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Soil and Air Temperature and Biomass After Residue Treatment

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Abstract

Air temperature at 0.5 m and soil temperature at 0.01 m were measured during May and early June after forest harvest on four residue treatment sites and a control. Broadcast burning or burning in piles increased daily accumulation of heat in air while scattered chips and scarified and cleared treatments were equal to the control (broadcast, untreated slash). During mid-afternoon, the pile and burn treatment was warmest; near sunrise, the broadcast burn was consistently warmer. Soil temperature within the chipped plot was colder than in the other plots.

For seeded and unseeded plots, the production of aboveground biomass showed the progression: burn pile < scarified < chipped < broadcast slash < broadcast burn.

Keywords: Residue treatments, temperature (air), temperature (soil), biomass, Oregon (Blue Mountains).

Introduction

The Barometer Watershed Program of the USDA Forest Service established a series of watersheds for evaluation of hydroclimatic factors and the effect of forest harvest on water yield and timing. One such watershed complex is in the Blue Mountains of northeast Oregon. Harvesting by small and large clearcuts and by shelterwood of three of the four calibrated watersheds was accomplished in 1976. Although the hydroclimatic features of these watersheds in the pretreatment (calibration) period have been described (Fowler, Helvey, and Johnson 1979), it will be several years before the overall effect of the forest harvest on the hydroclimate can be evaluated. More immediately observed are the changes in microclimate due to opening of the stands and subsequent residue treatment. Of special importance in the thermal regime is the time of year when weather conditions first become suitable for initiation of new growth, at this elevation usually late May or early June.

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For some forest tree species, germination of stratified seeds with adequate available moisture will occur with temperatures only slightly above 0°C.¹ Among the local species, germination of grand fir (*Abies grandis* [Dougl.] Lindl.) and Subalpine fir (*A. lasiocarpa* [Hook] Nutt.) has been observed on late-persisting snowbanks (Franklin and Krueger 1968). Lodgepole pine (*Pinus contorta* Dougl.) was shown to germinate (although poorly) at 3°C (Haasis and Thrupp 1931). Native grasses, herbs, and shrubs as well as planted and volunteer seedlings must respond quickly to the spring temperature flush. Site occupation depends on initial germination or sprouting success and continued competitive ability as soil moisture dwindles and temperature increases.

Because limited information was available about the effect of alternate residue treatments on the near surface thermal regime in this forest type, a preliminary study was initiated. The objective of this study was to determine whether soil temperature, air temperature, and biomass production (plant cover) are influenced by the method of residue treatment after forest harvest.

Methods and Materials

Within the harvested areas, the most suitable location for our study was an 8.5-ha clearcut on a northerly aspect with an average slope of about 15 percent. The customary residue treatment is pile and burn of larger residue with incidental broadcast burning of any material between burn piles. Four treatments, burn slash in piles (burn pile), broadcast burn of scattered residue, tractor scarified (all slash removed), and chipped residue on scarified areas were replicated on five 5-m diameter circular plots and compared to five control (unburned slash) plots. A representative of each condition was chosen by lot and instrumented in May 1977 with air temperature sensors at 0.5 m and a soil temperature sensor at 0.01 m. Depth of chips (native onsite material) was initially about 3 cm while untreated slash on the control sites was up to 50 cm in depth. Half of each circular plot was seeded in 1976 at a rate of 3.95 kg of seed per hectare.² No fertilizer was applied.

Air and soil temperatures were monitored, starting in May 1977 with integrating thermometers which printed (each 3 hours) the accumulated degree hour summary³ or by conversion the average temperature for the period. We (Fowler and Tiedemann 1979) had found that the air temperature degree hour summary at 0.5 m was adequate to evaluate phenological phase for a widely occurring local shrub and herb. Sensor response is a compromise between the uniqueness of each site as the surface is reached and spatial averaging as sensors are moved further from the surface. Measurement of soil temperature at 0.01 m was as close to the surface as our technique permitted.

¹Table of metric to English conversion on page 8.

²1.14 kg hard fescue, 0.87 kg intermediate wheat grass, 1.34 kg orchard grass, 0.56 kg white clover.

