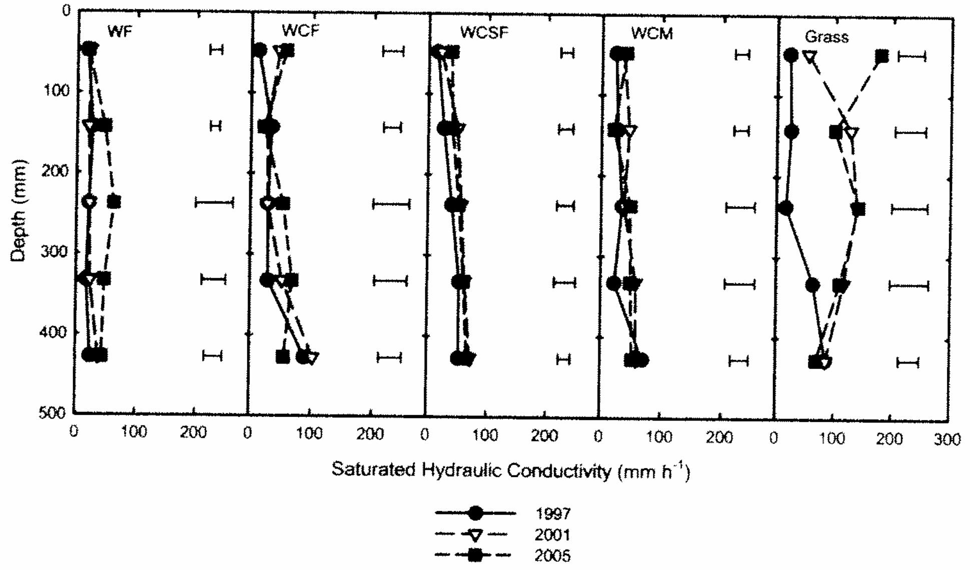

Fig. 5. Saturated hydraulic conductivity with depth for wheat–fallow (WF), wheat–corn–fallow (WCF), wheat–corn–sunflower–fallow (WCSF), and wheat–corn–millet (WCF) crop rotations and continuous grass plots in 1997, 2001, and 2005. Bars indicate the critical difference for means comparisons between years for each rotation and depth.

pore network. Increasing annual cropping intensity or changing crop species may help improve soil physical properties but the changes may not be apparent for decades.

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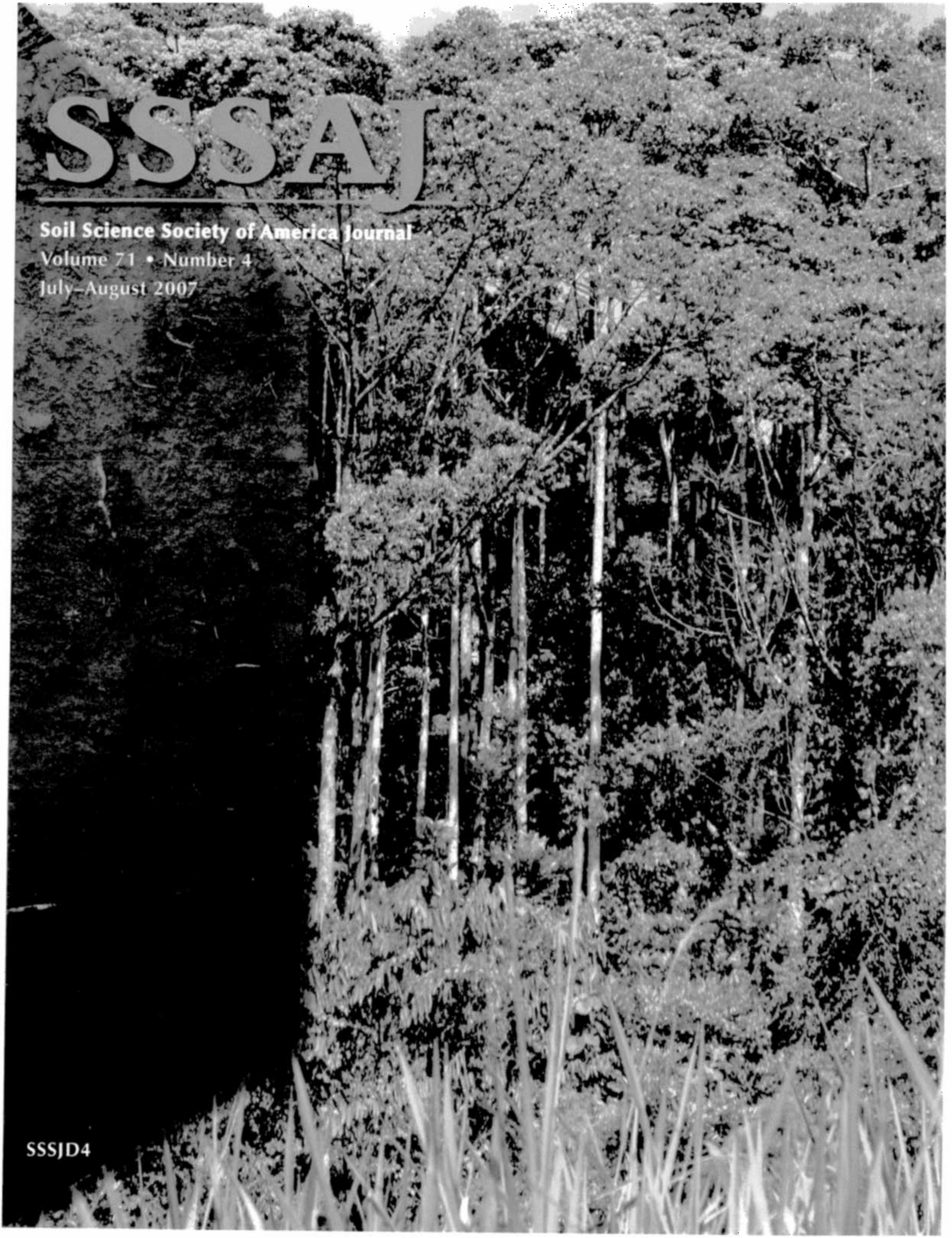

