WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

PAPERS OF THE

1989 ANNUAL MEETING

WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

COEUR D'ALENE, IDAHO

JULY 9-12, 1989

Grazing Impacts to Forage Production and the Rangeland Stocking Rate Decision

L. Allen Torell, William W. Riggs, E. Bruce Godfrey and Kenneth S. Lyon

The stocking rate decision has been described as the most important grazing management decision from the standpoint of vegetation, livestock, wildlife and economic returns (Holechek et al., p. 173). It is widely known, if stocking rates are heavy enough, livestock grazing can be detrimental to long-term range condition and forage production, and can alter the botanical composition of rangeland plant communities to include less desirable woody brush species. In practice, stocking rate recommendations and allowances are based on the perceived ability of forage plants to sustain grazing pressure (Holechek et al., Stoddart et al.). Economics has been of only minor importance in the stocking rate decision, although the profit motive of ranchers has been widely blamed for deterioration of some western rangelands.

Past economic stocking rate studies (Hildreth and Riewe, Hart et al. 1988a,b, Workman) have taken a myopic view and have excluded dynamic forage production impacts of grazing. This exclusion has not occurred because of failure to recognize its importance. Rather, lack of long-term data defining the magnitude of these impacts has generally precluded their inclusion.

In this paper we develop a dynamic economic model of stocking rates on rangeland. We first describe a traditional single-period economic model of optimal input use as applied to the economics of grazing. It is included so the conditions for traditionally defined economically-efficient stocking rates can be contrasted with the results of a more complex dynamic stocking rate model. It will also serve as an introduction to the dynamic model, and provide a review of procedures that have been used in previous economic stocking rate studies. The economic principles developed have general application to all types of rangeland and pastures, and although yearling steers and season-long grazing are considered here, the same principles are applicable to other livestock types, grazing systems and rangeland uses.

To demonstrate the economic principles involved, an example adapted from a long-term grazing study in eastern Colorado is used (Sims et al.). This example was chosen because it is one of the few grazing studies with adequate design and length to determine long-term impacts of grazing on livestock and forage production, and to evaluate the dynamics of the economic stocking rate decision.

A MYOPIC MODEL OF ECONOMICALLY OPTIMAL STOCKING RATES

The standard production economic model of efficient input use has been applied to the problem of stocking rates on rangeland by numerous authors including Hart et al. (1988a,b), Hildreth and Riewe, Riewe, Torell and Hart, and Workman. Although definition of the variable input differs, these economic evaluations start with definition of input/output relationships, the production function. Most recently, stocking rate studies have standardized the grazing input in the production process to grazing pressure (GP), which is defined to be the number of stockers grazing per unit of herbage (H) production per ha (Hart et al. 1988a, Scarnecchia).

$$GP = SD/H = v \cdot SR/H, \tag{1}$$

where SR = Stocking Rate, the number of stockers grazing per ha; v = length of the grazing period; and SD = Stocker Days, the number of stocker days of grazing per ha.

In this single-period model, herbage production and the length of the grazing period are exogenously determined and defined (or estimated) when the stocking rate decision is made. Thus, the choice variable is SR. The relationship between gain per animal per day (Average Daily Gain, ADG) and SR is defined to be a quasi-concave function given by

$$ADG = f(GP(SR)), \tag{2}$$

with $df/dSR < 0$ and $d^2f/dSR^2 \leq 0$ over the economically relevant range of production.

New Mexico State University

With definition of the ADG function, sale weight and beef production per ha are defined to be $W_s = [W_b + v \cdot ADG)]$ = stocker sale weight (kg); $b(GP(SR)) = SR \cdot W_s$ = total kg of beef sold per ha; and W_b = average stocker purchase weight (kg).

Heavier steers within the same weight class generally sell for less per kg (Schroeder et al.). Thus, while sale price (P_s) is determined by market forces outside the ranchers control, the rancher determines which market price to accept by the size of cattle produced. This depends on the stocking rate decision such that in addition to general market forces, P_s is a function of SR and other livestock characteristics;

$$P_s = P_s(W_s(GP(SR)),X), \tag{3}$$

with X = a vector of exogenous variables that identify relevant characteristics of the stockers at time of sale (e.g. breed, frame size, health, fill, sex, muscling), and price expectations.

We next define the profit function (i.e., return to land and improvements) to be

$$\pi(GP(SR)) = P_s(W_s(GP(SR)),X) \cdot b(GP(SR)) - (P_b W_b + r)SR - a, \tag{4}$$

with r = total per head input factor costs that vary with the number of stockers grazing the pasture; and a = total fixed production costs that do not vary with use rate of the pasture.

To find the economic optimum stocking rate over the single-period, equation (4) is differentiated with respect to SR, equated to zero and solved for the optimal SR. This procedure yields the standard result that at the economically efficient input use level the Value of the Marginal Product (VMP) from adding another steer to the pasture must equal the added cost of putting it there (Marginal factor Cost, MFC).

