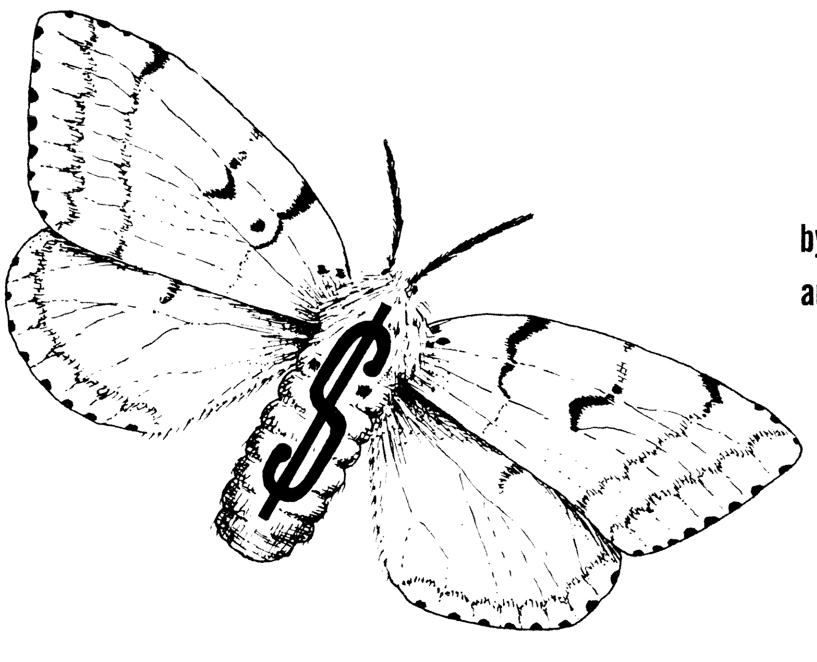
Economic Analysis of the Gypsy Moth Problem in the Northeast

I. Applied to Commercial Forest Stands



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This is the first in a series of publications on the economic impact of the gypsy moth. The next two reports are:

APPLIED TO RESIDENTIAL PROPERTY

APPLIED TO RECREATION

Future publications in the series are in preparation.

Economic Analysis of the Gypsy Moth Problem in the Northeast

I. Applied to Commercial Forest Stands

ABSTRACT

A method of calculating immediate and future losses caused by the gypsy moth is presented, using examples of pulpwood and sawtimber stands. Discounting of future losses to evaluate their cost in terms of current expenditure is explained. The effect of infestation on forest management is discussed and a format is given for considering control decisions.

INTRODUCTION

ECONOMIC EVALUATIONS are prerequisite to sound forest insect management decisions. In the past, many insect control decisions have been made without sufficient economic analysis. The value of insect suppression may be reflected in the form of dollars, job opportunities, aesthetics, or other benefits. This paper presents an approach that the authors employed in evaluating timber product loss from gypsy moth defoliation.

The model provides a vehicle for evaluating local opportunities for gypsy moth control using appropriate economic inputs e.g., treatment costs, return values and discount rates. Case studies showing the application of the method in pulpwood and sawtimber stands are presented. We also explain how uncontrolled gypsy moth infestation can limit timber management decisions.

METHODOLOGY

Estimation of stand value loss requires the following basic data: time dimension, extent of damage, and stand value. The time dimension establishes whether the losses we are dealing with are immediate or in the future. Immediate losses are evaluated by direct calculations using today's costs and values on existing merchantable timber. To calculate future losses we require information or assumptions about future growth rates, timber products, timber values, interest rates, and recurring defoliation.

Many times the most difficult part of an economic analysis is obtaining estimates of the extent of the damage. In many instances these estimates are divided into general categories. For example, a certain insect may kill a specified percentage of white oak trees, but only the low vigor white oak trees may be killed. The best estimates of value are obtained when the damage estimates are as specific as possible about the nature of the damage and the kinds of trees involved.

Forest stands are valued for many reasons. Some areas are important for timber production, other areas are valued for wildlife or scenic beauty, while still other areas have recreation values. Any of these values could be used in an economic analysis if the value is quantifiable. To estimate stand value loss we must be able to define and quantify the value that may be lost and determine how the lost value affects the residual value both now and prospectively.

