

FACTORS INFLUENCING OPTIMAL STOCKING RATES FROM A TENANT PERSPECTIVE

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ABSTRACT

The terms of grazing lease contracts potentially influence a tenant's incentive to preserve the vegetation resource. Annual stocking rate decisions dictate the degree of overgrazing, which can be cumulative over long periods of time. The objective of this study is to identify the impact the tenant's planning horizon and cost structure specified in the lease contract has on his/her profit-maximizing stocking rate. A multi-period, nonlinear programming model was developed to identify economically optimal stocking rates each year over a 24-year period. The model was solved under 1-, 4-, 8-, and 12-year leases on a "per acre" and "per head" basis. The relative importance of each lease alternative and input variable on the tenant's optimal stocking rate was ranked based on standardized ordinary least squares coefficient estimates between input values and optimal stocking rates. Planning horizon and cost structure had a minor impact on optimal stocking rates relative to non-lease factors such as livestock prices and production costs. Holding other factors constant, per acre leases generated a 2% higher average stocking rate than per head leases. Optimal stocking rates were inversely related to the length of the lease. Twelve-year lease agreements generated 18 and 13% lower optimal stocking rates than the 1-year per acre and per head lease agreements, respectively. The optimal stocking rate difference between an 8-year and a 12-year lease was negligible, suggesting the 8-year lease would provide a similar incentive to protect vegetation as a lease with a longer planning horizon.

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INTRODUCTION

Alternative forms of land tenure influence soil and vegetation protection incentives faced by agricultural producers. Overgrazing is a common cause of declining ecological condition on rangeland and pasture (Ellison 1960). Stocking rate, defined as the number of animals on a given land area for a fixed period of time, is the primary decision variable management can use to control overgrazing. Profit-maximizing stocking rates may vary depending on the livestock operator's property rights associated with the land. The terms of grazing leases impact stocking rate incentives by influencing the livestock operator's planning horizon, and/or the cost structure of the grazing enterprise.

Length of the Planning Horizon

The length of the planning horizon often is cited as an important factor in the livestock producer's incentive to stock appropriately (Torell et al. 1991, Workman 1986). A relatively short planning horizon may encourage tenants to overstock and exploit the forage resource for short-term profitability at the expense of long-term pasture productivity. A short-term planning horizon, however, does not guarantee that a tenant will have an incentive to overgraze a pasture. Grazing studies suggest excessive stocking can reduce profitability, even in a single year planning period. For example, Launchbaugh (1957) conducted grazing trials near Hays, Kansas, and found that light stocking rates were more profitable than heavy stocking rates. Shoop and McIlvain (1971) suggest producers who overgraze usually are not behaving in their economic self-interest. Workman (1986) suggests overgrazing is usually a result of ignorance and over-optimistic forage production estimates, and occurs in spite of the profit motive, not because of it.

Several studies estimating the economic optimal stocking rate, however, suggest livestock operators periodically have an incentive to deplete or "mine" the forage. Hart et al. (1988) estimated the profit-maximizing stocking rate near Cheyenne, Wyoming, assuming 1986–1987 price/cost conditions, to be 60 to 80% above the Soil Conservation Service (presently NRCS) recommended level to maintain range condition. Manley et al. (1997) reported that stocking rates higher than the NRCS recommended maintenance level were profitable during favorable cattle price periods. McCollum et al. (1999) found the most profitable stocking rate under continuous grazing in tall-grass prairie exceeded NRCS recommendations.

These studies used single-period models and did not consider the impact of the current stocking rate decision on future forage production. Evaluating stocking rate incentives under alternative forms of land tenure requires a model that considers the decision maker's relevant planning horizon. Dynamic optimization models consider the impact of future pasture productivity and profitability by maximizing the sum of the discounted income stream over the relevant time horizon. Pope and McBryde (1984) used a dynamic opti-

mization model to compare the profitability of systematic overstocking coupled with periodic re-vegetation treatments to maintaining a sustainable stocking rate. Optimal stocking rates approached the biological sustainable level as the planning horizon increased to perpetuity. The grazing strategy that maximized the sum of the discounted cash flow streams was to slightly overgraze and deplete the forage over a 10-year planning horizon.

Torell et al. (1991) compared optimal stocking and forage utilization rates for a single period to an extended planning horizon based on Colorado production data (Sims et al. 1976). Profit-maximizing stocking rates were slightly lower in the dynamic (long-term horizon) model relative to the myopic (single-period) model, but were not high enough in either model to substantially impair forage production. The authors concluded that inter-temporal impacts on forage production were a relatively minor consideration in the current stocking rate decision.

Cost Structure

Economically optimal stocking rates are influenced by the cost and revenue structure of the grazing enterprise (Workman 1986). The grazing lease denomination (per head or per acre lease payments) influences the cost structure of the grazing enterprise, and, consequently, profit-maximizing stocking rates. Cost structure refers to the proportion of total costs categorized as fixed and variable. Fixed costs do not change with the level of production. Examples of typical fixed costs include interest and depreciation. Variable costs change with the level of production. Typical variable costs in a livestock operation include feed or veterinary care.

Lease payments are fixed costs, with respect to stocking rate, when lease contracts specify compensation on a per acre basis. In this situation, lease payments are unrelated to the number of animals stocked on the pasture, as depicted in Figure 1. Tenants operating under this type of lease can reduce unit costs by increasing stocking rates. The value of a fixed cost does not impact the stocking rate decision (Workman 1986).

In contrast, lease payments are a variable cost when the lease calls for compensation on a per head basis. Total lease payments increase as the stocking rate increases (Fig. 1). This implies that lease costs can be lowered by reducing stocking rates. Given diminishing marginal productivity as animals are added to the pasture, optimal stocking rates are reduced as the lease rate increases.

The relationship between optimal stocking rates and cost structure can be demonstrated algebraically and graphically with a simple set of generalized equations. Consider a comparison of alternative profit functions specified as:

$$\pi_1 = TR_1(Q_1) - VC_1(Q_1) - LC_1(Q_1) - FC_1$$

Profit function for the per head lease model; and

$$\pi_2 = TR_2(Q_2) - VC_2(Q_2) - FC_2(LC_2)$$

Profit function for the per acre lease model;

where $TR_1(Q_1) = TR_2(Q_2)$; and $VC_1(Q_1) = VC_2(Q_2)$.