A DYNAMIC MODEL OF ECONOMICALLY OPTIMAL STOCKING RATES

To track the dynamics of the forage resource, we define an index of rangeland productivity at time t to be I(t). This index measures the flow of herbage production obtained under the grazing policy being evaluated, relative to average peak production sustainable through time under light or no grazing ($0 \leq I(t) \leq 1$[1]). We exclude random fluctuations in herbage production brought about by weather and environmental variations, and define $\bar{H}$ to be the average sustainable herbage yield under light or no grazing. The productivity index thus captures changes in long-term average herbage production as influenced by past stocking rate decisions.

The index changes through time, depending on the grazing history of the pasture. If relatively heavy stocking occurred last year, the herbage production index this year may be reduced. Movement of the index is defined to be a function of the previous period's GP and the previous period's index value. Herbage production at a point in time is then given by the equation

$$H(t) = I(t)\bar{H}, \tag{5}$$

with past impacts of grazing captured in I(t). By differentiating equation (5) the equation of motion for the state variable H(t) is given by a differential equation of the form

$$dH/dt = dI/dt \cdot \bar{H} = \Phi(GP(SR(t),H(t))). \tag{6}$$

Together with the initial condition that, at the start of the planning period $I(t_o) = 1$, or $H(t_o) = \bar{H}$, equation (6) defines the time path of herbage production, depending on the solution set to SR(t).

---

[1]/Normally, the maximum index value might be set at one, implying light or no grazing yields maximum herbage production. However, it is possible that with alternative grazing systems a heavier stocking rate would yield higher herbage production through time and thus give an index greater than one.

The annual profit function of equation (4) is now altered to include herbage production as an endogeneously determined state variable:

$$\pi(GP(SR(t),H(t))) = P_s(W_s(GP(SR(t),H(t))),X)\cdot b(GP(SR(t),H(t))) - (P_bW_b + r)SR(t) - a. \quad (7)$$

The rancher desires to maximize the discounted net present value (NPV) from grazing over all future years. The wealth from a single grass stand rotation is given by

$$C^1 = {}_{t_o}\int^S \pi(GP(SR(t),H(t)))e^{-\rho t}dt - K, \quad (8)$$

where ρ = the discount rate used to discount future returns, t = the year under consideration, and K = the cost of stand rejuvenation (e.g. brush control, reseeding, pasture re-establishment).

The integral is defined to start at time t_o ($0 \le t_o < S$), which reflects the specified grazing deferment policy associated with stand rejuvenation. In some cases, stand rejuvenation could possibly be obtained by deferment alone.

Assuming all rotations are alike, and following the asset replacement model of Perrin, the wealth from all future rotations is given by

$$C^\infty = C^1 + e^{-\rho S}C^1 + e^{-\rho 2S}C^1 + \ldots \quad (9a)$$

$$\text{or, } C^\infty = A(S)C^1, \quad (9b)$$

where $A(S) = 1/(1 - e^{-\rho S})$, which is the present value of a perpetual annuity received every S years.

The objective functional given by C^∞ is maximized subject to the initial stock of herbage available for grazing during period t_o and the equation of motion for the system as given by equation (6). If stand rejuvenation is possible, the optimal rotation period (S) must also be chosen. If stand rejuvenation is not economically feasible, then S is set to ∞, and maximizing C^1 or C^∞ is equivalent.

Using theorem 1 of Long and Vousden, the Hamiltonian for the problem can be written as

$$H = A(S)[\pi(GP(SR(t),H(t)))e^{-\rho t} - K] + \omega\cdot\Phi(GP(SR(t),H(t))), \quad (10)$$

where S is a control parameter, SR(t) is the control variable (function), H(t) is the state variable, and ω is the costate variable.

Given that an internal solution path [SR(t) > 0 and $t_o < S$] exists, the following conditions will hold along that path.

$$\partial H/\partial SR = A(S)\cdot\partial\pi/\partial SR\cdot e^{-\rho t} + \omega\cdot\partial\Phi/\partial SR = 0, \quad (11a)$$

$$\text{with } \partial\pi/\partial SR = \partial P_s/\partial SR\cdot b(GP(SR(t),H(t))) + P_s\cdot\partial b/\partial SR - (P_bW_b + r).$$

$$d\omega/dt = -\partial H/\partial H = -[A(S)\cdot\partial\pi/\partial H\cdot e^{-\rho t} + \omega\cdot\partial\Phi/\partial H], \quad (11b)$$

$$\text{with } \partial\pi/\partial H = \partial P_s/\partial H\cdot b(GP(SR(t),H(t))) + P_s\cdot\partial b/\partial H.$$

The optimal time path is the solution to equations (6) and (11), having initial condition $H(t_o) = \bar{H}$ and terminal conditions given by the following transversality conditions:

$$A(S)e^{-\rho S}[\pi(GP(SR(S),H(S))) + (e^{\rho S}/A(S))\cdot\omega(S)\cdot\Phi(GP(SR(S),H(S))) - \rho C^\infty] = 0, \quad (12a)$$

$$\omega(S) = 0 \text{ for } S < \infty. \quad (12b)$$

The partial derivative $\partial\Phi/\partial SR$ in equation (11a) is the rate of change of dH/dt per unit change in SR(t). Thus, over a time period of length one, it is approximately the rate of change of H per unit change in stocking rate. It is the marginal opportunity cost of SR(t) in terms of H and, when multiplied by ω, the shadow value of H, it is the marginal opportunity cost of SR(t) in dollars. The opportunity cost represents the discounted value of future income from livestock production not possible at each point in the future because herbage production was diminished by the current stocking rate decision.

