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Economic analysis of herbicide control of leafy spurge in rangeland

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Leafy spurge (*Euphorbia esula* L.) was first introduced in North America in the 19th century and was found in North Dakota in 1909. It 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 indigenous plants and provide it with natural defenses against cattle grazing. Leafy spurge can create serious economic losses for land managers and ranchers.

Control of the plant can be approached through chemical and/or biological strategies. Current herbicide technologies are ineffective in eradicating established infestations. Although long-term control of leafy spurge with herbicides is possible, it is difficult because the plant resists chemical agents and sustains itself against repeated treatments. Biological controls, while showing promise, are still being developed and lack wide-spread adoption. Nonetheless, herbicide treatments remain the cornerstone of control efforts. However, the most effective herbicides are expensive and the benefits of treatments are difficult to quantify, leaving many questions unanswered about the long-term economic feasibility of herbicide control.

OBJECTIVES

The purpose of this study was to provide an economic analysis of conventional herbicide control of leafy spurge in rangeland over extended periods. Specific objectives include 1) estimating the potential benefits of leafy spurge control, 2) estimating the costs of leafy spurge control, 3) identifying the factors affecting net returns from leafy spurge control, and 4) evaluating the long-term economic viability of herbicide control.

PROCEDURES

Decisions involving leafy spurge control can be complex. Factors to consider include land productivity, herbicide costs, amount of control, infestation spread, benefits from treatments, evaluations over extended periods, and selecting appropriate control strategies. Since few, if any, treatments are economical in the short term (5 years or less), economic evaluation of herbicide control of leafy spurge requires identifying the benefits and costs of treatment over time (for 20 years). This study focused on the economic feasibility of control, which compares long-term costs with long-term benefits. Financial feasibility, which generally addresses cash flow issues and financial constraints, was not included.

Model Development

A computer model was developed to evaluate the economics of controlling leafy spurge with herbicides. Given an initial leafy spurge infestation, patch spread and loss of grazing from that infestation is simulated (Figure 1). The difference between treatment expenses and benefits of control (grazing outputs) was discounted over time to provide a long-term perspective of each treatment scenario.

Some of the model's components were adapted from previous work. A leafy spurge patch expansion model was used to estimate infestation sizes over time given various expansion rates (Bangsund et al. 1993). The interaction between lost grazing capacity and infestation densities was included (Lym et al. 1993), along with the relationships among the amount of control, rate of spread, and density reduction.

The benefits of control included (1) recouping lost grazing outputs from the infestation through reducing patch density (grazing recovery) and (2) maintaining existing grazing capacity by preventing current infestations from expanding (grazing retention).

Although weed control can generally be put into four categories (prevention, eradication, reduction, and containment [Auld et al. 1987]), this study only evaluated population reduction and containment. With population reduction, the entire infestation is treated to reduce existing densities and to prevent patch spread. Containment strategies only treat the infestation edge to prevent patch expansion.

Two economic perspectives were considered for each control strategy: (1) compare treatment costs with treatment returns (i.e., classic cost/returns approach) and (2) determine potential losses with herbicide treatments compared to losses without control (least-loss, loss-minimization, or cost-effective approach). In the first analysis, treatment situations where returns are greater than costs are economical. In the second analysis, treatments where economic losses are less than would be incurred without control would be economically advisable, providing better control strategies were not available. When a no-control strategy (i.e.,

