SUMMARY RANGE MANAGEMENT REPORT

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Llewellyn L. Manske PhD
Research Professor of Range Science

North Dakota State University
Dickinson Research Extension Center
1041 State Avenue
Dickinson, ND 58601

Tel. (701) 456-1118
Fax. (701) 456-1199

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The worlds renewable natural resources (rangelands, grasslands, croplands, and forestlands) are traditionally managed for their use. As a result, the productivity of these renewable resources is gradually deteriorating. Traditional management practices neglect the vital cryptobiotic microorganism component. The microorganisms are the renewable portion of natural resource ecosystems. Microbes cycle essential elements from the unusable organic forms into the usable inorganic (or mineral) forms. Reduction in microorganism quantity or activity translates into reduction in usable essential elements. Diminishment in the quantity of available essential elements is the deterioration in productivity of renewable natural resources (Bloem et al. 2006).

The major essential elements in native rangeland ecosystems are carbon, hydrogen, nitrogen, and oxygen. The minor essential elements are the macronutrient and the micronutrients, and the presence of sunlight energy is essential.

Prairie ecosystems degrade when management causes the loss of essential elements to be greater than the capture of replacement essential elements. Conversely, prairie ecosystems aggrade when they are managed so as to make the capture of essential elements greater than the losses (McGill and Cole 1981). A large biomass of active soil microbes is required to aggrade renewable natural resource ecosystems (Coleman et al. 1983).

Traditional management practices based on their 'use' fail to replenish ecosystem major essential elements at quantities equal to or greater than the annual amount used or lost. The gradual increasing deficiencies between the quantity of available essential elements and the amount of essential elements needed for ecosystem functioning at biological potential levels causes incremental decreases in microorganism biomass and activity which is the primary factor causing the progressive deterioration in productivity of renewable natural resources.

The management treatment can affect the quantity of soil microorganism biomass and activity, the quantity of available essential elements, and the quantity of captured essential elements to replenish the amount used or lost. This study attempts to quantify the biomass and activity of soil microbes, the quantity of organic carbon, and the quantity of organic and inorganic nitrogen in prairie soil after 34 years of management with three treatments.

Study Area

The native rangeland study sites were on the NDSU Dickinson Research Extension Center (DREC) ranch, located in Dunn county, west of Manning and 20 miles north of Dickinson, in western North Dakota, USA.

Long-term mean annual temperature was 42.1° F (5.7° C). January was the coldest month, with a mean temperature of 14.6° F (-9.7° C). July and August were the warmest months, with a mean temperature of 69.6° F (20.9° C) and 68.5° F (20.3° C), respectively. Long-term mean annual precipitation was 17.2 inches (437.7 mm). The amount of precipitation received during the perennial plant growing season (April to October) was 14.5 inches (368.8 mm) and was 84.3% of annual precipitation (Manske 2015a).

Soils were primarily Typic Haploborolls, the native rangeland vegetation was the Wheatgrass-Needlegrass Type (Barker and Whitman 1988, Shiflet 1994) of the mixed grass prairie. The dominant native range grasses were western wheatgrass (Pascopyrum smithii), needle and thread (Hesperostipa comata), blue grama (Bouteloua gracilis), and threadleaf sedge (Carex filifolia).

Management treatments

Three management treatments were evaluated (1) long-term nongrazed control (NG), (2) traditional seasonlong (SL), and (3) twice-over rotation (TOR). These replicated treatments were located on land that had been similarly managed with long-term seasonlong grazing. The study started in 1983.

The long-term nongrazed control management treatment was designed with two large replicated exclosures that had not been grazed, mowed, or burned during the study.

The traditional seasonlong grazing system was designed with two replicated pastures. Each pasture was grazed for 137 days from early June to mid October stocked at 2.86 acres per cow-calf pair per month. During the initial phase of this study, 1983 to 1986, the seasonlong treatment was at a different location and moved to the permanent study location in 1987.

The twice-over rotation grazing system was designed with two replicated systems each with three pastures. Each pasture was grazed two times per growing season. Each system was grazed 137 days from early June to mid October stocked at 2.20 acres per cow-calf pair per month.

