B-1100
July 1970

Livestock Production and Economic Returns From Grazing Treatments

on the

Texas Experimental Ranch

TEXAS A&M UNIVERSITY • TEXAS AGRICULTURAL EXPERIMENT STATION • H. O. Kunkel, Acting Director, College Station, Texas

Cover photo by Joe Brown.

ACKNOWLEDGMENTS

The authors express appreciation to the Texas Experimental Ranch Committee and Swenson Land and Cattle Company for their support and contributions of time, money and materials which made this research possible.

Acknowledgment is made also to W. M. Self, former ranch foreman of the Texas Experimental Ranch; Gene Parker, former research associate; and Mrs. Wanda Hatter, secretary, for assistance in conducting this work.

Special thanks are due A. M. Sorensen, Jr. and Tom Morrow for time and effort spent in palpating the cows used in the study.

Plains Cooperative Oil Mill, Lubbock, Texas, and Paymaster Cotton Oil Mill, Abilene, Texas, donated some of the cottonseed cake used.

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SUMMARY

Studies of grazing management for cow-calf operations on native range were conducted on the Texas Experimental Ranch from 1960 through 1968. The response of livestock to nine different combinations of stocking rates, grazing systems and levels of winter supplementation was determined. The stocking rates studied were heavy, moderate and light which were designed to utilize 75 to 80 percent, 45 to 50 percent and 20 to 30 percent of the current year's forage production. Three grazing systems, continuous grazing, Merrill system deferred-rotation and switchback system deferred-rotation, were compared under moderate stocking and a medium level of supplementation. The three levels of supplementation were 3.0, 1.5 and 0.0 pounds of 41 percent crude protein cottonseed cake per cow per day, fed for 90 days during each winter. The three rates of supplementation were tested under both moderate and heavy continuous grazing.

Cow weights and calf weights both increased significantly as stocking rates decreased, but cow weights showed more response to changes in stocking rates than did calf weights. Cow weights increased 36 and 38 pounds from heavy to moderate and from moderate to light stocking, respectively, while calf weaning weights increased only 11 and 5 pounds from heavy to moderate and from moderate to light stocking, respectively. Decreasing stocking rates did increase production per animal unit, but production per acre decreased in proportion to the reductions in stocking rates. Reducing the stocking rate increased production costs per animal unit as a result of increasing land costs. Calculated net returns to capital and management per acre were $5.28 from heavy stocking, $3.03 from moderate stocking and $2.24 from light stocking for a landowner.

Calf production per animal unit from the switchback and Merrill systems was greater than from moderate continuous grazing by 17 and 46 pounds, respectively. Both deferred-rotation grazing systems also produced more pounds of calf per acre than did moderate continuous grazing. The average cow weights were 17 pounds heavier from the switchback and 33 pounds heavier from the Merrill system compared with those from moderate continuous grazing. The use of different grazing systems had little effect on production costs when stocking rate was held constant. Net returns per acre to capital and management for a landowner were $3.03 from moderate continuous, $3.22 from switchback system and $3.81 from the Merrill system. Returns to capital and management per animal unit for a lessee were $21.19 from moderate continuous, $24.97 from switchback system and $34.80 from the Merrill system.

Cow weights were greatly increased by supplementation on moderate continuously grazed pastures, but on heavy continuously grazed pastures, cow weights showed only a small response to supplementation. Under both stocking rates, supplementation reduced the magnitude of annual variation of cow weights. Under heavy continuous stocking, the medium and high levels of supplement increased calf production per animal unit 37 and 25 pounds, respectively. Under moderate continuous grazing, the medium level of supplement decreased calf production per animal unit by 6 pounds; the high level increased production by 13 pounds. The medium level of supplement on heavy continuous grazing yielded a net return to capital and management of $3.41 per animal unit above that of no supplement. Net returns to the high level of supplement on heavy stocking were lower than from no supplement. Under moderate continuous grazing, both the medium and high levels of supplement had lower net returns than did no supplement.

Among the nine treatments studied, heavy continuous stocking with the medium level of supplementation yielded the highest net returns for the 8-year period. The lowest returns were from light continuous stocking. Deferred-rotation grazing systems increased net returns compared with continuous grazing at the same stocking rate. Since precipitation was near average or above for the duration of the study, it would be hazardous to make long term recommendations based only on this study. The effects of drouth could greatly alter the response of livestock to the treatments studied.

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M. M. KOTHMANN, G. W. MATHIS, P. T. MARION AND
W. J. WALDRIP*

THE ROLLING PLAINS REGION OF TEXAS is among the most important in the United States for the production of feeder and stocker calves and yearlings. Approximately $90 million or about 41 percent of the total agricultural income of the region is derived from cow-calf operations producing stocker and feeder cattle. Most of these animals are produced on ranches which depend upon native vegetation for the bulk of their forage. Sixty-eight percent of the 15.8 million acres in the Rolling Plains is in rangeland. Continuous heavy grazing by domestic livestock for over three-quarters of a century has decreased the productivity and seriously deteriorated much of this rangeland (5).

Prior to the establishment of the Texas Experimental Ranch in 1959, no facilities were available for a range research program in this region. The nearest sources of research information pertaining to range problems were the Texas A&M University Agricultural Research Station at Sonora, Texas, and the U. S. Southern Great Plains Field Station near Woodward, Oklahoma.

Ranchers in the Rolling Plains were interested in starting a program of range research. This interest resulted in a cooperative agreement between ranchmen and the Texas Agricultural Experiment Station by which the ranchmen provided the land, livestock and improvements and the Experiment Station conducted the research.

This report covers livestock production from the first 9 years of grazing management research on the Texas Experimental Ranch. Vegetational changes resulting from the different grazing treatments will be reported in a separate publication.

The objectives of this study were

1. To determine effects of the following treatments upon livestock, vegetation and soil and water conservation:
   Different rates of stocking—light, moderate, heavy;
   Different systems of grazing management; and
   Different levels of nutrition for winter maintenance.
2. To make an economic analysis of the treatments applied in order to determine the influence of grazing practices, range improvement measures and winter maintenance practices upon the economy of range calf production.

EXPERIMENTAL AREA

Location

The Texas Experimental Ranch, located in Throckmorton County in the eastern portion of the Rolling Plains, comprises approximately 7,000 acres of native rangeland owned by Swenson Land and Cattle Company (Figure 1). The area has been managed for experimental purposes since 1959 by the Texas Agricultural Experiment Station under a cooperative agreement with the owners.

Climate

The average annual precipitation for Throckmorton County is 24.83 inches (7). However, the 8-year average at the ranch headquarters was 27.51 inches. Annual rainfall is generally quite variable in this area, but only 2 of the past 8 years were below the county average (Figure 2).

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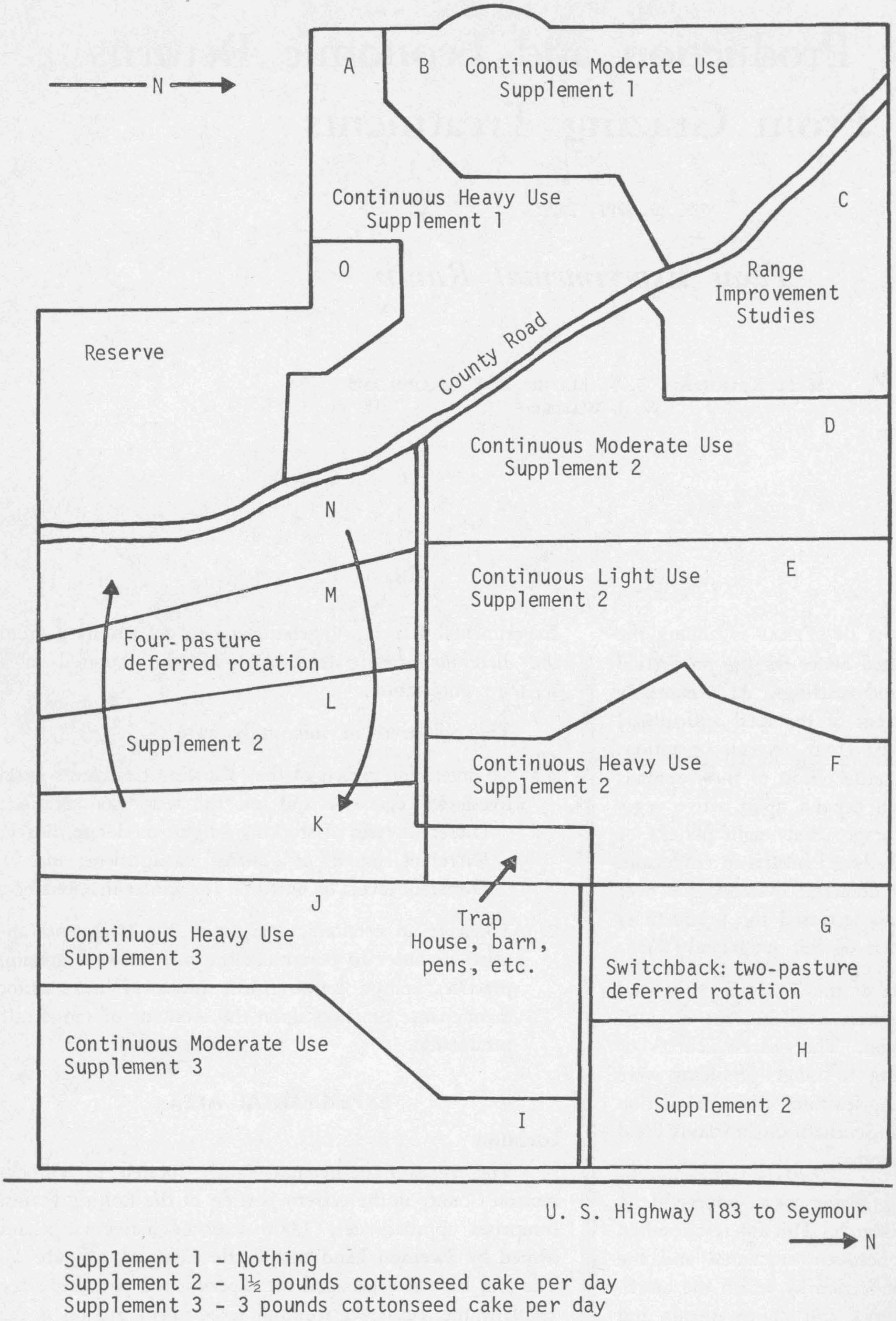

Figure 1. Map of the Texas Experimental Ranch — 4 miles long and 3 miles wide, containing 11 sections.

Most of the precipitation occurs as rainfall, but occasionally some moisture is received in the form of snow during the winter months.

Average monthly rainfall for the ranch during the 8-year period is shown in Figure 3. September had the highest average, 4.84 inches, and other peak months included April, May and June. The lowest monthly average was 0.83 inch, recorded during December. Monthly distribution in some years varied considerably with large amounts being received in 1 month followed by 3 or 4 months of limited rainfall (Appendix Table 1).

The average frost free period is approximately 220 days with the last average freeze date in the spring occurring March 31 and the first in the fall occurring November 6.

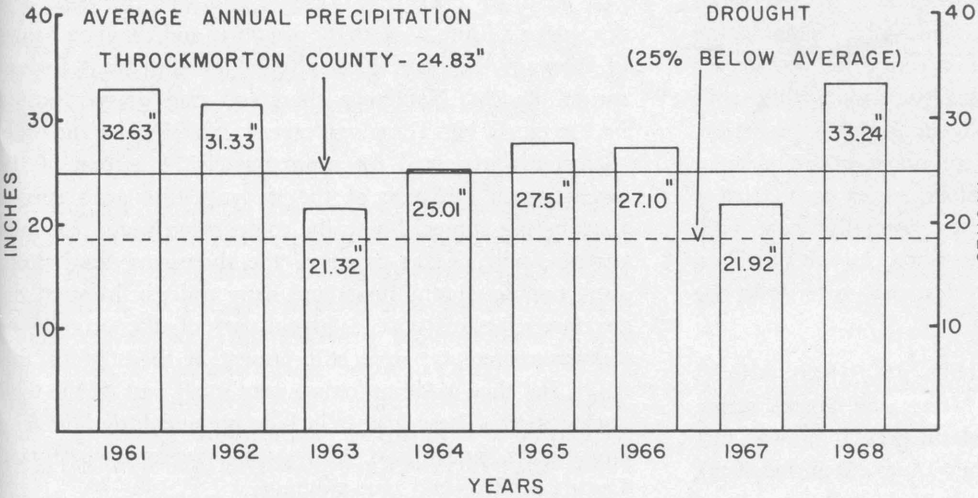

Figure 2.
Annual precipitation measured on the Texas Experimental Ranch from 1961 through 1968.

Average maximum and minimum temperatures recorded at the ranch during the study period were 80.2 and 48.3° F, respectively, resulting in a mean annual temperature of 64.3° F. Temperatures above 100° occur frequently during the summer months, and occasionally temperatures of 0° F or below are recorded during the winter months.

Soils and Range Sites

Soils on the Texas Experimental Ranch are mostly clays and clay loams that vary from deep alluvial creek bottoms to shallow rocky slopes. According to surveys made by the Soil Conservation Service, these soils were classified into 10 major soil series and grouped into 5 range sites (6). The percentage of area contained in each range site for the experimental pastures is shown in Table 1.

TABLE 1. LAND AREA OF THE EXPERIMENTAL PASTURES CONTAINED IN EACH RANGE SITE

	Range Site				
Pasture	Deep Upland	Rolling Hills	Shallow Redlands	Rocky Hills	Valley
			Percent		
A	30.	18.	1.	48.	3.
B	22.	23.	0.	47.	8.
D	36.	40.	5.	19.	0.
E	56.	29.	11.	3.	1.
F	18.	49.	13.	7.	13.
G & H	12.	43.	0.	34.	11.
I	53.	41.	4.	2.	0.
J	53.	37.	0.	10.	0.
K, L, M, N	66.	28.	6.	0.	0.

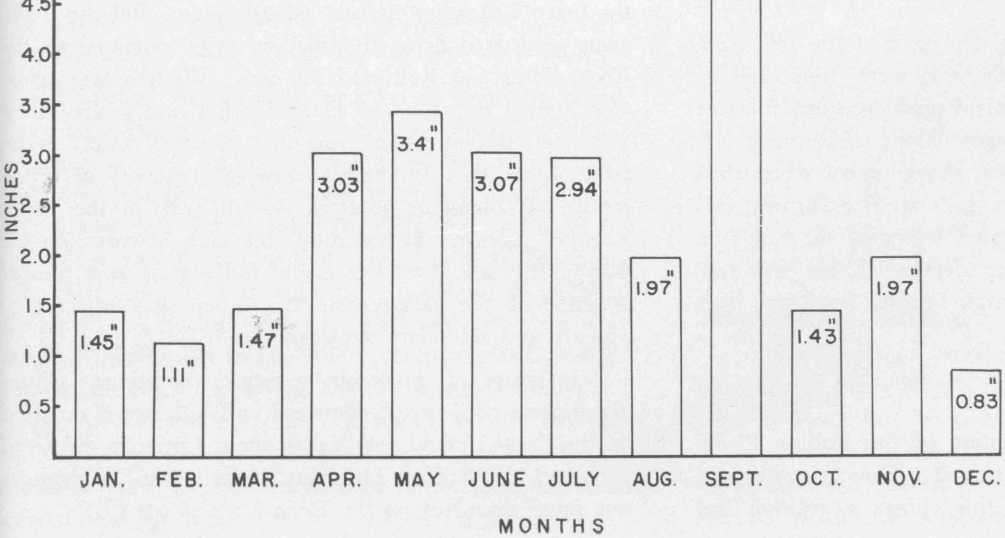

Figure 3.
Average monthly distribution of precipitation on the Texas Experimental Ranch for the 8-year period 1961-68.

The Abilene, Crawford, Rowena and Tobosa series were grouped into the Deep Upland site. This is the predominant site on the ranch and comprises 41 percent of the total experimental area. Characteristically, these soils are dark clays and clay loams, moderate to slowly permeable and well drained. Depth of top soil above parent material ranges from 20 to 80 inches. Slope varies from 0 to 3 percent. All soils in these series generally have high fertility levels and high available water capacities. They differ mainly in distribution of calcareous material in the soil horizons.

Grouped into the Rolling Hills site, which includes 34 percent of the area, were the Mereta and Throck series. Surface soils of these series are dark, greyish brown, silty clay loams, ranging in depth from 15 to 20 inches, with a slope of 1 to 5 percent. They are highly calcareous, and out-croppings of flat limestone pebbles occur frequently on the surface. These soils are moderately permeable and highly fertile, but water storage is restricted because of their shallow depth.

Soils of the Owens-Tarrant complex were designated as Rocky Hills site. These soils are shallow, stony clays and are characterized by limestone rocks on the surface that vary in size from small cobbles to large boulders. Depth of soil above parent material ranges from 5 to 20 inches. Fertility level is generally high, but permeability is moderate to very slow. These areas occur on steep slopes and rocky ridges where surface runoff is rapid. Water erosion is a hazard particularly on areas that have been closely grazed. Seventeen percent of the experimental ranch is contained in this site.

The Owens-Vernon soils were grouped into a Shallow Redland site containing 4 percent of the area. These soils consist of reddish to olive brown calcareous clays that range in depth from 5 to 20 inches. The subsoil is underlain by shaley clays. Surface runoff is rapid, and soil erosion is generally active because these areas are sparsely vegetated.

Included in the remaining 4 percent of the area were soils of the Spur series. These soils were designated as Valley site and occur in the valleys or depressions adjacent to primary or secondary drainages. Slope is normally less than 0.5 percent. Depth of soil above parent material is greater than 60 inches. Surface soils are dark brown, calcareous, clay loams with stratified layers of silt and fine sandy loam occurring at lower depths. These soils are slowly permeable and have a high fertility level and high available water capacity.

Vegetation

The original native vegetation of the Rolling Plains area included tall and mid grasses (1). Due to continuous close utilization by livestock, this climax vegetation has been reduced primarily to short and mid grasses. The Appendix (Table 2) lists the scientific and common names of many of the plant species found on the Texas Experimental Ranch. Numerous short and mid grasses existed on the ranch, but Texas wintergrass, buffalograss and sideoats grama accounted for approximately 73 percent of the vegetation at initiation of the study. Other grass species contributing appreciably to the composition were: common curlymesquite, Texas cupgrass, the threeawns, sand dropseed, tumble windmillgrass and hairy tridens. Most of the decreaser species, once a major part of the original or climax community, were still present at the start of this study, but they made up only a very small part of the total composition. These grasses include big and little bluestem, Indiangrass, switchgrass, blue grama, western wheatgrass, Canada wildrye and vine-mesquite.