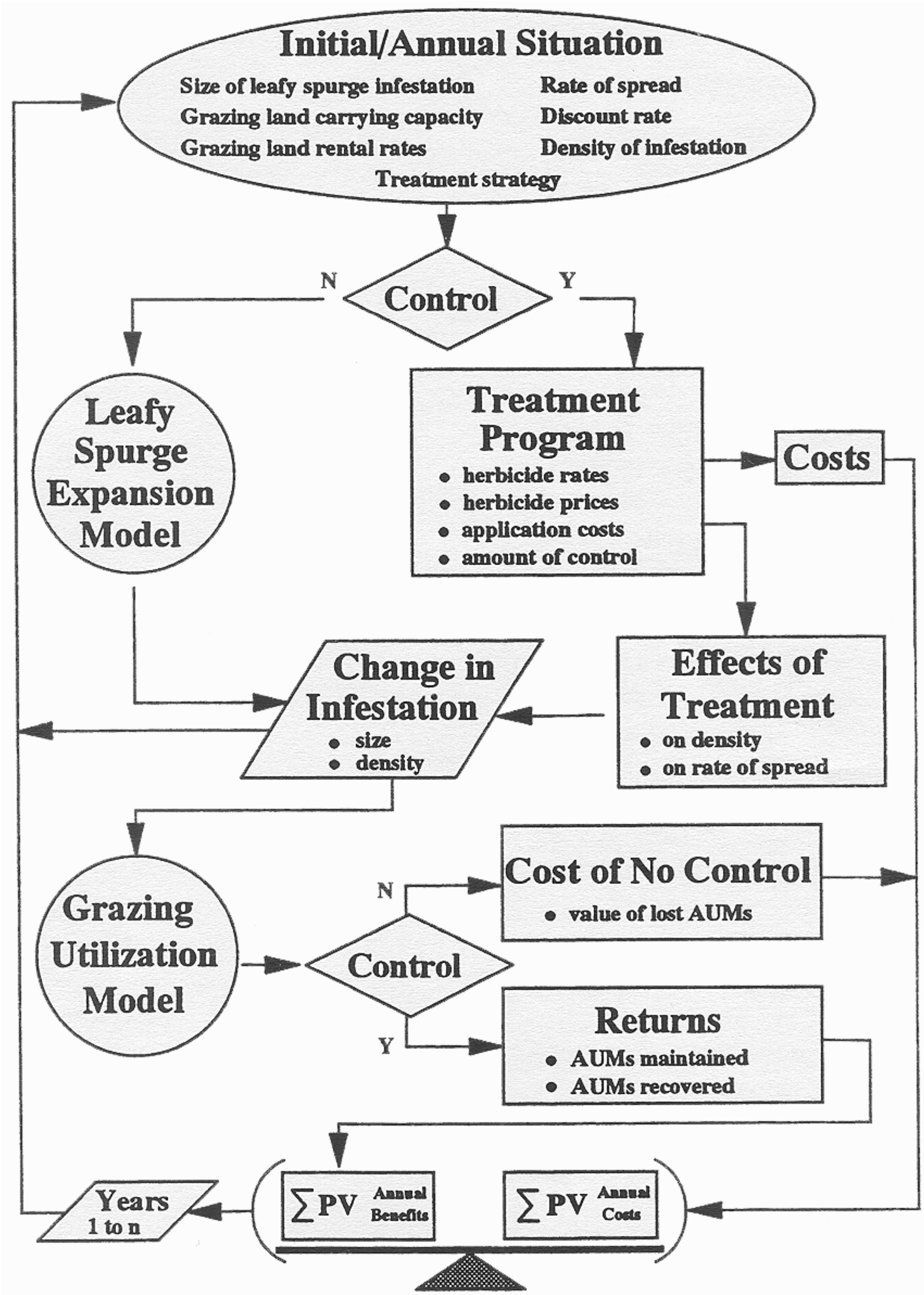

Figure 1. Economic Evaluation Model of Herbicide Control of Leafy Spurge

leaving the infestation alone) results in less economic loss than implementing a control strategy using herbicides, a "do nothing" strategy or one employing other methods might be optimal.

Herbicide Treatments

A number of herbicide treatments have been identified that result in the most effective physical control (population reduction) of leafy spurge (Lym et al. 1993). The most common herbicides used to control leafy spurge include picloram (trade name Tordon®), dicamba (trade name Banvel ®), 2,4-D ester and amine, and glyphosate plus 2,4-D (primary trade name Landmaster®). Fourteen treatment programs were evaluated for reducing the density (population reduction strategy) of leafy spurge infestations (Table 1). Six treatment programs were evaluated for only preventing spread (containment strategy) (Table 1).

Herbicide programs usually consist of annual applications (24D1 and 24D2), single-year treatments (Pic1, Pic2, Dic8), or multiple-year treatments (Pic.25, Pic.5, Pic.25+24D, GlPic+24D, etc.) (Table 1). Control with most treatments continues after the last application year. For example, under normal conditions, the Pic.25 program applies herbicide for four consecutive years, but delivers some control in each of the next three years, thereby providing control over a total of seven years (Table 1).

Herbicide prices were reflective of 1995 retail prices in North Dakota (Zollinger 1995). Treatments evaluated in this study did not contain surfactants or adjuvants. Application costs vary; however, an average application cost of $2.25 per acre was used in all treatment situations. Annualized treatment costs ranged from $4.24 per acre (GlPic+24Ds) to $110.75 per acre (Dic8) (Table 1).

Treatment Situations

A number of treatment situations were examined. Grazing was valued at $12, $15.50, and $19 per animal unit month[1] (AUM), representing common regional grazing values in North Dakota (1992 through 1994). Infestation size ranged from 0.022 acres (35-foot diameter patch) to 50 acres. Patch expansion rates of 1, 2, 3, and 4 radial feet/year were included in most scenarios. Various infestation densities were examined. The effects of reduced herbicide costs were evaluated. Other scenarios included restarting treatment programs earlier than normal, and some included reduced control and lowered grazing recovery. Treatment programs were repeated each time control reached zero over a 20-year period.

RESULTS

Results provide a look at the long-term economic feasibility of herbicide control of leafy spurge under a variety of plausible situations facing landowners in the Upper Great Plains. The influence of various economic and physical variables on returns from treatment also was evaluated.

