?

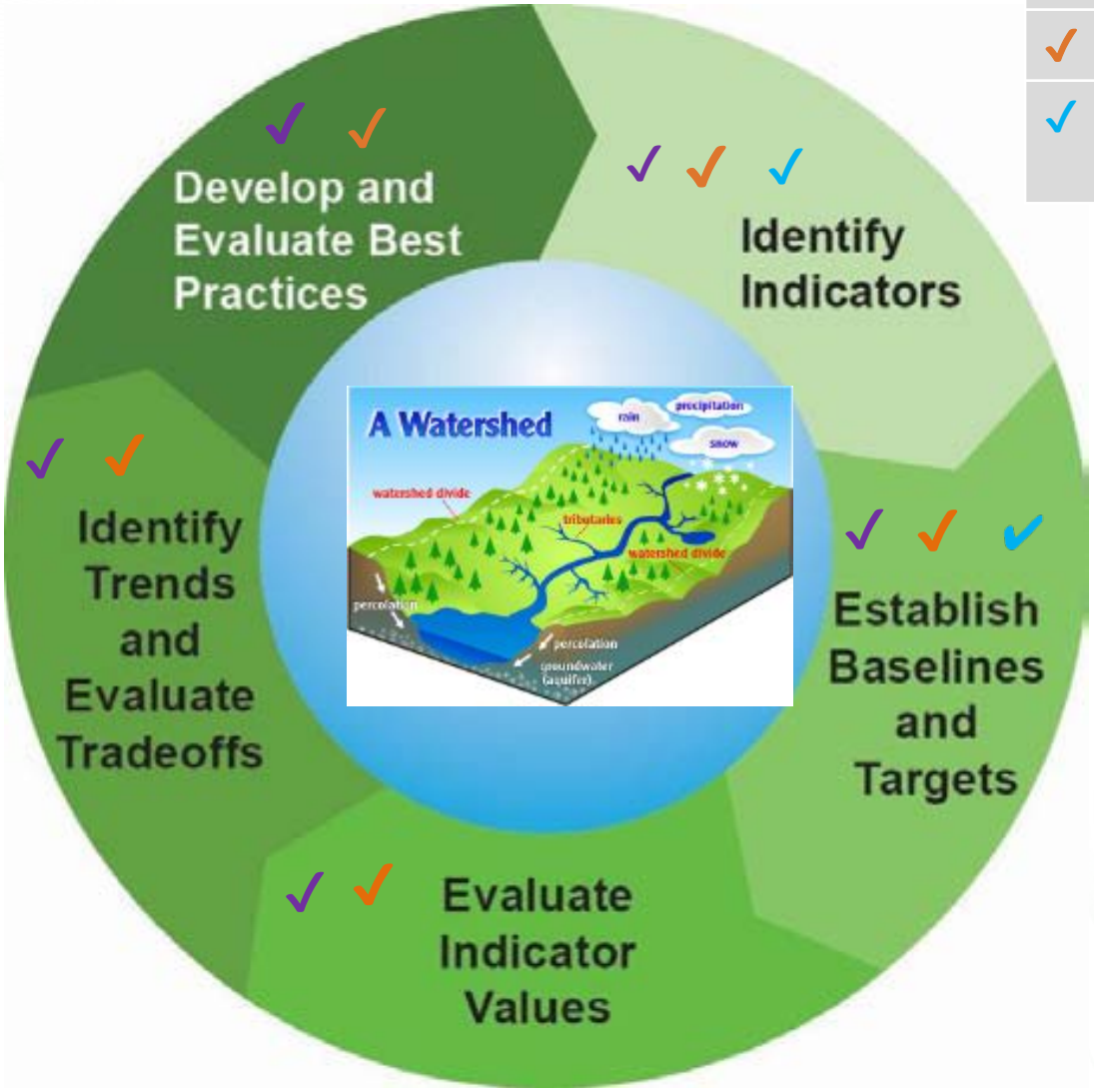
"an overused term"

- **Sustainability** is defined as the capacity of an activity to continue while maintaining options for future generations
- **ORNL's research agenda:**
  - Defining environmental & socioeconomic indicators for cost and benefits of bioenergy systems
  - Quantifying opportunities & risk associated with sustainable bioenergy in a specific context
  - Communicating challenges & opportunities associated with integrated biomass production systems
  - Applying and testing approaches via case studies & refining a path forward with stakeholders



Overview – BETO Approach

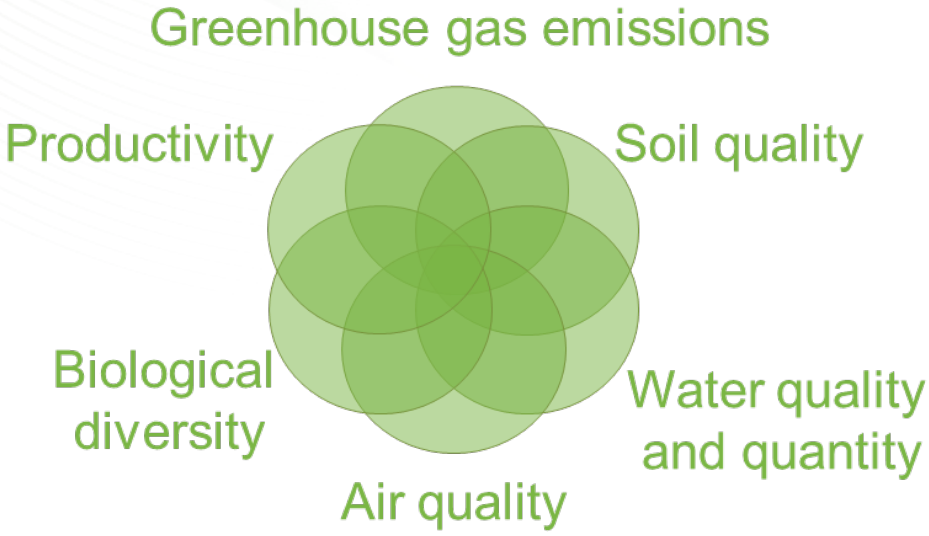
Code for checks	
✓	Reviewed
✓	Tested in East TN
✓	Iowa landscape design



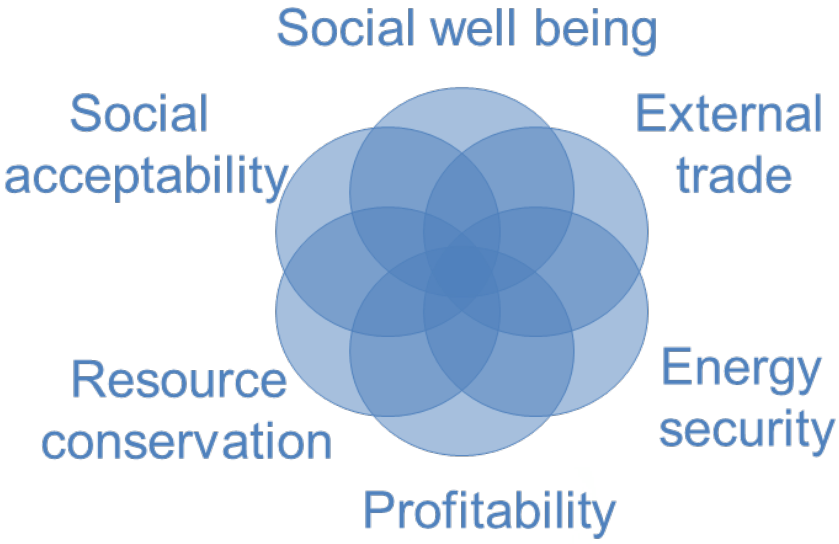
US Dept. of Energy, BioEnergy Technologies Office (BETO) Peer Review, March 2017 (in press), Denver Colorado (presentations by Dale and Kline)

Indicators for quantifying, enhancing, and communicating the value proposition of bioenergy

(35 indicators, 12 categories)



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



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

Depends on ***context*** (*Efroymson et al. 2013*). Analysis involves:

Quantifying effects using scientific approaches
Providing decision-relevant, credible information
Designing bioenergy systems that add value

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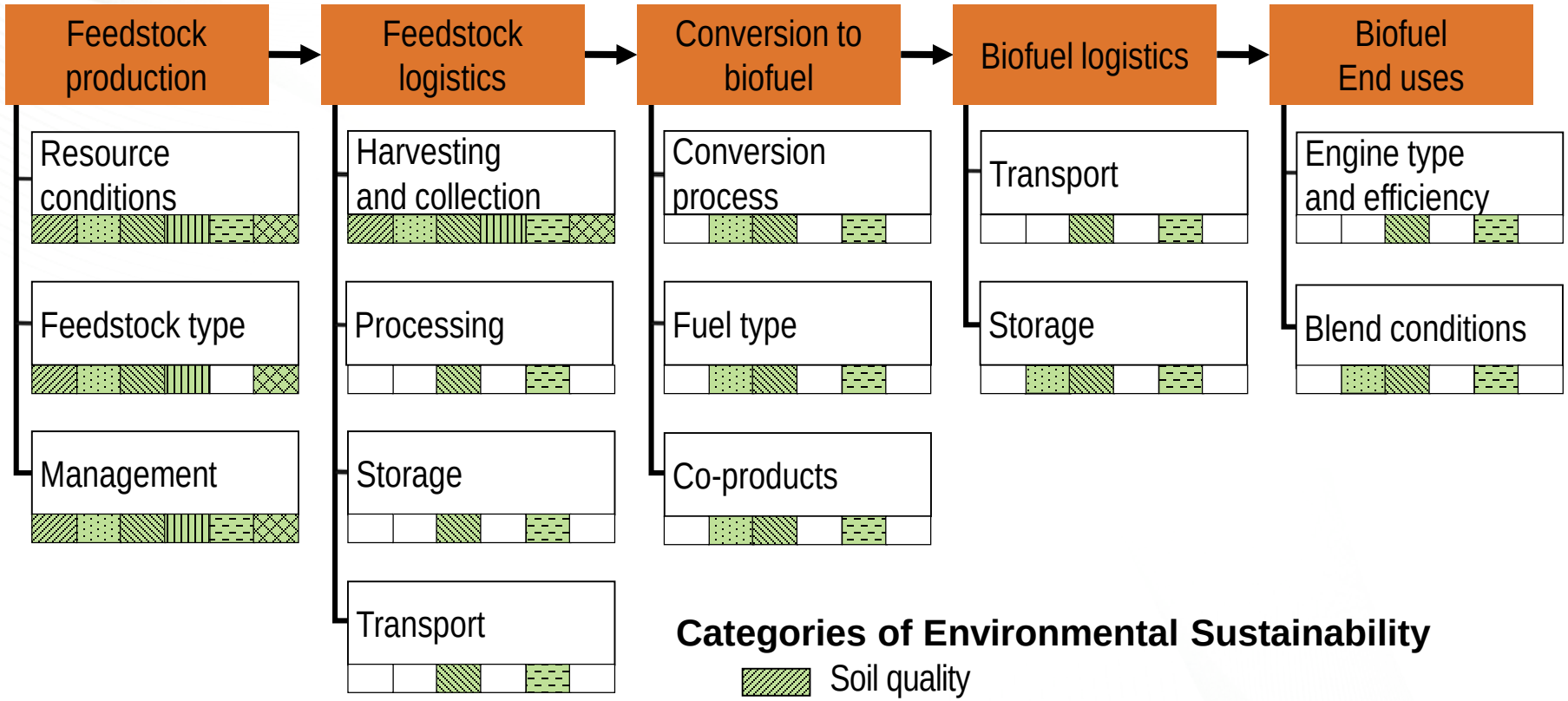
Consider the entire supply chain – example of environmental indicators



Categories of Environmental Sustainability

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

Efroymson et al. (2013) Environmental indicators of biofuel sustainability: What about context? Environmental Management 51:291-306.

