Incorporating Bioenergy into Sustainable Landscape Designs

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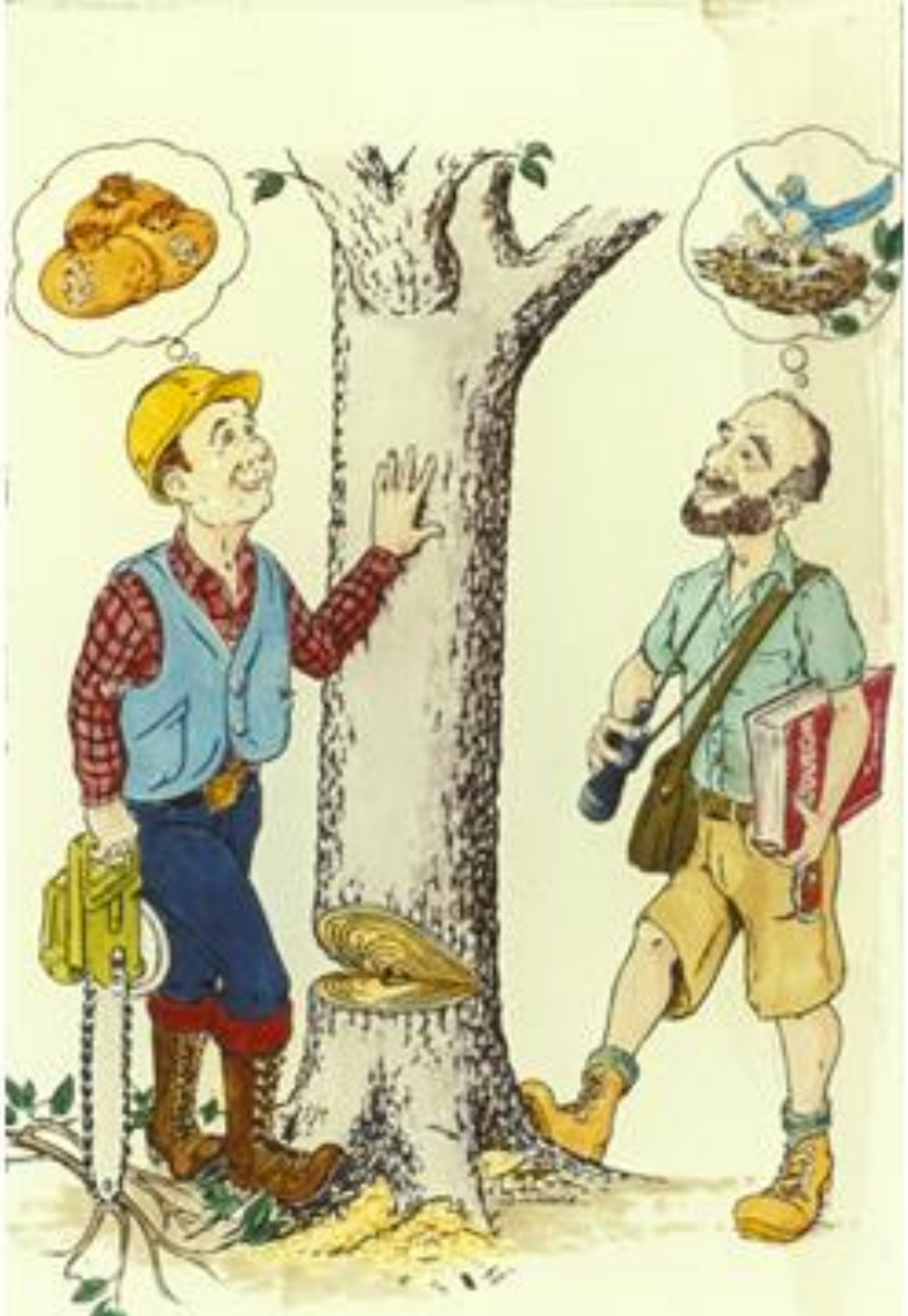
http://www.ornl.gov/sci/ees/cbes/

Discussion Topics

- Assessment of sustainability costs and benefits requires
  - Common understanding of "sustainability"
  - Measurable indicators
  - Case study of switchgrass in east Tennessee, USA
- Landscape design for sustainable bioenergy
- New direction in our research



ORNL Approach to Assessing Bioenergy Sustainability

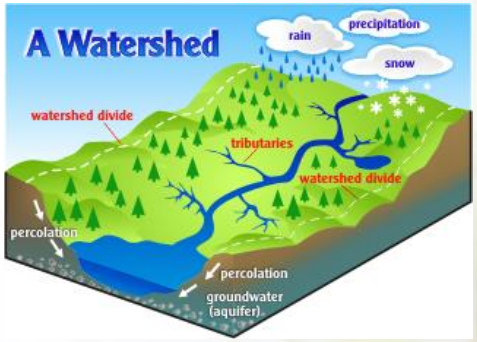
✔ Select Indicators

Establish baselines and targets

Evaluate indicator values

Identify trends and tradeoffs

Develop and test best practices



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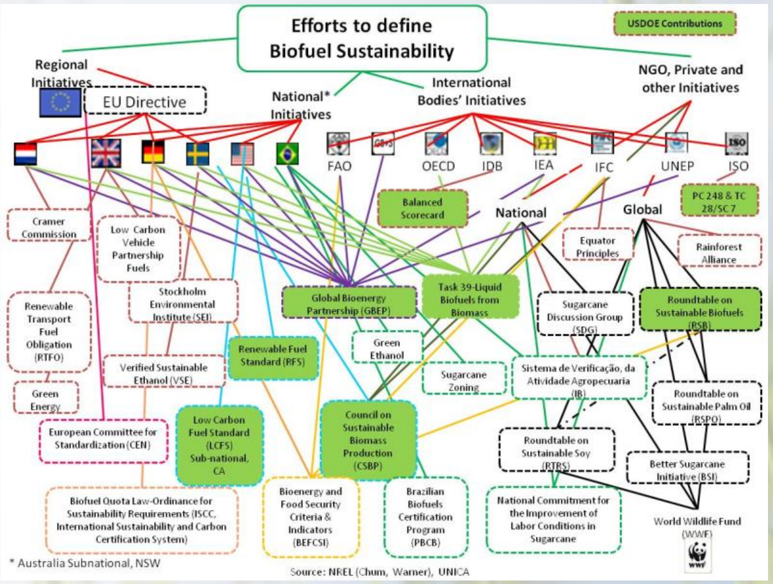
Many initiatives are exploring indicators for sustainability – e.g. for bioenergy…

- ISO (International Organization for Standardization)
- GBEP (Global Bioenergy Partnership)
- CSBP (Council on Sustainable Biomass Production)
- RSB (Roundtable on Sustainable Biofuels)
- Many more



BUT

- Some indicators focus on management practices although knowledge is limited about which practices are "sustainable"
- Implementation is limited by indicators being too
  - ✓ Numerous
  - ✓ Broad
  - ✓ Costly
  - ✓ Difficult to measure

Sustainability Indicators

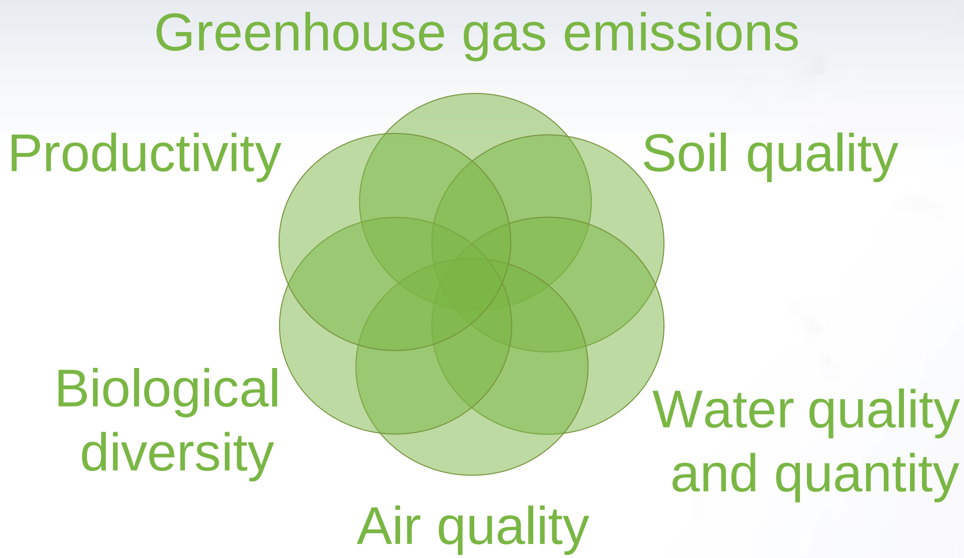
A measurement that provides information about the effects of human activities on the environment, society or economy.

