Economic Analysis of Controlling Leafy Spurge with Sheep

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INTRODUCTION

Leafy spurge (*Euphorbia esula* L.), first introduced in North America in the 19th century, was found in North Dakota in 1909, and was considered a threat to rangeland in the Great Plains as early as 1933 (Hanson and Rudd 1933). The weed currently infests large amounts of untilled land in the Plains and Mountain states. Once established on untilled land, the weed spreads quickly, displacing native vegetation. Leafy spurge has unique characteristics that give it a competitive advantage over most native plants and provide it with natural defenses against cattle grazing. Leafy spurge can create serious economic losses for land owners and ranchers.

Current control technologies are ineffective in eradicating established infestations. Although leafy spurge can be controlled through chemical, biological, and cultural methods, each control approach has limitations in its applicability and effectiveness in treating all leafy spurge infestations. However, many of the constraints prohibiting herbicides, tillage, and biological controls (i.e., prohibitive expense, unsuitable land, and physiological barriers) do not appear to eliminate sheep grazing as a possible control. Grazing with sheep and goats, while known to be effective in controlling leafy spurge since the 1930s, lacks widespread adoption (Sedivec et al. 1995; Sell et al. 1998). Many questions remain regarding the economic feasibility of using sheep to control leafy spurge. A goal of this study is to help determine how sheep grazing could fit into an integrated pest management approach to control leafy spurge by providing economic information for land owners to use in assessing their long-term control strategies.

OBJECTIVE

The purpose of this report is to evaluate the economic feasibility of using sheep to control leafy spurge in rangeland.

PROCEDURES

Since sheep will not eradicate leafy spurge, assessment of leafy spurge control requires identifying the benefits and costs of treatment over extended periods. This study focused on the economic feasibility of control, which compares long-term costs with long-term benefits. Financial and operational constraints, such as cash flow, available capital, and labor requirements, were not included.

Model Development

A model was developed to evaluate the benefits and costs of using sheep to control leafy spurge. Given an initial leafy spurge infestation, the model predicts leafy spurge

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spread and the corresponding annual losses in cattle grazing if the infestation was left uncontrolled over various periods. The effects of sheep grazing on infestation canopy cover (i.e., density), spread rates, grass rejuvenation, and grazing recovery rates for cattle were incorporated. The dynamics of control (i.e., changes in canopy cover, rate of spread, and grass recovery) were based on secondary information and consultation with weed and range scientists. The economic feasibility of using sheep to control leafy spurge was evaluated using various scenarios which reflect likely situations facing cattle ranchers implementing a sheep enterprise for leafy spurge control.

Costs of using sheep to control leafy spurge include fencing expenses and net returns from a sheep enterprise (which could be positive or negative) or expenses from leasing sheep. Benefits of control include (1) recouping lost grazing outputs (for cattle) from within the infestation (grazing recovery) and (2) maintaining existing grazing capacity by preventing current infestations from expanding (grazing retention).

Two economic perspectives were considered: (1) treatment costs were compared to treatment benefits (i.e., classic benefit-cost analysis) and (2) potential losses without control were compared to losses incurred using sheep to control leafy spurge (i.e., least-loss or cost-minimization analysis). In the first analysis, treatment situations where returns are greater than costs are economical. In the second analysis, treatments where economic losses are less when using sheep to control leafy spurge than would be incurred without controlling leafy spurge would be economically advisable, providing alternative control strategies were not available. When a no-control strategy (i.e., leaving the infestation alone) results in less economic loss than would be incurred when implementing a control strategy using sheep, a "do nothing" strategy or one employing other control methods (e.g., herbicides, biocontrol, and/or tillage/reseeding) might be optimal.

Sheep Enterprises

A basic premise in this study was that sheep would be added to leafy spurge infested rangeland either through (1) adoption of a sheep enterprise by an existing ranch or (2) leasing sheep during the grazing season.

Two lease rates were used in this study–$1 per head per month and $2 per head per month. The lessee would only be responsible for providing adequate fencing and water during summer grazing.

Sheep enterprises that would be used primarily for leafy spurge control were based on typical western North Dakota farm operations. Sheep were assumed to lamb prior to spring calving, thereby not interfering with beef operations. Only ewes and rams were used for leafy spurge control. Lambs were assumed to be weaned before summer grazing and retained in feedlots until fall.

Costs and revenues for several sheep enterprises were developed to accommodate different flock size, performance, and financial characteristics. Variable costs, such as shearing, utilities, fuel, etc., were assumed equal (i.e., per ewe) among all enterprises. Economic charges (depreciation) were not included for machinery and equipment that overlap with cattle production. Selling prices for lambs, cull ewes, and wool represented a 5-year average of North Dakota prices (ND Agricultural Statistics *various years*).

Two flock sizes were developed. Small flocks had 60 ewes and 2 rams and large flocks had 200 ewes and 6 rams. Flocks were further categorized by those with debt and those without debt. The enterprises with debt were

assumed to have 50 percent of the equipment and facility requirements financed for 5 years and 50 percent of the breeding stock purchases financed for 3 years. Loan interest rate was 10 percent. After the first three to four years of a grazing control program, the number of sheep needed for leafy spurge control generally decreases (Sedivec et al. 1995). Budgets for each production scenario were estimated annually over a 10-year period to accommodate changes in flock size and debt expiration. Production coefficients, selling prices, and variable expenses were fixed over the 10-year period.

Flock performance (e.g., lambing rate, weaning rate, rate of gain, death loss) will likely vary depending upon management ability, animal husbandry, and willingness and ability of ranchers to devote resources to flock management. One management situation was based on flock performance achieved by established sheep producers in North Dakota (good management scenarios). The other situation was based on flock performance levels below that of unassisted lambing flocks on the Hettinger Research Station (poor management scenarios) (Hettinger Research Extension Center 1999). The two management scenarios evaluated (good and poor) represent likely extremes in flock performance. Good management scenarios were designed to represent "best case" situations; whereas, poor management scenarios were designed to represent "worst case" situations. The most realistic outcome for the majority of ranchers adopting a sheep enterprise will likely be somewhere in between those two extremes.

Leafy Spurge Control

Leafy spurge control with sheep will vary depending upon the grazing system employed. Rotational (two 1-month periods) and seasonal (4 months) grazing strategies were considered. Both grazing systems were expected over time (several grazing seasons) to reduce existing infestation canopy cover and also prevent plant spread.

