

**Final report, Joint Fire Science Program
Project: 00-2-19**

Project Title: Stand and fuel treatments for restoring old-growth ponderosa pine forests in the Interior West

Project Location: Boise Basin Experimental Forest, southern Idaho

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SUMMARY OF FINDINGS TO DATE

Fire exclusion, especially in the dry forests (i.e. those dominated or potentially dominated by ponderosa pine) has most often altered tree and shrub composition and structure and, though often overlooked in many locales, the forest floor from conditions that occurred historically (pre-1900).

- When fires are excluded from the dry forests, bark slough and needle fall from mature ponderosa pine are not consumed and large quantities of these materials tend to accumulate at the base of trees.



Figure 1. Duff (litter, humus, decayed wood) accumulation surrounding the base of mature ponderosa pine trees.

- Even the largest ponderosa pine with an extensive tap root acquires nutrition and water from lateral roots often extending well beyond the spread of the tree's crown. Nutrient and water uptake in the fine lateral roots is aided and dependent on the formation of ectomycorrhizal fungi. The abnormal deep surface organic layers occurring because of fire exclusion are rich in nutrients and moisture, facilitating robust fine root development that historically occurred in the mineral soil. These organic surface layers and the roots and ectomycorrhizae they contain

are vulnerable to loss from both prescribed and wildfires. In a fire, even though the inner portions of large ponderosa pine are protected by the thick bark from heat, the destruction of the organic surface layers and the roots they contain stresses trees making them susceptible to both insect and disease attacks. In addition, the mechanical removal of these organic layers through raking the material from the base of trees causes the loss of the roots and sets trees up for pest attack.

- Therefore, restoring forests in which fire exclusion has changed both their vegetative character and soils requires treatments applied in concert that address both of these components.

Ponderosa pine forest restoration treatments

- Forest vegetative changes caused by plant succession, regeneration and development of seedlings and saplings, and changes in ground-level vegetation (shrubs, grasses, and forbs) often can be treated mechanically. In many circumstances mechanical removal of biomass may be preferred over fire because of the large amounts of material and fuel present. In addition, mechanical removal of biomass is more precise than wildland fire use or prescribed fire.



Figure 2. Untreated ponderosa pine stand on the Boise Basin Experimental Forest containing 75 trees/acre > 5 inches and over 1000 trees/acre < 5 inches and 92 ft² of basal area.

- On the Boise Basin Experimental Forest we used commercial timber harvest, commercial firewood harvest, and precommercial thinnings to create forest compositions and structures reminiscent of those that occurred historically (≈ 1900).

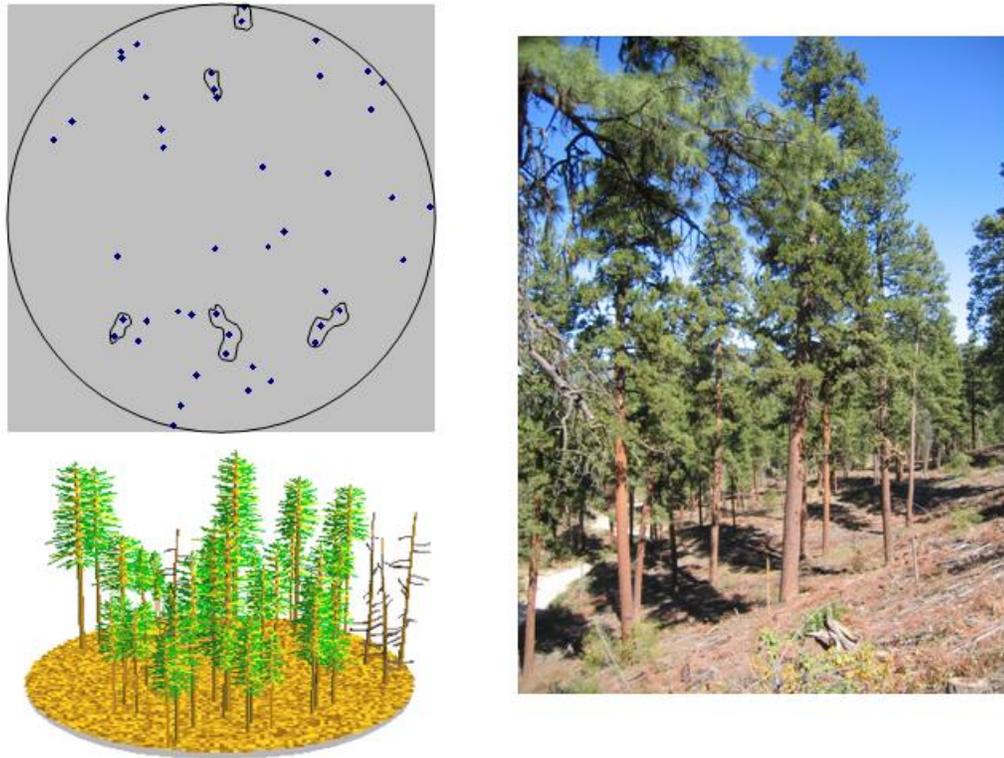


Figure 3. A stem map (upper left) and a visualization (lower left) of a typical one-acre plot and a photograph of the stand after the harvesting and precommercial thinning. Note how the stem map depicts the clumpy nature of the stand, presence of snags, and the large amount of open space.

