No-Till Management Effects on Soil Water and Wind Erodibility Parameters

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Summary

The extent to which no-till management improves water and wind erodibility parameters is not well understood. This study assessed changes in aggregate resistance to raindrops, dry aggregate wettability, and dry aggregate stability as well as their relationships with changes in soil organic carbon concentration in the central Great Plains. Three long-term tillage systems (conventional tillage, reduced tillage, and no-till) were studied at four sites across the central Great Plains: Hays and Tribune, KS, Akron, CO, and Sidney, NE. The kinetic energy of simulated raindrops required to disintegrate 4.75- to 8-mm aggregates from no-till soils was between two and seven times greater than that required for conventionally tilled soils in the 0- to 1-in. depth in all soils. No-till soils delayed water entry into aggregates by four times at Akron and Hays and by seven times at Sidney and Tribune compared with plowed soils. Aggregates from no-till soils were more stable under rain and less wettable than those from plowed soils, particularly at the soil surface. Reduced tillage had lesser beneficial effects than no-till management. Soil organic carbon concentration explained 35% of the variability across soils in aggregate wettability (a measure of how readily aggregates can repel water) and 28% of the variability in resistance to raindrops. Tillage system did not affect dry aggregate size distribution and stability. Aggregates in conventionally tilled soils were either stronger than or equally as strong as those in no-till soils when dry but were less stable when wet. Overall, no-till farming enhanced near-surface aggregate properties affecting water erosion but had small or no effects on dry aggregate stability.

Introduction

Characterization of near-surface soil aggregate structural properties such as aggregate size distribution, stability, and aggregate wettability is crucial to predicting soil erosion potential, structural development, and soil organic carbon dynamics. In fact, knowledge of resistance of near-surface soil aggregates to erosive forces of wind and rain is critical in determining the extent to which a soil will erode. This is especially important in semiarid regions, such as the Great Plains, where low precipitation, high evaporation, and variable and low biomass production in interaction with intensive tillage can alter aggregate properties and accelerate soil's susceptibility to wind and water erosion.

Most producers are aware that no-till can help control water and wind erosion because of increased surface residue. Crop residue helps diminish the impact of raindrops and reduces the erosive power of wind at the soil surface. What if surface crop residue is sparse in a no-till system? No-till and high surface residue levels do not always occur together. Surface residue may be sparse in no-till if crop yields are very low, if low residue producing crops are a part of the rotation, or if crop residue is removed for biofuels or some other use. Will no-till still help control water and wind erosion under those conditions? The answer to this question depends on whether no-till improves near-surface (upper few inches) soil structural properties. Soil aggregate stability is another factor involved in determining susceptibility of a soil to water and wind erosion. If soil aggregates in the upper layer of the soil are strong and stable, they will be more able to resist breakdown by striking raindrops and withstand the abrasive erosive energy of wind.

Although benefits of conservation tillage for increasing capture and retention of precipitation and intensification of cropping systems are well recognized, effects of these tillage systems on near-surface aggregate structural properties are not well understood. Previous studies have shown that conservation-tillage management may not always increase soil aggregate stability over plowed systems. By leaving crop residues on the soil surface and minimizing soil disturbance, conservation-tillage practices often increase soil organic carbon concentration. In some soils, this increase in soil organic carbon may lead to improved stability of aggregates over plowed systems because materials enriched with soil organic carbon provide organic binding agents to soil, which coalesce microaggregates into stable macroaggregates. Further assessment of tillage effects on near-surface parameters of soil erodibility and their relationships with soil organic carbon across a range of soils is needed.

Objectives of this study were to quantify changes in aggregate properties (e.g., size distribution, stability, resistance to raindrops, and wettability) and study their relationships to soil organic carbon concentration under various long-term tillage systems in the central Great Plains.

Procedures

Four representative long-term (between 19 and 43 years) tillage experiments across the central Great Plains were selected for this study. Field sites were located at Akron, CO, Sidney, NE, and Hays and Tribune, KS. Tillage systems were established in a randomized complete block design at each site. Crop rotations were winter wheat/grain sorghum/fallow at Hays and Tribune and winter wheat/fallow at Akron and Sidney. Soil samples were collected from each treatment plot at each site for the 0- to 4-in. soil depth for determination of aggregate resistance to raindrops, wettability, and dry aggregate stability in late summer 2008.

