WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

PAPERS OF THE

1989 ANNUAL MEETING

WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

COEUR D'ALENE, IDAHO

JULY 9-12, 1989

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

Dietary Habits of Antelope

Shrubs or browse make up the largest component of the antelope's diet (Table 2). Browse makes up nearly half of the diet in spring and served as the primary feed source during fall and winter according to Taylor (1975). This suggests that the Red Desert would make excellent habitat for antelope.

Even though browse in the form of big sagebrush is a primary part of the antelope's diet, antelope do not always utilize as much as one might expect. Sundstrom, Hepworth, and Diem (1973) found that big sagebrush had 81% TDN in the winter. This means fewer pounds of browse would be needed by an antelope to meet its nutrient requirements than if grass was utilized. Major browse species are utilized in fall and winter when other feeds are covered with snow (Sundstrom, et al, 1973). Severson (1966) estimated that 80 pounds of big sagebrush was available for consumption, but antelope consumed only 16.5 pounds per acre or approximately 21% of the available forage.

Grass plays a relatively minor role in the Pronghorn's diet (Sundstrom, et al, 1973). Grass use is highest in the spring, especially early spring. It is thought that grass consumption increases because it is typically the first green growth and most succulent in the early spring. The lowest grass consumption occurs in the winter months.

Forbs also play a minor role in the antelope diet. However, forb consumption varies across geographical areas, depending upon vegetative composition of the range. For example in Converse county (northeast of the study area) spring vegetation consists of forbs while Sweetwater county (west of the study area) has a small percentage of forbs. This is thought to account for the differential in grass use by Pronghorns in those two counties (Sundstrom, et al, 1973). This suggests that forbs are substitutes for grass in the antelope diet.

Based on a sample of 208 antelope over one year of age, Severson (1966) estimated the average live weight of an antelope to be 97 pounds, and determined the Pronghorn required 1.7 pounds of dry matter per day. Taylor (1975) found, however, that antelope weights in the Red Desert averaged 106.8 pounds excluding fawns. This would suggest dry matter (DM) intake might be higher than Severson's estimate.

Dietary Habits of Cattle

In almost all studies involving cattle, the most prominent plants in the diet were grasses (Gomes, 1983), although there are some seasonal changes. For example, over four seasons (winter, spring, early summer and summer) the steer diet in an Arizona desert grassland was composed of 67% to 97% grasses, 0% to 4% forbs and a trace to 33% shrubs (Gomes, 1983).

Breed or class of cattle seems to have little or no effect on diet. Herbel and Nelson (1966) found little difference between the diets of Herefords and Santa Gertrudis, even though Santa Gertrudis are presumably able to utilize greater amounts of low digestible forage material (Gomes, 1983).

As seen in Table 2, forbs are not a major part of cattle diets. The use of forbs can vary, however, based on availability and/or season. Holcheck

(1980) noted a reduction in forb content of the diet and a trend towards more grass as the grazing season advanced due to reduced availability and palatability. This seems to suggest that grass and forbs may be close substitutes in cattle diets.

Based on the composition of diets summarized in Table 2, there does not appear to be a strong competitive relationship for forage between cattle and antelope. For example, during the summer grazing season for stocker steers, there seems to be relatively low competition for grass by antelope and very low competition for shrubs by cattle. One would suspect a near supplementary relationship during summer grazing for the two animals.

Methodology

A linear programming model was used to derive a production possibilities curve of cattle and antelope, by estimating nine feasible cattle/antelope combinations with respect to available feed (Table 3). The objective function was designed to maximize total production of animals (steers and antelope) based on constraints of annual forage production (rows 2-3) and pounds of forage required per animal (rows 4-11). Seasonal forage rows (4-11) and columns (3-10) are accounting constraints and activities used to calculate the seasonal consumption of grass and shrubs given a particular combination of antelope and steers. These should not be viewed as constraints on the amount of either grass or shrubs available for a particular season, since the production possibilities are based on annual availability of grass and shrubs without regard to seasonal distribution. Given the goal of maximizing animal numbers, an equal weight was placed on antelope and cattle in the objective function.

Since forbs production was low in the study area, this category was combined with grasses. According to literature previously cited, forbs seem to substitute for grasses in the diets of both animals. If the LP program were optimized with forb production as a constraint, it would have been the most limiting constraint. Assuming substitutability with grass, this type of constraint could significantly understate the actual production possibilities of the range resource.

