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*Organic farming research project report submitted to the Organic Farming Research Foundation:*

**Project Title:**

## *Beef cattle finishing in summer/fall in a strip cropping system*

FINAL PROJECT REPORT

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## Abstract

Seven Texas longhorn beef yearlings were finished during summer/fall 1996 without supplemental feed by break-feeding 14 acres in fields of alfalfa aftermath and eastern gamagrass and in strips of cowpeas and pearl millet, part of an already established narrow strip cropping system. The seven yearlings gained an average of 121 lbs during the 14 weeks of finishing. They were slaughtered at 20 months with a mean liveweight of 1,049 lbs and a dressed standard-grade carcass of 61 percent. average daily weight gain during various stages of production was 1.6-1.9 lbs (Table 1), typical of rangeland beef operations (Bock et al. 1991). A partial budget analysis was done to compute the change in profit due to adding beef finishing, including installation of fence and water, onto the existing fields and cropping systenl Based on a value of $82/cwt of carcass from the 121 lbs of finished gain, the net loss was $169 per yearling, which was expected due to the low conventional market value for grass-fmished beef and also to the small scale of the fenced area. For the same finished gain and carcass value along with typical yardage costs, the herd size must be approximately 300 head finished on 600 acres to generate a net profit of $10 per head for the finishing phase alone. If a niche market could bring a price of $100/cwt, the same profit could be obtained from roughly I 10 head finished on 220 acres. From our soil quality research on the cowpea strips, grazed plots had significantly more nitrate than ungrazed plots at 0-15 and 15-60 cm depths seven weeks after completion of finishing. Further soil testing in spring 1997 provided suggestive evidence of winter leaching of this nitrate to 60-100 cm depth. Grazed plots also had greater bulk density than ungrazed plots due to compaction of soil by the cattle. The greater nitrate levels and bulk density did not persist after fall and spring discing for the subsequent grain sorghum crop. The fall 1997 yield of the grain sorghum crop was not different between the formerly grazed and ungrazed plots. If the benefits of soil fertility are to be retained from cattle grazing on legume cover crops in a crop rotation, then either fall tillage after summer cover crops must be reduced or winter cover crops must be instead. This study was critiqued by the Farmer and Scientific Advisory Committees for the Sunshine Farm Project and was featured during The Land Institute's Farmers Field Day, Prairie Festival, and Visitors Day.

Keywords: pasture-based beef finishing; Texas longhorns; partial budget analysis; soil quality; cowpeas

## Introduction

In this project, we finished Texas longhorn beef cattle on the Sunshine Farm by using polywire (temporary electric fence) to break-feed crop residues and forages in a narrow strip cropping system without supplemental feed. To close the nutrient cycle between cattle and crops, the project was recommended February 1995 by the seven-member Farmer Advisory Committee for the Sunshine Farm. The committee is part of the Heartland Sustainable Agriculture Network, administered by the Kansas Rural Center as a state-wide consortium of local groups of farmers for the purpose of sharing experience and information in sustainable agriculture. This project was part of The Land Institute's Sunshine Farm, an energy-integrated organic farm initiated in 1993 with research projects to determine if a farm can provide its own fuel and fertility (Bender 1995).

Since one-third to one-half of the cost of beef production is due to feed (Larson 1995), farmers have been showing interest in beef production systems that utilize more forage and fewer inputs. We used polywire to control daily access to forage and to reduce trampling of high quality forage (Smith 1995). Moreover, some of the crops in our two 5-year rotations provided a flexible cattle diet and a cushion against crop failure. The temporal overlap in the forages available in these rotations avoided fall forage deficit such as that encountered when moving cattle from native pasture to winter wheat forage. The advantage of conducting this project on the Sunshine Farm was that farmers generally do not have all the following components: narrow strip crops and required implements, cover crops, high-tensile fence around cropland (to which polywire can be attached for break-feeding), and beef cattle finishing on cropland. We conducted a partial budget analysis to determine the change in profit with the inclusion of beef finishing on an already established crop rotation.

Within the strip cropping system, we focused on the grazing of a legume cover crop, cowpeas *Vigna sinensis* L.), because it has regrowth and nitrogen fixation after grazing whereas crop residues do not. We did a field experiment to determine if grazed cowpeas would lead to subsequent grain sorghum yields and soil quality comparable to that for ungrazed cowpeas. This might be possible because grazing has been shown to stimulate nitrogen fixation in legumes and because manure disked in after grazing encourages soil microbial activity that may lead to more efficient nutrient cycling than in ungrazed cover crops (Rhonda Janke, Kansas State University, agronomy, pers. comm.). In other words, could we obtain some beef production without decreasing subsequent crop yields and soil quality? In our project, the cowpeas and other crop strips were break-fed twice as part of a rotational grazing regime, with cowpea regrowth in between. Measurement of soil quality was done on grazed and ungrazed control plots both before and after the grazing regime.

## Materials and methods

Beef finishing system. During 12 August - 18 November 1996, seven Texas longhorn yearlings from the Sunshine Farm's cow-calf herd were finished on crop strips consisting of 2.9 acres of cowpeas and 1.4 acres of pearl millet (*Pennisetum Glaucum* L.) plus some strips of wheat and oat stubble and on fields of 4.8 acres of alfalfa aftermath and 5.0 acres of eastern gamagrass (*Tripsacum dactyloides* (L.) L.). This was a total of 17.2 acres of grazed area. The yearlings were transferred to the crops from prairie which was in active growth during August. Hence, there was no compensatory gain as typically occurs when cattle are taken off an inactive prairie m late fall and put on growing cool-season pasture and feed. The yearlings received no supplemental feed or hormone implants, but bloat blocks were supplied. To prevent trampling, the crops were break-fed by moving polywire and water daily to expose fresh feed to the yearlings (Figure 1).

The yearlings were Gelbvieh sire X Texas longhorn dam crosses. They were taken from our cow/calf herd that went through at least 2 rotations of grazing in approximately 25 paddocks on 90 acres of native tallgrass prairie and replanted prairie each summer from early May to October. The average birth date of the 7 yearlings was 29 March 1995. The grazing pressure on this prairie during the past 3 years has not been enough to change the plant species composition (Guretzky 1997). The average herd size on the prairie during 1995-96 was 9 cow/calf pairs and 9 yearlings.

The cows and weaned calves were overwintered on this pasture with supplemental feed, followed by break-fed grazing on 7 acres of triticale during April.

Experimental site. The crops grazed by the yearlings were on a level Cozad silt loam (coarse silty, mixed, mesic Fluventic Haplustoll). At the Salina Federal Aviation Authority Airport weather station approximately 5 km WNW of the farm, the annual mean precipitation during 1950-1980 was 73 cm. Annual precipitation measured on the Sunshine Farm during 1994-97 was 59, 90, 88 and 71 cm, respectively. Experimental plots in the 1996 cowpea strips were located in a strip cropping system with the following 5-year rotation: grain sorghum, soybeans, oats, winter wheat and cowpeas (Figure, 1). The rotations were unfertilized and were started in 1993, with unfertilized wheat during the 4 years prior to that. No pesticides have been used since 1987.

