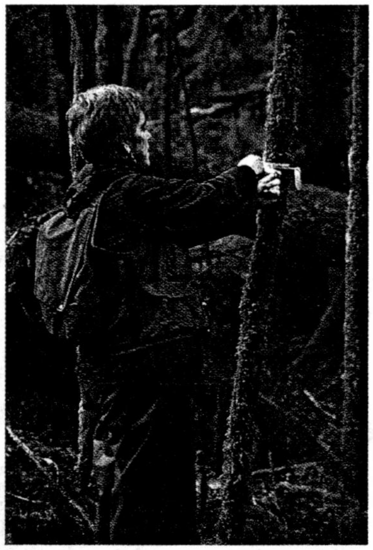
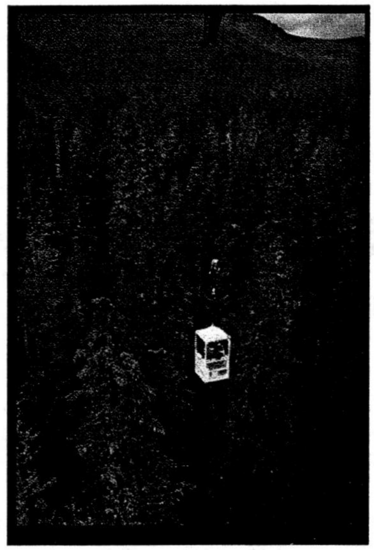
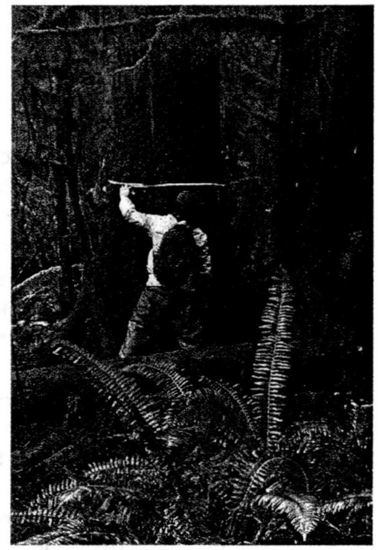
PERMANENT PLOTS
OF THE PACIFIC NORTHWEST, USA

REPORT NUMBER 1
PERMANENT PLOTS SURROUNDING THE WIND RIVER CANOPY CRANE

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October 1998

Citation

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Introduction

This report describes key characteristics of vegetation permanent plots that surround the canopy crane at Wind River Experimental forest. The objective of this set of plots is to describe the temporal and spatial variation in forest structure as well as processes including growth, recruitment, mortality, and production. The description of this stand therefore provides key background information on canopy process studies that are being conducted at the site. We also report preliminary estimates of key carbon pools at the site for those requiring these variables in modeling and other synthetic analyzes.

Location

The permanent plots lie within the 478 ha Thornton T. Munger Research Natural Area (RNA) in the area surrounding a free-standing tower crane associated with the Wind River Canopy Crane Research Facility (WRCCRF). The plot surrounding the crane (Lat. 45o 49' 13.76" Long. 121o 57' 06.88") is located at approximately 355 m in elevation on gentle (less than 10% slope) topography near the southeastern flank of Trout Creek Hill, an extinct volcano.

Study Area

The forest is classified as a western hemlock/salal cover type, and is estimated to be greater than 400 years old. Dominate tree species are Douglas-fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla). Associated tree species include western red-cedar (Thuja plicata), western white pine (Pinus monticola), Pacific silver fir (Abies amabilis), grand fir (Abies grandis) and noble fir (Abies procera). Understory trees include Pacific yew (Taxus brevifolia) and Pacific dogwood (Cornus nuttallii). Dominant understory shrub species are vine maple (Acer circinatum), salal (Gaultheria shallon) and dwarf Oregon grape (Berberis nervosa).

The climate is are characteristic of a temperate winter-wet, summer-dry climate. Annual precipitation totals 2528 mm with less than 10% occurring between June and September. Average annual snowfall is 2330 mm. Mean annual temperature is 8.7 degrees C.

Soils are of the Stabler series, coarse textured (shotty loamy sands and sandy loams) developing in 2 to 3 meters of volcanic ejecta over basalt bedrock. A seasonal stream runs through the plots (see topographic map), and an extensive wet area is located at approximately 300m to the east of the crane.

History of the Wind River Plots

In 1994 the first of three 4 ha reference stands was established surrounding the Wind River Canopy Crane (see map). This plot is referred to as the "Crane plot". An additional 4 ha plot was established in 1995 by Dr. Jiquan Chen to the west of the crane plot and is called the Michigan Tech Plot. The third and final 4 ha plot was also added by Dr. Chen in 1997-98 to the south of the other two plots and is called the Earthwatch Plot. All the plots are contiguous and form a 400- by 300-m plot with the long axis in the east-west direction. None of the plots has been remeasured at the time of this report, however, annual mortality checks have been conducted on one plot since 1995.

Methods

The boundaries of the 4 ha square "crane plot" were established in 1994 by a licensed surveyor and oriented to the four cardinal directions. The plot is divided into 4, 1 ha square quadrants (quadrant 0 = NE, 1 = SE, 2 = SW, 3 = NW) each of which are further divided into 16 numbered 25-m x 25-m subplots. Plot and subplot corners are numbered and monumented with iron bars and vinyl surveyor caps.

