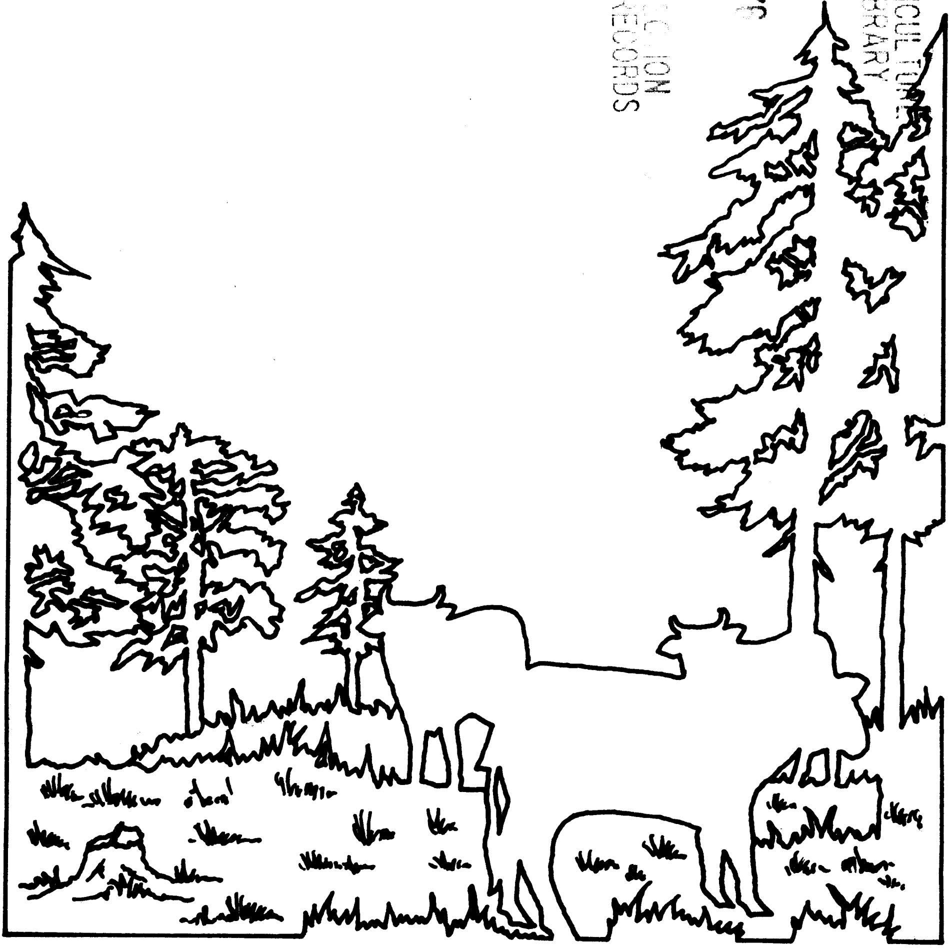
EFFECTS OF CATTLE GRAZING METHODS ON PONDEROSA PINE-BUNCHGRASS RANGE IN THE PACIFIC NORTHWEST

TECHNICAL BULLETIN NO. 1531

U.S. DEPARTMENT
OF AGRICULTURE
FOREST SERVICE



ACKNOWLEDGMENT

The authors extend special recognition to Cunha Brothers of Echo, Oregon, for cooperation in providing cattle throughout the study.

EFFECTS OF CATTLE GRAZING METHODS ON PONDEROSA PINE-BUNCHGRASS RANGE IN THE PACIFIC NORTHWEST

by

Jon M. Skovlin, Principal Range Scientist, Pacific Northwest Forest and Range Experiment Station, La Grande, Oreg.
Robert W. Harris, formerly Project Leader, Pacific Northwest Forest and Range Experiment Station, La Grande, Oreg. Now Director, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.
Gerald S. Strickler, Plant Ecologist, Pacific Northwest Forest and Range Experiment Station, La Grande, Oreg.
George A. Garrison, formerly Project Leader, Pacific Northwest Forest and Range Experiment Station, La Grande, Oreg. Now Assistant Director, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Technical Bulletin No. 1531
May 1976

United States Department of Agriculture
Forest Service

Skovlin, Jon M., Robert W. Harris, Gerald S. Strickler, and George A. Garrison. 1975. Effects of cattle grazing methods on ponderosa pine-bunchgrass range in the Pacific Northwest. U.S. Dep. Agric., Tech. Bull. 1531, 40 p.

An 11-year study of plant and animal responses to systems and levels of cattle grazing showed forested range was improved by deferred rotation; there was little change on intermingled grassland openings. Big game use decreased as cattle stocking increased. **Carex geyeri,** the most valuable forage, was favored by light deferred rotation.

Keywords: Cattle grazing systems, deer, elk, cattle relationships, factorial grazing design, levels of cattle stocking, ponderosa pine rangelands, cattle responses to grazing, bluebunch wheatgrass responses, elk sedge responses, grazing capacity.

CONTENTS

RESEARCH SUMMARY

A study of herbage production and cattle weight gains in the ponderosa pine zone of the Pacific Northwest showed a number of definite responses to grazing treatments.

Mountain rangeland pastures in a randomized block experiment compared three levels of stocking and two systems of grazing. Levels were 20, 30, and 40 acres per cow, with calf, over a 4-month, summer grazing season. Systems were season-long grazing and a two-unit deferred-rotation method. Units were rotated at midgrazing season, which was near the end of the active growing period.

Levels of stocking produced different degrees of utilization, but systems did not. Grazing treatment did not produce major changes in composition or yield from grassland openings; however, that of the forest understory was affected. Elk sedge, the most valuable forage species, was favored by light, deferred-rotation grazing.

Deferred-rotation grazing was superior to season-long grazing for improving ground cover in the grassland openings. No differences were found in soil compaction or erosion due to methods of grazing.

Light stocking produced the largest cow and calf gain per head and heavy stocking produced the poorest. Calf gain per acre was closely related to rate of stocking, but cow gain was not. System of grazing did not produce significant differences in weight gains.

As levels of cattle stocking increased, use by elk and, to a lesser extent deer, decreased. Systems of cattle grazing did not directly affect elk or deer distribution.

Cattle grazing treatment as imposed did not influence tree regeneration or growth. However, closure of the forest canopy resulted in some general decline in herbage production.

Relative to the moderate rate of stocking, the heavy rate depleted grazing capacity of these ranges at a more rapid pace than the light stocking rate restored them.

INTRODUCTION

The ponderosa pine-bunchgrass rangeland provides the most extensive and perhaps the most valuable forested grazing in North America. Occupying the zone between true forest and prairie grassland, this type produces resources vital to the economy of many communities throughout the West.

In Oregon and Washington alone, 11 million acres of ponderosa pine-bunchgrass type furnish summer grazing for 250,000 beef cattle and nearly as many sheep. The same area produces one-third of the national output of ponderosa pine (*Pinus ponderosa*)[1] timber as well as a substantial quantity of other related resources.

The Blue Mountains of northeastern Oregon and southeastern Washington, which contain the study area, include 40 percent of the ponderosa pine-bunchgrass range in the two-State region (fig. 1). These mountains provide about 100,000 cattle with 4 or 5 months of summer grazing; somewhat fewer sheep graze 3 to 4 months. During part of the year, an estimated 200,000 mule deer and 75,000 Rocky Mountain elk use this ponderosa pine range. These mountain rangelands are also principal watersheds for irrigation, recreation, and hydroelectric power.

[1] Common and scientific names of species are listed after Literature Cited section.

Demand for summer grazing throughout the interior Pacific Northwest is high. Summer range can provide only half enough forage for the number of domestic animals that can be maintained on spring-fall range. This imbalance exists partly because of past uncontrolled grazing. Present practice in the Blue Mountains has reduced livestock grazing 75 percent from the peak reached near the turn of the century. Despite reductions, some forest ranges continue to deteriorate.

Most stockmen using forested rangeland manage commercial cow-calf herds. The customary practice is to market calves at the end of the summer grazing season just before cows are returned to fall range. Because fluctuations in the summer forage supply cannot be predicted, ranchers set stocking according to the average-year condition (Harris 1954).[2]

Cost is the greatest deterrent to improving range conditions. In the past, low return on capital invested has dictated minimal management; installation and upkeep of range improvements are costly, risk from loss is high, and the difficulty in handling cows with calves on forested range is great.

As demands increase for timber, water, big game, and recreation,

[2] Names and dates in parentheses refer to literature cited.

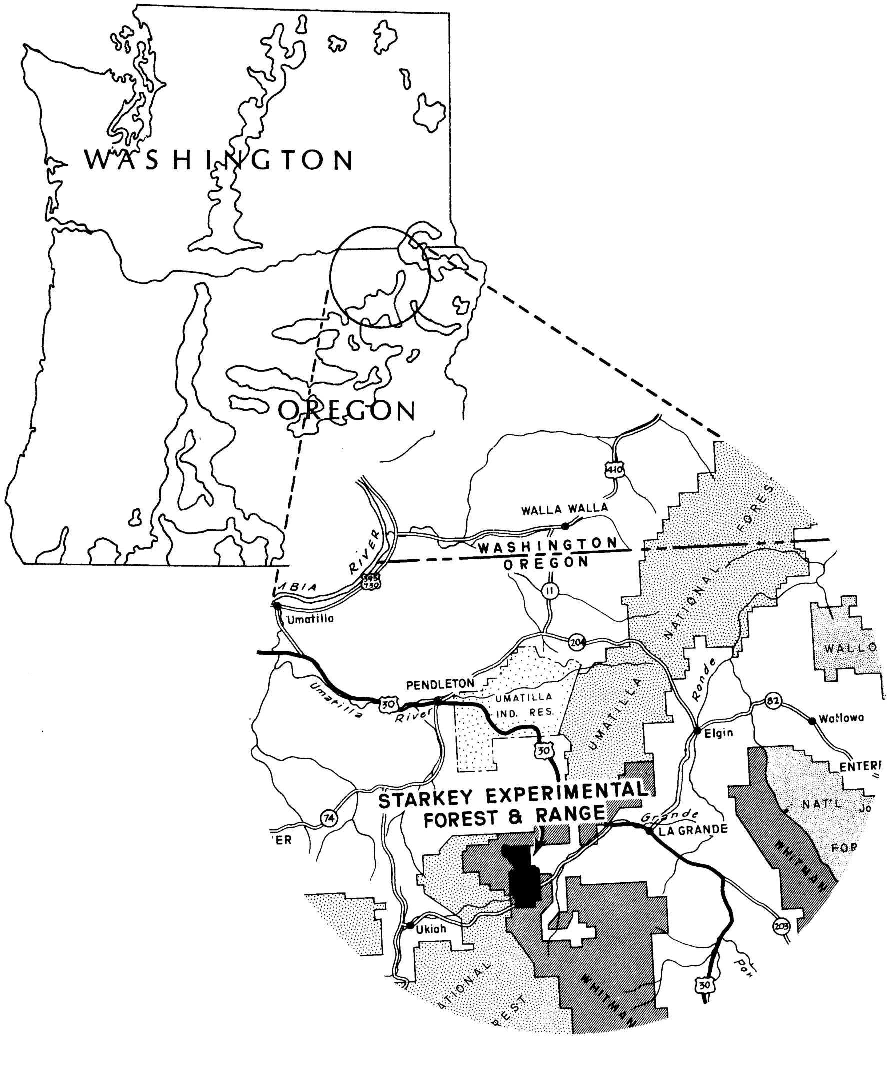


Figure 1.—Map of the ponderosa pine zone and geographic detail of the locality surrounding the study area.

resource management intensifies and often limits available forage supplies by altering grazing practices. Since use by livestock remains the practical means of harvesting large quantities of rangeland forage, management here must also intensify to sustain pastoral grazing.

With the hope of providing information that would help stockmen and public land and wildlife managers more successfully manage forested ranges, an integrated grazing study was begun on the Starkey Experimental Forest and Range in 1954. The Starkey range is situated in the pine zone of the central Blue Mountains 30 miles southwest of La Grande, Oregon.