The most abundant forbs were bitterweed, Texas broomweed, silverleaf nightshade, curlycup gumweed, filaree, plains beebalm and snow-on-the-mountain. Most of these forbs were present each year, but the annuals such as bitterweed, filaree and Texas broomweed occurred in greater abundance when moisture conditions were favorable during the fall and winter months.

The brush species included mesquite, lotebush, catclaw, pricklypear and tasajillo. Mesquite and lotebush were the dominant woody species and were present on all range sites. The original stand of mesquite on the experimental area was chained in 1948, and the regrowth was sprayed aerially with 2,4,5-T in 1964. Resprouting of mesquite has occurred since the aerial spraying, but the density in 1968 was not great enough to materially reduce forage production.

Vegetation and Range Site Relationships

Sample plots within the test pastures showed that certain species were consistently more abundant on certain range sites under all of the grazing treatments. Texas wintergrass and buffalograss occurred more frequently on the Deep Upland site while sideoats grama and the threeawns tended to favor the shallow soils contained in the Rocky Hills and Rolling Hills sites. Western wheatgrass was present only on the Deep Upland and Valley sites, primarily in depression areas that received runoff water from slopes above. Although low in frequency of occurrence, big bluestem occurred on all sites in the better managed pastures. It was most abundant, however, on the Rocky Hills site. Switchgrass and Indiangrass were present in some of the pastures on the Valley sites adjacent to primary and secondary streams.

In years of favorable moisture conditions, greater populations of Texas broomweed and bitterweed occurred on the Deep Upland and Valley sites. Curlycup gumweed preferred the Rolling Hills site and silverleaf nightshade was more abundant on the Deep Upland site.

Although mesquite and pricklypear occurred on all sites, greatest densities prevailed on the deeper soils of the Deep Upland and Valley sites. Lotebush was widely established on all sites except the Rocky Hills site.

PROCEDURE

Initially the Texas Experimental Ranch consisted of 7,000 acres fenced in one pasture. An intensive soil and range survey was made on the ranch, and the fence lines were placed so that the experimental pastures were as similar as possible. This resulted in some irregular pasture boundaries. Fence construction began in October 1959 and was completed in March 1960. Figure 1 shows the location, size and grazing treatment of the pastures, and Table 1 gives the percentage of the area in each range site within the pastures. It was not possible to include all of the range sites in all of the pastures, but the major sites, Deep Upland and Rolling Hills, are well represented in all treatments.

Bred Hereford heifers were obtained and randomly allocated to the treatments. These heifers had their first calves as 3-year-olds during the winter of 1959-60. Records were not obtained on this calf crop. Bulls were placed with the cows March 14 and removed June 15 of that year and of each successive year. All bulls were fertility tested just prior to breeding, and at least two bulls were used in each pasture. The cows were pregnancy tested in September of each year, and any cow that was open 2 consecutive years was permanently removed from the herd.

A reserve herd of comparable cows was kept on the ranch to provide replacements. Dry cows were removed from the treatment pastures and placed in reserve pastures. If they calved the following year in the reserve pasture, they were then returned to the treatment pasture. These cows were not included in the production records the first year after returning to the treatment. Wet cows from the reserve herd were placed in the treatment pastures in place of those removed to maintain the specified stocking rates. The purpose of this practice was to maintain a constant grazing pressure from producing cows on all treatments.

Individual records were kept on all cows and calves. Cows were tattooed in the ear and also identified with a neckchain and tag for easier recognition. Numbered plastic tags were placed in the calves' ears for identification. The calving date was recorded for each cow, and the cows and calves were paired so that calves could be identified with their cows. Calves were tagged, dehorned, castrated and earmarked during February. All cows and calves were weighed individually in late March, mid-June and September. At the March weighing, the calves were branded and vaccinated for blackleg. The calves were usually removed from the cows in early October. Salt and bonemeal were provided free choice in weatherproof feeders, and the cattle were treated for lice and flies.

Pasture	Stocking rate	Grazing system	Level of supplement
			lb/day
A	Heavy	Continuous	none
F	Heavy	Continuous	1.5
J	Heavy	Continuous	3.0
B	Moderate	Continuous	none
D	Moderate	Continuous	1.5
I	Moderate	Continuous	3.0
E	Light	Continuous	1.5
G-H	Moderate	Switchback	1.5
K-L-M-N	Moderate	Merrill	1.5

Figure 4.
Experimental treatments assigned to pastures on the Texas Experimental Ranch.

Treatments

The main effects and interactions of three treatments were studied using three levels of each treatment. The treatments were: stocking rates at three levels — heavy, moderate and light; grazing systems—continuous, 2-pasture deferred-rotation (switchback system) and 4-pasture deferred-rotation (Merrill system); and protein supplementation at three levels during the winter — none, 1.5 pounds per cow per day and 3 pounds per cow per day. The nine combinations of treatments and the respective pastures used are shown in Figure 4.

Stocking Rate

Three stocking rates were studied under a continuous grazing system. Three pastures were heavily stocked, three were moderately stocked and one was lightly stocked. The initial stocking rates in 1961 were 14.0 acres, 23.0 acres and 32.5 acres per animal unit for heavy, moderate and light stocking, respectively. The stocking rates were planned to utilize 75-80 percent, 45-50 percent and 20-30 percent of the current year's forage production. The actual percentage of the forage utilized under each stocking rate varied somewhat from year to year as the end-of-season use could not be predetermined. Generally, the actual percent utilization appeared to be lower than the desired levels for all stocking rates. As a result of plentiful rainfall and slightly understocked pastures, the stocking rates were increased several times (Table 2). The average stocking rates in 1968 were 11.1 acres, 16.4 acres and 23.9 acres per animal unit for heavy, moderate and light stocking, respectively.

Supplemental Feeding

Three levels of protein supplement were fed to the cows during the winter. Cottonseed cake (41 percent crude protein) was fed at the rate of 3.0, 1.5 and 0.0 pounds per cow per day. Of the three heavily stocked pastures, no supplement was fed on pasture A, the 1.5-pound rate was fed on pasture F and the 3-pound rate was fed on

Weighing time on the Texas Experimental Ranch. Individual records were kept for each cow and calf. *(Photo by Joe Brown)*

pasture J. The cows on the moderately stocked, continuously grazed pastures were supplemented as follows: pasture B, no supplement; pasture D, 1.5-pound rate; pasture I, 3-pound rate. The lightly stocked pasture and both deferred-rotation grazing systems were supplemented at the 1.5-pound rate.

Supplement was fed on Monday, Wednesday and Friday mornings for 90 days during the winter. Cows fed the 1.5-pound rate received a total of 135 pounds of cottonseed cake per cow per winter, and those on the 3-pound rate received 270 pounds.

Grazing Systems

A comparison of three grazing systems was made using a moderate stocking rate and a 1.5-pound-per-day level of supplement. The continuous grazing system was that used by the majority of landowners in the Rolling Plains. Under this system, a pasture was grazed yearlong at a constant stocking rate. The switchback system of deferred-rotation operated with two pastures of about equal carrying capacity and one herd of cattle (2). The size of the cow herd was determined by dividing the stocking rate (acres per animal unit) into the total acreage of the two pastures. This number of cows was then placed in one of the pastures. On March 15, June 15 and December 15 of each year, the cows were moved to the other pasture. Thus, each pasture had 3, 6, 3 months of graze, rest, graze, followed by 3, 6, 3 months of rest, graze, rest. During a 2-year period, each pasture was rested a total of 12 months with rest during each season.

The Merrill system of deferred-rotation consisted of four pastures of approximately equal carrying capacity and

Contrasting degrees of utilization under light and heavy stocking, January 1964. Abundant forage remained in the lightly stocked pasture (left), but forage was closely used in the heavily stocked pasture (right).

three herds of cattle (3). The stocking rate (acres per animal unit) was divided into the total acreage of the four pastures, and the total number of cows separated into three equal herds, leaving one pasture empty. Every 4 months one herd of cattle was moved into the rested pasture where it would remain for 12 months before moving again. This system resulted in a rotation of the livestock and a rotation of the season of deferred grazing. Four years were required to complete a cycle of rotational deferment. Within a 4-year period, each pasture was rested a total of 12 months with deferment during each season. Livestock were moved February 15, June 15 and October 15.

Statistical Analyses

Cow and calf weights from the nine treatments were analyzed statistically. Cow and calf weights from reserve or replacement cows were not used in the analysis of the treatments although some of these cows were in treatment pastures several years. Thus, all cow and calf data presented are from a uniform, even age cow herd. Year effects were confounded with age of cow, but neither affected the interpretation of the data.

Initially it was desired to analyze the data by using an unweighted least squares analysis on individual observations. However, it was concluded that the data were poorly conditioned for this statisical technique. Therefore, an analysis of the cow and calf weights was made using the unweighted means in a factorial analysis of variance. The mean cow weights for treatment, year and weighing period were analyzed, and Duncan's multiple range test for the 5-percent level of probability was used to test for significant mean differences. The analysis of variance table for cow weights is presented in the Appendix Table 3. Calf weights from each weighing period were analyzed

TABLE 2. STOCKING RATES BY YEARS FOR EXPERIMENTAL PASTURES

Pasture	Year								
	1961	1962	1963	1964	1965	1966	1967	1968	Avg
	Acres/animal unit								
A	14.1	14.7	13.2	12.8	12.8	12.7	12.7	12.1	13.1
F	13.9	14.3	13.1	12.7	12.6	13.0	12.2	10.8	12.8
J	13.2	13.5	12.4	12.2	12.1	12.3	11.7	10.5	12.2
B	23.0	23.3	21.4	20.8	20.3	20.8	19.7	16.6	20.7
D	23.0	23.4	21.5	21.1	20.3	20.9	19.7	16.3	20.8
I	22.6	22.8	21.3	20.4	21.5	20.9	19.9	16.2	20.7
E	32.5	32.5	28.9	27.6	27.0	27.5	27.6	23.9	28.4
G-H	22.5	23.8	21.5	20.7	19.8	20.4	19.5	17.2	20.7
K-L-M-N	22.5	22.7	20.4	19.8	19.3	19.9	18.1	15.4	19.8

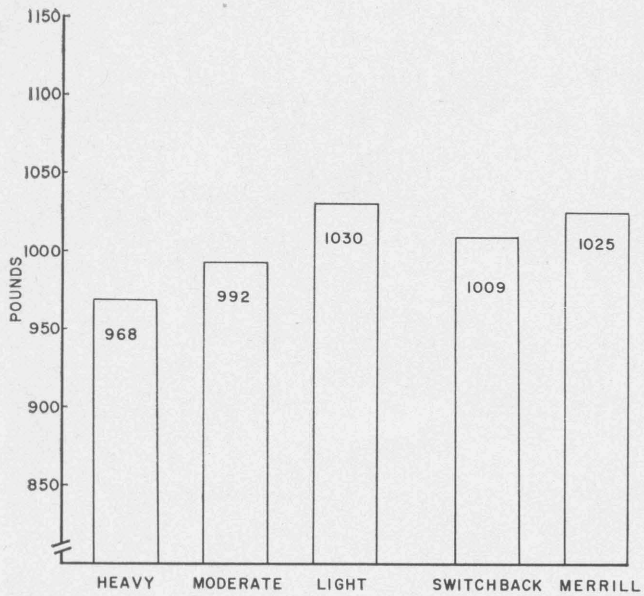

Figure 5.
Cow weights for three stocking rates and three grazing systems averaged across 8 years and three weighing periods per year.

separately resulting in an analysis of variance for each of the three weighing periods. Duncan's multiple range test was used to test for significant mean differences at the 5-percent level. The analysis of variance tables for the calf weights are presented in Appendix Tables 4, 5 and 6.

RESULTS AND DISCUSSION

Seasonal and annual fluctuations in the weight of a cow are direct indicators of her nutritional status. Average size and potential weight were assumed the same for all cow herds when they were allocated to the various treatments in this study. Hence, any resulting differences in the average weight of the cows on different treatments would be a reflection of the quantity and nutritive value of the diets ingested. The livestock data are presented in two parts: Stocking rates and grazing systems, first; levels of winter supplementation, second.

Stocking Rates and Grazing Systems

The five treatments considered in this section are heavy continuous, moderate continuous and light continuous stocking, and the switchback and Merrill deferred-

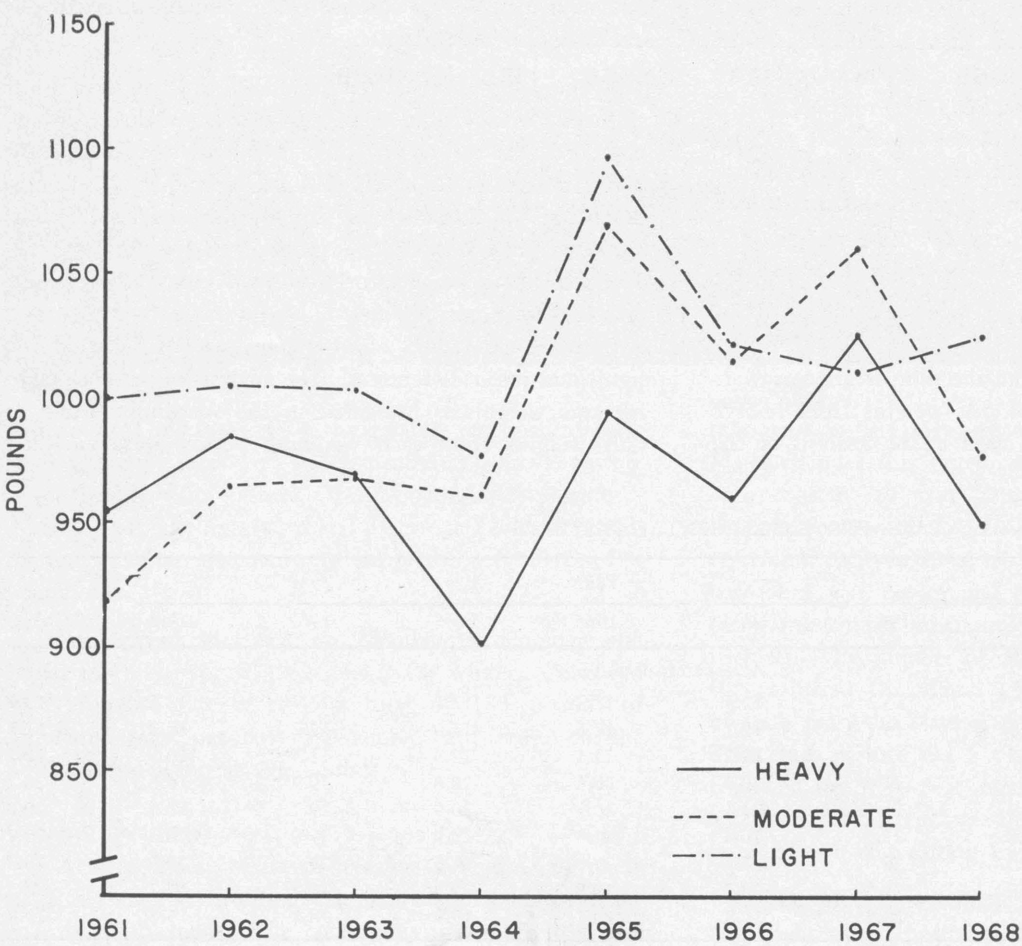

Figure 6.
Annual cow weights for three stocking rates averaged across spring, summer and fall weights.

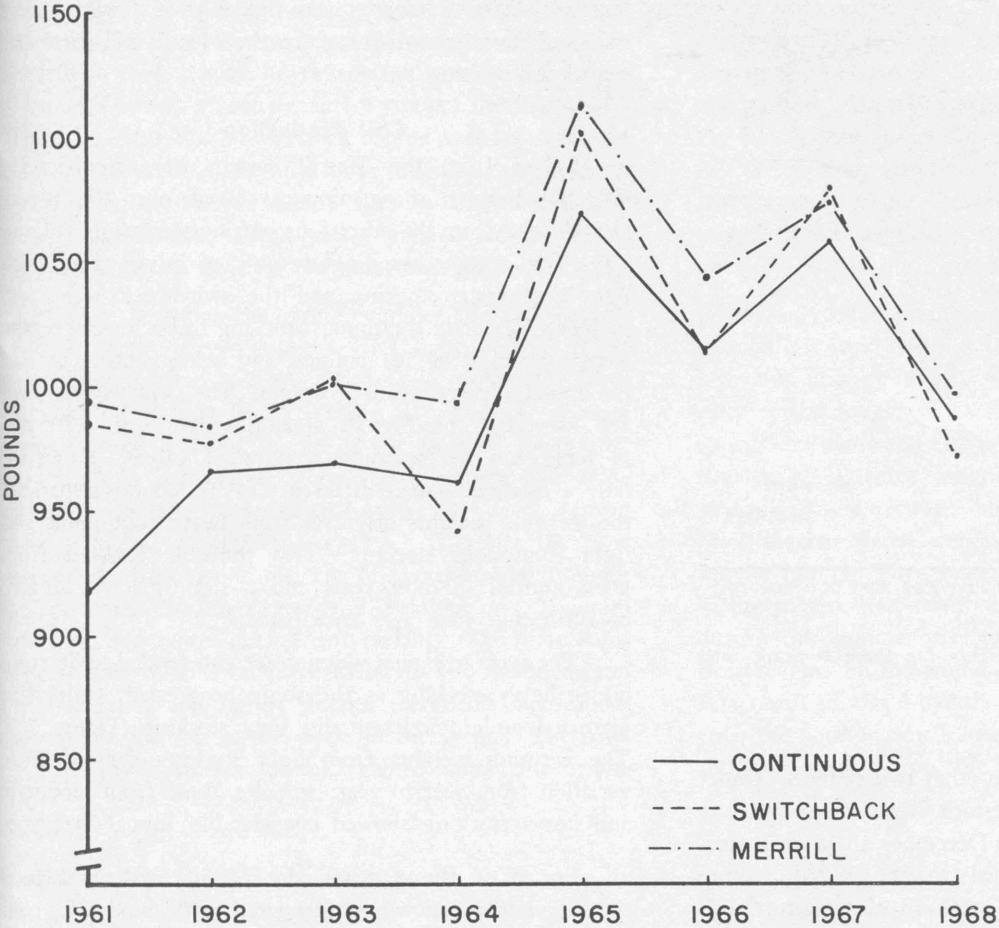

Figure 7.
Annual cow weights for three grazing systems averaged across spring, summer and fall weights.

rotation systems both with moderate stocking. All of the cows on these five treatments were fed the 1.5-pound level of supplement.