Following plot marker layout, all trees > 5 cm DBH were measured for diameter, height and location from which a stem map was constructed. All trees equal to or greater than 5 cm diameter at breast height (DBH) were tagged with aluminum tags. Tags begin with a C to signify their inclusion into the crane plot population. Diameter was measured with a tape to the nearest 0.1 cm directly above the tag. Horizontal (X) and vertical (Y) locations of trees from plot center were determined using a Criterion 400 laser range finder (Laser Technologies Inc.). Distances and angles to each tree's apparent central axis were measured from each of the 4 surrounding subplot corners. Given a clear line of sight, 4 measurements per individual could be obtained; however, given occluded vision fewer measurements may have been recorded. Distances and angles were processed through a triangulation routine which resulted in an averaged XY coordinate for each tree (Freeman 1996). The cosign corrected vertical height of each tree was also determined using the Criterion 400 laser range finder or for smaller individuals using height poles.

Biomass of all live plant parts and volume for the bole were calculated using equations from Biopak (Means et al. 1994). Leaf mass and leaf area index estimates are highly uncertain. Although site specific equations are currently being developed, it may be sometime before these estimates are available. We have therefore used several approaches to try to bracket the most likely values. This includes the Gholz et al. (1979) equations which are known to be high, a litterfall derived estimate assuming a leaf life-span of 5 years, and a sapwood area-based estimate using DBH-sapwood thickness relationships developed for the H.

J. Andrews forests (Means et al. in press). Total and single-sided leaf area estimates were made using the conversion factors of Gholz et al. (1976), Waring et al (1982) and Means et al. (in press). To convert single-side leaf area index values to projected ones divide by the following numbers: Pseudotsuga (1.18), Tsuga (1.07), and Thuja (1.5). Sapwood volume was estimated from equations developed by Harcombe et al. (1990) that predict the proportion of the total bole in sapwood.

Downed coarse woody detritus (>10 cm diameter at large end) was measured using the line intercept method (Harmon and Sexton 1996). The diameter, species and decay class of all downed wood crossing the boundaries between all the 25- by 25-m subplots was measured. Standing dead trees >10 cm DBH and >1m tall were inventoried on the entire plot by measuring the basal and top diameters and height. The mass of downed fine wood (<10 cm diameter) was measured by harvesting all the wood in twenty 1- by 1 m quadrats scatted randomly throughout the 4 ha Crane plot. Several woody detritus pools were estimated using assumptions based on the ratios of live parts, the relative decomposition rate of the parts, and their retention on dead boles. Below-ground fine woody detritus in the form of dead coarse roots was estimated assuming they form 10 to 15% of snag and log mass. This assumption, in turn, is based on the idea that (1) the ratio of above-ground to below-ground woody tissues holds for dead wood and (2) roots decompose two times faster than bole wood. Suspended fine woody debris on snags were estimated by assuming that only decay class 1 and 2 snags retained branches and that the suspended branch decomposition rate equaled that of snag boles.

Soil texture, rockiness, bulk density, as well as carbon and nitrogen content were determined in 10 soil pits that were at least 1 m in depth. The latter three variables were determined for three depths: 1) 0-20 cm, 2) 20-40 cm and 40- 100 cm. The mass of the organic layer was determined by 5 cores taken above the sampling face of the soil pit. These samples were composited for each soil pit.

General Stand Description

Site Description

- Longitude: 121o 57' 06.88"
- Latitude: 45o 49' 13.76"
- Elevation: 355 m
- Aspect: 90
- Slope: <10%
- Soil Depth: 2-3 m
- Soil Texture/ Rockiness: Loamy sand-Sandy loam/3%
- Age Class: Old-growth
- Plant Association: Tsuga heterophylla/Gautheria shallon

General Description: The forest sampled represents an old- growth forest on the low end of the productivity gradient in the Cascades. This is thought to be related to the soils and the cold nature of the site.

Mistletoe infections are quite common in Tsuga and conk-rot and butt rot are quite common in the Pseudotsuga. White pine blister rust has weakened a substantial proportion of the Pinus monticola, and mortality is primarily caused by subsequent bark beetle attacks.

Plot Statistics

These statistics are an average for the entire 12 ha area. The Crane Plot has a higher proportion of Pseudotsuga and Thuja than the average, as well as a slightly higher basal area, volume and biomass.

Live Trees

Basal Area: Total basal area averages 71.7 m2/ha with 40% and 44% comprised of Pseudotsuga and Tsuga, respectively.

Stem Numbers: The total number of stems >5 cm DBH is 444/ha with the majority being Tsuga (55%) and Taxus (23%).

Diameter Distribution: The normal diameter distribution of Pseudotsuga indicates a pulse of reproduction associated with past disturbance, ranging in DBH from 40 to 160 cm. All other major species have a reverse-J types diameter distribution indicating continual reproduction. The only species approaching the size of Pseudotsuga is Thuja, which ranges in diameter from 5 to 140 cm.

Height: The maximum tree height on the plots is 64.8 m. This is below average for old-growth forests of the region, and reflects the generally low site productivity of this particular location. Taller trees do grow on the surrounding slopes. The average tree heights of the dominant species are Pseudotsuga (52.2 m) and Tsuga (19.0 m). Height distributions are similar to diameter distributions with Pseudotsuga exhibiting a normal distribution and other species a reverse-J distribution.

Canopy Cover. Canopy cover averages 70% in the stand, but ranges from 0 to 100% cover on a 5 m grid.

Volume. Bole volume averages 1,256 m3/ha of which bole wood comprises 87%. Pseudotsuga comprises the majority of volume in this forest (approximately 44%). We estimate that sapwood comprises 24% of the bole volume.

