Reductions in greenhouse gas emissions due to the use of ethanol from winter wheat

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Introduction

- There is a goal to produce more bio-ethanol in the USA. Biofuels are regarded as a means to reduce greenhouse gas emissions.
- To reach an increased ethanol production and decreased greenhouse gas emissions different feedstock sources and production systems need to be evaluated.
- Winter cereals that are produced in the southeastern USA have a potential to serve as a feedstock for bio-ethanol production.
- A large fraction of the cropland in the southeastern USA is, currently, winter fallowed. This fallow land could be used for winter wheat or other winter cereal production.
- There is a lack of knowledge about the impact of climate, weather and soil variability on greenhouse gas emissions from wheat-ethanol and other biofuels from the agricultural sector.

Objectives

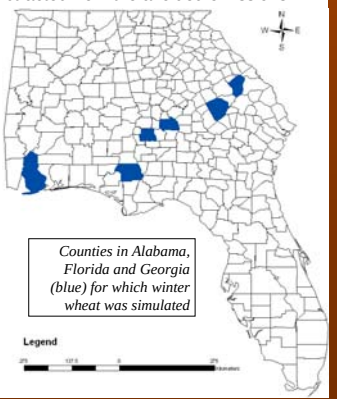
The objectives of this study were to determine:

1. The reduction in greenhouse gas emissions from wheat-ethanol production systems under different climate and soil conditions in the southeastern USA
2. The impact of weather variability on the reduction in greenhouse gas emissions from wheat-ethanol.

Winter wheat in Georgia, USA

Methods

- Winter wheat was simulated with the CSM-CERES-Wheat model for conditions in the southeastern USA.
- Two typical winter wheat cultivars for the southeastern USA: AGS 2000 and Pioneer 26R61 were simulated. Prior to the simulations, specific coefficients in the CSM-CERES-Wheat model were calibrated with variety trial data from Georgia.
- Simulations were conducted for soil and weather conditions representing 6 counties in Alabama, Florida and Georgia.
- Avoided greenhouse gas emissions were calculated for two scenarios: ethanol produced from wheat grain only, and ethanol produced from both grain and straw.
- The avoided greenhouse gas emissions were based on ethanol use in the form of E85 (85% ethanol and 15% gasoline) that replaced regular gasoline in a midsize flexfuel personal vehicle.
- The replaced greenhouse gas emissions from gasoline and replacements by co-product were calculated based on simulated wheat yield and literature information about greenhouse gas emissions.
- The replaced greenhouse gas emissions were expressed per km use in the flexfuel vehicle. Avoided emissions from gasoline use, and animal feed and electricity that could be replaced by co-products from the ethanol production were taken into account. Greenhouse gas emissions in the ethanol production chain were subtracted from the avoided emissions.



Counties in Alabama, Florida and Georgia (blue) for which winter wheat was simulated

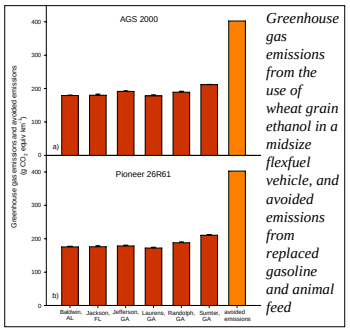
Results

- The replacement of gasoline with wheat-ethanol in a midsize personal vehicle could significantly reduce greenhouse gas emissions.
- The reductions of greenhouse gas emissions were significantly larger when ethanol from both the grain and the straw component of the wheat was used than when only the grain component was used.

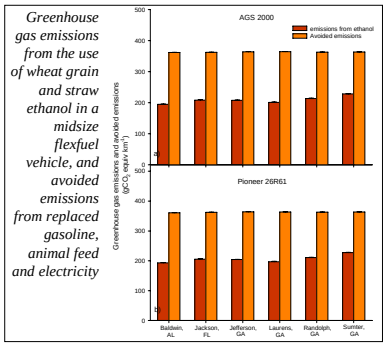
Greenhouse gas emissions and avoided emissions from the production and use of wheat ethanol

