Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/5/12/eaav9318/DC1

Supplementary Materials for

Management controls the net greenhouse gas outcomes of growing bioenergy feedstocks on marginally productive croplands

Virginia L. Jin*, Marty R. Schmer, Catherine E. Stewart, Robert B. Mitchell, Candiss O. Williams, Brian J. Wienhold, Gary E. Varvel, Ronald F. Follett, John Kimble, Kenneth P. Vogel

*Corresponding author. Email: virginia.jin@ars.usda.gov

Published 18 December 2019, *Sci. Adv.* **5**, eaav9318 (2019)
DOI: 10.1126/sciadv.aav9318

This PDF file includes:

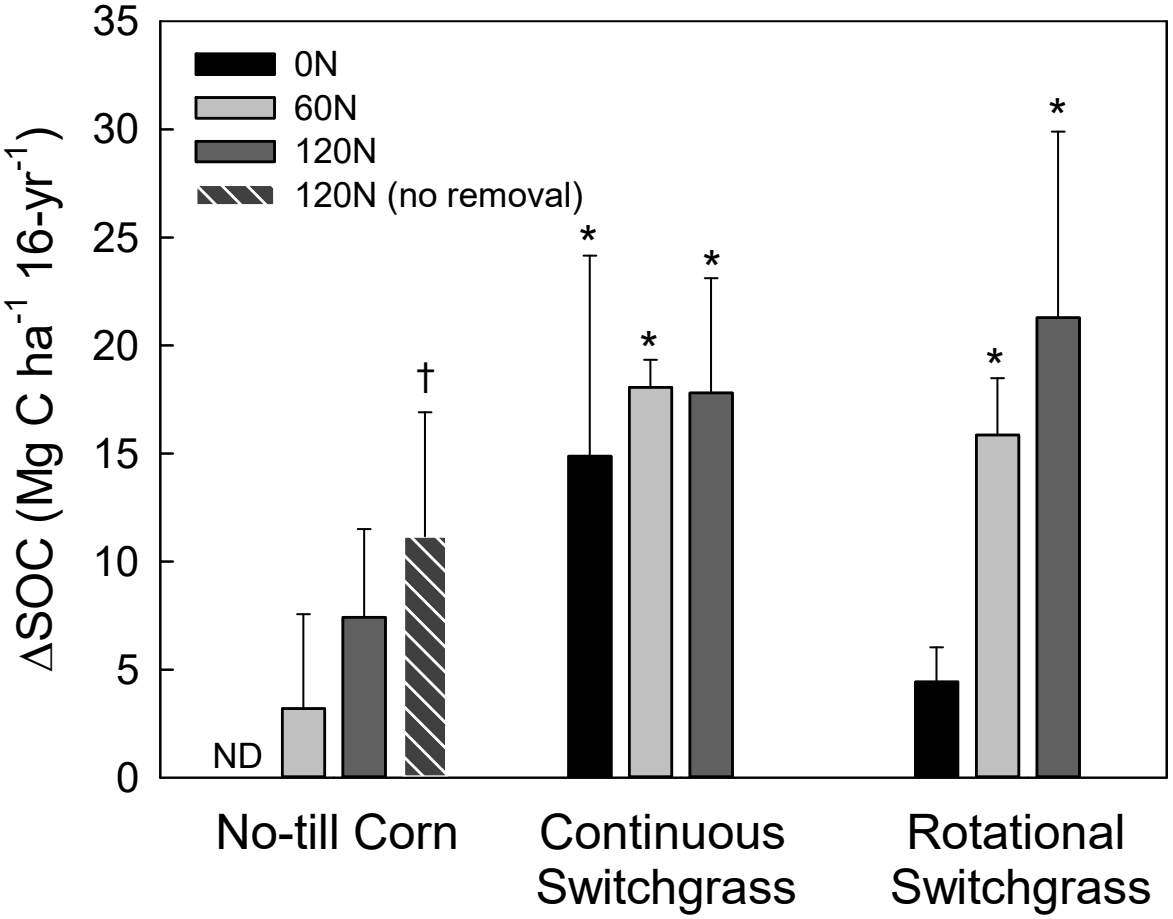

Fig. S1. Total 16-year change in SOC stocks in surface soils (1998–2014). Stock changes (mean ± se) were calculated on an equivalent soil mass basis approximating the top 30 cm of soil (4133 Mg/ha). Significance from zero indicated by $^{\dagger}P \leq 0.10$ and $^{*}P \leq 0.05$.

