Rehabilitating slash pile burn scars in upper montane forests of Boulder County, Colorado

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Abstract

Slash pile burning is a widespread fuels reduction treatment because of its practicality and cost-effectiveness, yet it often has undesirable ecological impacts. Native plant recovery in slash pile scars is often delayed for many years because the extreme soil temperatures generally kill all living plants and all seeds in the soil seedbank. The extreme temperatures also tend to negatively impact physical and chemical soil properties that promote subsequent native plant establishment. The scars, however, are often quickly colonized by non-native species that are well-adapted to disturbed soils. Simple slash pile scar treatments may be sufficient to alter soil properties in favor of native species establishment. In this ongoing research project conducted in lodgepole pine- and aspen- dominated forests of Boulder County, Colorado, we are analyzing plant and soils data collected within slash pile scars and in adjacent unburned areas to clarify the impacts of slash pile burning. We are also testing the effectiveness of rehabilitation treatments at reestablishing native species, reducing non-native species, and restoring soil properties within scars. Treatments include (1) mulching with masticated woody material; (2) scarifying the soil surface; (3) seeding with native species; (4) mulching and seeding; (5) scarifying and seeding; and (6) untreated control. Finally, we are examining the establishment and growth of native species used in the seeding treatments to determine which have the greatest success in slash pile scars. Treatments were installed in June 2008, and plant data were collected in July, while soils data were collected in October. Plant and soils data will also be collected in the summer of 2009. Results will benefit Boulder County Parks and Open Space managers by clarifying the impacts of slash pile burning on plants and soils, and by providing them with scientifically-developed restoration guidelines for effectively rehabilitating slash pile scars.

Introduction

Land managers throughout western North America are implementing fuels reduction treatments to decrease tree densities on forest lands. In some areas, these fuels reduction treatments are being used to minimize the risk of high severity wildfire within the wildland-urban interface (Hirsch and Pengelly 2000; Kalabokidis and Omi 1998); in areas where a century of fire suppression has increased forest density, fuels reduction treatments are being used to restore ecologically appropriate and sustainable forest stand conditions (Kaufmann et al. 2005). Regardless of the management objective, options for reducing woody fuels remain limited (Wolk and Rocca in press). For example, traditional timber harvests generally are not economically feasible because much of the material removed is small and unmerchantable. The use of prescribed fire is often restricted by air quality regulations and the risk of fire escape.

One practical and cost-effective fuels reduction treatment that is widely used by managers is piling and burning thinned woody material on site. However, slash pile burning often has undesirable ecological impacts. The extreme soil temperatures encountered under burning slash piles generally kill all living vegetation, as well as all viable seeds in the soil seed bank and beneficial soil biota such as mycorrhizae (Esquilin et al. 2007; Korb et al. 2004). Soil chemical and physical properties that are important for subsequent plant establishment and growth can also be altered (Esquilin et al. 2007; Korb et al. 2004; Massman et al. 2008). Consequently, native plant recovery is often delayed for many years following pile burning (Korb et al. 2004). The unsightly scars, however, can become hotspots for non-native plant invasion and soil erosion (Haskins and Gehring 2004; Korb et al. 2004; Wolfson et al. 2005). Given the widespread use of pile burning, it is important to develop effective methods of rehabilitating burned slash pile scars so that their impacts on soil properties and plant communities can be minimized.

Simple slash pile scar treatments may be sufficient to alter soil properties in favor of native species establishment. One treatment which may directly impact native plant establishment within slash pile scars is seeding the soil surface with natives (Korb et al 2004). A diverse mix of ecologically appropriate species could provide insight into which species have the greatest establishment and growth success and which can best compete with non-native species within burn scars. Mulching treatments may indirectly encourage native establishment by increasing soil moisture and by moderating summer soil temperatures (Binkley et al. 2003). Mulching may also enhance soil fertility as the woody material decomposes, though in the short term, available nitrogen may be reduced in mulched sites (Binkley et al. 2003). Scarifying treatments may encourage native establishment by disrupting water repellant layers that can inhibit water infiltration into the soil, and by mixing nutrients contained within the ash layer into the mineral soil.

