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IMPROVED HARVESTING METHODS

EQUIPMENT SURVEY NOTES

LOG DIMENSIONS AND THE SELECTION OF EQUIPMENT[1]

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Introduction

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Although considerable thought and effort are directed toward development of new equipment for handling logs, less attention is given to increasing the efficiency of existing equipment. After a tree is felled, all succeeding operations involve handling. Basic factors in handling are weight and number of pieces. Specifications for bucking the tree stem into logs control these two basic factors. Trees can be marked for log lengths according to grade specifications. Tree stems can then be bucked into one or more logs according to diameter, thus producing the minimum number of pieces of approximately equal weight and volume.

Once the load-weight limits for a particular timber tract or region have been determined, timber handling equipment of suitable and economic capacity can be selected. The following translation explains the considerations and procedures, based on sound statistical analysis, used to achieve efficient use and selection of equipment. The procedures outlined are practical and usable by nontechnical personnel. The basic procedures are the same regardless of timber size and present a new concept in harvesting timber.

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[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

LOG DIMENSIONS AND THE SELECTION OF EQUIPMENT

A view of logs stored at a sawmill, in a harbor, or at a loading place in the forest gives a strong impression of the great diversity of tropical logs. Impressive log diameters 160 to 200 centimeters (63 to 79 inches) attract attention because they are exceptional, sometimes unique. Upon a closer look, it will be noticed that the dimensions--diameter, length, volume and, as a consequence, weight--vary between wide limits and that the extreme weights are found in the logs of the largest dimensions. If we consider the extremes of diameter as 45 to 165 centimeters (18 to 65 inches), the major part of the volume occurs between the limits of 54 to 105 centimeters (21 to 41 inches). The variations in dimensions could make it difficult to select the correct unit of a given type of equipment, such as: Tractors for skidding in the felling area, machines for loading, and circular and frame saws, all of which could be selected by type according to their ability to handle logs of such variation and difference. This report covers research at storage areas to determine how to select the needed equipment in advance.

Inventory of Storage Places and Logs

Our study included 25 log storage yards in 12 different forest areas of the Ivory Coast, Cameroun, Gabon, and Congo. The logs in each yard were stored for many months during operations. We found some practical rules, which could be of help in choosing equipment.

In a managed forest of the type to which the majority of the forests in the temperate zones belong, logged trees show small variation in diameters and lengths because the silviculture treatment has a tendency to produce trees of little difference in size. In tropical forests, unmanaged in most cases, trees often vary considerably in diameter. In some tropical forests, even transition-type species that did not achieve full diameter and length are harvested--for example, Utile and Cola mahogany.

The main problem during the logging operation in a tropical forest is bucking the trees into logs. The bucking is controlled by varying conditions, among which are (1) the maximum log length, which is controlled by the means of transport (truck, trailer, pickup, etc.); (2) the log grading rules, source of the commercially based limits on the external defects such as knots, branches, etc.; and (3) the technological utilization objective, which concerns the length and diameter specifications for such uses as veneer.

Regardless of the many times logs are handled before they reach the place of their utilization, weight is rarely considered at the time of their bucking. Very often felled trees are cut into different diameters and lengths, therefore, the logs also show a great variation of dimensions. The bucking decision is often made by the person who is also busy with clearing of the felling area or loading operation, with transportation, or with management of the sawmill.

To determine the best bucking practice involves the following questions: What are the average log diameters? What are the extremes? What are the more frequent ones? What is the practical importance of each diameter class?

The answers to all these questions or even the especially important ones can be of great help to the people engaged in logging, hauling, and sawing operations.

From an inventory of the timber yard, it is quite easy to determine average sizes--diameter and length--and to determine the extreme values. In table 1 are shown figures for different areas. An analysis of the figures alone is not an adequate analysis of the stock.

A simple comparison between average and extreme sizes shows that these averages do not give a dependable relationship that could be used in practice. In the case of yard A, the average volume is 4.3 cubic meters (152 cubic feet) between two extreme volumes of 18.2 and 0.9 cubic meters (636 and 32 cubic feet), an average diameter of 0.75 meters (29.5 inches) between two extremes of 0.5 and 1.63 (20 and 64 inches), and an average weight of 2.3 metric tons (5,100 pounds) between two extremes of 0.5 and 11 metric tons (1,100 and 24,250 pounds).

Table 1.

	A. Okoumé Gabon	B. Limba Congo	C. Azobe Cameroun	D. Miscellaneous species Ivory Coast
Number of logs studied	964	1,888	972	2,158
Total volume meters				
Cubic meters	3,668	7,747	3,792	10,701
Cubic feet	(129,534)	(273,581)	(133,913)	(377,900)
Average log volume				
Cubic meters	3.8	4.1	3.9	5
Cubic feet	(134)	(145)	(138)	(177)
Maximum volume				
Cubic meters	18.2	8.66	9.03	25.4
Cubic feet	(643)	(306)	(319)	(897)
Average log weight,				
Metric tons	2.3	3.1	5.3	4.2
Pounds	(5,071)	(6,834)	(11,684)	(9,259)
Maximum log weight,				
Metric tons	10.9	6.5	12.2	21.6
Pounds	(24,030)	(14,330)	(26,896)	(47,620)

What the professional people are interested in is not the extreme or the average, but the more important relation that represents the distribution of volume, weight, or diameter. Determination of the proportion (statistical distribution) of maximum diameter or maximum volume really answers the problem so the choice of equipment for real requirements (can be made) without risk of purchasing equipment which cannot be utilized. Only the distribution of the logs in a yard, logs of different categories of diameter, length, and volume can give an exact picture of the composition in the yard. Such a distribution will permit analyzing the production of the area or of the entire forest zone.

The Graphic Representation of Logs

The only document available there is the inventory list (log scale tally). We recommend a simple method, understandable even by unqualified personnel, which gives a simple and direct picture of the size distribution of the logs in the storage yard. This method is easy, requires little time, and is based on the log scale tally.

The method is composed of two steps. First is the plotting of all given figures on graph paper. Millimeter cross-section paper is used, preferably transparent, on which the plotting is done using the abscisses and ordinates to represent the diameters and lengths of each log. Each log is represented by one point (by black ink) in the place which corresponds to its diameter and length. On one sheet, 2, 000 points could be plotted at the rate of 150 to 200 points per hour. We plotted 964 logs on figure 1, which represents the logging activity of an important region of Gabon during a period of approximately 1 month.

A general glance at the points allows us to see the density of black color--concentration of the most frequent dimensions; the zones of density form more or less dark regions. Logs of extremely large dimensions are represented by points completely separated. A single chart could thus successfully replace an entire bundle of inventory sheets for the storage yard. The quantity of data collected provides a possibility of drawing curves, which make the definition of categories easy. There are sufficient points (representing logs) in each zone or in each square, to enable establishing their relative importance or the percentage of the quantity analyzed.

There exists the possibility of establishing three types of plotting--according to the length, the diameter, or the volume. The precision of the study is determined by the class intervals. So for example, there could be established a diameter class interval of 10 centimeters or of 20 centimeters, and 1 cubic meter intervals of volume.

Reference Graph

(1) Distribution of Logs by Individual Volume Categories.

The object of the research is to accurately segregate the logs of the studied yard according to their individual volumes.

According to the nature of the problem studied, the distribution may be expressed in percentage of the total volume analyzed or in percentage of the number of the logs analyzed: For example, the logs of 3. 5 to 4. 5 cubic meters (124 to 159 cubic feet) present 15 percent of the total number of logs and 12 percent of the volume of the producing region.

The reference graph (figure 2) shows the limits of the equi-volume curves for each volume class. Thus, a distribution of logs by steps of 1 cubic meter must follow the curves for volumes 0. 5, 1. 5, 2. 5, etc.[3] cubic meters (17.7, 53.0, 88.3 cubic feet).

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[3] These curves are curves of the general second degree equation:

$V = \frac{\pi D^2}{4} \times L$, where V is volume in steps of 0. 5 - 1. 5 - 2. 5 etc. cubic meters

The curves are drawn with the help of a volume table. For example, in drawing the curve for the volume V = 3.5 cubic meters (124 cubic feet), we plot from the table the line for each diameter and length which corresponds to the volume 3.5 cubic meters (124 cubic feet). In this way, we will obtain the individual values shown in table 2. The points corresponding to these combinations, plotted on the millimeter graph paper, suffice for drawing the complete curve.

Table 2.

