Optimal Economic Timing of Range Improvement Alternatives: Southern High Plains

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Abstract

Profit maximizing combinations of livestock enterprises, plant control practices, and grazing management systems for ranches in the southern High Plains were examined. A typical ranch and a multi-period linear programming model were used to determine the combinations and timing of improvement practices and enterprises to maximize discounted net income with different investement capital constraints, cattle prices, and discount rates. All solutions included chemical control of sand shinnery oak *(Quercus havardii)* and a rotation grazing system. Timing of improvements and net income were affected by size of investment capital constraint.

Key Words: brush/noxious weed control, range improvements, multi-period linear programming

The southern part of the High Plains of west Texas and eastern New Mexico is semiarid. Average annual rainfall is 41 cm, occurring mostly in the growing season. Variable rainfall among and within years has contributed to overgrazing at some point on much of the rangeland in the region and, consequently, to the brush and weed problems. Soils vary from deep sands to sandy clay loams, elevation is about 1,067 m, and the frost-free period is about 200 days (USDA 1964).

Three dominant pest species on ranches in the area are sand shinnery oak *(Quercus havardii),* honey mesquite *(Prosopis glandulosa),* and broom snakeweed *(Xanthocephalum sarothrae).* Hereafter sand shinnery oak will be referred to as oak, honey mesquite as mesquite, and broom snakeweed as broomweed. Oak is native to the deep sandy soils and occurs mostly in dense infestations. It reduces grass yield and produces oak poisoning in livestock when consumed in the spring (Pettit 1979). Mesquite occurs on fine sandy loam and loamy fine sand soils in infestations ranging from light to moderate. It reduces grass production by competing for light and water (Dahl et al. 1978). Broomweed occurs on finer textured soils in the western part of the area and occurs mostly in heavy infestations (defined as over 50% canopy cover for purposes of this analysis), reducing grass production and causing abortions in cattle (Sosebee et al. 1979, Ueckert 1979).

It is assumed that ranchers want to maximize net returns over time. Profit maximization is not the only valid objective of ranchers, but it is an accurate predictor of producer behavior (Biswas et al. 1984). The decision to control noxious plants by chemical or other means is one of many decisions which the rancher must make in ranch management. Other decisions involve types of livestock enterprises and types of grazing systems to use. Expenditures on brush control and grazing system facilities such as fences and livestock watering facilities are long-term investments, and decisions about these may include *when* in addition to *if* these investments should be made. This may be especially relevant when financial capital is limited. The objective of this study was to determine the most profitable combinations and timing of several alternative livestock enterprises, pest plant control practices, and grazing systems for ranches in the southern High Plains (Fig. 1), given variation in the availability of investment capital, cattle prices, and discount rates.

Related studies include an analysis of net income from chemical control of mesquite in the Texas Rolling Plains under alternative livestock prices, forage responses to treatment, and income tax liability rates (Freeman et al. 1978). Sharp and Boykin (1967) evaluated investments in honey mesquite control and alternative beef cattle systems in the Texas Rolling Plains. Sharp and Boykin considered timing of investments, but neither of the above studies considered multiple improvement practices. Kothmann and Mathis (1979) examined income with 3 grazing systems and 3 stocking rates; control of noxious plants was not included in the study. Whitson and Scifres (1980) conducted a broad scope analysis of

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The authors acknowledge the contributions of Dean Hughes, Gary Condra, and Rodney Preston, the editors, and two anonymous reviewers in the preparation of the manuscript.

Manuscript accepted 14 July 1987.

