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A Program for Evaluating the Economic Effectiveness of Spruce Budworm Control with a Programable Hand-held Calculator

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Abstract

Uncontrolled spruce budworm infestations can cause substantial losses of spruce-fir. With this program, a hand calculator can compute the net present worth and composite rates of return of control investments, before and after taxes. A worked-out example is given. If input-output forms are prepared in advance, as suggested, the calculator can be used without a printer in the field to generate on-the-spot estimates.

Note:

The computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program.

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A Program for Evaluating the Economic Effectiveness of Spruce Budworm Control with a Programable Hand-held Calculator

Robert Marty

What this Program Does

Purpose. This program estimates the economic effectiveness of spruce budworm control, in individual stands or control blocks, by comparing the value of timber saved with control costs. It is designed to help forest managers and pest control specialists to identify those parts of an ownership where control benefits outweigh control costs.

The program described here was developed for use on a TI-59 pocket calculator, but can be used with appropriate modifications on any comparable programmable calculator. Program cards are available from the author, Robert Marty, Greentree Consultants, Inc., P.O. Box 27125, Lansing MI 48909, or from Daniel Schmitt, Northeastern Forest Experiment Station, 370 Reed Rd., Broomall, PA 19008.

Applicability. This program can be applied appropriately in the following circumstances:

- when an objective of management is commercial timber production
- when defoliation by spruce budworm has occurred for 2 or more consecutive years
- when harvest is not possible during the next 2 to 5 years because the stand is below merchantable size, or because markets are poor
- when an approved method of control exists and its application is feasible.

This program may be used both for public and private ownerships.

Inputs required. The following estimates are needed as program input:

- the number of years until the stand will be harvested
- full-stocking harvest volume
- the proportion of stand area occupied by fir
- the proportion of stand area occupied by spruce
- the proportion of fir volume which will be lost without control
- the proportion of spruce volume which will be lost without control
- the acceptable or guiding rate of return on control investments
- the anticipated stumpage price for fir
- the anticipated stumpage price for spruce
- the proportion of income accruing to the owner after taxes
- the proportion of cost incurred by the owner after taxes
- the number of years to each anticipated treatment
- the cost of each anticipated treatment

Outputs provided. The program outputs the following estimates:

- fir harvest volume without control
- spruce harvest volume without control
- fir harvest volume saved by control
- spruce harvest volume saved by control
- the discounted value of treatment costs
- the value of volume saved at harvest
- the discounted value of volume saved
- the net present value of control
- the rate of return to control
- the break-even percentage.

An Illustration of Analysis

Stand data inputs. Consider the following situation. Budworm control is under consideration for a stand where 52 percent of the stand area is occupied by fir and 8 percent by spruce. The stand is scheduled for harvest in 15 years when spruce-fir yield on fully stocked acres will be 46 cords. If budworm is not controlled we anticipate a loss of 75 percent of fir harvest volume, and 10 percent of spruce harvest volume.

Volume estimates. The program calculates that without budworm control, harvest volumes will average 6.0 cords per acre of fir and 3.3 cords per acre of spruce. Control will save an additional 15.2 cords of fir and 0.3 cords of spruce per acre.

Economic data inputs. Four percent has been selected as the minimum real rate of return (rate above the inflation rate) acceptable for control actions. We anticipate that the real price of pulpwood stumpage will increase modestly during the next 15 years to $7 per cord for fir and $10 per cord for spruce. Since this is a public ownership there are no reductions in costs or incomes due to tax effects. We expect that a control treatment will be necessary immediately, and then at 2-year intervals, on the average, until harvest. Treatment now costs about $5 per acre, and is not expected to increase in real terms.

Cost, value and profit estimates. The program calculates that the discounted value of the eight control treatments is $30.89 per acre, that the value at harvest of the volume saved by control will be $109.87 per acre, and that the discounted value of that income is $61.01. From these estimates the program further calculates that the net present value of control is $30.12 per acre, that the

rate of return to control is 8.8 percent, and that the control investment would still earn the minimum acceptable rate of 4 percent if stumpage prices were 51 percent of those expected. Figure 1 shows the printer output for this program, and Table 1 contains a glossary of printer output symbols.

