

## Comments on the BLM's Western Oregon Plan Revisions

Submitted by Jan Wroncy

I am submitting comments on my own behalf, and on behalf of Gaia Vision, Canaries Who Sing, and Coast Range Guardians.

### **We are vehemently opposed to the Preferred Alternative.**

We oppose cutting of any old growth trees, PERIOD. We oppose cutting of mature trees that will be the replacements for the old growth trees that will succumb to natural processes. How will we ever get more old growth forests back if we never let any mature trees live past 100 years? Tree plantations are not biodiverse natural forests. We oppose any clear cutting of any Bureau of Land Management forests.

We oppose any further destruction of habitat which is necessary for the survival of threatened, endangered species, or even species proposed for listing under the Endangered Species Act.

We oppose the massive logging disturbance and road building disturbance on Bureau of Land Management lands which will invite the spread of noxious weeds and invasive species, especially since the Bureau of Land Management is currently proposing massive spraying of toxic herbicides in 17 western states under the Record of Decision for the Final Vegetation Treatments Herbicides Programmatic Environmental Report (PER).

We believe further that it is ludicrous to propose more destruction of forests on public lands when climate change, global warming and carbon sequestering are such vital issues which must be addressed.

### **For the above mentioned reasons we support the No-Action Alternative.**

We incorporate by reference comments by Native Forest Council, Oregon Wild, Cascadia's Ecosystem Advocates, Oregon Heritage Forests, Cascadia Wildlands Project, Climate Crisis Working Group, and the McKenzie Flyfishers. We are also attaching the Scientific Evaluation of the Implications of the BLM's Western Oregon Plan Revisions (WOPR) to Forests and Watersheds of Southwest Oregon by Rich Nauman and Dominick A. DellaSala, National Center for Conservation Science & Policy, September 4, 2007 and Potential Upper Bounds of Carbon Stores in Forests of the Pacific Northwest by Erica A. H. Smithwick, Mark E. Harmon, Suzanne M. Remillard, Steven A. Acker, and Jerry F. Franklin 2002.

Signed: \_\_\_\_\_

Jan Wroncy, on my own behalf,  
Gaia Vision, Coast Range Guardians,  
and Canaries Who Sing  
Post Office Box 1101, Eugene, OR 97440

## POTENTIAL UPPER BOUNDS OF CARBON STORES IN FORESTS OF THE PACIFIC NORTHWEST

ERICA A. H. SMITHWICK,<sup>1,3</sup> MARK E. HARMON,<sup>1</sup> SUZANNE M. REMILLARD,<sup>1</sup>  
STEVEN A. ACKER,<sup>1,4</sup> AND JERRY F. FRANKLIN<sup>2</sup>

<sup>1</sup>Department of Forest Science, Oregon State University, Corvallis, Oregon 97331 USA

<sup>2</sup>College of Forest Resources, University of Washington, Seattle, Washington 98195 USA

**Abstract.** Placing an upper bound to carbon (C) storage in forest ecosystems helps to constrain predictions on the amount of C that forest management strategies could sequester and the degree to which natural and anthropogenic disturbances change C storage. The potential, upper bound to C storage is difficult to approximate in the field because it requires studying old-growth forests, of which few remain. In this paper, we put an upper bound (or limit) on C storage in the Pacific Northwest (PNW) of the United States using field data from old-growth forests, which are near steady-state conditions. Specifically, the goals of this study were: (1) to approximate the upper bounds of C storage in the PNW by estimating total ecosystem carbon (TEC) stores of 43 old-growth forest stands in five distinct biogeoclimatic provinces and (2) to compare these TEC storage estimates with those from other biomes, globally. Finally, we suggest that the upper bounds of C storage in forests of the PNW are higher than current estimates of C stores, presumably due to a combination of natural and anthropogenic disturbances, which indicates a potentially substantial and economically significant role of C sequestration in the region. Results showed that coastal Oregon stands stored, on average, 1127 Mg C/ha, which was the highest for the study area, while stands in eastern Oregon stored the least, 195 Mg C/ha. In general, coastal Oregon stands stored 307 Mg C/ha more than coastal Washington stands. Similarly, the Oregon Cascades stands stored 75 Mg C/ha more, on average, than the Washington Cascades stands. A simple, area-weighted average TEC storage to 1 m soil depth (TEC<sub>100</sub>) for the PNW was 671 Mg C/ha. When soil was included only to 50 cm (TEC<sub>50</sub>), the area-weighted average was 640 Mg C/ha. Subtracting estimates of current forest C storage from the potential, upper bound of C storage in this study, a maximum of 338 Mg C/ha (TEC<sub>100</sub>) could be stored in PNW forests in addition to current stores.

**Key words:** biomass; carbon offsets; carbon storage; disturbance; old-growth forests; Pacific Northwest, USA; sequestration.

### INTRODUCTION

Managing forests to enhance carbon sequestration is one means of reducing CO<sub>2</sub> concentrations in the atmosphere to mitigate potential threats from global climate change (Vitousek 1991, Brown 1996). The magnitude and duration of carbon (C) sequestration over the long term can be constrained by knowing the upper bounds (or limit) of C storage, relative to current C storage. The use of “baseline” studies in science has been long heralded as a way to bound scientific understanding. For example, Bender et al. (2000:6) conclude that scientists “. . . need to have baseline studies from relatively un-impacted regions of the earth to discern mechanisms and magnitudes of modern human impacts, and, importantly, examine factors that influ-

enced carbon and nutrient dynamics in pre-industrial environments.” We suggest that setting an upper bound to carbon sequestration potential is equally necessary to constrain estimates of uncertain C sequestration predictions and ideally to inform scientists and managers of the limits of the system. Once the upper bounds of C storage are identified over broad biogeoclimatic gradients, C sequestration, and its economic implications, can be assessed most effectively.

One way to measure past changes in carbon storage from the terrestrial biosphere to the atmosphere is to measure the change in C stores in terrestrial ecosystems between two points in time. This has been called the “difference” approach (Turner et al. 2000b). It has been used to measure changes in forest inventory data over time (Kauppi et al. 1992, Krankina and Dixon 1994) and to estimate the change in landscape C stores over time using multi-date remote sensing imagery (Cohen et al. 1996). Similarly, the difference approach can be used to constrain potential carbon sequestration by subtracting current C storage from the upper bounds.

However, while there is significant information on

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<sup>3</sup> Present address: Department of Zoology, University of Wisconsin, 430 Lincoln Drive, Madison, Wisconsin 53706. E-mail: easmithwick@facstaff.wisc.edu

<sup>4</sup> Present address: National Park Service, 909 First Avenue, Seattle, Washington 98104 USA.

current C stores, it is difficult to constrain the magnitude and duration of C sequestration potential because few stands exist in which the upper bounds of carbon storage can be measured directly. Most forests never reach their upper bound of C storage due to the combined effects of anthropogenic and/or natural disturbances that cause a reduction in C storage from their potential. While old-growth forests maintain higher levels of C storage than are found earlier in succession (Odum 1969, Janisch and Harmon 2002, Franklin et al., *in press*), managed forests in temperate regions may contain as little as 30% of the living tree biomass and 70% of the soil C found in old-growth forests (Cooper 1983). Disturbances of old-growth temperate forests may reduce C storage for at least 250 yr, and with continual harvesting, C storage may be reduced indefinitely (Harmon et al. 1990).

Due to the lack of field data to estimate the upper bounds of C sequestration potential, models are used to predict future C sequestration. However, many ecosystem models rely on current, rather than potential, estimates of C densities (C storage on an area basis) to initiate and validate model simulations, such as from remote sensing. Current C density estimates may reflect integrated ecosystem responses to past degradation and/or disturbance processes. For example, Brown et al. (1991) suggest that current C densities in the tropics reflect historical degradation by selective logging and other forms of human disturbance. Regrowth in these and other secondary forests may have a larger role in explaining the "missing" C sink than previously thought (Houghton et al. 1998).

It is also difficult to estimate C sequestration potential since most field studies do not account for all manageable pools of C. By including total ecosystem carbon (TEC), we provide sufficient data from which managers will be able to make accurate predictions about how much carbon can be sequestered in the future. We additionally calculate TEC to a depth of 100 cm (TEC<sub>100</sub>) and to a depth of 50 cm (TEC<sub>50</sub>), since the latter may be more amenable for C sequestration activities in the short term. We present TEC values to 100 cm unless otherwise specified to fully account for the upper bounds of these ecosystems.

In this paper we: (1) approximate the upper bounds of C storage in the Pacific Northwest (PNW) region of the United States by estimating TEC of 43 old-growth forest stands in five biogeoclimatic zones and (2) compare these TEC storage estimates to those from other regions, globally. These old-growth forests are at or near steady state (inputs  $\approx$  outputs) based on recent studies (Long and Turner 1975, Turner and Long 1975, DeBell and Franklin 1987; Acker et al., *in press*; Franklin et al., *in press*). The stands have not experienced catastrophic disturbances for 150–1200 yr and are therefore appropriate locations to determine the upper bounds of C storage in the absence of human or natural disturbances. Certainly, the stands have had minor gap-

phase disturbances such as single-tree mortality events from wind or disease. However, these are endogenous disturbances (Bormann and Likens 1979), resulting in an oscillation of steady-state conditions around a mean. In this paper, we are concerned with an estimate of the long-term, upper bound of C storage. We recognize, however, that at shorter temporal scales and smaller spatial scales, steady-state conditions may not occur.

Previously, Grier and Logan (1977) showed that late-successional *Pseudotsuga menziesii* forests of the western Cascades of Oregon had greater stores of biomass than had been measured by other studies in the region (Turner and Long 1975, Fujimori et al. 1976). This study extends the work of Grier and Logan (1977) by examining trends in a complete inventory of all the significant C pools along a wide biogeoclimatic gradient, not just the Oregon Cascades, providing estimates of the upper bounds of C storage as well as its variability between biogeoclimatic regions.

## METHODS

### *Site description*

Sampling was conducted in 43 stands at seven sites in western Oregon and Washington. The sites are located within five of the general physiographic provinces described by Franklin and Dyrness (1988). Assuming the sites are representative (Table 1; Franklin and Dyrness 1988), we designated each site to a respective province: Oregon Coast (ORCOAST), Washington Coast (WACOAST), Oregon Cascades (ORCASC), Washington Cascades (WACASC), or Eastern Oregon (OREAST). ORCOAST was represented by 8 stands at Cascade Head Experimental Forest; WACOAST was represented by 7 stands on the Olympic Peninsula; ORCASC was represented by 14 stands at the H. J. Andrews Experimental Forest; WACASC was represented by 10 stands at Mt. Rainier National Park and Wind River Experimental Forest (T. T. Munger Research Natural Area); and OREAST was represented by 4 stands at Metolius Research Natural Area and Pringle Falls Research Natural Area (Fig. 1, Table 1).

