A Sustainable Herbicide and Grass Establishment Approach for Land Reclamation: A Case of Russian Knapweed [*]

by

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Abstract

Controlling Russian knapweed with an integrated system of herbicide followed by seeding perennial grass is profitable in yielding an 8.7% average rate of return, and repaying the establishment costs in approximately six years. Moreover, the system is sustainable by exploiting plant competition and eliminating herbicide usage in later years.

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Introduction

Effective control or containment of noxious weeds on permanent forage land is a serious concern throughout the Western United States. Traditional approaches have often relied on repetitive herbicide treatments, either annually or biennially over an indefinite period of time. However, repetitive herbicide applications as a singular strategy have not always been very cost effective or sustainable. Moreover, repetitive applications are frequently at odds with environmental concerns over prolonged use of chemical herbicides. This has promoted increased interest in developing and examining more sustainable approaches for controlling and reclaiming valuable forage land from noxious weed infestations.

Seeding perennial grasses following an initial series of herbicide applications (to kill initial weed stands) represents a promising approach for achieving sustained weed control and containment (Bornman, et al., 1991). An integrated system can potentially exploit plant competition and consequently, reduce herbicide usage over time. Although systems which integrate herbicide and perennial grass seeding show promise for achieving sustained weed control, more information is needed with respect to their economic performance. Specifically, will the added value of future forage production offset the initial costs of applying herbicide and seeding grass? To further explore this issue, the economics of reclaiming sub-irrigated hayland infested with one particular weed species (Russian knapweed) is examined in the context of an integrated herbicide plus seed perennial grass approach.

Russian knapweed is an aggressive perennial found in at least 21 states located primarily across the West (Maddox et al., 1985), with the capacity to spread at an annual rate of 8% (Simmons, 1985). It tends to infest more productive lands, in particular open or disturbed riparian areas, as well as cultivated croplands. Rapid colonization occurs because of its extensive black fibrous root system which can penetrate to depths exceeding eight feet, enhancing its ability to draw moisture from lower soil profiles. Competing vegetation is readily suppressed in part because of its allelopathic properties. Infestations can cause economic stress through lost forage production and livestock utilization, since Russian knapweed is rejected by cattle and sheep as a source of feed and is actually toxic to horses. Indeed, in the absence of remedial control measures, land infested with Russian knapweed is simply abandoned. Even though limited short-term control might be achieved with repetitive herbicide treatments, sustainable long-term control is hypothesized to be best achieved by including competitive plant species to occupy bare ground once infested by knapweed.

As described more fully below, this analysis is based on using experimental field data and practices to estimate commercial costs and return values within a capital budgeting (net present value) framework. Economic performance measures from the capital budgeting model are then examined in a probabilistic manner to account for the risk and uncertainty resulting from variable forage yields and prices, as well as expected risk of occasionally failing to establish an adequate stand of grass in the initial year due to unfavorable weather or growing conditions.

Experimental Approach and Results

Data for forage yields and effectiveness of weed control were collected from a field site in Fremont County, two miles south of Riverton, in central Wyoming. The study area is sub-irrigated with moisture from a river bottom, and normally receives 6 to 14 inches of annual precipitation. Land at this site was virtually abandoned with large and uniform infestations of Russian knapweed, although without knapweed it would be suitable for sub-irrigated hay production. As a result, this particular study was designed to estimate the annual value of reclaimed land in terms of expected hay production as opposed to a controlled grazing experiment. Five perennial grasses (crested wheatgrass, western wheatgrass, thickspike wheatgrass, streambank wheatgrass and Bozoisky Russian wildrye) were selected for analysis, because of their durability and ability to establish under adverse climatic and soil conditions. Two of these grasses, crested wheatgrass and Russian wildrye, have been previously shown to compete well with leafy spurge and are well adapted to sites with as little as 8 inches of annual precipitation (Koch et al., 1989).

Table 1 summarizes the sequence and cost of field activities (herbicide, tillage and grass seeding) conducted at the experimental site, including the cost of harvesting hay from established grass, as would be expected if the improvement were adopted to a commercial site. In the first year (1991), seedbed preparation was preceded by the first application of herbicide (2 qt/acre of Curtail) to kill Russian knapweed. Tillage of surface residue (remaining after the initial kill) was necessary to hasten decomposition of allelochemicals which accumulate from knapweed foilage and are detrimental to establishing new grass. Seeding of perennial grass occurred in the spring of year 2 (1992) followed by a second application of herbicide in late summer. No additional costs were incurred in year 3 (1993) as the grass stand matured in the establishment phase. In year 4 (1994) the first crop of hay was harvested in late summer, after which, herbicide was reapplied for the third and final time. In 1995 hay was harvested for the second time, with no further herbicide applications.

