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Duff Reduction Caused by Prescribed Fire on Areas Logged to Different Management Intensities

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Abstract

A pilot study investigated the impact of two harvesting intensities on duff consumption from prescribed fire. Two units of old-growth Douglas-fir and western hemlock served as the sample. The units, located in the Willamette National Forest, were harvested in 1980 and burned in 1981. Duff consumption was 36 percent less on the unit logged to the closer specification of 6 inches by 6 feet than on the unit logged to the standard specification of 8 inches by 10 feet. Application of previously developed models for duff consumption was demonstrated.

Keywords: Prescribed burning, duff, litter, intensive harvesting.

Introduction

Utilization of forest residues for energy and wood products has increased during the past few years. Removal of larger fuels may reduce the impact of prescribed fire by decreasing the duration of fire. To understand the tradeoffs in nutrient capital brought about by intensive harvesting regimes and their associated residue treatments, intensive sampling of soil, duff, residue nutrient levels, fuel loading, and duff consumption should be made over an extensive population of harvesting regimes and site conditions. A pilot study was initiated as part of a larger research effort to investigate these concerns.

Maintaining nutrient capital while meeting objectives for hazard reduction and slash disposal is of continuing concern to land managers. Prescribed fire volatilizes nitrogen and sulfur in residue and duff and alters the chemical nature of the soil (Wells and others 1979). This chemical alteration can lead to increased loss of nutrients through leaching. The magnitude of heat transfer to the soil depends on the available fuel load and the moisture content of the duff. As the fuel load increases, duration of the fire and amount of fuel and duff consumed increases. As duff moisture decreases, the amount and duration of heat required to dry the duff to the point of ignition decreases. Little information exists on the combined effects of intensive harvesting and prescribed burning on duff consumption and resulting changes in nutrient capital and availability of nutrients (Sandberg 1980, Wells and others 1979). The study presented here provides some insights into the scope of the problem and provides initial estimates of sampling error necessary for efficient design of a sample.

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Methods

The Green Mountain timber sale in the Blue River Ranger District, Willamette National Forest, Oregon, was established as an administrative investigation of the differences in harvesting cost attributable to different yarding specifications.[1] Units 2 and 3 of the sale provided a suitable comparison of postharvest fuel loading resulting from two different levels of wood fiber removal. Unit 2 was yarded according to current practice; that is, all material larger than 20 cm in diameter (at the large end) by 3 m long (8 inches by 10 feet) was removed. Unit 3 was yarded to a closer utilization standard by removing all material greater than 15 cm by 1.8 m or 41 cm by 0.6 m (6 inches by 6 feet or 16 inches by 2 feet). Both units had supported old-growth timber over 300 years of age. Elevation of these units is about 730 m above sea level. Unit 2 lies with a north-northeasterly aspect and 15-percent slope. The preharvest inventory of unit 2 was 30.4 M board feet/ha of timber, 81 percent of which was Douglas-fir. Unit 3 has essentially no slope. The preharvest inventory of unit 3 was 27.5 M board feet/ha, 67 percent of which was Douglas-fir.

Fuel loading was determined on each unit by a line-intersect inventory of downed woody material (Brown 1974). Fifty plots were laid out on each unit using a systematic grid. Each plot consisted of a randomly oriented 30.5-m transect line 2 m high for inventory of downed woody material. Samples of fuel moisture were taken from fuels measuring 0.6 to 2.5 cm, 2.6 to 7.6 cm, and 7.7 cm to 15.24 cm in diameter just prior to burning. One sample per diameter class was taken at each of 22 plots used for duff consumption. Fuel consumption for material between 7.7- and 22.8-cm diameter outside bark was measured as a reduction in log diameter at one or more points on a log, depending on length. Fuel consumption for material between 2.54 and 7.6 cm in diameter was determined by comparing differences of loadings of this material before and after burning.

Duff consumption was measured as a reduction in the depth of duff according to the procedure developed by Beaufait and others (1977). Twelve metal spikes were inserted in the soil 1 m apart on a grid at each of 22 plots on unit 2 and 20 plots on unit 3. The heads of the spikes were inserted flush with the duff layer. If the head could not be placed flush with the duff layer, the exposed length of the spike was recorded. After the burn, measurements were taken to the nearest millimeter from the bottom of the head of the spike to the top of the duff layer and then to the top of the mineral soil. Total depth of preburn duff was therefore the length of the spike above mineral soil minus the length exposed before burning. Duff consumption was the length of the spike exposed above the remaining duff after burning less the length exposed before. Samples of upper and lower duff moisture were taken just prior to burning within the general area of each plot. All moisture samples were ovendried for 48 hours to determine moisture content. The preburn fuel and duff conditions of both units are listed in table 1 (see table 2 for English units).