The possibility exists that part of the value of trees lost will be compensated for by increased growth of the remaining trees. This factor has been ignored in the following examples. We also ignore retardation of growth in trees not killed by defoliation.

Immediate stand value loss for timber products is calculated as follows: Value loss for each class of trees (the same species, diameter, merchantable height, and quality) equals the mortality rate for that class times its total value. Total stand value loss is the sum of the losses in each class.

Some of the value loss may be recovered if the trees lost are merchantable and may be marketed immediately. The merchantability and market conditions for dead trees vary by locality, therefore for simplicity we have not included this value in our examples.

For the future loss calculations, the number of years until harvest must be estimated. The harvest age may be derived from tree growth rates and merchantability standards. Estimates for the value of the harvest and the percentage loss are required. The basic formula for the future stand value loss is as follows:

Formula 1. Future stand value loss in terms of current dollar values.

Expected value loss = harvest value X mortality rate.

Discount expected value loss to obtain a measure of the amount of money which, if invested now at the specified rate of compound interest, would equal the expected loss when the stand reaches harvest age.

Value loss in current dollars

$$= \frac{\text{expected loss}}{(1+i)^n}$$

where: i = interest rate
n = number of years until harvest

Most stands are too large for us to have information on every tree, therefore sample information that is representative of the whole stand must be taken. The sample information should be averaged and then multiplied by the proper sample-to-stand ratio to arrive at total stand value loss.

Case Study I – Calculating Immediate Loss in a Pulpwood Stand

Our first case study examines a pulpwood-size stand to determine the loss that would be caused by one year of heavy gypsy moth defoliation. Campbell and Valentine (*1*) have developed estimates of tree mortality based on defoliation histories and tree characteristics. We used the percentage tree mortality expected over a three year period (N+3) after one year of heavy defoliation (H). This percentage is most likely to include all the tree mortality that will result from one heavy defoliation.

Individual tree data were taken from 26 1/10-acre fixed plots. The tree data were summarized and averaged by plot (table 1). Data required to use the mortality tables included tree species, dominance class (dominant, intermediate, or suppressed), diameter class, and crown condition (good, fair, or poor).

The immediate loss is calculated by multiplying the total pulpwood volume, as determined from volume estimates, times $2.50 per cord,[1] times mortality rate, as determined from Campbell and Valentine. The average of the immediate loss values (table 1)–$4.65–is the loss per acre that may be expected by the third year after one year of heavy gypsy moth defoliation.

Case Study II – Calculating Future Loss in a Pulpwood Stand

For the future pulpwood loss we must estimate the harvest tree size and the number of years needed to reach that tree size in addition to the data collected for the immediate loss. We used 12 inches d.b.h. as harvest size for the pulpwood trees. Increment cores for establishing the average growth rate were obtained from sample trees. The number of years needed to reach harvest size is determined by multiplying the expected harvest tree size (in inches d.b.h.) times the number of years needed to grow one inch in diameter. For our case the calculations were completed as follows:

Average number of annual rings in 1 in. radial growth: 18.3
Average number of years to grow 1 in. in diameter: 9.15
Assume the average tree size at maturity to be 12.0 inches ∴ 12.0 x 9.15 ≈ 110 years for harvest
Present age of stand: 60 years
Years remaining to maturity: 50

The value at maturity requires an estimate of the average merchantable volume at maturity. For simplicity, we will assume the pulpwood values to be constant over time. The maturity value is then multiplied by the percentage of volume lost to obtain the value of the loss. This loss value should be discounted to arrive at a figure in terms of today's dollars, as shown below.

Average merchantable volume at maturity:
Average d.b.h. = 12.0 inches
Average merchantable height at maturity = 32 feet

[1]Pulpwood values based on $2.50 per cord and 90 cubic feet per cord were used for value estimates.

