Sustainability Indicators

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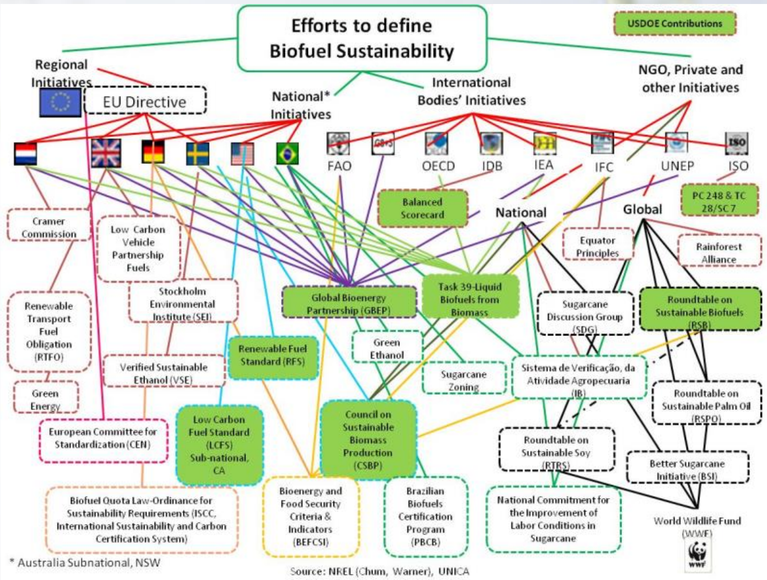
Discussion Topics

- Environmental and socioeconomic indicators of bioenergy
- Multimetric optimization approach to considering multiple objectives
- Next steps in research portfolio

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

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ORNL Approach to Assessing Bioenergy Sustainability

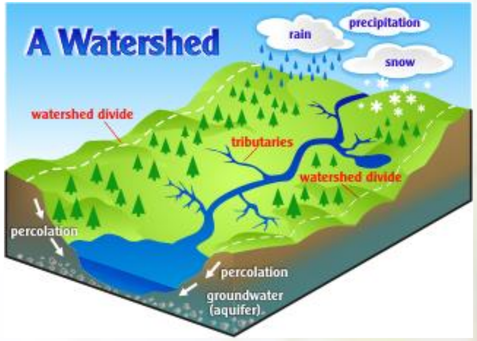
✔ Select Indicators

Establish baselines and targets

Evaluate indicator values

Identify trends and tradeoffs

Develop and test best practices



Sustainability Indicators

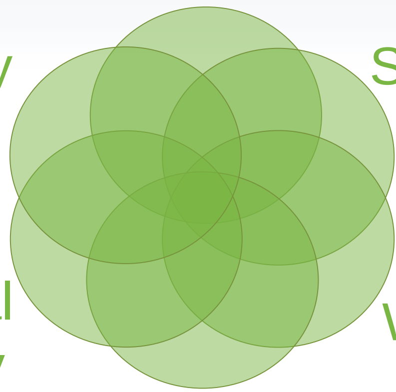
A measurement that provides information about the effects of human activities on the environment, society or economy.

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.

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Categories of environmental sustainability indicators