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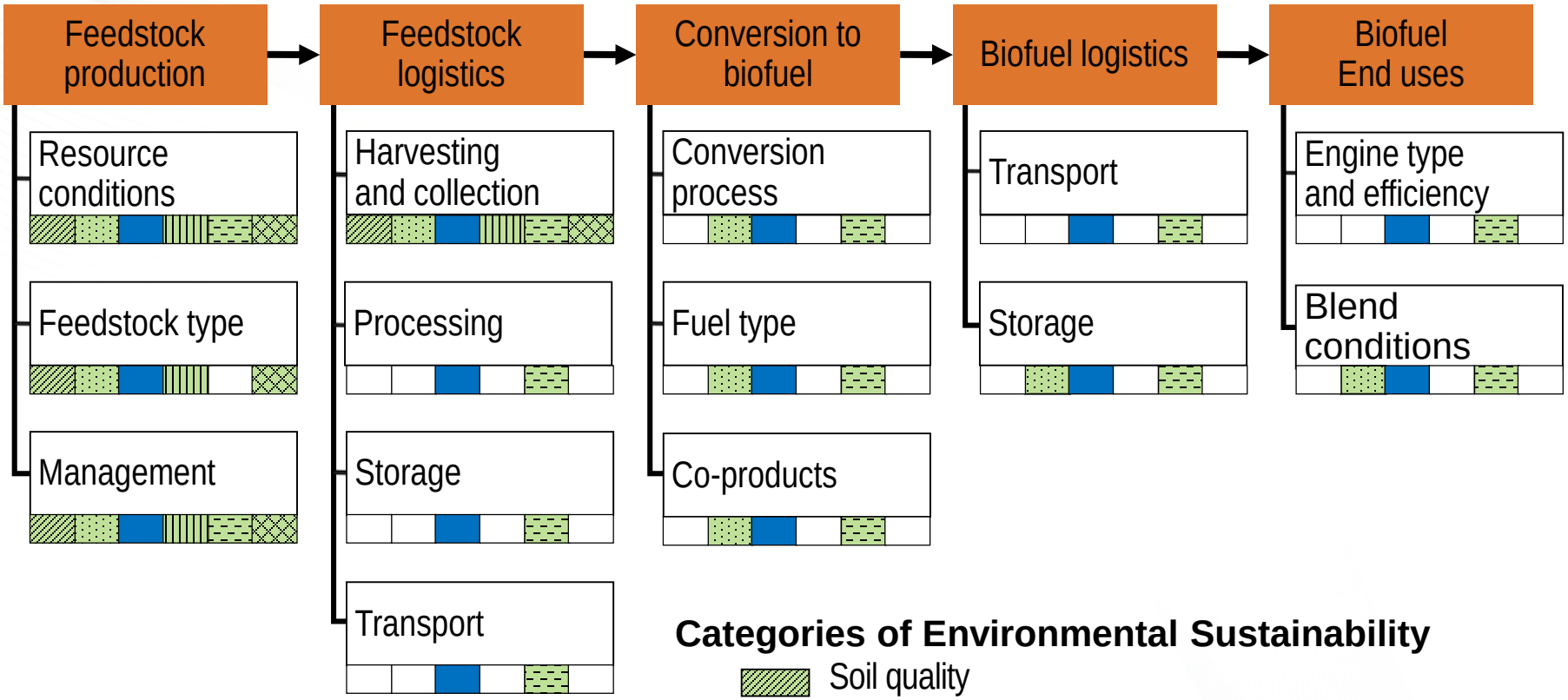
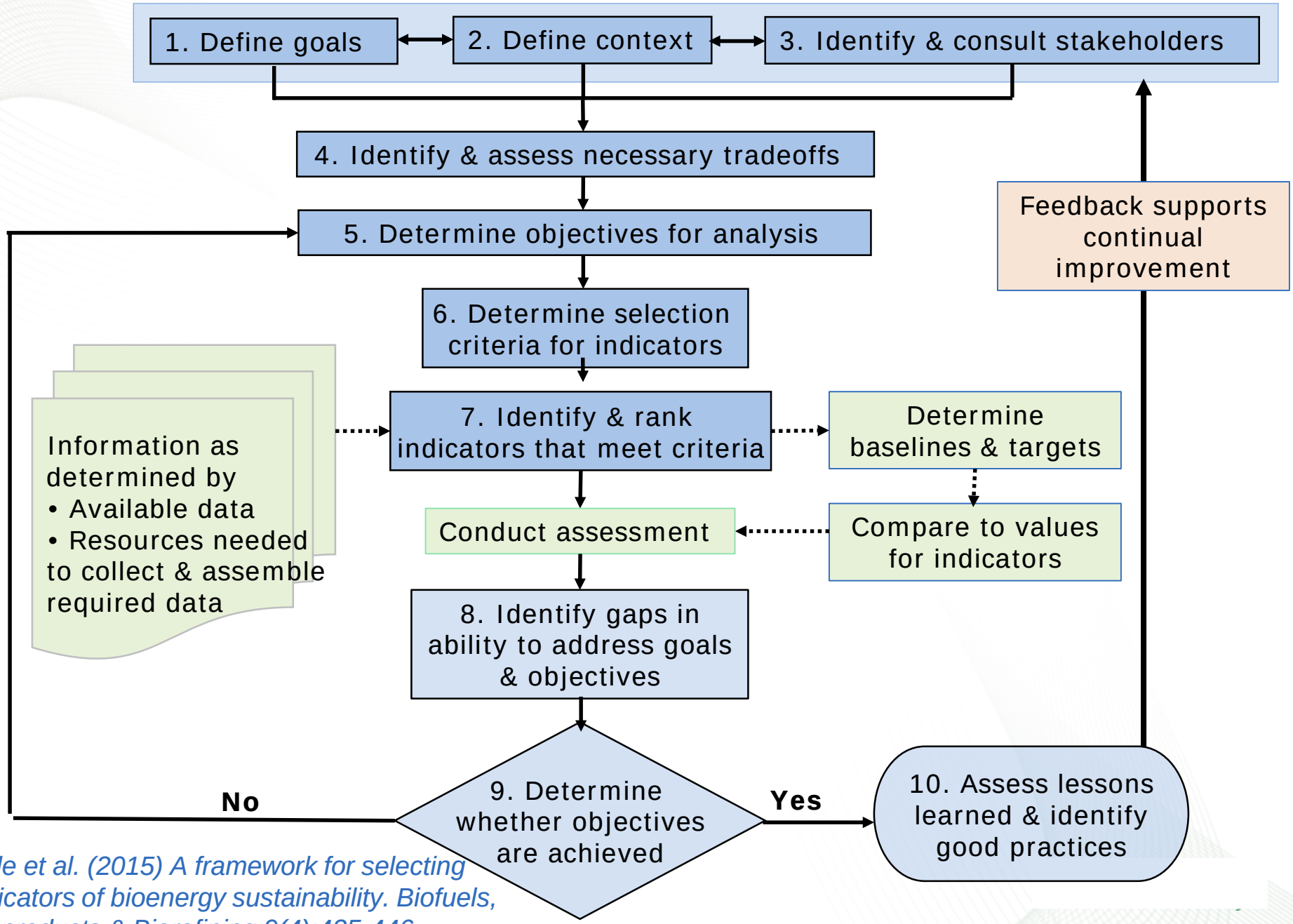
Greenhouse gas emissions occur across all steps of the supply chain but that doesn't mean that they are more important than other indicators

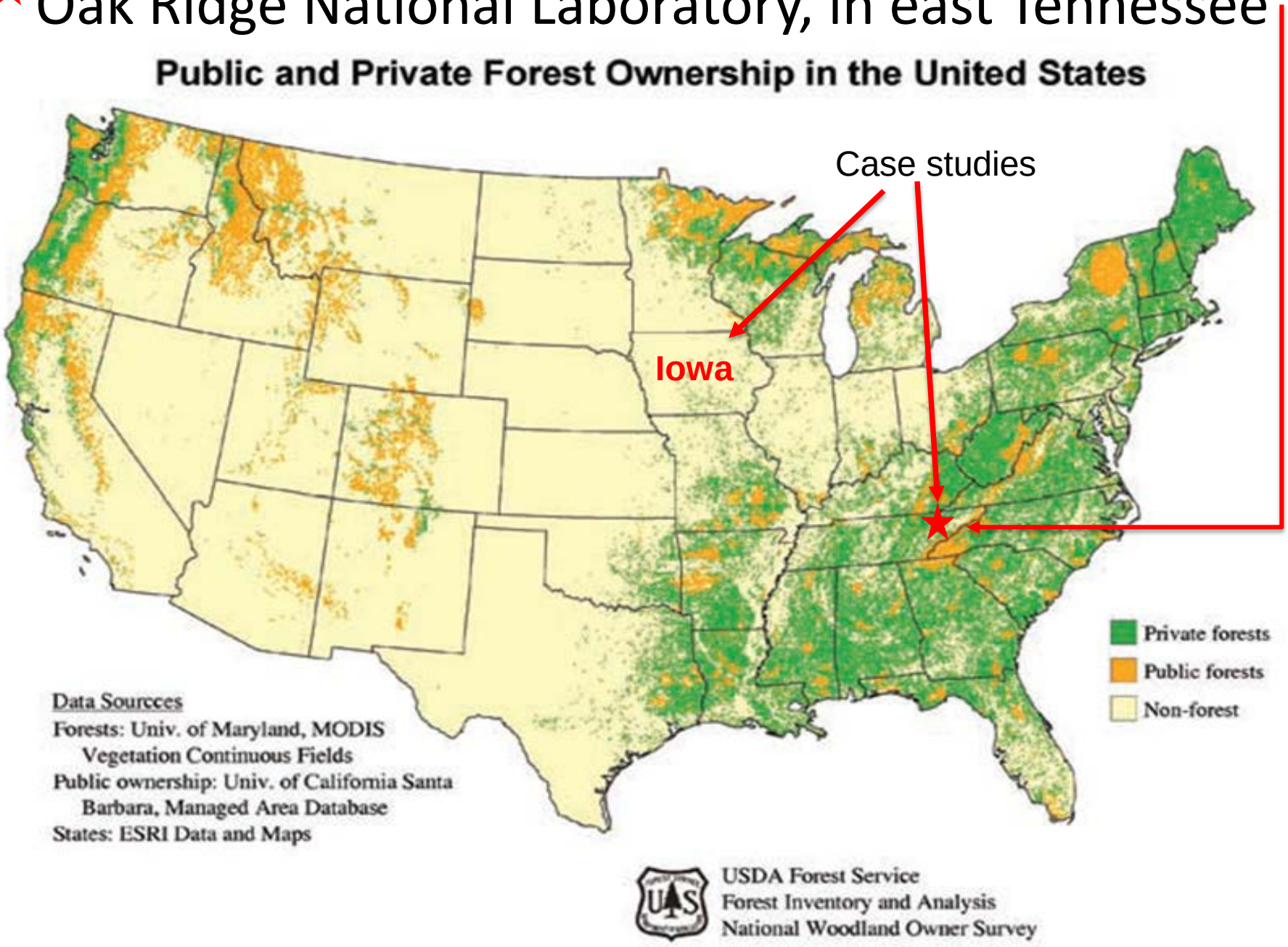


Framework for Selecting Indicators



Dale et al. (2015) A framework for selecting indicators of bioenergy sustainability. Biofuels, Bioproducts & Biorefining 9(4):435-446.

