Soil Carbon Sequestration by Switchgrass:
Potential and Management

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Bioenergy's Role in Soil Carbon Storage
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Switchgrass (*Panicum virgatum* L.)

Attributes

- Warm-season tallgrass species
- Highly productive
- Requires fewer inputs than annual crops
- Suitable for planting on marginal land
- Adapted to multiple ecoregions

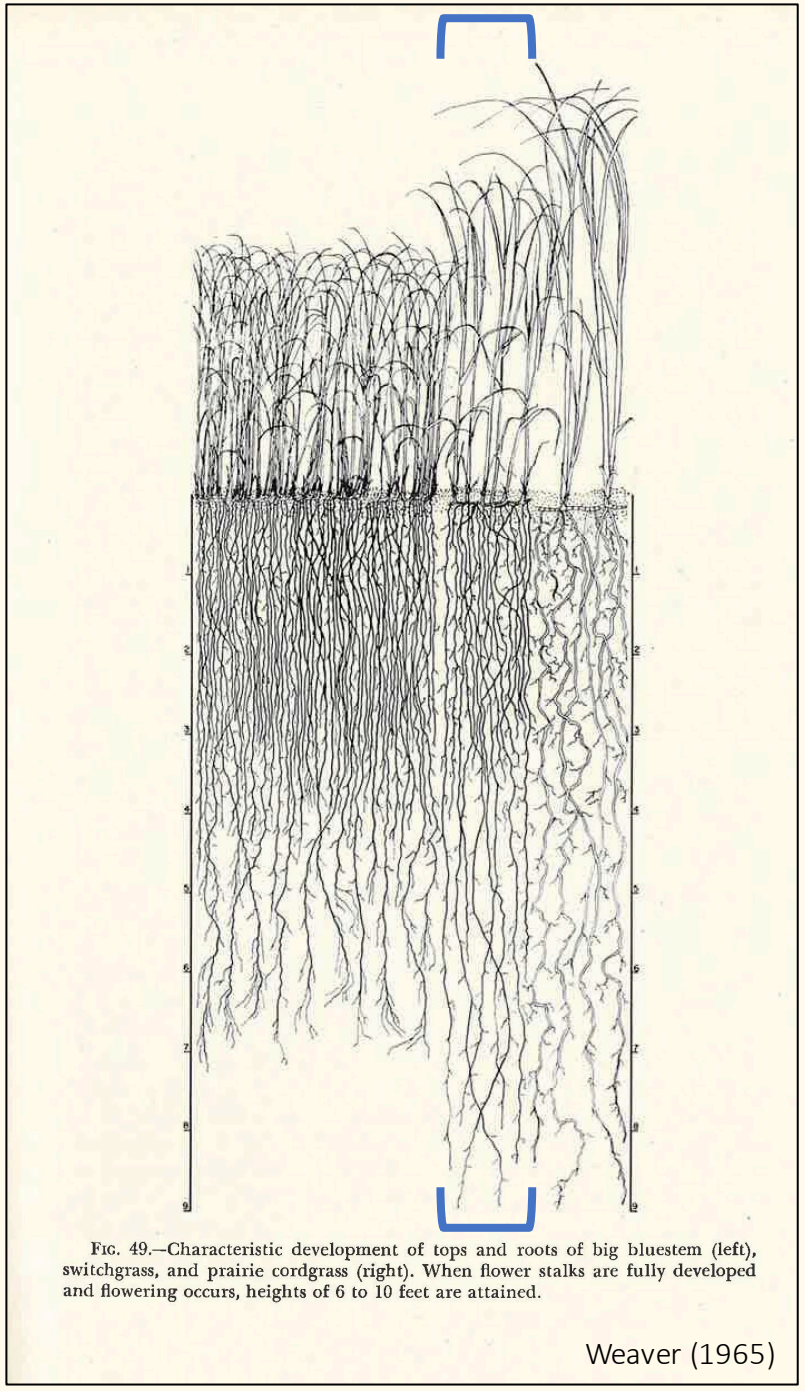


FIG. 49.—Characteristic development of tops and roots of big bluestem (left), switchgrass, and prairie cordgrass (right). When flower stalks are fully developed and flowering occurs, heights of 6 to 10 feet are attained.

Weaver (1965)

Switchgrass (*Panicum virgatum* L.)