For seedbed preparation of the cowpea strips, they were chisel plowed on 6 October 1995 and 17 January 1996, followed by disking on 23 March, 2 May and 11 June, and harrowing on 17 May and 11 June. The cowpeas were drilled at the rate of 29 lbs per acre on 14 June. The grazed cowpeas strips and manure deposited by the yearlings were disked down on 18 October 1996. Further seedbed preparation for grain sorghum during 1997 involved disking on 20 February and 24 April, harrowing on 5 May and 28 May. The sorghum was planted at the rate of 4.0 lbs per acre on 3 June, cultivated on 7 July and 25 July, and harvested on 7 October 1996.

Economic analysis. A partial budget analysis was done to compute the change in profit due to adding beef finishing onto our cropping system (Herbst and Erickson 1996). The output is the value of the beef gain during finishing. There are no taxes or land opportunity cost because the crop rotation was being done whether or not there was beef finishing on it. There is also no animal cost because we already own the yearlings. There is no forage crop costs because there was no change in field operations or machinery as a result of including beef finishing. There were also no supplemental feed or veterinary costs during the finishing. Finally, the change in grain yields of subsequent crops due to this beef finishing should also be included, ' but in this study no significant difference in grain sorghum yield was found. Thus, to compute the change in profit, only the following costs had to be determined: the yardage costs (labor and miscellaneous supplies) for finishing the yearlings, the cost of bloat blocks, and the annual operating interest on the investment in the fence and watering system.

The fence and water system also included some inefficient use of land: 1) grazed wheat and oat stubble with relatively low TDN (total digestible nutrients), and 2) crop strips that the cattle did not have access to (Figure 1). A crop rotation efficient for beef finishing would contain only high TDN forages, all accessible to the cattle. So, the capital cost of fence and water was prorated in the economic analysis to reflect such an efficient crop rotation. The prorating was done on the basis of the proportion of the fenced-in area containing the 14.1 acres of forages with high TDN, namely cowpeas, pearl millet, alfalfa and eastern gamagrass. Since the fence and water pipelines run mostly along the perimeter of the fenced-in area, one would expect the capital cost to be proportional to the perimeter around this fenced-in area. This expectation was found to be true in a comparison of our study with another one (see results section). Thus, assuming the area to be relatively square so that the perimeter is proportional to the square root of the area, the capital cost was prorated by the square root of the proportion of the fenced-in area containing high TDN forages.

Experimental design for soil quality and grain sorghum yields. A randomized complete block design was defined by the break-feeding areas outlined by the polywire fence. The break-feeding practice ensured that each grazing unit or block was independent of the other grazing units within a cowpea strip (Figure 1) and was not a pseudoreplicate (Hurlbert 1984). There were 20 blocks, each with two permanent adjacent experimental plots consisting of one randomly assigned gazed treatment and one ungrazed control enclosure. Each plot was 4 x 6 m, with the latter dimension parallel to the length of the strip. Within strips, each pair of plots was separated from other pairs by distances ranging from 57-88 m

Chemical soil properties and bulk density. Soil samples were collected several times before cattle grazing (15 March and 7 August 1996) and afterwards (4 November 1996 and 24 April 1997). The first and last dates reflected one-year changes in soil properties due to grazing and included the measurement of 7 chemical properties. The two intermediate dates were chosen to minimize other annual effects relative to grazing and included only nitrate, ammonium and bulk density. Since the sampling date of 4 November was after the plots had been disked on 18 October bulk density was also measured beforehand on 23 September soon after grazing was completed.

Within the 40 experimental plots, samples were composited from 3 subsamples taken at 0- 15 cm depth with a 1.8 cm diameter probe. For each plot, there was one sample for chemical -analysis and one for bulk density. Within 5 pairs of plots, one pair in each of the 5 crop strips, composited samples were collected in each plot at 15-60 and 60-100 cm depths, one for chemical analysis and one for bulk density.

The samples for chemical analysis were dried near 30º C in a greenhouse for approximately one week and then sent to the Kansas State University Soil Testing Laboratory. The 0-15 cm samples were ground and analyzed for I molar KCL extractable nitrate and ammonium, available Bray phosphorus (P-1 method) and exchangeable potassium (1 molar ammonium acetate extractant). Total nitrogen, total phosphorus and organic carbon were measured colorimetrically on a dual-channel Technicon Autoanalyzer. The 15-60 and 60-100 cm samples were analyzed only for nitrate and ammonium. Details of the chemical procedures are provided by the North Dakota Experiment Station (1988) and Technicon Industrial Systems (1977). Bulk density was determined by the core method (Blake and Hartge 1986) with gravimetric water content determined by oven g of soil samples at 105º C for 48 hours, which gave constant mass for the silt loam soils in the experimental plots.

<u>Soil water properties</u>. Aluminum irrigation pipe cut as a ring (12.7 cm length x 15.2 cm i.d.) was used for on-site measurement of water infiltration rate and water holding capacity (Sarrantonio et al. 1996). Measurements were made on 23 April 1996 and 17-18 June 1997 to reflect one-year changes due to grazing. Again, to minimize other annual effects relative to grazing, water infiltration rate was measured on 7 October 1996 soon after the yearlings were marketed. Due to anecdotal field observations on the correlation between remaining cowpea cover and soil moisture, antecedent soil water content was also measured at this time for use as a covariate in an analysis of covariance of the data on infiltration rate.

Infiltration rate in each plot was estimated by pounding the ring to 7.6 cm depth and recording the time for 463 ml of water (2.5 cm depth for the pipe) to seep in, leaving a glistening soil surface. Then, another 463 ml of water was added to the ring for determination of water holding capacity by a method that is an approximation of *in situ* field capacity (Cassel and Nielsen 1986). Nearly 24 hours later, a 5 x 5 cm sample was collected from within the ring, weighed and then oven dried at 105'C for 48 hours to calculate the gravimetric water content, which was approximately the field water holding capacity by this procedure.

<u>Soil respiration</u>. Soil respiration was measured in each plot during 23 June - 1 July 1997, to assess the effect of disking manure on the evolution of carbon dioxide by microbial activity in the grazed plots. Since the grain sorghum seedlings in these plots were only a few inches tall and since measurements were made between the rather wide 40-inch rows, it was unlikely that the measurements picked up any respiration from the seedlings. For short-tem *in situ* measurement of soil respiration, Sarrantonio et al. (1996) adapted a closed-chamber method described by Anderson (1982). The above aluminum ring was pounded into the soil to 7.6 cm depth and sealed with a plastic lid to make a closed chamber. The chamber was covered with a cardboard box to reduce heating by the sun. After 0.5 hour to equilibrate the $CO_2$ concentration in the chamber, soil respiration was estimated colorimetrically by passing 100 ml of headspace atmosphere through an open Drager 0.1 % $CO_2$ detection tube. Soil temperature within the ring was recorded at a depth of approximately 4 cm using a probe thermometer inserted through a tight hole in the plastic lid. Adjacent to the ring, soil samples were collected for determination of bulk density and gravimetric water content by above procedures. Then, 463 ml of water was added to the ring which was sealed with a plastic lid that had numerous slits in it to prevent $CO_2$ buildup. The cardboard box was placed back over the chamber. Roughly 24 hours later, the ring was sealed with a solid plastic lid and the procedure was

repeated to obtain a post-wetting measurement of soil respiration that gave an indication of the ability of soil microbes to respond to precipitation. Soil temperature, bulk density and gravimetric water content were again determined within the ring. All respiration values were adjusted to a non-limited respiration rate at 60% water-filled pore space and a common temperature of 25° C by use of algorithms provided by Sarrantonio et al. (1996).

