Environmental Sustainability Indicators

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Presentation to
Biomass Research and Development Technical Advisory Committee

August 27, 2015

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

Bioenergy Sustainability Research

- Advance common definitions of environmental & socioeconomic costs and benefits of bioenergy systems
- Quantify opportunities, risks, & tradeoffs associated with sustainable bioenergy production in specific contexts

CBES
Center for BioEnergy Sustainability

Oak Ridge National Laboratory

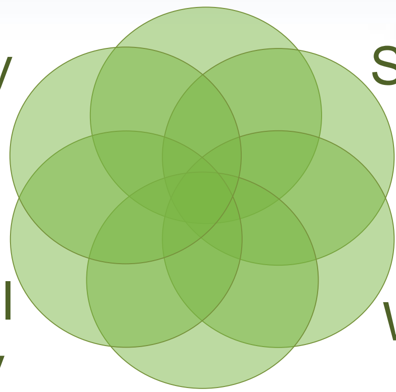
U.S. DEPARTMENT OF ENERGY

ORNL's goals support US Department of Energy objective:

Enable long-term supply of sustainable feedstock and clean, domestic bioenergy

Focusing on bioenergy sustainability brings together disparate perspectives.

Common categories for environmental and 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.

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	$gC/m^2/year$

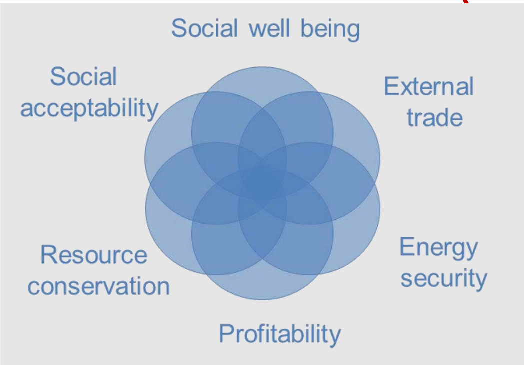
McBride et al. (2011) *Ecological Indicators* 11:1277-1289

Environmental indicators for algal based fuel

	Indicator
Soil quality	1. Bulk density
Water quality	2. Nitrate conc in streams (and export)
	3. Total P conc in streams (and export)
	4. Salinity
Water quantity	5. Peak storm flow
	6. Minimum base flow
	7. Consumptive water use
Greenhouse gases	8. CO_2 equivalent emissions (CO_2 and N_2O)

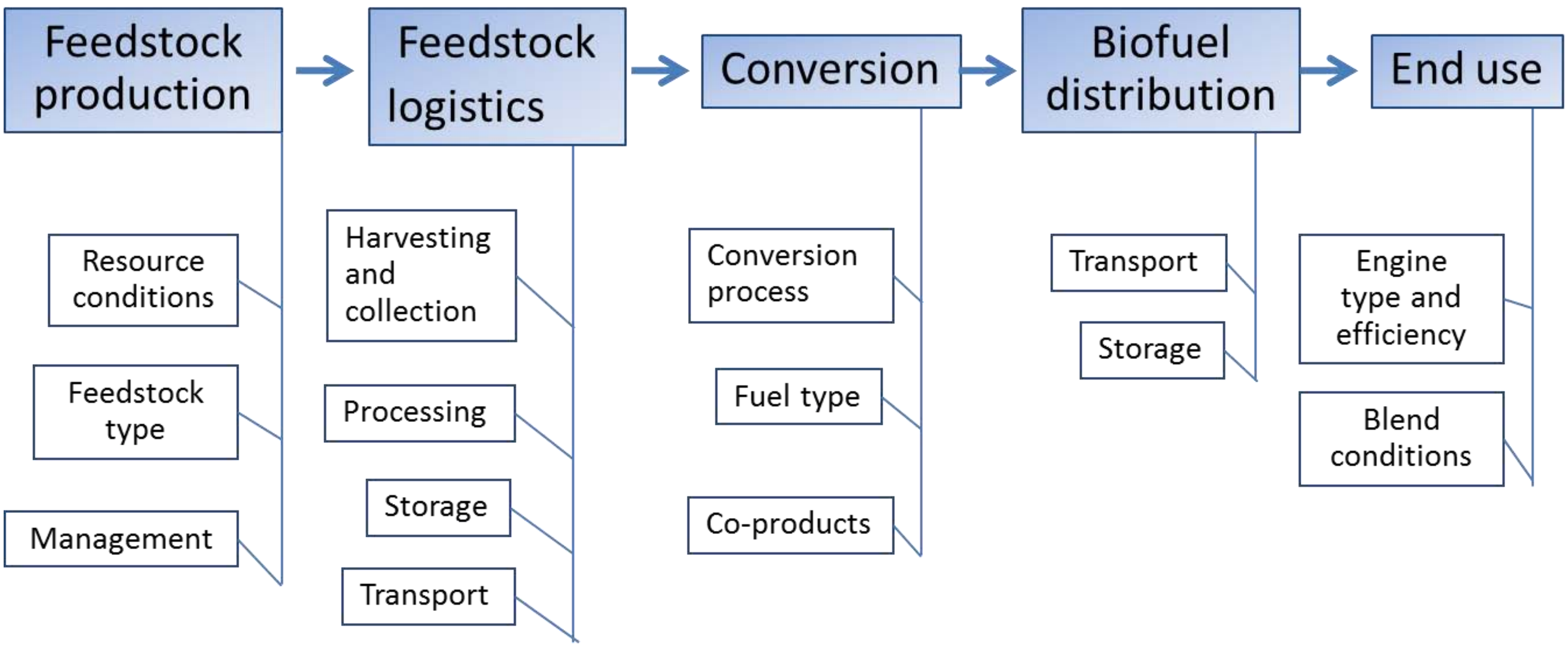
	Indicator
Biodiversity	9. Presence of taxa of special concern
	10. Habitat area of taxa of special concern
	11. Abundance of released algae
Air quality	12. Tropospheric ozone
	13. Carbon monoxide
	14. Total particulate matter less than 2.5μm diam. ($PM_{2.5}$)
	15. Total particulate matter less than 10μm diam. (PM_{10})
Productivity	16. Primary productivity or yield

Also have evaluated socioeconomic indicators

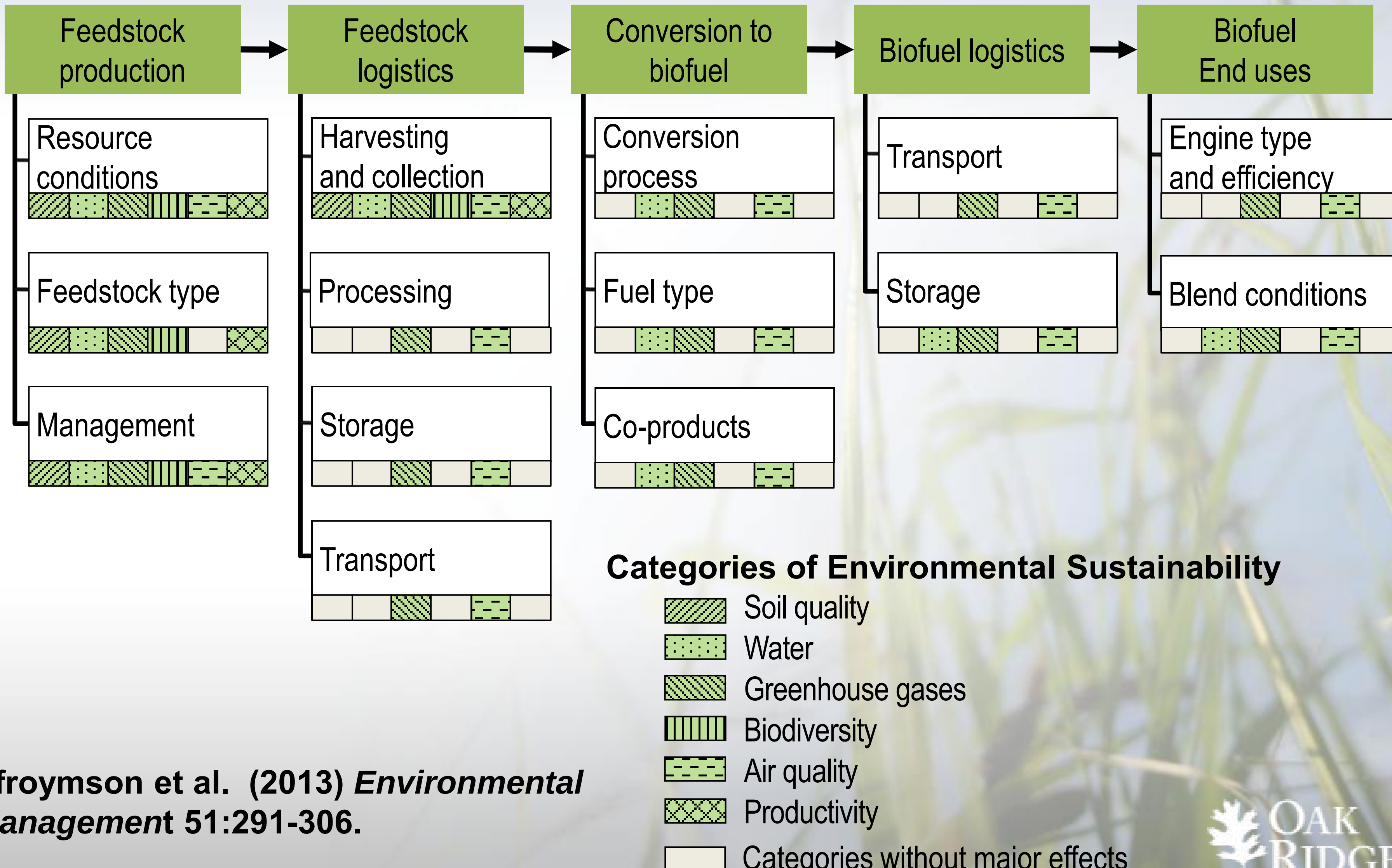


Efroymson & Dale. 2015. Environmental indicators for sustainable production of algal biofuels. Ecological Indicators 49:1-13.

Apply across supply chain



Looking at the biofuel supply chain in terms of environmental sustainability indicators



