Life Cycle Assessment of Net Greenhouse Gas Flux For Bioenergy Cropping Systems

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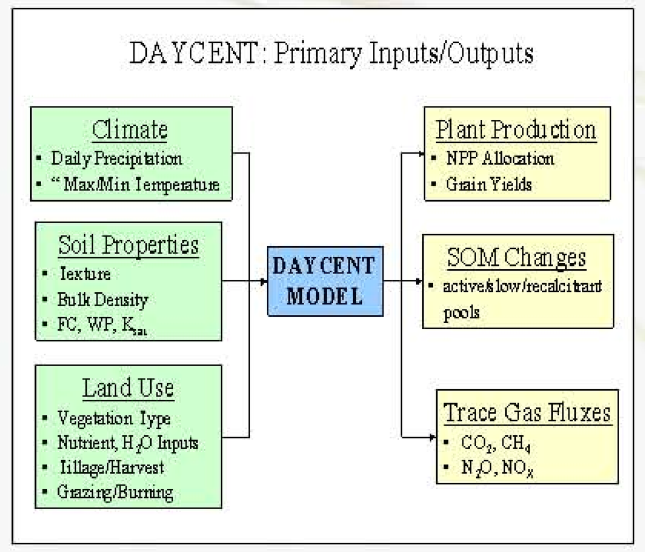
INTRODUCTION

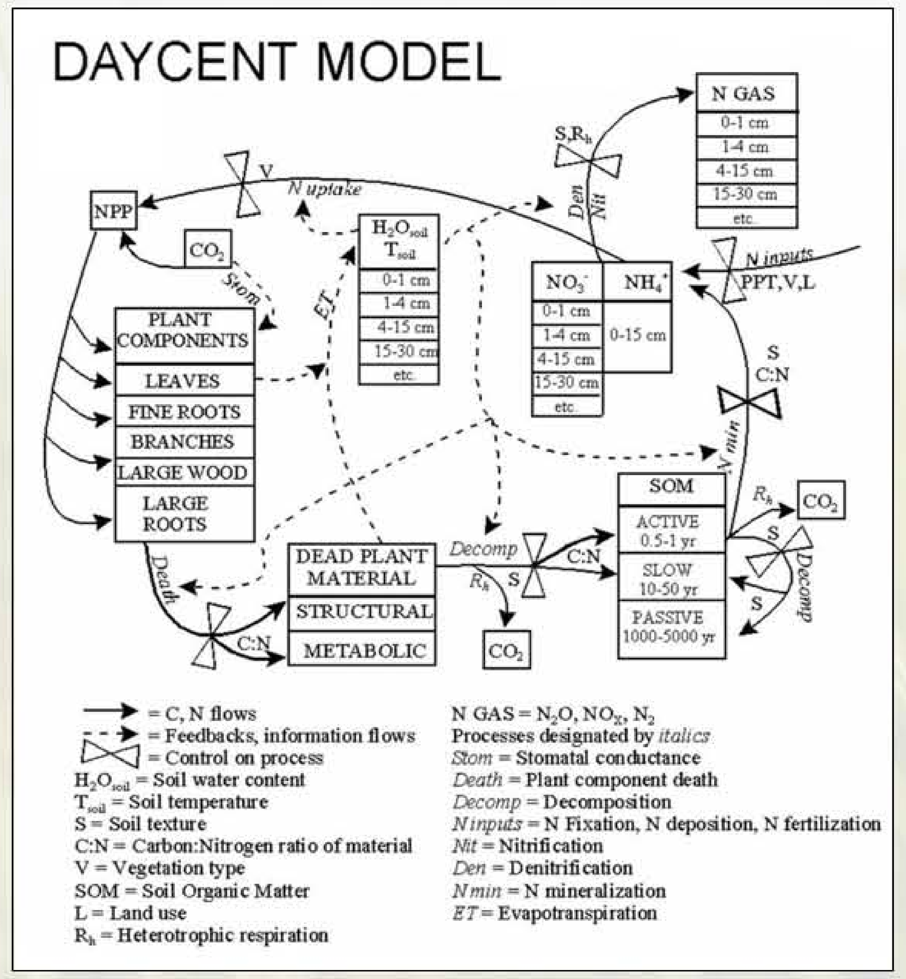
Bioenergy cropping systems could help offset greenhouse gas (GHG) emissions, but quantifying that offset is complex. Bioenergy crops offset CO_2 emissions by converting atmospheric CO_2 to organic carbon in crop biomass and soil and by supplying energy and useful co-products, but they also emit nitrous oxide (N_2O) and other GHG's. Growing the crops requires energy (e.g., to operate farm machinery, produce inputs such as fertilizer), and so does converting the harvested product to usable fuels (feedstock conversion efficiency). The DAYCENT ecosystem model was used to calculate crop yields and soil GHG fluxes. Model results were included in a full life cycle analysis to estimate net GHG emissions for several bioenergy cropping systems in Pennsylvania

