Determining the economic feasibility of salvaging gypsy moth-killed hardwoods

Chris B. LeDoux

Abstract

Oak sawlog and pulpwood losses in stands defoliated by gypsy moths have become a critical problem for some forest landowners. The salvage of gypsy moth-killed hardwoods can become an important source of pulpwood and sawlogs. This study documents a methodology and provides guidelines to determine defoliated oak stands that are economically salvageable. Stand data from 574 defoliated oak stands were integrated with stump-to-mill logging costs and wood values. Cable and ground-based logging costs were integrated with three levels of sawlog and pulpwood-fuelwood prices to determine if salvage would be economical. The data and methodology were used to develop feasibility matrices for red, white, chestnut, scarlet, and black oak. The results show that the most profitable salvage operations will be those in stands with high volumes, a valuable species mix, a large component of grade logs on gentle ground, which are salvageable by ground-based systems, and are close to the mill. Managers, planners, landowners, and loggers can use these matrices to determine which stands are profitable.

Since the introduction of the gypsy moth to the United States in 1869, the pest has become established in the Northeast. Some life stages of the insect have been found in nearly all states (1). Practically all forest stands in the Northeast are susceptible to gypsy moth defoliation. Stands containing oak, birch, and aspen are particularly vulnerable.

Although defoliation is important in predicting the extent of tree mortality, other factors, such as stand and site characteristics and composition and invasion by insects and fungi, have an overall influence on tree mortality. The challenge to managers and planners is to estimate defoliation and mortality, and also to determine which stands are economical to harvest.

Studies have documented oak sawtimber losses in gypsy moth-defoliated stands (2). The pulp and papermaking properties of gypsy moth-killed oaks have been evaluated and documented (6), as has the lumber recovery from gypsy moth-killed red and white oak trees (3). Generally, recovery studies suggest that pulp and lumber can be recovered provided the trees were harvested within 1 to 3 years of the tree's death. Methods have been developed to estimate potential tree mortality associated with gypsy moth defoliation (5). Silvicultural guidelines have been developed for managing Appalachian hardwood stands to minimize gypsy moth impact (4).

Although pulping and recovery studies have been conducted, mortality estimators developed, and silvicultural guidelines to minimize losses documented, a need exists for determining which stands would be economical to salvage. A rigorous financial analysis must be conducted using accurate estimates of logging costs for alternative logging technologies. The logging costs need to be integrated with wood value estimates to determine the economy of salvage. This paper provides estimates to determine which stands to harvest.

Logging costs

Stump-to-mill logging cost estimates were developed for salvaging gypsy moth-killed hardwoods for cable and ground-based logging systems. The cost estimates were developed using ECOST (7) and EASTCOST (8), microcomputer programs that, respectively, estimate the stump-to-mill cost of cable and ground-based logging in the mountainous terrain of the Northeast. Stand data were produced from 574 sample 1/10-acre plots in Pennsylvania established in 1978 before the gypsy moth infestation of the 1980s. Cumulative tree mortality was measured annually from 1979 to 1985 on each plot. Additional tree, log, and timber stand characteristics and attributes were also measured during this period. The summary of sample oak plot characteristics in Table 1 represents the production potential in plots of dead trees. The logging methods include the Clearwater[1] cable yarder for steep terrain applications, and a John Deere 540B skidder for moderate to gen-

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the USDA Forest Service of any product or service to the exclusion of others that may be suitable.

The author is an Industrial Engineer and Project Leader, USDA Forest Serv., Northeastern Forest Expt. Sta., Morgantown, WV 26505. This paper was received for publication in June 1989.

Forest Prod. J. 40(5):43-46.

TABLE 1. — *Sample oak plot characteristics, per acre.*

Characteristics	Average	Minimum	Maximum
DBH (in.)	9.33	5.70	15.97
Butt log grade[a]	3.71	2.17	4.00
Volume (ft.^{3})[b]	1,524.62	35.00	5,134.00
Volume (board feet)[c]	4,939.87	140.00	25,154.00
Age (yr.)	71.14	17.00	177.00
Slope (%)	24.00	0.00	67.00
Merchantable height (ft.)	30.39	8.00	52.89
No. of trees	154.00	30.00	360.00

[a] Smaller numbers indicate higher quality logs with 4 = pulpwood-fuelwood.
[b] Smalian's method.
[c] International 1/4-inch rule.

