IOWA STATE UNIVERSITY
Department of Agronomy
Crop, Soil, and Environmental Sciences

Integrated Systems for Biomass Feedstock Production

Linking Production Ecology with Environmental Protection

M. Liebman, R.P. Anex,
A.H. Heggenstaller, and K.J. Moore

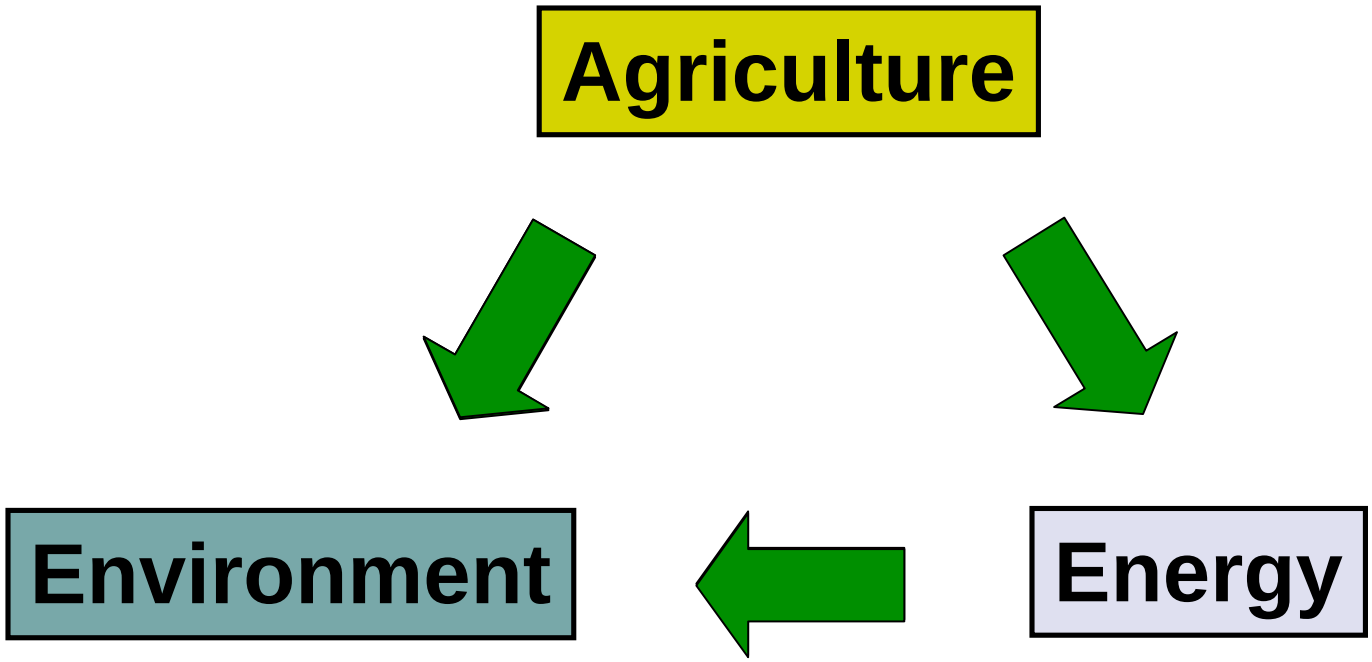
Cellulosic feedstocks:
A new stage for the bioeconomy?


Photo from NREL

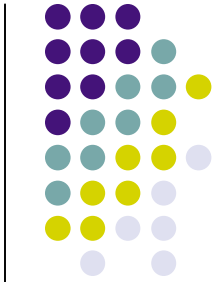

Photo from J. Sellers

- The conversion of biomass into ethanol and other fuels via integrated thermal and biological processes could:
- Increase the volume of biofuels produced;
- Improve the energetic efficiency of biofuel production;
- Create opportunities for new agricultural systems with more beneficial effects on the environment (reduced soil erosion, increased carbon storage, improved water quality).

