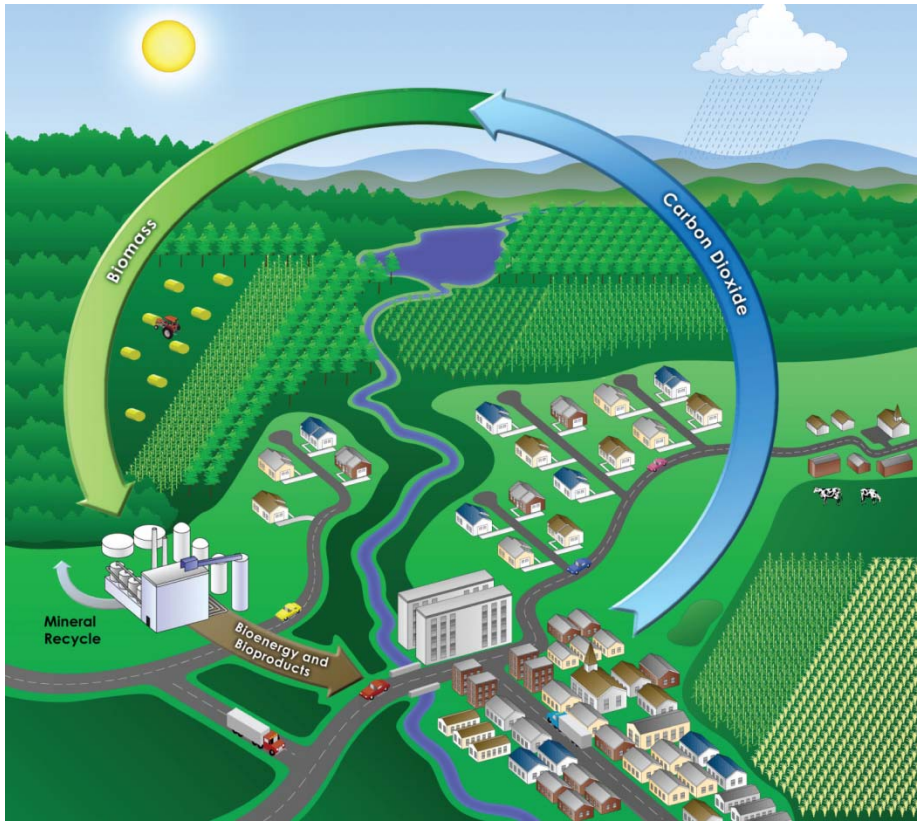
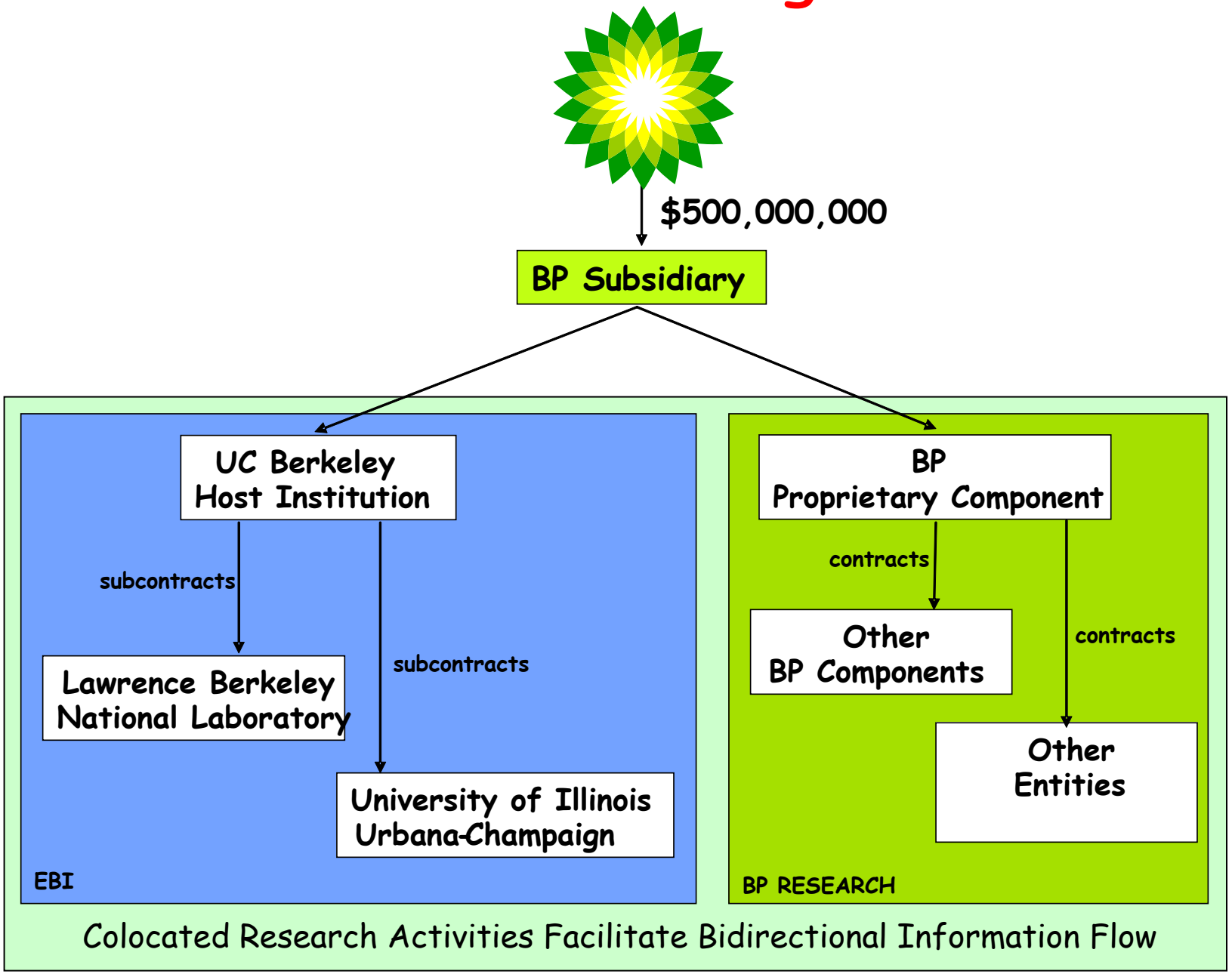
Development of Cellulosic Biofuels



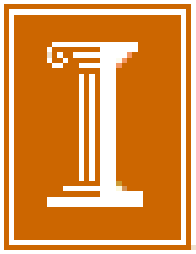
Chris Somerville
Energy Biosciences Institute
UC Berkeley, LBL, University of Illinois

EBI Funding


$500,000,000
BP Subsidiary
UC Berkeley
Host Institution
subcontracts
Lawrence Berkeley
National Laboratory
subcontracts
University of Illinois
Urbana-Champaign
EBI
BP
Proprietary Component
contracts
Other
BP Components
contracts
Other
Entities
BP RESEARCH
Colocated Research Activities Facilitate Bidirectional Information Flow

