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Crop Residue and Soil Physical Properties

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INTRODUCTION

Soil physical properties such as bulk density, porosity, water sorptivity, and aggregation dictate the water infiltration characteristics of the soil. Most important are the physical properties of the surface soil as this layer is the initial soil-water interface. Crop residue and tillage management may affect surface soil physical properties important to water capture and infiltration. Management practices that minimally disturb the soil and produce, return, and leave more residue biomass on the soil surface (such as no-till) have the potential to decrease soil bulk density, increase porosity, and increase sorptivity in the soil over time. Also, systems that produce, return, and leave the largest amounts of crop residue in the soil have the highest potential for increased root activity, soil aggregation, and channels that can increase water infiltration.

A study was conducted to determine the effect of crop residue on soil physical properties after 12 years of dryland no-till cropping management in eastern Colorado. Although the study was conducted under dryland conditions the principles behind crop residue and its effect on soil physical properties hold under irrigated condition as well. The objectives of the study were: (1) determine how differing amounts of crop residue affect bulk density, soil porosity, and soil aggregation in the surface 1 inch of soil after 12 years. And, (2) determine how these soil physical properties affect water sorptivity.

MATERIALS AND METHODS

Crop Residue:

Annual post-harvest above ground crop residue samples were collected across 3 cropping systems of increasing production intensity (wheat-fallow, wheat-corn-fallow, and continuous cropping) using a 39.4 inch quadrant for 12 years. Samples were sifted to remove any soil, dried, and weighed. The cropping systems created a gradient of crop residue returned to the system, from relatively low, to relatively high. The overall amount of residue returned to each system over a 12 year period was then tabulated.

Soil Bulk Density and Porosity:

Bulk density was determined using a modified core method. Exact procedures for determining bulk density are listed in Shaver et al. (2002).Samples were collected across 3 cropping systems of increasing production intensity (wheat-fallow, wheat-corn-fallow, and continuous cropping). Soil total porosity was then calculated using bulk density and particle density figures.

Sorptivity:

Sorptivity is defined as the cumulative infiltration proportionality constant and is essentially a measure of the amount time it takes a given head of water to infiltrate. Sorptivity measurements were collected across all positions using rings pushed into the soil surface by hand. Any debris or plant material that could be removed without disturbing the surface was removed. Water was poured into the ring to a depth of 1 cm (.4 inches). A stopwatch was used to measure the time it took for the water to infiltrate. Sorptivity was calculated using the following equation (Smith 1999):

Sorptivity (s) = $1 / \sqrt{t}$ Where: 1 = head of water (cm) t = time (seconds)

Aggregation and Organic Carbon:

Soil samples from each position were collected and then analyzed in the lab to determine aggregate stability. Organic carbon content was also determined from these samples. A detailed synopsis of the procedures are listed in Shaver et al. (2002).

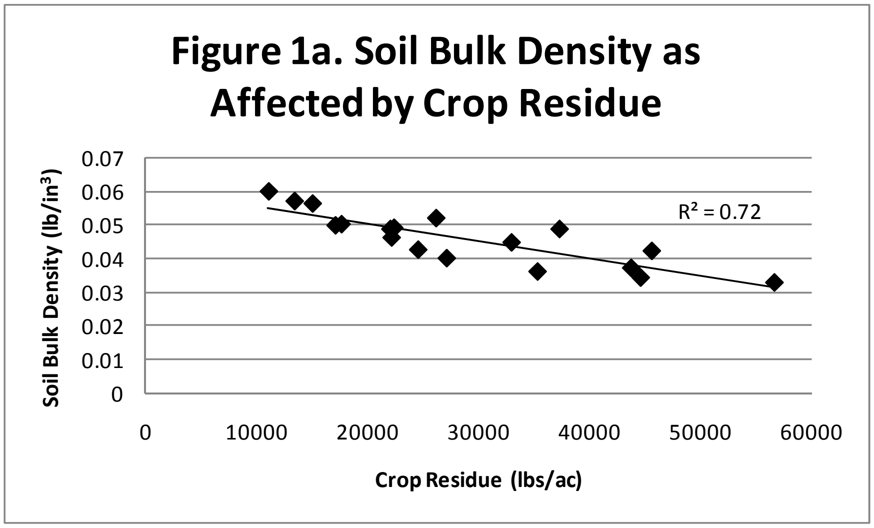
Analysis:

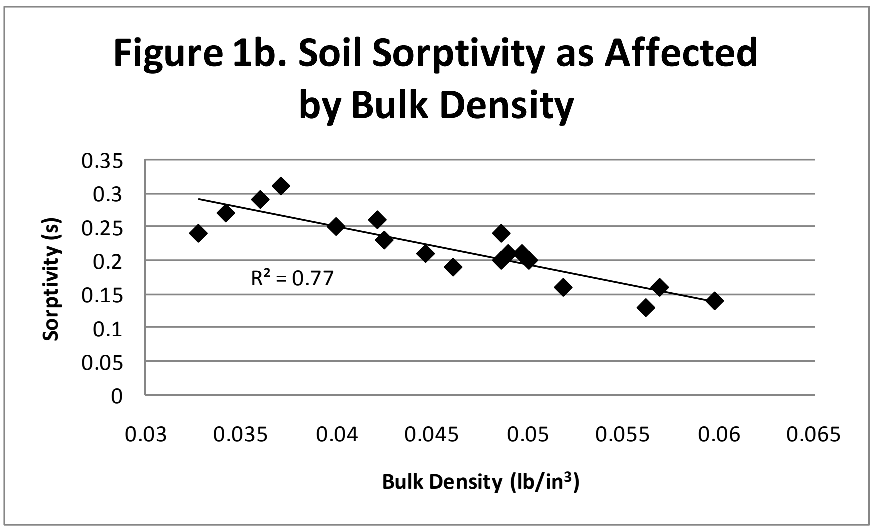
Regression analysis was performed to determine the linear relationship between crop residue and soil bulk density, soil porosity, soil aggregation, and aggregate organic carbon. Similar analysis was performed to determine the linear association between sorptivity and the aforementioned soil physical properties.

RESULTS

Bulk Density:

Bulk density is an important soil property because it affects soil porosity, which in turn affects water infiltration. Systems that produce and return more crop residue to the soil surface should reduce its bulk density because under no-till conditions the residue accumulates in the surface soil. This accumulation should do three things: 1) Residue is lighter than mineral matter, and therefore bulk density should decrease by dilution; 2) Residue decomposition products should promote more aggregation and thus reduce bulk density; and 3) The root activity in the surface should increase because of the improved water conditions and the root activity in turn favors aggregation.

