A Comparison of Organic Carbon, Hydrogen-ion Concentration, and Volume Weight of Some Central Oklahoma Soils[1]

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INTRODUCTION

Few data are available on measurements of edaphic factors of grassland soils in Oklahoma. This paper presents data on organic carbon content, *p*H, and volume weight measurements of a group of grassland plots near Norman, Oklahoma. The data were obtained in conjunction with vegetational analyses of the plots with the view in mind of correlating edaphic factors with plant succession.

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LOCATION AND DESCRIPTION OF THE PLOTS

The grassland plots are located approximately eight miles southwest of Norman, Oklahoma, along State Highway 9 in McClain County. All plots are within a radius of a quarter mile and are on gentle northeast facing slopes. Four plots were investigated—a small virgin prairie plot, a pasture protected from grazing, a grazed pasture, and a revegetating abandoned field.

The virgin prairie was represented by an area of approximately five acres which had not been burned or grazed in the past 25 years. The history of the plot prior to this time (1926) is not known but it is unlikely that it was ever greatly disturbed. A quadrat analysis revealed the dominants of the virgin prairie to be *Andropogon scoparius*,[3] *Panicum virgatum*, and *Sorghastrum nutans*. The protected pasture was a portion of a ten-acre area which was fenced in July, 1949. The area originally was included in a large pasture in which grazing had been light to moderate for the past several years. Except for the addition of *Andropogon Gerardi*, the dominants of this plot were the same as those of the virgin prairie. An area comparable in size to the virgin prairie was designated as a study area in a grazed pasture of approximately one thousand acres. Grazing had been as high as one head per four acres; at other times (under lighter grazing conditions) the grass was mowed for hay. Grazing during the period of study was moderate. Only two species, *Andropogon scoparius* and *Sorghastrum nutans*, occupied sufficient area in this plot to be considered dominants. The abandoned field consisted of a five-acre plot which was fenced at the same time as the protected pasture. The land was farmed for a period of 20 to 25 years prior to 1941. Korean lespedeza (*Lespedeza stipulacea*) was planted on the land in 1941. Since that time, the field has

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[3] Nomenclature of the grasses is according to the 2nd Edition of Hitchcock's *Manual of the Grasses of the United States*; that of the other species follows the 8th Edition of *Gray's Manual of Botany*.

been undisturbed except for grazing. Two annual species, *Aristida oligantha* and *Lespedeza stipulacea*, and one perennial species, *Panicum Scribnerianum*, were dominants of the abandoned field. Other vegetational data for the plots are shown in Table I.

TABLE I

Relative Position of Grassland Plots with Reference to Oven-dry Weight of Living and Dead Plant Material and Living Areal Cover.

VALUES	LIVING MATERIAL	DEAD MATERIAL	LIVING AREAL COVER
HIGHEST	Protected pasture	Protected pasture	Abandoned field
	Grazed pasture	Virgin prairie	Protected pasture
	Virgin prairie	Grazed pasture	Grazed pasture
LOWEST	Abandoned field	Abandoned field	Virgin prairie

METHODS

Soil samples for the determination of organic carbon and hydrogen-ion concentration (*p*H) were obtained from two levels of the soil—the first (0-6) and third (12-18) six inches. Two augers (1½ and 1¼ inches in diameter) were used to obtain the samples. The larger auger was employed to collect the soil from the first six inches and to reach the level of twelve inches; the smaller auger was used to obtain the 12-18 inch sample. In this way, contamination of the sample was avoided as it was pulled up. Six samples were taken from each level in each plot at each of the three sampling periods (December, 1949; April, 1950; and November, 1950).

Organic carbon (Walkley and Black method) and *p*H were determined by the methods outlined in Piper (10). A Beckman *p*H meter, Model H2, was used in the *p*H determinations. In the laboratory analysis of the soil samples, all organic matter, including both the dead and living roots was thoroughly mixed with the rest of the samples. Organic carbon and *p*H were determined from portions of the same sample.

Volume weight was determined in the following manner: A small hole approximately two inches in diameter and three inches deep was dug with a trowel and all the excavated material was placed in a small sack to be taken to the laboratory for oven-dry weight determinations. The volume of the hole was then measured by pouring Ottawa gravel into it from a graduated cylinder and noting the volume used. The graduated cylinder was filled in the same manner for each determination, care being taken not to tap the cylinder and pack the gravel. After the oven-dry weights of the soil samples were determined, the volume weight was calculated by dividing the oven-dry weight in grams by the volume of the soil in cubic centimeters. Volume weight samples were taken four times: November, 1949; February, 1950; August, 1950; and September, 1950.