The symbol π represents total profit; while TR, VC, LC, and FC represent total revenue, non-lease variable costs, lease costs, and fixed costs. The letter Q represents quantity of head stocked. The first-order necessary conditions for profit maximization are:

Variable Lease Costs

$$(\partial\pi_1/\partial Q_1) = TR_1'(Q_1) - VC_1'(Q_1) - LC_1'(Q_1) = 0$$

$$TR_1'(Q_1) = VC_1'(Q_1) + LC_1'(Q_1)$$

Fixed Lease Costs

$$(\partial\pi_2/\partial Q_2) = TR_2'(Q_2) - VC_2'(Q_2) - 0 = 0$$

$$TR_2'(Q_2) = VC_2'(Q_2)$$

The economic interpretation of $TR_1'(Q_1)$ is marginal revenue, while $VC_1'(Q_1) + LC_1'(Q_1)$ represents marginal cost for the profit function with a variable cost (per head) lease. The profit-maximizing stocking rate, therefore, occurs where marginal revenue equals marginal cost. Marginal cost in the per acre lease model is simply $VC_2'(Q_2)$. Marginal costs are greater at each level of Q when lease payments are variable costs with respect to number of head. Figure 2 graphically illustrates the effect of cost structure on optimal stocking rates. Greater marginal costs associated with variable lease

payments reduced the optimal stocking rate from Q_1 to Q_2 . This implies per acre leases may encourage tenants to stock heavily relative to per head leases.

OBJECTIVES

The objective of this study is to explore the relationship between alternative lease agreements common to grazing land (Langemeier 1997) and economically optimal stocking rates. Optimal stocking rates were estimated for each grazing season between 1975 and 1998 for each alternative lease agreement given price/cost conditions observed in the relevant year. The relative importance of cattle prices and lease terms in the stocking rate decision were ranked based on standardized regression coefficient estimates.

METHODS

Nonlinear programming models were used to estimate the optimal stocking rate each year over a 24-year period under per acre and per head 1-, 4-, 8-, and 12-year lease agreements. The objective function of each model was specified as follows:

$$(1) \text{Max } \prod_k = \sum_{t=1}^k [HD_t * (OSP_t * OSW_t - MSP_t * MSW_t - VCH_t - LRH_t) / (1+R)^t]$$

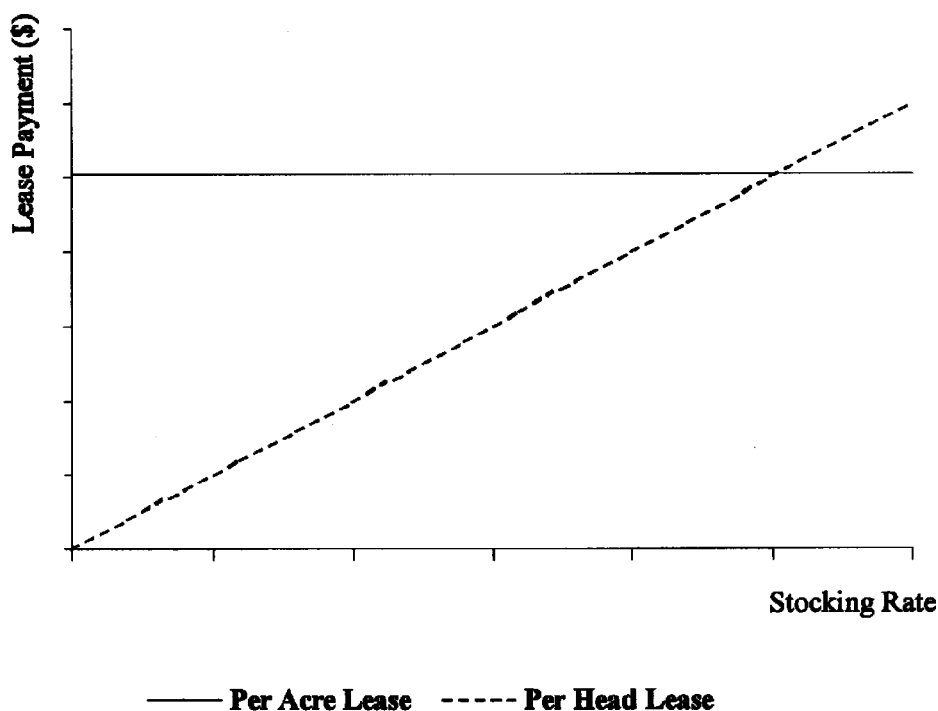


Figure 1. Relationship between stocking rates and total lease payments under per acre and per head lease agreements.

$$(2) \text{ Max } \Pi_k = \sum_{t=1}^k [\{ \text{HD}_t * (\text{OSP}_t * \text{OSW}_t - \text{MSP}_t * \text{MSW}_t - \text{VCH}_t) - \text{LRA}_t * 640 \text{Ac} \} / (1+R)^t]$$

Stocking rates are constrained by the following equations:

$$(3) \text{ OSW}_t = \text{MSW}_t + \text{DOP}_t * \text{ADG}_t$$

$$(4) \text{ ADG}_t = 2.45 - 0.0064 * \text{GP}_t$$

$$(5) \text{ GP}_t = \text{HD}_t * \text{DOP}_t / \text{AF}_t$$

$$(6) \text{ AF}_t = \text{FPC} * \text{HPI}_t$$

$$(7) \text{ HPI}_t = 0.4343 + 0.5824 \text{ HPI}_{t-1} - 0.00136 \text{ GP}_{t-1}$$

Variable names are defined as follows:

Π_k = Cumulative pasture profitability over the length of the lease

k = Length of the lease

HD_t = Number of head per section in year t

MSP_t = May steer price in year t

MSW_t = May steer weight in year t

OSP_t = October steer price projection for year t, made at the beginning of the lease arrangement

OSW_t = October steer weight in year t

VCH_t = Variable cost per head in year t

LRH_t = Lease rate per head in year t

LRA_t = Lease rate per acre in year t

R = Discount rate

DOP_t = Days on pasture in year t

ADG_t = Average daily gain in year t

GP_t = Grazing pressure in year t

AF_t = Available forage in year t

FPC = Forage production capacity

HPI_t = Herbage production index in year t

Equations 1 and 2 represent the objective functions for the per head and per acre lease models, respectively. The decision variable in all models is the number of head stocked on the pasture each year. Equations 3 through 7 express the relationships that limit the optimal stocking rate. MSW_t and DOP_t refer to the May steer weight in year t and the days on pasture in year t. For this paper, the MSW was assumed to be 600 lbs every year, and DOP was 150 days.