The DAYCENT Model

DAYCENT is the daily time-step version of the CENTURY (Parton et al. 1994) biogeochemical model. DAYCENT simulates fluxes of carbon (C) and nitrogen (N) between the atmosphere, vegetation, and soil.



From weather (daily maximum and minimum air temperature, precipitation), soil-texture class, and land-use inputs, DAYCENT can dynamically evaluate the impact of cropping systems on crop production, soil organic carbon, and trace-gas fluxes

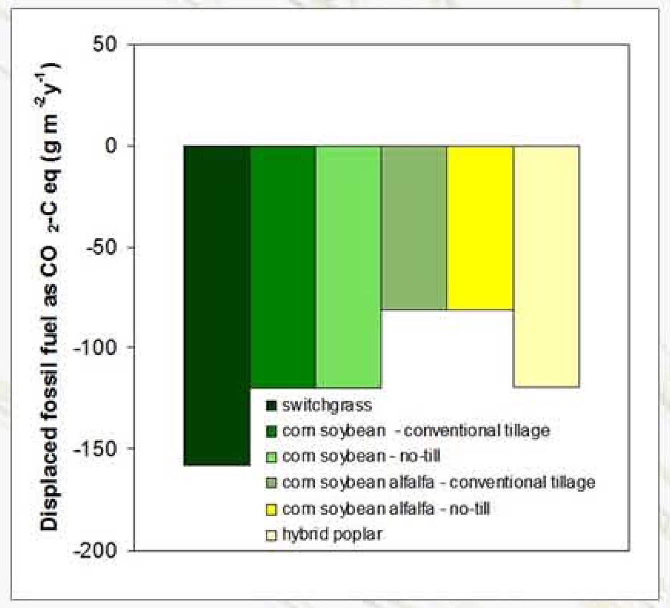


OBJECTIVES

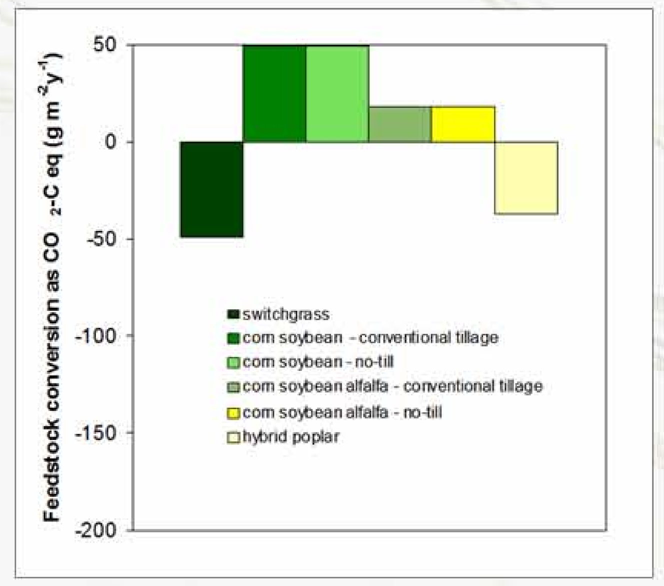
Use DAYCENT to model the net soil GHG emissions of bioenergy cropping systems in Pennsylvania for inclusion in a full carbon cycle analysis (farm inputs and operations, displaced fossil fuels, soil GHG fluxes).