The Bioeconomy: Creating new linkages between agriculture, energy and environment



System integration principles

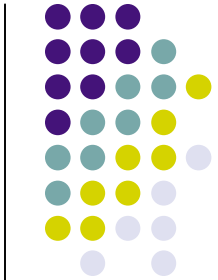


- Combine complementary technologies and crops to more fully utilize the resource base
- Cycle materials and energy within and between systems to maximize efficiency and minimize waste
- Develop systems that achieve multiple desirable outcomes

Integration of agricultural energy systems: Two examples

- Double cropping systems: More complete use of renewable resources to improve biomass yields and environmental quality.
- Linked production and conversion systems: Nutrient recycling between biomass production fields and biorefineries to improve the efficiency of biofuel production.

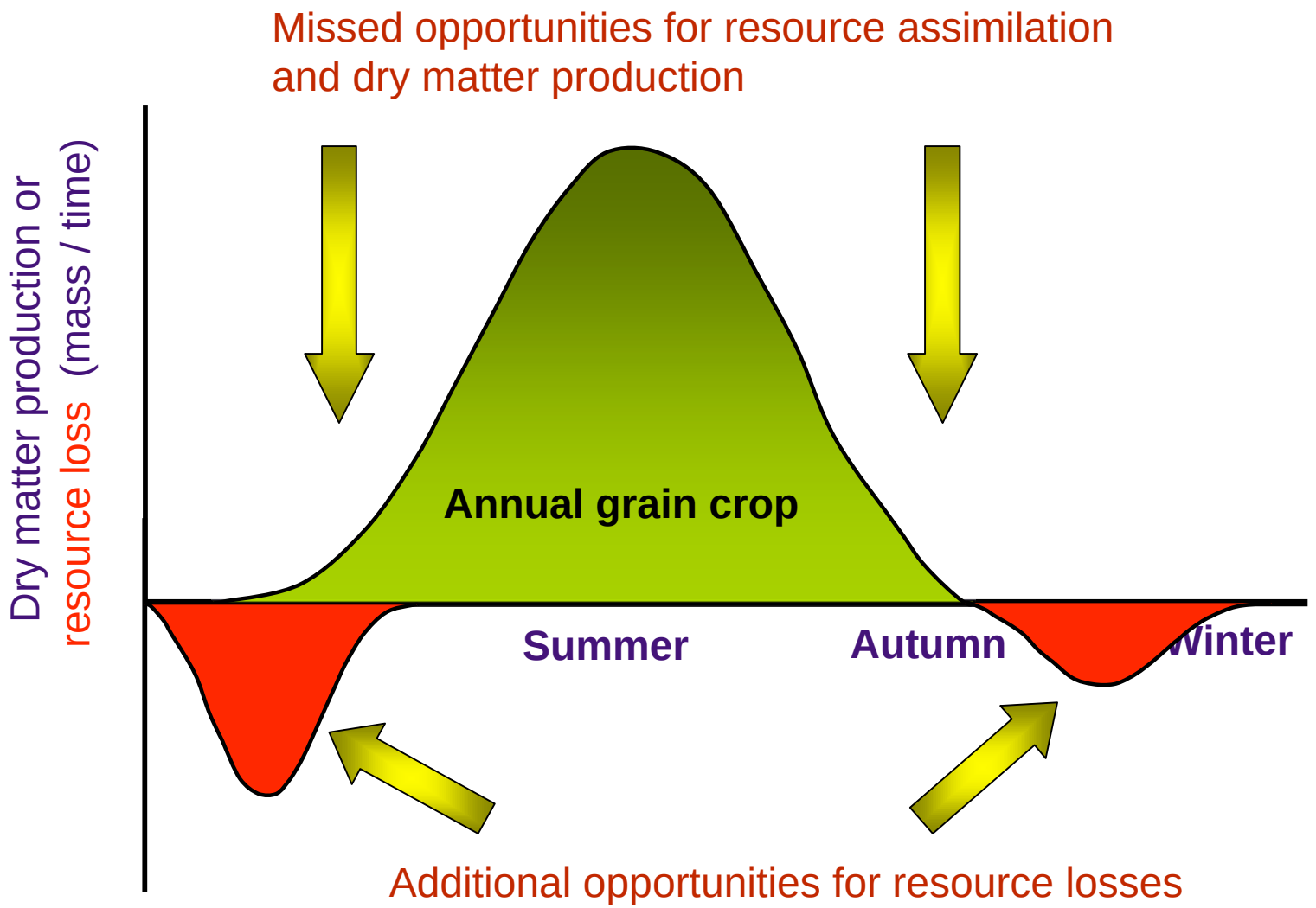
Double cropping systems for improved biomass production