Our research objectives are (1) to determine the effects of slash pile burning on understory plants and on soil properties that are important for plant establishment and growth; (2) to determine the effectiveness of slash pile scar rehabilitation treatments (including seeding, mulching, scarifying, and combinations thereof) at restoring pre-fire soil properties, reestablishing native species, and reducing non-native species within the scars; and (3) to determine which native understory species, when seeded into slash pile scars, have the greatest establishment and growth success.

Methods

Study area and study sites[1]

Our study was conducted at Reynolds Ranch, a 348 ha property located just outside Nederland, Colorado. Reynolds Ranch has been owned and managed by Boulder County Parks and Open Space (BCPOS) since 1999. Forests here are dominated by lodgepole pine (*Pinus contorta*) and/or aspen (*Populus tremuloides*), with ponderosa pine (*Pinus ponderosa*) and limber pine (*Pinus flexilis*) occurring intermittently. Topography is flat to rolling in the portions of Reynolds Ranch we sampled, with elevations ranging from 2600 to 2650 m. Soils are formed from deposited colluvium. Precipitation in nearby Nederland averages 46 cm annually, most of which falls during the spring and summer (www.wrcc.dri.edu). January is the coldest month, with average highs of 1.6°C and average lows of -11.7°C; the warmest temperatures occur in July, when maximum daytime temperatures average 24.0°C (www.wrcc.dri.edu).

We established three study sites at Reynolds Ranch (Table 1; Figure 1). The Powerline site is located in a lodgepole pine stand that was thinned in the summer of 2005. The thinned material was immediately piled, and the piles were burned in the winter of 2007-2008. The Old site is in the same thinned stand as the Powerline site, but piles were burned in the winter of 2006-2007. The Aspen site is located in a lodgepole pine – aspen stand that was thinned and piled in the summer of 2006; piles were burned in the spring of 2008. Slash pile scars range from 6.4 m diameter at the Powerline site to 4.1 m at the Old site and 3.6 m at the Aspen site.

[1] This study was originally funded to be conducted in ponderosa pine – dominated forests, but unfortunately, a variety of constraints limited the number of slash piles that BCPOS could burn in the winter of 2007-2008 in this system. However, BCPOS was able to burn many slash piles in forests dominated by lodgepole pine, so we conducted our 2008 research in lodgepole pine with the intension of expanding into ponderosa pine in 2009.

Rehabilitation treatments

Because abiotic and biotic conditions were often variable within a site, we grouped slash pile scars into blocks of three scars each (Figure 2). All scars within a block were as comparable as possible in terms of topography, soils, slash pile scar size, the condition of the surrounding understory and overstory, etc. We then randomly assigned one of three treatments to each slash pile scar in a block (Figure 3). For slash pile scars receiving the mulch treatment, we applied a 6-8 cm layer of masticated woody material. Slash pile scars receiving the scarification treatment were raked by hand to a depth of 8-10 cm with a McLeods. Control slash pile scars were left untreated. These three treatments are 'whole-pile' treatments, in that the treatment was uniformly applied to the entire pile. All treatments were installed in June 2008.

Half of each pile was also seeded by hand with a seed mixture of three native perennial grass species at a rate of 80 seeds per m^2 (Table 2). The seed was mixed with sand to ensure even seed distribution. Where piles were also mulched or scarified, the seed was applied prior to mulching but after scarification. If a slash pile scar was on sloping terrain, we applied the seed to the downhill half of the pile to avoid potential contamination caused from seed washing out of the seeded pile half and into the unseeded pile half. On flat terrain, we randomly assigned the seeding treatment to pile halves.