Rather than focusing on subtle differences in returns from individual treatment programs, returns from the most economic programs were averaged to provide a more

[1]An animal unit month (AUM) is an average figure of the amount of forage needed to feed one animal unit (AU) for one month. An AU is typically considered a mature cow weighing approximately 1,000 pounds or an equivalent grazing animal(s) based on an average feed consumption of 26 pounds of dry matter per day (Shaver 1977).

Table 1. Selected Herbicide Treatments for Leafy Spurge in Grazing Land

Label	Herbicide Used	Application Rate				Years of Effective Control in Treatment[a]	Annualized Cost[b]
		Year 1	Year 2	Year 3	Year 4		
Broadcast Treatments		----------------------- lbs/ac ------------------------					- $/acre -
Pic.25	Picloram	0.25	0.25	0.25	0.25	7	7.00
Pic.5	Picloram	0.5	0.5	0.5	0.5	9	9.89
Pic1	Picloram	1.0	0	0	0	3	14.08
Pic2	Picloram	2.0	0	0	0	5	16.45
Pic.25+24D	Picloram & 2,4-D	0.25,1	0.25,1	0.25,1	0.25,1	8	7.75
Pic.5+24D	Picloram & 2,4-D	0.5,1	0.5,1	0.5,1	0.5,1	8	12.75
Pic.5+24Ds	Picloram & 2,4-D	0.5,1	0.5,1	0.5,1	0,0	7	10.93
Dic2	Dicamba	2.0	2.0	2.0	2.0	8	42.38
Dic8	Dicamba	8.0	0	0	0	3	110.75
24D1	2,4-D	1.0 annually				1	5.50
24D2	2,4-D	2.0 annually				1	8.75
Glph.75	Glyphosate	0.75	0	0	0	3	4.33
GlPic+24D[c]	Glyphosate & 2,4-D and Picloram & 2,4-D	0.4,0.6	0.25,1	0.25,1	0.25,1	8	7.05
GlPic+24Ds[c]	Glyphosate & 2,4-D and Picloram & 2,4-D	0.4,0.6	0.25,1	0,0	0,0	6	4.25
Perimeter treatments							
Pic.25-pc	Picloram	0.25	0.25	0	0.25	3	8.17
Pic.5-pc	Picloram	0.5	0	0.5	0	2	6.13
Pic.25+24D-pc	Picloram & 2,4-D	0.25,1	0	0.25,1	0	2	7.75
24D1-pc	2,4-D	1.0 annually				1	5.50
Glph.75-pc	Glyphosate	0.75	0	0.75	0	2	6.50
GlPic+24D-pc[c]	Glyphosate & 2,4-D and Picloram & 2,4-D	0.4,0.6	0	0.25,1	0	2	4.97

[a] The total number of years that the treatment provided some control. Control for most treatments continues beyond the last year of application.
[b] Annualized cost = herbicide costs and application expenses ÷ by years of effective control.
[c] Glyphosate and 2,4-D applied in year 1 with picloram and 2,4-D applied in years 2 through 4.

SOURCE: Adopted from Lym et al. (1993).

representative perspective to the economics of herbicide control. The most economical treatment programs were Pic.25, Pic.25+24D, 24D1, 24D2, GlPic+24D, and GlPic+24Ds. With current herbicide prices, no economic justification exists for using the dicamba treatments (Dic2 and Dic8) to control leafy spurge on rangeland--they produced losses several times greater than would be incurred without treatment. The Pic1 and Pic2 treatments, under most conditions, were not economical. The Pic.5, Pic.5+24D, and Pic.5+24Ds treatments were only moderately economical with small infestations and fast-spreading, medium-sized infestations. The Glph.75 treatment was economical; however, the treatment has limitations for use in rangeland and was not averaged with the other economical treatments.

Control Entire Infestation

A common approach to leafy spurge control in rangeland is to treat the entire infestation to reduce stand density and inhibit seed development, thereby simultaneously recovering grazing capacity and stopping the infestation's ability to spread. Returns from this strategy varied considerably, depending largely upon infestation size, value of grazing, and carrying capacity (Table 2). Returns changed substantially (on a per-acre basis at any given carrying capacity) as infestation size changed from 0.1 acre (75-foot diameter patch) to 25 acres (Table 2). Net returns also varied considerably over the range of carrying capacities used for any given infestation. For example, returns from treating a 1-acre infestation changed by about $135/acre as carrying capacity changed from 0.20 to 1.0 AUMs/acre (Table 2).

The point where returns broke even or became positive (break-even carrying capacity) varied from about 0.20 AUMs/acre with small patches (0.05 acres or 50 feet in diameter) to around 0.90 AUMs/acre for 50-acre infestations (Figure 2). Break-even carrying capacities, for all infestation sizes, decreased with increased grazing values. The extent of the sensitivity of results to AUM values depends upon infestation size. The larger the infestation, hence the more AUMs involved, the more sensitive the break-even carrying capacity became to changing AUM values (Table 2).

