Soil organic carbon response to cultivation in the Community Land Model

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Motivation

The Community Land Model (CLM), is designed to estimate the land surface response to climate through simulated vegetation phenology and soil carbon and nitrogen dynamics. Since human influences play a significant role shaping the land surface, the vegetation has been expanded to include agriculture (CLM-Crop) for three crop types: maize, soybean, and spring wheat. Agriculture management can influence the inputs of carbon in the soil system. A new subroutine is added to CLM4.5 to evaluate the influence of grain harvest on plant productivity and soil organic carbon. Simulated soil carbon is compared with measurements from the International Soil Carbon Network.

CLM-Crop Description (Levis et al., 2012; Drewniak et al., 2013)

- Includes three crop types: Maize, Soybean, Spring Wheat
- Simulates GPP, NEE, and yield driven by climate inputs
- Global climate data from Qian et al.,2006, years 1972-2004
- Point atmospheric data from Bondville, IL (AmeriFlux), years 1996-2007
- Represented by four growth stages: planting, emergence, grain fill, and harvest
- Growth scheme based on Agro-IBIS (Kucharik and Brye, 2003)
- Nitrogen retranslocation
- Fertilizer
- Soybean fixation
- Calculating yield (bu/acre) = grainc * fyield * convfact / cgrain

grainc = grain carbon (g/m^2)
fyield = adjustment factor for grain portion that is actually harvested
convfact = conversion to get from g/m^2 to bu/acre
cgrain = amount of carbon in grain (0.45)

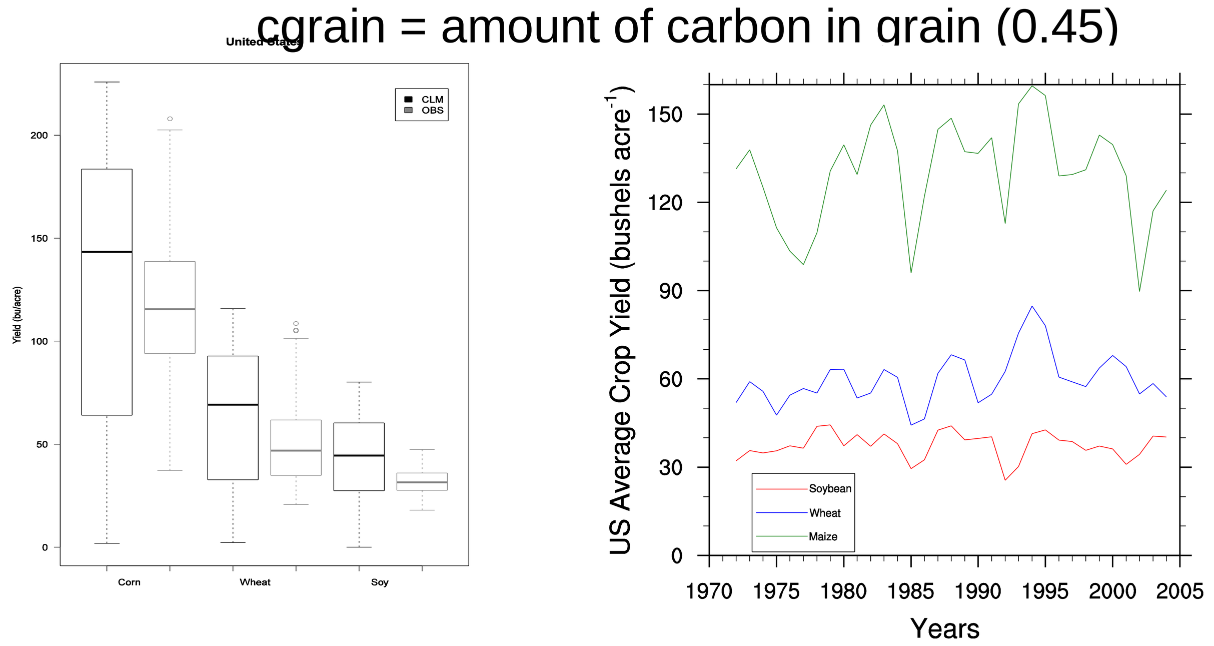


Figure 1: U.S. observed and CLM simulated yields for corn, spring wheat, and soybean (Left). CLM simulated annual variability of yields in the U.S. from 1927-2010.

