Grazing Alternatives in the Face of Declining Groundwater: A Case from the Southern High Plains of Texas

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ABSTRACT

In the Southern High Plains of Texas, current agricultural production primarily consists of cotton and grain production. However, with the depletion of the Ogallala aquifer and rising energy costs, other production systems are being considered. This study analyzed grazing scenarios with stocker steers grazing WW-B. Dahl bluestem pastures. The economic analysis included net returns from gain of grazing steers as a function of irrigation and fertilizer. The highest returns were obtained when nitrogen fertilizer was applied on dryland WW-B. Dahl pasture.

Key Words: irrigation, grazing steers, WW-B. Dahl bluestem

INTRODUCTION

Agriculture is the predominant industry in the Southern High Plains of Texas (SHPT). The total annual business effect of crop and cattle production in the region is $3.44 billion and $6.27 billion, respectively (HPUWCD1, 2004) , with beef cattle and cotton being the leading agricultural enterprises. Despite limited rainfall in the SHPT, cotton production boomed with the introduction of irrigation technology in the 1940's. In 2004, the region produced 3.4 million bales of cotton representing 15% of United States production (USDA-NASS, 2005a, 2005b). While only 37% of the region's cropland is irrigated, 75% of the value of major crop production came from irrigated land.

Agriculture production in the SHPT is largely supported by irrigation from the Ogallala Aquifer, with 95% of water pumped from the aquifer being used for irrigation. The average decrease in saturated thickness as a measure of depletion of the Ogallala Aquifer from 1996 to 2006 was 0.25 meters per year (HPUWCD1, 2006). Research has been conducted to develop more efficient irrigation methods; however, these improvements in efficiency may not lead to improved conservation. The best opportunities for water conservation lie in the use of improved irrigation systems in tandem with other conservation practices.

Managing cropping systems and water use to extend the life of the aquifer has become the goal of multiple water users and agricultural producers. Integrating cattle management systems into land management programs may provide an opportunity for farmers to improve water conservation and maintain profitability (Allen, et al., 2005; Krall and Schuman, 1996). Incorporating a stocker steer system into a cropping system would decrease water and chemical use while also decreasing variable costs. Many grass cultivars require fewer inputs than crops, such as water, fertilizer, and pesticides, to generate sustainable production. Sustainability in this case is defined as generating profitability without depleting resources. Also, stocker steer management systems do not require the extensive investment in equipment and maintenance associated with large-scale crop production. The SHPT was originally grassland and is well suited to stocker steer grazing. With better adapted cultivars of bluestem grasses in a stocker steer operation, producers could achieve higher yields than with native grass cultivars.

With the need to conserve water and maintain profitability, farmers in the SHPT are considering alternative management systems. One possible alternative is to graze stocker steers on improved grass cultivars. WW-B. Dahl (formally WW-857 and, scientifically, *Bothrichloa bladhii (RETZ.), S.T. BLAKE*) is a potential cultivar well adapted to the SHPT; however, information on the profitability of stocker steers grazing WW-B. Dahl bluestem is scarce. The purpose of this study was to determine the economic response of stocker steers grazing WW-B. Dahl bluestem using various levels of irrigation and nitrogen fertilization.

Specific objectives were to:

1. Develop an economic analysis of total stocker steer gains per hectare in response to grazing WW-B. Dahl bluestem.
2. Develop an economic analysis of total stocker steer gains per hectare in response to nitrogen fertilization and applied irrigation on WW-B. Dahl bluestem.
3. Develop an economic analysis of total stocker steer gains per hectare in response to starting weight when grazing WW-B. Dahl bluestem.

Old World Bluestem Varieties

Old World bluestems were first introduced to the United States because of their ability to produce a greater quantity of forage than native varieties. They have proven to be responsive to fertilization, tolerant of drought and cold, able to withstand close grazing, and palatable to cattle (Redfearn, 2004). WW-B. Dahl was native to India and Pakistan and selected for palatability, production, and later maturation by the Southern Plains Range Research Station in Woodward, Oklahoma, as a superior Old World bluestem strain worthy of release in central and southern Texas. Its lower winter hardiness makes it more suitable for the warmer climate of those regions (Bell and Caudle, 1994; U.S. Department of Agriculture-Agriculture Research Service, 1994). WW-B. Dahl is a warm-season, perennial bunchgrass of dark green foliage with basal and broader cauline leaves than other Old World bluestem strains. At maturity the cauline leaves measure 5-10 mm wide and 25-50 cm long with an average foliage height of 0.70-0.90 m. WW-B. Dahl reproduces asexually (apomictic reproduction), preventing mixing with other strains.

