The relationships among precipitation, range vegetation and range cattle production in the plains region of Montana
by William Glen Ballard

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Management
Montana State University

Abstract:
Research was initated in 1971 to determine the ecological impacts of proposed weather modification in the plains region of Montana.

The purpose of the present study was to determine the relationships among precipitation, range vegetation and range cattle production in the area in an attempt to provide background information. Information of this nature is necessary in predicting ecological impacts of weather modification on the total range ecosystem.

A review of the literature was made. Historical range vegetation production and precipitation data from the OW Ranch were summarized for analyses. Historical cattle production and precipitation data from the U.S. Range Livestock Experiment Station and Northern Agricultural Research Center (Rocky Boy's Grazing Permit No.2) were also summarized for analyses.

Range vegetation (pounds/acre dry weight) and cattle production data (average weight gains) were subjected to correlation and regression analyses. These techniques permitted examination of the relationships among precipitation, range vegetation and range cattle production.

They also gave indications of the influence that precipitation has on range vegetation and range cattle production.

The analyses from the OW Ranch study showed a low degree of relationship between precipitation and range vegetation production. Precipitation also had very little influence on vegetation production. Results from the cattle production studies showed a varying relationship among different classes of cattle and precipitation periods. The degree of influence that precipitation has on cattle production also varied.

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Date 6 August 1973

THE RELATIONSHIPS AMONG PRECIPITATION, RANGE VEGETATION AND RANGE CATTLE PRODUCTION IN THE PLAINS REGION OF MONTANA

by

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE

in

Range Management

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TABLE OF CONTENTS

INDEX TO TABLES

TABLE Page

TABLE Page

INDEX TO FIGURE

INDEX TO APPENDIX TABLES

ABSTRACT

Research was initated in 1971 to determine the ecological impacts of proposed weather modification in the plains region of Montana. The purpose of the present study was to determine the relationships among precipitation, range vegetation and range cattle production in the area in an attempt to provide background information. Information of this nature is necessary in predicting ecological impacts of weather modification on the total range ecosystem.

A review of the literature was made. Historical range vegetation production and precipitation data from the OW Ranch were summarized for analyses. Historical cattle production and precipitation data from the U. S. Range Livestock Experiment Station and Northern Agricultural Research Center (Rocky Boy's Grazing Permit No.2) were also summarized for analyses.

Range vegetation (pounds/acre dry weight) and cattle production data (average weight gains) were subjected to correlation and regression analyses. These techniques permitted examination of the relationships among precipitation, range vegetation and range cattle production. They also gave indications of the influence that precipitation has on range vegetation and range cattle production.

The analyses from the OW Ranch study showed a low degree of relationship between precipitation and range vegetation production. Precipitation also had very little influence on vegetation production. Results from the cattle production studies showed a varying relationship among different classes of cattle and precipitation periods. The degree of influence that precipitation has on cattle production also varied.

INTRODUCTION

Research was initiated in 1971 to determine the ecological impacts of proposed weather modification in the plains region of Montana. The purpose of the present study was to determine the relationship among precipitation, range vegetation and range cattle production in this area in an attempt to provide background information[1/]. Information of this nature is necessary in predicting ecological impacts of weather modification on the total range ecosystem.

Various investigators have determined that the limiting factor in range forage production is annual precipitation. Since this range forage is used in part to produce range livestock, both sheep and cattle, annual precipitation should therefore be a limiting factor in range livestock production.

Results from previous studies have shown that, depending upon the year, total annual precipitation may or may not be the limiting factor in range forage production. Forage production is determined not only by the amount but also by the nature and distribution of rainfall occurring throughout the year. It is also apparent that a combination of climatic factors including precipitation, temperature, wind and solar radiation all interact to affect range forage production.

Approximately 74.6 percent of the land area in the plains region of Montana is used for grazing purposes. This land is used primarily

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1/ This research was financed by the Bureau of Reclamation under Contract 14-06D7171. Administered by the Montana State Endowment Research Foundation.

for the production of range livestock, primarily cattle and sheep, as well as wildlife (SCS, 1970).

The climate of this region is generally considered to be semi-arid. It is characterized by extreme seasonal differences in temperature. Temperatures range from 100° F and over in the summer months to a minus 50° F or lower in the winter (U.S. Dept. of Com., 1972).

The average annual precipitation ranges from 10 to 16 inches with higher amounts (20-30 inches) occurring in the small mountain ranges within the study area. Most of this amount (9 to 10 inches) falls as rain during the growing season - at the most effective period for crop and forage production. The length of growing season varies with elevation. The lowest elevations along the river valleys have the longest frost-free periods, exceeding four months. The area is also characterized by recurring drought. These extremes in climate are moderated by relatively low humidity (U.S. Dept. of Com., 1972).

The plains regions of Montana are classified as a mixed prairie type. The major forage producing species are blue grama (Bouteloua gracilis), western wheatgrass (Agropyron smithii), needleandthread (Stipa comata), threadleaf sedge (Carex filifolia), green needlegrass (Stipa viridula), Sandberg bluegrass (Poa secunda), and bluebunch wheatgrass (Agropyron spicatum) (Houston and Woodward, 1966; Weaver and Albertson, 1956).

REVIEW OF LITERATURE

Relationship of Precipitation to Range Forage Production

Plant growth and distribution are limited when any factor in the environment falls below the minimum required by a particular species. A plant may also be limited when a factor exceeds the maximum tolerance level of the plant for that factor. A single factor often can limit the growth, reproduction, or distribution of a single plant species (Billings, 1952).

One reason plants grow where they do is that the whole environment in space and time has allowed seeds or propagules of various adapted plant species to reach a particular place. Plant communities are the results of such independent distribution as modified by other factors and change gradually or sharply as the whole environment or any component of the environment varies (Billings, 1952). Different plant communites are found on various sites. Hanson (1957) states that the relations of the species of a community to the environment reflect three principles:

1. Each species has certain minimum requirements that the site must satisfy - water, radiant energy and others.
2. Each species has a certain range of environmental conditions of a set of ecological amplitudes in which it can grow.
3. Each species has a certain efficiency in utilizing the resources of the environment.

The majority of plant species growing on the Northern Great Plains are adapted perennial plants. Well established plants are seldom damaged by climatic extremes. Perennials do not depend upon the annual

establishment of seedlings; therefore, vegetation dominated by perennials possesses considerable buffering against weather extremes, simply as a consequence of longevity (Daubenmire, 1956). For these reasons, plant species found within the plains of Montana are capable of withstanding extreme weather conditions.

Climate largely determines the type of native vegetation that occurs in any part of the world. Temperature, water supply and light are the three most important climatic factors from the standpoint of plant distribution. Temperature is the main factor that determines where native species can grow in belts north and south of the equator. Within belts of somewhat similar temperature conditions, precipitation is the most important factor in determining plant distribution (Hildreth, 1941).

Limited annual precipitation is the primary cause of restricted forage (species suitable for grazing use) production on most rangelands (Clawson, 1944). The production of forage in any year is also influenced by the character and distribution of the rainfall during the year. Most storms occurring during the growing season yield less than one-half inch of precipitation. Many of these storms are not effective[1/]. Likewise, when high intensity rains occur, a high proportion of the water runs off and is lost unless there is adequate vegetation cover to hold it in place. An unfavorable seasonal distribution of precipitation may render a relatively high annual total precipitation less

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1/ Taylor, John E. Personal communication.

effective.

The total annual precipitation dominates production on any given site. If annual rainfall in many range areas were to be permanently increased, other factors such as length of growing season, soil depth, etc., would become the limiting factor (Chapline, 1941; Clawson, 1948).

While precipitation is the most important factor in determining annual production of range forage, the other climate elements, including temperature, wind, etc., also are important and are interrelated in their effects on the plant organism. Temperature and light affect water requirements. Conversely the available moisture supply influences the effects of temperatures and light (Hildreth et al. 1941).

Blaisdell (1958), studying the effect of climatic factors on seasonal development and yield of native plants on the upper Snake River Plains, found that precipitation was the dominant factor. Precipitation prior to the growing season (July through March) had a greater influence on herbage weight than precipitation during the growing season (April through June). The chief effect of precipitation prior to the growing season was probably not its influence on the vegetation at that time, but rather an assurance of higher levels of soil moisture during the period of active growth.

Clawson (1944), using the Bureau of Agriculture Economics estimates of range, cattle, and sheep condition as reported by its crop reporters found, that the total amount of precipitation received

during the same or preceding year was the dominant factor affecting forage availability. A close relationship existed between forage availability, cattle and sheep condition.

On an ungrazed range on sierozem soil in Idaho, Passey and Hugie (1963) found no consistent relationship between herbage production and precipitation. The closest relation was found when comparing production with December-through-April precipitation preceding the date of yield determination. The study indicated that fluctuations may be more closely associated with available soil moisture during specific portions of the growing season than with the single climatic factor of precipitation.

Currie and Peterson (1966) used a regression analysis to determine the influence of monthly precipitation during the growing season on forage yields of crested wheatgrass (Agropyron desertorum) ranges grazed during spring, fall and spring-fall seasons in Colorado. They found that: (1) on ranges grazed only in the spring, 88 percent of the variation in yield was accounted for by the amount of precipitation received in April; (2) 94 percent of the variation on range grazed in the fall was accounted for by May-through-July precipitation for the spring and June-through-July precipitation for the fall.

Thomas and Osenbrug (1959) found that 62 percent of the variability in yield of smooth-brome grass-crested wheatgrass hay, under conditions of adequate soil fertility, was associated with the

variation in daily temperature. Seasonal precipitation accounted for less than 43 percent of the variability in yield and was not a reliable index for predicting yields. Low yields were associated with high temperatures.

Smoliak (1956) found that on shortgrass rangelands production, when correlated with May plus June precipitation, gave a highly significant correlation coefficient of 0.859. Seasonal (April through July) mean temperature, hours of bright sunlight, and wind mileage were all significantly, negatively correlated with forage production. Stitt (1958) found that seeded dryland grass yields in central Montana were highly correlated with April plus May rainfall.

Noller (1968) found that on blue grama sites in Wyoming total precipitation gave a better estimation of total production than either spring or fall precipitation. Total precipitation explained 84 percent of the variation in total production and each inch of total precipitation accounted for 71.6 pounds per acre of total production. Grass production was best estimated with spring precipitation. Spring precipitation accounted for 71 percent of the variation in grass yield with each inch accounting for 55.6 pounds per acre. Forb production was best estimated by fall precipitation. Fall precipitation explained 67 percent of the variation in production and each inch of precipitation increased forb production 123.3 pounds per acre.

Relationship of Precipitation to Range Cattle Production

Clark et al. (1958) studying production factors in range cattle under Northern Great Plains conditions found that birth weights of calves seemed to be little affected by environmental conditions unless these conditions were extremely severe. Gain from birth to weaning varied greatly among years with gain being very low in drought years. When growing season precipitation (April through September) was four inches or less, gains were materially reduced. When growing season precipitation was more than six inches, the excess over six inches seemed to have little effect.

They also found that the average fall cow weights were noticeably depressed when growing season precipitation totaled four inches or less. An excess of growing season precipitation over six inches appeared to have little effect on cow weights. Response of cow weight to growing season precipitation depended upon the stage of plant growth at which the precipitation fell and the botanical composition of the range.

Houston and Woodward (1966) in a study on the plains region of Montana found that May-through-June precipitation tended to reduce animal production in years of high rainfall and to improve animal production in years of low rainfall. The authors indicated that precipitation influence on animal production during these periods is probably related to the effects of forage quality, forage quantity, and grazing habits of the animals.

THE RELATIONSHIP OF PRECIPITATION TO RANGE GRASS PRODUCTION (OW RANCH STUDY)

Description of the Study Area

Location, Geology and Soils

The study area is located on the Kendrick Cattle Company's OW Ranch 22 miles northeast of Decker, Montana (figure 1). This ranch is located on Hanging Woman Creek in southeastern Big Horn County, Montana at a mean elevation of approximately 3,800 feet (Anderson and Wright, 1952).