Data collection

In July 2008, understory and abiotic cover data were collected along transects which extended from 2 m outside the pile on the seeded side, through the pile center, to 2 m outside the pile on the unseeded side (Figure 4). At the Powerline site, slash pile scars were large enough to contain two parallel sampling transects, but piles at the Old and Aspen sites were much smaller and so only one transect could be established (Figure 4). Six 0.25 m^2 (0.5 m x 0.5 m) subplots were located along each transect (Figure 4). Two subplots per transect (one on the seeded side and one on the unseeded side) were located in the pile interior, two were just inside the pile edge, and two were 2 m outside the pile in unburned forest. Within each subplot, we ocularly estimated percent plant cover by species. Nomenclature follows the USDA Plants Database (2008), though varieties and subspecies are not distinguished. We also used the USDA Plants Database to determine the growth form, lifespan, and nativity of each species. Voucher specimens are stored at the U.S. Forest Service Rocky Mountain Research Station in Fort Collins, Colorado. In each subplot we also estimated the percent cover of abiotic variables, including ash, duff, litter, mulch, rock, soil, stumps and wood. In addition, we had planned to determine the number and cover of seeded grass germinants per subplot, but none of the seed had germinated so these measurements could not be taken. Therefore, we revisited all subplots again in October 2008, after some germination had occurred. Measurements of understory richness and cover, the cover of abiotic variables, and the number and cover of seeded grass germinants will be repeated in July-August 2009.

Soil properties and degree of soil burn severity were also assessed along the sampling transects in areas immediately adjacent to the pile interior, pile edge, and outside pile subplots. At each sampling point, an ion exchange resin bag was buried in the mineral soil at 5-10 cm depth as an *in situ* index of plant-available nitrogen. The bags were constructed of a permeable nylon fabric and filled with mixed bed ion exchange resin that retains inorganic nitrogen forms (nitrate and ammonium) as they percolate through the surface mineral soil layer. Resin bags will continue to be installed, collected and analyzed throughout the duration of the study in order to characterize seasonal patterns in nitrogen availability and changes with time since time burning and rehabilitation. Soil color, water drop penetration, soil structure and consumption of the forest floor layer will be used to quantify the extent of severe and moderate soil burning within the interior and edge of burn scars. Mineral soil samples (0-15 cm depth) will also be collected for laboratory nutrient incubations and to analyze physical and chemical properties, including bulk density, coarse fragments, texture, pH, extractable cations, total soil carbon and nitrogen.. Soil incubations will measure the production of plant-available forms of inorganic nitrogen under laboratory conditions that remove the influence of the microclimatic factors (i.e. temperature and moisture) that can influence nutrient availability differences in the field.

Attribute data were collected for each slash pile scar, including pile diameter, slope, aspect, elevation, and UTMs. Percent cover of the forest overstory immediately surrounding each slash pile scar was also assessed using a spherical densiometer.

Statistical analyses

Statistical analyses will be conducted after the 2009 sampling. We will use SAS 9.1 (SAS Institute Inc., Cary, North Carolina) to test for differences among sites, treatments, subplot locations, and years for a wide range of variables: native and non-native species richness and cover, number and cover of seeded grass germinants, and soil nutrient, chemical and physical properties.

Results

Effects of slash pile burning on understory plants and soil properties

We encountered fifty-six species at the three sites (Table 3), of which forty-six were native to the continental United States and eight were non-native. Two of the species were of uncertain origin because they could be identified to genus only, and both these genera contain many native and non-native members.

Though statistical testing will not be conducted until after 2009 sampling is complete, preliminary data presented in Table 4 suggest that unburned areas adjacent to slash pile scars have greater native and non-native richness and cover than areas within the pile scars. Resin bags and soil samples have yet to be analyzed.

Effectiveness of slash pile scar rehabilitation treatments

Plant surveys conducted one month after treatment installation suggest that the rehabilitation treatments have not yet impacted native and non-native species richness and cover (Table 4), either by influencing the growth of plants already established within the piles, or by influencing regeneration from seed. However, some germination of seeded grasses was observed later in the fall, four months after treatment installation (Table 5, Figure 5). Germination of seeded grasses appears to be greater in seeded areas which were also mulched or scarified than in control areas, and thus, we suspect that these areas may contain more native richness and cover in the near future. Treatment impacts on soils have not yet been determined.

Germination and establishment success of seeded species

The germinants observed four months after treatment installation were too immature to identify in the field, but comparisons of field-grown and laboratory-grown specimens suggest that most germinants were *Elymus elymoides* and/or *Elymus trachycaulus*.

