Non-Carbon Effects of Bioenergy on Climate

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Results from GCEP project "Biomass Energy: The Climate Protective Domain"
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GCEP

The Climate-Protective Domain

If done right, using biomass for energy could:

- Reduce greenhouse gas emissions (GHGs)
- Reduce dependence on foreign oil
- Enhance rural economies and, in some cases, food security
- Mobilize investment in agricultural technologies and infrastructure

BUT, there are risks that bio-energy could:

- Compete with food, driving up food prices and food insecurity
- Divert attention from cheaper or more effective climate mitigation measures
- Actually worsen climate change

Implementation at scale will require understanding and managing these risks

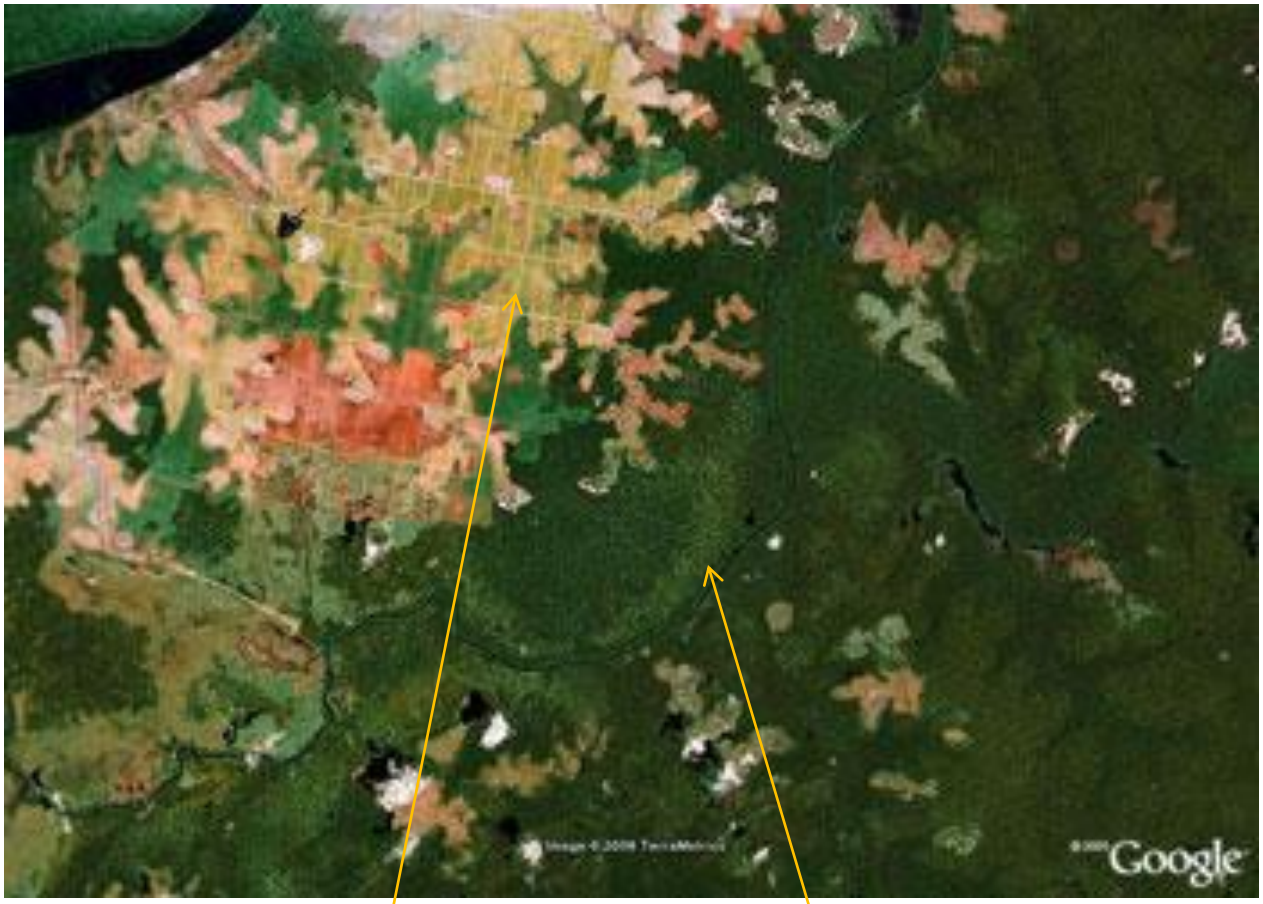
The Two Pathways of Climate Impact

1) Effects on Greenhouse Gas Emissions
   - -offsets of fossil fuel use
   - -"indirect" effects on land use emissions