Diameter:										
Centimeters	105	100	95	90	85	80	75	70	65	60
Inches	(41.3)	(39.4)	(37.4)	(35.4)	(33.5)	(31.5)	(29.5)	(27.6)	(25.6)	(23.6)
Length										
Meters	4.05	4.45	4.85	5.50	6.20	7.00	7.90	9.10	10.5	12.4
Feet	(13.3)	(14.6)	(15.9)	(18.0)	(20.3)	(23.0)	(25.9)	(29.9)	(34.4)	(40.7)

(The following is clarified by visualizing the transparent graph of figure 1 superimposed on figure 2.)

It is sufficient to superimpose the plot of points over the reference graph (figure 2) and count the points between two successive curves, designating this number by N; the percentage distribution by number is obtained immediately by dividing each value of N by the total number of logs in the yard. If we are interested in determining the percentage distribution by volume, we consider each log as of average volume for a given class. Logs located between the two curves V = 3.5 and V = 4.5 could be considered as having a volume of 4 cubic meters (141 cubic feet). This is true when the points are approximately uniformly distributed between two curves; in other cases, there is need for approximate interpolation. When the number of points is small, for example, around 10, it will be more exact to determine and record the individual volumes from the drawing according to their dimensions. Some points might be on the curve. In other cases, we can average by taking one over and the other under the curve. It should then be practical to put the figures in a table of the following type:

Table 3.

The category or volume class	Number	Distribution of the number		Volume	Distribution of volume	
		Percent	Cumulative percent		Percent	Cumulative percent

(2) Distribution According to Diameter Classes.

The procedure used is the same as for the preceding distribution by individual volumes. The reference chart (fig. 3) has horizontal lines through the ordinates corresponding to limits of each diameter class, and a series of equi-volume curves more highly defined. These two types of lines form a series of parallelograms within which are located the points representing logs of the same average volume corresponding to the chosen diameters.

In this way, figure 3 shows graphically the limits corresponding to the 90 to 100 diameter class and the 3. 5 to 4. 5 and 5. 5 to 6. 5 volume classes. Each log plotted within these parallelograms is considered as having a volume corresponding to the average volume of the parallelogram, either 4 or 6 cubic meters. A simple multiplication by the number of logs permits the determination of the volume in each class. The computed results are put in a table of the following type:

Table 4.

Diameter class	Unit volume in cubic meters	Number of logs	Volume of (class)	Percent in class	Percent, cumulative
50-60	1				
	2				
	3				
60-70	1				
	2				
	3				
	4				

It is also possible to follow another method: Considering the logs of the diameter included in the interval between 90 to 100, for example, they have a diameter common to the average for this interval which is 95; it should be sufficient to add their lengths to determine the volume of the logs corresponding to this interval, but such an operation seems to be longer than the former.

(3) Distribution by Length Classes.

It is clear that such a distribution holds less interest because the choice of log length is dependent on logging and industrial requirements, as we will describe it here. The reference chart is made this time by drawing vertical lines through the abscisses for the limits of each length class and by the equi-volume curves. These two groups of curves delimit the parallelograms within which appear the points for logs corresponding to the selected length classes and of the same average volume. In figure 4, the heavy lines show the length class limits of 6 and 7 millimeters and volume class limits of 4. 5 and 5. 5 cubic meters. Now, following the same reasoning as before, it will be sufficient to count the number of logs plotted and prepare a table similar to the former one to analyze the distribution.

Table 5.

Lumber yard	A	B	C	D	E	F
Number of logs	964	1,436	1,817	1,888	2,158	1,079
Total volume						
(Cubic meters)	3,668	6,980	8,725	7,748	10,702	5,540
(Cubic feet)	(129,531)	(246,495)	(308,119)	(273,167)	(377,936)	(195,642)
Distribution by individual volumes.						
Calculated total						
(Cubic meters)	3,631	6,959	8,817	7,754	10,701	5,414
(Cubic feet)	(128,227)	(245,754)	(311,368)	(273,829)	(377,900)	(191,193)
Difference	37	21	92	7	1	126
Total error	-1%	-0.3%	+0.1%	+0.1%	0	-2.3%
Distribution by diameters.						
Calculated total						
(Cubic meters)	3,626	6,965	8,748	7,748	10,823	5,496
(Cubic feet)	(128,050)	(245,965)	(308,931)	(273,617)	(382,209)	(194,088)
Difference	42	15	23	0	121	44
Total error	-1.1%	-0.2%	+0.3%	0%	+1.2%	+0.9%

Precision of the Method

This method has very small relative errors. For example, the distribution within the volume categories at six different yards had a total error varying from -1 to +2.3 percent based on calculations using the sum of lengths and the average diameter.

For the distribution by diameter classes at the same log storage yards, the total error varied between -1.1 to +1.2 percent based on calculations using the sum of lengths and the average diameter.

All these results (refer to table 5) must be considered as completely satisfactory, and the error in the comparison of categories is insignificant for all practical purposes.

Interpretation of Results

The results obtained by means of these reference charts are presented in the form of tables. Such tables are less convenient for comparison than when they are transformed into curves of relative frequency. The curves must be comparable between themselves. The raw figures in absolute values are transformed into tables of directly usable percentages.

The frequency curves more or less approach the form of the classical shape that are easy to read and very expressive (normal frequency curve). Based on the distribution by diameter classes or on individual volume classes, we can construct two curves expressing:

--the number of logs, in percentage of the total studied, occurring in each class;

--the log volume, in percentage of the total studied, occurring in the same classes.

We have grouped in figure 5 the curves of frequency by diameter class for different species--okoumé, limba, African mahogany, makore, nyangon and avodire. Each curve represents the production, from a single stand, of the species under consideration. Certainly these size distributions show the difficulty of logging nyangon, avodire, and makore from the same stand at the same time.

For the same species that were presented together in figure 6, the curves of frequency by individual log volume classes expressed in percentage of total volume permit the evaluation of the economic significance of each class. The curve for limba and that for azobe are very similar and indicate a comparable distribution of logs.

The distributions of logs of acajou (Sapele mahogany) and okoumé (gaboon) are very similar, but the bulky character and consequent weight of these logs present very difficult problems in hauling and transportation.

With the different problems that will be discussed later with several examples, it is desirable to know immediately how the logs conform to this or that condition limiting the volume or diameter: for this study, it is better to start with the bell-shaped frequency curve and construct a cumulative frequency curve. For example, figure 7 shows that the logs with a volume of less than 8 cubic meters (283 cubic feet) correspond to 33 percent of the production for makore and 82.5 percent for acajou (African mahogany).

We can also see that makore logs with a volume between 8 and 12 cubic meters correspond to 87.5 minus 33, or 54.5 percent for the given stand. For a single species, okoumé, the curves of log distribution by individual volume classes figured for four different large stands are shown in figure 8, in which it will be seen that logs with a volume less than or equal to 10 cubic meters (or 6 metric tons) constitute nearly the entire production, or 93 to 99 percent of the stand.

One may thus compare several distributions that, to a certain degree, characterize the production of stands in this area. Such data may serve to guide the selection of equipment needed in a given forest area when experience data from a comparable area is lacking.

These few curves, the simple frequency and the cumulative frequency curves, always help to determine and show what data are necessary for selection of equipment or for studies of various equipment according to the specific conditions in each stand.

The Advantage of Distribution Studies

The experience of professional people often enables them to quickly estimate and evaluate variations in length, diameter, or volume. There is a risk, however, that such evaluations may be influenced partly by former impressions. Many cases could be mentioned where observation and experience are not a safe basis for making decisions without a clear knowledge of log distribution. Many examples will be considered later.

Handling at a Forest Depot--Choice of a Fork-Lift Loader

In approaching this problem, we will consider the characteristics of volume, weight, and length. There is the question of what type of fork loader to choose. This problem exists only in areas of a quite high production; we will show here the method of study. For a given logging area, we adopt the power of the different models available as the sole basis for selection, without consideration of maintenance.

Suppose that the power of two available models, is hypothetically, 4 tons and 7.2 tons.[4] For a stand "A" operated for okoumé (gaboon) of an apparent density of 0.60, these machines have a capacity of 6.6 cubic meters and 12 cubic meters. We turn to the cumulative frequency curves classed by log volume for the logs of this area (fig. 9): Additional logs longer than 6 meters (23.6 feet) in length are susceptible to loading on the vehicle in two successive operations, one end after the other, according to the local conditions, and logs can be loaded by this procedure that have a volume 1.7 times the volume limit. The following table of utility can be prepared (table 6):

[4] The "Traxcavator 977" equipped as a log loader, with counterweights, jacks, and other heavy duty equipment, can handle loads of 16,000 pounds or about 7,200 kilograms.