The underlying geological material of the area is composed of Cenozoic sedimentary rocks. The area is dominated by Lithosols and Brown soils on uplands. These soils belong to the Bainville-Midway Association. The soils are light colored, calcareous throughout, shallow to moderately deep, and are formed over sandstone, shale and siltstone (Southard, 1969).

Climate

The climate is typical of the plains region of Montana. While complete precipitation and temperature data and their departures from normal are not available, precipitation records for the study period (1952-1971) from the Birney Weather Station, which is located approximately ten miles from the study area, show an average annual precipitation of 13.20 inches. Average growing season (April through August) precipitation for the study period was 8.36 inches. Temperature records from other stations in the vicinity indicate that the mean annual

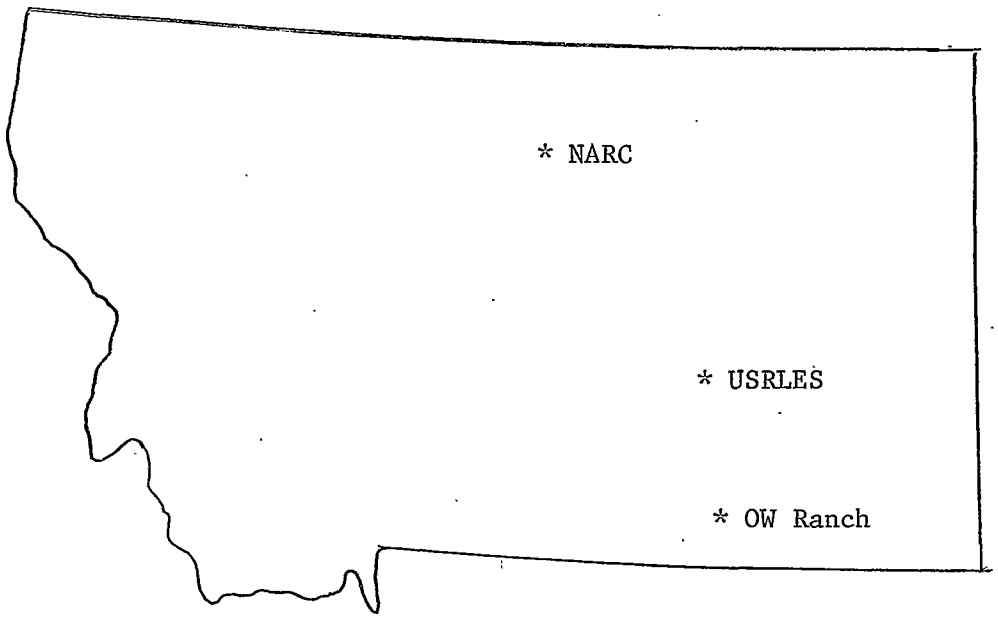

Figure 1. Study area locations. Northern Agricultural Research Center, (Rocky Boy's Grazing Permit No. 2). U. S. Range Livestock Experiment Station and OW Ranch.

temperature is approximately 45° F., with July being the hottest month of the year and January the coldest. Precipitation data for the study period are presented in table 1.

Vegetation

Kuchler (1964) has classified the vegetation as an eastern ponderosa pine forest (Pinus) type. This type is characterized by an overstory of a medium dense to open forest of low to medium tall needle-leaf evergreen treas. The understory is composed of a fairly open ground cover of grasses and forbs.

The primary species growing in this type is ponderosa pine (Pinus ponderosa). Western wheatgrass, blue grama and needleandthread are the dominant grass species.

Anderson and Wright (1952) have described the vegetation in more detail by describing five plant associations. They can be summarized as follows: (1) gently sloping; deep, well drained alluvial deposits dominated by big sagebrush (Artemisia tridentata), junegrass (Koeleria cristata), needleandthread and blue grama, (2) hills, benches and north facing slopes at lower elevations are dominated by bluebunch wheatgrass on gravelly sands, (3) sandy loam soils on bench tops and gentler slopes are dominated by needleandthread and western wheatgrass, (4) gravelly soils on steep western and southern slopes are composed of a variety of mid- and short-grasses, (5) clay soil flats and valley bottoms are dominated by western wheatgrass.

Table 1. Precipitation in inches by months, combined months, growing season and previous year at Birney, Montana, 1952-1971. 1/

Year	April	May	June	July	Aug	Apr-May	Growing Season Apr-Aug	Previous Years June-May	Previous Years Sept-Aug	Total Annual
1952	.01	2.27	2.19	1.41	.07	2.27	5.94			10.69
1953	2.19	3.93	2.43	1.98	1.79	6.12	12.32	14.21	16.74	18.50
1954	.64	.81	2.21	.30	1.08	1.45	5.04	15.15	12.54	
1955	.61	3.33	3.94	.74	.67	3.94	9.29			13.21
1956	.42	3.20	1.18	1.23	2.19	3.62	8.22	12.61	11.86	11.33
1957	1.44	1.85	3.17	.42	1.75	3.29	8.63	11.06	11.80	10.02
1958	2.97	.87	4.21	3.08	.39	3.84	11.52	12.41	14.75	16.38
1959	2.05	1.39	1.70	.92	.09	3.44	6.15	16.36	11.39	10.47
1960	.28	.95	1.24	.19	1.20	1.23	3.86	7.51	7.43	5.46
1961	1.21	3.18	1.54	.67	.08	4.39	6.68	8.98	8.64	12.13
1962	.73	2.24	2.49	1.33	1.01	2.97	7.80	10.84	13.38	11.27
1963	2.43	1.47	2.70	1.67	.57	3.9	8.84	12.82	12.93	13.81
1964	2.35	2.46	4.43	.41	1.59	4.82	11.25	14.34	14.83	12.88
1965	.64	1.8	2.62	2.03	1.20	2.45	8.30	11.73	11.15	11.27
1966	1.33	1.53	2.16	1.03	.42	2.86	6.47	11.43	9.19	11.69
1967	2.42	1.01	5.14	.34	.09	3.43	9.00	12.49	14.45	13.41
1968	.33	2.71	4.10	.16	2.39	3.04	9.69	14.16	15.23	15.95
1969	2.33	1.08	3.75	2.16	.38	3.41	9.70	15.37	15.01	
1970	2.54	4.49	1.84	.24	.03	8.13	10.24			19.56
1971	1.66	1.76	1.21	.75	2.92	3.42	8.30	16.43	19.20	19.65
Mean	1.43	2.17	2.71	1.05	1.00	3.60	8.36	12.82	13.03	13.20

1/ Data for the years 1952-1954 were taken at the Birney 11-E weather station, years 1955-1971 were taken at Birney 2-SE.

Description of Data

Vegetational data from this study area were yearly individual species production estimates (pounds per acre, dry weight) taken from 1951 through 1971[1/]. The data were obtained in a study to determine the effect of grasshoppers on Montana rangelands. The study area, experimental procedures, and methods of study have been described by Anderson and Wright (1952). In summary, these details can be described as follows: The study areas were located on ungrazed native range. Approximately one section of land was sprayed in 1950 and again in 1961 with one ounce per acre of dieldrin insecticide to keep grasshopper numbers below one per square yard. This sprayed area was used as a control. Adjacent to this area an unsprayed area was selected for comparison.

Within each of these two areas, two different vegetation types were selected. One of these types was dominated by western wheatgrass. The other was a bunchgrass type dominated by needleandthread. The treatments will be referred to as OW unsprayed wheatgrass, OW unsprayed bunchgrass, OW sprayed wheatgrass and OW sprayed bunchgrass. Grasses which were of major importance as forage species were sampled twice during the summer. The first sample was taken during the first part

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1/ Unpublished data furnished by Dr. Norman L. Anderson, Department of Zoology and Entomology, Montana State University.

of June and the second sample was taken around the middle of September. These samples will be referred to as June and September clipping, respectively. A minimum of 10 four foot square plot samples/clipping/year were air dried and weighed.

Methods of Study

Data Summarization

Production data (1952-1971), in average pounds per acre (dry weight) for each species having production estimate in eight or more of the 20 years in which data were collected were used in the analyses (Appendix tables I, II, III)[1/]. Due to the original field collection methods, total yearly grass and forage production data were unavailable for use.

Precipitation data from the Birney Weather Station were summarized into monthly, growing seasons (April-May and April-August), and previous yearly (June-May and September-August) totals for use in the statistical analyses (table 1).

Data Analyses

Data from the study area were analyzed statistically with the aid of a computer at Montana State University. The data were analyzed by correlation and regression analyses. To measure the degree of relationship that exists between the variables, a correlation matrix was computed. A linear regression analysis was used to find the influence of different precipitation periods on range grass production during the summer period.

1/ Production data from 1951 were not used in the analyses because precipitation data were unavailable for that year.

Results and Discussion

Wheatgrass Type, September Clipping, Sprayed

Western wheatgrass yields were significantly related to April, growing season and previous year precipitation, having significant correlation coefficients of 0.62, 0.63 and 0.52, respectively (table 2). Growing season (April-August) precipitation accounted for 40 percent of the yield variation, followed closely by April precipitation at 38 percent and the previous year precipitation at 27 percent. One inch of growing season precipitation increased the yield of western wheatgrass by 105.4 pounds. One inch of April precipitation increased western wheatgrass production by 244.7 pounds while the previous year precipitation only increased its production by 63.4 pounds.

Green needlegrass production was affected by both April and June precipitation. April precipitation accounted for 23 percent of the variation, with each inch of precipitation increasing the yield of green needlegrass by 91.51 pounds. Fifty-one percent of the variation could be accounted for by the June precipitation, with an additional inch of precipitation resulting in an increase of 77 pounds of green needlegrass.

Wheatgrass Type, September Clipping, Unsprayed

Western wheatgrass production on this treatment was correlated with April, May and growing season precipitation (table 3). April was the best estimator of western wheatgrass production, accounting for

Table 2. Correlation and regression of individual grass species production (wheatgrass type, Sept. clippings, sprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.62**1/	0.38	244.70	73.52	11.075**
May	0.21	0.04	62.76	69.72	0.810
June	0.32	0.10	98.50	69.30	2.020
July	0.34	0.11	154.2	101.80	2.295
August	-0.10	0.01	- 44.23	99.16	0.199
Apr-Aug	0.63**	0.40	105.4	30.70	11.787**
Sept-Aug	0.52*2/	0.27	63.41	26.86	5.57*
Green needlegrass					
April	0.48*	0.23	91.51	39.70	5.313*
May	-0.15	0.02	- 21.49	34.09	0.397
June	0.51*	0.26	77.00	30.33	6.447*
July	-0.21	0.05	- 47.39	51.06	0.862
August	-0.23	0.05	- 47.24	46.91	1.014
Apr-Aug	0.22	0.05	18.50	18.59	0.990
Sept-Aug	0.29	0.08	17.88	15.25	1.375

1/** Indicates significance at P=.01.
2/* Indicates significance at P=.05.

Table 3. Correlation and regression of western wheatgrass production (wheatgrass type, Sept. clipping, unsprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
April	0.51*1/	0.26	188.50	74.76	6.360*
May	0.45*	0.20	126.90	59.22	4.589*
June	0.18	0.03	53.19	66.86	0.633
July	0.03	0.00	14.76	100.50	0.021
August	-0.28	0.07	-109.5	89.14	1.508
Apr-Aug	0.47*	0.22	72.97	32.49	5.044*
Sept-Aug	0.47	0.22	32.96	15.99	4.248

1/* Indicates significance at P=.05.

23 percent of the variation. May precipitation accounted for 20 percent of the variation and growing season accounted for 22 percent. Each additional inch of April, May and growing season precipitation increased western wheatgrass production by 188.5, 126.9 and 72.97 pounds, respectively.

Bunchgrass Type, June Clipping, Sprayed

On this treatment only the production of needleleaf sedge (Carex eleocharis) was significantly related to precipitation (table 4). Based on the regression analysis May precipitation explained 28 percent of the changes in needleleaf sedge production, April-May precipitation explained 29 percent and the previous year precipitation explained 27 percent. May, April-May and previous year precipitation resulted in an increase in needleleaf sedge production of 2.93, 2.36 and 1.12 pounds per acre, respectively.