Discussion and Conclusion

The preliminary results presented here suggest that slash pile burning greatly diminishes understory plant richness and cover in upper montane forests. Our preliminary results also suggest that rehabilitation treatments which include seeding with native species may help restore understory communities, and treatments which combine seeding with mulching or scarification may be even more successful. However, at this early stage of our study we are unable to draw any firm conclusions. Continued monitoring of our sites is therefore necessary if this research is to benefit BCPOS managers by clarifying the impacts of pile burning on plant communities and soil properties, and by providing them with scientifically-developed restoration guidelines for effectively rehabilitating slash pile scars.

Duplicating our methods at other sites would provide further insight to BCPOS managers. Additional sites in ponderosa pine – dominated forests would be especially valuable, as ongoing restoration treatments in these forests produce large amounts of woody material which is commonly disposed by slash pile burning. To complement and expand the value of the work we initiated during 2008, we plan to install additional study sites in both lodgepole- and ponderosa pine- dominated areas of the Arapaho-Roosevelt National Forests in 2009, and we hope to install additional sites on Boulder County land as well.

Acknowledgements

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Table 1. Site and study design attributes of the Powerline, Old, and Aspen sites. Canopy cover is the cover of the area after thinning.

	Powerline	**Old**	**Aspen**
Site attributes			
Overstory dominants	Lodgepole pine	Lodgepole pine	Aspen, lodgepole pine
Mean canopy cover (%)	11.6	20.6	15.1
Mean elevation (m)	2637	2641	2608
Terrain	Flat to rolling	Flat	Flat
Year thinned	Summer 2005	Summer 2005	Summer 2006
Year piles burned	Winter 2007-2008	Winter 2006-2007	Spring 2008
Study design attributes			
No. of blocks	5	3	6
No. of transects per pile	2	1	1
Mean pile area (m^2)	31.5	13.5	10.1

Table 2. The three grass species seeded at the Powerline, Old, and Aspen sites, and the proportion of each species in the seed mix.

Species	Origin	% of Mix
Elymus elymoides, squirreltail	Collected on BCPOS properties (Meyers, Walker Ranch)	14
Elymus trachycaulus, slender wheatgrass	Purchased from Arkansas Valley Seed; grown out in North Dakota	36
Muhlenbergia montana, mountain muhly	Collected on BCPOS properties (Caribou, Mud Lake, Walker Ranch)	50

Table 3. Species found at the Powerline, Old, and Aspen sites.

Species	**Growth form**	**Nativity**
Achillea millefolium, common yarrow	Long-lived forb	Native
Agrostis scabra, rough bentgrass	Graminoid	Native
Anemone canadensis, Canadian anemone	Long-lived forb	Native
Antennaria parvifolia, small-leaf pussytoes	Long-lived forb	Native
Arctostaphylos uva-ursi, kinnikinnick	Woody plant	Native
Arnica chamissonis, Chamisso arnica	Long-lived forb	Native
Artemisia ludoviciana, white sagebrush	Long-lived forb	Native
Astragalus sp., milkvetch	Long-lived forb	Native
Astragalus miser, timber milkvetch	Long-lived forb	Native
Calamagrostis purpurascens, purple reedgrass	Graminoid	Native
Campanula rotundifolia, bluebell bellflower	Long-lived forb	Native
Carex sp., sedge	Graminoid	Native
Chamerion angustifolium, fireweed	Long-lived forb	Native
Chenopodium fremontii, Fremont’s goosefoot	Short-lived forb	Native
Chenopodium leptophyllum, narrowleaf goosefoot	Short-lived forb	Native
Cirsium sp., thistle	Variable	Variable
Cirsium arvense, Canada thistle	Long-lived forb	Non-native
Conyza canadensis, Canadian horseweed	Short-lived forb	Native
Corydalis aurea, scrambled eggs	Short-lived forb	Native
Dracocephalum parviflorum, American dragonhead	Short-lived forb	Native
Epilobium ciliatum, fringed willowherb	Long-lived forb	Native
Erigeron compositus, cutleaf daisy	Long-lived forb	Native
Erigeron subtrinervis, threenerve fleabane	Long-lived forb	Native
Fragaria sp., strawberry	Long-lived forb	Native
Galium boreale, northern bedstraw	Long-lived forb	Native
Geranium caespitosum, pineywoods geranium	Long-lived forb	Native
Juniperus communis, common juniper	Woody plant	Native
Lactuca serriola, prickly lettuce	Short-lived forb	Non-native
Lupinus argenteus, silvery lupine	Long-lived forb	Native
Mertensia lanceolata, prairie bluebells	Long-lived forb	Native
Oreochrysum parryi, Parry’s goldenrod	Long-lived forb	Native
Packera fendleri, Fendler’s ragwort	Long-lived forb	Native
Penstemon virens, Front Range beardtongue	Long-lived forb	Native
Phacelia heterophylla, varileaf phacelia	Short-lived forb	Native
Phleum pratense, timothy	Graminoid	Non-native
Pinus contorta, lodgepole pine	Woody plant	Native
Pinus flexilis, limber pine	Woody plant	Native
Poa sp., bluegrass	Graminoid	Variable
Poa pratensis, Kentucky bluegrass	Graminoid	Non-native
Populus tremuloides, quaking aspen	Woody plant	Native
Potentilla pulcherrima, beautiful cinquefoil	Long-lived forb	Native
Pseudocymopterus montanus, alpine false springparsley	Long-lived forb	Native
Pseudognaphalium viscosum, winged cudweed	Short-lived forb	Native

