Estimation of the Value of Old World Bluestem and Optimum Grazing Season under Alternative Stocking Rates

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Abstract: The production potential of OWB forage is evaluated under commercial rotational grazing management. The economic value of the forage is determined by the replacement value of the CP and TDN content. The optimal grazing period is determined where the MVP of grazing an additional day is equal to the MFC.

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Introduction

While enabling the rapid increase in production, the expansion of irrigated agriculture in the Texas High Plains has led to the significant depletion of the pre-development water resources available in the southern portion of Ogallala Aquifer. As withdrawal rates exceed recharge rates, the decline of the ground water table is expected to continue leading to the eventual depletion of this finite resource. Currently, the rising pumping costs resulting from declining water levels, increased energy prices, and low commodity prices have forced area farmers to consider shifting from irrigated cropping to either dryland farming or grassland farming. Alternatives like the establishment of improved grasses for grazing purposes are being investigated in order to stabilize and improve farm income.

Over 162 thousand hectares were sown to the warm season introduced grass, Old World Bluestem (OWB), under the Conservation Reserve Program. Since OWB is an introduced grass, many ranchers and cattlemen are not familiar with its production potential and management requirements. Such foraes need to be evaluated from a grazing management point of view to determine the nutritional value and beef-producing potential (Colette et al. 1994). Research on forage productivity, grazing strategies, and plant/animal interaction is needed to optimize the use of forage in beef production. Sims and Dewald (1982) suggest that when beef production from grazing OWB exceeds 150 pounds per acre and 300 pounds per yearling steer during a grazing season, then grazing of these grasses may be practical alternatives to crop production on marginal lands in the southern Great Plains. The qualitative relationship between forage and stocking rate interpreted in an economic context could help to ascertain the potential of old world bluestem as a livestock forage and alternative to dry-land crop production in the High Plains of Texas.

The objectives of this study are: 1) to determine the production potential of OWB under a rotational grazing system in the High Plains of Texas; 2) to evaluate the economic value of OWB, and 3) to determine the optimum grazing period for OWB, based on livestock average daily gain (ADG), given the nutritional quality of the forage.

Methods and Procedures

Study Area

This study involves a commercial grazing trial to evaluate a rotational grazing system at two grazing intensity levels. The trial was conducted in the summer of 1993 on a site located near Conway, Texas, in Carson County approximately 40 km east of Amarillo, Texas, on Interstate 40. This area's climate is cool temperate. Precipitation occurs most frequently from thunderstorms. The average annual rainfall over the 1961-90 period was 49.68 cm (U.S. Weather Bureau Amarillo, TX 1993) with an ambient summer temperature averaging 27.8 ^{o}C. The average speed of the wind is relatively high because of the topography of the area that offers little resistance to the wind. Yearly relative humidity averages 72 percent at 6:00 a.m. and 38 percent at 6:00 p.m. The altitude is 1070 m above sea level.

Project Design

For this grazing study, 130 ha of land sown with OWB was divided into two cells of four paddocks each, to accommodate a summer stocker program at two grazing intensity levels. The high intensity level was established at one animal per 0.4048 ha and the medium intensity level was set at one animal per 0.6071 ha. In the high intensity scenario, 167 heifers grazed on 68.41 ha for a stocking rate of 0.4096 ha per animal. In the medium intensity scenario, 98 heifers grazed on a 61.40 ha cell for a stocking rate of 0.6265 ha per animal.

Data Collection

A short duration grazing management system was used in the study where the livestock were rotated between paddocks every seven days. Therefore, a complete rotation throughout all paddocks was completed every 28 days. Each paddock was grazed for seven days and rested 21-days for regrowth. Individual animal weights were taken every 28 days. Forage samples were taken from one square meter areas on each of four schedules (i.e., pre-grazing samples, post-grazing samples outside cages, samples from caged enclosures after seven days and samples from cages after a 112-day period) to measure production, consumption and quality throughout the growing season. In the grazed areas, pre-grazing samples were taken prior to placing the cattle in each paddock to determine the amount and quality of forage available. Post-grazing samples were taken when the cattle were moved to the next paddock to determine the amount and quality of forage remaining after each seven-day grazing period.

The nutritive content of the forage was determined by laboratory analysis using standard chemical analysis procedures (AOAC methods 1975) for dry matter production, crude protein, crude fiber, total digestible nutrients, and digestible energy. The nutritive analyses were used to estimate the availability of nutrients during the growing season. The nutrient availability is calculated as the amount available prior to grazing plus the growth during the grazing period minus the residual amount after grazing.

