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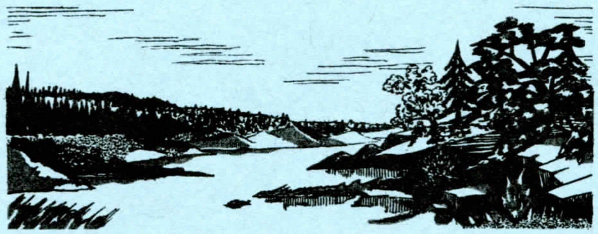

DIVISION OF FOREST MANAGEMENT

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INTRODUCTION

Cull in northern hardwood stands is often very heavy and is difficult to estimate. To help clarify this situation and aid the average cruiser to become more accurate in his estimates, the study reported here should prove very helpful.

The measured cull from the first clear cutting on the Upper Peninsula Experimental Forest at Dukes, Michigan, was 33 percent of the gross volume. This figure has run to as high as 45 or 50 percent in very defective old-growth stands in which sugar maple has predominated. Cull varies considerably over relatively short distances in the forest. Timber cruises which do not discount correctly for cull will be in error, no matter how carefully basic measurements are taken and despite the accuracy of volume tables employed.

Veteran timber cruisers can estimate cull in standing northern hardwood trees satisfactorily by sizing up outward signs of defects. Curisers new to the type frequently have difficulty, in spite of extensive experience elsewhere. Very little recorded information practical enough for them to make the necessary adjustments has been available.

The problem of evaluating cull is complex when it comes to appraising the growth in standing trees under the different cutting methods being tried out on the Experimental Forest. It was this complexity and the need for a systematic and reliable method of estimating cull that prompted the study.

FIELD STUDY

A study of cull was undertaken in 1944 in which data were collected from 600 sugar maple trees in Alger and Marquette counties, Michigan.[2] The sample trees were examined and scaled by Scribner Decimal C rule in accordance with instructions in the National Forest Scaling Handbook, which requires straight and sound timber for full scale. This was done after felling and bucking but before skidding.

Each of the 950 defects encountered in the trees under study was carefully examined and the outward indication of it described. In some cases rolling the logs with a cant hook was necessary to bring the defect clearly into view. The total loss in volume for each defect was then scaled out. Sometimes a single defect caused loss in more than one log. The loss due to each defect

1/ Maintained at University Farm, St. Paul, Minnesota, in cooperation with the University of Minnesota.

2/ The authors wish to acknowledge the extensive help in collecting the data for this study provided by W. A. Salminen of the Lake States Forest Experiment Station, Dukes, Michigan.

was then summarized for the tree as a whole and expressed as a percentage of the gross volume of the tree, scaled in standard 16-foot logs. These percentages form the basis for the comparisons which follow.

The general types of defects encountered in the field examinations were: broken or dead limb or top with suggestion of rot; butt rot and hidden defects, such as heart rot; rotten burl; presence of conk (sporophore); canker in advanced stage; crack or hole; scar or seam; crook or sweep; and ingrown bark.

Some types of defects were subdivided according to degree of severity and thus a total of 32 classes of defects were recognized.

Grade defects such as mineral stain, sound burls and live branches were disregarded. Only defects which either caused a loss in sound scale in the woods or would cause such a loss at the mill were considered.

PRACTICAL GROUPING OF DEFECTS

For each of the 32 types and degrees of defects the average percentage loss in volume was computed. Two almost identical defect groups were combined at once, reducing the number to 31. Since many of the defects caused similar percentage losses, they were regrouped later for convenience into six classes, as shown below and in table 1.

Class 1. Includes small broken or dead limb, sterile conk, ingrown bark, and small rotten burl.

Class 2. Hidden rot, small crack, slight crook or sweep in first log, slight to moderate crook or sweep in intermediate or top log, small hole, small scar, small straight seam.

Class 3. Large broken or dead limb, broken or dead top, large crack above first log, excessive crook or sweep in top log, large straight seam.

Class 4. Canker above first log, active conk above first log, moderate crook or sweep in first log, excessive crook or sweep in intermediate log, large hole above first log, large rotten burl, large scar.