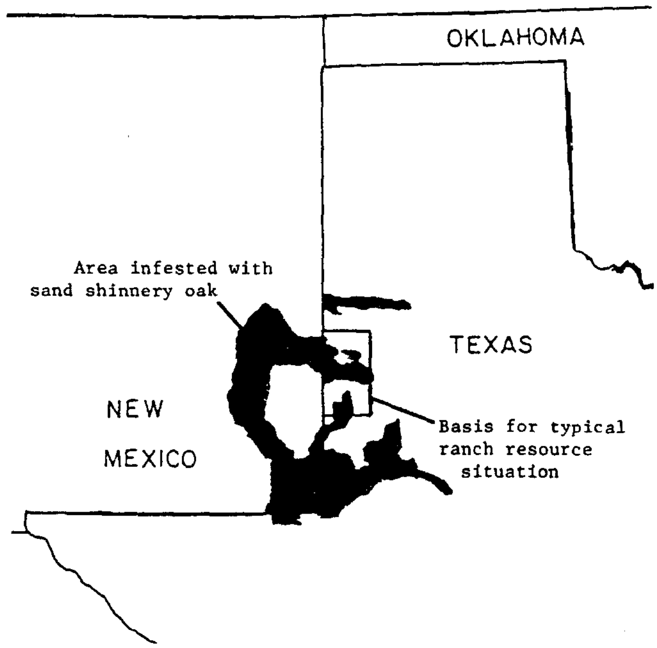

Fig. 1. *Southern High Plains study region.*

economic feasibility of mesquite control in 14 regions of Texas. Their analysis considered mesquite control independent from other plant pest species and other range improvement practices. Also, their High Plains region consisted of almost 3 million ha of rangeland rather than the relatively homogenous resource area defined for this study.

Methods and Procedures

The analysis for the region was done through a "typical ranch" a hypothetical composite of ranches and resource situations in the region which represents the region in general but no particular existing ranch. Ranch characteristics and resources—land area, soil types, types and extent of pest plant infestations, and livestock carrying capacity—were based on ranches in Cochran and Yoakum counties, Texas (Fig. 1). Data for defining the typical ranch were from USDA (1964) soil surveys, a sample survey of ranches, and interviews with USDA Soil Conservation Service personnel.

The typical ranch had 2,033 ha of rangeland in 6 soil associations. Cropland was not considered in the analysis. Mesquite occurs in light to moderate stands, oak in heavy infestations, and broomweed is most common on shallow soils over caliche, but the different pest plant infestations do not occur on the same site. About 11% (230 ha) of the typical ranch rangeland had no pest plant problem, 76% (1,539 ha) was heavily infested with oak, 9% (196 ha) had a light to moderate mesquite infestation, and 4% (68 ha) had light, moderate, or heavy broomweed cover. Yearlong stocking rates varied from 2 animal units/section (AU/sect) on land with heavy broomweed infestation to 25 AU/sect on land with no pest plants; average carrying capacity for the ranch without improvement was 8-9 yearlong AU/sect.

Improvement options included alternative pest plant control practices and a rotation grazing system. Plant control alternatives were limited to treatment of mesquite with 2,4,5-T (2,4,5-trichlorophenoxy acetic acid)[1], treatment of broomweed with picloram (4-amino-3,5,6-trichloropicolinic acid), and treatment of oak with tebuthiuron [N-(5-1,1-dimethylethyl 1,3,4-thiadiazol-2-yl)-N, N'-dimethylurea]. Grazing system options were a continuous grazing system and a rotation system. Livestock enterprises included were

[1]2,4,5-T is no longer available, but was available when the study was initiated, and there is no standard treatment at present.

Table 1. Additions to grass yields from pest plant control, southern High Plains.

	Sand shinnery oak		Honey mesquite		Broom snakeweed	
Year	Sandy soils	Sandy loam soils	Sandy loam soils	Fine sandy soils	Fine sandy soils	Loamy soils
	kg/ha					
1	437	375	473	550	252	699
2	577	515	379	440	252	699
3	624	562	283	284	252	699
4	647	586	189	220	252	699
5	662	599	97	110	252	699
•	•	•				
•	•	•				
•	•	•				
14	698	636				
15	699	637				

cow-calf and stocker steer. Plant control effects were incorporated via grass response functions (Table 1). The grass response relationships for mesquite treatment modified results from Ethridge, Dahl and Sosebee (1984) to reflect High Plains conditions, the relationships for oak treatment were from Ethridge et al. (1984) and the broomweed relationships were assumed, but based on experience of range management experts in the region (Sudderth 1984). These responses assumed historical and/or current treatment rates and practices for the area. The tebuthiuron rate was 0.56 kg/ha at a cost of $44.50/ha, the 2,4,5-T rate was 0.56 kg/ha at a cost of $21/ha, and the picloram rate was 0.28 kg/ha at a cost of $29.65/ha. Additional grass yield increases and stabilizes over time after the oak is root killed and the range grasses increase their density (Jones and Pettit 1984). Treatment life on oak was determined to exceed the planning horizon of the analysis and thus assumed to be permanent for this analysis. Added grass yield decreases over time with mesquite and broomweed control because of reinfestations; mesquite regrowth occurs from the base of the plant and broomweed reappears at its previous level of infestation. A 5-year treatment life was assumed for mesquite and broomweed. Broomweed infestation is erratic and control can be short or long lived. The 5-year life is an average, but there is uncertainty associated with that assumption. Livestock grazing was deferred for 1 year following treatment of oak and broomweed and for 6 months following treatment of mesquite (SCS recommendations).