To determine net revenues under different stocking rates, average prices of stocker heifers for different weight classes from May-June for buying and September-October for selling for the period of 1992-1998 were obtained from the USDA publication “Livestock, Meat, Wool Market News, the Weekly Summary and Statistics.”

Procedures for Data Analysis

To evaluate the economic value of OWB to forage producers the value of the forage, based on dry matter, is calculated as a function of the content of CP and TDN. The CP and TDN coefficients are estimated from the prices for alfalfa, barley, corn, cotton seed meal, oats, sorghum, soybean meal 44 (44 % protein), soybean meal HP (51.8 % protein), and wheat. These commodities are commonly used in beef cattle diets. The annual prices of these feeds from 1977 to 1996 were obtained from various issues of Agricultural Statistics (United States Department of Agriculture) and various issues of Feedstuffs. The CP and TDN values of these feeds were obtained from Nutrient Requirements of Beef Cattle (National Research Council 1996). The first order model with two independent variables was chosen as follows:

$$Y_i = \beta_1 (\%CP_i) + \beta_2 (\%TDN_i) + \varepsilon_i \qquad (1)$$

where Y_i = the price of the feed on DM basis,

CP_i = the CP percentage of the ith feedstuff,

TDN_i = the TDN percentage of the ith feedstuff,

ε_i = the error component, and

β_1 and β_2 = the parameters to be estimated.

The absence of the intercept term in the model indicates that the value of DM will be zero when there is no CP or TDN. It was assumed that the value of any feed increases as CP and TDN contents of that feed increase. The General Linear Model procedure of SAS (1990) was used to estimate the parameters of the model. These coefficients are used to determine the value of OWB forage depending on the basis of its CP and TDN contents during each week of the season.

To estimate potential returns from grazing OWB, the following average daily gain (ADG) function is developed to estimate predicted weight gain based on the nutritional quality of the forage.

$$ADG = f\ (DMI, CPP, TDNP) \qquad (2)$$

where ADG = average daily gain (kg/day),

DMI = dry matter intake (kg/day),

CPP = crude protein percentage (%), and

TDNP = total digestible nutrient percentage (%).

The above gain response function uses requirements of dry matter intake, CP, and TDN by heifers and steers depending upon their body weight and expected average daily gain extracted from <u>Nutrient Requirements of Beef Cattle</u> (National Research Council 1976). The estimated coefficients are then used to calculate predicted ADG and total gain from OWB grazing under both the high and the medium stocking rate given the nutritional contents of the forage during each week of the grazing season.

The cumulative gains for each stocking rate are used to estimate a weight gain response function over the growing period with total weight gain as a function of time.

$$GAIN = \beta_0 + \beta_1\ (DAY) + \beta_2\ (DAY^2) + \varepsilon \qquad (3)$$

where GAIN is the cumulative weight gain. The variable DAY is time in days since the last freeze and variable DAY^2 is the square term of DAY. The quadratic term is included because of the assumption that animal weight gain increases at a decreasing rate with respect to time of grazing in the available data range. The model specified is assumed to represent total physical product. Marginal physical products in terms of gain from grazing OWB for both the high stocking rate and the medium stocking rate is calculated by differentiating the equations with respect to time in days. The respective marginal physical products are multiplied by the selling price of beef (live weight basis) to obtain marginal value products. By equating marginal value product to marginal factor cost which is the animal buying price (live weight basis), the optimum number of grazing days related to the optimum gain and return from grazing OWB is estimated. The number of days for various buying and selling price combinations for maximum return at high stocking rate and medium stocking rate is also calculated using the gain equations estimated for OWB forage grazed.

Results and Discussion

Production per hectare of dry matter, total digestible nutrients, and crude protein is based on the laboratory analyses of the forage samples is reconciled with consumption requirements dictated by the weight and rate of gain of the livestock.

Value of Dry Matter in Feedstuffs

The value of dry matter in a feedstuff is based on the crude protein and total digestible nutrient content of the feed. The model is estimated using the composition of the primary feedstuffs utilized in the area. It is estimated without an intercept term based on the assumption that any dry matter without CP and TDN has no monetary value. The estimated model is significant ($P < 0.0001$) and the R^2 value is 0.9714 which indicates that 97.14 percent of the variation in the prices of the feeds has been explained by the independent variables CP and TDN, Table 1. The selected model to determine the value of dry matter (cents/kg) is presented as follows:

$$\text{Value of DM (cents/kg)} = \underset{(27.97)^*}{0.3125\,(CP)} + \underset{(19.07)^*}{0.0858\,(TDN)} \qquad (5)$$

The values in the parenthesis below the coefficients in the Equation 5 above are the t-values for the estimated coefficients. The estimated coefficients were statistically significant ($P < 0.0001$) and different from zero. Both the coefficients have positive sign, as expected indicating that CP and TDN content of a feed has a direct positive relationship with the price of that feed. The value of a feed increases as the CP and TDN contents of that feed increase. A one percent increase in CP content of feed will increase the value of dry matter by 0.3125 cents and one percent increase in TDN content of feed will raise the value of dry matter by 0.0858 cents.