Least-loss carrying capacities (the level of land productivity needed to incur less economic loss than without control) varied from 0.20 AUMs/acre to nearly 0.60 AUMs/acre, depending upon patch size and grazing values (Table 2). For example, the least-loss carrying capacity needed when treating a 0.25-acre infestation (with $12/AUM) would be 0.30 AUMs/acre, whereas, a 5-acre infestation, under similar conditions, would require a carrying capacity over 0.50 AUMs/acre to incur less economic loss than no treatment.

Only a brief discussion of the influence of other factors on returns has been included (see Bangsund et al. 1996 for complete results). The effects of changing the rate of patch expansion were substantial when treating small infestations, but had little influence on returns as infestations approached 10 acres. Generally, increasing the radial spread of leafy spurge patches from 2 to 4 feet/year increased returns about $30/acre and reduced break-even carrying capacities about 0.10 to 0.15 AUMs/acre (with 1-acre infestations). Doubling the expansion rate with large infestations usually increased returns less than $5/acre and had no effect on break-even carrying capacities. Reducing the spread rate to 1 radial foot/year with small infestations decreased returns and increased break-even carrying capacities.

Table 2. Present Value of Average Returns From Long-term Leafy Spurge Control Using Herbicides[a]

	Initial Size of Infestation																	
	0.1 Acre			0.25 Acre			0.5 Acre			1.0 Acre			5.0 Acres			25.0 Acres		
	Value per AUM			Value per AUM			Value per AUM			Value per AUM			Value per AUM			Value per AUM		
	\$12	\$15.50	\$19	\$12	\$15.50	\$19	\$12	\$15.50	\$19	\$12	\$15.50	\$19	\$12	\$15.50	\$19	\$12	\$15.50	\$19
AUMs/ac	---$/acre---																	
0.20	(54)	(38)	(22)	(68)	(56)	(45)	(74)	(65)	(56)	(78)	(70)	(62)	(83)	(76)	(70)	(85)	(79)	(74)
0.25	(40)	(20)	(0)	(58)	(44)	(30)	(66)	(55)	(43)	(71)	(61)	(52)	(77)	(70)	(62)	(80)	(73)	(66)
0.30	(26)	(3)	**21**	(49)	(32)	(15)	(58)	(45)	(31)	(64)	(53)	(41)	(72)	(63)	(54)	(75)	(67)	(59)
0.35	(13)	**15**	43	(39)	(19)	**0**	(50)	(34)	(19)	(58)	(44)	(31)	(67)	(56)	(45)	(71)	(61)	(52)
0.40	**1**	33	65	(29)	(7)	16	(43)	(24)	(6)	(51)	(36)	(20)	(62)	(49)	(37)	(66)	(55)	(44)
0.45	15	50	86	(20)	**6**	31	(35)	(14)	**7**	(45)	(27)	(10)	(56)	(43)	(29)	(61)	(49)	(37)
0.50	28	68	108	(10)	18	46	(27)	(4)	19	(38)	(18)	**1**	(51)	(36)	(21)	(57)	(43)	(30)
0.55	42	86	129	(0)	31	61	(19)	**6**	31	(31)	(10)	12	(46)	(29)	(12)	(52)	(37)	(22)
0.60	55	103	151	**9**	43	77	(11)	16	44	(25)	(1)	22	(41)	(22)	(4)	(47)	(31)	(15)
0.65	69	121	172	19	55	92	(4)	26	56	(18)	**8**	33	(35)	(16)	**4**	(43)	(25)	(7)
0.70	83	138	194	29	68	107	**5**	36	69	(11)	16	44	(30)	(9)	13	(38)	(19)	**0**
0.75	96	156	215	38	80	122	12	47	81	(4)	25	54	(25)	(2)	21	(34)	(13)	8
0.80	110	173	237	48	93	137	20	57	88	**2**	33	65	(20)	**5**	29	(29)	(7)	15
0.85	124	191	259	58	105	153	28	67	106	9	42	75	(14)	12	38	(24)	(1)	22
0.90	137	209	280	67	117	168	36	77	118	16	51	86	(9)	18	46	(20)	**5**	29
0.95	151	226	302	77	130	183	44	87	131	22	59	96	(4)	25	54	(15)	11	37
1.00	164	244	323	86	142	198	52	97	143	29	68	107	**1**	32	62	(10)	17	44
Least-loss[b]	0.23	0.20	0.20	0.30	0.23	0.20	0.35	0.28	0.23	0.42	0.33	0.27	0.52	0.40	0.33	0.58	0.46	0.38

[a]Average of returns from Pic.25, Pic.25+24D, 24D1, 24D2, GlPic+24D, and GlPic+24Ds treatments. Returns were based on 20 years of control under typical treatment conditions. Additional treatment parameters included patch expansion at 2 radial feet/year, maximum patch density, and a 4 percent discount rate.

