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Cropping system influences on soil chemical properties and soil quality in the Great Plains

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Abstract

Soil management and cropping systems have long-term effects on agronomic and environmental functions. This study examined the influence of contrasting management practices on selected soil chemical properties in eight long-term cropping system studies throughout the Great Plains and the western Corn Belt. For each study, soil organic C (SOC), total N (TN), particulate organic matter (POM), inorganic N, electrical conductivity (EC), and soil pH were evaluated at 0–7.5, 7.5–15, and 15–30 cm within conventional (CON) and alternative (ALT) cropping systems for 4 years (1999–2002). Treatment effects were primarily limited to the surface 7.5 cm of soil. No-tillage (NT) and/or elimination of fallow in ALT cropping systems resulted in significantly ($P < 0.05$) greater SOC and TN at 0–7.5 cm within five of the eight study sites [Akron, Colorado (CO); Bushland, Texas (TX); Fargo, North Dakota (ND); Mandan, ND; and Swift Current, Saskatchewan (SK), Canada]. The same pattern was observed with POM, where POM was significantly ($P < 0.05$) greater at four of the eight study sites [Bushland, TX, Mandan, ND, Sidney, Montana (MT), and Swift Current, SK]. No consistent pattern was observed with soil EC and pH due to management, although soil EC explained almost 60% of the variability in soil NO_3-N at 0–7.5 cm across all locations and sampling times. In general, chemical soil properties measured in this study consistently exhibited values more conducive to crop production and environmental quality in ALT cropping systems relative to CON cropping systems.

Key words: management practices, soil organic matter, electrical conductivity, soil acidity

Introduction

In agricultural systems, soil and crop management decisions will affect soil quality, soil nutrient dynamics, and soil chemical properties. These management decisions include crop rotation, residue management, and the intensity and frequency of tillage. Bowman et al.[1] measured a 20% increase in soil organic C (SOC) in the surface soils of continuously cropped no-till managed dryland systems, which previously were managed under conventionally tilled wheat–fallow. Bowman et al.[1] correlated the increase in SOC to greater annualized crop yield (greater annualized C additions as crop residue). In their analysis, 57% of the variability in SOC at the 0–5 cm depth could be explained by a simple linear relationship with annualized grain yield. Similarly, Pikul et al.[2] measured significantly greater SOC in continuous corn than in a corn–soybean rotation near Brookings, South Dakota (SD). In that study, greater SOC was also thought to be related to the greater C additions in

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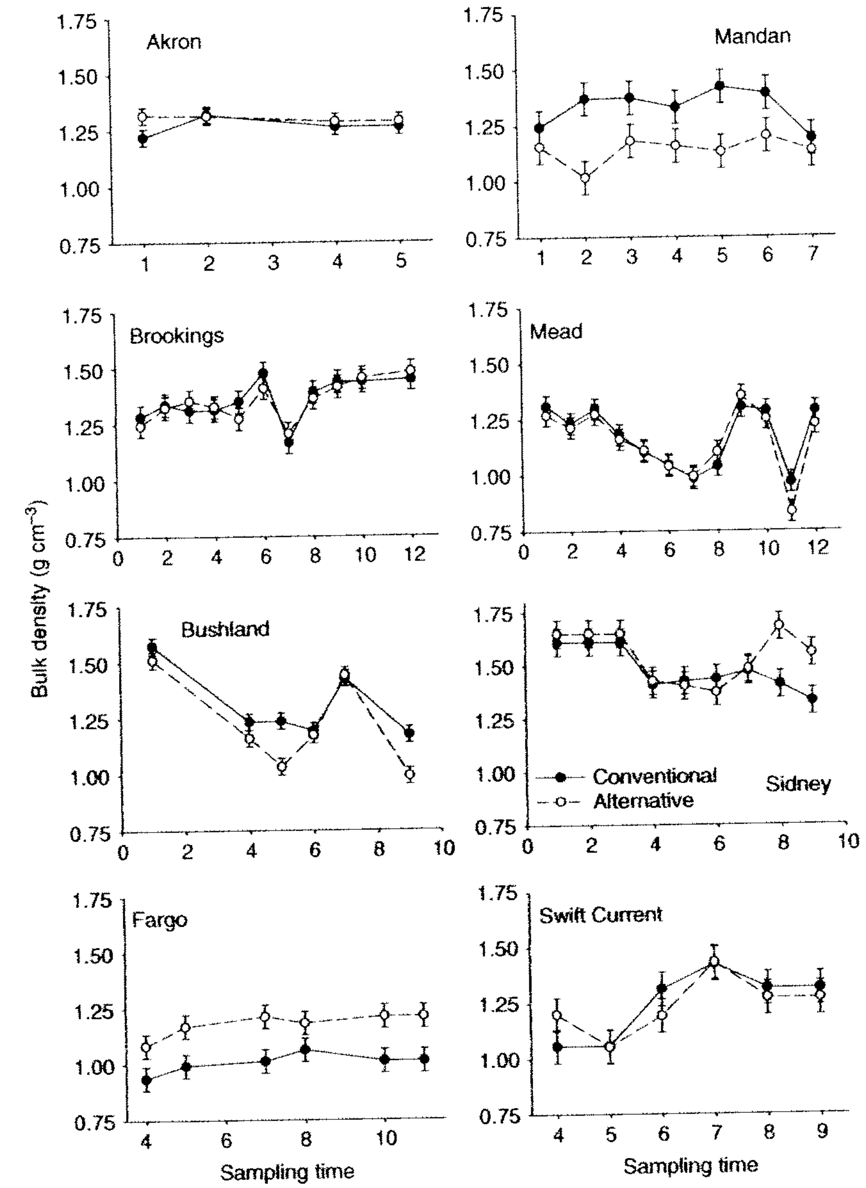

