SAWMOD: A TOOL FOR OPTIMIZING POTENTIAL PROFIT FROM BEETLE-KILLED SOUTHERN PINE SAWTIMBER[1]

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ABSTRACT

Currently the operators of small- to medium-sized sawmills have minimal information upon which to base processing decisions and profit estimations. This problem is further complicated when unusual variables, such as processing beetle-killed timber, are superimposed upon normal operating parameters.

SAWMOD (*SAW*mill decision *MOD*el) is a computer algorithm designed to provide accurate information for decision-making. By using actual lumber grade yields, estimated residue volumes, current market prices, and readily obtainable production variables, economically optimal processing schemes may be derived from SAWMOD. Potential economic returns from conversion into lumber and/or chips for each log diameter within six log quality classes are considered. Estimates of total profit and break-even log cost FOB mill for each log quality class are provided by SAWMOD. These estimates are based on a given log diameter distribution and total log volume.

Structured to be individualized for a given sawmill and periodically updated, SAWMOD is a powerful decision tool that will help to continue progress toward a highest-value utilization of our sawtimber resource.

Keywords: Sawmill, computer model, insect-killed, *Pinus*, softwood, *Dendroctonus*, operations-research.

Southern pine forests cover an estimated 100 million acres in 13 states. Southern pine as a host is susceptible to many forms of pathological and insect attack, the most notable being *Dendroctonus frontalis* Zimm., the southern pine beetle. Figures collected by Southeastern area state and private foresters reveal that from July 1974 to June 1975, 47% or 46.7 million acres throughout the Southeast were affected by outbreaks of the beetle (one infested tree per acre would include that acre as infested) (Anon. 1975). During 1973 alone, 170 million board feet of sawtimber were marketed from beetle-devasted stands at salvage prices, and three times that volume remains in the forest unsalvaged (Anon. 1975).

The potential resource in standing dead timber in other regions is also tremendous. Billions of board feet of standing dead timber exist in the Western United States (Snellgrove and Faley 1977). For the past 20 years, 1.3 million cubic feet of mature lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) has been killed annually by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in British Columbia (Safranyik et al. 1966). Yet it has been estimated that less than 10%

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of the total annual timber mortality is currently salvaged (Snellgrove and Faley 1977).

Such a low degree of salvage is due in part to the intuitive conclusion that if a tree is killed it automatically becomes of lower economic value. This conclusion has led to reluctance on the part of timber buyers to purchase this material and has resulted in lower prices and uncertainty about the value of these stands.

Several recent studies have investigated the quality and economic value of products from dead standing timber: Dobie and Wright (1978a and 1978b), Sinclair et al. (1977), Sinclair and Ifju (1979), and Snellgrove and Faley (1977). This information will certainly assist mill operators and landowners in estimating more accurately the potential profit from dead standing timber. However, the market for this timber and the products produced from it are dynamic. Few variables entering into the profit calculations remain relatively constant over any significant period of time. Therefore, static estimates of potential profits rapidly become inaccurate as market fluctuations occur. What is truly needed are not static statements of potential values or profits but rather a method to quickly arrive at estimates of potential profit. This method could use previously determined product quality information while allowing for current market prices and production costs. This would allow sound utilization decisions to be made on accurate, current information and not on conjecture or intuition.

SAWMOD

SAWMOD (*SAW*mill decision *MOD*el) is a computer alogrithm designed to fulfill this need.[2] SAWMOD combines information on lumber grade yields, residue volumes, current market prices, and readily available production variables to estimate potential profits and optimal processing schemes for sawmill operators.

The logic of SAWMOD is shown in Fig. 1. The inputs required by the model are represented as punch card symbols. These inputs are lumber grade yields, production rates, current residue prices, manufacturing costs, log costs FOB mill, log diameter distributions, and total log volumes.

