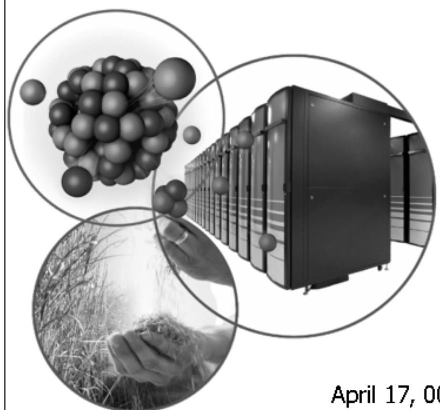
Designing Proactive Bioenergy Choices in a Landscape Context



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See http://bioenergy.ornl.gov

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Biomass: 2008

Key points

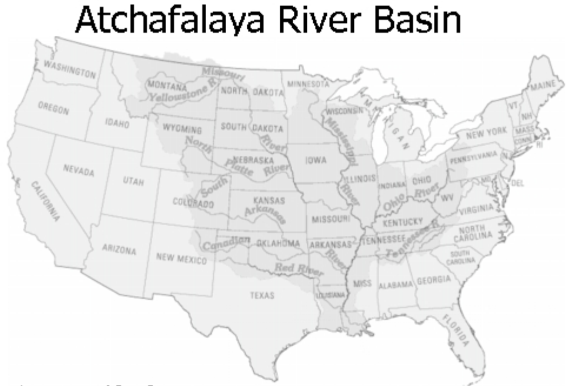
- Landscape implications of biofuel choices are large
- Multiple implications of biofuel choices require multiple indicators
- There is an opportunity to design biofuel choices to optimize socioeconomic and ecologic benefits

Hypoxia in the Gulf of Mexico

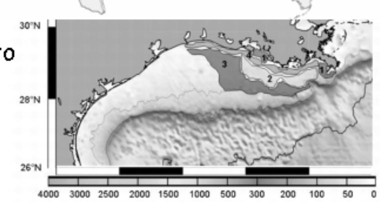
- *Hypoxia* = Very low dissolved oxygen concentrations, generally ≤ 2 mg/L

- It is due to
  - Nutrients
  - Stratification of shallow Gulf waters
- Excessive nutrients promote excessive growth of opportunistic bacteria, cyanobacteria, and algae.
  - Available nutrients are sequestered in plant biomass
  - Blooms die, decompose, and deplete dissolved oxygen in the water column and at the sediment water interface.
  - This oxygen depletion, known as *hypoxia,* occurs.
- Marine species either die or flee the hypoxic zone.

Map showing the extent of the Mississippi-Atchafalaya River Basin



Zones in Northern Gulf of Mexico differ with regard to
- Stratification
- Light limitation
- Nutrient limitation
- Hypoxia



Hypoxia Advisory Panel of EPA's Science Advisory Board
2007 Report
http://www.epa.gov/sab/panels/hypoxia_adv_panel.htm

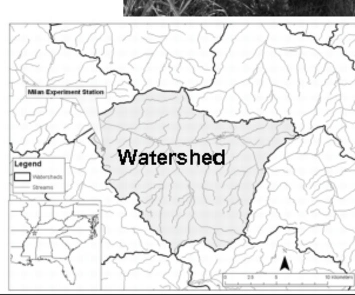
#1 recommendation: opportunities exist for N and P reduction that influences hypoxia

- ➢Conversion to alternative cropping systems
  - ➢Perennials
  - ➢Alternative rotation systems
- ➢Promotion of environmentally sustainable approaches to biofuel production in targeted areas of the basin.

"Not all approaches will be cost-effective in all locations."

Scale effects of bioenergy feedstock choices

- Choices made at field scale
- Environmental effects
  - – At field (or edge of field)
  - – Small watershed
  - – Entire basin
    - Hypoxia example
- Need indicators of diverse ecosystem services at relevant scales

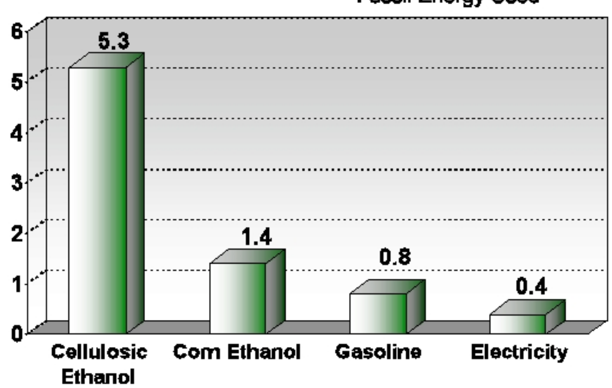


Innovations of Landscape Design

- Integrated — environmental & socioeconomic dynamics, consequences
- Alternative bioenergy regimes & policies
- Potential for spatial optimization
- Scale-sensitive
  - Economic, social, & environmental constraints & metrics at multiple scales

