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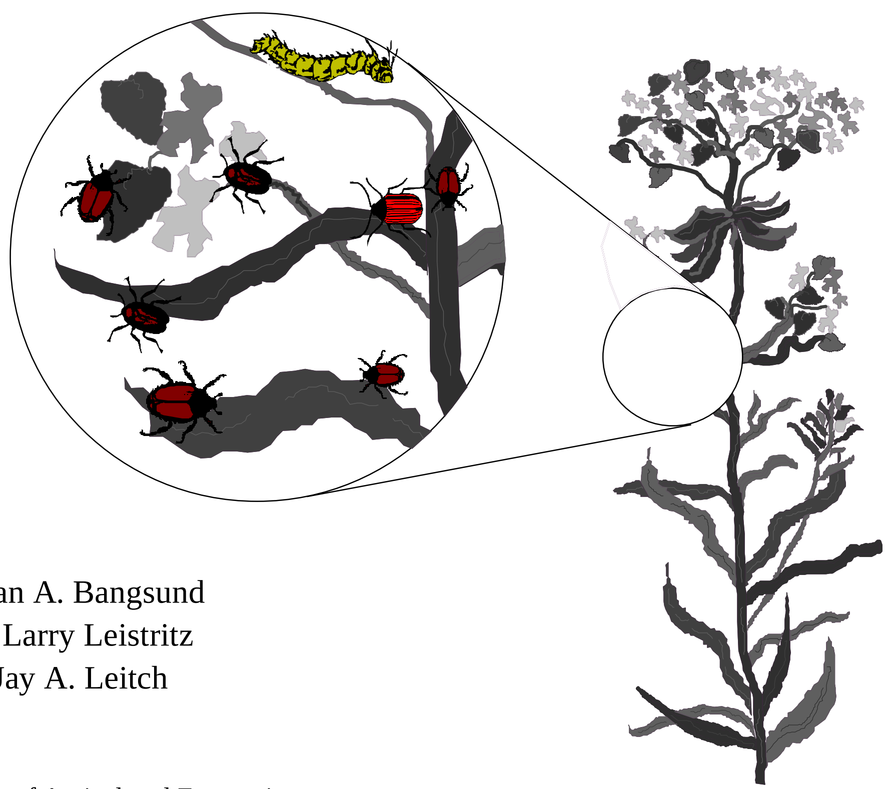
Predicted Future Economic Impacts of Biological Control of Leafy Spurge in the Upper Midwest



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Abstract

The Leafy Spurge Biological Control program was designed to use insects and plant diseases from the plant's original European habitat to control infestations in the United States. The widespread adoption of biological agents to combat leafy spurge and the initial success in reclaiming previously infested land has prompted an evaluation of the potential future economic benefits of the biological control of leafy spurge in the Upper Midwest.

Based on expert opinion and historical data, leafy spurge in Montana, North Dakota, South Dakota, and Wyoming was projected to infest 1.85 million acres, of which, 65 percent was estimated to controlled with biological agents by 2025. Based on a survey of county weed board personnel, North Dakota and Wyoming are further advanced in the use of biological control than Montana and South Dakota.

Recovery of rangeland outputs resulting from the biological control of leafy spurge was estimated to create $52.7 million in direct and secondary economic impacts. Biological control of leafy spurge on wildland was estimated to generate $5.6 million annually. By 2025, total economic impacts of the Leafy Spurge Biological Control Program were estimated at $58.4 million (1997 dollars) annually in the four-state region. An additional 876 full-time equivalent secondary jobs would be created as result of the program.

Although the economic estimates generated are based on expert opinion and remain sensitive to assumptions regarding the future efficacy of the biological control of leafy spurge, initial evidence suggests the program will be an economic success regardless of the eventual level of control. The assessment of the economic value of the biological control of leafy spurge would benefit from incorporation of additional information as the overall understanding of the biological control process grows.

Key Words: biological control, leafy spurge, economic impacts, Upper Midwest.

Highlights

Leafy spurge remains a troublesome weed in the Upper Midwest. Despite attempts to control the weed, it continues to spread and generate substantial economic losses in the region. The Leafy Spurge Biological Control Program, designed to implement insects and plant diseases from the weed's original European habitat to control infestations in the United States, was initiated in the mid-1980s. The widespread use of biological agents to combat leafy spurge and the initial success in reclaiming previously infested land has prompted an evaluation of the potential future economic benefits of this control method.

County weed board personnel were surveyed to assess the amount of biological control activity by local entities. North Dakota and Wyoming are further advanced in the use of biological control than Montana and South Dakota.

The future level of leafy spurge infestation and the amount of future infestation eventually controlled with biological agents were estimated based on historical data and expert opinion. Leafy spurge in Montana, North Dakota, South Dakota, and Wyoming was projected to infest 1.85 million acres, of which, 65 percent was predicted to be controlled with biological agents by 2025.

The economic benefits of biological control were based on changes in grazing output on rangeland and changes in wildlife-associated recreation and soil and water conservation benefits on wildland. By 2025, biological control was estimated to recover 320,500 animal unit months of grazing on rangeland, which translated into $16.5 million annually of additional production expenditures and revenues from expanded beef herds in the four-state region. Revenues and expenditures from expanded beef herds were estimated to generate $36.3 million in secondary impacts to the regional economy. Total future annual economic benefits of the biological control of leafy spurge on rangeland was estimated to be $52.7 million (1997 dollars) in the four-state region.

The future value of biological control of leafy spurge in wildland was estimated at $2.6 million annually. Changes in wildland outputs were estimated to create $3 million annually in secondary economic impacts. Total annual economic benefits of biological control of leafy spurge on wildland was estimated at $5.6 million (1997 dollars) in the four-state region by 2025.

The total economic value of the biological control of leafy spurge in the four-state region was estimated at $58.4 million annually (1997 dollars) by 2025. Secondary employment resulting from the increase in economic activity was estimated to create 876 full-time equivalent jobs.

Considering the geographic scope of leafy spurge in the United States and the widespread adoption of biological control throughout the infested regions, the potential value of the program could be substantially higher than levels predicted in this study. Even in a scenario of less control than predicted in this study, the program is still likely to be an economic success. The assessment of the economic value of the biological control of leafy spurge would benefit from incorporation of additional information as the overall understanding of the biological control process grows.

Predicted Future Economic Impacts of Biological Control of Leafy Spurge in the Upper Midwest

Dean A. Bangsund, F. Larry Leistritz, and Jay A. Leitch*

INTRODUCTION

Leafy spurge (Euphorbia esula) is an exotic, noxious perennial weed that has become widely distributed in the northern Great Plains. The plant is found primarily in nontilled agricultural land (pasture, rangeland, hayland, and idle cropland), in road ditches, around wetlands, wildlife production areas, shelterbelts, and in parks. Leafy spurge exhibits an exceptional ability to spread and thrive in a variety of habitats. This ability, combined with a lack of adequate controls, has made it a serious problem for farmers, ranchers, and land managers.

Leafy spurge was established primarily in Minnesota, North Dakota, Montana, and several eastern states in 1933; since then it has spread to 12 western states (Hanson and Rudd 1933; Cooperative Agricultural Pest Survey 1997a). Heavy infestations of leafy spurge are now found in North Dakota, South Dakota, Montana, Minnesota, Nebraska, Colorado, Idaho, and Wyoming. The rate of infestation in the late 1980s reached serious levels in many areas of the upper Great Plains, raising concerns from producers and policymakers over the amount of resources that should be used to develop viable leafy spurge control technologies.

Information on the economic losses created by leafy spurge was compiled to assess the importance of leafy spurge control and, if necessary, to allocate resources to develop new control technologies. The first work focused on estimating the economic impact of leafy spurge in North Dakota. Thompson (1990) indicated that leafy spurge caused $75 million in annual economic losses in North Dakota. Further work expanded the geographic scope of the estimates to include the impacts of leafy spurge in Montana, South Dakota, and Wyoming (Bangsund and Leistritz 1991). Additional refinement in the impact assessment of leafy spurge was accomplished by Wallace (1991), who drew distinction to the land uses infested with leafy spurge and estimated the economic impacts of leafy spurge infestations on non-agricultural land (i.e., wildland) in North Dakota. Estimates of the economic impacts of leafy spurge on wildland in other Midwestern states followed (Bangsund et al. 1993). The latest published estimate of the impact of leafy spurge in the upper Great Plains was completed by Leitch et al. (1994). Annual economic losses from leafy spurge were estimated at $130 million in Montana, North Dakota, South Dakota, and Wyoming.

Before the economic losses from leafy spurge were estimated, work was conducted to examine the physical effectiveness of herbicides and cultural control methods in restricting the spread of leafy spurge (Derscheid et al. 1985; Landgraf et al. 1984; Messersmith 1989). Herbicide treatments vary in effectiveness depending on a variety of factors. However, regardless of the treatment conditions, herbicides generally provide only short term control. Cultural control methods, such as sheep grazing, have been available for decades to control leafy spurge (Helgeson and Thompson 1939; Johnston and Peake 1960). However, most cultural practices have lacked

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widespread adoption and are not successful in eradicating leafy spurge. Only when herbicides have been used in conjunction with tillage, has leafy spurge been eradicated from untilled land (Lym and Messersmith 1993). However, tillage, along with other cultural control methods, often has constraints on its implementation in rangeland and other untilled lands (Watson 1985).

The long-term economic feasibility of herbicide treatments was recently examined (Bangsund et al. 1996). Net returns from the most effective herbicide treatments were seldom positive for most conditions found in rangeland in the Upper Midwest; however, repeated herbicide treatments over extended periods for most treatment scenarios in the upper Midwest resulted in less economic loss than no control. Comprehensive analyses of the long-term economic feasibility of cultural control methods have not been conducted. Biological control is currently viewed as a possible wide-spread, cost-effective management tool for leafy spurge (Hansen et al. 1997).

Much research on controlling leafy spurge over the last decade has focused on developing, expanding, and improving biological agents (insects and plant diseases). Biological control of weeds is the deliberate use of natural enemies (i.e., insects and plant diseases) to reduce the density of a target weed below an economic threshold (Harris et al. 1985). Leafy spurge was recognized as a potential candidate for biological control before organized efforts were undertaken to establish biological control programs (Harris 1979; Carlson and Littlefield 1983).

The desire to develop biological control methods for leafy spurge in North America surfaced in the late 1970s and early 1980s in response to (1) the growing levels of leafy spurge infestation and the concern over its future impact and (2) the apparent ineffectiveness of traditional control methods to provide long-term economical control. Organized efforts to establish a biological control program for leafy spurge in North America began in the mid 1980s (Great Plains Agricultural Council 1985). The biological control program required testing natural enemies of leafy spurge for host specificity, importing the agents, checking them for pathogens, and subsequently reproducing them for release in North America. The initial process of collecting and testing biological agents was slow. Early efforts focused on establishing insectaries to produce insects for collection and domestic redistribution. Few insects were released in the early stages of the biological control program (Richard et al. 1991; Richard 1989). Total release numbers remained low through the 1980s (Poritz 1989). However, within the last five years, biological control of leafy spurge has expanded beyond initial research stages to the general collection and release of agents by local entities (Hansen et al. 1997).