- Burning duff layers around the base of mature trees when the lower duff layers were moist and cold and breaking up the impermeable surface litter layer with a hoe were evaluated as possible methods of restoring soil conditions conducive to the use of prescribed fire without damaging fine tree roots and ectomycorrhizae.
- Forty large and mature ponderosa pine (out of 3,500+) were selected using a random number generator in the 90 acre stand in which the standing fuels had been modified by commercial timber and firewood harvest. Eight trees were randomly assigned to one of four treatments (single application of fire, second application of fire in a subsequent year, single surface layer mixing and a second surface layer mixing in a subsequent year) and a control.
- Fires were applied during the spring when snow surrounded the trees except the area within the drip line of the trees.



Figure 4. A Fuels specialist used a drip torch to ignite the surface organic layers around the base of a mature ponderosa pine within a snow-well.

Table 1. Snow-well burning conditions and the amount of material consumed by the burns.

	First fires-2002 16 trees	Second fires-2004 8 trees
Lower duff moisture content	$138 \pm 10\%$ ¹	$97 \pm 17\%$
Lower duff temperature	$40.0 \pm 0.6^\circ$ F	$41.5 \pm 1.0^\circ$ F
Duff consumption	1.2 ± 1.2 cm	10.0 ± 3.0 cm

¹Standard errors



Figure 5. After 100 years of fire exclusion the cat-faces (fire scars) which were often pitch covered were not resistant to fire. Inadvertent burning was easily extinguished using snow or prevented by filling the scar with snow before applying the fire.

- At the same time the prescribed fires were applied, the surface organic layers around the base of 16 trees were mixed using a hoe in 2002 and 8 trees were mixed a second time in 2004. This mixing was intended, without displacing the material, to allow moisture and heat to penetrate increasing the decomposition of these materials.



Figure 6. Disturbing (mixing) the surface organic layer around mature ponderosa pine when the lower duff moistures were high (100 % +) and the temperatures low ($\leq 40^{\circ}$ F).

- The autumn before and the autumn after each treatment, four soil cores (3.66 inches by 12 inches) were extracted. At three feet from the tree, three soil cores were extracted at 0, 120, and 240 degree azimuth (prior to treatment) using a slide-hammer core sampler. Subsequent cores after each treatment were adjusted by 30 degrees

(after first application soil cores were extract at 30, 150, 270 degrees around the tree) to avoid re-sampling error. The material in each core was separated into litter, decayed wood, humus, shallow mineral (0-10 cm), and deep mineral (> 10 cm) soil substrates. The volume of each substrate was measured and the fine roots within each substrate were carefully removed using a sieve and water. Ectomycorrhizal root tips were counted using a dissecting binocular microscope on each of the roots found in the various substrates. After the ectomycorrhizae were counted the roots were dried and weighed.

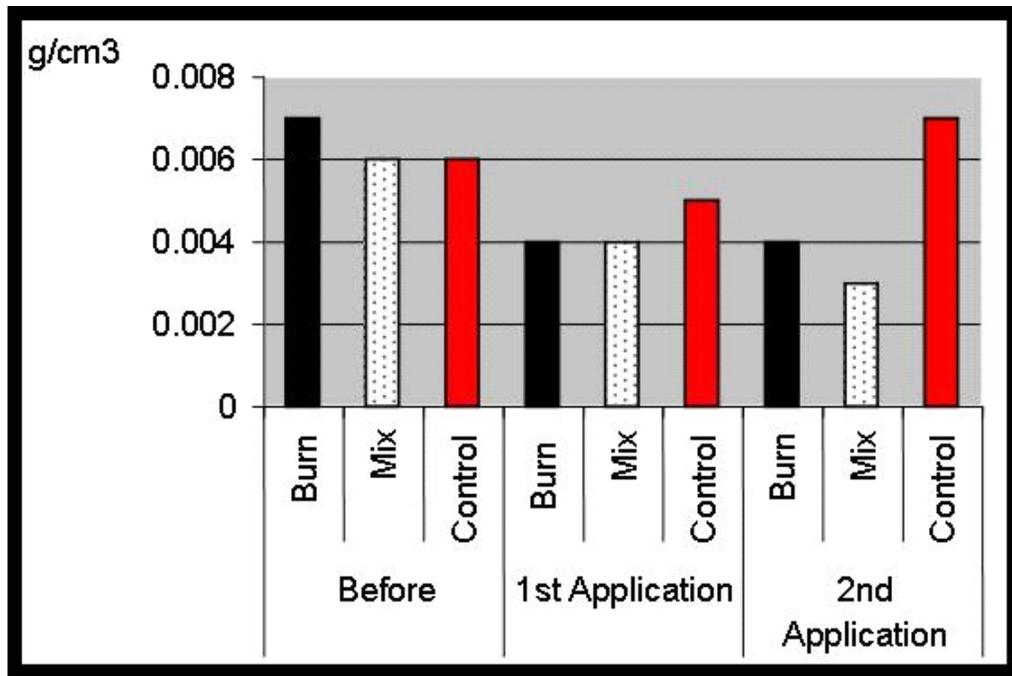


Figure 7. The concentration of fine roots occurring (grams cm^3) in the humus fraction of the organic material decreased in response to both the mixing and snow-well burning compared to the controls.

