The Effect of Agricultural Management Practices on Labile Soil Carbon and Nitrogen in Wisconsin

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ABSTRACT

Amid ever-increasing enthusiasm for soil health there remains uncertainty about how best to measure it, to interpret the results, and to adapt agricultural management accordingly. One factor of particular interest to farmers is the capacity of a soil to mineralize organic matter, making nutrients available to crops. This research takes a survey-based approach to identify how labile carbon (C) and nitrogen (N) – as permanganate oxidizable carbon (POxC), potentially mineralizable carbon (PMC) and potentially mineralizable nitrogen (PMN) – respond to variations in management across six watersheds in Wisconsin. Soil samples were taken from over 200 fields and 40 farms in spring of 2015, 2016 and 2017, before corn planting. Data were analyzed to identify the effect of no-till, cover crops, manure applications and more diverse crop rotations on soils' labile C and N pools via linear regression, multivariate analysis and regression tree analysis. Preliminary results suggest that no-till, cover crops and manure applications did not affect median POxC, PMC and PMN values. This reflects the importance of site specific co-variates in understanding the relationship between management and soil health. Findings from this study will highlight the degree at which these best management practices can improve biological nutrient cycling and thereby reduce fertilizer input requirements across varied landscapes in Wisconsin.

INTRODUCTION

Soil biota play an essential role in cycling nutrients and contributing to soil fertility. This biological nutrient cycling is largely responsible for mineralizing soil nitrogen (N) and carbon (C), converting it from organic to inorganic pools. Several studies have found that microbe-derived mineralization of organic matter supplies the majority of a crop's nitrogen (N) demand (Stevens et al., 2005; Schindler and Knighton, 1998; Franco et al., 2011; Kramer et al., 2002). Under ideal conditions, N mineralization of soil organic matter could even meet the peak N demand for corn (Osterholz et al., 2016). This labile portion of N and C (i.e. the portion that cycles quickly through the soil system) is considered an important indicator of soil health.

The relationships between soil health measurements of labile C and N, field characteristics, management practices and yield have not been widely investigated across working farms, particularly not in Wisconsin. This research takes a survey-based approach to identify if and how measures of labile C and N – as permanganate oxidizable carbon (POxC), potentially mineralizable carbon (PMC) and potentially mineralizable nitrogen (PMN) – relate to one another and to variations in management. Soil samples from over 200 farm fields across six watersheds in Wisconsin were evaluated. The objectives of this research are:

1. To better understand which soil factors and management practices play the largest role in building labile C and N pools.
2. To further qualify which soil tests are the most sensitive to changes in management.

MATERIALS AND METHODS

Soil samples were collected from over 200 farm fields representing 6 watersheds across Wisconsin during the spring of 2015, 2016 and 2017 (See Figure 1). Composite soil cores were taken to a depth of 1 foot from each field prior to corn planting. Soils were frozen for roughly one week before being sent to a lab to be dried, ground and subject to routine analysis (pH, SOM, P, K, Mg, Ca). Soil health tests for labile C and N were conducted on the remaining dried and ground soil.

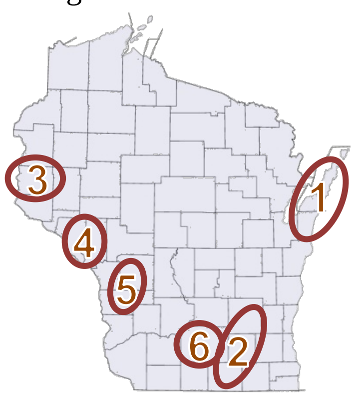

Figure 1 – Soil samples were collected from farms in 6 watersheds of WI:
1= Ahnapee;
2=Dodge-Jefferson-Rock;
3=Elk Creek;
4=Dry Run;
5=Jersey Valley;
6=Yahara

Tests for Labile C and N

Methods of measuring labile carbon (C) and nitrogen (N) were selected based on their being relatively quick and affordable. Among the soil health tests that meet these criteria, potentially mineralizable carbon (PMC), potentially mineralizable nitrogen (PMN), and permanganate oxidizeable carbon (POxC) were identified as particularly effective and practical tools for measuring these labile pools. PMC has been described as the best predictor of soil organic matter mineralization and crop agronomic performance (Hurriso et al., 2016; Culman et al., 2013; Franzleubbers et al., 2000). POxC measures the soil carbon (C) that is most sensitive to changes in management and is an early indicator of soil C sequestration (Culman et al., 2012; Morrow et al., 2015). PMN measures microbial mineralization of soil organic nitrogen and has been tied to corn grain yield and biomass (Culman et al., 2013). These tests have been adopted by a number soil testing laboratories and are part of the Comprehensive Soil Health Assessment (CASH) developed at Cornell University.

