T H E S I S

EFFECTS OF DIFFERENT SYSTEMS OF GRAZING ON CATTLE GAINS

Submitted by

Roland Snodgrass

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State College

of

Agriculture and Mechanic Arts

Fort Collins, Colorado

January, 1937

COLORADO STATE COLLEGE

OF

AGRICULTURE AND MECHANIC ARTS

February 8, 1937

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Roland Snodgrass

ENTITLED Effects of Different Systems of Grazing on Cattle Gains

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF Science

MAJORING IN Animal Husbandry

CREDITS 18

In Charge of Thesis

APPROVED

Head of Department

Recommendation concurred in

Committee on Final Examination

Committee on Graduate Work

This thesis, or any part of it, may not be published without the consent of the Committee on Graduate Work of the Colorado State College of Agriculture and Mechanic Arts

ACKNOWLEDGMENTS

The writer wishes to express his indebtedness to Professor E. W. Nelson of the Department of Range and Pasture Management, Colorado State College, and Mr. J. W. Tobiska, Chief Chemist, Chemistry Section, Colorado Agricultural Experiment Station, Fort Collins, Colorado for advice and assistance in arranging the vegetational and chemical data, respectively; and to Mr. M. S. Morris, Associate Professor, School of Forestry, University of Montana, Missoula, Montana, for assistance and suggestions in connection with the grazing studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Experimental Range

CHAPTER I

INTRODUCTION

Background of the Problem.- Investigations in range management were begun in 1920 by the Animal Investigations and Botany Sections of the Colorado Agricultural Experiment Station at Fort Collins. The objects of the work, as stated in 1924[1], were (1) to study the effect of early spring protection in building up the vitality and increasing the production of range grasses, and (2) to determine the value of a management system including early protection of forage grasses plus systematic rotation of cattle on typical low foothill range in Colorado.

Three systems of management were used:

(1) Continuous grazing from the first sign of general plant growth in the spring.

(2) Grazing deferred until range readiness.

(3) Grazing deferred until range readiness on one half of the pasture, and until seed maturity on the other half, combined with rotation every two years.

The effects of the different systems of management were to be shown in (1) total gains secured on cattle, and (2) deterioration or improvement of the range.

Since July 1926, intensive studies of the vegetation and vegetational changes have been conducted on the experimental range by the Botany Section. Since April 1936, this work has been carried on by the Department of Range and Pasture Management of Colorado State College.

The studies conducted by the author were begun in March 1936 and were concluded on October 23 of the same year.

During the time the experiment has been in operation, changes have been made in the manner of stocking and in the grazing periods, but there has been no essential change in the systems of management used. Vegetational records, however, have changed from time to time as different phases of the problem were studied. Records of the most complete series of investigations, from 1926 to 1931, were published in the latter year[3].

Investigations of a nature similar to those here reported have been conducted at other institutions and by other agencies. Those pertinent to this study are reviewed, briefly, in Chapter II, entitled REVIEW OF LITERATURE.

The Problem.- The present studies were undertaken to supplement the work previously completed with original data, and to satisfy, as far as possible, the objects originally set forth[1].

Minor Objectives.- It is proposed to accomplish these purposes by:

(1) Summarizing previous records of the same investigation.

(2) Comparing vegetational records of 1936 with those of previous years.

(3) Presentation of grazing and utilization records.

(4) Presentation of the results of chemical analyses of the major forage grasses.

(5) An analysis of cattle gains and their significance in the light of other records presented.

Sufficient material has been compiled for a short discussion

of palatability of plants and grazing preferences of cattle under the conditions of this investigation.

Procedure.- The diversity of the phases studied makes a description of procedures more convenient in connection with the records obtained.

CHAPTER II

REVIEW OF LITERATURE

Exclusive of the work done at this station, there have been made but two comprehensive studies of a similar nature in the range area of the West.

The first of these was conducted near Mandan, North Dakota by the Department of Agriculture in cooperation with the North Dakota Agricultural College. At this station, Sarvis[18] came to the conclusion that under the deferred and rotation system of grazing "... a greater utilization of the vegetation is obtained with less injury to it than in any other pasture, with the greatest total gain." In general, this statement is in accord with the opinions of other authorities. However, Blizzard, Hawkins, and Kiltz[20], on the basis of an eight year experiment near Marland, Oklahoma, come to an opposite conclusion: "The figures indicate no advantage from a standpoint of gains in beef through this system of combined rotation and deferred grazing. The percent of weeds on the two pastures has remained about the same. This is also true for the amount of grass left at the end of the season. A careful study of vegetative changes has revealed but little difference between the pastures." They suggest that grazing may not have been sufficiently severe to bring about expected changes.

Regarding the factors which contribute toward the superiority of the deferred and rotation system, Sampson[17] states "Where there is enough stock to use all the forage each year the requirements of plant growth are seriously interfered with, the forage crop becomes

weakened and is materially decreased, little or no seed is produced, reproduction is therefore prevented, and there is a gradual decline in the carrying capacity of the range." Sarvis[18] wrote in 1923 "Native pastures deteriorate when grazed because of (1) too early grazing in the spring, (2) continuous grazing, and of (3) over-grazing." In 1927, Jardine, Lindgren, and Potter[19] wrote "Premature grazing is undoubtedly a primary cause of the deterioration of range lands..... The damage to the forage plants from grazing is greatest immediately after growth begins and decreases as the season advances."

Sampson[16] has shown overgrazing to result in a reversal of the course thru which the range achieves its ecological climax. He says "The grazing capacity and forage value are highest where the cover represents a stage in close proximity to the herbaceous climax..... When a stand of bunch wheatgrass is opened up, there is an increase in the density of other plants." From a range standpoint, conspicuous signs of overgrazing, according to these authorities, are: (1) Erosion and demudation where the sod was originally intact. (2) Remnants of dead shoots of palatable woody plants. (3) An increasing abundance of unpalatable or poisonous plants.

Under moderate overgrazing, especially in the plains region, erosion is not commonly encountered except in small or localized areas. In the West, browse range is more or less confined to hilly or mountainous districts. In the plains area, the most reliable indication of such overgrazing is given by the behavior of the plants constituting the normal vegetation. The decrease of valuable

species, when attributable to grazing, and the increase of undesirable species, or the decrease of the vegetation as a whole are the criteria generally used.

Sampson[17] gives a list of indicator plants from which the trend of the vegetational change can be determined. For the Southwest, Jardine and Forsling[23] give, as indicators of the first stages of range deterioration, Eriogonum spp., Tribulus terrestris, Mentzelia multiflora, and annual species of Bouteloua, and of later stages of deterioration, Sporobolus spp., Croton corymbulosus, Solanum eleagnifolium, and Psilostrophe tagetinae which may be followed by Gutierrezia furfuracea. Hanson, Love, and Morris[3], in Colorado, consider Psoralea tenuiflora, Artemisia gnaphalodes, and Sophora sericea to indicate overgrazing by their increase, and in North Dakota, Sarvis[18] stresses the increase of Artemisia frigida on range where competition by other plants was removed by overgrazing. The work in Colorado, and that by Campbell[21] in southern New Mexico emphasizes the differences in succession due to soil, moisture, and topographical differences.

Sampson's statement[16] that "The wheatgrass range is the most permanent of any and withstands heavy grazing better than any other." appears to conflict with the conclusion of Sarvis[18] that "Bouteloua gracilis is the one species that appears to respond to frequent clippings better than any other species." The work of Hanson et al[3] seems to agree with the latter statement, and that of Morris[5] seems to place Buchloe dactyloides in the same category.

Jardine and Forsling[23], Sampson[16], Sarvis[18], and Hanson, Love, and Morris[3] show in various ways that decreases in density of cover

and in vigor and size of plants are effects of grazing too early in the season or at too great an intensity.

One of the chief advantages which the system of continuous grazing seems to hold over other systems is that of the possibility of increased yields of dry matter. McCreary[9], investigating the total yields of plots clipped at different intervals thruout the summer at Laramie, Wyoming found that plants cut two and three times during the summer gave the largest yields. They were followed, in order, by plats clipped five, ten, and one times. Graves, Dawson, Kopland, and Moseley[15] found that in total dry matter yield, plats clipped four times placed first and third, plats clipped three times placed second, and plats clipped twice during the year placed fourth.

An even greater advantage lies in the fact that the plants which are cropped earlier in the season are higher in digestible nutrients, and that frequent cropping prevents, to a great extent, the lowering the percent of digestible nutrients by maturity. Hopper and Nesbitt[7], in North Dakota, state "Close grazing reduces the yield of dry matter, but that which is obtained is of a superior composition and higher value." McCreary[9] adds "..... the highest amount of food is obtained from a pasture by close grazing." Graves et al[15] found the same relationship in protein as in dry matter, and state "On an acre basis four cuttings yielded over twice as much protein as two cuttings."

Morrison[4], Sampson[17], and McCreary[9] point out, however, that too frequent clipping or cropping of the grass may have the opposite effect, especially where the grass is not given a chance to

produce sufficient growth in the spring. Sampson cites experiments in the Wasatch Mountains of Utah in which "Plots harvested once each season, just before seed maturity, yielded more than five times as much air-dry forage as those from which the leafage was removed four times each season." In view of these findings, it appears logical to conclude that the number of times the herbage should be cropped during the season to get maximum production is dependent upon local factors, and that precipitation, species, and time of first harvesting are highly determinative.

As to the results of frequent removal of herbage on production in subsequent years, Sampson continues "It was significant, too, that at the end of the third year approximately 85 per cent of the plants harvested four times had died." This is similar in effect to results reported on closely grazed areas on the Jornada Range Reserve by Jardine and Forsling[23] and by other investigators.

Graves, Dawson, Kopland, and Moseley[15] recall "The fact that immature grasses are high in protein and low in crude fiber and that the percentage of protein declines and the percentage of crude fiber increases as the plant matures was discovered as far back as 1883 by research workers of the United States Department of Agriculture." There has been sufficient research to establish beyond all doubt the nature of seasonal changes in native range grasses. The work of Catlin[11], Knight, Hepner, and Nelson[8], and McCreary[9] is in agreement with the statement by Hopper and Nesbitt[7] that "As ripening approaches, the moisture content decreases and the dry substance increases accordingly. In the dry substance, the percentage of crude fiber increases, the percentage of nitrogen-

free extract generally increases, and the percentages of ash and ether extract (crude fat) remain about the same, although they may be variable." They agree also with McCreary when he says "Grasses of the plains reach their lowest stage in food value in November and remain at that stage during the winter....."

Regarding the digestibility of the nutrients, McCreary[9] states that "..... the digestibility and food values vary directly as the protein content." This should probably be interpreted to agree with the statement by Christensen and Hopper[12] that "Digestibility of all nutrients was greatest with most active growth." Catlin[11] suggests that water may have a value not fully recognized in determining digestibility.

The palatability of the feed undoubtedly plays an important role in all phases of the problem. It is shown to be related to animal gains and production by Willard[14] and by Graves et al[15] who write "Marked preference of cows for immature hay or silage was shown by a prompt decrease in consumption and production." That more palatable plants are more heavily grazed is inferred by the definition of palatability generally accepted. Hart, Guilbert, and Goss[13] state ".....grazing animals in general consume first the most desirable species and then the most desirable portion of the poorer species." It is justified, then, to conclude that greater pressure is put on more palatable species tending to drive them from the range, or, in other words, that palatability is an important factor in determining plant succession caused by overgrazing.

Factors determining palatability have not been conclusively demonstrated. Green[10] says "Accumulation of crude fiber will.....

decrease palatability." The same factor is noted by Willard[14] in hay feeding tests. He also found a close relation between relative palatability of Wyoming native hays and their sugar content. Most authorities agree that water affects the palatability of the feed. Morrison[4] stresses strongly the value of succulence in feed.

On the basis of an investigation into the utilization of browse by cattle in Utah, Forsling and Storm[22] conclude:

"Grazing of browse range should not begin before the leaves of birchleaf mahogany are 3/8 to 1/2 inches wide and 1/2 of an inch long.

"Browse range is much better adapted to late spring and fall grazing than to full season use, if more succulent feed is available for the midsummer period.

"Removal of cattle the latter part of June would provide for the recuperation of the palatable browse plants after spring grazing."

CHAPTER III

PLAN OF THE RANGE MANAGEMENT INVESTIGATION

The range management investigation was carried out over a period of sixteen years, from July 1920 until October 1936, co-operatively by the Animal Investigations and Botany Sections of the Experiment Station, the work of the latter being taken over by the Department of Range and Pasture Management in April 1936.

The purpose, as previously stated, was to determine the effects of continuous, spring deferred, and spring deferred together with biennial rotation, systems of grazing on cattle gains and on the range.

Experimental Range.- The range used in this investigation is an irregular tract containing approximately five hundred and thirty acres of grazing land, about four miles west of the College. About one half of the area is at an elevation of 5100 feet, the rest extending over the first foothill on the east slope of the Rocky Mountains. Until 1906 the area was open range. It was fenced in that year, and until the innovation of this investigation, was used as a breeding pasture for horses.

In 1920, fences were built dividing the area into three pastures, 146.4, 157.0, and 228.7 acres in area from north to south. The fences were run from east to west in order to give each pasture about the same proportion of plain and foothill land. A north-south fence divides the south pasture into two sections approximately equal in carrying capacity so that grazing may be rotated.

Nature of Plant Cover.- Each of the pastures contains two dis-

tinct vegetational types. The foothill slopes are inhabited by a chaparral type verging into a narrow band of yellow pine along the top of each ridge. The important species in this type are Cercocarpus parvifolius, Rhus trilobata, and an understory of Bromus tectorum. Where moisture conditions permit, Ribes, Amelanchier, Prunus americana and P. melanocarpa contribute to the chaparral, and Bouteloua curtipendula, Andropogon scoparius, Poa lucida, Zygademus sp., and Delphinium spp. to the understory.

The plains and small meadows in the foothills bear a shortgrass type of vegetation interspersed with tall grasses and forbs. The important species are Agropyron smithii, Bouteloua gracilis, and Buchloe dactyloides. Of lesser importance are Aristida longiseta, Artemisia dracunculoides, Artemisia frigida, Aster hebecladus, Astragalus spp., Distichlis spicata, Eurotia lanata, Grindelia squarrosa, Gutierrezia longifolia, Helianthus pumila, Hordeum jubatum, Muhlenbergia torreyi, Psoralea tenuiflora, Schedonnardus paniculatus, Senecio perplexus, Stipa comata, S. robusta, and S. viridula.

For about one month in the early summer, Allium reticulatum, Leucocrinum montanum, and Viola nuttallii are grazed sufficiently to be regarded as important. At least ninety species have been recorded in the shortgrass type.

Systems of Grazing.- On all pastures, steers grazed for the first and last three year periods during the summer only. For the other ten years, breeding cows were on the range the year-round.

The middle pasture was so grazed as to serve as a check on the other two. Grazing was continuous from the inception of plant growth[24] in the spring until the forage supply was depleted. Under the con-

ditions of summer grazing, this period began between the middle of March and the middle of April, usually ending in October. Since the early spring growth was not sufficient to support the animals allotted to this pasture, it was supplemented by hay until the range alone would maintain them.

In addition to the hypothetical reduction of plant vigor resulting from too early utilization, this range suffered from mechanical destruction of plants, during the time it was grazed year-long by the stock sliding and trampling them as the ground thawed.

Grazing was deferred in the north and south pastures until the important grasses had achieved sufficient growth to withstand pasturing without excessive loss of vigor. Ordinarily from three weeks to a month elapsed after grazing had begun in the checklot. From then on, in the north pasture, the range was given no further protection, the stock being allowed to graze over the entire area at will.

One half of the south pasture was grazed in a manner identical with that of the north pasture. The other half was closed to grazing until seed maturity. At this time the connecting gates were opened allowing the stock free access to all parts of the pasture. This system of grazing was rotated every two years. The supposed advantage of the system is that it allows two seed crops to mature without the interference of grazing, scattering and trampling of the seed after maturity, and protection of the seedlings for the early part of one summer.

Basis of Stocking.- With the assistance of the Forest Service, a reconnaisance survey was made in 1920 to determine the number of forage acres contained in each division of the range. Upon the

results of this survey, cattle were allotted to each pasture on the same forage allowance basis (.75 forage acre per cow month). In this manner it was attempted to secure a uniform density of cattle on each pasture as measured by the forage available[1].

Livestock.- Two-year-old Hereford steers were used on the range in 1921. In the years 1922, 1923, 1934, 1935, and 1936, yearling steers of the same breed were used. During the ten-year period when grazing was year-long, Hereford cows and their calves were run on the range. The calves were dropped in the spring and removed in the fall. During the winter, the cows were maintained on hay and cottonseed cake, and they found little occasion to stray from the feedlot. Protection from storms was afforded by sheds built in each pasture for that purpose.

The following table shows the number and kind of animals on each pasture during each year of the investigation:

Table 1.- Number and Class of Stock Used During Investigation.

Year	Class of Stock	Continuous Grazing	Deferred Grazing	Deferred-Rotation Grazing
1921	2-yr-old steers	17	13	32
1922	Yearling steers	17	17	30
1923	Yearling steers	19	19	28
1924 to 1933	Cows with calves	19	19	28
1934	Yearling steers	25	25	35
1935	Yearling steers	25	25	35
1936	Yearling steers	25	25	34

The adjustments in stocking during the first three years were based on the amounts of available forage ungrazed at the end of the grazing seasons[1]. Lister[24] found a heavier stand of vegetation than had been recorded by the Forest Service in the north pasture.

With the change from yearling steers, which were pastured for the summer only to cows and their calves, the cows staying on the range for the entire year less the time allowed for spring protection of the north and south pastures, there was a decided increase in the basis of stocking. However, Hanson, Love, and Morris[3], in 1931, indicated that no section of the range was regarded as sufficiently overgrazed to show clearly the effects of the increased stocking.

To maintain the intensity of grazing, the number of animals was again increased with the return to yearling steers in 1934, and it has been held constant since that time.

Cattle Weights.- Because of the loss by fire of the original records of the early years of this investigation, data referring to them is taken from a mimeographed report on the work by Maynard and McCarty[1] published in 1924, and from Lister's thesis[24].

From the beginning of the experiment thru 1934, individual weights were taken regularly every thirty days. During 1935 and 1936, group weights of each lot were taken every ten days and individual weights every thirty days. In order to coordinate gains more closely with grazing data during these years, the stock was penned near the scales at as near 8:00 A.M. as possible, and weighing started exactly at 1:00P.M. The purpose was to eliminate, as much as possible, fluctuations in weight due to unequal fill, especially of water. All animals were given an opportunity to drink

before penning.

Since cattle weights are prone to such great fluctuations, and since these fluctuations may constitute so large a percentage of a season's gain, initial and final weights were arrived at by weighing each animal separately on three consecutive days at each end of the season and averaging the results.

Weights were taken to the nearest five pounds at all times. Averages were calsulated to the second place. All calculations and transfers have been carefully checked to avoid errors.

Cattle Allotments.- Elimination of experimental error has received a large measure of attention during the investigation. The cattle, constituting the most important controllable variable, have been very carefully allotted. A discussion of allotment factors used during the last three years is presented:

(1) Weight.- That each pasture receive an equal or proportional weight as well as number of cattle is essential. A total variation from the exact average on not more than five pounds per lot was allowed. At the same time, each lot was given, as nearly as possible, an equal or proportional number of large, medium, and small individuals.

(2) Type.- Before being allotted, the steers were graded as Select, Choice, Good, Medium, or Poor, or placed in intermediate categories. These were divided proportionally among the three lots.

(3) Condition.- It is generally conceded that cattle may be in either too good or too poor condition to make maximum

gains when placed on the range. Steers were graded in condition as Choice, Good, Medium, or placed in intermediate grades, and these were divided proportionally as far as possible.

(4) Winter Ration.- Significant correlation between winter ration and winter gains indicates that the two may be treated as one. A fair negative correlation between winter and summer gains justifies the proportional allotment of calves wintered on different rations.

(5) Origin.- In order to secure a diversity of calves with respect to their origin, they have been purchased from as many as five different ranches. Proportional allotment of these calves has been practiced to minimize variations from this source and to render each lot more nearly average as to breeding.

(6) Breed.- Altho Hereford cattle have been used entirely, the presence of various grades of Shorthorn crosses in the range stock has led to equal division among the lots of animals showing marked hybrid characteristics.

(7) Color.- In absence of proof that color can, in any way, affect performance, the steers have been been graded as Dark, Medium, and Light, and divided accordingly. Feedlot investigations at the Colorado Experiment Station[6] indicate that there may be some slight difference in gains associated with coloring, and it is a known fact that poisoning by St.Johnswort on California ranges is selective in its intensity, most severely affecting animals of light

pigmentation.

CHAPTER IV

VEGETATION STUDIES PREVIOUS TO 1936

In July 1931, the Colorado Agricultural Experiment Station published Bulletin 377 entitled EFFECTS OF DIFFERENT SYSTEMS OF GRAZING BY CATTLE UPON A WESTERN WHEATGRASS TYPE OF RANGE by Herbert C. Hanson, L. Dudley Love, and M. S. Morris. Included in this publication are the results of ecological and vegetational investigations up to that time. The purpose of the investigations, as stated in the bulletin, was to determine what had been the effects of the continuous and deferred-rotation systems of grazing on the range.