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

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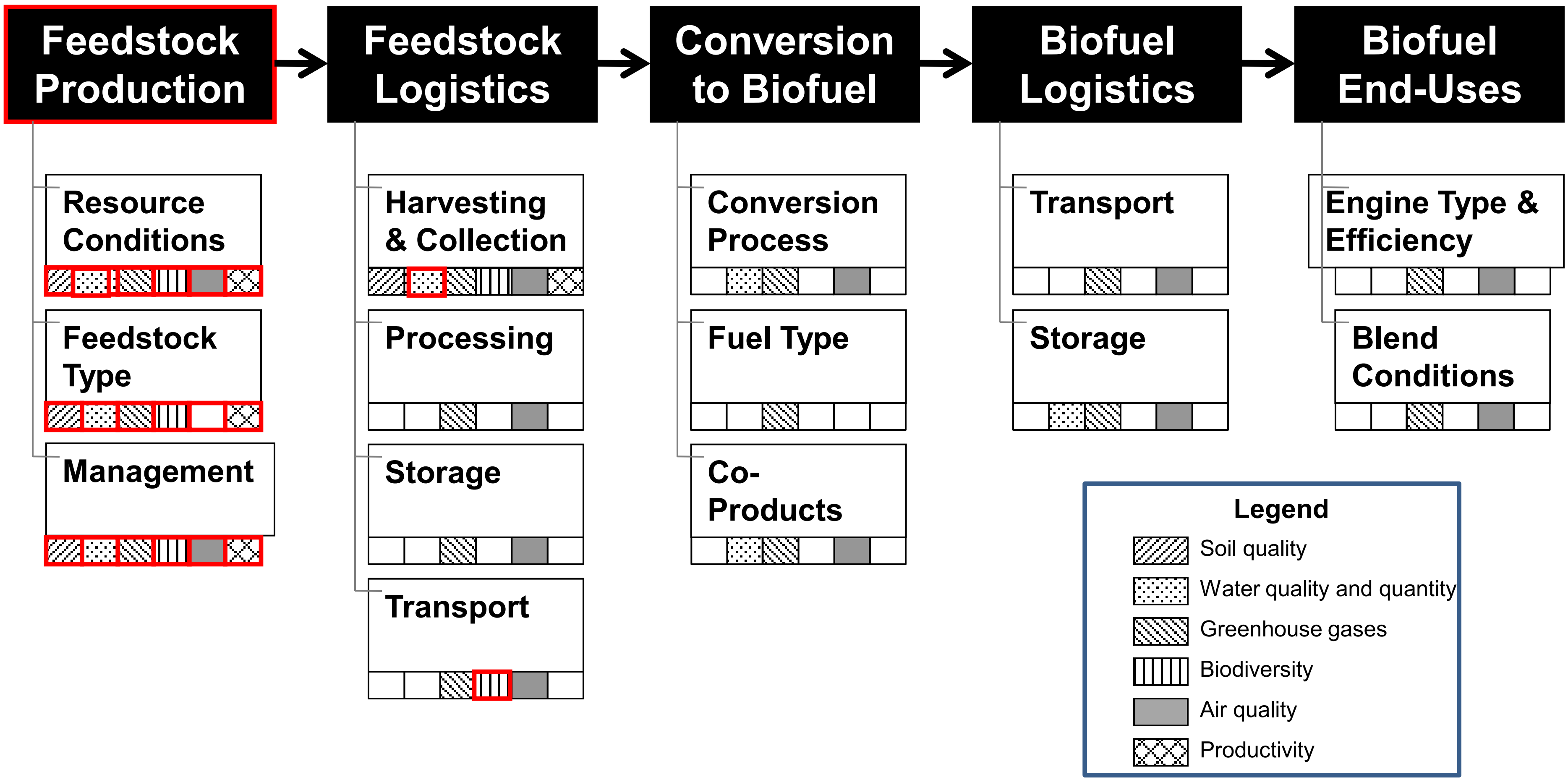
Red boxes highlight those environmental categories for indicators of progress toward sustainability bioenergy that are of particular importance for eucalyptus



Dale et al. 2013. International Journal of Forestry Research Article ID 215276, doi:10.1155/2013/215276.]

Categories of socioeconomic sustainability indicators

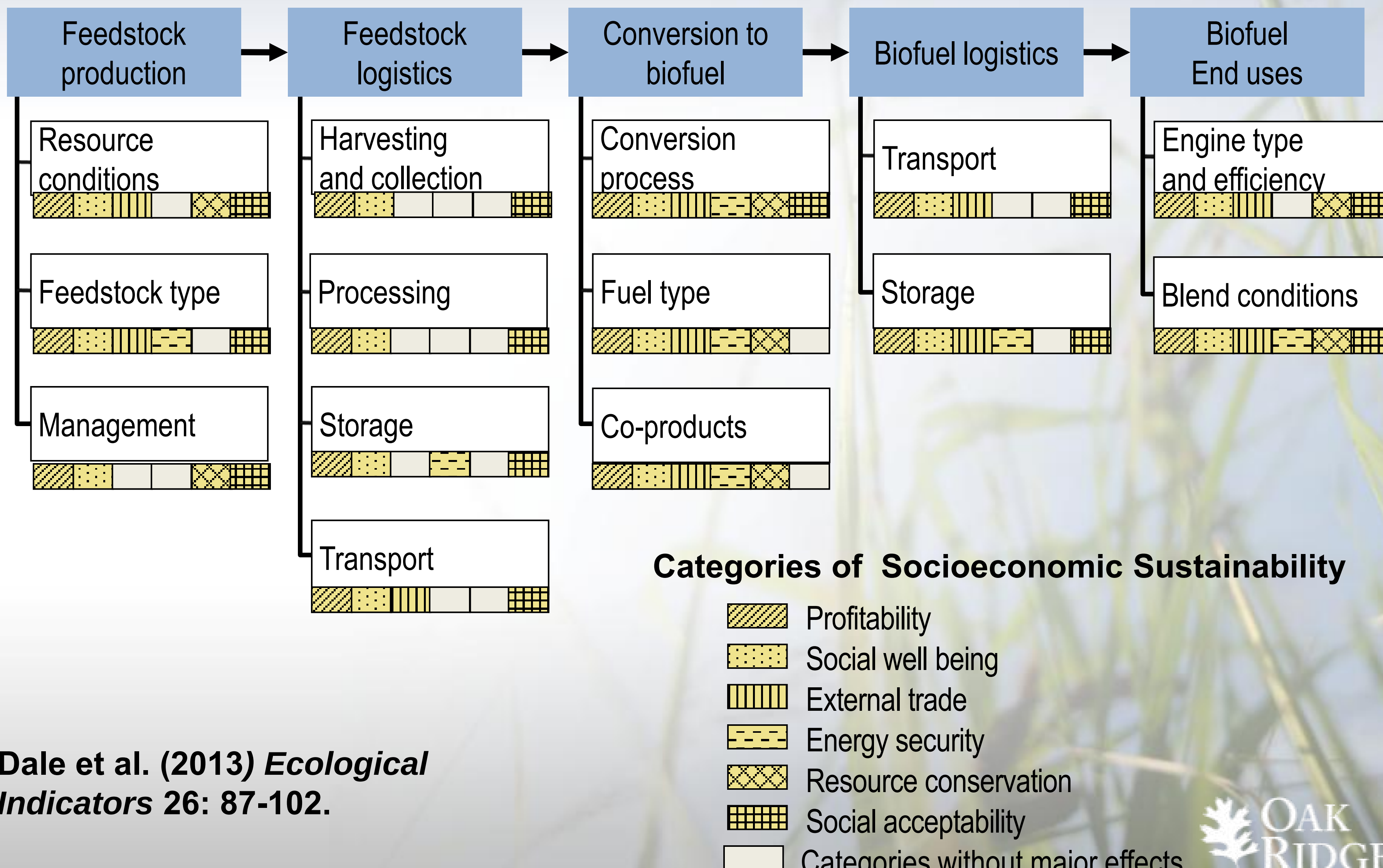
Ten minimum practical measures

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

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

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

Looking at the biofuel supply chain in terms of socioeconomic sustainability indicators



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

Framework for Selecting Indicators

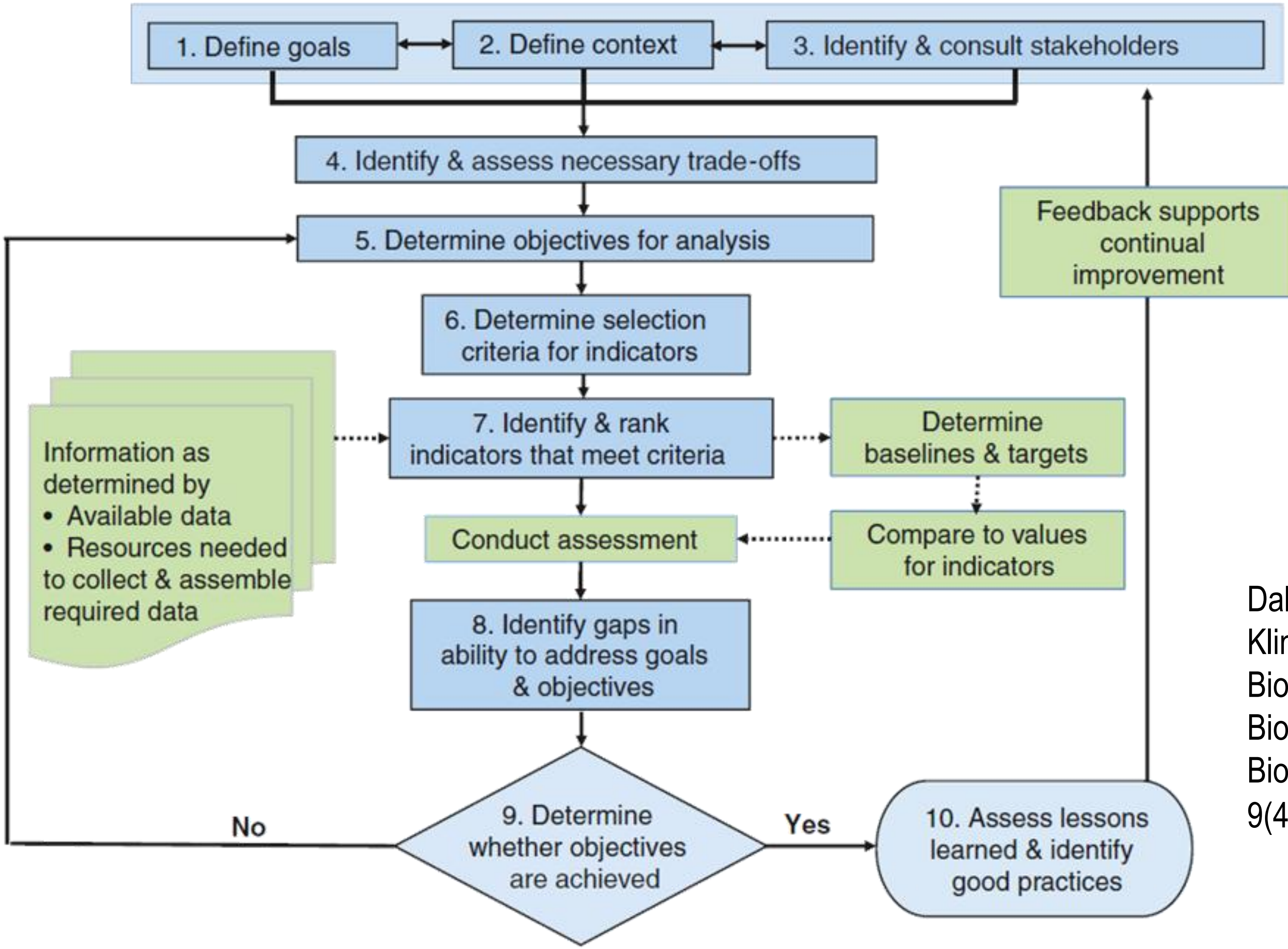


Figure 1. A framework for selecting and evaluating indicators of bioenergy sustainability. Steps for the framework are shown in blue; supporting components of the assessment process are in green. Note that steps 1, 2, and 3 interact and occur concurrently.

Dale, Efroymson, Kline, Davitt. 2015. Biofuels, Bioproducts & Biorefining 9(4):435-416.