Selected Research of Management of Old World Bluestem

Old World bluestems have shown production ranges from 1,350-11,000 kg of forage per hectare (ha) per year depending on the management techniques used and the surrounding environment. In previous studies, forage production has been known to drastically drop if needed nutrients are not available. Old World bluestems may require nitrogen fertilization to reach optimal forage quality and yield. Some studies show that applying nitrogen increased yields by 20-50 kg of forage per kg of nitrogen fertilizer applied. With 65-90 kg of nitrogen per ha, it is reasonable to expect 4,500-6,700 kg of forage per ha on fertile soils. In addition, nitrogen has been shown to improve crude protein content by 2-5%. Phosphorus fertilization on low phosphorus soils has resulted in a 10-70% increase in forage production (Berg, Dewald, and Sims, 1996; Bell and Caudle, 1994; Redfearn, 2004; Roberts, 2004).

Forage quality is important for daily gains in cattle. All released Old World bluestem varieties are similar in forage quality; however, the digestibility percentage ranges from 50-60% and crude protein from 4-13%. Forage quality is highest from May through June when the plant is growing. From May to July, Old World bluestems meet or exceed cattle nutrient requirements for animal growth. From July to August, they offer higher quality forage than many other grasses. However, native range has been preferred for wintering cattle (Bell and Caudle, 1994; Redfearn, 2004; Roberts, 2004).

By using proper establishment and management practices, summer and winter cattle grazing is usually acceptable. The recommended stocking rate for year-round grazing is 0.7-1.2 ha per yearling steer with gains ranging from 0.1-0.2 kg per day from December-March and 0.5-1.0 kg per day from April-September. However, studies have shown cattle gains can be significantly increased by increasing forage quality and yields. Increased forage quality is obtained with the proper amounts of water, fertilizer, temperature, and soil nutrients (Berg, Dewald, and Sims, 1996; Bell and Caudle, 1994; Redfearn, 2004, Roberts, 2004).

Research on weight gain response of cattle within a WW-B. Dahl grazing system includes irrigation and grazing systems effects, whole cottonseed and corn supplementation effects, biuret and urea protein supplementation effects, and irrigation level effects (Villalobos, et al., 2000; Bezanilla and Villalobos, 2000; Villalobos, et al., 2002; Ortega-Ochoa and Villalobos, 2003). A study by Benzanilla (2002) derived a production function for stocker steer gains at various levels of nitrogen and irrigation application. The results indicated that WW-B. Dahl was productive with or without irrigation and that irrigation increased average daily gain.

METHODS

Data

Two panel data sets for WW-B. Dahl bluestem forage production and quality were obtained from previous work at the Texas Tech University research farm in Lubbock County, Texas (33º.45'N, 101º.47'W), from 2001 to 2003 on Pullman soil (0-1% slope). The first data set was from a study which captured the effect of irrigation and nitrogen on the WW-B. Dahl bluestem forage and quality (Philipp, 2004). In Philipp's study, clippings were taken in July and October and analyzed for accumulated forage mass and quality. Various irrigation amounts were used (0%, 33%, 66%, and 100% of potential evapotranspiration (PET)) within each year while various nitrogen levels were used from 2001 to 2003. The second data set was similar to the first and was collected from 2001 to 2003 by Duch (2005) to study the effect of multiple cuttings on WW-B. Dahl for forage production and quality. Seventy-two kg of nitrogen were applied in

August each year of the study. A different plot was cut each month from May to September with second cuttings in October for all plots. The Philipp and Duch panel data sets were combined to provide 103 observations for forage quantity and 81 observations for forage quality. Philipp's data included 73 observations for quantity and 64 for quality. Duch's data provided 31 quantity and 17 quality observations.

Profit Maximization with Two Variable Inputs

Equation (1) specifies profit from stocker steer production subject to the production function, $Y=f(X_1, X_2)$,

(1) $\pi = P_Y Y - C = P_Y Y - R_1 X_1 - R_2 X_2 - b$,

where π represents profit and is equal to unit selling price (P_Y) multiplied by the amount of output minus the total cost (C). Furthermore, C is equal to the input price per unit for each input 1 and 2 (R_1 and R_2) multiplied by the number of units of inputs used (X_1 and X_2) plus total fixed costs (b). This leads to the final profit equation in which the production function (constraint) is substituted for Y. In this study, the two variables are irrigation and nitrogen fertilizer.

