ENVIRONMENTAL AND SOCIOECONOMIC INDICATORS FOR BIOENERGY SUSTAINABILITY AS APPLIED TO SHORT ROTATION WOODY CROPS

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Based on collaborations with LM Baskaran, S Beyeler, MR Davis, ME Downing, LM Eaton, RA Efroymson, C Garten, RL Graham, NA Griffiths, M Hilliard, H Jager, K Kline, PN Leiby, R Lowrance, M Langholtz, A McBride, R Middleton, PJ Mulholland, GA Oladosu, ES Parish, RD Perlack, P Robertson, D Rockwood, P Schweizer, A Sorokine, J Storey, NA Thomas, LL Wright

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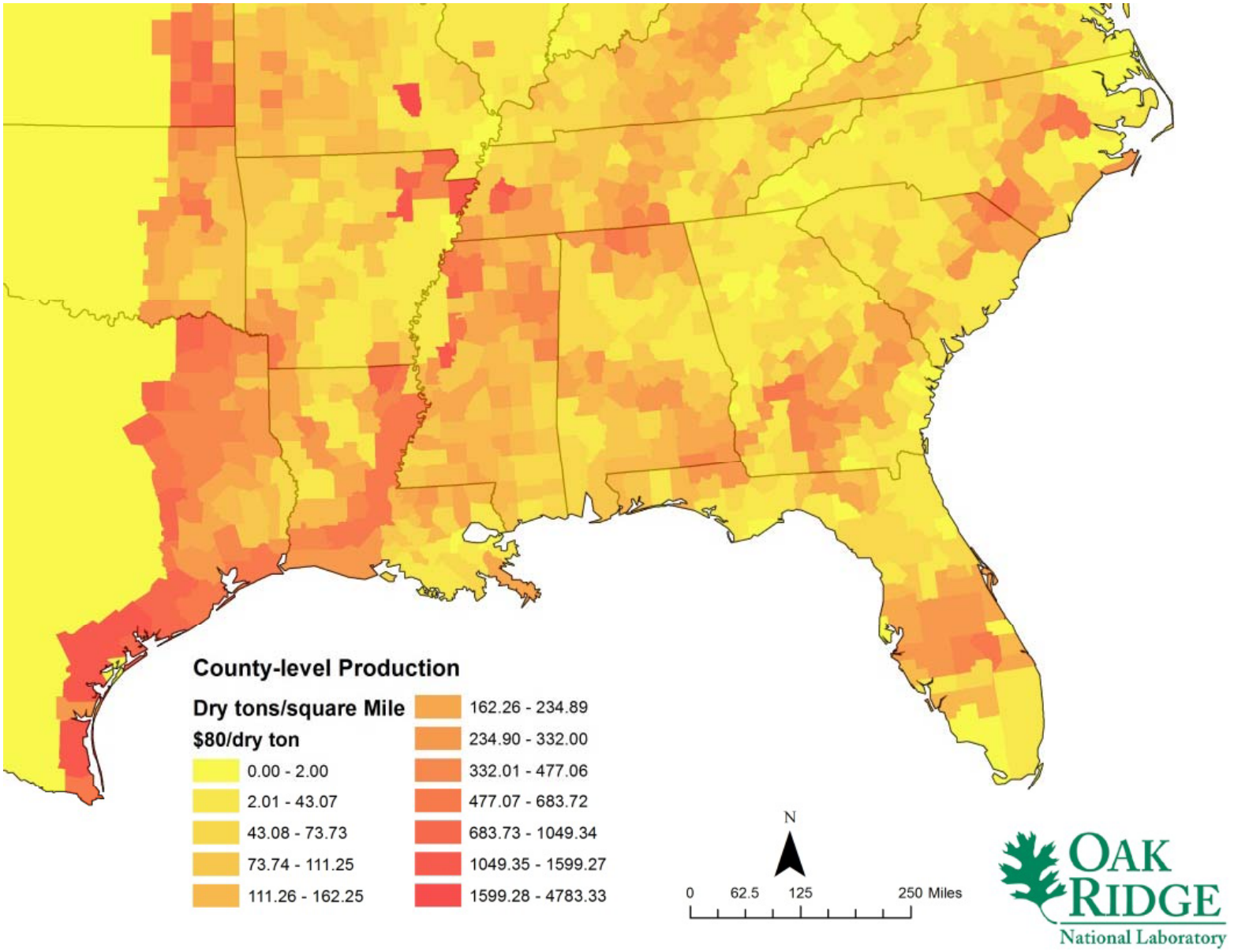
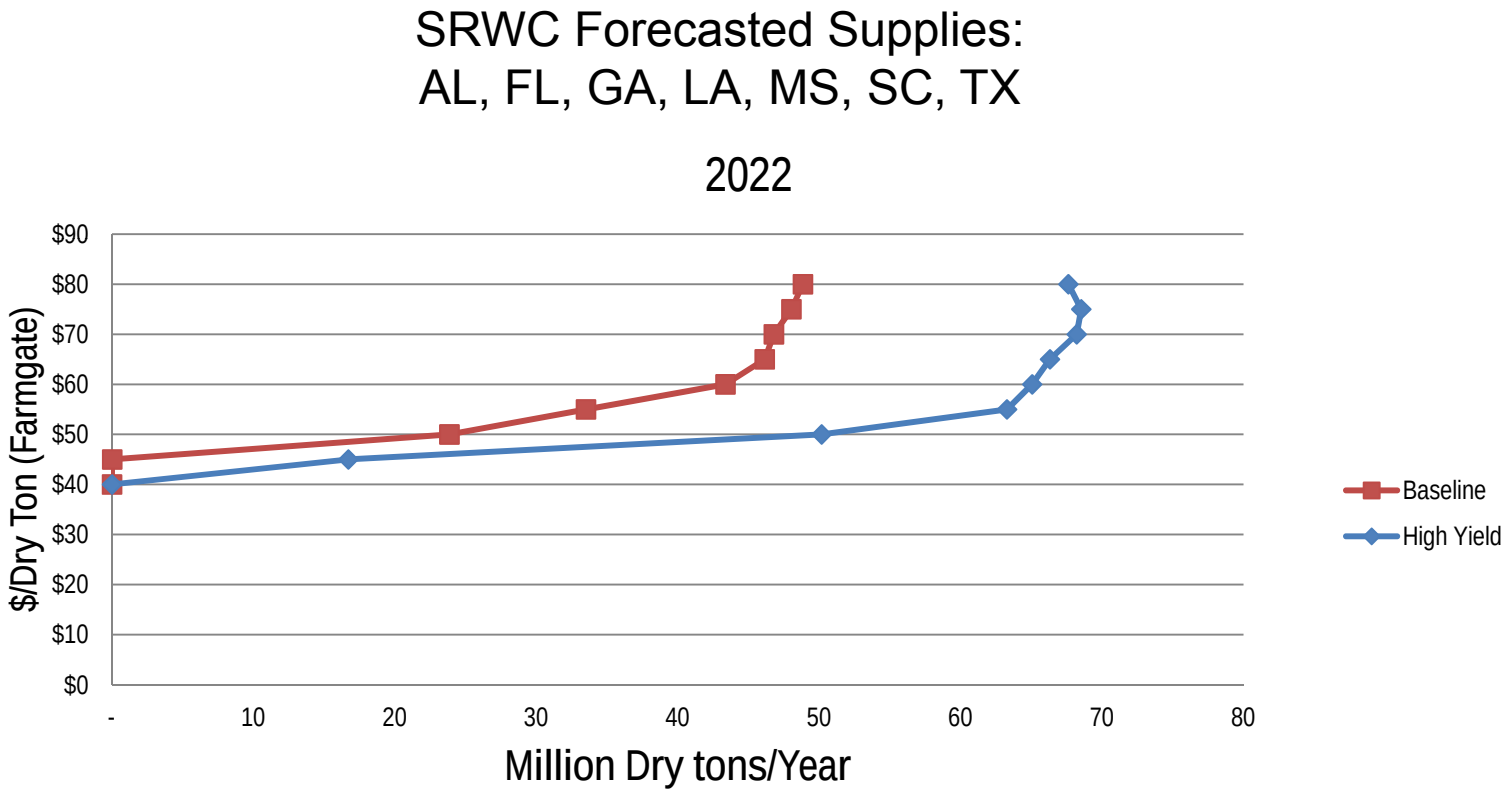
SRWC potential in the southeastern US