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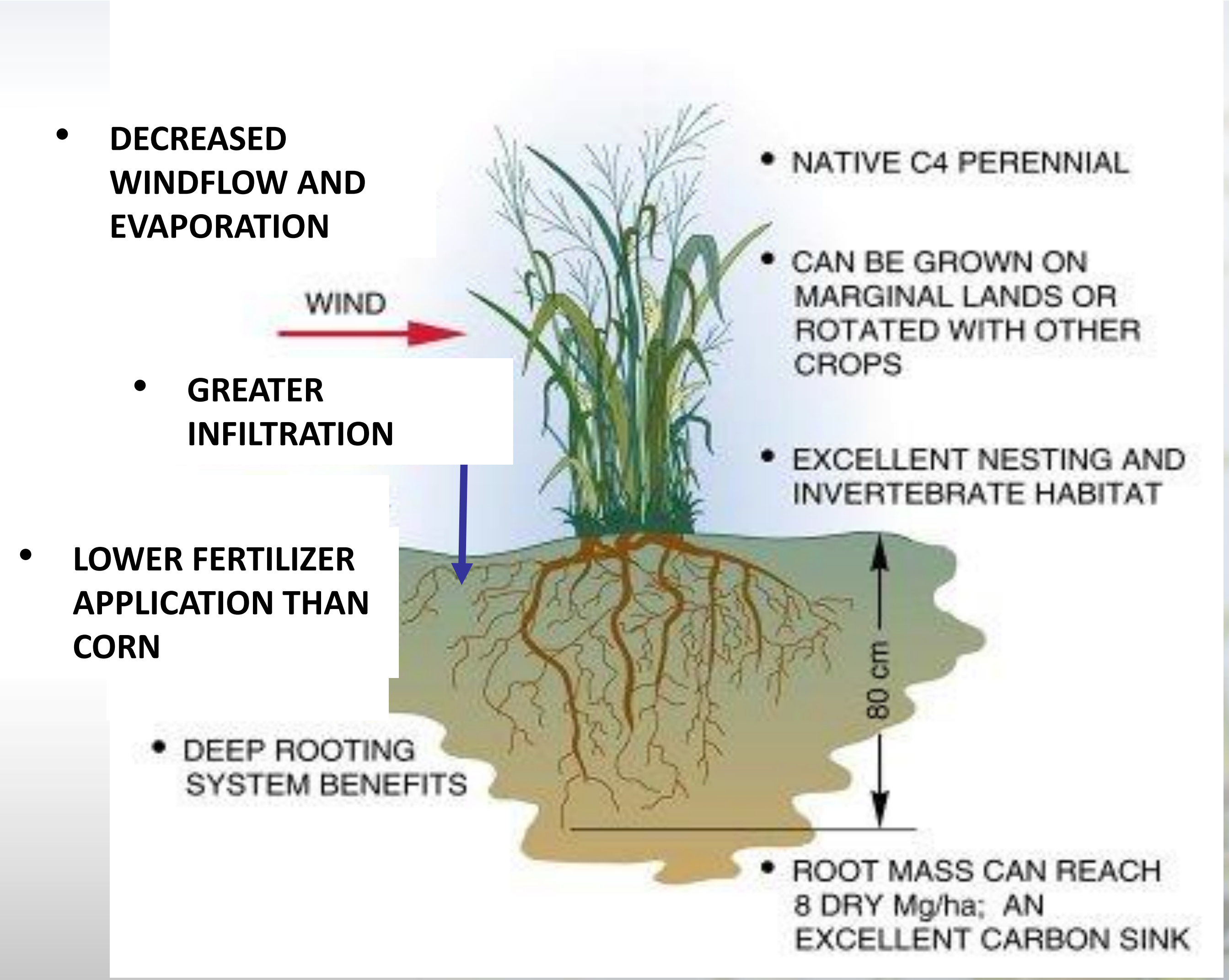
Sustainability benefits of switchgrass (a "model" perennial crop)

Note: Specific crops are appropriate for different conditions



Dale et al. (2011) *Ecological Applications* 21:1039-1054.

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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

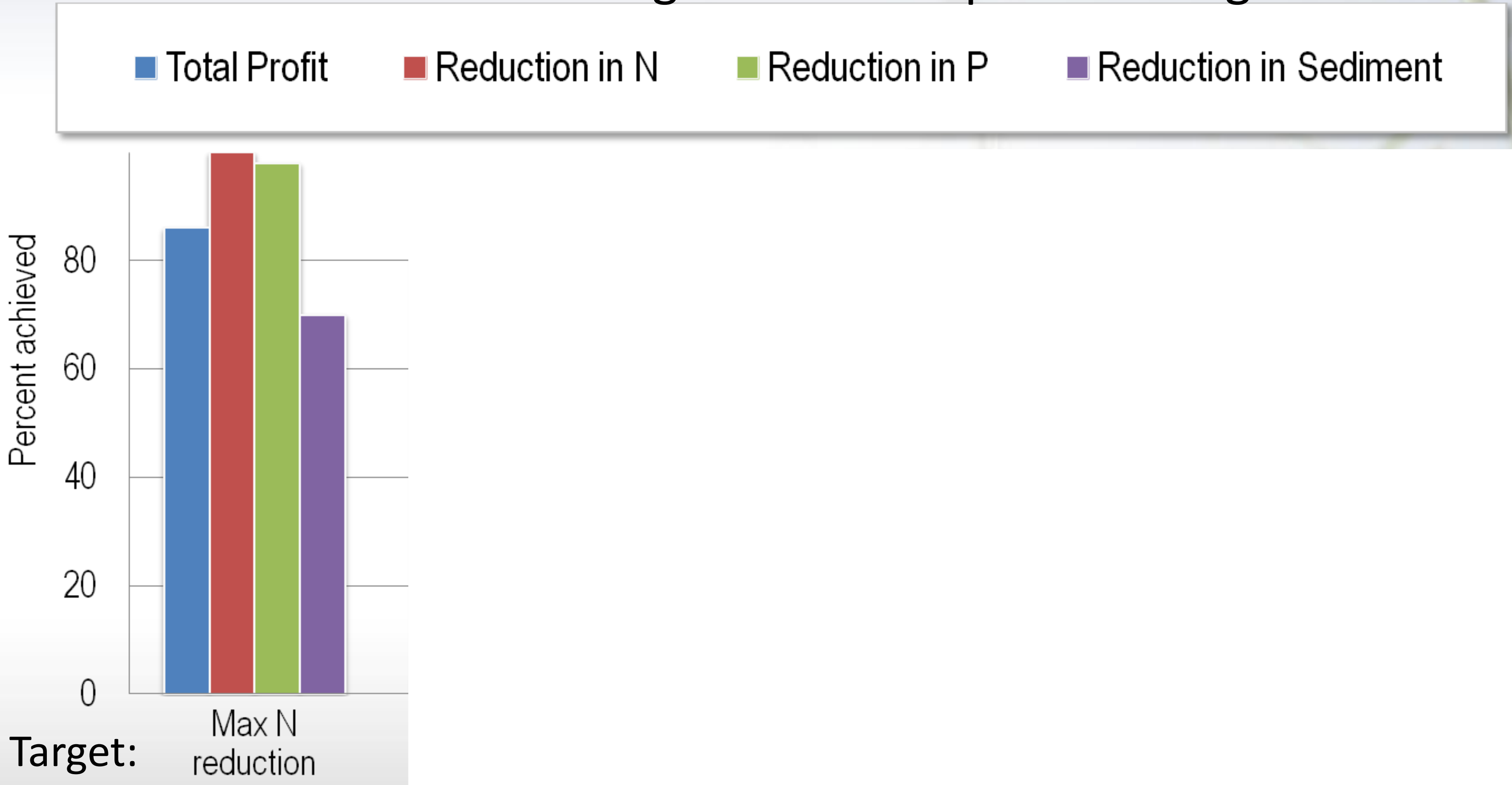
USDA

IBSS
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



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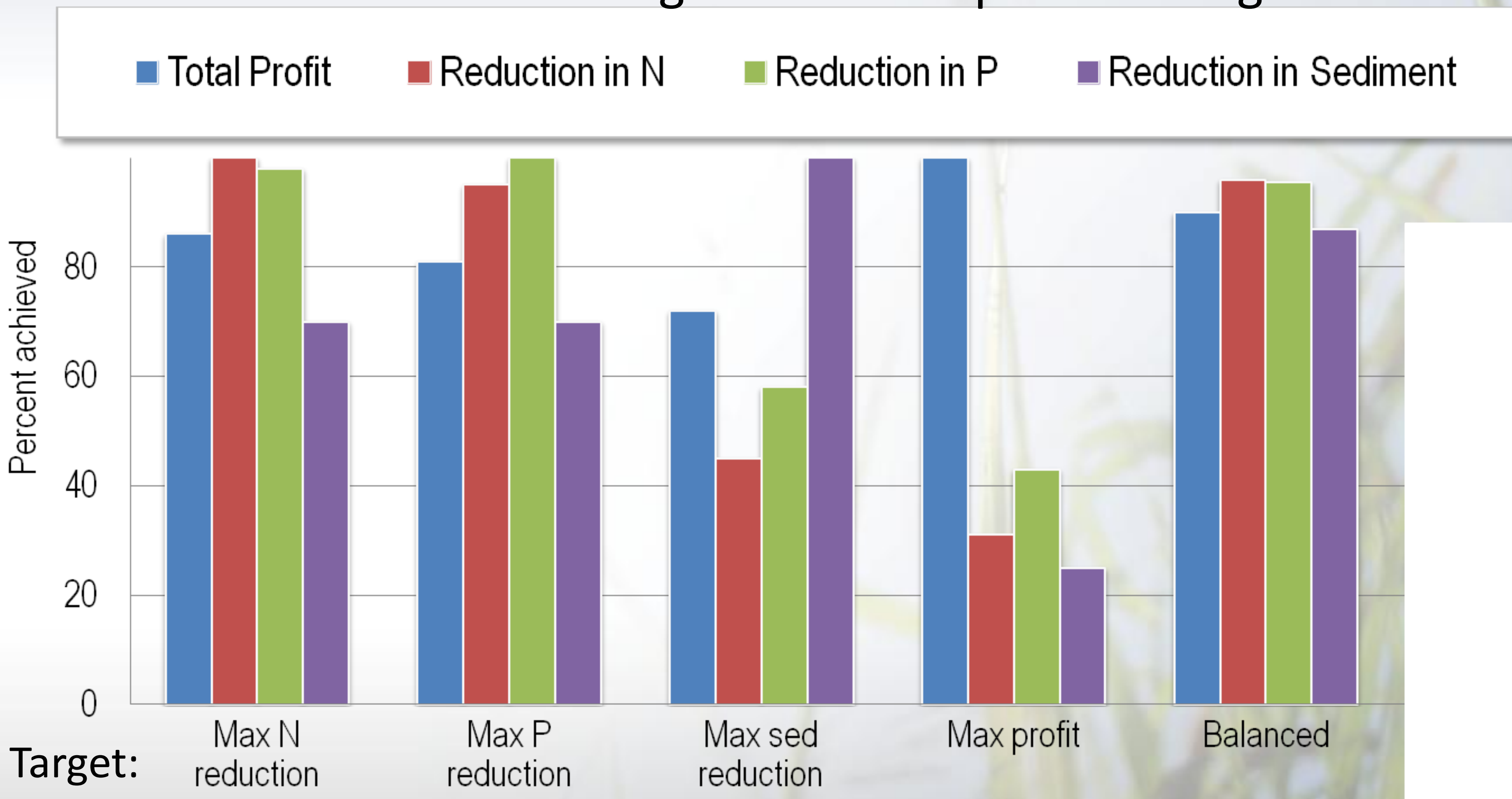
Balancing objectives: Design of cellulosic bioenergy crop plantings may both improve water quality and increase profits while achieving a feedstock-production goal