In the case of two different production functions that are one-product-two-factor production functions, one function can be created if the final product, (Y_2), is a function of the first product (Y_1). In this study, forage production is represented by Y_1 and beef production is represented by Y_2. These relationships are exhibited in the equations below.

(2) $Y_1= f(X_1, X_2)$,

(3) $Y_2= f(Y_1)$,

(4) therefore, $Y_2 = f[Y_1\, f\,(X_1, X_2)] = f(X_1, X_2)$.

The profit equation would be expressed as equation 1. To obtain profit maximizing factor levels, equations 1 and 4 must be simultaneously solved for X_1 and X_2 as functions of prices. The first order condition is

(5) $(\partial\pi /\partial X_1) = P_Y (\partial Y /\partial X_1) - R_{X1} = 0$, and

(6) $(\partial\pi /\partial X_2) = P_Y (\partial Y /\partial X_2) - R_{X2} = 0$.

Therefore,

(7) $P_Y = R_{X1} / (\partial Y /\partial X_1) = R_{X2} / (\partial Y /\partial X_2)$.

Then the rate of technical substitution (RTS) can be set equal to the ratio of marginal factor costs of X_1 and X_2 ($MFC_{x1,\, x2}$)

(8) $(\partial Y /\partial X_1) /(\partial Y /\partial X_2) = R_{X1}/ R_{X2}$.

At the point where RTS equals MFC, profit maximization occurs because the difference between total revenue and total cost is greatest. If the RTS is greater than the inverse MFC ratio, then more inputs could be used to increase total revenue at a faster rate than the increase in total cost. After this point, the RTS is less than the inverse MFC ratio, meaning that the marginal cost is more than the marginal profit.

Sensitivity analysis can show the response of returns above variable costs to selling price, yields, variable input use, and costs. The gross margin sensitivity equation is

(9) $GM = (\overline{P}_G * SSG) - (N * \overline{C}_N) - (I * \overline{C}_I) - VC$

where GM represents gross margin (returns above variable costs), SSG represents total stocker steer gains in kg (the production function), $\overline{P}_G$ represents the price of gain in dollars per kg, N represents the amount of nitrogen applied in kg, $\overline{C}_N$ represents the price of nitrogen per kg, I represents the amount of irrigation applied in mm, $\overline{C}_I$ represents the cost of irrigation per mm, and VC represents other variable costs.

Table 1. Returns Above Variable Costs (Best Case Scenario).

Fixed Variables		
$/kg gain	0.79	$/kg
Cattle Weight	181	kg
Nitrogen Amount		kg
Nitrogen Cost	0.44	$/kg
Irrigation Amount		mm ha
Irrigation Cost	0.51	$/mm ha
Other Costs	9.32	$/ha

	Nitrogen (kg)							
IRR (mm)	0	20	40	60	80	100	120	140
0	148.0	172.3	196.7	221.0	245.4	269.7	294.1	318.4
20	128.0	154.5	180.9	207.4	233.9	260.4	286.9	313.3
40	108.0	136.6	165.2	193.8	222.4	251.0	279.7	308.3
60	88.0	118.7	149.5	180.2	211.0	241.7	272.5	303.2
80	68.0	100.9	133.7	166.6	199.5	232.4	265.3	298.1
100	48.0	83.0	118.0	153.0	188.0	223.0	258.1	293.1
120	28.0	65.1	102.3	139.4	176.6	213.7	250.8	288.0
140	8.0	47.3	86.5	125.8	165.1	204.4	243.6	282.9
160	-12.0	29.4	70.8	112.2	153.6	195.0	236.4	277.9
180	-32.0	11.5	55.1	98.6	142.2	185.7	229.2	272.8
200	-52.0	-6.4	39.3	85.0	130.7	176.4	222.0	267.7

RESULTS

The production functions for stocker steer gain from May to July for three stocker steer starting weights, 181 kg, 227 kg, and 272 kg, are estimated to be

(10) $\text{Total Steer Gain}_{181\text{ kg}} = 199.1229+(0.02524{*}I)+(2.097876{*}N)+(0.00675{*}IN)$
(56.86) (0.85) (50.11) (19.08)

