DIRECT CONTROL OF INSECT DEFOLIATION IN OAK STANDS IS ECONOMICALLY FEASIBLE IN PREVENTING TIMBER VALUE LOSS[1]

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Abstract.--We used data from 106 defoliated forest stands in West Virginia to establish the quantity of timber (board feet) that was lost due to mortality. Mortality was highest in stands with a large component of oak growing on better sites. Break-even benefit-cost analysis was used where avoidance of anticipated loss was the benefit and spray (chemical plus application) was the cost. Anticipated loss was computed as the product of mortality and stumpage value. We assumed that the stands would not be harvested for 20 years and that spraying would need to be repeated on either a 5-year or a 10-year cycle. We applied the benefit-cost analysis to 5 hypothetical cases, ranging from pure oak stands to stands with no oak component. For each case, timber value was determined using West Virginia (higher) and Maryland (lower) stumpage figures. Only in a case which had no oak was the break-even spray cost lower than actual spray costs that were reported to us. We conclude that if prevention of economic loss is the only consideration of a forest manager, except where oak is absent from the stands, spraying can generally be justified.

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INTRODUCTION

The commercial forests of the southern Appalachians are facing the advancing front of gypsy moth *Lymantria dispar* L.. To avoid excessive losses due to defoliation, landowners must make some important decisions. Basically, the landowner has three options: do nothing, harvest the timber, or implement a control strategy to prevent or at least minimize loss.

With the "do nothing" strategy landowners accept the risks in the hope that their stands will not be defoliated or that the defoliation is not severe enough to cause widespread mortality. Where timber is mature and there is an existing market, harvesting is an obvious solution.

The final option is to implement some control strategy to prevent as much defoliation and damage as possible. Several different methods have been used over the years to attempt to control the gypsy moth. These include male moth trapping, sterile male release, the introduction of parasites and disease, silvicultural control, and the application of chemical pesticides.

The aerial application of chemical insecticides, specifically Dimilin, has provided some of the best results in controlling the gypsy moth (Nichols 1982) and was used in the analysis for this project.

This study uses mortality rates observed following insect defoliation in eastern West Virginia and western Maryland. Using economic analysis and given the expected mortality, we determined which stands we can afford to spray and retain profitability.

HOST SUSCEPTIBILITY AND VULNERABILITY

The susceptibility of a forest stand can be described as the probability that it will experience defoliation. It has been shown that a stand's susceptibility to defoliation depends largely on the species composition and the site and stand conditions such as aspect, slope position, and soil condition (McManus 1980).

Moser (1915) found that susceptibility was also affected by the stage of growth of the insect larvae. Some tree species were fed upon by all larval instars while others were preferentially eaten by certain instars.

Bess et al (1947) reported that the most susceptible stands in the northeast were those which grow on typically dry sites such as rocky ridges or deep sands. These highly susceptible stands have often been disturbed in some way. These disturbances include fire, ice, snow, or wind. The trees on these sites are often poorly formed, slow growing oaks which have structural features favorable to ovaposition by the gypsy moth. Structual features include deep bark fissures, bark flaps, and holes or wounds. Bess and coworkers also found susceptible stands to be open in nature and hosting understory plants such as blueberry, huckleberry, bracken fern, sweetfern, grasses, and sedges. Leaf litter in susceptible stands was shallow and exposed rocks and ledges were common. The forests in the northeast which were least likely to be defoliated were those that grow on well drained, loamy soils where soil moisture was not a limiting factor to growth. The sites were relatively undisturbed. Resistant stands were usually well stocked and contained a diversity of tree species. This species mixture may even include some which are highly preferred by the gypsy moth. The trees on the resistant sites were relatively fast growing and provided very few favorable structual features. The leaf litter in resistant stands was usually deep, thus providing habitat for gypsy moth preators. The understory species which were found to be prevalent in resistant stands include mapleleaf viburnum, woodland ferns, and wild sarsaparilla. Houston (1979), Houston and Valentine (1979), and Houston (1983) reported findings similar to those of Bess et.al. (1947).

In contrast to susceptibility, vulnerability refers to whether or not trees will die as a result of defoliation. Susceptibility and vulnerability are somewhat independent of one another. Houston (1983) reported that stands which were more susceptible were often less vulnerable because they were constantly stressed by the environment in which they grow and were acclimated to such conditions.

