APPRAISAL OF DAMAGE TO IMMATURE TIMBER

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INTRODUCTION

Although the topic as defined is rather technical, the need for better damage appraisals has arisen from very practical considerations. There has been a growing realization by fire control organizations that an economic criterion of damage would be useful in the development of operational guides for allocating detection and suppression strength, since fires can have minor or major importance depending on when and where they occur. A damage appraisal system can provide this criterion by specifying how fire damage can be measured, recorded, and finally analyzed in a way that would provide operational guidelines for the systematic deployment of fire control strength.

Perhaps the most important potential role of a damage appraisal system is in the budgeting process. With the advent of more sophisticated budgeting techniques such as program-budgeting (Novick, 1965), there has been increasing pressure on the fire control executive to justify fire control expenditures with the use of cost-utility studies. Since it is easier to show what damage has been in the past than what it might be in the future, a record of costs and damage, computed by the best means available, would be a useful document in the budgeting process.

This paper outlines how principles of forest valuation can be applied to one of the more difficult problems in damage appraisal -- measurement of damages to immature stands.

Contrary to common opinion, fire is the great destroyer of young, rather than mature, stands. Fire hazard is greater in immature stands, and after fire there is rarely a chance of salvage. Furthermore, natural regeneration is usually sparse, necessitating costly artificial regeneration.

Eventually, guidelines will be required for estimating the secondary effects of fires, especially large fires, on the provincial economy. Not the least of these effects is the dislocation of the forest-based industry, and adverse effects on communities in the vicinity of the fire. Guidelines for measuring damage to recreational and hydrological values will also be required.

A REVIEW OF THE PRINCIPLES AND APPLICATIONS OF FOREST VALUATION

Since the central problem of damage appraisal is to determine the pre-burn and post-burn values of a forest, damage appraisal can be viewed as a specific problem of forest valuation.

A basic concept in the application of valuation principles to individual forest sites is that bare forest land, just as a bond, derives its value from the periodic incomes that will accrue to the owner. A forest, unlike a bond, is maintained in a productive state by both annual and periodic expenses, and these must be taken into account in determining bare land value.

Another problem in forest valuation is the determination of the value of immature stands. This problem is comparable to calculating the present worth of the next annual dividend from a bond.

A brief example should clarify the use of the forest valuation formulae. Derivation of the standard formulae can be found in texts on forest valuation (Chapman, H.H. and W.H. Meyer, 1947).

<u>EXAMPLE</u> Valuation of an intensively managed even-aged stand.

Site expectation value before site preparation and planting....Se
Planting costs at year zero \$30.00............. Co = \$30.00
Thinning profit at age 30, 5 cords \$5.00........ Th = \$25.00
Yield at age 40, 50 cords \$10.00................ Y =\$500.00

Annual expenses: protection from fire \$1.00,
administration and road depreciation \$.50..... e = \$ 1.50
Annual income from campers...................... r = \$ 0.25
Selected rate of interest is 5%................. p = 0.05

Now the valuation of bare land before planting and site preparation, proceeds by the calculation of the present worth of all future incomes and expenses. The expression above the line in formula 1.1 is the value of the site and stand at rotation age. The expression below the line capitalizes a series of these rotation age values. Se is the site expectation value or simple bare land value of the stand.

$$1.1 \quad Se = \frac{\left[- Co\ (1.0p^{40}) - \frac{e-r}{.0p}\ (1.0p^{40} - 1) + Th\ 30\ (1.0p^{40-30}) + Y40\right]}{1.0p^{40} - 1}$$

Substituting the above data in this formula gives the answer Se = \$29.60

The cost value at age 30 is calculated as the present worth of expenses to produce the maturing crop, plus the value of the capital tied up in producing forests.

$$1.2 \quad C_{30} = \frac{e-r}{.0p}\ (1.0p^{30} - 1) + (Se + Co)\ 1.0p^{30}$$

Evaluating this formula, and rounding off, gives C = \$34.00:

Expectation value is a discount of future incomes and expenses.

$$1.3 \quad \text{Expectation Value} = V_{30} = Th_{30} + \frac{Y^{40}}{1.0p^{40-30}} - \frac{\frac{e-r}{.0p}\ (1.0p^{40-30} - 1)}{1.0p^{40-30}} + \frac{Se}{1.0p^{40-30}}$$

In this formula the first three terms are the value of the maturing stand at age 30, and the last component is the value of the site to produce subsequent crops. The third term appears complicated, but is only the present worth of the 10 years of annual expenses required to produce the maturing crop.

