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As Compared with Volume Measure

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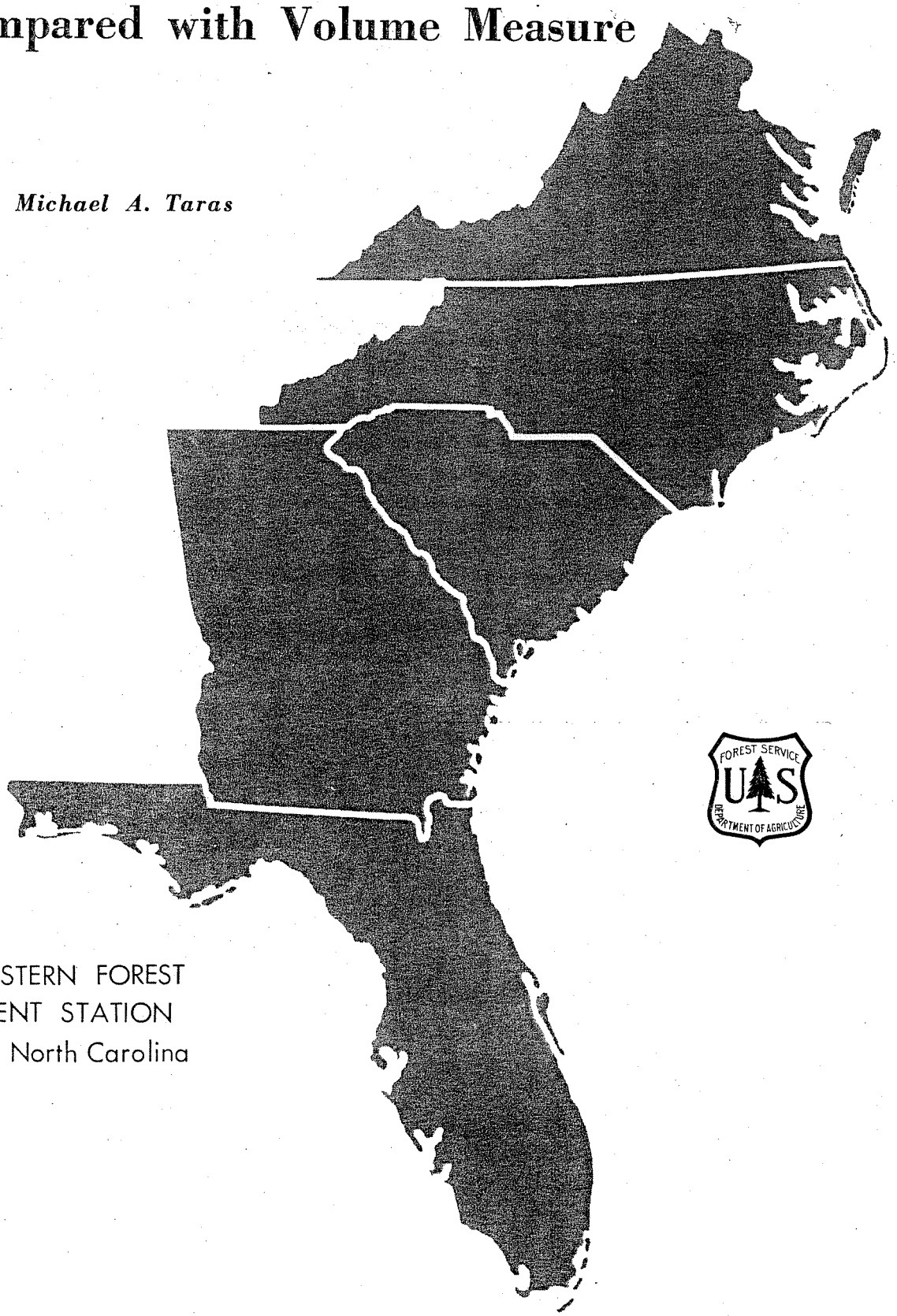

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U. S. DEPARTMENT OF AGRICULTURE - FOREST SERVICE

BUYING PULPWOOD BY WEIGHT:

As Compared with Volume Measure

by

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Introduction

During the past few years several pulp and paper companies in the Southeast have started to purchase pulpwood by weight rather than by volume. The trend toward buying by weight is strong and getting stronger.

