MILLER CREEK: ECOSYSTEM RECOVERY IN A WESTERN MONTANA FOREST 30 YEARS AFTER PRESCRIBED BURNING AND WILDFIRE

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ABSTRACT

Thirty years ago the effects of timber harvest, prescribed burning, and wildfire were investigated in a western larch/Douglas-fir forest on the Flathead National Forest in western Montana. The original study was designed to investigate the effects of prescribed burning on soil physical and biological properties, and on subsequent stand establishment and growth. Sixty 4-hectare units on different aspects representing 2 habitat type phases, *Menziesia ferruginea* (MEFE) and *Xerophyllum tenax* (XETE), were harvested from January 1967–January 1968. Prescribed burns of various intensities took place in July, August, and October 1967 and May–October 1968. A wildfire burned several areas in August 1967, providing an additional treatment. Subsequent research documented short-term fire effects on small mammal populations, soil chemical and physical properties, soil erosion, water quality, plant succession, and conifer regeneration. In 1995 we resampled the original plots with the goal of comparing present soil and stand conditions to those 30 years earlier. The topics addressed were: (1) changes in soil and forest floor organic matter, (2) the effects of those soil changes on stand development, and (3) a comparison of the above- and belowground conditions in harvested sites with those in adjacent old-growth stands. This paper presents an overview of impacts from both prescribed fire and wildfire on the plant communities of this western forest ecosystem after 30 years. Shrubs represented a larger plant component than forbs, grasses, or mosses, and reflected fire response with frequent occurrence of species that establish well after fire or are resistant to fire. The XETE habitat type phase treatments occur on dry south- and west-facing slopes and have a richer tree species mix than do the cooler east- and north-facing slopes in the MEFE phase treatments.

keywords: habitat types, prescribed burning, shrubs, succession, western larch forests, western Montana, wildfire.

Citation: Tonn, J.R., M.F. Jurgensen, G.D. Mroz, and D.S. Page-Dumroese. 2000. Miller Creek: ecosystem recovery in a western Montana forest 30 years after prescribed burning and wildfire. Pages 67–73 *in* W. Keith Moser and Cynthia F. Moser (eds.). Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

In many forests of the western United States, the fire regime for at least several centuries before European settlement included both lightning- and human-caused ignitions, some of the latter being deliberate burns (Arno 1980). In the northern Rocky Mountains, prescribed fire is now an important silvicultural tool for reducing logging slash, which is a wildfire risk and interferes with reforestation operations (Graham 1993). Prescribed burning also helps to create suitable environmental conditions for establishment and growth of conifer regeneration, and to manipulate secondary plant succession to favor the development of preferred species (Walstad and Seidel 1990).

Prescribed fire can affect forest productivity, but the degree of its impact depends on many factors, such as fire intensity and duration, absolute and relative amounts of organic matter consumed by the fire, nutrient content of the burned organic matter, and the importance of each nutrient to tree growth (McNabb and Cromack 1990). Prescribed fire is also an excellent method for managing coarse woody debris (woody residue >8 centimeters in diameter), which is an important long-term component of soil ecosystems (Edmonds 1991, Reinhardt et al. 1991, Jurgensen et al. 1997). Severe burns from a wildfire or prescribed fire can also result in nearly complete removal of surface organic matter and cause detrimental changes in the physical, chemical, and biological properties of the upper layers of the mineral soil (Neal et al. 1965, Chandler et al. 1991).

Before the 1960's, prescribed fire was used to emulate the natural role of fire in many western forest ecosystems, but the results were usually unpredictable. Knowledge of the environmental and biological impacts of fire on forest soil and water systems was also lacking (Shearer et al. 1994). In 1966 a multidisciplinary research project was initiated in a western larch (*Larix occidentalis*)/Douglas-fir (*Pseudotsuga menziesii*) forest at Miller Creek in western Montana to investigate the effects of prescribed fire intensity and duration on fuel removal, stand regeneration and early development, water quality, and soil properties (Shearer 1975, 1976, Beaufait et al. 1977, DeByle 1981).

In August 1967, as the study began, a wildfire burned several plots that were scheduled to be harvested or had already been harvested but not yet prescribed-burned. This was a severe fire that removed the forest floor, exposing mineral soil in many areas (Shearer and Stickney 1991). While this fire disrupted the original experimental design, it presented an opportunity to compare the effects of a wildfire with prescribed burning on similar, contiguous sites. In 1989 the Miller Creek Demonstration Forest was established, which would ensure that research on the recovery of this ecosystem from both prescribed burning and wildfire would continue (Shearer et al. 1994).