- Increase total annual biomass outputs.

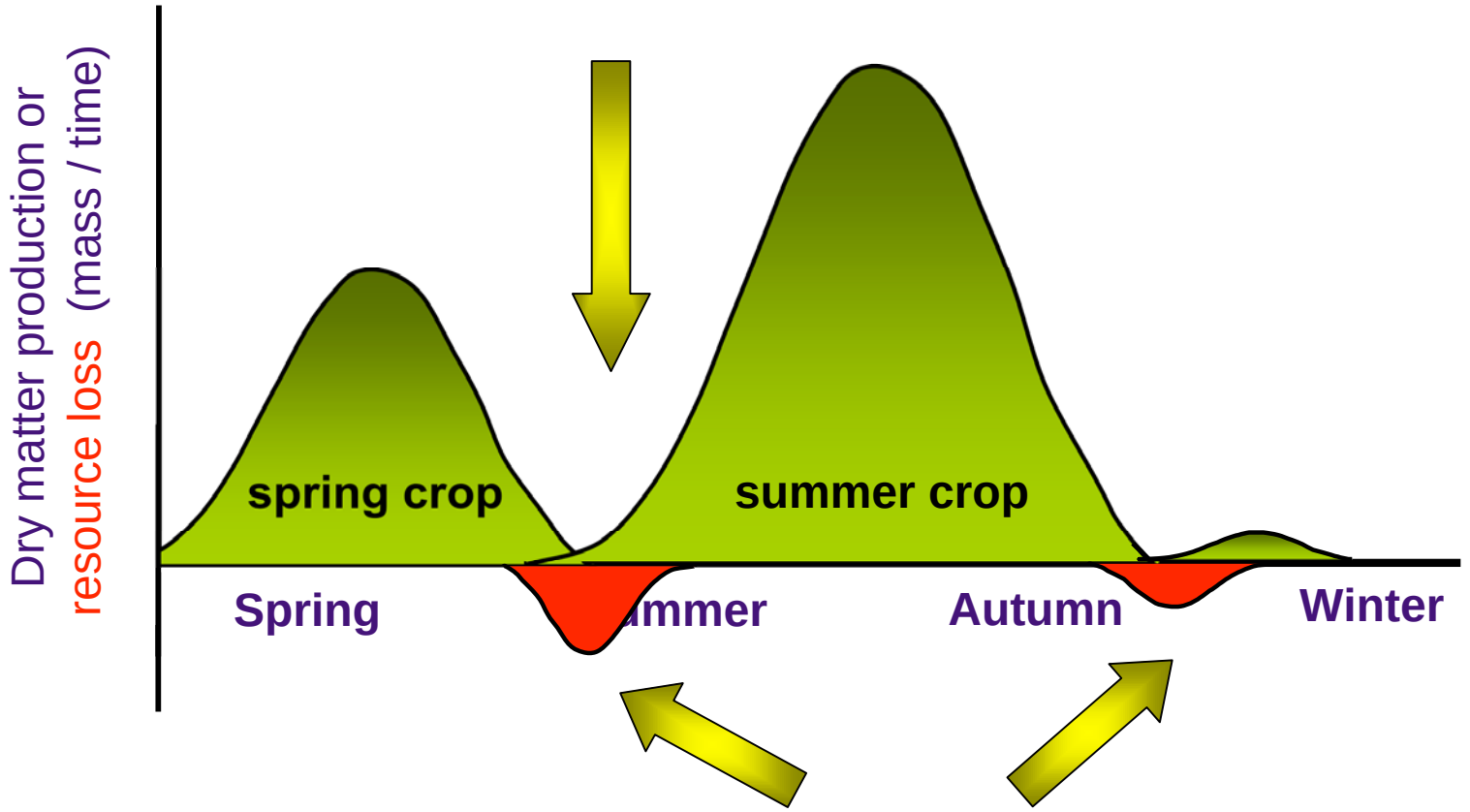
- Reduce nutrient and soil losses, mitigating the negative environmental impacts of biomass removal.

