Integration of bioenergy feedstocks into agricultural landscapes can reduce water impacts from agriculture

Q3: How can bioenergy systems be located, designed, and managed to optimize contributions to local, regional and global sustainability objectives ?

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UNEP Workshop: Bioenergy and Water: Developing Strategic Priorities for Sustainable Outcomes

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U.S. DEPARTMENT OF ENERGY

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ORNL Approach to Assessing Bioenergy Sustainability

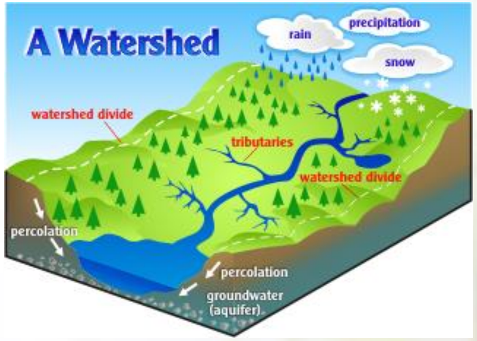
✓ Select Indicators

Establish baselines and targets

Evaluate indicator values

Identify trends and tradeoffs

Develop and test best practices



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Categories of environmental sustainability indicators

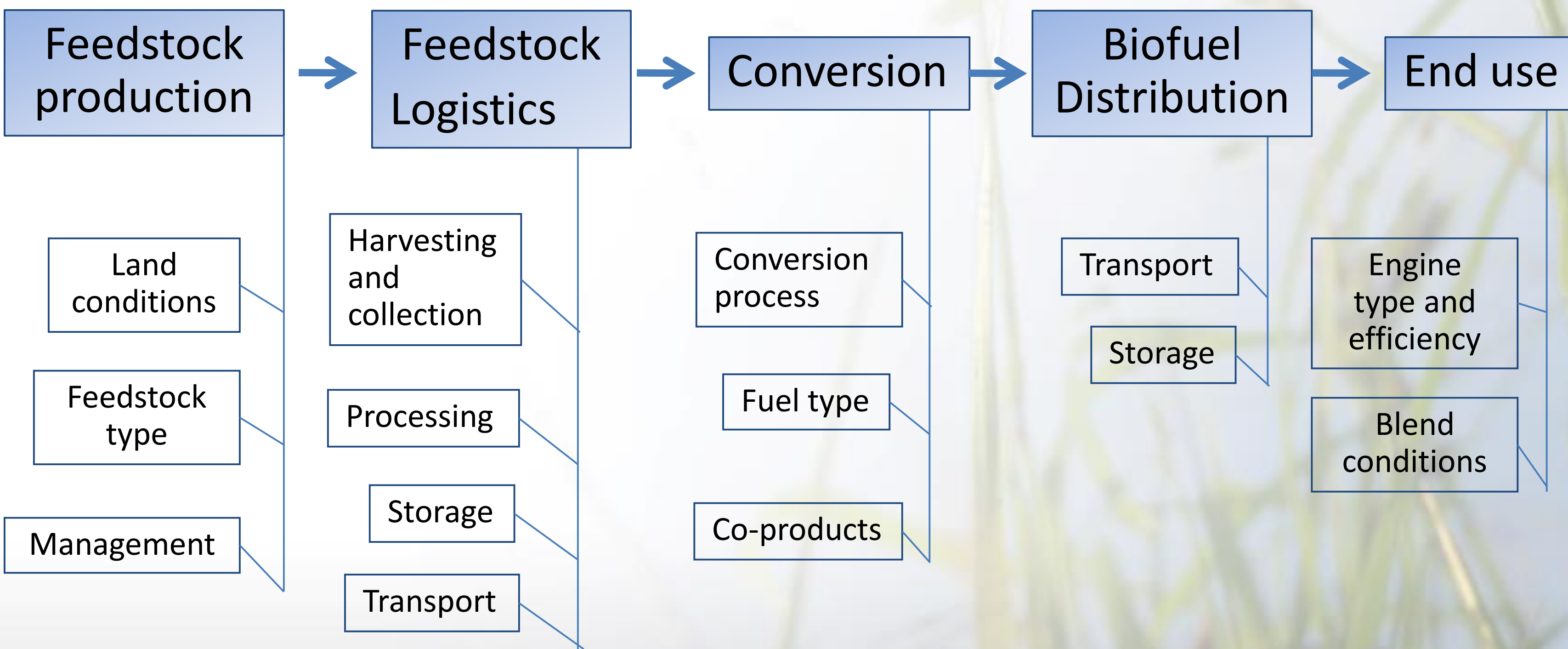
Environment	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus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