RESULTS

The percentages of organic carbon were lowest in the abandoned field and progressively greater in the virgin prairie, protected pasture, and the grazed pasture. This was true at both levels and for all three sampling periods (Table II). It should be emphasized that there was less organic carbon in the soil of the virgin prairie than in either the grazed or protected pastures. When tested statistically, the mean values obtained in the first six inches of the soil in the virgin prairie were found to be significantly

TABLE II

Walkley and Black Organic Carbon Values (with Standard Errors) Expressed as Per Cent of Air-Dry Weight of Soil (Each Figure an Average of Six Samples)*

Plots	0-6 Inches Fall 1949 (12-15-49)	Spring 1950 (4-10-50)	Fall 1950 (11-14-50)
Virgin prairie	1.07 ± .08	1.14 ± .06	0.98 ± .03
Protected pasture	1.18 ± .08	1.26 ± .04	1.14 ± .05
Grazed pasture	1.36 ± .02	1.37 ± .02	1.38 ± .03
Abandoned land	0.78 ± .05	0.82 ± .05	0.86 ± .02
	12-18 Inches		
Virgin prairie	0.45 ± .04	0.59 ± .05	0.47 ± .03
Protected pasture	0.59 ± .03	0.61 ± .02	0.53 ± .02
Grazed pasture	0.63 ± .02	0.64 ± .03	0.64 ± .03
Abandoned land	0.44 ± .03	0.38 ± .09	0.46 ± .09

* For appropriate organic matter values, multiply by 2.15.

different (0.01 level) from those obtained in the grazed pasture and the abandoned field at all three sampling periods. In the third six inches of the soil, significant differences were found between the percentages in the virgin prairie and the grazed pasture in the fall of 1949 and fall of 1950 and also between the virgin prairie and protected pasture in the fall of 1949. The differences between the virgin prairie and the abandoned field were not significant at the 12-18 inch sampling level.

The *p*H values of the first and third six inches of the soil of all plots followed the same general pattern (Table III). They were high in the fall of 1949, low in the spring of 1950, and high again in the fall of 1950. Less fluctuation of *p*H was encountered in the virgin prairie and protected pasture than in the abandoned field and grazed pasture at both of the sampled levels.

TABLE III

A Comparison of the pH of Two Levels of Soil of the Four Plots (Each Figure Based on an Average of the Hydrogen-Ion Concentration of Six Samples)

Plots	0.6 Inches Fall 1949 (12-15-49) Mean	Range	Spring 1950 (4-10-50) Mean	Range	Fall 1950 (11-19-50) Mean	Range
Virgin prairie	6.8	(6.6-7.0)	6.3	(6.1-6.6)	6.6	(6.4-6.8)
Protected pasture	6.8	(6.7-7.0)	6.4	(6.3-6.5)	6.6	(6.5-6.8)
Grazed pasture	6.7	(6.6-6.8)	5.8	(5.8-5.9)	6.6	(6.5-6.8)
Abandoned land	6.8	(6.6-7.0)	6.0	(5.6-6.4)	6.6	(6.3-7.8)
	12-18 Inches					
Virgin prairie	6.8	(6.7-8.2)	6.5	(6.4-6.6)	6.6	(6.5-6.7)
Protected pasture	6.8	(6.7-7.0)	6.3	(6.3-6.4)	6.7	(6.6-6.8)
Grazed pasture	6.6	(6.5-6.7)	5.7	(5.6-5.8)	6.7	(6.6-6.9)
Abandoned land	7.6	(7.2-8.6)	6.2	(5.7-7.6)	6.6	(6.4-9.6)

Volume weight measurements showed marked differences between the virgin prairie and the other three plots. The values for the virgin prairie were significantly lower in all cases (Table IV). Consistent differences were not found between the volume weights of the other plots. Those of the protected pasture were slightly lower than those of the other two plots, however. Although the actual numerical differences are not great, it should be pointed out that a change from 0.9 to 1.2 represents a one-third increase in volume weight.

TABLE IV

Volume Weight Measurements for the First Three Inches of Soil in the Four Plots (with Standard Errors)

PLOTS	NOV. 17, 1949	FEB. 18, 1950	AUG. 14, 1950	SEPT. 20, 1950
VIRGIN PRAIRIE	0.9 ± .05	0.8 ± .04	0.9 ± .04	0.9 ± .04
PROTECTED PASTURE	1.1 ± .03	1.1 ± .05	1.2 ± .04	1.0 ± .03
GRAZED PASTURE	1.2 ± .08	1.1 ± .03	1.2 ± .05	1.2 ± .02
ABANDONED LAND	1.2 ± .04	1.2 ± .03	1.2 ± .03	1.1 ± .03
NUMBER OF SAMPLES PER PLOT	10	10	10	25

DISCUSSION

The organic carbon content of the soil was much lower in the virgin prairie than in the grazed pasture, although much more dead plant material above ground was found in the virgin prairie. This suggests that there is little relationship between the amount of superficial organic matter and the content of organic carbon in the soil. The cover percentage and oven-dry weight of living plant material was also lower in the virgin prairie than in the grazed pasture. With more living material above the ground, one would expect to find more roots and hence more organic carbon in the soil. Aldous (2) suggested that increases in organic matter in pasture areas that he studied were due to increased root systems instead of increased organic matter on top of the soil. Gernert (6) reported higher organic matter percentages in pastures subjected to frequent clipping (and the clippings removed) than in grasslands along the roadside (relict areas) in north central Oklahoma.