Attributes

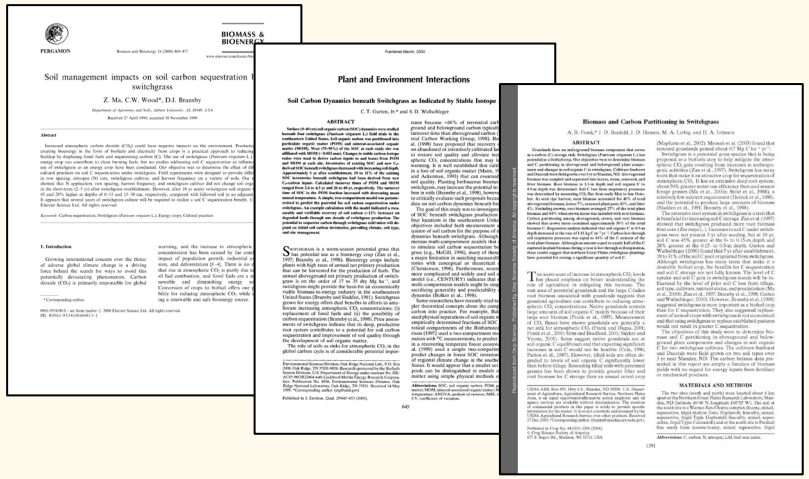
- **Root biomass can account for >75% of total biomass** (Frank et al., 2004)
- **Roots can extend below 2 m** (Weaver, 1965)
- **Soil-associated changes** (Blanco-Canqui, 2010)
  - Improved aggregation
  - Increased macroporosity
  - N & P removal
  - Carbon accrual