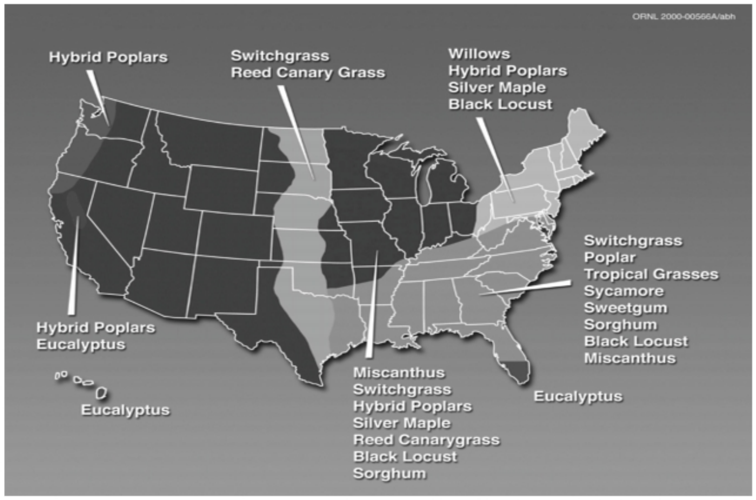
LS design uses cellulosic feedstocks, for they provide maximum fossil energy replacement ratio

Fossil Energy Ratio (FER) = $\frac{\text{Energy Delivered to Customer}}{\text{Fossil Energy Used}}$



Source: J. Sheehan & M. Wang (2003)

LS design considers geographic distribution of potential biomass crops

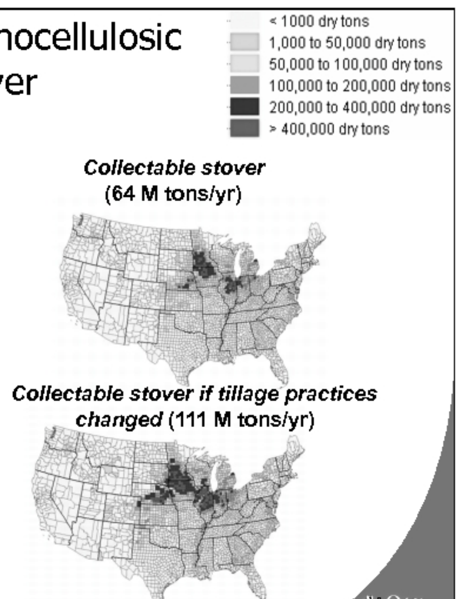


Wright et al. DOE-ORNL-EERE

LS design considers lignocellulosic biomass from corn stover

Depending on:

- Crop management approach
- Initial soil carbon levels and soil types



Source: Graham et al. (2007) Agron. J. 99:1-11.

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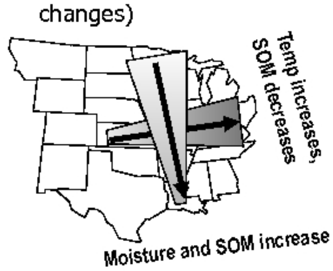
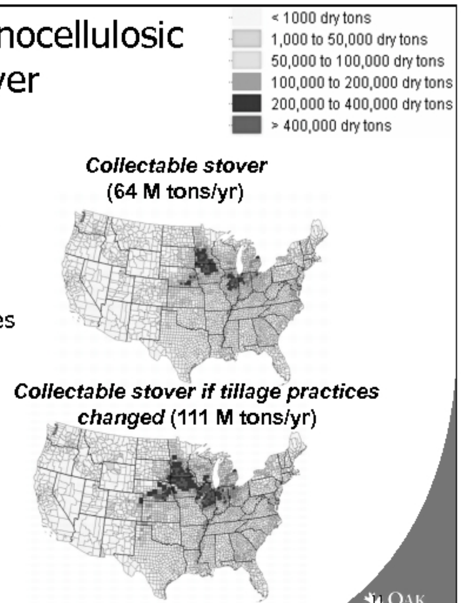
LS design considers lignocellulosic biomass from corn stover

Depending on:

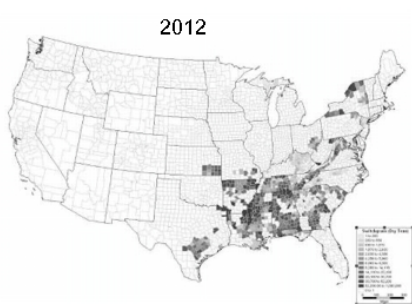
- Crop management approach
- Initial soil carbon levels and soil types
- Temperature ranges (and futures changes)

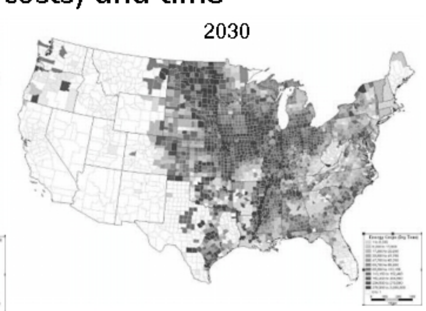




Source: Graham et al. (2007) Agron. J. 99:1-11.

LS design considers conditions needed for perennial crop availability: higher perennial yields, lower land costs, and time





Yields regional ~ 3-6 dt/ac/yr
Farmgate price <$30/dt
First plantings in 2009

Yields regional ~ 5-8 dt/ac/yr
Farmgate price <$40/dt

Land costs were based on 2005 USDA projections.

Source:
ORNL analysis using Agriculture Policy Simulation Model (POLYSYS) developed jointly by UT's Ag Policy Center, USDA/ERS, ORNL, and OSU Great Plains Ag Policy Center

LS design depends on improved soil carbon and root distribution of perennial crops

- Improved with land conversion
  - from traditional crops to perennial energy crops
  - tillage to no-till.
- Greatest increases in soil carbon on poorer quality sites
- Soil carbon increased mainly in upper 10 cm
- Switchgrass plantings changed carbon below 60 cm with root penetration > 120 cm
- Root penetration increased soil porosity, infiltration and reduced compaction

Sources:

Tolbert, VR et al. (2002) Environmental Pollution 116, S97-S106.

Mann L and Tolbert VR. (2000). Ambio 29: 492-498.

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LS design recognized that benefits of perennial energy crops are most positive when:

- Replacing annual crops or pasture, not forests
- Minimum tillage and cover crop management used
- Nutrient and chemical applications < annual crops
- Native or non-invasive species used
- Harvesting considers bird nesting timing.
- Used as buffers between annual crops and water ways

Sources: McLaughlin and Walsh. (1998). Biomass and Bioenergy. and Wright and Tolbert (several reports)

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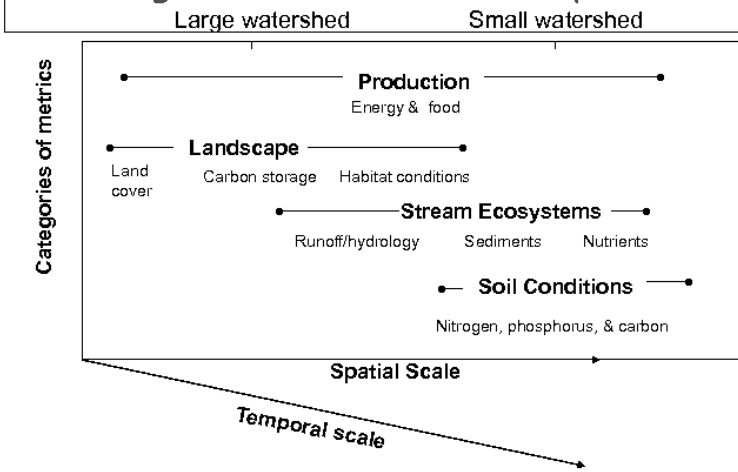
LS design uses metrics at multiple scales



Dale and Polasky. (2007) Measures of the effects of agricultural practices on ecosystem services. *Ecological Economics* 64:286-296.