Statistical analysis. Within each date of sampling, each soil quality indicator was compared between grazed and ungrazed plots within a soil depth by means of analysis of variance. For sampling dates prior to grazing, the comparison between the not-yet grazed and ungrazed plots served as a check that there was no prior bias between the two groups of plots. If there was a bias beforehand, then comparisons made after grazing could not be interpreted solely in terms of a grazing effect. For sampling dates after grazing, the comparison between the grazed and ungrazed plots revealed whether or not there was a grazing effect.

Note that the grazed plots are not compared before and after grazing. This is because any differences over time could not be explained solely in terms of a grazing effect, There would also be uncontrolled effects over time such as weather and soil sampling techniques. Also note that this experiment cannot be treated as a two-way factorial design with one factor having two grazing treatments (grazed and ungrazed) and the other factor having two sampling dates (before and after grazing). A factorial design requires that each treatment be present at all levels of the other factors. But, this is obviously not the case here because the so-called grazed plots were not grazed at the time of the sampling date that occurred prior to grazing. Finally, comparisons were not made between depths because they were irrelevant to the effects of interest in this study.

The general linear model was used for the analysis of variance (SYSTAT 1992). A significant treatment effect was declared if the probability of falsely declaring such an effect was 5 percent or less. In statistical parlance, this is noted as a significance level of $P \leq 0.05$. That is, the value of P is kept small so that it is unlikely that significant effects would be declared that really did not exist and were instead due to other random effects that cannot be controlled in an experiment

Residuals computed from these analyses met the assumptions of normality and homogeneity required for valid analysis of variance. In a few cases, logarithmic transformation of the data was required before analysis of variance, and raw means were reported instead of untransformed means, simply for the sake of consistent reporting of means.

The experimental design provided an acceptable statistical power or probability of finding differences in indicators between the grazed and ungrazed treatments @wnicld et aL 1988, Cohen 1965). That is, a coefficient of variation of 20 percent has been measured in previous years on the Sunshine Farm for grain sorghum yields and most soil properties (Mosca 1997, Walton 1997). With this coefficient of variation and testing at the 0.05 significance level, 20 replicates gave a respectable power of 87 percent for finding a difference between two treatments equal in magnitude to at least one standard deviation, or 20 percent of the overall mean (Cohen 1988). The one exception in the experiment was soil respiration, which generally had a coefficient of variation of 50 percent in previous measurements on the Sunshine Farm typical for *in situ* measurements with C02 detection tubes (Mosca 1997; Liebig et al. 1998). So, the power was 87 percent to detect a difference in soil respiration between two treatments equal in magnitude to at least one standard deviation, or 50 percent of the overall mean. Or alternatively, we had a power of 50 percent in detecting a difference of at least 32 percent of the overall mean (Cohen 1988).

## Results and Discussion

Beef production. The 7 yearlings gained an average of 121 lbs during the 14 weeks of finishing. The average liveweight was 1,049 lbs at slaughter with a dressed carcass of 61 percent (Table 1). After one week of cooled hanging, the standard-grade beef had a respectable rating of 6 for tenderness, juiciness and no off flavor (Earl Wright, Tallgrass Prairie Producers, 11/25/96). The average daily weight gain during various stages of production was 1.6-1.9 lbs (Table 1), typical of rangeland beef operations (Bock et al. 1991).

The 14 acres of high TDN forages provided an average of 2.0 acres per yearling, or a gain of 60 lbs per acre. Our acreage per head is within the reported range of 2.0-2.5 acres of row crop stubble per overwintering calf or cow in several experiments, but the overwintering cattle received feed supplements while our yearlings on green crops without supplements (Larson 1995; Klopfenstein 1994). Our gain per acre is half the gain of 120 lbs per acre for steers finished during an equivalent period at a stocking rate of 1 acre per head with two rotations of grazing on pasture of mixed tall fescue-legume species in central Missouri (Martz et al. 1996). The larger gain in the Missouri study was most likely due to the greater precipitation resulting in more forage. Their daily rate of gain was 1.2 lbs per head, much lower than the 1.6 lbs per head during our finishing period (Table 1).

Based on the oven-dry weights of the clipped, ungrazed forages and the literature values of their TDN contents, the four high TDN forages in our study provided the following percentages of the total TDN consumed: cowpeas, 32; pearl millet, 30; eastern gamagrass, 24; and alfalfa aftermath, 14 (data not shown). Hence, it was not unreasonable to focus on cowpeas in our study of soil quality in the cropping system.

Grain sorghum yields. During 1997, in the crop strips that were formerly cowpeas in 1996, grain sorghum yields were, 92.8 and 95.4 bushels per acre in the ungrazed and gazed plots, respectively. These yields were not significantly different (P = 0.32) by analysis of variance across 20 blocks. This is probably to be expected, given that only one year of grazing cowpeas within each crop strip is allowed within the five-year sequence of our crop rotation. A Nebraska study has shown that 3 years of calves grazing on dryland com stalks on the same ground during winter have not reduced subsequent crop yields (Institute of Agriculture and Natural Resources 1993).

Economic analysis. The perimeter fence included 24.5 acres of grazed fields (9.8 acres) and crop strips (7.4 acres gazed and 7.3 acres ungrazed for combine harvest). Hence, the yardage cost of $674 averaged $27.50 per acre (Table 2). This is much greater than the yardage cost of $17.00 per acre reported for larger pastures in conventional grazing (Martz et al. 1996) and rotational grazing (Kerr Center for Sustainable Agriculture 1989). This was probably due to our small grazing area and also to inexperienced interns requiring extra labor to move the interior fence and water daily.

The perimeter fence also included an additional 15.5 acres of unrelated research plots for a total of 40 acres. The capital cost, including labor and fuel, was $6,582 for water, interior fence and 1 mile of perimeter fence. This concurs with a figure of $6,225 per mile of perimeter fence estimated for water, interior fence and 2 miles of perimeter fence to establish rotational grazing on 160 acres of land (Institute for Agriculture and Natural Resources 1996). As expected, comparison of the two studies shows that as the area was quadrupled from 40 to 160 acres, the total cost of fence and water only doubled. Hence, the total capital cost was proportional to the perimeter, not the area, a fact that will be utilized in the following analysis.