³A measure of heating (or cooling) used in various forms by agriculturists, ecologists, and others for over 2 centuries. For home heating, a "heating degree day" is defined as the daily temperature excursion below 65° F. We measured a degree hour accumulation for all periods with temperatures above 0° C.

Results and Discussion

Temperature

In August 1977 a biomass sample was collected. All vegetation was removed from a centrally located, semicircular plot of 1.13-m radius for both the seeded and unseeded conditions in each treatment plot. Biomass is expressed in oven-dry weight, averaged over all similar treatments.

Air and soil temperatures started to rise early in these watersheds because of a droughty winter. Snow had disappeared from the High Ridge snow course by April 29. An 8-year average for this date is 0.97-m water equivalent. Based on a long-term soil temperature record at 0.02 m and 0.1 m adjacent to these plots, the first maximum temperature above 0°C (indicating no snow cover) was observed on April 23. Soil maximum temperature never dropped below 0°C until fall. Minimum soil temperatures at 0.02 m dropped to 1°C or below until June 2. Daytime maximum air temperatures, at weather shelter height, rose briefly into the 15°-20°C range after the snow disappeared in late April; but early and mid May were more seasonable with maxima below 10°C and minima often below 0°C.

Although some data on the temperature regime were collected on these plots from May to October, eight interruptions occurred in the record because of animal activity. Clearcuts in the area were heavily utilized by resident elk and a herd of cattle. Only one period was found to have overlapping data from all 10 sensors. This period, May 26 to June 7, was fortunately the transition period to summer conditions. At 0.5 m above the control plot, for example, average daily air temperature rose rapidly from 2.1 °C on May 26 to 18.6°C on June 7. Except for a brief period in early July, air temperatures for all conditions remained well above 10°C. Soil temperatures responded similarly. At 0.02 m, the average temperatures for 13-day periods before, during, and after the transition period were 7.0°C, 11.8°C, and 14.4°C, respectively.

Except for soil temperature on the chipped plot, which was cooler (by about 5°C), than other soils, differences in treatment effects on daily average temperatures were masked by the long period average. This was particularly true with differences in air temperature which were often small.

Since the recording process used in this study was continually integrating the area under the temperature curve, degree hour summaries are available for analysis for periods as short as 3 hours. A simple graphical technique that plots accumulated degree hours allows examination of changing response between the various conditions.

If the degree hour accumulations are equal, the slope of the line is 1.00. As seen below, this is a very sensitive graphical method for detecting the changing temperature relationships between these sites.

Air Temperature

Figure 1A shows the degree hour accumulation of the control site vs. treatments for 3-hour accumulations. It is obvious, compared to the 1:1 line, that the burn pile and the slash burn air temperatures are following a different course (warmer) than the control and the chipped or scarified sites. Little difference in air temperature is noted between the control and the chipped or scarified locations on a daily basis.

