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The Impact of Knapweed on Montana's Economy

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Abstract

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Keywords: knapweed (*Centaurea diffusa*, *C. maculosa*, and *Acroptilon repens*), Montana, economic impact, invasive weeds, rangeland, wildland

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The Impact of Knapweed on Montana's Economy

Steven A. Hirsch and Jay A. Leitch*

Introduction

Diffuse, spotted, and Russian knapweed (*Centaurea diffusa*, C. *maculosa*, and *Acroptilon repens*, respectively) are non-indigenous weeds that have become major components of rangelands, grazeable woodlands, and other untilled lands in Montana. At least one species, and frequently all three, is reported in every county in the state. Because of knapweed species' detrimental effects and their exceptional ability to spread and thrive in a variety of habitats, they have become a serious problem for farmers, ranchers, and public land managers in Montana.

Widespread infestations in Montana's grazing lands have drawn attention to the knapweed problem. Once established, knapweeds displace native vegetation, reducing forage production and threatening long-term rangeland productivity.

Montana's knapweed problem, however, is broader than just a grazing land problem. In addition to rangeland, knapweed invades other untilled areas like forest lands, railway embankments, road ditches, parks and wildlife areas, river banks, and built-up areas. Reduced plant diversity in these "wildlands" lowers their value as wildlife habitat and decreases their water and soil conservation benefits.

Objectives

The objective of this study was to assess the direct and secondary impacts of the common knapweed species on Montana's economy. Specific objectives include

- estimation of the extent of knapweed on each land use,
- identification of outputs (benefits) of infested lands and estimation of the economic impact of knapweed on these outputs, and
- estimation of the impact of knapweed infestations on Montana's economy.

This study does not assess the benefits of expenditures made for knapweed control or for controls, such as biological controls, that are being developed for use in the future.

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Procedure

Previous studies from Montana's Cooperative Extension Service and published literature on the knapweed species common to Montana were reviewed. Experts on knapweed and knapweed control, cattle grazing, and wildlife were consulted. Beneficial outputs of grazing land and wildland were identified, and impacts of knapweed and plants with similar adverse effects were examined.

County weed board questionnaire data were summarized to estimate the extent of Montana's knapweed infestation. The economic impact of knapweed was based on procedures developed for leafy spurge by the Department of Agricultural Economics at North Dakota State University (Leitch et al. 1994).

County weed board questionnaire. Questionnaires (Appendix A) were mailed to each county weed board in Montana. The survey instrument requested each board (1) to estimate total knapweed-infested acres in its county and (2) to estimate a percentage of total infested acres occurring on each land use according to land ownership (i.e., public or private). The survey questionnaire did not differentiate among knapweed species under the assumption all knapweed species have similar impacts.

Of 56 questionnaires mailed, nine were not returned. Infested acres from previous surveys (Sheley 1995) were substituted for missing acreage data in six counties. Infested acreage data for the three remaining non-respondents were estimated with a statistical program (Appendix B). Average percentages calculated from the 47 complete surveys were substituted for the missing land use percentage values in the nine non-respondent counties. Finally, knapweed-infested acres were estimated according to ownership and land use.

Grazing land impacts. The methods and analysis for estimating grazing land impacts caused by knapweed were similar to those used by Bangsund and Leistritz (1991) for leafy spurge (*Euphorbia esula*). Acres of infested private and public grazing land were estimated from the survey data. Grazing land carrying capacities were estimated by Bangsund and Leistritz (1991).

The amount of forage lost from knapweed infestations was estimated from the survey results and carrying capacities. Lost forage was valued with price data collected from state and federal agencies. A cow-calf budget measured foregone production outlays resulting from lost forage. Direct impacts, the value of lost forage plus foregone production expenditures, were applied to an input-output model to estimate secondary effects of knapweed-infested grazing land (Figure 1).

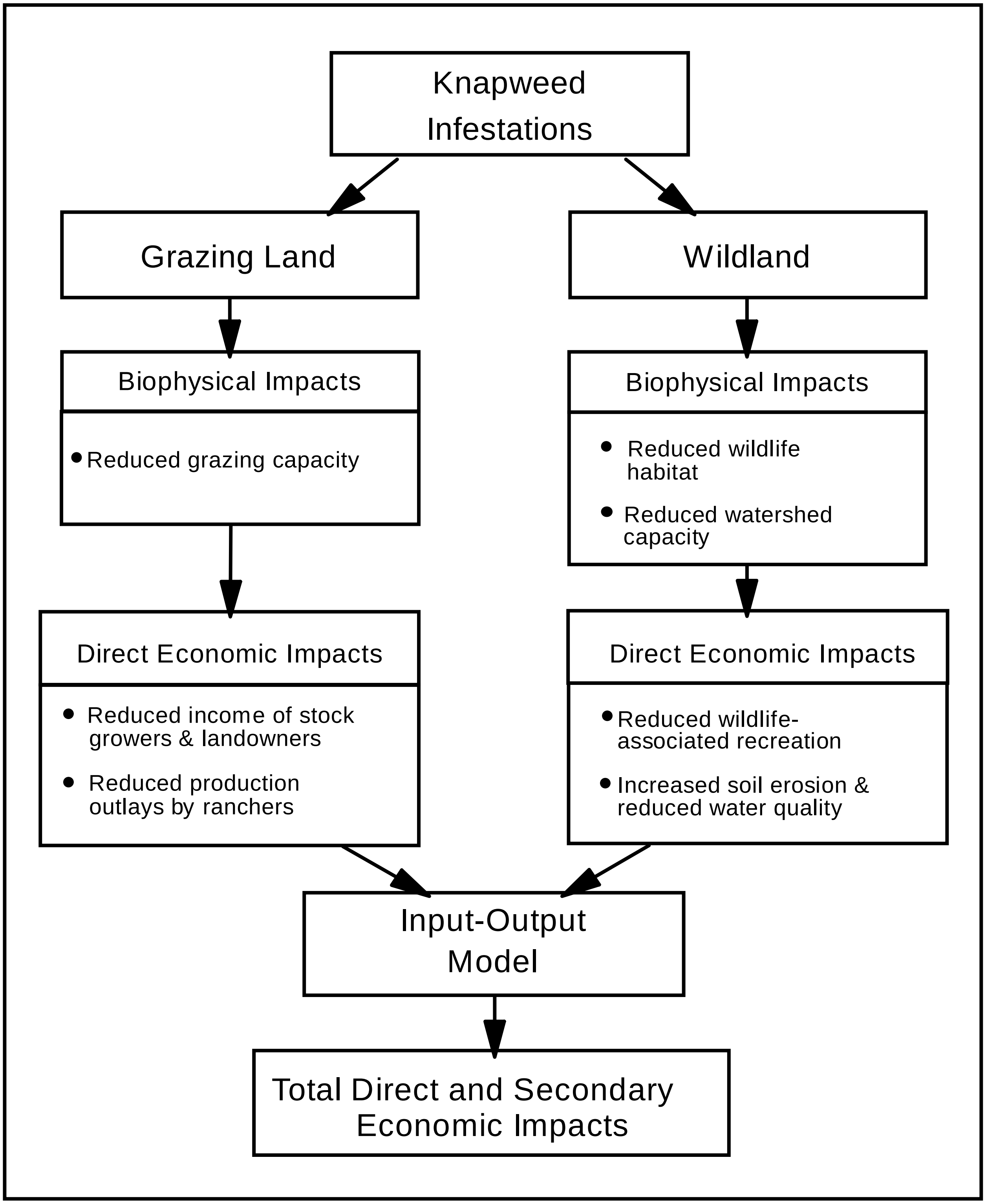

Figure 1. A Bioeconomic Model of Knapweed Infestation

Wildland impacts. The methods and analysis for wildland impacts were similar to those used by Wallace (1991) for leafy spurge. The definition of "wildland" used in this study was determined from the literature and published data. Wildland coefficients, the percentage of a land use that provides wildland benefits, were developed for Montana. Wildland acres and infested wildland acres were estimated from published data, wildland coefficients, and survey estimates of infested wildland.

Direct economic impacts of knapweed on wildlife-associated recreation benefits and soil and water conservation benefits were estimated from biophysical relationships identified by Wallace (1991). Direct impacts were applied to an input-output model to estimate secondary economic effects of knapweed on wildlands (Figure 1).

History of Knapweed

The common knapweeds are non-indigenous plants that have become widely established in Montana since the mid-1920s. A simple definition for a non-indigenous species is "a foreign taxon that enters an established ecosystem and contaminates it" (Wagner 1991). If the invading plant or animal is a well-behaved component of the ecosystem, the contamination may only violate the "purity" of the ecosystem. If contamination means the invader seriously disrupts the natural balance in an ecosystem, it becomes harmful and undesirable (Wagner 1991). Knapweeds are examples of such invaders. They have spread rapidly in Montana, especially in its western grazing lands and wildlands.

Diffuse, Russian, and spotted knapweed are common in lands along the eastern Mediterranean and near the Caspian Sea. Experts believe knapweeds were introduced and dispersed in the United States and Canada as contaminants in alfalfa seed (*Medicago sativa*) from those regions. Sales of domestically produced alfalfa seed and hay containing knapweed seed further contributed to its dispersal before knapweeds were recognized as a serious problem (Roche′ et al. 1986).

Soil carried as ship's ballast and unloaded at ports was another possible method of knapweed introduction. Knapweeds were included in early plant collections growing on or near ballast grounds at western U.S. seaports. Some of the earliest observations of spotted knapweed, for example, were along the western coastal areas of British Columbia and Washington (Roche′ et al. 1986).

Identification of Common Knapweeds

The common knapweeds can be identified by the shape and color of their flowers. Their tubular flower heads are round or egg-shaped. The modified leaves, or bracts, that surround the flower head are a characteristic of the species. The edges of these bracts vary from thin and paperlike to spiny, comblike appendages. The colors of these edges are often an identifying characteristic. Flower colors include white, pink, blue, and purple.

