Long Term Ecological Changes with Post-fire Emergency Seeding

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Post-fire emergency response treatments are developed to immediately protect life, property and watershed related values. However, many treatments have long-term effects on the soil and vegetation of the ecosystem. This study compares treated and non-treated vegetative composition eight years following post-fire emergency restoration efforts. The long term effects of seeding native grasses with two types of soil disturbances were evaluated. The use of native grass species for emergency rehabilitation was shown to decrease overall species diversity and prohibit the establishment of several native plant species following fire. Seeding of native grass species was shown to be successful only with treatments that included surface soil disturbance. The long-term implications of emergency restoration seeding and recommendations for its use are discussed.

Keywords: *soil, fire, vegetation, succession, rehabilitation, seeding, native*

Introduction

The Burned Area Emergency Response (BAER) program has been with the Forest Service since 1975 (USDA FS 2001). The program has evolved from watershed emergency stabilization to a program of emergency protection of identified values at risk. The values at risk under today's BAER program can range from the original watershed emphasis to listed species habitat, cultural resources, and infrastructure (USDA FS 2001). The objectives of the Forest Service BAER program are found in the Forest Service Manual (FSM) 2523 (USDA FS 2004). The objectives are: "To determine the need for and to prescribe and implement emergency treatments to minimize threats to life or property or to stabilize and prevent unacceptable degradation to natural and cultural resources resulting from the effects of a fire". Many types of treatments are prescribed and implemented to reduce the threats to the identified values at risk. The use and necessity of emergency treatments have been questioned as to the success and ecological consequences of treatments (Dellasala et al. 2004). Various monitoring efforts are being conducted to determine the applicability of many treatments to meeting the intended objectives.

One of the most common treatments for the past 30 years has been the use of grass seed to provide a vegetative cover on burned lands to reduce the rain drop impact and runoff energy associated with post-fire rain events. More recently, native grass seeding has been used to reduce the potential for invasive plants. The effectiveness of seeding burned areas, particularily by broadcast aerial or ground methods has been reviewed by Robichaud et al. (2000) and Byers (2004). Reviews of past monitoring information has showed that there is very little quantified data on the effectiveness of seeding burned areas to meet emergency restoration objectives. There is also very little data on long term (5+ years) effects of BAER seeding treatments on the ecological succession of burned areas.

Recently there has been an emphasis on the use of native species for all restoration and rehabilitation treatments. Executive Order 13112, Forest Service policy FSM 2081 (USDA FS 2004), and several Forest Service Regional policies direct the agencies land managers to use native species for any planting or seeding operations whenever possible. The direction to use native species is firm and BAER teams often use native species mixes when seeding treatments are prescribed for post-fire emergency protection. The Forest Service BAER program (FSM 2523) emphasizes natural recovery first and second the use of native species that originate from genetically local sources. Further down in preference is the use of non-native species that are non-persistent and not likely to spread beyond the treatment area.

The effectiveness and ecological effects of seeding are often not quantified during BAER implementation nor post BAER operations. The BAER program provides for funding to determine qualitatively if treatments are installed properly and/or if they are effective at meeting emergency objectives. However, the BAER program cannot fund the validation of treatment types, quantified measurements, nor the effects of treatments beyond the emergency period (FSM 2523). The effects of native species seeding to the post fire ecosystem processes may be much longer than the initial emergency period. There is very little information available on the long term (5+ years) effects of emergency

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seeding of native species in wildfire areas. This study quantitatively looks at the long term effects of native grass seeding as part of a BAER program.

Study Area

The study was conducted in August 2004 within the 12,000-acre (4860-ha) Buffalo Creek Fire that occurred in May 1996. The fire area is located adjacent to the town of Buffalo Creek, CO and is approximately 50 miles (80 km) southwest of Denver, CO. The pre-fire vegetation was predominantly continuous canopies of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). A depauperate understory existed under the closed canopies of the conifer species. Soils of the area are derived from the Pikes Peak Batholith (USDA NRCS 1992). The soils are referred to as decomposed granite (DG) soils. The soils are coarse textured with very little soil structure. The clay content is low and the water holding capacity is low. The soils are easily eroded when surface cover is removed. They also have a high potential to produce hydrophobic conditions following fire due to the high amount of coniferous litter and high volume of macro pore space. The elevation of the area is 2300 to 2600 m. Precipitation averages 40-46 cm per year. Severe thunderstorms are common during the summer months.