Greenhouse Gas Sinks

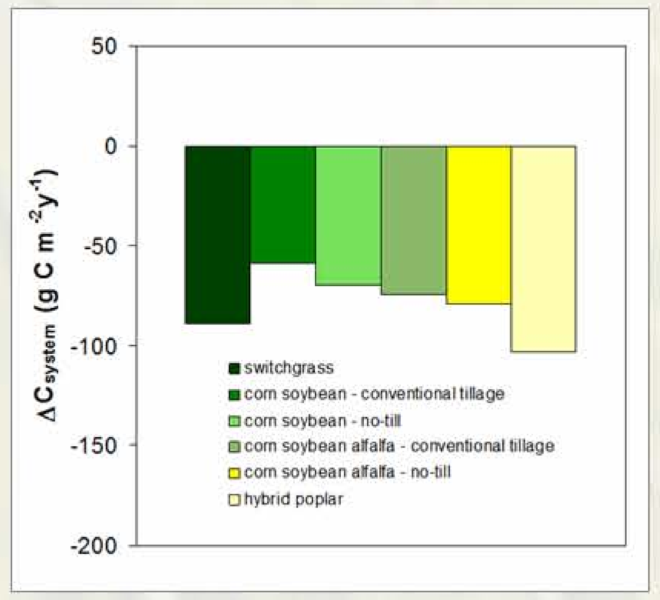
Displaced gasoline values (an estimation of energy security impacts) are based on fuel economy of gasoline compared with ethanol, total emissions of CO_2, CH_4, and N_2O during gasoline life cycle (Sheehan et al., 2004), and ethanol production from cropping systems.



Carbon values from fossil fuels used in feedstock transport to the biorefinery, conversion to biofuel, and subsequent distribution ($\pm C_{feedstock\ conversion}$) were positive or negative depending on the size of electricity credit at the biorefinery.

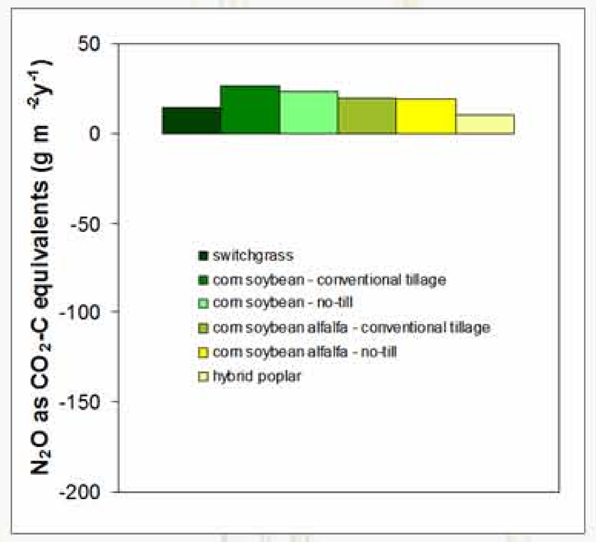


Change in system C (soil plus root C). ΔC_{system} will approach zero in long term, but differences in soil C concentration between cropping systems will remain.

