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APPRAISING FIRE DAMAGE TO MATURE FOREST STANDS

by

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ABSTRACT

A proposal for standardization of appraisal methods of forest fire damage to mature stands was developed. The proposal is based on division of the forests into accessibility zones and the application of market values or fractions thereof. The recommendations resulted from consideration of the possible types of fire damage, current appraisal methods of Canadian governmental agencies and the appropriate economic concepts, including the social rate of discount.

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J. S. MACTAVISH[1]

INTRODUCTION

This paper is the result of a study undertaken at the request of the Associate Committee on Forest Fire Protection of the National Research Council. The purpose of the study was to find an approach to standardization of the appraisal of forest fire damage to stands of mature timber, based both on sound economic concepts and on methods of appraisal currently used by government fire control agencies in Canada. Emphasis was placed on estimating damage to Crown-owned timber.

As Vaux (1953) succinctly defined it, economics is that social science which ". . . is concerned with the problems of allocating productive resources among the several alternatives that may be available, so as to maximize the net monetary and other returns obtained from them". This allocation of resources is performed primarily in the market by means of market prices, that is, value in exchange. It is this sort of value which is used in most appraisals.

Standardization of methods of appraising damages to mature timber is only a first stage in what may prove to be a long and difficult process — the development and adoption of economically sound methods of appraising damages to the forest resource as a whole, with all its characteristics being considered. Nevertheless, if standardization of methods can be achieved for one resource attribute, even with imperfect standards, it will constitute a step forward, and the adoption of future improvements may be facilitated. Once damage appraisal methods have been perfected and generally adopted, it will become practical to carry out further research toward determination of the optimum intensity of forest protection for an area, and toward the optimum distribution of effort among the various phases of forest protection. This paper is intended as a step in that direction.

Consideration of damages to only one aspect of the forest resource, mature standing timber, has placed the appraisal problem in a rather artificial context, thus making it desirable at times to consider other attributes of the resource in order to make the discussion more nearly complete and meaningful.

BASIC FRAMEWORK FOR DAMAGE APPRAISAL

Definition of Damage

It would be inappropriate to use an incomplete definition of forest fire damages even though it may be impossible, and in some instances unnecessary to measure, or even recognize, all injurious fire effects. There should be a standard, however idealistic, to which current or planned damage appraisal techniques may be compared. Forest fire damages emerge through decreases in current and/or future production of goods and services, and/or through increased costs of production. It is this production of benefits that confers value to the forest in the first instance. Damage from forest fires is defined as the resultant net total reduction in value and/or increase in cost of all factors of production, and other assets in the economy, directly or indirectly dependent on the forest resource.

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The important concept is that forest values and damages thereto are dependent on the production of goods and services. The implications of this principle are sometimes overlooked when damages are estimated. For example, if fire were to destroy a mature or overmature stand that would not have been logged in the normal course of events, because of economic inaccessibility or some other reason, no damage to timber values would have been incurred. In some instances the result might actually be beneficial.

Objectives of Appraisal

Appraisal of resources may be carried out for several reasons, each of which may result in different values being ascribed to the same resource. The variation in appraised value may result from different viewpoints of appraisal, from the recognition and consideration of different resource attributes, or from the use of different degrees of refinement in the appraisal process. In this paper damage appraisal is considered in the context of economic guides for choices of alternatives available in forest fire control activities in particular, and forest management in general.

Some Canadian forest fire control personnel have suggested that since it is often difficult to ascribe precise monetary values to several facets of the forest resource, no attempt should be made to do so. Some have recommended that a description of fire losses in terms of numbers of fires, areas burned, or volumes lost should be sufficient. Description of losses in such generalities may have been satisfactory in the past, but accumulating evidence reinforces the view that forest protection is no different from other endeavours in the economy in that it must eventually be reckoned in terms of dollars. Difficulties have been encountered, in some quarters, in convincing those controlling the purse strings that additional expenditures for fire control are warranted or that money should be spent to reforest burned areas. The New Brunswick Forest Development Commission (Anon. 1957) went so far as to state that "the ratio of cost of fire prevention and fire suppression to the evaluation of fire damage should go no higher." The invariable question, "will it pay?" can only be answered satisfactorily if fire control planning is based on economic arguments. The objective must be to describe fire damages as practicably as possible in monetary terms.

The nature of the forest is such that benefits therefrom may accrue in part to owners and tenants of forest lands, in part to individuals of the community, and in part to the community as a whole. This is true even if one considers only those values relating to merchantable timber. The forest owners and lessees receive returns from the sale of stumpage or manufactured products. Individuals in a community receive salaries and wages from logging and milling companies. In Canada, the export of forest products is so important as to account for some 30 per cent of our export trade, and is therefore a most significant factor in maintaining our high standard of living. The significance of the Canadian forests in the interest of society is reflected in that about 90 per cent of the productive forest land in the provinces has been retained in public ownership. Forest protection is in large measure provided by the provincial governments. The over-all national interest is reflected in the financial aid and research assistance given by the Canadian government to the provinces for fire control and other purposes under the terms of the Department of Forestry Act (Anon. 1960).

Considering the importance of the resource and the variety of beneficiaries, it would not seem consistent to select an economic goal for forestry at less than a maximum contribution to a maximum national real income in terms of goods and services. The definition of the appropriate economic standards for forest fire control should be based on this public viewpoint, for if it were not, some of the germane values would escape consideration. It is essential to appraise damages from the same viewpoint. It is recognized that a goal of maximized national in-

come may not coincide with an ideal goal of maximum social welfare because of economic inefficiencies and inequities that may result from imperfections in markets, skewed income distributions, and so forth.

Nevertheless, since either goal is highly elusive and distant, and considering the current undeveloped state of economic planning for fire control in Canada, differences between maximum income and welfare may be neglected, at least for the time being. Those interested in considering these differences are referred to Scitovsky (1951), Little (1957), and Marglin (1962). The common denominator for the components of national income is market price or estimates thereof. Although sometimes not an accurate indicator of social marginal values, it is, nevertheless, the only suitable framework for evaluating resources.

While taking maximization of national income as a tentative economic goal, it must be borne in mind that Canada's forests are constitutionally in the sphere of provincial jurisdiction, and fire control is primarily a provincial responsibility. It is necessary then to consider damages first from a provincial point of view, but recognizing that most provincial boundaries are arbitrary in relation to natural forest regions and to the movements of forest products. Economic effects of fire, both adverse and beneficial, extend beyond political boundaries and escape consideration unless an over-all national viewpoint is maintained in damage appraisals.

Measurement Goal

From the above it follows that the goal of measurement of damages should be that which results in consideration of the impact of all possible effects of fire, both short and long range, on individuals and on society as a whole. Damageable public values arise as distinct from private values for two reasons (Weitzell, 1953). First, there are those forest benefits which, because of their nature or tradition, cannot be controlled by private enterprise. These would include some values associated with the production of water, the preservation of scenery and wildlife, and the influences of forests on national health and security. Second, there are those values which occur so far in the future as to be beyond the planning horizon of private enterprise. The value of young growth for future timber supplies might at least partially escape measurement if considered only from a private view. Although difficult, if not impossible, to describe completely in monetary terms, damages to the public interest should be fully considered and described.

Damage appraisal should include both primary and secondary effects of fire. Primary damages result directly from the physical impairment of the forest. They include the values of timber and improvements destroyed, the effects of fire on site productivity, and so on. Secondary damages are those resulting from the reduction in production of goods and services beyond the stage of those directly damaged by fire. Included would be any net losses of income to sawmills, and to people employed in the sawmill industry, arising from a log shortage that might result from forest fire. Also included in secondary damages would be any reductions in income of associated industries selling to the sawmill industry. Craig, *et al.*, (1946) referred to these secondary damages as "socio-economic". It is the author's belief that secondary damages may sometimes be as great as primary damage to mature timber.

The Discount Rate

In the midst of discussion on a baffling subject, an economics professor once burst forth with the remark that if it had not been for original sin there would be no need for interest rates, or economics either for that matter. He meant, of course, that abundance would prevail. Keynes (1936) felt that it should be possible to make capital goods so abundant that the marginal return to capital would be zero. Before this could be accomplished, however, the rate of interest would

have to be similarly reduced, for the marginal efficiency of capital must exceed the interest rate if investment is to proceed.

