Lessons From the Hayman Fire: Forest Understory Responses to the Scarify-and-Seed Postfire Rehabilitation Treatment

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In unburned forests, organic plant litter and live vegetation help stabilize the soil and promote water infiltration. Much of this plant material is consumed during severe wildfires, leaving the bare ground susceptible to elevated postfire water runoff and soil erosion (Shakesby and Doerr 2006). Severe wildfires can also produce a water-repellant layer in the soil that further decreases water infiltration (DeBano 2000). Even after moderate rain events, runoff and erosion in severely burned areas can cause extensive and costly damage to roads, buildings, reservoirs, and ecosystems (Beyers and others 1998).

Land managers often prescribe seeding treatments immediately after wildfire in an attempt to minimize this potential damage. This relatively inexpensive rehabilitation treatment aims to stabilize the soil and decrease water runoff by rapidly increasing vegetative ground cover. Exotic grasses, including orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), and wheat (*Triticum aestivum*), are frequently used because seeds of these quick-growing species are readily available (Robichaud and others 2000). However, scientists and managers are beginning to realize that seeded species often do not establish densely enough to be effective at controlling runoff and erosion (Robichaud and others 2006, Wagenbrenner and others 2006).

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Consequently, managers are increasingly using other treatments, either alone or in conjunction with seeding; for example, seeding was combined with soil scarification on several large burns in the Colorado Front Range. Scarification is a mechanical soil treatment that aims to increase water infiltration by roughening up the soil surface and disturbing the water-repellant soil layer (Robichaud and others 2003). When combined with seeding, scarification may also help keep seeds on site until germination occurs. Unfortunately, the effects of the scarify-and-seed treatment on postfire runoff and erosion and on regenerating understory plant communities have not been closely analyzed. I seized an opportunity created by the 2002 Hayman Fire to assess the ecological impacts of the scarify-and-seed treatment by comparing understory establishment at two neighboring sites, one which burned but had no postfire rehabilitation treatment and the other which burned and was subsequently scarified and seeded.

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The 2002 Hayman Fire: A Research Opportunity

The Colorado Front Range has experienced several large and severe wildfires since the mid-1990s. These fires likely represent a shift in fire regimes—from one of mixed severity to one of high severity—that is partly a result of fire suppression and grazing activities since the late 19th century (Brown and others 1999, Kaufmann and others 2001). All these fires occurred partly in the wildland-urban interface, where human values were at risk from both fires and subsequent flooding and erosion. To date, the largest and most severe fire known to burn in the Front Range was the June

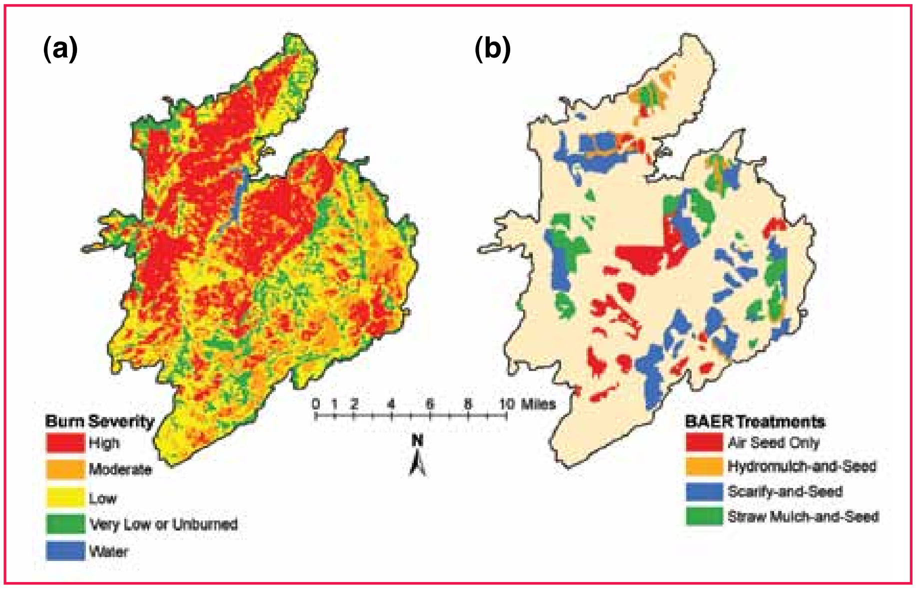

Figure 1—*Burn severity map of the Hayman Fire (a) and locations of Forest Service postfire rehabilitation treatments (b). The burn severity map was derived by the Forest Service from a SPOT4 satellite image and is largely based on overstory tree mortality (Robichaud and others 2003).*

2002 Hayman Fire, which burned 137,600 acres (55,800 hectares) of land dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). Over 50 percent of the Hayman burned as a moderate-severity to high-severity fire (fig. 1a), with complete or nearly complete overstory mortality and extensive crown, litter, and duff consumption (Robichaud and others 2003). Most of the Hayman Fire occurred on National Forest System land.

