IMPORTANCE OF SOIL ORGANIC MATTER IN THE DEVELOPMENT OF INTERIOR DOUGLAS-FIR

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ABSTRACT

Of the Northern Rocky Mountain conifers, interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) is one of the most sensitive to varying levels of soil organic materials. On dry habitats, fast growing natural regeneration frequently occurs on large deposits of soil humus or buried, decayed wood. Often, the best performing seedlings have the majority of their root systems and ectomycorrhizal root tips occurring in humus and decayed wood. Soil organic horizons and other organic deposits are high in moisture, rich in nutrients, and represent excellent substrata for ectomycorrhizal root formation. Because there are strong relationships between soil organic matter and tree performance, forest management activities that alter the characteristics of soil organic materials can affect both short- and long-term forest productivity. By mounding surface soil horizons rich in organic matter, up to a 200% increase in seedling productivity has been observed and 62% increase in long-term productivity projected. In contrast, the removal of organic layers can decrease short-term productivity (22%) and projected long-term (23%) productivity.

Keywords: Site preparation, regeneration, productivity, residue

INTRODUCTION

Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) occupies areas from the eastern mountains of British Columbia, Washington, Oregon, and California to the Rockies in central Montana, western Wyoming, and western Colorado. Its southern limits extend into the mountains of northern Mexico and it extends into north-central British Columbia. The Douglas-fir forest type is usually bordered at the lower elevations by the ponderosa pine (*Pinus ponderosa*) type and at the higher elevations by the subalpine fir (*Abies lasiocarpa*) type (Eyre 1980). The type occurs at elevations below 305 m (1,000 ft) along the Clearwater River in Idaho to over 3,048 m (10,000 ft) in the Southern Rockies.

The climate where interior Douglas-fir grows is as variable as the geographic regions. The northwestern portion of the range is influenced by the maritime climate of the Pacific Ocean with total precipitation over 1,270 cm (50 inches) possible. The eastern and southern portions of the range are influenced by the continental climate with annual precipitation totals as low as 36 cm (14 inches). Temperature extremes are from -54°C (-40°F) to highs over 37°C (100°F) (Buell 1965).

Because of the wide range of sites that interior Douglas-fir occupies, it occurs on a wide variety of geology and soils. Soil parent materials include glacial deposits, sedimentary, igneous, metamorphic, and volcanic materials. Many of the soils that support interior Douglas-fir are also covered by volcanic ash.

Interior Douglas-fir has adapted to these heterogenous environments that occur throughout its range. This can be viewed as physiological specialization for a relatively small portion of the environmental gradient. Populations separated by a relatively short distance along the environmental gradient tend to be different genetically (Rehfeldt 1989).

The plant associations containing interior Douglas-fir as a component range from dry associations where Douglas-fir is climax to moist sites where western hemlock (*Tsuga heterophylla*) or subalpine fir are climax and Douglas-fir is a major seral species (Cooper *et al.* 1987). Several coniferous species are associates of interior Douglas-fir including ponderosa pine, grand fir (*Abies grandis*), lodgepole pine, (*Pinus contorta*), western larch (*Larix occidentalis*), western redcedar (*Thuja plicata*), western hemlock, subalpine fir, Engelmann spruce (*Picea engelmannii*), and western white pine (*Pinus monticola*). Understory species range from grasses to tall shrubs. These species include Idaho fescue (*Festuca idahoensis*), pine grass (*Calamagrostis rubescens*), nine bark (*Physocarpus malvaceus*), mountain lover (*Pachistima myrsinites*), huckleberry (Vaccinium spp.), and false huckleberry (*Menziesia ferruginea*).

Wildfire or its absence has impacted forest development throughout the region creating a multitude of stand conditions. Stand compositions range from pure Douglas-fir to those containing over 10 coniferous species and often a deciduous component. Several successional stages occur from early seral to climax. Diseases play a major role in forest dynamics including shoe string root rot (*Armillaria spp.*), laminated root rot (*Phellinus weirii*), and mistletoe (*Arceuthobium douglasii*) (Hepting 1971). Insects such as bark beetles (*Dendroctonus pseudotsugae* and *Scolytus* spp.) and the spruce budworm (*Choristoneura occidentalis*) are common in many stands (Furniss and Carolin 1977).