Indicators should be

- Useful
  - Policymakers
  - Producers
- Technically effective
  - Sensitive to stresses on system
  - Anticipatory: signify impending change
  - Have known variability in response
- Practical
  - Easily measured
  - Consider context of measure
  - Broadly applicable
  - Predict changes that can be averted by management actions

Dale and Beyeler. 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators* 1: 3-10.

Categories for indicators of 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

Sustainability Should Apply to

- Entire supply chain
- Diverse feedstocks
- All conversion pathways

Feedstock production → Feedstock Logistics → Conversion → Biofuel Distribution → End use

- **Feedstock production**
  - Land conditions
  - Feedstock type
  - Management
- **Feedstock Logistics**
  - Harvesting and collection
  - Processing
  - Storage
  - Transport
- **Conversion**
  - Conversion process
  - Fuel type
  - Co-products
- **Biofuel Distribution**
  - Transport
  - Storage
- **End use**
  - Engine type and efficiency
  - Blend conditions

(Example shown is biofuel, but concepts are applicable to bioenergy as well)

Dale et al. 2013. *Environmental Management* 51(2): 279-290.

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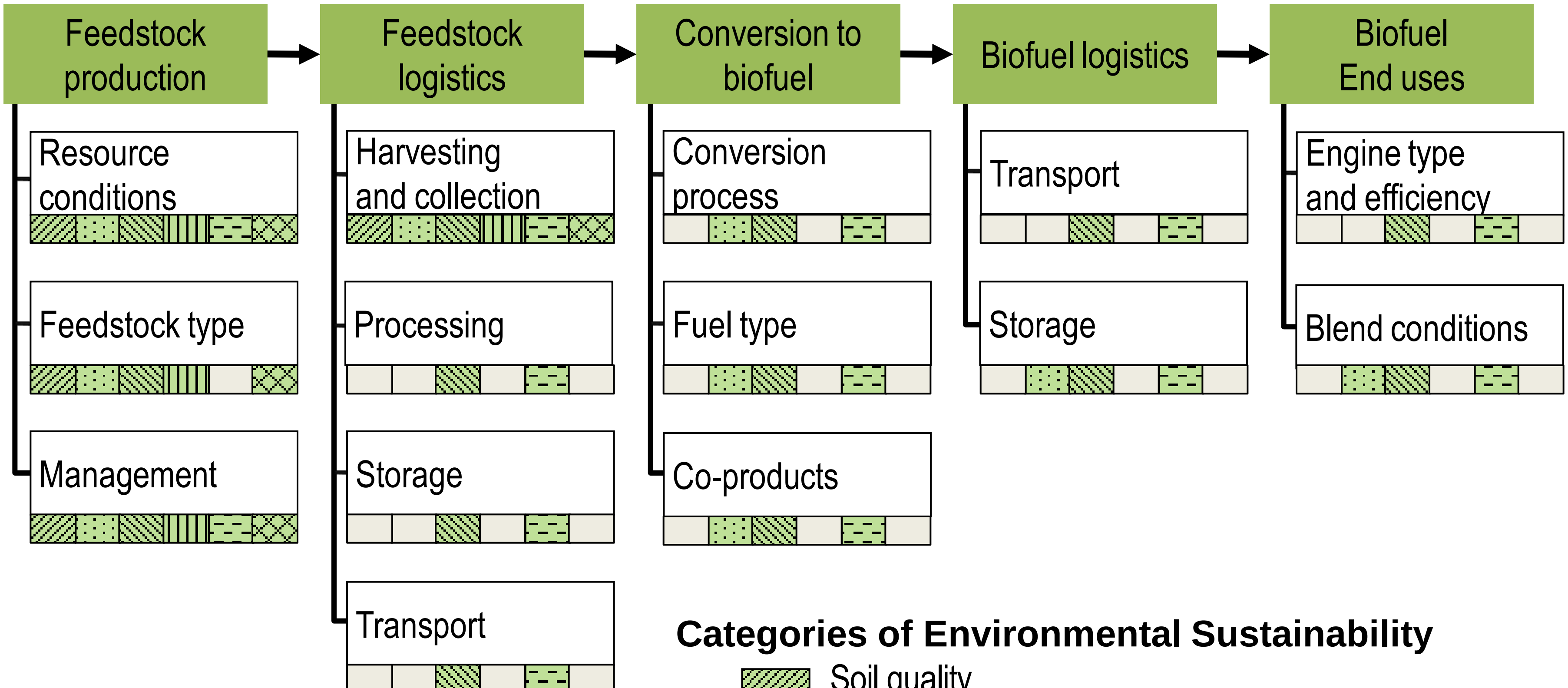
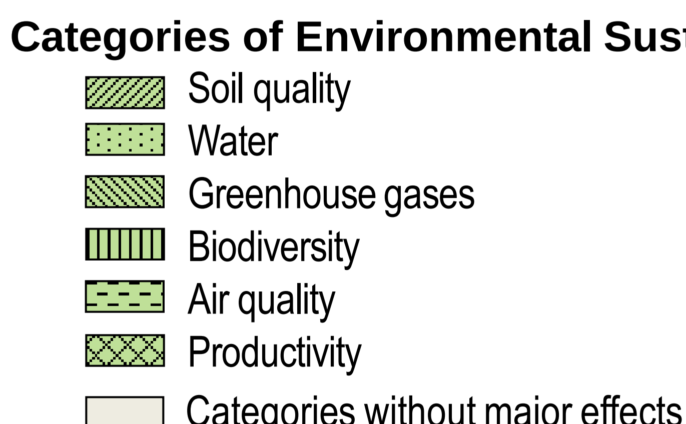
Looking at the biofuel supply chain in terms of environmental sustainability indicators





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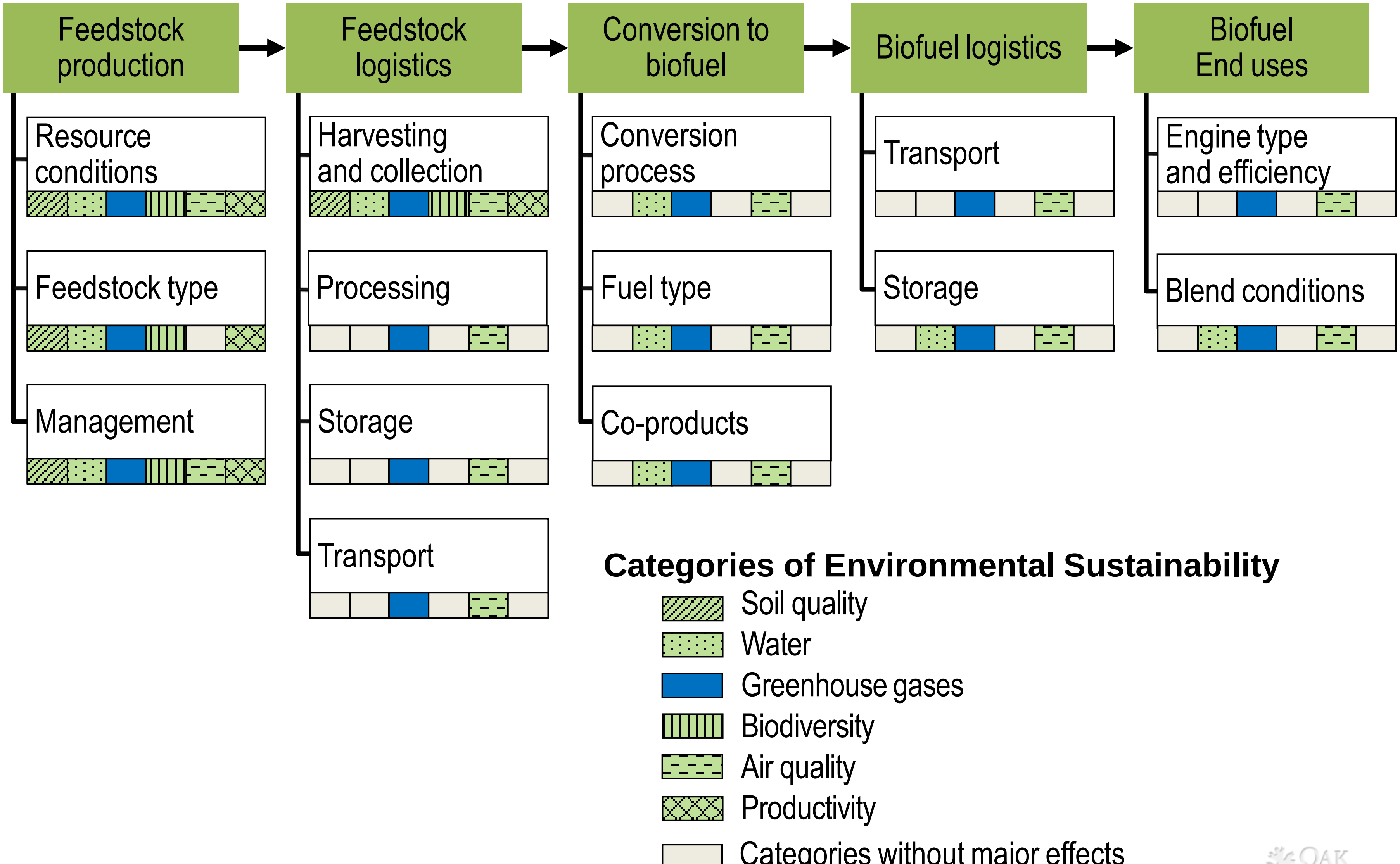
Greenhouse gas effects occur at all steps and substeps of the supply chain



