U.S. Department of Energy (DOE)
Bioenergy Technologies Office (BETO)
2017 Project Peer Review

4.2.2.40 Bioenergy Sustainability: How to define & measure it

March 6 (1:30 – 2:10)
Analysis and Sustainability

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Oak Ridge National Laboratory

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

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Goal Statement

- **Goals**
  - Define & advance <u>common definition</u> of ways to assess environmental & socioeconomic costs & benefits of bioenergy systems
  - <u>Quantify opportunities, risks, & tradeoffs</u> associated with sustainable bioenergy production in specific contexts

- **Relates to BETO's strategic goal:** "to understand and promote the positive environmental, economic, & social effects & reduce the potential negative impacts of bioenergy production activities" & <u>success factors:</u>
  - Consistent science-based message
  - Implementing indicators & methodology for evaluating & improving sustainability
- **Addresses industry needs**
  - Consistent & quantitative-based definition of bioenergy sustainability
  - Tools for quantification, aggregation of measures, & visualization
  - Examples of how to quantify sustainability in particular contexts

Quad Chart Overview

Timeline

- Project start date: FY16
- Project end date: FY18
- Percent completion: 47%

Barriers

- *Scientific consensus* on bioenergy sustainability (ST-A)
- Consistent & science-based message on bioenergy sustainability (ST-B)
- Implementing indicators & methodology for evaluating & improving sustainability (ST-D)

Budget

$k	FY16 Costs	FY17 Costs	Total Planned Funding (FY16-18)
DOE Funded	$750	$800	$2,400

In kind cost share by partners

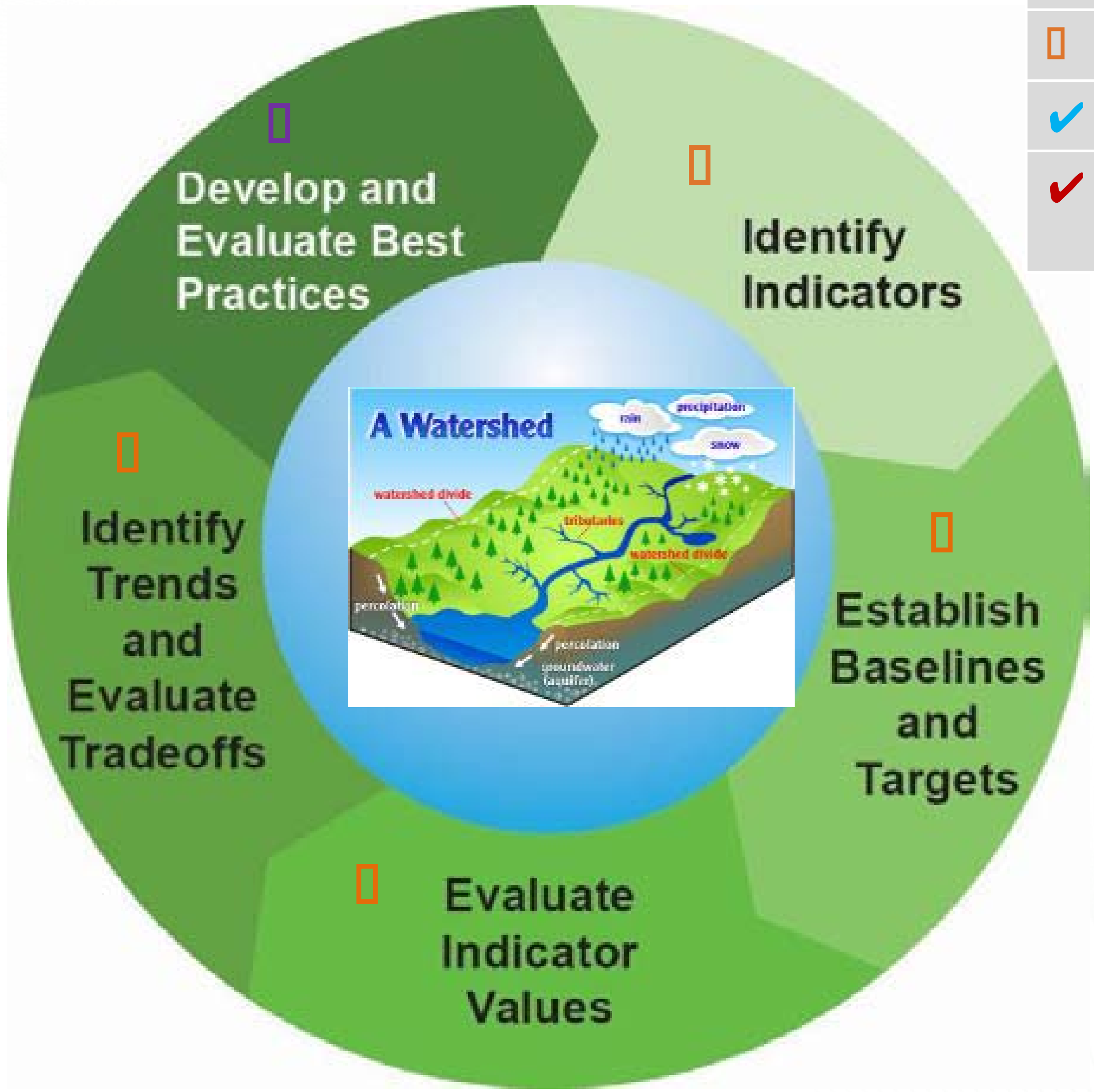
Partners

- Certification group: **SCS Global (.1%)**
- Universities: **Univ. Tennessee (8%)**, NC State Univ., Utrecht Univ., etc.
- Stakeholders: RSB (Roundtable on Sustainable Biomaterials), National Council on Air & Stream Improvement (NCASI), NGOs, Sustainable Forestry Initiative (SFI), etc.
- Other DOE Labs: NREL, ANL, INL, PNNL
- Other agencies: USDA, EPA, USFS, FAO (Food & Agriculture Organization), IEA Bioenergy
- Industry: Enviva, Genera, Weyerhaeuser

Only Univ. Tenn. & SCS Global received project funding; others provided their time

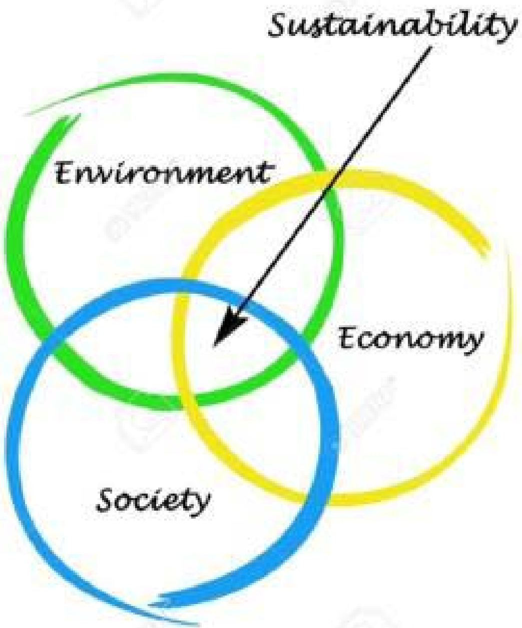
1 – Project Overview

Code for checks	
▯	Reviewed
▯	Tested in East TN
✔	SE woods pellets
✔	Iowa landscape design



ORNL developed this figure with BETO & NREL in 2009, & it still describes approach for assessing sustainability as set forth in BETO's Multi-Year Program Plan (MYPP)

Overview (continued)



- **Sustainability is the capacity of an activity to continue while maintaining options for future generations**
- **ORNL's research agenda includes**
  - Defining environmental & socioeconomic cost and benefits of bioenergy systems
  - Quantifying opportunities & risk associated with sustainable bioenergy and specific context.
  - Communicating the challenges & paths forward for sustainable bioenergy to a range of stakeholders
  - Deploying approach in case studies & thereby refining approach
- **Key challenges**
  - Scientific consensus on definition of sustainability
  - Quantitative & consistent way to implementing indicators & methodology for evaluating & improving sustainability

2 - Approach

- **Milestones defined & delivered**
  - Annual update of status of milestones
  - Quarterly reports & conference calls with BETO
- **Resources & partnerships leveraged**
  - Data & perspectives provided by others
    - University-led analysis (e.g., IBSS*)
    - Private: NGOs and industry
    - US agencies – esp. USDA
  - IEA Bioenergy has adopted ORNL's results & approaches
    - Task 43: Biomass Feedstocks for Energy Markets
    - Intertask on sustainability
    - Biweekly call with BETO focuses on international activities
  - Coordination with other National Labs
    - Bioenergy Study Tour & resulting analysis
    - Testing of indicator-to-best practices (BP) approach
    - Monthly sustainability & biweekly international calls
- **Go/no go test of visualization tool in conjunction with stakeholder community**
- **Science based results**
  - Posted on BETO's Knowledge Discovery Framework (KDF) & CBES website to archive & share
  - Presented in diverse workshops & meetings to gain input
  - Published in peer-reviewed literature, industry reports, & by IEA Bioenergy

*IBSS is Southeastern Partnership for Integrated Bioenergy Supply Systems (IBSS) supported by USDA (as an AFRI-CAP project)

2 - Approach

– ***ORNL Team:***
- Virginia Dale, landscape ecologist (PI)
- Latha Baskaran, watershed modeling
- Rebecca Efroymson, risk assessment
- Keith Kline, energy specialist & international issues
- Esther Parish, geographer
- Nate Pollesch, mathematician (now with EPA)
- Mike Hilliard, optimization analyst

– ***Contributing team***
- Other ORNL staff
- Scientists at other DOE Labs
- University partners
- Other agencies: USDA, EPA, FAO, IEA Bioenergy
- Private partners: Industry & NGOs

– ***Review of progress***
- Publications: 12 in peer reviewed journals for 2015-2017 (and 7 in review), 4 international reports & chapters, 1 dissertation, & 8 reports to BETO
- Presentations at conferences: > 30 for 2015-2017
- Engagement with stakeholders: April 2016 Bioenergy Study Tour, publications in industry reports, participation in stakeholder's workshops, etc.

