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Assessing the Economic Impact of Invasive Species: The Case of Yellow Starthistle (*Centaurea solsitialis, L.*) in the Rangelands of Idaho, United States

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ASSESSING THE ECONOMIC IMPACT OF INVASIVE SPECIES: THE CASE OF YELLOW STARTHISTLE (*Centaurea solsitialis, L.*) IN THE RANGELANDS OF IDAHO, UNITED STATES

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ABSTRACT. Yellow starthistle (*Centaurea solsitialis, L.*) is an invasive weed that creates problems for the management of Idaho's rangelands. A bioeconomic approach combined with an input-output economic model is used to estimate direct and secondary economic costs of the weed in relation to its interference with agricultural and non-agricultural benefits that rangelands provide. Direct economic costs of the infestations were estimated to be of 8.2 million '05 dollars per year, and secondary costs of 4.5 million '05 dollars per year, for a total of 12.7 million '05 dollars; agricultural related economic impacts accounted for 79 % of this total cost, and non-agricultural for 21 %.

Keywords: invasive species, yellow starthistle (*Centaurea solsitialis, L.*), economic impact, Idaho rangelands.

1. Introduction

The increasing invasion of non-indigenous species has become one of the top causes of global biodiversity loss and environmental change (Sala *et al.*, 2000; Mack *et al.*, 2000). Efforts have recently highlighted the urgent need for more rigorous and comprehensive assessments of the impacts and risks associated with these invasions, so that prevention and control strategies can be targeted appropriately (Mc Neely *et al.*, 2001; National invasive species Council, 2001). Assessments should recognize the interdisciplinary nature of the problem of species invasions: while ecosystem characteristics determine whether the appropriate conditions allow for the establishment of the invasive species, economic systems affect the state of the ecosystem through its use, and through the prevention and control measures implemented to stop the invasions. Thus, accounting for the economic and ecological links and feedbacks is critical in invasion assessments (Perrings *et al.*, 2002).

In this study, we make use of a bioeconomic approach to evaluate the impact of yellow starthistle (*Centaurea solsitialis, L.*) invasions on Idaho rangelands. Because of the ability of this weed to quickly establish itself and displace native vegetation, and the lack of adoption of appropriate management systems for its control, yellow starthistle has become a serious problem primarily in the northern part of the state.

Rangelands contribute to a regional economy in many ways: they provide agricultural commodities that can be valued in the market – such as forage for

grazing – and they also provide benefits that while not directly related to the agricultural sector - such as wildlife habitat - have an impact on the economy through activities that make use of them. Invasive species like yellow starthistle pose problems for managers of rangelands because they reduce the land's usefulness for grazing activities. In addition, they interfere with other non-agricultural functions that rangelands provide, like acreage of wildlife habitat and watershed quality related to soil erosion prevention. We capture the total economic loss that yellow starthistle infestations create on the economy of the state of Idaho in relation to both its agricultural and non-agricultural impacts. We make use of an input-output economic model to account for not only the direct losses associated with the industries that are directly affected by the infestations, but also losses associated with industries that are economically linked to them.

Our estimations show that there is a significant cost associated with yellow starthistle infestations in Idaho, and raise concerns about possible future costs that increases in the population of this weed may create if no measure is taken to prevent its spread.

The next section provides a brief background on yellow starthistle in Idaho rangelands. A third section presents the methods used to compute the estimated costs; the fourth section presents the results of the computations and a final section concludes with the results and policy implications.

2. Yellow Starthistle in Idaho Rangelands

Yellow starthistle is a non-indigenous, noxious weed that has spread into much of the semi-arid northwestern part of the United States. Native to Eurasia, it was introduced into the country via California in the early 1800's, and has continued to spread most severely in the western states of Idaho, Oregon and Washington. Field surveys conducted by University of Idaho scientists show that it has invaded Idaho rangelands at a rate of about 6,000 acres per year since 1981 (Callihan *et al*., 1996). In Idaho, yellow starthistle has primarily infested land of low economic value. Infestations usually occur on arid to semiarid rangeland and abandoned cropland, and infrequently on cultivated pastures. The weed dominates non-arable annual grassland sites that receive less than 20 inches of precipitation per year, and persists in areas of even higher rainfall (Callihan and Lass, 1996).

