Managed grazing's effects on soil quality and structure

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A long-term southern Wisconsin cropping systems study shows that soils under managed grazing have a number of positive characteristics compared to soils under other cropping systems.

Begun in 1989 with support from the USDA Agricultural Research Service, the Wisconsin Integrated Cropping Systems Trial (WICST) provides data on three cash grain cropping systems and three forage systems on field-scale plots in Columbia County at the UW-Madison Arlington Agricultural Research Station. Researchers Joshua Posner and Janet Hedtcke of the UW-Madison Department of Agronomy analyzed and compared data from these well-established plots that differ in crop rotation complexity and use of purchased inputs.

This Research Brief compares the results of the plots under managed grazing with dairy heifers to other cropping systems (see Table 1 for the cropping systems). In the WICST managed grazing plots, heifers with a starting weight of about 500 pounds were grazed from May to October after being acclimated to pasture for a few weeks each spring. The pastures, seeded in 1992, included red clover, smooth bromegrass, timothy and orchardgrass, with biennial overseeding of red clover and 40 lbs N/a/yr as commercial fertilizer applied in June or August, depending on forage availability.

To compare soil quality under the six systems, Posner and Hedtcke modeled and measured a suite of soil properties. They found some interesting differences between the systems in terms of erosion potential, earthworm counts, water stable aggregates, soil carbon, and the Soil Quality Index.

Findings from modeling

Soil conservation. Using the Revised Universal Soil Loss Equation 2 (RUSLE2), Posner and Hedtcke modeled soil erosion losses under the six different cropping systems over 18 years. In addition to estimating soil erosion loss in tons per acre, RUSLE2 generates a Soil Conditioning Index (SCI) which measures soil structure and organic matter changes, with positive values reflecting a gain in soil carbon and organic matter and negative values implying a loss. RUSLE2 also calculates the Soil Tillage Intensity Rating (STIR), an indication of the frequency and intensity of machinery passes that may oxidize soil organic matter, destroy soil structure and increase compaction and the potential for erosion. STIR ratings can range from 0 to 200 with values less than 30 being ideal. Erosion estimates for managed grazing at 0.2 t/acre, largely due to the initial seeding phase at establishment, were much lower than all other cropping systems. The managed grazing system also had excellent ratings for SCI at 1.46 and STIR at 15 (see Table 1).

Findings from measurements

Earthworm counts. Earthworms promote soil health and soil structure through feeding, burrowing and mixing. Higher numbers of earthworms are correlated with soil quality factors such as improved infiltration, aeration and nitrogen mineralization. In the WICST project, researchers collected topsoil dwelling earthworm counts from 1999 through 2001 on all six cropping systems. Earthworm counts were significantly higher in the three forage rotations (including managed grazing) than in the cash grain systems (Table 1). The number of earthworms in the managed grazing system did not differ significantly from the other two forage systems, both of which are alfalfa-based systems that incorporate manure and have a two- or three-year forage phase. Continuous corn had the fewest earthworms by far, while the no-till cash grain system had significantly more earthworms than the other two tilled cash grain systems. Posner and Hedtcke found that the use of manure as fertilizer and perennial forage stands of longer duration lead to higher earthworm counts than annual crops, and soils under no-till annual crops showed higher earthworm counts than those under annual crop systems with tillage.

Water-stable aggregates. Soil particles that bind together tightly are more able to withstand the destructive forces of tillage and water or wind erosion than loosely bound particles. At the Arlington WICST plots in 2008, researchers measured these water-stable aggregates (WSA) in the surface eight inches of the soil with a wet-sieving method. The managed grazing system had a significantly higher percentage of WSA than the other cropping systems, particularly in the surface two inches of soil (Table 1).

Soil carbon. Increased soil organic carbon (SOC) levels can improve soil structure, reduce erosion and

Soil variables on WICST at Arlington Research Station for six long-term cropping systems*

	Modeled (4% slope, 150-ft. length)			**Measured** (linear contrast, $p<0.05$)		
Crop rotation	Soil erosion tons/ac	SCI (-2 to +2)	STIR (<30 is ideal)	Earthworms system mean, #/sq yard (1999-2001)	% of Water stable aggregates (2008)	Change in Soil Organic Carbon (1989-2009) over 3-ft soil profile (ton C/ac)
CS1 All years - corn	1.5	0.27	165	23^{c}	77.8^{c}	-17.8^{a}
CS2 Yr 1 - strip till corn Yr 2 - no till soybeans	1.1	0.63	22	103^{b}	74.2^{c}	-6.2^{b}
CS3 (Organic) Yr 1 - corn Yr 2 - soybeans Yr 3 - winter wheat/red clover	3.6	-0.36	185	54^{c}	66.5^{c}	-5.8^{b}
CS 4 Yr 1 - corn Yrs 2,3,4 - alfalfa	2.0	0.44	71	125^{a}	80.9^{b}	-3.1^{b}
CS 5 (Organic) Yr 1 - corn Yr 2 - oats/alfalfa Yrs 3,4 - alfalfa	2.7	0.17	120	129^{a}	79.8^{b}	-5.6^{b}
CS 6 All years - managed grazing dairy heifers	**0.2**	**1.46**	**15**	**157^{a}**	**88.9^{a}**	**-0.3^{b}**

**Values with different letters within each column were statistically different from each other*

increase soil fertility. The soils at Arlington developed under tallgrass prairie and oak savannah communities, which allocated carbon to below-ground fine root biomass deep into the soil profile.

Since the amount of carbon that can be sequestered in the soil is highly related to land management, there is a great deal of interest in using agricultural soils to sequester atmospheric CO_2. Analysis of SOC levels in all of the six WICST systems at Arlington in 1989 and 2009 showed that other than the managed grazing system, most systems lost SOC throughout the three-foot soil profile. While the managed grazing system sequestered carbon in the top foot of the soil (4 ton/a), these gains were offset by losses at deeper levels (-4 ton/a), with the result of no net gain. Looking at all of the cropping systems, both no-till practices and the inclusion of perennial pasture and hay crops reduced SOC losses, but neither practice resulted in C sequestration over the entire soil profile. The greatest loss of SOC occurred in the continuous corn system.

The significant C sequestration in the surface soil in the managed grazing system is the result not only of the volume of root biomass in that system, but also the nature of that biomass. The below-ground biomass of perennial grass systems like the WICST managed grazing system is dominated by fine roots and root hairs that have greater surface area than large roots typically found under corn and soybean fields. These fine roots help maintain root-derived C and are thought to play a key role in the long-term stabilization of SOC. Longer-term monitoring of SOC in WICST will provide further insight.

Soil Quality Index (SQI). The SQI integrates several physical, chemical and biological properties to arrive at a single measure. These properties include water stable aggregrates, bulk density, total organic carbon and microbial biomass. The higher the SQI, the better the soil is able to perform the functions necessary for its intended use. Measured in 2008, the surface two inches of soil in the managed grazing system had a SQI of 96, which was significantly higher than all of the other cropping systems, which had an aggregate average of 87.

This study shows that managed grazing can have a positive overall effect on soil in comparison to other typical cropping systems in the Upper Midwest. The features of managed grazing that contribute to these results include its lack of tillage, the diversity of perennial pasture plant communities and their associated below-ground carbon inputs, and its re-integration of livestock/manure inputs back onto the land.

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