VERIFICATION OF TREE GRADING ALGORITHMS WITH A HYPOTHETICAL HARDWOOD FOREST[1]

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Abstract.--Standing tree grades in a hypothetical hardwood forest were obtained from execution of a newly designed tree grading algorithm, using computer simulated grading characteristics. For a hypothetical population of 500 trees, tree characteristics generated included diameter at breast height, diameter inside bark at the top of the grading section, Girard form quotient, number and lengths of clear cuttings, and percent cull due to sweep, crook and rot. These characteristics were inputs for a tree grading model consisting of a forester as hardware and the tree grading algorithm as software. Mental execution of the tree grading algorithm by the forester produced tree grade as output from the tree grading model. The purpose of this paper was to establish the correctness and to evaluate the efficiency of the tree grading algorithm that permits systematic classification of standing tree grade without using a computer in woods.

INTRODUCTION

Determining hardwood tree grades is not an amicable task for most beginning tree graders. Hanks (1976) and Miller et al. (1986) have devised methods to assist in learning the USDA Forest Service hardwood tree grading system. More recently, two tree grading algorithms-the general tree grading algorithm (TGA) and the form class tree grading algorithm (FCTGA)-were developed (Liu and McLaren 1987, Liu 1988) for determining hardwood tree grades. This paper presents grading characteristics of a hypothetical 500-tree population that was simulated for the verification of these tree grading algorithms.

Tree Grading Algorithms

Application of TGA for tree grade determination can be illustrated by visualizing a tree grading model (TGM) comprising a forester, acting like a piece of hardward, and the TGA, the software that prescribes activities constituting tree grading processes (fig. 1).

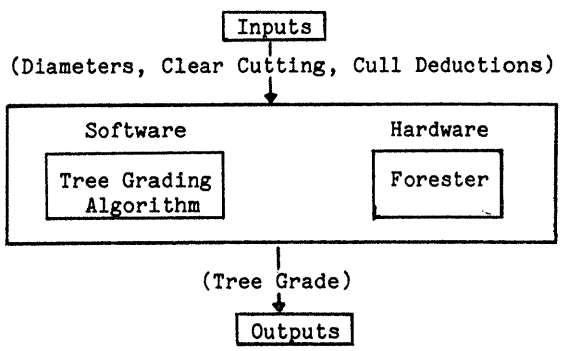

Figure 1.--Schematic representation of a tree grading model.

The TGA (fig. 2) is a set of logically arranged statements representing conditions required by the USDA Forest Service hardwood tree grade system. Tree characteristics such as stem diameter, number and lengths of clear-cuttings, and amount of cull deductions are used as input to the model. The forester executes the TGA by evaluating a statement and determining if it is true or false, based on the input data. The forester branches to another statement according to the sequence of control built in the TGA. The forester repeats this evaluation-branching activity until the output, the tree grade, is obtained. TGA systematizes tree grading by making it a methodical procedure that can be carried out easily and quickly by a forester without computer-related training and experience. FCTGA (fig. 3) is very similar to TGA except that it is used with a predetermined form class.

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General Tree Grading Algorithm (TGA)[‡]

	Yes/No
1. DBH ≥ 15.6" (14.6" for basswood & ash)	4/2
2. DBH ≥ 12.6"	7/3
3. DBH ≥ 9.6"	10/BG
4. DIT ≥ 19.6"	11/5
5. DIT ≥ 15.6"	12/6
6. DIT ≥ 12.6" (11.6" for basswood & ash)	13/7
7. DIT ≥ 11.6"	16/8
8. DIT ≥ 10.6"	17/9
9. DIT ≥ 9.6"	18/10
10. DIT ≥ 7.6"	19/BG
11. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC—each CC ≥ 3′	20/14
12. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC—each CC ≥ 5′	20/14
13. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC—each CC ≥ 7′	20/14
14. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1, 2 or 3 CC—each CC ≥ 3′	15/19
15. TCD ≤ 9% or [9% < ROT ≤ 40% and (no S&C nor SDF)]	G2/23
16. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1, 2 or 2 CC—each CC ≥ 3′	22/19
17. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1 or 2 CC—each CC ≥ 3′	22/19
18. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC—each CC ≥ 7′	22/19
19. SCC ≥ $6'_{12}$ $7'_{14}$ $8'_{16}$—all CC ≥ 2′	23/BG
20. TCD ≤ 9%	G1/21
21. S&C ≤ 15% and TCD ≤ 40%	G2/23
22. TCD ≤ 9%	G2/23
23. TCD ≤ 50%	G3/BG

[‡]Numerical subscripts represent lengths (ft) of grading sections. Symbols used in the table stand for: DBH—diameter outside bark at breast height; DIT—Diameter inside bark at top of grading section; CC—clear cutting(s); SCC—sum of the longest 1, 2, or 3 clear cuttings that are equal to or longer than the specified length of CC; TCD—total cull deduction (sweep, crook, & rot); S&C—cull deduction due to sweep and/or crook; SDF—surface defect(s) on grading face; G1—grade 1; G2—grade 2; G3—grade 3; and BG—below grade.