Yellow starthistle is a long-lived winter annual that forms dense infestations that rapidly deplete soil moisture, preventing the establishment of other species. As it displaces native vegetation, it reduces wildlife habitat and ecosystem diversity, and suppresses production of nutritious, palatable forage for wildlife and livestock, which leads to a reduction in grazing and wildlife carrying capacity. Soil and water conservation benefits of the region’s rangelands also decline - watershed quality declines in areas where the weed has advanced. In addition, a neurotoxin present in the plant creates a fatal malady called "chewing disease" in horses (Callihan *et al.*, 1996).

Herbicide effectiveness for the control of this highly invasive weed is high, but simply spraying without further renovation with competitive vegetation only opens these lands to re-infestation with dormant seeds and other weeds. Effective integrated management practices for yellow starthistle require a planned approach that requires combining herbicide application with biological suppression (three weevils and three flies are approved for biological control of yellow starthistle by the United States Department of Agriculture). This approach adds cost to the treatment, and is not feasible on most inaccessible Idaho rangelands. Past estimates of rates of return to investment in the control of yellow starthistle under alternative management systems suggested that this practice was only profitable on rangeland accessible to tractors. On rangeland too steep, where aerial treatment was necessary, rangeland renovation was not profitable without some other form of subsidy (Hartmans *et al.*, 1997). Even though Idaho ranchers perceive yellow starthistle as the most serious rangeland weed problem in the state (Carlson *et al*., 1989), investments for its control are usually not recoverable, and no significant action has been undertaken to prevent further invasions (Callihan and Lass, 1996).

3. Methods

To estimate the direct and indirect costs of yellow starthistle infestations in the rangelands of Idaho, we needed an approach that could relate the biophysical impacts of the weed to economic outcomes. We drew from Hirsch and Leitch (1996), who had developed a framework to estimate the economic impacts of leafy spurge (*Euphorbia esula, L.*) infestations in the state of Montana, United States. Figure 1 shows the rationale of the method employed.

[FIGURE 1]

We directly related yellow starthistle invasions to a decline in cattle carrying capacity (agricultural impact), wildlife carrying capacity, and watershed quality (non-agricultural impacts). Reductions in cattle grazing outlays accounted for the direct agricultural costs. In addition, we estimated reductions in wildland-associated recreation expenditures and increases in expenditures to mitigate damages from runoff and soil erosion to account for the non-agricultural losses. We then incorporated these estimated losses into an input-output model of Idaho's economy to compute total (direct plus secondary) regional economic costs that the state incurred due to the invasion of this noxious weed. Secondary effects included indirect and induced losses on the economy. Indirect losses are linked to economic sectors not necessarily directly affected by the infestations, but these sectors supply inputs needed by directly affected industries. Induced effects

represent changes in regional household spending patterns, caused by changes in regional employment that the direct and indirect effects generate.

3.1. ACREAGE OF YELLOW STARTHISTLE

A county weed board questionnaire conducted by University of Idaho scientists in the year 1999 reported a total of 665,576 acres infested with yellow starthistle in the state. The questionnaire did not differentiate among different use categories of the infested land. Since most of yellow starthistle invasions have occurred on low-value rangeland and unused land (Callihan and Lass, 1996) we assumed that all infested acres correspond to rangeland potentially used for grazing.

Idaho rangelands are a source of forage for cattle operations while simultaneously providing wildland benefits. For this reason, following Hirsch and Leitch (1996), we take the "multiple use" approach to the definition of wildland. We assumed that 40 % of the 665,576 acres infested (about 266,230 acres) contribute to wildland.