The first objective of the study was to determine the level of stocking that would sustain grazing in harmony with other resource uses. A second objective was to compare the effectiveness of deferred-rotation and season-long grazing systems for providing maximum cattle gains while maintaining or improving range and watershed conditions. Finally, an attempt was made to evaluate plant response under the different levels of stocking and systems of grazing as a basis for judging long-term trends in range and watershed condition.

The design of this study was replicated to provide results which would apply to pine-bunchgrass ranges generally throughout the Pacific Northwest. Specifically, findings apply to the Blue Mountains of Oregon and Washington.

LITERATURE REVIEW

From results of perhaps the first comparison of grazing systems on western range, Smith (1899) reported that alternate resting provided better recovery than when the herd had continuous grazing access. The first study of range restoration through grazing practices in northeastern Oregon began 70 years ago (Sampson 1913, 1914).

Over 50 years ago, Sarvis (1923) experimented with levels and systems of grazing. He found proper stocking on Great Plains range under continuous grazing to be about 1½ acres per animal unit month (AUM). Later, using a deferred-rotation system developed by Jardine (1916), he concluded that more cattle could be grazed under this system than under continuous grazing without injury to the range (Sarvis 1925).

Since these early studies, great advances have been made in grazing management of rangeland. Studies to establish proper levels of stocking in other regions are numerous (Bentley and Talbot 1951, Klipple and Costello 1960, Johnson 1953, Reed and Peterson 1961). Generally such work has shown that as rates of stocking increase, forage production and cattle gains diminish, but return per acre increases at least for a period. There is usually a level of optimum sustained production reported.

To illustrate, long-term studies on ponderosa pine–bunchgrass range in the Rocky Mountains showed 30 to 40 percent use on principal plants maintained forage values and provided efficient beef production (Smith 1967). Similar work on the northern Great Plains summer range showed that about 35 percent use of the two principal species, or 3 acres per AUM, yielded optimum range and cattle response (Houston and Woodward 1966).

Systems of grazing have not been so thoroughly investigated nor have generalized conclusions been broadly applied throughout range types. From a lifetime's experience and the available literature, Sampson (1951) concluded that some form of deferment or rotation of grazing seemed essential on mountain bunchgrass range and that local conditions had much to do with the success of grazing systems. Other reports (Aldous 1935, Clark et al. 1943, Hanson et al. 1931, McIlvain and Savage 1951) comparing grazing systems with the traditional continuous method have usually shown that the systems provided benefits in vegetative cover but seldom advantages from animal production.

STUDY AREA

Topography of the Starkey range is typified by broad rolling uplands separated by moderately deep canyon drainages. Elevations vary from 4,000 to 5,000 feet above sea level. Soils are derived from old basalts except on northeastern exposures where wind-deposited pumicite occurs (Strickler 1966).

Soils of the parklike openings within the forest are shallow, stony, and high in clay; they are mainly of the Rock Creek series. Residual forest soils belong to the Klicker series; they are deeper, less stony, and contain less clay than Rock Creek soils. The site-specific, pumicite-derived soil called Tolo maintains a mixed-conifer forest overstory; it is a weakly developed recent deposition of silt. Of the entire area, Rock Creek constitutes about 20 percent, Klicker 30 percent, and Tolo 35 percent. The remaining area consists of six minor soil series.

Annual precipitation averages 20 inches, two-thirds of which accumulates as snow during winter months (fig. 2). Snowmelt begins in April, and runoff extends into May. The growing season lasts about 120 days, but no months are considered frost-free.

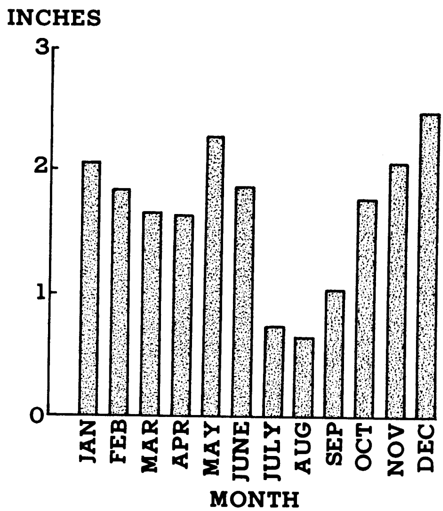


Figure 2.—Monthly precipitation at range headquarters over a 25-year period shows a slight bimodal pattern with a summer low.

Vegetation growth is mostly during late spring before soils begin to dry in early summer. Critical moisture for herbaceous growth is during June, but July moisture and temperature often determine the length of the adequate green forage period (Skovlin 1967). Although midsummers are dry, fall rains usually initiate some herbage regrowth.

A forest overstory dominates about three-fourths of the study area. Intermingled natural grassland openings ranging from 5 to 50 acres account for the remainder (fig. 3). Plants in these openings are common to Blue Mountain grasslands (Strickler 1965).

The most abundant species in the grasslands are usually bearded bluebunch wheatgrass, Sandberg bluegrass, or onespike danthonia. Other less common grasses include Idaho fescue, prairie junegrass, bottlebrush squirreltail, and Letterman needlegrass.

Openings also produce many different forbs but essentially no shrubs. Early-flowering succulent forbs are abundant but short-lived. Some summer forbs such as western yarrow, low gumweed, and rush pussytoes are also abundant but soon become stemmy, aromatic, or otherwise unpalatable.

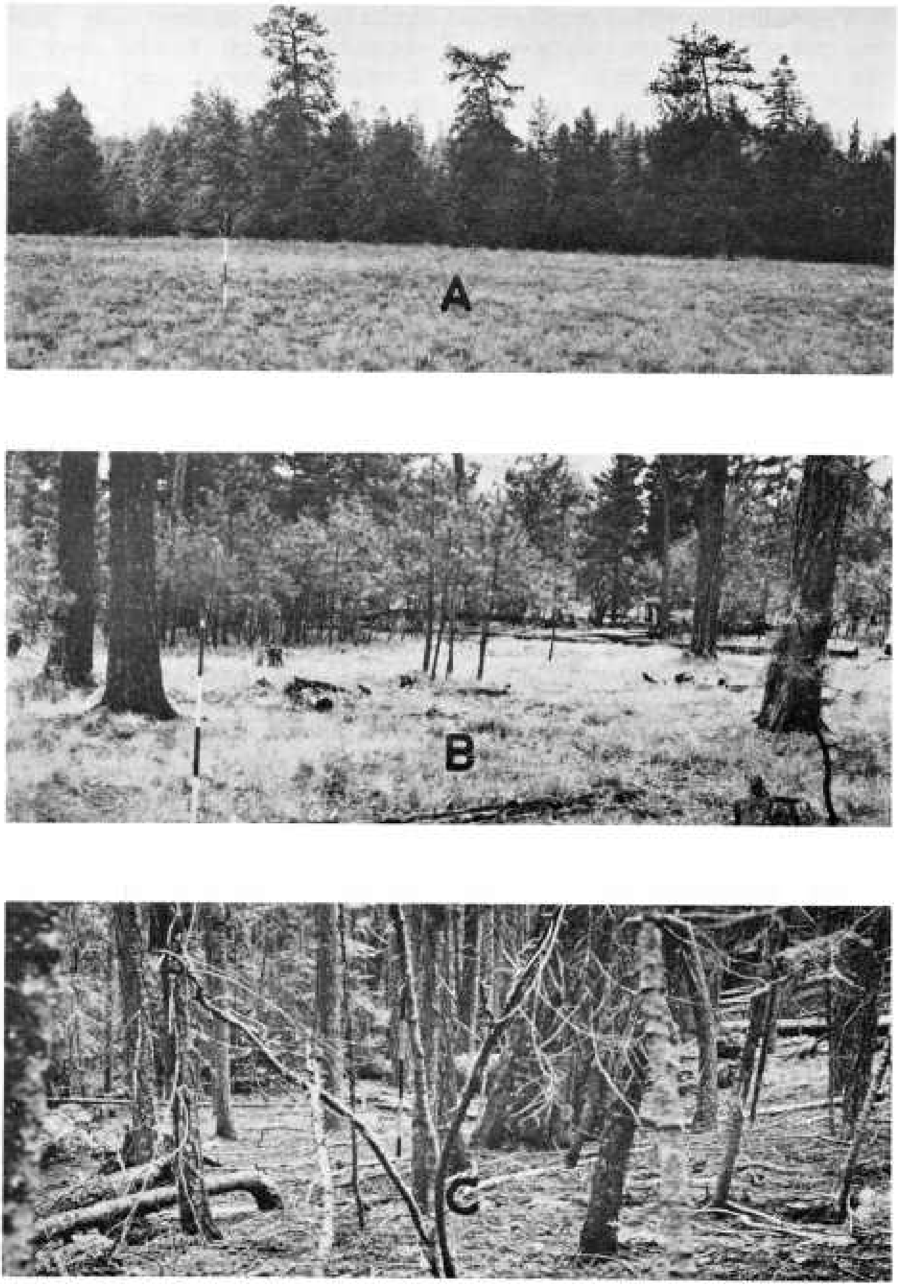
Open stands of ponderosa pine, or pine mixed with Douglas-fir, occupy two-thirds of the forested type and contain a varied understory. Principal herbaceous plants are elk sedge and pinegrass. Other less common grasses are Idaho fescue and prairie junegrass. Numerous minor sedges exist, of which northwestern sedge and Ross sedge are most common. A variety of forbs occur together with lesser amounts of low shrubs, such as birchleaf spiraea and common snowberry.

The remaining third of the forested type has a dense canopy of lodgepole pine or grand fir; sometimes western larch is also present. Only scattered herbaceous plants and a few evergreen shrubs grow under climax stands; however, seral stands produce a variety of forbs and other shrubs (Trappe and Harris 1958).

Previous work has shown that the "dense forest" type is unsuitable for cattle range (Harris 1954, Pickford and Reid 1948). Usable range in this study, therefore, considers only the natural openings hereafter called "grassland" type range and the open forest understory or "forest" type range.

Experimental treatments were tested in two areas representing somewhat different grazing conditions of the ponderosa pine zone. In one area, grasslands were dominated by Sandberg bluegrass and onespike danthonia on shallow soils derived from old basalt land surfaces. In the other, grasslands consisted of bluebunch wheatgrass-dominated communities on youthful dissected slopes; uplands were mostly forested.

History of the study area is well documented. Records beginning in 1910 show it was grazed by cattle and horses at a stocking rate of about 1½ acres per AUM. The allotment underwent a series of reductions in number and season until 1940, after which a constant rate of 8 acres per AUM was maintained from mid-June to mid-October.



F-521379, F-521380, F-521381

Figure 3.—Vegetation communities on the Starkey range are: A, the natural grassland openings comprising 25 percent cf the area and producing mostly bunchgrasses and forbs; B, the open forest occupying 50 percent and producing grasses, forbs, and low shrubs; and C, the remaining dense forest of mixed conifers with little herbaceous understory.

Since about 1920, big game have steadily increased until they are presently utilizing about one-fourth of the local forage supply (Skovlin et al. 1968).

The study area was logged between 1935 and 1940. The north portion was cutover of nearly all merchantable timber, whereas the southern part was logged of only select ponderosa pine. These two subareas, in which replication for the experiment was done, also had different postlogging treatment. Although there have been no wildfires in this century, logging slash was broadcast-burned throughout the northern portion but left untreated in the southern portion. Another difference was that the northern portion had sheep grazing until about 1940, whereas the southern part was nearly exclusively used by cattle since grazing began in 1865.

For a period of 8 years before the beginning of the study, the experimental range was grazed by livestock under a two-unit deferred-rotation system (Pickford and Reid 1948). Also during this time, range facilities were developed and cattle distribution was improved (Driscoll 1955, Skovlin 1965). By the early 1950's, forage on the study area had generally improved to a "fair" condition from a "poor" condition in 1939 (Harris 1954).

Fencing of the separate study ranges began in 1949, and grazing for calibration began in 1952. All ranges were grazed season-long at moderate stocking, as determined from earlier responses on the Starkey cattle allotment. Calibration records consisted of data on forage utilization and cattle weight gains. Minor adjustments in fences and animal numbers were made during these 3 pretreatment years.