The rule of "take half, leave half" was implemented through the forage production constraints. For example, total grass production was cut in half from 126,300 pounds to 63,150 pounds, to achieve the goal of maintained range productivity. In the case of shrubs, production was cut in half and then multiplied by 21% due to Severson's estimate of utilization by antelope. These estimates were used as constraints for total available dry matter from grass and shrubs.

A yearling stocker system is considered in this analysis as it tends to be common in the Red Desert. With this scenario steers graze four months (1 month, spring; 3 months, summer) at an average daily gain of 1.5 pounds with beginning and ending weights of 550 and 730 pounds respectively. Pounds of forage consumed were calculated by multiplying percent of diet of each plant class by pounds of DM required by the steers (approximately 2.5% of body weight each month) according to Ensminger and Olentine (1978). The TDN and crude protein requirements were approximately met at this level of gain and intake. Actual gain could vary depending on the animal, climate and distance traveled.

Total pounds of forage required per antelope per season were calculated by multiplying 1.7 pounds DM by percent diet for each season and by 90 days per season. This yielded DM consumption for each plant class by season. These estimates were the basis for the activity constraints in the LP solutions.

Given the physical constraints, the LP model was then used to calculate animal combinations. In order to find extreme points (i.e. all of one and none of the other), the constraints for cattle and then antelope were set equal to zero and a solution was optimized. Maximum number of animals was optimized when both animal constraints were relaxed from equalities and set to greater than zero. The other points were calculated by forcing specific numbers of animals found at midpoints along the curve in each of the animal constraints.

As stated above, the only two activities evaluated for public range use having potential economic value were cattle grazing and antelope hunting. The value of the benefits from cattle grazing was based on pounds of gain for the four month period multiplied by the number of animals and average market price for 1977-1986 equal to $65.25 (expressed in 1983 dollars using the Producer Price Index), minus total costs associated with using that land. Included in total cost was an opportunity cost associated with the investment in cattle. The opportunity cost was estimated to be $7.84/head using an average weight of 640 pounds multiplied by the 1977-1986 average price for that weight class (adjusted to 1983 dollars) times a 6% real interest rate for the four month public grazing period. Estimated costs of production associated with federal grazing were reported to be $14.67/AUM (Table 4). Net benefit per head of cattle ($67.65) equals $65.25/cwt. times 180 pounds minus $7.84/head opportunity cost and production costs of $41.96 (.715 * 4 mo. * $14.67/AUM).[1/]

Antelope were assumed to graze for the entire year. The value of antelope hunting was based on herd size multiplied by a harvest factor, a hunting value per day and the number of days per hunt. A value of $19.68/hunting day was estimated by Sorg and Loomis in Utah (1984) using a zonal travel cost method adjusted to reflect travel time, but not substitute sites. Adjusting the $19.68 to 1983 dollars using the GNP price deflator resulted in a value of $20.14/hunter day, used for this analysis. The average trip length was 1.5 days (Sorg, et al, 1984). Net benefits for antelope are the product of $20.14 value/hunting day times 1.5 days times a .455 harvest factor which equals $13.75.

A harvest factor of .455 was used to estimate the number of antelope harvested from a sustained herd size which reflects reproductive rates in the Red Desert and desired post-hunting season ratios of 40 bucks per 100 does in that area (Harjou, 1988). For example, in a herd of 1,000 antelope, 455 fawns would survive to yearling age and 455 permits would be issued. The hunting success rate in the Red Desert has typically been close to 100%.

1/ This calculation is based on observing average deflated spring purchase prices for light feeder steers as being approximately equal to average deflated fall sale price for heavier feeder steers over a recent (1977-1986) 10-year period. If spring purchase price for lighter animals proved to be greater than fall sale price of heavier steers, the net benefit of cattle would be less than the $67.65 per head value calculated above.

Results

Nine steer-antelope combinations were estimated along the production possibilities curve given the constraint of available forage production from the 1,000 acres of range (Table 5). Figure 1 is a graphical representation of the production possibilities curve given those points. Point A represents the maximum number of antelope (70) the range can sustain without any cattle grazing. Using an AUM coefficient of .20 (SCS, 1976) 70 antelope represent 168 AUMs. This estimate is close to Severson's estimated carrying capacity of 67 antelope on 1,000 acres in the Red Desert. Point I suggests that 38 steers could be supported by the range if no antelope were allowed to graze. The total AUMs at that point are 108.7. The maximum production of animals occurs at point D where it is estimated the range could support 67 antelope and 32 steers. Total AUMs at this point are 252.4.