Biomass production in annual cropping systems



Biomass production in double crop systems

Tradeoff: Missed opportunity for resource assimilation and dry matter production



Reduced opportunities for resource losses

Prototype double crop systems for biomass production

- **Winter crop: triticale**
  - Winter soil cover
  - Spring biomass harvest

- **Summer crops:**
- Corn
- Sorghum x sudangrass
- Crotalaria (legume)

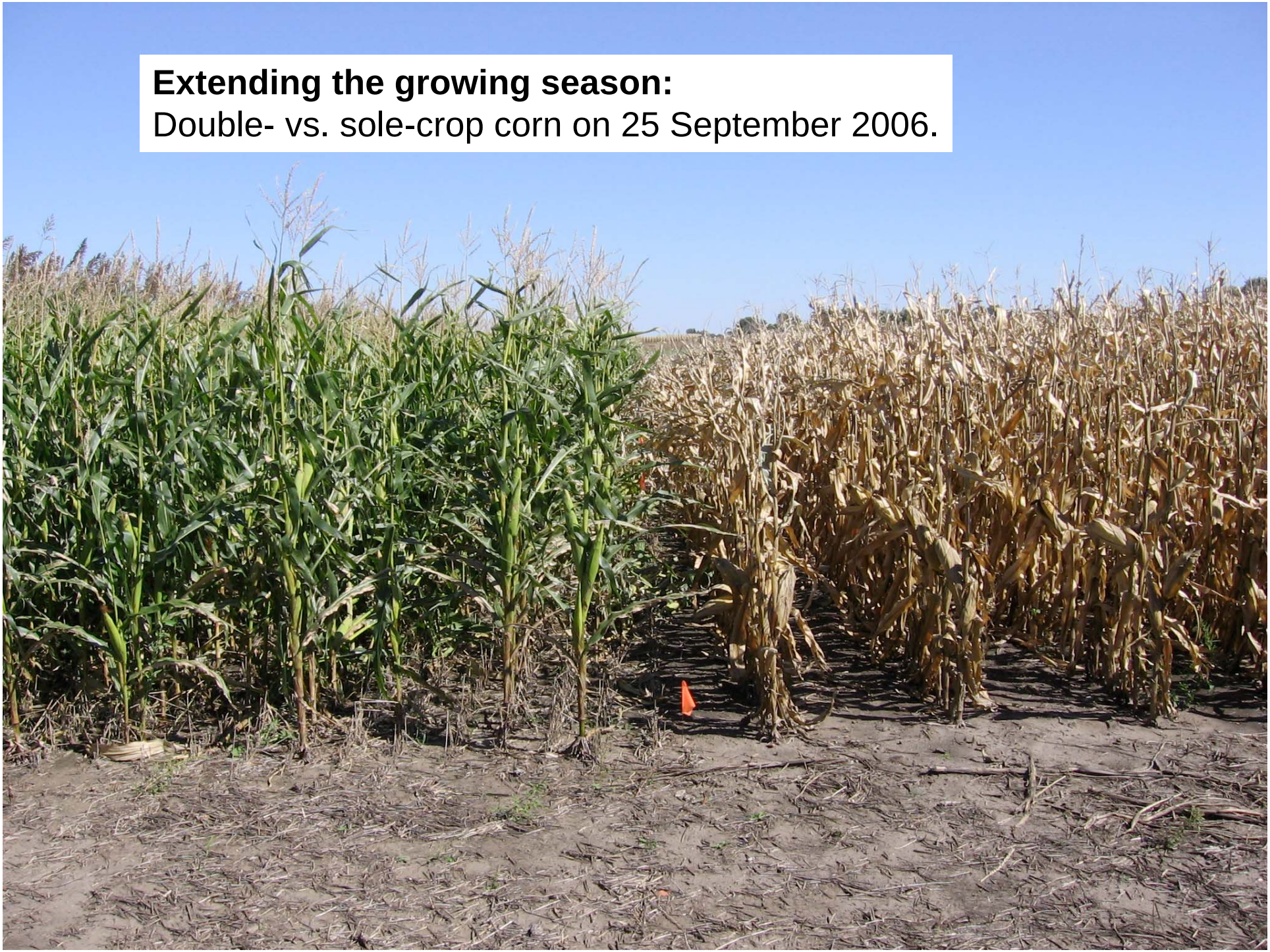
1) Corn

2) Sorgxsudan

3) Crotalaria

Biomass Harvest:
Fall planted triticale harvested on 5 June 2006.

Summer Crops Follow Triticale:
Double cropped sorghum x sudangrass on 31 August 2006.


Extending the growing season:
Double- vs. sole-crop corn on 25 September 2006.

