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Restoration of Plant Cover on Campsites in Subalpine Forests: Sawtooth Wilderness, Idaho

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Abstract

This study assessed the effectiveness of restoration treatments in enhancing the growth of *Vaccinium scoparium* transplants and plants established from seed on six closed campsites in subalpine forests in the Sawtooth Wilderness, Idaho. In the primary experiment, the soil on all plots was scarified and amended with organic matter; plots varied regarding the type and amount of organic matter in the amendments, whether or not they were fertilized, and whether or not they were covered with a mulch blanket. In the second experiment, plots varied regarding whether or not they were scarified, amended with organic matter, or received supplemental water. Compared to an earlier study in similar forests in the Eagle Cap Wilderness, Oregon, survival and growth of *Vaccinium scoparium* transplants was high, regardless of treatment, as long as campsites were closed and soils were scarified. In the primary experiment, 92 percent of transplants were still alive after five years and most transplants had increased in size. This greater success may reflect the larger size of transplants used in the Sawtooth study (mean of 315 cm^2). The most pronounced main effect of treatments in the primary experiment was the beneficial effect of fertilization with Biosol® on the establishment and growth of seedlings, particularly graminoids. Certain combinations of mulch and type and amount of organic matter were more beneficial than other combinations, but none of these treatments had either consistent or substantial positive effects. Supplemental watering increased restoration success, suggesting that recovery is limited by water. Our results suggest that native vegetation can be restored on highly disturbed campsites in these forests. They also reinforce the importance of avoiding impact in the first place given the lengthy recovery periods required in these ecosystems and the intensive restoration efforts needed to speed recovery.

Keywords: organic fertilizer, recreation impact, soil amendments, transplanting, *Vaccinium scoparium*

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Introduction

Subalpine landscapes, particularly those dotted with scenic lakes, attract a disproportionate amount of wilderness use. Consequently, the impacts of camping are particularly pronounced in subalpine forests. Wilderness managers frequently attempt to close and restore some of these campsites where camping impacts are severe, the number of campsites is considered excessive, or campsites are located in inappropriate places. Although little restoration research has been conducted on wilderness campsites (however, see Moritsch and Muir 1993), there is a substantial high-elevation restoration ecology literature that has demonstrated the effectiveness of restoration treatments, including transplanting (Conlin and Ebersole 2001), seeding (Smyth 1997), mulches (Petersen and others 2004), and organic amendments (Chambers 1997). All these studies stress that results likely vary with attributes of the situational context, particularly characteristics of the site and its disturbance history.

Throughout much of the Rocky and Cascade Mountains, extensive tracts of subalpine forest have an understory dominated by dwarf ericaceous shrubs, particularly *Vaccinium scoparium* (grouse whortleberry). Tree species in the overstory vary but the most common are *Pinus contorta* (lodgepole pine), *Pinus albicaulis* (whitebark pine), *Abies lasiocarpa* (subalpine fir), and *Picea engelmannii* (Engelmann spruce). The impacts of wilderness camping are probably more widespread in these vegetation types than in any others in the United States, making information about effective restoration treatments particularly useful in these forests.

Starting in 1995, experimentation with restoration treatments commenced on campsites at subalpine lakes in the Eagle Cap Wilderness, Wallowa Mountains, northeastern Oregon. Vegetation had an overstory of *Pinus contorta*, *Pinus albicaulis*, and *Abies lasiocarpa;* the discontinuous understory (about 50 percent cover) was highly dominated by *Vaccinium scoparium* (about 55 percent of understory cover). Specifically, experiments assessed the effectiveness of (1) soil scarification, (2) transplanting and seeding with local, native species, (3) ameliorating microclimatic conditions with a mulch mat, and (4) amending soils with organic matter, compost, and soil inoculum. Results of these experiments, followed for 15 years, indicated that most, but not all, treatments were effective in increasing vegetation recovery rates. Closure of the campsite to all use was necessary but not sufficient for recovery. Scarification, transplanting, seeding, and soil amendments individually and in combination facilitated more rapid revegetation, while the mulch mats had no effect (Cole 2007; Cole and Spildie 2006, 2007). The most pronounced failure was the response of the understory dominant *Vaccinium scoparium.* Only 45 percent of transplants survived, and the size of those plants that did survive declined for seven years. After 15 years, *V. scoparium* cover was only 1.4 percent.

This is similar to the cover of the original *V. scoparium* transplants (1.3 percent) but much less than the 27 percent cover on undisturbed sites.

So the question arises, how can *V. scoparium* be more effectively restored? Would it be more effective if transplant density and/or size were increased? Aradottir (2012) has shown that transplants of several deciduous dwarf-shrub *Vaccinium* species, morphologically similar to *V. scoparium,* were much more successful if they were at least 400 cm^2 in size. The mean diameter of *V. scoparium* transplants in the Eagle Cap study was only about 150 cm^2. Other questions are: (1) would the mulch mats have been more effective if summer conditions in the mid-1990s had not been so unusually moist; (2) if adding organic matter is beneficial, how much and what type is ideal; (3) would small amounts of bioorganic fertilizer provide some of the same benefits as large quantities of compost; and (4) since transplant mortality was particularly severe during droughty summers, would supplemental watering of plants increase success, both in addition to and instead of other restoration treatments? We implemented a series of restoration experiments on subalpine campsites in the Sawtooth Wilderness of central Idaho to address these questions.

Study Sites

The study was conducted on six campsites, three at Hell Roaring Lake (2260 m elevation) and three at Alpine Lake (2540 m elevation) (Fig. 1). The most abundant tree species around the campsites are *Pinus contorta* and *Abies lasiocarpa;* most tree regeneration is *A. lasiocarpa.* Understory vegetation is discontinuous (mean of 55 percent on undisturbed sites close to campsites). The most abundant species are *Vaccinium scoparium* (42 percent cover), *Carex geyeri* (elk sedge) (6 percent cover) and *C. rossii* (Ross' sedge) (2 percent cover). Soils are derived from granitic substrates. Although snow typically covers the ground until late June/early July, snowmelt is typically followed by hot-dry summers. The frequency of summer thunderstorms varies from year to year. When thunderstorms are infrequent, soils can be highly droughty for most of the growing season.

Figure 1—One of the campsites at Hell Roaring Lake, illustrating the high degree of groundcover disturbance prior to restoration.

Methods

Treatments

Campsite restoration began in 2006 with the closure of these sites to camping and day use, using closure signs and rope. The closures were highly effective. Over the five years of the study, nobody appeared to have camped on any of the sites. Two separate experiments were implemented on each campsite (Fig. 2). The primary experiment explored four factors and employed a split plot design. Sixteen treatment plots (1.25 m by 0.75 m) were established on each campsite. The soil was scarified on these plots using shovels, picks, pitchforks, hoes, and hand kneading to break up compaction and clods to a depth of about 20 centimeters. Substantial mixing of soil horizons was unavoidable in our resolve to develop a crumb texture. On several sites, large rocks were removed and numerous tree roots were cut and removed during scarification. This intensity of scarification exceeds that commonly undertaken on wilderness campsites.

Of the three factors in the primary split-plot experiment, the mulch treatment was the factor used to establish whole plot units because the most feasible technique was to apply mulch blankets over large areas. Eight contiguous plots on each site were covered with a mulch blanket made of curled aspen excelsior wood fibers stitched together with biodegradable thread (Curlex® NetFree™). The other eight contiguous plots were not mulched (Fig. 3). Within each of the two mulch whole plots, two levels of fertilization (fertilized or not), organic matter type (decomposed wood or decomposed wood mixed with needles and twigs), and organic matter amount (25 percent or 50 percent organic matter in the upper 15 cm of soil) were assigned to split-plot units in a completely randomized design. Each combination of these three factors occurred in each whole plot. Each campsite had a unique ordering of treatments within the mulch whole plots and provided one of six replicates.

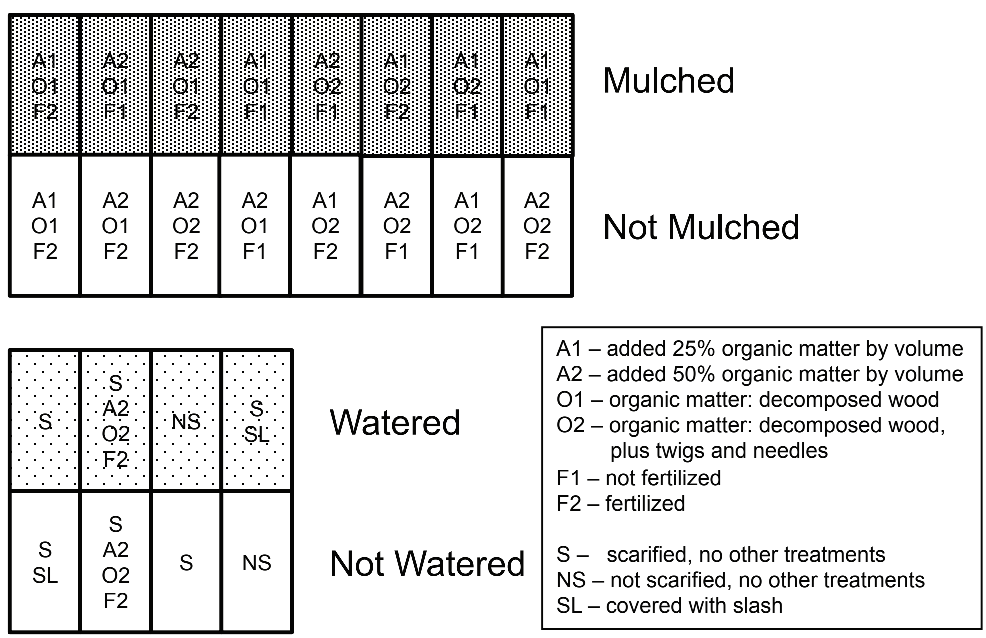

Figure 2—Distribution of treatments for the two experiments, illustrating random assignment of treatments within whole-plot mulch treatments (experiment 1) and water treatments (experiment 2).

Figure 3—Mulch treatment plots adjacent to plots that were not mulched.

Plots were prepared by adding organic matter to the scarified soil. In half the plots, the organic matter consisted entirely of highly decomposed wood, typically fallen trees that had disintegrated into wood chunks no larger than I cm in diameter (Fig. 4). In the other half of plots, the organic matter was a 2:1 mix of decomposed wood and twigs and needles from the lower branches of trees. Branches were cut to a length of no more than 15 cm with at least 50 percent green needles (Fig. 5). The reason for adding this type of organic matter was to add woody material that might resist the recompaction of soils, providing longer-lasting passages for water to enter the soil. The plots that received a lesser amount of organic matter were amended with either 25 liters of decomposed wood or 12.5 liters of decomposed wood and 6.25 liters of twigs and needles. The plots that received more organic matter were amended with either 75 liters of decomposed wood or 37.5 liters of decomposed wood and 18.75 liters of twigs and needles. After the organic matter was mixed into the soil, half of the plots received a surface application of fertilizer; the other half was not fertilized. The fertilizer applied was Biosol®, a slow release fertilizer made of 96 percent fungal biomass (dry mycelium), 3 percent potassium-magnesia and 1 percent water. It was applied at a rate of 2.5 dl per plot, the equivalent of 200 g/m, the application rate suggested for reclaiming poor soils.