The production possibilities curve in Figure 1 reflects a competitive relationship between cattle and antelope since there is a negative slope throughout its entire range. From Figure 1, the marginal rate of substitution of cattle for antelope (MRS-C*A) is equal to change in head of antelope with respect to change in head of cattle ($\Delta A/\Delta C$). Although the MRS-C*A is negative (competitive) throughout the entire range of cattle/antelope combinations, it is shown to change abruptly at point D. Specifically, the average MRS-C*A between A (no steers) and D (70-67) is very low or close to zero [i.e.. $\Delta A/\Delta C$ = (70-67)/(0-32) = -0.094], suggesting only a few antelope (3) have to be sacrificed when adding a comparatively large number of steers (32). However, from D to I (no antelope), the MRS-C*A becomes extremely high [i.e. $\Delta A/\Delta C$ = (67-0)/(32-38) = -11.167], suggesting a relatively large number of antelope (67) must be sacrificed given a few additional steers (6). This is not particularly surprising given the dietary habits of antelope and cattle, since the major component of the antelope's diet is browse while cattle diets consist primarily of grass. An important implication behind observing such a wide range of MRS-C*A (-0.094 to -11.167) is that net benefits from cattle versus antelope apparently have to be markedly different from each other, before an "all antelope" or "all cattle" policy supercedes a "combination of antelope and cattle" from an economic standpoint.

An isobenefit function was defined as the ratio of net benefits per head for cattle over net benefits per head of antelope ($67.65/$13.75). Given this isobenefit relationship and the nature of the production possibilities curve, point D represents the optimum combination of cattle and antelope, corresponding to the point with the highest total value in Table 6 ($3,069).

Finally, it should be noted that at point D (67 antelope and 32 cattle), annual forage harvest is likewise maximized at the upper limit of 63,150 lbs. of grass and 31,069 lbs. of shrubs from the 1,000 acre range site (Table 7). For all simulated combinations including more cattle and fewer antelope (E-I), grass harvest remained at the upper limit (63,150 lbs.), and the harvest of shrubs correspondingly declined, while the opposite occurred for those combinations having fewer cattle and more antelope (A-C). Also, for all of the combinations, grass consumption was minimal during the fall and winter seasons. However, with the exception of combination I (no antelope), consumption of shrubs was more evenly distributed over all four seasons.

Conclusions

Opposing public views exist concerning use of public rangeland. One view favors cattle grazing on public rangelands, while another does not. Given this specific study area (Red Desert of Wyoming) in conjunction with the particular biological and economic assumptions embedded in the analysis, the estimates of benefits suggest optimal economic use of the range resource occurs when managed for multiple use. Loss of social welfare and underutilization of this renewable resource could occur if the interests of any particular group (e.g. naturalists or livestock producers) were allowed to dictate management of public lands for only single purpose use in this case.

It should be emphasized that results and conclusions are based on characteristics of this particular study area as well as specific assumptions regarding the estimates of economic benefits, forage requirements, and availability. Consequently, results should be interpreted cautiously for general policy purposes. For example, production possibility relationships could be altered somewhat, it the amount of grass and shrubs were constrained on a seasonal versus an annual basis. Since data on seasonal forage production was not available, the analysis was conducted using annual forage production. Given the difference in diets, it is not anticipated that using seasonal constraints on forage would alter the production possibility relationship to the extent that the general conclusion would change.

Table 1. Average Annual Forage Production on the Study Area for 1964 and 1965, Determined by Clipping 2' X 4' Plots and Presented as Pounds Per Acre - Oven Dried Weight.

Species	1964	1965	Average
		lbs/acre	
Big sagebrush	147.0	266.7	206.85
Douglas rabbitbrush	89.4	88.7	89.05
Western wheatgrass	51.6	57.2	54.40
Needle and thread grass	19.3	21.1	20.20
Indian ricegrass	14.5	19.2	16.85
Squirreltail grass	13.0	14.9	13.95
Winterfat	10.0	6.7	8.35
Sandberg bluegrass	3.6	7.7	5.65
Obtuse sedge	3.1	8.1	5.60
Forbs	Trace	2.6	1.30
Total	351.5	492.9	422.20

Source: Severson, Keith E. Grazing Capacities and Competition of Pronghorn Antelope and Domestic Sheep in Wyoming's Red Desert. Ph.D. Thesis, Range Management, University of Wyoming, 1966.

Table 2. Average Percent of Diet by Season for Cattle and Antelope.