METHODS

The design for cattle grazing was a two-system by three-level factorial experiment replicated in two randomized blocks of about 5,000 acres each; block centers were 6 miles apart (fig. 4).

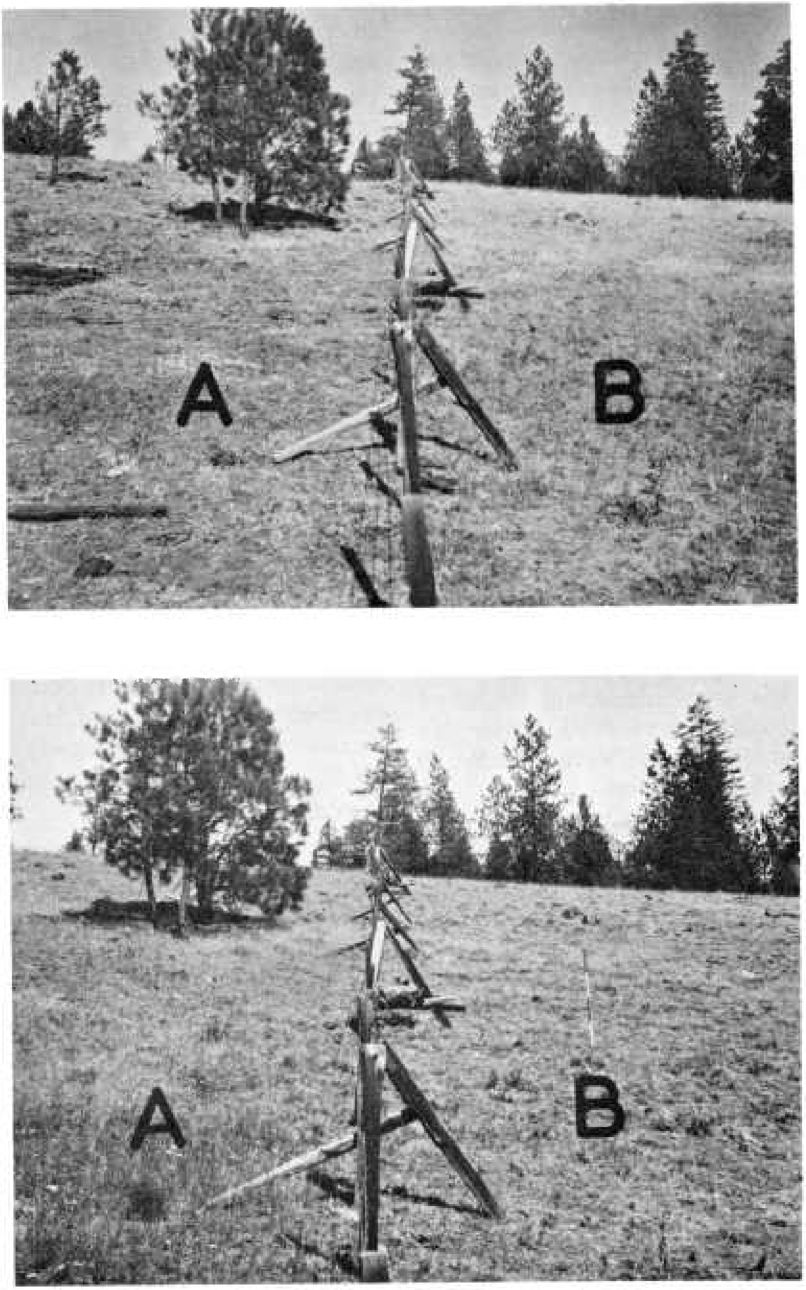
Each block contained six cattle ranges—three grazed season-long and three grazed under deferred rotation. Each system within a block had a light-, a moderate-, and a heavy-stocked range. These rates correspond to 40, 30, and 20 acres of usable range, respectively, per cow-calf unit for approximately 4 months of summer grazing. Grazing seasons usually began June 15 depending somewhat on soil and plant readiness from year to year; grazing terminated after about 115 days of use.

Cattle under season-long grazing had free choice within their assigned range throughout the season. Under deferred rotation, they were placed in half of the range (unit A) for 2 months, then moved to the other half (unit B) for the remaining grazing season (fig. 5). The following year, this early and late grazing pattern was reversed between units, i.e., A to B one year, B to A the next, etc. The object of this system was to give key forage plants a chance to complete growth every other year and still enable forage use of both units each year.

The 12 ranges contained about 800 acres each and were stocked with 14 to 26 pairs of Hereford cows and calves; the precise number

F-522993

Figure 4.—Replicated blocks of grazing treatment show intermingling of grassland openings in relation to forest on the Starkey range.



F-521382, F-521383

Figure 5.—Forage utilization at midseason within a heavily grazed, deferred-rotation range in 1961 (upper) and 1962 (lower). Unit A was grazed early for 2 months beginning about mid-June 1961. Unit B was grazed early for the same period the following year.

depended on the assigned stocking and calculated grazing capacity of the unit. One Hereford bull was placed in each range.

Grazing units were balanced before the study began. Using early range surveys (Reid et al. 1942), aerial photos, and other aids, units were designed to contain similar topography, vegetation, and grazing capacities. The 12 range units averaged 71 AUM's with a standard deviation of 5. As closely as possible, each range had representative amounts of grassland, forest, and dense timber types.

Problems of distribution were minimized before calibration began. By 1951, potential stock water was fully developed to furnish three sources of summer-long water in each range. Semipermanent salt grounds were placed in timbered areas away from stock water. No further attempts were made to improve distribution.

Grazing treatments were randomly assigned. In 1953, partition fences were constructed to equally divide deferred rotation ranges. The grazing experiment began in the north block in 1954; treatment in the south block began the following year. Staggering the time schedule more evenly distributed the work load for construction and assessment of treatment. Grazing ended in 1964 and 1965 after 11 years of differential treatment in each block. However, final effects were not measured until the year after grazing treatment stopped.

Adjacent to each block of six cattle ranges was one unit reserved for big game only. These two "game-only" ranges contained about 125 acres and were for the exclusive use of deer and elk. The research object in these units was to determine the amount of forage used by deer and elk throughout the study. Big game had equal access to all range units. Although game-only ranges had essentially full-term protection from cattle grazing, they were not completely operational until 1956.[3]

Inventory procedure for herbage production [4] by species was specifically developed in a study of subsampling described by Harris (1951). Plot layout for each experimental range employed 18 random clusters of four permanent and three temporary subplots in the grassland, and 27 similar clusters in the forest. Circular subplots contained an area of 24 square feet. Herbage production was remeasured after 3, 7, and 11 years of grazing treatment.

The technique for determining production was a weight-estimate-by-plot method adopted from Pechanec and Pickford (1937b). At each cluster during inventory years, herbage was estimated on the four permanent subplots and one unspecified temporary subplot.

---

[3] Initial vegetation inventory was again delayed to offset work loads. Factorial design of cattle and game ranges did not accommodate statistical comparison with game-only units.

[4] Herbage production represented the current season's peak standing crop. Under local climatic conditions, standing dead plant material was insignificant except for several grasslike species; for these, standing dead material was hand-separated before field weighing.

The temporary subplot was subsequently clipped to adjust the estimator's bias (Wilm et al. 1944). This double sampling technique provided one actual weight for every fifth estimated weight thus furnishing a measure of error used to adjust all of a surveyor's estimates.

This sampling layout gave production estimates within 15 percent of the true pasture average 95 percent of the time for eight principal species. Sandberg bluegrass, for example, had a sampling error of 4 percent of the pasture mean. Groupings such as total grasses, forbs, or shrubs, as well as all herbage in both types, were within 10 percent of the mean 95 percent of the time.

Conversion of green to dry matter was determined by species, using temporary-subplot plant material collected from each grazing treatment. Production figures are reported in pounds per acre on an air-dry basis.

The frequency of ground cover was estimated on each permanent grassland subplot to evaluate the impact of grazing on watershed characteristics. Surface conditions were classified as bare area, litter, rock, or vegetation using a ¾-inch loop adopted from a method described by Parker (1951) and modified by Driscoll (1958).

At the end of each grazing season, forage utilization was determined by the ocular-estimate-by-plot technique described by Pechanec and Pickford (1937a). Estimates were taken using the same sampling system employed for herbage production inventories. Use of this method confined observations to only those plants of a species within the 24-square-foot subplot. Team training for precision involved five steps: clipping ungrazed plants at simulated grazing levels, judging the percent weight removed, clipping to ground level and weighing the remainder of the plants, and calculating the actual percentage removed. The final step was to mentally correct personal errors to conform to actual use. Retraining sessions were practiced weekly throughout the utilization survey.

During the annual utilization survey, deer and elk pellet groups were counted and removed from all permanent and temporary subplots. Using a larger 100-square-foot plot, area samples were converted to groups per acre. An index to range use by big game, expressed in days use per acre, was derived from standard defecation rates of 13 groups per day for both deer and elk (Neff et al. 1965, Smith 1964).

Cattle gains were measured by the individual weight differences of 234 cows and their calves (Harris and Driscoll 1954). In June each year, after about 3 weeks grazing on adjacent range, cows and calves were gathered, paired, ear-tagged, dye-branded, weighed, randomly assigned treatments, trailed to their respective ranges, and paired again. About October 1, when calves were of weaning age, all cattle were gathered and reweighed.

A survey of soil compaction the summer after final grazing treatment assessed the effects of prolonged levels of animal trampling.[5] The gamma ray method provided an index to soil surface bulk density through use of a radiation source, a detector gage, a recovery scaler, and a calibration device (Van Bavel 1959).

Sampling in each of the 12 ranges consisted of 15 readings along either side of the seven herbage production clusters in both grassland and forest soils. This represented 180 readings in the dominant grassland soil series (Rock Creek) and 180 in the dominant forest series (Klicker) for each range. At each sample point the ground between large plants was smoothed and cleared of surface rock, litter, and minor herbaceous material before placing the gage on the soil for gamma emission. After point exposure of a standard radiation level, the square-foot-of-contact surface detector sensed backscattering radiation not absorbed and the scaler registered the remainder; low recovery indicated high density or compaction. Soil moisture samples were taken to derive the bulk density estimate.

To evaluate possible soil loss and deposition resulting from changes in watershed cover and expected differences in animal trampling due to grazing treatment, earthen settling basins were constructed across an intermittent drainage below small watersheds within each of the south block experimental ranges. Successive engineering rod and level profile measurements of sediment accumulation within the basins were used to evaluate differences due to grazing treatment.

The influence of grazing on forest regeneration and survival was determined by an inventory of tree-size classes before (1954) and after (1967) the experiment. Herbage production plot centers were used to delineate 100-square-foot circular plots on which to tally and measure the trees. Seedlings and three height classes within the browsing range were counted; saplings, poles, and mature trees falling within the plots were taped for diameter classes.

During the experiment, supplementary studies of short duration were made to help interpret preliminary results. These included: (1) seasonal forage quality, (2) seasonal cattle weight gains, (3) pocket gopher densities, (4) carbohydrate trends for two important forage plants, and (5) overstory cover in the forest type. Methods used in these separate study phases will be covered under the appropriate results.

RESULTS

Utilization

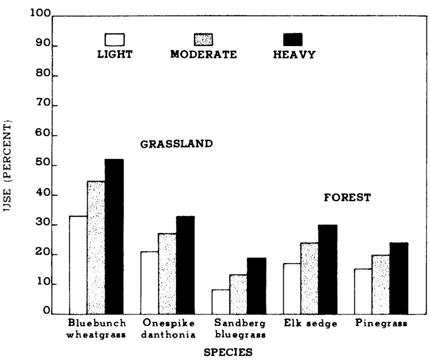
In general, about 10 percent of all herbage was consumed as forage in both grassland and forest. Grasses and grasslike plants constituted about half of the total herbage in either type, making up 96 percent of the forage from the grasslands and 88 percent of that from the forest. Elk sedge made the

[5] A preliminary technique study of four standard methods of determining compaction showed the radiation surface density gage (Troxler Laboratories, Inc.) provided the best comparison between heavy and ungrazed grassland range.

largest forage contribution of any species. Pinegrass was second, although bearded bluebunch-wheatgrass furnished nearly the same amount; wheatgrass made the largest contribution from the grassland.