Individuals or firms tend to place greater emphasis on goods and services immediately available than on those available later. A portion of current income goes toward current consumption, while the remainder is held for future use. The forms in which the latter portion is held, whether in money or some type of investment depend upon the individual's liquidity preference, arising from the familiar transactions, precautionary, and speculative motives. Keynes (1936) described the rate of interest as the price required to overcome liquidity motives to obtain funds for investment purposes.

Selection of the most appropriate rate of discount to use with publicly owned forest investments is difficult because of several rather unique features. Investments in new forest stands require long periods to mature and begin to yield cash incomes, while during the maturing process income in the form of wood growth is automatically reinvested in the stands. A developing stand could be considered similar to a cumulative preferred share that was allowed to accumulate over periods of 60 to 100 years, if such actually existed. On the one hand, the unusually long investment period with its accompanying risks and the rather poor development of markets for immature timber might tend to make forest investments unattractive except at relatively high prospective rates of returns. On the other hand, the automatic reinvestment feature of a developing stand augurs for a relatively low interest rate, since costs of reinvestment, including income taxes in particular, are avoided. In addition, the versatility of the timber capital-product is relatively high, offsetting the risks of investment to some extent. It may be stored as mature growing capital if desired pending favourable market conditions, and as a raw material it has a wide variety of uses.

The correct choice of a discount rate is of crucial importance for estimating values of immature or inaccessible forests, especially where there is an undeveloped market for stands of young growth, or where the policy is opposed to the sale of forest land, such as is the case with publicly owned Canadian forests. While a 20 per cent error in stumpage prices expected 80 years in the future can yield only a 20 per cent error in present worth calculations, assuming other factors were chosen correctly, a 20 per cent error in the discount can yield an error of more than 50 per cent in present worth calculations over 80 years because of the geometric nature of compound interest effects.

In recent years there has been considerable attention paid to selection of interest rates appropriate for evaluating public resource development projects, water resource projects in particular. Various discount rates have been proposed and have evolved from three basic concepts. One, represented by arguments of the U.S. Subcommittee on Evaluation Standards (Anon. 1958), recommends that the appropriate factor for public planning should be that rate expected to be returned in some other investment of similar duration and risk. Postulating that all calculable risks be removed from expected revenues, or added to costs, they recommend that the appropriate interest rate would be the projected average rate of return on the practically risk-free long-term government bonds. For Canada, Reuber & Wonnacott (1961) suggest that this rate is about 5.5 per cent.

The proponents of a second method stress that the appropriate interest rate for government projects should be the rate of return foregone in the private sectors of the economy whence the public funds were drawn, rather than the rate that could be earned in other similar investments of a risk-free nature. Reuber & Wonnacott (1961) attempted to find this rate of discount (opportunity cost of capital) suitable for use in planning Canadian public projects, the Columbia River Project in particular, assuming that the funds would be raised by bond issues. They felt that because of differences in lenders' risks, private borrowers find themselves pigeon-holed into various interest rate categories in which they can

borrow, and can undertake only those investments promising yields at least equal to these rates. They argued that although differences in liquidity characteristics of various types of investment, institutional lending conventions, and market conventions may cause some misallocation of the nation's resources, the resultant interest rate differentials must nevertheless be accepted as real differentials when calculating the opportunity cost of capital. After tracing prospective government borrowings to reduced consumption and investment elsewhere in the economy, they worked out a weighted average of the appropriate interest rates in the affected sectors of the economy. This average marginal rate was then reduced to "real" terms by removing an estimated inflation expectation factor of 0.75 per cent. The end result was an opportunity cost of capital, or discount rate of 5.6 per cent. Sewell, *et al.* (1962) adopted this procedure for selecting an interest rate for cost-benefit analyses in Canada. They estimated the rate to be about 5 per cent.

Similarly, Krutilla & Eckstein (1958) estimated the social cost of government financing in the United States, but assumed that government funds would be acquired through taxation rather than bonds. They attempted to estimate the marginal returns that might be expected to prevail in the various private sectors of the economy if there were slight decreases in taxation rather than public investment in water resource projects. They estimated the opportunity cost of public investments in the United States to be between 5 and 6 per cent in 1955. A corresponding rate in Canada would be about 0.5 to 1.0 per cent higher.

The technique of averaging rates of return on alternative private investments with different characteristics of risk, liquidity, terms and taxation, as used in both studies referred to above, is unfortunate. It would seem more desirable to estimate an interest rate for a public investment from a similar investment opportunity in the private sector of the economy where those factors affecting the interest rate would be similar for both alternatives. This would be especially desirable for forestry investments with their unique features of length and automatic re-investment already referred to.

If all forest fire control responsibilities were given to the private firms, it would be their taxes which would be most appropriately reduced. Hirshleifer, *et al.* (1960) recommended that the appropriate interest rate on a public investment should be that rate on an equivalent private investment having similar risk. They also pointed out the necessity of calculating the private rate before taxes, an important factor when private investments are made with equity capital. Although interest charges on bonded debt are deductible from corporate income taxes, the return to equity capital is not. Thus, if a firm's debt to equity ratio were 25 to 75, the charges on its funded debt 5.5 per cent, its desired marginal net yield on equity capital 6.0 per cent, and the corporate income tax rate 52 per cent, the marginal acceptable return to the firm would be 10.75 per cent. Exclusion of the tax effects when comparing public and private investments can yield social losses if it is assumed that a public agency can operate at a lower rate of return solely because it does not have to pay taxes.

There are several difficulties involved with the proposal of Hirshleifer, *et al.* (1960). The major timber-using concerns in Canada are vertically integrated and the average marginal return for these firms may have no normative significance to the business of sustained-yield forestry. The risks in the various divisions of the firms may differ. If, as is sometimes suggested, the firms hold more forest lands than actually required for current production rates, they may be doing so partly as insurance against higher prices of raw materials, as well as insurance against destructive losses in the forest itself. If the risks have become relatively lower in the woodland divisions, or if the woodland divisions bear insurance costs of the manufacturing divisions, then the acceptable rate of return in the woodland divisions may be expected to be relatively low. Again, the prices of stumpage in Canadian markets might be different if public agencies did not control the major portion of the forests.

In addition, the opportunity cost of capital sought is the average marginal real rate expected to be obtained over the long-run period, not the rates expected over the short term, which may be all that is considered when additional investment in manufacturing plants, with the rapid depreciation thereof, is contemplated. Again, as Reuber & Wonnacott (1961) stressed, the returns to large firms in oligopolistic markets, such as pulp and paper, may not be pertinent in a study to find the return to investment at the margin, that is the return to the last unit of investment where the return to this capital just balances the cost of the capital. It is doubtful if the returns to investments of such firms are marginal in respect to their costs of capital.

The inclusion of a risk premium in estimates of the opportunity cost of capital for public forestry investments must be handled with great care for two reasons. If risks are allowed for in the estimation of future benefits and costs and again as a risk premium included in the interest rate, there will be double counting of the risk elements. This may lead to misallocation of resources. Inclusion of a risk factor in the interest rate implies that risk increases over time at a geometric rate. Such an implication would be difficult to defend. In fact, risk of loss through fire damage may tend to decrease with stand age. As recommended by the U.S. Subcommittee on Evaluation Standards (Anon. 1958), it would seem most appropriate to include consideration of investment risks by reducing estimates of future returns by the required amounts, and excluding risk considerations from the interest rate.

A third method is available for estimating discount rates for public projects. It is generally agreed that historically, exploitation of publicly owned forests has been regulated so as to stimulate growth of the economy through investment in long-lived forest products manufacturing plants. If this be true, and if special inducements of one kind or another have been made to industrial concerns, it may be that the relevant rate of discount is something other than a market determined rate, something more closely related to the desired rather than the actual rate of economic growth in the country.