(11) $\text{Total Steer Gain}_{227\text{ kg}} = 169.3788+(0.075906{*}I)+(2.035336{*}N)+(0.00556{*}IN)$
(42.08) (2.23) (42.30) (13.67)

$$\text{(12)} \quad \text{Total Steer Gain}_{272\ kg} = \underset{(33.52)}{145.2936} + \underset{(3.30)}{(0.120988*I)} + \underset{(38.54)}{(1.996929*N)} + \underset{(10.79)}{(0.004724*IN)}$$

For a pasture lease, the price per kilogram of stocker steer gain ranges from \$0.44 to 0.79 per kg of gain (Johnson, 2005). The cost of nitrogen ranges from \$0.44 to 0.88 per kg (Bronson, Boman, and Segarra, 2005). Irrigation repair and maintenance variable costs are estimated at \$0.08 per mm ha (Smith and Yates, 2005). Energy cost for irrigation is \$0.51 per mm ha using electricity and \$0.97 per mm ha using natural gas. This energy cost is based on a 90-meter lift and a system pressure of 2.1 kg/cm (HPUWCD1, 2005). The other variable costs held constant through the analysis include phosphorus fertilizer at \$6.03 per ha with an application cost of \$3.29 per ha. For a profit sensitivity analysis, annual fixed costs are fencing at \$2.47 per ha, land at \$98.84 per ha, and irrigation system at \$74.13 per ha (Schuster, et al, 2001; Segarra, 2004; Smith and Yates, 2005).

In Table 1, with other variable costs fixed, returns above variable costs for nitrogen fertilization and applied irrigation are maximized. In this best case scenario, the price per kg of gain is \$0.79 and initial stocker steer weight is 181 kg, giving the highest revenue possible. Nitrogen and irrigation costs of \$0.44 and \$0.51, respectively, are reduced to the lowest levels. In cases where irrigation is heavily applied with a low nitrogen application, the costs of production are higher than the revenue. For instance, when applying 200 mm of water and 0 kg of nitrogen, the producer has a return above variable costs of -\$52.03 per ha. With other variable costs fixed, the producer's returns above variable cost were maximized at \$318.41 per ha with 0 mm of applied irrigation and 140 kg of nitrogen fertilization. In this study, average rainfall of 246.7 mm over the growing season is assumed.

Table 2 illustrates the returns above variable costs in a worst case scenario with the lowest \$/kg gain, high levels of nitrogen fertilization and low levels of applied irrigation are preferred. The table indicates that even with nitrogen fertilization prices at \$0.88 per kg, the returns from increased gains per ha due to the nitrogen fertilization outweighed the cost.

Table 3 is a sensitivity analysis illustrating the marginal change in returns above variable costs due to an increase in price per kg of stocker steer gain and cost of nitrogen fertilization. As shown in Table 3 with a steer weight of 181 kg, a \$0.05 increase in price per kg of gain causes an increase of \$24.64 per ha in returns above variable costs. A \$0.09 increase in nitrogen fertilizer cost decreases returns above variable costs by \$12.32 per ha.

Table 2. Returns Above Variable Costs (Worst Case Scenario).

Fixed Variables		
$/kg gain	0.44	$/kg
Cattle Weight	181	kg
Nitrogen Amount		kg
Nitrogen Cost	0.88	$/kg
Irrigation Amount		mm ha
Irrigation Cost	0.97	$/mm ha
Other Costs	9.32	$/ha

	Nitrogen (kg)							
IRR (mm)	0	20	40	60	80	100	120	140
0	78.3	79.2	80.0	80.9	81.7	82.6	83.5	84.3
20	39.7	41.8	43.8	45.9	47.9	50.0	52.0	54.1
40	1.1	4.4	7.6	10.8	14.1	17.3	20.6	23.8
60	-37.4	-33.0	-28.6	-24.2	-19.7	-15.3	-10.9	-6.5
80	-76.0	-70.4	-64.8	-59.2	-53.6	-48.0	-42.3	-36.7
100	-114.6	-107.8	-101.0	-94.2	-87.1	-80.6	-73.8	-67.0
120	-153.2	-145.2	-137.2	-129.2	-121.2	-113.2	-105.2	-97.3
140	-191.8	-182.6	-173.4	-164.2	-155.1	-145.9	-136.7	-127.5
160	-230.3	-220.0	-209.6	-199.2	-188.9	-178.5	-168.1	-157.8
180	-268.9	-257.4	-245.8	-234.3	-222.7	-211.1	-199.6	-188.0
200	-307.5	-294.8	-282.0	-269.3	-256.5	-243.8	-231.0	-218.3

Table 4 shows the effects of marginal changes in returns above variable costs due to an increase in the price per kg gain and cost of applied irrigation. The marginal change in returns above variable costs from a $0.05 change in price per kg gain is $28.52 per ha while the marginal change in returns above variable cost for a $0.09 change in the cost of applied irrigation is $14.72 per ha. Again, the price per kg gain has a larger effect on profitability than do input prices. However, input usage is within the producer's control while input and output prices are generally not.