- Statistical differences were detected using a mixed model analysis of variance with the treatments (3) and horizons (4 and 5) being fixed and the trees (16 and 8) being random. There were no significant (< 0.05) differences in root concentrations prior to the burning and mixing. After the first fire the concentrations of roots in the burn (significance 0.15) and mixed (significance 0.18) treatments were less than in the control. Also, after the second application of the treatments, the root concentration in the treated snow-wells was less than those occurring in the controls (burn significance 0.03 and mixed significance 0.004). Even though we designed the study to determine the impact burning and mixing had on forest floor dynamics the mere process of opening the stand and allowing more heat, wind, and water to the forest floor also appeared to alter the forest floor and the inherent root concentrations.

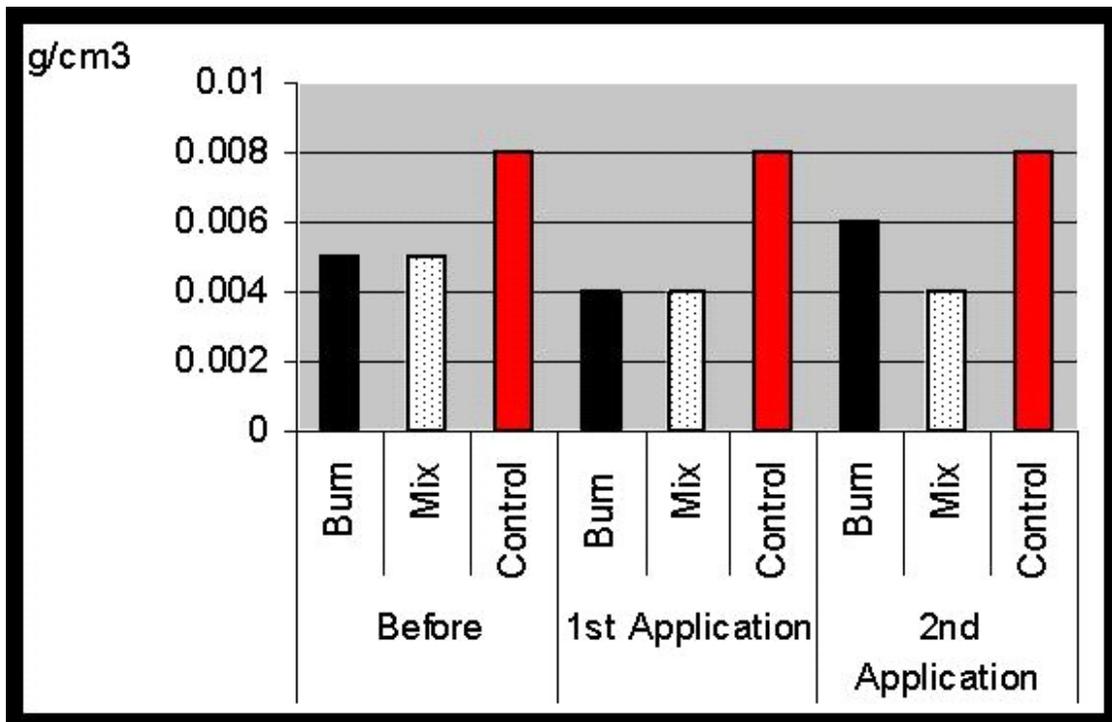


Figure 8. The fine root concentrations occurring in the mineral soil decreased in response to both mixing and burning the organic layers in snow-wells.

- There were no differences in the root concentrations occurring in the shallow (< 10 cm) mineral soil before the treatments were applied. After the first application of treatments, the concentration of roots in the burn treatment was less (significance 0.03) than those found in the control and the concentration of roots in the mixed treatment (significance 0.004) was less than that found in the control. This trend continued after the second treatments with the concentration of roots in the burn treatment (significance 0.12) and the mixed treatment (significance 0.12) being less than the control.
- The amount of ectomycorrhizae root tips also changed in the different soil substrates surrounding the large ponderosa pine trees in response to opening of the stand, the mixing of the surface organic layers, and snow-well burning treatments.

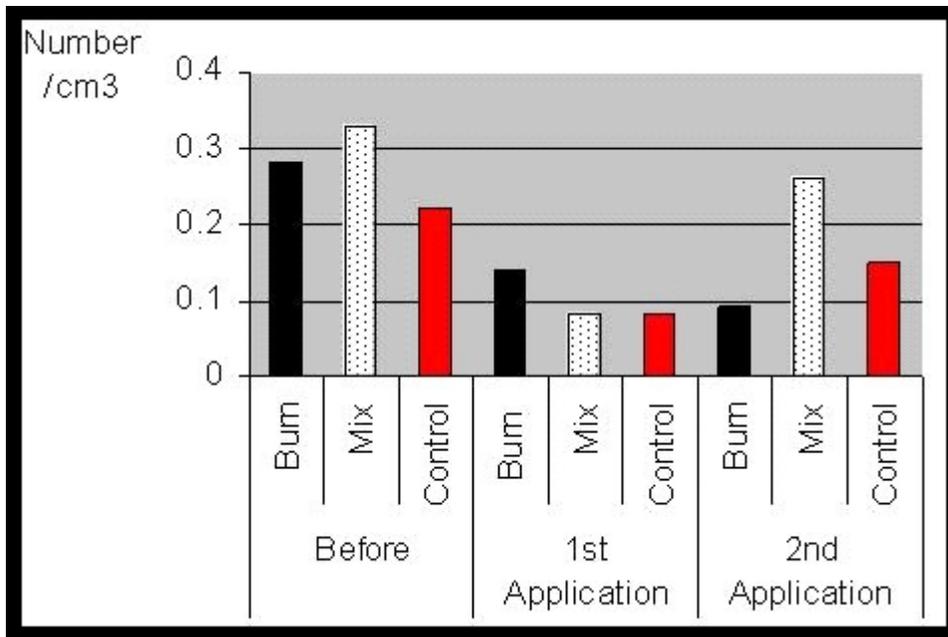


Figure 9. As with the fine root concentrations, there were no differences in the ectomycorrhizae concentrations within the humus soil fraction among the treatments before their application.

