Cellulosic biofuel production and climate mitigation potential from marginal lands

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Background

Concerns about the environmental consequences of fossil fuel use, high energy prices, and uncertain petroleum supplies have increased interest in the production of transportation biofuels. Cellulosic ethanol has the potential to partly replace currently used transportation fuels. In addition, cellulosic crop systems do not compete with food production if they are established on marginal lands currently abandoned.

Objectives

Assess cellulosic feedstock production and greenhouse gas mitigation potential from marginal lands in the US Midwest

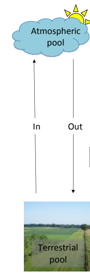
Methods

Calculations of GHG emissions mitigation by alternative cropping systems

Net C balance
(g CO_2e $m^{-2}y^{-1}$) = CO_2e out – CO_2e in

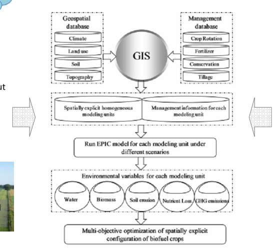
CO_2e out = *Soil carbon sequestration + Fossil fuel offset credit*

CO_2e in = *Soil GHG emission + Agronomic Inputs*



Fossil fuel offset credits calculated by GREET model.
Soil GHG emissions, soil C, and Ag. inputs calculated from KBS LTER datasets.

Modeling



Parameterization of Environmental Policy Integrated Climate model and modeling of crop productivity across 10 states of US Midwest

Marginal lands definition — Land Capability Classes V-VII with slope gradients <20% under non-forested vegetation;
Topography — Shuttle Radar Topography Mission (resolution 30 m);
Climate — The North America Regional Reanalysis (resolution 32 km);
Land use and cover — Crop Data Layer and SSURGO (resolution 60 m);
Productivity — KBS LTER station datasets;
Potential biorefinery locations — scenario with fertilization of 68 kg N ha^{-1} yr^{-1}. Aggregation of biomass yields on areas with 80 km radius to identify potential locations for biorefineries with productivity of 105 ×10^6 L ethanol yr^{-1} and higher.

*CO_2e balance calculation is explained in Gelfand et al. (2011) *PNAS 108*
Modeling approach is explained in Zhang et al. (2010) *GCB Bioenergy 2*

Soil GHG emissions

Ecosystem	N_2O-N	CH_4-C
	g $ha^{-1}d^{-1}$	
Conventional Tillage C-S-W	3.1 (0.6) [a]	-1.2 (0.2) [a]
No-Till C-S-W	3.8 (0.5) [a]	-1.2 (0.2) [a]
Alfalfa	3.4 (0.4) [a]	-1.6 (0.2) [b]
Poplar	1.4 (0.3) [b]	-1.4 (0.1) [a,b]
Successional	1.0 (0.1) [b]	-1.7 (0.3) [b]
Successional + N	2.6 (0.4) [a]	-1.5 (0.6) [a,b]

* Different low case letters indicate ANOVA repeated measurements, $p < 0.05$; C-S-W for Corn-Soybean-Wheat rotation

Table 1. Average fluxes of N_2O and CH_4 measured at KBS LTER site.

Productivity

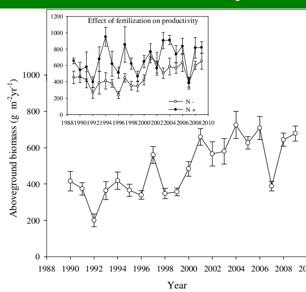


Figure 1. Aboveground biomass production and fertilization effect on cellulosic feedstock productivity of KBS successional field.

Fossil fuel offset credits

	Corn grain	Wheat grain	Soybean grain	Wheat Straw	Alfalfa	Poplar	ES	ES + N
			g CO_2e MJ^{-1}					
Conventional Tillage	38.6	30.2	225.6	107.8	-	-	-	-
No-Till	40.6	32.2	225.9	107.8	-	-	-	-
Cellulosic feedstock	-	-	-	-	94.7	101.5	97.3	74.6

Table 2. Fossil fuel offset credits for different biofuel feedstocks, modeled with adjusted to KBS inputs GREET.