Weed control, when evaluated on the basis of percent live canopy cover of Russian knapweed was found to be very effective (Table 2); and no significant difference was observed between grasses species in terms of their ability to control knapweed. Specifically, when taken as an average across all five species, percent live canopy cover was found to be substantially lower with treatments including herbicide and grass (6% in 1994 and 2% in 1995) as opposed to untreated plots excluding herbicide and grass (57% in 1994 and 56% in 1995). Moreover, knapweed control on treated plots improved slightly from 1994 (6%) to 1995 (2%).

While percent live canopy cover established the biological effectiveness of weed control, forage yields were necessary to evaluate economic benefits. To estimate potential hay yields, grass cuttings were evaluated in both 1994 and 1995. Forage production varied substantially between 1994 and 1995 due to the fact that 1994 was one of the driest summers on record (under 7 inches of precipitation), while 1995 was among the wettest (over 13 inches of precipitation). As a result, yields across all grass species were extremely low in 1994, ranging from 0.41 to 0.93 ton/acre, with an overall average of 0.60 ton/acre. In contrast, 1995 yields were much higher, ranging from 2.33 to 3.77 tons/acre, with an average across species of 2.80 tons/acre. Since yield data were collected under extreme conditions, a 2-year average of 1.70 tons/acre (0.60 + 2.80 ÷ 2) is used to represent a benchmark for long-term production. By way of comparison, this 2-year average is similar to a long term average yield observed for irrigated grass hay in Fremont County (1.80 tons/acre) as reported by the Wyoming Agricultural Statistics Service (1976-95).

Economic Analysis with Capital Budgeting

The economics of reclaiming land from Russian knapweed was evaluated in a capital budgeting (net present value) format over a 15-year period as shown in Table 4. The biological effectiveness of this stand points to at least a 15-year life as documented by earlier grass seedings (Whitson et al. 1991).

In Table 4, initial establishment costs and hay harvest costs (col. 5), were weighed against the subsequent value of added hay production (col. 4) from land which otherwise would be abandoned. The value of hay ($119 per acre) was derived as the product of average yield described above (1.70 ton/acre); and average hay price ($70/ton), based on a ten-year mean (1986-95) expressed in 1995 dollars (Wyoming Agricultural Statistics). Resulting annual net values (col. 6) were then discounted with a real (inflation-free) rate of 5 percent to derive their corresponding annual net present values (col. 7). Accumulated net present value at each given year (col. 8) was calculated as the sum of annual net present values (col. 7) for previous years up through the current year. From observing the level of net present value after 15 years, the reclamation project is shown to be profitable with a total worth of $367.91 per acre, given average price and yield conditions.

Two additional performance measures were used for economic evaluation, including a payback period to breakeven. Payback is measured in terms of the minimum number of years needed to generate enough discounted revenue from added hay production (after deducting harvest costs) to pay for initial establishments costs; or as described by White (1988), the number of years for cumulative NPV to reach or exceed zero. Table 4 (col. 8) shows that the improvement generates a "positive" net present value after six years given average yields and prices.

Finally a 15-year average rate of return was calculated for consistent comparison to other investments. In order to maintain a reinvestment rate for cash flows that corresponds to the 5 percent opportunity cost of capital, a modified internal rate of return (mIRR) was used in place of the more traditional internal rate of return (IRR). The IRR assumes cash flows are reinvested at the same rate as the calculated IRR, which may be unrealistic if the computed IRRs are larger than the assumed opportunity cost of capital (i.e., 5%). As described by Barry et al. (p. 283), the mIRR in this case represents the interest rate that equates the present value of cash outflows discounted at 5% (Pv_{CO}), with the future value of cash inflows compounded at 5% (PV_{CI}), over N=15 periods of times, i.e., $PV_{CO}=FV_{CI} / (1+mIRR)^N$. With specific reference to the 15-year series of cash flows in Table 4, the FV_{CI} at 5% (col. 4) = \$1894 per acre; and the PV_{CO} at 5% (col. 5) = \$543 per acre, yielding a favorable 15-year average rate of return (mIRR) equal to 8.7 percent.

Impact of Risk and Uncertainty

To account for risk and uncertainty with respect to: (1) variable hay yields, (2) variable hay prices, and (3) possible failure to successfully establish a stand of grass in the first attempt, the three performance measures (years to breakeven; 15-year NPV and 15-year mIRR) were computed in a probabilistic manner, using an @ Risk simulation approach (Palisade Corporation). In this setting, the capital budgeting worksheet (shown in Table 4) was recalculated a large number of times based on random hay yields and hay prices drawn from appropriate probability distributions (described below) as well as a chance event for successful versus unsuccessful establishment.