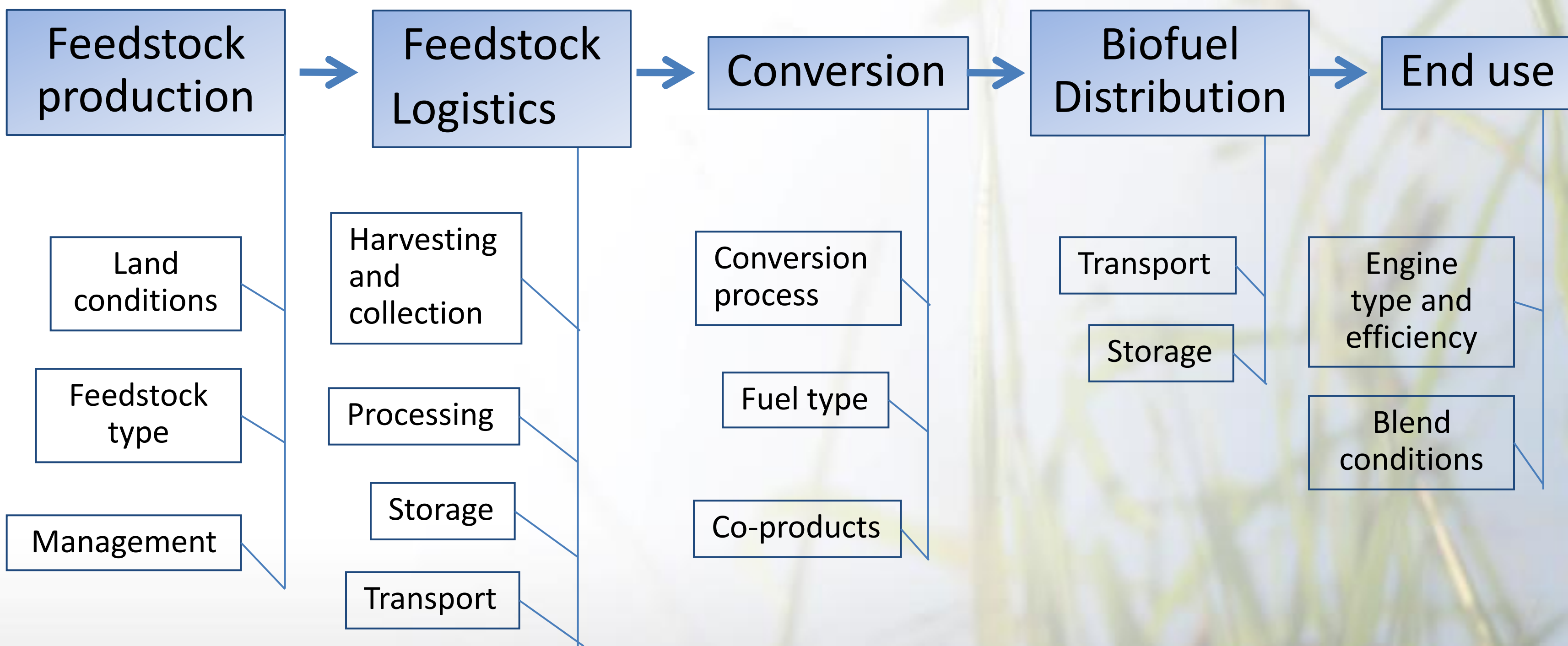
Environment	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus (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

