ESTIMATION OF ABOVEGROUND EASTERN REDCEDAR BIOMASS

By

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ESTIMATION OF ABOVEGROUND

EASTERN REDCEDAR

BIOMASS

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INTRODUCTION

In the past, eastern redcedar (Juniperus virginiana L.) was considered to be a weed that invaded Oklahoma's rangelands and was either burned or destroyed in some other way. However, because new uses have been developed and since it occupies such a large area throughout the state, eastern redcedar is now being viewed by some as a resource.

According to a survey by the Soil Conservation Service in 1985, eastern redcedar exists in heavy concentrations throughout much of the state (Snook 1985). Eastern redcedar can be found on its native range in 73 of the 77 counties in Oklahoma (Atkinson 1985). It is now estimated that there are 2.4 to 3.2 million hectares of eastern redcedar in the state (Bidwell and Stritzke 1989). Eastern redcedar seed can quickly be dispersed by birds and other wildlife. This acreage of eastern redcedar continues to increase because (1) of the quickness with which redcedar can regenerate, (2) it is adaptable to a variety of different sites, (3) of continued fire control efforts, and (4) control programs have been only mildly effective. This large area of

eastern redcedar suggests that an eastern redcedar industry may be sustainable over a long period of time.

Some uses for eastern redcedar have existed for many years while other uses are relatively new. Perhaps the oldest use for eastern redcedar is for fence posts, due to the durability of its heartwood. Other products of eastern redcedar wood include furniture, novelty items, closet linings, and wood shavings, which are used for pet bedding.

Eastern redcedar contains oils that are extracted commercially from the bolewood. These oils are used widely in the manufacturing of perfumes, shampoos, medicines, cold cremes, furniture polishes, soaps, and detergents. The oil contained in eastern redcedar wood is also used as an environmentally safe and natural insecticide (Adams et al. 1988). Research has shown that the highest yield of eastern redcedar oil comes from the heartwood (Runeberg 1960).

The heartwood of the tree is prized for its red to purple color, its spicy aroma, its durability, and its stability (Craighead 1985). The heartwood of eastern redcedar is more durable than the sapwood and is preferred in the making of eastern redcedar products which require durability. However, a mix of heartwood and sapwood is preferred in products where color and

visual qualities are more important than durability. Older trees generally have a higher proportion of heartwood, which is of greater value than the sapwood (Hoffmann and Smith 1988). Because the relative amounts of heartwood and sapwood can affect product value, the eastern redcedar industry is interested in easy, cost effective ways to predict the heartwood and sapwood biomass of standing trees.

Current Situation

Over the past few years, interest in eastern redcedar products has grown and an effort has been made to establish a viable eastern redcedar industry in Oklahoma. Several sawmills, which primarily process eastern redcedar, have been established across the state. Oklahoma eastern redcedar has been exported to other areas of the United States and to other countries. The establishment of an eastern redcedar industry in Oklahoma, is seen as an excellent opportunity to add to the economy of the state. A sustainable eastern redcedar industry would reduce the costs of clearing land for farmers and add to the economy of the state by providing new jobs.

Purpose

The purpose of this study is to provide information about eastern redcedar biomass (weight) which will aid in the development of a sustainable eastern redcedar industry in Oklahoma. This biomass information will be a great benefit to the makers of eastern redcedar products. This information will allow biomass for entire stands to be estimated using easily measured variables. Estimated fresh weights could be used by persons hauling trees to a mill. The data will also assist in the development of practices, such as pruning or thinning, which will aid in managing eastern redcedar for long term sustainability. No data for biomass estimation of eastern redcedar in Oklahoma currently exists. Previous biomass work on redcedar in Tennessee did not provide detailed site and stand conditions and therefore is of limited applicability to Oklahoma (Schnell 1976).

Objectives

The specific objectives of this study were to (1) develop reliable regression equations that would estimate eastern redcedar biomass by component part, (2) determine the effect that stand density and size class have on the biomass of various tree components, and (3) determine the proportion of heartwood, sapwood, and bark in relation to the entire bole.

Using regression equations for the purpose of predicting biomass of component tree parts from more easily measured tree variables (dbh, height, etc.) has proven to be a highly reliable method (Young 1976). The successful attainment of these objectives will facilitate further product development and contribute to the development of a sustainable eastern redcedar industry.

MATERIALS AND METHODS

Tree Selection Criteria

A total of 14 trees were selected, based on diameter class and stand density, from areas of high eastern redcedar concentration within the state. A number of different sites and soils were examined, but the sample sites were limited to where appropriate sample trees could be found (Table 1 and Figure 1). Trees were selected based on dbh (diameter at breast height) classes ranging from 12.7 centimeters to 48.3 centimeters (5 inches to 19 inches). These sample trees represent the size classes commonly harvested in Oklahoma for wood products. Stand density was examined by selecting trees that were either open or closed grown. Open grown trees were considered to be trees that were found in areas of low stand density and were free of other large trees on all sides. Closed grown trees were located in areas of high stand density where they were surrounded by other trees. All closed grown trees showed evidence of dead branches on the lower portion of the tree bole.

Table 1. Description of sample locations where eastern redcedar trees were collected.

County	Number of Trees Sampled	Physiographic Description	Major Soil Series
Dewey	2	Upland canyon on red -bed hills	Quinlan loam Woodward loam
Kingfisher	4	Sand hills north of Cimarron River	Dougherty loamy fine sand Eufaula loamy fine sand
Payne	5	Sloping uplands over sandstone	Stephenville fine sandy loam Darnell fine sandy loam
Woodward	3	Sandy uplands north of N. Canadian River	Nobscot fine sand Pratt loamy fine sand

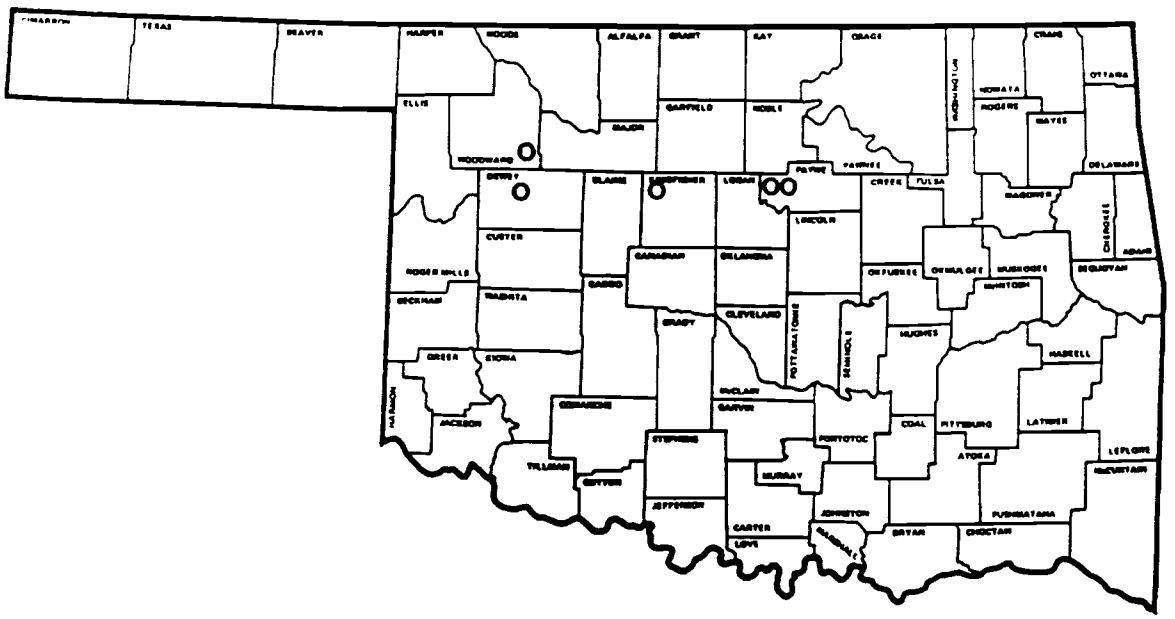

Figure 1.[1] Map of Oklahoma showing locations where sample trees were collected.

[1]More than one sample tree was harvested at some locations.

Field Work and Data Collection

Once a tree was selected for sampling, dbh and crown diameter were measured. Crown diameter was determined by calculating the average of two measurements taken at right angles about the tree. The tree was then cut at ground level and live crown length was measured. Ten live sample branches that were at least 2.54 centimeters (1 inch) in diameter at their base were selected (Appendices B1 - B14). The sample branches were selected evenly throughout the crown based on live crown length. Using calipers, the sample branches were divided by diameter into three categories: (1) < 0.64 centimeters (1/4 inch), (2) 0.64-2.54 centimeters (1/4-1 inch), and (3) >2.54 centimeters (1 inch). Anything < 0.64 centimeters (1/4 inch) contained mostly leaves and was therefore considered to be foliage. The division at 2.54 centimeters (1 inch) was made because preliminary study showed this to be the point where heartwood begins to appear in the wood. The fresh weight was recorded for each category of branches. The samples were then placed in paper bags and returned to the lab to be dried. Foliage samples were placed in cold storage until they were ready to be dried in order to prevent any weight loss to respiration or decomposition of the samples.

The remaining live branches were removed from the tree and weighed. A small bag of dead branches was randomly selected from the tree, weighed, and returned to the lab to be dried. The remaining dead branches were removed from the tree and their fresh weights determined. After all of the branches were removed from the tree, tree height and tree height to a 7.62 centimeter (3 inch) top were measured and recorded.

The bole of each tree was divided into five equal sections with each section representing 20 percent of the bole length. A sample disk about 2.5 to 7.6 centimeters (1 to 3 inches) thick was cut from the base of each section. The disks were numbered 1 to 5, with 1 representing the bottom bole section of the tree and 5 representing the top bole section of the tree. Each sample disk was then weighed, bagged, and returned to the lab where it was placed in cold storage. A sample log approximately 0.3 meters (1 foot) in length was cut from the base of the bole, to be used by other scientists for oil analysis. The sample log was weighed and it's weight was added in with the bole weight. The remaining parts of the bole were then cut into weighable segments and their fresh weights were recorded.

