Agricultural Land Use in CLM: Impacts of Management on Soil Carbon

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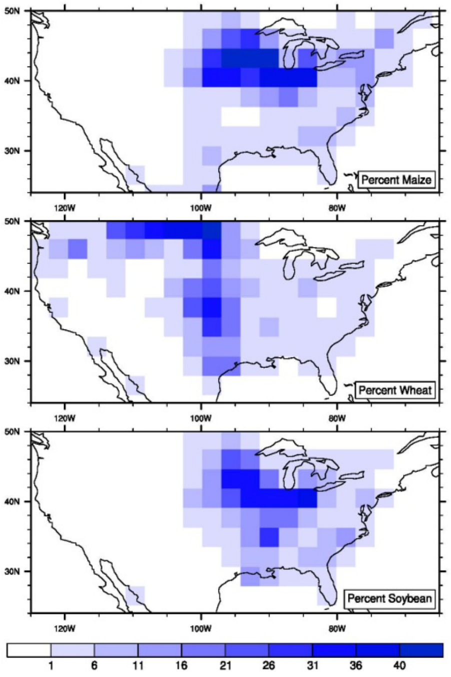
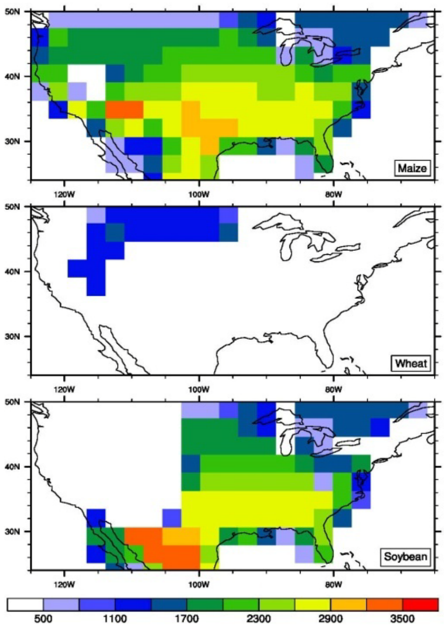
Introduction

- Biofuel demand is increasing (EISA, 2007)
  - Ethanol from maize expected to fulfill half of production resulting in:
    - Increase agricultural land use
    - Changes in management
    - Strain on land and water resources
- Agriculture plays a major role in the carbon cycle
  - Changes in land use – loss of native vegetation
  - Management practices: tillage, fertilizer application, residue, crop sequence
- Goals
  - Integrate Crops into CLM-CN
    - Maize, Spring Wheat, and Soybean
  - Evaluate management impacts on soil carbon for the US
    - Residue management
    - Fertilizer application

CLM-Crop Description

- Land use based on Leff et al. (2004)
- Fixed planting dates and GDDs for maturity based on Sacks et al., (in press)
- Four growth stages
- Nitrogen retranslocation during grain fill
- Dynamic root scheme
- Management Practices: Fertilizer and Residue