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the grass treatment than the wheat rotation treatments.

Analysis of ρ_b changes with years shows that ρ_b decreased with time in all treatments for most depths (Fig. 1). Grass plots had the fastest and greatest ρ_b decrease and grass was the only treatment to have a significant ρ_b decrease in Depth 1. In the 4 yr between 1997 and 2001, ρ_b in Depth 1 of the grass plots decreased from 1.48 to 1.28 Mg m^{-3}. At Depth 2, the decrease between 1997 and 2001 was from 1.43 to 1.29 Mg m^{-3}. Other depths in the grass plots had similar declines as those nearer the surface. There were no differences among wheat rotation treatments for the magnitude or speed of ρ_b decline. Using WF as an example, between 1997 and 2001, ρ_b in Depth 1 decreased from 1.41 to 1.37 Mg m^{-3}. In 2005, the ρ_b in Depth 1 of the WF treatment was 1.37 Mg m^{-3}. In Depth 2, the ρ_b decrease of the WF treatment between 1997 and 2001 was from 1.43 to 1.38 Mg m^{-3}. In 2005, the ρ_b in Depth 2 of the WF treatment was 1.33 Mg m^{-3}. For the wheat rotation treatments, significant ρ_b changes did not occur until 2005. Because the samples were removed from untrafficked areas of the field, the lack of ρ_b change with time near the surface of the cropped treatments could be attributed to near-surface compaction from disk openers, press wheels, and gauge wheels of planting equipment.