- After the first burn and mixing treatments there was a significantly ($p= 0.07$) higher concentration of ectomycorrhizae root tips in the humus around trees which received burning compared to the concentration of root tips in the humus of the control trees and those that received the mixing treatment. Also, there were apparent changes in the concentration of roots in response to the opening of the stands similar to the response noted with the changes in the fine roots before the treatments and after the treatments.

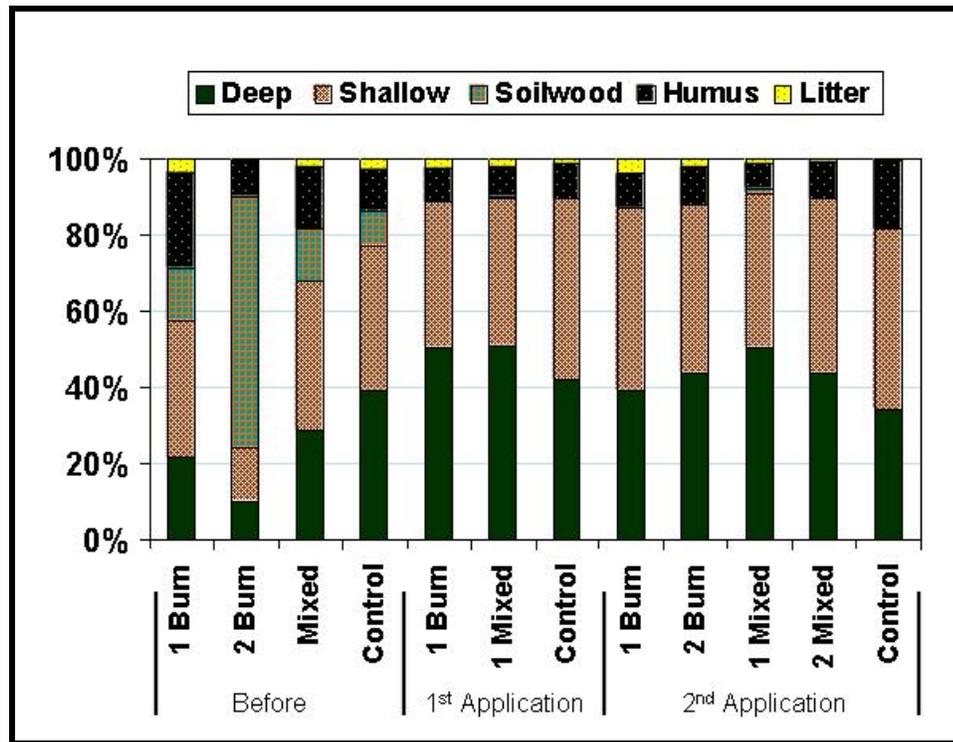


Figure 10. The proportion of roots occurring in the mineral soil tended to increase in response to the opening of the stand and mixing or burning the surface layers.

- Because the majority of the roots occurred in the mineral soil after the treatments, the using of fire to maintain the forest floor conditions using prescribed burns at intervals approaching those occurring historically, would protect these important tree structures from damaging heat.

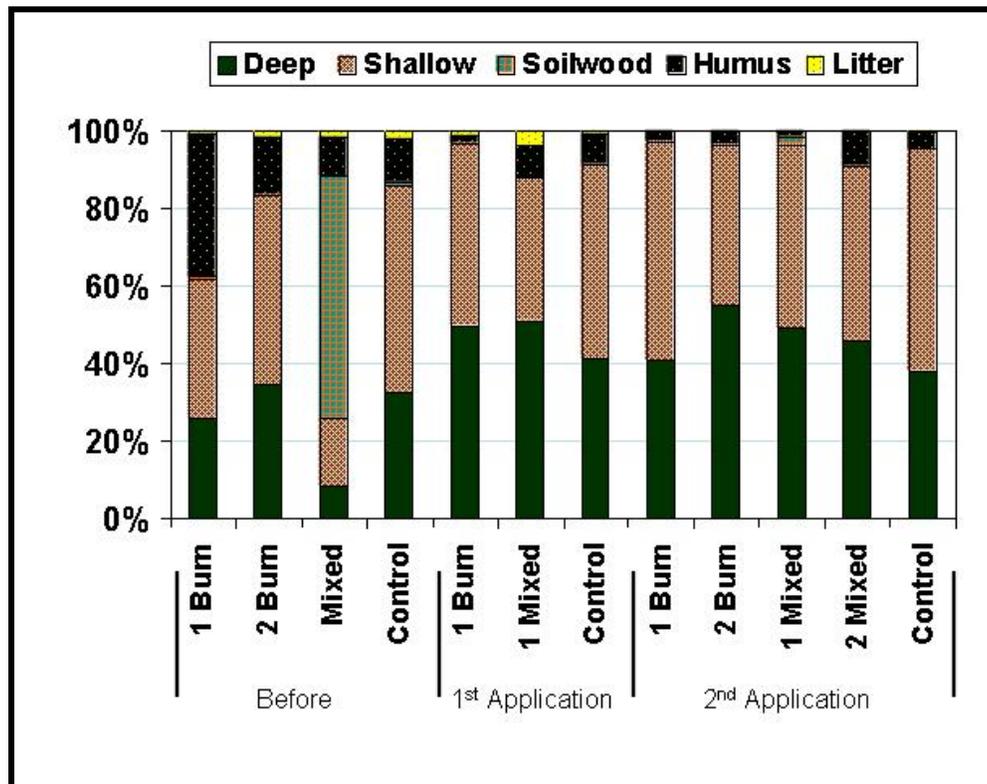


Figure 11. The distribution of ectomycorrhizae mirrored those of the fine roots after the treatments were applied.

