Cropping Intensity Effects on Organic Carbon, Aggregate Stability, and Hydraulic Properties of a No-till Silt Loam

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Abstract

Improved no-till management techniques have allowed greater cropping intensity in the central Great Plains. Organic carbon (OC) contents in the soil have increased because of greater plant biomass production and less carbon loss from oxidation. This study investigated the improvement of soil physical properties caused by increased OC in the soil. The plots were located at the Central Great Plains Research Station at Akron, Colorado in a Weld silt loam. Samples were collected at depth increments of 20-95 mm, 115-180 mm, 200-275 mm, and 295-370 mm. We measured OC increase from plots in a winter wheat–fallow rotation (WF), a winter wheat, corn, millet rotation (WCM), and a permanent grass treatment in 2005, after 15 years in the respective system. The permanent grass plots had the greater OC, greater water stable soil macroaggregates (> 0.25 mm), and greater saturated hydraulic conductivity compared with cropped plots. Plots with the WCM rotation had greater OC and macroaggregates than plots with the WF rotation. There were no cropping system effects on bulk density or pore size distribution. The greatest OC for all plots was in the surface Ap horizon. The greatest macroaggregation was in the Bt2 horizon at a 295-370 mm depth. There was poor correlation between OC and macroaggregation but a good correlation between macroaggregation and other soil properties. Increasing soil OC may improve soil properties over time but many years may be needed in this environment for measurable improvements to be noted. Investigation is needed in the constituents of soil OC provided by continuous grass species to identify the cause of the greater effects these species have on improving soil properties compared with crop species.

Introduction

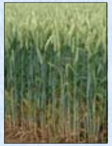
❖ Water savings in no-till agriculture has allowed increased cropping intensity.

❖ Traditional winter wheat (*Triticum aestivum* L.) – fallow rotations are steadily being replaced by more intensive rotations including summer crops such as corn (*Zea mays* L.), millet (*Panicum miliaceum* L.) , or sunflower (*Helianthus annus* L.).

❖ Increasing cropping intensity has led to increased organic carbon in the soil, particularly at the soil surface.

Objective

The objective of this study was to quantify changes in soil physical properties such as aggregate stability, bulk density, water storage porosity, and saturated hydraulic conductivity as related to changes in soil organic carbon.



Materials and Methods

Location: Central Great Plains Research Station USDA-ARS Akron, Colorado. (40.15° N lat, 103.15° W long, elev.1384 m)

Soil: Weld silt loam (fine, smectitic, mesic Aridic Paleustolls)

Plot Design: Randomized Complete Block
Three replications
First planting in 1990

Rotations: Winter wheat – Fallow (WF)

Winter wheat – Corn – Proso Millet (WCM)

Permanent Grass 45% smooth brome (*Bromus inermis* Leyss.), 40% pubescent wheat grass (*Agropyrons trichophorum* [Link] Richt.), 15% alfalfa (*Medicago sativa* L.)

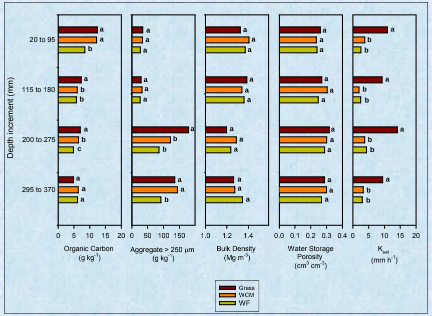
Tillage: All plots were no-till. Plots are maintained with controlled wheel traffic and samples were collected from non-trafficked areas.

Sampling time: Corn and millet samples – Spring, 2005, before planting
Wheat, Fallow, Grass samples – Summer, 2005, after harvest

Sampling depths: 20-95 mm
115-180 mm
200-275 mm
295-370 mm

Measurements: Organic Carbon (OC)
Water-stable Macro-aggregate (aggregates > 250 μm)
Bulk Density (ρ_b)
Water Storage Porosity (WSP)
Saturated Hydraulic Conductivity (K_{sat})

Figure 1. Cropping system effects on soil chemical and physical properties



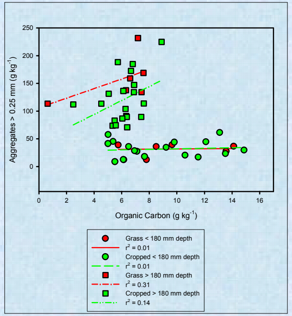
❖ Increased cropping intensity increased OC at depth 1 (20-95 mm)

❖ Most of the macro-aggregate change occurred in depth 3 (200-275 mm) and depth 4 (295-370 mm)

❖ There was no change in ρ_b or WSP caused by change in cropping intensity or OC

❖ K_{sat} was consistently greater, at all depths, in the grass plots compared with the cropped plots

Figure 2. Correlation between organic carbon and macro-aggregate stability at 0 to 180 mm depth and 180 to 370 mm depth.



❖ Little correlation between OC and aggregate stability in the surface 180 mm.

❖ Greater correlation between OC and aggregate stability below 180 mm.

❖ Similar correlations between OC and other physical and hydraulic properties such as K_{sat}, WSP and ρ_b

❖ Different microbial communities supported by each cropping systems may affect the bonding agents in aggregation leading to different relations between OC and other physical properties.

Acknowledgments

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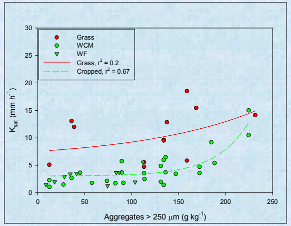
Figure 3. Correlation between macro-aggregates and saturated hydraulic conductivity, all depths combined.



❖ The r^2 between aggregate stability and K_{sat} for the grass plots was only 0.20 indicating a poor dependence of K_{sat} on aggregate stability.

❖ The r^2 between aggregate stability and K_{sat} for the cropped plots (WF and WCM) was 0.67 indicating a greater dependence of K_{sat} on aggregate stability

❖ Aggregate stability may be a better indicator than OC of improvements of other soil physical properties, such as K_{sat},.

Conclusions

❖ Soil OC increased with increasing cropping intensity

❖ Increased soil OC did not directly correlate with increased aggregate stability, increased water storage porosity, lower bulk density or increased saturated hydraulic conductivity.

❖ Aggregate stability and saturated hydraulic conductivity were greater for the grass plots than for the cropped plots, for the same soil OC content, indicating greater bonding of soil particles under grass vegetation.

❖ It is likely that the increased aggregate stability and saturated hydraulic conductivity in grass plots, compared with the annually cropped plots, is caused by a combination of greater root penetration and persistence combined with a microbial community that exudes more effective bonding agents to stabilize the aggregates and pore network.

❖ More emphasis on root architecture, root-associated rhizosphere communities, and microbial exudates seems warranted to quantify mechanisms for changes in soil physical conditions caused by changing cropping systems.