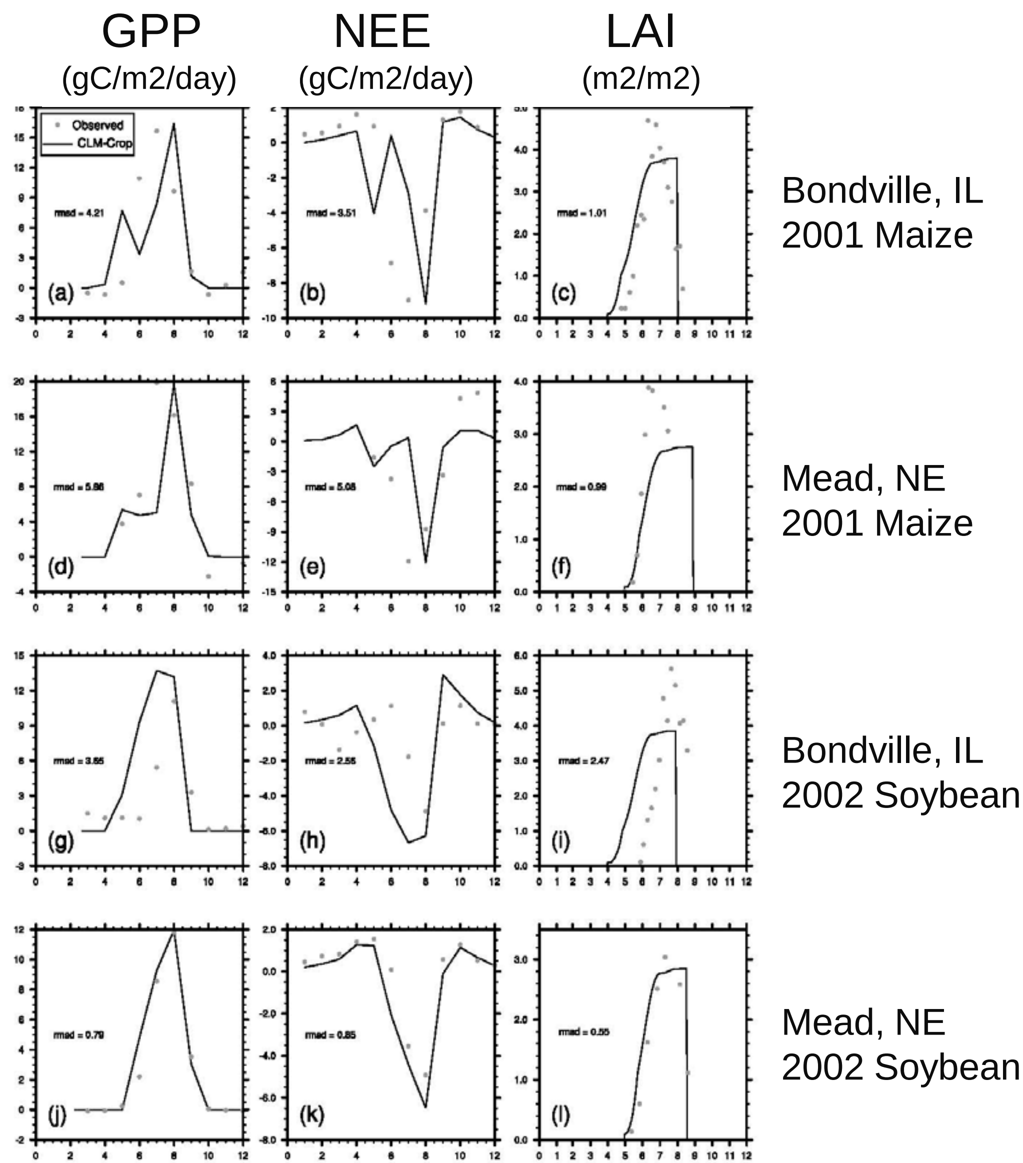


Simulations

Run Name	Land Use	Fertilizer	Residue
Control	Leff *et al.*, 2004	Yes 150 kg/ha – maize 80 kg/ha – wheat 25 kg/ha - soybean	30% - maize 30% - wheat 40% - soybean
High Residue	Leff *et al.*, 2004	Yes	90% - all crops
Low Residue	Leff *et al.*, 2004	Yes	10% - all crops
No Fertilizer	Leff *et al.*, 2004	No	90% - all crops
Grass	Bonan *et al.*, 2002	NA	NA