The wide-spread adoption of biological control agents by local entities (township and county governments), state and federal agencies, land managers, and ranchers has prompted a closer look at the value of this control method. Fiscal pressure at all levels of government has focused debate over the amount of public funds that should be used to facilitate development of biological control programs for problem weeds. Economic information on the benefits of biological control of leafy spurge helps decision makers weigh the merits of developing other biological control programs.

OBJECTIVES

The purpose of the study is to estimate the expected future economic benefits of biological control of leafy spurge in the upper Great Plains. Specific objectives include

1) quantify biological control efforts in the upper Great Plains,
2) estimate the recovery of agricultural land outputs resulting from biological control,
3) estimate the change in activities resulting from use of recovered land outputs,
4) estimate the annual direct economic benefits to state and regional economies, and
5) estimate the annual secondary and total economic benefits to state and regional economies.

PROCEDURES

This study largely follows the impact assessment methods presented by Leitch et al. (1994). The economic impacts of leafy spurge were primarily based on reductions in grazing outputs and reductions in nonagricultural benefits of wildland. Biological control can be effective in reducing the density of leafy spurge infestations below an economic threshold, although biological control by itself will not eradicate the weed. Generally, in successful applications of biological control, leafy spurge populations are reduced to a level where the plant is no longer an economic threat. Thus, rangeland productivity can approach near-normal levels, allowing for cattle grazing, and wildland can return to a diverse vegetative cover, thereby providing increased habitat value and greater soil and water conservation benefits.

Information on the extent of biological control of leafy spurge in the upper Great Plains was obtained from private and public entities. County weed board representatives in Montana, North Dakota, and South Dakota were surveyed to assess the scope of current biological control efforts and to obtain feedback on their perceptions of both current and future effectiveness of biological control (Appendix A). Information on county-level biological control efforts in Wyoming was obtained from the Wyoming Biological Control Steering Committee. Scientists and other individuals involved with insect dissemination, biological control research, and public land management were consulted to obtain information on the current and speculated future effectiveness of biological control of leafy spurge.

Information on rangeland capacity, rangeland acreage, leafy spurge infestation by land type, and wildland outputs was obtained from previous studies of the economic impact of leafy spurge (Bangsund and Leistritz 1991; Wallace et al. 1992; Bangsund et al. 1993; Leitch et al. 1994). Estimates of leafy spurge acreage were obtained from state agencies and other sources familiar with weed populations (Appendix B).

Data Limitations and Assumptions

The exact role biological agents will play in controlling existing leafy spurge infestations is unknown. Based on the current understanding of the success and efficacy of biological controls, it is impossible to precisely predict the future level of leafy spurge control with biological agents. Thus, the upper limits of the value of biological control of leafy spurge were based on a synthesis of expert opinions and speculation from scientists and land managers currently engaged in biological control work with leafy spurge.

Several aspects of this study relied on subjective information. The following information is currently unknown and was based on educated assessments:

1) future acreage or infestation levels of leafy spurge,
2) future values of land outputs,
3) future level of leafy spurge control with biological agents,
4) time required for biological agents to reach their maximum sustained control threshold, and
5) productivity of reclaimed rangeland and wildland.

Assessment of the future value of the biological control program for leafy spurge was based on several assumptions:

1) Leafy spurge infestations on rangeland reclaimed by biological control were expected to return to cattle grazing upon the suppression of leafy spurge and ranchers were willing and able to expand operations to coincide with expanded grazing output.

2) Leafy spurge infestations reclaimed by biological control were assumed to remain uninfested (i.e., devoid of other noxious weeds upon the suppression of leafy spurge).

3) Relationships between leafy spurge infestations and the economic impacts created by the weed remain unchanged from past studies (i.e., models currently used in the analysis are relevant for the relationships between leafy spurge and lost land outputs in the future--see Bangsund and Leistritz [1991], Bangsund et al. [1993], and Leitch et al. [1994] for discussion of the limitations of those methods).

4) Current values for land outputs are sufficient for valuing future land outputs (e.g., livestock prices, AUM[1] values, wildlife-related recreation expenditures, and off-site soil and water conservation benefits).

5) Existing biological agents remain the only biological controls available (i.e., additional biological agents are not cleared for release in North America).

[1] An animal unit month is an average 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).

BIOLOGICAL CONTROL PROGRAM FOR LEAFY SPURGE

The biological control program for leafy spurge is relatively young compared to the time required for most biological programs to become successful. Most efforts in the early stages of a program focus on research and study of biological agents and their environments. The leafy spurge biological control program has expanded greatly from its initial efforts in the late 1980s. The following sections briefly describe the current level of biological control activities in the Northern Plains.

Current Biological Control Activities

The leafy spurge biological control program (LSBCP) has been implemented since 1988 by the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (APHIS). The program was to be implemented in three phases. The goal of phase I was to establish a limited number of field insectary sites[2] (FIS) for each agent in each state. Phase II was designed to collect agents from phase I FIS to establish additional FIS for further collection and distribution. Phase III involves collection and distribution of agents from phase I and II FIS to landowners and managers throughout leafy spurge infested regions (Hansen et al. 1997). Many areas in the country are experiencing the transition from developing insectaries to collecting and distributing agents for general release. Although APHIS currently is tracking over 600 FIS in 184 counties in 19 states (Hansen 1997a), the goal of this study is to focus on the biological control activities in Montana, North Dakota, South Dakota, and Wyoming.

Hansen et al. (1997) identified most of the FIS currently monitored by APHIS; however, only information from APHIS and cooperating agencies were included in the report. Information on biological control activities of local, state, and other federal agencies and private individuals was generally not included in the report. Although the FIS identified by Hansen et al. (1997) indicated the status of the biological agents at those sites, information on the number of agents collected and released from those FIS was not provided. Montana, North Dakota, and Wyoming have been in the redistribution stages of phase III for nearly two years, while South Dakota appears to have entered phase III in 1997 (Hanson 1997b).

In an attempt to better understand the scope and success of general biological control efforts, county weed board representatives in three of the study states were surveyed. Additional information on biological control activities was also obtained from databases of state and federal agencies.

County weed board personnel in Montana, North Dakota, and South Dakota were surveyed. The survey had a 63 percent response rate (110 completed surveys out of 175 counties) (Table 1). Of the 106 counties reporting having leafy spurge, 90 percent had implemented local biological control programs for leafy spurge. Four counties reported having no

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[2]A field insectary site is a location managed to produce insects for redistribution to weed infested areas.

leafy spurge. Based on survey results, 10 counties reporting having leafy spurge but had not yet implemented a biological control program, four of those 10 counties indicated they were planning to implement a program within the next 5 years. County-level biological control information for Wyoming counties was obtained from the Cooperative Agricultural Pest Survey (CAPS) program and interviews with representatives of the Wyoming Biological Control Steering Committee. In Wyoming, 22 of 23 counties had biological control programs for leafy spurge.

Although local efforts to combat leafy spurge with biological agents are currently widespread in the four states, the success and extent of those activities vary considerably. The state-average length of time biological control programs have been in place in counties within the study area varied from over 7 years in Montana and Wyoming to about 3 years in South Dakota. Based on survey results, the amount of time biological control programs within individual counties have been implemented has ranged from 2 months to 17 years. The four-state average length of time counties have had biological control programs is 5.5 years. About 58 percent of the counties responding had biological control programs for 5 years or less. Little correlation existed between the length of time biological control programs have been in place within counties and the counties' reported acreage of leafy spurge.

The extent of biological control for leafy spurge, measured by the number of agents released and the number of release sites, varied by state (Table 1). Based on survey responses, 85 percent of all agents (30.8 million insects) have been released in North Dakota. When combined with information from Wyoming, the number of agents released in North Dakota and Wyoming accounted for 87 percent of the total number of agents released. Conversely, responding counties in South Dakota indicated they collectively released about 1 million agents or only 2.7 percent of the four-state estimated total. However, total numbers may not be appropriate indicators of biological activity, since each state has different amounts of leafy spurge and different survey response rates. Based on reported acreage of leafy spurge, counties in Wyoming released 8,900 agents per 1,000 acres of leafy spurge, compared to 5,300 for North Dakota, 1,400 for Montana, and 1,300 for South Dakota. The number of release sites per 1,000 acres of leafy spurge varied from 43 in Wyoming to less than 3 in South Dakota. North Dakota and Montana had similar ratios with 10 and 9 release sites per 1,000 acres of leafy spurge, respectively. The ratio of insectaries per 10,000 acres of leafy spurge were similar for all states--North Dakota, South Dakota, Montana, and Wyoming had 5.2, 4.2, 3.6, and 2.2, respectively. Information on the productivity of those insectaries was not obtained.

Table 1. Results of Biological Control Survey of County Weed Board Personnel in Montana, North Dakota, and South Dakota, 1997

Item	North Montana	South Dakota	Survey Dakota	Four State Totals	Wyoming[a]	Total
Number of counties surveyed	56	53	66	175	23	198
Number of returned questionnaires	38	30	44	111	na	na
Response rate	67.9%	56.6%	66.7%	64.0%	na	na
Counties with biological control programs	38	30	30	98	22	120
Duration of the program (years)	7.3	4.4	3.3	5.2	7.1	5.5
Reported acreage of leafy spurge	315,079	577,867	76,740	969,686	72,263	1,041,949
Number of release sites	2,727	5,707	210	8,644	3,131	11,775
Number of insectaries 112	299	32	444	16	460	
Biological agents brought into counties (#)	2,356,000	20,840,000	782,000	23,978,000	1,380,000	25,358,000
Agents collected and distributed from within the county (#)	2,144,000	9,962,000	201,000	12,307,000	5,048,000	17,355,000
Total agents released by reporting counties	4,500,000	30,802,000	983,000	36,285,000	6,428,000	42,713,000
Leafy spurge inoculated (acres)	36,067	48,959	6,440	91,466	68,650	160,116
Leafy spurge inoculated (% of reported acreage)	11.4	8.5	8.4	9.4	95.0	15.4
Survival rate of release sites[b]	47.7%	66.7%	43.1	60.1%	17.6%	48.8%
Reclaimed rangeland (1997)	205	875	282	1,362	35	1,397
Reclaimed other land (1997)	234	58	534	825	0	825
Total reclaimed land (acres)[c]	439	933	816	2,187	35	2,222
Percent of reported leafy spurge acreage reclaimed (1997)	0.1%	0.2%	1.1%	0.2%	0.05%	0.2%

- continued -

Table 1. Continued

Item	Montana	North Dakota	South Dakota	Survey Totals	Wyoming[a]	Four State Total
Reclaimed rangeland (eventually)	98,713	219,119	26,230	344,061	64,836	408,897
Reclaimed other land (eventually)	11,850	182,181	14,978	209,008	3,212	212,220
Total reclaimed land (acres)[d]	110,563	401,299	41,208	553,070	68,048	621,118
Percent of reported leafy spurge acreage	35.1%	69.4%	53.7%	57.0%	94.2%	59.6%
Years required for maximum control of leafy spurge with biological agents	36.0	17.7	22.9	25.3	20.0	24.2
Comparative statistics based on survey responses:						
Biological agents released per 1,000 acres of leafy spurge	1,428	5,330	1,281	3,742	8,895	4,099
Release sites per 1,000 acres of leafy spurge	8.7	9.9	2.7	8.9	43.3	11.3
Insectaries per 10,000 acres of leafy spurge	3.6	5.2	4.2	4.6	2.2	4.4

[a] Information on county-level biological control activities in Wyoming were obtained from the Wyoming Biological Control Steering Committee and the Cooperative Agricultural Pest Survey program.

