RESPONSE OF TRUE PRAIRIE VEGETATION ON MAJOR FLINT HILLS RANGE SITES TO GRAZING TREATMENT

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INTRODUCTION

Native prairie has been the home of grazing animals for untold centuries. Prairie plants are eminently adapted to grazing, and moderate grazing use is not detrimental to their development. Climax grassland, when properly grazed, retains essentially its natural composition. Yet, when livestock are placed on range too early in the season, when they are left there too long, or when too many animals are confined to an area, grazing becomes so excessive that normal plant cover cannot be maintained. Numerous changes in the vegetation then occur. The rate at which these changes take place depends on the degree of abuse. They sometimes take place so gradually that deterioration may not readily be recognized until the plant cover has been greatly modified, but when prairie is grazed intensively major changes may occur within a few years.

Native grassland still occupies some 2,800,000 acres of the 4 million-acre Flint Hills region of Kansas lying principally in the 30- to 38-in. rainfall belt between the 96th and 97th meridians as shown in Fig. 1. The Flint Hills area supports a year-round cattle population of perhaps 500,000 head plus some 300,000 additional ones shipped there each year to graze during summer. Utilization of bluestem range pastures has traditionally been through summer grazing by cattle, the period of heaviest use corresponding with

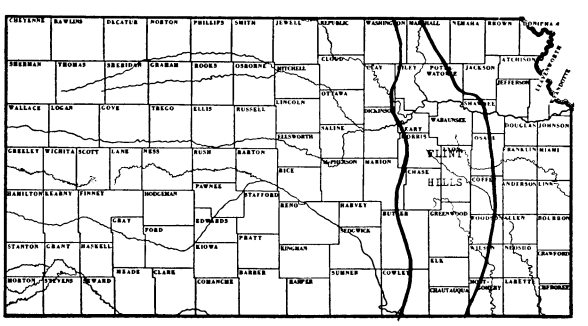

FIG. 1. Approximate (generalized) boundaries of the Flint Hills grazing area of Kansas.

that of the three months of most rapid grass growth, May, June, and July. Cattle often remain until fall, and some bluestem pastures are stocked year-long. Much of the Flint Hills remains in good to excellent range condition because of the nature of the grazing management. Transient cattle are grazed each year during the period of rapid vegetative growth and marketed in time for the range grasses to make sufficient top growth for adequate storage of root reserves.

The native vegetation of the area is classified as true prairie, dominated by little bluestem (*Andropogon scoparius*)[3] and big bluestem (*A. gerardi*) to-

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[3] Scientific names of grasses according to Hitchcock, A.S., U.S.D.A. Misc. Publ. 200, Rev. 1951, and of other plants according to Gates, F. C., The Flora of Kansas. 266 pp. Kansas Agric. Exp. Sta. Publ., 1940.

gether with several less abundant grasses of similar growth habit. Small amounts of short grasses occur, particularly on preclimax sites, while forbs, although often conspicuous at flowering time, seldom constitute a large portion of the climax vegetation. Sedges and rushes make up a small percent of the plant cover.

The history of range utilization in the Midwest has been one of exploitation followed by depletion of the vegetation. Aldous (1938) pointed out that there had been a steady decline in the grazing capacity of bluestem pastures in Kansas. "Prior to 1900 most of the pastures were stocked at the rate of two acres for a cow or mature steer. The average has been gradually decreased until in 1933 the best pastures were carrying one mature animal to four acres, while the average for the bluestem region as a whole was five acres per head for the summer grazing period." This has further declined in recent years until the best pastures now carry on the average only one animal unit per 5 acres or more.

Grazing use is the major factor affecting range conditions. The chief criterion for detecting and evaluating trend in range condition is change in species composition. Since quantitative data on the course of such change in Flint Hills bluestem grassland have not generally been available, a study of the effects of different grazing treatments on the vegetation and on the livestock was initiated in 1949 on typical bluestem range to provide such data.

Climate and Physiography

The climate conditions of the Flint Hills are typical of true prairie. Average annual precipitation varies from 30 in. in the northwestern part to 38 in. in the southeastern part of the region. About 75% of the moisture falls during the growing season, which ranges in length from an average of 170 days in the north to 190 days in the south.

Elevations vary from 1,500 ft in the central part of the region to 850 ft at its southeastern extremity. Physiographically a strongly dissected plain, the terrain is rolling to hilly with relatively smooth, narrow divides bordered by rock outcrops and steep slopes. Escarpments occur adjacent to major stream valleys.

The residual soils have developed from massive limestones, interbedded gray and yellow shales, and highly flinty or cherty limestones of the lower Permian formations (Fly 1946). Under the native bluestem vegetation the soils throughout the Flint Hills have developed dark, well-granulated silt loam or silty clay loam surface horizons. Texture and consistency of subsoil, depth of soil, and degree of stoniness vary widely with the character of the parent material and the degree of slope. Broken rock and chert allow moisture and plant roots to penetrate deeply. However, wide variations exist in the ability of the soils to support the regional climax type of vegetation. The surface soils are slightly acid in reaction and the fertility is moderate to high.

Vegetation-Soil Relationships

A study by Anderson & Fly (1955) of the relationship of the native plant population to soil differences on this experimental area revealed a number of distinct vegetation-soil units that were recognized as range sites. Six such sites were recognized and shown to be representative of broad areas of Flint Hills range. Major range sites occurring on the experimental area are outlined in Fig. 2. In the present study, comparisons have been made within these range sites and among grazing treatments.

Ordinary Upland Range Site. Lands having sufficient depth of soil with medium or loamy texture and hence with suitable soil-plant-moisture relations to support the type of vegetation that is climax on the zonal soils of the regional climate.

Limestone Breaks Range Site. Lands similar to the above but occurring on slopes of 35% or more and therefore subject to somewhat greater loss of moisture by runoff when closely grazed, and with less development. The vegetation, however, is like that of the above site in its major features and may be considered climax in nature.

Clay Upland Range Site. Lands having sufficient depth of soil but with somewhat less infiltration, slower permeability, and a smaller percentage of water available to plants than ordinary upland, hence supporting a somewhat preclimax vegetation.

Claypan Range Site. Lands having sufficient depth of soil, but with even more restrictive water relations than the clay upland sites, thus supporting a preclimax vegetation.

Very Shallow Range Site. Lands having insufficient depth of soil for normal water storage, hence supporting under proper grazing a vegetation distinctly preclimax.

Lowland Range Site (gullied). Lands receiving more water than normal and having, because of position and soil depth, such moisture relations as to

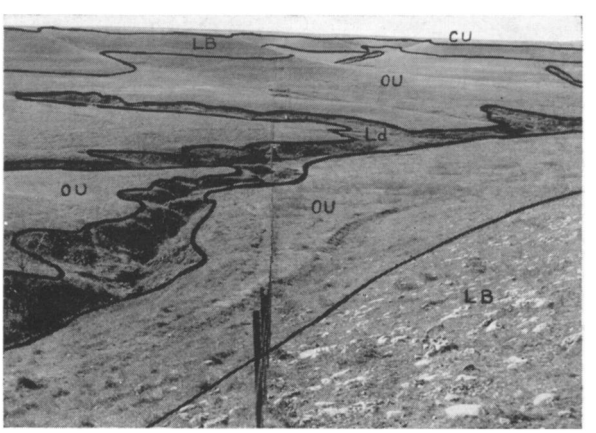

FIG. 2. Distribution of major range sites in typical Flint Hills range. Shown here are pasture 3 (light stocking) at the left and pasture 2 (heavy stocking).
OU = Ordinary upland
LB = Limestone breaks
CU = Clay uplands
Ld = Lowland (gullied)

support a post climax vegetation under proper grazing (with gullies controlled).

GRAZING EFFECTS ON VEGETATIONAL COMPOSITION

The grazing season in Flint Hills bluestem pastures usually begins about the time the dominant grasses begin to show spring growth and sometimes even earlier than this. Anderson (1951) pointed out that at that early date animals feed on cool season species such as prairie junegrass (*Koeleria cristata*), Kentucky bluegrass (*Poa pratensis*), and certain forbs. Weaver & Darland (1948) have shown that grazing use in similar grassland shifted to species of the bluestem type as soon as they were a few inches tall and that under heavy stocking these prairie species were repeatedly grazed until late fall. This resulted in a change in species composition away from the prairie dominants toward such pasture grasses as Kentucky bluegrass. Such an increase in Kentucky bluegrass was observed by Anderson (1940) to be widespread in the Flint Hills prior to the great drought of the 1930's, but this invading species practically disappeared in the extremely dry season of 1934.

CLASSIFICATION OF RANGE PLANTS

The task of maintaining natural grazing land is based upon a knowledge of the vegetation and its ecology. Most climax dominants and certain minor species of the true prairie, including many forbs, decrease under close grazing, but others members of the climax increase to take their place. If grazing pressure continues, the latter also begin to decrease, and invasion by weeds takes place. These responses were recognized by Smith (1940) who called attention to the fact that prairie species were forced out by grazing in the order of their palatability or edibility. Weaver & Hanson (1941) described stages of range deterioration from climax to depletion, classifying prairie species into 6 groups based on response to grazing. Decreasing, increasing, and invading grasses and forbs were listed. Dyksterhuis (1949) showed that degrees of grazing disturbance in grassland could be measured quantitatively by comparing the current relative coverage or production with that of the climax as determined by careful study of prairie relicts on the same kind of soil. Percentages of decreasers, increasers, and invaders were established as the basis for measuring degeneration.

