Demand for Forest Service Grazing in Colorado

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Abstract

Linear programming ranch models were constructed for size of ranch and species of livestock operation within 5 regions of Colorado. Options to improve existing ranch resources and regional forage supply were included in each model. Parametric programming was used to derive shadow prices to approximate demand for USFS grazing in Colorado. Demand was derived under 3 livestock price scenarios and 2 herd management assumptions. USFS grazing demand was found to be very sensitive to livestock price changes. Variable herd management maximized profits and was able to capitalize on high livestock prices, increasing herds, thereby increasing the price of USFS forage for any given quantity. With herd size constant, ranches that could not cover variable costs ceased operation and demanded no USFS forage. Higher livestock prices could not induce increased USFS forage demand as with variable herd management. Regional differences in demand were also noted, reflecting differential transportation costs and ranch productivity.

Key Words: grazing demand, linear programming, public lands

Prices serve society in 3 ways: (1) as a signal to producers determining the level of production, (2) as a signal to consumers determining the level of consumption, and (3) as a measure to allocate income. When resources are owned by government, prices may no longer determine production strategies and income distribution patterns. Government must select from alternative pricing and production strategies to either exercise market power, mimic competitive markets, or distribute wealth with an equity perspective. Current public land laws (e.g., Federal Land Policy and Management Act, Resources Planning Act, Public Rangelands Improvement Act) set in statute distribution and production policies. Explicitly, to achieve such goals, regulations stemming from the Resources Planning Act set forth:

> "...to the extent possible demand will be assessed as a price-quantity relationship" (USDA Forest Service 219.5 1979, page 53928).

Since no directly observable market exists for federal grazing, it becomes necessary to approximate the value of the resource through alternative methods. Price-quantity estimation techniques for federal grazing can be classified by estimation methods (Bartlett 1984): (1) comparison with appraised and/or market priced forage and feed sources, (2) capitalization of permit values, and (3) ranch production analyses. The first method adjusts market prices for forages or feeds that are similar or substitutes for federal grazing to infer the value of federal grazing. The most notable examples are the appraisals of grazing leases that have punctuated the history of federal grazing fees (Quigley et al. 1987). The second method estimates grazing values from the capitalized market price of federal grazing permits (e.g., Gardner 1962, Martin and Jefferies 1966). The third approach of deriving values from production functions has received less emphasis. Production valuation techniques through residual imputation include the method of ranch budgeting (Martin and Snider 1980) or shadow prices from linear programming (LP) models (Gee, unpub. mimeo[1]). The research reported here applied parametric LP to models of Colorado ranches to derive demand for the approximately 1.6 million AUM's of United States Forest Service (USFS) grazing in Colorado.

Theory

Linear programming has been used to address numerous issues in ranching operations. LP optimizes a linear objective function subject to simultaneous consideration of multiple inputs and outputs together with constraints on both. This advantage of simultaneous solution of the optimization problem has allowed LP to largely replace previous ranch budgeting analysis. Early examination of impacts of federal grazing fee increases or declining permit levels done with ranch budgets (Caton et al. 1965, Roberts and Gee 1963) have been replaced by LP analysis of the same issues (Gee 1981 and Gee 1984). However, LP analysis has not been extended to derive demand curves for ranch inputs as has been done, for example, with water (Kelso et al. 1973).

The technological representation of a ranching enterprise through LP provides the "production function" faced by the firm. The total product curve derived with LP is a piece-wise linear curve with the linear segments corresponding to the number of nonredundant basic activities. Using the technology represented within the LP model to approximate a livestock production function on ranches using federal grazing, a demand for the variable input (i.e., USFS forage) can be "derived." Parametric programming was chosen because it reveals precisely each solution change as a specific parameter in the LP varies over a wide range (Graves 1963). Furthermore, this analysis is not restricted to a point estimate of demand as with aforementioned techniques, but can estimate demand over a range of forage quantities. Each point on the piece-wise linear production curve where the slope changes corresponds to a basis change in the solution (Baumol 1977). Specifically, as the given parameter changes (i.e., USFS forage availability from 0% to 140%), all forage nonzero activities change linearly until 1 forage source reaches a right-hand-side constraint. At this point, a forage activity which had previously been zero enters the solution. At each optimal solution there is a dual variable which is interpreted in economics as the shadow price. This shadow price is the LP's internal barter price for inputs in terms of objective function revenues. If the price of the i^{th} factor exceeds the marginal value imputed to the i^{th} variable in the j^{th} activity, the factor will not be utilized by the j^{th} activity. This is analogous to the equal-marginal rule which stipulates that factors are utilized up to the value of their marginal product (Naylor and Vernon 1969). Thus, when this basis change occurs there is a step in the dual demand curve. The stepwise set of shadow prices parameterized over values of USFS grazing price or availability can then be interpreted as the value of the marginal product in livestock production for USFS forage.

