Fire Effects on Soils and Restoration Strategies

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Non-native and Native Seeding

Jan L. Beyers

Abstract

Post-fire seeding is used to stabilize burned slopes by increasing plant cover, prevent invasion of burned areas by noxious weeds, replace weedy annual grasses on burned rangelands, and reestablish desirable vegetation including tree species. Fast-growing pasture grasses and forbs have been most widely applied for post-fire stabilization and rehabilitation, but use of native species is increasing. Successful ground cover enhancement with seeded species depends on protection of the seed from predators and desiccation, the amount and timing of growing-season rainfall, and resting the area from grazing until seeded species and natural regeneration are well-established. As these conditions are often not met, grass seeding has a mixed record of success for erosion reduction and rangeland rehabilitation. In cases where post-fire erosion would threaten life or property, a more effective hillslope stabilization method should probably be used. Seeded grasses can displace native herbaceous plants in post-fire succession, and high grass cover can limit recruitment of tree and shrub seedlings on burned sites. Land managers must weigh the potential erosion control and noxious weed reduction benefits against the economic cost of seeding, the ecological cost of native plant suppression, and the possible economic cost to replant timber species.

INTRODUCTION

Seeding after fire is conducted for a variety of reasons. As noted in the Chapter 10, annual grasses are frequently seeded for erosion control as part of emergency stabilization treatments. In addition, perennial grasses and forbs are often used to rehabilitate burned rangelands, either because overgrazing had caused a shift to shrub dominance or because undesirable non-native annual grasses otherwise would predominate after fire. Tree seed spread for reforestation purposes constitutes post-fire restoration. This chapter describes the use of post-fire seeding for these purposes and reviews some of the

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literature on treatment effectiveness, with a focus on seeding used for slope stabilization. Changing trends in post-fire seeding, primarily in the western U.S.A., are discussed along with suggestions for needed research.

RATIONALE FOR POST-FIRE SEEDING

Sediment production from burned slopes and disturbed sites correlates inversely with vegetative cover (Noble 1965, Orr 1970), making vegetation enhancement a logical post-fire rehabilitation practice. Quick plant establishment is regarded as the most cost-effective method to promote rapid infiltration of water and to keep soil on hillsides (Rice et al. 1965, Miles et al. 1989). In the western USA, grass seeding is the most widely used post-fire hillslope stabilization treatment, typically involving seeds of annual and/or perennial species applied from an aircraft (Robichaud et al. 2000).

Land management agencies in the USA (USDA Forest Service 2004) and elsewhere (e.g., Australia [State of Victoria 2006], Canada [Pike and Ussery 2006], Greece [Raftoyannis and Spanos 2005]) are required to assess burned landscapes and determine whether post-fire erosion and runoff will threaten human life and property, soil productivity, natural and cultural resource values, or the quantity and quality of water produced from public lands. Post-fire assessments usually focus treatment on severely-burned areas, where plants, litter and duff have been removed by the fire. Seeding has long been prescribed as a hillslope stabilization treatment, with the following primary objectives:

- Reduce erosion by increasing ground cover (post-fire assessments often assume that much of the natural soil seed bank was killed by the fire in addition to standing vegetation)
- Promote water infiltration and reduce runoff
- Maintain site productivity by capturing nutrients that would otherwise be lost in runoff and erosion

Seeding with herbaceous species can provide additional benefits in post-fire rehabilitation:

- Prevent invasion by undesirable plants
- Provide forage for wildlife and/or livestock

Seeding with tree species is used to jump-start forest succession where fires were particularly intense or were outside the natural range of variation for the desired plant community, so that natural regeneration would be delayed (see Chapter 14).