The major decreasers in Flint Hills range include big bluestem, little bluestem, and indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and others. Major increasers include Kentucky bluegrass (an invader that has become naturalized and behaves in most respects as an increaser), sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), hairy grama (*B. hirsuta*), buffalograss (*Buchloe dactyloides*), tall dropseed (*Sporobolus asper*), pen sedge (*Carex pensylvanica*), and baldwin ironweed (*Vernonia baldwini*). Among the major invaders are annual bromes (*Bromus* spp.), little barley (*Hordeum pusillum*), sixweeks fescue (*Festuca octoflora*), western ragweed (*Ambrosia psilostachya*), wavyleaf thistle (*Cirsium undulatum*), hoary vervain (*Verbena stricta*), and curlycup gumweed (*Grindelia squarrosa*).

DROUGHT EFFECTS ON VEGETATION COVER

There is a close relationship between forage production and annual precipitation. Savage (1937) observed that on the Great Plains the drought of 1933-1934 caused a decline of 65% in basal area of major grass species on ungrazed plots. Weaver (1954) showed that in true prairie areas moderately affected by the drought of the 1930's spaces bare of living plants were more or less isolated. Open spaces were plentiful where drought had been more severe and formed an irregular network of unoccupied soil surface. The cover was so decimated in some places that terrain appeared almost bare throughout the summer of the following year. The more mesic little bluestem, indiangrass, and Kentucky bluegrass had disappeared from some areas, and only blue grama, sideoats grama, and certain xeric forbs remained. The major species to increase with the drought were western wheatgrass, buffalograss, blue grama, and sixweeks fescue.

Drought damage to plants may be affected materially by grazing use. Studies by Craddock & Forsling (1938), Nelson (1934) and Savage (1937) indicated that conservative grazing is little or no more harmful than total protection. Heavy grazing decreases both the depth to which roots penetrate and the volume of root production, hence overgrazed plants suffer great damage from drought. Savage (1937) found that decreases in production of the principal grasses of the Great Plains under drought conditions were directly proportional to the intensity of grazing.

DEFERRED-ROTATION GRAZING

Deferred-rotation grazing involves the division of a range into several units, one or more of which is deferred each year. Deferment allows plants on the protected areas to reach a stage of growth before grazing that will permit a substantial increase in plant food reserves and in some instances, seed production. Experiments have shown that increased grazing use can safely be practiced following deferment. Sarvis (1923), comparing a deferred-rotation system with season-long grazing of different intensities in the northern Great Plains, found that 7 acres were required to supply enough forage for one steer and yet maintain the forage cover under season-long grazing. From 4 to 5 acres per steer per season were enough when deferred-rotation grazing was practiced.

Studies in Colorado by Hanson, Love & Morris (1931) showed that 9 yrs of deferred-rotation grazing resulted in a 53% increase in density of vegetation, while the total number of undesirable plants actually decreased 18%.

Stoddart & Smith (1943) summarized the advantages of deferred-rotation grazing as follows: (1) in-

creased vigor of plants, resulting in more rhizomes, tillers, roots, and foliage, (2) increased seed production, (3) seedlings established more easily, (4) reduction of trampling, (5) maximum forage yield attained under full stocking, and (6) range improvement and other benefits ordinarily accompanying stock reduction can be obtained without curtailing stocking.

Anderson (1951) called attention to an additional benefit from deferred grazing that often is not recognized, the improved distribution of livestock over the range. Deferment requires that the range be divided somewhat by cross fencing, and this gives better control of livestock distribution. It has been shown that improper distribution of grazing animals may be a serious factor in range deterioration, often resulting in severe overgrazing of some parts of the range and underutilization of others (Brinegar & Keim 1942; Stoddart & Smith 1943).

Herbage Yields as a Range Indicator

Increase in dry matter probably is the best single measure of forage production (Hanson 1950). Ahlgren (1947) reported that clipping or mowing ungrazed plots or protected areas in pastures probably is the most common procedure used in measuring the results of pasture management research. It is particularly suited to trials which include a large number of variables and may give more precise yield estimates than those based on animal productivity and maintenance. Using movable cages, Nevens (1945) showed that the difference between the weight of clipped herbage produced within plots protected from grazing and of that remaining after grazing and then clipped was a measure of the quantity consumed by the livestock.

MATERIALS AND METHODS

The study reported here was designed to evaluate the response of true prairie vegetation on major Flint Hills range sites to grazing treatment. The treatments compared were heavy, moderate, and light season-long stocking and deferred-rotation grazing at the moderate stocking rate. The results are reported in terms of vegetational responses by range sites. Major emphasis is on species composition and on trends that have developed under the different treatments. Herbage and mulch yields are also given.

Experimental Area

The pastures in this study are typical Flint Hills grasslands, located 5 mi. northwest of Manhattan, Kansas. The vegetation is predominantly true prairie, with big bluestem, little bluestem, and indiangrass making up at least 50% of the vegetation on climax sites. Kentucky bluegrass has invaded the entire area.

Grazing Treatments

Six pastures of 60 acres each were included in the trials. Three of these were grazed season-long (May 1 to approximately the end of October) and 3 in a deferred-rotation plan. Season-long grazing was at 3 stocking rates, 3.75 acres per animal unit[4] (pasture 2), 5.0 acres per animal unit (pasture 1), and 7.5 acres per animal unit (pasture 3). These will be referred to as heavily, lightly, and moderately stocked pastures, respectively.

The 3 pastures in the deferred-rotation group (pastures 4, 5, and 6) were stocked on the average at the same rate as pasture 1. All of the animals were placed on two of the pastures during May and June while the third was being deferred. On approximately July 1 all these animals would be shifted to the deferred pasture in order to use the grass quickly and to allow summer protection of the two pastures grazed earlier. Toward fall, if the grass became short under this intensive summer use, the gates would be opened to allow free access to all 3 pastures. This treatment was rotated annually among the three pastures of the group so that the over-all average stocking rate was 5 acres per animal unit.

Stocking has been with yearling steers, each considered to equal approximately ⅔ of one animal unit. Five acres per animal unit for the 6 months beginning May 1 is considered moderate stocking for the Flint Hills.

Sampling Methods

Botanical composition and density were studied by means of plant census data obtained from randomized line transect samples as described by Canfield (1941) and Parker & Savage (1944) and adapted by Anderson (1942) to bluestem vegetation. The transects were not located permanently but were randomized each year. Approximately 75 such samples were taken each year in each 60-acre pasture. Each line sample was 10 m in length, and since it was assumed that an area 1 cm wide was sampled, each sample was considered to have an area of 1000 sq cm. All live vegetation with its basal portion beneath the line and all upright culms touching either side of the line were measured and counted. Where the line passed through a clump of vegetation the diameter of the clump directly under the line was measured in centimeters along the line. Where a single culm touched the line it was considered to occupy 1 sq cm. The samples were taken in June and July each year. Each sampling location was marked on an aerial photograph of the area.

Clipping samples were taken at the close of the 1953, 1954, and 1955 growing seasons to measure the top growth and mulch remaining. Ungrazed samples were obtained in 1955 by placing cages at randomized points on the 3 major range sites at the beginning of the grazing season. The cages were constructed of number 10, 48-in. woven wire, each covering an area four feet square. Approximately 10 samples were taken each year in each major range site (ordinary upland, limestone breaks, and clay upland) per pasture.

[4] An animal unit in this trial is defined according to Vinall, H. N. & A. T. Semple. Jour. Amer. Soc. Agron. **24**: 836-7. 1932.

Clippings were taken at the close of the growing season within a metal frame 25.04 in. square (1/10,000 acre). One clipping was taken under each cage and another adjacent to it. All the vegetation within the metal square was clipped at a uniform height as near soil level as possible. Unpalatable forbs were separated from the forage in the field in 1954 and 1955 since it had been found by Herbel (1954) that weighing unpalatable forbs with the forage confounded the results. All of the mulch within the metal square was also collected so that there was a sample of forage, unpalatable forbs, and mulch from each sampling area. Each was air-dried and weighed.

EXPERIMENTAL RESULTS

LINE TRANSECT DATA

Perennial grasses have averaged approximately 80% of the basal cover, but only two species, big bluestem and little bluestem, were present in quantities averaging above 10% each. Three species, indiangrass, sideoats grama, and Kentucky bluegrass, each averaged between 5 and 10% of the basal cover. These 5 grass species plus the sedges and rushes were the only ones present in sufficient quantity to permit statistical analysis. Statistical analyses were also calculated for total decreasing species of grasses, total increasing species of grass, total perennial grasses, total perennial forbs, and total vegetation. Total decreasers analyzed as a group in this study included b g bluestem, little bluestem, indiangrass, switchgrass, prairie junegrass, and prairie dropseed (*Sporobolus heterolepis*), while total increasing species of grass included sideoats grama, buffalograss, Kentucky bluegrass, blue grama, hairy grama, purple lovegrass (*Eragrostis spectabilis*), tumblegrass (*Schedonnardus paniculatus*), windmillgrass (*Chloris verticillata*), and sand dropseed (*Sporobolus cryptandrus*), scribner panicum (*Panicum scibnerianum*), and tall dropseed. Total perennial grasses include both groups plus traces of other less abundant ones not reported separately. Annual grasses, annual forbs, and shrubs made up such small portions of the plant cover that they were not analyzed statistically.