RSB ROUNDTABLE ON SUSTAINABLE BIOMATERIALS

GBEP Global Bioenergy Partnership

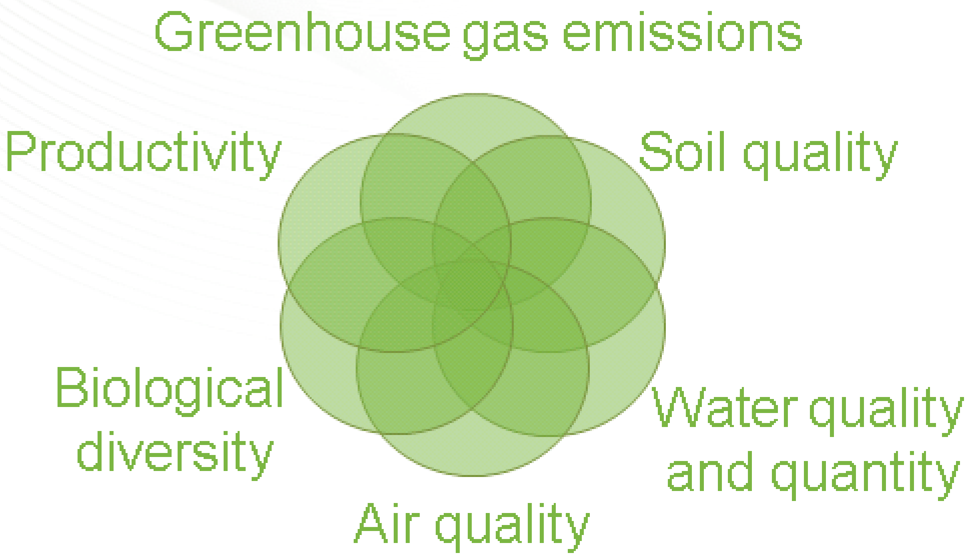
SUSTAINABLE FORESTRY INITIATIVE

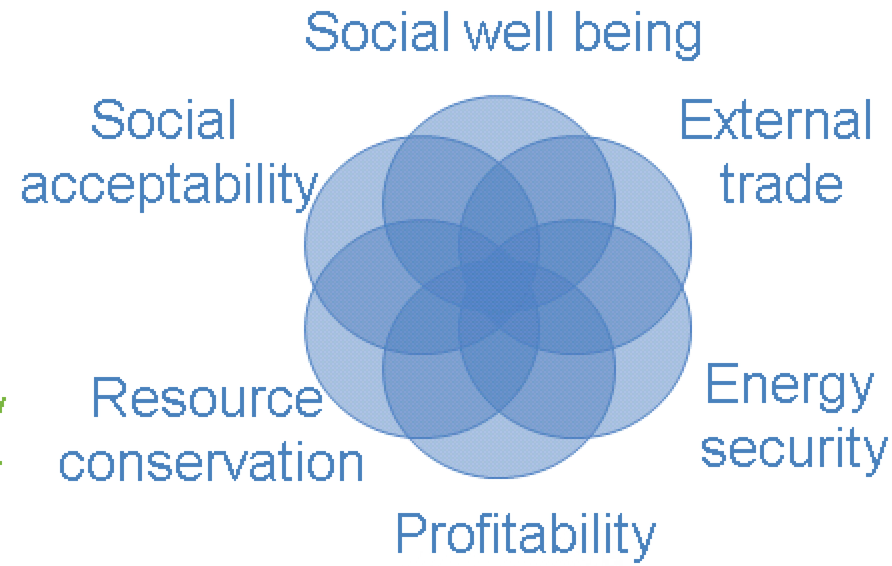
IEA Bioenergy

OAK RIDGE National Laboratory

ORNL's Sustainability Indicators

(35 in 12 categories)





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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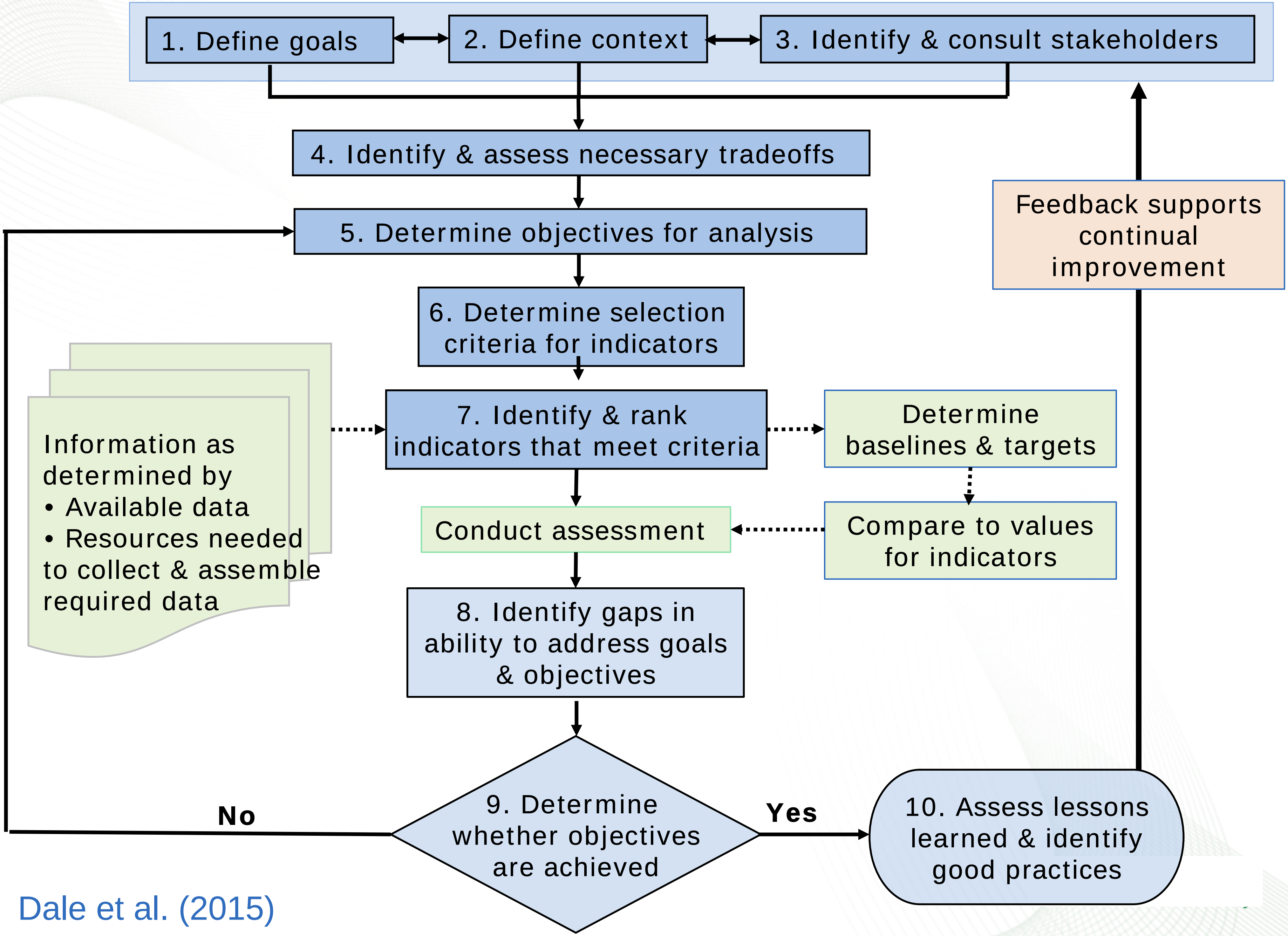
Framework for Selecting Indicators



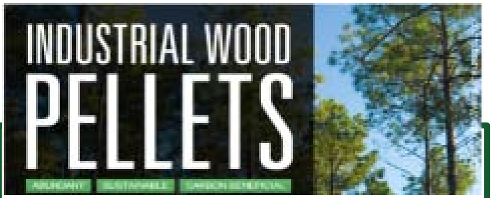
Dale et al. (2015)

Testing approach via case studies that integrate bioenergy goals via landscape design to improve resource management

Dale et al. (2016) Renew. & Sust. Energy Rev.

3 - Technical accomplishments & next steps

- **Testing approach via case studies**
  - Switchgrass in east TN used for ethanol
  - Wood-based pellets in SE US for bioenergy in Europe
  - Next step = cellulosics in Iowa used for ethanol
- **Making progress on approach to define & quantify progress toward sustainable bioenergy**
  - Relating indicators to ecosystem services
  - Normalization & aggregation
  - Next step = Visualization



Example of exports at risk: US pellet exports valued at $1 billion (2015)

Aggregating data about sustainability indicators

- **Multiple indicators span environmental, social & economic dimensions**
  - **Normalization** transforms measurements from original units to common measurement units

  - Advantages of **target normalization**
    - ➢ Allows for inclusion of context specific baselines & target values
    - ➢ Consistent functional forms across different bearing types for baseline (B) & target (T)
      - More is better (e.g., biodiversity) B → T
      - Less is better (e.g., nitrates in streams) T ← B
      - Medium is better (e.g., soil compaction) relative to lower & upper bounds (B_L & B_U) B_L ← T → B_U

  - **Aggregation**
    - ➢ Applies mathematical properties of aggregation functions
    - ➢ Inconsistencies arise if properties of aggregation functions aren't considered

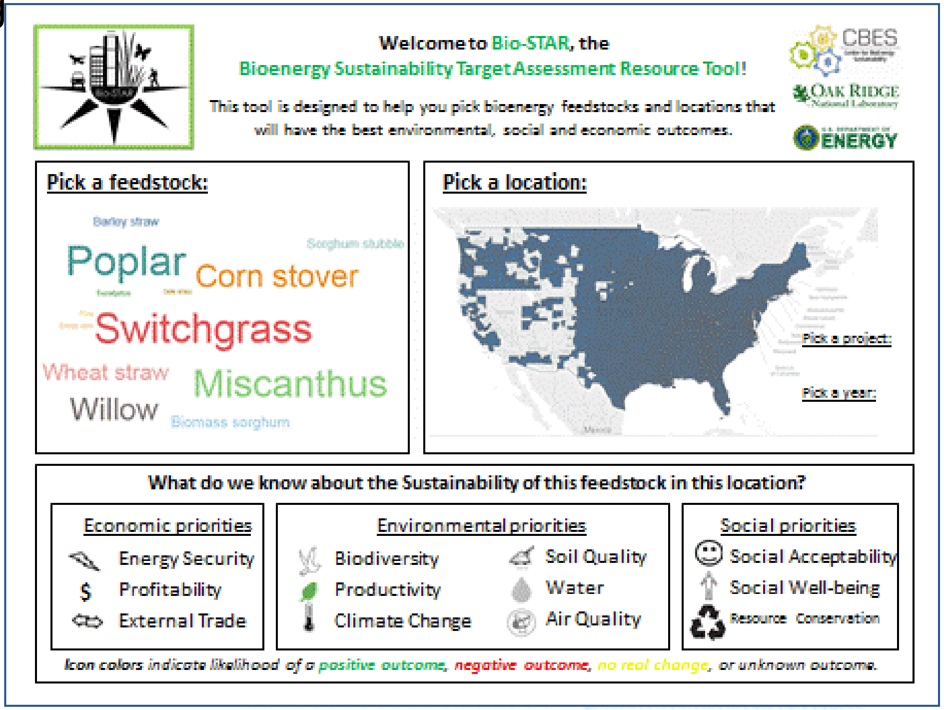
Pollesch & Dale (2015 & 2016) Ecol. Econ.
Pollesch (2016) PhD dissertation in Mathematics

Future work: Develop tool to visualize progress toward sustainability

- **Purpose:** Helps users move from amorphous concept of "sustainability" to priority conditions that can be measured & monitored.