The human-caused Buffalo Creek Fire was a very complete fire, leaving very few unburned islands of vegetation within the fire area. Approximately 3038 ha of the 4860 ha burn area was mapped as high fire severity (USDA FS 1996a). Hydrophobic soil conditions were reported in the fire area for several years. Infiltration rates were significantly reduced due to the hydrophobic soil conditions (Moody and Martin 2001a). Natural regeneration in the first few years following the fire was poor. There were very few pre-fire herbaceous understory plants or shrubs, and many seeds were consumed during the fire event.

Several major runoff events occurred in the first two years following the fire. These events caused losses to homes, lives, roads, water supply to the city of Denver, and other natural resources. The events removed surface horizons and moved sediment stored in drainages throughout the fire area. (Moody and Martin 2001b)

BAER Treatments

Emergency BAER treatments were installed in 1996, 1997, and 1998. Treatments varied as to type and location. Restoration measures were prescribed and implemented to protect lives and property, protect water quality, and protect long-term soil productivity. Some of the treatments implemented were grass seeding (aerial and ground), contour felling, contour trenching, dozer ripping, Rotoclear[1] mulching, bank stabilization, channel modification, and water source protective barriers. Grass seeding treatments included broadcast aerial and ground seeding. Species used in the treatments ranged from mixes of non-persistent grains to native grass species. A summary of the grass seeding operations is shown in Table 1.

Ground seeding was done on ground disturbing treatments including dozer ripping and Rotoclear chipping. The dozer ripping treatment included the use of shallow ripper teeth pulled behind a small dozer perpendicular to the slope. A broadcast seeder was mounted on the back of the dozer and seed was spread on the ripped path and outside of the ripped path more than twice the width of the ripped path. The ripped paths were spaced 12-15 m apart. The Rotoclear treatment included the use of a rotating, toothed drum that mulched materials passing beneath it (Figures 1 and 2). The Rotoclear was pulled behind a large Caterpillar D8 dozer. The dozer would

Figure 1. Rotoclear machine showing rotating drum.

Figure 2. Rotoclear machine with dozer.

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Table 1. Summary of seeding treatments for the Buffalo Creek Fire restoration.

Treatment	Species in Mix	Percent of Species in Mix by Weight	Estimated Total Pure Live Seeds per square meter	Hectares Seeded	Dates of Seeding
Aerial Seeding	white oats (*Avena sativa*)	100	110	2,025	June 1996
Aerial Seeding	white oats	50 estimated	210	2,025	March 1997
	slender wheatgrass (*Elymus trachycaulus*)	25 estimated			
	Canby bluegrass (*Poa canbyi*)	25 estimated			
Rotoclear	slender wheatgrass	23.41	430-530	405	August - December 1996
	thickspike wheatgrass (*E. macrourus*)	25.65			
	streambank wheatgrass (*E. lanceolatus*)	14.05			
	green needlegrass (*Nassella viridula*)	14.49			
	mountain brome (*Bromus marginatus*)	9.87			
	Canby bluegrass	5.05			
	Idaho fescue (*Festuca idahoensis*)	3.75			
	Arizona fescue (*F. arizonica*)	1.01			
Dozer Ripping	slender wheatgrass	23.41	430-530	608	April - May 1997
	thickspike wheatgrass	25.65			
	streambank wheatgrass	14.05			
	green needlegrass	14.49			
	mountain brome	9.87			
	Canby bluegrass	5.05			
	Idaho fescue	3.75			
	Arizona fescue	1.01			

push burned trees over and the Rotoclear mulched the tree into 8- to 13-cm chips and incorporated some of the woody material into the soil surface. The Rotoclear was pulled along the contour perpendicular to the slope. Two 4-meter-wide Rotoclear paths were created, spaced 12 to 15m apart. Grass seed was broadcast over the paths and outside the paths to more than twice the width of the path.

In general, the two aerial seedings did not provide adequate plant establishment. Neither were effective in controlling surface runoff and erosion (Bruggink et al 1998). Most of the seed did not germinate, was lost to overland flow, or was consumed by animals. The Rotoclear and dozer ripping treatments did show some effectiveness in controlling runoff and erosion (Bruggink et al. 1998), however, the effectiveness appeared to be related to the soil disturbance and addition of organic matter that allowed increased infiltration. The native seeding that was included in the treatments did germinate successfully in the areas with some soil disturbance within the first two years of seeding, but the contribution to reducing runoff was not evident (Bruggink et al. 1998). Ground based broadcast seed that fell adjacent to the disturbed soils had similar results to the aerial seeding.