From Table 3, hay yields were designed to vary around an average of 1.70 tons/acre, ranging from a low of 0.60 ton/acre (representing the average of different grasses during the dry summer of 1994), to a high of 2.80 tons/acre (representing an average of grasses during the wetter summer of 1995). As a consequence, variable hay yields were represented by a triangular distribution in the @ Risk spreadsheet, with corresponding parameters of a 0.60 ton minimum, a 1.70 ton most likely and a 2.80 ton maximum. In similar manner, hay prices in the @ Risk spreadsheet were designed to be normally distributed around a mean value of $70/ton, with a $12/ton standard deviation, based upon the ten-year (1986-95) price series from the Wyoming Agricultural Statistics.

Finally, the risk of failing to establish an initial stand of grass was represented by a discrete (zero/one) variable, with zero representing failure (30% of the time); and one representing successful establishment (70% of the time). The odds of unsuccessful (30%) versus successful (70%) establishment were based on histories of other grass seedings and their success rates, as observed at other locations across Wyoming under similar environmental conditions (Koch, 1997). The consequence of failing to establish a stand was accounted for by forcing the simulation spreadsheet to: (1) incur a doubling of selected establishment costs i.e., the $59.30/acre for seeding and herbicide as shown in Table 4 (col. 5) which would be incurred in not only year 2, but again in year 3; and (2) forego one year of hay production during the 15-year period (i.e., year 4 hay revenue = $0 versus $119/acre). Economic performance measures are adversely affected in the event of unsuccessful establishment. Specifically, in moving from a

0% to a 100% chance of establishment failure, the amount of time to breakeven increased from 6 to 8 years; the rate of return fell from 8.7 to 7.8%; and the 15-year NPV decreased from $368 to $265 per acre, given average yields and prices.

The @ Risk simulation worksheet (Table 4) and associated financial measures were recalculated 1,000 times given random prices and yields, with 300 of these trials evaluated with an extra year of costs and one-year loss of hay revenue. Mean values and associated measures of dispersion (standard deviation and cumulative probabilities) were generated for each of the three performance measures (years to payback, 15-year NPV and mIRR) as shown in Table 5.

On the average, payback from this integrated approach was favorable in terms of recapturing the establishment cost in six years, well before the end of the 15-year planning period. However, when factoring in potential price and yield variability, as well as a 30% chance of establishment failure, payback could vary from as few as 4.5 years, up to 10.5 years. Specifically, cumulative probabilities in Table 5 indicate a 100% chance of realizing a payback in 10.5 or fewer years; a 0.80 probability of payback in at least 8.2 years, and a 0.20 chance of breaking-even as soon as 5.6 years. Mean values for the 15-year NPV ($337.16) and mIRR (8.4%) were also quite attractive; and moreover their worst case scenarios were still profitable. Specifically, Table 5 shows 15-year NPV and mIRR could vary from respective lows of $163.82 and 6.82% to highs of $549.51 and 9.67%. In addition, cumulative probabilities show only a 0.20 chance of realizing a 15-year NPV less than $296.74, or a mIRR below 8.08%.

CONCLUSION

Based on results from this study, an integrated herbicide followed by seeding of perennial grass approach for reclaiming land appears to be very promising both biologically and economically, even under some worst case conditions. The projected 15-year life of perennial grasses for profitable forage production is believed to be conservative, beyond which long-term benefits could be even greater than depicted here. However, it must be emphasized that these performance levels are only pertinent for cases of better quality land having adequate moisture and suitable for hay production.

While long-run profitability appears favorable, cash flow deficits occurring in early years of establishment (prior to payback), are a possible concern for some landowners in terms of achieving financial feasibility. Because there are other factors not accounted for in this analysis which could benefit not only landowners, but others as well, (e.g., seed bank containment and elimination, positive wildlife impacts, water conservation as well as benefits to the regional economy), public cost sharing programs appear to be justified for at least some partial assistance in financing the initial establishment costs.

Finally, this study underscores the importance of using a more sustained system of weed control management, wherein herbicide treatments are followed by establishing competitive perennial grass. In the absence of establishing grass, leaving bare ground that was once infested with weeds, will simply generate more weeds.