All sites were part of a permanent plot network designed to observe and monitor changes in composition, structure, and functions of forest ecosystems over long time periods (see Acker et al. [1998] for a complete description of the history and characteristics of the network). The 43 old-growth sites used in this study are located on lands managed by either the United States Forest Service (USFS) or the National Park Service and are maintained by the H. J. Andrews Experimental Forest Long-Term Ecological Research program (LTER) and The Cascade Center for Ecosystem Management (a cooperative effort between Oregon State University, the Pacific Northwest Research Station of the USFS, and the Willamette National Forest). Data from the network is stored in the Forest Science Data

Bank of the Department of Forest Science at Oregon State University.

The youngest stands in our study were at Cascade Head, in the ORCOAST. Their average age is 150 yr, having developed after a catastrophic crown fire, the Nestucca Burn, in the late 1840s (Harcombe 1986; Acker et al., *in press*). Stands at the Olympic Peninsula have not had a stand-replacing disturbance for 230–280 yr, while the remaining stands have not had a catastrophic disturbance for 450–1200 yr (Table 1).

In the PNW, there is a strong east-west gradient in precipitation and temperature. Climate is generally mild and moist in the coastal sites, with cooler temperatures at high elevations and lower precipitation east of the mountains. For example, mean annual temperature ranges from 11.4°C at a low elevation stand in H. J. Andrews to 3.8°C at Pringle Falls. Mean annual precipitation ranges from 3669 mm at the South Fork of the Hoh River, Olympic Peninsula, to 355 mm at Metolius RNA. Sites within the Oregon and Washington coastal provinces are represented by *Tsuga heterophylla*–*Picea sitchensis* habitats, while higher elevation sites are represented by *P. menziesii*–*Thuja heterophylla* habitats. East of the Cascades, *Pinus ponderosa* habitats predominate.

At each site, between 3 and 14 stands were sampled. Each stand was composed of 1–72 (median = 16) plots (Table 1). In addition to aboveground measurements within the stand, soil C was estimated from soil pits located just outside the measured area of the stand. The C pools (in megagrams of carbon per hectare) that were measured are described below. A biomass:C ratio of 2:1 was used for all calculations except for soil organic carbon estimates, where C density values were calculated directly. Unless otherwise described, TEC for each stand was calculated as an average of the plots on a per-hectare basis. TEC for each province (e.g., ORCASC, ORCOAST, etc.) was calculated as the average of the stands in that province.

#### *Above- and belowground tree C*

Estimation of above- and belowground tree C included the following pools: stem wood, stem bark, live and dead branches, foliage, live and dead coarse roots, and fine roots. In each stand, the diameters of all trees (>5 cm diameter at breast height [DBH, measured at 1.3 m above the ground surface]) were measured. The biomass of stem wood, stem bark, and live and dead attached branches were calculated by applying species-specific allometric equations from BIOPAK (Means et al. 1994). In some cases, species-specific equations were not available so we made substitutions with equations for similar species. We tested the effect of these substitutions by switching equations within and between families of tree species (while maintaining the observed distribution of DBH). In general, within-family conifer substitutions accounted for very small variations in biomass (e.g., 2.7%, *Abies amabilis* for *Abies*

*procera*). Between-family conifer substitutions were more significant (e.g., 19%, *Tsuga heterophylla* for *A. amabilis*) but were rare. Hardwoods only occupied 1.3% of the stems in the region so we assumed that uncertainty in these equations was not significant.

Foliage carbon stores were calculated from leaf area index (LAI, in square meters per square meter) using species-specific leaf area (SLA, in grams per square centimeter) estimates found in the literature (Appendix B). We obtained LAI estimates from calculating sapwood area (SA, in square centimeters) or sapwood thickness from DBH using species-specific biomass equations (Appendix B). Predicting LAI from SA is preferable to prediction of LAI directly from DBH, as the latter overestimates LAI and leaf mass for mature and old-growth forests (Marshall and Waring 1986, Turner et al. 2000a). We derived species-specific allometric equations to predict SA from DBH for *Picea sitchensis*, *Pinus contorta*, and *Pinus ponderosa* using data from the permanent plots and published data from western softwoods (Lassen and Okkonen 1969). We applied appropriate substitution equations when species-specific allometric equations were lacking (Appendix B).

Fine-root biomass was not directly measured due to time constraints and due to its spatial and temporal variability. Instead, we assumed that fine-root biomass is ~2% of total aboveground biomass (Grier and Logan 1977: Table 7). Since ~1.6 times more fine-root biomass is present in dry sites than wet sites (Santantonio and Hermann 1985: Table 3), we assumed that ~3% of aboveground biomass ( $2\% \times 1.6$ ) is allocated belowground in OREAST, where precipitation is limited (Gholz 1980). This is in general agreement with current understanding about tree physiology that, in water- or nutrient-limited sites, more NPP is allocated to fine roots (Waring and Running 1998).

We estimated live, coarse-root biomass (>10 mm diameter) for each tree from equations for *Pseudotsuga menziesii* in Santantonio et al. (1977) and corrected the values for different tree species using species-specific green densities (U.S. Forest Products Laboratory 1974). Dead, coarse-root biomass was estimated by assuming that it is the same proportion of coarse woody debris (logs and snags) as the proportion of live coarse-root biomass is to aboveground tree biomass. For example, at stand RS01 (H. J. Andrews), live coarse-root biomass is 29% of aboveground tree biomass (live and dead branches, foliage, stem bole, stem bark). Therefore, we assumed that dead, coarse-root biomass was 29% of coarse woody debris (29% of 44.9) or 13.1 Mg C/ha. In this calculation, we assumed that the ratio of above- and belowground decomposition rates does not diverge through time. We tested this assumption by calculating dead, coarse-root biomass with differing decay rates and comparing the ratio of roots to boles through time. We would need to double the decay rates of dead, coarse roots to see a 10% decrease in the ratio

TABLE 1. Stand characteristics of the five study provinces in the Pacific Northwest, USA.

Site	Stand name (if applicable)	Stand	Size (ha)	Latitude N (°)	Longitude W (°)	Elevation (m)	Age (yr)†	
<b>ORCASC</b>								
H. J. Andrews		RS01	1.0	44.202	122.257	510	460	
		RS02	1.0	44.217	122.243	520	460	
		RS03	1.0	44.260	122.159	950	460	
		RS07	0.3	44.213	122.148	490	460	
		RS10	0.3	44.213	122.217	610	450	
		RS12	0.3	44.227	122.122	1020	460	
		RS15	0.3	44.212	122.236	720	460	
		RS16	0.3	44.214	122.241	670	460	
		RS20	1.0	44.222	122.249	700	450	
		RS22	1.0	44.274	122.140	1290	450	
		RS23	1.0	44.227	122.123	1020	450	
		RS27	1.0	44.254	122.175	790	450	
		RS29	1.0	44.231	122.146	800	450	
	RS31	1.0	44.262	122.181	900	450		
<b>ORCOAST</b>								
Cascade Head		CH01	0.4	45.046	123.897	305	150	
		CH03	0.4	45.044	123.901	280	150	
		CH04	0.4	45.065	123.941	259	150	
		CH05	0.4	45.065	123.942	259	150	
		CH07	0.4	45.063	123.939	244	150	
		CH08	0.4	45.065	123.944	271	150	
		CH10	0.4	45.062	123.990	396	150	
		CH12	0.4	45.049	123.898	280	150	
	<b>OREAST</b>							
	Metolius RNA Pringle Falls RNA		MRNA	4.5	44.488	121.631	933	300
		PF27	1.0	43.707	121.609	1353	400	
		PF28	1.0	43.709	121.603	1372	400	
		PF29	1.0	43.706	121.613	1353	500	
<b>WACASC</b>								
Mt. Rainier NP	White River (R.)	AB08	1.0	46.919	121.538	1050	500	
	Nisqually R.	AE10	1.0	46.768	121.742	1430	300	
	Nisqually R.	AG05	1.0	46.748	121.803	950	700	
	Nisqually R.	AV06	1.0	46.777	121.783	1060	750	
	Nisqually R.	TO04	1.0	46.741	121.887	640	750	
	Ohanapecosh R.	AO03	1.0	46.827	121.546	853	1000	
	Ohanapecosh R.	AV02	1.0	46.823	121.551	841	1000	
	Carbon R.	AV14	1.0	46.960	121.843	1080	1200	
	Carbon R.	TO11	1.0	46.995	121.880	610	550	
	Wind River	T. T. Munger RNA	MUNA	4.5	45.828	121.969	411	470
<b>WACOAST</b>								
Olympic Peninsula	S. Fork Hoh R.	HR01	1.0	47.779	123.908	244	280	
	S. Fork Hoh R.	HR02	1.0	47.779	123.908	244	280	
	S. Fork Hoh R.	HR02	1.0	47.779	123.908	250	280	
	S. Fork Hoh R.	HR04	1.0	47.779	123.908	250	280	
	Quinalt RNA	HS02	1.0	47.429	123.873	122	230	
	Quinalt RNA	HS03	1.0	47.430	123.873	122	230	
	Twin Creeks RNA	HS04	1.0	47.834	123.990	152	230	

Note: Site abbreviations are: ORCASC, Oregon Cascades; ORCOAST, Oregon coast; OREAST, eastern Oregon; WACASC, Washington Cascades; WACOAST, Washington coast.

† Ages were determined from tree core data (S. A. Acker and M. E. Harmon, unpublished data); Mt. Rainier ages were determined from age class maps (Franklin et al. 1988).

‡ Precipitation data were from PRISM (precipitation–elevation regressions on independent slopes model; Daly et al. 1994), and temperature data were from the POTT (potential temperature) model (Dodson and Marks 1997). Methods used to calculate the values for each stand are described by Remillard (1999).

§ Soil pit data used for stands RS01–RS16 are from Brown and Parsons (1972).

|| Abbreviations are from Garrison et al. (1976). See Appendix A for tree species names.

of roots to boles. Given the range of decay rates for this region reported by Chen et al. (2001), we would not expect this to be the case. Thus, we have confidence that this assumption is appropriate.

Alternatively, to improve confidence in our esti-

mates, we calculated coarse- and fine-root biomass with a regression equation developed by Cairns et al. (1997), which predicts total root biomass from aboveground biomass. We then calculated fine-root biomass as a ratio of fine roots to total roots (Cairns et al. 1997: Fig. 4).

TABLE 1. Extended.

