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BIOMASS OF SPECIES AND STANDS OF WEST VIRGINIA HARDWOODS

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ABSTRACT

Mixed Appalachian Mountain hardwood stands were sampled in southeastern West Virginia using ten, one-tenth acre plots to determine merchantable and total green and dry weights of above-ground forest biomass for stands, individual trees and components of each. Percent added utilization with whole tree utilization (WTU) was also determined. Species having similar potential for added utilization were separated into four groups. Regressions were developed using diameter as the independent variable to predict green and dry weights of 15 individual species and for the mixed stands.

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Biomass of Species and Stands of West Virginia Hardwoods

Measuring wood in volumetric terms is no longer practical with the implementation of whole-tree harvesting of entire stands. Weight measure is more convenient and accurate in determining yields of stands, whole trees and their component parts.

The complete tree concept developed by Young (1964) provided the initial impetus for weight measure in forestry. His concept, defined, was the biological and technological investigation and utilization of the entire tree from the root tips to leaf hairs. Promotion of whole-tree utilization (WTU) has since come from numerous investigators (Keays, 1974; Morey, 1975, and Young 1968, 1974). The wood-using industry in the U. S. was using over 480 mobile tree chippers in whole-tree harvesting operations in 1975 (Plummer, 1976); the number has decreased since then due to depressed market conditions for pulp and paper.

Increases in yields of 28 percent (Young, 1973), 100 percent (Napier, 1972 and Boyle, et al., 1973) and 300 percent (Keays, 1975) have been reported in several hardwood forest types. Yield increases using whole trees depends on species, stand density and quality, site, harvesting efficiency, and the merchantability limit to which whole-tree harvesting is compared.

The biomass yields of forest stands can be obtained either by summarizing the biomass of individual species or species groups within a stand and expanding these data to an area basis or, directly determining area yields by establishing sample plots in representative parts of a stand. For most stands, the development of species regression equations has been the most popular and least time consuming approach (Burkhart and Strub, 1973; Schlaegel, 1973; Clark and Taras, 1976; Clark and Schroeder, 1977).

Westvaco Corporation has been skyline logging and whole-tree chipping mountain hardwoods on its West Virginia Woodlands near Rupert, West Virginia, since 1973 (Figure 1 and 2). During this period, sample plots were established in stands of variable species composition to measure increases in yields

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Figure 1 - Clearfelled mixed hardwood stand prior to cable yarding.

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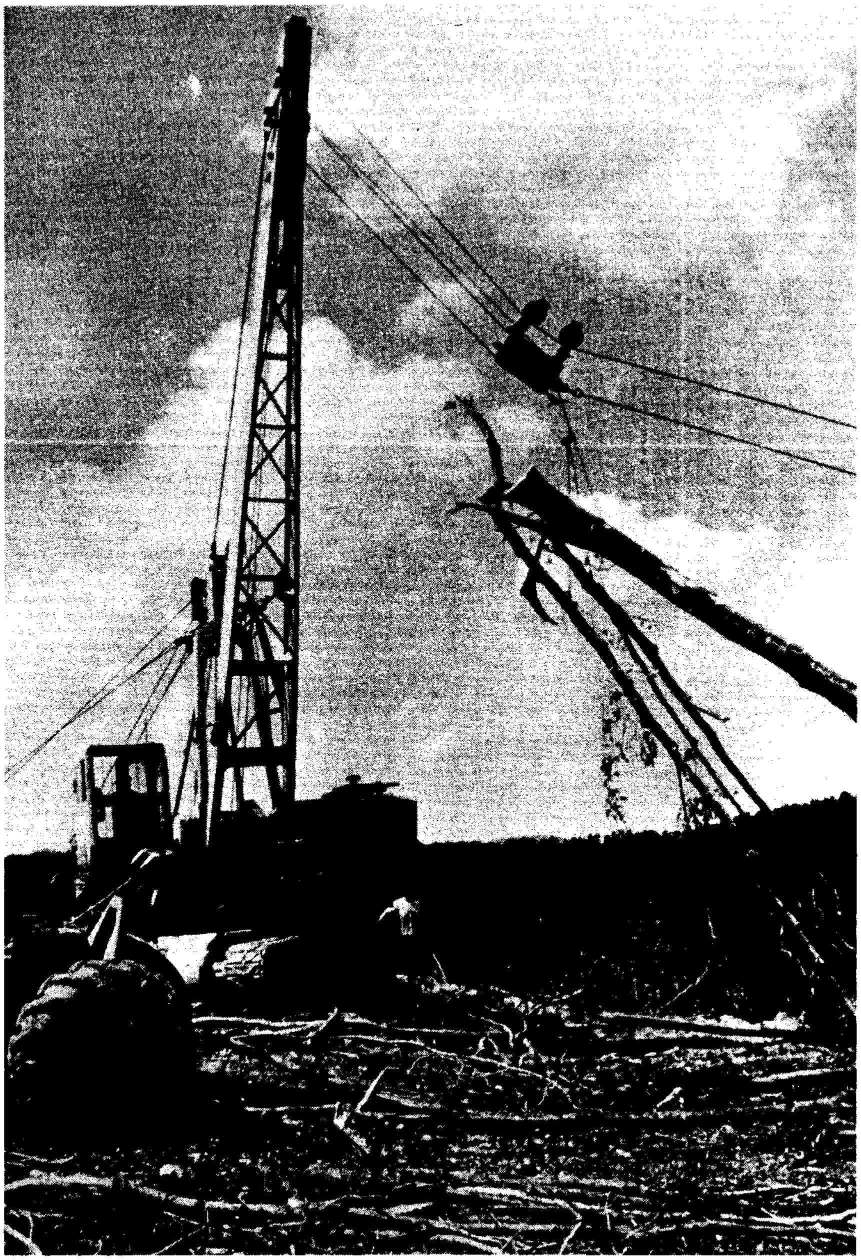