The steep, dissected topography and the highly erodible granitic soils common throughout the Hayman Fire area made moderately and severely burned areas extremely susceptible to elevated postfire runoff and erosion. Therefore, the Forest Service rehabilitated approximately 32,000 acres (12,800 hectares) of moderately and severely burned forest in the months following the fire (fig. 1b), at a cost of more than $16.5 million (Robichaud and others 2003). The scarify-and-seed treatment was implemented on 13,200 acres (5,300 hectares) and cost over $1.5 million to apply. Soil scarification was done along terrain contours, either by all-terrain vehicles pulling harrows (fig. 2) or by hand with McLeods. After scarification, a certified weed-free mixture of 70 percent barley (*Hordeum vulgare*) and 30 percent triticale (×*Triticosecale rimpaui*, a wheat-rye hybrid) was applied to the scarified area at a target density of 26 seeds per square foot (280 seeds per square meter). Both species are exotic annual cereal grasses that typically germinate quickly but persist on the landscape for only a few years.

In 2004, understory plant data were collected in unrehabilitated and rehabilitated study sites within the Hayman Fire area (fig. 1b). The unrehabilitated site and the twenty 0.25-acre (0.1-hectare) upland plots within it were originally established in 1996 as part of other research activities (Fornwalt and others 2003, 2009; Kaufmann and others 2000). Three of these plots were moderately or severely burned and were incorporated into this study. I also established a rehabilitated study site 2 miles (1.2 kilometers) to the east of the unrehabilitated site. The rehabilitated site is in an area that was moderately to severely burned by the Hayman Fire and was subsequently scarified and seeded (fig. 3); the site contains 14

Figure 2—*The scarify-and-seed treatment was implemented on 13,200 acres (4,340 hectares) of moderately to severely burned Forest Service land in the months following the Hayman Fire. Scarification was done in rows either by all-terrain vehicles pulling harrows (as shown in the photo) or by hand with McLeods. Barley and triticale seeds were spread on the scarified areas. Photo: Pete Robichaud.*

upland plots. The two sites are similar in elevation, topography, and pre-fire overstory structure. In each plot, the presence of all vascular plant species was recorded, and percentage vegetative cover by species was estimated in ten 11-square-foot (1-square-meter) subplots located within the plot. Only live plants were included in the surveys, with the exception of the seeded grasses; dead seeded grasses were also measured because of their potential to affect understory establishment. We tested for differences in understory response variables between sites using multiresponse permutation procedures, a nonparametric alternative to analysis of variance.

Figure 3—*Seeded grass establishment was generally imperceptible in scarified and seeded areas of the Hayman Fire, although in this area, establishment was uncharacteristically successful. The photo was taken in the summer of 2004, a year and a half after the treatment was applied. Photo: Paula Fornwalt.*

Impacts of the Scarify-and-Seed Rehabilitation Treatment on the Forest Understory

The Rehabilitation Treatment

Of the two grasses seeded, only triticale was found growing in the plots; barley was never encountered. Triticale was present at both sites. At the unrehabilitated site, live and dead triticale were found in 33 percent of the plots, while at the rehabilitated site, live triticale was found in 64 percent of the plots and dead triticale was found in 71 percent. It is unknown how triticale arrived at the unrehabilitated site; seeds may have been inadvertently dropped from aircraft while seeding other portions of the burn, or they may have dispersed in from upslope rehabilitated areas. The cover of both live and dead triticale was similar between the two sites ($p = 0.599$ and 0.484, respectively). Live and dead triticale, combined, averaged less than 0.5 percent and never exceeded 3.0 percent in any single plot. No visible evidence of the postfire scarification treatment (for example, recently disturbed mineral soil) was visible at survey time.

Scarification is a mechanical soil treatment that aims to increase water infiltration by roughening up the soil surface and disturbing the water-repellant soil layer. When combined with seeding, scarification may also help keep seeds on site until germination occurs.

I suspect that unfavorable weather conditions during 2002 and 2003 were at least partially responsible for the poor establishment of seeded grasses on upland slopes. These summers were among the warmest and driest on record in the Colorado Front Range; high temperatures and lack of moisture may have killed many seeds and germinated seedlings. The summer of 2004 then brought several high-intensity rainfall events that likely washed away much of the remaining viable seed.

Other researchers monitoring the effectiveness of the scarify-and-seed treatment in the Hayman Fire area also found that seeding did not increase vegetative cover (Rough 2007). In addition, they found that the average depth of scarification after the Hayman Fire was less than 1 inch (2.5 centimeters), and, therefore, scarification alone was not sufficient to break through the hydrophobic layer that extended nearly 4 inches (10 centimeters) into the soil profile. As a result, the treatment was not effective in reducing sediment yields immediately after the fire; indeed, the mechanical disturbance caused by scarification may have even increased sediment movement immediately after the treatment was implemented.

