ESTIMATING MOISTURE CONTENT OF TREE-LENGTH ROUNDWOOD

Alexander Clark III, USDA Forest Service, Southern Research Station, Forestry Science Laboratory, 320 Green ST, Athens, GA 30602 706-559-4323 aclark@fs.fed.us

Richard F. Daniels, University of Georgia, Warnell School of Forest Resources, Athens, GA 30602 706-5427892 ddaniels@smokey.forestry.uga.edu

ABSTRACT

The green weight of southern pine tree-length roundwood delivered to the pulp mill is generally known. However, for optimum mill efficiency it is desirable to know dry weight. The moisture content of tree-length pine logs is quite variable. The moisture content of pine tree-length logs increases significantly with increasing stem height. Moisture content also varies with tree age and geographic location. It is envisioned that a truckload of tree-length logs would be bored at the scales to extract chips for moisture content determination for converting green truckload weight to oven dry weight. This paper evaluates the predictability of estimating tree-length log moisture content from samples taken a various points along the length of the log. The variability of moisture content related to log diameter, tree age, and geographic location is discussed. Equations for estimating weighted average moisture content of tree-length logs from moisture content of samples taken at one, two or three locations along the log are presented for planted loblolly pine. The results of this research indicate that the moisture content of a truckload of tree-length logs can be accurately estimated by sampling three logs in a load at 4.7-meters for converting green truckload weight to bone dry tons.

INTRODUCTION

Southern pine tree-length roundwood furnish is weighed green at the pulp mill wood yard and the inventory for roundwood in the wood yard expressed in green tons. The moisture content of tree-length logs is very variable and decreases during storage making it difficult to maintain accurate accounting of green tons of round wood in inventory and correlating this information with bone dry tons for production. Pulp yields are most highly correlated with specific gravity or dry tons of wood furnish. If the green weight of roundwood furnish could be accurately converted to bone dry tons this would lead to higher mill efficiency.

Dry weight may be predicted from green weight after a sample to estimate moisture content is extracted from the load. After a truckload of tree length logs is weighted it would pull up to a power borer that would extract chips for moisture content determination for converting green truckload weight to bone dry weight. It is envisioned that a core of chips 5 cm in diameter would be extracted from a load of logs by boring 76 cm into the load. This paper evaluates the ability of predicting tree-length log moisture content from samples taken at various points along the length of the log. The variability of moisture content related to log large end diameter, tree age and geographic location is discussed. Equations are presented for estimating weighted average moisture content of tree-length logs from samples taken at one, two and three locations along the log. Assuming this boring system would extract chips from three logs in a load, the ability to predict average truckload moisture content from three randomly selected logs sampled at various points along the log is also examined.

PROCEDURES

To examine the ability of estimating average moisture content of tree-length logs from samples extracted at various points along the log, cross sectional disks were collected from 373 loblolly pine (Pinus taeda L.) logs (Table 1.). The 2.5 cm disks were collected at 1.5 m intervals from planted loblolly pine growing in the Costal Plain and Piedmont in the Southeast United States. The 22-25-year Coastal Plain loblolly pine was sampled at 3 locations in southeast Georgia. The 35- year Coastal Plain loblolly was sampled from one stand in Dooley County, Georgia.

The 9-15 year and 16-29 year Piedmont loblolly were sampled at various locations across the South Carolina and Georgia Piedmont. The 35- year Piedmont loblolly was sampled from one stand in Spalding County, Georgia.

Age Group		Logs	Log Large End Diameter		Moisture Content	
Mean	Range	Sampled	Mean	Range	Mean	Range
(years)		(no.)	(cm)		(%)	
			Coastal Plain			
24	22-25	27	23.0	13.2-36.6	53.1	46.9-59.8
35	35	48	21.8	15.7-31.5	48.2	42.9-55.1
			Piedmont			
12	9-15	105	15.6	12.7-25.9	56.1	47.2-62.8
20	16-29	145	19.2	12.7-32.0	53.5	42.8-61.2
35	35	48	28.2	21.3-39.4	52.4	46.0-60.0

Table 1- Summary of tree length logs sampled for wood moisture content by physiographic region and age group.