Table 1.—Glossary of printer output symbols.

YRS — The number of years until harvest
MAX — The spruce-fir yield per fully stocked acre of harvest, in cords
%F — The proportion of stand area occupied by fir, percent
%S — The proportion of stand area occupied by spruce, percent
-%F — The proportion of fir harvest volume which will be lost without control, percent
-%S — The proportion of spruce harvest volume which will be lost without control, percent
INT — The minimum acceptable or guiding rate of return to control, percent
P/F — The price of fir stumpage expected at harvest, dollars/cord
P/S — The price of spruce stumpage expected at harvest, dollars/cord
ATI% — The proportion of income that accrues to an owner after tax effects, percent
AIC% — The proportion of cost that is borne by an owner after tax effects, percent
YEAR — The number of years until a treatment occurs
COST — The cost of treatment per acre protected, dollars
ΣPVC — The sum of the present or discounted values of each treatment, dollars/acre
ATI — The amount of after-tax harvest income added by control, dollars/acre
PVI — The present or discounted value of ATI, dollars/acre
NPV — The net present value of control = PVI - ΣPVC, dollars/acre
CRR — The rate of return earned by the control investment, percent
BEP — The break-even percentage

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BUDWORM CONTROL

    15.     YRS
    46.     MAX
    52.      %F
     8.      %S
    75.     -%F
    10.     -%S

   6.0     FIR
   3.3     SPR
  15.2      +F
   0.3      +S

     4.     INT
  7.00     P/F
 10.00     P/S
   100.    ATI%
   100.    ATC%

     0.     YEAR
  5.00     COST
     2.     YEAR
  5.00     COST
     4.     YEAR
  5.00     COST
     6.     YEAR
  5.00     COST
     8.     YEAR
  5.00     COST
    10.     YEAR
  5.00     COST
    12.     YEAR
  5.00     COST
    14.     YEAR
  5.00     COST