Bunchgrass Type, September Clipping, Unsprayed

Western wheatgrass production was correlated with both April and June precipitation (table 5). June precipitation was the best estimator of western wheatgrass yield accounting for 50 percent of the variation. Each inch of precipitation resulted in an increase of 11.22 pounds per acre. April precipitation also had a significant influence on western wheatgrass production but not as great as June precipitation.

Production of needleandthread was related to both April and growing season precipitation with April precipitation explaining 23 percent

Table 4. Correlation and regression of individual grass species production (bunchgrass type, June clipping, sprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.16	0.02	23.52	36.05	0.426
May	-0.27	0.07	-30.80	26.88	1.313
Apr-May	-0.12	0.01	-10.86	22.10	0.241
May-June	0.17	0.03	10.22	15.68	0.425
Needleandthread					
April	0.01	0.00	2.04	35.21	0.003
May	0.03	0.00	3.75	26.90	0.019
Apr-May	0.03	0.00	3.15	21.45	0.022
May-June	0.51	0.26	23.76	10.72	4.914
Blue grama					
April	0.06	0.00	1.76	6.47	0.074
May	-0.18	0.03	- 3.70	4.88	0.575
Apr-May	-0.10	0.01	- 1.70	3.93	0.186
May-June	0.06	0.00	0.63	2.90	0.048
Sandberg bluegrass					
April	0.17	0.03	24.53	34.25	0.513
May	0.00	0.00	- 0.18	26.57	0.000
Apr-May	0.10	0.01	9.00	21.08	0.182
May-June	0.19	0.03	11.10	14.90	0.555
Japanese brome					
April	0.27	0.07	31.83	27.69	1.321
May	-0.26	0.06	-23.65	21.21	1.243
Apr-May	-0.04	0.00	- 3.22	17.51	0.034
May-June	0.04	0.00	1.71	12.58	0.018
Junegrass					
April	0.28	0.08	10.51	8.59	1.497
May	-0.22	0.05	- 6.29	6.67	0.887
Apr-May	0.00	0.00	- 0.09	5.46	0.000
May-June	0.32	0.10	4.93	3.87	1.618

Table 4. (Continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Needleleaf sedge					
April	0.18	0.03	1.32	1.72	0.588
May	0.53*1/	0.28	2.93	1.14	6.677*
Apr-May	0.54*	0.29	2.36	0.90	6.823*
May-June	0.52*	0.27	1.12	0.49	5.153*

1/* Indicates significance at P=.05.

Table 5. Correlation and regression of individual grass species production (bunchgrass type, Sept. clipping, unsprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.48*[1/]	0.23	9.74	4.26	5.217*
May	-0.03	0.00	- 0.43	3.73	0.013
June	0.71**[2/]	0.50	11.22	2.718	17.038**
July	0.00	0.00	0.07	5.54	0.000
August	-0.25	0.06	- 5.23	4.95	1.116
Apr-Aug	0.46	0.21	3.85	1.80	4.600*
Sept-Aug	0.34	0.12	2.23	1.54	2.115
Needleandthread					
April	0.48*	0.23	194.50	87.13	4.984*
May	0.03	0.00	10.84	75.81	0.020
June	0.29	0.09	94.51	74.72	1.599
July	0.38	0.15	178.6	103.90	2.952
Aug	-0.05	0.00	-22.52	103.70	0.047
Apr-Aug	0.49	0.24	83.37	35.87	5.399*
Sept-Aug	0.34	0.12	44.25	31.68	1.951
Blue grama					
April	0.35	0.11	19.00	12.91	2.164
May	-0.18	0.04	- 8.15	10.31	0.625
June	0.13	0.02	5.83	10.72	0.296
July	0.20	0.04	12.92	15.26	0.716
Aug	-0.12	0.01	- 7.18	14.26	0.253
Apr-Aug	0.13	0.02	3.10	5.65	0.300
Sept-Aug	0.00	0.00	- 0.04	4.67	0.000

1/* Indicates significance at P=.05.
2/**Indicates significance at P=.01.

of the variation and growing season explaining 24 percent. One inch of April precipitation resulted in an increase in needleandthread production of 194.5 pounds per acre while growing season increased the yield by 83.37 pounds per acre.

General Comments

From the correlation and regression analyses there was a varying relationship between precipitation and range grass production. Precipitation did not have a significant influence on or relationship to grass production on one-half of the treatments. No significant correlations were found in the following treatments: wheatgrass type, June clipping, sprayed; wheatgrass type, June clipping, unsprayed; bunchgrass type, June clipping, unsprayed; or bunchgrass type, September clipping, sprayed (tables 6, 7, 8, 9).

Western wheatgrass yield on the wheatgrass type, when clipped during September, was the only production estimate having a somewhat consistant significant relationship to precipitation, primarily April and growing season. The time of clipping apparently had an effect on the degree of relationship between and influence on precipitation and western wheatgrass production. The reasons for this cannot be explained on the basis of the information available.

Considering the lack of significance in the majority of comparisons, low correlation coefficients and coefficients of determination, range grass production is apparently dependent upon a combination of climatic

Table 6. Correlation and regression of individual grass species production (wheatgrass type, June clipping, sprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.42	0.17	178.30	94.20	3.581
May	0.16	0.03	53.83	78.14	0.475
Apr-May	0.39	0.15	100.5	58.31	2.973
May-June	0.39	0.15	61.89	39.57	2.484
Green needlegrass					
April	0.13	0.01	17.88	33.13	0.291
May	-0.20	0.04	- 20.69	25.04	-0.683
Apr-May	-0.07	0.01	- 6.52	20.31	0.103
May-June	-0.04	0.00	- 2.43	14.81	0.027
Japanese brome					
April	-0.15	0.02	- 30.52	48.47	0.396
May	0.09	0.01	14.42	37.31	0.149
Apr-May	-0.02	0.00	- 2.16	29.89	0.005
May-June	0.20	0.04	16.89	21.76	0.603

Table 7. Correlation and regression of individual grass species production (wheatgrass type, June clipping, unsprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.32	0.10	86.11	61.34	1.971
May	0.22	0.05	44.04	48.36	0.829
Apr-May	0.37	0.14	60.04	36.73	2.673
May-June	0.16	0.03	15.02	24.67	0.371
Japanese brome					
April	0.24	0.06	108.50	106.50	1.039
May	-0.14	0.02	- 49.60	89.95	0.358
Apr-May	0.03	0.00	8.79	11.83	0.017
May-June	0.20	0.04	35.97	47.08	0.583

Table 8. Correlation and regression of individual grass species production (bunchgrass type, June clipping, unsprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.29	0.09	7.96	6.28	1.604
May	0.17	0.03	3.62	4.95	0.535
Apr-May	0.32	0.10	5.26	3.80	1.917
May-June	-0.06	0.00	- 0.74	2.93	0.063
Needleandthread					
April	0.33	0.11	131.9	90.52	2.122
May	-0.18	0.03	-54.23	72.19	0.564
Apr-May	0.06	0.00	14.52	58.43	0.062
May-June	0.28	0.08	43.60	39.93	1.193
Bluegrama					
April	-0.18	0.03	- 4.16	5.42	0.589
May	0.05	0.00	0.93	4.21	0.048
Apr-May	-0.07	0.00	- 0.96	3.35	0.082
May-June	0.07	0.01	0.64	2.31	0.076
Sandberg bluegrass					
April	0.17	0.03	14.44	20.84	0.480
May	-0.02	0.00	- 1.61	16.15	0.010
Apr-May	0.08	0.01	4.35	12.84	0.115
May-June	0.34	0.12	12.29	8.99	1.870
Japanese brome					
April	0.02	0.00	7.24	73.44	0.009
May	-0.06	0.00	-13.97	56.04	0.062
Apr-May	-0.03	0.00	- 6.20	44.76	0.019
May-June	-0.05	0.00	- 7.11	32.83	0.04
Red threeawn					
April	0.05	0.00	0.79	3.27	0.059
May	-0.02	0.00	- 0.24	2.50	0.008
Apr-May	0.02	0.00	0.15	1.99	0.005
May-June	-0.01	0.00	- 0.06	1.27	0.002

Table 9. Correlation and regression of individual grass species production (bunchgrass type, Sept. clipping, sprayed) with precipitation for the OW Ranch, Big Horn County, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Western wheatgrass					
April	0.41	0.17	97.01	52.78	3.378
May	0.03	0.00	6.04	44.22	0.018
June	0.21	0.04	38.53	44.62	0.746
July	0.22	0.05	60.17	64.02	0.883
August	0.11	0.01	27.24	60.19	0.205
Apr-Aug	0.42	0.18	41.55	21.79	3.635
Sept-Aug	0.42	0.17	31.23	17.64	3.133
Needleandthread					
April	-0.06	0.00	11.56	46.03	0.063
May	0.10	0.01	14.63	35.13	0.173
June	-0.17	0.03	-26.01	35.83	0.527
July	0.23	0.05	50.06	50.98	0.964
August	0.17	0.03	33.99	47.61	0.510
Apr-Aug	0.14	0.02	11.13	18.97	0.344
Sept-Aug	0.02	0.00	1.16	15.73	0.005
Junegrass					
April	0.01	0.00	0.08	3.22	0.001
May	-0.21	0.04	- 2.19	2.41	0.820
June	0.12	0.01	1.32	2.53	0.271
July	0.39	0.16	5.96	3.37	3.129
August	-0.02	0.00	- 0.21	3.38	0.004
Apr-Aug	0.09	0.01	0.50	1.34	0.139
Sept-Aug	-0.09	0.01	- 0.40	1.09	0.131
Blue grama					
April	0.07	0.01	4.32	13.28	0.106
May	0.06	0.00	2.73	10.18	0.072
June	-0.05	0.00	- 2.21	10.49	0.443
July	0.32	0.09	19.70	14.36	1.882
August	-0.12	0.01	- 6.96	13.85	0.252
Apr-Aug	0.11	0.01	2.48	5.50	0.202
Sept-Aug	-0.10	0.01	- 1.72	4.39	0.154

Table 9. (continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
Needleleaf sedge					
April	0.11	0.01	0.83	1.82	0.210
May	0.04	0.00	0.25	1.40	0.033
June	0.09	0.01	0.55	1.44	0.146
July	0.10	0.01	0.87	2.07	0.178
August	0.01	0.00	0.11	1.91	0.004
Apr-Aug	0.16	0.02	0.51	0.75	0.455
Sept-Aug	-0.03	0.00	- 0.08	0.63	0.019

factors, timing of precipitation or other environmental factors not measured rather than the precipitation periods used in the analyses. Temperature, wind, solar radiation and combinations of these climatic factors, including precipitation, may have a greater influence on range grass production than precipitation alone. This also has been pointed out by other researchers (Hildreth et al. 1941; Houston and Woodward, 1966 and Ryerson et al. 1970). Another possible explanation for the low correlation coefficients and coefficients of determination is the precipitation data collection site. The precipitation data used in the analyses were taken from the Birney Weather Station records. The Birney Weather Station is approximately 10 miles from the OW Ranch study area. The analyses may have shown a higher relationship among the factors and a greater influence of precipitation on range grass production had the precipitation data been collected on the study area.

THE RELATIONSHIP OF PRECIPITATION TO RANGE CATTLE PRODUCTION

Description of the Study Areas

U. S. Range Livestock Experiment Station

Location, Geology and Soils. The study area is located about five miles southwest of Miles City, Montana on the U. S. Range Livestock Experiment Station (figure 1).

The underlying geological material of the area is composed primarily of Cenozoic sedimentary rocks. In eastern Montana these deposits belong to the Fort Union, Flaxville, Wasatch and White River formations (Mont. Agr. Exp. Sta., 1972). This area is dominated by Lithsols and Brown soils on uplands.

Soils of the area belong to the Bainville-Midway Association. These soils are light-colored, shallow to moderately deep over sandstone, shale and siltstone (Southard, 1969).