Class 5. Butt rot, active conk in first log, large crack in first log, excessive crook or sweep in first log, large hole in first log.

Class 6. Canker in first log, spiral seam.

The frequency distribution of percentage losses in the six classes is shown in table 1.

Table 1.--Frequency distribution of percentage losses by different classes of defect.

Cull percent	Defect class 1	2	3	4	5	6
	Relative frequency - percent					
1 - 5	79	50	3	1	-	-
6 - 10	21	38	23	13	3	-
11 - 20	-	10	58	55	27	17
21 - 30	-	1	15	15	38	24
31 - 40	-	0.5	1	9	15	21
41 - 50	-	-	-	6	10	11
51 - 60	-	0.5	-	1	3	4
61 - 70	-	-	-	-	2	17
71 - 80	-	-	-	-	2	3
81 - 90	-	-	-	-	-	-
91 - 100	-	-	-	-	-	3
Class averages	3.7	6.6	14.9	20.2	29.6	42.5

From table 1 it may be seen that although the six groups generally overlap each other, their averages or means are quite distinct and form a progressively increasing trend. Analysis of the data showed that the differences among the group averages are considerably larger than their respective standard errors, which means that while cull estimates for individual trees may be in considerable error, they are reasonably accurate for any one group.

The types and degrees of defects considered in the study are listed in table 2, grouped for convenience and briefly defined where necessary. The term "log" in each case refers to a 16-foot log.

Although hidden rot was considered in the study, it cannot be detected readily in the standing tree. In the 600 trees examined it occurred infrequently and caused a loss of only one percent from total gross volume involved. Hence, it is felt it can be disregarded without affecting accuracy too adversely.

EFFECT OF TREE SIZE ON CULL PERCENT

A check of the possible effect of diameter breast high upon cull percent disclosed no significant variation. The proportion of cull remained about the same as the trees increased in size radially. However, it should be noted particularly in table 2 that the cull percent varies with merchantable length. A given defect causes greater percentage loss in short trees than in tall trees. Correction for the effect of merchantable length was determined by applying the class averages from table 1 to the defects in the study trees which had been separated into merchantable length groups. The average difference between estimated and measured cull percentages was computed for each group. On the basis of these variations, a corrected percentage was prepared for each defect class by merchantable length.

Table 2.--Defects considered and cull percents[1] caused by them.

Defect	Position within merchantable length of tree	Condition or degree	Class	Cull percent[2] 1-log tree	2-log tree	2½-log tree	3-log tree	4-log tree
BROKEN OR DEAD LIMB								
(At least 6" in diameter)	Anywhere	Large	3	20	17	14	13	11
(Less than 6" in diameter)	Anywhere	Small	1	5	4	4	3	3
BROKEN OR DEAD TOP (Broken or rotten close enough to top limit of merchantability to indicate loss in scale.)	---	---	3	20	17	14	13	11
BUTT ROT (At least 1/3 of log lost. If not visible, detectable by blow.)	First log	Advanced	5	39	35	28	25	22
CANKER	First log	Advanced	6	56	50	41	36	32
	Above first log	Advanced	4	26	24	20	17	15
HIDDEN ROT (Cannot be detected in standing tree.)	Anywhere	---	2	9	8	6	6	5
CONK	First log	Active	5	39	35	28	25	22
	Above first log	Active	4	26	24	20	17	15
	Anywhere	Sterile	1	5	4	4	3	3
CRACK								
(Open. At least 1/3 of log lost.)	First log	Large	5	39	35	28	25	22
(Open. At least 1/3 of log lost.)	Above first log	Large	3	20	17	14	13	11
(Open. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
CROOK OR SWEEP								
(More than 2/3 volume lost.)	First log	Excessive	5	39	35	28	25	22
(1/3 to and including 2/3 volume lost.)	First log	Moderate	4	26	24	20	17	15
(Less than 1/3 volume lost.)	First log	Slight	2	9	8	6	6	5
(More than 2/3 volume lost.)	Intermediate log	Excessive	4	26	24	20	17	15
(To and including 2/3 volume lost.)	Intermediate log	Slight to moderate	2	9	8	6	6	5
(More than 2/3 volume lost.)	Top log	Excessive	3	20	17	14	13	11
(To and including 2/3 volume lost.)	Top log	Slight to moderate	2	9	8	6	6	5
HOLE								
(Cavity. At least 1/3 of log lost.)	First log	Large	5	39	35	28	25	22
(Cavity. At least 1/3 of log lost.)	Above first log	Large	4	26	24	20	17	15
(Cavity. Less than 1/3 of log lost.)	Anywhere	Small	2	9	8	6	6	5
INGROWN BARK (Bark folded into right cylinder.)	First log	---	1	5	4	4	3	3
ROTTEN BURL								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	1	5	4	4	3	3
SCAR								
(At least 1/4 of log affected.)	Anywhere	Large	4	26	24	20	17	15
(Less than 1/4 of log affected.)	Anywhere	Small	2	9	8	6	6	5
SEAM								
(Open or tight.)	Anywhere	Spiral	6	56	50	41	36	32
(Tight. At least 6 feet long.)	Anywhere	Large, straight	3	20	17	14	13	11
(Tight. Less than 6 feet long.)	Anywhere	Small, straight	2	9	8	6	6	5