★Oak Ridge National Laboratory, in east Tennessee



Case study: Switchgrass in east TN

- *Dale et al. (2011) Interactions among bioenergy feedstock choices, landscape dynamics and land use. Ecol. Appl. 21(4):1039-1054.*
- *Parish (2016) In Search of Sustainability. Auburn Speaks: On Biofuels in the Southeast.*

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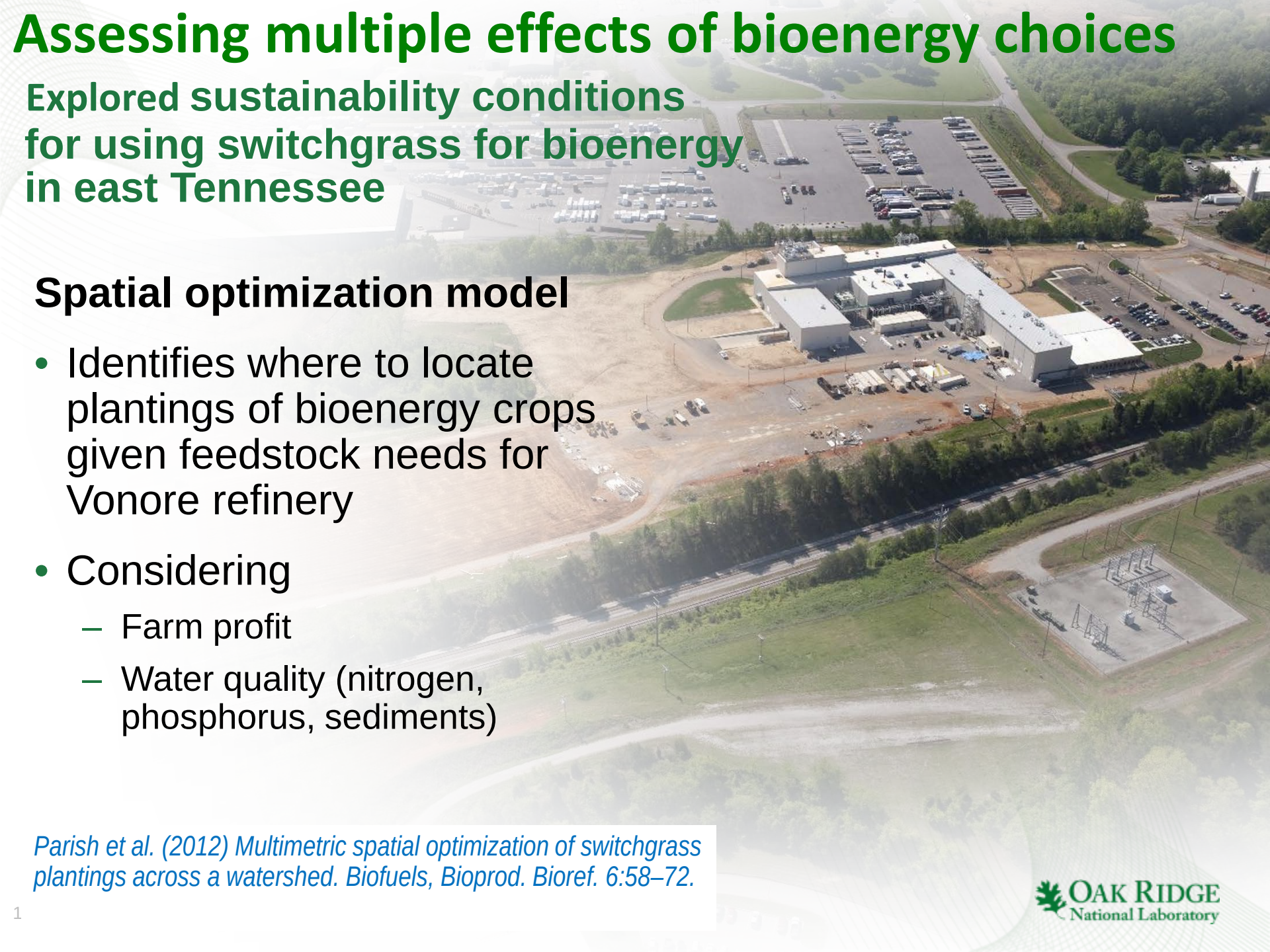
Assessing multiple effects of bioenergy choices

Explored sustainability conditions for using switchgrass for bioenergy in east Tennessee

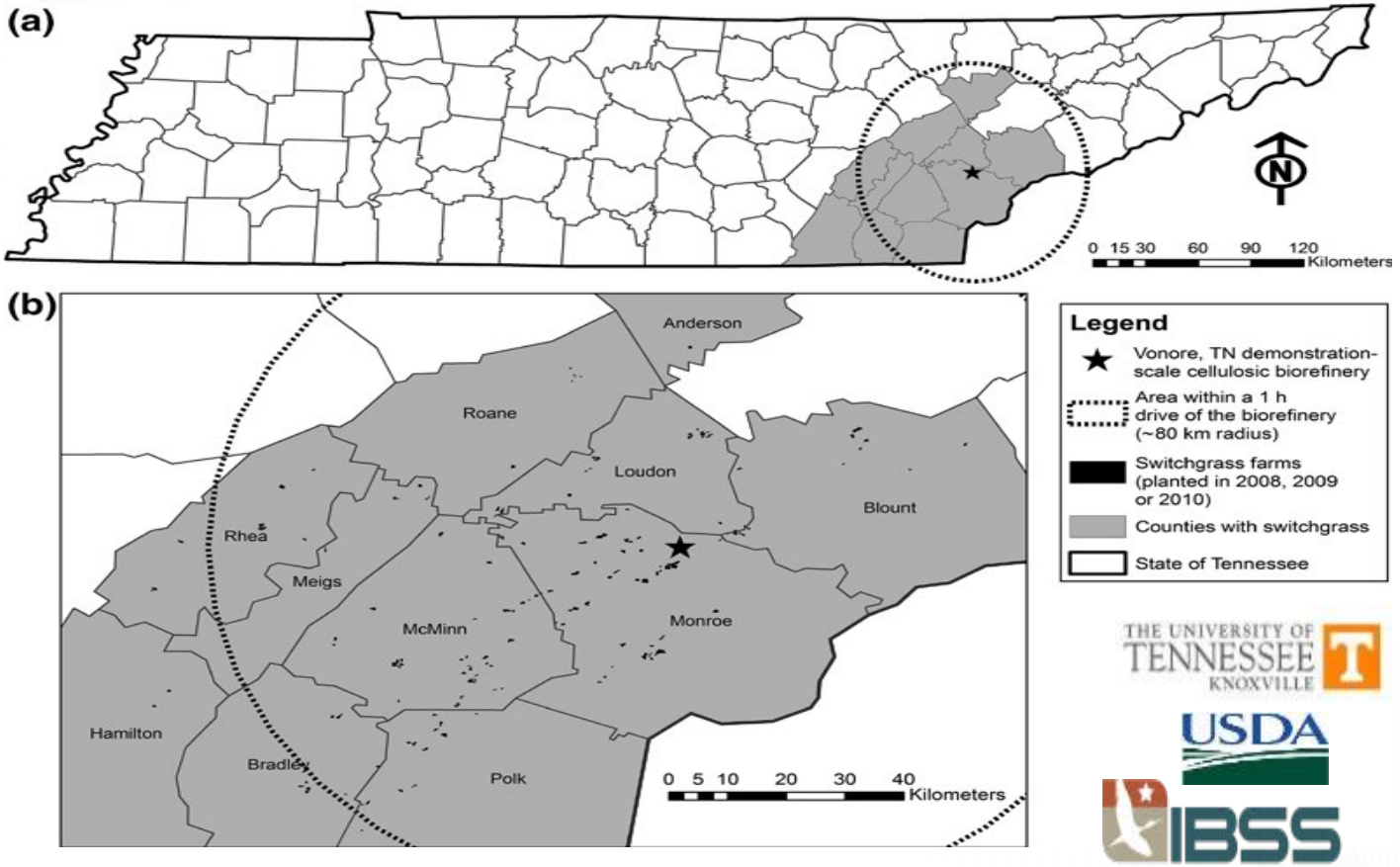


Spatial optimization model

- Identifies where to locate plantings of bioenergy crops given feedstock needs for Vonore refinery
- Considering
  - Farm profit
  - Water quality (nitrogen, phosphorus, sediments)

Parish et al. (2012) Multimetric spatial optimization of switchgrass plantings across a watershed. Biofuels, Bioprod. Bioref. 6:58–72.

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



THE UNIVERSITY OF TENNESSEE KNOXVILLE

USDA

IBSS
Southeastern Partnership for Integrated Biomass Supply Systems

Parish et al. (2016) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. Ecosphere 7(2).