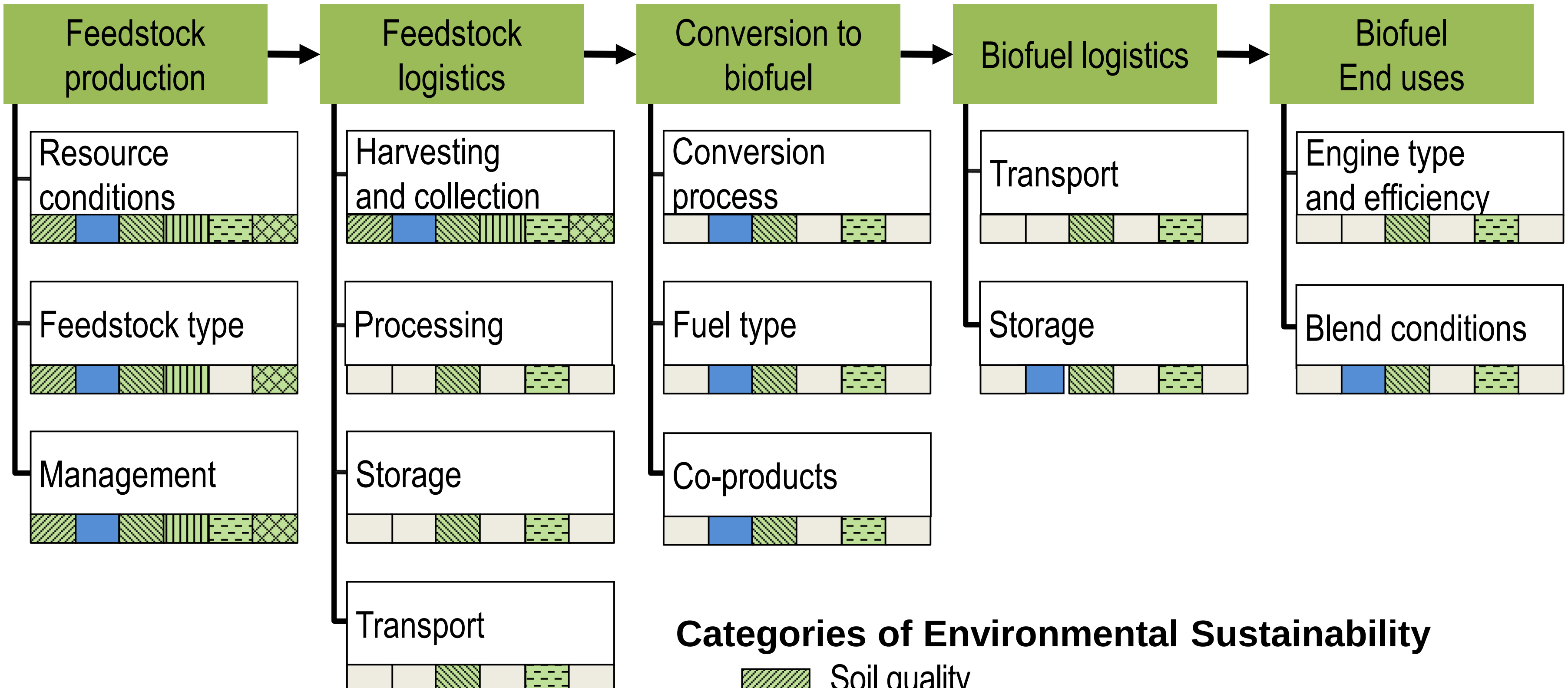
- Entire supply chain
- Diverse feedstocks
- All conversion pathways