Spotted Knapweed. Spotted knapweed, a short-lived perennial, grows 8 to 48 inches tall from an upright stem originating from a rosette of leaves at its base. A single purple flower is located on each branch. Each flower head has bracts marked with a dark fringe that distinguishes spotted knapweed from the other knapweed species. Spotted knapweed produces, on average, about 350 seeds per flowering plant, but seed production up to 1000 seeds per plant has been observed (Schirman 1981). Its seeds are oblong and measure about 1/8 inch long. Spotted knapweed, the most widespread species in Montana, was first collected in Gallatin County in the mid-1920s (Lacey et al. 1986).

Diffuse Knapweed. Diffuse knapweed, a biennial, grows 8 to 40 inches tall from a single upright stem originating from a rosette of leaves at its base. Its stem has numerous spreading branches and grows from a long tap root. A single white flower is located on each branch tip, and its seed heads do not have the dark spots that characterize spotted knapweed. Diffuse knapweed seeds are oblong and measure about 1/8 inch long. Annual seed production of diffuse knapweed averages about 1200 seeds per plant (Roche′ et al. 1986). Diffuse knapweed was first observed in Mineral County in 1951 (Lacey et al. 1986).

Russian Knapweed. Russian knapweed, also a perennial, grows about 8 to 40 inches with an upright stem. Russian knapweed differs from other knapweed species because its spread is primarily vegetative. Plants in dense infestations branch in the upper part of the plant. Each branch can produce a single, or a cluster, of purple or pink flowers similar to spotted knapweed. Russian knapweed produces fewer seeds than other common knapweed species, about 300 seeds per plant. This species was first observed in Fergus County in 1934 (Lacey et al. 1986).

Competitive Advantages of the Common Knapweeds

Early emergence of common knapweeds in the spring gives them a competitive advantage over other plants for acquiring soil moisture and nutrients. Knapweeds produce large amounts of seed and are believed to release chemical substances which inhibit surrounding vegetation. Because of these advantages and the lack of natural predators to keep its spread under control, knapweed often forms large, dense infestations in rangeland and other untilled lands.

Seed production and dispersal. Knapweeds are prolific seed producers. Seeds germinate and begin to grow in early May. Numerous flower buds form in early June and flower throughout

July and August. Knapweed seeds mature and disperse from mid-August through September. Under suitable conditions, knapweed seeds can germinate in the fall, and the plant can overwinter (Watson and Renney 1974, Watson 1980). Seed viability is an additional factor which makes knapweed difficult to control. Lacey (1985) believes spotted knapweed seed longevity could be as long as 12 years.

Seeds either fall and remain within a relatively short distance of the mature plant or are transported to other sites by wind, water, or animals. People, however, are the main cause of the broad dispersal of knapweed. Hikers and other recreationists spread the weed when they pick knapweed flowers and discard them along trails. Frequently, knapweed plants are caught in parts of recreational vehicles, farm machinery, or logging equipment, allowing seeds to be carried long distances (Lacey et al. 1986).

Vegetative reproduction. Spotted and Russian knapweeds also reproduce vegetatively, making them more difficult to control. Lateral shoots just beneath the soil surface grow horizontally to form new plants. These new plants mature the following season, but do not detach from the parent knapweed plant (Watson and Renney 1974, Watson 1980). Vegetative reproduction does not normally occur in diffuse knapweed.

Climate and soil. Knapweeds are adapted to a wide range of environments and soils. Diffuse knapweed, for example, has been observed at altitudes ranging from 450 feet to over 2700 feet (Watson and Renney 1974). Spotted knapweed has been observed at altitudes ranging from about 1900 feet to over 10,000 feet and in precipitation zones ranging from 8 to 80 inches annually (Lacey et al. 1986). Russian knapweed prefers drier regions (Watson 1980).

Knapweeds readily colonize in different soils at densities significantly correlated with the amount of soil disturbance. Off-road vehicles can disturb the soil surface, making it easier for knapweed to invade (Lacey et al. 1986). Knapweeds do not survive well on cultivated land or on irrigated pastures.

Knapweeds are competitive and can quickly infest good rangeland (Watson and Renney 1974, Roche′ et al. 1986). Chicoine et al. (1985) suspect knapweed plants thriving at a given location will also grow under similar conditions elsewhere. They conducted a study that matched physiographic variables (soil type, elevation, and precipitation) of 116 spotted knapweed sites in Montana with satellite maps. They estimate 50 percent of Montana (about 46.5 million acres) would potentially support knapweed infestations. When cultivated lands are subtracted, about 34 million acres of Montana's grazing lands and grazeable woodlands are potentially vulnerable to knapweed infestation (Chicoine et al. 1985).

Allelopathy. Laboratory and circumstantial evidence suggests the success of knapweed may be associated with the weed's impact on the germination and survival of other plants. This effect, called allelopathy, is defined as any direct or indirect harmful effect by one plant on another through the production of chemical compounds that escape into the environment (Rice 1984).

Fletcher and Renney (1963) first assessed knapweed's allelopathic potential and isolated an inhibitory substance, cnicin, in knapweed leaves. Allelopathy, however, appears to be an important process only for Russian knapweed. Experiments with spotted and diffuse knapweed provide no convincing evidence that allelopathy is functioning to any great extent (Kelsey and Bedunah 1989). Based on their research, and on conclusions of other studies, Kelsey and Bedunah (1989) believe factors other than allelopathy lead to the success of knapweed. They attribute plants' success to their ability to compete for nutrients and moisture.

Control of Knapweed

Developing more effective control methods has become the focus of research efforts. The most cost-effective method of knapweed control is largely a function of the size and location of the infestation. Small knapweed patches can be controlled or eliminated by periodic herbicide treatments, while cultural or biological methods may be required to treat widespread knapweed infestations. Biological controls are gaining support, especially with the concern over the safety of repeated herbicide applications.

Herbicides. Herbicides are widely used to control and limit the spread of knapweed. Herbicides, however, have disadvantages. Because they are toxic to trees, shrubs, and cultivated crops, their use is regulated, especially near water. In addition, the high cost of herbicide treatments usually outweighs their benefit when infestations are widespread, especially on less productive grazing lands (Bucher 1984).

Biological controls. Biological control for knapweed is the deliberate use of natural enemies to reduce the plant's density. As an alternative to herbicides, biological control offers the advantages that agents are self-perpetuating and host-specific. Five species of insects, all native to Eurasia, have been the focus of research. Two fly species, *Urophora affinis* and *Urophora quadrifasciata*, and three moth species, *Metzneria paucipunctella*, *Agapeta zoegana*, and *Pelochrista medullana*, have been introduced to Montana for knapweed control (Lacey et al. 1986). Both fly species induce galls in knapweed flower buds, reducing knapweed seed production. The larvae of *M. paucipunctella* feed on knapweed seed while *A. zoegana* and *P. medullana* larvae feed on knapweed root tissue (Story 1989).

Grazing animals are not an effective biological control for knapweed. Although knapweeds have nutritive value in the spring (Kelsey and Mihalovich 1987), mature plants are generally not selected by grazing animals when other forage is available (Lacey et al. 1986, Watson and Renney 1974).

Cultural controls. Cultural controls, cultivation, burning, and mowing, are farming practices used to control knapweed on cultivated land and grazing land. Mowing reduces weed size and seed production, while burning provides a temporary reduction in weed dominance (Roche′ et al. 1986). Cultivation is an effective knapweed control in cropland, but mechanical treatments used in grazing lands will disturb the soil and create a seedbed for knapweeds (Lacey et al. 1986).

Impacts to Grazing Land

Because cattle avoid grazing knapweed, impacts of knapweed infestations affect Montana's grazing industry, specifically ranchers, landowners, and businesses supplying livestock production inputs, and communities that rely on ranching as an economic base. Direct economic impacts are the sum of (1) the value of lost forage and (2) reduced sales of livestock production inputs associated with herd reductions. Reduced carrying capacity also lowers grazing land values, especially in the absence of alternative uses.

Grazing Land Data

Census of Agriculture 1992, Montana (Bureau of the Census 1992) data were used to estimate acres of private grazing land by county in Montana. The *Census* does not include state- or federally owned grazing land leased on an animal unit month (AUM) basis, so public acreage data collected by Bangsund and Leistritz (1991) were used in the analysis.

Total AUMs of forage available on private grazing lands were calculated from *Census* acreage data and grazing land carrying capacities estimated by Bangsund and Leistritz (1991). Data on total AUMs on public grazing lands were obtained from Department of State Lands (1995), Bureau of Land Management (1995), and Bangsund and Leistritz (1991).
Knapweed acreage, as reported by the county weed board survey, represents acres of grazing land containing some knapweed, although actual surface cover (i.e., plant density) varied. One acre with intermittent patches of knapweed and another, a knapweed monoculture, are both considered an acre of knapweed. Although this represents two quite different amounts, each was reported as one infested acre of grazing land.

Value of Lost Grazing

Lost forage, measured in AUMs, is the amount of feed required per month by a cow/calf unit (Vallentine 1990). For this analysis, (1) grazing land was assumed grazed to its full potential and (2) infested grazing land was assumed a knapweed monoculture with no forage output. Lost forage due to knapweed infestation, about 273,000 AUMs statewide in 1994, was calculated from county survey infestation data and carrying capacity estimates.

The value of all lost forage to ranchers and landowners was calculated using the average price per AUM for private grazing land, which was $11.80/AUM in 1994 (Montana Agricultural Statistics Service 1995). Although the value of forage produced on the state's public grazing lands could be estimated using public lease rates per AUM, AUMs produced on public lands were also assigned the price for private AUMs. Since the lease rates for public AUMs are less than the private grazing value ($4.09 and $1.98/AUM for state and all federal grazing lands, respectively), the price of forage on private grazing land better reflects the true economic value of public AUMs. The value of lost AUMs, about $3.221 million, represents a first approximation of the direct economic impact of knapweed infestations on ranchers and landowners from reduced forage output on private and public grazing land in Montana.

