Soil Compaction in Eastern Nebraska after 25 Years of Cattle Grazing Management and Weed Control

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Highlight: *The effect of 25 years of weed control and grazing management on several physical properties of surface soil was measured.*

Bulk density of continuously grazed plots was 1.22 g/cm³ in the top 7.6 cm of soil as compared to 1.14 g/cm³ on deferred and rotationally grazed plots, and 1.02 g/cm³ on plots protected from grazing. Saturated hydraulic conductivities of 7.6 cm top soil cores from the protected plots were four times higher than from the two grazed plots. Those for warm-season grasses averaged 28.3 cm/hour, whereas mowed and smooth brome plots averaged 14.8 cm/hour. The value for the continuously grazed mowed plots was 3.0 cm/hour.

The effect of long-term weed control and grazing management was reflected in the physical properties of soil which, in turn, influenced forage production by the increased water entry into soil.

Many pastures in eastern Nebraska and surrounding areas have decreased in forage productivity as numbers of weeds have increased. In addition, traffic of grazing animals changed the physical condition of soil in the pastures. Reduced water infiltration rate further reduced the productivity of the site.

Most investigations of animal traffic on soil have been on sites of rather short duration of grazing and showed increased bulk density of soil (Gradwell, 1968), increased resistance of penetrometer into soil (Keen and Cashen, 1932; Tanner and Mamaril, 1959), decreased air permeability (Steinbrenner, 1951; Tanner and Mamaril, 1959), decreased rate of water entry (Steinbrenner, 1951), increased runoff (Alderfer and Robinson, 1947), and reduced percentage of large pores (Gradwell, 1968). Literature on the effect of different grazing management and weed control treatments over a long period as they affect soil properties is limited.

We report here the long-term effects of common weed control practices and grazing management on bulk density, porosity, water-air relationships, hydraulic conductivity, and soil strength.

Materials and Methods

The pasture plots used in this study were part of an experiment that continued from 1950 through 1974 (McCarty et al., 1974a, 1974b). The soil type is a Pawnee silty clay loam of glacial origin, located 12.9 km (8 miles) south of Lincoln, Nebr. The soil is classified as Aquic Argiudoll.

The weedy pasture site has no history of tillage, except for establishment of certain seeding treatments in 1950. The surface soil is 20–30 cm thick and is in excellent physical condition.

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Weed control treatments and grazing managements were started in 1950. The weed control and seeding treatments were applied across three levels of grazing management in a split-plot design with three replications. The treatments used in this study were:

1. Check, no weed control treatments applied.
2. Mowed with a tractor at a height of 6–8 cm about June 10.
3. Isopropyl ester of 2,4-D [(2,4-dichlorophenoxy)acetic acid] at 1.12 kg/ha (1 lb/acre) applied about June 10.
4. Smooth brome seeded and supplementally sprayed with 2,4-D.
5. Warm-season grass mixture seeded and supplementally sprayed with 2,4-D.

Land for Treatments 4 and 5 was plowed in October 1949. On March 30, 1950, it was thoroughly disced and compacted with a treader. On March 31 smooth brome was seeded, and on May 17 the warm-season grass mixture was seeded after the soil had been double-disced and treaded again. The plots for weed control and seeded areas were 9.1 m wide and 70 m long. Continuously grazed, rotationally grazed, and nongrazed management treatments were superimposed across the weed control and seeded plots to give the split-plot design. The two grazing management strips were each 30.5 m wide and the nongrazed strip was 9.1 m wide.

About 20 cattle grazed the 24-ha (60-acre) pasture from early May through October or November, depending on grazing conditions. Age of livestock ranged from 1-year-old to mature cows. Utilization of the rotationally grazed portion of the pasture started about June 15 each year. The cattle were removed from these areas when the warm-season grass mixture reached about a 9- to 12-cm stubble height. When regrowth of grass warranted grazing, the livestock were again allowed into these areas. No livestock were present on the nongrazed areas since 1950.