Figure 2 - Skylok cable yarding system yarding whole trees.

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over those obtained by harvesting round wood to a 4 inch top from trees 5 inches dbh and larger and, for the construction of hardwood total tree weight tables. The initial approach was to process data on an area or stand basis with supplemental information assembled by species and individual trees.

This paper reports the green and dry weight yields of stands and 15 major Appalachian hardwood species in southeastern West Virginia.

PROCEDURES

Stands on various sites containing species mixtures typical of Appalachian mountain hardwoods were selected between 1974 and 1976 (Figure 3). These were well stocked and even-aged with trees of pole size or larger (Table I). The majority of stands originated following fairly complete clearcutting of the large, mature forest and were generally of good quality. All trees on ten 0.1-acre plots were classed by species as merchantable (5 inches dbh and larger) or submerchantable (2 to 4.9 inches dbh). After numbering, trees on each plot were cut and weighed to the nearest pound. The boles and main branches of merchantable trees containing merchantable wood were cut into 4-foot bolts to a top diameter of 4 inches dob and the bolts were weighed individually. Topwood < 4 inches dob and submerchantable trees were weighed individually. The weight of leaves was deducted from merchantable trees sampled during the growing season by subtracting five percent of the green bole weight from the green top weight, while seven percent of the total tree weight was subtracted from submerchantable trees due to higher average crown to bole ratios (Keays, 1971). Disks 1-1 1/4 inches thick were cut from the small end of each merchantable tree bolt and at one-quarter, one-half and three-quarter points for submerchantable trees. These disks were immediately bagged and used for laboratory determination of moisture content and dry weight. Tree component green weights were totaled to give complete tree green weights and were divided by (1 + moisture content) and totaled to give dry weights. Weight distribution in merchantable boles and tops was determined for individual species and stands. Complete tree weights of merchantable trees were then compared to bole weights to give potential yield increases by species and stands from utilizing tops. Weights of submerchantable trees plus tops of merchantable trees were then combined and compared to bole weights of merchantable trees to give the potential yield increases per acre from utilizing all components of trees above 2 inches dbh.

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Figure 3 - Typical Appalachian Mountain hardwood stand of mixed species, high quality and stocking.

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Table I. Predominate species and stand descriptions for ten one-tenth acre plots of Appalachian hardwoods and hemlock in southeastern West Virginia.

Plot	Predominant Species	Average Age	Basal[1/] Area	DBH[2/] (in.)	Ht.[3/] (ft.)	Number of Trees Sub.	Merch.
1	Red Oak (*Quercus rubra L.*) Yellow Poplar (*Liriodendron tulipifera L.*) White Oak (*Q. alba L.*)	37	118	9.2	42	15	22
2	Sugar Maple (*Acer saccharum Marsh.*) Red Oak Red Maple (*Acer rubrum L.*)	70	207	11.9	51	3	22
3	Sugar Maple Yellow Poplar	80	94	10.6	59	6	12
4	White Oak Black Gum (*Nyssa sylvatica Marsh.*)	75	107	8.4	50	10	24
5	Beech (*Fagus grandifolia Ehrh.*) Black Cherry (*Prunus serotina Ehrh.*) Sugar Maple	67	92	7.6	36	36	24
6	Sugar Maple, Black Cherry, Red Oak White Ash (*Fraxinus americana L.*)	37	134	8.0	28	37	30
7	Chestnut Oak (*Quercus prinus L.*) Red Oak, Red Maple	65	131	9.1	37	3	19
8	Yellow Birch (*Betula alleghaniensis Britton*) Hemlock (*Tsuga canadensis L. Carr.*) Beech	67	152	8.5	31	21	31
9	Shagbark Hickory (*Carya ovata (Mill.) K. koch*) Black Birch (*Betula lenta L.*)	72	136	9.5	46	22	20
10	Basswood (*Tilia americana L.*) Black Cherry, Red Oak	64	221	10.8	57	19	28
	Averages	63	139	9.4	44	17	23