Biomass. The most credible total biomass estimate averaged for the entire 12 ha is 813 Mg OM/ha. The high variability of estimates is based on the foliage calculation which are lowest for the litterfall method which gave a foliage mass of 10 Mg OM/ha assuming a needle longevity of 5 years. This gives a single-side leaf area index of 9.2 m2/m2, a value that is similar to vertical intersection methods (Thomas and Winner in prep.). The middle estimate of 18.4 Mg OM/ha of foliage was based on the sapwood area method. The highest, based on the Gholz equations, is 160 Mg OM/ha of foliage. As the foliage estimates based on the latter method are extremely high (implying a single-side LAI greater than 50 and a litterfall rate exceeding 15 Mg/ha/year!), we assume the total biomass is closer to 813 than 1080 Mg OM/ha. Single-side LAI, based on sapwood area, is 17 m2/m2, a value that is probably too high.

Tsuga comprises the majority of biomass (47%), with Pseudotsuga making up a roughly equivalent share (44%). Combined with Thuja (6%) these three species comprise 97% of the live biomass.

Woody Detritus:

Coarse Woody Detritus. Total volume of coarse woody detritus averages 683 m3/ha, with 66% as downed logs. Total mass of logs and snags is 94.8 and 68.5 Mg OM/ha, respectively. This is very close to the estimate made by Sollins (1982) of 150 Mg OM/ha. Pseudotsuga comprises the majority of the coarse woody detritus, with 42% of the logs and 76% of the snags. Tsuga is the second most abundant species for logs (28%), whereas Pinus monticola is the second most abundant species for snags (12%).

Fine Woody Detritus. Downed fine woody detritus averages 9 Mg OM/ha. Below-ground fine woody detritus in the form of dead coarse roots is estimated to be between 15 and 25 Mg OM/ha. Suspended fine woody debris on snags is approximately 7 Mg OM/ha. Total woody detritus stores on the site would therefore equal 194 to 204 Mg OM/ha or equivalent to 21% of the live woody biomass. This proportion is typical for old-growth of this region, which have a ratio of dead to live wood of 20 to 30% (Harmon and Chen 1991).

Soils: Sampled soil pits are consistent with the general description of the area. Texture ranged from shotty loam to clay. Rock content in the top 1 m averaged 3%, however, most pits were rock free. Most pits consisted of aggregated material >2mm in diameter which contained significant amounts of carbon and nitrogen. A hard layer or pan was present in many of the soil profiles at a depth of aproximately 70 to 80 cm, probably representing the interface of two ash layers. Bulk density ranged from 0.79 and 1.07 g/cm3, with a mean of 0.93 g/cm3. Total mineral soil nitrogen stores range from 0.42 to 2.15 kg.m2, with a mean of 0.78 kg/m2 The forest floor contributes an additional 0.01 to 0.07 kg/m2, with a mean of 0.04 kg/m2. Carbon stores in the mineral soil ranged from 8.0 to 14.1 kg C/m2, with a mean of 9.3 kg/m2 (Remillard et al.1997). These values are probably near the mean for the Pacific Northwest forests, which range from 3 to 35 kg of soil C/m2. The forest floor carbon stores ranged from 0.6 to 3.3 kg/m2, with a mean of 1.9 kg/m2. This means that only 17% of the "soil" carbon and 5% of the nitrogen are stored in the forest floor.

Preliminary Estimates of Carbon Stores.

We have converted the biomass figures presented above into carbon. In the case of soil and forest floor organic matter this was based on loss on ignition. For all other biomass components we assumed that 50% of the organic matter was carbon.

The total amount of carbon currently stored in and around the crane circle is estimated to be 614 Mg C/ha. Other values are probably overestimates given our assessment of the realism of the various foliage calculations. Of this total, live vegetation, detritus, and mineral soil comprise approximately 66, 19, and 15%, respectively. The total amount is slightly higher (0.5%) than those reported by Grier and Logan (1979) for Watershed 10 at the H. J. Andrews. More significantly the Wind River site has almost twice as much in mineral soil than Watershed 10 (9% of total). Based on unpublished data for the full range of forests in this region (coastal to eastside) Wind River probably falls near the average. Our lowest estimate of total carbon stores to date is 200 MgC/ha, whereas our highest is 1250 MgC/ha.

Related Publications

For additional description of the site and the forest ecosystem at the Canopy Crane Site the following references may prove useful.

Franklin, J. F., and D. S. DeBell. 1988. Thirty-six years of tree population change in an old-growth Pseudotsuga-Tsuga forest, Canadian Journal of Forest Research 18:633-639.

Northwest Forest Canopies. 1996. Northwest Science, Volume 70 , Special Issue.

Sollins, P. 1982. Input and decay of coarse woody debris in coniferous stands in Western Oregon and Washington. Canadian Journal of Forest Research 12:18-28.

Data Access

Raw data describing the vegetation, woody detritus, and soils of these permanent plots are available on the web upon request. Please click on the underlined text above to move to the appropriate HMTL.

Acknowledgments

Funding for the establishment of these plots was from the Pacific Northwest Research Station of the U.S. Forest Service, Portland, Oregon. Additional support was provided by WESTGEC-NIGEC, NSF-Long Term Studies (DEB-9632921) the Corvallis Environmental Laboratory of the U.S. Environmental Protection Agency.

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Freeman, E. 1996. Masters Thesis, University of Washington, Seattle, WA.

Gholz, H. L., F. K. Fitz, and R. H. Waring. 1976. Leaf area differences associated with old-growth forest communities in the western Oregon Cascades. Canadian Journal of Forest Resarch 6:49-57.

Gholz, H. L., C. C. Grier, A. G. Campbell, and A. T. Brown. 1979. Equations for estimating biomass and leaf area for plants in the Pacific Northwest. Research Paper 41, College of Forestry, Oregon State university, Corvallis, OR. 39 p.