Goal

Integrate a harvest scheme that treats grain as a product rather than litter and evaluate the impact on crop productivity and soil organic carbon (SOC) response.

Methodology

- At harvest, grain carbon and nitrogen pushed into product pool with a 1-yr decay (Figure 2)
- Coupled to atmosphere as respiration
- Option to put leaves and stems into product pool (currently not used)

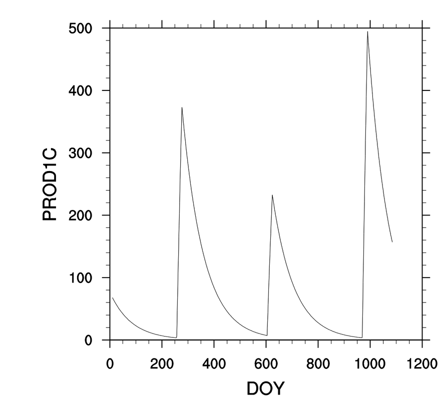


Figure 2: An example of the grain product pool decay

Results: Productivity

Corn: GPP matches observations for CLM-BGC
Soybean: GPP tends to be overestimated by CLM-BGC

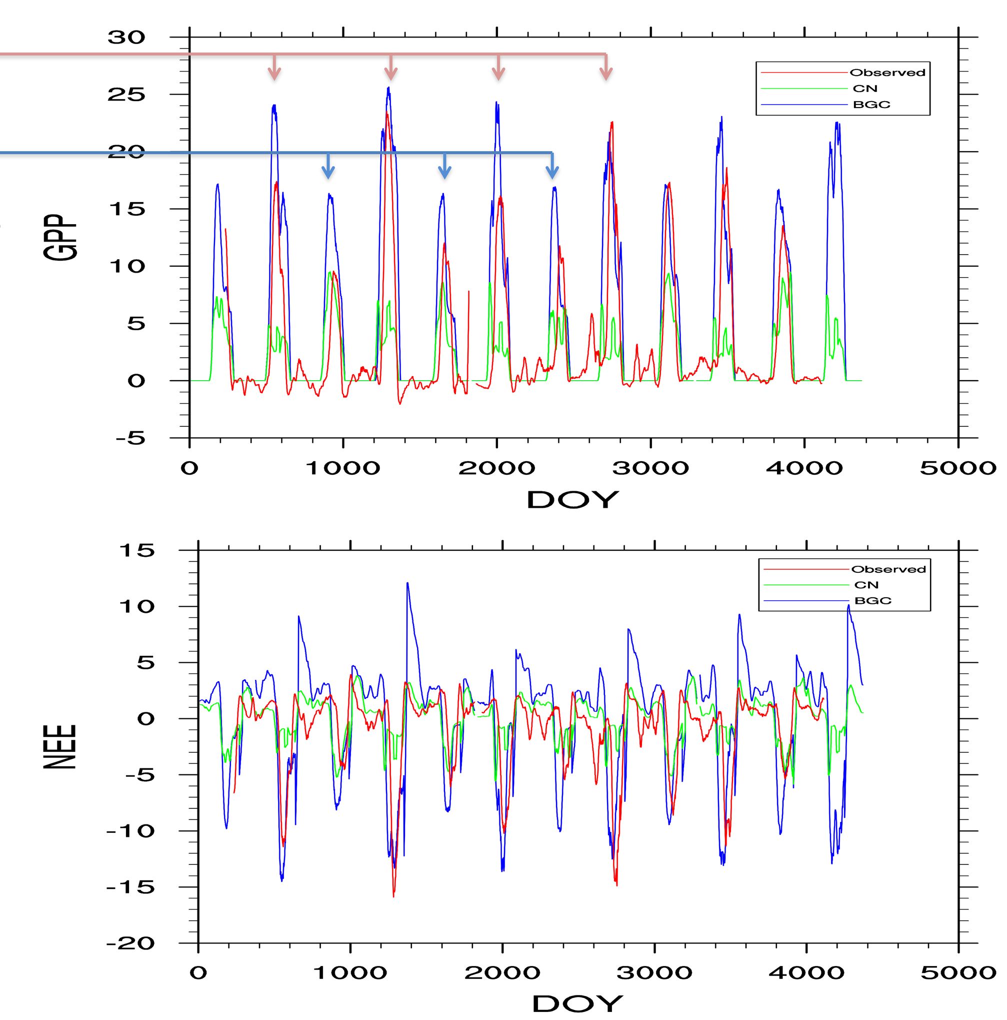
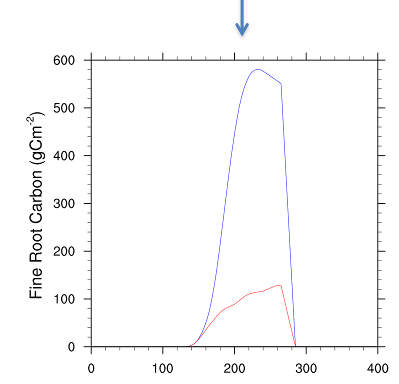