The assumption that future stumpage values equal current stumpage values is basic to the use of these formulae. The validity of this assumption is questionable, but yields discounted from two or more rotations in the future have a minor impact on present worth.

The challenge posed in the application of forest valuation principles should now be clear. Forest management costs must be explicitly attached to specific plantations or stands, these costs must then be capitalized over the life of the stand and compared to the discounted worth of benefits derived from the sale of primary forest products. If capitalized cost exceeds the value of tangible benefits, then full responsibility for identifying and measuring the secondary benefits of forest management rests squarely on the shoulders of provincial forestry executives.

PROBLEMS IN APPLYING CONCEPTS OF FOREST VALUATION TO DAMAGE ESTIMATES

A. Selecting a Rate of Interest

In legal cases, where a private forest owner is suing for forest damages, the usual procedure is to estimate the earned rate of interest for that particular forest.

Suppose that the essential statistics on the fire-killed forest are as follows.

Age at which stand burned	a =	20 yrs.
Rotation age	n =	60 yrs.
Stumpage value per acre	y =	$60.00
Planting costs per acre	Co =	$12.00
Annual expenses for administration, fire protection and roads	e =	$ 1.00
Site expectation value before planting and site preparation	Se	
Selected rate of interest	p	

The present worth of the maturing crop and the future expenses required to produce it is calculated with formula 2.1

$$2.1 \quad V_{20} = \frac{Y_{60}}{(1.0p)^{n-a}} - \frac{\frac{e}{.0p}(1.0p^{n-a} - 1)}{(1.0p)^{n-a}}$$

Present worth of the past expenses incurred in growing the crop is calculated by 2.2.