The set of shadow prices from parametric programming does not equal the derived demand of a twice differentiable continuous function (Vandermeulen 1971). For a LP solution to be feasible, all resources must be allowed to shift among the production activities unless constrained in the model formatting. Factors of production can be included or excluded from the solution as the ranch model expands or contracts herd size. When obtaining the "derived"

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demand represented by a LP, all other inputs are not *ceteris paribus* (Friedman 1962). Nor does permitting adjustment of all activities in the LP define the resulting demand curves as long run. Omission of fixed costs activities means that not all costs are variable, thereby retaining a short run aspect in the demand. While not equal to neo-classical derived demand, the set of shadow prices from parametric programming may provide a more realistic model of a ranch manager making decisions concerning federal grazing. With the LP model, the manager has the freedom to decide on optimal levels (in discrete amounts) of all activities when faced with changing federal grazing instead of conforming to the economists assumption of holding all other factors constant.

Methods

Research proceeded in several steps: (1) interviewing a sample of ranchers that used federal grazing in Colorado to obtain data for construction of ranch budgets, (2) formulating LP models from ranch budgets including options representing regional supply of forages and feeds, (3) parameterizing the LP's using USFS forage to obtain a set of shadow prices, and (4) aggregating the parameterization results into regional and state estimates of demand.

Ranch data, collected by personal interview using a stratified random sampling scheme, were compiled into budget models that described the economic and resource structure of an average ranch within a strata (complete ranch budgets are presented in Bartlett et al. 1979). Each of the 25 ranch models represented a herd size strata of ranches for each type of livestock in each region (15 cattle models, 4 sheep models, and 6 both sheep and cattle models). The 5 regions were: Northwest (NW), Northeast (NE), Southeast (SE), San Luis (SL), and Southwest (SW).

Both forage and economic budgets of each ranch model were incorporated into a LP that defined livestock production possibilities for the ranch model. The general framework of the LP followed D'Aquino (1974) with salient features discussed below.

Simultaneous with the feed and forage selection, rancher must decide up optimum level of livestock production. The rancher can either vary cattle or sheep numbers or maintain a constant herd when faced with changing amounts of USFS grazing. By varying herd size, the rancher is able to maximize profit. However, over the short run a rancher may wish to hold a constant herd size for reasons such as: (1) herd genetic management, (2) conformity to USFS regulations regarding nonuse, (3) market expectations, (4) tax management, and/or (5) support for a ranching lifestyle. Instead of maximizing profit, the LP decision is to find the least-cost feed ration to support a given herd. To encompass these 2 extremes in rancher management USFS demand was obtained under 2 objective functions scenarios for each LP ranch model: profit maximization with varying herd size and least-cost at the current herd size.

Both objective functions charged forage, feed, and other variable costs at the respective 1977 prices. Thus, the shadow price defined above was the return to commercial livestock (culls, calves, lambs, and yearlings), as revenues such as sales of breeding livestock, and other nonlivestock (e.g., mineral leases, crop enterprises) returns were excluded from the objective function. To make this research relevant to a range of prices, demand was derived under 3 price levels: low, average, and high prices from the 1969–1979 cattle cycle. The low, average, and high prices over the 1969–1979 cycle were normalized relative to the 1977 livestock price[2]. This normalization removed the affects of inflation relative to 1977 while maintaining the price variation of a cattle cyle (Bartlett et al. 1981).

All costs, revenues, forage usage and livestock production variables were proportional to the brood cow or ewe. For example, in a cattle model, each brood cow generated a fraction of a calf, yearling, cull cow, replacement heifer, dry cow, and bull and the corresponding forage requirements, costs, and revenues. All livestock production coefficients and cost data were determined from the ranch budgets, The LP analysis was short run in that ranch inputs that did not vary over 1 production cycle were held fixed by omission (i.e., ranch size was not an activity in the LP).