ORGANIC MATTER

Because of fire, disease, insects, geology, succession, and climate, there is a wide range in the amounts and kinds of woody material in and on the soil surface of interior Douglas-fir forests (Brown and See 1981; Harvey *et al.* 1987a). Organic matter can come from all types of plants, but the material usually associated with interior Douglas-fir forests originates from trees.

Organic matter can be placed into categories: residue, forest floor, soil wood, and the organic fraction of mineral horizons. Residue is composed of branch and stem parts. Residue can be divided into material less than 5 cm (3 inches) in diameter, which

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is often a high concern for fire hazard, and material 5 cm (3 inches) and larger in diameter that is a less fire hazard. Residue can be classified by its decay state as new, incipient (starting to rot), intermediate, or advanced (wood structure is lost).

The amount of residue on sites varies highly depending on stand history from little to extremely high loadings in excess of 336 Mg/ha (150 tons per acre) in stands decimated by insects and disease. Natural fuel loadings of inland Douglas-fir forests usually range between 29-67 Mg/ha (13 and 30 tons per acre)(Harrington, this proceedings).

Forest floor, often termed duff, consists of litter, humus, and soil wood. Litter is the unconsolidated loose material, undecomposed to somewhat decomposed, on the surface usually consisting of leaves, small branches, tree bark, and other small tree parts. Humus is the fermentation layer adjoining the surface of the mineral soil consisting of the unrecognizable plant parts. Soil wood is decayed (advanced) pieces of wood that can occur as part of the litter or can be buried, is an active part of the soil, and can contain plant roots. Soil wood is usually 100-300 years old and its originates predominantly from Douglas-fir (Table 1).

Table 1.—Species of soil wood for selected sites in Montana, Idaho, and Wyoming.

		Species[1]						
Site[2]	Number[3]	DF	WP	WL	WH	SAF	LPP	ES
		Percent						
DF/WL	101	77	0	8	2	6	4	3
WRC/WH	16	63	0	0	19	6	6	6
DF	22	100	0	0	0	0	0	0
DF/PP	23	87	0	0	0	0	13	0
WH	153	44	32	16	4	1	1	2
LPP	10	0	0	0	0	0	100	0

[1] Species: DF= Douglas-fir, WL = Western Larch, WRC = Western Redcedar, WH = Western Hemlock, PP = Ponderosa Pine, LPP = Lodgepole Pine.

[2] Site is designated by the primary overstory or covertype species.

[3] Number of samples of soil wood identified at each site. Identification services provided by Forest Products Laboratory, USDA-Forest Service, Madison, WI.

Even with the wide variety of stand conditions and residue loadings, the combined layers of organic matter on the surface are quite shallow for stands containing Douglas-fir (Harvey *et al.* 1987). Maximum depth observed was 3.8 cm (1.5 inches) in stands dominated by old-growth western hemlock, and the shallowest layers occurred in stands dominated by second growth lodgepole pine. Depth of organic materials in stands where Douglas-fir dominated averaged 2.3 cm (0.9 inches). A large proportion of the organic matter content of forest soils in these stands occurs in the woody residue, forest floor, and soil wood components (Table 2) (Jurgensen *et al.* 1990).

ORGANIC MATTER AND SOIL PROPERTIES AND PROCESSES

Organic matter is important for many soil properties and processes. Water holding capacity of soils increases with increasing organic matter. For example, on a Douglas-fir site in western Montana the humus fraction of the soil had 30% moisture, the soil wood fraction had 71% moisture, while the mineral fraction had less than 25% (Harvey *et al.* 1987a). Furthermore, organic matter increases structure, infiltration, percolation, and protects soil from compaction (Lull 1959).

Besides influencing physical properties, organic matter plays an important role in supporting nitrogen fixation and storage, and mycorrhizal activity. Independently or in combination these processes are excellent indicators of forest soil health. They can be used to show how important organic matter is to the development of interior Douglas-fir forests.

Greater than 50% of the soil nitrogen pool in a Douglas-fir forest can occur in the organic fraction and surface 5 cm (2 inches) of mineral soil (Table 3). In addition, the same layers contain the majority of the symbiotic nitrogen fixation capacity of a site (Table 3). Moreover, nitrogen fixation in Douglas-fir residue can vary by decay class with lesser amounts (8%) occurring in the incipient decay of class residue, moderate amounts (35%) in intermediate, and higher amounts (57%) in the advanced decay class of residue (Jurgensen *et al.* 1987).