Categories of socioeconomic sustainability indicators

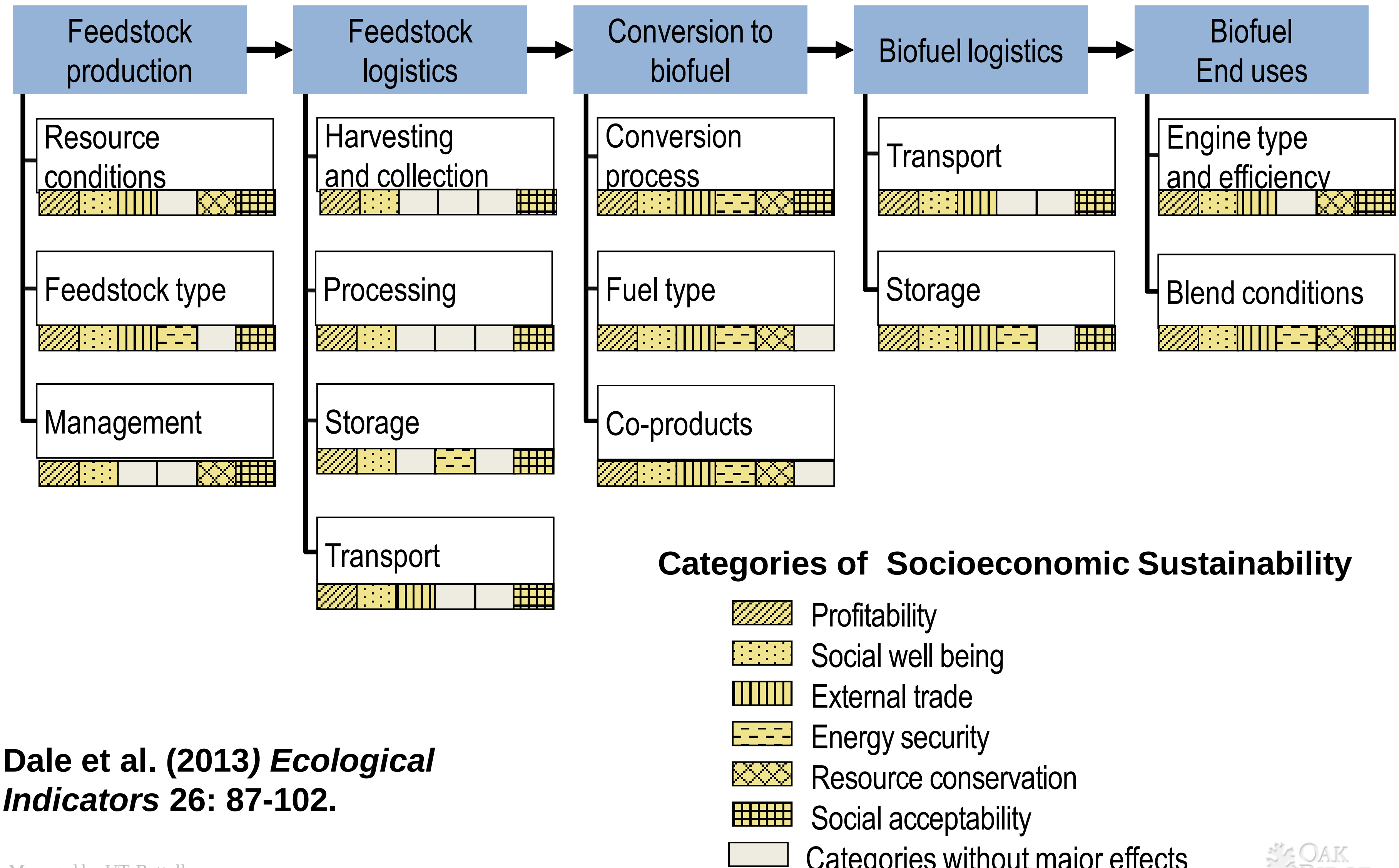
Ten minimum practical measures

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



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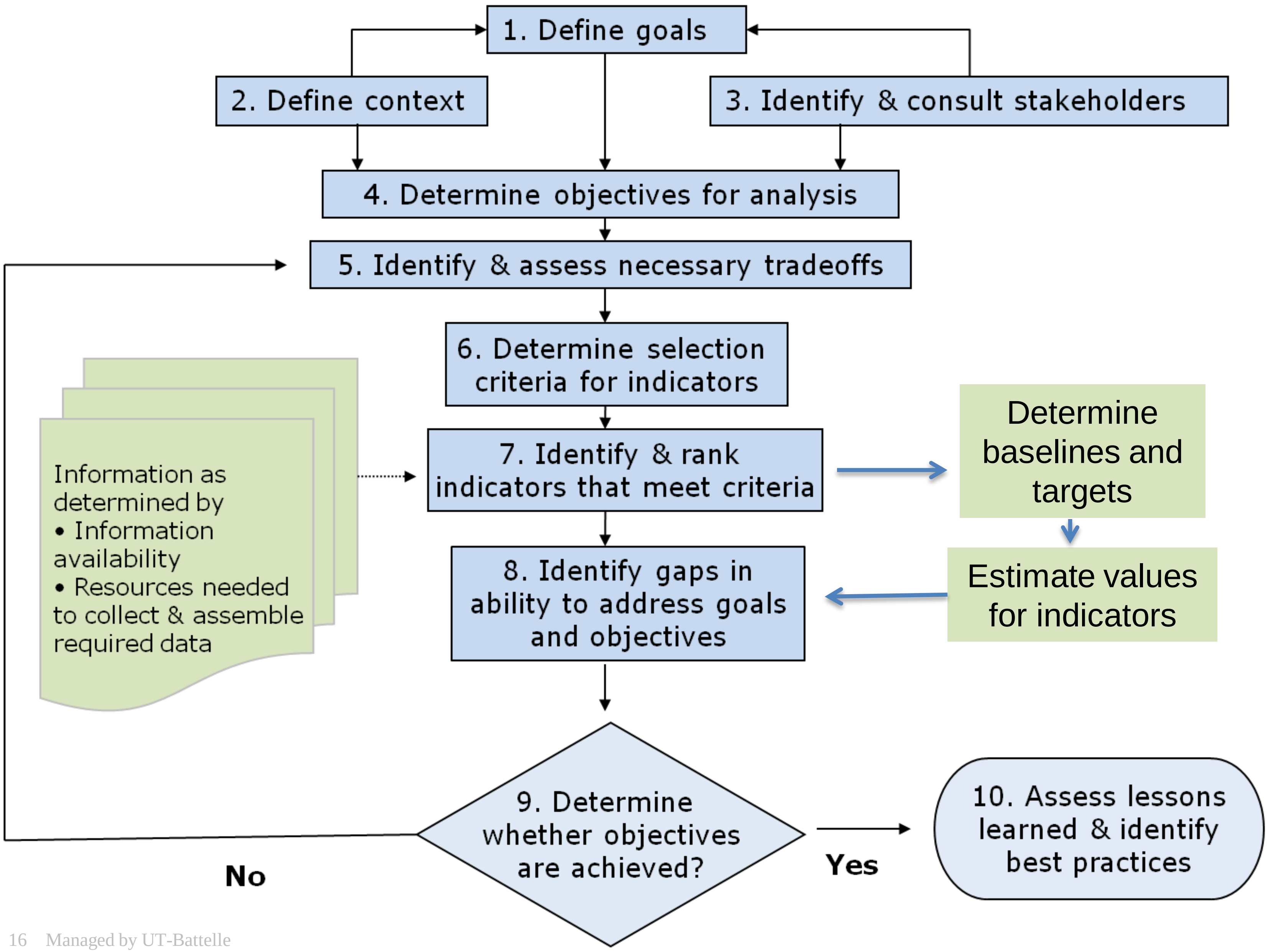
Adapting Suite to Particular Contexts

- **Indicator set is a starting point for sake of efficiency and standardization**
  - Particular systems may require addition of other indicators
  - Budget may require subtraction of some indicators
  - Some indicators more important for different supply chain steps
- **Protocols must be context-specific**

Interpreting Suite as a Whole

- Indicators constitute an integrated suite
- Multivariate statistical methods should be applied to measured values.
- Provide insights for tradeoffs in decision-making.