[1] USDA Study Plan (C6 911) Green Mountain Timber Sale Blue River Ranger District, Willamette National Forest, 1980 On file with the Forest Residues and Energy Program, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg

Table 1—Conditions of fuel and duff before burning on the Green Mountain timber sale, Blue River Ranger District, Willamette National Forest, Oregon[1]

(In metric units)

Item	Unit 2	Unit 3
Yarding specification	20 cm x 3 m	15 cm x 1.8 m and 41 cm x 0.6 m
Fuel loading for material:		
2.5- to 7.6-cm d.ob.b.[2]	[3] 9.19 ± 2.31 t/ha	7.67 ± 2.30 t/ha
7.7- to 15-cm d.o.b.	7.04 ± 1.64 t/ha	6.61 ± 1.26 t/ha
Greater than 15 cm	30.67 ± 8.50 t/ha	2.51 ± 1.59 t/ha
Greater than 7.7 cm	37.71 ± 10.56 t/ha	9.12 ± 2.13 t/ha
Fuel moisture content :		
For logs 7.6-to 22.8-cm d.o.b.	36 percent	28 percent
Litter depth	41 ± 5 mm	40 ± 6 mm
Duff depth	75 ± 8 mm	103 ± 9 mm
Duff moisture :		
Upper	129 ± 18 percent	147 ± 29 percent
Lower	184 ± 33 percent	194 ± 37 percent
Combined	157 ± 66 percent	171 ± 31 percent

[1] Values shown for fuel and duff are at the 95-percent confidence level.

[2] D.o.b. = diameter outside the bark

[3] T/ha = tonnes per hectare

Table 2—Conditions of fuel and duff before burning on the Green Mountain timber sale, Blue River Ranger District, Willamette National Forest, Oregon [1]

(In English units)

Item	Unit 2	Unit 3
Yarding specification	8 in x 10 ft	6 in x 6 ft, and 16 in x 2 ft
Fuel loading for material:		
1.0- to 3.0-in d.o.b. [2]	[3] 4.10 ± 1.03 ton/acre	3.42 ± 1.03 ton/acre
3.1- to 6.0-in d.o.b.	3.14 ± 0.73 ton/acre	2.95 ± 0.56 ton/acre
Greater than 6 in	13.68 ± 3.79 ton/acre	1.12 ± 0.71 ton/acre
Greater than 3.0 in	16.82 ± 4.71 ton/acre	4.07 ± 0.95 ton/acre
Fuel moisture content :		
For logs 3.1-to 9.0-in d.o.b.	36 percent	28 percent
Litter depth	1.61 ± 0.20 in	1.57 ± 0.24 in
Duff depth	2.95 ± 0.31 in	4.06 ± 0.35 in
Duff moisture :		
Upper	129 ± 18 percent	147 ± 29 percent
Lower	184 ± 33 percent	194 ± 37 percent
Combined	157 ± 66 percent	171 ± 31 percent

[1] Values shown for fuel and duff are at the 95-percent confidence level.

[2] D.o.b. = diameter outside the bark

[3] T/ha = tonnes per hectare

Results

Fuel Consumption

There were 9.19 t/ha of fuel 2.54 to 7.60 cm in diameter in unit 2 and 7.67 t/ha in unit 3 before burning. There were 0.96 t/ha and 2.31 t/ha in units 2 and 3, respectively, after burning. No significant difference was found between units in fine fuel loading before burning.[2] A significant difference was found in these fuels after burning.

Duff Consumption

Duff consumption, found by averaging the reduction in depth at all duff spikes, was 22 mm on unit 2 and 14 mm on unit 3. The difference of 8 mm between units was highly significant. When litter consumption was added to duff consumption, the difference of 20 mm between units was significant. Moisture content of fuel and duff before burning and depth of duff were comparable on the two units. Less ground was exposed to fire on unit 2 (19-percent of the spikes in duff had no burn) than on unit 3 (7 percent of the spikes had no burn). Exposure of mineral soil on unit 2 was 14 percent before and 29 percent after burning. Exposure of mineral soil on unit 3 was 11 percent before and 24 percent after burning. Statistics on consumption are summarized in table 3 (see table 4 for English units).