Comparing the necessary conditions for maximum profit between the myopic, single-period model and the dynamic model, it can be seen that with the dynamic model the necessary condition for

maximum profit is altered to include discounting and consideration of returns over all future years. But most important, the opportunity cost of future revenue foregone by any deterioration of the grass stand from the stocking rate decision is included directly in the analysis.

AN ILLUSTRATIVE EXAMPLE

The following example and model application is based on data from a long-term grazing trial conducted at the Eastern Colorado Range Experiment Station near Akron, CO. The study had the standard random block design with three levels of grazing, defined to be light, moderate and heavy, and two replications (Sims et al.). Under light grazing, 4 ha were allowed per grazing steer for a 150 day grazing season. Moderate and heavy grazing allowed 2 ha and 1.3 ha per steer, respectively. Table 1 shows the calculated grazing pressure (GP), forage utilization rate, herbage production response and index of herbage production for each grazing treatment. As shown, herbage production was negatively impacted by increased grazing pressure. Herbage production increased slightly under the light treatment, especially during the first 7 years of the study. It decreased under the heavy rate and remained relatively constant at the moderate rate. By 1965, when the light grazing treatment was discontinued, herbage production under moderate grazing averaged about 94% that of the light treatment, compared to 82% under the heavy treatment.

Table 1. Herbage production (HP), grazing pressure (GP) and forage utilization under three stocking rates, 1957-68, as reported by Sims et al.

	Stocking Rate										
	Light			Moderate				Heavy			
Year	GP	HP (kg/ha)	% Util.	GP	HP (kg/ha)	I(t)[a]	% Util.	GP	HP (kg/ha)	I(t)[b]	% Util.
1957	26	1,339	36	48	1,432	1.07	44	72	1,497	1.12	62
1958	23	1,752	35	46	1,762	1.01	43	74	1,691	0.96	63
1959	31	1,423	38	62	1 448	1.02	49	105	1,312	0.92	79
1960	24	1,738	36	55	1,521	0.88	46	99	1,316	0.76	57
1961	18	1,999	33	40	1,794	0.90	41	64	1,618	0.81	57
1962	18	2,005	33	45	1,546	0.77	43	67	1,604	0.80	62
1963	18	2,092	33	41	1,523	0.73	41	60	1,499	0.72	50
1964	23	1,662	35	54	1,399	0.84	46	98	1,206	0.73	70
1965	24	1,547	36	50	1,461	0.94	45	90	1,272	0.82	58
1966		1,623[c]			1,477	0.91			1,264	0.77	63
1967		1,329[c]			1,209	0.91			920	0.69	
1968		1,373[c]			1,250	0.91			532	0.38	
1957-65 Avg.	23	1,728	30	49	1,485	0.91	44	81	1,311	0.76	64

[a]/Herbage production under moderate grazing divided by herbage production under light grazing.

[b]/Herbage production under heavy grazing divided by herbage production under light grazing.

[c]/Herbage production for the light grazing treatment was not reported during 1966-68. For these years, an estimate of herbage production that would have occurred under light grazing was obtained by dividing the reported production under moderate grazing by the average 0.91 ratio for moderate grazing.

Model Definition

Using data from table 1 and other livestock response data reported by Sims et al., the various functions of the myopic and dynamic stocking rate models were estimated using ordinary least squares regression (table 2). Additional exogenous model parameters were defined based on application of the Sims et al. data and recent market conditions (table 3). Riggs (1989) conducted the empirical model application reported in this study and this thesis provides a more complete description of methods and results.

The dynamic model was formulated as a discrete time optimal control model, and solved using the MINOS nonlinear programming algorithm (Murtaugh and Saunders). In this model application, timing of the optimal rotation was not considered. An infinite planning horizon (considered to be 40 years) was used in the analysis to evaluate optimal stocking rates through time when the grass stand must be managed with no economically feasible range improvement alternatives available. In addition to solution of the dynamic model, the myopic model, which excludes intertemporal grazing impacts, was solved for each year of the planning horizon using a spreadsheet program.

Model Results

Optimal Stocking Rates. As shown in figure 1, dynamic optimal stocking rates determined by explicitly accounting for impacts to future forage production were not greatly different from myopic stocking rates that excluded these impacts. The cost/price relationship during the first year of the planning horizon (table 3), for example, resulted in an optimal grazing pressure that year of 38 steer days/tonne of herbage for the single-period myopic model. Optimal stocking rates were reduced to 34 steer days/tonne for the dynamic model. This difference of 4 steer days between optimal solutions represents a reduction of about 11% in the economically-optimal stocking rate when opportunity cost of increased stocking rates is considered.