Impact of Reduced Grazing

A cattle budget (Bangsund and Leistritz 1991) (Appendix B) with representative characteristics of Montana cow/calf operations was used to estimate ranchers' production expenditures, excluding the value of lost AUMs. Forage output potentially lost to knapweed infestations in 1994 would support a 29,000-cow herd and generate about $7.804 million in annual production expenditures beyond AUM payments.

Total direct economic impacts are the sum of (1) the value of forage lost by ranchers and landowners ($3.221 million) and (2) reduced livestock production inputs associated with lost forage output ($7.804 million). The estimated direct impacts of knapweed infestations in grazing land were about $11.025 million annually (Table 1) or $10.63 per infested grazing land acre.

Impacts to Wildland

Wildlands in Montana are diverse and include a wide variety of terrains and biotic communities. Their common characteristic, which makes them wildlands, is that human influence is less there than on other lands. Impacts of knapweed on wildland result from the plant's ability to crowd out native grasses and other vegetation. Although changes in most wildland outputs are not directly reflected in the marketplace, knapweed infestations reduce wildland's contribution to soil and water conservation, air quality, and its value as wildlife habitat.

Table 1. Annual Direct Economic Impacts of Knapweed in Montana, 1994

Business Sector	Grazing	Wildlife-associated Benefits	Soil & Water Conservation Benefits	Totals
	------------------------------losses in dollars---------------------------			
Ag. livestock	916,000	0	0	916,000
Ag. crops	3,922,000	0	556,000	4,478,000
Transportation	260,000	0	0	260,000
Communication, public utilities	175,000	0	0	175,000
Retail trade	1,738,000	883,000	0	2,621,000
Finance, insurance, real estate	434,000	0	0	434,000
Business, personal service	163,000	294,000	0	457,000
Households*	3,417,000	0	0	3,417,000
Government	0	0	1,341,000	1,341,000
Electrical generation	0	0	19,000	19,000
Totals	11,025,000	1,177,000	1,916,000	14,118,000

*The direct impact to households is the value of forage lost by ranchers and landowners, $3,221,000, plus the impact on households due to reduced livestock production, $196,000.

Wildland Definition

Wildland includes railway embankments, road ditches, parks and wildlife areas, and riverbanks. This study also considers "multiple uses," so lands having some commercial value were included in the wildland definition. Montana's rangelands and forest lands, for example, contribute wildland benefits in addition to their commercial use as grazing land and timberland. In addition to rangeland and forest land, other lands provide wildland benefits. Non-cultivated cropland and built-up areas classified as industrial and urban can provide some wildland benefits.

Wildland Benefits

Wildland provides a variety of outputs, such as grazing, forest, and mineral products (market goods), and recreation, wildlife production, habitat, erosion control, and watershed benefits (non-market goods) (Randall and Peterson 1984). Wildland provides 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 these additional benefits are inadequate for this study.

Wildlife-associated benefits. Wildland provides habitat for wildlife. The existence of wildlife (wildlife habitat and its wildlife output) is an important part of many outdoor recreation activities. Money spent to participate in consumptive (i.e., hunting) or non-consumptive (i.e., observation or photography) wildlife recreation impacts local and state economies.

Consumptive wildlife expenditures include purchases of guns and ammunition, licenses and fees, gas, lodging, and other goods and services. Resident hunting expenditures, about $88.196 million in 1991, were used as a proxy for all consumptive expenditures potentially impacted by knapweed infestations in Montana (Fish and Wildlife Service 1991). Non-consumptive wildlife expenditures include equipment rental and fees for guides, pack trips, lodging or camping equipment, photographic equipment, and public and private land use. Resident non-consumptive expenditures, about $102.205 million in 1991, were a proxy for all non-consumptive wildlife-associated expenditures potentially impacted by knapweed in the state (Fish and Wildlife Service 1991).

Total expenditures for consumptive and non-consumptive wildlife-associated recreation were about $190.401 million in 1991. When adjusted to 1994 dollars, total expenditures, were about $217.057 million.

Soil and water conservation benefits. Soil and water conservation benefits of wildland include preserving topsoil 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).

Ribaudo (1989) estimated the benefits of placing highly erodible cropland into the Conservation Reserve Program (CRP). The CRP was designed to take highly erodible cropland out of production and place it into permanent cover. Runoff and soil erosion are reduced when tilled land is converted to permanent cover, reducing off-site water quality damages. Benefits of reducing runoff are equal to the reduction in expenditures formerly necessary to mitigate damages from non-point source pollution (Ribaudo 1986).

Ribaudo (1989) estimated off-site benefits of placing cropland in CRP for Montana. The present value of those benefits was calculated by adjusting past values for inflation. Discounting benefits ($79.80 per acre) at 4 percent (Ribaudo 1989) over the 10-year life of the CRP contract resulted in annual benefits of $9.80 per acre. Wildland and CRP have similar soil and water conservation benefits (Wallace 1991), allowing the off-site water conservation benefits of pre-knapweed wildland to be estimated.

Other conservation benefits. Wind, like surface water runoff, is also a cause of soil loss. Protecting wildland from wind erosion will improve air quality in addition to preventing further soil losses. In the mountain states, the amount of soil lost to wind on nonfederal rangeland has been estimated to be 8 percent greater than soil losses caused by surface runoff (U.S. Department of Agriculture 1989). Considering rangeland's multiple uses, wind would also impact the benefits of the wildland component of rangeland. Wind, however, has negligible soil loss effects on nonfederal forest land and pastureland (U.S. Department of Agriculture 1989). The relationship between knapweed, its impact on the extent of soil erosion due to wind, and thereby the value of wildland's air quality benefits, is largely unknown at this time and is not included in this analysis.

Intangibles. Existence and option values are two non-market benefits of wildlands. Existence value is a subjective value individuals place on a resource from "knowing" it exists without intending to use the resource. Option values are similar, except they include the possibility of future use. These two types of values are generally thought to apply only to "unique" and irreplaceable resources.

At the margin, wildland may be neither unique nor irreplaceable. In addition, intangible benefits are non-market benefits that accrue to individuals as consumer surplus and do not monetarily impact the economy (Wallace 1991). Although intangibles are recognized as wildland benefits, they have no direct monetary impact on Montana's economy and were not included in this study.

Biophysical Models

Establishment of knapweed can be directly related to a decline in native vegetation, threatening native wildland vegetation. A substantial change in plant diversity that can result from knapweed infestations may not provide the necessary habitat to support wildlife and may negatively impact wildland soil and water conservation.

Wildlife-associated recreation. Plant monocultures can reduce the interspersion of cover types, reducing wildlife habitat (U.S. Department of Agriculture 1989). Assuming that changes in plant diversity on wildlands affect wildlife carrying capacities, a relationship between weed infestations and wildlife habitat values was used to estimate knapweed's impact on habitat value (see Wallace 1991). Based on the assumed knapweed monoculture, wildland's wildlife habitat value for big game grazers would be reduced by 80 percent (Figure 2). This estimate of reduced wildland habitat value is used to estimate the economic impact of knapweed on Montana's wildlife-associated recreation.

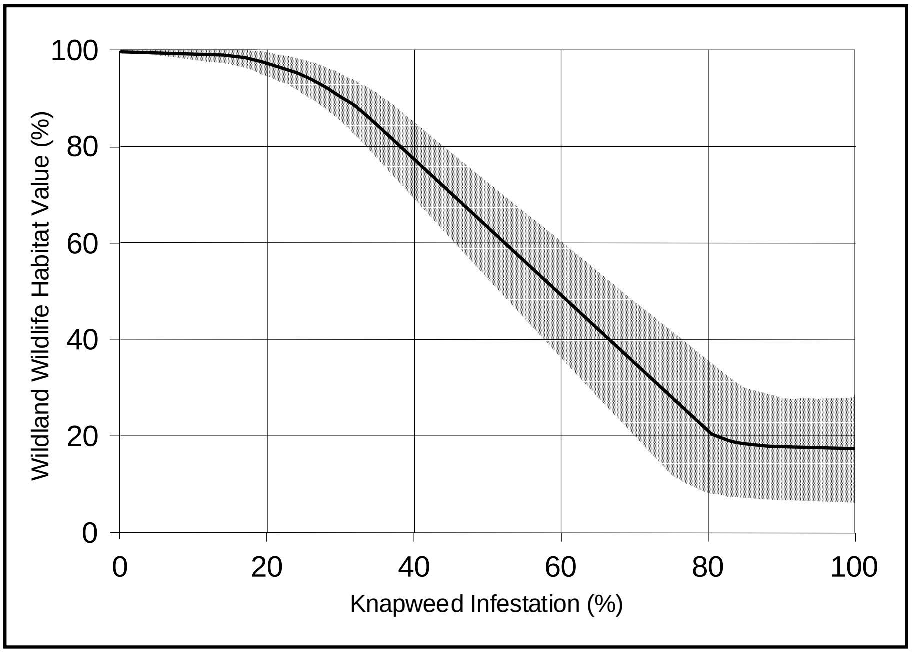

Figure 2. Estimates of Reduced Wildland Wildlife Habitat Value Caused by Various Knapweed Infestation Rates*

*Shading along the function indicates uncertainty with the assumed relationship.

Soil and water conservation. More diverse vegetative cover is generally more effective than less diverse cover for reducing soil erosion. Lacey et al. (1989) observed more open ground and less plant litter on sites dominated by knapweed in their study of knapweed's effect on surface water runoff and soil erosion. They concluded surface water runoff and erosion were greater on knapweed-dominated sites than on sites with more diverse cover. Knapweed infestations contributed to on-site topsoil losses (reduced productivity from lost soil structure and plant nutrients) and off-site damages.