- **Process:** Develop & test visualization tool (start with a demo: switchgrass in east TN)
  - Displays information about progress being made toward bioenergy sustainability
    - In a particular contexts
    - As defined by the users
    - As characterized by a suite of environ-mental, social & economic indicators
  - Mathematically robust
  - Allows consideration of tradeoffs

- **Audience**: Diversity of stakeholders: public, landowners, NGOs, industry, researchers, etc.
- **Input from stakeholders:** March 28, 2017 workshop



Bioenergy Sustainability Target Assessment Resource (BioSTAR)

Building from what we learned via interactive posters

- Learned how to visualize complex data
- Identified key opportunities & constraints for bioenergy
- Received input from diverse communities

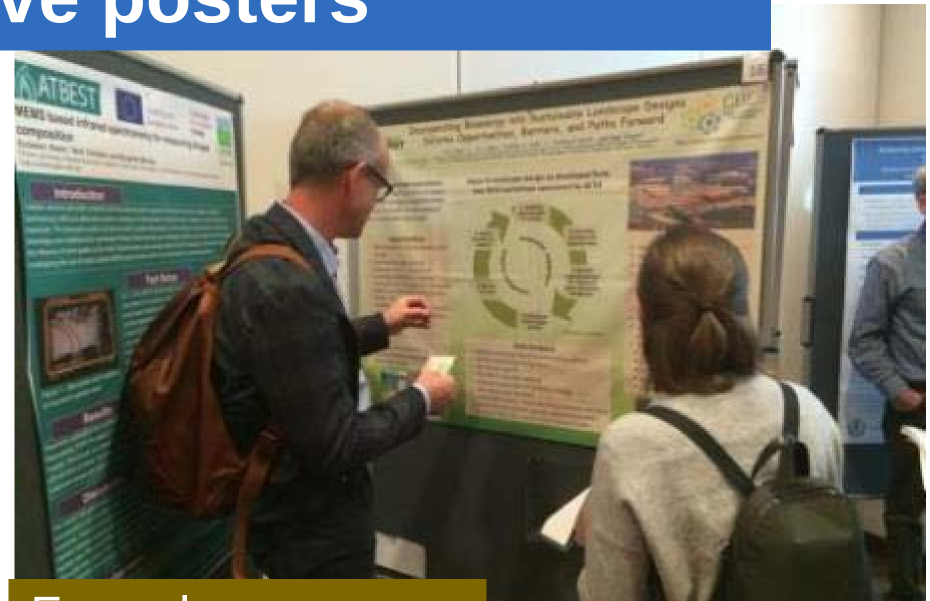
BIO ENERGY 2015

AGU American Geophysical Union

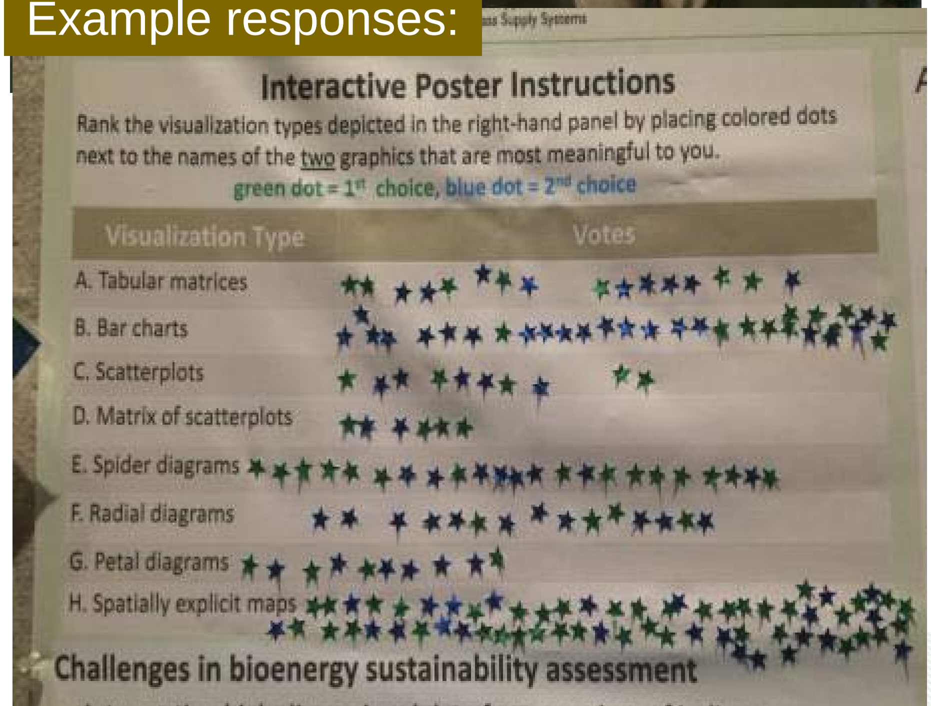
BIO ENERGY 2016

IEA Bioenergy

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



Example responses:

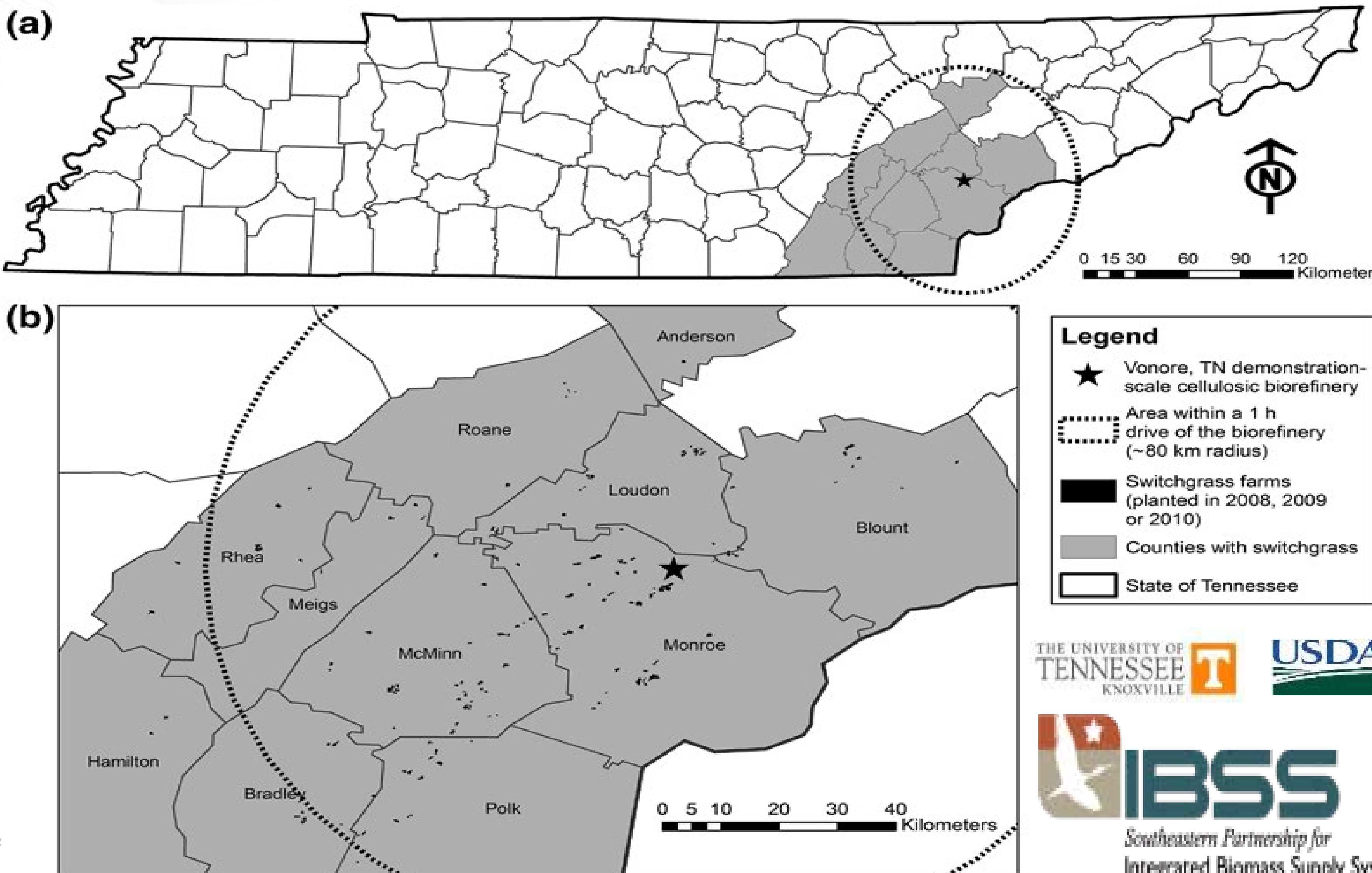


First case study: Switchgrass in east TN

- Dale et al. (2011) Ecological Applications 21(4):1039-1054.
- Parish et al. (2012) Bioprod. Bioref. 6(1):58-72.
- Parish (2016) Auburn Speaks: On Biofuels in the Southeast.

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)



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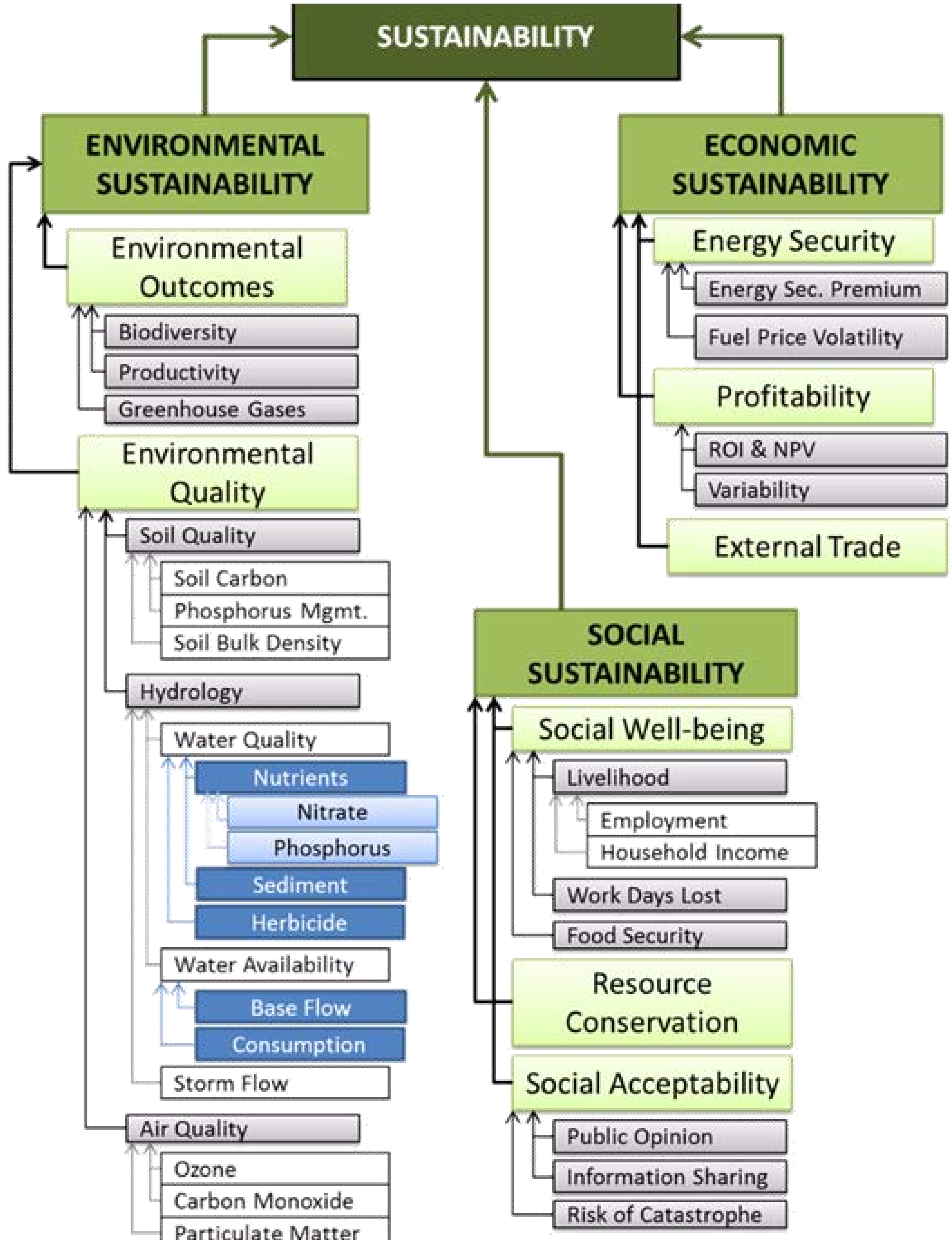
USDA

