Seasonal Variation in Chemical Characteristics of Soil Organic Matter of Grazed and Ungrazed Mixed Prairie and Fescue Grassland

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Highlight: At Manyberries and Stavely, Alberta, Mixed prairie and Fescue Grassland ranges were grazed at various intensities for 19 and 22 years, respectively. In 1973, 13 chemical characteristics were determined on the organic matter developed in the soils of the ungrazed and heavy grazed treatments at the two locations. Samples were taken in spring, summer, autumn, and winter. Organic matter characteristics at both locations were closely associated with seasonal fluctuations and grazing-induced pressures; therefore, the time of sampling and the type of management before sampling soils should be defined in range studies. The results further emphasize the fragility of the equilibrium under which the organic matter of the soil of heavily grazed Mixed prairie at Manyberries forms and exists.

Scientific management of rangelands must consider the importance of the soil, which is the source of mineral elements for the primary producers in the range ecosystem. One method of studying the influence of grazing on range soils is to assess the chemical characteristics of soils of ungrazed and grazed rangeland.

The effects of grazing on Mixed prairie soils in Alberta were assessed after 19 years of continuous summer use by sheep (Smoliak et al. 1972). Analyses of soil under heavy grazing (1.7 ha/animal unit month) showed lower values for pH and percent spring moisture, but higher values for total C, ethanol/benzene-extractable C, alkaline-extractable C, polysaccharides, and below-ground plant material than did analyses of soils under no grazing. Results were attributed to change in kinds and amounts of roots due to species change caused by grazing and to increased amounts of manure deposited by sheep on the heavily grazed fields.

Grazing of Fescue Grassland range by cattle for 17 years led to edaphic change (Johnston et al. 1971). Soil of a very heavily grazed field (0.2 ha/AUM), compared to that of a lightly grazed field (0.8 ha/AUM), was transformed to a soil characteristic of a drier microclimate.

Chemical parameters of the soil vary throughout the season. This has been shown for humification (Jacquin and Merlet 1975) and for such characteristics as organic-C (Sauerlandt and Tietjen 1971), total organic-P (Dormaar 1972), carbohydrates (Oades and Swincer 1968), and N-NH_4, humic acid, fulvic acid, and saccharase (Bauzon et al. 1974). Hofman and Appelmans (1975) showed a seasonal variation for aggregate stability; changes in composition and distribution of the soil organic matter were identified as one of the factors responsible for the variation.

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Changes in some characteristics of soil organic matter due to grazing (Johnston et al. 1971; Smoliak et al. 1972) were such that a more detailed examination was desirable. The purpose of this study was to assess seasonal variation in a number of chemical characteristics of the organic matter of soils in ungrazed and heavily grazed Mixed prairie and Fescue Grassland ranges.

Materials and Methods

The study was conducted at two locations:

a) Agriculture Canada Research Substation, Manyberries, Alta. Vegetation is typical of the *Stipa-Bouteloua* faciation of the Mixed Prairie Association (Coupland 1961); the soil is a member of the Brown Solod Subgroup of the Solonetzic Order; climate is semiarid; and annual precipitation averages about 310 mm.

b) Agriculture Canada Research Substation, Stavely, Alta. Vegetation is typical of the Fescue Grassland Association (Coupland and Brayshaw 1953); the soil is a member of the Orthic Black Subgroup of the Chernozemic Order; climate is dry subhumid; and annual precipitation averages about 500 mm.

In 1973, two sampling sites were selected at each location with three plots at each sampling site. At Manyberries, the sites were in an ungrazed exclosure protected since 1928 (Smoliak 1974) and in an adjacent field that had been heavily grazed (1.7 ha/AUM) by ewes with lambs during the period May 1 to November 1 from 1951–69, inclusive. At Stavely, they were in an ungrazed exclosure, protected since 1949, and in an adjacent field, heavily grazed (0.2 ha/AUM) by cows with calves since 1951. (The field at Stavely was grazed from May 15 to November 15 until about 1962; after that, because of deterioration of cover, the grazing season varied from about 2.5 to 5 months.) At each study site, the percent basal area of vegetation was determined by the vertical point method and root weight in the top 15 cm of soil was determined from 10 cores (7 cm in diameter).

The Ah horizon was sampled within five subplots in each of the three plots on each study site in spring, summer, autumn, and winter, 1973. Immediately after sampling, the subplot samples were bulked and stored at 4°C. Samples were dried and ground to pass a 1-mm sieve and were analyzed for soil organic matter.