POxC values were determined using the methods described by Weil et al., 2003. Two mL of 2 M $KMnO_4$ and 18 mL of deionized water were added to 2.5 g of soil in a 50 mL centrifuge tube. The mixture was shaken at 120 rpm for 2 minutes, after which it was given 10 minutes to settle in a dark place. Using a pipette, 0.5 mL of supernatent was transferred to a centrifuge tube with 49.5 mL of deionized water. The resulting solution was mixed, transferred to a plate and the resulting value for oxidized carbon was determined colorimetrically using a photospectrometer.

PMC values were determined by placing 10 g of soil inside a small plastic cup, which was set inside of a quart-sized jar. The soil was rewetted to 60% water filled pore space using deionized water and by evenly dripping the water from above using a pipette. The jar was capped with a lid containing air-tight valves and placed in an incubator at 25˚C for 24 hours. Afterwards, CO_2 was measured using a flow-through system whereby air was cycled from the jar into a LiCore-820 CO_2 gas analyzer and back to the jar. Concentrations were recorded in ppm every second via computer until the CO_2 levels stabilized. Each batch included a blank and standard soil and calibration gases of 0 ppm, 1000 ppm, and 5000 ppm of CO_2 were used to ensure accuracy. The 0 ppm N_2 gas was run through the system between each soil to standardize results.

To obtain PMN values, we followed the methods described by Drinkwater et al. (1996). Five grams of each soil sample was weighed three times and added to 50 ml centrifuge tubes. 50 mL of 2M KCl was added to the first centrifuge tube, placed on a shaker at 120 rpm for 1 hour and then centrifuged at 1320 rpm for 5 minutes. The supernatent was filtered and approximately 15 mL was added to plastic viles and frozen. Ten mL of deionized water was added to the remaining two centrifuge tubes, which were capped and incubated at 40˚C for 7 days. Afterwards, 40 mL of 2.5M KCl was added and, following the same steps, shook the solution for 1 hour, centrifuged them, and froze roughly 15ml of filtered supernatent. The liquid extracts were thawed and ammonium values were obtained using Berthelot reagents and colorimetry using a photospectrometer.

Farm Management Practices

In order to determine the influence of agricultural management practices on labile C and N, in-person interviews were conducted with each of the farmers. Information was collected to capture the effects of recent influences (e.g. the previous crop in the field, timing of manure applications in the past season, etc.) as well as long term management (e.g. number of years in a given crop rotation). The recording of long-term management history was conducted in summer 2017.

The following definitions were used to categorize farms. “Minimum Tillage” includes fields managed only with no-till, strip till, or vertical tillage implements, and/or field cultivators. “Tillage” refers to fields that used moldboard plows, chisels, discs, or subsoil rippers. “Manure” fields received manure in the previous year, whereas “No manure” fields did not. “Cover crops” includes only those fields planted with cover crops the prior winter.

RESULTS AND DISCUSSION

Agricultural Management Effects

Using the described parameters for categorizing agricultural practices, comparisons were made between farms that have implemented specific practices (i.e. no-till, manure applications, and cover crops) and those that have not. As shown in Figures 2-4, any single practice did not show clear effects on labile carbon or nitrogen pools. This is likely due to site specific covariates, including variation across farms’ soil type and local climate. These results demonstrate that it is not universally true that reduction in tillage, manure additions, or cover crop use increase soil biological measures of soil health.