A mixed-species grazing approach was assumed. The number of sheep required for control was based on one ewe per acre of leafy spurge. The stocking rate for cattle was assumed to remain unchanged the first year of sheep grazing and assumed to increase over time as the carrying capacity (for cattle) increased with improved levels of leafy spurge control. This study assumed (1) ranchers adjusted cattle stocking rates or grazing duration to accommodate the increase in grazing output, (2) initial cattle stocking rates were appropriate for the land prior to leafy spurge treatment, and (3) reductions in sheep stocking rates were implemented over time.

The expected level of leafy spurge control was based on information obtained from secondary sources and consultation with weed and range scientists. Control of leafy spurge was based on the number of years of grazing assuming the same flock is used to graze leafy spurge each year and that proper stocking rates are maintained (Figure 1). Control was defined as a percentage of the previous year's density or canopy cover {e.g., density(year 2)-[density(year 2) x control(year 2)] = density(year 3)}.

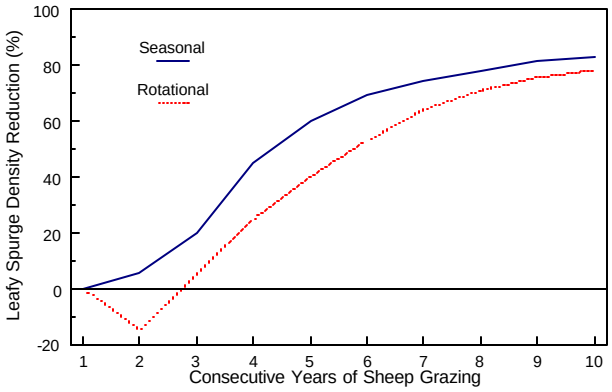

Figure 1. Leafy Spurge Control with Sheep Grazing, Seasonal and Rotational Strategies

The rate of leafy spurge spread was also based on the number of years of grazing. Since leafy spurge can expand at various rates, reduction in the rate of spread was estimated as a percentage of actual spread (Figure 2). In a seasonal grazing strategy, leafy spurge expansion is halted in the fourth year of sheep grazing. In a rotational grazing strategy, five years of sheep grazing would be required to halt leafy spurge expansion.

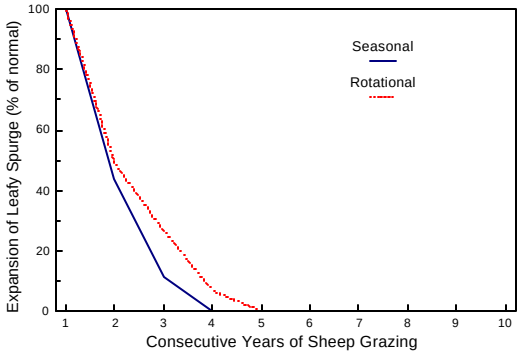

Figure 2. Rate of Leafy Spurge Expansion with Sheep Grazing, Seasonal and Rotational Strategies

Grazing Reduction Model

One of the key components in the model is the relationship between infestation density or canopy cover and lost grazing capacity (for cattle). In order to estimate the losses from leafy spurge infestations, the analysis of the economics of sheep grazing required estimating the amount of forage lost to cattle that results from various levels of leafy spurge infestation. The degree of lost grazing capacity within a leafy spurge infestation was estimated as linear function of canopy cover (Figure 3). The model assumes that a 30 percent canopy cover would roughly translate to about 80 to 130 stems/M^2.

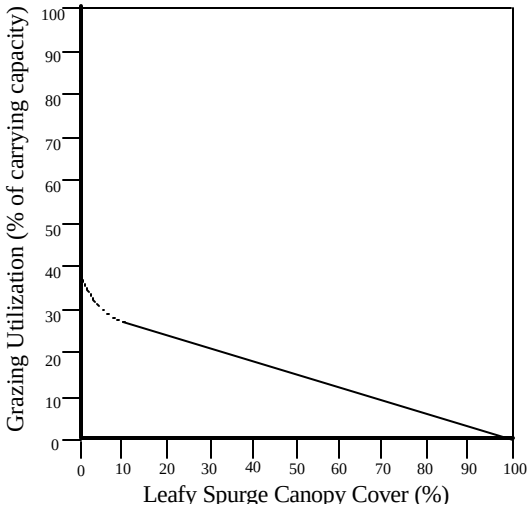

Figure 3. Reduction in Cattle Grazing within Leafy Spurge Infestations
Source: Kirby (1999).

Forage Recovery

The relationships between canopy cover reduction, grass utilization (cattle), and grass production over time were estimated from secondary sources (Lym et al. 1997; Sedivec et al. 1995) and from consultation with weed and range scientists.

The basic approach to estimating the amount of forage consumed by cattle was based on two factors: (1) the amount of grass available within leafy spurge infestations and (2) the amount of available grass that cattle would graze. The model assumes that as leafy spurge infestations increase in density, grass production within those infestations decreases (Figure 4). The relationship between leafy spurge density and grass production was based on the ability of leafy spurge to outcompete native vegetation and create near monocultures (Watson 1985; Messersmith et al. 1985).

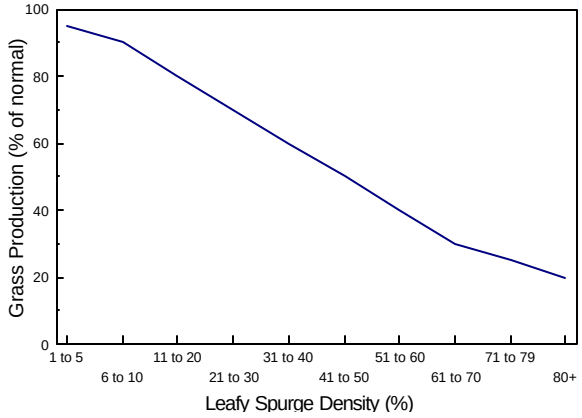

Figure 4. Grass Production and Leafy Spurge Infestation Density

Since sheep will not eradicate leafy spurge, the model assumes that sheep will not eliminate enough leafy spurge to bring infestation sites back to their pre-infestation carrying capacity. Since control was based on a function of time, the rate of grass consumption by cattle was also modeled as a function of the number of years of sheep grazing (Figure 5). Even though grass production within the infestation was modeled to increase over time as infestation density was reduced, grass production was assumed to remain below that of uninfested rangeland even after 10 years of sheep grazing.