In order to avoid confusion with later work, it is convenient to review that of Hanson, Love, and Morris separately.

REVIEW OF WORK PREVIOUS TO 1931

Of the two pastures, only the level plains areas were studied since they were most nearly identical in all conditions which might affect the results. Data were obtained on the following:

(1) Weather conditions

(2) Soil conditions

(3) Isolation transects with quadrats opened to grazing

(4) Systematically arranged list quadrats (two square meters)

(5) Ten-meter-square quadrats

(6) Clipped quadrats

The meteorological observations included measurements of precipitation, evaporating power of the air, humidity, and temperature. These factors were used to correlate plant development and to deter-

mine the sensitivity of various species to climatic factors.

Soil conditions studied were temperature, moisture, and physical and chemical properties of the different soil profiles. These data were used in the explanation of vegetational changes not traceable to grazing.

Records obtained from a study of the major quadrats enclosed in the isolation transects attempt to trace the effects of one, two, three, or four years grazing or protection, under both systems, upon the different species.

Systematically arranged list quadrats were found valuable for a study of the vegetation of the range as a whole.

The ten-meter-square quadrats, one in each pasture, were used to gather quantitave data by which to explain the apparently greater number of weeds in the check pasture, and to trace the increase or decrease of all plants under the two systems of grazing.

The clipped quadrats were included in order to determine what yields might be expected on this range and to indicate the results of climatic factors and grazing systems on the yield.

Results and Conclusions.- Plant growth and development was found to follow closely environmental factors, especially temperature and soil moisture. "Soil moisture in the upper 2 feet was usually ample from the latter part of March to the first part of June, but during the rest of June and extending into September it was frequently deficient..... Vegetative growth was usually completed by the latter part of June, when soil moisture was usually depleted. Bouteloua and Bulbilis (Buchloe), however, renewed vegetative growth later in the summer if soil moisture became ample due to showers.....

In June the blooming of the vegetation was at its height. In July drying began in several species.....

".....In early spring the growth rates of grasses was retarded by low temperatures. Stipa viridula was less sensitive than Agropyron Smithii and both of these were less sensitive than Bouteloua, Bulbilis (Buchloe),Schedonnardus, or Aristida."

A difference in plant vigor as expressed by growth height of flowering stalks of Stipa viridula and Agropyron smithii showed consistently for five years that plants in the isolation transects exceeded those in the deferred-rotation pasture, and that the latter plants exceeded those in the continuous pasture. As shown by the weight and germination percent of seeds of Stipa viridula, the same condition was true.

Hanson et al[3] state "The most valuable data on the effects of the grazing systems upon the vegetation in this study appear to be those from the 30 list quadrats (2 square meters) systematically distributed in each pasture. In 1929 there was an average of 912 $\pm$ 75.23 stalks per quadrat in the deferred and rotation pasture, and 597 $\pm$ 50.48 stalks per quadrat in the continuous pasture. This great difference (53 percent more stalks in one than in the other) appears to be due chiefly to the different systems of grazing in operation for 9 years. This is the chief effect that was found."

Regarding plant indicators of overgrazing Hanson[3] states ".....It appears from these data, however, that increasing abundance of Psoralea, Artemisia gnaphalodes, and Sophora sericea (none grazed) and decreasing abundance of Senecio perplexus, Helianthus pumilus, and Astragalus drummondii (all grazed) may be used as delicate indi-

dications of grazing methods that are not suitable for the maintenance of the kind of vegetation best suited to cattle. Many changes that developed in these quadrats, particularly in the case of Schedonnardus, appear to be due more to environmental conditions or to competition pressure, than to differences in the grazing systems."

REVIEW OF WORK BETWEEN 1931 AND 1936

From 1930 until April 1936 plant investigations were carried on under the supervision of Mr. M. S. Morris*[5] to whose records the author has been granted access. All tables presented in this discussion are from that source.

An important piece of work accomplished during this time was a continuation of the survey covering the quantitative behavior of all species found in the thirty 2-meter quadrats in each pasture. The results of observations made in 1927, 1932, and 1935, covering a period of eight years are presented in Table 2.

The term 'Frequency' has been used to designate the percent of quadrats in which the species is found. 'Abundance' has been determined by counting the total number of stalks in the thirty quadrats or by measuring the stand in square centimeters.

The following abbreviations are used: VS, very scarce; S, scarce; I, infrequent; F, frequent; Ab, abundant.

* Formerly Assistant Botanist at Colorado State College; now Associate Professor, School of Forestry, University of Montana, Missoula, Montana.

Table II. Comparison of Frequency and Abundance of Range Forage Plants under the Deferred-Rotation and Continuous Systems of Grazing

Species	Frequency						Abundance					
	Deferred-Rotation Grazing			Continuous Grazing			Deferred-Rotation Grazing			Continuous Grazing		
	1927	1932	1935	1927	1932	1935	1927	1932	1935	1927	1932	1935
Palatable Vegetation												
Agropyron smithii*	100	100	97	100	100	93	27,460	12,704	11,679	17,921	7,649	6,384
Aristida longiseta*	37	37	37	64	53	48	S	8,449	2,183	S	5,288	4,166
Bouteloua gracilis*	47	43	40	73	73	79	I	29,600	13,019	F	80,100	57,485
Buchloe dactyloides*	37	43	43	23	30	24	I	114,925	12,251	S	34,200	15,600
Schedonnardus paniculatus*	90	43	23	60	30	34	I	216	55	S	102	37
Stipa viridula	20	27	17	0	13	10	110	2,030	1,667	0	262	235
Artemisia dracunculoides	13	13	3	27	13	17	17	7	7	97	24	4
Aster hebecladus	13	27	33	37	53	62	282	195	46	195	111	116
Astragalus drummondii	60	37	30	30	10	17	113	35	25	61	5	10
Eurotia lanata	70	57	53	0	0	0	69	62	39	0	0	0
Gaura coccinea	97	53	100	93	57	90	342	77	278	194	37	225
Musineon divaricatum	97	90	93	97	70	93	1,910	394	981	771	159	533
Senecio perplexus	70	70	70	40	0	7	591	409	619	85	0	8
Unpalatable Vegetation												
Muhlenbergia torreyi	17	17	17	3	3	1		5,800	6,989	VS	6	30
Artemisia frigida	17	0	3	48	7	48	12	0	1	57	48	26
Artemisia gnaphalodes	43	33	27	53	37	31	278	62	89	260	69	118
Gutierrezia longifolia	77	43	60	73	27	69	75	31	31	48	43	58
Iva axillaris	67	77	60	43	57	28	716	194	142	606	167	222
Opuntia humifusa	23	23	33	13	10	17	8	10	16	3	31	10
Psoralea tenuiflora	63	67	63	100	93	89	165	136	219	544	398	332
Sophora sericea	100	97	97	43	53	44	466	449	666	173	163	293

*Stands in square centimeters - others as stalks or plants

Discussion of Table II.- It is apparent from a brief examination of Table II that there has been a progressive decrease in the total forage on the 30 quadrats in each pasture. Expressed as percent of original stand, Agropyron smithii, the main constituent of the vegetation, decreased from 100 percent in 1927 to 46.3 percent in 1932 and 42.5 percent in 1935 on the deferred-rotation pasture. In the continuously grazed pasture, it decreased to 42.7 percent in 1932 and 35.6 percent in 1935. Plants other than grasses, treated as a whole, decreased to 69 percent and 88 percent of the original stand on the deferred-rotation and continuously grazed pastures, respectively, by 1935. A greater decrease, evident in 1932, may have been due to a temporary encroachment by Bouteloua and Buchloe.

In the absence of control quadrats on ungrazed areas it is difficult to make a positive statement regarding this reduction. The indications are, however, that both pastures have been rather seriously overgrazed. This may or may not be substantiated by other data.

It is evident that the reduction of Agropyron has been greatest on the continuously grazed pasture and that this loss has not been made up by the slight relative increase in forbs. Expressed as percent of the same year's stand on the deferred-rotation pasture, Agropyron decreased 65.3, 60.2, and 54.7 percent, and forbs increased 70.7, 81.2, and 90.3 percent in the years 1927, 1932, and 1935 respectively. Most of the difference seems to have been taken up by the increasing abundance of the short grasses, particularly Buchloe in the continuously grazed pasture. Bouteloua has made the greatest increase in both pastures at the expense of wheatgrass, and appears to withstand grazing better than any other important species.

The behavior of individual species is held to be significant in determin ing the proper utilization of the range. Table II shows three species, Sophora sericea, Opuntia humifusa, and Muhlenbergia torreyi to have increased in abundance on both pastures. Further records[5] show that Quincula lobata and Argemone intermedia have done likewise. None of these is normally grazed. Excepting Buchloe dactyloides, Bouteloua gracilis, and Stipa viridula, every valuable grass, Musineon divaricatum, Artemisia dracunculoides, A. frigida, Astragalus drummondii, A. hypoglottis, Artemisia gnaphalodes, Iva axillaris, and Linum lewisii have decreased in abundance. All but the last three are grazed. This fact seems to substantiate the conclusion that both pastures have been overgrazed.

It is possible that the decrease of these unpalatable species on both pastures and of Psoralea tenuiflora, Astragalus bisulcatus and others on the continuous pasture might indicate that even these species were harmfully utilized.

Table III.- Total Forage Production on Ten 1-meter Plots in Wheatgrass and Grama Grass Types under Deferred-Rotation and Continuous Use.

Species	Grama Grass Type		Wheatgrass Type	
	Def-Rot.	Continuous	Def-Rot.	Continuous
	grams	grams	grams	grams
Agropyron smithii	19.30	39.30	834.30	387.30
Stipa viridula	25.00		25.10	28.30
Bouteloua gracilis	309.60	304.20		
Buchloe dactyloides	5.80			
Aristida longiseta		2.70	2.44	1.60

Discussion of Table III.- The total yields of ten 1-meter plots in the major types present in the two pastures, while they are not wholly conclusive because of small numbers, show two striking indications: (1) the yield of Agropyron in the wheatgrass type on the continuously grazed pasture is but 46.4 percent of what it is on the deferred-rotation pasture; and (2) the yield of Bouteloua does not differ significantly under the two systems of use.

Table II shows the stand on the continuous pasture of wheatgrass to be 54.7 percent of the stand in the other pasture. The greater reduction in yield shown by Table 3 may indicate a reduction in the yield of the individual plant similar to the reduction of plant vigor reported by Hanson[3].

Expressed as tons per acre, the yield of wheatgrass hay in the deferred-rotation pasture is .372 as compared to .173 in the continuous pasture. The yield of grama in both pastures is about .138 tons per acre. These figures apply only to the corresponding types.

Due to the open nature of the stand in the wheatgrass type, there is a much higher yield of weed material than in the grama type. Considering the two types as present in the deferred-rotation pasture to be typical of this range, the total yields of dry matter are .712 and .277 tons per acre, respectively. This comparison expresses the desirability of the wheatgrass type.

To conform with actual grazing conditions, the plants were harvested at heights determined to be close to the average grazing heights on these pastures by several years observation. The short grasses were clipped at one-half inch, tall grasses and forbs at one and one-half inches, and Eurotia, Gutierrezia, etc. at three inches.

Grazing Studies.- In 1935 a system was inaugurated whereby the amount of grazing on, and stock preference for the various species constituting the forage cover might be determined. A series of 100 list quadrats, each one meter square, was distributed systematically on the plains area of the continuously grazed pasture and a similar series was placed in the east half of the south pasture. These quadrats were located in three lines running east and west, parallel to the fences and approximately equidistant from them and each other. The interval between the quadrats was about one hundred feet in the middle lot and one hundred and five feet in the south lot. The plots were not permanent, being located by pacing and defined by a portable wooden frame enclosing a square meter. It was not the intention that the same exact area should be examined each time; rather that each vegetative type should receive equal observation.

The observations were made every ten days, falling on the steer weighing dates when conditions permitted. The species in each quadrat were listed, and the extent to which each contributed to the total forage cover in the quadrat was estimated and recorded. The percentage of grazing on each species was estimated at the same time, based on a rough count of stalks, leaves, or clumps grazed for tall grasses and weeds, and on area grazed for low-growing plants. Grazing was recorded irrespective of the degree to which plants were utilized; hence the figures should not be interpreted as a utilization record. By a large number of measurements, the average heights of growth and grazing on leaves and seed stalks were determined. The amount of grazing on each species over the entire pasture was found by averaging the estimates for each quadrat.

Table IV.- Grazing on Important Species under Continuous Use - 1935.

Species	5/15/35	6/1/35	6/13/35	6/21/35	7/1/35	7/11/35	7/22/35	8/12/35	8/28/35	10/19/
	%	%	%	%	%	%	%	%	%	%
Agropyron smithii	8.1	28.3	21.5	17.3	23.8	24.9	22.4	62.2	63.3	
Bouteloua gracilis		2.8	7.2	8.7	19.0	35.4	36.7	46.1	53.8	
Buchloe dactyloides			.3	2.9	24.7	25.5	25.3	28.4	29.8	39.1
Aristida longiseta						1.3	1.7	6.9	11.0	52.0
Stipa viridula			34.5	27.3	38.2	37.0	49.2	67.5	70.0	
Iva axillaris	20.0	.6	.5	.2		.1	2.4	.3	6.0	
Gutierrezia longifolia					3.8	3.8	6.4	11.2	17.0	60.5
Psoralea tenuiflora			6.2	4.7		.3	3.3	3.0		
Helianthus pumilus							1.7	11.8	41.7	
Senecio perplexus			.8	.1						

Discussion of Table IV.- The indications furnished by Table IV apply only to the joint relationship between plants and grazing animals, and vary with the factors which affect this relationship. They tend to show what species are grazed at different seasons and to what extent they are grazed. When applied to quantitative data regarding the forage composition of the pasture, they indicate the part played by each species in satisfying the needs of the stock. And in another sense, they indicate the preference of the stock, or conversely, the relative palatability of the species at different seasons.

Specifically, Agropyron is shown to have been grazed heavily during two periods: (1) from the beginning of grazing until about the middle of June, during which time it made up the bulk of the feed consumed on this part of the pasture; and (2) from the latter part of July or the early part of August on.

Bouteloua gracilis and Buchloe dactyloides are grazed very similarly, the former being slightly more early in its growth. Possibly because of its more upright habit, it is grazed to a greater extent.

The grasses mentioned above are the chief sources of feed on this range. Grazing on other plants, however, exhibits phenomena pertinent to grazing management. Stipa viridula would seem to be the most palatable species present. Aristida longiseta is grazed to some extent before the forage supply is greatly depleted, but when this does occur thru the drying up of the more palatable weeds and the consumption of the choicer grasses, it becomes very acceptable. The same statement applies to Helianthus and Gutierrezia.

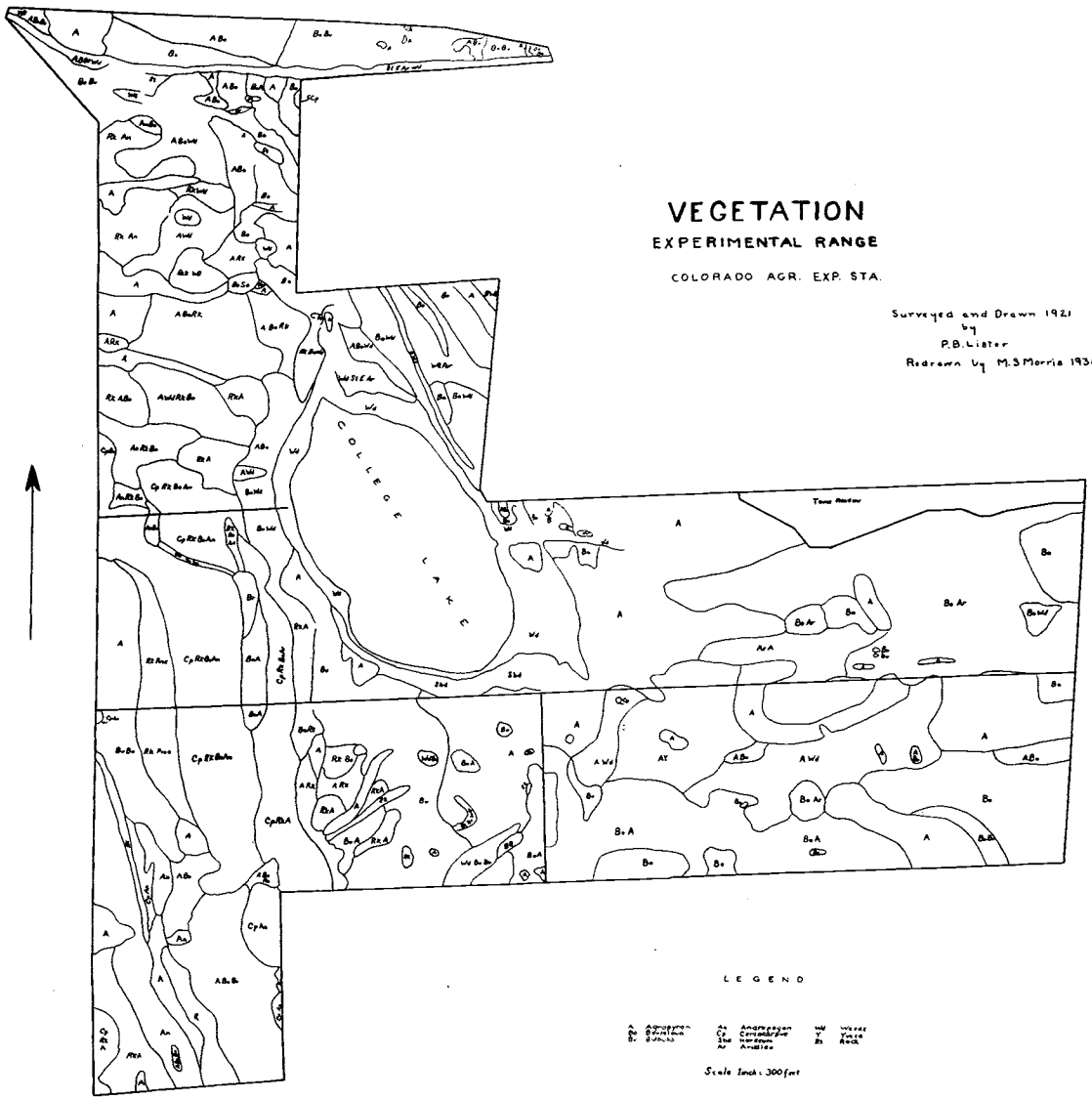
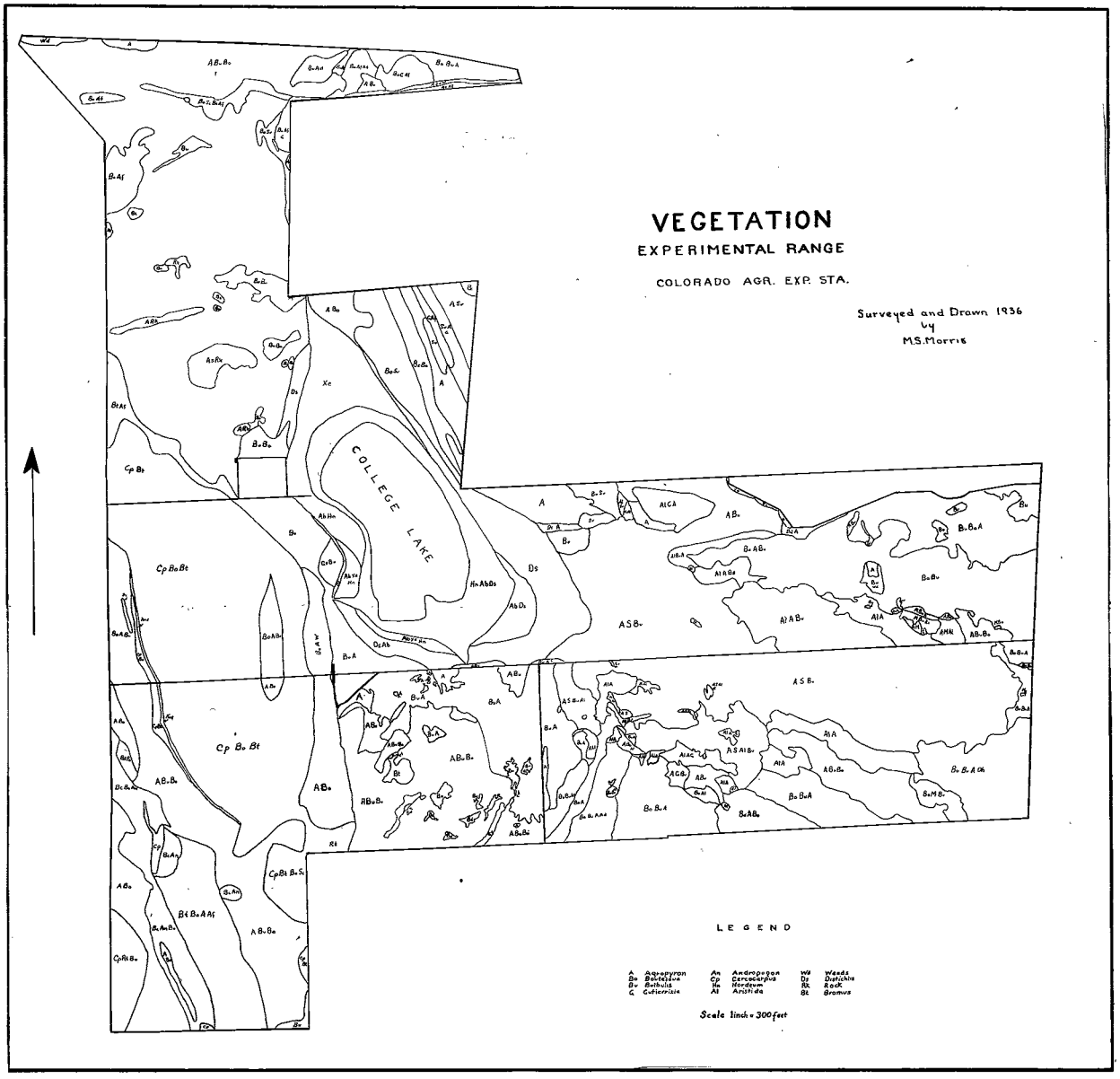


Figure 1.- Vegetation Type Map Showing the Distribution of the Dominant Species in 1921.



