Risk Planning for Fire Rehabilitation

A step-by-step guide for conducting a risk-adjusted cost-effectiveness analysis as part of a fire rehabilitation plan.

By Marina Whitacre and Nicole McCoy

Wildfires are a popular topic of local and national news media, whose stories describe danger, devastation, heroes and scandal. The effort and expenditure required to rehabilitate the blackened landscape are not nearly as exciting as the fires themselves and receive little to no media attention.

Behind the scenes, however, range managers write and implement revegetation plans, often before the fire is extinguished. Just as the media ignores the essential but perhaps unfamiliar topic of revegetation following fire, range managers often neglect including an economic analysis in their revegetation plans.

Following is a step-by-step guide for conducting a risk-adjusted cost-effectiveness analysis to illustrate how it can benefit land managers and future rehabilitation efforts by accounting for the risks and expenditures of post-fire revegetation projects.

Risk plays a critical role in project decision-making.

Post-fire Revegetation on Western Rangelands

In 1999, the National Interagency Fire Center reported a record fire year. Three thousand sixty-four fires in the Great Basin burned over 2.8 million acres (1). Largely responsible for the increase in fire size and frequency is the spread of cheatgrass, an invasive annual grass. Its ability to germinate in cool temperatures, exploit early spring moisture, and tolerate dry conditions has enabled cheatgrass to establish in unvegetated areas and provide a continuous understory of fuel.

The outcome is a shortened fire cycle that can result in fewer perennial plants, accelerated soil erosion and inadequate forage and wildlife habitat (2). Cheatgrass can also serve as a precursor to secondary weeds and subtle ecosystem alterations including changes in nutrient cycling and soil morphology (3).

Efforts to rehabilitate burned rangelands are limited by budget and personnel constraints and by the availability of seed and equipment. Fall seeding is recommended in the Great Basin prior to wetter winter and spring months.This creates a narrow window for rehabilitation and a bottleneck period when limited resources are in high demand. In addition, restoration efforts can be hindered by rough terrain and unpredictable and dry climatic conditions. As a result, only a small percentage of burned landscapes are seeded. For example, only 14% of the 3.2 million acres that burned in the West in 1996 was reseeded, costing over $21 million (4). Similarly, in 1999 it cost $40 million to reseed 33% of the 2.8 million acres burned in the Great Basin (1).The expense and uncertainty inherent to fire revegetation necessitates the evaluation of previous projects to make informed management decisions.

The Importance of Cost-Effectiveness Analysis

Benefit-cost analysis is a common measure of economic efficiency in which alternatives are evaluated by comparing monetary costs to benefits. However, benefit-cost analysis may be an impractical tool when seeking the least expensive means to reach a non-monetary goal or when benefits are difficult to monetize (e.g. soil stabilization and its benefits). In the context of rangeland rehabilitation, a different tool, cost-effectiveness analysis, may be more appropriate for determining the costs and effectiveness of proposed revegetation projects.

Unlike benefit-cost analysis, cost-effectiveness analysis does not assign a dollar amount to a project's benefits. Instead, it compares costs (in dollars) to measurable, but non-monetized benefits to generate an effectiveness ratio (e.g., number of seeded plants/dollar).

To complete a cost-effectiveness analysis, a manager must determine four pieces of information:

(1) project goals and objectives,
(2) estimates of plant establishment from similar, previously revegetated sites,
(3) the cost of potential reseeding techniques, and
(4) project risks.

In the broadest sense, the goal of revegetation is to increase plant cover. However, the project-specific goals will depend upon managerial objectives. For instance, one may seek high species diversity with an emphasis on restoring native vegetation, or if the threat of a weedy invasion is significant, managers may seek only to establish a given density of any perennial species.

The species specified objectives will measure project effectiveness, and as such, must be quantifiable (e.g., 4.5 seeded plants/yd^2). This effectiveness measure will be used to rank establishment results and estimate plant density for the proposed site. While no site will be identical to that of the proposed project, an effort should be made to acquire data from areas where soils, topography, range site, precipitation and seeding time are similar. Further, comparison sites should have been seeded using techniques feasible for the proposed project.