There were 14.1 acres of high TDN forages, or roughly 2 acres per yearling. After prorating the capital costs for the fence and water system to 14.1 acres to simulate a cropping system efficiently designed for grazing, the total annual cost for finishing the 7 seven Texas longhorn yearlings on forage would have been $1,605 (Table 2). The income from the beef gained only during the 14 weeks of finishing was $424, based on a value of $82 per hundredweight of cooled hanging standard-grade carcass (Martz et al. 1996). The resulting net loss of $1,181, or $169 per yearling, was expected due to the small scale of the system which leads to a lot of fence and water system relative to the grazed area surrounded by the fence.

This suggests that the net income during finishing would become positive if the length of the perimeter fence were enlarged enough since the gazed area would increase relative to the perimeter itself. If we maintain the per-acre stocking rate, then this will also be true for the herd size relative to the perimeter. That is, the yardage and capital costs for fence and water will increase as the square root of the increase in grazed area or herd size, as verified above. Also, the cost for bloat blocks will increase linearly with the increase in herd size. Since the costs in Table 2 are based on 7 yearlings, they are scaled by the factor x/7, where x is the herd size, to provide the following equation that will be used to generate some informative graphs:

net income = beef return - [bloat blocks + yardage + operating interest]

$$\text{net income} = x(1.21\ \text{cwt})(0.61)y - [(x/7)(\$204) + (x/7)^{0.5}(\$674) + (x/7)^{0.5}(\$727)] \quad (1)$$

The variable y is the market dollar value per hundredweight (cwt) of dressed carcass and the product (1.21 cwt)(0.61) was the amount of dressed carrass produced per yearling only within our beef finishing system. Dividing both sides of Equation (1) by x, we obtain:

$$\text{net income per head} = (1.21)(0.61)y - [(1/7)(\$204) + (1/7x)^{0.5}(\$674) + (1/7x)^{0.5}(\$727)] \quad (2)$$

Equation (2) is used to examine how net income per head from only the finishing period varies with herd size and market value of dressed carcass. Examination of Figure 2 shows that the above $82 per hundredweight of cooled hanging standard-grade carcass, yearling herd size must be at least 300 head to make a profit from the finishing alone. At the above stocking rate of 2 acres per head, the grazed area for finishing yearlings must be at least 600 acres. Herds of 500 and 1,000 head finished on 1,000 and 2,000 acres, respectively, would result in profits of $7.70 and $14.64 per head. Since our yardage cost was excessive compared to several other studies above, Figure 3 was generated with $239 (14.1 acres times $17 per acre) substituted for the figure of $674 in Equation (2). In this case, for the carcass value of $82/cwt, the herd size must be at least 150 head finished on 300 acres to make any profit. Likewise, herds of 300 and 500 finishing on 600 and 1,000 acres, respectively, would generate net incomes of $10.30 and $15-05 per head.

Higher prices for dressed carcass could be obtained by means of niche markets or future change in general consumer preference for pasture-finished beef. As an indication of potential higher prices, values for select- and choice-grade beef have lately ranged from $55 to $70 per hundredweight of liveweight beef, or $92 to $117 per hundredweight of cooled hanging dressed carcass. If we were to receive $100 per hundredweight of carcass, then based on our original yardage cost of $674, a herd of at least 150 head on 300 acres of finishing area would be required to break even (Figure 2). Likewise, based on a perhaps more realistic yardage cost of $239, the herd size must be least roughly 70 head finished on 140 acres to make any profit (Figure 3). A profit of $10 per head would require a herd of roughly 110 head finished on 220 acres.

One-year changes in soil properties. As a check that there was no prior bias in the plots before the experiment, there were no significant differences between the not-yet grazed and ungrazed plots on 15 March 1996 for all soil chemical and physical properties (Tables 3, 4 and 5). Soil samples from grazed and ungrazed plots on 24 April 1997 showed that grazing of cowpeas did not cause any statistically detectable one-year differences in soil chemical or physical properties at any depth (Tables 3, 4 and 5). Measurements of soil respiration did not show greater microbial activity in the grazed plots in terms of respired carbon dioxide (Table 5). It should be noted that the nitrate level at 60-100 cm was almost significantly greater ($p = 0.057$) in grazed plots than in ungrazed plots (Table 4; $p = 0.057$). With the higher level of nitrate in grazed plots at shallower depths in November 1996, this suggests that leaching of nitrate may have occurred during winter. This was certainly possible since the plots were disked in October 1996 and February and April 1997.

The lack of significant differences may have been due to grazing effects that were short-term or small enough to be masked by various random effects during the year. From statistical power analysis, we had expected more detectable one-year differences between grazed and ungrazed plots in the post-grazing soil samples. This does not mean that there were no real grazing effects other than that on nitrate. Instead, the actual grazing effects were simply too small to be declared significant at the 0.05 significance level, even though power analysis prior to the experiment showed that 20 replications should have been enough (see methods). That is, random effects were large enough to mask any real grazing effect. Power analysis does allow us to state how potentially large these grazing effects could have been and still not be detected. This is far more informative than simply saying that an effect does not exist (i.e., was not detectable).

For this significance level and number of replications, there was 87 percent power or probability that the magnitude of the difference for each soil property between the grazed and ungrazed plots could have been as large as one standard deviation for the overall mean of that property (Cohen 1988). For example, the actual grazing effect on Bray (available) phosphorus, or the difference between the phosphorus levels of the grazed and ungrazed plots, could have been as large as one standard deviation or roughly 18 lbs per acre (crudely, the average of 16.5 and 19.6; Table 3). However, various random effects resulted in a measurable difference of only 8 lbs per acre (Table 3), which reduced or masked the potential grazing effect.

There is not sufficient information on ecologically relevant nutrient concentrations from previous research to enable us to determine the biological implications of a grazing effect of 18 lbs of available phosphorus per acre, or for that matter, any of the other nutrients reported in this study. This is the case for essentially all indicators of soil quality (Reganold and Palmer 1995). This argues for more emphasis on biological significance than on statistical significance. Reganold and Palmer (1995) and Yoccoz (1991) provide succinct discussions on this point To assess biological significance, there is clearly need for much more knowledge on ecologically relevant levels for various soil indicators.

While not within the scope of this study, it should be noted that most of the soil chemical and physical properties, when averaged across grazed and ungrazed plots, had significantly greater values in 1997 than in 1996 (Tables 3, 4 and 5). Other studies of soil quality on the Sunshine Farm also showed a general increase in chemical and physical values from 1996 to 1997 (Hinners 1997, Weingartner 1997). However, the values in 1995 were generally not different from those in 1997. In other words, the values dropped in 1996 relative to those in 1995 and 1997. This pattern may have been due mostly to uncontrolled factors each year such as soil sampling by different interns and the time and amount of tillage relative to the dates of soil sampling. This is one example of why a comparison of means for grazing plots from different dates cannot be explained solely in terms of grazing effects (see methods section).

