# Cropping System Effects on Net Global Warming Potential in a Semiarid Region

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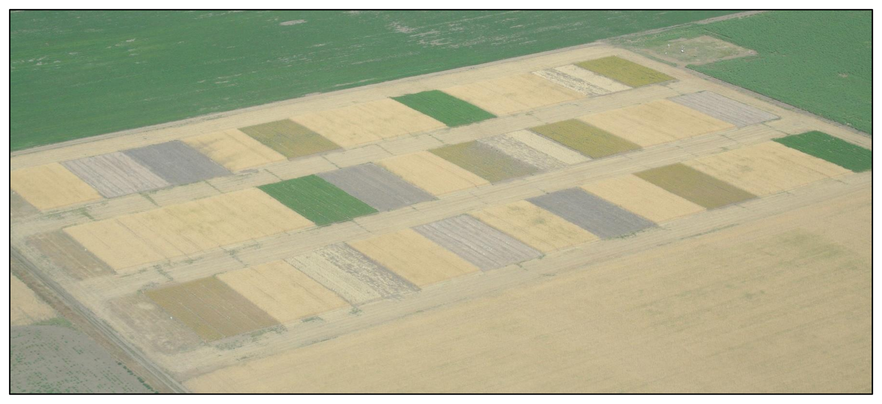
## RATIONALE AND OBJECTIVE

Previous net global warming potential (GWP) evaluations in semiarid regions have focused on determining individual management practice effects on GWP, but few have considered cropping systems, where assessments are focused on combined management (e.g., tillage, crop rotation, nutrient management, residue removal, etc.). The objective of this study was to determine net GWP for three cropping systems in a long-term experiment in the northern Great Plains of North America.

## METHODS



### Experimental Site

The experimental site was located approximately 6 km south of Mandan, North Dakota, USA (46.77, -100.95; 591 m) on the Area IV Soil Conservation Districts Cooperative Research Farm. The site is on gently rolling uplands (0-3% slope) with Temvik-Wilton silt loam soils. Climate is characterized as semiarid to sub-humid continental, with cold and dry winters, warm to hot summers, and erratic precipitation.

### Treatments

Evaluated treatments were part of a long-term cropping system experiment established in 1994 and included 1) spring wheat (*Triticum aestivum* L.) – fallow (SW-F), 2) continuous spring wheat with residue retained (CSW), and 3) spring wheat – safflower (*Carthamus tinctorius* L.) – fallow/rye (*Secale cereale* L.) [SW-S-R]. All crop sequences were managed using no-tillage, and phases of each crop sequence were present every year. Treatments were replicated three times.

### Determination of Net GWP

Net GWP was calculated as the sum of emitted $CO_2$ equivalents from seven factors:

- Seed, fertilizer, and pesticide production, respectively (Özilgen and Sorgüven, 2011; Lal, 2004; West and Marland, 2002).
- Field operations, inclusive of seeding, pesticide application, and harvest (West and Marland, 2002).
- Soil organic carbon stock change over an 18-yr period assuming a soil profile mass of 18885 Mg $ha^{-1}$ (Ellert and Bettany, 1995).
- Soil-atmosphere $CH_4$ and $N_2O$ flux over a 3-yr period using static chamber methodology (Hutchinson and Mosier, 1981).

Differences between cropping systems were considered significant at P≤0.05.

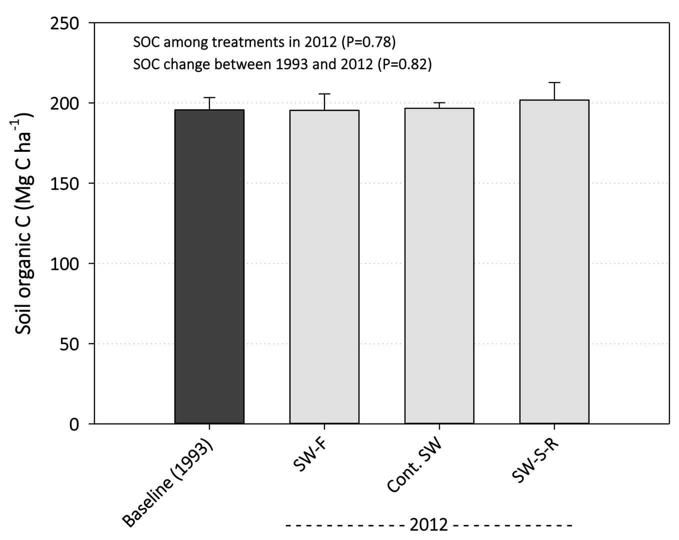
## RESULTS

### *Production Inputs and Field Operations*

Emissions associated with production inputs and field operations were generally greatest for the least diverse cropping system (CSW), intermediate for the most diverse cropping system (SW-S-R), and lowest for the cropping system with alternate years of fallow (SW-F). This trend was largely driven by N fertilizer requirements and the frequency of grain harvest within each cropping system.

