Determining the long-term impact of bioenergy crops on the global warming potential of energy use

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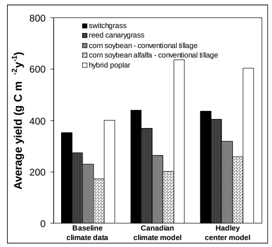
OBJECTIVES

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_{net}) 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, soil C sequestration, and N_2O and CH_4 emissions.

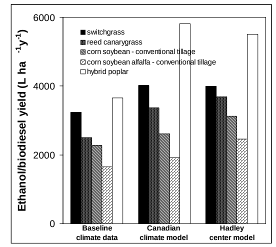
Crop Yield

Average annual yield from cropping systems were predicted from DAYCENT and varied with climate change. The corn • soybean rotation was 2 y corn followed by 1 y soybeans. The corn • soybean • alfalfa rotation was 3 y corn, 1 y soybeans, followed by 4 y of alfalfa (only 50% of corn stover was harvested to minimize soil erosion; alfalfa harvest shown only includes stems, about 50% of total biomass). Switchgrass and reed canarygrass were harvested annually and had a lifespan of 15 y. The harvest cycle for hybrid poplar was 10 y.



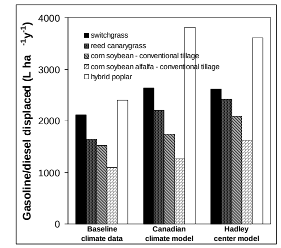
Biofuel Yield

Ethanol and biodiesel yields were calculated from the product of grain and biomass yields and the theoretical ethanol and biodiesel yields (U.S. DOE, 2005).



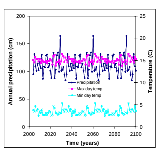
Fossil Fuel Displaced

The quantity of fossil fuel displaced by biofuel production (an estimation of energy security impacts) was calculated from the product of biofuel yield and the vehicle fuel economy ratio of fossil fuel/biofuel (Sheehan et al., 1998, 2004).

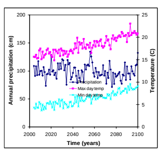


Climate scenarios

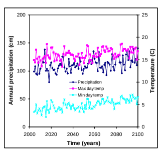
VEMAP-baseline



Canadian climate model



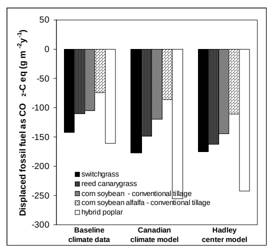
Hadley center model



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.

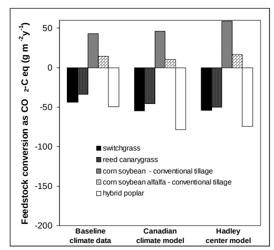
GHG Emissions Displaced by Biofuel

Displaced GHG emissions from fossil fuel were calculated from the product of the quantity of displaced fossil fuel and the total emissions of CO_2, CH_4, and N_2O during the fossil fuel life cycle (Sheehan et al., 1998, 2004).



Feedstock Conversion

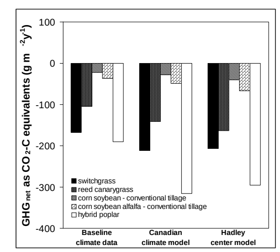
GHG emissions from fossil fuels used in feedstock transport to the biorefinery, conversion to biofuel, and subsequent distribution (Sheehan et al., 2004), were positive or negative depending on the size of electricity credit at the biorefinery ($\pm C_{feedstock\ conversion}$).



Net Greenhouse Gas Emissions

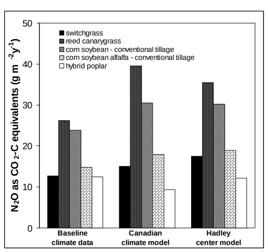
$$GHG_{net} = (-C_{displaced\ fossil\ fuel}) + (-C_{CH_4}) + (\pm C_{feedstock\ conversion}) + C_{N_2O} + C_{N\ fertilizer} + C_{ag.\ Machinery}$$

Long-term GHG_{net} (soils assumed to be C saturated) was reduced by using biofuels compared to fossil fuels. Biofuel was generated by conversion of grain and biomass to ethanol or biodiesel.

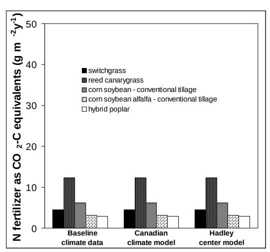


Greenhouse Gas Sources

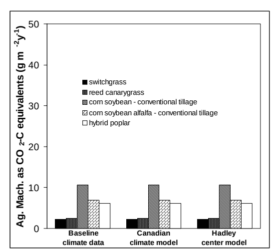
N_2O emissions were predicted from DAYCENT and converted to CO_2–C equivalents based on it being a 296 times more potent greenhouse gas.



GHG emissions from the 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 (12.7), switchgrass (5.6), reed canarygrass (15.4), 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).



CONCLUSIONS

1) $C_{displaced\ fossil\ fuel}$ was the largest GHG sink. A range of 1,100-3,800L/ha/y of gasoline and diesel were displaced by production of ethanol and biodiesel.
2) N_2O emissions were the largest GHG source.
3) Crops respond differently to climate change.
4) All cropping systems reduced the GWP of energy use relative to fossil fuels and it increased with climate change.