[2] Differences between units were tested throughout using the student's t-test

Table 3—Consumption of fuel, filter and duff on the Green Mountain timber sale, Blue River Ranger District, Willamette National Forest, Oregon [1]

(In metric units)

Item	Unit 2	Unit 3
Yarding specification	20 cm x 3 m	15 cm x 1.8 m, and, 41 cm x 0.6 m
Fuel consumption:		
Total consumption for material less than 7.6-c.m. d.o.b.[2]	[3] 8.23 t./ha	5.36 t/ha
Average diameter reduction for material greater than 7.6-cm d.o.b.	86.1 mm	88.4 mm
Duff consumption	22 ± 4 mm	14 ± 3 mm
Litter and duff consumption	61 ± 7 mm	41 ± 7 mm
Mineral soil exposure :		
Before burning	14 percent	11 percent
After burning	29 percent	24 percent
Portion of unit unburned	19 percent	7 percent

[1] Values shown for fuel, litter, and duff are at the 95-percent confidence level.

[2] D.o.b. = diameter outside the bark

[3] T/ha = tonnes per hectare

Table 4—Consumption of fuel, filter and duff on the Grass Mountain timber sale, Blue River Ranger District, Willamette National Forest, Oregon [1]

(In English units)

Item	Unit 2	Unit 3
Yarding specification	8 in x 10 ft	6 in x 6 ft. and 16 in x 2 ft
Fuel consumption:		
Total consumption for material less than 3.0-in d.o.b. [2]	[3] 3.67 ton/acre	2.39 ton/acre
Average diameter reduction for material greater than 3.0-in d.o.b.	3.39 in	3.48 in
Duff consumption	0.87 ± 0.16 in	0.55 ± 0.12 in
Litter and duff consumption	2.40 ± 0.28 in	1.61 ± 0.28 in
Mineral soil exposure :		
Before burning	14 percent	11 percent
After burning	29 percent	24 percent
Portion of unit unburned	19 percent	7 percent

[1] Values shown for fuel, litter, and duff are at the 95-percent confidence level.

[2] D.o.b. = diameter outside the bark

[3] T/ha = tonnes per hectare

Discussion

Both units on Green Mountain were within the maximum limits acceptable for duff consumption (40 percent) and the area of mineral soil exposed (40 percent for sites of low erosion hazard) established by Boyer and Dell (1980). These limits are designed to protect water quality and nutrient capital. On steep terrain, the maximum limits decrease for duff consumption and the area of mineral soil exposed. Increased utilization on unit 3 reduced the level of consumption and area exposed; it may prove useful in meeting standards set for steep slopes.

Sandberg (1980) developed theoretical and empirical models for duff reduction by prescribed underburning in Douglas-fir stands and tested existing models developed in other geographic areas on a common data set. His conclusions can be summarized as follows. Surface fire duration was more important than total heat load (fuel consumption) in explaining duff reduction. Fire duration was successfully estimated from the reduction in diameter of woody fuels. The duff layer dried to a depth proportional to the square root of fuel diameter reduction. Duff was then consumed to that depth by a smoldering fire. Reduction was also found to be influenced by the moisture content of duff or by a meteorological estimator of duff moisture. Duff layers with an initial moisture content above 120 percent did not burn. Finally, the proportion of mineral soil exposed could be predicted by raising the proportion of duff consumed to a power of 2.12. Woody fuel loadings in all size classes were substantially lower and duff thicknesses were greater at Green Mountain than in any of the underburning units.

A theoretical approach involving fire duration and moisture content of duff (Sandberg 1980, equation 3) underpredicted duff reduction on unit 2 (conventional utilization) by 20 percent and overpredicted reduction on unit 3 (close utilization) by 10 percent. Using fire duration alone (Sandberg 1980, equation 6) under-predicted reduction in unit 2 by 23 percent and overpredicted reduction in unit 3 by 17 percent. Empirical models (Sandberg 1980, equations 7 and 8) predicted duff reduction within 10 percent on unit 3 but were in error by as much as 40 percent on unit 2. No explanation is offered for the poor performance of the models in this pilot study.

The proportion-of-mineral-soil-exposed relationship was confirmed at Green Mountain. Our failure to tie duff consumption to meteorologically derived estimates of duff moisture indicates that these estimates were not representative of the conditions on units 2 and 3.

On Green Mountain unit 3, a reduction in fuel loading corresponded to a 35 percent reduction in fine fuel consumption and a 36-percent reduction in duff consumption. Removal of large residues should have a mitigating effect on duff reduction caused by prescribed fire. Since this study involved only two units, the relationship demonstrated between harvest level and fire effects should not be extrapolated to areas harvested under different conditions. The results presented here show that intensive harvesting can have a positive effect on retention of nutrient capital during prescribed burning. Research is now underway to determine the amount of reduction in duff consumption and nutrient loss caused by incremental changes in harvesting levels.

English Equivalents

1 millimeter (mm) = 0.0394 inch
1 centimeter (cm) = 0.394 inch
1 meter (m) = 3.28 feet
1 hectare (ha) = 2.47 acres
1 tonne per hectare (t/ha) = 0.446 tons per acre

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