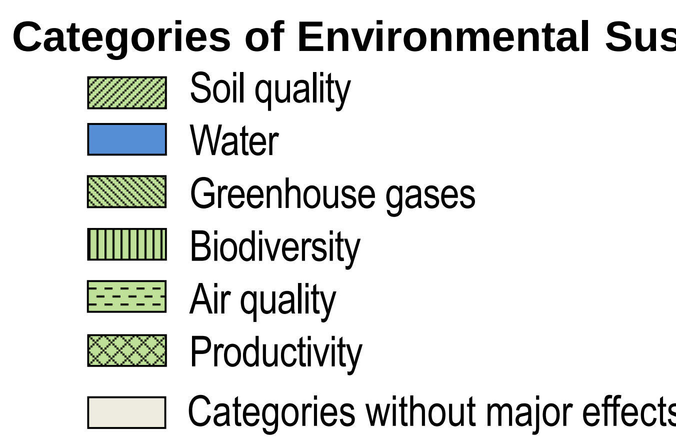


(Example shown is biofuel, but concepts are applicable to bioenergy as well)

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

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





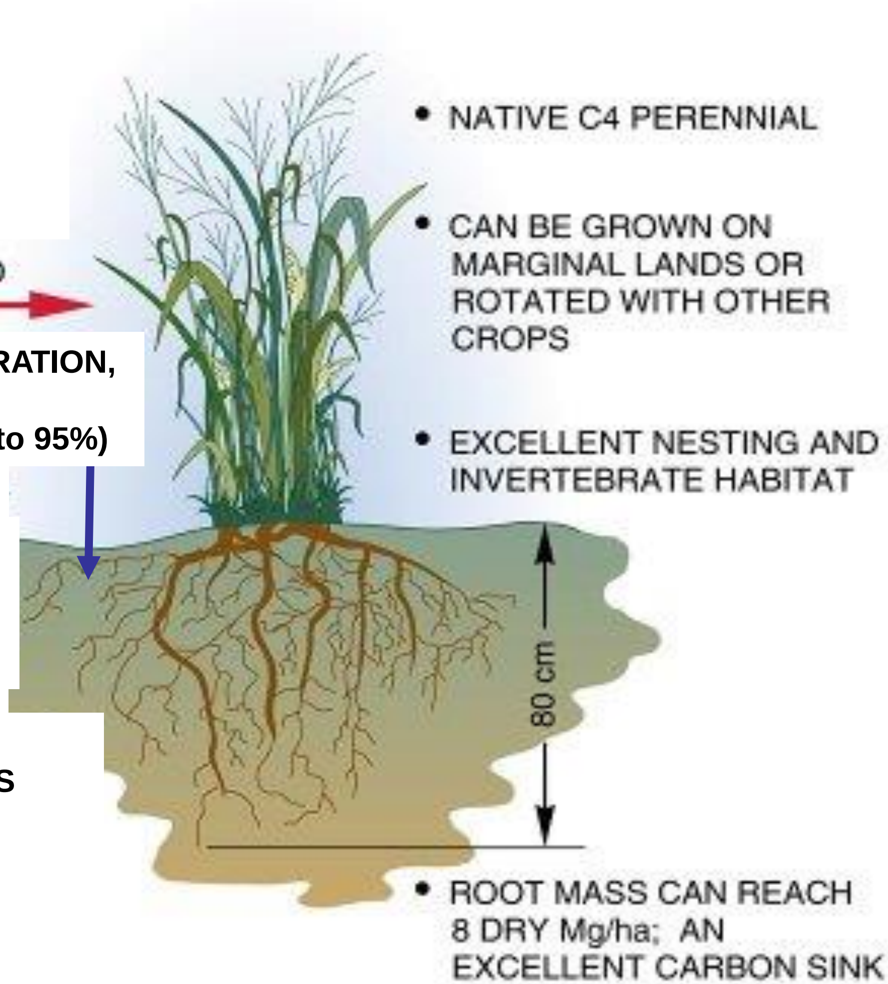
Efroymson et al. (2013) *Environmental Management* 51:291-306.

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.