Grier, C. C. and R. S Logan. 1977. Old-growth Pseudotsuga menziesii communities of a western Oregon watershed: biomass distribution and production budgets. Ecological Monographs 47:373-400.

Harmon, M. E., and J. Sexton. 1996. Guidelines for measurements of woody detritus in forest ecosystems. LTER Network Publication No. 20. University of Washington, Seattle, WA. 91 p.

Harmon, M. E. and Chen, H. 1991. Coarse woody debris dynamics in two old-growth ecosystems: Changbai Mountain Biosphere Reserve, People's Republic of China and H. J. Andrews Experimental Forest, USA. Bioscience 41: 604-610 .

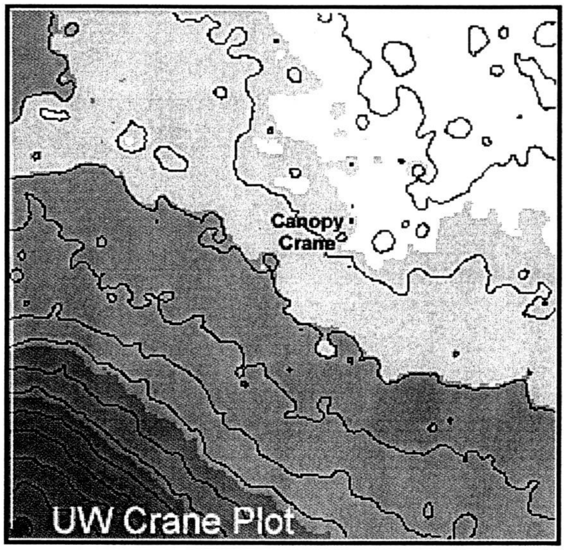
Means, J. E., H. A. Hansen, G. J. Koerper, P. B. Alaback, and Mark W. Klopsch. 1994. Software for computing plant biomass- BIOPAK users guide. USDA Forest Service General Technical Report PNW-GTR-340. 184 p.

Remillard, S. M., P. S. Homann, B. T. Bormann, and M. E. Harmon. 1997. Distribution of soil organic carbon and its relation to climate and site characteristics in western Oregon and Washington. Soil Science Society of America Annual Meeting, Anaheim, CA.

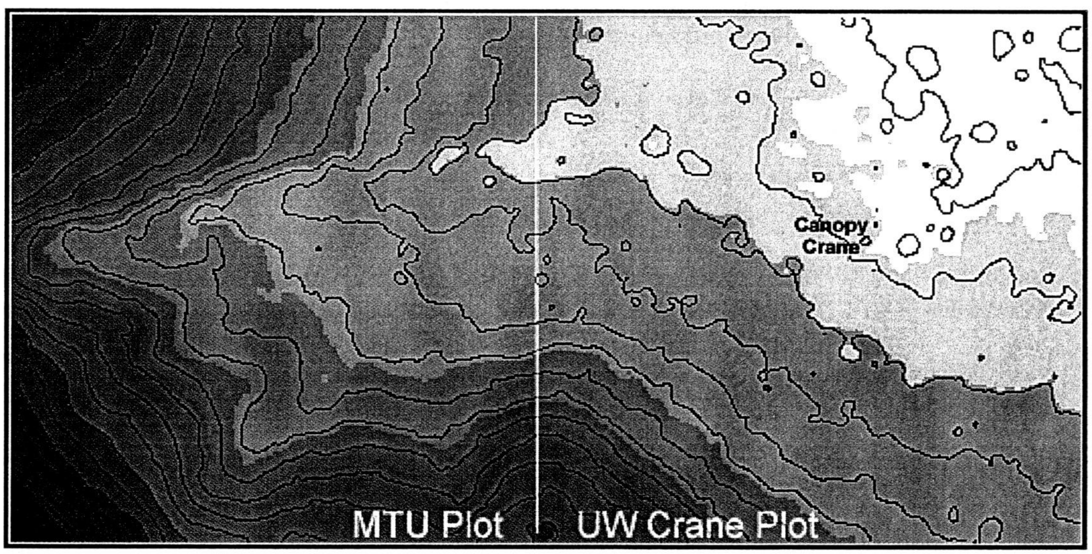
Waring, R. H., P. E. Schroeder, and R. Oren. 1982. Application of the pipe model theory to predict canopy leaf area. Canadian Journal of Forest Research 12:556-560.

WRCCRF DB: 4 ha "Crane Plot" and 8 ha "Extended Plot" DEM image

DEM images provided by Dr. Jiquan Chen, Michigan Tech.



Contour map 1 m resolution (200 m x 200 m; North is up)



Contour map 1 m resolution (200 m x 400 m; North is up)

WRCCRF DB: 4 ha "Crane Plot" Grid and Tree Stemmap

Plot Grid

In 1994, the boundaries of the 4 ha square "crane plot" were established by a licensed surveyor on the T. T. Munger RNA (Figure 1). The plot is divided into 4, 1 ha square quadrants (quadrant 0 = NE, 1 = SE, 2 = SW, 3 = NW) each of which is further divided into 16 numbered 25 m x 25 m subplots. Plot and subplot corners are numbered and monumented with iron bars and vinyl surveyor caps. In 1995 a free-standing tower crane was installed at X=105.80, Y=103.36 (Lat. 45 deg. 49' 13.76" N, Long. 121 deg. 57' 06.88") on the crane plot. The maximum reach of the crane's load jib is approximately 85m and defines the "crane circle".