Figure 2.--General Tree Grading Algorithm (TGA).

Form Class (80) Tree Grading Algorithm.[†]

	Yes/No
1. DBH ≥ $22.69''^{12}$ $23.11''^{13}$ $23.56''^{14}$ $24.02''^{15}$ $24.50''^{16}$	8/2
2. DBH ≥ $18.06''^{12}$ $18.40''^{13}$ $18.75''^{14}$ $19.12''^{15}$ $19.50''^{16}$	9/3
3. DBH ≥ $15.60''^{12}$ $15.60''^{13}$ $15.60''^{14}$ $15.60''^{15}$ $15.75''^{16}$	10/4
[‡] DBH ≥ $13.43''^{12}$ $13.68''^{13}$ $13.94''^{14}$ $14.22''^{15}$ $14.50''^{16}$	10/4
4. DBH ≥ $13.43''^{12}$ $13.68''^{13}$ $13.94''^{14}$ $14.22''^{15}$ $14.50''^{16}$	13/5
5. DBH ≥ $12.60''^{12}$ $12.60''^{13}$ $12.74''^{14}$ $12.99''^{15}$ $13.25''^{16}$	14/6
6. DBH ≥ $12.60''^{12}$ $12.60''^{13}$ $12.60''^{14}$ $12.60''^{15}$ $12.60''^{16}$	15/7
7. DBH ≥ $9.60''^{12}$ $9.60''^{13}$ $9.60''^{14}$ $9.60''^{15}$ $9.60''^{16}$	16/BG
8. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC-each CC ≥ 3'.....	17/11
9. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC-each CC ≥ 5'.....	17/11
10. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC-each CC ≥ 7'	17/11
11. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1, 2 or 3 CC-each CC ≥ 3'.....	12/16
12. TCD ≤ 9% or [9% < ROT ≤ 40% and (no S&C nor SDF)]	G2/20
13. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1, 2 or 3 CC-each CC ≥ 3'.....	19/16
14. SCC ≥ $8'_{12}$ $9'4''_{14}$ $10'8''_{16}$ in 1 or 2 CC-each CC ≥ 3'.....	19/16
15. SCC ≥ $10'_{12}$ $11'8''_{14}$ $13'4''_{16}$ in 1 or 2 CC-each CC ≥ 7'.....	19/16
16. SCC ≥ $6'_{12}$ $7'_{14}$ $8'_{16}$-all CC ≥ 2'.....	20/BG
17. TCD ≤ 9%	G1/18
18. S&C ≤ 15% and TCD ≤ 40%	G2/20
19. TCD ≤ 9%	G2/20
20. TCD ≤ 50%	G3/BG

[†]Numerical superscripts represent heights at the top of grading sections while numerical subscripts represent lengths of grading sections. Symbols used stand for: DBH—diameter outside bark at breast height; DIT—diameter inside bark at top of the grading section; CC—clear cuttings(s); SCC—sum of clear cuttings; TCD—total cull deduction (sweep, crook, & rot); S&C—cull deduction due to sweep and/or crook; SDF—surface defect(s) on grading face; G1—grade 1; G2—grade 2; G3—grade 3; BG—below grade.

[‡]For basswood and ash only.

Figure 3.--Form Class (80) Tree Grading Algorithm.

Distributions of Tree Characteristics

To establish the correctness and to evaluate the efficiency of the TGA, the procedure just described was repeated by grading 500 trees in a hypothetical hardwood forest. Grading characteristics of the 500 trees were computer generated by hypothesizing their distributions. For example, dbh distribution was assumed to be inverse J-shaped and the distribution of Girard form quotient was programmed to reproduce that of the sum of form-class averages of all species in table 4 of the pamphlet "Tables For Estimating Board-Foot Volume of Timber" (Mesavage and Girard 1946). Lacking any information about the number and lengths of clear-cuttings, the distribution of clear-cuttings was purely imaginary.

Distributions of grade characteristics are shown in figure 4. All 500 trees in the population have dbh's from 10 to 34 inches (fig. 4-a). Generated distributions of sweep (fig. 4-b), crook (fig. 4-c), and rot (fig. 4-d) are continuous ones with a maximum amount of 25%, 25%, and 50%, respectively. For presentation purposes, these data are aggregated into either 4 or 5 groups with division lines drawn to match limitations set forth by the grading rules. For any tree, the Girard form quotient falls between .746 and .835 (fig. 4-e). As can be seen in fig. 4-f, number of clear-cuttings progressively decreases as the length of clear-cuttings increases.

