Grazing System Effects on Soil Compaction in Southern Iowa Pastures

A.S. Leaflet R2987

James R. Russell, Professor of Animal Science;
Justin Bisinger, Graduate Assistant

Summary and Implications

Soil compaction was measured as soil bulk density to a depth of 3 inches and soil penetration resistance to a depth of 6 inches at distances of 10 to 300 feet from a water source in pastures grazed by continuous, rotational or paddock strip-stocking at a stocking rate of 0.8 cows per acre over 3 years. Soil bulk density and penetration resistance 10 feet from the water source were greater than measurements further from the water sources. While stocking system had no main effects on soil bulk density and penetration resistance, paddocks grazed by strip-stocking had lower penetration resistance at depths of 0, 5, and 6 inches than continuous stocked pastures in October of each year. Results imply that producers should avoid placing of congregation areas like water sources in areas that would be sensitive to soil erosion and nutrient run off. Use of stocking systems like paddock strip stocking that provide long rest periods may be somewhat helpful in maintaining plant growth and water infiltration in pastures.

Introduction

Measured as bulk density or penetration resistance, soil compaction will inhibit plant production by obstructing root growth and, thereby, reducing water and nutrient uptake. Soil compaction may also inhibit water infiltration which will increase precipitation run off, soil erosion, and nutrient loading of surface water sources while reducing soil water storage. Thus, soil compaction reduces resilience of the pasture to both floods and droughts.

The static compression force by a standing beef cow has been estimated to be 123 kPa. However, because of added force resulting from the kinetic energy associated with walking that may be carried on two or three legs, the compression forces of walking cows on soils is more than double the static force. While this force would be greater than the 74 to 84 kPa exerted by an unloaded tractor, the smaller area of contact by hooves reduces the depth of influence of the force below the soil surface resulting in the largest effects of grazing livestock near the soil surface.

Because of these forces, cattle grazing will increase soil compaction in comparison to nongrazed exclosures whether measured as bulk density or penetration resistance as a result of increased soil strength and fewer, smaller, and less continuous macropores in pasture soils. The depth of the effects of grazing livestock on soil compaction have ranged from 1 to 6 inches from the surface with damage occurring at the greater depths when treading occurs at high soil moistures. Because of the repeated exposure to treading, the greatest effects of treading on soil compaction occurs near cattle congregation sites like trails, supplementation sites or near shade or water sources. While grazing increased soil compaction in comparison to nongrazed exclosures, grazing at different stocking rates has had little effect on soil bulk density or penetration resistance in long-term studies conducted on western rangelands. However, while we have found greater soil bulk densities to a depth of 3 inches and penetration resistance measurements to 4 inches for 3 years subsequent to pastures being exposed to a single spring grazing by moderate density-moderate duration stocking (moved once daily) than in nongrazed exclosures, there were no differences in soil bulk densities or penetration resistance measurements between grazing exclosures and pastures exposed to a single grazing event by high density-short duration stocking (moved 4 times daily) even though both grazing treatments had equal stocking rates. This result implies that even at a high stocking density, the effects of grazing on soil compaction may be minimized by reducing the length of time a given area is exposed to treading. Furthermore, while there is evidence in the literature that the length of the rest period has greater effects on the hydrologic condition of pasture soils than stocking density or length of the grazing period, there has been little research directly evaluating the effects of rest period length on soil bulk density or penetration resistance.

Rotational stocking may affect soil compaction by ensuring even distribution of grazing animals across a pasture and ensuring that each area of a pasture has grazing and rest periods. Controlling forage allowance by strip stocking each paddock ensures more thorough forage utilization and much longer rest periods. Stocking system may not only affect forage utilization, but the soil physical properties as well. Therefore, the objective of this study was to evaluate the effects of stocking system on the physical properties of soils.

Materials and Methods

In April 2012, six 10-acre cool-season pastures at the McNay Research Farm near Chariton, Iowa were divided into two blocks based on soil types. The predominant forage species on these pastures were the cool season grasses; smooth bromegrass, orchardgrass, and reed canarygrass and the legumes; red clover and birdsfoot trefoil. Two pastures within each block were subdivided into 10 paddocks with electric fencing. Each pasture had a waterer that had been in its present location since 1990. In addition, a secondary waterer was placed in the corner of the second paddock of each subdivided pasture. The secondary waterers served as the water source for cattle when they were confined to this paddock in each rotation, serving as a model for rotational and strip stocking systems with a waterer in each paddock. However, because of the cost and inconvenience of maintaining waterers in every paddock, cows accessed the primary waterer in each pasture when stocked in the remaining paddocks.