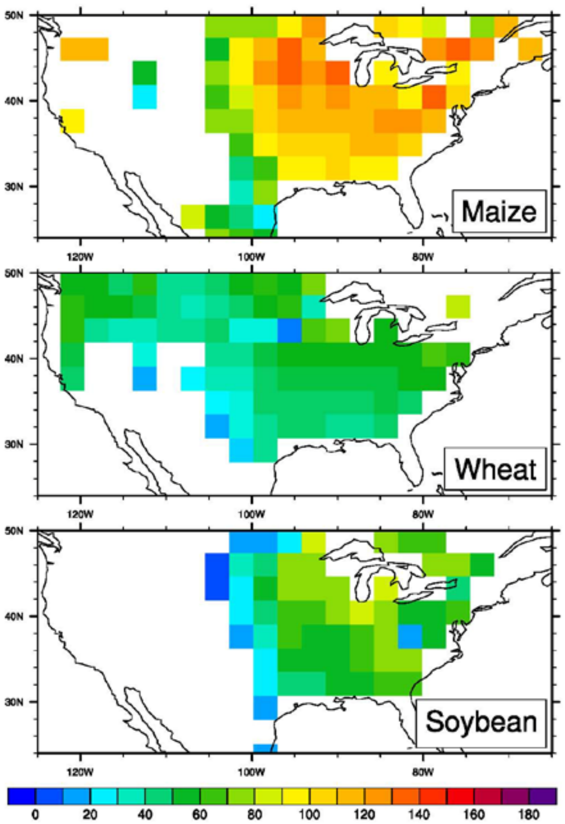
CLM-Crop Agrees with Observations

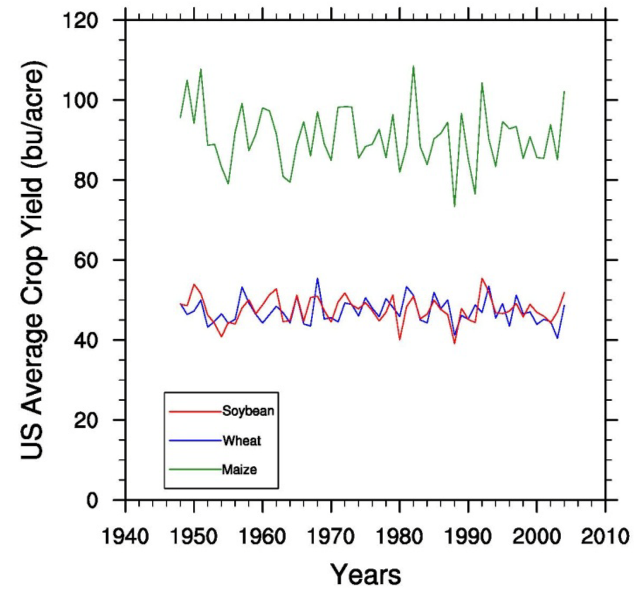
- CO_2 Fluxes and LAI
  - GPP, NEE, LAI compared with measurements from AmeriFlux sites (maize-soybean rotation)
    - Bondville, IL
    - Mead, NE
  - Maize
    - Drop in GPP, NEE from nitrogen stress
    - GPP peaks later in growth season
    - LAIs underestimated by CLM-Crop
  - Soybean
    - Late planting in CLM-Crop at Bondville site
    - LAI underestimated at Bondville by the model
- LAI decline not simulated
- Plant Carbon is estimated well



Yields

- Maize: Midwest yields within 20% of Monfreda et al. (2008); underestimated in west
- Wheat and Soybean: generally overestimated in Central US

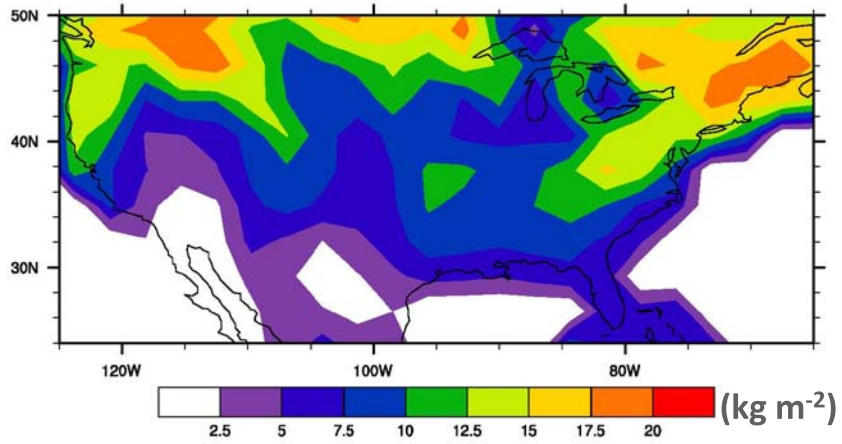


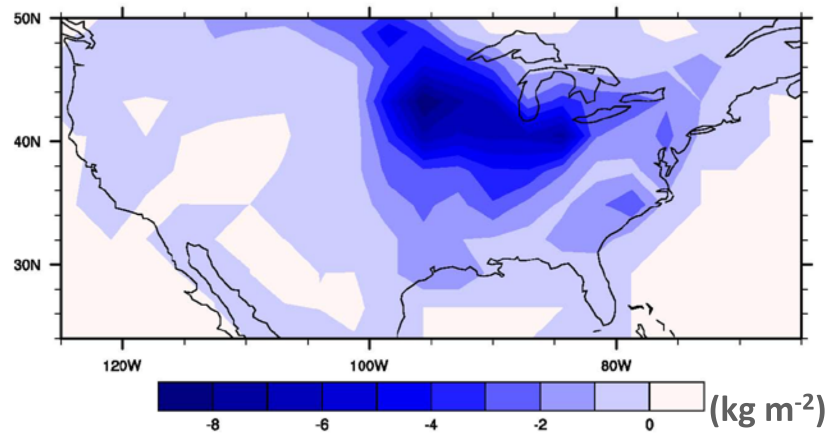


- Average yields:
  - Maize – 91 bu/acre
  - Wheat – 47 bu/acre
  - Soybean – 47 bu/acre
- Current observed increases in yield not simulated
  - No technology in model
- Year-to-Year variability results from rain events
  - More precipitation = higher yield
  - No irrigation in model