Immediate changes in soil properties. Measurements were also made during August, September and November 1996 to minimize other annual effects relative to grazing. Measurements and statistical analyses for soil nitrate, ammonium and bulk density in August 1996 immediately before grazing were fairly consistent with those in spring 1996 (Tables 3 and 6). That is, there were no significant differences between grazed and ungrazed plots, except for bulk density at 15-60 cm depth (Table 6). Since no differences were expected between the ungrazed and not-yet grazed plots, the difference in bulk density at this depth may have been due to the expression of spatial field variation for this property in the means based on a low number of samples (n = 5). That is, a much larger number of samples presumably would have averaged out any large variation in this soil property.

Measurements in September and November 1996 soon after grazing found significant effects for nitrate levels and for bulk density. Grazed plots had significantly more nitrate than ungrazed plots at 0-15 and 15-60 cm depths (Table 6). This may have been due to more mineralization of nitrogen in the manure and urine dropped on the grazed plots or to stimulation of nitrogen fixation in cowpeas by grazing. Grazed plots also had greater bulk density than ungrazed plots, most likely due to compaction of the soil by the cattle (Table 7). It is well known that intensive grazing can compact soil (Warren et al. 1986, Worrell et al. 1992, Trimble and Mendel 1995). After the plots were disked on 18 October, measurement of bulk density on 4 November 1996 showed that disking had eliminated the soil compaction in the grazed plots relative to the ungrazed plots (Table 6).

Also soon after grazing, water infiltration rate was found to be greater in the grazed than in the ungrazed plots (Table 7). However, with the ungrazed plots having less soil compaction (Table 7), we would have expected the ungrazed plots to have the greater infiltration rate instead, as reported by other studies (Branson et al. 1972, Gifford and Hawkins 1978). Casual observation and immediately subsequent measurement revealed greater water content in the ungrazed plots (Table 7), perhaps due to the greater shading by the more abundant cowpea cover on the ungrazed plots compared to the grazed plots. Two rounds of rotational grazing removed almost all of the cowpea cover in the grazed plots. It was possible that the greater soil water content of the ungrazed plots was impeding the infiltration rate.

In response to this observation, an analysis of covariance was performed on infiltration rate with antecedent water content as the covariate. This adjusted the infiltration rates to reflect rates that would have been measured on grazed and ungrazed plots with the same soil moisture content. The difference in adjusted infiltration rates between and ungrazed plots was not significant (Table 7). This provides some explanation as to why the ungrazed plots did not have the greater infiltration rate. However, it also possible that despite the greater soil compaction in the grazed plots, the disturbance of the soil by the cattle could have created cracks and macropore channels which increased the infiltration rates compared to the ungrazed plots. In summary, the removal of cowpea cover by gazing led to lower antecedent soil moisture despite the greater water infiltration rate in the grazed plots.

## Conclusion

Our partial budget analysis showed that large herd sizes and grazing areas would be required to generate a profit from the beef produced only within our finishing system. It was not surprising since ranchers know intuitively that capital costs of perimeter fencing increase more slowly than herd size as the pasture area is enlarged. The range of net income for these large herd sizes, roughly $5-15 per head, concurs with the $20 profit per head suggested by data from a study on fescue pasture-based finishing in Missouri (Martz et al. 1996). A larger net income would be possible if we could utilize forage crops with a longer duration of finishing to increase the net beef gain per acre.

It was expected that intensive grazing of cowpeas would lead to an immediate increase in surface soil compaction and nitrate level at 0-15 cm depth. Since the cowpeas were disked three times in preparation for the next crop, it was not surprising that both effects did not persist to spring 1997. There was evidence for winter leaching of this nitrate to the 60-100 cm depth. Hence, if benefits for soil fertility are to be gained from cattle grazing on legume cover crops in a crop rotation, then practices must be adopted to reduce fall tillage so that plant cover is maintained on the soil during winter. This is further complicated by the problem that two rounds of rotational grazing removed almost all of the cowpea cover in the grazed plots. This lower cover also exposed the ground to the sun so that it had less soil moisture, which could be a problem for subsequent crops. An alternative would be to plant a winter legume cover crop such as Austrian winter peas that could be grazed in spring and then plowed down prior to a summer crop.

Members of the Farmer Advisory Committee for the Sunshine Farm Project were pleased that our results confirmed their anecdotal observations of cattle grazing on cover crops on their own farms. A member of the Scientific Advisory Committee did inform us that grazing has been known to stimulate nitrogen fixation in legume crops. This experiment was shown to approximately 10 and 20 farmers, respectively at our Farmers' Field Days in August 1996 and 1997. Each year, this study was included in the research tours atibe Land Institute's annual spring Prairie Festival (roughly 200 visitors) and fall Visitors' Day (100).

Beef production in this integrated system has the potential to provide immediate economic value for the use of soil-conserving cover crops which might otherwise require subsidy by government payments to encourage their use. However, more research is needed to verify the profits suggested for the projected herd sizes in this study and to assess the effects of grazing cover crops on soil quality and yields of subsequent grain crops.

Acknowledgment. While conducting research on long-term soil quality at the Sunshine Farm, Land Institute intems Jerry Glover and Laura Weingartner provided valuable assistance in this study. We also thank the Farmer Advisory Committee of the Sunshine Farm Project for their encouragement and critique of this project. This committee is part of the statewide Heartland Sustainable Agriculture Network administered by the Kansas Rural Center as a consortium of local groups of farmers for the purpose of sharing experience in sustainable agriculture.