On May 11, 2012, May 14, 2013, and May 12, 2014, 48 August-calving Angus cows in late gestation were weighed, condition-scored, and allotted by weight and body condition to the six pastures until October 12, 2012, October 17, 2013, and October 4, 2014. Cows in pastures without paddocks were continuously stocked for the entire season. Cows in one of the divided pastures within each block were grazed by rotational stocking to maintain high forage quality. To limit forage maturity within these pastures, cows in these pastures were moved between six of the ten paddocks until late June, 2012 and July, 2013. Forage from the remaining 4 paddocks was harvested as hay on May 21, 2012 and June 17, 2013 and the paddocks were incorporated into the grazing system in 35 days. Because of rainy weather, forage could not be harvested as hay in June, 2014. Therefore, cows had access to all 10 paddocks throughout the grazing season. Forage mass was estimated with a falling plate meter (4.8 kg/m^2) and forage was allowed at 4.0, 4.8, and 6.0% of the cows' bodyweight from the initiation of grazing, August 1, and September 14 in 2012, 4.0, 6.0, and 7.2% of the cows' bodyweight from the initiation of grazing, July 22, and August 19, 2013, and 4.8 and 6.0% of the cows' bodyweight from initiation of grazing and August 1, 2014. As forage yields became limiting in September, cows in rotationally stocked pastures were never moved more frequently than every 3 days. Therefore, rest periods ranged from 27 to 38 days. Cows in the remaining subdivided pasture within each block strip-grazed each paddock with strips providing daily live forage DM allowances of 2.0, 2.4, and 3.0% of the cows' bodyweights from May 11, August 1, and September 14 in 2012, 2.0, 3.0, and 3.6% of the cows' bodyweights from May 14, July 22, and August 19 in 2013 and 2.4 and 3.0% of the cows' bodyweights from May 12 and August 1 in 2014. Cows in the strip-stocked paddocks were provided a new strip daily with no back fence. Forage in the strip-stocked pastures was allowed to mature and only controlled by grazing and trampling activity occurring during cattle presence. Rest periods in the strip-stocked pastures ranged from 116 to 142 days. Cows in the pastures with rotational or strip-stocking were confined within the second paddock in these pastures when rotated into it. However, when stocked in the remaining paddocks, cows had access to a lane to the primary water source.

Because soil physical properties are laterally and vertically distributed from shade and water sites in pastures, a minimum of six transects were located for determination of soil bulk density, penetration resistance, and organic carbon concentration. The angle of the arc limited by fences on either side of the primary water source in the continuously stocked pastures or the secondary water source in the second paddock within the rotationally and strip-stocked pastures was measured. The size of the angle was determined and six transects were located along the arms of five congruent, adjacent angles with the water source as the vertex. To prevent an excessive concentration of sampling sites where cattle congregation was likely heaviest, measurement sites at 10 feet from the vertex were located on only three of the transects. Measurement sites were also located at 25, 50, 100, 150, 200, and 300 feet along the transects to the length possible so that there were a minimum of 30 measurement sites per pasture or paddock. If paddock shape and size did not allow for 30 measurement sites using six transects, a seventh transect was located along the longest line possible from the water source and locations were established at the farthest distances to provide a total of 30 measurement locations. After location, each site was marked with fiberglass post.

To measure soil bulk density and total and particulate SOC, two soil samples were collected to a depth of 3 inches (7.5 cm) in a plexiglass sleeve within a core sampler with a 1.88-inch (4.78 cm) diameter at each measurement site within each pasture in May, 2012 and October, 2014. After collection, the sample height was recorded and the sample was transported to a laboratory for further processing. Within the laboratory, soil samples were quantitatively removed from the sleeve, weighed, placed in a plastic bag, and frozen until later analysis. For determination of bulk density, one-half of each sample was weighed, dried at 105°C for 24 hours and re-weighed for determination of dry matter (DM). Soil bulk density was calculated multiplying the wet weight of the total core sample by the sample DM and dividing that value by π times 2.39^2 times the height of the sample. The remaining soil from the two samples from each measurement site was composited and dried at room temperature for 4 days and will be used for measurement of organic carbon. In May and October of each year, soil penetration resistance was measured at 1 inch (2.5 cm) intervals to a depth of 6 inches (15 cm) with a Field Scout SC 900 penetrometer with a 0.5 inch (1.25 cm) diameter cone tip at each sampling site within each pasture.