Cropping systems influence water quality

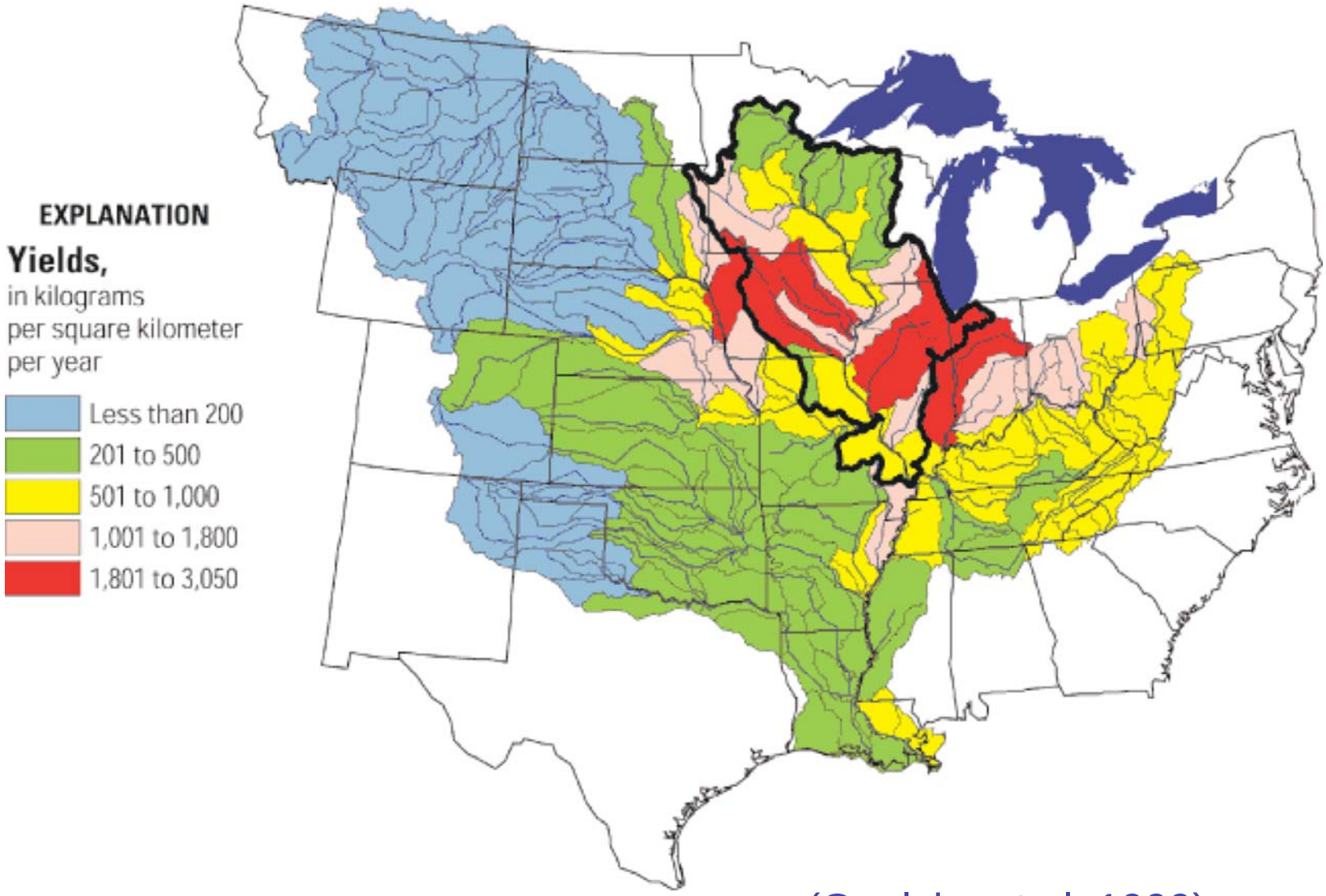
Source: USDA-NRCS

Nitrate-Nitrogen Loss in Tile Drainage

(Randall et al., 1997)

Cropping system	NO_3-N loss ($kg\ ha^{-1}\ yr^{-1}$)
Continuous corn	55
Corn-soybean rotation	51
Alfalfa	2
CRP (perennial grasses and alfalfa)	1

Nitrogen lost from land to streams



(Goolsby et al.,1999)

Perennial biofuel crops offer environmental advantages:

- Building and conserving soil
- Capturing and storing carbon
- Holding and filtering water
- Providing wildlife habitat
- Cycling nutrients efficiently

Photo courtesy of J. Neal, Leopold Center

Nutrient Recycling

- Conversion of biomass to biofuels creates opportunities for recovering nutrients that are important for plant growth.

- Cycling nutrients between facilities used for biofuel processing and fields used for biomass production could increase energetic efficiency and reduce fertilizer requirements.

What's in an acre of switchgrass?

