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The Effects of Grazing and Trampling Upon Certain Soil Properties

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THE EFFECTS OF GRAZING AND TRAMPLING UPON

CERTAIN SOIL PROPERTIES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Grazing is the only economically feasible method of utilizing many vast areas of rough and broken lands of the western states. Maximum livestock gains can be secured only if the pasture is maintained to provide the best conditions for the adapted vegetation. This necessarily involves a knowledge not only of vegetation but also of soils and their productivity. Heavy grazing, with all its consequences on vegetation and soils, is a major factor facing the farmer and rancher using these areas.

Many studies of grazing effects on vegetation have been previously reported. Few workers have included soil data in grassland studies. Lodge (1954) reported the effects of heavy grazing on chemical and structural conditions in the soil and on the phosphorus and protein content of forage in a study of the mixed prairie of Saskatchewan. Chandler (1940) studied the influence of grazing on soil and climatic conditions in farm woodlands in New York. He found decreases in soil moisture, organic matter, and relative humidity, and increases in volume-weight ratios and soil and air temperatures in grazed areas.

The purpose of this study was to obtain basic information about the effects of grazing and trampling on various physical properties of the soil. Included are data on soil texture, rate of infiltration, soil moisture, degree of compaction, aggregate stability, and yields of vegetation under three main treatments. Research was also carried out in paths, congested areas, and artificially compacted plots. The paths were located on moderately-deep soil on a gently-sloping hillside. Composition of the vegetation was similar to that of the moderately-grazed site.

DESCRIPTION OF AREAS

The studies were conducted in two pastures, one heavily grazed and the other moderately grazed. The heavily-grazed pasture is located 2 miles south and 2.5 miles west of Hays. It was composed of approximately 100 acres and for several years had carried about 4 animal units per acre per month (Fig. 1). The moderately-grazed area was the college pasture about 2 miles west of Hays (Fig. 2). Grazing rate had been about one animal unit per acre per month. The ungrazed site was an exclosure in this pasture which has been fenced since 1941. All areas studied were on gently sloping uplands.

Soils

Profile. The soils have been derived from loessial material capping limestone hills. The topsoil on the ungrazed and moderately-grazed areas was about 10 inches deep with a granular structure. Color was dark reddish-brown, gradually lightening to a grayish-yellow at 20 inches. Structure of the transitional zone from 10 to 20 inches was blocky. Prismatic structure, typical of the B horizon in this region was first evident at a depth of 28 inches and extended to about 40 inches. Major carbonate concentrations were from 30 to 36 inches, but they occurred

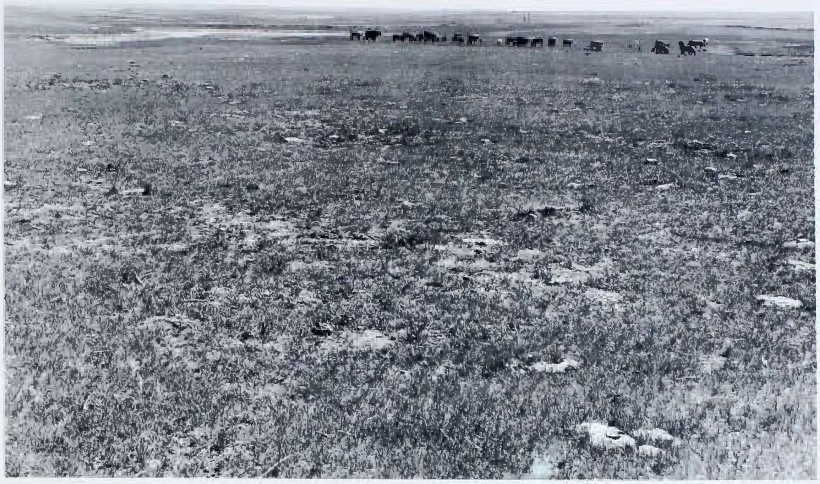

Figure 1. General view of heavily-grazed pasture, showing abundant cow chips and much bare soil. May, 1954.

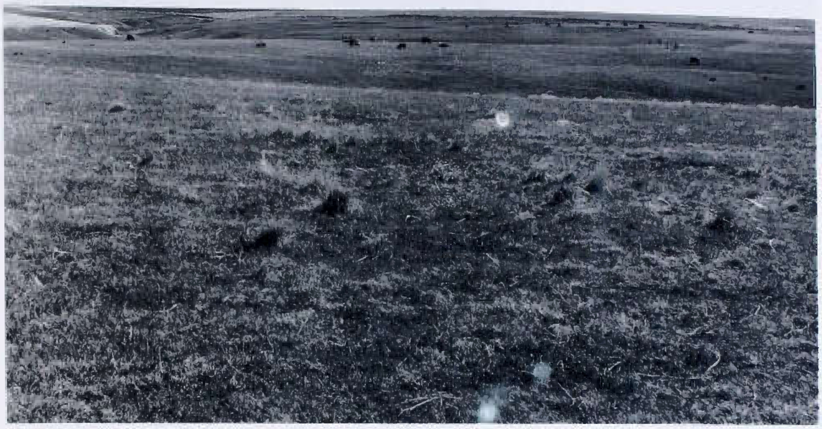

Figure 2. General view of moderately-grazed pasture showing excellent cover and rolling topography. Clumps in foreground are three-awn grass. May, 1954.