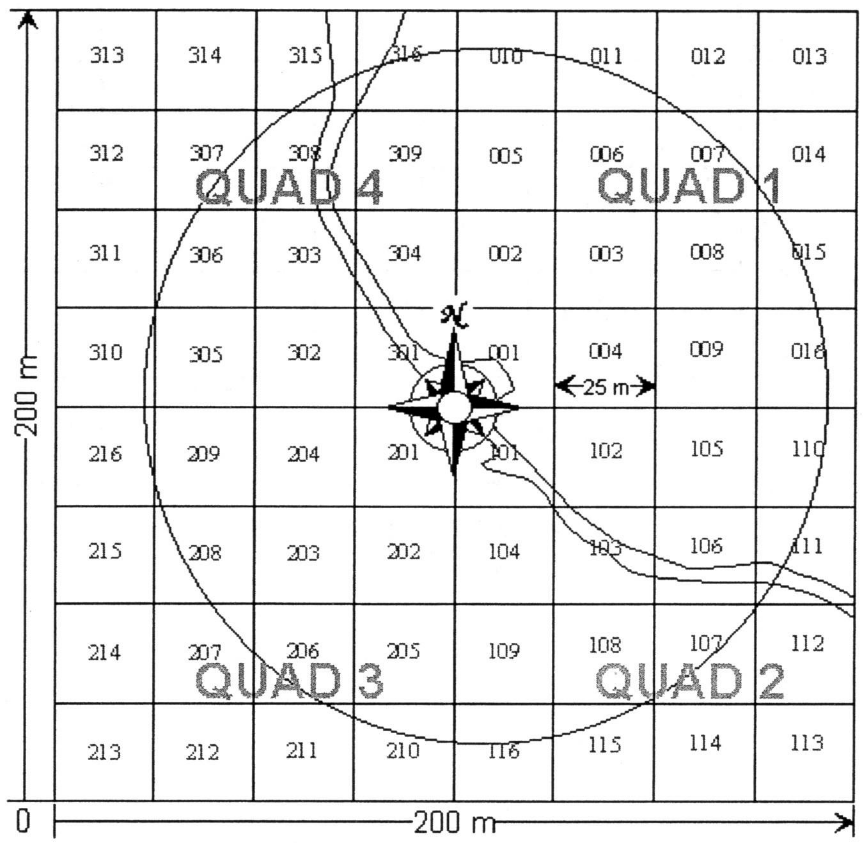


Figure 1. The master grid of the WRCCRF 4 ha "crane plot".

Tree Stemmap

Following establishment of the crane plot, a tree stemmap was constructed (Figure 2). All tree species equal to or greater than 5 cm in diameter at 1.37m above the forest floor (DBH) were tagged with aluminum tree tags. Tags begin with a C to signify their inclusion into the crane plot population. Tree locations were determined using a Criterion 400 laser range finder (Laser Technologies Inc.). Distances and angles to each tree's apparent central axis were measured from each of the 4 surrounding subplot corners. Given a clear line of sight, 4 measurements per individual could be obtained; however, given occluded vision fewer measurements may have been recorded. Distances and angles were processed through a triangulation routine which resulted in an averaged XY coordinate for each tree (*see* Elizabeth Freeman, University of Washington Masters Thesis). Cosign corrected vertical height of each tree was also recorded using lasers with smaller individuals begin measured via height poles. Go to tree stemmap data request page.

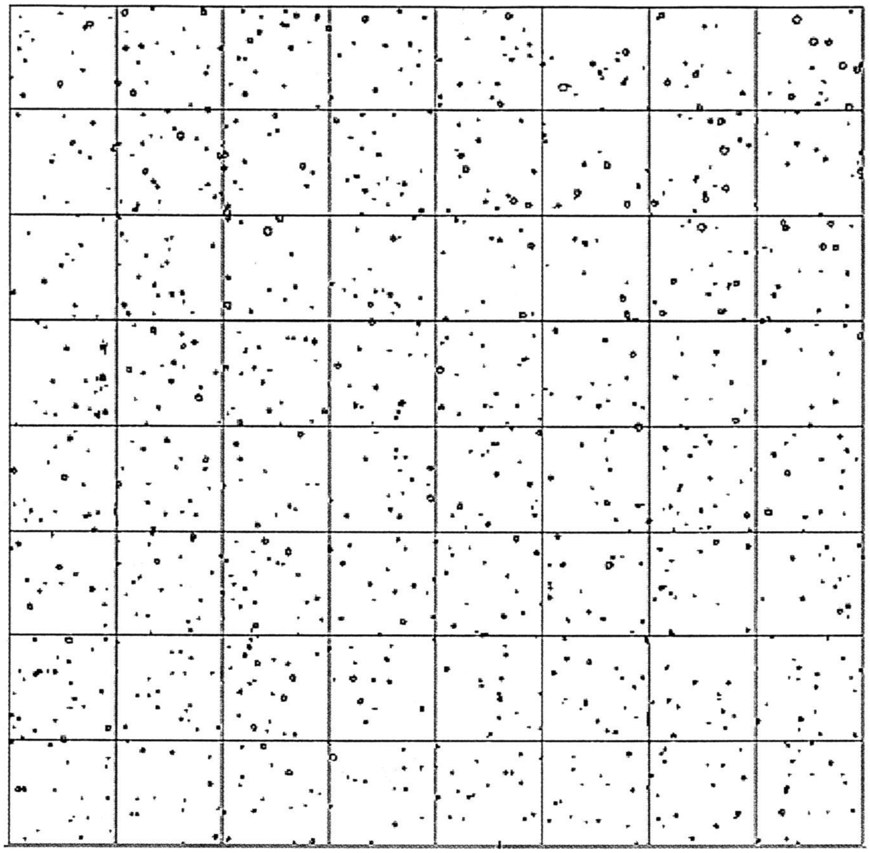


Figure 2. General spatial pattern of large trees on the 4 ha "crane plot".