EBI Mission

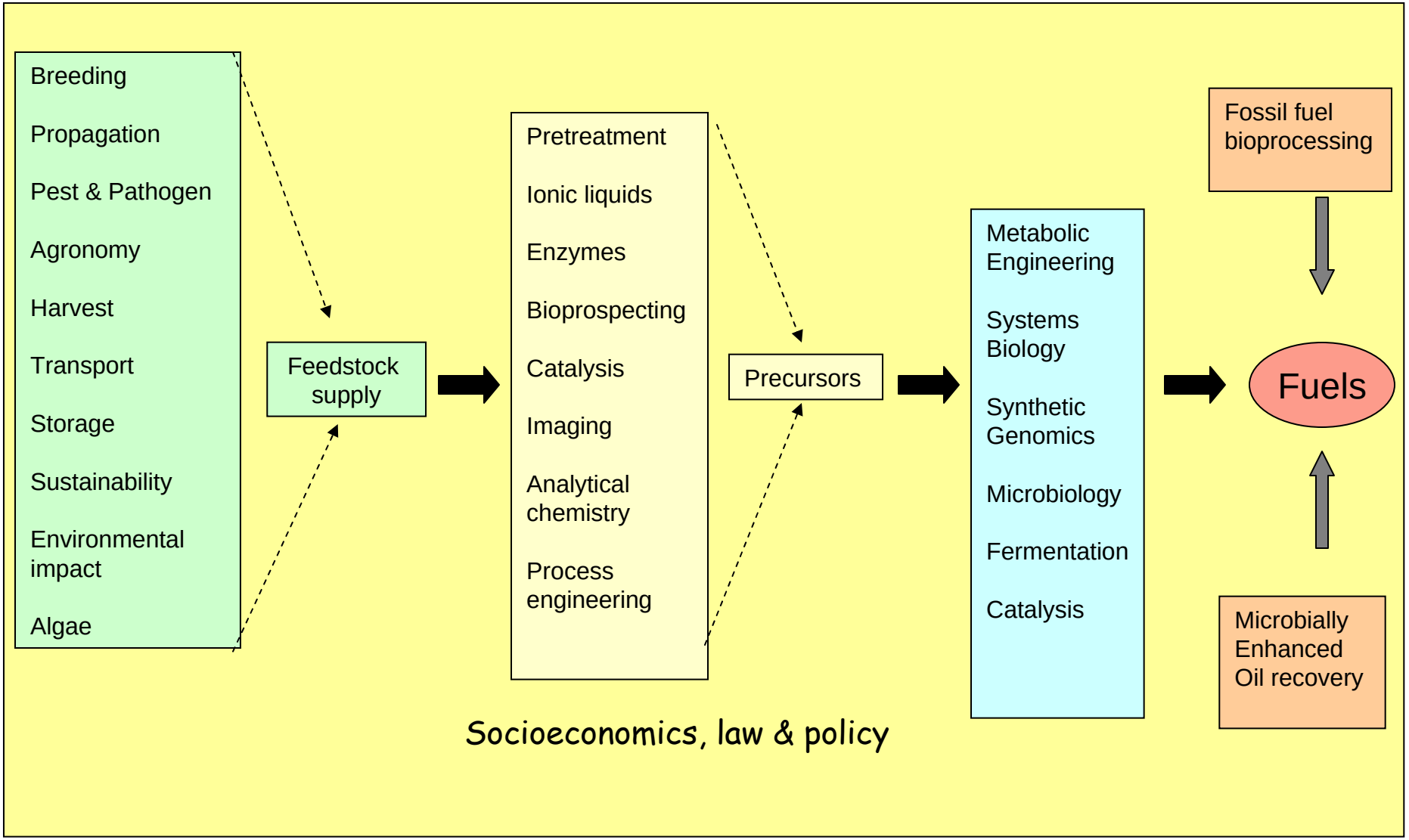
- Mandate to explore the application of modern biological knowledge to the energy sector
  - Cellulosic fuels
  - Improved fossil fuel recovery and processing
  - Other



EBI Vision

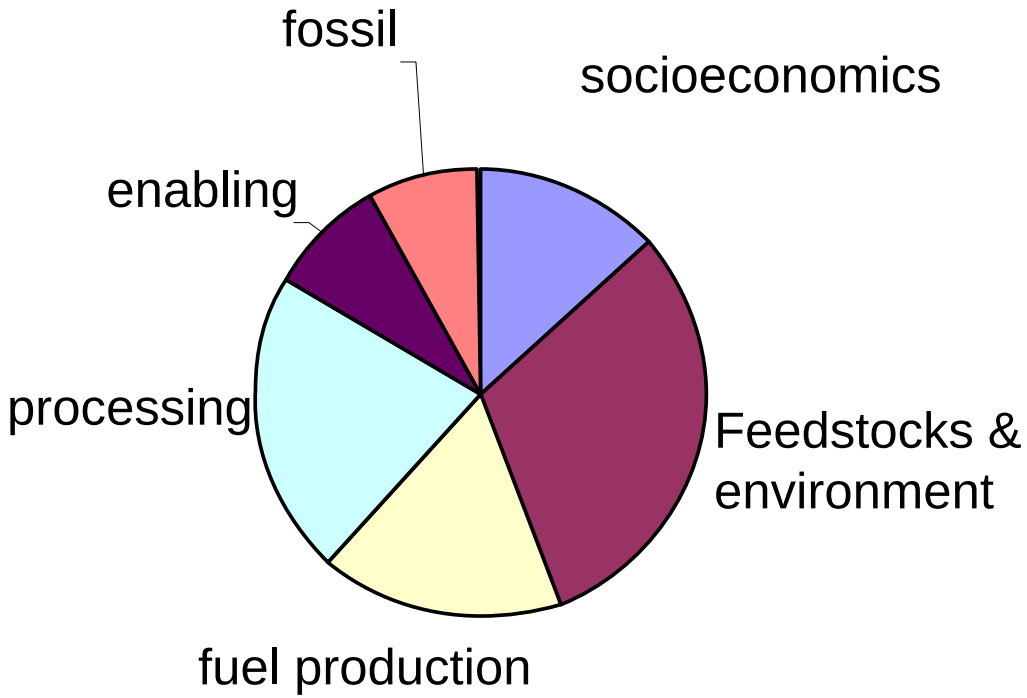
- Create and organize coherent knowledge of the field
  - Rare
  - Enabling
  - Allows timely & efficient investment
  - Compatible with strengths of Universities
  - Builds on the fact that discoveries will happen in many places