A number of economists have suggested that the social rate of discount may not be equivalent to a market-determined rate. Marglin's (1962 and 1963) recent thesis is perhaps the most convincing. His argument is based on the premise that an individual's satisfactions may depend on the consumption of other individuals as well as upon his own. Briefly, he argues that were the investment market perfectly competitive, and everyone's marginal rate of substitution between present and future consumption were adjusted to the market rate of interest, the market rate still might not be suitable for public investment planning. An individual places a premium on his own current consumption as opposed to both present and future consumption by others. These preferences may not be expressible in the market, but may be in the political sphere where majority decision rules. With a public investment, the individual knows that his sacrifice of current consumption to provide for someone else's future consumption is accompanied by similar sacrifices by all his contemporaries. He also knows that his share of the total sacrifice is very small. Consequently the individual's rate of time preference in the public investment sphere may depend not so much on the premium he places on his own current consumption as opposed to someone else's future consumption as on the lower ratio of his preferences for other peoples' current consumption to other peoples' future consumption.

Marglin (1963) goes on to remind us that since the rate of economic growth is dependent on time preference and the marginal productivity of investment, the social rate of discount could be lower than the market rate of interest if it were considered that the economy was not growing fast enough. Unless it were the policy to redistribute income towards future generations, however, it would not seem desirable to employ a discount rate significantly below market rates.

As Krutilla & Eckstein (1958) emphasized, an artificially low rate could result in social loss by justifying investments at the expense of others that could produce higher returns, the proceeds of which could be reinvested.

To sum up, the range of possibilities seems to depend on whether it is assumed the funds for government projects are drawn from private consumption or investment alternatives. The possibilities run from a lower limit approximated by the average expected yields of long-term government securities, or something a little less, adjusted for inflation expectations, about 4.5 per cent, to an upper limit approximated by the average expected marginal investment yields of private forestry firms, adjusted for risk. For reasons previously mentioned this rate is unknown.

Intuitively one may wish to select the lower rate based on individual social rate of discount, perhaps with the feeling that the forests provide many benefits other than timber, some of which collective and individual benefits are not measurable in terms of dollars. But here we must beware of a serious pitfall. In the discounting process, estimates of the values of future benefits must always be placed in the numerator, never in the denominator as a part of the discount rate. To do the latter would infer that the real value of the "intangibles" benefits begins as a definite fraction of the measurable benefits but increases at an exponential rate over time.

If the discount rate is to be based on private investment alternatives, consideration of hypothetical corporate income taxes should be included somewhere in a cost-benefit analysis of public agencies. To some extent taxes, if there actually were any, would be reflected in stumpage prices; that is to say, if Crown agencies were required to pay corporate taxes, stumpage prices, especially those administratively set, might be expected to be somewhat higher than at present. In fact, however, stumpage income from Canadian Crown-owned forests is not taxed, and even if it were, taxation regulations would in all likelihood consider the Crown agencies' stumpage revenues as untaxable capital gains. To compare current public ownership with alternative private ownership, it is necessary to assume that manufacturing firms would remain in the same position; that is, they would continue to buy standing timber, the only difference being that the standing timber would be privately rather than publicly owned. Thus the private stumpage seller might not be subjected to corporate income taxes, his income being considered capital gains. Under these conditions, the upper limit of the discount rate range, that approximated by the expected average marginal yield in private forestry, might be in the order of 5 or 6 per cent, adjusted for inflation expectations.

Pending further work required to estimate long-term expected marginal yields, it appears that a rate of 5 per cent, or a little less, is a reasonable approximation of the current real opportunity cost of public investment capital, or the social rate of discount. This is considerably higher than the 2 per cent rate used to estimate young values in British Columbia (Anon. 1956), the only province known to apply discount formulae to future forest values. A rate so much below apparent rates on alternative opportunities suggests extraordinary interest in future resources. If the social rate of time discount selected were so much below expected real long-term rates on government bonds, both rates should be used, the higher rate to indicate the actual costs of public projects.

In Canada the rate of economic growth and the marginal productivity of capital are so dependent on external influences, especially those of the United States economy, that interest rates here will in all likelihood continue to remain slightly higher than those of the United States for some extended time if we are to continue to attract foreign investment. The tentatively selected discount rate of 5 per cent falls between the rates recommended for public project planning in the United States by the Subcommittee on Evaluation Standards (Anon. 1958), and by Krutilla and Eckstein (1958), but considerably below the rate recommended by Hirshleifer *et al.* (1960).

DAMAGE APPRAISAL TECHNIQUES

Primary Damages

Damage has been defined as the net decrease in value of factors of production; consequently, forest fire damage to stands of mature timber would be equal to the decrease in market value of forest property resulting from fire. This difference may be estimated directly if a reasonably developed market for forest land exists, but in many parts of Canada these markets are only poorly developed and, more important, it is not the general policy of the provinces to sell publicly-owned forest property. It is usually necessary, therefore, to estimate values by capitalizing expected revenues or by estimating costs of restoration. The cost approach is not recommended when damages are to be estimated for economic planning purposes, although the method might have merit for settling insurance claims and legal actions for damages. The cost approach to damage appraisal could yield the rather odd consequence of estimated values for young stands exceeding the market value of merchantable stands. As Mitchell (1954) put it, should the costs of producing a stand exceed its eventual market value, cost excesses should be charged to poor investment practice rather than damages. For planning purposes, where market values are not available, damages should be based on capitalized revenue expectations.

The following discussion of appraisal mechanics pertains to even-aged sustained-yield forest management. Formulae used are standard ones quoted by a number of authorities such as Chapman and Meyer (1947). Restricting the discussion to even-aged management appears appropriate considering the desirability of selecting as simple an appraisal standard as possible for nationwide use. The majority of Canada's forests are managed on an even-aged basis, at least in a broad sense of the term. Although not all the timber of commercial species may be harvested at one time, in most areas it is not usual for stands to be relogged, at least for the same species, before succeeding stands become merchantable. The term sustained-yield management is defined here to mean that production tending to yield maximum annual revenue. Although some firms may not manage their forests on such a basis, certainly the provinces employ at least "continuing-yield" policies. It seems justifiable, therefore, to consider appraisal from the viewpoint of even-aged sustained-yield management.

The value of land for growing timber is derived, logically enough, from the trees it produces or is expected to produce. If an acre of bare land were expected to yield a net stumpage revenue of Y at the end of each rotation period of n years, the capitalized value of the land could be represented by the formula

$$Se = \frac{Y}{1.0p^n - 1} - E, \text{ where:}$$

1. Se = net present worth per acre;
2. Y = net stumpage revenue per acre;
3. $E = \frac{e}{.0p,}$ the capitalized value of annual costs of management;
4. p = the rate of discount;
5. n = the length of rotation period.

This capitalized value, often referred to as expectation value, is an estimation of the present worth of the soil for growing timber at rate of discount "*p*". An important feature of this, and other capitalization formulae, is that it yields a *maximum* estimation of market value, assuming correct selection of the alternate rate of return. Were a firm contemplating the purchase of land, estimation of the soil's expectation value would yield the firm the maximum price it could pay and

still make a profit. Depending on the relative bargaining powers of buyer and seller, the final price would tend to be below this maximum.

Just before merchantable timber is harvested the net present worth of forest property becomes:

$$\text{N.P.W.} = Y + \frac{Y}{1.0p^n - 1} - E.$$

The amount of damage sustained by merchantable stands can be estimated as the difference between this value and the property value after burning. Confining consideration to the damage done to the trees alone might result in either excessive or insufficient damage being calculated. For example, destruction of 30-year-old timber, which normally would have been harvested when 50 years old, would result in the release of the soil for the next, and all succeeding, generations of timber 20 years earlier than expected. Although the current generation of timber would have been lost, the fire would have brought the expected income from each succeeding generation 20 years closer to the present, and this ameliorating factor would have to be included in net damage calculations. Similarly, if the site were damaged so that the soil would support only an inferior species, the reduction in *Se* value would be added to the timber damages.

To appraise damage adequately account must be taken of all expected future benefits and costs. Past costs do not enter the calculations except indirectly through their effects on future returns and costs. Taking the simplest case, that of complete destruction to naturally regenerating timber with no additional damages, the appraisal procedure would be as follows:

The first factor to consider is the value per acre of timber destroyed. If this is a future return expected in the rotation year n, it must be discounted to the present, the age of the stand when burned, represented by a. Thus the factor in the damage formula for the complete destruction of a future crop is $\frac{Y}{1.0p^{n-a}}$.