Next, the total cost of each reseeding technique must be calculated. These costs include (but may not be limited to) seed purchases, equipment purchase or rental, fuel, and labor hours. Although costs from comparison sites may provide a working estimate, current cost information is required for final calculations.

Risk plays a critical role in project decision-making. Rangeland seeding in semi-arid sites (sites receiving less than 12 inches of rainfall/year) presents a significant risk of failure from a lack of moisture.Other risks may include pest outbreaks or wildfire. To help quantify risk, probabilities are assigned by asking, "What is the probability that the seeding will receive sufficient rainfall for good establishment?" or "What is the probability of a grasshopper outbreak during seedling development?"

While it is tempting to treat the likelihood of these events as unknowns, we can assess the probability of success for each strategy by specifying a set of comprehensive and mutually exclusive contingencies. In other words, possible outcomes are specified such that only one will occur. A rehabilitation site will receive either greater or less than 12 inches of annual precipitation in a given year (but not both). This process is called an expected outcome analysis.

To illustrate the use of a risk-adjusted cost-effectiveness analysis for rangeland rehabilitation, we will apply it to a hypothetical planning process.

Case Study: Revegetation in Skull Valley, Utah

The area we want to reseed lies within a burn located in Skull Valley, Utah (Figure 1) and is adjacent to the Davis Knolls burn where there is a six-year-old 5900-acre seeding of Nordan crested wheatgrass.

Project Goals and Objectives

The goal of our project is to reduce the risk of cheatgrass invasion and soil erosion by establishing crested wheatgrass, a well-adapted, competitive species introduced from Eurasia. To measure success of our seeding and determine the most-cost-effective technique, we will use Vallentine's (1989) plant establishment guidelines for a foothill rangeland site in the Intermountain West: excellent establishment: greater than 6.75 plants/yd^2 (36,300/acre), good: between 4.5 and 6.75 plants/yd^2 (20,230-

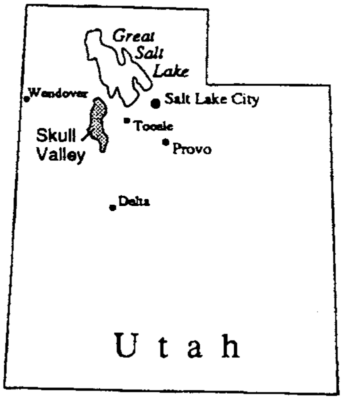

Figure 1. *Skull Valley, Utah (9).*

36,300/acre), fair: 2.25 to 4.5 plants/yd^2 (10,120-20,230/acre) and poor: fewer than 2.25 plants/yd^2 (10,120/acre). Our goal is a seeded plant density greater than 4.5 plants/yd^2 or 20,230 plants/acre (i.e., "good" establishment).

Site Descriptions

Both our project and the seedings used for reference are located within the mid-elevation zone of Skull Valley (between 4,590 and 5,250 ft) where soils are shallow to moderately deep and well drained. The dominant vegetation is shadscale, Indian ricegrass, bottlebrush squirreltail, Wyoming big sagebrush, Russian thistle and cheatgrass.

The local 41-year average annual precipitation is 7.6 inches with maximum and minimum yearly amounts totaling 15 and 3.3 inches, respectively. Most precipitation arrives during the winter and early spring, with little rain between mid-June and October. As such, precipitation during the first 6 months of the year is critical for seedling establishment, and fall seeding provides an opportunity for cool season plants to acquire early spring moisture.

The plant establishment data we used to evaluate the potential effectiveness of our project are from three, 1996 fall fire rehabilitation projects in Skull Valley. The seed mix consisted primarily of crested wheatgrass and was applied aerially (with and without chaining) and by drill seeding, methods appropriate for use on our site. Two of the rehabilitation projects were completed within the Davis Knolls burn, and the third site was within the Sheeprock burn (Table 1). The range site at our proposed site is the same as Davis Knolls, a semi desert gravelly loam.

