Climate Change Effects on Greenhouse Gas Emissions from Bioenergy Cropping Systems in Pennsylvania

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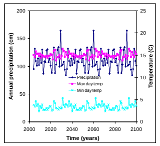
OBJECTIVES

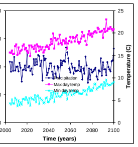
Reducing the net global warming potential (GWP) of energy use is a major factor driving interest in biofuels. The objective of the study was to use DAYCENT to model the impact of climate change on net greenhouse gas (GHG) emissions of bioenergy cropping systems in Pennsylvania for inclusion in a full C cycle analysis. DAYCENT can integrate climate, soil properties, and land use (Del Grosso et al. 2001) and was used to predict crop yield, C sequestration in soil, N_2O emissions, and N use efficiency.

Climate scenarios

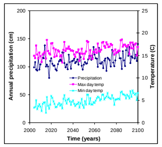
VEMAP-baseline



Canadian climate model



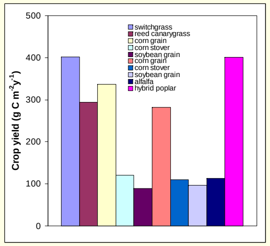
Hadley center model



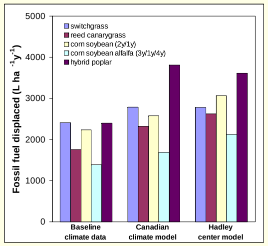
Impact of climate change scenarios are compared for 2081-2100. From 2004-2100, CO_2 doubled (360-720ppm) and N rates increased by 0.4%/y to prevent N from limiting crop growth as CO_2 increased.

Crop Yield

Yield of individual crops (corn stover harvest was set at 50% to minimize soil erosion; alfalfa harvest shown only includes stems, about 50% of total biomass).

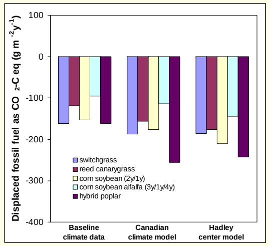


Cropping system yields expressed as amount of fossil fuel displaced by biofuel produced.

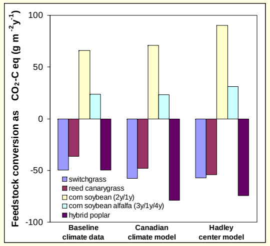


Greenhouse Gas Sinks

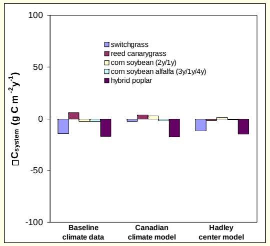
Displaced fossil fuel values (an estimation of energy security impacts) are based on fuel economy of fossil fuel compared with biofuel, total emissions of CO_2, CH_4, and N_2O during fossil fuel life cycle (Sheehan et al., 2004), and biofuel production from cropping systems.



Carbon values from fossil fuels used in feedstock transport to the biorefinery, conversion to biofuel, and subsequent distribution (Sheehan et al., 2004), were positive or negative depending on the size of electricity credit at the biorefinery ($\pm C_{feedstock\ conversion}$).

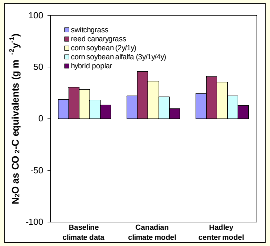


Change in system C (soil plus root C). ΔC_{system} will approach zero in long term, but differences in soil C concentration between cropping systems will remain.

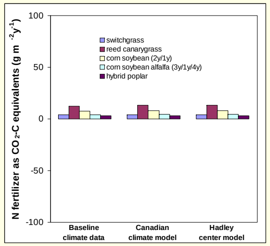


Greenhouse Gas Sources

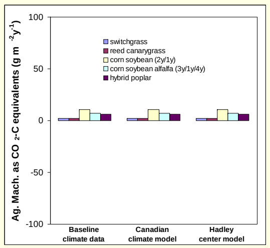
N_2O emissions were converted to CO_2 equivalents based on it being about a 310 times more potent greenhouse gas.



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 (5), reed canarygrass (15.7), and hybrid poplar (8.4 in years 3, 5, 7, and 9).

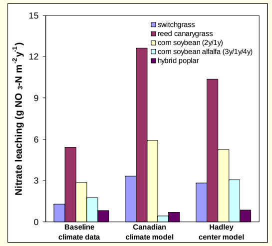


The Integrated Farm System Model (Rotz, 2004) was used to calculate diesel fuel use for management practices based on ASAE Machinery Management Standards data (ASAE, 2000).



Nitrate Leaching

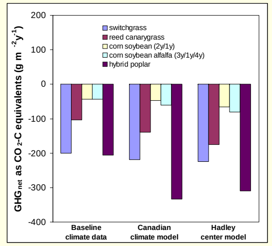
Cropping systems differed in N use efficiency.



Net Greenhouse Gas Emissions

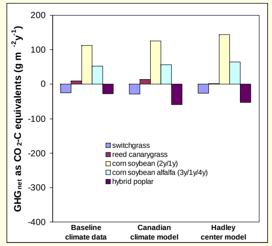
Reduction in GHGs by using biofuels compared to fossil fuels.

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



Long-term reduction in GHGs by using biofuels when soils are C saturated.

$GHG_{net} = (\pm C_{feedstock\ conversion}) + C_{N_2O} + C_{N\ fertilizer} + C_{ag.\ machinery}$



CONCLUSIONS

1) $C_{displaced\ fossil\ fuel}$ was the largest GHG sink. A range of 1,400-3,800L/ha/y of gasoline and diesel were displaced by production of ethanol and biodiesel.
2) N_2O emissions were the largest GHG source.
3) 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.