Figure 3: Simulated GPP (top) and NEE (bottom) for Bondville, IL CLM-BGC, CLM-CN, and observations from 1996-2007 (corn-soybean)

Peak LAI triggers shift in carbon allocation from above ground (leaves and stems) to below ground (roots).



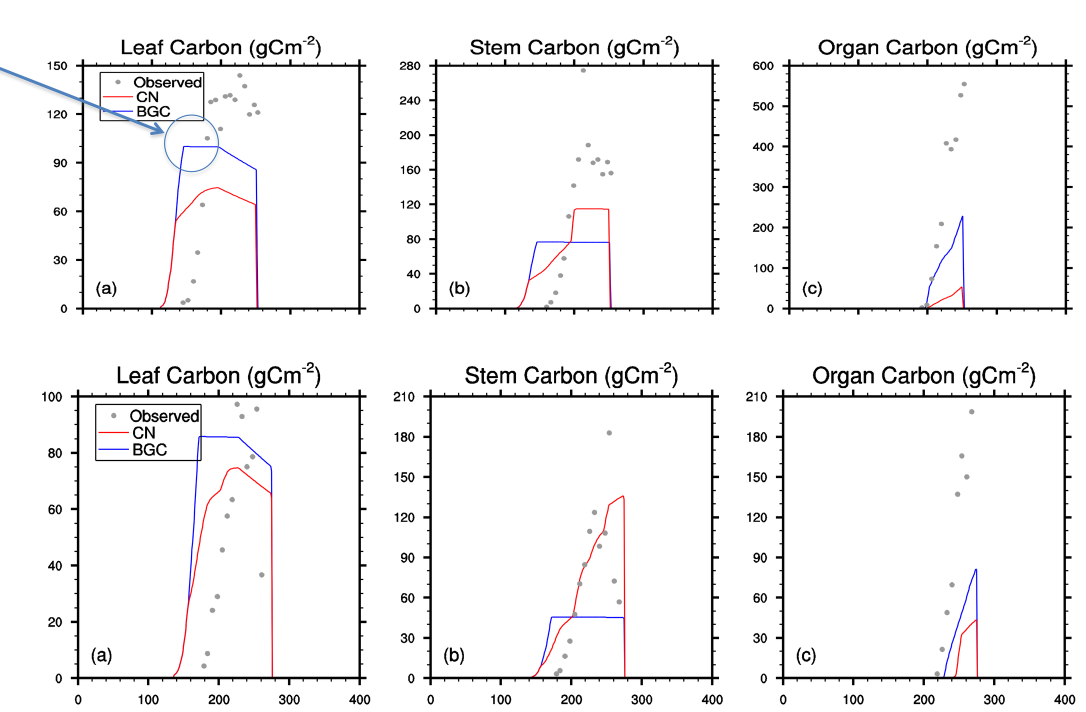


Figure 4: Right: Simulated carbon for various plant components for corn in 2001 (top) and soybean in 2002 (bottom) for Bondville, IL from CLM-BGC, CLM-CN, and observations. Left: An example of carbon allocated to roots during 2002 for soybean.