Year-to-year differences in utilization of principal species were significant [6] and depended on the amounts of forage produced in any particular year. Significantly different amounts of forage were removed from principal species as levels of cattle stocking varied (fig. 6).

Figure 6.—Average utilization of important forage plants is shown at three levels of stocking over a period of 8 years.



Utilization of principal grasses and grasslike plants showed real differences due to levels of stocking, but shrubs did not. Use of forbs was generally light and variable.

Systems of grazing did not produce differences in species utilization. Bluebunch wheatgrass alone of the important forage plants showed significantly different degrees of utilization; use in season-long units averaged 6 percent more than use in deferred rotation units.

Viewed together, levels and systems of grazing revealed an interacting shift in utilization. Use always averaged more under season-long grazing at heavy levels, but at light levels, deferred rotation produced more use (table 1). However, of the species tested, only onespike danthonia showed a significant interaction. Interaction was more pronounced for grassland than for forest species.

Grazing on most principal species was significantly less when a unit was grazed early than when it was grazed late. Regrowth from early grazed units was not sufficient to interfere with utilization assessment. Higher utilization in late season, deferred-rotation units was mainly due to the normal loss of secondary forage in late summer. Annuals and spring forbs became shattered or unpalatable after midseason, placing heavier grazing pressure on principal plants remaining. Increasing demands of rapidly growing calves also accounted for some of this increased use.

Herbage Production

Total production declined under all treatments over the 11-year period. In the grassland, grasses increased 20 percent and forbs about 5 percent. All categories declined in the forest, shrubs maintaining nearly original production, grasses and grasslike plants declining 33 percent, and forbs losing about 70 percent.

[6] In this paper, significant and highly significant are at the 0.05 and 0.01 probability levels, respectively.

TABLE 1.—Average utilization at three levels of stocking for two systems of grazing and for early- and late-season use under deferred-rotation grazing [1] (in percent)

Type, species, and level of stocking	System		Use	
	Season-long	Deferred rotation	Early-season	Late-season
GRASSLAND				
Bluebunch wheatgrass:				
Light	34	34	26	43
Moderate	49	41	33	49
Heavy	55	50	45	54
Onespike danthonia:				
Light	18	25	20	30
Moderate	32	23	20	27
Heavy	35	31	28	34
Sandberg bluegrass:				
Light	7	8	7	10
Moderate	16	11	8	14
Heavy	21	17	13	21
FOREST				
Elk sedge:				
Light	15	19	18	21
Moderate	24	24	21	26
Heavy	32	31	29	33
Pinegrass:				
Light	11	18	18	18
Moderate	20	20	18	21
Heavy	25	24	24	24

[1] Average represents 8 years of record.

STOCKING RATE EFFECTS

In the grassland, although some variances occurred, there were no significant differences caused by grazing intensity (table 2). Wheatgrass doubled production under light stocking, and nearly doubled under moderate; but under heavy stocking it showed only a slight increase over original amounts. These average differences, although large, were not significant statistically.

Other principal grasses showed a variety of responses to stocking level. Onespike danthonia increased somewhat more than wheatgrass, but differences among levels were not as great. Sandberg bluegrass production decreased, showing little or no response to levels. Other grasses, including Idaho fescue, prairie junegrass, Letterman needlegrass, and bottlebrush squirreltail, showed modest increases but did not reflect levels of stocking.

Response of principal grassland forbs under light and moderate grazing varied. Under heavy grazing, all three forbs increased. Western yarrow increased generally with stocking rate; low gumweed and rush pussytoes decreased under light grazing and increased under heavy. Other forbs, such as balsamroots and biscuitroots, decreased noticeably under heavy grazing.

In the forest, changes in grass and grasslike plant production were directly related to intensity of stocking. As a group, differences among levels of stocking were highly significant.

Some species responded more than others. For example, elk sedge lost about one-sixth, one-third, and one-half under light, moderate, and heavy stocking, respectively. Although pinegrass losses were greater than those of elk sedge, changes in pinegrass were not significantly different but changes in elk sedge were highly significant. Initial production of pinegrass was highly variable among ranges, whereas that of elk sedge was not.

The 10-percent net increase of other grasses and grasslike species under light stocking contrasted sharply with losses exceeding 20 and 30 percent under moderate and heavy stocking. These differences were significant, as were those for northwest sedge, a major contributor to this group.

Forest forb losses varied among levels of stocking. Western yarrow losses were greater under light grazing than under moderate or heavy, while hawkweed losses grew as stocking increased. Other forb groups, such as lupines, lost about three-fourths of original production, regardless of stocking. Shrubs did not show any conclusive response to levels of stocking.

GRAZING SYSTEM EFFECTS

In the grassland, no species or groups showed significant differences in response to system of grazing (table 3). Bluebunch wheatgrass showed a nonsignificant but larger average gain under season-long grazing than under deferred rotation, a difference resulting from a noticeable interacting effect with stocking level. Wheatgrass responded best to season-long grazing at the light and moderate levels, while at the heavy level it responded better to deferred rotation.

Of the forest plant groups, grasses and grasslike plants showed differences due to system. Analysis of variance showed the greater average loss of 9 pounds per acre under season-long than deferred rotation was significantly different.

Elk sedge, the major forage contributor in the forest, lost significantly less production under deferred rotation than under season-long grazing. No other species or group revealed striking differences due to system of grazing.

RESPONSE TO PROTECTION FROM CATTLE

Statistical tests for production differences between game-only and dual-use cattle ranges are not valid, but comparisons are nevertheless interesting. Under no cattle grazing, bluebunch wheatgrass production increases averaged between those increases obtained under moderate stocking and those obtained under heavy stocking. Onespike danthonia produc-

TABLE 2.—Average herbage production per acre and changes after 11 years of grazing at three levels of stocking

Type, group, and species	Level of stocking: Light			Moderate			Heavy		
	1954–55 (pounds)	1965–66 (pounds)	Difference (percent)	1954–55 (pounds)	1965–66 (pounds)	Difference (percent)	1954–55 (pounds)	1965–66 (pounds)	Difference (percent)
GRASSLAND									
Grasses:									
Bluebunch wheatgrass	22	44	100	20	38	90	28	33	18
Onespike danthonia	20	50	150	24	63	163	19	38	100
Sandberg bluegrass	70	51	−27	72	47	−35	67	53	−21
Other	29	33	14	23	26	13	33	39	18
All grasses	141	178	26	139	174	25	147	163	11
Forbs:									
Western yarrow	28	34	21	32	39	22	31	50	61
Rush pussytoes	31	27	−13	28	28	0	23	27	17
Low gumweed	24	19	−21	24	16	−33	23	25	9
Other	95	104	9	98	121	23	89	57	−36
All forbs	178	184	3	182	204	12	166	159	−4
All grassland	319	362	13	321	378	18	313	322	3

FOREST

Grasses and grasslike:									
Elk sedge	38	32	−16	46	32	−30	40	20	−50
Pinegrass	54	41	−24	42	23	−45	35	12	−66
Other	20	22	10	23	17	−22	24	16	−33
All grasses and grasslike	112	95	−15	111	72	−35	99	48	−52
Forbs:									
Western yarrow	8	5	−38	8	6	−25	8	6	−25
Hawkweed spp	8	6	−25	8	5	−38	9	5	−44
Other	113	28	−75	102	17	−83	90	25	−72
All forbs	129	39	−70	118	28	−76	107	36	−66
Shrubs:									
Birchleaf spiraea	5	4	−20	5	5	0	5	5	0
Common snowberry	3	3	0	5	6	20	5	5	0
All shrubs	8	7	−13	10	11	10	10	10	0
All forest	249	141	−43	239	111	−54	216	94	−56

TABLE 3.—Average herbage production per acre and 11-year changes under two systems of cattle grazing and 10-year changes under protection

Type, group, and species	System of grazing: Deferred rotation 1954–55 (pounds)	Deferred rotation 1965–66 (pounds)	Deferred rotation Difference (percent)	Season long 1954–55 (pounds)	Season long 1965–66 (pounds)	Season long Difference (percent)	Protection from cattle grazing (game only) 1955–56 (pounds)	Protection 1965–66 (pounds)	Protection Difference (percent)
GRASSLAND									
Grasses:									
Bluebunch wheatgrass	28	39	39	20	38	90	23	30	30
Onespike danthonia	17	39	129	26	61	135	52	70	35
Sandberg bluegrass	59	44	−25	80	57	−29	85	40	−53
Other	32	37	16	25	29	16	25	42	68
All grasses	136	159	17	151	185	23	185	182	−2
Forbs:									
Western yarrow	28	39	39	33	43	30	34	31	−9
Rush pussytoes	28	29	4	26	25	−4	14	13	−7
Low gumweed	20	17	−15	27	23	−15	36	12	−67
Other	92	111	21	96	78	−19	54	69	28
All forbs	168	196	17	182	169	−7	138	125	−9
All grassland	304	355	17	333	354	6	323	307	−5

FOREST									
Grasses and grasslike:									
Elk sedge	37	28	−24	45	28	−38	47	43	−9
Pinegrass	43	25	−42	44	26	−41	69	78	13
Other	20	16	−20	26	21	−19	30	21	−30
All grasses and grasslike	100	69	−31	115	75	−35	146	142	−3
Forbs:									
Western yarrow	8	6	−25	8	6	−25	8	4	−50
Hawkweed spp.	12	6	−50	9	4	−56	7	4	−43
Other	96	27	−72	107	20	−81	74	16	−78
All forbs	116	39	−66	124	30	−76	89	24	−73
Shrubs:									
Birchleaf spiraea	5	5	0	5	5	0	9	6	−33
Common snowberry	5	5	0	4	4	0	6	5	−17
All shrubs	10	10	0	9	9	0	15	11	−27
All forest	226	118	−48	248	114	−54	250	177	−29

tion increased by one-third, a smaller increase than under any level of cattle stocking. Sandberg bluegrass lost half of its initial production, equaling about twice the losses under any cattle grazing. Other grasses benefited from protection from cattle grazing, increasing two-thirds over initial production, or four times more than increases produced under any cattle grazing treatment.

Principal grassland forbs lost more herbage under protection than under most cattle treatments, but secondary forbs gained more under protection.

Protected from cattle use in the forest, elk sedge lost only about half the production lost under light stocking, and pinegrass actually showed an increase. Other grasses and grasslike plants lost slightly more under protection than they lost under heavy cattle grazing; forb and shrub species lost more under protection than under any level of cattle grazing.

MAJOR TRENDS IN PRODUCTION

Losses of herbage in forest understory and in some grassland species resulted partly from diminished rainfall (fig. 7). Understory vegetation, dominated by trees, was more affected by lower rainfall than grassland vegetation. Canopy closure also contributed in some measure to loss of understory production.

Although not greatly influenced by levels of stocking, changes in bluebunch wheatgrass production displayed some meaningful trends over the study (fig. 8). Production under light stocking showed a strongly increasing gain, while moderate stocking produced a diminishing gain, and heavy stocking produced essentially no gain at all. Based on 11-year trends, significant differences among levels of stocking probably would have been apparent by about the 15th year of treatment. The poor response of wheatgrass to protection may indicate that some grazing stimulates production.

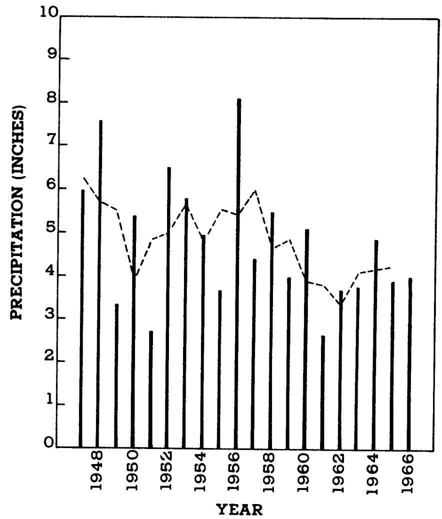


Figure 7.—Yearly growing season precipitation (May, June, and July) at range headquarters for a 20-year period showing trend (dashed line) based on a 3-year average.