 30.89     ΣPVC
109.87      ATI
 61.01      PVI
 30.12      NPV
   8.8      CRR
  0.51      BEP
```

Figure 1.—Printer output for the illustrative analysis.

How to Run this Program

The sequence of steps. The "Input-output guide" (Fig. 2) shows the exact sequence of steps necessary to carry out an analysis. The user first enters the program into program memory and initializes the program. The stand data are entered, volume estimates are outputted, economic data are inputted, and cost, value and profit measures are outputted. The "input" column on the guide has boxes for recording input data, and it shows the keys that must be pressed to enter each input and obtain each output. The guide, with blank boxes, is reproduced on the back cover. Make a copy of it when you want to do an analysis.

Program detail. This section tells you exactly what the calculator is doing each time you input data or output results. It provides the formulas used to calculate outputs from input data, gives guidance in developing inputs, and provides interpretations of outputs.

Doing an analysis. Make a copy of the Input-Output Guide and enter the values for inputs in the appropriate boxes. Follow the guide in entering inputs and outputting results. Record results in the appropriate boxes in the "output" column if you are not using a printer.

Program Detail

Program location keys pressed[1]	Explanation	Display[1]
	——STEP 0. ENTER AND INITIALIZE PROGRAM——	
2, 2nd OP, 17	Partitions memory as required by this program into 800 program locations and 20 data registers.	
1	Read program card, side 1	1.
2	Read program card, side 2	2.
3	Read program card, side 3	3.

A program card side has been entered when its number appears in the display. If a flashing zero appears instead, clear it by pressing CE and re-enter the side. After the program is entered do the illustrative problem and make sure you can reproduce the indicated output values. This helps to assure you that the program is entered correctly in memory.

000	A	Resets program pointer to 000, prints title, clears data registers and display.	0

[1] Data, input and display values are from the illustrative analysis just given.

INPUT-OUTPUT GUIDE

Input		Explanation	Output
		STEP 0. ENTER AND INITIALIZE PROGRAM	
2, 2nd OP,17		Partitions memory as required Read cards, three sides	
	A	Starts program and prints title	
		STEP 1. INPUT STAND DATA	
15	R/S	Years to harvest	
46	R/S	Full-stocking harvest volume, cds/acre	
52	R/S	Area occupied by fir, percent	
8	R/S	Area occupied by spruce, percent	
75	R/S	Fir volume loss, percent	
10	R/S	Spruce volume loss, percent	
		STEP 2. OUTPUT VOLUME ESTIMATES	
	B	Fir volume without control, cds/acre	6.0
	R/S	Spruce volume without control, cds/acre	3.3
	R/S	Fir volume saved by control, cds/acre	15.2
	R/S	Spruce volume saved by control, cds/acre	0.3
		STEP 3. INPUT ECONOMIC DATA	
4	C	Guiding rate of return, percent	
7.00	R/S	Fir stumpage price, $/cd	
10.00	R/S	Spruce stumpage price, $/cd	
100	R/S	After-tax income percent	
100	R/S	After tax cost percent	
0	R/S	Years to first treatment	
5.00	R/S	First treatment cost, $/acre	
		Repeat year and cost inputs for other treatments	
		STEP 4. OUTPUT COST, VALUE AND PROFIT ESTIMATES	
	E	Discounted value of treatment costs, $/acre	30.89
	R/S	Value of volume saved at harvest, $/acre	109.87
	R/S	Discounted value of volume saved, $/acre	61.01
	R/S	Net present value of control, $/acre	30.12
	R/S	Rate of return to control, percent	9.3
	R/S	Break-even percentage	0.51

Figure 2.—Spruce budworm control economics program

Program location keys pressed		Explanation	Display
----------STEP 1. INPUT STAND DATA----------			
046	15, R/S	Enters into display, stores, and prints the number of years until harvest.	15.
063	46,R/S	Enters into display, stores, and prints full stocking volume at harvest, in cords per acre.	46.

Literature cited lists four sources of yield information for spruce-fir: Meyer's (1929) normal yield tables for red spruce, white spruce, and balsam fir in the Northeast; Westveld's (1953) empirical yield tables for spruce-fir in the Northeast; Gevorkiantz and Olsen's (1950) yield tables for upland balsam fir in the Lake States; and Bowman's (1944) spruce-fir yield tables for northern Michigan. Use these sources to estimate full stocking volume at harvest if you do not have an estimator of your own that you prefer.

082	52,R/S	Enters into display, stores and prints the proportion of stand area occupied by balsam fir, in percent. Entered as a whole number and stored as a decimal fraction.	0.52