The values of dry matter of OLB available in each grazing period at the high and medium stocking rates are calculated by using equation 5. These values and cumulative values through the season are reported in Table 2. The dry matter available to the high stocking rate represents a value of $125.15 per hectare and the dry matter available to the medium stocking has a value of $76.93 per hectare. These data indicate the increased revenues of grazing OWB forage according to the high stocking rate rather than the medium stocking rate is $48.22 per hectare. However, it is important to understand that the optimum stocking rate should be at the point that does not damage the ranch production and does not increase soil erosion for the coming growing season.

Value of Old World Bluestem to Beef Producers

The objective of most grazing systems is to optimize animal performance and maintain or improve the production potential of the vegetation. Beef producers before putting the livestock on OWB will be interested in knowing the feeding value of herbage grown. Their objective is to produce a level of animal product per hectare that maximizes economic returns. As mentioned earlier, the feeding value of OWB is reduced as the plants mature. Therefore, beef producers are faced with controlling the grazing so as to provide a high yield without sacrificing quality.

Beef producers need to know expected average daily gain, a measure of individual animal performance, by the animals grazing OWB and total gain for the entire grazing season. The total gain is a measure of productivity (animal product) per unit of land area sown with OWB grass. To estimate predicted average daily gain from grazing OWB a model was developed using requirements of dry matter intake, crude protein, and TDN by heifers and steers depending upon their body weight and desired average daily gain. The data were extracted from Nutrient Requirements of Beef Cattle (National Research Council 1976,1984) to estimate this model. The average daily gain (ADG) has been estimated as a function of dry matter intake, crude protein percentage, and TDN percentage. The estimated model is as follows:

$$ADG = - 2.5800 + 0.1104\,(DMI) + 0.1309\,(CP) + 0.0181\,(TDN). \qquad (6)$$

$$\qquad\quad (-25.19)^* \quad (10.84)^* \qquad (7.72)^* \qquad (8.47)^*$$

The estimated coefficients have positive signs as expected. The values in parenthesis below the coefficients are the t-values. All the estimates are statistically significant and different from zero ($P < 0.0001$). The estimated coefficient for dry matter intake (DMI) indicates that an increase in DMI by one kg will increase ADG by 0.1104 kg. An increase in CP and TDN content of feed by one percent will increase ADG by 0.1309 and 0.0181 kg, respectively. The R^2 value for this model was 0.9765 which indicates that 97.65 percent of the variation in the ADG in the beef animals has been explained by the independent variables DMI, CP, and TDN. This model is then used to determine ADG and total gain from OWB grazing under both the high and medium stocking rates when considering nutritional quality of the forage during each week. The gain for each week of grazing and total gain in kilograms at the end of 112 days grazing period for high and medium stocking rates is reported in Table 3. The total weight gain for the high stocking rate is 88.38 kg per hectare over a grazing period of 112 days. The total gain for the medium stocking rate is 84.92 kg per hectare over 112 days of grazing on OWB. Animal productivity from OWB supports the high stocking rate. This is in agreement with Hart et al. (1988), who stated that the rotational grazing systems increase stocking capacity of a pasture while maintaining or improving animal gains, pasture condition, and forage production; and with Heitschmidt and Walker (1983), who suggest that an increase in stocking rate can be possible because of an increase in forage quality in the growing season. Forage quality is improved because live plant tissue has a higher nutritional value than senescent tissue.

Optimal production from grazing OWB is gained when the need of the animals and the production capacity of the pasture when considering its quality are balanced. The response in total animal output per unit land area reflects the yield of forage digestible matter. The harvesting of forage generally increases its nutritive value through inhibition of the maturation process as is evident from the results of this grazing study. The point of maximum forage yield is not identical to that for maximum animal yield because the animal response also depends on the quality of the forage being produced.

