NUTRIENT LESSONS FROM LONG-TERM CROPPING SYSTEM STUDIES

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ABSTRACT

The long-term efficiency of applied nutrients in agricultural soils depends not only on the efficiency of use by the immediate crop, but also on the efficiency of use for residual forms. However, determining this efficiency is difficult due to the slow turnover of residual forms, large soil nutrient reserves, and multiple processes controlling the fate and crop utilization of nutrients. Long-term cropping system studies are useful in this regard because they allow small changes to accumulate and become measurable. For example, soil organic matter is a significant source and sink for nitrogen, but cannot be monitored on an annual basis. In the northern Great Plains, declining soil organic matter (SOM) after the conversion of grassland to annual cropping provided abundant nitrogen for wheat production, but also led to concerns of depleted soils, which spurred the establishment of multiple long-term cropping studies. These studies demonstrated that once a new steady-state level of SOM was achieved, nitrogen fertilizer was necessary to maintain yield and protein levels and was recovered at an efficiency of 50 to 60% over the long-term. Increases in SOM due to adoption of zero-tillage or continuous cropping increased N fertilizer requirements initially (thus lowering crop recovery), but ultimately also increased soil N supply. Concepts and implications of long-term crop N efficiency will be presented based on several long-term cropping system studies.

INTRODUCTION

Long-term crop rotation experiments were initiated in western Canada starting in the early 1900s to address questions that are still relevant today: “finding for each soil and climatic zone the system that is at once the most profitable and the most permanent”. These studies enable detection of changes in properties that change too slowly to be measurable within one or several years. For example, SOM is a significant source or sink of crop nutrients, but impacts on soil nutrient supply are difficult to detect due to large reserves and field variability. Slow change and intrinsic variability also exist for soil pH, nutrient balances, soil-borne diseases, soil structure, and accumulation of metals or pesticides.

Most of the change in SOM occurs within one decade for modest changes in land management (e.g., tillage, summer fallow frequency), while significant changes in SOM may continue for several decades following major practice change (e.g., perennial vs. annual cropping) (Figure 1). Long-term cropping studies are valuable to determine the total gain or loss in SOM that can be expected, which can then be utilized to estimate impacts on soil N supply.

The objective of this paper is to review expected changes in SOM from long-term studies in western Canada and implications for nitrogen use efficiency.

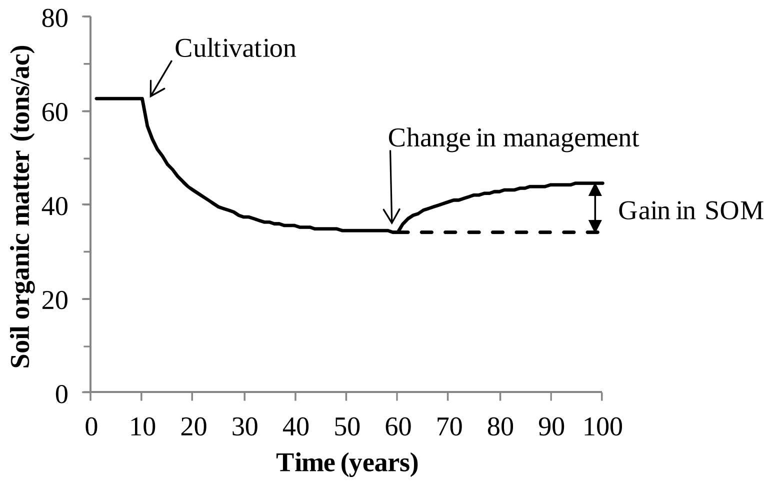

Figure 1 Soil organic matter dynamics following a change in land management.

MATERIALS AND METHODS

Soil samples were obtained from a large range of long-term cropping system studies in western Canada in 2005 using a consistent methodology and used to estimate impacts on SOM (VandenBygaart et al., 2010). Soil organic matter and N budgets were also obtained more recently from the Rotation ABC study in Lethbridge, AB (Karimi et al., 2017) and from the Long Term Rotation Study in Bow Island, AB (Bremer et al., 2011).