Only 3 range sites, ordinary upland, limestone breaks, and clay upland occurred in areas large enough in all 6 pastures to permit adequate sampling for statistical analyses. Since the grazing treatments began in 1949, statistical analyses were computed on the 1950 through 1955 data. The statistical treatment consisted of separate analyses of variance for the 11 species or groups of species for each of the 6 yrs and each of the 3 major range sites. Analyses of variance for each year showed how the species behaved each season under the various treatments. Annual behavior is important in interpreting trends. In addition, trends were calculated for nine of the species or groups of species over the 6-year period in each of the major range sites. Analyses of variance were also calculated for the 11 species or groups of species for each of the 3 sites on the 1947 population sampling data to determine the degree of homogeneity among pastures.

All statistical analyses were calculated on actual numbers of culms or the square centimeter basal coverage of a species or a group of species per 10-m line transect. Thus, any changes or significant differences indicated by the statistical analyses apply directly to changes in density or basal coverage. Since percentage of total vegetation instead of basal cover is commonly used in range condition estimates, a separate study of such percentages is also included for each of the major species and groups of species.

1947 Data. The grazing treatments on all the pastures except pasture 3 began in 1949. Pasture 3 was deferred in 1949 and thereafter grazed season long each year at the light stocking rate. The experimental area had been uniformly grazed as a single large pasture prior to fencing in 1948. An analysis of variance on data taken in 1947 on each of the above mentioned species or groups of species showed that in only 8 of the 33 vegetation-range site combinations were there significant differences.

Natural vegetation usually shows much variability, and some of the important differences found in 1947 remained through several years of sampling. Using least significant differences it was found that before the trials were started ordinary upland had significantly more big bluestem in what became the heavily grazed pasture than in the pastures later stocked moderately. This carried over throughout the sampling period (1950-1955). Similarly, Kentucky bluegrass on ordinary upland in pasture 5 of the deferred group ranked high in most years. The lightly stocked pasture ranked high in sideoats grama in its limestone breaks range site at first but this increaser gradually declined. The clay upland site in the lightly stocked pasture was high in increasing species of grass in most years. Because of its location, animals tended to congregate on this site and to utilize it closely. The other differences noted above did not seem to influence subsequent sampling.

Total Decreasers. In summarizing range plant populations, certain species have been grouped as decreasers because they diminish in abundance under heavy grazing use. Average basal areas of total decreasing species of grasses in square centimeters per 10-m line transect were studied each season on each range site by means of analysis of variance and regression coefficient. Decreasing grasses as a group declined in the three major range sites during the 1950-55 period. Average declines did not differ significantly among grazing treatments except in the limestone breaks site where the moderately stocked pasture had a significantly greater decline than all the other pastures except the lightly stocked one. Some significant differences occurred within certain seasons. For example, the decreasers had become significantly less abundant in ordinary upland, limestone breaks, and clay upland in the heavily stocked pasture, but general declines due to the drought tended to obscure this by 1955. Some-

what similar trends were noted for the moderately stocked pasture, although in the clay upland site striking declines continued in this pasture. In the very shallow site there was a reduction in quantity of total decreasers in all pastures over the six-year period, the overstocked pasture having the smallest number in 1954 and 1955. This group of grasses has also declined on the claypan site.

Relative quantity of decreasers is an important measure of range condition. Percentages of decreasers for the years 1950 through 1955 for all range sites are presented in Table 1. In the ordinary upland range site there has been a relative decline in all pastures, particularly the heavily stocked one. In limestone breaks there has been a marked decline of decreasers in pastures stocked moderately to heavily, a slight increase in the lightly stocked pasture, and no important change in deferred pastures. In clay upland this group of grasses has suffered a sharp percentage decline in the pasture stocked moderately and a slight to moderate decline in the others. The pasture stocked heavily actually showed an increase in the percentage of decreasers in 1955 when compared to 1954 but, as shown later, this resulted from the sharp drop in quantity of Kentucky bluegrass in this site in this pasture. In the very shallow range site there has been wide fluctuation in relative cover of total decreasers, most pastures showing a decrease. These grasses have also declined in the claypan range site.

TABLE 1. Total decreasers. Percentages in the total plant cover for 1950-1955 for all of the range sites.

Range site	Pasture No.	Years					
		1950	1951	1952	1953	1954	1955
Ordinary upland	1	68.9	65.2	60.3	61.4	58.4	56.2
	2	60.3	58.2	55.2	49.5	35.9	29.1
	3	54.6	63.2	59.6	62.2	52.6	53.1
	4	67.8	59.9	54.0	59.4	51.5	45.8
	5	63.4	70.1	60.8	57.8	53.6	44.9
	6	63.5	63.1	64.0	68.7	59.5	42.3
Limestone breaks	1	67.2	67.7	65.0	57.2	51.5	46.4
	2	62.9	51.8	60.8	54.5	51.4	44.6
	3	58.6	55.6	68.9	74.8	74.3	70.2
	4	70.0	61.6	76.1	70.8	69.1	65.4
	5	64.6	70.1	75.0	79.2	71.4	65.9
	6	69.2	69.7	71.2	71.1	69.9	67.1
Clay upland	1	54.7	53.5	42.9	46.4	27.2	13.1
	2	32.1	44.2	42.9	30.3	22.3	29.7
	3	31.8	51.5	46.3	44.3	30.6	21.2
	4	49.3	52.9	52.2	46.0	39.0	21.4
	5	47.9	56.6	54.1	46.7	40.0	26.5
	6	40.9	55.6	55.2	61.1	37.7	40.6
Very shallow	1	....	....	71.0	42.9	50.7	52.5
	2	14.7	30.9	27.2	34.9	19.4	7.9
	3	42.6	46.9	41.0	32.4	18.7	24.3
	4	....	64.5	40.6	38.0	22.1	15.7
	5	77.1	61.2	72.1	61.8	37.2	31.8
	6	....	....	49.6	27.5	40.4	13.3
Claypan	4	18.9	32.9	26.4	19.1	21.8	10.6
	5	....	17.4	15.5	0.9	15.2	10.7

Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

Big Bluestem. This grass has high palatability or grazing preference and is selected by livestock even where other forage is abundant (Weaver & Tomanek 1951). It is the most abundant and most important tall grass in the true prairie. Big bluestem and little bluestem together may constitute 50% or more of the plant cover. Big bluestem fluctuated but little among grazing treatments, although a general decrease in its density occurred. However, some significant difference may be noted. The basal coverage of big bluestem in ordinary upland showed a somewhat significantly greater decrease in the lightly stocked pasture than in the moderately stocked or the deferred-rotation pastures. In the limestone breaks site basal coverage of big bluestem decreased significantly more in the moderately stocked pasture than in the deferred-rotation group. In the clay upland site big bluestem decreased significantly less under light stocking than under any other treatment. Both the limestone breaks and clay upland range sites occupy only small areas in the pasture stocked moderately, mostly near the watering place, and tend, therefore, to be somewhat overutilized. Although the number of transect samples obtained from these two limited sites was deemed insufficient for statistical analysis, it was noted that big bluestem decreased on them.

Expressing the abundance of a species as a percentage of the population gives a measure of its relative importance in that population. In the ordinary upland range site only the overstocked pasture has shown a pronounced decrease in percentage of big bluestem. In the limestone breaks range site decreases occurred only in the season-long, moderately and lightly stocked pastures, the others remaining relatively stable throughout the six-year period. In the clay upland range site big bluestem increased at first, then decreased sharply in all pastures. The percentages fluctuated somewhat in the very shallow range site but generally were lowest in 1955.

Little Bluestem. This mid grass is the most abundant dominant in the true prairie. The average basal coverage of little bluestem by pasture, range site, and year is given in Table 2 together with the results of analyses of variance and regression coefficients.

Little bluestem has tended to decline more sharply than the other decreasers under the combined effects of heavy utilization and drought. This species is not so deep rooted as the tall grass decreasers and thus is affected more readily by severe droughts. It gives the appearance of not being grazed closely after early summer, but cattle actually pull the outer leaves from the bunches and thus use it rather closely. Where it is moderately or closely grazed it will remain palatable throughout the grazing season and will continue to be regularly utilized. When this happens increasers and invaders exert greater and greater competitive pressure. The fact that differences were significant in 10 of the 18 analyses of variance given in Table

TABLE 2. Little bluestem; average basal area in number of sq cm per 10-m line transect by range sites and pastures for the years 1950-1955. Results of statistical analyses are given where applicable.