The second factor of importance is the value of the soil for producing future stands. Assuming the timber producing qualities of the soil unchanged, there remain two soil value considerations that enter the appraisal formula. First, along with destruction of the expected value of the current stand, the bare land value would not reappear in the year n, following logging, as expected. This loss may be represented by the factor $\frac{Se}{1.0p^{n-a}}$. On the other hand, fire releases the soil for production of future crops immediately, and gross damages should be reduced by the factor *Se*. The element in the damage formula for soil value becomes $\frac{Se}{1.0p^{n-a}}$ Se. The net effect of this factor is a small decrease in gross damages since, as a result of fire, succeeding crops should appear n-a years earlier than previously anticipated.

Before the yield Y could have been received had there been no fire, annual expenses for administration, protection, and taxes would have been incurred. The factor Y must be reduced by the present value of these future annual expenses to arrive at a figure for net damage. These costs would have amounted to $e(1.0p^{n-a} - 1) / .0p$. Discounted to the time of the fire, where $e/.0p = E$, the capitalized value of expenses, the element for future costs in the damage formula becomes:

$$\frac{e(1.0p^{n-a} - 1)}{.0p\ (1.0p^{n-a})} = E - \frac{E}{1.0p^{n-a}}.$$

If it were assumed that fire caused no damages other than to the existing stand, Y, *Se*, n, and E might be expected to remain the same for succeeding stands.

Under such assumptions the formula for damage resulting from complete destruction to an even-aged stand may be represented by a summation of the above factors:

$$D = \frac{Y}{1.0p^{n-a}} + \frac{Se}{1.0p^{n-a}} - Se - E + \frac{E}{1.0p^{n-a}}$$

Recalling that $Se = \frac{Y}{1.0p^{n} - 1} - E$, the factors may be combined to yield the basic formula for estimating damage to even-aged stands:

$$D = \frac{Y\ (1.0p^{a} - 1)}{1.0p^{n} - 1}$$

In reality what is lost is the accumulated yield of the growth potential of the site for a period of *a* years. Translated into economic terms, the loss equals the accumulated interest on the gross soil value, Seg, for the period of *a* years, where $Seg = \frac{Y}{1.0p^{n} - 1}$ and $D = Seg\ (1.0p^{a} - 1)$. A basic assumption here is that the values of growing forests increase geometrically at a rate of 1.0p. Were markets developed for timberlands of all age classes, this assumption could be tested. It might well be that young timber would be discounted at a higher rate than nearly mature timber because of greater uncertainty of eventual income from the younger timber. Fortunately, these considerations do not apply to the problem at hand, the appraisal of mature timber.

Timber that is of merchantable size by local cutting practices, and therefore marketable, is normally considered as mature for damage appraisal purposes. In the basic formula *a*, the age of the stand when burned, becomes equivalent to *n* the rotation age, and the damage formula becomes:

$$D = \frac{Y\ (1.0p^{n} - 1)}{(1.0p^{n} - 1)}$$

$$D = Y$$

The unadorned nature of the damage formula results from the simplifying assumptions made along the way. It was assumed that the economic value of mature stands would be completely destroyed by fire, but that no other damages would be suffered by the timber-producing attributes of the site. Even fires, although killing the trees, often do little damage to the wood itself; but salvage operations usually must be completed promptly before insect and disease activities render the timber useless. Prebble and Gardiner (1958) reporting on studies made following the infamous Mississagi-Chapleau fires in Ontario, found that sawlog salvage operations in white and red pine stands must be completed quickly to prevent serious degrade from fungi and wood-borer attack. Degrade was found to be most rapid in high quality trees that had been killed outright by fire, especially white pine. They found, for example, that value loss averaged nearly 60 per cent in killed, high quality white pine only 17 months after the fire.

Skolko (1947) reported that deterioration of pulpwood stands of spruce, balsam fir, and jack pine was inversely proportional to the intensity of burning, and was most rapid in balsam fir. (Charring, very important when considering the feasibility of salvaging pulpwood, would be directly proportional to fire intensity). On severely burned areas the rate of deterioration, excluding windfall and heartrot, was found to be about the same for the three species, less than one per cent for the first four years. In some instances at least, then, salvage operations may be feasible for a number of years. For example, timber was salvaged from the devastating 1923 fires in New Brunswick for at least nine years (Anon. 1932). In the event of salvage operations, damage represented by *Y*

would overstate the net damage by the value of material salvaged. Where S is the per acre value of timber salvaged, the damage formula becomes:

$$D = Y - S$$

On occasion it may be necessary to increase protection intensity following a forest fire. The increase in costs would only be required until the increased hazard had abated, no longer than one and probably no longer than half a rotation. The item to be entered as damage would be the present worth of a terminating annual cost. Where f is the extra protection cost and e the number of years over which it will be incurred, the factor to be added to the damage formula becomes:

$$D_1 = \frac{f(1.0p^e - 1)}{(.0p)\ (1.0p^e)}$$

Increased costs for establishing new stands following fire should also be considered when estimating total damage. Where natural regeneration is depended upon, the damage factor would be the interest on the soil value, Se, for the extra number of years required for natural regeneration to take place following fire, x, as compared to logging. In the formula the damage factor would be:

$$D_2 = \frac{Se(1.0p^x - 1)}{1.0p^x}$$

Of course, there will be occasions when fire in mature timber will actually shorten the regeneration period compared to the cycle following logging. This could happen in jackpine stands. Then the damage factor, D_2, becomes negative and damages are reduced. When planting costs are required following fire in areas normally regenerated naturally following logging, the cost of planting should be added to the damage total. In such circumstances, however, there may be factors lessening the apparent extra damage indicated by the planting cost. The yield following planting might be larger and become merchantable sooner than ordinarily expected with natural regeneration following logging. Damage would be reduced by the difference between the present worth of the planted and natural stands, expected in p and n years respectively:

$$\frac{Yp}{1.0p^p} - \frac{Yn}{1.0p^n}$$

There would be a further slight decrease in damages since succeeding crops would be expected $p - n$ years sooner, but this factor may be ignored since it would be very small.

Sometimes burned areas may be invaded by inferior species, or succeeding stands of the same species may not be as well stocked as the previous stands. The resultant decrease in expected future income would be added to damages as the reduction in present worth of the next succeeding crop. It is unlikely that such a change would persist for more than one rotation. In formula form this factor would be represented as:

$$D_3 = \frac{Y - Y_1}{1.0p^n}$$

When stands are not destroyed but only injured by fire, account must be taken of the expected reductions in expected future income caused by insect and disease attacks and by reduced growth rates. The damage factor would be the present worth of the difference in value of the yields expected with and without fire injury:

$$D_4 = \frac{Y - Y_1}{1.0p^{n-a}}$$

The foregoing discussion, although not covering all possible variations of damage to standing timber, should be adequate for current conditions in Canada, and demonstrates the overriding principle that damage must be estimated as the

difference in property value caused by fire. Where the forest attributes in question are commonly marketed, market values should be used in appraisals; otherwise values must be approximated by estimating the present worth of future expected incomes and costs. Throughout the discussion it has been assumed that stands succeeding logging will have real dollar values, when mature, equal to those of their predecessors. This assumption does not imply that next-generation stands will reproduce the same species, volumes or qualities. The equal value assumption is probably conservative considering past trends in rising real prices of stumpage and the influences of improved silvicultural techniques should become more important in the future. On the other hand, and in spite of popular misconceptions to the contrary, use of compound discount formulae with the proper discount rate to estimate present worths of individual stands tends to overestimate market values. The equal real-value assumption seems to be the best expedient in the absence of knowledge of the future.

This discussion of primary damage has been confined to timber values. No attempt has been made to include other resource attributes such as watershed or recreation values. These aspects of the appraisal problem do not fall within the terms of references of this study.