Table I.—Pulpwood value loss

Plot	Number of trees per plot (1/10 acre)	Average tree d.b.h.	Pulpwood[a] value per acre	Mortality[b] loss	Immediate value loss per acre
	Number	*Inches*	*Dollars*	*Percent*	*Dollars*
1	48	5.7	36.80	7.6	2.80
2	33	6.7	43.26	9.0	3.89
3	19	6.9	23.50	9.0	2.12
4	40	5.9	32.86	12.0	3.94
5	38	6.3	44.96	13.0	5.84
6	31	6.7	40.40	9.0	3.64
7	24	7.4	43.76	10.0	4.38
8	22	7.5	44.46	7.0	3.11
9	23	6.7	32.36	13.0	4.21
10	20	6.6	28.80	10.0	2.88
11	20	7.5	40.70	8.0	3.26
12	26	7.6	59.36	8.0	4.75
13	22	7.2	54.10	4.0	2.16
14	32	5.9	30.80	8.0	2.46
15	48	6.0	44.80	18.0	8.06
16	59	5.4	36.60	16.0	5.86
17	47	5.7	35.80	18.0	6.44
18	23	7.4	43.30	11.0	4.76
19	41	6.4	49.70	17.0	8.45
20	30	6.8	46.80	8.0	3.74
21	20	6.7	34.56	13.0	4.49
22	25	7.0	40.10	8.0	3.21
23	21	7.8	41.70	16.0	6.67
24	21	8.0	46.96	10.0	4.70
25	24	9.0	63.46	8.0	5.08
26	25	9.2	68.96	15.0	10.34
Average	30	6.7	42.64	10.9	4.65

[a]Pulp values calculated at $2.50 per cord and 90 cu. ft. per cord.
[b]Mortality rates adapted from *Tree Condition and Mortality Following Defoliation by the Gypsy Moth* by Robert W. Campbell and Harry T. Valentine.

Average merchantable volume from Schnur's (7) volume tables ≈ 12 cu. ft./tree
Average number trees per plot = 30
Average number trees per acre = 300
Average merchantable volume at maturity:
300 trees x 12 cu. ft./tree = 3,600 cu. ft.

$$\frac{3{,}600 \text{ cu. ft.}}{90 \text{ cu. ft./cd.}} = 40 \text{ cd.}$$

Value at maturity:
40 cd. x $2.50/cd. = $100.00
Value loss due to gypsy moth:
Expected mortality rate due to one heavy defoliation = .109
$100.00 x .109 = $10.90 per acre

$$\text{Discounted value: } \frac{\text{expected loss}}{(1+i)^n}$$

Discounting period (n) = 50 years
Interest rate (i) = 5 percent

$$\frac{\$10.90}{11.4674} = \$0.95 \text{ per acre.}$$

Thus, for this particular example, $0.95 per acre is the amount that could prudently be spent on control measures if it eliminated all the expected mortality. It would give the same rate of return as putting the money in a bank at 5 percent compound interest.

If we knew the amount some control measure would cost per acre, and its effectiveness, we could determine what the rate of return would be if the control methods were applied. For instance, in this example, if the control method cost $10.90 per acre and were 100 percent effective, the rate of return would be zero. If $2.00 per acre were the cost of control, the rate of return would be determined as follows:

$$\frac{\$10.90}{\$2.00} = 5.4500$$

Looking up 5.4500 in compound interest tables for 50 years, we find the rate of return very close to 3.45 percent.

Case Study III – Calculating Immediate Loss in a Sawtimber Stand

The immediate sawtimber losses were calculated in the same general way as immediate pulpwood losses, but the details of the calculation are different. To obtain a value estimate, we must estimate the quality of lumber that may be sawn from each tree. This may be done by using log grading techniques *(6)*. For our sawtimber examples, immediate and future, we used sawlog values developed by J. J. Mendel.[2] His sawlog values were calculated by subtracting from the estimated standing tree values for grade lumber all direct costs of converting the tree into lumber. For some trees the conversion cost was higher than the standing tree value, which resulted in some negative sawtimber values.

The immediate sawtimber value loss per sample plot in this case is \$15.08. As these sample plots are 1/5 acre, this value multiplied by five represents the immediate loss per acre that may be expected from one year of heavy gypsy moth infestation (\$15.08 x 5 = \$75.40) (table 2).

[2]Joseph J. Mendel. Unpublished.

Case Study IV – Calculating Future Loss in a Sawtimber Stand

Prediction of harvest value for a sawtimber stand requires consideration of volume, quality, and future value. Projecting sawtimber quality into the future is hazardous, but a recent study by McCay and DeBald (5) developed a method for projecting quality changes by using probabilities. The probabilities were based on the changes that had occurred in a sample area over the last 10 years (fig. 1).