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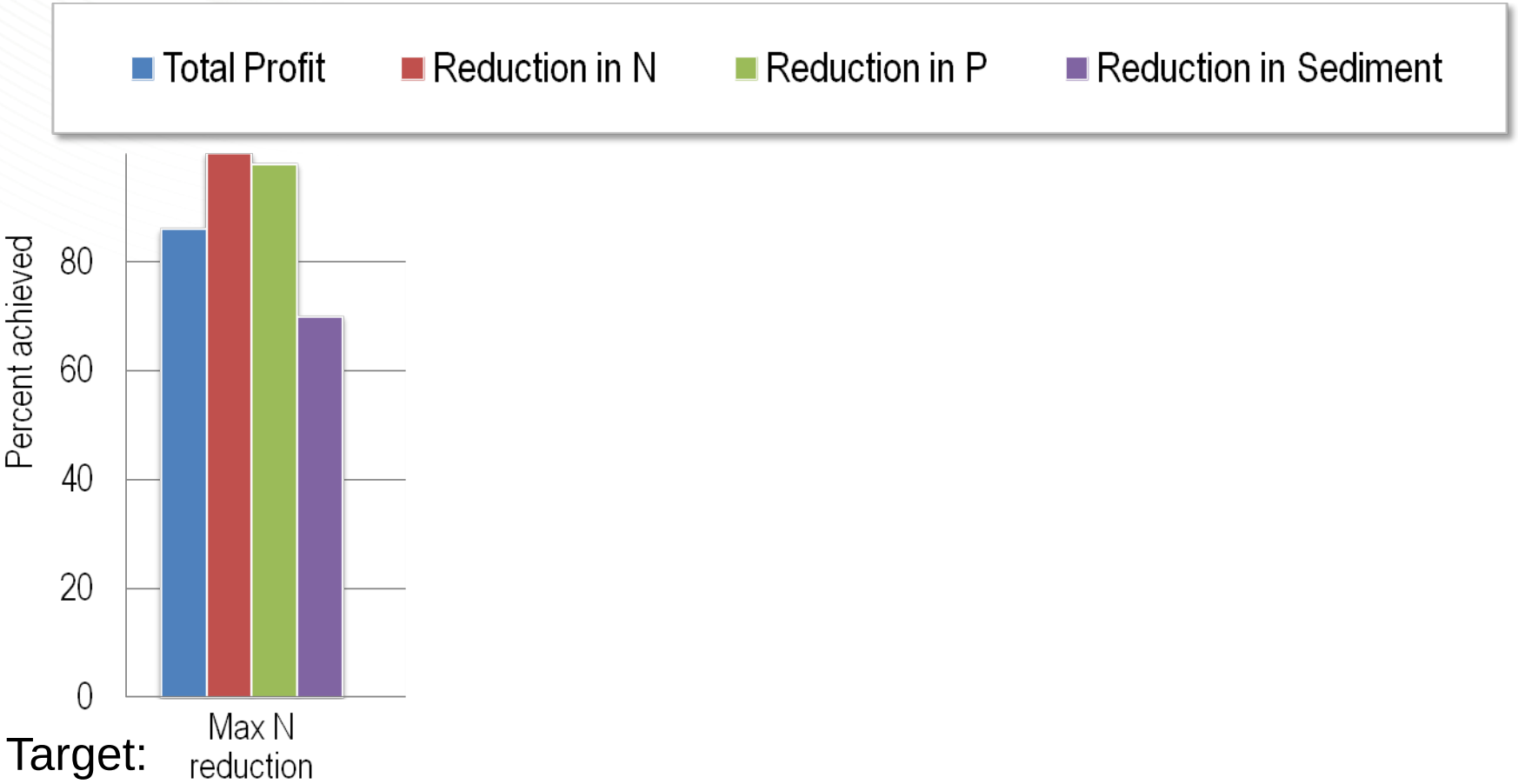
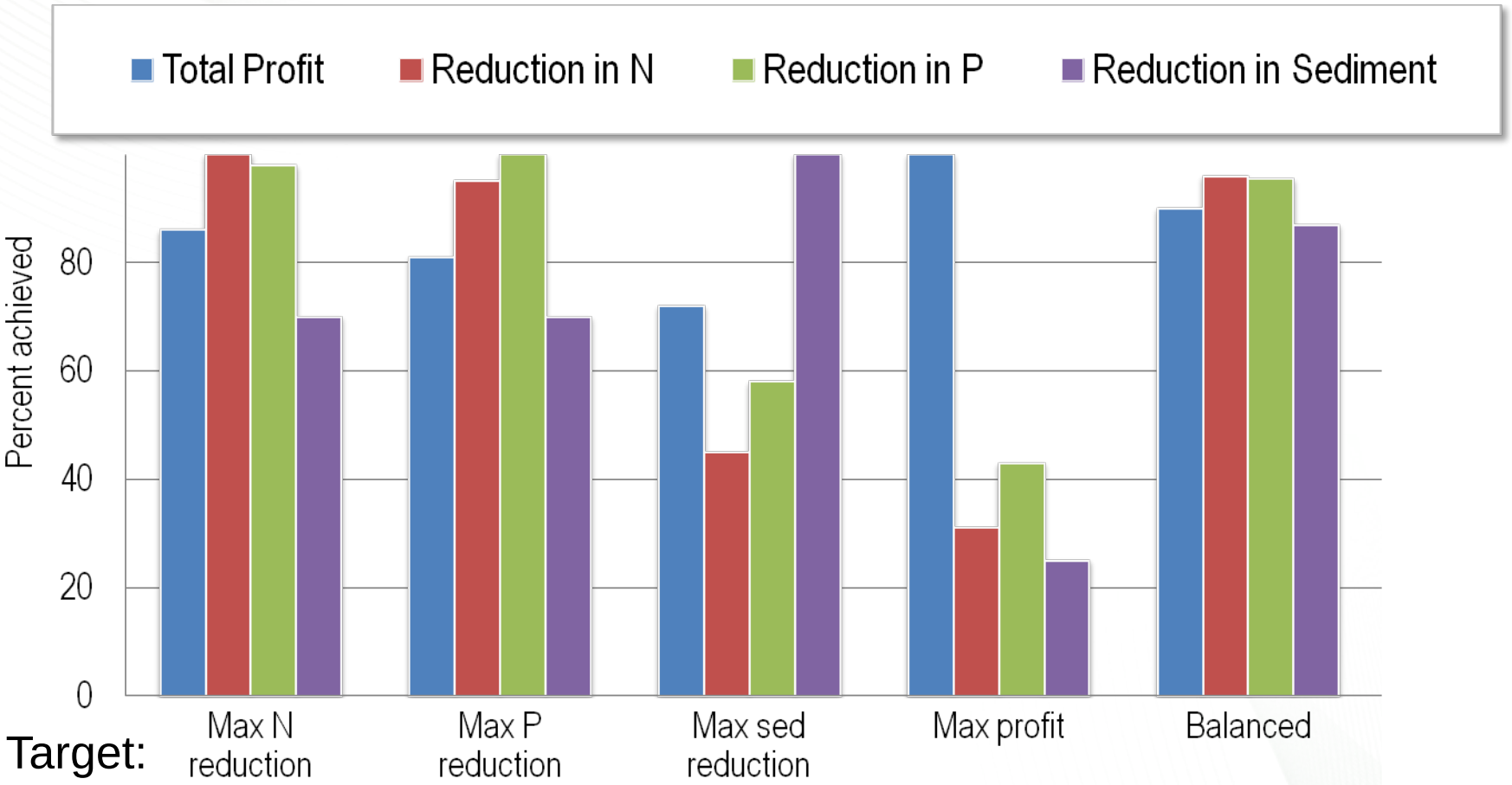
Balancing objectives: Identify optimal locations for switchgrass plantings with respect to defined targets while achieving a feedstock-production goal



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



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

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Conclusions from study of switchgrass in East TN

- Approach to assess progress toward sustainability targets was developed & tested.
- Results
  - Perennial grasses such as switchgrass offer benefits
  - But lacking demand or grower contracts, they are not sustainable.
- Other incentives, such as payments for ecosystem services could change outcomes

High production potential but low demand

DuPont biorefinery was established in Iowa

Applying learnings to “Enabling Sustainable Landscape Design for Continual Improvement of Operating Bioenergy Supply Systems” (BETO multi-disciplinary project) using cellulosic feedstock in Iowa

Iowa case:

ANTARES Group Incorporated

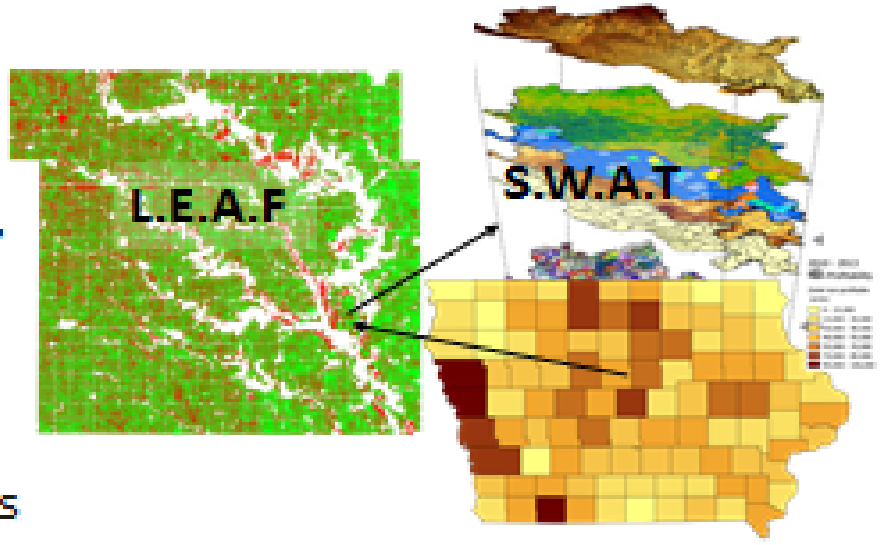
www.antaresgroupinc.com

Landscape Design for Sustainable Bioenergy Systems

Project Summary:

- Multidisciplinary team
- Working with growers and biomass end-users
- Using agronomic, optimization, and assessment models
- Assembling new data sets
- Targeting existing cellulosic ethanol feedstock supply sheds
- Designing and testing conservation practices

$9M awarded from DOE over 5 years



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Integrating goals via landscape design

Dale et al. (2016) Incorporating bioenergy into sustainable landscape designs. Renew. & Sust. Energy Rev.

Iowa Landscape Design: Assembling Pieces of a Puzzle

Advanced Harvest & Logistics
2nd Pass, developing single pass

Regional Impact Modeling & Monitoring

Perennial Grass for Conservation & Biomass Supply

Implementation of Conservation Practices (Cover Crops, Buffer Strips, etc.)