Each seasonal forage and feed source (including current feed purchases, forage leases, and crop production) was allocated among the 4 seasons according to current utilization and constrained by the amount specified in the ranch model forage budgets. Operating capital, management, and labor were not restricted. Forage and feed for each of 4 seasons were separate activities tied to seasonal forage requirements of each livestock class. Interseasonal transfer of forage was barred because each season was defined upon barriers (e.g., snow cover, plant growth) that prevented utilization of forage from the previous season. Forage requirements were computed in animal unit months (AUM's) per head per season for each animal class using Cook et al. (1977).

Faced with changing availability or price of USFS grazing, a ranch manager must allocate existing ranch forage and decide upon purchase or cultivation of alternative feeds as necessary to maintain yearlong forage balance. If increased availability of USFS forage allowed increased herd size, the LP increased feeds complementary to summer USFS grazing (such as hay) to maintain a year-round herd. There being no feed and forage reservoir beyond current fully utilized ranch resources, the ranch faced an upward sloping supply curve.

The first option of the upward sloping supply was to allow each ranch model to improve a percentage of its rangeland, irrigated pasture, and hayland with diminished returns. Irrigated pasture was assumed to yield 3 successive increases in forage with increased rates of fertilization (Ludwick and Rumberg 1977). Only 30% of the irrigated pasture of any ranch could be fertilized due to consistent availability of irrigation water to prevent fertilizer burn. Three increases in hayland productivity were also permitted at increasingly costly methods of fertilization, reseeding, and cropping methods (Rumberg 1975). These practices were amenable to only 70% of hayland acreage. A total of 45% of the rangeland for any ranch model was considered for improvement through chemical or mechanical treatment. Each 15% increment in rangeland productivity increased discounted cost from \$7/AUM to \$10/AUM, to \$13.50/AUM (Nielson and Hinckley 1975, Bradshaw and Bartlett 1978). Increased hay production was fed only in the winter and other improvement practices provided spring, summer, or fall forage.

The second component of the upward sloping supply reflected the assumption that each ranch model (which represented a group of ranches) responded identically to changing availability or price of USFS grazing and thus if all firms increased purchases in the regional feed market they could do so only at higher costs. The purchase of alfalfa and hay inside and outside the region were included as complements to additional USFS grazing. For the hay surplus regions (Northeast, Southeast, and San Luis) a local transportation charge (20 miles) was added to the 1977 purchase price of hay with unlimited hay purchases allowed within these regions. For the hay deficit Northwest and Southwest regions, a higher local charge was assumed reflecting a 40-mile transportation radius. In addition, feed purchased from outside these 2 deficit regions was charged for a 200-mile transportation radius. Local hay and alfalfa purchases for the most deficient Northwest region were limited to 10% of current alfalfa or hay purchases of each ranch model. For the Southwest, where feed was more abundant, this constraint was set at 20%. Purchases of alfalfa from outside both regions were not constrained. In addition to hay purchases, a total of 20% increase in private pasture leasing was allowed: 10% at current price of \$6.37 per AUM, and the second 10% at half again

[2]November and September prices for the weight classes of calves, yearlings, culls, and lambs were used (Colorado Crop and Livestock Reporting Service 1980) as indicated by averaged sale dates and weights from rancher survey. Calf prices, for 438 pound calves were \$34.90, \$57.27, and \$81.00 per cwt. Yearling prices, for 754 pound, yearlings were \$34.33, \$52.04, and \$66 per cwt. Lamb prices, for 98 pound lambs, were \$41.63, \$48.52, and \$58.70 per cwt. Cull cows were \$21.38, \$32.19, and \$44.73 per cwt.