In summer 2003 (seven years after the burn), the burn area was visited by the author. At that time there were visual differences in the type and amount of vegetative species on both the dozer ripped and Rotoclear treatment areas compared to areas that were seeded without soil disturbance and areas that were not treated. There was a noticeable difference in species composition, species cover, and the amount of bare ground between areas treated with ground disturbance treatments and those with no soil disturbance. The areas that received broadcast seeding without any soil disturbance appeared similar in species composition and diversity to areas that were not treated.

Table 2. Cover class mid-points used in calculations.

Data Sheet Code	Canopy Cover Range (percent foliar cover)	Canopy Cover Midpoint used in calculations (percent foliar cover)
T	0-1.0	0.5
1	1.1-5.0	3.0
2	5.1-25.0	15.0
3	25.1-50.0	37.5
4	50.1-75.0	62.5
5	75.1-95.0	85.0
6	95.1-100.0	97.5

In summer 2004, the vegetation was sampled on the Rotoclear, dozer ripped, aerial seeded, ground seeded without soil disturbance, untreated, and unburned sites. The sampling was intended to determine the long term successional effects of seeding burn areas, to determine the difference in seeding with soil disturbance compared to seeding without soil disturbance, and to determine the long term effects of BAER treatments in reducing erosion.

Methods

Sampling sites were stratified by the type of treatment. The aerial seeding was dropped from the list of treatments due to the following reasons.

1. The first aerial seeding included only a non-persistent cereal grain (white oats, *Avena sativa*) that was not successful according to the 1998 monitoring report.
2. The second aerial seeding was also reported as having very poor success in the 1998 monitoring report. This mix did include two native species; however these species were also included in the dozer ripping and Rotoclear treatments where seed was spread both on disturbed and non-disturbed soils. An assumption was made that the ground broadcast seeding between the dozer ripped and Rotoclear paths would represent all broadcast seeding (aerial and ground) where no soil disturbance was used. These areas became the controls for the soil disturbance and seeded applications.
3. Very little to no visual difference could be detected between non-seeded areas and areas that received broadcast seeding with no soil disturbance.

A total of four sites were sampled. Vegetation data at each of the sites were collected. The vegetation sampling method followed USDA Forest Service Region 2 Rangeland Handbook (USDA FS 1996b) protocols for cover-frequency transects. The transects included 30.48 m transects with 20 Daubenmire (Daubenmire 1959) 20-cm x 50-cm frames (subplots) along each transect to determine percent cover by species. Six cover classes were used plus a trace class. The class midpoints shown in Table 2 were used in calculations for cover data. Data for each frame included life form, species, and cover class. Ground cover type and it's cover class were also collected for each frame. Species frequency was determined for each species by transect and average species canopy cover. Three transects were completed for each treatment type as well as for each control. The only exception was the control for the dozer ripping, where only two transects were completed (Table 3). The Rotoclear and dozer ripped sites had both transects along the soil disturbance paths that were seeded, and also between the paths that were seeded but had no soil disturbance.

Analysis

General averages of vegetation and ground cover by treatment typ, and Student's t-tests (Steel and Torrie 1980) (two-tailed, unequal variances) for significant ($p < 0.05$ and $p < 0.01$) species differences within treatment types were calculated. Sample size for treatments was $n = 60$ except for the dozer ripping treatment where $n = 40$. The general summaries by treatment type included total species richness (total species counts), cover percents of seeded species (mean percent cover), total number of unique species (total species counts unique to treatment type), and percent effective ground cover (mean percent ground cover). Selected species were compared between soil disturbed seeding and non-soil disturbance seeding for

Table 3. Summary of sites and replications.

	Site 1 - Dozer Ripping		Site 2 - Rotoclear		Site 3 - Control	Site 4
	Soil Disturbance	No Soil Disturbance (control)	Soil Disturbance	No Soil Disturbance (control)	Untreated	Unburned
Number of Transects	3	2	3	3	3	3
Average Slope Percent	20	20	10	8	25	10
Average Aspect (degrees)	275	275	30	35	276	280
Date Sampled	16 Aug. 2004	16 Aug. 2004	17 Aug. 2004	17 Aug. 2004	16 Aug. 2004	17 Aug. 2004

Table 4. Average effective ground cover eight years post-treatment.