2) Direct changes to surface energy and water budgets

   - -Albedo = amount of incident light absorbed by surface
   - -Evapotranspiration (ET) = flux of water vapor from land to atmosphere

Deforestation in Indonesia



High albedo, Low evapotranspiration

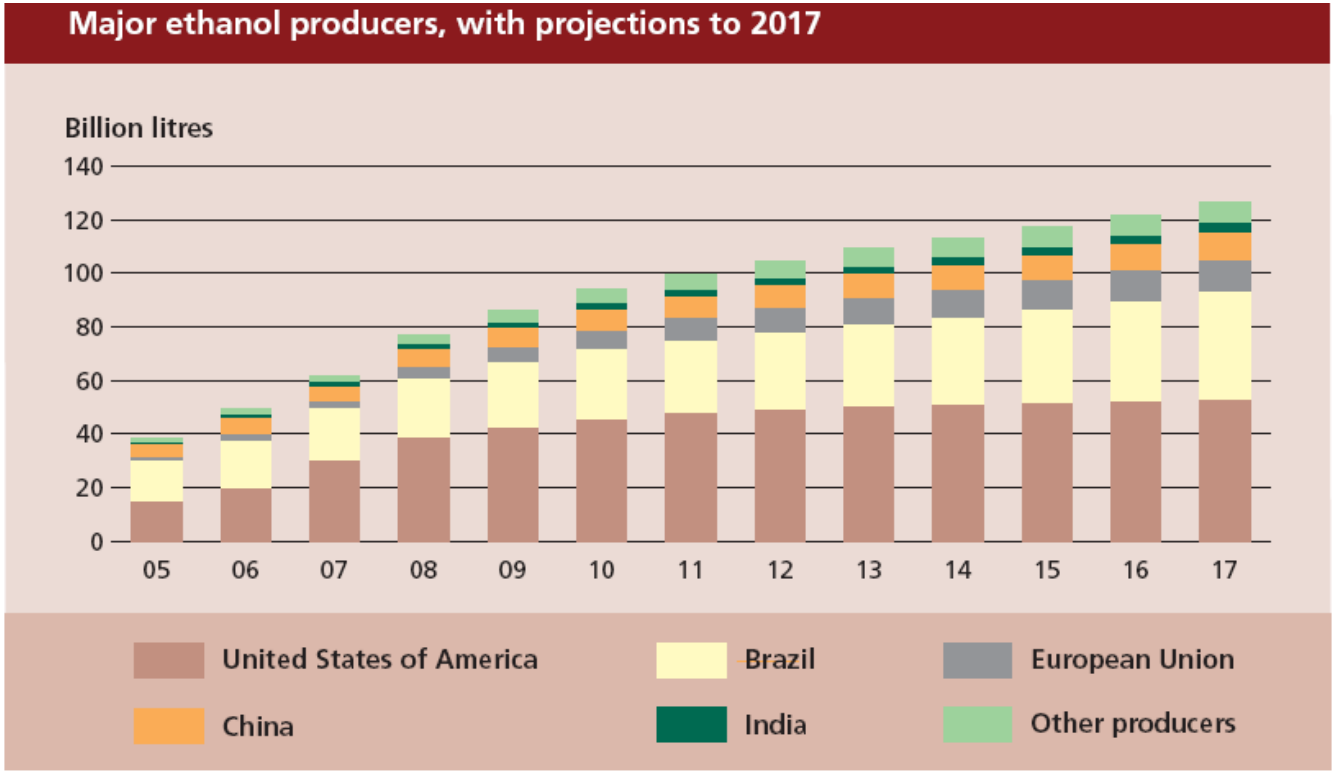
Low albedo, High ET

Overview of this talk

Two case studies of direct climate effects from bioenergy

1) Sugarcane in Brazil (already happening)

2) Cellulosic ethanol in US (not yet, but likely)