Gain and Return Optimization

From the total gains for each stocking rate grazed on OWB, a growth response function over the growing period with total weight gain as a function of time is estimated. In addition to linear estimation the data are also transformed into quadratic, as well as, natural logarithmic forms to identify the best estimation. The estimated equations for the high and medium stocking rates are reported in equations 7 and 8, respectively. The t-values for estimated coefficients are reported in parenthesis below each coefficient. The R^2 for the high stocking is 0.997 and for the medium stocking rate is 0.998. An asterisk on the t value indicates that the coefficient is statistically significant ($P < 0.0001$). These equations are:

High Stocking Rate

$$\text{Total gain} = -43.7170 + 1.2728\,(\text{Day}) - 0.002552\,(\text{Day}^2) \quad (7)$$

$$(-11.95)^* \qquad (15.71)^* \qquad (-6.19)^*$$

Medium Stocking Rate

$$\text{Total gain} = -43.4518 + 1.2840\,(\text{Day}) - 0.002800\,(\text{Day}^2) \quad (8)$$

$$(-15.88)^* \qquad (21.20)^* \qquad (-9.11)^*$$

The estimated coefficients for Day and Day^2 need to be interpreted simultaneously. The signs of these coefficients indicate that total gain increases at a decreasing rate with respect to grazing time. The predicted response curves for each stocking rate are shown in Figure 1. Response curves indicate that the rate of total gain from grazing OWB is greatest for the high stocking rate. The models in equations 7 and 8 indicate that on 100^{th} day of grazing OWB with high and medium stocking rates total gain will be 58.043 kg/ha and 56.9482 kg/ha, respectively.

Equations 7 and 8 estimate total physical product in terms of gain from grazing OWB for the high and medium stocking rates, respectively. The marginal physical products are derived by differentiating these equations with respect to time in days. The respective marginal physical products are then multiplied by the average selling price to obtain marginal value products. By equating marginal value product to marginal factor cost which is the buying price, the number of grazing days that will determine optimum gain from grazing OWB are estimated. The number of days for various buying and selling price combinations for maximum return at high and medium stocking rates, respectively are reported in Tables 4 and 5. These tables may be used as a predictive tool by beef producers to determine the number of days the animals should be placed on OWB forage for grazing to maximize gain and returns at various buying and selling price combinations. For instance, a producer planning to stock animals at the "high" stocking rate, who purchased animals at an average of $1.76/kg and expects to sell the animals at an average of $1.87/kg, should graze the OWB no more than 65 days.

Conclusion

Including OWB for grazing is an economic alternative to cropping systems given the scarce water supplies in the Texas Panhandle. The higher stocking rate had a positive effect on the returns. The value of the forage varies through out the season as the nutrient composition of the forage changes. The value is directly related to the levels of CP and TDN in the forage. A one percent increase in CP increases the value of a kg of dry matter by 0.3125 cents and an increase of one percent in TDN raises the value by 0.0858 cents. Optimum length of grazing depends on the relative purchase and sale prices of the stocker cattle, with optimal seasons ranging from 0 days to 128 days.

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Table 1. Model for estimating the value of old world bluestem forage based on its nutrient contents.

Source	DF	SS	MS	F Value	Pr > F	Estimate	Pr > T	Std Error
CP	1	50921.53	50921.53	6381.14	0.0001	0.3125	0.0001	0.0112
TDN	1	2902.10	2902.10	363.67	0.0001	0.0858	0.0001	0.0045
Error	198	1580.02	7.98					
Total	200	55403.65						

Table 2. Value ($) of available DM and cumulative value ($) through the grazing season of old world bluestem forage grazed at high and medium stocking rates over time.

Date	Value of Available DM		Value of Cumulative DM	
	--------------------------------$/ha-----------------------------			
	High	Medium	High	Medium
June 4	7.83	5.19	7.83	5.19
June 11	6.84	4.74	14.67	9.93
June 19	7.62	5.74	22.30	15.67
June 26	10.11	4.80	32.40	20.47
July 2	7.11	4.96	39.51	25.42
July 9	7.91	4.39	47.42	29.81
July 16	8.21	6.15	55.63	35.96
July 23	11.36	4.34	66.98	40.30
July 30	6.20	4.73	73.19	45.03
August 8	6.86	4.47	80.04	49.50
August 13	7.98	6.28	88.02	55.79
August 20	10.36	4.28	98.38	60.07
August 29	6.28	3.80	104.66	63.86
September 5	5.54	4.12	110.20	67.99
September 12	6.37	5.17	116.57	73.16
September 17	8.58	3.77	**125.15**	**76.93**

Table 3. Weekly predicted animal gain (kg/ha) and total animal gain (kg/ha) through the grazing season of old world bluestem forage grazed at high and medium stocking.