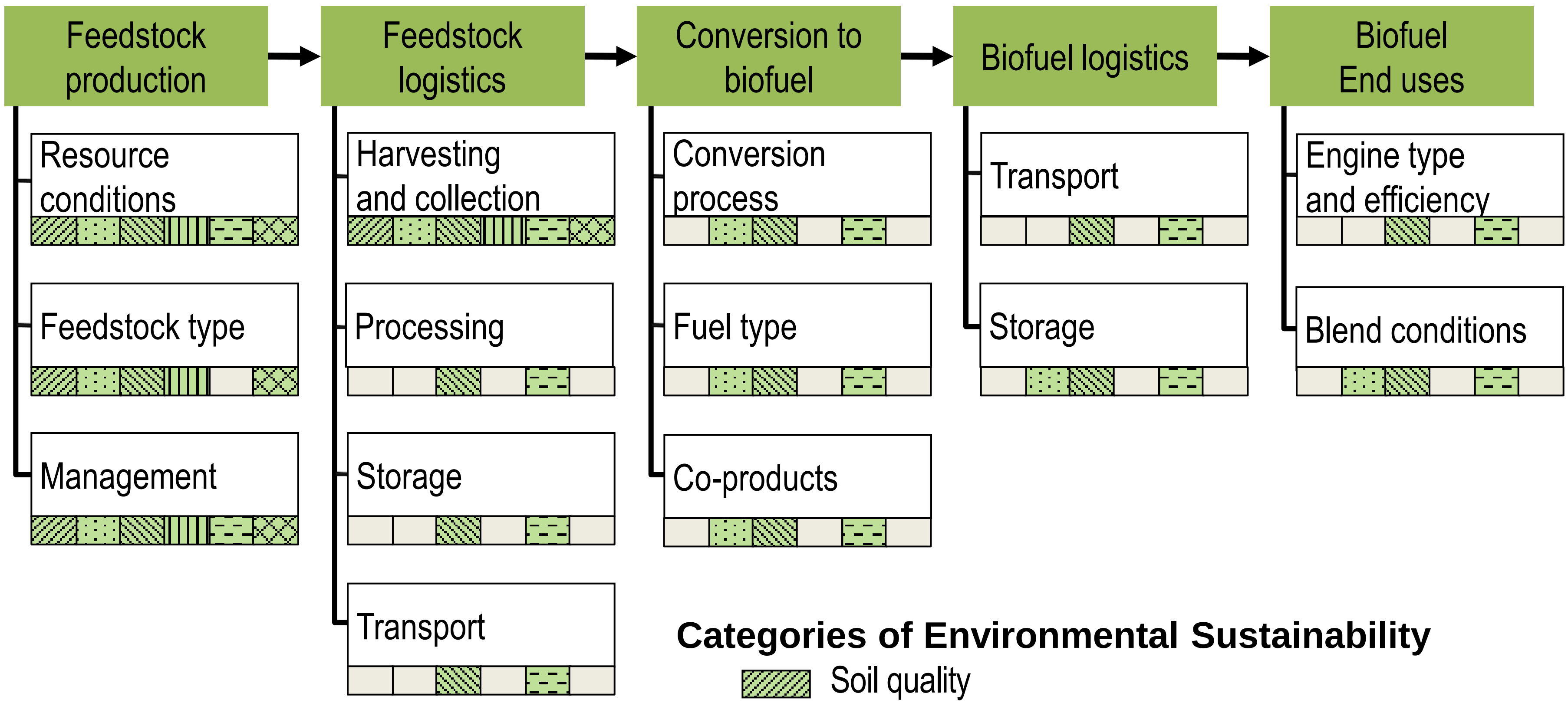
- Entire supply chain
- Diverse feedstocks
- All conversion pathways