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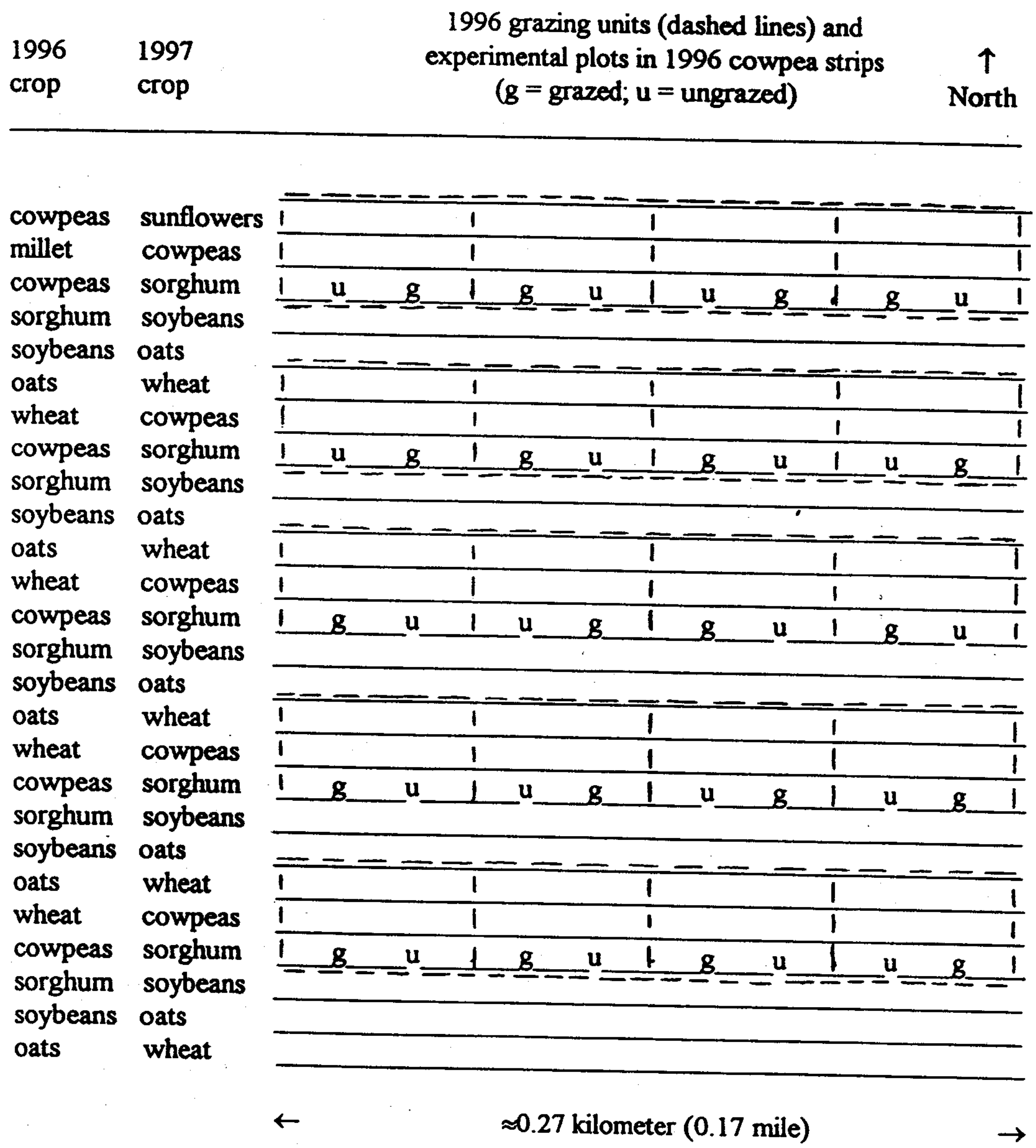
Figure 1. Map of the experimental plots within each grazing unit in 1996 cowpea strips and the 1996 and 1997 crops by strip (not drawn to scale). Although the order of the 5 year crop rotation (1996 and 1997) is grain sorghum, soybeans, oats, wheat and cowpeas, some strips do not fit this rotation because of adjacent experiments on this farm. There are 20 grazing units or replicates. The ungrazed plots will be protected by enclosures. The first treatment within each grazing unit is determined by blind selection of an even (grazed) or odd number (ungrazed) from a table of 10,000 random digits, and the second treatment by default. Strips are 4.1 meters wide (4 rows, 40 inches each).



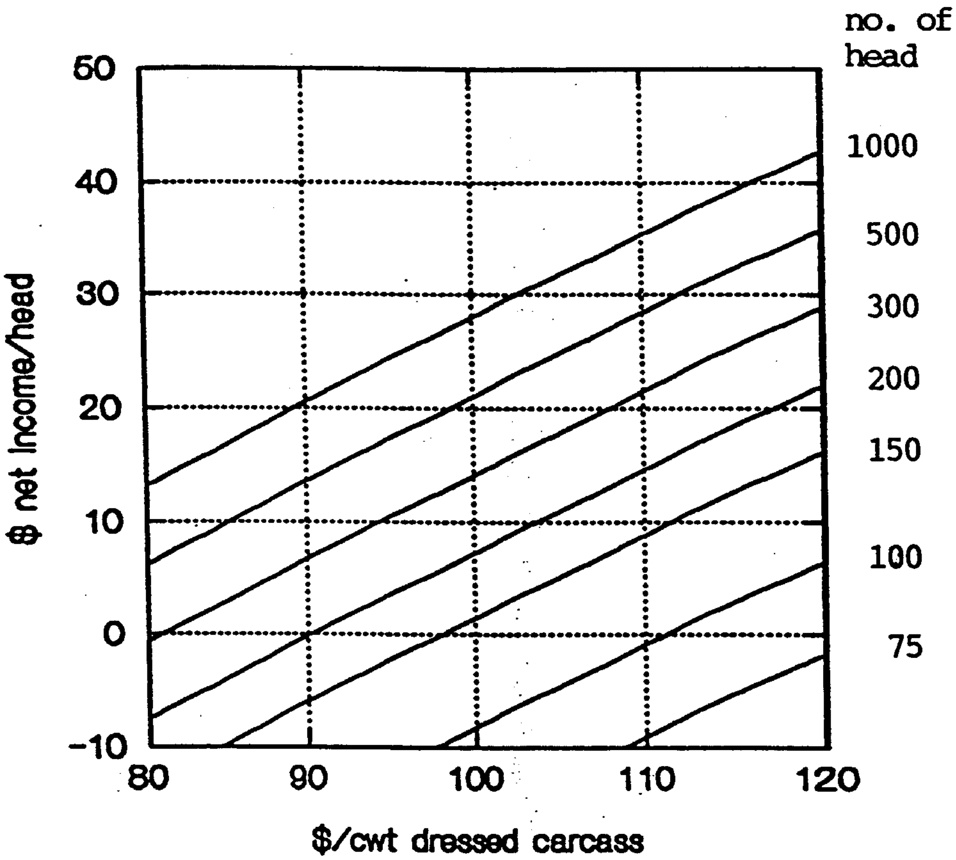



Figure 2. Net income per finished beef yearling according to the value ($) per hundredweight of cooled dressed hanging carcass and the number of yearlings. The increase is based only on the beef gained during finishing (Table 1) and on the costs reported in the partial budget analysis (see Table 2). The graph was generated by means of Equation (2) in the text.