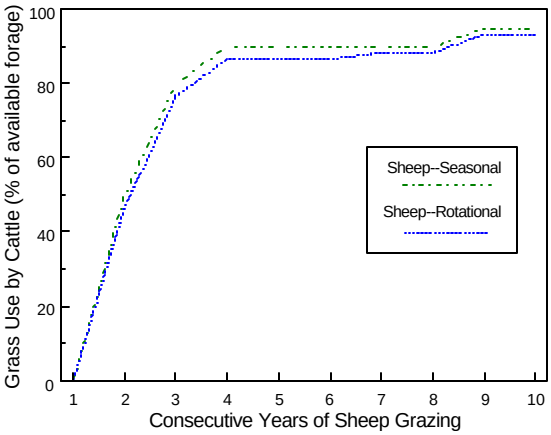

Figure 5. Grass Consumption by Cattle within Leafy Spurge Infestations Controlled with Sheep Grazing

RESULTS

Results provide a look at the long-term economic feasibility of using sheep to control leafy spurge under a variety of plausible situations facing landowners in the upper Great Plains. Actual control and treatment conditions will likely differ from those used in this study.

Sheep Enterprises

Several possible sheep enterprise scenarios were budgeted to accommodate differences in flock performance, debt structure, and flock size. Annual budgets were generated to accommodate changes in flock size and debt expiration over time. Net returns, excluding fence costs and taxes, for the various sheep enterprises ranged from ($5.82) to $45.14 per ewe in year 1 of the 10-year budgeting period (Table 1).

Fencing costs were estimated separately from the sheep enterprise budgets to accommodate various combinations of pasture size and leafy spurge infestations for all scenarios. Thus, fencing costs would reflect the appropriate expense for multiple combinations of pasture size, new or modified fence, and infestation size, regardless of the other factors influencing enterprise returns. Fencing materials were based on August 1998 retail prices for wire and posts in Hettinger, North Dakota. Labor expense was not included. Water development costs also were not included as existing pastures were assumed to have adequate water sources which would require minimal effort to modify for their use by sheep.

Fencing expenses included modifying an existing fence or constructing new fence. Modified fencing was based on adding 2 barb wires to an existing 3- or 4-wire fence. New fence was based on 6 barb wires, including requirements for line and corner posts. Five percent of total fencing expenses was charged to the enterprise budgets each year.

Table 1. Returns to Unpaid Labor, Management, and Equity for Various Sheep Enterprise Scenarios, Western North Dakota[a]

	Good Management[b]				Poor Management[c]			
	Debt[d]		No Debt		Debt		No Debt	
Year	Small[e]	Large[e]	Small	Large	Small	Large	Small	Large
	dollars per ewe							
1 & 2	30.09	41.25	34.56	45.21	(5.58)	(3.25)	(1.23)	0.62
3	22.02	32.88	26.48	36.85	(16.45)	(14.40)	(12.09)	(10.54)
4 & 5	30.26	32.46	31.59	32.99	(3.79)	(0.78)	(2.46)	(0.25)
6	31.59	32.99	31.59	32.99	(2.46)	(0.25)	(2.46)	(0.25)
7	26.18	27.99	26.18	27.99	(10.57)	(8.04)	(10.57)	(8.04)
8 - 10	24.54	31.67	24.54	31.67	(6.90)	(1.64)	(6.90)	(1.64)

[a] Net returns do not include fencing costs or taxes.
[b] Good management based on flock performance (i.e., lambing rate, weaning rate, death loss, etc.) obtained by proven sheep producers in North Dakota (Hettinger Research Extension Center 1999).
[c] Poor management represents a low level of flock efficiency and productivity, specifically, performance below that of unassisted lambing flocks at the Hettinger Research Extension Center (Hettinger Research Extension Center 1999).
[d] Debt included financing one-half of the breeding flock for three years and one-half of equipment and building expenses for five years at 10 percent interest.
[e] Small flocks based on 60 ewes and large flocks based on 200 ewes. Flock reductions occurred in years 4 and 8.

Within the range of fencing costs examined, fencing expense (i.e., 5 percent of total fence expense) ranged from $0.10 to $8.49 per ewe per year with seasonal grazing. In the scenarios including debt, 50 percent of total fencing costs was assumed to be financed for five years at 10 percent interest. The interest expense in financing fencing debt was included as an additional fencing expense. Fencing costs per ewe for new fence were generally five to six times higher than costs of modifying an existing fence.

Feasibility of Long-term Control--Sheep Enterprises

This section discusses the economic feasibility of using sheep to control leafy spurge through adding a sheep enterprise to an existing ranch. Several variables were held constant across all analyses. Pasture size was limited to 350 acres. Grazing recovery and retention were valued at $15 per AUM. All analyses were evaluated using 5, 15, and 30 percent canopy cover for the leafy spurge infestation, which correspond with low (17 percent loss), moderate (50 percent loss), and high (100 percent) grazing losses (for cattle) within the leafy spurge infestation, respectively. Results are presented for a 10-year period.

Seasonal Grazing

Seasonal grazing strategies were based on grazing sheep for four months, with grazing initiated in May. Four of the eight scenarios evaluated had positive net returns for the sheep enterprise (see Table 1). Under those circumstances, even with modest levels of leafy spurge control, using sheep as a leafy spurge

control will be economical. However, with negative enterprise returns, the cost of control (i.e., money lost maintaining the sheep enterprise) must be balanced with the benefits of control (i.e., value of leafy spurge control and grazing output for cattle).

Benefit-cost Analysis

The good management scenarios revealed substantial positive returns from leafy spurge control. Total net returns (discounted treatment returns less discounted treatment costs) from leafy spurge control, with rangeland carrying capacities of 0.20 AUMs per acre, ranged from $123 to $219 per acre of leafy spurge, depending upon fencing obligations, debt, and flock size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control ranged from $137 to $262 per acre of leafy spurge (Table 2).

The poor management scenarios revealed that net returns from leafy spurge control were sensitive to rangeland productivity and leafy spurge canopy cover. Total net returns from leafy spurge control, with rangeland carrying capacities of 0.20 AUMs per acre, ranged from $(72) to $(1) per acre of leafy spurge, depending upon fencing obligations, debt, and flock size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control ranged from $(58) to $42 per acre of leafy spurge (Table 2).

