Agricultural Management Effects on Properties of Semi-Arid Sandy Soils

T. M. Zobeck[1], D. M. Halfmann[2], V. Acosta-Martinez[1], K. F. Bronson[3], and D. R. Upchurch[1];

[1]USDA-ARS, [2]Texas Tech University [3]Texas Agric. Exp. Stn., Lubbock, Texas

INTRODUCTION

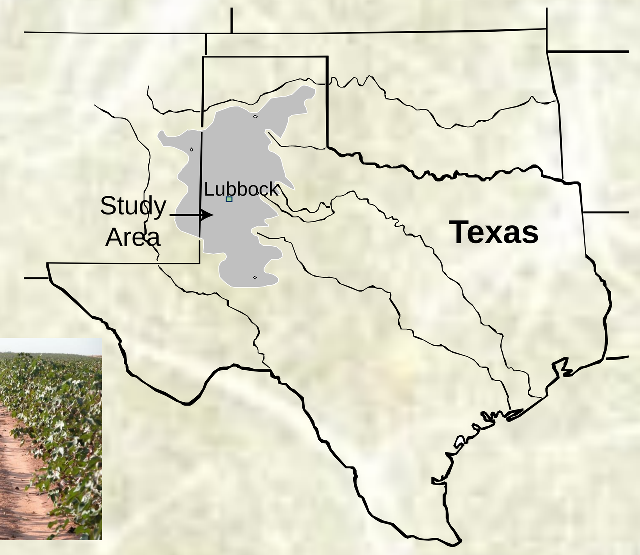
Although no-tillage farming systems have been shown to reduce soil erosion and modify soil chemical, biochemical, and physical properties in many areas of the US, little information is available for semi-arid sandy soils of the Southern High Plains. The objective of this study was to test the hypothesis that long-term no-tillage management will provide more favorable soil chemical, biochemical, and physical properties for ecosystem functioning than conventionally-tilled systems on sandy soils in west Texas.

METHODS

Two sites were located in Terry County, West Texas, USA on Amarillo loamy fine sand (fine-loamy, mixed, superactive, thermic Aridic Paleustalfs). Site 1 included conventionally-tilled dryland cotton (Dryland Cotton Conv), no-till irrigated and dryland cotton/wheat rotations (Irrigated Cotton NT and Dryland Cotton NT, respectively), conservation reserve grassland (Conservation Grassland), and native rangeland. Site 2 included conventionally-tilled irrigated cotton, no-till irrigated cotton/wheat rotation, and conservation reserve grassland.


Native Rangeland


Conservation Reserve Grassland

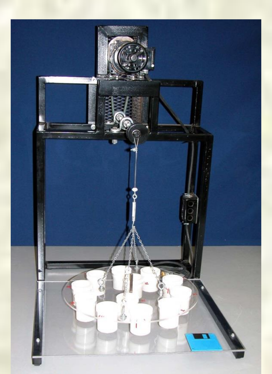



Irrigated Cotton/Wheat No-Till


Dryland Cotton/Wheat No-Till


Dryland Cotton Conventional

Each system was sampled at the following four depths: 0-5, 5-10, 10-15, and 15-30 cm. Three replications were sampled in each system. Samples were collected with a Giddings probe. A specially designed steel sleeve was used to line the probe sampling tube. Even though the soils were quite sandy, bulk density was accurately determined using the same soil cores used for carbon analyses. Field moisture content was measured gravimetrically on subsamples. Soil subsamples were air-dried, ground overnight in a roller mill and total C and N were determined using the Vario Max Elementar CN analyzer (D-63452 Hanau, Germany). Particulate organic matter (POM) carbon was measured according to the procedure of Gregorich and Ellert, (1993). Penetration resistance was measured using a hand-held cone penetrometer. Fifteen penetrometer insertions were recorded per replication. A 12.83 mm diameter cone with a 30° cone angle was pushed into the soil to a depth of 30 cm (ASAE, 2003). The penetrometer readings were averaged and placed into 5 cm depth classes for statistical analysis.



Wet aggregate stability was performed on air-dried 1-2 mm diameter aggregates of the 0-5 and 5-10 cm layers (Kemper and Rosenau, 1986).