Cow Weights

Stocking rates and grazing systems significantly influenced the average weights of cows on the treatments during the 8-year period (Figure 5). There was no significant difference between the average cow weights from light stocking and from the Merrill system of deferred-rotation. All other treatments differed significantly ($P<.05$) with heavier stocking resulting in lower cow weights. Cows on both deferred-rotation grazing systems were significantly heavier than those on moderate continuous grazing.

Cow weights from year to year showed similar trends for all three stocking rates (Figure 6), but unfavorable climatic conditions in 1964 and 1966 affected cows on the heavily stocked pasture more than those on the moderate and lightly stocked pastures. With the exceptions of 1964 and 1965, cow weights on the lightly stocked pasture showed little variation from year to year. The weights of cows on the Merrill system were similar to those from light stocking (Figure 7). Cows on the switchback system showed an adverse response to drouth conditions similar to that of cows on heavy stocking; however, they responded more rapidly to favorable conditions in 1965 than did the cows on heavy stocking. Following precipitation, forage production increased rapidly on the switchback, but slowly on the heavy stocking. This probably accounts for the difference in results between these two treatments in 1965.

There were significant seasonal changes in the average weights of cows on all treatments. Cows on the heavily stocked pasture lost the most weight during the winter, gained the most during the spring and lost the least during the summer (Figure 8). The greatest differences among treatments were in the early spring, and the smallest differences were in the fall. During the spring and summer months, when there was adequate rainfall, ample forage (apparently of high quality) was available even on heavily stocked pastures. As the grazing season progressed through the fall and winter, the effects of different stocking rates became more apparent.

Cow weights from the Merrill system showed a seasonal pattern very similar to that from light continuous stocking (Figure 9). Average weights from the Merrill system were heavier at all three weighings than those from the switchback or moderate continuous stocking. Average cow weights under the switchback system showed

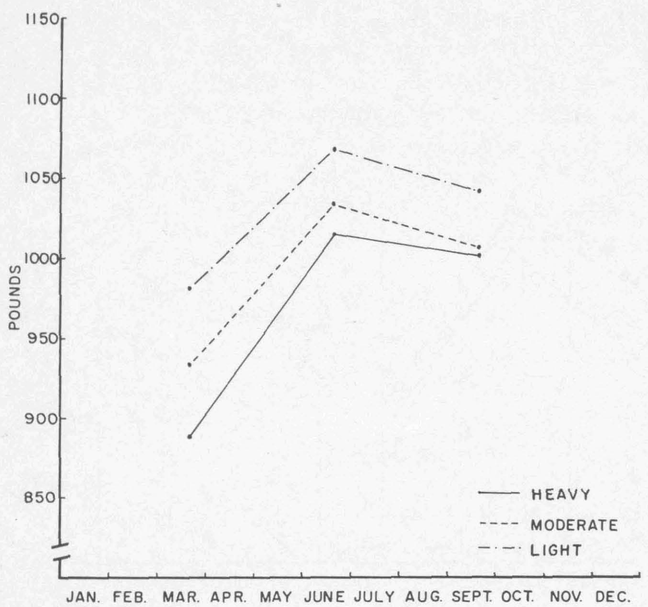

Figure 8.
Spring, summer and fall cow weights for three stocking rates averaged across 8 years.

more fluctuation than under the other two systems. Under the switchback system, the livestock were concentrated in one pasture from June 15 until December 15 of each year. When the cows were switched to the rested pasture December 15, much of the forage in that pasture had matured. As a result, daily intake may have been less than under the Merrill system or under moderate continuous grazing. Forage quality is correlated with the stage of maturity; therefore, the forage in the pasture which had rested for 6 months was probably of lower quality than was the regrowth forage on the Merrill and moderate continuous grazing systems.

Calf Production

Calves from the Merrill system were significantly ($P < .05$) heavier at weaning, averaged over the 8-year period, than from the other four grazing treatments (Figure 10). The average weaning weights of calves from both light continuous stocking and the switchback were 506 pounds. Moderate continuous stocking had a lower average weaning weight of 501 pounds, and heavy continuous had the lowest average weaning weight. The switchback system and especially the Merrill grazing system were effective in increasing the weaning weights of calves. However, only a relatively small difference of 16 pounds separated the weaning weights of calves from heavy continuous and light continuous stocking. This probably resulted from good rainfall in most years and a slightly lower degree of utilization than was anticipated.

The average annual weaning weights tended to decrease under heavy stocking as the study progressed while they increased under moderate and light stocking (Figure 11). The weaning weights from light stocking showed little variation from year to year; whereas, those from moderate and heavy stocking showed considerable annual variation.

For 6 of the 8 years, the Merrill system weaned the heaviest calves when compared with moderate continuous stocking and the switchback system (Figure 12). The switchback had the heaviest calves in 1965, and continuous stocking had the heaviest in 1968. The greatest differences among treatments were during the first 3 years

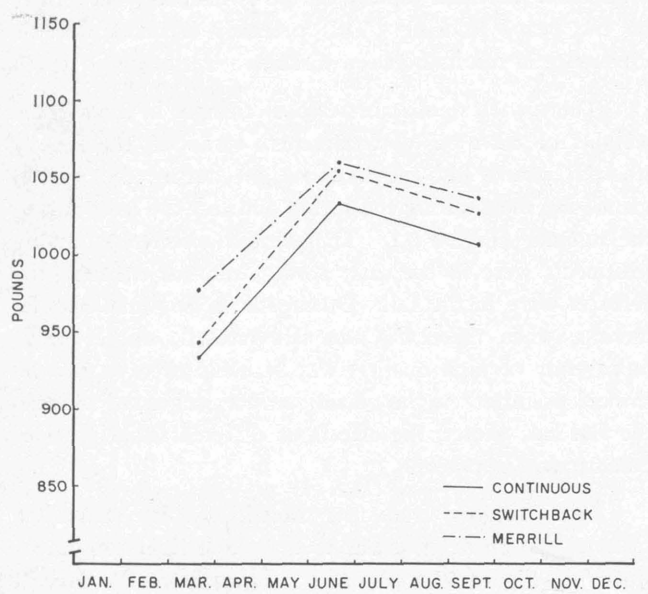

Figure 9.
Spring, summer and fall cow weights for three grazing systems averaged across 8 years.

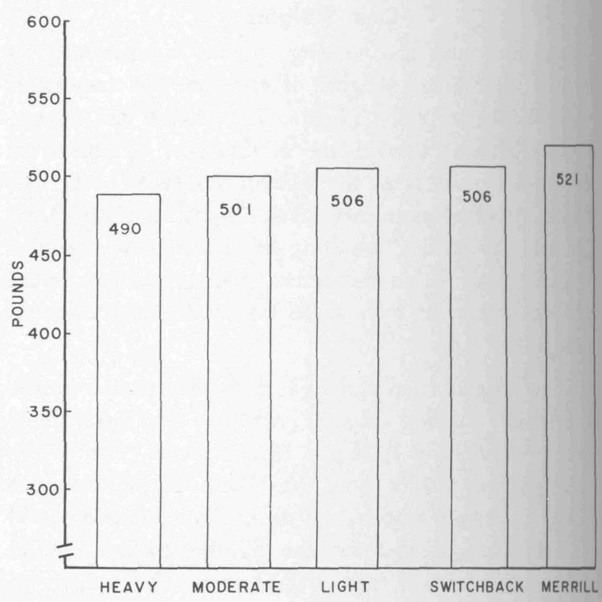

Figure 10.
Weaning weights of calves from three stocking rates and three grazing systems averaged across 8 years.

and in 1966. The initial response of the vegetation to deferment, when the rotation systems were started, probably resulted in their having heavier weaning weights than the continuous use system for the first 5 years of the study. The greater concentration of livestock on the switchback would lead one to expect a slightly lower weaning weight from it than from the Merrill system. Drouth conditions during spring and summer 1966 had a greater effect on the switchback system than on the other two grazing systems.

Figure 13 shows the spring, summer and fall weights of calves from heavy, moderate and light stocking. The treatments appeared to have little effect on average birth dates of calves (Appendix Table 7). The calves were approximately 2.5 months old at the time of the March weighing. In late March, warm season grasses had made little growth, and cool season plants were just starting their period of rapid spring growth. This was the time of greatest difference in quantity of forage available under the different stocking rates and resulted in maximum treatment differences during early spring. The differences between calf weights on the heavily stocked treatment and the moderately and lightly stocked treatments were about the same in the fall as they were in the spring. The cows on the heavily stocked pasture gained more during the spring and summer than did those on the moderately and lightly stocked pastures (Figure 8), and the calves on the heavily stocked pasture gained at a comparable rate during this period. Therefore, the nutritive intake of cows on the heavily stocked pastures must have been comparable to that of the cows on other pastures during the spring and summer. From these data it appears that the detrimental effect of heavy stocking on livestock production occurred largely during the fall and winter.

Seasonal calf weights from the three grazing systems showed the same trend as the calf weights from the stocking rates (Figure 14). Differences among treatments in early spring remained essentially the same throughout the spring and summer. Calves from the Merrill system were heaviest at all three weighings. Cows and calves on the switchback system were moved to the rested pasture just prior to the March weighing and again just before the June weighing. They gained more during the spring while in the pasture that received the winter rest than they did during the summer while in the spring rested pasture. Because grass in the winter rested pasture was always short as a result of the 6-month grazing period of the previous year, the spring growth was little mixed with old growth and was readily available and high in nutritive value.

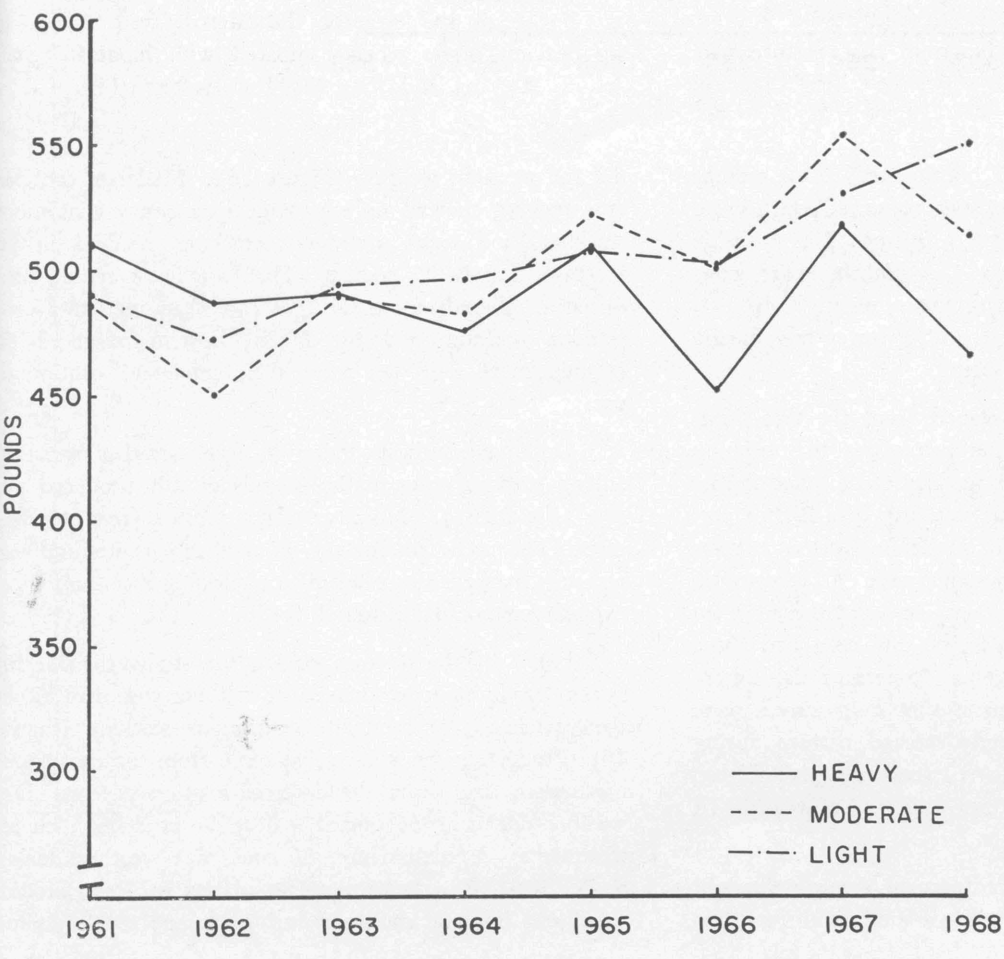

Figure 11.
Weaning weights of calves from continuously grazed pastures stocked at three different rates.

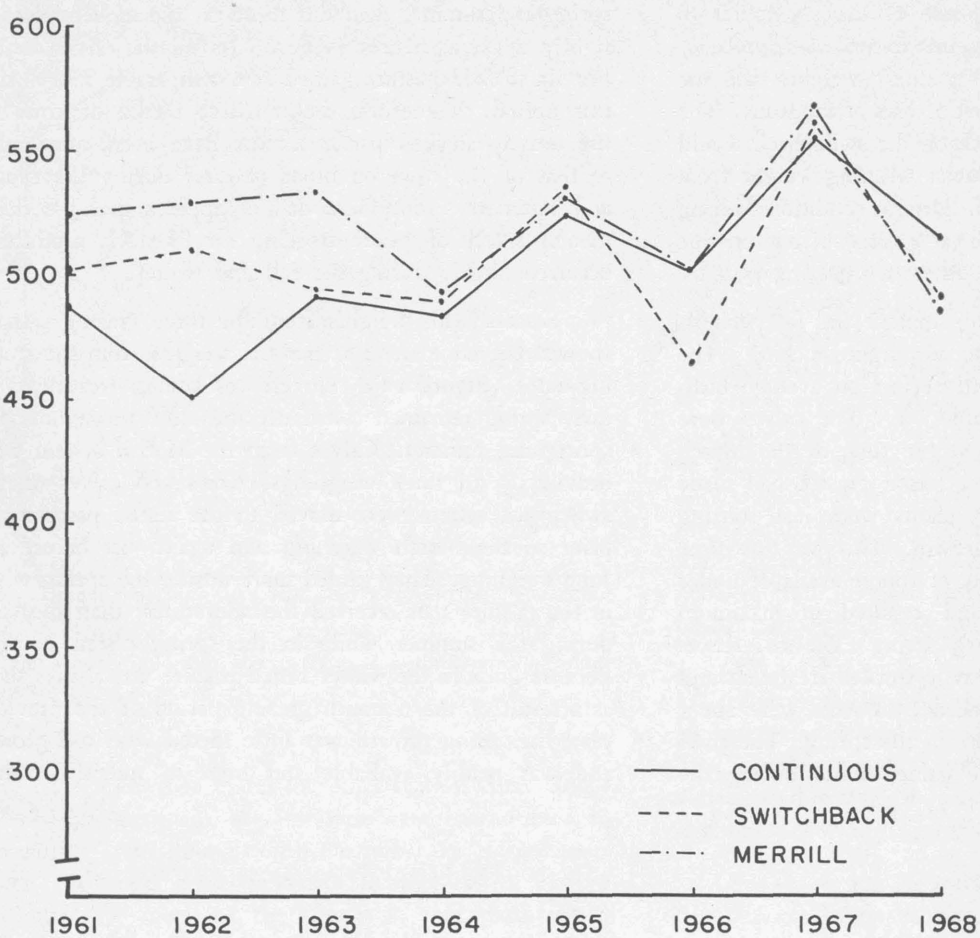

Figure 12.
Weaning weights of calves from three grazing systems stocked at a moderate rate.

The spring rested pasture had been rested for 6 months the previous year, and forage was rank and starting to mature when the cows were rotated in June. This probably resulted in lower quality forage and slightly lower gains for the switchback system during the summer. Calves on all treatments tended to gain at a little lower rate during the summer than during the spring.

The percent calf crops weaned from the five treatments followed about the same pattern as the weaning weights (Figure 15). One discrepancy to be noted is that the data showed heavy stocking resulting in a higher percent calf crop weaned than did moderate stocking. Prior to the 1968 calf crop, the averages were 90 percent on moderate and 89 percent on heavy. In 1968 the cows on heavy stocking weaned a 95-percent calf crop and those on moderate stocking weaned a 75-percent calf crop. A possible explanation for this is that more calves were born and lost on the moderately stocked pasture during the severe ice storms which occurred frequently that winter. With this exception, the percent calf crops weaned fit the pattern of the previous data.

The pounds of calf produced per cow (weaning weight times percent calf crop) varied more among treatments than did the weaning weights (Figure 16). Moderate continuous stocking showed no advantage over heavy continuous stocking, and light continuous stocking resulted in an increase of only 25 pounds. The switchback system produced 17 pounds more calf per cow than moderate continuous stocking, and the Merrill system produced 46 pounds more calf per cow than moderate continuous use.

On an annual basis, there was a great deal of variation among stocking rates in the pounds of calf produced per cow (Figure 17). No clear trend resulted from stocking rates. The cyclic production on moderate continuous use was very marked, but, other than random chance, no logical explanation could be found for it.

For 7 of the 8 years during the study, the Merrill system produced more pounds of calf per cow than either the switchback or moderate continuous stocking (Figure 18). Production per cow varied more from the continuous use system than from the deferred-rotation systems. Dry weather during 1966 caused a drop in production on all treatments. A combination of cold, wet weather during winter 1967-68, a tremendous population of Texas broomweed and low soil moisture during August 1968 resulted in a marked drop in production for that year. Although total rainfall was low in 1967 (Appendix Table 1), the winter was dry and mild, and near ideal rainfall distribution during the spring and summer resulted in a high level of production.

Calf production per acre differed markedly among treatments (Figure 19). The production per acre increased in direct proportion to the stocking rate with heavy stocking having the highest production. Production per acre was very low from light stocking. The switchback system produced 0.9 pound more calf per acre than did moderate continuous use, while the Merrill system produced 3.4 pounds more calf per acre than did moderate continuous use. Heavy stocking, however, still produced almost 10 pounds more calf per acre than did the Merrill system.