	Greenhouse gas emissions grain only scenario	Greenhouse gas emissions grain straw ethanol scenario	unit	source
Soil N_2O emissions from farming	235.4	235.4	kg CO_2 equiv ha^{-1}	De Klein et al., 2006
Soil carbon sequestration	-875.9	-875.9	kg CO_2 equiv ha^{-1}	Frankenbeen et al., 1998
Fuel for field management	68.45	68.45	kg CO_2 equiv ha^{-1}	Diesel Fuel use from Lee et al., 2008; Emissions per amount of used diesel fuel from Waldron et al., 2006
Seed production	38.80	38.80	kg CO_2 equiv ha^{-1}	epp-estimated from this calculation; assumed production of 4000kg ha^{-1}
Nitrogen fertilizer	9.776	9.776	kg CO_2 equiv kg N^{-1}	Wang et al., 1997; Snyder et al., 2007
Phosphorous fertilizer	1.051	1.051	kg CO_2 equiv kg $P_2O_5^{-1}$	Wang et al., 1997; Snyder et al., 2007
Potassium fertilizer	0.7279	0.7279	kg CO_2 equiv kg K_2O^{-1}	Wang et al., 1997; Snyder et al., 2007
Herbicides	0.02495	0.02495	kg CO_2 equiv kg^{-1}	Wang et al., 1997; Lilka et al., 2009
Insecticides	0.0261	0.0261	kg CO_2 equiv kg^{-1}	Wang et al., 1997; Lilka et al., 2009
Harvest	49.42	49.42	kg CO_2 equiv ha^{-1}	Diesel Fuel use from Lee et al 2008; Emissions per amount of used diesel fuel (Waldron et al., 2006)
Drying	0.0054	0.0054	kg CO_2 equiv kg CO_2 equiv $grain^{-1}$	Derived from McNeill and Overhalts, 2009 Lee et al., 2008
Straw collection	-	14.83	kg CO_2 equiv ha^{-1}	Wang et al., 1997
Ethanol transport from field to processing facility Ethanol distribution	1.303 0.02968	1.303 0.02968	kg CO_2 equiv ha^{-1} kg CO_2 equiv L^{-1}	Wang et al., 1997 Lilka et al., 2009 Representing US average
Avoided emissions from gasoline	-1.708	-1.708	kg CO_2 equivalents L^{-1}	Derived from Wang et al., 1997
Replaced GHG related to replaced feed from maize and soybean	-1.287	-1.287	kg CO_2 equivalents L^{-1} grain ethanol $^{-1}$	Amount of replaced feed (S&T2Consultants, 2003); avoided emissions per amount feedstuff from Hill et al., 2006
Replaced GHG related to replaced electricity	-	2.63	kg CO_2 equivalents L^{-1} straw ethanol $^{-1}$	Derived from the Energy Information Agency, 2009

1. In the straw and grain ethanol scenario, the greenhouse gas emissions that can be reduced by the use of co-products as animal feedstock depends on the grain-straw harvest ratio which vary due to environmental conditions.
2. The total avoided emissions depend on the straw grain straw harvest ratio, which vary due to environmental conditions.



Greenhouse gas emissions from the use of wheat grain ethanol in a midsize flexfuel vehicle, and avoided emissions from replaced gasoline and animal feed

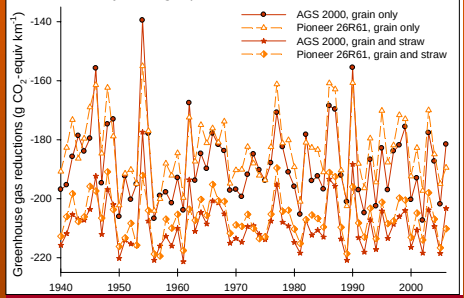


Greenhouse gas emissions from the use of wheat grain and straw ethanol in a midsize flexfuel vehicle, and avoided emissions from replaced gasoline, animal feed and electricity

Results

- The reduction in greenhouse gas emissions differed among the wheat production locations in the southeastern USA.
- The differences in reductions in greenhouse gas emissions among wheat production locations were due to spatial climate and soil variability in the southeastern USA.
- Also temporal weather variability had a large impact on the reductions in greenhouse gas emissions.

Variation in the reduction in greenhouse gas emissions due to temporal climate variability. Average of 6 locations in the southeastern USA



Conclusions and further work

- Wheat ethanol can be used as a means to reduce greenhouse gas emissions.
- Spatial soil and climate variability impacted the reductions in greenhouse gas emissions.
- Temporal weather variability impacted the reductions in greenhouse gas emissions.
- Further work could be focused on determining the climate and soil impact on greenhouse gas emissions in bio-ethanol production under climate change scenarios.

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