Procedure

Replicated soil core samples were collected at silty ecological sites with the 1 inch Veihmeyer soil tube at incremental depths of 0-6, 6-12, and 12-24 inches at monthly periods during May to October on the long-term nongrazed control, the traditional seasonlong, and the twice-over rotation treatments. The June and July monthly soil samples were delivered to the Ward Laboratory in Kearney, NE. Biomass of functional groups of soil microbes were determined by phospholipid fatty acid (PLFA) analysis. Microbial activity in soil was measured with the Solvita 1-day CO_2-C procedure that determines soil biological CO_2 respiration from the quantity of CO_2-C in ppm released in 24 hr from soil microbes after the soil had been dried and rewetted. Percent organic matter, soluble salts, and soil pH were determined by standard methods. Total organic carbon and total nitrogen were determined by the water extraction method. Inorganic nitrogen (both nitrate and ammonium), and total phosphorus (both organic and inorganic) were determined by the plant organic acids (H3A) extraction method.

Replicated soil core samples were collected at silty ecological sites with the 1 inch Veihmeyer soil tube at incremental depths of 0-6, 6-12, and 12-24 inches at monthly periods during May to October on the long-term nongrazed control, the traditional seasonlong, and the twice-over rotation treatments. The monthly soil samples were delivered to the NDSU Soil Testing Laboratory, Fargo, ND. Inorganic nitrogen, nitrate, and ammonium were determined by wet chemistry.

Weight of silty soil in southwestern North Dakota was determined from average silty soil bulk density from analysis of comparable soils (Anonymous circa early 1980's) at incremental depths of 0-6, 6-12, and 12-24 inches. Weight of soil organic matter (SOM) was determined from the weight of silty soil and percent soil organic matter from analysis conducted by the NDSU Soil Testing Laboratory of replicated soil core samples collected at silty ecological sites at incremental depths of 0-6, 6-12, and 12-24 inches during June and July on the long-term nongrazed control, the traditional seasonlong, and the twice-over rotation treatments. Weight of soil organic carbon (SOC) was determined from the weight of silty soil and percent soil organic matter multiplied by 0.58 (58% organic carbon content of soil organic matter) (Anonymous nd, NRCS Staff 2009, Pluske et al. 2015) of soil core samples at silty ecological sites on each of the management treatments. Weight of soil organic nitrogen (SON) was determined from the weight of silty soil and percent soil organic matter multiplied by 0.058 (estimated 5.8% organic nitrogen content of soil organic matter) of soil core samples at silty ecological sites on each of the management treatments.

Results

After 34 years, the twice-over rotation treatment consistently had lower soil microbial biomass for each functional group than those on the seasonlong and nongrazed treatments (table 1). However, the soil microbe biological CO_2 respiration test showed that soil microorganism activity on the twice-over rotation was 5.3% greater than that on the seasonlong and 54.4% greater than that on the nongrazed treatments (table 1). This would indicate that microbial populations would have some type of mechanism to select for groups of organisms that have greater activity with lower biomass.

The lower biomass of soil microorganisms on the twice-over rotation treatment had accumulated a greater percentage of organic matter than that on the seasonlong and nongrazed treatments (table 2). Over 34 years, the lower biomass of soil microbes on the twice-over treatment had captured organic carbon at rates 45.7% greater than that on the seasonlong and at rates 57.8% greater than that on the nongrazed treatments (table 2). The soil microbes on the twice-over rotation treatment had captured organic nitrogen at rates 39.5% greater than that on the seasonlong and at rates 42.2% greater than that on the nongrazed treatments (table 2). The quantity of total nitrogen on the twice-over rotation treatment was 50.1% greater than that on the seasonlong and 55.5% greater than that on the nongrazed treatments (table 2).

The lower biomass of soil microbes on the twice-over rotation treatment were able to mineralize nitrate at rates 109.6% greater than that on the seasonlong and 183.2% greater than that on the nongrazed treatments (table 3). The soil microbes on the twice-over rotation treatment were able to mineralize ammonium at rates 120.0% greater than that on the seasonlong and 163.4% greater than that on the nongrazed treatments (table 3). The total amount of mineralized inorganic nitrogen available on the twice-over rotation treatment was 118.1% greater than the amount available on the seasonlong and 168.3% greater than the amount available on the nongrazed treatments (table 3). The quantities of inorganic nitrogen, nitrate and ammonium, analyzed by the plant organic acids extract is claimed to more closely indicate the quantity available for plant usage compared to the wet chemistry method.

The quantity of available inorganic phosphorus on the twice-over rotation treatment was 25.2% greater than that on the seasonlong and 60.7% greater than that on the nongrazed treatments (table 3).