Total organic C, total N, ethanol/benzene-extractable C (solvent-extractable C), and chelating resin-extractable C (resin-extractable C) were determined on the whole soil. Also total ash, C, and N, total and carboxyl acidity, and infrared spectra were obtained on dialized, resin-extractable humic substances (Dormaar 1973). 'Hydroxyl' acidity was obtained by subtracting carboxyl from total acidity. Assignments of the various bands in the i.r. spectra were obtained from Avram and Mateescu (1972). The data were subjected to an analysis of variance and discussion of significance is based on the 5% level of probability.

Results and Discussion

All characteristics of organic matter, except for the C content of the humic substances, differed significantly between the two locations. Treatment differences were always significant. The location × treatment interaction was not significant for the solvent- and resin-extractable organic matter and the carboxyl acidity of the extracted humic substances. However, since the soils were subject to widely different hydrothermal regimes, the two locations will be discussed separately before comparisons are made between them.

Manyberries

Vegetation

Percent basal area of vegetation differed on the ungrazed and heavily grazed study sites (Table 1). *Bouteloua gracilis* dominated the heavily grazed site whereas *Stipa comata* dominated the ungrazed site. *Selaginella densa* increased considerably

Table 1. Percent basal area of vegetation on study sites at Manyberries, Alta., 1969.

Species	Study sites in 1969 by grazing treatments: Ungrazed	Heavily grazed
Agropyron smithii	1.3	0.7
Bouteloua gracilis	0.3	3.6
Stipa comata	2.2	0.7
Other grasses	1.4	1.1
Carex spp.	0.4	1.1
Artemisia frigida	0.2	0
Phlox hoodii	0.2	0.1
Selaginella densa	9.6	26.0
Other forbs and shrubs	0	0.3

with grazing intensity. The change in vegetation was accompanied by a change in dry matter (DM) of the root mass in the top 15 cm of soil in each study site, which averaged 15.0 t DM roots/ha on the ungrazed site and 24.0 t DM roots/ha on the heavily grazed site.

Soils

Grazing treatment significantly affected all characteristics examined except the ash content and the C/N ratio of the humic substances (Table 2) when considered over all seasons. The time of sampling significantly affected all characteristics examined although the trend was not always the same for each characteristic. All the interactions between season and grazing treatment were significant.

Table 2. Characteristics of the organic matter of Ah horizons of heavily grazed (HG) and ungrazed (UG) Mixed prairie at Manyberries, Alta. (Average of 3 samples.)

Characteristic measured	Spring HG	Spring UG	Summer HG	Summer UG	Autumn HG	Autumn UG	Winter HG	Winter UG
				Soil				
Total C (%)	1.96	1.09	1.14	0.99	1.55	1.19	2.83	2.19
Total N (%)	0.12	0.11	0.10	0.11	0.15	0.13	0.22	0.18
C/N	16.3	9.9	11.4	9.0	10.3	9.2	12.9	12.2
Extractable C								
Solvent*	3.85	2.75	3.49	2.86	3.78	2.76	3.99	3.96
Resin*	21.7	25.7	28.9	34.1	22.3	26.8	17.5	20.0
			Resin-extractable humic substances					
Ash (%)	36.6	37.3	39.3	38.3	41.7	42.8	38.7	34.9
Total C (%)	49.1	46.2	48.9	45.7	48.1	45.6	48.2	46.3
Total N (%)	3.11	3.04	3.54	3.47	4.42	3.92	2.98	2.89
C/N	15.8	15.2	13.8	13.2	10.9	11.6	16.2	16.0
Acidity (meq/g)								
Total	6.97	5.42	9.80	12.35	7.58	7.78	7.33	5.72
Carboxyl	2.72	2.60	2.44	2.46	2.98	2.93	2.86	2.69
'Hydroxyl'	4.25	2.82	7.36	9.89	4.60	4.85	4.47	3.03
1710/1620 cm^{-1}	0.79	0.73	0.69	0.63	0.92	0.72	0.88	0.74

* Solvent-extractable C = ethanol/benzene-extractable C as percent of total C.
Resin-extractable C = chelating resin-extractable C as percent of total C.

Total C and solvent-extractable C were higher in soil of the heavily grazed field than in the soil of the ungrazed field, thus confirming our earlier finding (Smoliak et al. 1972). The resin-extractable C, on the other hand, was higher in soil of the ungrazed field than in soil of the heavily grazed field. The earlier study used 0.1*N* NaOH as the extracting agent. It has been noted that the humic substances extracted by chelating resin were more condensed than those removed by alkali (Ortiz de Serra and Schnitzer 1972).

Since the total C of soil of the heavily grazed field was higher than that of soil of the ungrazed field, it may be concluded that the quality of the organic matter changed due to grazing treatment. Smoliak et al. (1972) showed that changes in C content were due to changes in amount and kind of roots and to increased amounts of manure deposited by sheep on the heavily grazed field. The chemistry of the roots contributes to the chemistry of the humic substances as well (Lutwick and Dormaar 1976). This contribution will be accentuated by the change in root mass due to grazing.