The winter and spring precipitation (1997) following the Davis Knolls and Sheeprock seedings was 188% of average, and the crested wheatgrass establishment was good to excellent for the aerial/chained and drill seeded treatments (Table 1).

Common and Scientific Plant Names

Grasses	
Bottlebrush squirreltail	*Elymus elymoides*
Cheatgrass	*Bromus tectorum*
Indian ricegrass	*Achnatherum hymenoides*
Nordan crested wheatgrass	*Agropyron desertorum*
Forbs	
Russian thistle	*Salsola iberica*
Shrubs	
Shadscale	*Atriplex confertifolia*
Wyoming big sagebrush	*Artemisia tridenta* spp. *wyomingensis*

Costs of Potential Reseeding Techniques

Rangeland drill seeding

In areas accessible by tractor where soil textures are not too fine, drill seeding can be both efficient and effective. Advantages include one-step seeding and soil coverage, calibrated seed boxes for uniform seed distribution, and the ability to adjust planting depth to accommodate the species seeded (5).

These advantages make drill seeding more efficient than other methods, in part because it requires less seed (Table 2), while maintaining high establishment rates that are potentially 3–7 times those of broadcast seeding (6). In addition, implementation costs are relatively low. Table 2 summarizes the costs of the seeding methods.

Broadcast seeding with and without chaining

Broadcast seeding is the act of scattering seed on the soil surface without soil coverage. Seed can be applied from an airplane or helicopter, by hand, or

Table 1. Summary of Skull Valley burn sites used for cost-effectiveness analysis and risk analysis.

Burn	Area reseeded	Method of	Elevation	Average annual rainfall	Range site	Seeded plant density 1997	1999
	(acres)	reseeding	(feet)	(inches)		(plants yd^2)	
Davis Knolls	5,000	Drill	5,000	7.7	Semi-desert	9.5	5.1
(34,138 acres)	900	Aerial/chained	5,200		gravelly loam	6.75	6.75
Sheep Rock	2,200	Aerial	5,800	9.7	Upland stony loam	1.8	2.25
(9238 acres)		Aerial/chained§				21.6	7.2

§ BLM report did not specify the number of acres treated by each seeding method.

Table 2. Summary of fire revegetation costs on 5000 acres.

Seeding Method	Seeding rate	Seed total	Seed Cost[1]	Seed Application Application cost	 Seed Handling[3]	Total	Cost/acre
	(lb/acre)	(lbs)		(acres)(cost/acre)[2]			
Drill Seed	2.5	12,500	$26,250	(5000) ($8) = $40,000	$3,182	$69,432	$13.89
Aerial Seed	7	35,000	$73,500	(5000) ($6) = $30,000	$8,840	$112,340	$22.47
Aerial Seed/Chain	7	35,000	$73,500	(5000) ($6 + $20) = $130,000	$8,840	$212,340	$42.47

1.Seed cost based on Nordan crested wheatgrass pure live seed ($2.10/lb).

with broadcasters mounted on a tractor or tillage implement. It is a widely used seeding technique and a quick method of direct planting on rough terrain where drilling is impractical or impossible.

Broadcast seeding is most effective in areas with unconsolidated litter, naturally loose soils, and little vegetation. Species best suited to broadcasting germinate under brief, favorable conditions or in cool, dry environments. Small seeded species are also well suited since they are easily incorporated into the soils.

Limitations include poorly covered and distributed seed, which can result in slow establishment and low success. As a result, heavy seeding rates are necessary because most seeds aren't placed in favorable microsites for establishment and are susceptible to rodent and bird depredation (Table 2).

If aerially broadcast seed is covered, established plant numbers are more comparable to drill seeding. Seed coverage is frequently accomplished by chaining, a mechanical technique used to increase seed-to-soil contact, and although expensive, it can greatly increase seeding success. At Davis Knolls, the 900 acres that were chained yielded four times the plant density than a solely broadcast seeded area (Table 1). Call and others (2000) suggest that follow-up chaining made the difference between excellent and poor seedling establishment and reduced cheatgrass cover.