1/ Rounded off to nearest whole number.

2/ Class Averages

GENERAL APPLICATION

In order to determine cull in the standing tree, it is necessary only to multiply the gross volume by the percent shown in table 2 for each defect present, or by the sum of percents in case of more than one defect. Trees obviously worthless according to utilization standards applicable to the stand being cruised should be recorded as 100 percent cull. On the other hand, a defect which "cuts out" with another defect already considered should be disregarded.

Application of the cull percents shown in table 2 involves considerable computing. The basis for a much simpler method is evident from examination of the class averages in table 1. They are seen to follow closely multiples of 7 as shown in table 3.

Table 3.--Multiple relationship for defect classes.

Defect class	Average cull percent	Rounded off average	Multiples
1	3.7	3.5	1/2
2	6.6	7.0	1
3	14.9	14.0	2
4	20.2	21.0	3
5	29.6	28.0	4
6	42.5	42.0	6

This multiple relationship holds true for trees of any merchantable length, although the number 7 is applicable only to 2 1/2 log trees. The correct percentages to which to apply the multiples for 5 merchantable length classes are given in table 4.

Table 4.--Cull percent for trees of different merchantable length.

No. of 16-foot logs	Cull percent
1	10
2	8
$2\frac{1}{2}$	7
3	6
4	5

In order to determine the correct cull percent to apply to any defect in the standing tree, it is necessary only to multiply the cull percent shown in the above table for a tree of its merchantable length class by the number of multiples given for the appropriate defect class in table 3. In the case of several defects in the same tree, the cull percent is multiplied by the sum of the individual defect multiples.

For example: A 3-log tree is found upon examination to contain a large crack in the first log and excessive crook in the top log The sum of the multiples for these defects from tables 2 and 3 is 6. The cull percent for a 3-log tree from table 4 is 6. 6 x 6 = 36 percent, the correct average cull percent to apply to this particular tree.

To take another example: A 2-log tree contains these outward signs of defect: a conk in the first log, a small dead limb in the second log, and a broken top. The sum of the multiples from tables 2 and 3 for these defects is $6\frac{1}{2}$. The cull percent for a 2-log tree (from table 4) is 8. $6\frac{1}{2}$ x 8 = 52, the cull percent in this case.

With a little practice the estimator goes directly from defect to multiples without first considering defect class.

It must be remembered that this method is based on <u>average</u> percentage losses caused by different defects. For any one standing tree the estimate based on these averages may be in considerable error. For a number of trees it should be reasonably accurate. Because of possible variations in the manifestations of decay, adjustment of defect class averages might occasionally be required. It is recommended as a general rule that they be checked before extensive use of the method is attempted at any great distance from Dukes.