	Winter		Spring		Summer		Fall	
Plant Class	Antelope	Cattle	Antelope	Cattle	Antelope	Cattle	Antelope	Cattle
Grass	12.75	81.75	21.90	91.0	5.13	78.14	5.02	78.00
Shrubs	80.57	13.75	60.74	2.0	64.04	1.80	83.11	15.80
Forbs	7.18	4.00	12.76	8.0	30.13	18.83	8.86	5.00

Source: Holman, Thomas L. A Model for Economic Evaluation of Agricultural and Recreational Uses of Public Lands. M.S. Thesis, Agricultural Economics, University of Wyoming, 1976. (Percentages do not necessarily add to 100%, since they are derived by Holman as a composite average from several sources.)

Table 3. Linear Programming Matrix.

	(hd) Antelope (1)	(hd) Steers (2)	(lb) Wtr. Grass (3)	(lb) Spg. Grass (4)	(lb) Sum. Grass (5)	(lb) Fall Grass (6)	(lb) Wtr. Shrub (7)	(lb) Spg. Shrub (8)	(lb) Sum. Shrub (9)	(lb) Fall Shrub (10)	RHS
MAXIMIZE											
1) No. of animals	1	1									
Subject To:											
2) Total grass (lb)			1	1	1	1					≤63,150
3) Total shrubs (lb)							1	1	1	1	≤31,069
4) Wtr. grass Req. (lb)	30.5		-1								= 0
5) Wtr. shrubs Req. (lb)	123.3						-1				= 0
6) Spg. grass Req. (lb)	53.0	382.2		-1							= 0
7) Spg. shrubs Req. (lb)	92.9	9.0						-1			= 0
8) Sum. grass Req.(lb)	53.9	1263.0			-1						= 0
9) Sum. shrubs Req.(lb)	98.0	42.0							-1		= 0
10) Fall grass Req. (lb)	21.2					-1					= 0
11) Fall shrubs Req.(lb)	127.2									-1	= 0
12) Specified no.(hd)	1.0										= K
13) Specified no. (hd)		1.0									= K

Table 4. Costs Experienced by Wyoming Permittees in Grazing Livestock on Federal Lands: 1983.

	($/AUM)
Turn-out	1.28
Gathering/takeoff	2.30
Routine management	3.41
Maintenance	1.86
Salting, feeding and veterinary services	0.35
Meetings	0.43
Death loss	3.00
Fees and rents	1.41
Other	0.63
Total costs	14.67

Source: Obermiller and Lambert (1985).

Table 5. Nine Sustainable Combinations of Antelope and Cattle on Red Desert.

	Antelope		Cattle		
Point	Head	AUMs	Head	AUMs	Total AUMs
A	70	168.0	0	0	168.0
B	69	165.6	12	34.4	200.0
C	68	163.2	21	60.0	223.2
D	67	160.8	32	91.6	252.4
E	56	134.4	33	94.4	228.8
F	45	108.0	34	97.2	205.2
G	25	60.0	36	103.0	163.0
H	14	33.6	37	105.8	139.4
I	0	0	38	108.7	108.7

AUM is defined as forage required to maintain a 1,000 lb. cow for 1 month. The AUM coefficient used for the steers is .715.

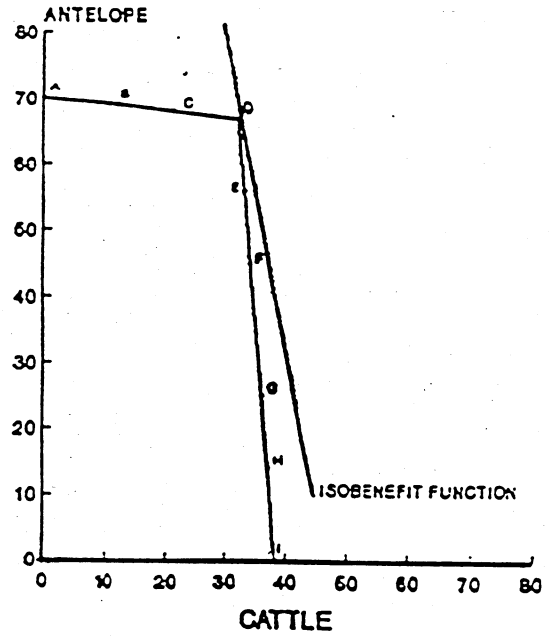

Figure 1. Production Possibilities.

Table 6. Estimated Value of Each Simulated Combination of Activities.