Enzyme activity was measured for β-glucosiminidase, β-glucosidase, and arylsulfatase. Each enzyme activity was assayed in 1 g of air-dried soils using a final concentration of 10mM of the specific enzyme substrate (p-nitrophenyl derivate), buffered at the enzyme optimal pH, and incubated for 1 h at 37deg C (Tabatabaai, 1994, Parham and Deng, 2000). The product of the three enzyme reactions was determined colorimetrically at 400 nm in a spectrophotometer.

A double-ring infiltrometer was used to calculate for water infiltration rates under saturated conditions. Two sub-samples were completed for each replication until the steady-state infiltration rate was obtained. The infiltration measurements for the inner ring (vertical flow) were calculated using the equation taken from ASTM (1994).

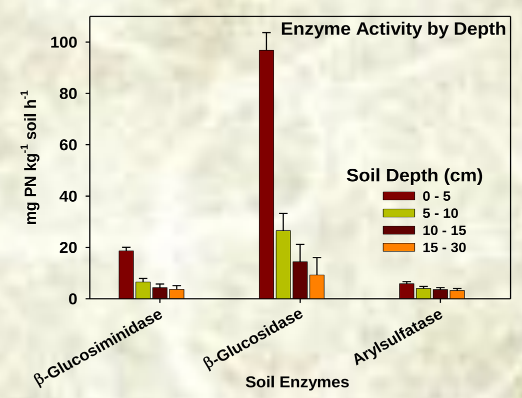
Unsaturated hydraulic conductivity, K(h), was measured using a 20 cm Soil Measurement Systems, Inc. (Tucson, AZ) tension infiltrometer. Two sub-samples were completed for each replication until the steady-state infiltration rate was obtained. K(h) values were calculated based on Wooding's equation for unconfined (three-dimensional) steady-state water infiltration (zero ponding) from a circular source and Gardner's equation (Ankeny et al., 1991)

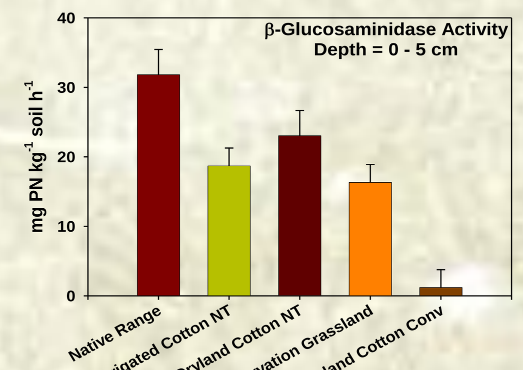
RESULTS AND DISCUSSION

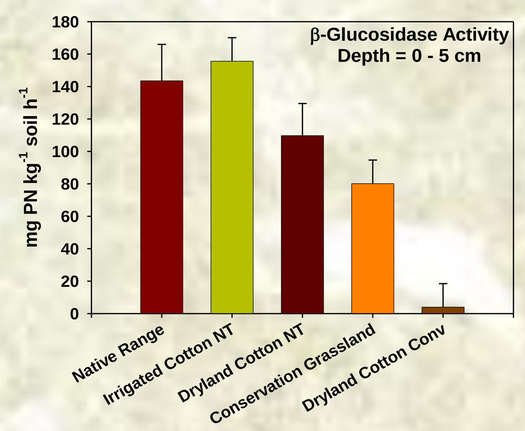
The soil enzymes studied participate in key reactions of soil biogeochemical cycling that affect soil functioning. Specifically, β-glucosidase is key to cellulose degradation (C cycling), β-glucosaminidase is key to chitin degradation (C and N cycling), and arylsulfatase is key to soil organic matter mineralization (S cycling).