The majority of the ectomycorrhizal activity occurs in the organic horizons of Douglas-fir soils (Table 4). Soil wood and humus are the most important substrata (Harvey *et al.* 1979). Even though 15% or less of the soil profile can be in soil wood

Table 2.—Organic matter content of soils in old-growth stands of the Inland Northwest that contain Douglas-fir (Jurgensen *et al.* 1990).

	Organic Content					
Site	Woody residue	Forest floor	Soil wood	Mineral[1] soil	Total	Proportion in mineral soil
Montana	Mg ha-1					Percent
Cedar/hemlock	83	50	51	145	329	44
Subalpine fir	146	36	36	153	371	41
Douglas-fir	45	26	37	133	241	55
Ponderosa pine	<20	7	2	160	<189	>85
Idaho						
Cedar/hemlock	154	23	48	201	426	47

[1] Sampled to a depth of 30 cm. These values do not include root weights.

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and humus, greater than 80% of the ectomycorrhizal activity can occur in these substrates. The relationship between soil organic horizons and ectomycorrhizal activity are similar for both second growth and old-growth stands. The organic horizons of the soil profile for both types of stands contain the majority of ectomycorrhizal activity (Table 5). Moreover, the majority of ectomycorrhizal activity on Douglas-fir root systems occurs in organic horizons (Harvey *et al.* 1987b).

Because of the importance organic matter has in the maintenance of desirable forest soil properties and related microbiological activities, soils with adequate levels of organic matter can be considered healthy and should support a healthy forest.

Table 3.—Nitrogen fixation rates and storage associated with residues and soil components of an old-growth forest located on a Douglas-fir/ninebark habitat type (Harvey *et al.* 1987a).

	Nitrogen fixation		Nitrogen storage	
Component	N-fixation amount	Site total	Total N pool	Site total
	g/ha/yr	Percent	kg/ha/N	Percent
Residue	160	21	68	3
Soil wood	94	12	419	16
Forest floor	93	12	438	17
Mineral, 0-5 cm	106	14	543	21
Mineral, 5-30 cm	320	41	1,162	44

Table 4.—Proportion of upper 30 cm of soil represented by the soil fraction from each habitat type that has Douglas-fir as a major component and the percentage of the total ectomycorrhizal tips occurring from June through October in each soil fraction from each site (Harvey *et al.* 1979).

Soil fraction	PSME/PHMA[1] Soil	PSME/PHMA[1] Tips	ABLA/CLUN Soil	ABLA/CLUN Tips	TSHE/CLUN Soil	TSHE/CLUN Tips
	———	———	———	Percent	———	———
Litter	2	4	2	0	5	14
Humus	10	28	11	70	15	40
Soil wood	12	36	12	16	14	24
Charcoal	.2	0	.3	1	.1	12
Mineral 0-5 cm	16	29	16	11	16	8
Mineral 5-30 cm	59	3	58	1	49	1

[1] Habitat types: PSME/PHMA = *Pseudotsuga menziesii/Physocarpus malvaceus*, ABLA/CLUN = *Abies lasiocarpa/ Clintonia uniflora*, and TSHE/CLUN = *Tsuga/heterophylla/ Clintonia uniflora.*

ORGANIC MATERIAL AS A SEED BED

Interior Douglas-fir seed will germinate and develop on many different substrata. It will germinate and develop rapidly on substrates rich in organic matter (Day and Duffy 1963). On some sites live organic matter such as mosses can provide an adequate seed bed (Geier-Hayes 1987). It will germinate well on burned over organic surfaces (Haig *et al.* 1941). The only organic substrate where Douglas-fir does not appear to germinate well is unconsolidated litter that can dry out rapidly or is too thick to allow seeds or radicles to contact a moist underlying layer.

Table 5.—Distribution of active ectomycorrhizal root tips in soil strata of stands that have Douglas-fir as a major component; all samples taken during June to July peak activity period (Harvey *et al.* 1986)

Site	Litter	Humus	Soil wood	Mineral 0-5 cm	Mineral 5-30 cm
	———	———	Percent	———	———
Old-growth					
WP-ID	10	57	26	6	1
WH-ID	6	67	16	8	3
WH-MT	6	32	51	10	1
SAF-MT	0	74	19	6	1
GF-ID	26	13	31	20	10
DF-MT	14	30	31	21	2
Second-growth					
SAF-MT	6	47	35	10	2
DF-MT	20	0	46	33	1

[1] Species: DF = Douglas-fir, WP = Western white pine, GF = Grand Fir, WH = Western Hemlock, SAF = Subalpine fir. States: ID = Idaho, MT = Montana.