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WRCCRF DB: 4 ha "Crane Plot" Conifer TPH, Biomass, etc.

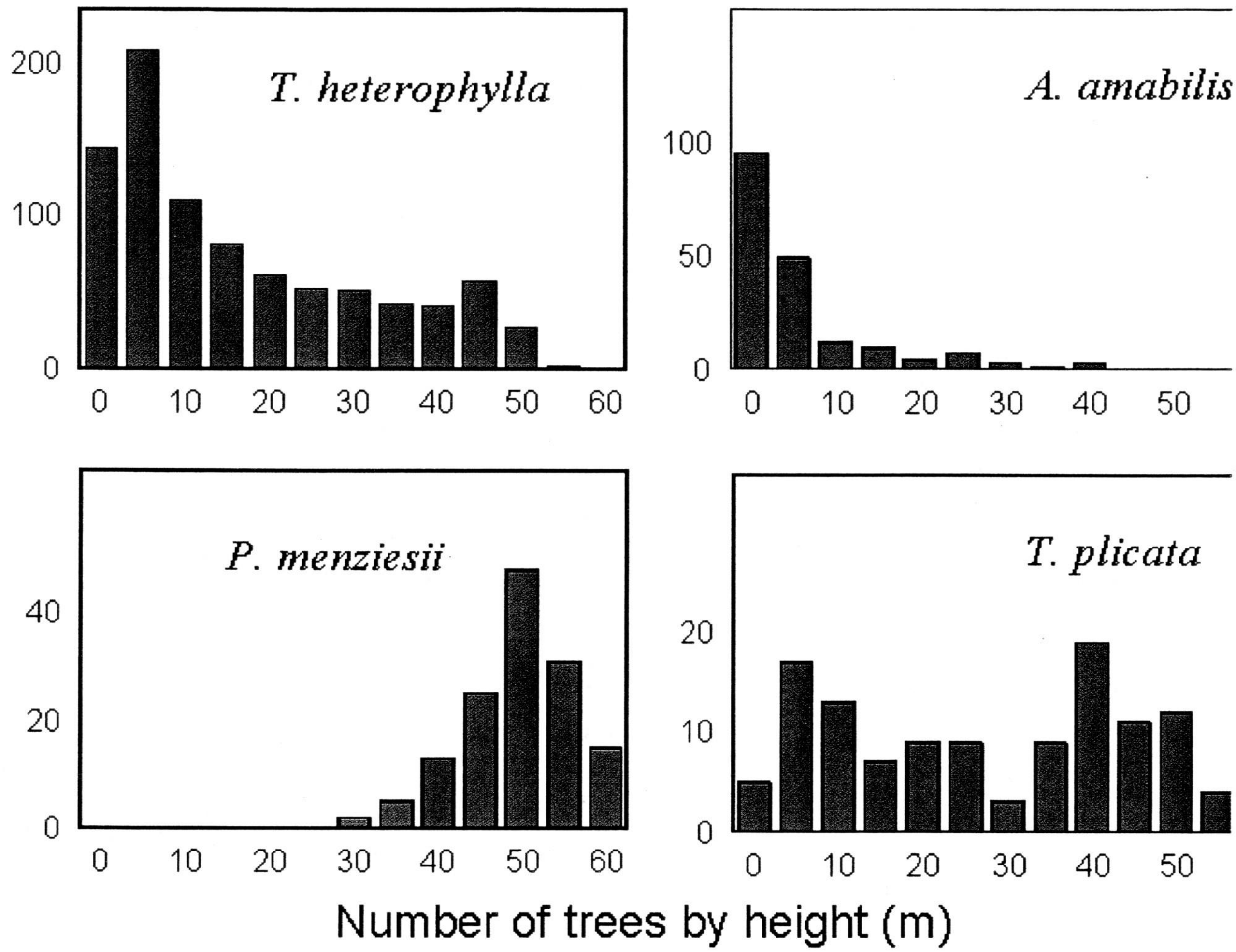
(Rev. 10/4/98)