[b]Minimum carrying capacity (AUMs/acre) needed for herbicide treatments to result in less loss than no control.

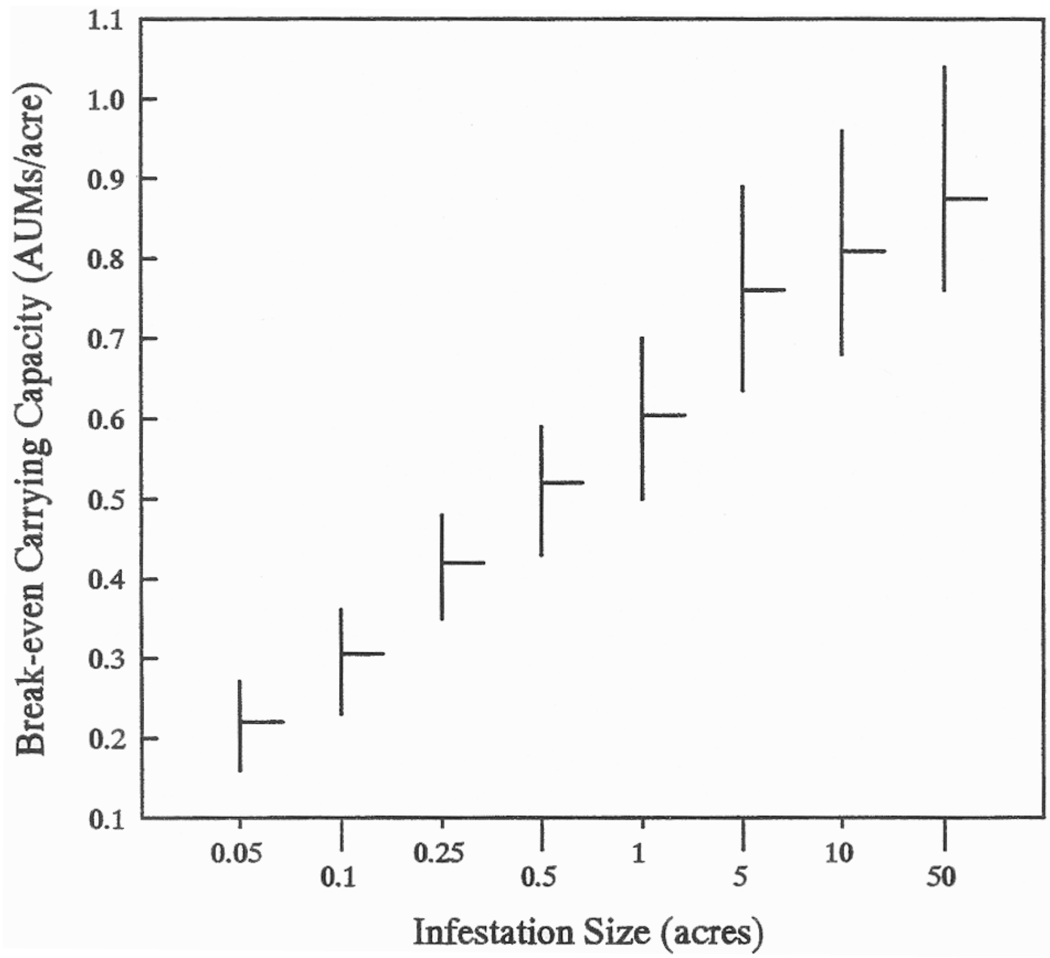

Figure 2. High, Low, and Average Break-even Carrying Capacities for Leafy Spurge Herbicide Treatments in Rangeland

Restarting treatments before control reached zero produced mixed results with returns changing about $10/acre and break-even carrying capacities shifting 0.05 AUMs/acre. With herbicide prices reduced 20 percent, returns typically increased from $10 to $25/acre and break-even carrying capacities decreased about 0.05 to 0.10 AUMs/acre.

Reductions in control (20 percent) and grazing recovery (10 percent) were evaluated in the event that actual treatments did not produce the simulated levels of control used in this study. Returns from reduced control scenarios decreased about $10/acre, but generally had little effect on break-even carrying capacities.

Perimeter Control

An alternative to controlling an entire infestation is to treat only the edge. This strategy was considered to be a viable alternative to no treatment in the event that entire infestation was not economical. Break-even carrying capacities from this strategy were not affected by infestation size, but were influenced by grazing values (Table 3). Returns (measured as total dollars from treatment) for each carrying increased. Least-loss carrying capacities for perimeter treatments also were unaffected by infestation size. Depending upon AUM values, least-loss carrying capacities ranged from 0.20 to 0.30 AUMs/acre for all-sized infestations.

