DISTURBED FORESTLAND REVEGETATION EFFECTIVENESS MONITORING -- RESULTS OF 30 YEARS[1]

Larry K. Holzworth, Harold E. Hunter, Susan R.Winslow[2]

Abstract. Wildfires, combined with extended drought, have impacted millions of acres of forest and grazing lands in the West. Over the past 3 years, more than 272,000 wildfires occurred on 18.5 million acres across the United States. In the aftermath of such fire seasons, important questions arise: (1) should intense burns be seeded, and with what species and what methods, (2) will soil and water resources be protected and invasive species suppressed at reasonable costs, and (3) will seeded species impact timber regeneration and understory plant community composition? Similar questions have been raised in treating forestland disturbed by timber harvest. In 1974, the USDA Natural Resources Conservation Service (NRCS) began investigating these issues. Eventually, three field evaluation plantings (FEP's) representing four different forest environments were established on privately owned land in western and eastern Montana, from which timber was harvested. The FEP's were installed as replicated and unreplicated plots in the fall or winter following disturbance. In 1988, following widespread criticism of extensive aerial seeding conducted under the NRCS Emergency Watershed Program (EWP), six fire-impacted watershed-monitoring studies were established. The burned, and harvested and mechanically scarified sites were seeded with herbaceous species, mainly grasses. On all sites, the plan was to monitor results during years 1-3, 5, and 10 years after treatment. Results indicate grass seeding had little effect on tree regeneration, invasive species were suppressed on some sites by some seeded species, and on average, soil erosion was reduced by 39% on burned sites and 28% on logged sites in the cool-moist environment. There was no change in unseeded species numbers on the cool-moist and a loss of two unseeded species on the warm-moist environments, but only on the burned sites. Tree establishment was greater on both burned and logged sites in the cool-moist environment. On the burned sites, the numbers of seedlings were 67% of the controls, and on the logged sites numbers of seedlings were 53% of the controls. Even though seedling numbers were reduced, the site is considered fully stocked (1,195 trees ha^{-1} or 484 trees ac^{-1}). The planting of

---

[1]Paper was presented at the 2003 National Meeting of the American Society of Mining and Reclamation and The 9th Billings Land Reclamation Symposium, Billings, MT, June 3-6, 2003. Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

2 Larry K. Holzworth, Plant Materials Specialist, USDA – Natural Resources Conservation Service (NRCS),10 East Babcock St. Federal Bldg., Rm. 443, Bozeman, MT 59715, 406.587.6838; larry.holzworth@mt.usda.gov. Harold E. Hunter Former State Forester, NRCS, 1755 Moffit Gulch Rd., Bozeman, MT 59715; HHunter355@aol.com. Susan R.Winslow Agronomist, USDA-NRCS, Bridger Plant Materials Center, RR2 Box 1189, Bridger, MT 59014, 406.662.3579, susan.winslow@mt.usda.gov

Proceedings America Society of Mining and Reclamation, 2003 pp 386-409
DOI: 10.21000/JASMR03010386

https://doi.org/10.21000/JASMR03010386

adapted native or introduced forage grass species provides the benefits of reduced erosion and enhanced forage resourcess on a variety of sites without affecting the survival of tree seedlings on most sites.

Additional Key Words: wildfire seeding, erosion, weeds, forage.

Introduction

Wildfires, combined with extended drought, have altered millions of acres of forest and grazing lands in the West. Over the past 3 years, more than 272,000 wildfires occurred on 18.5 million acres across the United States (NIFC News, 2002). These fires have brought forward management concerns such as should intense burns be seeded; with what species and what methods; will soil and water resources be protected and invasive species suppressed; and how will seeded species impact coniferous timber regeneration and forest understory plant community development? Similar questions have been raised in treating forestland disturbed by timber harvest. One method to help alleviate these concerns is to seed herbaceous vegetation, mostly perennial grasses.

Fire is an important disturbance influencing the characteristics of plant ecosystems across the west. Fire can reduce dense vegetation, thus improving wildlife habitat and lessening the potential for large disastrous wildfires (NIFC News, 2002). However, the lack of vegetation on hillsides following the fire increases the likelihood of flooding and soil erosion. Soil movement into streams, lakes, and riparian zones may degrade water quality and change the geomorphic and hydrologic characteristics of these systems. Soil loss from hillsides may reduce site productivity (Robichaud et al., 2000). Noxious weeds are likely to become established in many burned areas because fire-produced disturbances favor weed colonization (Goodwin et al., 2002, and Roche and Roche, 1991).

Aerial seeding of disturbed forest sites has been primarily used to address erosion and water quality concerns. Other potential benefits have been recognized as well, e.g. weed suppression and forage resource enhancement. A wide variety of grass species or mixtures and application rates have been used over the years in post-fire treatments. Grass seeding does not assure adequate plant cover during the first critical year after a fire. However, ground cover and a decrease in erosion and weed encroachment can be expected the second and subsequent years (Robichaud et al., 2000). Several species commonly used for post-fire seeding, due to rapid growth and wide adaptability (Klock et al., 1975), have been found to be strongly competitive with conifer seedlings in experimental plots. Orchardgrass (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*), and timothy (*Phleum pratense*) reduced growth of ponderosa pine seedlings in tests conducted in California (Baron, 1962). Orchardgrass and crested wheatgrass (*Agropyron desertorum*) reduced ponderosa pine growth in Arizona (Elliot and White, 1987). As an emergency treatment, rapid revegetation establishment has been regarded as the most cost-effective method to promote rapid infiltration of water, keep soil on hillslopes and out of channels and downstream areas (Robichaud et al., 2000). Native species may not compete well with some of the grass species that are planted to prevent erosion and noxious weed invasion (Griffin, 1982).

In 1976, USDA-Natural Resources Conservation Service (NRCS) in Montana began a study to evaluate the practice of seeding herbaceous vegetation in a forest environment. The study was initiated in response to a request from the Beaverhead Conservation District, also supported by Headwaters Resource Conservation and Development Project, Project Measure 76B9, “Revegetating Clear-cut Forest Areas," to assess the value of seeding different herbaceous species (primarily grasses) in a disturbed forest environment.

The NRCS, who is responsible for administering the National Emergency Watershed Protection Program (EWP, 1978), had the opportunity to apply what was learned from monitoring of the Tash Field Evaluation Planting (FEP) study to the Pattee Canyon and North Hills fires under the EWP. The national program authorizes necessary measures to safeguard lives and property threatened by any natural occurrence on these and other EWP projects. Working with other government agencies and organizations, NRCS became aware that seeding herbaceous species, particularly if they were not native, was a concern of some individuals and groups. The fires of 1988 resulted in the use of additional seeding under EWP. An additional cooperative FEP was established in 1984 and 1985 with Champion Timberlands on three different environments within the Blackfoot River drainage.

Several additional EWP projects were completed after the 1988 fire season. Three fire impacted watershed-monitoring studies were initiated the following year (Canyon Creek, Storm Creek, and Warm Springs) and three studies were initiated on subsequent fires (Beartooth, Black Butte, and Burnette Peak) to document the effectiveness of herbaceous seeding on stabilizing soils. An additional FEP was established in cooperation with the Fulton Ranch in southeastern Montana, 1995.

Materials and Methods

Field Evaluation Plantings were established on private timberlands in southwest, southeast, and western Montana. Nine EWP monitoring sites were established in representative forest environments throughout western Montana. The effort to document the effect of the NRCS seeding activities under the EWP program has been called the Fire Impacted Watershed Monitoring Study (FIWMS). NRCS concentrated site selection on private lands impacted by the fire.

It is important to establish that the authors feel there is a difference in the successional dynamics of the sites evaluated as FEP and those evaluated as FIWMS. The FEP sites were sawlog stands. At the time of logging, the tree canopy of the stands was open enough to permit significant development of an understory plant community, estimated to be in excess of 336 kg ha^{-1} (300 lb ac^{-1}) -- dry weight measured to a height of 1.52 m (5 ft). All of the sites treated under EWP were, before the fire, dense pole and sawlog stands. Prior to the fire, these stands generally had minimum canopies of 60%. The understory plant community was thin with production less than 168 kg ha^{-1} (150 lb ac^{-1}). A nearly continuous litter and duff layer covered the soils surface.