Absorption increased in the region of 1,550 to 1,510/cm of the i.r. spectra of organic matter in soil of the heavily grazed field. This region is assigned to NH (amide II) deformation vibration of secondary, non-cyclic amides such as *N*-alkylamides of aliphatic acids, although Becher (1956) regards the amide II band as having more C-N than NH character. Since changes in organic matter characteristics were, in part, attributed to increased amounts of manure deposited by sheep (Smoliak et al. 1972), a closer examination of the effect of sheep manure added to the soil may be in order since amides have been extensively studied in urea derivatives (Becher 1956).

These results emphasize the fragility of the equilibrium under which the organic matter of the soil of heavily grazed Mixed prairie forms and exists. The organic matter of the Manyberries soils is inherently low and seems to have little resistance to ecological changes. The slightest pressure, be it man-induced or climatically induced, sets off an immediate change within the soil organic matter system. In this context, it should be noted that the organic matter of Brown Chernozemic soils from the same general vicinity was much less resistant to biological decomposition than that of Black Chernozemic soils (Dormaar 1975).

Stavely

Vegetation

Percent basal area of vegetation differed on the ungrazed and heavily grazed study sites (Table 3). *Festuca scabrella* dominated on the ungrazed study site but was essentially eliminated from the heavily grazed study site. Secondary plants—"Other grasses" and "Other forbs and shrubs" (Table 3)—were more abundant on the heavily grazed site than on the ungrazed site. The change in vegetation was accompanied by a change in root mass in the top 15 cm of soil at each study site and averaged 17.2 t DM roots/ha on the ungrazed site and 25.3 t DM roots/ha on the heavily grazed site.

Soils

Grazing did not significantly affect the total C or N contents, the C/N ratio of the soil, or the C content and carboxyl acidity of the humic substances (Table 4), which would indicate a stable

Table 3. Percent basal area of vegetation on study sites at Stavely, Alta., 1973.

Species	Study areas in 1973 by grazing treatments: Ungrazed	Heavily grazed
Agropyron dasystachyum	0.3	1.3
Danthonia parryi	2.3	2.3
Festuca idahoensis	1.0	2.2
Festuca scabrella	14.1	0.1
Stipa spartea var. *curtiseta*	0.1	0.5
Other grasses	0.7	3.5
Carex spp.	0.4	1.1
Galium boreale	0.3	0.6
Geum triflorum	0.3	0.4
Taraxacum officinale	0	1.4
Other forbs and shrubs	1.3	4.9

Table 4. Characteristics of the organic matter of Ah horizons of heavily grazed (HG) and ungrazed (UG) Fescue Grassland at Stavely, Alta. (Average of 3 samples.)

Characteristic measured	Spring HG	Spring UG	Summer HG	Summer UG	Autumn HG	Autumn UG	Winter HG	Winter UG
Soil								
Total C (%)	10.10	9.23	8.24	7.15	8.99	8.05	10.70	11.70
Total N (%)	0.86	0.68	0.69	0.64	0.74	0.66	0.99	0.92
C/N	11.7	13.6	11.9	11.2	12.1	12.2	10.8	12.7
Extractable C								
Solvent*	3.18	2.26	3.12	2.73	3.17	3.07	4.10	3.95
Resin*	32.6	39.2	38.9	39.1	34.9	36.5	28.0	34.4
Resin-extractable humic substances								
Ash (%)	18.9	24.7	19.2	24.3	19.6	25.8	18.5	25.3
Total C (%)	47.7	47.0	47.3	46.8	46.7	45.6	49.7	48.1
Total N (%)	3.74	3.37	3.89	3.59	3.92	3.64	2.91	2.80
C/N	12.8	13.9	12.2	13.0	11.9	12.5	17.1	17.2
Acidity (meg/g)								
Total	6.12	6.07	9.17	7.18	7.36	7.08	6.62	6.46
Carboxyl	2.91	2.84	2.78	2.54	3.01	2.97	3.34	3.15
'Hydroxyl'	3.21	3.23	6.39	4.64	4.35	4.11	3.28	3.31
1710/1620 cm^{-1}	1.05	1.07	0.87	0.87	1.05	0.97	1.10	1.09

* Solvent-extractable C = ethanol/benzene extractable C as percent of total C.
Resin-extractable C = chelating resin-extractable C as percent of total C.

equilibrium of the organic matter. Except for the ash content of the humic substances, all chemical characteristics varied significantly among the seasons, even though the trend was not always the same for each characteristic. Only the interactions between grazing and season for the C/N ratio and the 'hydroxyl' acidity of the humic substances were significant.