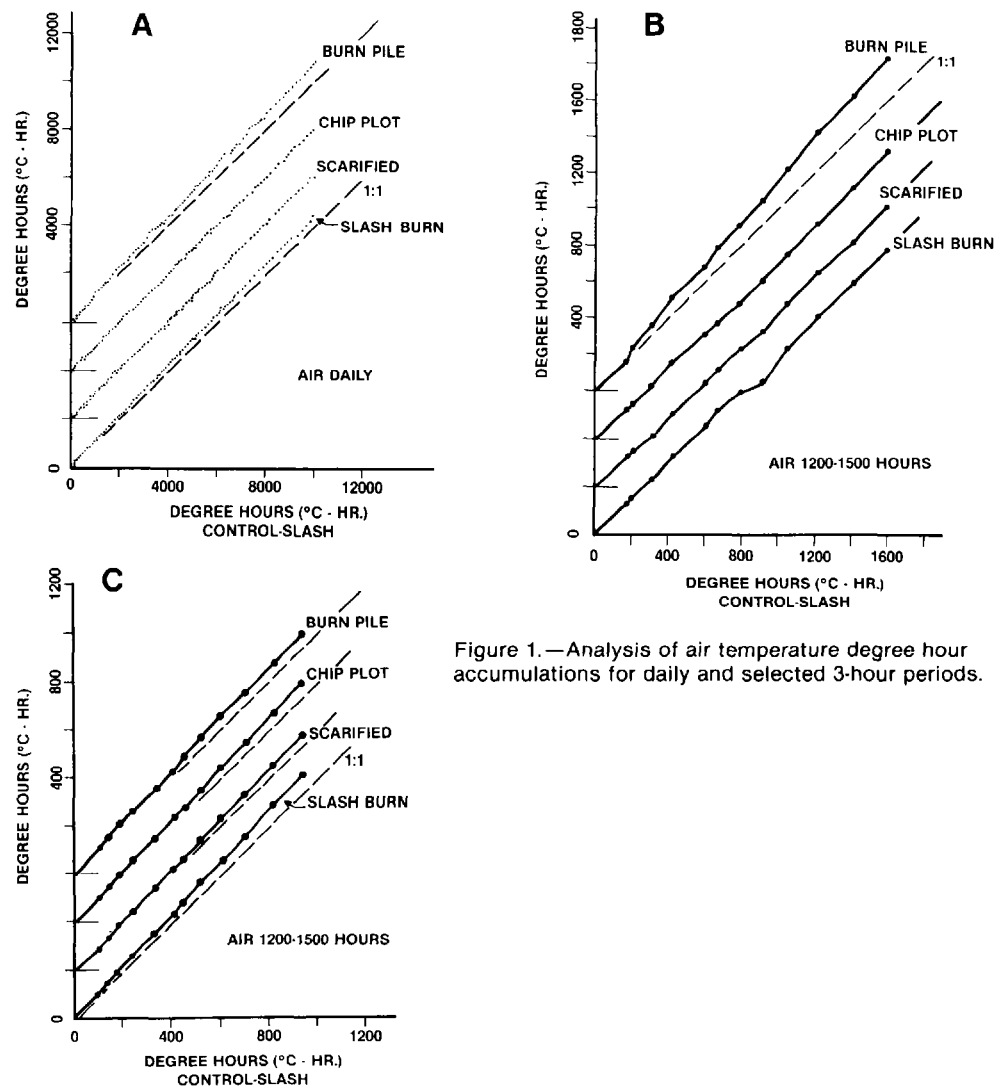


Figure 1.—Analysis of air temperature degree hour accumulations for daily and selected 3-hour periods.

When we look at selected 3-hour periods during the day we find, for example, in figure 1B for the 1200- to 1500-hour period that the air temperature over the burn pile is departing most (warmer) from all other treatments and the control. During the period 0300 to 0600, the broadcast slash burn area was warmer than all others, which were similar to the control. For this particular set of conditions, it appears that for the burn pile, the midafternoon period was most effective in affecting total degree hour accumulation. For the broadcast burn, the period near sunrise was most likely creating the difference in degree hour accumulation. It is also noticeable in figure 1C that all treatments were slightly warmer than the control during the 0300-0600 period. It is equally reasonable to say for this period that the control plot, with its covering of up to 50 cm of slash, was colder than all others at sensor height. The sensor itself was actually closer to the air-surface interface on this plot and may be reflecting a slight difference in the local inversion layer during this period.

For the remainder of the spring and throughout the summer, we can expect these trends to continue. On the burn pile plots, excessive temperatures may be expected. For the broadcast slash burn, daytime temperatures may increase somewhat over other treatments; but the warmer nighttime condition may be the more advantageous to plant growth. Horizontal exchange in the air over the relatively small chip covered areas may have dampened any reduction of heating in the air because of the lowered solar energy absorption.

