Soil Physical and Biological Responses to Cattle Grazing of Cover Crops

Alan J. Franzluebbers and John A. Stuedemann

Abstract

Integration of crops and livestock could be either detrimental or beneficial to soil properties, depending upon timing and intensity of animal traffic and residue cover of the soil surface. We determined surface-soil properties of a Typic Kanhapludult in northeastern Georgia USA during the first three years of an experiment evaluating the effect of tillage [conventional (CT), conservation (NT)], cropping system (summer grain-winter cover, winter grain-summer cover), and cover crop utilization (grazed, ungrazed) variables. With initially high soil organic C due to previous pasture management, depth distribution of total and microbial biomass C became widely divergent between CT and NT following cropping management. Soil bulk density was reduced at a depth of 3-12 cm with CT, but soil became reconsolidated below 12 cm, similar to that under NT. Ponded water infiltration tended to be lower under grazed than under ungrazed cover crop management, especially at higher antecedent soil water contents. The interaction of cover crop management with antecedent soil water content on water infiltration indicates that long-term cropping system effects on soil physical quality will be partly influenced by timing and intensity of cattle traffic. Although CT management could initially alleviate compaction with periodic tillage, NT management may also have an advantage in pasture – crop rotation systems by preserving the organic matter-enriched surface soil to buffer against compactive forces.

Keywords: Bulk density, infiltration, microbial biomass, organic carbon, soil water content

Introduction

Soil organic matter is a critical component in maintaining soil quality in the southeastern USA. Pastures are known to improve soil organic matter, which leads to retention of organically bound nutrients and improved water relations. Cropping systems that are appropriate in this region under conditions of high soil organic matter have not been evaluated since much of the cropland has been stripped of soil organic matter from previous degradative cropping practices.

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The impact of grazing animals on the environment is more often than not viewed as negative. A large portion of the land area in the southeastern USA is devoted to pasture production of cattle. Our previous work has shown that grazing of warm season grasses in the summer can have positive impacts on soil organic C and N accumulation and no observable detriment to surface soil compaction (Franzluebbers et al., 2001). However, the role of grazing animals in pasture – crop rotations does not have to be limited to the medium- or long-term pasture phase alone. Cover crops following grain or fiber crops can be an excellent source of high quality forage to be utilized in mixed use farming operations, which have the potential for adoption throughout the southeastern USA. A potential impact of animals grazing cover crops, however, could be compaction due to trampling, as was observed in two soils under relatively low soil organic matter conditions (Tollner et al., 1990). Surface residue cover may provide a significant buffer against animal trampling effects, such that no tillage crop production following long-term pasture could alleviate negative animal trampling effects.

A long-term pasture – crop rotation experiment was established in 2002 to determine the influence of tillage, cropping system, and cover crop management on productivity and environmental quality in the Southern Piedmont. Our objective was to quantitatively evaluate three management factors (i.e., tillage, time of cover cropping, and cover crop management) for their impacts on soil physical and biological properties. The factorial arrangement of treatments allowed us to isolate interactions among management factors, which should lead to a better understanding of the processes controlling productivity and environmental quality.

Materials and methods

The experiment was located at the J. Phil Campbell Sr. Natural Resource Conservation Center (33° 52' N, 83° 25' W) in Watkinsville GA on Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludult). A set of 18 experimental paddocks (0.7-ha each) were previously arranged as part of a long-term design initiated in 1981 to study tall fescue (*Festuca arundinacea* Schreb.) – endophyte effects on cattle productivity, performance, and other miscellaneous animal response variables until 1997. Fertilization was terminated prior to 1998 and forage grazed on an ad hoc basis thereafter. Pasture growth during the past five years without fertilization was expected to remove any differences among paddocks in residual inorganic soil N. All paddocks were limed (2.2 Mg ha^{-1}) immediately prior to termination of the tall fescue. The 18 experimental paddocks were regarded as an excellent starting point for the proposed research because soil organic matter was at a high level (Franzluebbers et al., 1999) and grazing infrastructure was mostly in place at the site (fencing, gates, shades, mineral feeders, watering troughs, and animal handling facility).

The experimental design of the current investigation consisted of a completely randomized design with a split-plot arrangement within main plots. Main plots were a factorial arrangement of (a) tillage and (b) time of cropping and split plots within main plots were (c) cover crop management. Main plots

were replicated four times. Grazed plots were 0.5 ha in size and ungrazed plots were 0.2 ha. Two paddocks remained in perennial pasture to serve as uncropped controls.