Table 6.

	Machine type	
	I	II
In one operation:		
The capacity limit:		
(Cubic feet)	(233)	(424)
(Cubic meters)	6.6	12
Logs loaded	92.5%	99%
Volume loaded	81%	97.5%
In two operations:		
The capacity limit:		
(Cubic feet)	(395)	(720)
(Cubic meters)	11.2	20.4
Logs loaded	98%	100%
Volume loaded	96%	100%

These results show that the type I loader should not be retained because of two reasons: First, 2 percent of the number and 4 percent of total volume of logs are too heavy and must be loaded by some method other than by fork-lift loader. To avoid this, it would be necessary to eliminate these especially heavy logs by changing the bucking length. Second, the number of logs which must be loaded in two operations (7.5 percent) is very important. It must be remembered that the method of loading in two operations considerably decreases the speed of operation.

In short, only the type II loader can be chosen: Only one log in a hundred necessitates loading in two operations, unless rules are adopted to limit the log lengths, as will be mentioned later. Further this machine will have the advantage of being used more often with a good margin of safety.

In the second stand (B) where the average specific gravity of wood can be taken as 0.85, the same method of analysis is used, substituting the particular curves for this stand (fig. 9); a resumé of the potentialities of the equipment is given in table 7, derived as for the preceding table for stand A.

Table 7.

	Machine type I	Machine type II
In one operation:		
The capacity limit:		
(Cubic feet)	(166)	(297)
(Cubic meters)	4.7	8.4
Logs loaded	55%	89%
Volume loaded	33%	75.5%
In two operations:		
The capacity limit:		
(Cubic feet)	(283)	(501)
(Cubic meters)	8	14.2
Logs loaded	87.5%	99.5%
Volume loaded	74.5%	99%

Considered from the standpoint of power only, the more powerful machine, (model II) is the only one suitable for stand B with the condition that 11 percent of the logs, or 24.5 percent of the volume, must be loaded in two operations. This condition is unavoidable. A daily shipment averaging 230 cubic meters (8,122 cubic feet), or about 46 logs, requires the loading each day of 6 logs of more than 9 cubic meters by the double loading operation. Apparently it is not possible to use a fork-lift loader in stand B, and recourse must be had to an entirely different solution.[5]

Log Bucking Rules

Examination of tables 6 and 7 shows that the exceptionally heavy blocks are quite infrequent and not important in the entire production. This raises the question--why not change the bucking instructions to eliminate the excessively heavy logs? What will the result be, and will there be any undesirable consequences in such a case? In other words, if the choice of operating equipment is made on the basis of horsepower, what disadvantages will result from bucking the logs into such sizes that no logs will be too heavy for the equipment? If economies are achieved by equipment, will they compensate any losses resulting from revised bucking practices?

We revert to the cumulative frequency curves for number of logs by log volume class. For a stand such as the stand "A," the results are presented in table 8.

[5] Note that there are caterpillar fork-lift loaders of higher power than the type II (for example, HD. 16 G). Their price, however, is too high for economic use in areas of average importance. The wheel loaders, however, present a different situation.

Table 8.

Weight limit:										
Pounds			(17,637)		(15,432)		(13,228)		(11,023)	
Metric Tons			8		7		6		5	
Volume limit of okoumé logs:										
Cubic Meters			13.3		11.7		10		8.4	
Cubic Feet			(470)		(413)		(353)		(297)	
Diameter			Corresponding length limit							
Meters		Inches	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet
160		63	6.6	21.6	5.8	19.0	5	16.4	4.2	13.8
140		55	8.6	28.2	7.5	24.6	6.5	21.3	5.4	17.7
120		47	11.7	38.4	10.3	33.8	8.8	28.9	7.4	24.3
110		43	.....	.....	12.3	40.3	10.5	34.4	8.8	28.9
100		49	.....	.....	.....	.....	12.7	41.7	10.7	35.1
Logs handled--Percent			99		98.5		98		96	
Logs too heavy--Percent of number			1		1.5		2		4	
Logs too heavy--Percent of volume			1		3		5		9	
Maximum possible loss per thousand			0.1		0.3		0.7		1.5	

Weight and volume limits are given at the top of each column of this table with the corresponding length limits below for various log diameters. We know what percentage of production represents logs of the same or smaller volume limit ("Logs handled--percent"), and the proportion of logs too heavy, expressed in percent of total number and in percent of total volume.

It is assumed that in relation to the length limits shown in the table, additional bucking must be done on each log that we estimate as too heavy. The resulting logs will be shorter by 0.2 meter, (8 inches) and the loss in each log will be 2 to 4 percent of the length and the volume. In relation to the entire lot under consideration, these losses in volume and value will be extremely small, amounting to 0.1 to 1.5 per thousand, as shown in the last line of table 8.

The compensation for this insignificant loss of wood is the advantage of using much cheaper equipment. In the example for stand "A," the reduction in maximum weight from 9 to 6 tons gives an economy in equipment in all stages of the work.

The preparation of the yard at the sawmill or hauling will be very much easier; since the preparation of the yard assures easy movement of the rolling stock it is evident that rolling stock of 6 ton capacity will be much less expensive, perhaps by half, than rolling stock of 9 or 10 ton capacity. From the safety point of view, the handling of heavy logs is always a dangerous operation with a higher accident frequency rate. Analogous reasoning, followed for the different areas, showed that bucking limits adapted to each stand presented a considerable economic advantage.

The Choice of a Tractor for Skidding

We have seen how to establish the graphic representation of the distribution of merchantable logs by volume or diameter classes. Will application of the same principles to merchantable logs, entire trees, or logs before bucking help our judgment in determining the power needed for skidding tractors? In other words, will a diagram that represents the logs to be skidded, permit estimation of tractor efficiency?

Figure 10 represents the distribution of individual volume of 1,000 okoumé trees by individual volumes taken up to the first limb just after felling and bucking, and 970 logs of African mahogany (Acajou) and makore (average specific gravity 0.85) skidded by a caterpillar tractor. This distribution is based on the percentage of the total number of trees or logs analyzed. It is obvious that certain okoumé tree lengths have a volume greater than that of the skidded logs of acajou and makore. This indicates, in effect, the trees which exceed the tractor capacity and which have to be bucked at the stump before skidding. Assume that a choice must be made of one of the tractors with the characteristics presented in table 9.

The weight of the heaviest tree that can be skidded profitably in one trip by a given tractor is termed "maximum economic load." This will indicate that when a tree surpasses this weight, it can be skidded more rapidly in two trips, each with half of the stem. Experience proved that, on the average, the maximum economic load of a tractor with arch is slightly more than the weight of the tractor itself. Table 9 compares the characteristics of different tractors and the permissible "economic loads."

Table 9.

	Tractor A	Tractor B	Tractor C
Horsepower	190	125	100
Weight with bulldozer and logging arch:			
Ton	23	16	12.3
Maximum economic load:			
Okoumé:			
Cubic meters	40	28	21
Cubic feet	(1,413)	(989)	(742)
African mahogany and makore:			
Cubic meters	28	20	15
Cubic feet	(989)	(706)	(530)

In difficult or swampy terrain, these figures must be reduced. Note that each load may consist indiscriminately of one or more logs. In fact, the skidding of two or three logs together is rather rare; either the forest does not yield them or the practice has not become customary. It must, however, be stated that skidding of small isolated logs is a rule in at least three quarters of the cases.

Skidding of Okoumé

To construct a curve of distribution of okoumé trees, figure 10, we must prepare a table showing, for each type of tractor, the proportion of tree lengths that corresponds to an overload, a normal load, or an underload (table 10). The percentages are based on number of trees and theoretically correspond to the same number of tractor trips, that is to say, one tree per trip.

Table 10.

Distribution of tree lengths	Tractor A	Tractor B	Tractor C
Overload, percent (entire trees)[1]	2	12	31
Normal load, percent (smaller trees)[2]	33	47	47
Underload, percent (small trees)[3]	65	41	22

[1]Overload--a load exceeding the maximum economic load.

[2]Normal load--a load between the maximum and average economic loads.

[3]Underload--a load smaller than the average economic load.

Consider a lot of 100 okoumé trees, corresponding to the distribution shown by the curve of figure 10. How will the skidding be done with each of the tractors A, B, and C? Table 11 shows the considerations involved in this problem.

All trees corresponding to an overload should, in principle, be bucked at the stump to provide normal loads for two (exceptionally three) trips (line 1, table 11).

The small trees corresponding to the underload should be skidded in bunches.[6] Five small trees will require one normal-load trip (line 3) and three underload trips (line 5).