Each study site was described on the basis of aspect, elevation, geomorphology, soil characteristics, and forest habitat type (Table 1). Soil survey data provided a basis for selecting comparable seeded and unseeded (control) sites, and for extrapolating monitoring results to other forested areas. Percentage canopy cover by species was determined on seeded and control treatments to capture change in species composition over time and to compare the successional species dynamics on seeded sites to control sites on which "natural" succession was occurring. Total number of species and adjusted number of species (total number minus seeded number = adjusted number) were determined to help describe the influence the seeding had on unseeded species presence. Percentage canopy cover of forest understory species also served to provide an index of competition to tree species. Percentage canopy cover by species (grasses, weeds) was also used in the Revised Universal Soil Loss Equation (RUSLE) to estimate differences in soil loss (USDA-ARS, 1997). Tree regeneration, if not adequately captured in the transect data, was dealt with by determining numbers per hectare on heavily scarified areas. Residual tree canopy over each site, where relevant, was estimated using a spherical densiometer. At the beginning of monitoring, overstory tree canopy cover was less than 10%. The established evaluation frequency for each site was years 1, 2, 3, 5, and 10.

Table 1. Species Indicators of Study Site Groupings.

Environment	Climax Forest Overstory Species	Other Adapted Forest Overstory Species	Common Understory Species
Cool-Moist	subalpine fir	lodgepole pine	huckleberry
	Engelman spruce	western larch	common snowberry
	Douglas fir		twinflower
			pinegrass
			wintergreen
			fireweed
Warm-Moist	Douglas fir	Ponderosa pine	dwarf huckleberry
			mallow ninebark
			common snowberry
			white spiraea
			pinegrass
			elk sedge
			aster
Warm-Dry	Douglas fir	Ponderosa pine	bluebunch wheatgrass
	Ponderosa pine		Idaho fescue
			rough fescue
			common snowberry
Warm	Ponderosa pine		little bluestem
			sideoats grama
			common snowberry
			common chokecherry

Broadcast seeding on the logged FEP and fire impacted sites was done in the fall or winter after disturbance. The general broadcast seeding rates in NRCS Field Office Technical Guides are 430 seeds m^2 (40 seeds ft^2). Most of the seeding rates used on the study sites ranged from 430 to 645 seeds m^2 (40 to 60 seeds ft^2). Seeding rates are reported in table 2 for the cool-moist environment sites and in table 3 for the warm-moist environment sites.

Table 2. Treatment Seeding Rates by Site on the Cool-Moist Environments.

Site & Treatments (plants)	Pure Live Seed	Pure Live Seed
	kg ha^{-1}	*seeds m²*
Champion FEP Replicated		
'Latar' orchardgrass	3.85	398
M-1 Nevada bluegrass	1.09	258
Latar orchardgrass and 'Garrison' creeping foxtail	1.96 3.06	204 377
Champion FEP Unreplicated		
'Sherman' big bluegrass	2.48	430
'Bromar' mountain bromegrass	30.60	441
'Oahe' intermediate wheatgrass	1.67	430
'Reubens' Canada bluegrass	0.79	377
'Troy' Kentucky bluegrass	0.95	452
'Kenmont' tall fescue	8.17	441
'Penneagle' bentgrass	0.24	441
'Manchar' smooth bromegrass	15.92	441
Garrison creeping foxtail	2.16	344
Tash FEP Unreplicated		
Latar orchardgrass	13.45	549
'Luna' pubescent wheatgrass	30.27	1022
M-1 Nevada bluegrass	7.50	1797
Kenmont tall fescue	29.93	1496
Garrison creeping foxtail	13.68	2249
'Rosana' western wheatgrass	7.73	807
'Redondo' Arizona fescue	7.40	2109
NDL 45 birdsfoot trefoil	5.83	484
P-15606 perennial vetch	30.94	183
'Whitmar' beardless wheatgrass	19.28	538
'Bandera' Rocky Mountain penstemon	8.63	538
Canyon Creek Fire		
'Potomac' orchardgrass	1.68	194
'Lincoln' smooth bromegrass	2.24	62
'Revenue' slender wheatgrass	1.68	60
Oahe intermediate wheatgrass	1.68	39
White clover	0.56	97
Storm Creek Fire		
Cereal rye	17.60	774
Mountain bromegrass	4.04	76
Orchardgrass	2.58	280
Hard fescue	0.81	97
White clover	0.94	161
Burnette Peak Fire		
Potomac orchardgrass	3.36	322
'Pryor' slender wheatgrass	2.24	65
'Critana' thickspike wheatgrass	2.80	108
Yellow blossom sweetclover	0.56	32

Table 3. Treatment Seeding Rates by Site on the Warm-Moist Environments.

Site & Treatments (plants)	Pure Live Seed	Pure Live Seed
	kg ha^{-1}	*seeds m²*
Champion FEP Replicated		
Latar orchardgrass	3.85	398
M-1 Nevada bluegrass	1.09	258
Latar orchardgrass and Manchar smooth bromegrass	1.95 7.96	240 215
Champion FEP Unreplicated		
'Regar' meadow bromegrass	21.64	312
Óahe intermediate wheatgrass	18.72-23.32	430-538
Whitmar beardless wheatgrass	18.27	538
Sherman big bluegrass	2.47	430
Redondo Arizona fescue	7.96	441
Kenmont tall fescue	9.92	527
'Friend' perennial ryegrass	15.81	430
'Shoshone' beardless wildrye	13.45	538
'Prairieland' Altai wildrye	24.77	430
Beartooth Fire		
Pryor slender wheatgrass	1.12	43
Critana thickspike wheatgrass	2.91	112
'Secar' bluebunch wheatgrass	3.14	98
Latar orchadrgrass	1.46	174
Annual ryegrass	1.12	56
Black Butte Fire		
Revenue slender wheatgrass	2.24	76
Manchar smooth bromegrass	2.24	65
Potomac orchardgrass	3.41	387
Yellow blossom sweetclover	1.08	65
Burnette Peak Fire		
Potomac orchardgrass	3.36	322
Pryor slender wheatgrass	2.24	65
Critana thickspike wheatgrass	2.80	108
Yellow blossom sweetclover	0.56	32

The Revised Universal Soil Loss Equation (RUSLE) was used to estimate the value of the various seeded species in relation to the controls in reducing soil erosion. RUSLE requires an estimation of roots within the upper 4 inches of the soil surface for grasses and for weeds. Little such information exists for forest understory plant communities; however, a search of relevant literature provided a basis for developing the required information. The factors selected from the RUSLE database to convert kilograms (lb) of herbage to kilograms (lb) of roots in the upper 10.16 cm (4 in) of the soil were 0.59 (1.3) for grasses and 0.23 (0.5) for weeds.

Field Evaluation Plantings (FEP logged)

Permanent 15.24 m (50 ft) transects within each replicated treatment were established to measure species percentage canopy cover and bareground (including rock and litter) to the nearest 0.3 cm (0.01 ft). Transect locations were selected on a heavily scarified area within the treatment plot where establishment of the seeded species was representative. Three representative, 0.89 m^2 (9.6 ft^2) circular plots were clipped for total annual biomass production on heavily scarified areas. Herbage production was separated into seeded and other categories. Tree regeneration was determined by an appropriate method based on the number of trees present in the plot areas.