Month and Day	Weekly Gain		Total Gain	
	------------------------------kg/ha------------------------------			
	High	Medium	High	Medium
June 4	9.31	9.20	9.31	9.20
June 11	6.68	5.82	15.99	15.02
June 19	4.83	5.45	20.83	20.47
June 26	4.94	6.91	25.76	27.38
July 2	6.82	7.91	32.58	35.29
July 9	8.57	4.41	41.15	39.70
July 16	5.27	5.56	46.40	45.26
July 23	6.58	5.45	52.98	50.71
July 30	5.29	6.88	58.26	57.59
August 8	6.08	4.63	64.34	62.22
August 13	5.28	5.53	69.62	67.75
August 20	5.19	5.20	74.81	72.95
August 29	4.93	3.54	79.74	76.50
September 5	3.23	3.38	82.97	79.88
September 12	2.48	2.54	85.45	82.41
September 17	2.94	2.51	**88.38**	**84.92**

Table 4. Maximum grazing time in days for different buying and selling price combinations to maximize return from grazing old world bluestem at the high stocking rate.

Sell	**Buying Prices ($/kg)**										
Price	**1.43**	**1.54**	**1.65**	**1.76**	**1.87**	**1.98**	**2.09**	**2.20**	**2.31**	**2.42**	**2.53**
	Maximum Grazing Time in Days										
1.54	67	54	40	26	12						
1.65	80	67	54	40	27	14	1				
1.76	90	78	66	54	41	29	17	5			
1.87	100	88	77	65	54	42	30	19	7		
1.98	108	97	86	75	64	54	43	32	21	10	
2.09	115	105	95	84	74	64	54	43	33	23	12
2.20	122	112	103	93	83	73	63	54	44	34	24
2.31	128	119	110	100	91	82	72	63	54	44	35

Table 5. Maximum grazing time in days for different buying and selling price combinations to maximize return from grazing old world bluestem at the medium stocking rate.

Sell	**Buying Prices ($/kg)**										
Price	**1.43**	**1.54**	**1.65**	**1.76**	**1.87**	**1.98**	**2.09**	**2.20**	**2.31**	**2.42**	**2.53**
	Maximum Grazing Time in Days										
1.54	63	51	38	25	12						
1.65	75	63	51	39	27	15	3				
1.76	84	73	62	51	40	28	17	6			
1.87	93	82	72	61	51	40	30	19	9		
1.98	100	90	80	71	61	51	41	31	21	11	1
2.09	107	98	88	79	70	60	51	41	32	23	13
2.20	113	104	95	86	77	69	60	51	42	33	24
2.31	119	110	102	93	84	76	68	60	51	42	34

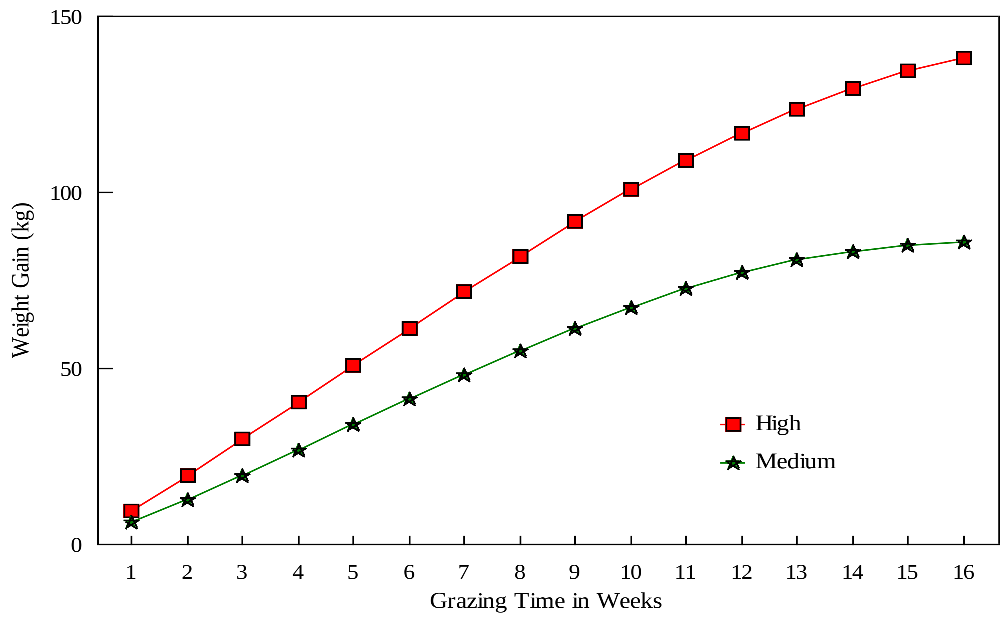

Figure 1. Cumulative weight gain response curves of high and medium stocking rates of old world bluestem grazing for 16 weeks in summer.