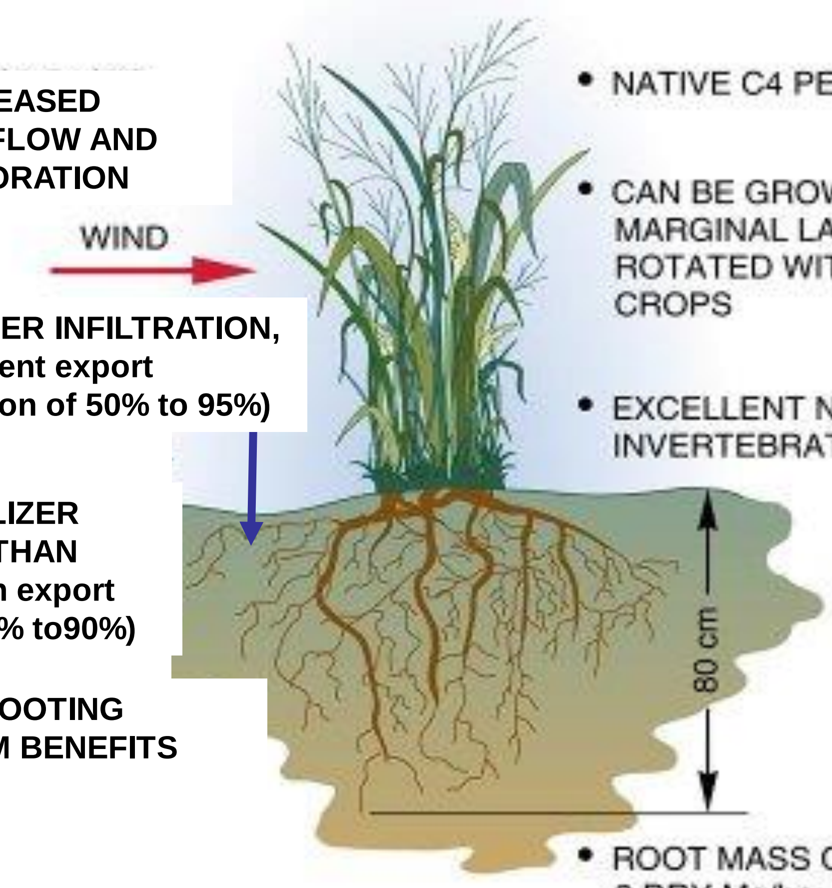
Framework for Using Indicators to Assess Issues



Documented sustainability benefits of switchgrass (a “model” perennial crop)

Yet specific crops are appropriate for different conditions

DECREASED WINDFLOW AND EVAPORATION



GREATER INFILTRATION, (Sediment export reduction of 50% to 95%)

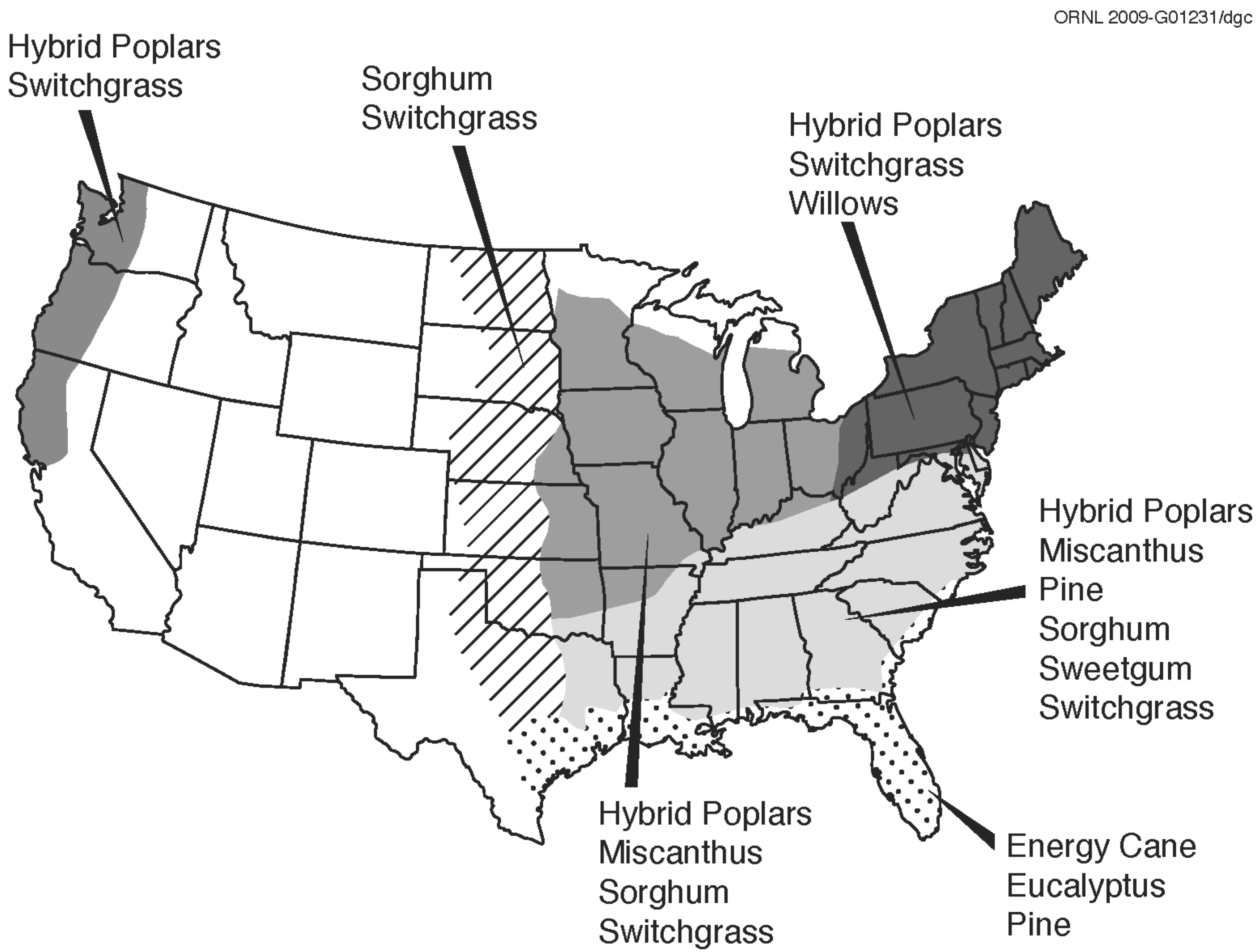
LOWER FERTILIZER APPLICATION THAN CORN (nitrogen export reduction of 25% to90%)

DEEP ROOTING SYSTEM BENEFITS

- NATIVE C4 PERENNIAL
- CAN BE GROWN ON MARGINAL LANDS OR ROTATED WITH OTHER CROPS
- EXCELLENT NESTING AND INVERTEBRATE HABITAT
- ROOT MASS CAN REACH 8 DRY Mg/ha; AN EXCELLENT CARBON SINK

Dale et al. (2011) *Ecological Applications* 21(4):1039-1054.

Recommended Biofuel Feedstock Plantings in Regions of the U.S.



Dale et al. (2011) *Ecological Applications* 21(4):1039-1054.

Assessing multiple effects of bioenergy choices

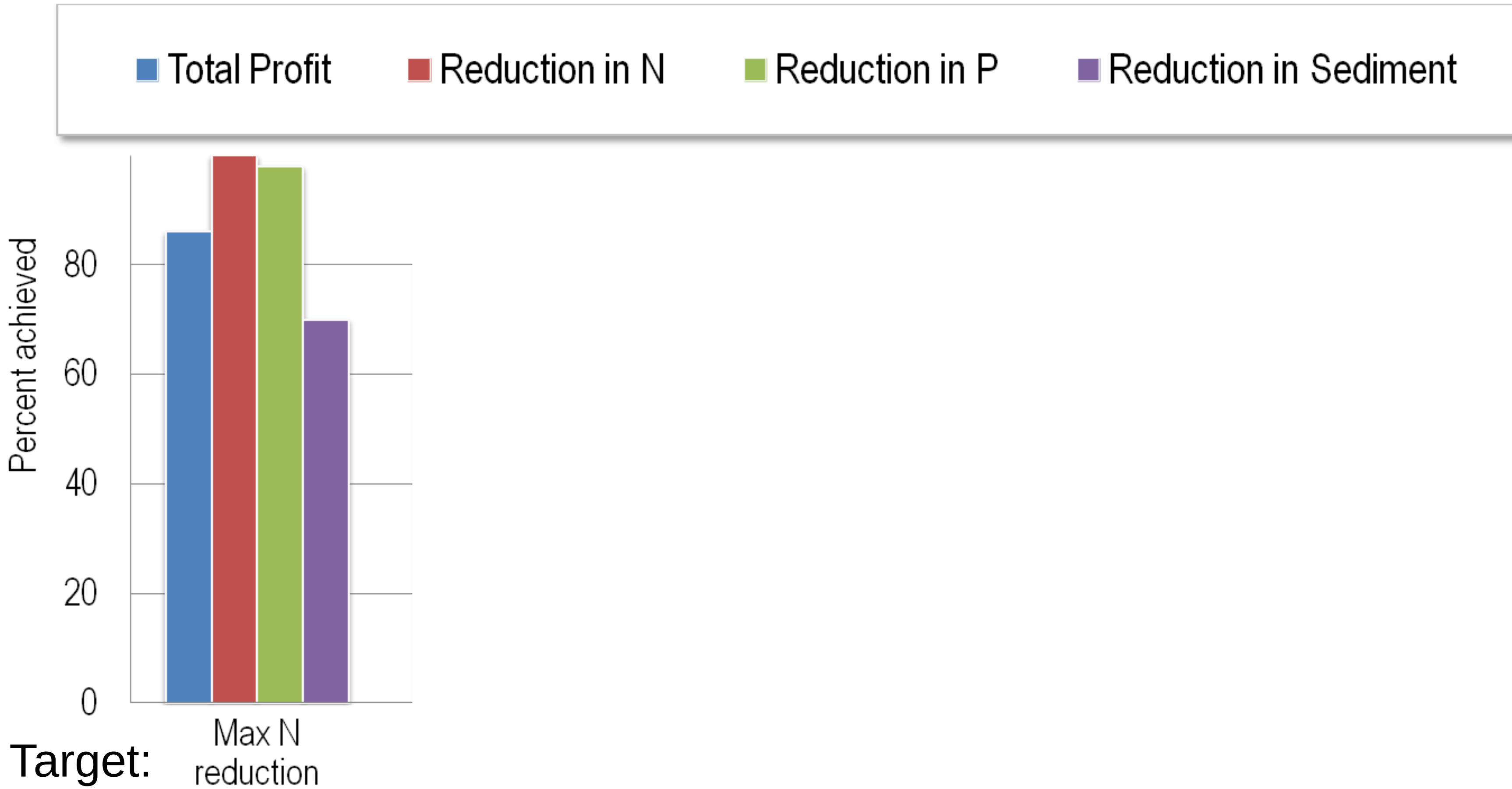
An optimization model identifies "ideal" sustainability conditions for using switchgrass for bioenergy in east Tennessee