Stocking rates would optimally vary each year, depending on beef prices, forage conditions and variable production expenses. During good beef price years, such as defined for 1986 and 1987 when the price margin between purchase and sale price of stockers was relatively small (table 3), optimal stocking rates would increase. The 1986 price situation, for example, resulted in a relatively high grazing pressure of 71 steer days/tonne of herbage for the dynamic model and 77 steer days/tonne for the myopic model. These are stocking rates near the heavy rates stocked by Sims et al. (table 1).

The current stocking rate recommendation for this midgrass praire range site is to utilize 45% of available forage (i.e., a constant GP of 52 steer days/tonne of forage) (Holechek et al.). This recommendation, based largely on non-economic factors, is amazingly close to the average economic optimal use rate shown in figure 1.

As the planning period draws to a close, the difference between dynamic and myopic model stocking rates is reduced until the final year when the two rates are equal. This occurs because there is no additional future value to remaining forage, i.e. the opportunity cost of increased grazing is zero.

Optimal Rangeland Productivity. Corresponding to the fluctuations in optimal stocking rates, average herbage production varies optimally through time, after reaching a long-term level of production equilibrium. This is true for both the dynamic and myopic models. After an initial drop in herbage production from the beginning 1,728 kg/ha, optimal herbage production declined to about 1,500 kg/ha for the dynamic model and 1,450 kg/ha for the myopic model (figure 2). In neither case was long-term production of the grass stand estimated to be severely impacted, a result consistent with data reported from the long-term grazing study of Sims et al. for the defined moderate stocking rate.

Net Present Value. By reducing stocking rates and foregoing revenue in the early years of the planning period, revenue in future years was increased for the dynamic model. Solution to the dynamic model resulted in an increase in NPV of discounted returns to land and improvements, calculated over an infinite planning horizon, of $1.94/ha. The NPV of C^{∞} for the myopic model was -$6.94/ha and the dynamic model was -$5.00/ha. While this represents a 28% increase in NPV, given the 40 years planning period, it is an insignificant amount. Further, as indicated by the negative objective function values, alternative resource uses may be expected over the long-term.

Table 2. Selected Equations of the Stocking Rate Models.

Average Daily Gain (kg/head/day)[a]

$$ADG = f(GP_t) = 0.82 - 0.0029 \cdot GP_t$$

Sale Weight (kg/head)[a,b]

$$W_s = [W_b + v \cdot ADG)] = 338 - 0.436 \cdot GP_t$$

Livestock Gain per ha (kg/ha)[b]

$$Gain = SR_t \cdot v \cdot ADG = SR_t(\underset{(6.2673)^c}{123} - \underset{(0.0845)}{0.436} \cdot GP_t) \qquad R^2 = 0.99$$

Beef Production per ha[b]

$$b(GP(SR)) = SR_t \cdot W_s = SR_t(338 - 0.436 \cdot GP_t)$$

Equation of Motion

$$I_t = \underset{(0.1222)}{0.4343} + \underset{(0.1169)}{0.5824} \cdot I_{t-1} - \underset{(0.0005)}{0.00136} \cdot GP_{t-1} \qquad R^2 = 0.72$$

$$H_t = I_t \cdot \bar{H}$$

Percent Forage Utilization

$$U_t = \underset{(3.582)}{17.8008} + \underset{(0.0628)}{0.5220} \cdot GP_t \qquad R^2 = 0.73$$

Beef Prices

$$P_b = 1.5064 + 0.465 \cdot Fut_{spring} - 0.00348 \cdot W_b + 0.000002 \cdot W_b^2$$

$$P_s = 0.5626 + 0.314 \cdot Fut_{fall} + 0.00238 \cdot W_s - 0.000004 \cdot W_s^2$$

[a]/ The equation for livestock gain per ha was estimated directly from data presented by Sims et al. The ADG, sale weight and beef production per ha functions were algebraically estimated from this equation.

[b]/ Assumptions: $W_b = 215$ kg and $v = 150$ days.

[c]/ The standard error of the estimate is presented in parentheses.

Table 3. Definition of exogenous model parameters.

Description	Model Parameter	Defined Value
1. Length of grazing period	v	May 1 to Oct. 1, 150 days
2. Purchase Weight	W_b	215 kg
3. Sale Weight	W_s	Variable as determined by the stocking rate decision
4. Beef Price Model	P_b and P_s	Estimated using the model of Schroeder et al.[a]
Lot Size		50 head
Uniformity		Uniform
Health		Healthy
Horns		Mixed
Condition		Fleshy
Fill		Shrunk
Muscling		Medium
Frame Size		Medium Upper and lower
Breed		Mixed
Time of Sale		2nd Quarter
Market Location		Market 5
Futures Price ($/kg)		Estimated Market Price ($/kg)[b]
Year / Mav1 / Sept.1		Year / Purchase / Sale
1979 / $2.01 / $1.83		1979 / $1.79 / $1.44
1980 / 1.50 / 1.65		1980 / 1.55 / 1.39
1981 / 1.57 / 1.46		1981 / 1.59 / 1.32
1982 / 1.48 / 1.46		1982 / 1.54 / 1.33
1983 / 1.43 / 1.30		1983 / 1.52 / 1.27
1984 / 1.41 / 1.43		1984 / 1.51 / 1.32
1985 / 1.43 / 1.39		1985 / 1.52 / 1.30
1986 / 1.17 / 1.37		1986 / 1.40 / 1.30
1987 / 1.54 / 1.73		1987 / 1.57 / 1.41
1988 / 1.74 / 1.70		1988 / 1.67 / 1.40
5. Variable Production Costs	r	$55/head for 150 days
6. Fixed Production Expenses	a	$18/ha
7. Renewal Cycle	S	40 years
8. Deferment	t_o	0 years
9. Treatment Cost	K	$0.00/ha
10. Discount Rate	ρ	7%

[a]/The beef price forecasting model of Schroeder et al. was used with the parameter specification outlined to estimate beef selling and purchase price.