It is assumed that primary fire damage to improvements such as buildings, bridges, length of useful service of woods roads, wood-in-process, etc., would be appraised separately following all forest fires. The appraisal criterion would be the difference in sale value resulting from fire, or the depreciated cost value for non-saleable property. This aspect of appraisal has caused little difficulty to fire control agencies, but it leads naturally to discussion of another aspect, secondary or indirect damage, that has received very little attention in Canada.

Secondary Damages

Secondary forest fire losses may be defined as net decreases in income or in the value of "things" related to wood production. Following a severe fire, or series of fires, in addition to the primary loss of stumpage, secondary losses could include effects on the values added by harvesting, transporting, milling and final manufacturing of wood products, plus any losses of income to businesses supplying the affected industries. To avoid double counting, any costs of fire control received by those temporarily unemployed because of the fires should be deducted from gross secondary damages. These costs already will have been included in the fire suppression accounts as distinct from damage.

As an example, it may be supposed that the small isolated world of community A is largely dependent upon a local sawmill that draws its logs from forests nearby, and a furniture plant that purchases its lumber from the sawmill. Suppose further that the timber holdings of the sawmill are fairly typical of Canadian conditions and contain a stock of mature timber plus a developing series of even-aged stands. Should a forest fire burn a portion of the mature timber stock, what sort of damages could result in addition to the primary timber damage that would amount to the value of timber burned calculated at going stumpage rates minus the value of material salvaged? First, the woods labour force might become temporarily unemployed for the duration of the fire, or more likely would change employment and become fire fighters. In both cases their loss of income would constitute a secondary damage chargeable to the fire. Only if their wages as fire fighters equalled their regular wages, an unlikely event, would there be no wage loss factor chargeable to the fire.

If the loggers were unable to carry on their normal employment, log production would be interrupted for the duration of the fire. If there were full employment of men and equipment in the community, the lost log production could not be made up later, and the firm would lose the value that would have been added to that of the standing timber through processing it to finished

lumber. The gross secondary loss factor would then equal the market value of the finished lumber production lost. The net secondary loss would be the market value of the lumber minus stumpage and loggers' wages. Stumpage values must be omitted since the trees were left standing for another time, while the loggers' wages have already been accounted for above.

If, in turn, the local sawmill were the sole source of supply for the furniture plant, the latter would also suffer a secondary loss because of the fire. This loss would equal the market value of furniture production less the cost of its lumber component. The remainder, the value added in furniture manufacture, would include secondary loss factors of other firms supplying the furniture plant.

In addition to the primary and secondary losses there could be tertiary losses chargeable to the fire. Secondary income losses suffered by the loggers, mill workers and others involved in the production of wood products could be shared by other businesses with whom the income losers normally dealt. The secondary losses would tend to have a negative multiplier effect on other incomes in the isolated community, resulting in magnified losses to the community at large. However, since the multiplier effect would be dependent upon society's marginal propensity to save, and since people would tend not to save or even to reduce savings in temporary periods of income loss, the negative multiplier effect would in all probability be very small.

In some instances fires may be so severe as to permanently disrupt the economy of a community. In such cases, secondary damages could loom large but could be estimated from decreased values of business, real estate and personal incomes, always guarding against double counting. If workers or businesses were forced to move to other communities to find employment, their costs of moving and re-establishment would be legitimate additions to secondary fire losses, assuming full employment elsewhere in the economy.

Returning from the artificial situation of the isolated community economy to the real world, we find the situation not nearly so bleak, but the secondary effects of fire more difficult to trace. To estimate net damages one must determine whether or not the losses suffered in one community are offset there or in some other community, as might occur if there were less than full employment. The affected sawmill might be able to make up its log shortage either by increasing its own cutting schedule or by purchasing logs elsewhere. If the replacement logs could be delivered to the mill for the same price as those that would have been delivered in the normal course of events, there would be no addition to the firm's damages above the primary timber damages. If fire were to destroy the most accessible timber on the firm's limits, a secondary loss would be the increased cost of operating less accessible stands than would have been logged in the absence of fire. If logging costs were expected to be higher for the next decade, the secondary damage would be the present value of this series of extra costs, assuming full employment. With something less than full employment, some or all of the extra costs would result in net benefit to otherwise unemployed factors.

There could be instances where forest fires so change the supply of available timber in a locality that the same demand for timber could result in higher stumpage prices being charged. The increase in stumpage price might be looked at as a benefit from the narrow viewpoint of the timber owner, but it would be offset by a corresponding loss to the forest products manufacturer, or to his customers if he were able to maintain production and pass his increased stumpage costs on to the consumer. Under such conditions the net secondary effect would be only a transfer of money. If, as would be more likely, the manufacturer were unable to pass his stumpage cost increase on to the consumer, except over an extended time, his manufacturing output would tend to fall, with concomitant ramifications through the local community. If the loss of production were not made up

elsewhere in the economy, assuming full employment, the secondary losses would equal the present worth of lost production. In turn, tertiary losses could be felt by these firms and individuals indirectly dependent on the manufacturing plant. If there were less than full employment elsewhere in the industry, the loss of production might be made up elsewhere, partially offsetting the secondary and tertiary losses.

Considering damages from the provincial or national viewpoint, a further source could be reductions in taxation revenues. Income, business, real estate and sales taxes could be affected and net reductions would be appropriately considered as additions to fire losses, but only if primary and secondary damages were calculated on an after-tax basis. Normally these damages would be worked out on a before-tax basis and possible reductions in taxation revenue would have been considered automatically.

Obviously, the secondary economic effects of fire will be difficult to measure. Generally they will be small enough to ignore, but following severe fire seasons such as experienced in 1958, 1960 and 1961, they could form an important component of the total. This is a field in which considerable basic research will be required if the full economic consequences of forest fires are to be determined. In the meantime, it is important to recognize the existence of secondary effects and to attempt to follow them through the economy. The principle of estimating the present worths of net decreases in income apply regardless of the type of damage involved.

DAMAGE APPRAISAL PROCEDURES OF CANADIAN PROVINCES

Appraisal of Damage to Crown Timberlands

Since about 90 per cent of the productive forest land in the provinces is publicly owned, problems of determining economic timber values become apparent immediately. Generally there are few competitive timber markets. The Crown in most provinces may be considered a monopolist vendor. In provinces where timber is sold by auction or tender some sort of market is present, but prices are still largely controlled by the Crown. In provinces where timber prices are established administratively there hardly may be a market at all in the economic sense. Charges for Crown timber may vary considerably above or below the marginal values of any particular stand of timber.

Some question arises as to which types of values are pertinent when considering publicly-controlled Crown lands. Should the values to be considered be those of the province as the vendor, or those of the wood-using firm purchasing Crown stumpage? Primary fire damages are incurred by those owning the timberlands; therefore, it is the value to the province that constitutes primary damages. The first consequence of fire in merchantable timber on Crown lands is that the destroyed timber cannot be sold, and the province is the initial loser. Secondly, damages may be suffered by those dealing directly or indirectly with the province, by other individuals, and by society collectively.

How then are damages to merchantable timber stands to be appraised? A discussion of stumpage appraisal methods, timber marketing, and determination of true economic worth of stumpage are beyond the scope of this paper. They are eminently important and difficult questions, but do not bear directly on the study at hand, namely standardization of damage appraisal techniques based on methods currently in use and sound principles, if indeed these are compatible. Even if current stumpage prices may not be accurate reflections of real worth in exchange, the position taken here is that the existing stumpage prices are consciously accepted by the provinces as value received, and must therefore be used in appraising primary damages.

Although primary damages are incurred by the Crown, this does not imply that damages do not also fall on the private firm purchasing from the province. Should a fire occur on a firm's limits of leased Crown lands and upset the firm's management plan and production schedule, heavy damages may result to the firm. The firm may be forced to log more expensive wood. But these damages, described in economic terms are secondary damages, are in *addition* to those suffered by the province as owner of the timberlands, and must be added to the primary damages when calculating total net damages, unless offset elsewhere in the forest economy.