All data were analyzed by the mixed procedure of SAS with pasture as the experimental unit. The model for analysis of the soil bulk density included the main effects of and interactions between year, stocking system and distance from the water source. The model for analysis of penetration resistance at each depth of measurement included the main effects of and interactions between year, month, stocking system, and distance from the water source.

Results and Discussion

Soil bulk density at a distance of 10 feet from the water sources was greater ($P < 0.05$) that at distances of 25 to 300 feet from the water sources (Fig. 1). Across treatments, soil bulk density decreased ($P < 0.10$) from May, 2012 to October, 2014. However, there were neither any main effects of treatment nor interactions of treatment with year or distance from the water sources.

Similar to soil bulk density, soil penetration resistance measurements at 10 feet from the water sources were greater ($P < 0.05$) than distances of 25 feet and further from the water sources at depths of 0 to 3 inches from the soil surface, greater ($P < 0.05$) than distances of 50 feet and further from the water sources at a depth of 4 inches, and greater ($P < 0.05$) than distances of 100 feet and further from the water sources at depths of 5 and 6 inches (Fig. 2). While there were no differences in penetration resistance beyond 25 feet at depths of 0 and 1 inch, penetration resistance measurements at depths of 3 and 4 inches did not differ beyond 100 feet from the water sources and penetration resistance measurements at depths of 5 and 6 inches did not differ beyond 50 feet from the water sources

At depths of 3 and 4 inches, penetration resistance measurements at distances of 10 and 25 feet from the water sources were greater ($P < 0.05$) in continuously stocked than strip-stocked pastures. However, there were no differences between stocking systems at other distances or depths. Penetration resistance measurements in May were lower ($P < 0.05$) than October for the respective treatments likely due to greater soil moisture in the spring and freeze-thaw activity over winter (Fig. 3). While there was no main effect of stocking system on penetration resistance, penetration resistance measurements at depths of 0, 5, and 6 inches in strip-stocked pastures were lower ($P < 0.05$) than continuously stock pastures. Also at depths of 1 and 2 inches, while penetration resistance in continuously stocked pastures was lower than rotationally or strip stocked pastures in year 1, penetration resistance in strip stocked pastures was lower than continuously stocked pastures in years 2 and 3 (Year x Stocking System, $P < 0.05$).

Results imply that the major factor affecting soil compaction is the distance from congregation areas like water sources. These effects are relatively rapid as although the primary water sources in continuously stocked pastures were established 32 years before the initiation of the project and the secondary water sources in the rotationally and strip-stocked pastures were established at the start of this research project, there were few distance by stocking system interactions on soil bulk density or penetration resistance at most depths. The effects of treading on soil compaction around a congregation area was very localized being within 25 feet from the water sources. While stocking system did not have major effects on soil compaction, there is evidence that the long rest periods associated with a system of strip-stocking paddocks will result in less soil compaction than continuously stocked pastures. This reduction in soil compaction should increase water infiltration while reducing sediment and nutrient transport in precipitation run off. Furthermore, a we've previously observed no differences in water infiltration between nongrazed grasslands and pastures grazed by rotational stocking to a residual sward height of 4 inches, soil compaction may be more sensitive to the amount of residual forage remaining after each grazing period than it is to the length of the grazing period.

Acknowledgements

This project was funded, in part, by the Leopold Center for Sustainable Agriculture. The authors thank Kevin Maher, Nick Piekema, and Brad Evans at the McNay Research Farm for their management of the cows on this project and Matt Kriha and Jenna Malachek for assisting in grazing management and sample collection.

Figure 1. The effect of distance from water source on soil bulk density across treatments and years. Differences between means with different letters are significant, P < 0.05.