Aggregate resistance to raindrops was determined by using a raindrop simulator. Wettability of soil aggregates was determined on 4.75- to 8-mm air-dry aggregates by using the water drop penetration time method, which consists of placing a drop of deionized water on top of individual aggregates with a microsyringe and recording time (seconds) required for the drop to completely enter the aggregate. Dry aggregate stability was determined by using a column of sieves with different openings. Soil retained in each sieve was weighed to compute the mean weight diameter of aggregates. Soil organic carbon concentration was determined by the dry combustion method.

Results

Soil Water Erodibility Parameters

No-till farming increased both soil aggregate resistance against raindrops (Figure 1A) and water repellency (Figure 1B) compared with plowed systems, particularly at the soil surface (0- to 1-in. depth). Kinetic energy of raindrops needed for aggregate disintegration in no-till soils was consistently greater than in plowed soils. At Tribune, no-till management increased kinetic energy for aggregate disintegration at all depth intervals from 0 to 4 in. Kinetic energy for aggregate disintegration between reduced tillage and conventional tillage did not differ in most soils. In the 0- to 1-in. depth, water drop penetration time in no-till soils was four times greater at Akron and Hays and seven times greater at Sidney and Tribune compared with plowed soils (Figure 1B). Water drop penetration time values averaged across soils at Akron and Hays were 2.5 seconds for no-till and 0.6 seconds for conventional tillage, whereas at Sidney and Tribune, water drop penetration time averages were 11 seconds for no-till and 1.5 seconds for plowed soils in the 0- to 1-in. depth.

Soil organic carbon in no-till was greater than in plow tillage in most soils in the surface 0 to 1 in. The greater aggregate resistance to breakdown was partly due to the greater soil organic carbon concentration in no-till soils. Kinetic energy of raindrops for disintegration of aggregates increased positively with the increase in soil organic carbon concentration in all soils (Figure 2). Organic matter is the key to the improvement in aggregate stability found in no-till soils. Soils rich in organic carbon most likely provide organic binding agents, which join microaggregates together into stable macroaggregates. The increase in soil organic carbon concentration with no-till farming also reduces rapid wetting of soil aggregates. Soil organic carbon compounds often coat soil aggregates and impart slight hydrophobic properties, which are critical for aggregate stabilization. The slight reduction in water entry into aggregates reduces both aggregate slaking and the amount of soil which will be eroded. Results suggest that soil organic carbon increase with no-till improved aggregate resistance to raindrops by inducing slight water repellency and by binding soil particles into stable aggregates.

The bottom line is that aggregates from no-till soils were more water-stable, less wettable, and had greater organic carbon concentration than soils under conventional tillage. Aggregates of plowed soils were weaker against water and wetting forces because of frequent soil disturbance, which disrupts aggregate formation and accelerates losses of soil organic matter. It is, however, important to note that no-till soils can also become susceptible to water erosion in the long term if crop residue is continually removed at high levels for expanded uses, such as cellulosic ethanol production. Continued removal of residue can eventually reduce wet aggregate stability and other structural parameters influencing soil water erodibility.

Soil Wind Erodibility Parameters

Results of this regional study also show that under very dry soil conditions, aggregates in no-till soils may be no more stable (or even less stable) than those in plowed soils. The lack of differences of dry aggregate stability contrasted with the large and positive effects of no-till on aggregate wettability and resistance to breakdown under raindrops. The greater soil organic carbon enriched materials in no-till soils may have a more positive effect on stabilizing wet aggregates than dry aggregates because of greater adhesive (e.g., glue-like binding substances) forces of organic materials acting in wet aggregates. This finding suggests that no-till soils, if left without residue cover, can be eroded by wind at equal or even at higher rates than plowed soils.

This points out the crucial need for maintaining surface residue cover to protect soil from wind erosion. Residue cover buffers the erosive forces of wind, reduces evaporation, and minimizes abrupt fluctuations in wetting and drying cycles that weaken soil aggregates. No-till soils with limited aboveground biomass production are more vulnerable to wind erosion compared with plowed soils, for which the transient roughness created by tillage may reduce wind erosion.

Under typical no-till conditions with high levels of residue on the surface, wind erosion rates are expected to be lower in no-till soils. Depending on the amount of residue, no-till soils tend to be wetter than plowed soils because of reduced evaporation, which reduces soil detachment by wind. The greater the water content of surface soils, the lower the wind erosion rates.