Surface water runoff carrying soil, fertilizers, and pesticides may cause off-site damages (Ribaudo 1985, 1989). Off-site erosion damages include increased flooding, damage to aquatic ecosystems, reduced water-based recreation, increased municipal and industrial water treatment costs, lost water storage capacity, and siltation of water conveyance channels (Ribaudo 1985, 1989).

The relationship between knapweed and wildland's soil and water conservation benefits is essentially undocumented, so estimates of erosion control benefits provided by Conservation Reserve Program (CRP) land were used as a proxy. By placing highly erodible land in the CRP, less diverse vegetative cover (crop monoculture) is replaced by a more diverse vegetative cover (grasslands and trees). The shift to a more diverse vegetative cover improves on- and off-site conservation benefits. The opposite effect occurs when knapweed infests wildland. As vegetative cover changes from more diverse (native grasses and other vegetation) to less diverse (knapweed monocultures), wildland's conservation benefits decrease. Knapweed monocultures were assumed, conservatively, to reduce wildland's off-site water conservation benefits by 25 percent.

Wildland data. The Natural Resources Conservation Service (1992) provides state-level acreage data by land use classification in the *Natural Resources Inventory 1992, Montana* (*NRIM*). Some lands may provide multiple uses such as providing wildland benefits while simultaneously producing the output described (e.g., grazing) by its *NRIM* land use classification.

Wildland coefficients were estimated for each *NRIM* land use classification to estimate total wildland-like benefits in Montana. The wildland coefficient represents the extent of wildland-like benefits, such as wildlife habitat, enhanced water quality, or reduced soil erosion, provided by another land use. The wildland coefficient for Montana's grazing land, for example, is 0.40, which means grazing acres provide 40 percent as much wildlife and conservation benefits as wildland. Wildland-like contributions of each *NRIM* classification are estimated by multiplying total acres of each classification by its respective wildland coefficient. Total equivalent acres of wildland, the sum of the wildland-like acres contributed by each classification, was estimated to be about 34.332 million acres in Montana (Appendix B).

The extent of the wildland knapweed infestation, about 782,000 acres or about 2.3 percent of total wildland acres, was estimated by multiplying estimates of infested acres on each *NRIM* land classification by its respective wildland coefficient (Appendix B).

Infested wildland acreage represents any land containing knapweed, although stem densities may vary. One acre with intermittent patches of knapweed, and another, a knapweed monoculture, were both considered an acre of knapweed. In this study, however, any infested acres of wildland were assumed to be a knapweed monoculture.

Impacts on Wildlife-associated Recreation

Direct economic impacts from changes in wildlife-associated recreation activity are the result of changes in expenditures that impact suppliers of recreational goods and services. Wallace (1991) expressed the reduction in expenditures (R) from weed infestations as

$$R = (E * C)(H * W)(S)$$

where

R = the change in wildlife-associated expenditures due to weed infestations in wildland,
E = total consumptive/non-consumptive wildlife-associated recreation expenditures,
C = a species/land use coefficient,
H = the percentage reduction in wildland wildlife habitat value from infested wildland,
W = knapweed infestation rate (the percentage of infested wildland), and
S = percentage of expenditures lost to the state's economy.

Total expenditures for consumptive and non-consumptive wildlife-associated recreation (E), about $217.057 million in 1994, represented all wildlife-associated expenditures that could be impacted by knapweed. The estimated reduction in wildlife habitat value (H) caused by a knapweed monoculture was 80 percent (see Figure 2). The knapweed infestation rate (W) for wildland, the percentage of total wildland acres infested, is about 2.3 percent (782,000 infested acres of 33.432 million total wildland acres). Knapweed infestations on wildland were estimated to reduce the overall contribution of wildlife habitat to wildlife expenditures, (H * W), by 1.8 percent in Montana.

The species/land use coefficient (C), developed by Leitch (1978), represents the percentage of wildlife populations estimated to be supported on wildland. The species/land use coefficient for Montana is 0.69 (Bangsund et al. 1993) which means Montana's wildlife depends on wildland for 69 percent of its existence. The species/land use coefficient multiplied by total wildlife-associated expenditures would provide an estimate of expenditures attributable to wildland. Multiplying the reduction in wildland's wildlife habitat value, (H * W), by wildlife-associated expenditures attributable to wildland, (E * C), gives an estimate of the reduction in wildlife-associated expenditures from knapweed infestations on wildland.

If wildlife-associated recreation opportunities within the state decrease, some expenditures previously used for wildlife-associated recreation would be spent on other in-state activities; but some may be spent in other states representing a loss to Montana's economy. The wildlife-expenditure coefficient (S) is the percentage of spending lost to the state's economy because of reduced wildlife-associated recreation opportunities. For Montana, this value is assumed to be 0.42, or 42 percent, which has been estimated for North Dakota (Bangsund et al. 1993). Combining these factors into the equation, the direct economic impact of reduced wildlife-associated recreation due to wildland knapweed infestations was estimated to be about $1.177 million annually (Table 1).

Impacts on Soil and Water Conservation

Direct economic impacts from reduced soil and water conservation are the increases in expenditures to mitigate damages from water runoff and soil erosion. The increase in the cost of water treatment, for example, is one cost of decreased water quality.

To measure the economic impact of knapweed on wildland's conservation benefits, the knapweed monoculture on infested wildland was assumed conservatively to reduce conservation benefits by 25 percent. Annual erosion control benefits of $9.80 per acre were estimated for Montana's wildlands (Bangsund et al. 1993). Applying the assumed 25 percent reduction in erosion control benefits to the $9.80 per acre value results in an estimated $2.45 per acre reduction in annual soil and water conservation benefits. Multiplying the $2.45 per acre reduction in benefits by 782,000 acres of infested wildland resulted in annual damages of about $1.916 million from decreased water quality in the state (Table 1).

Total direct impacts of knapweed on wildland are the sum of (1) reduced wildlife-associated recreation expenditures ($1.177 million) and (2) decreased soil and water conservation benefits ($1.916 million). Total direct impacts on Montana's economy from infested wildland are about $3.093 million annually or $3.95 per infested acre.

An unquantified impact of knapweed on less intensively managed wildland is its potential role as a nursery or seed bank from which it can infest additional wildland, rangeland, or other areas. However, it is difficult to isolate the contribution or future potential of wildland to facilitate the spread of knapweed.

Total Economic Impacts

Direct impacts that result from knapweed infestations have secondary impacts on Montana's economy. Reduced economic activity in one sector, or component, of the economy can have substantial effects on employment, incomes, and expenditures in other sectors. Estimates of secondary impacts are used to draw attention to the adverse effects of knapweed on the state's economy.

The secondary impacts were estimated using the North Dakota Input-Output Model (Coon et al. 1985) which was assumed to adequately represent Montana's economic conditions for this first approximation. Input-output 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 particular sector. North Dakota's model has 17 sectors and was developed from business and household survey data from within the state.

The majority of impacts from reduced grazing capacity affect *household*, *retail trade*, and *agricultural crops* sectors. Direct plus secondary impacts from infested grazing land were about $36.035 million annually. The reduction in business activity could have supported about 376 full-time equivalent (FTE) jobs in the state's economy (Table 2).

Table 2. Annual Direct Plus Secondary Economic Impacts of Knapweed in Montana, 1994

Business Sector	Grazing	Wildlife-associated Benefits	Soil & Water Conservation Benefits	Totals
	-----------------------------losses in dollars---------------------------			
Ag. livestock	1,846,000	90,000	44,000	1,980,000
Ag. crops	4,816,000	32,000	608,000	5,456,000
Nonmetal mining	64,000	3,000	4,000	71,000
Construction	811,000	47,000	45,000	903,000
Transportation	380,000	13,000	6,000	399,000
Communication, public utilities	1,154,000	79,000	47,000	1,280,000
Ag processing, misc. manufacturing	1,424,000	47,000	91,000	1,562,000
Retail trade	9,179,000	1,257,000	456,000	10,892,000
Finance, insurance, real estate	2,037,000	83,000	95,000	2,215,000
Business, personal service	783,000	326,000	38,000	1,147,000
Professional, social service	767,000	39,000	36,000	842,000
Households	11,727,000	567,000	544,000	12,838,000
Government	1,047,000	58,000	1,395,000	2,500,000
Coal mining	0	0	3,000	3,000
Electrical generation	0	0	19,000	19,000
Totals	36,035,000	2,641,000	3,431,000	42,107,000
Secondary FTE Jobs	376	34	108	518

The majority of impacts from reduced wildlife-associated expenditures affect the *retail trade, household*, and *business and personal service* sectors of Montana's economy. The impacts from reduced soil and water conservation primarily affected the *government, agricultural crops*, and *household* sectors of the economy. Direct plus secondary impacts for wildland were about \$6.073 million annually. The reduction in business activity could have supported about 142 FTE jobs in the state's economy (Table 2). Total annual economic impacts (direct plus secondary) on Montana's economy from knapweed infestations were estimated to be over \$42.107 million in 1994, enough economic activity to support 518 FTE jobs (Figure 3).