On the FEP's, both replicated plots and non-replicated (screening) plots of 12.19 x 30.48 m (40 x 100 ft) were utilized. The screening plots were used to evaluate herbaceous species entries thought to have merit. For those that performed well in the screening plots, permanent monitoring transects were set up. For each monitoring site, three mixtures were formulated for testing in a replicated, randomized complete block design. Three replications were seeded for comparison with the unseeded controls (Table 2 and Table 3). Selected grasses were thought to be well adapted to each environment, and they could function effectively as erosion control plants, productive forage plants, and compete against weeds. One replication set at each environment was seeded to a grass seed mixture expected to offer substantial competition to tree regeneration. The replication was an attempt to assess the impact of seeding a competitive mixture containing a rhizomatous as well as a bunchgrass species versus seeding mixtures containing a single bunchgrass species on tree regeneration. On the Tash FEP, none of the treatments were replicated. For the replicated treatments, subplots were designed to assess tree establishment from natural seed sources, broadcast seed treatments of varying intensity, and planted tree seedlings.

Fire Impacted Watershed Monitoring Studies (FIWMS)

At each of the fire impacted areas, a minimum of two paired plots was established. On projects selected for evaluation after 1988, comparison sites were determined before the seeding operation began. An entire landscape segment for each plot pair was not seeded to provide ample opportunity for the location of a suitable control plot. Sites were selected based upon aerial photo interpretation, soil survey information, geology maps, and scientist/resource manager's knowledge of the area.

At each plot, a single permanent 20.1 m (66 ft) transect was established at a mid-slope position and in an area representative of the seeding success on the site. Ten, 25.4 x 50.8 cm (10 x 20 in) microplots were read at 1.83 m (6 ft) intervals along the transect as specified in the USDA-FS Ecodata Handbook. In addition, 10 points located around the perimeter of the microplot frame were used to determine ground cover (percentage basal vegetation, gravel, rock, litter, wood, moss, bare soil) at each station (USDA FS, 1987). The ECODATA methodology used on the burned sites was adopted at the request of the USDA Forest Service so that data could be shared among organizations.

Results and Discussion

Cool-Moist Environment, Burned and Logged

Canopy Cover. Total percentage canopy cover on the fire-impacted sites was increased by approximately 13, when compared to the corresponding unseeded control (Fig.1). On the FEP logged timber harvest areas, total percentage canopy cover on the more successful replicated seedings was 8% more than on the corresponding unseeded controls (Fig. 2). The seeded treatments represent a substantial increase in the amount of grass cover when compared to the unseeded sites (maximum unseeded grass cover on these sites averaged 14%). There were few plants before the fire to provide seed and underground stems from which new growth could sprout. That factor, we believe, coupled with the thorough fire consumption of the litter and duff layers (which may have contained seed), resulted in little opportunity for the pre-fire plant community to quickly provide cover after the fire. Consequently, a very different successional dynamic resulted. The increased grass cover may provide for weed suppression, reduced erosion and sedimentation, and an increased herbage production as compared to the controls. Seeding on fire sites resulted in a 30% increase in total cover by Year 2 in which seeded species made up over one-half of the total cover at that time. The contribution of seeded species to total cover generally declined over time. The overall increase in cover, and large increase in cover observed in Year 2 of the seeding, indicates the fire seeding significantly changed the character and dynamics of the plant community.

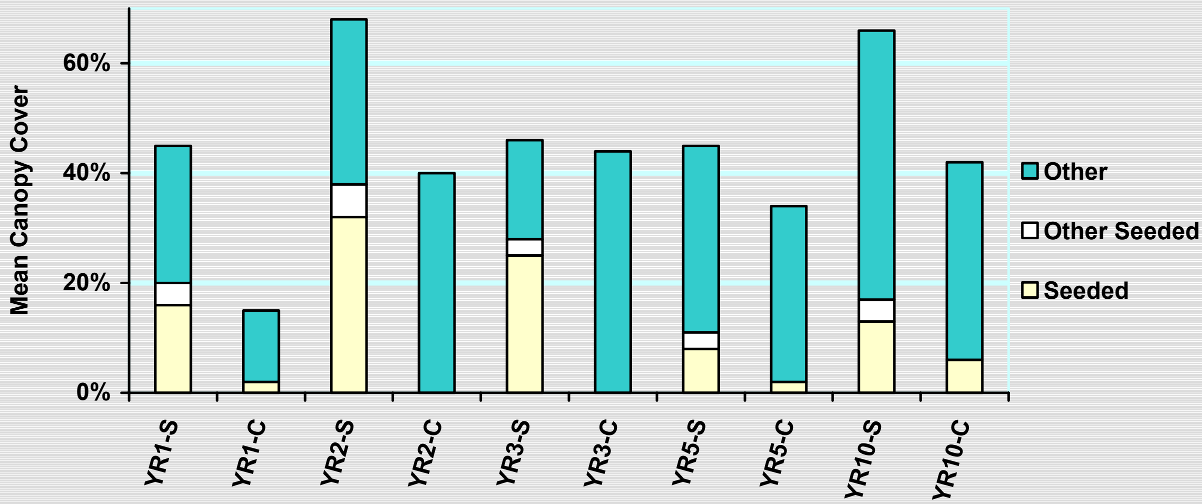

Figure 1. Percentage canopy cover on fire sites of seeded (S) and control (C) treatments over 10 years in cool-moist environments.

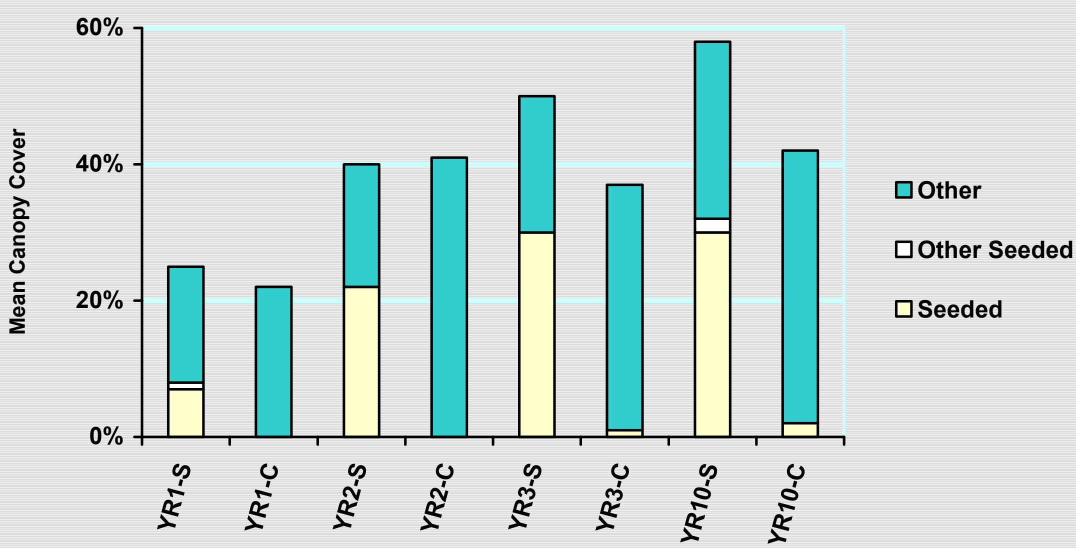

Figure 2. Percentage canopy cover on logged sites of seeded (S) and control (C) treatments over 10 years (YR) in cool-moist environments.

Seedings of the logged FEP sites also contributed to an increase in overall cover and in the cover of grass species. The increase in total cover was more gradual and the seeded grass component remained relatively constant after Year 2 for the 10-year monitoring period. A visit to a FEP site in 2002 revealed that cover of the successfully seeded species was generally reduced to less than 10%. Canopy cover of western larch saplings averaged at least 60%. Presumably, the aggressive establishment of western larch on the site contributed to the decline of seeded species. The more rapid decline in cover of seeded species on the fire sites was due to rapid establishment of lodgepole pine on the Canyon Creek fire sites.

Erosion. On the fire impacted sites, the average cover factor for the seeded sites was 61% of the controls indicating erosion was decreased by at least 39% (Fig. 3). On some fire sites, enough erosion occurred on the unseeded controls to concentrate gravels on the surface. Had that not occurred, the effectiveness of the grass seeding would appear higher -- any gravel percentages included in computation of the cover factor result in a lower factor. On FEP sites (logged), the average cover factor for the seeded sites was 72% of the controls, indicating erosion was decreased by 28%. Based on the results of the fire seeding treatments and the two successful replicated FEP treatments, erosion rates potentially can be reduced by 28 to 39%.