The second experiment was designed primarily to assess the effects of supplemental watering, scarification, and the general effects of the soil amendments tested in the first experiment. In addition, the effects of covering the ground surface in slash were assessed. This experiment also employed a split-plot design, this time with eight plots (1.25 m by 0.75 m). Watering was the factor used to establish whole plots. Four plots on each campsite received about 7.5 liters of water once a week throughout the summer (Fig. 6); the other four plots were not irrigated.

Figure 4—Campsite at Alpine Lake with a pile of decomposed wood to be used as an organic soil amendment.

Figure 5—Amending the soils with organic matter, in this plot a combination of decomposed wood, twigs, and branches.

Figure 6—Half of the plots in experiment 2 were given supplemental water every week for five years.

Within each of the watering whole plots, each of four treatments was randomly assigned. One plot received no soil treatment—not even scarification. Another plot was just scarified. The third treatment was scarification and covering with slash, small tree branches with live needles. The fourth treatment was a replication of one of the treatments from the first experiment. It was fertilized and amended with the larger quantity of both decomposed wood and twigs and needles; there was no mulch. The slash on the plots with slash was often removed by campers and, therefore, was perceived to be ineffectual. Analysis indicated that these plots never differed significantly from those that were only scarified. Consequently, they are not included in the analysis.

Every plot in both experiments was planted in an identical manner. Each plot received three *Vaccinium scoparium* transplants dug up in the vicinity. Only a few of the transplants had established plants of other species, although many could have harbored viable seed. Transplants were variable in size but most were between 150 and 400 cm^2 with a mean of 315 cm^2. Transplanting involved digging a hole and placing transplants in the hole (Fig. 7) along with Vita-start (vitamin B-1) to reduce transplant shock and giving each transplant 0.6 liters of water. One transplant in each plot had about one-half of its foliage pruned to assess the effect of pruning. On mulched plots, holes were cut in the blanket so transplants emerged from underneath the blanket.

Figure 7—Planting a *Vaccinium scoparium* transplant.

Each plot was also seeded with an equivalent quantity of locally collected seed. At Hell Roaring campsites, each plot received seed in the following quantities: 5.75 g of *Symphyotrichum spathulatum* (western mountain aster), 8.3 g of *Packera streptanthifolia* (Rocky Mountain groundsel), and 3.2 g of *Festuca idahoensis* (Idaho fescue). At Alpine Lake campsites, each plot received seed in the following quantities: 3.5 g of *Juncus parryi* (Parry's rush), 4.3 g of *Antennaria microphylla* (rosy pussy-toes), 8 g of *Packera streptanthifolia,* 4 g of *Arnica cordifolia* (heart-leaf arnica), 5.5 g of *Penstemon globosus* (globe penstemon), and 3.5 g of *Chionophila tweedyi* (Tweedy's snowlover). The quantity of seed we had was minimal. Seeds were broadcast prior to transplanting and many were undoubtedly buried during transplanting. Only 176 individuals of the species we seeded ever established. This is less than 15% of the individuals that established from seed and suggests that results would have been little different if we had not seeded plots.

Measurements

Vegetation response measurements were taken every year for five years in 1 m by 0.5 m quadrats, centered within each plot. This left an unmeasured 0.25 m buffer between quadrats. We measured transplant survival and size, seedling density, and cover by species. For each live transplant, we mapped the areal extent of canopy cover using a 1 m by 0.5 m PVC frame with a 5 cm by 5 cm grid (Fig. 8), providing estimates of both the area of each transplant and the percent cover of transplants. We also recorded the maximum height of each transplant. Measurements were taken immediately after transplanting and pruning (September 2006) and in late August or early September of each year thereafter.

Figure 8—Transplant area was assessed by mapping each transplant using a gridded quadrat.

Plants that established from seed were counted, by species, within a 1 m by 0.5 m PVC frame. For each of these species, we also ocularly estimated cover to the closest percent if cover was 10 percent or less and in 10 percent increments thereafter. Density measures were most precise during the first years after treatment; as graminoids particularly coalesced, it became increasingly difficult to decide on the number of individuals in a clump. Conversely, cover estimates became increasingly precise over time as the size of individuals increased. A few mature plants that were harbored within the transplants are undoubtedly included.

Total vegetation cover and the cover of individual species were estimated in undisturbed plots near to each restored campsite. The means from these six plots are used as targets for successful restoration.

Data Analysis and Presentation

For the primary experiment, we performed repeated measures analyses of variance, appropriate for split-plot designs (using an autoregressive covariance structure, PROC GLIMMIX in SAS 9.3). The density data approximated a Poisson distribution; they were square-root transformed to better comply with assumptions about normality. The transplant and cover data did not require transformation. For the four factors included in the split-plot design (mulch, fertilization, organic type, and organic amount), main effects of each factor and interactions among factors were assessed. In some cases, factor main effects interacted significantly with time since treatment. In these cases, we describe treatment effects for each of the five years of the experiment, but the significance of effects is only assessed at the end of the experiment in 2011. In cases where treatment interactions with time were not significant, we report results of the repeated measures analyses.

We used data from the second experiment to assess hypotheses that scarification, slash, and supplemental watering would each have positive effects. As noted before, the slash treatment was compromised, ineffectual, and will not be discussed further. As with the primary experiment, we performed repeated measures analyses of variance, appropriate for split-plot designs. The two factors in the split-plot design were watering and treatment. Within treatment, we compared plots that were not scarified with plots that were scarified but received no other soil amendments. We assessed our hypothesis that scarification would be beneficial using one-tailed Tukey-Kramer tests. We also assessed the effects of pruning on transplants using two-tailed t-tests.

Finally, to assess whether the types of soil amendments we included in the primary experiment were beneficial, we compared plots that were scarified but did not receive any soil amendments (from the second experiment) to the non-mulched plots in the primary experiment. We used a univariate analysis of variance, with campsite as a block, to evaluate the hypothesis that the soil amendments generally would have a positive effect.

Results

Over the first five years following treatment, total vegetation cover increased from 0 to 31 percent on the plots with soil amendments (Fig. 9). The response of the transplants differed substantially from that of plants that established from seed. Transplant

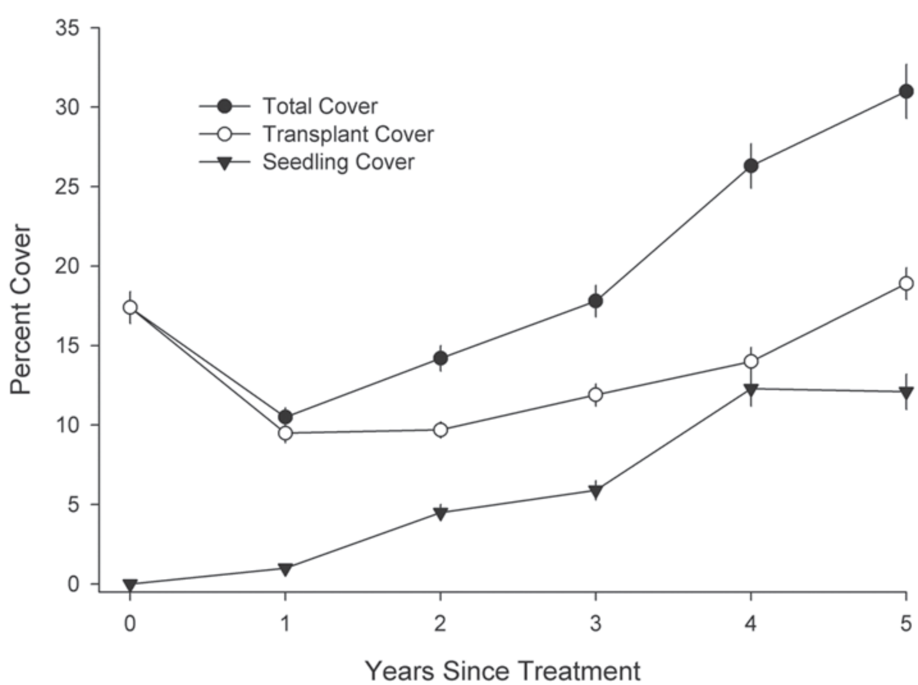

Figure 9—Variation in the cover of transplants, plants that established from seed and total cover, on plots that received soil amendments over the five years of the experiment.

cover declined the first year after treatment and increased slowly thereafter. After five years, *Vaccinium scoparium* transplant cover (19 percent) exceeded the cover that was planted on the plots (17 percent). Seedling cover increased more steadily and rapidly for the first four years after treatment, declining slightly in the fifth year.

Five years after treatment, total vegetation cover was significantly higher on plots that were scarified but without soil amendments (27 percent) than on plots that were not scarified (16 percent) (Tukey-Kramer, $t = 3.0$, $p<0.01$). Both plots that were and were not irrigated are included. Total vegetation was also significantly higher on plots with soil amendments (31 percent) than on plots that were scarified but neither amended nor irrigated (19 percent) (ANOVA, $F = 3.9$, $p = 0.02$). None of the treatments explored in the primary experiment had as pronounced a beneficial effect on total vegetation cover as scarification and organic soil amendments. Fertilization had a significant but small effect on total vegetation cover (Table 1). After five years, mean total vegetation cover was 33 percent on plots that were fertilized and 29 percent on plots that were not fertilized. Cover did not vary significantly with mulch, organic type, or organic amount. However, the effects of these treatments on the transplants differed from effects on plants that established from seed. Consequently, these effects will be explored separately.

Table 1—Effects of fertilizer, organic type, organic amount, and mulch on total vegetation cover, repeated measures analysis of variance[a].

Effect	df	F	p
Fertilizer	1	4.7	**0.03**
Organic Type	1	0.3	0.61
Organic Amount	1	2.2	0.14
Mulch	1	0.1	0.80
Year	4	80.4	**<0.01**

[a] Interactions that are not significant ($p \leq 0.05$) are not shown. Effects with bold numbers are significant.

Effects on Transplants

Changes in *Vaccinium scoparium* transplant cover were reflective of both transplant survival and change in the size of surviving transplants. Transplant survival was high; 92 percent of the transplants in the primary experiment were still alive after five years. Transplant survival was significantly higher on plots that were scarified but without soil amendments (89 percent) than on plots that were not scarified (72 percent) (Tukey-Kramer, $t = 1.9$, $p = 0.03$). Survival was also higher on plots with soil amendments (92 percent) than on plots that were scarified but neither amended nor irrigated (83 percent); however, this difference was not statistically significant (ANOVA, $F = 2.0$, $p = 0.08$). Moreover, none of the treatments in the primary experiment (mulch, fertilization, organic type, or organic amount) had a significant effect on transplant survival.

Mean Transplant Area—The mean size of transplants was affected by scarification, soil amendments, and, to a lesser degree, the nature of those amendments. Five years after treatment, the mean size of surviving transplants on plots that were scarified but without soil amendments was 331 cm^2. This is significantly higher (Tukey-Kramer, $t = 2.5$, $p = 0.01$) than on plots that were not scarified (259 cm^2) (Fig. 10). Mean surviving transplant area was also higher on plots with soil amendments (335 cm^2) than on plots that were scarified but neither amended nor irrigated (211 cm^2) (ANOVA, $F = 5.0$, $p = 0.01$) (Fig. 11).