Responses a function of soil type, climate, management, and time

Switchgrass and Soil Carbon

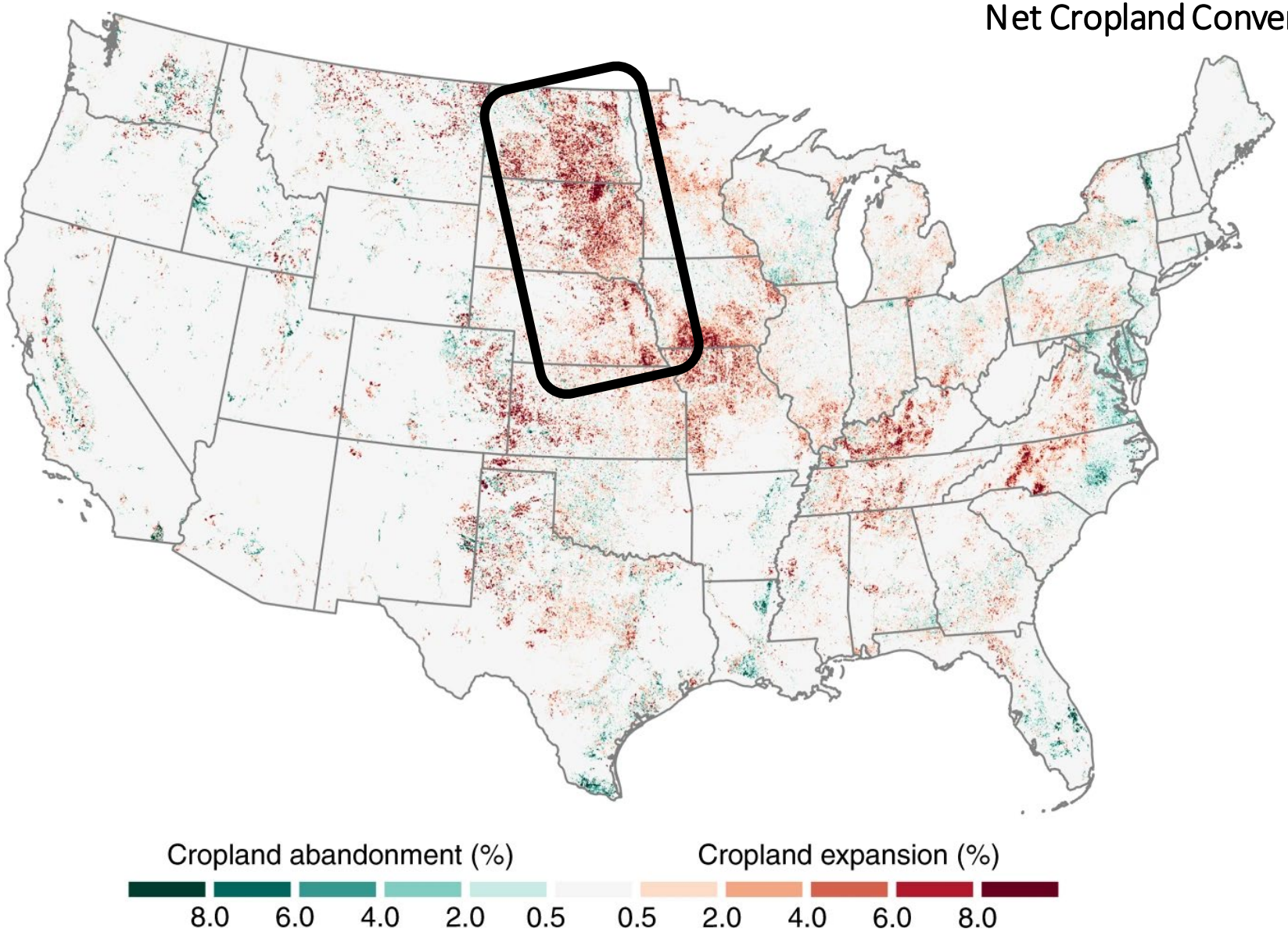
Early evaluations; Follow-on questions

- Switchgrass found effective at increasing soil organic carbon
- But research was often conducted under controlled conditions with small plots



- *What soil responses might we observe on working farms?*
- *How might management affect soil responses?*

Net Cropland Conversion, 2008-2016

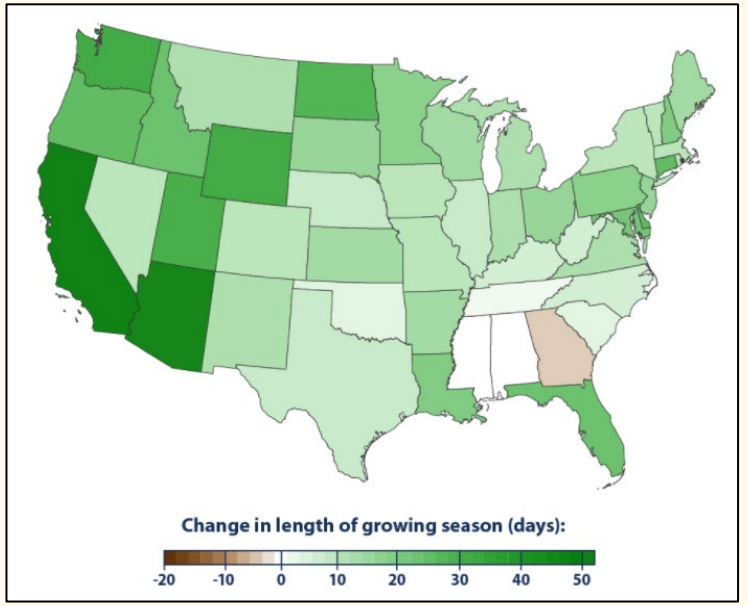


Lark et al. (2020)

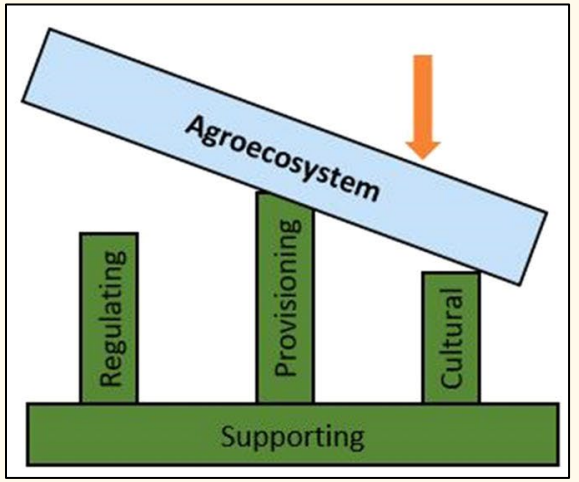
Region of Evaluation

Northern Great Plains / Western Corn Belt

- Abundance of HEL and saline-affected soils (NRCS, 1997)
- Longer growing season (Kunkel et al., 2004)
- Loss of perennial vegetation (Wright and Wimberly, 2013)
- Decreased crop diversity (Aguilar et al., 2015)
- Unbalanced delivery of ecosystem services (O'Brien et al., 2020)