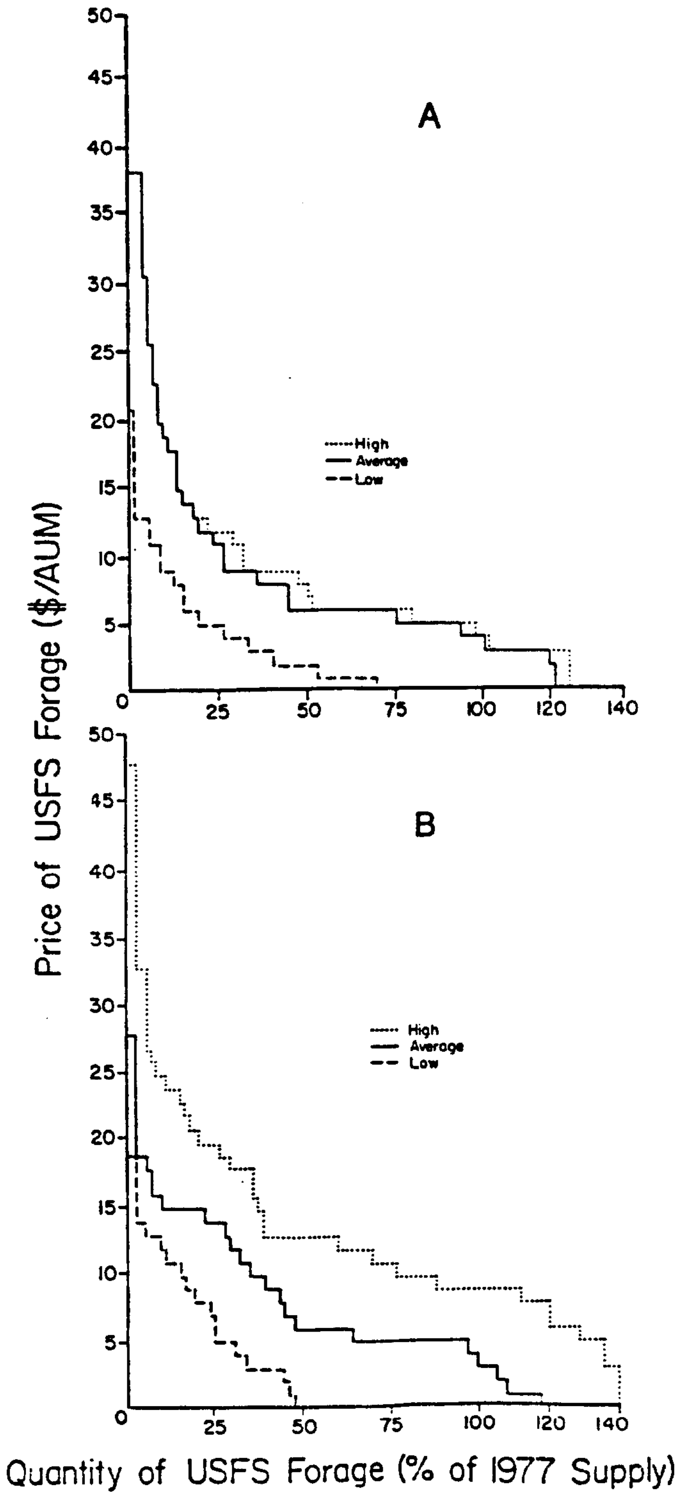

Fig. 1. *Aggregate demand for USFS grazing in Colorado, comparing the effects of low, average, and high livestock prices. A is demand under the least-cost constant herd size management. B is demand given profit maximizing, variable herd size management.*

current price. Feeding of this additional hay was restricted to spring, fall, and winter feeding and leased grazing was available only in the spring, summer, and fall.

The demand for USFS grazing was derived for each ranch model under 6 different scenarios; combinations of 2 management objective functions and 3 livestock price forecasts (discussed above). The quantity of USFS forage was parameterized from 0% to 140% of the current amount of USFS grazing in each ranch model. The upper limit of the parameterization was an arbitrary bound placed on livestock grazing in the context of multiple use goals. The forage demand for each ranch model under each of the 6 scenarios was then expanded by the number of ranches represented by that model's sampling strata. Regional demand functions were then obtained horizontally summing price-quantity results for all the ranch models within that region. Similarly, state functions were obtained by horizontal summation of the 5 regional demand functions.

Results

The 6 different demand scenarios in each region allowed comparisons permitted livestock price, management, and regional comparisons. Discussion of results will proceed in that order.