Spatial optimization model

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

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

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



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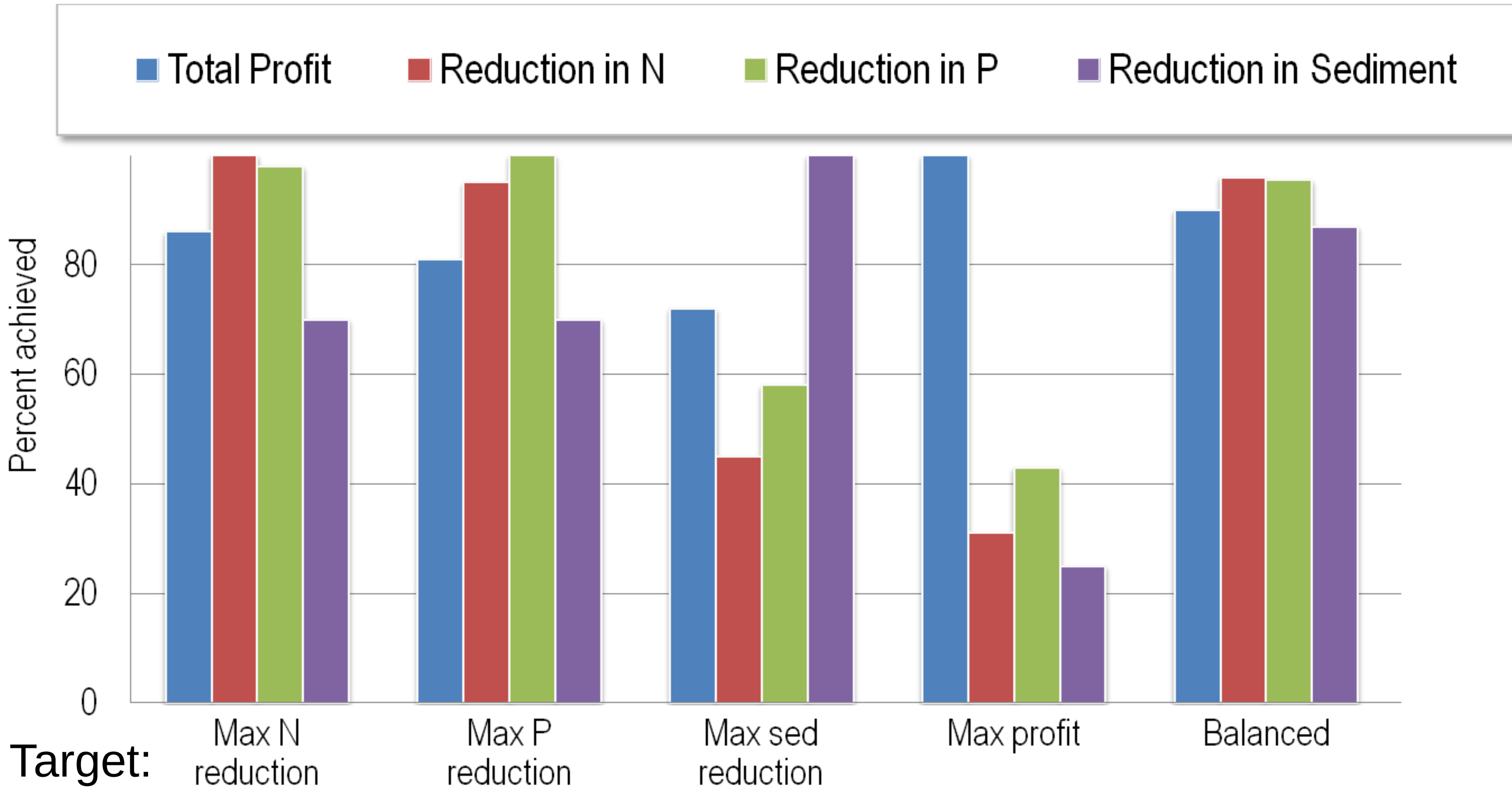
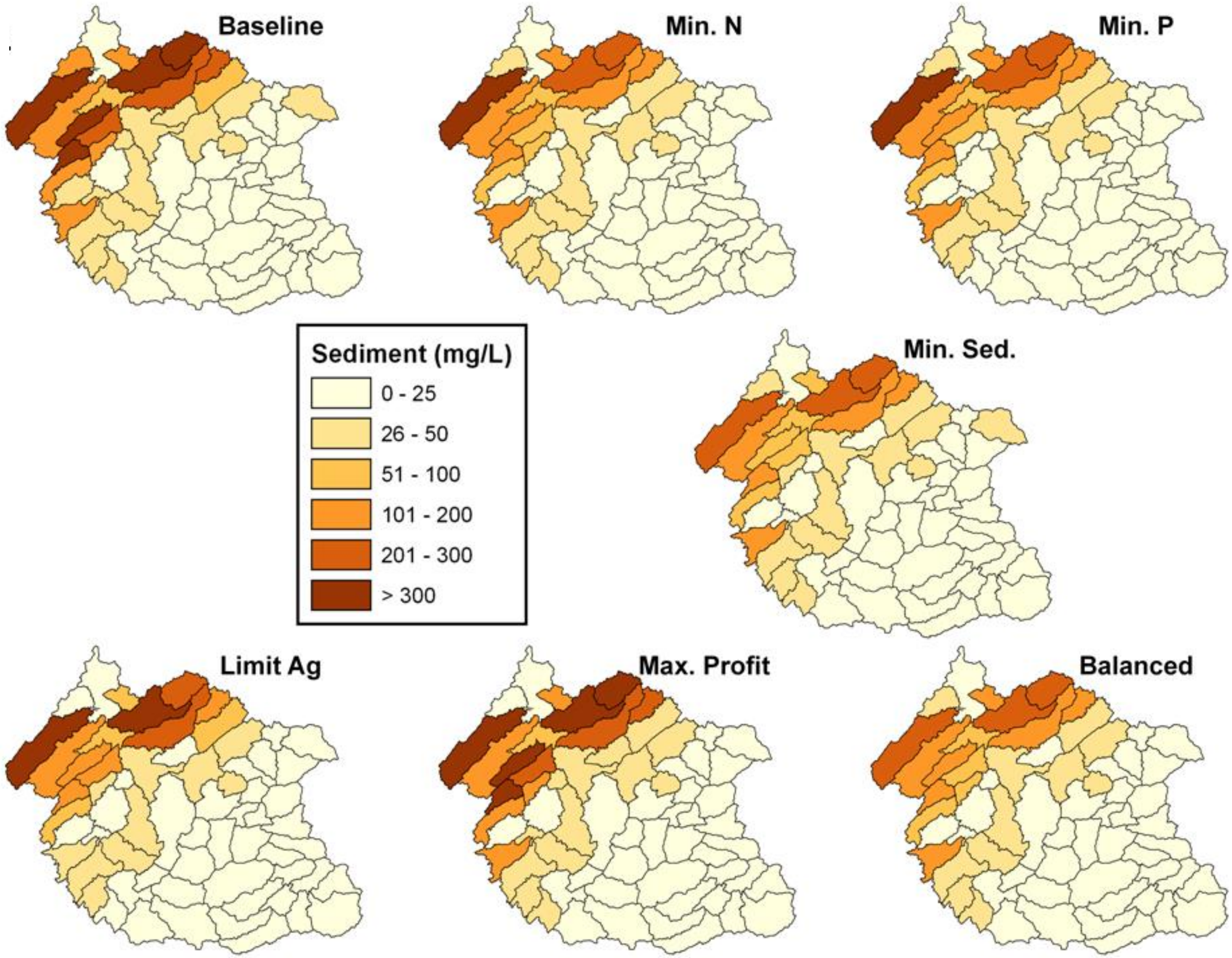