The cross sectional disks were sealed in polyethylene bags immediately after being cut from freshly felled trees and stored in a freezer for processing at the laboratory. Each disk was weighed green without bark, its diameter measured, its green volume determined by displacement and dried for 48 hours at 103 C to determine disk oven dry weight. Disk wood moisture content based on green weight was calculated using equation (1):

$$DKMC = ((DKGNWT-DKODWT)/DKGNWT) * 100 \quad (1)$$

Where: DKMC = Disk wood moisture content in percent
DKGNWT = Disk wood green weight in grams
DKODWT = Disk wood oven dry weight in grams

Weighted average tree-length log moisture content was calculated by weighting disk values in proportion to disk basal area.

The correlation between tree-length log moisture content and that of a disk from along the log was examined. Based on these correlations regression equations based on all 373 logs were developed to predict log moisture content based on one, two and three disks sampled along the log. The following equation was developed based one disk sampled at 4.6 meters along the log:

$$LGMC = a + b\,(DKMC1) \quad (2)$$

Where: LGMC = Weighted tree-length log wood moisture content in percent
DKMC1 = Moisture content of a disk at 4.6 meters in percent
a and b = Regression coefficients

The following equation was developed based on sampling two disks one at 1.5 meters and one at 4.6 meters along the log:

$$LGMC = a + b\,(DKMC1) + c\,(DKMC2) \quad (3)$$

Where: DKMC1 = Moisture content of a disk at 1.5 meters in percent
a, b and c = regression coefficients

The following equation was developed based on sampling three disks, one at 1.5 meters, one at 4.6 meters and one at 7.6 meters along the log:

$$LGMC = a + b\,(DKMC1) + c\,(DKMC2) + d\,(DKMC3) \quad (4)$$

Where: DKMC3 = Moisture content of a disk at 7.6 meters in percent
a, b c and d = regression coefficients

Simulated truckloads of logs were developed from the study logs to test the accuracy of predicting average truckload moisture content based on disks from three randomly selected logs per truckload. Truckloads were developed using the 12- year old trees sampled in the Piedmont and the 35- year old trees sampled in the Coastal Plain and in the Piedmont. Two simulated loads were developed for each 35- year old stand consisting of 35 randomly selected logs. Forty-eight logs from the 12- year tree class were used to develop the 12- year truckload. Disks from 10 sets of three randomly selected logs were used to estimate average truckload moisture content.

RESULTS

The moisture content of the tree-length loblolly pine logs sampled varied significantly. The logs form the 35- year old loblolly stand in the Coastal Plain contained 14 % less water and 16 % more dry wood per green ton than the logs from the 12- year old loblolly pine in the Piedmont. This difference occurs because the 35-year loblolly have an average wood moisture content of 48 % and a specific gravity of 0.50 compared to a moisture content of 56 % and specific gravity of 0.43 for the 12 year old loblolly.

Average wood moisture content increased significantly from the butt to top of the log (Figure 1). This increase in moisture content up the log was observed for all age classes and geographic locations. However, log moisture content at the same sample points along the log was lower with increasing tree age. Weighted log moisture content averaged across geographic areas was 56 % for the 12-year trees, 53 % for the 20- year trees and 50 % for the 35-year trees. The moisture content of the tree-length logs sampled in the Piedmont was higher than that for the same age trees sampled in the Coastal Plain (Figure 2). The Piedmont trees averaged 52 % moisture content compared to 48 % for the Coastal Plain 35 year old trees. Weighted average log moisture content was positively correlated with log large end diameter (LED) for all age classes and geographic locations. However, the LED of logs from the two Coastal Plain locations and the 12- year old logs from the Piedmont were not significantly correlated with log moisture content. The LED of the 20- year and 35- year logs form the Piedmont were significantly correlated with log moisture content and had correlations of .26 and .36 respectively.