Options to fix carbon allocation inconsistencies:

1) Calibrate parameters (e.g., CN ratios, specific leaf area, leaf orientation, etc.)
2) Modify algorithm partitioning carbon and nitrogen to plant components

Soil Organic Carbon: Comparison between models

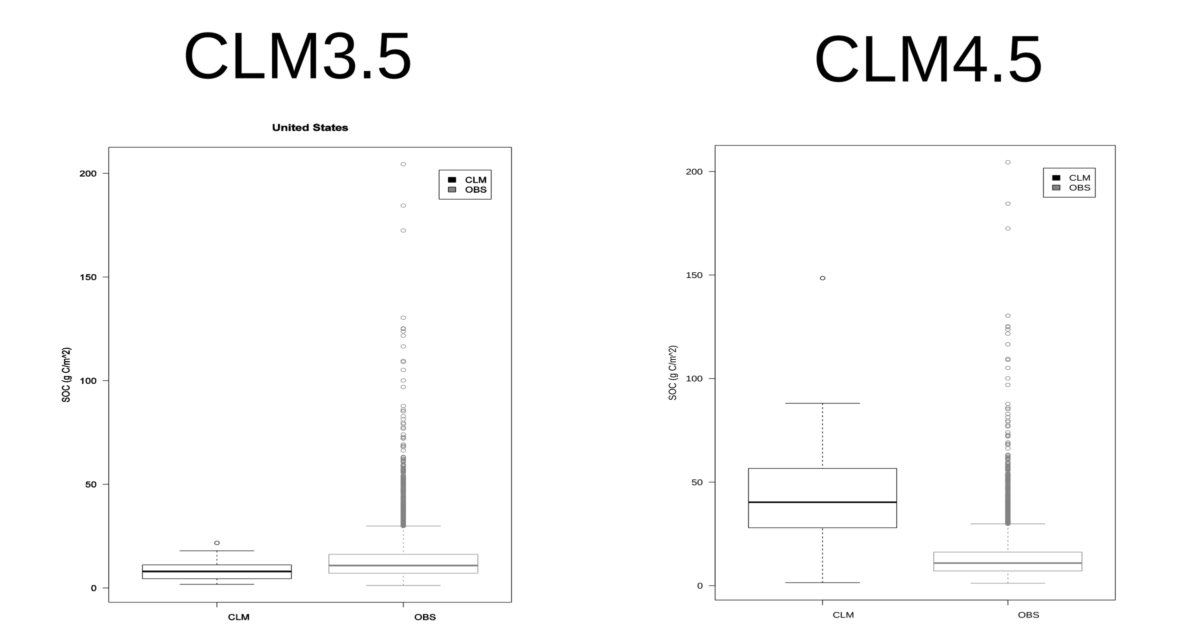


Figure 4: Box plot of total SOC from CLM3.5 (left) and CLM4.5 (right) compared to observations from the ISCN.

Comparing soil organic carbon in *agricultural soils* to the International Soil Carbon Network (ISCN): Over 4000 measurements from the ISCN are used to evaluate how CLM estimates the SOC for managed crops. CLM3.5(CN) does a better job simulating SOC than CLM4.5(BGC) (Fig. 4). Overall, CLM3.5 tends to underestimate SOC while CLM4.5 overestimates SOC (Fig 5). For CLM4.5, the overestimate of SOC could be related to the overproduction of roots. Neither model captures very high SOC found in some observations.