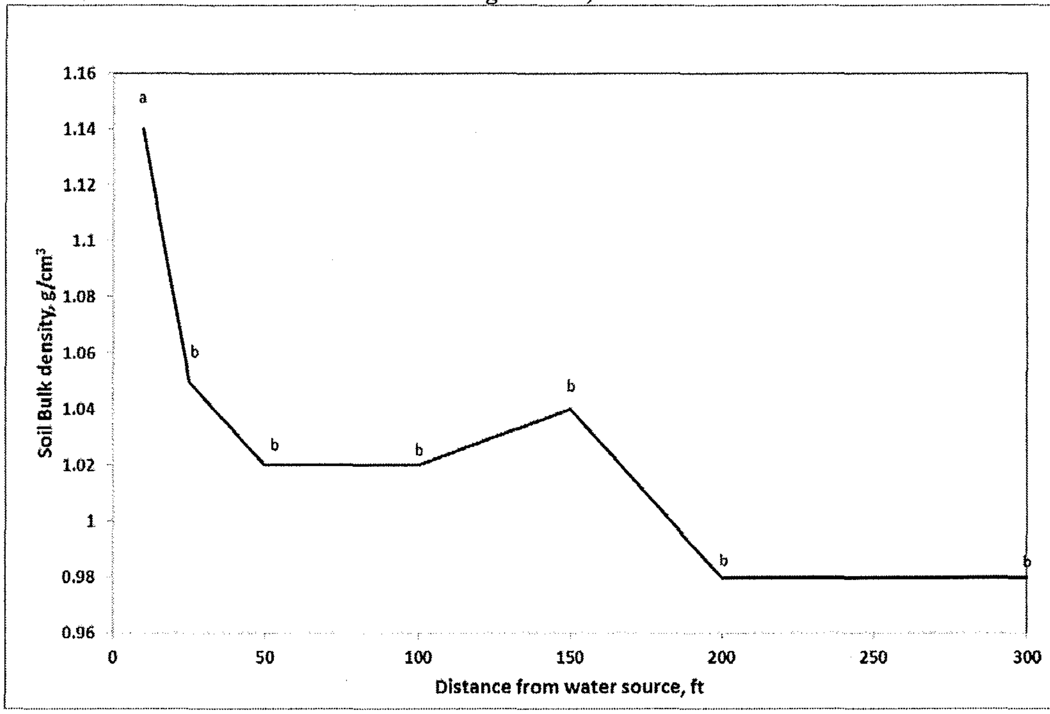

Figure 2. The effect of distance from water source on soil penetration resistance at depths of 0, 1, 2, 3, 4, 5, and 6 inches across treatments, years, and months. Differences between means with different letters within each depth are significant, P < 0.05.

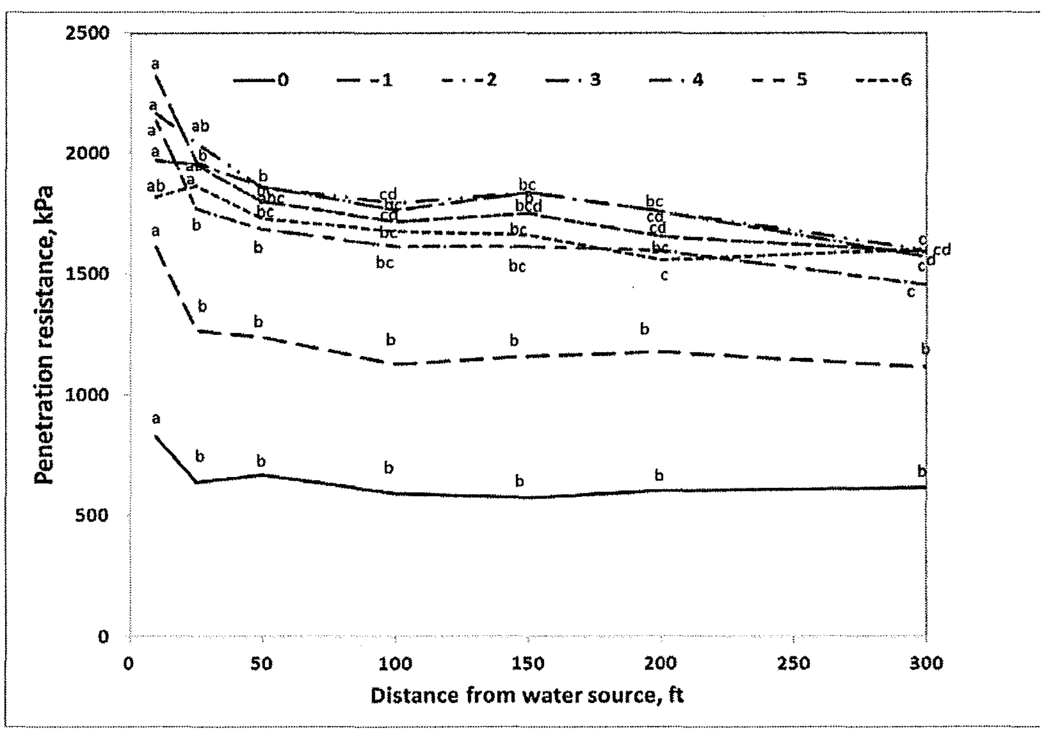

Figure 3. The effects of month and stocking system on soil penetration resistance at different depths across years and distances from water source. Differences between means with different letters within each depth are significant, P < 0.05.