S = Stipa viridula

Figure 2.- Vegetation Type Map Showing the Distribution of the Dominant Species in 1936.

VEGETATION MAPS

The vegetation of the experimental range was surveyed and a map prepared in 1921 by P. B. Lister. In March 1936, the author assisted M. S. Morris resurvey the area for which Mr. Morris prepared a new map.

A comparison of the original map with the new one is valuable in tracing the effects of the different systems of use over a period of sixteen years.

In comparing the plains areas on the east side of the range, the most noticeable changes are:

(1) The great reduction of the Agropyron type.

(2) The invasion of Buchloe (Bulbilis) into the Agropyron and Bouteloua types forming new types.

(3) The withdrawal of Aristida from the Bouteloua type and its increase in the Agropyron type.

(4) The decrease in the area occupied by the lake and the invasion of Distichlis spicata.

(5) The invasion of Xanthium echinatum at the north end of the lake.

The most apparent changes in the North Pasture are:

(1) The great increase of the Agropyron type at the expense of all others.

(2) The replacement of Andropogon scoparius and Bouteloua gracilis by Bromus tectorum in the southwest corner.

The most apparent changes in the west and southwest foothills area are:

(1) The decrease of Andropogon scoparius.

(2) The invasion of Bromus tectorum.

(3) The invasion of Agropyron type by Bouteloua and Buchloe.

These are the major changes which have taken place on the range during the course of the experiment.

CHAPTER V

VEGETATION STUDIES IN 1936

During the summer of 1936, the author assisted in taking forage samples and records covering the vegetational phases studied, devoting most time to gathering and assembling the data from the list quadrats. Not all phases of the summer's investigations on the pastures fall within the scope of this paper. All data presented in this chapter are derived from the original records of the Department of Range and Pasture Management of Colorado State College[2].

TECHNIQUE

Detailed observations of the range were made at ten-day intervals, falling on the cattle weighing dates. From one to three days were necessary to go over the range completely. Clippings were made to secure yield data and samples for chemical analysis.

One hundred temporary quadrats were located in each the middle and southeast pastures at approximately the same places as in 1935. Fifty quadrats were located in each the north and southwest pastures. Those in the north pasture were placed at intervals of about one hundred and five feet in three lines running east and west. Twenty-five of these quadrats were near the north side, 15 were near the south, and 10 were midway between them. This arrangement was necessary because of the irregularity of the pasture. The quadrats in the southwest pasture were arranged in three rows of 17, 16, and 17, also running east and west, and about ninety-five feet apart.

The areas covered in the latter two pastures lay at the base of the foothills, extending but a short distance up the slope.

As in 1935 quadrats were defined by a portable wooden frame, and their location was determined by pacing, attempting only to give equal stress to each portion of the areas under observation.

Records were obtained on the continuously grazed pasture from April 19 until September 5 when the cattle were taken off because of a shortage of feed. On the southwest pasture, they were taken from May 11 until July 16 when the deferred half was opened, after which the steers rarely strayed from it. From that date on, observations were made on the deferred half until October 15 when the steers were removed, again because of feed shortage. Records were kept on the north pasture only during the latter part of the summer as there were no antecedent records for comparison.

The following records were made for each quadrat:

(1) Density (coefficient of total ground cover).

(2) List of species included.

(3) Estimated percent which each species contributed to total cover.

(4) Estimated percent of leaves or stalks grazed on each species.

(5) Three to fifteen measurements of each ungrazed culms and leaves on each species (usually every third quadrat).

(6) Numerous measurements of grazed culms and leaves on each species (usually every third quadrat).

Occasionally notation was made of the stage of development of different species, but this practice was dropped as it became very inaccurate when grazing became general. Such records were, however, completed on plants growing within exclosures.

In order to understand the significance of the quadrat records

the following calculations were necessary:

(1) Total density of forage in pasture

$$\frac{\Sigma \text{ Dens.}}{N}$$

(2) Species density in each quadrat

$$(\text{Dens.} \times \% \text{ Comp.})$$

(3) Species density in pasture

$$\frac{\Sigma (\text{Dens.} \times \% \text{ Comp.})}{N}$$

(4) Percent composition of species in pasture

$$\frac{\Sigma(\text{Dens.} \times \% \text{ Comp.}) \times 100}{\Sigma \text{ Dens.}}$$

(5) Grazing percent on each species

$$\frac{\Sigma (\text{Dens.} \times \% \text{ Comp.} \times \% \text{ Graz.}) \times 100}{\Sigma (\text{Dens.} \times \% \text{ Comp.})}$$

(6) Derivation of arithmetic means of growth and grazed heights of fruiting stalks and leaves. The quadrat means were first determined. They were then averaged.

In the above calculations the following abbreviations and symbols were used:

Dens. - abbreviation for density.

Comp. - abbreviation for composition.

Graz. - abbreviation for grazing.

N - symbol for 'number of quadrats.'

Σ - symbol for 'sum of'.

$\times$ - symbol for multiplication

COMPARISON OF PASTURES

On the basis of a single year's survey of the experimental range, evaluation of the effects of different systems of grazing over a period of time is possible only by a comparison of areas assumed to have been the same originally. It is then only probable that the differences found are attributable to the grazing methods used.

Table V.- Average Density and Species Composition of Pastures.

Grazing System	Density	Composition				
		%	%	%	%	%
		Agropyron	Bouteloua	Buchloe	Stipa	Aristida
Continuous (June)	10.7	17.6	41.3	16.6	1.3	6.8
Deferred-Rotation (East half) (June)	10.4	39.2	16.7	13.2	2.3	5.9
Deferred (Aug.)	12.8	46.7	20.7	22.2		
Deferred-Rotation (West half) (Aug.)	12.2	30.4	20.1	33.1		

Discussion of Table V.- The areas most comparable from the standpoint of topography, moisture, etc. have been placed together for comparison. The different periods of use, and consequently, of observation have made it necessary to use different months.

The figures given are the average results of the three quadrat readings during the months indicated.

The small differences in density between the pastures are probably too small to be significant.

Density.- Table V shows that there is an essential difference between the two types in vegetation. Both pastures located on the low foothill slopes possess a definitely heavier stand of vegetation than those which are located on the plains area. An important factor contributing to this difference is moisture, the slopes receiving the excess which drains from above during rains.

In the east half of the deferred-rotation pasture and the continuous pasture, if the slight difference in density is significant, it is probably due to the heavier stands of the short grasses.

From the data presented in Table V, it seems logical to conclude that there has been no significant variation in total density of vegetation which may be attributed to the different systems of grazing followed. It would seem that some other factor, possibly moisture, controls the density within the limits reached by this investigation, and that as certain species have been reduced in extent, other species, better able to withstand the conditions, have replaced them.

Species Composition.- Disregarding the slight difference in density, the stand of Agropyron smithii in the deferred-rotation pasture (west half) is but 62.9 percent of what it is in the comparable deferred pasture. Similarly, the stand of Agropyron in the continuous pasture is only 44.9 percent of what it is in the similar east half of the deferred-rotation pasture. This is the greatest and most significant difference that has been found between the different pastures.

On the hillside areas, the stand of Bouteloua has remained about the same altho its distribution is quite different, being much more general in the deferred-rotation pasture than in the deferred. The

stand of Buchloe is nearly 50 percent greater in the hillside portion of the rotation pasture than in the deferred pasture showing that most of the difference in Agropyron has been made up by this species. The rest has been made up by weeds.

The stands of both Buchloe and Bouteloua on the continuous pasture exceed those on the east half of the deferred-rotation pasture, but that of Bouteloua does so by a far greater margin, its stand being 270.6 of that on the latter on the latter range.

It is also significant that the percent of weeds appears to be greater, and of grass to be smaller on the rotation pasture. The difference in area occupied by desirable grasses is about 7.5 percent in favor of the continuous range.

In view of these facts, the following conclusions are indicated:

(1) The deferred system of grazing has been most suitable to the growth of the most productive species, Agropyron smithii.

(2) The deferred-rotation has been more favorable to the maintenance of the stand of Agropyron than has the continuous system.

(3) The short grasses, Bouteloua and Buchloe, have been predominant in replacing Agropyron where the stand has been opened.

(4) Succession varies with moisture, soil, and topographical conditions.

(5) Continuous grazing favors the replacement of a wheatgrass cover by Bouteloua under the conditions of this experiment, on the plains region.

(6) The short grasses tend to drive out weeds.

In the same connection, a comparison of the maps made in 1921 and 1936, seems to show that Buchloe tends to invade a stand of Bouteloua, and to be somewhat more favored by intensive grazing.

Among species of less importance on this range, it appears also from Table V that Aristida is relatively favored to a slight extent by continuous grazing, and that Stipa viridula is favored by the deferred-rotation system.

It is thot that the comparisons which have been made are applicable despite the necessity for assuming the original similarity of the pastures because this similarity was one of the factors used in dividing them[24].

Table VI.- Average Leaf Height at Maturity.

Species	Continuous	Deferred-Rotation		Deferred
		East half	West half	
	mm.	mm.	mm.	mm.
Agropyron smithii	167	169	273	289
Bouteloua gracilis	45	45	42	64
Buchloe dactyloides	42	43	44	41

Discussion of Table VI.- The figures presented in Table VI are the averages of measurements taken from time to time after growth had reached its maximum of all the leaves on plants selected at random from all parts of the various pastures outside the exclosures. It is evident that comparisons should be drawn only between the plants on similar pastures.

Plant Growth.- As in Table V, Table VI shows that there is a

great difference between the foothill and plain areas.

There appears to be a slight, possibly insignificant, difference in leaf height in favor of the deferred-rotation system over the continuous system of Agropyron and Buchloe.

On the low foothills, Agropyron and Bouteloua seem to be favored by the deferred grazing system over the deferred-rotation system, while the opposite seems to be true of Buchloe.

However, in view of the great difference in growth evidently caused by conditions associated with the topography of the areas examdned, it seems more justifiable to conclude that Table VI indicates no superiority of any of the three systems as shown by average leaf height on the three more important grasses.

By way of observation, it appears that since the deferred system of grazing has shown a decided advantage over the system introducing the rotation practice in the maintenance of the wheatgrass stand, some harm must be worked by the rotational phase. During the first half of July, it was very apparent that very severe grazing was taking place on the southeast pasture. The concentration of stock on a half of the range allotted to them allowed the cattle to graze down the plants more rapidly than growth took place, with the result that these plants received more injury than any others on the entire range.

It was also noticed that very few seedlings were found, altho the range was gone over very closely thruout the season. It seems quite possible that the predominant method of revegetation of the plants on this range is by vegetative methods rather than by seed.

The primary advantage of any rotational method is that it favors

seed production. If seed production is not important, rotation loses its value. And if vegetative vigor receives a setback by any phase of the rotational system, with a consequent reduction of reproduction dependent on such vigor, the system is definitely undesirable. The advantages of deferred grazing alone are more than sufficient to account for the superiority of the deferred-rotation system over the continuous system from a standpoint of condition of the range.

Unfortunately, the phase here discussed was not studied in any detail and no positive statement can be made. The suggestions are offered for what they are worth.

COMPARISON OF METHODS

Since the density-list quadrat method of analysis used here is not one of great accuracy, introducing the personal element too frequently in the estimates made, an interesting comparison can be made with the more exact chart-quadrat method used on the same areas in 1935. The following table illustrates the essential points of difference:

	Hanson - Love - Morris[3]	Morris[5] - Author
Number of Quadrats	30	100
Size of Quadrats	2-square meters	1 square meter
Location	3 rows north and south	3 rows east and west
Observations	During June	10-day intervals thruout season
Method	Chart - Count	Density-estimate List

The two methods have but one common determination, frequency or the percent of quadrats in which a species is found. Density of species cannot be compared directly with stem counts or area measurements, but the ratio between the pastures should be comparable.

The following tables compare frequencies and ratios of stands in the continuous and deferred-rotation pastures as found by the 30 chart quadrats in 1935 and by the 100 density-list quadrats in 1936.

Table VII.- Comparison of Frequency Determinations.

Species	Continuous Grazing		Deferred-Rotation Grazing	
	Chart Quadrats 1935*	Density-list Quadrats 1936	Chart Quadrats 1935*	Density-list Quadrats 1936
Agropyron smithii	93	97	97	96
Bouteloua gracilis	79	52	40	32
Buchloe dactyloides	24	26	43	32
Aristida longiseta	48	44	37	37
Stipa viridula	10	13	17	17
Gutierrezia longifolia	69	36	60	39

* Taken from Table II.

Discussion of Table VII.- Altho the two methods show a general agreement, the frequencies for Bouteloua and Gutierrezia show decided discrepancies. Frequency being but an index to the distribution of the species, the chances are that the method employing the greater number of quadrats is the more reliable.

It is shown by Table VII that the distribution of Agropyron has not been greatly affected by the systems of use. The same appears to hold true for the unpalatable species, Gutierrezia longifolia. Bouteloua gracilis and Aristida longiseta appear to have had greater frequency originally or to have spread under the system of use in the continuously grazed pasture. Buchloe dactyloides and Stipa viri-

dula are shown to have a wider distribution in the deferred-rotation pasture.

Table VIII.- Comparison of Ratios of Abundance and Density.

Species	Chart Quadrats[5], 1935.		Density-list Quadrats, 1936.	
	Def-Rot. Grazing	Continuous Grazing	Def-Rot. Grazing	Continuous Grazing
	%	%	%	%
Agropyron smithii	100.0	54.7	100.0	44.9
Bouteloua gracilis	100.0	441.5	100.0	247.3
Buchloe dactyloides	100.0	127.3	100.0	125.8
Aristida longiseta	100.0	195.4	100.0	115.3
Stipa viridula	100.0	14.1	100.0	56.2
Gutierrezia	100.0	187.1	100.0	55.2

Discussion of Table VIII.- Since neither the estimated density of a species within an area nor the percent composition is directly comparable to figures derived by measurement of typical areas, it has been necessary to devise some other means of comparison. Regarding the stand within the deferred rotation pasture as measured by either method as 100 percent, and the stand within the continuous pasture as measured by the same method in terms thereof seems to fit the requirements.

The lesser stand of Agropyron on the middle pasture is most certainly more accurately measured by the chart method. Some reduction might be expected due to the elapse of one year between observations. However, the chart quadrat method tended to overemphasize the frequency of Bouteloua and Gutierrezia, due to an insufficient

cross-section of the range. The abundance figures reflect the same tendency. The very close agreement between the ratios for Buchloe shows the methods to agree when the cross-section is typical.

It seems to be definitely indicated by a study of these tables that where the number of quadrats is too limited by the labor and time requirements of the method of study, a more accurate picture of the range may be attained by a less exact method employing sufficiently larger number of quadrats. Species with wide distributions are obviously more accurately measured by mechanical instruments. Species whose distribution is limited, however, may furnish distorted results unless large numbers of quadrats are used.

Further Comparison of Pastures.- Tables VII and VIII furnish the following indications:

(1) The decrease in Agropyron is characterized by a reduction in the area occupied by the individual plants.

(2) The stand of Bouteloua is definitely much greater in the middle than in the southeast pasture.

(3) The stands of Buchloe are heavier in the middle pasture but more widespread in the southeast pasture.

(4) Stipa viridula was originally less, or has suffered a greater reduction on the continuously grazed pasture.

CHAPTER VI

CHEMICAL COMPOSITION STUDIES

At least three phases of the range management problem are closely related to the chemical composition of the forage:

(1) The effects of forage composition on cattle gains.

(2) The effects of forage composition on palatability and grazing preferences.

(3) The effects of overgrazing on composition.

A series of analyses of the three major forage grasses on this range, Agropyron smithii, Bouteloua gracilis, and Buchloe dactyloides, was made by the author in the chemical laboratory under the supervision of the Chemistry Section of the Experiment Station. Expenses were shared by the Animal Investigations Section and the Department of Range and Pasture Management.

Only those nutrients which it seemed might have a relatively great influence on the problem were determined, namely: crude protein, crude fiber, total ash, and moisture.

The samples were composites of the clipped quadrat and forage samples gathered between March 1935 and April 1936 at as near monthly intervals as possible. This year was selected as most typical.

The green weights of samples not being available for 1935, moisture was determined on the 1936 clippings.

TECHNIQUE

All determinations were carried out as described by the OFFICIAL AND TENTATIVE METHODS OF ANALYSIS of the Association of Official Agricultural Chemists. A slight modification used and reccommended

by the Chemsitry Section was introduced into the technique for fiber.

RESULTS

The results of these analyses, excepting total moisture, are shown in the accompanying table. All figures are on an oven-dry basis (100°C.).

Table IX.- Monthly Composition of Major Range Forage Grasses.

	Agropyron smithii			Bouteloua gracilis			Buchloe dactyloides		
Month	Crude Prot.	Ash	Crude Fiber	Crude Prot.	Ash	Crude Fiber	Crude Prot.	Ash	Crude Fiber
	%	%	%	%	%	%	%	%	%
1935									
April	5.95	5.0	37.4	7.18	7.1	----*	5.87	8.1	31.1
May	21.71	7.8	27.7	18.31	9.0	28.2	----*	---*	----*
June	16.28	8.6	31.3	16.37	8.4	30.2	17.60	8.9	26.6
July	9.72	6.2	33.4	11.29	7.5	31.3	11.82	6.2	26.6
Aug.	----	---	----*	----	---	----*	----	---	----*
Sept.	----	---	----*	----	---	----*	----	---	----*
Oct.	8.05	5.8	37.2	9.02	8.4	30.7	9.46	8.1	26.5
Nov.	5.34	8.9	37.3	6.30	7.8	34.9	7.27	9.2	30.0
Dec.	6.73	9.7	34.0	6.48	8.9	34.4	6.22	7.1	31.9
1936									
Jan.	5.34	8.2	35.5	6.74	8.8	33.7	6.92	9.2	30.2
Feb.	5.78	8.4	35.6	6.65	8.5	33.6	6.04	7.8	29.1
March	----	--	----*	----	---	----*	----	---	----*
April	5.60	8.3	36.1	6.57	10.4	34.0	6.48	8.4	29.4

* No samples available.

A slight difference in moisture-holding capacity in the air-dry condition was also found. Agropyron lost 6.12 percent of its weight, Bouteloua lost 7.77 percent, and Buchloe lost 8.31 percent on the average in conversion to the oven-dry condition. It may be significant that these differences vary inversely with the crude fiber.

Discussion of Table IX.- The facts illustrated by Table IX are for the most part well known. The most significant fluctuations are those shown by crude protein and crude fiber. It is evident that these grasses show three distinct periods:

(1) Spring range.- The forage of this period is characterized by a high protein content and a low fiber content. The period extends from the inception of growth until early July.

(2) Summer range.- During this period, the protein and fiber contents may be regarded as normal, the protein slightly above the average of hays of the same species[4]. This period extends from early or mid-July until October.

(3) Winter range.- With the complete cessation of plant growth in the fall and the leaching action of the first snows, the protein content is reduced to a minimum and the fiber is increased to a maximum from which they fluctuate but little during the winter.

A discussion of the effects of these periods on steer gains is reserved until later.

It would appear that the fluctuations of protein are reflected by an opposite and smaller fluctuation of fiber during the growing season. One result of the decrease of fiber during the spring and early summer months is a net increase in the percent of digestible nutrients.

Table IX also shows that Buchloe has the lowest fiber content thruout the year. Agropyron is highest, and Bouteloua occupies a position midway between them. During the period of most rapid growth, however, there is no great difference in fiber content among the three grasses.

It is definitely indicated that the fiber content of Agropyron reaches its maximum earlier in the season than does that of the other two grasses. Unfortunately, no samples were available for the months of August and September, and consequently it is not shown just when this takes place.

These data are of especial value in interpreting forage utilization and forage preference figures, and a discussion is reserved for a later section.

Whether the overgrazing of this range has resulted in a change in the chemical composition of these grasses cannot be shown from this series of analyses since all the material analyzed is from the same pasture. In order to answer the question, the most nearly comparable analses in point of plant development by Hopper and Nesbitt[7] in North Dakota have been calculated to a moisture-free basis and are presented in contrast to the author's determinations in Table X.

Since there is an unnavoidable difference of slight but incomensurable extent in the dates and stages of development of the plants, it seems that the small variations may be disregarded. Upon the basis of the comparison made in Table X, it may be said there has been no detectable difference in protein and fiber contents of these grasses due to overgrazing.