Species	Growth form	Nativity
Pyrola chlorantha, greenflowered wintergreen	Woody plant	Native
Rosa sp., rose	Woody plant	Native
Rubus idaeus, American red raspberry	Woody plant	Native
Salix sp., willow	Woody plant	Native
Sedum lanceolatum, spearleaf stonecrop	Long-lived forb	Native
Solidago simplex, Mt. Albert goldenrod	Long-lived forb	Native
Symphyotrichum sp., aster	Long-lived forb	Native
Taraxacum officinale, common dandelion	Long-lived forb	Non-native
Thalictrum fendleri, Fendler's meadow-rue	Long-lived forb	Native
Thermopsis divaricarpa, spreadfruit goldenbanner	Long-lived forb	Native
Trifolium repens, white clover	Long-lived forb	Non-native
Trifolium pratense, red clover	Short-lived forb	Non-native
Verbascum thapsus, common mullein	Short-lived forb	Non-native

Table 4. Mean ± standard error of native and non-native species richness and percent cover at the Powerline, Old, and Aspen sites.

	Seeded			**Unseeded**		
	Pile Interior	**Pile Edge**	**Outside Pile**	**Pile Interior**	**Pile Edge**	**Outside Pile**
Native richness (number of species per 0.25 m^2)						
Mulch	0.1 ± 0.1	0.8 ± 0.2	1.8 ± 0.4	0.1 ± 0.1	1.0 ± 0.3	1.8 ± 0.4
Scarify	0.1 ± 0.1	0.5 ± 0.3	2.3 ± 0.7	0.1 ± 0.1	0.8 ± 0.2	2.4 ± 0.8
Control	0.1 ± 0.1	0.8 ± 0.2	1.9 ± 0.4	0.2 ± 0.1	1.5 ± 0.4	1.6 ± 0.4
Non-native richness (number of species per 0.25 m^2)						
Mulch	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.2
Scarify	0.0 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.5 ± 0.2
Control	0.1 ± 0.1	0.0 ± 0.0	0.4 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.4 ± 0.2
Native cover (%)						
Mulch	0.2 ± 0.1	6.2 ± 2.6	16.3 ± 7.0	1.4 ± 1.4	3.1 ± 1.2	11.5 ± 3.2
Scarify	0.1 ± 0.1	4.1 ± 2.8	10.3 ± 4.5	0.5 ± 0.4	6.4 ± 2.4	13.4 ± 4.8
Control	0.3 ± 0.3	7.4 ± 2.5	18.5 ± 5.6	0.8 ± 0.5	9.8 ± 3.0	13.5 ± 4.4
Non-native cover (%)						
Mulch	0.0 ± 0.0	0.0 ± 0.0	8.7 ± 5.3	0.0 ± 0.0	0.0 ± 0.0	6.9 ± 3.9
Scarify	0.0 ± 0.0	0.1 ± 0.1	0.6 ± 0.4	0.6 ± 0.6	0.0 ± 0.0	7.7 ± 5.1
Control	0.1 ± 0.1	0.0 ± 0.0	1.1 ± 0.7	0.4 ± 0.4	0.1 ± 0.1	3.7 ± 2.5