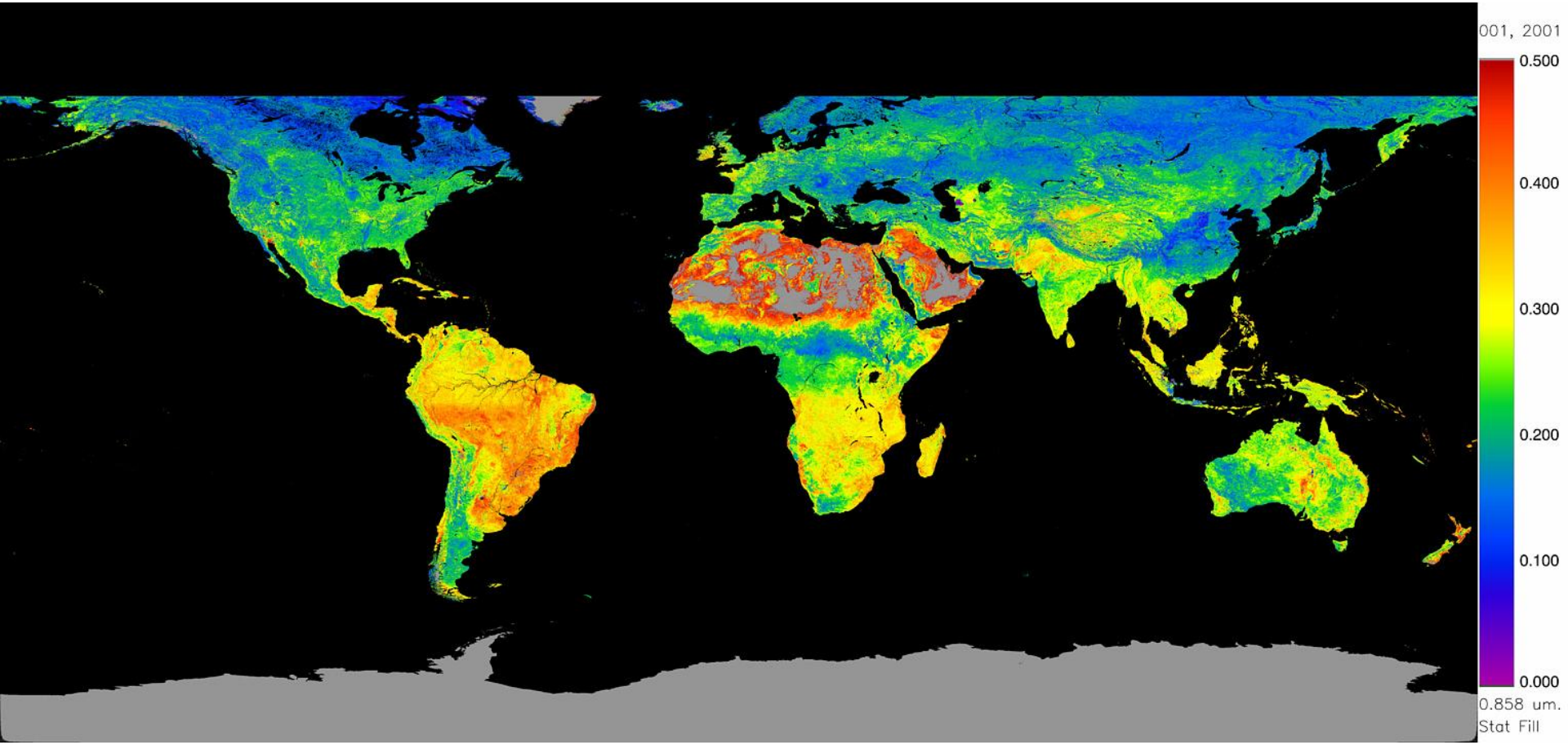


Source: based on data from OECD–FAO, 2008.

Options for estimating direct climate effects

1) Directly observe changes in energy and water flux over areas with active bioenergy expansion