Generally, net returns from leafy spurge control were about $12 to $23 per acre higher for scenarios having no debt versus those with debt (e.g., good management without debt compared to good management with debt) (Table 2). Over a 10-year period, net returns from leafy spurge control were $26 per acre less for scenarios with new fence versus modified fence across all management scenarios with small infestations and net returns from leafy spurge control were $8 per acre less with large infestations. Net returns per acre from leafy spurge control were higher with large infestations (250-acre) versus small infestations (50-acre) across all scenarios. In a 10-year period, net returns from large infestations compared to small infestations improved by $17 to $45 per acre for all scenarios with modified fence. For all scenarios with new fence over the same period, net returns from leafy spurge control improved by $33 to $66 per acre when comparing large to small infestations.

Least-loss Analysis

Least-loss analysis compares the economic losses that would occur if a leafy spurge infestation was left uncontrolled to the losses incurred with control. In situations where economic losses with treatment are more than the economic losses incurred with no control, the treatment program or method would not be recommended.

The good management scenarios had positive enterprise returns (even after fencing expenses), which resulted in positive returns from control. Thus, least-loss analyses were not conducted for those scenarios. Least-loss scenarios were conducted for the poor management scenarios.

Over a 10-year period, most sheep grazing scenarios with high rangeland productivity and high leafy spurge cover resulted in less economic loss than with no control (Table 3). Many of the scenarios with new fence and low leafy spurge cover would not be recommended within a 10-year period. However, with new fence and high leafy spurge cover, both large and small infestations could be recommended for all but the least productive rangeland. In a 10-year period, none of the small flock scenarios would be recommended at rangeland carrying capacities of 0.20 AUMs per acre (Table 3).

Table 2. Total Net Returns Per Acre from the Control of Leafy Spurge Using Sheep with Seasonal Grazing Scenarios over 10 Years[a]

Carrying Capacity	50-acre Infestation: Infestation Canopy Cover: Low	Medium	High	Low	Medium	High	250-acre Infestation: Infestation Canopy Cover: Low	Medium	High	Low	Medium	High
	------ Modify Fence ------			------- New Fence -------			------ Modify Fence ------			------- New Fence -------		
AUMs/acre	---------- good management with no debt ----------											
0.20	167.8	171.6	177.4	145.9	149.7	155.5	209.5	213.3	219.0	202.9	206.7	212.5
0.40	172.6	180.2	191.8	150.7	158.3	169.9	214.2	221.7	233.2	207.6	215.2	226.7
0.60	177.4	188.8	206.2	155.5	166.9	184.3	218.9	230.2	247.5	212.3	223.6	240.9
0.80	182.1	197.4	220.6	160.3	175.5	198.7	223.6	238.6	261.7	217.0	232.1	255.1
	---------- good management with debt ----------											
0.20	152.3	156.1	161.9	122.7	126.6	132.4	197.4	201.2	206.9	188.6	192.3	198.1
0.40	157.0	164.7	176.3	127.5	135.2	146.8	202.1	209.6	221.2	193.3	200.8	212.3
0.60	161.8	173.3	190.7	132.3	143.8	161.2	206.8	218.1	235.4	198.0	209.2	226.5
0.80	166.6	181.9	205.1	137.1	152.4	175.5	211.5	226.6	249.6	202.7	217.7	240.7
	---------- poor management with no debt ----------											
0.20	-27.7	-23.9	-18.1	-49.5	-45.7	-39.9	-10.5	-6.7	-0.9	-17.0	-13.3	-7.5
0.40	-22.9	-15.3	-3.7	-44.8	-37.1	-25.5	-5.8	1.8	13.3	-12.3	-4.8	6.7
0.60	-18.1	-6.7	10.7	-40.0	-28.5	-11.1	-1.1	10.2	27.5	-7.6	3.7	20.9
0.80	-13.3	1.9	25.1	-35.2	-19.9	3.3	3.6	18.7	41.7	-2.9	12.1	35.2
	---------- poor management with debt ----------											
0.20	-42.9	-39.1	-33.3	-72.4	-68.6	-62.8	-22.2	-18.5	-12.7	-31.1	-27.3	-21.6
0.40	-38.1	-30.5	-18.9	-67.6	-60.0	-48.4	-17.5	-10.0	1.5	-26.4	-18.9	-7.4
0.60	-33.3	-21.9	-4.5	-62.8	-51.4	-34.0	-12.8	-1.6	15.7	-21.7	-10.4	6.9
0.80	-28.5	-13.3	9.9	-58.1	-42.8	-19.6	-8.1	6.9	29.9	-17.0	-2.0	21.1

[a]Fencing costs based on a 350-acre pasture. Returns discounted annually at 4 percent. Low, medium, and high rates of leafy spurge canopy cover translate to about 17, 50, and 100 percent reductions in cattle grazing within the leafy spurge infestations, respectively. AUMs valued at $15. Debt included one-half of breeding stock financed for three years and one-half of equipment financed for five years. Interest rate at 10 percent.

Table 3. Least-loss Analysis of the Control of Leafy Spurge Using Sheep, Poor Flock Management, Seasonal and Rotational Grazing Scenarios[a]

Carrying Capacity	50-acre Infestation: Infestation Canopy Cover						250-acre Infestation: Infestation Canopy Cover					
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
	------ Modify Fence ------			------- New Fence -------			------ Modify Fence ------			------- New Fence -------		
AUMs/acre	---------- poor management, no debt, seasonal grazing ----------											
0.20	no	no	no	no	no	no	no	yes	yes	no	no	yes
0.40	no	yes	yes	no	no	yes	yes	yes	yes	no	yes	yes
0.60	no	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes
0.80	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
	---------- poor management, with debt, seasonal grazing ----------											
0.20	no	no	no	no	no	no	no	no	yes	no	no	no
0.40	no	no	yes	no	no	no	no	yes	yes	no	no	yes
0.60	no	yes	yes	no	no	yes	yes	yes	yes	no	yes	yes
0.80	no	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes
	---------- poor management, no debt, rotational grazing ----------											
0.20	no	no	no	no	no	no	no	yes	yes	no	no	yes
0.40	no	yes	yes	no	no	no	yes	yes	yes	no	yes	yes
0.60	no	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes
0.80	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
	---------- poor management, with debt, rotational grazing ----------											
0.20	no	no	no	no	no	no	no	no	yes	no	no	no
0.40	no	no	yes	no	no	no	no	yes	yes	no	no	yes
0.60	no	yes	yes	no	no	no	no	yes	yes	no	yes	yes
0.80	no	yes	yes	no	no	yes	yes	yes	yes	no	yes	yes

[a]Fencing costs based on a 350-acre pasture. Returns discounted annually at 4 percent. Low, medium, and high rates of leafy spurge canopy cover translate to about 17, 50, and 100 percent reductions in cattle grazing within the leafy spurge infestations, respectively. AUMs valued at $15.