Effects of other factors are only discussed briefly here (see Bangsund et al. 1996 for more detail). The effects of changing the rate of patch expansion were substantial. Under fast spread conditions (3.0 and 4.0 radial feet/year), break-even carrying capacities decreased by 0.10 to 0.25 AUMs/acre. Some treatments under scenarios of rapid spread (4.0 radial feet/year) provided positive net returns down to carrying capacities of 0.20 AUMs/acre. Spread rates of 1.0 radial foot/year generally decreased net returns by $45 across all treatments when compared at break-even carrying capacities. Reduced spread rates increased break-even carrying capacities by 0.45 AUMs/acre and increased least-loss carrying capacities by 0.20 AUMs/acre.

Perimeter treatments also appear to be sensitive to the width of patch edge treated. The default amount was 15 feet; however, for each 2.5 radial feet reduction in edge treated, break-even carrying capacities decreased 0.05 AUMs/acre. Reducing herbicide prices by 20 percent resulted in similar changes in returns and break-even carrying capacities as observed with AUM values changing from $15.50 to $19.

DISCUSSION

Assessing the trade-offs of leafy spurge control with herbicides requires consideration of a variety of issues and concerns. These issues and some general interpretations and recommendations are discussed in the following sections.

Developing Long-term Control Strategies

This study provides a useful first approximation of the rangeland situations where herbicide control of leafy spurge is economical. Observations and interpretations from this study can provide insights into leafy spurge control strategies.

Density reduction strategies (treating the entire infestation) showed an inverse relationship between infestation size and treatment payoff (Figure 3). However, returns from containment strategies (perimeter treatments) were not sensitive to size. Individuals can formulate the best (most economical) herbicide strategy for treating various-sized infestations since typical break-even carrying capacities and least-loss carrying capacities can be estimated for both strategies for various infestation sizes.

Generally, small infestations (0.5 acre or less) were economical to treat over long periods with herbicides in a wide range of treatment situations. However, the most appropriate herbicide strategy for large infestations is more difficult to assess.

Table 3. Present Value of Average Returns From Long-term Leafy Spurge Perimeter Control Using Herbicides[a]

	Initial Size of Infestation														
	1 Acre			5 Acres			10 Acres			25 Acres			50 Acres		
	Value per AUM			Value per AUM			Value per AUM			Value per AUM			Value per AUM		
	$12	$15.50	$19	$12	$15.50	$19	$12	$15.50	$19	$12	$15.50	$19	$12	$15.50	$19
AUMs/ac	total $														
0.20	(15)	(12)	(10)	(34)	(27)	(21)	(47)	(39)	(30)	(74)	(61)	(47)	(105)	(86)	(64)
0.25	(13)	(9)	(6)	(28)	(20)	(13)	(40)	(29)	(18)	(63)	(46)	(29)	(89)	(65)	(39)
0.30	(10)	(6)	(2)	(23)	(14)	(4)	(32)	(19)	(6)	(51)	(31)	(10)	(72)	(44)	(15)
0.35	(8)	(3)	**2**	(18)	(7)	**4**	(25)	(10)	**5**	(39)	(16)	**8**	(56)	(23)	**10**
0.40	(5)	**1**	6	(12)	**0**	13	(18)	(0)	17	(28)	(1)	26	(40)	(2)	34
0.45	(3)	4	10	(7)	7	21	(10)	**9**	29	(16)	**14**	45	(23)	**19**	58
0.50	(0)	7	14	(2)	14	29	(3)	19	41	(5)	29	63	(7)	41	83
0.55	**2**	10	18	**4**	21	38	**5**	28	52	**7**	44	81	**9**	62	107
0.60	5	13	22	9	28	46	12	38	64	19	59	100	26	83	131
0.65	7	17	26	14	35	55	20	48	76	30	74	118	42	104	156
0.70	10	20	30	20	41	63	27	57	88	42	89	137	58	125	180
0.75	12	23	34	25	48	72	34	67	99	53	104	155	75	146	204
0.80	15	26	38	30	55	80	42	76	111	65	119	173	91	167	229
0.85	17	30	42	36	62	88	49	86	123	77	134	192	107	188	253
0.90	20	33	46	41	69	97	57	96	135	88	149	210	123	209	278
0.95	22	36	50	46	76	105	64	105	146	100	164	228	140	230	302
1.00	25	39	54	52	83	114	72	115	158	111	179	247	156	251	326
Least-loss[b]	0.28	0.22	0.20	0.28	0.22	0.21	0.28	0.23	0.21	0.29	0.23	0.21	0.29	0.23	0.21

[a]Average of returns from Pic.25-pc, Pic.25+24D-pc, 24D1-pc, Glph.75-pc, and GlPic+24D-pc treatments. Returns were based on 20 years of control under typical treatment conditions. Additional treatment parameters included patch expansion at 2.0 radial feet/year, maximum patch density, 15 feet of periphery treated, and a 4 percent discount rate.