at greater depths in cracks and along root channels. There were no rock fragments to 40 inches. Soil was moderately permeable and well-drained.

The topsoil in the heavily-grazed site was about 10 inches deep and light reddish-brown in color. Structure was granular except for the top 0.5 inch, which was platy. The granules were not well defined but quite compact. In the upper part of the transition zone, the color remained somewhat dark but the structure became prismatic. The prisms were 1 to 2 inches in diameter and 3 to 6 inches long. B horizon began at 18 inches but reached maximum development at about 28 inches where the huge columns (6 to 9 inches in diameter and 8 to 10 inches long) were coated with a white layer of lime. Drought cracks from 0.25 to 0.75 inch in diameter occurred from 12 to 32 inches. The prisms gradually decreased in size and at 38 inches the structure was blocky. Yellow color typical of loess became evident at 40 inches.

Texture. The hydrometer method was used to determine the percentage of each of the textural components of the soils (Bouyoucos 1936). Duplicate samples were taken from 0 to 6 inches, 6 to 12 inches, and from each foot thereafter to 5 feet.

Sand content was usually less than 10 per cent at all depths except in the top 6 inches in the heavily-grazed pasture (Table I). Clay content was least in the 0 to 6 inch layer. In the heavily-grazed pasture it increased from 19.6 per cent near the surface to about 35 per cent at a depth of 3 feet. In the other areas clay increased from 28.7 per cent to about 40 per cent at 3 feet.

Table I. Per cent sand, silt and clay in soils in ungrazed, moderately-grazed and heavily-grazed pastures.

DEPTH (in inches)	UNGRAZED AND MODERATELY-GRAZED			HEAVILY-GRAZED		
	Sand	Silt	Clay	Sand	Silt	Clay
0-6	6.8	64.5	28.7	16.4	64.0	19.6
6-12	5.7	62.6	31.7	9.4	61.2	29.4
12-24	5.5	57.5	37.0	6.4	52.7	30.9
24-36	2.6	56.1	41.3	10.0	55.0	35.0
36-48	8.0	52.0	40.0	9.9	55.0	35.1
48-60	7.1	57.3	35.6	9.3	57.1	33.6

In every case silt content was high. The soils were similar in clay content at most depths although the heavily-grazed site had somewhat less in the topsoil. At most depths, differences were probably not great enough to cause major changes in results of other soil tests.

Vegetation

The vegetation of the college pasture has been described in detail by Albertson (1937). Changes due to drought and grazing in this general area have been recorded by Albertson (1938, 1939, and 1941), Albertson, *et al.* (1953), and Tomanek and Albertson (1953).

Basal area and composition of the vegetation were determined by the square-foot method as described by Voight and Weaver (1951). One hundred samples were taken in each area. Total cover exhibited the same trend as found by Tomanek (1948). Basal area ranged from 39.3 per cent in the heavily-grazed area to 48.8 per cent where grazing had been moderate (Table II).

The two shortgrasses, blue grama (*Bouteloua gracilis*)[1] and buffalo grass (*Buchloe dactyloides*), composed the greatest part of the cover in all three sites. These grasses were about equally abundant in all pastures (Fig. 3). Other grasses common to all areas were the three-awn grasses (*Aristida* spp.) which composed only about

[1] Nomenclature of plants follows Rydberg's "Flora of the Prairies and Plains of Central North America."

Table II. Percentage composition of the principal grasses and total basal cover in relation to intensity of grazing.

SPECIES	UNGRAZED	MODERATELY-GRAZED	HEAVILY-GRAZED
Buffalo grass	39.9	46.0	46.0
Blue grama grass	46.7	46.0	49.0
Three-awn grass	3.2	3.0	1.0
Western Wheat grass	4.6	T.	2.0
Others	5.8	5.0	2.0
Total	100.0	100.0	100.0
Basal Cover	43.4	48.8	39.3

Figure 3. Close-up view of vegetation in ungrazed site. Vegetation mostly blue grama and buffalo grass. Note large amount of litter. May, 1954.

3 per cent of the cover. Western wheat grass (Agropyron smithii) was the only other important species in the heavily-grazed site.