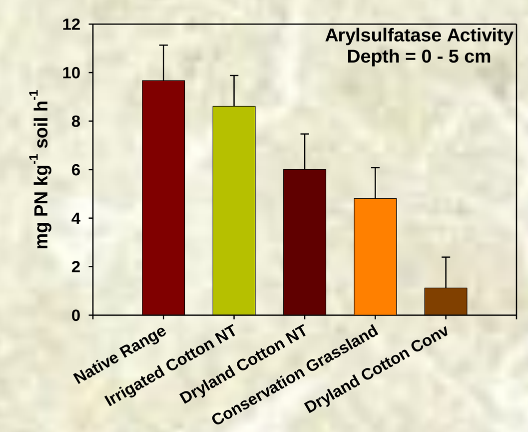
Management Effect on Enzyme Activities

All enzymes activities studied showed significant decreases with depth (P<0.01). The enzyme activities at the surface 0 - 5 cm of the native rangeland, conservation grassland and no-till management systems were significantly greater (P<0.01) than those of the conventionally tilled dryland cotton. The activity of β-glucosidase and arylsulfatase in the irrigated, no-till cotton/wheat system were greater than those found in the conservation grassland. These results demonstrate the degradation of soil properties that control critical soil processes when conventional tillage is used with continuous cotton monoculture for these semi-arid soils.



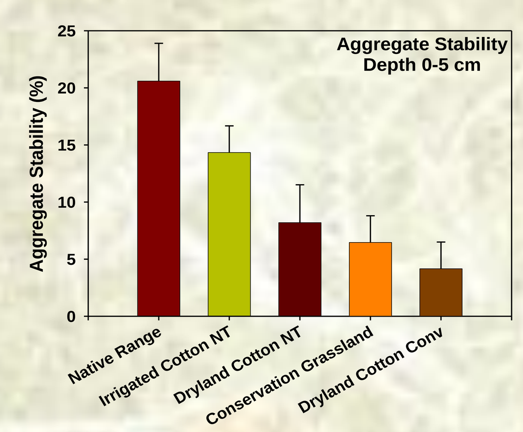


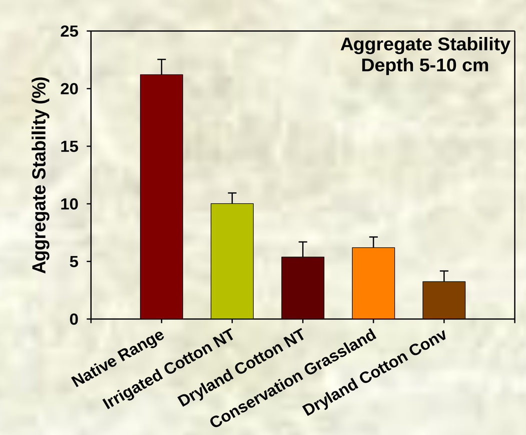




Management Effect on Aggregate Stability

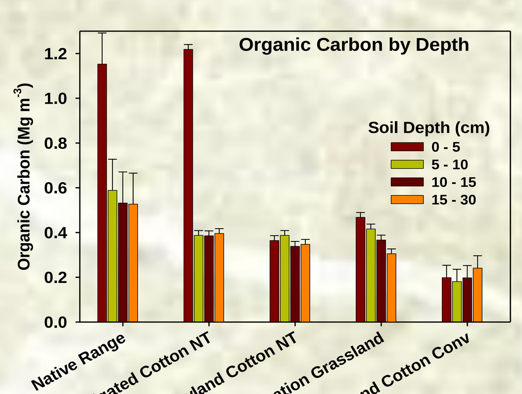
Although aggregate stability was relatively low on these very sandy soils, management systems had a great impact. The wet aggregate stability in the surface 0 – 10 cm layer of the native rangeland was about five times that of the dryland cotton monoculture. Wet aggregate stability tended to decrease with depth within a management system.