On an annual basis, calf production per acre showed less variation than did weaning weights or production per cow (Figure 20). There was a gradual increase in production from all treatments as the study progressed, but the difference between heavy and moderate stocking was as great or greater at the end of the study as it was at the start. This increase in production resulted from increases in stocking rates (Table 2). Each time stocking rates were increased, they

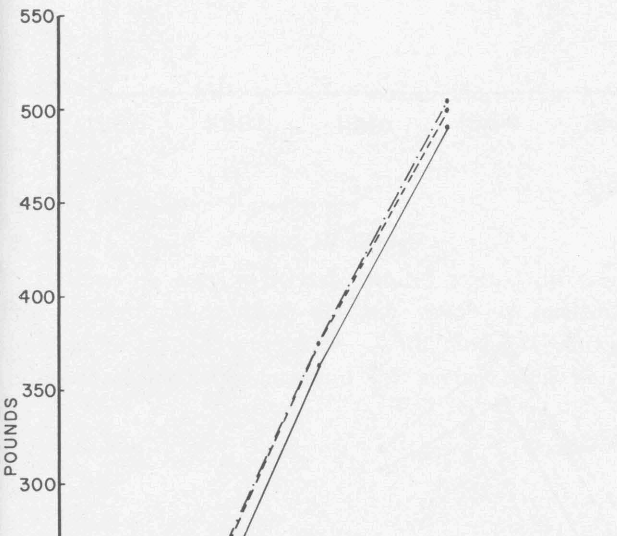

Figure 13.
Spring, summer and fall weights of calves from three stocking rates averaged across 8 years.

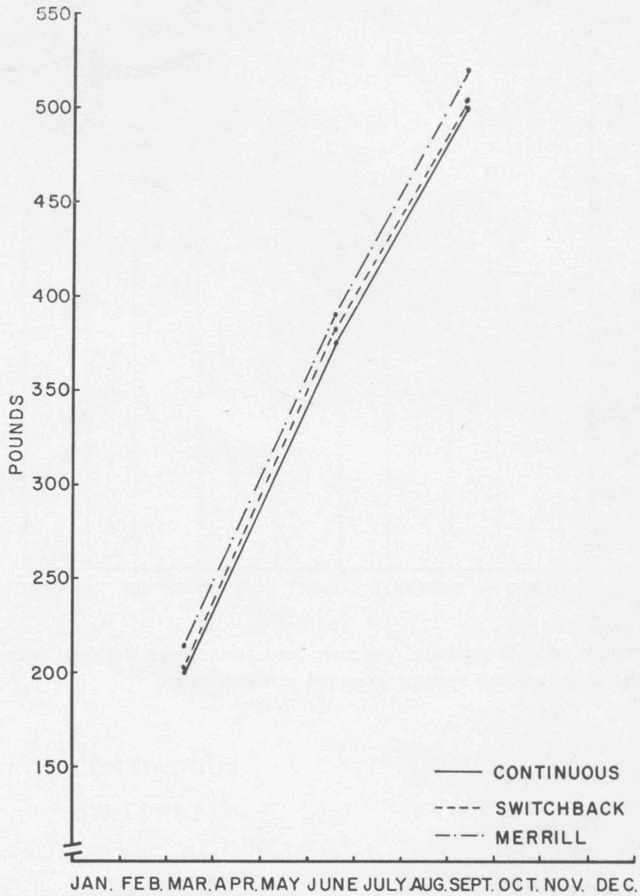

Figure 14.
Spring, summer and fall weights of calves from three grazing systems averaged across 8 years.

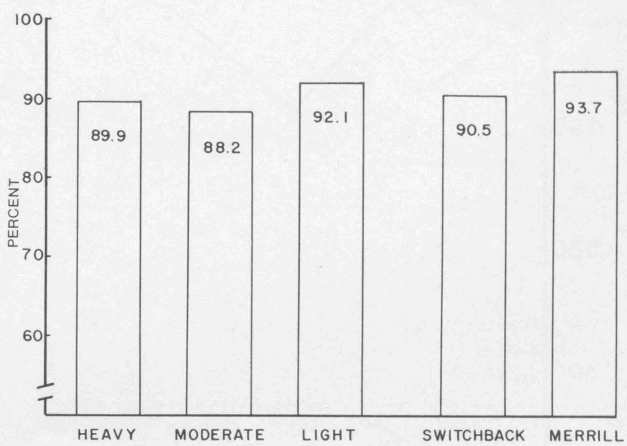

Figure 15.
Percent calf crop weaned from three stocking rates and three grazing systems averaged across 8 years.

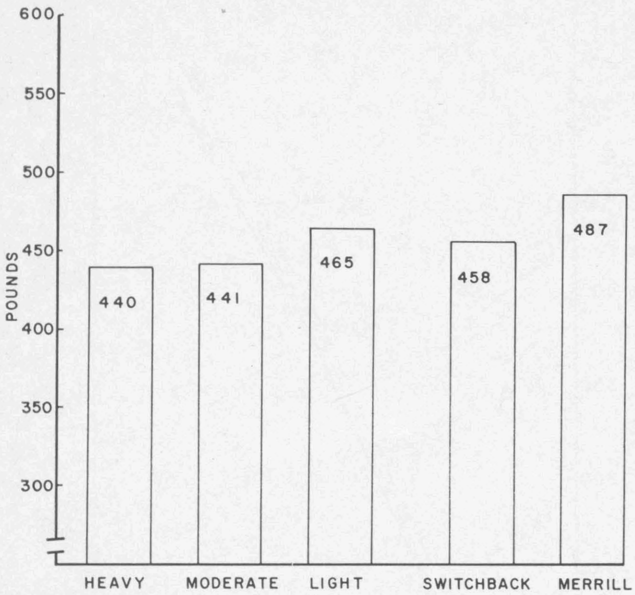

Figure 16.
Pounds of calf produced per cow bred from three stocking rates and three grazing systems averaged across 8 years.

were increased by the same percentage on each pasture. Heavy stocking was influenced more than the other treatments by the short drouth during 1966. Production from light stocking was almost constant from year to year.

Production per acre was similar for the three grazing systems all stocked at the moderate rate (Figure 21). However, the Merrill system always produced more pounds of calf per acre than did the switchback system or continuous use. The switchback system produced at about the same level as continuous use for 5 years, and in 3 years it produced more. Potential differences among grazing systems lie in their influence on kinds of volunteer vegetation they develop over a long period and in resulting increases of carrying capacities and stocking rates. The deferred-rotation grazing systems improved the vigor of existing vegetation, and over another decade significant changes in vegetative composition are expected. The effects of deferred-rotation grazing systems used in this study were not as immediately noticeable as were the effects of stocking rates. However, the long term potential for improving the range resource is the real test of a grazing system.

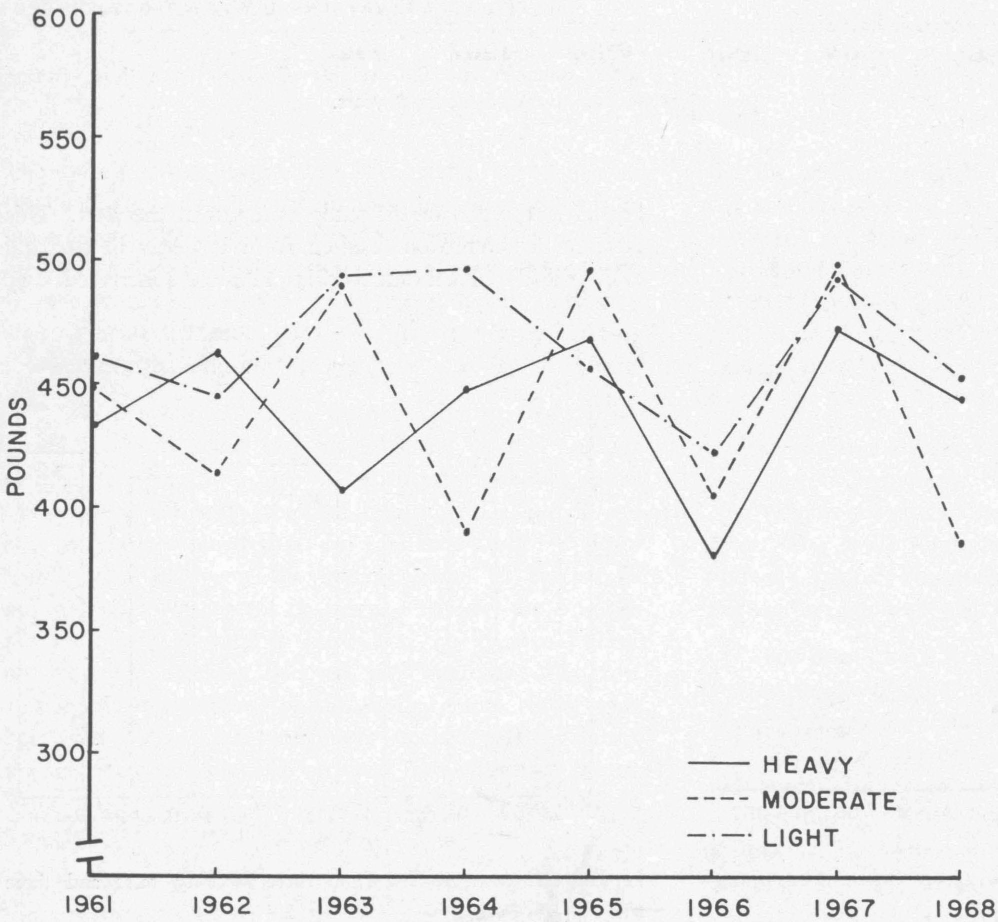

Figure 17.
Pounds of calf produced per cow bred from continuously grazed pastures stocked at three different rates.

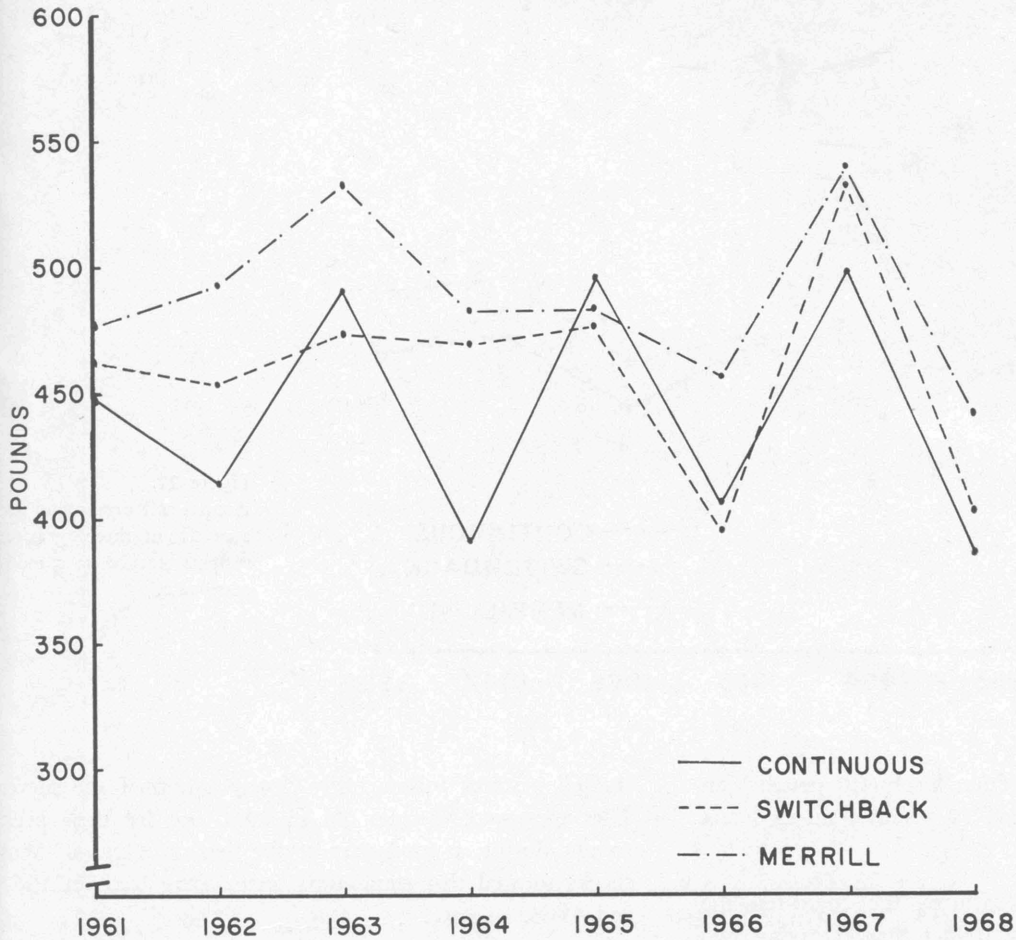

Figure 18.
Pounds of calf produced per cow bred from three grazing systems stocked at a moderate rate.

Levels of Winter Supplement

Cow Weights

Cows on heavily stocked pastures reacted differently to supplementation than did the cows on moderately stocked pastures (Figure 22). With moderate stocking, supplement markedly increased the average cow weight. However, on heavy stocking, cows on the high level (3 pounds) of supplement weighed significantly less than those on the medium level. At all levels of supplementation, cows on moderately stocked pastures weighed more than those on heavily stocked pastures. The mean cow weights for all treatments differed significantly ($P<.05$)

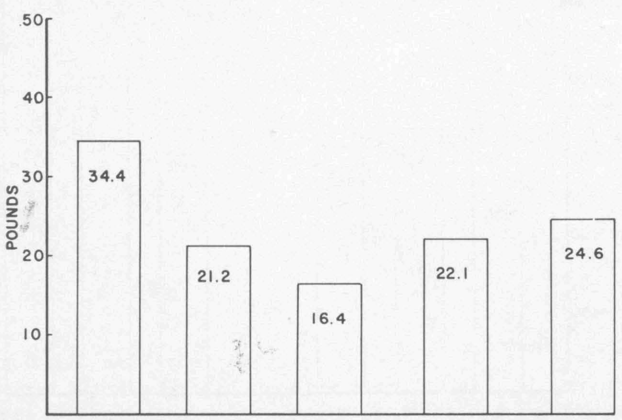

Figure 19.
Calf production per acre from three stocking rates and three grazing systems averaged across 8 years.

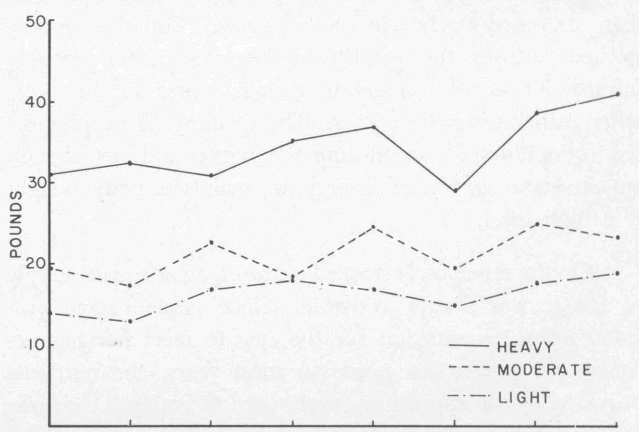

Figure 20.
Annual calf production per acre from continuously grazed pastures stocked at three different rates.

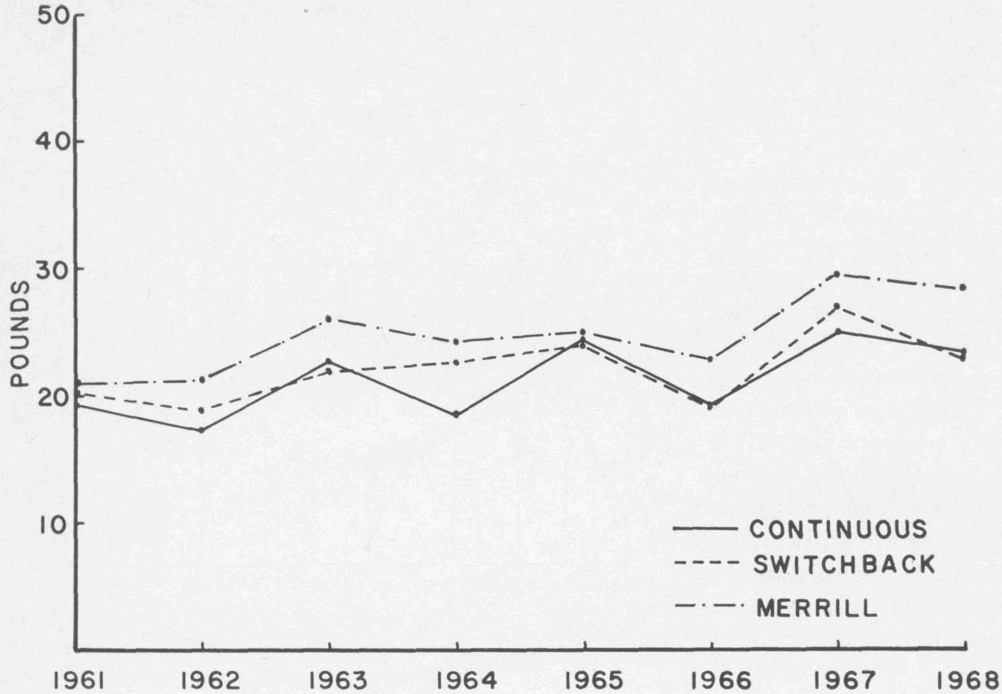

Figure 21.
Annual calf production per acre from three grazing systems stocked at a moderate rate.

with the exception of the medium level (1.5 pounds) on heavy stocking and the low level (0 pounds) on moderate stocking (Appendix Table 3).

On the heavily stocked pastures, the cows fed the high level of supplement were lighter than the other two groups at the beginning of the study (Figure 23). The difference between the medium and high-level cows narrowed progressively until in 1965 the high level cows were heavier. Average cow weights on all three levels of supplement differed very little in most years. These data suggest that the high-level treatment may have had smaller type cows than the medium-level treatment. Whether or not this was true, supplement had less effect on the average body weight of the cows on heavily stocked pastures than on moderately stocked pastures. On the heavily stocked pastures, the quantity of forage available probably limited intake of forage at various times of the year other than during the winter. The quantity of supplement fed for a limited time during the winter did not contain an adequate supply of energy to maintain body weight at a high level.

On the moderately stocked pastures, an adequate supply of forage was always available. Since range forage provided adequate nutrition for the cow to meet her maintenance and production needs in most years, the nutrients provided by the supplement were used to increase the body weight (Figure 24). During good years such as 1965, all of the cows gained a considerable amount of weight, but those receiving no supplement gained the most. The annual weights of cows from all three of these moderately stocked pastures follow fairly closely a normal age curve. The cows were 4 years old in 1961 and hit their peak weight during a good year at the age of 8 years. Spot checks showed that some cows were losing teeth in 1967 and 1968.