The Billion Ton Update (DOE 2011) projected potential quantities of feedstocks at a range of prices.



SRWC potential in the Gulf South

Projections include up to 70 million dry tons/year of SRWC production in seven Gulf South states, depending on price.



40 million dry tons/yr @ 6 dt/a/yr=6.6 million acres, or 2% of land area

Indicator is a measure of performance

- Purpose influences the choice of indicators (Cairns *et al.* 1993).
  - To assess the condition of the environment
  - To monitor trends in condition over time.
  - To provide an early warning signal of changes in the environment
  - To diagnose the cause of an environmental problem.

- Tradeoffs between desirable features, costs, and feasibility often determine the choice of indicators.

The set of indicators should be widely applicable

- Useful to:
  - Policymakers
  - Agronomists
  - Producers
- Improve empirical underpinning for management indicators

Indicators should be

Technically effective

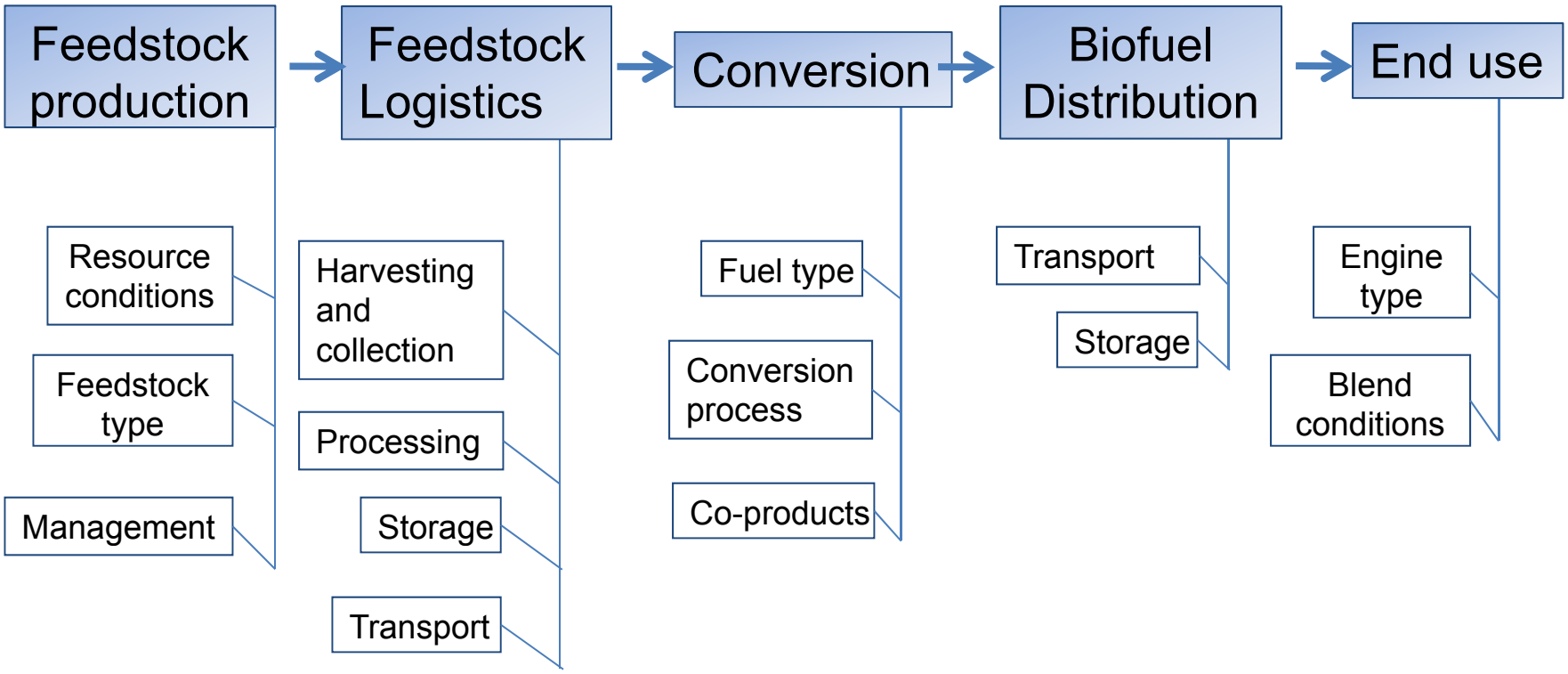
- Sensitive to stresses on system
- Respond to stress in a predictable manner
- Anticipatory: signify an impending change in the ecological system
- Have a known response to natural disturbances, anthropogenic stresses, and changes over time
- Have known variability in response
- Integrative

Practically useful

- Easily measured
- Predict changes that can be averted by management actions
- Consider spatial and temporal context of measure
- Broadly applicable across the system of interest and to other systems

Dale and Beyeler (2001)

Set of indicators should apply to entire supply chain (example for biofuels)



Dale et al. (in review)

Bioenergy system decisions occur at all points along supply chain and at different scales.

Individual perspective:

Land Manager's decisions: What to plant? Where to plant it? How to manage it?	Feedstock logistic decisions: How to harvest and collect feedstock? How to process? How to store? How to transport?	Conversion decisions: What process to use? What fuel type to produce? What coproducts?	Biofuel logistics decisions: Where and how to transport? Where and how to store?	End user decisions: What type of vehicle to buy? What blend of fuel to use?

Cumulative perspective:

Land cover and use patterns and practices	Collection, processing, storage and movement of goods across the landscape	Distribution of conversion facilities across the landscape	Transportation and storage of biofuels for a region and the nation	National and regional choices of vehicles and fuels

Dale et al. (in review)

Some groups working to develop indicators for bioenergy sustainability

- GBEP (Global Bioenergy Partnership)
- BRDi (Biomass Research & Development)
- RSB (Roundtable on Sustainable Biofuels)
- CSBP (Council on Sustainable Biomass Production)

BUT

- These efforts often focus on management practices, but knowledge is limited about which practices are sustainable.