[b] Based on sites surviving three winters after release. Several survey responses indicated that many of their release sites were created within the last few years, and it was premature to determine whether or not they survived. Survival rates in Wyoming were based on different criteria.

[c] Seven hundred of the reported 816 reclaimed acres were from one county.

[d] Respondents were asked to speculate how many acres of rangeland and other land, currently infested with leafy spurge, would eventually be controlled with biological agents.

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Although total release numbers are helpful in identifying the general level of biological control activities by local entities, the dates of the releases and the species released remain unknown. The various species of biological agents are not equally effective in suppressing leafy spurge. The *Aphthona* species[3], to date, are clearly the most effective agents in terms of reducing leafy spurge density and reclaiming infested areas (Richard 1997). Much of the initiation of local release activity coincided with the availability of those agents. *Aphthona nigriscutis*, the most effective biological agent cleared for release in the United States, was cleared for release in June of 1989; however, collectable numbers of the specie were not available for about two years (Richard 1997). The average time many of the counties began implementing biological control programs is consistent with the availability of *Aphthona nigriscutis* and other *Aphthona* species. Although some counties reported having implemented biological control programs for leafy spurge for over a decade, many of the agents released in the early stages of the program have proven to be relatively ineffective in reclaiming leafy spurge infestations. Also, the overall number of agents released in the early stages of the LSBCP was low (Poritz 1989; Richard 1989; Richard et al. 1991). Thus, the majority of the releases of the most effective agents has occurred within the last 5 years.

The amount of reclaimed land (i.e., land previously infested with leafy spurge where the plant is now a non-impact weed) as a percent of reported leafy spurge acreage was similar for all states (Table 1). However, estimates (speculation) on the total amount of land that would eventually be recovered with biological agents varied from about 70 percent in North Dakota to 35 percent in Montana. Information from Wyoming sources speculated that nearly 90 percent of all leafy spurge infestations would be controlled with biological agents in that state. Collectively, survey results and information from Wyoming indicated that about 60 percent of all leafy spurge infestations in the four states would eventually be controlled with biological agents (Table 1).

The initial stages of reclaiming land infested with leafy spurge have begun, as evidenced by the amount of land reclaimed to date. Many counties indicated that biological controls were just starting to make an observable impact on leafy spurge infestations; however, many other counties reported that they had not seen any evidence of stand reduction by biological agents. Based on survey results, the percentage of land inoculated[4] with biological control agents remains low (9 percent) and the county-by-county survival rate (after three winters) of biological control releases varied considerably (100 percent to 0 percent).

North Dakota and Wyoming are further along with their biological control programs than South Dakota and Montana. Based on information from sources in Wyoming and North Dakota, the amount of biological activity, measured by the number of biological agents released, has increased substantially in recent years (Cooperative Agricultural Pest Survey 1997b; North Dakota Department of Agriculture 1997a).

Future Biological Control of Leafy Spurge

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[3] The *Aphthona* species approved for release include *Aphthona cyparissiae*, *Aphthona czwalinae*, *Aphthona lacertosa*, *Aphthona flava*, and *Aphthona nigriscutis*.

[4] Inoculation rates in the survey states were not based on physical measures or predetermined criteria. Respondents were asked to speculate, based on the distribution and acreage within the county, on the percentage of leafy spurge infestations that had been inoculated or exposed to biological agents.

Methods for assessing the impacts of leafy spurge on rangeland and wildland in the northern Great Plains were developed in the early 1990s (Thompson 1990; Wallace 1991). Discussion of the models and limitations of the impact assessment process also has been documented (Bangsund and Leistritz 1991; Leistritz et al. 1993, Bangsund et al. 1993; Leitch et al. 1994). This study retained the models and methods previously employed in developing impact estimates for leafy spurge. However, several key components in this analysis were derived from a synthesis of information from published and unpublished sources.

An assessment of the future value of the LSBCP was derived from interviews with scientists and other individuals involved with research and tracking of biological control activities and from the results of the county weed board survey. Two key components in the analysis are largely unknown: the future level of leafy spurge infestation and the amount of future infestation that will eventually be controlled with biological agents. Also unknown is the time required for biological agents to reach their maximum sustained control threshold.

Future Acreage of Leafy Spurge

Based on (1) the growth of reported leafy spurge acreage in the late 1980s and the 1990s and (2) the amount of control activities ongoing in the individual states, estimates of the future amount of leafy spurge were developed. Intertwined within the process of estimating the future acreage of leafy spurge in each state was the anticipated future point in time when biological controls would halt the advancement of leafy spurge infestations (i.e., the point in time when new expansions of leafy spurge become less than the acreage of land recovered with biological controls and acreage of uncontrolled infestations began to decrease).

Acreage of leafy spurge in the four states was projected to increase about 4.5 percent from 1996 to 2000 (Table 2). Although uncontrolled leafy spurge acreage was projected to peak at 1.85 million acres in 2000, acreage in South Dakota and Montana was projected to peak in 2005. Total leafy spurge infestations (controlled and uncontrolled infestations) were projected to reach 1.865 million acres. Total leafy spurge acreage after the turn of the century was forecast to decrease through 2025, when biological control was expected to reach an equilibrium with leafy spurge infestations.

Table 2. Actual and Projected Acreage of Leafy Spurge in Montana, North Dakota, South Dakota, and Wyoming, 1997

Year[a]	Montana	North Dakota	South Dakota	Wyoming	Total
	--	--	acres	--	--
1990	431,200	851,400	79,900	61,300	1,423,800
1992	431,800	830,000	172,600	64,000	1,498,400
1996	477,467	992,500	220,200	72,300	1,762,500
2000	504,867	1,011,300	259,900	75,600	1,851,700
2005	504,867	960,800	272,900	74,000	1,812,600
2010	454,380	606,800	259,300	56,700	1,377,100
2015	302,920	424,800	191,000	31,700	950,500
2020	227,190	354,000	122,800	26,400	730,400
2025	176,704	354,000	95,500	26,400	652,600

[a] Acreage in 1990, 1992, and 1996 was from state agencies responsible for tracking weed inventories and from information obtained in the biological control survey of county weed boards. Acreage in the remaining years in each state were projected based on previous expansion, current conventional control efforts, and current progress of biological control activities.

Future Control of Leafy Spurge With Biological Agents

The future level of biological control, measured in terms of acreage of leafy spurge suppressed[5], is dependent upon a number of factors, many of which are not fully understood. Given the level of knowledge currently available on biological control of leafy spurge, most experts contacted suggested that about 60 to 70 percent of future leafy spurge infestations eventually will be controlled with biological agents. The time needed for biological agents to reach their maximum level of control fell into the range of 10 to 30 years.

Some areas in the northern Great Plains will likely experience greater control than 60 or 70 percent of existing leafy spurge infestations; however, other areas or infestations will achieve less control. Based on success to date, low- to medium-density leafy spurge stands appear best suited to control with biological agents in the United States (McClay et al. 1995; Hansen et al. 1997). Success to date has been poor in riparian or other high moisture areas or infestations in shaded environments. It remains uncertain (1) if current biological agents, cleared for use in North America, can be adapted to be effective in those environments that currently have proven difficult to control or (2) if new biological agents can be discovered and cleared for use in North America that may prove to be better suited to those environments.

Future control with biological agents is difficult to predict since (1) the amount and type of infestations that may remain unsuitable for biological control in the future is unknown and (2) the percentage of existing infestations that are in suitable or favorable habitats for control with existing biological agents is unknown (i.e, acreage of leafy spurge considered to be low- to medium-density stands in suitable environments). Thus, 65

[5]Control also can be measured as a reduction in leafy spurge density.

percent of the total future leafy spurge acreage was assumed to be controlled with biological agents by the year 2025 (Figure 1).

Populations of biological control agents for leafy spurge, given proper conditions, can increase at logarithmic rates (Spencer 1994; Hansen et al. 1997). Anecdotal evidence suggests that the amount of area controlled by biological agents also is capable of increasing at logarithmic rates. Availability of biological control agents may no longer be the limiting factor in the expansion of the LSBCP in some locations. Instead, manpower, needed to collect and redistribute the agents, may be the limiting factor. It would appear unlikely that constraints on manpower could be removed to the extent that efforts to collect and redistribute agents could keep up with logarithmic increases in insect populations. However, some of the biological agents may inoculate infestations without human assistance. Mobility of biological agents in field situations is not well understood and the role of insect mobility in inoculating leafy spurge infestations has not been documented. Thus, insect population dynamics, collection and distribution efforts, and insect mobility will affect the continued growth of the LSBCP.

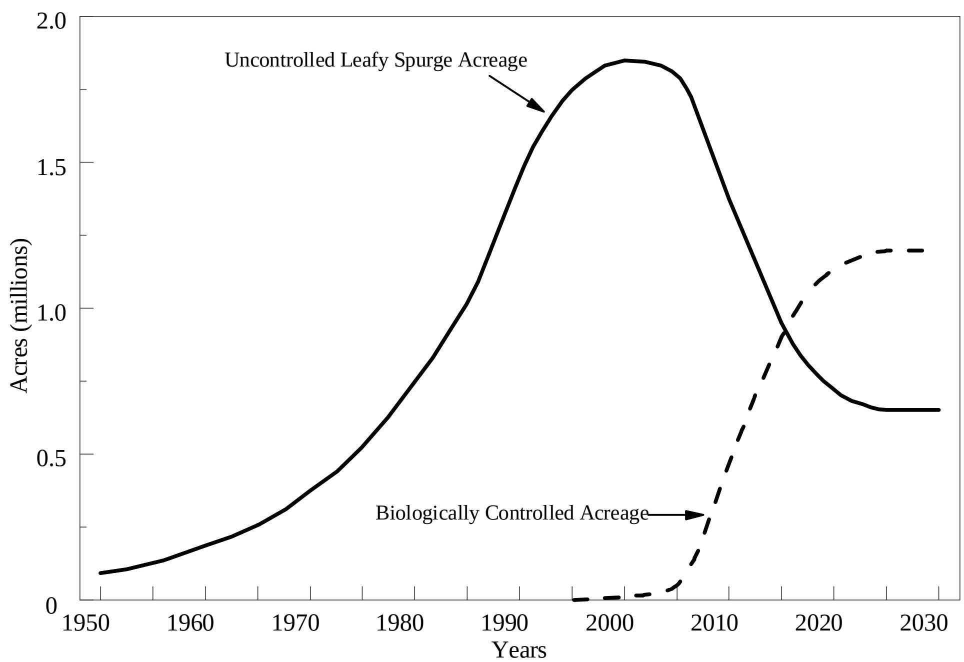

Figure 1. Postulated Future Leafy Spurge Acreage and Acreage of Leafy Spurge Controlled With Biological Agents in Montana, North Dakota, South Dakota, and Wyoming, 1997

ECONOMIC IMPACTS OF BIOLOGICAL CONTROL

Economic impacts of a project, program, or policy can be categorized into direct and secondary impacts. Direct impacts are those changes in output, employment, or income that represent the initial or direct effects of a project, program, or event. The secondary impacts (sometimes further categorized into indirect and induced effects) result from subsequent rounds of spending and respending within the economy. This process of spending and respending is sometimes termed the multiplier process, and the resultant secondary effects are sometimes referred to as multiplier effects (Leistritz and Murdock 1981).

