







Development of Second Generation Biofuel Crops

Steve Long, Deputy Director, EBI
 Plant Biology, Crop Sciences, Institute for Genomic Biology, National Center for Supercomputer Applications, University of Illinois.





 Energy Biosciences Institute 

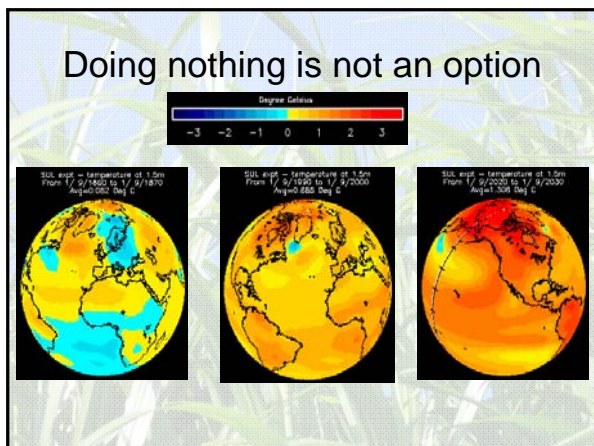


Roadmap

-  Why fuels from crops?
-  What is the ideal biomass crop?
-  Performance of *Miscanthus* and switchgrass.
-  Food vs. Fuel

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ABOUT THE EBI 

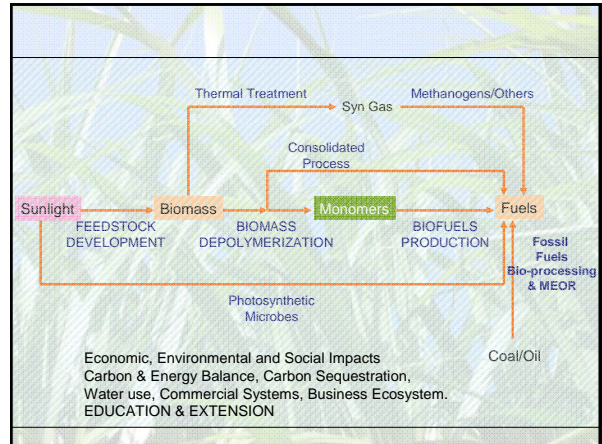



RESEARCH & DEVELOPMENT GOAL:
 Environmentally and economically sustainable second generation feedstock and biofuel business


\$500M investment over 10 years by BP

IP Belongs to the Universities.

DIRECTOR:
 Chris Somerville (Berkeley)
DEPUTY DIRECTOR:
 Steve Long (Illinois)
ASSOCIATE DIRECTOR:
 Paul Willems (BP Group)




INTEGRATING PROGRAMS 

Under One Roof 

Programs **Projects**

- Feedstock Development
- Feedstock Deconstruction
- Fuel Synthesis
- Environment, Economics & Policy

R&D DIVIDED INTO 18 PROGRAMS FROM GENOMICS AND AGRONOMY TO ECONOMICS AND LAW 

Chris Somerville, DIRECTOR, UC Berkeley

Steve Long, DEPUTY DIRECTOR, Illinois

- Biomass Depolymerization (x2)
- Feedstock Development (x4)
Miscanthus x giganteus
Switchgrass, Sorghum, Sugar cane.
- Environmental, Social and Economic Dimensions (x3)

Paul Willems, BP ASSOCIATE DIRECTOR
 Proprietary R&D

UC Berkeley PROGRAMS

Roadmap

- Why fuels from crops?
- What is the ideal biomass crop?
- Performance of *Miscanthus* and switchgrass. Basis of differences
- Miscanthus* and potential biofuel production.





Arguments against biofuels from crops.

- Photosynthetic efficiency too low - 0.1% suggested.
- Not enough land, will cause starvation.
- Not enough water
- Not sustainable.
- Invasive



Fuel from crops

Corn requires very high inputs:

- Annual cultivation and sowing.
- High nutrient demand, esp. N.
- Selected over centuries for nutrition.
- Soil erosion, esp. marginal lands.