Laboratory

The samples of dead branches, the samples of live branches, and the foliage samples were oven dried (at 67 degrees Celsius) to a constant weight and these dry weights were recorded. The age of each disk was then determined using caution to avoid counting the many false rings that are found in eastern redcedar (Kuo and McGinnes 1973). Several radial and diameter measurements were taken on the heartwood, sapwood, and bark of each sample disk so that the cross sectional surface area of each component could be determined. Eight radial measurements of the bark and sapwood were taken and 4 diameter measurements were obtained from the heartwood (Appendices C1-C14). Figure 2 shows a cross section of a tree bole with the outside ring being bark, the middle ring being sapwood, and the inside ring being heartwood. Several radial measurements were needed because of the irregularity in the shape of the heartwood and sapwood. The heartwood, sapwood, and bark were then separated from each of the sample disks, using wood chisels, and the fresh weights of each component were recorded. The samples were then dried to a constant weight and the dry weights were recorded. These data were used to determine the percentage of heartwood, sapwood, and bark in the bole by fresh weight and dry weight.

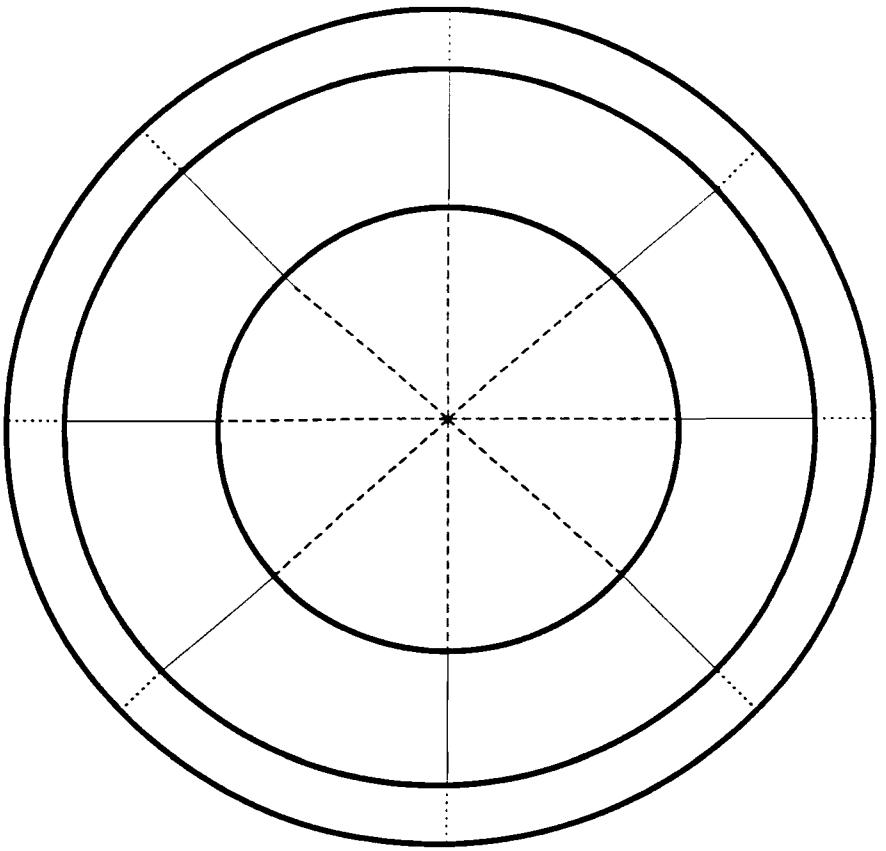

Figure 2. Location of the eight radial measurements for bark (.....) and sapwood (———) and four diameter measurements for heartwood (-----) on each sample disk.

Analysis

The components evaluated for each tree were foliage, 0.64-2.54 cm branchwood, > 2.54 cm branchwood, total live branches and foliage, dead branches, heartwood, sapwood, bark, and total bolewood. Data obtained from drying the branch and disk samples were used in conjunction with the fresh weight of each tree, to determine total dry weights for each of the tree components. The radial measurements taken on the heartwood, sapwood, and bark components of each disk were used to determine the percentage of each component in the bole by cross sectional surface area. Fresh and dry weights of open and closed grown trees were then subjected to a standard regression analysis, using a variety of different independent variables, in order to determine the equation that best predicted biomass by component part. The cross sectional area of sapwood near the base of the live crown, for open and closed grown trees, was determined from the radial measurements taken on the sample disk that was closest to the live crown base for each tree.

RESULTS AND DISCUSSION

Basic Data

The results of this study include information obtained from the sampling of eastern redcedar trees. Of the 14 sample trees, 8 were open grown and 6 were closed grown. The values and means of the values representing dbh, age, height, crown diameter, crown length values, and dry weights of the live crown and bolewood, for open and closed grown trees, are provided in Table 2. A paired t-test was conducted and showed that the open grown trees had significantly larger live crown weights than the closed grown trees as shown in Figure 3 ($P < .01$). While open grown trees had a crown/tree length ratio of 100 percent (live branches were found along the entire length of the bole), the ratios on the closed grown trees ranged from 35 to 79 percent. Figure 3 suggests that open grown trees put more energy into producing branches and foliage than closed grown trees do. Original data for each sample tree is provided in Appendices A1 through A14.

Table 2. Basic data for the sample trees.

OPEN GROWN

Tree #	DBH (cm)	Age (years)	Tree Height (m)	Crown Dia. (m)	Live Crown Length (m)	Live Crown Dry Weight (kg)	Dry Weight of Bolewood (kg)
13	14.48	22	5.73	4.77	5.73	121.70	30.30
3	19.33	31	6.84	6.80	6.84	227.12	46.72
2	23.37	32	9.24	7.50	9.24	264.60	94.78
8	28.07	47	8.60	7.28	8.60	395.64	113.49
12	33.02	38	9.44	9.49	9.44	510.00	146.98
14	38.86	55	11.46	7.16	11.46	483.80	215.30
4	45.47	61	10.59	10.67	10.59	690.33	291.47
6	50.17	51	11.37	11.55	11.37	607.77	293.45
Mean	31.59	42.13	9.16	8.15	9.16	412.62	154.06

CLOSED GROWN

Tree #	DBH (cm)	Age (years)	Tree Height (m)	Crown Dia. (m)	Live Crown Length (m)	Live Crown Dry Weight (kg)	Dry Weight of Bolewood (kg)
9	13.34	52	8.56	2.51	2.99	9.78	27.26
5	16.64	45	8.32	4.34	6.55	29.83	39.42
1	23.62	70	11.00	4.36	6.25	60.97	100.82
11	28.14	78	15.97	3.54	7.65	80.93	205.60
7	33.48	63	14.51	5.43	8.90	111.02	245.32
10	37.34	82	18.04	6.64	9.02	153.03	383.20
Mean	25.43	65.00	12.74	4.47	6.89	74.26	166.94

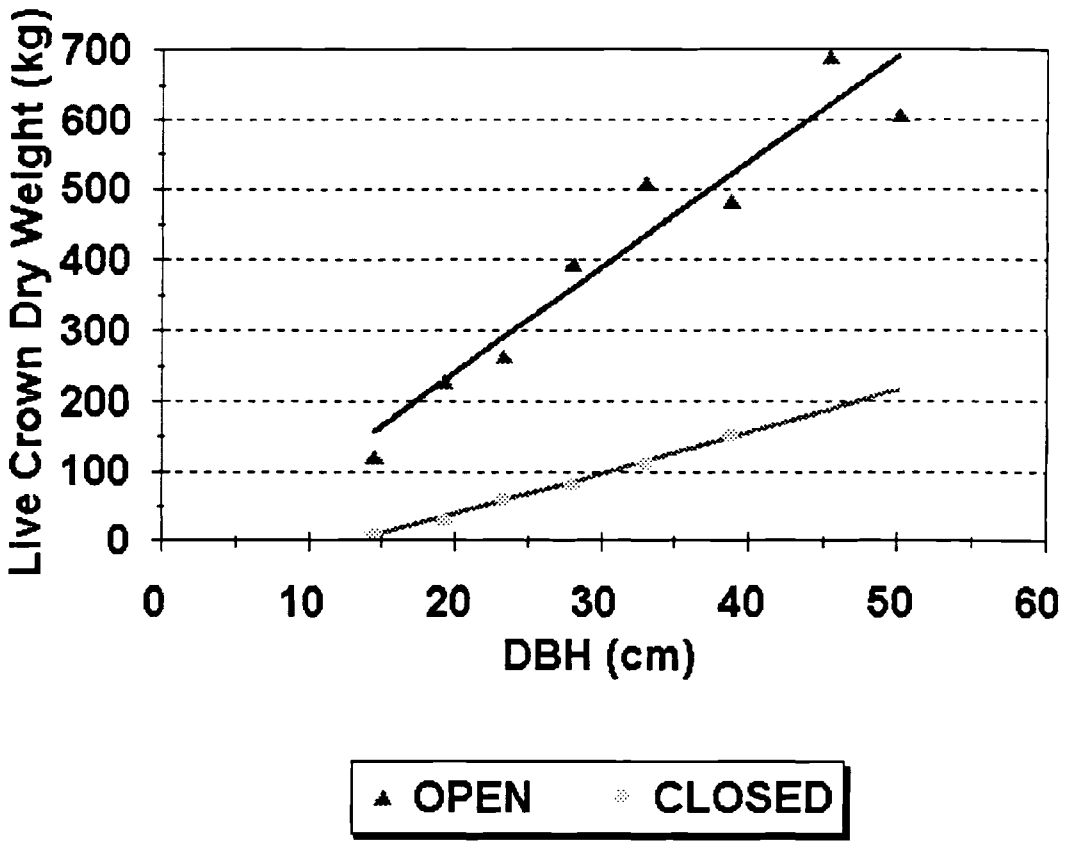

Figure 3. Dry weight of the live crown versus dbh for open and closed grown sample trees.