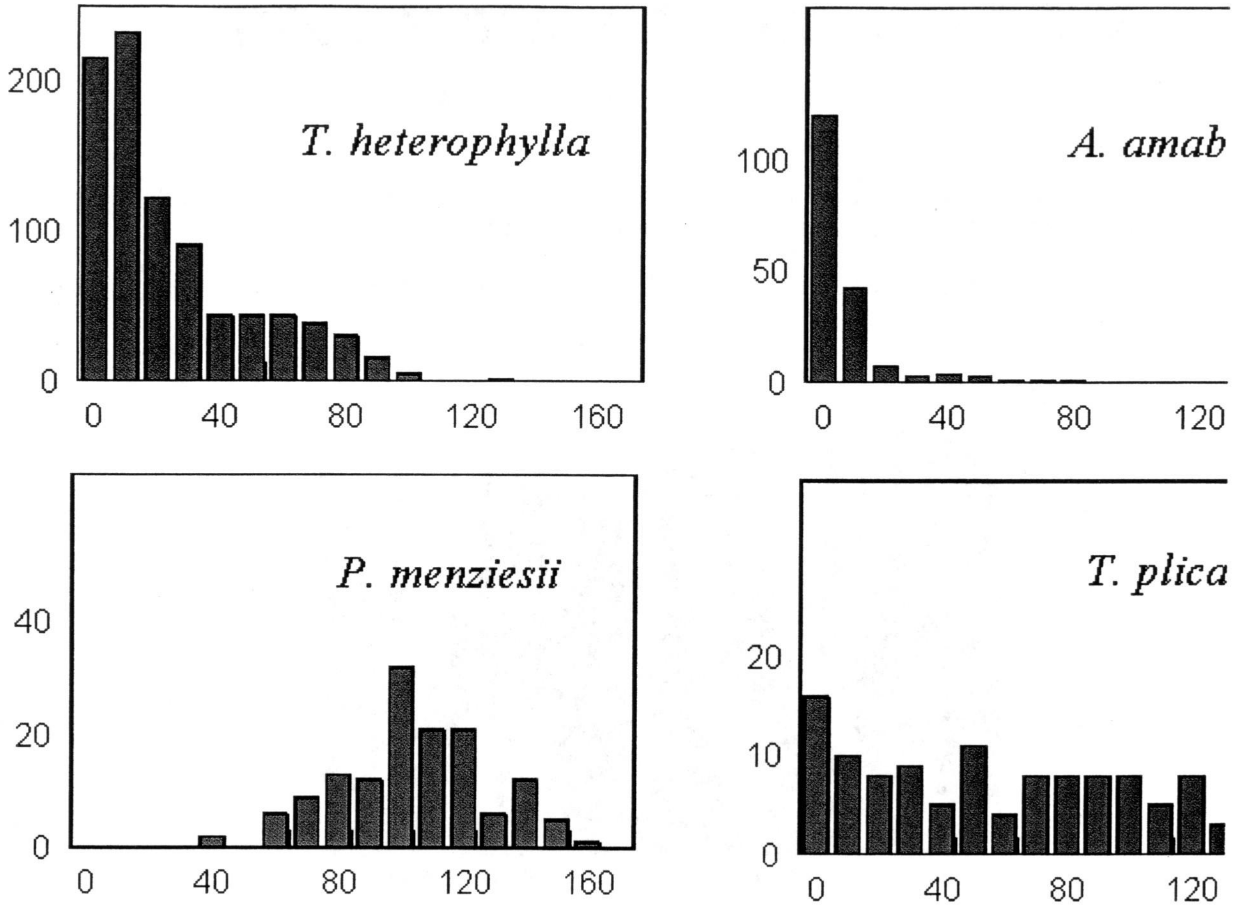
	ABIES	PSME	TABR	THPL	TSHE	TOTAL
Trees per ha	54	37	89	30	225	**435**
Stem wood (m3/ha)	32.48	569.37	NC	202.72	385.07	**1,189.64**
Stem bark (m3/ha)	2.86	125.96	NC	11.90	41.23	**181.95**
Sapwood (m3/ha)	11.63	105.40	NC	16.97	171.16	**305.16**
Sapwood area (m2/ha) *	NC	4.63	NC	1.41	1.73	**7.77**
Basal area (m2/ha)	2.39	35.57	2.01	16.32	25.81	**82.10**
total leaf area (m2/m2)	1.49	11.42	0.59	2.74	18.21	**34.45**
Stem wood (Mg/ha)	12.99	257.35	10.20	63.25	162.12	**505.91**
Stem bark (Mg/ha)	1.63	55.17	1.49	3.96	17.11	**79.37**
Branches live (Mg/ha)	1.90	21.77	0.76	10.99	49.40	**84.81**
Branches dead (Mg/ha)	NC	4.05	0.35	1.09	1.91	**7.39**
Foliage total leaf area (Mg/ha)	0.68	6.55	0.38	3.01	8.94	**19.56**
Roots coarse (Mg/ha)	NC	98.27	2.21	44.70	48.28	**193.45**
TOTAL Biomass (Mg/ha)	**17.20**	**443.15**	**15.39**	**126.99**	**287.75**	**890.49**

NC = not calculated

* THPL > 15 cm and TSHE > 13 cm DBH

WRCCRF DB: 4 ha "Crane Plot" Tree Diameter and Height Distributions





Number of trees by diameter at breast height
(DBH in cm at 1.37 meters above forest floor)