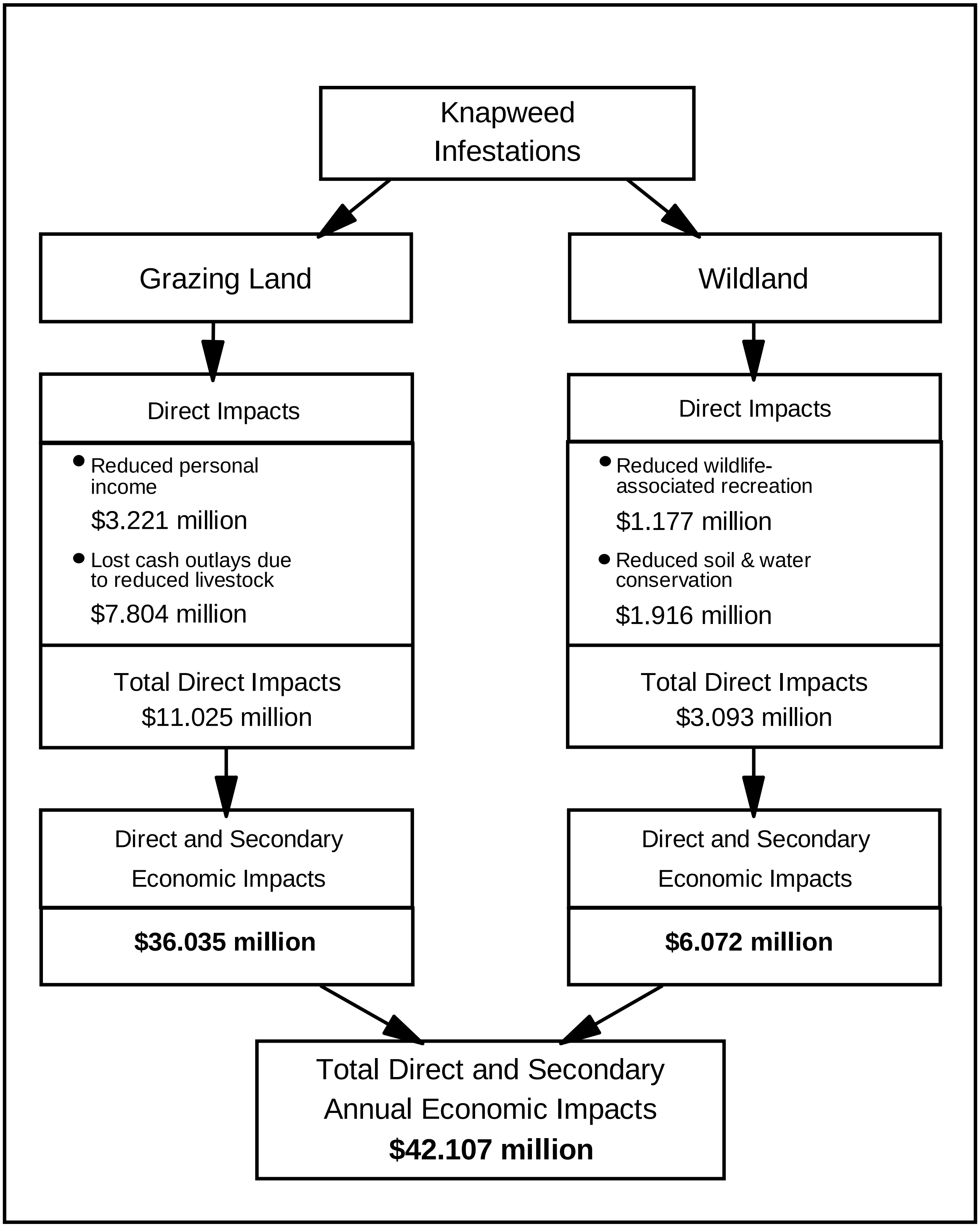

Figure 3. Bioeconomic Impact Assessment of Knapweed in Montana

Conclusions

The common knapweed species, diffuse, spotted, and Russian knapweed (*Centaurea diffusa*, *C. maculosa*, and *Acroptilon repens*, respectively) are non-indigenous weeds that have become major components of rangeland, grazeable woodland, and other untilled land in Montana. At least one species, and frequently all three, is reported in every county in the state. Knapweeds exhibit an exceptional ability to spread and thrive in a variety of habitats and have become a serious problem for ranchers, landowners, and public land managers.

First approximations of the direct and secondary economic impacts of knapweed were based, in part, on grazing and wildland studies for leafy spurge, a noxious weed with similar biophysical and economic impacts. Results indicate knapweed has substantial direct economic impacts on livestock producers, but infestations also impact other groups like water users, hunters, and outdoor recreationists.

The direct impacts of knapweed, over $14 million annually, result in secondary impacts to other sectors of Montana's economy. Direct plus secondary impacts of knapweed infestations total about $42 million annually which could support 518 FTE jobs in the state's economy.

The results of this first approximation of knapweed's impact are sensitive to the following assumptions:

- a knapweed monoculture exists on all infested grazing land/wildland acres;
- effects of the common knapweed species are similar;
- all grazing land is grazed at full potential, and none is idle;
- the biophysical relationships used in this study are reasonable approximations of wildland conditions;
- parameter values used for the species/land coefficient, the wildlife expenditure coefficient, and the cattle budget are appropriate; and
- North Dakota's input-output model is appropriate for estimating secondary economic impacts on Montana's economy.

This study is sensitive to its assumptions, models, and parameter values. If others are used, the results of this analysis will likely be somewhat different, but the policy implications should be invariant with respect to less-than-drastic changes.

Implications

Implications for both policymakers and scientists can be drawn from this first approximation of the economic impacts of knapweed in Montana. First, policymakers become aware of the economic impacts of the current situation, and the potential for additional adverse impacts if the knapweed problem is not abated. Second, scientists will have a better idea of the importance of developing control solutions and the role they can play in understanding the benefits of control. Third, economists have methods and techniques and can construct models for defining issues and arranging information so that policymakers are better informed. However, economists depend heavily upon inputs from other disciplines to accurately assess impacts. Scientists alerted to several information shortcomings in the impact estimation process may be encouraged to refine the components of the economic impact models. Additional information that would help to refine this first approximation of the economic impact estimate includes

- more precise inventories of knapweed infestations; (e.g., the difference between a knapweed monoculture and intermittent or isolated patches);
- an expanded county inventory to include land use, ownership (public or private), and managing agency;
- a better model of the biophysical relationships between knapweed infestations and soil erosion caused by surface water runoff and wind; and
- a better model of the biophysical relationships between knapweed and wildlife habitat functions.

This additional research would refine the economic impact estimates and allow for estimates at smaller geographic scales than the state level.

The potential overstatement or understatement of economic impacts is an area of concern because

- the study assumes grazing lands are grazed at full capacity; and, if used at less than full capacity, impacts to the grazing industry would be overstated;
- the wildland coefficients are unknown, and those used may understate (overstate) the extent of wildland-like benefits of some primary *NRIM* land uses;
- the common knapweeds may provide some conservation benefits on disturbed rangeland or wildland, which, if not accounted for in the analysis, would overstate impacts to soil and water conservation; and
- summing adverse impacts by weed species may lead to an aggregate impact estimate greater than if impacts of all weeds were estimated simultaneously.

Nevertheless, this first approximation of about $42 million annually suggests continued attention to Montana's knapweed problem is warranted.

The economic impact of widespread knapweed infestations in Montana should alert policymakers, landowners, and land managers to its potential threat. Knapweeds spread quickly; and, if ignored, an invasion could threaten the long-term productivity of rangelands, forests, and wildlands in other states and regions.

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APPENDIX A - SURVEY

APPENDIX A: SURVEY COVER LETTER

March 7, 1995

Name
Street Address
City, State, Zip

The Department of Agricultural Economics at North Dakota State University in cooperation with the Animal and Plant Health Inspection Service (APHIS) is conducting research on the impacts of knapweed on Montana's economy. In order to assess the impacts, it is necessary to identify what percentage of the total knapweed infestation occurs on various land uses. Your help in identifying affected areas would be very helpful to the completion of this study.

The enclosed questionnaire asks about public and private land affected by knapweed in your county. Please complete the questionnaire at your earliest convenience--right now, if you can--and place it in the return envelope provided. If you have questions or comments, please call me at 701-231-7467, or Steven Hirsch at 701-231-9464.

Thank you for your help.

Sincerely,

Jay A. Leitch
Professor

Enclosure

APPENDIX A: COUNTY WEED BOARD SURVEY

(Name) COUNTY

A. In 1991, a Montana noxious weed questionnaire estimated the infestation for all knapweed species at (number) acres in your county. Do you agree with this estimate? If not, please give us your best guess of what the infestation is. Your estimates are better than ours!

A better estimate of the total knapweed infestation in this county is _____________ acres. Remember, your guess is better than ours.

B. What percentage of total knapweed acres in your county occurs on **Private Land** and on **Public Land**?

	________ %	**Private Land**
+	**________ %**	**Public Land**
=	**100 %**	

C. Of the knapweed on **Private Land**, what percentage is on:

	________ %	**Private Rangeland or Pastureland**
+	**________ %**	**Private Cropland** (tilled or untilled)
+	**________ %**	**Other Private Land** (shelter belts, drainage ditches, wetlands, rights of way, undeveloped industrial lands)
=	**100 %**	

D. Of the knapweed on **Public Land**, what percentage is on:

	________ %	**Road ditches**, **Rights of Way**
+	**________ %**	**Public Rangeland** (BLM, State Land, Forest Service, etc.)
+	**________ %**	**Public Recreation Areas** (State and US Parks and Recreation, Corps of Engineers, etc.)
+	**________ %**	**Public Wildlife Areas** (US Fish and Wildlife, State Game and Fish, etc)
+	**________ %**	**Military Lands** (US Army, Air Force, Nat'l. Guard)
+	**________ %**	**Other Lands** (Please Specify ________________________________)
=	**100 %**	

E. What was the county weed board's **approximate expenditure for knapweed control** in 1994? $ _____________________________

Comments:

APPENDIX B - TABLES

Appendix Table B1. County Weed Board Survey: Public Land Knapweed Estimates

County	Total Infested Acres	Percent Infestation on Public Land	Estimated Acres of Knapweed on Public Lands	Percent Infestation on Public Grazing	Percent Infestation on Transportation	Percent Infestation on Public Land	Estimated Acres of Knapweed on Public Grazing Land	Estimated Acres of Knapweed on Transportation	Estimated Acres of Knapweed on All Other Public Land
Beaverhead	3,000	80%	2,400	50%	40%	10%	1,200	960	240
Big Horn	12,840	75%	9,630	0%	10%	90%	0	963	8,667
Blaine	2,000	10%	200	25%	0%	75%	50	0	150
Broadwater	16,600	57%	9,462	79%	13%	8%	7,475	1,230	757
Carbon	20,000	25%	5,000	20%	15%	65%	1,000	750	3,250
Carter	45	15%	7	0%	75%	25%	0	5	2
Cascade	10,000	40%	4,000	5%	60%	35%	200	2,400	1,400
Chouteau	12,000	25%	3,000	93%	5%	2%	2,790	150	60
Custer	800	10%	80	100%	0%	0%	80	0	0
Daniels	10	50%	5	20%	20%	60%	1	1	3
Dawson	20	50%	10	0%	100%	0%	0	10	0
Deer Lodge	18,800	20%	3,760	74%	2%	24%	2,782	75	902
Fallon	20	5%	1	50%	50%	0%	1	1	0
Fergus	3,600	35%	1,260	70%	10%	20%	882	126	252
Flathead	65,000	40%	26,000	50%	5%	45%	13,000	1,300	11,700
Gallatin	2,500	40%	1,000	15%	30%	55%	150	300	550
Garfield [a]	1,217	42%	511	35%	21%	44%	179	107	225
Glacier	85,000	35%	29,750	30%	35%	35%	8,925	10,412	10,413
Golden Valley	5,200	10%	520	5%	10%	85%	26	52	442
Granite	55,000	25%	13,750	60%	25%	15%	8,250	3,438	2,063
Hill	1,400	71%	994	3%	2%	95%	30	20	944
Jefferson	1,500	40%	600	60%	10%	30%	360	60	180
Judith Basin	2,000	25%	500	90%	9%	1%	450	45	5
Lake	100,000	50%	50,000	5%	5%	90%	2,500	2,500	45,000
Lewis & Clark	18,500	35%	6,475	25%	15%	60%	1,619	971	3,885
Liberty	350	80%	280	66%	1%	33%	185	3	92
Lincoln	240,000	75%	180,000	15%	25%	60%	27,000	45,000	108,000
McCone	10	70%	7	0%	100%	0%	0	7	0
Madison	150,000	40%	60,000	40%	10%	50%	24,000	6,000	30,000
Meagher	70,000	25%	17,500	5%	30%	65%	875	5,250	11,375

(Continued)

Appendix Table B1. County Weed Board Survey: Public Land Knapweed Estimates (Cont.)

County	Total Infested Acres	Percent Infestation on Public Land	Estimated Acres of Knapweed on Public Lands	Percent Infestation on Public Grazing	Percent Infestation on Transportation	Percent Infestation on Public Land	Estimated Acres of Knapweed on Public Grazing Land	Estimated Acres of Knapweed on Transportation	Estimated Acres of Knapweed on All Other Public Land
Mineral	120,000	70%	84,000	10%	7%	83%	8,400	5,880	69,720
Missoula	500,000	30%	150,000	80%	10%	10%	120,000	15,000	15,000
Musselshell [a]	15,000	42%	6,300	35%	21%	44%	2,205	1,323	2,772
Park	5,000	10%	500	15%	75%	10%	75	375	50
Petroleum [a]	300	42%	126	35%	21%	44%	44	26	55
Phillips [a]	610	42%	256	35%	21%	44%	90	54	113
Pondera [b]	28,000	42%	11,760	35%	21%	44%	4,116	2,470	5,174
Powder River	200	65%	130	75%	24%	1%	98	31	1
Powell [b]	137,000	42%	57,540	35%	10%	55%	20,139	5,754	31,647
Prairie	10	50%	5	100%	0%	0%	5	0	0
Ravalli	15,000	30%	4,500	50%	10%	40%	2,250	450	1,800
Richland	230	10%	23	5%	75%	20%	1	17	5
Roosevelt	10	80%	8	0%	30%	70%	0	2	6
Rosebud	4,500	65%	2,925	0%	12%	88%	0	351	2,574
Sanders	175,000	33%	57,750	25%	30%	45%	14,438	17,325	25,988
Sheridan	5	0%	0	0%	0%	100%	0	0	0
Silver Bow	50,000	20%	10,000	80%	10%	10%	8,000	1,000	1,000
Stillwater	300	50%	150	5%	15%	80%	8	23	120
Sweetgrass [a]	7,400	42%	3,108	35%	21%	44%	1,088	653	1,368
Teton	20,000	60%	12,000	50%	25%	25%	6,000	3,000	3,000
Toole [b]	28,000	42%	11,760	35%	21%	44%	4,116	2,470	5,174
Treasure	150	25%	38	10%	50%	40%	4	19	15
Valley	141	20%	28	0%	50%	50%	0	14	14
Wheatland [a]	1,300	42%	546	35%	21%	44%	191	115	240
Wibaux	10	90%	9	0%	100%	0%	0	9	0
Yellowstone	8,000	40%	3,200	10%	65%	25%	320	2,080	800
Totals	2,013,578		843,364				295,595	140,576	407,192

Source: Survey of County Weed Boards.
[a] Data are from previous surveys provided by Roger Scheley, Montana state weed coordinator.
[b] Data were estimated with a statistical program.

Appendix Table B2. County Weed Board Survey: Private Land Knapweed Estimates

County	Total Infested Acres	Percent Infestation on Private Land	Estimated Acres of Knapweed on all Private Land	Percent Infestation on Private Grazing	Percent Infestation on Crop Land	Percent Infestation on All Other Private Land	Estimated Acres of Knapweed on Private Grazing Land	Estimated Acres of Knapweed on Private Cropland	Estimated Acres of Knapweed on All Other Private Land
Beaverhead	3,000	20%	600	57%	12%	31%	342	72	186
Big Horn	12,840	25%	3,210	60%	30%	10%	1,926	963	321
Blaine	2,000	90%	1,800	25%	50%	25%	450	900	450
Broadwater	16,600	43%	7,138	85%	5%	10%	6,067	357	714
Carbon	20,000	75%	15,000	50%	10%	40%	7,500	1,500	6,000
Carter	45	85%	38	100%	0%	0%	38	0	0
Cascade	10,000	60%	6,000	60%	5%	35%	3,600	300	2,100
Chouteau	12,000	75%	9,000	75%	2%	23%	6,750	180	2,070
Custer	800	90%	720	60%	20%	20%	432	144	144
Daniels	10	50%	5	50%	0%	50%	3	0	3
Dawson	20	50%	10	80%	0%	20%	8	0	2
Deer Lodge	18,800	80%	15,040	90%	1%	9%	13,536	150	1,354
Fallon	20	95%	19	100%	0%	0%	19	0	0
Fergus	3,600	65%	2,340	85%	0%	15%	1,989	0	351
Flathead	65,000	60%	39,000	80%	10%	10%	31,200	3,900	3,900
Gallatin	2,500	60%	1,500	45%	15%	40%	675	225	600
Garfield [a]	1,217	58%	706	63%	9%	28%	445	64	198
Glacier	85,000	65%	55,250	70%	5%	25%	38,675	2,763	13,813
Golden Valley	5,200	90%	4,680	10%	5%	85%	468	234	3,978
Granite	55,000	75%	41,250	75%	10%	15%	30,938	4,125	6,188
Hill	1,400	29%	406	97%	1%	2%	394	4	8
Jefferson	1,500	60%	900	80%	0%	20%	720	0	180
Judith Basin	2,000	75%	1,500	90%	9%	1%	1,350	135	15
Lake	100,000	50%	50,000	75%	10%	15%	37,500	5,000	7,500
Lewis & Clark	18,500	65%	12,025	55%	10%	35%	6,614	1,203	4,209
Liberty	350	20%	70	100%	0%	0%	70	0	0
Lincoln	240,000	25%	60,000	15%	5%	80%	9,000	3,000	48,000
McCone	10	30%	3	100%	0%	0%	3	0	0
Madison	150,000	60%	90,000	70%	25%	5%	63,000	22,500	4,500
Meagher	70,000	75%	52,500	80%	10%	10%	42,000	5,250	5,250
Mineral	120,000	30%	36,000	10%	40%	50%	3,600	14,400	18,000

(Continued)

Appendix Table B2. County Weed Board Survey: Private Land Knapweed Estimates (Cont.)

