Nitrogen fertilizer rate effects on soil organic carbon in Iowa continuous corn and corn-soybean systems

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Introduction

- Nitrogen fertilizer rate is a key factor affecting soil organic C (SOC) in corn-based cropping systems:
    - Nitrogen fertilizer increases crop productivity and residue inputs. Greater residue inputs typically lead to greater SOC.
    - However, N fertilizer may also enhance SOC mineralization, which may cause neutral or negative C balances despite increased residue inputs.

Objective

- To determine the effects of N fertilizer rate on change in SOC over time in continuous corn and corn-soybean systems.

Hypotheses

1. An increase in N fertilizer rate from zero to the agronomic optimum N rate (AONR) will have a positive effect on residue inputs and SOC change.
2. An increase in N fertilizer rate from the AONR to an excessive rate will not affect residue inputs and increase soil inorganic N, causing a neutral or negative effect on SOC change.

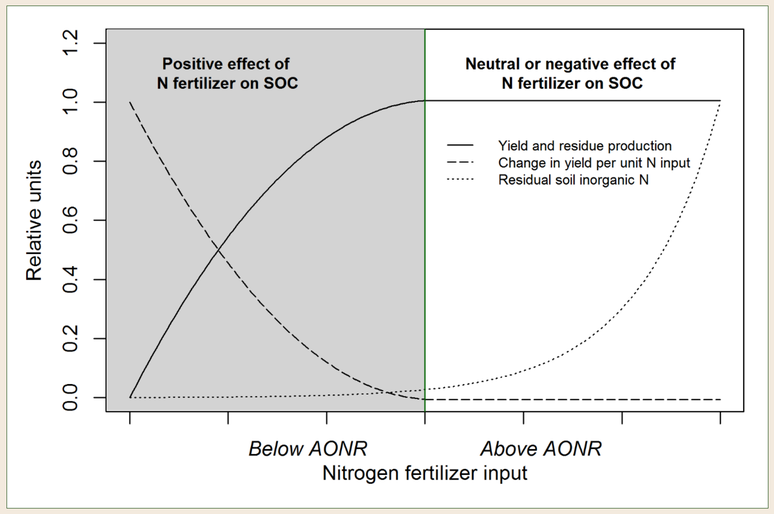

Figure 1. Conceptual relationships among N fertilizer input relative to the agronomic optimum N rate (AONR), crop production (residue and yield), and post-harvest residual soil inorganic N. The green vertical line represents the AONR.

Methods

- In two long-term N fertilization trials, specific N rates (0-269 kg N ha^{-1}) have been applied to corn in the same continuous corn and corn-soybean plots since 1999. Quadratic or quadratic-plateau models were fit to corn yield data to determine the AONR for each system.
- Corn and soybean yields (2000-2014) were used to estimate average annual aboveground dry matter production, assuming harvest index values of 0.50 for corn and 0.44 for soybean.
- Soil samples (0-15 cm) were collected in 1999 and 2014 and analyzed for organic C and total N concentrations.

Figure 2. An example of N fertilizer rate effects on corn growth. Corn in the foreground received no N fertilizer, while corn in the background received N fertilizer at the agronomic optimum N rate.

Table 1. Soil properties at two study locations. Textures and soil organic C concentrations are for the surface 15 cm.

Location	Soil order	USDA texture class	Soil organic C (% in 1999)
Ames, IA	Mollisol	Loam	2.08
Chariton, IA	Mollisol	Silt loam	2.24

Results

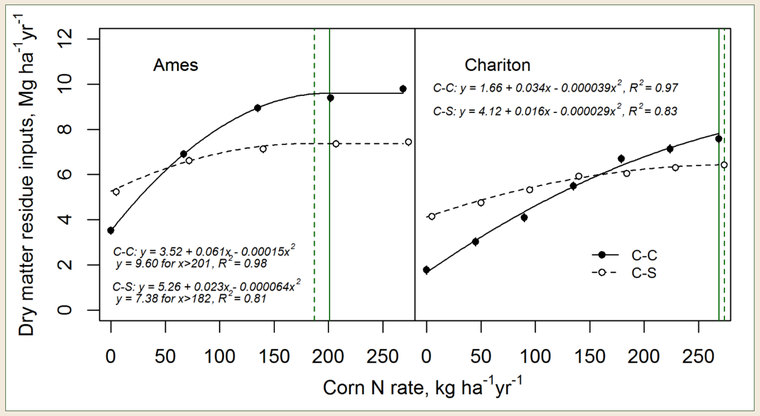

Figure 3. Average annual aboveground dry matter residue inputs (not including grain) in response to N fertilizer rate applied to corn in continuous corn (C-C) and corn-soybean (C-S) rotations at two locations in Iowa. Curves are quadratic or quadratic plateau models fit to the data. Error bars represent ± one standard error. The green vertical lines indicate agronomic optimum N rates (solid for C-C; dashed for C-S). X-axis values for the C-S rotations were slightly offset for visual clarity.