104	8, R/S	Enters into display, stores and prints the proportion of stand area occupied by spruce, in percent. Entered as a whole number and stored as a decimal fraction.	0.08

Most spruce-fir stands are not fully occupied by spruce and fir, but will have openings and areas occupied by other vegetation. For example, forest survey data for Wisconsin (Essex and Hahn 1976) show that only 54 percent of the volume on survey plots typed as spruce-fir was of those species. Hemlock, pine, and larch may also be defoliated by the spruce budworm. If any of these species is being defoliated, include its stand area with the spruce.

126	75, R/S	Enters into display, stores and prints the proportion of balsam fir harvest volume which it is anticipated will be lost without budworm control, due both to growth loss and unsalvaged mortality, in percent. Entered as a whole number and stored as a decimal fraction.	0.75
150	10, R/S	Enters into display, stores and prints the proportion of the harvest volume for spruce and other susceptible species which it is anticipated will be lost without budworm control, in percent. Entered as a whole number and stored as a decimal fraction.	0.10

Estimates of losses due to budworm infestation are uncertain. Some of the available information on loss is presented in the Appendix, to help you make a judgement about what level of loss to anticipate. It is appropriate to repeat your analysis using several different loss estimates.

Program location keys pressed		Explanation	Display
———STEP 2. OUTPUT VOLUME ESTIMATES———			
175	B	Calculates, prints and displays the volume of balsam fir at harvest without control, in cords per acre.	5.980

This estimate is calculated according to the following formula:

FIR = MAX(%F) 1 - (-%) (see Table 1)

For the illustrative example the calculation becomes:

FIR = 46(.52)(1 - .75) = 5.98 cords/acre.

211	R/S	Calculates, prints and displays the volume of spruce at harvest without control, in cords per acre. Calculated as above.	3.312
245	R/S	Calculates, prints and displays the volume of balsam fir that will be added to harvest volume if budworm control is undertaken, in cords per acre.	15.249

This estimate is calculated according to the following formula:

+F = 0.85(MAX)(%F)(-%F)

For the illustrative example the calculation becomes:

+F = 0.85(46)(.52)(.75) = 15.249 cords/acre.

279	R/S	Calculates, prints and displays the volume of spruce that will be added to harvest volume if budworm control is undertaken, in cords per acre. Calculated as above.	0.3128

Harvest volume estimates in this program assume clearcutting at harvest and are stated in terms of cords per acre. Conversion factors given in the Appendix may be used to convert cords to other measures of output where appropriate. This program should not be used where partial or selection harvests are planned.

The calculations for the volume that can be saved by control assume that 85 percent of the volume which will be lost to budworm infestation can be saved by control. If control experience in the situation under analysis differs substantially from this, reprogram program locations 258-9 and 292-3.

Program location keys pressed		Explanation	Display
———STEP 3. INPUT ECONOMIC DATA———			
314	4,C	Enters into display, prints and stores the guiding, or minimum acceptable rate of return to control investments. The guiding rate is entered as a whole number and stored as one plus the interest rate expressed as a decimal fraction.	1.04

The guiding rate of return should be selected carefully to reflect the best alternate use of investment funds. The rate of interest may be a nominal rate or a real rate. A nominal rate of return includes the anticipated inflation rate, while the real rate does not. Thus, if the minimum acceptable rate of return to control investments is 4 percent above the inflation rate, and an 8-percent inflation rate is anticipated, then the real guiding rate is 4 percent and the nominal guiding rate is given by: 1.04(1.08) = 1.1232 or 12.32%. It is usually simpler to use a real guiding rate and to express costs and incomes in constant dollars. If a nominal rate is used inflated (or deflated) costs and prices must be used as well.

343	7, R/S	Enters in display, prints and stores the fir stumpage price anticipated at harvest, in dollars per cord.	7.

364	10, R/S	Enters in display, prints and stores the spruce stumpage price anticipated at harvest, in dollars per cord.	10.