Temperature (°C)‡	Precipitation (mm)‡	No. soil pits§	No. plots	Habitat type	Dominant species
11.4	1719	2	16	PSME/HODI	PSME, ACMA
10.9	1868	2	16	TSHE/BENE	PSME, TSHE
7.8	2202	2	16	TSHE-ABAM/RHMA-LIBO	PSME, THPL
5.8	2260	2	1	TSHE/OXOR	PSME, TSHE
10.1	2003	2	1	TSHE/RHMA/GASH	PSME, TSHE
7.0	2332	2	1	ABAM/VAAL/COCA	PSME, TSHE
8.9	1906	2	1	TSHE/POMU	PSME, TSHE
10.3	1869	2	1	TSHE/CACH	PSME, PILA
10.4	1859	1	16	PSME/HODI	PSME, PILA
3.8	2282	2	16	ABAM/VAME/XETE	ABPR, PSME
7.1	1240	2	16	ABAM/VAAL/COCA	TSHE, PSME
8.5	2118	2	24	TSHE-ABAM/RHMA-LIBO	PSME, TSHE
8.0	2264	2	16	TSHE-ACCI/POMU	PSME, THPL
8.1	2101	2	16	TSHE-ABAM/RHMA-LIBO	PSME, THPL
8.3	2658	2	4	TSHE/OXOR	TSHE, PISI
8.6	2660	2	4	TSHE/OXOR	TSHE, PISI
9.0	2554	2	4	TSHE/OXOR	TSHE, PISI
9.0	2552	2	4	TSHE/OXOR	TSHE, PISI
8.7	2559	2	4	TSHE/OXOR	TSHE, PISI
9.0	2549	2	4	TSHE/OXOR	TSHE, PISI
7.9	2417	2	4	TSHE/OXOR	TSHE, PISI
8.5	2651	3	4	TSHE/OXOR	TSHE, PISI
8.1	355	4	72	PIPO/PUTR	PIPO
5.7	545	2	16	PIPO	PIPO, PICO
5.0	539	2	16	PIPO	PIPO, PICO
5.8	549	2	16	PIPO	PIPO, PICO
7.3	2076	2	16	ABAM/BENE	TSHE, THPL
4.1	2812	1	16	ABAM/ERMO	ABAM, CHNO
6.1	2421	2	16	ABAM/GASH	ABAM, THPL
6.0	2658	2	16	ABAM/VAAL	ABAM, TSHE
8.8	2166	2	16	TSHE/OPHO	TSHE, PSME
6.6	2257	1	16	ABAM/OPHO	ABAM, TSHE
5.4	2249	1	16	ABAM/VAAL	ABAM, TSHE
3.9	2500	2	16	ABAM/VAAL	ABAM, TSHE
8.1	2112	2	16	TSHE/OPHO	PSME, TSHE
7.8	2496	8	21	TSHE/BENE	PSME, TSHE
8.2	3669	2	16	TSHE/OXOR	TSHE, PISI
8.2	3669	2	16	TSHE/OXOR	TSHE, PISI
8.2	3669	2	16	TSHE/OXOR	TSHE, PISI
8.2	3669	2	16	TSHE/OXOR	TSHE, PISI
8.9	2899	2	16	TSHE/OXOR	TSHE
8.9	2893	2	16	TSHE/OXOR	TSHE, PISI
8.9	3026	2	16	TSHE/OXOR	TSHE, PISI

We compared the fine, and live, coarse-root biomass estimates from these two methods. Since the methods used in Santantonio et al. (1977) allow for the separation of live and dead coarse roots, we present these root estimates in the final TEC calculations.

#### Understory C

To determine understory C, dimensional measurements including cover and/or basal diameters were taken within each stand. Small tree (<5 cm) and shrub diameters, as well as shrub and herb cover, were measured along four transects within the stand. Transects

were either 25 m or 50 m in length, depending on stand size.

The percentage of shrub and herb cover was measured using line transects. Herb cover classes were noted for each species in 0.2 × 0.5 m micro-plots placed at systematic intervals of ~1 m. Diameters of shrub and small tree stems were tallied in a 1 m wide belt transect by species and basal diameter classes (i.e., diameter at ground). Allometric biomass equations for total aboveground biomass (BAT) were selected using BIOPAK (Means et al. 1994) by assembling the appropriate combination of equations describing com-

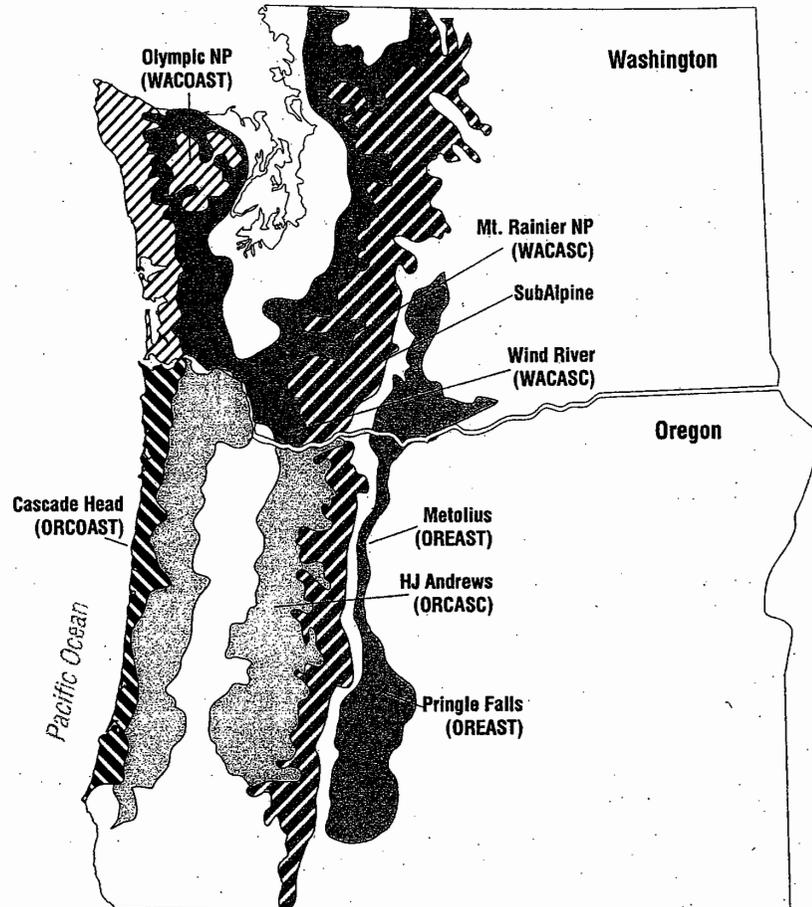


FIG. 1. Locations of sites used to measure old-growth biomass in the Pacific Northwest, USA, within each of the physiographic provinces (ORCASC, Oregon Cascades; ORCOAST, Oregon coast; OREAST, eastern Oregon; WACASC, Washington Cascades; WACOAST, Washington coast). Boundaries of provinces were adapted from Franklin and Dyrness (1998: Fig. 27).

ponents of biomass. For shrubs, if we could not predict BAT by one equation, we used a combination of equations (e.g., entire aboveground = live branch + total stem + total foliage). We assigned a substitute equation for shrub and herb species whose biomass equations could not be found or whose basal areas or cover values were outside of the range for which the species-specific equations were developed. Total biomass per stand was calculated by summing biomass per species on each transect and then averaging the biomass per transect for each stand.

#### *Coarse-woody-debris C*

Coarse woody debris (CWD) included standing and fallen detrital biomass ( $\geq 10$  cm diameter;  $\geq 1$  m in length). For each fallen tree, we measured the length, end diameter, and middle diameter. For each snag, we measured the height and end diameters. In addition to these dimensions, we recorded the species and decay class of each piece. The decay class is an index of the stage of decay of the log or snag, indicating its physical

and biological characteristics, density, and nutrient content (Harmon and Sexton 1996). We converted the data to volumes and then to biomass using wood densities specific to its decay class and species (Harmon and Sexton 1996).

#### *Fine-woody-debris C*

Downed, fine-woody-debris biomass ( $\geq 1$  cm,  $< 10$  cm diameter) was estimated by harvesting downed branches and twigs in five  $1\text{-m}^2$  micro-plots placed evenly along the transects used to sample herbs, shrubs, and small trees. The fresh mass of dead branches was determined on a portable electronic scale (Harmon and Sexton 1996) and subsamples were weighed in the field and later oven dried to determine a dry mass : wet mass correction factor.

#### *Organic horizon C*

This pool included the forest floor and buried rotten wood. A 5 cm diameter corer was used to collect samples of the O horizon at five locations along each tran-

sect that was used to sample fine woody debris. We separated the samples into fine, litter-derived material and coarse, wood-derived material based on color and texture. Each core sample was oven-dried (55°C), weighed and analyzed for loss on ignition (LOI) to determine ash-free mass, which was used to calculate the proportion of organic matter in the sample. Organic matter was converted to C using a 2:1 ratio of ash-free biomass to C.

#### Mineral soil C

Mineral soil organic C (SOC, in megagrams of carbon per hectare) estimates for these stands were reported by Remillard (1999), and detailed methods are described therein; we will describe the methods briefly here. On the perimeter of each stand, one to three 1-m<sup>3</sup> soil pits were used for a total of 79 soil pits. Pits were located to best represent the stand in terms of slope, aspect, vegetation density, and cover. The number of soil pits per stand ranged from one to eight, depending on soil heterogeneity. At each pit, soil samples were collected from three mineral soil layers (0–20 cm, >20–50 cm, and >50–100 cm).

SOC was calculated on a layer basis using the following formula:

$$\text{SOC} = C \times D \times S \times L \times 100$$

where *C* is the organic C concentration (in carbon grams per kilogram) of the C-bearing fraction; *D* is the bulk density (in grams per cubic centimeter) of this fraction; *S* is the C-bearing fraction as a proportion of total sample volume; *L* is the layer depth (in centimeters); and 100 is the conversion factor (10<sup>8</sup> cm<sup>2</sup>/ha × 10<sup>-6</sup> Mg/g) to yield the desired units (megagrams of carbon per hectare).