The major forbs of the ungrazed- and moderately-grazed areas were Psoralea tenuiflora Pursh., Malvastrum coccineum, Ambrosia psilostachya, and Cirsium undulatum. The most abundant forbs of the heavily-grazed site were Opuntia macrorrhiza, Cirsium ochrocentrum, Psoralea tenuiflora Pursh., and annual weeds such as Helianthus annuus and Solanum rostratum.

There were only a few scattered annual grasses in the ungrazed plot. The moderately-grazed site had clumps of annual brome grasses (Bromus spp.) scattered throughout, especially around cow chips and other bare areas. Abundance of annual weeds was greatest in the heavily-grazed pasture; major species was little barley (Hordeum pusillum). It was quite heavily utilized until May 18, when it began to mature.

CLIMATOLOGICAL DATA[1]

The 1954 growing season was extreme. Since 1868 precipitation was less only in the summers of 1913 and 1936, and temperature was higher only in 1934 and 1936. Total rainfall for the 3 months from June to August, inclusive, was only 6.5 inches. About 5.5 inches were received in May, but this had been used by July. In addition, there

[1] U. S. Department of Commerce, Climatological Data: Kansas, Vol. LXVIII, Nos. 5-8.

was a severe shortage of subsoil moisture due to the reduced precipitation of 1952 and 1953. Evaporation from a free-water surface for June, July, and August totaled 49.3 inches as compared to an average of 28.5 inches. Temperature rose to 100 degrees or above on 17 days in July. On 10 of these days it was above 105 degrees. These high temperatures together with low rainfall were a major factor in causing reduced plant growth.

A storm on August 1, 1954, was very destructive to the vegetation in this area. Large hailstones (up to 1.5 inches in diameter) driven by a hard wind caused the dry and brittle leaves to be detached from the plants. This material, together with large amounts of mulch, was washed away by the accompanying 1.15 inches of rain. The soil surface was compacted by the force of the hail and moisture penetrated only to a 3-inch depth. Runoff was great and ponds were filled with water and debris from the pastures. The heavily-grazed site was not damaged as it was out of the major storm area.

RESULTS

Increased utilization of native pastures and range lands due to large numbers of cattle and decrease in pasturable acres has led to vast changes in composition, yield, and usefulness of ranges. Both composition and yield depend upon habitat conditions, which are greatly altered by intensive grazing.

Volume-weight

Effects of compaction on soil properties have been reported by several authors. Chandler (1940) in Pennsylvania reported volume-weight ratios of 1.15 and 0.92 in grazed and ungrazed sites, respectively. Aldefer and Robinson (1952) attributed low rates of infiltration on heavily-grazed sites to high volume-weight ratios caused by trampling. Free, et al. (1947) found soils high in organic content offered the greatest resistance to compaction. Hubbell and Gardner (1948) indicated that compaction produced greater lowering of aggregation and microbial populations than did puddling and cultivation. Highly compacted soils do not permit the entrance of plant roots and the use of soil moisture from lower areas (Veihmeyer and Hendrickson 1948). It has been shown that yields of native grasses are decreased by compaction (Knoll 1953).

The degree of compaction was determined by the method described by Jamison, et al. (1950). Six samples, 3 inches deep and about 4 inches in diameter were removed from each site with a hammer-driven soil corer. Similar soil moisture conditions existed in each site at the time of sampling.

Average volume-weight ratios were 1.08, 1.17, and 1.27 on the ungrazed, moderately-grazed, and heavily-grazed areas, respectively. Porosity in the same areas was computed to be 59.2, 55.9, and 52.1 per cent using a specific gravity of 2.65 (Millar and Turk 1951). The increase in volume-weight of the moderately- and heavily-grazed areas was possibly due to trampling, although decreased organic content and raindrop compaction may have been factors (Kennedy and Russell 1948, Ellison 1945).

Infiltration

Permeability of the soil profile is an important factor in infiltration of water in most soils. It should be judged on several characteristics of the soil including porosity, stability of aggregates, and direction of natural fracture (O'Neal 1949). In addition to these structural qualities, texture is also, under some circumstances, a reliable clue to permeability.

Aldefer and Robinson (1947) found water runoff was high from heavily-grazed pastures. Klute and Jacob (1950) reported compaction from 0 to 5 inches caused decreased infiltration. Musgrave and Free (1936) placed much emphasis upon the percentage of porosity as a factor in permeability. Percolation increases due to increased size of aggregates was reported by Hubbell and Chapman (1947). Crop residues may be expected to increase infiltration and reduce evaporation (Duley and Russell 1939).