Kunkel et al. (2021)



O'Brien et al. (2020)

Switchgrass and Soil Carbon

Select evaluations: 2000-2011

- ✓ SOC stocks under cropland and switchgrass – MN, SD, ND (42 sites)
- ✓ SOC stocks under switchgrass over time – NE, SD, ND (10 sites)
- ✓ SOC stocks under perennial monocultures and mixtures over time – ND (5 sites)
- ✓ SOC stocks under different fertility treatments over time – SD (1 site)

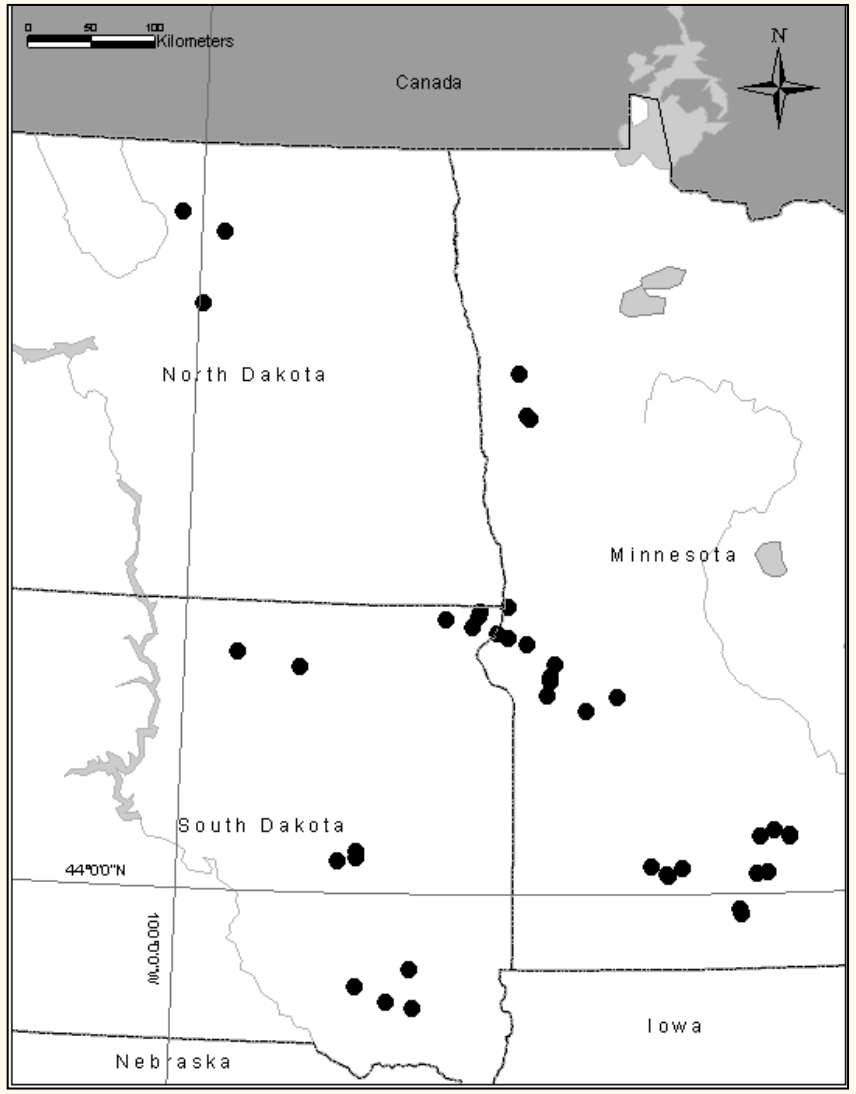
Switchgrass and Soil Carbon

Land use contrast (MN, SD, ND)

- 42 sampling sites
- 8 MLRAs

- Cropland vs. CRP (switchgrass)
- Matching soil type/paired site
- 0-1.2 m (7 increments)