The hypothetical rotation grazing system consisted of 1,067-ha blocks of 8 paddocks, each with water facilities in the center. All cattle were placed in 1 paddock and rotated on the basis of forage conditions. Costs of establishing the system were budgeted at $13.81/ha (Sudderth 1984) and included no brush control costs. The rotation system was assumed to increase stocking capacity (usable forage production) by 30% on noninfested and all types of treated land and 15% on all infested land except the heavy oak and broomweed infestations, where the rotation system made no difference.

Additional grass production was converted to livestock production by calculating grass requirements of livestock, range maintenance requirements, and weight gains of livestock. Each cow producing unit (CPU) grazing yearlong consisted of a cow and calf, 14% of a replacement heifer, 3% of a horse, and 5% of a bull (Kennedy 1970) and was assumed to require 9,870 kg of total grass/year (Ethridge et al. 1984). Each stocker steer unit (SSU) required 2,608 kg of total grass/yr. The stocker cattle were assumed to be bought on 1 May and removed on 31 October, averaging a weight gain of .68 kg/day. Production costs and returns for cow-calf and stocker steer enterprises were budgeted using cattle prices from the Amarillo and San Angelo, Texas, markets. Calves and cull cows were sold in the fall and stocker steers were purchased in the spring and sold in the fall. Net returns

Table 2. Conditions for alternative model solutions.

	Baseline	Severe capital constraint	No capital constraint	High livestock prices	Low livestock prices	High discount rate	Low discount rate
Prices ($/kg)							
227 kg steers	1.59	1.59	1.59	1.74	1.44	1.59	1.59
204 kg heifers	1.39	1.39	1.39	1.52	1.24	1.39	1.39
Cull cows	0.93	0.93	0.93	1.01	0.80	0.93	0.93
181 kg steers	1.79	1.79	1.79	1.88	1.61	1.79	1.79
272 kg steers	1.51	1.51	1.51	1.57	1.40	1.51	1.51
Discount Rate (%)	5	5	5	5	5	8	2
Investment capital constraint							
Borrowed capital ($)	35,000	0	No constraint	35,000	35,000	35,000	35,000
SCS subsidy ($)	35,000	35,000	35,000	35,000	35,000	35,000	35,000

to land and management were estimated to be $86.13/CPU/yr and $31.96/SSU/yr, except when cows and calves were on oak-infested range year-around, when net returns were $74.63/CPU/yr (Tex. Agr. Extension Serv. 1983).

A multi-period linear programming model was developed to determine the combinations of cattle enterprises and range improvement practices to maximize the present value of net ranch income over a 15-year planning horizon. Model solutions were obtained using 3 different cattle prices (1979–1983 seasonal average for each cattle group at the San Angelo and Amarillo, Texas, markets, the second highest price for each group, and the second lowest); 3 discount rates (1979–1983 annual average, the second highest, and the second lowest); and 3 investment capital constraints (Table 2). Two types of model activities were included in each year of the planning horizon: range improvement practices which, when initiated, produce grass in the year initiated and in subsequent years of the planning horizon and livestock enterprises, which use grass each year. Two types of transfers were made from one year to the next within the model: transfers which allowed land treated for brush/noxious weeds to be considered for rotation in the following years of the planning horizon and vice versa and transfers of investment capital and cost share funds between years. The resource constraints each year were the amount of grass available, land available for treatment, and available investment capital.

Table 3. Optimal range improvement practices, cattle enterprises, and net income; baseline conditions, selected investment capital constraints.

	Units	Years 1	2	3	4	5	6	7	•••	14	15	Residual
Improvement practices												
No capital constraint												
Oak treatment	ha	1,539							•••			
Rotation system	ha	247	1,539						•••			
Moderate capital constraint												
Oak treatment	ha	1,258			214	67			•••			
Rotation system	ha	247	700	558		214	67		•••			
Severe capital constraint												
Oak treatment	ha					11	74	38	•••	123	145	
Rotation system	ha		46	59	77	65	11		•••			
Cattle enterprises												
No capital constraint												
Steers	SSU		110						•••			
Cow-calf	CPU	36	132	200	201	201	201	202	•••	203	203	
Moderate capital constraint												
Steers	SSU	12	102	12	3	15	4		•••			
Cow-calf	CPU	37	101	171	171	184	198	201	•••	203	203	
Severe capital constraint												
Steers	SSU	53	53	53	53	53	52	53	•••	41	37	
Cow-calf	CPU	30	31	33	34	36	37	39	•••	74	83	
Net ranch income												
No capital constraint												
Annual	$	3,100	13,780	15,339	15,414	15,414	15,414	15,489	•••	15,563	15,563	80,593
Total discounted	$	94,400							•••			
Moderate capital constraint												
Annual	$	3,570	11,212	13,571	13,283	14,625	15,319	15,415	•••	15,563	15,563	80,593
Total discounted	$	90,800							•••			
Severe capital constraint												
Annual	$	4,278	4,364	4,536	4,622	4,795	4,837	4,944	•••	7,247	7,791	39,772
Total discounted	$	50,500										

