Field-Scale Cropping System N Use Efficiency after 10 Years of Continuous No-tillage

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Introduction

- Evaluation of N use efficiency (NUE) over multiple growing seasons may provide an improved assessment of NUE as compared to NUE assessed for a single crop.
- NUE will also vary spatially (and temporally) across landscapes and soils, which is rarely considered when evaluating NUE of a field.
- Increased understanding of N in agricultural systems is a fundamental goal of a USDA NIFA, AFRI, CAP entitled "Regional Approaches to Climate Change for Pacific Northwest Agriculture" (REACCH). REACCH is funded through Award #2011-68002-30191 from USDA National Institute of Food and Agriculture.

Objective

- Use an N mass balance approach to increase understanding of how no-tillage and crop rotation influence field-scale NUE after 10 years.

Materials and Methods

- A field-scale multi-year cropping systems study under no-tillage was initiated in 1998 on a 92-ac field of the Washington State University Cook Agronomy farm (CAF) near Pullman, WA. The farm was under continuous small grain production using inversion tillage prior to the initiation of the study.
- The site was planted to spring wheat in 1999 and spring barley in 2000. Spring wheat (SW) – winter wheat (WW) – alternative crop (spring and winter plantings of barley (B), canola (C) and pea (P)) rotations were initiated in 2001 following a complete block design with 3 replications.
- Soil samples (0.1 ft by 5 ft) were collected in the fall of 1998 and spring of 2008 from 183 geo-referenced locations in a systematic non-aligned grid across the 92-ac CAF (Figure 1).
- Soil cores sampled in 1998 were divided into 0.3 ft increments for the surface foot and by soil horizon for 1-5 ft. By 2008, a litter-mineral layer had formed within the surface 0.3 ft under continuous no-tillage, this was sampled and analyzed separately. The rest of the soil core was sampled and analyzed as in 1998. Bulk density was determined for each increment.
- Soil samples were air dried and roller ground before being analyzed for total soil N and carbon (C) using dry combustion.
- Harvested grain samples were collected annually from the 183 geo-referenced locations and were analyzed for grain N and C.
- Fertilizer applications were made annually based on crop requirements and soil test results.
- The influence of time, crop rotation, soil series, and field on soil N (lbs ac^{-1}), soil N concentration (%), soil N mass balance, and NUE were assessed using Proc Mixed and General Linear Models (SAS software; Version 9.4; SAS Institute Inc. 2013).
- Nitrogen mass balance was calculated using the following equation:

$$2008\ N - (Initial\ N + Total\ fertilizer\ N - Total\ grain\ N)$$

- Nitrogen use efficiency was calculated using the following equation:

$$\left(\frac{Total\ grain\ N + (Soil\ N\ 2008 - Soil\ N\ 1998)}{Total\ fertilizer\ N}\right) \times 100$$

- Initial and final soil N were interpolated using inverse distance-squared weighting and mapped using ArcMap (ESRI 2011).