Equation 4 represents average daily gain (ADG) in year t. The linear functional form and equation specification was taken from Torell et al. (1991). Coefficient values were recalibrated to match weight gains observed at various stocking rates in the Flint Hills tallgrass region (Smith and Owensby 1978, Launchbaugh and Owensby 1978). A linear relationship between stocking rate and ADG is supported by experimental research (Hart 1972, Jones and Sandland 1974, Hart 1993, Manley et al. 1997).

Figure 3 shows the production function derived from Equation 4. The inverse relationship between stocking rate and per head weight gain limits the economic incentive to overgraze. Maximum weight gain per head at very low stocking rates was approximately 340 lbs over the entire grazing season, representing an ADG of 2.8 lbs. Maximum weight gain per acre was approximately 65 lbs at a stocking rate of 260 head for the grazing season.

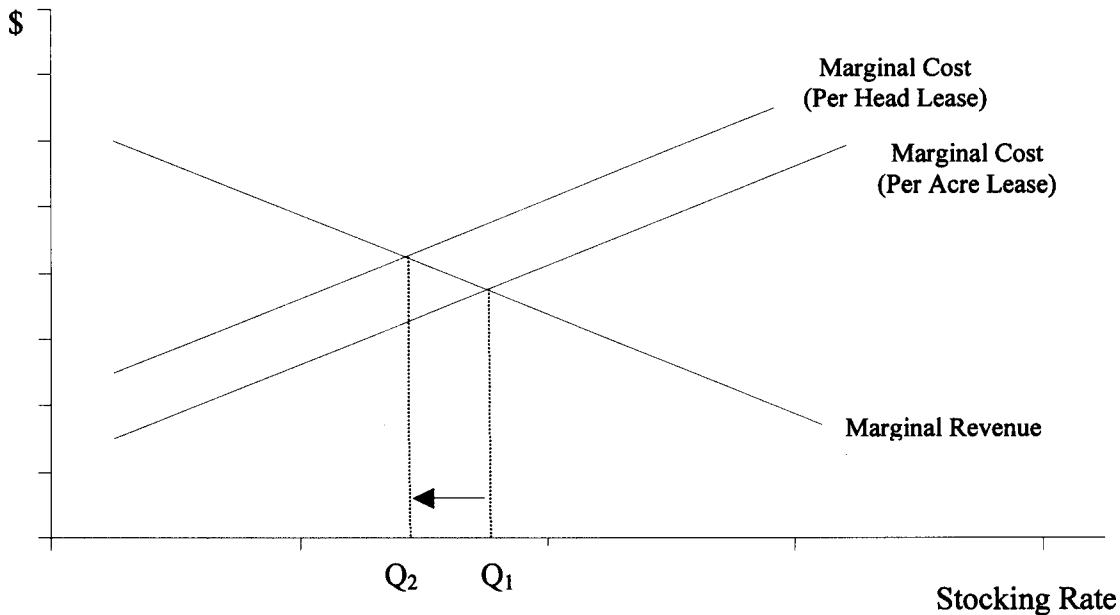


Figure 2. Effect of cost structure on optimal stocking rates.

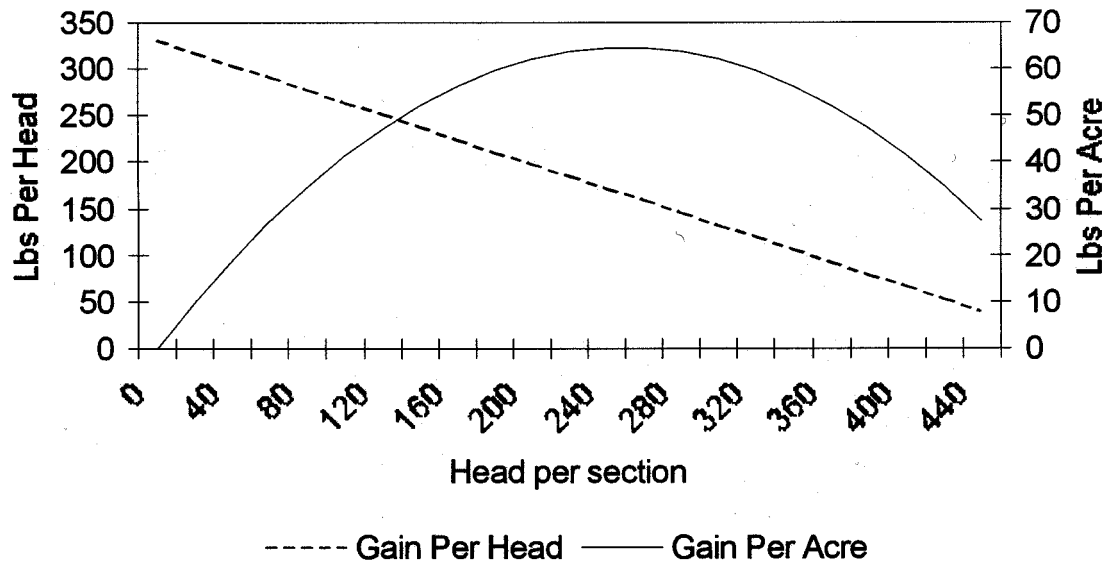


Figure 3. Functional relationship between stocking rate and weight gain on a per head and per acre basis.