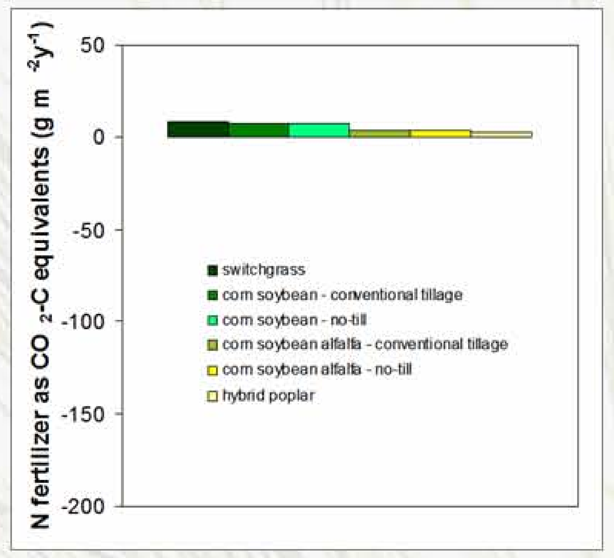


Greenhouse Gas Sources

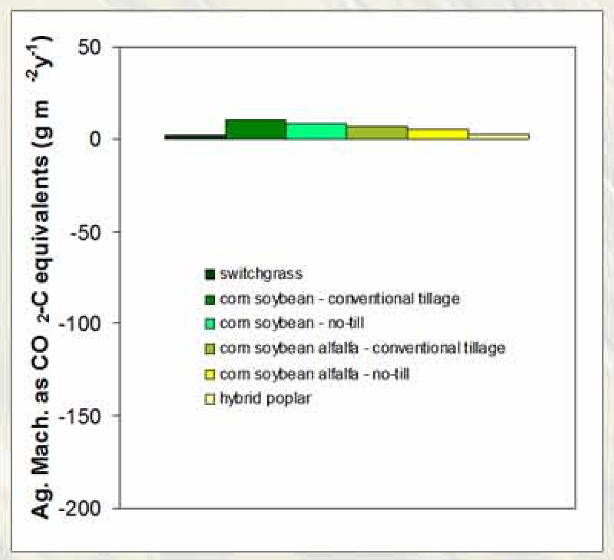
N_2O emissions were converted to CO_2 equivalents based on it being about a 300 times more potent greenhouse gas. Switchgrass had lower N_2O emissions than other cropping systems relative to the amount of N applied.



CO_2-C equivalents based on emissions from fossil fuel energy requirement of N fertilizer production (West and Marland, 2002). N fertilizer application rates were (g N m^{-2} y^{-1}): for corn (13), switchgrass (10), and hybrid poplar (8.4 in years 3, 5, 7, and 9).



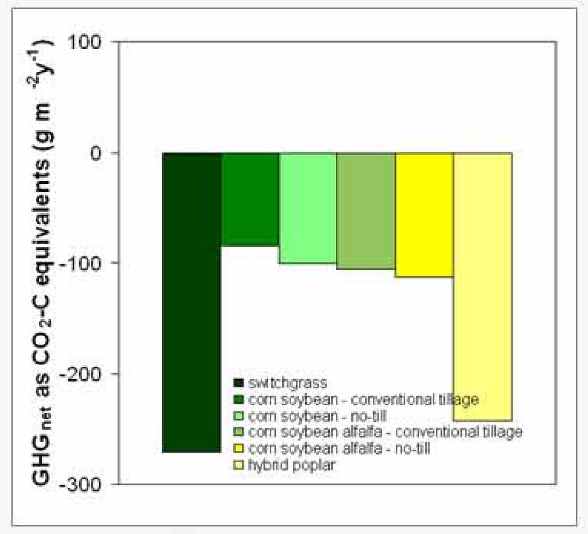
The Integrated Farm System Model (Rotz, 2004) was used to calculate diesel fuel use for management practices based on ASAE Machinery Management Standards data (ASAE, 2000).