To obtain the organic C concentration, samples were sieved and hand-sorted into the following components: <2 mm C-bearing soil fraction, 2–4 mm C-bearing soil fraction, >4 mm C-bearing soil fraction, >2 mm rock (non-C-bearing), and >2 mm buried wood, roots, and charcoal. The C-bearing fraction >2 mm was either hardened soil aggregates or soft, weathered rocks, which have been shown to be nutrient-rich and an important component of C stores (Ugolini et al. 1996, Corti et al. 1998, Cromack et al. 1999). Buried wood, roots, and charcoal accounted for <3% of the sample mass and were disregarded in mineral SOC estimates. Subsamples (50–100 g) of the <2 mm, 2–4 mm, and >4 mm C-bearing fractions were analyzed for total C and N concentration using a LECO CSN 2000 analyzer (St. Joseph, Michigan, USA) by the Central Analytical Laboratory, Oregon State University, Corvallis, Oregon, USA. A mass-weighted C concentration was computed for each size class by knowing the total C concentration (in carbon grams per kilogram) and the oven-dry mass of the material. Bulk density was determined for each soil layer with a core sampler for non-rocky soils or by excavating a known volume of

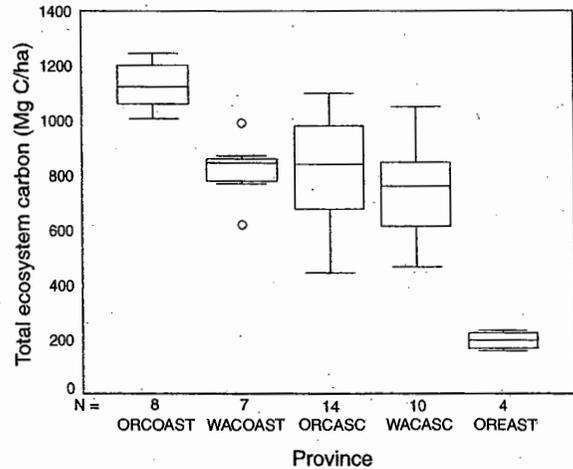


FIG. 2. Boxplot of stand total ecosystem carbon by province. Box length is the interquartile range, which is the distance needed to span the middle 50% of the cases. The "whiskers" are the adjacent values, which are the most extreme cases that are within 1.5 box lengths of the upper and lower edge of the box. See legend to Fig. 1 for explanations of province abbreviations.

soil for rocky soils. In addition to these 79 soil pits, data from Brown and Parsons (1972) for eight soil pits (0–100 cm depth) in the H. J. Andrews, ORCASC, were also used (Table 1).

#### Epiphytes

We did not include epiphytes in our estimate of TEC. Epiphytes may account for only 0.06% of aboveground tree biomass (e.g., 17.8 kg of 29 174 kg in Pike et al. 1977) or perhaps even less (0.003%; M. E. Harmon, K. Bible, M. J. Ryan, H. Chen, and J. Klopatek, *unpublished manuscript*), indicating that the exclusion of this pool does not lead to significant underestimates of total C stores.

#### RESULTS

There was significant variation of TEC<sub>100</sub> averages between provinces (Fig. 2) and among the stands (Table 2). ORCOAST stands stored, on average, 1127 Mg C/ha (1006–1245 Mg C/ha, *n* = 8), which was the highest for the study area, while stands in OREAST stored the least, 158 Mg C/ha (158–252 Mg C/ha, *n* = 4). In general, ORCOAST stands (mean = 1127 Mg C/ha, range = 1006–1245 Mg C/ha, *n* = 8) stored slightly more than WACOAST stands (mean = 820 Mg C/ha, range = 767–993 Mg C/ha, *n* = 7). Similarly, ORCASC stands (mean = 829 Mg C/ha, range = 445–1097 Mg C/ha, *n* = 14) stored more, on average, than the WACASC (mean = 754 Mg C/ha, range = 463–1050 Mg C/ha, *n* = 10). The lowest C density among the 43 stands was at Pringle Falls, OREAST (PF27), where only 158 Mg C/ha was stored, while the highest C density was at stand CH04 at Cascade Head, ORCOAST, with 1245 Mg C/ha.

TABLE 2. Average C pools (in megagrams of carbon per hectare) for 43 old-growth stands in the Pacific Northwest, USA.

Stand	Live branch	Dead branch	Foliage	Stem bark	Stem wood	Fine roots	Live coarse roots	Dead coarse roots
ORCASC								
RS01	18.0	4.0	4.2	57.4	208.5	5.8	85.0	13.1
RS02	28.6	4.9	4.7	55.5	230.8	6.5	93.6	19.7
RS03	42.1	7.1	5.4	60.1	309.3	8.5	136.0	34.2
RS07	37.1	6.3	4.2	71.0	299.8	8.4	106.9	15.3
RS10	22.4	5.3	5.1	57.8	227.1	6.4	69.1	9.3
RS12	66.2	11.0	4.9	98.0	441.7	12.4	152.8	24.2
RS15	42.3	6.9	4.4	98.9	380.0	10.6	141.4	32.2
RS16	28.9	5.1	4.0	86.9	306.3	8.6	115.9	14.6
RS20	16.9	4.0	4.4	50.3	186.5	5.2	71.4	5.9
RS22	31.0	5.2	8.9	53.0	244.2	6.8	93.9	46.0
RS23	52.5	8.6	4.3	43.9	262.6	7.4	99.0	25.5
RS27	54.8	9.4	5.9	108.1	452.4	12.6	189.8	17.9
RS29	45.2	7.2	4.4	91.4	413.9	11.2	198.3	20.5
RS31	45.4	7.5	5.9	88.3	364.7	10.2	157.0	27.4
ORCOAST								
CH01	77.5	12.5	6.3	22.0	291.9	8.2	102.8	22.2
CH03	60.6	9.6	5.8	22.3	389.1	9.7	148.7	21.8
CH04	55.9	9.4	6.9	26.4	416.3	10.3	153.0	21.4
CH05	56.1	8.8	6.7	26.5	448.5	10.9	170.0	18.3
CH07	69.1	11.3	6.8	24.1	338.9	9.0	119.1	16.1
CH08	73.1	11.8	6.9	21.7	285.5	8.0	94.4	18.6
CH10	51.8	7.7	5.6	21.1	400.0	9.7	155.5	16.3
CH12	67.7	10.9	5.8	20.7	317.1	8.4	115.7	26.3
OREAST								
MRNA	13.9	1.6	0.5	15.6	53.0	2.5	24.9	8.6
PF27	11.2	1.0	0.4	11.7	44.0	2.1	20.1	5.3
PF28	13.0	1.3	0.4	14.4	49.6	2.4	22.7	4.3
PF29	17.6	1.6	0.8	17.7	71.7	3.3	36.1	5.5
WACASC								
AB08	42.5	7.1	12.5	25.4	197.2	5.7	94.1	21.0
AE10	37.1	11.2	9.2	34.1	271.2	7.3	99.1	11.8
AG05	33.0	7.5	9.1	47.1	266.8	7.3	99.2	20.2
AO03	60.0	12.6	11.4	47.7	380.2	10.2	147.0	28.6
AV02	58.4	11.8	9.1	35.4	284.9	8.0	96.2	27.8
AV06	24.1	5.1	8.6	24.0	147.9	4.2	48.2	12.9
AV14	53.7	11.9	8.7	30.8	295.1	8.0	121.7	9.8
MUNA	41.1	7.2	4.8	49.3	248.5	7.0	31.8	3.8
TO04	43.4	7.1	4.4	39.7	266.1	7.2	100.1	9.2
TO11	55.0	8.7	5.1	68.1	419.8	11.1	159.6	36.1
WACOAST								
HR01	39.7	5.6	6.1	13.5	240.2	6.1	95.3	26.3
HR02	51.0	5.8	8.6	17.6	389.5	9.4	161.5	26.5
HR03	31.2	3.4	5.4	9.9	236.9	5.7	99.5	22.6
HR04	59.5	7.8	6.9	14.5	332.7	8.4	137.1	18.6
HS02	61.7	9.5	5.9	14.5	237.3	6.6	89.3	23.8
HS03	50.8	7.5	7.4	14.5	266.6	6.9	100.6	18.7
HS04	53.9	8.2	6.6	24.7	289.6	7.7	116.3	35.0

Notes: See Table 1 for study province abbreviations. The abbreviation nm means "not measured."

† Values are means from other reported values in the field.

Almost all C pools were consistent between provinces in their percentage of TEC (calculated from Table 2). The live branch pool averaged  $5.9 \pm 0.4\%$  (means  $\pm 1$  SE) of  $TEC_{100}$  for all provinces ( $n = 5$ ). The dead branch and foliage pool averaged  $0.9 \pm 0.1\%$  and  $0.7 \pm 0.1\%$ , respectively. Stem wood averaged  $33.8 \pm 1.7\%$  while stem bark averaged  $5.1 \pm 1.4\%$  of  $TEC_{100}$ . The fine-root pool averaged  $1.0 \pm 0.1\%$  of  $TEC_{100}$  for all provinces while live and dead coarse roots averaged  $13.4 \pm 0.5\%$  and  $2.6 \pm 0.2\%$ , respectively. The standard deviation of fine-root biomass could be much larg-

er or smaller since fine-root biomass was calculated simply as a ratio to aboveground biomass and therefore represents the variability of the latter numbers. Fine woody debris averaged  $2.0 \pm 0.6\%$ , forest floor averaged  $2.7 \pm 0.6\%$ , and rotten wood averaged  $1.8 \pm 0.7\%$ . The log pool averaged  $5.6 \pm 0.6\%$ , and the snag pool averaged  $3.3 \pm 0.6\%$ . Of all ecosystem C pools, stem wood was the most significant component, ranging from 28.0% of  $TEC_{100}$  in OREAST stands to 37.0% in the Cascades.

Mean SOC values varied widely between provinces

TABLE 2. Extended.

Fine woody debris	Forest floor	Rotten wood	Logs	Snags	Soil	Shrubs	Herbs	Total
9.5	13.3	0.0	20.8	24.1	122.5†	1.0	nm	587.4
16.4	22.5	0.0	45.0	23.4	122.5†	0.6	nm	674.8
29.2	18.3	15.9	60.6	45.9	122.5†	2.2	nm	897.3
13.1	13.0	17.1	38.9	21.1	122.5†	0.2	nm	775.0
13.9	16.1	10.5	35.6	7.1	122.5†	1.6	nm	609.9
7.0	31.3	25.2	32.3	66.1	122.5†	1.5	nm	1097.3
11.0	7.5	0.0	33.9	87.3	122.5†	0.1	nm	978.9
8.3	22.9	0.0	18.5	35.8	122.5†	2.2	nm	780.5
13.8	21.3	0.0	12.4	9.4	41.9	0.1	0.4	443.8
33.3	28.5	22.2	69.0	98.5	179.2	0.5	0.3	920.4
5.1	18.5	26.0	36.6	59.1	102.8	1.7	0.3	753.9
12.6	23.3	11.2	54.3	5.1	121.8	0.5	0.3	1079.8
9.7	6.4	29.8	49.5	8.5	146.5	0.6	0.4	1043.4
8.6	19.5	0.0	75.9	13.4	143.2	1.7	0.2	969.0
18.1	16.9	54.9	53.5	35.0	472.3	2.3	0.1	1196.4
15.2	21.4	0.0	45.0	26.5	346.7	0.8	0.3	1123.5
11.2	27.7	24.5	40.0	32.0	407.4	2.6	0.2	1245.2
18.1	16.7	23.8	45.0	14.0	339.2	0.8	0.3	1203.8
17.4	30.5	25.7	40.0	21.0	275.4	1.0	0.1	1005.7
20.0	40.3	4.4	54.0	24.5	377.2	2.0	0.1	1042.4
16.8	13.8	3.4	34.5	16.5	326.3	0.8	0.4	1080.4
18.4	13.1	37.6	69.4	26.5	380.1	0.9	0.3	1118.9
6.9	14.9	0.0	14.3	14.8	58.7	1.0	0.3	231.6
8.5	6.1	0.0	8.9	9.0	29.2	0.0	0.0	157.5
10.1	8.6	0.0	9.3	5.6	32.1	0.1	0.0	173.7
8.2	10.1	0.0	8.8	7.9	27.0	0.2	0.0	216.5
11.2	11.3	61.1	57.4	6.3	59.9	0.5	0.2	613.3
24.1	11.2	21.2	25.6	17.8	262.6	1.2	0.0	844.9
10.0	9.0	41.8	53.1	20.8	54.7	0.6	0.1	680.2
10.5	17.5	27.5	55.3	44.3	95.9	0.3	0.2	949.6
10.4	26.9	45.9	84.9	30.4	109.3	1.8	0.1	841.1
6.0	28.3	18.1	32.1	24.0	78.1	1.5	0.3	463.1
15.0	6.5	37.3	20.2	12.2	204.8	1.4	0.2	837.2
9.4	33.3	17.1	16.6	24.9	116.6	1.4	0.8	613.5
5.8	30.8	25.1	4.6	28.5	75.6	0.5	0.3	648.5
20.9	16.3	13.9	85.6	40.3	109.0	0.2	0.4	1050.1
5.4	6.7	21.5	73.1	11.0	216.5	nm	nm	767.0
17.2	8.2	15.8	66.4	11.3	204.2	nm	nm	993.0
13.2	8.8	12.1	53.0	12.0	109.0	nm	nm	622.8
5.6	10.3	0.0	44.8	12.5	131.6	nm	nm	790.3
7.7	10.1	0.0	74.7	13.1	288.5	0.2	0.4	843.3
9.2	18.4	19.3	50.5	14.0	264.6	0.3	0.4	849.7
6.0	23.0	30.7	87.0	28.4	153.3	0.8	0.5	871.6