Duplicate soil cores were analyzed for inorganic nitrogen, nitrate and ammonium, by the standard wet chemistry methods (table 4). The values determined for nitrate were not much different analyzed by the plant organic acids extract method or by wet chemistry method. The values determined for ammonium were much greater by the wet chemistry method (tables 3 and 4). Analysis by wet chemistry indicated that the lower biomass of soil microbes on the twice-over rotation treatment were able to mineralize nitrate at rates 61.7% greater than that on the seasonlong and 115.8% greater than that on the nongrazed treatments (table 4). The soil microbes on the twice-over treatment were able to mineralize ammonium at rates 22.1% greater than that on the seasonlong and 26.8% greater than that on the nongrazed treatments (table 4). The total amount of mineralized inorganic nitrogen available on the twice-over rotation treatment was 25.7% greater than the amount available on the seasonlong and 33.3% greater than the amount available on the nongrazed treatments (table 4).

The nitrate and ammonium inorganic nitrogen available during the growing season months on the twice-over rotation treatment (table 7) was 14.3% greater than the amount available on the seasonlong (table 6) and 25.7% greater than the amount available on the nongrazed treatments (table 5).

The quantity of soil organic matter (SOM) that had accumulated over 34 years was greater on the twice-over rotation treatment. Soil organic matter (SOM) on the twice-over rotation treatment had 20.0% greater weight than that on the seasonlong and had 18.2% greater weight than that on the nongrazed treatments (table 8). Soil organic carbon (SOC) composes 58% of the soil organic matter. The weight of soil organic carbon (SOC) was greater on the twice-over rotation treatment than the weight on the seasonlong and nongrazed treatments (table 8). Soil organic nitrogen (SON) has been estimated to compose 5.8% of the soil organic matter. The weight of soil organic nitrogen (SON) was greater on the twice-over rotation treatment than the weight on the seasonlong and nongrazed treatments (table 8).

Discussion

A study to evaluate productivity under three types of management treatments, long-term nongrazed control, traditional seasonlong, and twice-over rotation treatments, was started in 1983. The soil microbe biomass and the quantity of carbon and nitrogen would have been at the same low levels on all treatments at the beginning. After 34 years of continuous treatments, the biomass of functional groups of soil microbes, bacteria, fungi, and protozoa, was determined by the different signature phospholipid fatty acids in their cell walls. The descending order of the biomass for the total microbe population was seasonlong greatest, nongrazed middle, and twice-over rotation with the lowest biomass on all functional groups of microbes (table 1). However, the soil microbe activity level on the twice-over rotation treatment, as measured by the 24 hr soil biological CO_2 respiration levels, was greater than those on the seasonlong and nongrazed treatments (table 1). The quantities of carbon and nitrogen were measured by two different concepts. The new concept quantified carbon and nitrogen by water extract and by plant organic acids (H3A) extract methods (tables 2 and 3). The traditional concept quantified carbon and nitrogen by standard wet chemistry methods (tables 4, 5, 6, 7, and 8).

Both concept methods showed that the symbiotic relationship between grass plants and soil microorganisms had captured greater quantities of organic carbon and organic nitrogen over the course of 34 years on the twice-over treatment than those on the seasonlong and nongrazed treatments (tables 2 and 8). In prairie ecosystems, the organic form of the major essential elements is a stable way to store elements. They are less likely to volatilize or leach in the organic form than in the inorganic form. However, plants cannot use the essential elements in the organic form, rhizosphere microbes are needed to mineralize the organic form into the inorganic form. The greater the biomass and activity of the microbes, the greater the quantity of available inorganic essential elements. The inorganic forms of nitrogen, nitrate and ammonium, had greater quantities available on the twice-over rotation treatment than those on the seasonlong and nongrazed treatments (tables 3 and 4).

The quantity of mineral (inorganic) nitrogen available in a soil is the net difference between the total quantity of organic nitrogen mineralized by soil microorganisms and the quantity of mineral nitrogen immobilized as organic nitrogen by plants and soil microbes (Brady 1974, Legg 1975). The quantity of available mineral nitrogen varies cyclically with changes in soil temperature, soil microorganism biomass and activity, and plant phenological growth and development during the growing season (Whitman 1975). The relationships between soil microorganism activity and phenology of plant growth activity results in a dynamic cycle of available mineral nitrogen (Goetz 1975). When mineralization activity by soil microbes is greater than plant growth activity, the quantity of available mineral nitrogen increases. When immobilization of mineral nitrogen by plant and soil microbe growth activity is greater than mineralization activity, the quantity of available mineral nitrogen decreases. The growing season dynamics of mineral nitrogen is shown for the nongrazed treatment on table 5, for the seasonlong treatment on table 6, and for the twice-over rotation treatment on table 7.