Table 1. Sequence of Field Activities and Per Acre Costs Associated with Eradication of Russian Knapweed from Herbicide and Seeding of Perennial Grass.[a]

Month & Year	Activities	Per Acre Costs		
		Operations	Material	Subtotal
		$/acre		
1) Oct. 1991	Apply herbicide (Curtail	3.70	--	
	@ 2 qt/ac)	--	18.00	
Oct. 1991	Soil preparation, tillage and leveling	25.17	--	
	Subtotal, year 1	28.87	18.00	46.87
2) Apr. 1992	Drill grass	15.00	--	
	(grass seed)	--	22.60	
Aug. 1992	Reapply herbicide	3.70	--	
	(Curtail @ 2 qt/ac)	--	18.00	
	Subtotal, year 2	18. 70	40.60	59.30
3) 1993	No cost activities			
	(grass establishing)	--	--	
	Subtotal, year 3	0.00	0.00	0.00
4) Aug. 1994	Harvest hay for 1st time: swath, bale, stack and haul @ $32.80/ton	55.76	--	
Aug. 1994	Reapply herbicide	3.70	--	
	(Curtail @ 2 qt/ac)	--	18.00	
	Subtotal, year 4	59.46	18.00	77.46
(5) Aug. 1995	Harvest hay for 2nd time	55.76	--	
	Subtotal, year 5 and thereafter	55.76	0.00	55.76

[a] Feuz, p. 36.

Table 2. Effectiveness of Russian Knapweed Control (Percent Live Canopy) Between Treated versus Untreated Plots by Grass Species: 1994 and 1995.[a/]

Grass Species	1994 Treated Plots	1994 Untreated Plots	1995 Treated Plots	1995 Untreated Plots
	- - - - - - - - - %	- - - - - - - - - - -	- - - - - - - - - %	- - - - - - - - - - -
1) Streambank wheatgrass	3	54	0	68
2) Thickspike wheatgrass	5	59	7	52
3) Crested wheatgrass	4	55	1	50
4) Western wheatgrass	5	56	1	52
5) Russian wildrye	10	61	0	59
Average	6	57	2	56

[a/] Feuz, p. 25-25.

Table 3. Estimated Forage Yields (ton/acre) by Grass Species: Cuttings in 1994 and 1995.[a/]

Grass Species	1994	1995	Average
	- - - - - - - - - - - - - - - - - - - ton per acre	- - - - - - - - - - - - - - -	
1) Streambank wheatgrass	0.67	2.63	1.65
2) Thickspike wheatgrass	0.49	2.94	1.71
3) Crested wheatgrass	0.93	3.77	2.35
4) Western wheatgrass	0.41	2.33	1.37
5) Russian wildrye	0.52	2.80	1.44
Average	0.60	2.80	1.70

[a/] Feuz, p. 30.

Table 4. Capital Budgeting Format for Deriving Net Present Value of Reclaiming Land from Russian Knapweed.

(1) Year	(2) Hay Yield ton/ac	(3) Hay Price $/ton	(4) Annual Hay Revenue $/ac	(5) Annual Cost[a/] $/ac	(6) Annual Net Value $/ac	(7) Annual Discounted Net Present Value[b/] $/ac	(8) Accumulated Net Present Value at a Given Year[c/] $/ac
1	--	--	--	46.87	-46.87	-44.64	-44.64
2	--	--	--	59.30	-59.30	-53.79	-98.42
3	--	--	--	0.00	0.00	0.00	-98.42
4	1.70	70.00	119.00	77.46	41.54	34.18	-64.25
5	1.70	70.00	119.00	55.76	63.24	49.55	-14.70
6	1.70	70.00	119.00	55.76	63.24	47.19	32.49
7	1.70	70.00	119.00	55.76	63.24	44.94	77.43
.	.	.	.	.	.	.	.
14	1.70	70.00	119.00	55.76	63.24	31.94	337.49
15	1.70	70.00	119.00	55.76	63.24	30.42	367.91

[a/] Annual costs derived from Table 1.

[b/] Discounted net present value calculated as the annual net value (col. 6) divided by a discount factor of $(1+i)^n$, with i=.05.

[c/] Accumulated net present value at a given year is calculated as the sum of discounted net present values for previous years up through the current year (col. 7).

Table 5. Summary Statistics from the Risk Based Simulation for each of the Three Performance Measures.

	(1) Payback (yrs.)	(2) 15-yr NPV ($/acre)	(3) 15-yr mIRR (%)
Mean	6.0	337.16	8.40
Standard deviation	1.4	77.13	0.60
Minimum	4.5	163.82	6.82
Maximum	10.5	549.50	9.67
Cumulative Probabilities[a/]			
0.00	4.5	163.82	6.82
0.10	5.4	257.52	7.75
0.20	5.6	296.74	8.08
0.30	6.4	322.89	8.31
0.40	6.5	344.68	8.51
0.50	6.6	364.29	8.67
0.60	6.7	383.90	8.80
0.70	7.5	403.51	8.94
0.80	8.2	427.48	9.07
0.90	8.8	455.81	9.26
1.00	10.5	549.51	9.67

[a/] Cumulative probabilities reflects the odds of a given performance measure (payback, NPV and mIRR) falling below the designated amounts.

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