County	Total Infested Acres	Percent Infestation on Private Land	Estimated Acres of Knapweed on all Private Land	Percent Infestation on Private Grazing	Percent Infestation on Crop Land	Percent Infestation on All Other Private Land	Estimated Acres of Knapweed on Private Grazing Land	Estimated Acres of Knapweed on Private Cropland	Estimated Acres of Knapweed on All Other Private Land
Missoula	500,000	70%	350,000	60%	5%	35%	210,000	17,500	122,500
Musselshell [a]	15,000	58%	8,700	63%	9%	28%	5,481	783	2,436
Park	5,000	90%	4,500	85%	5%	10%	3,825	225	450
Petroleum [a]	300	58%	174	63%	9%	28%	110	16	49
Phillips [a]	610	58%	354	63%	9%	28%	223	32	99
Pondera [b]	28,000	58%	16,240	63%	9%	28%	10,231	1,462	4,547
Powder River	200	35%	70	40%	40%	20%	28	28	14
Powell [b]	137,000	58%	79,460	63%	9%	28%	50,060	7,151	22,249
Prairie	10	50%	5	100%	0%	0%	5	0	0
Ravalli	15,000	70%	10,500	60%	10%	30%	6,300	1,050	3,150
Richland	230	90%	207	40%	10%	50%	83	21	104
Roosevelt	10	20%	2	0%	0%	100%	0	0	2
Rosebud	4,500	35%	1,575	63%	9%	28%	992	142	441
Sanders	175,000	67%	117,250	75%	5%	20%	87,938	5,863	23,450
Sheridan	5	100%	5	0%	0%	100%	0	0	5
Silver Bow	50,000	80%	40,000	84%	1%	15%	33,600	400	6,000
Stillwater	300	50%	150	90%	0%	10%	135	0	15
Sweetgrass [a]	7,400	58%	4,292	63%	9%	28%	2,704	386	1,202
Teton	20,000	40%	8,000	90%	0%	10%	7,200	0	800
Toole [b]	28,000	58%	16,240	63%	9%	28%	10,231	1,462	4,547
Treasure	150	75%	113	60%	10%	30%	68	11	34
Valley	141	80%	113	20%	5%	75%	23	6	85
Wheatland [a]	1,300	58%	754	63%	9%	28%	475	68	211
Wibaux	10	10%	1	100%	0%	0%	1	0	0
Yellowstone	8,000	60%	4,800	50%	20%	30%	2,400	960	1,440
Totals	2,013,578		1,170,214				741,422	104,932	323,860

Source: Survey of County Weed Boards.
[a] Data are from previous surveys provided by Roger Scheley, Montana state weed coordinator.
[b] Data were estimated with a statistical program.

Appendix Table B3. Estimated Lost AUMs of Forage on Public Grazing Land in Montana, 1994

County	Potential State AUMs [a]	Potential BLM AUMs [b]	Potential USFS AUMs [c]	Total AUMs	Total State and Federal Grazing Acres	Estimate of Public Grazing Land Carrying Capacity (AUMs)	Estimates of Knapweed Infested Acres on Public Grazing Land [d]	Estimated Lost AUMs on Public Grazing Land
Beaverhead	91,743	80,181	76,523	248,447	1,312,487	0.189	1,200	227
Big Horn	23,240	4,895	0	28,135	114,659	0.245	0	0
Blaine	39,186	67,577	0	106,763	619,349	0.172	50	9
Broadwater	4,783	6,348	17,038	28,169	141,508	0.199	7,475	1,488
Carbon	8,521	12,591	7,175	28,287	282,251	0.100	1,000	100
Carter	31,983	95,863	32,357	160,203	718,132	0.223	0	0
Cascade	17,469	1,890	8,491	27,850	116,749	0.239	200	48
Chouteau	46,408	14,750	6,622	67,780	319,409	0.212	2,790	592
Custer	30,522	67,602	0	98,124	472,459	0.208	80	17
Daniels	31,901	20	0	31,921	112,689	0.283	1	0
Dawson	18,927	11,812	0	30,739	134,739	0.228	0	0
Deer Lodge	1,876	479	4,672	7,027	45,065	0.156	2,782	434
Fallon	15,006	27,587	0	42,593	176,660	0.241	1	0
Fergus	31,042	47,186	6,474	84,702	502,255	0.169	882	149
Flathead	2,917	0	3,794	6,711	51,774	0.130	13,000	1,685
Gallatin	10,336	1,047	25,805	37,188	111,158	0.335	150	50
Garfield	36,529	88,942	0	125,471	654,698	0.192	179	34
Glacier	1,430	267	2,092	3,789	11,337	0.334	8,925	2,983
Golden Valley	10,592	162	1,202	11,956	55,729	0.215	26	6
Granite	4,124	2,903	14,535	21,562	135,727	0.159	8,250	1,311
Hill	22,544	1,316	0	23,860	101,712	0.235	30	7
Jefferson	6,409	6,960	26,663	40,032	261,529	0.153	360	55
Judith Basin	27,169	995	18,840	47,004	113,668	0.414	450	186
Lake	1,511	0	0	1,511	9,635	0.157	2,500	392
Lewis & Clark	29,338	5,451	14,604	49,393	264,114	0.187	1,619	303
Liberty	15,055	2,940	0	17,995	65,387	0.275	185	51
Lincoln	1,031	0	10,265	11,296	197,586	0.057	27,000	1,544
McCone	31,209	39,303	0	70,512	280,048	0.252	0	0
Madison	19,215	26,256	74,892	120,363	596,903	0.202	24,000	4,839
Meagher	24,487	1,441	40,180	66,108	185,154	0.357	875	312

(Continued)

Appendix Table B3. Estimated Lost AUMS of Forage on Public Grazing Land in Montana, 1994 (Cont.)

County	Potential State AUMs [a]	Potential BLM AUMs [b]	Potential USFS AUMs [c]	Total AUMs	Total State and Federal Grazing Acres	Estimate of Public Grazing Land Carrying Capacity (AUMs)	Estimates of Knapweed Infested Acres on Public Grazing Land [d]	Estimated Lost AUMs on Public Grazing Land
Mineral	378	0	1,231	1,609	13,260	0.121	8,400	1,019
Missoula	4,598	512	4,508	9,618	102,008	0.094	120,000	11,314
Musselshell	16,873	26,570	0	43,443	176,175	0.247	2,202	543
Park	8,825	1,080	19,229	29,134	100,080	0.291	75	22
Petroleum	12,155	60,602	0	72,757	398,317	0.183	44	8
Phillips	37,327	167,820	0	205,147	1,264,163	0.162	90	15
Pondera	8,637	176	1,118	9,931	33,758	0.294	4,116	1,211
Powder River	31,622	56,037	92,976	180,635	680,749	0.265	98	26
Powell	14,152	2,322	11,689	28,163	182,496	0.154	20,139	3,108
Prairie	18,703	103,288	0	121,991	517,426	0.236	5	1
Ravalli	5,100	0	8,186	13,286	101,107	0.131	2,250	296
Richland	19,321	12,673	0	31,994	122,872	0.260	1	0
Roosevelt	4,470	1,170	0	5,640	20,517	0.275	0	0
Rosebud	36,815	33,743	21,320	91,878	486,886	0.189	0	0
Sanders	3,513	0	4,875	8,388	35,482	0.236	14,438	3,413
Sheridan	7,983	50	0	8,033	30,676	0.262	0	0
Silver Bow	2,681	1,603	11,329	15,613	99,032	0.158	8,000	1,261
Stillwater	10,240	970	6,345	17,555	58,423	0.300	8	2
Sweetgrass	12,823	2,599	11,837	27,259	79,512	0.343	1,088	373
Teton	22,498	1,663	3,064	27,225	116,997	0.233	6,000	1,396
Toole	17,867	4,442	0	22,309	100,183	0.223	4,116	917
Treasure	7,394	1,941	0	9,335	47,454	0.197	4	1
Valley	48,915	129,349	0	178,264	1,210,189	0.147	0	0
Wheatland	19,877	219	2,608	22,704	82,779	0.274	191	52
Wibaux	6,586	5,664	0	12,250	52,602	0.233	0	0
Yellowstone	16,179	10,888	0	27,067	152,756	0.177	320	57
Totals	1,032,035	1,242,143	592,539	2,866,717	14,430,469		295,595	41,857

[a] AUM data supplied by Department of State Lands, Montana, 1994.
[b] AUM data supplied by Bureau of Land Management, 1995.
[c] USFS AUM data is from Bangsund and Leistritz (1991).
[d] Estimates of knapweed infested acres are from the Survey of County Weed Boards. Infested acres are assumed to have no grazing value (a knapweed monculture).

Appendix Table B4. Estimated Lost AUMs of Forage on Private Grazing Land in Montana, 1994

County	Grazed Cropland Acres [a]	Grazable Woodland Acres [a]	Pasture and Grazing [a]	Total Private Grazing Acres	Adjusted Carrying Capacity (AUMs) [b]	Potential Private AUMs	Estimates of Knapweed Infested Acres on Private Grazing Land [e]	Estimates of Lost AUMs on Private Grazing Land
Beaverhead	64,748	26,303	1,070,765	1,161,816	0.291	338,088	342	100
Big Horn	33,922	179,722	2,343,731	2,557,375	0.313	800,458	1,926	603
Blaine	33,401	14,750	1,675,216	1,723,367	0.228	392,928	450	103
Broadwater	17,384	16,201	295,898	329,483	0.263	86,654	6,067	1,596
Carbon	55,214	10,072	404,422	469,708	0.246	115,548	7,500	1,845
Carter	39,363	31,358	1,356,361	1,427,082	0.254	362,479	38	10
Cascade	47,940	42,384	853,845	944,169	0.328	309,687	3,600	1,181
Chouteau	0	0	929,961	929,961	0.247	229,700	6,750	1,667
Custer	13,144	10,508	1,860,229	1,883,881	0.260	489,809	432	112
Daniels	0	0	243,510	243,510	0.226	55,033	3	1
Dawson	0	0	844,703	844,703	0.283	239,051	8	2
Deer Lodge	0	0	103,997	103,997	0.331	34,423	13,536	4,480
Fallon	0	0	712,157	712,157	0.281	200,116	19	5
Fergus	76,755	96,874	1,407,875	1,581,504	0.330	521,896	1,989	656
Flathead	21,181	114,971	32,777	168,929	0.331	55,915	31,200	10,327
Gallatin	38,236	15,216	403,036	456,488	0.291	132,838	675	196
Garfield [c]	18,031	20,138	1,661,828	1,699,997	0.226	384,199	445	101
Glacier	16,322	10,273	1,156,816	1,183,411	0.313	370,408	38,675	12,105
Golden Valley	11,613	17,980	517,856	547,449	0.330	180,658	468	154
Granite	17,435	33,030	249,266	299,731	0.331	99,211	30,938	10,240
Hill	0	0	477,697	477,697	0.208	99,361	394	82
Jefferson	26,196	22,572	261,021	309,789	0.291	90,149	720	210
Judith Basin	44,363	15,042	561,888	621,293	0.479	297,599	1,350	647
Lake	56,245	111,595	359,358	527,198	0.337	177,666	37,500	12,638
Lewis & Clark	21,268	74,543	683,249	779,060	0.325	253,195	6,614	2,150
Liberty	0	0	311,276	311,276	0.228	70,971	70	16
Lincoln	4,324	12,206	16,924	33,454	0.331	11,073	9,000	2,979
McCone	0	0	731,919	731,919	0.291	212,988	3	1
Madison	0	0	1,059,441	1,059,441	0.325	344,318	63,000	20,475
Meagher	0	0	749,654	749,654	0.330	247,386	42,000	13,860

(Continued)

Appendix Table B4. Estimated Lost AUMs of Forage on Private Grazing Land in Montanna, 1994 (Cont.)