[b]/A 10 year cycle of beef prices (1979-1988) as estimated using the Schroeder et al. model was used in the stocking rate models. This resulted in different economic conditions for each year of stocker production. The 10-year cycle of prices was repeated for the 40 year planning horizon.

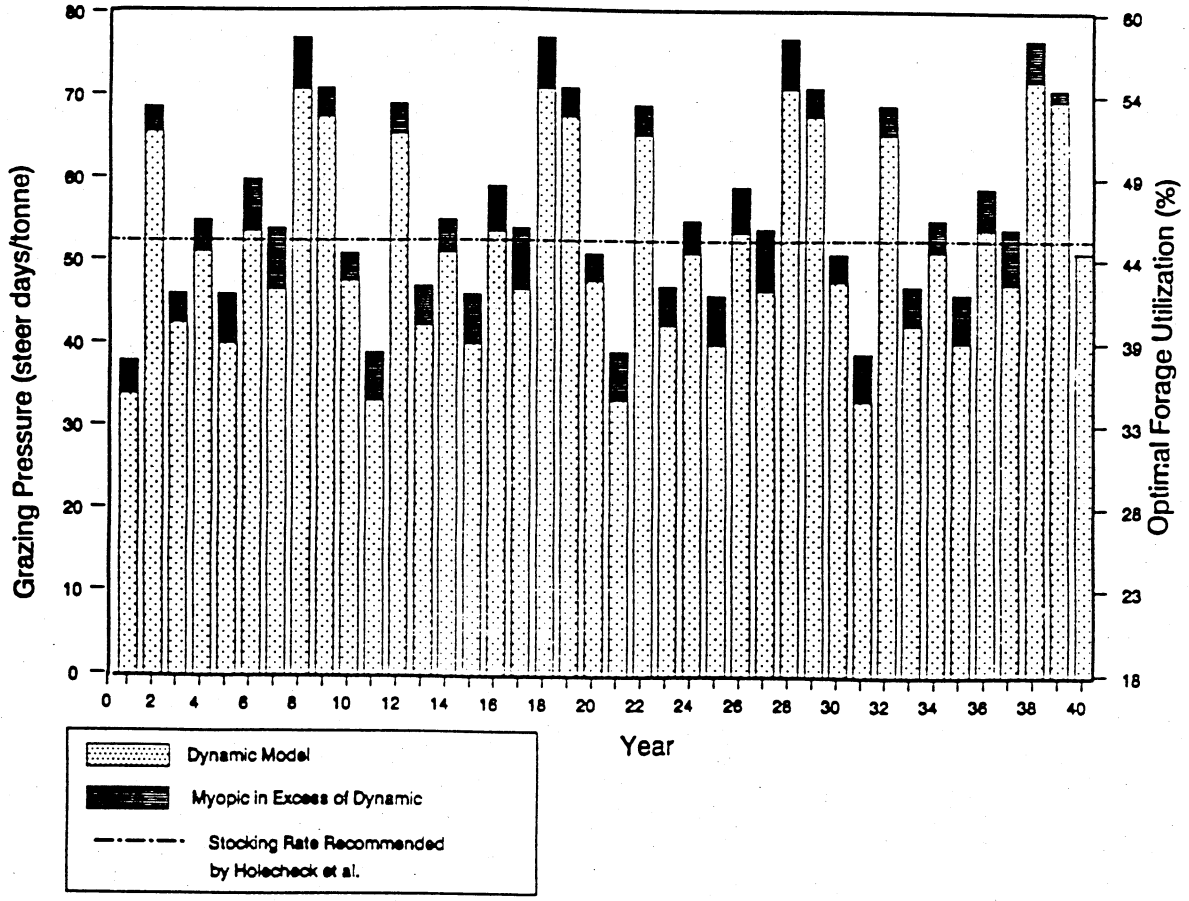


Figure 1. Time path of optimal grazing pressure.