Table 5 displays the marginal change in returns above variable costs as nitrogen fertilization and applied irrigation costs increase. For input levels of 181 kg steers, 140 kg per ha of nitrogen, and 80 mm per ha of irrigation, the marginal response for a $0.13 increase in nitrogen fertilizer price is a decrease of $17.64 per ha return above variable costs and for a $0.09 increase in applied irrigation cost, a decrease of $14.72 per ha return above variable costs.

Table 6 shows the impact of initial steer weight on returns. From 181 to 227 kg initial steer weight, the increase of 46 kg will decrease returns above variable costs by $16.94 per ha with cost of gain at $0.44 per kg, and by $30.42 per ha with a cost of gain at $0.79 per kg. From 227 and 272 kg initial steer weight, returns will decrease by $12.96 per ha at $0.44 per kg gain and $23.27 per ha at $0.79 per kg gain. The effect of the price of gain becomes more significant as stocker steer weight increases.

Table 3. Returns Above Variable Costs Comparing Gain ($/kg) and Nitrogen ($/kg).

Fixed Variables		
$/kg Gain		$/kg
Cattle Weight	181	kg
Nitrogen Amount	140	kg
Nitrogen Cost		$/kg
Irrigation Amount	0.00	mm ha
Irrigation Cost	0.51	$/mm ha
Other Costs	9.32	$/ha

	Gain ($/kg)							
N ($/kg)	0.44	0.49	0.54	0.59	0.64	0.69	0.74	0.79
0.44	145.9	170.6	195.2	219.8	244.5	269.1	293.8	318.4
0.48	139.8	164.4	189.0	213.7	238.3	263.0	287.6	312.3
0.53	133.6	158.2	182.9	207.5	232.2	256.8	281.5	306.1
0.57	127.4	152.1	176.7	201.4	226.0	250.7	275.3	299.9
0.62	121.3	145.9	170.6	195.2	219.8	244.5	269.1	293.8
0.66	115.1	139.8	164.4	189.0	213.7	238.3	263.0	287.6
0.70	109.0	133.6	158.2	182.9	207.5	232.2	256.8	281.5
0.75	102.8	127.4	152.1	176.7	201.4	226.0	250.7	275.3
0.79	96.6	121.3	145.9	170.6	195.2	219.9	244.5	269.1
0.84	90.5	115.1	139.8	164.4	189.0	213.7	238.3	263.0
0.88	84.3	109.0	133.6	158.2	182.9	207.5	232.2	256.8

Table 4. Returns Above Variable Costs Comparing Gain ($/kg) and Irrigation ($/mm ha).

Fixed Variables		
$/kg Gain		$/kg
Cattle Weight	181	kg
Nitrogen Amount	140	kg
Nitrogen Cost	0.66	$/kg
Irrigation Amount	80.00	mm ha
Irrigation Cost		$/mm ha
Other Costs	9.32	$/ha

	Gain ($/kg)							
IRR $/mm ha	0.44	0.49	0.54	0.59	0.64	0.69	0.74	0.79
0.51	67.7	96.2	124.7	153.2	181.8	210.3	238.8	267.3
0.56	60.3	88.8	117.4	145.9	174.4	202.9	231.4	260.0
0.60	53.0	81.5	110.0	138.5	167.0	195.6	224.1	252.6
0.65	45.6	74.1	102.6	131.2	159.7	188.2	216.7	245.3
0.69	38.2	66.8	95.3	123.8	152.3	180.8	209.4	237.9
0.74	30.9	59.4	87.9	116.4	145.0	173.5	202.0	230.5
0.79	23.5	52.0	80.6	109.1	137.6	166.1	194.6	223.2
0.83	16.2	44.7	73.2	101.7	130.2	158.8	187.3	215.8
0.88	8.8	37.3	65.8	94.4	122.9	151.4	179.9	208.5
0.92	1.4	30.0	58.5	87.0	115.5	144.0	172.6	201.1
0.97	-5.9	22.6	51.1	79.6	108.2	136.7	165.2	193.7

Table 5. Returns Above Variable Costs Comparing Nitrogen ($/kg) and Irrigation ($/mm ha).