IBSS
Southeastern Partnership for Integrated Biomass Supply Systems

Previously aggregated the 35 indicators

Case Study goals:

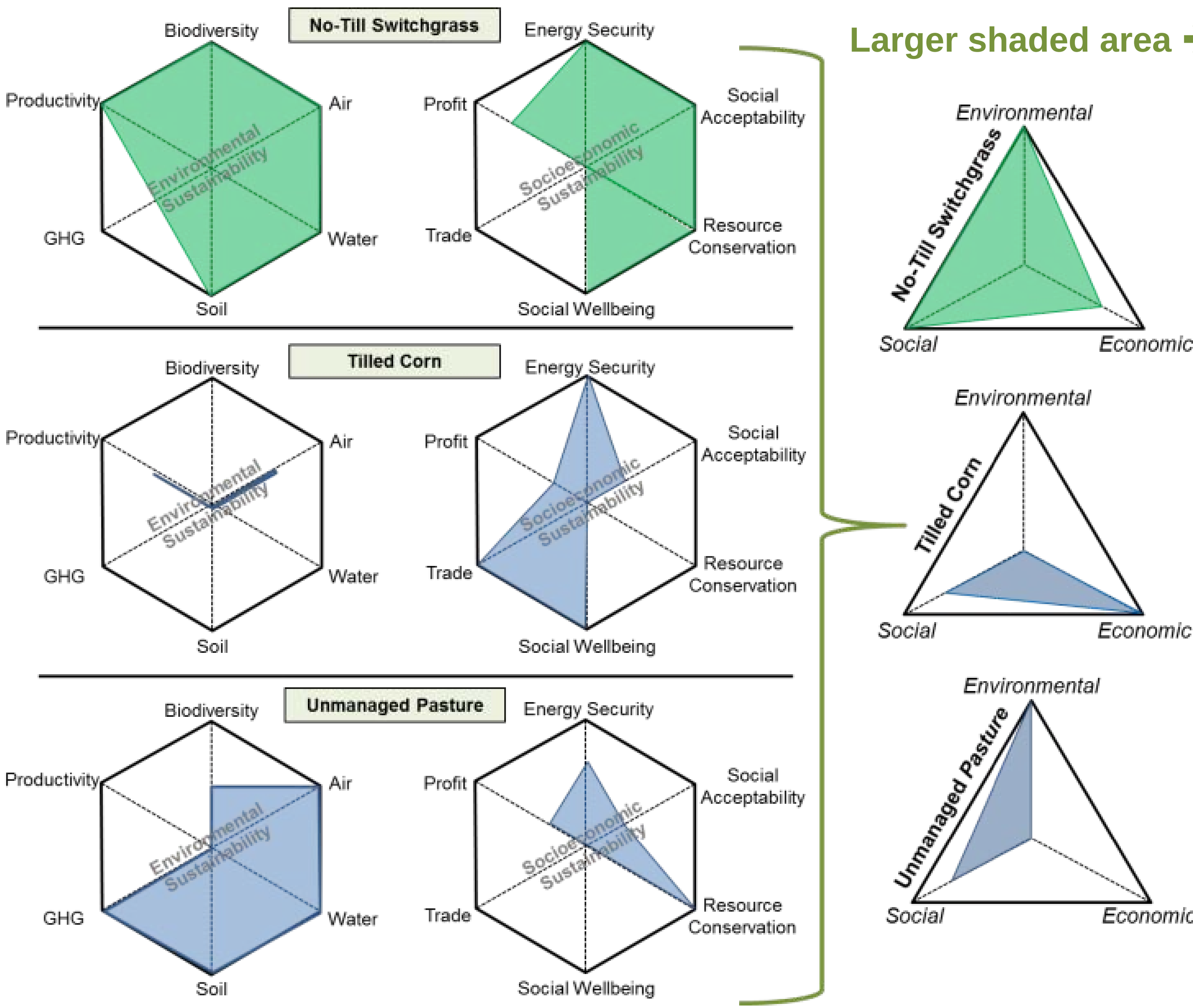
- Collect data for as many of the 35 recommended ORNL bioenergy sustainability indicators as possible
- Appropriately aggregate them within a framework that can be adjusted according to stakeholder priorities.



Parish, ES, VH Dale, BE English, S Jackson, and D Tyler (2016) Assessing multimetric aspects of sustainability: Application to a bioenergy crop production system in East Tennessee. *Ecosphere7(2):1-18*

Example: Aggregation of sustainability indicators

Larger shaded area ➔ more sustainable



Conclusion

East TN switchgrass production

- Improves environmental quality
- Can provide income & jobs.

Parish et al. (2016) Ecosphere

Future work: Improve Understanding of the Certification Process

- **Team:** ORNL & Univ. TN working with Genera Energy & the Roundtable on Sustainable Biomaterials (RSB)
- **Goal:** to evaluate the costs & benefits of certification of switchgrass for bioenergy in East TN
- **Verification:** by independent auditor (SCS Global Services)
- **Process will document**
  - Benefits & costs to industry of the certification process
  - Steps involved.

RSB ROUNDTABLE ON SUSTAINABLE BIOMATERIALS

GENERA

THE UNIVERSITY OF TENNESSEE KNOXVILLE

SCSglobal SERVICES

Of interest to BETO & IEA Bioenergy InterTask on Sustainability

IEA Bioenergy

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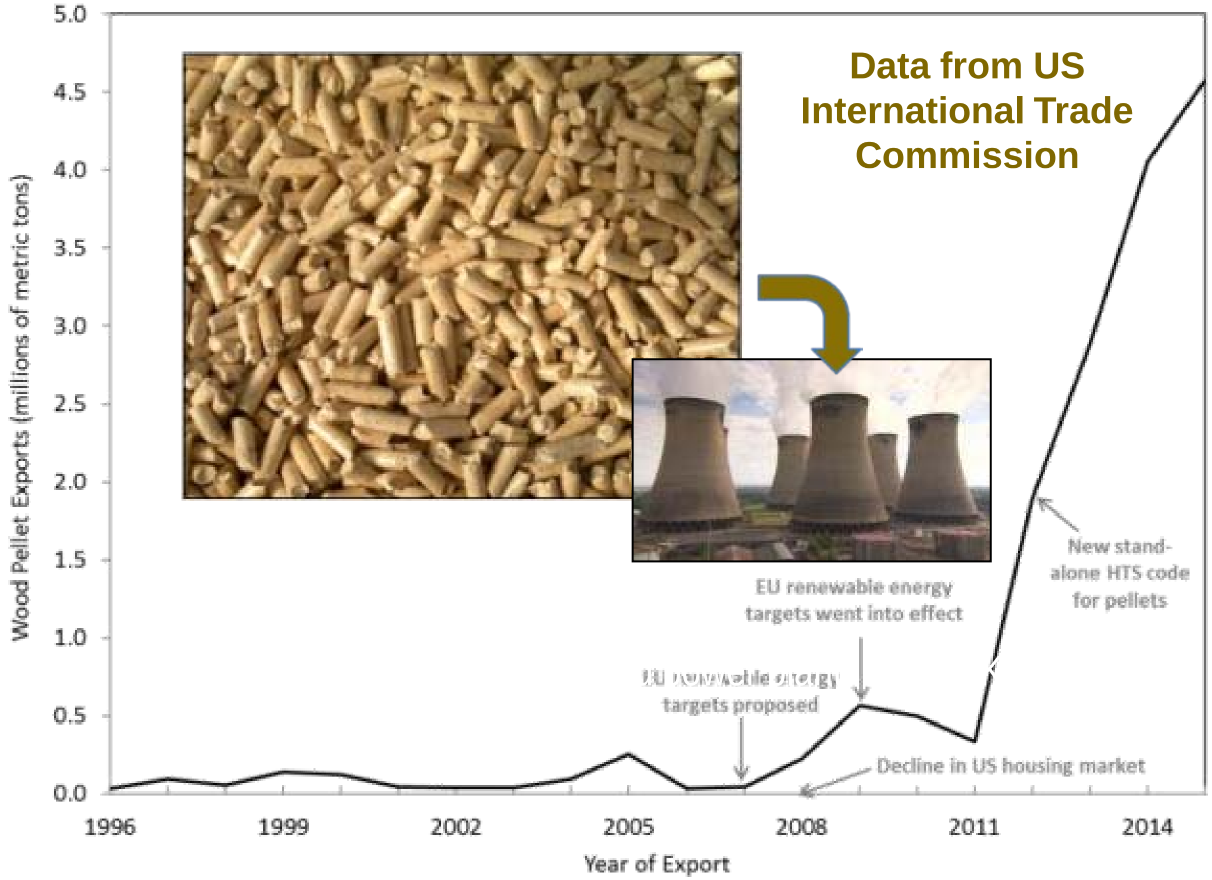
Second case study:
How sustainable are SE US wood pellet exports to Europe?