Climate. Precipitation for the study area is typical of the plains region of Montana. Thirty-five years of continuous records from the Miles City Federal Aviation Administration Airport Weather Station show an average annual precipitation of 12.14 inches, with 7.88 inches of this amount occurring during the growing season (April through August). Average annual precipitation for the study period was 12.63 inches with 8.63 inches occurring during the growing season. During the study period, extremes of 5.5 to 18.96 inches were recorded at the Miles City FAA AP Weather Station in 1934 and 1944, respectively. Precipitation data for the study period are presented in table 10.

Table 10. Monthly, annual, growing-season and previous year precipitation in inches at Miles City[1/], and Miles City FAA[2/], 1933-1959 (excluding 1936, 1937, 1946-1949).

	Precipitation														
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Annual	Growing Season (Apr-Aug)	Previous Year (Sep-Aug)
1933	1.35	.18	.66	1.20	1.69	.80	.49	1.38	.90	.39	.41	.79	10.24	5.56	10.90
1934	.12	.05	1.05	.40	.34	.66	.67	.42	1.04	.03	.38	.35	5.51	2.49	6.20
1935	.41	.05	1.65	.90	.96	1.84	1.83	1.87	.14	.64	.48	.77	11.54	7.40	11.31
1938	.33	.21	1.04	.27	.06	2.50	.97	1.17	.49	1.25	.35	.20	10.84	6.97	11.01
1939	.19	.12	.08	.82	1.67	4.04	.92	.46	.56	.08	.04	.18	9.16	7.91	10.59
1940	.42	.26	.71	1.86	1.62	2.82	1.97	1.04	.42	2.70	.24	.34	14.40	9.31	11.56
1941	.09	.19	.25	1.60	2.47	2.39	1.78	2.15	4.67	1.24	.51	.73	18.07	10.39	14.62
1942	.22	.30	.36	1.06	3.27	5.13	1.41	1.58	1.22	.78	.26	.07	15.66	12.45	20.48
1943	.55	.26	.27	.29	1.38	6.12	1.04	2.57	.31	1.65	.55	.02	15.01	11.40	14.81
1944	.65	.31	.96	1.53	1.49	9.78	.68	2.09	.87	.01	.35	.24	18.95	15.57	20.02
1945	.43	.08	.89	.59	2.95	2.01	1.53	1.23	1.91	.46	.19	.33	12.60	8.31	11.17
1950	.29	.62	1.83	1.10	.94	3.99	1.05	1.48	2.09	.40	.52	.35	13.66	7.56	13.32
1951	.08	.28	.15	.67	1.54	3.05	1.56	4.00	1.42	.70	.32	1.14	14.91	10.82	14.69
1952	.42	.92	.59	.10	1.68	2.06	1.48	.95	.93	.01	.61	.11	9.86	6.27	11.78
1953	.71	.53	.53	2.54	4.06	2.43	2.40	1.37	.23	1.57	.02	.22	16.61	12.80	16.23
1954	.47	.08	.90	.80	.82	2.52	.82	2.40	1.03	.35	.14	.05	10.38	7.36	10.85
1955	.17	.63	.38	1.47	5.33	1.96	.73	.17	.31	.63	.75	.53	13.06	9.66	12.41
1956	.52	.13	.08	.43	2.43	.98	1.83	1.52	.26	.54	.61	.22	9.55	7.19	10.14
1957	.58	.35	.90	1.92	1.89	3.01	.38	1.24	.58	.50	1.25	.02	12.62	8.44	11.90
1958	.32	.47	.64	1.61	.24	2.85	3.58	.45	.14	1.16	1.26	.50	13.22	8.73	12.51
1959	.81	1.30	.07	1.02	1.34	1.59	.22	.40	1.26	.53	.91	.03	9.48	4.57	9.80
Mean	.43	.35	.62	1.06	1.82	2.98	1.30	1.43	.99	.74	.48	.34	12.63	8.63	12.68

1/ Precipitation data location for the years of 1933-1938.
2/ Precipitation data location for the years of 1939-1959.

Records show an average annual temperature of 45.8° F. July, the hottest month of the year, has an average temperature of 75.3° F. The coldest month, January, has an average temperature of 16.5° F.

Vegetation. The vegetation type is grama-needlegrass-wheatgrass (Bouteloua-Stipa-Agropyron) (Küchler, 1964). The vegetation of the study area was described by Houston and Woodward (1966). The principle forage species are the short-grasses, blue grama and buffalo grass (Buchloe dactyloides); the mid-grasses, western wheatgrass and needleandthread; and threadleaf sedge (Carex filifolia). Other common perennial grasses found on the study area are: Sandberg bluegrass, sand dropseed (Sporobolus cryptandrus), alkali sacaton (Sporobolus airoides), tumble grass (Schedonnardus paniculatus), needleleaf sedge, saltgrass (Distichlis stricta), and red threeawn (Aristida longiseta). Shrubs common to the area are big sagebrush, silver sagebrush (Artemisia cana), plains prickly pear (Opuntia polyacantha) and western snowberry (Symphoricarpos occidentalis). Common forbs are textile onion (Allium textile), Hood's phlox (Phlox hoodii) and scarlet globe mallow (Sphaeralcea coccinea).

Northern Agricultural Research Center (Rocky Boy's Grazing Permit No. 2)

Location, Geology and Soils. This study area is a tract of land, known as Rocky Boy's Grazing Permit Number 2, leased for summer grazing from the Rocky Boy's Indian Reservation by the Northern Agricultural

Research Center (NARC)[1/]. The area is located in the Bear Paw Mountains on the southeast corner of the reservation (figure 1), thirty miles southeast of the Research Center at Fort Assiniboine, near Havre, Montana (Bergstedt, 1936).

The underlying geological material of the area is composed of Late Mesozoic and Early Cenozoic intrusive and extrusive rock which include a great variety of mafic and felsic volcanic rocks. The mafic rocks are red-gray to dark-gray in color and the felsic rocks are commonly light-gray, brownish gray, and yellowish-gray in color (Pecora, et al. 1957).

The area is dominated by Mollisol and Alfisol soils. These soils belong to the Spring Creek-Blaine-Woodhurst Association. These soils are associated with the igneous rocks that form the Bear Paw Mountains. The area is used primarily for range and timber production (Southard, 1969).

Climate. The climate of the study area is atypical of the Northern Great Plains because it is located in a small mountain range at an elevation of approximately five thousand feet. The temperatures are much cooler and the precipitation much higher than those of the surrounding plains country.

No complete weather data are available for the locality. From

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1/ Formerly known as the North Montana Branch Station.

summer weather records, and from those from other areas having approximately the same elevation and conditions, indications are that the average annual precipitation ranges from 18 to 22 inches with about nine inches occurring as growing season (June-August) precipitation. Summer precipitation data for the study period are presented in table 11.

Summer temperature records from the study area show July to be the hottest month of the year with a mean monthly temperature of 60° F. (Anderson, 1971). Freezing temperatures can occur during every month of the year, so the area is characterized by a relatively short growing season. No November through May temperature records are available.

Vegetation. The vegetation has been classified as a Douglas fir forest (Pseudotsuga) type (Küchler, 1964). Because of the topography of the area, several different plant associations can be found. Bell (1936) described the plant associations. Non-timbered southeast and southwest facing slopes are dominated by bluebunch wheatgrass, Idaho fescue (Festuca idahoensis), Junegrass, bluegrass species (Poa spp) and other less important species belonging to the Bromus, Agropyron and Elymus genera. The bottom lands and water courses where the moisture is higher are dominated by common timothy (Phleum pratense), alpine timothy (Phleum alpinum), reed canary grass (Phalaris arundinacea) and various Calamagrostis, Agrostis and Carex species. Timbered north

Table 11. Seasonal rainfall in inches by months and combined months for June through October, 1952-1971, at the Northern Agricultural Research Center's Rocky Boy's Grazing Permit No. 2, Rocky Boy's Indian Reservation, Hill County, Montana.

Year	June	July	June-July	Aug	June-Aug	Sep	Oct	Sep-Oct
1952	2.30	2.30	4.60	1.09	5.69	1.04	.21	1.25
1953	7.21	1.48	8.69	.34	9.03	2.03	.32	2.35
1954	7.68	.67	8.35	3.45	11.80	3.83	.97	4.80
1955	3.60	6.03	9.63	.18	9.81	1.20	.80	2.00
1956	4.22	1.57	5.79	3.53	9.32	1.60	.68	2.28
1957	5.10	1.54	6.65	1.13	7.77	1.78	2.80	4.58
1958	4.30	2.95	7.25	.50	7.75	2.28	2.52	4.80
1959	7.65	.15	7.80	1.04	8.84	1.93	2.40	4.33
1960	4.86	1.69	6.55	2.27	8.82	.28	.97	1.25
1961	1.81	1.63	3.44	.30	3.74	2.66	1.01	3.67
1962	3.32	4.18	7.50	2.47	9.97	1.69	1.91	3.60
1963	5.06	1.17	6.23	1.17	7.40	2.23	1.32	3.55
1964	3.74	2.44	6.18	9.05	15.23	5.32	.81	6.13
1965	8.27	1.78	10.05	3.78	13.83	5.96	.37	6.33
1966	7.57	3.65	11.22	2.59	13.81	.67	2.12	2.79
1967	1.12	.58	1.70	.18	1.88	6.27	3.20	9.47
1968	5.26	1.24	6.50	5.11	11.61	3.30	1.75	5.05
1969	6.52	2.90	9.42	.16	9.58	.71	3.90	4.61
1970	5.20	1.99	7.19	1.41	8.60	2.81	1.91	4.72
1971	5.15	.32	5.47	1.22	6.69	1.26	1.05	2.31
20-Year Average	4.99	2.01	7.01	2.05	9.06	2.13	1.55	4.00

facing slopes and valleys are dominated by Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), western yellow pine (Pinus ponderosa), quaking aspen (Populus tremuloides), various willows (Salix spp.) and lower growing shrubs. Grasses found in this association belong to the genera Bromus, Calamagrostis, Agrostis, Elymus and Agropyron. On the nontimbered northwest to northeast facing slopes, rough fescue, (Festuca scabrella) is common along with the species mentioned on the southern slopes. Bunchgrasses are especially common and the plant density is higher on these northern slopes than on the southern slopes.

Description of the Data

U. S. Range Livestock Experiment Station

The data used for this portion of the study were obtained from a grazing intensity study conducted from 1932 through 1959 at the U. S. Range Livestock Experiment Station. It was conducted cooperatively by the U. S. Forest Service, the Animal Husbandry Research Division of the Agriculture Research Service and the Montana Agricultural Experiment Station (Reed and Peterson, 1961).

The data were in the form of individual Hereford cow and calf weights taken every twenty-eight days throughout the summer period (May to October). The pastures were grazed at three different intensities during the study period, the intensities being referred to as light, moderate and heavy. Detailed descriptions of the experimental range design, stocking

rates, cattle management and data collection procedures have been given by Reed and Peterson (1961) and Houston and Woodward (1966).

Northern Agricultural Research Center (Rocky Boy's Grazing Permit No. 2)

The data from this study area are in the form of Hereford cow and calf weights. Data used were from the years 1952 through 1971 with the exception of dry cow weights which were only taken from 1955 through 1971. Data were available for years prior to 1952 but due to inconsistency in the methods of collection they were not considered in the present study.

Cattle weights were taken three times during the summer period when the cattle were grazed on the lease. Weights of wet cows, dry cows, yearling heifers and calves were taken the first week in June when they were moved onto the lease and divided into breeding herds, again the first week in August when the bulls were removed from the herds and finally in the first week in October when the calves were weaned. Weights for each class of cattle were averaged for each weighing and listed as a summary table in the annual report (Anderson, 1971).

Methods of Study

Data Summarization

U. S. Range Livestock Experiment Station. Data from the U. S. Range Livestock Experiment Station were obtained in the form of individual yearly cow and calf weight records punched on computer cards[1/].

1/ Computer cards were obtained from Colorado State University, Fort Collins, Colorado.