Livestock Price Comparisons

The sensitivity of demand to revenue changes was revealed by plotting the aggregate state demand curves derived under the 3 livestock price scenarios, given constant and variable herd management (Fig. 1). When herd size could be set at profit maximizing levels, each successive livestock price decline caused a downward shift in demand (Fig. 1B). With herd size variable, the price of USFS forage for the state at the current level (100%) of grazing dropped from $8.68/AUM at high livestock prices to zero at low livestock prices (Table 1). At amounts above current levels of USFS grazing, the gap in forage value between high and low

Table 1. USFS forage values ($/AUM) for the profit maximization, variable herd size management scenario for 6 USFS forage levels and 3 livestock price levels.

		USFS Forage (percent of 1977 use)					
Region	Livestock price	25%	50%	75%	100%	120%	140%
NE	low	$ 4.85	$ 2.21	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE	mean	12.20	6.01	6.01	5.22	4.92	4.40
NE	high	13.25	13.25	13.25	13.04	13.04	12.20
NW	low	10.70	2.31	0.00	0.00	0.00	0.00
NW	mean	15.34	9.01	4.68	0.71	0.27	0.00
NW	high	23.78	12.98	9.78	5.84	4.80	0.91
SE	low	0.04	0.04	0.00	0.00	0.00	0.00
SE	mean	6.10	5.47	5.08	5.08	5.08	0.04
SE	high	12.50	12.20	8.62	8.62	7.77	7.50
SL	low	9.01	0.38	0.38	0.38	0.38	0.38
SL	mean	13.48	7.81	1.27	0.38	0.38	0.38
SL	high	19.94	10.45	8.63	7.62	5.02	
SW	low	3.74	1.94	0.00	0.00	0.00	0.00
SW	mean	12.20	6.69	5.09	3.67	1.59	0.00
SW	high	17.90	12.75	11.74	9.36	8.17	5.86
State	low	6.81	0.00	0.00	0.00	0.00	0.00
State	mean	13.48	6.20	5.09	2.93	0.27	0.00
State	high	19.94	12.98	10.40	8.68	7.50	0.91

livestock price remained until demand was truncated at 140%. For the state-wide demand at 120%, this gap was $7.50/AUM but fell to $0.91/AUM at 140% (Table 1). The higher livestock price allowed sufficient profitability so that increased USFS grazing was utilized with the purchase of high priced feed sources that complement the increased summer USFS grazing to 120 and 140% of 1977 amounts. For example, with a 20% increase in USFS summer grazing in the state, ranches would have to purchase additional feeds that complement USFS summer grazing. To utilize this 20% increase, the ranch has to be sufficiently profitable to purchase these higher priced feeds. With variable herd size, the ranches would not only be able to do such, but would also be willing to pay $7.50/AUM for USFS grazing (Table 1) at the highest livestock price. At reduced levels of USFS grazing, USFS forage acts as a summer grazing complement to the low priced forages available to the ranch. Because other forage sources are inexpensive and relatively less feed is needed to carry reduced herd sizes, ranchers can afford to pay up to \$6.81/AUM for 25% of the current level of grazing even at low livestock prices and close to \$20/AUM at high livestock prices. Thus, when the supply of forage diminished, the price spread between high and low livestock prices became even more exaggerated (i.e., over a \$13/AUM difference at 25% of current grazing in Table 1).

The sensitivity of demand response to livestock prices is also evident in the fixed herd size management scheme but through a different mechanism. When revenues could not cover variable production costs in the LP, ranch operation ceased and USFS forage demand went to zero. Thus, USFS demand reflected the ranch shutdown level as well as substitution of USFS grazing for other forages and feeds. The shutdown of ranches was the reason that the state (and some regional) demand for USFS forage at low livestock prices shifted downward with respect to the demand at high and average livestock prices (Fig. 1A). Thus, at low livestock prices only the most efficient ranches remained in business to demand USFS forage. Whereas, at high and average prices all ranches were above the shutdown point, making the demand curves for these 2 livestock price levels coincident (Fig. 1A).

Management Alternative Comparisons

Constant and variable herd size management scenarios were compared by plotting aggregate state demand curves holding constant livestock price (Fig. 2). Evident from Figure 2 was that alternative management schemes did not affect demand until livestock price was at its highest levels. At low livestock prices, some ranch models under constant herd size management failed to break even and thus did not demand USFS forage. The low livestock price demand curve, with fewer ranch models demanding USFS forage (constant herd size), was coincident with the profit maximizing management aggregate demand curve at low livestock prices (Fig. 2A).