The particular version of SAWMOD described in the following text was developed specifically for six groups or quality classifications of southern pine sawtimber as listed below:

Class 1: Butt logs from green healthy trees (controls)
Class 2: Upper logs from green healthy trees (controls)
Class 3: Butt logs from beetle-killed trees 12 months dead
Class 4: Upper logs from beetle-killed trees 12 months dead
Class 5: Butt logs from beetle-killed trees 20 months dead (2 summer and 1 winter season)
Class 6: Upper logs from beetle-killed trees 20 months dead (2 summer and 1 winter season)

Previously reported lumber grade yield information collected at test sawings

[2] SAWMOD is written in FORTRAN IV, a very common computer language and will run on most FORTRAN compilers. It has been successfully operated on large computers such as the IBM 370, Cyber 172 and Cyber 74 and also on smaller computers such as the IBM 360-30.

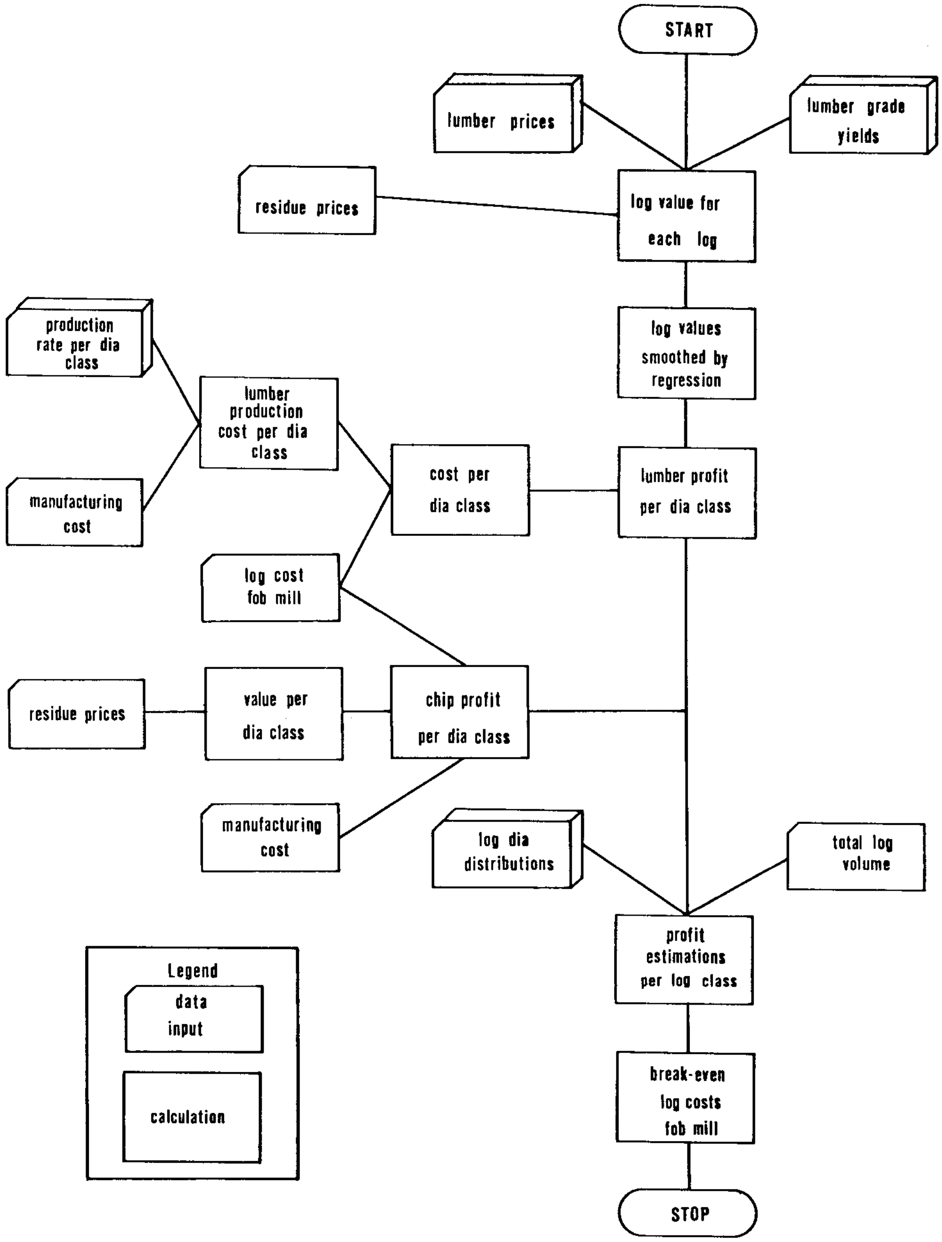

FIG. 1. Flow chart of SAWMOD.

in a commercial sawmill provide an experimental data base for SAWMOD (Sinclair et al. 1977 and Sinclair and Ifju 1979).