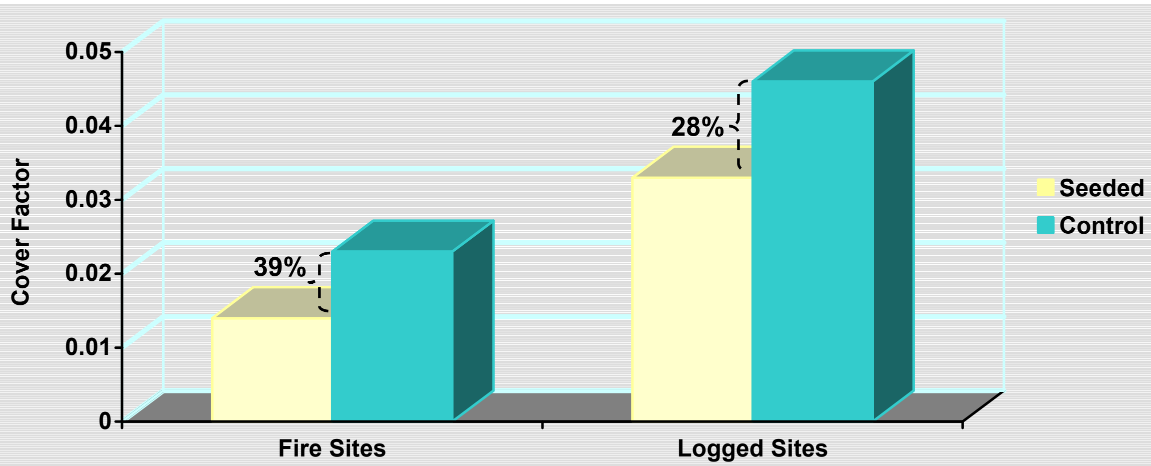

Figure 3. RUSLE Cover Factor averages for seeded (S) and control (C) treatments for the first 5 years on the cool-moist environment sites.

Species Number. Direct seeding compared to unseeded control treatments resulted in an increase in total number of species on the fire sites across the monitoring period and at the 10th year -- 2 and 1, respectively (Fig. 4 and Fig. 5). Adjusted number of species on the fire sites was the same across the two monitoring periods. The logged FEP sites show a decrease in all seeded species numbers by 2, until the 10th year, when seeded treatments increased species numbers by 1 (Fig. 4 and Fig. 5, respectively). The average of all sites total species numbers was the same for the seeded when compared to the controls (Fig. 4). And, the all site average adjusted species numbers on the seeded sites was 2 less than the controls. However, the 10th year average of all species on seeded sites, increased by 2 species (Fig. 5). At the 10th year, average adjusted species numbers of the seeded compared to the controls was also the same (Fig. 5).

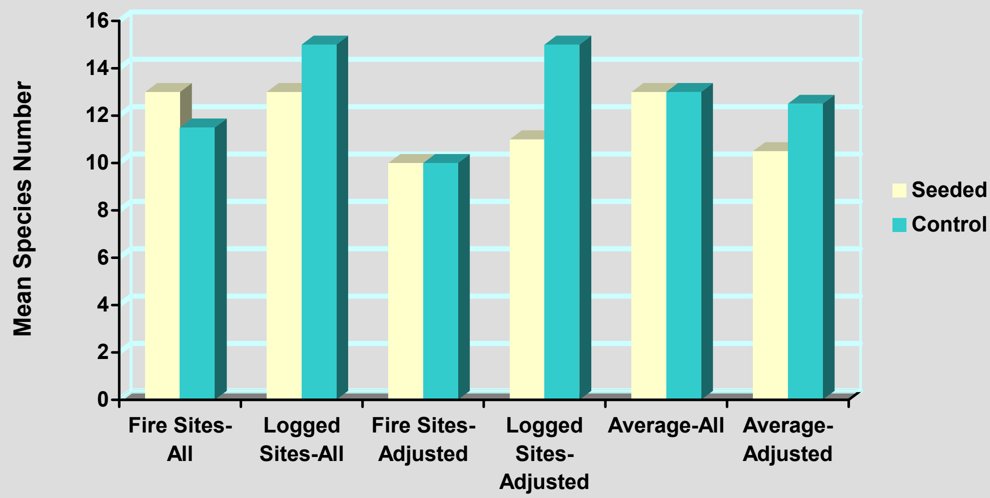

Figure 4. Species numbers on the fire and logged sites of seeded and control treatments in the cool-moist environments.

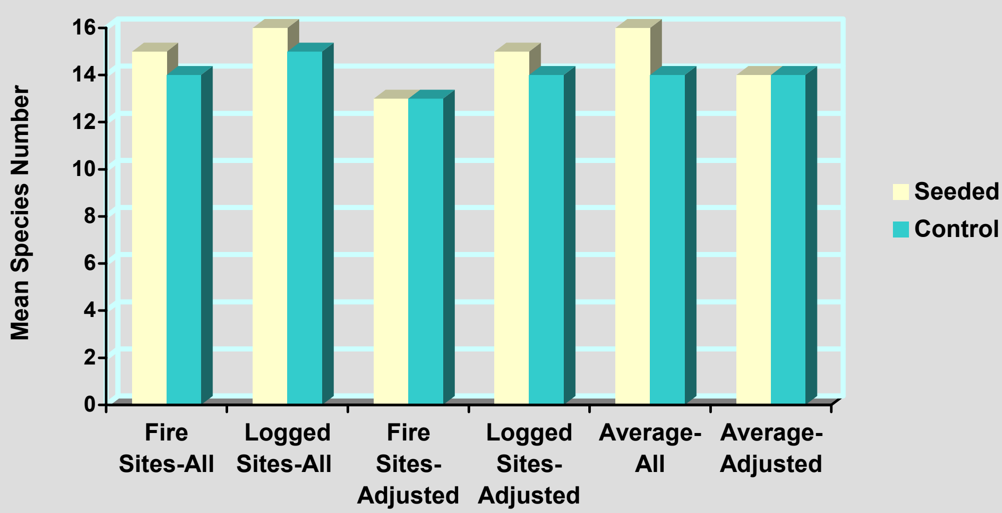

Figure 5. Tenth-year species numbers of the fire and logged sites on seeded and control treatments in the cool-moist environments.

Herbage Production. Fourteen different species were seeded on the three fire and two FEP sites. Of those 14 species, orchardgrass was consistently one of the more successfully seeded species. Orchardgrass canopy cover averaged 21% over the 10-year monitoring period. With the exception of the Tash FEP, where M-1 Nevada bluegrass performed well, the majority of the herbage production was orchardgrass (Table 4). On the Tash FEP, the herbage production contributed by M-1 Nevada bluegrass was almost equal to orchardgrass. During the 10-year monitoring period, seeded treatments produced more total biomass than the unseeded (control) treatments. The successfully seeded treatments exceeded the controls in herbage values for many classes of grazing animals.

Table 4. Herbage production from fire and successful FEP seeded treatments in comparison to unseeded controls on the cool-moist environment sites.

	Period Average†				Final Year†			
Site	Seeded		Control		Seeded		Control	
	lb ac^{-1}	*kg ha*$^{-1}$	*lb ac*$^{-1}$	*kg ha*$^{-1}$	*lb ac*$^{-1}$	*kg ha*$^{-1}$	*lb ac*$^{-1}$	*kg ha*$^{-1}$
Champion‡	978 (78)	1,096	771 (0)	864	1,262 (78)	1,415	1,197 (0)	1,342
Tash§	1,344 (89)	1,507	926 (0)	1,038	1,814 (78)	2,033	2,290 (0)	2,567
Canyon Creek	1,496 (30)	1,677	1,136 (33)	1,274	1,578 (2)	1,769	1,008 (8)	1,130
Storm Creek	1,186 (48)	330	631 (0)	707	1,239 (42)	1,389	856 (0)	986
Mean	1,251 (61)	1,402	866 (8)	971	1,473 (37)	1,651	1,338 (2)	1,500

† Percentage of seeded species production is in parenthesis.
‡ Latar orchardgrass and Garrison creeping foxtail.
§ Luna pubescent wheatgrass, Latar orchardgrass, and Nevada bluegrass.