Why is high yield the critical factor?



- Less land.
- Greater adoption in vicinity of plant.
- Shorter transport distances.

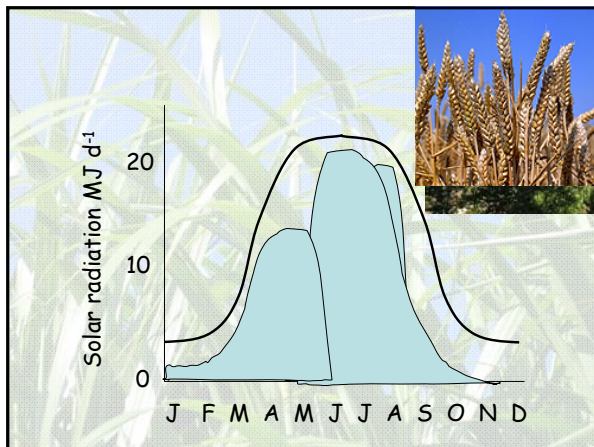
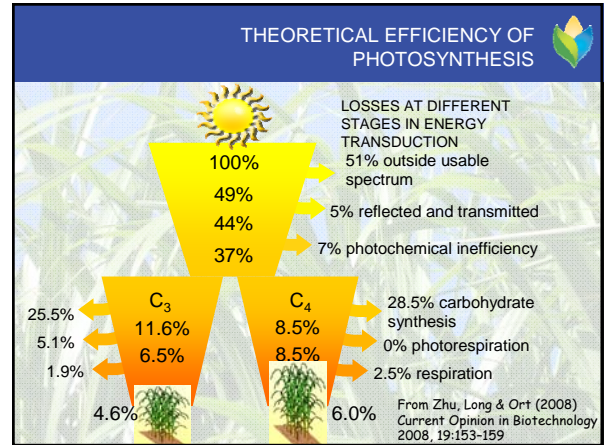
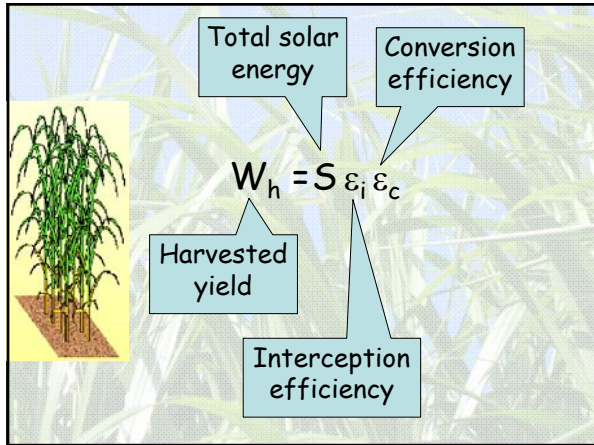
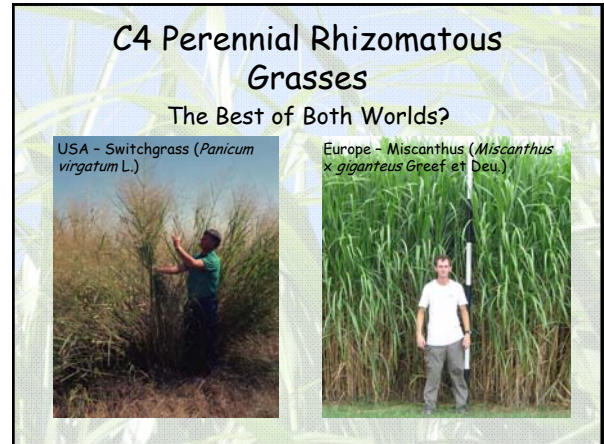
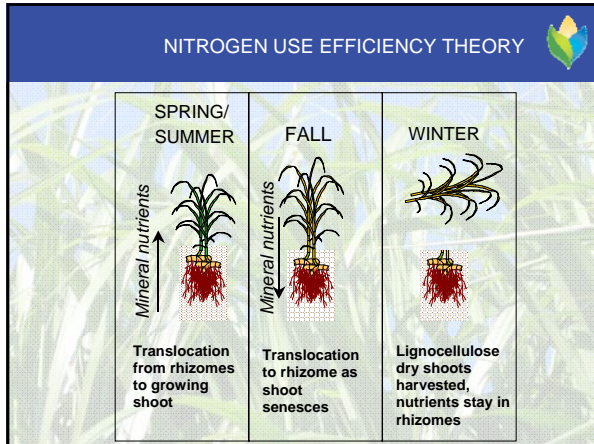
Why is low input a critical factor?