(Table 3), highlighting the large biogeoclimatic variability in the PNW. The percentage of SOC<sub>100</sub> relative to TEC<sub>100</sub> ranged between 15.0% for the Washington Cascades to 32.0% at the Oregon Coast with a mean of 21.1% (SE = 3.3%). ORCOAST stands stored 10 times the SOC that is stored in OREAST (365.5 vs. 36.7 Mg C/ha). ORCOAST stands stored, on average, 130 Mg C/ha more SOC than stands at WACOAST and about three times as much as was found in the stands in the Oregon and Washington Cascades. As a percentage of TEC<sub>50</sub>, SOC<sub>50</sub> was, in general, a smaller proportion of total C, ranging from 11.4% in the WA-

CASC to 24.5% in ORCOAST (16.5 ± 2.4%, mean ± 1 SE).

In each of the five provinces, total tree C, total detrital C, and total understory C were consistent percentages of TEC, respectively (Table 3). Understory biomass was very small in all provinces (0.1 ± 0.02%). Aboveground tree C (live and dead branches, foliage, stem wood, and bark) was the largest component of TEC<sub>100</sub> and TEC<sub>50</sub>. Aboveground tree C was between 41% and 52% of TEC<sub>100</sub> (46 ± 2.1%) and 45–54% of TEC<sub>50</sub> (49 ± 1.7%). Belowground tree C (fine roots, live and dead coarse roots) ranged between 14.4% (OR-

TABLE 3. The relative amounts of understory, above- and belowground tree, detrital, and soil organic carbon (SOC) in the five study provinces as a percentage of total ecosystem carbon (TEC; in megagrams of carbon per hectare).

Study province	TEC <sub>100</sub> †	TEC <sub>50</sub> ‡	Understory§	Tree	
				Aboveground	Belowground¶
ORCASC	829.4	805.7	1.1 (0.13, 0.14)	431.7 (52.0, 53.6)	152.6 (18.4, 18.9)
ORCOAST	1127.0	1009.0	1.6 (0.14, 0.16)	464.7 (41.2, 46.1)	161.8 (14.4, 16.0)
OREAST	194.8	187.0	0.4 (0.21, 0.21)	85.3 (43.9, 45.6)	34.5 (17.7, 18.4)
WASCASC	754.2	719.3	1.2 (0.16, 0.17)	380.2 (50.4, 52.9)	125.4 (16.6, 17.4)
WACOAST	819.7	767.7	0.4 (0.05, 0.01)	363.5 (44.3, 47.4)	146.0 (17.8, 19.0)

Notes: See Table 1 for study province abbreviations. Values in parentheses represent the percentages of TEC<sub>100</sub> and TEC<sub>50</sub>, respectively.

† Understory, tree, detrital, and SOC (0–100 cm).

‡ Understory, tree, detrital, and SOC (0–50 cm).

§ Shrubs and herbs.

|| Live and dead branch, foliage, stem bark, and stem wood.

¶ Fine roots and live and dead coarse roots.

# Fine woody debris, forest floor, rotten wood, logs, and snags (excluding dead coarse roots, dead branches).

COAST) and 18.4% (ORCASC) of TEC<sub>100</sub> (17.0 ± 0.71%) and between 16.0% (ORCOAST) and 19.0% (WACOAST) of TEC<sub>50</sub> (17.9 ± 0.6%). ORCOAST had the lowest percentage of total tree C. This is because soil C represents a larger proportion of TEC at ORCOAST relative to the other provinces (Table 3). Detrital carbon (fine woody debris, dead coarse roots, dead branches, forest floor, rotten wood, logs, snags) ranged between 14.5% in the ORCOAST to 23.2% of TEC in the OREAST (19 ± 1.5%) for TEC<sub>100</sub> and between 13.2% (ORCOAST) and 20.3% (OREAST) for TEC<sub>50</sub> (16.3 ± 1.28%). Stands in eastern Oregon had much less detritus C (45.2 Mg C/ha) compared to coastal and Cascades stands (145.7–163.9 Mg C/ha), even though the percentage relative to TEC was the greatest. Among detrital pools, however, there was significant variation between provinces (see Table 2). ORCOAST had 46% more fine, woody debris and forest floor than WACOAST and 39% more snag C. However, WACOAST had 35% more C in the form of logs than ORCOAST. ORCASC and WASCASC stands had a similar distribution of C in their detrital pools although the WASCASC stands had >60% more rotten wood than ORCASC.

The percentage of root C relative to TEC differs depending on the method used to estimate root C. When using the regression equation developed by Cairns et al. (1997), TRCD averaged 13.4% of TEC. When using the Santantonio et al. (1977) equations, and adjusting for species density, roots averaged 17.0% of TEC. Root to shoot ratios (R:S) were the same for the ORCOAST and ORCASC regardless of which method was used. Both methods showed higher R:S for stands in OREAST, where more resources are stored belowground.

## DISCUSSION

### Confidence in site estimates

As a proportion of TEC, estimation errors of the foliage pool are not significant. Foliage biomass is only 0.7%, on average, of TEC in these old-growth forests,

and therefore even gross estimation errors would not significantly affect TEC. Indeed, we would have to increase the foliage pool 18 times to increase TEC by 10%. Similarly, we would have to increase shrub biomass 100 times to increase TEC by 10%. Nonetheless, prediction of foliage and understory biomass is critical for estimation of productivity and further species-specific equations need to be developed for this purpose.

Because of the effort required to directly measure coarse- and fine-root biomass, we used published allometric relationships instead. Review of the available root biomass literature is complicated because measurements often reflect limited spatial and temporal domains, making comparisons difficult, and because different authors use dissimilar definitions of fine and coarse roots. Dead coarse-root biomass averaged 2.6% of TEC. We would need to increase dead, coarse-root C by five times to change TEC by 10%. We would have to increase fine-root C 11 times to increase TEC by 10%. Therefore, although our estimates of these pools are rough, we have confidence that small changes in these pools will not affect TEC significantly. In contrast, live, coarse-root C is ~13.4% of TEC. Therefore, we would need to increase this pool only 1.5 times to observe a 10% increase in TEC.

Estimation errors in the stem wood pool have the potential to provide the greatest uncertainty in TEC since this pool represents the largest proportion of TEC (34%, on average). Yet, these are the pools about which we have the most confidence since >14 000 trees were measured for stem wood volume and since the allometric equations used to calculate biomass are well documented and validated (see BIOPAK, Means et al. 1994).

In addition, by including coarse soil aggregates and estimating SOC to a depth of 1 m, the soil C estimates used in this study represent an improvement on previous regional estimates of C storage in the PNW. Remillard (1999) found that 39–66% of SOC in soil pits was below 20 cm and up to 44% of SOC was found

TABLE 3. Extended.

Detrital#	SOC	
	0-100 cm, 0-50 cm	
121.4 (14.6, 15.1)	122.5, 98.8	(14.8, 12.3)
133.5 (11.8, 13.2)	365.5, 247.5	(32.4, 24.5)
37.9 (19.5, 20.3)	36.7, 28.9	(18.8, 15.5)
130.7 (17.3, 18.2)	116.6, 81.7	(15.5, 11.4)
114.4 (14.0, 14.9)	195.4, 143.0	(23.8, 18.6)

in C-bearing material >2 mm. Therefore, by reducing the degree that these C pools are underestimated results in more reliable estimates of the upper bounds of C storage in this region.

#### Role of disturbance

Our estimates of the upper bounds of C storage simply place a limit on C storage for the region, based on the unrealistic assumption that all forests eventually reach old-growth conditions. Instead, natural disturbances such as fire, wind storms, and landslides, as well as land conversion and management, create a mosaic of age classes on a landscape (Bormann and Likens 1979). In theory, some old-growth stands persist due to the stochastic nature of disturbance processes (Johnson and Van Wagner 1985), but natural and managed landscapes will store less C than landscapes covered completely by old-growth forests because of the high proportion of younger forests, which store less C than old-growth forests (Harmon et al. 1990). Despite these caveats, the theoretical construct of a completely old-growth landscape is useful as a neutral model (Gardner et al. 1987) in which one predicts the pattern (of C storage) in the absence of a process (e.g., human or natural disturbances; Turner 1989). Such models could be used to distinguish systematically the effects of different management strategies on C storage. By bounding estimates of C sequestration potential, managers can determine the efficacy of different sequestration strategies relative to their potential. Further, they would be able to determine the potential economic and environmental costs and benefits of various management strategies. By providing an upper bound on C storage in the region (based on sites where those processes have been absent), we place an upper limit on the results of such analyses.