- At the two sites, increasing N fertilizer rate from zero to the AONR increased average annual aboveground dry matter residue inputs by 2.7 and 4.8-fold in continuous corn and by 1.4 and 1.5-fold in corn-soybean.

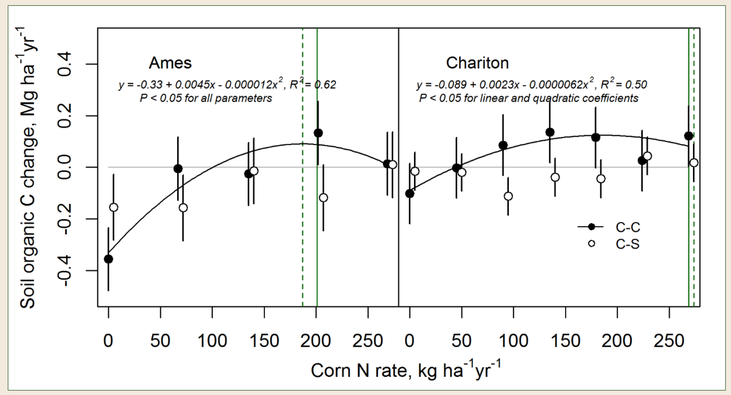

Figure 4. Average annual soil organic C change in response to N fertilizer rate applied to corn in continuous corn (C-C) and corn-soybean (C-S) rotations at two locations in Iowa. Curves are quadratic models fit to the data. Error bars represent 95% confidence intervals. The green vertical lines indicate agronomic optimum N rates (solid for C-C; dashed for C-S). X-axis values for the C-S rotations were slightly offset for visual clarity.

- For continuous corn at both sites, the average annual change in SOC increased significantly from below 0 Mg C ha^{-1} yr^{-1} where no N was applied, to a maximum of ~0.13 Mg C ha^{-1} yr^{-1} at N rates between 150 and 200 kg N ha^{-1}.
- For corn-soybean rotations, the average annual change in SOC was generally at or below 0 Mg C ha^{-1} yr^{-1}.
- Soil organic C change was positively related to average annual aboveground dry matter residue inputs for continuous corn, but not for corn-soybean.

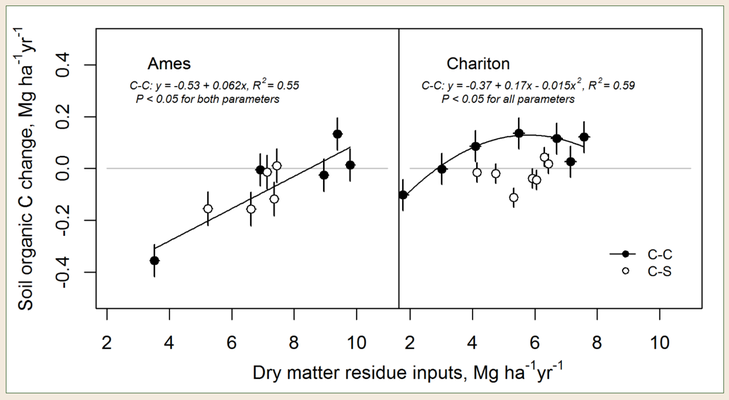

Figure 5. Average annual soil organic C change related to average annual aboveground dry matter residue inputs in continuous corn (C-C) and corn-soybean (C-S) rotations at two locations in Iowa. Curves are linear or quadratic models fit to the data. Error bars represent ± one standard error.

Conclusions

- Optimally fertilized continuous corn systems accrued SOC, whereas optimally fertilized corn-soybean systems did not.
- Fertilizing above the AONR slightly decreased the positive effect of residue inputs on SOC change for Ames continuous corn.

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