Rates of infiltration were determined by forcing 6 steel cylinders, 15 inches long and 6 inches in diameter, into the soil in each area to a depth of 3 inches. The cylinders were then filled with water, which was allowed to soak into the soil for 48 hours. This caused the upper portion of drought cracks to close. Water was then applied for a 2-hour period. Metal baffles were used and the natural mulch retained to prevent disturbance to the soil surface. A depth of 1 to 2 mm. of water was maintained throughout the period.

Total infiltration was 2.58, 2.08, and 1.58 inches in the ungrazed, moderately-grazed, and heavily-grazed sites, respectively

(Table III). Over half of the total in each area, was absorbed during the initial 30-minute period. Decreases were not uniform throughout the sampling, but lowest rates of infiltration occurred in the final period.

Soil moisture

The importance of soil moisture as a limiting factor in plant production in the mixed prairie was stressed by Weaver and Albertson (1944). Their intensive studies of the drought have indicated that yields are inversely proportional to available soil moisture. Chandler (1940) in Pennsylvania found that moisture content of soils under grazing was less than where ungrazed.

Soil moisture was determined monthly in the ungrazed, moderately-grazed, and heavily-grazed areas. Samples were taken from 0 to 6 inches, 6 to 12 inches, and each foot thereafter to a depth of 5 feet. Amounts of moisture were nearly always least in the heavily-grazed pasture through July. Greatest differences were in the top 6 inches and from 12 to 24 inches (Table IV). At the latter level, the heavily-grazed site contained about 21 per cent moisture in May and June, as compared to about 27 per cent in the ungrazed area. During May the heavily-grazed tract had only 51 per cent as much moisture from 24 to 36 inches as the ungrazed area. These differences persisted to a considerable extent for the next two months. Differences between the heavily-grazed and moderately-grazed sites were not so great although the

Table III. Rates of infiltration in inches in each of the pastures. Data represent inches of water and are averages of six samples.

AREA	TIME IN MINUTES				TOTAL
	0-30	30-60	60-90	90-120	
Ungrazed	1.38	.39	.43	.38	2.58
Moderately-Grazed	1.05	.32	.47	.24	2.08
Heavily-Grazed	.86	.35	.21	.16	1.58

Table IV. Amounts of total soil moisture in percentages of oven-dry weight of soil in 1954 to a depth of five feet under three intensities of grazing.

DEPTH	MAY			JUNE			JULY			AUGUST			SEPTEMBER		
(in inches)	U.G.*	M.G.*	H.G.*	U.G.	M.G.	H.G.	U.G.	M.G.	H.G.	U.G.	M.G.	H.G.	U.G.	M.G.	H.G.
0 to 6	28.2	29.4	25.0	26.4	24.7	20.3	9.6	8.3	6.2	7.8	8.2	9.5	7.4	6.8	6.3
6 to 12	27.3	28.0	28.0	20.7	25.0	23.8	10.8	10.6	11.5	10.6	9.9	10.6	11.2	9.0	10.9
12 to 24	27.3	27.0	20.6	27.2	22.6	21.3	13.9	12.7	12.6	9.9	10.9	11.4	11.4	11.7	11.4
24 to 36	21.4	15.8	11.0	24.7	14.6	11.6	18.7	10.8	11.6	11.9	9.8	10.7	10.9	9.8	10.5
36 to 48	13.3	11.7	12.4	16.7	10.4	12.4	17.2	10.3	12.5	13.4	9.8	11.5	12.0	9.9	11.6
48 to 60	14.3	11.6	14.0	15.8	11.2	13.2	14.6	11.3	13.4	12.8	10.7	10.2	11.3	10.8	11.0

* U.G., M.G., and H.G. refer to ungrazed, moderately-grazed and heavily-grazed, respectively.

latter contained about 25 per cent more moisture in the second and third foot during May. The drought condition which existed after May caused complete depletion of available soil moisture by July 1 except at the lower depths in the ungrazed area. Even this was exhausted by August. Albertson (1937) found the hygroscopic coefficient of similar soils to be 12.4, 12.6, and 13.3 per cent in the A, B, and C horizons, respectively. Therefore, moisture was generally unavailable throughout July, August, and September except for short periods following showers. The 3- to 5-foot layer had no available moisture during the growing season except small amounts in the ungrazed site up to early July. Limited rainfall during the previous 2 years had caused the moisture depletion of this layer.

Aggregate Stability

Stability of structure refers to the resistance that the aggregates offer to the disintegrating influence of water and mechanical manipulation. The stability of the aggregate is of utmost importance in forming and preserving good structural relationships in soils.

