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Depth distribution of soil organic matter as a tool to evaluate restoration of critical soil functions

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Introduction

Soil organic matter sustains many key soil functions by providing the energy, substrates, and biological diversity to support biological activity, which affect:

- ☐ aggregation (important for habitat space, oxygen supply, and preventing soil erosion),
- ☐ infiltration (important for leaching, runoff, and crop water uptake)
- ☐ decomposition (important for nutrient cycling and detoxification of amendments)

Lack of residue cover and exposure of soil to high-intensity rainfall results in:

- ☐ poor aggregation
- ☐ reduced plant water availability
- ☐ erosion
- ☐ off-site impacts of sedimentation and poor water quality

My hypothesis is that degree of soil organic matter stratification with depth can be used as an indicator of "soil quality", because surface organic matter is essential to erosion control, water infiltration, and conservation of nutrients.

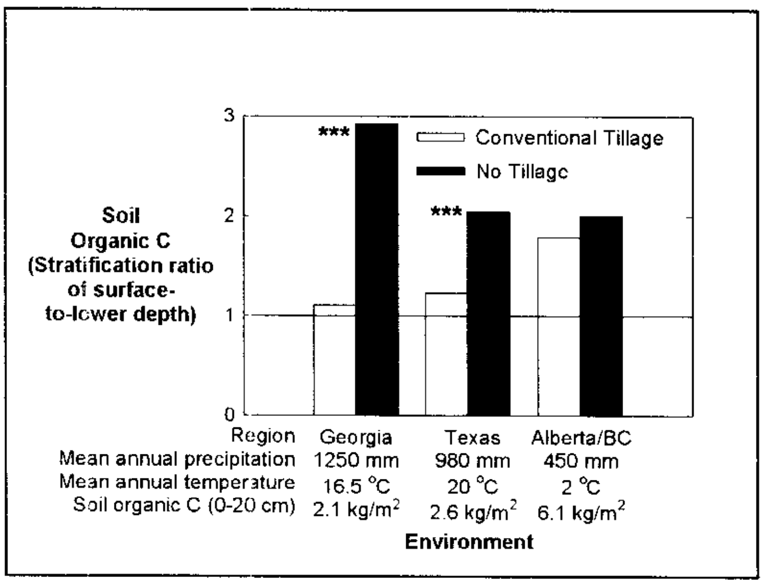

Figure 1. Soil organic matter stratification under conventional and no tillage in Georgia, Texas, and Alberta/British Columbia. *** indicates significance between tillage management within an environment at $P<0.001$.

Stratification ratio overcomes the limitation that each environmental region has a unique background level of soil organic matter. For example, soils in cold regions often contain organic matter levels much higher than in warm regions, irrespective of management. The absolute amount of soil organic matter alone would not be useful across regions of whether a particular management strategy were improving soil quality (Fig. 1).

My objective was to quantify the effects of soil disturbance on:

- ☐ soil organic C depth distribution
- ☐ soil bulk density and porosity
- ☐ infiltration rate

Materials and methods

Two sites under ~25 years of continuous management were selected near Watkinsville, Georgia, USA. Management systems were long-term conventional tillage (CT) with winter small grains and long-term no tillage (NT) with summer/winter double cropping. Soil under CT had not been tilled for ~14 months prior to sampling, which resulted in a consolidated soil that was free from recent disturbance. Soils were Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults). Long-term mean annual temperature is 16.5 °C, precipitation is 1250 mm, and potential evapotranspiration is 874 mm (Fig. 2). Mean elevation is 230 m.

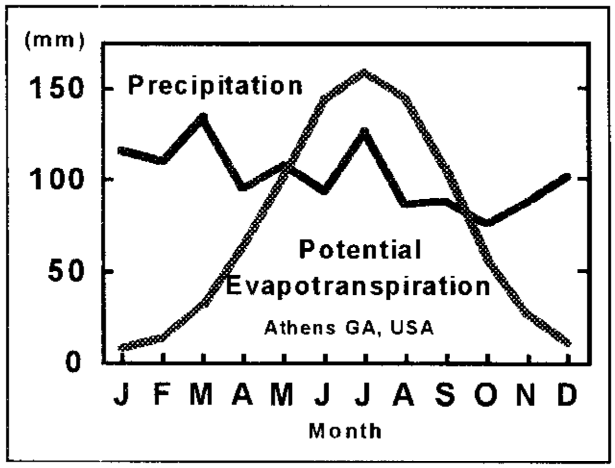

Figure 2. Long-term mean monthly precipitation and potential evapotranspiration recorded at a nearby weather station.

