Soil Organic Carbon Dynamics of Tree Windbreaks in the U.S. Great Plains

INTRODUCTION

Tree windbreaks (linear arrangements of trees & shrubs) have been planted extensively in the U.S. Great Plains since the 1930s. They have long been recognized for their ability to sequester carbon in soils and tree biomass. Along with carbon-sequestration, tree windbreaks provide multiple ecological services such as enhancing local microclimate, improving crop growth, protecting crops from damaging winds, and controlling wind erosion (Fig.1). Trees do offer a great potential to improve soil quality of degraded or marginal lands.

OBJECTIVE

To quantify carbon sequestration potential and the changes in relevant soil properties beneath windbreak plantings located throughout the Northern Great Plains (NGP) region.

METHODS

Two sites were identified in each of 4 NGP states (ND, SD, KS, NE; see fig. 2 & table 1) that represent common windbreak plantings and soils of the region, with a range of mean annual temperature (MAT) of 6.8 to 12.8 °C, mean annual precipitation (MAP) of 569.7 to 832.7 mm.

Soil samples were collected to ~ 1.5 m depth within tree plantings and adjacent crop field from soil pits and two adjacent hand auger holes.

Soil was passed through 2mm sieve, air-dried, & roller-milled before soil organic carbon and total nitrogen determination by dry combustion on a Fison NA 15000 E-Analyzer.

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EXAMPLE FINDINGS

For All Study Sites

Figure 3: 1; TN(kg m⁻²) and 2; SOC Stocks to 1.25 m (kg m⁻²) for all study sites

McPherson Site, KS

Figure 4: 1; SOC Concentration (g kg⁻¹) and 2; SOC Stocks (kg m⁻²) for McPherson site, KS

Figure 5: 1; Bulk Density (g cm⁻³) and 2; Hydraulic conductivity (cm hr⁻¹) for McPherson site, KS

Table 1: Summary of study sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Soil</th>
<th>Tree (age-year)</th>
<th>Crop (age-year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McLeod, ND</td>
<td>Fine Sand</td>
<td>Ponderosa pine</td>
<td>Ponderosa pine</td>
</tr>
<tr>
<td>Medora, ND</td>
<td>Clay Loam</td>
<td>Elkhorn oak</td>
<td>Elkhorn oak</td>
</tr>
<tr>
<td>Corinna, SD</td>
<td>Silty Clay</td>
<td>Honey locust</td>
<td>Honey locust</td>
</tr>
<tr>
<td>Corinna, SD</td>
<td>Silt Loam</td>
<td>Quakies knowlton</td>
<td>Quakies knowlton</td>
</tr>
<tr>
<td>Medora, ND</td>
<td>Silty Clay</td>
<td>Green ash</td>
<td>Green ash</td>
</tr>
<tr>
<td>Medora, ND</td>
<td>Silt Loam</td>
<td>Alder</td>
<td>Alder</td>
</tr>
<tr>
<td>McPherson, KS</td>
<td>Loam</td>
<td>Black locust</td>
<td>Black locust</td>
</tr>
<tr>
<td>Marquette, KS</td>
<td>Silt Loam</td>
<td>Elkhorn oak</td>
<td>Elkhorn oak</td>
</tr>
</tbody>
</table>
| 1 Water Stable Aggregates (WSA) % 0-10 cm  1 Distribution and Stability of WSA 0-10 cm depth

- Tree
- Crop

Figure 7: 1; WSA % at 0-10 cm depth and 2; Distribution and Stability of WSA, McPherson, KS

Preliminary Summary

SOIL ORGANIC CARBON AND TOTAL NITROGEN

SOC stocks in the soil to 1.25 m beneath tree plantings were an average 2.9 kg m⁻² greater than adjacent pastures, hay, and row crop fields. However, two sites had lower stocks beneath tree plantings. (Figure 3.2)

Differences in SOC stocks between tree plantings and the adjacent fields ranged from +10.5 to -5.0 kg m⁻². Trends in TN content followed very closely with those for SOC content. (Figure 3.2)

The relationships among land uses with depth for SOC on a mass basis (kg m⁻²) followed similar patterns as for SOC concentration but with some differences due to variation in soil bulk densities.

SOIL PHYSICAL PROPERTIES

Generally, lower bulk densities were observed for soils beneath trees and in surface layer. (Figure 5.1)

Kₑₑₑ at the 0-5 cm depth is higher for trees than for crops. (Figure 5.2)

The preliminary data indicates increased macroaggregate stability beneath trees relative to crops. (Figure 7.1 and 7.2)

ECOSYSTEM AND ECONOMIC BENEFITS

Trees offer great potential to improve soil quality of degraded or marginal lands primarily through fundamental changes in organic matter and nutrient cycling.

Trees can provide food, fiber, and fuel. Aside from this, trees also provide shade for crops and animals, and do contribute to diversify on-farm income streams.

As part of the broader project funding this research, a social survey found that 61% of Northern Great Plains farms and ranch operators have some degree of interest in woody biomass production, particularly in the context of biomass within conservation practices such as windbreaks.

Continued Work

More investigation, analyses, and interpretations are still needed; our final work will include:

- Root and tree biomass measurements are scheduled for summer 2017.
- Measuring tree biomass and plant tissue analyses.
- Climate data (the relationship between soil organic carbon and climate).
- Carbon isotope analyses to determine source of SOC.
- Correlations between SOC and various soil properties including pH, bulk density, particle size, particular organic matter, hydraulic conductivity, and aggregate stability will be investigated to ascertain any functional relationships.