Three cylindrical soil cores 7.6 × 7.6 cm were taken from the surface of each plot in November, 1973. The top and bottom portion of each soil core was trimmed to the exact volume of metal cylinder. Moist cores from the field were weighed and stored at 5°C until physical measurements were taken. Natural soil cores taken from storage were wetted from below. After overnight wetting, a hydraulic gradient of 1.5 was established on the cores for measuring saturated hydraulic conductivities. Five hundred milliliters of water flowed from the bottom to the top of the inverted soil core. The saturated core was weighed and placed on a ceramic plate in a pressure cell with 60 cm water suction on the plate. When drainage ceased, the soil core was reweighed. Difference in weight from saturated and 60 cm water suction was measured air porosity. Soil cores were dried at 105°C and their weights recorded. The oven-dried cores were removed from the metal cylinder and placed in a hydraulic press and the modulus of rupture was recorded. Particle density for each weed control treatment and management practice was obtained with a pycnometer bottle. Porosity of soil was calculated from the bulk and particle densities. Calculated saturation was obtained by assuming that all the soil pores were filled with water; hence, the air content of saturation is the difference between calculated saturation (or porosity) and measured saturation. The calculated air porosity is the difference between calculated total porosity and air volume at 60 cm water suction.

Results and Discussion

Bulk density data of surface soil from plots with different weed control treatments and grazing management are shown in Table 1. Continuous grazing for the past 25 years showed significant compaction in the top 7.6 cm of soil as compared to deferred-rotation and protected plots. In 1957, after 8 years of grazing, the bulk density was 1.17 g/cm^3 on continuously grazed plots (McCarty et al., 1974b). Seventeen years later the bulk density had increased to 1.22 g/cm^3. Plots protected from grazing averaged 1.04 g/cm^3 in 1974. Plots deferred and rotationally grazed averaged 1.14 g/cm^3 and showed no change in bulk density over the past 17 years.

Table 1. Bulk density (g/cm^3) of surface soil from plots with different weed control treatments and grazing management (means of 9 values).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Mowed	1.23 ab[1]	1.15 d	1.08 e	1.15 p
2,4-D	1.26 a	1.14 d	1.04 f	1.15 p
Check	1.14 d	1.14 d	1.00fg	1.09 q
Smooth brome	1.25 a	1.17 cd	1.01 fg	1.14 p
Warm-season grasses	1.20 bc	1.09 e	0.97 g	1.09 q
Average	1.22 x	1.14 y	1.02 z	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

Total porosity of the surface soil (Table 2) followed the same trend as the bulk density with regard to weed control treatments and grazing management.

Table 2. Total porosity (%) of surface soil plots with different weed control and grazing management (means of 9 values).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Mowed	52.8 gh[1]	55.9 e	58.7 d	55.8 s
2,4-D	51.9 h	56.3 e	60.2 e	56.1 s
Check	56.3 e	56.3 e	61.8 ab	58.1 r
Smooth brome	52.2 h	55.2 ef	61.3 bc	56.2 s
Warm season grasses	53.9 fg	58.1 d	63.0 a	58.3 r
Average	53.4 x	56.4 y	61.0 z	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

Water contents of soil cores on a volume basis (26.3–26.8%) at field sampling from plots with different weed control treatments were not significantly different. On a weight basis, the continuously grazed plots averaged 19.5% water content and were significantly lower than the protected plots, which contained 25.3% water. The value for deferred and rotated plots was 23.5%. The grass cover for the continuously grazed plots was less dense and the soil was more compact. This allowed less water to enter the soil profile and provided less protection from water evaporation from the surface.

The water contents at saturation and at 60 cm water suction did not show any significant differences among the weed control treatments. The grazing management practices, however, showed significant difference both on the weight and volume basis. Of interest is the air content of saturated soil cores, that is, the difference of saturated volume of water in soil cores from the total porosity as shown in Table 3. Soils with the warm-season grass mixture had the highest air content, ranging from 8.3 to 9.5%. The large air content is attributed to the dense root system in the soil cores in which the water did not displace the air adsorbed. The air content of mowed plots was the lowest, with 7.0%.

Table 3. Air content (%) in saturated soil cores from plots with different weed control treatments and grazing management (means of 9 values).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Mowed	6.8 bcd[1]	6.3 cd	7.9 a-d	7.0 s
2,4-D	6.6 bcd	7.7 a-d	8.1 a-d	7.5 s
Check	7.6 a-d	8.0 a-d	8.0 a-d	7.9 s
Smooth brome	6.2 d	6.9 bcd	8.8 ab	7.3 s
Warm-season grasses	8.6 abc	8.3 a-d	9.5 a	8.8 r
Average	7.2 x	7.4 x	8.5 y	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

Two types of air porosity were calculated: (a) Total porosity minus percent of water on volume basis at 60 cm suction = calculated air porosity, and (b) percent water on volume basis at saturation minus percent volume of water at 60 cm suction = measured air porosity. The calculated air porosity is larger than the measured porosity (Table 4). In both types of calculation the effects of the grazing management were significant. The differences among the weed control treatments were not pronounced. The warm-season grass mixture contained the most calculated air porosity, 23% at 60 cm suction. The amount of air porosity needed for growth of grasses according to Kopecky (1928) should exceed 5%. If consideration is based on measured air