Predictor Equations

Initially, several simple regression equations were developed and examined using dbh, dbh^2, basal area, basal $area^2$, tree height, crown length, and crown diameter as independent variables to predict biomass of the sample trees by component. Evaluation of the standard errors of the Y estimates and r^2 (coefficient of determination) values showed that dbh gave the best overall predictions of biomass by component. The r^2 values were generally better for the dry weights, probably because the dry weights eliminate the variation due to moisture content. The r^2 values were generally better for major components such as the bolewood.

Several dual multiple regression equations were also developed using the before mentioned independent variables in all possible combinations. With the exception of the foliage and 0.64-2.54 centimeter branch components, multiple regression techniques did not improve or only slightly improved on most of the simple regression estimates. However, for those interested the simple or multiple regression equation that best predicted biomass for each component is included in Appendices D1-D4. The dbh measurement was chosen as the independent variable because it gave the best

overall estimates for a single variable, because it can be easily obtained in the field and because it can be easily applied to the predictor equations.

The result was the development of a prediction equation in the following form:

$$Y_i = b_0 + b_1(x)$$

where

Y = predicted biomass (kg)

i = tree component

b_0 = intercept

b_1 = slope

x = dbh (cm)

The equations needed for the prediction of biomass by component are provided in Table 3. These equations use dbh to predict the fresh and dry biomass of open and closed grown trees, by component. Dried biomass, by component, for a 28 centimeter (11 inch) diameter open and closed grown tree was predicted using the regression equations and was then compared to actual data for both a 28 centimeter open and closed grown tree (Table 4). Dry weights were predicted to eliminate variation due to moisture content.

Table 3.[1] Prediction equations for eastern redcedar biomass from dbh.

	OPEN GROWN					
	FRESH WEIGHT			DRY WEIGHT		
COMPONENT	b_0	b_1	R^2	b_0	b_1	R^2
Bolewood	-152.27	13.52	0.96	-100.68	8.06	0.98
Heartwood	-98.00	6.40	0.97	-79.07	5.00	0.97
Sapwood	-44.89	6.33	0.82	-15.54	2.55	0.83
Bark	-9.38	0.79	0.94	-6.07	0.51	0.93
Live Br&Fol	-26.03	23.54	0.85	-59.31	14.94	0.92
Foliage	119.88	5.42	0.49	51.95	3.60	0.63
1/4-1"Branch	28.80	3.13	0.51	7.56	2.08	0.58
>1"Branch	-174.72	14.99	0.85	-118.82	9.26	0.87
Dead Branches	-16.24	0.81	0.77	-14.65	0.73	0.76
Total Tree	-194.54	37.87	0.93	-174.63	23.73	0.96

	CLOSED GROWN					
	FRESH WEIGHT			DRY WEIGHT		
COMPONENT	b_0	b_1	R^2	b_0	b_1	R^2
Bolewood	-294.04	22.49	0.96	-193.06	14.16	0.93
Heartwood	-178.10	12.38	0.89	-133.80	9.24	0.89
Sapwood	-98.83	8.75	0.95	-44.70	3.92	0.98
Bark	-19.49	1.39	0.78	-14.56	1.00	0.71
Live Br&Fol	-106.77	9.34	0.99	-66.86	5.55	0.98
Foliage	-34.80	3.60	0.92	-22.56	2.09	0.97
1/4-1"Branch	-16.58	1.75	0.91	-11.20	1.10	0.85
>1"Branch	-55.38	3.99	0.98	-33.10	2.36	0.99
Dead Branches	-26.53	2.37	0.66	-24.84	2.14	0.70
Total Tree	-427.34	34.20	0.98	-284.75	21.85	0.95

[1] $y = b_0 + b_1$ (dbh) Y is the predicted biomass in kilograms and dbh is in centimeters.

Table 4.[1] Predicted versus actual biomass.

	OPEN GROWN				CLOSED GROWN			
COMPONENT	PREDICTED		ACTUAL		PREDICTED		ACTUAL	
Heartwood	61.4	(12.5%)	44.1	(8.6%)	126.2	(38.2%)	118.8	(38.6%)
Sapwood	55.9	(11.4%)	61.9	(12.1%)	65.6	(19.9%)	70.9	(23.0%)
Bark	8.4	(1.7%)	7.4	(1.4%)	13.6	(4.1%)	15.9	(5.2%)
Foliage	152.9	(31.1%)	213.5	(41.8%)	36.2	(11.0%)	33.7	(11.0%)
1/4 - 1" Branches	66.0	(13.4%)	61.8	(12.1%)	19.8	(6.0%)	16.2	(5.3%)
> 1" Branches	141.1	(28.7%)	120.4	(23.6%)	33.4	(10.1%)	31.1	(10.1%)
Dead Branches	5.8	(1.2%)	1.5	(< 1%)	35.3	(10.7%)	20.9	(6.8%)
Total	491.5	(100%)	510.6	(100%)	330.1	(100%)	307.5	(100%)

[1] Biomass is reported as dry weight in kg and as a % of total tree dry weight.
Dbh for the open grown tree was 28.07 cm and dbh for the closed grown tree was 28.14 cm.

Looking at the actual data in Table 4, the heartwood for the open grown tree is about 9 percent of the total tree dry weight, while the heartwood is about 39 percent of the total tree dry weight for the closed grown tree. Total bolewood accounts for only about 21 percent of the weight of the open grown tree, while it accounts for about 62 percent of the total weight of the closed grown tree. About 78 percent of the total dry tree weight for the open grown tree was live branches and foliage, compared to only 33 percent for the closed grown tree. The closed grown tree also had a much higher percentage of dead branches. The fact that the closed grown trees had a greater percentage of heartwood may be attributed to the fact that they were much older than the open grown trees (Table 2). Due to the competition that closed grown trees are under, they cannot put on a lot of branches and foliage, so their growth is slowed and a higher percentage of heartwood is present (Sellin 1994).

When comparing the actual versus predicted values, the percentages of the values were generally close. For the open grown tree, the total predicted weight was off by less than 4 percent and for the closed grown tree the difference was 7 percent. The prediction of the foliage on the open grown tree was underestimated by about 11 percent. This may be attributed to the

fact that the tree used in this example had a large amount of foliage. This 28 centimeter diameter tree had more foliage than either the 33 or 38 centimeter diameter sample tree. This large amount of variation is probably why the r^2 value for the fresh weight of the foliage was low. Overall the prediction equations seemed to be reliable, being slightly better for the major components (such as bolewood) than for the minor components (such as dead branches).

Heartwood / Sapwood Distribution

Table 5 shows the proportion of the bolewood that is heartwood, sapwood, and bark by fresh weight, dry weight, and cross sectional surface area, for open and closed grown trees. For the open grown tree, 34 percent of the fresh weight of the bole was heartwood, while 50 percent of the fresh weight of the bole was heartwood for the closed grown tree. One reason for the increase in the percentage of heartwood in closed grown trees may be that, when compared to open grown trees of the same dbh, the closed grown trees were found to be much older. Previous research on Norway spruce (Picea abies) has shown this to be true (Sellin 1994). Because the closed grown trees in this study contain a greater percentage of heartwood than a

Table 5. Proportion of heartwood, sapwood, and bark.

AVERAGE % OF TOTAL BOLE BY FRESH WEIGHT

	OPEN GROWN			CLOSED GROWN		
Section[1]	Heartwood	Sapwood	Bark	Heartwood	Sapwood	Bark
1	34.6	59.0	6.4	46.8	46.9	6.3
2	39.7	55.6	4.7	52.8	42.6	4.6
3	26.6	67.8	5.6	45.5	49.4	5.1
4	20.0	73.3	6.7	30.4	65.1	4.5
5	3.5	89.3	7.2	11.0	84.5	4.5

AVERAGE % OF TOTAL BOLE BY DRY WEIGHT

	OPEN GROWN			CLOSED GROWN		
Section[1]	Heartwood	Sapwood	Bark	Heartwood	Sapwood	Bark
1	46.3	46.1	7.6	57.6	35.5	6.9
2	51.3	43.5	5.2	63.7	31.1	5.2
3	35.9	57.3	6.8	57.3	37.8	4.9
4	25.1	66.2	8.7	41.1	55.0	3.9
5	6.7	93.3	0.0	4.9	95.1	0.0

AVERAGE % OF TOTAL BOLE BY CROSS SECTIONAL SURFACE AREA

	OPEN GROWN			CLOSED GROWN		
Section[1]	Heartwood	Sapwood	Bark	Heartwood	Sapwood	Bark
1	44.2	49.5	6.3	54.8	38.5	6.7
2	49.8	41.9	8.3	61.8	31.5	6.7
3	34.6	54.4	11.0	52.3	39.2	8.5
4	24.7	62.3	13.0	36.6	53.7	9.7
5	5.0	79.5	15.5	8.3	77.9	13.8

[1] Section refers to sample disks collected at the base of each of the 5 equal parts of the total bole length. Section 1 refers to the bottom disk of the tree and section 5 refers to the disk collected at the base of the uppermost bole section of the tree.

similar sized open grown tree, they may be more valuable to the redcedar wood industry. They may also contain fewer knots in their wood, because they are less branchy. However, the drawback to this is that the closed grown trees are older and take more time than an open grown tree to reach the same dbh.

Sapwood Cross Sectional Area

A linear best fit relationship was developed using sapwood cross sectional area near the base of the live crown to predict the dry weight of foliage (Figure 4). Previous research on loblolly pine has shown that the cross sectional area of sapwood at the live crown base is highly correlated with leaf area (Blanche et al. 1985).