TYPES OF SPECIES SEEDED

Many public lands in the USA were severely overgrazed by the late 1890s, leading to disastrous erosion and a need to identify plant species useful for rangeland rehabilitation (Monsen and McArthur 1995). At the same time, lands laid bare by forest fires had poor capacity for herbaceous regeneration. Considerable research was conducted in the 1930s, '40s, and '50s to find grasses and forbs that would grow quickly after fires, hold soil in place, and withstand grazing by wildlife and livestock (e.g., Forsling 1931, Christ 1934, Friedrich 1947a, b, Evanko 1955, Hull and Johnson 1955, McClure 1956). Besides reducing erosion, post-fire plant establishment was regarded as a way to get useful production – beef cattle and/or sheep that could graze on the herbaceous plants – from lands that would not produce timber revenue for decades. Seed mixes were refined for particular areas as germination and establishment success were evaluated. Most contained annual grasses to provide quick cover, perennial grasses to establish long-term protection, and often legumes to add nitrogen to the soil (Klock et al. 1975, Ratliff and McDonald 1987). Seeded grasses and forbs in the USA were typically pasture species from Europe and Asia, although some selections from native species have been developed as well (Monsen et al. 2004).

Seed of forest trees may be broadcast after fire, particularly where high intensity fires burned through young forest stands just regenerating after timber harvest or a previous fire and natural seed sources would be scarce. However, planting seedlings has largely replaced broadcast seeding in most areas of the USA and Canada (Densmore et al. 1999).

Shrublands, such as the California chaparral or Spanish matorral, are often seeded after fires with annual grasses that will hold soil in place for a few years, until shrub cover is re-established, and then die out. Annual ryegrass (*Lolium multiflorum*) has been the species of choice in the USA because it is inexpensive, readily available in large quantities, and can be easily applied from the air (Fig. 1; Barro and Conard 1987). Cereal grains such as barley (*Hordeum vulgare*) or oats (*Avena sativa*) may be used instead of ryegrass. Post-fire seeding with annual ryegrass or other species and subsequent prescribed fire has also been used to reduce shrub density for range improvement and increased water yield (Schultz et al. 1955, Hibbert et al. 1974).

Most post-fire seeding projects in shrub-steppe or other range types have dual objectives of soil stabilization and rangeland rehabilitation (Friedrich 1947b, Pellant 1990). In the intermountain west of the USA, establishment of non-native annual cheatgrass (*Bromus tectorum*) in sagebrush-steppe vegetation has created continuous fuel beds that promote fire spread, leading to shrub death and increased dominance by cheatgrass (Whisenant 1990). Post-fire rehabilitation has generally used aggressive non-native perennial grass species, including crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*Agropyron intermedium* [*Elymus hispidus*]), smooth brome (*Bromus inermis*), orchard grass (*Dactylis glomerata*), hard fescue (*Festuca ovina*), and meadow foxtail (*Alopecuris pratensis*) (Monsen and McArthur 1995). Interest in restoring rather than just rehabilitating rangelands using native species has increased in recent years (Allen 1995).

Fig. 1 Loading annual ryegrass for post-fire seeding in California, USA (Photo credit: USDA Forest Service).

NATIVÉ VERSUS NON-NATIVE SPECIES

As described above, post-fire seeding has historically been done with commercially available non-native species selected for vigorous germination, rapid establishment, high production, and grazing tolerance. Public interest in ecological restoration has spurred greater use of native plants for stabilization and rehabilitation. In the USA, federal land management agencies are now directed to use native species, when practicable, for revegetation projects, including post-fire rehabilitation (Richards et al. 1998). However, the difficulty of acquiring enough native seed to cover burned areas after large fires, combined with concern about the ecological impacts of using non-local genotypes of native species, has limited the amount of post-fire seeding actually done with native plants (Richards et al. 1998, Goodrich and Rooks 1999, Robichaud et al. 2000). In some cases the 'native' species used for post-fire seeding were not found at the burn site before the fire (Hunter and Omi 2006). Goodrich and Rooks (1999) point to the need to develop native plant materials that are more competitive with cheatgrass for seeding burned, degraded rangelands; they argue that letting concerns about genetic pollution prevent use of non-local native species may be unrealistic in the face of the greater problems caused by continued cheatgrass dominance of vast rangeland areas (see also Jones 2003). Post-fire rehabilitation in the western USA is now likely to be done with a mix of cereal grains and some native species. In Spain, Pinaya et al. (2000) found that seeded native species produced cover faster and survived a drought period better than non-native annual ryegrass, suggesting that the native species are a better choice there for post-fire rehabilitation . More research is needed on the use of native species for post-fire seeding.

HOW WELL DOES SEEDING WORK?