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

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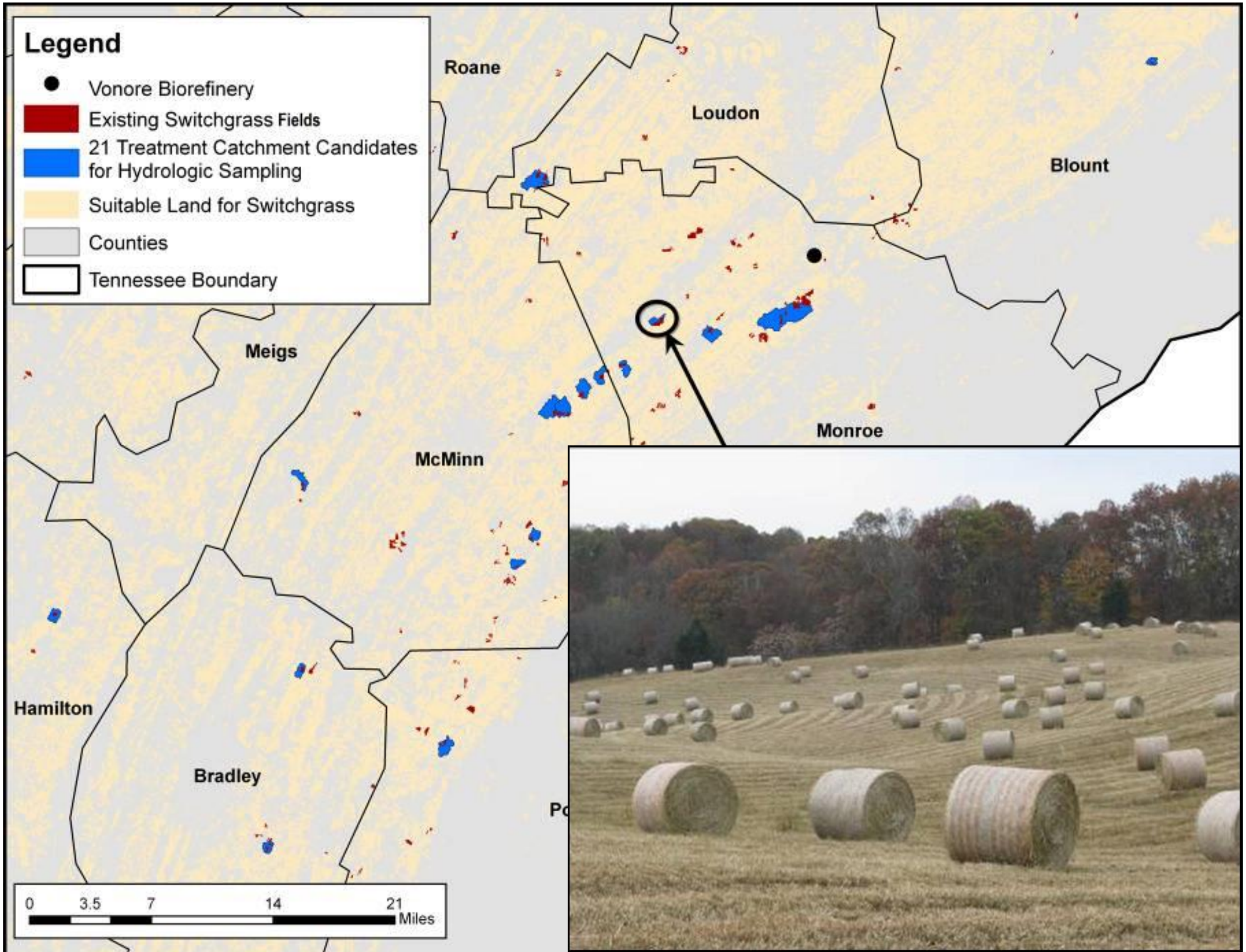
Using Multi-Attribute Decision Support System (MADSS): to compare sustainability of 3 scenarios in east Tennessee

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

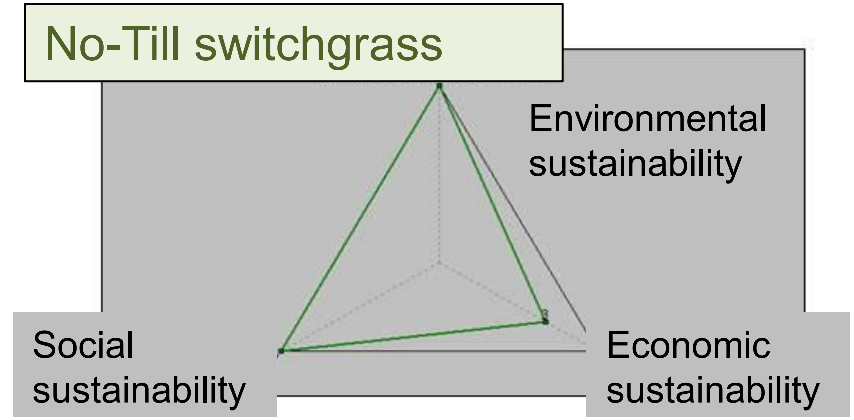


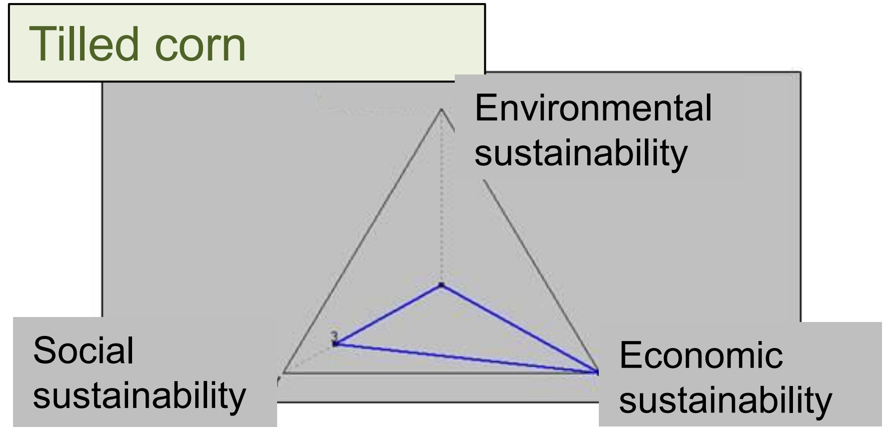
Southeastern Partnership for Integrated Biomass Supply Systems

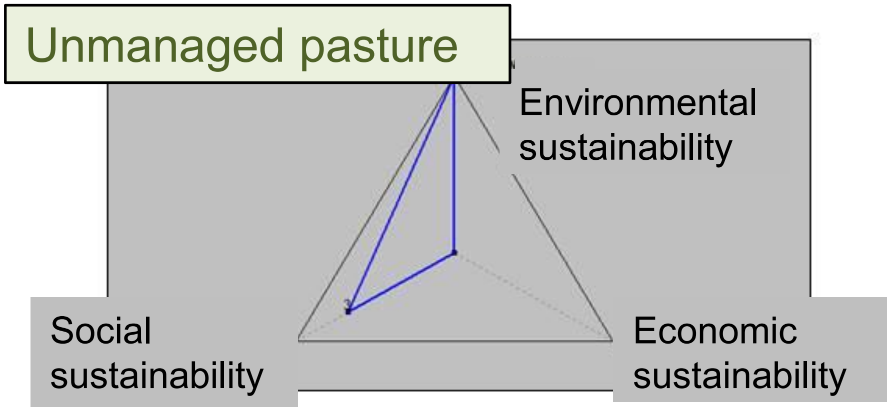
USDA

Case Study of MADSS Applied to East TN:

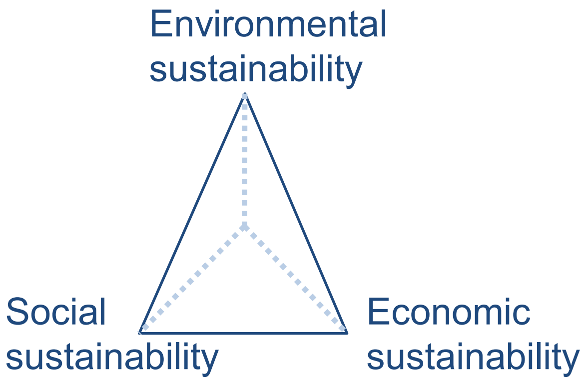
Determines relative contributions of three “pillars” to overall sustainability







Key to chart



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

By–products of tree harvest for saw timber and pulp in Southeast Region (SE) of US are increasingly used for bioenergy

U.S. Wood Pellet Trade

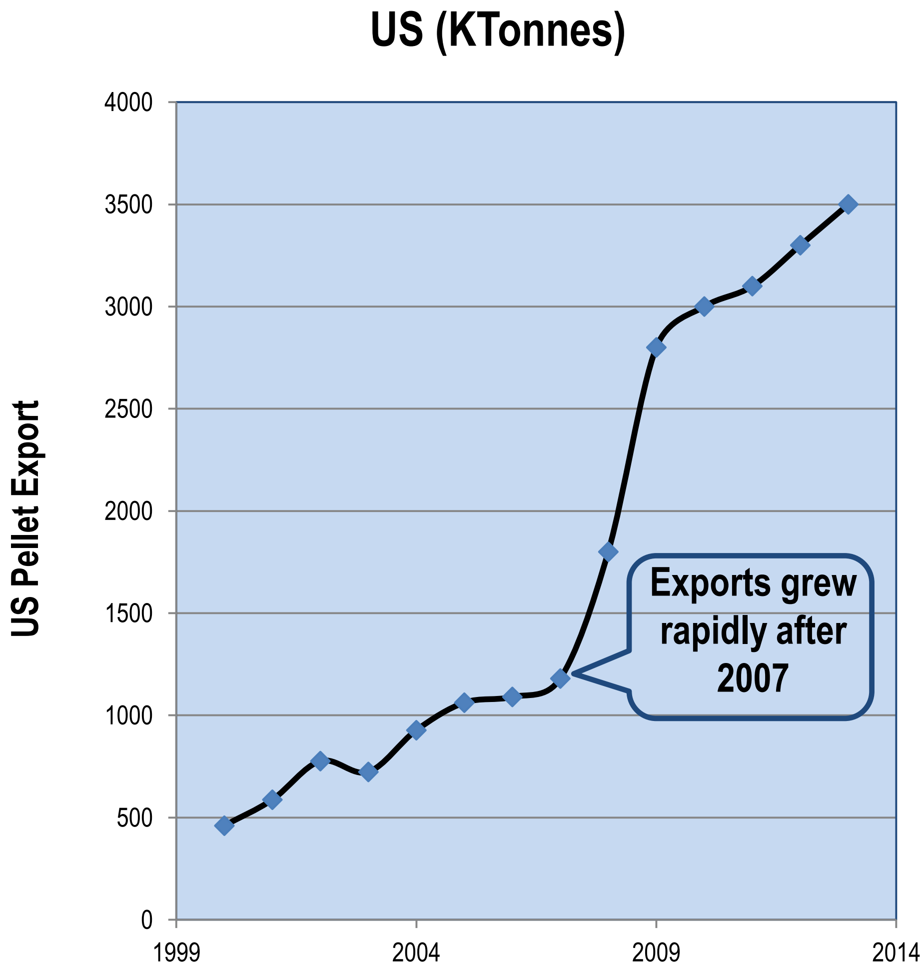
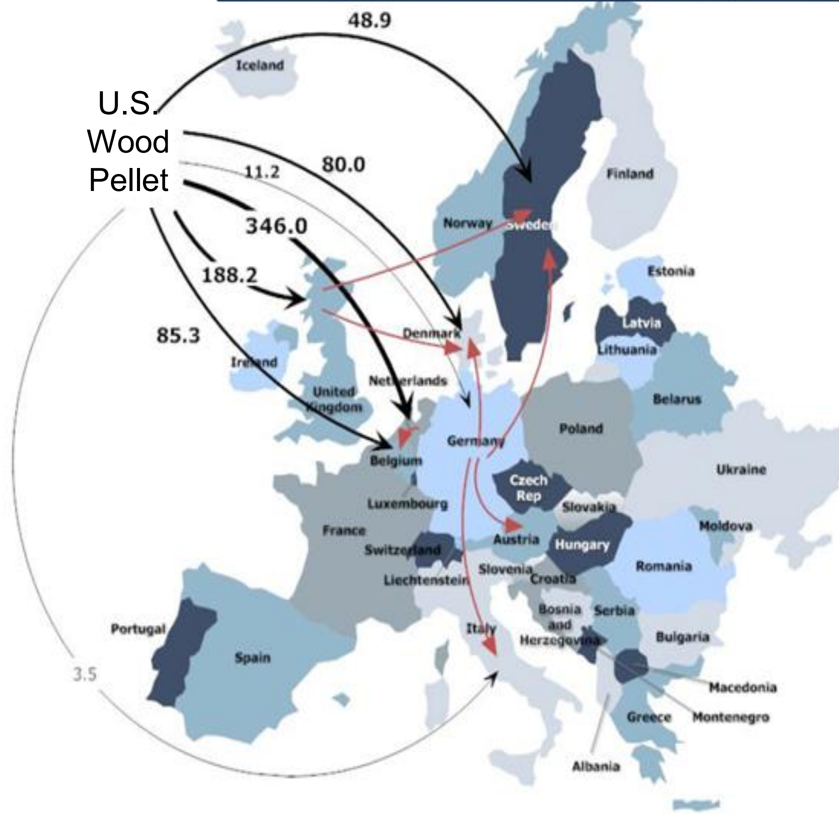


Figure: U.S. Pellet Export (US EIA, 2014)

Example: exports at risk, US pellet exports Valued $650M in 2013, > $1B (est.) by 2016