Many workers have experimentally determined the effects of various soil treatments upon soil aggregates. Clay, with biologically active organic matter, is the chief cementing agent (Robinson and Page 1951, Stallings 1952). Aldefer and Merkel (1941) found that structural stability is closely related to organic matter content. In Nebraska, McHenry and Newell (1947) found an increase in aggregation in soils under grasses as compared to weedy plots. By monthly sampling, Strickling (1951) established that dynamic seasonal trends existed in aggregate stability. In studies conducted in Montana on shortgrass prairies grazed at three different intensities, Tebbe, et al. (1947) found small but consistent reductions in amount of organic matter in the surface soil under grazing.

Percentage of water-stable aggregates was determined by a modified wet-sieving process (Yoder 1936). Twenty-five grams of air-dry granules from 3 to 5 mm. in diameter were allowed to soak for one minute and then sieved under water for two minutes. A total of 60 strokes, 1.25 to 1.5 inches in magnitude, were applied to each sample. Determinations were made as to air-dry amounts remaining on 2, 1, and 0.5 mm. sieves. Duplicate samples to a depth of 0.5 inch were tested from each of the three areas.

Total per cent of water stable aggregates was 89.0, 63.6, and 55.6 in the ungrazed, moderately-grazed, and heavily-grazed pastures, respectively (Table V). The greatest differences occurred in the amount of granules larger than 2 mm. Differences in breakdown of aggregates during a rain would probably be even greater on the heavily-grazed site because of lesser amounts of mulch and plant cover. Lack of structural stability could have been caused by disturbance from the animals and disintegration from raindrops on the relatively bare soil surface (Osborn 1954).

Table V. Percent of water-stable aggregates of various diameters from the surface 0.5 inch of soil. Samples were composed of aggregates 3 to 5 mm. in diameter.

AREA	2 mm.	1 mm.	½ mm.	Total
Ungrazed	79.3	5.4	4.3	89.0
Moderately-grazed	55.8	5.4	2.4	63.6
Heavily-grazed	42.6	7.8	5.2	55.6

Growth and Yields

Extensive studies have been made on the effects of various degrees of utilization of mixed-prairie vegetation. Tomanek (1948) found that vegetative cover on moderately-grazed tracts was nearly twice that of over-grazed sites. Albertson, et al. (1953) reported that unclipped grasses produced nearly 1000 pounds more forage per acre than where closely clipped. After the effects of clipping stimulus ceased to be a factor, growth increment of closely-clipped areas was always least and total increment was inversely proportional to the intensity of clipping.

Growth began about the middle of April in each of the pastures. Cattle were turned into the heavily-grazed pasture on April 14, 1954. Growth had just started and extent of past use was very evident from abundant cow chips and lack of debris. Old vegetation was only about 1 inch tall and the green appearance was caused mainly by the thick stand of annual grasses. The old vegetation in the moderately-grazed area was about 2.5 inches in height. Cattle were not placed here until April 29. Most of the early grazing was confined to the cool-season grasses of the lowlands. In the ungrazed tract, old vegetation was about 7 inches tall.

By May 13, most forbs were being used in the heavily-grazed pasture. Wild alfalfa was grazed to a height of 2 to 3 inches. Annual grasses of the upland and western wheat grass of the lowland were used extensively during this part of the season. Short grasses were about 3 inches in height. Due to the obscuring effect of old vegetation, the moderately-grazed and ungrazed areas still did not appear as green as the heavily-grazed pasture. Wild alfalfa was 8 inches tall and very few of the plants were grazed. Short grasses were about 4 inches tall.

By June 28, the heavily-grazed site showed definite signs of drought. Short grasses were grazed to about 2.5 inches, but in exclosures they were 4 to 6 inches tall. Annual grasses were nearly ripe and were no longer grazed. Vegetation in the moderately-grazed pasture was only slightly wilted. Ungrazed and grazed heights were 4 and 1 inches, respectively. Grasses in the ungrazed plot were 7 to 8 inches tall and showed no evidence of drought.

By July 21, all grasses were dormant. Those in the heavily-grazed area had turned brown and were grazed to a stubble height of 1 inch. Cattle had been removed from the moderately-grazed pasture after grazing it to about 3 inches.

There was no general renewal of growth after July 1, when available moisture became depleted and grazing removed only the dormant vegetation. After the rain and hail storm of August 1, growth was noticeable in the heavily-grazed pasture only in areas adjacent to drought cracks or in depressions. The moderately-grazed pasture appeared quite bare and soil could be seen between the grass clumps. The grasses in the ungrazed area resumed growth but again became dormant by August 12.

On September 10, the grass was only 0.75 inch tall in the heavily-grazed pasture and about 25 head of cattle were added to the herd. This resulted in complete removal of forage on much of the pasture.

Yields were determined by clipping from 5 to 8 representative meter quadrats on selected sites in each of the areas. These quadrats were protected from grazing by Tepee-Type exclosures. Annual grasses were removed when mature and perennial vegetation was clipped at mulch level at the end of the growing season. Forage was air-dried, weighed, and converted to a pounds-per-acre basis.