Soil Organic Carbon Loss from Agriculture

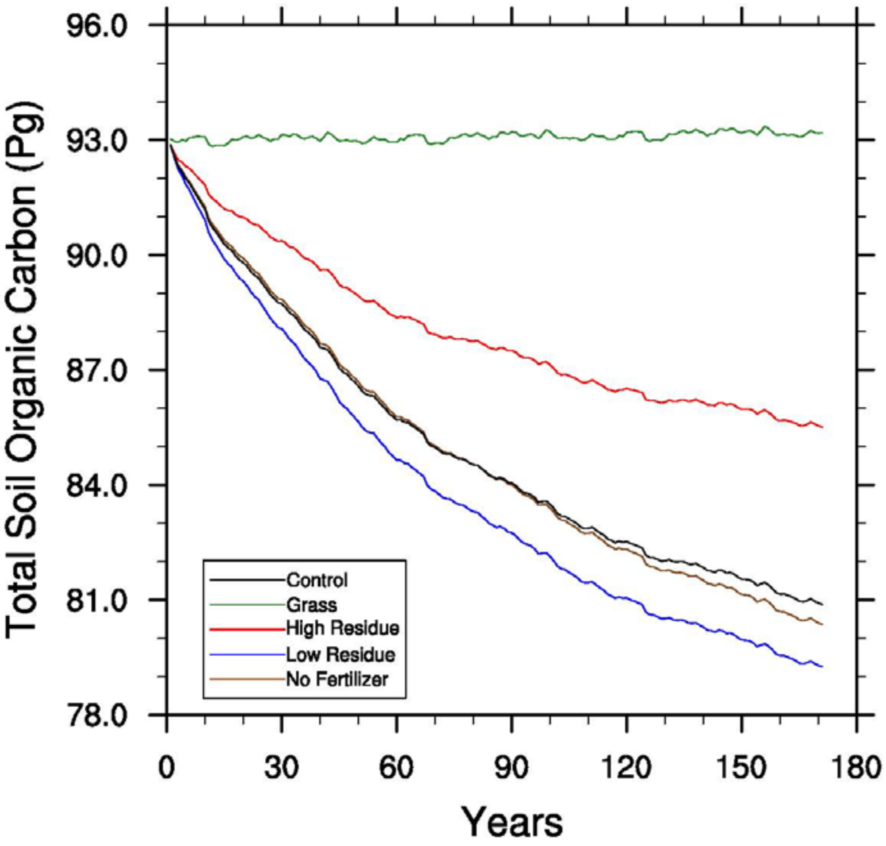
- Control Simulation
  - Total Stored SOC in US: 80 Pg C
  - Range from 2 to 20+ kg m^{-2}
  - Highest concentrations in boreal regions
  - Lowest concentration in southern US
- Control – Grass Simulation
  - Greatest change over agriculture regions
  - Concentrated where all three crops grown intensively
  - Individual grid cells lost 8 – 52% SOC
  - Soil column loss
    - Mead, NE: Maize site – 62%
      Soybean site – 59%
    - Bondville, IL: Maize site – 65%
      Soybean site – 54%





Soil Organic Carbon Loss from Management

- All scenarios result in a loss of SOC compared to natural vegetation
- Control Simulation
  - 12 Pg (15%) loss from conversion of grass to agricultural land use
- Management Impacts
  - High Residue – 6% gain in SOC
    - Better soil fertility; increased crop yields
  - Low Residue – 2% loss of SOC
    - Soil degraded; decreased yields
  - No Fertilizer – 0.5% loss of SOC
    - 50% decrease in maize and wheat yields



Conclusions and Future Work

- Cultivation has serious impacts on terrestrial carbon cycle
- Agriculture land use results in SOC lost for any management practice
- Residue management plays the most significant role on SOC
- Increasing residue removed for cellulosic ethanol production could result in additional soil carbon loss

Next Steps…

- Incorporate other management practices
  - Tillage
  - Irrigation
  - Improved fertilizer and nitrogen schemes
- Add dynamic land unit capability
  - Test with past and projected future land use types
- Include biofuel crops
  - Switchgrass
  - Miscanthus