Note: In situations where net returns from using sheep to control leafy spurge are negative, least-loss analysis indicates if using sheep grazing to control leafy spurge would result in less economic loss than if the leafy spurge infestation was left uncontrolled. A “yes” implies that the scenario will result in less economic loss than no treatment. A “no” implies that the scenario will result in more economic loss than no treatment.

Rotational Grazing

Rotational (two 1-month periods) grazing strategies were evaluated. In a rotational system, sheep would graze the infestation for one month periods at a higher stocking rate than used in seasonal grazing. Sheep grazing would be initiated in May. Sheep would graze the same pasture a total of two nonconsecutive months during the grazing season. Other rotational grazing programs were not evaluated.

Benefit-cost Analysis

The good management scenarios revealed substantial positive returns from leafy spurge control with rotational grazing systems. Total net returns (discounted treatment returns less discounted treatment costs) from leafy spurge control, with rangeland carrying capacities of 0.20 AUMs per acre, ranged from $114 to $218 per acre of leafy spurge, depending upon fencing obligations, debt, and flock size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control ranged from $127 to $259 per acre of leafy spurge (Table 4).

The poor management scenarios revealed that net returns from leafy spurge control were sensitive to rangeland productivity and leafy spurge canopy cover. Total net returns from leafy spurge control, with rangeland carrying capacities of 0.20 AUMs per acre, ranged from $(81) to $(2) per acre of leafy spurge, depending upon fencing obligations, debt, and flock size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control ranged from $(68) to $39 per acre of leafy spurge (Table 4).

The pattern of net returns from control using rotational grazing strategies were similar to those with seasonal grazing strategies for all periods. Total returns over a 10-year period for all of the poor management, rotational grazing scenarios with low leafy spurge canopy cover remained negative with moderate to high rangeland carrying capacities (i.e., less than 0.80 AUMs/acre). However, in one scenario with high leafy spurge canopy cover, net returns over a 10-year period were positive down to 0.30 AUMs per acre carrying capacity (Table 4).

Generally, returns from leafy spurge control in rotational grazing scenarios were about $12 to $25 per acre higher for scenarios having no debt versus those with debt (Table 4). Over a 10-year period, returns from leafy spurge control with rotational grazing systems were $31 per acre less for scenarios with new fence versus modified fence across all management scenarios with small infestations, and $9 per acre less with large infestations. In a 10-year period, returns from large infestations compared to small infestations improved by $18 to $46 per acre for all scenarios with modified fence. For all scenarios with new fence over the same period, returns from leafy spurge control improved by $37 to $71 per acre when comparing large to small infestations.

Least-loss Analysis

The good management scenarios in the rotational grazing systems had positive enterprise returns (even after fencing expenses), which result in positive returns from control. Thus, least-loss analyses were not conducted for those scenarios. However, least-loss scenarios were conducted for the poor management scenarios.

Over the 10-year period, most scenarios with high rangeland productivity and high leafy spurge cover with large infestations resulted in less economic loss than with no control (Table 3). Many of the scenarios with new fence and low leafy spurge cover would not be recommended over a 10-year period. However, with new fence and high leafy spurge cover, both large and small flock scenarios could be recommended for all but the least productive rangeland. No small flock scenarios would be recommended at rangeland carrying capacities of 0.20 AUMs per acre (Table 3).

Table 4. Total Net Returns Per Acre from the Control of Leafy Spurge Using Sheep with Rotational Grazing Scenarios over 10 Years[a]

	50-acre Infestation Infestation Canopy Cover						250-acre Infestation Infestation Canopy Cover					
Carrying Capacity	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
	------ Modify Fence ------			------- New Fence -------			------ Modify Fence ------			------- New Fence -------		
AUMs/acre	---------- good management with no debt ----------											
0.20	166.1	169.9	175.6	139.5	143.4	149.0	208.7	212.5	218.1	200.7	204.5	210.1
0.40	170.5	178.2	189.5	143.9	151.6	162.9	213.0	220.6	231.8	205.0	212.6	223.8
0.60	174.9	186.4	203.3	148.3	159.8	176.8	217.3	228.6	245.5	209.3	220.7	237.5
0.80	179.3	194.6	217.2	152.7	168.0	190.6	221.6	236.7	259.2	213.6	228.7	251.2
	---------- good management with debt ----------											
0.20	150.1	154.0	159.6	114.2	118.1	123.7	196.5	200.3	205.9	185.7	189.5	195.1
0.40	154.5	162.2	173.5	118.6	126.3	137.6	200.8	208.4	219.6	190.0	197.6	208.8
0.60	158.9	170.4	187.4	123.0	134.5	151.5	205.1	216.4	233.3	194.3	205.7	222.5
0.80	163.3	178.6	201.2	127.4	142.7	165.3	209.4	224.5	247.0	198.6	213.7	236.2
	---------- poor management with no debt ----------											
0.20	-29.4	-25.5	-19.9	-55.9	-52.1	-46.5	-11.2	-7.5	-1.8	-19.2	-15.4	-9.8
0.40	-25.0	-17.3	-6.0	-51.6	-43.9	-32.6	-6.9	0.6	11.8	-14.9	-7.4	3.9
0.60	-20.6	-9.1	7.9	-47.2	-35.7	-18.7	-2.6	8.7	25.5	-10.6	0.7	17.6
0.80	-16.2	-0.9	21.7	-42.8	-27.5	-4.8	1.7	16.8	39.2	-6.3	8.8	31.3
	---------- poor management with debt ----------											
0.20	-45.0	-41.2	-35.5	-80.9	-77.1	-71.4	-23.2	-19.4	-13.8	-33.9	-30.2	-24.5
0.40	-40.6	-33.0	-21.6	-76.5	-68.9	-57.5	-18.9	-11.3	-0.1	-29.6	-22.1	-10.8
0.60	-36.2	-24.8	-7.8	-72.1	-60.7	-43.7	-14.6	-3.2	13.6	-25.3	-14.0	2.8
0.80	-31.9	-16.5	6.1	-67.8	-52.4	-29.8	-10.3	4.8	27.3	-21.0	-5.9	16.5

[a]Fencing costs based on a 350-acre pasture. Returns discounted annually at 4 percent. Low, medium, and high rates of leafy spurge canopy cover translate to about 17, 50, and 100 percent reductions in cattle grazing within the leafy spurge infestations, respectively. AUMs valued at $15. Debt included one-half of breeding stock financed for three years and one-half of equipment financed for five years. Interest rate at 10 percent.