SEEDLINGS FROM SEED

Douglas-fir seedlings respond to organic matter from the time of germination. First seedling growth is responsive to soil organic matter levels. For example, three soils were prepared in a greenhouse from field collections for planting Douglas-fir seeds (Table 6): an organic soil, 50/50 mix by volume of organic material and a mineral soil, and mineral soil. Bulk densities were similar among the soils, but more available moisture was present in the organic soils with the least amount in the mineral soil. Total nitrogen was highest in the organic soils with the least amount in mineral soil. These data further illustrate how important organic matter can be to maintaining desirable physical and chemical properties of forest soils (Page-Dumroese *et al.* 1990).

After one growing season, trees grown in the organic soil were the tallest, and those grown in mineral soil were the shortest (Table 6). Total nitrogen concentrations in the seedlings also showed a similar pattern with the highest concentration found in the trees grown in the organic soil and the lesser amounts in trees grown in the mineral soil. The results were similar for soils collected from either a western redcedar or subalpine fir habitat type.

Furthermore, there is evidence that natural occurring Douglas-fir seedlings respond to differing amounts of organic matter in the soil. Often on dry habitats naturally occurring seedlings can be observed growing on buried decayed logs. More specifically, on a subalpine fir habitat type Douglas-fir seedlings with the majority of their root system in soil wood performed better than trees with the majority of their root systems in mineral soil (Harvey *et al.* 1987b).

SITE PREPARATION AND ARTIFICIAL REGENERATION

Organic materials on and in forest soils are altered by site preparation. Although through site preparation surface organic layers can be mounded, thus increasing the volume of organic

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matter available in the rooting zone, the point concentration of organic matter will not necessarily increase (Table 7) (Page-Dumroese *et al.* 1986). Through soil displacement (scalping) the volume of organic matter available in the rooting zone will decrease, and usually the point concentration of organic matter will also decrease. Available soil moisture can be increased by mounding surface layers and decreased by displacing surface layers. Likewise, total nitrogen increased with mounding and decreased when soils were displaced. Even greater changes may occur to the availability of nitrogen when organic matter is altered through site preparation (Page-Dumroese *et al.* 1989).

It appears that site preparation on both the mesic grand fir habitat type and moist western hemlock habitat type created similar patterns of soil characteristics (Table 7). The physical and chemical properties created by these site preparations were similar to those created by the soils prepared in the greenhouse described earlier.

Site preparation also provides both favorable and unfavorable conditions for vegetation other than trees (Graham *et al.* 1989a). For example, after site preparation on sites with sod-forming grasses (grand fir), mounding created a heavy stand of grasses and forbs (Table 8).

Performance of newly planted Douglas-fir is dependent on the interaction of organic matter and its related effects on soil properties and competing vegetation (Graham *et al.* 1989a). During the first three years after planting, grasses and forbs can have a severe impact on tree growth. The most favorable site preparation for seedling growth creates a microsite that maintains or increases soil organic matter and minimizes competing vegetation. For example, Douglas-fir growing in mound

Table 6.—Soil and tree characteristics for Douglas-fir seedlings growing in artifically prepared soils (Page-Dumroese *et al.* 1990).

Soil source	Soils			Trees		
	Organic matter	Available moisture	Total N	Height	Total weight	Total N
	Percent			cm	g	Percent
			Western redcedar habitat type			
Organic	56.0a[1]	52.1a	0.03a	5.8a	0.31a	1.96a
50/50 mix	37.3b	33.6b	.03a	4.8a	.22b	1.33ab
Mineral	9.6c	31.0b	.01a	4.6b	.14c	1.17b
			Subalpine fir habitat type			
Organic	68.2a	48.6a	.10a	4.4a	.33a	3.78a
50/50 mix	42.4b	45.6a	.03b	3.9ab	.21b	2.38b
Mineral	7.7c	31.0b	.03b	3.6b	.12c	1.09b

[1]Different letters indicate significant differences among soil sources.

Table 7.—Soil properties within the seedling rooting zone the first growing season (Page-Dumroese 1986, 1989 *et al.*).