Documented sustainability benefits of switchgrass (a "model" perennial crop)

Yet specific crops are appropriate for different conditions



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

Assessing multiple effects of bioenergy choices

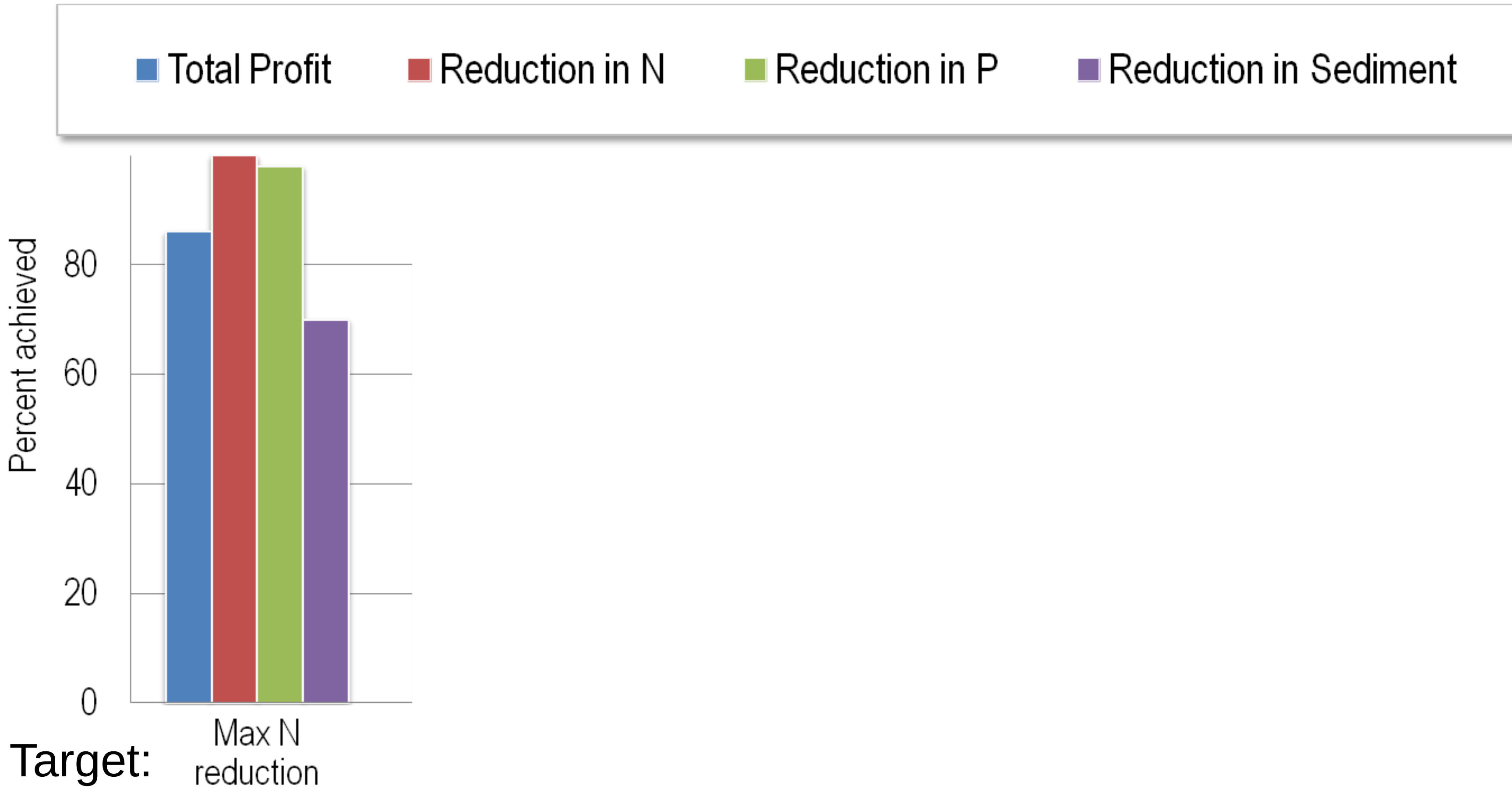
An optimization model identifies "ideal" sustainability conditions for using switchgrass for bioenergy in east Tennessee