LOG VALUES

A value in dollars is calculated for each log in each of the six classes. This value is calculated from the market price of the lumber sawn plus the residue prices. Lumber values are determined from the current lumber prices of the actual sizes and grades of lumber sawn at the test sawings. Lumber prices used in the examples given in this text are from *Random Lengths* (Anon. 1977). Residue values are based on the estimated residue weights and current prices for sawdust, shavings, bark, and chips. Residue prices used in the examples given in this text are: sawdust \$9.50/ton, shavings \$9.50/ton, bark \$4.00/ton, and chips \$21.00/ton. Residue weights for healthy control logs are estimated by the following previously published equations:

$$\text{Bark weight (lbs)} = (0.639DL) + (0.0176D^2L)$$
(Row et al. 1965)

$$\text{Sawdust weight (lbs)} = (0.005454)\left(\frac{K}{W}\right)LD^2 52$$
(adapted from Bennett and Lloyd 1974)

$$\text{Chip weight (lbs) butt logs} = (2.12DL) - (9.75L)$$
(Row and Guttenburg 1966)

$$\text{Chip weight (lbs) upper logs} = (1.63DL) - (4.45L)$$
(Row and Guttenburg 1966)

$$\text{Shavings weight (lbs)} = (V_g - V_f)S37$$

where: D = scaling diameter (inches)
L = log length (feet)
K = saw kerf (inches)
W = rough green width of board plus one saw kerf (inches)
S = shrinkage factor = 0.9385, based on 15 percent final moisture content
V_g = green volume of lumber (cubic feet)
$_f$ = finished volume of lumber (cubic feet)

In actual applications, the sawmill manager would likely develop mill specific residue estimating equations.

For logs from beetle-killed trees, the previous equations are multiplied by reduction factors to allow for lower residue weights due to drying of the trees. The bark weight was more severely reduced because a majority of the bark on beetle-killed pines comes off during felling, skidding, and other rough handling before the log reaches the debarker.

Limited data are available concerning long-term moisture content reductions of southern pine sawtimber after a beetle attack. Assuming a green moisture content of 100%, the following reduction factors for sawdust weight and chip weight put the moisture content of butt logs from beetle-killed trees at 70% and upper logs at 50% for this example:

Bark weight (0.3)
Sawdust weight butt logs (0.85)
Sawdust weight upper logs (0.75)
Chip weight butt logs (0.85)
Chip weight upper logs (0.75)

TABLE 1. *Example of information supplied by SAWMOD—market value, cost, and potential profit or loss of various log diameters in log quality class 1 when converted into lumber and chips.*

Diameter (inches)	Market value of lumber and residues ($/cubic foot)	Cost ($/cubic foot)	Potential profit or loss ($/cubic foot)
7	1.963	0.904	1.060
8	2.041	0.882	1.160
9	2.107	0.878	1.230
10	2.164	0.875	1.288
11	2.213	0.884	1.328
12	2.255	0.905	1.350
13	2.293	0.933	1.360
14	2.326	0.958	1.369
15	2.356	0.980	1.376
16	2.382	0.995	1.387
17	2.406	1.007	1.399
18	2.427	1.018	1.409
19	2.447	1.023	1.424
20	2.465	1.029	1.436

In practice, the reduction factors would be jointly based on the measured moisture contents of various residues at the mill and on the purchasing policies of residue buyers to arrive at realistic market values.

After all residue and lumber values have been summed for each log, each class of log values is smoothed by a least squares regression of the form:

$$\text{Log Value (\$)} = a + b_1(D) + b_2(D^2)$$

where: D = scaling diameter (inches)

a, b_1, b_2 = parameters that are estimated from the sample data for each log class

The form of this equation was chosen using a heuristic process of fitting the experimental data to many equations and selecting the equation that best fit the data. The criteria for best fit was the highest coefficient of determination values.