Rangeland Impacts

Impacts from leafy spurge on rangeland stem from the plant's ability to reduce livestock carrying capacity. The economic benefits of biological control on rangeland were based on changes in grazing output. Increases in grazing output were assumed to translate into increases in cow-calf production. Changes in cow-calf herds were then used to estimate a change in production expenditures associated with cow-calf operations.

Change in Rangeland Output

The percentage of leafy spurge on rangeland and wildland by county was previously estimated (Bangsund et al. 1993; Wallace et al. 1992). Assuming the allocations between rangeland and wildland were valid for future expansions, county-level estimates of future leafy spurge infestations on rangeland were estimated.

Rangeland output, after the biological suppression of leafy spurge infestations, is a function of overall range health, grazing management, amount and type of forage present, density of pre-control leafy spurge infestation, and degree of leafy spurge suppression (Kirby 1997). Little scientific information exists on the amount of grazing output from rangeland after the biological suppression of leafy spurge, at least as a percentage of pre-infestation rates. Due to the characteristics of leafy spurge infestations and the nature of biological control, a return of rangeland productivity to pre-infestation rates is unlikely. Since biological control does not eliminate the weed, some leafy spurge remains. The remaining leafy spurge presence has some suppressing effect on rangeland productivity. Also, the amount and composition of forage in post-infested leafy spurge rangeland varies. Leafy spurge, over time, can reduce the composition and amount of forage plants within dense infestations. Due to the above factors, rangeland carrying capacity, after biological control of leafy spurge, was assumed to be 75 percent of its pre-infested carrying capacity.

Rangeland output after biological control was based on acreage controlled and rangeland carrying capacities. Carrying capacity of post-infested leafy spurge rangeland was reduced by 25 percent. The value of increased grazing output was based on dividing county-level cash rents by county-level rangeland carrying capacities multiplied by the number of recovered AUMs. Carrying capacities and cash rents used in this study were compiled in previous studies (Bangsund and Leistritz 1991; Leitch et al. 1994).

Direct Economic Impacts

Direct impacts to the state economies of Montana, North Dakota, South Dakota, and Wyoming are considered to be the value of grazing output (i.e., AUMs) and the production expenditures associated with changes in ranchers' cow-calf herd operations. Biological control was estimated to suppress about 243,000, 420,900, 109,100, and 46,400 acres of leafy spurge in rangeland in Montana, North Dakota, South Dakota, and Wyoming, respectively (Table 3). The suppression of leafy spurge was estimated to recover about 48,400, 186,150, 74,600, and 11,300 AUMs of grazing in Montana, North Dakota, South Dakota, and Wyoming, respectively. The value of recovered AUMs were estimated at $675,000, $3,108,000, $1,098,000, and $98,300 (1997 dollars) in Montana, North Dakota, South Dakota, and Wyoming, respectively (Table 3).

Table 3. Future Annual Biological Control Benefits in Rangeland in the Upper Great Plains

Item	Montana	North Dakota	South Dakota	Wyoming	Total
Future Acres Infested	373,813	647,601	169,002	71,356	1,261,772
Future Acres Controlled	242,979	420,941	109,851	46,382	820,152
AUMs recovered	48,398	186,145	74,602	11,317	320,463
Value of recovered AUMs ($)	675,000	3,108,000	1,098,000	98,000	4,980,000
Increase in beef herds (number of cows)	5,175	23,558	9,441	1,210	39,384
Increase in beef herd expenditures and revenues (1997 dollars)	1,491,000	6,726,000	2,845,000	409,000	11,470,000
Total Direct Economic Impact (1997 dollars)	2,166,000	9,834,000	3,942,000	507,000	16,450,000

The AUMs recovered in Montana, North Dakota, South Dakota, and Wyoming are expected to increase beef-cow herds by about 5,200, 23,600, 9,400, and 1,200 cows, respectively, based on state-average herd characteristics (Bangsund and Leistritz 1991; Leistritz et al. 1993). Using budgets and techniques from previous analyses (Bangsund and Leistritz 1991; Leistritz et al. 1993), production expenditures and revenues were developed for the additional herd animals (Appendix C). Production expenditures (e.g., feed, marketing, veterinary expenses) used in previous analyses were retained, although livestock prices and some feed inputs used were a 10-year average (1987 through 1996) of prices received in North Dakota (North Dakota Agricultural Statistics Service *various years*).

The expanded beef-cow herds were expected to annually generate about $1.491 million, $6.726 million, $2.845 million, and $0.409 million (1997 dollars) in revenues to input suppliers and related businesses in Montana, North Dakota, South Dakota, and Wyoming, respectively (Table 3). The total annual direct economic impacts (value of recovered AUMs and increased production expenditures) from biological control of leafy spurge on grazing lands in Montana, North Dakota, South Dakota, and Wyoming were $2.166 million, $9.834 million, $3.943 million, and $0.507 million, respectively (Table 3).

Total recovered AUMs by year 2025 were estimated at 320,500. Beef herds were expected to increase by 39,400 cows in the four-state region. Additional production expenditures and revenues resulting from biological control of leafy spurge were estimated to reach $16.45 million (1997 dollars) annually in the four-state region by 2025 (Table 3).

Secondary Economic Impacts

The secondary impacts of the biological control of leafy spurge infestations on grazing lands in Montana, North Dakota, South Dakota, and Wyoming were estimated by using the North Dakota Input-Output Model (Coon et al. 1985). Input-Output (I-O) analysis is a mathematical tool that traces linkages among sectors of an economy and calculates the total business activity resulting from a direct impact in a basic sector. The I-O model has 17 sectors, is closed with respect to households, and was developed from primary (survey) data from firms and households in North Dakota. This I-O model was deemed appropriate for measuring impacts in Montana, South Dakota, and Wyoming because (1) the economic structure of these three states is similar to that of North Dakota and (2) empirical testing has indicated that the North Dakota Input-Output coefficients are accurate in estimating changes in levels of economic activity for Montana and Wyoming (Chase et al. 1982; Coon et al. 1983).

Production expenditures and returns were allocated to the appropriate economic sectors of the I-O Model. The **retail trade** sector, which represents a substantial number of production expenses, and the **households** sector, which includes the value of AUMs and producer returns, were the two most impacted economic sectors. Other economic sectors with direct impacts included **finance, insurance, and real estate**; **agriculture-crops**; **agriculture-livestock**; **business and personal service**; **communication and public utilities**; and **transportation**.

Total direct impacts of about $16.5 million from the biological control of leafy spurge infestations in rangeland in the four-state region generated about $36.3 million in secondary impacts to the region's economy, which included about $11.8 million of personal income (**households** sector), $11.2 million in **retail trade**, and $2.4 million in the **finance, insurance, and real estate** sector (Table 4). Total economic impacts from biological control of leafy spurge on rangeland was estimated at $52.7 (1997 dollars) million annually by 2025.

In addition to estimating income and business activity, secondary employment resulting from recovered grazing and expanded grazing activities was estimated. Secondary employment represents the number of indirect jobs gained by the level of business volume generated from activities associated with expanded grazing activities. Total secondary employment in the four-state region was estimated to reach 758 jobs annually by 2025 (Table 4).

Table 4. Direct, Secondary, and Total Future Annual Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland in Montana, North Dakota, South Dakota, and Wyoming by 2025[a]

	Economic Impacts		
Economic Sector	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	829	1,304	2,133
Agriculture-crops	5,157	1,089	6,246
Nonmetal mining	0	93	93
Construction	0	1,240	1,240
Transportation	351	174	525
Communication and public utilities	242	1,491	1,733
Agricultural processing and miscellaneous manufacturing	0	1,755	1,755
Retail trade	2,424	11,180	13,604
Finance, insurance, and real estate	574	2,425	2,999
Business and personal service 217	929	1,146	
Professional and social service	0	1,199	1,199
Households	6,655	11,806	18,461
Government	0	1,582	1,582
Totals	16,450	36,266	52,716
Number of jobs supported			758

[a] Direct, secondary, and total impacts for biological control of leafy spurge on rangeland were calculated separately for each state (see Appendix D) and summarized here.

Wildland Impacts

Wildland provides a variety of outputs, such as grazing, forest products, and mineral resources (market goods); and recreation, wildlife production and habitat, erosion control, and watershed benefits (nonmarket goods) (Randall and Peterson 1984). Wildland may have additional benefits, such as aesthetics, education, or natural products, which may have direct or indirect economic impacts; however, the physical science and the valuation techniques to identify and quantify them are inadequate (Wallace 1991).

Wildland, like other land types, provides habitat for wildlife. The existence of wildlife (i.e., wildlife habitat and its outputs) is an important part of many outdoor recreation activities. Soil and water conservation benefits on wildland include preserving topsoil and plant nutrients and reducing water runoff. Benefits from reduced water runoff include lower water treatment costs, lower sediment removal costs, decreased flood damage, and increased recreational fishing (Ribaudo 1989).

Leafy spurge possesses the ability to literally choke out most existing native vegetation (Belcher and Wilson 1989; Messersmith et al. 1985; Watson 1985). The establishment of leafy spurge can be directly related to a decline in native vegetation, threatening native and existing wildland vegetation (Belcher and Wilson 1989).

A substantial change in plant diversity resulting from leafy spurge infestations decreases habitat value and negatively impacts wildland soil and water conservation.

Change in Wildland Output

Leafy spurge acreage on wildland was estimated from assumptions on the continued expansion of leafy spurge. The percentage of leafy spurge on rangeland and wildland by county was previously estimated (Bangsund et al. 1993; Wallace et al. 1992). Assuming the allocations between rangeland and wildland were valid for future expansions, county-level estimates of future leafy spurge infestations on wildland were calculated.

Information on post-biological control relationships on wildlife habitat productivity and effects on soil and water conservation was unavailable. Biological control of leafy spurge is expected to reduce existing densities to a level where the plant no longer has substantial effects on the land's ability to support indigenous wildlife and retain normal soil and water conservation benefits. Although this study assumes a 100 percent return of pre-infestation wildland outputs after biological control of leafy spurge, minor impacts on wildlife habitat and soil and water conservation benefits may be present. However, the effect is likely sufficiently small as to be of relatively minor economic consequence.

Direct Economic Impacts

Direct economic impacts from leafy spurge infestation of wildland include (1) changes in wildlife-associated recreationist expenditures that impact local suppliers of related goods and services and (2) changes in user expenditures to mitigate damages from runoff and soil erosion.

The acreage of leafy spurge controlled with biological agents was used with previous estimates of the values of soil and water conservation benefits and wildlife-associated recreationist expenditures to estimate the economic impact of reclaimed wildland outputs. Benefits to wildlife habitat value were estimated by calculating the difference between wildlife recreation expenditure impacts without biological control and estimating the impacts after biological control. The increase in wildlife-related recreationist expenditures was the value of improved wildland habitat resulting from biological control of leafy spurge in wildland. Per-acre values for soil and water conservation benefits were multiplied by the acreage of leafy spurge controlled with biological agents to estimate the value of increased soil and water conservation benefits.