There may be a further question when considering damages to publicly-owned timberlands. Should the damages be estimated as reductions in market values of forest property, or should they be estimated some other way so as to include consideration of the "public" or "social" viewpoint? Perhaps estimated market value of timberlands does not fully describe the public interest in the resource. How then should this problem be tackled? The principle of employing market values, or estimates thereof, is just as sound for appraisal of damages to Crown timberlands as it is for private timberlands. If, however, social values not reflected in market prices are damaged, these must be considered in *addition* to primary damages suffered by the province and secondary damages suffered by individuals or firms.

In summary then, damages to Crown timberlands should be appraised in the same way as those to private lands. First, the reduction in value of Crown timberlands must be determined. Second, the present worth of net income reductions of individuals and firms should be estimated. Third, damages to individual and collective "intangible" or social values should be considered.

Summary of Damage Appraisal Methods

The following table summarizes the relative excellence, in the economic sense, of the techniques used by the provinces to appraise damages to stands of mature timber. The headings indicate the more important economic concepts that should be used in damage appraisal. Whether or not these concepts are employed is indicated in the body of the table. Thus, if "Yes" is shown for all items for a province, the appraisal technique of that province could be considered as soundly based on economic principles. It does *not* necessarily indicate, however, that the appraisals so based, would yield accurate results. The methods of applying the concepts may not be ideal. Unit values used may not be reasonable estimates of marginal use value. The table applies only to the estimation of primary forest fire damages to stands of mature timber. As far as can be ascertained, no province attempts to estimate secondary losses to either private firms or to society.

Specific details of methods used by the various provinces are not given except in some instances where a method used in one province is significantly different than in others. It is the principles of appraisal that are of immediate concern. It is apparent from the table that none of the listed principles has been adopted unanimously. Some have not been adopted at all. The use of some of them will require considerable research to determine what happens following fires of various intensities in different seasons, on different sites, bearing different species. Nevertheless, enough of the principles are in common use to readily permit standardization of methods.

PROPOSED STANDARDIZATION OF APPRAISAL METHODS

If no consideration is given, for the time being, to some of the facets of damage appraisal that have not been adopted by the majority of the provinces, standardization may not be as difficult as it might appear. Rather than prescribe an ideal economic standard, it would be more appropriate at the outset to aim at an initial goal something less than perfect.

TABLE 1. CHECKLIST OF PRINCIPLES FOR APPRAISING DAMAGES TO MATURE TIMBER STANDS

Province	Timber Appraisal:						Consideration Given to:			
	Based on unit volumes	Rates varied for species	Rates varied to account for variations in logging chance	Rates based on end use	Rates equal to stumpage prices	Considers salvage values	Damage to site productivity	Increased protection costs	Increased establishment cost of next crop	Composition of succeeding stand
N.S.	No	No	No	No	No	No	No	No	No	No
N.B.	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No
P.Q.	Yes	No[1]	No	No	No[3]	No	Yes	Yes	No	No
Ont.	Yes	Yes	No	Yes	No[4]	No	No	No	No	No
Man.	Yes	Yes	Yes[2]	Yes	Yes	Yes	No	No	No	No
Sask.	Yes	Yes	No	Yes	Yes	No	No	No	No	No
Alta.	Yes	Yes	No	Yes	No[5]	No	No	No	No	No
B.C.	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No

[1] One rate for conifers and for deciduous.
[2] Rates not reduced below a minimum valuation scale.
[3] Includes allowances for increased protection and other costs.
[4] Average prices by species by management units.
[5] Equal to General Rates of Dues determined annually and used as upset prices for timber berth sales.
NOTE: Insufficient information was available regarding methods used in Newfoundland.

General Definition

Examination of methods currently in use suggests the following as a reasonable standard toward which to work. *Damage to stands of merchantable timber should be appraised as the reduction in market values of these properties, assuming that the succeeding crops will be similar to those which would have occurred following logging.* The simplifying assumption that stands succeeding fire would be similar to those succeeding logging is suggested because of the lack of information in the literature to suggest just what the differences might be, and because only two provinces currently consider damage to site productivity. Until fire effects on site productivity become documented, estimations of damages resulting from these effects should not be included in fire loss statistics, except as a separate item.

If the above definition of damages is accepted as a provisional goal, only a few relatively easily determined factors are required. These are the market value of timber per unit volume, timber volume per acre, number of acres burned, and value of material salvaged. In formula form, damages per acre are calculated as:

$$D = Y - S$$

as previously shown, or if P is the market value per unit volume of undamaged timber V_1, and S is the salvage value per unit volume salvaged, V_2, then:

$$D = PV_1 - SV_2.$$

It should be noted that this proposed standard appraisal method applies to *merchantable* timber only. It is expanded to include mature but non-merchantable timber in the following discussion.

Implications of Standard

The damage appraisal methods of most provinces are already similar to the proposed standard method except that some do not apply their regular stumpage appraisal techniques to damage appraisal and most neglect the ameliorating influence of salvage values. As shown in the Table some provinces base damage calculations on criteria such as administratively set general rates used as upset prices for timber sales, over-all average unit-volume values irrespective of species, or flat rates per acre irrespective of species or volumes involved. Damage estimates should be based on the market prices that would have obtained had the damaged stand been logged prior to burning. Damages would then be correctly based on prospective end uses and going prices of the timber involved.

More disconcerting implications arise when considering the inclusion of salvage values in the appraisal formula, especially for those provinces in which stumpage is sold, and damages appraised, at flat rates per unit volume depending only on species and end use. In provinces employing variants of standard stumpage appraisal techniques, such as the Rothery, overturn, or investment methods, the inclusion of salvage value in the damage calculation should create no particular difficulties. On the other hand, the inclusion of salvage considerations by provinces selling timber at single province-wide rates could yield strange results. As things stand now, damages from fires in readily accessible stands would be the same as those in similar but more remote stands as a result of these province-wide stumpage rates. This anomalous situation apparently would be accentuated if gross damage estimates were reduced to account for the value of timber salvaged, since the economic feasibility of salvage operations decreases with distance from markets, other factors being equal. It is sometimes argued, therefore, that salvage values should not be considered in damage appraisals. The root of the problem, however, is not the inclusion of salvage in the damage formula, but the use of province-wide stumpage prices in the calculation of damages. A means for at least partially overcoming this difficulty is proposed in the following discussion.

"Surplus" Timber

A dominant characteristic of Canadian forests is the relative abundance of mature timber. Unlike the model firms described in textbooks where forests, built up from bare land, consist of even-aged blocks of timber with one block becoming merchantable each year, the forests of Canadian concerns, at least the larger ones, tend to consist of reserves of mature timber plus developing sequences of even-aged stands. The currently surplus reserves of mature timber must serve as stocks for present and future logging until previously logged areas will have produced second crops. Here one of the principal features differentiating forestry from other businesses comes into play; the merchantable product, timber, may be stored for a number of years as capital, in many instances continuing to add to the final size, quality, and value of the eventual product. In some respects these reserves of mature timber are economically akin to developing stands of young growth. For example, a firm contemplating purchase of a block of mature timber to be harvested over a period of years would not evaluate all the stands at going stumpage prices. Even assuming the hypothetical situation of a completely homogeneous forest with equal logging chances throughout, the firm nevertheless would be willing to pay only discounted prices for all timber in excess of its immediate requirements. Although mature, the values of timber to be harvested in future years would be estimated much in the same way as if it were currently immature.

It sometimes has been suggested that fire damage to stands of mature timber should be treated in much the same way. Since, at least on a broad provincial basis, there is a surplus of currently available mature timber, it would require a very large fire, or series of fires, before current actual production of pulpwood or sawlogs would be affected. Even assuming complete destruction of stands burned over, a most unusual circumstance, logging plans could be altered in the event of fires, and other mature stands could be logged. On this basis it is argued that, except for stands currently being exploited, the economic effects of fire in mature forests are not immediate, but can be postponed until some time in the future when the stands eventually would have been harvested as the last mature ones available. Consequently, goes the argument, the majority of fire losses to mature timber should be appraised at discounted rates.