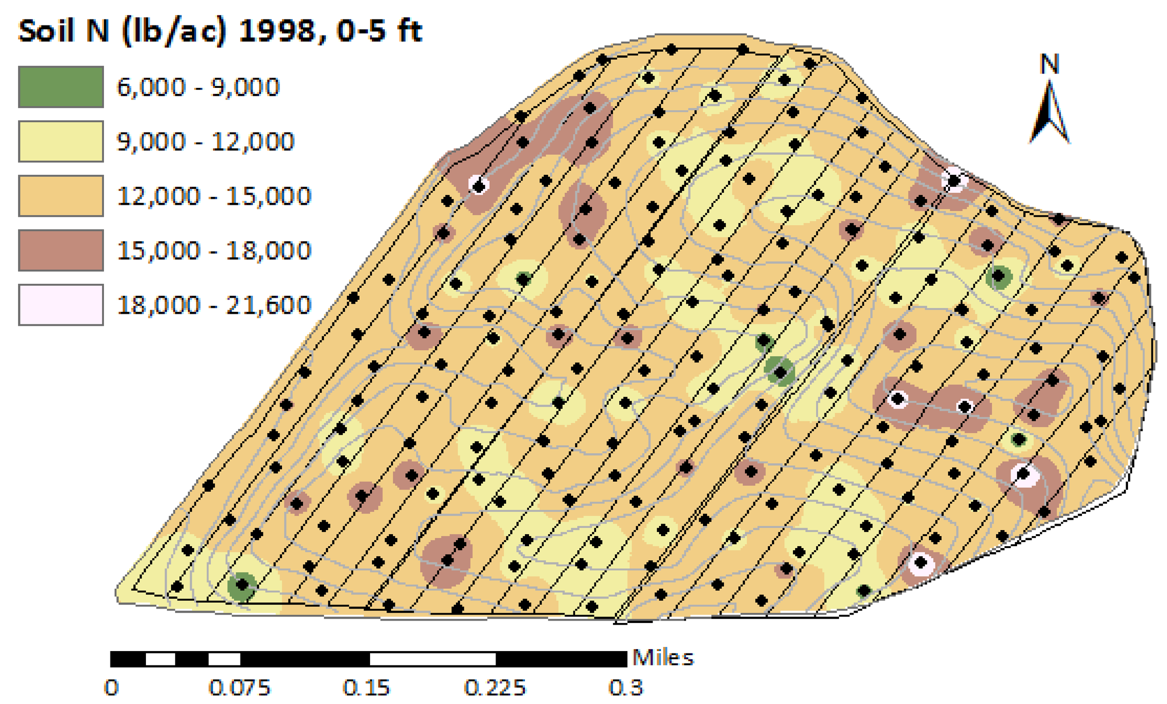

Figure 1. Total soil profile N (lbs ac^{-1}) in 1998 on the Cook Agronomy Farm. Sampling locations are marked as black points and grey lines are contour intervals (9.8 ft). Each strip is marked with black lines.

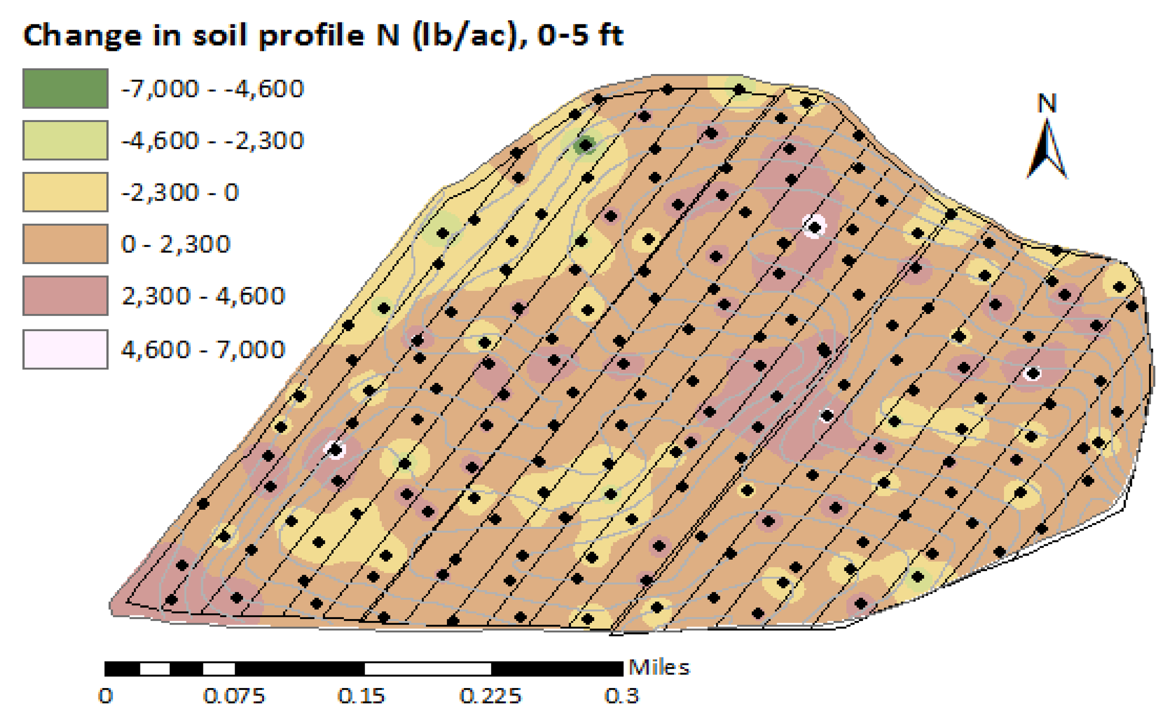

Figure 2. The change in total soil profile N (lbs ac^{-1}) from 1998 to 2008 on the Cook Agronomy Farm. Sampling locations are marked as black points and grey lines are contour intervals (9.8 ft). Each strip is marked with black lines.

Table 1. P-values for different soil sampling depths from the 1998 and 2008 sampling of the 92-ac Washington State University Cook Agronomy farm.

	1998 0-1 ft	1998 1-5 ft	1998 0-5 ft	2008 0-1 ft	2008 1-5 ft	2008 0-5 ft
General rotation	na	na	na	0.19	0.16	0.19
Field	0.09	0.20	0.19	0.27	0.01	0.07
Soil series	< 0.001	0.01	0.002	< 0.001	0.01	< 0.001

Table 3. Inputs, outputs, and soil N based on rotation in the 92-acWashington State University Cook Agronomy farm.