- Better energy and carbon balance.
- Lower or no environmental impact.
- Marginal lands







Prairie, Steppe and Savanna perennial grasses are sustainable if cropped or burned annually, and accumulate carbon in the soil.

But average yield very low - 2.4 t ha^{-1}




The "Ideal" Biomass Crop?	Maize	SRC	C4PRG
C4 photosynthesis	★		★
Long canopy duration		★	★
Recycles nutrients to roots			★
Clean burning			★
Low input		★	★
Sterile - non-invasive	N/A		★
Winter standing		★	★
Easily removed	★		★
High water use efficiency			★
No known pests/diseases			★
Uses existing farm equipment	★		★

Roadmap

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-  Performance of *Miscanthus* and switchgrass.
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Inter-specific hybrid

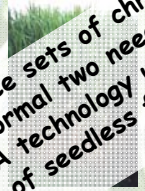
Miscanthus sinensis



"D₄ instead of normal two needed for fertility. cultivation of seedless fruits - e.g. banana."

2n=2x


Miscanthus sacchariflorus



"Tetraploid"

2n=4x=76

Miscanthus giganteus

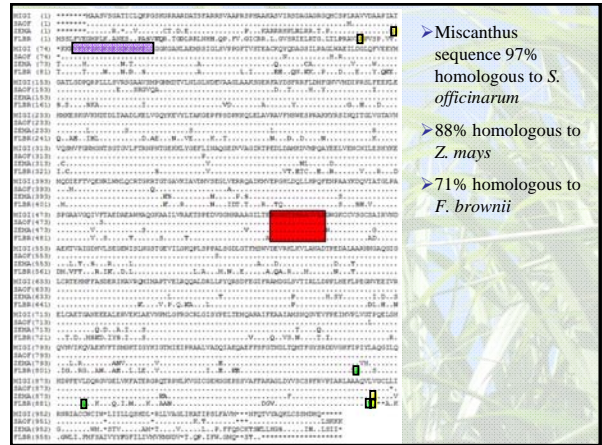
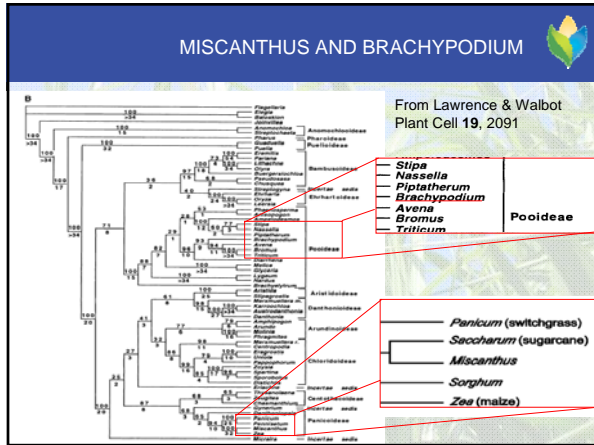