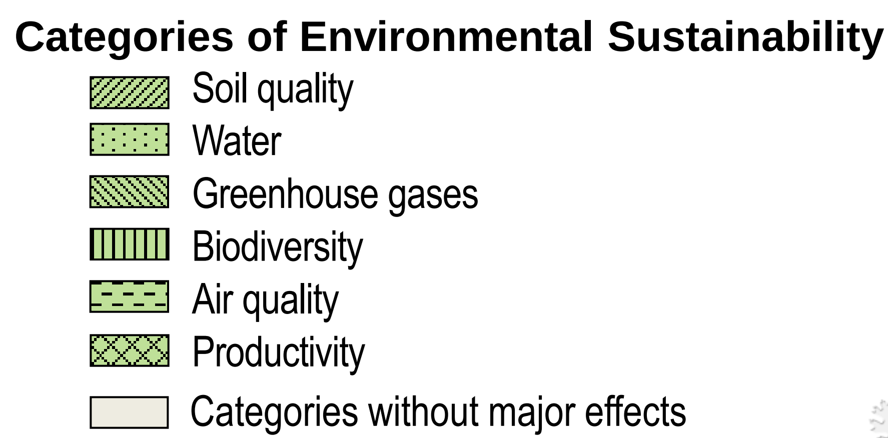


(Example shown is biofuel, but concepts are applicable to bioenergy as well)

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

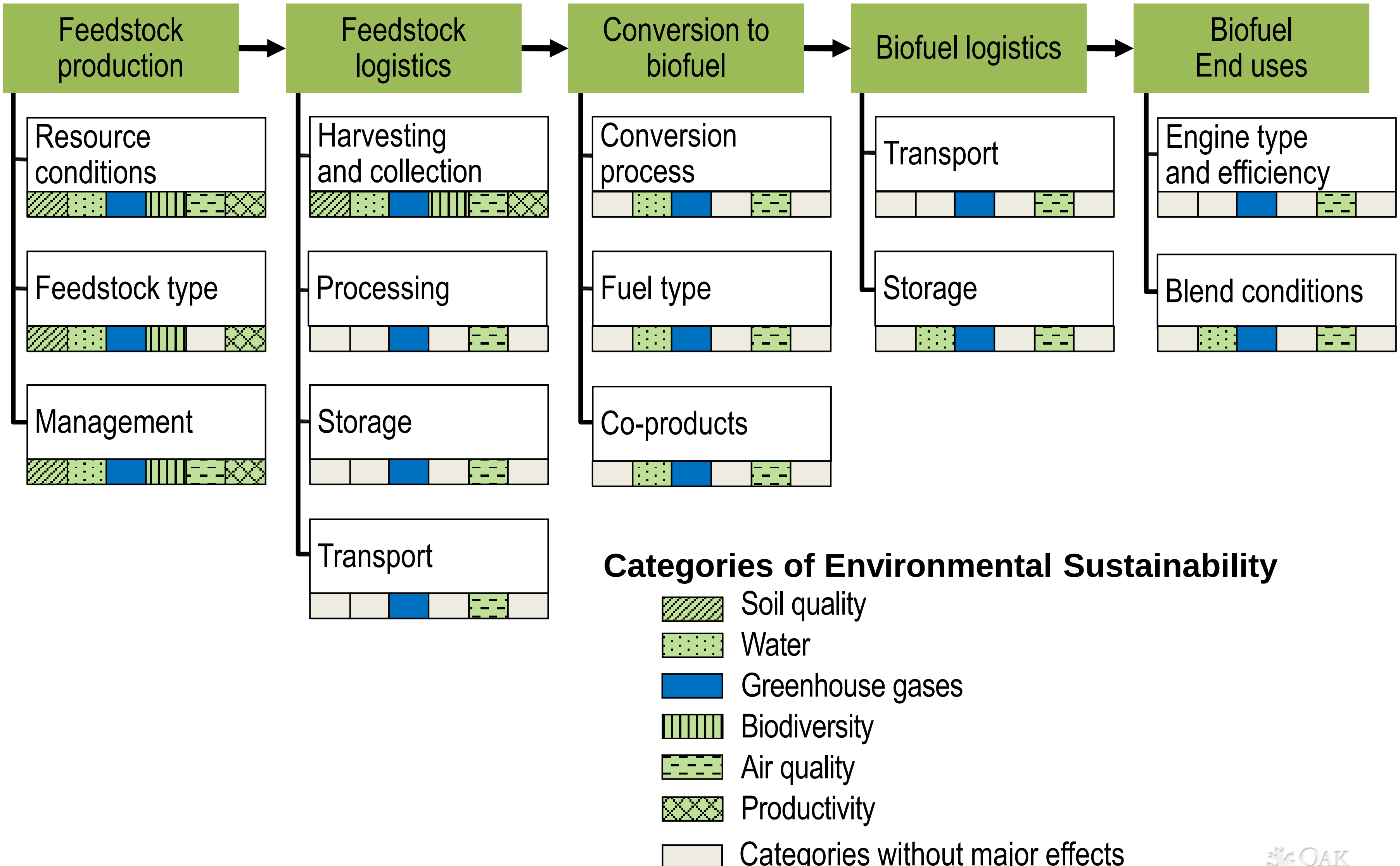
Looking at the biofuel supply chain in terms of environmental sustainability indicators