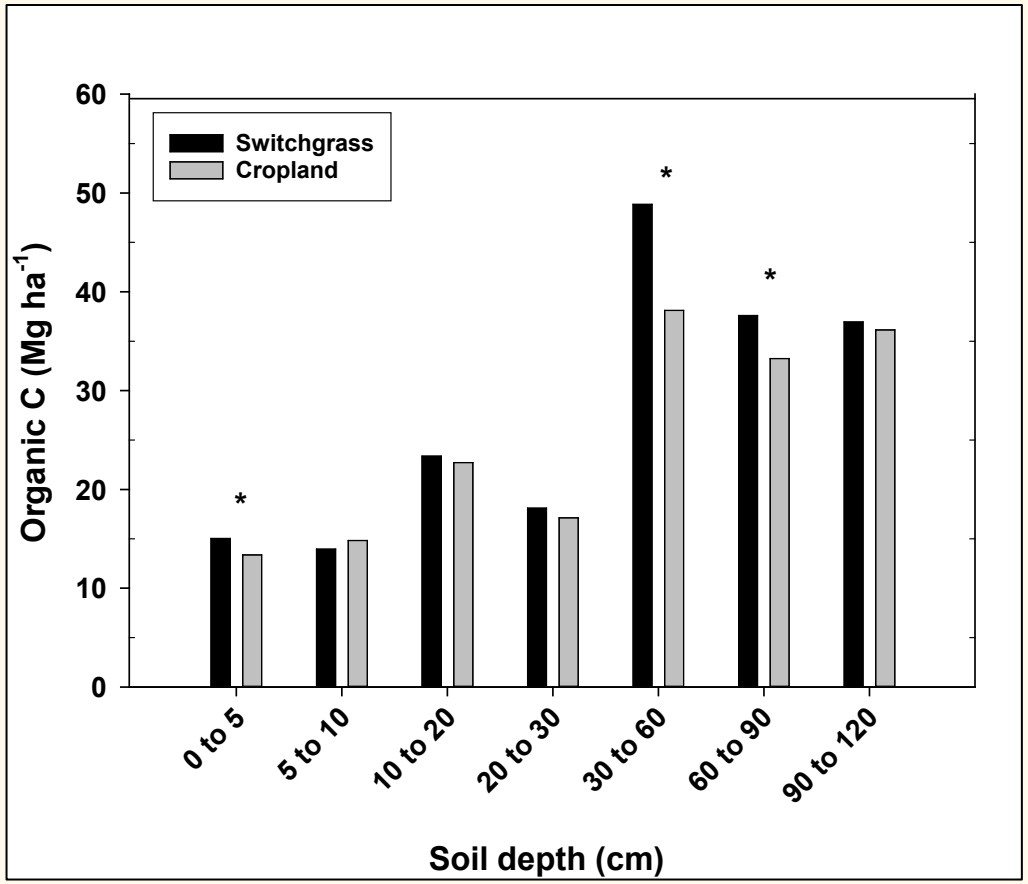
- Sampling, 2000 and 2001



Switchgrass and Soil Carbon

Land use contrast (MN, SD, ND)

- Across sites, SOC found greater under switchgrass in near surface and subsoil depths
- When evaluated within sites, few differences in SOC between land uses emerged (≈20%)
- Age of switchgrass stand weakly related to SOC ($R^2 \leq 0.25$).



Liebig et al. (2005)