Point	Antelope # Antelope	Antelope # Hunted	Antelope $ Value	Cattle # Cattle	Cattle Revenue[a/]	Cattle (-) Cost[b/]	Cattle $ Value	$ Total
A	70	32	967	0	0	0	0	967
B	69	31	937	12	1,409	599	810	1,747
C	68	30	906	21	2,466	1,045	1,421	2,327
D	67	30	906	32	3,758	1,595	2,163	3,069
E	56	25	755	33	3,876	1,644	2,232	2,987
F	45	20	604	34	3,993	1,692	2,301	2,905
G	25	11	332	36	4,228	1,793	2,435	2,767
H	14	6	181	37	4,346	1,842	2,504	2,685
I	0	0	0	38	4,463	1,893	2,570	2,570

a/ Rev=#hd.xlbs.x$65.25/cwt.(10 yr avg for med frame no. 1 700-800 lb. steers).
b/ Cost=#AUMs(x) $14.67/AUMs (estimated cost/AUM associated with federal grazing) plus estimated opportunity cost associated with the cattle ($7.84/hd.).
Sources: Antelope Hunting, Sorg and Loomis (1984) adjusted to 1983 $. Price of Steers, Kearl (1987). Cost of Grazing, Obermiller and Lambert (1985).

Table 7. Simulated Seasonal Forage Consumption by Selected Animal Combinations.

Pt.	No. Animals Antp.	Catt.	Grass Wtr.	Spg.	Sum.	Fall	Total	Shrubs Wtr.	Spg.	Sum.	Fall	Total
	-(hd)-		(lbs/1,000 ac.)									
A	70	0	2,147	3,731	3,794	1,492	11,164	8,679	6,539	6,898	8,953	31,069
B	69	12	2,105	8,243	18,875	1,463	30,686	8,508	6,518	7,266	8,777	31,069
C	68	21	2,073	11,628	30,186	1,441	45,328	8,379	6,503	7,542	8,645	31,069
D	67	32	2,034	15,748	43,954	1,414	63,150	8,223	6,484	7,878	8,484	31,069
E	56	33	1,704	15,573	44,689	1,184	63,150	6,886	5,486	6,860	7,105	26,337
F	45	34	1,387	15,405	45,394	964	63,150	5,608	4,631	5,885	5,785	21,909
G	25	35	755	15,070	46,801	524	63,150	3,049	2,622	3,936	3,146	12,753
H	14	37	438	14,903	47,505	304	63,150	1,771	1,667	2,961	1,827	8,226
I	0	38	--	1,467	48,479	--	63,150	--	345	1,612	--	1,957

References

Ensminger, M.E. and C.G. Olentine, Jr. Feeds & Nutrition - Abridged. Ensminger Publishing Co., Clovis, Calif., 1978.

Gomes, Hilton De Souza. Forage Preference and Grazing Behavior of Hereford and Barzona Cattle on Southern Arizona Range. M.S. Thesis, University of Arizona, 1983.

Harjou, Harry. Head Biologist, Wyoming Game and Fish Commission, Personal Interview, November, 1988.

Holcheck, Jerry Lee. The Effects of Vegetation Type and Grazing System on the Performance, Diet and Intake of Yearling Cattle. Ph.D. Thesis, Oregon State University, 1980.

Holman, Thomas L. A Model for Economic Evaluation of Agricultural and Recreational Uses of Public Lands. M.S. Thesis, University of Wyoming, 1976.

Kearl, W.G. "Marketing of Wyoming Cattle Including Average Prices of Cattle and Calves, Eastern Wyoming and Western Nebraska, 1968-1986." Bulletin 891, Agricultural Experiment Station, University of Wyoming, 1987.

Obermiller, Fredrick W. and David K. Lambert. "Costs Incurred by Permittees in Grazing Livestock on Public Lands in Various Western States." Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon, 1985.

Severson, Keith E. Grazing Capacities and Competition of Pronghorn Antelope and Domestic Sheep in Wyoming's Red Desert. Ph.D. Thesis, University of Wyoming, 1966.

Sorg, Cindy F. and John P. Loomis. Empirical Estimates of Amenity Forest Values: A Comparative Review. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-107, Fort Collins, Colorado, 1984.

Soil Conservation Service. National Range Handbook. United States Department of Agriculture, Washington, D.C., 1976.

Sundstrom, Charles, William G. Hepworth and Kenneth L. Diem. "Abundance, Distribution and Food Habits of the Pronghorn (A Partial Characterization of the Optimum Pronghorn Habitat)." Wyoming Game and Fish Commission, Bulletin 12, 1973.

Taylor, ElRoy. "Pronghorn Carrying Capacity of Wyoming's Red Desert." Wildlife Technical Report No. 3, Wyoming Game and Fish Department, 1975.