Table X.- Comparison of Fiber and Protein Analyses from a Normal and an Overgrazed Range.

Species and Period	Hopper and Nesbitt		Author	
	Crude Protein	Crude Fiber	Crude Protein	Crude Fiber
	%	%	%	%
Agropyron smithii				
Bloom	10.56	34.40		
July			9.72	33.40
Bouteloua gracilis				
July 24	11.87	32.74		
July			11.29	31.30
Buchloe dactyloides				
July 28	11.75	26.89		
July			11.82	26.60

In grazing as at any other time, cattle must consume a certain amount of digestible dry matter for normal metabolism irrespective of the amount of water the feed contains. From the nutritional standpoint as compared to the grazing preference standpoint, the most important analyses are those on a dry matter basis.

However, in grazing, cattle ordinarily have access to several different kinds of plants which are at different stages of succulence and maturity. It is accepted that cattle prefer the more succulent or immature herbage as a general rule. But the question occurs as to what factors influence the forage preference of stock when

confronted with a range on which the most desirable herbage has been consumed, or on which all species are at the same stage of maturity as in the fall and early winter.

It is then necessary to compare the different important forage plants as they are actually present on that range. To do this, it is necessary to transpose all analyses to a green basis.

Figure 3 shows graphically the relationship between the fiber contents of the three major grasses upon the experimental range as they are actually grazed. The monthly averages have been plotted at the midpoints of each month during the active grazing season.

Agropyron, with a more succulent, rapidly growing stem, is shown to have a lower fiber content than the other two grasses during May and part of June. The same is true in April. As all of the plants do not mature at the same time, there is undoubtedly an appreciable amount of such young growth extending into July. This is readily confirmed by observation. But during the latter part of June, the average composition of Agropyron on this range shows an appreciably higher fiber content than does that of the two short grasses. In view of observations made by different authorities and investigators, a decrease of its relative palatability would be expected. At the same time, Buchloe, with the lowest fiber content would be expected to exhibit its greatest relative palatability as maturity advances.

Table IX shows only minor fluctuations taking place in fiber content during the winter. Such variations as are caused by rains and snows are not regarded in the same light as moisture variations during the growing season.

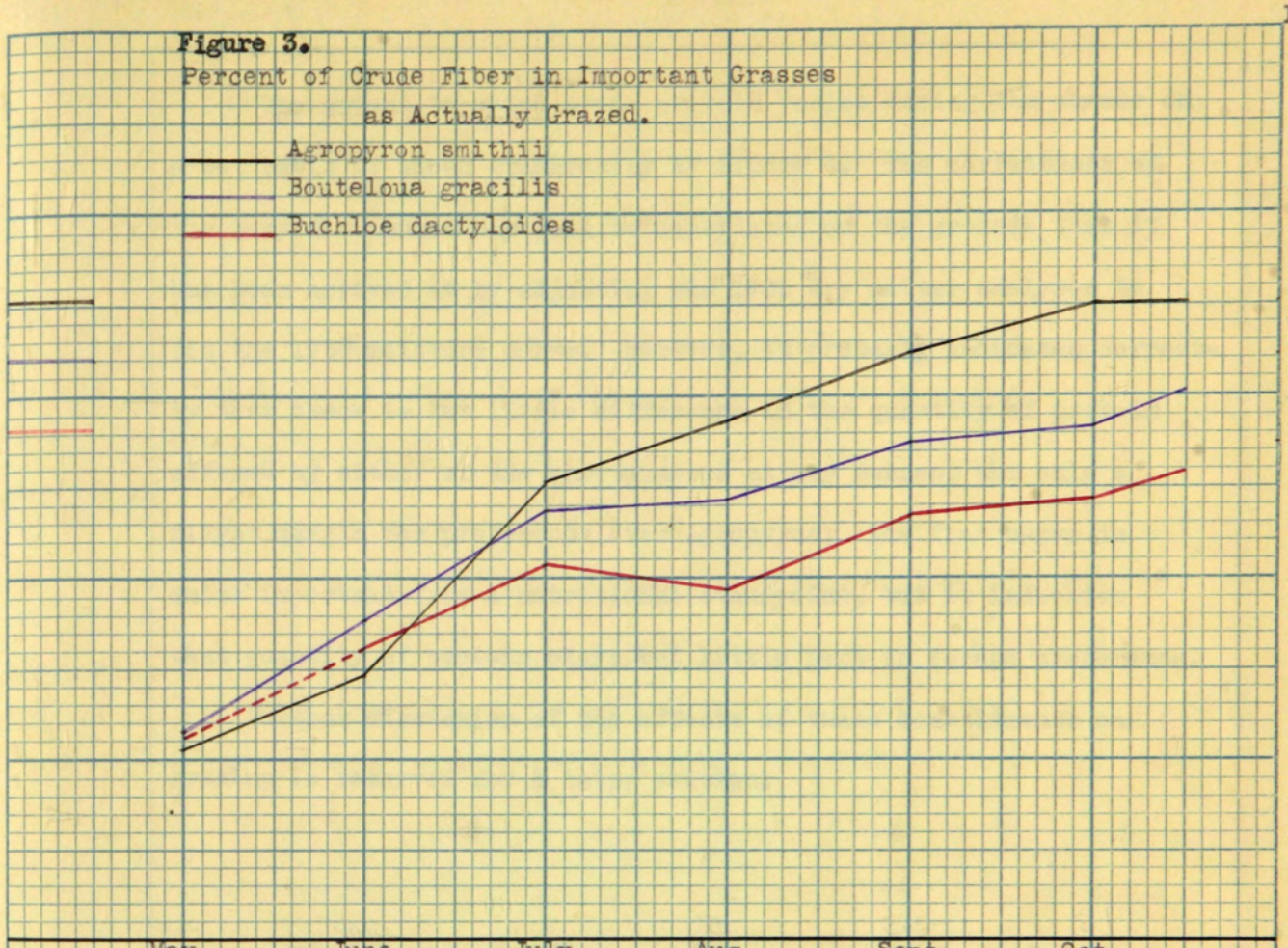


Figure 3.
Percent of Crude Fiber in Important Grasses as Actually Grazed.

Agropyron smithii
Bouteloua gracilis
Buchloe dactyloides

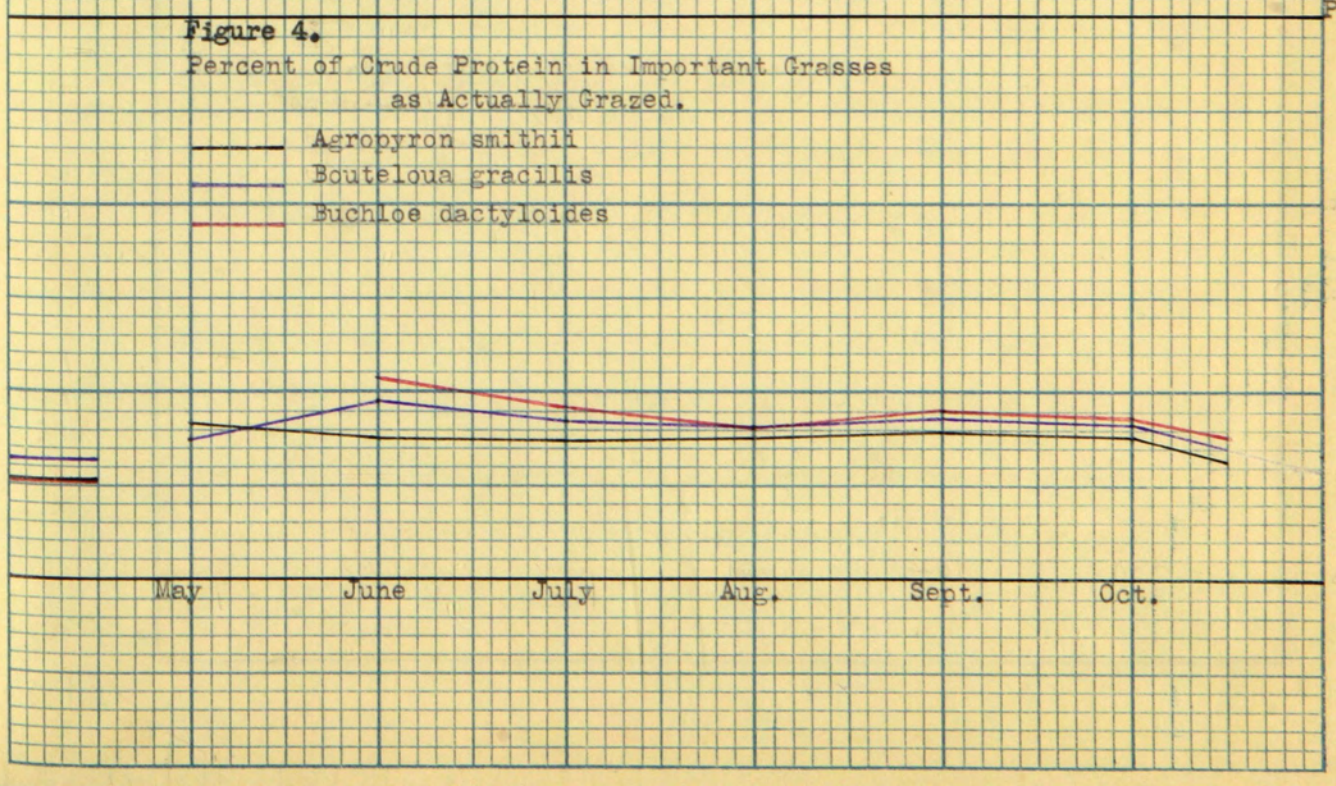


Figure 4.
Percent of Crude Protein in Important Grasses as Actually Grazed.

Agropyron smithii
Bouteloua gracilis
Buchloe dactyloides

The extent to which crude protein varies during the summer on a wet basis is shown graphically by Figure 4. The correctness of the very flat curve may well be questioned on the grounds that it has been arrived at by adjusting the 1935 dry matter analyses to fit the 1936 moisture curve. However, it probably indicates correctly that there is but little difference in the quantity of protein offered by either of the shortgrasses at any season, and only a slight margin for preference over Agropyron. The flat curve is quite important from a nutritional standpoint, but it indicates that quantity of protein plays but little part in forage preference.

Further discussion of the effects of these constituents on grazing is reserved for a later section.

CHAPTER VII

GRAZING STUDIES

The objects of these studies are as follows:

(1) To determine the relative palatability of important range plants at different seasons of the year.

(2) To observe some of the factors which influence palatability.

(3) To find the effects of the deferred-rotation and continuous systems on the grazing habits of the steers.

(4) To ascertain the role played by the main species in producing gains in cattle weight.

Data have been derived from the daily log of the range management experiment[6], from the quadrat studies in 1935[5] and 1936[2], and from personal observation. Results of the 1935 studies have been presented on page 28. The method of recording grazing data has been described on page 35, and the mathematical treatment of this data is shown on page 36.

There is no satisfactory method for the accurate determination of the amount of forage grazed during different periods. The figures presented in Tables IV and XI are approximations based on estimated number of stems, leaves, clumps, or area grazed on each species within the average quadrat. This method alone does not determine the amount of utilization, and it often shows a confusing decrease in grazing percent caused by the increase in leaf numbers in the spring and early summer or following rain. The exactness is further reduced as the season advances by the trampling of all

Table XI.- Grazing on Important Species under Continuous Use - 1936.

Species	4/19	4/29	5/18	5/28	6/6	6/17	6/26	7/6	7/16	7/27	8/6	8/16	8/26	9/5*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Agropyron smithii	6.4	5.5	11.1	26.4	23.6	38.6	40.9	42.0	47.2	47.6	49.5	49.7	50.8	68.1
Bouteloua gracilis	.1		.1	.8	2.7	8.8	12.0	11.9	10.5	29.0	39.3	50.8	55.9	88.7
Buchloe dactyloides				3.8	5.4	6.3	6.6	8.9	6.5	36.2	40.5	54.2	55.1	67.7
Aristida longiseta	.4	.		.6	6.7	2.2	2.7	9.5	6.6	24.9	46.7	57.9	53.8	76.0
Stipa viridula		21.0	33.0	67.7	81.7		82.6	82.3	81.7	94.4	93.2	82.8		99.8
Leucocrimum montanum		13.1	21.0	16.2	29.4									
Allium reticulatum		2.0	9.9	13.8										
Gutierrezia longifolia										.8		2.2	18.7	52.5

* Twenty quadrats.

species, particularly the tall grasses, and by the rolling of the leaves of the short grasses, particularly Buchloe, as drying takes place.

Discussion of Table XI.- The indications furnished by Table IV are generally supported by Table XI. Agropyron smithii is grazed heavily up to the middle of June and again starting in late August or early September. The two short grasses are grazed similarly thruout the season, Bouteloua being grazed earlier and to a greater extent than Buchloe, possibly because of its less procumbent habit. The increment of grazing for Buchloe rises to a peak in July and early August. Aristida is grazed thruout the season, but more heavily as other feed becomes scarcer. Its close,upright habit and longer leaves render it more accessible than Buchloe or Bouteloua. Stipa viridula is again shown to be the most palatable species as indicated by heavy grazing thruout the year. It should be mentioned that close grazing did not allow the formation of seed stalks which normally prevent grazing and which were found ungrazed in the other pastures.

Leucocrinum montanum and Allium reticulatum, together with other palatable weeds contribute considerably to the amount of herbage consumed until dry weather eliminates them. Gutierrezia longifolia is grazed only when desirable food is very scarce.

An explanation of the low consumption of extensive species in the spring is found in the range log[6] which shows that in addition to receiving some hay until April 28, the steers spent almost all of the time on the foothill part of the pasture until May 12. Growth was more ad vanced on the foothills than on the plains. Ex-

amination of this part of the pasture showed that in addition to browse, largely furnished by Cercocarpus parvifolius, and numerous weed species, the grasses, Poa lucida and Bromus tectorum, were eaten extensively.

The unusually high percent of leaves grazed shown at the end of the season may be explained by the fact that grazing was continued until all available forage had been consumed.

Two factors contributing to the shortness of the grazing were an infestation of grasshoppers and insufficient moisture. The total precipitation at the end of July was but 71.8 percent, and at the end of September, 75.5 percent of the 1935 norm for the same periods. Records of yearly and monthly precipitation may be found in the Appendix.

Effects of Leaf Height on Grazing.- It is obvious that there is a height below which effective grazing is not possible. Observation confirms the preference of cattle for taller grasses, other things being equal. Tables IV and XI indicate that this preference is particularly operative during April and early May. Figures 5, 6, 7, and 8 show graphically the relation between grazing and grazed height and height of growth of Agropyron smithii, Bouteloua gracilis, Buchloe dactyloides, and Aristida longiseta, respectively. Figure 9 illustrates the relation between grazed height and growth height of Gutierrezia longifolia.

It is noticeable that grazing commences on Agropyron as soon as the steers are placed on the range indicating that height does not limit grazing under the conditions of this investigation. Grazing on Bouteloua and Buchloe (Figures 6 and 7) is delayed, however,

Figure 5.
Average Heights of Growth and Grazing under Continuous Use
Agropyron smithii - 1936.

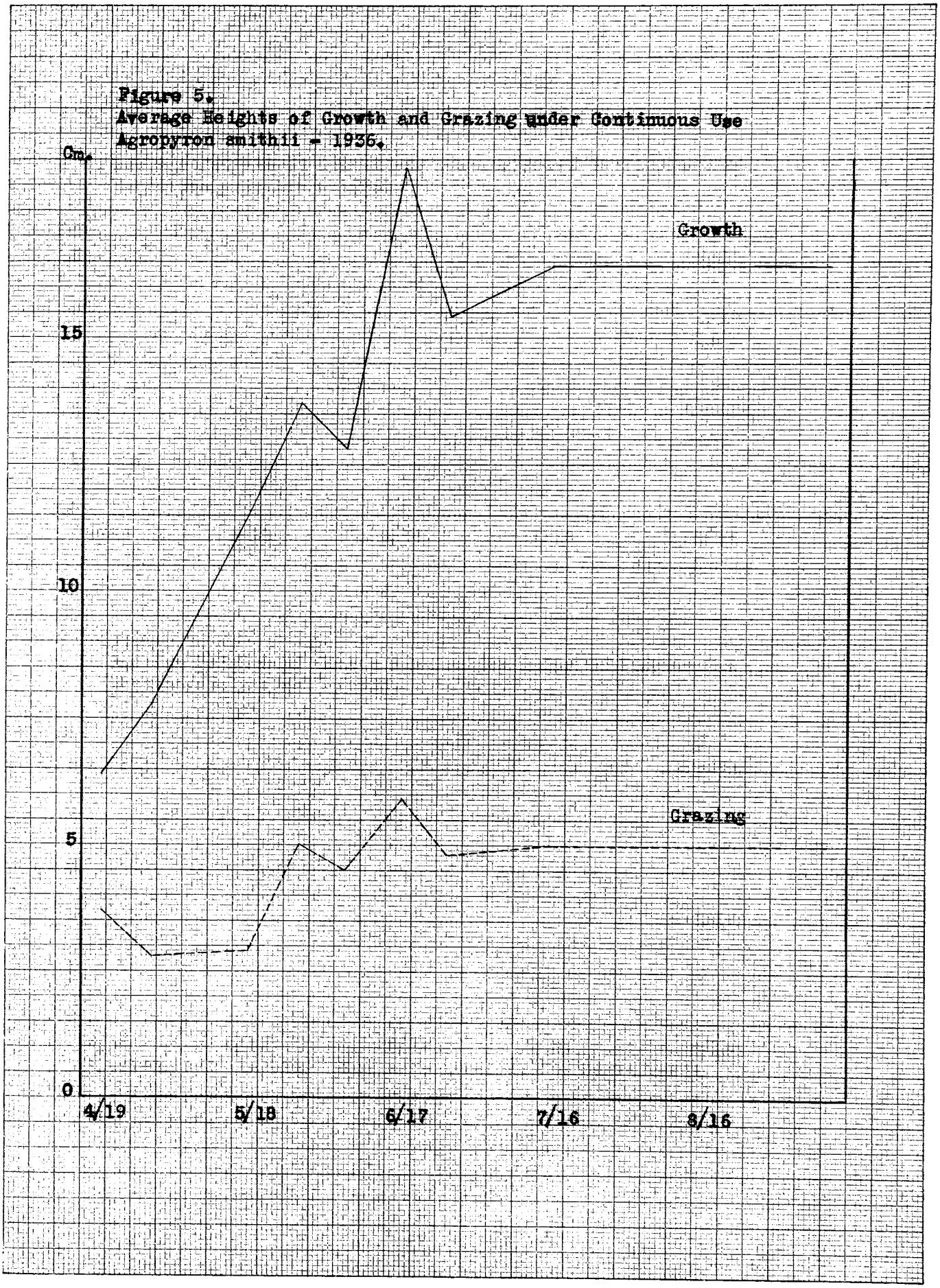


Figure 6.
Average Heights of Growth and Grazing under Continuous Use
Bouteloua gracilis - 1936.

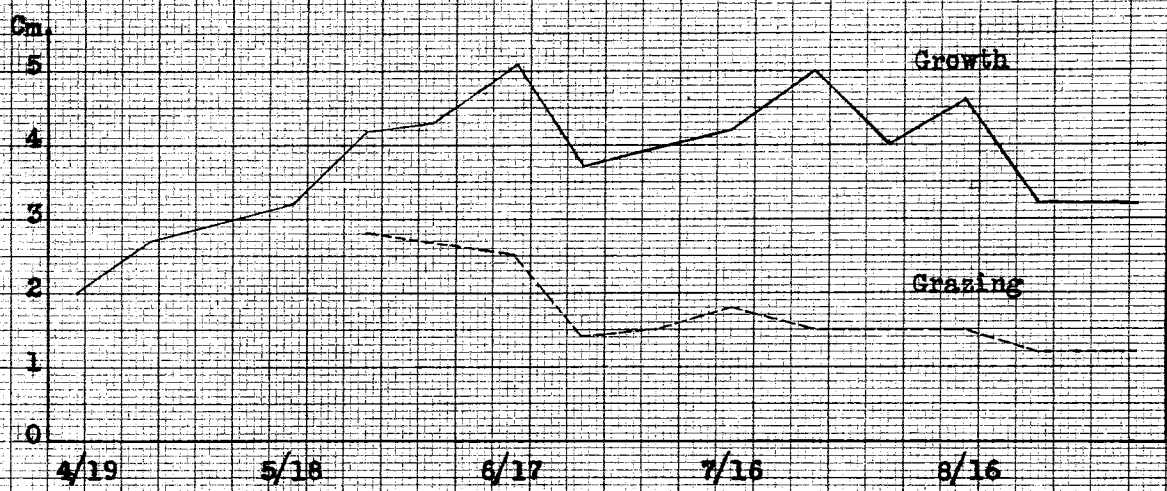
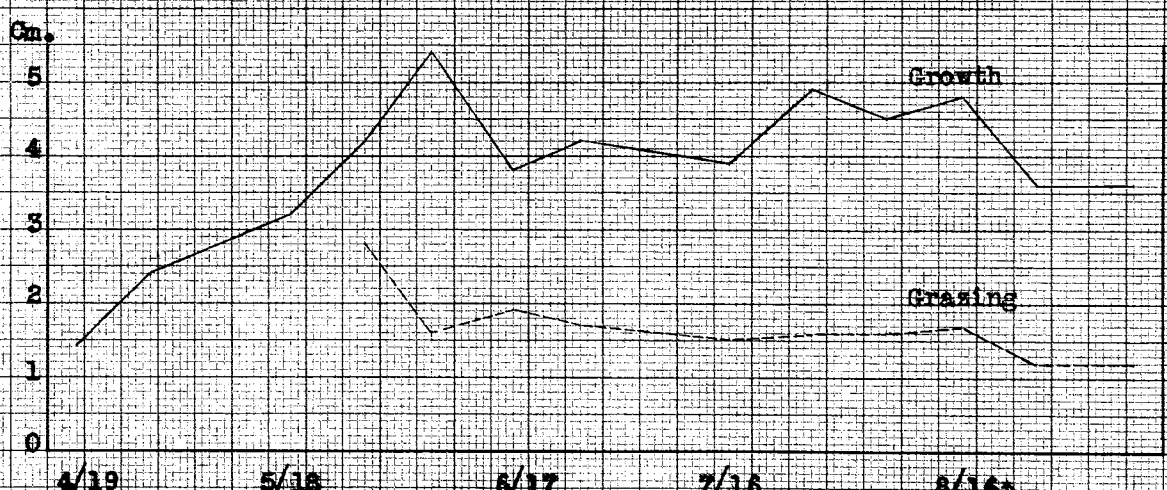


Figure 7.
Average Heights of Growth and Grazing under Continuous Use
Buchloe dactyloides - 1936.