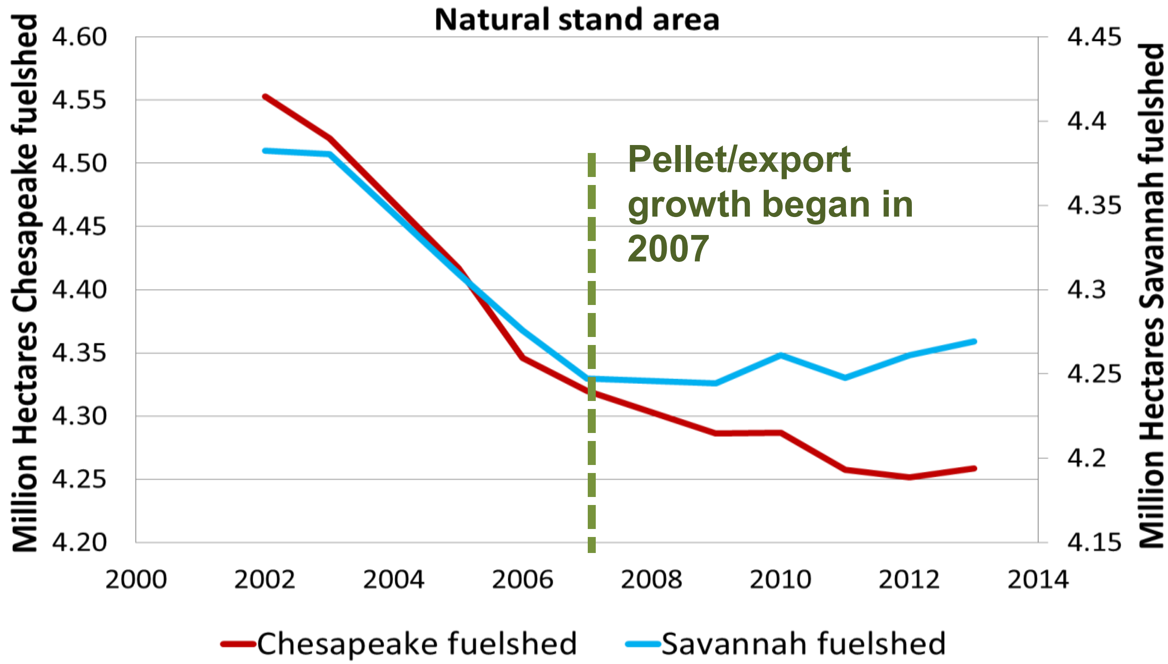
2010 Wood Pellet Trade flow from US to major EU markets and from Net exporters within EU , in 1000 MT

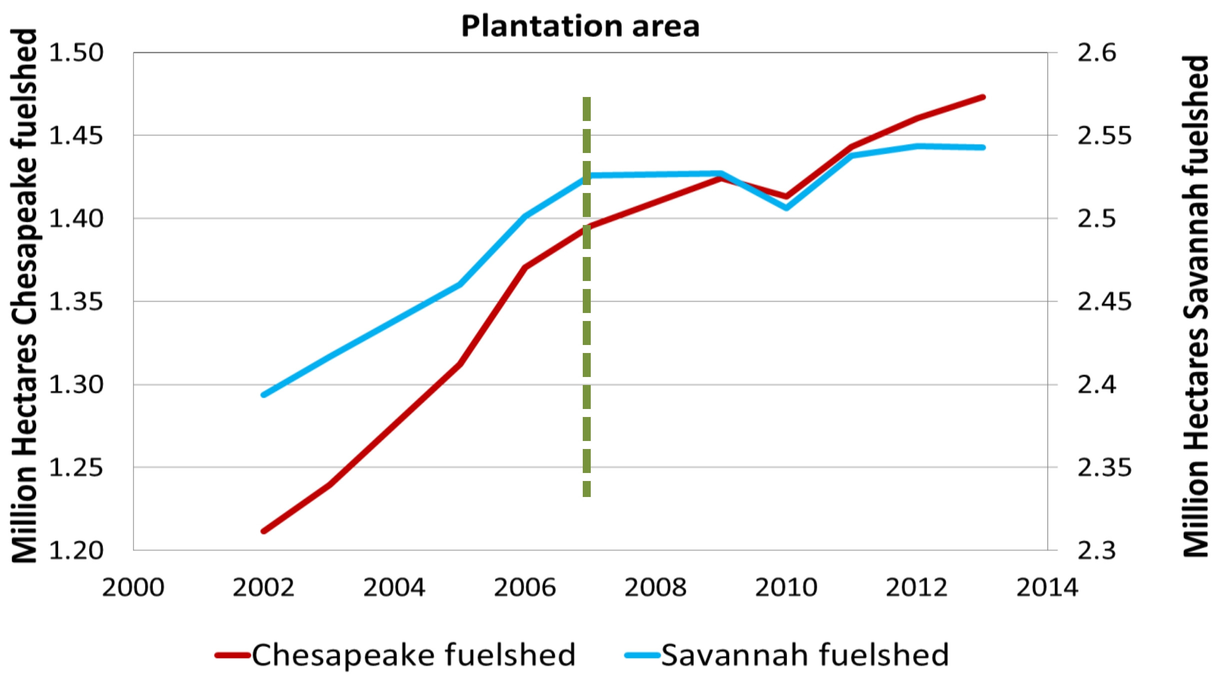
Data source: Lamers et al., 2013 and Eurostat, 2012

Natural forest area

- Replaced by:
  - Agriculture
  - Development
  - Plantations
- In Savannah fuelshed, area increased since 2007

Plantation area continues to expand in both fuelsheds

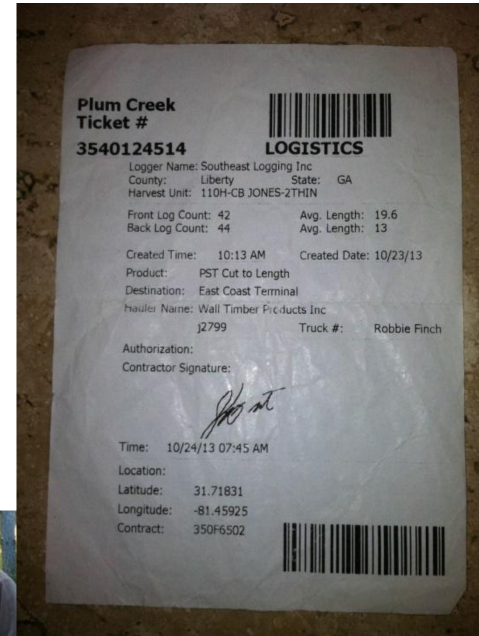




Data description: FIA RPA 2012

Observations to date

- Pellets industry is expanding but is not a major driver of forest activity
- Forest harvest is primarily driven by demand for lumber
- Ecological objectives can be achieved with wood-derived bioenergy (Dale et al. 2015. Frontiers in Ecol and Evol)
- Sustainability concerns
  - Biodiversity
  - Changes in land use or management
  - GHG and climate forcing effect estimates
    - Reference conditions
    - Time and space (scales)
  - Opportunities
    - Jobs
    - Water quality improvement
    - Preserving land as forests
    - Continual improvement in practices = increasing sustainability
  - **Need stakeholder engagements**
    - Communications
    - Science-based reviews


Plum Creek
Ticket #
3540124514
LOGISTICS
Logger Name: Southeast Logging Inc
County: Liberty State: GA
Harvest Unit: 110H-CB JONES-2THIN
Front Log Count: 42 Avg. Length: 19.6
Back Log Count: 44 Avg. Length: 13
Created Time: 10:13 AM Created Date: 10/23/13
Product: PST Cut to Length
Destination: East Coast Terminal
Hauler Name: Wall Timber Products Inc
j2799 Truck #: Robbie Finch
Authorization:
Contractor Signature:
Time: 10/24/13 07:45 AM
Location:
Latitude: 31.71831
Longitude: -81.45925
Contract: 350F6502

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

Recommended practices

- Avoid negative effects
  - Identify & conserve priority biodiversity areas
  - Apply location-specific management of biofuel feedstock production systems.
- Attend to site selection and environmental effects in the
  - Selection and location of the feedstock
  - Transport of feedstock to the refinery
  - Refinery processing
  - Final transport and dissemination of bioenergy.
- Monitor, assess & report on key measures of sustainability
- Attend to what is "doable"
- Communicate opportunities and concerns to the stakeholders and get their feedback
- Employ adaptive management

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Next steps for ORNL research

- ❖ **Continue to develop and test tools for assessment of progress toward bioenergy sustainability**
  - ➢ Using diverse approaches
    - ✓Mathematical aggregation
    - ✓Multi-Attribute Decision Support Systems (MADSS)
    - ✓Landscape design approach
    - ✓Social effects (field survey instrument/application)
  - ➢ Focus on particularly challenging indicators
    - ✓ Biodiversity
    - ✓ Water quality
- ❖ **Case studies of evaluating progress toward sustainability**
  - ➢ Pellet production in SE US
  - ➢ Cellulosic feedstocks in midwestern US – new BETO project led by Antares Group, Inc.

Thank you!

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

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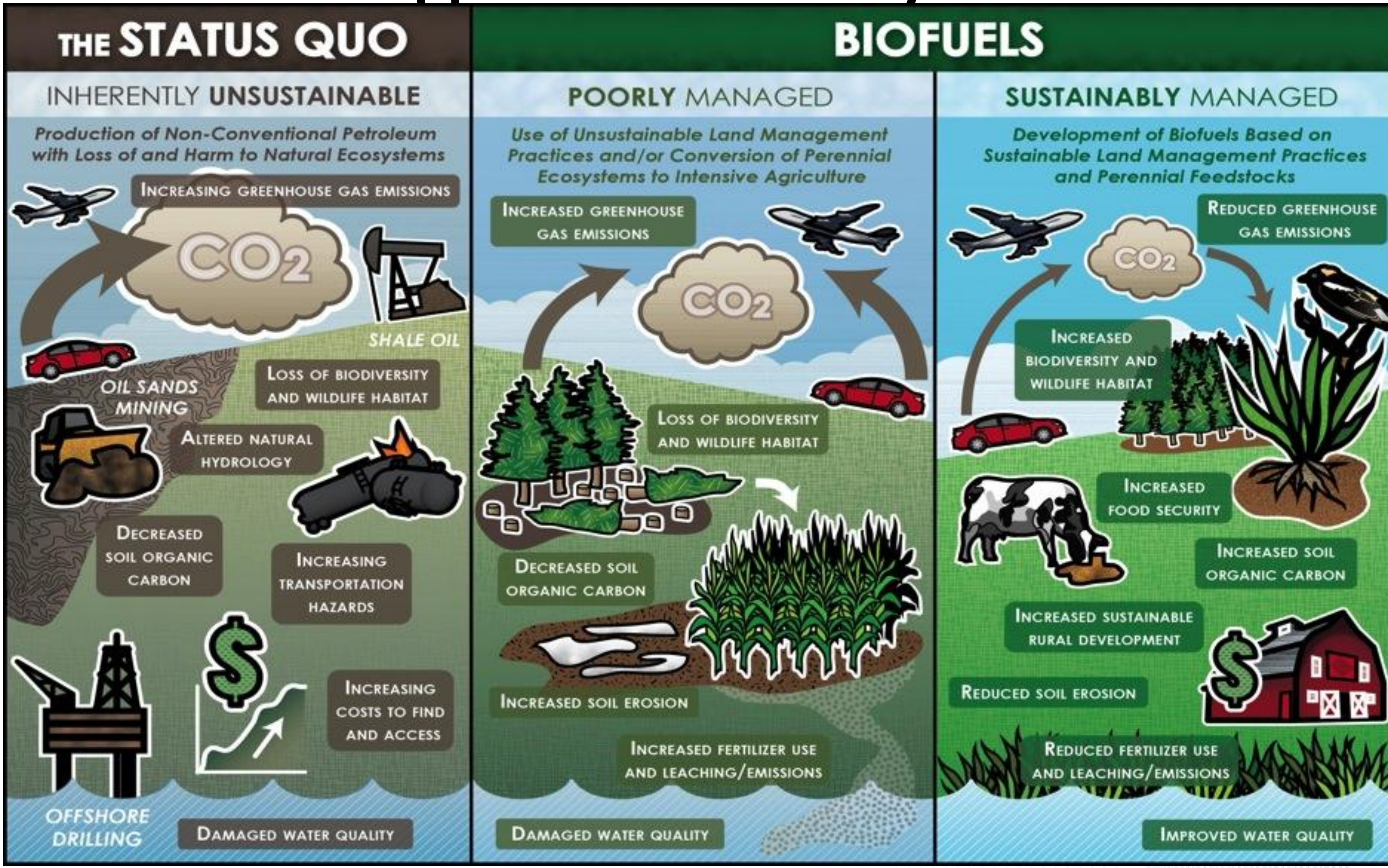
This research is supported by the U.S. Department of Energy (DOE) Bio-Energy Technologies Office and performed at Oak Ridge National Laboratory (ORNL). Oak Ridge National Laboratory is managed by the UT-Battelle, LLC, for DOE under contract DE-AC05-00OR22725.