Land area recommended for switchgrass in this watershed: 1.3% of the total area (3,546 ha of 272,750 ha)

Projected sediment concentrations under 6 BLOSM scenarios



But measuring water quality is costly and difficult

Consider indirect measures:

Land-use change

↓

Changes in water quality

↓

Changes in habitat

↓

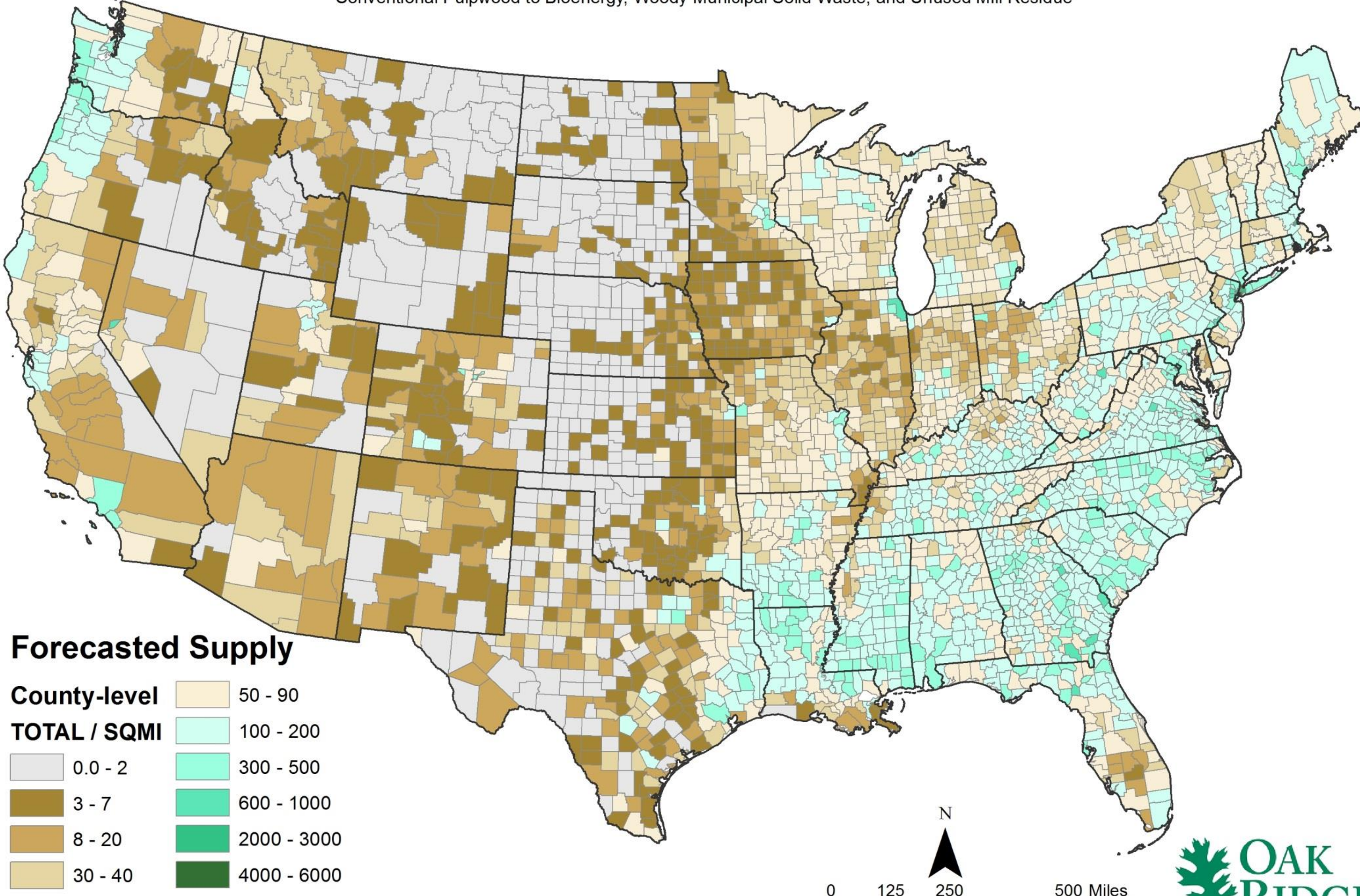
Changes in macroinvertebrate species

EPT richness = number of distinct taxa in the insect orders:

- Ephemeroptera (mayflies)
- Plecoptera (stoneflies)
- Trichoptera (caddisflies)

Potential Forestry Biomass Resources, 2012

Includes all potential primary and secondary resources excluding Federal Lands (when available) at $80 per dry ton or less:
Logging Residues, Simulated Forest Thinnings, Other Removal Residue, Treatment Thinnings (other forestland),
Conventional Pulpwood to Bioenergy, Woody Municipal Solid Waste, and Unused Mill Residue



Source: U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p.

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

Negative impacts of bioenergy can be avoided or reduced by attention to three principles:

1. Conserve other ecosystem and social services (e.g., food, feed, fiber or area of high biodiversity).
2. Consider local context (effects of bioenergy on social and ecosystem services are context specific so recommended practices should also be location-specific).
3. Monitor effects of concern and adjust plans to improve performance over time.

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Landscape design is a plan for resource allocation.

- Offers a means to make appropriate use of current conditions
- Provides for a sustainable bioenergy system

Pressures and incentives for landscape design

- Legal demands or regulations
- Customer demands
- Response to stakeholders
- Competitive advantage
- Environmental and social pressure groups
- Reputation loss

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

Obstacles to developing and deploying landscape design

- Up front planning required
- Coordination complexity/effort
- Higher costs
- Insufficient/missing communication in supply chain

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

What promotes landscape designs?

- Communication across the supply chain
- Management systems (e.g., ISO 14001)
- Training education of purchasing employees and suppliers
- Integration into the corporate policy

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

Recommended practices

- Attention to site selection and environmental effects in the
  - location and selection of the feedstock
  - transport of feedstock to the refinery
  - refinery processing
  - final transport and dissemination of bioenergy.
- Monitoring and reporting of key measures of sustainability
- Attention to what is "doable"
- Communication of environmental opportunities and concerns to the stakeholders

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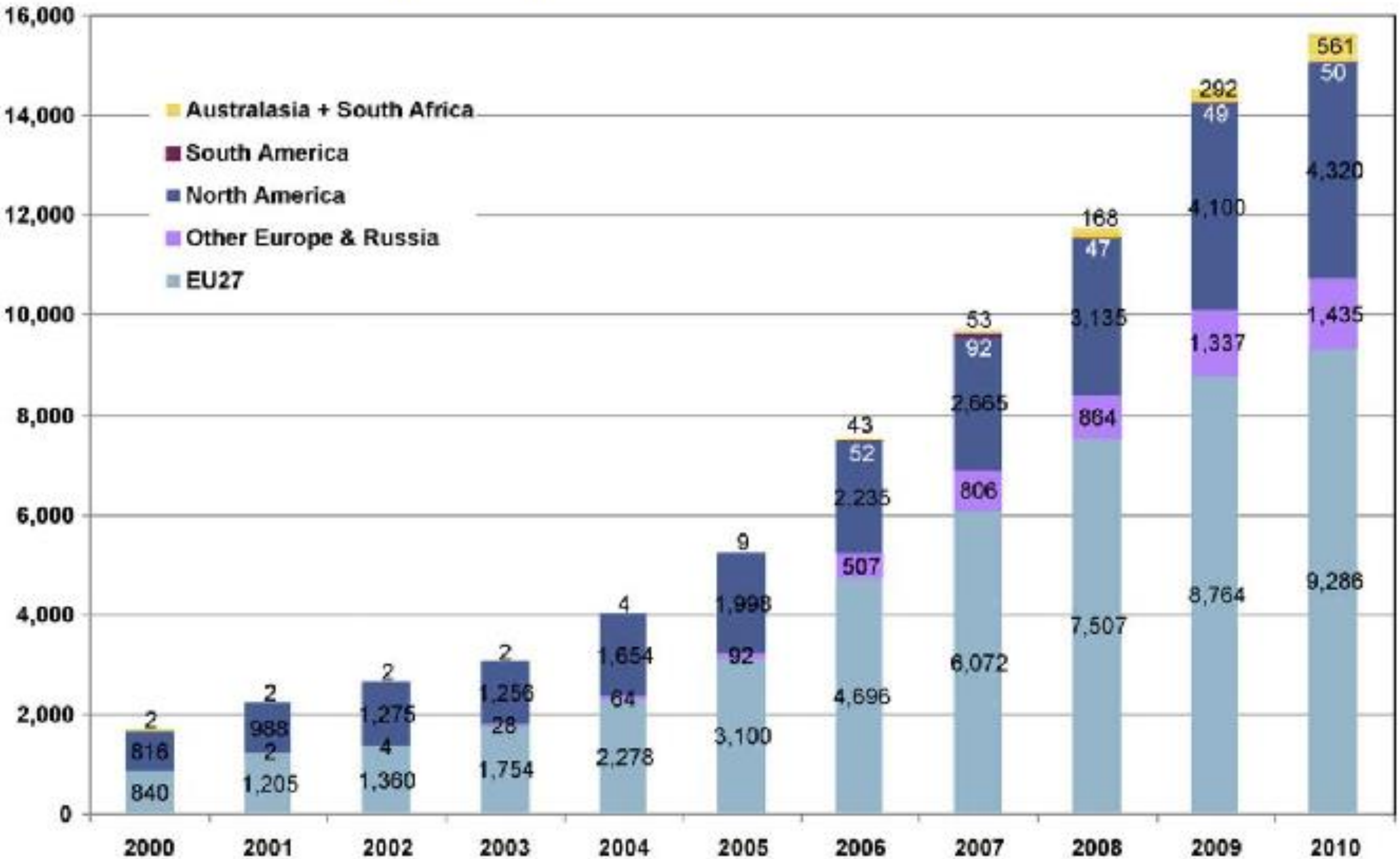
Global wood pellet production 2000 - 2010