*Leaves badly rolled. They were unrolled for measurement.

Figure 8.
Average Heights of Growth and Grazing under Continuous Use
Aristida longiseta - 1956.

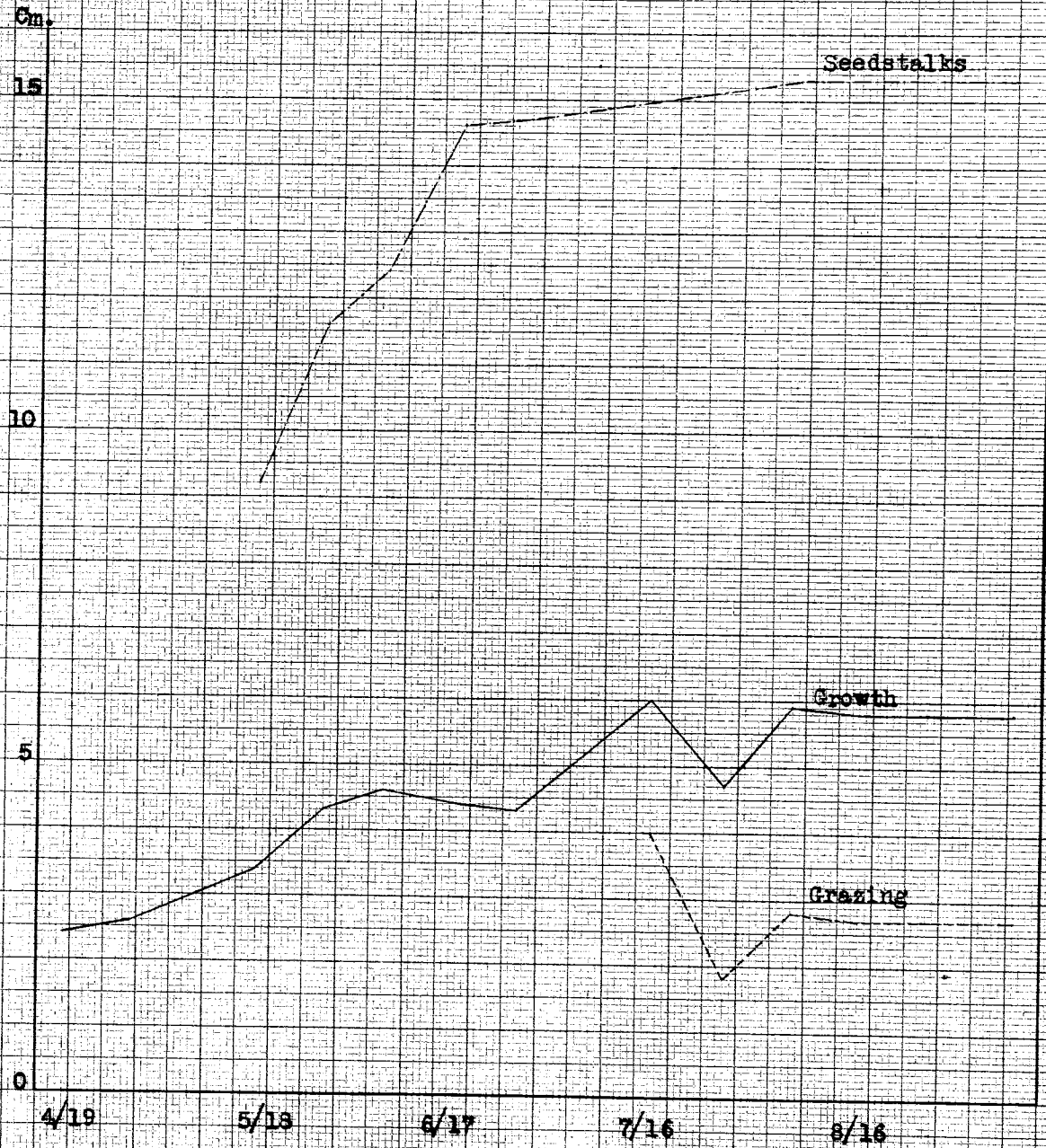
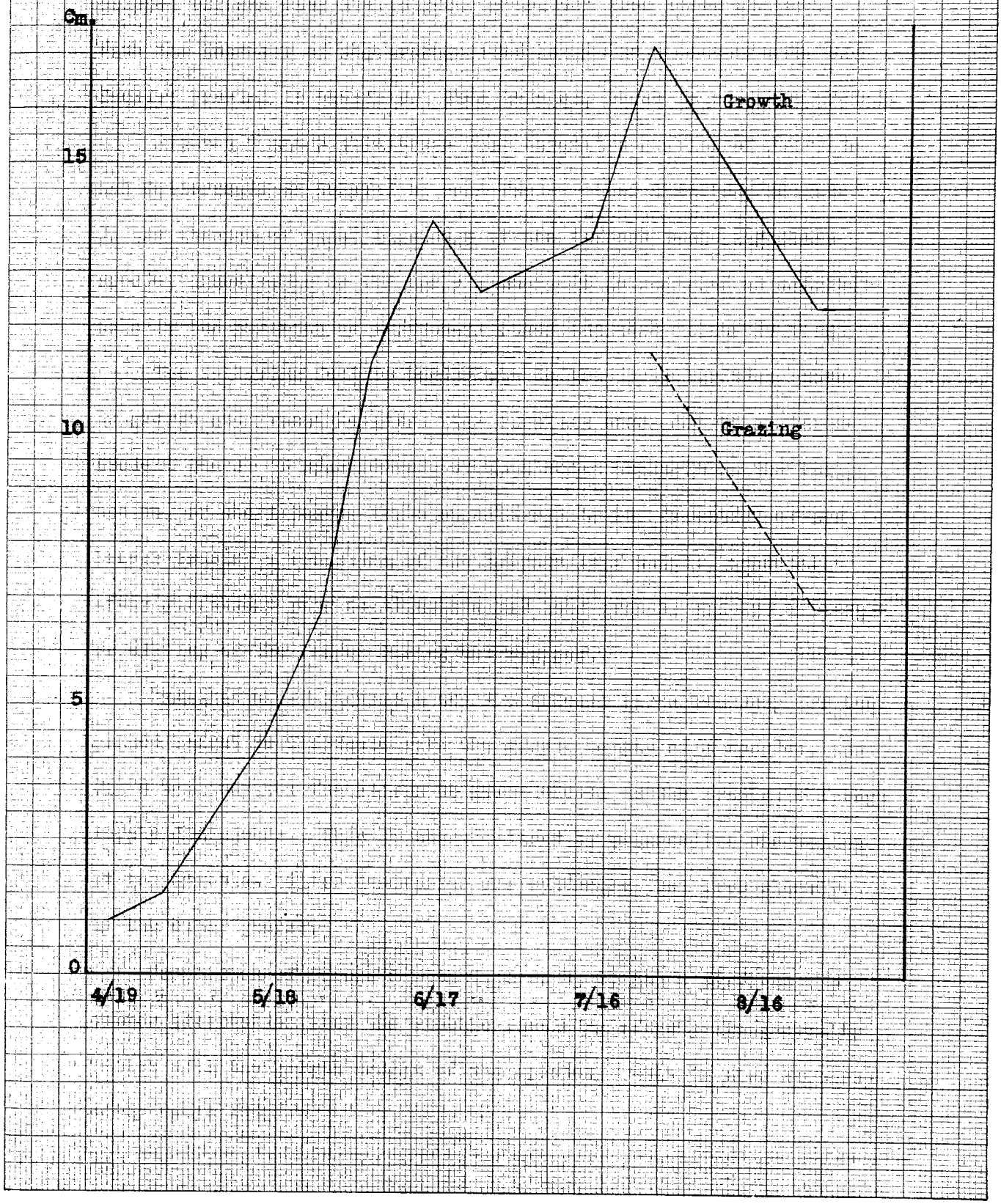


Figure 9.
Average Heights of Growth and Grazing under Continuous Use
Gutierrezia longifolia - 1936.



until the average leaf height is about three centimeters. At that height, grazing is very erratic. Only the tips of the leaves are clipped off and very little food is derived from these grasses. With the increase of the average leaf length to 4 centimeters, effective grazing is possible. From then on, these species are grazed.

Figures 8 and 9 illustrate that extensive grazing of Aristida and Gutierrezia is delayed by some factor other than leaf height. In the absence of exact knowledge of the factors rendering these species undesirable in the early summer, it is regarded as attributable to the presence of sufficient other and more palatable feed.

The following factors contribute to the irregularities shown in growth and grazed heights: (1) sampling error due to an insufficient number of measurements or unbalanced emphasis on the tall, medium, or short leaves found on each plant; (2) formation of new leaves causing a reduction of the average leaf height, especially after sufficient rain to stimulate new leaf growth; and (3) curling or wilting of the leaves during hot weather.

Examination of Figures 6 and 7 discloses (1) a tendency for the grazed height to fluctuate with the growth height of a species, and (2) a tendency for the steers to graze closer as the available forage supply diminishes. This is charactedized by progressive shortening of the stubble. These tendencies are evidenced, but less clearly, by the other graphs.

Comparison of Figure 5 with Figures 6, 7, and 8 confirms the common observation that the stubble remaining after grazing usually varies with the growth height of the species. This is also supported by Table XII.

Table XII.- Utilization, Growth, and Grazed Height of Average Leaf at End of Grazing Period under Different Systems of Use - 1936.

System	Agropyron smithii			Bouteloua gracilis			Buchloe dactyloides		
	Growth	Grazed	Percent Leaf Used	Growth	Grazed	Percent Leaf Used	Growth	Grazed	Percent Leaf Used
	mm.	mm.	%	mm.	mm.	%	mm.	mm.	%
Continuous	167	50	70.1	45	12	73.3	42	12	71.4
Deferred-Rotation (East)*	169	57	66.3	45	11	75.6	43	12	72.1
Deferred-Rotation (West)	273	85	68.9	42	14	66.7	44	14	68.2
Deferred	289	113	60.9	64**	12	81.3**	41	12	70.7
Average			66.6			74.2			70.6

* Heavily used until July 16 but not grazed thereafter.

** Insufficient measurements.

Discussion of Table XII.- It is not altogether correct to regard the indications furnished by Table XII as typical of the different grazing systems under proper utilization. The table should be regarded, rather, as referring to fully utilized ranges in which vegetative vigor and the spring deferred period are the essential differences.

Subject to this qualification, the following inferences are drawn:

(1) Intensive grazing tends to increase the percent of leaf utilization.

(2) Tallness and coarseness of growth of Agropyron tend to reduce percent of leaf utilization.

(3) Tallness of short grasses tends to increase percent of leaf utilization.

(4) Under intensive grazing, Bouteloua is used to the greatest extent, Buchloe next, and Agropyron least.

The last inference would lead to the conclusion that heavy grazing exerted a greater adverse pressure on Bouteloua and Buchloe than on Agropyron. Tables IV and XI, and Figures 5, 6, and 7, however, show that, under continuous use, the short grasses are allowed nearly two months more than Agropyron in which to build up a reserve of energy sufficient to withstand grazing, largely due to their shortness in the spring. This is probably one of the chief factors contributing toward the replacement of Agropyron by Bouteloua and Buchloe under heavy grazing.

Utilization of Individual Species.- The nature of grazing on different species has been indicated by Tables IV and XI. It has been pointed out that utilization might be derived from grazing percent figures in those tables by applying quantitative data to them. The product of the percent of average leaf utilization (Table XII) and the percent of leaves grazed (Table XI) on each species furnishes a close approximation of the utilization of the current season's growth of the species as a whole at any time. The total utilization on each pasture is regarded, this year, as 100 percent of the 'forage within easy reach of stock'. The increments of utilization on each species occuring during ten-day periods shown as percents of the totals utilized thruout the summer furnish a good

Averaged Percent of Total Grazing on Important Grasses
at Ten-Day Intervals
1936.

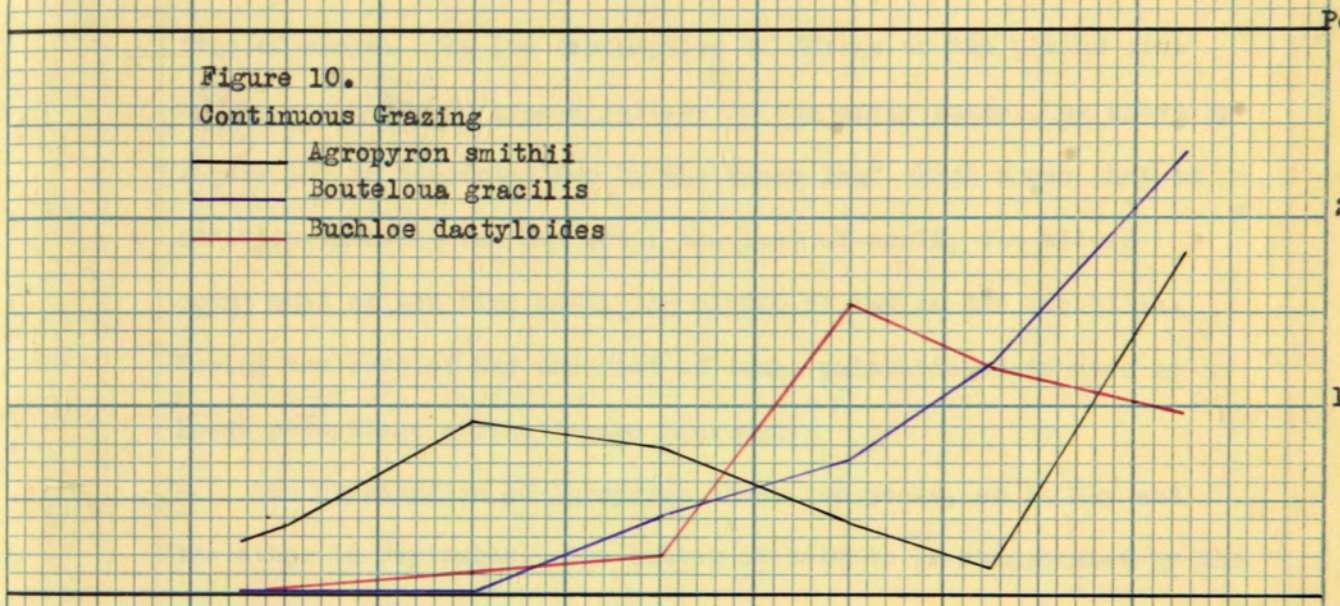


Figure 10.
Continuous Grazing
Agropyron smithii
Bouteloua gracilis
Buchloe dactyloides

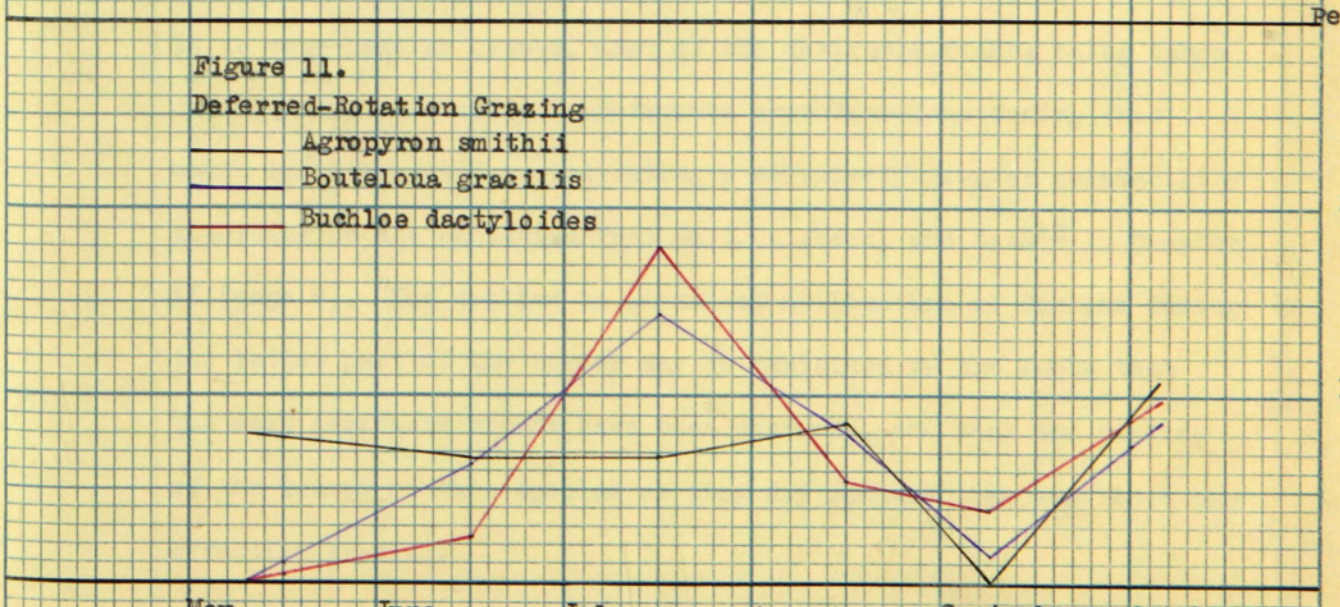


Figure 11.
Deferred-Rotation Grazing
Agropyron smithii
Bouteloua gracilis
Buchloe dactyloides

indication of the nature of grazing.

Figures 10 and 11 illustrate the relative utilization of important grasses by ten-day intervals under continuous and deferred-rotation grazing. Figure 10 is thot to present a rather typical picture of uninterrupted grazing thruout the growing season on this type of range. The low consumption of forage on the plains area of the continuously grazed pasture in the early summer, as shown by Figure 10, is accounted for by the range log[6] which shows that in addition to being fed hay until the last of April, the steers spent most of the time until the middle of May in the foothills. During the rest of May and most of June, palatable weeds made up a large percentage of the forage consumed.

The utilization of Agropyron shows two peaks, on in May and the other in September. The latter is held to be exaggerated by the shortage of feed observed at that time. Bouteloua is grazed in increasing quantity thruout the season and constitutes the main source of feed in the fall. As soon as Buchloe achieve a suitable height, it is very heavily grazed, most of the desirable stands being taken during July. Its evident preference over Bouteloua during this month is interpreted as indicating a relatively greater palatability according to the quotation from Hart, Guilbert, and Goss[13] in Chapter II (page 9). The decline in amount of utilization of Buchloe during the latter part of the summer may be explained by the facts that the most desirable stands have been consumed, and that the curling of the leaves of this species as they dry renders them too short for effective grazing.