Tree Regeneration. On the fire sites, lodgepole pine was the primary species establishing from native seed sources. As shown in figure 6, seeded treatments established five times more tree seedlings than the controls when measured at the end of the 10-year monitoring period. On the FEP sites planted to western larch, seedling tree survival was nearly twice that of the controls at the end of 5 years. Monitoring observations indicate grass seeding treatments did not suppress tree establishment from transplants or native seed sources. Orchardgrass was the dominant grass species establishing in each of these treatments.

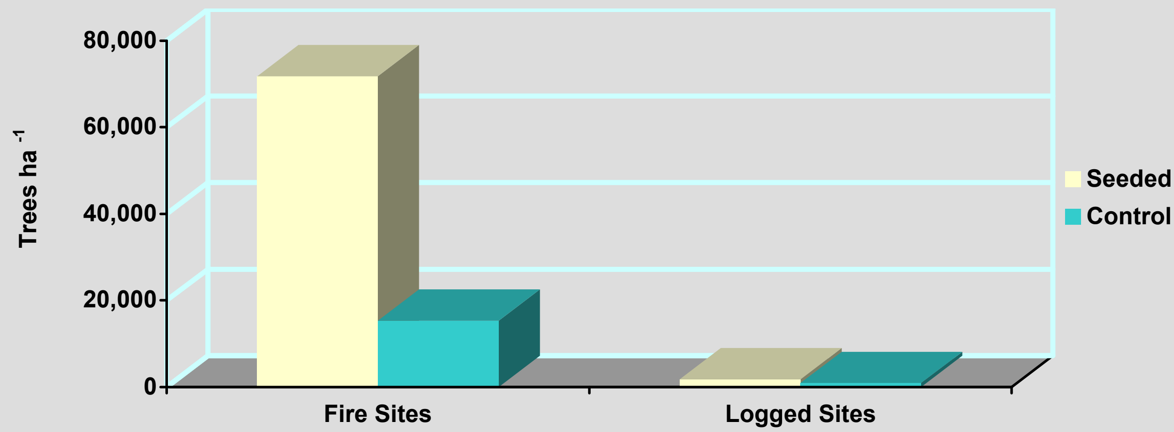

Figure 6. Tree regeneration at year 10 of seeded and control treatments in the cool-moist environments.

Warm-Moist Environment, Burned and Logged

Canopy Cover. Total percentage canopy cover on the fire seeded sites was increased by 4% (average for monitoring period) when compared to the controls (Fig. 7). Total percentage canopy cover on the successful seeding treatments of the FEP logged sites decreased 9% when compared to the controls (average for monitoring period) (Fig. 8). But, the seeding treatments consistently represent a significant increase in grass cover (average maximum canopy cover of unseeded grass species on these sites is 14 %).

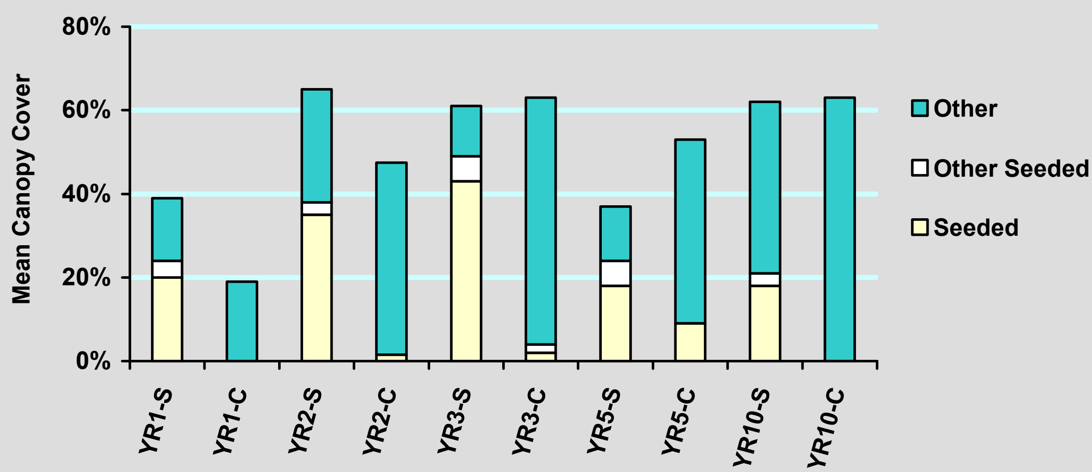

Figure 7. Percentage canopy cover for all fires sites of seeded and control treatments over 10 years in warm-moist environments.

Seeding on the fire sites significantly increased total cover and grass cover in relation to the unseeded controls the first and second years. The effect was less dramatic and less consistent in subsequent years. As in the cool-moist environment, the contribution of seeded species to total cover declined over time. On these sites, during the monitoring period, overstory tree canopy remained near zero. Cover on the controls generally increased throughout the monitoring period and nearly equaled cover on the seed sites by year 10. These patterns suggest that the unseeded species are "reclaiming the site." Logged FEP seedings also contributed to an increase in overall cover and in cover of grass species. However, the increase in total cover and seeded species cover was not as dramatic, particularly Years 1 and 2, as on the fire sites. The relative response is comparable to what occurred on fire and logged sites in the cool-moist environment.

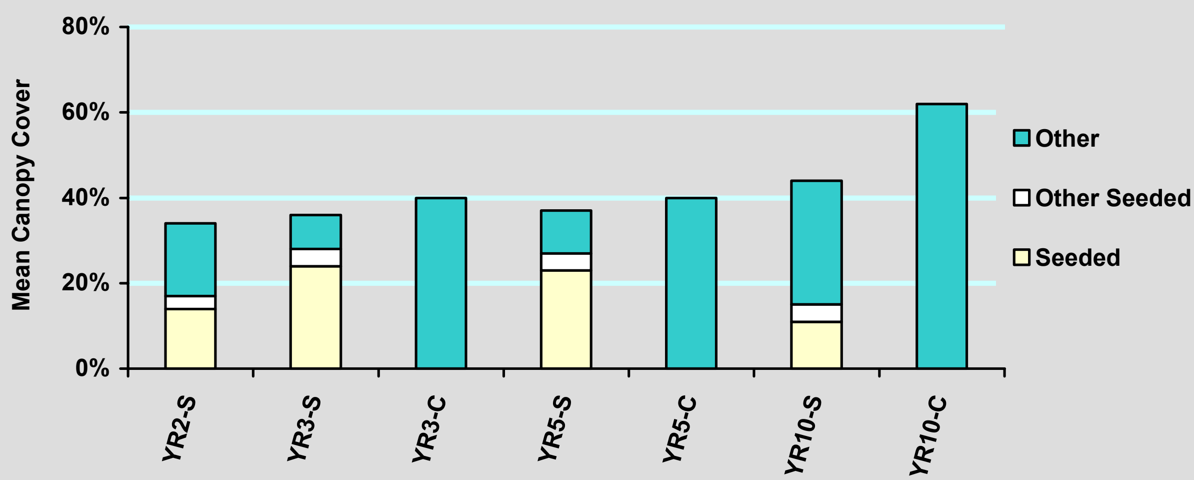

Figure 8. Percentage canopy cover on all logged sites of seeded and control treatments over 10 years in warm-moist environments.

Erosion. On the fire impacted sites, the average cover factor for the seeded sites was 50% of the controls, indicating erosion was reduced by one-half (Fig. 9). On the FEP sites (logged) the average cover factor was 87% of the controls indicating erosion was only reduced by 13%. Based on the results of the fire and FEP seeding treatments erosion rates can be reduced 13 to 50%.