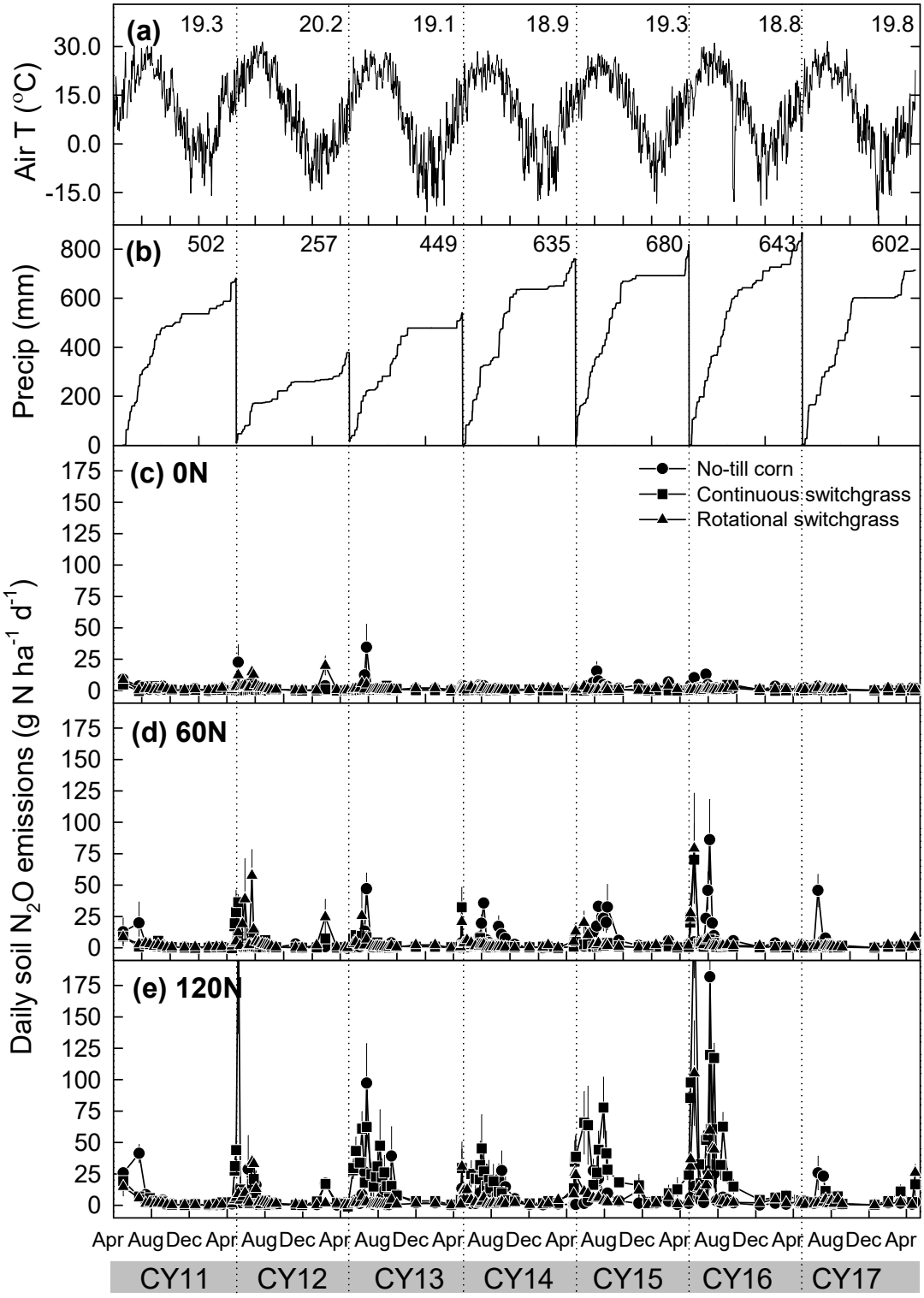

Fig. S2. Environmental conditions and soil N_2O emissions for crop years 2012–2017.

(**a**) Average daily air temperature, mean growing season temperature shown; (**b**) Precipitation curve showing total growing season precipitation inputs; and (**c-e**) daily emissions under 0, 60, and 120 kg N ha^{-1} yr^{-1}, respectively. Dotted vertical line indicates beginning of each crop-year.

Table S1. Annual energy requirements and GHG emissions for off-site agrochemical manufacturing and field agronomic operations.