Total yields of the moderately- and heavily-grazed sites were about equal. Greatest differences were in the portion of the total that was composed of annual grasses. In the heavily-grazed site, cover was open and annuals yielded 597 pounds, which was 38 per cent of the total yield (Table VI). On the moderately-grazed pasture only 186 pounds of weeds was produced and none occurred in the ungrazed site. Production of perennial grasses was 1,884, 1,358, and 979 pounds per acre in the non-grazed, moderately-grazed, and heavily-grazed pastures, respectively. Thus, the ungrazed pasture produced nearly twice as much perennial grass as the heavily-grazed pasture. During the latter part of the growing season yields in each area were reduced because of the lack of available soil moisture.

Mulch

Debris left on the soil as a mulch after the grazing season is a chief factor in maintaining soil productivity. Considerable research has been done on both cultivated and pasture soils to determine the effects of mulch. Aldefer and Robinson (1947) in Pennsylvania associated

Table VI. Yields of vegetation and amounts of mulch in pounds per acre under various treatments.

YIELDS	UNGRAZED	MODERATELY-GRAZED	HEAVILY-GRAZED	CONGESTED SITE	ARTIFICIALLY COMPACTED
Weeds	0	186	597	0	0
Perennial Grasses	1,884	1,358	979	405	759
TOTAL YIELD	1,884	1,544	1,576	405	759
Mulch	6,415	1,759	238	----	----

high rate of water runoff from heavily-grazed pastures with lack of soil cover. The condition of the soil surface is an important physical factor in evaluating water intake (Baver 1949). Pillsbury (1947) and Aldefer and Merkel (1944) reported great reduction in infiltration rate upon the destruction of the surface litter. Hopkins (1954) found that soil moisture and permeability decreased while soil temperature and evaporation increased with the removal of mulch. Stallings (1952) indicated that to maintain a high state of aggregation, a continuous supply of fresh organic matter must be supplied. Soil splash from raindrop impact and possible subsequent erosion of as much as 160,000 pounds of soil per acre was found by Osborn (1954) on grassland without mulch.

Mulch was determined by collecting all debris of plant materials in 6 selected 0.25-square-meter plots in each of the pastures. Air-dry weights were determined and data were converted to pounds per acre. The ungrazed area had 6,415 pounds of mulch compared to 1,759 pounds in the moderately-grazed site and only 238 pounds in the heavily-grazed pasture (Table VI). This compares favorably with amounts on similar pastures described by Tomanek and Albertson (1953) and Hopkins (1954).

Amount on the moderately-grazed site may have been greater had the samples been taken prior to the hail storm of August 1 when a great deal of the mulch was broken loose and carried down the slopes. Vegetation and mulch formed a sufficiently dense cover on the ungrazed site to prevent such destructive action.

Paths

A short-grass hillside site with 3 adjacent parallel paths was selected for study. The paths were located on a moderately-deep soil on a gently-sloping hillside. Vegetation was similar to that of the moderately-grazed site. The center path had been eroded to a depth of 8 to 14 inches and was no longer used. The path to the left had been used for two seasons and the one to the right for one season. Neither had been severely eroded. A barrier was erected across the paths on May 3, in order to cause the formation of new paths (Fig. 4).

Vegetation did not occur in the eroded path and the two-year-old path was only sparsely covered with old buffalo grass stolons and crowns. Roots of the occasional clumps of short grass were exposed and the path was depressed about 1.5 inches. The one-year-old path had a good cover of short grasses although many of the clumps were dead. Stolons were frequent and only a slight depression was discernible. By September, the new path around the barrier was nearly devoid of mulch and had little more cover than the one-year-old path where the latter was protected by the barrier.

Six volume-weight samples were removed from the surrounding area and each of the paths except the old eroded path. Samples from the new path were removed in July and September, but were taken in May in all other sites.

The average volume-weight in the vicinity of the paths was 1.22. In the one- and two-year-old paths it was 1.30 and 1.33, respectively (Table VII). By September the new path also had a volume-weight ratio

Figure 4. View of path area showing severe erosion in oldest path. Note barrier erected to cause formation of new path.

Table VII. Volume-weight ratios in areas studied. Data are averages of six samples.

AREA			VOLUME-WEIGHT
Ungrazed			1.08
Moderately-grazed			1.17
Heavily-grazed			1.27
Path Area	Control		1.22
	New Path	July	1.25
		September	1.30
	One-year-old path		1.30
	Two-year-old path		1.33
Congested area			1.31
Artificially compacted area			1.35

of 1.30 as compared to 1.25 in July. Compaction appears to be greatest during the first season of path use. Decrease in pore space in the new path was from 53.8 per cent to 52.7 per cent in July and then to 50.2 per cent in September.