This conversion from volume to weight measurement of pulpwood brings up many questions. For instance, is the weight basis fair to both buyer and seller? What are exact weight equivalents for a cord of wood? So far, the weight basis seems to be working out with reasonable justice to buyer and seller. With regard to equivalents, we do not have exact answers because the matter is complicated by differences in species, age, season, region, time since cutting, diameter of average stick, length of average stick, height of tree, rate of growth, whether bark is attached or removed, etc. Some valuable work has been done on equivalents; this paper is a gathering-together of such work to help clarify the subject.

Measuring Wood by Volume

Problems of volume measurements of stacked wood were studied in Germany as early as 1765; between 1879 and 1881 some reliable figures were published on the wood content of a cord (10).

The cord method of measurement was adopted and used in this country because it was simple and convenient, being easy to apply anywhere, especially in the forest, and not because of its accuracy, as can be easily pointed out. For lack of a better method, the cord has been used for over a half century without too much apparent suffering by either the producer or supplier.

Today, the most generally accepted definition of a standard cord is a stack of wood whose gross volume equals 128 cu.ft. In Canada, cord dimensions of 4 ft. x $4\frac{1}{4}$ ft. x 8 ft., which equal 144 cu.ft., have been used. In various parts of the United States, stack dimensions of 4 ft.x 5 ft.x 8 ft., having a stacked volume of 160 feet and known as a "unit" have been used and still are in use. Thus, it is still necessary to specify the gross volume when speaking in terms of cords. In an effort to standardize, some states have passed laws expressing a specific stacked gross volume of 128 cu.ft. as the standard cord.

Studies as early as 1881 showed that the solid wood content of a cord varied from 51 to 92 cu. ft. (10). More recent work shows a range of 64.0 to 102.4 cu.ft. Chapman and Meyers (8) report that for straight wood 8 inches in diameter and larger, the greatest actual solid content per cord of piled wood is about 105 cu.ft., or 82 percent of 128 cu.ft. of combined air space and wood. The solid wood content can drop to 65 cu.ft. for wood 3 inches in diameter, and as low as 50 cu.ft. for 1- and 2-inch sticks.

The influence of stick length on the variability of solid wood volume in a cord is shown in figure 1 (15), and the effect of stick quality (crook) on volume variability is illustrated in figure 2 (10).

Some species are cylindrical or tapering, thick or thin barked, rough or smooth barked, or characteristically knotty, and all of these factors influence the volume per cord. In recent Forest Service studies covering the entire South, an average cord of pine was assumed to have 72 cu.ft. of solid wood per cord, and hardwoods 79 cu.ft. (7).[1]

MacKinney and Chaiken (12) in a study on loblolly pine in the Mid-Atlantic Coastal Region found an average cord contained about 78 cu. ft. of solid wood; figure 3 shows the variability in solid wood volume of a cord with different average bolt diameters.

In addition to these measurable variables, differences occur with the scaler; his methods, mental attitude, and application of correction factors for cull often have an influence on measurement.

Measuring Wood by Weight

Measuring and purchasing wood by weight is by no means new, but it was only in recent years that sufficient interest was stimulated in the system and attempts were made to introduce it as a method of purchasing pulpwood. Weight purchases in the past were almost impossible because the purchase was usually made in the woods and because of the weight differences.

It is no longer inconvenient to apply this method, since most wood is now scaled at the mill or concentration yard and not in the forest. However, the other reasons for questioning the system still exist. A limited number of studies have been made on cord volume and weight relationships, but no uniform conversion factors have been developed.

Schumacher (14) in 1946 worked out factors to convert the weight of green wood with bark to cords. This study disclosed that the volume-weight ratio for pulpwood varied significantly from one area to another, and a single conversion factor could not be used.

1/ The greater amount of volume in a cord of hardwood is attributable to the larger diameter of average hardwood.