General Rotation	Crops	1998 N 0-1 ft (lbs ac^{-1})	1998 N 1-5 ft (lbs ac^{-1})	1998 N 0-5 ft (lbs ac^{-1})	Total fertilizer N (lbs ac^{-1})	Total grain N (lbs ac^{-1})	N balance index (lbs ac^{-1})	2008 N 0-1 ft (lbs ac^{-1})	2008 N 1-5 ft (lbs ac^{-1})	2008 N 0-5 ft (lbs ac^{-1})
1	SW-WW-SB	4,613	8,315	12,928	1,445	678	419	4,978	8,645	13,615
2	SW-WW-SC	4,996	8,315	13,321	1,392	696	446	5,300	8,886	14,177
3	SW-WW-SP	4,541	8,520	13,062	1,178	678	517	5,041	9,341	14,382
4	SW-WW-WB	4,862	8,538	13,401	1,472	651	393	5,094	9,841	14,935
5	SW-WW-WC	4,604	8,574	13,178	1,374	678	437	5,023	8,574	13,597
6	SW-WW-WP	4,675	8,556	13,231	1,204	651	482	5,157	9,074	14,231

Table 4. Mass balance approach to soil N and NUE based on rotation in the 92-ac Washington State University Cook Agronomy farm.

General Rotation	Crops	Mass balance 0-1 ft (lbs ac^{-1})	Mass balance 0-5 ft (lbs ac^{-1})	NUE 0-1 ft (lbs ac^{-1})	NUE 0-5 ft (lbs ac^{-1})
1	SW-WW-SB	-241	116	732	937
2	SW-WW-SC	-384	178	642	990
3	SW-WW-SP	-187	598	785	1,312
4	SW-WW-WB	-473	1,017	580	1,606
5	SW-WW-WC	-259	-152	723	785
6	SW-WW-WP	-187	357	758	1,133

Results

- There were no significant differences in initial (1998) soil N among assigned crop rotation strips (Table 1).
- Initial (1998) and 2008 soil N (lbs ac^{-1}) for 0-1 ft, 1-5 ft, and 0-5 ft depths were influenced by soil series (Table 1). Caldwell had the most soil N and Staley had the least amount of soil N across all three sampling depths and for both sampling times (Table 2).
- Field affected 2008 soil N (lbs ac^{-1}) for the 1-5 ft sampling depth (Table 1). Field A contained the most soil N (9,627 lbs ac^{-1}) at the 1-5 ft sampling depth, followed by Field B (9,038 lbs ac^{1}) and Field C (8,413 lbs ac^{-1}).
- Soil N (lbs ac^{-1}) increased over 10 years by 9.3% for 0-1 ft ($p < 0.001$), 11.7% for 1-5 ft ($p < 0.001$), and 9.9% for 0-5 ft ($p < 0.001$) sampling depths (Figure 2) across all rotations (Table 3).
- Soil N concentrations increased over 10-years from 13.1% (1998) to 16.4% (2008) for the 0-1 ft sampling depth ($p < 0.001$) and from 4.2% (1998) to 4.5% (2008) in the 1-5 ft sampling depth ($p < 0.001$).
- There was no difference in harvested grain N or N balance index (Total grain N/Total fertilizer N) based on field, strip, or rotation (Table 3).
- Mass balance soil N was affected by field at the 0-5 ft sampling depth ($p < 0.001$). Field A (1,231 lbs ac^{-1}) added N to the system that cannot be accounted for over the course of the study, while Field B (-223 lbs ac^{-1}) and Field C (-125 lbs ac^{-1}) lost N from the system that cannot be accounted for over the course of the study.
- Soil N mass balance and NUE were not affected by rotation (Table 5) based on the 0-1 ft and 0-5 ft sampling depths.

Table 2. Average soil N (lbs ac^{-1}) for each sampling depth in 1998 and 2008 in the 92-ac Washington State University Cook Agronomy farm.

Soil Type	1998 0-1 ft (lbs ac^{-1})	1998 1-5 ft (lbs ac^{-1})	1998 0-5 ft (lbs ac^{-1})	2008 0-1 ft (lbs ac^{-1})	2008 1-5 ft (lbs ac^{-1})	2008 0-5 ft (lbs ac^{-1})
Caldwell	5,335	10,126	15,462	5,817	10,376	16,193
Latah	4,800	8,744	13,544	5,228	9,993	15,221
Naff	4,327	7,610	11,938	4,711	8,369	13,080
Palouse	4,693	8,628	13,321	5,175	9,011	14,186
Staley	4,265	6,754	11,019	4,443	7,628	12,071
Thatuna	5,023	8,984	13,999	5,255	9,689	14,953

Conclusions

Overall, the NUE in this study was very high. All rotations accumulated N throughout the soil profile and nearly all had a positive mass balance, indicating N input sources were not all accounted for and/or measurement errors occurred. One explanation for overall profile N increase would be the buildup in soil organic matter when converting to no-tillage. It is important to bear in mind that N concentrations in the subsoil were relatively low, which could result in analytical and mass balance calculation errors.

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