1/ Square feet per acre.
2/ Average for merchantable tree, ≥5.0 inches DBH.
3/ For merchantable trees to a 4.0-inch top DOB.

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Regression equations were developed for each species and all species combined to predict total tree green and dry weights by diameter classes. Twenty-five additional merchantable trees were cut adjacent to the plots and included with the ten plot data set to assure a balanced diameter class distribution for selected species. The regression model took the form of a Log_{10} transformation of $y = ax^b$ (Baskerville, 1972) using diameter (DBH) as the independent variable. Individual species regressions were compared with regressions for all species combined.

RESULTS AND DISCUSSION

The forest site types studied were variable ranging from moist, supporting yellow birch - hemlock to moderately dry supporting chestnut oak - red maple (Table I). Intermediate sites were well-drained and supported various hardwood species combinations. Site quality not only affected species composition but also stand stocking, while site quality and age influenced average stand diameter and merchantable height. Land use history also influenced composition, site and stand quality but such influence was difficult to assess. Stands ranged in age from 37 to 80 years (average 63 years) and basal area ranged from 92 to 221 $ft.^2$ per acre (average 139 $ft.^2$).

Tree form is dependent on apical dominance and whether a species has excurrent branching (strong apical dominance and well-defined central bole) or deliquescent branching (weak apical dominance and predominance of high ascending lateral branches), will greatly influence biomass distribution within the tree. Most hardwoods such as the oaks, maples and birches exhibit a deliquescent branching habit, however yellow poplar and sweetgum, are typically excurrent.

Biomass distribution in 15 major Appalachian hardwoods and hemlock is shown in Table II. The values listed are for the percent of weight in merchantable bole to a 4 inch top dob, and the upper stem (less than 4 inches dob) together with branches. The species are classed into four groups accordingly. The first group is composed of those species whose tops contain less than 15 percent of the total tree above ground biomass. This includes yellow poplar, basswood, cucumber magnolia *(Magnolia acuminata L.)*, and white oak. The second group, composed of those species containing 15 to 20 percent of the total tree biomass in tops includes red oak, shagbark

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Table II. Distribution of weight in the component parts of 252 merchantable Appalachian hardwoods and hemlock in southeastern West Virginia

		Percent of total Green Weight		Percent of total Dry Weight	
Species	Number Trees	Main Bole	Tops	Main Bole	Tops
GROUP I					
Yellow-Poplar	12	90	10	91	9
Basswood	13	88	12	90	10
Cucumber Magnolia	6	87	13	88	12
White Oak	29	85	15	86	14
GROUP II					
Red Oak	23	82	18	81	19
Shagbark Hickory	13	82	18	83	17
Black Cherry	24	81	19	83	17
White Ash	13	81	19	81	19
GROUP III					
Black Birch	6	78	22	77	23
Red Maple	13	77	23	78	22
Chestnut Oak	12	77	23	78	22
GROUP IV					
Beech	24	74	26	75	25
Yellow Birch	15	74	26	73	27
Sugar Maple	38	72	28	73	27
Hemlock	11	66	34	64	36
Averages		80	20	80	20

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hickory, black cherry, and white ash. The third group is composed of black birch, red maple and chestnut oak which contain 20 to 25 percent of the total tree biomass in tops. The last group contains beech, yellow birch, sugar maple, and hemlock which have greater than 25 percent of the total tree biomass in tops.

With the exception of white oak and basswood, the species in group I have an excurrent branching pattern. The hardwoods in all other groups are deliquescent. Hemlock, although excurrent, showed the highest top percent in group IV. However, this species is very tolerant and has large branches which persist in the crown and on the lower bole. Clark (1978) surveyed biomass distribution in southern hardwoods and used yellow poplar and red oak as representative of excurrent and deliquescent species respectively. He found pulpwood-size yellow poplar (trees 5.0 to 10.9 inches dbh) had 15 to 35 percent of their biomass in tops while sawtimber-size trees (trees ≥ 11.0 inches dbh) had 7 to 12 percent of their biomass in tops. Red oak had 20 to 26 percent and 21 to 30 percent of their biomass in tops of pulpwood, and sawtimber-size trees respectively. Trees of these species in our sample were both pulpwood and sawtimber size but generally show a similar trend in biomass distribution. For the 15 species we evaluated, there were no significant differences between green and dry weight biomass distribution and the averages were identical (Table II).