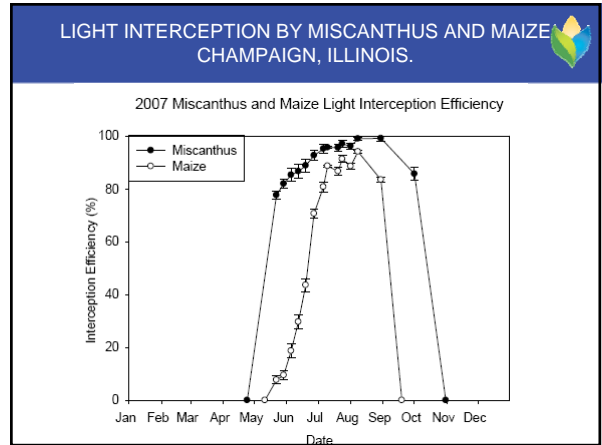
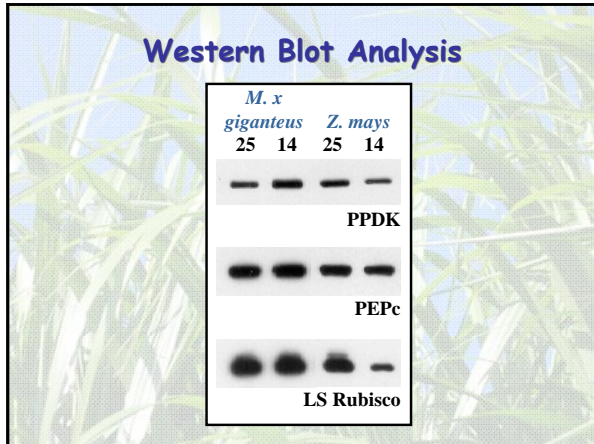
"Triploid"

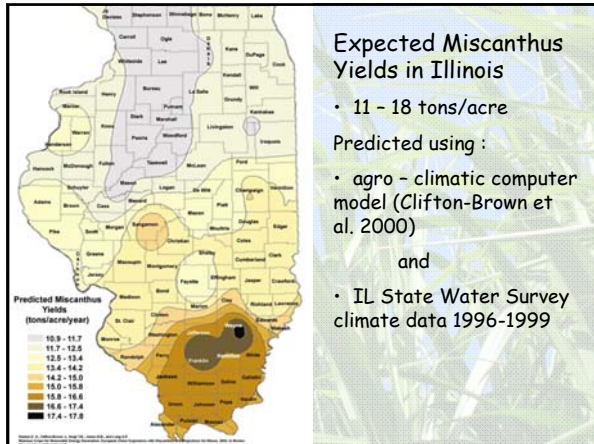
2n=3x=57

STERILE

Triploid - three sets of chromosomes. A technology used in



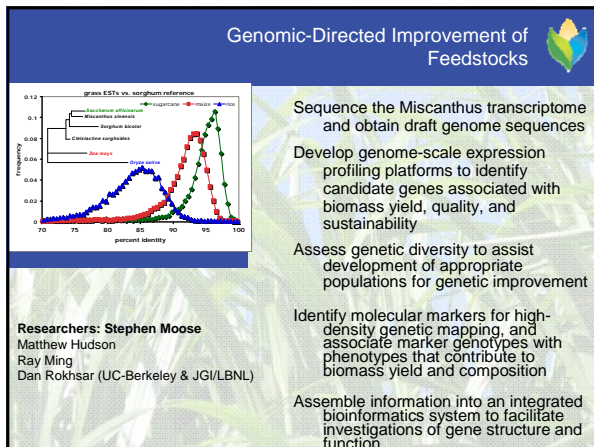
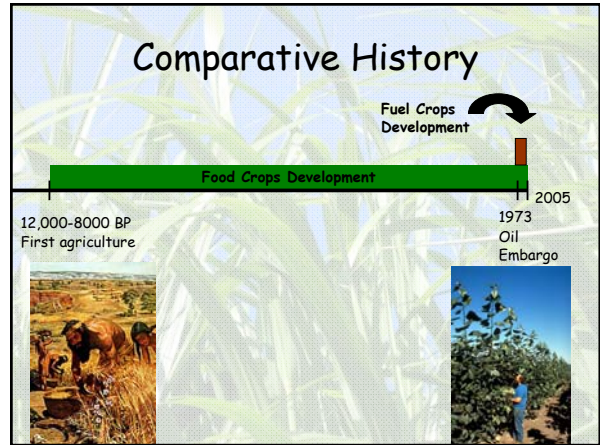
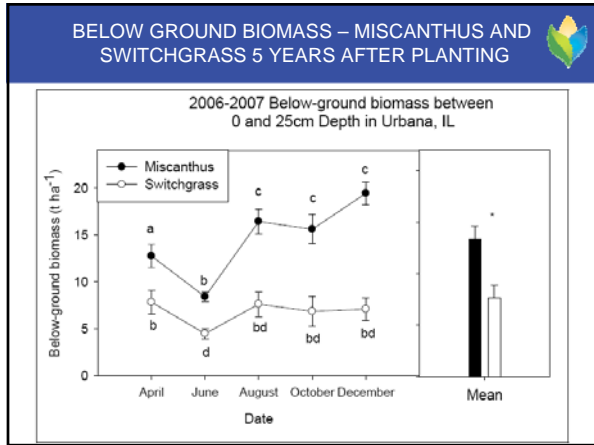