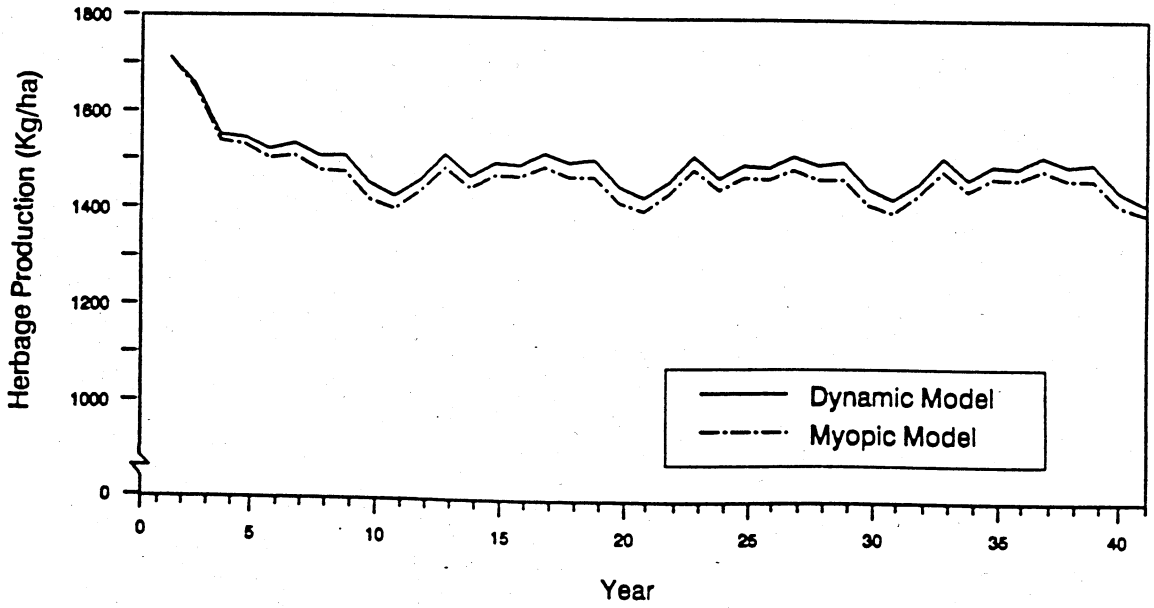


Figure 2. Time path of optimal herbage production.

CONCLUSIONS

Our results indicate the profit motive of the livestock producer will not result in economically-optimal stocking rates high enough to significantly deteriorate the range, given realistic price/cost situations faced by livestock producers. This may not be universally true, however. Other long-term grazing trials (e.g., Launchbaugh, Klipple and Costello) have found heavy grazing to be more detrimental to forage production then data reported by Sims et al.

Of the two detrimental grazing impacts that have been identified from increased stocking rates on rangeland, 1) decreased per head performance of grazing animals and 2) decreased future forage production, the first impact on animal performance drives the economic stocking rate decision. A profit maximizing rancher should quit increasing stocking rate because of falling animal performance well before the point where long-term range condition and trend would be significantly impacted. This was true for the Colorado stocking rate study considered in this model application, and would likely be true for many other rangeland areas.

LITERATURE CITED

Bement, R. E. 1969. *A stocking rate guide for beef production on blue-grama range.* J. Range Manage. 22:83-86.

Godfrey, E.B., L. Sharp and E. Sellasie. 1979. *The economic returns from seeding an area to crested wheatgrass.* Univ. of Idaho, Agr. Exp. Sta. Bul. No. 588.

Hart, R.H., M. J. Samuel, P. S. Test, and M. A. Smith. 1988a. *Cattle, vegetation, and economic responses to grazing systems and grazing pressure.* J. Range Manage. 41:282-286.

Hart, R.H., J.W. Waggoner, Jr., T.G. Dunn, C.C. Kaltenbach, and L.D. Adams. 1988b. *Optimal stocking rate for cow-calf enterprises on native range and complementary improved pasture.* J. Range Manage. 41:435-441.

Hildreth, R.J. and M.E. Riewe. 1963. *Grazing production curves II. determining the economic optimum stocking rate.* Agron. J. 55:370-372.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1989. *Range management principles and practices.* Prentice Hall, Inc., Englewood Cliffs, NJ.

Klipple, G.E., and D.F. Costello. 1960. *Vegetation and cattle response to different intensities of grazing on shortgrass ranges on the Central Great Plains.* USDA Tech. Bull. 1216.

Launchbaugh, J.L. 1967. *Vegetation relationships associated with intensity of summer grazing on a clay upland site in the Kansas 20- to 24-inch precipitation zone.* Kansas Agr. Exp. Sta. Bull. 154.

Long, N.V. and N. Vousden. 1977. *Optimal control theorems,* In J. D. Pitchford and S. J. Tunousky (eds). Applications of control theory to economic analysis. North Holland Publishing Co.

Murtaugh, B.A. and M.A. Saunders. 1977. *MINOS users guide.* Stanford Univ. Systems Optimization Laboratory, Dept. of Operations Research, tech. Report 77-9.

Perrin, R.K. 1972. *Asset replacement principles.* Am. J. Agr. Econ. 54:60-67.

Riewe, M.E. 1981. *The economics of grazing,* P. 517-526. In J.L. Wheeler and R.D. Mochrie. Forage evaluation: concepts and techniques. Proceedings of Bilateral Workshop held October 27-31 1980, Armidale, NSW, Australia. American Forage and Grassland Council, Lexington, KY.

Riggs, W.W. 1989. *Economic principles for myopic VS dynamic stocking rate decisions.* New Mexico State University, Dept. of Agr. Economics. Masters Thesis.