Range site	Pasture No.	Years						Regression coefficient
		1950	1951	1952	1953	1954	1955	
		cm	cm	cm	cm	cm	cm	
Ordinary upland	1 (a)	83.0	47.2	37.7	48.6	39.8	28.8	−6.39
	2	59.8	38.4	28.3	33.3	18.6	19.5	−6.88
	3	56.8	46.5	43.5	65.1	42.4	32.5	−3.14
	4	80.1	58.7	37.9	65.5	44.2	36.4	−6.21
	5	68.6	52.8	38.0	55.5	45.6	39.6	−3.40
	6	97.3	50.5	51.5	68.6	55.0	33.2	−6.43
	R (c)							−5.23
Anova results	(b)	ns	ns	**	**	**	*	
Limestone breaks	1	42.0	53.0	39.0	39.5	20.5	11.8	−8.98
	2	44.1	25.0	28.6	26.5	30.5	22.3	−1.88
	3	84.9	39.7	48.4	76.9	61.2	38.0	−3.45
	4	97.0	45.3	62.1	67.8	53.5	48.9	−2.34
	5	65.4	62.4	41.9	74.0	64.9	41.8	−0.82
	6	75.1	43.1	50.4	53.8	49.0	40.5	−3.19
	R							−2.17
Anova results		ns	**	**	**	**	**	
Clay upland	1	44.5	32.0	33.0	38.0	14.6	4.9	−6.86
	2	38.0	27.1	27.9	24.2	16.5	18.6	−3.14
	3	44.8	40.2	28.6	41.3	26.3	19.0	−4.96
	4	67.9	38.4	25.2	34.7	30.8	10.9	−6.79
	5	48.3	35.5	37.2	41.8	32.5	17.9	−4.09
	6	51.8	37.2	38.0	52.1	26.9	26.7	−3.77
	R							−4.98
Anova results		ns	ns	ns	ns	ns	**	
Very shallow (d)	1	....	....	31.3	9.7	20.2	19.7	
	2	3.0	11.1	10.2	18.8	4.3	1.4	
	3	64.2	30.9	24.9	28.8	12.0	18.6	
	4	....	39.0	21.7	20.5	11.8	8.2	
	5	62.0	35.0	52.0	50.0	16.0	21.3	
	6	....	....	16.0	5.0	10.4	11.3	
Claypan (e)	4	17.2	19.6	14.1	11.5	13.3	5.5	
	5	....	9.7	8.0	....	12.0	1.0	

(a) Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.
(b) Results of the analysis of variance for each year by major range site, ns indicating non-significance at the 5% level, * indicating significance at the 5% level, and ** indicating significance at the 1% level.
(c) The weighted mean of the regression coefficient for pastures 4, 5, and 6.
(d) This site occurs in only small areas, thus not enough samples were available for statistical analysis.
(e) This site occurs only in two pastures.

2 suggests that little bluestem fluctuates widely in response to the different grazing treatments. There was significantly less little bluestem on ordinary upland in the overstocked pasture than in the others by 1952, and by 1955 it had also fallen off in the other two season-long pastures. It will be noted that the overstocked pasture had approximately the same amount of little bluestem in 1955 as in 1954, but that substantial reductions occurred in the other pastures from 1954 to 1955.

In the limestone breaks site the overstocked and moderately stocked pastures had significantly less little bluestem than the others during the early years of the experiment and by 1954 the differences were highly significant. In clay upland little bluestem declined in all pastures, especially the one stocked at the medium rate, and by 1955 it was significantly lower in that pasture than in all others except pasture 4 of the deferred group. This species has also declined throughout the very shallow and claypan range sites.

The relative abundance of little bluestem was also considered in terms of percent of total vegetation. In the ordinary upland range site it has declined sharply in the overstocked pasture and less sharply in the one stocked moderately. The understocked pasture showed a slight increase in percent of little bluestem, while the pastures in the deferred-rotation group fluctuated somewhat. In the limestone breaks range site this species showed a marked percentage decline in the moderately stocked pasture, a slight decline in the heavily stocked one, and remained at about the same level in the others. In the clay upland site there has been a decline in the percentage of little bluestem in all but two pastures, and there it has remained fairly constant. It has decreased in both the very shallow and claypan sites in all pastures.

Indiangrass. This is a tall, coarse grass with water requirements and growth habits similar to those of big bluestem. Next to big bluestem, it is the most abundant tall grass in the experimental area and is an important forage species.

Regression coefficients on data from the three major range sites indicate that indiangrass has decreased in density in all pastures. Its behaviour in this respect resembled that of big bluestem, but there was somewhat greater variability within years of sampling, although the differences among pastures did not continue over the years. Indiangrass declined in the very shallow and claypan range sites.

The percentage of indiangrass has declined in the ordinary upland range site on all pastures since 1952, the heavily stocked having the smallest percentage in both 1954 and 1955. In the limestone breaks and clay upland sites there has also been a general decline in all pastures, the lightly stocked one having the smallest percentage in limestone breaks and the moderately stocked one in the clay upland site. In the very shallow site it was highest under moderate stocking.

Other Decreasers. Switchgrass, prairie dropseed, and prairie junegrass make up such a small percent of the cover in these pastures that statistical analyses were not attempted. However, some observations are of interest. In ordinary upland switchgrass showed a slight, general increase in density but it exhibited no definite trends in the other range sites.

Prairie junegrass is a cool-season mid grass of widespread occurrence but is rather small in stature and seldom is sufficiently abundant in true prairie to be highly productive. In ordinary upland it showed a decrease, especially in the overstocked pasture. It decreased in limestone breaks to the extent that by 1955 it was encountered in the transect samples on only two of the six pastures. There also has been a decrease in clay upland, very shallow, and claypan sites.

Prairie dropseed is a warm-season, mid grass characteristic of the drier uplands in true prairie.

In ordinary upland and limestone breaks it showed an increase in 1955 over the 2 preceding years but no trends were observed in the clay upland, very shallow, or claypan range sites.

Total Increasers. Major increasing grass species taken together make up a considerable part of the vegetation. Change either in their actual or relative abundance may be considered evidence of change in range condition. The grass species making up this total in the trial pastures are sideoats grama, Kentucky bluegrass, buffalograss, blue grama, hairy grama, tumblegrass, windmillgrass, purple lovegrass, scribner panicum, sand dropseed, and tall dropseed.

In practically every instance grasses of this group had shown an actual decrease prior to the drought, but they increased more or less steadily after the drought began. A study of regression coefficients revealed a sharp rise in the overstocked pasture in the ordinary upland range site. The increase was significantly greater in this pasture than in any of the other pastures, and since 1953 this pasture has had more increasers in ordinary upland than any of the others, although at the outset it contained about the same quantity. In the limestone breaks site of the overstocked and moderately stocked season-long pastures, increasers showed a slight rise in contrast to the rather pronounced declines recorded in the other pastures. By 1954 these 2 pastures had significantly greater populations of increasers than the other pastures, and by 1955 the overstocked pasture was even farther ahead in increasers. In the clay upland range site total increasers showed a significant increase in the moderately stocked pasture, a slight increase in the deferred-rotation group, and an actual decrease under heavy stocking.

Increasers taken as percent of plant cover are summarized by pasture, years, and range sites in Table 3. The most significant change is their sharp percentage rise in ordinary upland under close grazing. The percentage rise in limestone breaks was less marked, while in clay upland there was a relative decrease under close grazing, due largely to a sharp drop in Kentucky bluegrass during drought. The overstocked pasture had had the highest percentage of increasers in 1953 and 1954. In the very shallow range site all pastures except the one stocked moderately showed relative increases, while in the claypan site the percentage of increasers remained about the same.

Sideoats Grama. This probably is the most important increaser in the trial area and is one of the most important ones in the true prairie as a whole. Analysis of variance on each year's data within the three major range sites revealed significant differences among pastures in ordinary upland and limestone breaks for all six years. Differences in clay upland tended to be non-significant.

Since 1952 in the ordinary upland range site there has been significantly more sideoats grama in the overstocked pasture than in any of the others. In the limestone breaks site this pasture has had significantly more sideoats grama than the others since 1953, although the moderately stocked pasture also has been high toward the end of the period.

There was little indication of trend in the density of sideoats grama, although some significant differences were noted in limestone breaks and clay upland. In limestone breaks this species decreased significantly under light grazing while under close, season-long grazing it increased significantly. There was a significantly greater increasing trend in clay upland under moderate and light season-long stocking than under deferred-rotation grazing. In the very shallow range site there was a general decline in 1955 in all pastures. In the claypan site the averages were about the same for 1953 through 1955.

The relative abundance of sideoats grama has also been considered. In ordinary upland there was an increasing percentage difference between the overstocked pasture and the others. In limestone breaks the major differences were that in the heavily stocked pasture sideoats grama has shown a marked relative increase while in the lightly stocked pasture it declined sharply. The moderately stocked and heavily stocked pastures had substantially more sideoats grama than the others in both 1954 and 1955. In clay upland the heavily stocked one had a higher percentage in 1955 than any of the other pastures. In the very shallow site there

TABLE 3. Total increasers; percentages in the total plant population for 1950-1955 for all of the range sites.

Range site	Pasture No.	Years					
		1950	1951	1952	1953	1954	1955
		%	%	%	%	%	%
Ordinary upland	1	17.0	16.4	20.0	18.9	23.5	20.2
	2	25.9	23.4	26.2	33.0	46.7	57.1
	3	31.1	19.5	22.3	19.6	28.9	25.7
	4	21.5	25.7	30.1	23.2	30.1	32.6
	5	26.0	17.6	24.6	29.4	32.8	37.9
	6	26.7	20.4	19.4	15.9	25.0	35.3
Limestone breaks	1	21.3	8.3	19.3	12.4	32.1	21.7
	2	23.9	33.4	21.4	24.4	25.6	37.9
	3	24.8	31.9	17.6	11.0	10.2	12.3
	4	18.0	25.2	8.7	14.1	15.6	18.2
	5	25.1	16.7	11.3	7.0	13.5	16.9
	6	17.8	16.0	10.5	8.6	12.5	13.3
Clay upland	1	30.2	28.7	41.4	34.9	59.3	67.0
	2	54.2	42.6	39.4	48.2	64.1	48.7
	3	58.3	33.5	38.7	37.7	56.8	65.4
	4	41.1	34.1	31.2	30.9	44.8	51.3
	5	41.6	31.4	30.2	40.7	48.6	55.1
	6	49.8	28.0	27.1	23.0	49.9	34.3
Very shallow	1	....	....	18.3	34.9	37.5	15.3
	2	77.1	57.6	64.8	43.5	72.7	82.1
	3	47.7	44.2	46.3	43.0	71.9	63.2
	4	....	22.4	42.4	46.5	66.6	54.8
	5	5.7	29.8	14.0	28.4	45.5	51.1
	6	....	....	34.0	39.9	39.2	74.5
Claypan	4	68.9	53.1	51.3	41.2	55.6	60.1
	5	....	67.4	60.6	80.2	75.9	67.8

Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

has been a decline in sideoats grama in all pastures, but in claypan the percentage has remained virtually unchanged. This species may actually behave as a decreaser in these rather difficult, preclimax sites.