The constraints on capital investment in the model included $35,000 of government cost share money, the current federal cost-share limit per ranch, which provided initial investment capital for improvement practices. The cost share fund could be used to pay half the cost of an improvement practice; the other half came from net returns from the ranch or from borrowed funds. Borrowed funds were either not limited (no investment capital constraint), limited to $35,000 for the 15-year period (moderate capital constraint), or limited to no borrowing (severe capital constraint). Net revenue from ranching enterprises less family living expenses ($4,000/yr—the amount of net income the model ranch generates in its native state; i.e., with the cow-calf enterprise and no improvements) was made available for investment in improvements. While the $4,000/yr is not sufficient for family subsistence, it reflects that ranching is part-time activity for many operators in the region. The typical ranch also has farming activities and petroleum revenue. Any available investment capital or cost share funds not used in a given year were available for investment in subsequent years.

Since treatment of oak with tebuthiuron affects rangeland productivity beyond the 15-year planning horizon, the residual value of treatment was accounted for in the model as the added market value of the land. Land values were estimated by local Soil Conservation Service specialists to increase by $44.50 to $49.40 per ha at the end of the planning horizon. Since mesquite and broomweed treatments were in the 5-year intervals, these improvements could also have residual value for as many as 4 years. If mesquite and broomweed treatment effects extended beyond the 15-year horizon, their values were accounted for as value of added grass production rather than an increase in land value. These were included in the model as an average annual value of grass production to simplify programming; these residual values varied with livestock prices. A residual value of the rotation grazing system was also estimated at $4.94/ha.

The first situations analyzed, identified as baseline solutions, were with 5-year season average cattle prices and real discount rate (prime rate minus inflation rate). Effects of higher and lower cattle prices on the ranch plan were then considered with other variables held constant. The discount rate was also varied to higher and lower levels with baseline cattle prices. Conditions for alternative models are summarized in Table 2.

Results and Discussion

In the no and moderate capital constraint baseline solutions, all noninfested range was put into a rotation system in year 1 (Table 3). This was followed by all oak range being treated and put into a rotation system. All improvements were completed by year 2 with no capital constraint and year 6 with the moderate capital constraint. In the high capital constraint solution, noninfested range was put into rotation in years 2 through 5 until completed. Treatment of oak began in year 5 and continued through year 15, with only 53% of infested acres treated. Under the baseline high capital constraint, fewer improvement practices were done and feasible improvement practices were spread over a longer time period. Chemical treatment of mesquite and broomweed were not feasible in any of the baseline solutions and treatment of mesquite did not enter any of the solutions for the conditions examined.

The stocker steer enterprise was included with the cow-calf enterprise while improvement practices were taking place. Once improvements were completed, the ranch included only the cow-calf enterprise. Cow-calf and steer numbers increased throughout the 15-year period in each of the 3 solutions due to increased carrying capacity from the range improvement practices.

Net income varied little in year 1 among the investment capital constraint conditions. After adoption of improvements, income increased gradually in each case through year 15. Discounted income for the 15 years was highest under the no capital constraint baseline solution at $94,400 compared to $90,800 and $50,500 with

Table 4. Optimal range improvement practices with alternative livestock prices and discount rates.