	Average Percent Effective Ground Cover
Rotoclear Seeded	76 bd
Non-Rotoclear Control, Seeded	52 be
Dozer Ripping Seeded	84 a
Non-Dozer-Ripping Control, Seeded	88 c
Burn Control, Unseeded	65 acde
Unburned Control	96 abc

a, b, c, e, f - significant difference at p < 0.01 level
d - significant difference at p < 0.05 level

*Table 5. Average foliar cover eight years post-treatment. *The unburned control includes only foliar cover from vegetation less than 3.7 m in height.*

	Average Percent Foliar Cover
Rotoclear Seeded	65 a
Non-Rotoclear Control, Seeded	44 a
Dozer Ripping Seeded	41 c
Non-Dozer-Ripping Control, Seeded	51 b
Burn Control, Unseeded	39 ab
Unburned Control	24* abc

a, b, c - significant difference at p < 0.01 level

significant ($p < 0.05$ and $p < 0.01$) differences of foliar cover. All summary statistics and t-test of significance were performed using Microsoft Excel (2002) software.

RESULTS

Effective Ground Cover

One of the objectives of the study was to determine the long-term soil protection and stability of the dozer ripping and Rotoclear treatments. Total effective ground cover was used as an indicator to determine long-term soil protection from erosion and to determine long-term maintenance of soil productivity. Ground cover has beenshown to be a reliable, quantifiable and repeatable indicator for measuring soil health and stability (Beasley 1974; O'Brien et al. 2003; Pannkuk and Robichaud 2003). Ground cover in the form of coarse woody debris is also essential to maintaining long-term soil productivity (Graham et al. 1994). Effective ground cover for the study included living and dead vegetation on the soil surface, as well as rock greater than 1.9 cm in diameter (USDA FS 2003). There were significant differences in effective ground cover 8 years following treatment application both within and between treatments (Table 4). The Rotoclear seeded treatment had significantly higher ($p < 0.01$) effective ground cover than the area that was seeded but had no Rotoclear treatment. The dozer ripping and seeded treatment showed no difference in effective ground cover compared to the area that was seeded but received no dozer ripping. Only the Rotoclear seeded showed average differences within a site location compared to its control. This indicates that the Rotoclear seeded treatment 8 years post-fire has a significantly higher amount of effective ground cover compared to its control. However, much of the ground cover consisted of wood chips created from the mulching of trees by the Rotoclear. The dozer ripping and seeding treatment showed no difference compared to its control.

Foliar Cover

Foliar cover is often used as a surrogate to determine production and to give an estimate of soil health and stability (Dadkhah and Gifford 1980; Meyer et al. 2001); however, foliar cover can vary significantly from year to year or by season, especially with grass and forb species, and it is not a good predictor of soil loss (Hardy 2002). In this study, foliar cover was used to verify the ground cover estimates and to determine productivity differences between treatments and their controls (Table 5). The results show a similar trend to effective ground cover when

Table 6. Plant species richness across treatments and controls.

	Total Species	Total Forbs	Total Grasses	Total Shrubs	Total Trees	Unique Species
Rotoclear Seeded	33	23	9	1	0	8, compared to control seeded
Non-Rotoclear Control, Seeded	43	27	14	2	0	18, compared to Rotoclear seeded
Dozer Ripping Seeded	32	18	13	1	0	9, compared to non-dozer ripping seeded
Non-Dozer-Ripping Control, Seeded	36	24	10	1	0	13, compared to dozer ripping seeded
Burn Control, Unseeded	38	28	7	3	0	
Unburned Control	25	15	5	3	2	

comparing the treatments to their controls. However, there was a jump in foliar cover for the Rotoclear treated transects. This indicates that the Rotoclear treated sites had a much higher plant production during the 2004 growing season. The increase in plant production may be due to the increase in soil carbon with the woody material, the increase in soil moisture due to the surface cover from the wood chips that may have reduced evaporation and drying the of the soil, or to both mechanisms.