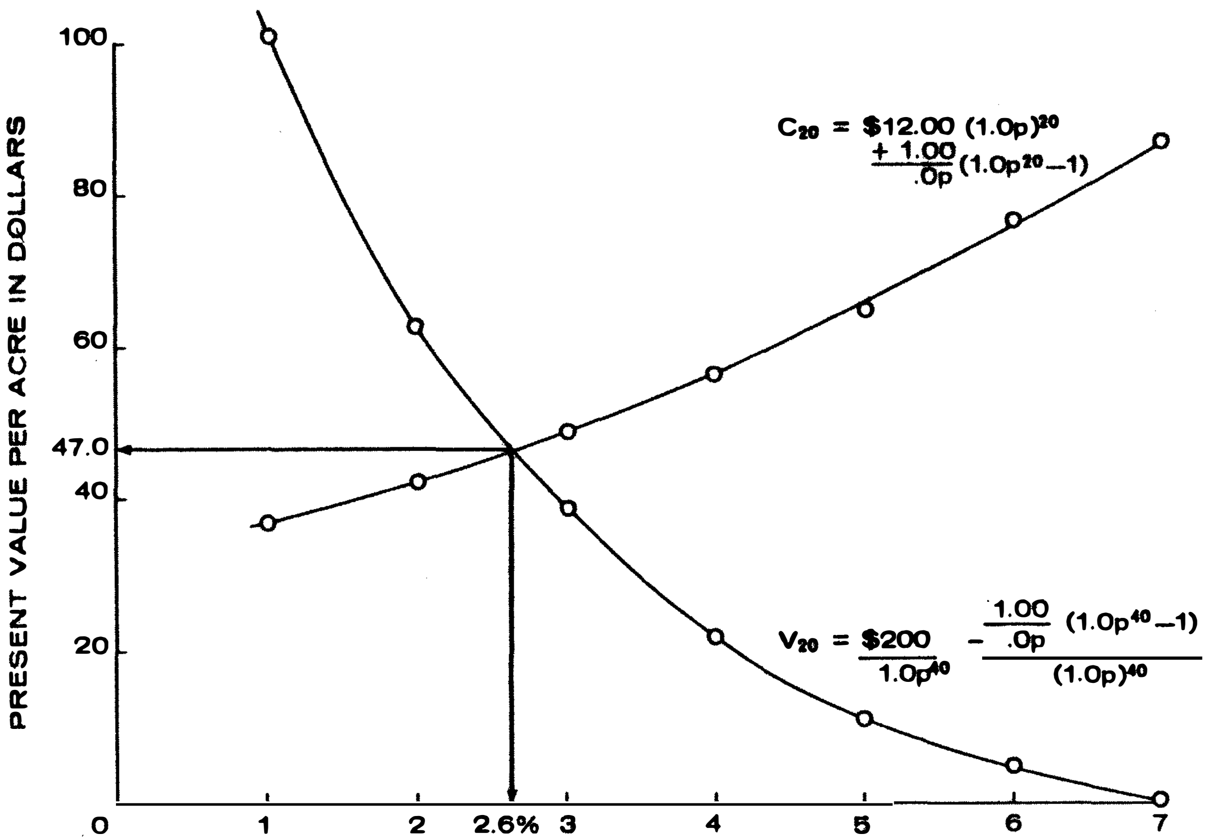
$$2.2 \quad C_{20} = Co\ (1.0p)^{a} + \frac{e}{0p}\ (1.0p^{a} - 1)$$

Now the problem is to calculate the rate of interest at which C and V will be equal. This earned rate of interest is used to calculate a single value which compromises the demands of the claimant, who might prefer to calculate the present worth of his costs at a very low rate of interest, and those of the defendant, who would prefer a present worth value based on a high rate of discount on future crops.

The graphical solution to the earned rate of interest is given below.

FIGURE I

GRAPHICAL SOLUTION TO THE EARNED RATE OF INTEREST



INTEREST RATE p

EARNED RATE = 2.6 PERCENT

Calculating earned rates of interest for all fire-killed stands in public forests would be a task too cumbersome to warrant the effort. In public forests the rate of interest can be viewed as an administrative tool to set the relative importance of damage to immature as compared to mature stands. The lower the rate of interest selected, the greater will be the value of stands at intermediate ages. A provincial policy decision on a suitable rate of interest will be required. The effect of interest rate on calculated damage is illustrated in the tables included in examples 1 and 2 below. Damage is estimated as the difference in value between bare land value before site preparation and planting, and the value of site and stand at age 20.

Example 1 Damage estimates for a natural stand, assuming complete mortality and no damage to the site

Yield at age 60 .... y = \$150.00/AC.
Scarification costs at year zero .... Co= \$ 2.00/AC.
Annual Expenses .... e = \$ 0.20/AC.
Age at which stand burned, 20 yrs. .... a = 20
Site expection value .... Se
Rate of interest .... p

$$Se = \frac{\$2.00\,(1.0p)^{60} - \frac{.20}{.0p}\,(1.0p^{60} - 1) + \$150.00}{1.0p^{60} - 1}$$

Formulae

$$C_{20} = (Se + \$2.00)\,1.0p^{20} + \frac{.20}{.0p}\,(1.0p^{20} - 1)$$

$$V_{20} = \frac{(\$150.00 + Se)}{1.0p^{40}} - \frac{\frac{.20}{.0p}\,(1.0p^{40} - 1)}{1.0p^{40}}$$

Table 1

Rate of Interest	Site Expectation Value	Cost Value	Expectation Value	Damage Estimate
P	SE	C	V	C - SE
1	159.21	201.11	201.11	41.90
2	52.80	86.41	86.41	33.53
3	21.59	47.90	47.90	26.39
4	8.55	29.06	29.06	20.51
5	2.37	18.21	18.21	15.84
6	.71	11.51	11.51	12.22

Example 2 Damage estimates for a planted stand, assuming complete mortality and no damage to the site.