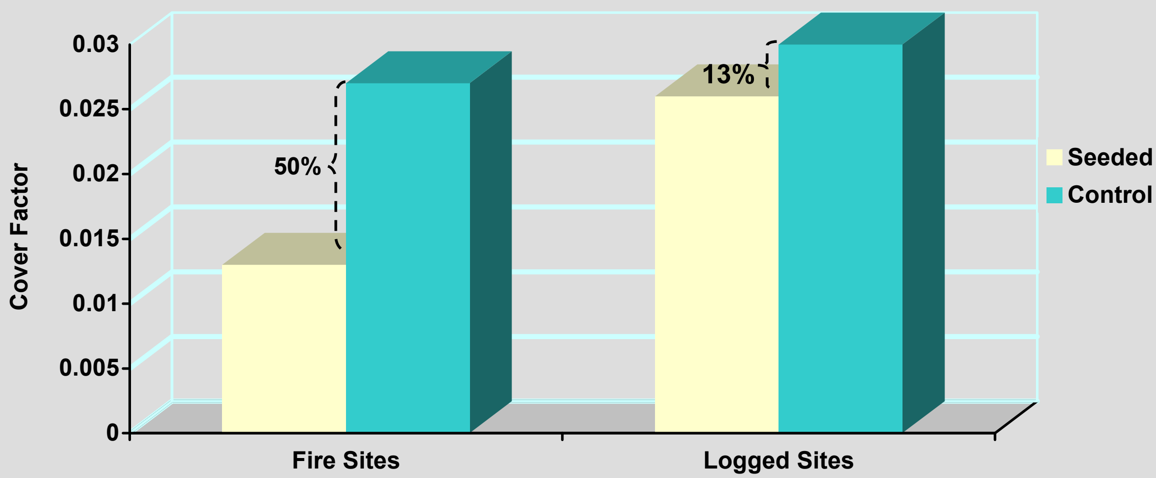

Figure 9. RUSLE Cover Factor averages of fire and logged sites for seeded and control treatments in warm-moist environments.

Species Number. Comparison of the seeded and unseeded control treatments on the fire sites reveals a lower total number of species on seeded sites across the monitoring period and at the 10th year, 3 and 5 respectively (Fig. 10 and Fig. 11). There was also a decrease on the fires site in the adjusted species number across the monitoring period and at the 10th year, 4 and 6 respectively (Fig. 10 and Fig. 11). The logged FEP sites also reveal 3 less on seeded sites in the all species category when compared to the controls (Fig. 10). At the 10th year, the logged all species and adjusted species numbers for the seeded treatments were 0 and 1 less, respectively, when compared to the controls (Fig. 11).

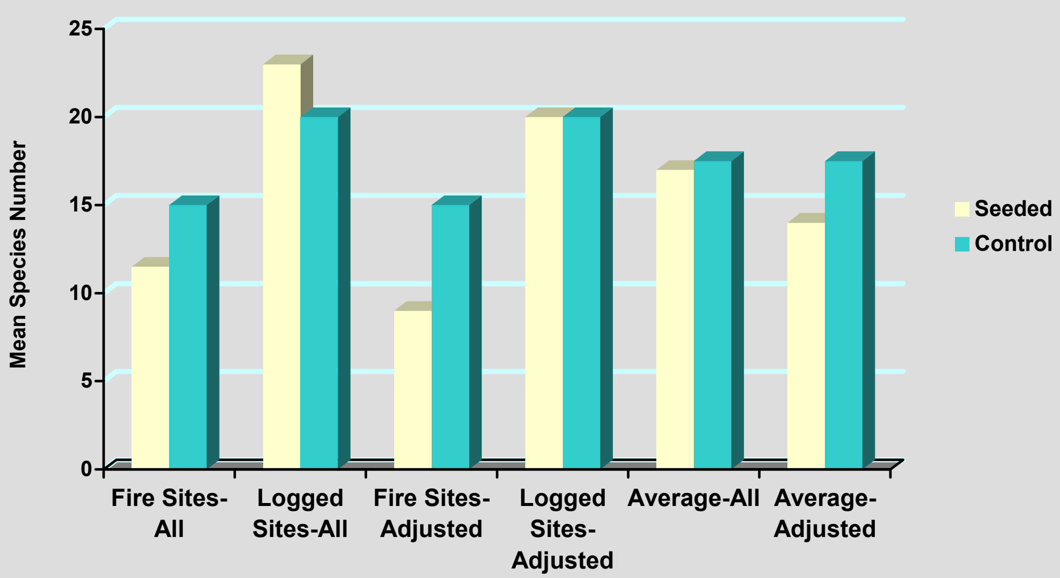

Figure 10. Species numbers on the fire and logged sites of seeded and control treatments in the warm-moist environments.

A lower trend also occurred in the average all and the average adjusted species numbers categories, 1 and 4, respectively, of the seeded compared to the control treatments (Fig. 10). An analysis of the 10th year average for all species numbers shows a decrease of 3 species on the seeded treatment when compared to the control (Fig. 11). The 10th year for average adjusted species numbers is 2 less for the seeded treatment when compared to the control treatment. Unlike the seeding in the cool-moist environments, the seeding in the warm-moist environments did reduce unseeded species numbers, at least through the 10th year.

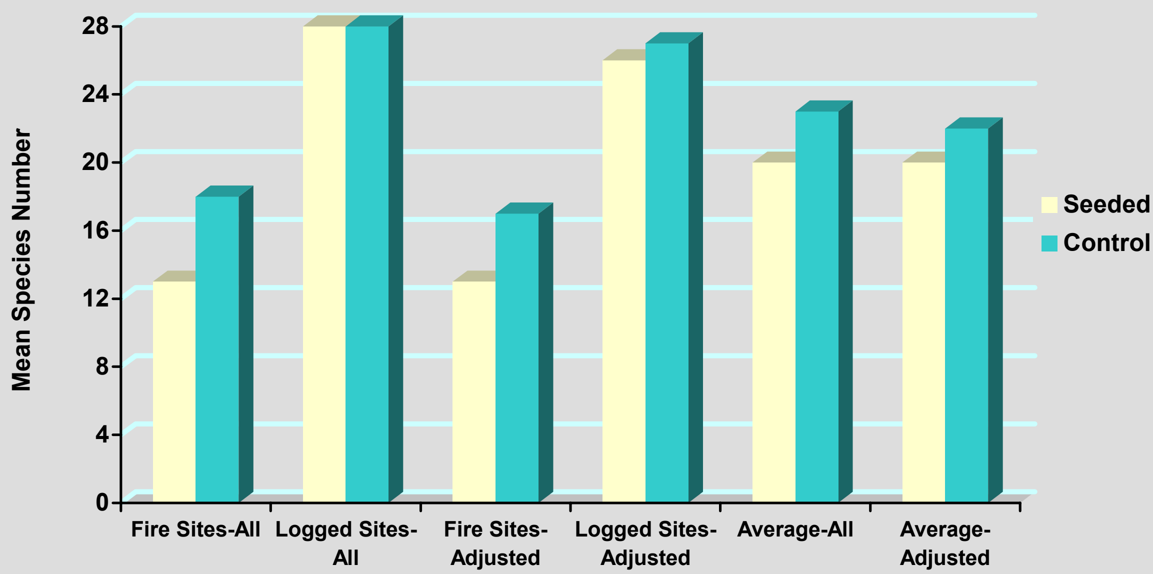

Figure 11. Tenth-year species numbers of the seeded and control treatments in the warm-moist environments.

Herbage Production

Seventeen species were seeded on three fire and one logged site. Of those 17 species, orchardgrass was consistently the most successful seed species (table 5). Orchardgrass canopy cover averaged 25% over the 10-year monitoring period. During the 10-year monitoring period, average production on the seeded treatments was greater than the controls. However, last year production on the controls was greater than the seeded treatments. Regardless, for the 10-year period the herbage value for many classes of grazing animals on the seeded treatments exceeded that of controls.