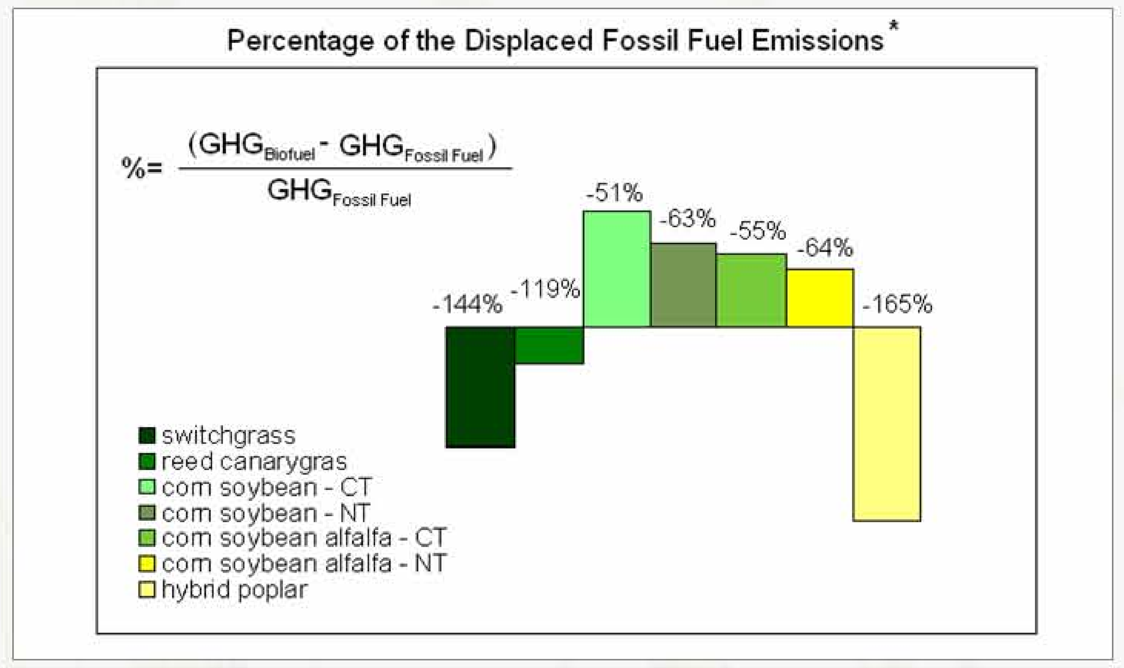


Net Greenhouse Gas Fluxes

Reduction in GHGs by using biofuels compared to fossil fuels.

$$GHG_{net} = (-C_{displaced\ fossil\ fuel}) + (-\Delta C_{system}) + (\pm C_{feedstock\ conversion}) + C_{N_2O} + C_{N\ fertilizer} + C_{ag.\ machinery}$$





Percentage reduction in net GHG emissions for a unit of energy produced by biofuels compared to fossil fuels. The percentage reduction in GHG emissions was calculated as the difference between emissions produced by a given crop and the would-be-emissions of displaced fossil-fuel, expressed as a percentage of the displaced fossil-fuel emissions. *Can be more than 100% negative depending on the size of the electricity credit for combustion of the coproduct lignin at the biorefinery during production of biofuel from Biomass. The lignin fraction of biomass is not converted to ethanol, but to electricity when combusted. Hybrid poplar, switchgrass, and reed canarygrass were net producers of energy during conversion.

CONCLUSIONS

1) $C_{displaced\ gasoline}$ was the largest GHG sink. A range of 1,800-3,600L ethanol and biodiesel/ha/y were produced and 1,200-2,400L gasoline and diesel displaced.
2) ΔC_{system} (soil plus root C) was the second largest GHG sink. Although, as soils become saturated, it will approach zero in the long term.
3) N_2O emissions were the largest GHG source. Switchgrass and hybrid poplar had higher N use efficiency and lower N_2O emissions than other cropping systems relative to the amount of N applied.
4) Use of switchgrass and hybrid poplar for production of biofuels has the potential to be GHG neutral and may even be a long-term sink for GHGs.

Adler P.R, Del Grosso, S.J and Parton, W.J. 2007. Life cycle assessment of net greenhouse gas flux for bioenergy cropping systems. *Ecological Applications*. 17(3):675–691.