The amount of mortality that occurs after defoliation is related to such factors as the intensity of defoliation, the number of defoliations, the trees' condition before defoliation, the site and stand conditions such as aspect, slope percent, slope position, and environmental factors such as drought and late spring frosts before and after defoliation (Mason et. al. (1987).

Hicks and Fosbroke (1987), working in the Appalachian Plateau region of Pennsylvania, found that trees which were most vulnerable to mortality were oaks (especially white oaks), growing on steeper slopes, southwesterly aspects, and on sites with a higher site index.

In the Pocono Mountain Region of Pennsylvania, Gansner and Herrick (1984) found that oaks (especially white oaks), with poor crowns and low vigor, on poor growing sites and on westerly aspects were more likely to die.

Working in Pike and Monroe counties PA, Herrick et. al. (1979) found that stands that were more vulnerable to mortality were those in which the trees had poor crowns, were growing at higher elevations, had a greater distribution of grees 11 inches DBH or less, were composed of largely preferred species such as oaks, and were located on lower slope positions.

PHYSIOLOGICAL EFFECTS OF DEFOLIATION ON TREES

Defoliation of a tree by insects causes the tree to be stressed. If the defoliation stress is severe or if it is coupled with other stresses the tree becomes predisposed to attack by secondary organisms. These secondary agents further stress the tree and often ultimately cause death.

Wargo (1978) reported that the degree to which a tree is affected by defoliation depends on several factors: the percentage of foliage eaten; how many successive years the tree was defoliated; what time of year the tree was defoliated; the weather conditions after defoliation; if secondary agents attacked the tree; and vigor of the tree before defoliation (Graham 1963, Acciavatti 1982).

The percentage of foliage which is eaten by any defoliator is very important in determining whether or not the tree can recover from defoliation. In any case, we can assign a probability of mortality to trees or stands and that probability is associated with the susceptibility, vulnerability and likelihood of epidemic-level insect populations.

ECONOMIC ANALYSIS

With an insect such as gypsy moth which is invading the southern Appalachian region, imminence of defoliation can be forecast using available survey and detection. Therefore, an effective method to determine if control is economically feasible is important to the forest landowner.

Canham (1986) presented a break-even benefit cost analysis used to make sound forestry decisions. Future costs and revenues are discounted at a given interest rate to a present value. This value represents the minimum benefit required for a control project to at least break even. We utilized a procedure of this type in our study.

McCay and White (1973) conducted a similar study in which they calculated immediate losses and estimated future sawtimber losses from gypsy moth defoliation on a per acre basis. The future losses were discounted back to present values. The present value of the losses represents the amount of money the landowner could afford to pay for forest protection.

Another method for estimating the benefits of some control strategy has been presented by Gansner and Herrick (1987). Measurements were taken on plots in central Pennsylvania from 1978 to 1985. The percent loss in timber value and compound rate of change in value for all susceptible trees were calculated. The dollar values represented the standing trees' net value in the production of 4/4 inch lumber and/or pulpwood, allowing for the cost of conversion.

METHODS

STUDY AREAS

The data for this research were collected from two different study areas, Sleepy Creek Public Hunting and Fishing area in the eastern panhandle of West Virginia and Green Ridge State Forest in western Maryland (fig. 1).

Sleepy Creek Public Hunting and Fishing area, which is maintained by the West Virginia Division of Wildlife, is located on the Morgan-Berkeley county line in West Virginia and is about 6 miles southeast of Berkeley Springs and 11 miles west of Martinsburg. It is comprised of 23,000 acres of mountainous and rolling terrain consisting of mostly pine-oak and oak-hickory forest types. Sleepy Creek contains two mountains; Sleepy Creek Mountain and Third Hill, which range in elevation from 880 to 2,172 feet above sea level. The soils are shallow, shaley to stony loams with low moisture levels.