In 1995 we initiated a follow-up study to examine fire-mediated changes in plant communities and soil properties since 1967. This paper describes the plant communities that developed in this western forest ecosystem 30 years after both prescribed burning and wildfire.

STUDY AREA

The study site was within the Miller Creek Demonstration Forest on the Flathead National Forest in northwestern Montana. Elevations range from 1,280–1,524 meters with an average slope angle of 24%. Cool, moist climatic conditions persist throughout the study area. Annual precipitation (approximately 65% as snow) averages 64 centimeters. The *Abies lasiocarpa/Clintonia uniflora* (ABLA/CLUN) habitat type (Pfister et al. 1977) predominates. Species composition of the old-growth preharvest forest was: Engelmann spruce (*Picea engelmannii*), 31%; Douglas-fir, 31%; western larch, 26%; subalpine fir (*Abies lasiocarpa*), 6%; and lodgepole pine (*Pinus contorta*), 6% (Shearer 1989). Two habitat type phases were present on the study site: (1) *Xerophyllum tenax* (XETE) on dry south- and west-facing slopes, and (2) *Menziesia ferruginea* (MEFE) on the cool middle and upper east- and north-facing slopes.

In 1966 60 4-hectare clear-cut units were harvested so that 1/4 of each unit was generally facing each of the 4 cardinal directions. The clear-cuts were burned over a broad range of weather conditions during 1967 and 1968. A wildfire in August 1967 burned or reburned clear-cuts facing east, south, and west (Beaufait et al. 1977, Shearer 1989). In 1995, 10 of the units from the original study at Miller Creek were located. Six old-growth uncut units adjacent to the harvested units were also established: 3 in the dry XETE phase and 3 in the moist MEFE phase.

METHODS

In 1996 and 1997, vegetation was sampled in 6 treatments in the XETE phase and 4 treatments in the MEFE phase. A system of nested quadrats was used to sample the vegetation (Bonham 1989).

Tree diameters for all trees ≥5 centimeters in diameter at ground level were recorded. Ten 15-meter quadrats were sampled in each treatment. Total crown cover on each 15-meter quadrat was also estimated.

Shrubs ≥0.5 meters tall were tallied by species into 2 diameter classes: <2 centimeters and ≥2 centimeters at ground line in 4-meter quadrats in 1 corner of each of the 15-meter quadrats.

Ocular cover estimates of lichens/mosses, grasses/sedges, herbaceous vegetation, and shrubs on 2 1-meter quadrats in each 15-meter quadrat were recorded.

All plants <0.5 meters tall on each 1-meter quadrat were clipped at ground level and dried at 60°C to obtain total plant biomass weight.

The data were analyzed using the SAS Mixed procedure with a hierarchical design. Forb classes, as random effects, were nested within the different burn treatments, which were fixed effects. Because of the nested design, not all classifications of forbs were present in each burn treatment. SAS adjusted the means for the unequal cell sizes using a least square means procedure with differences detected at the $P \leq 0.05$ level (Kirk 1995).

RESULTS AND DISCUSSION

Plant Coverage

Plant regeneration and growth after the various fire treatments strongly reflect habitat type phase. In the XETE habitat phase, shrub mean percent coverage (52%) in the prescribed burn was significantly larger than the means of the other treatments (Table 1). Thirty years after treatment, the prescribed burn produced the greatest number of shrubs that may be desirable for wildlife. The mean shrub coverage for the unburned treatment was not significantly different from the prescribed burn/wildfire, wildfire/uncut, and wildfire/harvested treatments. Perhaps the wildfire killed more of the shrubs than did the prescribed burns, or it did not provide a hot enough heat treatment for the *Ceanothus sanguineus* to germinate (Noste and Bushey 1987). In addition, greater duff reduction by the wildfire may have caused such a harsh microclimate that shrubs were unable to regenerate. The unburned treatment is on a harsh, dry south aspect, which may account for the low shrub coverage.

Grass coverage in the XETE habitat phase showed that the unburned treatment and the wildfire/harvested treatment were not significantly different from each other, but the amounts in the wildfire/harvested treatment were different from the amounts in the prescribed burn, prescribed burn/wildfire, wildfire/uncut, and old growth. The unburned and wildfire/harvested treatments also had the lowest amount of cover. The harvesting disturbance may have had a greater impact on grass reproduction than did the wildfire.