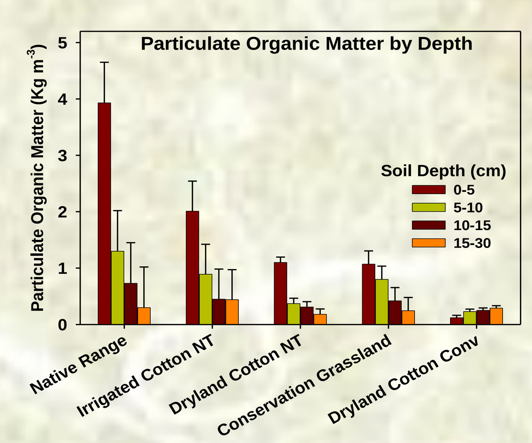




Total Organic Carbon and Particulate Organic Matter

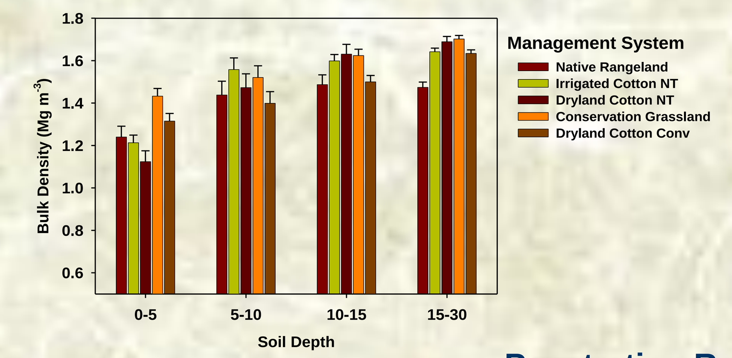
Due to relatively high variability in organic carbon mass measurements, only the surface 0 – 5 cm of the irrigated cotton/wheat no-till system had higher organic carbon mass than the other soil layers for comparisons by depth within management systems (P<0.05). No difference in organic carbon mass with depth was found in any other system tested. In comparisons by depth among management systems, the native range had significantly higher organic carbon mass than all other systems at each depth (P<0.05). Particulate organic matter (POM) decreased with depth. Generally, the surface 0 – 5 cm had statistically greater POM (P<0.001) than all other depths. The native rangeland and the irrigated no-till cotton/wheat system had greater surface 0 – 5 cm POM than the dryland cotton surface. The other systems had similar soil surface 0 – 5 cm POM.

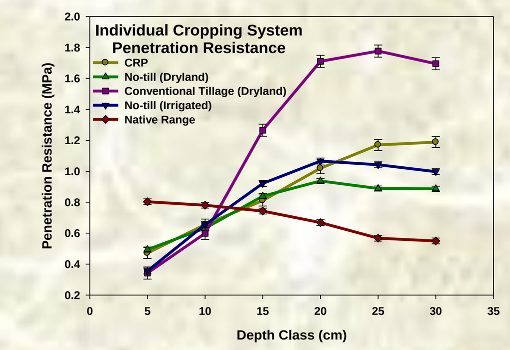




Management Effect on Bulk Density

Bulk density increased with depth in all systems tested. The lower part of the tilled zone seems to have developed a tillage pan for all systems with the exception of the native rangeland. This pan was present even in the conservation grassland which was previously cropped about 13-15 years prior to this study.



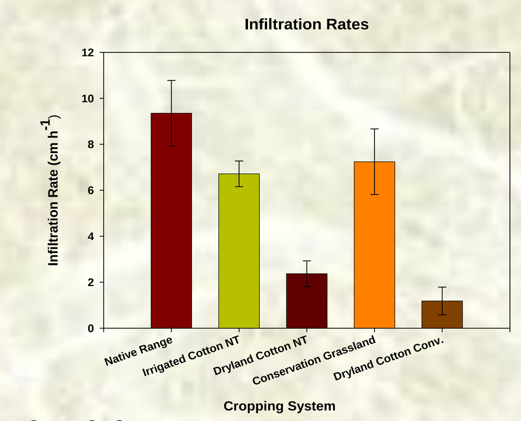


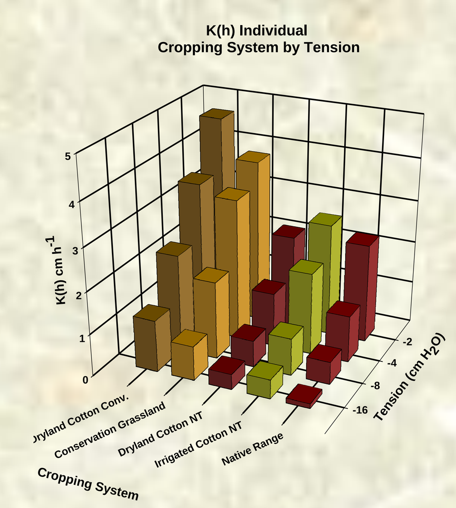
Penetration Resistance

Penetration resistance showed a significant difference for depth class (P<.0001). The 0-5 cm and 5-10 cm depths had significantly lower resistances than the lower depths. All individual cropping systems showed significant differences with depth class (P<0.0001). The native rangeland had the lowest resistance throughout all depths. The conventional tillage dryland cotton system showed a dramatic increase with depth through the 10 to 20 cm range. The other systems were comparable to each other by showing gradual increases in resistance through 20 cm and leveling off to the bottom depth.