From 1981 to 1983 various areas of West Virginia's eastern panhandle received heavy defoliation. The looper complex which defoliated the areas in the eastern panhandle consisted mainly of Phigalia titea (Cramer). Other species which were involved included P. strigateria (Minot), Erranis tiliaria (Harris), and Alsophilia pometaria (Harris) (Butler 1985). Loopers have similar host preference and feeding season as gypsy moth, therefore we felt the looper data were applicable to gypsy moth.

FIELD PROCEDURES

Field data was collected from 141 one-tenth acre plots. The plots were separated into those areas which according to reports had received 1, 2, or 3 years defoliation (106 plots) and control plots which received no defoliation (Crow 1985). Tree data which were collected on each plot included: tree number, azimuth from north, distance from plot center, species, dbh, crown vigor estimate, tree grade (trees 9.6 inches DBH and greater),

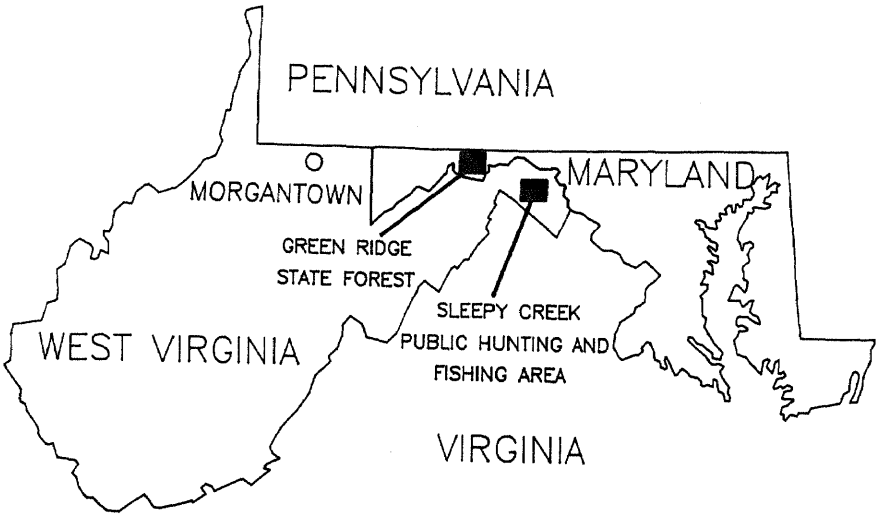

Figure 1.--Location of study sites.

crown class, merchantable height (to a 4 inch top), and total height. Plot data which were collected included: plot number, date, number of years defoliated, aspect, slope percentage, slope position, and an estimation of the percentage of exposed rock (Crow 1985).

Merchantable volume in board feet was calculated for each tree with a diameter breast height (dbh) of at least 10 inches and a tree grade of 1, 2, or 3.

Because original heights were taken to a 4 inch top, Wiant and Yandle's (1984) taper system formula for predicting tree merchantable height, given an 8-inch diameter limit, was used.

The tree's dbh and the calculated merchantable height was then used in volume equations produced by Wiant (1986) to predict the board foot volume for each tree. The equation for predicting International 1/4 inch volume (form class 78) was used in this analysis.

The volumes were then separated into live and dead categories for each species. The total volume, live volume, and dead volume for each species were accumulated for each plot.

ECONOMIC ANALYSIS PROCEDURES

Mortality ratios were developed by dividing the total dead volume for each species by the total volume (live and dead) for that species. For example, if red oak dead volume was 30 board feet and total red oak volume was 100 board feet then the mortality ratio would be 30/100 X 100 or 30%. This was done for each of the species or species group. The per acre volumes and the mortality ratios are shown in Table 1.

The average volume per acre for each species was multiplied by the mortality ratio for that species to calculate a volume loss per acre for the species. Stumpage values received from the West Virginia Department of Agriculture and the Maryland Forest Service for the areas in which the research plots were located were then applied to the volume losses for each species to derive a per acre value loss for each species. These loss values for each species were then summed to develop a total value loss per acre.

This total loss per acre is considered to be a benefit assuming that the landowner would spray and consequently the mortality loss would not occur. Other losses such as growth loss, aesthetic value loss, and recreational losses which could be incorporated into the benefit category if the gypsy moth was controlled by spray were not accounted for because of the difficulty in assessing an accurate value loss for each of these variables. Conversely, value loss was not adjusted for salvage value, presuming mortality occurred. Also stand operability for logging was not taken into consideration.