At average livestock price, all ranches participated in demanding USFS grazing with constant herd management. But average livestock prices were still insufficient to induce the profit maximizing manager to demand more USFS grazing over a manager that minimized costs maintaining the current herd. The resulting demand curves for the 2 managements were similar (Fig. 2B). At Colorado's present level of USFS grazing and average livestock price, the value difference between profit maximization and least cost management was \$0.38 (Tables 1 and 2).

Release from a static herd size allowed the increased profitability of higher livestock prices to realize full effect (Fig. 2c). The highest livestock price at the current level of grazing under variable herd size management increased to \$8.68 (Table 1) USFS forage demand over constant herd management value of \$3.75 (Table 2). Higher livestock prices made increased herd size profitable thereby increasing USFS demand as well as using higher-priced complementary forages. A mix of the 2 management scenarios may best represent management behavior of Colorado ranchers: the fixed herd size as livestock prices drop and variable herd size as livestock prices rise. Ranchers may readily undertake profitable herd expansions but be reluctant to decrease herd size for the considerations mentioned above.

Regional Comparisons

Regions which exhibit greater productivity for complementary private ranch resources and lower cost purchased feed available have greater potential response to USFS grazing. These 2 factors combined to make USFS grazing in northeast Colorado most valuable. Northeast Colorado ranches with USFS grazing are within one of the most productive agricultural counties in the US. Conversely, Northwest Colorado ranches have relatively less forage productivity available from improvement practices, local feed supplies are limited, and trucking costs prohibitive. These factors