Figure 1. Soil bulk density (g cm^{-3}) in the 0–7.5 cm depth as a function of sampling time (multiple years) under the conventional and alternative management systems at eight locations in the Great Plains. Bars represent 1 SEM. Sampling times correspond to preplant = 1, 4, 7, and 10; peak biomass = 2, 5, 8, and 11; and post-harvest = 3, 6, 9, and 12.

year from each replicate of the treatments (for details of the sampling method, see Varvel et al.[13]). A total of 15–18 cores were collected to provide 500 g of oven-dry soil at each site on each sampling date. The actual mass of oven-dried soil and the volume of soil collected (calculated using the soil probe diameter, number of cores, and depth increment) were used to calculate bulk density. Upon collection, samples were saved in double-lined plastic bags and placed in cold storage (4°C) until processing.

Samples were air-dried and passed through a 2-mm sieve prior to analyses. Each site performed its analysis. Soil total C and TN were determined by dry combustion using a Leco IR C/N analyzer (CHN-2000, St. Joseph, MI, USA, 49085) or a Carlo Erba C/N analyzer (Carlo Erba Instruments, Milan, Italy) on soil ground to pass a 0.106-mm sieve. To determine SOC, inorganic C was subtracted from total C. Inorganic C was measured on soils with a pH$\geqslant$7.2 by quantifying the amount of CO_2 produced after application of dilute HCl stabilized with $FeCl_2$[14]. Inorganic N was determined by extracting 10 g of soil with 100 ml of 2 *M* KCl after shaking for 1 h at 300 rpm on an orbital shaker. The supernatant was filtered through Whatman filter paper No. 2 and stored at 4°C until analyzed colorimetrically for NH_4-N and NO_3-N using the method described by Keeney and Nelson[15]. Soil pH and EC were determined using soil : water in the ratio 1 : 1 (w : w)[10].

POM was determined using the procedure of Cambardella et al.[16]. Briefly, POM was measured by adding 90 ml