Seeding after wildfire for erosion control has a mixed record of success (see review in Beyers 2004). Robichaud et al. (2000) examined published literature and numerous USDA Forest Service monitoring reports to assess the effectiveness of a wide range of post-fire rehabilitation practices, including seeding. Relatively few studies reported erosion measurements, so most of the assessment was based on recorded vegetation cover. Cover percentage greater than 30 was regarded as partially effective for erosion control, while 60 percent cover was considered effective, based on findings of Noble (1965) and Orr (1970). Robichaud et al. (2000) found that seeding did increase the likelihood of achieving partially or completely effective ground cover (Table 1), but the proportion of sites with at least 60 percent cover in the first year after seeding was still much less than half. A greater proportion of both seeded and unseeded sites had partially effective cover, more so in seeded sites. Cover was more likely to reach 60 percent the second year after a fire (Table 1).

Table 1: Percentage of study sites in publications and monitoring reports reviewed by Robichaud et al. (2000) that had at least 30 percent and at least 60 percent cover by the end of the first and second growing seasons after a fire. All published studies contained data from both seeded and unseeded plots. Monitoring reports did not always contain both treatments. Multiple study sites within one publication or report were counted separately (Modified from Robichaud et al. 2000).

Study sites	Percentage of sites with >30% cover		Percentage of sites with >60% cover	
	Seeded	Unseeded	Seeded	Unseeded
Number	Percentage			
	First Post-fire Year			
Publications				
19	42	26	26	10.5
Reports				
21	74	38	35	8
	Second Post-fire Year			
Publications				
18	78	67	56	17.
Reports				
4	75	75	25	50

A flurry of recent research has included erosion measurements, with continued mixed results on seeding effectiveness. Pinaya et al. (2000) found that seeding with a commercial mix including annual ryegrass or with a mixture of native species was equally effective in reducing erosion on granitic soil in Spain, but seeding had no impact on post-fire runoff. Total soil loss from seeded plots was only about 10 percent of that from controls. Seeding with a mixture of native and naturalized species, with or without straw mulch, reduced erosion on calcareous and gypsiferous soils as well (Badía and Martí 2000). In contrast, seeding with white winter wheat (*Triticum aestivum*) produced relatively little cover and had no impact on erosion in central Washington USA (Robichaud et al. 2006). Wagenbrenner et al. (2006) also reported no reduction in erosion due to seeding at a site in Colorado, USA. Precipitation, especially during the summer, was below average in the latter two studies, affecting seeded grass establishment. Robichaud et al. (2006) also looked at the effectiveness of post-fire fertilization, a common practice in the Pacific Northwest of the USA, for increasing growth of seeded grasses. They found that fertilizers had no impact on seeded grass cover or erosion during the four years of the study.

The efficacy of grass seeding for reducing populations of undesirable species has a similar mixed record of success. Evans and Young (1978) found that seeding must be done immediately after fire to effectively reduce abundance of cheatgrass, and the seeded perennials must be protected from grazing to establish successfully. Goodrich and Rooks (1999) recorded less cheatgrass, yellow salsify (*Tragopogon dubius*), and musk thistle (*Carduus nutans*), a noxious weed, growing six seasons after fire on a Utah, USA site seeded with aggressive non-native perennial grasses (crested wheatgrass, intermediate wheatgrass, orchardgrass, and smooth brome). Squirreltail (*Elymus elymoides*), a native perennial grass, was more abundant on the seeded plots. On the other hand, Ratzlaff and Anderson (1995) found no difference in the amount of cheatgrass on seeded compared to unseeded plots in an Idaho, USA sagebrush rangeland; however, cheatgrass had not been particularly abundant before the fire, and establishment of seeded species was poor because of low precipitation the first year after fire. Floyd et al. (2006) found lower densities of several non-native invasive species on plots in areas seeded after fire with various mixtures of native perennial grasses at Mesa Verde National Park (Colorado, USA), but cheatgrass abundance was not affected by the treatments. In forested areas, researchers have found lower abundance of non-native species in seeded areas compared to non-seeded plots (Schoennagel and Waller 1999, Barclay et al. 2004, Keeley 2004).

Broadcast seeding of tree species can be done successfully (Densmore et al. 1999, Zagas et al. 2004), though planted container-stock seedlings have better survival and grow faster than those germinating from seed. Some type of site preparation enhances the germination rate and establishment of trees (see below).