A good relationship between sapwood area near the live crown base and dry weight of foliage was found (Figure 4). The equation for this relationship is $y = 24.39 + 0.17(x)$ where y is the dry weight of foliage and x is the sapwood cross sectional area near the base of the live crown. The r^2 value for this relationship is 0.84. Foliage weight increases as sapwood cross sectional area increases. This suggests that pruning open grown trees and decreasing the leaf area could increase the amount of valuable

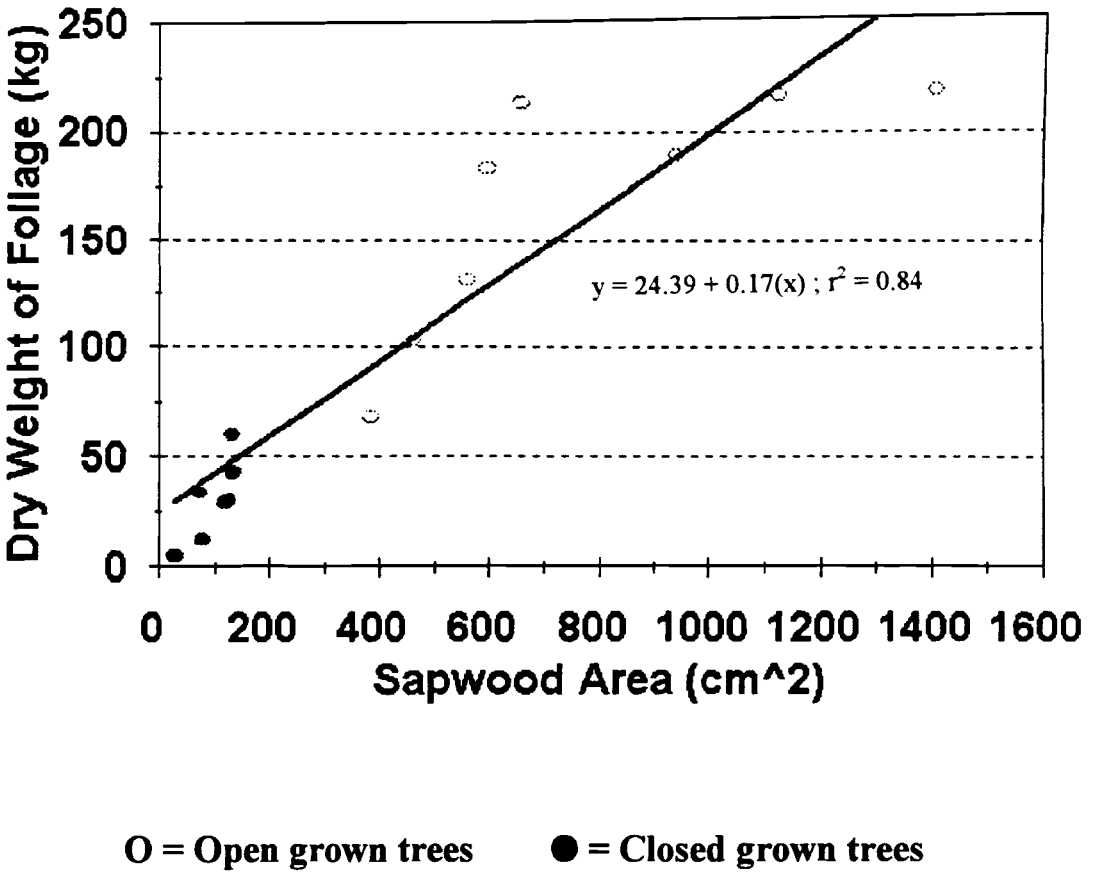

Figure 4. Relationship between sapwood area near the base of the live crown and the dry weight of the foliage.

heartwood produced. The advantage of this would be trees that produced more heartwood in a shorter time. The sapwood is the pipeline for water and nutrients to the crown of the tree. By eliminating some of the lower foliage, the tree might not need as much sapwood to provide the foliage with water and nutrients. Perhaps pruning to decrease foliage would promote more heartwood formation. However, pruning might reduce photosynthesis and carbohydrate production to such a great degree that growth would be slowed down. If growth was slowed enough it could take much longer, as it does with closed grown trees, to reach a marketable size. Further research in this area is needed to determine if pruning would increase heartwood formation in open grown trees, and if so to determine how much to prune, when to prune, etc.

Study Limitations

During the course of this research, several limitations were identified. Sample trees were harvested at different times of the year so differences in moisture content may affect fresh weight values. Trees were sampled that ranged in dbh from 12.7 to 48.3 centimeters, therefore the prediction equations may not be accurate for trees outside that dbh range. All of the

sample trees were either open or closed grown, so predictions for trees that fall in between these categories may be affected. Trees were selected on a variety of different sites but not all sites could be sampled. Therefore, the biomass prediction for trees on sites different from those sampled may be affected. Only male trees were selected for this study because female trees contain berries which could cause variation in the determination of the foliage weight. Because of this, live crown and foliage weights for female trees may be affected.

CONCLUSIONS

Regression equations are provided that predict fresh and dry biomass, by component part, for open and closed grown eastern redcedar trees. The measurement of dbh was found to be an easy and reliable independent variable to predict biomass. The regression equations were slightly better at predicting the major components (such as bolewood) than the minor components (such as dead branches). Open grown trees had more weight in live branches and foliage. Closed grown trees had a greater percentage of weight in the bole of the tree and less in the live crown. Closed grown trees of all sizes were found to contain a higher percentage of heartwood than open grown trees. This could be attributed to the fact that closed grown trees were much older than open grown trees with the same dbh. Closed grown trees may be more valuable to the manufacturers of eastern redcedar products since heartwood is preferred in both the wood and oil industries. A good relationship was found to exist between sapwood area near the base of the

live crown and foliage. Further research in determining how open grown trees could be stimulated to produce more heartwood, in looking at age to predict heartwood formation, and in studying below ground biomass to predict heartwood would be useful.

LITERATURE CITED

Adams, R.P., F.L. Carter, and C.A. McDaniel. 1988. Termiticidal activities in the heartwood, bark/sapwood and leaves of Juniperus species from the United States. Biochem. Syst. Ecol. 16:453-456.

Atkinson, K.L. 1985. Nursery production and distribution of eastern redcedar and its perception. P. 17-25 *in* Proc. Eastern Redcedar in Okla. Conf. E-849. Div. of Agric., Okla. State Univ., Stillwater, Okla.

Bidwell, T.G., and J.F. Stritzke. 1989. Eastern redcedar and its control. Coop. Ext. Serv., Div. of Agric., Okla. State Univ., No. 2850. 4 p.

Blanche, C.A., J.D. Hodges, and T.E. Nebeker. 1985. A leaf area-sapwood area ratio developed to rate loblolly pine tree vigor. Can. J. For. Res. 1181-1184.

Craighead, M.R. 1985. Economic potential for eastern redcedar in Oklahoma. P. 35-39 *in* Proc. Eastern Redcedar in Okla. Conf. E-849. Div. of Agric., Okla. State Univ., Stillwater, Okla.

Kuo, M.L., and E.A. Mcginnes, Jr. 1973. Variation of anatomical structure of false rings in Eastern Redcedar. Wood Science. 5:205-210.

Hoffmann, M., and R. Smith. 1988. Formation of redcedar heartwood. Unpublished manuscript. Missouri Dept. of Cons. Branson, Mo.

Runeberg, J. 1960. The chemistry of the natural order cupressales XXVIII* constituents of Juniperus virginiana L. Acta Chem. Scand. 14:1288-1294.

Schnell, R. L. 1976. Biomass estimates of eastern redcedar tree components. Div. of For., Fish., and Wild. Development, Tenn. Valley Auth. Tech. Note B15. 15 p.

Sellin, A. 1994. Sapwood-heartwood proportion related to tree diameter, age, and growth rate in Picea abies. Can. J. For. Res. 24:1022-1028.

Snook, E. C. 1985. Distribution of eastern redcedar on Oklahoma rangelands. P. 45-52 *in* Proc. Eastern Redcedar in Okla. Conf. E-849. Div. of Agric., Okla. State Univ., Stillwater, Okla.

Young, H. E. 1976. Seven wooden poles in a maginot fence. IUFRO Biomass Studies, H. Young ed. Univ. of Maine press P. 1-10.

APPENDIXES

Appendix A1. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
1	70	CLOSED	23.62	4.36	6.25

DATE OF HARVEST	TREE HEIGHT (M)	HT AT 3 " TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
12/7/93	11.00	8.66	.044	357.84	205.01

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
122.4	60.97	68.54	28.86	20.81	11.49

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
33.05	20.62	51.95	43.22	183.49	100.82

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
80.74	54.9	85.69	40.96	8.26	4.96

Appendix A2. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
2	32	OPEN	23.37	7.50	9.24

DATE OF HARVEST	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
4/7/94	9.24	7.41	.043	678.00	362.42

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
481.73	264.6	245.68	131.93	81.89	44.96

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
154.15	87.71	3.58	3.04	192.69	94.78

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
42.16	29.01	141.83	59.71	8.7	6.06

Appendix A3. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
3	31	OPEN	19.33	6.80	6.84

DATE OF HARVEST	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
5/17/94	6.84	4.10	.029	482.05	274.62

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
401.72	227.12	180.37	103.17	88.78	49.45

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
132.57	74.5	1.00	.78	79.33	46.72

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
31.41	24	42.84	19.49	5.08	3.23

Appendix A4. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
4	61	OPEN	45.47	10.67	10.59

DATE OF HARVEST	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
6/1/94	10.59	7.76	.162	1740.21	1006.33

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
1189.18	690.33	388.86	217.76	129.62	76.86

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
670.7	395.71	27.62	24.53	523.41	291.47

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
195.23	120.62	297.82	120.62	30.36	19.16

Appendix A5. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
5	45	CLOSED	16.64	4.34	6.55

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
6/2/94	8.32	5.62	.022	123.57	74.58

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
48.13	29.83	21.95	12.73	17.33	11.2

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
8.85	5.9	6.42	5.33	69.02	39.42

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
24.43	18.18	40.86	18.55	3.73	2.69

Appendix A6. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
6	51	OPEN	50.17	11.55	11.37

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
6/16/94	11.37	8.35	.198	1463.38	926.72

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
949.51	607.77	284.85	184.01	190.85	121.00

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
473.81	302.76	28.33	25.5	485.54	293.45

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
236.46	183.49	221.41	91.22	27.68	18.74