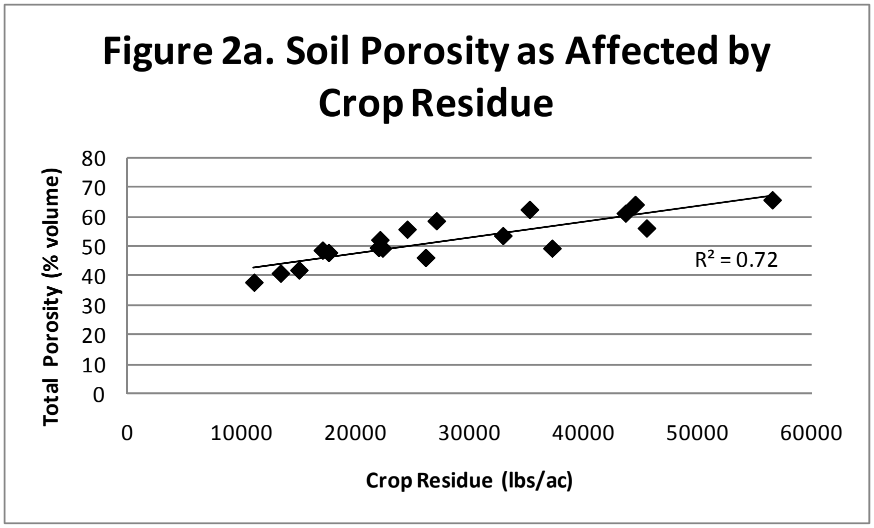


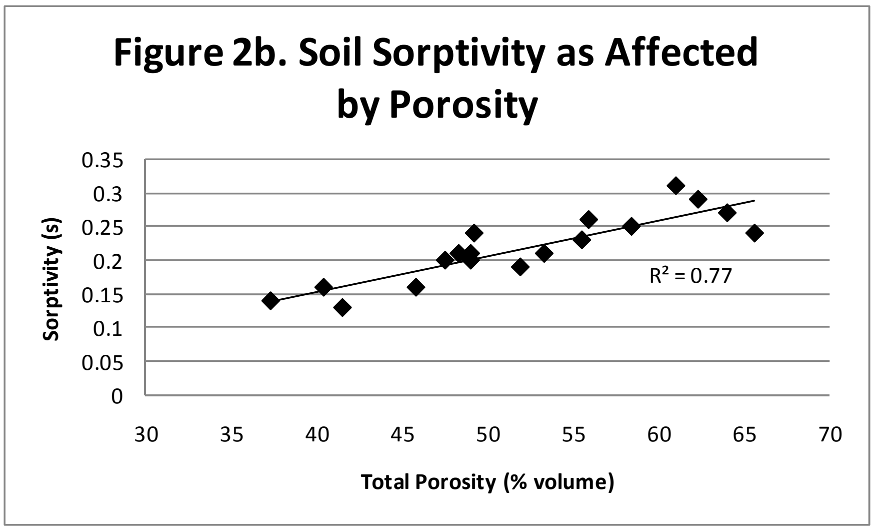


Our results indicate that increased quantities of crop residue decrease soil bulk density over time and that 72% of the variability observed in bulk density was explained by the amount of crop residue returned to the system over the 12 year period (Figure 1a). As soil bulk density decreases with crop residue addition, water sorptivity increases linearly with bulk density (Figure 1b) meaning water enters the soil more quickly as bulk density decreases. Results also show that 77% of the variability observed in sorptivity can be explained by bulk density. These results suggest that increased amounts of crop residue coupled with no-till management can lead to beneficial soil properties that can increase levels of water sorptivity and infiltration.

Porosity:

Porosity is directly related to bulk density because as bulk density decreases, porosity increases. As aggregates form and increase in size, inter-aggregate and intra-aggregate cavities form and increase. These cavities connect with other cavities creating conduits for fluid transport.