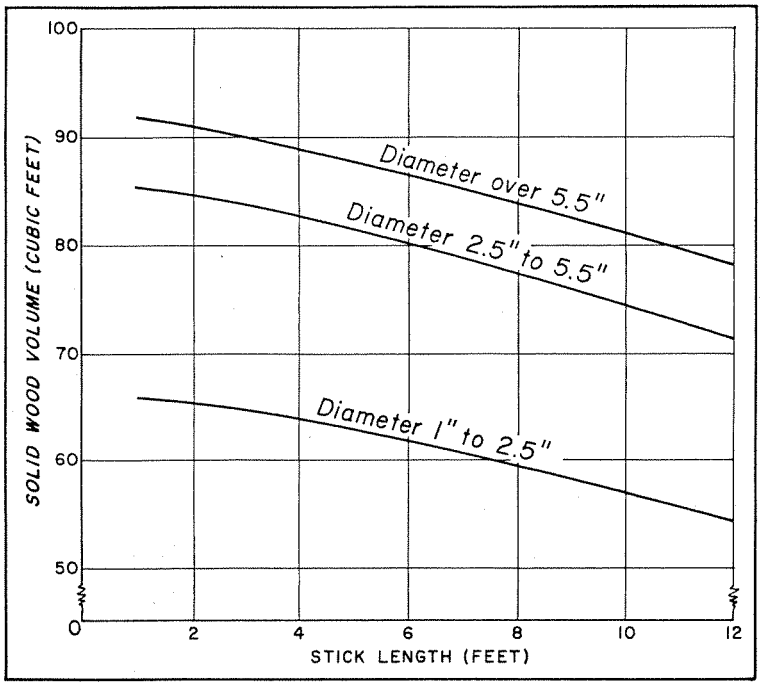

Figure 1.--Influence of length of stick upon solid wood volume of a cord, for conifers (15).

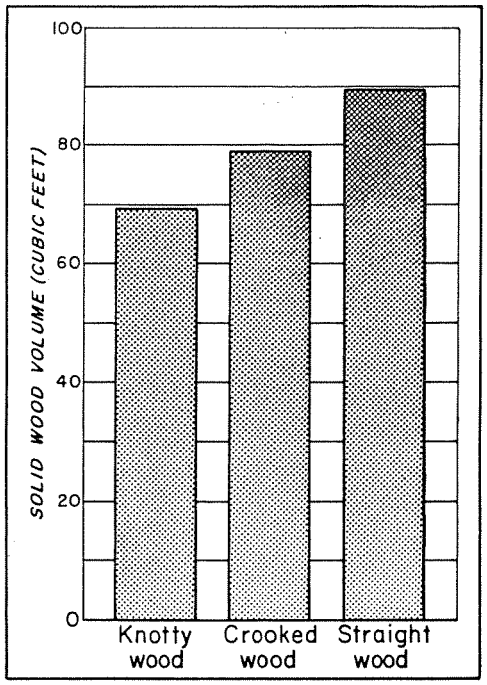

Figure 2.--Influence of stick quality on solid wood volume of 5-foot cordwood (10).