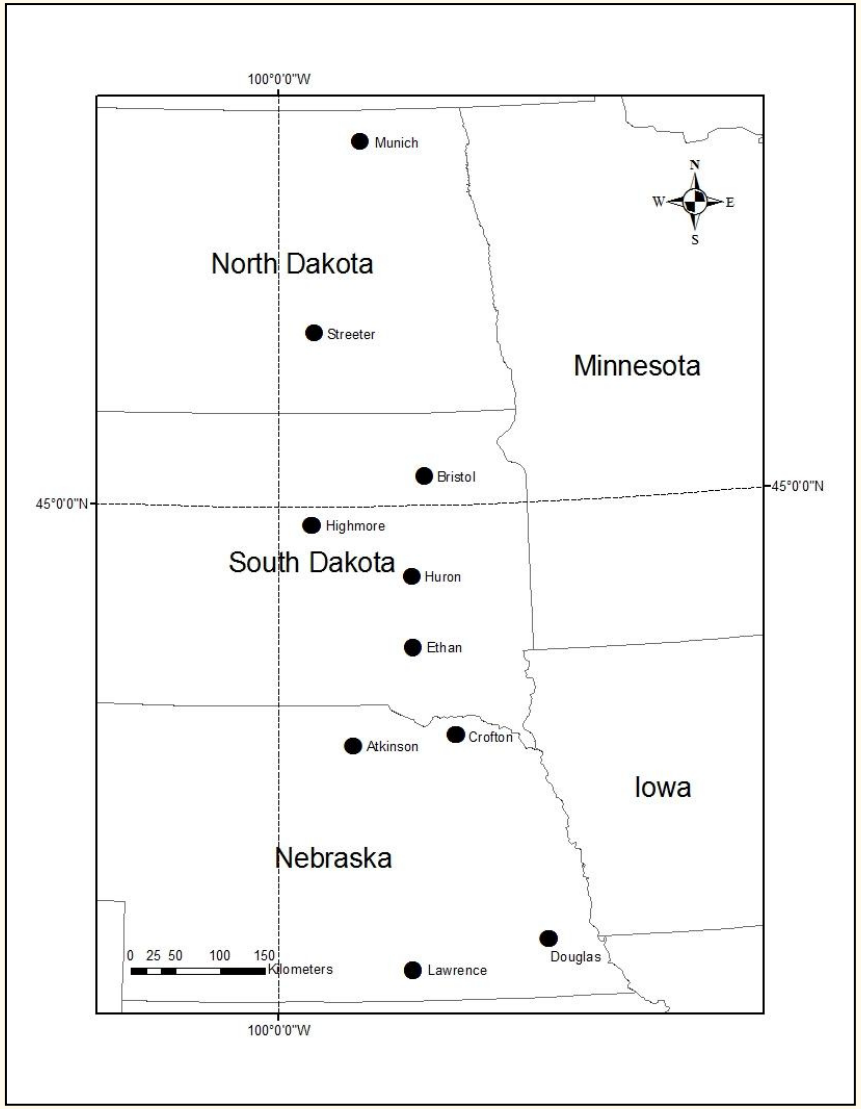
Switchgrass and Soil Carbon

Change over time (NE, SD, ND)

- 10 sampling sites
- 9 MLRAs

- Monoculture switchgrass
- 0-1.2 m (7 increments), NE
- 0-0.3 m (4 increments), SD & ND

- Sampling, 2000/2001 and 2005/2006



Switchgrass and Soil Carbon

Change over time (NE, SD, ND)

			- - - - - - - - Soil organic C (Mg C/ha) - - - - - - - -			
Location	**Depth (m)**	**P-value**	**'00/'01**	**'05/'06**	**Change**	**Change/yr**
Munich, ND	0-0.3	0.22	79.6	87.9	8.3	1.7
Streeter, ND	**0-0.3**	**0.03**	**83.6**	**87.8**	**4.2**	**0.8**
Bristol, SD	0-0.3	0.17	75.3	97.0	21.7	4.3
Ethan, SD	0-0.3	0.25	52.5	49.3	-3.2	-0.6
Highmore, SD	**0-0.3**	**0.09**	**67.5**	**74.2**	**6.7**	**1.3**
Huron, SD	0-0.3	0.35	61.3	58.7	-2.6	-0.5
Atkinson, NE	**0-0.3**	**0.10**	**34.4**	**40.2**	**5.8**	**1.2**
Crofton, NE	0-1.2	0.60	120.3	126.7	6.4	1.3
Douglas, NE	0-1.2	0.14	115.6	134.0	18.4	3.7
Lawrence, NE	**0-1.2**	**0.01**	**56.5**	**75.3**	**18.8**	**3.8**