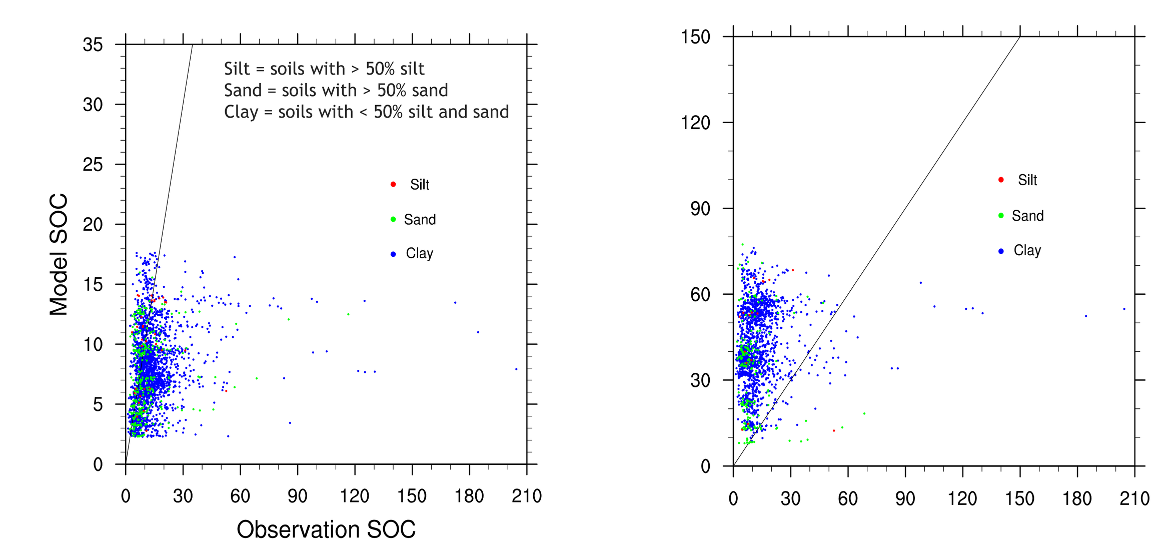


Figure 5: Modeled vs. observed soil organic carbon for CLM3.5 (left) and CLM4.5 (right) for different soil textures. Black line is 1:1.

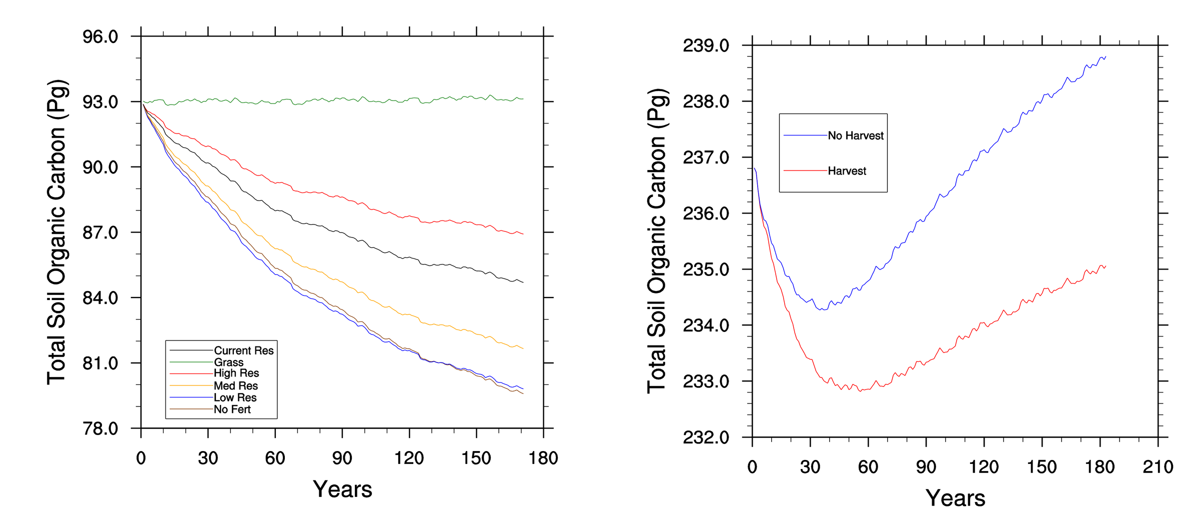


Figure 6: Total SOC lost over the U.S. for different harvest scenarios with CLM3.5 (left and CLM4.5 (right)

SOC output for all grid cells show a loss of SOC when crops (and residue) are harvested, but after about 50 years, CLM4.5 shows an increase in SOC.

Conclusions

CLM4.5-BGC crops are more productive than crops in CLM4.5-CN. However, the productivity is not reflected in the plant carbon partitioning and results in a disproportionate amount of carbon allocated to roots. A calibration procedure is near completion to improve estimates of several parameters.

CLM4.5 estimates more SOC than CLM3.5, but this could be partially related to the high amount of below ground carbon inputs. SOC is related to above ground plant productivity; it is important to explore the difference in response between the two model versions since crop improvements from calibration and addition of new management practices (e.g., residue harvest and tillage), will modify SOC.

References
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