3.2. REDUCTION IN AGRICULTURAL PRODUCTION OUTLAYS

The direct economic costs related to the agricultural use of Idaho's rangelands are based on the weed's ability to reduce livestock carrying capacity - measured in animal unit month (AUMs)[1] - of the infested acres. Since the principal use of Idaho's rangelands is for beef cattle production, with cow-calf herds the

predominant enterprise, decreases in grazing output were assumed to lead to proportional decreases in cow-calf outlays. We used a cow/calf budget with representative characteristics of Idaho's rangeland operations developed by Smathers *et al*. (1999) to estimate the reduction in production outlays that arose from the decreases in AUMs.

The average carrying capacity of Idaho's non-infested grazing rangeland is 3 acres/AUM [2]. Assuming monoculture and no forage value of the weed [3], a total of 221,858 AUMs are lost per year to the range cattle activity in Idaho due to the 665,576 infested acres. Smathers *et al.* (1999) developed the cow-calf budget mentioned above for the management of 250 cows spending the summer on range and winter feeding necessary. According to their estimations, a herd of 250 cows requires 2,133.3 AUMs of deeded summer range per year. The lost AUMs could have then supported 26,000 heads of cows and calves.

3.3. REDUCTIONS IN NON-AGRICULTURAL EXPENDITURES

We consider reductions in hunting-associated and wildlife-watching related expenditures in the state of Idaho as a proxy to measure the economic impact that yellow starthistle has in connection to the reduction of wildlife habitat capacity.

To approximate a value for changes in wildlife-associated expenditures, we used the equation suggested by Wallace (1991) to calculate expression R (change in regional wildlife-associated expenditures due to the infestation).[4] The estimation of Wallace's expression involved a number of assumptions with

respect to the relationship of yellow starthistle with the environment. We assumed that yellow starthistle infested acres are 100 % covered with the weed, and following Hirsch and Leitch (1996), we assumed that 40 % of the 665,576 acres infested (about 266,230 acres) contribute to the support of wildlife.

We assumed also that monoculture of yellow starthistle reduced wildlife's habitat value for big game grazers (H) by 80 %.[5] The species/land use coefficient (C) represents the relative importance of different land uses in supporting current wildlife populations. This coefficient multiplied by total wildlife associated expenditures provides an estimate of wildlife-associated expenditures attributed to wildland; we assumed a value of 0.8 for Idaho's rangelands.[6] In addition, we assumed that 42 % of the total reduction in expenditures related to recreational activities would be lost to the state's economy (S); the rest would be reallocated in other industries of the region. [7] The annual estimate of lost wildlife habitat value was 1,020,028 ’05 dollars per year.

Yellow starthistle infestations decrease water quality due to higher soil erosion levels from the degraded rangelands. We modeled this effect as an increase in the cost of water treatment. Ribaudo (1989) estimated the off-site benefits of placing cropland highly susceptible to erosion into the Conservation Reserve Program (CRP) and restoring it to permanent cover. Runoff and soil erosion are reduced when tilled land is converted to permanent cover, reducing off-site water quality damages. Benefits of the reduced runoff are equal to the reduction in expenditures formerly necessary to mitigate damages from non-point source pollution (Ribaudo, 1986). CRP and wildland have similar soil and water

conservation benefits (Wallace, 1991) allowing the water conservation benefits of yellow starthistle pre-infested wildland to be estimated. We assumed that yellow starthistle infestations generate the reverse effect of restoring croplands to permanent cover. Estimates reported by Ribaudo (1989) were discounted and brought to a per year basis to obtain an approximation of the increased costs attributable to losses in water quality due to the infestations The annual estimate of the cost of reduced water quality was 630,772 ‘05 dollars per year.