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

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.

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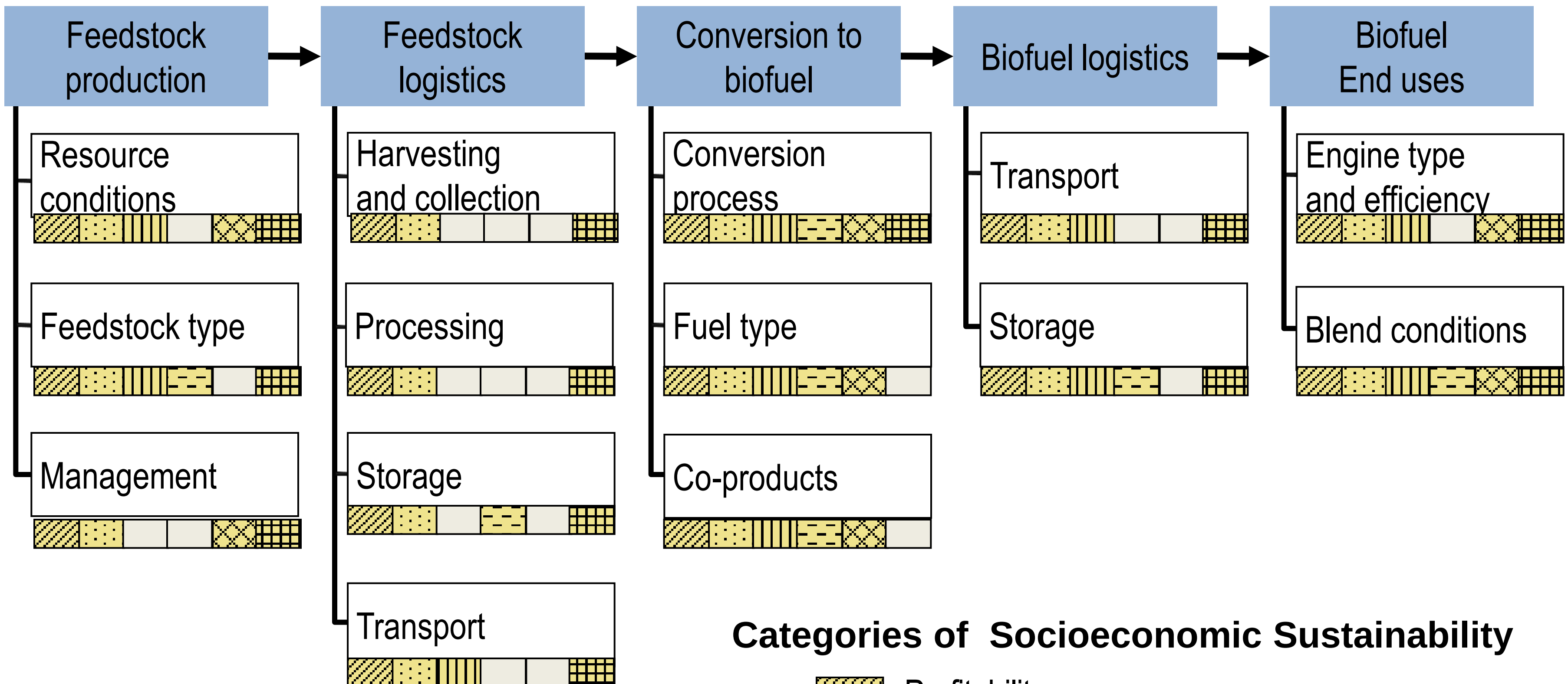
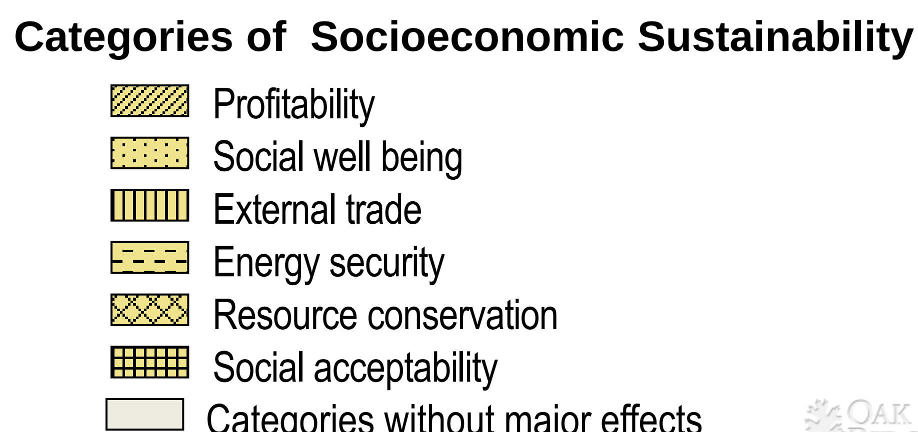
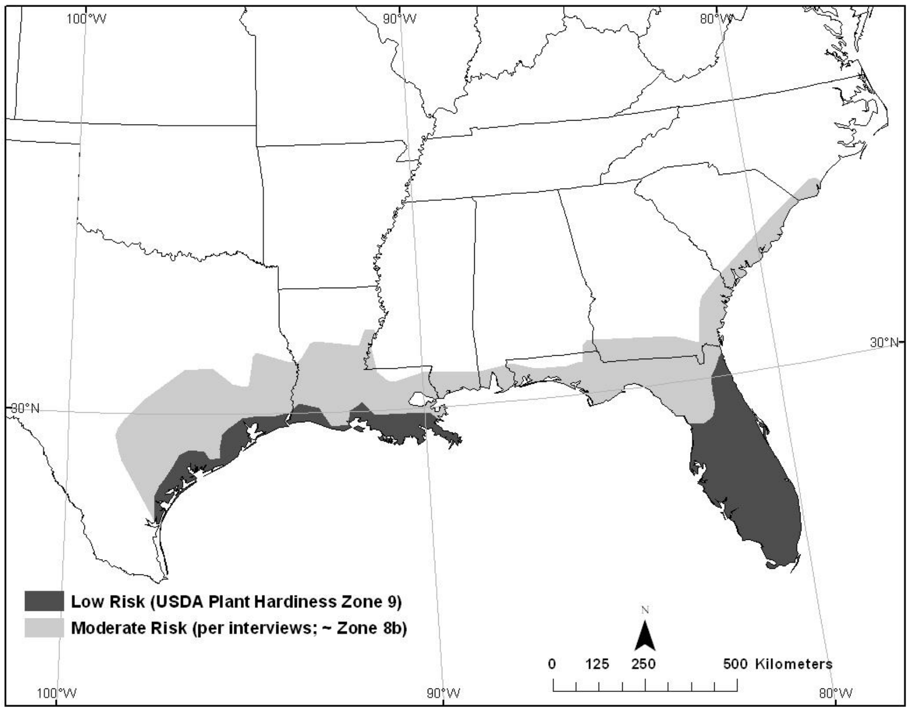