Table 5. Mean number of seeded grass germinants per 0.25 m^2 ± standard error at the Powerline, Old, and Aspen sites.

	Seeded			Unseeded		
	Pile Interior	**Pile Edge**	**Outside Pile**	**Pile Interior**	**Pile Edge**	**Outside Pile**
Mulch	20.0 ± 4.2	8.9 ± 2.4	0.0 ± 0.0	0.5 ± 0.3	0.3 ± 0.1	0.0 ± 0.0
Scarify	7.7 ± 2.9	3.4 ± 1.1	0.2 ± 0.2	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0
Control	2.3 ± 0.7	2.3 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Figure 1. Location of the Powerline, Old and Aspen sites at Reynolds Ranch.

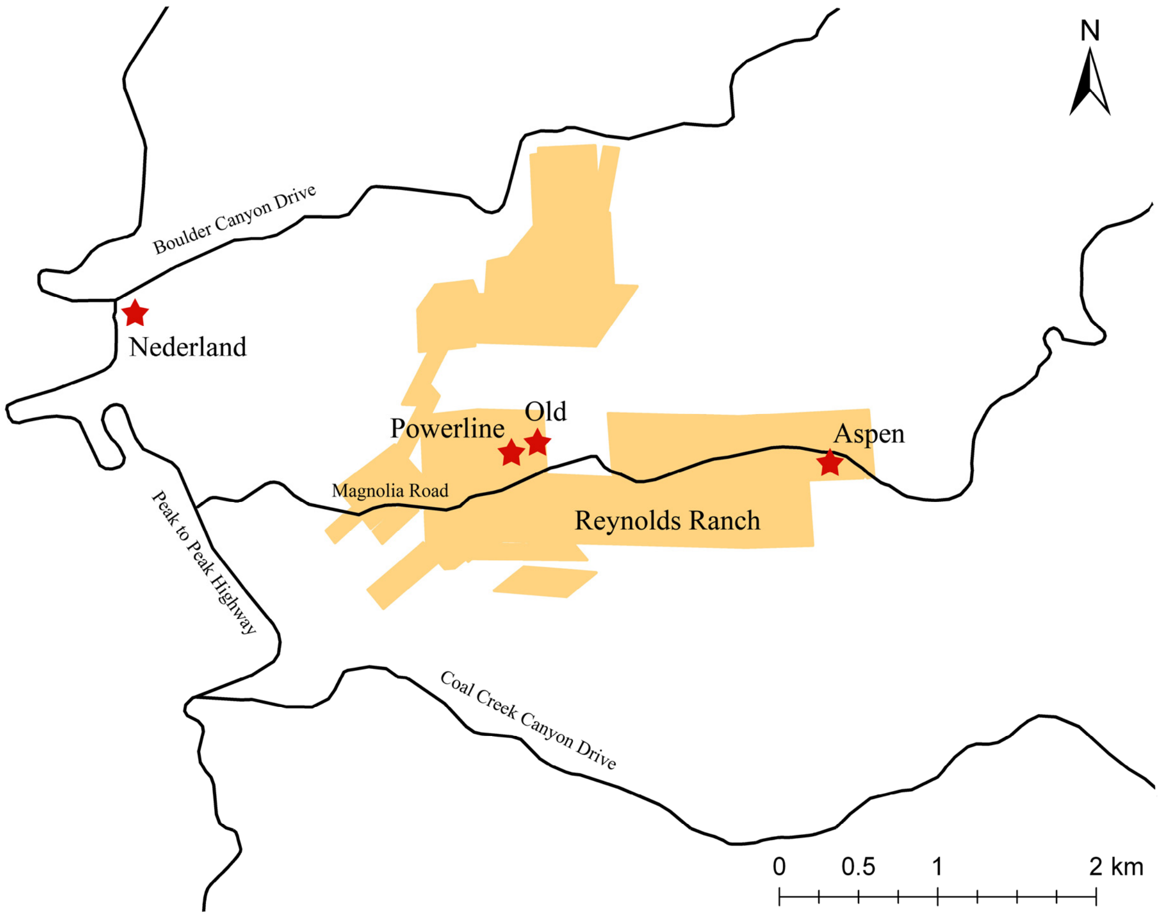


Figure 2. Schematic diagram presenting a hypothetical layout of blocks within a site (schematic is loosely modeled after the Aspen site). Whole-pile treatments are denoted as follows: M = mulch, S =scarify, and C = control.

