Surface-Soil Properties in Response to Silage Intensity under No-Tillage Management in the Piedmont of North Carolina

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RATIONALE

Soil quality is a concept based on the premise that management can deteriorate, stabilize, or improve soil ecosystem function.

Crop residues left at the soil surface as a surface mulch are important for feeding the soil biology, suppressing weed seed germination, and suppressing wide fluctuations in temperature and moisture that can limit plant development.

Dairy producers in North Carolina rely on maize (*Zea mays*) and barley (*Hordeum vulgare*) silage as sources of high-quality feedstuffs in their rations. High-intensity silage cropping is typically practiced to maximize the amount of feedstuffs produced per unit of land area. High-intensity silage cropping, however, leaves little residue at the soil surface, offering little buffer against equipment traffic.

Lack of residues under high-intensity silage cropping brings into question issues of long-term compaction, water-use efficiency, nutrient cycling, and soil erosion when conservation tillage is used.

OBJECTIVE

Determine the impact of alternative silage cropping systems that returned more crop residues to the soil than the traditional maize-barley silage cropping system on various surface-soil properties, including bulk density, aggregation, soil organic C and N, soil microbial biomass C, and potentially mineralizable C.

MATERIALS and METHODS

Location

Dairy farm in Iredell Co., NC
Southern Piedmont Major Land Resource Area

Soil and environment

Fairview sandy clay loam (fine, kaolinitic, mesic Typic Kanhapludult) in Replication 1.
Braddock loam (fine, mixed, semiactive, mesic Typic Kanhapludult) in Replication 2.
Soils classified as well drained with moderate permeability.
Mean annual precipitation is 48" (122 cm) and mean annual temperature is 58 °F (14.4 °C).

Management

Three cropping systems replicated twice in 1000'-long strips, 50-75' wide managed by farm owner with his field equipment.
Replication 1 established in 1998 and Replication 2 in 2000.
Several years previously, land managed with NT and high silage intensity.

Year 1	Year 2	Silage/year	Silage intensity	Residue return
Maize silage Barley silage	Maize silage Barley silage	2	High	Low
Maize silage Rye cover	Maize silage Rye cover	1	Medium	Medium
Maize silage Barley grain	Sudangrass cover Rye cover	0.5	Low	High

Sampling

Eight soil cores (4-cm diam) collected from each plot in Dec 2000 and in Feb 2002 at depths of 0-3, 3-6, 6-12, and 12-20 cm.

RESULTS and DISCUSSION

Sampling in December 2000 was after 3 years of treatment in Replication 1 and after 1 year of treatment in Replication 2. The value of this experiment will be enhanced with time. Despite this, the changes in soil-surface properties during the first few years of evaluation should be revealing towards possible future effects.

Soil physical properties

Soil bulk density increased with depth under all management systems (Table 1). The depth distribution of soil bulk density highlights the need to assess potential compaction problems under conservation tillage systems at a finer spatial scale than simply the traditional plow layer.

Soil bulk density in December 2000 was greater under high than under low silage cropping intensity down to a depth of 12 cm (Table 1). Taken to a depth of 20 cm, soil bulk density was significantly greater under medium and high silage intensity than under low silage intensity.

Soil bulk density in February 2002 was not affected by silage cropping intensity (Table 2). There was a similar trend that soil bulk density was greater under high than under low silage intensity, especially nearest the soil surface.

Table 1. Soil physical properties within depth sections as affected by silage cropping intensity in December 2000.

Soil depth		Silage cropping intensity				
Inches	cm	Low	Medium	High	LSD (P=0.1)	
		Soil bulk density ($Mg \cdot m^{-3}$)				
0-1.2	0-3	0.93	0.95	1.02	0.08	†
1.2-2.4	3-6	1.25	1.36	1.35	0.09	†
2.4-4.7	6-12	1.36	1.47	1.46	0.08	*
4.7-7.9	12-20	1.47	1.53	1.52	0.10	
0-7.9	0-20	1.32	1.40	1.40	0.07	†
		Stability of macroaggregates [g (wet) $\cdot g^{-1}$ (dry)]				
0-1.2	0-3	0.86	0.88	0.81	0.05	*
1.2-2.4	3-6	0.85	0.87	0.85	0.03	
2.4-4.7	6-12	0.79	0.83	0.82	0.05	
4.7-7.9	12-20	0.75	0.72	0.71	0.04	†
0-7.9	0-20	0.79	0.79	0.78	0.03	
		Stability of mean-weight diameter [mm (wet) $\cdot mm^{-1}$ (dry)]				
0-1.2	0-3	0.69	0.77	0.66	0.09	*
1.2-2.4	3-6	0.69	0.74	0.70	0.07	
2.4-4.7	6-12	0.64	0.71	0.67	0.07	†
4.7-7.9	12-20	0.58	0.55	0.53	0.05	
0-7.9	0-20	0.62	0.65	0.61	0.05	

† and * indicate significance at P≤0.1 and P≤0.05, respectively.