- Both with the majority of the fine roots and ectomycorrhizae residing in the mineral soil these structures would be readily resistant to the application of fire. However, bark slough and needle fall are continual processes so treating the surface fuels is suggested to keep these layers from rebuilding.

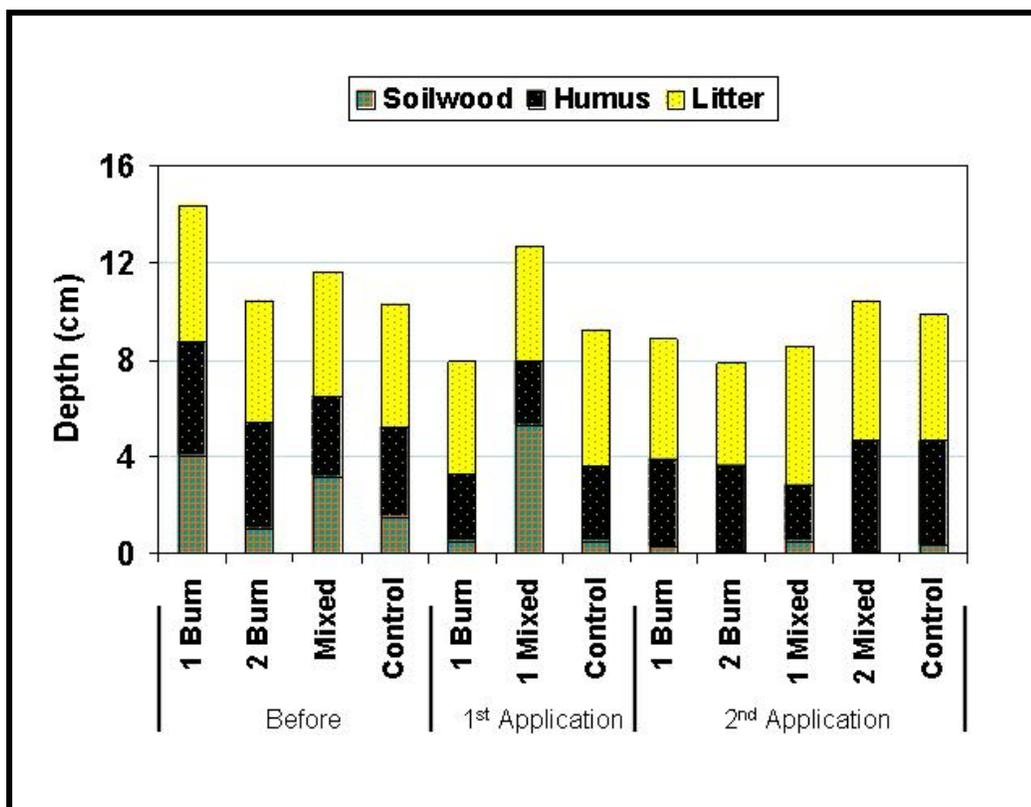


Figure 12. Bark slough and needle fall quickly rebuild after they were treated.