The total of normal-load trips (line 4) is made up of those with heavy trees bucked into two parts (line 1), those with single trees forming normal loads, and those with small trees skidded in groups of two (line 3).

The speed of transportation with the same relative loads is nearly the same whatever the type of machine, but it varies with the relative load. Chronometers were used to show that for an average distance of 300 meters (984 feet), smaller loads require 85 percent of the time for normal loads. To compare the relative working times of machines A, B, and C in skidding 100 okoumé trees, we multiply the time of normal trips by a coefficient of 1 (line 8) and the under load trips by a coefficient of 0. 85 (line 9).

The relative unit cost of tractor B is considered the base unit (line 11).

Taking into account the elements of the unit price that have been considered, we are led to conclude that tractor A is eliminated; it is more expensive than the others to purchase and operate.

[6]This is an average estimate. Actually, each area is different and accordingly, this problem must be considered separately. Table 11 is a method of consideration.

Tables 11.--Skidding of 100 typical okoumé trees

Line		Tractor A	Tractor B	Tractor C
	Number of trips:			
1	Normal loads--heavy trees	2 x 2 = 4	12 x 2 = 24	31 x 2 = 62
2	--average trees	33 x 1 = 33	47 x 1 = 47	47 x 1 = 47
3	--small trees	65 x 1/5 = 13	41 x 1/5 = 8	22 x 1/5 = 4
4	--total	50	79	113
5	Underloads----small trees	65 x 3/5 = 39	41 x 3/5 = 25	22 x 3/5 = 13
6	Total number of trips (4 + 5)	89	104	126
7	Proportion of underload trips (5)	44%	24%	10%
	Relative working time:			
8	Normal load trips (line 4)	50	79	113
9	Underload trips (line 5 x 0.85)	39 x 0.85 = 33	25 x 0.85 = 21	13 x 0.85 = 11
10	Total time (8 + 9)	83	100	124
11	Relative cost per hour	1.5	1	0.8
12	Relative cost of skidding 100 okoumé trees (line 10 x line 11)	125	100	100

Between tractors B and C, which perform the skidding at the same cost, is the choice of the one or the other of little importance? We must take into consideration the following elements in addition to the mere cost factor.

--Tractor C is slower by 24 percent (line 10).

--The choice of tractor C will impair the uniformity of the yard.

--With tractor C, the necessity of bucking 31 percent of the trees at the stump (instead of 12 percent if tractor B is used) will complicate the organization of the work.

--If the large diameters are frequent in the area, tractor B will be better suited than tractor C.

--Tractor B involves a larger investment. It must be concluded that, if funds are available, the preference should be given to tractor B which gives a greater margin of power even though it is more expensive. A small operation that cannot afford the higher expenses must be satisfied with tractor C.

Hauling of Acajou and Makore

Another study, analagous to that made for okoumé, may be made of the efficiency of a type B tractor in skidding the lot of acajou and makore logs. The question to be considered is whether or not tractor B is really suitable.

Following the same reasoning as okoumé for the logs to be skidded the details of skidding are classified in table 12.

Table 12.

Distribution of logs to be skidded	Tractor A	Tractor B	Tractor C
Trips with overload (large logs) percent	0	12	32
Trips with normal load--Percent	38	52	48
Trips with underload (small logs) percent	62	36	20

The conclusions, based on table 13, are the same as for okoumé, especially in relation to tractor A, which is not acceptable. It is necessary, however, to note the following differences:

--For makore, which has large diameters, tractor B is more convenient.

--The use of tractor C depends on bucking 32 percent of the logs; since observations were based on skidded logs, it may be assumed that a certain number of them came from trees already bucked. There is, then, a risk that use of tractor C will require systematic bucking at the stump into more than two lengths in addition to the bucking practiced at the loading point.

It could be stated that in the majority of cases, the choice of tractor B is further confirmed by experience that has proved particularly wise.

Table 13.--Skidding of 100 typical makore and acajou logs

Line		Tractor A	Tractor B	Tractor C
	Number of trips:			
1	Normal loads--big logs	0	12 x 2 = 24	32 x 2 = 64
2	--average logs	38 x 1 = 38	52 x 1 = 52	48 x 1 = 48
3	--small logs	62 x 1/5 = 12	36 x 1/5 = 7	20 x 1/5 = 4
4	--total	50	83	116
5	Underload-----small logs	62 x 3/5 = 37	36 x 3/5 = 22	20 x 3/5 = 12
6	Total number of trips (4 + 5)	87	105	128
7	Proportion of underload trips (line 5)	43%	21%	9%
	Relative working time:			
8	Trips with normal load (line 4)	50	83	116
9	Underload trips (line 5 x 0.85)	31	19	10
10	Total time	81	102	126
11	Relative cost per hour	1.5	1	0.8
12	Relative cost of skidding 100 logs (lines 10 x 11)	121	102	101

It is possible, as in the study of machines for loading and skidding, to show how knowledge of the distribution of logs by diameters can be used to determine the most suitable size of band head saw for the sawmill. However, taking into account the reactions now very frequent among French sawyers, such an analysis will be of practically no significance. To tell a sawyer of acajou and similar species he should avoid the purchase of a 3-meter bandsaw that is suitable for sawing 1.70 meter logs and to content himself with a bandmill of 2.20 to 2.50 meters on condition that he abandon to other sawyers or accomplish by other means the sawing of logs over 1.20 meters is of no interest to that sawyer if he is determined to proceed with the installation of a bandmill of less than 1.50 meters in diameter.

After deciding on the method of operation, the sawyer can benefit considerably from a visit to a colleague who is already satisfied with his selection of suitable equipment of dimensions based on the statistical distribution of log diameters. Such an analysis could avoid the sad consequences of a deliberately erroneous choice at the start.

It is noted, however, that the minimum diameter and width of the band wheel chosen *a priori* may be far below that which will be suitable; it remains to see how the other characteristics of the saw may best be determined.

Granting that special accidental deviants are eliminated and that the stretching force on the blade and the power of the motor have been suitably selected, the one factor of prime importance that remains is the determination of the distance between the two band wheels.

Before any attempt is made to choose this distance, it will be helpful to have a clear picture of what must be done.

The choice of the sawyer.--If we seek to analyze the motives that induce the sawyers to avoid the purchase of saws with large wheels, it must be stated that in a very large number of cases the fear of a very high investment is not the deciding factor.

In the first place, in reality, these sawyers do not hesitate to buy costly accessories, sometimes fragile, often unnecessary or even detrimental, and of minor importance, such as speed changers, variable-speed motors, and automatic sorters. They may sometimes even buy two or three head saws to obtain, at the cost of a very high investment, a very inferior production that could be attained with one saw suitably equipped. In other instances, the sawyers very often are not aware of the real value of a saw of large size.

In fact, the sawmill owners do not buy saws of large size because they are fearful; they fear that they do not know how to make the best use of them and cannot find personnel qualified to maintain the blades.

The choice of the manufacturer. --It might be thought that manufacturers do not make large saws because of technical difficulties in production. It is, in fact, objectively difficult to cast and machine the large band wheels. These technical grounds cannot be considered significant. The sawmill manufacturers may be obliged to turn to certain machine tools or to import certain accessories for their fabrication. They can buy the large band wheels from suppliers abroad and produce by combining them with the other components of a log bandmill.

In fact, if we recoil from such an operation through fear of launching a new venture we contribute to poor evolution that will not be popular.

The common choice. --In the face of the difficulties of sawing the greater part of the tropical woods, sawyers and manufacturers adopt the usual policy of not facing up to the obstacles.

Such an attitude is often economically disadvantageous yet, in some cases, it may be considered justified, provided it is resolved to accept as such a refusal by the opposite group to regulate their actions accordingly by specifying a log diameter limit in proportion to that which has been fixed for the selection of the band wheels. Unfortunately, such a position is psychologically very difficult to hold; a policy cannot , in good conscience, be based on a refusal. A natural need for give and take induces the sawyers and manufacturers to agree to regain in saw capacity that which has been lost in rigidity: They are tending to select a type of saw having very widely spaced wheels, to which the name "Colonial" has been given.

In thus spacing the wheels we reduce very much the rigidity of a blade that is already too weak. Cases are observed where this wide-spacing practice is carried so far that the saw is almost incapable of sawing. This is, however, attributed to a poor choice of cutting speed, hook angle, or tooth spacing, whereas the difficulties arise from a complete disregard of the elementary laws of mechanics.

A saw can not be adapted to tropical woods by spacing the wheels widely or bringing them together as much as possible.