Fixed Variables		
$/kg Gain	0.44	$/kg
Cattle Weight	181	kg
Nitrogen Amount	140	kg
Nitrogen Cost		$/kg
Irrigation Amount	80.00	mm ha
Irrigation Cost		$/mm ha
Other Costs	9.32	$/ha

	Nitrogen ($/kg)							
IRR $/mm ha	0.44	0.50	0.57	0.63	0.69	0.76	0.82	0.88
0.51	98.5	89.7	80.8	72.0	63.2	54.4	45.6	36.7
0.56	91.1	82.3	73.5	64.7	55.8	47.0	38.2	29.8
0.60	83.8	74.9	66.1	57.3	48.5	39.7	30.8	22.0
0.65	76.4	67.6	58.8	49.9	41.1	32.3	23.5	14.7
0.69	69.0	60.2	51.4	42.6	33.8	24.9	16.1	7.3
0.74	61.7	52.9	44.0	35.2	26.4	17.6	8.8	-0.1
0.79	54.3	45.5	36.7	27.9	19.0	10.2	1.4	-7.4
0.83	47.0	38.1	29.3	20.5	11.7	2.9	-6.0	-14.7
0.88	39.6	30.8	22.0	13.1	4.3	-4.5	-13.3	-22.2
0.92	32.2	23.4	14.6	5.8	-3.1	-11.9	-20.7	-29.5
0.97	24.9	16.1	7.2	-1.6	-10.4	-19.2	-28.1	-36.9

Table 6. Returns Above Variable Costs Comparing Gain ($/kg) and Initial Steer Weight (kg).

Fixed Variables		
$/kg Gain		$/kg
Cattle Weight		kg
Nitrogen Amount	140	kg
Nitrogen Cost	0.66	$/kg
Irrigation Amount	0.00	mm ha
Irrigation Cost	0.51	$/mm ha
Other Costs	9.32	$/ha

	Gain ($/kg)							
Steer Weight (kg)	0.44	0.49	0.54	0.59	0.64	0.69	0.74	0.79
181	115.1	139.8	164.4	189.0	213.7	238.3	263.0	287.6
227	98.2	120.9	143.6	166.3	189.0	211.8	234.5	257.2
272	85.2	106.5	127.7	149.0	170.2	191.4	212.7	233.9

CONCLUSION

Changes in forage mass production and quality resulting from irrigation and nitrogen management have significant implications for stocker steer gains. The amounts and combinations of irrigation water and nitrogen result in different costs which have large effects on stocker profitability. Analysis of input combinations at the different input prices and stocker steer prices provides insight into appropriate management systems for stocker steers grazing WW-B. Dahl grass.

Total stocker steer gains increase with increasing nitrogen and irrigation use. However, the increased gains achieved by high input use often do not outweigh the cost. Nitrogen has a greater impact than irrigation in terms of economic returns from steer gains. This study showed that, with average rainfall during the growing season, grazing WW-B. Dahl pasture under dryland conditions could produce the highest returns over variable costs, especially if used with high levels of nitrogen. The SHPT currently faces increasing pumping lifts and increasing energy costs, making irrigated crop production an expensive and often unprofitable alternative, thus having a dryland pasture and grazing cattle system alternative increases in importance. With irrigation in both May and June, the cost of irrigation outweighs the value of increased steer gains. Conversely, in the sensitivity analysis, nitrogen use had a greater positive effect than irrigation in all scenarios, even when nitrogen prices were high.

Another finding was the importance of selecting cattle at lower starting weights to maximize stocking rates and total gains. Since these lighter cattle have a lower individual dry matter intake, they can be stocked at higher rates on the early high quality grass.

While this study found dryland pasture to be the most profitable with average rainfall during the growing season, irrigation may be necessary in a dry year to maintain an adequate level of plant-available water. Management can be used for nitrogen and irrigation. Small amounts of irrigation at crucial times during the growing season may result in higher returns over variable costs than would dryland production, especially if used with high levels of nitrogen. By applying irrigation only at selected times in the growing season, costs could be reduced so that stocker steer gains could be achieved more economically. Such an analysis was beyond the scope of this study and would provide an avenue for future research.

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