RESULTS AND DISCUSSION

Management factors impacting soil organic matter

Cultivation of native prairie grassland reduced soil organic matter by 20 to 40%, releasing up to 4,000 lb N/ac over a period of three to five decades. This was more than enough to meet early crop N requirements for high-protein wheat in the northern Great Plains. However, once a new steady state of SOM was achieved (Figure 1), N inputs were required to maintain agronomic yield and protein levels for cereal crops. With no N inputs, external inputs (e.g., atmospheric deposition) and continued slow decline in SOM were only sufficient to supply about 20 to 30 lb N/ac/year.

Elimination of summer fallow increased soil organic C by 1 to 3 tons/ac (VandenBygaart et al., 2010). Corresponding increases in soil organic N were 150 to 500 lb N/ac, which over a period of ten years is equivalent to an additional N input requirement of 15 to 50 lb N/ac/year.

Similarly, adoption of zero-tillage increased soil organic N by 100 to 500 lb N/ac, mostly within ten years.

In comparison, establishment of perennials may increase soil organic N by 1000 lb N/ac or more, generally over two or more decades and with large variation depending on species, soil and management.

Irrigation and organic amendments also significantly affect SOM dynamics.

Impact on N fertilizer recovery

The long-term recovery of added N fertilizer in harvested products from agricultural systems depends on both the recovery by the immediate crop and the recovery of residual forms by future crops. Recovery of applied fertilizer in harvested products in a 24-year study at Bow Island increased substantially over time in fallow-wheat and grass treatments, indicating appreciable uptake of residual N forms over time (Figure 2). In contrast, recovery of applied N increased slowly in a continuous wheat treatment, which was attributable to greater recovery by initial crops and by limited uptake of residual forms.

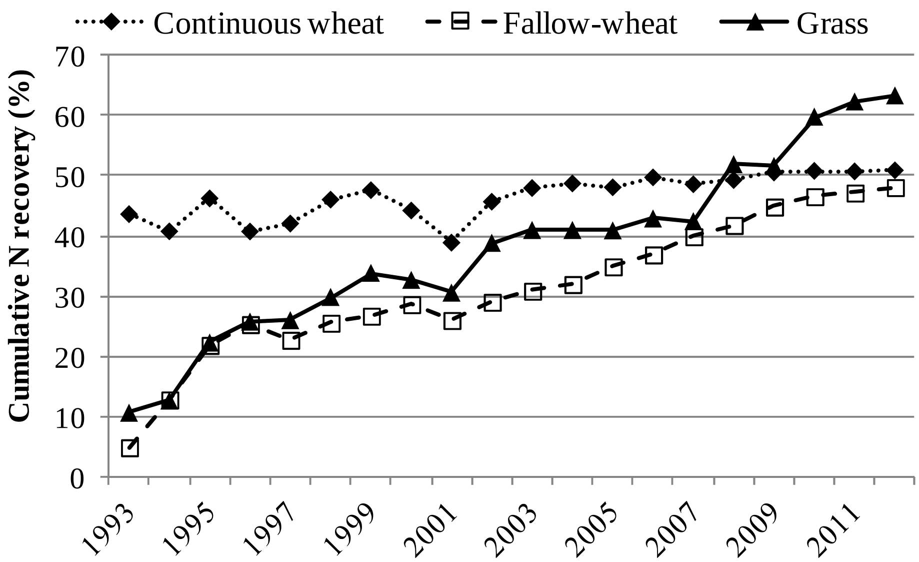

Figure 2 Cumulative recovery of added N fertilizer in harvested products over 24-years as affected by cropping system at Bow Island, AB.

Balanced crop nutrition is also important for long-term N use efficiency. In a long-term study at Lethbridge, AB, not applying P fertilizer reduced N fertilizer recovery by 32% over a 47-year period (Karimi et al., 2017), while in a long-term study at Breton, AB, not applying P, K or S fertilizer over a 75 year-period reduced N recoveries by 65, 28 and 62%, respectively (Miles Dyck, personal communication).

SUMMARY

Changes in land use that increase SOM reduce crop N fertilizer efficiency and increase crop fertilizer N requirements in the short term. However, provided crop recovery of mineralized N is effective, crop fertilizer N requirements will eventually decrease and fertilizer N recovery will increase, generally within a period of about ten years.

REFERENCES

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