Seasonal fluctuations of cow weights from three levels of supplement on heavily stocked pastures are shown

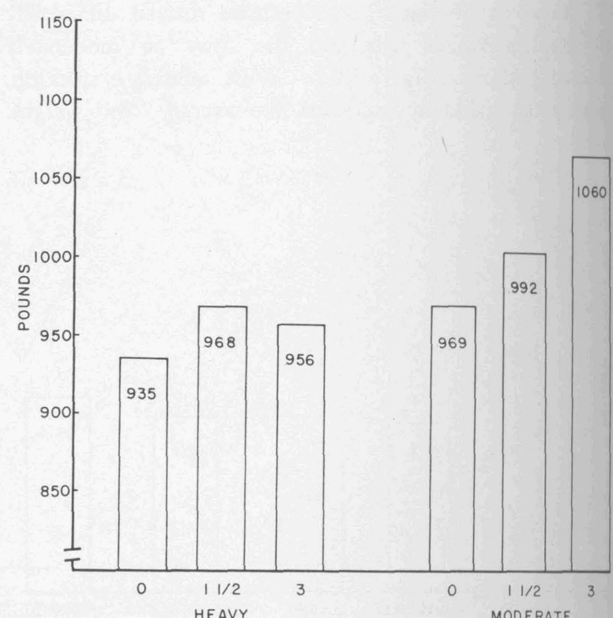

Figure 22.
Average weights of cows fed three levels of protein supplement on heavily and moderately stocked pastures.

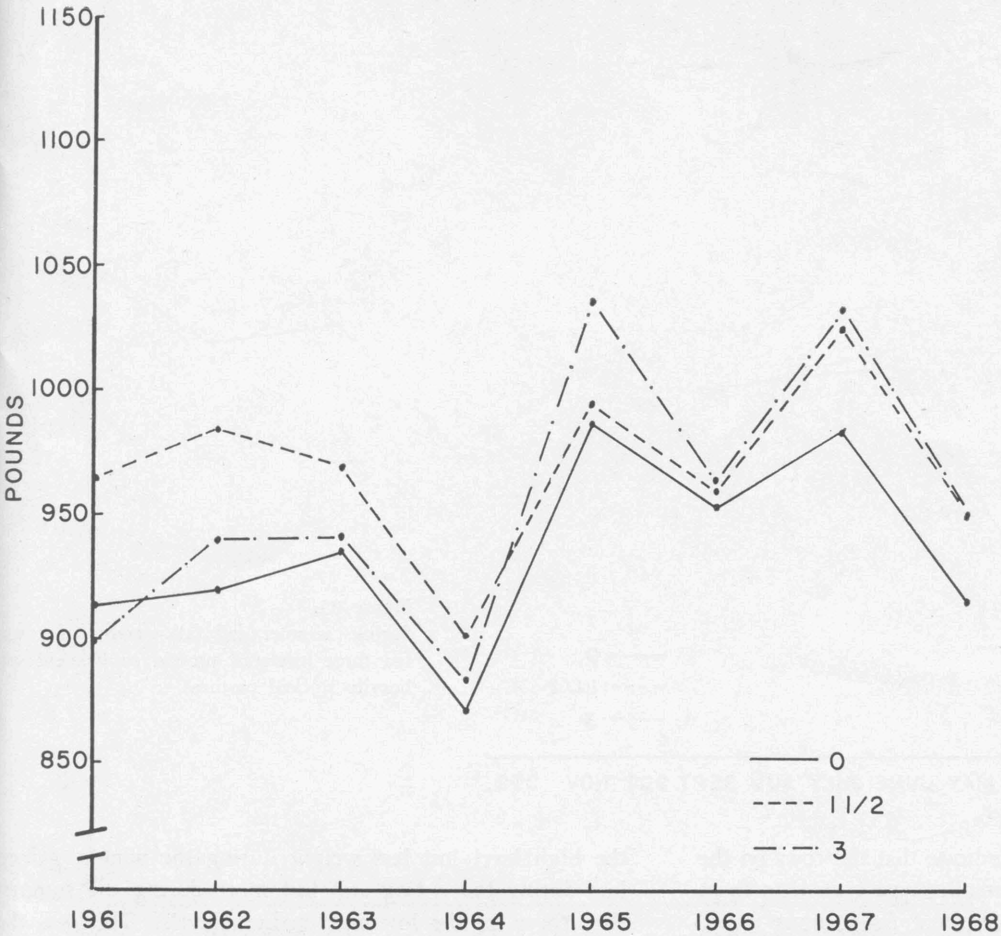

Figure 23.
Average annual weights of cows fed three levels of protein supplement on heavily stocked pastures.

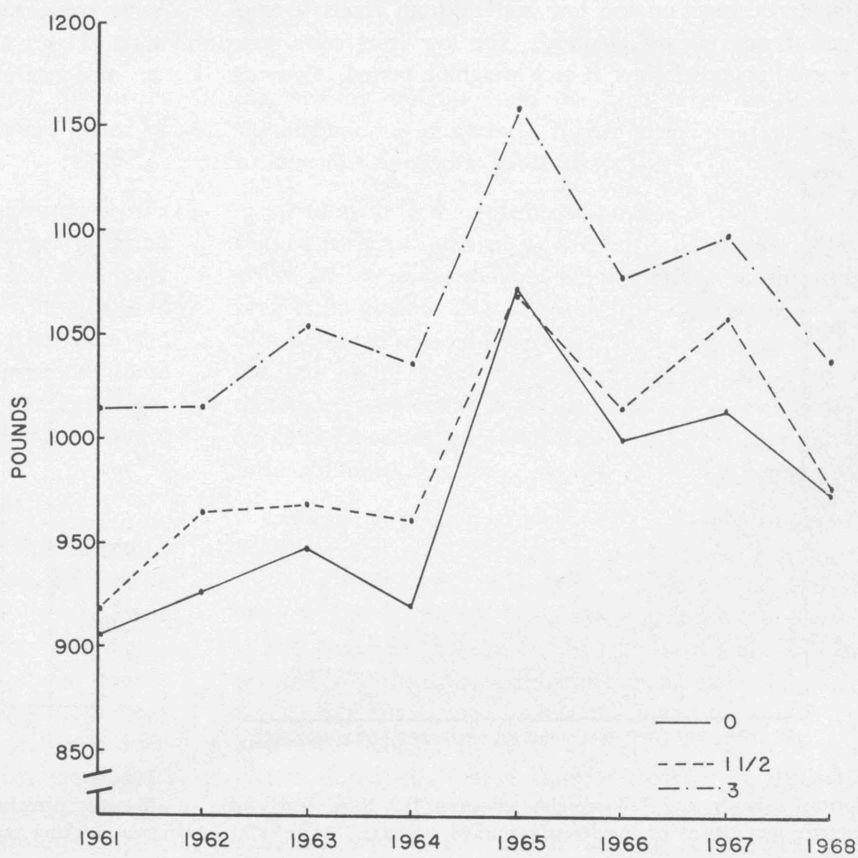

Figure 24.
Average annual weights of cows fed three levels of protein supplement on moderately stocked pastures.

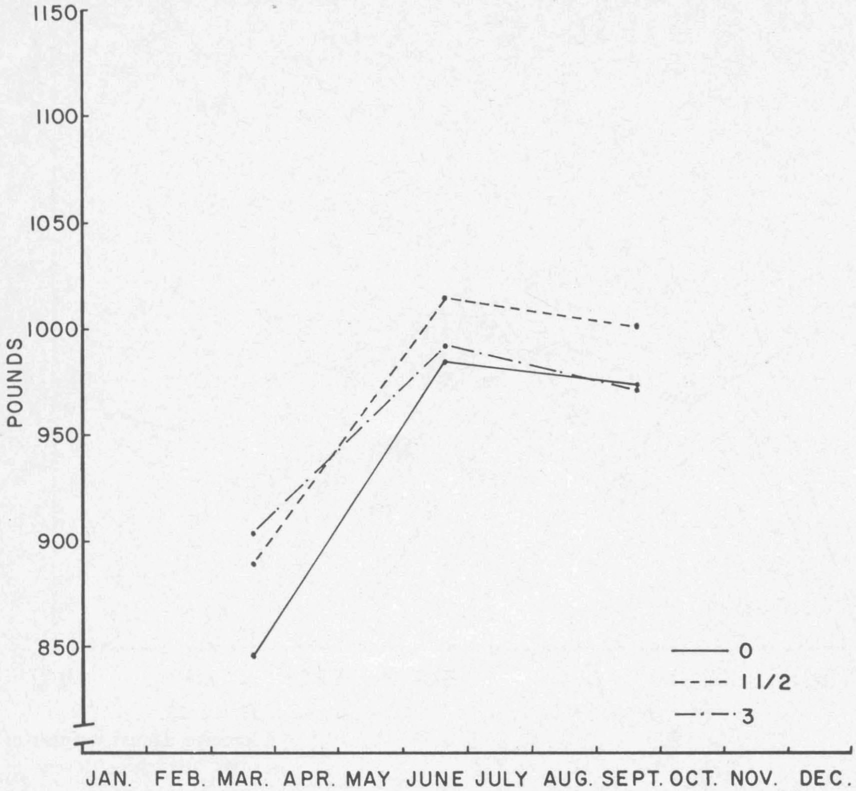

Figure 25.
Spring, summer and fall weights of cows fed three levels of protein supplement on heavily stocked pastures.

in Figure 25. These data also indicate that the cows on the high level of supplement were smaller type cows than those on the other two treatments. Seasonal fluctuations in the weights of cows on the low and medium levels of supplement were almost identical. The low level cows were about 40 pounds lighter at each weighing period. Cows on the high level lost less weight during the winter, gained less during the spring and lost more during the summer than those on the low and medium levels. This was the same trend that was observed among the three stocking rates (Figure 8) and among the three levels of supplement on moderately stocked pastures (Figure 26). Apparently

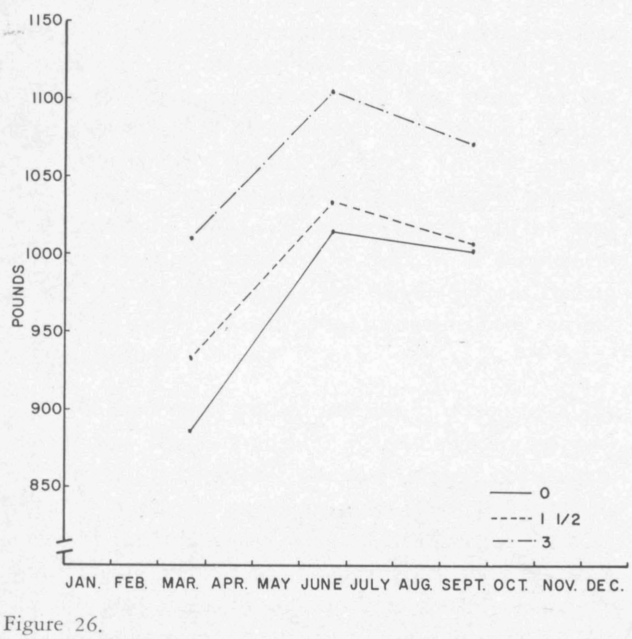

Figure 26.
Spring, summer and fall weights of cows fed three levels of protein supplement on moderately stocked pastures.

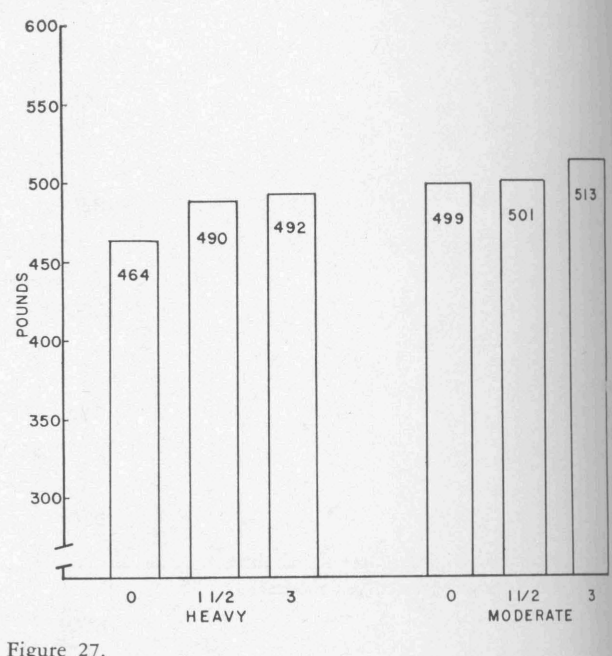

Figure 27.
Weaning weights of calves from three levels of supplement and two stocking rates averaged across 8 years.

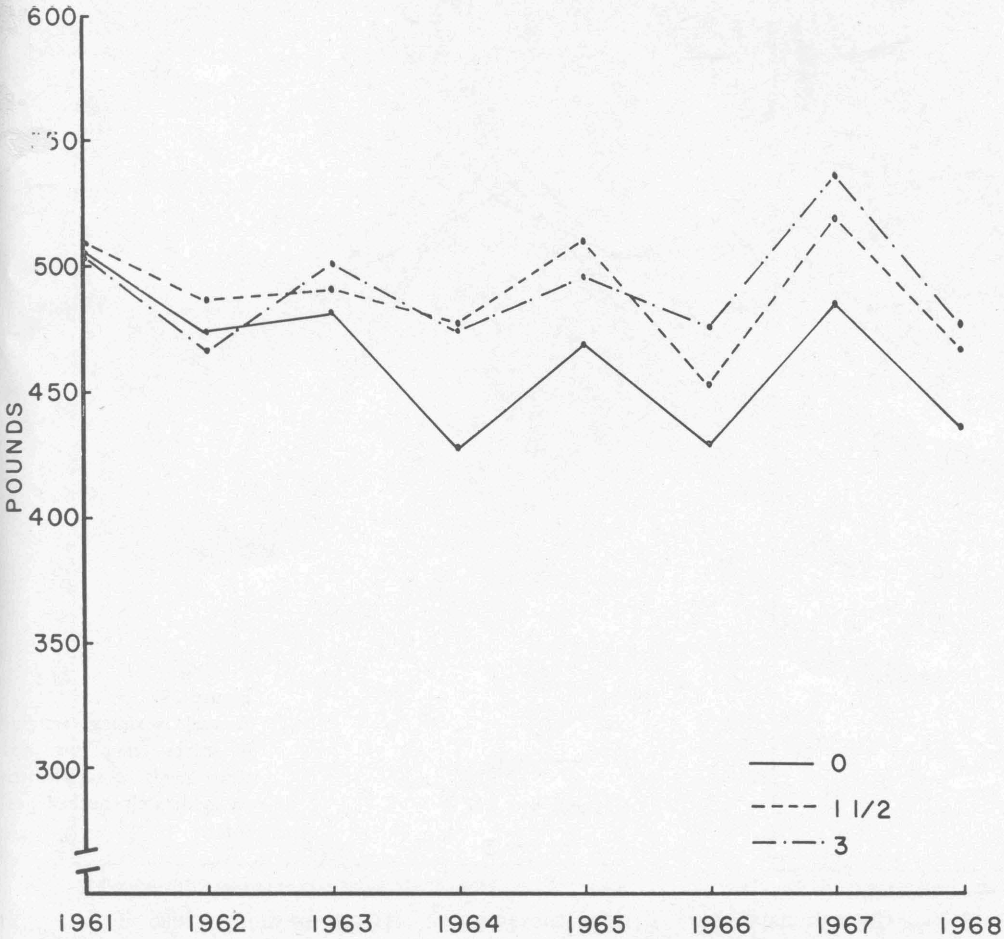

Figure 28.
Annual weaning weights of calves from cows fed three levels of supplement on heavily stocked pastures.

cows on the lower levels of nutrition during the winter made compensatory gains during the subsequent period of high nutritional intake during the spring.

The cows fed the high level of supplement on the moderately stocked pasture were significantly heavier at all weighing periods compared with those fed the other levels (Figure 26). Fall weights of cows on the low and medium levels of supplement were almost the same, but the cows receiving no supplement lost 45 pounds more weight during the winter. As in all other cases, the March weights were the lowest and the June weights the highest.

Calf Production

While cow weights are one measure of the nutritional status of the cow, the returns from supplementation will be primarily in the form of calf production. The average weaning weights from the three levels of supplement varied 28 pounds with heavy stocking and 14 pounds with moderate stocking (Figure 27). Supplement appeared to have influenced weaning weights more on the heavily stocked pastures than on the moderately stocked pastures. Calves weaned from the low level on heavy stocking were significantly lighter than from all other treatments, and the weaning weights from the high level on moderate stocking were significantly higher than from all other treatments (Appendix Table 6b).

Failure to feed supplemental protein to cows on heavily stocked pastures appeared to have an accumulative adverse effect on weaning weights of the calves as the study progressed (Figure 28). For the first 2 years the amount of supplement showed little effect on the weaning weights, but starting in 1964 and throughout the remainder of the study, supplement significantly increased the weaning weights. However, the 3-pound level of supplement showed little additional response compared to the 1.5-pound level.

Weaning weights on moderately stocked pastures did not show an accumulative effect of supplement; supplement appeared to have almost no effect (Figure 29). Only in 1961 and 1964 did the treatments respond to supplement as they might be expected to. In 5 of the 8 years, weaning weights from the no-supplement treatment were as heavy or heavier than from one or both of the other treatments. The differences among the three levels of supplement were greater during the first 4 years of the study than during the last 4 years. Improving range condition under the moderate stocking rate may have been responsible.