This regional study shows that no-till farming has large and positive effects on improving soil structural properties and reducing soil water erodibility, even if surface crop residue levels are sparse. But effects of no-till on aggregate properties influencing wind erosion appear to be limited; adequate surface crop residue levels must be maintained for no-till to reduce wind erosion. The ability of no-till to control water erosion has enormous implications because intense rainstorms can cause large losses of soil in semiarid regions. Increasing soil organic concentration through no-till and other best management practices is crucial for reducing soil erosion while improving soil quality and sustaining crop production.

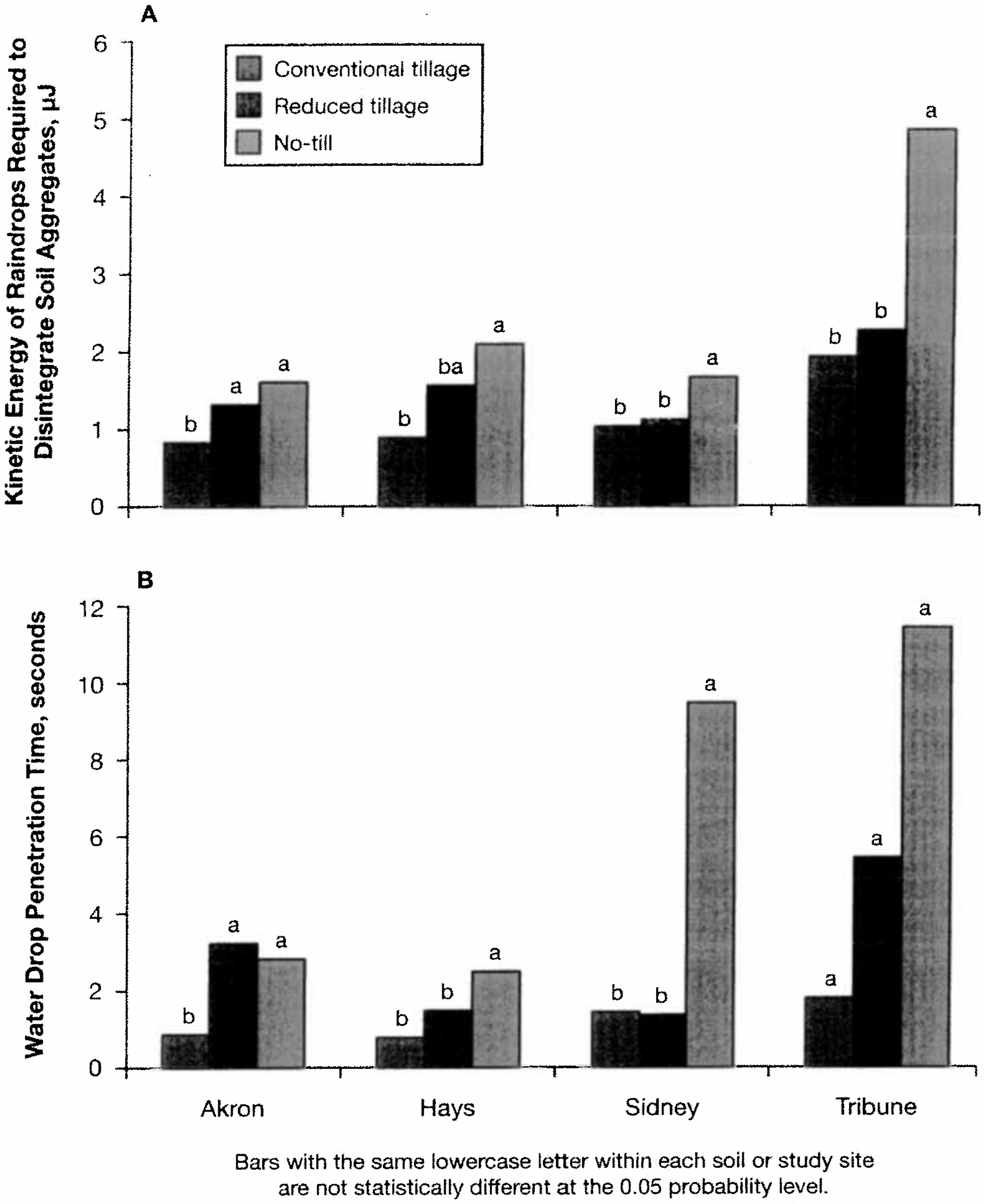

Figure 1. Effect of tillage on two properties of near-surface soil aggregates including (A) resistance to raindrops and (B) water repellency in four soils for the 0- to 1-in. depth in the central Great Plains.