From the mechanical point of view, a saw band acts as a stretched beam carrying tools. The force that can be applied through the tools is rigidly fixed by the limit of the beam's resistance to such force.

It is mechanically demonstrable, and verified by experience, that the resistance of a stretched thin blade is practically inversely proportional to its length.[7]

On the other hand, it can be stated that for the working conditions of a thin blade, the power that can be transmitted usefully to the blade, and through the effect of the speed

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[7] See for example on this topic: Timoshenko, Resistance des materiaux (TII); Timoshenko, Théorie de la stabilité élastique; Yoshio Saito et Minoru Mori, Etudé sur le flambage des lames de scie a ruban minces. Industrie du bois (Vol. 8; Nos. 77 et 78, Japon, 1953).

of feeding the wood to the saw, is proportional to the pressure (cutting resistance) that the wood exerts on that blade.[8] From these two statements, it may be deduced that for a saw with small-diameter wheels, the speed of sawing possible to attain, other conditions being equal, is practically inversely proportional to the capacity of the saw.

In the choosing of a bandmill, sawyers are easily tempted to think: "Which can do the most, which the least?" and their interest stops at the capacity rather than the strength. Such reasoning is not exact; with respect to bandsaws-- those which can do the most, can do the least very badly. As an example, consider the sawing of acajou and sapele. To provide for the sawing of nearly all of the logs, it is necessary to buy a saw with a capacity of 1.6 meters (5.2 feet). In examining the statistical distribution of logs according to diameter classes (fig. 2), however, it can be stated that omission of the upper 11 percent of the volume of logs (5 percent of their number), will make possible the use a saw of 1.20 meters (3.9 feet) capacity for which sawing speed will be in the ratio of 160 to 120, or an increase in output of 25 percent. It is abnormal to forego an increase of such importance on the basis of taking up a few exceptional logs. If we assume that handling will be in keeping with the sawing pace, we can calculate that what is most expensive is the sawing of logs of more than 1.2 meters.

In a saw with a capacity of 1.60 meters, 100 conventional units of volume may be treated as 100 conventional units of time. If a saw with a capacity of 1.20 meters is used, it will be necessary to set aside 11 units of volume, leaving 89 units requiring 0.89 x 120/160 or 66.6 units of time.

Inclusion of the 11 exceptional units will, however, require the expenditure of at least 33.3 additional time units.

Logs of less than 1.20 meter diameter should be considered in the ratio of 0.75 unit of time per unit of volume, whereas it is very necessary that logs more than 1.20 meters in diameter, if accepted, should by realistic accounting be considered in the ratio of 3 units of time per unit of volume. In other words, their sawing is four times as difficult.

Under such conditions, should we not consider purchasing the large logs at a price much lower in comparison to that of others which are less difficult to saw?

In exceptional cases, when such logs are sufficiently numerous it is always possible to take advantage of a special method to reduce them to acceptable dimensions. For example, a chain saw may be considered for splitting.[9]

Also, if a sawyer is obliged to select a saw of too small a wheel diameter, he must demand one in which the wheels are brought extremely close together to get the best performance possible. The improvement to be expected in the previous case, as we have seen, was on the order of 25 percent, whereas the choice of equipment of suitable

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[8] See, for example, Hikoichi Sugihara, Etudé du rapport entre l'effort de siiage et l'effort d'avancement du bois le siiage au ruban (Journal de la Sté Forestière du Japon, 34; 1, Jan. 1952). It is necessary to note that for a thick blade the work of the teeth for removal of the sawdust is not strongly proportional to the total power and pressure so that limits indicated here are not taken into further consideration.

[9] Cf. A. Chardin, Les scies a chaine Sciesachaine poursciage en long B. F. T. No. 44, P. 37.

size permits the attainment of improvement on the order of 200 to 300 percent, and even more. In conclusion: The four examples studied above were not chosen to illustrate an idea, but were part of a systematic study of dimensions, individual volumes, diameters, and lengths of logs. The work was limited to consideration of distribution of those characteristics, as they occurred in practice on various areas and excluded all theoretical data. We will be satisfied if the discussion of these problems will facilitate choice of equipment best adapted to needs of operators and industry.

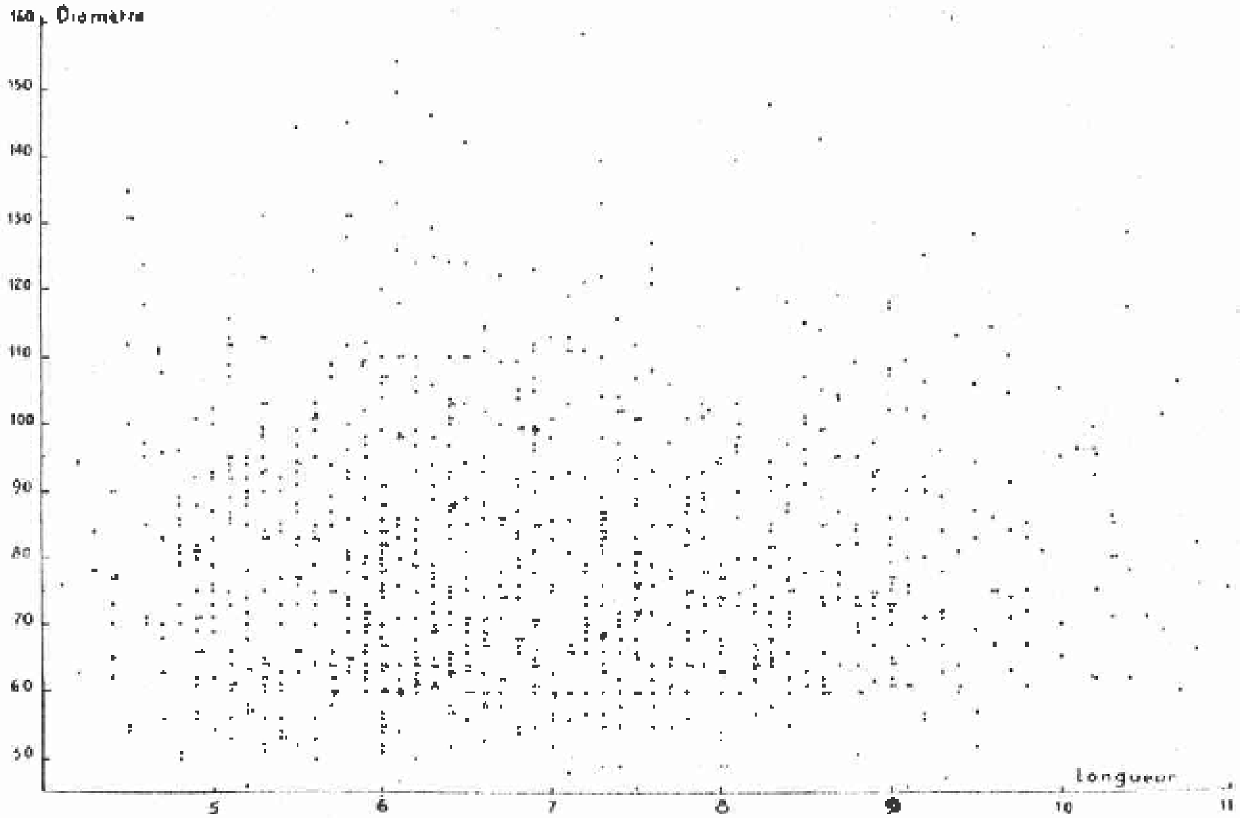

Figure 1. --The graphical presentation of the okoumé logs: 964 logs of 3,668 cubic meters (129,534 cubic feet).