Individual weights for every twenty eight day period throughout the year were recorded.

In order for the data to be analyzed statistically, average weights, starting the middle of May for every twenty-eight day period, for each class of cattle and grazing intensity were calculated. From these average weights, weight gains for different periods throughout the summer for each year, grazing intensity and class of cattle were calculated (Appendix tables IV, V). Weight gain periods for the wet cows were May-September, May-Early October, June-September and June-Early October. Weight gain periods for the calves were May-Early October, May-Late October, June-September, June-Early October and June-Late October.

April, May, June, July and August precipitation data were obtained from U. S. Weather Bureau records from the Miles City FAA Weather Station. Growing season (April-August) and previous year (September-August) precipitation totals were also calculated for use in the analyses.

Rocky Boy's Grazing Permit No. 2. Data from the Rocky Boy's study area were taken from Anderson (1971). These data were in the form of average weights for four classes of cattle (wet cows, dry cows, yearling heifers and calves) taken during the first weeks of June, August and October.

For statistical analyses, average weight gains from the first of June through the first of October were computed for all four classes of cattle. An average weight gain from the first of June through the

first of August was also computed for the wet cows but not for the other three classes (Appendix table VI).

Monthly precipitation data from the 1971 annual report were also used. In addition to the monthly totals, June-July, growing season (June-August) and September-October totals were also calculated for use in the analyses (table 11).

Data Analyses

Data from the study areas were analyzed statistically with the aid of a computer at Montana State University. The data were analyzed by correlation and regression analyses. To measure the degree of relationship that exists between the variables, a correlation matrix was computed. A linear regression analysis was used to find the effects of different precipitation periods on cattle weight gains during the summer period.

Results and Discussion

U. S. Range Livestock Experiment Station

Wet cow weight gains (light grazing intensity). The correlation analysis indicated that growing season (April-August) and the previous year (September-August) precipitation were both significantly related to June-September and June-Early October weight gains, with correlation coefficients ranging from 0.49 to 0.55 (table 12).

June-Early October weight gain was best estimated by either growing season or the previous year precipitation. The coefficient of determination (r^2) indicates that 30 percent of the variation in gain was explained by growing season or previous year precipitation. Each inch of either growing season or previous year precipitation caused an increase of approximately 10 pounds weight gain per cow.

June-September gain was also best estimated by growing season or previous year precipitation. Twenty-eight and 24 percent of the variation in weight gain was caused by changes in the amount of growing season and previous years precipitation, respectively. One inch of growing season precipitation accounted for an increase in weight gain of 9.75 pounds, while each inch of previous year precipitation resulted in an additional gain of eight pounds.

Wet cow weight gains (moderate grazing intensity). Under moderate grazing intensity, June-September and June-Early October, wet cow weight gains were both correlated with growing season and previous year precipitation (table 13). Growing season precipitation accounted

Table 12. Correlation and regression of average wet cow weight gains (light grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Sept Gain					
April	0.41	0.17	48.80	27.77	3.089
May	0.26	0.07	14.93	14.17	1.111
June	0.22	0.05	6.89	7.77	0.788
July	-0.16	0.03	-13.79	21.67	0.404
Aug	0.02	0.00	1.56	18.16	0.007
Apr-Aug	0.30	0.09	6.64	5.41	1.509
Sept-Aug	0.31	0.09	6.18	4.86	1.622
May-Early Oct Gain					
April	0.22	0.04	26.81	31.84	0.709
May	0.19	0.04	10.25	14.21	0.519
June	0.27	0.07	8.11	7.67	1.116
July	-0.19	0.04	-16.29	22.27	0.535
Aug	0.18	0.03	12.08	17.70	0.466
Apr-Aug	0.33	0.11	7.53	5.68	1.756
Sept-Aug	0.38	0.14	7.14	4.72	2.293
June-Sept Gain					
April	0.50*[1]	0.25	42.39	16.99	6.226*
May	0.37	0.13	16.41	9.56	2.949
June	0.31	0.09	8.15	5.77	1.998
July	0.07	0.00	4.66	15.88	0.086
Aug	0.15	0.02	8.91	13.34	0.446
Apr-Aug	0.53*	0.28	9.75	3.54	7.570*
Sept-Aug	0.49*	0.24	8.01	3.29	5.913*
June-Early Oct Gain					
April	0.38	0.14	35.14	20.80	2.854
May	0.29	0.09	13.54	10.65	1.615
June	0.32	0.10	8.76	6.30	1.936
July	0.04	0.00	2.67	18.08	0.021
Aug	0.29	0.09	18.19	14.45	1.586
Apr-Aug	0.55*	0.30	10.97	4.07	7.281*
Sept-Aug	0.54*	0.30	9.28	3.50	7.046*

[1]/* Indicates significance at P=.05.

Table 13. Correlation and regression of average wet cow weight gains (moderate grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Sept Gain					
April	0.42	0.18	49.68	28.83	2.969
May	0.23	0.05	13.21	14.96	0.779
June	0.44	0.20	13.98	7.55	3.430
July	-0.16	0.02	-14.32	23.94	0.358
Aug	0.03	0.00	1.95	19.55	0.009
Apr-Aug	0.47	0.22	11.09	5.51	4.048
Sept-Aug	0.50*[1/]	0.24	10.01	4.77	4.407
May-Early Oct Gain					
April	0.35	0.12	43.74	31.32	1.950
May	0.16	0.02	8.80	14.63	0.361
June	0.39	0.15	12.03	7.51	2.567
July	-0.24	0.06	-20.51	22.58	0.825
Aug	0.06	0.00	4.37	18.39	0.056
Apr-Aug	0.39	0.15	8.93	5.69	2.462
Sept-Aug	0.44	0.20	8.63	4.67	3.409
June-Sept Gain					
April	0.44	0.19	37.24	18.13	4.221
May	0.27	0.07	12.01	10.25	1.373
June	0.39	0.15	10.50	5.81	3.270
July	0.09	0.01	6.71	17.20	0.152
Aug	0.12	0.01	7.39	14.21	0.270
Apr-Aug	0.56*	0.31	10.71	3.77	8.074*
Sept-Aug	0.54*	0.29	9.09	3.33	7.456*
June-Early Oct Gain					
April	0.42	0.18	37.18	19.45	3.654
May	0.21	0.04	8.98	10.41	0.748
June	0.33	0.11	8.73	5.98	2.131
July	0.03	0.00	2.15	17.25	0.015
Aug	0.20	0.04	12.09	14.11	0.734
Apr-Aug	0.50*	0.24	9.51	4.02	5.601*
Sept-Aug	0.53*	0.28	8.70	3.36	6.723*

1/ * Indicates significance at P=.05.

for 29 percent. One inch of growing season and/or previous year precipitation resulted in an increase in weight gain of 10.71 and 9.09 pounds, respectively.

June-Early October gain was also best predicted by growing season and previous year precipitation. Twenty-four percent of the variation in gain was explained by growing season precipitation. The previous year precipitation explained 28 percent of the variation in weight gains, with each inch of precipitation resulting in an increase of 8.7 pounds of weight gain. One inch of growing season precipitation caused an increase in weight gain of 9.51 pounds.

Wet cow weight gains (heavy grazing intensity). May-September weight gain was significantly correlated with May precipitation on the heavy grazing intensity (table 14). This relationship did not exist on the other two grazing intensities. The coefficient of determination indicates that 28 percent of the variation in weight gain was explained by May precipitation. One inch of May precipitation increased weight gain by 38.24 pounds.

June-September weight gain was significantly associated with both growing season and previous year precipitation, with correlation coefficients of 0.47 and 0.43, respectively. These correlation coefficients were somewhat lower than those derived from similar comparisons on the light and moderate grazing intensities. Growing season precipitation accounted for 22 percent of the variation in weight

Table 14. Correlation and regression of average wet cow weight gains (heavy grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Sept Gain					
April	0.40	0.16	60.50	35.47	2.909
May	0.53*[1/]	0.28	38.24	15.83	5.835*
June	0.16	0.03	6.25	10.00	0.391
July	-0.33	0.11	-36.05	26.32	1.877
Aug	-0.02	0.00	1.71	23.09	0.006
Apr-Aug	0.31	0.09	8.74	6.85	1.627
Sept-Aug	0.20	0.04	5.10	6.37	0.642
May-Early Oct Gain					
April	0.25	0.06	38.13	39.94	0.911
May	0.43	0.18	29.71	16.46	3.257
June	0.14	0.02	5.29	9.97	0.281
July	-0.19	0.04	-20.42	28.14	0.527
Aug	0.04	0.00	3.05	22.71	0.018
Apr-Aug	0.29	0.09	8.38	7.28	1.325
Sept-Aug	0.19	0.04	4.58	6.31	0.725
June-Sept Gain					
April	0.46	0.21	40.65	18.24	4.969*
May	0.45	0.20	21.06	9.60	4.809*
June	0.37	0.14	10.26	5.89	3.033
July	-0.13	0.01	- 9.60	16.51	0.338
Aug	-0.09	0.01	- 6.10	14.05	0.188
Apr-Aug	0.47*	0.22	9.01	3.87	5.439*
Sept-Aug	0.43*	0.19	7.44	3.56	4.365
June-Early Oct Gain					
April	0.30	0.09	22.28	17.13	1.692
May	0.36	0.13	13.08	8.32	2.472
June	0.34	0.12	7.47	4.99	2.239
July	0.01	0.00	0.83	14.46	0.003
Aug	-0.16	0.02	- 7.71	11.92	0.418
Apr-Aug	0.42	0.18	6.78	3.52	3.716
Sept-Aug	0.48*	0.23	6.63	2.91	5.201*

[1/]* Indicates significance at P=.05.

gain and the previous year precipitation accounted for 19 percent. One inch of growing season precipitation increased weight gain by 9.10 pounds while the previous year precipitation increased gain by 7.44 pounds.

June-Early October weight gain was signficantly correlated only with the previous year precipitation. This precipitation period explained 23 percent of the variation in weight gain and each inch of precipitation accounted for an average increase of 6.63 pounds weight gain per cow.

General Comments

Results from the data analyses indicate that under conditions (precipitation, vegetation, grazing intensities, etc.) similar to those of the study, growing season and previous year precipitation are related to wet cow weight gain from June through October. Increases in precipitation during the growing season or previous year resulted in a slight increase in average weight gain.

This increase in gain is evidently a result of increased forage production. May through Early October gain was not related to growing season, previous year or any of the other precipitation periods except for two isolated cases. The average gain for the June-Early October periods was related to and influenced by growing season and previous precipitation while average gain for the May-Early October periods was not, regardless of grazing intensity. One possible explanation may be related to forage availability and dry matter intake. A lack

of adequate forage and a high water content of the forage from the time the cattle started grazing the summer pastures, approximately the 15th of May, until the June weighing, may have caused a reduction in weight or merely no gain (Houston and Urick, 1972).

Calf weight gains (light grazing intensity). Under the light grazing intensity May-Early October gain was significantly correlated with August growing season and previous year precipitation (table 15). Weight gain was best estimated by the growing season precipitation. The August and previous year precipitation were also good estimators but not significantly better than growing season precipitation. Fifty-eight percent of the variation in weight gain was caused by changes in growing season precipitation, while the August and previous year precipitation accounted for only 26 and 41 percent of the variation, respectively. Each additional inch of growing season precipitation resulted in additional weight gain of 7.14 pounds. An inch of previous year precipitation increased weight gain by 5.11 pounds. August precipitation had no significant influence on May-Early October weight gain detected by the regression analysis.

May-Late October gain was related only to growing season precipitation. Growing season precipitation explained 46 percent of the variation in weight gain during this period. One inch of precipitation increased weight gain by 6.67 pounds.