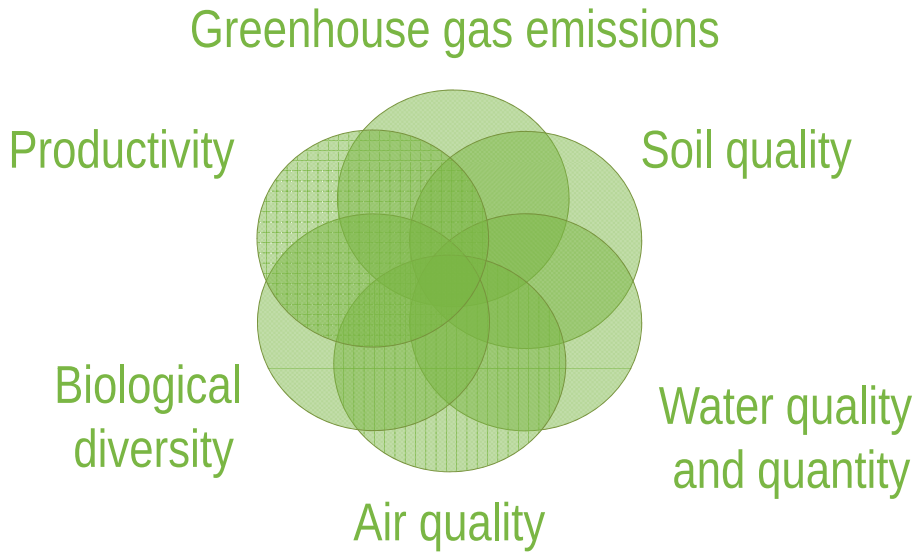
- These suites can be too numerous and/or too broad for practical implementation.

Process for indicator selection

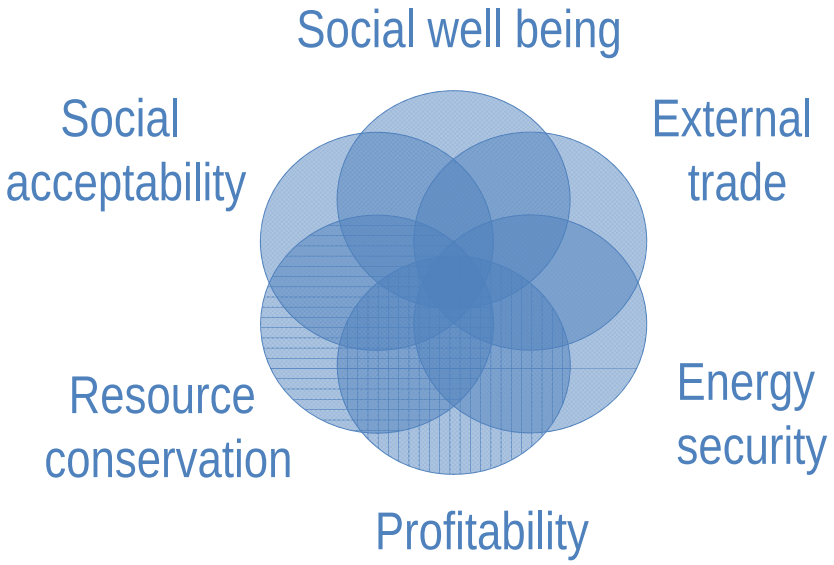
- Select indicators within idealized framework
- Caveats
  - Measure what is measurable today
    - Effects of greatest interest
    - Interpret indicators in light of
      - How they change over time and space
      - How other factors change over time and space
      - Full suite of socioeconomic and environmental metrics
  - Plan to obtain new measures more closely related to effects of interest

William Bruce Cameron:
"Not everything that can be counted counts, and not everything that counts can be counted."

Categories for indicators of environmental and socioeconomic sustainability



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



Dale et al. (In press)
Ecological Indicators
DOI 10.1016/j.ecolind.2012.10.014

Recognize that measures and interpretations are context specific [Efroymson et al. (In press) *Environmental Management]*