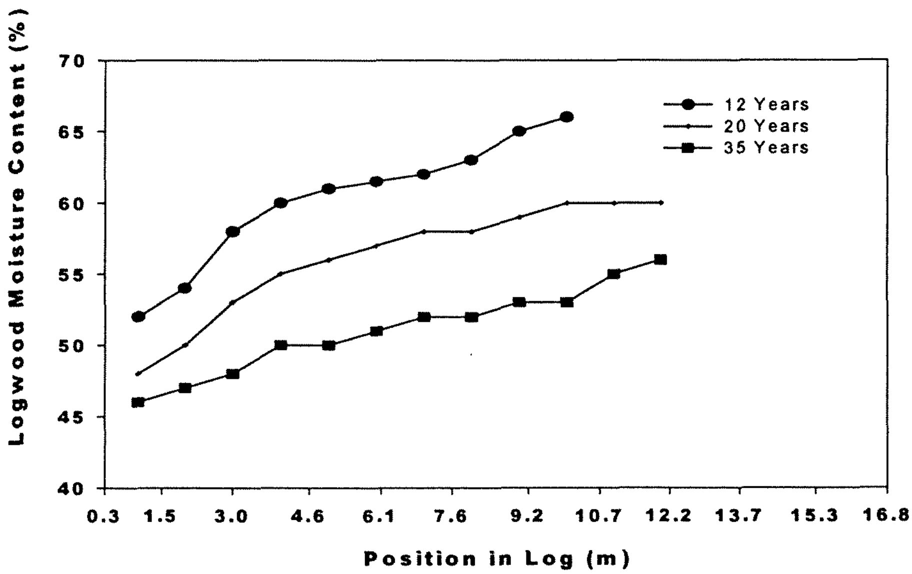

Figure 1—Effect of stand age and position in tree-length log on wood moisture content of 12-, 20- and 35 year old planted loblolly pine.

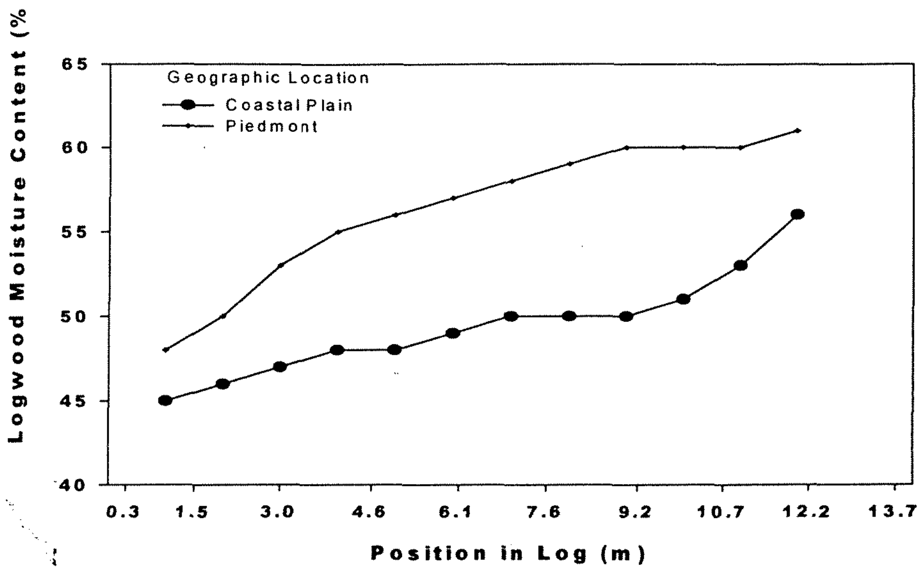

Figure 2—Effect of geographic location and position in tree-length log on wood moisture content of 35 year old planted Loblolly pine.

To determine where to sample a log to estimate log moisture content the correlation of disk moisture content with average weighted log moisture content was examined (table 2). The moisture contents of the disks sampled at 3.0- and 4.6- meters were most highly correlated (R= .90) with average weighted log moisture content and the disk sampled at the butt of the log had the lowest correlation (R= .81). The disks sampled at 1.5-, 6.1-, 7.6-, and 12.2- meters had a correlation of 0.87 with average log moisture content.

Log Position (m)									
0.3	1.5	3.0	4.6	6.1	7.6	9.2	10.7	12.2	13.7
(r)									
0.81	0.87	0.90	0.90	0.87	0.87	0.85	0.83	0.87	0.85

Table 2.-Correlation coefficients (r) for weighted tree-length log moisture content correlated with radial disk moisture content by position in log.

Regression equations were developed to predict average log moisture content from disks sampled at 4.6 meters, 1.5- and 4.6- meters and 1.5-, 4.6 and 7.6-meters along the log (Table 3). The equation based on one disk at 4.6 meters accounted for 81 % of the variation in log moisture content. The equation based on sampling disks at 1.5- and 4.6- meters accounted for 86 % of the variation and the equation based on sampling at 1.5-, 4.6-, and 7.6-meters accounted for 88 % of the variation in log moisture content.

Equation Model	Dependent Variable and Coefficients: Intercept a	DKMC1 b	DKMC2 c	DKMC3 d	Coefficient of Determination (R^2)	Coefficient of Variation (CV)	Standard Error
					(%)	(%)	(%)
1	19.0509		0.6447		0.81	3.2	1.7
2	14.6939	0.3542	0.3805		0.86	2.7	1.5
3	11.6561	0.3182	0.2592	0.2055	0.88	2.4	1.3

Table 3- Regression coefficients for estimating tree-length log wood moisture content based on moisture contents of disks sampled at 4.6-meters, 1.5- and 4.6-meters, and 1.5-, 4. 6-, and 7.6-meters along the log.