The correlation coefficient for the June-September weight gain

Table 15. Correlation and regression of average calf weight gains (light grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Early Oct Gain					
April	0.24	0.05	12.13	13.75	0.779
May	0.31	0.09	6.92	5.93	1.364
June	0.47	0.22	5.80	3.04	3.628
July	0.26	0.06	9.12	9.51	0.921
Aug	0.51*1/	0.26	14.80	6.86	4.659
Apr-Aug	0.76**2/	0.58	7.14	1.69	17.90**
Sept-Aug	0.64*	0.41	5.11	1.72	8.878*
May-Late Oct Gain					
April	-0.06	0.00	- 3.08	16.91	0.033
May	0.01	0.00	0.24	6.44	0.001
June	0.60	0.34	5.97	2.80	4.550
July	-0.06	0.00	- 1.74	9.61	0.033
Aug	0.56	0.32	20.55	10.06	4.173
Apr-Aug	0.68*	0.46	6.67	2.40	7.680*
Sept-Aug	0.47	0.22	3.60	2.26	2.529
June-Sept Gain					
April	0.30	0.09	8.91	6.53	1.863
May	0.26	0.06	4.04	3.47	1.359
June	0.14	0.02	1.30	2.10	0.384
July	0.36	0.13	8.63	5.20	2.757
Aug	0.32	0.10	6.66	4.46	2.226
Apr-Aug	0.46*	0.21	2.94	1.30	5.124*
Sept-Aug	0.41	0.17	2.33	1.20	3.755
June-Early Oct Gain					
April	0.29	0.09	11.88	9.29	1.633
May	0.27	0.07	5.44	4.64	1.376
June	0.32	0.10	3.79	2.73	1.929
July	0.30	0.09	9.84	7.46	1.740
Aug	0.48*	0.23	12.92	5.74	5.07 *
Apr-Aug	0.65**	0.43	5.66	1.59	12.608**
Sept-Aug	0.54*	0.29	4.00	1.52	6.977*

Table 15. (continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
June-Late Oct Gain					
April	0.08	0.01	3.22	11.49	0.078
May	0.08	0.01	1.62	5.53	0.086
June	0.34	0.11	3.67	2.90	1.610
July	0.11	0.01	3.23	8.40	0.148
Aug	0.44	0.19	16.15	9.56	2.851
Apr-Aug	0.52	0.27	4.95	2.34	4.40
Sept-Aug	0.35	0.12	2.64	2.04	1.675

1/* Indicates significance at P=.05.
2/** Indicates significance at P=.01.

period and growing season precipitation shows a low significant relationship between the two factors. Growing season precipitation accounted for 21 percent of the variation in weight gain and an inch of growing season precipitation increased June-September average weight gain by only 2.94 pounds.

June-Early October weight gain was significantly related to August, growing season and previous year precipitation as was the May-Early October gain. Growing season precipitation was the best estimator of June-Early October weight gain accounting for 43 percent of the variation. One inch of growing season precipitation accounted for an increase in June-Early October weight gain of 5.66 pounds. August precipitation accounted for 23 percent of the variation and the previous year precipitation explained 29 percent. An inch of August precipitation resulted in an increase of 12.92 pounds during the June-Early October weight gain period. One inch of previous year precipitation showed an increase of four pounds during the same period.

Calf weight gains (moderate grazing intensity). June, growing season and the previous year precipitation were all related to weight gain during the May-Early October period, having correlation coefficients of 0.52, 0.79 and 0.65, respectively, the last two being highly significant (table 16)[1/].

1/ Significant at P=.05.

Table 16. Correlation and regression of average calf weight gains (moderate grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Early Oct Gain					
April	0.50	0.25	24.85	11.80	4.432
May	0.24	0.06	5.18	5.84	0.785
June	0.52**[1]	0.26	6.19	2.85	4.716**
July	0.22	0.05	7.43	9.27	0.642
Aug	0.46	0.21	12.89	6.84	3.548
Apr-Aug	0.79*[2]	0.63	7.17	1.54	21.717*
Sept-Aug	0.65*	0.42	5.01	1.64	9.348*
May-Late Oct Gain					
April	0.16	0.03	8.82	18.06	0.239
May	-0.01	0.00	- 0.25	6.96	0.001
June	0.58	0.33	6.43	3.03	4.509
July	-0.16	0.03	- 5.17	10.26	0.254
Aug	0.58	0.33	22.73	10.75	4.473
Apr-Aug	0.68**	0.46	7.17	2.61	7.538**
Sept-Aug	0.47	0.22	3.88	2.44	2.529
June-Sept Gain					
April	0.08	0.01	3.21	8.80	0.133
May	0.19	0.03	3.88	4.55	0.725
June	0.11	0.01	1.33	2.72	0.239
July	0.44*	0.19	13.81	6.45	4.591**
Aug	0.11	0.01	3.05	6.05	0.254
Apr-Aug	0.33	0.11	2.68	1.79	2.242
Sept-Aug	0.29	0.08	2.16	1.63	1.763
June-Early Oct Gain					
April	0.30	0.09	14.84	11.25	1.742
May	0.21	0.05	5.14	5.72	0.808
June	0.30	0.08	4.26	3.34	1.629
July	0.44	0.20	17.35	8.53	4.139
Aug	0.31	0.09	10.24	7.54	1.845
Apr-Aug	0.59**	0.35	6.26	2.05	9.284**
Sept-Aug	0.48*	0.23	4.37	1.91	5.218*

Table 16. (continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
June-Late Oct Gain					
April	0.02	0.00	1.03	14.16	0.005
May	0.14	0.02	3.24	6.75	0.230
June	0.28	0.08	3.63	3.63	0.005
July	0.27	0.08	9.89	9.98	0.981
Aug	0.28	0.08	12.83	12.53	1.047
Apr-Aug	0.48	0.23	5.67	2.96	3.665
Sept-Aug	0.32	0.10	2.99	2.53	1.393

1/**Indicates significance at P=.01.
2/* Indicates significance at P=.05.

Growing season and previous year precipitation were again the best indicators of May-Early October weight gain. Growing season precipitation explained 63 percent of the variation in weight gain while the previous year precipitation accounted for 42 percent. June precipitation accounted for 52 percent of the variation. Each inch of June, growing season and previous year precipitation increased May-Early October average weight gain by 6.19, 7.17 and 5.01 pounds, respectively.

May-Late October weight gain was significantly related only to growing season precipitation. Based on the regression analysis growing season precipitation explained 46 percent of the change in calf weight gain for the period, with each inch of additional precipitation increasing weight gain by 7.17 pounds.

June-September weight gain was correlated with the July precipitation. Only 19 percent of the variatibn in weight gain was accounted for by July precipitation, with each inch of precipitation increasing the average weight gain by 13.81 pounds.

June-Early October weight gain was related to both growing season and previous year precipitation. Weight gain was best explained by the amount of growing season precipitation. Growing season precipitation explained 35 percent of the variation in calf weight gain. One inch of growing season precipitation gave an increase of 6.26 pounds in average weight gain. The previous year precipitation also influenced June-Early October weight gain but not to the extent of growing

season precipitation.

Calf weight gains (heavy grazing intensity). May-Early October gain was significantly related to June precipitation and highly correlated with growing season and previous year precipitation (table 17). The best estimators of May-Early October weight gain were growing season and previous years precipitation which explained 70 and 53 percent of the variation, respectively. June precipitation accounted for 30 percent of the variation. One additional inch of June, growing season and previous year precipitation increased weight gain by 7.79, 8.78 and 6.51 pounds, respectively.

June, growing season and previous year precipitation were all related to May-Late October weight gain, all correlation coefficients being highly significant. Growing season precipitation accounted for 73 percent of the change in weight gain while June precipitation accounted for 53 percent and previous year precipitation accounted for 50 percent. An inch of growing season precipitation resulted in an increase of 9.74 pounds in May-Late October weight gain while June and previous years precipitation increased the average gain by 9 and 6.52 pounds, respectively.

Considering the other weight gain periods animal weight increases were all significantly correlated with growing season and previous year precipitation. The June-Late October gain was also related to June precipitation. The previous year precipitation also had a significant

Table 17. Correlation and regression of average calf weight gains (heavy grazing intensity) with precipitation for the U.S. Range Livestock Experiment Station, Miles City, Montana.

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
May-Early Oct Gain					
April	0.43	0.18	24.30	14.32	2.878
May	0.38	0.14	9.49	6.45	2.161
June	0.56*1/	0.31	7.79	3.19	5.967*
July	0.18	0.03	6.96	10.83	0.413
Aug	0.40	0.16	12.87	8.20	2.46
Apr-Aug	0.84**2/	0.70	8.78	1.60	30.336**
Sept-Aug	0.73**	0.53	6.51	1.71	14.438**
May-Late Oct Gain					
April	0.08	0.006	4.37	17.30	0.064
May	0.10	0.01	2.35	6.71	0.122
June	0.79**	0.53	9.00	2.55	12.430**
July	-0.12	0.02	- 4.30	10.31	0.174
Aug	0.39	0.15	11.18	7.88	2.014
Apr-Aug	0.86**	0.73	9.74	1.78	30.04**
Sept-Aug	0.70**	0.50	6.52	1.96	11.080**
June-Sept Gain					
April	0.33	0.11	10.82	7.16	2.284
May	0.40	0.16	6.95	3.64	3.637
June	0.36	0.13	3.64	2.19	2.756
July	0.27	0.07	7.24	5.94	1.487
Aug	0.22	0.05	5.04	5.09	0.979
Apr-Aug	0.62**	0.38	4.38	1.27	11.818**
Sept-Aug	0.50*	0.25	3.21	1.26	6.486*
June-Early Oct Gain					
April	0.42	0.18	19.90	10.43	3.639
May	0.44	0.19	10.27	5.13	4.019
June	0.44	0.20	6.23	3.05	4.190
July	0.29	0.08	11.01	8.86	1.543
Aug	0.29	0.08	8.88	7.42	1.432
Apr-Aug	0.77**	0.60	7.92	1.56	25.284**
Sept-Aug	0.64**	0.41	5.58	1.64	11.593**

Table 17. (continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-value
June-Late Oct Gain					
April	0.07	0.01	3.02	12.12	0.062
May	0.15	0.02	3.29	5.73	0.330
June	0.61*	0.38	7.68	2.64	8.449*
July	-0.04	0.001	- 1.25	9.11	0.019
Aug	0.25	0.06	7.39	7.51	0.970
Apr-Aug	0.71**	0.50	7.74	2.05	14.243**
Sept-Aug	0.55*	0.30	4.84	1.97	6.039

1/* Indicates significance at P=.05.
2/**Indicates significance at P=.01.

effect on weight gain but not as great as growing season precipitation. Growing season precipitation explained 38, 60 and 50 percent of the variation in weight gain during the June-September, June-Early October weight gain periods, respectively. One inch of growing season precipitation increased June-September weight gain by 4.38 pounds, June-Early October gain by 7.92 pounds and June-Late October gain by 7.74 pounds.

General Comments

Results from the data analyses indicated that calf weight gains for different periods throughout the summer (May-Late October) have a higher relationship to precipitation, primarily growing season and previous year, than wet cows weight gain during similar periods (tables 18, 19). Precipitation also appears to have a somewhat greater influence on calf weight gain than on cow weight gain. This suggests that and increase in precipitation increases the amount of milk produced by the cow through an increase in range forage production. Houston and Urick (1972) observed a similar phenonmenon in that calf responses were apparently more sensitive indicators of forage production than were cow responses.

Calf weight gains on the heavy grazing intensity showed a higher relationship to precipitation, primarily growing season and previous year, than calf weight gains on the moderate and light grazing intensities. Range condition ratings in 1958 for the light, moderate and

Table 18. Percent variation in cattle weight gains under three grazing intensities accounted for by growing season precipitation at the U. S. Range Livestock Experiment Station, Miles City, Montana.

	GRAZING INTENSITY					
	Light		Moderate		Heavy	
Weight Gain Period	Wet Cow	Calf	Wet Cow	Calf	Wet Cow	Calf
May-Early Oct	11	58**1/	15	63*	9	70**
June-Sept	28*2/	21*	31*	11	22*	38**
June-Early Oct	30*	43**	24*	35**	18	60**
May-Sept	9	a3/	22	a	9	a
May-Late Oct	a	46*	a	46**	a	73**
June-Late Oct	a	27	a	23	a	50**

1/** Indicates significance at P=.01.
2/* Indicates significance at P=.05.
3/ "a" indicates that adequate weight gain data were not available for that period.