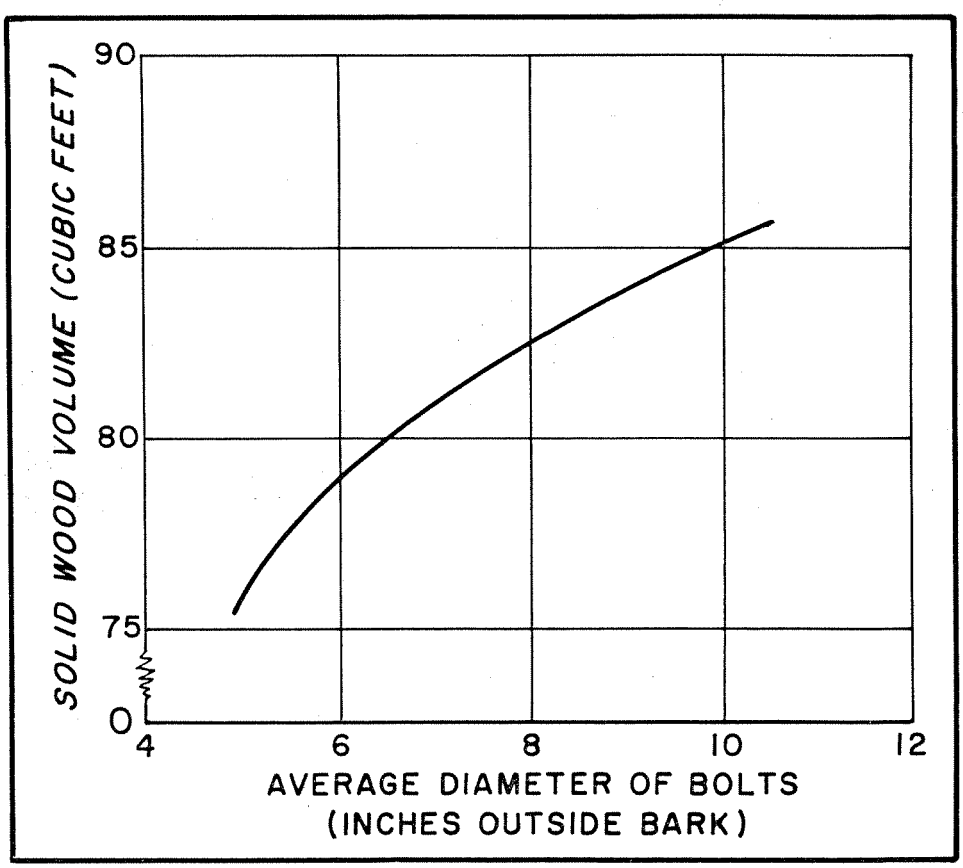

Figure 3.--Influence of average bolt diameter on solid wood volume of stacked cordwood (12).

In 1941, R. H. Miller (13) of the Forest Products Laboratory made a study on measuring green southern yellow pine pulpwood by weight and by cord. One hundred truckloads of pulpwood were studied. Most of the pulpwood was loblolly pine, with some slash and longleaf. This study showed that a standard cord of green unbarked southern yellow pine weighed an average of 5,603 pounds. Other statistics pertaining to this study are as follows:

Item	Diameter	Weight of bark	Moisture content	Volume of solid wood	Volume per ton of green wood
	Inches	Percent	Percent	Cu. ft.	Cu. ft.
Average	5.3	10.4	54	73.76	26.33
Range	2-14	6.4-23.0	42-65	59.5-86.5	22.5-30.0

A correlation was found between the amount of solid wood per ton, the average diameter, and the number of bolts, as well as between solid volume of wood in a cord, the average diameter of the bolts, and the number of bolts in a cord. However, neither weight measure nor cord measure showed a marked superiority in determining the actual amount of solid wood in a cord.

The Forest Products Laboratory (1, 4, 5, 6, 9) over a period of 30 years has accumulated some data on cord volumes and weights of various species in the United States. Some of the cord weights of the various species growing in the Southeast and worked on at the Laboratory are shown in table 1.

The weight values in the following table show the variability that exists between species, as well as within species. The factors influencing these variations in weight are as follows:

1. Volume--the amount of wood in a cord, as pointed out previously, is affected by stick diameter, length, bark thickness, and quality.

2. Density--volume for volume, wood density varies between species, as well as within a species. It is readily affected by percent of summerwood, rate of growth, and position in the tree.

3. Moisture content--the moisture content of wood varies between species and within species between heartwood and sapwood.

Current Weights Developed

Several pulp companies have approached the problem of determining the weight equivalents from a scientific standpoint and are studying the influence of the various factors causing weight variation. Others have actually

weighed and scaled thousands of cords of wood and have developed an average weight for a cord. The weight equivalents being used today vary by species, pulp mills, and localities or points of origin. Figure 4 shows the variation between weights per cord being used by various pulp companies throughout the Southeast. The average weight for pine is 5,232 pounds and hardwood 5,758 pounds. The rather large variations may be justified because of the weight variables in different species and different sections of the South.