Several assumptions were made to complete the economic analysis. The first assumption was that the stand age is 60 years which is a reasonable average for many stands in the region. The second assumption was that the rotation age is 80 years. The 80 year rotation age was derived using Schnur's yield tables for upland oaks (Schnur 1937) to calculate the rotation age at which mean annual increment was maximum. The final

Table 1.--Dead and total volumes with mortality ratios for each species for the 106 defoliated plots.

Species	Total Dead Bdft	Total Bdft	Dead Bdft Per Acre	Total Bdft Per Acre	Percent Mortality
Red Oak	6391	19588	603	1848	33%
Misc Oak	4197	40284	396	3800	10%
White Oak	1742	17671	164	1667	10%
Chestnut Oak	18897	32460	178	3062	58%
Hickory	4455	6478	420	611	69%
Other	357	6599	34	623	5%
Total	36040	123081	3400	11611	29%

assumptions were that landowners will need to spray every 5 years or every 10 years until harvest.

After the value per acre loss or benefit was calculated for a stand, the cost of control was then calculated. Periodic spray costs which would occur in the future were discounted back to present values using 6 percent as the rate of return.

Benefits were then compared to costs; if the benefits were greater than costs, the implication is that the landowner could afford to spray. The benefit-cost analysis was calculated until a spray cost was found that made benefits and costs essentially equal. The point at which the benefits and costs are equal can be considered the break-even point.

The benefit-cost analysis was conducted on the actual losses by species groups that were experienced on the 106 defoliated research plots in West Virginia and Maryland. Stumpage values from West Virginia and Maryland were used to see how stumpage prices affect the break-even point. Maryland stumpage values were considerably lower than West Virginia stumpage values because of the lower timber quality, lack of available markets, and the amount of salvaged timber which was being cut.

Five hypothetical cases were then constructed to see how stand composition would affect the break-even point. Three species groups were used for the hypothetical stand analysis. These were red oak, chestnut oak, and other, the later includes yellow-poplar, red maple, sugar maple, black cherry, black gum etc. Only three species groups were used in the hypothetical stands to limit the number of different stand compositions and because these species would affect the benefits the most. Red oak and chestnut oak had high mortality rates so benefits would be high and the "other" species group suffered only minor losses and would derive lower benefits from spraying. The average volume per acre of 11.6 MBF/acre from the 106 research plots was used and the three species groups were broken up to represent different proportions to the total volume. Actual mortality ratios to predict the volume losses for each species were also taken from the values calculated for the 106 research plots.

The species composition for each of the hypothetical stands

	Percent of Volume				
Species	Case 1	Case 2	Case 3	Case 4	Case 5
Red Oak	70	33	0	0	0
Chestnut Oak	30	33	70	30	0
Other	0	33	30	70	100

Benefit-cost analyses were conducted for each of the hypothetical cases to find the break-even spray cost. Each of the cases was analyzed using West Virginia and Maryland stumpage values and five and ten year spray intervals. The future costs were discounted to present values using a 6% interest rate. Stand age was assumed to be 60 years and rotation age was assumed to be 80 years.

RESULTS

Because losses were so great on the 106 research plots, a landowner could afford to spray in any of the senarios using actual losses from our stands (Tables 2,3). Actual spray costs ranged from $2 per acre using fixed wing aircraft to spray tracts that are approximately 500 acres or larger in size to $50 per acre using helicopters and spraying less than 100 acres. However stumpage price does have a dramatic effect on the break-even cost as can be seen by comparing the present value (PV) of costs column in Tables 2 & 3.

The total value loss per acre, and break-even spray costs for the hypothetical

cases are shown in Table 4. The highest loss values and break-even spray costs occur in hypothetical cases 1, 2, and 3. In these cases the stand volume is made up mostly of one or both of the oak species. The oak species not only suffer high rates of mortality, but also have the highest stumpage values which adds up to extremely high value losses.

The lowest loss values and subsequent break-even spray costs occur in hypothetical cases 4 and 5. In these two cases the "other" species group makes up 70 and 100 percent, respectively, of the total stand volume. This species group consists of speceis which are less vulnerable to mortality and have generally lower stumpage values.