Table III shows top weights as a percentage of merchantable bole weights for each species or, the added utilization from whole tree chipping. The lowest percent added utilization was for yellow poplar with 10 percent on a dry weight basis. Hemlock was highest with 55 percent. The average for all species was 26 percent and there was no significant difference in green or dry weight percent added utilization. As expected, species with characteristically larger branchy tops like hemlock, sugar maple and beech yielded greater amounts of added fiber than smaller crowned species. Although not evaluated separately, age and stand stocking also contribute to added utilization with generally younger and more open-grown trees giving higher percents.

Biomass yields per acre and weight distribution by component based on ten one-tenth acre plots are shown in Table IV. Average green weight yields for all material above 2

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Table III. Percent added utilization from harvesting tops of 252 merchantable Appalachian hardwoods and hemlock in southeastern West Virginia[1/]

Species	Number Trees	Percent added Utilization	
		Green Weight	Dry Weight
GROUP I			
Yellow-Poplar	12	11	10
Basswood	13	14	11
Cucumber Magnolia	6	15	14
White Oak	29	18	16
GROUP II			
Red Oak	23	22	23
Shagbark Hickory	13	22	20
Black Cherry	24	23	21
White Ash	13	23	23
GROUP III			
Black Birch	6	29	29
Red Maple	13	29	29
Chestnut Oak	12	29	29
GROUP IV			
Beech	24	36	33
Yellow Birch	15	36	37
Sugar Maple	38	38	37
Hemlock	11	52	55
Averages		26	26

1/ Percent added utilization = (Top weight/main bole weight) x 100

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Table IV. Average green and dry weights and weight distribution within trees and components of Appalachian hardwoods and hemlock based on ten one-tenth acre plots in southeastern West Virginia.

	Green Weight			
	Main Bole	Tops	Submerchantable	Total
Average Green Weight (lbs. per acre)	240,975	61,889	14,617	317,481
Weight Distribution Within Components (Percent)	75.9	19.5	4.6	100.0
	Dry Weight			
Average Dry Weight (lbs. per acre)	134,419	34,402	7,710	176,530
Weight Distribution Within Components (Percent)	76.1	19.5	4.4	100.0

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inches dbh (main boles and tops of merchantable trees plus submerchantable trees) was 317,481 lbs. per acre. Average dry weight yield of all material was 176,530 lbs. per acre or 56 percent of total green weight. Dry weight of main boles of 134,419 lbs. per acre when compared to green weight was also 56 percent. Average green weight of merchantable tree tops was 61,889 lbs. per acre. Average dry weight of tops was 34,402 lbs. per acre or 56 percent of top green weight. Submerchantable trees gave the smallest average green weight yield per acre. Dry weight yield of submerchantable trees at 52 percent of submerchantable tree green weight was also the smallest.

For our sample plots, there was no significant difference in the weight distribution within component for green or dry weight. Frederick et al. (1978) have used the stand parameters: average basal area, diameter, height and number of submerchantable trees per acre to predict area weight yields and percent yield increases with tops and submerchantable trees of these sampled stands with good success. Weight information on small hardwoods is limited (Sollins and Anderson, 1971; Wartluft, 1976 and Phillips, 1977) however, indications are that small hardwoods in certain stands can comprise a significant portion of stand biomass.

The average percent added utilization realized by harvesting tops of merchantable trees was 25.7 and 25.6 percent respectively for green and dry weight (Table V). Harvesting submerchantable trees (6.0 and 5.7 percent) in addition to tops gave 31.7 and 31.3 percent yield increase respectively for green and dry weight. There was no significant difference in percent added utilization of tops, submerchantable trees or total when compared on a green and dry weight basis.

The increased yield from using whole tree harvesting over conventional logging is low compared to reported increases above given merchantability limits with WTU in other forest types (Keays, 1975). The sampled stands are above average in quality and stocking and occupy good sites (Figure 3). Also no cull was deducted leaving all trees >5.0 inches dbh up to a 4 inch dob top in the merchantable category. Stands on poorer sites, of lower stocking or quality, and smaller average diameter would yield higher increases.

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Table V. Average percent added utilization by harvesting tops and submerchantable trees of Appalachian hardwoods and hemlock based on ten one-tenth acre plots in southeastern West Virginia.