#### Regional implications

To estimate the upper bounds of C storage for the PNW region, we multiplied the proportional area of each province (based on the area of the corresponding vegetation provinces in Franklin and Dyrness [1988]) by the average C storage in each province. These area-weighted estimates for each province were then summed. We used the following approximations of the area of each province to calculate the weighted estimates: *Picea sitchensis* zone in Oregon (i.e., OR-

COAST) was 8% of the study area; *P. sitchensis* in Washington (i.e., WACOAST) was 9%; *Tsuga heterophylla* in Oregon (i.e., ORCASC) and Washington (i.e., WACASC) was 32% and 17%, respectively; *Pinus ponderosa* (i.e., OREAST) was 13%; and *Abies amabilis* (subalpine zone) was 21% (adapted from Franklin and Dyrness [1988]: Fig. 27). Since subalpine stands were not represented by our study sites, we used a value of 401 Mg C/ha in the *A. amabilis* zone, taken as the average from studies by Boone et al. (1988: Fig. 1), Kimmins and Krumlik (1973: Tables 6 and 7, assuming soil and roots are each 20% of live biomass), and Grier et al. (1981: Table 2). Without a more formal geospatial analysis, this weighting procedure is a good first attempt at a regional estimate, allowing us to further constrain our estimate of the upper bounds of C storage. Before weighting, the average, upper bound of C storage was 745 Mg C/ha ( $n = 43$  stands) to a depth of 100 cm. After weighting, the average upper bound of C storage was 671 Mg C/ha. Recalculating to SOC to 50 cm, a depth more amenable to forest sequestration practices in the short term, the average, upper bound of C storage was 640 Mg C/ha. For the latter calculation, SOC in the subalpine zone was assumed to be half of that in the former calculation to 100 cm.

At the regional level, exogenous disturbances such as increasing CO<sub>2</sub>, natural disturbances, and climate change will further change this regional capacity to store additional carbon. The eventual regional capacity to sequester C in the PNW may be, therefore, much different than the potential capacity we outline here. Regional predictions of actual carbon sequestration will require a more detailed accounting of all significant endogenous and exogenous factors that control it. However, by constraining these estimates with the potential values we describe, it may be possible to place limits on the system.

#### Comparison with global studies

The C densities we measured in old-growth forests of the PNW are higher than C density values reported for any other type of vegetation, anywhere in the world (Fig. 3; Appendix C). Unfortunately, comparisons of our study to other carbon-density estimates is hampered since estimates often reflect sites whose disturbance histories are poorly documented. The biomass or C estimates of other studies often include effects of non-catastrophic, disturbance legacies (e.g., selective logging, light fires) or may represent stands that are in early to middle stages of succession after a stand-clearing disturbance such as a harvest, blow down, or heavy fire. Moreover, definitions of major ecosystem pools (live, detrital, soil) differ among studies. For example, Schlesinger (1977:51) defined detrital C as "the total carbon in dead organic matter in the forest floor and in the underlying mineral soil layers," while Grier and Logan (1977) excluded soil C in their definition of detritus. In general, the distinction between litter, de-

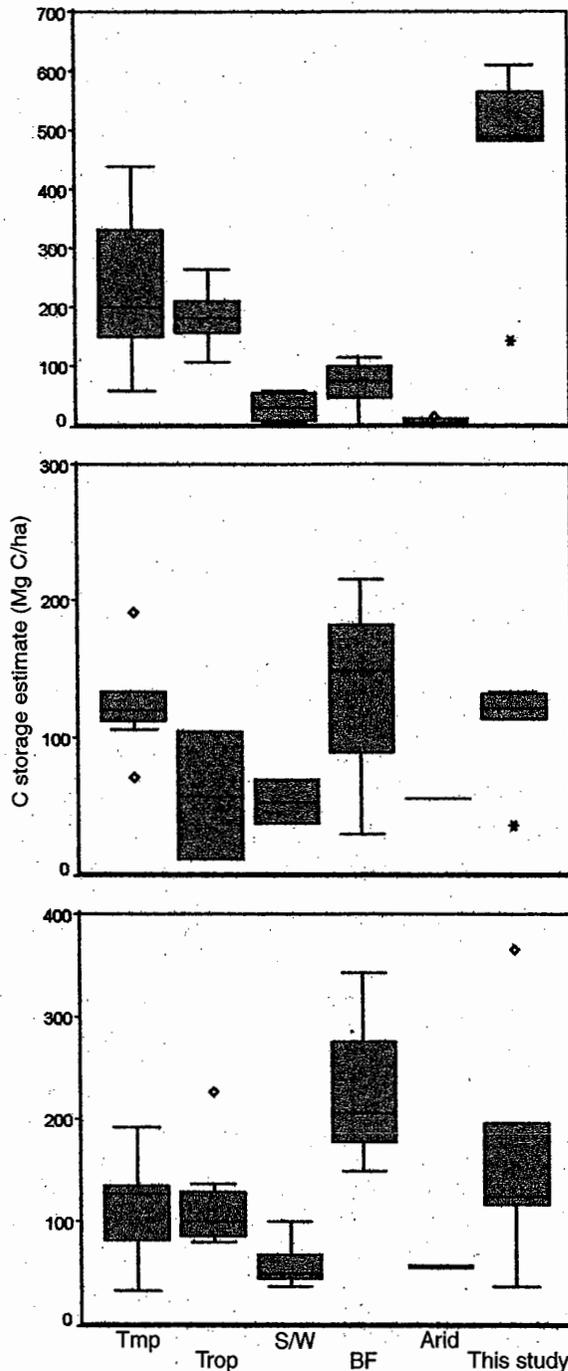


FIG. 3. Boxplots describing C storage estimates from the literature for (a) live, (b) detrital, and (c) soil organic carbon pools, compared to the mean C storage among provinces in the Pacific Northwest, USA. Box length is the interquartile range, which is the distance needed to span the middle 50% of the cases. The "whiskers" are the adjacent values, which are the most extreme cases that are within 1.5 box lengths of the upper and lower edge of the box. A mild outlier (diamond) is between 1.5 and 3 box lengths from the upper or lower edge of the box. An extreme outlier (asterisk) is more than 3 box lengths from the upper or lower edge of the box. Note different y-axis values. Tmp, temperate forest; Trop, tropical forest; S/W/G, savanna, woodland, grassland; BF, boreal forest. Sources may be found in Appendix C.

tritus, and soil C is not consistent between studies, making comparisons difficult (Matthews 1997).

Other limited studies in the region have demonstrated the potential of PNW old-growth forests to support large amounts of biomass. Fujimori et al. (1976), measuring only stem, branch, and leaf dry masses, reported biomass values of 669–882 Mg/ha (335–441 Mg C/ha) in *Picea sitchensis*, *T. heterophylla*, and *A. amabilis* zones in Oregon and Washington. Means et al. (1999) estimated aboveground biomass (trees, foliage, shrubs, herbs) at the H. J. Andrews forest as  $965 \pm 174$  Mg/ha (or  $483 \pm 87$  Mg C/ha). Grier and Logan (1977), who studied a 450-yr old-growth stand in Watershed 10 of the H. J. Andrews, found total organic matter accumulations, including SOC to 1 m, ranging from 1008 to 1514 Mg/ha (or 504–757 Mg C/ha). These studies at the H. J. Andrews were within the range of TEC that we measured at the H. J. Andrews (445–1097 Mg C/ha).

#### Why does old-growth in the PNW store so much C?

Trees in the PNW can reach massive sizes. Mild fall and winter conditions in much of the PNW facilitate continued productivity by coniferous evergreens at a time when deciduous trees are not able to photosynthesize. In addition, long, dry summers further hinder deciduous tree growth (Waring and Franklin 1979). Large conifer trees are able to maintain their growth by continued water conductivity through long, dry summers, which is facilitated with a tracheid xylem structure (Mencuccini and Grace 1996). The absence of frequent fires or storms in the productive regions of the PNW further supports massive trees with long lifetimes (Waring and Franklin 1979). In high-elevation sites, winter dormancy by coniferous tree species facilitates survival in cold conditions (Havrenek and Tranquillini 1995).

The large size of PNW trees means that they occupy a large proportion of ecosystem C storage relative to the national average. For example, Turner et al. (1995) estimated that half of actual total forest C in the conterminous U.S. was in the soil and that only 33% was in trees. Woody debris represented 10% of total C; the forest floor was 6% and the understory was 1% of total forest C. Birdsey et al. (1993) similarly estimated that only 31% of total C in the U.S. is currently in tree C (51% merchantable: 17% roots, 3% foliage, 6% snags, 24% other) and 59% was soil C. Litter, humus, and downed, coarse woody debris comprised 9% while understory was 1% of total C. These national averages are different than the 15–32% SOC and 53–67% tree C in the old-growth stands reported in this study. It should be noted that the absolute amount of SOC in the PNW is higher than the global average, although the relative proportion of ecosystem C that they represent is less due to the large amount of tree C in old-growth PNW forests. The detailed methods used to measure SOC probably allowed us to find higher ab-

solute C stores for this pool. However, the large proportion of tree C in this system, relative to the other studies mentioned above, indicates that the PNW may be more amenable to storing C through management and conservation efforts than other systems that store more C in soil.

#### *C sequestration and economic implications*

Future C management (e.g., Parson and Keith 1998) will require information on the upper bounds of C storage and the extent to which current forest C storage differs from it. In the U.S., Birdsey (1992) used national forest inventory data and other selected studies to estimate current (1987) organic C storage for trees, soil, forest floor, and understory vegetation. In this assessment, PNW forests accounted for 39% of TEC in the United States. Total C averaged 193.6 Mg C/ha for Oregon forests and 227.1 Mg C/ha for Washington forests (mean = 208.3 Mg C/ha, weighted by forest area [Birdsey 1992]). Turner et al. (1995) report an average C storage in PNW forests of 330 Mg C/ha. These studies present estimates that are significantly lower than our regional approximation of the upper bounds of C storage (671 Mg C/ha for TEC<sub>100</sub> and 640 Mg C/ha for TEC<sub>50</sub>). In fact, our estimate is twice that of Turner et al. (1995) and more than three times that of Birdsey (1992).

Subtracting the estimate of Turner et al. (1995) of average current C storage in western Oregon and Washington from the upper bound of C storage in the region, forests could, theoretically, store an additional 310–341 Mg C/ha. To increase the C store to this level would require forest management aimed toward C sequestration, which may include protection from catastrophic, natural disturbances, lengthening of harvest rotations, and improvement in soil C storage.

Given recent estimates of the value of C in economic analyses (e.g., Romm et al. 1998) the average worth of each hectare of forest land could be thousands of dollars for additional C sequestration. Multiplied by the area of forest land in Oregon and Washington, this additional C storage would be worth billions of dollars (given the current value of the dollar). While we realize it is unlikely that large areas may be converted to old-growth forests given the other demands on timber resources, this rough calculation indicates a significant economic value that carbon storage could represent in this region.

#### CONCLUSIONS

Old-growth forest ecosystems can be used as an upper bound (or upper limit) on additional C sequestration potential. Currently, forest C storage in the PNW is less than this upper bound due to management practices and natural disturbances that lower the average age of the forests, reducing the time for large tree boles, detrital biomass, and soil C to accrue. The relative effect of natural disturbances and human management on fu-

ture C sequestration can be best gauged by comparisons to the upper bounds of C storage as presented in this study. The upper bound (or limit) of the global, terrestrial biosphere to sequester additional carbon could be improved with similar studies in other regions. If management strategies were such to allow forests to return closer to the C stores found in old-growth forests, the PNW would have considerable ability to sequester additional C. This could have significant economic implications.