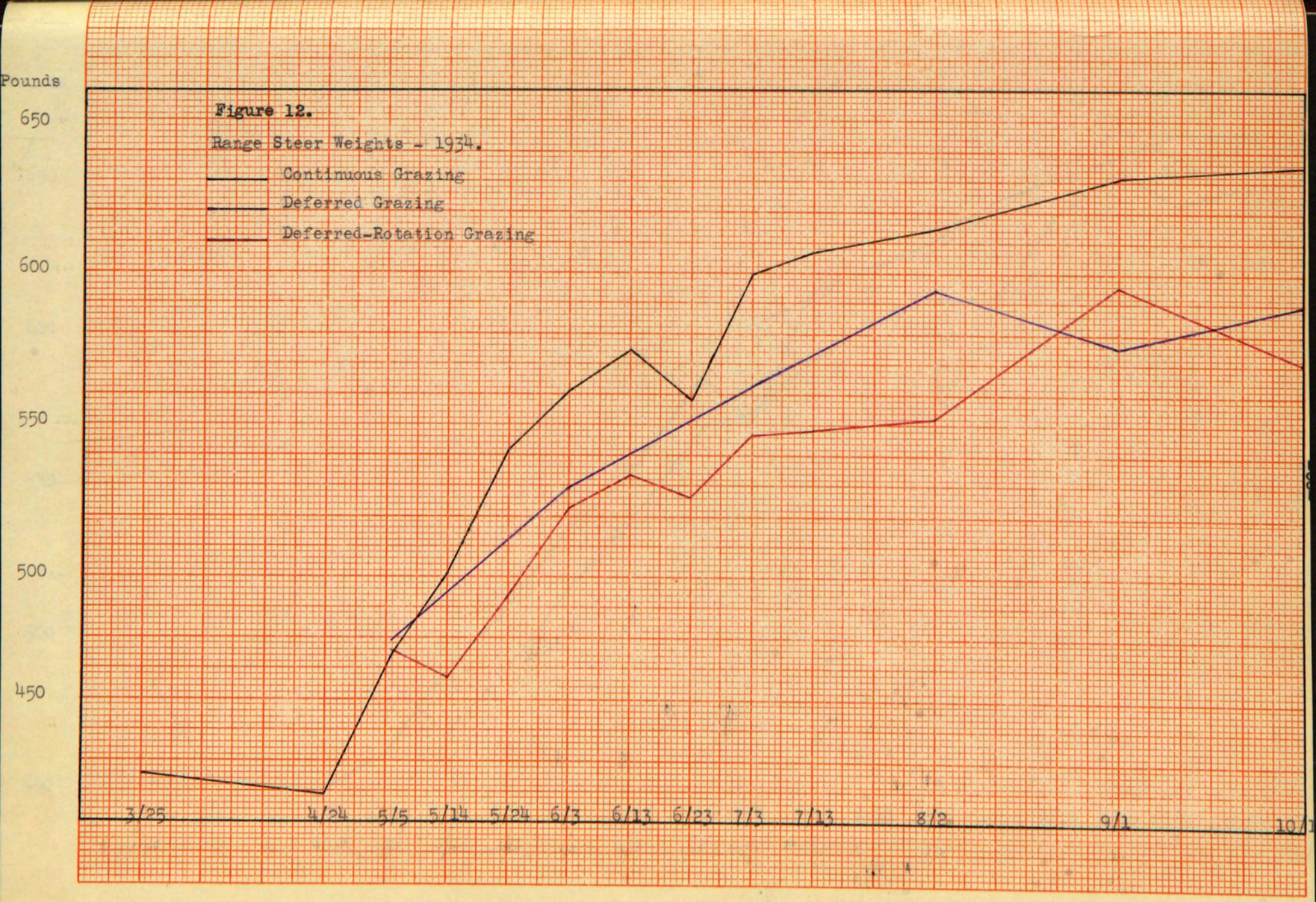
Figure 11 is not thot to be a properly balanced representation

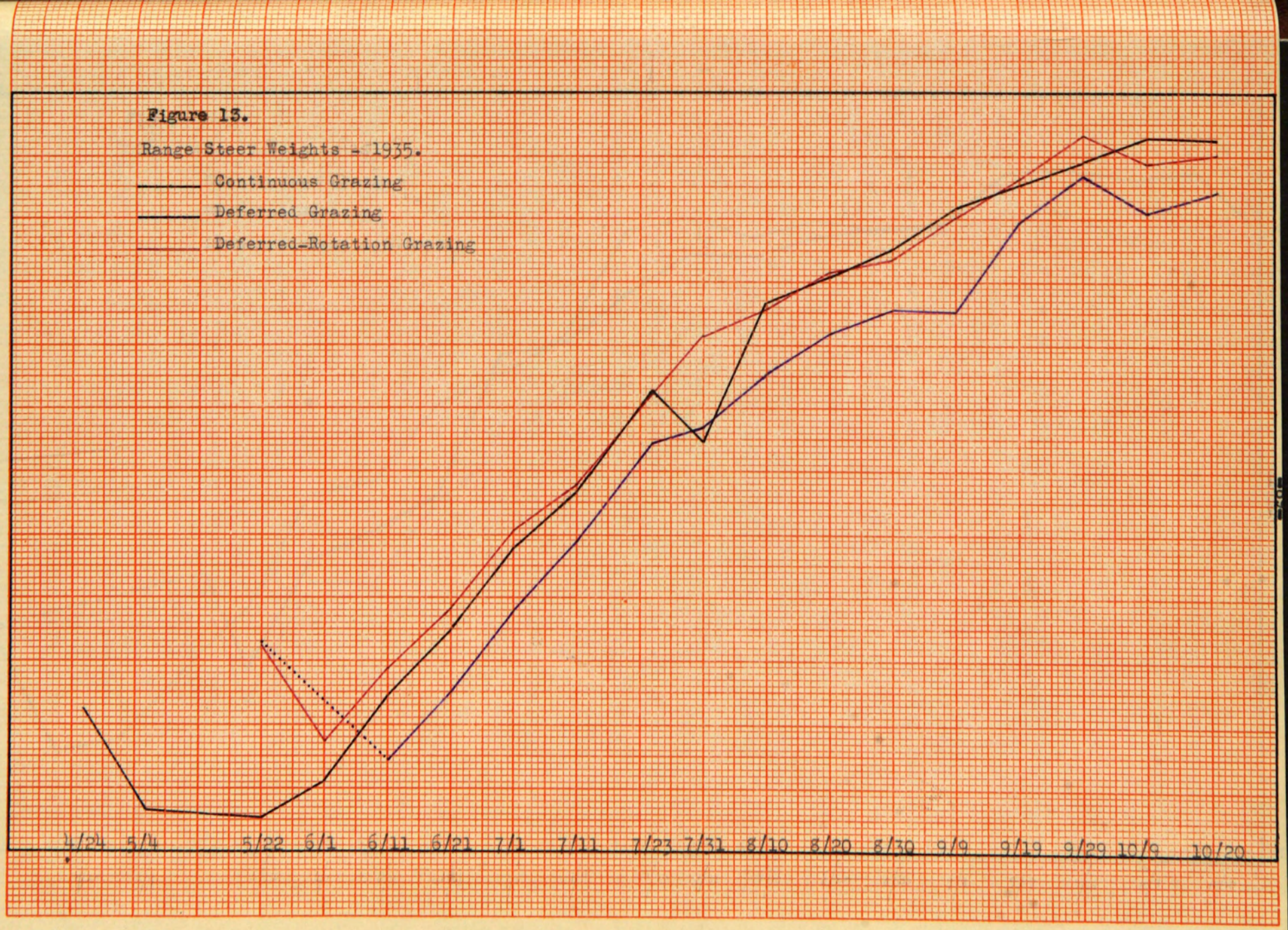
of grazing on the deferred-rotation pasture. After the deferred half was opened, the steers grazed almost exclusively for several weeks on the grass area at the base of the foothills. Later, most of the grazing took place in the chaparral and foothill meadows. Observation quadrats, which were placed only on the lower slopes, seem to yield unreliable results because of poor distribution in the pasture.

A comparison of Figures 3 and 10 discloses that the percentage utilization of Agropyron drops below the percentage utilization of the short grasses very soon after its average crude fiber content rises above theirs. As long as the factor of forage insufficiency is inoperative, crude fiber seems to control the preference of the stock between Agropyron and the short grasses.

The lower fiber content of Buchloe would appear to be strongly associated with its consumption rising to a peak earlier than that of Bouteloua.

Unfortunately, no studies of this nature were conducted on a winter range. It is felt that such an investigation would be highly relevant in determining the effect of crude fiber on palatability of range forage.


Pounds
650
600
550
500
450
Figure 12.
Range Steer Weights - 1934.
Continuous Grazing
Deferred Grazing
Deferred-Rotation Grazing
3/25
4/24
5/5
5/14
5/24
6/3
6/13
6/23
7/3
7/13
8/2
9/1
10/1


Pounds
650
600
550
500
450
Figure 13.
Range Steer Weights - 1935.
Continuous Grazing
Deferred Grazing
Deferred-Rotation Grazing
4/24
5/4
5/22
6/1
6/11
6/21
7/1
7/11
7/23
7/31
8/10
8/20
8/30
9/9
9/19
9/29
10/9
10/20

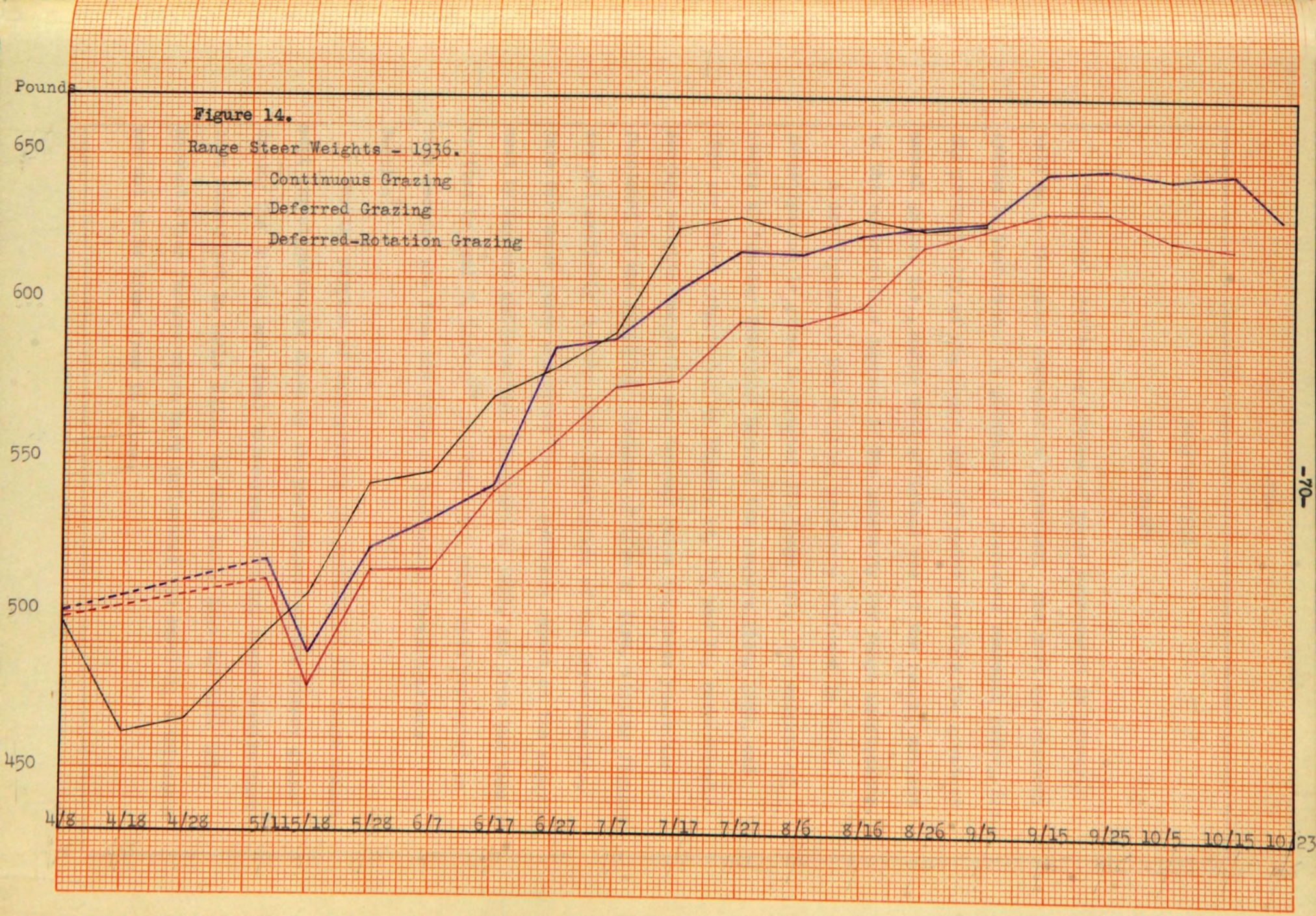


Figure 14.

Range Steer Weights - 1936.

——— Continuous Grazing

——— Deferred Grazing

——— Deferred-Rotation Grazing

CHAPTER VIII

CATTLE GAINS

The final test of any system of range management is properly held to be the gains produced on livestock. The most satisfactory system is that which (1) maintains or increases seasonal gains, i.e., the productivity of the range, and (2) makes possible the greatest annual gains, i.e., makes most efficient use of the range, subject to the restrictions imposed by the necessity for range maintenance.

A description of the weighing procedure followed in this investigation is given in Chapter III (page 15). The weights of steers at ten-day intervals thruout the summers 1934, 1935, and 1936 are shown graphically by Figures 12, 13, and 14, respectively. Average weights and daily and ten-day gains for these years are furnished in the Appendix. Because of loss by fire, similar figures are not available for the first three years of the investigation. Data for these years are taken from a progress report on the experiment by Maynard and McCarthy[1], published in 1924, and from the thesis written by Paul B. Lister[24] in 1922. All other data presented in this section are from the files of the Animal Investigations Section[6].

For the purpose of interpreting the results of the range management investigation as shown by the performance of the steers grazed during the initial and final three-year periods, these results have been summarized in Table XIII. As this table does not take into account other factors which have influenced the results, conclusions are not to be drawn from it alone.

Table XIII.- Summary of Initial and Final Three Year Periods of the Range Management Investigation.

Year of Test	1921			1922			1923		1934			1935			1936		
Range	Center	North	South	Center	North	South	Center	North	South	Center	North	South	Center	North	South	Center	North	South
Method of Handling	Check	Deferred Grazing	Deferred Rotation Grazing	Check	Deferred Grazing	Deferred Rotation Grazing	Check	Deferred Grazing	Deferred Rotation Grazing	Check	Deferred Grazing	Deferred Rotation Grazing	Check	Deferred Grazing	Deferred Rotation Grazing	Check	Deferred Grazing	Deferred Rotation Grazing
Number of Acres	157.0	146.4	228.7	157.0	146.4	228.7	157.0	146.4	228.7	157.0	146.4	228.7	157.0	146.4	228.7	157.0	146.4	228.7
Number of Days Grazed	174	150	150	152	134	134	166	141	141	190	149	149	180	152	152	150	167	157
Number of Steers	17	13	32	17	17	30	19	19	28	25	(25)* 23	35	25	(25)* 22	(35)* 34	25	25	(34)* 33
Steer Days on Range	2958	1950	4800	2584	2278	4020	3154	2679	3948	4529	3549	5250	4500	3054	5230	3750	4125	5277
Acres per Head	9.2	11.3	7.2	9.2	8.6	7.6	8.3	7.7	8.2	6.3	5.9	6.5	6.3	5.9	6.5	6.3	5.9	6.7
Average Initial Weight	5/3 689.4	5/27 757.6	5/27 773.3	5/19 433.9	6/6 460.9	6/6 456.8	5/4 456.5	5/4 496.3	5/4 478.5	3/25 435.5	5/5 478.9	5/5 475.3	4/24 484.9	5/22 505.9	5/22 504.5	4/8 497.0	5/11 517.8	5/11 511.4
Average Final Weight	10/24 1005.6	10/24 1036.5	10/24 1011.9	10/17 693.8	10/17 703.2	10/17 675.3	10/17 755.2	10/17 742.6	10/17 722.0	10/1 635.0	10/1 589.6	10/1 570.7	10/19# 673.4	10/19# 652.1	10/19# 674.7	9/5 628.5	10/15 631.0	10/23# 621.2
Average Gain per Head	316.2	278.9	238.6	259.9	242.3	218.5	318.7	246.3	243.5	199.5	110.7	95.4	188.5	146.1	170.3	131.5	130.6	109.8
Average Daily Gain	1.82	1.86	1.59	1.71	1.81	1.63	1.92	1.75	1.73	1.05	0.74	0.64	1.05	0.97	1.13	0.88	0.69	0.70
Total Lot Gain	5375.4	3625.7	7635.2	4418.3	4119.1	6555.0	6055.3	4679.7	6818.0	4986.8	2545.2°	3339.7	4712.5	3215.0°	5785.0°	3287.5	2830.0	3623.3°
Pounds Gain per Acre	34.2	24.8	33.4	28.1	28.2	28.8	38.4	32.0	29.7	31.8	17.4°	14.6	30.0	22.0°	25.3°	20.9	19.3	15.8°

* Original number; others removed or died during summer.

° Number of animals reduced; see above.

\# Single weighing.

Discussion of Table XIII.- If the length of the grazing season is taken into account, the different systems of use can be compared with each other by the average gains produced or by daily gain per head. Comparison is possible by total lot gains if allowance is made for length of grazing season and difference in numbers of animals.

The productive trends of the pastures under different grazing systems can be determined by comparison of the initial and final records of the same pastures. Here also, allowance must be made for changes in the rate of stocking.

Both comparisons are based on the assumption that all extraneous factors affect the different pastures to the same extent.

It should be noted that the grazing systems cannot be compared properly by the gains produced per acre because of the original inequality of the vegetation which was theoretically eliminated by stocking the ranges on an equal forage acre basis. This figure is included for determination of the trends of productivity, and to furnish a practical indication as to the value and type of range used in the investigation.

MAINTENANCE OF RANGE PRODUCTIVITY

The maintenance of at least the original level of productivity of the range is obviously the most important single consideration to be dealt with by any system of range management.

Table XIII shows conclusively that there has been a decided decrease in the productivity of every pasture during the course of the sixteen year experiment. In the following comparisons, the results obtained in 1921 are omitted because of unbalanced stocking

and because older animals were used. The average of 1922 and 1923 is compared with that of 1934, 1935, and 1936 in order to minimize the individuality of single seasons.

Total lot gains constitute the most unassailable measure of pasture productivity. Table XIII shows that the production of the continuous, deferred, and deferred-rotation pastures by this standard has been reduced to 82.6, 65.2, and 63.5 percent, respectively, of the original level. It should be recognized, however, that the requirements for maintenance of stock have been increased by the larger numbers of animals and longer average grazing periods in the last three years. This is illustrated by the increase in steer days on pasture shown by the summary table.

Assuming the size of each pasture had remained constant as shown in the table, gains per acre would have shown exactly the same reduction as total lot gains. Actually, there has been an increase in the grazing area on the middle pasture caused by the drying of the lake over a period of years. The extent of this increase has not been measured from year to year.

Rate of gain as expressed by the average daily gain is a less satisfactory measure of productivity because it is greatly affected by lengthening the grazing period. It is, tho, a very important factor. Reduction in daily gains has amounted to 45, 55, and 51 percent of the original amounts on the continuous, deferred, and deferred-rotation pasture, respectively.

Factors Influencing Range Productivity.- Incomplete data on ungrazed controls thruout the course of the experiment makes it impossible to determine the extent to which overgrazing is responsible

for the decrease in the productivity of the pastures. It is certain that the reduction of precipitation has been an extremely important factor in producing the difference in gains apparent between the 1922-23 and 1934-35-36 averages. Meteorological reports[25] show that the average precipitation for the first three-year period was 16.8 inches and that for the last three-year period, it was but 12.2 inches. This 27.4 percent reduction, based on three-year averages, in a semiarid region might be sufficient to account for the greater part of the reduction in gains. Until 1928, the normal precipitation at Fort Collins maintained an average of over 15.0 inches a year. Continued low annual precipitation has reduced the fifty year norm to 14.7 inches in 1936. It is logical to assume that reduced vegetation is a natural result.

During 1934 and 1936, grasshoppers became sufficiently numerous to further reduce the supply of forage available to the steers. There is no record of similar invasions in the early years of the experiment.

Effects of Grazing Systems.- The results in the first three years of the experiment indicate that distinct advantages are possessed by the continuous system of grazing in the middle pasture. Comparison of the extents to which productivity has been reduced on the various pastures shows that this pasture has suffered least. This is altogether contrary to observation and vegetation studies. An explanation is to be found in the maps (Figures 1 and 2) prepared in 1921 and 1936 and in the range log[6]. The lake in the middle pasture, reacting to the reduced annual precipitation, has retreated to little more than half of its original area. The moisture condi-

tions on the area uncovered have encouraged the growth of a dense stand of Distichlis spicata and Hordeum jubatum. The range log indicates that nearly one half of the 1936 grazing season was spent in this lake area. Quadrat data show that after complete utilization of the Distichlis during early August, the steers consumed practically all the normally unpalatable Hordeum after it had ripened.

In view of this knowledge, cattle gains on this pasture must be discarded as a criterion of range maintenance. Upon the basis of vegetation studies and observation, the continuously grazed pasture is found to have least satisfactorily accomplished the prime requisite of range maintenance.

The three-year average total lot gain of the north pasture steers is lowered by the loss, in 1935, of three poisoned animals. A further loss of gain was occasioned by the removal of these steers to another pasture where they were barely maintained for two weeks. Figure 13 shows that they were unable to make up this loss of gain. In spite of these handicaps, Table XIII shows that deferred grazing on the north pasture has maintained its productivity at a relatively higher level than has been maintained by deferred-rotation grazing on the south pasture.

SEASONAL EFFICIENCY OF GRAZING SYSTEMS

Without considering the restrictions necessitated by the maintenance of range productivity, it is apparent from an examination of Table XIII that the largest average total gain per head has been produced under the system of continuous grazing with deferred grazing in second place and the rotation system last. This is partly due to the longer season. However, in average daily gains, the same

ranking holds true in the averages and in most years. An exception is made for the deferred lot for reasons given above.

The nature of conditions resulting in greatest seasonal gains is suggested by Figures 12, 13, and 14. Most rapid gains are shown to have been made early in the summer. In 1934 and 1936, very little gain was made after the middle of July. From this, it would appear that, provided there remained enough feed to prevent losses in the fall, the system which allowed the cattle the most time on the spring range would enable them to make both largest seasonal and daily gains. Table XIII shows that such gains have been made under continuous grazing, and Figures 12 to 14 indicate that the longer spring period of more rapid gains provides the agency by which they have been made.