In the MEFE habitat phase, the cover of shrubs in the unburned and prescribed burn was not significantly different. In this moist habitat the prescribed burn may

Table 1. Average coverage (mean %) and biomass (megagrams per hectare) of plants <0.5 meters tall at Miller Creek, 1996 and 1997.

Treatment	Mean % Coverage[a] Shrubs	Mosses	Grass	Biomass Megagrams/hectare
Xerophyllum Phase (XETE)				
Unburned	18A[b]	3AB	3AB	3.84B[c]
Prescribed burn	52B	8AB	16BC	2.80A[c]
Prescribed burn/wildfire	21A	7AB	20BC	3.59AB
Wildfire/uncut	18A	3B	24C	2.98AB
Wildfire/harvested	22A	10AB	2A	3.09AB
Old growth	15A	12A	28C	3.04AB
Menziesia Phase (MEFE)				
Unburned	29A	21A	0.4A	0.86A
Prescribed burn	24A	24A	0.5A	0.64A
Old growth	17B	29A	0.7A	0.33B

[a] Coverage of tree seedlings <0.5 meters tall was very low and is not included. Tree seedlings are included in the biomass weights.
Coverage Classes:

Percent	Midpoint
1 = 0–1%	0.5%
2 = 1–5%	3.0%
3 = 6–25%	15.5%
4 = 26–50%	38.0%
5 = 51–75%	63.0%
6 = 76–100%	88.0%

[b] Different letters indicate significant ($P \leq 0.05$) differences among treatments.
[c] Difference significant at the $P \leq 0.10$ level between these 2 treatments.

have burned incompletely and did not hinder shrub regeneration. There may have been high duff moisture, less duff reduction, and therefore, lower mortality of existing shrubs.

In the XETE habitat phase, the largest amount of herbaceous, grass, and small shrub biomass (3.84 megagrams per hectare) was in the unburned treatment. Biomass in this treatment was significantly different from the prescribed burn treatment and indicated more favorable conditions for shrub communities. The prescribed burn may have destroyed some of the shrub habitat and restricted shrub development (Table 1).

In the moist, cold MEFE habitat phase, neither of the treatments was significantly different from the old growth with respect to grass production.

In the MEFE habitat phase, the biomass in the old growth was significantly different and lower than the amounts in the unburned and prescribed burn treatments. The old-growth overstory likely reduced shrub growth and reproduction. The shrubs in the unburned treatment apparently had the advantage of not being suppressed, in contrast with shrubs in the prescribed burn. The fuel loading and resulting fire in the prescribed burn may have increased shrub mortality.

Shrubs

When total numbers of shrubs per hectare (Table 2) in the XETE habitat phase were compared, the unburned treatment was not significantly different from the wildfire/harvested treatment. Both *Shepherdia canadensis* and *Spiraea betulifolia* were well represented in these treatments, and both are somewhat fire-resistant. The wildfire may have burned incompletely, causing conditions similar to the unburned treatment. The prescribed burn produced the highest total number of shrubs; it also had the highest mean percent coverage (Table 1), which was significantly different from the other treatments. This treatment was on a west-facing aspect at a higher elevation than the other treatments.

In the moist, cold MEFE habitat phase, a significantly greater number of shrubs developed in the unburned treatment compared to the prescribed burn or old growth. The shrubs in the unburned treatment were able to continue growing and reproducing, but those in the prescribed burn were likely killed by the fire.

Table 2. Three most prevalent shrubs (by diameter class) at Miller Creek, 1996 and 1997.