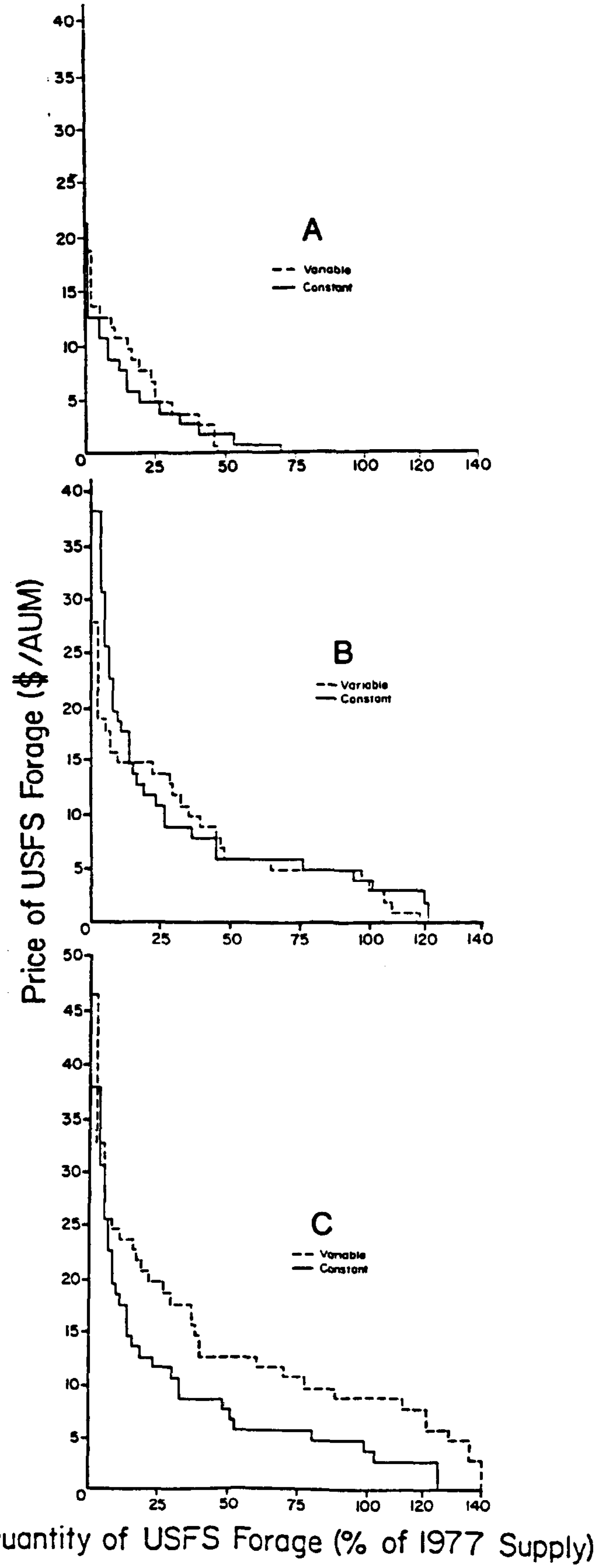

Fig. 2. *Aggregate demand for USFS grazing in Colorado comparing the effects of management scenarios. A, B, and C depict demand given low, average, and high livestock prices.*

Table 2. USFS forage values ($/AUM) for the least-cost, constant herd size management scenario for 6 USFS forage levels and 3 livestock price levels.

Region	Livestock price	USFS Forage (percent of 1977 use) 25%	50%	75%	100%	120%	140%
NE	low	$ 3.72	$ 3.72	$ 0.00	$ 0.00	$ 0.00	$ 0.00
NE	mean	12.20	9.01	5.84	5.84	0.51	0.00
NE	high	12.20	9.01	5.84	5.84	0.51	0.00
NW	low	7.68	2.93	2.27	0.00	0.00	0.00
NW	mean	12.30	5.84	5.22	3.69	2.78	2.27
NW	high	12.30	8.59	5.22	3.75	2.78	2.27
SE	low	2.27	2.27	2.27	2.27	0.00	0.00
SE	mean	5.84	5.47	5.22	2.85	2.78	2.27
SE	high	5.84	5.47	5.22	2.85	2.78	2.27
SL	low	9.01	2.27	0.00	0.00	0.00	0.00
SL	mean	9.01	7.68	5.22	2.85	2.27	0.00
SL	high	12.56	9.01	5.84	4.93	2.85	2.27
SW	low	2.43	2.27	2.27	0.00	0.00	0.00
SW	mean	12.20	6.20	5.66	4.93	0.00	0.00
SW	high	12.20	7.68	5.66	4.93	0.00	0.00
State	low	4.93	2.27	0.00	0.00	0.00	0.00
State	mean	10.99	5.84	5.47	3.54	2.43	0.00
State	high	12.20	6.92	5.47	3.75	2.78	0.00

caused the value of present levels of USFS grazing to decline from $5.22 for the Northeast to $0.71 for the Northwest (given profit maximization management and mean livestock price in Table 1). Remaining regions mix the costs of isolation and productivity and fall between the extremes of the Northeast and Northwest. When management is keyed toward a static herd size the full impact of regional productivity and feed availability cannot be fully expressed. With static herd size the Northeast still has the most valuable USFS grazing at $5.84 but order of value in the other regions changed (100% of current amount and mean price in Table 2).

Summary and Conclusions

Demand for USFS grazing was found to be very sensitive to livestock price changes. When herd size was allowed to vary, outward demand shifts were substantial as livestock prices ranged from low to high. Variable herd management maximized profits and was able to capitalize on high livestock prices, increasing herd size, thereby shifting USFS forage demand outward.

With herd size constant, ranches that could not cover variable costs ceased operation and demanded no USFS forage. Further, higher livestock prices could not induce herd expansion and increased USFS forage demand as with variable herd management. Regional differences in demand were also noted, reflecting differential transportation costs, and ranch productivity.

We have attempted with this study to provide a choice of livestock prices and management alternatives from which USFS grazing can be evaluated and applied. This is the strength of LP derived demand approach, that different scenarios can be input, solved, and the results compared. Just as important, however, are those underlying forage technologies that remained static in the ranch models. The usefulness and accuracy of derived demand through LP parameterization depends in large on the elasticity of forage supply both from within the ranch and regionally. Further empirical investigation can be made concerning feed and forage supply to strengthen this avenue of research to price goods for which no market exists.

Literature Cited

Bartlett, E.T. 1984. Estimating benefits of range for wildland management and benefits. p. 143-156. *In:* Peterson, G.L., and Randall, A. (Eds.) Valuation of Wildland Resource Benefits. Westview Press, Boulder, Colo.

Bartlett, E.T., R.G. Taylor, and J.R. McKean. 1979. Impacts of federal grazing on the economy of Colorado. Dep. Range Sci., Colorado State Univ., Ft. Collins.