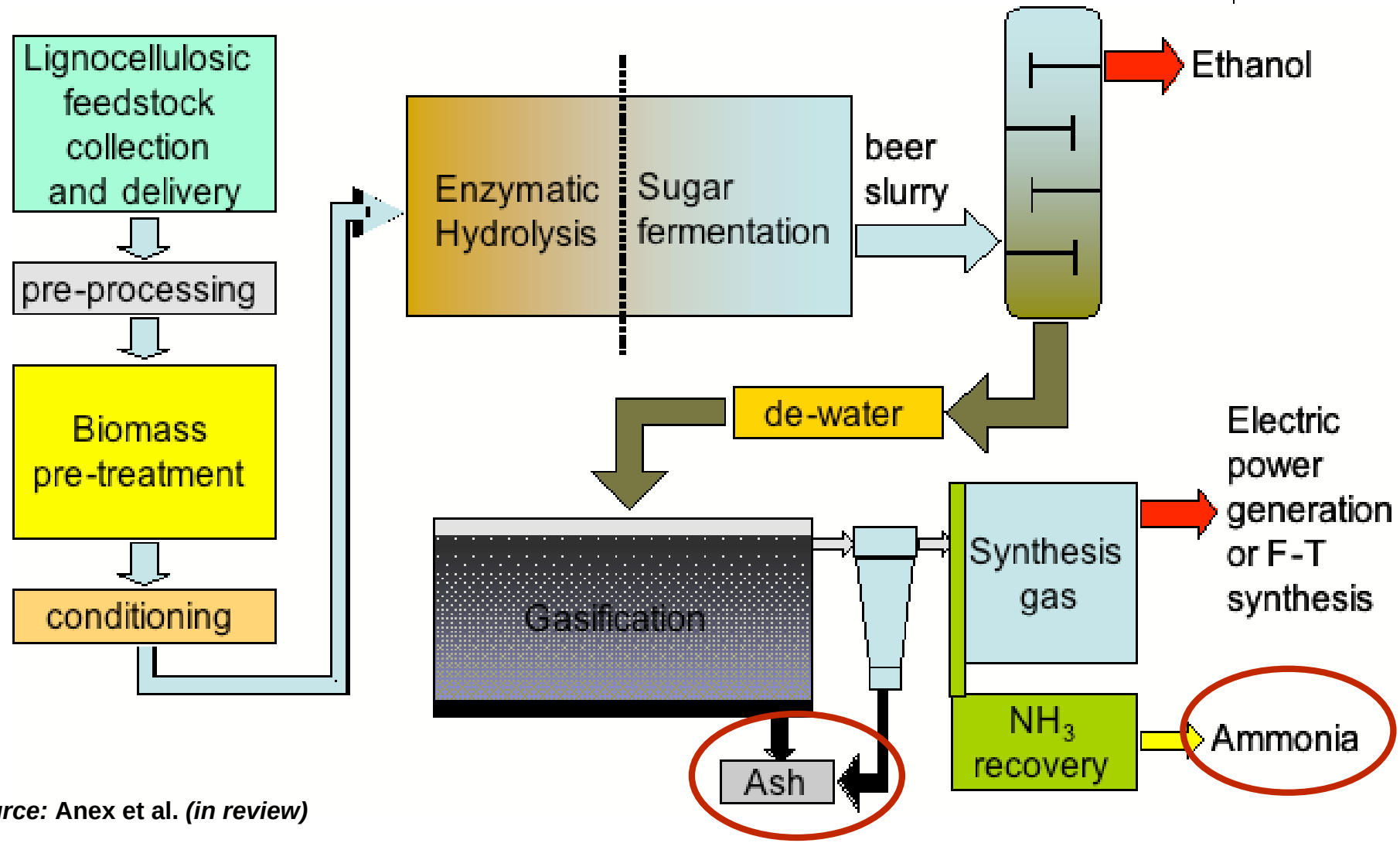
Lignocellulose ~95%

"Contaminants" ~5%

Element	Composition (% dry weight)
Carbon	48
Oxygen	42
Hydrogen	6
Elements in Ash	3.5
Nitrogen	> 1
Chlorine	> 0.01

Most "contaminants" contained in biomass are important plant growth nutrients that could potentially be recovered during processing and returned to crop fields.

Integrated cellulosic biorefinery with nutrient recovery



Source: **Anex et al.** ***(in review)***

Closing the nitrogen cycle could increase biofuel efficiency (modeled switchgrass system)