Twenty-four soil cores (15-cm diam, 12-cm deep) were collected within each long-term management system from an area of approximately 3 m^2 in January 2000. Polyvinyl chloride tubing (15-cm long) was pushed gently into the soil with a hydraulic probe. Half of the soil cores from both long-term management systems were sieved (<8 mm), mixed, and repacked into cores to create a uniform distribution of organic matter. Intact soil from long-term CT served to separate recent disturbance effects from stratification effects on water infiltration and other soil properties.

Soils were incubated in a glasshouse for 13 weeks. Water was applied to each soil core at a rate of 28 mm within a 10 second period. The time required for all water to pass through the soil surface was recorded. Leachate was collected the following day and analyzed for ammonium, nitrate, and phosphate. Soil organic C and N and bulk density were determined at depths of 0-1, 1-3, 3-6, and 6-12 cm at 2, 6, and 13 weeks.

Results and discussion

Soil organic C was uniform with depth when tilled (either in the short-term or in the long-term), but highly stratified when soil under long-term NT remained intact (Fig. 3). Soil organic C under long-term NT was nearly double that under long-term CT. Stratification ratios were 1.0 with sieving of both soils, 1.4 when intact under long-term CT, and 5.7 when intact under long-term NT.

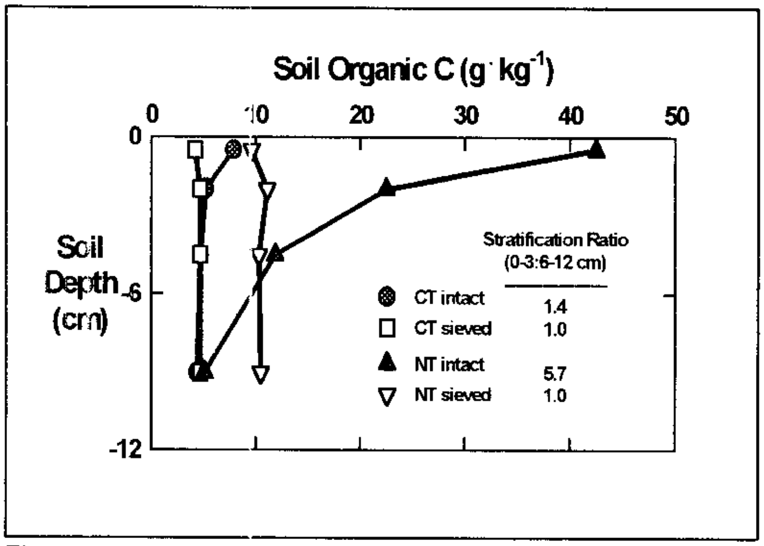

Figure 3. Soil organic C depth distribution as affected by long-term management (CT or NT) and short-term disturbance (sieved or intact).

Soil bulk density was inversely related to soil organic C (Fig. 4). Recent disturbance by sieving alleviated some compaction of the soil under long-term CT at depths below 1 cm. Disturbance by sieving in the soil under long-term NT, however, caused greater soil bulk density at the soil surface and lower bulk density at depths of 3-6 and 6-12 cm. The higher organic matter content of the soil under long-term NT helped to alleviate more of the compaction at lower soil depths. Stratification ratios of bulk density were near 1, except under intact soil under