Rate of infiltration was determined in July and September by the procedure described. Infiltration was inversely proportional to volume-weight. The area in the vicinity of the paths absorbed 2.67 inches of water during the 2-hour-period with 1.08 inches being absorbed during the first 30 minutes (Table VIII). In the new path, total infiltration on July 26 was 1.61 inches and 0.92 inches of this was absorbed in the first half hour. Total infiltration on September 10 was only 0.99 inches and 70 per cent of this was absorbed in the first 30 minutes. After the initial period, however, the rate decreased markedly in all tests.

Congested Area

Cattle usually form paths or grazing routes along enclosing fences. They also tend to congregate in certain areas for grazing, bedding down, and other activities (Weaver and Tomanek 1951).

The congested site was located in a heavily-grazed and trampled corner of the college pasture. Cover had been reduced to approximately 20 per cent and the short grasses had been partially replaced by less desirable species. Buffalo grass and sand dropseed (Sporobolus cryptandrus) composed 90 per cent of the cover. Mulch was lacking and the soil between the grass clumps was exposed.

Table VIII. Rate of infiltration in the compacted sites. Data represent inches of water and are averages of six samples.

AREA		TIME IN MINUTES				TOTAL
		0-30	30-60	60-90	90-120	
Path Area	Control	1.08	.49	.61	.49	2.67
	July	.92	.20	.29	.21	1.61
	September	.70	.11	.11	.08	.99
Congested Area		.46	.14	.10	.07	.77
Artificial Compaction		.50	.08	.11	.14	.83

The volume-weight ratio of the soil in this site was 1.31. This indicates approximately the same degree of compaction as occurred in a path after one season of use. Estimating the volume-weight of a similar soil under moderate grazing to be 1.20, this represents a reduction in porosity from 55.7 per cent to 50.5 per cent.

Total infiltration in the congested area was 0.77 inches (Table VIII). Nearly two-thirds of the total was absorbed during the initial half hour. In the remaining period, infiltration was reduced to an average of 0.10 inches per half hour.

Yields were obtained from 3 square-meter quadrats protected from grazing. Vegetation was clipped at the end of the growing season and yields calculated on the dry-weight basis. Average forage production was 405 pounds per acre. Annual grasses were seldom present and were not included. This was the lowest yield from any of the areas studied.

Artificial Compaction

This study was included to differentiate between the effects of compaction alone and the effects of grazing and trampling. On April 18, areas of about 18 square feet in the moderately-grazed site were compacted with a tamping bar to a volume-weight of 1.28. Further compaction to 1.35 was done on May 2, after growth had started. This soil was then more compact than even the two-year-old path.

Total average infiltration in this area was 0.83 inches (Table VIII) of which 60 per cent was absorbed in the first half hour. The rate decreased greatly until only 0.11 inches was absorbed per half hour during the remaining periods.

Yields were determined by clipping 10 square-foot plots at the end of the season. Average production was 758.6 pounds per acre which was only 56 per cent as much as from perennial grasses in the adjacent moderately-grazed area. Annual weeds had been destroyed by the compacting operation.

DISCUSSION

General soil characteristics of each of the major areas studied were similar. This study was an attempt to determine changes which had been brought about by varying treatments.

Increased volume-weight ratios were always proportional to degree of utilization. Chandler (1940) attributed compaction of soils under grazing to trampling, lower organic content, and the lower percentage of the larger aggregates. The lighter color of the topsoil in the heavily-grazed pasture indicated that organic content may have been less than where moderately grazed. Trampling is also a major factor in causing compaction as evidenced by the study of paths and congested areas. For example, volume-weight in a new path increased from 1.22 to 1.30 during only one season.

Reduction in rate of infiltration paralleled increases in volume-weight in most cases. An exception occurred in the artificially compacted plots. This may have been due to the greater amount of mulch present on this site as compared with the relatively bare soil of the heavily-grazed areas. However, only 0.83 inches were absorbed in the artificially-compacted plots as compared with 2.08 inches in the adjacent moderately-grazed sites. The only difference between these areas was the amount of compaction. Hopkins (1954) reported extensive decreases in rate of infiltration upon removal of mulch. Decreases in porosity due to compaction, instability of aggregates at the soil surface, and lack of mulch on heavily-grazed sites were probably all factors causing decreased rates of water intake. These lowered rates of infiltration, and consequent higher runoff, have resulted in decreased soil moisture in heavily utilized pastures.