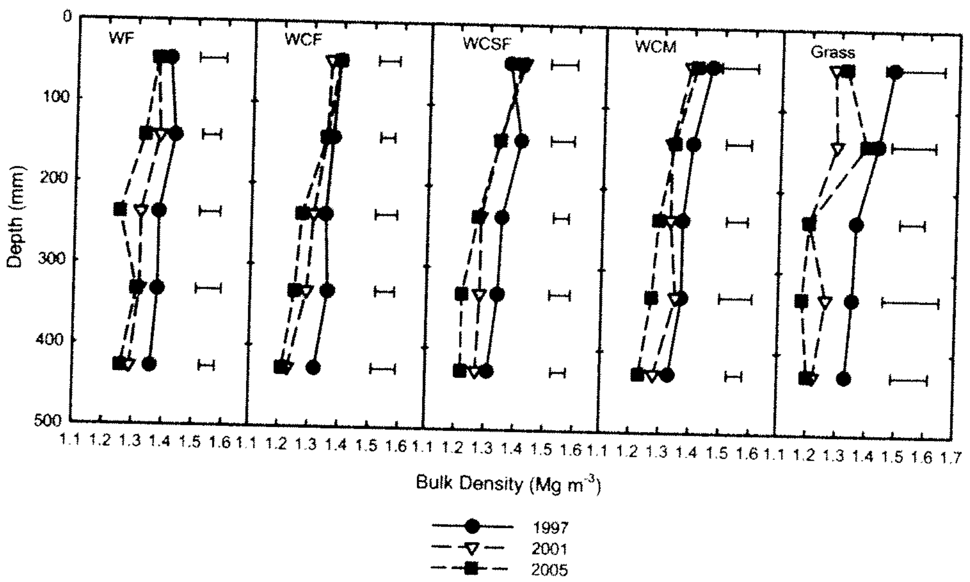

Fig. 1. Bulk density distribution with depth for wheat–fallow (WF), wheat–corn–fallow (WCF), wheat–corn–sunflower–fallow (WCSF), and wheat–corn–millet (WCF) crop rotations and continuous grass plots in 1997, 2001, and 2005. Bars indicate the critical difference for means comparisons between years for each rotation and depth.

Significant changes in ϕ_{macro} generally occurred below Depth 1 (Fig. 2). Together with the decrease in ρ_b in the grass treatment was an increase in ϕ_{macro}. The greatest increases for grass plots were in Depths 2 and 3. Changes in ϕ_{macro} with the wheat rotation treatments occurred only sporadically with the WF, WCF, and WCM treatments. In Depth 3, there was a significant increase in ϕ_{macro} for the WF treatment but not for the other wheat rotation treatments. In Depth 4, there was a significant increase in ϕ_{macro} for the WCF and WCM treatments but not for the other wheat rotation treatments. None of the wheat rotation treatments resulted in an increase in φ_{macro} in Depth 5.

There were no significant changes with time in ϕ_{meso} or ϕ_{ws} for any of the treatments (Fig. 3 and 4). The decrease in ρ_b with time exhibited in many of the wheat rotation treatments was not reflected in a change in the smaller pore sizes, but only in ϕ_{macro}.

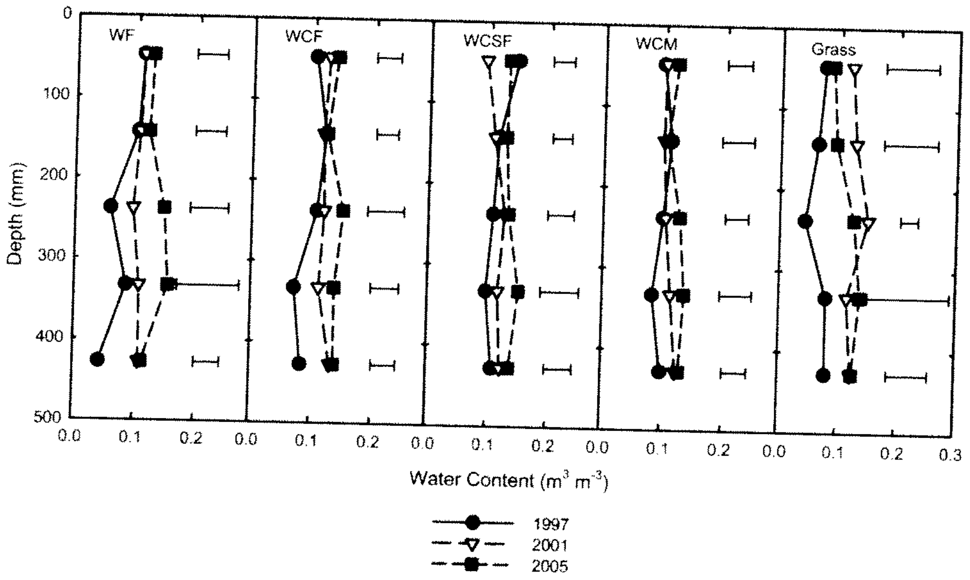

Fig. 2. Macroporosity with depth for wheat–fallow (WF), wheat–corn–fallow (WCF), wheat–corn–sunflower–fallow (WCSF), and wheat–corn–millet (WCF) crop rotations and continuous grass plots in 1997, 2001, and 2005. Bars indicate the critical difference for means comparisons between years for each rotation and depth.

The greatest increase in K_{sat} occurred with the grass treatment (Fig. 5). After 7 yr, the K_{sat} of the grass plots was approximately 21 mm h^{-1} to Depth 3 and was not significantly different from the cropped treatments. After 11 yr, the K_{sat} in Depth 1 of the grass plots was approximately 54 mm h^{-1}. After 15 yr, the K_{sat} in Depth 1 of the grass plots was approximately 178 mm h^{-1}. A similar K_{sat} increase was observed at other depths. The wheat rotation treatments showed little change in K_{sat} during the years of the study with the exception of the WF rotation. There was a significant increase in K_{sat} at Depths 2, 3, and 4 for this rotation alone in the 8 yr between 1997 and 2005.