Appendix A7. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
7	63	CLOSED	33.48	5.43	8.90

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
6/23/94	14.51	11.80	.088	651.43	390.68

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
196.53	111.02	74.88	42.76	36.55	21.71

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
85.1	46.55	37.08	34.34	417.82	245.32

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
189.69	143.22	211.42	92.39	16.71	9.71

Appendix A8. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
8	47	OPEN	28.07	7.28	8.60

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
7/14/94	8.60	6.19	.062	938.86	510.61

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
720.32	395.64	384.65	213.48	112.37	61.8

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
223.3	120.36	1.67	1.48	216.87	113.49

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
59.64	44.13	146.39	61.92	10.84	7.44

Appendix A9. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
9	52	CLOSED	13.34	2.51	2.99

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
7/19/94	8.56	5.61	.014	71.86	42.78

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
17.03	9.78	9.13	5.25	6.74	3.85

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
1.16	.68	6.38	5.74	48.45	27.26

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
21.95	15.89	23.84	10.23	2.66	1.14

Appendix A10. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
10	82	CLOSED	37.34	6.64	9.02

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
8/3/94	18.04	14.78	.110	923.69	603.61

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
249.79	153.03	104.41	59.72	55.95	36.26

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
89.42	57.05	76.14	67.38	597.76	383.2

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
346.7	255.87	209.22	96.66	41.84	30.67

Appendix A11. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
11	78	CLOSED	28.14	3.54	7.65

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
8/4/94	15.97	13.26	.062	524.82	307.47

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
150.74	80.93	61.8	33.68	29.4	16.17

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
59.54	31.08	23.88	20.94	350.2	205.6

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
156.89	118.77	171.25	70.9	22.06	15.93

Appendix A12. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
12	38	OPEN	33.02	9.49	9.44

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
9/29/94	9.44	6.21	.086	1170.87	664.11

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
907.16	510.00	339.28	189.66	220.44	125.43

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
347.44	194.91	7.92	7.13	255.79	146.98

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
107.94	79.55	134.03	59.51	13.82	7.92

Appendix A13. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
13	22	OPEN	14.478	4.77	5.73

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
11/17/94	5.73	3.05	.016	292.86	152.14

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
232.2	121.7	131.42	68.08	58.98	30.96

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
41.8	22.66	.20	.14	60.46	30.3

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
13.91	9.32	42.14	17.99	4.41	2.99

Appendix A14. Individual Tree Data

TREE NUMBER	AGE IN YEARS	STAND DENSITY	DBH (CM)	CROWN DIA. (M)	CROWN LENGTH (M)
14	55	OPEN	38.86	7.16	11.46

DATE OF EXTRACTION	TREE HEIGHT (M)	HT AT 3" TOP (M)	BASAL AREA (M^2)	TREE GREEN WT. (KG)	TREE DRY WT. (KG)
12/19/94	11.46	9.17	.119	1249.49	703.2

LIVE BR&FO GREEN WT. (KG)	LIVE BR&FO DRY WT. (KG)	FOLIAGE GREEN WT. (KG)	FOLIAGE DRY WT. (KG)	BR 1/4-1" GREEN WT. (KG)	BR 1/4-1" DRY WT. (KG)
858.83	483.8	374.45	216.43	137.41	76.54

BR >1" GREEN WT. (KG)	BR >1" DRY WT. (KG)	DEAD BR GREEN WT. (KG)	DEAD BR DRY WT. (KG)	BOLEWOOD GREEN WT. (KG)	BOLEWOOD DRY WT. (KG)
346.97	190.83	5.01	4.10	385.65	215.3

HEARTWOOD GREEN WT. (KG)	HEARTWOOD DRY WT. (KG)	SAPWOOD GREEN WT. (KG)	SAPWOOD DRY WT. (KG)	BARK GREEN WT. (KG)	BARK DRY WT. (KG)
146.93	110.64	214.42	88.77	24.3	15.89

APPENDIX B1. Sample Branch Data for Tree Number 1.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	X	X	0.93	0.53	0.27	0.16	0.25	0.15
2	X	X	2.06	1.12	0.22	0.13	0.42	0.24
3	X	X	1.85	0.99	0.25	0.14	0.40	0.20
4	X	X	1.26	0.69	0.13	0.07	0.20	0.11
5	X	X	1.38	0.75	0.22	0.12	0.26	0.13
6	X	X	0.35	0.17	0.31	0.17	0.06	0.04
7	X	X	2.90	1.53	0.66	0.36	1.10	0.63
8	X	X	2.08	1.18	1.00	0.55	1.95	1.31
9	X	X	3.73	2.02	1.99	1.09	3.28	2.13
10	X	X	X	X	X	X	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was collected for that component of the branch.

APPENDIX B2. Sample Branch Data for Tree Number 2.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	5.1	3.47	3.08	1.67	0.98	0.55	2.70	1.51
2	5.0	3.69	2.38	1.27	1.55	0.86	2.03	1.25
3	4.3	3.44	1.88	1.02	1.03	0.58	1.59	0.97
4	6.3	3.32	6.06	3.27	1.66	0.94	4.61	2.55
5	3.0	1.95	0.86	0.46	0.66	0.37	0.05	0.03
6	4.2	2.71	2.03	1.10	0.58	0.31	1.19	0.68
7	4.1	2.62	2.01	1.06	0.58	0.29	0.60	0.32
8	4.6	2.65	2.72	1.45	0.59	0.31	1.27	0.70
9	4.0	2.35	1.71	0.92	0.57	0.31	0.75	0.42
10	4.3	2.74	3.19	1.70	0.59	0.31	1.67	0.93

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B3. Sample Branch Data for Tree Number 3.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	5.1	3.37	2.46	1.44	1.43	0.81	2.59	1.53
2	3.7	2.32	0.87	0.52	0.59	0.33	0.35	0.22
3	6.7	3.28	3.93	2.32	1.78	1.04	3.76	2.12
4	4.6	2.51	1.51	0.90	0.72	0.41	1.09	0.62
5	3.6	2.16	0.85	0.49	0.62	0.34	0.31	0.18
6	5.8	2.52	3.59	2.03	1.66	0.93	2.41	1.33
7	5.5	2.16	2.81	1.52	1.24	0.65	1.80	0.96
8	3.7	1.94	1.09	0.59	0.33	0.17	0.66	0.33
9	2.6	1.36	0.36	0.19	0.22	0.11	X	X
10	1.9	1.14	0.18	0.09	0.12	0.06	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was collected for that component of the branch.

APPENDIX B4. Sample Branch Data for Tree Number 4.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	7.9	4.05	3.70	2.07	2.01	1.42	8.13	5.60
2	10.0	5.18	6.87	3.98	2.47	1.49	15.74	9.61
3	11.2	4.97	11.44	6.77	3.94	2.33	23.15	13.31
4	9.5	4.75	8.16	4.20	2.54	1.45	15.44	8.95
5	7.3	3.96	3.82	2.12	1.10	0.62	5.82	3.49
6	6.8	3.51	2.99	1.73	0.86	0.52	4.53	2.64
7	7.4	3.72	4.48	2.50	1.62	0.91	6.24	3.45
8	6.8	2.99	3.17	1.70	0.66	0.33	3.38	1.76
9	5.0	1.77	3.07	1.71	0.91	0.52	1.46	0.76
10	4.7	2.29	1.67	0.86	0.42	0.22	1.27	0.69

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B5. Sample Branch Data for Tree Number 5.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	2.5	1.86	0.26	0.16	0.44	0.31	X	X
2	2.4	2.01	0.42	0.24	0.45	0.30	X	X
3	3.1	2.44	0.33	0.21	0.49	0.33	0.13	0.09
4	4.1	2.47	1.08	0.61	0.65	0.40	0.86	0.57
5	3.2	2.19	0.49	0.30	0.44	0.28	0.37	0.26
6	3.8	1.68	0.89	0.53	0.34	0.21	0.69	0.45
7	2.5	2.16	0.39	0.22	0.35	0.23	X	X
8	2.8	1.80	0.57	0.32	0.36	0.23	0.08	0.05
9	2.5	1.68	0.34	0.19	0.28	0.18	X	X
10	2.7	1.74	0.52	0.29	0.38	0.23	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was cooected for that component of the tree.

APPENDIX B6. Sample Branch Data for Tree Number 6.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	3.9	2.26	0.88	0.53	0.73	0.56	0.55	0.41
2	7.6	5.76	2.75	1.76	3.18	2.09	8.44	6.03
3	7.5	4.36	4.40	2.77	3.04	2.01	5.96	3.90
4	6.8	4.79	2.97	1.89	2.27	1.49	5.69	3.77
5	7.7	4.97	4.44	2.73	2.38	1.54	8.48	5.47
6	6.9	4.11	4.01	2.47	1.87	1.17	5.67	3.60
7	8.4	5.12	5.34	3.22	3.25	1.92	9.56	5.57
8	6.9	4.21	3.96	2.47	1.98	1.17	3.80	2.11
9	3.9	2.13	1.14	0.68	0.53	0.29	0.77	0.41
10	3.0	1.37	0.84	0.50	0.46	0.25	0.06	0.03

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B7. Sample Branch Data for Tree Number 7.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	6.3	4.42	2.04	1.13	1.00	0.65	5.42	3.12
2	3.8	2.80	0.29	0.21	0.41	0.30	0.78	0.60
3	6.9	3.69	3.10	1.75	1.80	1.15	5.76	3.07
4	6.9	4.11	4.79	2.74	2.37	1.49	6.47	3.53
5	8.4	3.78	8.65	4.80	4.94	2.77	8.43	4.45
6	3.9	2.32	1.05	0.64	0.46	0.28	0.92	0.55
7	3.8	2.41	0.74	0.45	0.49	0.29	0.67	0.40
8	8.8	3.41	5.77	3.25	1.81	1.01	3.86	1.96
9	3.4	1.92	1.55	0.94	0.41	0.21	0.43	0.24
10	2.8	1.74	0.87	0.56	0.40	0.22	0.10	0.05

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B8. Sample Branch Data for Tree Number 8.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	2.6	2.77	0.42	0.24	0.69	0.42	0.03	0.03
2	8.0	3.84	10.92	5.92	3.13	1.74	8.10	4.36
3	4.8	2.83	2.49	1.40	1.00	0.56	2.06	1.16
4	5.7	2.83	4.83	2.73	1.48	0.82	2.74	1.49
5	6.0	2.90	5.24	3.02	1.37	0.75	2.80	1.49
6	5.7	2.71	4.03	2.26	1.05	0.57	2.26	1.19
7	4.2	2.01	2.14	1.18	0.49	0.25	0.79	0.44
8	4.8	1.92	3.32	1.79	0.77	0.41	1.12	0.58
9	3.7	1.86	1.47	0.83	0.38	0.20	0.58	0.31
10	4.1	1.98	1.80	0.97	0.35	0.17	0.79	0.41

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B9. Sample Branch Data for Tree Number 9.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	3.3	2.35	0.69	0.38	0.72	0.40	0.19	0.11
2	3.1	1.77	0.74	0.44	0.62	0.37	0.15	0.09
3	2.5	1.46	0.47	0.28	0.39	0.23	X	X
4	2.2	1.09	0.46	0.26	0.21	0.11	X	X
5	1.3	0.70	0.32	0.18	0.04	0.02	X	X
6	X	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X
9	X	X	X	X	X	X	X	X
10	X	X	X	X	X	X	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was collected for that component of the branch.