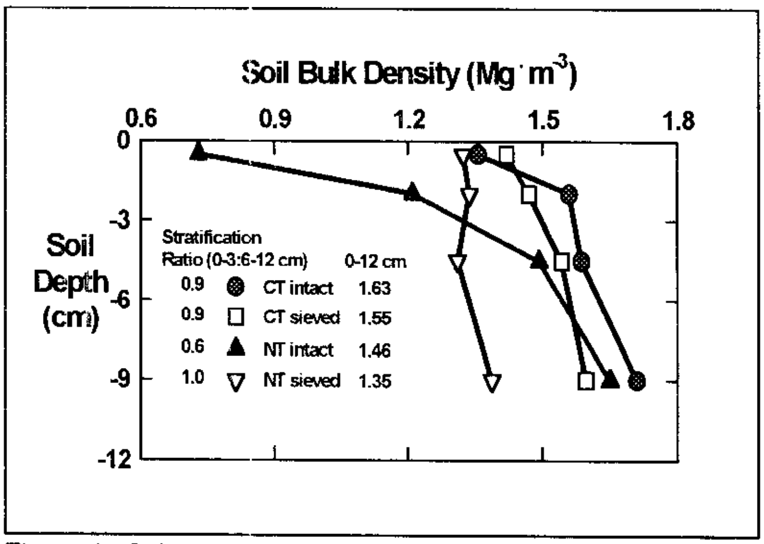

Figure 4. Soil bulk density as affected by long-term management (CT or NT) and short-term disturbance (sieved or intact).

long-term NT.

Infiltration rate during the 13 weeks of incubation averaged 18 cm · hr^{-1} with intact and sieved soil under long-term CT, 26 cm · hr^{-1} with sieved soil under long-term NT, and 68 cm · hr^{-1} with intact soil under long-term NT. Infiltration rate decreased logarithmically with time in both soils that were intact, due to degradation of soil surface condition (Fig. 5). Infiltration rate was positively related to stratification of both soil porosity (inverse relationship to bulk density) and soil organic C. Sensitivity as a predictive tool would be better with soil organic C than with soil porosity, because very small changes in soil porosity were associated with large changes in infiltration rate. Soil porosity may be more directly related with infiltration rate, but soil organic C is highly associated.

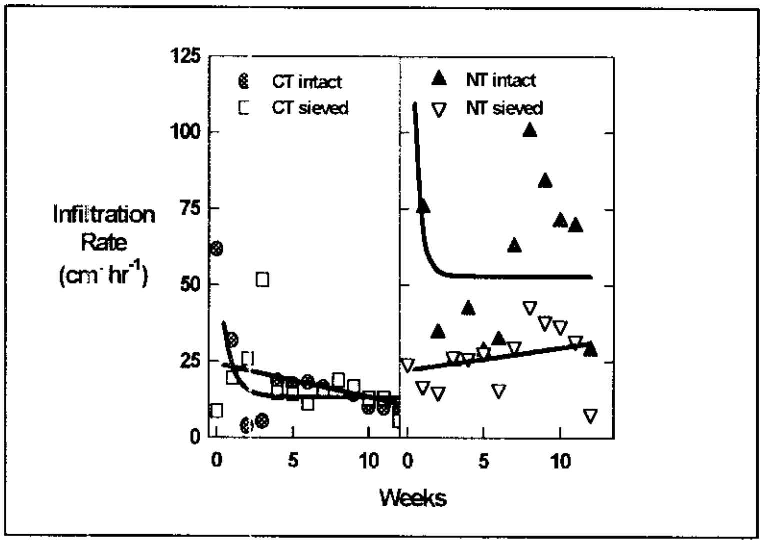

Figure 5. Ponded infiltration rate in soil as affected by long-term management (CT or NT) and short-term disturbance (sieved or intact).

Summary and conclusions

Tillage of previously stratified soil:

- ☐ led to uniform distribution of soil organic C
- ☐ reduced soil bulk density and increased water retention, at least initially

Greater total soil organic C content:

- ☐ reduced soil bulk density by 13%
- ☐ improved water infiltration by 44%

Greater stratification of soil organic C content:

- ☐ reduced soil bulk density by 10%
- ☐ improved water infiltration nearly 4-fold

Stratification ratio of soil organic C could be used as a simple diagnostic tool to identify land management strategies that can restore critical soil functions.