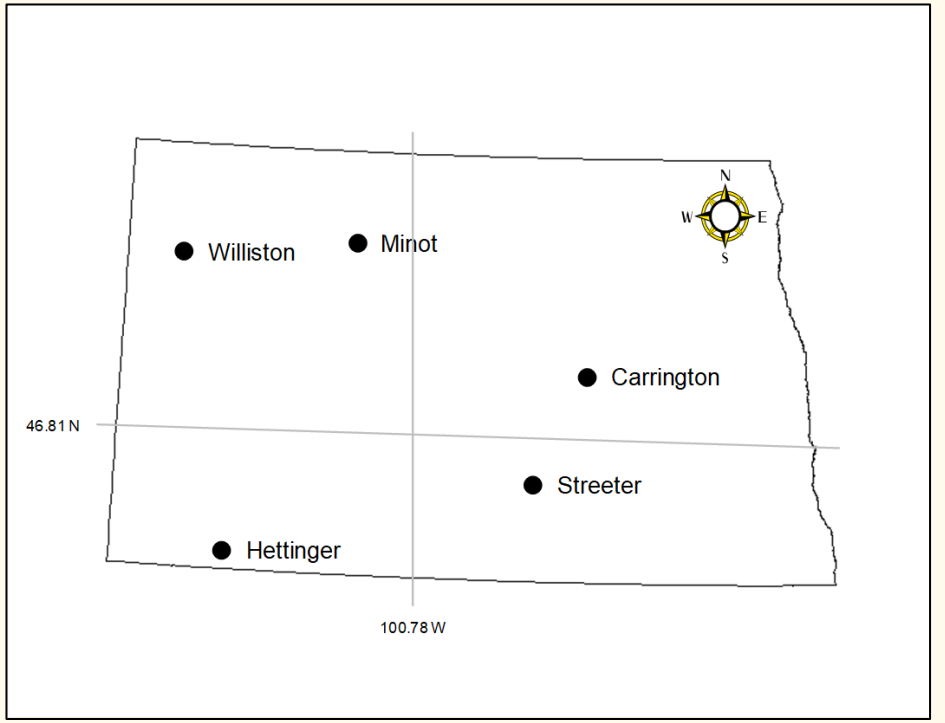
- SOC increases were statistically significant for 4 of 10 sites
- Sites in NE were more responsive to SOC than sites in SD and ND
- SOC accrual ranged from 0.8 to 3.8 Mg C/ha/yr

Schmer et al. (2011); Liebig et al. (2008)

Switchgrass and Soil Carbon

Vegetation composition; Change over time (ND)

- 5 sampling sites
- 7 vegetation treatments
  - 2 monoculture switchgrass
  - 2 monoculture wheatgrass
  - 3 mixtures
- 0-1.2 m (7 increments)
- Sampling, 2006 and 2011



Switchgrass and Soil Carbon

Vegetation composition; Change over time (ND)

- SOC stocks and change did not differ among vegetation treatments
- Across treatments, SOC increased significantly at two sites:
  - Minot, 2.9 Mg C ha^{-1} yr^{-1}
  - Williston, 5.7 Mg C ha^{-1} yr^{-1}

	- - - - - ΔSOC (Mg/ha) - - - - -	
Location	**Change***	**Change/yr**
Carrington	14.7	2.9
Hettinger	0.5	0.1
Minot	**14.7**	**2.9**
Streeter	8.0	1.6
Williston	**28.3**	**5.7**

* 7300 Mg/ha soil mass (≈0-0.9 m).

Liebig et al. (2017); Wang et al. (2014)

Switchgrass and Soil Carbon

Added fertility; Change over time (SD)

- 1 sampling site (CRP, eastern SD)
- 5 fertility treatments
  - 0 N (control)
  - 112 and 224 kg N ha^{-1} (NH_4NO_3)
  - 112 and 224 kg N ha^{-1} (beef cattle manure)
- 0-0.9 m (6 increments)
- Sampling, 2000 and 2004

Switchgrass and Soil Carbon

Added fertility; Change over time (SD)

- No change in ΔSOC without added fertility
- Greater ΔSOC with manure application

	ΔSOC (Mg/ha), 0-0.3 m		ΔSOC (Mg/ha), 0-0.9 m	
Treatment	**Change**	**Change/yr**	**Change**	**Change/yr**
0 N	0.02	<0.01	1.27	0.32
112 N	0.50	0.13	**7.58**	**1.90**
224 N	0.25	0.06	**11.27**	**2.82**
112 N (manure)	**4.32**	**1.08**	**17.03**	**4.26**
224 N (manure)	**8.59**	**2.15**	**15.01**	**3.75**

Lee et al. (2007)

Closing Reflections…

- Outcomes from marginal soils – Should we temper our expectations?
- Drought effects on establishment success and subsequent biomass production – How might this affect SOC dynamics in the future?
- In the NGP, the climate regulation picture is fuzzy – More evaluations of greenhouse gas balance needed

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