Comparison of Figures 12, 13, and 14 shows that the deferred-rotation system is inferior to deferred grazing as indicated by average gain per head. Table XIII further bears out this conclusion by showing that range productivity has been kept at a higher level under the deferred grazing system.

Factors Influencing Cattle Gains.- Figures 15 and 16 have been constructed to show the rate of gain in pounds per ten-day period thruout the grazing seasons 1935 and 1936.

Cattle gains are to be regarded as the resultant of a number of factors. The influence of variations in these factors may be expressed in (1) amount of gain, and (2) rate of gain. A number of these factors such as number of cattle, water and salt supply, shelter, original forage supply, and those discussed under the heading "Cattle Allotments" (page 16) have been controlled. A dis-

cussion of some other factors affecting the gains is presented.

(1) Shrink and Fill.- As has been mentioned previously, the factors of shrink and fill may be responsible for large apparent fluctuations in cattle weights. Unless some environmental condition can obviously be held responsible for the irregularities in the growth curves shown by Figures 12 to 14, these irregularities are regarded as being due to unequal shrink or fill. Water plays the largest part in creating them.

That this interpretation is correct is indicated by the abnormal increase in gains generally following a period of such depression. It is probable that by eliminating the weights shown by these apparent shrinks, a truer picture of growth might be attained.

The marked loss of weight indicated by these graphs immediately following the turning of the steers on the range is occasioned by scouring due mainly to the washiness of the young green grass. The initial weights of the steers were taken at the feedlot. Some loss is caused by driving the steers four miles to the range after they have been weighed.

The losses shown at the termination of the grazing seasons have two possible explanations: (1) shrink, caused by severe weather, snow, etc., and (2) actual loss of weight due to forage insufficiency. Only in 1936 has a condition been reached when there might be said to be insufficient forage for maintenance. In this year, the stock was removed before any severe losses could take place.

(2) Precipitation.- Comparison of the average gains per head as shown by Table XIII with total annual precipitation (Table XIV, Appendix) shows that greatest gains have been made, usually, in years

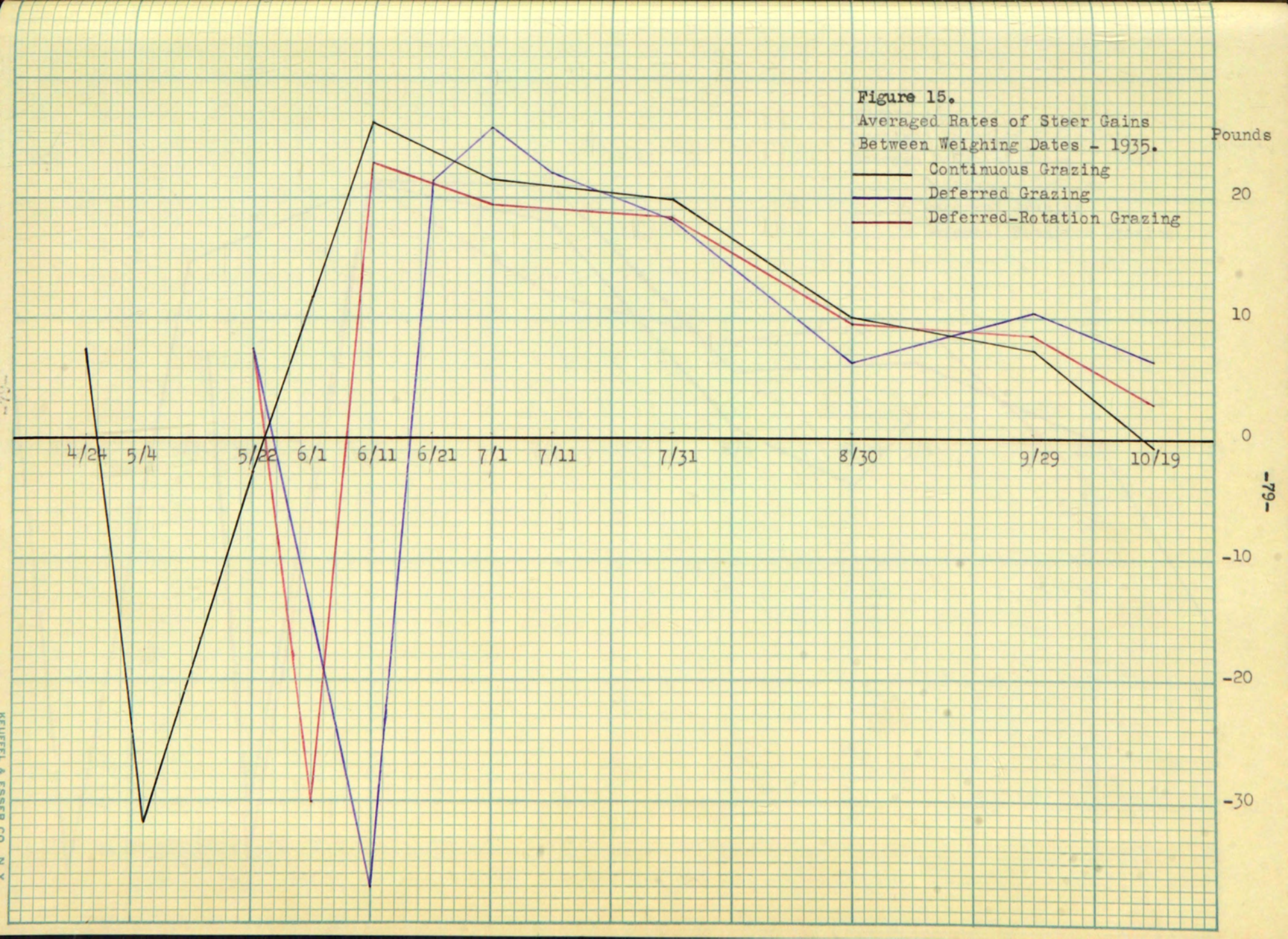


Figure 15.
Averaged Rates of Steer Gains
Between Weighing Dates - 1935.
Continuous Grazing
Deferred Grazing
Deferred-Rotation Grazing
Pounds
20
10
0
-10
-20
-30
4/24
5/4
5/22
6/1
6/11
6/21
7/1
7/11
7/31
8/30
9/29
10/19

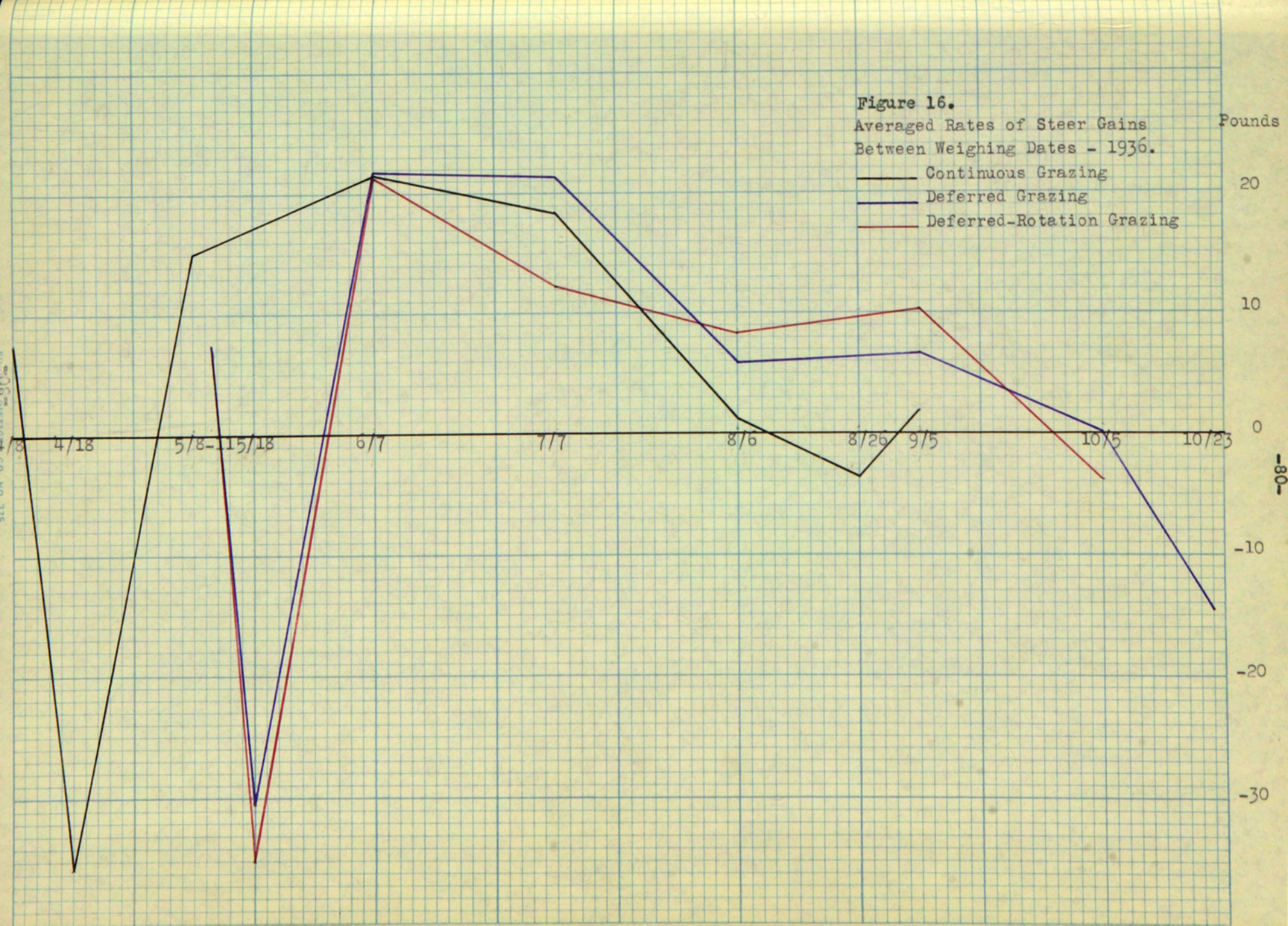


Figure 16.
Averaged Rates of Steer Gains
Between Weighing Dates - 1936.
Continuous Grazing
Deferred Grazing
Deferred-Rotation Grazing
Pounds
20
10
0
-10
-20
-30
4/18
5/8-15/18
6/7
7/7
8/6
8/26
9/5
10/5
10/23

of greatest precipitation. This is to be expected when the range is normally utilized to or beyond the proper amount as the immediate effect of precipitation on forage yield directly determines the amount of gains which can be produced.

No detailed study was made to determine the effect of the seasonal distribution of moisture. It is significant that the steer weights of 1935 (Figure 13) show continued gain after the middle of July. Table XV shows an unusually high summer precipitation with 6.71 inches in May and 3.29 in September of that year. The explanation is probably to be found in renewed vegetative growth as reported by Hanson et al[3] (page 20) and the greater gains shown by Figures 12, 13, and 14 to be made during the period of most active growth.

(3) Plants Grazed.- Comparison of Figures 10 and 16 indicates that while most gain is made during the time Agropyron is most heavily grazed, high gains are sustained for a time after Bouteloua and Buchloe form the major portion of the forage consumed. The indication is, then, that the stage of development of the plant is more important than the species.

(4) Chemical Composition of Forage.- On the assumption that, from a grazing standpoint, changes in chemical composition are the essential differences between plants in different stages of development, stage of growth and forage analyses are treated under the heading of chemical composition.

It was suggested, in the discussion of the chemical analyses presented in Table IX, that chemically, the range forage was shown to fall in three periods during the entire year. The spring and

summer periods fall within the grazing season for steers during this experiment. Figures 15 and 16 show that the rate of gain shows a high and low period corresponding quite well in point of time with the limits of the spring and summer periods suggested by the chemical analyses.

The period of rapid spring gains does not terminate sharply with the decline in protein or increase in fiber shown by Table IX. Since all plants do not ripen at the same time, and since steers select the greener, more palatable leaves, such a lag is to be expected. The period of summer gains agrees much better with that indicated by Table IX in termination. This, also, is to be expected since cold weather ends all plant growth within a short time.

Since intake of dry matter varies within much narrower limits than that of green material, the results of Table IX are most applicable to this discussion. It is apparent that highest gains are correlated with highest protein and lowest fiber contents of the forage, and that gains are lowered as protein decreases and fiber increases. As ash remains about constant and the sum of the protein and fiber contents is greatest in the spring, crude fat and nitrogen-free extract must increase as the summer advances. This is opposite to the change in gains and would indicate that gains are more affected either by amount of crude protein, or by total nutrients.

Considering that the variation in total nutrients is not a wide one, and that the variations shown by gains and crude protein are both relatively wide and occur at the same time, it is most probable that chemical factors determining gains rank in the following order: (1) crude protein, (2) total nutrients, and (3) moisture

(succulence) to whatever extent it determines the amount of food eaten.

CHAPTER IX

SUMMARY

The conclusion in 1936 of a sixteen year investigation in range management by the Animal Investigations and Botany Sections of the Colorado State Agricultural Experiment Station provided an unusual opportunity for original study on the effects of different systems of range use. The objects of the investigation were (1) to study the effect of early spring protection in building up the vitality and increasing the production of range grasses, and (2) to determine the value of a management system including early protection of forage grasses plus systematic rotation of cattle on typical low foothill range in Colorado. The present thesis resolves into a study of some of the specific effects of continuous, deferred, and deferred-rotation systems of grazing, and the tracing of these effects to their culmination in cattle gains.

Specifically, the following studies have been made:

(1) A detailed survey of the more important plants on large comparable areas of the pastures under the different systems of use, including the following phases:

   (a) Rate and amount of growth of average plants.

   (b) Extent and nature of the stand of different species.

(2) A study of the effects of the different systems of use on the growth, distribution, and perpetuation of the important grasses, based on comparison of recent vegetational records with older records.

(3) A study of grazing by steers upon the different plants at

different periods thruout the year, and of some of the factors affecting grazing.

(4) A series of chemical analyses on the major forage grasses, and a study of some of the inter-relations between chemical composition and intensive grazing.

(5) Analysis of cattle weight records and their relation to other information obtained.

Cattle weights show very definitely that the productivity of all experimental pastures has been decidedly reduced during the course of the experiment. The intensive utilization of these pastures has tended to clarify the results, and to indicate, more positively than otherwise possible, the relative merits of the different grazing systems.

Vegetational data are not sufficiently complete on ungrazed control areas to ascertain positively to what extent overgrazing has contributed to the reduced productivity of the range. These data do, however, show the changes which have taken place on the range, and indicate the nature of plant succession under such conditions.

Cattle records show that continuous grazing allows stock to make most efficient use of the seasonal forage growth with the result that larger daily and seasonal gains are produced. Deferred grazing is shown to have resulted in consistently greater production than deferred-rotation grazing. The advantage of the continuous system appears to lie in the fact that the stock is allowed a longer period on the more nutritious green forage. In addition, the stock is enabled to keep the range grazed down, delaying the

maturity of the taller plants.

However, evidence of quadrat studies of the vegetation shows that the continuous grazing of the taller, higher-yielding grasses results in a reduction of the size of the clumps followed by gradual elimination. The area is then occupied by weeds. These, in turn, are crowded out by Bouteloua and Buchloe. These short grasses will slightly increase the density of the vegetative cover, but not enough to overcome the disadvantage of the lower yield.

Chemical analyses show that during the spring months, the major grasses carry a high protein and a low fiber content. During the summer, protein decreases and fiber increases until the winter period in which the protein remains at a low percent, while the fiber is at its highest. Total nutrients vary inversely with the fiber. An analysis of cattle gains shows that the period of most rapid growth coincides with the spring period of the forage, and that reduced growth accompanies the summer period of less nutritious forage.

Quadrat data show that Agropyron supplies the main portion of the forage consumed during the spring and early summer. During July, it is largely replaced by Bouteloua and Buchloe. From the early part of August on, Bouteloua is grazed most heavily. Shortage of desirable forage in the fall leads to further utilization of Agropyron, together with the less desirable portions of Bouteloua and Buchloe.

Chemical analysis indicates that the crude fiber content of Agropyron is lower and that its succulence is greater than in the short grasses until the latter part of June. Grazing studies indicate that utilization of the short grasses excedes that of Agropyron shortly

after its fiber content becomes higher. These studies indicate that, after maturity has been reached, Buchloe is preferable to Bouteloua, which, in turn, is preferred to Agropyron. The short grasses must, however, attain an average height of nearly four centimeters before they can be effectively grazed.

Bouteloua and Buchloe are too short to graze until nearly two months after growth starts. This, together with the reduction of competition from the taller grasses, may account for their being favored by intensive grazing.

Cattle records indicate that continuous grazing has best maintained the range, but because of uncontrollable factors, these results must be discarded. Vegetational records show conclusively that the continuously grazed range has been most seriously depleted.

On this type of range, deferred-rotation grazing is shown, both by cattle and vegetational records, to be inferior to deferred grazing. A probable explanation is that altho seed production is obviously favored by rotational grazing, reproduction by seeds is comparatively unimportant on this range in most years while vegetative reproduction is most common. The concentration of all the stock on half the area of the pasture until seed maturity is reached on the other half results in very severe grazing with a reduction of plant vigor upon which vegetative reproduction is so dependent.

Deferred grazing appears to have improved the range type by allowing the spread of Agropyron at the expense of Bouteloua, and at the same time it has produced satisfactory gains. In this investigation, it has proven the most desirable system.

CHAPTER X

CONCLUSIONS

The following conclusions apply to a fully stocked range of the type found along the low foothills in Colorado under moisture conditions similar to those near Fort Collins:

(1) Early spring protection is essential to the maintenance of the range.

(2) The rotational system of range management for the purpose of allowing increased reproduction by seed is not a beneficial practice.

(3) A conservative basis of stocking, together with spring protection of the range, will furnish the most satisfactory grazing system.

(4) Too intensive grazing, whether spring protection is furnished or not, results in a decrease in vegetative vigor and production of all grasses.

(5) Grazing continuously from the inception of growth in the spring temporarily produces the largest gains but results in a deterioration of the range.

(6) Deterioration of the Agropyron type of range is characterized by a reduction in size and vigor of the individual plant, followed by gradual elimination. The abandoned area may be invaded by weeds. It is finally occupied by Bouteloua gracilis and Buchloe dactyloides.

(7) The replacement of Agropyron smithii by Bouteloua and Buchloe results in a great reduction of the amount of available

forage produced.

(8) Amount and distribution of precipitation greatly influence the amount of gains made on the range.

(9) Most rapid gains are made during active growth of the range plants. This accounts for the high gains made under continuous grazing.

The following conclusions are based on the results of studies conducted during a single season and are not to be regarded as final:

(10) Gains are more dependent on the maturity of the plants grazed than on the species.

(11) During spring and early summer, height largely controls the amount of grazing on palatable species.

(12) When all palatable vegetation is high enough to be effectively grazed, succulence and fiber content largely control the forage preference of cattle.

(13) After maturity, the crude fiber content of the forage appears to be the most important single factor determining the forage preference of cattle.

(14) Quantity of crude protein does not seem to be an important factor in determining forage preference.

(15) On an oven-dry basis, the important forage grasses show three distinct periods of chemical composition: (1) a spring period of high protein and low fiber; (2) a summer period of lower protein and increasing fiber; and (3) a winter period of lowest protein and increasing fiber.

(16) A period of high cattle gains corresponds with the period of high protein and low fiber contents of range plants. Reduced

gains accompany the reduced nutritional value of forage during the summer.

(17) The reduction in gains as the season advances is due to (1) reduction of protein in the feed, (2) reduction of total nutrients in the feed, (3) reduced consumption following the decrease in succulence, and (4) reduced digestibility of the feed. On an overstocked range, shortage of feed will cause a further reduction.

(18) Overgrazing has caused no significant change in the chemical composition of the major grasses.

BIBLIOGRAPHY

1. Maynard, E. J. and McCarty, E. C.
Progress Report on Range Management Investigations, 1924.
Mimeographed Circular, Colorado Agricultural Experiment Station.

2. Department of Range and Pasture Management, Colorado State College.
Unpublished Data.

3. Hanson, Herbert C., Love, Dudley L., and Morris, M. S.
Effects of Different Systems of Grazing by Cattle Upon a Western Wheatgrass Type of Range.
Bul. 377, Colorado Agricultural Experiment Station, 1931.

4. Morrison, F. B.
Feeds and Feeding.
The Morrison Publishing Company, Ithaca, New York, 1936.

5. Morris, M. S.
Unpublished Data

6. Animal Investigations Section, Colorado Agricultural Experiment Station.
Unpublished Data.

7. Hopper, T. H. and Nesbitt, L. L.
The Chemical Composition of Some North Dakota Pasture and Hay Grasses.
Bul. 236, North Dakota Agricultural Experiment Station, 1930.

8. Knight, Henry G., Hepner, Frank E., and Nelson, Aven.
Wyoming Forage Plants and Their Chemical Composition, Studies Nº 4.
Bul. 87, Wyoming Agricultural Experiment Station, 1911.

9. McCreary, O. C.
Wyoming Forage Plants and Their Chemical Composition, Studies Nº 9.
Bul. 184, Wyoming Agricultural Experiment Station, 1931.