Treatment	Average No. Per Hectare ($\times 10^3$) <2 centimeters	≥2 centimeters	Total No. Per Hectare ($\times 10^3$)	% of Total
Xerophyllum Phase (XETE)				
Unburned			13.9C[a]	
Shepherdia canadensis	10.6	1.7	12.3	88.5
Spiraea betulifolia	1.0	0.0	1.0	7.2
Vaccinium globulare	0.6	0.0	0.6	4.3
Prescribed burn			58.4E	
Pachistima myrsinites	25.4	0.0	25.4	43.5
Alnus sinuata	4.1	5.2	9.3	15.9
Spiraea betulifolia	8.8	0.0	8.8	15.1
Prescribed burn/wildfire			39.5D	
Ceanothus velutinus	22.1	0.3	22.4	56.7
Salix scouleriana	10.7	1.1	11.8	29.9
Spiraea betulifolia	4.4	0.0	4.4	11.1
Wildfire/uncut			12.0B	
Ceanothus velutinus	4.6	0.2	4.8	40.0
Spiraea betulifolia	4.1	0.0	4.1	34.2
Salix scouleriana	1.4	0.5	1.9	15.8
Wildfire/harvested			13.5C	
Salix scouleriana	5.4	0.5	5.9	43.7
Shepherdia canadensis	3.3	0.7	4.0	29.6
Spiraea betulifolia	1.6	0.0	1.6	11.9
Old Growth			1.7A	
Vaccinium globulare	1.0	0.03	1.0	60.6
Rosa gymnocarpa	0.2	0.0	0.2	11.8
Acer glabrum	0.1	0.0	0.1	5.0
Menziesia phase (MEFE)				
Unburned			111.1A	
Vaccinium globulare	53.8	0.3	54.1	48.7
Menziesia ferruginea	38.4	0.6	39.0	35.1
Pachistima myrsinites	8.7	0.0	8.7	7.8
Prescribed burn			31.1B	
Alnus sinuata	8.6	6.7	15.3	49.2
Menziesia ferruginea	4.7	0.03	4.7	15.1
Vaccinium globulare	3.7	0.0	3.7	11.9
Old Growth			13.0C	
Vaccinium globulare	5.7	0.0	5.7	43.8
Menziesia ferruginea	3.7	0.1	3.8	29.2
Pachistima myrsinites	1.2	0.0	1.2	9.2

[a] Different letters indicate significant ($P \leq 0.05$) differences among treatments.

Table 3. Average number of trees per hectare <5 centimeters in diameter at Miller Creek, 1996 and 1997.

Treatment	*Abies lasiocarpa*	*Larix occidentalis*	*Picea engelmannii*	*Pinus contorta*	*Populus tremuloides*	*Pseudotsuga menziesii*	*Taxus brevifolia*	Total
Xerophyllum Phase (XETE)								
Unburned	0	0	0	0	0	0	0	0A[a]
Prescribed burn	875	625	815	0	125	250	0	2,690D
Prescribed burn/wildfire	60	310	125	690	1,875	315	190	3,565E
Wildfire/uncut	95	250	95	0	30	30	0	500B
Wildfire/harvested	185	440	255	815	560	250	0	2,505CD
Old growth	1,110	0	20	0	0	80	1,250	2,460C
Menziesia Phase (MEFE)								
Unburned	120	0	60	0	0	250	0	430A
Prescribed burn	2,530	30	2,435	0	0	470	0	5,465B
Old growth	1,210	0	60	0	0	190	190	1,650C

[a] Different letters indicate significant ($P \leq 0.05$) differences among treatments.

There were fewer shrubs in the old growth because of competition for nutrients, light, and moisture.

Shrub composition in these treatments (Table 2) reflects fire response. *Ceanothus velutinus* was not present in the prefire vegetation on any of the units (DeByle 1981), but was common on most of the burned treatments in the XETE phase. The greatest potential for establishing *C. velutinus* is after hot fires on south-facing slopes (Noste 1985, Noste and Bushey 1987). *C. velutinus* resprouts from the root crown after being burned and is usually shade intolerant (Noste and Bushey 1987). *Shepherdia canadensis,* which is moderately fire-resistant (Fischer and Clayton 1983, Noste and Bushey 1987), occurred more frequently in the XETE phase. *Amelanchier alnifolia* was generally present in the smallest diameter classes and in low numbers. The XETE phase treatments had large numbers of *Spiraea betulifoia,* which can sprout after fires on dry sites (Tiedemann and Klock 1976, Noste and Bushey 1987).

As expected, *Vaccinium globulare* and *Menziesia ferruginea* were the dominant shrubs in the MEFE phase. Arno et al. (1985) found severe fire treatments from both burning of slash and wildfire greatly decreased *V. globulare* for about 15 years (Noste and Bushey 1987). Large numbers of *V. globulare, M. ferruginea,* and *Pachistima myrsinites* were present in the unburned treatment in the MEFE phase. These species survived after the unit was clear-cut and have continued to thrive. The wildfire killed much of the *V. globulare,* which continues to be sparsely represented. *Salix scouleriana* was not found on any of the units before burning (Noste and Bushey 1987). *Alnus sinuata* and *M. ferruginea,* which probably colonized from onsite seed sources, typically grow on mesic sites, as our sampling indicated.