MANUFACTURING COSTS

Annual operating cost for the sawmill is divided by the hours of operation per year to obtain an average hourly cost. The annual operating cost should include any reasonable costs of goods and services used up in the process of obtaining revenues such as salaries and wages, utilities, capital recovery, insurance, property taxes, and maintenance expenses.

Manufacturing costs per log are determined by the time it takes the slowest machine in the mill to process the log. In most conventional sawmills, the headsaw is the limiting or slowest machine. Therefore, for various diameters of control and beetle-killed logs the time required by the headsaw to prepare the log for further processing was measured. Sawing times were not different for control and beetle-killed logs, so only one data set is required to represent sawing times for both groups. For simplicity, the initial data base of SAWMOD was comprised totally of 16.3-foot-long logs.

TABLE 2. *Log diameter distributions and total cubic feet of logs used in linear programming subroutine for total profit estimations.*

Log diameter (inches)	Percentage of log/volume	
	Butt logs	Upper logs
7	5%	5%
8	6%	6%
9	8%	8%
10	10%	10%
11	12%	12%
12	15%	15%
13	13%	13%
14	10%	10%
15	6%	6%
16	5%	5%
17	5%	5%
18	2%	2%
19	2%	2%
20	1%	1%
	100%	100%
Total log volume (cubic feet)	10,000	10,000

Manufacturing costs for sawed logs are then based on the sawing times for each log diameter and the average hourly cost to operate the sawmill, which in the examples given is $250/hour. Different log costs may be assigned to control and beetle-killed logs. In the examples given, these costs are $100/MBF for control logs and $75/MBF for beetle-killed logs.[3] Total costs per log are converted to a cost per cubic foot and subtracted from the log value on a cubic foot basis. The remainder is the profit or loss per cubic foot of log for each scaling diameter in each of the six classes. This is illustrated by the sample chart shown for class 1 in Table 1.

SAWMOD also considers the feasibility of totally chipping low quality logs either for fuel or pulp chips, and a separate hourly cost for chipping may be given to SAWMOD. In the examples $250/hour is used as the hourly chipping cost.

Chipping production costs and log costs are then subtracted from chipping log values, and a profit or loss per cubic foot of each scaling diameter is generated for each of the six classes.

ESTIMATED PROFITS

Log diameter distributions and total cubic foot volumes for butt logs and upper logs as shown in Table 2 for this example are inputted and used as constraints in a linear programming subroutine. The linear programming subroutine then determines the optimal method to process each scaling diameter in each of the six classes and derives the optimum dollar return for each class based on the assigned diameter and volume constraints. An example of the optimum return per class is shown in Table 3.

[3] The version of SAWMOD described in this paper requires log costs to be expressed in $/MBF International 1/4 scale.

TABLE 3. *Example of information supplied by SAWMOD—optimum estimated profit for each log quality class.*

Log quality class	Optimum estimated profit ($/total log volume)
1	13,182.46
2	12,359.64
3	9,653.43
4	7,642.52
5	4,015.66
6	3,069.95

The objective function and constraints of the subroutine are listed below:

Let: L_i = number of ft^3 of log diameter i, given that log is sawn, where i's range is from 7 to 20 inches

P_i = profit ($/$ft^3$) of log diameter i, given that log is sawn, where i's range is from 7 to 20 inches

C_j = number of ft^3 of log diameter j, given that log is chipped, where j's range is from 7 to 12 inches

P_j = profit ($/$ft^3$) of log diameter j, given that log is chipped, where j's range is from 7 to 12 inches

$$\text{Maximum Profit} = P_iL_i + \cdots + P_{20}L_{20} + P_jC_j + \cdots + P_{12}C_{12}$$

Subject to:

$$\begin{aligned}
L_7 + C_7 &= \text{given \% of total ft}^3 \\
L_8 + C_8 &= \text{given \% of total ft}^3 \\
&\vdots \\
L_{12} + C_{12} &= \text{given \% of total ft}^3 \\
L_{13} &= \text{given \% of total ft}^3 \\
&\vdots \\
L_{20} &= \text{given \% of total ft}^3 \\
L_7 + C_7 + L_8 + C_8 + \cdots + L_{20} &= \text{total ft}^3
\end{aligned}$$

BREAK-EVEN LOG COSTS

SAWMOD equates costs with potential revenues and calculates the break-even log costs FOB mill for each of the six classes. Break-even log costs are taken to be that level of log costs at which the sawmill operator will neither make a profit nor operate at a loss. An example of this information is given in Table 4.