Table 19. Percent variation in cattle weight gains under three grazing intensities accounted for by previous year precipitation at the U. S. Range Livestock Experiment Station, Miles City, Montana.

	GRAZING INTENSITY					
	Light		Moderate		Heavy	
Weight Gain Period	Wet Cow	Calf	Wet Cow	Calf	Wet Cow	Calf
May-Early Oct	14	41*1/	20	42*	4	53**2/
June-Sept	24	17	29*	8	19*	25*
June-Early Oct	30*	29	28*	23*	23*	41**
May-Sept	9	a3/	24*	a	4	a
May-Late Oct	a	22	a	22	a	50**
June-Late Oct	a	12	a	10	a	30*

1/* Indicates significance at P=.05.
2/** Indicates significance at P=.01.
3/ "a" indicates that adequate weight gain data were not available for that period.

heavy grazing intensity pastures showed that as grazing intensity decreased percent range condition increased. The term range condition as used here is defined as "total percentage, by weight, of vegetation on a site that is the original or climax kinds for that site" (Houston and Woodward, 1966). These two facts suggest that range forage production on a heavily grazed range with less than good range condition will show a slightly greater response to increased precipitation than will range forage production on a lightly grazed range with a higher range condition. However, it should be noted that heavy grazing decreased forage production on the heavily grazed pastures (Houston and Woodward, 1966). They also suggested that the large gully that developed on these pastures after the study was initiated was a result of the heavy grazing.

Northern Agricultural Research Center (Rocky Boy's Grazing Permit No. 2)

The correlation analysis indicated that there was no consistant relationship between summer weight gain and precipitation (table 20). Precipitation and weight gain were significantly related in only two comparisons. These were negative correlations between yearling heifer June-October gain with September-October precipitation and wet cow June-October gain with August precipitation. The correlation coefficients for these two comparisons were -0.45 and -0.55, respectively.

Based on the regression analysis, 20 percent of the variation in yearling heifer June-October weight gain was due to September-October

Table 20. Correlation and regression of average cattle weight gains with precipitation for the Northern Agricultural Research Center Rocky Boy's Grazing Permit No. 2, Rocky Boy's Indian Reservation, Hill County, Montana

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-Value
Yearling heifer (June-Oct Gain)					
June	0.08	0.00	1.13	3.35	0.115
July	-0.01	0.00	-0.23	4.82	0.002
Jun-Jul	0.07	0.00	0.85	3.06	0.077
Aug	-0.21	0.04	-2.72	3.09	0.077
Jun-Aug	-0.09	0.01	-0.77	2.06	0.141
Sep	-0.41	0.17	-6.83	3.68	3.446
Oct	-0.25	0.06	-7.92	7.57	1.094
Sep-Oct	-.45*1/	0.21	-6.50	3.06	4.521*
Wet Cow (June-Aug Gain)					
June	-0.12	0.01	-1.62	3.21	0.254
July	-0.42	0.00	-0.83	4.64	0.032
June-July	-0.13	0.01	-1.63	2.88	0.320
Aug	0.19	0.03	2.44	2.98	0.674
June-Aug	0.03	0.00	0.29	2.02	0.021
Wet Cow (June-Oct Gain)					
June	0.05	0.00	1.54	7.05	0.047
July	0.08	0.01	3.62	10.15	0.128
Jun-Jul	0.09	0.01	2.65	6.31	0.176
Aug	-0.55*	0.30	-15.48	5.53	7.843*
Jun-Aug	-0.30	0.09	-5.58	4.21	1.758
Sep	-0.31	0.09	-10.84	7.58	1.846
Oct	-0.13	0.01	-7.72	13.93	0.307
Sep-Oct	-0.34	0.11	-10.40	6.91	2.268
Calf (June-Oct Gain)					
June	-0.05	0.00	-0.67	3.48	0.037
July	-0.21	0.04	-3.75	4.56	0.677
Jun-Jul	-0.22	0.05	-3.12	3.61	0.747
Aug	0.09	0.01	1.06	3.01	0.124
Jun-Aug	-0.07	0.01	-0.65	2.41	0.073
Sep	0.12	0.01	2.01	4.29	0.218
Oct	-0.41	0.17	-9.97	5.91	2.844
Sep-Aug	-0.14	0.02	-2.31	4.17	0.307

Table 20. (Continued)

Comparison	r	r^2	Regression Coefficient	Standard Error	Computed F-Value
Dry Cow (June-Oct Gain)					
June	0.26	0.07	5.44	6.771	0.644
July	0.45	0.21	12.66	11.58	2.328
June-July	0.39	0.16	6.57	5.07	1.680
Aug	-0.16	0.03	-2.66	5.32	0.251
June-Aug	0.15	0.02	1.69	3.65	0.215
Sep	-0.55	0.31	-11.86	5.41	4.032
Oct	0.46	0.21	18.16	11.82	2.360
Sep-Oct	-0.32	0.10	-6.13	5.98	1.051

1/* Indicates significance at P=.05.

precipitation. Each inch of precipitation decreased gain by 6.50 pounds. August precipitation explained 30 percent of the variation in wet cow June-October gain. An inch of August precipitation decreased wet cow June-October weight gain by 15.58 pounds. Precipitation had no significant influence on any of the other comparisons.

Grazing permit regulations and grazing management on the NARC's Rocky Boy's Grazing Permt No. 2 are such that even in years of below normal precipitation and forage production, adequate forage was apparently available throughout the growing season (Anderson, 1971). Although no current range condition surveys are available, it would appear from personal observations of the pastures within the study area that average range condition was good to excellent.

These facts suggest that under conditions similar to the study and study area, e.g. precipitation, range condition, grazing management etc., changes in spring and summer precipitation do not influence cattle weight gains. The possible exception would be in extreme drought situations.

SUMMARY AND CONCLUSIONS

Research was initiated in 1972 to study the relationship of precipitation to range cattle and grass production in the plains region of Montana. Historical cattle production data from two experimental areas and range grass production data from one area were analyzed.

Based upon this research, the following conclusions are presented:

1. Results from the OW Ranch study indicate that: (a) Western wheatgrass production tends to be related to and influenced by precipitation that occurs during the growing season; the degree of influence depends upon time of harvest and type. Significant correlation coefficients for western wheatgrass clipped in September on the wheatgrass type range from 0.47 to 0.71, while the coefficients of determination ranged from 22 percent to 50 percent. (b) The degree of relationship that exists between precipitation and annual production of the majority of grass species is very low. Of the 10 grass species used in the analyses only, four species (western wheatgrass, green needlegrass, needleandthread and needleleaf sedge) were significantly related to or influenced by precipitation. Western wheatgrass was the only species of the four that had significant correlation coefficients over 0.60 and coefficients of determination greater than 30 percent. (c) The majority of the correlation coefficients and coefficients of determination were low, less than 0.50 and 20 percent, respectively. Non-significant correlation coefficients and low coefficients of determination indicate that factors other than precipitation determine grass production.

2. Results from the U. S. Range Livestock Experiment Station study indicate that (given the same or similar conditions that existed for the study): (a) The average weight gain of wet cows during the summer is not highly related to or influenced by precipitation. All of the correlation coefficients were below 0.60, including those that were significant. With the exception of three comparisons, precipitation accounted for less than 30 percent of the variation in weight gain. (b) The average weight gain of calves during the summer is significantly related to growing season and previous year precipitation. Calf weight gains showed a consistent significant relationship to both growing season and previous year precipitation with 59 percent of the significant correlations being greater than 0.60. Coefficients of determination were consistently above 30 percent. The results indicate that an increase of one inch in either growing season or previous year precipitation would result in a slight increase, less than 10 pounds, in the average weight gain made by calves during the summer. (c) Precipitation has a somewhat greater influence on calf weight gain than wet cow weight gain during the summer. (d) The significant regression analyses indicate that the average weight gain made by calves on a heavily grazed pasture is approximately one to two pounds more per each additional inch of precipitation than gain made by calves on the moderately and lightly grazed pastures. The benefit from the increased average weight gain would probably not compensate for the damage to the resource

resulting from the heavy grazing, e. g. decreased range condition, a decrease in plant vigor and subsequent reduction in forage production as well as increasing erosion problems and downstream water pollution.

3. Results from the NARC (Rocky Boy's Grazing Permit No.2) suggest that on ranges estimated to be in good condition or better and under moderate grazing use, an increase in precipitation apparently does not affect cattle weight gains. Of the 37 comparisons made only two were significant. All of the correlation coefficients were less than $\pm$ 0.60. The coefficients of determination were all very low, less than 20 percent, with two exceptions. The exceptions were 21 and 30 percent.

APPENDIX

Appendix Table I. Yield of various grass species, lbs/acre dry wt., (wheatgrass type, sprayed and unsprayed, June and Sept. clipping) for the OW Ranch, Big Horn County, Montana.

	Sprayed					Unsprayed		
	Western wheatgrass		Green needle-grass		Japanese brome	Western wheatgrass		Japanese brome
YEAR	June	Sept	June	Sept	June	June	Sept	June
1952	439	452	0	0	0	222	338	0
1953	779	645	0	0	0	518	406	0
1954	301	186	6	0	0	163	114	a[1]/
1955	199	706	20	23	0	205	389	a
1956	581	540	1	8	1	566	432	a
1957	a	468	a	54	a	a	346	a
1958	422	797	72	8	1	343	706	184
1959	478	386	184	93	1	408	422	11
1960	153	99	48	21	1	156	102	16
1961	192	127	27	12	0	147	50	43
1962	549	622	53	30	23	319	159	463
1963	1570	1603	68	192	48	358	178	1414
1964	0	914	0	192	36	215	295	1121
1965	451	549	528	79	119	722	418	212
1966	506	262	257	33	77	955	312	114
1967	516	619	203	781	219	711	806	326
1968	686	449	26	94	816	456	358	943
1969	1149	1046	202	252	0	672	662	126
1970	1244	1180	168	234	139	935	1617	0
1971	1046	676	64	157	267	447	408	661
Mean	593	616	101	113	92	448	426	352

1/ "a" indicates that no yields were taken for that clipping date.

Appendix Table II. Yield of various grass species, lbs/acre dry wt., (bunchgrass type, June and Sept. clippings, sprayed) for the OW Ranch, Bigi Horn County, Montana.

	Needleandthread		Western wheatgrass		Junegrass		Needleleaf sedge		Sandberg bluegrass	Blue grama		Japanese brome
YEAR	June	Sept	June	Sept	June	Sept	June	Sept	June	June	Sept	June
1952	308	372	85	72	11	13	6	6	0	13	3	0
1953	314	364	144	132	7	10	8	4	0	36	30	0
1954	276	282	115	52	14	9	4	0	0	70	26	0
1955	630	a[1]/	16	a	27	a	1	a	0	29	a	0
1956	320	547	34	65	6	17	10	7	3	4	115	1
1957	a	712	a	181	a	10	a	28	a	a	7	a
1958	439	506	137	136	65	48	1	4	52	37	95	12
1959	302	418	174	77	48	6	10	1	64	74	56	29
1960	133	240	48	10	13	11	1	1	5	10	1	41
1961	48	70	47	117	0	0	5	5	38	66	115	0
1962	166	128	264	264	0	0	10	10	398	7	180	77
1963	102	177	85	768	0	0	1	15	192	29	96	298
1964	336	229	16	540	0	0	12	2	0	0	73	209
1965	377	273	504	468	39	0	14	0	55	0	0	51
1966	253	101	353	179	16	28	3	0	77	39	47	133
1967	163	40	276	84	96	0	3	0	155	0	0	353
1968	111	79	146	240	22	17	8	2	145	0	22	264
1969	278	229	451	612	0	0	11	13	110	6	52	67
1970	207	355	192	384	34	0	27	6	207	0	13	16
1971	394	242	223	504	128	0	20	0	479	0	0	32
Mean	271	282	174	257	28	9	8	6	104	22	49	83

1/ "a" indicates that no yields were taken for that clipping date.