Three projections were made—high, expected, and low. The high projections represent what the trees would be at harvest if all of them developed as did the upper 10 percent in the frequency distributions. The low projections use the lowest 10 percent. The expected projections used the median of the probability distributions.

Each tree in the sample plots was evaluated according to the following example:

Present Characteristics

White oak

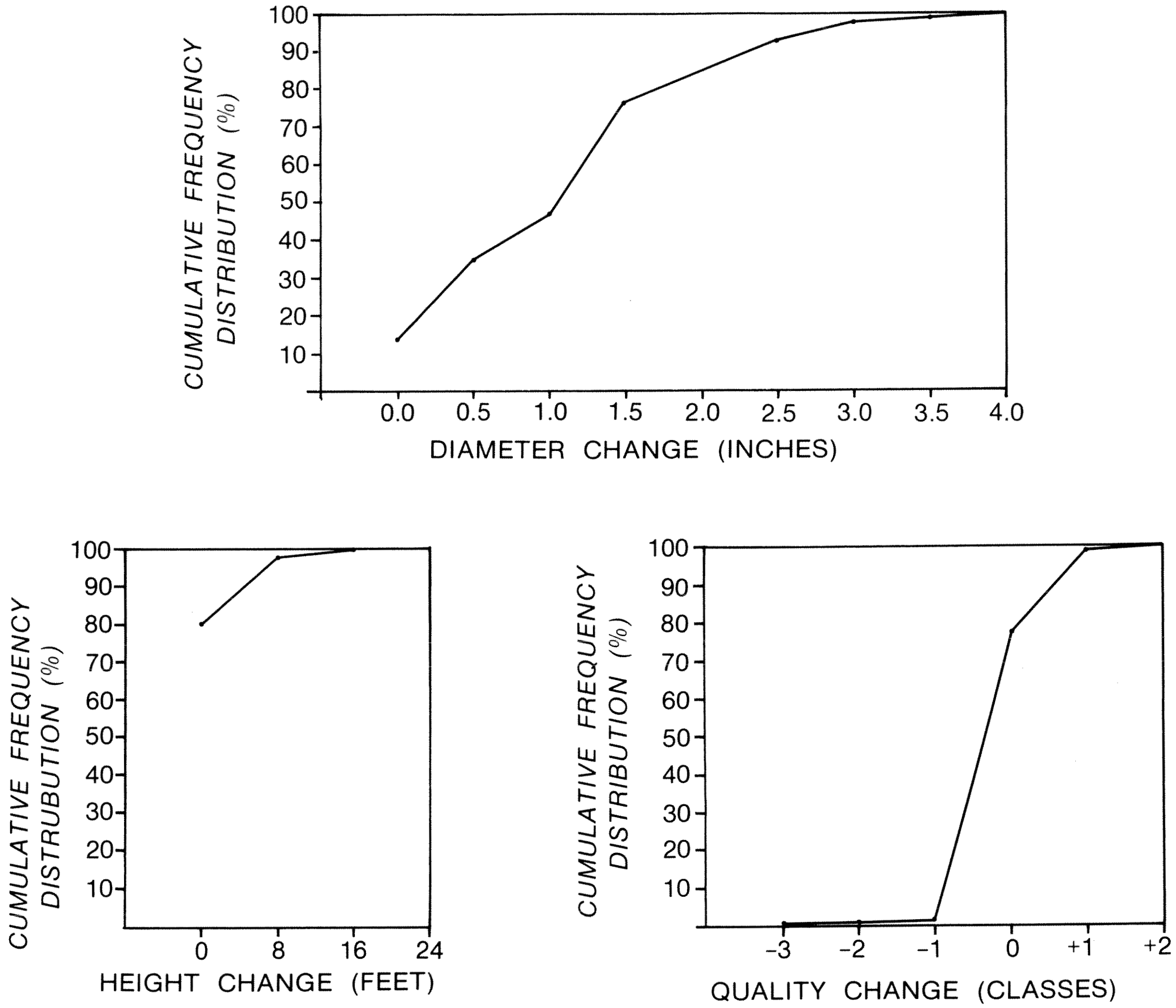
Diameter breast high	–	14.6	inches
Merchantable height	–	32	feet
Butt log grade	–	3	