Table 5. Herbage production from fire and selected logged seeded treatments in comparison to unseeded controls on the warm-moist environment sites.

Site	Period Average†				Final Year†			
	Seeded		Control		Seeded		Control	
	lb ac⁻¹	*kg ha⁻¹*	*lb ac⁻¹*	*kg ha⁻¹*	*lb ac⁻¹*	*kg ha⁻¹*	*lb ac⁻¹*	*kg ha⁻¹*
Beartooth	1,116 (44)	1,251	958 (2)	1,074	920 (2)	1,031	853 (12)	956
Champion	718 (62)	805	626 (0)	702	1,063 (38)	1,192	1,198 (0)	1,343
Mean	917 (53)	1,028	792 (1)	888	992 (20)	1,112	1,026 (6)	1,150

† Percentage of seeded species production is in parenthesis.

Tree Regeneration. Douglas fir and ponderosa pine were the primary species regenerating on these sites. On the fire sites, numbers of trees averaged about 600 ha^{-1} (243 trees ac^{-1}) fewer on the seeded sites than on the controls at the end of the monitoring period (Fig. 12). However, all sites were considered adequately stocked. On the logged FEP sites, numbers of trees averaged about 96 ha^{-1} (39 trees $ac^{-1)}$ less on the seeded as compared to the controls at the end of the monitoring period. Neither the seeded treatments nor controls were considered adequately stocked on the logged FEP's. Controls for all five sites (fire and logged) averaged approximately 1000 trees ha^{-1} (405 trees ac^{-1}), which is considered adequate stocking. Average stocking on seeded sites (fire and logged) averaged about 650 trees ha^{-1} (263 trees ac^{-1}).

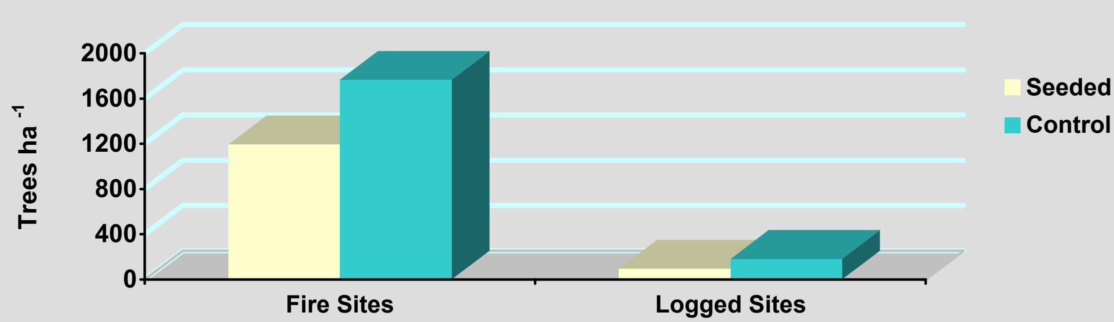

Figure 12. Tree regeneration at the 5-10 year period of the seeded and control treatments in the warm-moist environments.

This difference indicates that seeding did reduce number of trees, but seedling numbers were adequate on the seeded fire sites. Heavy deer browsing contributed significantly to poor survival of tree seedlings on the logged FEP's from all sub-treatments (planted, seeded, and naturally seeded). There is the possibility that without the heavy deer browsing tree stocking would have been adequate on the successful seeded treatments and the controls.

Discussion

Canopy Cover

Successful seeding treatments for the warm-moist and cool-moist environments, increased cover on the fire sites when compared to the FEP (logged) sites 8% when averaged for the 10-year monitoring period. This corresponds to the cover factor relationship where percentage soil loss reduction was greater on fire sites than logged sites from seeding treatments. Seeding on fire sites provides a large boost in total cover in years 1 and 2 after seeding. Figure 1 indicates that the average gain in cover for all fire sites in years 1 and 2 after disturbance is approximately 30%. Increased cover on all logged sites appears more gradual and can extend into the 10th year.

Erosion

Average cover factors (for the 5-year period after seeding) computed for treatments in the cool-moist environments, was less for all of the six seeded treatments when compared to corresponding controls. Average soil loss reduction, as reflected in the cover factor, was 33% on fire sites and 29% on logged sites. The lower erosion rate on the logged sites is expected because logged sites generally have more vegetation remaining after harvest to assist in the "recovery" than the understory of fire impacted sites.

The soil loss reduction reflected in the data presented above may be conservative. Summer thunderstorms the summer after fire, impacted control plots more than the seeded plots as reflected in estimated soil erosion depths. As a result, gravels were concentrated at the soil surface, which in turn lowered cover factor values on these treatments. We chose not to make computation adjustments of the RUSLE cover factor, as the above data is a reflection of what actually happened.

The average cover factors for the 5-year period after seeding computed for treatments in the cool-moist environments was less for three of four treatments when compared to corresponding controls. Average soil loss was reduced by 50% on fire sites and 13% on logged sites, as reflected in the cover factor. As for the cool-moist environment, the percentage soil loss reduction was less on the logged sites than the fire sites. The most effective treatment on the logged sites was Oahe intermediate wheatgrass unreplicated treatment. The cover factor computed for the Oahe treatment was 63% of the control, suggesting a 37% erosion reduction.

The effectiveness of seeding treatments in the warm-moist and cool-moist environments appears to be the same (29% reduction) when comparing the average of all seeded treatments in each environment to controls. Seeding treatments in the warm-moist and cool-moist environments reduced erosion by 39 to 50% on fire sites and 13 to 28% on successfully seeded logged sites.

Species Numbers

Total number of species and adjusted total number of species were presented in this paper to partially describe the impact of successful seeding on unseeded species. The adjusted total number of species reflects the number of unseeded species on the site.

Within the cool-moist environment, an increase of 1 in numbers of all species occurred on the fire sites throughout the monitoring period and at the 10th year, when compared to the control. A steady state occurred on the seeded fire sites in the adjusted number of species throughout the monitoring period. On the logged FEP sites in the cool-moist environment, a decrease in the average numbers of all species and adjusted numbers of species (2 and 4 respectively) occurred on seeded sites when compared to the controls. At the 10th year, the average of all and adjusted number of species has increased by 1 on the seeded sites when compared to the control sites. At the 10th year, the average all and average adjusted was higher on both the seeded and control treatments than the corresponding average categories in the monitoring period.

On seeded fire sites in the warm-moist environment, there is a decrease in all species and adjusted all species numbers (3 to 6 respectively) based upon the monitoring period categories. Patterns for the 10th year is similar. The all species numbers and the adjusted species numbers is 5 less on the seeded sites than the controls and the adjusted species numbers is 4 less. In the cool-moist environment, the all species total is greater in each category and the adjusted species numbers are the same, suggesting that seeding on the fire sites in the warm-moist environment may reduce species numbers more than in the cool-moist environment. On the logged sites in the warm-moist environment, seeding appeared to have little effect on species numbers, and less effect than on seeded logged sites in the cool-moist environment. However, seeding on logged sites in both the warm- and cool-moist environments appeared to have little effect on species numbers by the 10^{th} year. Average all species numbers increased by 3 on logged sites in the warm-moist environment. Average adjusted species number increased by 1 on the logged sites in the warm-moist environment. At the 10^{th} year, the two average categories show an increase in total numbers of species (seeded and control) by 3 to 6, over the same two categories in the monitoring period.

Another measure of assessing the effect of seeding on unseeded species is to examine the canopy cover of the unseeded species (other species) on the seeded sites and the control. Figure 1 and Figure 2 indicate that the average cover of other species on all fire and all logged sites is less on the seeded sites the first year after seeding. Over time, the difference in other species cover between the seeded treatments and the controls becomes less, indicating that unseeded species are "reclaiming" the site.