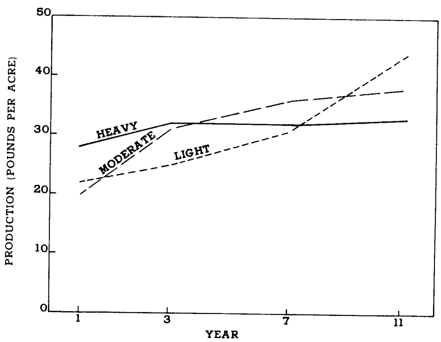


Figure 8.—Average trends in bluebunch wheatgrass production over 11 years of grazing at three levels of stocking.

Shallow-rooted Sandberg bluegrass, the most abundant species, was seldom grazed over 20 percent. Uniform and heavy losses under all treatments showed it was greatly affected by the general drought. During intermediate years, bluegrass production was highly variable and was quite dependent on amounts of rainfall.

Under heavy stocking, principal grassland forbs flourished because of reductions in the more palatable secondary forbs. At the light grazing level, in competition with palatable secondary forbs and grasses, principal forbs diminished. Changes in both forb groups under protection were consistent with changes under levels of cattle stocking; where competition was greatest, principal forbs lost most and secondary forbs gained.

In the forest, nearly all herbaceous species and groups reflected the effects of diminished rainfall, increased tree density, and increased cattle grazing. Most striking was that herbage loss in the grasses and grasslike group was directly proportional to rate of stocking. Consistent losses of the other forbs under all treatments and protection reflect stress from overstory crown closure; low shrubs, however, were persistent.

Elk sedge displayed the most dramatic change of any species. Highly significant production differences in response to correspondingly small differences in percent utilization make proper stocking level critical to the maintenance of this valuable species.

Elk sedge lost significantly less under deferred-rotation than under season-long grazing, and it actually increased production, despite adverse weather and tree overstory conditions, under deferred-rotation light grazing (table 4). Light season-long grazing apparently discouraged sedge as much as moderate grazing under either system. Garrison (1966) found these impacts of grazing levels and systems, measured by available carbohydrate content, pronounced and different, even after a growing season of rest following the end of grazing treatment.

TABLE 4.—Average changes in elk sedge production following 11 years of grazing treatment

[Pounds per acre]

Grazing system	Level of stocking			Average
	Light	Moderate	Heavy	
Deferred rotation . . .	3	−14	−18	−10
Season-long .	−15	−15	−22	−17
Average.	−6	−14	−20	--

Pinegrass was even more reduced by grazing then elk sedge, although utilization was lower. Protected from cattle, it did increase, but otherwise showed no system response. The different system response between elk sedge and pinegrass can be partly attributed to the early maturity of elk sedge and the late maturity of pinegrass. Elk sedge was protected from early grazing during its critical maturation period, every other year, by deferred rotation grazing, while pinegrass, because of its late maturity, was not protected by the deferment to midseason.

Other grasses and grasslike plants in the forest decreased in response to stocking and also under protection. Like the losses of hawkweed and shrubs, this loss under protection was probably caused by selective grazing from deer and elk.

Watershed Cover

Grassland soil surface characteristics related to watershed protection were influenced by certain grazing treatments. Amounts of bare area increased and litter decreased as grazing rates became heavier. Both rock area and total vegetation increased with the level of grazing, but these changes were not significant (table 5). Bare area decreased under deferred rotation and increased under season-long grazing. In this case, the net difference of 14 percent was highly significant.

No other items showed differences due to grazing system, but some changes in vegetation cover were of interest. Analysis following the first 3 years of treatment revealed that total vegetation increased with increased stocking. During the last 8 years of the study, though, grass cover diminished with increased rates of stocking (table 6), with the exception of Sandberg bluegrass which showed no response. Other grasses lost under heavy stocking but gained substantially under light stocking. As stocking increased, losses in perennial forb cover increased, but losses in annual forb cover decreased. Responses to systems of grazing were not so conclusive. Bluebunch wheatgrass cover changed little under deferred rotation but increased greatly under season-long grazing. Onespike danthonia and Sandberg bluegrass showed general cover increases but opposing responses to systems. Other grasses gained substantially under deferred rotation, but lost cover under season-long grazing. In both the perennial and annual forb groups, cover losses were greatest under season-long grazing.

On an overall cover basis weighted by composition, deferred rotation produced a vegetation cover increase about two times greater than season-long grazing.

TABLE 5.—Average initial cover and 11-year change due to weather and grazing treatment (in percent)

Cover item	Composition	Level			System	
		Light	Moderate	Heavy	Deferred rotation	Season-long
Bare area	39	−3	1	3	−6	8
Litter	32	−30	−34	−40	−32	−37
Rock	6	−25	−18	7	−14	−13
Vegetation	23	56	59	68	73	51

TABLE 6.—Average vegetation cover and 8-year changes due to grazing treatment (in percent)

Cover item	Composition	Level			System	
		Light	Moderate	Heavy	Deferred rotation	Season-long
Bluebunch wheatgrass	4	54	57	−15	4	63
Onespike danthonia	7	66	52	40	60	48
Sandberg bluegrass	26	21	25	23	18	28
Other grasses	11	45	18	−16	27	−5
Perennial forbs	29	−1	−2	−12	−2	−9
Annual forbs	23	−21	−10	−1	−8	−18

Soil Impacts

Surface bulk density was used as an indicator of compaction from animal trampling. Neither rates of stocking nor systems of grazing produced significant differences in bulk density of the main grassland or forest soils.

Lack of differences in bulk density due to treatment is not surprising. Other studies have shown that results vary depending on seasons, soils, and disturbance levels (Reynolds and Packer 1963). For example, some investigators have found that trampling may not increase bulk density over protection from grazing (Daubenmire and Colwell 1942); others have found significant differences in density even between levels of stocking (Reed and Peterson 1961).

A compensating variable affecting compaction due to levels of cattle stocking in this study was trampling by deer and elk. Results discussed later show that big-game use increased, as cattle stocking decreased, a relationship that confounded the effect of trampling due to cattle alone. For instance, under light rates of cattle stocking, days of use for deer and elk exceeded those for cattle. Moreover, it is likely that the total effect of big-game trampling exerted as much or more compaction than that by cattle, because seasonal migration patterns placed heaviest game use during the periods of wet and saturated soils. Trampling impact due to cattle on this range was restricted to periods of firm soil and maximum plant cover.

As expected, the difference in bulk density between the grassland and the forest soil was significant. Although a comparison of densities between blocks was not an element of statistical testing, it is of interest that the large difference encountered probably contributed variation to vegetation responses due to treatment.

Results of the engineering profile (rod and level) survey in sediment collecting basins of south block ranges again showed no real differences due to grazing treatment. Although grazing levels may not have actually produced different rates of erosion from upslope grasslands, other variables make these results inconclusive. For example, if big game trampling confounded soil compaction by cattle, it could also have affected erosion and deposition in the same manner. Another confounding feature was the geomorphic soil pattern which produces natural filtering bands of forest cover in varying widths. These bands tend to trap runoff silt loads before they reach the downslope settling basin.

Using the number of soil mounds left by The Dalles pocket gophers as an index to relative populations, a count of mounds on subplots in the fall of 1964 showed no significant differences caused by cattle grazing treatment. However, the difference between an average of 1,031 mounds per acre in the grasslands compared with 142 per acre in the forest was highly significant. In the grassland, light grazed ranges averaged 25 percent fewer than moderate, and moderate, 34 percent fewer than heavy. However, these differences in mound densities were not significant due largely to variability in one block.

Cattle Response

Summer cattle gains were variable over the 10 years of continuous record. During the best season, cows gained an average of 69 pounds per head and calves gained 195 pounds. During the poorest season, cows lost 44 pounds and calves gained only 161 pounds. Over the decade beginning in 1955, cows averaged 21 pounds of annual summer gain, and calves, 181 pounds.

Effects of stocking level on cattle weights became apparent during the first year of treatment. Heavy stocking consistently produced the lowest individual cow and calf gains, cows showing average losses in 5 of 10 years. Light stocking outproduced moderate stocking in 9 of 10 years, and in only 1 year did cows under moderate or light stocking lose weight.

On the average, moderate stocking outproduced heavy by 33 pounds per cow per summer and 12 pounds per calf per summer. Light stocking outproduced moderate by 8 pounds per cow and 14 pounds per calf. As stocking increased, these average cow and calf gains per head decreased significantly (table 7). Average cow gain **per acre,** however, remained the same as stocking increased from light to moderate, but heavy stocking resulted in a loss per acre, which was significantly different from light or moderate stocking gains. Calf gain per acre increased significantly as stocking level increased.

Systems of grazing did not produce significant differences in average cow or calf gains per head or per acre.

In both classes of cattle, differences between systems in gain per head and gain per acre were larger at the heavy stocking level than at light stocking; differences in gain between systems were usually least at the moderate level.

Over a period of years, cow and calf gain per acre declined regardless of grazing treatment (fig. 9), but gains under light or moderate stocking held up better than those under heavy. Diminishing cow gains from heavy stocking clearly illustrate the result of losses in forest forage due to the prolonged period

TABLE 7.—Average cattle response per head per year and per acre per year to 10 years of differential grazing treatment

System	Level: Light	Level: Moderate	Level: Heavy	Average
	Pounds per head			
Cows:				
Deferred rotation	31	27	−12	15
Season-long	44	30	5	26
Average	37	29	−4	21
Calves:				
Deferred rotation	194	178	165	179
Season-long	193	183	171	182
Average	194	180	168	181
	Pounds per acre			
Cows:				
Deferred rotation	0.7	1.0	−0.6	0.4
Season-long	1.3	1.1	.4	.9
Average	1.0	1.0	−.1	.6
Calves:				
Deferred rotation	4.6	6.1	7.3	6.0
Season-long	5.6	6.4	8.8	6.9
Average	5.1	6.2	8.0	6.5

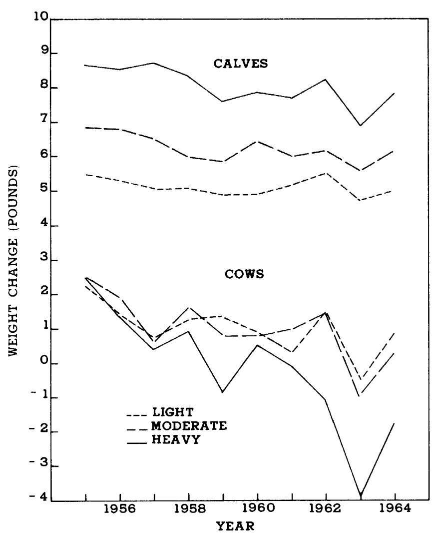


Figure 9.—Average weight change of cows and calves per acre over 10 years of grazing treatment.

of excessive utilization. Conversely, calf gain per acre at the light rate was sustained over the years in spite of the overall decline in cattle gains.

Several factors cause the general decline in summer gains by cattle over the years. An upward trend in initial (oncoming) cow weights through better herd management had the effect of limiting the capacity of cows to gain on summer range. Also, a general reduction in the percentage of young cows had the same effect. Initial calf weights, however, remained about the same.

A less apparent cause was the effect of weather and tree crown closure which indirectly contributed to declining gains of both cows and calves, through the general loss of production from forage plants in the forest. During the dry season on mountain rangelands, an abundance of high quality forest forage plants such as elk sedge and, to a lesser extent, pinegrass, had been found essential to the maintenance of cattle gains (Skovlin 1962, 1967); forage on shallow grassland soils dries and becomes stemmy by early August.

Under light stocking, some areas remained ungrazed or only lightly grazed; thus, little additional gain per head would have been realized by increasing the amount of range available per animal, except in drought years. At the moderate rate, few areas were ungrazed and some were excessively grazed. Under heavy stocking, no ungrazed areas remained and many parts were excessively grazed, creating a chronic shortage of forage near the end of the grazing season, especially during the last few years of study. Any further restriction in acreage allowance per animal at the heavy rate would have led to untenable conditions under set stocking.