Table 2.—Sawtimber plot information

Plot	Trees per plot (1/5 acre)	Average tree d.b.h.	Sawtimber value per acre[a]	Expected mortality loss[b]	Sawtimber value change per acre[c]
	Number	*Inches*	*Dollars*	*Percent*	*Dollars*
1	16	14.9	835.00	34.6	−288.90
2	12	13.4	10.50	33.8	− 3.55
3	22	13.1	550.65	25.7	−141.50
4	8	14.4	−10.05	9.0	+ .90
5	13	11.4	144.50	26.0	− 37.55
6	15	13.8	453.75	19.5	− 88.50
7	17	18.7	387.80	29.3	−113.65
8	16	13.4	214.40	13.1	− 28.10
9	17	13.1	283.30	39.5	−111.90
10	21	10.8	115.90	23.9	− 27.70
11	28	9.7	−43.85	25.1	+ 11.00
Average	17	13.3	267.44	28.0	− 75.40

[a]Sawtimber values from J. J. Mendel's unpublished data, Columbus, Ohio. Negative value is due to conversion cost's being higher than value returned.
[b]Mortality losses adapted from *Tree Condition and Mortality Following Defoliation by the Gypsy Moth* by Robert W. Campbell and Harry T. Valentine.
[c]Two plots increased in value due to losing trees that had negative values.

Figure 1.—Probability of changes in sawtimber tree characteristics.



From figure 1 the low projection would have no change in d.b.h., no change in height, and no change in quality. The high projection would increase d.b.h. by 2.5 inches, increase height by 8 feet, and increase quality by 1 class. The projections for this tree could be summarized as follows:

	Present Characteristics		
	D.b.h. (inches)	*Height (feet)*	*B.l.g.*
Low	14.6	32	3
Expected	16.1	32	3
High	17.1	40	2

Once the projected tree characteristics were determined tree values were applied and multiplied by the expected mortality (values were held constant for the entire time frame). The result is the loss that might be caused by the gypsy moth. The plot values were summed, averaged, and converted to a per-acre basis (table 3). The per-acre values were discounted to determine the value loss in terms of today's dollars (table 4). The discounting period was 10 years because this stand would reach maturity in that time.

Table 3.—Future sawtimber loss per acre

Projection	Value before gypsy moth	Value after gypsy moth	Dollar loss due to gypsy moth
Low	$294.15	$218.75	$ 75.40
Expected	399.60	284.50	115.10
High	652.60	457.55	195.05

Table 4.—Future sawtimber losses per acre, discounted over 10 years

Projection	Discounting rate		
	3%	5%	7%
Low	$\frac{75.40}{1.34392}$ = \$ 56.10	$\frac{75.40}{1.62889}$ = \$ 46.29	$\frac{75.40}{1.96715}$ = \$ 38.33
Expected	$\frac{115.10}{1.34392}$ = \$ 85.64	$\frac{115.10}{1.62889}$ = \$ 70.66	$\frac{115.10}{1.96715}$ = \$ 58.51
High	$\frac{195.05}{1.34392}$ = \$145.14	$\frac{195.05}{1.62889}$ = \$119.74	$\frac{195.05}{1.96715}$ = \$ 99.15

Impact of Gypsy Moth on Forest Management Opportunities

As mentioned earlier, a forest may suffer losses in one or more forms. One form of loss is the restriction of forest management alternatives.

Forest management altrnatives are the choices of techniques by which young stands are manipulated to produce mature stands ready for harvest. As a stand grows toward maturity various timber management alternatives are available to the forest manager. The choice depends on the stand characteristics at a given time. One guide for timber management decisions developed by Gingrich (*4*) is based on stocking percentage. He classifies the stocking level as follows: below understocked = less than 42 percent stocked; understocked = 42 percent to 58 percent stocked; fully stocked = 58 percent to 100 percent stocked; and overstocked = more than 100 percent stocked.