Table 2..Economic Analysis for Actual Losses Using West Virginia Stumpage Prices.

Species	Loss/Acre (Bdft)	WV Stumpage $/MBF	Value Loss/Acre $/Acre
Red Oak	603	$ 148	$ 89
Misc Oak	396	98	39
White Oak	164	94	15
Chestnut Oak	1783	98	175
Hickory	420	88	37
Other	34	96	3
		Present Benefits =	$ 358

Break Even Cost Analysis - 5 Year Spray Interval

Activity	Cost/Acre	Year	PV of Costs
Spray	$ 132	0	$ 132
Spray	132	5	98
Spray	132	10	73
Spray	132	15	55
		Present Value of Costs =	$ 358

Break Even Cost Analysis - 10 Year Spray Interval

Activity	Cost/Acre	Year	PV of Costs
Spray	$ 230	0	$ 230
Spray	230	10	128
		Present Value of Costs =	$ 358

Table 3.--Economic Analysis for Actual Losses Using Maryland Stumpage Prices.

Species	Loss/Acre (Bdft)	MD Stumpage $/MBF	Value Loss/Acre $/Acre
Red Oak	603	$ 70	$ 42
Misc Oak	396	50	20
White Oak	164	70	11
Chestnut Oak	1783	50	89
Hickory	420	50	21
Other	34	50	2
		Present Benefits =	$ 185

Break Even Cost Analysis - 5 Year Spray Interval

Activity	Cost/Acre	Year	PV of Costs
Spray	$ 69	0	$ 69
Spray	69	5	51
Spray	69	10	37
Spray	69	15	28
	Present Value of Costs	=	$ 185

Break Even Cost Analysis - 10 Spray Interval

Activity	Cost/Acre	Year	PV of Costs
Spray	$ 119	0	$ 119
Spray	119	10	66
	Present Value of Costs	=	$ 185

Table 4.--Economic Analysis for Hypothetical Cases 1 Through 5 Using West Virginia and Maryland Stumpage Prices.

Hypothetical Case	Total $ Loss/Acre	Spray Costs ($/Acre) Per 5 Year Interval	10 Year Interval
Case 1 - WV	595.00	218.00	381.00
Case 1 - MD	289.00	106.00	185.00
Case 2 - WV	428.00	157.00	274.00
Case 2 - MD	211.00	78.00	136.00
Case 3 - WV	479.00	175.00	306.00
Case 3 - MD	244.00	90.00	157.00
Case 4 - WV	237.00	88.00	152.00
Case 4 - MD	121.00	45.00	78.00
Case 5 - WV	56.00	20.00	36.00
Case 5 - MD	29.00	11.00	19.00

CONCLUSIONS

The amount of mortality which will occur in any given forest stand depends on factors such as stand susceptibility and vulnerability; timing and intensity of defoliation, and number of defoliation events; climatic conditions before and after defoliation; secondary agents; and tree condition before and after defoliation.

The main objective of this study was to supply foresters and private landowners with an efficient method to determine whether or not spraying insec-

ticides to control imminent gypsy moth defoliation is feasible based on benefits and costs.

The highest benefit values and break-even spray costs were experienced on those stands which consisted mostly of vulnerable, high value species such as red and chestnut oak. Stands which consist mainly of less vulnerable and lower value species have lower benefit values and lower break-even spray costs.

From this study, landowners might conclude that they could afford to spray to protect their forest stands in almost any situation. This is probably not true. Normal mortality was not considered when calculating losses in this study. Landowners may also need to consider the fact that they may not get 100 percent protection from spraying insecticides. With decreasing effectiveness of spray, the benefit to cost relationship will become lower and the landowner can afford less to protect his or her forestland.

On the other hand, mortality losses could be underestimated because of factors such as aesthetic, wildlife, and recreation losses which cannot be measured in dollars and are not accounted for in this analysis. Other factors which will affect the break-even spray cost are salvage values, growth increase of residual trees, and the cost of survey and detection of insect populations.

Any landowner who is faced with defoliation by the gypsy moth should consider all of these factors along with their personal management objectives and the risks involved when conducting a benefit-cost analysis to determine the feasibility of spraying to control defoliation.

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