Technical reach of the EBI



Current budget allocation

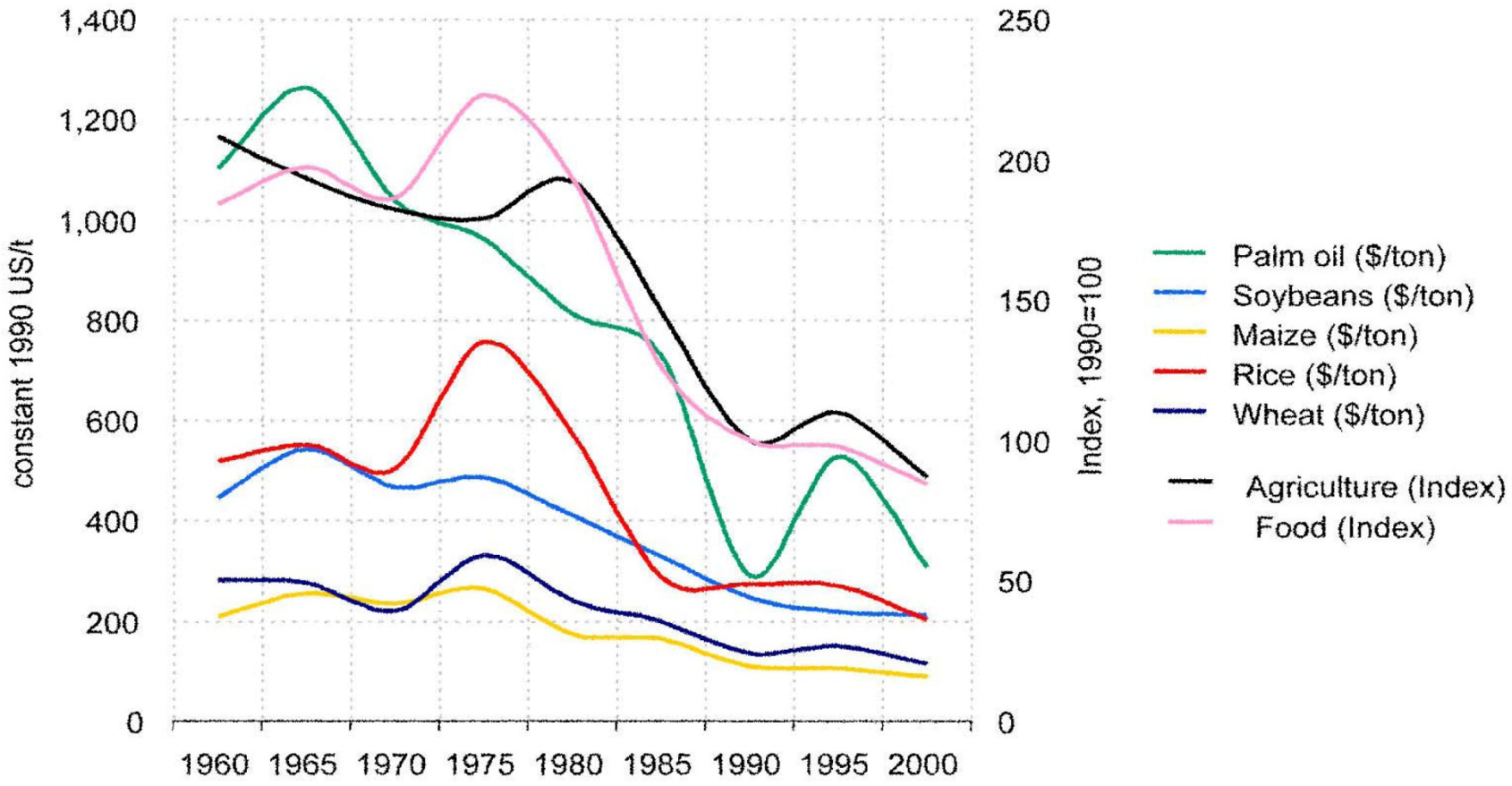
EBI currently supports >120 faculty and >170 graduate students and postdocs



Indirect land use concept

- Diversion of land from feed to fuel production shifts production of feed to other land
- Some of the "other land" may be undeveloped
- Use of undeveloped land causes large CO_2 emissions from burning and soil emissions

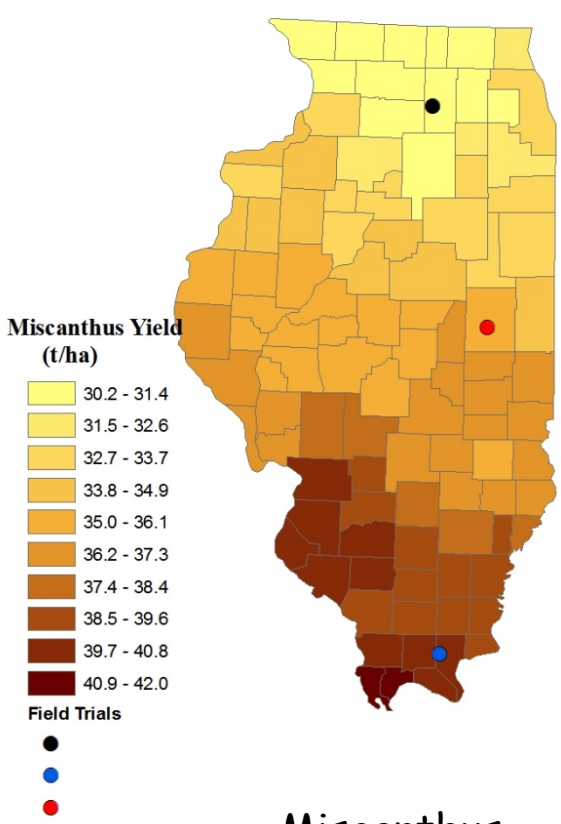
Will long-term food price trend reverse?



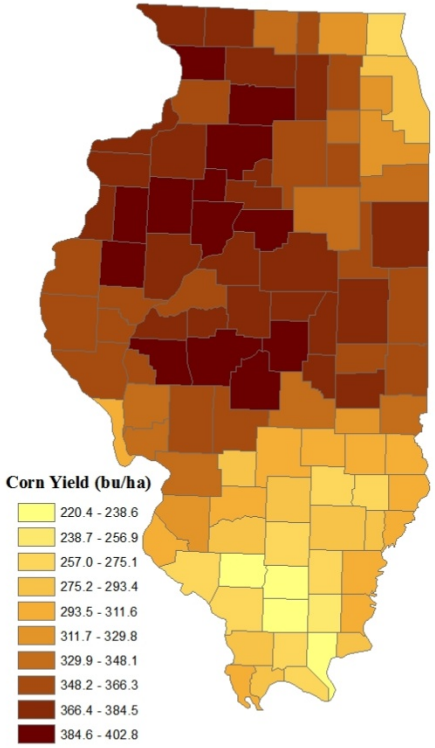
D. Dijk, Rabobank (2007)