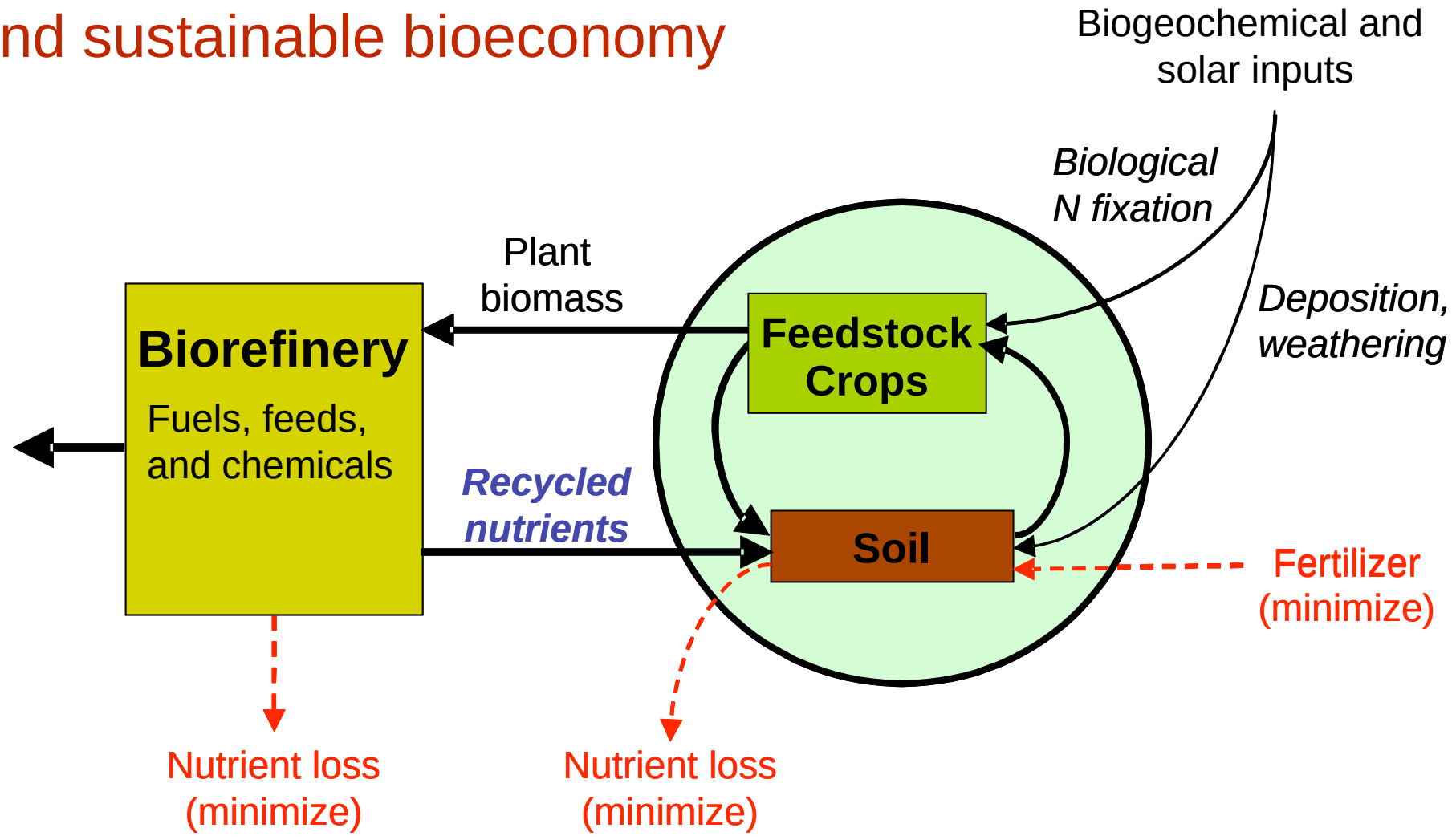
Switchgrass nitrogen flows (kg/ha/yr)	Nitrogen import	Nitrogen export
Fertilizer applied	113	
Crop harvest		91
Atmospheric deposition	7	
Volatilization		11
Soil denitrification		18
Total	120	120
Biorefinery nitrogen recovery potential		
Mass (kg/ha/yr)	75	
Percent of fertilizer applied	77	
Energy embodied in recovered fertilizer (MJ) [1]	2460	

[1]Delivered to farm

Source: **Anex et al.** ***(in review)***

Integrated Agricultural Energy Systems:

New cycles in agriculture
can help to create a productive
and sustainable bioeconomy



Acknowledgements

- **Projects:**

  Lance Gibson, Lee Lynd, Robert Brown

- **Funding:**

  National Science Foundation

  Leopold Center for Sustainable Agriculture

  ISU Plant Sciences Institute

  Univ. of Iowa Center for Global and Regional Environmental Research

  Monsanto

  ISU Departments of Agronomy and Agricultural and Biosystems Engineering