Table 1 — Weights of Cordwood Determined in Pulping Experiments at the U. S. Forest Products Laboratory

Species	Weight Unbarked (Lbs.)	Weight Barked (Lbs.)	Calculated Oven Dry Wt. (Lbs.)	Solid Wood Vol. (Cu. Ft.)	Moisture Content[1] (Percent)	Spec. Grav.[2]
Longleaf pine						
Rapid growth (butts)	6245	5615	2908	78.4	93.1	.55
Medium growth (butts)	6374	5714	2920	82.3	95.7	.56
Medium growth (tops)	5967	5236	2418	81.5	116.5	.49
Slow growth (butts)	6152	5310	2895	76.2	83.4	.59
Shortleaf pine						
Rapid growth..	5713	4903	1916	73.9	155.8	.41
Medium growth..	5669	4994	2037	77.4	145.1	.42
Slow growth	5763	5207	2478	85.5	110.1	.46
Slash pine						
Rapid growth	5504	4490	....	66.2	....	.45
Rapid growth (no heartwood)	5271	4333	....	67.7	....	.43
Medium growth	5759	5011	....	72.9	....	.52
Medium growth (contains heartwood)	5577	4763	....	75.8	....	.51
Slow growth	5794	4906	....	72.2	....	.54
Loblolly pine						
Straight, clear	5500	4920	....	80.2	....	.52
Slightly crooked & knotty	5750	5280	....	82.0	....	.49
Markedly crooked & knotty	5390	4950	....	75.9	....	.45
Sand pine	5083	4517	2386	84.4	89.3	.46
Sand pine	4520	4186	2713	90.8	54.3	.46
Cypress (stunted)	4587	3915	....	71.8	....	.46
Swamp blackgum	5724	5096	3088	78.1	65.0	.55
Swamp blackgum	5677	4900	....	76.2	....	.52
Sweetgum	5670	4880	....	....	....	....
Sugarberry	5540	4890	....	....	....	....
Blackjack oak	5760	4700	....	....	....	....
Green ash	4930	4320	....	....	....	....

[1] Based on oven-dry weight

[2] Based on oven-dry weight and volume green

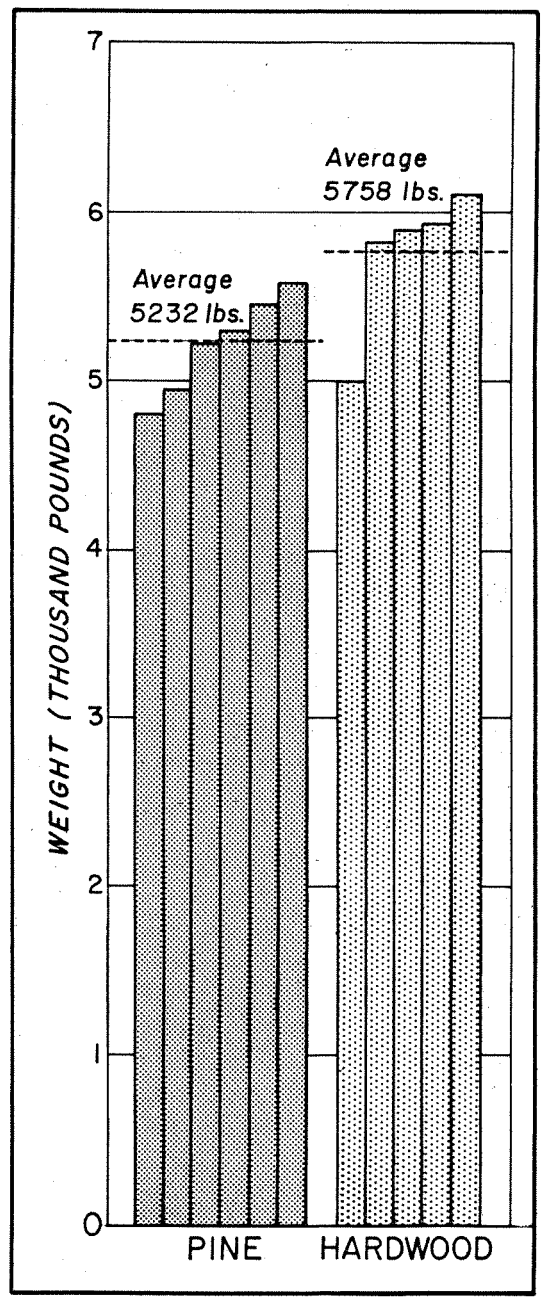

Figure 4.--Weights per cord currently being used by pulp companies in the Southeast.