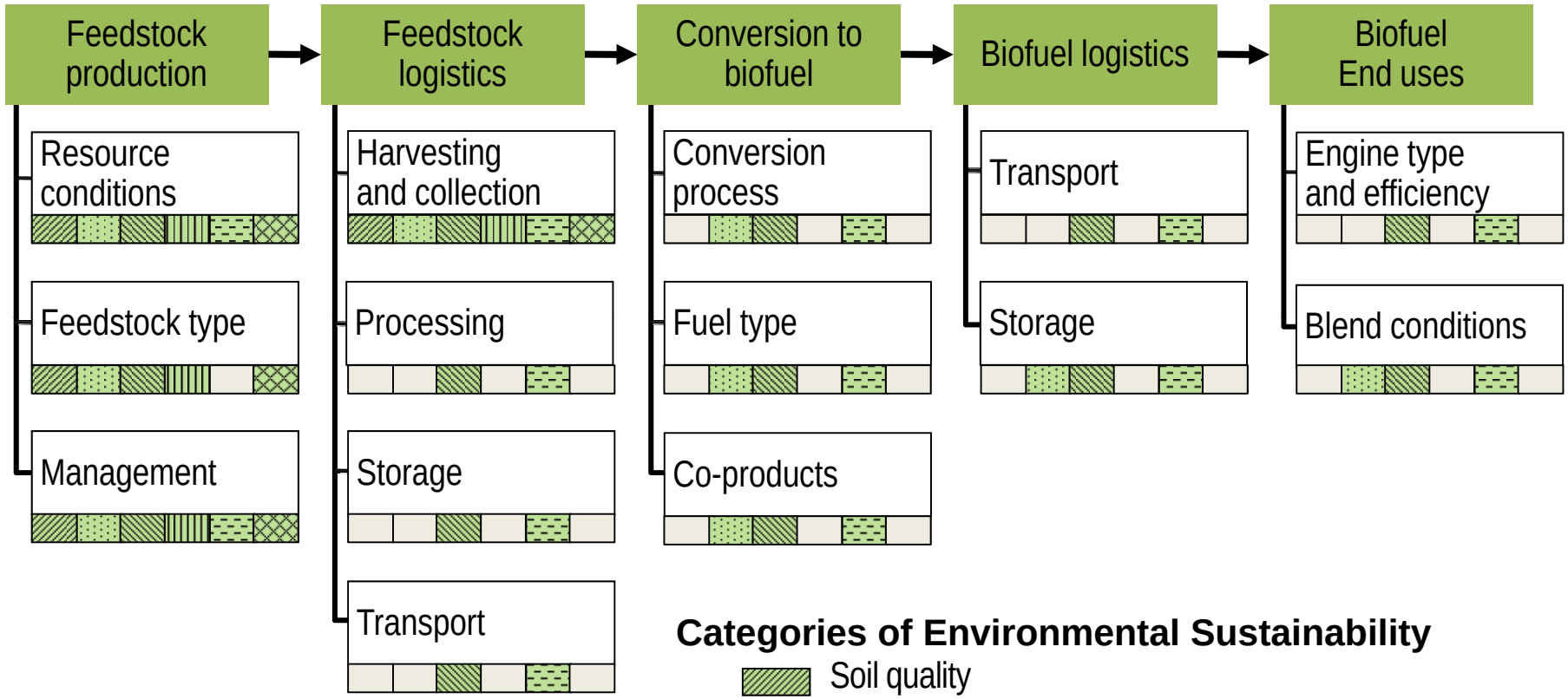
Categories of environmental sustainability indicators

Category	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

Category	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

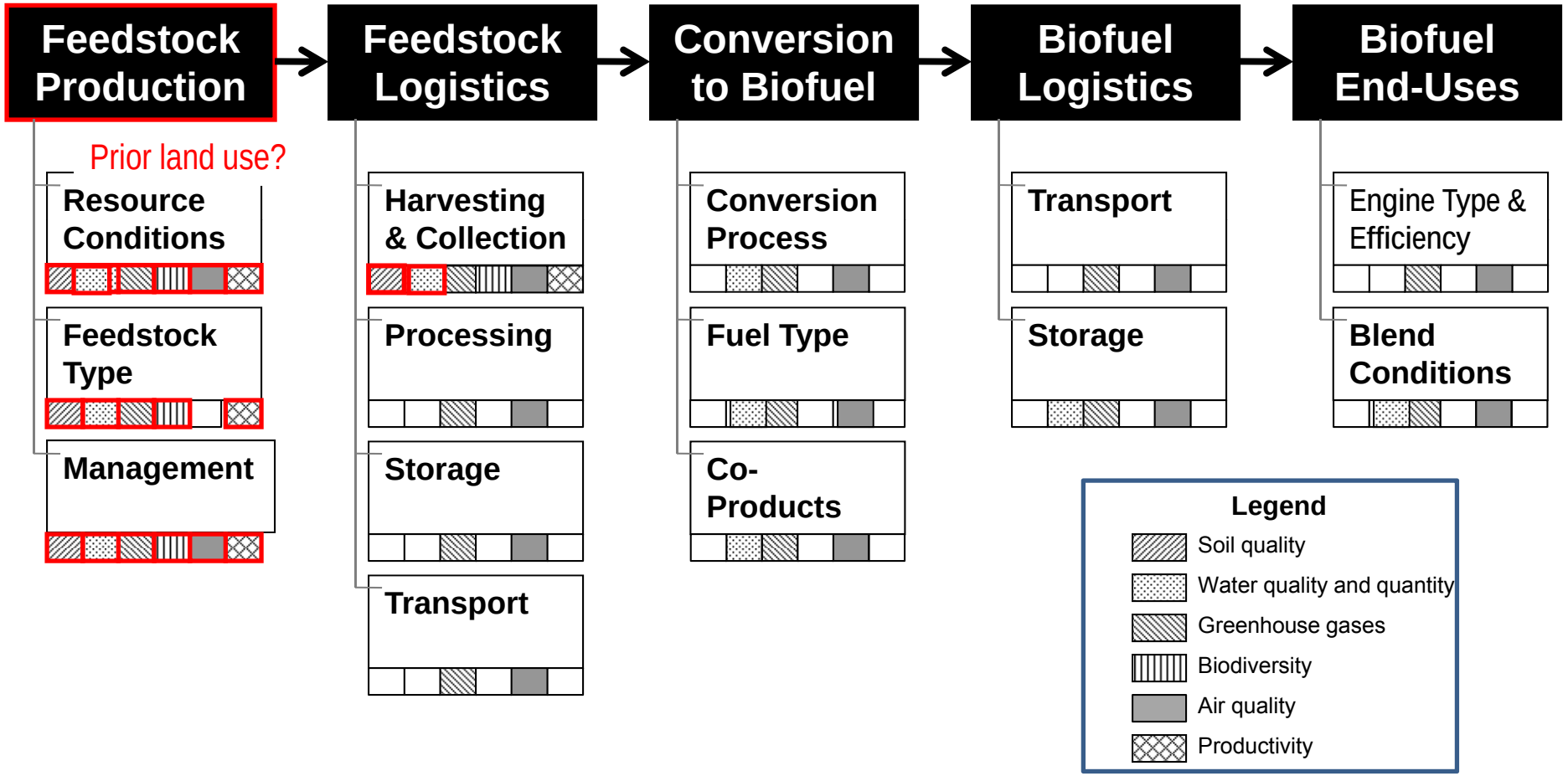
McBride et al. (2011)