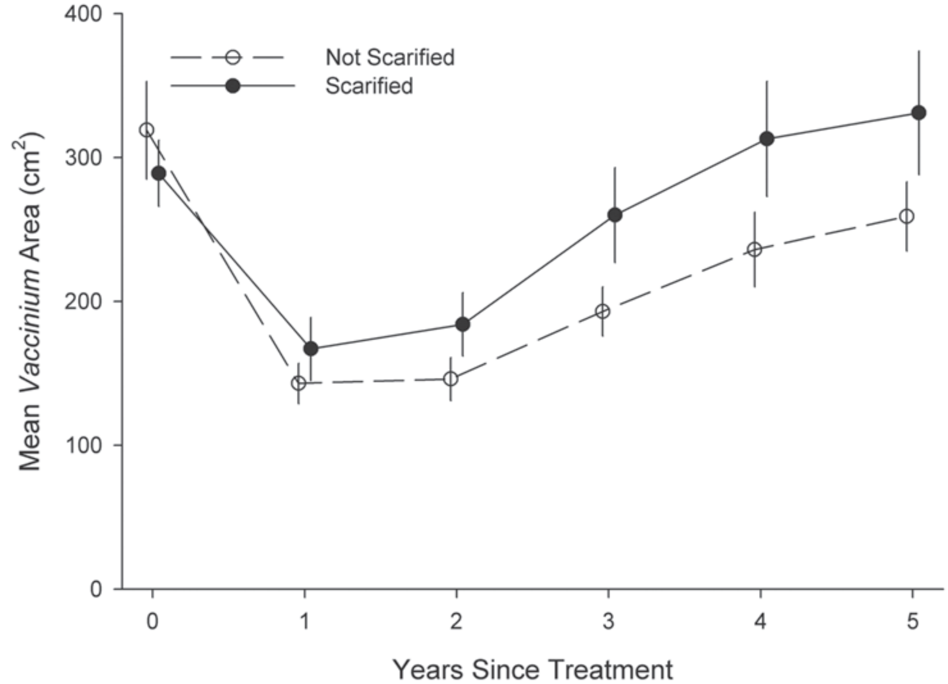

Figure 10—Effect of scarification on the mean size of *Vaccinium* transplants. Both irrigated and non-irrigated plots are included.

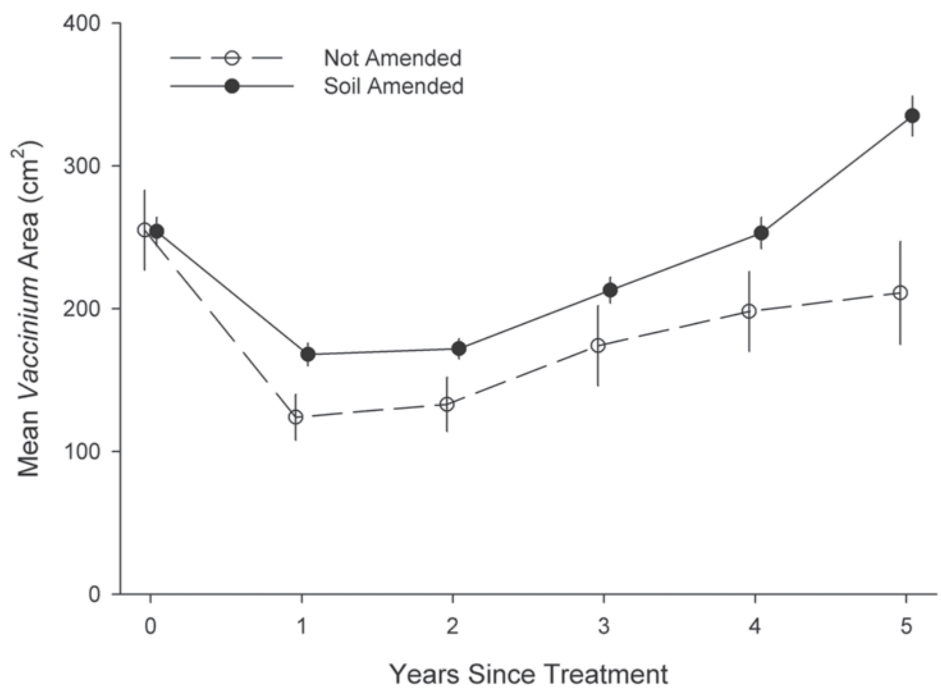

Figure 11—Effect of organic soil amendments on the mean size of *Vaccinium* transplants.

The effects of mulch, fertilization, and the organic amendments did not interact with year, so the results of the repeated measures analysis of variance can be used (Table 2). Results suggest that variation in the effectiveness of these treatments was small in comparison to the effectiveness of scarification and amending soils with organic matter. Of the main effects, only amount of organic matter significantly affected transplant size (Fig. 12); transplant size was greater when less organic matter was applied—25 percent by volume rather than 50 percent. However, there were complex significant interactions among mulch, fertilizer, organic type, and organic amount (Table 2). This suggests that certain combinations of treatment might be substantially more effective than other combinations.

Table 2—Effects of fertilizer, organic type, organic amount, and mulch on mean size of surviving transplants, repeated measures analysis of variance[a].

Effect	df	F	p
Fertilizer (F)	1	0.0	0.99
Organic Type (OT)	1	1.2	0.28
Organic Amount (OA)	1	8.4	**<0.01**
Mulch (M)	1	2.6	0.17
M*OT	1	6.4	**0.01**
F*OT	1	4.6	**0.04**
M*OT*OA	1	3.7	**0.05**
Year	4	55.4	**<0.01**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

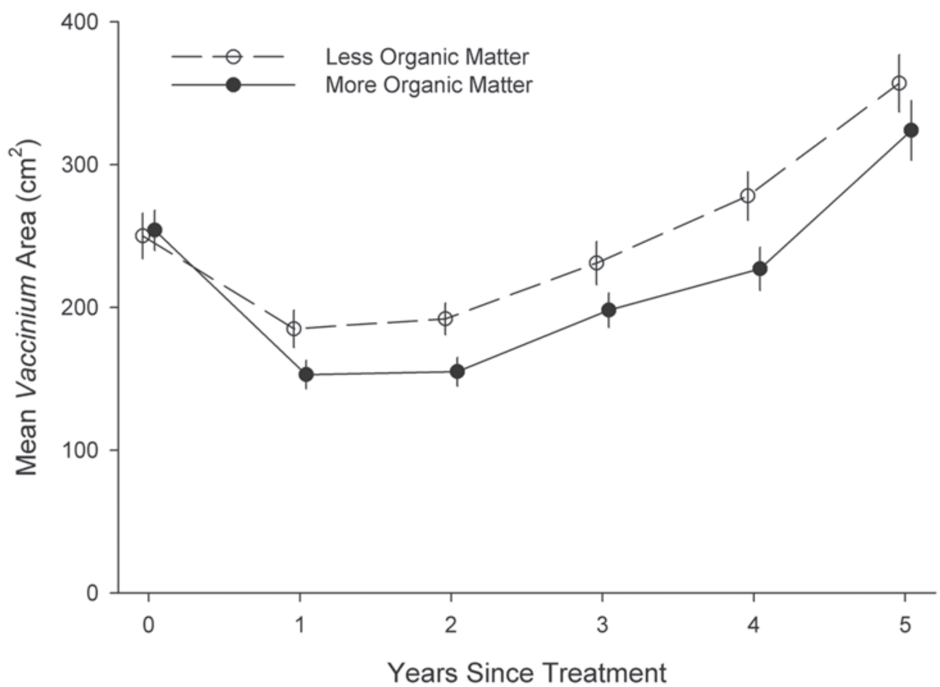

Figure 12—Effect of the amount of organic matter added to the soil on the mean size of *Vaccinium* transplants.

If plots were fertilized, mean transplant size in 2011 differed little between plots amended with decomposed wood (336 cm^2) and those amended with decomposed wood and twigs/needles (341 cm^2). However, on plots that were not fertilized, mean transplant size in 2011 was substantially less on plots amended with decomposed wood (302 cm^2) compared to those amended with decomposed wood and twigs/needles (380 cm^2). The beneficial effect of using a lesser amount of organic matter is consistent but only substantial on plots that were not mulched and amended with decomposed wood and twigs/needles (Fig. 13). On mulched plots, organic type and amount did not have a substantial effect on transplant size. On plots that were not mulched, however, transplant size was substantially higher on plots that were amended with lower quantities of decomposed wood and twigs/needles than on plots amended with either decomposed wood only or larger quantities of decomposed wood and twigs/needles.

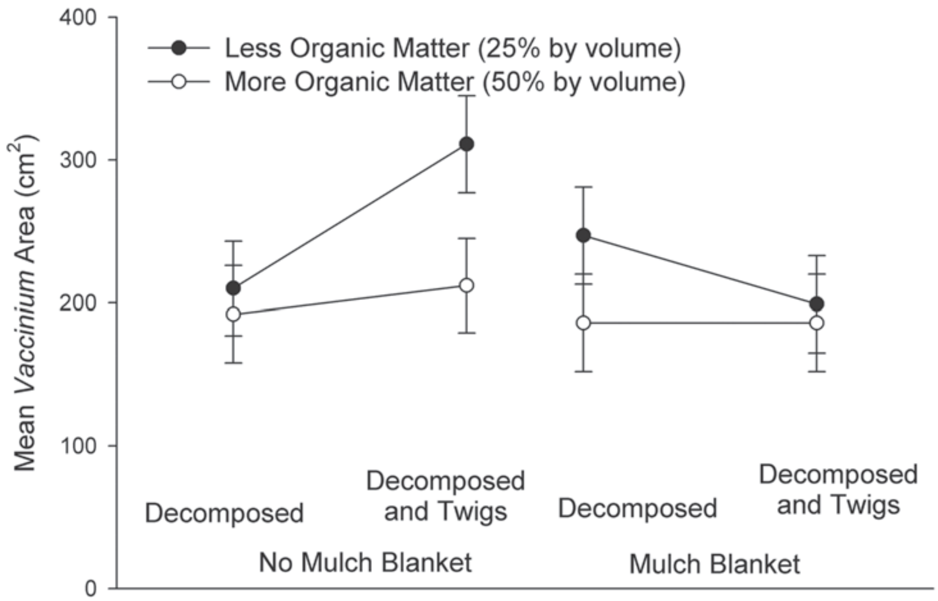

Figure 13—Interactive effect of mulch, organic type, and organic amount on the mean size of *Vaccinium* transplants, averaged across the five years following treatment.

Mean Transplant Height—Five years after treatment, the mean maximum height of surviving transplants on plots that were scarified but without soil amendments was 12.1 cm. This is significantly higher (Tukey-Kramer, $t = 2.2$, $p = 0.02$) than on plots that were not scarified (11.0 cm). Mean surviving transplant height was not significantly higher on plots with soil amendments (11.8 cm) than on plots that were scarified but neither amended nor irrigated (11.3 cm) (ANOVA, $F = .30$, $p = 0.30$). However, height did vary significantly, if not substantially, with treatment. As was the case with transplant area, the only significant main effect was organic amount (Table 3), but there were complex significant interactions among mulch, fertilization, organic type, and organic amount.

Five years after treatment, mean maximum height was 12.3 cm on plots that received lesser quantities of organic matter and 11.5 cm on plots that received more organic matter. However, this difference was only substantial on plots that were either fertilized but not mulched or mulched but not fertilized (Fig. 14). If plots were fertilized, organic matter type made little difference. However, on plots that were not fertilized, transplant height in 2011 was substantially less on plots amended with decomposed wood (10.2 cm) compared to those amended with decomposed wood and twigs/needles (12.1 cm).