Factors Affecting Seeding Success and Effectiveness

The quantity of seed applied can obviously affect the likelihood of successful establishment. Target seeding rates of 400 to 600 seeds per m^2 are commonly used, taking into account percent viability of the seed stock. Very high cover levels have been observed where large amounts of seed were applied (Keeley 2004). More importantly, grass establishment and persistence are affected by the amount, timing, and intensity of rainfall (Ratzlaff and Anderson 1995, Robichaud et al. 2000, 2006, Barclay et al. 2004), as is establishment of trees from seeding (Zagas et al. 2004). If the first rains that fall after seeding are not gentle and regular, little seeded grass will be established. Heavy rains wash seed off of steep hillslopes and into channels (Wagenbrenner et al. 2006), and strong wind events before rains fall may blow seed away, necessitating reseeding (Keeley et al. 1995). Second year cover, especially for annual species, depends on favorable conditions for growth and seed-set during the first growing season.

Seed predation by birds and rodents can be significant, especially for large-seeded species like cereal grains (personal observation). Seeding into ash or just before snowfall help minimize seed loss to animals. Covering broadcast seed with mulch can greatly improves plant establishment and the success of the seeding treatment (Dean 2001). Mulch both protects seed from predators and helps retain soil moisture. While Badía and Martí (2000) did not observe greater seeded species cover with mulch added, plant weight was significantly enhanced on mulched plots. Seeds lying on the soil surface may germinate, but their roots can have a hard time penetrating the ground (Fig. 2). Most species used for rangeland rehabilitation do best if planted with a rangeland drill or otherwise covered with a small amount of soil (Monsen et al. 2004). Soil scarification before broadcast seeding may improve tree seeding success by providing favorable microsites for seedling establishment (Densmore et al. 1999).

Evans and Young (1978) found that attempted rangeland rehabilitation without protection from grazing was unsuccessful. Similarly, rehabilitation team members interviewed by Robichaud et al. (2000, Appendix B) identified protecting burned areas from grazing by livestock and native ungulates for several years as the most important factor favoring successful seeded species establishment and natural plant regeneration.

Ecological Consequences of Seeding

The practice of post-fire seeding has its critics (Keeley et al. 2006). The same qualities that make certain grass and forb species useful for watershed stabilization, namely fast growth and wide adaptability, also make them highly competitive with naturally-regenerating vegetation. Foresters have long been aware that successful grass establishment can interfere with tree seedling survival (Pearson 1942, Friedrich 1947a, Larson and Schubert 1969, Elliott

Fig. 2 Seeded grass seedling with roots mostly on top of the soil (arrow). Most of the seedlings on this site dried out and died (Photo credit: USDA Forest Service).

and White 1987, Ratliff and McDonald 1987). Sites in California, USA aerially-seeded after a fire with annual ryegrass had low pine (*Pinus*) seedling densities on plots with annual ryegrass cover greater than 40 percent (Griffin 1982, Conard et al. 1991); Barclay et al. (2004) found a similar relationship in New Mexico. In the southern Cascades, high mortality of planted sugar pine (*Pinus lambertiana*) seedlings occurred during the first year after fire on plots with high annual ryegrass cover (49 percent when seedlings were planted, 85 percent by mid-summer) (Amaranthus et al. 1993). Seedlings planted during the second year after a fire had greater survival on seeded plots, which by then contained only mulch from dead ryegrass, while pine seedlings in unseeded plots faced competition from native shrubs (Amaranthus et al. 1993). Once conifer seedlings are well established, grass competition is generally less detrimental to their growth than shrub competition (McDonald and Oliver 1984, McDonald 1986). Even cereals such as wheat can competitively suppress tree seedlings in the first year after fire when seeded grass density is high (Keeley 2004).