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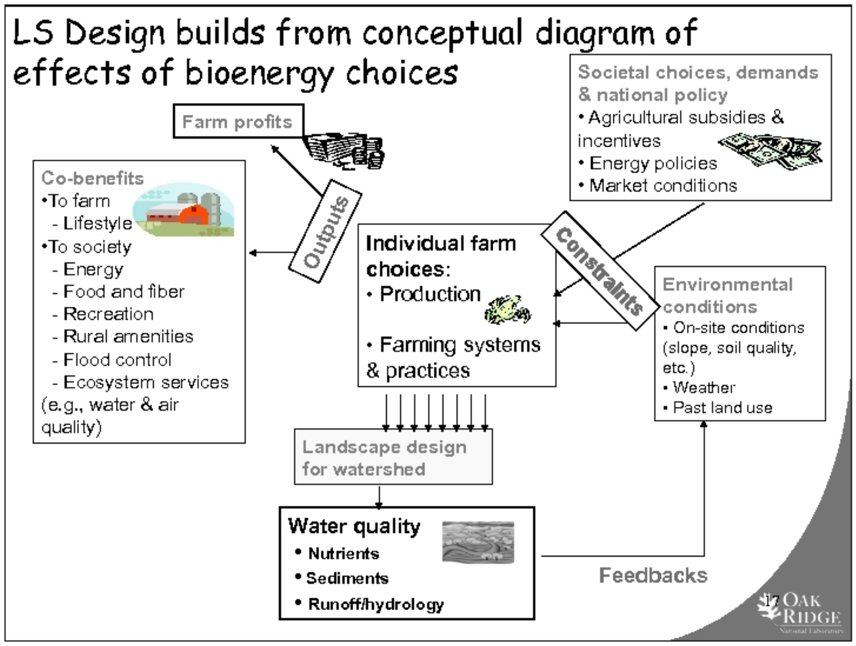
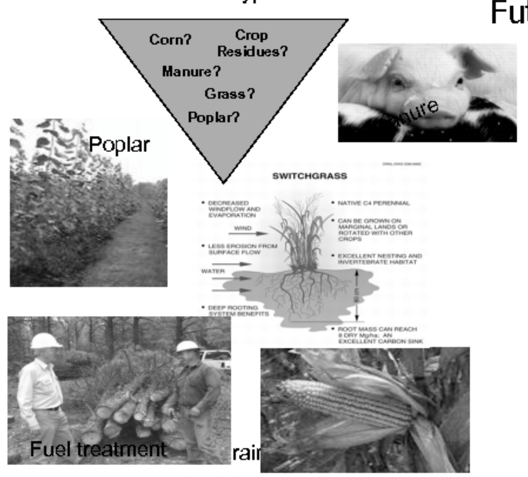
LS design considers unintended consequences of land-use change but recognizes that these changes are complex

- Driven by
  - Interactions among cultural, technological, biophysical, political, economic, and demographic forces
  - Within a spatial and temporal context
- Making it essential to understand the forces behind land-clearing.
- Cannot assume that biofuel production in the US causes forests and grasslands elsewhere to be converted to agriculture.
  - Current evidence based on
    - Indirect data (remote sensing some years after clearing)
    - No cause and effect analysis



The challenge of sustainability What do we need to consider?

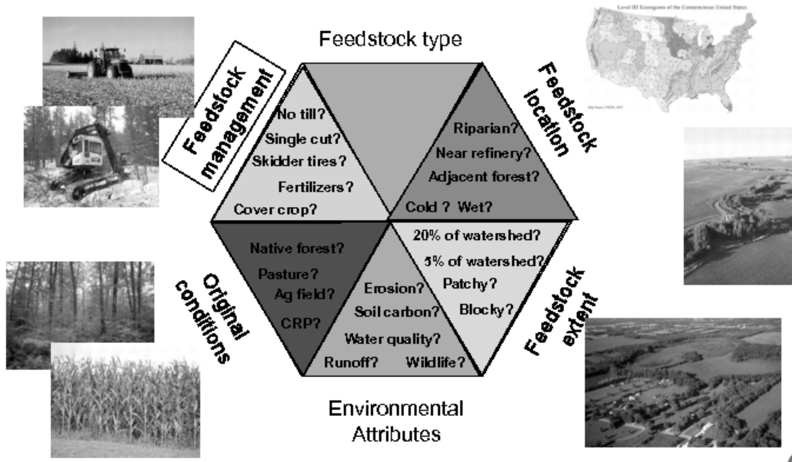
I. Feedstock type



Future feedstocks

- Agricultural feedstocks for cellulosic fuels
  - Crop residues (e.g. stover)
  - Perennial grasses (e.g. switchgrass)
  - Short rotation tree crops (e.g. poplar)
- Forest feedstocks
  - Fuel reduction treatments
  - Industrial wastes

The challenge of sustainability



Is addressing all 6 dimensions throughout world

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Conclusions

- Landscape implications of biofuel choices are large
  - Illustrated by hypoxia in Gulf
  - Mandates need for systems approach
- Multiple implications of biofuel choices require multiple indicators
- There is an opportunity to design biofuel choices to optimize socioeconomic and ecologic benefits

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Overall Conclusion

Different places and different goals
have unique solutions.