During the drought of 1961, cattle from the two heavy-stocked ranges of the north block were gathered 3 weeks early because no more forage was available. By 1963, cows in these two ranges lost an average of about 78 pounds despite light initial weights; some cows lost over 200 pounds (fig. 10).

Calf gain per acre increased as rates of stocking increased because growth requirements were met largely through suckling; thus, more calves per acre equaled more calf gain per acre. Average cow gains did not improve between light and moderate stocking and were sharply reduced under heavy stocking, because of the reduction of forage caused by stocking competition. Species making the greatest contribution to forage supply in quantity and quality were most affected, leaving only inferior plants and plant parts available for late season grazing.

Calves under light stocking, deferred-rotation grazing made the highest gains because abundant and nutritious, ungrazed forage was available to them after midseason, when calves begin to graze substantially as milk production from the cows diminishes. At heavier levels of use, or under season-long light grazing, cows competed with their calves for high quality forage in late season.

In general, slightly better gains were made under season-long grazing since cattle were able to graze the entire range when forage was most suitable and nutritious. Under deferred-rotation grazing, cattle could only select forage from half of the range: they could not selectively graze in the late half because annuals and forbs are available or palatable only during the early season. Similarly, late use of shrubs and fall regrowth is also restricted to half the range.

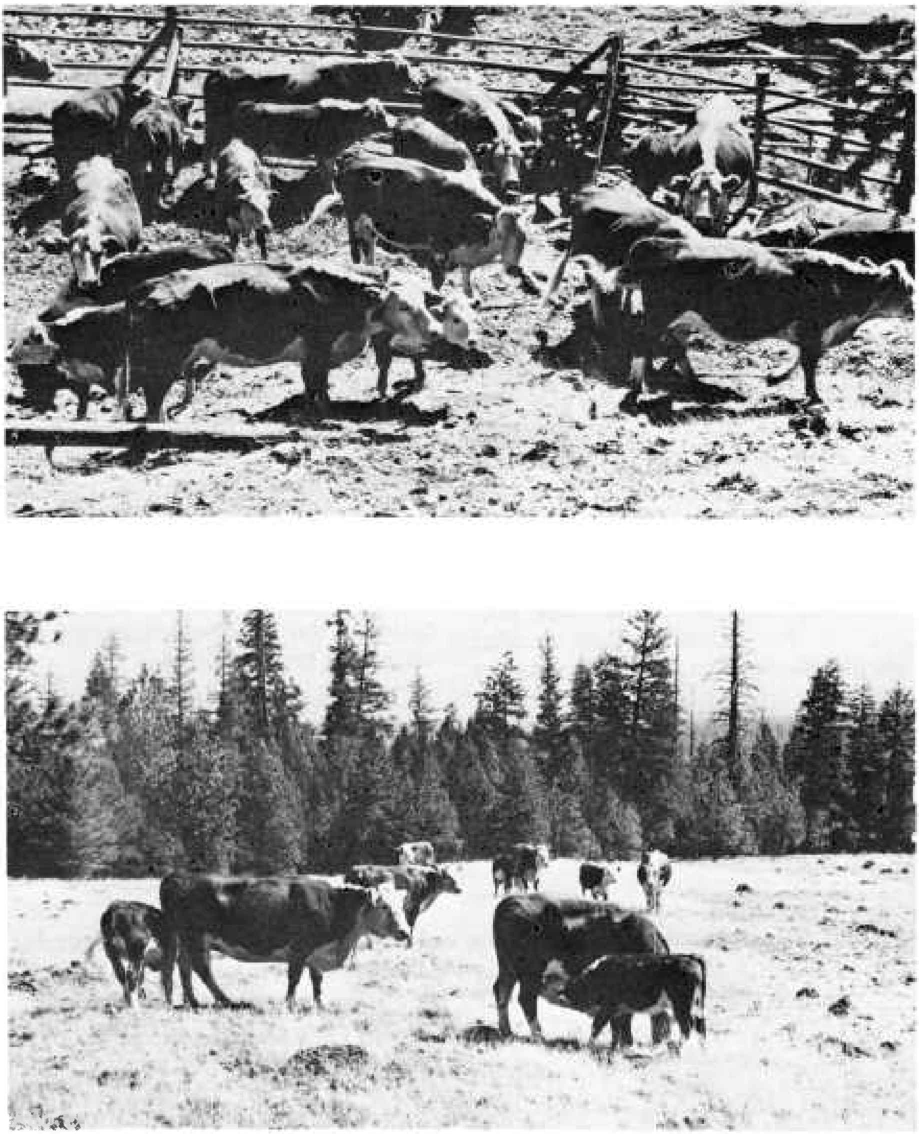


Figure 10.—The effects of heavy stocking became more apparent as the study progressed; cows and calves grazing at heavy (upper) and light (lower) levels in the same block showed differences in condition as well as real differences in weight.

Big Game Effects

Throughout the experimental areas grazed by cattle, days of deer use per acre were nearly twice those of elk, based on pellet group densities, and combined deer and elk use nearly equaled the days of cattle grazing. Forage utilization by big game, however, was less than one-fourth that of cattle, based on forage requirements by body weight. Fall utilization of principal species by big game alone was small in comparison with that of cattle and game (table 8).

Seasonal forage preference under game-only use, as reported by Edgerton and Smith (1971), helped evaluate changes in herbage production. For example, they showed shrub use on spiraea and snowberry in game-only ranges continued to increase well past the end of cattle grazing. Continued big game use on shrubs in the highly preferred game-only units could explain why shrub production decreased there but was generally maintained under dual-use grazing.

Deer, and to a lesser extent elk, spent more time in the forest than in the grassland, but both made more use of the grasslands as the rate of cattle grazing increased (fig. 11). Cattle spent about equal time between these two forage types.

Deer and elk use diminished as cattle stocking rate increased. Also, elk use was significantly higher in game-only units. Deer use in game-only units averaged more than in dual-use units, but the difference was not significant. Game-only ranges were preferred largely because of the greater availability of ungrazed forage plants.

Deer preferred deferred-rotation units over season-long units, but elk were not affected. Differences between deer and elk use of the

TABLE 8.—Utilization by big game only compared with dual use under three levels of cattle stocking [1] (in percent)

Type and species	Big game only	Cattle and big game		
		Light	Moderate	Heavy
Grassland opening:				
Bluebunch wheatgrass	2	31	43	50
Onespike danthonia	1	20	25	32
Sandberg bluegrass	4	7	12	17
Open forest:				
Elk sedge	2	18	24	31
Pinegrass	0	15	20	24
Birchleaf spiraea	9	17	19	24
Common snowberry	7	17	19	21

[1] Utilization represents a 7-year average of fall observations.

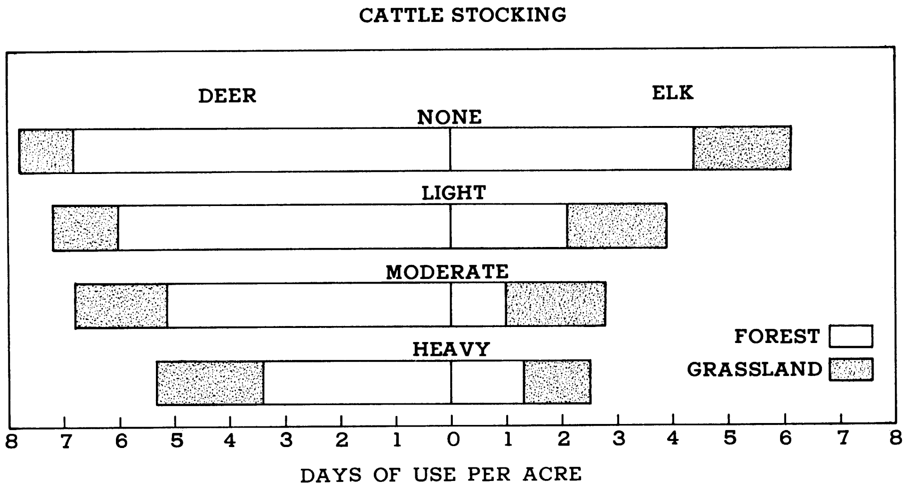


Figure 11.—Average days of deer and elk use per acre was influenced by levels of cattle stocking over a 7-year period.

two systems of cattle grazing may have been related to the seasonal feature that deer were summer-long residents but elk were not.

Elk grazed the lightly-stocked, season-long cattle ranges more often than lightly-stocked, deferred-rotation ranges; under heavy levels of cattle use, elk preferred deferred-rotation units over season-long units. This system-level interaction of elk use was highly significant. In all probability, this preference interaction by elk was related to the opposite forage utilization interaction by cattle grazing, further demonstrating the importance of forage availability to elk. Since the bulk of elk use did not occur during the cattle grazing season, antisocial elk behavior was not a reason for low elk density under high cattle stocking.

Tree Reproduction and Growth

Most striking over the 13-year period of study was a 12-fold increase in seedling density (table 9). However, this increase was apparently not a result of increased cattle use of the forest, since the same response was apparent in game-only units and there was no significant difference in tree reproduction among cattle grazed treatments. Tree density in the young and sapling classes decreased slightly, although there was some recruitment from the seedlings. Age analysis indicated that the high sapling density resulted from successful seedling establishment following selective pine logging in the late 1930's. The increase in density of pole and mature classes contra-

TABLE 9.—Forest stand density before and after the grazing management study

[Number of trees per acre]

Species	Size class[1]										Total	
	Seedling		Young		Sapling		Pole		Mature			
	1954	1967	1954	1967	1954	1967	1954	1967	1954	1967	1954	1967
Ponderosa pine	19	201	50	19	278	196	25	78	19	26	391	520
Douglas-fir	34	463	76	56	244	273	32	75	31	49	417	916
Grand fir	26	368	17	17	16	25	1	5	2	4	62	419
Lodgepole pine	5	44	7	4	16	13	5	19	2	5	35	85
Western larch	5	42	2	2	10	6	2	5	4	5	23	60
Total	89	1,118	152	98	564	513	65	182	58	89	928	2,000

[1] Seedling, 0–12 inches high; young, 12–36 inches high; sapling, 36 inches high to 4-inch d.b.h.; pole, 4- to 11-inch d.b.h.; mature, 11-inch d.b.h. and over.

dicts normal mortality over time but may indicate healthy stand conditions.

The increased density in larger tree classes undoubtedly reduced understory herbage production through increased shading, precipitation interception, and soil moisture competition. An estimate of canopy cover [7] from nearly half the forest clusters in 1958 and again in 1967 showed a significant difference amounting to a 15-percent increase; final forest crown canopy averaged 74 percent. Assuming the same rate of canopy increase during early study years, the 1954 canopy coverage would have been about 53 percent (a spread of 1.6 percent per year).

If the low rainfall and the high initial forest grazing conditions are discounted, each added percentage of crown spread between 1954 and 1967 reduced understory production about 5 pounds per acre. Reduced production for two classes of foliage under the different levels of grazing is shown in the following tabulation.

Cattle stocking	Grasses and grass-like	Forbs and shrubs	All foliage
None..........	0.2	3.3	3.5
Light..........	.8	4.3	5.1
Moderate......	1.8	4.2	6.0
Heavy.........	2.4	3.4	5.8

[7] Tree canopy was estimated with a spherical densiometer described by Lemmon (1956) and tested and modified by Strickler (1959); estimates from 182 cluster averages in 1958 showed canopy coverage to vary from a low of 16 percent to a high of 95 percent.

If herbage loss under no cattle grazing represented the natural reduction from crown spread alone, these results are comparable to responses reported from other areas (McConnell and Smith 1970, Pace 1958). On the study area, however, grasses and grasslike species were less affected by crown spread and forbs were more affected. Also, different big game use and successional trends between game-only and dual-use cattle range here caused some variability in understory response due to crown spread.