Direct economic impacts (increased annual expenditures) from wildlife-associated recreation due to the biological control of leafy spurge infestations on wildland were $119,000, $1,543,000, $168,000, and $14,500 (1997 dollars) in Montana, North Dakota, South Dakota, and Wyoming, respectively (Table 5). Increases in soil and water conservation benefits from biological control of leafy spurge were $287,000, $376,000, $106,000, and $16,600 (1997 dollars) in Montana, North Dakota, South Dakota, and Wyoming, respectively (Table 5). The total annual increase in wildlife-related recreationist expenditures in the four-state region in the year 2025 was estimated at $1.8 million (1997 dollars). The total annual increase in soil and water conservation benefits in the four-state region in the year 2025 was estimated to be $785,000 (1997 dollars). The value of biological control of leafy spurge in wildland in the year 2025 was estimated at $2.6 million (1997 dollars) annually (Table 5).

Table 5. Future Annual Benefits of Biological Control of Leafy Spurge in Wildland in the Upper Great Plains

Item	Montana	North Dakota	South Dakota	Wyoming	Total
Future Acres Infested[a]	180,634	393,923	108,446	10,454	693,457
Future Acres Controlled	117,061	256,050	70,490	6,795	450,396
Value of increased wildlife-related expenditures (1997 dollars)	119,120	1,543,300	168,286	14,513	1,845,219
Increase in soil and water conservation benefits (1997 dollars)	286,799	375,753	106,087	16,649	785,288
Total Direct Impacts (1997 dollars)	405,920	1,919,053	274,373	31,161	2,630,507

[a] Includes estimates of leafy spurge on federal rangeland.

Secondary Economic Impacts

The secondary impacts of the biological control of leafy spurge infestations were estimated using the North Dakota Input-Output Model. The first step in calculating the secondary impacts was to allocate the direct impacts into the appropriate economic sectors. Direct economic impacts from increased wildlife-associated recreation were allocated to the **retail trade** (67 percent) and **business and personal services** (33 percent) sectors. Direct economic impacts from reduced soil and water conservation benefits were allocated to the **government**, **agriculture-crops**, and **electricity generation** sectors.

Total direct impacts of $2.6 million from the biological control of leafy spurge infestations on wildland in the four-state region generated $3 million in secondary economic impacts to the regional economy, which included $1.2 million of personal income (**households** sector), $0.8 million of retail trade activity, and $0.2 million in the **finance, insurance, and real estate** sector (Table 6).

Table 6. Direct, Secondary, and Total Future Annual Economic Impacts of the Biological Control of Leafy Spurge Infestations on Wildland in Montana, North Dakota, South Dakota, and Wyoming by 2025[a]

	Economic Impacts		
Economic Sector	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	0	151	151
Agriculture-crops	228	70	298
Nonmetal mining	0	7	7
Construction	0	94	94
Transportation	0	22	22
Communication and public utilities	0	152	152
Agricultural processing and miscellaneous manufacturing	0	108	108
Retail trade	1,237	802	2,039
Finance, insurance, and real estate	0	177	177
Business and personal service 609	71	680	
Professional and social service	0	80	80
Households	0	1,157	1,157
Government	550	118	668
Others[a]	8	1	9
Totals	2,632	3010	5,642
Number of jobs supported			118

[a] Direct, secondary, and total impacts for biological control of leafy spurge on wildland were calculated separately for each state (see Appendix D) and summarized here.

Secondary employment estimates represent the number of jobs supported by the amount of business activity that was gained from an increase in wildlife habitat quality and soil and water conservation values. The biological control of leafy spurge on wildland would create enough business activity to support 118 jobs in the four-state region in 2025 (Table 6).

Combined Impacts

Biological control was speculated to ultimately control 65 percent of the 1,865,000 acres of future leafy spurge infestations. The 1,212,000 acres of leafy spurge on rangeland and wildland controlled by biological agents was estimated to generate an annual direct economic impact of $19.1 million (1997 dollars). Total, direct and secondary, economic impacts, from the biological control of leafy spurge in the Upper Midwest were estimated at $58.4 million annually. An additional 876 secondary jobs would be supported in the four-state region as a result of biological control of leafy spurge (Table 7).

Table 7. Direct, Secondary, and Total Future Annual Economic Impacts of the Biological Control of Leafy Spurge in Montana, North Dakota, South Dakota, and Wyoming by 2025

	Economic Impacts		
Economic Sector	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	829	1,455	2,284
Agriculture-crops	5,385	1,159	6,544
Nonmetal mining	0	100	100
Construction	0	1,334	1,334
Transportation	351	196	547
Communication and public utilities	242	1,643	1,885
Agricultural processing and miscellaneous manufacturing	0	1,863	1,863
Retail trade	3,661	11,982	15,643
Finance, insurance, and real estate	574	2,602	3,176
Business and personal service 826	1,000	1,826	
Professional and social service	0	1,279	1,279
Households	6,655	12,963	19,618
Government	550	1,700	2,250
Others[a]	8	1	9
Totals	19,082	39,276	58,358
Number of jobs supported			876

[a] Direct, secondary, and total impacts for biological control of leafy spurge on rangeland and wildland were summarized for each state (see Appendix D).

SUMMARY

The current infestation (1.76 million acres in 1996) of leafy spurge in the Upper Midwest was forecast to increase to 1.85 million acres around the turn of the century. Leafy spurge was forecast to ultimately infest 1.865 million acres, as acreages in South Dakota and Montana were expected to continue expanding until 2005. Biological agents were estimated to eventually control about 1.21 million acres or about 65 percent of leafy spurge in untilled land--820,000 acres in rangeland and 392,000 acres in wildland. Rangeland productivity was assumed to return to 75 percent of pre-infestation output. The net increase in rangeland output was estimated at about 320,500 AUMs of grazing valued at $5 million (1997 dollars) annually. The increase in grazing output was expected to support an increase in beef cattle operations equivalent to a 39,400 beef-cow herd. The increase in grazing activities was expected to generate $11.5 million annually in additional production expenditures to local economies. Total direct economic impacts from the biological control of leafy spurge on rangeland were estimated at $16.45 million (1997 dollars) in 2025. Secondary economic impacts, those arising from the spending and respending of production outlays, were estimated to generate another $36.3 million in annual impacts. Total, direct and secondary, economic impacts from the biological control of leafy spurge on rangeland were estimated at $52.7 million (1997 dollars) annually in 2025.

Biological agents were estimated to ultimately control about 392,000 acres of leafy spurge on wildland (450,000 when federal rangeland is included in the total). Wildland outputs (i.e., wildlife habitat and soil and water conservation benefits) on controlled acres were assumed to return to 100 percent of pre-infestation productivity. Biological control was estimated to be responsible for $1.8 million (1997 dollars) in increased wildlife-related recreationist expenditures in the four-state region in 2025. Also, an additional $785,000 in increased soil and water conservation benefits were expected to result from the biological control of leafy spurge on wildland. The $2.6 million in direct economic impacts were expected to generate another $3 million in secondary economic impacts. Total economic impacts from the biological control of leafy spurge on wildland was estimated at $5.6 million (1997 dollars) annually in 2025.

Biological control was speculated to ultimately control 65 percent of the 1,865,000 future acres of leafy spurge in Montana, North Dakota, South Dakota, and Wyoming. The 1,212,000 acres of leafy spurge on rangeland and wildland controlled by biological agents was estimated to generate an annual direct economic impact of $19.1 million (1997 dollars). Total annual secondary economic impacts were estimated at $39.3 million (1997 dollars). Total, direct and secondary, economic impacts from the biological control of leafy spurge in the Upper Midwest were estimated at $58.4 million annually. An additional 876 secondary jobs would be supported in the four-state region as a result of biological control of leafy spurge.

IMPLICATIONS

Biological control programs have been developed largely with public resources. The use of public funds is often debated. Although the use of public funds to develop and implement biological control programs for troublesome weeds may not be a high priority in the era of budget shortfalls and revenue reductions, the payback is likely to be substantially higher than the costs to develop the program.

CONCLUSIONS

If the level of leafy spurge control postulated in this study is eventually achieved, the biological control program would enhance economic activity in the Upper Midwest. Assuming 65 percent control of the future acreage of leafy spurge, the LSBCP should provide an economic benefit of nearly $60 million (1997 dollars) annually in the Upper Midwest. Success to date indicates that the LSBCP will be an economic success regardless of the precise amount of future control. For example, if actual suppression of leafy spurge only reaches about half the level predicted in this study (37 percent instead of 65 percent of future infestations), the program would still generate nearly $25 to $30 million (1997 dollars) in annual economic benefits (direct and secondary) in the four states. In addition to the economic benefits realized in the Upper Midwest, substantial infestations of leafy spurge can be found in other western states. Leafy spurge infestations in those states are currently being inoculated with biological control agents, and it would appear likely that those states will experience similar benefits from biological control, thereby raising the value of the LSBCP in the United States.

As with previous studies of the economic impacts (losses) of leafy spurge, refinement in the models used would narrow the uncertainty of the estimates. The results of this study are particularly sensitive to several subjective assessments of key components of the analysis. The consequence of using these assessments is that results represent at best, an educated guess of the future value of the LSBCP. Considering the rapid growth and success of the LSBCP, our "best guesses" would be less speculative in perhaps as little as five years. The assessment of the economic value of the LSBCP would benefit from incorporation of additional information as the overall understanding of the biological control process grows.

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Appendix A
County Weed Board Biological Control Survey

Bio-control of Leafy Spurge in ___________ County

How many acres of leafy spurge does your county have? _________ acres

If you have no leafy spurge, stop here and mail back. Thanks!

Are biological agents being used in your county to control leafy spurge? yes / no

If yes, how long has bio-control been used? __________ years

If no, does your county plan to implement a bio-control program or start using bio-control agents within the next 5 years? yes / no

Please provide *estimates* for the following questions. Even if you are unsure of the answer, your guess is better than ours!

How many insect release sites are there in your county? ________

How many of those sites are considered insectaries? ________

How many insects have been brought into your county for bio-control? __________

How many insects have been collected and redistributed within your county? __________

Based on the distribution and acreage of leafy spurge infestations in your county, what percent has been exposed/inoculated with bio-control agents? ________%

Effectiveness of Bio-control

Of the insect releases that have been made, what percentage of those sites have showed evidence of surviving after three winters (without additional releases)? _________ %

How many acres of leafy spurge infested-land have been reclaimed by bio-control agents to the extent that leafy spurge has minimal impact?

Rangeland? _________ acres

Other land? _________ acres (scenic areas, parks, wildlife production areas, shelterbelts, etc.)