Energy crops may not compete directly with food crops

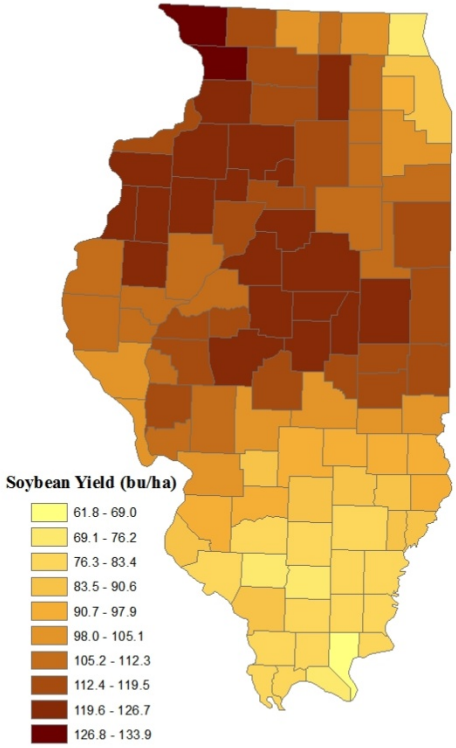
(yield per HA for Miscanthus, Corn, Soybean)



Miscanthus



Corn



Soybean

Madhu Khanna, University of Illinois, Urbana

EBI Energy Farm

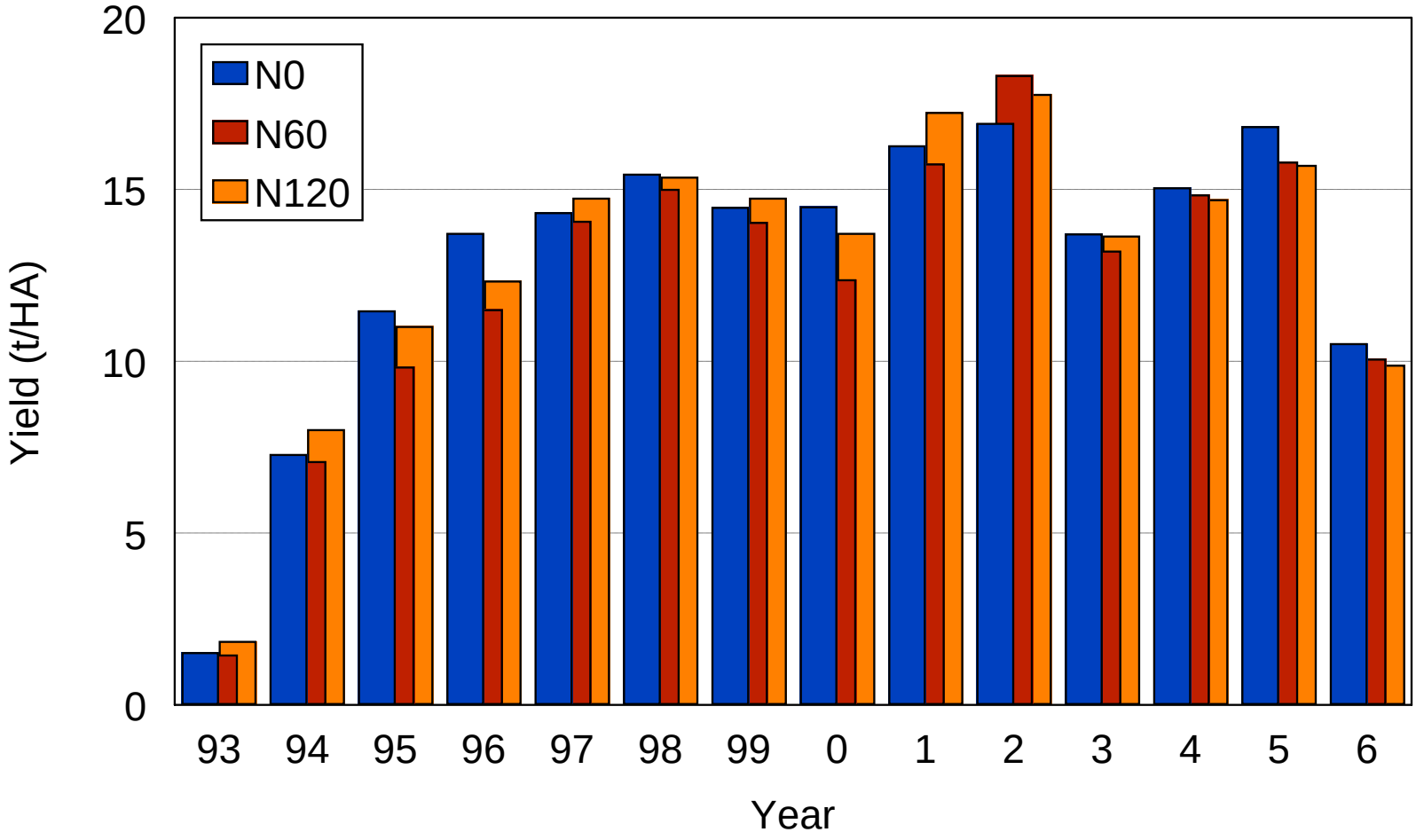
- 320 acres plus 8remote sites
- State-of-the-art remote sensing of crop growth
- Continuous greenhouse gas exchange monitoring installed over large scale trials of continuous corn, mixed prairie, switchgrass, Miscanthus and other feedstocks.
- Instrumented field drains installed below these crops to measure runoff.
- Interpretation and education facility, for student, farmer and lay groups.

An energy crop

Yield of 26.5 tons/acre observed by Young & colleagues in Illinois, without irrigation

