Biogeophysical Effects of Biofuel Cultivation

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CESM Land Model Working Group Mtg, Mar 16, 2011
Implications of Limiting CO₂ Concentrations for Land Use and Energy

Marshall Wise, Katherine Calvin, Allison Thomson, Leon Clarke, Benjamin Bond-Lamberty, Ronald Sands,* Steven J. Smith, Anthony Janetos, James Edmonds†
This is not your ordinary grass (or crop)
Biofuel - Climate Interactions

- Biofuel Crops
- Plant Properties
- Biogeochmistry
- Biogeophysics
- Growth Conditions (Weather)
- Climate
- Management
- Future Forcing
Biofuel - Climate Interactions

Biofuel Processing / Use

- Technology
- Demand
- GHG
- Future Forcing

Biofuel Crops

- Plant Properties
- Management

Biogeochemistry

Biogeophysics

Growth Conditions

(Weather)

Climate
Biofuel - Climate Interactions

- Plant Properties
- Management
- Biogeochemistry
- Biogeophysics
- Growth Conditions (Weather)
- Future Forcing
Biofuel - Climate Interactions

Biofuel Crops

Indirect Land Use

Plant Properties
Management
Markets
Technology

Biogeochemistry
Biogeophysics

Growth Conditions (Weather)

Climate

Future Forcing
Guiding Questions

• What are the climate implications of biofuel crop cultivation across regional and global scales?

• When and where do they represent a climate stabilizing versus destabilizing endeavor?

• What factors (e.g. plant properties, management options) control the climate interactions of crops in general?

• Are biofuel crops likely to differ from traditional crops in terms of these critical factors?

• Are there important differences among biofuel crops?

• Is the supply of biofuel feedstocks robust to changing climatic conditions?

• How can we effectively characterize both regional scale and global scale climate effects of crop cultivation?
Approach

- Develop plant functional types for the Community Land Model (CLM)
- Initial focus on C4 grass crops
- New model structures and processes
- Systematic Global Sensitivity Analysis
- Data Assimilation
- Coupled Global Land-Atmosphere Experiments
Model Development
Morphology

Generic CLM Grass

More Realistic Grass
Phenology

- Spring Emergence
- Vegetative Growth
- Stem Elongation
- Grain Fill
- Senescence and Litterfall
- Harvest
Management

- Fertilization
- Irrigation
- Tillage
- Crop Rotation
simulated carbon allocation by maize over 4 years
Changes to the CLM Grid Cell Structure

Slide modified from S. Levis
Central U.S. (30-50°N 105-90°W)

AMERIFLUX sites:

Bondville IL

Mead NE

Slide modified from S. Levis
Site-Level Parameterization
Observations - Leaf Area Index

![Graph showing observations of leaf area index for Miscanthus and Switchgrass over the months from January (J) to December (D). The y-axis represents leaf area index in m²/m², and the x-axis represents the months from January to December.]
Parameter Selection

- 72 Parameters + 8 Hidden Constants
  - 21 are inconsequential
  - 17 from DiVittorio switchgrass lit review
    - CN ratios, SLA, leaf longevity, stomatal sensitivity
  - 17 from c4 Grass PFT
    - optical properties, roughness, photosynthesis, root depths
  - 16 from Corn PFT
    - phenology and carbon allocation
  - 9 “Tuned”
Model vs. Observations - Leaf Area Index

Changes

- Extended Season
- Extended Veg Phase
Model vs. Observations - Leaf Area Index

Changes

- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase
Model vs. Observations - Leaf Area Index

Changes

- Inc Leaf Allocation
- Earlier “Planting”
- Further Extended Season
- Extended Veg Phase
~14 tons/ha
m^2 / m^2
Regional Scale Effects
Land Area Converted to Biofuel
Leaf Area Index

Difference

\(m^2 / m^2\)
Latent Heat Flux

Difference

W / m^2
Systematic Sensitivity Analysis
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<th>Light Capture Efficiency</th>
<th>Corn</th>
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The table shows different crops and their light capture efficiency.
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Systematic Sensitivity Analysis

- Goal is to compute a metric representing the importance of each parameter in the variance of a model output of interest

- Sobol First Order Term
  - $S_i = \frac{V[E(Y|X_i)]}{V(Y)}$

- Sobol Total Effect Term
  - $ST_i = 1 - \frac{V[E(Y|X \sim_i)]}{V(Y)}$
Systematic Sensitivity Analysis

- Using approximation method of Saltelli et al.
- Several 10,000’s of model runs at Mead Site
- 27 parameters
- Uniform distributions over a broad area of the parameter space
First Order Effect (Si) of Selected Parameters on LAI Goodness-of-Fit

Total Effect (STi) of Selected Parameters on LAI Goodness-of-Fit
First Order Effect (Si) of Selected Parameters on Annual Mean LAI

Total Effect (STi) of Selected Parameters on Annual Mean LAI
Next Steps

• Near Term
  • Further constrain parameters with carbon allocation data
  • Coupled biogeophysical simulations

• Longer Term
  • management
  • flux data assimilation
  • standing dead biomass
  • N retranslocation
  • sensitivity to interannual variability, geography
Thank You

• Margaret Torn
• Bill Collins
• Bill Riley
• Mike O’Hare
• Sam Levis
• Peter Thornton
• Zack Subin
• Lisa Murphy
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Miscanthus
Switchgrass
Georgescu et al. 2011