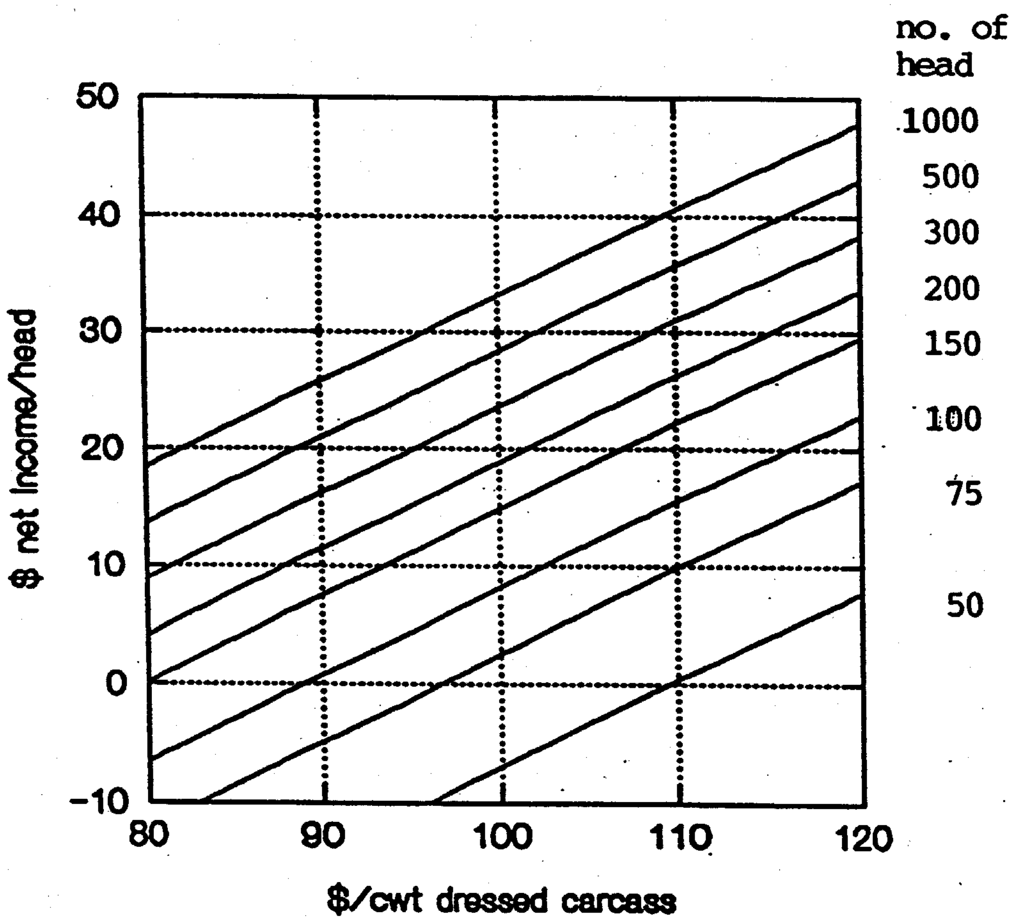



Figure 3. Net income ($) per finished beef yearling according to the value per hundredweight of cooled dressed hanging carcass and the number of yearlings. The increase is based only on the beef gained during finishing (Table 1) and on the costs reported in the partial budget analysis (see Table 2), except that a more efficient yardage cost of $239 was assumed (see text). The graph was generated by means of Equation (2) with the assumed yardage cost (see text).

Table 1. The average weights and daily weight gains between various ages for the 7 Texas longhorn yearlings in the beef finishing project on the Sunshine Farm. The period of finishing was from 08/06/96 to 11/18/96.

| Date | Age (months) | Weight (lbs) | Daily weight gain (lbs) |
|---|---|---|---|
| 03/29/95 | birth | --- | |
| 11/03/95 | 7 | 487 | --- |
| 04/04/96 | 12 | 692 | 1.7 |
| 08/06/96 | 16 | 928 | 1.9 |
| 11/18/96 | 20 | 1,049 | 1.6 |

a) Average dressed carcass was 61 percent.

Table 2. Costs and returns for a partial budget analysis on the finishing of 7 operator-owned Texas longhorn yearlings on 14.1 acres of high TDN (total digestible nutrients) forages in crop strips and small fields on the Sunshine Farm. There was no cost for animals, land opportunity use, forage crop production, feed supplements or veterinary services (see text). There was no change in income for grain crops following grazed forages in the crop rotation because grazing did not have a significant effect on subsequent grain yields (see text).

| Transactions | dollars |
|---|---|
| Costs | |
| yardage | 674 |
| bloat blocks | 204 |
| annual operating interest [a)] | 727 |
| total | 1,605 |
| Returns | |
| Beef from finishing only [b)] | 424 |
| Net income | -1,181 |

a) The investment in fence and water capital, including construction labor and fuel costs, was $6,582 for 24.5 acres of cropland containing some low TDN forages and inaccessible grain crops to be harvested by combine (see text). Since the proportion of the fenced-in area containing high TDN forages was 14.1/24.5, or 0.576, the fence and water investment was prorated by the square root of 0.576, or 0.759 (see text). This gave a cost of $4,996 for assumed fencing and water capital around only the 14.1 acres of high TDN forages, which effectively represents a cropping system efficiently designed for grazing. A 10-year loan with an interest rate of 8 percent and monthly payment was assumed.

b) Based on an average gain of 121 lbs liveweight with a dressed carcass of 61 percent (Table 1). A value of $82 was assumed per hundredweight of cooled hanging standard-grade carcass (Martz et al. 1996).

Table 3. Pre- and postgrazing means (standard deviation, n=20) for soil chemical properties, 0-15 cm depth, from 1996 cowpea (*Vigna sinensis* L.) strips. Soil was collected on 15 March 1996 and 24 April 1997. Cowpeas were planted June 14, 1996 and rotationally grazed by Texas Longhorn yearlings from 27 August through 12 September 1996. For each property, two analyses of variance were performed, one for each year, because the experiment was not a true two-way factorial design (see text). No treatment differences were found to be significant ($p \leq 0.05$). For discussion outside the context of the experiment, a two-way factorial analysis of variance did show the main effect of year to be significant for all properties.

| Year | Treatment | Bray1-P | K | O.M | $NH_4^+$ | $NO_3^-$ | Total N | Total P |
|---|---|---|---|---|---|---|---|---|
| | | lbs/acre | lbs/acre | % | lbs/acre | lbs/acre | lbs/acre | lbs/acre |
| 1996 | grazed | 22.0<br>(10.2) | 748.3<br>(105.0) | 2.5<br>(0.3) | 4.4<br>(1.4) | 7.4<br>(2.3) | 1917.9<br>(237.6) | 612.9<br>(53.7) |
| 1996 | ungrazed | 26.1<br>(15.6) | 772.8<br>(134.5) | 2.6<br>(0.3) | 4.6<br>(1.1) | 8.3<br>(3.3) | 1960.6<br>(216.7) | 630.2<br>(65.5) |
| 1997 | grazed | 30.5<br>(16.5) | 1111.8<br>(165.8) | 2.3<br>(0.3) | 5.2<br>(1.4) | 17.6<br>(4.8) | 2165.4<br>(217.5) | 750.5<br>(59.0) |
| 1997 | ungrazed | 31.7<br>(19.6) | 1120.3<br>(161.2) | 2.3<br>(0.1) | 5.5<br>(1.8) | 18.4<br>(4.4) | 2192.0<br>(269.1) | 744.4<br>(80.1) |

Table 4. Soil bulk density, ammonium ($NH_4$), and nitrate ($NO_3$) means (standard deviation, n=20 for 0-15 cm, n=5 for 15-10(km) by depth for 1996 cowpea *(Vigna sinensis* L.) strips. Soil was sampled on 15 March 1996 and 24 and 28 April 1997. Cowpeas were planted 14 June 1996 and rotationally grazed by Texas Longhom yearlings from 27 August through 12 September 1996. Analyses of variance were performed for each depth separately because differences between depths were not relevant to the experiment and also because of the following reason. For each property, two analyses of variance were performed, one for each year, because the experiment was not a true two-way factorial design (see text). All treatment differences were found to be not significant (p>0.05). For discussion outside the context of the experiment, two-way factorial analyses of variance within each depth did show the main effect of year to be significant for all properties.