Spatial optimization model

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

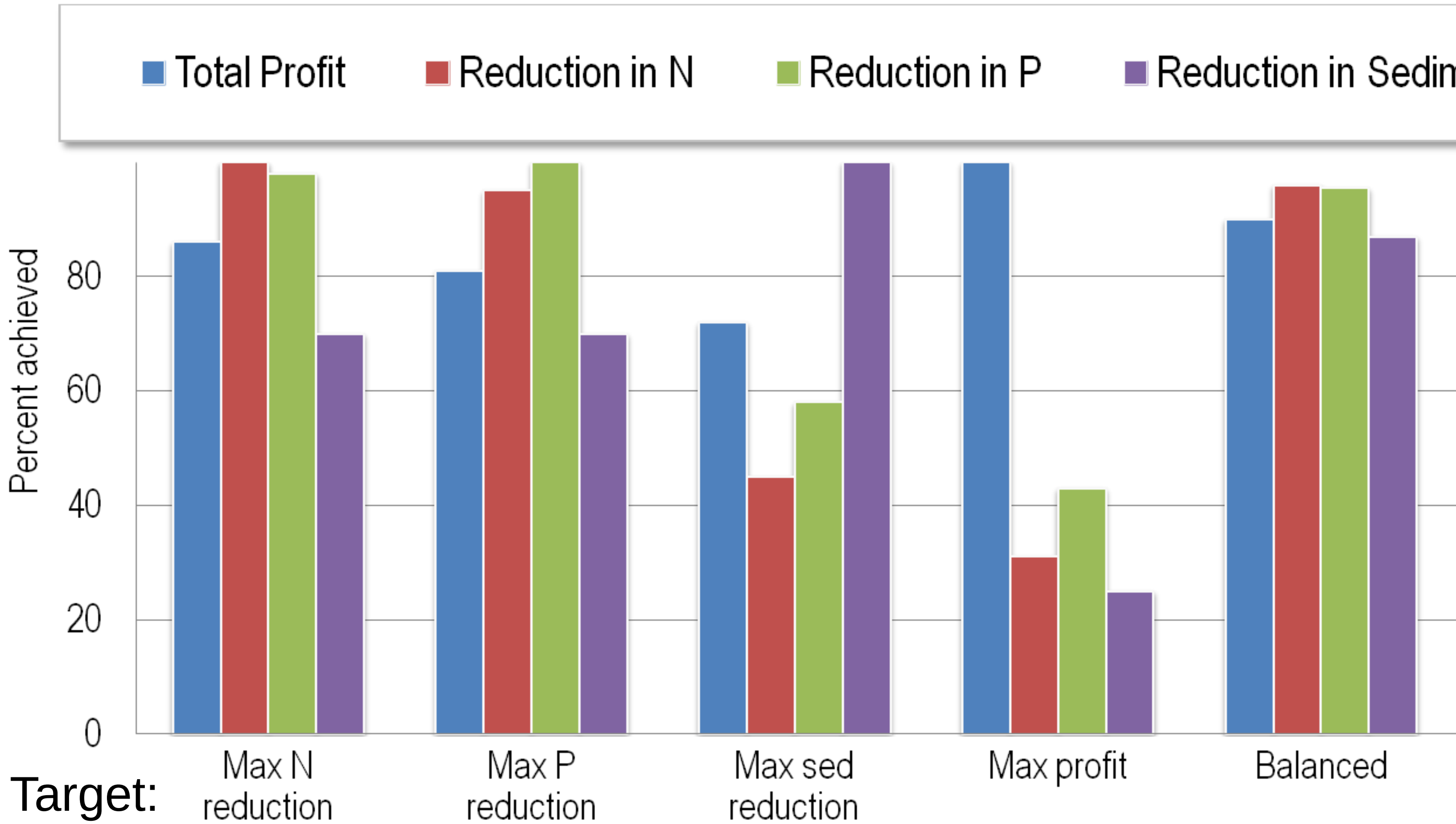
Parish et al. (2012) *Biofuels, Bioprod. Bioref*. 6:58–72.

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



Target:

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)

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)

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

Landscape design is a plan for resource allocation.

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

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

- System is fragmented with disparate goals in different parts
- 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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Thank you!

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Center for BioEnergy Sustainability

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

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

1. Conserve ecosystem and social services

2. Consider local context

3. Monitor effects of concern and adjust plans to improve performance over time.

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