Courtesy of Steve Long et al

Response of Miscanthus to nitrogen fertilizer

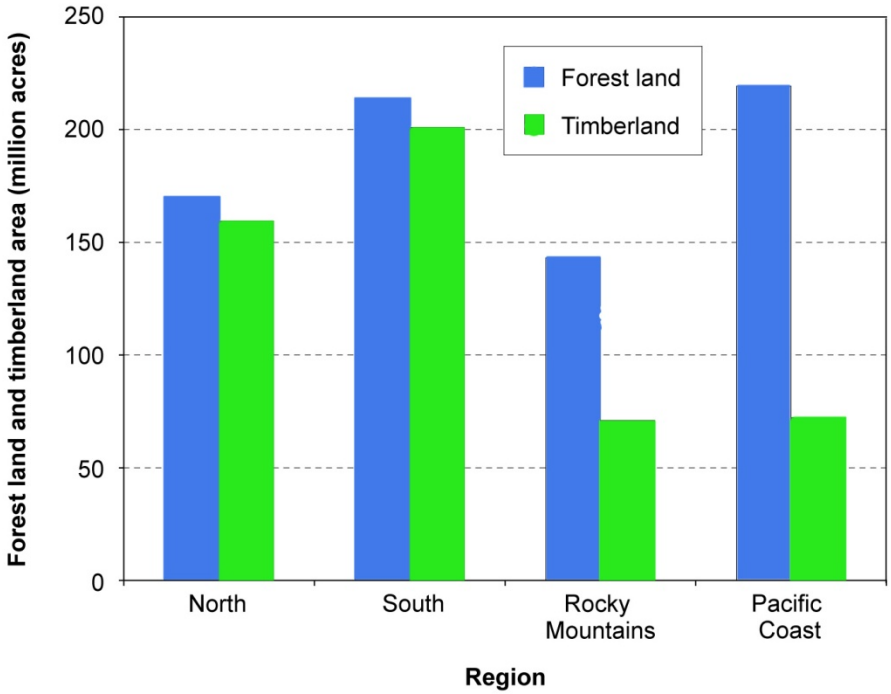


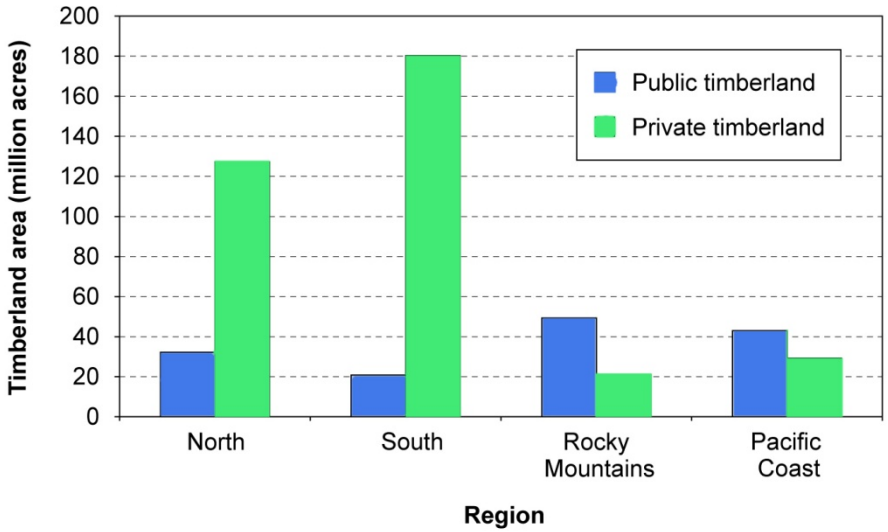
Christian, Riche & Yates Ind. Crops Prod. (2008)