Dale et al. (2013) ***Ecological Indicators*** **26: 87-102.**

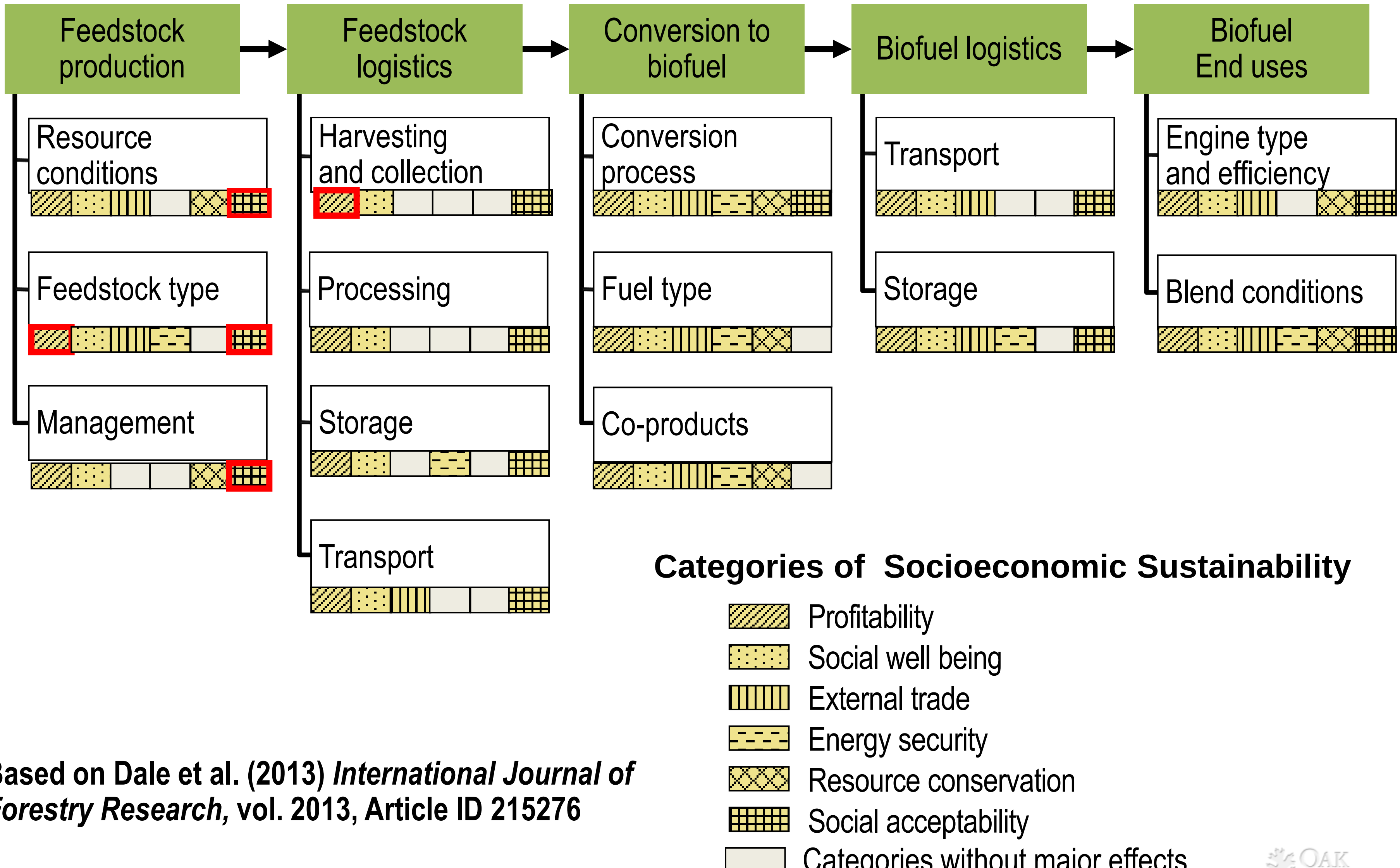
Sustainability indicators apply uniquely to specific contexts

For example, *Eucalyptus* is being considered for planting in the southeastern US.



Kline and Coleman (2010) *Biomass and Bioenergy* 34(12):1655-1666.

Major effects within the biofuel supply chain for *Eucalyptus* grown for bioenergy in southeastern US



Based on Dale et al. (2013) *International Journal of Forestry Research*, vol. 2013, Article ID 215276

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**

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

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.