Landscape Design Approach

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

Opportunities for Management of Biofuel Systems to Support Sustainability Goals



Dale B et al. (2014) Take a Closer Look: Biofuels Can Support Environmental, Economic and Social Goals. *Environmental Science & Technology* 48: 7200-7203.

Ecological objectives can be achieved with wood-derived bioenergy

Dale, Kline, Marland, Miner. 2015. *Frontiers in Ecol and Enviro* 13(6): 297-299.

- EPA's Clean Power Plan proposal recognizes the complexity and importance of system boundaries in time and space.
- With increasing demand for forest products, forest area in the US typically expands
- Managed forests benefit neighboring landscapes by
  - ✓ limiting intrusion of disturbances
  - ✓ enhancing ecosystem services
- Net benefits from bioenergy can accrue immediately or within a few years with sustainable forest management practices

Wood remaining on the ground after a clear- cut harvest at the Oak Ridge Forest (University of Tennessee – Forest Resources AgResearch and Education Center)

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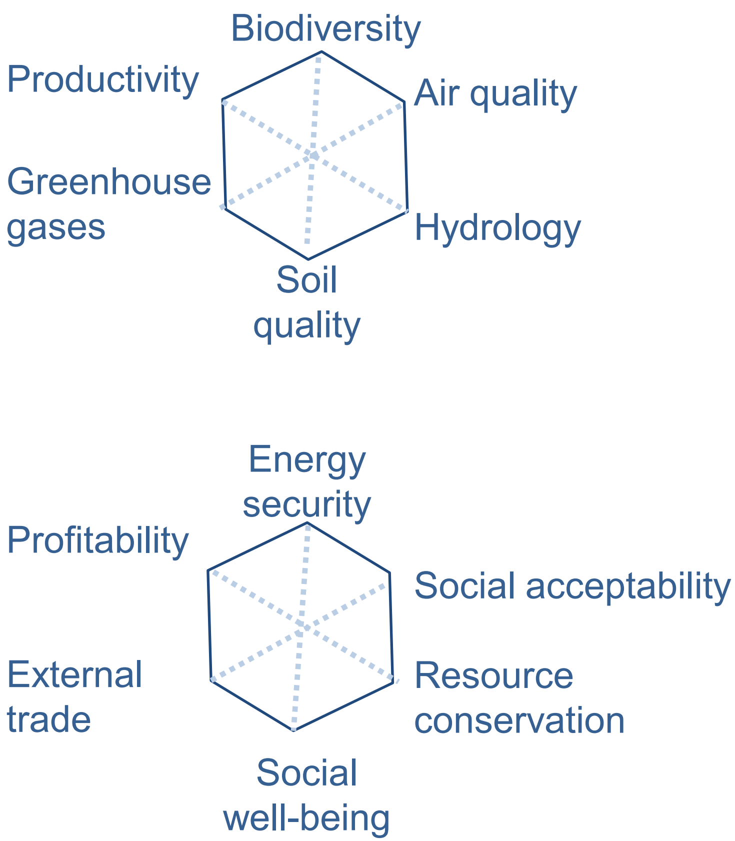
Obstacles to developing and deploying more sustainable landscape designs

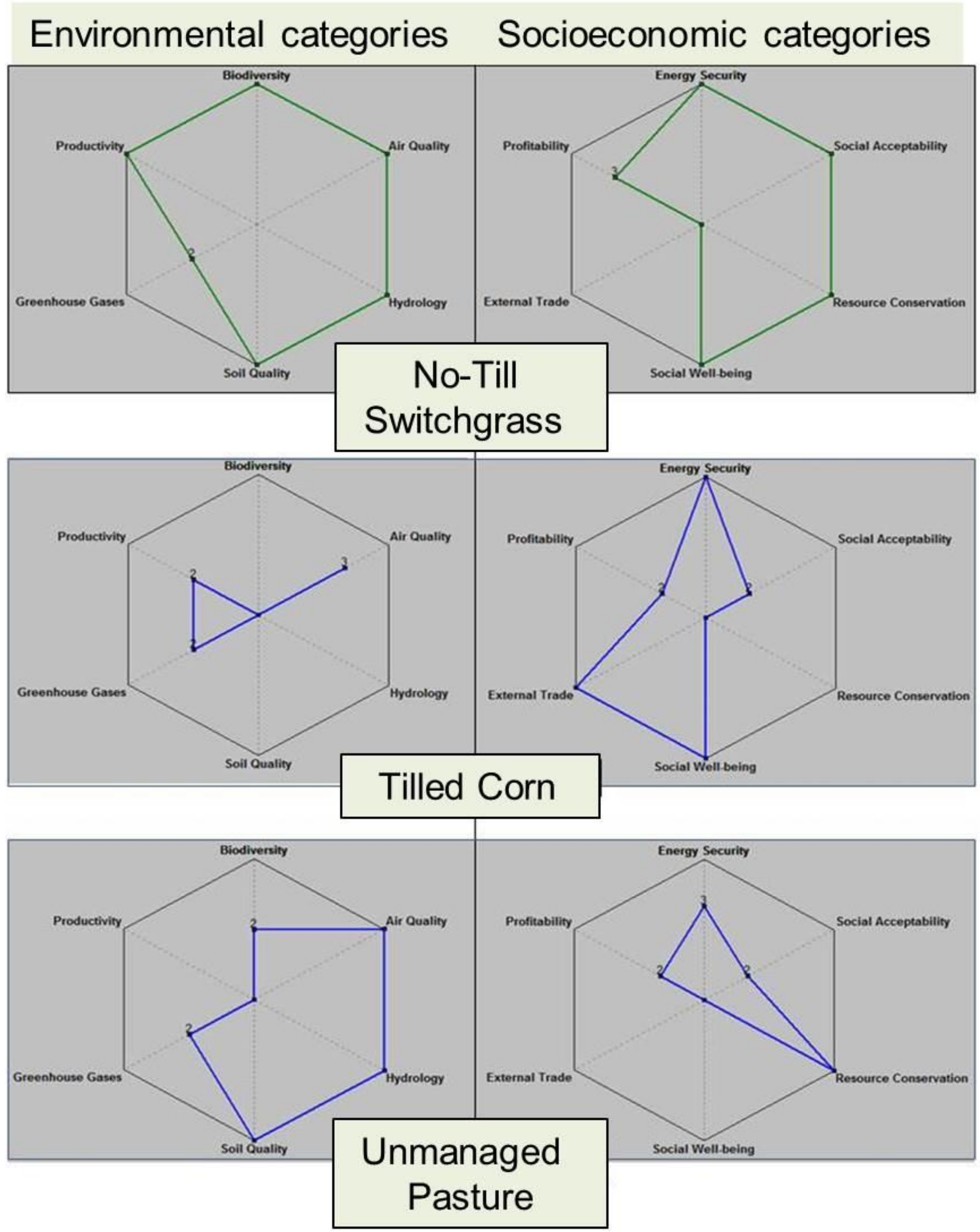
- Landowner rights
- Traditional practices
- Up front planning required
- Coordination and outreach, stakeholder engagement
- Complexity/level of effort
- Higher initial costs
- Lack of consensus on objectives, priorities

[Building from Seuring and Muller (2008) Journal of Cleaner Production 16:1699-1710]

Case Study of MADSS Applied to East TN:
Rates environmental & socioeconomic sustainability