Potential biorefineries locations

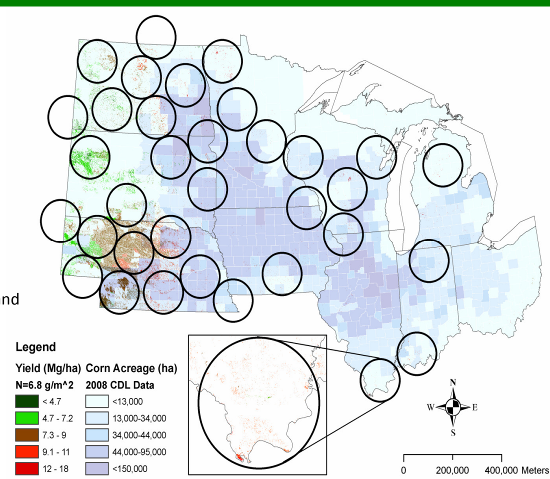


Figure 2. Modeled locations of biorefienries on marginal lands of the US Midwest. Circles represent biomass collection area (radius 80 km). Model simulations resolution is 60 × 60 m.

GHG balances of alternative cropping systems

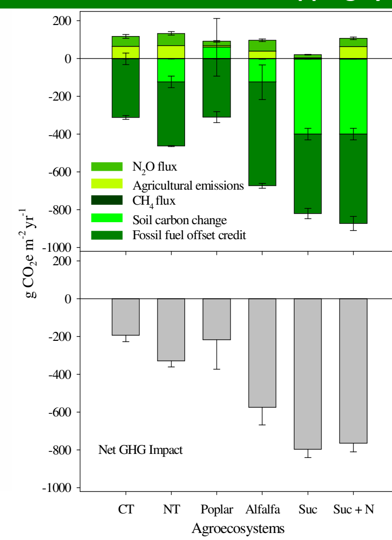


Figure 3. Detailed and Net GHG balances of potential biofuel feedstock production systems based on data from KBS LTER.

Marginal lands acreage

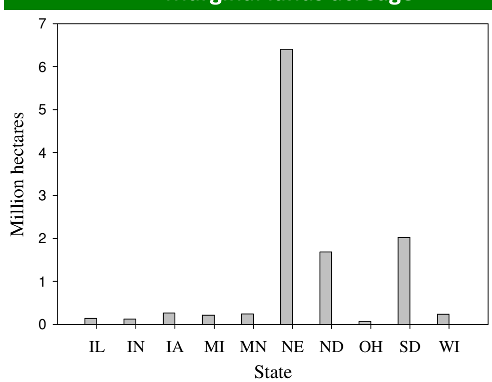


Figure 4. Available acreage of marginal lands across US Midwest. Modeled from CDL and SSSURGO datasets with resolution of 60 × 60 m.

Biomass and ethanol production by state

State	Total biomass production	Total cellulosic ethanol production
	Mg × 10^6	*GL yr^{-1}*
Illinois	2.41	0.33
Indiana	2.11	0.29
Iowa	3.46	0.47
Michigan	2.07	0.28
Minnesota	5.7	0.78
Nebraska	78.79	10.78
N. Dakota	24.75	3.38
S. Dakota	28.57	3.91
Wisconsin	5.21	0.72

Table 3. Modeled biomass and ethanol production from fertilized (68 kg ha^{-1} yr^{-1}) marginal lands across US Midwest.

Conclusions

1. **Cellulosic feedstock production has a large climate mitigation potential and can be established on marginal lands across US Midwest.**
2. **Fertilized successionnal communities could provide a significant amount of biomass for renewable fuels production, perhaps equivalent to that provided by purpose-grown switchgrass monocultures.**
3. **There are sufficient marginal lands within 80 km of potential biorefineries locations in 10 Midwest states to produce 21 GL per year of cellulosic ethanol.**

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