Trees

Most of the species normally found in these 2 habitat type phases were found 30 years after treatment, with a few exceptions (Table 3). Early seral species (*Larix occidentalis, Pinus contorta*) predominated after fire on the warm, dry XETE phase, compared to the cooler, wetter MEFE phase. Before treatment, *Taxus brevifolia* occurred on 80% of the units; during the 9 years after burning it failed to appear on any of them (Stickney 1981). Thirty years later *Taxus* was present in the prescribed burn/wildfire treatment. *Populus tremuloides,* which was not found in any of the old-growth stands, occurred only in the burned XETE units. For the most part the stands are in the stem exclusion stage of development. The exception was the unburned treatment in the XETE phase. This site is a harsh south aspect and is dominated by forbs and shrubs. It consequently has a richer species mix than does the cooler MEFE phase. The unburned treatments in both habitat type phases have few stems in the <5 centimeters size class. Without fire or other disturbance to the forest floor after harvesting, conifer regeneration in this habitat type is slow (Shearer and Stickney 1991).

In the XETE habitat phase, total numbers of trees <5 centimeters in the wildfire/harvested and old growth were not significantly different from each other. Each had approximately 2,500 trees per hectare (Table 3). The wildfire/harvested treatment provided a habitat for the trees that emulated the old growth. Even though most of the trees were killed, they still dispersed seed and provided shade for seedlings. The prescribed burn/wildfire treatment had the greatest number of trees per hectare, which was significantly different from all the other treatments. The prescribed burn had the second highest number of trees per hectare; hence, the prescribed burn treatments furnished ideal sites for natural regeneration.

In the XETE habitat phase, total number of trees per hectare ≥5 centimeters was lowest in the unburned and prescribed burn/wildfire treatments; these totals were not significantly different from each other (Table 4). Because these treatments were on south-facing slopes and at higher elevations than the other treatments, they were not as conducive to conifer establishment and regeneration. The other treatments were significantly different from each other.

In the XETE habitat phase, numbers of trees in all of the treatments were significantly different from each other. The prescribed burn treatment produced by far the highest number of trees per hectare because it provided a favorable seedbed for conifer regeneration.

Table 4. Basal area (square meters per hectare) and number of trees per hectare ≥5 centimeters in diameter at Miller Creek, 1996 and 1997.

Treatment	*Abies lasiocarpa* No. per hectare	*Abies lasiocarpa* Basal area m²/ha	*Larix occidentalis* No. per hectare	*Larix occidentalis* Basal area m²/ha	*Picea engelmannii* No. per hectare	*Picea engelmannii* Basal area m²/ha	*Pinus contorta* No. per hectare	*Pinus contorta* Basal area m²/ha	*Pseudotsuga menziesii* No. per hectare	*Pseudotsuga menziesii* Basal area m²/ha	Total No. per hectare	Total Basal area m²/ha
Xerophyllum Phase (XETE)												
Unburned	293	3	13	<1	0	0	9	<1	13	<1	392A	4A[a]
Prescribed burn	111	<1	1,230	8	226	<1	9	<1	542	2	2,082E	11D
Prescribed burn/wildfire	4	<1	133	2	71	<1	58	3	75	<1	270A	6B
Wildfire/uncut	0	0	280	3	47	<1	1,150	6	60	<1	1,468C	9C
Wildfire/harvested	11	<1	349	6	122	<1	113	3	178	1	679B	10D
Old growth	882	11	108	10	306	6	154	4	323	11	1,684D	42E
Menziesia Phase (MEFE)												
Unburned	391	6	9	<1	80	<1	9	<1	58	<1	573A	7A
Prescribed burn	173	<1	127	1	673	2	20	<1	155	1	1,199B	5B
Old growth	852	13	49	9	459	13	0	<1	105	12	1,493C	48C

[a] Different letters indicate significant ($P \leq 0.05$) differences among treatments.

In the MEFE habitat phase, numbers of trees per hectare ≥5 centimeters in all treatments (including the old growth) were significantly different from each other. The largest number of trees per hectare occurred in the old growth, which indicates the disturbance adversely affected the number of trees per hectare.