3.4. THE INPUT-OUTPUT MODEL

We used the program IMPLAN (Impact Analysis for Planning) with data of the year 1996 to build a 528-sector model of the state of Idaho and conduct the analysis. Input-output models can be used to estimate the regional economic gains or losses resulting from a change in final demand for a commodity or group of commodities. Typically, changes resulting from management or policy decisions are incorporated in the model as changes in final demand, and the model computations provide total changes in regional income that result from the final demand changes.[8]

The direct effects presented in section 3.1 represent production-side changes associated with the immediate effects of yellow starthistle infestations. In order to use the IMPLAN input-output model, we had to convert these supply side direct effects of the weed into equivalent changes in the model’s final demand variables.

To translate rancher's reduced production outlays into final demand effects, we converted the reduced output into rancher's foregone expenditures for goods and services and producer net incomes stemming from the reduced cattle production. We distributed this figure according to the cow/calf budget provided by Smathers *et al*. (1999). The losses were grouped into three regional final demand categories: losses in final demand to industries, losses in household earnings and losses in state and local government revenues.[9]

To translate the total reduction in wildlife-associated expenditures (R) into final demand effects, we distributed this figure according to the distribution of expenditures reported by the National Survey of Hunting, Fishing and Wildlife-Associated Recreation (1991). The direct impacts were grouped into two major categories: losses to industries due to a reduction in expenditures for wildlife hunting and losses due to reduction in wildlife watching. Finally, increased water treatment costs were applied to the "water quality" sector of the input-output model.[10]

4. Results

This section presents the results of the input-output model computations made according to the methodology presented in section 3. To gain clarity in the presentation, we aggregated the 528 sectors of the Idaho IMPLAN model into 11 major groups to report the distribution of impacts across the different sectors of Idaho's economy (see Figure 1).

The combined effect of yellow starthistle on grazing activities and non-agricultural benefits of Idaho rangelands resulted in a total economic cost (regional income loss) of $12,736,300 '05 dollars; 64% of this total cost was the result of the direct impact of the weed; the remaining was the result of the weed's indirect and induced costs in the region. About 79 % of the total loss was attributable to a reduction in the agricultural benefits of rangelands; the rest was due to the non-agricultural sectors affected by the infestations (see Table 1).

[TABLE 1]

Table 2 presents the distribution of all costs (agricultural plus non-agricultural) by sector that result from the weed infestation. Overall, the sectors most adversely affected by yellow starthistle infestations are the agriculture-crops (the lost forage value), trade, and services, accounting for 62.4 % of the total regional costs.

[TABLE 2]

The agricultural losses associated with reductions in cattle production outlays generated a total cost of $10,124,000 '05 dollars. About 64 % of this loss was directly associated with losses in direct expenditures on regional goods and services needed for the cow/calf operations. The remaining 36 % represent indirect and induced effects. Agricultural-Crops sectors are more affected by yellow starthistle infestations on grazing rangeland than any other sector, bearing about 33 % of the total effect. Following these sectors in relative importance was the service and wholesale and retail trade related industries (see Figure 2).

[FIGURE 2]

The 266,230 infested acres that were lost to the support of wildlife generated a total cost of $ 2,612,000 '05 dollars due to reduction in expenditures for hunting and wildlife watching-related economic activities and an increase in the cost of water treatment. About 63 % of those were directly associated with losses in direct expenditures on regional goods and services needed for hunting, wildlife watching and water treatment activities; the rest of the cost was the result of secondary effects on the economy. The retail trade and services sectors were the ones mostly affected, accounting together for about 62 % of the total loss (see Figure 2).

5. Summary and Conclusions

The purpose of this study was to estimate the economic cost of yellow starthislte infestations on Idaho's rangelands. We estimated the costs that the weed generated in relation to forage production of grazing rangelands as well as its impacts on non-agricultural benefits of wildland. We used a biophysical framework combined with an input-output model built for the state of Idaho to estimate regional direct and secondary effects on the different sectors of the economy.