The same arguments used to support this position can also be used against it to support what appears to be a more logical view. If logging plans could be altered after a fire, presumably they could have been altered prior to the fire, thereby preventing damage to the mature stands. The fact that the average forester does not have access to the requisite divine prophet when drawing up logging plans is inconsequential. The important point is that, other things being equal as in our hypothetical forest, logging plans can be altered. The approximate economic equivalent of currently surplus mature timber and young growth ends with the occurence of fire. Even though a firm may not consider logging a particular mature stand for, say, 15 years from date of purchase, and consequently may value it at time of purchase at only about half current stumpage rates, depending on the discount rate, the same firm would appraise damages to the stand at full stumpage rates should it be burned earlier, even in the year of purchase. The mature timber was also merchantable, even though held as a part of capital reserves for future logging. (The interesting implications of these arguments in relation to the insurance of standing timber and the settlement of claims are left to the reader.) Since the timber capital is mature, it is capable of being converted immediately to timber product, unlike young timber stocks that must be held for a number of years as accumulating capital before becoming convertible to product.

Another way to look at values of currently surplus mature timber would be to consider the surplus itself as insurance. If firms hold more forest lands than their current utilization rates indicate are necessary, the "excess" may be held, at

least in part, for insurance reasons. These considerations might include insurance against natural catastrophes such as fire, insurance of increased wood supplies for future plant expansion, or insurance against rising prices for purchased wood. The marginal cost of this insurance to society would be the going prices of standing timber obtainable in the market were the timber not held as insurance. This does not mean that all currently surplus accessible mature timber could be sold, and sold at going prices, but only the fractional extra amounts typical of annual forest fire losses that are marginal in relation to annual cutting budgets.

These arguments hold only for those regions where there is a timber market. What of those forested regions where there is no current market for timber? The presently inaccessible productive forests of most provinces contain large volumes of mature timber. The Prairie Provinces, for example, contain millions of cords of pulpwood, but at this time there are only limited markets. Until very recently there was only a small timber market in the Peace River region of British Columbia, but in 1964 a number of firms announced plans to build pulp mills in the region, thus creating a market for pulpwood. Recent announcements suggest a mill may be established to draw raw material from currently unmarketable Labrador forests. Perhaps here lies the key to damage appraisal of marketless mature timber stands. On one hand such material is similar to young growth in that it has values only in the future, and damages to it should be estimated accordingly. But currently marketless mature timber is unlike immature timber in market areas in that it may be impossible to estimate just when the future market can be expected to come into existence, while merchantability ages for immature timber in market areas can be established readily. The present worth of currently inaccessible mature timber is considerably more speculative than the present worth of young stands in timberlands currently being exploited. Indeed it may not be heretical to suggest that some of these economically inaccessible mature forests should be allowed to burn so that succeeding stands would be closer to prime condition when the areas eventually become accessible for logging. On the other hand, a "road to resources" could suddenly change the entire accessibility picture. The problem is so shrouded with uncertainty that it would be folly to attempt any complicated or detailed method of appraising damage in such areas, particularly in light of the generalized appraisal techniques in use for accessible forests.

Fire Damage Appraisal Zones

Damage appraisal techniques would be improved even if only a rough rule of thumb could be developed for appraisals in inaccessible areas. To delineate the problem area it is proposed first that the forests of each province or region thereof be divided into three zones based on economic accessibility. The first might be termed the "Zone of Logging Management". It should include all that productive forest land where timber is now or could now be extracted by efficient operators and placed on the competitive market without financial loss. The definition of this zone stipulates the existence of a market; consequently the zone boundaries may be expected to differ for different species and products. For instance, in a pulpwood timbershed of a firm using only softwoods, stands of poplar might have only speculative future values unless used for some other purpose. The general fire damage appraisal techniques already discussed apply in the Zone of Logging Management.

A second zone, the zone of potential wood supply might be termed the "Zone of Speculation" for damage appraisal purposes. This is the zone where the productive forests are still inaccessible and valuation of standing timber is difficult because of the uncertainties entailed in estimating how long it will be before the timber actually becomes merchantable. It is thought that the definition of this zone will have to be rather arbitrary. The Zone of Speculation is defined

to include those productive forest areas where timber cannot be extracted economically at present but which are expected to become economically accessible within the next 45 years. The third zone, might be called the "Zone of Insignificance" for timber damages and includes all non-productive forest areas and those productive forest areas expected to remain economically inaccessible for logging for at least 45 years. The reasoning behind these definitions and use of the zones for appraisal follow.

The general formula for damages in inaccessible areas would be similar to that previously described:

$$D = \frac{Y}{1.0p^x} + \frac{Se}{1.0p^x} + \frac{E}{1.0p^x} - Se - E,$$

where x is the period of speculation, the number of years between the time a mature stand burns, the present, and the year the stand otherwise would have been expected to become merchantable. Recalling that the value of the land for growing timber, Se, is equal to the present worth of all future crops, or $\frac{Y}{1.0p^n - 1}$ — E, where n is the rotation age, it is apparent that the estimation of value of inaccessible timber is primarily dependent on three factors: Y, x and n. If the assumption is made that the monetary yield, Y, expected from all future stands will be the same as that current in the nearest portion of the Zone of Logging Management, and this assumption seems no worse than others that might be made, then the elements remaining, x, and n, both relate to time speculation. A single rotation age, n, is required, one that would permit development of merchantable-sized stands of all species. Because of site and species characteristics, any such magic number would be a very rough estimation indeed; but since only a rule of thumb is required, some latitude for error is allowable. Consultation with silviculturists and perusal of the literature indicates that 80 years might be a reasonable average rotation age to produce stands of at least minimum merchantability.

The period of speculation, x, will vary depending on the location of the stands in question, on species, and on products under consideration; however, it should be possible to reduce the limits of x from 1 to x years to some more significant range. To begin with, acceptance of a rotation, n, of 80 years immediately reduces the period of concern to 80 years, since burned stands more than 80 years away from economic accessibility would be expected to be replaced naturally before logging operations reached them.

Because the appraisal of damages to future values requires the discounting of these values to the present, and since the assumptions required are open to error, it would not seem logical to be concerned with values amounting to but small fractions of the market values of currently accessible stands. Sewell *et al.* (1962) used 10 per cent as the cut off point in their discussion of cost-benefit analysis, and it seems sensible to adopt the same procedure here. The discount rate employed has a strong influence on the time required to reduce present worths to 10 per cent of expected future returns, but if the rate of 5 per cent were used, combined with a rotation period of 80 years for stands following fire, it would produce present values of less than 10 per cent of future expectations for any period beyond about 45 years. Any stands not expected to be economically accessible in the next 45 years are assigned to the Zone of Insignificance, leaving the Zone of Speculation with those currently inaccessible stands that are expected to become accessible sometime during the next 45 years.

Looking into the future, Davis *et al.* (1957) estimated that between 1954 and 1980 total annual forest depletion, including losses through fire, would amount to 74 per cent of the allowable cut on forests considered accessible in 1954, and 57 per cent of the country's total forest potential. In the Atlantic region the

depletion estimated for 1980 was but 52 per cent of the allowable cut at that time, the large surplus mainly accounted for by forests of Labrador. The same depletion would amount to 70 per cent of the accessible Maritimes portion of the region. In Ontario and Quebec depletion was expected to amount to 61 per cent of the allowable cut for all species in 1980, but with softwoods accounting for only 65 per cent of the potential cut. In the Prairies and North region, total depletion was estimated at only 27 per cent of the expected allowable cut in 1980. In British Columbia, however, depletion was expected to grow to 86 per cent of the allowable cut, requiring considerable development of new sources of timber in the interior of the province.

On the whole, these estimates suggest that there may be little requirement for extension of logging operations beyond currently accessible timber for the next 15 years. But our appraisal zones for fire losses do not coincide with the generalized accessibility criteria used by Davis *et al.* (1957). Our Zone of Logging Management would differ considerably from their criteria, depending as it does upon the marketability of the individual species involved. While the softwoods of an entire pulpwood lease might be considered in the Zone of Logging Management, stands of poplar in the same area would be in the Zone of Speculation if there were currently no local market for that species. It does not seem possible to push the first significant data of speculation further into the future than one year since in some areas, and for some species, there are strong expectations of markets developing within a very few years. It should be possible, however, to divide the Zone of Speculation into sections to improve the appraisal technique. It would seem logical to suppose that speculation for the short-term future, perhaps a decade, would be more accurate than that for the long-run. Vision of the middle future, perhaps up to 25 years, is hazy, while beyond that it is close to fogbound.