Site preparation	Organic[1] components	Organic matter	Soil moisture	Total N	Available N	Soil bulk density
	Percent				$mg\ kg^{-1}$	$g\ cm^{-1}$
		Grand fir habitat type				
Bed[2]	64.1a[3]	15.0a	49.3a	0.27a	16.0a	0.69a
Displaced	14.2b	9.7b	46.6a	.12b	.6b	1.08b
Minimal	38.2c	14.0a	48.9a	.18c	8.3ab	.75a
		Western hemlock habitat type				
Bed	68.3a	26.8a	71.3a	.31a	50.6a	0.58a
Displaced	13.4b	5.1b	45.1b	.34a	2.8b	0.93b
Minimal	48.4c	29.5a	65.5a	.28b	49.3a	0.66a

[1]The proportion of the rooting zone containing organic materials.

[2]Site preparations: Bed, bedded top soil and organic matter; Displaced, weeds and surface soil layers removed; Minimal, minimum soil disturbance.

[3]Different letters indicate significant ($p < .05$) differences among site preparations.

Table 8.—Competing vegetation, survival, height, and total biomass for Douglas-fir planted in four site preparations three years after planting (Graham *et al.* 1989a).

Site prep.	Competing vegetation	Survival	Total weight	Height
kg ha^{-1}	Percent	g	cm	
		Grand fir habitat type		
Bed[1]	9,192a[2]	54a	6.8b	33.9bc
Bed-herb	280b	76b	32.1a	39.4a
Displaced	684c	78b	9.6b	29.9c
Minimal	3,760d	76b	10.6b	34.9b
		Western hemlock habitat type		
Bed	1,711a	79a	12.3ab	35.9a
Bed-herb	<50b	79a	17.6a	37.4a
Displaced	<50b	91a	8.0b	26.8b
Minimal	<50b	85a	9.1ab	33.1ab

[1] Site preparation: Bed, bedded top soil and organic matter; Bed-herb, bedded soil treated with glyphosate; Displaced, weeds and surface soil layers removed; Minimal, minimum soil disturbance.
[2] Different letters indicate significant differences among the site preparations.

with small amounts of competing vegetation were 234% heavier and 32% taller than seedlings growing in a scalped treatment with similar amounts of competing vegetation but much less soil organic matter (Table 8). The trends were similar for trials on both the grand fir and western hemlock habitat types. Furthermore, reduction in competing vegetation through scalping does not necessarily increase seedling performance because the loss of organic matter and its related properties can be more important to tree growth than reducing competition. Therefore, the scalped preparation had the least amount of organic matter, the least amount of competing vegetation, and the poorest performing trees. A balance must be maintained between reducing competing vegetation through scalping and maintaining organic layers. On both the grand fir and western hemlock habitat types, 3-year height and total weight of Douglas-fir seedlings were not improved or reduced by scalping compared to minimally disturbed sites that had as much or more competing vegetation. Therefore, scalping should be used with a purpose to meet well defined and understood objectives. The trends established by the site preparation trials three years after planting continued through five years (Table 9).

LONG-TERM PRODUCTIVITY

A key issue in site preparation is how long the treatment effects will last. For competing vegetation control site preparation effects usually lose effectiveness 3-4 years after treatment. But if tree growth is good, this time should be adequate for the trees to overcome the competing vegetation. What has the greatest effects on seedlings is the lasting changes in soil properties, specifically changes in organic matter that may have occurred as a result of site preparation.

There are several reports that indicate, at least to the sapling stage, tree growth is influenced by site preparation (Clayton *et al.* 1987, Cole and Schmidt 1986, Graham *et al.* 1989b). One method to illustrate site preparation impact on future stand development is to use forest projection systems such as the prognosis model (Wykoff *et al.* 1982). Using this model and data

Table 9.—Tree descriptions at 5-years after planting and projections to age 100 years using the prognosis model.

	Age 6-years		Age 100-years								
			Short-term calibration[1]				Long-term calibration[2]				
Site prep.	Mean Ht.	Trees /ha	Mean Dia.	Mean Ht.	Merch. Vol.	Trees /ha	Mean Dia.	Mean Ht.	Merch. Vol.	Trees /ha	Cal.[3] Fac.
	cm		cm	m	m^3 ha^{-1}		cm	m	m^3 ha^{-1}		
				Grand fir habitat type							
Bed[4]	61	5053	26.9	23.5	388	912	23.1	22.3	272	1072	0.72
Bed-herb	125	4784	28.7	25.3	435	882	34.0	26.2	576	786	1.51
Displaced	61	5320	26.2	23.5	373	1038	23.1	22.3	285	1097	.73
Minimal	73	4514	27.4	23.8	392	937	26.2	23.5	356	959	.89
				Western hemlock habitat type							
Bed	107	4838	31.2	26.8	522	818	31.2	26.8	522	818	1.00
Bed-herb	122	4675	32.5	27.4	535	756	34.8	27.4	594	722	1.17
Displaced	64	4568	30.7	25.3	483	835	24.9	24.4	320	929	.63
Minimal	82	4408	32.3	26.2	514	766	28.5	26.2	416	828	.78