Subfield Precision Business Planning

Advanced Harvest & Logistics, First Pass

Sustainable Residue Harvest

Multi-stakeholder Outreach

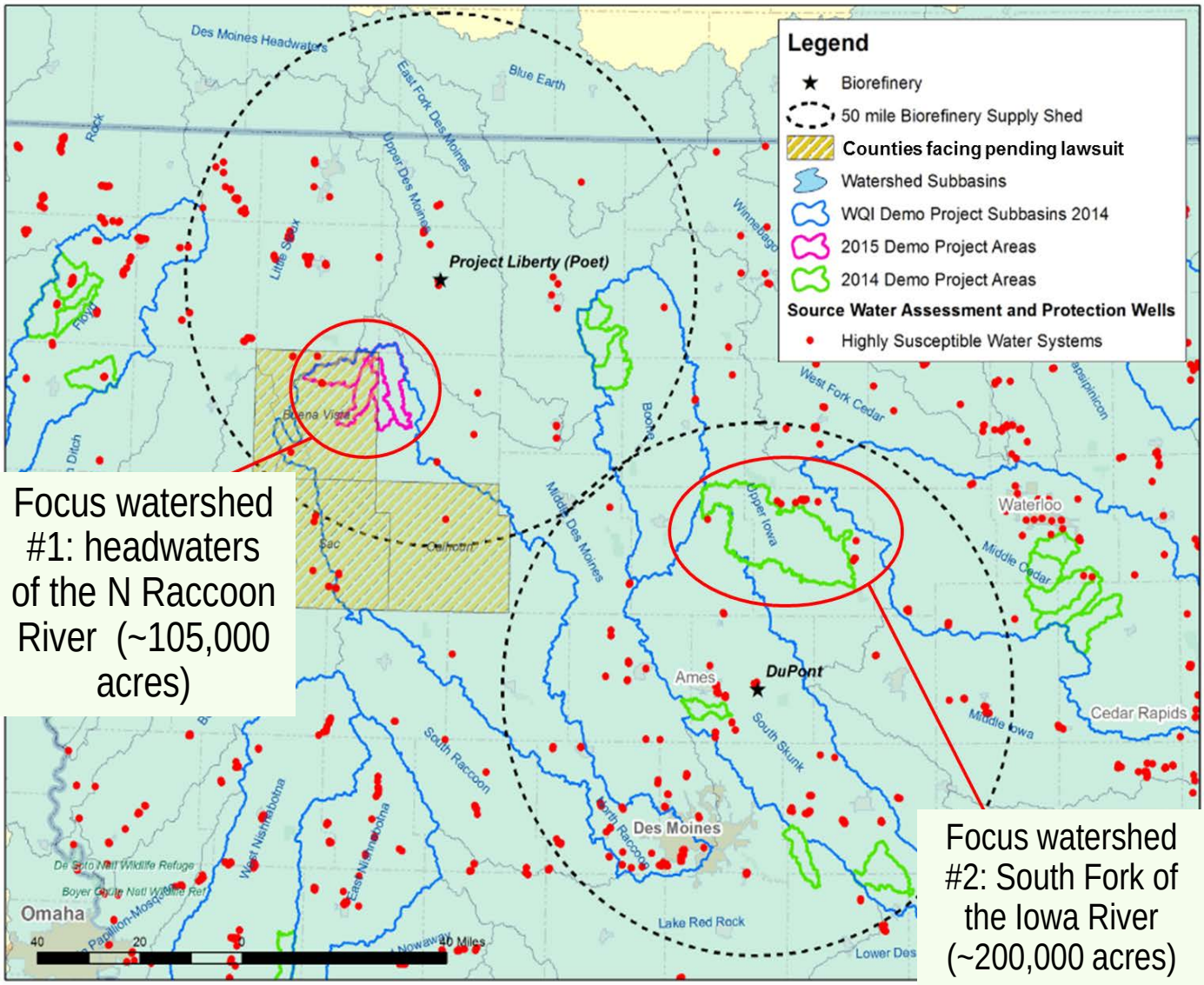
"*Enabling Sustainable Landscape Design for Continual Improvement of Operating Bioenergy Supply Systems*"

ORNL areas of focus:

1. Multi-Stakeholder Landscape Design Process
2. Assessment of Environmental Sustainability Indicators
3. Improve Feedstock Supply and Logistics
4. Support development of template for future biorefinery projects.

Iowa: Two focal watersheds

- **Two biorefineries in start-up mode**
- **Iowa Nutrient Reduction Strategy Goals**
  - Non-point source
  - 41% less N
  - 29% less P
- **~ $115 million spent in 2015 towards goals**
- **Better modelling capabilities needed for planning**



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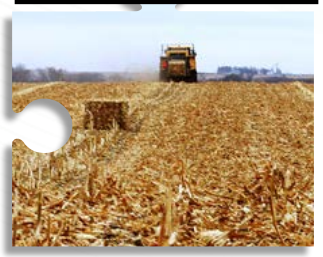
Stakeholders associated with different parts of the agriculture to biofuel supply chain

Feedstock production → Feedstock logistics → Conversion to biofuel → Biofuel logistics → End uses





Individual perspective:

Farmer's decisions:
- What to plant?
- Where to plant it?
- How to manage it

Feedstock logistic decisions:
- How to harvest and collect feedstock?
- How to process?
- How to store?
- How to transport?

Conversion decisions:
- What process to use?
- What fuel type to produce?
- What coproducts?

Biofuel logistics decisions:
- Where and how to transport?
- Where and how to store?

End user decisions:
- What type of vehicle to buy?
- What blend of fuel to use?

Cumulative perspective:

Land cover and use patterns and practices

Collection, processing, storage and movement of goods across the landscape

Distribution of conversion facilities across the landscape

Transportation and storage of biofuels for a region and the nation

National and regional choices of vehicles and fuels

Dale et al. 2013. Communicating about bioenergy sustainability. Env Mgmt 51: 279-290

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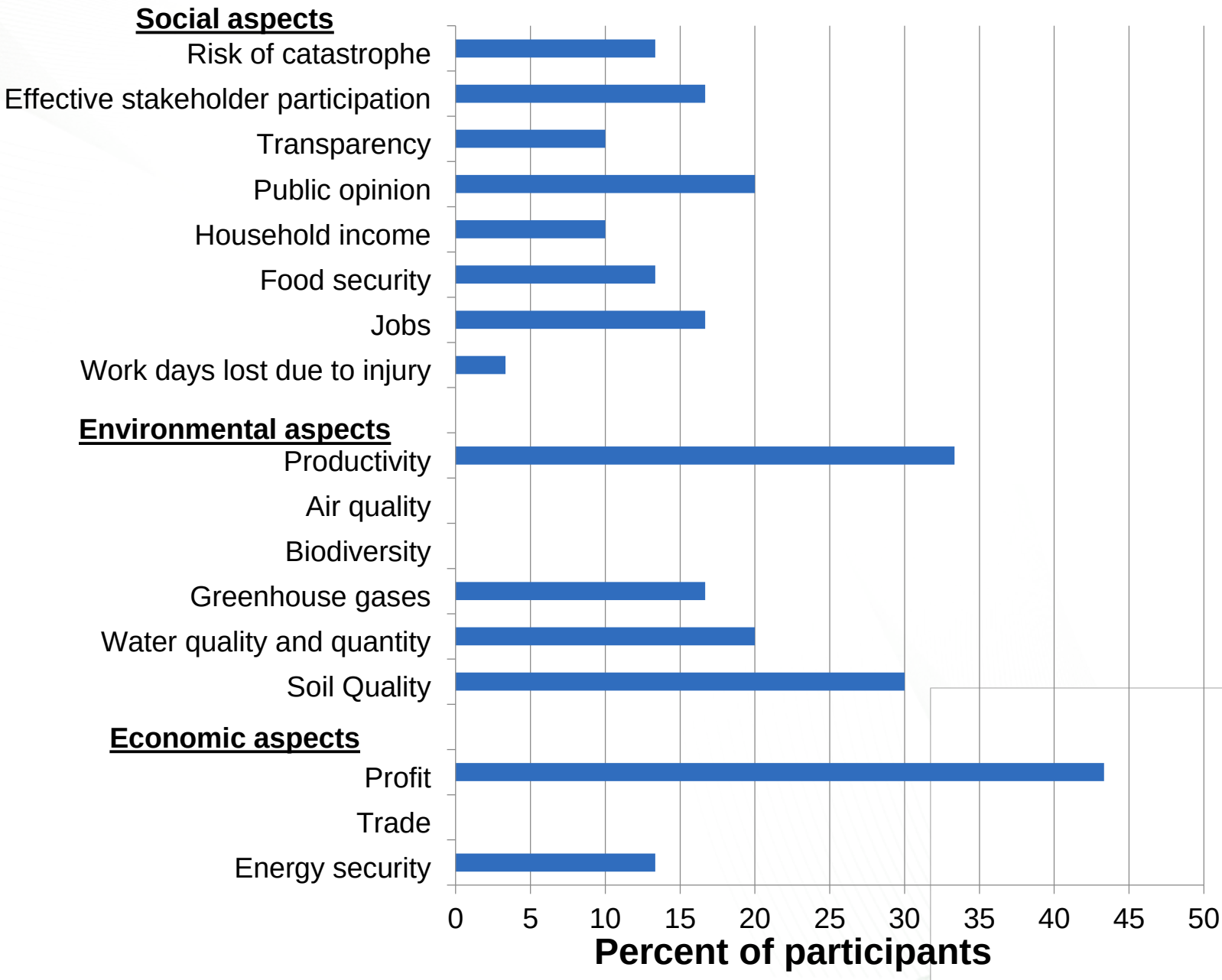
Collected information about stakeholders concerns via

- **Literature review**
- **Survey by Drake University**
- **Stakeholders meetings**
- **Project meeting**

Dale et al. (In review) Selecting indicators of changes in ecosystem services due to cellulosic-based biofuel in the midwestern US. Biomass and Bioenergy.