10. Green, Jesse
Composition of Montana Feeds and Forages.
Bul. 283, Montana Agricultural Experiment Station,

11. Catlin, C. N.
Composition of Arizona Forages with Comparative Data.
Bul. 113, Arizona Agricultural Experiment Station, 1925.

12. Christensen, F. W. and Hopper, T. H.
Effect of Weathering and Stage of Maturity on the Palatability and Nutritive Value of Prarie Hay.
Tech. Bul. 260, North Dakota Agricultural Experiment Station, 1932.

13. Hart, G. H., Guilbert, H. R., and Goss, H.
Seasonal Changes in the Chemical Composition of Range Forage Plants and Their Relation to Nutrition of Farm Animals.
Bul. 543, California Agricultural Experiment Station, 1932.

14. Willard, H. S.
Factors Influencing the Palatability of Hay.
Bul. 199, Wyoming Agricultural Experiment Station, 1933.

15. Graves, R. R., Dawson, J. R., Kopland, D. V., and Moseley, T.W.
Feeding Value for Milk Production of Pasture Grasses When Grazed, When Fed Green, and When Fed as Hay or Silage.
Tech. Bul. 381, United States Department of Agriculture.

16. Sampson, Arthur W.
Plant Succession in Relation to Range Management.
Bul. 791, United States Department of Agriculture, 1919.

17. Sampson, Arthur W.
Range and Pasture Management.
John Wiley and Sons, New York, 1923.

18. Sarvis, J. T.
Effects of Different Systems and Intensities of Grazing Upon the Native Vegetation at the Northwest Plains Field Station.
Bul. 1175, United States Department of Agriculture, 1923.

19. Jardine, J. T., Lindgren, H. A., and Potter, E. L.
Management of Range Grazing Land.
Bul. 397, Oregon Agricultural Extension Service, 1927.

20. Blizzard, W. L., Hawkins, E. L., and Kiltz, B. F.
Management of Native Pastures.
Biennial Report, Oklahoma Agricultural Experiment Station, 1934.

21. Campbell, R. S.
Plant Succession and Grazing Capacity on Clay Soils in Southern New Mexico.
Jour. Agr. Res. , Vol. 43, No. 12, Dec 15, 1931, pp. 1027-1051.

22. Forsling, C. L. and Storm, Earle V.
The Utilization of Browse Forage on Summer Range for Cattle in Southwestern Utah.
Circ. 62, United States Department of Agriculture, 1929.

23. Jardine, James T. and Forsling, Clarence L.
Range and Cattle Management During Drought.
Bul. 1031, United States Department of Agriculture, 1922.

24. Lister, Paul. B.
A Study of Beef Production on a Low Range of Colorado.
Thesis, Colorado State College, 1922.

25. Caperton, Harry O.
Meteorological Reports.

APPENDIX

Table XIV.- Annual Precipitation.

Year	Total	Normal
1920	11.65	15.05
1921	14.83	15.01
1922	9.98	14.88
1923	25.57	15.18
1924	10.64	15.07
1925	14.50	15.05
1926	13.56	15.02
1927	15.77	15.03
1928	13.54	15.00
1929	13.73	14.98
1930	15.17	14.97
1931	9.88	14.89
1932	12.79	14.85
1933	15.65	14.87
1934	8.87	14.74
1935	15.95	14.77
1936	11.79	14.71

Table XV.- Monthly Precipitation.

Month	1934	1935	1936	1935 Normal
Jan.	.01	.07	.04	.39
Feb.	1.11	.89	.39	.62
March	.71	.21	.71	.99
April	1.41	1.24	1.17	1.99
May	1.92	6.71	1.10	2.90
June	1.25	.62	2.92	1.54
July	1.33	1.14	.95	1.70
Aug.	.28	.50	1.46	1.35
Sept.	.79	3.29	1.11	1.26
Oct.	.00	.62	1.38	1.09
Nov.	.06	.66	.18	.49
Dec.	T	.00	.38	.45

Table XVI.- Steer Weights and Gains Under Continuous Grazing, 1934.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
March 25		435.53		
April 24	30	428.68	-6.85	- .23
May 5	11	474.40	45.72	4.16
May 14	9	501.00	26.60	2.96
May 24	10	541.80	40.80	4.08
June 3	10	560.60	18.80	1.88
June 13	10	574.40	13.80	1.38
June 23 P.M.	10	558.00	-16.40	-1.64
July 3 A.M.	10	618.40	60.40	6.04
July 3 P.M.	10	599.80	41.80	4.18
July 13 A.M.	10	626.00	7.60	.76
July 13 P.M.	10	606.60	6.80	.68
Aug. 2 A.M.	20	632.80	6.80	.34
Aug. 2 P.M.	20	614.20	7.60	.38
Sept. 1 A.M.	30	643.20	10.40	.35
Sept. 1 P.M.	30	631.00	16.80	.56
Oct. 1 A.M.	30	651.80	8.60	.28
Oct. 1 P.M.	30	635.00	4.00	.13

Beginning June 23, all weights were taken as designated. Cattle were penned up early in the morning as usual and no water was given to them until after weights were taken.

Table XVII.- Steer Weights and Gains Under Deferred Grazing, 1934.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 5		478.91		
June 3	29	528.91	50.00	1.72
July 3 A.M.	30	576.96	48.05	1.60
July 3 P.M.	30	562.39	33.48	1.12
Aug. 2 A.M.	30	612.17	35.21	1.17
Aug. 2 P.M.	30	594.13	31.74	1.06
Sept. 1 A.M.	30	583.48	-28.69	- .96
Sept. 1 P.M.	30	575.43	-18.70	- .62
Oct. 1 A.M.	30	603.26	19.78	.66
Oct. 1 P.M.	30	589.57	14.14	.47

Table XVIII.- Steer Weights and Gains Under Deferred-Rotation Grazing, 1934.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 5		475.29		
May 14	9	466.71	- 8.58	- .95
May 24	10	491.86	25.15	2.52
June 3	10	522.29	30.43	3.04
June 13	10	533.43	11.14	1.11
June 23 P.M.	10	526.14	- 7.29	- .73
July 3 A.M.	10	566.57	40.43	4.04
July 3 P.M.	10	546.86	20.72	2.07
July 13 A.M.	10	568.86	2.29	.23
July 13 P.M.	10	548.14	1.28	.13
July 23				
Aug. 2 A.M.	20	565.86	- 3.00	- .15
Aug. 2 P.M.	20	552.00	3.86	.19
Sept. 1 A.M.	30	607.86	42.00	1.40
Sept. 1 P.M.	30	595.29	43.29	1.44
Oct. 1 A.M.	30	588.00	-19.86	- .66
Oct. 1 P.M.	30	570.71	-24.58	- .82

Table XIX.- Steer Weights and Gains Under Continuous Grazing, 1935.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
April 24		484.90		
May 4	10	453.20	-31.70	-3.17
May 22	18	450.40	- 2.80	- .16
June 1	10	462.20	11.80	1.18
June 11	10	488.60	26.40	2.64
June 21	10	510.00	21.40	2.14
July 1	10	535.20	25.20	2.52
July 11	10	553.40	18.20	1.82
July 23	12	585.40	32.00	2.67
July 31	8	569.20	-16.20	-2.03
Aug. 10	10	613.20	44.00	4.40
Aug. 20	10	621.20	8.00	.80
Aug. 30	10	630.20	9.00	.90
Sept. 9	10	643.40	13.20	1.32
Sept. 19	10	650.40	7.00	.70
Sept. 29	10	658.00	7.60	.76
Oct. 9	10	665.60	7.60	.76
Oct. 19	10	673.40	7.80	.78

Table XX.- Steer Weights and Gains Under Deferred Grazing, 1935.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 22		505.91		
June 1	10	*	*	*
June 11	10 (20)	468.86	-37.05	-1.85
June 21	10	490.00	21.14	2.11
July 1	10	515.91	25.91	2.59
July 11	10	537.95	22.04	2.20
July 23	12	568.41	30.46	2.54
July 31	8	573.86	5.45	.68
Aug. 10	10	590.45	16.59	1.66
Aug. 20	10	603.41	12.96	1.30
Aug. 30	10	610.91	7.50	.75
Sept. 9	10	610.23	- .68	- .07
Sept. 19	10	638.64	28.41	2.84
Sept. 29	10	653.86	15.22	1.52
Oct. 9	10	642.05	-11.81	-1.18
Oct. 19	10	652.05	10.00	1.00

* Steers were in north Animal Husbandry pasture from May 28 until June 11.

Table XXI.- Steer Weights and Gains Under Deferred-Rotation Grazing, 1935.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 22		504.46		
June 1	10	474.41	-30.05	-3.01
June 11	10	497.35	22.94	2.29
June 21	10	516.47	19.12	1.91
July 1	10	541.76	25.29	2.53
July 11	10	555.88	14.12	1.41
July 23	12	584.26	28.38	2.37
July 31	8	602.65	18.39	2.30
Aug. 10	10	611.32	8.67	.87
Aug. 20	10	622.94	11.62	1.16
Aug. 30	10	627.06	4.12	.41
Sept. 9	10	640.15	13.09	1.31
Sept. 19	10	652.50	12.35	1.24
Sept. 29	10	666.32	13.82	1.38
Oct. 9	10	657.35	- 8.97	- .90
Oct. 19	10	674.71	17.36	1.74

Table XXII.- Steer Weights and Gains Under Continuous Grazing, 1936.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
April 8		497.00		
April 18	10	461.40	-35.60	-3.56
April 28	10	466.08	4.68	.47
May 11	13	493.20	27.12	2.09
May 18	7	506.80	13.60	1.94
May 28	10	542.80	36.00	3.60
June 7	10	546.40	3.60	.36
June 17	10	571.40	25.00	2.50
June 27	10	580.40	9.00	.90
July 7	10	592.40	12.00	1.20
July 17	10.	626.00	34.20	3.42
July 27	10	630.20	3.60	.36
Aug. 6	10	624.60	- 5.60	- .56
Aug. 16	10	630.20	5.60	.56
Aug. 26	10	626.60	- 3.60	- .36
Sept. 5*	10	628.50	1.90	.19

* Steers were removed because of insufficient forage.

Table XXIII.- Steer Weights and Gains Under Deferred Grazing, 1936.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 11		517.80		
May 18	7	487.20	-30.60	-4.37
May 28	10	522.00	34.80	3.48
June 7	10	531.60	9.60	.96
June 17	10	542.40	10.80	1.08
June 27	10	587.40	45.00	4.50
July 7	10	590.40	3.00	.30
July 17	10	606.20	15.80	1.58
July 27	10	619.40	13.20	1.32
Aug. 6	10	618.60	- .80	- .08
Aug. 16	10	625.00	6.40	.64
Aug. 26	10	627.80	2.80	.28
Sept. 5	10	629.40	1.60	.16
Sept. 15	10	645.20	15.80	1.58
Sept. 25	10	646.40	1.20	.12
Oct. 5	10	643.60	- 2.80	- .28
Oct. 15	10	645.60	2.00	.20
Oct. 23	8	631.00	-14.60	-1.83

Table XXIV.- Steer Weights and Gains Under Deferred-Rotation Grazing, 1936.

Date	No. Days	Av. Weight	Av. Gain	Av. Daily Gain
May 11		511.36		
May 18	7	476.32	-35.04	-5.01
May 28	10	514.56	38.24	3.82
June 7	10	514.85	.29	.03
June 17	10	540.15	25.30	2.53
June 27	10	556.18	16.03	1.60
July 7	10	574.85	18.67	1.87
July 17	10	576.82	1.97	.20
July 27	10	596.18	19.36	1.94
Aug. 6	10	595.88	- .30	- .03
Aug. 16	10	601.62	5.74	.57
Aug. 26	10	621.21	19.59	1.96
Sept. 5	10	626.52	5.31	.53
Sept. 15	10	632.58	6.06	.61
Sept. 25	10	632.73	.15	.02
Oct. 5	10	623.94	- 8.79	- .88
Oct. 25*	10	621.16	- 2.78	- .28

* Steers were removed because of insufficient forage.

Table XXV.- Scientific and Common Names of Plants Mentioned in Text.

Scientific Name	Common Name
Agropyron smithii	Western wheatgrass
Allium reticulatum	Wild onion
Amelanchier sp.	Service-berry
Andropogon scoparius	Little blue-stem
Argemone intermedium	Prickly poppy
Aristida longiseta	Three-awn grass
Artemisia dracunculoides	Wormwood sage
Artemisia frigida	Mountain sage
Artemisia gnaphalodes	Sage
Aster hebecladus	Wild aster
Astragalus drummondii	Drummond's vetch
Astragalus hypoglottis	Vetch
Bromus tectorum	Downy brome
Bouteloua curtipendula	Side-oats grama
Bouteloua gracilis	Blue grama
Buchloe dactyloides	Buffalo grass
Cercocarpus parvifolius	Mountain mahogany
Croton corymbulosus	Leatherweed
Delphinium sp.	Larkspur
Distichlis spicata	Saltgrass
Eriogonum sp.	Sulfur flower
Eurotia lanata	Winterfat
Gaura coccinea	Gaura
Grindelia squarrosa	Rosin weed

Table XXV. (Continued)

Scientific Name	Common Name
Gutierrezia furfuracea	Snakeweed
Gutierrezia longifolia	Snakeweed
Helianthus pumila	Perennial sunflower
Hordeum jubatum	Foxtail barley grass
Iva axillaris	Poverty weed
Leucocrinum montanum	Sand lily
Linum lewisii	Wild flax
Mentzelia multiflora	Whitestem
Muhlenbergia torreyi	Ring Muhly
Musineon divaricatum	Musineon
Opuntia humifusa	Prickly pear cactus
Poa lucida	Bluegrass
Prunus americana	Wild plum
Prunus melanocarpa	Choke cherry
Psilostraphe tagetinae	Yellowbush
Psoralea tenuiflora	Indian turnip
Quincula lobata	Quincula
Rhus trilobata	Skunk-brush
Ribes sp.	Currant
Schedonnardus paniculatus	Texas crab grass
Senecio perplexus	Groundsel
Solanum eleagnifolium	Silvery nightshade
Sophora sericea	Silky sophora
Sporobolus spp.	Dropseed grasses

Table XXV. (Continued)

Scientific Name	Common Name
Stipa comata	Needle and Thread grass
Stipa robusta	Sleepy grass
Stipa viridula	Green needle grass
Tribulus terrestris	Caltrops
Viola nuttallii	Violet
Zygadenus sp.	Death Camas

ABSTRACT OF THESIS

EFFECTS OF DIFFERENT SYSTEMS OF GRAZING ON CATTLE GAINS

The conclusion in 1936 of a sixteen year investigation in range management by the Animal Investigations and Botany Sections of the Colorado Agricultural Experiment Station provided an unusual opportunity for original study on the effects of different systems of range use. The objects of the investigation were (1) to study the effect of early spring protection in building up the vitality and increasing the production of range grasses, and (2) to determine the value of a management system including early protection of forage grasses plus systematic rotation of cattle on a typical low foothill range in Colorado. The present thesis resolves into a study of some of the specific effects of continuous, deferred, and deffered-rotation systems of grazing, and the tracing of these effects to their culmination in cattle gains.

Specifically, the following studies have been made:

(1) A detailed survey of the more important plants on large comparable areas of the pastures under the different systems of use, including the following phases:

(a) Rate and amount of growth of average plants.

(b) Extent and nature of the stand of different species.

(2) A study of the effects of different systems of use on the growth, distribution, and perpetuation of the important grasses, based on comparison of recent vegetational records with older records.

(3) A study of grazing by steers upon the different plants at different periods thruout the year, and of some of the factors af-

fecting grazing.

(4) A series of chemical analyses on the major forage grasses, and a study of some of the inter-relations between chemical composition and intensive grazing.

(5) Analysis of cattle weight records and their relation to other information obtained.

Cattle weights show very definitely that the productivity of all experimental pastures has been decidedly reduced during the course of the experiment. The intensive utilization of these pastures has tended to clarify the results, and to indicate, more positively than otherwise possible, the relative merits of the different grazing systems.

Vegetational data are not sufficiently complete on ungrazed control areas to ascertain positively to what extent overgrazing has contributed to the reduced productivity of the range. These data do, however, show the changes which have taken place on the range, and indicate the nature of plant succession under such conditions.

Cattle records show that continuous grazing allows stock to make most efficient use of the seasonal forage growth with the result that larger daily and seasonal gains are produced. Deferred grazing is shown to have resulted in consistently greater production than deferred-rotation grazing. The advantage of the continuous system appears to lie in the fact that the stock is allowed a longer period on the more nutritious green forage. In addition, the stock is enabled to keep the range grazed down, delaying the maturity of the taller plants.

However, evidence of quadrat studies of the vegetation shows that the continuous grazing of the taller, higher-yielding grasses results in a reduction in the size of the clumps followed by gradual elimination. The area is then occupied by weeds. These, in turn, are crowded out by Bouteloua and Buchloe. These short grasses will slightly increase the density of the vegetative cover, but not enough to overcome the disadvantage of the lower yield.

Chemical analyses of the major forage grasses at intervals thruout the year show a strong correlation between gains and chemical composition of the forage.

Quadrat data show that Agropyron supplies the main portion of the forage consumed during the spring and early summer. During July, it is largely replaced by Bouteloua and Buchloe. From the early part of August on, Bouteloua is grazed most heavily. Shortage of desirable forage in the fall leads to further utilization of Agropyron, together with the less desirable portions of Bouteloua and Buchloe.

Chemical analysis indicates that the crude fiber content of Agropyron is lower and that its succulence is greater than in the short grasses until the latter part of June. Grazing studies indicate that utilization of the short grasses excedes that of Agrophyron shortly after its fiber content becomes higher. These studies indicate that, after maturity has been reached, Buchloe is preferable to Bouteloua, which, in turn, is preferred to Agrophyron. The short grasses must, however, attain an average height of nearly four centimeters before they can be effectively grazed.

Bouteloua and Buchloe are too short to graze until nearly two

months after growth starts. This, together with the reduction of competetion from the taller grasses, may account for their being favored by intensive grazing.

Cattle records indicate that continuous grazing has best maintained the range, but because of uncontrollable factors, these results must be discarded. Vegetational records show conclusively that the continuously grazed pasture has been most seriously depleted.

On this type of range, deferred-rotation grazing is shown, both by cattle and vegetational records, to be inferior to deferred grazing. A probable explanation is that altho seed production is obviously favored by rotation grazing, reproduction by seeds is comparatively unimportant on this range in most years while vegetative reproduction is most common. The concentration of all the stock on half the area of the pasture until seed maturity is reached on the other half results in very severe grazing with a reduction of plant vigor upon which vegetative reporudction is so dependent.

Deferred grazing appears to have improved the range type by allowing the spread of Agropyron at the expense of Bouteloua, and at the same time it has produced satisfactory gains. In this investigation, it has proven the most satisfactory system.

<u>The following conclusions apply to a fully stocked range of the type found along the low foothills in Colorado under moisture conditions similar to those near Fort Collins</u>:

(1) Early spring protection is essential to the maintenance of the range.

(2) The rotational system of range management for the purpose of allowing increased reproduction by seed is not a beneficial

practice.

(3) A conservative basis of stocking, together with spring protection of the range, will furnish the most satisfactory grazing system.

(4) Too intensive grazing, whether spring protection is furnished or not, results in a decrease in vegetative vigor and production of all grasses.

(5) Grazing continuously from the inception of growth in the spring temporarily produces the largest gains but results in a deterioration of the range.

(6) Deterioration of the Agropyron type of range is characterized by a reduction in size and vigor of the individual plant, followed by gradual elimination. The abandoned area may be invaded by weeds. It is finally occupied by Bouteloua gracilis and Buchloe dactyloides.

(7) The replacement of Agropyron smithii by Bouteloua and Buchloe results in a great reduction in the amount of available forage produced.

(8) Amount and distribution of precipitation greatly influence the amount of gains made on the range.

(9) Most rapid gains are made during active growth of the range plants. This accounts for the high gains made under continuous grazing.

The following conclusions are based on the results of studies conducted during a single season and are not to be regarded as final:

(10) Gains are more dependent on the maturity of the plants grazed than on the species.

(11) During the spring and early summer, height largely controls the amount of grazing on palatable species.

(12) When all palatable vegetation is high enough to be effectively grazed, succulence and fiber content largely control the forage preference of cattle.

(13) After maturity, the crude fiber content of the forage appears to be the most important single factor determining the forage preference of cattle.

(14) Quantity of crude protein does not seem to be an important factor in determining forage preference.

(15) On an oven-dry basis, the important forage grasses show three distinct periods of chemical composition: (1) a spring period of high protein and low fiber; (2) a summer period of low protein and increasing fiber; and (3) a winter period of lowest protein and highest fiber.

(16) A period of high cattle gains corresponds with the period of high protein and low fiber contents of range plants. Reduced gains accompany the reduced nutiritional value of the forage during the summer.

(17) The reduction in gains as the season advances is due to (1) reduction of protein in the feed, (2) reduction of t tal nutrients in the feed, (3) reduced consumption following the decrease in succulence, and (4) reduced digestibility of the feed. On an overstocked range, shortage of feed will cause a further reduction.

(18) Overgrazing has caused no significant change in the chemical composition of the major grasses.