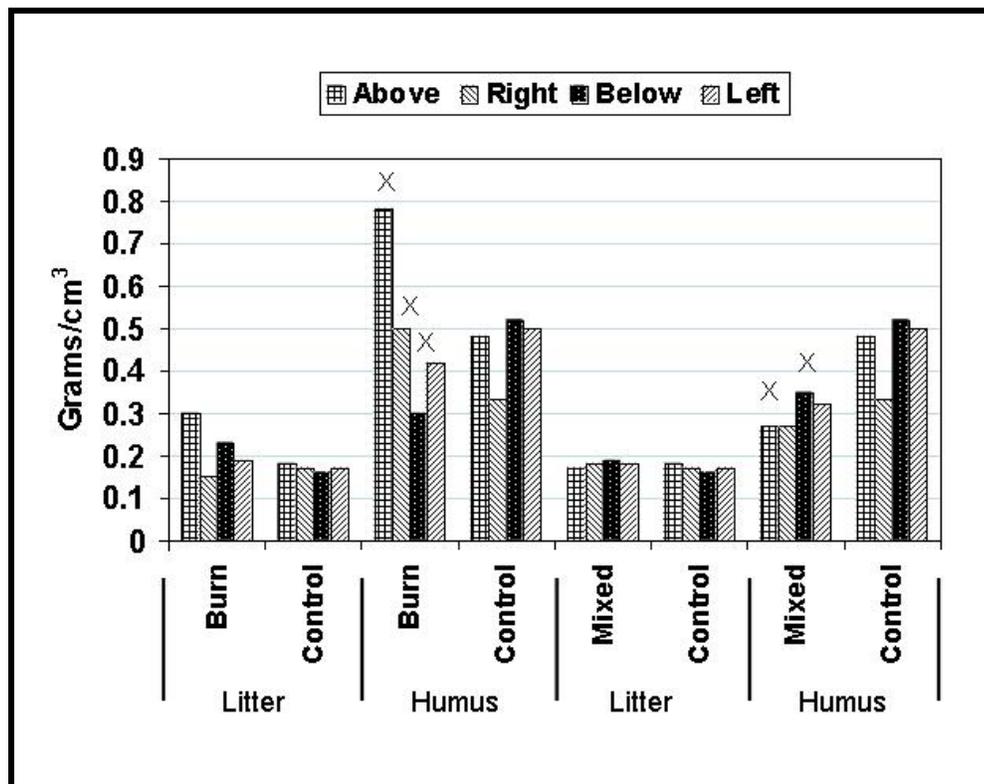


Figure 13. Duff accumulation and removal by decomposition and fire is not uniform around trees. The Xs indicate significant ($p \leq 0.10$) differences among these substrate concentrations and their respective controls for the different positions (on the uphill side of the tree-**Above**, on the down hill side of the tree-**Below**, on the **Left** side of the tree looking up hill and on the **Right** side) around the trees.

- As noted in figure 13, the dispersion of organic materials both with and without treatment is not uniform around trees. The humus layer especially tends to accumulate on the uphill side of trees and remain even after burning. The relevance of this finding is that uniformity in the forest floor around trees is not the norm and a variety of surface conditions are encountered and would be expected.



Figure 14. In the spring of 2005 after mixing and snow-well burning the duff layers in 2002 and 2004, the entire 90 acre stand was burned using prescribed fire. At the time of ignition the lower duff moistures averaged $121 \pm 8\%$ and the temperature of the lower duff averaged $37 \pm 2^\circ$ F. Under these burning conditions, the average amount of duff consumed around the base of the trees was 2 ± 0.4 cm.

- By the fall of 2006, over 4 years since the first mixing and snow-well treatments were applied, within the 90 treated acres 5 trees have succumbed to bark beetles and 4 trees were killed when the snow-well fires ignited a cat-face that could not be extinguished. These 9 dead trees represent only 0.2% of the trees occurring on the 90 acres.

Key Points

- All ponderosa pine forests are different and their propensity to accumulate organic materials at the base of trees is dependent on disturbance (weather, fire, diseases, and insects), developmental and successional stages, physical location, and ecological conditions (figure 1). As such an assessment of root presence in materials at the base of trees is warranted before these materials are mechanically removed (i.e., raked away) or destroyed by burning. A grab sample of the lower duff (i.e., humus) taken with a shovel from around the base of several trees and visually examined for the presence of roots will provide an indication if mixing the surface layers or snow-well burning is warranted before prescribed fire is applied (figure 1).
- The opening (i.e., thinning, canopy reduction, ladder fuel removal) of stands by itself increases heat, moisture, and wind reaching the forest floor and may be enough to encourage the decomposition of organic materials (figures 2 and 3).

- Disturbing roots containing organic materials through burning or mixing should be accomplished when the temperature of the lower duff layers are below 40° F (when root growth is minimal) and lower duff moisture exceeds 100% (figures 4 and 6).
- Several forest floor treatments may be necessary before the root and ectomycorrhizae activity is such that prescribed fire can be used. The effectiveness of the treatments can be easily determined by sampling the layers for the presence of roots (figure 1).
- Snow-well burning and surface layer mixing often are generally no more complex and costly than marking trees for harvest.
- Bark slough and needle fall quickly rebuild making the maintenance of the forest floor condition through the use of prescribed fire essential.
- As humus layers become thinner, root concentrations increase in these layers reinforcing the importance of these layers to a forest soil.
- Most importantly, these treatments need to be incorporated into a silvicultural system (a planned series of treatments through the life of a forest) and documented in silvicultural prescription.

Deliverables

Demonstration site-On the Boise Basin Experimental Forest (BBEF) in southern Idaho, canopy and ladder fuels were treated mechanically leaving a heterogeneous ponderosa pine stand (figure 2). The uncharacteristically deep organic layers surrounding over 3,700 mature and yellow-barked ponderosa pines were treated with snow-well burning or mixing of the surface layers. After two (spring 2002, 2004) treatment applications, the surface fuels of the 90 acre stand were operationally burned (spring 2006). The resulting stand and forest floor structure and composition is reminiscent of those that occurred historically before the advent of successful wildfire exclusion (figure 14).

The BBEF is located 35 miles from Boise Idaho which is home of the Boise National Forest and the National Interagency Fire Center. The proximity to Boise allows us to use the BBEF frequently for field trips. The following is a sample of over **15 field** trips we have had demonstrating our restoration treatments:

1. Graham, Russell T.; Jain Theresa B. 2000. Ponderosa pine fire relationships. Fire ecology workshop, Forest Service and Bureau of Land Management, Boise, ID, May 8-11, 2000.
2. Graham, Russell T.; Jain, Theresa B. 2001. Dry forest restoration: saving large ponderosa pine. Joint Fire Sciences field tour, Boise Basin Experimental Forest, Idaho City, ID, October 17, 2001.
3. Graham, Russell T.; Jain, Theresa B. 2001. Science for informing Forest Planning. Southwestern Idaho Forest Planning meeting, Boise, ID, October 18, 2001.