[b]Minimum carrying capacity (AUMs/acre) needed for herbicide treatments to result in less loss than no control.

The break-even carrying capacity is important since treating infestations on rangeland with carrying capacities below the break-even point will (under conditions simulated in this study) likely result in negative returns. For example, treating a 5-acre infestation on rangeland with a carrying capacity of 0.50 AUMs/acre will probably generate negative returns after 20 years of control (Figures 2 and 3).

Another consideration is whether treatments will result in less economic loss than without control. Treating infestations with carrying capacities lower than the least-loss carrying capacity will (under conditions simulated in this study) probably result in greater economic loss than not using herbicides. For example, treating a 5-acre infestation on rangeland with carrying capacities of 0.25 AUMs/acre (or less) will result in

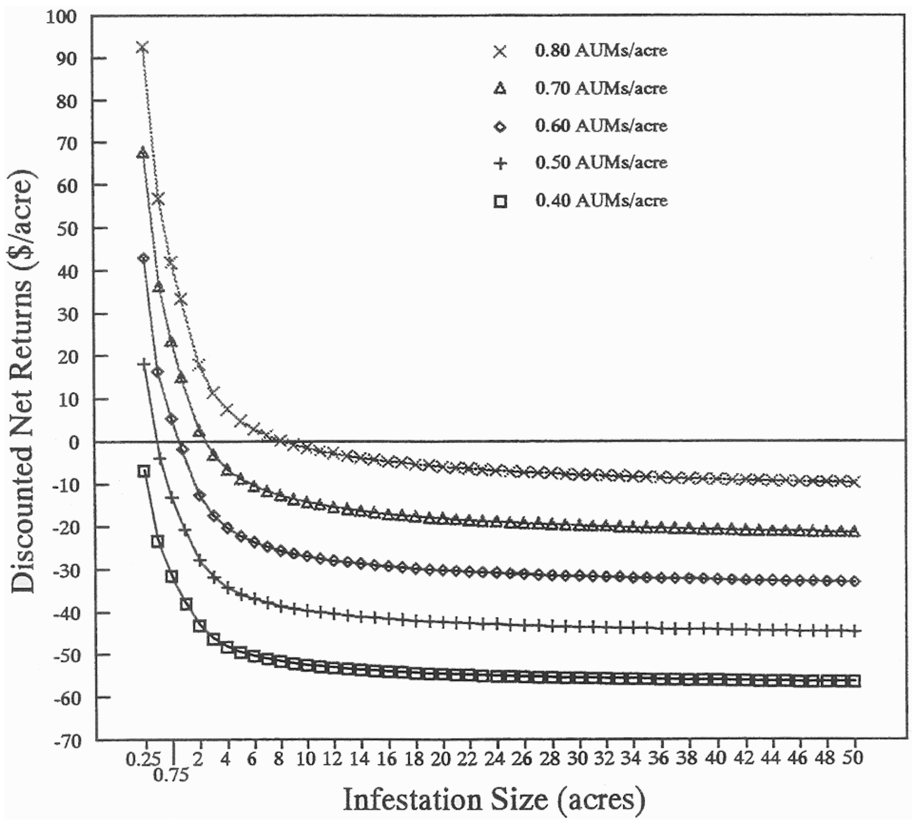

Figure 3. Average Net Returns from Leafy Spurge Control in Rangeland

more economic loss than without treatment. In these situations, other control methods or strategies (perhaps perimeter control) may be optimal.

Least-loss carrying capacities for perimeter treatments were generally lower than those for broadcast treatments of treating the

large infestations. Break-even carrying capacities for perimeter treatments of large infestations were similar to the least-loss carrying capacities for broadcast treatments of the same-sized infestations. Thus, perimeter treatments of large infestations could be

capacity increased as infestation size

economical, possibly even producing positive returns in situations when treating the entire infestation would not be recommended.

Implications

The results in this study were based on repeating treatment programs several times over 20 years; a long time to wage war on any weed infestation. However, considering the current effectiveness of control methods, 5, 10, or 15 years of treatments are not likely to change the weed's ability to reduce grazing outputs. Since many treatment programs require roughly 20 years to generate positive net returns, landowners should recognize the long-term commitment required to combat the weed. Hopefully, more effective controls may appear within that time frame; however, no guarantee exists that adopting those controls at that time would be preferable to no treatment today. Some treatments may generate positive net returns in time periods shorter than 20 years; however, whether treatments produce positive net returns in 6, 12, or 16 years is not entirely relevant. In the absence of superior control methods, treatments should continue since the weed will likely continue to thrive.

A substantial number of the leafy spurge infestations on private grazing land may not meet minimum thresholds for economical treatment. About 40 percent of all leafy spurge infestations in North Dakota are found on grazing land with carrying capacities less than 0.60 AUMs/acre, the most common break-even point for herbicide treatments. Without additional economic incentives, wide-scale efforts to combat the weed may not succeed.