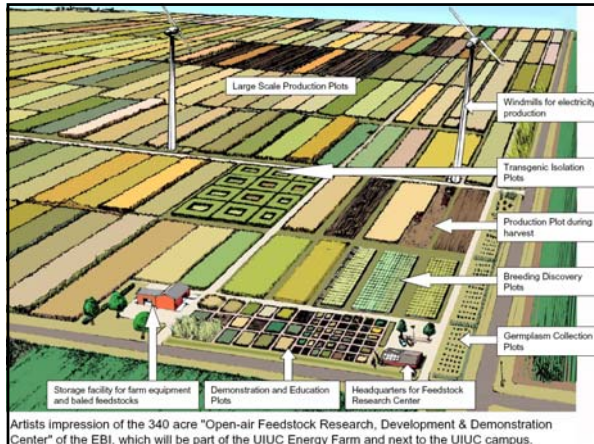


WHY DOES PRODUCTIVITY MATTER?

Feedstock	Harvestable Dry Biomass (t/ha)	Ethanol (liters/ha)	Mha needed for 133 billion liters of ethanol	% 2006 harvested US cropland
Corn grain	10.1	3,830	35	24.4
Corn stover	6.71	2,554	52	37.2
Corn Total	17.5	6,640	20	14.8
Prairie mix	3.8	1,447	92	72.5
Switchgrass	12.5	4,767	28	22.0
Miscanthus	29.1	11,066	12	9.3

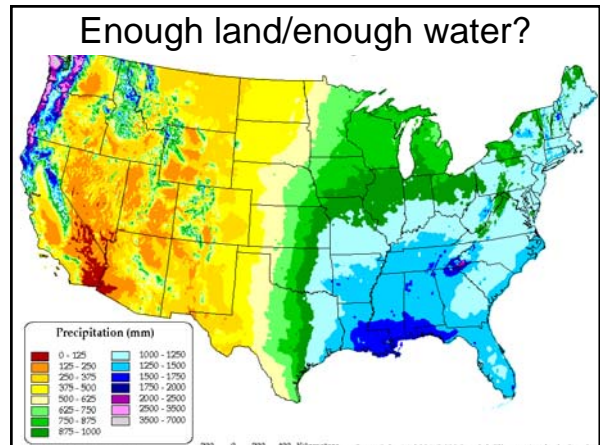
Source: Heaton, Dohleman & Long (GCB submitted)