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



Efroymson et al. In press. Environmental indicators of biofuel sustainability: What about context? Environmental Management

Contexts for Environmental Indicators of Sustainability in the SRWC Biofuel Supply Chain



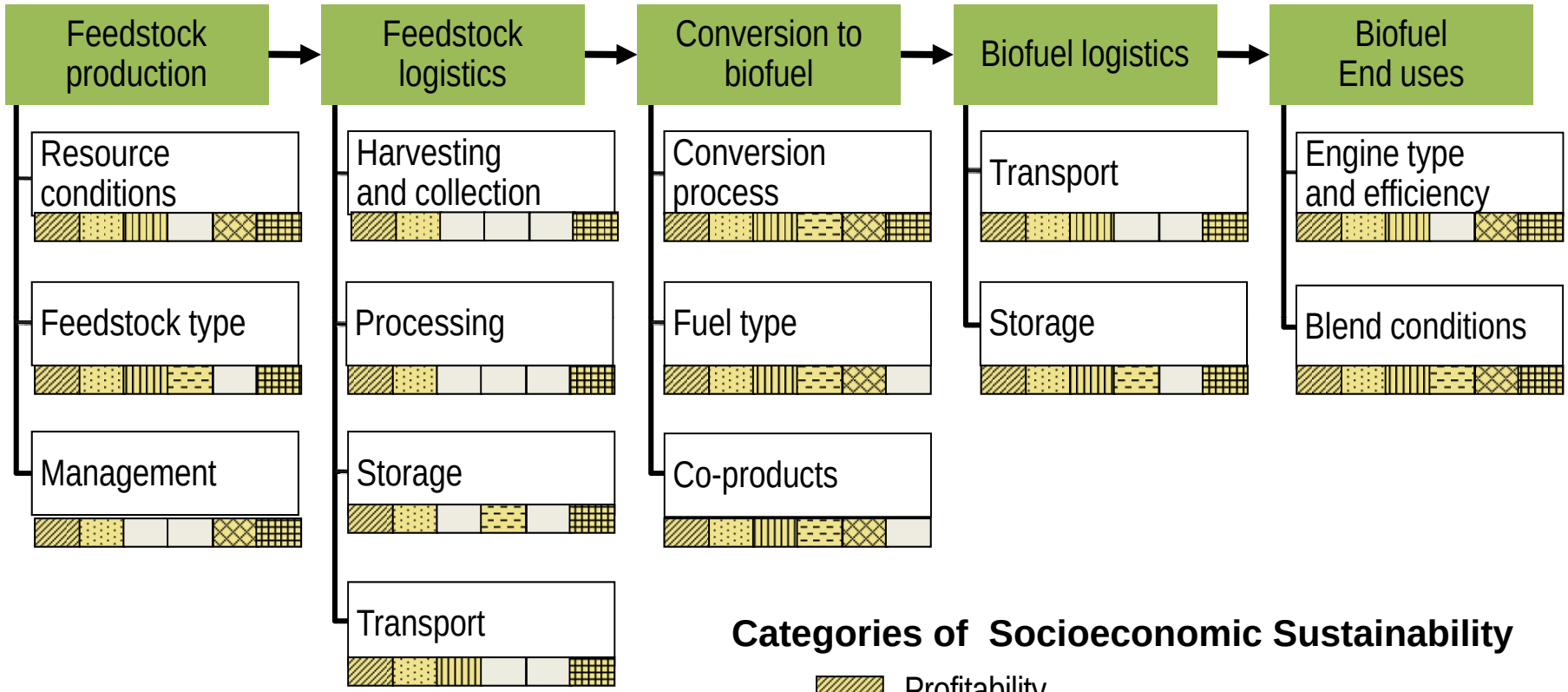
Categories of socioeconomic sustainability indicators