The prices entered above should reflect the mix of products anticipated and, in the case of spruce price, the weighted average price of all susceptible species included. For example, if half of the spruce harvest will be pulpwood selling for $10 per cord, and the other half will be sold as sawtimber at $80 per Mbf, then converting the sawtimber value to a cord basis at 450 bd. ft. per cord gives $36.00 per cord for the sawtimber portion, and an average price per cord of $10.00 + $36.00 /2 or $23.00 per cord.

385	100, R/S	Enters into display, prints and stores the proportion of a revenue which is retained by the owner after income tax effects, in percent. Entered as a whole number and stored as a decimal fraction.	1.
411	100, R/S	Enters into display, prints and stores the proportion of an expenditure which remains after income tax effects, in percent. Entered as a whole number and stored as a decimal fraction.	1.

Enter 100 percent for both revenues and expenditures when the stand being analyzed is in public ownership. If the stand is privately owned, then the appropriate percentages must be ascertained from the owner, since different owners are in different tax circumstances.

440	0, R/S	Enters into display, prints and stores the number of years until the first control treatment will be applied to the stand.	0.
459	5,R/S	Enters into display, prints and stores the before-tax cost per acre protected of the first treatment, in dollars per acre. Computes the discounted value of the after-tax cost.	5.

Repeat the year and cost entries for each expected treatment. Use zero for the year of first treatment when that treatment is expected in less than 1 year. If control is applied to an area larger than the stand area, compute cost per acre by dividing the total cost of the treatment by the number of acres in the stand. In this way both costs and benefits will be expressed as an average number of dollars per acre contained in the stand. Discounted values of costs are calculated by the formula:

$$PVC = Cost\ (ATC\%)/(1+INT)^{Year}$$

In the illustrative analysis the discounted value of the second year cost is:

$$PVC = 5(1.0)/(1.04)^2 = \$4.62.$$

The present values of the after-tax treatment costs are summed in a data register as they are computed.

Program location keys pressed		Explanation	Display
		STEP 4. OUTPUT COST, VALUE AND PROFIT ESTIMATES	
502	E	Prints and displays the sum of the discounted values of all treatments, in dollars per acre.	30.89...
525	R/S	Calculates, prints and displays the after-tax value at harvest of volume saved by control, in dollars per acre.	109.871

This calculation is made using the following formula:

$$ATI = ATI\%\ (+F)(P/F) + (+S)(P/S)$$

In the illustrative analysis this calculation is:

$$ATI = 1.00\ (15.249)(7.00) + (0.3128)(10.00) = \$109.87$$

572	R/S	Calculates, prints and displays the discounted value of harvest volume savings, in dollars per acre.	69.00...

The discounted or present value of after-tax harvest income saved by control is given by:

$$PVI = ATI/(1+INT)^{Years}$$

For the illustrative analysis the present value of income becomes:

$$PVI = 109.87/(1.04)^{15} = \$61.01$$

604	R/S	Calculates, prints and displays the net present value of control, in dollars per acre.	30.11...

Net present value is defined as:

$$NPV = PVI - PVC$$

For the illustrative analysis NPV is given by:

$$NPV = 61.01 - 30.89 = \$30.12$$

When net present value is positive it indicates that the control opportunity earns more than the guiding rate of return and thus is acceptable from the financial point of view.

631	R/S	Calculates, prints and displays the rate of return to control, in percent per year.	8.82...

Rate of return is calculated according to the following formula:

$$CRR = YRS\ \ ATI/\ PVC\ -1$$

In the illustrative analysis CRR is given by:

$$CRR = 15\ \ 109.87/30.89\ -1 = 8.8\%$$

This rate of return is the composite rate of return and is consistent with the net present worth measure of effectiveness. CRR indicates the average rate of return to the investment in control and can be compared directly with the guiding rate. Any control opportunity with a CRR larger than the guiding rate will also have a positive NPV. CRR can be used to rank control opportunities.

671	R/S	Calculates, prints and displays the present value of costs as a percentage of the present value of income, called the break-even percent.	0.506...

Break-even percent is given by the following formula:

$$BEP = PVC/PVI$$

In the illustrative analysis BEP becomes:

$$BEP = 30.89/61.01 = 0.51$$