Grazing pressure in year t (GP_t), expressed in Equation 5, is defined as stocker days per unit of available standing herbage (Hart et al. 1988). Available forage (AF_t), represented in Equation 6, is a function of pasture forage production capacity (FPC) and the herbage production index in year t (HPI_t). Pasture FPC was exogenously assigned the equivalent of 3,200 lbs per acre (Launchbaugh and Owensby 1978).

HPI_t , expressed in Equation 7, provides a link between past grazing pressure and current forage production. HPI_t values, ranging between zero and one, represent the proportion of FPC available for grazing in year t . The functional form and coefficient values were derived from Torell et al. (1991). HPI_{t-1} and GP_{t-1} represent the herbage production index and grazing pressure in the previous year. Specifying HPI_t as a function of the previous year GP and HPI suggests HPI_t is an implicit function of all past GP levels.

The Models

Lease alternatives investigated in the study were 1-, 4-, 8-, and 12-year per head and per acre agreements. The model solved for annual stocking rate k years at a time without considering impacts on future forage production beyond the length of the lease. Future income was discounted at a rate of 11.5% per year. This rate represents the average operating loan rate over the 24-year study period reported by the Federal Reserve Bank of Kansas City (Various Issues). The lease rate assigned to each term was the average rate observed over the relevant lease period reported by Kansas Agricultural Statistics Service.

Lease payments in the per head scenarios were modeled with a mixed cost structure as depicted in Figure 4. Lease payments were constant until the stocking rate reached a minimum level (point A on the horizontal axis), and then increased linearly as animals were added to the pasture. The stocking rate represented by point A was based on the annual acreage guarantee¹ reported by Kansas Agricultural Statistics Service (Various Issues).

Multi-year leases typically guarantee a minimum annual payment for the duration of the lease, effectively creating a mixed variable/fixed cost structure. Conversely, a lease payment on a 1-year per head contract would theoretically be a pure variable cost. A landlord, however, would unlikely accept a tenant wishing to pay for very few head. Consequently, a tenant would likely face some minimum payment in order to lease the pasture at all, even in a 1-year lease. The minimum lease payment demanded by the landlord depends on the allocation of market power between landlords and tenants. The acreage guarantee observed each year was assumed to be an approximation of the minimum stocking rate dictated by the grazing lease market.

Data Sources

All price and cost data were expressed in nominal dollars. Pasture lease rates were regional historic averages taken from

¹ The acreage guarantee reported by Kansas Agricultural Statistics Service refers to the acres of grass guaranteed per head when lease payments are on a per head basis.

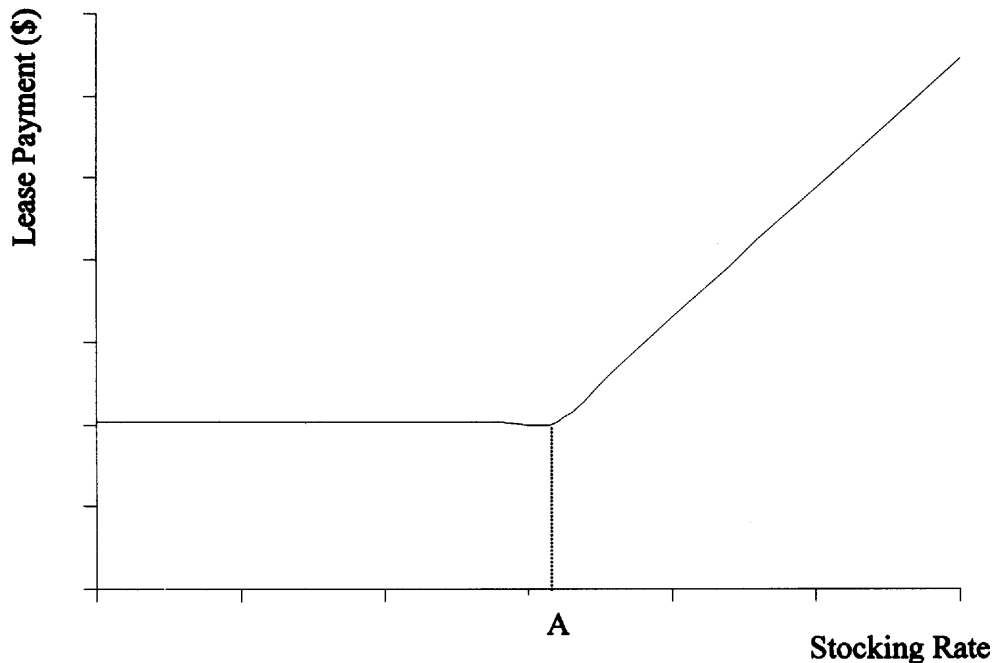


Figure 4. Relationship between stocking rates and total lease payments under per head lease agreements.

the Bluestem Pasture Report (Kansas Agricultural Statistics Service Various Issues).

May and October Dodge City, Kansas, feeder cattle prices from 1975 through 1998 were used to represent incoming and outgoing stocker cattle prices. Price projections for OSP in the 1-year models, and in the first year of the multi-year lease models, were basis adjusted October futures prices observed in May. Price projections for both MSP and OSP for years 2 through k of the multi-year lease models were based on 5-year moving average cash prices. Table 1 shows the method of modeling price expectations over multi-year leases using a 4-year lease agreement as an example. In the first year of the lease, the model was solved for years 1 through 4. In year 2 of the lease, the model was solved for years 2 through 4 based on new price information observed in year 2. In the third year, the model was solved for years 3 and 4, while in the fourth year, the model was solved for year 4. This process allowed the model to allocate the effects of the current stocking rate decision over the relevant planning horizon based on expected long- and short-term cattle prices.

Calf prices typically decrease as the weight of the animal increases. This trend, referred to as the weight price slide, was approximated with a linear interpolation between the 700 and 800 weight prices observed each year. The calf weight price slide, which varies from year to year, typically places upward pressure on optimal stocking rates by favoring lighter animals. The model used the average price slide of \$-0.02/cwt

observed over the study period. For each pound OSW increases, OSP decreases by \$0.02/cwt.