Table 3—Effects of fertilizer, organic type, organic amount, and mulch on mean height of surviving transplants, repeated measures analysis of variance[a].

Effect	df	F	p
Fertilizer (F)	1	0.3	0.60
Organic Type (OT)	1	0.6	0.46
Organic Amount (OA)	1	6.1	**0.02**
Mulch (M)	1	0.1	0.83
F*OT	1	6.6	**0.01**
M*F*OA	1	3.8	**0.05**
Year	4	6.0	**<0.01**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

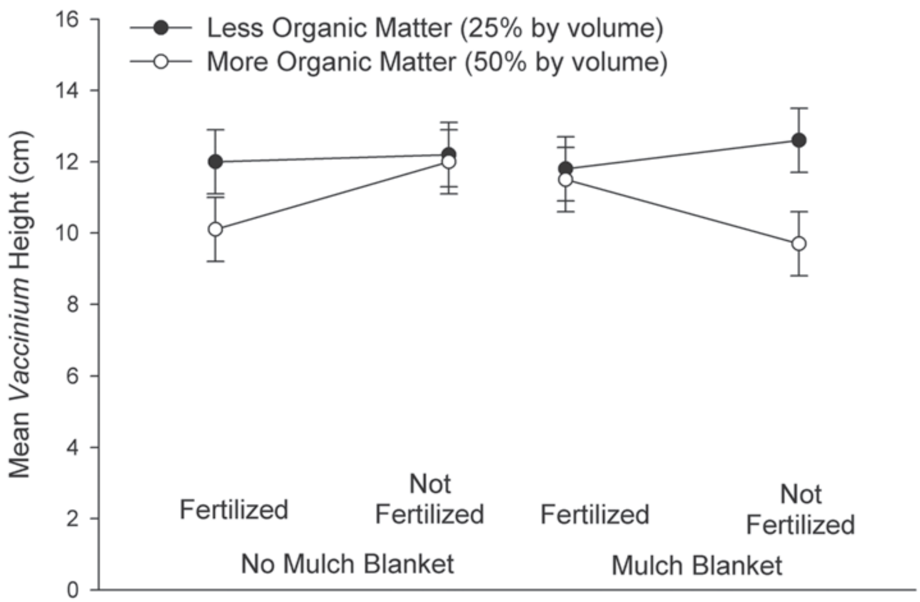

Figure 14—Interactive effect of mulch, fertilizer, and organic amount on the mean maximum height of *Vaccinium* transplants, averaged across the five years following treatment.

Effect of Pruning—Pruning the foliage of *Vaccinium scoparium* transplants after they were planted did not have a beneficial effect on transplant survival or growth. After five years, the survival rate of pruned transplants (90 percent) did not differ significantly from the survival rate of transplants that were not pruned (91 percent) (chi-square, $X^2 = 0.1$, p = 0.81). The mean size of pruned transplants was smaller than the mean size of transplants that were not pruned. This difference was statistically significant for the first four years after treatment. By 2011, however, the difference between pruned transplants (316 cm^2; SE = 18 cm^2) and non-pruned transplants (344 cm^2; SE = 15 cm^2) was not significant (t-test, t = 1.2, p = 0.23).

Effect of Transplant Size—The original size of *Vaccinium scoparium* transplants ranged from 20 cm^2 to 1173 cm^2. Survival declined as original transplant size declined (Fig. 15). The mean size of transplants that died was 215 cm^2 (SE = 25 cm^2) compared to a mean size of 300 cm^2 (SE = 11 cm^2) for transplants that survived (t-test, $t = 3.1$, $p < 0.01$). However, if they survived, the smaller transplants grew more than the larger transplants. Change in transplant area between 2006 and 2011 was negatively correlated with original transplant area ($r = -.43$, $p<0.01$). The mean change in area of the 100 smallest transplants (originally ≤200 cm^2 in size) was an increase of 115 cm^2 (SE = 17 cm^2); the mean change for the 100 largest transplants (originally ≥315 cm^2 in size) was a decrease in area of 37 cm^2 (SE = 17 cm^2).

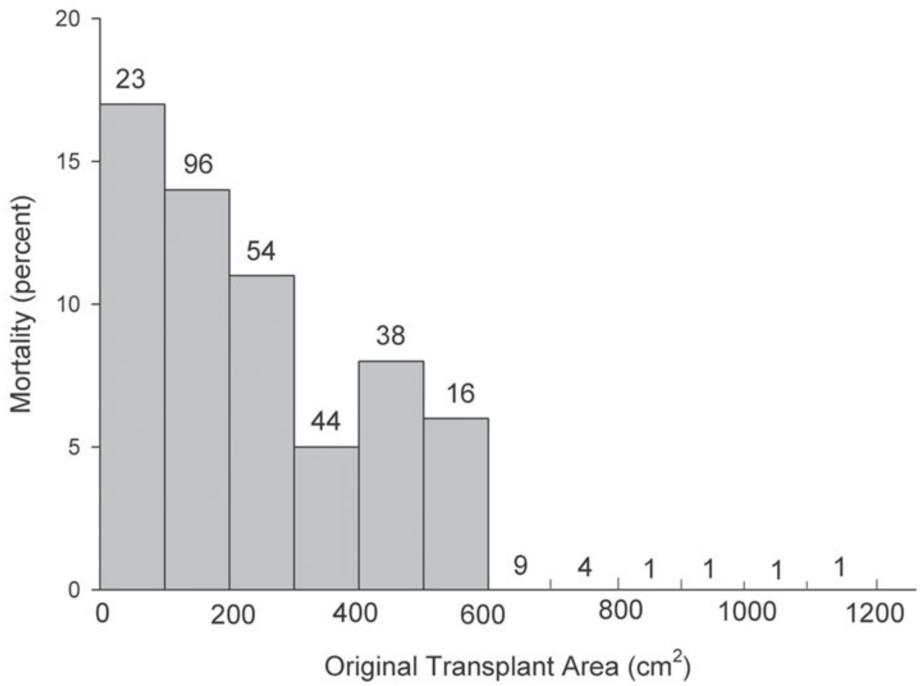

Figure 15—Variation in mortality with original size of *Vaccinium scoparium* transplants. Values are the number of transplants in that size class.

Effects on Plants Establishing From Seed

For the plants that established from seed, we assessed both plant density and plant cover. The density of tree seedlings and forbs were relatively constant over time (Fig. 16). Most of the plants that established did so the first year after treatment. Graminoid density increased for the first three years after treatment and decreased thereafter. This decrease may be an artifact of the tendency for individuals to coalesce as they grow, making density appear to be less than it actually is. Seedling cover of each of these growth forms increased much more over time (Fig. 17).

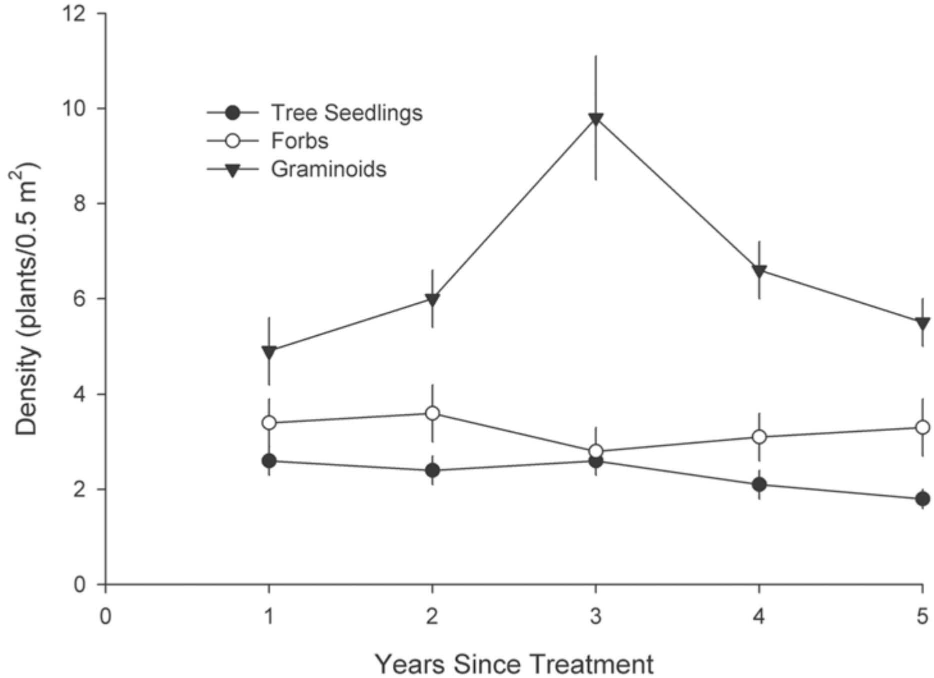

Figure 16—Variation in the density of trees, graminoids, and forbs that established from seed on plots that received soil amendments, over the five years of the experiment.

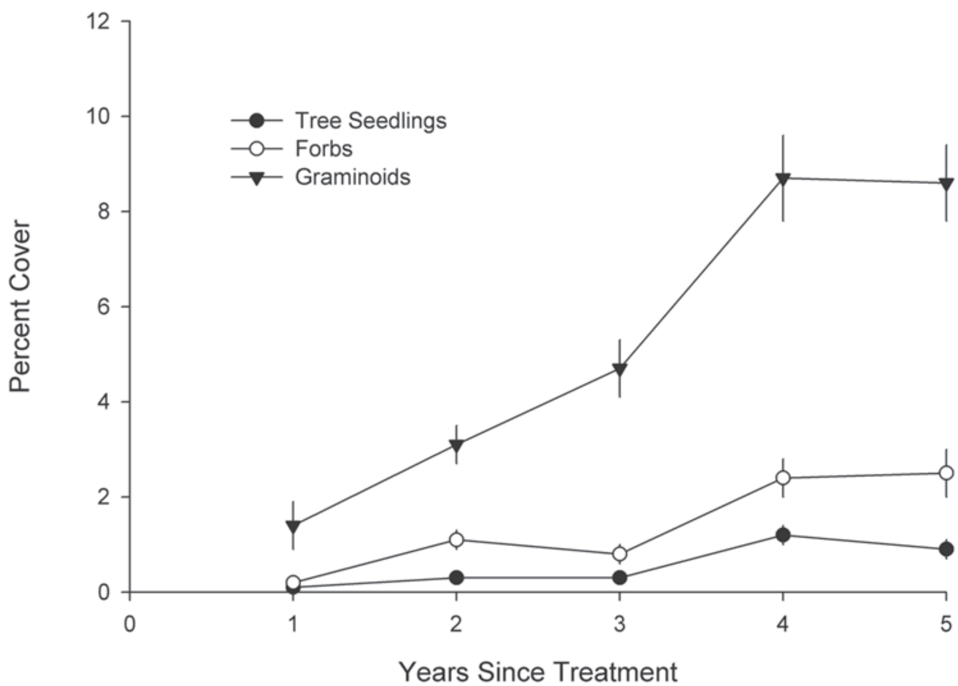

Figure 17—Variation in the percent cover of trees, graminoids, and forbs that established from seed on plots that received soil amendments, over the five years of the experiment.