Feasibility of Long-term Control--Sheep Leasing

An alternative to adopting a sheep enterprise would be to lease sheep for leafy spurge control. Leasing sheep for leafy spurge control would have some advantages over adding a sheep enterprise to an existing ranch. Many financial and operational constraints (e.g., capital, labor, facilities) inherent with adding another enterprise to an existing ranch operation would be eliminated with sheep leasing. However, leasing sheep would likely eliminate the potential net revenue generated from an additional enterprise. Expenses for leasing sheep would be similar in context to annual treatment expenses associated with herbicides (i.e., a rancher would be expected to pay some charge per acre per year for leafy spurge control).

Lease arrangements between a sheep owner and an individual desiring leafy spurge control could be numerous. The arrangement used for this study assumed that the animals would be leased on a monthly basis for only the time required for leafy spurge control. The lessee would not be responsible for death loss, health, or other flock maintenance duties during summer grazing. The lessee would be responsible for providing adequate fencing and water, along with sufficient forage for the period leased. Transportation was assumed the responsibility of the lessor. The only expenses for the lessee would be the monthly lease rate and fencing costs.

A critical assumption in the evaluation of leasing sheep for purposes of leafy spurge control was that the same flock would be leased over several years. The relationship between sheep grazing and leafy spurge control, in this study, was based on sheep becoming acclimated to eating leafy spurge. If, in a leasing arrangement, a rancher used sheep each year that were not acclimated to eating leafy spurge, control of leafy spurge would likely be less than the amount estimated in this analysis.

The economics of leasing sheep for leafy spurge control were evaluated using $1 per head per month and $2 per head per month lease rates. Each lease rate was evaluated according to the same format used in the sheep enterprise analyses. Seasonal grazing strategies were based on grazing sheep for four months, with grazing initiated in May. Rotational grazing strategies were not evaluated with sheep leasing.

Benefit-cost Analysis

Benefit-cost analysis of the two lease rates revealed that returns from leafy spurge control were sensitive to infestation size, infestation canopy cover, fencing costs, and lease rate. In a 10-year period, net returns for the $1 lease rate varied from ($50) to $(9) per acre of leafy spurge at 0.20 AUMs per acre carrying capacity, depending upon fencing obligations and infestation size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control with the $1 lease rate ranged from $(36) to $33 per acre of leafy spurge (Table 5).

Total net returns for the $2 lease rate varied from $(72) to $(31) per acre of leafy spurge at 0.20 AUMs per acre carrying capacity, depending upon fencing obligations and infestation size. When rangeland carrying capacity increased to 0.80 AUMs per acre, total net returns from leafy spurge control with the $2 lease rate ranged from $(58) to $11 per acre of leafy spurge (Table 5).

Table 5. Benefit-cost and Least-loss Analyses of the Control of Leafy Spurge Using Sheep Grazing, Sheep Leasing, Seasonal Grazing[a]

Carrying Capacity	50-acre Infestation Infestation Canopy Cover						250-acre Infestation Infestation Canopy Cover					
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
	------ Modify Fence ------			------- New Fence -------			------ Modify Fence ------			------- New Fence -------		
AUMs/acre	---------- $1 per head per month lease rate ----------											
0.20	-23.6	-19.8	-14.0	-49.8	-46.0	-40.2	-18.7	-15.0	-9.2	-24.0	-20.2	-14.5
0.40	-18.8	-11.2	0.4	-45.0	-37.4	-25.8	-14.0	-6.5	5.0	-19.3	-11.8	-0.3
0.60	-14.0	-2.6	14.8	-40.3	-28.8	-11.4	-9.3	1.9	19.2	-14.6	-3.3	14.0
0.80	-9.2	6.0	29.2	-35.5	-20.2	3.0	-4.6	10.4	33.4	-9.9	5.1	28.2
	---------- $2 per head per month lease rate ----------											
0.20	-45.8	-42.0	-36.2	-72.0	-68.2	-62.4	-41.0	-37.2	-31.4	-46.2	-42.5	-36.7
0.40	-41.0	-33.4	-21.8	-67.3	-59.6	-48.0	-36.3	-28.7	-17.2	-41.5	-34.0	-22.5
0.60	-36.2	-24.8	-7.4	-62.5	-51.0	-33.6	-31.6	-20.3	-3.0	-36.8	-25.5	-8.3
0.80	-31.5	-16.2	7.0	-57.7	-42.4	-19.2	-26.9	-11.8	11.2	-32.1	-17.1	6.0
	---------- $1 per head per month lease rate ----------											
0.20	no	no	yes	no	no	no	no	no	yes	no	no	no
0.40	no	yes	yes	no	no	yes	no	yes	yes	yes	yes	yes
0.60	yes	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes
0.80	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
	---------- $2 per head per month lease rate ----------											
0.20	no	no	no	no	no	no	no	no	no	no	no	no
0.40	no	no	yes	no	no	no	no	no	yes	no	no	yes
0.60	no	yes	yes	no	no	yes	no	yes	yes	no	yes	yes
0.80	no	yes	yes	no	no	yes	no	yes	yes	no	yes	yes

[a]Fencing costs based on a 350-acre pasture. Returns discounted annually at 4 percent. Low, medium, and high rates of leafy spurge canopy cover translate to about 17, 50, and 100 percent reductions in cattle grazing within the leafy spurge infestations, respectively. AUMs valued at $15.