Harvesting Miscanthus

http://bioenergy.ornl.gov/gallery/index.html

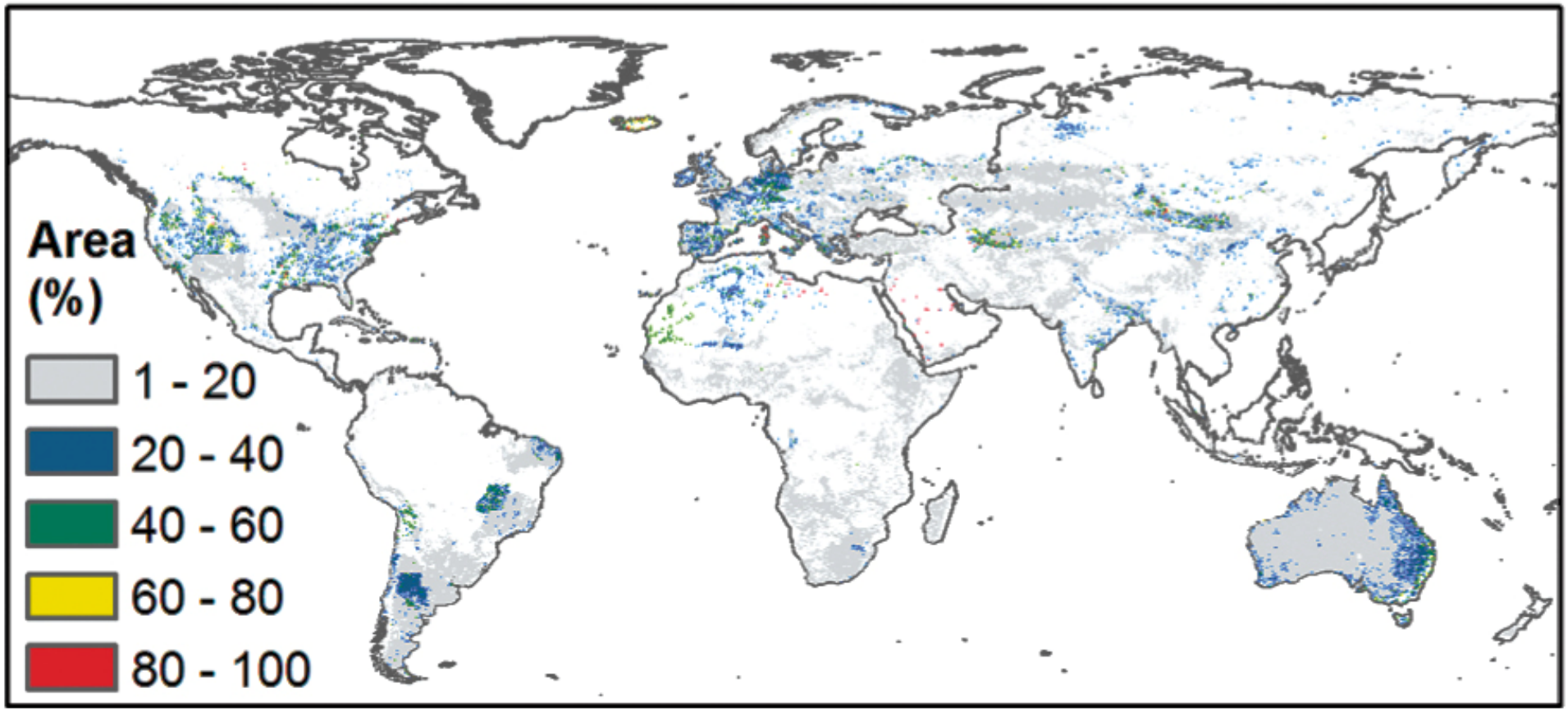
Private forests are extensive





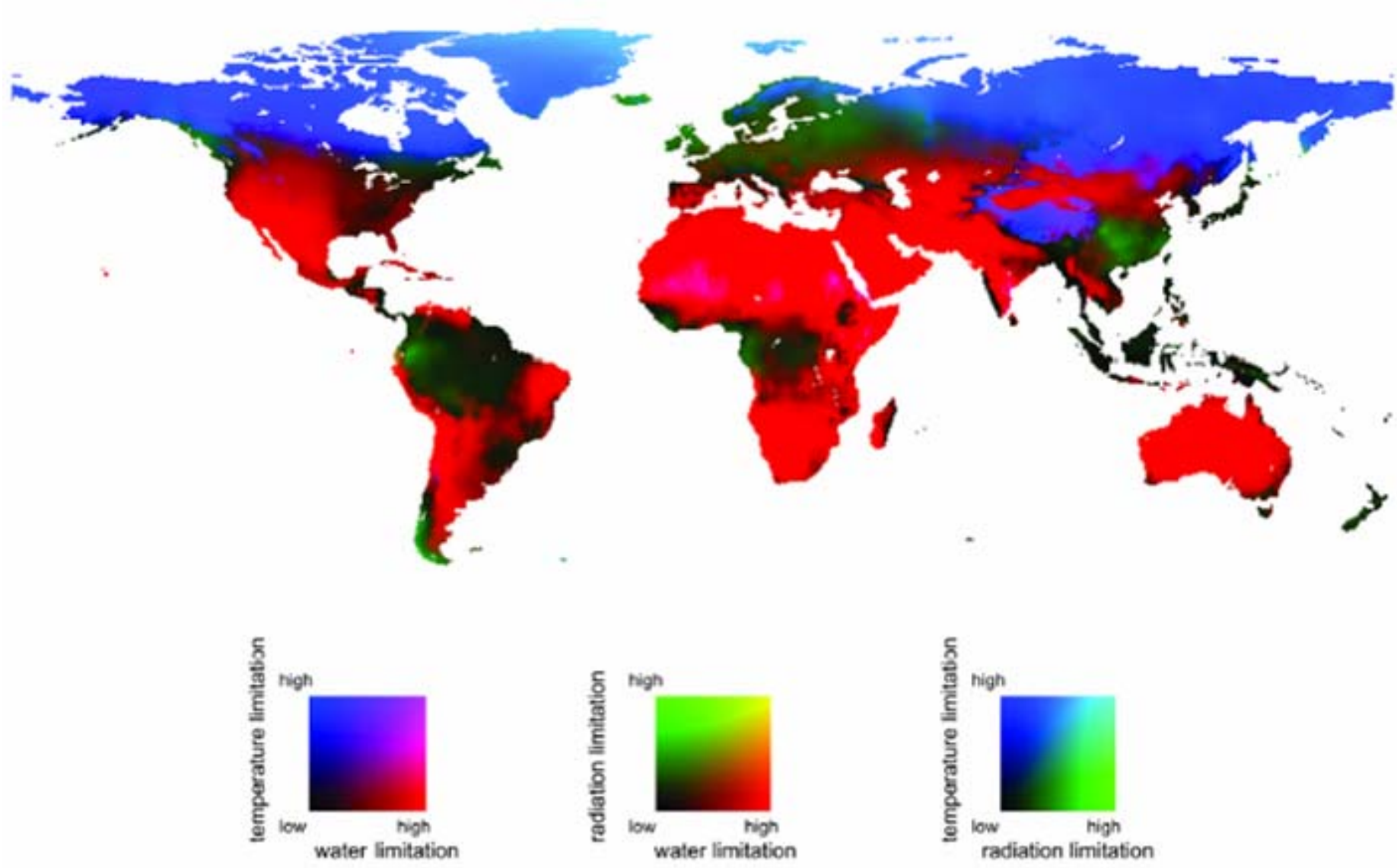
Alig & Butler (2004)USDA Forest Service PNW-GTR-613

>>A billion acres of agricultural land have been abandoned



Campbell et al., Env. Sci. Technol. (2008) 42,5791

Limiting factors for global NPP



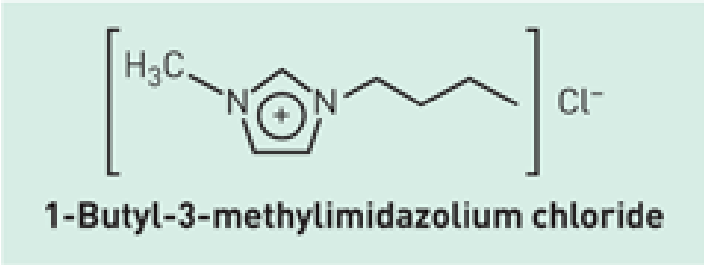
Baldocchi et al. 2004 SCOPE 62

Agave in Madagascar

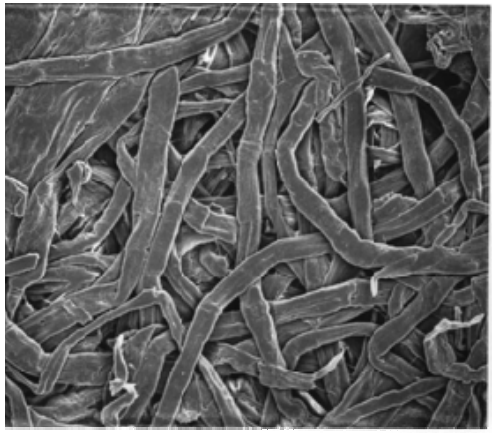
Borland et al. (2009) J. Exp. Bot. doi:10.1093/jxb/erp118

Dissolution of cellulose in an ionic liquid

(novel pretreatment methods may create fundamental changes)



1-Butyl-3-methylimidazolium chloride



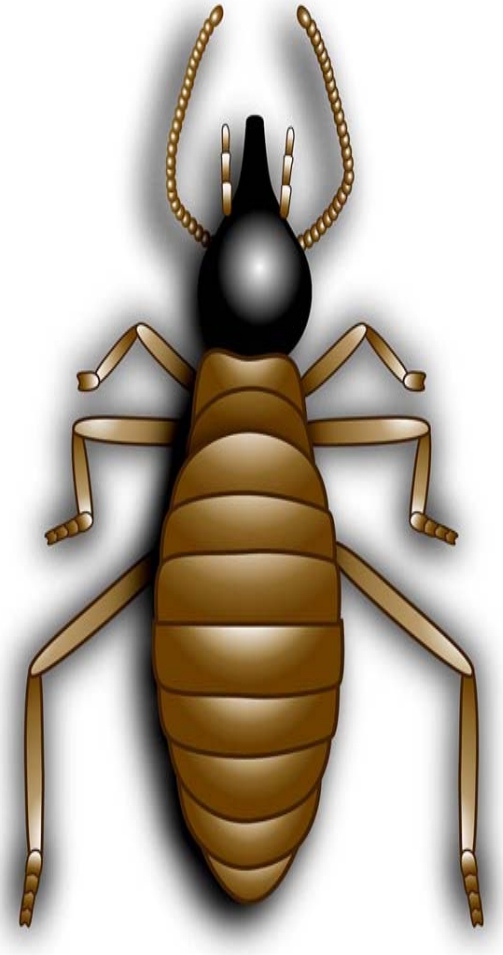
Untreated

Treated

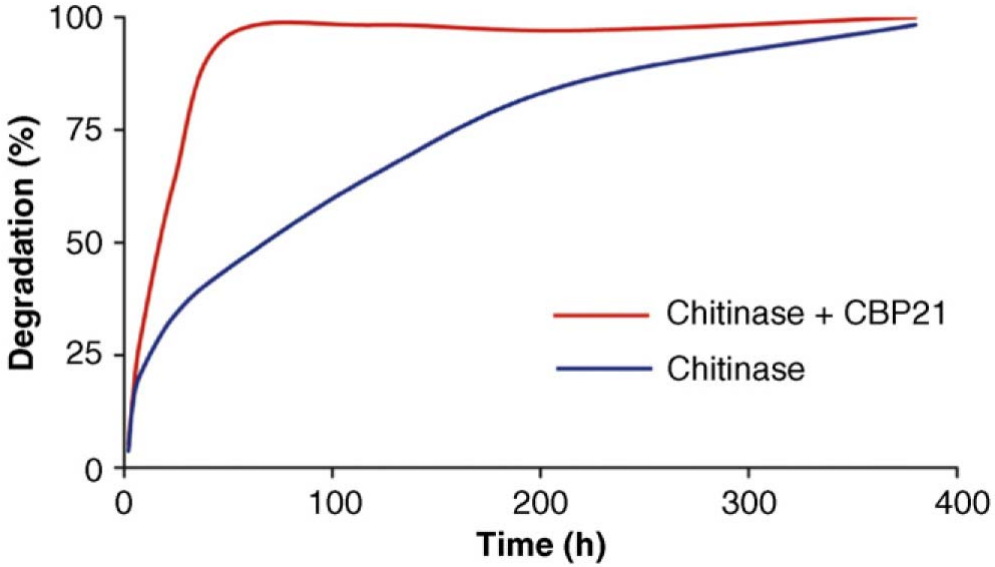
Swatloski, Spear, Holbrey, Rogers *J. Am. Chem. Soc.,* 124 (18), 4974 -4975, 2002