Southern Longleaf Pine Forest

Bottomland Hardwood Forest

US industrial wood pellet trade is growing



Existing markets in US could grow

Key sustainability research questions

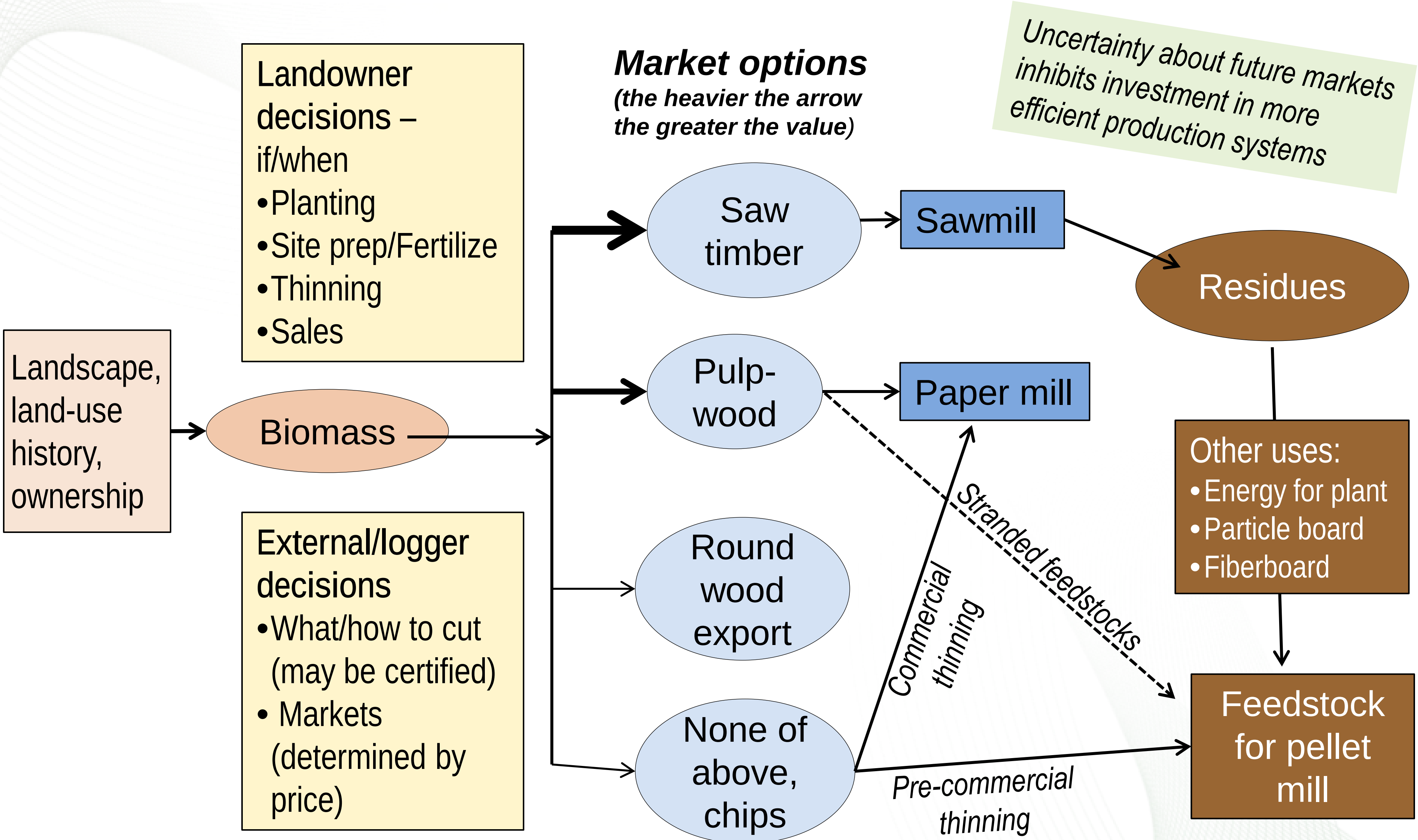
- **How does SE US pellet production for export to EU differ from business-as-usual case of no pellet production?**
  - ➢ Under what conditions does the pellet industry complement or compete with pulpwood use?
  - ➢ Will pellet industry alter amount of land staying in the forest?

- **Are there significant changes to key indicators?**
  - ➢ Biodiversity
  - ➢ GHG emissions
  - ➢ Soil quality
  - ➢ Jobs
  - ➢ Water & air quality
  - ➢ Preserving land as forest

- **How can forest conditions be monitored & good practices implemented?**
  - ➢ Analysis of Forest Inventory & Analysis (FIA) data
  - ➢ Best Management Practices (BMPs)
  - ➢ Other

Participants of ORNL's Bioenergy Study Tour are helping address these questions

Factors to consider: woody biomass for pellets is at end of value chain



What we have learned?

- Sustainability concerns
  - NGOs most concerned about biodiversity, GHG emissions, loss of old growth & bottom land forests
  - EU is requiring certification of wood used for energy
- Owners of SE US forests
  - 85% are owned private nonindustrial (e.g., families)
  - Family landowners make decisions based on immediate needs (e.g., health care, education)
- Mills that export pellets require feedstock to originate from sites supervised by logging professionals trained in wildlife habitat conservation, water quality, & other BMPs.
  - Logger training is a component of the Sustainable Forestry Initiative's (SFI's) certified Fiber Sourcing Standard.
  - 92% of certified acres in the SE US are certified to SFI or ATFS

Bottom-line: ORNL is
- **building from existing certification & monitoring systems &**
- **assessing how they relate to the DOE/ORNL's approach.**

Dale + 33 coauthors (Revision in review) *GCB Bioenergy*

OAK RIDGE National Laboratory

Monitor outcomes

Using USDA Forest Inventory & Analysis (FIA)

FIA demonstration plot at Univ. TN Arboretum in Oak Ridge

Considered major export ports of pellets in SE USA:

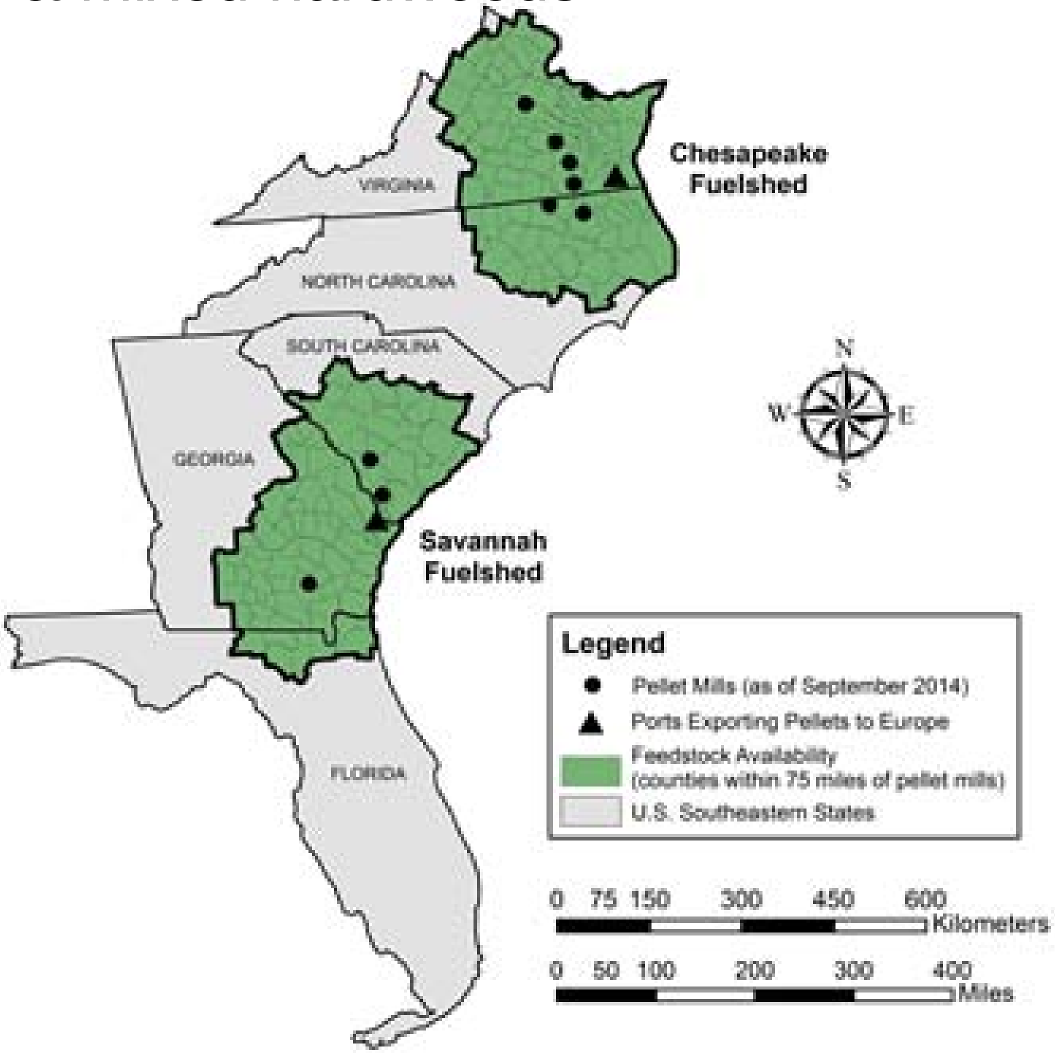
- Savannah: mostly intensively managed pine plantations
- Chesapeake: both pine & mixed hardwoods

***Fuelsheds*: Counties within 120 km (75 miles) of pellet mills that supply ports**

Each fuelshed area has an area of ~12 million ha.

Chesapeake Fuelshed:
- 33 NC counties
- 69 VA counties

Savannah Fuelshed:
- 22 SC counties
- 54 GA counties
- 7 FL counties



Dale et al. (Revision in review) *For Ecol & Mgt*

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Results from analysis of FIA data

- **Both fuelsheds:** Significant increases in
  - ➢ Timberland volume in plantations
  - ➢ Areas with large trees
  - ➢ # standing dead trees/ha in naturally regenerating stands
- **Chesapeake fuelshed:** Sign. Increases in
  - ➢ Timberland volume in plantations
  - ➢ Harvestable carbon
- **Savannah fuelshed**
  - ➢ Sign. increases in
    - ➢ Timberland volume
    - ➢ All carbon pools
  - ➢ Sign. decreases in # standing dead trees/ha in plantations

Conclusions

- Provides empirical support of prior estimates that production of wood-based pellets in the SE US can enhance GHG sequestration.
- Calls for further study of effects on biodiversity of declines in # of standing trees/ha
  - ➢ Note: others recommend thinning & hardwood midstory control in pine plantations to provide habitat for declining bird species (consistence with use of biomass for energy & reducing risk of fire).
  - ➢ ORNL will focus analysis on an organism that may be affected by such declines

Dale et al. (Revision in review) *For Ecol & Mgt*

Future work: Determine if taxa of special concern are being affected

Either

Directly, via declines in populations

Or

Indirectly, through losses of habitat (e.g., pine forests)

Red cockaded woodpecker
(Picoides borealis)

Gopher tortoise
(Gopherus polyphemus)

Tortoise burrows provide homes for many organisms

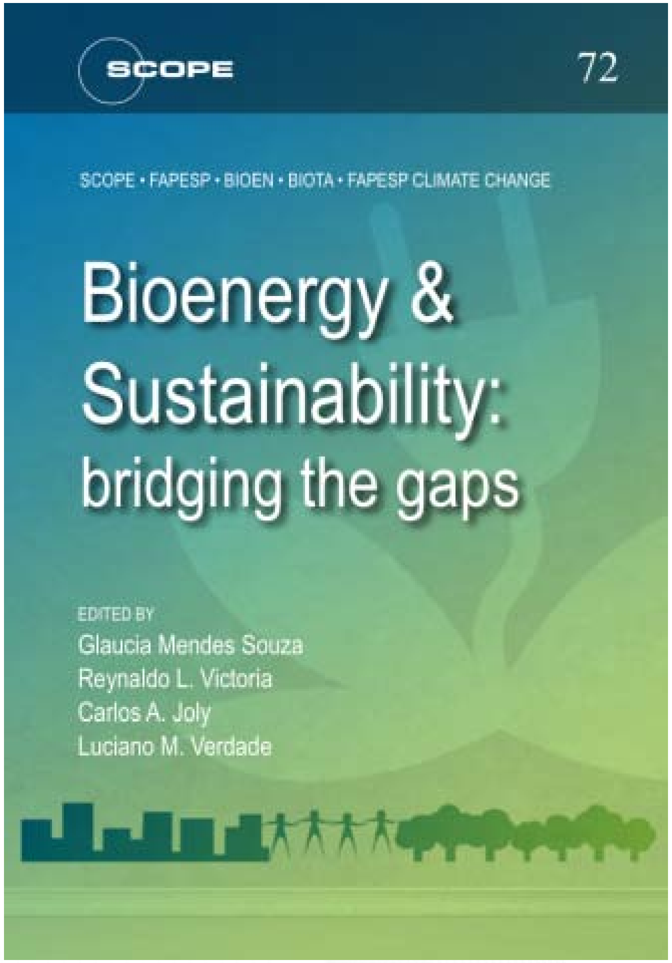
Biodiversity analysis will build from SCOPE chapter: *Biofuel Impacts on Biodiversity & Ecosystem Services*