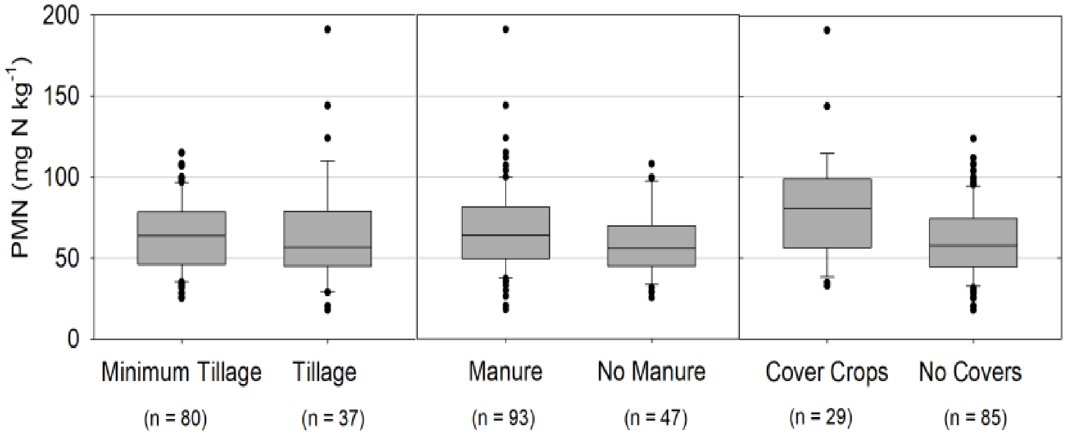

Figure 2 – A change in just one agricultural management practice shows no effect on potentially mineralizable nitrogen (PMN).

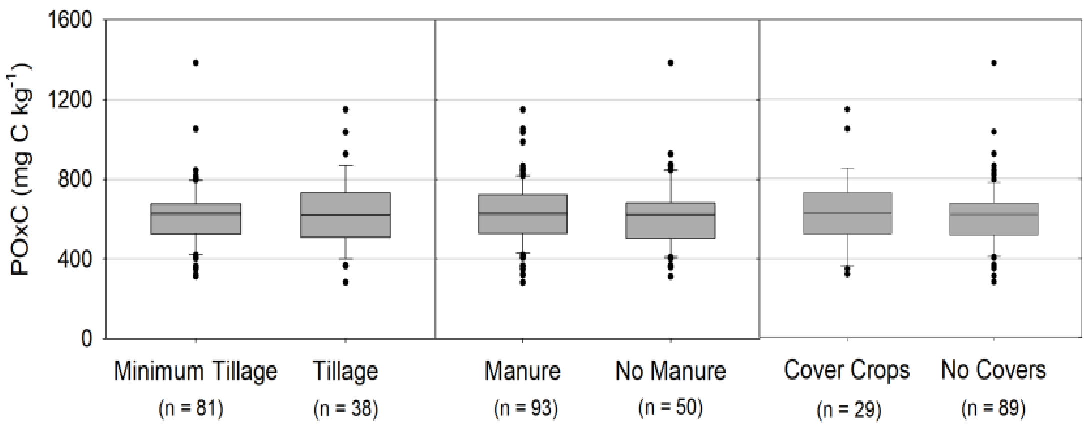

Figure 3 – A change in just one agricultural management practice shows no effect on permanganate oxidizable carbon (POxC).

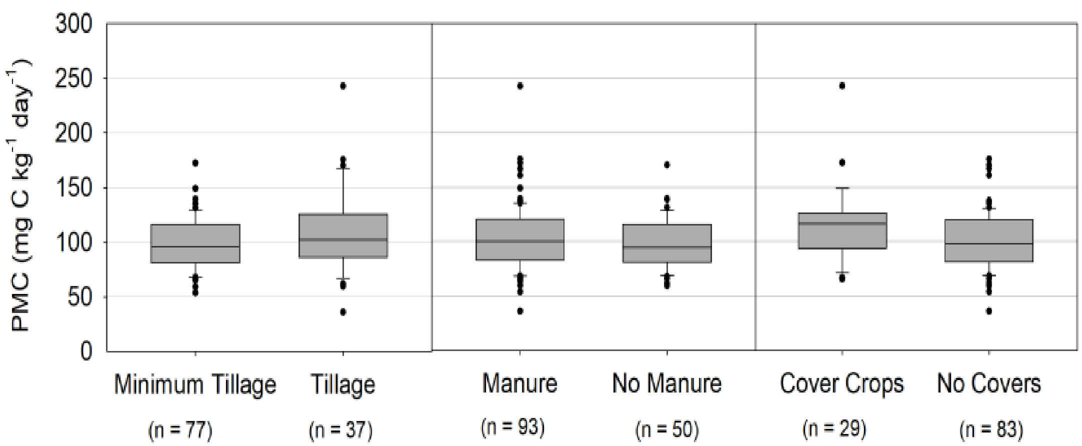

Figure 4 – A change in just one agricultural management practice shows no effect on potentially mineralizable carbon (PMC).