Project Risk

Our project considers only insufficient precipitation in the risk analysis. Of the risk factors associated with revegetation efforts, it is the simplest to estimate and is recognized as the greatest limiting factor on semi-arid/arid rangelands. Other factors that can be used to predict plant establishment are partially captured in annual precipitation such as consecutive above-average years, temporal distribution, event intensity and associated cooler temperatures. Additional project risks may include grasshopper or Mormon cricket outbreaks, fire, and the presence of invasive weedy species.

To determine how rainfall years before and after the seeding compare to the average, we obtained a long-term precipitation record (1950–2001) recorded by the Western Regional Climate Center at Dugway Proving Grounds, 3 miles from the burn (7). Between January and June of 1997, Skull Valley received 188% more precipitation than the 6-month average (7.9 vs. 4.3 inches). The first 6 months of 1999 also received above average precipitation (131% of normal). By 1999, the plant density at Davis Knolls and Sheeprock was "good", averaging 5.3 plants/yd^2 (Table 1). In contrast, plant density was low at seven similar sites seeded following the 1998 Skull Valley burns (0–1.8 seeded plants/yd^2) (7).

If we assume a lack of precipitation is solely responsible for the failure of the 1998 seedings, then a successful seeding requires precipitation to be between 131 and 188% of average. Additional precipitation and revegetation data would help narrow this estimate and possibly rule out (or in) other sources of risk. However, with no additional data, we decided 150% of normal (6.4 inches) as necessary for success (i.e., a seeded plant density of 4.5/yd^2).

Five (1980, 1986, 1995, 1997, 1998) out of 41 complete years of data collected at the U.S. Army Dugway Proving Grounds received greater than 6.4 inches of moisture within the first 6 months of the year. This equates to a 12% (5/41) chance that a seeding will produce the desired plant density. Further, we assumed that precipitation between 4.3 and 6.4 inches (100–149% of normal) between

January and June will give us a 37% chance of establishing a fair to poor seeding. Below average precipitation (less than 4.3 inches) occurs greater than half the time (51%); therefore, the likelihood of failure is significant.

Does this mean we should not attempt to reseed the site? Not necessarily. In years with normal precipitation, some seeds may germinate and establish while others may "wait" for favorable conditions. There is also a 49% chance that our site will receive adequate precipitation. However, while it is tempting to seed and hope for the best, such a strategy may result in a waste of time and resources. Therefore, we will evaluate possible plant densities based on the probability of each precipitation scenario (above average, average, below average) by conducting an expected outcome analysis.

In Table 3, the far left column shows the probability of each precipitation scenario. While the probability that any one scenario will occur is less than 100%, it's certain that for any given year the amount of precipitation from January to June will fall into one of these categories. Rows 1–3 show expected plant densities for each seeding method/precipitation combination, and the bottom row shows the results of the expected outcome analysis by seeding method.

To calculate *Total expected outcome* for drill seeding, multiply *Probability* (left column) and *Expected outcome by drill seeding* (second column) [i.e., (0.12 x 21,450 = 2,574); (0.37 x 10,115 = 3,746); (0.51 x 0 = 0)]. The sum of these three values (2,574, 3,746, 0) equals *Total expected outcome* (6317). Note that this number does not predict how many plants will be generated on our site by drill seeding. Instead, it allows us to compare, within our proposed site, the risk of drill seeding with alternative seeding methods. We could also use the total expected outcomes generated to compare seeding risk relative to other revegetation sites.

Table 3. Using probabilities to determine expected outcomes (number of seeded crested wheatgrass plants/acre) by seeding method.

	Expected outcomes by seeding method[1]		
Probability	Drill	Aerial/Chain	Aerial
		(plants/acre)	
.12	21,450	32,375	30,350
.37	10,115	14,160	13,310
.51	0	0	0
Total Expected outcome[2]	6,317	9,124	8,567

[1] Expected outcomes are based on the seeding rates given in Table 2.