### *Soil organic C*

Mean SOC stocks were 195.6 ± 6.8 Mg C $ha^{-1}$ in 1993 prior to treatment deployment. Eighteen years later, mean SOC stocks were 198.0 ± 4.6 Mg C $ha^{-1}$ and did not differ from baseline stocks nor among cropping systems. Change in SOC stocks over 18 years did not differ among cropping systems (P = 0.87). Numerical outcomes suggested CSW and SW-S-R were minor and moderate C sinks, while SW-F was a minor C source.




| Factor | Spring wheat – Fallow | Continuous spring wheat | Spring wheat – Safflower – Rye |
|---|---|---|---|
| | - - - - - - - - - - - - - kg $CO_{2equiv.}$ $ha^{-1}$ $yr^{-1}$ - - - - - - - - - - - - - | | |
| Seed production | 21 b† | 42 a | 47 a |
| Fertilizer production | 66 c | 238 a | 171 b |
| Pesticide production | 112 | 82 | 99 |
| Field operations‡ | 93 c | 143 a | 128 b |
| SOC change | 69 | -205¶ | -1244 |
| $CH_4$ flux | -19 | -11 | -14 |
| $N_2O$ flux | 479 | 1658 | 799 |
| **Net GWP** | **822** | **1948** | **-14** |

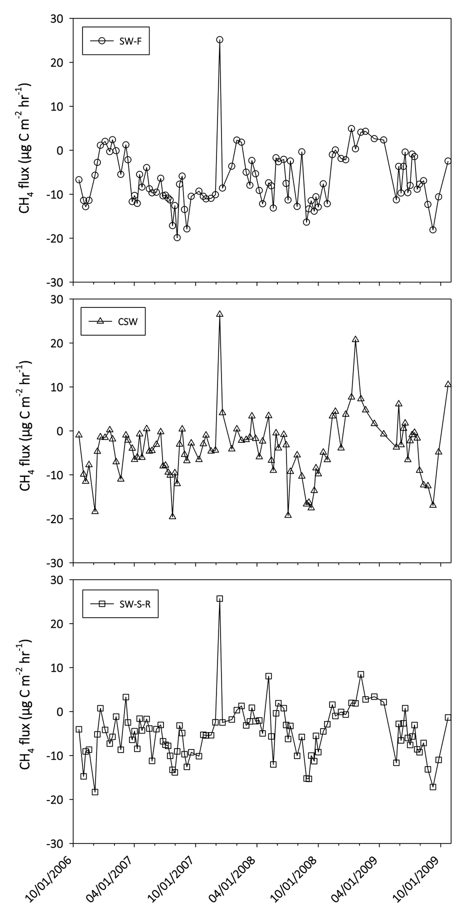
† Means in a row with unlike letters differ (P≤0.05).
‡ Inclusive of emissions associated with seeding, pesticide application, and harvest.
¶ Negative values imply net $CO_2$ uptake.

### *Net GWP*

Factors contributing to net GWP across cropping systems decreased in relative impact in the order of soil-atmosphere $N_2O$ flux, SOC change, $CO_2$ emissions associated with fertilizer production, field operations, pesticide production, and seed production, and soil-atmosphere $CH_4$ flux. Soil-atmosphere $N_2O$ flux comprised the majority of emissions in SW-F and SW-S-R, accounting for 58 and 85% of net GWP, respectively. Nitrous oxide emission accounted for 64% of the soil C sink capacity in SW-S-R when expressed on a $CO_{2equiv.}$ basis, while SOC change negated 12% of observed $N_2O$ emission in CSW. Net GWP did not differ among cropping systems (P = 0.17).

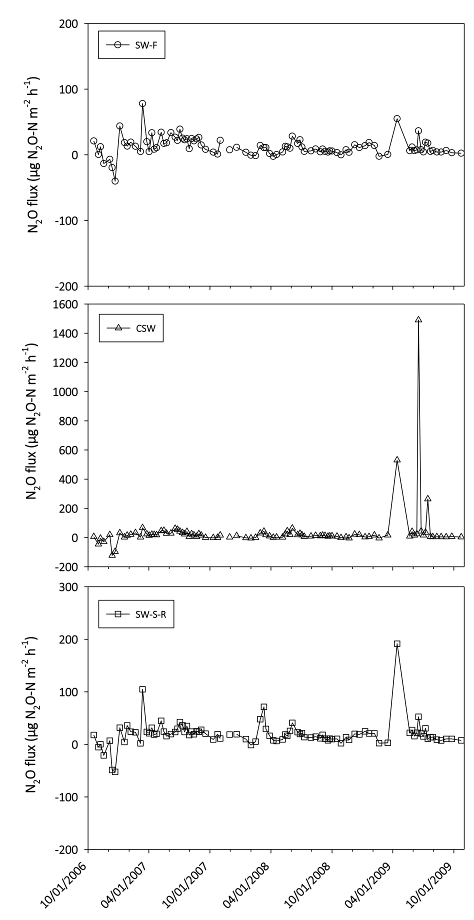
### *$CH_4$ Flux*

Methane uptake was the dominant exchange process throughout the evaluation period, as all cropping systems were minor $CH_4$ sinks. Methane uptake did not differ among cropping systems.




### *$N_2O$ Flux*

Net emission of $N_2O$ to the atmosphere was dominant during the evaluation period. Notable 'hot moments' for $N_2O$ flux aligned with late-winter snowmelt or after significant rainfall. Despite large numerical differences, $N_2O$ flux did not differ among cropping systems.




## DISCUSSION

This study and others prior highlight the challenges associated with creating cropping systems that are net greenhouse gas (GHG) sinks in semiarid regions. Transitioning semiarid cropping systems to GHG sinks will require new technology and methods to improve efficiency of N use by crops, thereby decreasing contributions of soil-atmosphere $N_2O$ flux to net GWP. Concurrent to improved N management is the need for adoption of cultural practices known to increase SOC stocks well above C accrual rates typical of continuously cropped, no-tillage systems. Inclusion of perennial crops for forage and/or biofeedstock production in semiarid cropping systems can result in large increases in SOC due to abundant and deep-rooted biomass. However, management practices are needed to ensure GHG mitigation benefits from SOC stock increases are retained throughout the perennial-annual rotation cycle.

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