Water Infiltration

The overall analysis of the water infiltration rates showed significance among systems (P<0.05). The native range had the highest infiltration rate while the conventional tillage and no-till dryland cotton systems had the lowest infiltration rate.





Unsaturated Hydraulic Conductivity

Mean K(h) values showed a significant difference among cropping systems (P<0.05) and tension setting (P<.0001). The conventionally tilled dryland cotton system had the highest mean K(h) value, while the native range had the lowest. All other systems were not statistically different. As anticipated, the lowest tension settings (-2 and -4 cm H_2O) had the highest K(h) values, while the highest tension settings (-8 and -16 cm H_2O) had the lowest K(h) values.

CONCLUSIONS

Conventionally-tilled cotton fields are usually disturbed (cultivated, bedded, etc) at least 3 or more times annually. This cultivation buries plant residues and stirs the soil, exposing surfaces to oxidation and other biogeochemical processes. The surface soils of no-tillage fields are only disturbed to plant seeds. The conservation grassland soils of this study were formerly tilled but have not been disturbed for the last 13 to 15 years. The native grassland had never been disturbed, other than occasional grazing by cattle. The effects of these practices on soil properties are shown in this study. The native rangeland had the highest amounts of organic matter and enzyme activities, the most stable surface soil aggregates, the highest infiltration rate under saturated conditions, and lowest soil density and penetration resistance. The no-till fields had about the same levels of these as the conservation grassland. However, the irrigated no-till cotton/wheat system had higher β-glucosidase and arylsulfatase activities than the dryland no-till cotton/wheat system and conservation grassland and about the same as the native grassland. The conventionally-tilled field had only about 20 percent or lower levels of all soil properties tested in the surface 0 – 5 cm, with the exception of bulk density which was about the same for all systems. This study suggests that no-tillage cropping systems in sandy soils in semi-arid regions are as beneficial as conservation grassland in improving soil properties that relate to soil biogeochemical and physical properties.

REFERENCES

American Society of Agricultural Engineers (ASAE). 2003. Procedures for using and reporting data obtained with the soil cone penetrometer. ASAE EP542, St. Joseph, Michigan,: *Amer. Soc. Agric. Eng.*, pp.1009-1011.

American Society for Testing and Materials (ASTM). 1994. Standard test method for infiltration rate of soils in field using double-ring infiltrometer. ASTM D 3385-94, Philadelphia, Pennsylvania,: *Amer. Soc. Test. Mat.*, pp. 1-6.

Ankeny, Mark D., Mushtaque Ahmed, Thomas C. Kaspar, and Robert Horton. 1991. Simple field method for determining unsaturated hydraulic conductivity. *Soil Sci. Soc. Am. J.* 55:467-470.

Gregorich, E. G. and G. H. Ellert. 1993. Light fraction and macroorganic matter in mineral soils. P. 397-407. *In* M. R. Carter (ed.) Soil sampling and methods of analysis. Lewis Publ., Boca Raton, FL.

Kemper, W. D. and R. C. Rosenau. 1986. Aggregate stability and size distribution. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agronomy 9:425-446

Parham, J. A. and S. P. Deng. 2000. Detection, quantification and characterization of b-glucosaminidase activity in soil. Soil Biol. Biochem. 32: 1183-1190.

Tabatabai, M. A. 1994. Soil Enzymes. p. 775-833. In R. W. Weaver, J. Angle, and P. S. Bottomley (ed.) Methods of soil analysis. Part 2. SSSA Book Ser. 5, SSSA, Madison, WI.

Contact: Dr. Ted M. Zobeck, USDA-ARS, Lubbock, TX 79415 ted.zobeck@ars.usda.gov