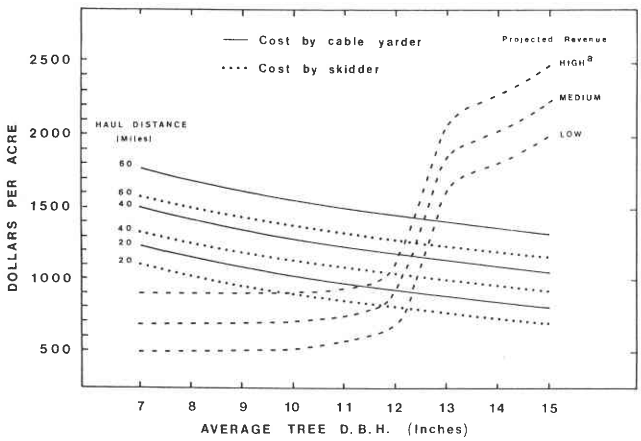

Figure 1. — Simulated cost and revenue (per acre) by average tree DBH, haul distance, and estimated revenue for red oak, volume removal of 2,000 ft.^{3}/acre.

eral terrain. Chain saw felling was assumed in this analysis. Haul distances ranged from 20 to 60 miles. Figure 1 shows the resulting stump-to-mill cost curves for both logging methods, by haul distance, to the mill. The curves were developed using ECOST and EASTCOST. The logging cost estimates were integrated with the value of wood delivered to a sawmill.

Estimating wood value

Three levels (high, medium, and low) of delivered prices for four species of oak sawlog and pulpwood-fuelwood were used to estimate revenue from the wood (Table 2). The prices were obtained from forest products reports from three states (9-11). Only sawlog and pulpwood-fuelwood products were evaluated because these were the products the reports suggested would be most likely to be salvaged from gypsy moth-killed trees. The prices represent market prices of salvaged sawlogs and pulpwood-fuelwood on the East Coast. Figure 2 shows the relative revenues from the salvaged products of red, white, chestnut, scarlet, and black oak, with red oak the highest, bringing a little more than $2,200 per acre. Relative revenue curves by dollars per acre and average cut-tree diameter at breast height (DBH) for red oak with a fixed volume removal of 2,000 ft.^{3} are displayed in Figure 1. The curves rise sharply in the range of 12- to 13-inch average tree DBH. This is because more medium and large sawlogs are produced from larger trees and larger logs bring higher prices.

Economic feasibility

Economic feasibility is shown at the intersections of the cost and revenue curves (Fig. 1). Each intersection defines the minimum average DBH feasible for the specified cost and revenue assumptions. The intersections define break-even salvage harvest conditions. Conditions beyond the break-even points represent the profit potential in salvaging gypsy moth-killed hardwoods. For example, stands with trees averaging 10 inches DBH can be salvaged using ground-based logging equipment when the haul is 20 miles or less. In contrast, for cable logging, stands must contain trees averaging 11.5 to 12 inches DBH and be within a 20-mile haul in order to be economical. Figure 1 is specific to red oak and a fixed volume removal of 2,000 ft^3. It would be beyond the scope of this paper to show all the possible revenue-cost curves for each volume removal and oak species. However, the results from Figure 1 can be expanded in a matrix, such as Figure 3.

TABLE 2. — *Market values by species and product.*[a]

Delivered price	Large sawlogs[b]	Medium sawlogs[c]	Small sawlogs[d]	Pulpwood-fuelwood[e]
	($/MBF)			($/cord)
Northern red oak				
High	300	250	125	40
Medium	275	225	100	30
Low	250	200	80	20
White oak				
High	255	225	125	40
Medium	220	170	100	30
Low	200	150	80	20
Chestnut oak				
High	235	185	125	40
Medium	210	160	100	30
Low	190	140	80	20
Scarlet and black oak				
High	135	115	95	40
Medium	110	90	70	30
Low	90	70	50	20

[a] International 1/4-inch rule.
[b] Minimum small-end diameter ≥ 13 inches, length ≥ 10 feet.
[c] Minimum small-end diameter ≥ 11 inches, length ≥ 8 feet.
[d] Minimum small-end diameter ≥ 10 inches, length ≥ 8 feet.
[e] Wood size is 89 ft.^{3}/cord, minimum small-end diameter ≥ 4.0 inches, which will not make large, medium, or small sawlogs.

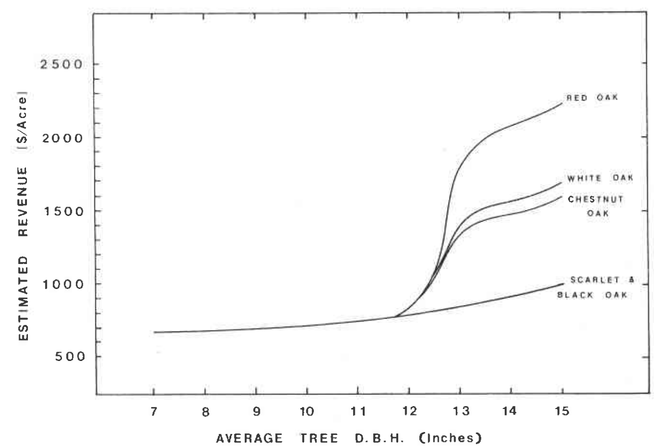

Figure 2. — Estimated revenue per acre by average tree DBH and oak species, volume removal of 2,000 ft^3. The price level is medium.