Results show that the state bears an economic loss (in the form of potential regional income lost to the region) of about $12.7 million ’05 dollars per year at the levels of infestation evaluated. Losses are incurred not only by the industries directly affected, but also by sectors of the economy that are indirectly linked to them. Further invasions of this weed and degradation of Idaho's rangelands could quickly multiply the estimated costs; our results suggest that the economy would benefit from further investments in measures of control and prevention that may protect the environmental quality of the rangelands as well as the economic sectors that directly and/or indirectly make use of them.

The policy implications of the calculations made in this study are important. Yellow starthistle infestations occur primarily in land of low economic value. However, our study shows how the economic costs of the invasion extend well beyond the rancher’s loss. In fact, the rancher’s direct loss loss (6,518,000 ’05 dollars) is only fifty one percent of the total cost to the state. Obviously, non-market effects such as loss of wildlife habitat and losses in water quality play an

important role in determining the cost of the invasions. Estimates of secondary effects are also important in showing by how much private ranching cost diverge from costs imposed on the public at large. These broader costs estimates are useful in thinking about what it would be worth to control the infestations from a state-wide perspective.

Policy implications regarding the management of land of low value by use of public incentives and private agents, so that it does not fall prey to invasive species comes out of this work. When the rancher looks at the control of the weed he/she looks at the marginal cost of control versus the marginal benefit of increased grazing provided by the control. This marginal benefit represents the return to the rancher's land, labor and capital associated with the marginal increase in grazing. The break even cost of control from the state's perspective, however, is much higher. Assuming, for example, 50 percent return of total product value (roughly 3,259,000 '05 dollars of the total value of 6,518,000 '05 dollars noted above), the break even cost from the state's perspective would roughly be four times the value of the ranching sector's perspective (12,736,000 '05 dollars; see Table I).

There are a number of challenges that remain to be addressed to improve the present estimations. Further research should be conducted to narrow the uncertainty of the estimates and contribute to a better understanding of the potential impact of this highly invasive weed. Examples are (1) increase the precision of the coefficients that describe the biophysical relationship between yellow starthistle and Idaho's wild land and wildlife populations (2) incorporate a

comprehensive accounting of non-market values (such as loss in aesthetic values of the rangelands and other ecological services) related to the invasions and (3) the inclusion of alternative scenarios concerning rancher's responses to the infestation and management practices. Future estimates should be computed with updated infestation levels and regional input-output economic data.

Notes

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

[2] Figures reported by the United States Department of Agriculture (USDA), Moscow Soil Conservation Service.

[3] Yellow starthistle's nutritional value is below the general requirements for most grazing animals (Hartmans *et al.*, 1997). This assumption and the assumption of monoculture of the weed does inflate the economics loss associated with yellow starthistle. But given the nature of the infestations, these seem like reasonable initial assumptions.

[4] According to Wallace (1991), $R = (E * C)(H * W)(S)$. R denotes change in regional wildlife-associated expenditures due to the infestation; E denotes total consumptive/non-consumptive wildlife-associated recreation expenditures; C denotes species/land use coefficient; H denotes percent reduction in wildlife habitat value from infested wildland; W denotes infestation rate, and S denotes percent expenditures lost to the state's economy

[5] We used the same values used by Hirsch and Leitch (1996) to estimate the impact of knapweed on Montana's wildlands.

[6] We approximated this value from a species/land use coefficient (C) curve developed by Bangsund *et al.* (1993) and based on the work of Wallace (1991) and Leitch (1978). The curve can be used to estimate coefficients with situations with varying amounts of wildland.

[7] Baltezore and Leitch (1992) reported that 42 % of recreationists would pursue their favorite recreation activities out of state if they were not available in North Dakota. We used the same estimate for Idaho.

[8] For a thorough description of input-output models and applications, see Miller and Blair (1985).

[9] Examples of the industries directly affected by the agricultural impacts of yellow starhtisle are feed expenses, veterinary medicine, trucking, and vehicles and equipment; losses in income were attributed to the hired labor, return to risk and management and capital categories of the IMPLAN model and losses in state and local government were attributed to expenditures in property taxes.