	Years									
Improvement practices	1	2	3	4	5	6	7	8	•••	15
Moderate capital constraint										
High livestock prices										
Oak treatment	1,373		38	4					•••	
Rotation system	247	10	529	996	21				•••	
Broomweed treatment					17				•••	
Low livestock prices										
Oak treatment	1,221			161	106	51			•••	
Rotation system	247	713	509		161	106	51		•••	
High discount rate										
Oak treatment	1,191		93	173	81				•••	
Rotation system	247	927	264	93	52	81			•••	
Low discount rate										
Oak treatment	1,462			77					•••	
Rotation system	247		540	418	582				•••	
	Years									
	1	2	3	•••	10	11	12	13	14	15
Severe capital constraint										
High livestock prices										
Oak tratment			27	•••	211	578	8			
Rotation system		139	108	•••	167					
Low livestock prices										
Oak treatment				•••						
Rotation system				•••						
High discount rate										
Oak treatment				•••	63	74	87	103	122	144
Rotation system		46	59	•••						
Low discount rate										
Oak treatment				•••	64	76	89	106	125	147
Rotation system		46	59	•••						

the moderate and high capital constraints, respectively.

Impacts of different cattle prices and discount rates on timing and feasibility of improvement practices included in the optimal ranch plan are summarized in Table 4. With the moderate capital constraint, improvements in the model solutions were the same as in the moderate capital constraint baseline solution except with higher cattle prices improvements were completed a year sooner, treatment of all the heavy broomweed land (17 ha) became economically feasible, and the treated broomweed range was also put into rotation. In all other solutions with the moderate capital constraint, improvement practices were the same as the baseline, but the timing of implementation was slightly different.

In the severe capital constraint solutions, improvement practices were the same as in the corresponding severe capital constraint baseline solution except that 75% more oak was treated with higher cattle prices and 5% less oak was treated at the higher discount rate. A solution for the lower cattle price and severe capital constraint could not be determined because cattle enterprises could not generate enough net income to meet the $4,000 per year family living expense imposed on the model.

At higher cattle prices, total discounted income increased 54% (to $90,800) and 55% (to $78,500) in the moderate and high capital constraint solutions, respectively, as compared to the baseline solutions. With lower cattle prices, total discounted income fell 26% (to $67,100) in the moderate capital constraint solution compared to baseline. Total discounted income fell by 43% (to $50,300) and 23% (to $38,900) in the moderate and high capital constraint solutions with the higher discount rate. With the lower discount rate, total discounted income increased 61% (to $146,800) and 34% (to $68,000) in the moderate and severe capital constraint solutions, respectively, as compared to baseline.

Changes in cattle prices and discount rates had no major effect on the mix of cattle enterprises in the optimal ranch plan except with lower cattle prices. In the moderate capital constraint solution with lower cattle prices, the stocker steer enterprise entered the solution exclusively instead of the cow-calf or cow-calf, stocker steer combination. This occurred because the purchase price of 181 kg steers fell more than did the selling price of 272 kg steers, and net returns per head for the stocker steer enterprise increased relative to the cow-calf entrprise.

Conclusions

Several range improvement practices were shown to be generally profitable on the coarse soils of the southern High Plains of West Texas and Eastern New Mexico. These include a rotation grazing system on rangeland without serious pest plant infestations and chemical treatment of sand shinnery oak with tebuthiuron. Chemical control of mesquite is generally not economically feasible, and treatment of broomweed with 0.28 kg/ha of picloram is feasible only under restricted conditions. For chemical mesquite control to be feasible in the area on a widespread basis, treatment cost would have to fall by at least 70%, although there may be isolated cases where treatment is cost effective. Chemical control of broomweed appears feasible only with a sustained high level of cattle prices or with a decrease in treatment costs of at least 27%. As economic conditions change or more cost effective methods to control these 2 plant pests are developed, the economic feasibility of treating them may change. In fact, the cost of broomweed treatment has recently declined from the $29.65/ha used in the analysis to $22.24/ha, a decrease of 25%. Consequently, broomweed control is approaching economic feasibility, especially if there is some increase in calving percentage and livestock production.

The optimal order of investments in improvement practices indicated by the model solutions individually and collectively for the study region is: (a) establishment of a rotation grazing system on all noninfested range, (b) chemical treatment of oak, and (c) establishment of a rotation system on range which has been chemically treated. Further, this *sequence* for investment is not sensitive to investment capital constraints, cattle prices, or discount rates. However, the *timing* in many cases must be extended over more years as investment capital is more limited, and the investment capital limitations decrease the present value of the net income stream.

The cow-calf operation was determined to be more profitable after range improvements have been made. However, the difference in net returns between cow-calf and stocker steer enterprises was small. Stocker steers were a part of the modeled ranch plan while ranch improvements were being made because timing of treatments and deferment requirements favor the shorter production cycle of stocker cattle. The exception of the above conclusions was with persistent low cattle prices; when all cattle prices are low, the purchase-sale price differential for stocker cattle narrows and the stocker enterprise becomes more profitable.

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