Selecting salvageable stands

From the data and methodology, economic feasibility matrices were developed for red, white, chestnut, scarlet, and black oak (Fig. 3). Because there are similar price levels and end results when using the cable yarder, the

a

VOLUME SALVAGED -Ft^3/Acre-	HAUL DISTANCE -Miles-	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
3000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L

b

VOLUME SALVAGED -Ft^3/Acre-	HAUL DISTANCE -Miles-	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H	H M	H M L
2000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M	H M	H M L
2500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M	H M	H M L
3000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M	H M	H M L

c

VOLUME SALVAGED Ft^3/Acre-	HAUL DISTANCE -Miles-	AVERAGE D. B.H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H	H M	H M L
2000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H	H M	H M L
2500	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H	H M	H M L
3000	20	N	N	N	N	N	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H	H M	H M L

d

VOLUME SALVAGED - Ft^3/Acre -	HAUL DISTANCE - Miles -	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	N	N	H	H	H M
	40	N	N	N	N	N	N	N	N	H
	60	N	N	N	N	N	N	N	N	H
2000	20	N	N	N	N	N	N	H	H	H M
	40	N	N	N	N	N	N	N	N	H
	60	N	N	N	N	N	N	N	N	H
2500	20	N	N	N	N	N	N	H	H	H M
	40	N	N	N	N	N	N	N	N	H
	60	N	N	N	N	N	N	N	N	H
3000	20	N	N	N	N	N	N	H	H	H M
	40	N	N	N	N	N	N	N	N	H
	60	N	N	N	N	N	N	N	N	H

e

VOLUME SALVAGED Ft^3/Acre	HAUL DISTANCE Miles	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	H	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2000	20	N	N	N	N	H	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2500	20	N	N	N	H	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
3000	20	N	N	N	H	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L

f

VOLUME SALVAGED -Ft^3/Acre	HAUL DISTANCE -Miles-	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	H	H	H M	H M L	H M L
	40	N	N	N	N	N	N	H M	H M L	H M L
	60	N	N	N	N	N	N	H M	H M L	H M L
2000	20	N	N	N	N	H	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M	H M L	H M L
2500	20	N	N	N	H	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M	H M L	H M L
3000	20	N	N	N	H	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L

g

VOLUME SALVAGED Ft^3 Acre	HAUL DISTANCE Miles	AVERAGE D. B. H. (Inches)								
		7	8	9	10	11	12	13	14	15
1500	20	N	N	N	N	H	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2000	20	N	N	N	N	H	H	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
2500	20	N	N	N	N	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L
3000	20	N	N	N	H	H	H M	H M L	H M L	H M L
	40	N	N	N	N	N	N	H M L	H M L	H M L
	60	N	N	N	N	N	N	H M L	H M L	H M L

Figure 3. — Interactive effects of logging system (cable or skidder), species, price level, and haul distance on the economic feasibility of salvage operations. H = high prices; M = medium prices; L = low prices; and N = not economical at high prices. Species and logging systems are: a. red oak, cable yarder; b. white oak, cable yarder; c. chestnut oak, cable yarder; d. scarlet and black oak, cable yarder; e. red and white oak, skidder; f. chestnut oak, skidder; and g. scarlet and black oak, skidder.

scarlet and black oak matrices were combined. Due to similar results, the red and white oak and the scarlet and black oak were combined for ground-based logging technology.

The major differences in the matrices in Figure 3 are the interactive effects of logging technology, species, price levels, and haul distances. For example, stands containing primarily red oak trees averaging 13 inches DBH, 1,500 ft.^{3} of volume removal, using cable logging technology, with 60-mile haul distances, are economically feasible to harvest at high, medium, and low prices (Fig. 3a). In contrast, considering similar combinations of logging technology, volume removal, and haul distance for stands of white oak trees, 60-mile hauls are economical only at the high-price level (Fig. 3b). Because the combinations of logging technology and haul distance remain the same, the difference in economic feasibility in this case is due to the difference in prices for red and white oak products.

Another major difference shown in the matrices is the effect produced by the interaction of logging technology and volume harvested on the economic feasibility of harvesting a stand. For example, stands consisting of chestnut oak trees, using cable logging technology (Fig. 3c), are economical if the trees average at least 12 inches DBH, with at least 1,500 ft.^{3} of volume, high-price levels, and are within 20 miles of a mill. Comparing similar species, prices, and haul combinations, using ground-based technology (Fig. 3f), stands with trees averaging at least 10 inches DBH and 2,500 ft.^{3} of volume can be harvested economically if the price level is high and the stand is located within 20 miles of a mill.