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

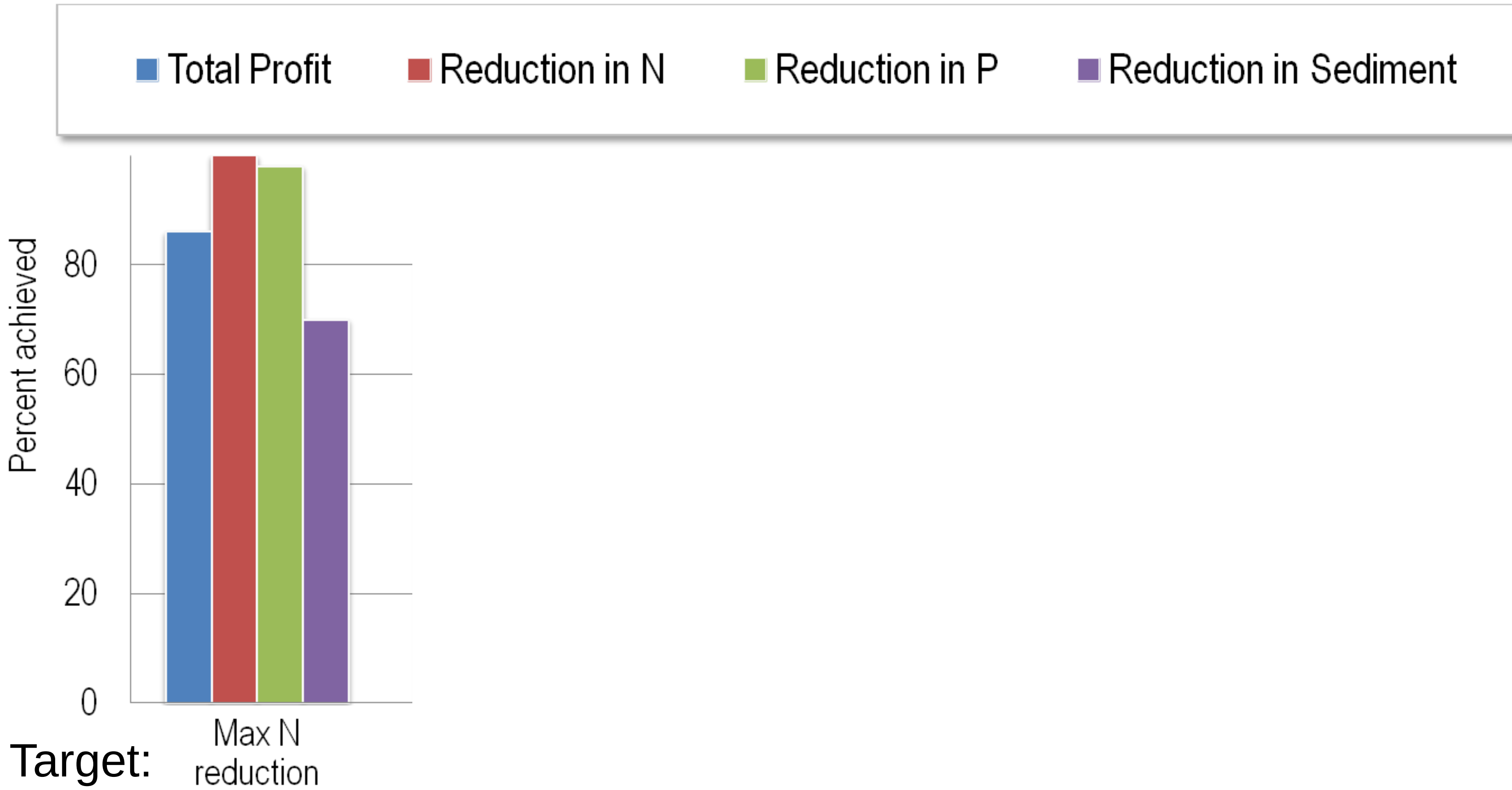
Parish et al., *Biofuels, Bioprod. Bioref*. 6,58–72 (2012)

Scenarios considered (to date)

- Targets based on potential thresholds of stream eutrophication that resulted from these nutrients (Dodds 2007).
- Model run to identify maximum achievable target in the Lower Little Tennessee watershed and then optimizations are compared to target

- Baseline: business as usual (no target)
- Minimize nitrogen: used to determine whether nitrogen concentration levels of ≤1 mg/L could be achieved by planting the target tonnage of switchgrass throughout the study area
- Minimize phosphorus: used to determine whether phosphorus concentration levels of ≤ 0.1 mg/L could be achieved by planting the target tonnage
- Minimize sediment: examined the possibility of achieving sediment concentrations of ≤ 50 mg/L through planting the target tonnage
- Maximize profit: solved for the greatest net returns achievable
- Balanced: All three water quality goals and economic profit were equally weighted