Five years after treatment, on plots in the primary experiment, 31 species had established from seed (Table 4). Most of these species were infrequently encountered and contributed little cover. Only 11 of these species occurred on at least 10 percent of the plots, including 3 of the 8 species that were seeded—*Festuca idahoensis*, *Juncus parryi*, and *Penstemon globosus*. Only *Carex rossii, C. geyeri*, and *Pinus contorta* had a mean cover that exceeded 0.5 percent (Fig. 18); none of these were seeded. However, both *Carex rossii* and *C. geyeri* were present in some of the *Vacciunium scoparium* transplants. Five years after treatment, *Carex rossi* accounted for 56 percent of total seedling cover.

Seedling Density—As was the case with the transplants, the density of plants that established from seed was affected by scarification, soil amendments, and, to a lesser degree, the nature of those amendments. Five years after treatment, the mean density of plants established from seed on plots that were scarified but without soil amendments was 21 plants/m^2, with a standard error of 5 plants/m^2. This is significantly higher (Tukey-Kramer, $t = 2.5$, $p = 0.01$) than on plots that were not scarified (10 plants/m^2; SE = 3 plants/m^2). Mean density was also higher on plots with soil amendments (21 plants/m^2;

Table 4—Frequency, density, and cover of species that established from seed on plots in the primary experiment.

Species	Number of plots	Total seedlings	Mean density (#/m^2)	Mean cover (%)
Abies lasiocarpa	21	36	0.8	0.1
Achillea millefolium	2	10	0.2	0.1
Anaphalis margaretacea	2	2	<0.1	<0.1
Arnica cordifolia (s)*	9	32	0.7	0.3
*Arnica mollis**	14	44	0.9	0.4
Calamagrostis canadensis	5	17	0.4	0.1
Calamagrostis rubescens	7	9	0.2	0.2
*Carex geyeri**	16	18	0.4	0.6
Carex microptera	3	3	<0.1	<0.1
*Carex rossii**	86	424	8.8	6.8
*Chamerion angustifolium**	13	26	0.5	0.2
Chionophila tweedyi (s)	4	9	0.2	<0.1
Danthonia intermedia	2	2	<0.1	<0.1
Dodecatheon jeffreyi	1	1	<0.1	0.1
*Erigeron peregrinus**	14	43	0.9	0.4
Festuca idahoensis (s)	14	15	0.3	0.4
*Hieracium gracile**	15	38	0.8	0.2
Juncus drummondii	1	1	<0.1	<0.1
Juncus parryi (s)	10	19	0.4	0.2
Ligusticum tenuifolium	1	1	<0.1	<0.1
Muhlenbergia filiformis	3	5	0.1	<0.1
Packera streptanthifolia (s)	9	33	0.7	0.3
Pedicularis racemosa	2	4	0.1	<0.1
Penstemon globosus (s)	10	18	0.4	0.1
Phlox longifolia	2	5	0.1	<0.1
Pinus contorta	64	138	2.9	0.8
Poa secunda	2	2	<0.1	<0.1
Ribes sp.	1	1	<0.1	<0.1
Solidago multiradiata	3	10	0.2	0.2
Stipa lettermanii	6	11	0.2	0.2
Trisetum spicatum	1	1	<0.1	<0.1
Valeriana edulis	2	7	0.1	0.1
*Viola adunca**	7	30	0.6	0.1

(s) Seeded species.
* A few of these individuals were present in the *Vaccinium scoparium* transplants.

Figure 18—A plot with substantial *Carex rossii* cover, as well as tree seedlings and a flowering *Erigeron peregrinus.*

SE = 2 plants/ m^2) than on plots that were scarified but neither amended nor irrigated (16 plants/m^2; SE= 5 plants/ m^2). Based on the repeated measures analysis, this difference is statistically significant (ANOVA, $F = 3.8$, $p = 0.03$) and amendment effects do not interact with year (ANOVA, $F = 1.0$, $p = 0.38$); however, in 2011, differences were not statistically significant at an alpha level of 0.05 (ANOVA, $F = 2.6$, $p = 0.06$) (Fig. 19).

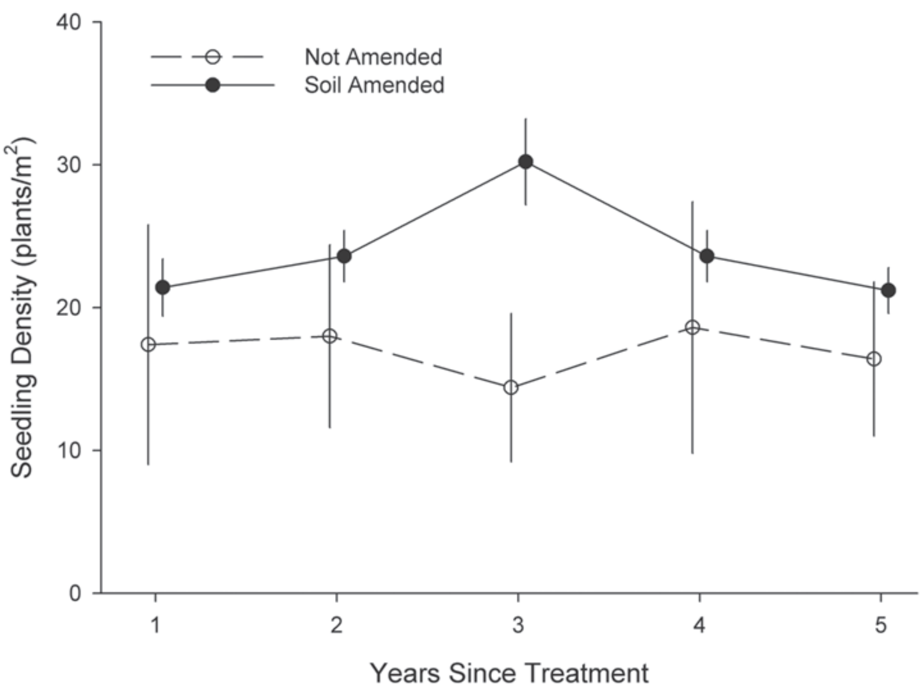

Figure 19—Effect of organic soil amendments on the density of plants that established from seed.

In the repeated measures ANOVA, the effects of mulch and organic type interacted significantly with year, so only the 2011 results are presented. Significantly more plants established from seed on plots that were fertilized (Table 5). Mean seedling density in 2011 was 24 plants/m^2 on fertilized plots compared to 19 plants/m^2 on plots that were not fertilized (Fig. 20). The significant interaction between mulch and organic amount suggests that (1) when less organic matter is applied (25 percent by volume), mulched plots have significantly higher densities; and (2) when there is no mulch, plots amended with higher quantities of organic matter (50 percent by volume) have higher densities.

The effects of these treatments varied between growth forms. Since most seedlings are graminoids (Fig. 16), the treatments that affect graminoid density (primarily fertilization) are the treatments that affect total seedling density. However, the density of tree seedlings was not significantly affected by fertilization; instead, it was influenced by organic amount. In 2011, plots amended with less organic matter had significantly more tree seedlings (5 plants/m^2) than plots amended with more organic matter (3 plants/m^2) (ANOVA, $F = 21.5$, $p<0.01$). Forb density was also influenced by organic amount but in an opposing manner. In 2011, plots amended with less organic matter had significantly fewer forb seedlings (7 plants/m^2) than plots amended with more organic matter (5 plants/m^2) (ANOVA, $F = 4.3$, $p = 0.04$).

Table 5—Effects of fertilizer, organic type, organic amount, and mulch on density of plants that established from seed, in 2011[a].

Effect	df	F	p
Fertilizer	1	6.5	**0.01**
Organic Type	1	3.4	0.07
Organic Amount (OA)	1	0.0	0.85
Mulch (M)	1	0.5	0.51
OA*M	1	4.8	**0.03**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

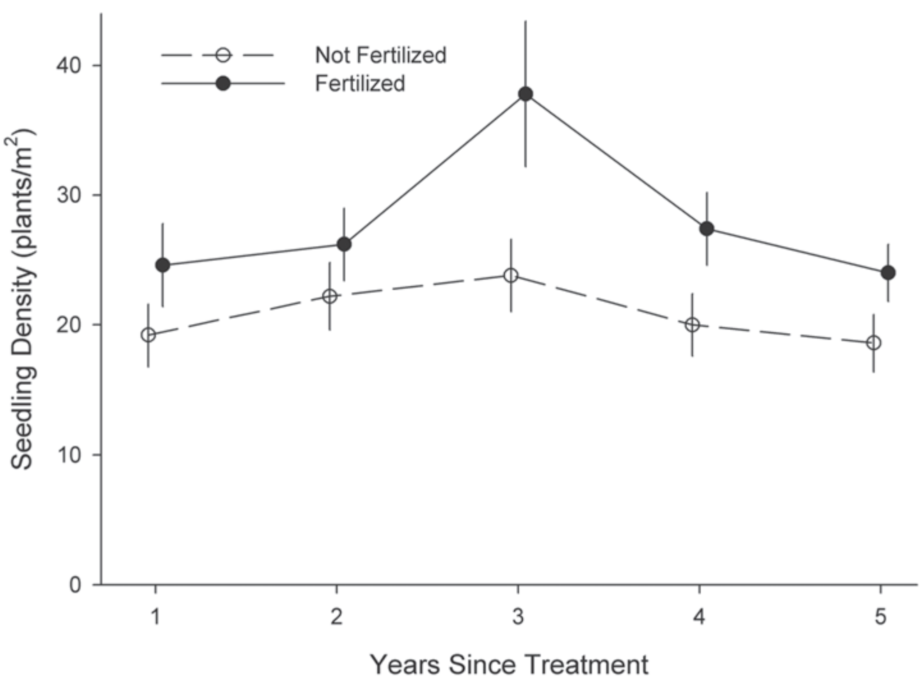

Figure 20—Effect of fertilization on the density of plants that established from seed.

Seedling Cover—Seedling cover was affected by scarification and particular types of soil organic amendments. Five years after treatment, the mean cover of plants established from seed on plots that were scarified but without soil amendments was 10 percent, with a standard error of 3 percent. Mean cover was substantially lower on plots that were not scarified (5 percent; SE = 2 percent), but the difference was not statistically significant (Tukey-Kramer, t = 1.7, p = 0.05). Mean cover was also higher on plots with soil amendments (12 percent; SE= 1 percent) than on plots that were scarified but neither amended nor irrigated (8 percent; SE = 4 percent). Although this difference was also not statistically significant (ANOVA, F = 1.1, p = 0.14), the effects of scarification and amendment appear to be additive. The difference between plots that were both scarified and amended (12 percent cover) and plots that were neither scarified nor amended (5 percent cover) was highly significant (Tukey-Kramer, t = 3.1, p<0.01).

In the repeated measures ANOVA, the effects of fertilization interacted significantly with year, so only the 2011 results are presented. The cover of plants established from seed was significantly higher on plots that were fertilized (Table 6). Mean seedling cover in 2011 was 14 percent on fertilized plots compared to 10 percent on plots that were not fertilized (Fig. 21). As was the case with seedling density, there is a significant interaction between mulch and organic amount. Mean seedling cover varied from 17 percent (SE = 3 percent) on mulched plots that received less organic matter to 8 percent (SE = 1 percent) on plots that were not mulched and received less organic matter; cover was 11 percent (SE = 2 percent) on plots that received more organic matter and were mulched and 12 percent (SE = 2 percent) on plots that received more organic matter and were not mulched. Differences associated with organic amount were not significant regardless of whether plots were mulched (t-test, t = 1.7, p = 0.10) or not mulched (t-test, t = 1.7, p = 0.10). When less organic matter was applied, seedling cover was significantly higher when plots were mulched (t-test, t = 2.6, p = 0.01); seedling cover did not vary significantly with mulch treatment when more organic matter was applied (t-test, t = 0.5, p = 0.62).