APPENDIX B10. Sample Branch Data for Tree Number 10.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	5.3	2.93	1.52	0.97	1.51	1.14	2.11	1.55
2	4.2	2.26	0.73	0.44	0.60	0.44	0.84	0.60
3	4.6	3.02	2.02	1.12	0.77	0.46	2.09	1.34
4	4.6	2.32	0.77	0.47	0.60	0.45	1.10	0.83
5	5.1	3.54	2.05	1.17	1.09	0.75	2.45	1.56
6	5.6	2.68	2.33	1.30	1.26	0.77	2.35	1.40
7	4.2	1.83	1.76	0.97	0.65	0.40	0.98	0.57
8	5.1	2.90	2.91	1.65	1.43	0.82	1.86	1.04
9	4.3	2.19	2.37	1.33	0.87	0.50	1.08	0.60
10	3.0	1.77	0.98	0.55	0.54	0.31	0.05	0.03

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown.

APPENDIX B11. Sample Branch Data for Tree Number 11.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	4.3	2.90	0.95	0.53	0.72	0.38	1.67	0.88
2	8.0	3.57	5.06	2.76	2.81	1.61	7.64	4.06
3	6.4	3.60	3.37	1.83	1.30	0.72	3.63	1.91
4	5.5	2.80	3.05	1.68	1.11	0.61	2.55	1.29
5	4.7	2.59	2.17	1.17	0.81	0.47	1.64	0.85
6	2.8	1.22	0.60	0.34	0.42	0.22	X	X
7	3.8	2.16	1.58	0.85	0.49	0.27	0.78	0.39
8	2.9	1.77	0.72	0.38	0.47	0.24	0.10	0.05
9	2.7	1.58	0.62	0.34	0.38	0.18	0.07	0.03
10	3.0	1.77	0.75	0.41	0.47	0.24	0.09	0.03

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was collected for that component of the branch.

APPENDIX B12. Sample Branch Data for Tree Number 12.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	3.5	3.32	0.74	0.43	1.11	0.69	0.83	0.57
2	3.7	4.02	1.85	1.10	2.15	1.32	2.32	1.46
3	6.1	4.60	3.71	2.12	2.73	1.59	5.86	3.29
4	5.1	4.33	2.53	1.38	1.83	1.01	3.16	1.78
5	7.9	4.18	7.97	4.42	4.05	2.29	9.02	4.92
6	7.0	3.66	6.70	3.74	4.39	2.42	5.91	3.23
7	4.8	3.20	2.88	1.59	0.97	0.54	2.14	1.16
8	3.4	2.19	1.33	0.74	0.82	0.45	0.59	0.33
9	2.9	2.29	0.91	0.48	0.64	0.33	0.08	0.03
10	2.5	1.83	0.58	0.32	0.33	0.18	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was available for that component of the branch.

APPENDIX B13. Sample Branch Data for Tree Number 13.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	3.8	2.38	1.78	0.91	0.94	0.49	0.57	0.33
2	3.8	2.41	1.94	1.02	0.83	0.44	0.72	0.39
3	4.4	2.44	2.29	1.17	1.36	0.74	0.57	0.32
4	3.4	2.56	1.40	0.73	0.74	0.39	0.41	0.22
5	4.1	2.50	1.58	0.82	0.49	0.25	0.83	0.44
6	3.0	1.77	0.74	0.39	0.37	0.18	0.08	0.05
7	3.8	2.19	1.50	0.80	0.42	0.21	0.60	0.30
8	2.0	1.10	0.51	0.24	0.15	0.08	X	X
9	1.6	0.91	0.19	0.10	0.05	0.03	X	X
10	X	X	X	X	X	X	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was available for that component of the branch.

APPENDIX B14. Sample Branch Data for Tree Number 14.[1]

			< 1/4" BRANCH		1/4 - 1" BRANCH		> 1" BRANCH	
Sample Branch #	Branch Dia. (cm)	Branch Lgth (m)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)	Fresh Wt. (kg)	Dry Wt. (kg)
1	5.9	3.23	3.55	2.00	2.02	1.09	3.95	2.25
2	12.5	3.69	20.86	11.97	6.33	3.46	20.99	11.24
3	7.6	4.21	4.01	2.38	1.84	1.09	4.26	2.53
4	6.4	2.96	3.18	1.92	1.46	0.88	3.29	1.92
5	6.0	3.02	2.49	1.45	0.73	0.40	2.05	1.11
6	4.8	2.71	2.24	1.29	0.68	0.39	2.40	1.28
7	3.5	2.01	1.32	0.76	0.63	0.34	0.42	0.23
8	4.0	1.89	1.85	1.05	0.81	0.43	0.47	0.26
9	3.1	1.37	1.27	0.74	0.34	0.18	0.24	0.13
10	2.4	1.16	0.34	0.21	0.23	0.13	X	X

[1] Sample Branches 1 - 10 were collected evenly throughout the live crown. An X means that no data was available for that component of the branch.

APPENDIX C1. Disk Measurement Data for Tree Number 1.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.5	0.3	0.3	0.3	0.3
	0.5	0.3	0.3	0.3	0.3
	0.3	0.3	0.3	0.2	0.4
	0.6	0.4	0.6	0.2	0.1
	0.4	0.2	0.4	0.3	0.3
	0.4	0.4	0.3	0.2	0.3
	0.4	0.3	0.3	0.2	0.2
	0.3	0.3	0.1	0.2	0.2
Sapwood Radius Measurements (cm)	8.5	2.0	2.8	1.5	1.9
	2.2	2.2	2.4	2.5	1.6
	4.1	1.9	2.3	1.4	2.2
	2.9	2.1	2.2	2.4	2.3
	4.6	2.3	1.4	0.5	2.5
	3.5	1.7	0.0	2.5	1.9
	3.7	1.9	2.9	1.7	2.3
	6.1	2.5	2.2	2.4	2.6
Heartwood Diameter Measurements (cm)	21.1	15.4	12.0	7.4	3.0
	19.6	17.3	15.0	6.2	2.1
	21.2	15.8	15.1	8.5	1.9
	23.3	16.2	12.4	6.5	2.1

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C2. Disk Measurement Data for Tree Number 2.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.9	0.5	0.4	0.3	0.1
	0.7	0.5	0.4	0.4	0.2
	0.4	0.5	0.3	0.4	0.2
	0.5	0.5	0.0	0.5	0.1
	0.5	0.3	0.4	0.4	0.1
	0.2	0.3	0.4	0.3	0.2
	0.9	0.4	0.4	0.3	0.1
	0.3	0.5	0.4	0.0	0.1
Sapwood Radius Measurements (cm)	7.5	4.0	4.4	2.8	1.6
	5.7	2.8	3.7	2.3	1.3
	9.9	3.4	3.8	2.6	1.3
	7.6	4.0	3.6	2.0	1.6
	7.4	2.8	4.2	2.6	1.5
	4.6	1.4	3.3	2.5	1.3
	6.7	5.0	3.5	2.2	1.5
	8.7	4.7	3.8	2.8	1.7
Heartwood Diameter Measurements (cm)	15.3	10.6	6.9	3.9	0.1
	15.8	10.9	7.0	3.1	0.1
	18.6	11.5	7.4	3.0	0.1
	19.7	18.2	6.4	4.2	0.1

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C3. Disk Measurement Data for Tree Number 3.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	1.1	0.5	0.6	0.3	0.2
	0.8	0.7	0.5	0.4	0.2
	0.9	0.5	0.4	0.2	0.2
	0.6	0.9	0.6	0.3	0.2
	0.9	0.5	0.5	0.3	0.2
	0.5	0.5	0.5	0.5	0.2
	1.1	0.9	0.4	0.2	0.1
	0.8	0.8	0.7	0.5	0.3
Sapwood Radius Measurements (cm)	5.0	2.5	2.1	1.9	1.1
	6.5	2.2	2.6	1.1	1.3
	5.3	2.4	2.3	1.6	0.4
	6.6	2.3	2.4	2.0	1.3
	5.7	2.5	2.5	2.0	1.0
	3.4	2.2	2.4	2.4	1.4
	7.7	2.3	3.0	2.2	1.1
	3.2	2.1	2.3	1.8	1.2
Heartwood Diameter Measurements (cm)	24.5	11.3	6.5	6.0	0.2
	18.6	15.9	6.5	4.2	0.9
	19.8	10.8	6.1	3.4	0.2
	24.3	11.0	6.9	4.8	0.2