A significant temporal change in soil bulk density occurred between low and high silage cropping intensity (Fig. 1). These results suggest that compaction was occurring at a slow rate with high silage cropping intensity, but that compaction could be alleviated by low silage cropping intensity with high surface residue return. The slow conversion of organic matter from crop residues into soil organic C, especially at the soil surface, can lead to a large reduction in soil bulk density.

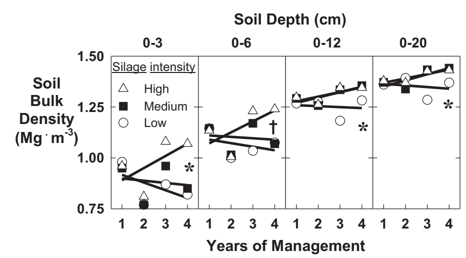

Fig. 1. Soil bulk density within the surface 20 cm of soil as affected by number of years under a particular silage intensity. † and * indicate significance at P<0.1 and P<0.05, respectively, between regression lines.

Stability of macroaggregates and of mean-weight diameter of aggregates with wet sieving was greater under medium than under high silage cropping intensity at a depth of 0-3 cm (Table 1). Overall, few significant changes in aggregate stability occurred at other depths. Aggregate stability can be viewed as a secondary response variable that is dependent upon surface residue retention, soil organic C, soil microbial activity, and compaction. We expect that aggregate stability will improve slowly with higher residue-retention systems.

Table 2. Soil bulk density within depth sections as affected by silage cropping intensity in February 2002.

Soil depth		Silage cropping intensity			
Inches	cm	Low	Medium	High	LSD (P=0.1)
		Soil bulk density ($Mg \cdot m^{-3}$)			
0-1.2	0-3	0.80	0.81	0.94	0.24
1.2-2.4	3-6	1.28	1.27	1.31	0.18
2.4-4.7	6-12	1.52	1.56	1.48	0.25
4.7-7.9	12-20	1.53	1.51	1.54	0.19
0-7.9	0-20	1.38	1.38	1.40	

Soil biochemical properties

Soil organic, microbial biomass, and potentially mineralizable C were highly stratified with depth under all management systems (Table 3). This result at an early stage in this study was likely a result of the long-term management with conservation tillage on this farm. Although not significant, soil organic C and microbial biomass C tended to be higher with lower silage intensity, especially nearest the soil surface. With time, we expect that C pools will become significantly greater with low than with high silage intensity.

Although soil microbial biomass represented only 4.7% of the soil organic C pool, it plays a major role in organic matter decomposition and nutrient cycling as the agent that mediates elemental transformations.

The flush of CO_2 following rewetting of dried soil is an indicator of potential soil microbial activity and soil microbial biomass. Even at an early stage in this study, the flush of CO_2 was greater under lower than higher silage intensity at depths of 0-3 and 3-6 cm. The flush of CO_2 can be a sensitive indicator and may predict changes in mineralizable N supply due to tillage/crop management.

Table 3. Soil biochemical properties within depth sections as affected by silage cropping intensity in December 2000.

Soil depth		Silage cropping intensity				
Inches	cm	Low	Medium	High	LSD (P=0.1)	
		Soil organic C ($mg \cdot g^{-1}$)				
0-1.2	0-3	38.2	33.3	30.0	12.7	
1.2-2.4	3-6	16.6	14.6	15.9	2.2	
2.4-4.7	6-12	10.3	10.4	10.8	2.6	
4.7-7.9	12-20	7.6	6.4	6.8	1.6	
0-7.9	0-20	12.9	11.6	11.8	2.4	
		Soil microbial biomass C ($\mu g \cdot g^{-1}$)				
0-1.2	0-3	1711	1515	1340	479	
1.2-2.4	3-6	877	836	781	168	
2.4-4.7	6-12	422	471	532	126	
4.7-7.9	12-20	373	288	305	59	*
0-7.9	0-20	599	550	556	82	
		Flush of CO_2-C following rewetting of dried soil ($\mu g \cdot g^{-1} \cdot 3\ d^{-1}$)				
0-1.2	0-3	544	643	402	153	*
1.2-2.4	3-6	291	293	220	45	*
2.4-4.7	6-12	148	173	150	41	
4.7-7.9	12-20	99	81	88	33	
0-7.9	0-20	188	198	160	29	*

† and * indicate significance at P≤0.1 and P≤0.05, respectively.

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