The BEP in this case indicates that even if incomes from control are only half of those expected, or costs are twice those expected, or any equivalent combination of the two, the control investment will still earn the guiding rate. BEP is a measure of the safety margin against an unacceptable outcome.

700	Program ends.

DATA REGISTERS

00. Full stocking volume at harvest—cords per acre
01. Percent area occupied by fir—stored as a decimal fraction
02. Percent area occupied by spruce and other susceptible species—stored as a decimal fraction
03. Percent of fir harvest volume that will be lost to budworm—stored as a decimal fraction
04. Percent of harvest volume of spruce and other susceptible species that will be lost to budworm—stored as a decimal fraction
05. Fir volume saved by control—cords per acre
06. The volume of spruce and other susceptible species saved by control—cords per acre
07. The guiding rate of interest—stored as (1+i)
08. Time to harvest—years
09. Price of fir stumpage at harvest—dollars per cord
10. Weighted average price of spruce and other susceptible species at harvest—dollars per cord
11. After-tax income as a proportion of before-tax income—stored as a decimal fraction
12. After-tax cost as a proportion of before-tax cost—stored as a decimal fraction
13. Time until treatment j—years
14. Cost of treatment j—dollars per acre protected, before taxes
15. Present value of treatment j—dollars per acre protected, after taxes.
16. Sum of the present values of all treatments—dollars per acre protected, after taxes
17. After-tax additional income at harvest due to control—dollars per acre
18. Present value of added income—dollars per acre
19. Intermediate calculations

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Appendix

Estimates of Volume Loss

Volume loss estimates are uncertain at best. The data presented in Tables 2 and 3 indicate the degree of mortality that can be expected as the result of an uncontrolled spruce budworm infestation which continues for 5 or more years. The location, frequency and severity of budworm infestation currently is not predictable. There have been 10 major spruce budworm infestations since 1904, giving an average frequency of one infestation every 25 or 30 years in some part of the range of the spruce-fir type in eastern North America.

Table 2. Mortality related to spruce budworm—Eastern Canada

Stand age (years)	Fir and spruce stocking (percent of total)	Percent of basal area killed	
		Fir	Spruce
60 or more	80 or more	98	
			31
	Less than 80	76	
Less than 60		59	16

Source: MacLean (1980).

Table 3. Mortality related to spruce budworm—Minnesota. In percent of fir basal area killed

Basal area of other species (percent)	Balsam fir basal area (ft^2 per acre)					
	20	40	60	80	100	120
0	75	88	90	91	93	93
10	55	75	83	86	89	90
20	35	65	77	81	84	87
30	15	55	68	76	80	83
40		45	62	71	76	79
50		35	55	65	72	76
60		22	48	60	68	72

Source: Batzer and Hastings (1980).

Table 4. Product conversion factors: Equivalents of 1 cord of wood plus bark

Dbh[a/]	Cubic feet of solid wood	Total cubic feet of stumpage	International Rule board feet
4"	77	167	—
6"	84	130	250
8"	87	107	450
10"	90	107	550
12"	92	107	600

Source: Bowman (1944).

[a/] Dbh class of tree of average basal area for all trees 3.5 inches dbh and larger.

INPUT-OUTPUT GUIDE

Input		Explanation	Output
		STEP 0. ENTER AND INITIALIZE PROGRAM	
2, 2nd OP,17		Partitions memory as required Read cards, three sides	
	A	Starts program and prints title	
		STEP 1. INPUT STAND DATA	
	R/S	Years to harvest	
	R/S	Full-stocking harvest volume, cds/acre	
	R/S	Area occupied by fir, percent	
	R/S	Area occupied by spruce, percent	
	R/S	Fir volume loss, percent	
	R/S	Spruce volume loss, percent	
		STEP 2. OUTPUT VOLUME ESTIMATES	
	B	Fir volume without control, cds/acre	
	R/S	Spruce volume without control, cds/acre	
	R/S	Fir volume saved by control, cds/acre	
	R/S	Spruce volume saved by control, cds/acre	
		STEP 3. INPUT ECONOMIC DATA	
	C	Guiding rate of return, percent	
	R/S	Fir stumpage price, $/cd	
	R/S	Spruce stumpage price, $/cd	
	R/S	After-tax income percent	
	R/S	After tax cost percent	
	R/S	Years to first treatment	
	R/S	First treatment cost, $/acre	
		Repeat year and cost inputs for other treatments	
		STEP 4. OUTPUT COST, VALUE AND PROFIT ESTIMATES	
	E	Discounted value of treatment costs, $/acre	
	R/S	Value of volume saved at harvest, $/acre	
	R/S	Discounted value of volume saved, $/acre	
	R/S	Net present value of control, $/acre	
	R/S	Rate of return to control, percent	
	R/S	Break-even percentage	

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