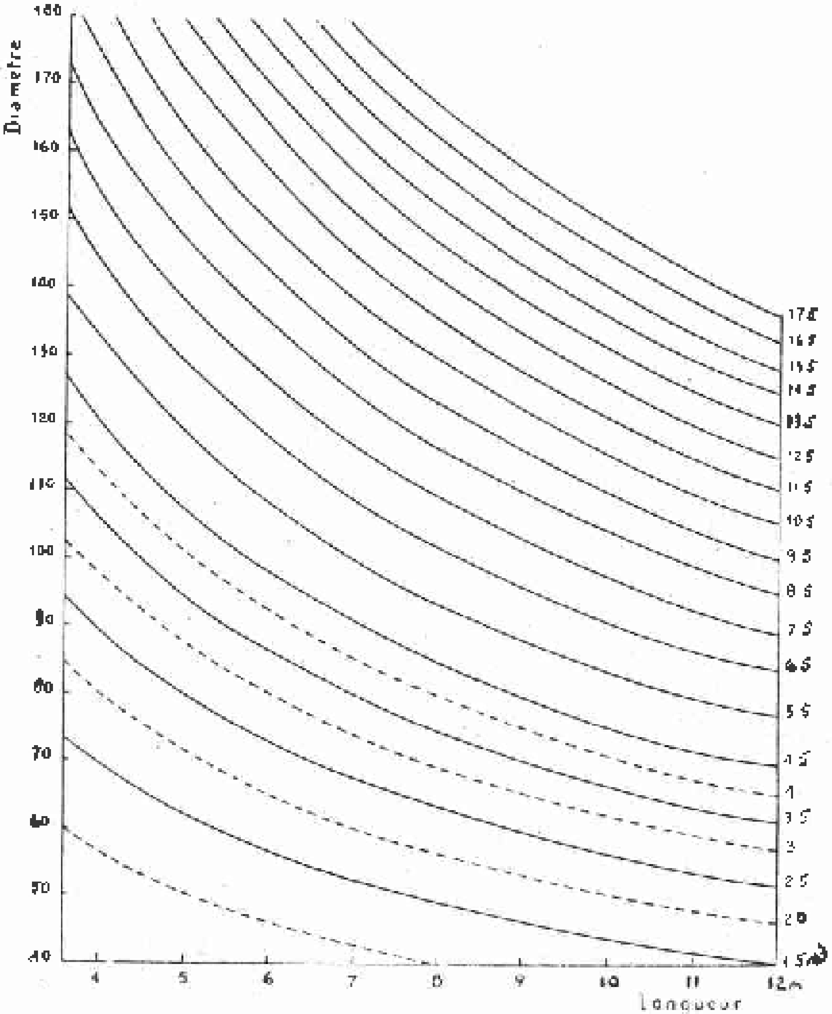

Figure 2.--Reference chart for distribution of logs by individual volume class.

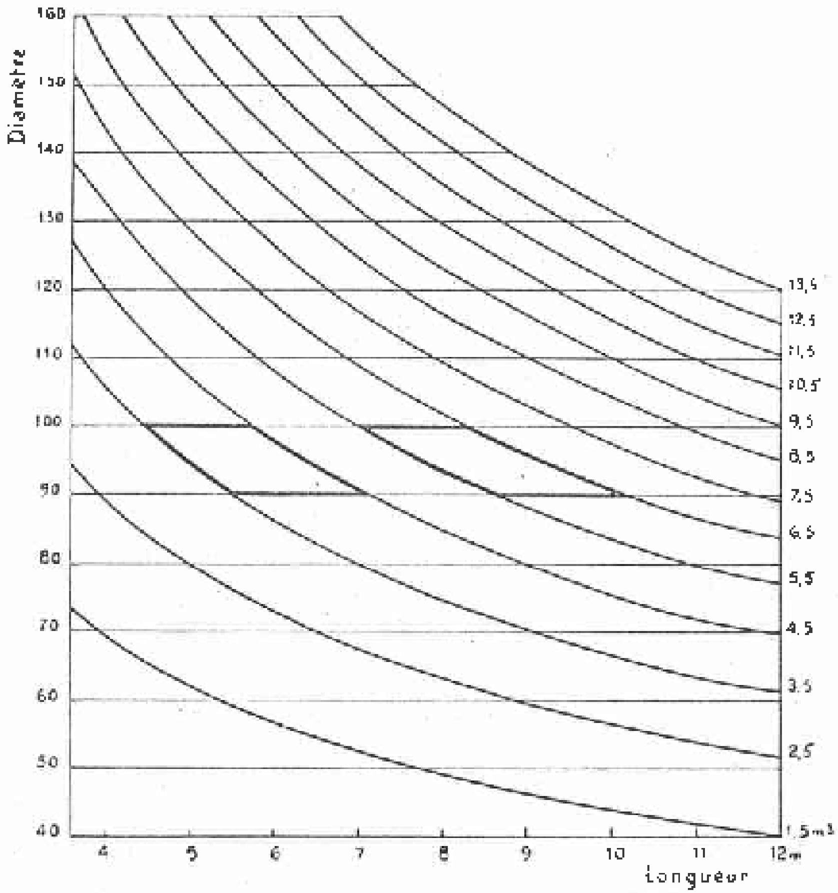

Figure 3. --Reference chart for distribution of logs by diameter classes.

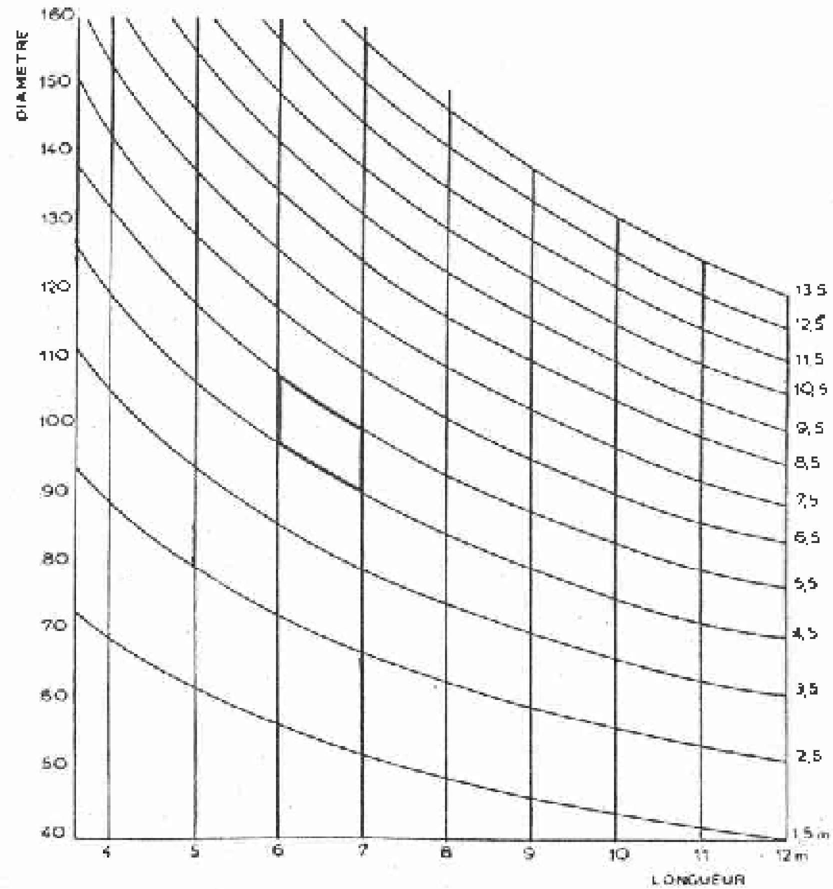

Figure 4. --Reference chart for distribution of logs by length classes.

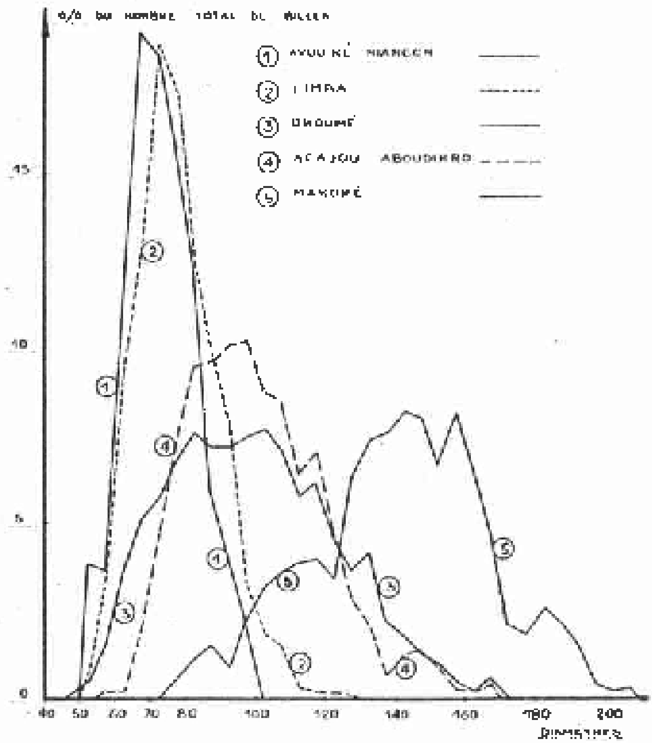

Figure 5.--The frequency of number of logs by diameter class for different species.