Species Richness

The total number of vegetative species found, grouped by each life form class, was determined for the treatments studied and their controls (Table 6). Based on total counts, the controls that had no soil disturbance had higher total number of plant species. The burned non-seeded control also had a higher total species richness than the seeded treatments with soil disturbance. The greatest differences by life form showed that more forbs were present in the controls without soil disturbance and more grasses in the soil disturbance treatments. The higher richness of grasses in the soil disturbance is due to the success of the native species that were seeded. The total number of unique species was higher in the treatment controls. The summary results point to a long term reduction in total species richness when native grass species are used for emergency fire restoration and successful establishment occurs.

Species and Genera Differences

The Rotoclear seeded treatment was compared to its seeded control, and the dozer ripped and seeded treatment was compared to its control (Table 7 and Table 8). Some plants could be identified only to genus, while others displayed enough identifying characteristics to be classified to species level. The species and genera that showed significantly higher ($p < 0.01$) canopy cover in the non-Rotoclear control included three native forb species and genera, and one native *Carex* species (Table 7). The Rotoclear and seeded plots had significantly higher ($p < 0.05$ and $p < 0.01$) canopy cover for two seeded native grasses and one non-seeded native grass. There was also a higher ($p < 0.05$) canopy cover for an unidentified *Poa* species that is believed to be one of the seeded grasses, *Poa canbyi*. The Rotoclear treatment created conditions that provided favorable conditions for seeded native grasses. These grasses and the soil conditions created by the treatment prohibited the establishment of several native species that would likely have been present without the Rotoclear and seeding treatment.

Several species and genera showed significantly higher canopy cover for the dozer ripped and seeded treatment compared to the control (Table 8). The control had higher canopy cover for one native forb species ($p < 0.05$), one native family (Asteraceae) ($p < 0.05$), one native *Carex* species ($p < 0.05$), and one native grass species ($p < 0.01$). The dozer ripped and seeded showed significantly higher canopy cover for two of the native grasses ($p < 0.01$) that were seeded, and for one native forb species ($p < 0.05$). These results are similar to the Rotoclear treatment in that the soil disturbance with native seeding prohibited the establishment of several native species. The successional pathways and species composition eight years following the emergency rehabilitation treatments is dissimilar to the natural fire recovery of the area.

Conclusions

This study has shown that soil disturbance was required for successful immediate establishment of native grass species following fire on decomposed granitic soils. Areas that were broadcast seeded without soil preparation showed no evidence of successful grass seed establishment. The total amount of effective ground cover only increased with the Rotoclear treatment or the treatment where woody material was distributed on the soil surface. Seeded native grasses competed with the native flora. Species diversity

Table 7. Canopy cover differences by species and genera for Rotoclear seeded and non-Rotoclear control.

Control	Rotoclear Seeded
Carex species ** (*Carex* spp.)	Slender Wheatgrass ** (*Elymus trachycaulus*)
Dogbane ** (*Apocynum cannabinum*)	Arizona Fescue * (*Festuca arizonica*)
Penstemon species ** (*Penstemon angustifolius*)	Bluebunch Wheatgrass * (*Pseudoroegneria spicata* ssp. *spicata*)
Potentilla species ** (*Potentilla* spp.)	*Poa* species * (*Poa* sp.)

** Significance level p < 0.05; ** Significance level p < 0.01*

Table 8. Canopy cover differences by species and genera for dozer ripped and seeded and non-dozer ripped control.

Control	Rotoclear Seeded
Carex species * (*Carex* sp.)	Slender Wheatgrass ** (*Elymus trachycaulus*)
Poa species ** (*Poa* sp.)	Idaho fescue ** (*Festuca idahoensis*)
Aster species * (Asteraceae Family)	Little Goldenrod * (*Solidago nana*)
Potentilla species * (*Potentilla* sp.)	

** Significance level p < 0.05; ** Significance level p < 0.01*

was reduced in areas where the native seeded grasses were established following emergency post-fire restoration activities. Where the native grass seed was successful, the emergency restoration activities have created a long term successional pattern that differs from the natural fire recovery successional pattern.

Recommendations

Recommendations for future use of native grass species for emergency fire restoration on similar soil and pre fire vegetation types include:

1. Consider non-persistent or sterile species for immediate post-fire protection needs.
2. The use of native species for emergency protection post-fire must consider the long-term vegetation objectives. If there are no defined desired conditions for future vegetation composition, then it may be better to use only non-persistent species.
3. Soil preparation may be required for establishment of native grass species following fire on soil and pre-fire vegetation types similar to those in this study.

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