Table 1. Method of modeling price expectations in a 4-year lease agreement.

Decision year	----- Solved for years -----			
	1	2	3	4
1	A	B	B	B
2		A	B	B
3			A	B
4				A

A = The stocking decision was based on the actual observed MSP, and a basis adjusted futures price for OSP.

B = The stocking decision was based on 5-year moving average cash prices for both MSP and OSP.

Operating costs included in the model are normally incurred on a per head basis. Operating cost estimates were taken from Kansas summer stocker budgets compiled by Jones and Dhuyvetter (1999), and include interest on purchased livestock, veterinary care, labor, mineral, and miscellaneous costs. A continuous operating cost data series was not available for the relevant time period. Nominal costs, therefore, were assigned to each year by inflating Jones and Dhuyvetter (1999) estimates using the producer price index. Interest on purchased livestock was calculated from operat-

ing loan rates observed each year and reported by the Federal Reserve Bank of Kansas City (Various Issues).

Ranking the Impact of Lease Terms on Optimal Stocking Rates

The relative importance of the grazing lease terms, live-stock prices, and production costs in the stocking rate decision was ranked based on standardized ordinary least squares (OLS) regression coefficients estimated from the models represented in Equations 8 and 9. Standardizing coefficients entails scaling OLS coefficient estimates by the ratio of the standard deviation of the independent variable to the standard deviation of the dependent variable (Pindyck and Rubinfeld 1998). This calculation converts OLS estimates to unit-free coefficients whose absolute magnitudes are directly comparable, revealing the relative impact of the independent variables on the dependent variable. The regression models were specified as follows:

$$(8) HD_t^* = f(\text{LENGTH}_t, \text{DENOM}_t, VC_t, \text{MSP}_t, \text{OSP}_t)$$

$$(9) HPI_t^* = f(\text{LENGTH}_{t-1}, \text{DENOM}_{t-1}, VC_{t-1}, \text{MSP}_{t-1}, \text{OSP}_{t-1})$$

HD_t^* and HPI_t^* denote the optimal HD and HPI level observed in year t . The length of the lease was 1, 4, 8, or 12 years. Lease denomination (DENOM) was a binary variable assigned a value of zero if the lease was specified on a per head basis, and a value of 1 if the lease was specified on a per acre basis. VC_t denoted variable operating costs observed each year, while MSP_t and OSP_t represent May steer price and October steer price, respectively. Since HPI_t is a function of previous year grazing pressure and HPI value, the independent variables in Equation 9 were all lagged one year.

Parametric analysis was used to examine the sensitivity of the model to other input variables that could potentially impact the results. Inter-temporal vegetative condition responses to grazing pressure would potentially influence the relationship between planning horizon and the current stocking rate decision. This relationship was incorporated into the model through Equation 7. The coefficient values in Equation 7 were estimated from data collected in eastern Colorado (Sims et al. 1976). These values may depend on regional growing conditions and, therefore, may not accurately represent eastern Kansas. Parametric analysis was used to identify the sensitivity of the results to changes in the coefficients. Each model was solved after changing coefficient and constant values, one term at a time, to 80 and 120% of the original estimates.

To compare leases with alternative time horizons, future income flows should be discounted to their present value. Discounting places a greater value on income received in the near future relative to the distant future, increasing the incentive to mine the forage. The rate at which future income is discounted may impact the stocking rate decision. The discount rate, however, may not have a significant impact on

optimal stocking rates if price/cost conditions frequently do not favor exceeding the steady state grazing pressure. Sensitivity of average optimal stocking rates to the discount rate was evaluated by solving the models at alternative discount rate values and comparing the results.

RESULTS

Optimal Stocking Rates

Table 2 shows the optimal number of head stocked each year under per head and per acre lease agreements. The average number of steers stocked on the 640 acre pasture in the 1-year per acre lease scenario was 144 head, while the solution for the 4-, 8-, and 12-year lease agreements were 130, 124, and 122, respectively. The per head lease scenario reveals a similar trend. The average number of steers stocked was 136, 131, 123, and 120 head in the 1-, 4-, 8-, and 12-year leases, respectively.

As the length of the lease increased, average optimal stocking density decreased. The largest decrease in the per acre scenario occurred when the lease jumped from one to four years, while the largest jump in the per head scenario occurred between the four and eight year leases. In both per head and per acre leases, the optimal stocking rate difference between 8- and 12-year leases was minimal. Average stock density in the 1-year per acre and per head lease agreements was 22 and 16 head greater than the corresponding 12-year lease agreements. This represents an 18 and 13% difference in optimal stocking rates between the extreme planning horizon scenarios included in the study. Furthermore, there was a large degree of year-to-year variability in optimal stocking rates with all lease arrangements.

The per acre lease agreements generated an average profit-maximizing stocking rate similar to the per head lease agreements. Removing the landlord imposed minimum lease payment, however, substantially reduced the optimal stocking rate in the per head agreement. Solving the 1-year model using a strictly variable per head lease agreement reduced the average optimal stock density to 91 head. This represents a 33 and 37% reduction in average optimal stocking rates relative to the original per head and per acre models. Furthermore, solving the 1-year model based on a strictly variable per head lease generated a lower optimal stocking rate than the long-term leases with a fixed cost component.

Vegetative Conditions

Figures 5 and 6 show the profit-maximizing HPI time path under per acre and per head lease agreements. The 1-year per acre lease maintained an HPI value strictly lower than all other alternatives. A clearly dominant lease strategy does not emerge from the data as the lines cross frequently. In general, the HPI time path is inversely related to the stocking density. Average HPI values, therefore, increased with the length of the lease, but were similar across lease denomination, consis-

Table 2. Optimal number of head stocked in a full-section pasture each year under alternative land tenure arrangements.