Russell, K.D., R. Hironaka and D.B. Wilson. 1981. *An economic analysis of alternative management techniques for beef production on irrigated pastures in Alberta.* Canadian Farm Economics 16:1-17.

Scarnecchia, D.L. 1985. *The relationship of stocking intensity and stocking pressure to other stocking variables.* J. Range Manage. 38:558-559.

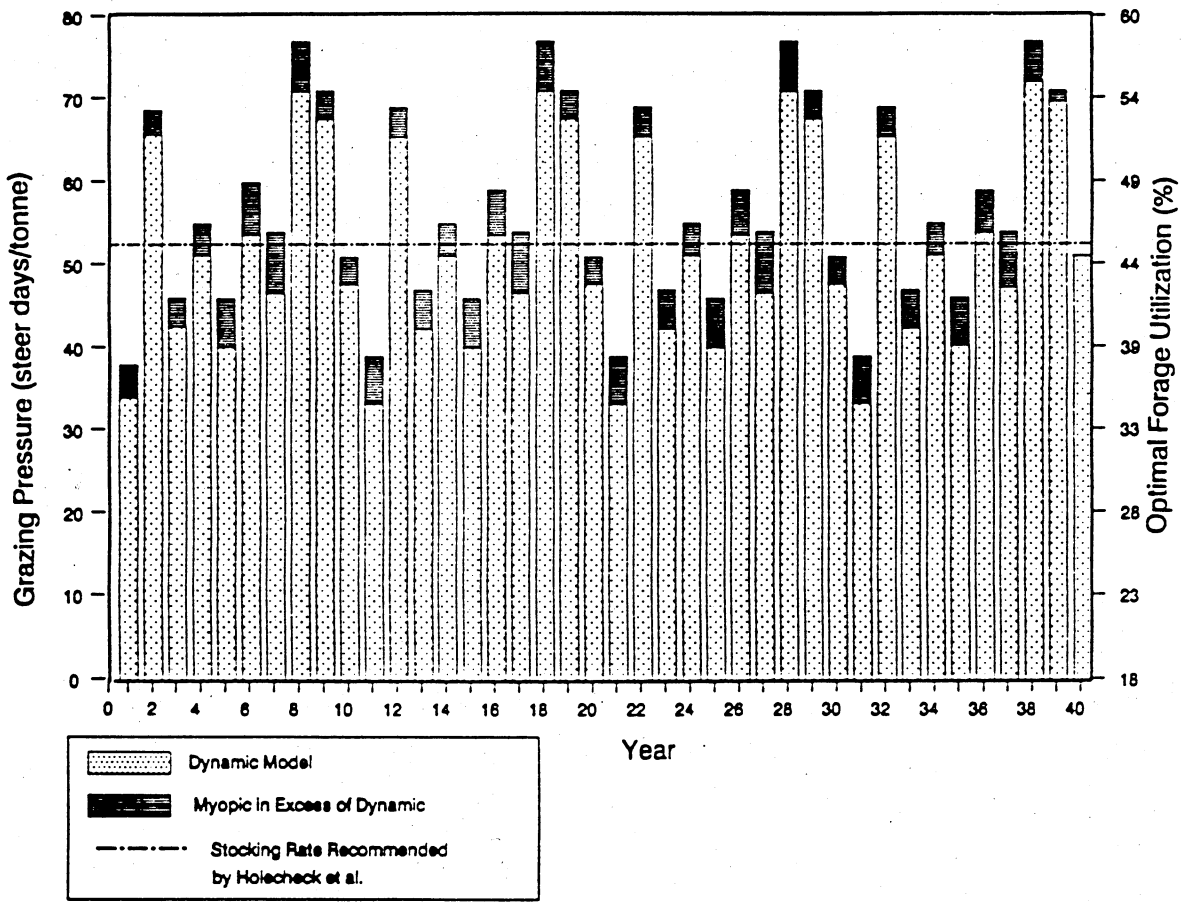
Schroeder, T., J. Mintert, F. Brazle, and O. Grunewald. 1988. *Factors affecting feeder cattle price differentials.* Western J. Agr. Econ. 13:71-81.