Tops	Submerchantable	Total
	Green Weight	
25.7	6.0	31.7
	Dry Weight	
25.6	5.7	31.3

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Regression equations for predicting total green and dry weights of all trees developed using the Log_{10} transformation of the equation $Y=ax^b$ with dbh as the independent variable are shown in (Table 6).

$$Log_{10} \text{ Weight Yield} = Log_{10}\, a + b\, Log_{10}\, (dbh)$$

The R^2 values for both equations are high indicating that species mixtures can be sampled and biomass predicted with good success. When transforming the logarithmic values back to original units in pounds, a downward bias exists as the antilogs estimate the geometric rather than the arithmetic mean of the skewed distribution (Cunia, 1964). This systematic underestimation was compensated by adding one half the sample variance ($S^2y.x$) of the logarithmic equation to the value of $Log_{10}Y$ of that same equation. The antilog of that sum is now an unbiased estimate of the true arithmetic mean (Baskerville, 1972). Regressions for predicting green and dry weights using dbh as the independent variable were also developed for the fifteen predominant Appalachian hardwoods and hemlock (Tables 7 and 8). For each species, from 6 to 119 trees were sampled ranging from 2 to 20 inches dbh. R^2 values ranged from .95 to .99 for both green and dry weights. In an earlier study, Wiant et al. (1977) found diameter accurately predicted weight yields of northern West Virginia hardwoods and the inclusion of total or merchantable height did not improve predictions.

These regressions may be easily converted into dry and green total tree weight tables, to be entered with stand inventory information. The combined regressions must be applied cautiously, as they reflect the species composition of the sampled stands and the preponderance of certain species within those stands. Individual species equations should be relatively unaffected by stand composition and would be particularly suitable in pure stands or stands comprised of only a few species.

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Table VI Regressions for predicting total tree green and dry weights (pounds) using dbh (inches), ($Y=ax^b$) based on 429 Appalachian hardwoods and hemlock in southeastern West Virginia.

	Number Trees	a	b	R^2	Coefficient of Variation
Green Weight	429	4.3426	2.4594	.98	3.7290
Dry Weight	429	2.4544	2.4627	.97	5.1150

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Table VII Regressions for predicting total tree green weights (pounds) using dbh (inches), ($Y=ax^b$) of major Appalachian hardwoods and hemlock in southeastern West Virginia.

Species	Number Trees	a	b	R^2	Coefficient of Variation
Yellow poplar	12	2.6171	2.6388	.99	1.2398
Basswood	13	2.5465	2.5701	.96	2.2443
Cucumber magnolia	6	2.8402	2.5627	.99	1.0831
White oak	29	2.4459	2.7253	.96	2.8741
Red oak	24	4.6304	2.4362	.95	3.0472
Shagbark hickory	14	3.4572	2.6259	.99	0.9547
Black cherry	26	3.6254	2.5459	.99	1.8706
White ash	15	4.1914	2.4309	.99	2.4120
Black birch	8	4.2713	2.4964	.99	2.0304
Red maple	27	4.6661	2.4050	.99	2.6256
Chestnut oak	13	2.3122	2.7970	.99	1.7351
Beech	56	3.6429	2.5798	.97	4.9078
Yellow birch	24	5.0315	2.3951	.97	3.7514
Sugar maple	119	4.1503	2.5493	.98	3.6348
Hemlock	21	3.0290	2.4773	.96	3.7943

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Table VIII Regressions for predicting total tree dry weights (pounds) using dbh (inches), ($Y=ax^b$) of major Appalachian hardwoods and hemlock in southeastern West Virginia.

Species	Number Trees	a	b	R^2	Coefficient of Variation
Yellow Poplar	12	1.0259	2.7324	.98	1.7310
Basswood	13	1.4416	2.5328	.96	2.4202
Cucumber magnolia	6	1.4359	2.5622	.98	1.6688
White oak	29	1.5647	2.6887	.95	3.6075
Red oak	24	2.4601	2.4572	.95	3.4575
Shagbark hickory	14	2.0340	2.6349	.99	1.0346
Black cherry	26	1.8082	2.6174	.99	1.8747
White ash	15	2.3626	2.4798	.99	2.7722
Black birch	8	1.6542	2.6606	.99	2.1845
Red maple	27	2.0772	2.5080	.99	3.1215
Chestnut oak	13	1.5509	2.7276	.99	1.5567
Beech	56	2.0394	2.5715	.97	5.1922
Yellow birch	24	3.1042	2.3753	.97	4.2784
Sugar maple	119	2.4439	2.5735	.98	4.0478
Hemlock	21	1.3449	2.4500	.96	4.6204

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