Available soil mineral nitrogen is the major limiting factor of herbage growth on native rangeland ecosystems (Wight and Black 1979). Deficiencies in mineral nitrogen limit herbage production more often than water in temperate grasslands (Tilman 1990). A minimum rate of mineralization that supplies 100 pounds of mineral nitrogen per acre is required to sustain herbage production at biological potential levels on rangelands (Wight and Black 1972). Soil mineral nitrogen available at the threshold quantity of 100 lbs/ac is required for activation of the ecological biogeochemical processes important for rangeland grass production. Wight and Black (1972, 1979) determined that the processes associated with precipitation (water) use efficiency in grass plants were not fully activated unless 100 lbs/ac of mineral nitrogen was available. Manske (2010a, b) determined that the compensatory physiological mechanisms, and vegetative reproduction by tillering also had the same threshold requirements of 100 lbs/ac of mineral nitrogen for activation and full functionality (Manske 1999, 2011a, b).

The quantity of available mineral nitrogen was greater than 100 lbs/ac on the twice-over rotation treatment measured with the plant organic acids (H3A) extract methods (table 3) and was greater than 100 lbs/ac on the twice-over rotation, seasonlong, and nongrazed treatments measured with the wet chemistry methods (table 4). The wet chemistry methods determined much greater quantities of ammonium than the plant organic acids (H3A) extract methods (tables 3 and 4).

The biomass of the rhizosphere microorganisms was lower but more active on the twice-over treatment than the microbes on the seasonlong and nongrazed treatments (table 1). The activity of the microbes on the twice-over treatment was greater as a result of two grazing periods that coordinated grazing activity with grass phenological growth resulting in greater quantities of short chain carbon energy exudated into the rhizosphere for the microbes from roots of partially defoliated lead tillers when between the 3.5 new leaf stage and the flower stage during the first grazing period, early June to mid July. The additional exudated energy increased microbial activity that mineralized greater quantities of organic nitrogen into mineral nitrogen. Microbial digestion produces both ammonia and ammonium. The ammonia can readily be hydrolyzed (with hydrogen ions) into stable ammonium. Some of the ammonium can be oxidized during nitrification to produce nitrate. These processes result in greater quantities of available mineral nitrate and mineral ammonium on the twice-over rotation treatment (tables 3, 4, and 7) (Manske 1999, 2009a, b, 2011a, 2014, 2015b).

Grass plants, soil microbes, and grazing graminivores have developed numerous complex symbiotic mechanisms and processes. The twice-over rotation grazing strategy is designed to fully activate and maintain these internal plant mechanisms and ecosystem biogeochemcial processes to function at potential levels, in order to meet the biological requirements of all biotic organisms, and for the native rangeland ecosystems to produce at their biological potential level.

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Table 1. Soil microbe biomass (lbs/ac) by phospholipid fatty acid (PLFA) analysis at soil depths to 24 in deep, June and July 2016.

			Management Treatments		
Soil Microbes		Soil Depth inches	Nongrazed 34 yrs.	Seasonlong 30 yrs	Twice-over 34 yrs.
Microbial Activity CO_2-C released/24 hr					
	lbs/ac	0-6	204.60	283.73	319.36
		6-12	133.05	143.53	191.43
		12-24	71.47	172.83	121.01
		0-24	409.12	600.09	631.80
Total Microbes					
	lbs/ac	0-6	4152.39	3463.45	2408.63
		6-12	1382.00	1635.60	832.80
		12-24	1337.52	2695.71	1922.67
		0-24	6871.90	7794.75	5164.10
Total Bacteria					
	lbs/ac	0-6	2187.83	1821.25	1194.94
		6-12	541.60	670.00	349.20
		12-24	568.53	1108.84	810.25
		0-24	3297.96	3600.09	2354.39
Total Fungi					
	lbs/ac	0-6	564.74	366.94	281.66
		6-12	105.60	172.80	133.60
		12-24	120.29	317.45	309.61
		0-24	790.63	857.19	724.87
Protozoa					
	lbs/ac	0-6	25.83	15.22	13.80
		6-12	4.80	5.20	4.80
		12-24	0.00	7.83	3.96
		0-24	30.63	28.25	22.56
Unknown					
	lbs/ac	0-6	1374.34	1280.57	921.06
		6-12	730.00	788.00	345.20
		12-24	647.15	1261.59	798.85
		0-24	2751.48	3330.16	2065.11

Table 2. Essential element weight (lbs/ac) by water extract at soil depths to 24 in deep, June and July 2016.