Participants at Project kick-off meeting prioritized indicators



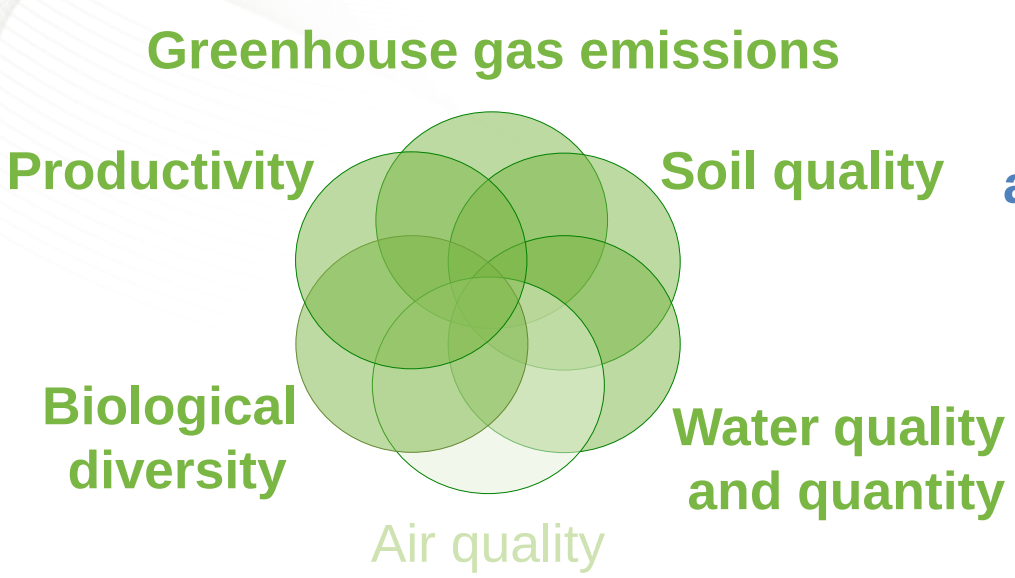
Collected information about stakeholders concerns via

- Literature review
- Survey by Drake University
- Stakeholders meetings
- Project meeting
- **Interviews with selected stakeholders (farmers, NGOs)**

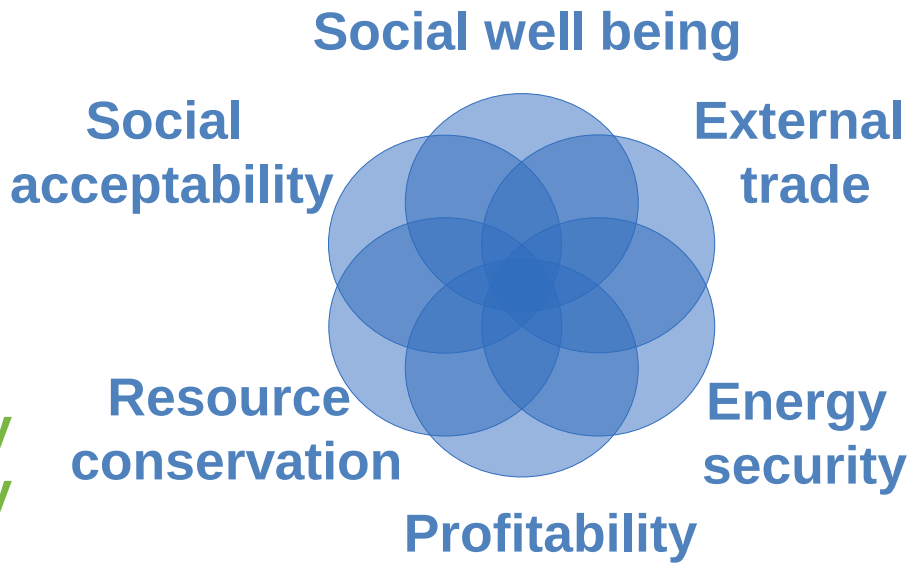
Dale et al. (In review) Selecting indicators of changes in ecosystem services due to cellulosic-based biofuel in the midwestern US. Biomass and Bioenergy.

Aspects of bioenergy sustainability of concern for agriculture in Iowa in 2016

Dale et al. (in review)



McBride et al. (2011) *Ecol. Ind.* 11:1277-1289.



Dale et al. (2013) *Ecol. Ind. 6:87-102* ,

Results thus far:

- **Environmental and socioeconomic concerns identified**
- **Soil health is key issue linked with productivity & profit**
- **Without market demand and profit potential, energy crops are unlikely to expand regardless of other potential benefits**

Example: biodiversity indicator approach for Hardin County, Iowa

Category	Indicator	Baseline	Target
Biodiversity 	Presence of taxa of concern	• Northern long-eared bat • Prairie bush clover • Western prairie fringed orchid • Pheasant	Maintain population size or breeding pairs
	Habitat of taxa of concern	1,782 acres (721 ha)	Conserve or expand area of habitat
	Invasive species	(analysis ongoing)	Reduce area and threat of expansion
Social well being	Household income	$140/day	> $140/day (no decline)

Contributions from Penn State researchers (Armen Kemanian and Tom Richard) and students (Rachel Rozum, Kyra Sciaudone, and Veronika Vazhnik)

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Major concerns in other case studies (just getting started)

Yaqui Valley Mexico wheat systems

- Water & nutrient efficiency
- Reduce risk via market stabilization & diversification
- Access to export markets
- Chemical use and handling

Guatemala Uplands maize systems

- Improve system yields
- Erosion control/soil health
- Access to market information
- Resilience to system disturbance

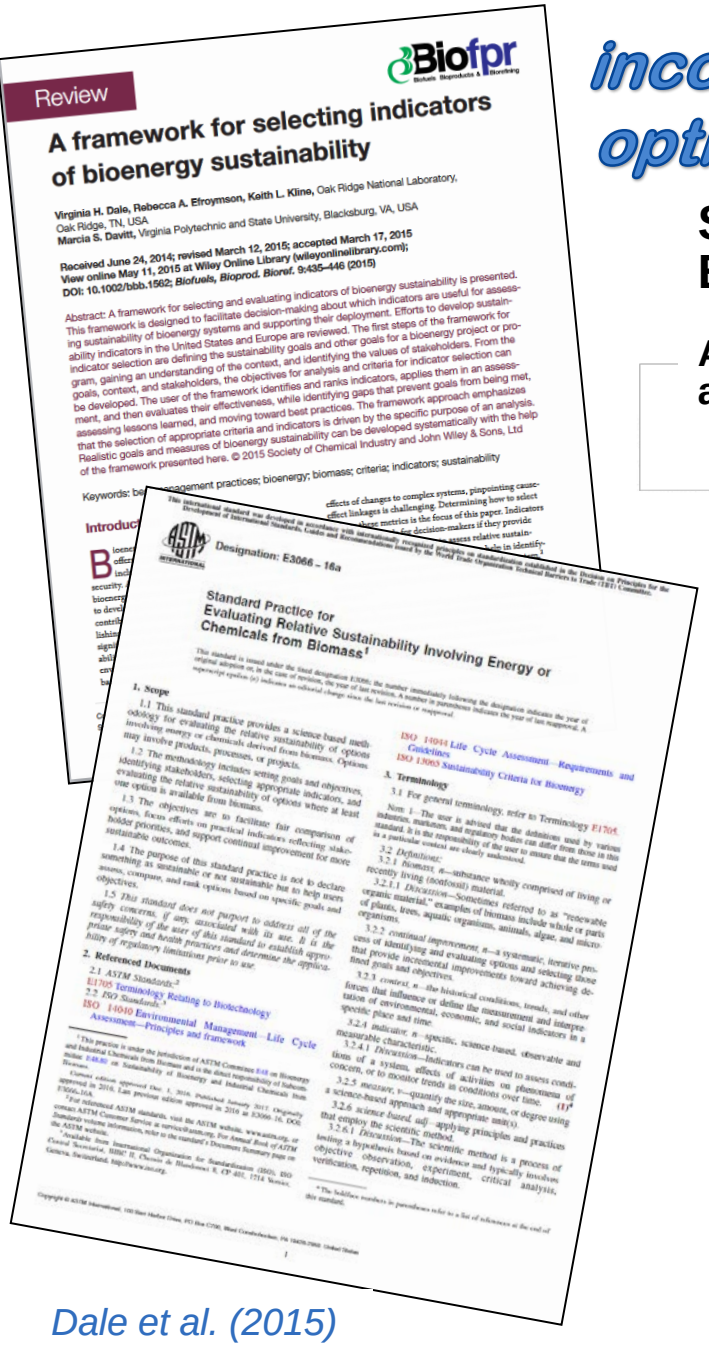
Sustainability is always relative and typically involves comparison of trajectories

"To make the concept of sustainability operational, objectives must be defined within a specified context, stakeholders engaged, and consistent approaches applied to facilitate comparable, science-based assessments."

– ASTM E3066 (2017)

Photo credit: Orbiter News Dec. 22, 2010

Sustainability involves a process incorporating continual reassessment of options and adaptation for improvement


Review

Biofpr

A framework for selecting indicators of bioenergy sustainability

Virginia H. Dale, Rebecca A. Efroymson, Keith L. Kline, Oak Ridge National Laboratory, Oak Ridge, TN, USA
Marcia S. Davitt, Virginia Polytechnic and State University, Blacksburg, VA, USA

Received June 24, 2014; revised March 12, 2015; accepted March 17, 2015
View online May 11, 2015 at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.1562; *Biofuels, Bioprod. Bioref.* 9:435–446 (2015)

Abstract: A framework for selecting and evaluating indicators of bioenergy sustainability is presented. This framework is designed to facilitate decision-making about which indicators are useful for assessing sustainability of bioenergy systems and supporting their deployment. Efforts to develop sustainability indicators in the United States and Europe are reviewed. The first steps of the framework for indicator selection are defining the sustainability goals and other goals for a bioenergy project or program, gaining an understanding of the context, and identifying the values of stakeholders. From the goals, context, and stakeholders, the objectives for analysis and criteria for indicator selection can be developed. The user of the framework identifies and ranks indicators, applies them in an assessment, and then evaluates their effectiveness, while identifying gaps that prevent goals from being met, assessing lessons learned, and moving toward best practices. The framework approach emphasizes that the selection of appropriate criteria and indicators is driven by the specific purpose of an analysis. Realistic goals and measures of bioenergy sustainability can be developed systematically with the help of the framework presented here. © 2015 Society of Chemical Industry and John Wiley & Sons, Ltd

Keywords: best management practices; bioenergy; biomass; criteria; indicators; sustainability

Designation: E3066 – 16a

Standard Practice for Evaluating Relative Sustainability Involving Energy or Chemicals from Biomass[1]

1. Scope

1.1 This standard practice provides a science based methodology for evaluating the relative sustainability of options involving energy or chemicals derived from biomass. Options may involve products, processes, or projects.

1.2 The methodology includes setting goals and objectives, identifying stakeholders, selecting appropriate indicators, and evaluating the relative sustainability of options where at least one option is available from biomass.

1.3 The objectives are to facilitate fair comparison of options, focus efforts on practical indicators reflecting stakeholder priorities, and support continual improvement for more sustainable outcomes.

1.4 The purpose of this standard practice is not to declare something as sustainable or not sustainable but to help users assess, compare, and rank options based on specific goals and objectives.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:[2]
E1705 Terminology Relating to Biotechnology

2.2 ISO Standards:[3]
ISO 14040 Environmental Management—Life Cycle Assessment—Principles and Framework
ISO 14044 Life Cycle Assessment—Requirements and Guidelines
ISO 13065 Sustainability Criteria for Bioenergy

3. Terminology

3.1 For general terminology, refer to Terminology E1705.

Note 1—The user is advised that the definitions used by various industries, marketers, and regulatory bodies can differ from those in this standard. It is the responsibility of the user to ensure that the terms used in a particular context are clearly understood.

3.2 Definitions:

3.2.1 *biomass, n*—substance wholly comprised of living or recently living (nonfossil) material.

3.2.1.1 *Discussion*—Sometimes referred to as "renewable organic material." examples of biomass include whole or parts of plants, trees, aquatic organisms, animals, algae, and microorganisms.

3.2.2 *continual improvement, n*—a systematic, iterative process of identifying and evaluating options and selecting those that provide incremental improvements toward achieving defined goals and objectives.