Under most conditions, soil moisture is the limiting factor in forage yield in this area (Albertson and Weaver 1944). Increased evaporation due to lack of mulch has probably also been a factor in decreasing soil moisture (Hopkins 1954). Depth to which moisture extended was proportional to rate of infiltration. As drought conditions became more intensive, soil moisture first became unavailable in the areas where utilization was greatest and vegetation in these areas became dormant.

Organic matter is an important factor in the formation of soil aggregates (Stallings 1952). It may have been a factor causing the reduction in stability of the larger aggregates in the soils under grazing (Tebbe 1947; Chandler 1940). Evidence of granule disintegration was apparent in the surface inch of the heavily compacted soils. Osborn (1954) indicated that raindrop impact on bare soil surfaces may cause disintegration of the aggregates. Actual manipulation of the aggregates by the hooves of grazing animals should not be discounted as a factor. Destruction of aggregates permits the migration of colloids and subsequent sealing of pore spaces. This has been shown to be an important factor in causing the decrease in water intake of compacted soils.

Growth of vegetation was limited by the lack of soil moisture. All areas suffered in this respect although it was most intense in the heavily-grazed sites. The vegetation on these areas became dormant in early July while that of the ungrazed site maintained growth until August. Yields were reduced as compared to more favorable seasons (Hopkins, et al. 1952). Amount of mulch was proportional to the degree of utilization. This is due to low forage production and also, where grazing is heavy, to removal by wind and water. A greater reduction in yield in the heavily-grazed location would have been expected with normal amounts of rainfall.

Differences in production in the artificially compacted plots, as compared to the congested site, may have been due to several factors. Since the former was not compacted until May, the change in rate of infiltration would have had little effect upon soil moisture content, while it is probable that much of the precipitation ran off the congested site. Also, vegetation in the artificially compacted tract had been moderately grazed while that of the congested area had been heavily utilized so that plant vigor may have been a factor.

SUMMARY

Overgrazing is a major problem facing in the livestock industry. Little research has been done on the effects of heavy grazing on soil properties. This study was initiated to obtain basic information about reactions of soil to various degrees of utilization and trampling. The studies were conducted in the college pasture near Hays, Kansas, and in a heavily-grazed pasture on a similar site. All areas were on gently-sloping uplands with deep, well-developed loessial soils. Blue grama and buffalo grass were the dominant species.

The growing season during 1954 was extreme. High temperatures and low rainfall and consequent depletion of soil moisture throughout the summer months characterized the weather.

Volume-weight ratios in the ungrazed, moderately-grazed, and heavily-grazed pastures were 1.08, 1.17, and 1.27, respectively. In a two-year-old path, it was 1.33 as compared to 1.22 in the area surrounding the paths. A new path increased in volume-weight from 1.25 in July to 1.30 in September. A congested location had a volume-weight of 1.31.

Soil aggregates were less stable under grazing than where grazed. Total percentages of water-stable aggregates greater than 0.5 mm. were 89.0, 63.6, and 55.6 per cent in the ungrazed, moderately-grazed, and heavily-grazed sites, respectively. The greatest differences were in the amount of granules larger than 2 mm. in diameter.

Infiltration in a 2-hour period was 2.58, 2.08, and 1.58 inches in the ungrazed, moderately-grazed, and heavily-grazed areas, respectively.

Total infiltration in the area adfacent to the paths was 2.67 inches. In the new path, 1.61 inches were absorbed in July but only 0.99 inch penetrated in the September test. The congested site and artificially compacted plot absorbed less than an inch.

Available soil moisture was not below 2 feet in the heavily-grazed pasture in May, but it extended to a depth of 3 feet in the moderately- and ungrazed pastures. These differences persisted to a considerable extent until July, when moisture became unavailable in all sites. This condition existed for the remainder of the growing season, except for short periods following showers.

Utilization on the upland site in the heavily-grazed pasture was confined, for the most part, to annual grasses during early spring. Perennial grasses became dormant in July and utilization was discontinued in the moderately-grazed pasture. However, cattle remained in the heavily-grazed pasture and vegetation was grazed to a stubble height of one inch by July 21. Forbs had been extensively used only in the heavily-grazed pasture.

Total yields in the ungrazed, moderately-grazed, and heavily-grazed sites were 1,884, 1,576, and 1,544 pounds per acre, respectively. Weeds composed 38 per cent of the total in the heavily-grazed pasture but only 12 per cent under moderate grazing. There was 405 pounds of grass in the congested site and 759 pounds where the soil had been artificially compacted.

Mulch decreased from 6,415 pounds per acre in the ungrazed tract to 1,759 pounds where moderately grazed and 238 pounds under heavy utilization. It was lacking on all heavily trampled areas.

Decreases in porosity, per cent of water-stable aggregates, soil moisture, and yield of vegetation occurred where pastures were grazed. The extent of the decreases were usually proportional to the degree of utilization.

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