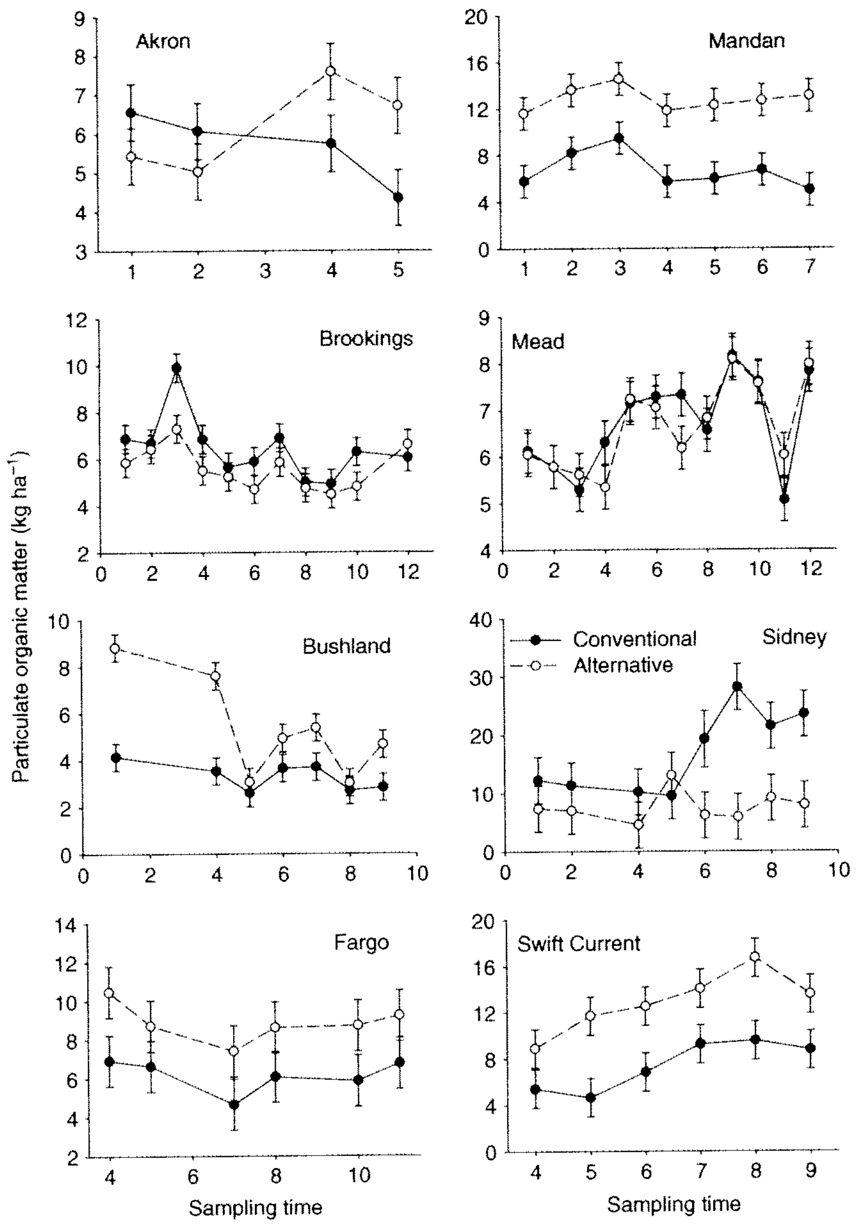

Figure 6. Particulate organic matter (kg ha^{-1}) in the 0–7.5 cm depth as a function of sampling time (multiple years) under the conventional and alternative management systems at eight locations in the Great Plains. Bars represent 1 SEM. Sampling times correspond to preplant = 1, 4, 7, and 10; peak biomass = 2, 5, 8, and 11; and post-harvest = 3, 6, 9, and 12.

CON and ALT treatments were tilled may have masked the cropping sequence differences.

At Swift Current, TN (Fig. 2) and SOC (Fig. 3) were greater in the ALT treatment than in the CON treatment. The increase associated with the ALT treatment is probably due to a reduction in the incidence of fallow, since NT was used in both the CON and ALT treatments (Table 1). In general, summer fallow enhances SOM decomposition, thereby decreasing SOC[8]. Additionally, C additions to the soil are lower in summer fallow systems since a crop is growing every other year[22].

POM was greater in the 0–7.5 cm depth of the ALT treatment than the CON treatment at Bushland, Mandan, Sidney, and Swift Current (Fig. 6). POM was 44% greater in soils from the ALT treatment than in soils from the CON treatment at Fargo ($P = 0.06$). Overall, the increase in POM within the ALT system was associated with a reduction in tillage intensity and fallow frequency. Beare et al.[23] observed 20% greater POM in NT managed soils compared to conventionally tilled soils. Treatment differences in POM in the 7.5–15 cm increment were observed at Mandan (4.0 kg ha^{-1} in the CON treatment versus 6.9 kg ha^{-1} in the ALT treatment) and at Swift Current (5.2 kg ha^{-1} in the CON treatment versus 7.9 kg ha^{-1} in the ALT treatment). Treatment differences in POM in the 15–30-cm depth were observed at Swift Current (4.4 kg ha^{-1} in the CON treatment versus 6.8 kg ha^{-1} in the ALT treatment). Temporal dynamics were exhibited by POM in all soil