Tillage management was with (1) conventional disk tillage (CT) following harvest of each grain and cover crop and (2) no tillage (NT) with glyphosate to control weeds prior to planting. Conventionally tilled plots were broken from sod with a moldboard plow to a depth of 25 to 30 cm and disk plowed to approximately 15 cm thereafter. No tillage plots were broken from sod with application of glyphosate.

Cropping systems included:

(1) winter grain cropping [wheat (Triticum aestivum L.); November planting and May harvest] with summer cover cropping [pearl millet (Pennisetum glaucum (L.) R. Br.); June planting and October termination] and

(2) summer grain cropping [grain sorghum (Sorghum bicolor (L.) Moench); May-June planting and October harvest] with winter cover cropping [cereal rye (Secale cereale L.); November planting and May termination].

'Tifleaf 3' pearl millet was drilled in 7-cm-wide rows under CT and 19-cm-wide rows under NT at a rate of 15-17 kg ha^{-1}. 'Pioneer 83G66' grain sorghum was drilled in 34-cm-wide rows under CT and 38-cm-wide rows under NT at a rate of 6-7 kg ha^{-1}. Ammonium nitrate was spread on sorghum and millet at 45-52 kg N ha^{-1} in mid June to mid July. Wheat ('Crawford', '518W', and 'Coker 9663') and rye ('Hy-Gainer' and 'Wrens Abruzzi') were drilled in 19-cm-wide rows at a rate of 92-132 kg ha^{-1}. Ammonium nitrate was spread on wheat and rye at 40-53 kg N ha^{-1} in late February to early March.

Cover crops were managed (1) without cattle by mowing (CT) and mechanical rolling (NT) at maturity and (2) stocking with cattle for 40-70 days to consume available forage produced. Cover crops were stocked with yearling Angus steers in Summer 2002 (initial weight 262 $\pm$ 22 kg) and in Spring 2003 and with cow/calf pairs (initial cow weight 503 $\pm$ 40 kg and initial calf weight 168 $\pm$ 15 kg) thereafter. Ungrazed cover crops were grown until 2-4 weeks prior to planting of the next crop.

Soil was sampled in May 2002 (initiation) and in November/December 2002 (end of 1 yr), 2003 (end of 2 yr), and 2004 (end of 3 yr). Soil was sampled at depths of 0-3, 3-6, 6-12, and 12-20 cm in May 2002 and additionally at 20-30 cm depth thereafter. A composite sample of 8 cores in grazed plots and 5 cores in ungrazed plots was collected with a 4-cm diameter probe following surface residue collection from a 0.04-m^2 area at each subsampling location. Soil was dried at 55°C for >3 days and passed through a 4.75-mm screen to remove large stones. Soil bulk density was determined from the total dry weight prior to sieving and volume of coring device. A subsample was ground in a ball mill for analysis of total C and N with dry combustion. Soil microbial biomass C was determined from 25- to 65-g subsamples following rewetting of dried soil using a chloroform fumigation-incubation technique (Jenkinson and Powlson, 1976; Franzluebbers et al., 1996).

Water infiltration was determined from the linear rate of water intake during 1 hour within a 30-cm diameter steel ring inserted approximately 4 cm into the ground. Water was supplied with a Mariotti system and volume of water

recorded every 10 minutes. Linear regression was used to determine rate of water infiltration. Accounting for a 5-cm head of water, the intercept from the linear regression allowed estimation of air-filled macroporosity. Infiltration was determined from two locations in each grazed and ungrazed plot on several occasions. Soil water content was determined at a depth of 0-20 cm with time-domain reflectrometry from the average of five measurements within a 2-m radius of each infiltration ring.

Significance of difference in soil properties among management systems was assessed with the general linear model procedure of SAS and non-linear relationships of water infiltration with antecedent soil water content. Significant differences were declared at $p \leq 0.1$.