In the XETE habitat phase, the prescribed burn and wildfire/harvested treatment produced almost the same amount of basal area in trees ≥5 centimeters. As expected, the old growth had the greatest basal area (Table 4). Excluding the old growth, the highest basal areas in the XETE phase were *Larix occidentalis* in the prescribed burn and the wildfire/harvested, and *Pinus contorta* in the wildfire/uncut.

In the MEFE habitat phase, old growth again had the greatest basal area, and the 2 habitat type phases were significantly different from each other. Total basal area of the MEFE phase treatments was about the same due to the presence of *Abies lasiocarpa* in the unburned treatment. In the MEFE phase *A. lasiocarpa* (unburned) had a noticeably higher basal area than in the burned treatments. The unburned treatment had a much lower basal area than did the burned treatments but not for all species. In the unburned treatment in the MEFE phase, the sparse basal area for *Pseudotsuga menziesii, Larix occidentalis,* and *Pinus contorta* may be related to the original clear-cutting and slashing. The trees left at the time of treatment were the ones too small for slashing, and the *A. lasiocarpa* present survived as advance regeneration. Because the *A. lasiocarpa* responded well to release, site preparation apparently would not have been necessary to obtain adequate stocking. In the other treatments advance regeneration was eliminated by clear-cutting and slashing. In the prescribed burn treatment in the MEFE phase, early *Picea engelmannii* growth was better than on the other clear-cuts, and continued to have higher basal area compared to other tree species in this treatment. *Pinus contorta* did not survive the fire treatments, but did reestablish (DeByle 1981); in most treatments its basal area was comparable to the old-growth basal area.

MANAGEMENT IMPLICATIONS

Results from Miller Creek offer a rare glimpse of ecosystem recovery after disturbance. By comparing the treatment units with the old-growth units, we can gain insight into the use of fire to obtain desired stand conditions and ecosystem recovery after fire. Thirty years after treatment, our results show that fire is a key element in plant regeneration and succession in this western forest ecosystem.

Burn intensities control the kind and amount of seedbed, which greatly affects the kind and amount of plant regeneration and vegetative competition. The degree of stocking can be directly related to burn intensity, and burning may result in high mortality to shade-tolerant shrubs and trees. Shrubs also have different levels of fire resistance.

The best conifer regeneration in the XETE and MEFE phases was in the prescribed burn/wildfire and wildfire treatments, which supports the fact that fire tends to set the stage for regeneration in this ecosystem. Shearer (1991) pointed out that without fire or other site modifications after timber harvest, conifer regeneration is slow and often excludes shade-intolerant species (such as *Larix occidentalis* and *Pinus contorta*). Our results show that wildfires and prescribed fires can give rise to different communities.

If our treatments were applied operationally with the same species, we would expect the same responses. However, partial harvest treatments with fire would have taken longer to reach this stage of succession (Haig et al. 1941). Much like clear-cutting effects, fire would favor the establishment of shade-intolerant, long-lived conifer species. Partial harvest treatments without fire would have resulted in different species mixes for conifers and other vegetation—primarily more shade-tolerant species. Initial vegetation following partial harvest treatments would have consisted of fewer shrub species than after clear-cutting. Over time species abundance would have followed a different pattern. Partial harvest treatments may have provided less shrub competition, particularly in the early years after treatment.

The Miller Creek Demonstration Forest not only provides research sites for professionals studying ecosystem management but also serves as a classroom for the public. The Forest affords an excellent opportunity for participation and education at the landscape level. Because of the significance of using fire in regenerating shade-intolerant species, much is currently being written about when and where to use fire. Therefore, this study enhances understanding of fire effects by continuing to track succession and treatment effects, identifying possible adaptive management practices, and recognizing potential problems. Subsequent publications will address changes in soil and forest floor organic matter and their effect on stand development, and compare belowground conditions in harvested sites with those in adjacent old-growth stands.

Summarizing the opportunities at Miller Creek, Shearer et al. (1994) wrote that past, current, and future research at Miller Creek provides or will provide baseline information to evaluate new ecosystem management practices. This information can aid the manager in judging the degree of success of different practices. Mapping with Geographic Information Systems will help managers use ecosystem management principles at the landscape level. Managers of other areas within the western larch forest type can take advantage of the wealth of information at Miller Creek and extrapolate it to their location.

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