Impacts on Native Species

A total of 128 native plant species were found within the two sites. Native plant richness and cover were similar at the rehabilitated and unrehabilitated sites ($p = 0.256$ and 0.381, respectively), with native richness averaging 42 species per plot and native cover averaging 19 percent.

Many of the native species found in the rehabilitated and unrehabilitated sites are perennial species that are abundant throughout unburned Front Range forests, including the graminoids Ross' sedge (*Carex rossii*), prairie Junegrass (*Koeleria macrantha*), and mountain muhly (*Muhlenbergia montana*); and the shrub kinnikinnick (*Arctostaphylos uva-ursi*). The perennial forbs hairy false goldenaster (*Heterotheca villosa*), prairie bluebells (*Mertensia lanceolata*), and eastern pasqueflower (*Pulsatilla patens*) are also abundant in the Front Range (fig. 4). Each of these species occurred in more than 75 percent of plots studied here, and together, they constituted nearly 30 percent of the native plant cover. The cover of each species appears to have been unaffected by the scarify-and-seed treatment ($p > 0.250$ in all cases).

These findings suggest that the scarify-and-seed treatment had little to no impact on native plant establishment after the Hayman Fire. This is not surprising, given that there was likely little competition from the seeded grasses. Furthermore, many of the native understory species are adapted to regenerate quickly after disturbance, either by sprouting from surviving underground parts or by geminating from seeds in the soil seedbank (USDA Forest Service 2009). Indeed, native plant richness and cover at both sites were similar to that observed in the unrehabilitated site before the fire, suggesting that understory recovery in this system can naturally occur in as little as 2 years (Fornwalt and others 2003, 2009). Others also have found that low levels of seeded grass cover did not affect native species in fire-adapted ecosystems (Keeley and others 1981), but high levels of seeded grass cover decreased native plant establishment and growth in many cases (Keeley and others 1981, Keeley 2004, Schoennagel and Waller 1999).

Impacts on Exotic Invaders

Fourteen exotic species were found in the plots (excluding triticale). In general, the number and cover of exotic species per plot were low, with an average exotic richness of four species per plot and an average exotic cover of only 0.6 percent. Neither exotic plant richness nor cover differed significantly between sites ($p = 0.835$ and 1.000, respectively).

Six of the exotic species, cheatgrass (*Bromus tectorum*), musk thistle

Figure 4—*The native species prairie bluebells (top left), kinnikinnick (top center), and eastern pasqueflower (top right) are abundant throughout the Colorado Front Range and appear to have been unimpacted by the scarify-and-seed rehabilitation treatment. Canadian thistle (bottom left), mullein (bottom center), and musk thistle (bottom right) were three of the six noxious weed species found in the unrehabilitated and rehabilitated sites, though they were uncommon and do not appear to have been stimulated by the postfire rehabilitation activities. Kinnikinnick photo by Laurie Huckaby; all other photos by Paula Fornwalt.*

(*Carduus nutans*), Canadian thistle (*Cirsium arvense*), Saint Johnswort (*Hypericum perforatum*), butter-and-eggs (*Linaria vulgaris*), and mullein (*Verbascum thapsus*), are noxious weeds in Colorado (see fig. 4). All these species had negligible cover: butter-and-eggs cover was less than 0.5 percent, while all other species had less than 0.1 percent cover each. None of the species appear to have been affected by the scarify-and-seed treatment ($p > 0.500$ in all cases).

Exotic species often increase following disturbances by taking advantage of reduced competition for resources, and management activities such as firefighting and rehabilitation may also introduce exotic species to locations where they did not previously occur (Keeley and others 2006). Although these results suggest that the scarify-and-seed treatment per se had little or no effect on exotics, the fire as a whole did increase exotic richness and cover relative to prefire levels, especially in the most severely burned areas (Fornwalt and others, in review). While exotic richness and cover in the Hayman Fire area remain low at this point in time and exotic species do not yet appear to be affecting native plant recovery, they should nonetheless continue to be monitored in both rehabilitated and unrehabilitated areas.

Management Implications

Managers have implemented the scarify-and-seed treatment after several recent Colorado Front Range fires, but the effects of the treatment on the forest understory had never before been documented. While the interpretation of these findings is somewhat constrained by the small number of plots and lack of study site replication, they nonetheless suggest that the scarify-and-seed treatment had little to no effect on understory recovery after the Hayman Fire. This is likely because the scarify-and-seed treatment effects were nearly imperceptible: seeded grass establishment was negligible, and signs of soil scarification were not visible a year and a half after treatment was applied. Furthermore, other researchers working in the Hayman Fire found that the scarify-and-seed treatment had no impact on postfire erosion. In light of the considerable cost and increasingly widespread use of this rehabilitation treatment, it is imperative that researchers and managers continue to learn more about both the effectiveness and the ecological impacts of scarification and seeding after fire.

For more information about this study or for copies of related publications, contact Paula Fornwalt, Forest Service, Rocky Mountain Research Station, 240 West Prospect Road, Fort Collins, CO 80526, email pfornwalt@fs.fed.us, phone 970-498-2581.

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