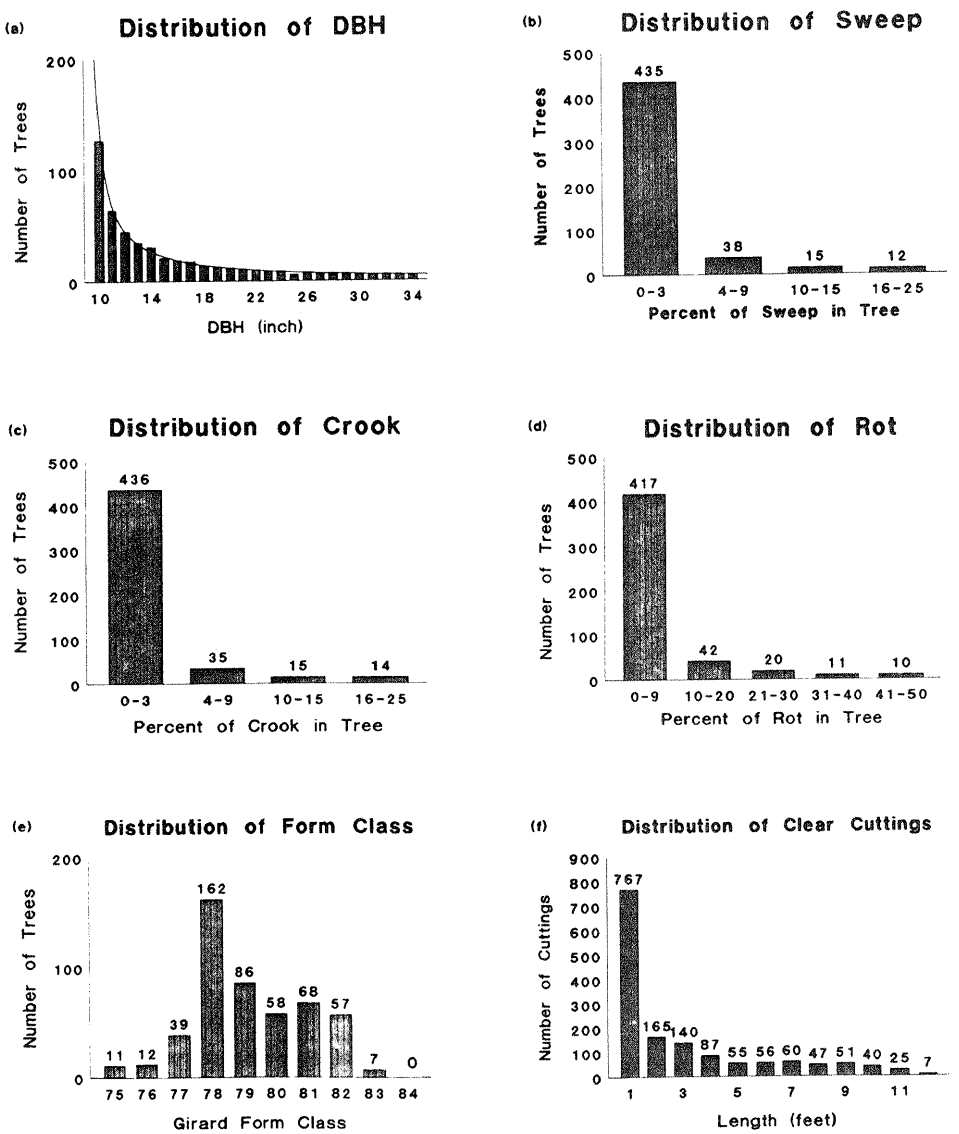

Figure 4.--Distribution of tree characteristics in a computer simulated hypothetical hardwood forest: (a) dbh, (b) sweep, (c) crook, (d) rot, (e) form class, and (f) clear cuttings.

Tree Grades in the Hypothetic Population

Tree grades obtained from 500 simulation runs of the TGM are presented in figure 5. There are, respectively, 18, 82, and 273 trees classified as grade 1, grade 2, and grade 3, while 127 trees were below grade. Note that the distribution of tree grades in this hypothetical population represents a combination of distributions of all grade characteristics considered.

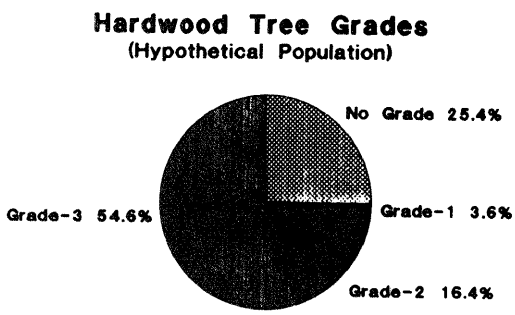

Figure 5.--Grade distribution in a computer simulated hypothetical hardwood forest.

For each and every tree in the population, the computer generated grade was verified by checking the grade obtained from the USDA Forest Service Hardwood Tree Grade for Factory Lumber (Hanks 1976) and was found to be correct. The average number of steps needed to obtain a tree grade using TGA is approximately 6.

DISCUSSION

Tree grading algorithms logically place grade factors involved in a grading system in a set of sequentially arranged branching statements; they not only systematize tree grade procedures but also promote understanding of grading rules. Although these algorithms are devised for grading hardwood trees for factory lumber, the algorithmic methodology used can be readily transferred into other areas of forest management, especially decision-making processes under field conditions.

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