Bartlett, E.T., P.N. Kehmeier, R.G. Taylor. 1981. Valuation and demand for Forest Service grazing in Colorado. Completion report, U.S. Forest Service Coop. No. 16-769-CA. Dep. of Range Science, Colo. State Univ., Ft. Collins.

Baumol, W.J. 1977. Economic theory and operational analysis. 4 ed. Prentice-Hall Inc. Englewood Cliffs, N.J.

Bradshaw, R.L., and E.T. Bartlett. 1978. Expected benefits from range improvements in Colorado ecosystems. Range Sci. Series No. 30. Colorado State Univ., Ft. Collins.

Caton, D.D. et. al 1965. Effects of changes in grazing fees and permitted use of public rangelands on incomes of western livestock ranches. USDA Econ. Res. Serv. ERS-248. Wash. DC

Colorado Crop and Livestock Reporting Service. 1980. Colorado agricultural statistics. Colorado Dep. of Agr. Denver.

Cook, C.W., R.D. Childs, and L.L. Larson. 1977. Digestible protein in range forages as an index to nutrient content and animal response. Range Sci. Series No. 29. Colo. State Univ. Fort Collins.

D'Aquino, S.A. 1974. A case study for optimal allocation of range resources. J. Range Manage. 27:228-233.

Friedman, M. 1962. Price theory: A provisional text. Aldine Publishing Co. Chicago, Ill.

Gardner, B.D. 1962. Transfer restrictions and misallocation in grazing public range. J. Farm Econ. 44:53-60.

Gee, C.K. 1981. Estimating economic impacts of adjustments in grazing on federal lands and estimated federal rangeland forage values. Colorado State Univ. Exp. Sta. Tech. Bull. 143. Ft. Collins.

Gee, C.K. 1984. The impact of alternative federal grazing fees on western livestock businesses. USDA. Econ. Res. Serv. Washington, DC.

Graves, R.L. 1963. Parametric linear programming. p. 201-210. *In:* Graves, R. L., and Wolfe, P. eds. Recent Advances in Mathematical Programming. McGraw-Hill Book Co.

Kelso, M.M., W.E. Martin, and L.E. Mack. 1973. Water supplies and economic growth in an arid environment. Univ. of Arizona Press.

Ludwick, A.E., and C.B. Rumberg. 1977. Nitrogen fertilizers for meadow hay production. Prog. Rep. No. 6 Exp. Sta. Colorado State Univ. Ft. Collins.

Martin, W.E., and G.L. Jefferies. 1966. Relating ranch prices and grazing permit value to ranch productivity. J. Farm Econ. 48:233-242.

Martin, W.E., and G.B. Snider. 1980. The value of forage for grazing cattle in the Salt-Verde Basin of Arizona. Univ. of Arizona Dep. of Agr. Econ. Rep. No. 22.

Naylor, T.H., and J.M. Vernon. 1969. Microeconomics and decision models of the firm. Harcourt, Brace and World Inc.

Nielsen, D.B., and S.D. Hinckley. 1975. Economic and environmental impacts of sagebrush control on Utah rangelands: A review and analysis. Utah Agr. Exp. Sta. Res. Rep. No. 25. Utah State Univ., Logan.

Quigley, T.M., R.G. Taylor, and R.M. Cawley. 1987. Public resource pricing: An analysis of range policy. Gen. Tech. Rep., USDA Forest Serv. Pacific Northwest Range Exp. Sta., La Grande, Ore.

Roberts, N.K., and C.K. Gee. 1963. Cattle ranches using public ranges year-long: Income adjustments to grazing fee and permit changes. Agr. Exp. Sta. Bull. No. 440. Utah State Univ., Logan.

Rumberg, C.B. 1975. Alternative meadow and livestock management systems: A comparison of forage and livestock production with an economic analysis. Exp. Sta. Bull. 5658. Colorado State Univ., Fort Collins.

United States Department of Agriculture, Forest Service. 1979. National forest system land and resources management planning. Federal Register Vol. 44, No. 181 p. 53928-53929. Washington, DC.

Vandermeulen, D.C. 1971. Linear Economic Theory. Prentice-Hall Inc., Englewood Cliffs, NJ.