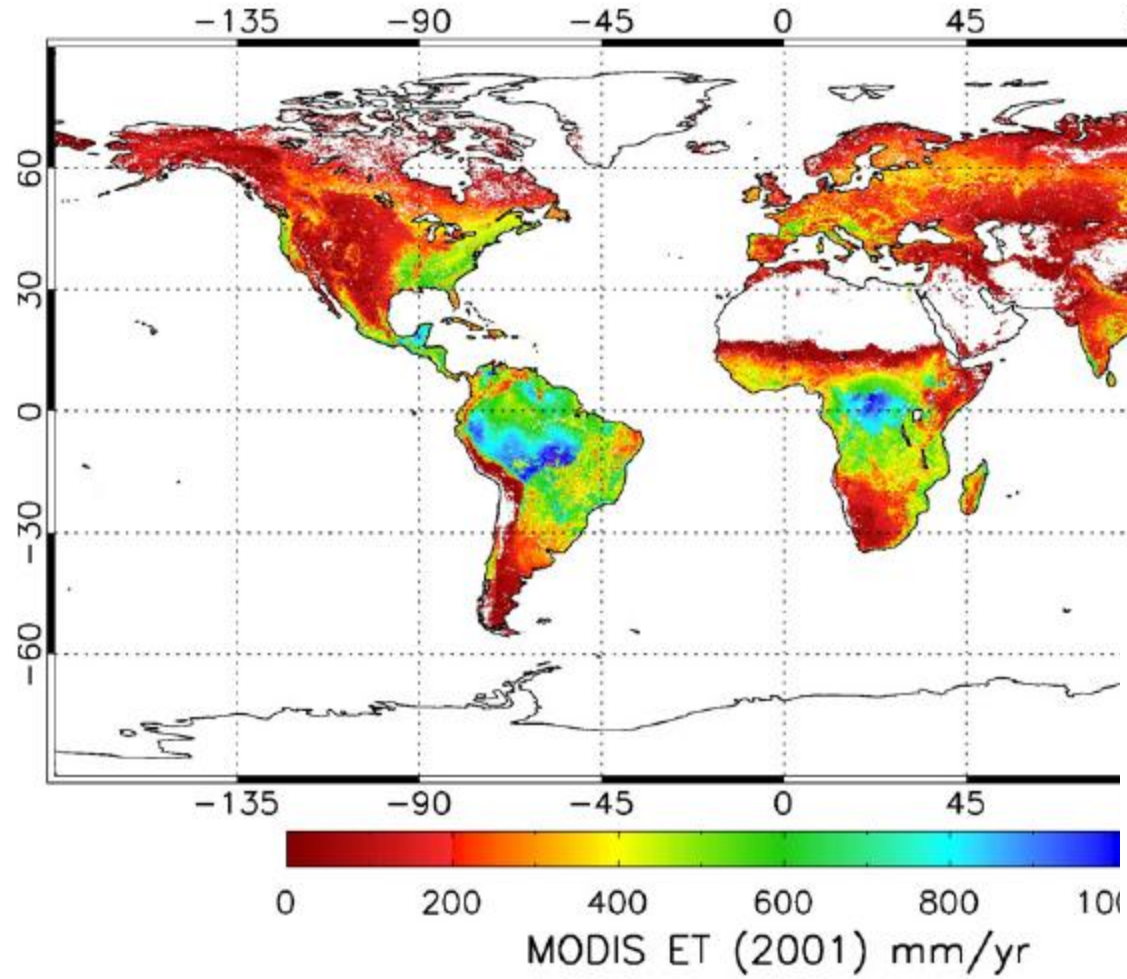
Albedo is relatively straightforward to measure from space

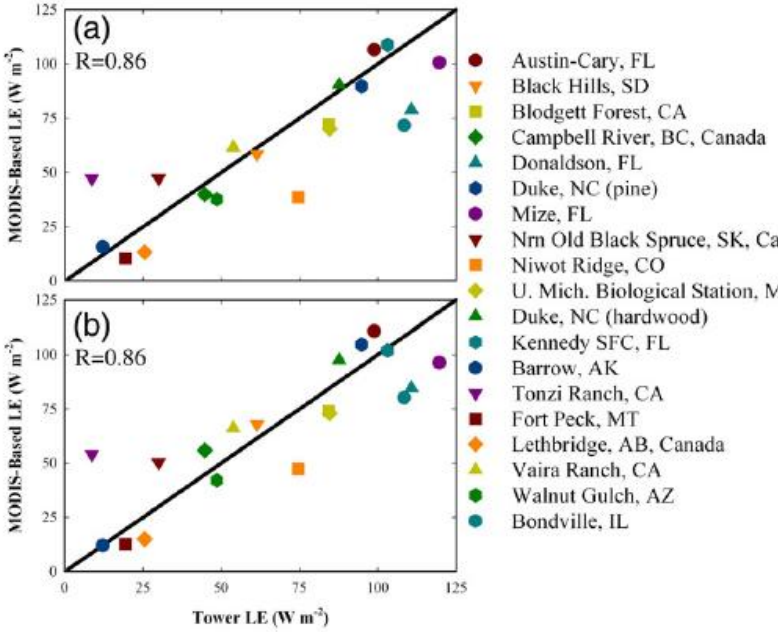


MODIS derived shortwave albedo, Jan 1-16, 2001

ET is harder, but has recently become more reliable and available

Q. Mu et al. / Remote Sensing of Environment 111 (2007) 519–536





How does Brazilian Sugarcane Affect Climate?