Given the findings, additional analyses could be applied to identify the influence of these management practices on labile C and N in soil. Advanced regression techniques like regression tree analysis would enable incorporation of additional co-variates and may be more appropriate for analyzing survey-based soil health data. Further incorporation of long-term management histories could help differentiate farms based on their management practices. In addition, future research could analyze how the combination of these practices influence results rather than each in isolation.

Relationship of Labile Tests to SOM

Results from the three labile C and N tests were analyzed using linear regression to determine their relationship with soil organic matter (SOM). For the soils collected in 2015 and 2016, the R^2 values range between 0.20 and 0.40 (Figures 5-7). This indicates that each test explains less than half to less than a quarter of the variation in SOM. As such, these tests of labile C and N generate results that are distinct from total SOM. This is expected, as labile pools generally account for only 5-10% of SOM and are more prone to change than the remaining stable organic matter fractions.

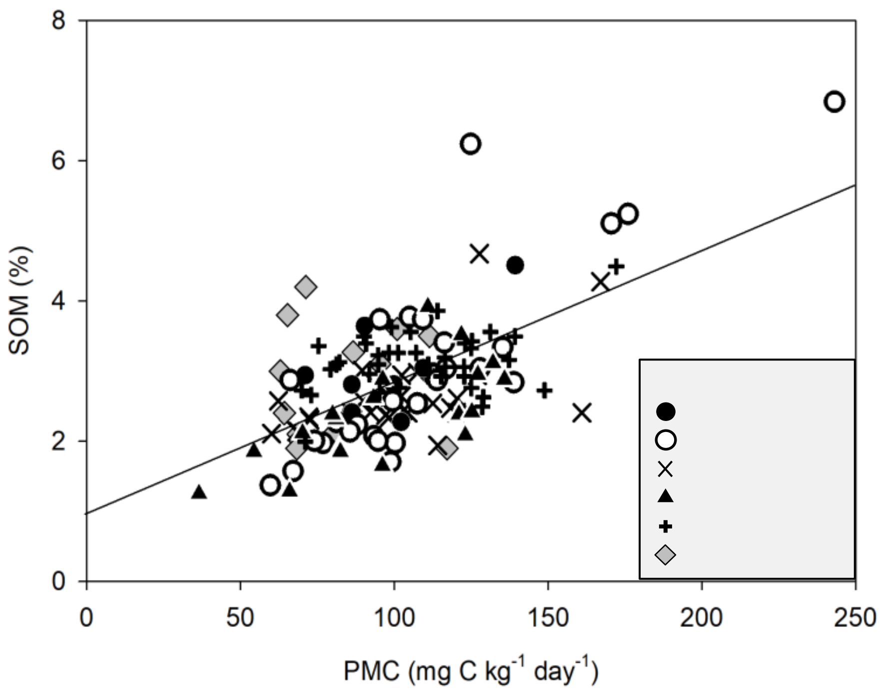

Figure 5 – Linear regression analysis comparing SOM and PMC shows that 40% of the variation in PMN is described by SOM.