This study demonstrates that other, more economical, controls for leafy spurge need to be developed. Additional research is needed to (1) discover more economical long-term herbicide treatments and/or (2) develop alternative treatment methods that can substitute or complement existing programs. Other methods, such as cultural (grazing, plant competition) or biological control (insects, plant diseases), used independently or cooperatively, need further study.

Economic Relationships

Probably the most pronounced finding in this study is the inverse relationship between infestation area and treatment payoff, which indicates early detection and control are best. Results also suggest the economics of long-term herbicide treatments are sensitive to land productivity. The study showed that average returns become negative between 1- to 2-acre infestations (carrying capacities ranging from 0.40 to 0.60 AUMs/acre).

Patch expansion dynamics play an important role in the relationship between infestation area and treatment returns. Small (less than an acre in size) patches spread much faster, as a percentage of original area, than do large infestations, thereby, generating proportionally more grazing loss from expansion than loss from the original infestation. Although large patches consume more area as they expand than small patches, area consumed by expansion is proportionately (compared to original area) less than smaller patches, causing returns from large infestations to be largely dependent on grazing recovery.

More frequent treatments at lower herbicide rates (e.g., Pic.25 and Pic.25+24D) appear more economical than less frequent treatments using higher herbicide rates (e.g., Pic1 and Pic2). Multiple-year treatments have advantages over high-rate, single-year treatments. They are generally (1) more effective in reducing stand density over time, (2) less risky (control is less responsive to single applications), and (3) have lower cumulative treatment costs.

Spread rates influenced returns in many treatment situations. Returns from treating small infestations appear responsive to expansion rates, whereas, doubling normal spread rates in large infestations (5 acres and larger) had little influence on returns (treating the entire infestation). However, expansion rates decisively influenced returns from perimeter treatment strategies. Thus, spread rates differing from the rates used in this study will likely affect long-term returns and influence long-term treatment strategies.

Method and Data Shortcomings

Leafy spurge expansion rates were simplified to patches with distinct boundaries, consistent expansion rates, and no constraints on expansion. In reality, leafy spurge infestations do not necessarily have convenient boundaries or consistent expansion. Patches within large infested areas will converge over time, while others run into man-made and natural boundaries, and still others may expand at various/inconsistent rates. Under these conditions the benefits from preventing expansion in this study will likely be overstated from those realized in the field.

An important assumption used in the model was the amount of grazing recovery received from treatments. Grazing recovery is a critical component in assessing the long-term economics of herbicide control. Stocking rates, grass injury, insufficient control, and other factors affecting grazing recovery will directly affect long-term returns.

Herbicide prices, the amount of herbicide used, and application costs will differ from this study. Thus, individual herbicide application practices and changing herbicide prices will influence long-term returns.

One of the problems with projecting returns and costs for 20 years is uncertainty about the future. Twenty years is a long time to assume constant technology and static economic values. The effect of changing technology (changes in herbicide control or the development/discovery of other methods), environmental regulations, societal preferences, and other intangible factors are unknown. As these and other factors change, the economics of long-term control should be reassessed.

Benefits of treatment not included in this study included (1) suppression of seed development (i.e., reducing the likelihood of new patches starting from spreading seeds) and (2) maintenance, preservation, and/or slowing the loss of land values by keeping leafy spurge "in check". The influence of established infestations creating new patches through seed dispersal remains unquantified. The influences of leafy spurge infestations (with or without control) on land values was not included.

Individual results from management programs will likely differ from those in this study. Additional information on grazing recovery rates and on the characteristics of spreading infestations would improve these estimates. The results presented in this study represent only *an attempt* to provide insight on the economics of long-term control of leafy spurge using herbicides and are first approximations of average conditions.

CONCLUSIONS

Leafy spurge, a troublesome weed in untilled land, spreads rapidly, resists control, and reduces land outputs, presenting long-term problems to land managers in the Upper Midwest. A variety of intensive herbicide treatment programs, currently the mainstay of combating the weed, has been effective in controlling, but not eradicating, the weed. Thus, efforts to control and restrict the spread of leafy spurge require long-term commitments; however, tradeoffs between control costs and returns from control have until now remained unquantified.

Under some rangeland conditions found in the Upper Great Plains, long-term (20 years) herbicide control of leafy spurge can produce positive returns. Returns, however, vary across a variety of factors, but those having the greatest influence on returns from long-term herbicide control include infestation size, spread rate, land productivity, and frequency and rate of herbicide applications.

Generally, herbicide treatments provided positive discounted returns when applied to small (0.5 acre or less) infestations. However, as infestations became larger and more established, returns diminished quickly, and in many cases, treatment became economically questionable. Current herbicides (and prices) cannot provide long-term positive returns from leafy spurge control in all situations in the Upper Great Plains. However, in most situations, long-term control of leafy spurge using herbicides is a viable economic alternative to no treatment.

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