Table 4. Measured and calculated air porosity (%) of soil cores at 60 cm suction from plots with different weed control treatments and grazing management (means of 9 values).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Measured air porosity				
Mowed	4.3 ef[1]	7.3 cd	11.5 b	7.7 rs
2,4-D	4.1 ef	6.9 cde	13.0 ab	8.0 rs
Check	6.0 def	6.4 cde	15.2 a	9.2 r
Smooth brome	3.3 f	5.8 def	12.4 b	7.2 s
Warm-season grasses	4.2 ef	8.9 c	13.8 ab	9.0 r
Average	4.4 x	7.0 y	13.2 z	
Calculated air porosity				
Mowed	11.2 ef	13.6 cde	19.4 b	14.7 t
2,4-D	10.7 ef	14.6 cd	21.1 ab	15.5 st
Check	13.6 cde	14.4 cd	23.2 a	17.1 rs
Smooth brome	9.5 f	12.7 de	21.3 ab	14.5 t
Warm-season grasses	12.6 de	16.0 c	23.3 a	17.3 r
Average	11.5 x	14.3 y	21.7 z	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

porosity, the continuously grazed plots restricted grass productivity. Protected plots were well above the required 5% air porosity. If consideration is based on calculated air porosity, the continuously grazed plots had adequate air porosity. Field observation and measured yields from the plots indicated that Kopecky's value of 5% would be a good index for measured air porosity and 12–14% should be used for calculated air porosity.

The saturated hydraulic conductivities of soil cores are given in Table 5. The mean values for continuous grazing and deferred grazing are not statistically significant. The protected plots are four times higher in conductivities than the other two grazing plots. The conductivities for soil cores seeded to warm-season grasses averaged 28.3 cm/hour, whereas the mowed plots and smooth brome plots averaged roughly half as much, 14.8 cm/hour. The value for the continuously grazed mowed plot was 3.0 cm/hour. Although forage production was lower on the mowed plots, the cattle spent extra time grazing because of the regrowth following mowing.

Table 5. Saturated hydraulic conductivities (cm/hour/hydraulic gradient) of soil cores as affected by weed control treatments and grazing management (means of 9 vaues).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Mowed	3.0 e[1]	16.0 cde	25.2 bcd	14.7 s
2,4-D	9.0 cde	9.9 cde	38.6 ab	19.2 rs
Check	7.8 de	7.9 de	53.7 a	23.1 rs
Smooth brome	9.9 cde	4.7 de	29.7 bc	14.8 s
Warm-season grasses	16.1 cde	11.3 cde	57.6 a	28.3 r
Average	9.2 x	10.0 x	40.9 y	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

Modulus of rupture of oven-dried soil cores is given in Table 6. The cores from protected plots were significantly more friable than were the other two grazing management plots. It appears that the lower modulus of rupture values for mowed, 2,4-D, and check plots was associated with fewer roots for binding the core. The roots were more prevalent in cores with smooth brome and warm-season grasses.

Forage production on the various plots was last summarized in 1969 (McCarty et al., 1974b). This reflected the accumulative effect of 20 years of weed control and grazing management on botanical composition. It is difficult to separate out the many factors that have an effect on production of desirable forage. In the check plots, total production was about 70% weeds where continuously grazed and 55% weeds where deferred and rotationally grazed. In the warm-season grass plots rotationally grazed, desirable forage made up more than 95% of the total production, and roughly 75% in the smooth brome and sprayed plots. The average production of the plots deferred and rotationally grazed was about 13% greater than those continuously grazed.

Table 6. Modulus of rupture (kg/cm^2) of oven-dried soil cores from plots with different weed control treatments and grazing management (means of 9 values).

	Grazing management			
Weed control	Continuous	Deferred & rotated	Protected	Average
Mowed	0.54 b-f[1]	0.65 a-d	0.48 c-f	0.56 qr
2,4-D	0.54 b-f	0.61 b-e	0.36 f	0.50 r
Check	0.45 d-f	0.65 a-d	0.35 f	0.48 r
Smooth brome	0.72 ab	0.85 a	0.62 b-e	0.73 p
Warm-season grasses	0.73 ab	0.68 abc	0.40 ef	0.60 q
Average	0.60 x	0.69 x	0.44 y	

[1]Means in a column or row followed by the same letter are not significantly different at the 5% level.

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