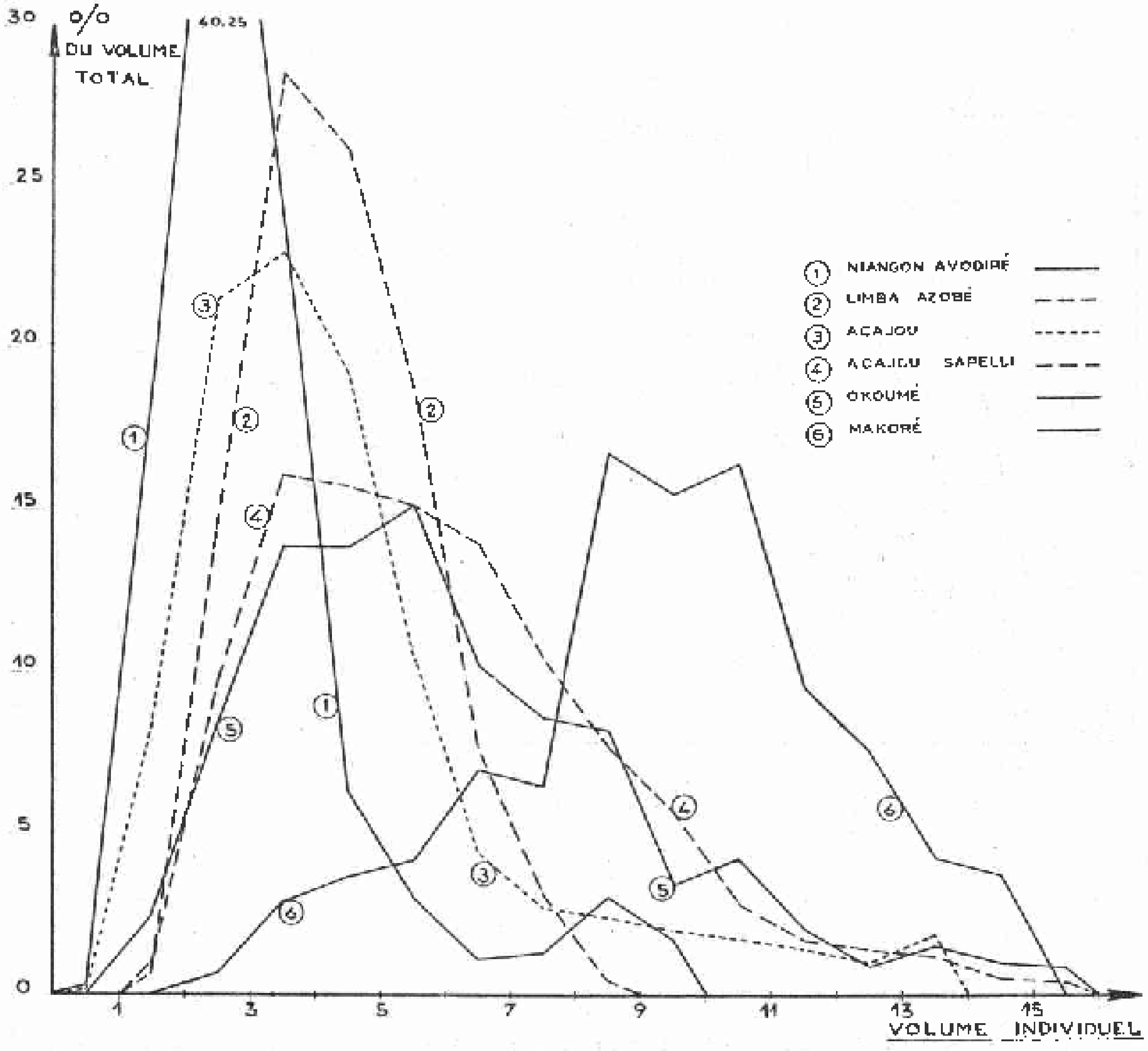

Figure 6. -- The frequency curves by the individual volume.

-- The curve of acajou (African Mahogany) No. 3 corresponds to the region where the large dimension trees were cut the first time, around 1930.

-- The curve of acajou sapelli (Sapele Mahogany) No. 4 corresponds to the zone cut the first time.

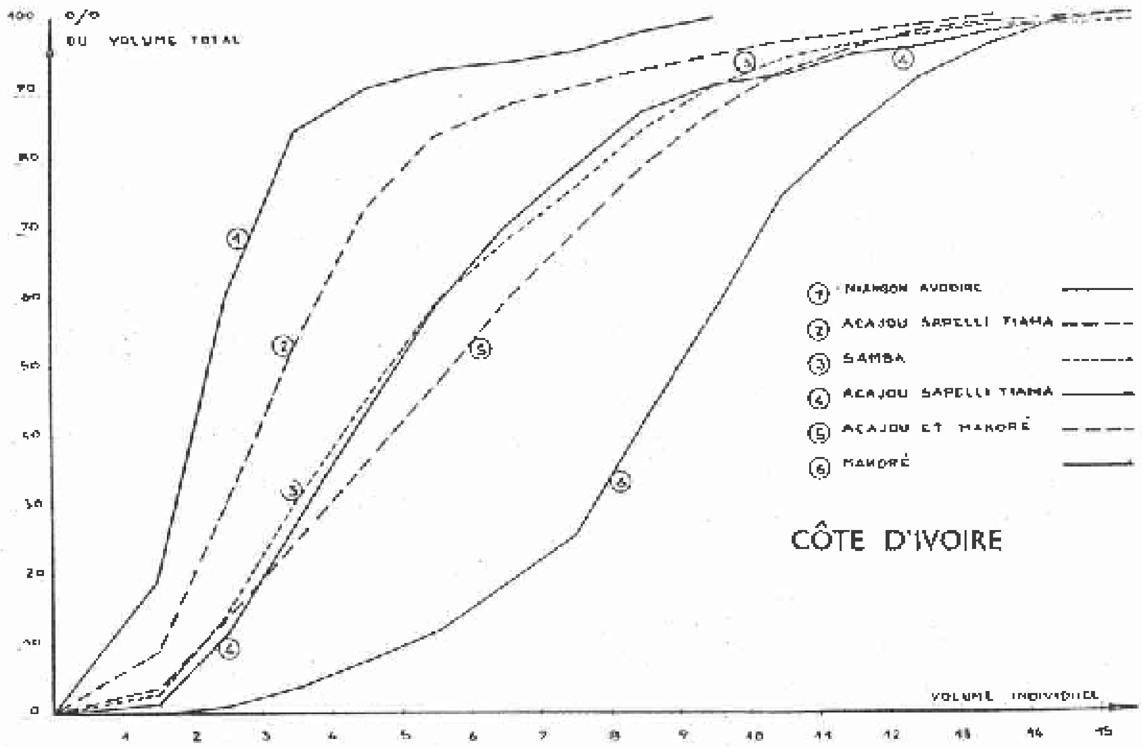

Figure 7. --Cumulative curves of frequency. For curves Nos. 2 and 4 for acajou, sapelli, and tiama see the explanation on figure 6.

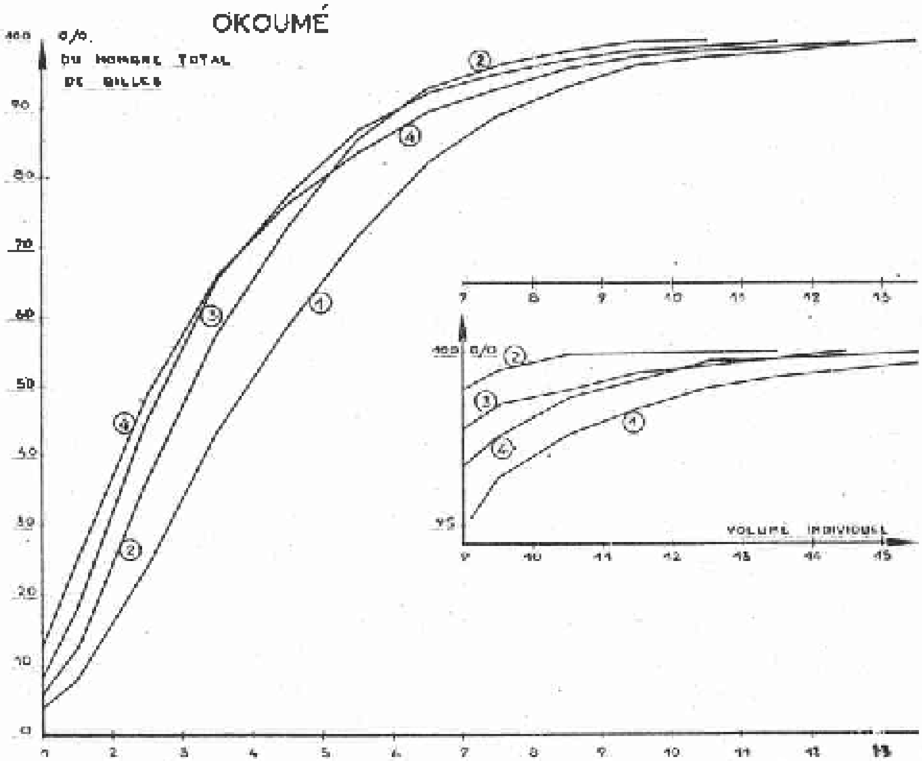

Figure 8a. --The cumulative numerical frequency of logs by individual log volumes for different stands of okoumé in percentage of the total number of logs.