4. Graham, Russell T.; Jain, Theresa B. 2004. Coarse woody debris: their importance for maintaining soil productivity and their management in the dry forests of the northern Rocky Mountains. Agenda 2020 annual meeting, Boise, ID, April 28, 2004.
5. Graham, Russell T.; Jain, Theresa B. 2004. Coarse Woody Debris Management. Forest Service, southwest ecogroup coarse woody debris, snags, and fuels management, Boise, ID, September 8-9, 2004.
6. Graham, Russell T.; Jain, Theresa B. 2004. Stand and fuel treatments for restoring old-growth ponderosa pine. Forest Service, Boise National Forest, ponderosa pine and coarse woody debris workshop, Boise, ID, September 8-9, 2004.
7. Graham, Russell T.; Jain, Theresa B. 2006. Landscape level fuels reduction: effective strategies for reducing the risk of wildfire in Idaho's forests. Idaho wildland fire conference building partnerships for safer communities, Boise, ID, September 26-27, 2006.

In addition to the on-site use of the demonstration area, results from this work have been presented at over **110 local, regional, national and international scientific meetings and workshops** and this is a sampling of those presentations:

1. Graham, Russell T.; Jain, Theresa B. 2000. Coarse woody debris its role and management in western forests. Southwestern Idaho Forest Planning Meeting, McCall, ID, December 5-6, 2000.
2. Graham, Russell T.; Jain, Theresa B. 2001. How silvicultural treatments affect fire behavior. Forest Service, Region 4 silviculture/fire workshop. Ogden, UT, March 6-8, 2001.
3. Graham, Russell T. 2001. Role of silviculture in fuels management. Forest Service, Region One Silviculture workshop, Missoula, MT, March 27-28, 2001.
4. Jain, Theresa B.; Graham, Russell T. 2001. Coarse woody debris its role and management in the Black Hills. Forest Service, Black Hills National Forest silviculture, fire, and wildlife meeting, Custer, SD, May 21-24, 2001.
5. Graham, Russell T.; Jain, Theresa B. 2001. Silvicultural treatments and fire behavior and severity. Great Basin Fuels Committee, Cedar City, Utah, October 22-26, 2001.
6. Graham, Russell T. 2002. Silviculture and fuel treatments. Forest Service, Region 2 silviculture and fuels workshop, Denver, CO, March 4-6, 2002.
7. Graham, Russell T. 2002. How can management effectively restore/recreate/maintain important features required to conserve biodiversity. BorNet International Conference on biodiversity conservation in boreal forests, Uppsala, Sweden, May 27 - 28, 2002.

8. Graham, Russell T. 2002. Silvicultural options for producing diverse forest structures. Oregon State University, Extension Forestry, diverse forest structure management, Sisters, OR, June 24-27, 2002.
9. Graham, Russell T.; Jain, Theresa B. 2002. Experimental Forests of Idaho. National Experimental Forest Meeting, H. J. Andrews Experimental Forest, Eugene, OR, October 22, 2002.
10. Graham, Russell T.; Jain, Theresa B. 2003. Integrating silviculture into mechanical and fire fuel treatments. Interregional Fuel Treatment Training, Albuquerque, NM, January 28, 2003.
11. Graham, Russell T. 2003. Science for informing fuel treatment decisions. Deputy Under-Secretary of Agriculture Briefing, Washington, DC, April 24, 2003.
12. Jain, Theresa B.; Graham, Russell T. 2003. Coarse woody debris and fuel treatments. Agenda 2020 annual meeting, Kelso, WA, May 1, 2003.
13. Graham, Russell T. 2003. Science for informing fuel treatment decisions in the forests of Idaho. Idaho Conservation League Annual Meeting, Red Fish Lake, ID, May 17-18, 2003.
14. Graham, Russell T. 2003. Burn severity and vegetation (fuels) management. Wildland Fire Impacts on Watersheds Understanding, Planning and Response, Denver, CO, October 21-23, 2003.
15. Graham, Russell T. 2003. Fuels planning: Science synthesis and integration. National Fire Plan Meeting, Orlando, FL, November 20, 2003.
16. Graham, Russell T.; Jain, Theresa B. 2004. Integrating silviculture into mechanical and fire fuel treatments. Interregional Fuel Treatment Training, Spokane, WA, January 13, 2004.
17. Graham, Russell T.; Jain, Theresa B. 2004. Mechanical and fire fuel treatments and their effects. Bureau of Land Management Fuel Treatments Workshop, Miles City, MT, February 17, 2004.
18. Graham, Russell T.; Jain, Theresa B. 2004. Current thoughts and policies on coarse woody debris in our National Forests. Ecological Society of America, Portland, OR, August 3-5, 2004.
19. Graham, Russell T.; Jain, Theresa B.; Cannon, Phil. 2004. Stand establishment and tending in Rocky Mountain Forests. Productivity of western forests: A forest products focus, Kamiche, WA, September 20-23, 2004.
20. Graham, Russell T.; Jain, Theresa B. 2004. Ponderosa pine ecosystems. Ponderosa pine: management, issues, trends, Klamath Falls, OR, October 19-21, 2004.