Minimum list of 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 per gallon biofuel
	Fuel supply 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)	Dollars (present value of benefits minus present value of costs)
Resource conservation	Depletion of non-renewable energy resources	Amount of petroleum extracted per year (MT)
	Fossil Energy Return on Investment (fossil EROI)	Ratio of amount of fossil energy inputs to amount of useful energy output (MJ) (adjusted for energy quality)
Social acceptability	Public opinion	Percent favorable opinion
	Transparency	Percent of indicators for which timely and relevant performance data are reported
	Effective stakeholder participation	Percent of documented responses to stakeholder concerns and suggestions reported on an annual basis
	Risk of catastrophe	Annual probability of catastrophic event

Dale et al. (In press)

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

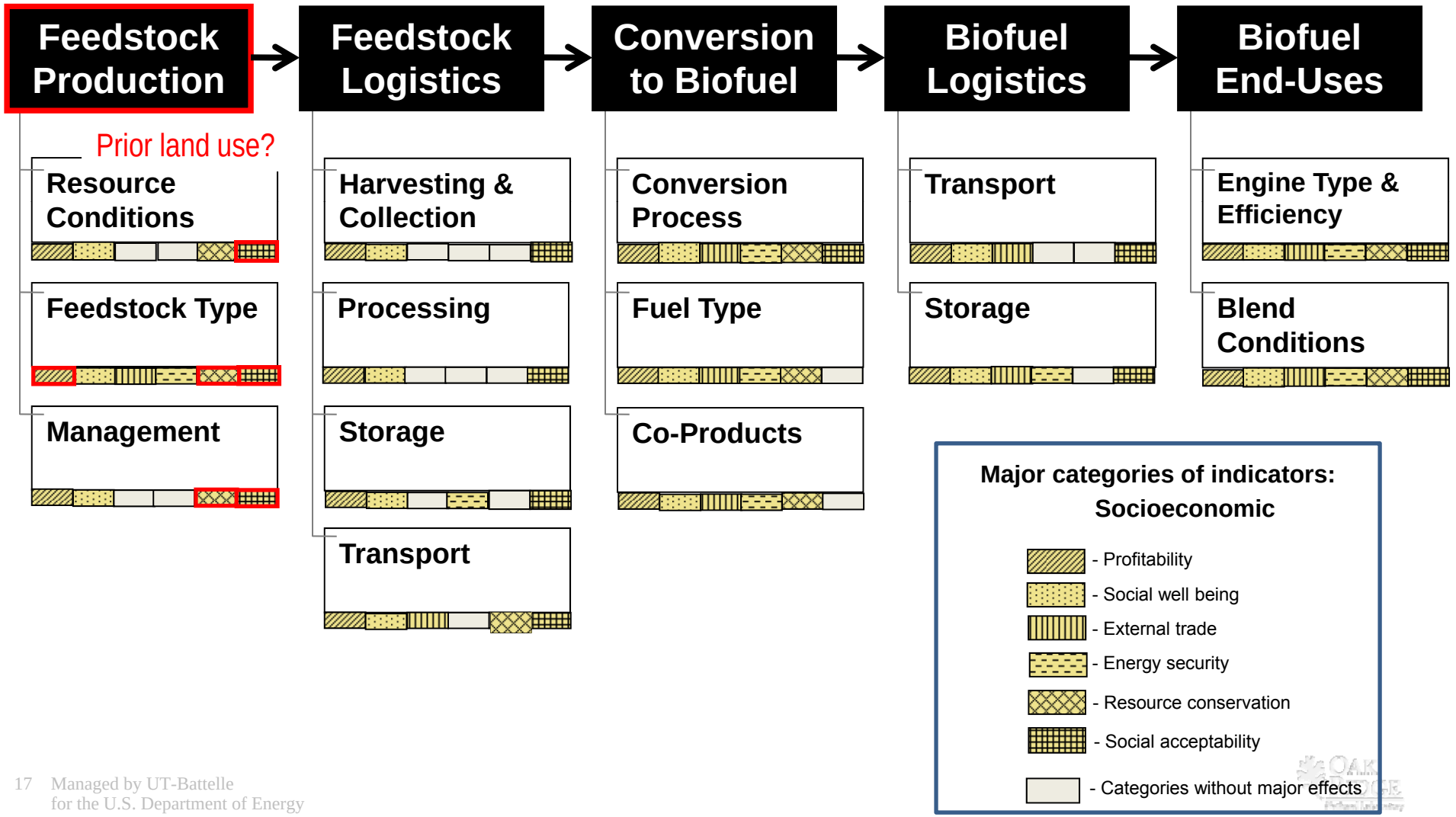


Categories of Socioeconomic Sustainability

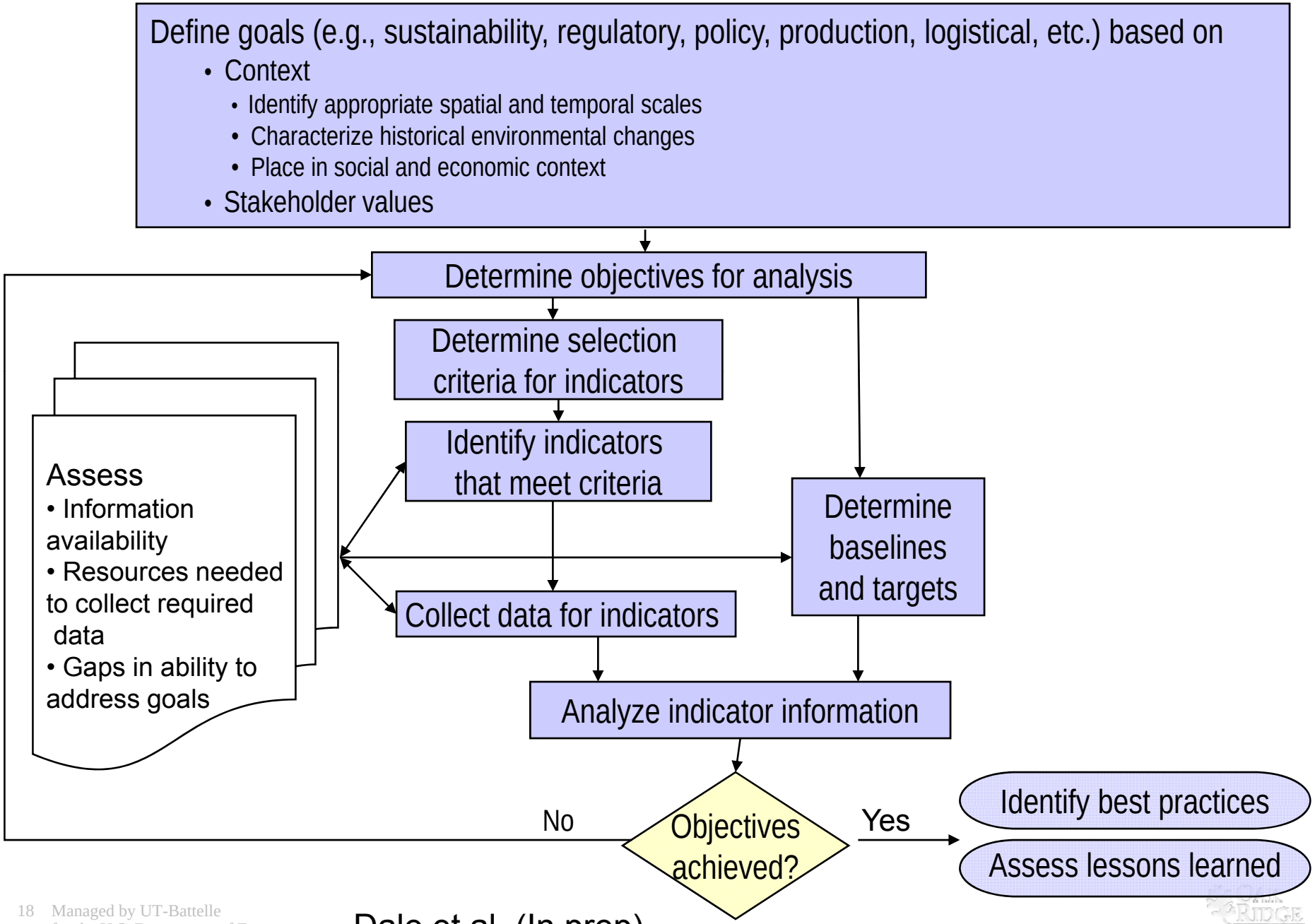
- Profitability
- Social well being
- External trade
- Energy security
- Resource conservation
- Social acceptability
- Categories without major effects

Based on Dale et al. (in press) Ecological Indicators.

Depiction of Where Categories of Sustainability Indicators Experience Major Effects within the SRWC Biofuel Supply Chain



Framework for selecting sustainability indicators for bioenergy



Dale et al. (In prep)

Challenge: Documenting sustainability costs and benefits for different feedstock crops

Barrier: Specific crops are appropriate for different environmental conditions and management regimes

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

Thank you!

CBES
Center for BioEnergy Sustainability

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

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