PER ACRE DATA

Yield at age 60 .... y = \$200.00
Planting cost .... Co= 12.00
Annual expenses .... e = 1.00
Site expectation value before planting and
soil preparation .... Se

Age of stand burning, 20 yrs. .... a = 20
Rate of interest .... p

Formulae

$$Se = \frac{-\$12.00\,(1.0p)^{60} - \frac{\$1.00}{.0p}(1.0p^{60} - 1) + \$200.00}{1.0p^{60} - 1}$$

$$C_{20} = (Se + \$12.00)\,1.0p^{20} + \frac{\$1.00}{.0p}(1.0p^{20} - 1)$$

$$V_{20} = \frac{\$200.00 + Se}{1.0p^{40}} - \frac{\frac{\$1.00}{.0p}(1.0p^{40} - 1)}{1.0p^{40}}$$

Table 2

Rate of Interest	Site Expectation Value	Cost Value	Expectation Value	Damage Estimate
P	SE	C	V	C - SE
1	118.20	180.88	180.88	62.68
2	20.42	72.47	72.47	52.34
3	- 6.90	36.08	36.08	42.98
4	- 17.25	18.27	18.27	35.52
5	- 21.37	8.22	8.22	29.59
6	- 22.79	2.18	2.18	24.97

A practical way of gauging the effect of interest rate on damage is to follow the calculations above for representative forest types and for several age classes.

As a general rule, the discount rate for government purposes is usually set between 4 and 6 percent. The niceties of the interest rate argument extend through entire tomes, but the overall logic used to estimate a suitable discount rate is as follows: The appropriate cost of money to the government is its "opportunity cost". The opportunity cost is the value of taxation money if left in the private sector. This value can be expressed as a rate of return on capital, adjusted for risk.

B. Allowance For Risk and Uncertainty.

Logically, one would expect that one of the reasons immature stands are worth less than mature is that for each year a stand is immature it is subjected to a probability of complete loss from fire, insects and disease, whereas most of the mature timber in a zone of logging management would be salvaged. In some areas this probability is so high that the prevalent attitude about fire losses in immature timber is that "....it wasn't worth anything since we would have lost it anyhow".

An analysis of provincial forest fire loss statistics shows this probability to range from .05% to about 2% annually, depending on the province. Interest rate models incorporate this probability in an allowance for risk formula. Risk rate formulae are discussed by Fisher (1930), and their application to forestry problems by Guttenberg (1950) and Duerr (1960).

Although there are mathematical problems involved in adding the risk rate of interest to the basic rate to obtain the actual rate (Duerr, 1960), this process gives good results with moderate probabilities of loss (Guttenberg, 1950).

Actual rates calculated for the two extreme probabilities of risk, added to the basic rate of 5%, are 5.05% and 7.00% respectively.

Adding .05% to the interest rate has little importance, but adding 2% makes the value of present worth dwindle to zero. For example, take the following case where a value of $60.00 per acre will be realized 60 years from now.

At a 5% discount, present worth is calculated as:

$$\frac{60}{(1.05)^{60}} = 3.21$$

Risk rates of interest can also be used to evaluate forest protection expenses in immature stands. We have seen that the value of a crop maturing in 60 years and the expenses required to produce it can be calculated with the following formula.

$$\frac{Y}{(1.0p)^{60}} - \frac{\frac{e}{.0p}\,(1.0p^{60} - 1)}{1.0p^{60}}$$

Now if the current protection program costs $.03 per acre per year, and the risk of loss is 2%, then the yield of $100./acre would be discounted at 7% (basic rate of 5% plus 2%). If increasing protection program to $.10 per acre results in a .05% risk of loss, then the value of the immature stand is more than doubled even though annual expenditures were increased by 3.3 times.