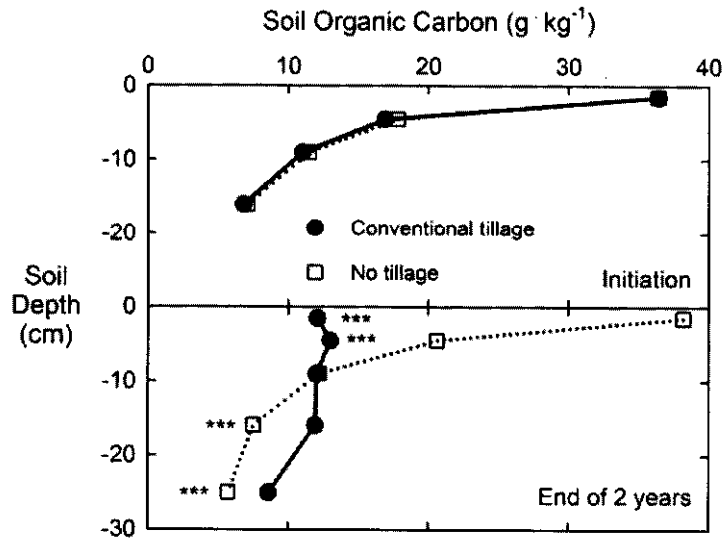

*Fig. 1: Soil organic C concentration with depth as affected by tillage management and year of sampling. *** denotes significance between tillage means within a depth at p = 0.001.*

Results and discussion

Soil organic C (SOC) concentration was initially very high at the soil surface and declined rapidly with depth (Fig. 1). At the end of one year of cropping, SOC under NT remained highly stratified with depth, similar to that at initiation. Under CT however, SOC became relatively uniformly distributed due to moldboard plowing that inverted soil within the surface 30 cm and subsequent disk tillage that mixed residues throughout the tillage layer. Similar SOC results were obtained at the end of two years of cropping. Although SOC was removed from the soil surface with CT, SOC concentration became enriched lower in the plow layer relative to that under NT.

Soil microbial biomass C (SMBC) at the end of 3 years of management followed a pattern similar to that of SOC with respect to tillage and depth

(Table 1). Whether cattle grazed cover crops or not had no effect on SMBC under CT, but grazing improved SMBC within the surface 6 cm of soil compared with ungrazed cover cropping under NT. Soil microbial biomass C was not different between NT and continuous perennial pasture at any soil depth. Data suggest that grazing of cover crops had no detrimental effect on general soil biological quality, and in fact, helped to improve it when practiced with NT. The return of feces to the soil surface, rather than crop residues only, appeared to have sustained the quantity of C sources necessary to maintain SMBC.

Table 1: Soil microbial biomass C as affected by land use (pasture and cropped), tillage (conventional and no tillage), cover crop management (ungrazed and grazed), and sampling depth at the end of 3 years (December 2004).

Soil depth	Grazed pasture	No tillage			Conventional tillage	
		Grazed		Ungrazed	Grazed	Ungrazed
cm	---------- mg kg^{-1} ----------					
0-3	1604	1706	*	1348	712	803
3-6	853	765	**	606	585	646
6-12	406	311		290	410	419
12-20	324	282		239	348	331
20-30	219	194		200	220	222

* and ** indicate significance between grazed and ungrazed means at $p = 0.1$ and $p = 0.01$, respectively.

Soil bulk density following long-term pasture and prior to this cropping experiment was relatively low at the soil surface (1.1 Mg m^{-3}) and increased dramatically with depth to about 6 cm, at which point maximum bulk density occurred (~1.5 Mg m^{-3}), similar to lower depths (Fig. 2). With CT, soil bulk density was reduced at depths of 3-12 cm, but not at the surface and below this depth. Tillage operations after the initial breaking of sod were limited to approximately the surface 15 cm, which led to reconsolidation without subsequent mechanical loosening in the 12 to 30 cm zone. Under NT, soil bulk density did not appear to change with time compared to the initial pasture condition. Maintenance of the low bulk density at the soil surface with NT was likely possible only with the high concentration of SOC present. Whether cover crop was grazed or not had no effect on bulk density in the 0-3-cm depth under NT (1.13 Mg m^{-3}), but bulk density was lower with grazing than ungrazed condition under CT (1.08 vs 1.15 Mg m^{-3}, $p = 0.07$). This result was at the end of 3 years, suggesting that longer term evaluations will be needed.

Water infiltration was negatively related to antecedent soil water content (Fig. 3). Water infiltration tended to be lower under grazed than ungrazed condition, especially with high soil water content. These results indicate a dominating influence of antecedent soil water conditions on additional water infiltration. They also indicate that grazing of cover crops had only a slight tendency to limit water infiltration. Timing of cattle traffic during the year may greatly impact the development of physical soil quality in the long-term.