During the study, tree basal area increased from 89 square feet per acre in 1954 to 140 square feet in 1967, averaging 3.9 square feet net basal area increment per acre per year. Much of this growth increment was contributed by mixed-conifer stands on Tolo soils. Basal area does not exert a direct effect on understory herbage, other than growing space, but, it provides a good index for estimating herbage change because it is closely correlated with crown cover (McConnell and Smith 1965, Hedrick et al. 1968, Pearson and Jameson 1967).

Basal area measurements are also more commonly available than crown cover or stand density information and are therefore more often used in assessing the effects of logging release or crown closure. In this study, each percentage increase in crown cover was accompanied by a 2.4–square–foot increase in total basal area.

Relating the foregoing timber stand informatoin to herbage production data, some measure of the increased forage available after logging can be demonstrated. For example, if a similar forested range were to be logged for a 50-percent basal area timber removal, and forest managers estimated a present stand basal area of 140 square feet, the crown cover would be reduced nearly 30 percent ($70 \div 2.4 = 29.2$), with an expected herbage increase of 102 pounds per acre ($29.2 \times 3.5 = 102.2$). On ranges like the Starkey allotment, this would represent an increase in herbage of about 40 percent. These data are only approximate, however, since they assume a linear relationship between crown cover change and herbage production change, which usually is not the case.

Care in logging and postlogging forest treatment will determine how much of the increased herbage will be available for grazing. Such practices as winter logging, thorough slash disposal, grass seeding of disturbed soil, and grazing deferment will reduce the adverse effects of logging and can further add to the naturally increased grazing capacity (Reid 1965).

Grazing Capacity Changes

Herbage production change following long-term cattle grazing treatment was used to calculate a potential available grazing capacity. Herbage gains or losses per acre for each range were converted to animal months of forage using local forage requirements and proper use factors. Capacity changes were expressed as differences from the base year moderate stocking (table 10).

TABLE 10.—Average changes in grazing capacity based on 11-year differences in available forage [1] (AUM's)

System and forage type	Level			Average
	Light	Moderate	Heavy	
Deferred rotation:				
Grassland	13	9	10	11
Forest	−3	−12	−14	−10
Total	10	−3	−4	1
Season-long:				
Grassland	18	24	2	15
Forest	−9	−13	−20	−14
Total	9	11	−18	1
Average	10	4	−11	1

[1] Each entry represents the average of 2 range units, 1 from each block; initially these treatments averaged 71 AUM's with a standard error of 3.

Although total herbage production did decline, net forage production remained about the same. Most of the herbage losses occurred in the unpalatable forest forbs. Grazing capacity differences among stocking rates were highly significant. Net changes in AUM's of available forage after 11 years of treatment showed a 14-percent increase under light stocking, a 5-percent increase under moderate stocking, and a 16-percent loss under heavy stocking. Analysis of the separate contribution that grassland or forest made to the total grazing capacity changes showed significant differences among levels for the capacity of grasslands and highly significant differences among levels in forests.

Systems of grazing produced no difference in overall capacity change, yet there was a significant interaction between systems and levels. This suggests deferred-rotation grazing performed better than season-long grazing at the heavy level, but that the reverse was true at the moderate level. Apparently the latter was due to better response of grassland forage under season-long moderate grazing.

Although the consistently smaller loss of AUM's in the forest under deferred rotation than season-long was not significant, successive trends over time suggest that only a few years of additional treatment would have produced real differences between systems.

Grazing capacity should not be considered static regardless of the methods of management selected, since capacity, even based on long-term average production, varies over time. Weather cycles may influence average production directly by reducing or increasing available forage (Hurtt 1951), and indirectly by encouraging shifts in plant composition (Clark et al. 1943), such as an increase in onespike danthonia and a decrease in Sandberg bluegrass.

Within the ponderosa pine type, long- and short-term weather cycles occur. Weather patterns are complex, but short-term precipitation peaks and lows appear to occur at intervals ranging between 10 and 15 years in eastern Oregon and Washington (Keen 1937, Meyer 1934). Both short- and long-term cycles alter forage values and grazing capacity.

Forest growth and management practices in the pine type also create fluctuations in grazing capacity. Natural increase in tree overstory reduces understory herbage growth, a trend which can be checked by periodic thinning or timber removal (McConnell and Smith 1970). Postharvest recovery of forage is slow (Garrison 1961, 1965, but proper logging methods, slash treatment, and reseeding can sustain long-term grazing capacity. (Reid 1965).

Management Alternatives

Based on the outcome of this study, considerable latitude exists in selecting appropriate methods of grazing. Proper application depends on: (1) rangeland characteristics; (2) management objectives; (3) the capability of capitalizing on benefits other than cattle gains; and (4) the time over which benefits must repay investments.

Important rangeland characteristics are the balance between grassland and forest range, plant composition, range condition, and cattle distribution. On timbered rangeland where most forage comes from intermingled grassland openings, management should be keyed to the response to grazing of bunchgrass species in the openings. Where rangelands are predominantly forested, maintenance of understory forage species should have first consideration.

Species composition is important in selecting a proper grazing system. For example, ranges capable of supplying 25 pounds per acre or more of usable elk sedge are best suited for deferred-rotation grazing at a conservative stocking level. Where pinegrass predominates, light season-long grazing with occasional rest periods might be more practical. In any case, periods of rest or deferment should be keyed to providing maximum protection for the most valuable species, based on particular growth requirements.

Range condition has a good deal to do with anticipated response to methods of grazing. Rangeland in good condition may not improve under light stocking, so the objective must be maintenance with optimum animal production. On ranges in poor condition, light stocking under deferred rotation would restore range and watershed values and maintain good animal production; heavy stocking would be uneconomical. Closure of these mountain ranges to cattle is unnecessary as a restorative measure, if proper distribution is achieved.

Normal distribution problems were minimized in this experiment. For example, cattle seldom trailed more than one-half mile to water. To reduce the effect of poor distribution on extensive timbered range, practices to obtain more uniform forage use should be improved or the rate of stocking reduced to match the degree of development.

The overall objectives of the range operation also influence the method of grazing selected. Assuming long-term heavy stocking to be uneconomical, season-long moderate stocking may provide the best short-term return from cattle, forage, and capital investment; but it contributes no long-term advantage in forage improvement in the forest type. If intensive timber culture, such as thinning, is an option on forested summer range, valuable species like elk sedge would be encouraged. This in turn could enable greater use of the grassland forage without injury, and the total available forage resource would be balanced for increased production.

As an economic reality, the rancher's primary concern in range resource management is to maintain the forage supply and to convert it to profit, as cheaply as possible, through cattle sales. Associated range resources may be of no direct benefit to the rancher; therefore, he must charge all costs against beef production.

On multiple use public lands, however, other benefits are derived from stocking the range below the level for maximum cattle production. These assets can absorb land costs and offset small losses in beef production per acre. Conservative stocking is accompanied by better individual animal performance, so that total gain is not lost in direct proportion to loss in stocking.

In this study, for example, light stocking reduced calf gain per acre by 18 percent over moderate, but this was partly offset by an 8-percent greater gain per head. Although light stocking provided for 25-percent fewer cattle than did moderate stocking, it furnished about 15-percent more days use by big game. In this study, light stocking provided much better forage conditions in the forest than did moderate stocking.

SUMMARY AND CONCLUSIONS

A study of forage production and cattle gains on ponderosa pine range in the Blue Mountains of the Pacific Northwest produced valuable information on the effects of grazing. In the course of the study, rates of stocking were 40, 30, and 20 usable acres per cow-calf unit, over a 4-month, summer grazing season. Systems of management were a two-unit, deferred rotation method, and the traditional season-long grazing.

The acreage of intermingled grassland openings was half that of the usable forest range, but it supplied nearly an equal amount of forage. About 10 percent of the total herbage was used as forage. Grasses and grasslike plants made up nearly half of the total production of either type, but they constituted about 90 percent of the cattle diet.

Over the decade of study, weather, grazing patterns, and forest canopy closure caused a general decrease in forest understory herbage and an increase in that of the grasslands.

Rates of stocking produced different degrees of utilization for most of the principal species, but grazing systems did not. However, late-season deferred-rotation grazing consistently produced higher use than did early-season grazing.

In the grasslands, light stocking usually accounted for the greatest forage improvement and heavy stocking the poorest. Changes in grasses were varied and depended on species. Unpalatable forbs decreased under light grazing and increased under heavy grazing, while palatable secondary forbs did the opposite. Protection from cattle grazing barely maintained grasses, palatable forbs increased more, and unpalatable ones decreased more than under any methods of cattle use.

Systems of grazing caused no major changes in grassland herbage production; but deferred rotation grazing was superior to season-long grazing for most aspects of watershed cover improvement.

In the forest, response to grazing treatment was more pronounced than in the grassland, particularly in the case of important forage groups and certain species. Grasses and grasslike plants were directly related to stocking; differences among levels of stocking were highly significant. Also, deferred-rotation ranges lost significantly less of this herbage than season-long ranges.

Elk sedge, the single most important forage, lost considerably less herbage under light than under moderate or heavy stocking, and production was significantly better under deferred rotation than under season-long grazing. Forbs as a group were not affected by levels or systems of grazing, but different species, according to degree of palatability, showed different responses. Shrub production changes were not pronounced except in game-only areas where losses were incurred.

Methods of cattle grazing caused no differences in soil compaction or erosion siltation under the study conditions.

Cattle gains diminished over the term of the study, largely because high quality forage was lost in the forest. Light stocking produced the largest gains per head and heavy stocking invariably produced the poorest. Real differences in gain were caused by levels of stocking for both cows and calves. During the final years of the study, rate of gain for both cows and calves declined rapidly under heavy stocking. This was largely due to rapid depletion of nutritious grasses and grasslike plants in the forest.

Cattle gains per acre varied by grazing method and by class of animal. Gain per acre for suckling calves was greatest under heavy stocking and least under light stocking. Cow gain per acre diminished sharply between moderate and heavy stocking. Although gains averaged slightly more under season-long grazing than under deferred-rotation grazing, the difference was not significant. Differences in gain per acre between systems were smallest at moderate stocking levels for both cows and calves.

Deer and elk accounted for about one-fourth of the forage consumed but did not use much forage important to cattle. Conversely, cattle used large amounts of forage important to deer and elk. As the rate of cattle stocking increased, total use by deer and elk decreased. Increased cattle grazing also caused big game to spend more time in the grassland openings and less time in their preferred forest habitat.

Cattle stocking had no influence on tree reproduction or growth over the course of the study. However, growth and canopy closure in the pole- and mature-size classes of all tree species depressed understory production, magnifying the effects of grazing on forage in the forest.

To conclude:

(1) Heavy stocking lowered grazing capacity, depleted ground cover, reduced cattle gains, and limited game use.

(2) Moderate stocking maintained grazing capacity, provided acceptable cattle gains, and slightly lowered the amount of high quality forage.

(3) Light stocking provided a substantial increase in capacity and the best cattle gains per head but not per acre; it permitted the highest game density under dual use.

(4) Protection from cattle use slightly improved the composition of high quality forage species, produced little change in potential grazing capacity, furnished no marketable product, but provided the greatest game use.

It is not recommended that deferred rotation invariably replace properly stocked season-long grazing on mountain summer range if good livestock distribution can be accomplished. However, deferred rotation is superior for improving forage on forested range and for restoring mountain watersheds while maintaining cattle production.

As a long-term management practice, deferred rotation grazing at a conservative rate of about 9.0 usable acres per AUM should provide optimum returns from multiple use rangeland with conditions similar to those of the Starkey Experimental Forest and Range.

LITERATURE CITED

Aldous, A. E.
1935. Management of Kansas permanent pastures. Kan. Agric. Exp. Stn. Bull. 272, 44 p., illus.

Bentley, J. R., and M. W. Talbot.
1951. Efficient use of annual plants on cattle ranges in the California foothills. U.S. Dep. Agric. Circ. 870, 52 p., illus.

Clark, S. E., E. W. Tisdale, and N. A. Skoglund.
1943. The effects of climate and grazing practices on short-grass prairie vegetation. Can. Dep. Agric. Publ. 747, Tech. Bull. 46, 53 p., illus.