Recommendations for protection:

- **<u>Priority biodiversity areas</u> are conserved;**

- **<u>Context specific</u> effects of biofuel feedstock production on biodiversity & ecosystem services are identified;**

- **<u>Location-specific management</u> of biofuel feedstock production systems should be implemented to maintain biodiversity & ecosystem services.**



Joly, Huntley, Verdade, Dale, Mace, Muok, Ravindranath (2015)

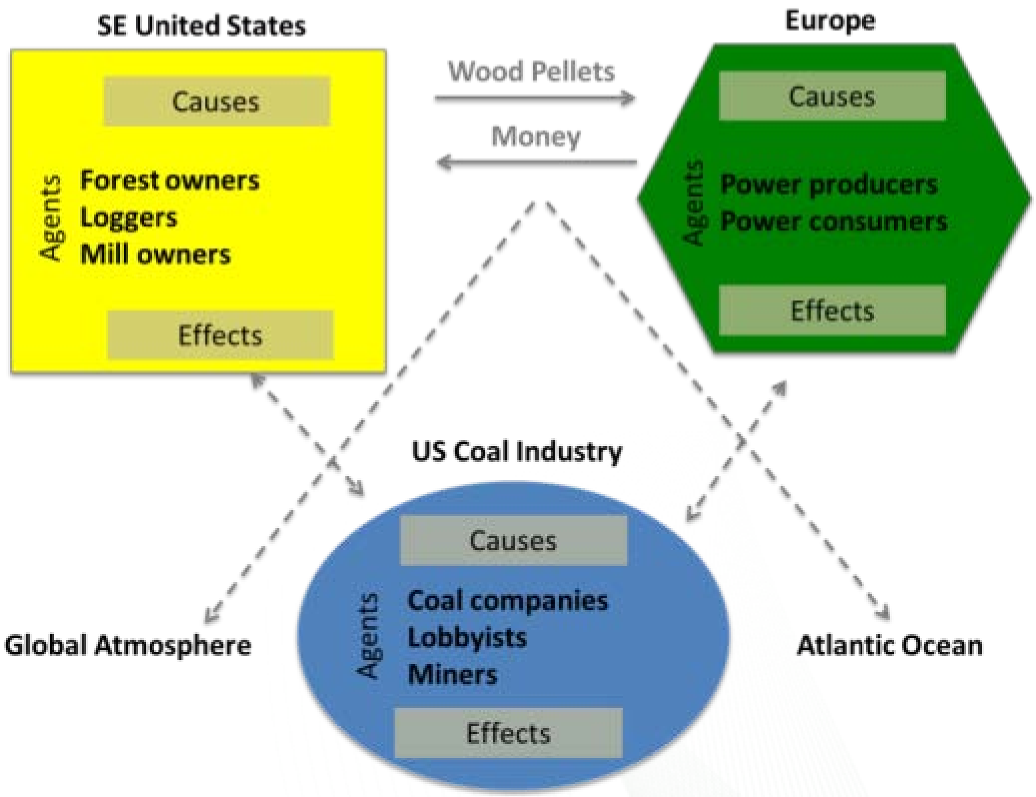
http://bioenfapesp.org/scopebioenergy/index.php

Effects of the transatlantic wood pellet trade suggested from telecoupling analysis

System can provide benefits for both SE US & Europe.

- Environmental benefits
  - Enhanced management of SE US forests using income from bioenergy products can benefit water quality, biodiversity, carbon sequestration, & forest productivity
  - Reduction in
    - o Toxic air emissions related to coal combustion
    - o GHG emissions from energy production
    - o Air pollution due to reduced burning of woody debris
  - Preservation of EU forest land & associated ecosystem services
- Social economic benefits
  - Additional market opportunity for woody biomass helps SE US land remain in forest
  - Avoided job losses in rural SE US
  - Reduced risk of wildfires due to increased forest management

Telecoupled wood pellet trade system



Parish et al. (in review)

Relevance: Different groups have different priorities: We are filling gaps & making connections

Indicator categories	Stakeholder groups					
	NGOs	EU & UK	Industry (?)	Landowner		Workers
				Industrial	Family (?)	
GHG	+	+		+		
Soils	+	+		+		
Water	+			+		
Biodiversity	+	+		+	+	
Air	+			+		
Productivity	+			+		
Profit			+	+	+	
Energy security						
External trade		+	+			
Social wellbeing				+	+	+
Social acceptability			+	+		
Resource conservation	+					

Future work

- **Conduct surveys to learn about concerns of family foresters & industry & related opportunities**
  – ORNL and Univ. TN are deploying a survey to private nonindustrial landowners in SE US
  – Pinchot Society is deploying survey to pellet producers in SE US
  – Both results will be presented to IEA Bioenergy intertask workshop in May 2017
- **Assess effects of projected future changes in pellet demand** (working with Bob Abt – NCSU)
  – What are appropriate scenarios?
  – What are affects on forest conditions & key indicators?
  – Special attention to effects on biodiversity

Pellet mill visited during ORNL's Bioenergy Study Tour

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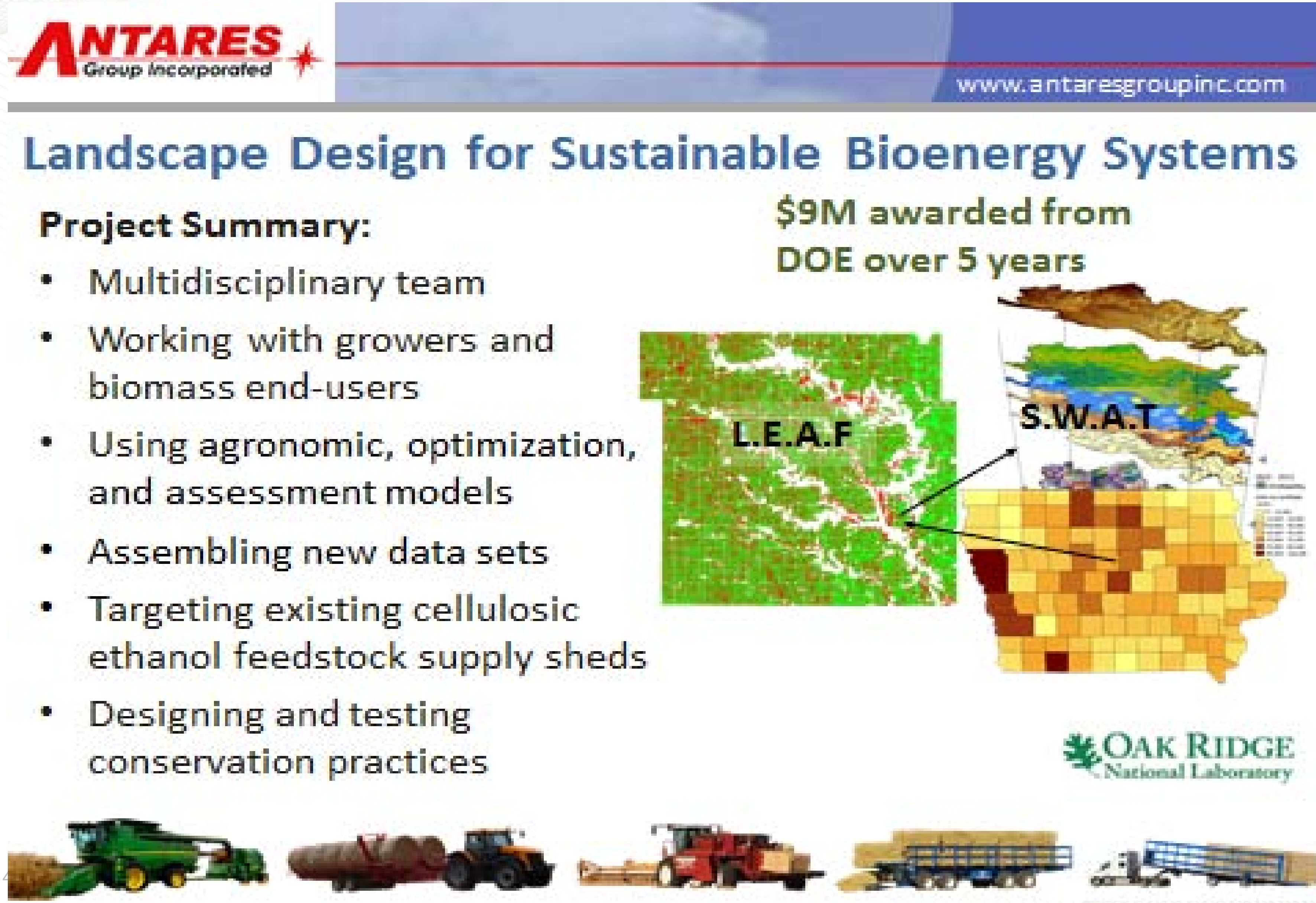
Future work: Third case study: Cellulosics in Iowa used to produce ethanol



4 – Relevance

- **Decreasing uncertainty in bioenergy industry**
  - Providing means to assess progress toward sustainable bioeconomy
- **Improving understanding about how to make progress toward sustainable bioenergy**
  - Providing tools to facilitate assessment
- **Reducing confusion about sustainability**
  - Focusing evaluation on measurable attributes that represent diversity of social, economic & environmental concerns
- **Enhancing benefits**
  - Identifying good practices

***"This is foundational to all of the other projects in BETO"* (2015 review)**

- **Other BETO efforts are building from our sustainability indicator approach**
  - ✓ Billion Ton Vol 2 takes a first step toward applying this approach
  - ✓ 4.2.1.41 conveys this approach to international & certification groups
  - ✓ BETO's algae work adopting this approach
- **Other programs use our concepts & approach**
  - ✓ DOE EERE Water Power Technologies Office
  - ✓ IEA Bioenergy

5 – Future Work

- Complete visualization tool for assessing progress toward sustainable bioenergy
- Case studies
  - Switchgrass in east TN
    - Analysis of certification process
  - Woody biomass in the SE US
    - Survey of family landowners in SE US
    - Stakeholder concerns & engagement (with IEA Bioenergy)
    - Appropriate scenarios, baseline & targets
    - Implications of future change in demand
  - Adapt & apply approach to third case study: landscape design project in Iowa
  - Assemble lessons learned
- Evaluate overall approach to assess progress toward bioenergy sustainability & its application
- Engage with IEA Bioenergy in interpreting & disseminating results to industry, NGOs, etc.