Since, for most characteristics, treatment × season was not significant, the single effects can be considered in more detail. The N content of the humic substances increased toward autumn, then decreased over winter. This fluctuation was probably the result of increased killed biomass over winter. A more detailed examination of winter vs autumn levels of resin-extractable humic substances would be useful to determine the effect or participation of microorganisms on these humic substances. The total N of the soil, on the other hand, was high in winter and low in summer. Thus, mineralization mainly occurs early in the growing season.

Johnston et al. (1971) concluded that soil of the very heavily grazed field was being transformed into a soil characteristic of a drier microclimate. The i.r. spectra of the humic substances of the heavily grazed soil showed increased absorption near 2,920 and 2,850/cm (in-phase and out-of phase stretching vibrations of the H-atoms of the CH_2 group of straight chain saturated alkanes) and increased absorption in the region of 1,550 to 1,510 cm^{-1}. Dark Brown Chernozemic soils have more aliphatic CH_2 and secondary, non-cyclic amides than Black Chernozemic soils (Lutwick and Dormaar 1976). The i.r. spectra thus support the conclusion of transformation to a drier microclimate due to grazing.

A higher 1,700/1,620 cm^{-1} ratio reflects higher carboxyl acidity. This relationship is supported by the actual carboxyl content of these materials. Carboxyl acidity was highest in the winter and lowest in the summer samples. This was partly the result of variation in decomposition of the organic matter and partly the addition of new root growth over the season. Total soil C and N also were highest in the winter and lowest in the summer samples.

Manyberries vs Stavely

A number of the changes over the seasons were the same at both locations. However, the higher C and N contents in the winter were indicative of more incorporated organic matter, as most of the free roots were eliminated when samples were ground to pass a 1-mm sieve before analyses. Bremner and Zantua (1975) have shown that significant enzyme activity occurs in soils below 0°C. It may be postulated that, in winter, the balance between formation of resistant organic matter and mineralization of organic matter favors the former. The decrease of total, carboxyl, and 'hydroxyl' acidity through the winter may be related to the observation (Yarkov 1956) of increased Ca linkages in humic substances over winter. This is supported by the decrease of resin-extractable organic matter over winter. Even though chelating resin is a good extractant for organic matter *per se* (Dormaar 1973), it may not be effective in breaking these Ca bridges. The enzyme activity could make an important contribution to the quality of soil organic matter over winter.

The main difference between the two soils was in their reaction to long-term grazing pressures. The organic matter of the soil of the Stavely location, about ten times greater than that of the Manyberries location, generally responded to grazing pressures and seasonal pressures independently, while these two pressures interacted for the soil of the Manyberries location. The organic matter of the Manyberries soil was much more fragile in terms of its response to grazing-induced changes than the organic matter of the Stavely soil, despite the fact that the latter soil was being transformed to a soil characteristic of a drier microclimate. This may be an important consideration not only from the point of view of range management, but also possibly of soil structure and source of mineral elements for the primary producers.

The research presented does not answer the question as to the indispensability of organic matter of soils in terms of management of these ranges. It does indicate, however, that organic matter characteristics are closely related with seasonal fluctuations. Studies designed to further examine the indispensability of organic matter to the range should define at least the time of sampling and the type of management before sampling.

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THESIS: TEXAS A&M UNIVERSITY

The Botanical and Nutritive Composition of Winter Diets of Cattle Grazing Prairie on the Texas Gulf Coast, by Albert Johnson Durham, Jr., MS, Range Science. 1975.

Four esophageally fistulated cows were used to determine botanical and nutritive composition of diets selected during the winter and spring by cattle grazing native prairie of the Texas Gulf Coast. Forage available to cattle included only warm-season perennial grasses and Macartney rose. Rattail smutgrass and brownseed paspalum were the most preferred species selected during the study, although they were minor components of the available forage. Crude protein and digestible organic matter content of diets increased from lows in January to a high in late March as a result of cow selectivity. However, cow requirements were not met by the forage until spring growth was initiated. Energy was not supplemented in sufficient amounts during winter and therefore was assumed to be the first limiting nutrient in cow diets. Daily intake of ranch cattle was calculated by comparing digestible energy content of the diet, based on in vitro digestible organic matter, with digestible energy requirements for known metabolic weight, activity, and production of cattle. Daily intake during the period January 9 to February 22, 1974, was inadequate as indicated by weight losses in cows and calves. Poor grazing distribution within pastures was mainly responsible for low intake levels. Daily intake reached normal levels of about 9.3 kg air-dry forage in late spring resulting in cow and calf weight gains. Management alternatives to correct nutritional deficiencies were aimed at increasing grazing distribution and improving supplementation to meet requirements of cattle for the period from mid-January to late February.