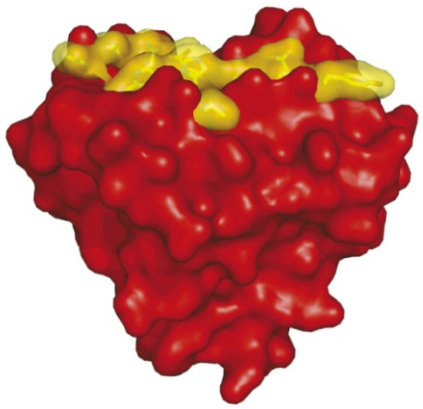
Possible routes to improved catalysts

- Explore the enzyme systems used by termites (and ruminants) for digesting lignocellulosic material
- Compost heaps and forest floors are poorly explored
- In vitro protein engineering of promising enzymes
- Develop synthetic organic catalysts (for polysaccharides and lignin)



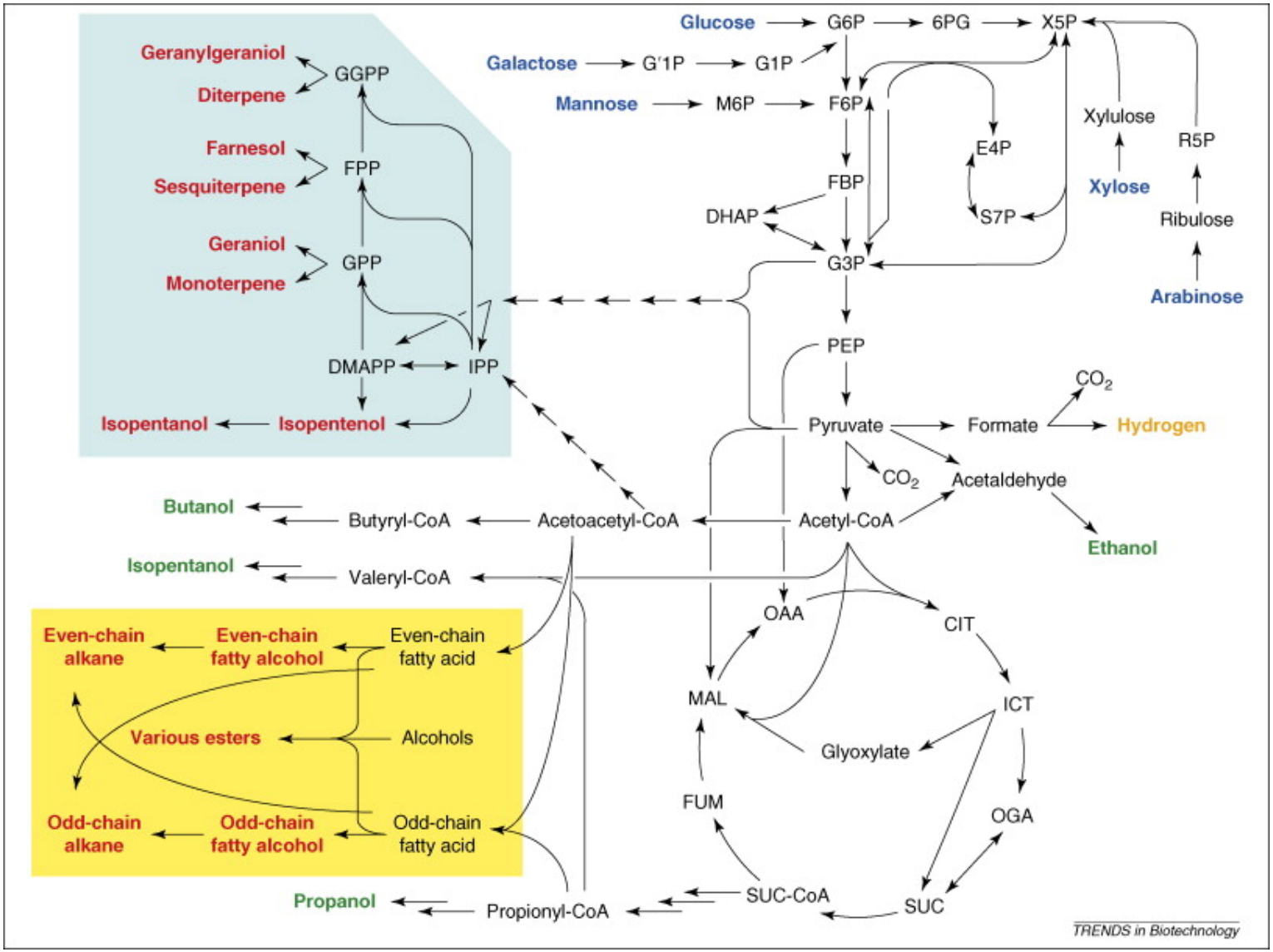
Accessory proteins stimulate activity of cellulases and chitinases