This work addresses strategic goals (from BETO's 2016 plan)

- Enhancing bioenergy value proposition
- Mobilizing our nation's biomass resources
- Cultivating end-use markets & customers
- Expanding stakeholder engagement

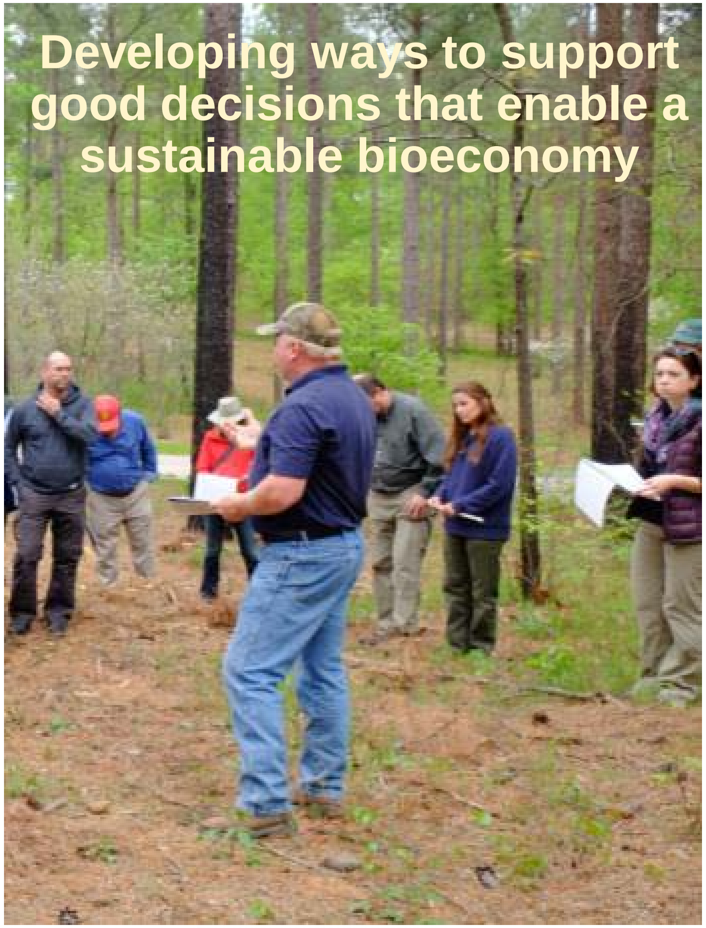
Summary (1)

Bringing stakeholders together to address goals

- **Overview:** Approach to define, quantify, communicate & deploy ways to make progress toward sustainable bioeconomy
- **Approach**
  - ✓ History & context: Developing & deploying approach that quantifies indicators & identifies good practices
  - ✓ Technical approach: Test analysis tools via case studies
  - ✓ Management:
    - Use of milestones & Go/No go to monitor progress
    - Disseminate broadly via publications, industry reports, workshops, etc.
  - ✓ Success factors: Incorporation by industry, NGOs, certification groups, & governmental bodies of consistent approach & means to assess progress toward sustainable bioeconomy
  - ✓ Challenges: "Sustainability" poorly defined & uses too many indicators that are too broad & too costly
- **Technical accomplishments/Progress/Results**
  - ✓ Identified checklist of indicators to advance common definition of bioenergy sustainability
  - ✓ Developed & adopted robust analysis tools
  - ✓ Quantified opportunities, risks, & tradeoffs in specific contexts
  - ✓ Began adoption of aggregation theory for assessment of bioenergy sustainability
  - ✓ Developing understanding of how to assess progress toward bioenergy sustainability
- **Relevance**
  - ✓ Decreasing uncertainties in bioeconomy
  - ✓ Improving understanding about how to make progress toward sustainable bioenergy
  - ✓ Reducing confusion about sustainability
  - ✓ Enhancing benefits

Summary (2)

- **Future work**
  - **Complete development, testing & deployment of tools for assessing progress toward sustainable bioenergy**
    - Go /No go decision for visualization tool
    - Engagement of stakeholders
  - **Case studies**
    - Switchgrass in east TN
      - Analysis of certification process
    - Woody biomass in the SE US
      - Survey of family landowners in SE US
      - Stakeholder engagement (with IEA Bioenergy)
      - Appropriate scenarios, baseline & targets
      - Implications of future change in demand
    - Landscape design project in Iowa
    - Assemble lessons learned
  - **Evaluate overall approach to assess progress toward sustainability bioeconomy**
  - **Technology transfer**
    - Engage with IEA Bioenergy to interpret & disseminate knowledge
    - Post information on BETO's Knowledge Discovery Framework (KDF) & CBES website to support archiving & sharing
    - Disseminate via journal articles, industry reports, workshops, & presentations
    - Provide indicators, framework, tools & ideas



Audience:
- IEA Bioenergy
- Industry
- Certifications efforts
- Land owners & managers
- Governmental bodies
- NGOs
- Scientists

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Thank you!

CBES

Center for BioEnergy Sustainability

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

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Acronyms

- AFRI-CAP = USDA's Agriculture and Food Research Initiative - Coordinated Agricultural Projects
- ANL = Argonne National Laboratory
- BETO = Bioenergy Technologies Office
- BMAS = Biomass Market Access Standards
- BMP = Best Management Practices
- CBES = Center for Bioenergy Sustainability (at Oak Ridge National Lab)
- EPA = US Environmental Protection Agency
- EPT richness = number of taxa in the insect orders Ephemeroptera, Plecoptera, & Trichoptera
- FAO = Food and Agriculture Organization
- GBEP = Global BioEnergy Partnership
- IBSS = Southeastern Partnership for Integrated Bioenergy Supply Systems (supported by USDA)
- IEA = International Energy Agency
- INL = Idaho National Laboratory
- MADSS = Multi-Attribute Decision Support Systems
- NCASI = National Council on Air and Stream Improvement
- NCSU= North Carolina State University
- NEWBio = Northeast Woody/Warm Season Biomass Consortium (supported by USDA)
- NGO = Non-governmental organization
- NREL = National Renewable Energy Laboratory
- PNNL = Pacific Northwest National Laboratory
- RSB = Roundtable for Sustainable Biomaterial
- SCOPE = Scientific Committee on Problems of the Environment
- USDA = US Department of Agriculture

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Journal Articles & Book Chapters: 2015 to 2017

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

In review

- Baskaran L, Tran L, Dale VH. (In review). Analyzing aquatic macroinvertebrate taxa richness indices across ecoregions in Tennessee. *American Midland Naturalist*.
- Baskaran L, Dale VH, Tran L. (In review) Potential of aquatic macroinvertebrates as water quality indicators: an evaluation across Tennessee, USA. *Freshwater Science.*
- Dale VH, Parish ES, Kline KL, Tobin E. (Revision in review) How does wood-based pellet production affect forest conditions in the southeastern United States? *Forest Ecology and Management.*
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- Parish ES, Herzeberger AJ, Phifer CC, Dale VH (In review) Telecoupled transatlantic wood pellet trade provides benefits in both the sending and receiving systems. *Ecology and Society* special feature on "Telecoupling: A New Frontier for Global Sustainability."
- Parish ES, Dale VH, Tobin E, Kline KL (In review) Data for assessing how wood-based pellet production affects forest conditions in the southeastern United States. Forest Ecology and Management.

2017

- 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*
- Hanssen SV, Duden AS, Junginger HM, Dale VH, van der Hilst F (2017) Wood pellets, what else? Greenhouse gas parity times of European electricity from wood pellets that are produced in the south-eastern United States using different softwood feedstocks. *GCB Bioenergy*. DOI: 10.1111/gcbb.12426.
- 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*.
- Souza G, Ballester MVR, Cruz CHB, Chum H, Dale B, Dale VH, Fernandes E, Foust T, Karp A, Lynd L, Maciel R, Milanez A, Nigro F, Osseweijer P, Verdade L, Victoria R, Van Der Wielen L (2017) The role of bioenergy in a climate-changing world. *Environmental Development Journal.*

Requests for our list of publications have come from : GBEP Global Bioenergy Partnership IEA Bioenergy

Journal Article & Book Chapters: 2015 to 2017

(Continued)

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- Berndes G, Abt R, Asikainen A, Cowie A, Dale VH, Egnell G, Lindner M, Marelli L, Paré D, Pingoud K, Yeh S (2016) Forest biomass, carbon neutrality and climate change mitigation. From Science to Policy 3. European Forest Institute, Finland. http://www.alphagalileo.org/AssetViewer.aspx?AssetId=116589&CultureCode=en A ThinkForest brief of the report is posted at http://www.efi.int/files/attachments/publications/efi_thinkforest-brief_carbon_neutrality.pdf\
- Dale VH, Parish ES, Kline KL. (2016) Lessons from the Forest Pages 18-22 in *World Biomass*. DCM Productions, United Kingdom. http://www.dcm-productions.co.uk/flippages/flipbook/index.html?page=1
- 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
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- 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.
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- Pollesch N, Dale VH (2016) Normalization in sustainability assessment: Methods and implications*. Ecological Economics* 130:195-208. http://dx.doi.org/10.1016/j.ecolecon.2016.06.018

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- Dale VH, Parish ES, Kline KL. 2015. Risks to global biodiversity from fossil-fuel production exceed those from biofuel production. *Biofuels, Bioproducts & Biorefining* 9(2):177-189.
- Dale 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
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- Pollesch N, Dale VH (2015) Applications of aggregation theory to sustainability assessment. *Ecological Economics* 114: 117-127.
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Environmental indicators for bioenergy sustainability & associated ecosystem services

Category	Ecosystem service: type	Sustainability Indicator
Soil quality	**Supporting & regulating service:** soil quality	Total organic carbon (TOC)
		Total nitrogen (N)
		Extractable phosphorus (P)
		Bulk density
Water quality and quantity	**Provisioning service:** drinking water; **Regulating service:** water purification **Cultural service:** recreation	Nitrate concentration in streams
		Total phosphorus (P) concentration in streams
		Suspended sediment concentration in streams
		Herbicide concentration in streams
		Peak storm flow
		Minimum base flow
		Consumptive water use (incorporates base flow)
Produc-tivity	**Provisioning services:** food, feed, fiber and fuel	Yield

McBride et al. (2013) & Dale et al. (in review)

Green-house gases	**Regulating services:** carbon sequestration & climate regulation **Crosscutting:** agrochemical use, feedstock transport/treatment and biofuel combustion.	CO_2 equivalent emissions (CO_2 and N_2O)
Air quality	**Provisioning service:** clean air	Tropospheric ozone
		Carbon monoxide
		Total particulate matter <2.5μm diameter ($PM_{2.5}$)
		Total particulate matter <10μm diameter (PM_{10})
Bio-diver-sity	**Diverse services depending on species & context:** for example pollination, seed dispersal, pest mitigation; **Supporting service:** habitat	Presence of taxa of special concern
		Habitat area of taxa of special concern

Socioeconomic indicators for bioenergy sustainability & associated ecosystem service

Category	Ecosystem service: type	Sustain-ability Indicator
Social well-being	**Cultural services:** jobs & family income; **Provisioning service**: food	Employment
		Household income
		Work days lost due to injury
		Food security
Energy security	**Provisioning service:** energy	Energy security premium
		Fuel price volatility
External trade	**Provisioning services**: food, feed, fuel & fiber	Terms of trade
		Trade volume

Profita-bility	**Provisioning services**: food, feed, fuel & fiber	Return on investment (ROI)
		Net present value (NPV)
Resource conserva-tion	**Provisioning services:** fuel, chemicals, plastics	Depletion of non-renewable energy resources
		Fossil Energy Return on Investment (fossil EROI)
Social accepta-bility	**Provisioning services**: food, feed, fuel & fiber	Public opinion
		Transparency
		Effective stakeholder participation
		Risk of catastrophe