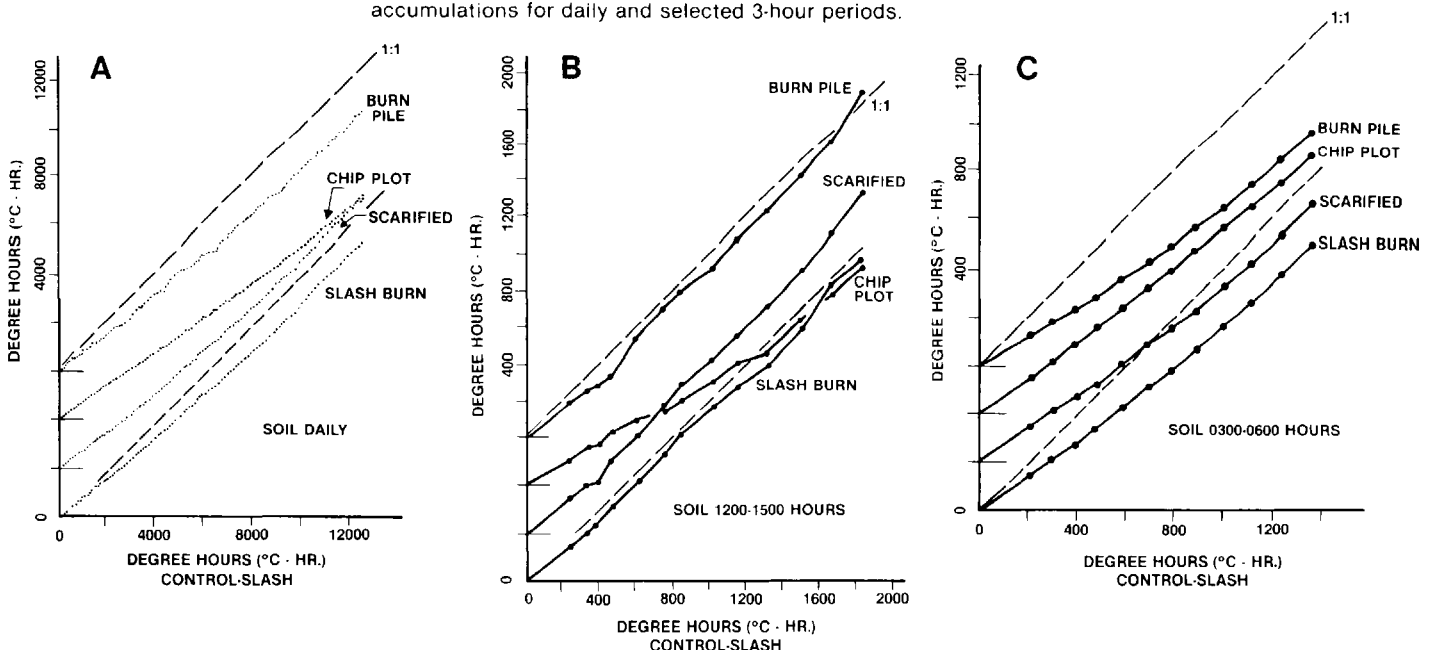
Soil Temperature

In the analysis of soil temperatures (fig. 2A), the burn pile, scarified, and slash burn plots are similar. The exception is the soil temperature under the chipped slash. For the burn pile, scarified, and slash burn treatments, total degree hours for all periods are less than the control initially. After the 8000-degree hour point for the control was reached on May 30, 1977, however, slope of accumulations changed to a ratio of nearly 1:1 with the control. The chipped plot was obviously cooler throughout the period. The fresh chips, with an albedo around 60 percent compared to more solar energy absorbent material in the other plots (Fowler 1974), were effective in reducing the heating of the underlying soil.

Soil temperature degree hour accumulation on the chipped plot during the period 1200-1500 (fig. 2B) was only about 65 percent of the control. Other treatments were essentially the same as the control at this time. For the sunrise hours, 0300-0600 in figure 2C, all soil temperatures initially fell below the control, but the indication of a ratio of nearly 1:1 being achieved near the end of period of record is seen on all except the chipped plot.

All soil temperatures with the exception of the chipped plot can be expected to at least equal, and most likely exceed, the control for the summer. This may be, as noted, especially true for the burn piles. The higher moisture content of the soil in the chipped plot, owing to the mulching effect, would also help to reduce its soil temperature.

Figure 2.—Analysis of soil temperature degree hour accumulations for daily and selected 3-hour periods.



Biomass

Yearly biomass production reflects intrinsic site productivity, initial or carryover plant establishment, and the influence of external agents. Productivity and external influences are presumed to be approximately equal on all sites prior to harvest. Our measurements of preharvest ground cover based on 162 circular plots of 1.61 m radius at a similar site (within 8 km of the clearcut) showed cover to average about 5 percent. Fifty-four percent of these plots, however, showed no living ground cover of any kind under the heavy overstory. We might speculate that initial conditions were changed as:

1. Scarifying further reduced carryover plants on chipped and/or scarified plots.
2. Burning of scattered residue or burning in piles may have increased some nutrient levels. Material in piles also contained additional topsoil brought in from scarified areas.