Essential Elements		Soil Depth inches	Management Treatments Nongrazed 34 yrs.	Seasonlong 30 yrs.	Twice-over 34 yrs
Soil pH					
		0-6	6.95	6.79	6.59
		6-12	6.95	6.94	7.09
		12-24	7.25	7.54	7.90
Soluble Salts					
	m mho/cm	0-6	0.11	0.17	0.26
		6-12	0.09	0.11	0.27
		12-24	0.13	0.25	0.34
Organic Matter					
	%	0-6	3.25	4.73	5.12
		6-12	2.25	2.37	2.87
		12-24	1.65	2.02	2.00
Total Organic Carbon					
	lbs/ac	0-6	1367.24	1690.29	2236.86
		6-12	978.93	939.78	1796.34
		12-24	685.25	650.99	748.89
		0-24	3031.42	3281.06	4782.09
Total Nitrogen					
	lbs/ac	0-6	124.16	147.66	212.11
		6-12	78.24	75.50	146.19
		12-24	59.07	47.86	48.40
		0-24	261.46	271.01	406.69
Organic Nitrogen					
	lbs/ac	0-6	109.40	125.08	171.05
		6-12	69.10	68.97	116.00
		12-24	53.03	42.00	42.26
		0-24	231.52	236.04	329.31

Table 3. Essential element weight (lbs/ac) by H3A (plant organic acids) extract at soil depths to 24 in deep, June and July 2016.

			Management Treatments		
Essential Elements		Soil Depth inches	Nongrazed 34 yrs.	Seasonlong 30 yrs.	Twice-over 34 yrs
Inorganic Nitrogen					
	lbs/ac	0-6	19.09	27.20	50.74
		6-12	12.65	11.37	43.67
		12-24	7.18	9.30	10.01
		0-24	38.92	47.87	104.41
Nitrate					
	lbs/ac	0-6	5.22	7.39	14.08
		6-12	1.23	1.21	4.41
		12-24	0.82	1.21	2.07
		0-24	7.26	9.81	20.56
Ammonium					
	lbs/ac	0-6	14.04	19.86	36.65
		6-12	11.43	10.22	39.32
		12-24	6.37	8.05	7.88
		0-24	31.83	38.12	83.85
Total Phosphorus					
	lbs/ac	0-6	32.63	44.05	42.42
		6-12	22.84	21.21	29.37
		12-24	17.95	13.05	6.53
		0-24	73.42	78.31	78.32
Organic Phosphorus					
	lbs/ac	0-6	22.19	26.81	25.67
		6-12	16.48	15.88	16.90
		12-24	10.28	8.81	4.24
		0-24	48.95	51.49	46.81
Inorganic Phosphorus					
	lbs/ac	0-6	9.06	17.72	16.92
		6-12	5.06	4.83	13.38
		12-24	6.61	4.03	2.99
		0-24	20.72	26.58	33.29

Table 4. Essential element weight (lbs/ac) by wet chemistry at soil depths to 24 in deep, June and July 2016.

			Management Treatments		
Essential Elements		Soil Depth inches	Nongrazed 34 yrs.	Seasonlong 30 yrs.	Twice-over 34 yrs
Inorganic Nitrogen					
	lbs/ac	0-6	48.05	57.51	62.03
		6-12	35.12	34.20	48.60
		12-24	33.51	32.04	44.92
		0-24	116.68	123.75	155.55
Nitrate					
	lbs/ac	0-6	3.50	6.00	9.17
		6-12	2.00	2.34	4.17
		12-24	3.00	3.00	5.00
		0-24	8.50	11.34	18.34
Ammonium					
	lbs/ac	0-6	44.55	51.50	52.86
		6-12	33.12	31.87	44.44
		12-24	30.51	29.04	39.92
		0-24	108.18	112.41	137.22

Table 5. Mean mineral nitrogen, nitrate (NO_3) and ammonium (NH_4), at incremental depths in lbs/ac with quantities available in the soil during the growing season on silty ecological sites of the long-term nongrazed prairie, 2016.