#### ACKNOWLEDGMENTS

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#### APPENDIX A

A table presenting scientific and common names of observed tree species and their abbreviations is available in ESA's Electronic Data Archive: *Ecological Archives* A012-012-A1.

#### APPENDIX B

A table presenting the source of equations used to calculate foliage biomass is available in ESA's Electronic Data Archive: *Ecological Archives* A012-012-A2.

#### APPENDIX C

A table presenting a comparison with estimates from the literature for vegetation, detritus, and soil carbon stores in ecosystems around the globe is available in ESA's Electronic Data Archive: *Ecological Archives* A012-012-A3.



# National Center for Conservation Science & Policy

## Scientific Evaluation of the BLM's Western Oregon Plan Revisions (WOPR) Impacts on Forests and Watersheds

**Richard S. Nauman and Dominick A. DellaSala**  
**National Center for Conservation Science & Policy**  
**September 4, 2007**

*Executive Summary – The Bureau of Land Management (BLM) is revising its management plans across six districts in Western Oregon affecting approximately 2.6 million acres in response to a settlement agreement regarding interpretation of the Oregon and California Railroad and Coos Bay Wagon Road Grant Lands Act of 1937 (O&C Act) with the American Forest Resource Council and the Association of O&C Counties. BLM agreed to revise the Resource Management Plans and to develop at least one alternative that eliminates reserves established under the Northwest Forest Plan (NWFP) except as required to avoid jeopardy for listed species under the Endangered Species Act. The BLM is interpreting the O&C Act's sustained yield timber provisions as the purpose and intent of realigning its district management plans and has placed the O&C Act's timber provisions above other uses as defined in the Federal Land Policy and Management Act. Notably, BLM lands in Western Oregon provide important habitat for salmon, resident fish, other aquatic species and wildlife. The more than 20,400 miles of rivers and streams (6,700 miles are perennial) and 218,199 acres of lakes, ponds, and wetlands found on BLM lands in Western Oregon provide clean water, fish and wildlife habitat in addition to drinking water and recreational opportunities. BLM O&C lands also contain ~900,000 acres of mature and old-growth forests, including some of the last remaining tracts of low elevation, intact forests in southwest Oregon. In particular, the BLM's proposed alternative would nearly triple logging from 268 million board feet (mmbf)/year to 769 mmbf/year, including a doubling of the area of old growth forests logged. The average annual logging levels from 1995-2003 for the entire 25 million acre NWFP planning area was 526 mmbf thus the BLM proposes increasing logging to 146% of the average NWFP level on 10% of the NWFP land base. In the first decade, BLM proposes to clearcut<sup>1</sup> 143,400 acres (= 224 square miles) or 12% of the harvest land base. We estimate that this rate of logging corresponds to about 10,841 football fields per year for the next ten years. In addition, the agency's preferred alternative would reduce late-successional reserves (LSRs) established under the NWFP by 47% from approximately 936,000 acres to 494,000 acres and Riparian Reserves by 57% from approximately 364,000 acres to 156,000 acres. The BLM WOPR has numerous scientific flaws, including models that predict limited or no impacts from logging to fisheries or endangered species in spite of substantial reductions in stream buffer widths and old growth forest protections. It relies on a draft spotted owl recovery plan that recently*

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<sup>1</sup> Note – BLM refers to these as “regeneration harvests,” which in reality are clearcuts. Areas of treatment types taken from Table 172, Pg. 581 DEIS.

*failed scientific peer review and it is hitched to reductions in critical habitat proposed for the threatened northern spotted owl and marbled murrelet by the Fish & Wildlife Service. Southwest Oregon therefore will cumulatively experience reductions in habitat protections for listed species as a result of the BLM WOPR and related rollbacks to old growth forest and streamside protections. We note that the courts have previously ruled that the NWFP was the bare minimum necessary to provide for the survival needs of the northern spotted owl and other old-growth associated species. However, BLM's WOPR was apparently designed to allow the agency to come out from under the protective provisions of the NWFP by lowering the bar on old-growth forest and riparian protections and therefore may not be legal. In addition, we believe that a reduction in riparian buffers will make it difficult for BLM to comply with the Clean Water Act as the extremely narrow stream buffer widths and lack of green tree retentions in uplands will likely result in additional sediment runoff, higher stream temperatures, and greater potential for landslides and floods. Because the agency has relied on flawed science – such as the draft owl recovery plan and model outputs not supported in science – we recommend that the entire WOPR go through independent peer review. Finally, alternative management strategies that rely on logging of small trees (<80 years old) that were dismissed by BLM could actually produce a sustainable source of timber from O&C lands while protecting the last remaining stands of old-growth timber and the forests, salmon, and clean water valued by Oregonians.*

## **KEY FINDINGS**

The Bureau of Land Management (BLM) has published a Draft Environmental Impact Statement for the Revision of the Resource Management Plans of the Western Oregon Bureau of Land Management Districts<sup>2</sup> (DEIS). This plan presents three alternative management strategies that significantly increase timber harvest. Only the No Action alternative maintains current protections afforded salmon and other aquatic species as well as old-forest and old-forest associated species of terrestrial organisms.

*“The BLM is proposing to revise existing plans to replace the Northwest Forest Plan land use allocations and management direction...” (DEIS XLIII)*

- The BLM proposes to eliminate Northwest Forest Plan (NWFP) protections of old-growth forests and old-forest associated species and abandon the NWFP Aquatic Conservation Strategy.
- The preferred alternative more than doubles the area of old-growth forest clearcut.
- The DEIS claims minimal or no-effect on fish, wildlife, peak flows, and sediment in spite of an overall 3-fold increase in logging.
- The BLM interprets the O&C Act as placing timber production above other land uses and values including protecting watersheds, regulating stream flows, and providing recreational facilities that are specifically mentioned in the O&C Act as

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<sup>2</sup> USDI 2007. Draft Environmental Impact Statement for the Revision of the Resource Management Plans of the Western Oregon Bureau of Land Management Districts of Salem, Eugene, Roseburg, Coos Bay, and Medford Districts, and the Klamath Falls Resource Area of the Lakeview District. Oregon State Office, Portland, OR 1606 pp. Available at: <http://www.blm.gov/or/plans/wopr/index.php>

well as the protection of areas with special designations such as Areas of Critical Environmental Concern.

- The proposed alternatives increase fire hazard and severity throughout the plan area while reducing the resiliency of forests to fire.
- The DEIS fails to adequately assess the impacts of Global Climate change and does not address the effects of logging old forests on carbon cycles.
- The DEIS underestimates the potential impacts of the exotic plant disease Sudden Oak Death and fails to disclose the effects of a large increase of logging on the spread of this emerging disease.
- Relies on a flawed Recovery Plan for the Northern Spotted Owl.
- Alternative management strategies could produce a sustainable source of wood from BLM lands while protecting the last remaining stands of old-growth timber on BLM lands and the forests, salmon, and clean water valued by Oregonians.

## **NORTHWEST FOREST PLAN VS. THE WOPR PREFERRED ALTERNATIVE**

BLM has identified a preferred alternative as required by NEPA implementing regulations, which we evaluate here. The final decision may choose one of the three action alternatives or some combination of the alternatives with or without mitigation. Alternative #2 was selected as the preferred alternative by BLM because it best fits the stated purpose and need. It also predicts the greatest logging levels and likely poses the greatest threat to other resources and values.

The BLM proposes to eliminate Northwest Forest Plan (NWFP) protections of old-growth forests and old-growth forest associated species and abandon the NWFP Aquatic Conservation Strategy.

During the first decade of the plan the preferred alternative will:

- Clearcut<sup>3</sup> 143,400 acres (= 224 square miles) or 12% of the harvest land base
- Thin 76,700 acres
- Clearcut 109,600 acres of mature forests greater than 120 years old
- Clearcut 34,800 acres of old-growth forests greater than 200 years old
- Increase logging by 2.9 times from 268 mmbf/year to 769 mmbf/year
- Reduces the late-successional reserve system by 47% from approximately 936,000 acres to 494,000 acres.
- Reduces the Riparian Reserve System by 57% from approximately 364,000 acres to 156,000 acres.

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<sup>3</sup> Note – BLM refers to these as “regeneration harvests,” which in reality are clearcuts. Areas of treatment types taken from Table 172, Pg. 581 DEIS.

## **IMPACTS TO FISH, WATER, AND WILDLIFE**

BLM lands in Western Oregon provide important habitat for salmon, resident fish, other aquatic species and wildlife. The more than 20,400 miles of rivers and streams (6,700 miles are perennial) and 218,199 acres of lakes, ponds, and wetlands found on BLM lands in Western Oregon provide clean water, fish and wildlife habitat in addition to drinking water and recreational opportunities.

Watersheds with BLM lands in the WOPR project area provide water for 76 communities (Table 270, DEIS Pg. 1120).

In watersheds with BLM ownership, 704 miles of stream are listed as water quality impaired under section 303d of the Clean Water Act. The most common cause of listing is temperature (569 miles). Other causes are excessive sediment (27 miles), low dissolved oxygen (65 miles), high bacteria levels (35 miles) and heavy metal contamination (8 miles; DEIS Pg. 365).

The preferred alternative makes drastic cuts to the aquatic reserve system and the NWFP's Aquatic Conservation Strategy that will likely increase the severity of impacts to streams already experiencing water quality problems. These are summarized as follows:

- On perennial fish-bearing streams and rivers the riparian buffers are reduced to 100 feet and logging is allowed to within 25 feet of the bank (these stream widths are well below scientifically recognized stream buffers for minimizing aquatic impacts, and minimizing problems with land slides and floods).
- Yarding corridors and other operational activities associated with logging would be allowed in the Riparian Management Zone if needed to access nearby areas (DEIS Pg. 52).
- While emerging science<sup>4</sup> emphasizes the importance of intermittent streams and headwater areas for the conservation of species and the functioning of watershed processes, landslide-prone intermittent streams are given a 25 foot buffer while all other intermittent streams are unprotected.
- Predicts the need to build over 600 miles of new road (DEIS Pg. 1111) and over 1000 miles of all road types (Figure 196, DEIS Pg. 585).

## **FIRE HAZARD AND SEVERITY**

The DEIS and preferred alternative appears to be a departure from recent thinking in ecosystem function and the role of fire in the forests of Western Oregon. The proposed alternative appears to be a return to suppression oriented fire management.