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C4. Disk Measurement Data for Tree Number 4.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.5	1.2	0.9	0.5	0.2
	0.4	0.6	0.7	0.5	0.2
	1.1	1.0	0.5	0.5	0.1
	0.8	0.8	0.5	0.4	0.3
	1.2	1.2	0.7	0.5	0.3
	0.6	0.9	0.8	0.7	0.2
	0.8	0.6	0.6	0.3	0.1
	1.1	1.0	0.7	0.4	0.2
Sapwood Radius Measurements (cm)	6.3	1.5	2.7	3.1	0.4
	8.4	10.0	3.3	2.9	1.8
	8.5	2.7	2.8	3.2	0.8
	9.3	4.5	2.2	1.1	0.9
	10.0	6.8	3.5	3.1	1.7
	7.6	2.4	2.6	3.1	1.4
	7.3	5.7	3.4	2.1	0.9
	6.4	3.7	4.4	2.9	0.8
Heartwood Diameter Measurements (cm)	42.7	27.2	13.6	7.5	1.3
	45.4	35.9	14.2	4.7	1.9
	51.7	34.6	13.1	5.0	1.4
	53.3	26.9	14.2	5.9	1.2

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C5. Disk Measurement Data for Tree Number 5.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	1.2	0.4	0.3	0.1	0.2
	0.5	0.4	0.2	0.2	0.2
	0.3	0.3	0.3	0.2	0.2
	1.1	0.5	0.9	0.3	0.3
	0.2	0.2	0.3	0.2	0.2
	0.7	0.3	0.3	0.3	0.2
	0.5	0.3	0.4	0.2	0.2
	1.0	0.5	0.5	0.2	0.2
Sapwood Radius Measurements (cm)	2.3	1.8	2.2	2.5	1.5
	2.4	1.8	2.4	2.4	2.0
	2.8	1.9	2.7	2.5	1.6
	1.3	0.2	0.9	1.6	1.5
	5.1	1.5	2.4	2.4	1.7
	3.8	2.7	2.4	2.1	1.7
	4.0	1.5	1.9	1.2	1.7
	1.9	2.3	2.4	2.9	1.8
Heartwood Diameter Measurements (cm)	14.4	12.7	8.6	3.2	1.2
	17.7	12.8	7.6	3.0	0.7
	16.1	13.0	7.6	3.2	0.7
	14.7	13.9	7.8	4.4	0.8

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C6. Disk Measurement Data for Tree Number 6.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.8	0.9	0.3	0.4	0.1
	0.5	0.6	0.3	0.4	0.1
	1.7	0.4	0.4	0.3	0.2
	0.8	0.7	0.5	0.2	0.3
	0.8	0.6	0.4	0.5	0.1
	0.9	0.7	0.4	0.5	0.2
	0.9	0.2	0.5	0.3	0.1
	0.6	0.5	0.8	0.3	0.2
Sapwood Radius Measurements (cm)	2.3	3.0	2.6	2.1	1.7
	4.7	0.0	2.2	2.2	1.5
	2.2	2.8	2.8	2.6	1.4
	6.3	4.8	2.5	1.9	1.8
	4.0	3.2	1.5	0.0	2.1
	4.3	2.9	2.2	2.1	1.6
	5.0	3.5	2.5	2.4	1.5
	5.4	0.0	2.8	1.8	1.6
Heartwood Diameter Measurements (cm)	35.6	28.5	16.2	6.7	1.2
	40.7	40.3	21.1	7.4	1.1
	43.9	41.5	14.9	7.4	1.3
	41.1	27.6	16.2	9.5	1.1

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C7. Disk Measurement Data for Tree Number 7.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.3	0.2	0.2	0.2	0.2
	0.2	0.3	0.5	0.2	0.2
	0.5	0.2	0.4	0.3	0.2
	0.4	0.3	0.4	0.2	0.1
	0.6	0.3	0.2	0.3	0.1
	0.3	0.2	0.3	0.3	0.2
	0.5	0.3	0.5	0.2	0.1
	0.4	0.3	0.4	0.3	0.2
Sapwood Radius Measurements (cm)	4.0	2.7	2.0	2.4	3.0
	7.2	3.0	2.8	0.0	2.0
	6.1	2.6	1.2	2.1	1.8
	4.3	3.1	1.6	2.8	2.4
	4.1	3.2	3.0	2.3	2.6
	4.3	3.1	1.8	2.3	1.9
	4.8	2.8	1.4	2.8	1.9
	4.5	2.8	2.9	2.7	2.5
Heartwood Diameter Measurements (cm)	31.7	21.6	19.9	16.3	2.6
	30.1	20.5	18.0	11.9	2.5
	24.9	22.6	18.7	12.2	2.4
	27.8	20.7	18.1	11.5	2.5

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C8. Disk Measurement Data for Tree Number 8.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.7	0.5	0.4	0.2	0.2
	1.0	0.3	0.4	0.2	0.3
	0.6	0.2	0.5	0.4	0.3
	0.6	0.5	0.5	0.5	0.3
	0.5	0.5	0.3	0.3	0.1
	0.2	0.5	0.5	0.4	0.2
	1.2	0.9	0.5	0.5	0.2
	0.6	0.3	0.7	0.5	0.2
Sapwood Radius Measurements (cm)	1.8	4.3	3.5	2.9	1.7
	6.1	0.0	3.6	2.5	1.9
	10.0	0.5	3.0	0.4	1.8
	7.3	4.3	3.2	2.9	2.0
	8.3	4.0	2.1	2.8	1.8
	5.9	4.6	3.2	2.5	1.8
	10.0	2.0	3.7	3.0	2.0
	8.3	10.2	3.3	3.1	2.2
Heartwood Diameter Measurements (cm)	19.1	22.5	9.5	5.0	1.5
	21.1	21.0	10.1	8.2	1.5
	24.2	14.9	10.4	5.3	1.5
	23.4	13.5	9.4	5.4	1.4

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C9. Disk Measurement Data for Tree Number 9.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.3	0.1	0.1	0.2	0.1
	0.3	0.3	0.2	0.2	0.1
	0.3	0.3	0.2	0.3	0.1
	0.2	0.4	0.3	0.3	0.2
	0.3	0.2	0.2	0.1	0.1
	0.4	0.2	0.2	0.2	0.2
	0.4	0.2	0.2	0.2	0.2
	0.5	0.5	0.2	0.3	0.1
Sapwood Radius Measurements (cm)	1.4	0.7	1.4	1.7	1.5
	2.4	0.8	0.8	1.2	1.5
	1.8	1.0	0.9	1.2	2.5
	1.7	1.0	1.1	2.0	1.6
	1.5	1.0	0.9	1.8	1.6
	1.5	1.0	1.6	1.2	1.7
	1.4	1.1	1.0	1.3	1.7
	1.7	1.0	1.1	1.5	1.7
Heartwood Diameter Measurements (cm)	12.6	9.4	6.9	4.5	1.6
	11.2	9.2	7.9	4.8	1.6
	11.9	9.0	7.3	4.3	1.6
	11.2	9.7	7.6	4.7	1.4

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C10. Disk Measurement Data for Tree Number 10.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.4	0.5	0.6	0.2	0.2
	0.3	0.5	0.4	0.8	0.2
	0.5	0.6	0.9	0.6	0.2
	1.3	0.8	0.9	0.4	0.3
	0.2	0.3	0.8	0.6	0.1
	0.8	0.7	0.5	0.5	0.2
	1.0	0.8	0.2	0.7	0.2
	0.4	0.7	0.6	0.4	0.2
Sapwood Radius Measurements (cm)	1.2	2.0	2.3	1.9	1.2
	2.7	0.0	2.7	2.6	1.4
	3.7	2.3	2.6	2.2	0.3
	2.5	2.1	2.0	2.5	1.8
	2.5	2.8	1.8	2.3	1.2
	3.8	2.6	1.3	2.2	0.5
	3.0	2.0	4.1	2.6	0.6
	3.3	2.5	2.1	2.3	1.5
Heartwood Diameter Measurements (cm)	31.7	19.7	18.3	10.4	0.8
	33.0	27.0	16.9	10.2	1.7
	33.0	26.6	19.5	10.4	1.6
	35.5	28.0	18.2	10.3	1.9

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C11. Disk Measurement Data for Tree Number 11.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.4	0.3	0.4	0.2	0.2
	0.6	0.4	0.3	0.2	0.2
	0.5	0.3	0.4	0.3	0.1
	0.6	0.3	0.4	0.5	0.1
	0.6	0.4	0.3	0.6	0.1
	0.5	0.4	0.2	0.6	0.3
	0.0	0.5	0.5	0.2	0.2
	0.6	0.2	0.4	0.3	0.2
Sapwood Radius Measurements (cm)	3.1	2.0	2.4	2.9	2.1
	6.1	2.6	1.6	2.1	1.9
	5.1	1.9	2.8	2.3	2.2
	4.9	1.8	2.2	2.1	1.8
	3.7	2.2	2.3	2.6	2.1
	3.0	2.3	2.1	2.4	2.1
	0.0	2.4	2.4	1.6	1.8
	6.2	2.5	2.4	2.5	1.7
Heartwood Diameter Measurements (cm)	24.2	19.4	10.4	7.9	0.7
	30.5	20.0	12.3	7.9	0.6
	29.0	20.1	11.8	7.2	0.7
	29.9	19.9	11.9	8.1	0.6

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these disks.