| | | Bulk Density (g/cm3) | | $NH_4$ (lbs/acre) | | $NO_3$ (lbs/acre) | | |
|---|---|---|---|---|---|---|---|---|
| Depth | Treatment | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | |
| | grazed | 1.3 | 1.5 | 4.4 | 5.2 | 7.4 | 17.6 | |
| | | (0.1) | (0.1) | (1.4) | (1.4) | (2.3) | (4.7) | |
| 0-15cm | | | | | | | | |
| | ungrazed | 1.3 | 1.5 | 4.6 | 5.5 | 8.3 | 18.4 | |
| | | (0.1) | (0.2) | (1.1) | (1.8) | (3.3) | (4.4) | |
| | grazed | 1.4 | 1.4 | 17.6 | 16.8 | 4.7 | 53.5 | |
| | | (0.1) | (0.2) | (3.6) | (5.5) | (0.9) | (20.4) | |
| 15-60cm | | | | | | | | |
| | ungrazed | | 1.5 | 1.6 | 18.1 | 11.3 | 4.0 | 37.4 |
| | | (0.1) | (0.2) | (5.9) | (2.7) | (0.7) | (4.6) | |
| | grazed | 1.5 | 1.6 | 18.1 | 11.3 | 4.0 | 20.7 | |
| | | (0) | (0.2) | (5.9) | (2.7) | (1.0) | (8.3) | |
| 60-100cm | | | | | | | | |
| | ungrazed | 1.6 | 1.4 | 15.9 | 13.3 | 3.4 | 12.1 | |
| | | (0.1) | (0.2) | (3.2) | (3.3) | (0.9) | (2.4) | |

Table 5. Means (standard deviation, n=20) for water infiltration rate, water holding capacity and soil respiration rate in 1996 cowpea *(Vigna sinensis* L) strips. Infiltration rate is the time required for one inch of water to infiltrate the field soil. Water holding capacity is the gravimetric water content measured 24 hours after field soil was saturated with 5 cm of water. These two properties were measured on 23 April 1996 and 17-18 June 1997. Soil respiration rate is a short-term, *in situ* measurement of carbon dioxide evolution by a closed-chamber method (see text). It was measured during 23 June- 1 July 1997. Cowpeas were planted 14 June 1996 and rotationally grazed by Texas Longhorn yearlings from 27 August to 12 September 1996. For water infiltration rate and water holding capacity, two analyses of variance were performed, one for each year, because the experiment was not a true two-way factorial design (see text). No treatment differences were found to be significant ($p \leq 0.05$).

| | water infiltration rate (sec) | | water holding capacity (g/g) | | soil respiration rate (lbs carbon/acre/day) |
|---|---|---|---|---|---|
| Treatment | 1996 | 1997 | 1996 | 1997 | 1997 |
| grazed | 41.1<br>(30.3) | 2278.7<br>(1570.4) | 0.29<br>(0.3) | 0.28<br>(0.2) | 31.1<br>(18.9) |
| ungrazed | 50.5<br>(36.2) | 2268.8<br>(1967.1) | 0.29<br>(0.2) | 0.28<br>(0.3) | 31.2<br>(25.6) |

Table 6. Pregrazing (7 August 1996) and postgrazing (4 November 1996) means (standard deviation, n=20 for 0-15 cm and n=5 for 15-100 cm) by depth for soil bulk density, ammonium ($NH_4^+$), and nitrate ($NO_3^-$) from 1996 cowpea (*Vigna sinensis* L.) strips. Cowpeas were planted June 14, 1996 and rotationally grazed by Texas Longhorn yearlings from 27 August through 12 September 1996. For each property and within each depth, two analyses of variance were performed, one before and one after grazing, because the experiment was not a true two-way factorial design between date and treatment and because differences between depths were not relevant to the experiment (see text).

| | | Bulk Density ($g/cm^3$) | | | $NH_4^+$ (lbs/acre) | | | $NO_3^-$ (lbs/acre) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | depth (cm) | | | | | | | | |
| Date | Treatment | 0-15 | 15-60 | 60-100 | 0-15 | 15-60 | 60-100 | 0-15 | 15-60 | 60-100 |
| pregrazing | grazed | 1.2 (0.07) | 1.3 (0.05) | 1.3 (0.03) | 4.3 (1.2) | 8.3 (1.7) | 6.7 (1.5) | 9.5 (9.0) | 16.9 (4.8) | 4.9 (1.9) |
| | | | * | | | | | | | |
| | ungrazed | 1.2 (0.10) | 1.2 (0.03) | 1.2 (0.1) | 4.2 (0.8) | 9.1 (3.2) | 6.4 (2.0) | 8.1 (5.5) | 13.3 (9.1) | 6.2 (0.6) |
| postgrazing | grazed | 1.0 (0.11) | 1.2 (0.1) | 1.2 (0.05) | 2.8 (1.2) | 5.6 (1.2) | 5.9 (1.4) | 13.6 (6.1) | 15.0 (5.0) | 4.6 (1.9) |
| | | | | | | | | *** | ** | |
| | ungrazed | 1.0 (0.05) | 1.2 (0.03) | 1.2 (0.03) | 2.9 (1.4) | 8.6 (4.2) | 6.3 (3.5) | 7.6 (2.3) | 8.8 (4.7) | 4.8 (1.6) |

*, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.0001$. All other treatment differences were not significant ($p > 0.05$).

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Table 7. Postgrazing means (standard deviation, n=20) of soil bulk density(0-15cm), water infiltration rate and antecedent volumetric water content (0-7.5 cm) in 1996 cowpea *(Vigna sinensis* L.) strips. Soil was collected on 7 October 1996. Cowpeas were planted June 14 and grazed by Texas Longhorn yearlings 27 August through 12 September 1996.

| Treatment | Bulk Density[1] ($gm/cm^3$) | Infiltration Rate (cm/min) | Adj. Infiltration Rate[2] (cm/min) | Volumetric Water Content[3] (cm/cm) |
|---|---|---|---|---|
| grazed | 1.29 (±0.04) | 0.024 (±0.020) | 0.017 | 0.23 (±0.02) |
| ungrazed | 1.24 (±0.04) | 0.010 (±0.015) | 0.013 | 0.25 (±0.03) |
| Analysis of Variance | *** | ** | NS | * |

By F-test: NS, nonsignificant; *, $p<0.05$; **, $p<0.01$; ***, $p<0.001$.

[1] These measurements were taken on 23 September 1996.

[2] By Analysis of Covariance (SYSTAT 1992); slopes were homogeneous as required for valid analysis; adjusted infiltration rate with volumetric water content as covariate.

[3] Measurements of antecedent soil moisture conditions at same time and place of water infiltration measurements.