Year	Per acre leases				Head per section	Per head leases			
	1-Year	4-Year	8-Year	12-Year		1-Year	4-Year	8-Year	12-Year
1975	218	135	122	122	156	235	203	196	
1976	238	223	215	215	152	62	36	35	
1977	221	221	204	203	152	152	152	152	
1978	137	152	121	120	145	231	145	145	
1979	167	156	173	171	157	108	122	117	
1980	128	110	118	110	139	139	139	139	
1981	160	161	160	142	142	142	142	134	
1982	103	116	119	66	125	145	145	105	
1983	113	68	63	87	125	49	60	70	
1984	147	123	113	135	145	145	145	145	
1985	155	159	144	166	142	107	89	112	
1986	110	125	62	128	119	172	145	181	
1987	106	64	80	59	110	145	145	145	
1988	108	80	88	68	110	128	139	120	
1989	134	123	129	99	135	149	149	139	
1990	109	123	125	70	110	140	144	102	
1991	121	89	85	98	122	56	54	56	
1992	134	104	92	99	134	152	152	152	
1993	112	103	84	87	113	112	81	81	
1994	144	159	127	129	144	98	74	71	
1995	162	131	145	146	149	149	149	149	
1996	141	102	108	109	144	156	156	156	
1997	139	142	145	145	143	117	126	125	
1998	142	161	162	163	141	55	57	57	
Average	144	130	124	122	136	131	123	120	

tent with the stocking rate observations. Mean HPI values were 0.66, 0.73, 0.75, and 0.76 in the 1-, 4-, 8-, and 12-year per acre leases, and 0.71, 0.71, 0.75, and 0.76 in the 1-, 4-, 8-, and 12-year per head leases, respectively.

All land tenure arrangements examined in this study periodically reached optimal grazing intensities that reduced HPI levels. The 1-year per acre lease achieved the lowest HPI value of 0.54 observed in 1982. This index value suggests that economically optimal stocking rates reduced forage production to 54% of its capacity. Lease denomination impact on HPI values appears to decline as the length of the planning horizon increases. Mean HPI values were five percentage points higher in the per head relative to the per acre agreements, but equivalent in the 8- and 12-year leases.

Factors Influencing Optimal Stocking Rates

Coefficient estimates of the dependent variables listed in Equation 8 were statistically significant ($p = 0.05$) except for lease denomination. Figure 7 graphically illustrates the relative importance of cattle prices, production costs, lease denomination, and the planning horizon in the profit-maximizing stocking rate, based on standardized coefficient values from the regression. Cattle prices were the most important

factors influencing optimal stocking rates. Figure 7 suggests that, for each standard deviation livestock purchase and selling prices increase above the mean, optimal stocking rates decrease by 1.327 and increase by 1.169 standard deviations, respectively, from its mean. As expected, variable operating costs were inversely related to stocking rates.

The input variables representing grazing lease terms were the lowest-ranked factors influencing a tenant's optimal stocking rate. Lease denomination was specified as a binary variable with the per head agreement designated as the base. Regression results suggest that holding all other variables constant, per acre leases increased optimal stocking rates by an average of 2 head on the 640-acre pasture. This value was not statistically significant ($p = 0.05$). In addition, the length of the lease had a relatively minor impact on the optimal stocking rate. The standardized coefficient value of -0.176 was statistically significant ($p = 0.05$), but substantially lower than corresponding values for cattle purchase and selling prices. These results suggest expected short-term livestock price/cost margins and the stocking rate weight gain trade-off carry a larger influence on current optimal stocking rates than expectations regarding future forage production.

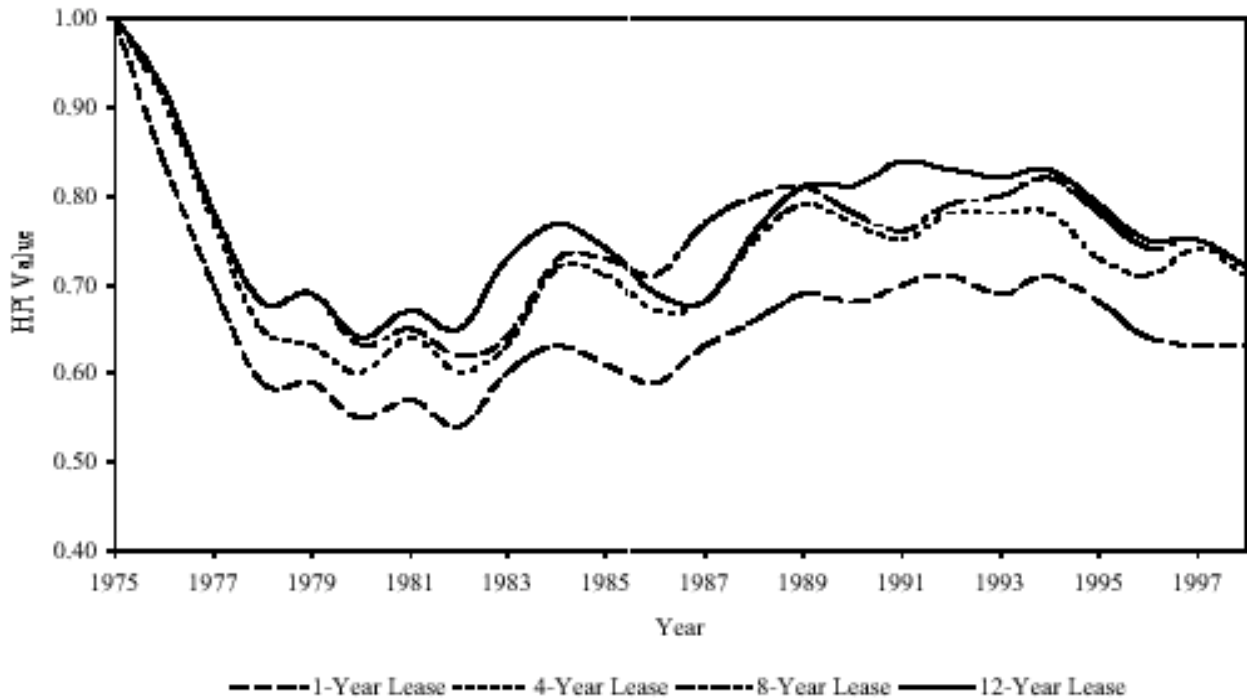


Figure 5. Optimal HPI time path under alternative per acre lease agreements.