Kentucky Bluegrass. This exotic species has become more or less naturalized and, while it actually is an invader, it behaves generally as an increaser except in periods of prolonged drought when it may virtually disappear under close use.

Kentucky bluegrass does not occur in as large amounts on the limestone breaks site, but in both ordinary upland and clay upland it showed a substantial decline in 1955 because of the drought. The regression coefficients indicate that in most pastures the density remained about the same. In ordinary upland Kentucky bluegrass increased significantly more in the overstocked pasture than in the moderately stocked pasture and the pastures in the deferred-rotation group. In limestone breaks it increased significantly more in the overstocked pasture than in the deferred pastures. In clay upland heavy grazing seemed to favor it until the drought caused it to decline sharply. An outstanding feature in the very shallow site was the large increase of this species in the heavily stocked pasture. In the claypan range site there has been a sharp reduction in the amount of Kentucky bluegrass.

In ordinary upland the percentage of Kentucky bluegrass in the total plant population declined in all pastures from 1954 to 1955. In limestone breaks it showed a decided increase only in the pastures stocked moderately and heavily. In clay upland it increased in these pastures up to 1954, but in 1955 it declined sharply in the latter.

Other Increasers. Buffalograss, blue grama, hairy grama, tumblegrass, windmillgrass, purple lovegrass, scribner panicum, sand dropseed, and tall dropseed occurred in such small amounts in most of the pastures and range sites that statistical analyses were not attempted. The short grasses, buffalograss, blue and hairy grama, tumblegrass, and windmillgrass are actually invaders on climax and postclimax sites in this area, and while they are not abundant on these sites, they sometimes become abundant on the preclimax sites, clay upland, very shallow, and claypan.

The stoloniferous shortgrass, buffalograss, spreads readily when taller competitors are reduced by range depletion. It is especially abundant on drier sites. It has shown some increase in ordinary upland, especially in the overstocked pasture. Only small amounts of buffalograss occur in limestone breaks. In the clay upland, very shallow, and claypan range sites this grass has shown a general though variable increase.

Blue grama is a short bunch grass that occurs sparingly in undisturbed true prairie and usually only in the driest situations where mid grasses do not grow abundantly enough to produce a dense shade. In this study it was present in only small amounts in ordinary upland and limestone breaks, but was relatively more abundant in the preclimax sites.

Hairy grama, a short grass, usually is abundant only on thin droughty soils and rocky outcrops. It has increased in this trial on ordinary upland and limestone breaks sites, but no definite trend has been established in clay upland.

Tumblegrass and windmillgrass are sparingly distributed in the prairie. There was an increase of windmillgrass in the overstocked pasture in the limestone breaks and very shallow sites but no trends were detected in the other sites and pastures.

Purple lovegrass also is sparsely distributed and did not show trends in the small amounts present. Scribner panicum is a low growing, rosette forming perennial that grows between the tufts and bunches of other grasses. Only small amounts of this grass were present in all the sites and trends were not observed.

Sand dropseed is a mid grass that increases readily under droughty conditions. In ordinary upland it increased in the overstocked pasture. In clay upland there was a substantial increase in the moderately and lightly stocked pastures in 1955, while in the very shallow site there was an increase in the lightly stocked pasture in 1955.

Tall dropseed is a drought resistant perennial bunch grass that normally forms only a small part of the vegetation. There was some fluctuation in the amounts present in the experimental area but no trends have developed.

Total Perennial Grasses. Perennial grasses, which constitute the bulk of the plant cover in true prairie, have decreased in abundance on all range sites during the dry years since 1951.

In the ordinary upland site perennial grasses decreased significantly less in the overstocked pasture than in the others and in limestone breaks significantly less in this pasture than in all except the moderately stocked one. In the clay upland site they decreased significantly more in the deferred-rotation pastures than in pastures stocked moderately and lightly. Although some significant differences were found in the three major range sites within years, no one pasture or group of pastures was consistently different from any of the others.

The relative amount of perennial grass in the total plant cover is of some importance. In the ordinary upland and limestone breaks sites all pastures except the overstocked one showed a decline in the percentage of perennial grasses in 1955, and in clay upland all pastures declined in percentage of perennial grasses in the drought year of 1955, the lightly stocked pasture showing the smallest decline. In the very shallow and claypan range sites there has been considerable fluctuation but no very definite trends.

Sedges and Rushes. These are cool season species, resuming spring growth several weeks ahead of the bluestem. Sedges (*Carex* spp.), rush (*Juncus interior*), and spikesedge (*Eleocharis tenuis*) have been grouped together in this study.

The sedges and rushes have shown considerable stability regardless of treatment in all pastures, the only clear cut difference occurring in limestone breaks

where the moderately stocked pasture had significantly more sedges and rushes than any other pasture in 1953 and 1955. There have been percentage declines in both ordinary upland and limestone breaks in 1955. In the very shallow site the moderately stocked pasture showed an increase and deferred grazing a decrease. In claypan, the sedges and rushes have decreased somewhat in pasture 4 of the deferred group.

Annual Grasses. All annuals are invaders in true prairie, their presence in any considerable amount being evidence of decline in range conditions. Of the 14 annual grasses occurring on the experimental area, those most frequently encountered in the sampling were little barley, sixweeks fescue, and annual brome. None of the treatments has as yet caused the invasion of any substantial amounts of annual grasses.

Perennial Forbs. Certain perennial forbs are naturally present in true prairie. Some are relished by stock and decrease under grazing, others increase, and still others stand ready to invade if depletion should occur. The major forbs detected in the sampling thus far are western ragweed, prairie catspaw (*Antennaria campestris*), sagewort (*Artemisia ludoviciana*), heath aster (*Aster ericoides*), goldenrod (*Solidago* spp.), wooly verain, and baldwin ironweed. Smaller amounts of some 80 other perennial forbs were also found.

Differences in numbers of perennial forbs among pastures generally were not statistically significant and did not appear to display any consistent change that might be interpreted as trends. A striking difference in aspect was noted in the over-grazed pasture in the later years of the trial. Baldwin ironweed and buckbrush (*Symphoricarpos orbiculatus*) were much in evidence in this pasture on the limestone breaks and ordinary upland range sites. This difference is illustrated in Fig. 3.

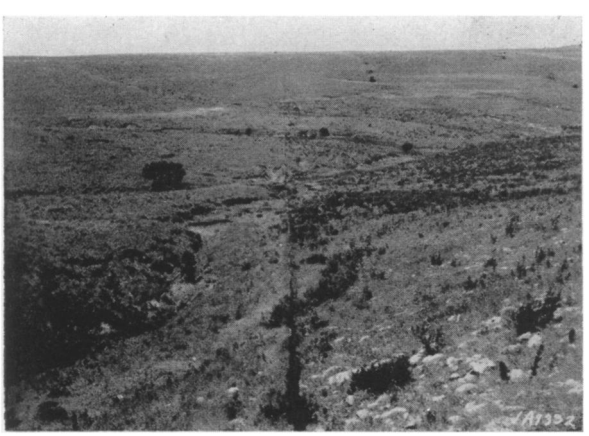

FIG. 3. Contrast in nature of the cover on pasture 2 (heavy stocking) on the right and pasture 3 (light stocking) on the left. Photo taken in mid July, 1954, the sixth year of treatment.

The percentage of perennial forbs for 1950 through 1955 for the 5 range sites was also observed. In ordinary upland this percentage remained about the same in the moderately stocked pasture while showing an increase in the others. This percentage increase is due to actual reductions in number of grass plants. Similar trends occurred in limestone breaks, but no striking changes occurred in the other sites.

Annual and Biennial Forbs. All of the plants included in this group are invading weeds in the prairie. Some of the most prominent in the experimental area are wavyleaf thistle, curlycup gumweed, croton (*Croton monanthogynus*), Carolina draba (*Draba reptans*), daisy fleabane (*Erigeron ramosus*), snow-on-the-mountain euphorbia (*Euphorbia marginata*), rough falsepennyroyal (*Hedeoma hispida*), wooly plantain (*Plantago purshii*), and johnyjumpup (*Viola rafinesquii*). Many others are present in smaller quantities, but taken as a group they have not occurred in significant amounts in the trial area.

Woody Plants. Small amounts of shrubs and half-shrubs are present naturally in unmowed prairie. Some, like inland ceanothus (*Ceanothus ovatus*) and leadplant amorpha (*Amorpha canescens*), are useful browse plants. Others are weedy in habit and may increase sharply under abusive grazing. The woody plants detected by the sampling include leadplant amorpha, inland ceanothus, nipple cactus (*Mamillaria* sp.), smooth sumac (*Rhus glabra*), prairie rose (*Rosa suffulta*), and buckbrush. A few other woody species are found primarily in the draws. There did not appear to be any striking differences among pastures or years in the small amounts present.