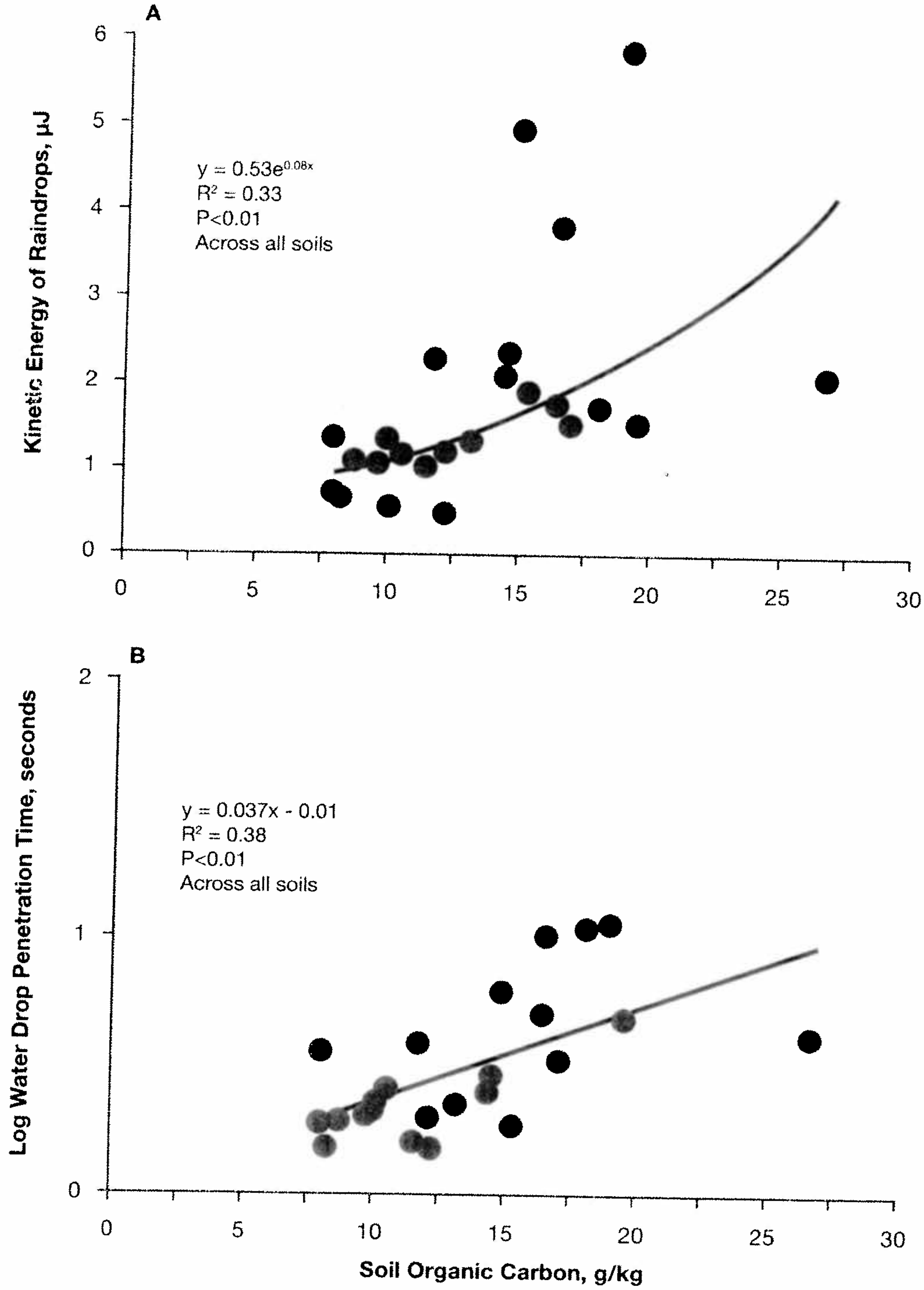

Figure 2. Influence of soil organic carbon concentration on (A) kinetic energy of raindrops required to disintegrate 4.75- to 8-mm air-dry soil aggregates and (B) water repellency across four soils under conventional tillage and no-till in the 0- to 1-in. depth in the central Great Plains.