21. Graham, Russell T. 2004. Silviculture, Fuels, and Landscapes. Science and application in forest and wildlife management in the greater Black Hills, Dakota Society of American Foresters Annual Meeting , Rapid City, SD, October 26-28, 2004.
22. Graham, Russell T.; Jain, Theresa B.; Mathews, Susan J. 2005. Fuel Management in Forests of the Inland Western United States. Cumulative effects of fuel treatments on watersheds, Salt Lake, UT, April 5-6, 2005.
23. Graham, Russell T.; Jain, Theresa B. 2006. Thinning strategies to moderate fire behavior and create desired stand structure. USDA Forest Service, Region 5, 2006 Fuels and Vegetation Conference, Reno, NV, January 31-February 2, 2006.
24. Graham, Russell T.; Jain, Theresa B. 2002. Restoring dry forests of the inland northwestern United States. IUFRO Conference on restoration of boreal and temperate forests, Billund/Vejle, Denmark, May 2, 2002.
25. Graham, Russell T.; Jain, Theresa B. 2004. Application of free selection in mixed forests of the inland northwestern United States. IUFRO Meeting the Challenge: silvicultural research in a changing world, La Grande Motte, Montpellier, France, June 14-18, 2004.
26. Graham, Russell T.; Jain, Theresa B. 2005. Free selection: a silvicultural option. Forest Service, Restoring fire-adapted forested ecosystems. 2005 National Silviculture workshop, Lake Tahoe, CA, June 6-10, 2005.

Publications

The following publications contain references to or data from the demonstration site:

1. Graham, Russell T. 2002. Historical landscapes and forest structures. In: Baumgartner, David M.; Johnson, Leonard R.; Deput, Edward J. Comp. Small diameter timber: Resource management, manufacturing, and markets. February 25-27, 2002, Spokane, WA. Pullman, WA: Washington State University. 25-31.
2. Graham, Russell T. 2002. How can management effectively restore/recreate/maintain important features required to conserve biodiversity. in: Leech, Susan; Whitaker, Carolyn; Innes, John. Eds. BorNet International Conference on biodiversity conservation in boreal forests. May 27 - 28, 2002, Uppsala, Sweden. Vancouver, British Columbia: University of British Columbia. 32-33.
3. Graham, Russell T.; Jain, Theresa B. 2002. Restoring dry forests of the Inland Northwestern United States. in: Gardiner, Emile S.; Breland, Lynne J. Comps. Proceedings of the IUFRO conference on restoration of boreal and temperate forests-documenting forest restoration knowledge and practices in boreal and temperate ecosystems. Vejle, Denmark. Fredeniksberg, Denmark: Danish Centre for Forest, Landscape and Planning. 155-156.

4. Graham, Russell T. 2004. Burn severity and vegetation (fuels) management. In: Ruth Harrison. Ed. *Wildland Fire Impacts on Watersheds Understanding, Planning and Response*. October 21-23, 2003, Denver, CO. Boulder, CO: The Geological Society of America. CD.
5. Graham, Russell T.; Jain, Theresa B. 2004. Boise Basin Experimental Forest. in: Adams, Mary Beth; Loughry, Linda; Plaughter, Linda. *Comps. Experimental Forests and Ranges of the USDA Forest Service*. Gen. Tech. Rep. NE-321. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 105-106.
6. Graham, R. T.; Jain, T. B. 2005. Application of free selection in mixed forests of the inland northwestern United States. in: Parrotta, John A.; Auclair, Daniel. Eds. *Meeting the challenge: silvicultural research in a changing world*. June 14-18, 2004, La Grande Motte, Montpellier, France. Vienna, Austria: IUFRO Headquarters. 49-52.
7. Graham, Russell T.; Jain, Theresa B. 2005. Application of free selection in mixed forests of the inland northwestern United States. *Forest Ecology and Management* 209(1-2): 131-145.
8. Graham, Russell T.; Jain, Theresa B. 2005. Silvicultural treatments in forests burned by mixed fires. In: Lagnene, Taylor; Zelnik, Jessica; Cadwallader, Sara; Hughes, Brian. *Compilers and Editors. Mixed severity fire regimes*. November 17-19, 2004, Spokane, WA. Pullman, WA: Washington State University Extension, Washington State University. 45-58.
9. Graham, Russell T.; Jain, Theresa B.; Cannon, Phil. 2005. Stand establishment and tending in Rocky Mountain Forests. in: Harrington, Constance A.; Schoenholtz. Tech. Eds. *Productivity of western forests: A forest products focus*. September 20-23, 2004, Kamiche, WA. Gen. Tech. Rep. PNW-GTR-642. Portland, OR: Pacific Northwest Research Station. 47-78.
10. Jain, Theresa B.; Graham, Russell T. 2005. Restoring dry and moist forests of the inland northwestern U.S. in: Stanturf, John A.; Madsen, Palle. Eds. *Restoration of boreal and temperate forests*. Boca Raton, FL: CRC Press. 463-480.
11. Graham, Russell T.; Jain, Theresa B. 2006. Ponderosa pine ecosystems. In: Richie, Martin W.; Maguire, Douglas A.; Youngblood, Andrew. *Tech. Coords. Ponderosa pine: management, issues, trends*. October 18-21, 2004, Klamath Falls, OR. Gen. Tech. Rep. PSW-GTR-198. Albany, CA: U. S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 1-32.
12. Graham, Russell T.; Jain, Theresa B.; Sandquist, Jonathan 2006. Free selection: a silvicultural option. In: Powers, Robert. Ed. *Restoring fire-adapted forested ecosystems*. 2005 National Silviculture workshop. June 6-10, 2005, Lake Tahoe, CA. Gen. Tech. Rep. PSW-GTR-203. Albany, CA: U. S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 121-156.

13. Graham, Russell T.; Jain, Theresa B.; Mathews, Susan J. In Press. Fuel Management in Forests of the Inland Western United States. In: Audin, Lisa; Elliot, William. Eds. Cumulative watershed effects of fuel treatments. Gen. Tech. Rep. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.