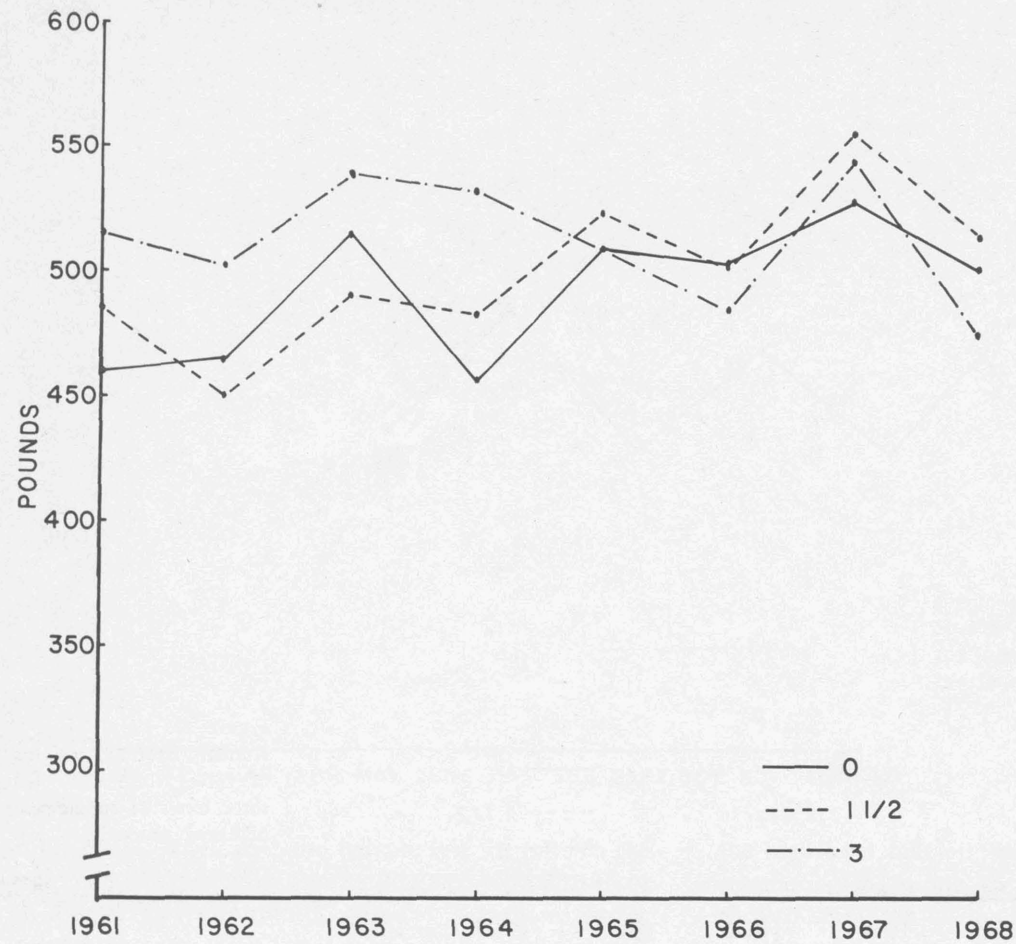

Figure 29.
Annual weaning weights of calves from cows fed three levels of supplement on moderately stocked pastures.

Calves on the heavily stocked pasture where no supplement was fed were significantly ($P<.05$) lighter at all three weighing periods compared with those receiving the medium and high levels of supplement (Figure 30 and Appendix Tables 4b, 5b and 6b). Calf weights from the medium and high levels of supplement did not differ significantly at any of the weighing periods. A small response to the high level of supplement was noted at the March weighing, but at the summer and fall weighings, only two pounds separated the average calf weights from the medium and high levels of supplement. Calves from the zero level of supplement gained at a slightly lower rate during the spring and summer than those from the medium and high levels.

On the moderately stocked pastures, calf weights showed little response to different levels of supplement at the spring weighing (Figure 31). At the summer weighing, calves from the high level weighed significantly ($P<.05$) heavier than those that received no winter supplement (Appendix Table 5b). At the fall weighing the calves from the high level were significantly heavier than both the low and medium level groups (Appendix Table 6b). No explanation is available for this response; it may be a result of the supplement fed or of differences in the vegetation of the pastures. To fully interpret this response would require a more intensive investigation.

The percent calf crop weaned from the treatments showed little response to the level of supplement fed (Figure 32). The highest average percent calf crop of all six treatments was from the 1.5-pound level of supplement with heavy stocking. On both the heavily and moderately stocked pastures, the percent calf crops were the same for the low and high level groups. With heavy stocking, the medium level of supplement had the highest percent calf crop, whereas, with moderate stocking, the medium level had the lowest. The percent calf crops from moderately stocked pastures tended to be higher than from the heavily stocked pastures.

On the heavily stocked pastures, the medium level of supplement produced 37 more pounds of calf per cow (weaning weight times percent calf crop) than no supplement, but the high level of supplement produced less than the medium level (Figure 33). Production on the heavily stocked pastures was lower than on the moderately stocked pastures. On the moderately stocked pastures, the high level of supplement produced 13 pounds more calf per cow than no supplement, whereas the medium level

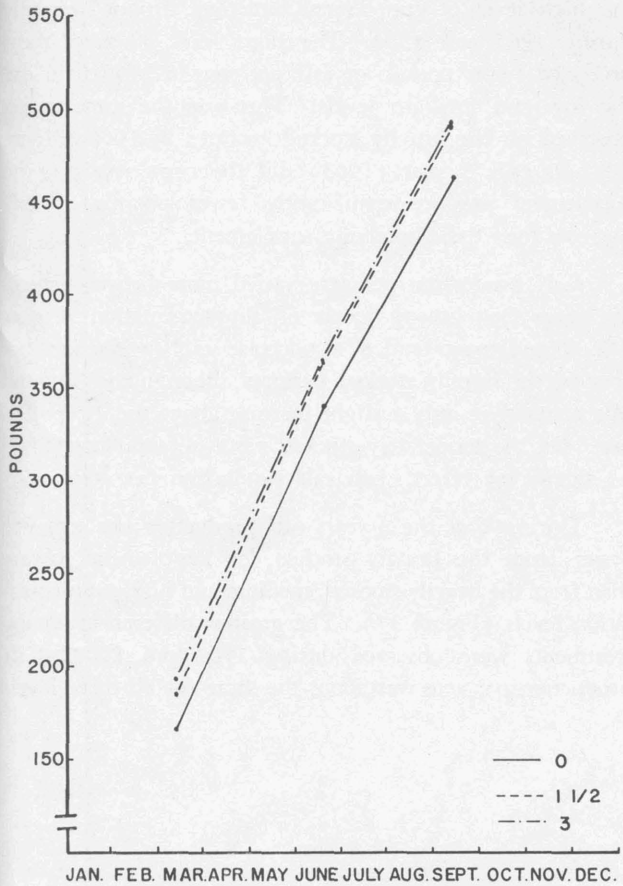

Figure 30.
Spring, summer and fall weights of calves from cows fed three levels of protein supplement on heavily stocked pastures.

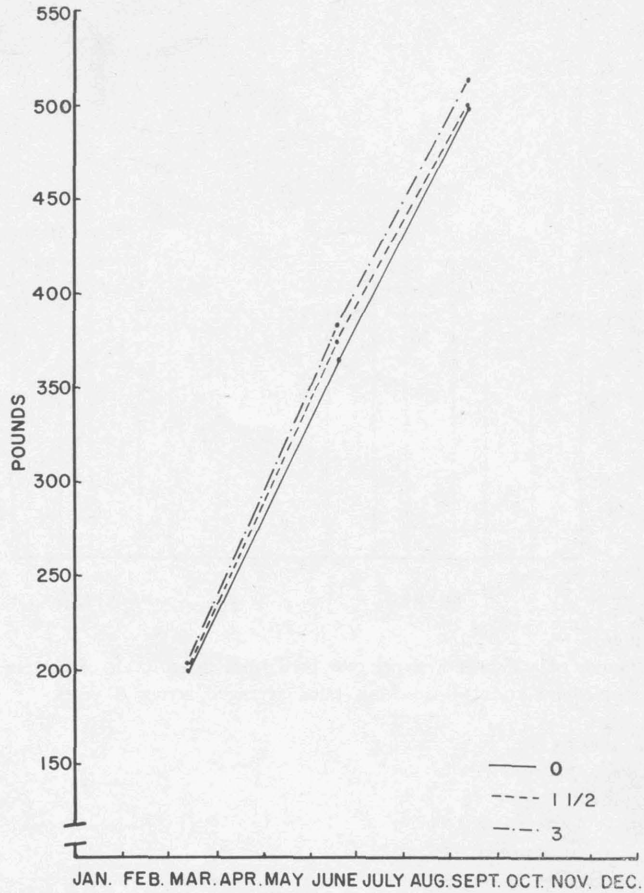

Figure 31.
Spring, summer and fall weights of calves from cows fed three levels of protein supplement on moderately stocked pastures.

of supplement produced an average of 6 pounds less calf per cow than no supplement.

Calf production per cow on the heavily stocked pastures varied relatively little for the first 3 years of the study (Figure 34). Supplement appeared to have little effect on calf production until 1964. Production dropped sharply in 1964 and 1965 on the no-supplement treatment. A 67-percent calf crop weaned on the high level of supplement in 1966 greatly reduced production that year; however, in 1967 the same treatment weaned a 100-percent calf crop resulting in an increase in production of 218 pounds of calf per cow. Production from the heavily stocked pastures varied more from year to year on all three levels of supplement as the study progressed. No consistent differences among levels of supplement were observed. Production from the cows receiving no supplement was significantly lower than from those receiving the medium and high levels for 4 years, but for 2 years, the low level of supplement produced more pounds of calf per cow than either the medium or high levels. In only 2 of the 8 years did the high level of supplement produce the most pounds of calf per cow.

On the moderately stocked pastures, calf production per cow varied less on the low level of supplement than on the medium and high levels (Figure 35). Calf production increased almost linearly for the first 4 years on

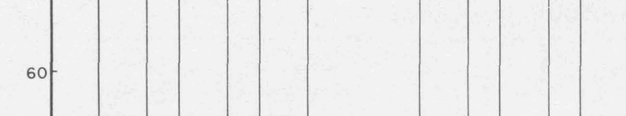

Figure 32.
Percent calf crop weaned from three levels of protein supplement and two stocking rates averaged across 8 years.

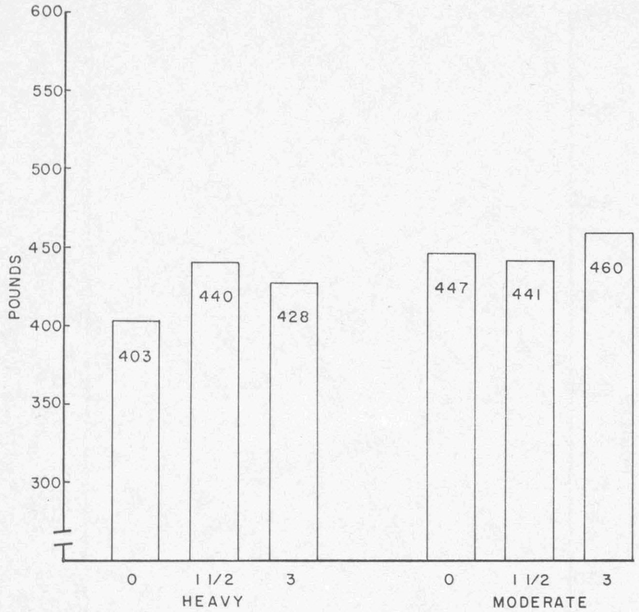

Figure 33.
Pounds of calf produced per cow bred from three levels of protein supplement and two stocking rates averaged across 8 years.

the high level of supplement but then dropped sharply during 1965 and 1966. The high level of supplement produced fewer pounds of calf per cow in 1966 than did the low and medium levels. This was the same effect observed on the heavily stocked pastures in 1966 (Figure 34). In only 1 year (1963) did the cows receiving no supplement produce significantly fewer pounds of calf per cow than those receiving supplement.

Calf production per acre varied more between stocking rates than among levels of supplementation (Figure 36). Supplement tended to increase calf production per acre on the heavily stocked pastures although the 3-pound rate resulted in only a slight increase above the 1.5-pound rate. On the moderately stocked pastures, supplement had no significant effect upon calf production per acre.

During 6 of the 8 years calf production per acre was lower from the heavily stocked, no supplement pasture than from the heavily stocked, medium and high supplementation levels (Figure 37). The greatest differences among treatments were observed during 1967 and 1968. Calf production per acre was about the same for all three levels

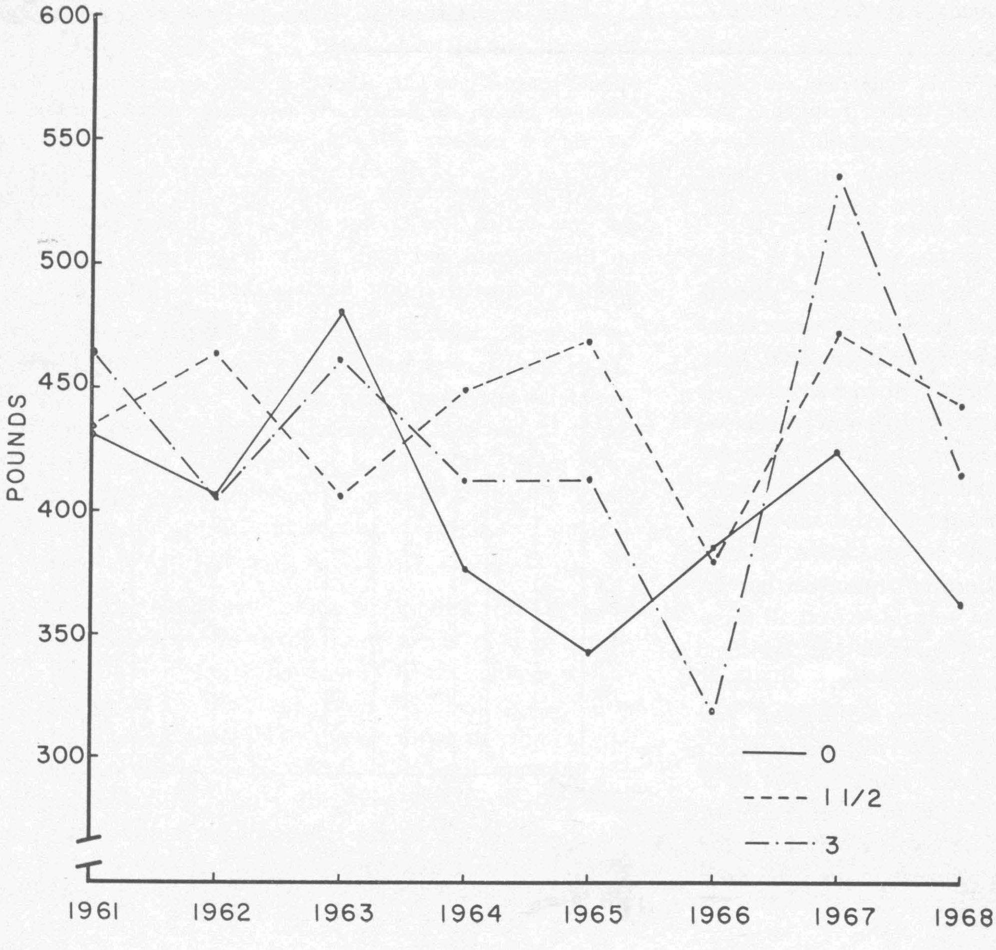

Figure 34.
Pounds of calf produced per cow bred from three levels of protein supplement fed on heavily stocked pastures.

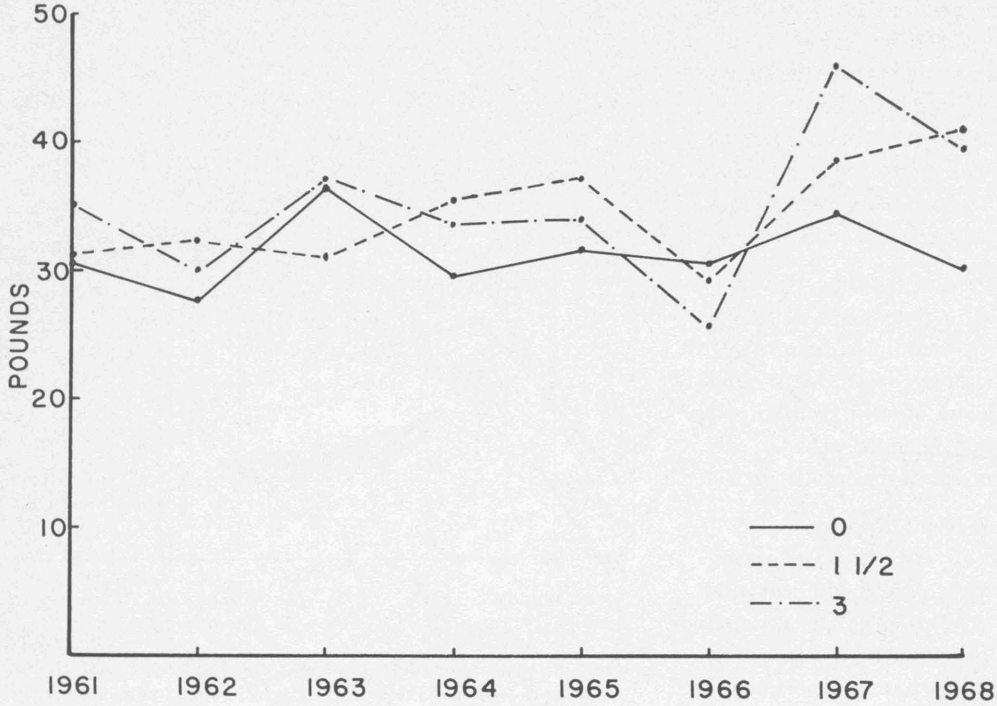

Figure 37.
Pounds of calf produced per acre from three levels of supplement fed on heavily stocked pastures.

supplementation. The treatments with the highest longevity were moderate continuous stocking with no supplement and heavy continuous stocking with no supplement. The two treatments with the lowest longevity were heavy and moderate continuous stocking, both with the high level of supplementation.