Factors Influencing HPI Values

Figure 8 shows the impact of cattle prices and lease terms on estimated HPI values. Since HPI values are inversely related to stocking rate (Equation 5), factors influencing stocking rates could also be expected to influence HPI values. Figure 8 supports this expectation. The ranking was similar to the stocking rate value factors illustrated in Figure 7. The signing of the coefficients, however, was opposite. Expected selling price had the greatest impact on HPI values with a standardized coefficient value of -1.731 , followed by cattle purchase price with a value of 1.498 . Planning horizon and lease denomination carried the lowest impact, with standardized coefficient values of 0.409 and -0.029 , respectively. The coefficient estimate for lease denomination was not statistically significant.

Parametric Analysis Results

The discount rate does not appear to bear a significant influence on the optimal stocking rate. Reducing the discount rate from 11.5 to 6% reduced average optimal stocking density by 1, 2, and 2 head in the 4-, 8-, and 12-year per acre lease agreements, respectively. The discount rate reduction had a similar impact on the per head lease agreement, reducing optimal stock density by 0, 1, and 1 head in the 4-, 8-, and 12-year models, respectively. The discount rate is not a factor in the 1-year lease models. Due to the minimal stocking rate

difference generated by two relatively extreme discount rate values, further investigation into the sensitivity of discount rate changes was not warranted.

Adjusting the coefficient values in Equation 7 affects optimal stocking rates and HPI values, but not the relative importance of lease terms and livestock prices. In all cases, rankings were consistent with Figures 7 and 8. Of the three terms in Equation 7, the coefficient value for HPI_{t-1} had the greatest impact on optimal stocking rates.

DISCUSSION AND CONCLUSIONS

Understanding the interaction between economic incentives and long-term physical impacts on grazing land is an important component of addressing management-induced pasture deterioration. Expected price/cost margins emerged as the most important factors in the stocking rate decision. This result may diminish the opportunity for landlords to indirectly address vegetative condition through the length or denomination of grazing leases. A landlord wishing to maintain a minimum vegetative condition may need to directly specify appropriate stocking rates in the lease.

Planning Horizon

Although livestock prices and operating costs clearly play a dominant role in the stocking rate decision, short-term



Figure 6. Optimal HPI time path under alternative per head lease agreements.

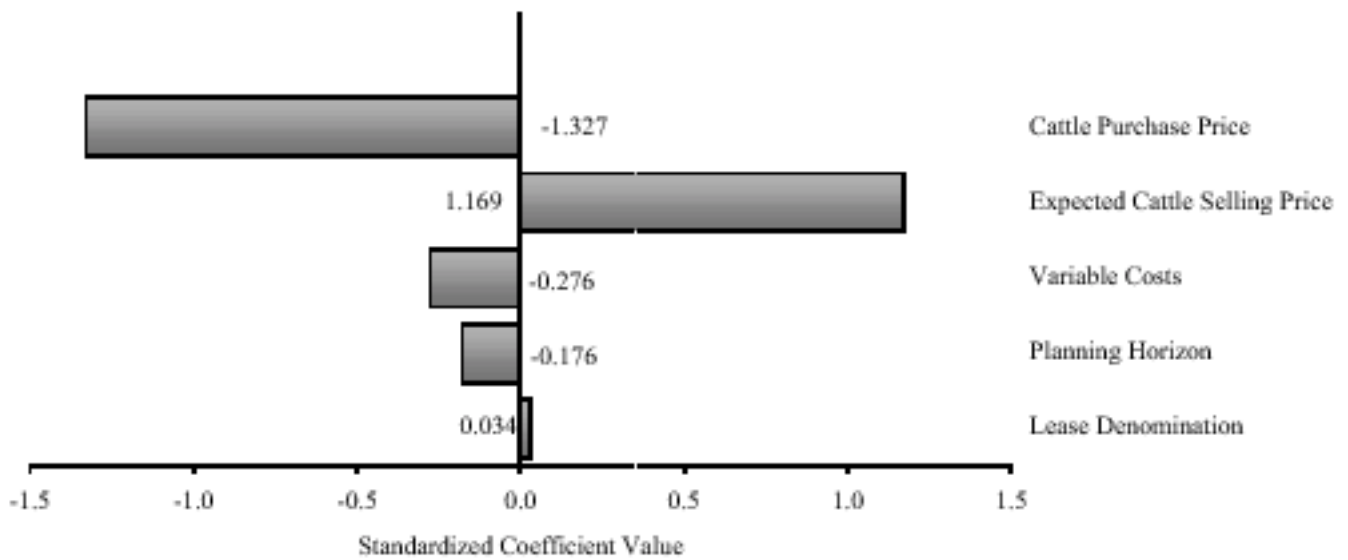


Figure 7. Relative impact of each input variable on profit-maximizing stocking rates.