The effects of these treatments varied between growth forms. Graminoid cover was significantly higher when the soil on plots was amended with organic matter and when the amendments included fertilization, but scarification did not have a significant effect. Five years after treatment, mean graminoid cover was 5 percent on plots that were scarified but without soil amendments and 3 percent on plots that were not scarified (Tukey-Kramer, t = 0.8, p = 0.20). Graminoid cover was 9 percent (SE = 1 percent) on plots with soil amendments and 4 percent (SE = 2 percent) on plots that were scarified but neither amended nor irrigated (ANOVA, F = 2.7, p = 0.05) (Fig. 22). Fertilized plots had significantly more graminoid cover (mean = 11 percent; SE = 1 percent) than plots that were not fertilized (mean = 7 percent; SE = 1 percent) (Table 7).

Table 6—Effects of fertilizer, organic type, organic amount, and mulch on cover of plants that established from seed, in 2011[a].

Effect	df	F	p
Fertilizer	1	6.4	**0.01**
Organic Type	1	0.5	0.48
Organic Amount (OA)	1	0.5	0.47
Mulch (M)	1	1.4	0.29
OA*M	1	7.1	<**0.01**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

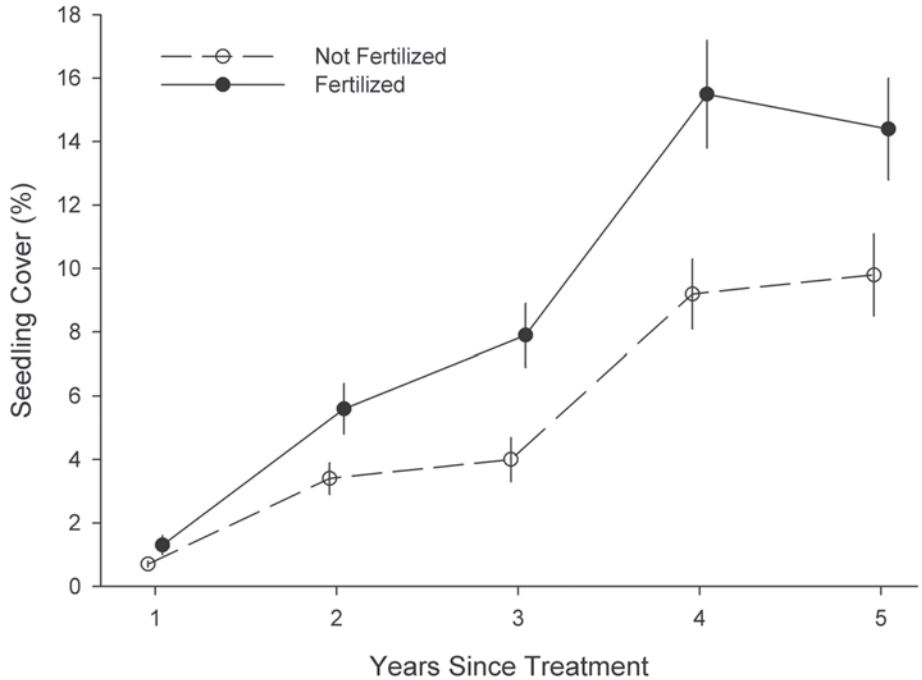

Figure 21—Effect of fertilization on the cover of plants that established from seed.

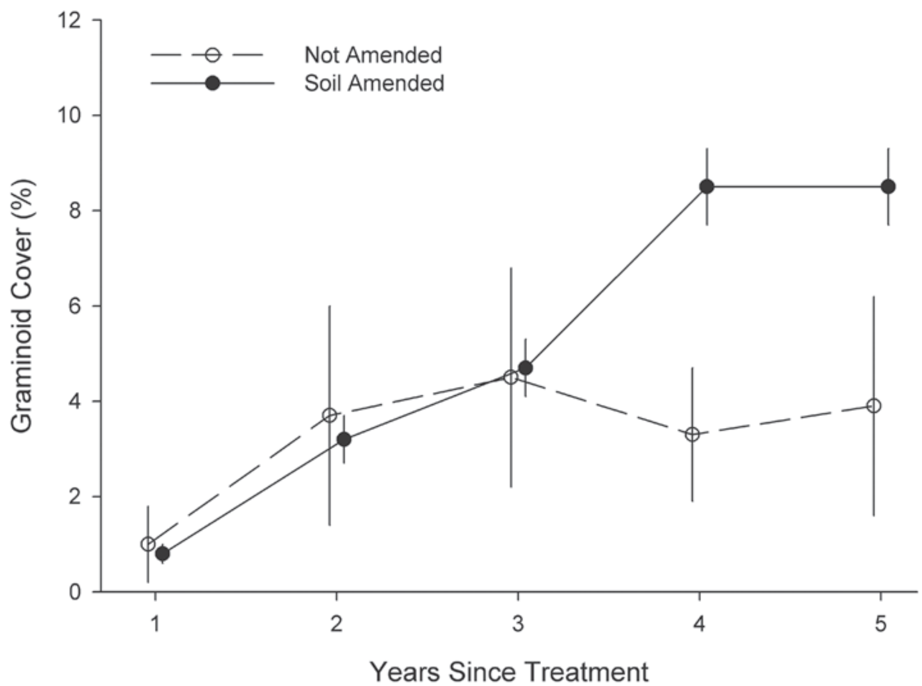

Figure 22—Effect of organic soil amendments on the cover of graminoids that established from seed.

Table 7—Effects of fertilizer, organic type, organic amount, and mulch on cover of graminoids that established from seed, in 2011[a].

Effect	df	F	p
Fertilizer (F)	1	9.3	<**0.01**
Organic Type	1	0.0	0.96
Organic Amount (OA)	1	0.5	0.49
Mulch (M)	1	1.6	0.26
OA*M	1	4.9	**0.03**
F*OA*M	1	4.4	**0.04**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

Overall, mulching did not have a significant effect on graminoid cover (Fig. 23). There was also a significant interaction among fertilization, mulch, and organic amount. Mean graminoid cover varied from 14 percent (SE = 3 percent) on plots that were mulched, fertilized, and received less organic matter to 5 and 4 percent (SE = 1 percent) on plots that were not mulched and not fertilized, with less and more organic material, respectively. Teasing this apart, when not fertilized, graminoid cover was significantly higher on plots that were mulched (9 percent; SE = 2 percent) than on plots that were not mulched (4 percent; SE = 1 percent) (ANOVA, F = 5.3, p = 0.03). Graminoid cover was also significantly higher on mulched plots (12 percent; SE = 2 percent) than on non-mulched plots (6 percent; SE = 1 percent) when less organic matter (25 percent by volume) was applied (t-test, t = 2.3, p = 0.03). Mulching did not affect graminoid cover when more organic matter (50 percent by volume) was applied (t-test, t = 0.2, p = 0.82).

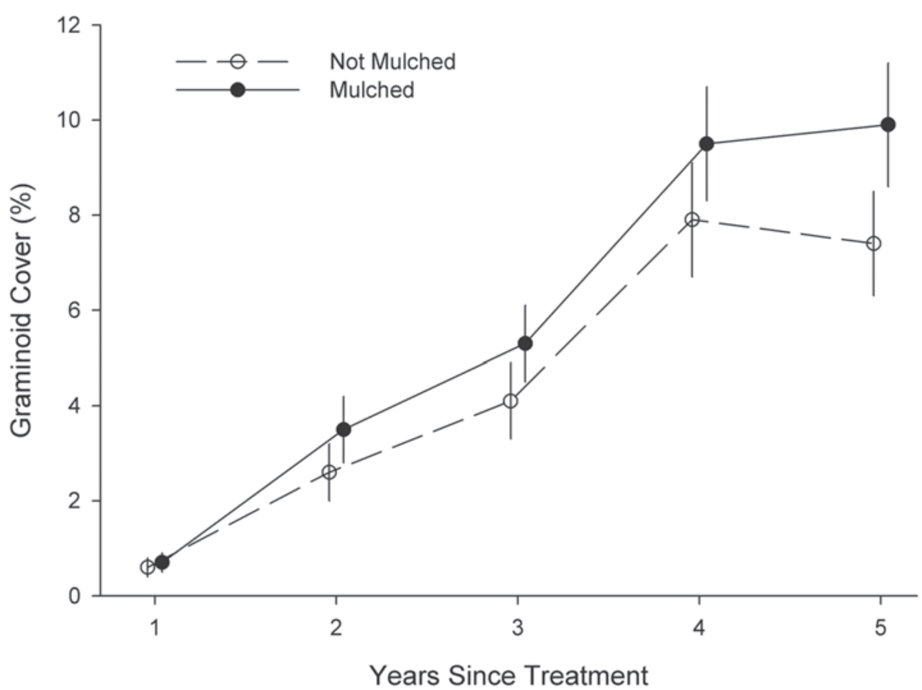

Figure 23—Effect of the mulch blanket on the cover of graminoids that established from seed. The mulch was beneficial on plots that were not fertilized or amended with less organic matter.

The cover of tree seedlings did not differ significantly (at an alpha of 0.05) with either scarification (ANOVA, F = 1.4, p = 0.08) or with the soil amendments (ANOVA, F = 0.2, p = 0.31). As was the case with tree seedling density, tree seedling cover differed significantly with organic amount (Table 8). Cover was significantly higher on plots that were amended with less organic matter (Fig. 24). Forb cover also did not differ significantly with either scarification (ANOVA, F = 1.0, p = 0.17) or with the soil amendments (ANOVA, F = 0.1, p = 0.44). The specific amendments applied also made little difference (Table 9). Exploration of the significant interaction between mulch and organic amount showed that when there was no mulch, forb cover was significantly higher on plots amended with more organic matter (3 percent; SE = 1 percent) than on plots with less organic matter (1 percent; SE<1 percent) (t-test, t = 2.2, p = 0.03).

Table 8—Effects of fertilizer, organic type, organic amount, and mulch on tree seedling cover, repeated measures analysis of variance[a].

Effect	df	F	p
Fertilizer	1	1.6	0.21
Organic Type	1	1.3	0.26
Organic Amount	1	4.2	**0.04**
Mulch	1	0.0	0.93
Year	4	19.8	**<0.01**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

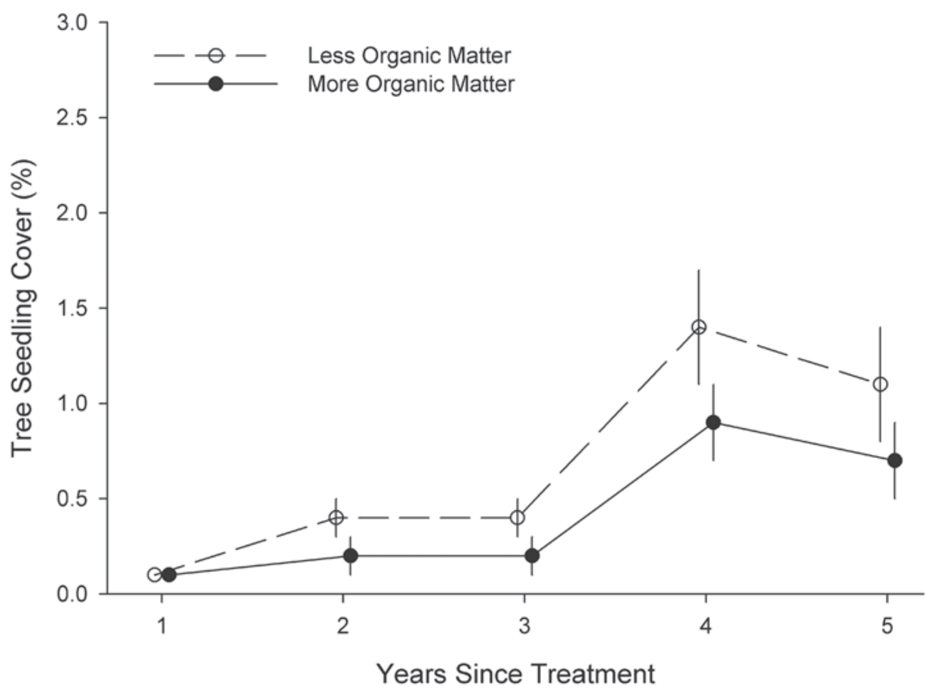

Figure 24—Effect of the amount of organic matter added to soil on the cover of tree seedlings.