Managers, planners, landowners, and loggers can use the matrices to determine which stands to salvage. For example, a landowner planning to salvage a stand with heavy mortality, trees averaging 10 inches DBH, with a volume of 3,000 ft.^{3}, and primarily scarlet oak on moderate ground, would use the matrices in Figure 3d and 3g, because the stand could be logged with either kind of equipment. Using Figure 3d, the landowner would recognize that to cable-yard this stand would not be economical. Figure 3g suggests that ground-based logging of the stand would be economical if the haul distance were less than or equal to 20 miles and the market price was only at the high level. Other evaluations would follow a similar logic.

These methods could be linked to inventory or stand databases to determine which stands have salvage potential and to develop salvage guidelines. Management focus could then be restricted to the stands offering the most potential. In practice, the analysis could be repeated as often as necessary with changes in product markets, prices, harvesting technology, or silvicultural objectives.

Considerations for managers

The study shows that as average DBH (cut-tree) increased, logging costs decreased. This matches practical experience because large trees are cheaper to harvest. Also, logging costs increased with longer haul mileage. The difference in logging costs between cable and ground-based technology, in this analysis, ranged from 10 to 15 percent. The cost differences are due largely to initial equipment investments. Cable logging technology is generally more expensive than comparable ground-based logging technology.

The most profitable stands will be those with high volumes, a valuable species mix, grade-log trees on gentle ground, a potential for ground-based salvage, and short hauls to the mill. The trees should be salvaged, if possible, before they die, but if dead, within 1 year in order to minimize pulpwood and lumber recovery losses. For safety reasons, salvaging within 1 year provides a less dangerous tree to the feller.

Individual stands can be examined for salvage feasibility by considering stump-to-mill costs and species product prices at any point in time. Submarginal salvage candidates may be combined with more profitable stands into one economical harvest. For profit in stands with low volumes of dead material, thinning live trees can increase the volume and value of the logging operation. This is desirable biologically because the thinned stands will grow faster and yield products of higher quality. Live trees selected in the thinning should be those most likely to die in the near future or in the next outbreak of defoliation. These methods can be used with existing inventories to evaluate stands for salvage operations. The process can be computerized for a quick and inexpensive analysis of salvage feasibility as prices, markets, locations, costs, and pest infestations change.

Though the analysis here includes data from only 2 types of logging technologies, 574 sample plots, 3 levels of market price, and 3 haul distances, one can add simulation runs for easy evaluation of other scenarios.

Literature cited

1. Bullard, A.T. and D.E. Donley. 1984. Current status and potential spread of the gypsy moth to the southern Appalachians. Paper presented to the Appalachian Tech. Div. of the American Pulpwood Assoc., York, Pa., 3 pp.
2. Donley. D.E. and D.L. Feicht. 1984. Oak sawtimber losses in gypsy moth defoliated stands. *In:* Proc. National Gypsy Moth Review. Charleston, W.Va. 7 pp.
3. Garges, L.D., P. Labosky, R.R. Blankenhorn, and L.E. Rishel. 1984. Lumber recovery from gypsy moth-killed red and white oak trees. Forest Prod. J. 34(7/8):45-50.
4. Gottschalk, K.W. 1986. Managing Appalachian hardwood stands to minimize gypsy moth impacts. *In:* Proc. Guidelines for managing immature Appalachian hardwood stands. pp. 181-207. 1986. H. Clay Smith and Maxine C. Eye, eds. SAF Publ. 86-02. West Virginia Books. Morgantown, W.Va. 283 pp.
5. Herrick, D.W. and D.A. Gansner. 1987. Mortality risks for forest trees threatened with gypsy moth infestation. Res. Pap. NE-RN-338. USDA Forest Serv., Northeastern Forest Expt. Sta., Broomall, Pa. 4 pp.
6. Kessler, K.R. and P. Labosky. 1988. Pulp and papermaking properties of gypsy moth-killed trees. Wood and Fiber Sci. 20(3):386-396.
7. LeDoux, C.B. 1985. Stump-to-mill timber production cost equations for cable logging eastern hardwoods. Res. Pap. NE-566. USDA Forest Serv., Northeastern Forest Expt. Sta., Broomall, Pa. 6 pp.
8. ________. 1988. EASTCOST — stump-to-mill timber production cost equations and computer program. Unpublished report on file at USDA Forest Serv., Northeastern Forest Expt. Sta., Morgantown, W.Va.
9. Ohio Agricultural Statistics Service. 1989. Ohio Timber prices. Feb. Columbus, Ohio. 2 pp.
10. Pennsylvania State University. 1989. Pennsylvania Woodlands Timber Market Report. April-June. University Park, Pa. 3 pp.
11. Tennessee Division of Forestry. 1989. Tennessee Forest Prod. Bull. April-June. Nashville, Tenn. 13 pp.