Expansion occurring in Cerrado. Much more is planned

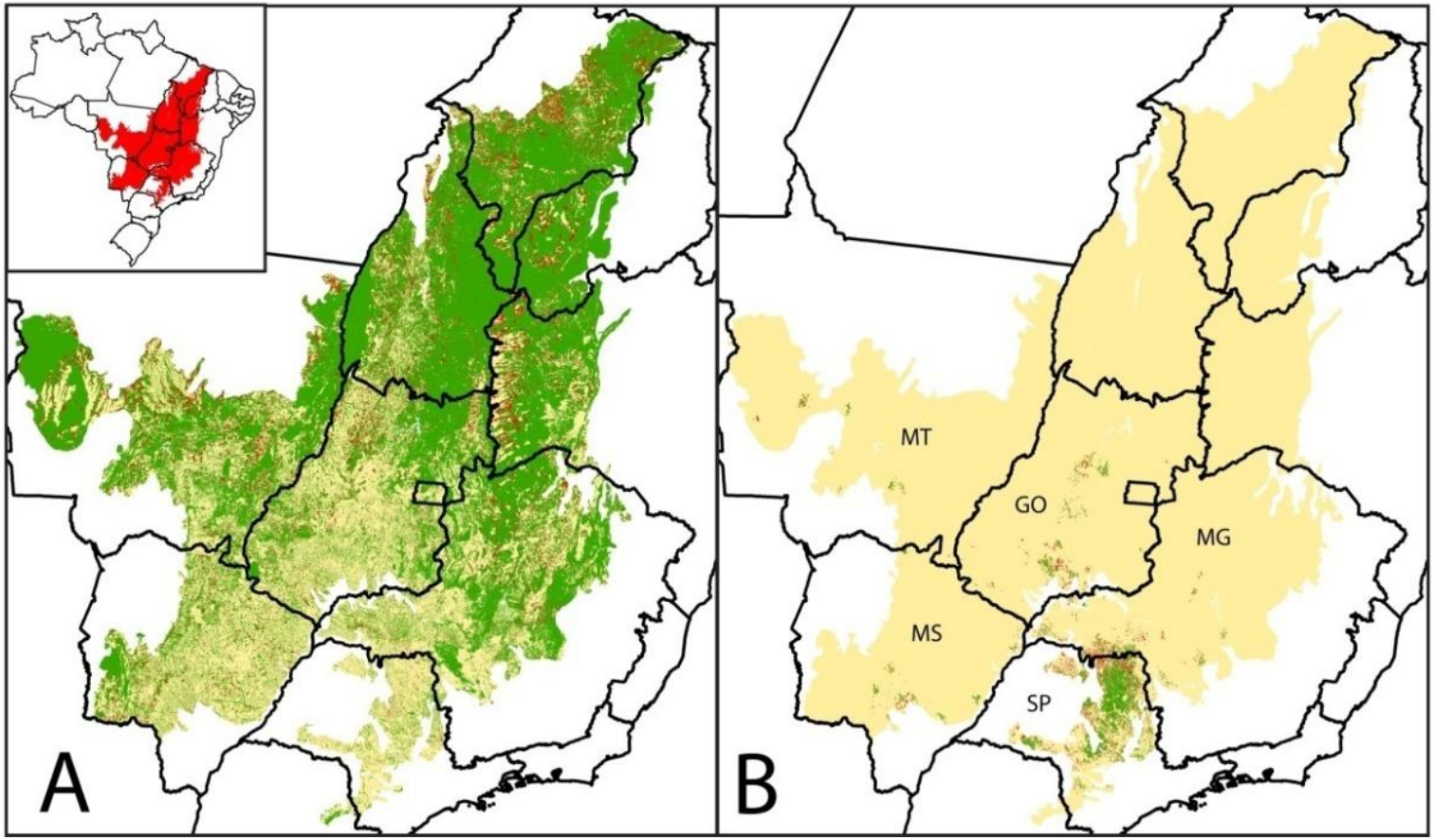
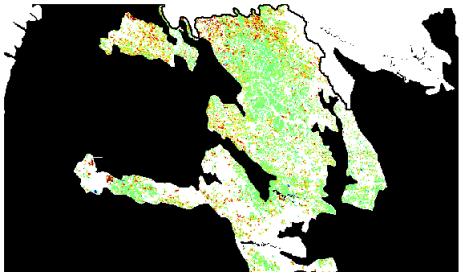