When a truckload of logs is bored it is assumed that boring 76 cm into the load would sample three logs. To evaluate how accurately sub-sampling three logs would estimate the average moisture content of a truckload of 35 or more logs the equations in table 3 were applied to 10 sets of three randomly selected logs for five simulated loads (Table 4). Sampling three logs in a load did a good job estimating average load moisture content and accounted for load differences associated with age and geographic location. The difference in predicted load moisture content was minimal when comparing estimates based on one, two or three disks from a log. The average absolute difference between the observed and predicted load moisture content for the 10 sets of three logs per load was 1.1 % for estimates based on one disk, 1.2% for estimates based on two disks and 1.0 % moisture content for estimates based on three disks. Because of the log–to-log variability in a load, estimating the moisture content of a log more accurately with three disks compared to one disk did little to improve the estimated moisture content of a truckload. The average range of the residuals (observed –predicted) for the 10 sets of 3 logs per load was-1.4- to +1.7 % for load moisture contents based on one disk, -1.9 to +1.5 % for load moisture contents based on two disks and –2.2 to + 2.0 for load moisture contents based on three disks.

CONCLUSIONS

The moisture content of tree-length logs varies significantly with in the log, with tree age and geographic location. Weighted average log moisture content can be estimated accurately based on the moisture content of sub-samples taken at various points along the log. Linear regression equations developed to estimate weighted log moisture content based on the moisture content of one cross- sectional disk sampled 4.6 meters accounted for 81 % of the variation in log moisture content. Equations based on disks sampled at 1.5- and 4.6- meters accounted for 86 % of the variation in log moisture content and equations based on disks sampled at 1.5-, 4.6-, and 7.6- meters accounted for 88 % of the variation in log moisture content.

To estimate the moisture content of a truckload of logs it is envisioned that a core of chips 5 cm in diameter would be extracted from three logs per load by boring 76 cm into the load. Truckload moisture content estimated by applying the prediction equations based on disk moisture content taken at one, two and three sample points on the log from three random logs did a good job estimating average truckload moisture content. Sub-sampling three logs per load accounted for load differences associated with age and geographic location. Estimating the moisture content of a log by sampling three disks compared to one or two disks did little to improve the estimated moisture content of a truckload because of the log–to-log variability in a load. Sampling additional logs in a load rather than sampling additional locations within a log would improve the accuracy of estimating truckload moisture content.

Based on this research the moisture content of a truckload of tree-length logs could be accurately estimated by sub-sampling three logs in a load at 4.7-meters for converting green truckload weight to bone dry tons.

Stand Location	Stand Age	Truck Load	Observed Moisture Content of Load	Predicted Moisture Content of Load Based on 10 Sets of 3 logs	
				Average	Range
	(years)	(no.)	(%)	(%)	(%)
		Disk at 4.6 meters			
Piedmont	12	1	56.5	57.8	56.6-58.8
Piedmont	35	2	52.5	51.4	50.0-52.6
Piedmont	35	3	52.8	51.9	49.4-53.6
Coastal Plain	35	4	48.1	49.1	47.8-50.8
Coastal Plain	35	5	48.4	49.4	47.7-51.3
		Disk at 1.5- and 4.6- meters			
Piedmont	12	1	56.5	58.0	56.1-60.0
Piedmont	35	2	52.5	51.5	49.0-53.0
Piedmont	35	3	52.8	51.5	48.3-53.5
Coastal Plain	35	4	48.1	49.1	47.8-50.7
Coastal Plain	35	5	48.4	49.4	47.6-51.2
		Disk at 1.5-, 4.6- and 7.6- meters			
Piedmont	12	1	56.5	57.7	56.5-60.3
Piedmont	35	2	52.5	51.4	48.6-52.8
Piedmont	35	3	52.8	51.4	48.2-53.8
Coastal	35	4	48.1	48.6	47.1-50.9
Coastal	35	5	48.4	49.0	47.4-51.0

Table 4-.Average difference and range of predicted truckload moisture content compared to observed moisture content based on 10 sets of 3 randomly selected logs sampled at 4.6-meters, 1.5- and 4.6- meters, and 1.5-, 4.6-, and 7.6-meters along the log.