Table 9—Effects of fertilizer, organic type, organic amount, and mulch on cover of forbs that established from seed, repeated measures analysis of variance[a].

Effect	df	F	p
Fertilizer	1	0.4	0.55
Organic Type	1	1.2	0.27
Organic Amount (OA)	1	1.2	0.27
Mulch (M)	1	0.2	0.69
OA*M	1	4.0	**0.05**
Year	4	19.8	**<0.01**

[a] Interactions that are not significant (p≤0.05) are not shown. Effects with bold numbers are significant.

Effects of Supplemental Watering

The purposes of experimenting with supplemental watering were to assess: (1) how the benefits of watering compared to the benefits of treatments designed to improve soil quality, and (2) whether the effects of watering and soil treatments were additive. Total vegetation cover responded positively to supplemental watering (Fig. 25). In 2011, vegetation cover was significantly higher on plots that were watered (35 percent) than on plots that were not watered (18 percent) (ANOVA, F = 8.0, p = 0.02). Similarly, the cover of *Vaccinium scoparium* transplants was significantly higher on plots that were watered (22 percent; SE = 2 percent) than on plots that were not watered (12 percent; SE = 1 percent) (ANOVA, F = 6.4, p = 0.03). Transplant survival was higher on watered plots (94 percent; SE = 3 percent) than on plots that were not watered (82 percent; SE = 5 percent) (ANOVA, F = 3.6, p = 0.05), and the mean size of surviving transplants was higher on watered plots (394 cm^2; SE = 30 cm^2) than on plots that were not watered (239 cm^2; SE = 20 cm^2) (ANOVA, F = 6.4, p = 0.03). The cover of plants that established from seed was significantly higher on plots that were watered (12 percent; SE = 3 percent) than on plots that were not watered (6 percent; SE = 1 percent) (ANOVA, F = 8.1, p = 0.02), and the density of plants that established from seed was significantly higher on plots that were watered (11 plants/m^2; SE = 2 plants/m^2) than on plots that were not watered (7 plants/m^2; SE = 1 plant/m^2) (ANOVA, F = 5.5, p = 0.03).

The benefits of supplemental watering to restoration success were as substantial as those associated with scarifying and amending soils with organic matter and fertilizer (Fig. 26). There were no significant differences between plots that were watered and neither scarified nor amended and plots that were scarified and amended but not watered for total vegetation cover (Tukey-Kramer, t = 0.3, p = 0.82), transplant cover (Tukey-Kramer, t = 0.0, p = 1.00), or seedling cover (Tukey-Kramer, t = 0.4, p = 0.74). Moreover, the benefits of watering generally supplemented the benefits of the soil treatments (Fig. 26). For total vegetation cover, plots that were both watered and amended had significantly more cover than plots that were only amended (Tukey-Kramer, t = 2.2, p = 0.03) and plots that were only watered (Tukey-Kramer, t = 2.3, p = 0.02). Plots that were both watered and amended had more seedling cover than plots that were only amended and plots that were only watered; the contrast with only watered plots was significant (Tukey-Kramer, t = 1.9, p = 0.04), but the contrast with only amended plots did not meet the 0.05 criterion for significance (Tukey-Kramer, t = 1.5, p = 0.08). Plots that were both watered and amended had more transplant cover than plots that were only amended and plots that were only watered, but neither of these contrasts was significant (Tukey-Kramer, t = 1.8, p = 0.09 for each).

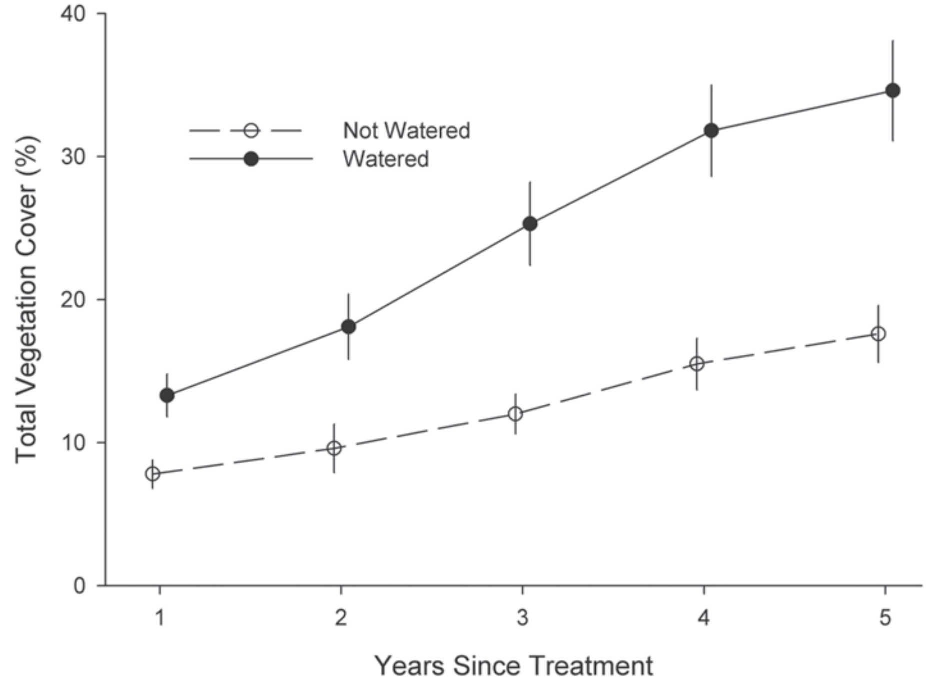

Figure 25—Effect of supplemental watering on total vegetation cover.

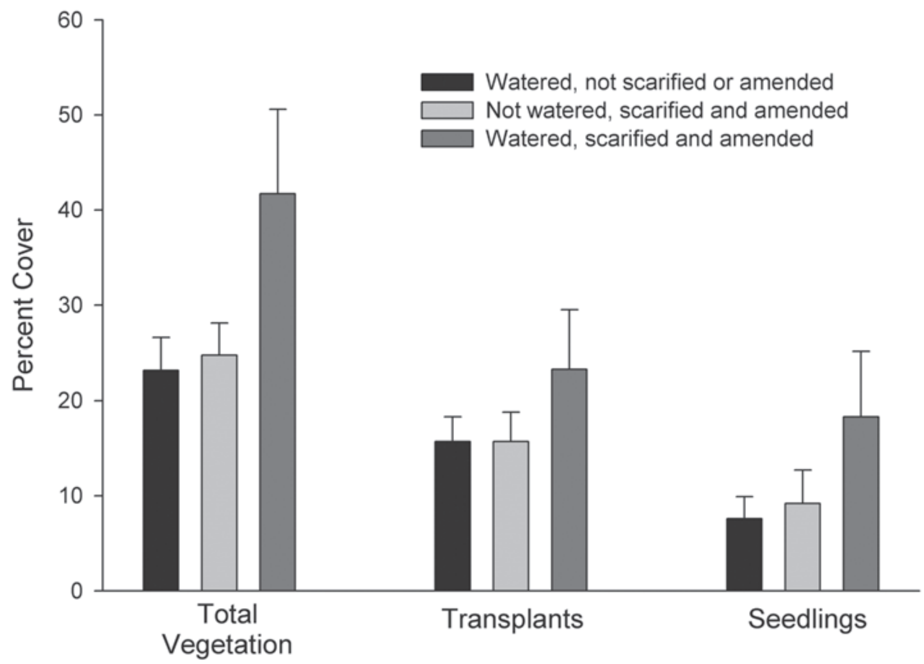

Figure 26—Effect of supplemental watering compared to the effect of soil treatments for total vegetation cover, transplant cover, and the cover of plants that established from seed.

Discussion and Management Implications

The purposes of this research were to verify the effectiveness of restoration treatments applied in the Eagle Cap Wilderness and to extend that work (Cole 2007; Cole and Spildie 2006, 2007). Specifically, we wanted to explore ways to increase success with planting *Vaccinium scoparium* and to experiment with various quantities and types of organic soil amendments. As was the case with the Eagle Cap trials, we were successful at partially restoring native vegetation on these highly disturbed campsites. Starting with sites devoid of all vegetation cover, we planted enough *Vaccinium scoparium* shrubs to provide 17 percent cover. Five years later, total cover was 31 percent (Fig. 27). Although a substantial improvement, this is still less than the 55 percent cover typically found on undisturbed sites (Fig. 28; Table 10). The primary species with diminished cover was *Vaccinium scoparium*. Coverage of other species collectively was equivalent on campsites (12 percent) and references sites (13 percent). Among associated species, the primary distinction between campsites and reference sites was in the relative abundance of *Carex geyeri* and *C. rossii. Carex geyeri* was more abundant on reference sites and *C. rossii* was more abundant on the restored campsites. *Carex rossii* was also the species that volunteered most abundantly on closed campsites in the Eagle Cap Wilderness (Cole and Spildie 2007).

Despite the diminished cover of *Vaccinium scoparium* five years after treatment, this species was much more successful in the Sawtooth trials than in the Eagle Cap trials. In the Sawtooths, 92 percent of transplants in the primary experiment survived after five years, and the mean change in size of those that survived was an increase of 16 percent (46 cm^2). Consequently, *Vaccinium scoparium* cover increased from 17 percent immediately after planting to 19 percent five years later. On the Eagle Cap sites, only 53 percent of transplants survived the first five years, and the mean change in size of those that survived was a decrease of 14 percent (18 cm^2). Consequently, after five

Figure 27—Substantial vegetation cover, five years after restoration, on the campsite shown in Figure 4.

years, *Vaccinium scoparium* cover was less than one-half what it was after planting (Cole and Spildie 2006, 2007).

Higher survival and growth rates of *Vaccinium scoparium* transplants in the Sawtooth trials might reflect any of a number of uncontrolled variables—differences in soil, disturbance history, weather patterns, population genetics, and so on. However, greater success could also be the result of using larger transplants. As previously noted, working in Iceland, Aradottir (2012) found that transplants of several deciduous dwarf-shrub *Vaccinium* species, morphologically similar to *V. scoparium,* were much more successful if they were at least 400 cm^2 in size. The size of *V. scoparium* transplants in the Eagle Cap study was only about 150 cm^2 compared to a mean size of 315 cm^2 in the Sawtooth trials. In the Sawtooths, we found that smaller transplants were less likely to survive; however, when they did survive, they grew more than larger transplants. This

Figure 28—The groundcover adjacent to the campsites suggests what complete recovery might look like.