[2] This number does not predict how many plants will occur on our site. Instead, we would expect to generate one of the actual results such as 21,450, 10,115, or 0 for drill seeding.

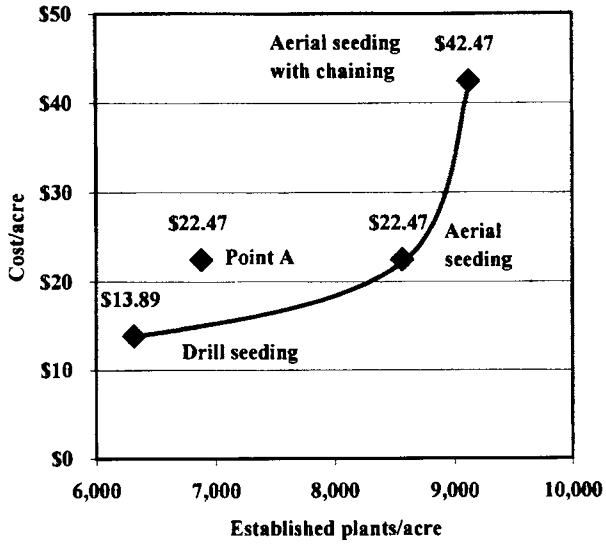

Figure 2. *Cost-effectiveness comparison for seeding crested wheatgrass using 4 different seeding techniques.*

Putting It Together

Now that we have determined the four required pieces of information, (1) the goal of the project (20,230 plants/acre), (2) estimates of plant establishment from monitoring data collected from sites similar to our own, (3) the cost of various reseeding techniques (drill $13.89/acre, aerial $22.47/acre, and aerial/chaining $42.47/acre), and (4) project risk (total expected seedlings/acre: drill, 6,317; aerial, 8,567; aerial/chaining, 9,124), we can calculate the cost-effectiveness of our project.

Table 4 summarizes the costs and expected effectiveness of each seeding project. These results are shown graphically as an effectiveness curve in Figure 2. Unfortunately, the expected outcome analysis shows the likelihood of any method achieving our goal of 20,230 plants/acre is very low. The largest expected outcome calculated is 9,124 plants/acre. Therefore, we are left with three possible decisions regarding our site: (1) alter our goal to maximize seedling success or to correspond with a fixed budget, (2) evaluate alternative seeding methods to potentially increase plant density, or (3) abandon reseeding efforts at our site, reserving resources for a site with a better chance of success.

Although this paper will not discuss (2) and (3), it may be reasonable for us to alter our reseeding goal. If we decide the presence of any seeded plant (regardless of density) will benefit the site, one option might be to maximize the number of plants/dollar spent or to minimize the cost/plant. Under either alternative, drill seeding offers both the highest number of plants/dollar (455) and the lowest cost/plant ($.002), making it the most cost-effective choice (Table 4).

Table 4. Cost and effectiveness summary for seeding crested wheatgrass using 4 seeding techniques

Cost and Effectiveness	Aerial/Chaining	Aerial	Drill	Point A[§]
Cost/acre[1]	$42.47	$22.47	$13.89	$22.47
Effectiveness (number of plants/acre)[2]	9124	8567	6317	6880
CE ratio (cost per plant)	\$4.65 x 10^{-3}	\$2.62 x 10^{-3}	\$2.20 x 10^{-3}*	\$3.27 x 10^{-3}
EC ratio (plant per $1 spent)	215	381	455*	306

1. Includes the cost of seed, seed handling and application
2. Risk-adjusted established plant numbers

§ Hypothetical seeding technique

*CE or EC ratio of the most cost-effective alternative

Another option is to maximize the number of plants/acre. Although it's considerably more expensive than the other two methods, aerial seeding with chaining is expected to generate highest density (9,124 plants/acre). This may be a viable alternative if there is a threshold, say 9,000 plants/acre (1.9 plants/yd^2), below which any establishment is considered a failure. However, if we are concerned about both threshold success and working under a budget constraint of $25/acre, then aerial seeding (without chaining) becomes the most cost-effective solution.