Appendix Table III. Yield of various grass species, lbs/acre dry wt., (bunchgrass type, June and Sept. clippings, unsprayed) for the OW Ranch, Big Horn County, Montana.

	Needleandthread		Western wheatgrass		Blue grama		Sandberg bluegrass	Red threeawn		Japanese brome
YEAR	June	Sept	June	Sept	June	Sept	June	June	Sept	June
1952	383	511	6	0	35	34	0	6	5	0
1953	667	615	77	21	37	58	0	9	6	0
1954	495	502	12	4	21	29	1	3	3	0
1955	582	a[1/]	21	a	51	a	1	35	a	0
1956	782	670	21	10	17	58	0	0	2	0
1957	a	758	a	3	a	173	a	a	18	a
1958	696	816	20	33	11	142	23	0	14	33
1959	605	713	22	9	72	142	8	12	14	220
1960	194	15	1	4	9	5	1	0	0	88
1961	516	309	22	4	27	53	18	6	4	38
1962	687	771	34	29	62	0	97	10	0	1209
1963	1114	821	8	13	1	13	39	0	0	527
1964	1192	1536	0	21	3	5	0	0	0	300
1965	1584	1368	34	0	7	4	0	0	0	39
1966	1327	686	62	2	17	0	0	0	0	7
1967	744	562	96	79	0	65	25	47	0	201
1968	600	89	17	24	0	0	12	0	0	336
1969	1488	1229	14	22	18	33	62	0	0	89
1970	648	928	42	25	0	12	72	0	0	125
1971	986	769	9	0	0	26	360	0	0	255
Mean	805	719	27	16	20	45	39	7	3	182

1/ "a" indicates that no yields were taken for that clipping date.

Appendix Table IV. Average calf weight gains (pounds) at periodic intervals for three grazing intensities for years 1933-1959, at the U. S. Range Livestock Experiment Station, Miles City, Montana[1/].

	GRAZING INTENSITY														
	Light					Moderate					Heavy				
YEAR	May-Early Oct	May-Late Oct	June-Sept	June-Early Oct	June-Late Oct	May-Early Oct	May-Late Oct	June-Sept	June-Early Oct	June Late Oct	May-Early Oct	May-Late Oct	June-Sept	June-Early Oct	June-Late Oct
1933	210	222	131	174	186	212	224	125	172	184	210	222	131	174	186
1934	172		111	129		165		106	122		172		111	129	
1935	240	260	148	196	216	250	261	151	197	208	240	260	148	196	216
1938	217		132	171		219		128	159		217		132	171	
1939			139	214	250			167	223	264			139	214	250
1940	255	290	157	205	240	261	295	153	205	239	255	290	157	205	240
1941	270	305	161	225	260	278	312	164	225	259	270	305	161	225	260
1942	259	281	162	213	235	243	272	153	201	230	259	281	162	213	235
1943	274	317	161	220	263	259	301	148	207	249	274	317	161	220	263
1944	258	292	161	206	240	268	303	162	213	239	258	292	161	206	240
1945	270	265	162	211	206	233	250	159	204	221	270	265	162	211	206
1950	259		165	210		245		167	210		259		165	210	
1951	282		169	225		258		154	206		282		169	225	
1952			163					169					163		
1953			193	238	269			198	253	281			193	238	269
1954			178	235				170	232				178	235	
1955	252	264	150	195	207	247	260	142	185	198	252	264	150	195	207
1956			190	212	252			190	210	241			190	212	252
1957	253	282	163	198	227	259	285	95	149	175	253	282	163	198	227
1958	244	253	161	197	206	238	240	157	202	204	244	253	161	197	206
1959			168					169					168		
Mean	248	276	158	204	233	242	273	154	199	228	224	247	146	184	206

1/ Years when no weight gain data are given indicate that no weights were taken either at the beginning, at the end of the period or both.

Appendix Table V. Average wet cow weight gains (pounds) at periodic intervals for three grazing intensities for years 1933-1958, at the U. S. Range Livestock Experiment Station, Miles City, Montana[1/].

	GRAZING INTENSITY											
	Light				Moderate				Heavy			
Year	May-Sept	May-Early Oct	June-Sept	June-Early Oct	May-Sept	May-Early Oct	June-Sept	June-Early Oct	May-Sept	May-Early Oct	June-Sept	June-Early Oct
1933	159	173	72	86	146	142	79	75	158	161	75	78
1934	-85	-84	-129	-128	170	-62	-103	-95	-71	-77	-65	-70
1935	136	135	65	64	106	113	10	17	65	47	-38	-56
1936	94	92	28	26	123	109	34	20	109	92	33	16
1939		109	89	70		126	93	70		94	63	27
1940	157	122	92	57	150	136	53	39	148	90	63	5
1941	82	77	48	43	98	94	40	36	46	20	13	-13
1942	117	105	76	64	137	126	71	60	107	98	61	52
1943	105	127	58	80	120	96	54	30	101	116	57	72
1944	131	124	75	68	182	168	95	81	135	94	79	38
1945	140	89	75	24	115	76	79	40	80	27	54	1
1950	246	238	134	126	279	274	167	162	-108	-159	133	82
1951	108	124	53	69	101	114	69	82	-21	-24	-20	-23
1952	55		0		59		4		-39		-83	
1953			144	160			156	156			122	93
1954			85	82			68	66			-14	-49
1955	147	123	67	43	147	122	37	12	174	136	58	20
1956			40	15			35	17			37	32
1957	163	124	66	27	156	160	41	45	150	132	29	11
1958	63	37	16	-10	81	45	41	5	-11	39	-35	15
1959	146		56		133		11		120		11	
Mean	116	107	58	51	121	115	56	48	67	55	30	17

1/ Years when no weight gain data are given indicates that no weights were taken either at the beginning, at the end of the period, or both.

2/ - indicates a weight loss.

Appendix Table VI. Average cattle weight gains (pounds) at periodic intervals from 1952-1971 at the Northern Agricultural Research Center's Rocky Boy's Grazing Permit No. 2, Rocky Boy's Indian Reservation, Hill County, Montana[1/]

	Weight Gain				
Year	Wet cows June-Aug	Wet cows June-Oct	Dry cows June-Oct	Yearling heifers June-Oct	Calves June-Oct
1952	180	199		244	273
1953	170	187		237	259
1954	204	219		264	254
1955	189	206		243	235
1956	191	218		250	252
1957	177	120		216	207
1958	188	126		220	253
1959	206	162	282	245	232
1960	173	183	169	258	245
1961	183	224		248	260
1962	148	160		180	169
1963	165	164	223	216	
1964	206	-45	278	210	258
1965	190	161	213	188	234
1966	175	208	281	256	
1967	217	169	220	213	
1968	150	144	194	184	
1969	132	138	345		240
1970	146	163	247	172	220
1971	103	76	257	208	220
Mean	175	159	255	224	238

1/ Years when no weight gains are given indicates that no weights were taken either for the entire summer grazing period or part of the period.

LITERATURE CITED

Anderson, Donald. 1971. Report of grazing unit number two, Rocky Boy's Indian Agency. Annual Report, NARC. 18 pp.

Anderson, N. L. and J. C. Wright. 1952. Grasshopper investigations on Montana range lands. Mont. Agr. Exp. Sta. Bull. No. 486 46 pp.

Bell, M. A. 1936. Botanical observations made in 1936, in Bergstedt, C. B. 1936. Report of grazing unit number two, leased from Rocky Boy's Indian Agency by the North Montana Branch Station, Hayre, Montana. Annual Report, NMBS. 43 pp.

Bergstedt, C. B. 1936. Report of grazing unit number two, leased from Rocky Boy Indian Agency by the North Montana Branch Station, Havre, Montana. Annual Report, NMBS. 43 pp.

Billings, W. D. 1952. The environmental complex in relation to plant growth and distribution. Quart. Rev. Biol. 27:251-265.

Blaisdell, J. P. 1958. Seasonal development and yield of native plants on the upper Snake River Plains and their relations to certain climatic factors. USDA Tech. Bull. No. 1190 68 pp.

Chapline, W. R. and C. K. Cooperrider. 1941. Climate grazing. USDA Agr. Yearbook 1941:459-476.

Clark, R. T., C. E. Shelby, J. R. Quesenberry, R. R. Woodward and F. S. Willson. 1958. Production factors in range cattle under Northern Great Plains conditions. USDA Tech. Bull. 1181 22 pp.

Clawson, M. 1948. Range and livestock conditions in relation to annual precipitation. Amer. Cattle Prod. 25 (8):12-19.

Clawson, M. 1948. Range forage conditions in relation to annual precipitation. Land Economics. 24:264-280.

Cooper, C. F. and W. C. Jolly. 1969. Ecological effects of weather modification: A problem analysis. Univ. Mich., Dept. of Resource and Conservation. 158 pp.

Currie, P.O. and L. Peterson. 1966. Using growing season precipitation to predict crested wheatgrass yields. J. Range Manage. 19:284-286.

Daubenmire, R. R. 1956. Climate as a determinant of vegetation distribution in eastern Washington and northern Idaho. Ecol. Monog. 26:131-154.

Hanson, H. C. 1957. The use of basic principles in the classification of range vegetation. J. Range Manage. 10:26-33.

Hildreth, A. C., J. R. Magnes and J. W. Mitchel. 1941. Effects of climatic factors on growing plants. USDA Agr. Yearbook 1941. 292-307 pp.

Houston, W. R. and R. R. Woodward. 1966. Effects of stocking rates on range vegetation and beef cattle production in the Northern Great Plains. USDA Tech. Bull. No. 1357. 58 pp.

Houston, W. R. and J. J. Urick. 1972. Improved spring pastures, cow-calf production, and stocking rate carryover in the Northern Great Plains. USDA Tech. Bull. 1451. 21 pp.

Küchler, A. W. 1964. Potential natural vegetation of the continuous United States. Amer. Geog. Soc. Spec. Pub. 36. 155 pp.

Montana Agricultural Experiment Station. 1972. Impacts of induced rainfall on the Great Plains of Montana - an interm report. Res. Rep. 26. p 46B.

Montana Soil and Water Conservation Needs Inventory. 1970. USDA Soil Conservation Service, Bozeman, Montana.

Noller, T. L. 1968. The relationship of forage production to precipitation, cover and soils in North Central Wyoming. Ph.D. Thesis. Range Manage., Univ. of Wyoming. 153 pp.

Passey, H. B. and O. K. Hugie. 1963. Fluctuating herbage production on an ungrazed sierozem soil in Idaho. Jour. of Soil and Water Conserv. 18:8-11.

Pecora, W. T., I. J. Witkind and D. B. Stewart. 1957. Preliminary general geologic map of the Lando Quandrangle, Bearpaw Mountains, Montana. Misc. Geologic Investigations. Map I-234.

Ryerson, D. E., J. E. Taylor, L. D. Baker, H. A. R. Houlton and D. W. Stroud. 1970. Clubmoss on Montana Rangelands: Distribution, Control, Range Relationships. MAES Bull. 645. 116 pp.

Smoliak, S. 1956. Influence of climatic conditions on forage production of shortgrass rangelands. J. Range Manage. 9:89-91.

Southard, A. R. 1969. Soils in Montana. Mont. Agr. Exp. Sta. Bull. 621. 42 pp.

Stitt, R. E. 1958. Factors affecting yield and quality of dryland grasses. Agron. Jour. 50:136-138.

Thomas, J. R. and A. Osenbrug. 1959. Effect of manure, nitrogen, phosphorus, and climatic factors on the production and quality of bromegrass-crested wheatgrass hay. Agron. Jour. 51:53-66.

U.S. Department of Commerce Weather Bureau. 1972. Annual summary for 1972 - Montana. U. S. Government Printing Office. Washington D. C. 75:294-308.

Weaver, J. E. and F. W. Albertson. 1956. Grasslands of the Great Plains--Their Nature and Use. Johnson Publ. Co., Lincoln, Nebr. 395 pp.