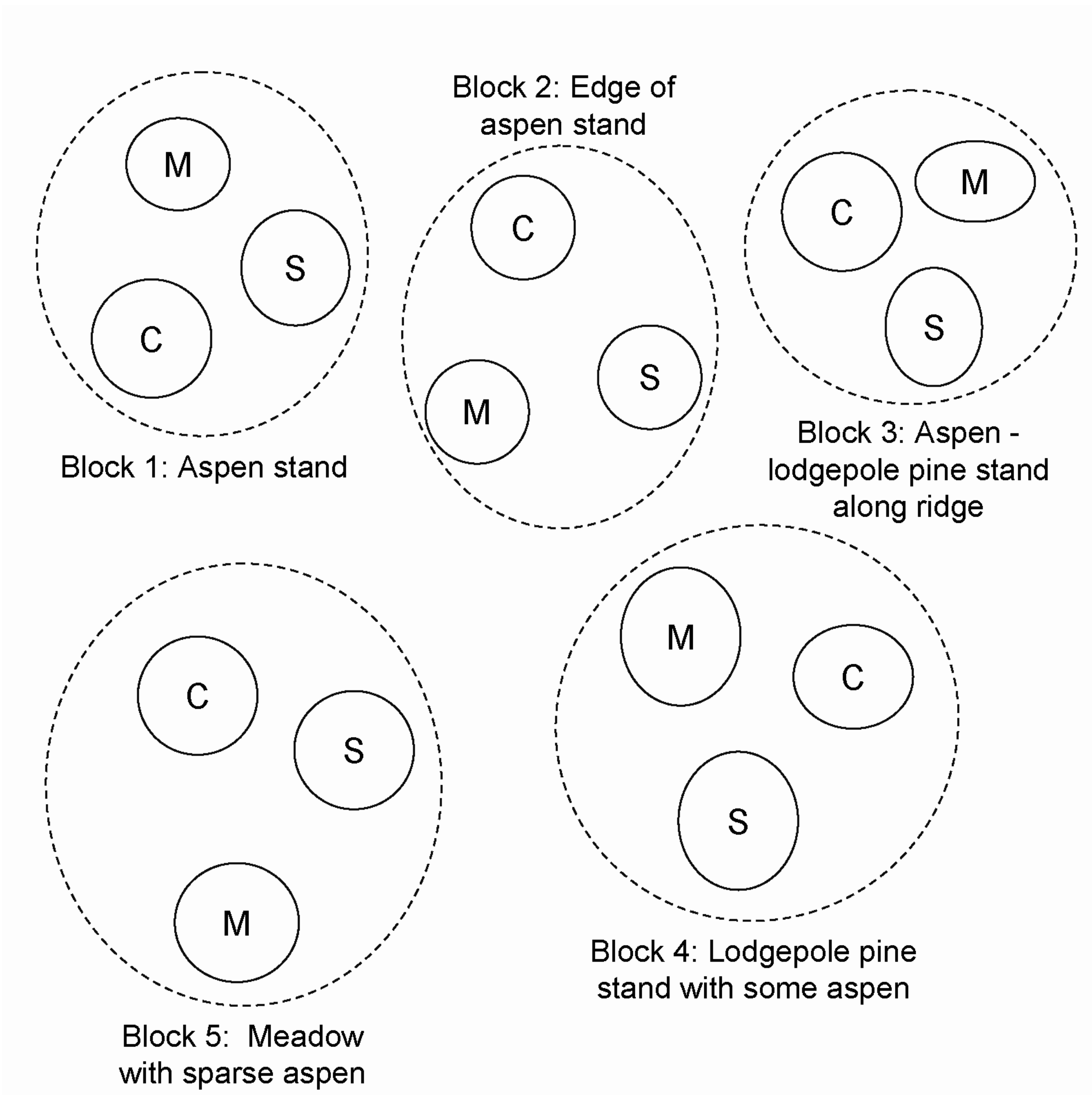


Figure 3. Whole-pile treatments included (a) mulch, (b) scarify, and (c) untreated control.

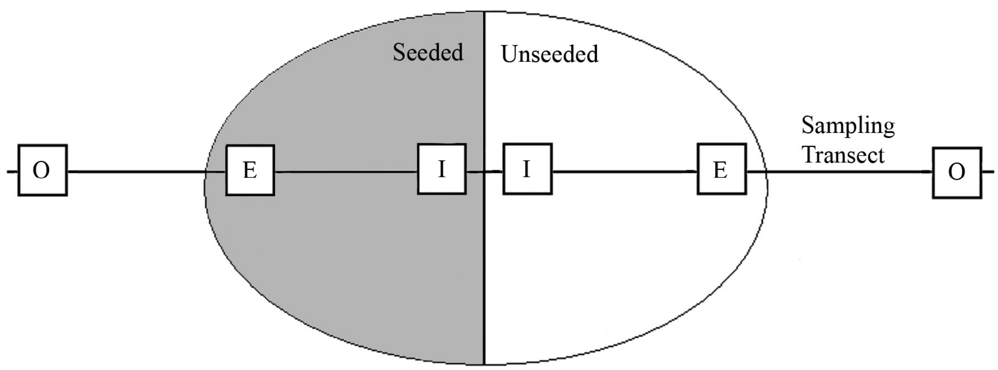
(a) Mulch applied to a pile at the Old site.

(b) Scarifying a pile at the Old site.

(c) Control slash pile at the Old site.

Figure 4. Slash pile sampling methods at (a) the Aspen and Old sites, and (b) the Powerline site. Each slash pile received one of three whole-pile treatments (mulch, scarify or control). Half of each pile also received a seeding