Soil Depth (inches)	May	Jun	Jul	Aug	Sep	Oct
NO_3 nitrate						
0-6 Available	4.25	3.25	3.50	3.00	3.00	5.00
6-12 Available	4.00	2.75	1.50	2.50	2.00	1.00
12-24 Available	5.00	5.00	2.00	5.00	4.00	3.00
0-24 Available	13.25	11.00	7.00	10.50	9.00	9.00
NH_4 ammonium						
0-6 Available	45.52	37.12	47.97	38.34	30.67	44.70
6-12 Available	36.47	32.80	35.08	30.02	28.88	31.98
12-24 Available	32.71	32.47	32.47	28.55	24.80	26.27
0-24 Available	114.70	102.39	115.52	96.91	84.35	102.95
$NO_3 + NH_4$						
0-6 Available	49.77	40.37	51.47	41.34	33.67	49.70
6-12 Available	40.47	35.55	36.58	32.52	30.88	32.98
12-24 Available	37.71	37.47	34.47	33.55	28.80	29.27
0-24 Available	127.95	113.39	122.52	107.41	93.35	111.95

Table 6. Mean mineral nitrogen, nitrate (NO_3) and ammonium (NH_4), at incremental depths in lbs/ac with quantities available in the soil during the growing season on silty ecological sites of the seasonlong 8 grazing system, 2016.

Soil Depth (inches)	May	Jun	Jul	Aug	Sep	Oct
NO_3 nitrate						
0-6 Available	5.67	3.83	6.67	7.33	5.67	4.00
6-12 Available	4.34	1.84	2.67	3.67	2.67	2.00
12-24 Available	6.67	2.34	3.33	6.67	4.00	2.67
0-24 Available	16.68	8.01	12.67	17.67	12.34	8.67
NH_4 ammonium						
0-6 Available	57.49	48.24	48.40	44.60	48.40	37.09
6-12 Available	42.97	35.95	30.46	31.43	34.59	27.19
12-24 Available	39.65	33.77	27.41	29.80	26.32	24.36
0-24 Available	140.11	117.96	106.27	105.83	109.31	88.64
NO_3 + NH_4						
0-6 Available	63.16	52.07	55.07	51.93	54.07	41.09
6-12 Available	47.31	37.79	33.13	35.10	37.26	29.19
12-24 Available	46.32	36.11	30.74	36.47	30.32	27.03
0-24 Available	156.79	125.97	118.94	123.50	121.65	97.31

Table 7. Mean mineral nitrogen, nitrate (NO_3) and ammonium (NH_4), at incremental depths in lbs/ac with quantities available in the soil during the growing season on silty ecological sites of the twice-over rotation system, 2016.

Soil Depth (inches)	May	Jun	Jul	Aug	Sep	Oct
NO_3 nitrate						
0-6 Available	7.34	6.84	8.67	7.00	5.00	6.67
6-12 Available	8.34	4.00	3.00	3.33	2.00	6.67
12-24 Available	5.67	7.00	2.67	4.67	6.67	9.33
0-24 Available	21.35	17.84	14.34	15.00	13.67	22.67
NH_4 ammonium						
0-6 Available	60.15	50.31	48.30	46.01	40.57	50.03
6-12 Available	46.66	43.62	45.47	28.72	31.65	36.33
12-24 Available	40.52	41.01	37.85	42.09	25.89	30.67
0-24 Available	147.33	134.94	131.62	116.82	98.11	117.03
$NO_3 + NH_4$						
0-6 Available	67.49	57.15	56.97	53.01	45.57	56.70
6-12 Available	55.00	47.62	48.47	32.05	33.65	43.00
12-24 Available	46.19	48.01	40.52	46.76	32.56	40.00
0-24 Available	168.68	152.78	145.96	131.82	111.78	139.70

Table 8. Soil organic matter (SOM), Soil organic carbon (SOC), and Soil organic nitrogen (SON) in lbs/ac at increment depths to 24 in. on silty ecological sites, June and July, 2016.

Soil Organic Component	Management Treatments		
Soil Depth inches	Nongrazed	Seasonlong	Twice-over
SOM			
lbs/ac			
0-6	60,067.48	92,051.47	106,873.31
6-12	43,210.60	44,974.30	62,611.28
12-24	114,942.05	77,806.93	88,416.96
0-24	218,220.13	214,832.70	257,901.55
SOC			
lbs/ac			
0-6	34,792.33	53,358.65	61,939.72
6-12	25,044.51	26,102.73	36,332.18
12-24	66,843.23	45,269.49	51,281.84
0-24	126,680.07	124,730.87	149,553.74
SON			
lbs/ac			
0-6	3,479.23	5,335.86	6,193.97
6-12	2,504.45	2,610.27	3,633.22
12-24	6,684.32	4,526.95	5,128.18
0-24	12,668.00	12,473.08	14,955.37

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