Economic Evaluation

Calf production, cow weights and longevity of the cows were used to calculate the average income and costs per animal unit for each treatment. Operating costs were separated into those that were the same for all of the treatments and those that varied as a result of the treat-

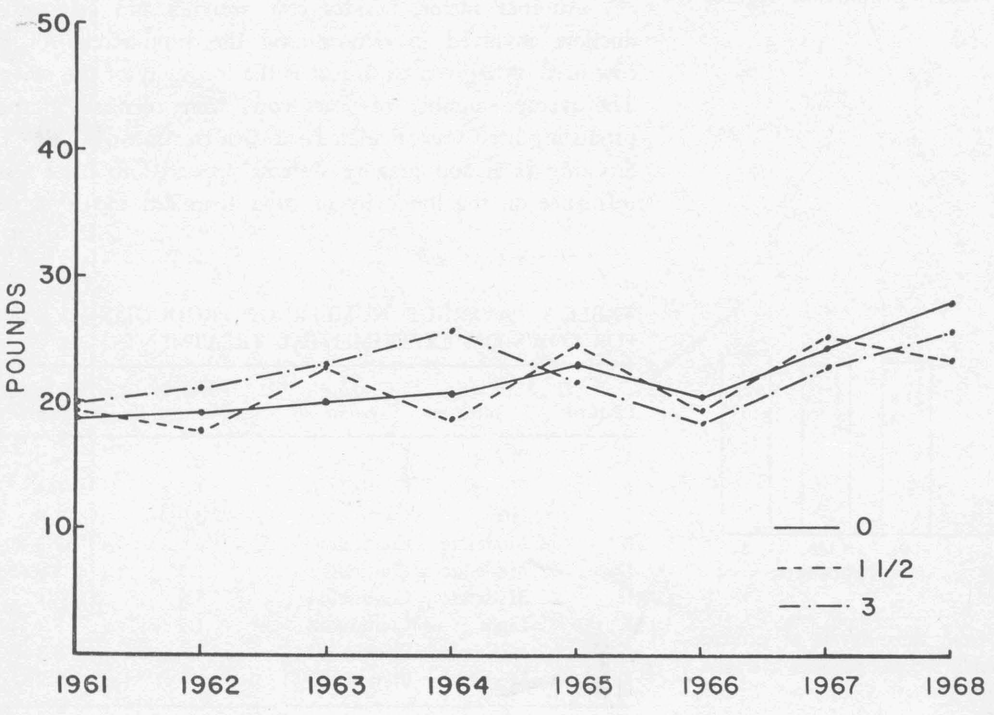

Figure 38.
Pounds of calf produced per acre from three levels of supplement fed on mod-ately stocked pastures.

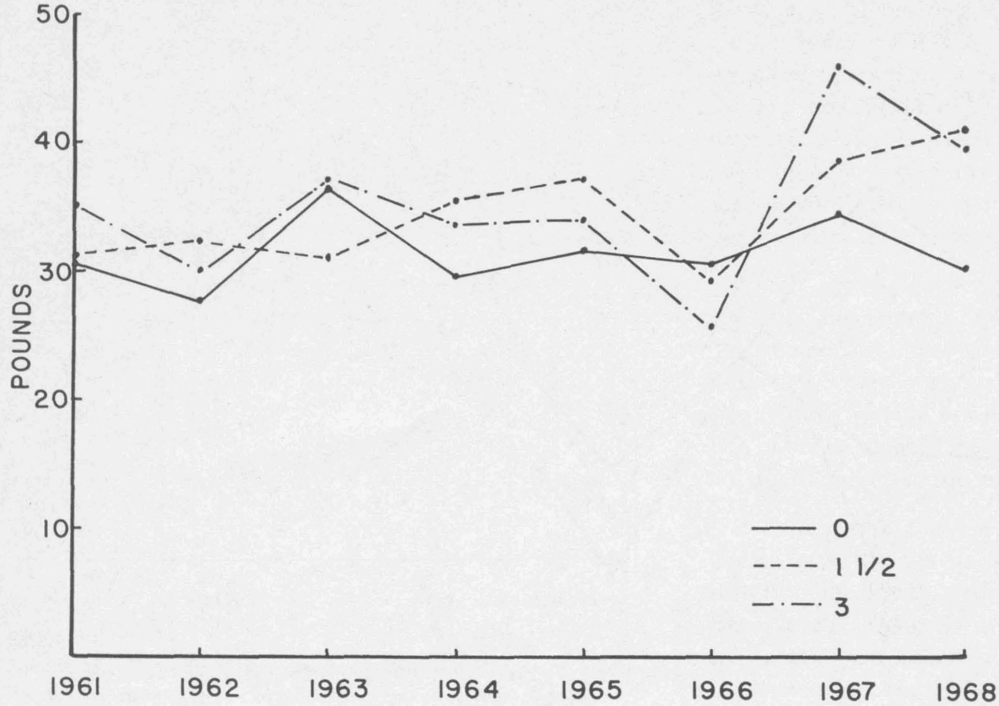

Figure 37.
Pounds of calf produced per acre from three levels of supplement fed on heavily stocked pastures.

supplementation. The treatments with the highest longevity were moderate continuous stocking with no supplement and heavy continuous stocking with no supplement. The two treatments with the lowest longevity were heavy and moderate continuous stocking, both with the high level of supplementation.

Economic Evaluation

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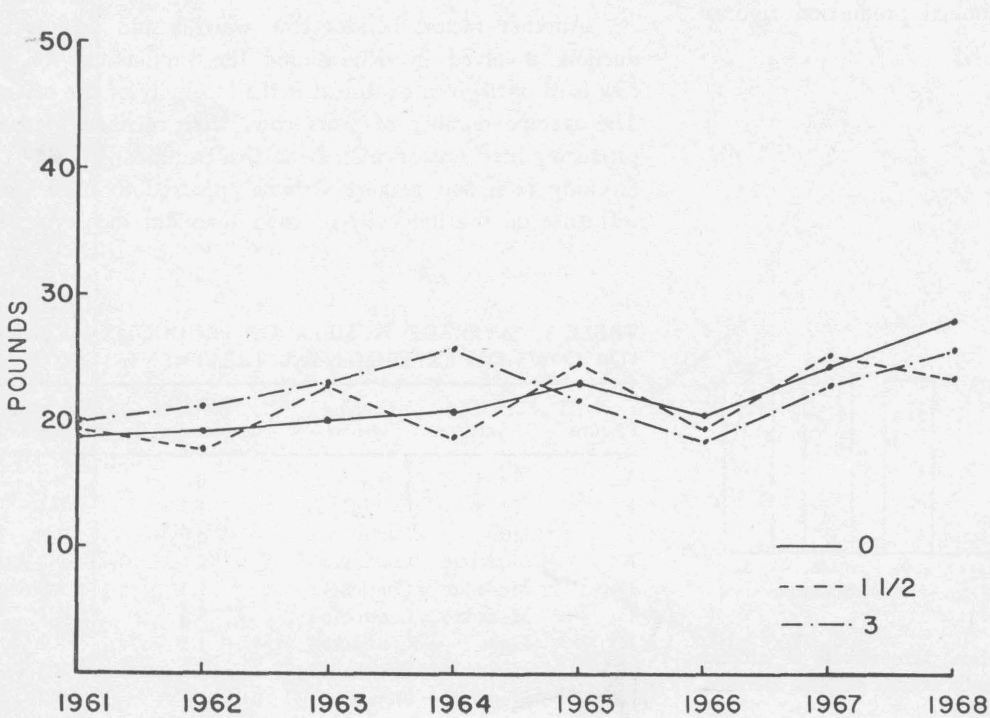

Figure 38.
Pounds of calf produced per acre from three levels of supplement fed on mod-ately stocked pastures.

ment. The constant operating expenses, those that were the same for all treatments, included veterinary and medical, hauling to market, bull cost, pickup expense, repairs, salt and bonemeal, labor, interest and property taxes on the cow (Table 4). Some of these costs were taken from Tom Prater's estimates for the eastern Rolling Plains (4), and the remainder were calculated from station data. Interest on herd capital was not included as a cost but was included in returns to capital and management.

TABLE 4. OPERATING COST DATA PER ANIMAL UNIT FOR ALL EXPERIMENTAL TREATMENTS ON THE TEXAS EXPERIMENTAL RANCH

Expenses:		Cost/animal unit
Veterinarian and medicine		$ 2.50[1]
Hauling to market		2.60[1]
Bull cost		6.00[1]
Pickup expense		2.50[1]
Repairs		1.60[1]
Salt and bonemeal		.75
Labor (7.5 hr/cow)		11.25
Sub-total		$27.20
Interest on operating expenses @ 7% (6 mo)		.95
County and school property tax on cow		1.15
Total		$29.30
Interest on herd capital ($140/cow @ 5%)		7.00[2]
Taxes		
County	$0.53/cow	$0.22/acre
School	0.62/cow	0.20/acre

[1]Cost figures taken from Estimates on Annual Beef Cow Cost by Areas, Tom E. Prater, AECO-5.
[2]If the operator uses borrowed capital, this interest will be a cost. In this analysis it has been included in the returns to capital and management.

Those costs that varied with the treatment were itemized on an animal unit basis (Table 5). Expenses were calculated for two types of operators, landowners and lessee. Expenses for the landowner were land tax; depreciation on fences, pens, buildings and other improvements; feed cost; and replacement cost. No charge for land use was made for the landowner since net returns were calculated on the basis of returns to capital and management. Expenses for the lessee included feed cost, replacement cost and a land charge of $2.50 per acre per year. The land tax and depreciation would generally be borne by the owner and not the lessee.

Replacement costs were calculated on the basis of keeping heifers and breeding them to calve as 2-year-olds. During the year the heifer was kept, the cow was sold, and the value of the cow exceeded the value of the replacement heifer for all treatments. The amount of income from the sale of the cow in excess of the value of the replacement heifer was considered the salvage value of the cow. This salvage value per cow for each treatment was divided by the average number of productive years that cows remained on that treatment to give an annual return (Table 5). All costs incurred by the replacement heifer while she was a yearling were tabulated (Appendix Tables 8 and 9). The cost of raising replacement heifers on the various treatments followed the same pattern as the operating expenses for the treatments. The replacement cost would vary considerably among individual operators and be dependent on many variable factors. For example, breeding heifers to calve at 3 years old would approximately double the replacement cost for some small operators, whereas for large operators it may be more economical. In this study an attempt was made to apply a uniform policy for calculating replacement costs to all of the treatments so that they could be compared objectively.

The total annual costs per animal unit for a lessee were considerably higher than for a landowner (Table 5). Increasing the level of supplement fed and increasing the number of acres per animal unit were the two primary factors that resulted in increased costs. Light stocking and moderate stocking with 3.0 pounds of supplement resulted in the highest operating costs for both types of operators. The grazing system used had little influence upon the operating expenses as long as the stocking rate and level of supplement remained the same.

The value of the calf produced per cow bred on each treatment, figured at $25 per hundredweight, ranged from $100.75 from pasture A to $122 from the Merrill system (Table 5). The salvage value of the cows, when it was spread over the productive life of the cow, varied little among treatments. Therefore, total income reflected primarily the calf production from each treatment. Grazing systems affected income more than did the stocking rate or the level of supplement. Income from the deferred-rotation systems was higher than from the continuously grazed treatments.

No attempt has been made to separate the returns to capital and to management for the treatments in this study. Table 6 gives the net returns to capital and to management combined for both landowner and lessee-type operators. These returns have been expressed in two ways, as returns per animal unit and as returns per acre. Returns per animal unit were calculated by subtracting the total annual cost per animal unit from the total annual income per animal unit for each treatment. Returns per acre were calculated by dividing the annual returns per animal unit by the stocking rate (acres per animal unit).

The returns per animal unit for a landowner indicate several things. First, on heavily stocked pastures, the medium level of winter supplement was profitable, whereas the high level was not. On the moderately stocked, continuously grazed pastures, feeding protein supplement during the winter was not profitable at either level. The stocking rate on the continuously grazed pastures had little

TABLE 5. ANNUAL COSTS AND INCOME PER ANIMAL UNIT FOR GRAZING TREATMENTS ON THE TEXAS EXPERIMENTAL RANCH

Pasture	A	F	J	B	D	I	E	G-H	K-L-M-N
Stocking rate	Heavy	Heavy	Heavy	Moderate	Moderate	Moderate	Light	Moderate	Moderate
Grazing system	continuous	continuous	continuous	continuous	continuous	continuous	continuous	2-pasture	4-pasture
Level of supplement (pounds)	0	1½	3	0	1½	3	1½	1½	1½
	dollars								
EXPENSES PER ANIMAL UNIT									
Landowner									
Fixed operating expenses[1]	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Land tax per animal unit	5.50	5.35	5.10	8.60	8.60	8.57	11.77	8.61	8.13
Depreciation on fences and equipment	3.07	2.98	2.85	4.80	4.80	4.80	6.57	4.80	4.54
Feed costs	0.35	5.40	10.80	0.00	5.40	10.80	5.40	5.40	5.40
Replacement costs	3.65	4.60	5.51	3.80	4.74	5.88	5.55	5.05	5.10
Total annual costs	41.87	47.63	53.56	46.50	52.84	59.35	58.59	53.16	52.47
Lessee									
Fixed operating expenses[1]	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
Feed costs	0.35	5.40	10.80	0.00	5.40	10.80	5.40	5.40	5.40
Replacement costs	5.61	6.64	7.55	7.03	7.84	9.25	10.10	8.35	8.24
Land charge (@ $2.50/acre)	32.72	31.82	30.35	51.17	51.17	51.02	70.05	51.25	48.37
Total annual costs	67.98	73.16	78.00	87.50	93.71	100.37	114.85	94.30	91.31
INCOME									
Calf per animal unit ($25/cwt)	100.75	110.00	107.00	111.75	110.25	115.00	116.50	114.50	122.00
Salvage value of cow[2]	4.87	4.79	4.91	4.30	4.65	5.64	4.84	4.77	4.11
Total annual income	105.62	114.79	111.91	116.05	114.90	120.64	121.34	119.27	126.11

[1]Taken from Table 4.
[2]Salvage value of cow equals value of cow less the value of a replacement heifer divided by the average years of productive life of the cow.

TABLE 6. RETURNS TO CAPITAL AND MANAGEMENT FROM GRAZING TREATMENTS ON THE TEXAS EXPERIMENTAL RANCH

Pasture	A	F	J	B	D	I	E	G-H	K-L-M-N
Stocking rate	Heavy	Heavy	Heavy	Moderate	Moderate	Moderate	Light	Moderate	Moderate
Grazing system	continuous	continuous	continuous	continuous	continuous	continuous	continuous	2-pasture	4-pasture
Level of supplement (pounds)	0	1½	3	0	1½	3	1½	1½	1½
	dollars								
LANDOWNER									
Dollars per animal unit per year	63.75	67.16	58.35	69.55	62.06	61.29	62.75	66.11	73.64
Dollars per acre per year	4.87	5.28	4.81	3.40	3.03	3.00	2.24	3.22	3.81
LESSEE									
Dollars per animal unit per year	37.64	41.63	33.91	28.55	21.19	20.27	6.49	24.97	34.80
Dollars per acre per year	2.88	3.28	2.79	1.39	1.04	0.99	0.23	1.22	1.80

influence upon the net returns per animal unit. The Merrill system of deferred-rotation returned $11.58 per animal unit more than did moderate, continuous stocking at the same level of supplement. The returns per animal unit from the Merrill system were the highest of all treatments for a landowner.

While returns per animal unit reveal some interesting effects of the treatments, returns per acre more clearly represent the rate of return for the landowner since his major investment is in land. The per-acre returns were highest from the heavily stocked pastures and lowest from the lightly stocked pasture, for the term of this research. Long-term economic effects of stocking rates on either range degeneration or secondary plant succession are unknown. The only profitable supplement treatment under continuous grazing was the medium level on heavy continuous stocking. The returns per acre from the Merrill system were higher than from any other moderately stocked pasture but were not as high as from heavy stocking.

The major capital investment for a lessee is livestock; hence, returns per animal unit are more significant to a lessee than to a landowner. As was the case for the landowner, heavy, continuous stocking with the medium level of supplement was the most profitable treatment for a lessee. However, per-animal unit returns to the lessee from the Merrill system were comparable to those from heavy continuous stocking at the zero and 3-pound levels of supplementation. Returns from light stocking were very low for a lessee because of the high land cost. Returns per acre were similar to returns per animal unit for the lessee except that differences among treatments tended to be greater when expressed on a per-acre basis.

Discussion

Of what value is this publication to a rancher? Should he adopt the treatment that showed the highest returns per animal unit or the highest returns per acre or neither of these? Each rancher will have to develop a program that will work for him. Factors such as the present condition of his rangeland, the climate, the kind of soils and the size and type of operation that he has all will influence his choice of stocking rate and grazing systems. The value of this publication will be to inform him of the kind of livestock response that he may expect from different grazing systems, stocking rates and levels of winter supplementation.

The basic natural resources of the rancher are his soils and the native vegetation growing on them. A separate publication will deal with the vegetational responses observed on the Texas Experimental Ranch during this study. However, some general observations and projections are presented here.

Grazing management consists principally of determining how much forage will be utilized by livestock (stocking rate) and in what manner it will be harvested (grazing system). Then, based upon the quality and quantity of forage being consumed by livestock at a given time, supplemental feeding may or may not be advisable.

During this study, rainfall was seldom limiting. Under such conditions heavy stocking can be maintained without encountering serious problems. However, under a system of heavy continuous grazing, forage production is on a "hand-to-mouth" basis. The standing crop of forage is always small, and the vigor of existing grasses and forbs is low. Should a dry period occur, the available forage

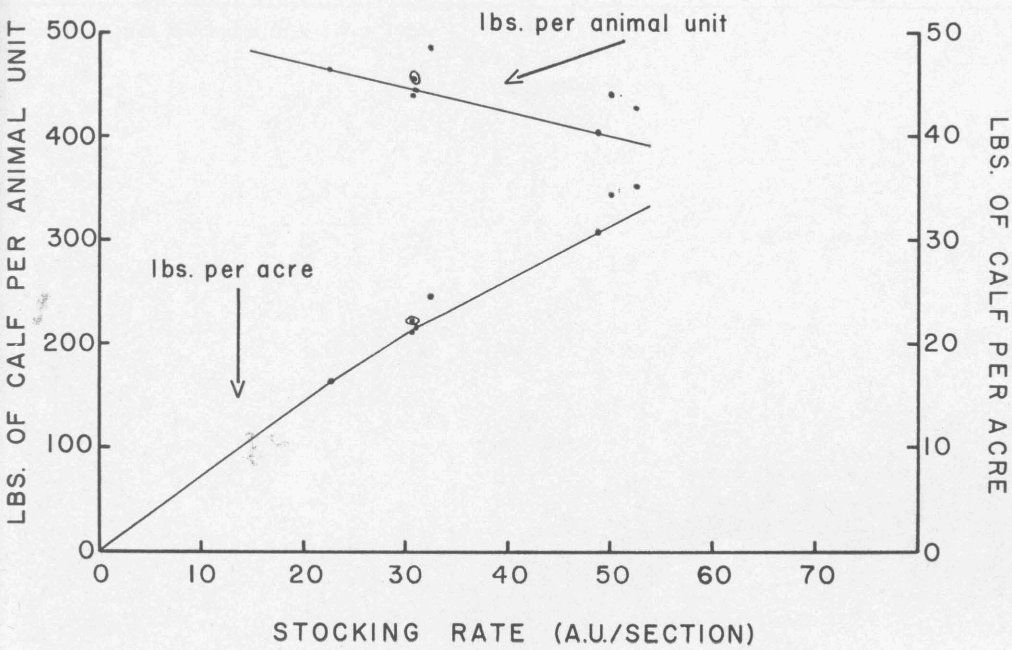

Figure 39.
The relationship between stocking rate and pounds of calf produced per animal unit and pounds of calf produced per acre.

will be depleted quickly. The rancher is then faced with the decision of feeding his livestock at a high cost or selling them. Under a moderate stocking rate, a good supply of reserve forage is maintained on the ground. In good years, net returns from moderate stocking will be less than from heavy stocking. However, in dry years, production can be maintained on moderately stocked pastures by using only a small amount of supplemental feed.