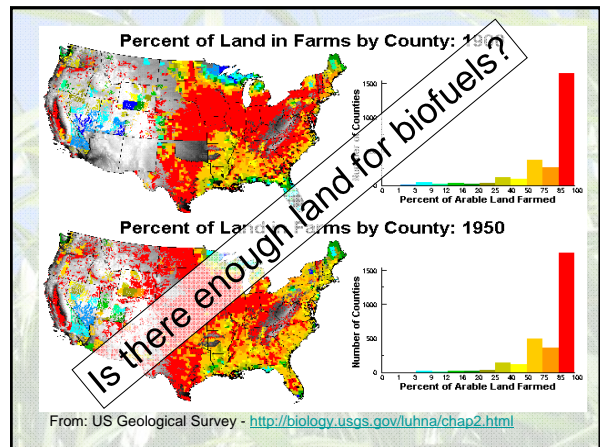
Roadmap

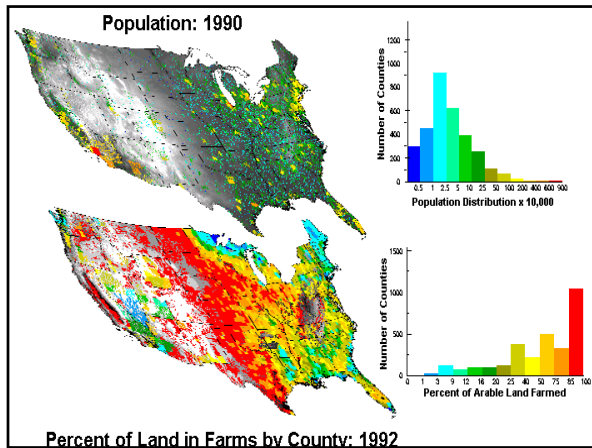
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How much water?

- $10 \text{ g kPa}^{-1} \text{ kg}^{-1} = 0.1 \text{ t ha}^{-1} \text{ kPa}^{-1} \text{ mm}^{-1}$
- 1000 mm at 1.0 kPa would allow 100 t ha^{-1}
– (assumes all water available)
- 500 mm at 4.0 kPa would allow 12.5 t ha^{-1}





- Miscanthus yields: **40** dry tons/ha feasible
- 400 liters of ethanol / dry ton \Rightarrow 16000 liters/ha
- 40 M out of 200 M ha \Rightarrow ~640 B liters / year of ethanol
- US consumption (2004) = 780 B liters ethanol equivalent (excludes diesel)

Hawaii -

Sugarcane acres decreased from 1934 to 2007
118,000

Dry mass yields - 40 t/acre

Sugar + Lignocellulose - 110 gal/t

= 520 Million gallons

Spartina anglica 60 t/ha growing in seawater.


Agave spp.
Semi-arid
Mexico


5-10 t/ha


ALTERATION	% Increase in ϵ_c relative to current value.	Speculated time horizon (years)
Improved canopy architecture	10% (0-40%)	0-10
Rubisco with decreased oxygenase activity	30% (5-60%)	>20
C4 photosynthesis engineered into C3 crops	12% (2-35%)	>30
Increased rate of recovery from photoprotection of photosynthesis	15% (6-40%)	5
Introduction of higher catalytic rate foreign forms of Rubisco	22% (17-30%)	5-10
Altered allocation of resources within the photosynthetic apparatus	40% (0-60%)	0-5

Arguments against biofuels from crops.

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- Not enough land, will cause starvation.
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EBI PROGRAMS 



FEEDSTOCK PRODUCTION/ AGRONOMY PROGRAM
Tom Vogt

ENGINEERING SOLUTIONS FOR BIOMASS FEEDSTOCK PRODUCTION
K.C. Ting

BIOFUEL ECONOMIC AND ENVIRONMENTAL IMPACTS
Madhu Khanna

ENVIRONMENTAL IMPACT AND SUSTAINABILITY OF FEEDSTOCK PRODUCTION
Evan DeLucia

ASSESSING IMPACT OF INSECT PESTS AND PLANT PATHOGENS ON BIOMASS PRODUCTION
Michael Gray

GENOMIC-DIRECTED IMPROVEMENT OF FEEDSTOCKS
Stephen Moore

BIOFUELS LAW AND REGULATION
Jay Keenan

ENGINEERING ENZYMES AND METABOLIC PATHWAYS TO DEGRADE PLANT CELL WALL LIGNOCELLULOSE
John Gerlt

DISCOVERY OF ENZYMES TO DEGRADE PLANT CELL WALL LIGNOCELLULOSE
Isaac Cann