[10] Industries affected by the non-agricultural impacts of yellow starthistle included food, lodging, transportation, privileges and fees, boating costs, hunting

equipment, auxiliary equipment, photographic equipment, bird food, food for other wildlife, nest boxes, bird feeders, and water quality.

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FIGURE 1: Bioeconomic Impact of Yellow Starthisle (*Centaurea solsitialis, L.*)

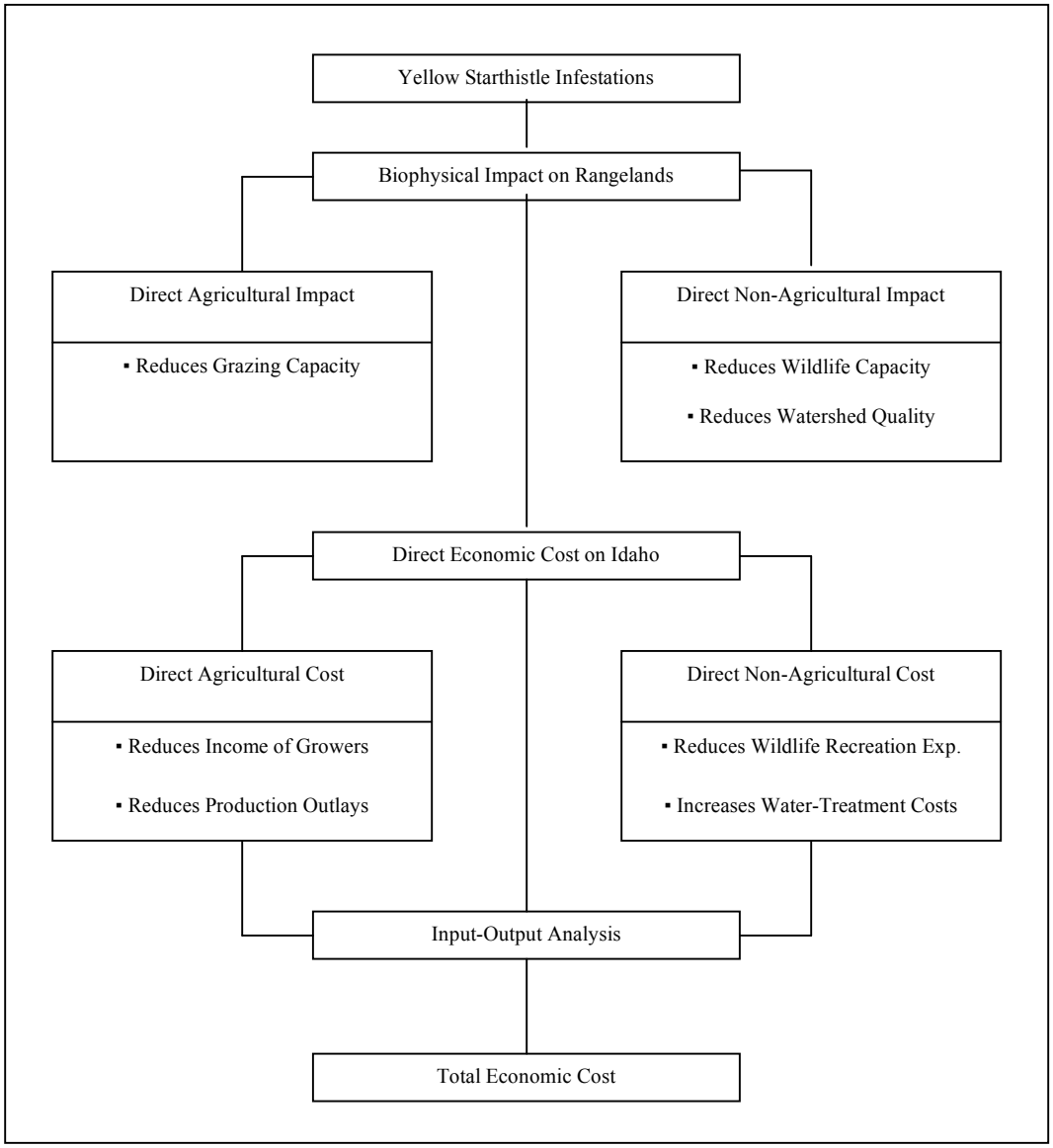

FIGURE 2
Distribution of Agricultural and Non-Agricultural Costs by Sector

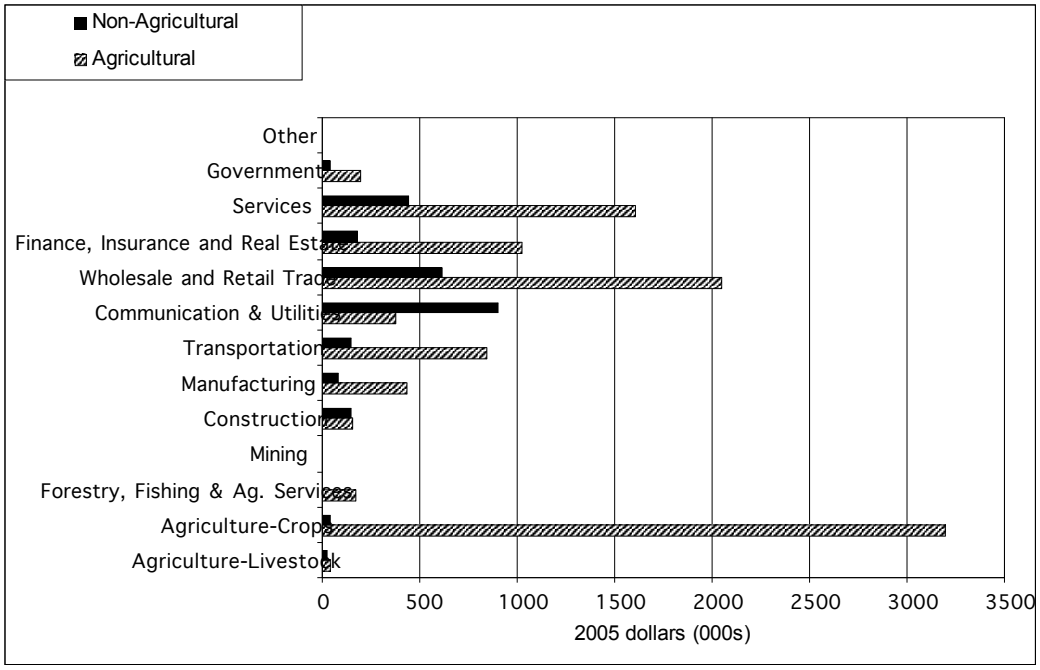

TABLE 1
Yellow Starthistle Costs

	Direct	Secondary	Total	
Sector	---------2005 dollars (000s)----------			%
Agricultural	6 518	3 606	10 124	79
Non-Agricultural	1 651	961	2 612	21
All Sectors	8 169	4 567	12 736	100

TABLE 2
Distribution of All Costs by Sector

Economic Sector	Direct	Secondary	Total
	----------2005 dollars (000s)----------		
Agriculture-Livestock	10.4	54.5	64.9
Agriculture-Crops	3 184.7	48.1	3 232.9
Forestry, Fishing & Ag. Services	0.5	179.6	180.0
Mining	0.2	6.2	6.4
Construction	10.4	291.3	301.8
Manufacturing	57.1	460.8	517.9
Transportation	650.8	341.5	992.5
Communication & Utilities	1 052.3	224.5	1 276.9
Wholesale and Retail Trade	1 819.1	845.1	2 664.3
Finance, Insurance and Real Estate	238.8	960.2	1 199.2
Services	973.1	1 079.1	2 052.3
Government	165.2	71.1	236.4
Other	5.6	4.4	10.1
Total	8 169.0	4 567.3	12 736.3