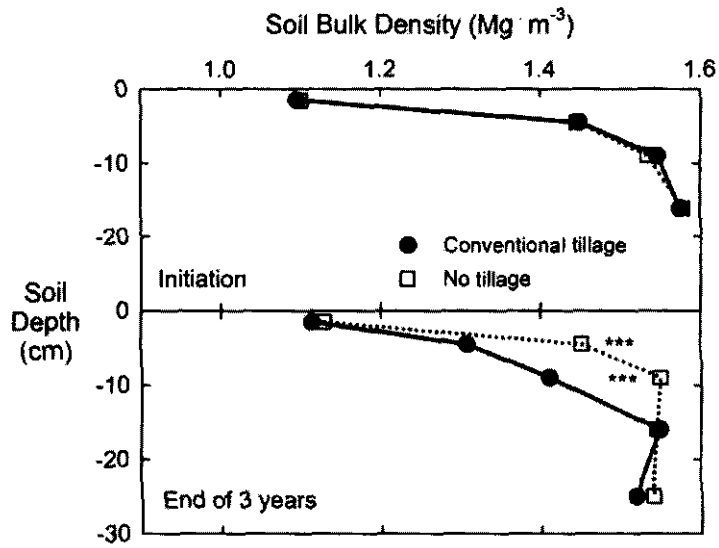

*Fig. 2: Soil bulk density as affected by tillage, depth, and year of sampling. *** indicates significance between tillage means at $p < 0.001$.*

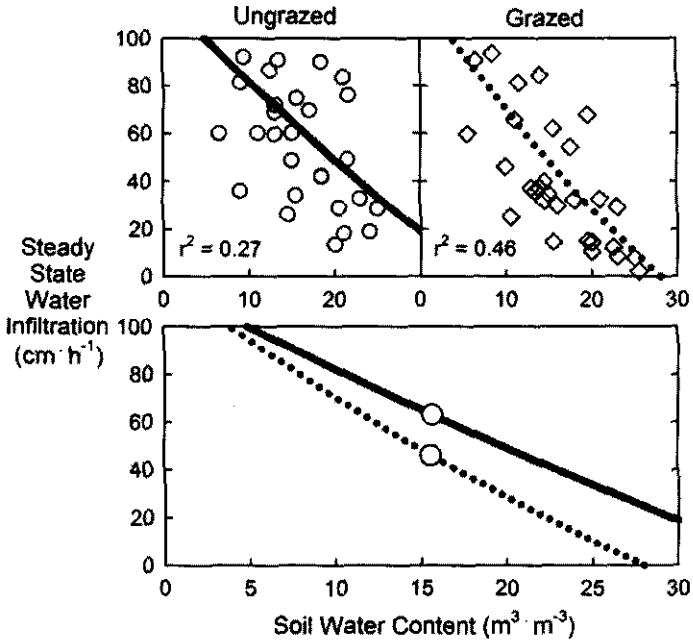

Fig. 3: Water infiltration determined on four dates (15 October 2003, 3 May 2004, 27 July 2004, and 20 October 2004) as affected by cover crop management. Circles in bottom panel indicate mean soil water content and associated infiltration.

Summary and conclusions

Crop management following termination of long-term pasture resulted in significant changes in soil properties during the first three years. Termination of pasture with moldboard plowing and subsequent disking (CT) for seedbed preparation led to relatively uniform distribution of SOC and soil microbial biomass C within the plow layer. Termination of pasture with herbicide and subsequent NT management of crops maintained a highly stratified distribution of organic matter in soil. Although CT loosened soil initially throughout the plow layer (0-30 cm), soil at lower depths became reconsolidated after the first year, resulting in less dense soil with CT compared with NT only at a depth of 3-12 cm thereafter. Water infiltration was highly related to antecedent soil water content. Cover crop management interacted with antecedent soil water content, such that grazing tended to reduced water infiltration only at high soil water contents. Preservation of surface soil organic matter with NT was a critical condition that allowed cattle grazing of cover crops to (1) improve soil microbial biomass, (2) resist surface soil compaction, and (3) apparently limit degeneration of the soil pore network that influences water infiltration.

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