Calculating the Weight of Wood

The weight per cubic foot of any wood can be readily calculated if we know its specific gravity (based on oven-dry weight and green volume) and moisture content. Weight values have been worked out by the Forest Products Laboratory and are published in Technical Note No. 218 (2) and the Wood Handbook (3). The weight per cubic foot of wood at any moisture content can be calculated by the formula:

$$\text{Density} = \text{specific gravity} \times 62.4 \left(1 + \frac{\text{percentage moisture content}}{100}\right)$$

In order to use this formula, it is necessary to have an accurate determination of both specific gravity and moisture content of the wood being measured.

Table 2 compares calculated weights and actual weights of the solid wood content of several cords of longleaf pine, shortleaf pine, sand pine, and swamp blackgum. Actual weights were determined by weighing and are taken from table 1. Calculated weights were determined by the above formula, using the moisture content, specific gravity, and volume listed in table 1.

These data show that in some cases, as in shortleaf pine, the difference between actual weight and calculated weight is very small and does not vary greatly. However, in the case of longleaf pine, sand pine, and swamp blackgum, some of the values vary considerably. These large differences could be due to inaccuracies in measuring the moisture content and specific gravity of the wood.

Small variations from the true specific gravity or moisture content can mean considerable changes in weight. For each drop or gain in specific gravity of .02 at the 100-percent-moisture-content level, the weight of wood will change about 2.5 pounds per cubic foot. A difference in moisture content of 5 percent around the 100-percent-moisture-content level will cause a change of from 1 to 2 pounds per cubic foot. In a cord containing 72 cubic feet of solid wood, a variation of .02 from the true specific gravity at 100 percent moisture content would mean a loss or gain of 180 pounds per cord. In the case of swamp blackgum, the presence of heartwood and variation in moisture content between heartwood and sapwood are also influencing factors.

The determinations in table 2 were based on solid wood volume alone in order to show applicability of the formula and did not include bark, which is another variable to consider. Some studies have shown that the bark averages about 10 percent of the total weight of the cord and may vary from 8 to 20 percent. Little information is available at present on bark weight and its influence on cord weight.

The question may be asked, "Why can't average values be used to determine cordwood weights?" Average values for specific gravity and moisture content may possibly be suitable if the results are within limits of acceptable error. Calculated weights based on average values of specific gravity and moisture content are only approximations because of variability in specific

gravity and moisture content. It is known that the specific gravity of a species may vary from region to region because of site quality. If average values are suitable, the regional effect should be taken into consideration and average values computed for different regions. Suitable information on average moisture content between species, as well as within species, is lacking. There is also limited information on storage time and its effect on weight. Lindgren (11), in a pulpwood storage study, shows very little loss in moisture content for slash pine cut in July and seasoned for 2 months.

A comparison of actual weights and calculated weights based on average moisture content and average specific gravity of several species is shown in table 3. The actual weights were determined by weighing and were obtained from table 1. The calculated weights are based on the average specific gravity and average moisture content listed for the species by the Forest Products Laboratory (2).

In table 3, the calculated weights determined from average values in general are lower than the actual weight, indicating that either the average specific gravity or average moisture content, or both, are not truly representative of the cords measured.

In considering average values only, that is, for specific gravity and moisture content, assuming a standard cord to contain an average of 72 cu.ft. of solid wood, we would develop weights as shown in table 4.

Table 2 — Comparison of Actual and Calculated Weights of Cordwood

Species	Actual Weight of Barked Wood (Pounds)	Solid Wood Volume (Cu. Ft.)	Calculated[1] Weight of Barked Wood (Pounds)	Difference from Actual Weight (Pounds)
Longleaf pine				
Rapid growth (butts)	5615	78.4	5190	— 425
Medium growth (butts)	5714	82.3	5629	— 85
Medium growth (tops)	5236	81.5	5387	+ 151
Slow growth (butts)	5310	76.2	5128	— 182
Shortleaf pine				
Rapid growth	4903	73.9	4840	— 63
Medium growth	4994	77.4	4961	— 33
Slow growth	5207	85.5	5147	— 60
Sand pine	4517	84.4	4574	+ 57
Sand pine	4186	90.8	4013	— 173
Swamp blackgum	5096	78.1	4420	— 676

[1] Weight based on volume, moisture content, and specific gravity listed in Table 1.