[1] The growth rate established by the 5-year height increment of the seedlings slowly attenuates to the average growth rate for the site by the time the trees reach 7.6 cm–12.7 cm (3 to 5 inches) in diameter.
[2] The growth rate established by the 5-year height increment of the seedlings is maintained for the 100 years of the projection.
[3] Calibration factor from the prognosis model. This is a multiplier used to establish growth rates in the model. A factor of 1.00 indicates that the trees are growing at the rate established for that specific site defined by location, slope, aspect and habitat type in the model.
[4] Site preparations: Bed, bedded top soil and organic matter; Bed-herb, bedded soil treated with glyphosate; Displaced, weeds and surface soil layers removed; Minimal, minimum soil disturbance.

from the site preparation trials described, the impacts of these treatments on long-term productivity can be estimated (Table 9). The prognosis model was calibrated using 5-year height increment data and physical site information appropriate for the Douglas-fir growing in the four site preparations on both the grand fir and western hemlock sites.

Calibration factors produced by the prognosis model show how the actual stand is growing compared to the average growth rates established by the model. A calibration factor of 1.00 indicates that the sample stand is growing at the same rate the model would predict. For example, the calibration factor for the mound with competing vegetation on the grand fir site was 0.72 indicating that the trees were growing slower than what the model would predict as average for that species and site. In contrast, trees growing in the mound where competing vegetation was controlled had a factor of 1.51 indicating that the trees were growing faster than the model would predict, or a 110% difference in growth rates for trees in the two preparations. The factor for the displaced treatment was 0.73 indicating an 18% decrease in growth compared to the minimally disturbed soil (0.89).

One may argue that the impacts from site preparations will be short-lived and the trees will eventually outgrow the affects of the organic matter loss and associated soil changes. The prognosis model can be used to project these conditions and adequately display the results. The prognosis model will slowly attenuate the early growth rates used to calibrate the projection until their effects are nil. This occurs by the time trees reach diameters of 7.5-12.5 cm (3-5 inches). Even with this attenuation projections to 100 years indicate that 5-6% less volume will be produced in the areas where the soil surface layers were displaced compared to areas that were minimally disturbed (Table 9). These data also show that by early control of competing vegetation and mounding of organic layers volumes can be increased up to 11% even if the affects of the site preparations are short-lived.

If the affects of the site preparation are long-lasting, meaning early growth rates are maintained, the projections show a greater impact of the preparations on long-term productivity. On the grand fir site the volume decrease from displacing organic layers would be 20%, and on the western hemlock site it would be 23%. Likewise, increases greater than 60% in volume can be obtained by mounding surface layers.

These results show that a more productive site (western hemlock) with deep rich soils is as vulnerable to productivity loss from surface layer displacement as a less productive site (grand fir). Western hemlock sites have better productivity, but they also have more to lose. Therefore, we believe that productivity changes from organic matter manipulation on these sites are conservatively displayed by the short-term estimates and pessimistically or perhaps optimistically displayed by the long-term estimates, and the true impact lies somewhere in between.

CONCLUSIONS

Interior Douglas-fir is sensitive to changes in the organic matter content of forest soils possibly because of its genetic specialization. Soil organic matter plays a critical role in the development of stands and forests of Douglas-fir, from seed germination through maturity. Timber harvesting and site preparation activities that alter surface horizons of forest soils can either negatively or positively affect tree growth. Even if impacts from harvesting activities are short-lived they can substantially affect long-term forest growth. But more likely the impacts of these operations are not short-lived and will persist through the life of the forest. Because of increasing demand for goods and services from our forests, the potential for acid deposition, and the potential for climate change, forest soils need to be as healthy as possible to support the Douglas-fir forests of the interior West. The primary method of maintaining healthy forest soils is to conserve and manage the organic resource carefully and prudently.

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