Please *speculate* on what you expect the total leafy spurge acreage reclaimed by bio-control to be:

In 5 Years	In 10 Years	Eventually or Ultimately
Rangeland? _______ acres	Rangeland? _______ acres	Rangeland? _______ acres
Other land? _______ acres	Other land? _______ acres	Other land? _______ acres

Please speculate on the number of years before the maximum amount of leafy spurge control with bio-control agents is achieved? ________years

Comments: ____

____

____

____

Thank you for your assistance! Would you like to receive a copy of the final report? Yes / No

Appendix B

Leafy Spurge Acreage by County for Montana, North Dakota, South Dakota, and Wyoming, 1996

Appendix Table B1. Acreage of Leafy Spurge by County by Land Type in Montana, 1996

County	Total Acres	Infestations by Land Type	
		Rangeland	Wildland
Beaverhead	50	47	3
Big Horn	5,000	3,913	1,088
Blaine	2,000	1,700	300
Broadwater	3,000	1,500	1,500
Carbon	10,000	9,600	400
Carter	8,000	6,663	1,337
Cascade	25,000	17,750	7,250
Chouteau	20,000	19,264	736
Custer	4,500	4,050	450
Daniels	100	91	10
Dawson	60,000	19,650	40,350
Deer Lodge	19,000	15,865	3,135
Fallon	3,583	3,535	48
Fergus	10,000	7,913	2,087
Flathead	1,000	100	900
Gallatin	2,500	1,727	773
Garfield	1	0	0
Glacier	800	684	116
Golden Valley	120	119	1
Granite	1,500	1,026	474
Hill	80	59	21
Jefferson	1,500	1,463	38
Judith Basin	10,000	9,400	600
Lake	647	146	501
Lewis & Clark	1,200	888	312
Liberty	300	197	103
Lincoln	120	82	38
Madison	20,000	18,040	1,960
McCone	50	41	9
Meagher	15,000	13,500	1,500
Mineral	750	638	113
Missoula	6,000	5,847	153
Musselshell	50	40	10
Park	5,000	4,300	700
Petroleum	.	0	0
Phillips	5,616	2,415	3,201
Pondera	10,000	7,003	2,998
Powder River	10,000	8,329	1,671
Powell	2,500	1,710	790

- continued -

Appendix Table B1. Continued

County	Total Acres	Infestations by Land Type Rangeland	Wildland
Prairie	700	607	93
Ravalli	400	290	110
Richland	40,000	37,520	2,480
Roosevelt	35,000	31,227	3,773
Rosebud	600	537	63
Sanders	840	681	159
Sheridan	550	535	15
Silver Bow	4,000	3,882	118
Stillwater	35,000	27,650	7,350
Sweet Grass	53,900	37,191	16,709
Teton	20,000	8,600	11,400
Toole	4,000	2,040	1,960
Treasure	10	9	1
Valley	10,000	7,520	2,480
Wheatland	6,400	5,254	1,146
Wibaux	800	496	304
Yellowstone	300	195	105
State	477,467	353,526	123,940

Source: Cooperative Agricultural Pest Survey (1997c).

Note: Most current acreage estimates were obtained from the Cooperative Agricultural Pest Survey program; however, acreage for some counties was obtained from past published estimates (Bangsund et al. 1993) and from the county weed board biological control survey. Information from Bangsund et al. (1993) was used to determine acreage on rangeland and wildland based on current infestation levels.

Appendix Table B2. Acreage of Leafy Spurge by County by Land Type in North Dakota, 1996

County	Total Acres	Infestations by Land Type	
		Rangeland	Wildland
Adams	17,851	13,255	4,595
Barnes	8,400	5,009	3,391
Benson	14,000	10,326	3,674
Billings	77	49	28
Bottineau	35,000	19,999	15,001
Bowman	10,600	5,690	4,910
Burke	16,000	13,408	2,592
Burleigh	20,500	9,926	10,574
Cass	1,500	1,046	455
Cavalier	5,675	2,592	3,083
Dickey	4,500	1,436	3,065
Divide	41,000	13,464	27,536
Dunn	26,000	15,505	10,495
Eddy	108,000	83,808	24,192
Emmons	36,600	16,848	19,752
Foster	56,776	27,707	29,069
Golden Valley	30,500	9,366	21,134
Grand Forks	11,000	3,476	7,524
Grant	17,100	10,055	7,045
Griggs	1,000	386	614
Hettinger	3,900	2,582	1,318
Kidder	6,000	3,578	2,422
LaMoure	3,000	1,789	1,211
Logan	8,100	4,009	4,091
McHenry	300	190	110
McIntosh	4,000	3,032	968
McKenzie	1,050	626	424
McLean	10,800	9,680	1,120
Mercer	31,500	17,000	14,500
Morton	1,865	1,218	647
Mountrail	14,000	8,064	5,936
Nelson	19,350	14,111	5,239
Oliver	55,000	48,558	6,442
Pembina	7,500	6,349	1,151
Pierce	5,100	3,627	1,473
Ramsey	8,000	5,736	2,264
Ransom	20,300	10,150	10,150
Renville	1,960	1,446	514
Richland	70,000	49,490	20,510

- continued -

Appendix Table B2. Continued

County	Total Acres	Infestations by Land Type	
		Rangeland	Wildland
Rollette	79,860	30,804	49,056
Sargent	16,000	12,774	3,226
Sheridan	1,440	1,308	132
Sioux	300	171	129
Slope	1,000	847	153
Stark	33,000	26,928	6,072
Steele	7,950	3,438	4,512
Stutsman	4,400	3,725	675
Towner	73,000	66,620	6,380
Traill	1,300	1,252	48
Walsh	284	240	44
Ward	1,400	901	499
Wells	7,775	5,722	2,053
Williams	31,000	26,242	4,758
State	992,513	635,554	356,958

Source: North Dakota Department of Agriculture (1997b).

Note: Information from Wallace et al. (1992) was used to determine acreage on rangeland and wildland based on current infestation levels.

Appendix Table B3. Acreage of Leafy Spurge by County by Land Type in South Dakota, 1996

County	Total Acres	Infestations by Land Type	
		Rangeland	Wildland
Aurora	6,400	3,840	2,560
Beadle	6,000	2,160	3,840
Bennett	5	3	2
Bon Homme	800	182	618
Brookings	2,600	1,559	1,041
Brown	9,400	8,046	1,354
Brule	16,250	14,138	2,113
Buffalo	0	0	0
Butte	50	25	25
Campbell	3,600	3,204	396
Charles Mix	250	134	116
Clark	15,595	11,384	4,211
Clay	5,178	0	5,178
Codington	16,000	8,960	7,040
Corson	30	25	5
Custer	450	416	34
Davison	900	812	88
Day	3,700	444	3,256
Deuel	28,500	15,672	12,828
Dewey	230	78	152
Douglas	400	304	96
Edmunds	9,500	7,790	1,710
Fall River	302	206	96
Faulk	15	12	3
Grant	6,500	5,194	1,307
Gregory	600	480	120
Haakon	0	0	0
Hamlin	6,000	3,120	2,880
Hand	2,205	1,676	529
Hanson	1,800	1,080	720
Harding	720	713	7
Hughes	600	327	273
Hutchinson	1,100	691	409
Hyde	70	14	56
Jackson	0	0	0
Jerauld	275	223	52
Jones	20	9	11
Kingsbury	300	63	237

- continued -

Appendix Table B3. Continued

County	Total Acres	Infestations by Land Type Rangeland	Wildland
Lake	1,075	452	624
Lawrence	1,800	1,683	117
Lincoln	2,800	1,960	840
Lyman	0	0	0
Marshall	16,000	13,260	2,740
McCook	3,500	1,575	1,925
McPherson	2,000	900	1,100
Meade	1,005	967	38
Mellette1	2,423	4,100	8,324
Miner	450	450	0
Minnehaha	440	99	341
Moody	525	402	123
Pennington	3,500	2,363	1,138
Perkins	2,600	2,340	260
Potter	2	1	1
Roberts	2,975	1,613	1,362
Sanborn	2,440	1,952	488
Shannon	0	0	0
Spink	3,075	1,845	1,230
Stanley	300	243	57
Sully	16	4	12
Todd	2,628	158	2,471
Tripp	2,900	2,111	789
Turner	6,802	2,024	4,778
Union	1,805	843	962
Walworth	1,325	769	557
Yankton	1,400	1,197	203
Ziebach	100	81	19
State	220,232	136,375	83,857

Source: South Dakota Department of Agriculture (1997).

Note: Acreage of leafy spurge on rangeland and wildland calculated from information obtained from Bangsund et al. (1993).

Appendix Table B4. Acreage of Leafy Spurge by County by Land Type in Wyoming, 1996

County	Total Acres	Infestations by Land Type	
		Rangeland	Wildland
Albany	66	66	0
Big Horn	10	10	0
Campbell	350	334	16
Carbon	950	701	249
Converse	275	191	84
Crook	40,000	38,744	1,256
Fremont	4,000	3,780	220
Goshen	350	166	184
Hot Springs	5	5	0
Johnson	6,775	6,165	610
Laramie	600	423	177
Lincoln	1,800	1,584	216
Natrona	35	32	3
Niobrara	50	50	0
Park	15	5	10
Platte	175	94	81
Sheridan	13,895	13,645	250
Sublette	1	0	0
Sweetwater	90	90	0
Teton	6	5	1
Uinta	165	165	0
Washakie	1	0	1
Weston	2,650	1,991	659
State	72,263	68,248	4,015

Source: Cooperative Agricultural Pest Survey (1997a).

Note: Acreage of leafy spurge on rangeland and wildland calculated from information obtained from Bangsund et al. (1993).

Appendix C

Beef-cow Herd Production Budgets for Montana, North Dakota, South Dakota, and Wyoming

This appendix lists the herd characteristics and assumptions used in the cow-calf budgets.

Due to lack of current information on owner-operator debt, cow-calf budgets were generated assuming no debt. Replacement heifers were assumed to be raised, not purchased.

Investment figures for land, equipment, and buildings and depreciation rates, repairs, taxes, and insurance on equipment, buildings, and land, along with investment per cow and heifer were extracted from Hughes et al. (1989).

Selling prices for steers, heifers, cull cows, and cull heifers and oats and hay prices were ten-year averages received in North Dakota, 1987 through 1996 (North Dakota Agricultural Statistics Service *various years*). Other costs and expenses were extracted from Bangsund and Leistritz (1991) and Bangsund and Leistritz (1992).

Cow-calf Herd Characteristics

	North Dakota/South Dakota	Montana/Wyoming
•	1.1 AUM for cows	1.1 AUM for cows
•	1.0 AUM for bulls	1.0 AUM for bulls
•	0.9 AUM for heifers	0.9 AUM for heifers
•	91.0% calf crop	91.7% calf crop
•	15.0% replacement rate	15.2% replacement rate
•	1.0% cow loss	1.7% cow loss
•	25 breeding animals (cows and heifers) per bull	21 breeding animals (cows and heifers) per bull
•	3.0 years useful bull life	3.9 years useful bull life
•	180 days grazing period	210 days grazing period
•	Steer calves sold at 528 lbs.	Steer calves sold at 528 lbs.
•	Heifer calves sold at 499 lbs.	Heifer calves sold at 499 lbs.
•	Cull cows sold at 900 lbs.	Cull cows sold at 900 lbs.
•	Cull heifers sold at 875 lbs.	Cull heifers sold at 875 lbs.
•	Cull bulls sold at 2100 lbs.	Cull bulls sold at 2100 lbs.