County	Grazed Cropland Acres [a]	Grazable Woodland Acres [a]	Pasture and Grazing [a]	Total Private Grazing Acres	Adjusted Carrying Capacity (AUMs) [b]	Potential Private AUMs	Estimates of Knapweed Infested Acres on Private Grazing Land [e]	Estimates of Lost AUMs on Private Grazing Land
Mineral	2,744	4,131	2,129	9,004	0.331	2,980	3,600	1,192
Missoula	19,276	254,363	80,937	354,576	0.299	106,018	210,000	62,790
Musselshell [c]	11,503	75,266	780,851	867,620	0.330	286,315	5,438	1,795
Park	38,617	44,450	567,051	650,118	0.258	167,730	3,825	987
Petroleum [c]	0	0	566,505	566,505	0.206	116,700	110	23
Phillips [c]	39,525	7,268	1,324,493	1,371,286	0.231	316,767	223	52
Pondera [d]	29,246	4,164	281,890	315,300	0.241	75,987	10,231	2,466
Powder River	28,872	37,025	1,406,964	1,472,861	0.260	382,944	28	7
Powell [d]	16,835	93,784	489,794	600,413	0.331	198,737	50,060	16,570
Prairie	0	0	529,961	529,961	0.301	159,518	5	2
Ravalli	37,756	26,136	108,426	172,318	0.334	57,554	6,300	2,104
Richland	42,584	6,633	645,573	694,790	0.221	153,549	83	18
Roosevelt	28,272	9,897	635,533	673,702	0.226	152,257	0	0
Rosebud	0	0	2,232,202	2,232,202	0.232	517,871	992	230
Sanders	18,387	83,502	228,884	330,773	0.331	109,486	87,938	29,107
Sheridan	0	0	315,592	315,592	0.181	57,122	0	0
Silver Bow	5,911	2,228	83,197	91,336	0.291	26,579	33,600	9,778
Stillwater	40,648	12,779	581,570	634,997	0.266	168,909	135	36
Sweet Grass [c]	26,626	28,047	700,221	754,894	0.258	194,763	2,704	698
Teton	39,302	4,081	543,495	586,878	0.273	160,218	7,200	1,966
Toole [d]	0	0	361,064	361,064	0.217	78,351	10,231	2,220
Treasure	0	0	533,479	533,479	0.236	125,901	68	16
Valley	44,642	3,457	905,542	953,641	0.172	164,026	23	4
Wheatland [c]	0	0	693,369	693,369	0.330	228,812	475	157
Wibaux	0	0	343,445	343,445	0.311	106,811	1	0
Yellowstone	43,630	23,674	1,015,360	1,082,664	0.217	234,938	2,400	521
Totals	1,171,461	1,596,623	39,294,203	42,062,287		11,554,650	741,382	231,277

[a] Private Pasture and Grazing Land Acres: Bureau of the Census, 1992.
[b] Bangsund and Leistritz (1991).
[c] Data are from previous surveys provided by Roger Scheley, Montana state weed coordinator.
[d] Estimated with a statistical program.
[e] Estimates of knapweed-infested acres are from the Survey of County Weed Boards. Infested acres are assumed to have no grazing value (a knapweed monculture).

Appendix Table B5. Livestock Operation Budget

Herd Characteristics

Herd Size

Cow/calf pairs	29,190
Calf crop rate	91.7%
Cow loss	1.7%

Selling Weights

Steer calves	464 lbs.
Heifer calves	430 lbs.

(Calves sold in the fall with 4% transit loss)

AUM Grazing Requirements

Grazing period	2.10 days
AUMs/cow	1.1
AUMs/bull	1.0
AUMs/replacement heifer	0.9

Receipts

Steers	13,384	head	@	445 pounds	x	$0.93/lb	=	$5,526,560
Heifers	7,580	head	@	413 pounds	x	$0.84/lb	=	$2,628,380
Cull cows	3,941	head	@	985 pounds	x	$0.42/lb	=	$1,630,392
Cull hfrs.	1,367	head	@	780 pounds	x	$0.72/lb	=	$767,707
Cull bulls	555	head	@	1547 pounds	x	$0.55/lb	=	$472,222
				Total receipts				$11,025,261
				Total receipts/cow				$378

Feed Expenses

			Economic Cost
210 Days on Pasture/Aftermath Grazing			
Cows/Bulls	236,428 AUMs	$ 11.80/AUM =	$2,789,846
Rpl. hfrs.	36,565 AUMs	$ 11.80/AUM =	$431,469
Min. & salt	335.92 Ton	$400.00/ton =	$134,367
155 Days on Winter Feeding			
Oats	65,982 bushels	$ 1.34/bu =	$88,415
Protein	724 ton(s)	$240.00/ton =	$173,739
Hay	64,473 ton(s)	$ 59.00/ton =	$3,803,931
Corn silage	0 ton(s)	$ 13.00/ton =	$0
Oat straw	0 ton(s)	$ 20.00/ton =	$0
Minerals	247.94 ton(s)	$400.00/ton =	$99,176
Aftermath	0 day(s)	$ 0.10/day =	$0
	Total feed expenses		$7,520,945
	Total feed expense/cow		$258

Livestock Expenses

		Economic Cost
Medicine	$ 9.10/cow	$265,629
Veterinary services	$ 5.00/cow	$145,950
Supplies	$ 7.00/cow	$204,330
Bull semen check	$10.00/bull	$16,664
Custom hired	$ 4.00/cow	$116,760
Utilities	$ 6.00/cow	$175,140
Power and fuel	$ 9.00/cow	$262,710
Miscellaneous	$ 5.00/cow	$145,950
Bedding	$ 1.00/cow	$29,190
Marketing	$ 8.92/cow	$260,375
Bull depreciation		$916,037
Bull insurance		$41,660
Interest expense		$206,669
	Total livestock expenses	$2,787,064
	Livestock expense/cow	$95

Fixed Expenses

		Economic Cost
Land investment	$0	$0
Repairs	1.0%	$0
Taxes	1.0%	$0
Insurance	1.0%	$0
Building investment[a]	$1,459,500	
Repairs	7.0%	$102,165
Taxes	0.0%	$0
Insurance	0.0%	$0
Depreciation	0.0%	$0
Equipment investment[b]	$2,919,000	
Repairs	12.0%	$350,280
Taxes	0.0%	$0
Insurance	0.0%	$0
Depreciation	0.0%	$0
Herd insurance[c]	($0.50 x herd value/100)	$116,760

[a]Building investment $ 5,000 per 100 cows
[b]Equipment investment $10,000 per 100 cows
[c]Herd value $23,352,000
Budget assumes no long-term debt

Total fixed expenses	$569,205
Fixed expense per/cow	$20

Cost/Returns Summary

	Economic Cost
Total receipts	$11,025,261
Less feed and livestock expenses	$10,308,008
Returns above expenses	717,252
Less fixed expenses	$ 569,205
Returns: Labor, mgt., & capital	$148,047
Total receipts/cow	$377.71
Total expenses/cow	372.63
Returns: Labor, mgt., & capital/cow	$5.07

Allocation of Expenditures/Returns to I/O Sectors

Sector:	
Ag livestock	$916,037
Ag crops	3,921,537
Transportation	260,375
Communications & public utilities	175,140
Retail trade	1,738,346
Finance, insurance, and real estate	365,089
Business & personal service	162,614
Households*	3,486,123
Direct economic impacts	$11,025,261

*Household sector includes:

Value of lost AUMs	$3,221,316
Value of hired labor	116,760
Returns to management	78,672
Impacts to households:	$3,416,748

Source: Bangsund and Leistritz (1991).

Appendix Table B6. Estimated Acres of Wildland in Montana

Land Use	Acres	Infested Acres	Wildland Coefficient [a]	Estimated Wildland Acres	Infested Wildland Acres
Crop (non-cultivated)	2,750,000	105,000	40%	1,100,000	42,000
Federal (all uses)	26,965,000	594,000	40%	10,786,000	238,000
Forest	5,156,000	114,000	40%	2,062,000	46,000
Miscellaneous/Minor	1,384,000	19,000	25%	346,000	5,000
CRP Land [c]	2,781,000	0	100%	2,781,000	0
Pasture	3,370,000	--	40%	1,348,000	--
Rangeland	36,835,000	1,037,000[b]	40%	14,734,000	415,000
Transportation	802,000	141,000	25%	201,000	35,000
Built up	294,000	4,000	25%	74,000	1,000
Cropland	12,285,000	N/A	N/A	N/A	N/A
Large water	1,047,000	N/A	N/A	N/A	N/A
Small water	284,000	N/A	N/A	N/A	N/A
Totals	93,953,000	2,014,000	--	33,432,000	782,000

Source: Natural Resources Conservation Service, 1991.

[a] Some lands may provide multiple uses such as providing wildland benefits while simultaneouslly producing the ouput described in its NRIM land use classification.

[b] Infested grazing acres are infested acres on both public and private pasture and rangeland.

[c] CRP acres are part of Miscellaneous/Minor. Montana's CRP benefits are similar to those of wildland. The knapweed infestation on CRP is assumed zero.