(Source: Lamers et al. RSER, 16(2012) 3176-3199

By–products of tree harvest for saw timber and pulp in southeast US are used for bioenergy

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Trees are cut and sorted by size.

- Harvest meets standards of Forest Sustainability Initiative (FSI)
- Branches returned to forest
- Protection of places providing unique ecosystem service

Largest trees are cut to fit into containers and shipped to China to be used for concrete forms.

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

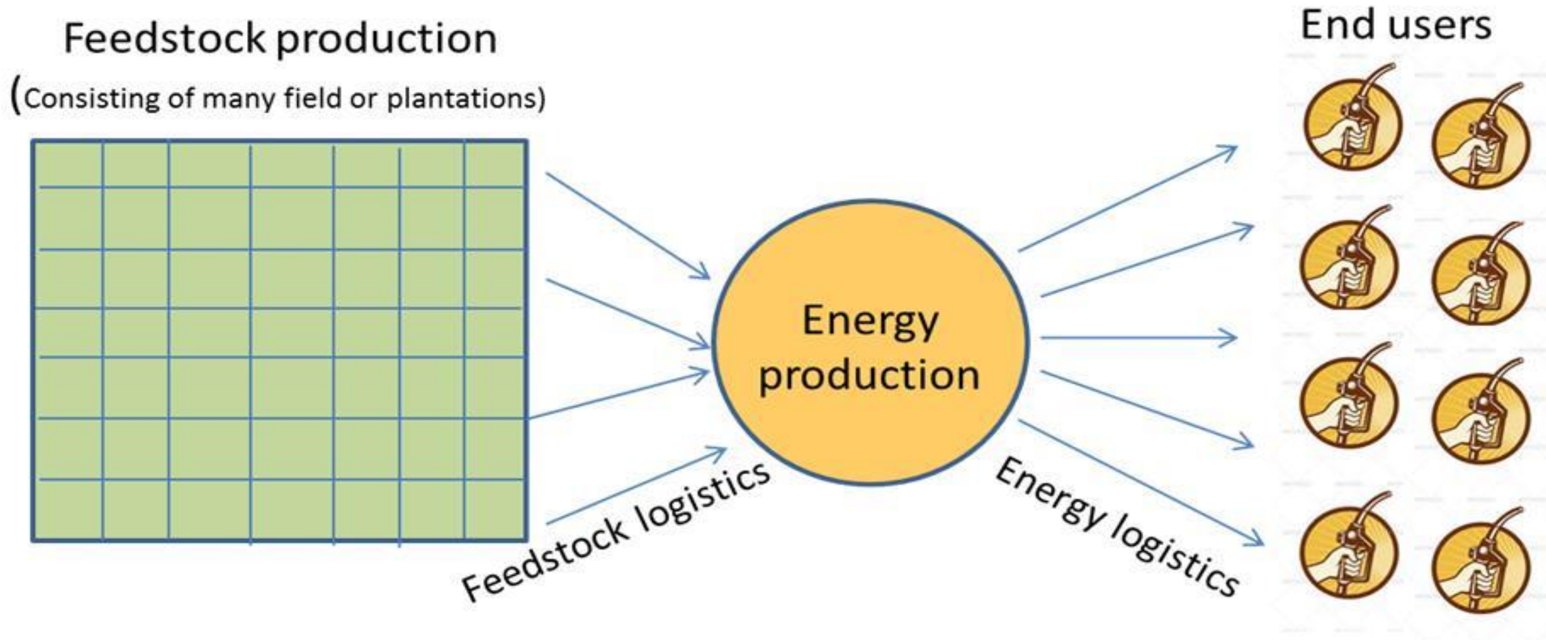
Created Time: 10:13 AM Created Date: 10/23/13
Product: PST Cut to Length
Destination: East Coast Terminal
Hauler Name: Wall Timber Products Inc
j2799 Truck #: Robbie Finch

Authorization:
Contractor Signature:

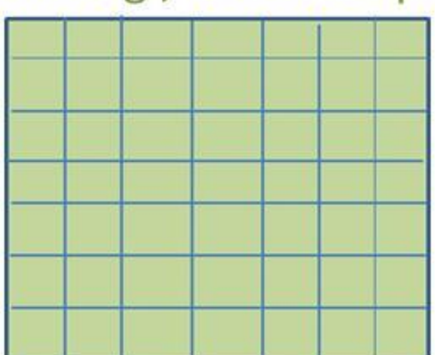
Time: 10/24/13 07:45 AM
Location:
Latitude: 31.71831
Longitude: -81.45925
Contract: 350F6502

The scale of the bioenergy production system may be

(A) The entire supply system



(B) Just one part of the supply system: e.g., feedstock production



(C) A set from one part of the supply system: e.g., a few fields where energy crops are produced or residues are collected

Landscape design approach for bioenergy should be applied via five steps:

- Set goals
- Consider constraints
- Address wastes
- Evaluate and apply solutions
- Monitor for adaptive management

Next steps in our research

- Integration of sustainability indicators
  - Multi-Attribute Decision Support System (MADSS)
  - Aggregation theory
  - Visualization
- Gaming as a way to learn about how people value ecosystem and social services

MADSS integration of sustainability indicators

Esther Parish and others

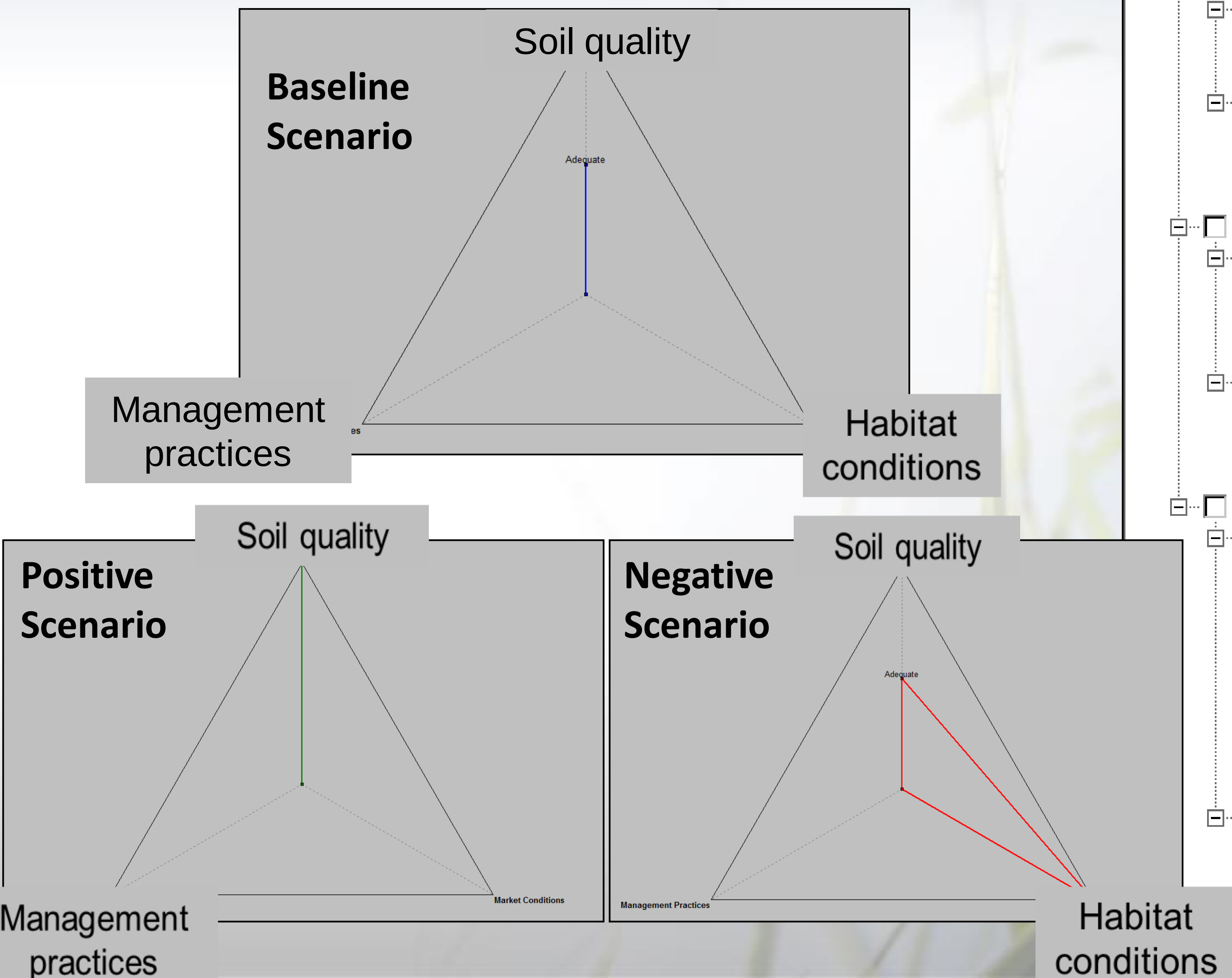
A <u>Multi-Attribute Decision Support System (MADSS)</u> for a given objective is developed by defining:

- ***Attributes:*** qualitative variables representing decision subproblems
- ***Scales:*** ordered or unordered sets of symbolic values for attributes
- ***Tree of attributes:*** hierarchical structure representing decomposition of decision problem
- ***Utility functions:*** rules that define the aggregation of attributes from bottom to the top of the tree

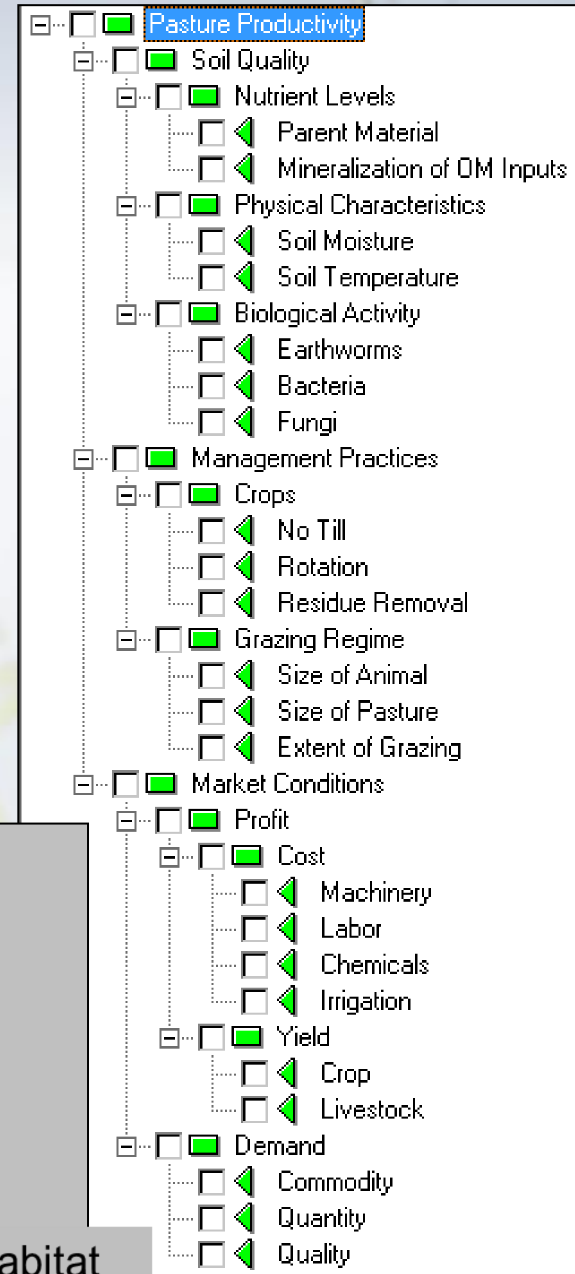
We are building a MADSS using software developed by the Jožef Stefan Institute in Slovenia:

Example of MADSS approach:

Exploring relative importance of factors critical to pasture productivity in New Zealand



Aggregation hierarchy:



Aggregation Theory

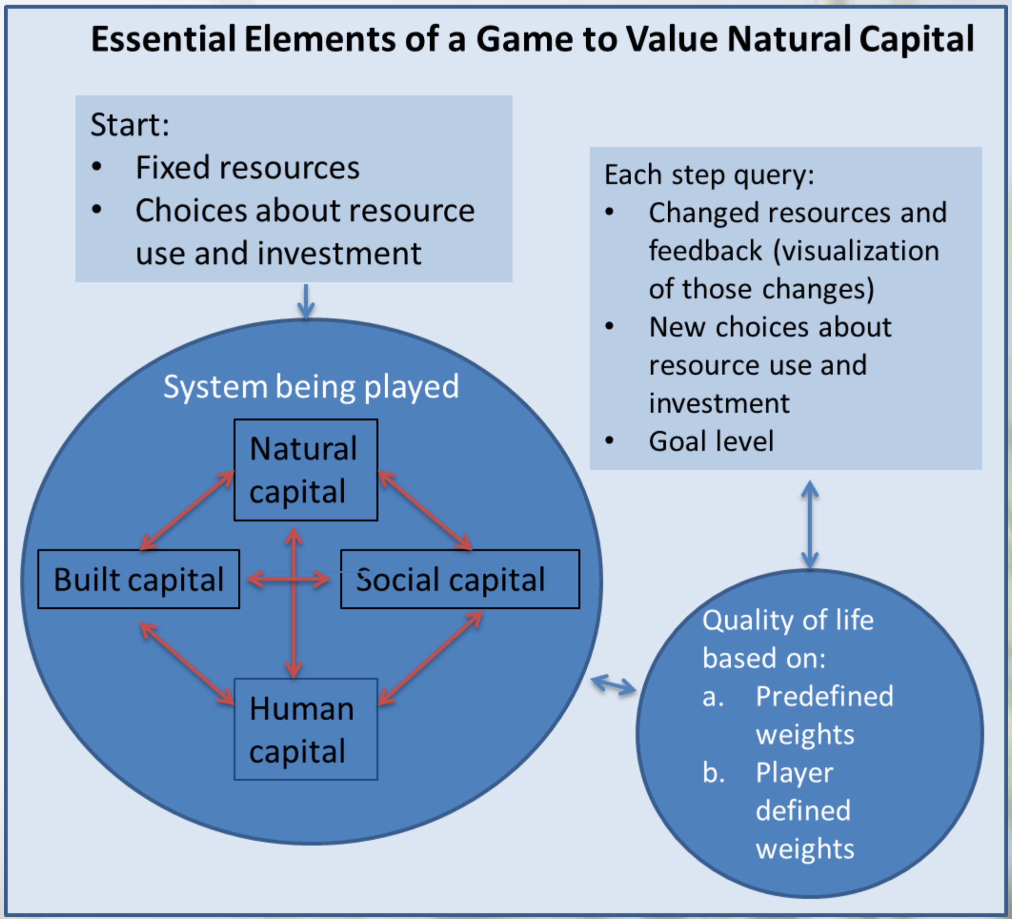
Nate Pollesch and others

- Aggregation is the process of fusing information
  - The task of an aggregation function is to compute a single, representative, output value for a set of input values.
- Aggregation is ubiquitous in the sciences
  - Aggregation theory have been motived by, and risen out of, work in economics, ecology, the social sciences, and mathematics
- Aggregation theory and sustainability assessment
  - There are links between basic properties of aggregation functions and sustainability assessment goals.
  - E.g. 'Weak vs strong' sustainability (the ability for compensation across the three pillars) can be linked to the property of internality of an aggregation function.

Gaming as a way to learn about how people value ecosystem and social services

Bob Costanza, Rick Ziegler and 20+ others

- **Gaming is a huge activity**
  - Global consumer spending on digital games in 2010 ~ $55.5 billion
  - 58% of Americans play digital games with the average age being 30, and 45% are female
  - Globally, gamers play ~ 3 billion hours per week
- **Opportunities for education and research**
  - Crowdsourcing ecosystem services information
  - Crowdsourcing simulations and scenarios
  - Integrated modeling platforms
  - Valuation sampling from large and diverse population



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Thank you!

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