treatment. Understory vegetation and abiotic sampling were conducted in subplots distributed along transects which extended from 2 m outside the pile on the seeded side to 2 m outside the pile on the unseeded side. Soil sampling was conducted adjacent to the subplots. O = outside pile (unburned) subplots, E = slash pile edge subplots, and I = slash pile interior subplots.

a). Aspen and Old sites



b). Powerline site

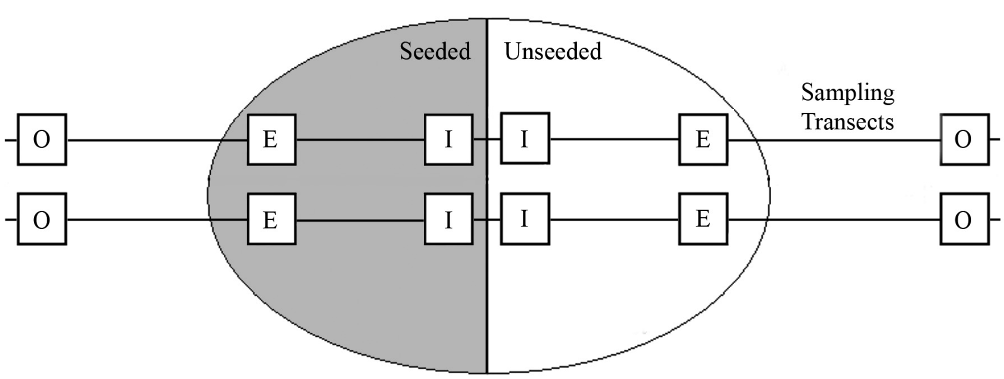


Figure 5. Newly germinated grass seed growing in the seeded portion of a slash pile.