APPENDIX C12. Disk Measurement Data for Tree Number 12.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.5	0.5	0.2	0.2	0.1
	0.6	0.6	0.3	0.0	0.2
	0.7	0.7	0.4	0.2	0.2
	1.0	0.8	0.8	0.3	0.0
	1.0	0.4	0.3	0.3	0.1
	0.3	0.7	0.4	0.3	0.2
	1.1	0.8	0.4	0.3	0.1
	0.5	0.0	0.6	0.4	0.3
Sapwood Radius Measurements (cm)	5.0	3.2	4.3	2.2	0.1
	5.5	3.6	3.4	2.7	0.2
	4.5	3.9	2.6	2.5	0.2
	4.4	3.6	3.6	1.3	0.0
	8.4	3.7	3.2	2.7	0.1
	5.8	4.0	3.9	2.1	0.2
	4.7	1.6	2.6	2.2	0.1
	8.5	0.0	3.1	2.5	0.3
Heartwood Diameter Measurements (cm)	36.9	20.5	9.3	4.4	0.0
	44.5	16.2	9.5	7.6	0.0
	49.1	25.3	8.1	4.5	0.0
	51.7	21.1	10.1	4.5	0.0

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C13. Disk Measurement Data for Tree Number 13.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.3	0.3	0.3	0.1	0.1
	0.4	0.4	0.4	0.2	0.1
	0.6	0.4	0.4	0.3	0.1
	1.0	0.4	0.5	0.3	0.1
	0.3	0.2	0.3	0.1	0.1
	0.4	0.3	0.3	0.1	0.1
	0.4	0.3	0.4	0.2	0.1
	0.5	0.4	0.4	0.5	0.1
Sapwood Radius Measurements (cm)	5.9	2.8	2.3	2.1	1.6
	7.7	2.5	2.4	2.2	1.6
	4.8	2.5	2.6	1.5	X
	6.1	3.1	2.6	1.8	X
	5.4	2.9	2.8	1.9	1.4
	6.5	2.9	2.9	1.9	1.6
	7.7	3.1	2.3	1.7	X
	5.8	3.3	2.3	2.1	X
Heartwood Diameter Measurements (cm)	12.0	7.8	3.5	1.2	0.0
	13.7	6.6	3.8	0.7	0.0
	14.3	6.4	3.6	0.7	0.0
	13.6	8.0	3.2	0.9	0.0

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

APPENDIX C14. Disk Measurement Data for Tree Number 14.[1]

	SAMPLE DISKS				
	1	2	3	4	5
Bark Radius Measurements (cm)	0.3	0.4	0.2	0.5	0.2
	0.4	0.5	0.5	0.5	0.3
	0.7	0.6	0.5	0.6	0.3
	0.7	0.6	0.6	0.7	0.4
	0.4	0.3	0.2	0.3	0.2
	0.4	0.5	0.4	0.3	0.2
	0.7	0.5	0.5	0.5	0.2
	0.5	0.7	0.5	0.6	0.3
Sapwood Radius Measurements (cm)	7.0	2.8	2.2	1.6	2.1
	8.8	3.2	2.9	1.9	2.1
	4.9	2.9	1.8	2.9	2.1
	7.5	3.5	2.6	2.8	2.1
	7.6	3.8	2.7	4.1	2.2
	8.7	4.1	3.6	4.2	2.4
	7.4	3.3	3.2	3.0	2.1
	9.6	3.8	2.6	2.6	1.8
Heartwood Diameter Measurements (cm)	41.4	23.8	14.8	10.2	2.8
	37.3	24.7	16.6	14.2	2.7
	37.8	22.8	16.0		2.6
				9.8	
	39.4	31.2	16.1	10.6	2.7

[1] The bole of each tree was divided into 5 equal sections and a sample disk was cut from the base of each of these sections.

Appendix D1.[1] Prediction equations for eastern redcedar biomass.

OPEN GROWN
FRESH WEIGHT

COMPONENT	DBH EQUATION	R^2	BEST EQUATION	R^2
Bolewood	-152.27 + 13.52(dbh)	0.96	-152.27 + 13.52(dbh)	0.96
Heartwood	-98.00 + 6.40(dbh)	0.97	-7.68 + 0.10(dbh^2)	0.99
Sapwood	-44.89 + 6.33(dbh)	0.82	-116.19 + 3.94(dbh) + 16.05(crle)	0.85
Bark	-9.38 + 0.79(dbh)	0.94	-4.58 + 1.03(dbh) + -1.51(crdia)	0.96
Live Br&Fol	-26.03 + 23.54(dbh)	0.85	-627.83 + 66.26(dbh) + -0.66(dbh^2)	0.92
Foliage	119.88 + 5.42(dbh)	0.49	-327.70 + 37.20(dbh) + -0.49(dbh^2)	0.89
1/4-1"Br	28.80 + 3.13(dbh)	0.51	-43.10 + 4.80(trht) +15.54(crdia)	0.60
>1"Branch	-174.72 + 14.99(dbh)	0.85	-35.66 + 19.66(dbh) +-31.30(crle)	0.87
Dead Branches	-16.24 + 0.81(dbh)	0.77	13.67 + 0.02(dbh^2)+ -2.83(trht)	0.91
Total Tree	-194.54 + 37.87(dbh)	0.93	-761.21 + 78.10(dbh) + -0.62(dbh^2)	0.95

[1]The first column of equations are those predicted using dbh and the second column of equations are the equations that predicted best for each component. dbh = diameter at breast height in centimeters; trht = tree height in meters; crdia = crown diamter in meters; crle = crown length in meters

Appendix D2.[1] Prediction equations for eastern redcedar biomass.

OPEN GROWN
DRY WEIGHT

COMPONENT	DBH EQUATION	R^2	BEST EQUATION	R^2
Bolewood	-100.68 + 8.06(dbh)	0.98	-100.68 + 8.06(dbh)	0.98
Heartwood	-79.07 + 5.00(dbh)	0.97	-8.73 + 0.08(dbh^2)	1.00
Sapwood	-15.54 + 2.55(dbh)	0.83	-47.01 + 1.49(dbh) + 7.08(trht)	0.86
Bark	-6.07 + 0.51(dbh)	0.93	6.71 + 0.01(dbh^2)+-1.00(crdia)	0.96
Live Br&Fol	-59.31 + 14.94(dbh)	0.92	-291.00 + 31.38(dbh) + -0.25(dbh^2)	0.95
Foliage	51.95 + 3.60(dbh)	0.63	-172.72 + 19.54(dbh) + -0.25(dbh^2)	0.92
1/4-1"Br	7.56 + 2.08(dbh)	0.58	-24.81 +0.48(dbh) + 10.19(crdia)	0.68
>1"Branch	-118.82 + 9.26(dbh)	0.87	-8.81 + 12.95(dbh) +-24.76(trht)	0.90
Dead Branches	-14.65 + 0.73(dbh)	0.76	12.69 + 0.02(dbh^2)+ -2.62(trht)	0.91
Total Tree	-174.63 + 23.73(dbh)	0.96	-232.94 + 20.84(dbh)+ 18.35(crdia)	0.97

[1] The first column of equations are those predicted using dbh and the second column of equations are the equations that predicted best for each component. dbh = diameter at breast height in centimeters; trht = tree height in meters; crdia = crown diameter in meters; crle = crown length in meters

Appendix D3.[1] Prediction equations for eastern redcedar biomass.

CLOSED GROWN
GREEN WEIGHT

COMPONENT	DBH EQUATION	R^2	BEST EQUATION	R^2
Bolewood	-294.04 + 22.49(dbh)	0.96	-171.47 + 0.30(dbh^2) + 18.06(trht)	1.00
Heartwood	-178.10 + 12.38(dbh)	0.89	42.59 + 1.72(trht)	0.97
Sapwood	-98.83 + 8.75(dbh)	0.95	-77.87+10.90(dbh)+-16.91(crdia)	0.98
Bark	-19.49 + 1.39(dbh)	0.78	-0.14 + 0.12(trht)	0.96
Live Br&Fol	-106.77 + 9.34(dbh)	0.99	-106.77 + 9.34(dbh)	0.99
Foliage	-34.80 + 3.60(dbh)	0.92	-34.80 + 3.60(dbh)	0.92
1/4-1"Br	-16.58 + 1.75(dbh)	0.91	-30.95 + 2.39(trht) + 6.34(crdia)	0.99
>1"Branch	-55.38 + 3.99(dbh)	0.98	-51.26 + 4.42(dbh)+ -3.33(crdia)	0.99
Dead Branches	-26.53 + 2.37(dbh)	0.66	-45.60 + 2.33(trht)+ 11.10(crdia)	0.73
Total Tree	-427.34 + 34.20(dbh)	0.98	-45.44 + 0.68(dbh^2)	0.99

[1]The first column of equations are those predicted using dbh and the second column of equations are the equations that predicted best for each component. dbh = diameter at breast height in centimeters; trht = tree height in meters; crdia = crown diameter in meters; crle = crown length in meters

Appendix D4.[1] Prediction equations for eastern redcedar biomass.

CLOSED GROWN
DRY WEIGHT

COMPONENT	DBH EQUATION	R^2	BEST EQUATION	R^2
Bolewood	-193.06 + 14.16(dbh)	0.93	59.69 + -8.55(dbh)+ 0.45(dbh^2)	0.98
Heartwood	-133.80 + 9.24(dbh)	0.89	93.98 + -11.23(dbh) + 0.41(dbh^2)	0.96
Sapwood	-44.70 + 3.92(dbh)	0.98	-39.23 + 4.48(dbh)+ -4.41(crdia)	0.99
Bark	-14.56 + 1.00(dbh)	0.72	-23.76 + 2.14(trht) + 1.64(crdia)	0.87
Live Br&Fol	-66.86 + 5.55(dbh)	0.98	-4.97 + 0.11(dbh^2)	0.99
Foliage	-22.56 + 2.09(dbh)	0.97	-21.54 + 2.24(dbh) + -0.72(crle)	0.98
1/4-1"Br	-11.20 + 1.10(dbh)	0.85	-21.13 + 1.31(trht)+ 4.74(crdia)	0.97
>1"Branch	-33.10 + 2.36(dbh)	0.99	-6.95 + 0.05(dbh^2)+ 0.05(trht)	1.00
Dead Branches	-24.84 + 2.14(dbh)	0.70	-33.73 + 1.23(dbh)+ 7.17(crdia)	0.76
Total Tree	-284.75 + 21.85(dbh)	0.95	-443.18 + 35.86(trht)+ 57.52(crdia)	0.99

[1]The first column of equations are those predicted using dbh and the second column of equations are the equations that predicted best for each component. dbh = diameter at breast height in centimeters; trht = tree height in meters; crdia = crown diameter in meters; crle = crown length in meters

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