Soil Physical Characteristics of Contrasting Cropping Systems in the Great Plains: Preliminary Findings

J. L. Pikul, Jr.[1], R. Schwartz[2], J. Benjamin[3], L. Baumhardt[2], and S. Merrill[4]

[1]USDA-ARS, Brookings, SD 57006; [2]USDA-ARS, Bushland, TX 79012; [3] USDA-ARS, Akron, CO 80720; [4]USDA-ARS, Mandan, ND 58554. Corresponding author, J. L. Pikul, Jr. (605-693-5258; jpikul@ngirl.ars.usda.gov)

Abstract

Agricultural systems may produce both damaging and beneficial effects on soil physical condition. We conducted a multi-location study during 1999 to 2002 to evaluate physical, chemical, and biological attributes of soil quality. Our hypothesis was that increased diversity of cropping system improves soil quality attributes. This report provides preliminary findings of cropping systems effects on water infiltration, aggregate size distribution (expressed as mean weight diameter, MWD), and bulk density (BD). We identified no significant cropping system effect on water infiltration for locations having the same tillage operations within the cropping system. MWD was significantly greater at Bushland and Fargo; locations that have different cropping intensity or no tillage. Tillage resulted in increased, decreased, or unchanged BD near the soil surface, when compared with no tillage, depending on time of year. Measurements of infiltration, MWD, or BD made at only one time in a rotation cycle do not convey meaningful information on soil quality because of significant temporal variation in these properties.

Introduction

The state of the soil physical environment is important for maintaining sustained agronomic production, a concept embodied in the presumption that good soil tilth is a precursor to high crop productivity. Agricultural systems may produce both damaging and beneficial effects on soil physical condition. Soil compaction frequently occurs when agricultural equipment passes over a field but little is known about the long-term interaction of crop systems, residue and fertilizer management on soil physical condition. Soil organic matter (SOM) is linked to fertility and a desirable soil physical state and often has a disproportionate effect on soil physical behavior (Boyle, et al. 1989). Maintenance of SOM seems to be the key to sustaining the soil resource and crop productivity (Doran et al., 1998). A multi-location study was conducted during 1999 to 2002 to evaluate a number of physical, chemical, and biological properties associated with assessment of soil quality. Objectives were to 1) quantify temporal dynamics of soil quality attributes in established cropping systems, 2) assess soil quality attributes between treatments of contrasting management intensity, and 3) evaluate recently developed methods for assessing soil quality (Wienhold, et al. 2003). The purpose of this report is to present preliminary findings on selected soil physical attributes.

Materials and Methods

Contrasting management treatments within eight long-term cropping system located near Akron, CO, Brookings, SD, Bushland, TX, Fargo, ND, Mandan, ND, Mead, NE, Sidney, MT, and Swift Current, SK were used in the study. Treatments selected at each site differed in management intensity as characterized by either type or frequency of tillage, cropping intensity, and/or crop rotation diversity. Varvel et al. (2003) describes these long-term field experiments.

Soils were sampled prior to planting, at peak crop biomass, and after harvest during a period of four years at each location. Samples were collected in the same plots throughout the duration of the study. Soil cores from depth increments of 0 to 7.5, 7.5 to 15, and 15 to 30 cm were collected locations for the track position to over 100 cm/h at the Fargo location. Generally the track position had lower infiltration rates than the no track or row positions.

A system by time interaction was significant at the Akron, Fargo, and Mandan locations indicating that the significant cropping system effects were not consistent throughout the time of the experiment. The significant time effect on infiltration rate at the Brookings location (Table 1) exhibited a cyclic pattern through the growing season. For the non-trafficked position, infiltration rate increased during the year. At the row-position and trafficked-position, infiltration rate was lowest at first sampling of the year, increased at the time of the second sampling, then decreased again. A similar, but less pronounced pattern occurred at the Mead location.

Aggregate size distribution Cropping system significantly affected MWD at Fargo and Bushland (Table 2). Cropping systems at Fargo have a tillage variable; no tillage was compared to conventional tillage. Both systems at Bushland are under no tillage. Soil organic C at Bushland was greatest under continuous wheat (CW) compared to a wheat-sorghum-fallow (WSF) rotation. Average (all dates) MWD at Bushland was 10.85 mm under CW and 8.95 mm under WSF. At Fargo, MWD was greater under the no-tillage system. A large MWD value represents an aggregate size distribution having a large portion of large aggregates. Data suggest that soil aggregates formed under no tillage (a system having elevated organic C) resist disintegration compared with aggregates under tillage. Studies at Brookings of a no tillage and conventional tillage corn-soybean rotation (Pikul, 2003, unpublished data) support the observation that dry aggregate stability (represented by MWD) is greater under no tillage compared with conventional tillage. There was a significant effect of time on MWD at all locations (Table 2). At Brookings, MWD under the alternative system (4-year rotation) was significantly greater than the continuous corn (CC) system in the 4th year of the rotation (alfalfa phase). A similar comparison at Mead showed a smaller MWD under a 4-year rotation compared with CC.

Bulk density At the eight locations (Table 2), BD ranged from 0.8 Mg m^{-3} at the surface (0 – 75 mm) under native grassland (grassland not shown) to 1.6 Mg m^{-3} for the lower depth increment (clay loam to clay textures) at two locations (analysis not shown). Bulk densities were greatest for cropped land as compared with native grassland. Greatest source of variation in BD was observed with time of sampling especially below the 75 mm depth. Differences in BD between cropping systems were most frequently observed for the surface depth increment (5 locations). Changes in BD over time displayed no obvious trends but they probably represent seasonal and annual variations generated by phases in the rotation, tillage and subsequent reconsolidation, and wetting-drying histories.

Kemper, W. D. and Rosenau, R. C. 1986. Aggregate stability and size distribution. p. 425-444. *In* Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods. Agronomy Monograph No. 9, 2nd ed. ASA, Madison, WI, USA.

Lowery, B., W.J. Hickey, M.A. Arshad, and R. Lal. 1996. Soil water parameters and soil quality. p. 143-155. *In*: J.W. Doran and A.J. Jones (Eds.) Methods for Assessing Soil Quality. SSSA Spec. Pub. 49. SSSA, Madison, WI.

Varvel, G., W. Riedell, D. Tanaka, M. Vigil, R. Schwartz, V. Cochran, E. Deibert, and B. McConkey. 2003. Great Plains soil quality assessment project: Locations and cropping systems. IN: J. Krupinsky (Ed.) Proc. Dynamic Cropping Systems: Principles, Processes, and Challenges. USDA-ARS, Northern Great Plains Res. Lab., Mandan, ND.

Wienhold, B., J.L. Pikul Jr., M. Liebig, M. Vigil, G. Varvel, and J. Doran. 2003. Cropping system effects on soil quality in the Great Plains: Summary from a regional project. IN: J. Krupinsky (Ed.) Proc. Dynamic Cropping Systems: Principles, Processes, and Challenges. USDA-ARS, Northern Great Plains Res. Lab., Mandan, ND.