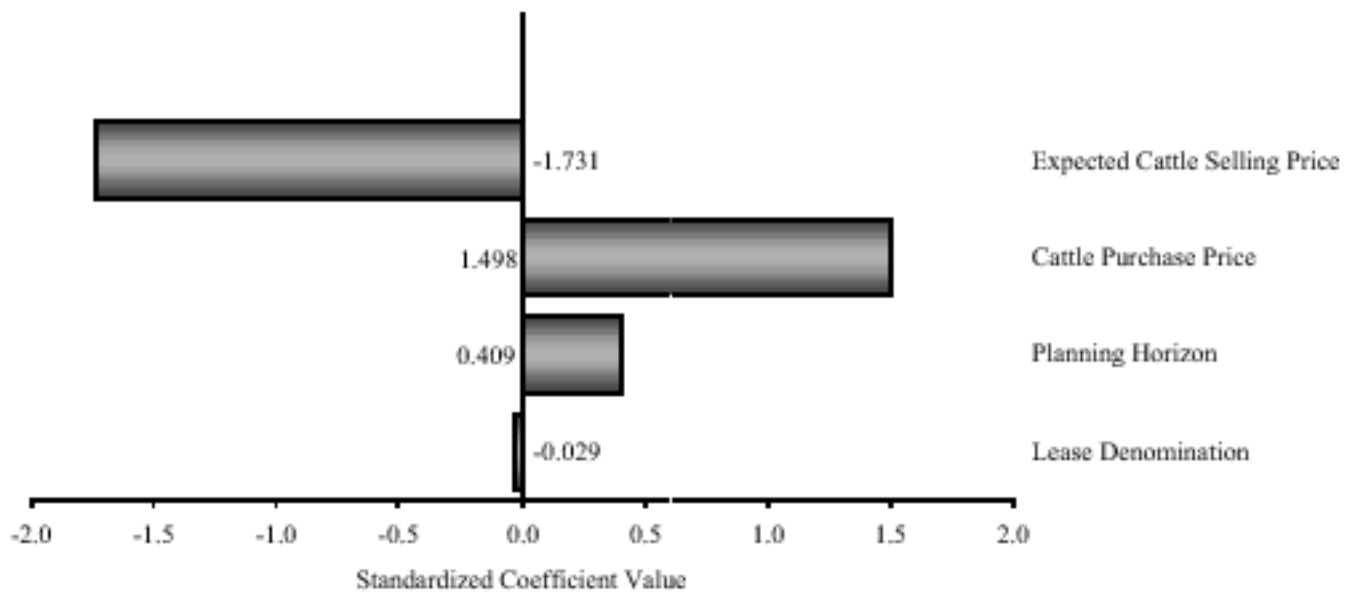


Figure 8. Relative impact of each input variable on HPI values.

pasture leases may promote heavier stocking rates than long-term leases. As the length of the lease increased, the optimal stocking pattern appears to approach that of an owner-operator with a perpetual planning horizon. Solving the model with a 24-year planning horizon generated results similar to the model with a 12-year planning horizon. Furthermore, optimal stocking rates in the 12-year lease were only slightly lower than the 8-year lease. These results suggest that, holding cost structure constant, an 8-year planning horizon would provide a stocking rate incentive similar to land tenure alternative providing a perpetual planning horizon.

Range scientists typically define “proper” stocking rates as a level that will maintain or improve ecological condition (Ohlenbusch and Watson 1994, White and McGinty 1992, Launchbaugh and Owensby 1978). By this definition, all land tenure alternatives examined in this study periodically provided an incentive to overgraze. HPI values in each model declined rapidly from the initial value of one, and converged to a steady state ranging between 0.60 and 0.80.

Although statistically significant HPI value differences were observed among alternative planning horizon scenarios, the differences may not be substantial in terms of actual forage production. The mean difference in the HPI scale between the 4- and 12-year per acre models was three percentage points, or approximately 100 lbs of forage per acre. The spread between mean HPI values in the 1-year and 12-year per head lease models was five percentage points, or 160 lbs of forage per acre. The 1-year per acre lease agreement stands out as maintaining an HPI value substantially lower than all other lease alternatives considered in the study.

Mean HPI values in the 1-year per acre lease model were 10 and seven percentage points lower than the 12-year and 4-year per acre lease models, amounting to approximately 225 lbs of forage per acre. This spread was robust over all the alternative coefficient values examined in the parametric analysis of Equation 7.

The HPI values appeared to be cyclical. Furthermore, cases where vegetative conditions improved under one lease agreement while deteriorating under another were rare, supporting the hypothesis that stocking rates and subsequent HPI values were primarily driven by livestock price cycles and production costs, not by future forage production concerns. This conclusion is consistent with Torell et al. (1991) suggesting inter-temporal impacts on forage production carry a minor impact on the current stocking rate decision.

Cost Structure

Lease denomination had a relatively small impact on the optimal stocking decision, particularly in the long-term leases. This result can be attributed to the method of modeling lease costs in the per head agreement. Imposing a minimum lease payment effectively created a mixed variable/fixed cost structure faced by the tenant. At optimal stocking rates to the left of point A in Figure 4, the lease cost structure effect on stocking rates in the per head agreement was identical to that of the per acre agreement. Since price/cost margins usually maintained stocking rates below this point, stocking rate incentives were similar across lease types. This study demonstrated, however, that relaxing the required minimum lease payment and converting fixed costs to variable costs reduces the profit-maximizing stocking rate. This suggests pasture

lease market conditions or other circumstances that force tenants into lease contracts that require minimum lease payments increase optimal stocking rates.

Limitations of the Study

This study was based on forage production and price/cost conditions observed in the Kansas Flint Hills. Another issue is whether these results can be generalized to other geographical areas. Inter-temporal impacts of the stocking rate decision would vary depending on regional soil and climate conditions. Inter-temporal impacts depend on the coefficient values of Equation 7, which were estimated from data collected in eastern Colorado (Sims et al. 1976). The Flint Hills grassland appears capable of recovering quickly from overgrazing relative to rangeland in the arid regions of the western United States (Owensby, personal communication). Adjusting the coefficients in Equation 7 to reduce the vulnerability of the vegetation to overgrazing would strengthen the conclusion that current grazing decisions are driven by price/cost margins rather than impacts on future forage production. This result, however, may not be applicable to other regions such as the relatively fragile desert rangeland in the southwestern United States.

This study was intended to identify the economic incentives confronting landlords and tenants, not necessarily to describe actual behavior. Actual behavior depends largely on the perceptions and objectives of the livestock operator. These results assume perfect knowledge of current stocking rate decision impacts on future grazing capacity. Furthermore, this model assumes a profit-maximization objective. Livestock producers may not necessarily manage to maximize profit.

The models did not account for the impact of precipitation and temperature variation on forage availability. Model results, therefore, should be interpreted as “holding weather conditions constant.” Actual forage production and vegetation conditions are impacted by the weather. Additional research could focus on how incorporating weather risk would affect the results. In addition, the results of this study clearly reveal that profit-maximizing stocking rate behavior results in multi-year cyclical stocking rate behavior. An untested, but plausible, hypothesis is that this behavior is the result of long-term cattle price production cycles. Future research needs to further examine the interface between cattle cycles and stocking rate economic incentives.

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