Cropping Intensity Effects on Physical Properties of a No-till Silt Loam

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No-till cropping systems in the semiarid West have the potential to improve soil physical properties by increasing cropping intensity and crop diversity. An investigation at Akron, CO, compared soil conditions in winter wheat (*Triticum aestivum* L.)–summer fallow (WF) plots with soil conditions in wheat–corn (*Zea mays* L.)–fallow (WCF), wheat–corn–sunflower (*Helianthus annus* L.)–fallow (WCSF), wheat–corn–millet (*Panicum miliaceum* L.) (WCM), and a perennial grass/legume mix. The study began in 1990. Bulk density, pore size distribution, and saturated hydraulic conductivity were measured 7, 11, and 15 yr after inception. Bulk density in the grass plots decreased from 1.39 to 1.25 Mg m^{-3} in 15 yr. Bulk density in the annually cropped plots decreased from 1.38 to 1.30 Mg m^{-3} during the same time period. The pore size distribution became more uniform among the cropped treatments 15 yr after the start of the experiment. Saturated hydraulic conductivity increased in the grass plots from 27 mm h^{-1} to 98 mm h^{-1} in 15 yr. Saturated hydraulic conductivity in the annually cropped plots increased from about 14 to about 35 mm h^{-1} during the same period. The results from this study show that improving soil physical properties by cropping system alone may take many years. Perennial vegetation may be more effective than annually cropped systems at improving soil physical conditions because of less surface compaction from planting operations and the apparent ability of perennial root systems to create a more stable, continuous pore network.

During the last 90 yr in the Great Plains, much of the native range has been converted to crop production. This conversion has resulted in significant soil degradation from the loss of organic C. Bauer and Black (1981) showed that cultivated soils lost between 28 and 38% of the original organic C, compared with virgin grassland, after 25 yr of cultivation, depending on the tillage system. Bowman et al. (1990) showed that, after 60 yr of tillage, approximately 60% of the original organic C was lost in the surface 150 mm of a sandy soil in eastern Colorado. Most of the C loss occurred in the first 3 yr after the onset of cultivation.

Soil physical conditions have a direct effect on soil productivity for crop production by determining water holding capacity, aeration, and soil strength limitations for root activity (Benjamin et al., 2003). Some researchers have suggested that study of the functional traits of soil structure, as exemplified by the pore system, may be instructive to determine the effects of cropping system on soil physical quality (Young et al., 2001; Ball et al., 2005).

Soil physical properties may change with the loss of organic matter. Bowman et al. (1990) measured lower water content at field capacity (−33 kPa) and lower cation exchange capacity associated with the loss of organic matter. On the other hand, Bauer and Black (1981) measured no significant soil bulk density differences between cropped and grassland soils at depths to 450 mm.

Organic matter increases from additions of manure have been shown to improve selected soil physical properties. Pikul and Allmaras (1986) reported lower bulk density, increased volume of soil pores >50 μm, and greater saturated hydraulic conductivity in a wheat–fallow cropping system when manure was added to the soil compared with only returning the straw to the system.

The use of no-till cropping systems in the semiarid western USA has resulted in significant water savings and has allowed greater cropping intensity and crop diversity for this region. To take advantage of summer rainfall, there has been a shift from a predominately wheat–fallow rotation to rotations that include summer annuals. Some of the crops being grown in rotation with wheat include corn, sorghum [*Sorghum bicolor* (L.) Moench], proso millet, and sunflower. Increasing cropping intensity, while decreasing fallow, in no-till systems has the potential to increase organic C in the soil profile both by increasing C additions to the system and by decreasing oxidation caused by tillage (Bowman et al., 1999; Mikha et al., 2006; McVay et al., 2006). Ball et al. (2005) showed that changes in crop species and soil management may influence soil structure. It is conceivable that different crop species may affect soil properties differently because of different rooting characteristics and rooting depths.

Most changes in soil organic matter caused by a change in cropping system have been limited to the surface 50 to 75 mm (Bowman et al., 1999; Mikha et al., 2006; McVay et al., 2006). Changes in other soil physical properties, however, may extend to significantly greater depths. Plant roots exert forces on the soil and can be used to change soil physical conditions, particularly

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