Daubenmire, R. F., and W. E. Colwell.
1942. Some edaphic changes due to overgrazing in the Agropyron-Poa prairie of southeastern Washington. Ecology 23:32–40.

Driscoll, Richard S.
1955. A guide to the Starkey Experimental Forest and Range. U.S. Dep. Agric. For. Serv. Pac. Northwest For. & Range Exp. Stn., 21 p., illus. Portland, Oreg.

Driscoll, Richard S.
1958. A loop method for measuring groundcover characteristics on permanent plots. J. Range Manage. 11:94, illus.

Edgerton, Paul J., and Justin G. Smith.
1971. Seasonal forage use by deer and elk on the Starkey Experimental Forest and Range, Oregon. U.S. Dep. Agric. For. Serv. Res. Pap. PNW–112, 12 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

Garrison, G. A.
1961. Recovery of ponderosa pine range in eastern Oregon and eastern Washington by seventh year after logging. Soc. Am. For. Proc. 1960:137–139, illus.

Garrison, G. A.
1965. Changing conditions in Northwest forests and their relation to range use. Soc. Am. For. Proc. 1964:67–68.

Garrison, George A.
1966. A preliminary study of response of plant reserves to systems and intensities of grazing on mountain rangeland in northwest U.S.A. 10th Int. Grassl. Congr. Proc. Helsinki, Finland 10:937–940.

Hanson, Herbert C., L. Dudley Love, and M. S. Morris.
1931. Effects of different systems of grazing by cattle upon a western wheat grass type of range near Fort Collins, Colorado. Colo. Agric. Exp. Stn. Bull. 377, 82 p., illus.

Harris, Robert W.
1951. Use of aerial photographs and sub-sampling in range inventories. J. Range Manage. 4:270–278, illus.

Harris, Robert W.
1954. Fluctuations in forage utilization on ponderosa pine ranges in eastern Oregon. J. Range Manage. 7:250–255, illus.

Harris, Robert W., and Richard S. Driscoll.
1954. Gains made by cattle on summer range. Oreg. Cattleman 3:5, 24.

Hedrick, D. W., J. A. Young, J. A. B. McArthur, and R. F. Keniston.
1968. Effects of forest and grazing practices on mixed coniferous forests of northeastern Oregon. Oreg. Agric. Exp. Stn. Tech. Bull. 103, 24 p., illus.

Hitchcock, C. Leo, Arthur Cronquist, Marion Ownbey, and J. W. Thompson.
1955–69. Vascular plants of the Pacific Northwest. 5 vols. Univ. Wash. Press, Seattle.

Houston, Walter R., and R. R. Woodward.
1966. Effects of stocking rates on range vegetation and beef cattle production in the northern Great Plains. U.S. Dep. Agric., Tech. Bull. 1357, 58 p., illus.

Hurtt, Leon C.
1951. Managing northern Great Plains cattle ranges to minimize effects of drought. U.S. Dep. Agric. Circ. 865, 24 p., illus.

Ingles, Lloyd G.
1965. Mammals of the Pacific States: California, Oregon, and Washington. 506 p. Stanford Univ. Press, Stanford, Calif.

Jardine, James T.
1916. Improvement and management of native pastures in the West. U.S. Dep. Agric., Yearb. Agric. 1915:299–310, illus.

Johnson, W. M.
1953. Effect of grazing intensity upon vegetation and cattle gains on ponderosa pine-bunchgrass ranges of the Front Range of Colorado. U.S. Dep. Agric. Circ. 929, 36 p., illus.

Keen, F. P.
1937. Climatic cycles in eastern Oregon as indicated by tree rings. Mon. Weather Rev. 65:175–188, illus.

Klipple, G. E., and David F. Costello.
1960. Vegetation and cattle responses to different intensities of grazing on short-grass ranges on the central Great Plains. U.S. Dep. Agric., Tech. Bull. 1216, 82 p., illus.

Lemmon, Paul E.
1956. A spherical densiometer for estimating forest overstory density. For. Sci. 2:314–320.

McConnell, Burt R., and Justin G. Smith.
1965. Understory response three years after thinning pine. J. Range Manage. 18:129–132.

McConnell, Burt R., and Justin G. Smith.
1970. Response of understory vegetation to ponderosa pine thinning in eastern Washington. J. Range Manage. 23: 208–212, illus.

McIlvain, E. H., and D. A. Savage.
1951. Eight-year comparisons of continuous and rotational grazing on the Southern Plains Experimental Range. J. Range Manage. 4:42–47, illus.

Meyer, Walter H.
1934. Growth in selectively cut ponderosa pine forests of the Pacific Northwest. U.S. Dep. Agric. Tech. Bull. 407, 64 p., illus.

Neff, D. J., O. C. Wallmo, and D. C. Morrison.
1965. A determination of defecation rate for elk. J. Wildl. Manage. 29:406–407.

Pace, Charles P.
1958. Herbage production and composition under immature ponderosa pine stands in the Black Hills. J. Range Manage. 11:238–243.

Parker, Kenneth W.
1951. A method for measuring trend in range condition on national forest ranges. U.S. Dep. Agric. For. Serv., 26 p. Washington, D.C. [Unpublished report, Range Management Staff, Administrative Studies (Conditions and Trends).]

Pearson, Henry A., and Donald A. Jameson.
1967. Relationship between timber and cattle production on ponderosa pine range: the Wild Bill range. U.S. Dep. Agric. For. Serv., Rocky Mt. For. & Range Exp. Stn., 10 p. Fort Collins, Colo.

Pechanec, Joseph F., and G. D. Pickford.
1937a. A comparison of some methods used in determining percentage utilization of range grasses. J. Agric. Res. 54:753–765.

Pechanec, Joseph F., and G. D. Pickford.
1937b. A weight estimate method for the determination of range or pasture production. J. Am. Soc. Agron. 29:894–904.

Pickford, G. D., and Elbert H. Reid.
1948. Forage utilization on summer cattle ranges in eastern Oregon. U.S. Dep. Agric. Circ. 796, 27 p., illus.

Reed, Merton J., and Ronald A. Peterson.
1961. Vegetation, soil, and cattle responses to grazing on northern Great Plains range. U.S. Dep. Agric., Tech. Bull. 1252, 79 p., illus.

Reid, Elbert H.
1965. Forage production in ponderosa pine forests. Soc. Am. For. Proc. 1964: 61–64, illus.

Reid, Elbert H., G. D. Pickford, and N. Talmage Nelson.
1942. An appraisal of range survey methods from the standpoint of effective range management. U.S. Dep. Agric. For. Serv., Pac. Northwest For. & Range Exp. Stn. Range Res. Rep. 2, 66 p., illus. Portland, Oreg.

Reynolds, Hudson G., and Paul E. Packer.
1963. Effects of trampling on soils and vegetation. *In* Range research methods: a symposium, p. 116–122. U.S. Dep. Agric. Misc. Publ. 940, 172 p.

Sampson, Arthur W.
1913. Range improvement by deferred and rotation grazing. U.S. Dep. Agric. Bull. 34, 16 p., illus.

Sampson, Arthur W.
1914. Natural revegatation of range lands based upon growth requirements and life history of the vegetation. J. Agric. Res. 3:93–148, illus.

Sampson, Arthur W.
1951. A symposium on rotation grazing in North America. J. Range Manage. 4:19-24.

Sarvis, J. T.
1923. Effects of different systems and intensities of grazing upon the native vegetation at the northern Great Plains Field Station. U.S. Dep. Agric. Bull. 1170, 45 p., illus.

Sarvis, J. T.
1925. Cooperative grazing experiment. U.S. Dep. Agric. Bull. 1301: 70–79.

Skovlin, Jon M.
1962. Cow and calf weight trends on mountain summer range. U.S. Dep. Agric. For. Serv., Pac. Northwest For. & Range Exp. Stn. Res. Note 220, 7 p., illus. Portland, Oreg.

Skovlin, Jon M.
1965. Improving cattle distribution on western mountain rangelands. U.S. Dep. Agric. Farmers' Bull. 2212, 14 p., illus.

Skovlin, Jon M.
1967. Fluctuations in forage quality on summer range in the Blue Mountains. U.S. Dep. Agric. For. Serv. Res. Pap. PNW–44, 20 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

Skovlin, Jon M., Paul J. Edgerton, and Robert W. Harris.
1968. The influence of cattle management on deer and elk. N. Am. Wildl. Nat. Resour. Conf. Trans. 33:169–179, illus.

Smith, Arthur D.
1964. Defecation rates of mule deer. J. Wildl. Manage. 28:435–444.

Smith, Dwight R.
1967. Effects of cattle grazing on a ponderosa pine-bunchgrass range in Colorado. U.S. Dep. Agric., Tech. Bull. 1371, 60 p., illus.

Smith, Jared G.
1899. Grazing problems in the southwest and how to meet them. U.S. Dep. Agric., Div. Agrostology, Bull. 16, 47 p., illus.

Strickler, Gerald S.
1959. Use of the densiometer to estimate density of forest canopy on permanent sample plots. U.S. Dep. Agric. For. Serv., Pac. Northwest For. & Range Exp. Stn. Res. Note 180, 5 p. Portland, Oreg.

Strickler, Gerald S.
1966. Soil and vegetation on the Starkey Experimental Forest and Range. Soc. Am. For. Proc. 1965:27–30.

Trappe, James M., and Robert W. Harris.
1958. Lodgepole pine in the Blue Mountains of northeastern Oregon. U.S. Dep. Agric. For. Serv., Pac. Northwest For. & Range Exp. Stn. Res. Pap. 30, 22 p., illus. Portland, Oreg.

Van Bavel, C. M. H.
1959. Soil densitometry by gamma transmission. Soil Sci. 87:50–58.

Wilm, H. G., David F. Costello, and G. E. Klipple.
1944. Estimating forage yield by the double-sampling method. J. Am. Soc. Agron. 36:194–203.

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED [8]

PLANTS

Grasses and Grasslike

Bearded bluebunch wheatgrass	**Agropyron spicatum** (Pursh) Scribn. & Sm.
Bottlebrush squirreltail	**Sitanion hystrix** (Nutt.) J.G. Sm.
Elk sedge	**Carex geyeri** Boott
Idaho fescue	**Festuca idahoensis** Elm.
Letterman needlegrass	**Stipa lettermanii** Vas.
Northwestern sedge	**Carex concinnoides** Mack.
Onespike danthonia	**Danthonia unispicata** (Thurb.) Munro ex Macoun
Pinegrass	**Calamagrostis rubescens** Buckl.
Prairie junegrass	**Koeleria cristata** Pers.
Ross sedge	**Carex rossii** Boott
Sandberg bluegrass	**Poa secunda** Presl.
Western fescue	**Festuca occidentalis** Hook.

Forbs

Balsamroot	**Balsamorhiza** spp.
Hawkweed	**Hieracium** spp.
Low gumweed	**Grindelia nana** Nutt.
Lupine	**Lupinus** spp.
Rush pussytoes	**Antennaria luzuloides** T. & G.
Western yarrow	**Achillea millefolium** var. **lanulosa** (Nutt.) Piper

Shrubs

Birchleaf spiraea	**Spiraea betulifolia lucida** (Dougl.) C. L. Hitchc.
Common snowberry	**Symphoricarpos albus** (L.) Blake

Trees

Douglas-fir (interior)	**Pseudotsuga menziesii** var. **glauca** (Beissn.) Franco
Grand fir	**Abies grandis** (Dougl.) Lindl.
Lodgepole pine	**Pinus contorta** Dougl. ex Loud.
Ponderosa pine	**Pinus ponderosa** Dougl. ex Loud.
Western larch	**Larix occidentalis** Nutt.

ANIMALS

Mule deer	**Odocoileus hemionus hemionus**
Rocky Mountain elk	**Cervus canadensis nelsoni**
The Dalles pocket gopher	**Thomomys spp.**

---

[8] Nomenclature follows that used by Ingles (1965) and Hitchcock et al. (1955–69).

U.S. GOVERNMENT PRINTING OFFICE:1976 O—211-606