Note: In situations where net returns from using sheep to control leafy spurge are negative, least-loss analysis indicates if using sheep grazing to control leafy spurge would result in less economic loss than if the leafy spurge infestation was left uncontrolled. A “yes” implies that the scenario will result in less economic loss than no treatment. A “no” implies that the scenario will result in more economic loss than no treatment.

Over a 10-year period, returns from leafy spurge control with $1 and $2 lease rates, averaged over various carrying capacities, increased about $26 per acre when leafy spurge canopy cover increased from 5 percent to 30 percent (Table 5). Net returns from leafy spurge control were $26 per acre less for scenarios with new fence versus modified fence across all scenarios with small infestations, and $5 per acre less with large infestations. Net returns per acre from leafy spurge control were higher with large infestations (250-acre) versus small infestations (50-acre) across all scenarios. In a 10-year period, net returns from large infestations compared to small infestations improved by $5 per acre for $1 and $2 lease rates.

Least-loss Analysis

Over a 10-year period with the $1 lease rate, nearly all scenarios with high rangeland productivity (0.60 AUMs per acre or higher) and high leafy spurge cover (30 percent canopy cover) resulted in less economic loss than with no control. Some of the scenarios with new fence and low leafy spurge cover would not be recommended over a 10-year period (Table 5). However, with new fence and high leafy spurge cover, both large and small infestations could be recommended for all but the least productive rangeland. In a 10-year period, the small infestation scenario with low leafy spurge cover and new fence would not be recommended, regardless of rangeland carrying capacity.

Over a 10-year period with the $2 lease rate, no scenarios with low leafy spurge cover would be recommended, regardless of rangeland productivity (Table 5). Some of the scenarios with modified fence and high leafy spurge cover would be recommended down to rangeland carrying capacities of 0.40 AUMs per acre. Most of the new fence, small infestation scenarios would not be recommended with the $2 lease rate over a 10-year period. Similarly, in the new fence, large infestation scenarios, only those with productive rangeland would be recommended (Table 5).

DISCUSSION

The following section identifies data and method shortcomings present in this study. Also, a general discussion of the factors influencing the economics of using sheep to control leafy spurge has been included.

Data and Method Shortcomings

A number of data and method shortcomings were present in this analysis. First, some key components of the model were based on "best estimates" of range and weed scientists. The first three to four years of leafy spurge control using sheep was based on range research; however, control in the remaining years was largely extrapolated from existing research data. The exact nature of leafy spurge control using sheep in years 5 through 10 has not been fully quantified. Also, the exact relationship between leafy spurge control and grass recovery is unknown.

A number of additional analyses could be used to show the sensitivity of net returns from leafy spurge control with different sets of model parameters (e.g., adjust model for less or more control, increase or decrease the amount of grass availability, use various rates of grass recovery). However, for sake of brevity, and since most of the existing relationships used in the model have not be been fully researched, additional scenarios showing the effects of different model parameters were not included.

All analyses were evaluated based on leafy spurge canopy cover levels of 5, 15, and 30 percent. These percentages were used to evaluate low, moderate, and high levels of grazing loss to cattle within leafy spurge infestations. Higher canopy cover percentages

would not affect the amount of lost grazing to cattle, but would have implications for grass recovery and potential returns to control.

Sheep prices, enterprise proficiency, production costs, debt levels, and grazing values were fixed over the analysis period. Their values will likely fluctuate over time or vary for individual ranchers. The effects of changes in those values were not addressed in this study.

The effects of changing the values of some initial situation inputs were not included in the analysis. For example, all analyses were conducted using one spread rate for leafy spurge infestations. Also, the annual rate of increase in leafy spurge canopy cover was fixed across all analyses. Other fixed inputs included the overall size of the pasture (all analyses used a 350-acre pasture) and fixed sizes of leafy spurge infestations (only a 50-acre and 250-acre infestation). The sensitivity of net returns to changes in those values was not addressed, and the study results could be improved by including these additional analyses.

Multiple species grazing has been shown to improve range health and increase grazing output on rangeland, assuming proper stocking rates. Any additional benefits obtained from multiple species grazing were not included in the analysis. Sheep may also help control other weeds on rangeland, in addition to controlling leafy spurge. Potential benefits from additional weed control and improvements in range productivity stemming from multiple species grazing were not included in this study.

Labor costs were not included in the sheep enterprise budgets or in the fencing expenses. Thus, even though returns may be positive for many control situations, returns from control may not be sufficient to adequately compensate a rancher for labor inputs. What a rancher would consider adequate compensation for time and labor inputs is a question best resolved by individual ranchers.

This study examined the economics of using sheep grazing to control leafy spurge; however, the issue of the economics of control may be irrelevant if a ranch operation has other constraints to adopting a sheep enterprise. Other issues, which should be examined, include financial and operational constraints to using sheep as a control tool for leafy spurge. These constraints may include the financial feasibility of adding a sheep enterprise to an existing ranch. Financial feasibility would address the availability of capital, cash flow, and other financial characteristics of a ranch operation that may prohibit adoption of an additional enterprise. Operational constraints, such as labor availability and seasonal labor demands, may also pose restrictions on adopting an additional enterprise.

Factors Influencing Returns from Control

A multitude of factors can influence the economics of using sheep to control leafy spurge. One of the biggest factors influencing returns from leafy spurge control would be enterprise returns. When enterprise returns were positive, net returns from leafy spurge control were positive in all of the treatment situations examined. In some cases, returns from leafy spurge control were substantial. However, when sheep are leased or enterprise returns were negative, a number of other factors influence the economics of control.

Large infestations were more economical to treat than small infestations, based on the fundamental assumptions used in this study. Fencing costs were modeled to be less with larger infestations, since overall pasture size was fixed across infestation sizes. In reality, per acre fencing costs for a 200-acre infestation could be the same as a 50-acre infestation. Also, because some efficiencies in sheep

production occur when moving from small flocks (e.g., 50 ewes) to large flocks (e.g., 200 ewes), enterprise returns (i.e., $ per ewe) improved with flock size. Thus, lower per ewe fencing costs and more favorable enterprise returns were major reasons for returns from control being more favorable with larger infestations.

With good flock management, returns from control were positive with both rotational and seasonal grazing strategies. However, rotational grazing scenarios were less economical than seasonal controls, due to reduced leafy spurge control and higher fencing costs associated with rotational grazing systems. However, differences in leafy spurge control between the two grazing systems for any particular situation may not match those used in this report.