PROCESSING SCHEMES

In most small- to medium-sized sawmills, two primary products may be manufactured, sawn timber products and/or wood chips. Therefore, SAWMOD compares profits for each log diameter in each quality class for totally chipping the log or converting it to sawn products and chips. The optimum processing scheme is taken to be that method that produces the most profit or least loss. The optimum method for processing each log diameter within each quality class is determined by SAWMOD.

TABLE 4. *Example of information supplied by SAWMOD—break-even log cost FOB mill for each log quality class.*

Log quality class	Break-even log costs FOB mill ($/MBF*)
1	303.10
2	290.42
3	223.73
4	192.75
5	136.87
6	122.30

* MBF based on International 1/4 scale.

APPLICATIONS

Because of the many variables affecting profitable processing of beetle-killed pine, sawmill operators face tough decisions when given the option to purchase this material. With the information available through SAWMOD, these decisions could be more easily and accurately made.

Break-even log costs give sawmill operators an excellent guideline in purchasing logs. This is a particularly important guideline for southern pine sawmills where log costs comprise a major cost of operation. By subtracting a margin for profit and risk from the break-even cost of logs, an operator could readily bid on logs with the information contained in SAWMOD.

In addition, SAWMOD allows the sawmill operator to examine the results of changing production or market variables on profits before the actual changes occur. One market factor subject to potential change is the structure of the lumber grading rules. As an example, suppose all structural lumber from beetle-killed pine is lowered one grade. What would be the effect on the profitability of processing beetle-killed pine? A solution to this problem could be to simulate the effect of lower lumber grades by reducing the grades of all structural lumber from beetle-killed material by one grade. Grade 4 or Economy would remain the lowest grade since it is generally not suitable for structural applications.

By running SAWMOD once with the current grades and once with the lowered grades in the data base while holding all other variables constant, the effect on profits caused by such a change in the lumber grading rules could be assessed. This was done, and the results are shown in Fig. 2. Potential profit of the control logs, classes 1 and 2, remains unchanged; however, the potential profit of the beetle-killed logs, classes 3, 4, 5 and 6, drops dramatically. The logs from trees dead 12 months before harvesting, classes 3 and 4, exhibit the greatest loss of profit while the trees dead 20 months before harvesting, classes 5 and 6, show a smaller profit loss. The smaller loss of profit for log classes 5 and 6 is readily understood by noting that the lumber grade yield of these groups of logs had large amounts of Grade 4 or Economy lumber before the grading rule change was simulated (Sinclair and Ifju 1979).

With this change in the grading rules, the break-even log cost FOB mill drops from $122.30 MBF to $93.87 MBF for class 6 logs. Although Fig. 2 still indicates a profit at this level, a break-even log cost of below $100 MBF could easily serve as an indicator to the mill operator that this log class is approaching a point at which further purchases of this low quality material should be postponed.

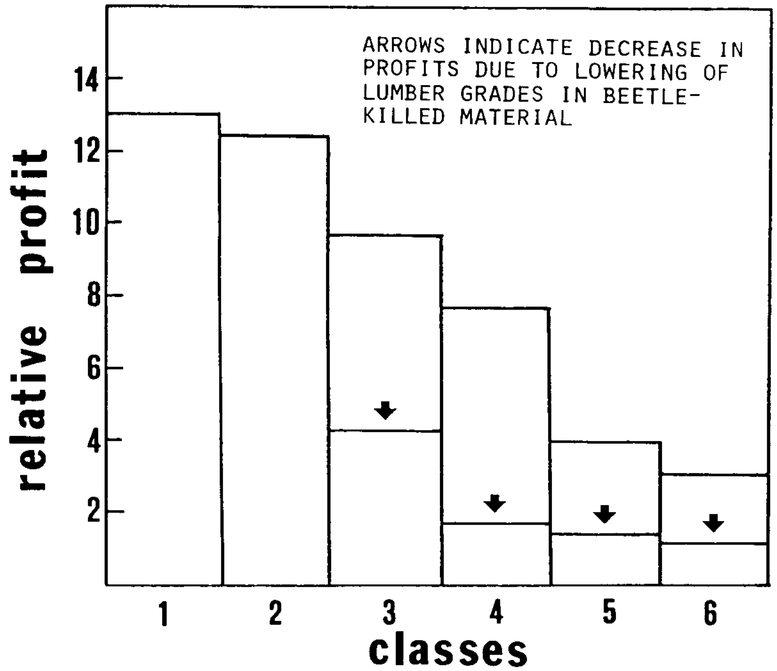

FIG. 2. Estimated profits using current lumber grades and lowered grades for beetle-killed material with all other variables held constant.