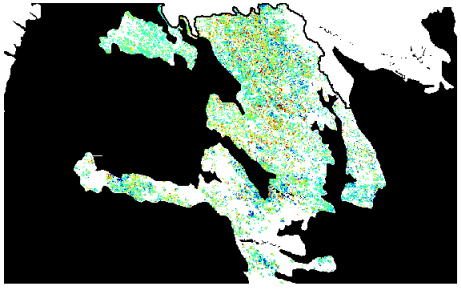
Fig. 1. (A) Remaining natural vegetation in 2008 (green) and areas cleared after 2002 (red) in the Brazilian cerrado (colored areas). **(B)** Sugarcane in the 2005/06 crop year (green) and new sugarcane in the 2008/09 crop year (red). Black lines show Brazilian states. The study area comprises the cerrado portions of the five labeled states.

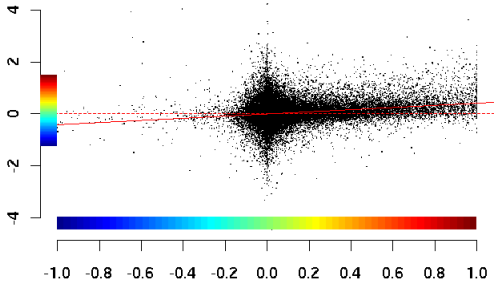
How does Brazilian Sugarcane Affect Climate?

Change in Sugarcane Area in Sao Paolo 2003-2008 (from Landsat)

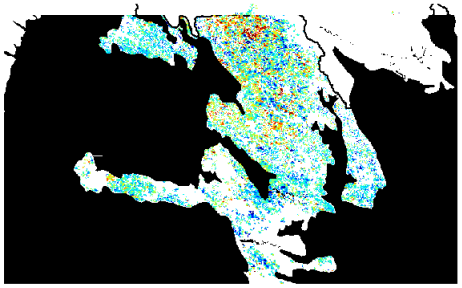


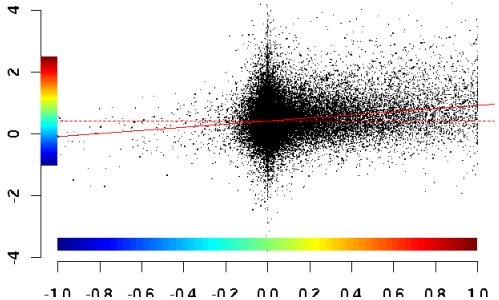
Change in Surface ET (from MODIS)



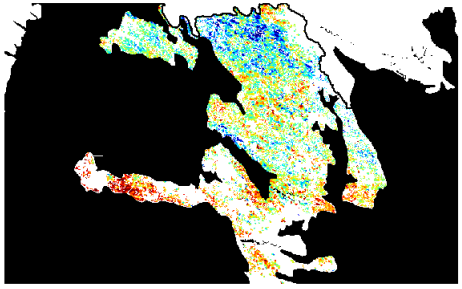


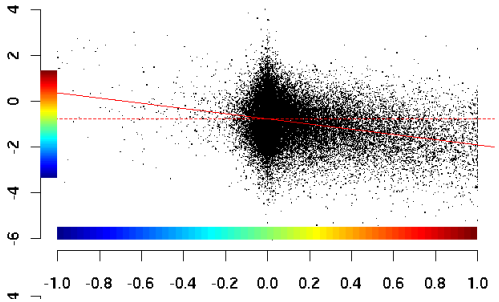
Change in Surface Albedo (from MODIS)





Change in Surface Temperature (from MODIS)





Options for estimating direct climate effects

1) Directly observe changes in energy and water flux over areas with active bioenergy expansion