Obviously, estimates of cull will vary according to the degree of utilization practiced in logging. Where better utilization increases the volume recovered, the cull percent will be reduced proportionately. With poor utilization the reverse is true. For this study utilization on the cuttings visited was average; in some cases complete, in others poor.

HOW TO DETERMINE SAMPLE NEEDED

In actual practice, the work of estimating cull should be regarded as an integral part of the general timber inventory and be carried on in conjunction with the main cruise. The first matter to be determined, then, is the size of sample needed to meet the requirements of the job.

The sample trees to be examined for cull can be selected either along the cruise lines or on sample plots, as the case may be. The cruise should be conducted in such a manner that the variations of cull present on the tract are represented in the sample.

For estimating cull percent on tracts of different sizes, the following practical guide may be helpful:

Number of merchantable trees per tract	Limit of error percent 1/	Percent sample needed	Number of merchantable trees per tract	Limit of error percent 1/	Percent sample needed
800	9.6	20	16,000	3.4	9
1,600	7.5	17	20,000	3.3	8
4,000	5.6	13	40,000	2.5	7
8,000	4.3	11	80,000	2.1	5

1/ Odds are 10 to 1 that a chance discrepancy between the estimated (sampling) and true cull percent for the stand will not exceed the limit of error indicated. The coefficient of variation of cull percent is .75.

The guide will apply to all northern hardwood stands and will fit nearly all types of cruising jobs. It is so adjusted that the resulting gain in accuracy of the final estimate by the addition of the cull cruise will considerably outweigh its cost.

Once the number of trees decided upon for a sample have been analyzed and tallied by the method described, it is a simple matter to compute the gross volume and the cull volume and determine the cull percent for the stand in question.

FIELD TESTS OF RESULTS

Five checks which give an indication of the accuracy of this method of cull determination in northern hardwoods have been completed thus far at Dukes, Michigan, and at the Menominee Indian Reservation in Wisconsin. Although sugar maple predominated in these stands, some other species, such as yellow birch, basswood, elm, beech, and red maple, were present. All trees marked for cutting on four small blocks of timber at Dukes were cruised for cull before felling, using the defect percentages employed in the method outlined. On the Menominee Reservation the cull present in forty-eight trees, selected as they came in advance of felling, was estimated by the method described. The trees were scaled later following cutting. The pertinent facts from these field tests are summarized briefly in tables 5 and 6.

Table 5.--Cull determination tests
Dukes, Michigan.

Volume - board feet Scribner			Error expressed as percentage of gross volume
Gross	Estimated cull	Measured cull	
23,881	10,190	10,851	-2.8
6,751	2,079	2,381	-4.5
7,077	2,640	2,187	+6.4
6,929	2,710	2,859	-2.2

Table 6.--Cull determination tests Menominee Indian Reservation.

Species	Volume - board feet Scribner: Gross	Estimated cull	Measured cull	Error expressed as percentage of gross volume
Sugar maple	16,637	5,574	6,447	-5.3
Yellow birch	3,984	1,579	1,364	
Basswood	1,475	531	485	
Beech	440	310	260	
Total	22,536	7,994	8,556	-2.5

Some inaccuracy was to be expected since no allowance was made for hidden rot and occasional defect signs were undoubtedly overlooked or misinterpreted. Then, too, the discrepancy may be partly accounted for by the possible difference between gross volume table figures, on which the cull estimates were based, and the actual scale of the cut logs. A tested gross volume table should in all cases be employed.3/ However, error was nominal in these tests and it does appear that reasonably accurate cruises for cull percent in northern hardwood stands can be made by the method described.

3/ The volume table used in this study was that presented in Technical Note No. 203, issued in August, 1943, by the Lake States Forest Experiment Station.

Furthermore, it has been suggested that in training cruisers a systematic method of cull determination as employed here in the northern hardwood type has a definite value. Learning to recognize and evaluate the seriousness of various defects will be greatly expedited by such an approach.

It also provides a standard by which the effectiveness of stand improvement or silvicultural cuttings can be measured now and over a period of time. It gives the forest manager more assurance in judging the type of trees that will prove to be a good risk.