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<sup>4</sup>For example see: Olson et al. 2007. Biodiversity management approaches for stream-riparian areas: Perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. *Forest Ecology and Management* 246:81-107

- The Fire and Fuels Management Objectives common to all alternatives appear to conflict with the specific Management Actions and the effects of the preferred alternative. For example, the Management Objective “Promote ecosystem function and resiliency” is difficult to reconcile with the Management Action “Immediate action to control and suppress all wildfires would be taken in all areas” (DEIS Pg. 33).
- Across all districts in the WOPR analysis, the area of stands with a high fire hazard is from roughly 30% to 460% higher under the preferred alternative than the No Action Alternative (Figures 272-273, DEIS Pg. 768-769).
- In all but one case, the preferred alternative has the largest area of high fire severity stands.<sup>5</sup>
- On the Medford District, the preferred alternative will result in 200,00 more acres of high fire severity stands than the No Action Alternative (Figure 273, DEIS Pg. 769).
- On the Medford District and the Klamath Falls Resource Area, the preferred alternative would result in a significant reduction in fire resilient stands from the current condition.
- On the Medford District and the Klamath Falls Resource Area, the preferred alternative would result in roughly ¼ and ½ of the area of fire resilient stands as the No Action alternative (Figure 274, DEIS Pg. 771).
- The preferred alternative would create 14,340 acres/year of even-aged plantations that are highly susceptible to crown fire (DEIS Pg. 770).

We are concerned that the WOPR DEIS has used an overly broad definition of Wildland Urban Interface (WUI). The Wildland Urban Interface as depicted in Map 6 (DEIS Pg. 155) encompasses most of the Bureau of Land Management Lands in the project area. Other sources, such as the Oregon Department of Forestry, classify a much smaller part of the project area as WUI<sup>6</sup>. We can find no definition of WUI in the DEIS document other than general descriptions. WUI lands must be correctly identified to direct limited resources to areas where they are most needed and avoid applying treatments intended to safeguard homes to remote areas where they may have negative ecological impacts and provide little or no benefit to the protection of homes.

## GLOBAL CLIMATE CHANGE

*“The analysis assumes no change in climate conditions, because the specific nature of regional climate change over the next decades remains speculative.” (DEIS Pg. 491)*

- The WOPR ignores the latest climate science, including recent studies demonstrating: (1) old-growth forests are carbon sinks and sequester more carbon

<sup>5</sup> Figure 272, DEIS Pg. 768. The Roseburg District has a slightly larger area of high severity fire stands under alternative #3 than under alternative #2.

<sup>6</sup> Data available at: <http://egov.oregon.gov/ODF/GIS/gisdata.shtml>

per acre than any forests on earth<sup>7</sup>; and (2) logging in western Oregon forests releases significant amounts of carbon that otherwise would be sequestered by forests managed for long-term sequestration<sup>8</sup> (Turner et al. 2007).

## SUDDEN OAK DEATH

Sudden Oak Death (*Phytophthora ramorum*) is a plant disease first observed in California in 1995. Its origin is unknown but is likely introduced to North America like its relative Port Orford Cedar Root Rot (*Phytophthora lateralis*). It is fatal to Tan Oaks, Coast Live Oaks, and Black Oaks. It also infects and causes disease in other species common to Western Oregon such as Rhododendron, Madrone, Evergreen Huckleberry, Bay Laurel, Bigleaf Maple, Manzanita, Coast Redwood, Douglas Fir, and Coffeeberry. It was found in Curry County, Oregon in 2002.

- The DEIS fails to assess the risks posed by this introduced plant pathogen and provides a misleading interpretation of the existing science. The DEIS reports:

“Future spread of the disease into Oregon is uncertain. Models identify different levels of risk of sudden oak death spread across the planning area (Kelly et al. 2005).”<sup>9</sup>

and concludes:

“However, because future spread of the disease and subsequent tree mortality in the planning area is speculative, there is no basis on which this analysis can assume future changes to forest composition, structure, and process as a result of Sudden Oak Death.”

- Contrary to the conclusions of the DEIS, the General Technical Report cited, a habitat model for Sudden Oak Death created by the USDA Forest Service’s Pacific Southwest Research Station, found that all five models examined “...were consistent in their prediction of some SOD risk in coastal CA, OR and WA.”. Three of the five models predict high risk for almost all of the WOPR area and a composite model placed most of the WOPR area in the highest two risk categories.<sup>10</sup>

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<sup>7</sup> Harmon, ME et al. (2004). Production, respiration, and overall carbon balance in an old-growth Pseudotsuga/Tsuga forest ecosystem. *Ecosystems* 7:498-512.

<sup>8</sup> Turner, DP et al. 2007. Scaling net ecosystem production and net biome production over a heterogeneous region in the western United States. *Biogeosciences* 4:597–612.

<sup>9</sup> DEIS Pg. 492

<sup>10</sup> Kelly MD, SQ Guo, and D Liu. 2005. Modeling risk for SOD nationwide: what are the effects of model choice on risk prediction? General Technical Report PSW-GTR. Pacific Southwest research Station, U.S. Department of Agriculture, U.S. Forest Service. Available at: <http://nature.berkeley.edu/comtf/pdf/KellyetalSOD2-22-05.pdf>

This plant disease has already killed over one million oak and tan oak trees in 14 counties in California with devastating impacts on the wildlands and wildlife habitats.<sup>11</sup>

Dismissing the threat posed by this disease as speculative fails to consider the grave implications to its spread. Because the disease is spread through the movement of wet soil on vehicles, boots, and equipment, the activities proposed in the WOPR DEIS may increase the rate of spread. A reasonable first approximation would be that a tripling of logging as proposed by the preferred alternative would triple the rate of spread on the disease through the movement of log trucks, forestry crews, and other associated activities.

- Although the DEIS reports only one infected site in Southwestern Oregon, at least 53 localities have been reported.
- The DEIS fails to use the best available science and does not cite an important comprehensive summary of the literature.<sup>12</sup>

## ACECS AND OTHER SPECIAL AREAS DESIGNATIONS

*“This document acknowledges the primacy of O&C Act in regards to the management of timber resources. Therefore, specific changes to the current management direction for areas of critical environmental concern and research natural areas, scenic values as identified through a visual resource management inventory, and sensitive species protection are proposed across the alternatives.” DEIS Page XL*

The preferred alternative eliminates or reduces areas recognized for their special values.

- Eliminates 23 existing Areas of Critical Environmental Concern (ACEC)
- Partially eliminates (O&C Act lands removed) in 13 existing ACECs

These include important areas such as:

North Santiam ACEC  
Sandy River Gorge ACEC and Outstanding Natural Area  
Cottage Grove Old Growth ACEC  
Umpqua River Wildlife Area ACEC  
North Umpqua River ACEC  
North Fork Coquille River ACEC  
Jenny Creek ACEC  
Rough and Ready ACEC  
Upper Klamath River ACEC

<sup>11</sup> For more information on Sudden Oak Death see: <http://nature.berkeley.edu/comtf/>

<sup>12</sup> Kliejunas, John T. 2007. Sudden Oak Death and *Phytophthora ramorum*: A Summary of the Literature. Albany, California. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 42 pages. Available at: [http://nature.berkeley.edu/comtf/html/sod\\_literature\\_summary.html](http://nature.berkeley.edu/comtf/html/sod_literature_summary.html).

The DEIS provides little detail regarding the extent or impacts of eliminating or reducing the area of ACECs and combines proposed and existing special designation lands in the analysis making interpretation of the impacts to individual areas difficult.

### **NORTHERN SPOTTED OWL**

The BLM WOPR relies on the draft spotted owl recovery plan and proposed critical habitat exemptions by Fish & Wildlife Service. However, the recovery plan recently failed scientific peer review<sup>13</sup> due, in part, because it would lower habitat protections for owls in relation to the Northwest Forest Plan. Interestingly, the proposed critical habitat determination – which is also tied to the failed recovery plan – would lower critical habitat protections by 1.5 million acres range-wide with greatest losses proposed in southern Oregon.

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<sup>13</sup> Peer reviews are available at: <http://www.fws.gov/pacific/ecoservices/endangered/recovery/peer.html>

Table 1. Summary of DEIS Alternatives (based on table 1 DEIS Pg. XLIX).

	<b>No Action</b>	<b>Alternative 1</b>	<b>Alternative 2</b>	<b>Alternative 3</b>
LSRs/LSMAs	NWFP	Similar area and distribution to NWFP	LSMAs 47% smaller than No Action	No LSMAs
	No treatments in stands over 80 years	Treatments to promote development of structurally complex forests	Treatments to promote development of suitable habitat	50% of assessment of area must be older than 90 years north of Grants Pass and 140 years south of Grants Pass
	MM critical habitat matches LSRs;	MM critical habitat matches LSRs;	Critical habitat of MM and NSOP partially match the LSMAs;	No special management for MM or NSO critical habitat
	NSO critical habitat partially matches LSRs	NSO critical habitat partially matches LSRs		Retains 215 acre owl activity centers until 50% target is met.
	1.1 snags/acre	2 to 6 snags/acre depending on vegetation series	2 to 6 snags/acre depending on vegetation series	2 to 4 snags/acre depending on vegetation series
	Down wood standards 120 to 240 ft./acre	Down wood standards variable but higher than alt #2 and < NA	Down wood standards variable	Down wood standards similar to NA
	Salvage allowed when disturbance is > 10 acres	No Salvage except for operational or safety reasons	Salvage for Economic Purposes	Salvage for economic purposes
Area **	936,000	728,000	494,000	None

Table 1. Continued

	No Action	Alternative 1	Alternative 2	Alternative 3
Riparian Reserves/RMAs	NWFP  Fish-bearing streams – 2 site potential trees  Non-fish-bearing streams – 1 site potential trees	½ NWFP  Perennial streams – 1 site potential tree  Intermittent non-fish-bearing streams – ½ site potential trees	Perennial streams 0-25 ft. no harvest 25-60 ft. 80% shade retention* 60-100 ft. 50% canopy retention  Debris-flow prone intermittent non-fish bearing streams 0-25 ft. no harvest  Other Intermittent 0-25 ft. noncommercial vegetation and 12 trees/acre	Perennial streams 0-25 ft. no harvest 25-60 ft. 80% shade retention* 60-100 ft. 50% canopy retention  Intermittent non-fish-bearing streams 0-25 ft. no harvest
Area **	364,000	234,000	156,000	182,000
TMA/Matrix	Retains owl activity centers known as of Jan 1994  Green tree retention standards  Snags retention standards  Down wood standards  Salvage for economic purposes	No NSO activity centers retained  No Green tree Retention  Noncommercial snags only  Noncommercial down wood only  Salvage for economic purposes	Retains no Owl activity centers in TMAs  No green tree retention;  Noncommercial snags only  Noncommercial down wood only  Salvage for economic purposes	
Area **	572,000	962,000	1,274,000	1,742,000 “general landscape area”
WUI (includes much of the LSR/LSMA)		Salvage to reduce hazards across all allocations	Salvage to reduce hazards across all allocations	Salvage allowed

\* Note that this is “shade” retention and not canopy retention.

\*\* In acres - Estimated from graphs on DEIS pages 67, 75, 89, 101 – TMA estimates include the BLM lands surrounding the Coquille Lands.