Key to chart

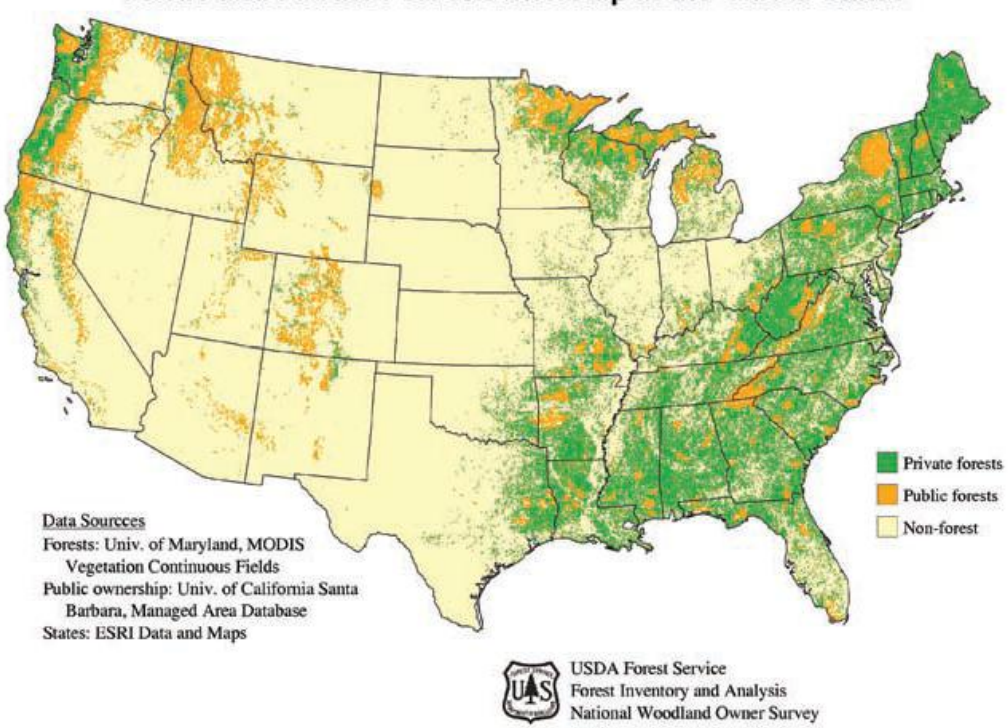


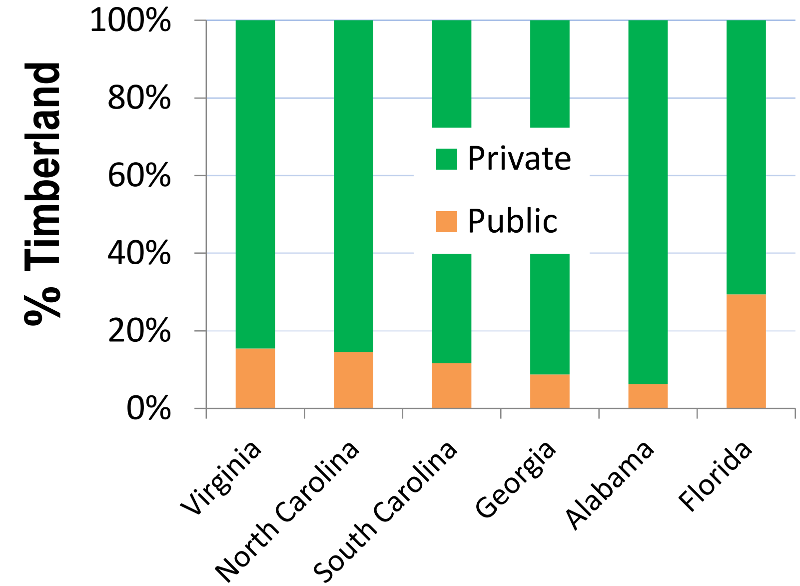


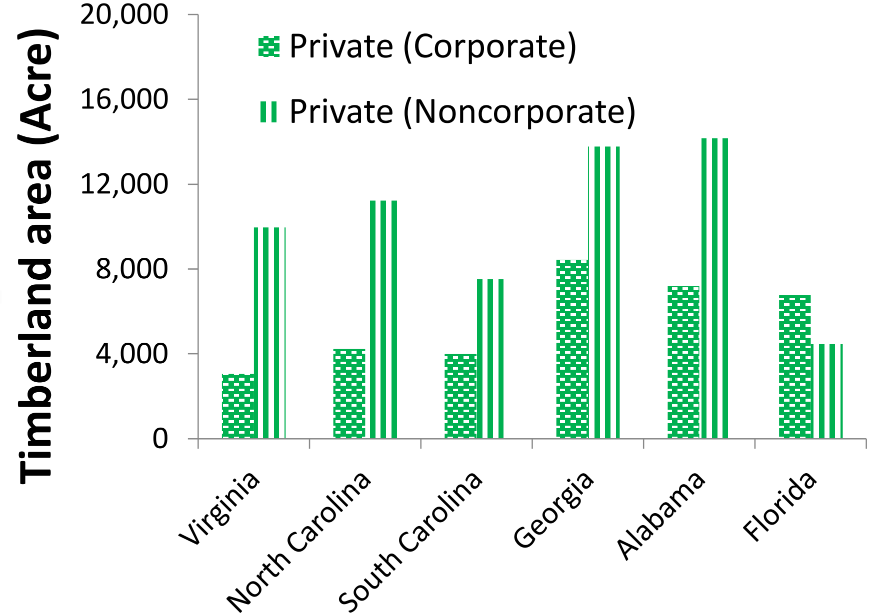
[Parish et al. (In review) Assessing multimetric aspects of sustainability. *Ecosphere*]

Most US timberland is in SE, under private, non-corporate ownership

Public and Private Forest Ownership in the United States







Source: FIA RPA 2012; Timberland: forestland capable of >20cft/acre-year of industrial wood

Application of landscape design approach

Two major export ports for energy pellets in SE USA:

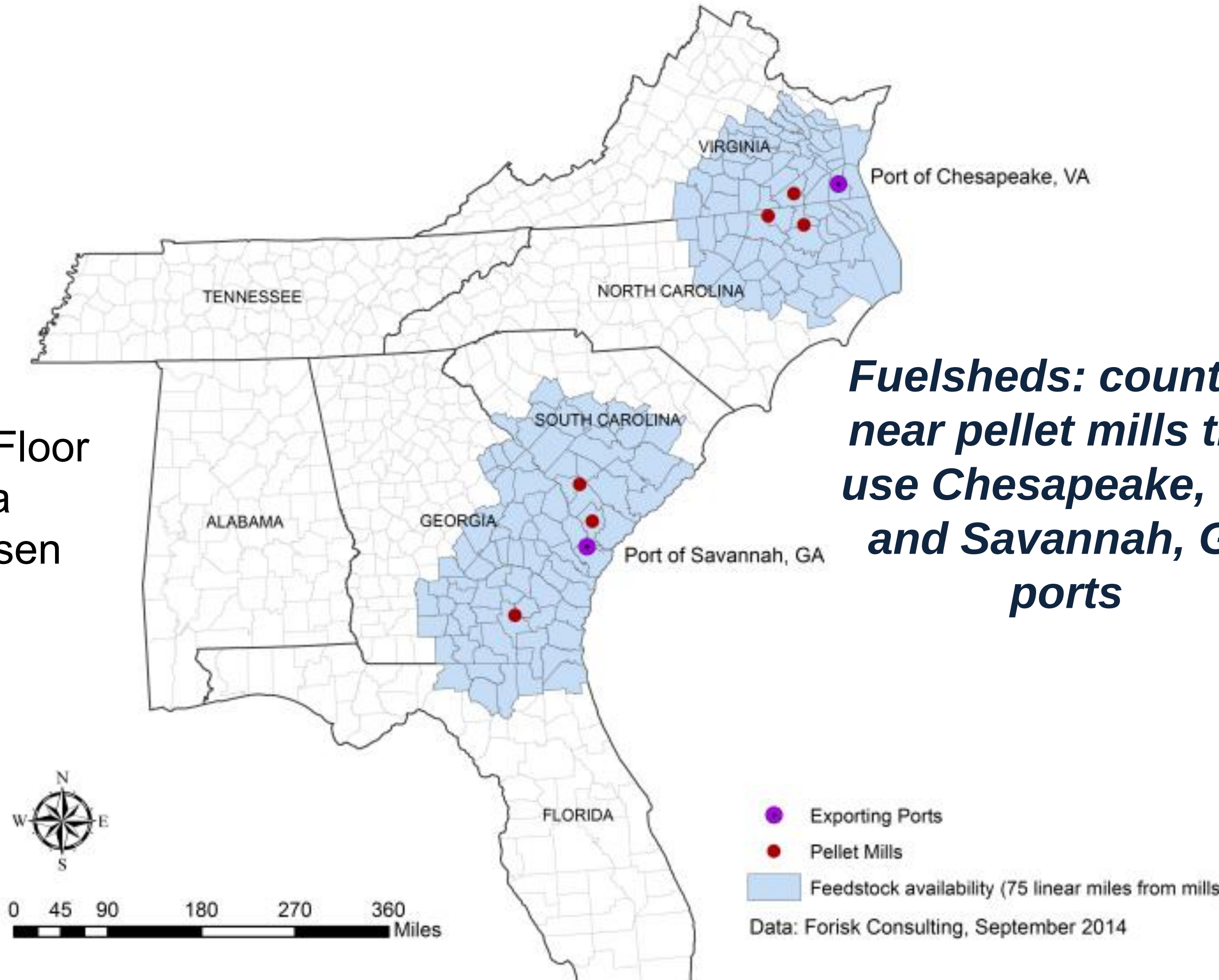
- Savannah: mostly intensively managed pine plantations
- Chesapeake: both pine and mixed hardwoods

Advisory team:

- NCASI
- Weyerhaeuser
- Plum Creek

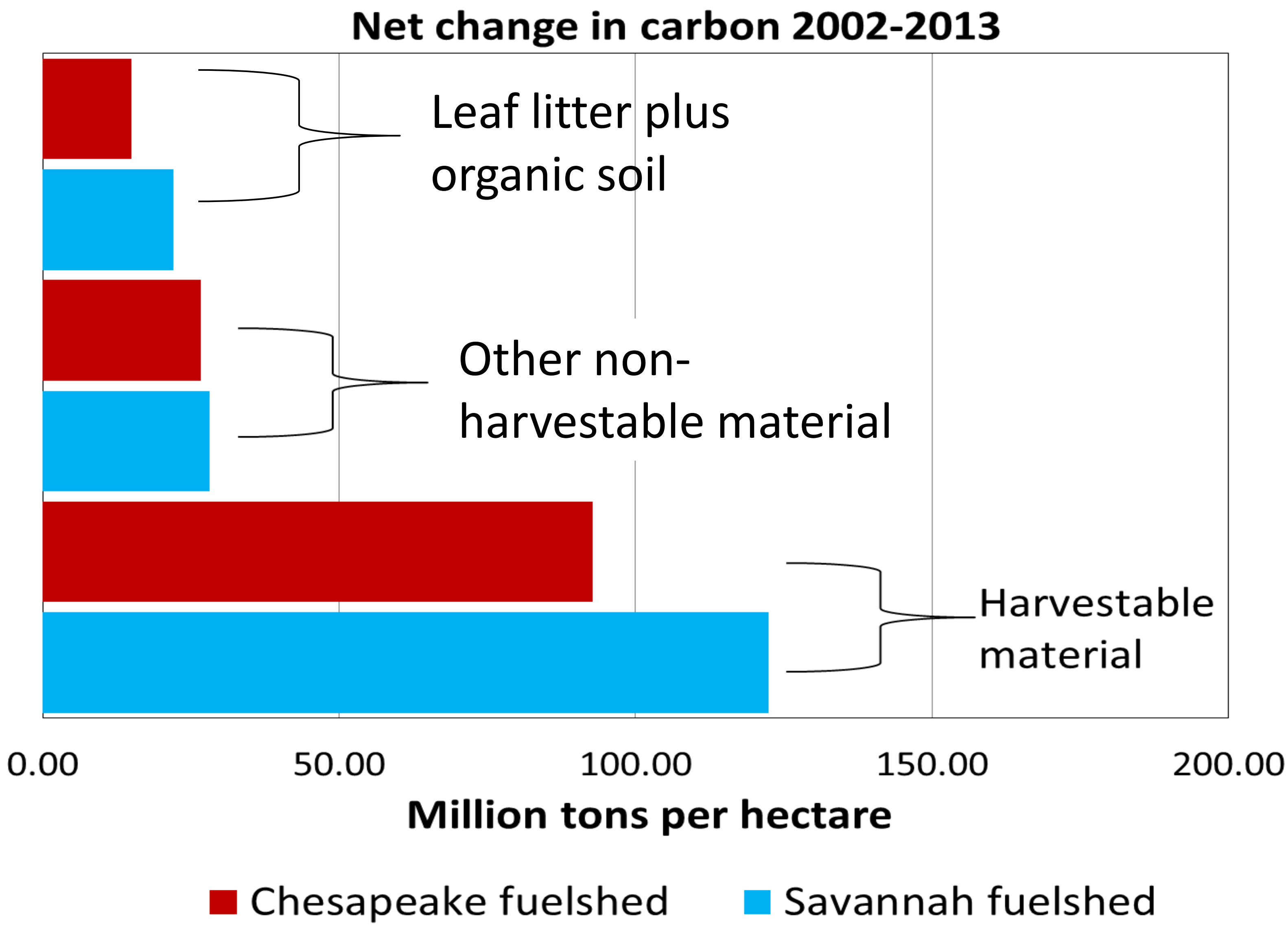
Collaborators:

- NCSU: Bob Abt
- USDA: Karen Abt
- Utrecht University: Floor Van der Hilst, Anna Duden, Steef Hanssen

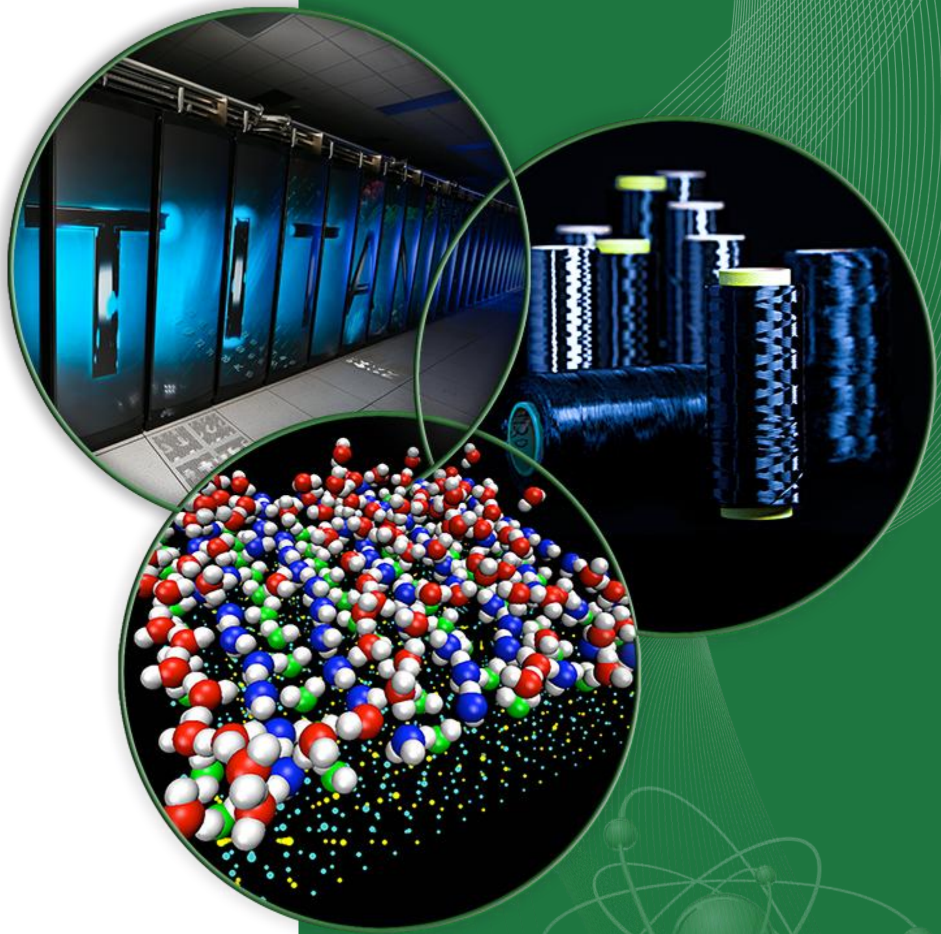


Fuelsheds: counties near pellet mills that use Chesapeake, VA, and Savannah, GA ports