Successful establishment of seeded grasses frequently results in decreased growth of native herbaceous species as well (Beyers 2004). Considerable controversy arose over post-fire seeding in southern California chaparral ecosystems (Barro and Conard 1987) because a specialized annual flora takes advantage of the light, space and soil nutrients available immediately after fire (Sweeney 1956, Keeley et al. 1981). In addition, some dominant chaparral shrub species regenerate after fire only from seed (Sampson 1944, Keeley 1991; Fig. 3). Competition from seeded grasses could potentially have long-term impacts on plant community composition (Barro and Conard 1987). Because research demonstrated that seeded ryegrass reduced native plant cover, diversity, and shrub seedling density – often without increasing total plant cover – but seldom reduced erosion (Nadkarni and Odion 1986, Taskey et al. 1989, Beyers et al. 1994, 1998, Wohlgemuth et al. 1998), the U.S. Forest Service now does not seed chaparral slopes in southern California after most fires.

Fig. 3 Shrub seedlings (*Adenostoma fasciculatum, Ceanothus* spp.) and fire-following herbaceous plants take advantage of the high-light environment in post-fire chaparral (Photo credit: USDA Forest Service).

Seeded annual grasses that establish thick cover can become fuel for the next fire after they cure during summer. This increases the risk that a site will reburn before major tree and shrub species have matured enough to set seed (Crane et al. 1983, Zedler et al. 1983).

TO SEED OR NOT TO SEED?

Whether or not to seed after fire depends on the land manager's objectives, ecosystem, and ecological concerns. If immediate post-fire erosion protection is needed, mulch is much more effective at keeping soil on the slopes (see Chapter 13). With post-fire seeding, there is always the risk that the amount and timing of precipitation will not allow successful establishment. For rehabilitation of rangeland infested with cheatgrass or other invasive annuals, seeding with perennial grasses is the best strategy for establishing vegetation that will not be as likely to carry fire; the land manager's dilemma is whether to use proven non-native species or take a chance with more expensive native seed. Few studies have been conducted on the efficacy of post-fire grass seeding for suppression of invasive species in other vegetation types. Seeding remains the least expensive way to get some kind of ground cover on burned areas for site stabilization, unless expensive native species must be used, and it remains the only method applicable to very large areas.

The risk of woody plant regeneration failure with post-fire seeding in forests needs to be acknowledged. While 30 percent grass cover will begin to reduce erosion (Table 1), this is also the percentage grass cover that Schultz et al. (1955) found would increase shrub seedling mortality, and the 60 percent cover sufficient to virtually eliminate sediment movement is strikingly similar to the amount of grass cover that Schultz et al. (1955) would eliminate shrub seedlings altogether (55 percent). Tree seedlings probably respond similarly. The dilemma for the land manager is thus obvious: if seeding produces enough cover to effectively control erosion, it will also effectively suppress or eliminate woody plant seedlings in the seeded area. This could have repercussions for forest stand development and browse regeneration for wildlife.

For the land manager concerned primarily with erosion, Table 1 suggests that seeding may be a reasonable gamble for trying to increase plant cover during the first year after a fire. Seedling is likely to stabilize a site more quickly than natural regeneration. Where control of erosion for protection of life, property, or infrastructure is essential, however, seeding would not be a good choice – effective control of sediment movement is likely to be achieved at the end of the first year only one third of the time by seeding. More expensive but effective treatments such as straw mulch should be considered, especially where protection is needed from the first storms that occur after the fire.

Table 1 also expresses the risks to conifer and other woody seedling regeneration faced by the manager considering seeding. A greater proportion of seeded sites could experience woody regeneration failure due to competition with herbaceous plants than would occur naturally. Partial control of erosion with only partial suppression of woody regeneration is a more likely outcome, however. Land managers must weigh the potential erosion control benefit against the economic cost of seeding, the ecological cost of native plant suppression, and the possible economic cost to replant timber species. Rates of seeding or grass species which are likely to produce high levels of first year cover should probably be reserved for high value timberland that will be replanted and intensively managed.

In the western USA, where large high-intensity wildfires are a major public concern, post-fire seeding of burned areas has decreased dramatically since the 1980s (Robichaud et al. 2000). Efforts now focus on areas of high burn severity, where soil erosion is likely to be high and the potential for weed

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invasion is great, rather than on seeding every acre of every burn. The increasing use of post-fire seeding for suppression of invasive species in forest lands creates the same management dilemma as for erosion control: seeded grass establishment that will effectively suppress noxious weeds may also inhibit tree regeneration. The decision to seed after a fire must be made with these possible consequences in mind.

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