Total Plant Cover. Density of plants fluctuates with changes in precipitation as it expresses variation in amount of growth resulting from variations in moisture supply. There also may be a tendency toward denser cover under the same weather conditions when plant composition shifts under grazing pressure from tall dominants to short, spreading grasses.

Overstocking caused a smaller decrease in total plant density in the major range sites than did the lighter stocking treatments (Table 4). A study of the regression coefficients shown in Table 4 indicates that in ordinary upland the total plant cover decreased significantly more in pastures stocked moderately and lightly than in the one stocked heavily. In limestone breaks the latter declined significantly less in plant density than all of the other pastures. In clay upland the pastures in the deferred-rotation system showed a significant decreasing trend in plant cover. There was, however, a change in species composition from the tall climax grasses to the short spreading species in the overstocked pastures. There was no definite pattern in the differences among pastures within years. In both the very shallow and claypan range sites there has been some yearly fluctuation, but no trend.

CLIPPING DATA

Forage production on native range may vary widely under natural conditions even in climax. Clippings were taken on the three major range sites in 1953, 1954, and 1955. In 1953 limestone breaks and

TABLE 4. Total plant population; average basal area in number of sq cm per 10-m line transect by range sites and pastures for the years 1950-1955. Results of statistical analyses are given where applicable.

Range site	Pasture No.	Years						Regression coefficient
		1950	1951	1952	1953	1954	1955	
		cm	cm	cm	cm	cm	cm	
Ordinary upland	1 (a)	212.8	147.8	139.5	147.7	136.0	99.2	−14.23
	2	201.0	148.6	151.0	149.6	153.2	161.4	− 3.93
	3	217.7	153.9	158.8	161.8	145.0	105.5	−13.91
	4	213.9	170.6	151.7	176.6	162.1	135.8	− 9.94
	5	213.2	144.3	163.3	156.2	157.8	136.1	− 6.56
	6	235.1	163.5	163.4	155.2	150.5	138.2	−11.76
	R (c)							− 9.25
Anova results	(b)	ns	*	ns	ns	*	**	
Limestone breaks	1	183.0	152.4	115.0	115.0	118.0	102.5	−12.27
	2	168.3	132.8	131.0	119.4	134.6	117.7	− 2.59
	3	216.3	145.7	159.0	152.2	142.1	94.1	−15.77
	4	220.0	141.2	152.0	155.4	134.7	120.2	− 9.33
	5	202.5	153.3	116.3	142.6	144.5	109.8	−10.84
	6	187.7	135.2	151.2	138.3	133.7	103.4	−11.22
	R							−10.68
Anova results		ns	ns	**	*	ns	ns	
Clay upland	1	182.0	144.9	154.5	180.3	172.5	154.0	1.22
	2	256.5	155.3	166.1	168.4	184.5	139.5	− 5.56
	3	258.3	161.1	162.7	170.8	175.5	182.0	− 4.14
	4	231.7	159.1	130.3	160.3	165.5	148.9	− 5.48
	5	212.0	157.4	165.4	161.7	179.6	143.0	− 4.70
	6	240.4	163.0	162.7	156.2	154.0	127.6	−14.16
	R							− 8.09
Anova results		**	ns	ns	ns	ns	ns	
Very shallow (d)	1	.....	.....	93.0	79.3	95.4	87.0	
	2	227.0	141.6	129.6	119.1	142.9	161.0	
	3	256.1	136.5	106.7	148.7	155.1	165.1	
	4	.....	107.0	162.7	106.4	134.0	142.4	
	5	140.0	131.8	129.0	148.0	130.2	154.0	
	6	.....	.....	116.0	89.0	98.0	172.3	
Claypan (e)	4	230.0	165.1	166.3	191.1	182.9	198.4	
	5	.....	128.0	213.0	328.0	187.8	145.0	

(a) Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.
(b) Results of the analysis of variance for each year and major range site, ns indicating non-significance at the 5% level, *indicating significance at the 5% level, and **indicating significance at the 1% level.
(c) The weighted mean of the regression coefficient for pastures 4, 5, and 6.
(d) This site occurs in only small areas, thus not enough samples are available for statistical analysis.
(e) This site occurs in only two pastures.

ordinary upland were not treated separately but were sampled as one unit. In 1953 both total amount of the top growth and mulch were sampled. After studying the samples taken in 1953 it was felt that the amounts of forbs not grazed might bias the utilization estimates, so the relatively unpalatable forbs were thereafter separated from the forage. Thus in 1954 and 1955 each sample was taken in three parts, forage, weeds, and mulch. At the beginning of the 1955 grazing season cages were placed at randomized locations on the three major sites in each pasture so that utilization estimates could be corrected for differences, if any, in quantity of forage produced.

1953 Data. Clippings in 1953 emphasized the close use observed in the overstocked pasture and in the pasture deferred that year.

Differences in mulch were not clear cut, but in ordinary upland and limestone breaks the pastures grazed season long had only a little more than 70% as much mulch as the pastures in the deferred-rotation group. In clay upland differences were less pronounced.

1954 Data. Again the overstocked pasture and the deferred one had the smallest forage residues in both ordinary upland and limestone breaks (Table 5),

TABLE 5. The average amounts of forage, weeds, and mulch in lbs per acre remaining at the close of the 1954 grazing season. Significant differences are shown where applicable. The means are based on an unequal number of samples.

Past.	Ordinary upland	Past.	Limestone breaks	Past.	Clay upland
	lbs per acre		lbs per acre		lbs per acre
Forage					
2	1089	2	655	2	454
5	1338 *	1	780	1	571
4	1728 *	5	1475*	3	798
6	1878	4	1806*	4	1305*
1	1964 *	3	1876	5	1396
3	2145	6	2105	6	1667
Weeds					
4	90	5	119	4	117
5	150	3	152	3	139
1	209	6	161	2	163
2	227 ns	4	183 ns	5	181 ns
6	227	2	225	1	205
3	243	1	284	6	209
Mulch					
2	930	2	597	2	520
4	1199	1	820	3	1058 *
1	1754*	3	1854*	1	1254
6	2200	4	2101	4	1287
5	2403	6	2379	6	1391
3	2443	5	2568	5	1515

ns indicates non-significance at the 5% level and * indicates significance at the 5% level.
Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

indicating close removal by livestock. In clay upland, the pastures in the deferred-rotation group had significantly greater amounts of forage cover at the close of the season than those grazed season long, but there were no significant differences in the amount of weeds. The heavily stocked pasture, as was expected, had the smallest quantity of mulch in the three sites sampled, but on the pasture deferred in 1954 the quantity of mulch was low in ordinary upland and in the moderately stocked pasture it was low in limestone breaks.

1955 Data. Wire cages, each covering an area of 4 by 4 ft., were placed at randomized locations on the 3 major range sites in each of the 6 pastures at the beginning of the 1955 grazing season. This made it possible to obtain estimates of differences in production resulting from previous treatment and thereby to correct the 1955 clipping samples of grazed areas. Thus a more accurate estimate of utilization was obtained from the yields taken at the close of the grazing season (Table 6).

The total quantity of forage produced during the growing season in 1955 was substantially smaller in closely grazed areas as the result of a reduction in the

TABLE 6. Forage production in lbs per acre for the 1955 growing season on the 3 major range sites for all 6 pastures. Significant differences are shown where applicable. The means are based on an unequal number of samples.

Past.	Ordinary uplands	Past.	Limestone breaks	Past.	Clay uplands
	lbs		lbs		lbs
2	1318	1	1499	2	505
1	1749*	2	1528	3	968*
5	1836	3	1916*	1	1116
6	1887	5	1947	4	1259
3	2080	4	1958	5	1358
4	2132	6	2083	6	1422
Av.	1834	Av.	1822	Av.	1105

* Indicates significance at the 5% level.
Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

vigor of overgrazed plants. This was reported by Weaver (1950) to result also in a reduction in root growth, forcing plants to be more reliant on surface moisture. In comparisons of the average production per range site, it was found that ordinary upland and limestone breaks produced over 50% more forage than clay upland.

Estimates of the average amounts of forage removed during the grazing season were obtained by correcting the differences between grazed and ungrazed (caged) samples by analyses of covariance for the significant differences found in the ungrazed samples (Table 7). These analyses related grazing use to stocking and to site.

TABLE 7. Average amount of forage removed in lbs per acre for the 6 pastures and the 3 major range sites in 1955. Significant differences are shown where applicable. Means are based on an unequal number of samples.

Past.	Forage removed on the 3 major range sites		Site	Forage removed on the 6 pastures
	lbs			lbs
3	390		Limestone breaks	459
6	503	*	Ordinary upland	741*
4	712	*	Clay upland	816
1	752			
2	833			
5	842			

* Indicates significance at the 5% level.
Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

The limestone breaks range site showed significantly lighter utilization than the other two major range sites (Table 8).

Comparisons of beef production[5] and clipping yields were then made on 1955 data (Table 8). When the estimates of forage removal are compared with the beef production per acre it may be observed that there is a close relationship and that beef production

[5] Beef gain data were supplied by Professor Ed. F. Smith, Department of Animal Husbandry, Kansas State College.

TABLE 8. The average beef production in lbs per acre for the 1955 grazing season for the 4 grazing treatments.

Pasture	Beef production per acre (lbs)
3	33.8
R	42.5
1	54.0
2	63.4

Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and R is the average of the pastures in the deferred-rotation system.

and forage removal fall in the same order. The average amount of forage removed on the deferred-rotation pastures was 686 lbs per acre over the 3 major range sites.