RECEIPTS

	-- Hd --				
Steers	2,373	528 lbs.	$0.86/lb	=	$1,077,532
Heifers	1,344	499 lbs.	$0.84/lb	=	$563,577
Cull Cows	699	900 lbs.	$0.44/lb	=	$276,804
Cull Heifers	242	875 lbs.	$0.76/lb	=	$159,871
Cull Bulls	76	2,100 lbs.	$0.55/lb	=	$87,780
			Total Income Per Herd	=	$2,165,564
			Total Income Per Cow	=	$418

FEED EXPENSES

					Economic Costs
		210 Days of Summer Grazing			
5,175	Cows @ 1.1 AUM =	39,848 AUMs @	$13.95/AUM	=	$555,728
1,029	RHfr @ 0.9 AUM =	6,483 AUMs @	$13.95/AUM	=	$90,409
295	Bulls @ 1 AUM =	2,065 AUMs @	$13.95/AUM	=	$28,833
Mineral and Salt		59.55 Tons @	$400/Ton	=	$23,822
		155 Days of Winter Feeding			
Oats	11,698	Bushels	$1.36/Bu	=	$15,909
Protein	128	Tons	$240.00/Ton	=	$30,802
Hay	11,430	Tons	$53.00/Ton	=	$605,805
Mineral and Salt	43.96	Tons	$400.00/Ton	=	$17,583
			Total Feed Costs Per Herd	=	$1,368,889
			Total Feed Costs Per Cow	=	$265

LIVESTOCK EXPENSES

	Rate Per Hd		Economic Costs
Veterinary and Medicine	$14.10/Cow	=	$72,968
Supplies	$7.80/Cow	=	$40,365
Bull Semen Check	$10.00/Bull	=	$2,954
Utilities and Custom Hire	$11.15/Cow	=	$57,701
Power and Fuel	$9.28/Cow	=	$48,024
Bedding	$1.14/Cow	=	$5,900
Marketing	$8.96/Cow	=	$46,368
Miscellaneous	$5.34/Cow	=	$27,635
Bull Insurance	(Estimated at 1% of Total Bull Value)	=	$7,386
Interest Expense	(9.0 % @ 6 mnths x Lvstck & Feed Exp)	=	$47,259
Bull Depreciation	(Purchase Price - Salvage Value)/Years of Use	=	$101,885
	Total Livestock Expenses Per Herd	=	$458,444
	Total Livestock Expenses Per Cow	=	$89

Beef Cow-calf Production Budgets for Montana
Estimation of Direct Impacts -- 5,175-COW HERD

FIXED EXPENSES

	Investment	Repairs Depreciation Insurance & Taxes		Economic Costs
Land	$0	1%	=	xxxxxx
Buildings	$258,750	7%	=	$18,113
Equipment	$517,500	12%	=	$62,100
Investment per Cow	$800	1%	=	xxxxxx
Investment per Heifer	$700	1%	=	xxxxxx
Cow Herd Insurance			=	$20,700
Bull Investment	$8,998,500	1%	=	xxxxxx
	Total Fixed Costs Per Herd		=	$100,913
	Total Fixed Costs Per Cow		=	$20

Economic costs for land investment, bull investment, and cow herd investment were not included in the budget as an expense. Those costs would be extracted from returns to labor, management, and equity. Taxes were not included in the budget.

Cow herd insurance was calculated with the following formula ((Number of cows x Investment per cow)/100 x $0.50).

COSTS/RETURNS SUMMARY

	Economic Costs/Returns
Receipts	$2,165,564
Less Feed and Livestock Expenses	$1,827,333

Returns Above Variable Costs	$338,230
Less Fixed Expenses	$100,913

Returns to Labor, Management, & Equity Capital for the Herd	$237,318

Total Receipts Per Cow	$418.47
Less Total Expenses Per Cow	$372.61

Returns to Labor, Management, & Equity Capital Per Cow	$45.86

Beef Cow-calf Production Budgets for North Dakota
Estimation of Direct Impacts -- 23,558-COW HERD

RECEIPTS

	-- Hd --				
Steers	10,719	528 lbs.	$0.86/lb	=	$4,867,284
Heifers	6,285	499 lbs.	$0.84/lb	=	$2,635,476
Cull Cows	3,298	900 lbs.	$0.44/lb	=	$1,306,008
Cull Heifers	900	875 lbs.	$0.76/lb	=	$594,563
Cull Bulls	76	2,100 lbs.	$0.55/lb	=	$430,815
			Total Income Per Herd	=	$9,834,146
			Total Income Per Cow	=	$417

FEED EXPENSES

		Economic Costs
180 Days of Summer Grazing		
23,558 Cows @ 1.1 AUM = 155,483 AUMs @ $16.70/AUM	=	$2,596,018
4,434 RHfr @ 0.9 AUM = 23,944 AUMs @ $16.70/AUM	=	$399,774
1,120 Bulls @ 1 AUM = 6,720 AUMs @ $16.70/AUM	=	$112,176
Mineral and Salt 59.55 Tons @ $400/Ton	=	$23,822

170 Days of Winter Feeding					
Oats	58,404	Bushels	$1.37/Bu	=	$80,014
Protein	641	Tons	$240.00/Ton	=	$153,787
Hay	57,069	Tons	$53.00/Ton	=	$3,024,671
Mineral and Salt	238.83	Tons	$400.00/Ton	=	$95,337
Crop Aftermath	15	Days	$0.10/day/cow	=	$35,337
			Total Feed Costs Per Herd	=	$6,590,259
			Total Feed Costs Per Cow	=	$280

LIVESTOCK EXPENSES

	Rate Per Hd		Economic Costs
Veterinary and Medicine	$14.10/Cow	=	$332,378
Supplies	$7.00/Cow	=	$164,906
Bull Semen Check	$10.00/Bull	=	$11,197
Utilities and Custom Hire	$10.00/Cow	=	$235,580
Power and Fuel	$9.00/Cow	=	$212,022
Bedding	$1.00/Cow	=	$23,558
Marketing	$8.92/Cow	=	$210,137
Miscellaneous	$5.00/Cow	=	$117,790
Bull Insurance	(Estimated at 1% of Total Bull Value)	=	$27,992
Interest Expense	(9.0 % @ 6 mnths x Lvstck & Feed Exp)	=	$224,951
Bull Depreciation	(Purchase Price - Salvage Value)/Years of Use	=	$501,990
	Total Livestock Expenses Per Herd	=	$2,062,291
	Total Livestock Expenses Per Cow	=	$88

Beef Cow-calf Production Budgets for North Dakota
Estimation of Direct Impacts -- 23,558-COW HERD

FIXED EXPENSES

	Investment	Repairs Depreciation Insurance & Taxes		Economic Costs
Land	$0	1%	=	xxxxxx
Buildings	$1,177,900	7%	=	$82,453
Equipment	$2,355,800	12%	=	$282,696
Investment per Cow	$800	1%	=	xxxxxx
Investment per Heifer	$700	1%	=	xxxxxx
Cow Herd Insurance			=	$94,232
Bull Investment	$8,998,500	1%	=	xxxxxx
	Total Fixed Costs Per Herd		=	$459,381
	Total Fixed Costs Per Cow		=	$20

Economic costs for land investment, bull investment, and cow herd investment were not included in the budget as an expense. Those costs would be extracted from returns to labor, management, and equity. Taxes were not included in the budget.

Cow herd insurance was calculated with the following formula ((Number of cows x Investment per cow)/100 x $0.50).

COSTS/RETURNS SUMMARY

	Economic Costs/Returns
Receipts	$9,834,146
Less Feed and Livestock Expenses	$8,652,550

Returns Above Variable Costs	$1,181,596
Less Fixed Expenses	$459,381

Returns to Labor, Management, & Equity Capital for the Herd	$722,215

Total Receipts Per Cow	$417.44
Less Total Expenses Per Cow	$386.79

Returns to Labor, Management, & Equity Capital Per Cow	$30.66

Beef Cow-calf Production Budgets for South Dakota
Estimation of Direct Impacts -- 9,441-COW HERD

RECEIPTS

	-- Hd --				
Steers	4,296	528 lbs.	$0.86/lb	=	$1,950,728
Heifers	2,519	499 lbs.	$0.84/lb	=	$1,056,287
Cull Cows	1.322	900 lbs.	$0.44/lb	=	$523,512
Cull Heifers	361	875 lbs.	$0.76/lb	=	$238,486
Cull Bull	150	2,100 lbs.	$0.55/lb	=	$173,250
			Total Income Per Herd	=	$3,942,263
			Total Income Per Cow	=	$418

FEED EXPENSES

				Economic Costs
180 Days of Summer Grazing				
9,441 Cows	@ 1.1 AUM =	62,311 AUMs	@ $14.72/AUM =	$917,343
1,777 RHfr	@ 0.9 AUM =	9,596 AUMs	@ $14.72/AUM =	$141,246
449 Bulls	@ 1 AUM =	2,694 AUMs	@ $14.72/AUM =	$39,661
Mineral and Salt		93.13 Tons	@ $400/Ton =	$37,250

					Economic Costs
170 Days of Winter Feeding					
Oats	23,406	Bushels	$1.37/Bu	=	$32,066
Protein	257	Tons	$240.00/Ton	=	$61,631
Hay	22,871	Tons	$53.00/Ton	=	$1,212,154
Mineral and Salt	95.71	Tons	$400.00/Ton	=	$38,285
Crop Aftermath	15	Days	$0.10/day/cow	=	$14,162
			Total Feed Costs Per Herd	=	$2,493,798
			Total Feed Costs Per Cow	=	$264

LIVESTOCK EXPENSES

	Rate Per Hd		Economic Costs
Veterinary and Medicine	$14.10/Cow	=	$133,118
Supplies	$7.00/Cow	=	$66,087
Bull Semen Check	$10.00/Bull	=	$4,487
Utilities and Custom Hire	$10.00/Cow	=	$94,410
Power and Fuel	$9.00/Cow	=	$84,969
Bedding	$1.00/Cow	=	$9,441
Marketing	$8.92/Cow	=	$84,214
Miscellaneous	$5.00/Cow	=	$47,205
Bull Insurance	(Estimated at 1% of Total Bull Value)	=	$11,218
Interest Expense	(9.0 % @ 6 mnths x Lvstck & Feed Exp)	=	$86,901
Bull Depreciation	(Purchase Price - Salvage Value)/Years of Use	=	$201,176
	Total Livestock Expenses Per Herd	=	$823,226
	Total Livestock Expenses Per Cow	=	$87

Beef Cow-calf Production Budgets for South Dakota
Estimation of Direct Impacts -- 9,441-COW HERD

FIXED EXPENSES

	Investment	Repairs Depreciation Insurance & Taxes		Economic Costs
Land	$0	1%	=	xxxxxx
Buildings	$472,050	7%	=	$33,044
Equipment	$944,100	12%	=	$113,292
Investment per Cow	$800	1%	=	xxxxxx
Investment per Heifer	$700	1%	=	xxxxxx
Cow Herd Insurance			=	$37,764
Bull Investment	$8,998,500	1%	=	xxxxxx
	Total Fixed Costs Per Herd		=	$184,100
	Total Fixed Costs Per Cow		=	$20

Economic costs for land investment, bull investment, and cow herd investment were not included in the budget as an expense. Those costs would be extracted from returns to labor, management, and equity. Taxes were not included in the budget.

Cow herd insurance was calculated with the following formula ((Number of cows x Investment per cow)/100 x $0.50).