Table 3 — Comparison of Actual and Calculated Weights of Cordwood Based on Average Moisture Content and Average Specific Gravity Values

Species	Actual Weight of Barked Wood (Pounds)	Solid Wood Volume (Cu. Ft.)	Calculated[1] Weight of Barked Wood (Pounds)	Difference from Actual Weight (Pounds)
Longleaf pine				
Rapid growth (butts)	5615	78.4	5417	— 198
Medium growth (butts)	5714	82.3	5687	— 27
Medium growth (tops)	5236	81.5	5632	+ 396
Slow growth (butts)	5310	76.2	5265	— 45
Shortleaf pine				
Rapid growth	4903	73.9	4663	— 240
Medium growth	4994	77.4	4884	— 110
Slow growth	5207	85.5	5395	+ 188
Loblolly pine				
Straight, clear	4920	80.2	4836	— 84
Slightly crooked & knotty	5280	82.0	4945	— 335
Markedly crooked & knotty	4950	75.9	4576	— 374

[1] Weight based on average moisture content values and average specific gravity values of the respective species as listed by the Forest Products Laboratory.

Table 4 — Weights for the Various Pine Species in the Southeast

Species	Specific Gravity	Moisture Content (Percent)	Density (Lbs. Cu. Ft.)	Vol. Per Cord (Cu. Ft.)	Calculated Wt. Without Bark (Lbs.)	Estimated Wt. of Bark (Lbs.)	Calculated Wt. with Bark (Lbs.)
Loblolly pine	0.46	110	63.3	72	4557	700	5257
Longleaf pine	0.53	105	67.8	72	4881	650	5331
Shortleaf pine	0.44	120	60.4	72	4349	500	4849
Slash pine	0.52	120	71.4	72	5140	500	5640

A comparison of the calculated hypothetical values listed above and those that are being used by the pulp industry today can be seen in figure 5. The calculated values fall in the same range of values being used by the pulp companies, from 4,800 to 5,600 pounds. Though the species are not noted in the data obtained from the pulp companies, the areas from which they come and their weights are indicative of what they might be. The heavier groups (5,450, 5,583) are probably longleaf and/or slash pine. The others are probably shortleaf and loblolly pine.

The current practice in purchasing pulpwood by weight is to pay for it on a hundredweight basis. Current prices are about 27 to 31 cents per hundred pounds. If a cord of wood weighs 4,800 pounds, it will bring a price of $13.44. A cord weighing 5,583 pounds will bring $15.48. For an individual to lose a dollar on a cord of wood, the values being used by the pulp companies would have to be approximately 400 pounds below the average.

Summary and Conclusions

From the data presented, it has been shown that measuring wood by the cord or volume method can be unfair to either buyer or seller because cord volume is influenced by stick diameter, length, quality, and other factors.

It has also been shown that the weight of a cord of wood varies considerably because of the variations that exist in wood density and moisture content.

Since wood is a heteregenous material, it is not possible to develop one single factor that will serve all existing variables and can be used for wood in general.

Weight scaling is now being considered favorably for several reasons:

1. Positive records of a transaction can be made without human judgment entering the picture.

2. The method is quick, requiring no special handling, and saves time for both the buyer and seller.

3. It provides an incentive for better piling of wood on trucks and thus increases volume handled by the supplier.

4. A greater volume of wood can be handled in less time and with less personnel.

5. It encourages prompt delivery of green wood to the mill, which is desirable from the standpoint of pulping.

6. Inventories are more easily maintained.

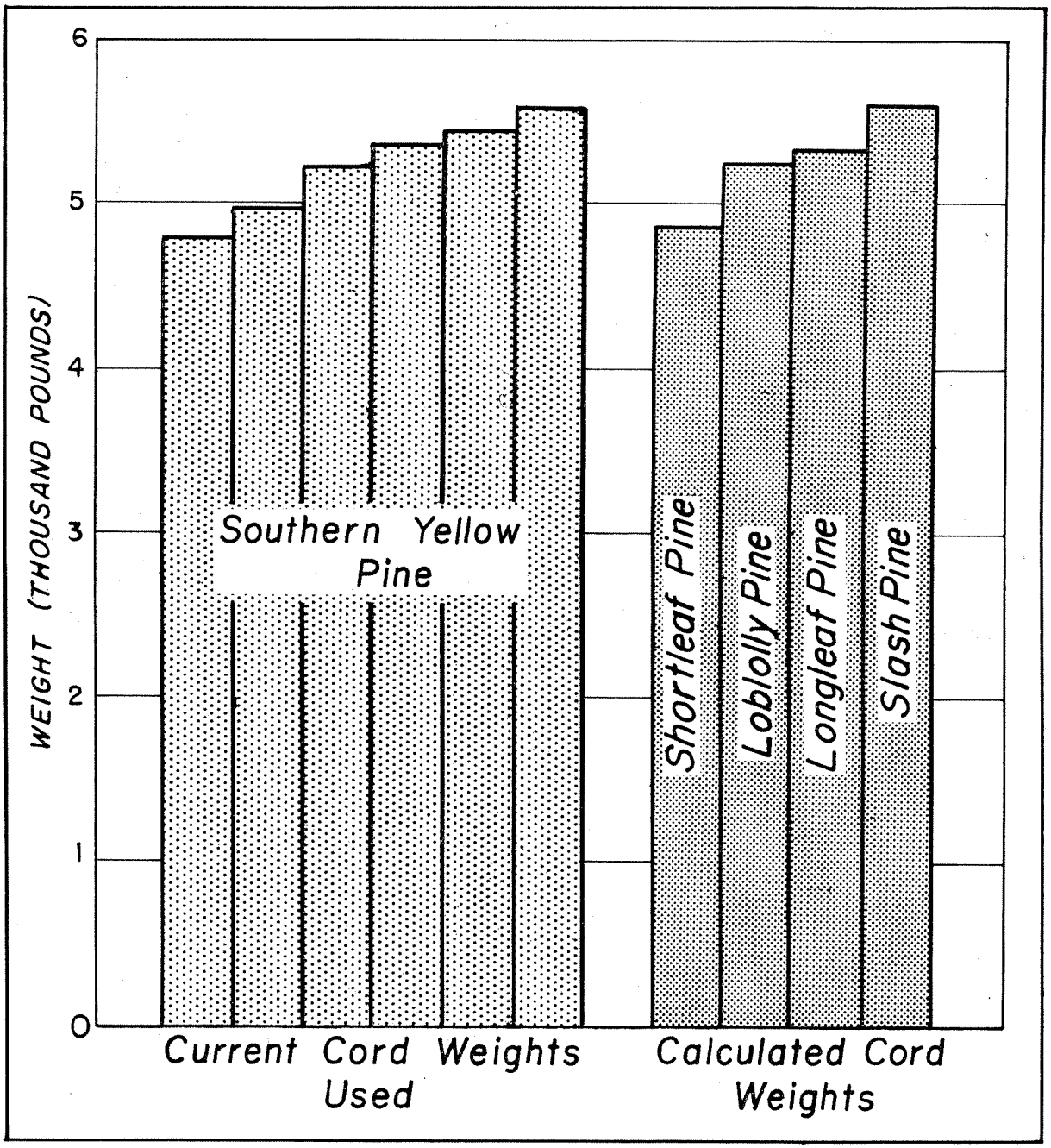

Figure 5.--A comparison of cord weights used by pulp companies, and calculated weights based on average specific gravity, average moisture content, and a cord volume of 72 cu. ft.

There appears to be no real necessity for developing conversion factors to convert cord measure to weight or vice versa since the weight measure can stand on its own, as it has for many other agricultural commodities.

Forestry cruise data are easily converted into cubic feet and can be transposed to weight figures with average data now available. Much more accurate measurements of weight of wood in standing trees can be obtained if field measurements are made of specific gravity and moisture content. Research is now under way on methods of determining specific gravity in the field.

There is an opportunity for a great deal more research in measuring and handling wood and wood residue by weight. It is hoped that government, state, and industry will continue such research with a free interchange of information so that the public can be fully informed.

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