Deferred-rotation grazing systems compared with continuous grazing showed promise of increasing forage production. More forage production means more potential for livestock production. To further analyze the livestock production from the nine treatments studied, production per animal unit and per acre in relationship to the stocking rates have been plotted on the same graph (Figure 39). Each point on the graph represents an 8-year average for one of the nine treatments. There was a negative relationship between stocking rate and calf production per animal unit but a positive relationship between stocking rate and production per acre. The lines were drawn to pass through the following three treatments for each of the variables: light continuous stocking, 1.5 pounds of supplement; moderate continuous stocking, 0 pound of supplement; heavy continuous stocking, 0 pound of supplement. This line represents the base line for production from native vegetation on the Texas Experimental Ranch with no inputs of supplemental feed or deferred-rotation grazing. The point above the line at 32 animal units per section is the Merrill system of deferred-rotation. All other moderately stocked treatments had essentially the same level of production. The effect of supplement in increasing production at a heavy stocking rate is evident.

Based upon the data presented in Figure 39, it would appear that all of the stocking rates used were too light to be representative. Light stocking should have been about 25 to 30 animal units per section, moderate stocking about 40 to 50 animal units per section and heavy stocking about 55 to 60 animal units per section. In favorable years, such as during this study, maximum annual production per acre could be obtained by stocking at about 60 animal units per section and feeding supplement. However, the most desirable stocking rate appears to have been about 40 to 45 animal units per section with supplement fed only in dry years.

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APPENDIX

APPENDIX TABLE 1. PRECIPITATION DATA, TEXAS EXPERIMENTAL RANCH

Month	Throckmorton average	Actual 1961	1962	1963	1964	1965	1966	1967	1968
January	1.13	1.77	.23	.49	1.21	.71	1.52	.01	5.66
February	1.31	1.84	.27	.33	2.21	1.43	.81	.47	1.54
March	1.35	2.81	1.18	.00	1.39	.68	.40	2.41	2.86
April	2.29	.12	1.97	2.56	1.10	3.76	12.24	.65	1.80
May	4.32	1.04	.36	5.55	3.30	7.50	.00	3.03	6.51
June	3.37	6.53	5.03	3.31	1.99	2.78	.41	2.08	2.43
July	1.84	6.34	4.21	1.55	.30	.35	.43	5.37	5.00
August	1.69	.32	.31	.13	4.77	3.02	5.36	.10	1.77
September	2.27	5.75	12.40	3.15	4.64	3.07	4.81	3.85	1.05
October	2.54	1.26	2.39	1.05	.06	3.50	.83	1.64	*
November	1.50	3.67	1.79	2.17	3.51	.00	.25	.86	
December	1.35	1.18	1.19	1.03	.53	.71	.04	1.45	
TOTAL	24.96	32.63	31.33	21.32	25.01	27.51	27.10	21.92	28.62

*This study was concluded in October 1968.

APPENDIX TABLE 2. PLANT SPECIES FOUND ON TEXAS EXPERIMENTAL RANCH

Scientific name	Common name
MAJOR SPECIES	
Grasses	
Aristida spp.	Threeawn grasses
Bouteloua curtipendula (Michx.) Torr.	Sideoats grama
Buchloe dactyloides (Nutt.) Engelm.	Buffalograss
Eriochloa sericea (Scheele) Munro	Texas cupgrass
Hilaria belangeri (Steud.) Nash	Common curlymesquite
Schedonnardus paniculatus (Nutt.) Tvel.	Tumblegrass
Sporobolus cryptandrus (Torr.) Gray	Sand dropseed
Stipa leucotricha Trin. & Rupr.	Texas wintergrass
Forbs	
Aster ericoides L.	Heath aster
Gutierrezia texana (DC) T. & G.	Texas broomweed
Browse	
Condalia obtusifolia (Hook.) Weberb.	Lotebush
Prosopis glandulosa Torr.	Mesquite
MINOR SPECIES	
Grasses	
Agropyron smithii Rydb.	Western wheatgrass
Andropogon gerardi Vitman	Big bluestem
Andropogon saccharoides Swartz var. *torreyanus* (Steud) Hack	Silver bluestem
Andropogon scoparius Michs. var. *frequens* F. T. Hubb	Little bluestem
Bouteloua gracilis (Willd.) Lag.	Blue grama
Bouteloua hirsuta Lag.	Hairy grama
Bouteloua rigidiseta (Steud.) Hitchc.	Texas grama
Bouteloua trifida Thurb.	Red grama
Bromus japonicus Thunb.	Japanese brome
Bromus unioloides (Willd.) H. B. K.	Rescuegrass
Chloris verticillata Nutt.	Tumble windmillgrass
Elymus canadensis L.	Canada wildrye
Erioneuron pilosum (Buckl.) Nash	Hairy tridens
Festuca Octoflora Walt.	Sixweeks fescue
Hilaria mutica (Buckl.) Benth.	Tobosa
Hordeum pusillum Nutt.	Little barley
Panicum hallii Vasey	Halls panicum
Panicum obtusum H. B. K.	Vine-mesquite
Panicum virgatum L.	Switchgrass
Poa arachnifera Torr.	Texas bluegrass
Sorghastrum nutans (L.) Nash	Indiangrass
Sporobolus asper (Michx.) Kunth	
var. *asper*	Tall dropseed
var. *hookeri* (Trin.) Vasey	Meadow dropseed
Trichachne californica (Benth.) Chase	Arizona cottontop
Tridens albescens (Vasey) Woot & Standl.	White tridens
Tridens muticus (Torr.) Nash	
var. *muticus*	Slim tridens
var. *elongatus* (Buckl.) Shinners	Rough tridens
Trisetum interruptum Buckl.	Prairie trisetum
Forbs	
Allium drummondi Regel	Drummond onion
Ambrosia psilostachya DC.	Western ragweed
Astragalus lindheimeri Gray	Lindheimer milkvetch
Daucus pusillus Michx.	Southwestern carrot
Erodium texanum Gray	Texas filaree
Euphorbia marginata Pursh	Snow-on-the-mountain
Evax multicaulis DC.	Manysystem evax
Gaura parviflora Dougl.	Smallflower gaura
Grindelia squarrosa (Pursh) Dunal	Curlycup gumweed
Hymenoxys odorata DC.	Western bitterweed
Lactuca serriola L.	Prickly lettuce
Leucelene ericoides (Torr.) Greene	Baby-white aster
Linum pratense (Norton) Small	Meadow flax
Melampodium leucanthum T. & G.	Rock daisy
Monarda pectinata Nutt.	Plains beebalm
Nemastylis geminiflora Nutt.	Prairie pleatleaf
Oenothera laciniata Hill	Cutleaf eveningprimrose
Plantago rhodosperma Dcne.	Redseed plantain
Schrankia uncinata Willd.	Catclaw sensitivebriar
Scutellaria drummondii Benth.	Drummond skullcap
Solanum elaeagnifolium Cav.	Silverleaf nightshade
Solanum rostratum Dunal	Buffalobur
Verbena bipinnatifida Nutt	Dakota verbena
Verbena pumila Rydb.	Pink vervain
Browse	
Opuntia leptocaulis DC.	Tasajillo
Opuntia sp.	Pricklypear
Yucca sp.	Yucca

APPENDIX TABLE 3a. ANALYSIS OF VARIANCE FOR COW WEIGHTS FROM NINE TREATMENTS TAKEN THREE TIMES ANNUALLY FOR 8 CONSECUTIVE YEARS

Source	Degrees of freedom	Mean squares	Standard error	F
Total	215			
Year	7	57,616.	3.33	192.45**
Treatment	8	40,247.	3.53	134.43**
Year x treatment	56	1,060.	9.99	3.54**
Weighing period (WP)	2	229,200.	2.04	765.57**
Year x WP	14	5,721.	5.77	19.11**
Treatment x WP	16	1,584.	6.12	5.29**
Residual	112	299.		

**Significant at .01-level of probability.

APPENDIX TABLE 3b. DUNCAN'S MULTIPLE RANGE TESTS OF DIFFERENCES AMONG MEAN COW WEIGHTS[1]

Treatments

Moderate continuous 3.0 lb	Light continuous 1.5 lb	Moderate Merrill 1.5 lb	Moderate switchback 1.5 lb	Moderate continuous 1.5 lb	Moderate continuous 0 lb	Heavy continuous 1.5 lb	Heavy continuous 3.0 lb	Heavy continuous 0 lb
1063.	1030.	1025.	1009.	992.	969.	968.	956.	935.
/———/								
	/———	———/						
			/———/					
				/———/				
					/———	———/		
							/———/	
								/———/

Years

1965	1967	1966	1963	1968	1962	1961	1964
1071.	1054.	1006.	981.	978.	969.	955.	942.
/———/							
	/———/						
		/———/					
			/———	———/			
				/———	———/		
						/———/	
							/———/

Weighing periods

Summer	Fall	Spring
1037	1015	930
/———/		
	/———/	
		/———/

[1]Means not underscored by the same line differ significantly at the .05-level.

APPENDIX TABLE 4a. ANALYSIS OF VARIANCE FOR SPRING CALF WEIGHTS FROM NINE TREATMENTS FOR 8 CONSECUTIVE YEARS

Source	Degrees of freedom	Mean squares	Standard error	F
Total	143			
Year	7	3,492.	2.37	34.61**
Treatment	8	2,696.	2.51	26.72**
Year x treatment	56	303.	7.10	3.01**
Sex	1	4,378.	1.18	43.39**
Year x sex	7	96.	3.35	0.95
Treatment x sex	8	107.	3.55	1.06
Residual	56	101.		

**Significant at .01-level of probability.

APPENDIX TABLE 4b. DUNCAN'S MULTIPLE RANGE TEST OF DIFFERENCES AMONG MEAN SPRING CALF WEIGHTS[1]

Treatments

Moderate Merrill 1.5 lb	Moderate continuous 3.0 lb	Moderate switchback 1.5 lb	Light continuous 1.5 lb	Moderate continuous 1.5 lb	Moderate continuous 0 lb	Heavy continuous 3.0 lb	Heavy continuous 1.5 lb	Heavy continuous 0 lb
214.	203.	202.	201.	200.	200.	193.	186.	169.
———								
	———	———	———	———	———			
				———	———	———		
						———	———	
								———

Years

1965	1963	1967	1968	1962	1961	1964	1966
219.	208.	205.	200.	195.	183.	181.	181.
———							
	———	———					
		———	———				
			———	———			
					———	———	———

Sex

Steers	Heifers
202.	191.
———	
	———

[1]Means not underscored by the same line differ signicantly at the .05-level.

APPENDIX TABLE 5a. ANALYSIS OF VARIANCE FOR SUMMER CALF WEIGHTS FROM NINE TREATMENTS FOR 8 CONSECUTIVE YEARS

Source	Degrees of freedom	Mean squares	Standard error	F
Total	143			
Year	7	4,923.	3.30	25.14**
Treatment	8	3,616.	3.50	18.47**
Year x treatment	56	561.	9.90	2.86**
Sex	1	13,495.	1.65	68.91**
Year x sex	7	272.	4.66	1.39
Treatment x sex	8	175.	4.95	0.89
Residual	56	196.		

**Significant at .01-level of probability.

APPENDIX TABLE 5b. DUNCAN'S MULTIPLE RANGE TESTS OF DIFFERENCES AMONG MEAN SUMMER CALF WEIGHTS[1]

Treatments

Moderate Merrill 1.5 lb	Moderate continuous 3.0 lb	Moderate switchback 1.5 lb	Light continuous 1.5 lb	Moderate continuous 1.5 lb	Moderate continuous 0 lb	Heavy continuous 3.0 lb	Heavy continuous 1.5 lb	Heavy continuous 0 lb
391.	384.	383.	377.	376.	368.	365.	363.	340.
/———	———	———/						
	/———	———	———	———/				
			/———	———	———/			
				/———	———	———/		
					/———	———	———/	
								/——/

Years

1967	1963	1965	1962	1966	1964	1968	1961
401.	387.	382.	367.	364.	364.	362.	349.
/——/							
	/———	———/					
			/———	———	———	———/	
							/——/

Sex

Steers	Heifers
382	362
/——/	/——/

[1]Means not underscored by the same line differ significantly at the .05-level.

APPENDIX TABLE 6a. ANALYSIS OF VARIANCE FOR FALL CALF WEIGHTS FROM NINE TREATMENTS FOR 8 CONSECUTIVE YEARS

Source	Degrees of freedom	Mean squares	Standard error	F
Total	143			
Year	7	6,808.	3.28	35.25**
Treatment	8	4,264.	3.47	22.08**
Year x treatment	56	737.	9.83	3.81**
Sex	1	35,942.	1.64	186.09**
Year x sex	7	404.	4.63	2.09
Treatment x sex	8	225.	4.91	1.17
Residual	56	193.		

**Significant at .01-level of probability.

APPENDIX TABLE 6b. DUNCAN'S MULTIPLE RANGE TESTS OF DIFFERENCES AMONG MEAN FALL CALF WEIGHTS[1]

Treatments

Moderate Merrill 1.5 lb	Moderate continuous 3.0 lb	Light continuous 1.5 lb	Moderate switchback 1.5 lb	Moderate continuous 1.5 lb	Moderate continuous 0 lb	Heavy continuous 3.0 lb	Heavy continuous 1.5 lb	Heavy continuous 0 lb
521.	513.	506.	506.	501.	499.	492.	490.	464.
/———	———/							
	/———	———	———/					
		/———	———	———	———/			
				/———	———	———/		
					/———	———	———/	
								/———/

Years

1967	1965	1961	1963	1968	1962	1964	1966
537.	511.	507.	505.	489.	484.	481.	480.
/———/							
	/———	———	———/				
				/———	———	———	———/

Sex

Steers	Heifers
515.	483.
/———/	
	/———/

[1]Means not underscored by the same line differ significantly at the .05-level.

APPENDIX TABLE 7. AVERAGE BIRTH DATE FOR EIGHT CALF CROPS FROM NINE GRAZING TREATMENTS

Pasture	1961	1962	1963	1964	1965	1966	1967	1968	Avg.
A	1/25	1/20	1/6	1/16	1/23	1/21	1/14	1/5	1/16
B	1/16	1/18	1/4	1/14	1/16	1/11	1/13	1/9	1/13
D	1/25	1/19	1/16	1/11	1/11	1/19	1/10	12/28/67	1/13
E	2/17	1/28	1/7	1/16	1/15	1/23	1/15	1/1	1/19
F	2/3	1/22	1/11	1/13	1/19	1/23	1/15	1/3	1/17
G-H	1/28	1/10	12/31/62	1/11	1/15	1/25	1/5	1/3	1/12
I	1/29	1/10	1/10	1/12	1/24	1/24	1/11	1/17	1/17
J	1/27	1/13	1/5	1/9	1/13	1/15	1/17	1/1	1/12
KLMN	1/23	1/11	1/8	1/12	1/13	1/12	1/3	1/11	1/12

APPENDIX TABLE 8. CONSTANT OPERATING EXPENSES PER ANIMAL UNIT FOR REPLACEMENT HEIFERS

Expenses:	Cost per heifer
Veterinarian and medicine	$ 2.50
Pickup expense	2.50
Repairs	1.60
Salt and bonemeal	.75
Labor	11.25
Property tax (county and school)	1.05
Total	$19.65

APPENDIX TABLE 9. REPLACEMENT COST ANALYSIS FOR KEEPING HEIFERS BRED TO CALVE AS 2-YEAR-OLDS FOR GRAZING TREATMENTS ON TEXAS EXPERIMENTAL RANCH

Pasture	A	F	J	B	D	I	E	G-H	K-L-M-N
Stocking rate	Heavy	Heavy	Heavy	Moderate	Moderate	Moderate	Light	Moderate	Moderate
Grazing system	continuous	continuous	continuous	continuous	continuous	continuous	continuous	2-pasture	4-pasture
Level of supplement (pounds)	0	1½	3	0	1½	3	1½	1½	1½
	Dollars								
Landowner									
Constant operating expenses[1]	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65
Land tax	3.69	3.59	3.42	5.77	5.77	5.75	7.89	5.77	5.45
Feed costs	0.35	5.40	10.80	0.00	5.40	10.80	5.40	5.40	5.40
Sub-total (operating expenses)	23.69	28.64	33.87	25.42	30.82	36.10	32.94	30.82	30.50
Interest on operating expenses @ 7%	1.66	2.01	2.37	1.78	2.16	2.53	2.31	2.16	2.14
Interest on heifer @ 5%	5.04	5.51	5.35	5.59	5.51	5.75	5.82	5.72	6.10
Depreciation on fences and equipment	2.06	2.00	1.91	3.22	3.22	3.22	4.41	3.22	3.04
Total costs	32.45	38.16	43.50	34.23	41.71	47.60	45.48	41.92	41.78
Replacement costs per year[2]	3.65	4.60	5.51	3.80	4.74	5.88	5.55	5.05	5.10
Lessee									
Constant operating expenses[1]	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65	19.65
Feed costs	0.35	5.40	10.80	0.00	5.40	10.80	5.40	5.40	5.40
Land charge	21.92	21.32	20.33	34.28	34.28	34.18	46.93	34.34	32.41
Sub-total (operating expenses)	41.92	46.37	50.78	53.93	59.33	64.63	71.98	59.39	57.46
Interest on operating expenses @ 7%	2.93	3.25	3.55	3.78	4.15	4.52	5.04	4.16	4.02
Interest on heifer @ 5%	5.04	5.51	5.35	5.59	5.51	5.75	5.82	5.72	6.10
Total costs	49.89	55.13	59.68	63.30	68.99	74.90	82.84	69.27	67.58
Replacement costs per year[2]	5.61	6.64	7.55	7.03	7.84	9.25	10.10	8.35	8.24

[1]Taken from Appendix Table 8.

[2]Total cost of producing a replacement divided by average years of productive life of cow equals average cost per year for replacements.

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