Table 10—Mean percent cover of species, growth forms, and all vegetation on treated campsites, five years after treatment, and undisturbed reference sites.

	Campsites	Undisturbed
Total vegetation cover	31	55
Vaccinium scoparium	19	42
Associated species	12	13
Carex rossii	7	2
Carex geyeri	1	6
Other graminoids	1	1
Forbs	3	4

suggests that using larger transplants increases success, but this does not completely explain the greater success in the Sawtooth study. We also scarified soils to a depth of 20 cm compared to 15 cm in the Eagle Cap. Although this could have contributed to success, 56 percent of transplants survived on the plots that were not watered or scarified.

The lack of an effective seeding treatment in the Sawtooth trials resulted in reduced seedling densities compared to the Eagle Cap trials. Five years after treatment, mean seedling density on Sawtooth plots (21 plants/m^2) was comparable to the density of volunteer seedlings on Eagle Cap plots (23 plants/m^2) but much lower than the density of plants on seeded plots (177 plants/m^2) (Cole 2007). Differences in seedling cover were less pronounced, however. Five years after treatment, mean seedling cover on Sawtooth plots (12 percent) was comparable to the mean seedling cover of seeded Eagle Cap plots (13 percent). This suggests that seeding sites may have little long-term effect on vegetation recovery on these sites. Indeed, 15 years after treatment seeding did not have a significant effect on seedling cover of the Eagle Cap plots (unpublished data).

Treatment Effects

The Sawtooth results confirmed a number of the findings from the Eagle Cap study regarding treatment effects. Soil scarification was beneficial to restoration success, as was amending soils with organic matter. The effect of the mulch blanket, however, was not substantial. The trials with mulch, fertilization, and different types and amounts of organic matter suggest that, although none of these treatments is vastly superior to any other, some treatment combinations may be somewhat more beneficial than others. However, treatment benefits vary between transplants and plants that grow from seed, as well as between growth forms and probably species. Watering is also beneficial but will seldom be feasible.

The most pronounced main effect of treatments other than watering was the beneficial effect of fertilization with Biosol® on the establishment and growth of seedlings, particularly graminoids. As was the case in the Eagle Cap study where the source of fertilizer was compost, fertilization was neither beneficial nor harmful to *Vaccinium scoparium* transplants or to tree seedlings (Cole and Spildie 2007). In Rocky Mountain National Park, Colorado, fertilization with Biosol® was also effective at increasing the cover of native graminoids (Paschke and others 2000).

The only other statistically significant main effect was from the amount of organic matter added to the soil. The growth of *Vaccinium scoparium* transplants was greater if less organic matter was added to the soil. The advantage of less organic matter might be due to the immobilization of available soil nitrogen by microbial populations that expand as they consume the increased carbon in the organic matter amendments (Tate 1995). In the Eagle Cap study, the growth of *Vaccinium scoparium* transplants was not affected, for better or worse, by organic matter amendments. This suggests that any benefit from increased organic matter (for example, improving soil porosity and water holding capacity) may be small and easily offset by decreased available nitrogen. If so, larger quantities of organic matter could be detrimental. This explanation is consistent with our finding that on plots that were not fertilized, mean transplant size and height were substantially less on plots amended with decomposed wood compared to those amended with decomposed wood and twigs/needles; the amount of carbon in a given volume of decomposed wood is much greater than when that wood is mixed with needles and twigs. It is also consistent with our finding that when plots were fertilized, compensating for the immobilization of nitrogen, neither the type nor the amount of organic material mattered. The density of tree and forb seedlings also differed significantly with amount of organic matter, but in opposing ways. Tree density declined with increases in organic matter while forb density increased.

The significant interaction between the effect of mulch and organic matter amount on seedling density and cover suggest that the effects are additive. More organic matter is beneficial in the absence of the mulch blanket, whereas the mulch blanket is beneficial if less organic matter is applied. If the benefits of organic matter are improved water relations, this might be explained by the mulch blanket keeping the soil from drying out as rapidly. However, if that were the case, we might have expected a generally positive effect of the mulch blanket. These complex interactions suggest that there are positive and negative consequences of these treatments that also vary with growth form and species. The *Vaccinium scoparium* transplants responded in an opposing manner, growing most when there was both no mulch and the least carbon amendment—a lesser amount of decomposed wood mixed with twigs and needles.

Identifying the Best Treatment

As noted earlier, all of the treatments used in the primary experiment were effective in promoting restoration of these campsites. However, identifying the "best" treatment is difficult, both because (1) differences among treatments are not that substantial in relation to the variability within treatments, and (2) treatment effectiveness varies among growth forms and species. What is best for the *Vaccinium scoparium* transplants may not be best for plants establishing from seed. Nevertheless, we can make a series of assumptions and use our data to separate some of the better options from some of the worst. For example, the treatment combination that was worst for both the *Vaccinium scoparium* transplants and seedlings was no mulch, no fertilization, and a lesser quantity of decomposed wood.

First, let us assume that regular watering is not an option and that we are primarily concerned about the survival and growth of *Vaccinium scoparium* transplants and the establishment and spread of graminoids. Trees can readily be established through transplanting, so tree seedling density should not be a concern. Moreover, the forbs responded equally well to all of these treatments. Second, because fertilization is important to graminoid seedlings, let us assume that fertilizer will be applied. When fertilizer was applied, none of the other treatments had a significant effect on either the *Vaccinium scoparium* transplants or graminoid seedlings. However, mulch effects interacted with organic amount effects. For both *Vaccinium scoparium* transplants and graminoid seedlings, less organic matter was better if there was a mulch blanket and more was better if there was not. This suggests that the best treatment for both *Vaccinium scoparium* transplants and graminoid seedlings is either fertilizer, mulch, and less organic matter; or fertilizer, no mulch, and more organic matter. The type of organic matter made little difference, although growth of both *Vaccinium scoparium* transplants and graminoid seedlings was somewhat (but not significantly) better if decomposed wood was used when there was a mulch blanket and when decomposed wood was combined with twigs and needles in the absence of a mulch blanket.

Effects of Supplemental Watering

The beneficial effect of supplemental watering indicates that vegetation recovery on these campsites is limited by water. We found that plant growth was comparable on plots with scarified and amended soils that were not watered and plots that were watered but not scarified or amended. This finding is consistent with our belief that much of the benefit of soil scarification and amendment results from improvements in water infiltration into the soil and the availability of soil water for plant uptake. Our finding that the effects of supplemental watering and soil amendment are additive suggest that any treatment that would further improve soil-plant water relations would be beneficial.

Management Prescription

Cole and Spildie (2007) provided a prescription for campsite restoration based on the Eagle Cap study. On the basis of another five years of observation on those campsites and the results of the Sawtooth trials, that prescription can be revised as follows:

1. Effectively close the campsite to all use. Rope off the perimeter and post signs that instruct people to stay off the site and explain why.
2. Scarify soils to a depth of at least 15 cm, preferably 20 cm. Break up all clods to produce a crumb texture.
3. Decide whether or not to use a mulch covering such as the excelsior blanket used in this study. Our results suggest that lesser quantities of organic matter are needed if a mulch blanket is used.
4. If using a mulch blanket, amend soils with a 5 cm layer of locally collected, well-decomposed organic matter. This is about 50 liters or 13 gallons per m^2. Without a mulch blanket, add more organic matter--up to the 15 cm layer of locally collected, well-decomposed organic matter we added in this study. Some of the decomposed wood can be replaced with twigs and needles. In our study, the addition of twigs and needles was somewhat beneficial when larger quantities of organic matter were added and there was no mulch blanket. Some of this organic matter could be replaced by compost, although that increases transportation costs.
5. Sprinkle a bioorganic fertilizer such as Biosol® over the surface at a rate of about 20 kg per 100 m^2.
6. Transplant *Vaccinium scoparium* in large turfs (300 to 400 cm^2). Plant enough to provide cover equal to between 50 and 100 percent of the cover of *Vaccinium scoparium* on undisturbed sites. Recovery times are largely dependent on the amount of *Vaccinium scoparium* planted on the site. Consider growing these shrubs in nurseries from seed collected close to the site. Using nursery-grown shrubs rather than local transplants becomes increasingly important as the area to be restored increases. However, we have not experimented with the success of nursery-grown plants and do not know what density of nursery plants to use. It also seems highly beneficial to transplant some small trees. If only a few sites are being restored, it may not be necessary to grow trees in nurseries.
7. If all the plants come from nurseries, the soil should be inoculated with native biota. This can be done by collecting soil from around the root zone of plants in the vicinity, particularly *Vaccinium scoparium.* Make a soil-water slurry by adding this soil to some water and sprinkling it over the amended soil prior to transplanting. In the Eagle Cap study, we used 1.2 liters of soil mixed with 20 liters of water to inoculate 7 m^2 of campsite. This might be most easily done by collecting a few plants for transplanting and obtaining soil for inoculation and using plants grown in nurseries for the rest.
8. Seeding is not critical but can be a way to rapidly add species diversity. To do so, collect seed from a wide variety of species growing in the vicinity, preferably a year before restoration. Match the species sown to site conditions.
9. If possible, water plants regularly during long, dry spells. This is probably most important in the first few growing seasons.
10. At a minimum, inspect the closures at the start of every year to verify that ropes and signs are still intact.

Further Research

One fruitful new research avenue would be to experiment with *Vaccinium scoparium* plants grown from seed in nurseries. This is the only sustainable way to restore *Vaccinium scoparium* communities over large areas, given the large numbers of transplants required. Therefore, we need to learn more about how to grow them in nurseries, when to transplant them and at what densities. We also need to understand the effects of restoration treatments on these younger, smaller plants.

Beyond this, it would be worthwhile to experiment further with the combination of treatments employed in this study. This might determine whether the combinations of treatments that worked well in this study do so elsewhere. There might be value in experimenting further with the magnitude of organic matter amendments, given that *Vaccinium scoparium* responded positively to organic amendments but particularly in lesser quantities. There also might be other treatments to explore, such as the judicial use of fire.

Conclusions

Even with effective closure of campsites in these forests, recovery to conditions that approximate those that existed pre-disturbance will probably require many centuries (Cole and Spildie 2007). The results of this study and the earlier study in the Eagle Cap Wilderness show that recovery times can be reduced to several decades or even less. To do so, however, requires substantial investment of resources. To achieve the shortest recovery times requires intensive scarification and amendment of the soil followed by plantings at densities close to those found on undisturbed sites. Our experience suggests that soil preparation and planting of a moderate size campsite with 100 m^2 devoid of vegetation might require 30 person/days of work. We spent at least a day working on each site with a crew that always exceeded six people and only restored about 20 m^2 on each site. Although work crews would probably become much more efficient, this estimate suggests the magnitude of investment. Additional time and resources might be needed to gather seed, grow plants in nurseries, and transport materials to the site.

This estimate of the high cost of effective restoration emphasizes the importance of avoiding camping impacts in the first place in environments with low resilience. In places that receive regular use, concentration of use, perhaps on designated sites, can be beneficial (Marion and Farrell 2002). High costs also suggest that there is little value in expending resources on restoration unless available resources are sufficient to do it correctly. Managers must be highly strategic about which places to restore and develop realistic budgets and time frames for restoration work.

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