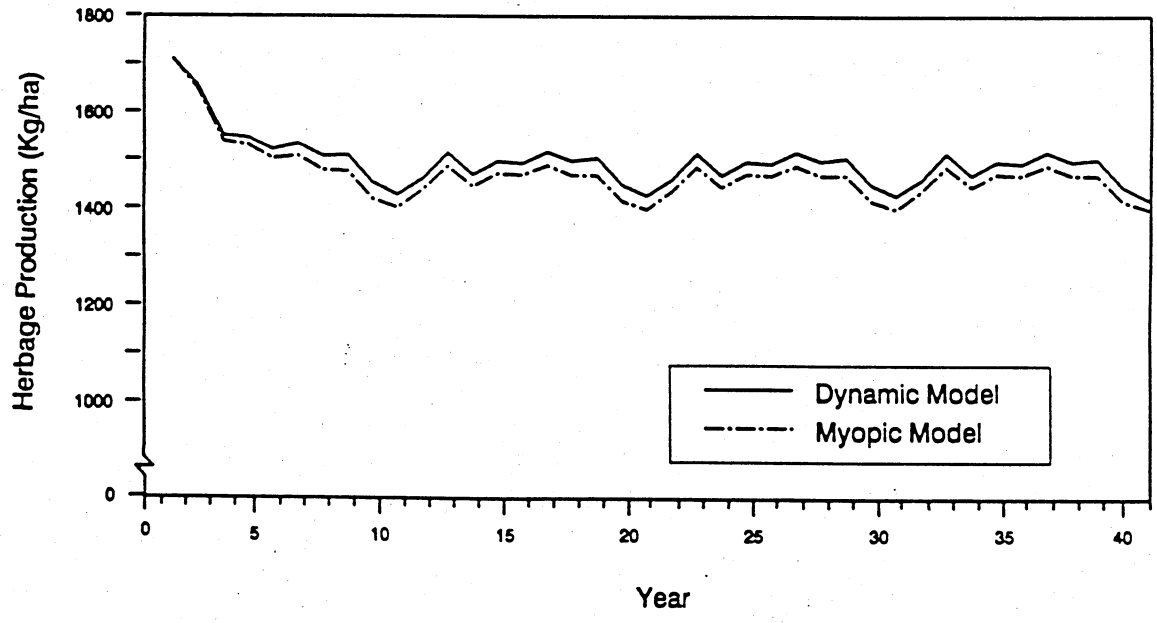
Sims, P.L., B.E. Dahl, and A.H. Denham. 1976. *Vegetation and livestock response at three grazing intensities on sandhill rangeland in eastern Colorado.* Colorado State Univ., Agr. Exp. Sta. Tech. Bull. 130.

Stoddart, L.A., A.D. Smith, and T.W. Box. 1975. *Range Management.* McGraw Hill, Inc., New York, NY.

Torell, L.A. and R.H. Hart. 1988. *Economic consideration for efficient stocking rates on rangeland,* P. 71-76 In R.S. White and R.E. Short [eds.] Proc. Symp. Achieving efficient use of rangeland resources. Montana State Univ. Agr. Exp. Sta. and USDA-ARS, Miles City, Montana.

Workman, J.P. 1986. *Range Economics.* MacMillan, New York, NY.


Grazing Pressure (steer days/tonne)
Optimal Forage Utilization (%)
Year
Dynamic Model
Myopic in Excess of Dynamic
Stocking Rate Recommended by Holecheck et al.


1800
1600
1400
1200
1000
0
Herbage Production (Kg/ha)
0
5
10
15
20
25
30
35
40
Year
Dynamic Model
Myopic Model

MULTIPLE USE OF PUBLIC RANGELAND: AN EVALUATION OF ANTELOPE AND STOCKER CATTLE

Chris T. Bastian, James J. Jacobs and Larry J. Held*

Problem Statement

Forage from rangeland is one of the most inexpensive feed types used by range livestock producers. The general public shows increased interest in using renewable resources from public lands for both consumptive and non-consumptive activities. Recreational activities such as photography, hiking, camping, hunting and fishing have been increasing on public lands. However, domestic animals utilizing public lands may be perceived to detract from these recreational activities. For example, hunters or hikers may not find livestock aesthetically pleasing and may even view them as detracting from their activities. Given these two opposing interests, the government must manage these lands for multiple use with an overall goal of maximizing social welfare.

Objective

This study considers and evaluates a specific piece of public land managed for grazing by cattle and antelope. The objectives of the study are to: (1) determine a production possibilities frontier of cattle and antelope (including the two extremes of no cattle and no antelope) given a fixed range resource, and; (2) determine the most economically efficient combination of grazing cattle and antelope. By placing a value on the activities supported by public land, determining a point of greater, if not maximum, benefits should be possible. The point of greatest benefits received by users will be assumed to represent the greatest social welfare, regardless of distribution.

Defining Activities and Study Area

For this study a defined block of public land (1,000 acres in Wyoming's Red Desert under BLM management) will be used for a case analysis. The two activities or uses of public land considered in this simulated analysis are cattle grazing and antelope hunting. The point of maximum benefits received from these two activities will represent the optimum allocation of the range resource.

A Brief Description of the Red Desert Study Area

Vass and Lang (1938) placed geographic boundaries on the Red Desert, defining it as the area in southern Wyoming lying between the North Platte and Green Rivers, lying south of the Sweetwater divide and extending to the Medicine Bow National Forest and the Colorado state line (Severson, 1966). The forage production data used is from a site near Wamsutter, which is approximately in the center of the Red Desert area as defined above.

Shrubs, grasses and forbs are the classes of plants used to determine the production relationships between cattle and antelope. The 1,000 acres of rangeland was considered to be homogeneous in production of forage. It was also considered to have adequate water to support both cattle and antelope with the factor limiting animal production being forage yield. A common rule of thumb, take half and leave half of the foreage, was imposed so the range resource was not depleted. Table 1 shows the forage production for 1964 and 1965 in pounds of dry matter. The average of these two years was used as the level of forage production for the study area.

University of Wyoming