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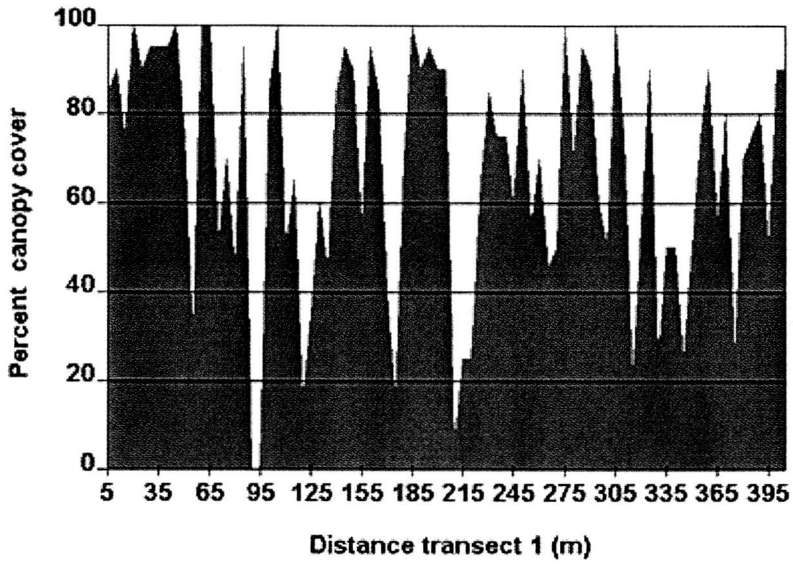
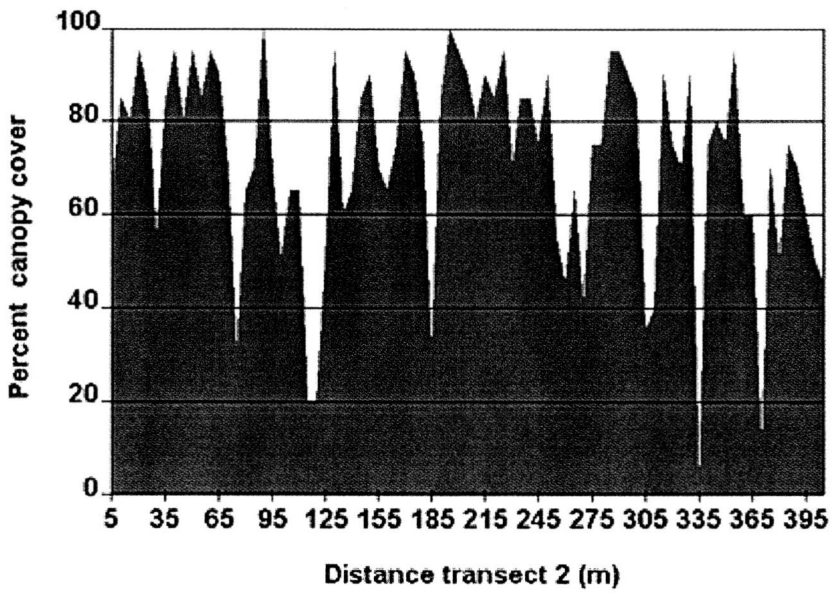
WRCCRF DB: 400 Meter Canopy Cover Transects

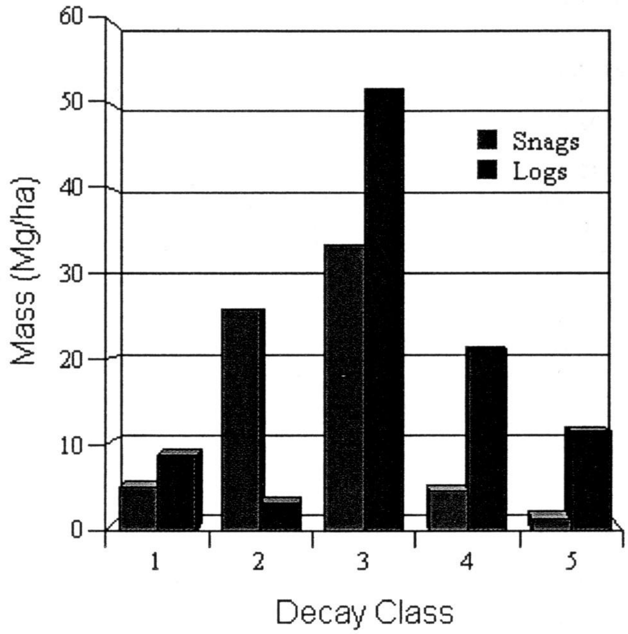
Canopy cover results in press: Song, Bo et. al. In Press. Canopy Structure of an Old-growth Douglas-fir Forest at the Wind River Canopy Crane Research Facility (WRCCRF) Area.

Both transects begin at EAST boundary of the 4 ha crane plot and extend west 400 meters. Canopy percent cover was estimated every 5 meters.

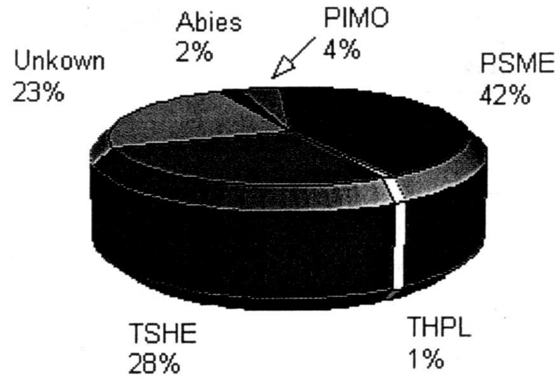




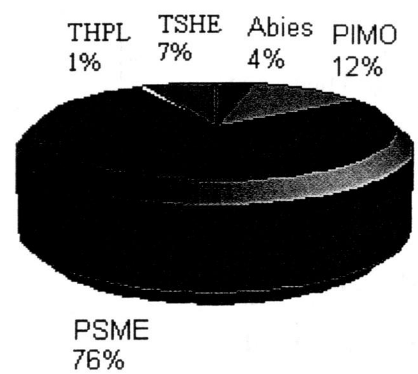
WRCCRF DB: 4 ha "Crane Plot" CWD



Mass of CWD by Decay Class



Mass CWD-Logs Total = 93.9 Mg/ha



Mass CWD-Snags Total = 67.7 Mg/ha

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WRCCRF DB: 12 ha Carbon Stocks

Rev. 10/4/98
Table courtesy of Dr. Mark E. Harmon Oregon State University

Component	**Carbon Store MgC/ha**
Live	**402.5**
Stem Wood	237.3
Stem Bark	36.0
Live branches	43.0
Dead branches	3.2
Foliage	5.0
Coarse roots	78.0
Fine roots	10.0
Detritus	**118.6**
Snags	34.2
Logs	47.4
Downed fine wood	4.5
Suspended fine wood	3.5
Dead coarse roots	10.0
Forest floor (O1+O2)	19.0
Mineral Soil	**93.0**
Ecosystem Total	**614.1**