Returns from control improved as leafy spurge canopy cover increased. As grazing losses for cattle increased, returns from leafy spurge control also increased. This relationship directly influenced the amount of grazing recovery that could be expected from leafy spurge control. Returns from leafy spurge control improved proportionally to changes in grazing recovery. Also, since sheep grazing was only evaluated using relatively large infestations, the value of grazing retention (i.e., grazing output retained by preventing infestation spread) was a small component of overall returns. The effects of much higher leafy spurge densities and levels of canopy cover would affect net returns from leafy spurge control if grass recovery and forage available within the infestations differed from the levels/relationships assumed in this study.

Returns from control were directly proportional to the productivity of rangeland. Returns also improved proportionally with increases in AUM values. As the two components increased, returns increased proportionally with changes in rangeland productivity and grazing output values. Thus, holding all other factors constant, returns were greater on more productive rangeland. Similarly, holding all factors constant, returns improved as AUM values increased.

The level of debt used in this study did affect returns from leafy spurge control. The level of debt used in this study had sufficient influence on returns from control (about $12 to $23 per acre) to affect decisions regarding the economics of using sheep to control leafy spurge. The effects of debt were most influential in the poor management scenarios. Debt expenses reduced enterprise returns and increased fencing expenses. If enterprise returns are positive after debt expenses, returns from control will still be positive. However, when enterprise returns were negative, debt expenses were sufficient in some situations to make sheep grazing of leafy spurge uneconomical. The effects of multiple debt levels and debt expenses were not included in this study.

The added expense for new fence had a much greater effect on returns from small infestations (expense was divided among fewer acres). Returns from control improved by $26 per acre with modified fence compared to new fence with small infestations; however, returns from control only increased by $7.50 per acre with modified fence compared to new fence with large infestations. The difference in net returns between new fence and modified fence scenarios for rotational grazing were greater than the differences with the seasonal grazing strategies. The increased fencing expense assumed in the rotational grazing systems accounted for the difference.

Lease rates of $2 per head per month were not economical in most control situations. However, a lease rate of $1 per head per

month was economical in many of the control situations.

To recap, the factors influencing returns from using sheep to control leafy spurge have been highlighted:

AUM values--returns from control changed proportionally with changes in AUM values.

Rangeland productivity--returns from control changed proportionally with changes in rangeland productivity.

Enterprise returns--the level of management, or financial performance, of the sheep enterprise had substantial effects on returns. Labor costs were not included in either the sheep budgets or fencing expenses.

Sheep leasing--leasing sheep for leafy spurge control may be an attractive alternative to adding a sheep enterprise to an existing operation. However, lease rates above $1 per head per month were not economical in many situations.

Infestation size--returns from control increase as infestation size increased across constant pasture sizes. Between the two infestation sizes evaluated, large infestations substantially increased net returns per acre over smaller infestations.

Fence expenses--modified fence was more economical than new fence, although the additional cost of new fence was not as prevalent in large infestations, assuming fixed pasture size. Expenses for new fence had more effect on returns from control in rotational grazing systems.

Debt costs--returns from control were less in the enterprise scenarios with debt; however, debt costs alone did not greatly influence overall returns from leafy spurge control.

Grazing system--seasonal grazing was more economical than rotational grazing, largely because rotational grazing had lower leafy spurge control rates and higher fencing costs.

Infestation canopy cover--as infestation canopy cover increased (ability of cattle to graze within the infestation decreased), returns from control increased. The range of canopy cover evaluated only ranged from 5 to 30 percent. Returns from control of much denser leafy spurge infestations would likely differ from the results presented in this study.

CONCLUSIONS

Very little information is available regarding the economics of using sheep to control leafy spurge. The primary goal of this research was to evaluate the economics of using sheep to control leafy spurge over a wide range of situations. Although a wide range of situations were evaluated, many of the key relationships between sheep grazing and forage recovery (cattle) have not be quantified. These relationships were estimated, for purposes of this study, based on assumptions and "best estimates" of weed and range scientists. Thus, until these relationships can be further refined, much of the economic analysis provided by this research remains sensitive to those key assumptions and relationships. However, the results from this preliminary research do provide important insights into the economics of using sheep to control leafy spurge.

The basic premise for this study was that sheep would be added to leafy spurge infested rangeland either through (1) adoption of a sheep enterprise by an existing ranch or (2) leasing sheep during the grazing season.

Several possible sheep enterprise scenarios were developed, which would represent a reasonable range of flock performance and financial conditions which could be expected from cattle ranchers. Sheep grazing as a leafy spurge control method was economical across many of enterprise scenarios developed. However, a number of other factors, such as additional labor requirements and financial constraints, need to be considered before implementing a grazing control strategy. Labor costs were not included in the sheep enterprise budgets or in the fencing expenses. Thus, even though returns may be positive for many control situations, returns from control may not be sufficient to adequately compensate a rancher for labor inputs. Providing these constraints do not prohibit adding a sheep enterprise to an existing ranch, the economics of using sheep grazing to control leafy spurge appear favorable. In many of the scenarios with negative sheep enterprise returns, the benefits of leafy spurge control outweighed the costs of control (enterprise returns and fencing expenses). Thus, controlling leafy spurge with sheep grazing can be economical even if the sheep enterprise had negative enterprise returns.

The economics of using sheep grazing to control leafy spurge appear promising. While using sheep to control leafy spurge could be economical in many situations (based on the limitations in this study), a careful evaluation using site- and rancher-specific inputs would be recommended before implementing sheep grazing as a leafy spurge control method. As with any decision regarding a long-term strategy to control leafy spurge, information in this study should be used in conjunction with other information and with consultation with weed scientists when formulating long-term control strategies.

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This document is a summary of a more comprehensive report which contains additional information. Additional copies of this summary and single copies of the main report, *Economic Analysis of Controlling Leafy Spurge with Sheep*, are available free of charge. Please address your request for additional copies to Carol Jensen, Department of Agricultural Economics, P.O. Box 5636, North Dakota State University, Fargo, ND 58105-5636, (phone 701-231-7441, fax 701-231-7400), E-mail: cjensen@ndsuext.nodak.edu or these documents are available on the world wide web at http://agecon.lib.umn.edu/ndsu.html

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