The percentage utilization for 1955 (Table 9) was calculated as follows:

$$\frac{\text{forage under the cages} - \text{forage outside the cages}}{\text{forage under the cages}}$$

TABLE 9. Utilization percentage for the 1955 grazing season by pasture and range site.

Pasture	Ordinary upland	Limestone breaks	Clay upland	Ave
	%	%	%	%
1	44	30	82	52
2	60	45	69	58
3	30	3	53	29
4	54	25	56	45
5	60	44	49	51
6	34	34	30	33
R	49	34	45	43

Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 (R) grazed in a deferred-rotation system.

The percentage utilization on the pastures in the deferred-rotation group in 1955 was lower than that on the moderately stocked, season-long pasture, despite the fact that they have been stocked at the same average rate (Table 9). The lightly stocked pasture had an average utilization only half as great as that of the heavily stocked pasture. This is in agreement with the acreage allowances per animal unit. In all of the pastures grazed season-long the utilization is greater on clay upland than on ordinary upland. Limestone breaks tend generally to show the lightest utilization.

Pasture 6 of the deferred-rotation group had a significantly greater yield of unpalatable forbs than any of the other pastures as indicated by samples from the cages. The reason for this is not clear, but the 1955 line transect data had already shown that this pasture had a larger number of perennial forbs.

Pasture 5, also of the deferred-rotation group, actually had a lower yield of weeds in the sample areas protected by cages than in the grazed areas outside the cages, indicating little or no use of weeds under this degree of use. The heavily stocked pasture showed the largest amount of weed removal.

There was no significant difference in the utilization of weeds among the three major range sites.

An important factor in preventing excessive water loss by runoff and evaporation from prairie soil is the protective cover of mulch. Mulch cover has been greatly reduced by close use (Table 10), the heavily stocked pasture exhibiting considerable depletion of the mulch cover. Clay upland had significantly less mulch than the other two major range sites over all six pastures. This site is less productive and more closely utilized than the others, and both factors contribute to the smaller quantity of mulch found there.

TABLE 10. Mulch; the average in lbs per acre found at the close of the 1955 growing season on the 3 major range sites for all 6 pastures. Significant differences are shown where applicable. The means are based on an unequal number of samples.

Past.	Mulch		Range site	Mulch
	lbs			lbs
2	734		Clay upland	1091
4	1252*		Limestone breaks	1550*
1	1435		Ordinary upland	1693
6	1612	*		
5	1744	*		
3	1900			

* Indicates significance at the 5% level.
Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed in a deferred-rotation system.

CONCLUSIONS

The goal of range research is to obtain information or to develop techniques that will make it possible to produce maximum, sustained range livestock yields consistent with the maintenance of the forage resource. This study has been concerned with the effects of four grazing treatments on botanical composition, plant density, and herbage and residue yields of true prairie range. Species composition is the most use useful criterion by which to estimate range condition and, over a period of years, to detect trend in range condition. Plant density is closely related to weather cycles and other factors which affect the microclimate. Herbage yield comparisons are important in obtaining relative utilization estimates.

Two major factors have influenced the changes in species composition observed in these trials, (1) the grazing treatments and (2) the changing weather cycle from abundant moisture prior to mid 1951 to drought conditions that prevailed since that time. The effect of drought and grazing pressure may not always be easily distinguished, but trends under light stocking and deferred-rotation grazing have furnished some evidence of the influence of drought alone, while trends in the moderately and heavily stocked pastures have shown how drought accentuates the harmful effects of close grazing.

There was an abnormal amount of precipitation in 1951, particularly in May, June, and July, and this had been preceded by 4 yrs of approximately average precipitation. Unusually dry periods occurred in 1952 and 1953, particularly in June and July, and there was a moisture deficit of approximately 6.5 in. in 1954. In 1955 there was not enough early season moisture to compensate for the previous years of drought.

The concept of "climax for the site" deals with the equilibrium of plant composition for any given range site as determined by the combined physical factors of the environment. This equilibrium is considered to represent the potential maximum that the combination of environmental factors will support and, therefore, climax for a range site is not necessarily the climatic climax of the region. However, certain range sites such as ordinary uplands do support the regional climax. An earlier study of the experimental area by Anderson & Fly (1955) revealed six distinct vegetation-soil units termed range sites. In the present study sufficiently large areas of only 3 range sites, ordinary upland, limestone breaks, and clay upland, occurred in all pastures to permit adequate sampling for statistical analyses. However, a few samples were also taken in most years in the very shallow and claypan range sites in the pastures where these sites occurred. Thus it was possible to make some observation on these range sites. The sixth site, lowland, was not sampled because of the great amount of variation due to its gullied condition.

Since the grazing treatments had been started in 1949, line transect data for 1950 through 1955 were used to study the effects of the grazing treatments on botanical composition. The 1947 data were also analyzed to study the degree of homogeneity prior to differential grazing.

The overstocked pastures showed a steady decline in percent of total decreasers in all sites except clay upland where, as a result of the sharp decline in Kentucky bluegrass under drought stress, there actually occurred a slight increase in the percentage of decreasing species of grass in 1955. In the limestone breaks and clay upland range sites there was a great decline of decreasers in the moderately stocked pasture because of the overgrazing of these two sites. Although there was a pronounced decreasing trend in the density of decreasers in all pastures, there were only small changes in the percent of plant population except under heavy grazing use. Little bluestem, a mid grass decreaser, has declined more sharply than the other decreasers under the combined effects of heavy utilization and drought. The percentage of big bluestem has not declined in most pastures, while indiangrass showed a decreasing trend because of the drought.

In contrast to that of the decreasers, both the density and the percentage of increasing species showed a marked increase under close grazing, with the exception that a decrease occurred in 1955 in the heavily stocked pasture. There also was a large increase in the lightly stocked pasture in the clay upland range site because cattle tended to congregate on about two-thirds of this site and graze it rather closely.

The species responsible for the greater part of the change in total increasers have been sideoats grama, buffalograss, and blue grama. Sideoats grama, a mid grass that is tolerant to both overgrazing and drought, showed a marked increase due to overgrazing in both the ordinary upland and limestone breaks range sites. Buffalograss showed a substantial increase on overgrazed ordinary upland. On clay upland there was an increase of both buffalograss and blue grama in pastures moderately and lightly stocked but a decline in the heavily stocked pasture. This would seem on the surface to indicate that the increasing species of grasses have reached a point in deterioration under close use where they too have started to decrease and now are being replaced by invaders. In this case, however, much of the loss of increasers in clay upland were due to the killing of Kentucky bluegrass under close grazing. This ruderal has become more or less naturalized and behaves as an increaser in periods of favorable moisture, but its lack of drought resistance causes it to die out during drought, especially under close use, and thus gives it the appearance of a decreaser. This decline in a species which normally is treated as an increaser, has resulted in a percentage or relative increase of true decreasers when there was no actual increase in their basal cover.

Weaver & Albertson (1939) reported that in the great drought of the 1930's little bluestem, Kentucky bluegrass, and indiangrass were the first species to be affected. The same trends have been observed in these trials. However, they have not yet become so pronounced as those reported by Weaver and Albertson even though the deficit in precipitation has been about as great in the present drought. Higher temperatures accompanied the drought of the 1930's while the drought of the mid 1950's, on the other hand, was preceded by a period of abnormally heavy precipitation.

The percentage of climax or original vegetation is the sum of all decreasers present plus the amounts of increasers normally present in the climax. This value is a quantitative expression of range condition (Dyksterhuis 1949). Table 11 gives an estimate of range condition based only on the perennial grasses for 1950 and 1955 for the 6 pastures on the three major range sites. These figures are quite conservative, therefore, since forbs and sedges were not included.

Heavy grazing has caused a marked reduction in the percentage of climax grasses in ordinary upland. There also has been a reduction, although less marked, under moderate grazing and deferred-rotation grazing. The drought appears to be responsible for this later effect since even moderate stocking under normal conditions is likely to behave as overstocking in dry years. The climax vegetation remained virtually unchanged under light stocking on ordinary upland. There has been a decline in range condition in limestone breaks in pastures stocked both heavily and moderately, while the pastures in the deferred-rotation group have remained virtually unchanged and the lightly stocked pasture has shown an improvement in range condition.

TABLE 11. Range condition percentage based on the percentage of perennial grasses in the climax vegetation for 1950 and 1955.

Site	Pasture	1950	1955
Ordinary upland	1	75	63
	2	67	36
	3	69	59
	4	74	53
	5	68	51
	6	68	52
Limestone breaks	1	73	53
	2	69	52
	3	64	75
	4	76	71
	5	75	76
	6	79	73
Clay upland	1	69	40
	2	55	54
	3	62	50
	4	77	50
	5	68	71
	6	60	62

Pasture 1 moderately stocked, pasture 2 heavily stocked, pasture 3 lightly stocked, and pastures 4, 5, and 6 grazed at an average stocking rate equivalent to that of moderate stocking but in a deferred-rotation system.

That density is not a good indicator of range condition is indicated by the great relative decrease of total cover in the pastures with the highest range conditions. This is due to the fact that the mid and tall grass dominants have a smaller basal coverage than the less productive short grass increasers. Clippings made at the close of the 1953, 1954, and 1955 growing seasons gave added evidence that heavy stocking is detrimental. The sampling in 1953 and 1954 was on grazed areas only and showed that the utilization was high in the major range sites under heavy stocking and in limestone breaks and clay upland in the pasture stocked moderately. Placing cages in the 3 major range sites on all 6 pastures at the beginning of the 1955 grazing season made it possible to obtain estimates of total ungrazed forage production for the year.