3.2.3 *context, n*—the historical conditions, trends, and other forces that influence or define the measurement and interpretation of environmental, economic, and social indicators in a specific place and time.

3.2.4 *indicator, n*—specific, science based, observable and measurable characteristic.

3.2.4.1 *Discussion*—Indicators can be used to assess conditions of a system, effects of activities on phenomena of concern, or to monitor trends in conditions over time. (1)[4]

3.2.5 *measure, v*—quantify the size, amount, or degree using a science-based approach and appropriate unit(s).

3.2.6 *science-based (adj)*—applying principles and practices that employ the scientific method.

3.2.6.1 *Discussion*—The scientific method is a process of testing a hypothesis based on evidence and typically involves objective observation, experiment, critical analysis, verification, repetition, and induction.

[1] This practice is under the jurisdiction of ASTM Committee E48 on Bioenergy and Industrial Chemicals from Biomass and is the direct responsibility of Subcommittee E48.06 on Sustainability of Bioenergy and Industrial Chemicals from Biomass.

Current edition approved Dec. 1, 2016. Published January 2017. Originally approved in 2016. Last previous edition approved in 2016 as E3066-16. DOI: E3066-16A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland. http://www.iso.org.

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

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1

Dale et al. (2015)

Standard Practice Guide for Evaluating Relative Sustainability

ASTM International E-3066-2017 Committee E-48: Energy and chemicals from biomass

FIG. 1 Representation of Process for Evaluating Relative Sustainability

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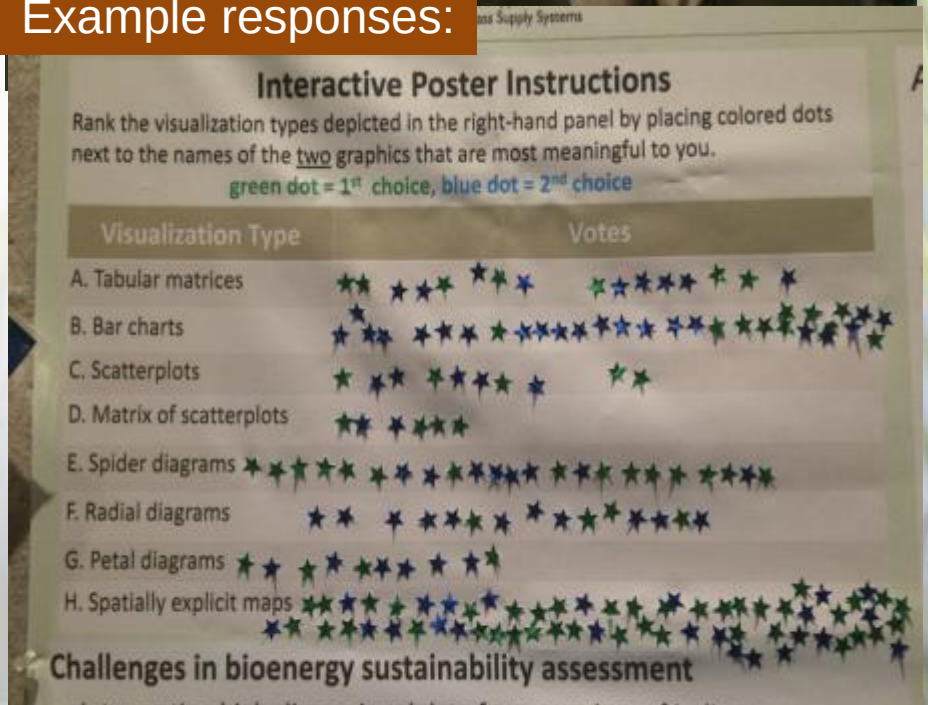
Approaches to identify stakeholder priorities

- Literature reviews
- 3rd party surveys
- Legal proceedings
- Focus group meetings
- Interactive posters:
  - Engaging stakeholders
  - Perceptions about opportunities & constraints for bioenergy

Example responses:



Dale VH, Kline KL. (2017) Interactive Posters: A valuable means for enhancing communication & learning about productive paths toward sustainable bioenergy. *Biofuels, Bioprod. Bioref.*

What have we learned?

Criteria for assessing governance standards:

- Goals and options are clearly stated
- Priorities are defined with local stakeholders
- Indicators are
  - ✓ Relevant and useful
  - ✓ Capture intended criteria and effects in timely manner
  - ✓ Quantifiable using a citable, standard measurement method
- Facilitates fair comparisons across different contexts
- Results are verifiable by third parties
- Practical; implemented without undue burden and expense
- Transparently shares information in near “real time”
- Systematic, periodic reviews verify & enhance utility, validity and the cost-effectiveness of tools to support defined goals

(Source: Kline et al., USIALE 2017)

Can barriers to acceptance of biomass for energy be overcome?

An IEA Economist (L.Varro)* was “not optimistic” [about supply of] “genuinely sustainable biomass”

*http://www.endseurope.com/article/46959/iea-not-optimistic-about-future-role-of-bioenergy

Photo by Kline: LUC near Tampa, FL

- **Challenges – building scientific consensus on**
  - Definitions, methods and measurements to operationalize ‘sustainability’
  - Consistent, quantitative assessment of effects
  - Attribution to bioenergy system within dynamic and changing contexts
  - Land-use change and reference scenarios

- **Science-based information is required to guide decisions and address challenges**:
  - Defining terms and Indicators (e.g., McBride et al. 2011; Dale et. al. 2014; 2015)
  - Apply Causal Analysis (Efroymson et al. 2016; Kline et al. 2016)
  - Develop and Apply Standard Procedures (see ASTM 3066a - 2017)

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Thank you!

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

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References

For more information see http://www.ornl.gov/sci/ees/cbes/

- Dale VH, KL Kline, D Perla, A Lucier. 2013. Communicating about bioenergy sustainability. Environmental Management 51(2): 279-290. DOI: 10.1007/s00267-012-0014-4.
- Dale VH, Kline KL. (2017) Interactive Posters: A valuable means for enhancing communication and learning about productive paths toward sustainable bioenergy. *Biofuels, Bioprod. Bioref. DOI: 10.1002/bbb.1753*
- *Dale VH, Kline KL, Richard TL, Karlen DL, Belden WW (In review) Selecting indicators of changes in ecosystem services due to cellulosic-based biofuel in the midwestern United States. Biomass and BioenergyDale VH, RA Efroymson, KL Kline, and M Davitt. (2015) A framework for selecting indicators of bioenergy sustainability. Biofuels, Bioproducts & Biorefining 9(4):435-446. DOI: 10.1002/bbb.1562*
- *Dale VH, KL Kline, MA Buford, TA Volk, CT Smith, I Stupak (2016) Incorporating bioenergy into sustainable landscape designs. Renewable & Sustainable Energy Reviews 56:1158-1171. http://authors.elsevier.com/sd/article/S1364032115014215*
- *Efroymson RA, Kline KL, Angelsen A, Verburg PH, Dale VH, Langeveld JWA, McBride A (2016) A causal analysis framework for land-use change and the potential role of bioenergy policy. Land Use Policy (59) 516–527 http://dx.doi.org/10.1016/j.landusepol.2016.09.009*
- *Kline KL, Msangi S, Dale VH, Woods J, Souza G, Osseweijer P, Clancy J, Hilbert J, Mugera H, McDonnell P, Johnson F (2016) Reconciling food security and bioenergy: priorities for action. Global Change Biology Bioenergy doi: 10.1111/gcbb.12366.*
- *Parish ES, VH Dale, BC English, SW Jackson, DD Tyler. 2016. Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. Ecosphere 7(2):e01206. 10.1002/ecs2.1206.*
- *Joly CA, Huntley BJ, LM Verdade LM, Dale VH, Mace G, Muok B, Ravindranath NH (2015) Biofuel impacts on biodiversity and ecosystem services. Chapter 16 in (Souza GM and Joly CA, editors) Scientific Committee on Problems of the Environment (SCOPE) Rapid Assessment Process on Bioenergy and Sustainability, Paris, France.*
- *Smith, CT et al. (including Kline KL, Parish ES, and Dale VH) (2015) Mobilizing Sustainable Bioenergy Supply Chain, Inter-Task Project Synthesis Report, IEA Bioenergy ExCo:2015:04 http://www.ieabioenergy.com/publications/mobilizing-sustainable-bioenergy-supply-chains*
- Kanter DR, Musumba M, Wood SLR, Palm C, Antle J, Balvanera P, Dale VH, Havlik P, Kline KL, Scholes RJ, Thornton P, Tittonell P, Andelman S (2017) Evaluating agricultural trade-offs in the age of sustainable development. *Agricultural Systems*.

Additional References

- Dale VH, KL Kline, ES Parish, AL Cowie, TC Smith, NS Bentsen, G Berndes, et al., 2017. Status and prospects for renewable energy using wood pellets from the southeastern United States. GCB Bioenergy. GCB Bioenergy doi: 10.1111/gcbb.12445. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12445/full
- Dale VH, RA Efroymson, KL Kline, MH Langholtz, PN Leiby, GA Oladosu, MR Davis, ME Downing, MR Hilliard. 2013. Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures. Ecological Indicators 26: 87-102. http://dx.doi.org/10.1016/j.ecolind.2012.10.014
- Dale VH, Kline KL, Marland G, Miner RA. 2015. Ecological objectives can be achieved with wood-derived bioenergy. Frontiers in Ecology and the Environment 13(6):297-299.
- Dale VH, Parish ES, Kline KL, Tobin E (2017) How is wood-based pellet production affecting forest conditions in the southeastern United States? Forest Ecology and Management 396: 143-149. doi.org/10.1016/j.foreco.2017.03.022 https://authors.elsevier.com/a/1UxyW1L~GwCo5V
- Dale VH and KL Kline. 2017. Interactive Posters: A valuable means for enhancing communication and learning about productive paths toward sustainable bioenergy. Biofuels, Bioprod. Bioref. 11:243-246. DOI: 10.1002/bbb.1753 http://onlinelibrary.wiley.com/doi/10.1002/bbb.1753/epdf
- Doerr SH, Santın C. 2016. Global trends in wildfire and its impacts: perceptions versus realities in a changing world. Phil. Trans. R. Soc. B 371:20150345. http://dx.doi.org/10.1098/rstb.2015.0345
- Efroymson RA et al. 2013. Environmental indicators of biofuel sustainability: What about context? Environ Mgmt 51(2): 291-306. http://web.ornl.gov/sci/ees/cbes/Publications/EfroymsonetaI2012biofuelindicatorcontextEMfinal10%201007_s00267-012-9907-5.pdf
- Efroymson RA, Kline KL, Angelsen A, Verburg PH, Dale VH, Langeveld JWA, McBride A (2016) A causal analysis framework for land-use change and the potential role of bioenergy policy. Land Use Policy (59) 516–527 http://dx.doi.org/10.1016/j.landusepol.2016.09.009
- Giglio L., J. T. Randerson, G. R. van derWerf, P. S. Kasibhatla, G. J. Collatz, D. C. Morton, and R. S. DeFries. Assessing variability and long-term trends in burned area by merging multiple satellite fire products. Biogeosciences, 7, 1171–1186, 2010.
- Kline KL, Msangi S, Dale VH, Woods J, Souza G, Osseweijer P, Clancy J,Hilbert J, Johnson F, McDonnell P, Mugera H (2016) Reconciling food security and bioenergy: priorities for action. Global Change Biology-Bioenergy. DOI: 10.1111/gcbb.12366
- Koponen K, Soimakallio S, Kline KL, Cowie A, Brandão M (Resubmitted 2017) Quantifying the climate effects of bioenergy - choice of reference system. RSER-D-16-02849R1 Renewable & Sustainable Energy Reviews
- McBride A et al. (2011) Indicators to support environmental sustainability of bioenergy systems. *Ecological Indicators* 11(5) 1277-1289.
- Randerson JT, Chen Y, Van Der Werf GR, Rogers BM, Morton DC. 2012 Global burned area and biomass burning emissions from small fires. J. Geophys. Res. Biogeosci. 117, G04012
- U.S. Department of Energy. 2017. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1. RA Efroymson, M. H. Langholtz, K.E. Johnson, and B. J. Stokes (Eds.), ORNL/TM-2016/727. Oak Ridge National Laboratory, Oak Ridge, TN. 642p. doi 10.2172/1338837. https://www.bioenergykdf.net/billionton2016vol2
- U.S. Depart of Energy (DOE) 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448 pg.
- Wear, DN and JW Coulston 2015. From sink to source: Regional variation in U.S. forest carbon futures. Sci. Rep. 5, 16518; doi:10.1038/srep16518
- Weir D, Greis J. The Southern Forest Futures Project: Technical Report Gen. Tech. Pre. SRS-178. United States Department of Agriculture. Forest Service, Research and Development, Southern Research Station, 2013. 553 pg.