Another likely occurrence would be for chip prices to increase, especially if their use as a fuel source becomes widespread. But what if chip prices double while structural lumber grades for beetle-killed pine are lowered one grade as in the previous example? Intuition would indicate that the lowered lumber grades would reduce profitability and higher chip prices would increase profitability. However, an accurate assessment of the resulting level of profitability by traditional methods would be a difficult and time-consuming task. On the other hand, these changes can quickly and accurately be made in SAWMOD to give mill operators the information needed for decision-making.

As chip prices were doubled, chipping the entire log became more profitable than sawing for diameters 7, 8 and 9 inches. In fact, on a cubic foot basis, chipping became 6.7 times more profitable than sawing for a 7-inch-diameter log in class 5, 2.3 times more than profitable for an 8-inch-diameter log, and 1.5 times more profitable for a 9-inch-diameter log. Intuition alone may not have allowed an individual to realize this degree of shift in profitability.

MARKETABILITY OF LUMBER FROM BEETLE-KILLED PINE

The market acceptance of lumber from beetle-killed pine varies with the local market conditions, relative price of lumber, and the availability of lumber from green pine. Many sawmills have indicated that dimension lumber sawn from beetle-killed pines can be sold with little difficulty as long as evident decay or borer holes are not widely present. A survey of sawmills processing beetle-killed pine during 1975 in Virginia reported that 71% of those mills responding had little or no difficulty marketing lumber from beetle-killed pine (Sinclair and Ifju 1977).

The initial lumber grade yield data base for SAWMOD was developed by maximizing 8/4 dimension lumber. This was done for several reasons. Blue-stain, a common characteristic of lumber from beetle-killed pine, is not a basis for degrade under the Southern Pine Inspection Bureau (1970) grading rules for structural light framing and structural joists and planks. In addition, there is a large market and a generally accepted set of lumber grades with corresponding prices for southern pine dimension lumber. However, a less defined and more uncertain market does exist for the use of lumber from beetle-killed pine as decorative boards and timbers. The discoloration and insect holes in this product can be considered character markings rather than potentially degrading features. Several sawmills in the Northwest have very profitably sawn beetle-killed ponderosa pine (*Pinus ponderosa* Laws.). During the initial year after death, 8/4 dimension stock is the primary product sawn; however, as the grades of the dimension stock drop because of continuing decay and insect damage, the primary product becomes decorative boards for paneling.[4]

In practice, the sawmill's marketing strategy for lumber from beetle-killed pine will exert tremendous influence on the profitability and mix of lumber products sawn. The corresponding lumber grade yields would also be highly influenced by the resulting lumber product mix. SAWMOD's lumber grade yield data base would, therefore, in most situations need to be individualized for a mill's marketing strategy as well as associated production constraints.

SUMMARY

SAWMOD is a powerful tool designed to provide better information for more profitable decision-making. Its current data base is for beetle-killed southern pine dimension lumber; however, with a different data base and by altering a few equations, it could quickly be readied to provide profitability estimates for a different sawtimber type or mix of solid wood products. With the price of small in-house computers and time-sharing terminals for larger computers becoming less and less, it may only be a few years before such hardware is commonplace in many sawmills. Software such as SAWMOD, which is designed to be individualized and periodically updated for a given sawmill, will give future mill operators valuable decision tools.

Certainly as stumpage prices and competition for stumpage continue to increase, our nation's sawtimber resource must be more fully and efficiently utilized. Techniques like SAWMOD can give timber managers and sawmill operators the information they need to more accurately set stumpage prices or place bids on damaged timber at a level that will allow for profit and thereby encourage full utilization of our sawtimber resource.

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