Cropping system, agrochemical	Timing of operation	Field operation	# Events	Energy†	Annual GHG Emissions‡
			# yr^{-1}	GJ ha^{-1}	kg CO_2 eq ha^{-1} yr^{-1}
No-till corn	Annually	Planting	1	0.43	44.21
		Fertilizer application	1	0.06	6.17
		Herbicide application	2	0.10	20.56
		Grain harvest	1	1.28	131.61
		Stover harvest	1	0.34	34.96
Switchgrass	Seeding yr	Herbicide application	1	0.10	10.28
		Drill planting	1	0.33	33.93
		Mowing	1	0.26	26.73
		Baling	1	0.33	33.93
	Established	Fertilizer application	1	0.06	6.17
		Herbicide application§	0-1	0.10	10.28
		Mowing	1	0.33	33.93
		Baling	1	0.45	46.27
	Transition	Planting	1	0.43	44.21
		Herbicide application	2	0.10	20.56
		Grain harvest	1	1.21	124.41
Ammonium nitrate‖	1999-2007	Broadcast	4.48 kg CO_2 eq kg^{-1} N		
Urea‖	2008-present	Broadcast	9.18 kg CO_2 eq kg^{-1} N		
Herbicides¶	1998-present	Commercial sprayer	25.00 kg CO_2 eq kg^{-1} AI		
N treatment (kg N ha^{-1} yr^{-1})			0	60	120
Total emissions from fuel use and manufacturing			kg CO_2 eq ha^{-1} yr^{-1}		
No-till corn with stover removal			309.68	753.85	1191.85
No-till corn with no stover removed			—	—	1156.89
Continuous switchgrass			118.14	534.55	945.17
Rotational switchgrass			139.98	521.25	898.27

†(*38*); ‡Diesel, 102.82 kg CO_2 eq GJ^{-1} (*39*); §Herbicide applied as needed, not in all years; ‖(*40*); ¶(*17*), per kg active ingredient (AI).

Table S2. Net GHG outcomes for the agronomic phase of biofuel feedstock production over 16 years of management. Values in parentheses indicate percent of total gross flux represented by each category. *"+R" indicates residue retention (0% stover removal).

System	N rate	Fuel use & manufacturing		Direct emissions		SOC change		Net GHG ± se	
	kg N ha^{-1}	——— Mg CO_2 eq ha^{-1} $16\text{-}yr^{-1}$ (% Total gross emissions) ———							
No-till continuous corn	0	6.6	(23%)	9.9	(35%)	-11.7	(42%)	4.7	± 14.7
	60	13.5	(30%)	20.1	(44%)	-11.7	(26%)	21.9	± 16.8
	120	20.3	(25%)	32.6	(41%)	-27.2	(34%)	25.7	± 17.6
	120+R*	19.8	(19%)	42.1	(41%)	-40.9	(40%)	21.0	± 26.0
Continuous switchgrass	0	1.9	(3%)	3.7	(6%)	-54.5	(91%)	-48.9	± 33.6
	60	8.3	(10%)	11.9	(14%)	-66.2	(77%)	-46.1	± 4.3
	120	14.6	(10%)	68.7	(46%)	-65.3	(44%)	18.0	± 27.9
Rotational switchgrass	0	2.4	(9%)	8.4	(31%)	-16.3	(60%)	-5.4	± 5.8
	60	8.3	(10%)	17.1	(20%)	-58.1	(70%)	-32.8	± 9.3
	120	14.0	(12%)	20.9	(19%)	-78.0	(69%)	-43.1	± 33.0

Table S3. Mean daily air temperatures and precipitation inputs (1998–2017) for the growing season (May 1 to October 31) and for crop year (May 1 to April 30).

Year	Daily air T, ºC	Precipitation, mm	Daily air T, ºC	Precipitation, mm
	Growing season		Crop-year	
1998	20.6	601	11.6	870
1999	19.0	483	11.4	624
2000	20.8	425	10.0	603
2001	19.8	494	11.3	680
2002	19.6	423	10.6	555
2003	18.8	337	10.1	574
2004	18.8	360	10.5	636
2005	20.3	386	11.6	643
2006	19.2	435	10.4	731
2007	20.6	645	9.9	860
2008	19.0	765	9.9	881
2009	17.7	549	9.0	779
2010	19.9	661	10.1	828
Mean	**19.6**	**505**	**10.5**	**713**
SE	**0.2**	**36**	**0.2**	**33**
2011	19.3	502	11.6	681
2012	20.2	257	10.5	377
2013	19.1	449	9.1	541
2014	18.9	635	10.1	761
2015	19.3	680	11.4	820
2016	18.8	643	11.1	868
2017	19.8	602	10.1	714
Mean	**19.3**	**538**	**10.5**	**680**
SE	**0.2**	**56**	**0.3**	**64**