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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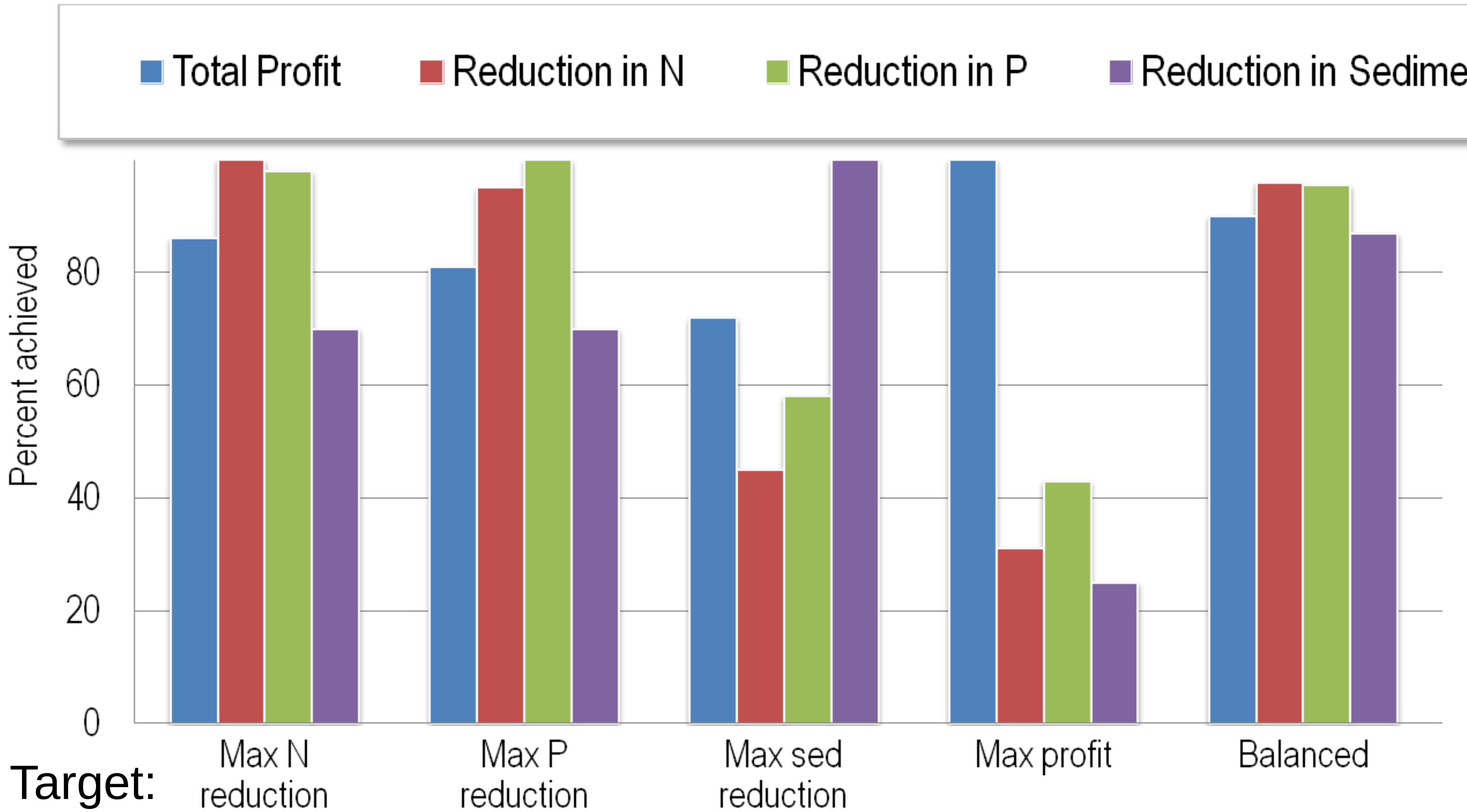

Land area recommended for switchgrass in this watershed:
1.3% of the total area (3,546 ha of 272,750 ha)

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

Next steps

- Case study of switchgrass in east TN
  - Validate BLOSM model projections
  - Assess ability of aquatic macroinvertebrate diversity to be surrogate indicator for water quality
- Consider ways to assess multiple indicators in collective fashion
  - Conduct multi-attribute decision support system (MADSS) analysis for suite of indicators -- switchgrass in East TN
  - Employ visualization tools
  - Develop method to combine indicators
- Develop landscape design approach
  - Formalize approach
  - Work with FAO to design sustainable bioenergy systems that foster energy and food security in particular contexts
  - Test approach for
    - Switchgrass in east TN
    - Woody biomass in southeast US

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Thank you!

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