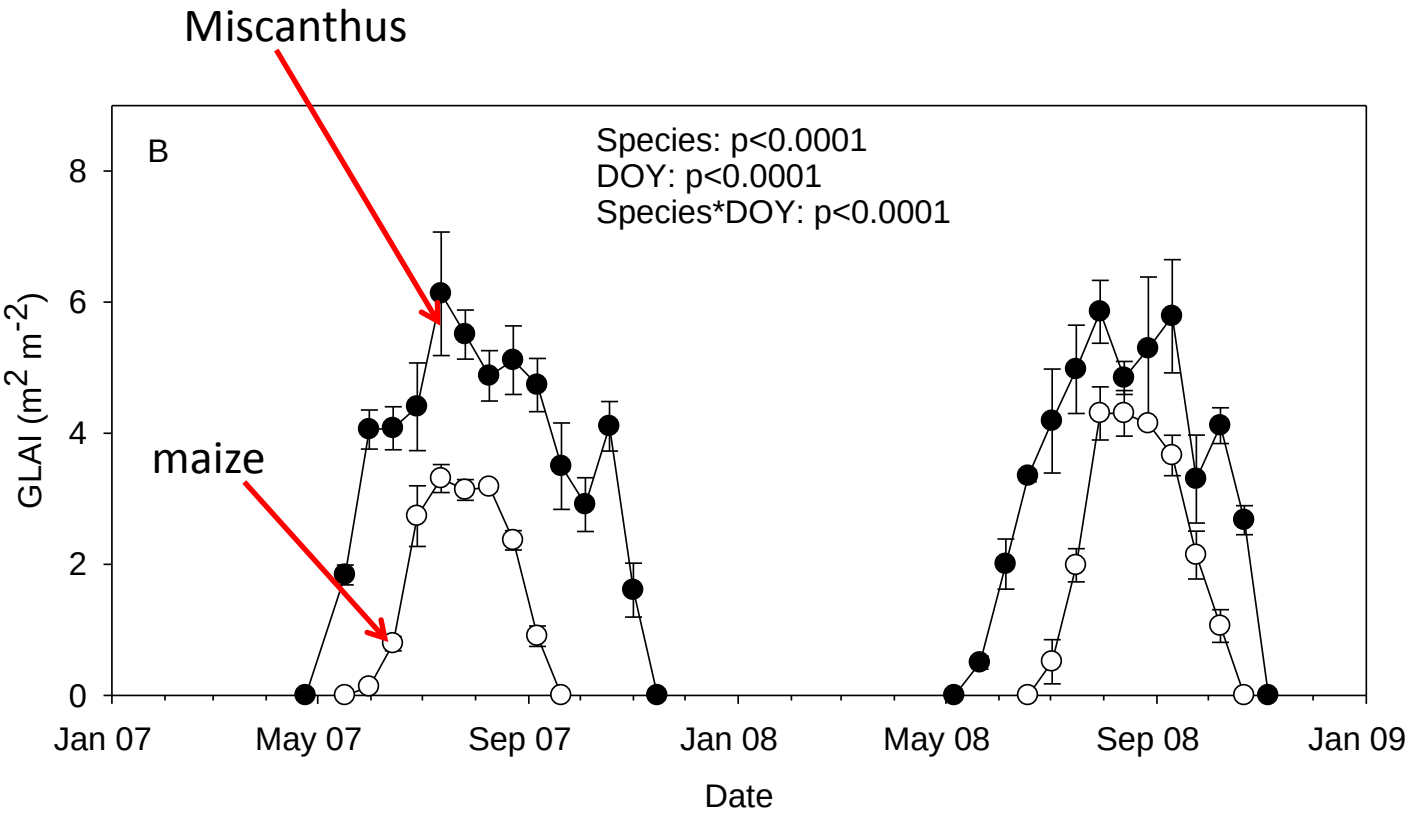
2) Use climate model experiments
   - -useful for gaining insight into magnitudes and mechanisms
   - -the only possibility for evaluating hypothetical futures

How would US Cellulosic Ethanol Affect Climate?

http://miscanthus.illinois.edu

How would US Cellulosic Ethanol Affect Climate?

Leaf area index of Miscanthus (black circles) and maize (white circles) over the 2007 and 2008 growing seasons.