Clipping data in 1955 revealed that over all the pastures, limestone breaks showed only 62% as great a degree of utilization as ordinary upland. This may be taken to indicate that in pastures having steep slopes along with gently rolling uplands the proper degree of use for the steep slopes would be only about 30 to 35% rather than the customary 50%. Heavier utilization than this on the steep slopes would lead to overutilization of the less steep parts of a range pasture. It also is quite likely that the extra residue accumulated under light use is required on the steeper slopes to control runoff and soil loss.

Another important finding was that the clay upland range site produced only 60% as much forage as the ordinary upland and limestone breaks sites in 1955. Therefore, in estimating safe stocking rates for this preclimax site it may be appropriate to use

grazing values from the rainfall belt of 10 in. below the average for climax sites instead of 5 in. below as suggested by Dyksterhuis (1949) and outlined in the Soil Conservation Service Technicians Guides for the Flint Hills.

Utilization of weeds in 1955 was greater in the overstocked pasture than in the others despite the fact that this pasture included a greater amount of the less palatable increasing and invading species. Cattle on this pasture apparently were forced to graze those less palatable ones because of a reduction in amount of readily available forage.

Underutilization, as in the lightly stocked pasture, resulted in a significantly larger accumulation of mulch than did moderate use. Experiments by Weaver & Fitzpatrick (1934) showed that heavy accumulations of debris may greatly retard growth in spring. This retardation of plant growth in early spring is considered by Flint Hills ranchers to be a hindrance in grazing management where rapid early season gains are desired. Weaver & Rowland (1952) reported that a dense mulch also resulted in sparser stands of the dominants and lower yields from them. In these trials the plant density has been greatly reduced under light stocking but forage yields have remained unaffected.

Continuous overutilization of forage resulted in a significantly smaller amount of mulch. Reduction in amount of soil-protecting mulches leads to increased water losses by runoff and perhaps also to increased surface evaporation. Excessive moisture losses contribute to reductions in plant vigor and the subsequent establishment of the less productive, drought resisting species. Thus droughtier soil conditions can be brought about by overgrazing alone. This appears to have occurred in the overstocked pasture. A continuation of overgrazing will result in still droughtier conditions with an increase in unpalatable weeds and short-lived annual plants which can take advantage of the rainfall shortly after it occurs. Meanwhile the vegetation and mulch become more sparse until there is more and more bare ground. This may allow severe erosion. At any point in this chain of events, a subsere may be initiated simply by reducing the grazing pressure. Thus under proper stocking and with average precipitation climax vegetation may be eventually restored, the length of time required depending upon the degree of depletion and the seral stage.

SUMMARY

An experimental area was set aside in 1949 to evaluate the response of true prairie vegetation on major Flint Hills range sites to grazing treatment. The grazing treatments compared were heavy, moderate, and light season-long stocking and deferred-rotation stocking at the moderate rate. The results are reported in terms of vegetational responses by range sites. Major emphasis is on species composition and on trends which develop under the different intensities and methods of utilization. Herbage and mulch yields also were studied.

The major factors influencing the changes in plant composition in the trials were the grazing treatments and the changing weather cycle from abundant moisture prior to mid 1951 to drought conditions that prevailed through 1955. However, major differences may be separated. Heavy stocking caused a steady decline in percent of total decreasing species of grasses in all range sites except clay upland. Little bluestem has declined more sharply than the other decreasers under the combined effects of heavy utilization and drought. In clay upland there was a slight increase in the percentage of decreasers in 1955 due largely to the sharp decline in Kentucky bluegrass. In the limestone breaks and clay upland range sites there was a significant decline of decreasers in the moderately stocked pasture because these sites are located near the source of stock water in this pasture and would be overgrazed even under light stocking. The percentage of increasing species of grasses showed a marked rise under close grazing except in 1955. The species most responsible for the change in increasers are sideoats grama, buffalograss, and blue grama.

Uneven distribution of grazing use has resulted in overgrazing of small areas in both the moderately and lightly stocked pastures.

Six years of overgrazing resulted in a decrease in amount of forage produced due to the reduction in vigor of the range plants and a shift to less productive preclimax species.

Moderate season-long stocking resulted in closer use of the forage than occurred under deferred-rotation stocking at the same average stocking rate.

Proper degree of forage use on the limestone breaks range site was suggested as being 30 to 35% rather than the 50% customary on gentler slopes if overgrazing of the latter is to be avoided.

Clay upland produced only 60% as much forage as ordinary upland and limestone breaks. This must be taken into account when calculating stocking rates for areas including such droughty, preclimax sites.

Plant density has been greatly reduced under light stocking, but the forage yields have remained unaffected. The large amount of mulch that accumulated on understocked ordinary upland and limestone breaks sites has tended to encourage excessive utilization of clay upland where the mid and short grasses prevail and where the mulch accumulation was much smaller.

Continuous overutilization of forage resulted in significantly reduced amounts of mulch. This will permit increased loss of water by runoff.

These results suggest that for sustained maximum forage production, range management based on range condition classification is essential.

LITERATURE CITED

Ahlgren, H. L. 1947. A comparison of methods used in evaluating the results of pasture research. Agron. Jour. 39: 240-259.

Aldous, A. E. 1938. Management of Kansas bluestem pastures. Jour. Amer. Soc. Agron. 30: 244-253.

Anderson, K. L. 1940. Deferred grazing of bluestem pastures. Kans. Agr. Expt. Sta. Bull. 291.

———. 1942. A comparison of line transects and permanent quadrats in evaluating composition and density of pasture vegetation of tall prairie grass type. Agron. Jour. **34**: 805-822.

———. 1951. The effects of grazing management and site conditions on Flint Hills bluestem pastures in Kansas. Unpublished Ph.D. thesis, University of Nebraska, Lincoln, Nebraska.

Anderson, K. L. & C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. Jour. Range Mgt. **8**: 163-169.

Brinegar, T. E. & F. D. Keim. 1942. The relations of vegetative composition and cattle grazing on Nebraska range land. Nebr. Agr. Expt. Sta. Res. Bull. **123**.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Jour. Forestry **39**: 388-394.

Craddock, G. W. & C. L. Forsling. 1938. The influence of climate and grazing on spring-fall sheep range in southern Idaho. U. S. Dept. Agr. Tech. Bull. **600**.

Dyksterhuis, E. J. 1949. Condition and management of range land based on quantitative ecology. Jour. Range Mgt. **2**: 104-115.

Fly, C. L. 1946. Natural agricultural resource areas of Kansas. Soil Conservation in Kansas. Kans. State Bd. Agr. Rpt. **65**: 126-195.

Hanson, H. C. 1950. Ecology of the grassland. II. Bot. Rev. **16**: 283-360.

Hanson, H. C., L. D. Love & M. S. Morris. 1931. Effects of different systems of grazing by cattle upon a western wheat-grass type of range near Fort Collins, Colorado. Colo. Agr. Expt. Sta. Bull. **377**.

Herbel, C. H. 1954. The effects of date of burning on native Flint Hills range land. Unpublished M.S. thesis, Kansas State College, Manhattan, Kansas.

Nelson, E. W. 1934. The influence of precipitation and grazing upon black grama grass range. U.S. Dept. Agr. Tech. Bull. **409**.

Nevens, W. B. 1945. A comparison of sampling procedures in making pasture yield determinations. Jour. Dairy Sci. **28**: 171-185.

Parker, K. W. & D. A. Savage. 1944. Reliability of the line interception method in measuring vegetation on the Southern Great Plains. Agron. Jour. **36**: 97-110.

Sarvis, J. T. 1923. Effects of different systems and intensities of grazing upon the native vegetation at the Northern Great Plains Field Station. U.S. Dept. Agr. Bull. **1170**.

Savage, D. A. 1937. Drought survival of native grass species in the central and southern Great Plains, 1935. U.S. Dept. Agr. Tech. Bull. **549**.

Smith, C. C. 1940. The effect of overgrazing and erosion upon the biota of the mixed-grass prairie of Oklahoma. Ecology **21**: 381-397.

Stoddart, L. A. & A. D. Smith. 1943. Range Management. New York: McGraw-Hill Book Co. 547 pp.

Weaver, J. E. 1950. Effects of different intensities of grazing on depth and quantity of roots of grasses. Jour. Range Mgt. **2**: 100-113.

———. 1954. North American Prairie. Johnsen Publ. Co., Lincoln, Nebr. 348 pp.

Weaver, J. E. & F. W. Albertson. 1939. Major changes in grassland as a result of continued drought. Bot. Gaz. **100**: 576-591.

Weaver, J. E. & R. W. Darland. 1948. Changes in vegetation and production of forage resulting from grazing lowland prairie. Ecology **29**: 1-29.

Weaver, J. E. & T. J. Fitzpatrick. 1934. The prairie. Ecol. Monog. **4**: 109-294.

Weaver, J. E. & W. W. Hanson. 1941. Native midwestern pastures, their origin, composition, and degeneration. Nebr. Conserv. & Surv. Div. Bull. **22**: 93 pp.

Weaver, J. E. & N. W. Rowland. 1952. Effects of excessive natural mulch on development, yield, and structure of native grassland. Bot. Gaz. **114**: 1-19.

Weaver, J. E. & G. W. Tomanek. 1951. Ecological studies in a midwestern range: the vegetation and effects of cattle on its composition and distribution. Univ. Nebr. Cons. & Surv. Div. Bull. **31**.