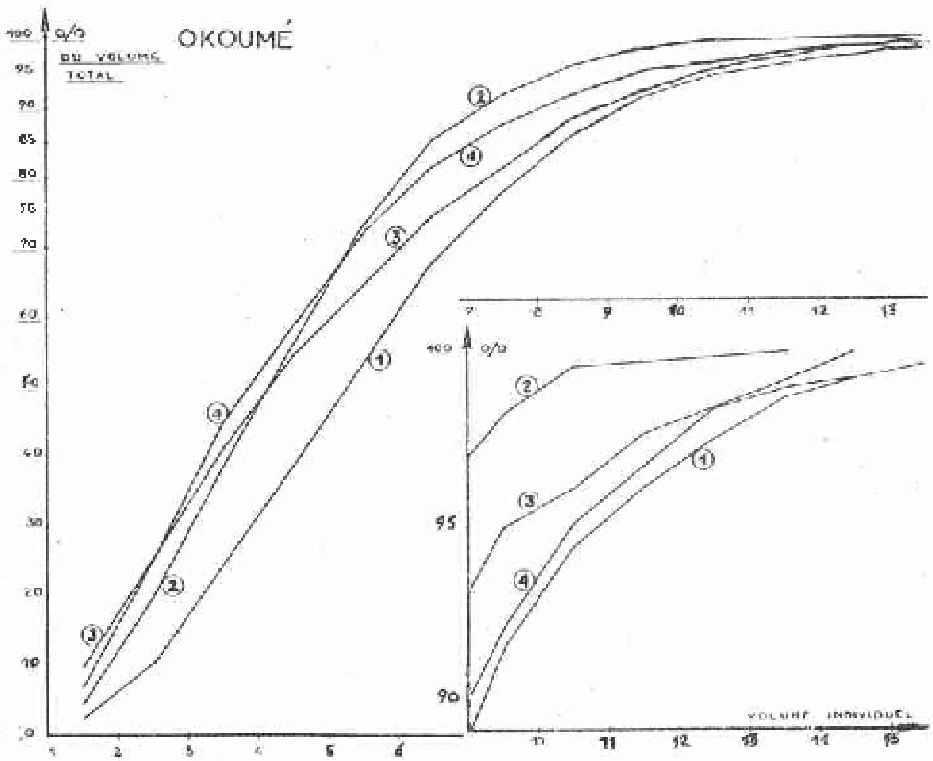

Figure 8b. --The cumulative volumetric frequency of logs by individual log volume for different stands of okoumé in percentage of the total volume harvested.

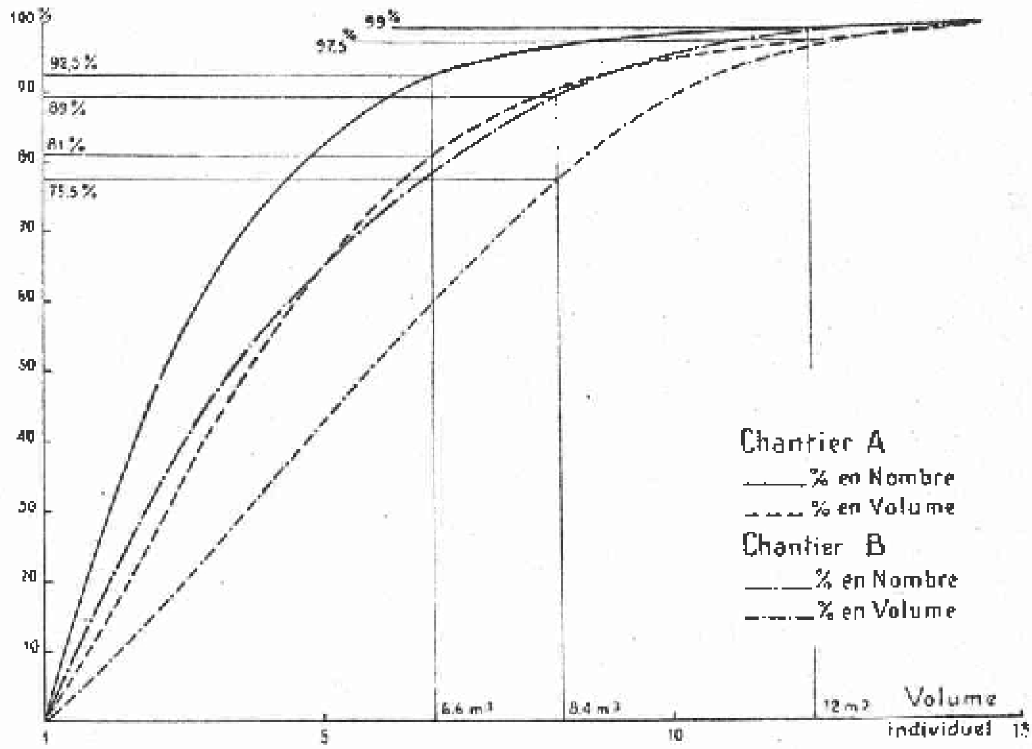

Figure 9. -- The cumulative frequency of logs by individual log volume (in stands A and B).

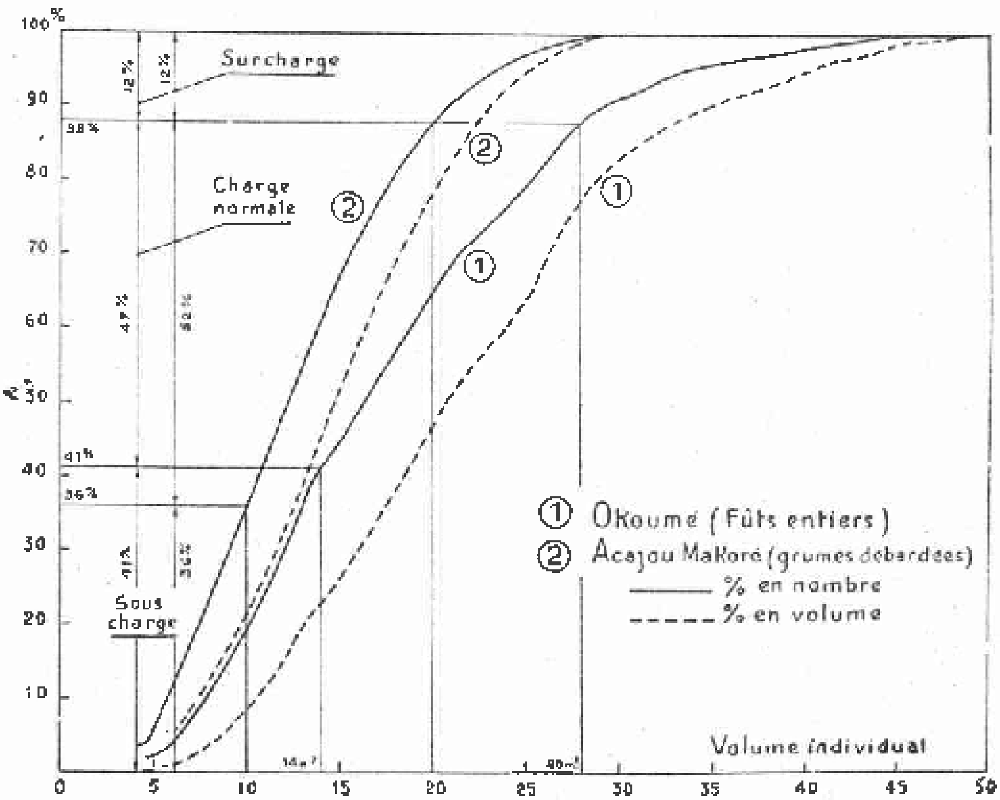

Figure 10. --Cumulative frequency of volumes of okoumé trees and African mahogany and makore logs in the skidding operation.