A somewhat unexpected external factor was noted on the burn in pile treatments. Heavy animal use of these areas was noticeable from early in the 1977 season. All areas were heavily utilized, even a heavy wire mesh failed to keep the large animals away from sensor locations. Figure 3 shows the barren condition of a typical burn plot. It is unknown as to what the plant development was on the burn piles in the spring. These areas through the year, however, were kept almost barren by grazing; including the apparent ingestion of some surface material, soil, and plant ash, presumably for the "salt" content.



Figure 3.— Surface conditions on burn pile plot in August 1977.

Average biomass production (ovendry weight) for both the seeded and unseeded areas showed the progression: burn pile < scarified < chipped < control < broadcast burn. Table 1 shows the lowest average production was 6 gm/m² on the unseeded burn piles; highest was 142 gm/m² on the seeded broadcast burn. Seeding generally increased biomass production into the next treatment class. For example, seeded + scarified was almost equal to chipped non-seeded; chipped + seeded was equal to slash non-seeded. Within each treatment, biomass was always greater in the seeded plot. The biomass ratio of seeded to unseeded ranged from 1.21 for the burn in piles treatment to 2.84 for the scarified treatment. The average of the ratios for all five treatments was 2.06.

Table 1—Biomass production, 1977, values in gm/m²

Treatment	Burn in piles	Scarified	Chipped	Broadcast slash (unburned)	Broadcast slash (burned)
Seeded	6.8	20.6	39.7	59.8	142.1
Unseeded	5.6	7.3	17.2	38.9	59.4
<u>Seeded</u> <u>Unseeded</u>	1.21	2.84	2.31	1.54	2.39

Conclusions

Although data on the temperature regime were unfortunately limited in time, one of the more critical time periods for seed germination and early plant growth and development was examined. Treatment effects and the direction of the summertime temperature regime can be seen in the figures above as degree hour accumulations change slope relative to the control measurements. Burning was the most effective treatment in increasing air temperatures above these plots; the covering of chips was most effective in delaying soil heating.

We might have expected, even without these residue treatments, that near surface daytime air and soil temperatures would increase with overstory removal and exposure to sunlight. This response was immediate. After the harvest, in September 1976, soil temperatures were measured at 0.02 m, under light, unburned, broadcast slash, during the week of September 23 to 30. (Air temperature sensors had not been reinstalled.) Average soil temperature for the logged area was 20.4°C for the period 1200-1500 hours compared to 17.5°C for the unlogged. Between 1500 and 1800 hours, the temperature was 19.8°C in the logged compared to 15.7°C for the unlogged. Daily soil temperature range also increased; a 13.8°C maximum range in the clearcut compared to 8.9°C in the unlogged.

The effect of residue treatment on springtime temperatures is predictable based on changes in thermal properties of the surface (Fowler 1974). The results reported here, however, are local and should be used with caution in ascribing direction or amplitude of response for other site and treatment combinations.

Biomass production was poor on the scarified areas which were heavily compacted and had topsoils partially removed. Also on the chipped plots, depth of chips impeded rooting, soil temperatures remained cooler, and the highly reflective surface increased heat load on any established plants. On the burn piles, additional topsoil and nutrients were made available, but the advantage or disadvantage of this condition is not clear because of excessive animal activity.

If plant cover, equated here with biomass production, is effective in control of erosion from water impact, the regularity of the increase in biomass under these treatments suggests that minimum initial disturbance by residue treatment and postharvest seeding should provide the best erosion control. With the gentle slopes in this particular area, other considerations such as aesthetics or fire control, may be more important in selecting residue treatments.

Seeding in all instances improved above ground biomass production. For this 1st year, on all plots less than 20 volunteer tree seedlings were observed with no preference to their location being observed.

Conversion Table

To convert:	to:	multiply by:
temperature (°C) + 17.78	°F	1.8
hectares (ha)	acres	2.471
meters (m)	feet	3.281
centimeters (cm)	inches	0.3937
kilogram (kg)	pounds	2.205
gram (g)	ounce	0.03527
square meter (sq m)	square foot	10.76

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