After one year of heavy gypsy moth defoliation, the stocking level remained in the same class for 77 percent of the pulpwood plots (table 5). Twenty-two of the 26 plots were in the class that fully utilized the site. Therefore,

Table 5.—Pulpwood management loss

Plot	Stocking percentage	
	Before gypsy moth	After gypsy moth
1	97	74
2	88	81
3	51	47
4	86	76
5	98	85
6	80	73
7	72	66
8	75	69
9	62	55
10	55	48
11	68	62
12	98	91
13	80	75
14	70	62
15	108	88
16	108	93
17	102	85
18	88	73
19	110	92
20	88	82
21	61	54
22	75	62
23	73	61
24	77	70
25	98	92
26	112	95
Average	84	74

we could still manage the area for timber production without destroying the existing stand and starting a new one. Our loss is the value of merchantable pulpwood from any proposed thinning operation. The value of the pulpwood loss has been discussed earlier and management flexibility is not an issue.

Examination of the sawtimber-size stands reveals that four of eleven plots drop from understocked or better to below understocked after one year of heavy gypsy moth defoliation (table 6). (One plot is below understocked before defoliation.) The management recommendation for areas below the understocked level is to clearcut and regenerate a new stand. Before this is done, we should consider other factors such as location of understocked plots, market conditions, condition of remaining timber, value of stand as wildlife habitat, etc.

Table 6.—Sawtimber management loss

Plot	Stocking percentage	
	Before gypsy moth	After gypsy moth
1	82	48
2	57	35
3	88	40
4	40	25
5	42	30
6	68	46
7	120	82
8	69	50
9	71	48
10	62	38
11	68	48
Average	70	45

The average plot information indicates that on the other plots the stocking level drops from fully stocked to understocked after the defoliation. Assuming no subsequent defoliations, these stands should reach fully stocked in 10 years. Therefore, the gypsy moth has performed a thinning operation at a cost equal to the value of the trees that might have been marketed. The procedure for estimating the value of this loss has been discussed earlier.

DISCUSSION

Because the forests are used for many things, we must consider more than wood production when trying to establish the value loss caused by the gypsy moth. The importance of the other uses will vary with the individual forest, the type of damage and control measures, and the people setting priorities for the forest. A format for listing and evaluating forest uses and alternative control measures has been developed (table 7). More items of concern and new control measures may be added to assure a complete evaluation for a local forest.

The following abbreviated example indicates how the table may be interpreted. (The values used are hypothetical.)

	Do nothing	*A*
Probability of success	5%	98%
Cost	$0	$8/acre
Air quality	No effect	Effect
Water quality	No effect	Effect
Soil	No effect	Effect
Resource values	Lose $80/acre	Lose $2/acre
Federal	—	Banned

Control measure A was the application of DDT and if we ignored the federal ban and were willing to accept any consequences to the soil and water, then DDT is a feasible alternative when compared to the do-nothing alternative. But DDT is banned, which eliminates it from consideration, and the do-nothing alternative may then be compared with other alternative control measures.

SUMMARY

Basic information required for an economic evaluation of the effect of defoliation on trees is time frame, damage caused, and values. Time frame establishes whether we are dealing with the present or the future. Direct calculations can be made for the present; calculations for the future require some predictions about

Table 7.—Format for evaluating the impact of alternative gypsy moth control measures

Item of concern	Do Nothing	Alternative control measures				
		A	B	C	D	E
1. Program factors						
Prob. of success						
Cost						
2. Environmental factors						
Air quality						
Water quality						
Soil						
Temp. & humidity						
Noise						
Flora & fauna						
3. Socio-Economic factors						
Resource values						
Access						
Ethnic & cultural values						
Ownership responsibility						
Management alternatives						
4. Political						
Local						
State						
Federal						

changes that may occur during the time before harvest. These changes involve growth rates, quality measures, interest rates, price variations, mortality estimates, etc.

The damage caused by the defoliation determines how great any loss will be. Some trees are lost because of one heavy defoliation.

Applying economics to a problem requires some measure of value. Trees have many values to various people; these values must be defined and measured before they can be used.

These principles were applied to a pulpwood and a sawtimber stand subjected to one year of heavy gypsy moth infestation. For these examples, the final loss values represent what a prudent owner could spend to protect his forested area from one heavy gypsy moth defoliation. All the dollar values presented in our sample calculations are not recommended for other forested areas; conditions, markets, prices, and objectives may be different. We suggest that you use proper methods to arrive at values for your area.

Another factor for consideration is the effect of defoliation on forest management alternatives. Our example was based on stocking percentage. The sample analysis indicates no change in alternatives for the pulpwood stand. The sawtimber stand changes from fully stocked before defoliation to understocked after defoliation.

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