Apparently the amount of organic carbon in the soil of the abandoned land has been reduced by cultivation and erosion. When compared to the virgin prairie, the amounts in the first and third six inches of the soil in the abandoned field were 23 and 14 per cent lower, respectively. Daniel and Langham (4) found an 18 per cent decrease in organic matter in the surface layers of soil due to cultivation in the Oklahoma Panhandle. According to Hide and Metzger (7), the organic carbon of some Kansas soils has been decreased by as much as 40 per cent by cultivation and erosion.

Few differences between the *p*H measurements of the soil in the four plots were obtained. The reasons for the lower values obtained in the spring of 1950 are not evident. In this region, it would seem that a given soil would become more acid after a rain due to the leaching of the basic ions. However, the precipitation from January through April, 1950, was considerably below normal and would not account for any unusual leaching.

The high *p*H (7.6) obtained in the third six inches of the soil in the abandoned field was undoubtedly due to the zone of carbonate accumulation which was found in that plot and which was not evident in the other three plots. The depth at which this zone is found in the abandoned field varies from 12 to 24 inches depending upon the amount of sheet erosion that has taken place. During the spring, two of the six samples from the abandoned field included material from this zone, the *p*H values for these two samples being 8.4 and 8.1.

The differences in the *p*H of the soils of the four plots in the spring could not be correlated with differences in organic carbon or soil moisture. The large differences between the organic carbon content of the grazed pasture and the abandoned field suggest that the factors contributing to the increased acidity in the two plots are quite different.

The *p*H data obtained in this investigation are in fair agreement with those obtained by other investigators in Oklahoma. Daniel, *et al.* (5) reported values for virgin soil in north central Oklahoma of *p*H 5.8 to 6.4 for the surface layers and 7.8 to 8.1 for subsurface layers. They also reported values ranging from 6.3 to 7.5 for surface layers and 6.1 to 8.4 to subsurface layers of cultivated soils. Gernert (6) in north central Oklahoma, reported a *p*H 6.28 for the first three inches of soil in roadside (relict) grassland and pasture areas.

Volume weight measurements are particularly valuable for the comparison of structural conditions in various soils. The soil samples are easily and quickly obtained in the field, and the laboratory calculations may be done on a slide rule. Lyon and Buckman (8) pointed out that soil structure is the major factor accounting for normal fluctuations in volume weight since the real specific gravity of soils shows no great variation. Present volume weights indicate that the soil of the virgin prairie has a more desirable structure in that it is not as compact as the soils in the other plots. The data indicate that grazing and cultivation increase the volume weight or compaction of the soil. Nease (9) compared relict prairie areas which had not been subjected to grazing with a secondary tall grass prairie (an area which had been overgrazed in 1924 but which is now described as excellent tall grass prairie) and found that the soil was 31 per cent more compact in the secondary tall grass prairie than in the relict prairie. He suggested that soil structure (as measured by compaction) of such areas is not restored as rapidly as is the climax vegetation. Auten (3) found that grazing reduced porosity and increased volume weight. The present writer believes that the high compaction of the soils of the plots subjected to grazing is due largely to trampling by cattle which has effectively altered the soil structure.

In Pennsylvania, Alderfer and Merkle (1) compared soils and found that the volume weight of blue-grass sod was lower (1.03 to 1.07) than that of cultivated plots (1.25 to 1.41). Lower volume weights for surface layers of virgin soil than for cultivated soils in Iowa have been reported by Swanson and Peterson (11).

At present, the soil reaction appears to have little or no influence in determining the wide differences between the vegetational composition of the abandoned field and the other three plots. The low organic carbon content and the high volume weight of the soil in the abandoned field may be partially responsible for the slow rate of plant succession. However, more investigation is needed before any definite statement can be made regarding the effects of any edaphic factors on plant succession in grasslands in central Oklahoma.

SUMMARY

1. Organic carbon, *p*H, and volume weight measurements were made at two levels (0-6 and 12-18 inches) of the soil of four grassland plots (a virgin prairie, a pasture protected from grazing, a grazed pasture, and a revegetating, abandoned field) near Norman, Oklahoma, in the autumn of 1949 and during the growing season of 1950.
2. The percentages of organic carbon (Walkley and Black method) were lowest in the abandoned field, and progressively greater in the virgin prairie, protected pasture, and grazed pasture.
3. Few differences were noted in the *p*H values of the various soils. The values were relatively high in the fall of 1949, low in the spring of 1950,

and high again in the fall of 1950. The greatest fluctuation of *p*H was encountered in the abandoned field soil.

4. The volume weight measurements were significantly lower in the virgin prairie than in the other three plots. Consistent differences were not found between the volume weights of the other plots.

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