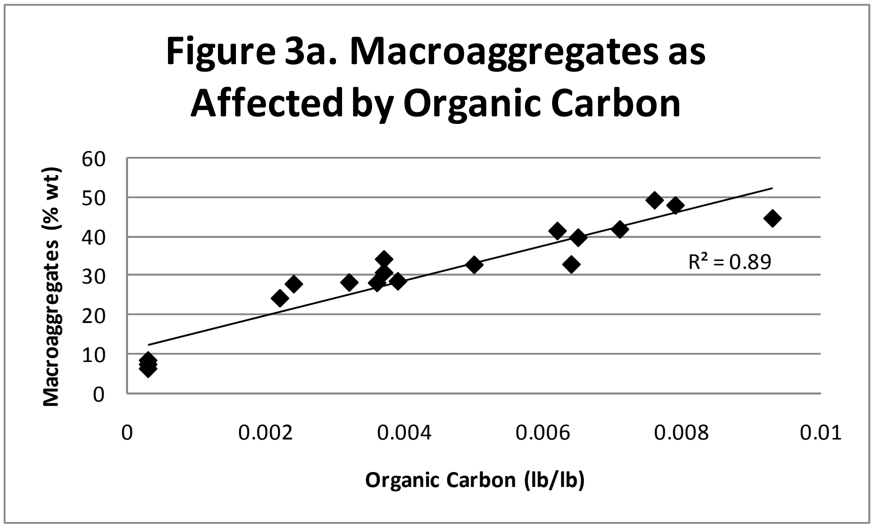


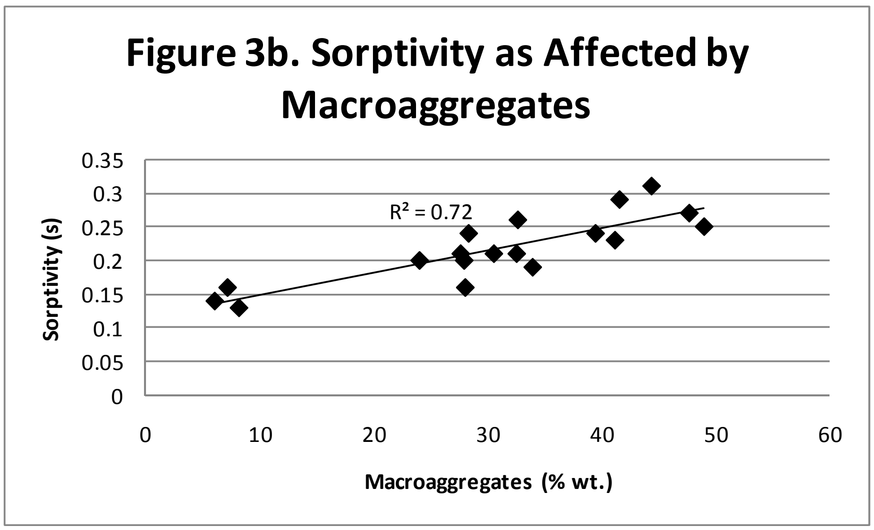


By utilizing management practices that increase the porosity we should be able to increase water capture as well. Our results show that porosity was related to crop residue production (Figure 2). As crop residue increased, so did soil porosity and nearly 72% of the variability in porosity was explained by biomass production. Our results also show that sorptivity is highly related with soil porosity (Figure 2b). This is to be expected as the pores are how the water moves into and through the soil. These results again suggest that increased crop residue can lead to the development of soil physical properties that increase the potential for water getting into the soil.

Aggregation:

Aggregation is an important soil physical property because it affects water infiltration, wind and water erosion, and crop yield. Aggregation is affected by many factors, but most importantly by organic matter (from crop residue and roots) and soil texture. Aggregation is also a dynamic factor that is affected (reduced) by tillage. Increasing aggregation is important because of its affects on bulk density, porosity, and subsequently, infiltration and water use efficiency of the system. It is also important in decreasing soil erosion. All of these factors are important to crop production and sustainability.





Aggregates are generally placed in one of two categories, macroaggregates, and microaggregates. Microaggregates form first, and then combine to form larger and larger aggregate structures eventually building into macroaggregates (Elliott, 1986; Tisdall and Oades, 1982). Microaggregate stability itself is not affected by management practices or soil organic matter content (Elliott, 1986; Tisdall and Oades, 1980). Aromatic humic materials associated with amorphous Fe and Al compounds and polyvalent metal cations are thought to be responsible for microaggregate stability (Elliott, 1986; Tisall and Oades 1982). Macroaggregate stability has been correlated to sterols, lipids, organic carbon and many other organic matter structures (Monreal et al. 1995) that bind and stabilize macroaggregates. Thus, macroaggregates should increase as these binding agents increase with increased residue production and decomposition. Our study confirms past findings showing that as organic carbon increases so too did macroaggregation (Figure 3a), and organic carbon is directly related to crop residue quantities. Macroaggregation is important for water infiltration. As macroaggregates form larger channels and pores in the soil also form allowing for greater water capture. This is shown in Figure 3b. As macroaggregation increased sorptivity increased as well.

CONCLUSIONS

Overall, the results of systems that create and return higher levels of crop residue to the soil are positive. Soil physical properties are directly related to crop residue and by decreasing the bulk density and increasing porosity there is increased potential for rapid capture of water (both irrigated and rainfall), greater infiltration, and increased water use efficiency for the system. The decreased bulk density and increased porosity and macro-aggregation also decrease the potential for runoff, erosion, and evaporation by increasing the potential for faster water capture leaving more water available for plant use. This ultimately leads to a more efficient, sustainable, and economically viable system.

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