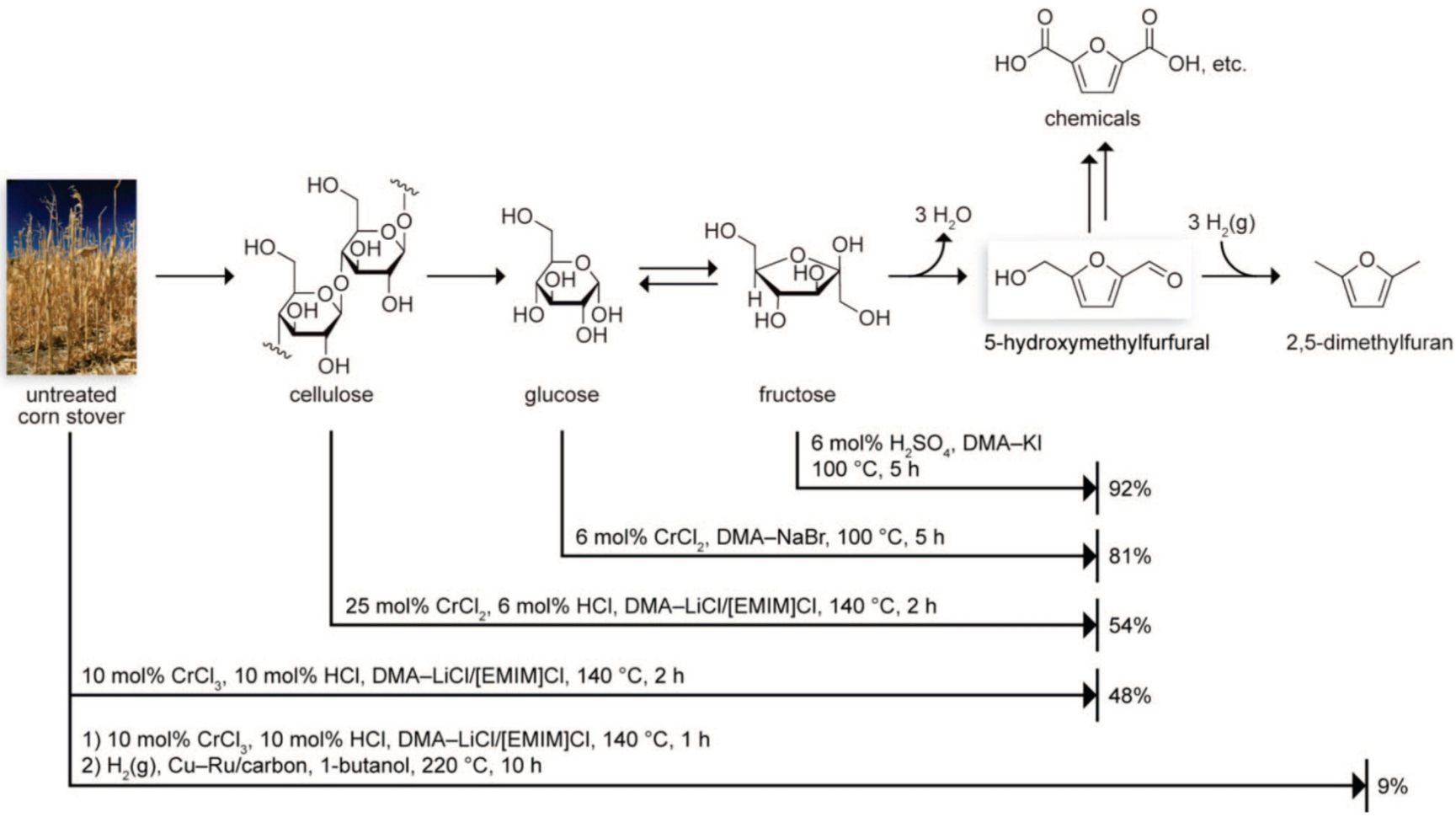
Eijsink et al, Trends Biotechnol 26,228

Routes to potential fuels



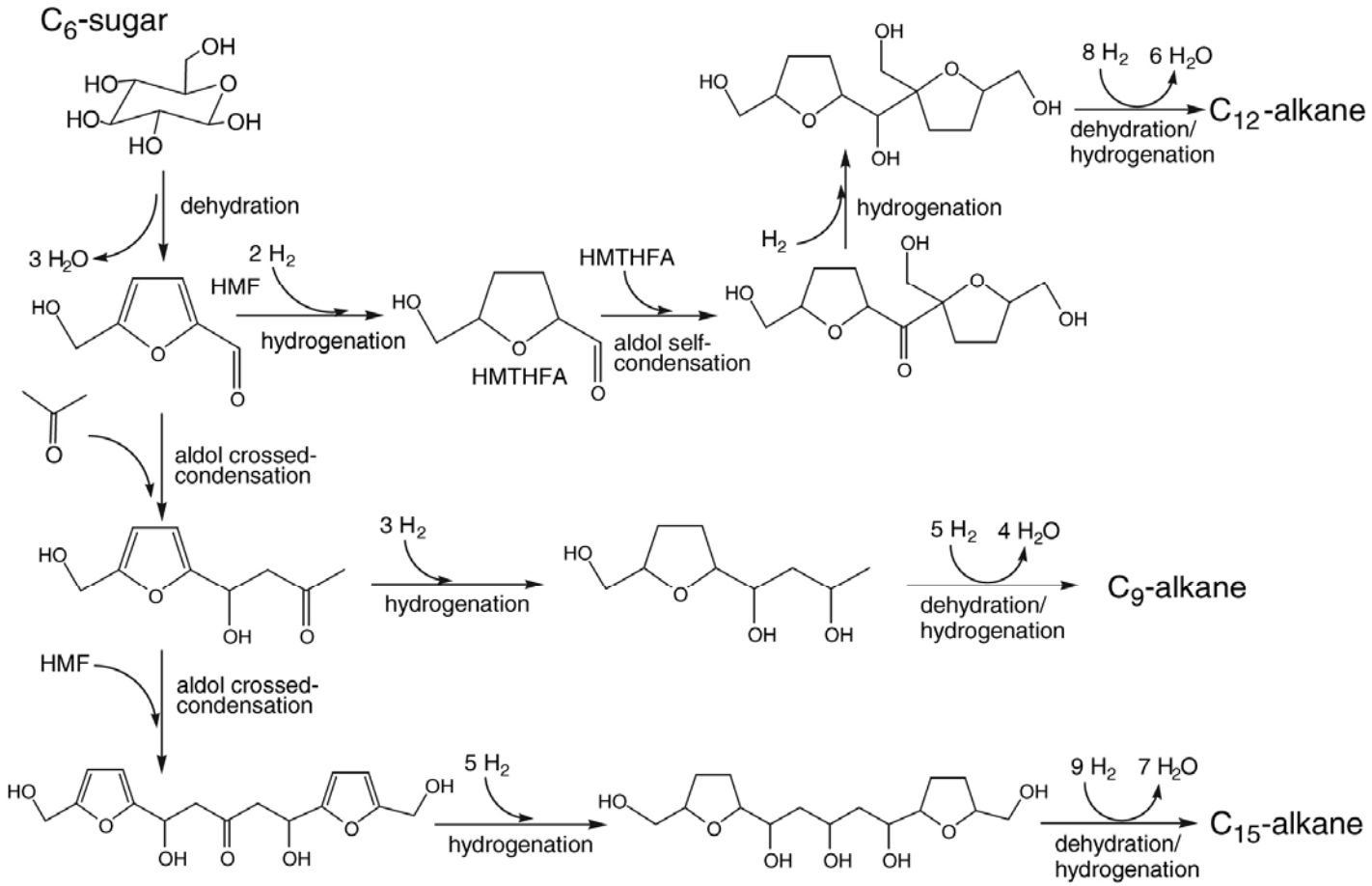
Fortman et al, Trends Biotechnology 26,375

Cellulose to intermediates



Binder and Raines JACS 2009

Conversion of sugar to alkanes



Huber et al., (2005) Science 308,1446

Summary of priorities

- Develop energy crops and associated agronomic practices
- Identify or create more active catalysts for conversion of biomass to sugars and sugars to fuels
- Develop improved industrial microorganisms
- Develop new types of microorganisms that produce and secrete hydrophobic compounds
- Understand the social, economic, and environmental implications