Key to this discussion is understanding that any of the methods we select are potentially cost-effective and that the most cost-effective alternative is solely dependent upon how we have defined our goals. This is not to say, however, that any reseeding method could be cost-effective. Suppose we evaluated a fourth reseeding method (Point A) that costs the same as aerial seeding yet results in fewer plants/acre. This would not be a cost-effective solution (Table 4, Figure 2).

Summary

The expense and uncertainty associated with semi-arid revegetation make rehabilitation efforts risky. Although risk cannot be eliminated, it can be evaluated within the context of various rehabilitation practices with the use of expected outcome and cost-effectiveness analyses.

We utilized a risk-adjusted cost-effectiveness analysis to evaluate a hypothetical revegetation project in Skull Valley, Utah. Our cost-effectiveness analysis employed an expected outcome calculation to incorporate risk by assigning probabilities to several precipitation scenarios. The analyses showed the likelihood of achieving our goal (20,230 plants/acre) was very low. This may be reason to evaluate additional seeding methods, modify the project goals, or revegetate an alternate site.

It should be noted that we provide a simplified example where only one risk (insufficient precipitation) is included and one species (crested wheatgrass) is seeded. Although these calculations are more straightforward than those that include a risk of insect infestation, they can be misleading. Because we are attributing any seeding failure to a lack of precipitation only our calculations are less likely to reflect true probabilities, and may underestimate the likelihood of success. For instance, during the spring of 1999 there was an outbreak of Mormon crickets, which likely had a negative effect on plant density for the 1998 seedings (8). This creates an obvious complication. How much of the difference in plant establishment on the 1996 and 1998 seedings can be attributed to insect herbivory, and how much to less rainfall?

Another simplification made, concerns plant species selection. Crested wheatgrass is commonly used in rehabilitation projects on western rangelands. However, if natives were seeded it is likely that revegetation costs would increase and plant establishment would decrease. The overall result would likely be higher costs and lower effectiveness.

When interpreting the results of a cost-effectiveness analysis, it is important to recognize the omission of risks that are difficult to quantify. However, regardless of the necessary simplifications, cost-effectiveness analysis provides a tangible comparison of revegetation practices and enables managers to make better-informed decisions. In addition, the practice of quantifying the cost and expected plant density may increase awareness regarding the expense and risk of fire rehabilitation and encourage the development of more proactive range management practices.

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References

1. **U.S. Department of Interior, Bureau of Land Management. 1999.** Out of ashes, an opportunity. National Office of Fire and Aviation, Boise, Idaho.
2. **Young, J.A. and R.A. Evans. 1978.** Population dynamics after wildfires in sagebrush grasslands. J. Range Manage. 31:283-289.
3. **Gill R.A. and I.C. Burke. 1999.** Ecosystem consequences of plant life form changes at three sites in the semiarid United States. Oecologia 121:551-563.
4. **Roundy, B. A., N. L. Shaw and D. T. Booth. 1997.** *In:* Shaw, N. L. and B.A. Roundy (comps.), Proceedings: Using seeds of native species on rangelands. INT-GTR-372. U.S.D.A., Forest Service, Intermountain Research Station, Ogden, Utah.
5. **Vallentine, J.F. 1989.** Range Developments and Improvements, 3rd Ed. Academic Press, Inc., Harcourt Brace Jovanovich, Publishers, San Diego, California.
6. **Hull, A.C., Jr. 1959.** Pellet seeding of wheatgrass on southern Idaho rangelands. J. Range Manage. 12:155-163.
7. **Western Regional Climate Center (WRCC). 2001.** www.wrcc.dri.edu (March 31, 2003).
8. **Call, C.A., S. Tobler and G.A. Rasmussen. 2000.** Revegetation and fire modeling in Skull Valley, Utah. USU/BLM Assistance Agreement 1422-DAA99-0200. Task Order No. 4. Logan, Utah.
9. **Sack, D 1993.** Quaternary map of Skull Valley, Tooele County, Utah. Department of Geography, University of Wisconsin, Madison, Wisconsin.