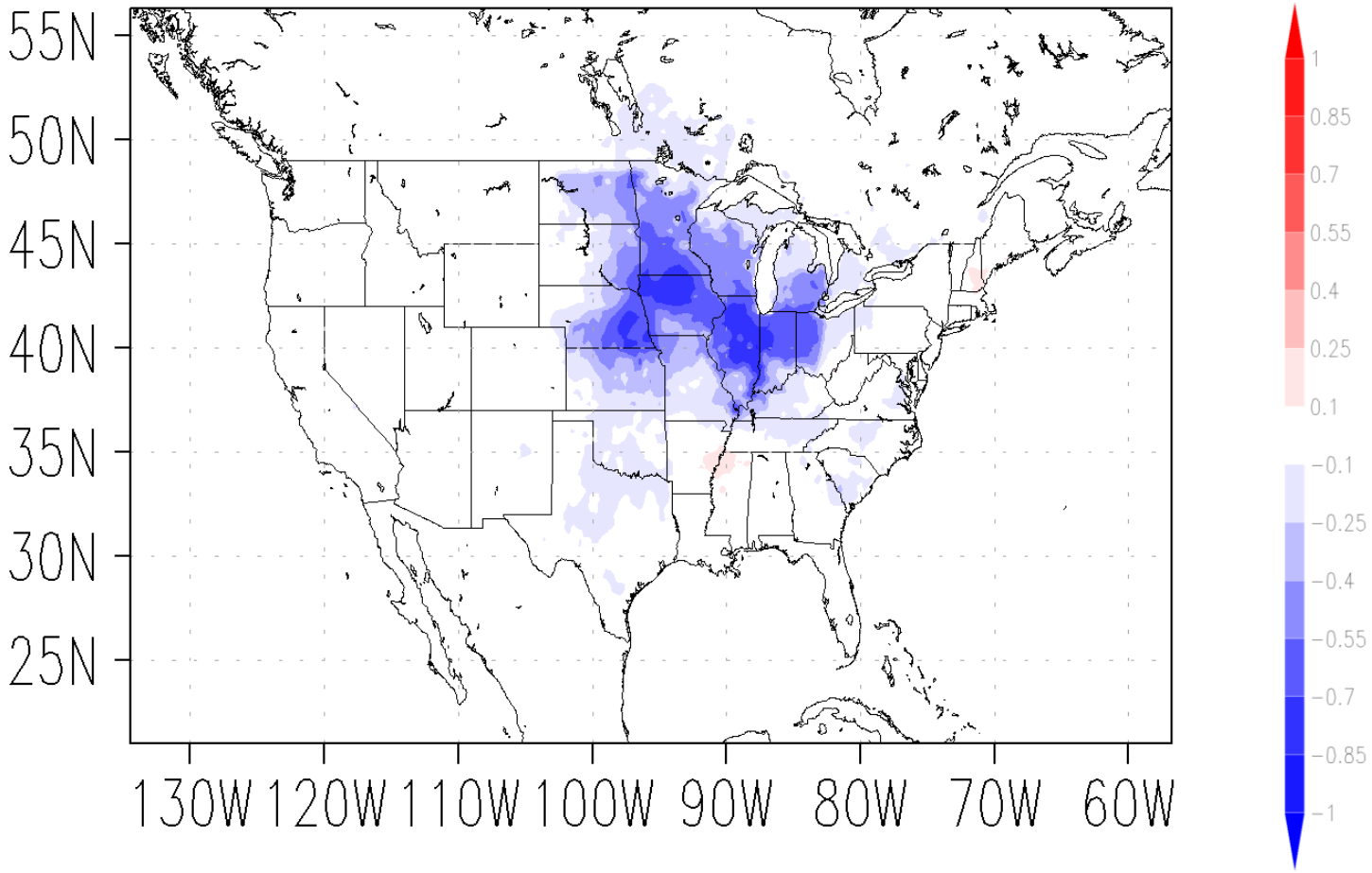


[F. G. Dohlman and S. P. Long *Plant Phys.* **150**, 2104 (2009)].

How would US Cellulosic Ethanol Affect Climate?

Climate models used to simulate the effects of large-scale implementation → significant local cooling

Difference (°C) between Apr-Oct mean air temperature with and without switch to perennial grasses



Do These Direct Effects on Climate Really Matter?

In general, they are *orders of magnitudes* bigger for *regional climate* than the C effect of displacing fossil fuels

For example:
If Miscanthus was grown on 84 million ha (total crop area in simulation), at a saving of 140 g CO_2e-C m^{-2} yr^{-1}, this could offset about 120 million metric tons of CO_2 yr^{-1}

This equates to ~0.06 ppmv atmospheric CO_2 yr^{-1} or < 0.001 °C yr^{-1}

Even for global climate...

The albedo increase represents a radiative forcing of ~ -0.0053 W m^{-2} when averaged over the surface of the Earth, which is the equivalent of ~ -0.37 ppmv.

So it takes about 6 years for the global C savings to match the albedo effect

Summary

- Nearly all current evaluation of bioenergy impacts on climate focus exclusively on GHG effects.

- In the regions where the land is being used for bioenergy, direct effects on climate are considerably larger.

- In these two cases, converting existing croplands to biofuels appears to significantly cool local climate.

- The main mechanism is greater evaporation, which assumes availability of soil moisture to maintain intended yields.

- Incorporating these effects into project design and bioenergy policy will be a challenge, but ignoring them brings risks of major unintended local impacts.