Net carbon in fuelsheds is increasing



Data description: FIA RPA 2012



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

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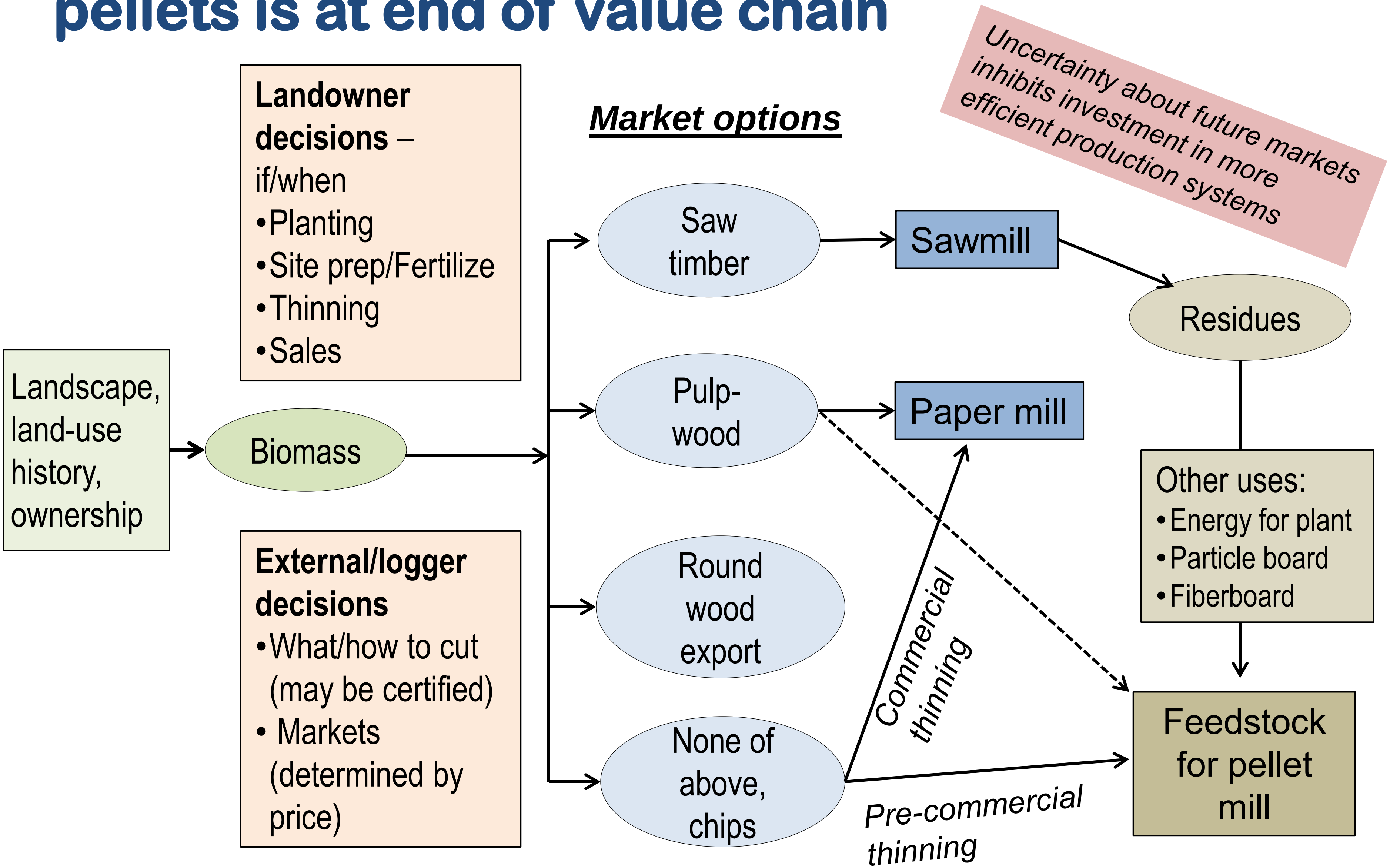
Factors to consider: woody biomass for pellets is at end of value chain



Project Title: *Enabling Sustainable Landscape Design for Continual Improvement of Operating Bioenergy Supply Systems*

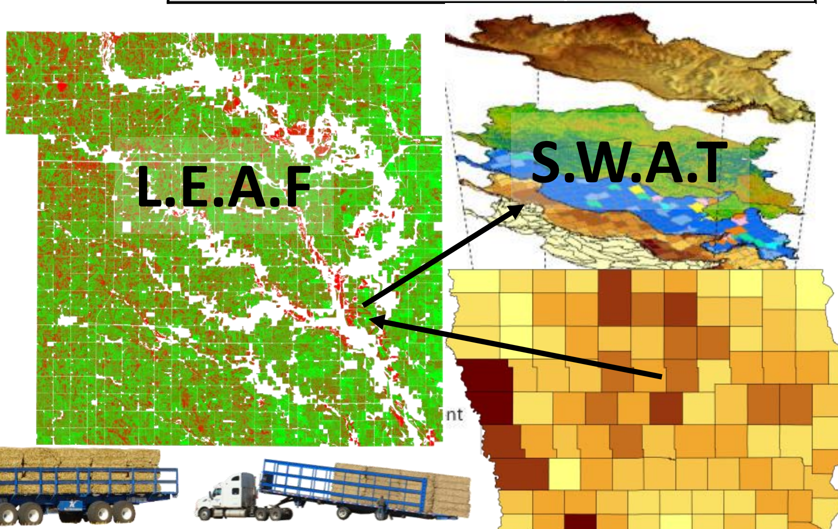
Principle Investigator: Antares Group, Inc.

Key Participants: FDC Enterprises • Poet-DSM • DuPont Industrial Biosciences • Iowa Ag Biofibers • Idaho National Lab • Oak Ridge National Lab • Argonne National Lab • AgSolver • USDA Agricultural Research Service • U.S. Geological Survey • Biomass Market Access Standards (BMAS) Group • Pennsylvania State University • Iowa State University • Purdue University • PacificAg • Scientific Certification Systems (SCS) • Iowa Department of Agriculture and Land Stewardship (IDALS) • Agricultural Technology Innovation Partnership (ATIP) • Monsanto

Proposed Project Goals:

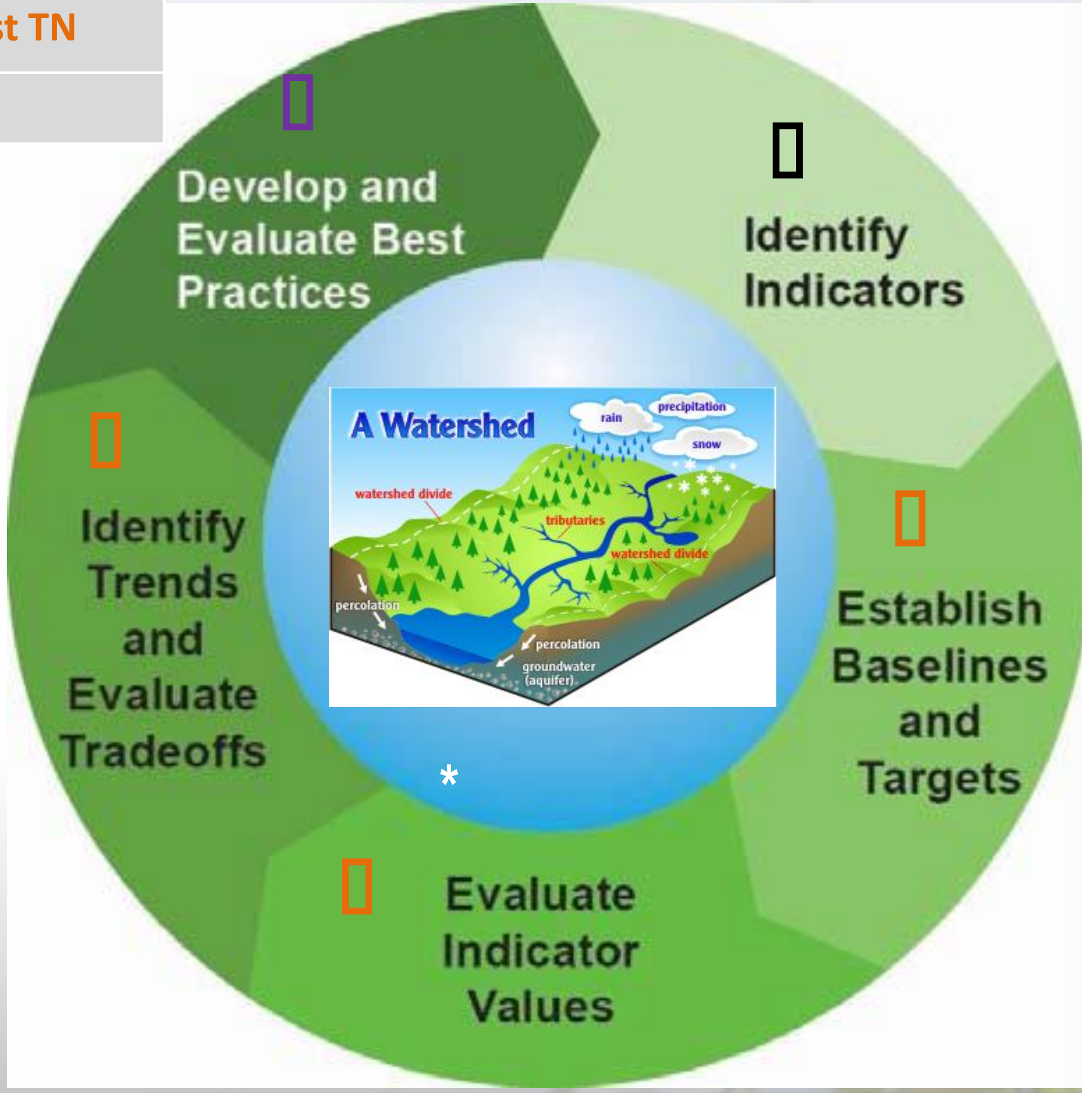
- Identify and monitor key environmental sustainability indicators over time along with the impacts from conservation practices being implemented
- To provide outreach to biomass end-users and growers and to increase the implementation herbaceous perennial energy crops over time.
- Chart a course for continuous improvement and provide an adaptive backdrop for environmental, social and economic activities in biomass fuel sheds
- To collect detailed feedstock production and logistics data and perform associated techno-economic, lifecycle analyses.
- To create new or improved subfield analysis business and conservation tools for farm-level landscape planning which are applicable to target cellulosic feedstocks

Total Project Budget	$13,247,189
EERE Funds Requested	$9,979,990
Applicant Cost Share	$3,267,199



Overall Approach

Code for checks	
▯	Completed
▯	Tested in East TN
▯	Reviewed



From the Multi-Year Program Plan DOE's Bioenergy Technologies Program