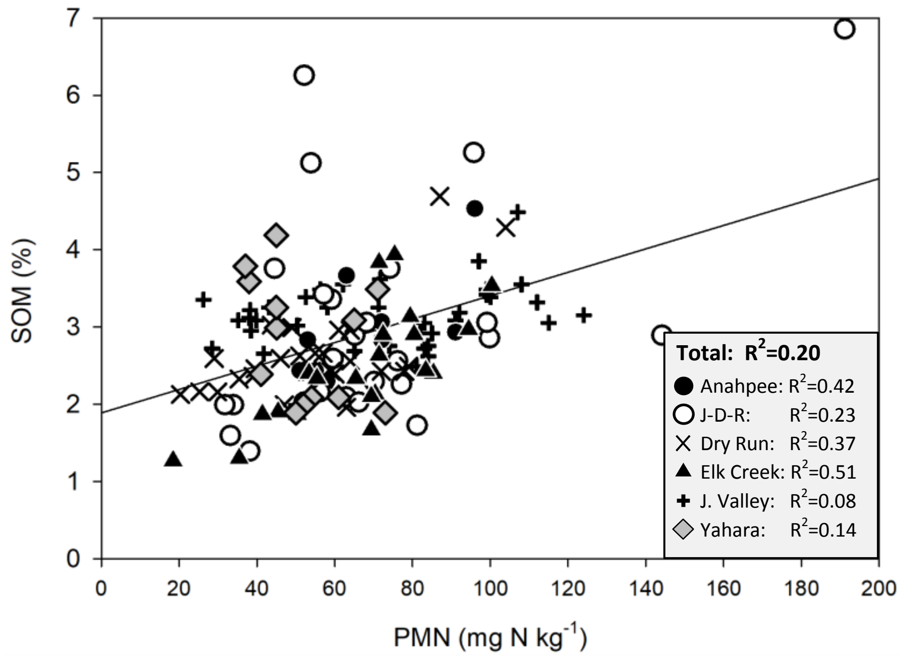

Figure 6 – Linear regression analysis comparing SOM and PMN shows that 20% of the variation in PMC is described by SOM.

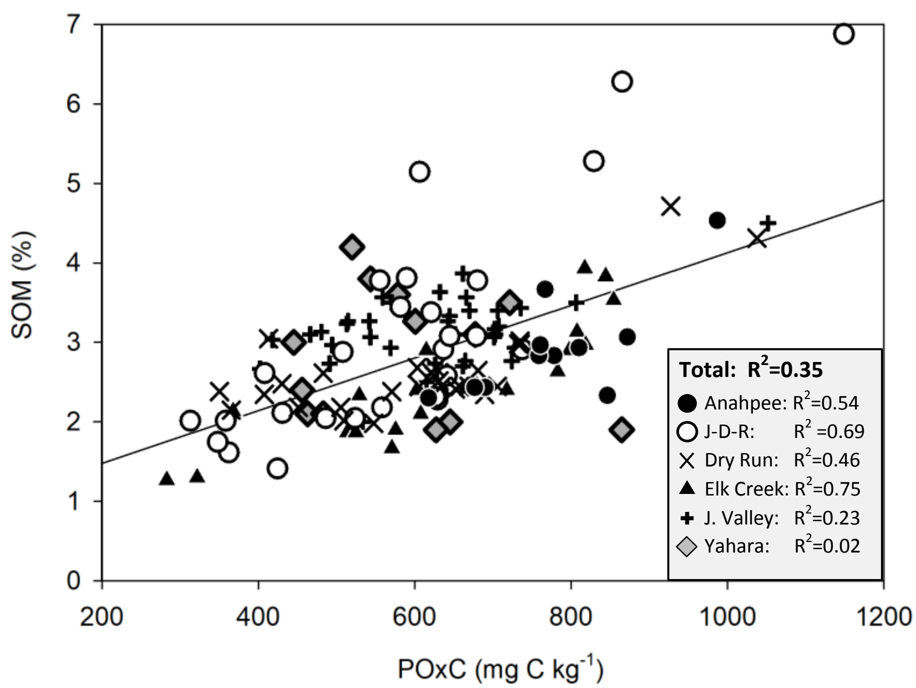

Figure 7 – Linear regression analysis comparing SOM and POxC shows that 35% of the variation in POxC is described by SOM.

SUMMARY

The three tests used to measure labile pools of C and N (PMC, PMN, and POxC) were not dependent on SOM values and thus can be valuable measurements, independent of organic matter tests. The implementation of specific management practices (e.g. no-till, cover crops, and manure applications) did not appear to directly influence these biological measures of soil health, yet this includes fields from a range of soil types and local climates. Future research will utilize regression tree and multivariate analyses, which may be better suited for identifying the factors that impact labile C and N pools using a survey based approach.

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