Herbage Production

For the monitoring period, total herbage production was greater for all seeded sites in the warm-moist and cool-moist environments than corresponding controls. Average production from seeded grasses on the combined environments was 57% of the total production. Expressing that production as animal unit month (AUM) values gives the following result. Average AUM/hectare (cattle) for seeded treatments for the monitoring period in the cool-moist and warm-moist environments is estimated to be 0.84 AUM/ha^{-1} (0.34 AUM/ac^{-1}). Average AUM/hectare of all control treatments is 0.44 ha^{-1} (0.18 ac^{-1}). For the monitoring period, the seeded treatments average 188% greater forage for cattle than the control treatments. The above AUM/hectare values are "potential" AUM/hectare. They are not adjusted for factors affecting grazing distribution.

Grass Species

Of all grasses seeded on the fire and FEP (timber harvest sites), in both the cool-moist and warm-moist environments, orchardgrass (Latar and Potomac) was the outstanding species. It established quickly, consistently, and produced canopy cover greater than 20% at some time during the monitoring period. It also produced a significant amount of herbage. Impacts on tree regeneration and unseeded species numbers, if any, appear to be small.

Other species showing promise on some sites were Critana thickspike wheatgrass, Revenue and Pryor slender wheatgrass, Manchar smooth bromegrass, M-1 Nevada bluegrass, Regar meadow bromegrass, Whitmar beardless wheatgrass, Sherman big bluegrass, Kenmont tall fescue, Friend perennial ryegrass, Garrison creeping foxtail, Rosana western wheatgrass, Redondo Arizona fescue, and Oahe intermediate wheatgrass. Some of these grasses eventually provided more cover than orchardgrass, but were very slow to establish -- Regar meadow bromegrass and Whitmar beardless wheatgrass, for example. Others provided quick cover exceeding that of orchardgrass but stand life was short. Friend perennial ryegrass, for example, which developed maximum canopy cover of 32%, had disappeared from the warm-moist site between year 3 and 5. Some, such as M-1 Nevada bluegrass, Kenmont tall fescue, Oahe intermediate wheatgrass, and Canada bluegrass may be as useful as orchardgrass, but additional testing is needed. The opportunities to observe them in this project were limited. The full seeding rate of 430 pure live seed/m^2 (40 pure live seed/ft^2) for Oahe intermediate wheatgrass on the warm-moist site was clearly superior to orchardgrass in terms of canopy cover and production. But, it is also very competitive. On the Oahe treatment, unseeded species numbers were obviously less than on the associated controls. We anticipate adverse impacts to tree regeneration as well. Although when the planting was visited in 2002, three conifer trees (approximately 74 trees ha^{-1} or 30 trees ac^{-1}) had established on the treatment.

Seeded species failing to develop decent stands at any point in time during the monitoring period (less than 8% cover) were: Secar bluebunch wheatgrass, annual ryegrass, yellow blossom sweetclover, Shoshone beardless wildrye, Prairieland Altai wildrye, white Dutch clover, hard fescue, Bromar mountain bromegrass, Troy Kentucky bluegrass, and Penneagle bentgrass. Low seeding rates of some species may have handicapped their performance. But our judgment is that these species are of limited value in these environments.

Tree Seedling Survival

Data for seeded treatments from both the fire sites and logged sites in the cool-moist environment indicate trees more successfully established on the seeded sites than on controls. The controls on the logged sites, on average, had the lowest number of seedlings per acre. That average number (953 trees ha^{-1} or 434 tree/ac^{-1}) approximates the minimum number desired for a fully stocked stand of trees. Of the 10 seeded treatments in the cool-moist environment, one treatment was under stocked. Of the seven control plots, three were under stocked.

For the warm-moist environment, data suggest the seedings are lowering tree seedling survival on both fire and FEP sites. Seedling numbers are about one-third less on the seeded treatments in both the fire and FEP sites. Overall stocking of tree seedlings average near the minimum desired in fully stocked stands on the fire sites. Stocking of tree seedlings on FEP sites are low on both the seeded and control site. The heavy deer browsing on the FEP site likely contributes to the low stocking on all treatments.

Seeding appears to have increased seedling establishment success on both fire and FEP sites in the cool-moist environment. The opposite appears to be true in the warm-moist environment. Average stocking was adequate only on the control treatments on fire sites.

Weeds

General observations were made in 2002 of the logged FEP sites. Spotted knapweed had reached both sites. Scattered knapweed plants (<1% canopy cover) occurred on successfully seeded sites and on controls on the cool-moist logged FEP. Seeding had no obvious effect on the distribution of spotted knapweed, possibly because the canopy covers of seeded species on the successfully seeded treatments were all low. Presumably in response to a 60% canopy cover of 3.66 to 4.57 m tall (12 to 15 ft) western larch that uniformly covered the entire site. On the warm-moist site, the effects of the seeding were obvious for several of the successful treatments. Two Latar/Manchar treatments occur along the lower edge of the study area and adjoin a log landing area that is heavily infested with knapweed (>50% canopy cover). Latar/Manchar canopy cover on the two plots averaged about 35% and knapweed cover within the plots averaged less than 20%. Knapweed canopy on adjoining controls or unsuccessful seeding treatments ranged 25 to 50%.

Conclusions

When compared to corresponding controls, successful seedings reduced erosion in both environments and on fire and FEP (logged) sites. As a result of seeding, the erosion reduction was greater on fire sites than on timber harvest sites. Seeding adversely impacted tree regeneration on logged sites in the warm-moist environments. While tree seedling numbers were also reduced on seeded treatments on fire impacted sites in the warm-moist environments, seedling numbers were adequate for full stocking. Adjusted number of understory species were reduced on the fire sites in the warm-moist environment. Effects were minimal on other environment/site combinations. Forage production was significantly enhanced on all seeded treatments. The average gain for all successfully seeded treatments was 188%. The effect of the seeding on weeds was not captured in the data during the monitoring period.

Literature Cited

Baron, F.J. 1962. Effects of different grasses on ponderosa pine seedling establishment. Res. Note PSW-199. Berkley, CA. P. 1-8. USDA USFS, Pacific Southwest Forest and Range Exp. Sta.

Elliot, K.J. and A.S. White. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Science. 33(2): 356-366.

Emergency Watershed Program. EWP is authorized in Section 216, Public Law 81-516 and Section 403 of Title IV of the Agriculture Credit Act of 1978, Public Law 95-134 – Emergency Conservation Program.

Griffin, James R. 1982. Pine seedlings, native ground cover, and *Lolium multiflorum* on the Marble-Cone Burn, Santa Lucia Range, California. Madrono, Vol. 29, No. 3; 177-188.

Goodwin, K., R. Sheley and J. Clark. 2002. Integrated Noxious Weed Management after Wildfires. P. 31. MT St. Univ. Ext. Serv. Bull. 160.

Klock, G.O., A.R. Tiedemann and W. Lopushinsky. 1975. Seeding recommendations for disturbed mountain slopes in North Central Washington. Res. Note PNW-244. Portland, OR. USDA USFS Pacific Northwest Forest and Range Exp. Sta.

National Fire News. National Interagency Fire Center. 2002. Fire: A prescription for healthy ecosystems. http://www.nifc.gov

Roche, C.T., and B. Roche. 1991. Meadow knapweed invasion in the Pacific Northwest, U.S.A., and British Columbia, Canada. Norwest Science Vol. 65, No. 1:53-61.

Robichaud, P.R., J.L. Beyers and D.G. Neary. Sept. 2000. Evaluating the effectiveness of postfire rehabilitation treatments. P. 6-19. USDA USFS Rocky Mt. Sta. Gen. Tech. Rep. RMRS-GTR-63.

USDA Agriculture Research Service. 1997. Agriculture handbook No. 703. Predicting soil erosion by water: A guide to conservation planning with the revised universal soil loss equation (RUSLE). US Gov. Printing Office, Washington D.C.

USDA Forest Service. 1987. Ecosystem classification handbook. Chapter four -- ecodata sampling method. FSH 12/87 R-1, Missoula, MT.