Table 3 Combined effect of annual expenditure and risk rate on current stand value. Basic rate of interest is 5%.

Annual Expenditure	Risk of Fire Loss	Present value of annual expenditure	Present value of $100 yield at rotation age	Net Present Value
.03	2.0%	$ .42	$1.73	$1.31
.10	.05%	$1.89	$5.35	$3.46

At a 7% discount the value is $1.04, which is a mathematical way of saying that the risk is so great that the regeneration has little value.

In forest districts with a high probability of loss, interest rate models will indicate a zero value damage to very young stands.

The implication for damage appraisal is that interest rates used to discount future values should take the risk rate into account. Standard tables of damage, based on a 5 percent interest rate, would not be realistic where the annual probability of stand loss is greater than 1 percent.

SURPLUS TIMBER AND UNDER-UTILIZED SPECIES

A common argument in appraising damages to less accessible young timber is that there will be plenty of alternative sources of timber when it would have been mature. Furthermore, at this future date, a good distribution of age classes will in fact be a benefit rather than a loss. In these circumstances, one could argue that there would be no loss of future revenue.

One way to approach this argument is to consider the problem of "surplus" in the framework of "allowable cut" versus actual cut plus depletion. Now if, in a given forest district, we say that a specific fire caused damage, this amounts to saying that this depletion will result in decreased stumpage revenues. This decrease from stumpage revenues can come about in two ways.

1. A decrease in actual cut because of a decrease in allowable cut following a fire.

2. A decrease in actual cut in that forest district because the remaining sources of wood are too costly.

An example will help to illustrate this point.

A 1000-acre fire in mature white spruce. Total volume loss after salvage = 10,000 units. Current stumpage rate for white spruce in the forest district in which fire occurred = $5.00/unit.

If this loss is recorded at 10,000 x $5.00 = $50,000. damage, this amounts to saying that the present worth of stumpage revenues lost as a result of the fire is $50,000. However, if no decreases in stumpage sales are expected in that forest district as a result of the fire, then the loss can be $0.

In the estimation of damage to immature stands, the assumption will be made that stumpage sales in the forest district where the fire occurred will be reduced at the expected date of stand maturity by the amount, (volume loss) x (current stumpage price). The only alternative to this assumption would be to estimate what fraction of the full stumpage rate should be used in damage estimates.

A CRITERION OF VALUE FOR BURNED AND GREEN STANDS

Since the value of immature stands is derived from their expected value at maturity, two simplifying assumptions must be made. First of all, it is assumed that the value of future crops will be the same value now being realized from currently mature timber of that species and in a similar location. Secondly, the assumption is made that the value of immature stands can be viewed as a discounted future value per unit volume or simply "y".

Some of the possible measures of value (y) for mature stands are as follows.

1. Stumpage price
   Stumpage price is the most widespread available measure of value, but is a very restrictive one since the provincial government also obtains income from corporation taxes, etc., as a result of wood conversion

2. Selling price of primary industry production
   This measure of (Y) is less restrictive since it takes into account the value of secondary production. Higher selling price values indicate that the local wood sources are contributing more to the public purse and to the local economy.

The measurement of (Y) actually used will depend mostly on available statistics, but the second criterion of value appears to be the more realistic.

Finally, there is the argument that stumpage value or any of its close relatives give incomplete and misleading indications of forest value. That, may well be so, but consider the following argument in defense of their use: for allocating fire control budgets within a province what is needed is an indication of the <u>relative</u> amount of damage from one forest district to another. Therefore if stumpage can be considered some constant fraction of full value, then it can be used in damage appraisal formula.

THE SILVICULTURAL BASIS OF FOREST DAMAGE

A. <u>Stands Completely Fire-Killed</u>

In addition to the destruction of the currently maturing stand, fire frequently has a deleterious effect on stocking in the next rotation. The best available broad scale data on this secondary source of damage is from a broad scale regeneration survey, (Candy, 1951). By combining all Candy's regeneration survey data for eastern Canadian forest types, the following table was prepared.