COSTS/RETURNS SUMMARY

	Economic Costs/Returns
Receipts	$3,942,263
Less Feed and Livestock Expenses	$3,317,025

Returns Above Variable Costs	$625,238
Less Fixed Expenses	$184,100

Returns to Labor, Management, & Equity Capital for the Herd	$441,138

Total Receipts Per Cow	$417.57
Less Total Expenses Per Cow	$370.84

Returns to Labor, Management, & Equity Capital Per Cow	$46.73

Beef Cow-calf Production Budgets for Wyoming
Estimation of Direct Impacts -- 1,210-COW HERD

RECEIPTS

	-- Hd --				
Steers	555	528 lbs.	$0.86/lb	=	$252,014
Heifers	314	499 lbs.	$0.84/lb	=	$131,669
Cull Cows	163	900 lbs.	$0.44/lb	=	$64,548
Cull Heifers	57	875 lbs.	$0.76/lb	=	$37,656
Cull Bull	18	2,100 lbs.	$0.55/lb	=	$20,790
			Total Income Per Herd	=	$506,677
			Total Income Per Cow	=	$419

FEED EXPENSES

					Economic Costs
210 Days of Summer Grazing					
1,210 Cows	@ 1.1 AUM =	9,317 AUMs	@ $8.69/AUM	=	$80,965
241 RHfr	@ 0.9 AUM =	1,518 AUMs	@ $8.69/AUM	=	$13,191
69 Bulls	@ 1 AUM =	483 AUMs	@ $8.69/AUM	=	$4,197
Mineral and Salt		13.92 Tons	@ $400/Ton	=	$5,570
155 Days of Winter Feeding					
Oats	2,735	Bushels	$1.37/Bu	=	$3,747
Protein	30	Tons	$240.00/Ton	=	$7,202
Hay	2,673	Tons	$53.00/Ton	=	$141,647
Mineral and Salt	10.28	Tons	$400.00/Ton	=	$4,111
			Total Feed Costs Per Herd	=	$260,630
			Total Feed Costs Per Cow	=	$265

LIVESTOCK EXPENSES

	Rate Per Hd		Economic Costs
Veterinary and Medicine	$14.10/Cow	=	$17,061
Supplies	$7.80/Cow	=	$9,438
Bull Semen Check	$10.00/Bull	=	$691
Utilities and Custom Hire	$11.15/Cow	=	$13,492
Power and Fuel	$9.28/Cow	=	$11,229
Bedding	$1.14/Cow	=	$1,379
Marketing	$8.96/Cow	=	$10,842
Miscellaneous	$5.34/Cow	=	$6,461
Bull Insurance	(Estimated at 1% of Total Bull Value)	=	$1,727
Interest Expense	(9.0 % @ 6 mnths x Lvstck & Feed Exp)	=	$9,741
Bull Depreciation	(Purchase Price - Salvage Value)/Years of Use	=	$23,829
	Total Livestock Expenses Per Herd	=	$105,890
	Total Livestock Expenses Per Cow	=	$88

Beef Cow-calf Production Budgets for Wyoming
Estimation of Direct Impacts -- 1,210-COW HERD

FIXED EXPENSES

	Investment	Repairs Depreciation Insurance & Taxes		Economic Costs
Land	$0	1%	=	xxxxxx
Buildings	$60,500	7%	=	$4,235
Equipment	$121,000	12%	=	$14,520
Investment per Cow	$800	1%	=	xxxxxx
Investment per Heifer	$700	1%	=	xxxxxx
Cow Herd Insurance			=	$4,840
Bull Investment	$8,998,500	1%	=	xxxxxx
	Total Fixed Costs Per Herd		=	$23,595
	Total Fixed Costs Per Cow		=	$20

Economic costs for land investment, bull investment, and cow herd investment were not included in the budget as an expense. Those costs would be extracted from returns to labor, management, and equity. Taxes were not included in the budget.

Cow herd insurance was calculated with the following formula ((Number of cows x Investment per cow)/100 x $0.50).

COSTS/RETURNS SUMMARY

	Economic Costs/Returns
Receipts	$506,677
Less Feed and Livestock Expenses	$366,520
Returns Above Variable Costs	$140,157
Less Fixed Expenses	$23,595
Returns to Labor, Management, & Equity Capital for the Herd	$116,562
Total Receipts Per Cow	$418.47
Less Total Expenses Per Cow	$322.41
Returns to Labor, Management, & Equity Capital Per Cow	$96.33

Appendix D

Direct, Secondary, and Total Economic Impacts for Montana, North Dakota, South Dakota, and Wyoming

Appendix Table D1. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland in Montana, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	102	170	272
Agriculture-crops	628	137	765
Nonmetal mining	0	12	12
Construction	0	164	164
Transportation	46	23	69
Communication and public utilities	36	198	234
Agricultural processing and miscellaneous manufacturing	0	221	221
Retail trade	316	1,469	1,785
Finance, insurance, and real estate	75	320	395
Business and personal service	29	122	151
Professional and social service	0	160	160
Households	934	1,531	2,465
Government	0	209	209
Totals	2,166	4,736	6,902
Number of jobs gained			73

Appendix Table D2. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Wildland in Montana, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	0	15	15
Agriculture-crops	83	11	94
Nonmetal mining	0	1	1
Construction	0	12	12
Transportation	0	2	2
Communication and public utilities	0	16	16
Agricultural processing and miscellaneous manufacturing	0	18	18
Retail trade	80	108	188
Finance, insurance, and real estate	0	23	23
Business and personal service	39	9	48
Professional and social service	0	10	10
Households	0	141	141
Government	201	14	215
Coal Mining	0	0	0
Electricity Generation	3	0	3
Totals	406	380	786
Number of jobs gained			18

Appendix Table D3. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland in North Dakota, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s)	----------------	
Agriculture-livestock	502	781	1,283
Agriculture-crops	3,128	657	3,785
Nonmetal mining	0	56	56
Construction	0	741	741
Transportation	210	104	314
Communication and public utilities	141	890	1,031
Agricultural processing and miscellaneous manufacturing	0	1,058	1,058
Retail trade	1,452	6,686	8,138
Finance, insurance, and real estate	347	1,449	1,796
Business and personal service	129	555	684
Professional and social service	0	715	715
Households	3,924	7,081	11,005
Government	0	945	945
Totals	9,834	21,717	31,551
Number of jobs gained			357

Appendix Table D4. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Wildland in North Dakota, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s)	----------------	
Agriculture-livestock	0	120	120
Agriculture-crops	109	51	160
Nonmetal mining	0	5	5
Construction	0	72	72
Transportation	0	18	18
Communication and public utilities	0	120	120
Agricultural processing and miscellaneous manufacturing	0	77	77
Retail trade	1,034	603	1,637
Finance, insurance, and real estate	0	134	134
Business and personal service	509	54	563
Professional and social service	0	61	61
Households	0	888	888
Government	263	91	354
Coal Mining	0	1	1
Electricity Generation	4	0	4
Totals	1,919	2,295	4,214
Number of jobs gained			84

Appendix Table D5. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland in South Dakota, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	201	313	514
Agriculture-crops	1,254	263	1,517
Nonmetal mining	0	22	22
Construction	0	297	297
Transportation	84	42	126
Communication and public utilities	57	357	414
Agricultural processing and miscellaneous manufacturing	0	424	424
Retail trade	582	2,681	3,263
Finance, insurance, and real estate	136	581	717
Business and personal service	52	223	275
Professional and social service	0	287	287
Households	1,577	2,837	4,414
Government	0	379	379
Totals	3,943	8,706	12,649
Number of jobs gained			140

Appendix Table D6. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Wildland in South Dakota, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	0	15	15
Agriculture-crops	31	7	38
Nonmetal mining	0	1	1
Construction	0	9	9
Transportation	0	2	2
Communication and public utilities	0	15	15
Agricultural processing and miscellaneous manufacturing	0	12	12
Retail trade	113	82	195
Finance, insurance, and real estate	0	18	18
Business and personal service	56	7	63
Professional and social service	0	8	8
Households	0	116	116
Government	74	12	86
Coal Mining	0	0	0
Electricity Generation	1	0	1
Totals	275	304	579
Number of jobs gained			10

Appendix Table D7. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland in Wyoming, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	24	40	64
Agriculture-crops	147	32	179
Nonmetal mining	0	3	3
Construction	0	38	38
Transportation	11	5	16
Communication and public utilities	8	46	54
Agricultural processing and miscellaneous manufacturing	0	52	52
Retail trade	74	344	418
Finance, insurance, and real estate	16	75	91
Business and personal service	7	29	36
Professional and social service	0	37	37
Households	220	357	577
Government	0	49	49
Totals	507	1,107	1,614
Number of jobs gained			12

Appendix Table D8. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Wildland in Wyoming, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	0	1	1
Agriculture-crops	5	1	6
Nonmetal mining	0	0	0
Construction	0	1	1
Transportation	0	0	0
Communication and public utilities	0	1	1
Agricultural processing and miscellaneous manufacturing	0	1	1
Retail trade	10	9	19
Finance, insurance, and real estate	0	2	2
Business and personal service	5	1	6
Professional and social service	0	1	1
Households	0	12	12
Government	12	1	13
Coal Mining	0	0	0
Electricity Generation	0	0	0
Totals	32	31	63
Number of jobs gained			0

Appendix Table D9. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland and Wildland in Montana, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	102	185	287
Agriculture-crops	711	148	859
Nonmetal mining	0	13	13
Construction	0	176	176
Transportation	46	25	71
Communication and public utilities	36	214	250
Agricultural processing and miscellaneous manufacturing	0	239	239
Retail trade	396	1,577	1,973
Finance, insurance, and real estate	75	343	418
Business and personal service	68	131	199
Professional and social service	0	170	170
Households	934	1,672	2,606
Government	201	223	424
Coal Mining	0	0	0
Electricity Generation	3	0	3
Totals	2,572	5,116	7,688
Number of jobs gained			91

Appendix Table D10. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland and Wildland in North Dakota, 2025

Economic Sector	Economic Impacts		
	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	502	901	1,403
Agriculture-crops	3,237	708	3,945
Nonmetal mining	0	61	61
Construction	0	813	813
Transportation	210	122	332
Communication and public utilities	141	1,010	1,151
Agricultural processing and miscellaneous manufacturing	0	1,135	1,135
Retail trade	2,486	7,289	9,775
Finance, insurance, and real estate	347	1,583	1,930
Business and personal service	638	609	1,247
Professional and social service	0	776	776
Households	3,924	7,969	11,893
Government	263	1,036	1,299
Coal Mining	0	1	1
Electricity Generation	4	0	4
Totals	11,753	24,012	35,765
Number of jobs gained			441

Appendix Table D11. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland and Wildland in South Dakota, 2025

	Economic Impacts		
Economic Sector	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	201	328	529
Agriculture-crops	1,285	270	1,555
Nonmetal mining	0	23	23
Construction	0	306	306
Transportation	84	44	128
Communication and public utilities	57	372	429
Agricultural processing and miscellaneous manufacturing	0	436	436
Retail trade	695	2,763	3,458
Finance, insurance, and real estate	136	599	735
Business and personal service	108	230	338
Professional and social service	0	295	295
Households	1,577	2,953	4,530
Government	74	391	465
Coal Mining	0	0	0
Electricity Generation	1	0	1
Totals	4,218	9,010	13,228
Number of jobs gained			150

Appendix Table D12. Direct, Secondary, and Total Future Economic Impacts of the Biological Control of Leafy Spurge Infestations on Rangeland and Wildland in Wyoming, 2025

	Economic Impacts		
Economic Sector	Direct	Secondary	Totals
	------------- 1997 dollars (000s) ----------------		
Agriculture-livestock	24	41	65
Agriculture-crops	152	33	185
Nonmetal mining	0	3	3
Construction	0	39	39
Transportation	11	5	16
Communication and public utilities	8	47	55
Agricultural processing and miscellaneous manufacturing	0	53	53
Retail trade	84	353	437
Finance, insurance, and real estate	16	77	93
Business and personal service	12	30	42
Professional and social service	0	38	38
Households	220	369	589
Government	12	50	62
Coal Mining	0	0	0
Electricity Generation	0	0	0
Totals	539	1,138	1,677
Number of jobs gained			12