Dale et al. (2015 & in review)

Responses to 2015 Review of 4.2.2.40

- Strengths (selected quotes from 2015 review)
  - “This project brings together all elements that are needed to understand sustainability of bioenergy writ large.”
  - “This is foundational to all of the other projects in BETO. It is innovative in its approach to providing a balanced, yet scientifically based approach to the issue.”
- Weaknesses/challenges (selected quotes from 2015 review)
  - “It is not clear exactly what has been accomplished in the evaluation of sustainability metrics for wood pellet production and trading.”
    - **Response: That part of the project was (and is) under development. Our 2015 framework paper now describes how to select indicators depending on the context, goals and stakeholders involved. We are conducting a survey this winter to learn more about the goals of private land owners (the first step in the process of selecting indicators), and our IEA bioenergy partners are surveying the pellet industry. Meanwhile we have been learning about current certification schemes, assessment data, and best management practices as they relate to production of wood-based pellets in the SE US for bioenergy. This work will continue into FY18.**
  - “The project has introduced a new approach to simplifying the presentation of metrics that seems to involve a rigorous mathematical technique for aggregating the complex set of metrics of sustainability in a set of high level indicators. This approach was not explained in any detail.”
    - **Response: We are still working to apply a rigorous and transparent mathematical technique for aggregating metrics (when appropriate). The deployment of this approach is under development & will be tested at a “Go/ No Go” workshop with key stakeholders (farmers, industry, representatives, logistics operators, BETO, etc.). The first version of the tool will be deployed in FY18. Slides 47 to 51 provide background on the approach.**

Results of 2015 Review for existing projects

Evaluation Criteria	Sustain-ability Platform Mean	This Pro-ject
Project overview	8.1	8.2
Project approach	7.9	8.5
Technical progress & accomplish-ments	8.0	8.7
Project relevance	8.4	9.0
Future work	7.8	7.8
Overall weighted average	7.8	8.53

Responses to 2015 Review:

Progress on normalization & aggregation

Why is Normalization Important in Sustainability Assessment?

- *Normalization:* The process of transforming measurements from the original units to common measurement units or unit-less quantities
- Normalization is done to:
  - Compare different indicator measurements
  - Prepare measurements for aggregation
  - Aid interpretation. For example, target-baseline normalization transforms measurements to values, which can be interpreted as some percentage of target attained

What Is Data Aggregation & Why Should You Care?

“Data aggregation is any process in which information is expressed in a summary form for purposes such as reporting or analysis. Ineffective data aggregation is currently a major component that limits query performance. And, with up to 90 percent of all reports containing aggregate information, it becomes clear why proactively implementing an aggregation solution can generate significant performance benefits, opening up the opportunity for companies to enhance their organizations’ analysis and reporting capabilities.”

Source: https://tdwi.org/articles/2005/04/26/data-aggregationseven-key-criteria-to-an-effective-aggregation-solution.aspx

Responses to 2015 Review:
Progress on normalization & aggregation

Terminology used in normalization & aggregation

- *Indicator Bearing:* Attribute of indicator that specifies if, for a given measure, more is better, less is better, or there is some ideal value from which measures should not differ too much
- *Normalization Scheme:* A family or group of normalization functions that may be necessary for operating on indicators of multiple bearings
  - Ratio Normalization
  - Target-baseline normalization
  - Z-score normalization
  - Unit Equivalence Normalization

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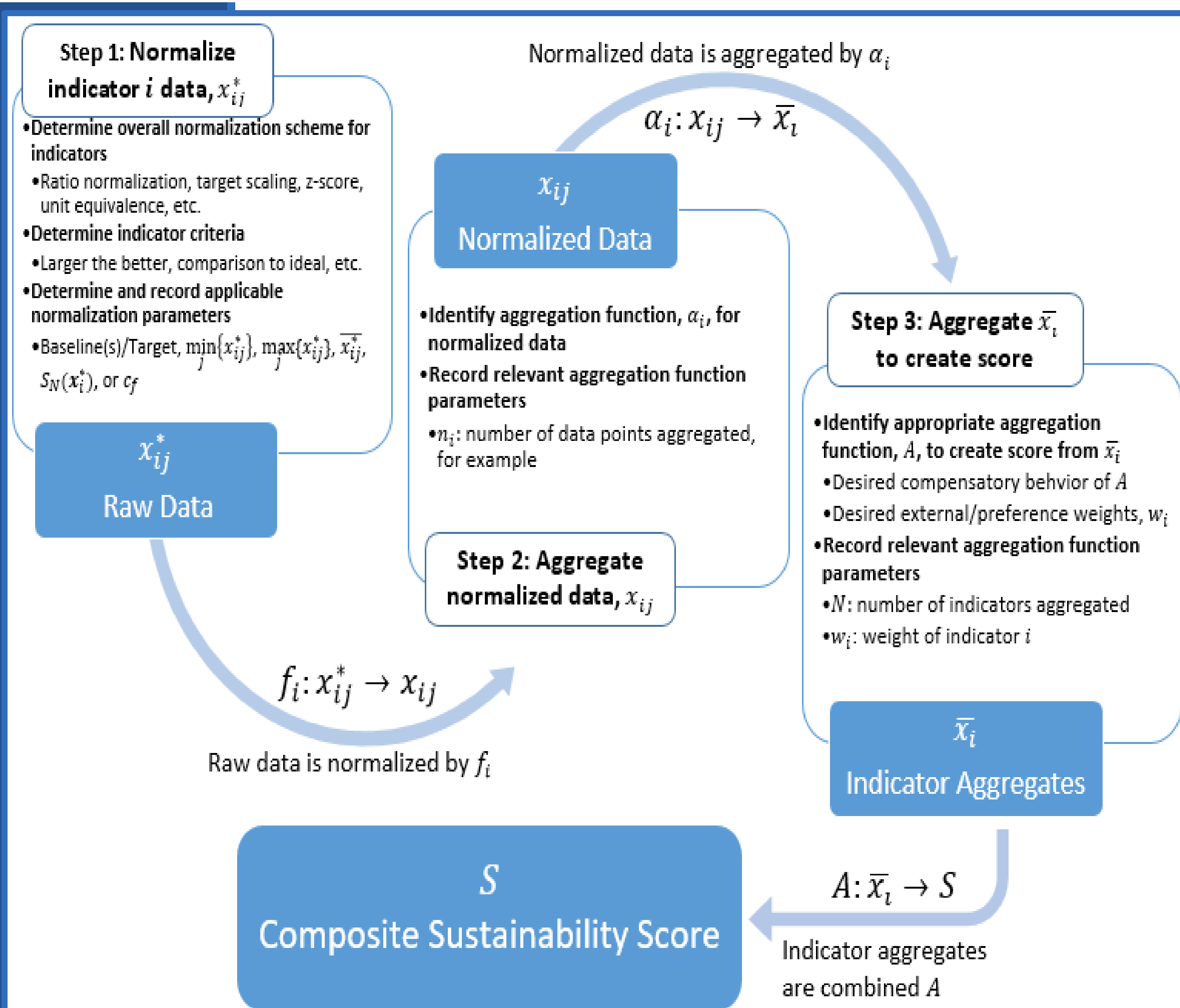
Responses to 2015 Review: Progress on normalization & aggregation

Steps for normalization & aggregation in sustainability assessment

(Pollesch & Dale 2016)



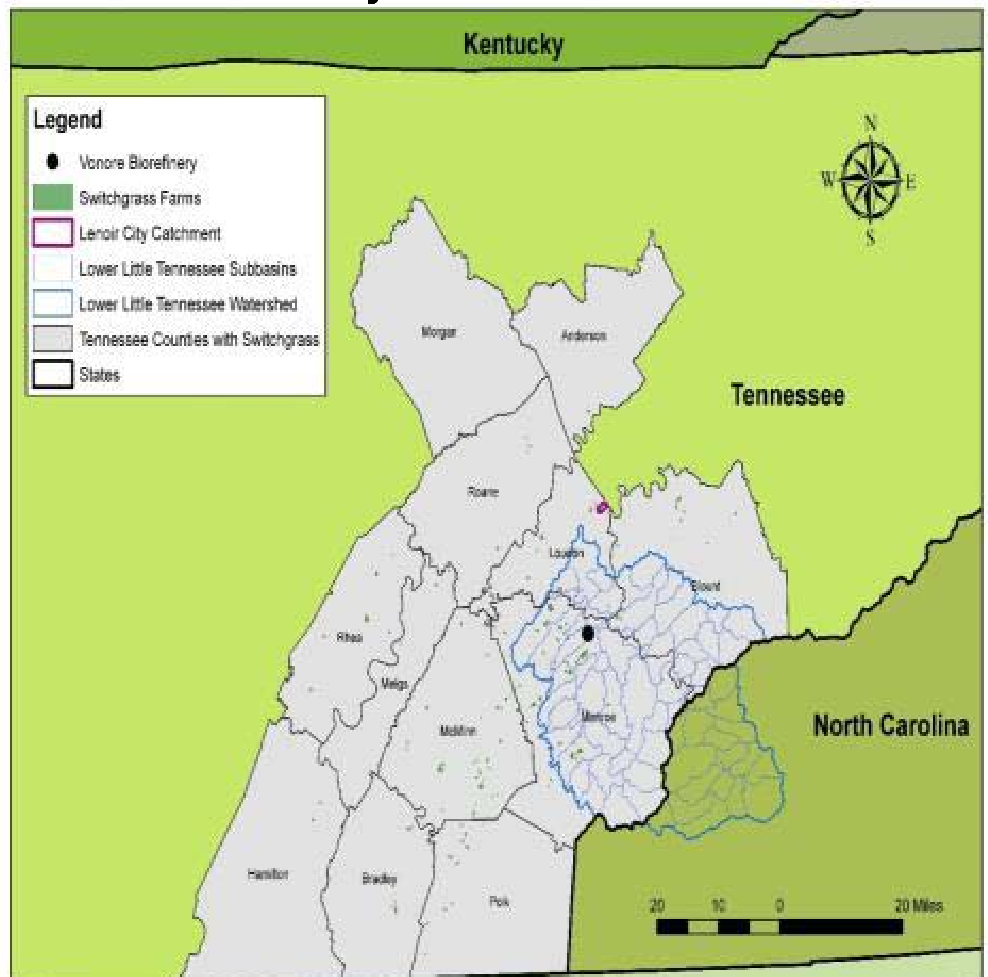
Responses to 2015 Review:
Progress on normalization & aggregation

Complexities in Bioenergy Sustainability Data & challenges for defining protocols

- Attributes of datasets vary greatly by indicator
  - Number of replicates measured & expected
  - Spatio-temporal resolution & representativeness of measurements
  - Indicator-specific contextual attributes
    - Interpretation of *Soil Quality* indicators may be informed by soil-type or previous land-use
    - This same information may be relevant to *Productivity & Water quality*, but is likely irrelevant to *Transparency*
  - Overall data quality

A well-conceived method for storing & accessing data is important for defining normalization & aggregation protocols

Example: Mismatch in spatial resolutions of county versus watershed



Responses to 2015 Review : Database to support normalization & aggregation

Overview of database structure supporting Bio-STAR

Comprised of 5 bases, attributes within each base are provided & shapes/colors indicate if an attribute is linked to another base.