Table 4 Number of trees per acre, 60 to 20 years after disturbance

Original	No. "per acre"		
	After Logging	Logging Followed by fire	Fire only
Black spruce	4,800	900	2,700
Balsam-Black spruce-jack pine	2,900	400	3,400
Balsam-black spruce-hemlock	4,500	500	2,200
Balsam-black spruce	2,800	700	1,900
Average	3,700	870	2,500
Jack Pine	1,400	3,000	4,200
Jack pine-black spruce	1,100	1,400	6,500
Average	1,250	2,200	5,350

From this table it can be seen that there is a trend for stands containing balsam and black spruce to regenerate very slowly following fire on a recent cutover compared to jack pine. Some of the reasons for this difference have been investigated (Jarvis 1966, Rowe 1955).

The patterns of re-establishment described by Kagis (1954) and MacArthur (1963) form the basis for modelling the deleterious effects of individual fires on balsam and spruce sites. Their studies show that regeneration can be modelled as two concentric rings. The outer ring extending six to ten chains from the stand edge is adequately restocked during the first two decades after the fire, the inner area remains inadequately stocked during the first rotation. The reason why re-establishment rates should dwindle to zero after the second decade is still not fully known, but is suspected to be related to a process of seed bed "maturation".

If we assume that the stocking of the stand in the outer ring will be similar to that of the unburned stands and the inner area unstocked, then the merchantable volume on the burn, at rotation can be estimated by calculating the area of the outer ring and multiplying this area, in acres, by an estimate of expected volume per acre. By using a circular fire model, the area that will be restocked adequately (A) can be estimated with the following formula.

$$A = \frac{\chi (\gamma_1 - \gamma_2)^2}{10}$$

(r_1) is the radius of the burn in chains when modelled as a circle, and (r_2) is the radius of the inner unstocked circle.

Given this model, rotation age volumes following the burn can be calculated.

Volume following = normal volume per acre for that species at rotation age x stocking estimate at rotation age.

Determining the variable (stocking estimate at rotation age) is not a simple matter. The starting point in its estimation is the assumption stated above. Stocking of the stand in the outer ring will be identical to that of the unburned stand when the two are of the same age. Given this starting point, the problem is one of yield prediction, i.e. what will the rotation age stocking and volume be, given stand condition at an intermediate age.

For a discussion of techniques of yield prediction for even-aged stands based on normal yield table methods, or variable-density yield table methods, a standard text on the subject is suggested. (Bruce, D. and F. Schumacher 1950, see pp. 411 to 432.)

In addition to these components, damage also stems from the increased costs of protection on hazardous burnovers, and from restocking costs following burning of immature stands. There is no known way of estimating increased protection costs, but the increased site preparation costs can be estimated.

B. Stands Partially Damaged by Fire

Some species, especially eastern Canadian hardwoods, are frequently damaged by fires of sub-lethal intensity.

The lowest intensity fires have no detrimental effect, or possibly even a beneficial effect, on growth (MacArthur, A.G. 1968) but higher intensity fires cause cambial damage that leads to extensive secondary damage by both fungi and insects.

Before damage rates can be devised for damaged hardwoods, research must be planned to investigate the volume and grade loss following fires of varying sub-lethal intensities.

CONCLUSION

A rigorous application of forest valuation principles to damage appraisal in immature stands would greatly increase the confidence that can be placed in damage estimates.

Before these principles can be applied, present practices must be revolutionized - forest management costs must be attached to individual stands, direct forest revenues from stumpage must be discounted and compared to costs, and indirect benefits must either be stated as some percentage of direct revenues or explicitly measured in individual cases.

While the conceptual, administrative and technical problems in applying damage formula to individual stands are being solved, the following basic data should be collected by burned stands -- area burned by forest type, age class, and location.

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