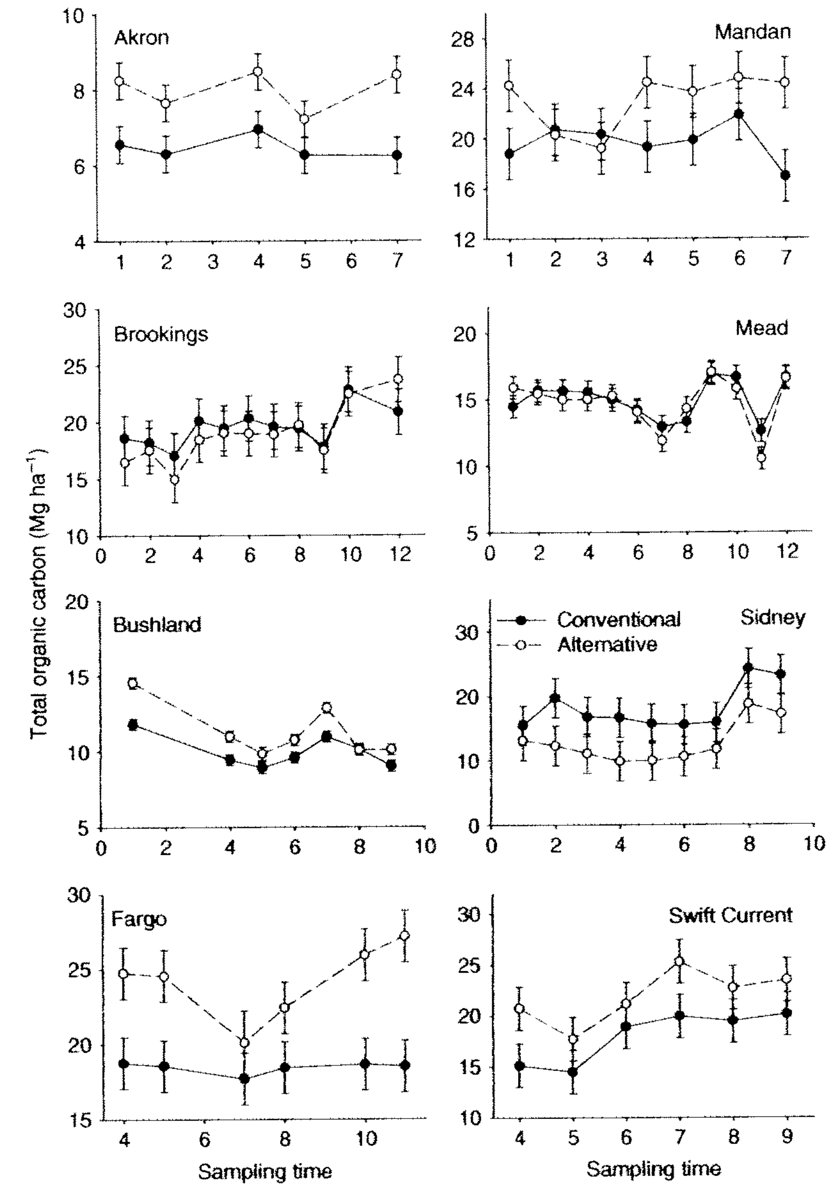

Figure 3. Total soil organic carbon (Mg C ha^{-1}) in the 0–7.5 cm depth as a function of sampling time (multiple years) under the conventional and alternative management systems at eight locations in the Great Plains. Bars represent 1 SEM. Sampling times correspond to preplant = 1, 4, 7, and 10; peak biomass = 2, 5, 8, and 11; and post-harvest = 3, 6, 9, and 12.

completely randomized split plot design with system as the main plot and sampling time as the subplot. The analysis of variance F-tests were used to determine treatment differences and F-protected t-tests were used on pairwise comparisons as a follow-up for any significant finding. The analysis of variance and mean separation difference were conducted for each site using Proc Mixed in SAS[17]. Soil depths were also analyzed independently. All results were considered significantly different at $P < 0.05$ unless noted otherwise.

Results and Discussion

Management treatments affected soil TN, NO_3-N, SOM (both organic C and LOI), POM, EC, and pH in the 0–7.5 cm increment at most study locations. Treatment effects in measured variables in the 7.5–15 and 15–30 cm increments were less commonly observed and when present were usually at locations where the CON and ALT differed in tillage intensity (Brookings, Fargo, Mandan, and Mead). Temporal variation was common for all measured variables in all depth increments and at all locations. A significant treatment by time interaction was infrequently observed. There were no consistent trends for the effect of time, and the observed temporal variation was likely due to changes in bulk density (BD) among growing seasons. BD (0–7.5 cm depth) exhibited temporal variability at Brooking, Bushland, Mead, Sidney, and Swift Current (Fig. 1). The effect of time on BD was significant ($P < 0.05$). In reality, changes in BD developed slowly