Related reading

- Dale B et al. 2014. Take a closer look: biofuels can support environmental, economic and social goals. ES&T48(13):7200-7203
- Dale VH et al. 2013. Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures. Ecological Indicators 26: 87-102. http://dx.doi.org/10.1016/j.ecolind.2012.10.014
- Dale VH et al. 2016. Incorporating bioenergy into sustainable landscape designs. *Renewable & Sustainable Energy Reviews* 56:1158-1171. http://authors.elsevier.com/sd/article/S1364032115014215
- Dale VH et al.(Submitted 2016 for Biomass & Bioenergy Special Issue on Biofuels and Ecosystem Services) Selecting indicators of changes in ecosystem services due to cellulosic-based biofuels in the midwestern US.
- Efroymson RA et al. 2013. Environmental indicators of biofuel sustainability: What about context? Environmental Management 51(2): 291-306. http://web.ornl.gov/sci/ees/cbes/Publications/Efroymsonetal2012biofuelindicatorcontextEMfinal10%201007_s00267-012-9907-5.pdf
- FAO (2015a) Hunger Map 2015. FAO Statistics Division, Rome. Available: http://www.fao.org/hunger/en/
- FAO (2015b) Forty-second Session Report, Committee on World Food Security, Rome, Italy, 12-15 October 2015. Global Strategic Framework for Food Security & Nutrition (GSF) Available at: http://www.fao.org/3/a-mo187e.pdf Last Accessed 10/10/2015.
- FAO, IFAD, WFP (2013) The State of Food Insecurity (SOFI) in the World 2013 -The multiple dimensions of food security. And FAO, IFAD, WFP (2014) SOFI Strengthening the enabling environment for food security and nutrition. FAO Rome. And FAO, IFAD, WFP (2015) SOFI Meeting the 2015 international hunger targets: taking stock of uneven progress. FAO, Rome, Italy
- Kline KL, Dale VH (2008) Biofuels, causes of land-use change, and the role of fire in greenhouse gas emissions. Science, 321, 199.
- Kline KL, Dale VH, Lee R, Leiby P (2009) In Defense of Biofuels, Done Right. Issues in Science and Technology, 25(3), 75-84
- Kline KL, Oladosu GA, Dale VH, McBride AC (2011) Scientific analysis is essential to assess biofuel policy effects. Biomass and Bioenergy, 35, 4488-4491
- Kline KL (2014) Advanced School on Present and Future of BioEnergy, ESPCA–FAPESP–University of Campinas, 10-17 October, 2014. Campinas, SP Brazil.
- Kline KL et al. (2016) Reconciling biofuels and food security: priorities for action. GCB-Bioenergy. http://onlinelibrary.wiley.com/doi/10.1111/gcbb.12366/full
- McBride A et al. (2011) Indicators to support environmental sustainability of bioenergy systems. *Ecological Indicators* 11(5) 1277-1289.
- Parish ES et al. (2012) Multimetric spatial optimization of switchgrass plantings across a watershed. *BioFPR*. 6(1):58-72
- Parish ES, Kline KL, Dale VH, Efroymson RA, et al., (2013) Comparing Scales of Environmental Effects from Gasoline and Ethanol Production. Environmental Management 51(2):307-338
- REN 21 Renewables (2016) and (2014) Global Status Report Paris, REN21 Secretariat. http://www.ren21.net/status-of-renewables/global-status-report/
- IRENA (Jeff Skeer) (2016) Boosting Biofuels: Sustainable paths to greater energy security. www.irena.org
- Rainforest Alliance (2008) Impact of FSC Certification on Deforestation and the Incidence of Wildfires in the Maya Biosphere Reserve. http://www.rainforest-alliance.org/forestry/documents/peten_study.pdf
- Roser M (2015) Our World in Data. www.OurWorldinData.org
- Souza GM, Victoria RL, Joly CA and Verdade M, editors 2015. Scientific Committee on Problems of the Environment (SCOPE), Bioenergy & Sustainability: bridging the gaps. SCOPE 72. Paris, France and Sao Paulo, Brazil. ISBN: 978-2-9545557-0-6. http://bioenfapesp.org/scopebioenergy/index.php
- Sumner DA (2009) Recent commodity price movements in historical perspective. American Journal of Agricultural Economics, 91(5) 1250-1256
- Thurow R, Kilman S (2009) Enough: Why the World's Poor Starve in an Age of Plenty. BBS Public Affairs, New York.
- UNEP (2016) Unlocking the Sustainable Potential of Land Resources: Evaluation Systems, Strategies and Tools. Working Group on Land and Soils, International Resource Panel (IRP UNEP). Herrick, JE, O Arnalds, B Bestelmeyer, S Bringezu, G Han, MV Johnson et al. , ISBN: 978-92-807-3578-9
- USDA Economic Research Service (2015) Definitions of Food Security: Ranges of Food Security and Food Insecurity. U.S. Department of Agriculture
- Woodall et al. 2015. Monitoring Network Confirms Land-Use Change is a Substantial Component of the Forest Carbon Sink in eastern United States

Related reading cont

- Arezki et al. 2014. Understanding international commodity price fluctuations. Journal of International Money and Finance 42 (2014) 1–8
- Babcock, B. A. (2011 June). The impact of US biofuel policies on agricultural price levels and volatility. International Centre for Trade and Sustainable Development (35)
- Cowie A, Berndes G, and Smith T. 2013. On the timing of greenhouse gas mitigation benefits of forest based bioenergy. IEA Bioenergy ExCo: 2013:04 www.ieabioenergy.com/publications/on-the-timing-of-greenhouse-gas-mitigation-benefits-of-forest-based-bioenergy. Viewed 31 May 2015.
- Charles, C. (2012 April). Should we be concerned about competition between food and fuel? International Institute for Sustainable Development.
- de Gorter, H., & Just, D. R. (2010). The social costs and benefits of biofuels: The intersection of environmental, energy and agricultural policy. Applied Economic Perspectives and Policy.
- Economic Research Service, Amber Waves, 10(2 (June)), 2012.
- Durham, C., Davies, G., & Bhattacharyya, T. (2012, June). Can biofuels policy work for food security? Department for Environment Food and Rural Affairs.
- FAO, IFAD, IMF, OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI, and the UN HLTF. (2011, June 2). Price volatility in food and agricultural markets: Policy responses. Policy Report for the G-20 .
- King R (Oxfam), Kelbert A (IDS), Chisholm N (University College Cork), Hossain N (IDS). 2014. Help Yourself - Food Rights and Responsibilities: Year 2 findings from Life in a Time of Food Price Volatility. Joint Agency Research Report. www.ids.ac.uk and www.oxfam.org
- Kline KL, Msangi S, Dale VH, Woods J, Souza G, Osseweijer P, Clancy J,Hilbert J, Johnson F, McDonnell P, Mugera H (2016) Reconciling food security and bioenergy: priorities for action. Global Change Biology-Bioenergy. DOI: 10.1111/gcbb.12366
- Leonardo WJ, Florin MJ, van de Ven GWJ, Udo H, Giller KE Leonardo et al., 2015. Which smallholder farmers benefit most from biomass production for food and biofuel? The case of Gondola district, central Mozambique Biomass and Bioenergy 83:257-268
- Locke, A., Wiggins, S., Henley, G., & Keats, S. (2013 April). Diverting grain from animal feed and biofuels. London : Overseas Development Institute.
- McPhail, Lihong Lu, & Du, X. (2012). Ethanol Strengthens the Link Between Agriculture and Energy Markets.
- Peterka, A. (2012 31-July). Livestock groups urge EPA to waive ethanol mandate. Governors' Biofuels Coalition.
- Schafer, E. (2012 8-March). Proposed RFS changes spark food vs. fuel debate. Feed & Grain.
- Sepp S. 2014. Multiple-household fuel use; a balanced choice between firewood, charcoal and LPG. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (www.giz.de/hera), Eschborn, Germany, on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ). http://www.eco-consult.com/fileadmin/user_upload/pdf/Multiple-Household_Fuel_Use.pdf
- Thornhill S, Vargyas E, Fitzgerald T, Chisholm N (2016) Household food security and biofuel feedstock production in rural Mozambique and Tanzania. Food Security 8:953-972.
- Tyner, W. E., Taheripour, F., & Hurt, C. (2012 16-August). Potential impacts of a partial waiver of the ethanol blending rules. Farm Foundation and Purdue University.
- Wright, B. (2011, February). Biofuels and food security: Time to consider safety valves? . IPC Policy Focus, International Food and Agricultural Trade Policy Council.
- *2016 Billion-Ton Report. Volume 2: Advancing Domestic Resources for a Thriving Bioeconomy. Volume 2. Environmental Sustainability Effects of Select Scenarios:* https://energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-volume-2-environmental-sustainability-effects
- BT16 Resource Assessment for US biomass supplies volume 1: https://energy.gov/eere/bioenergy/2016-billion-ton-report

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