The search for a rule-of-thumb appraisal technique for the Zone of Speculation has now been narrowed considerably. If the discount rate of 5 per cent were used, current damage to timber not expected to have become marketable for up to a decade would range down from about 94 to 60 per cent of expected future values. If it could be assumed that there were approximately equal areas of mature timber for each year of speculation *X1*, from 1 to 10 years, and that these would tend to be burned in equal proportions, then average damages would amount to about 77 per cent of average expected future returns. Using the same reasoning, average damages to timber in the midportion of the Zone of Speculation, *X2*, expected to become merchantable between 11 and 25 years in the future, would amount to 41 per cent of expected future returns. In the far period of speculation, 26-45 years, average damages would be about 17 per cent of anticipated returns. Considering the number of rather brash assumptions made to this point, however, it would seem appropriate to round off the value percentages in order to simplify calculations. It is proposed that in the Zone of Speculation, mature timber expected to become merchantable in 1 to 10 years be appraised at 80 per cent of current stumpage rates, and timber expected to become merchantable in the 11 to 25 and 26 to 45 year periods of the future be appraised at 40 per cent and 20 per cent of current stumpage rates respectively. As the name suggests, it is proposed that no economic damage be ascribed to standing timber in the Zone of Insignificance.

Consolidation of Recommendations

For damage appraisal purposes it is recommended that the forests of each province be divided into three zones for each timber species. The definition of zones and appraisal techniques applicable thereto are as follows:

Zone of Logging Management:

Includes all that productive forest land where timber is now or could now be extracted by efficient operators and placed on the competitive market without

financial loss. Fire damage to mature merchantable timber per acre is appraised by the standard formula:

$$D = PV_1 - SV_2$$

where P is the market value per unit volume of undamaged timber; V_1 is the volume per acre of undamaged timber; S is the value per unit volume of material salvaged; V_2 is the volume per acre salvaged.

Other facets of damage, such as to site productivity or secondary interests should be treated separately from the main timber damages. If sufficient data are available, the techniques described elsewhere in this paper may be applied.

Zone of Speculation:

Includes all those productive forest areas where timber of individual species cannot be extracted economically at present but which are expected to become economically accessible within the next 45 years. Mature timber in this zone should be appraised at one of three proportions of the market values of the nearest similar stands in the Zone of Logging Management, the appropriate proportion depending on when the timber is expected to become merchantable in the absence of fire. The valuation percentages selected are as follows:

Years of Speculation	*Valuation Percentage*
1 — 10	80
11 — 25	40
26 — 45	20

Zone of Insignificance:

Includes all productive forest areas not expected to become economically accessible within 45 years as well as all non-productive forest areas. Fire damage to mature timber in this zone is considered to be nil.

SUMMARY

At the request of the Associate Committee on Forest Fire Protection, National Research Council, this study was undertaken to find an approach to standardization of methods of appraising forest fire damages to stands of mature timber. Any proposal offered for Canada-wide adoption was to be based on both sound economic concepts and on methods of appraisal currently used by governmental fire control agencies. Emphasis was placed on estimating damage to Crown-owned timber.

Damages were considered in the context of economic guides for choices of alternatives available in forest management, fire control in particular. Damage from forest fires was defined as the resultant net total reduction in value and/or increase in cost of all factors of production, and other assets, in the economy directly or indirectly dependent on the forest resources.

The goal of forestry, and therefore fire control, was taken to be a maximum contribution to a maximum national income, recognizing that this goal might produce something less than maximum economic welfare. To be consistent with this goal it was argued that forest fire damage appraisal techniques should recognize and describe, in monetary terms whenever possible the impact of all effects of fire both short and long range, borne by individuals and by society as a whole.

For economic planning purposes damages should be estimated from market values. Where market values are unavailable they should be estimated as capitalizations of expected future market values.

Dealing with future values requires selection of a discount rate. A rate of 5 per cent was tentatively selected as representing the expected average rate of social time discount.

A set of standard formulae was presented for appraising most types of primary damage to the timber producing aspects of the forest resource. Methods for estimating possible secondary damages were also explored. Little documentation on the

effects of fire as compared to logging on regeneration and other site characteristics was found in the literature. In addition, analysis of current provincial appraisal procedures indicated that any first proposal for standardization of methods on a Canada-wide basis should be confined to damage to existing mature timber.

It was proposed that the forests of each province be divided into three zones, by species, for damage appraisal purposes. These zones were referred to as Logging Management, Speculation and Insignificance. In the Zone of Logging Management it was proposed that damage to merchantable timber be estimated as the market value of timber damaged less the market value of timber salvaged. In the Zone of Speculation the inaccessible mature timber should be appraised at 80, 40 or 20 per cent of current market values of the nearest similar accessible stands, the percentage depending on whether the area in question is expected to become accessible within 10 years, from 11 to 25 years, or from 26 to 45 years in the future. Mature timber not expected to become accessible for at least 46 years was classed in the Zone of Insignificance. It was proposed that no damage to standing timber be ascribed in this zone.

SOMMAIRE

La présente étude a été entreprise à la demande du Comité adjoint de la protection contre les incendies de forêt du Conseil national de la recherche *("Associate Committee on Forest Fire Protection of the National Research Council")*, afin de trouver un moyen de normaliser les méthodes utilisées pour évaluer les dommages causés par les incendies de forêt aux peuplements de bois arrivé à maturité. Toute proposition avancée en vue de son adoption dans l'ensemble du Canada devait être fondée à la fois sur des principes économiques sains et sur des méthodes d'évaluation couramment appliquées par les services gouvernementaux de lutte contre les incendies. L'accent a été mis sur l'évaluation de dommages causés à du bois appartenant à la Couronne.

La question des dommages a été envisagée dans le contexte des directives économiques pour le choix d'une des solutions possibles en matière de gestion forestière en général, et de lutte contre les incendies en particulier. Les dommages causés par les incendies de forêt se définissent comme étant une diminution totale nette de valeur et (ou) un accroissement du coût de tous les facteurs de production, ainsi que des autres éléments d'actif économiques qui dépendent directement ou indirectement des ressources forestières.

On a admis que la sylviculture et, par voie de conséquence, la lutte contre les incendies, a pour but d'apporter une contribution maximale à un revenu national maximal, tout en reconnaissant que cet objectif pourra ne pas coïncider totalement avec celui du bien-être économique maximal. Pour répondre à cet objectif, on a fait observer que les procédés d'évaluation des dommages causés par les incendies de forêt devraient identifier et décrire, en termes monétaires chaque fois que possible, les répercussions de toutes les conséquences de l'incendie, aussi bien à court qu'à long terme, tant pour des particuliers que pour l'ensemble de la collectivité.

Aux fins de la planification économique, les dommages devraient être évalués à partir des valeurs marchandes. Lorsqu'on ne dispose pas de valeurs marchandes, les dommages devraient être évalués sur la base d'une capitalisation des valeurs marchandes futures prévues.

Lorsqu'on traite de valeurs futures, il faut choisir un taux d'escompte. Le taux de 5% a été provisoirement choisi comme représentant le taux social d'escompte moyen prévu.

Une série de formules standard ont été proposées pour évaluer la plupart des types de dommages primaires causés aux capacités productrices de bois des ressources forestières. On a également examiné des méthodes d'évaluation des dommages secondaires éventuels. La documentation publiée n'a fourni que peu de

renseignements sur les effets comparés des incendies et des coupes d'exploitation sur la régénération et sur d'autres facteurs intéressant la forêt affectée. En outre, l'analyse des procédés d'évaluation actuellement appliqués dans les provinces a montré qu'une première proposition tendant à normaliser les méthodes pour l'ensemble du Canada devrait viser uniquement le cas de dommages causés à du bois arrivé à maturité déjà existant.

Il a été proposé qu'aux fins d'évaluation des dommages, les forêts de chaque province soient subdivisées en trois zones, par essences. Ces zones ont été désignées sous les noms de Zone d'exploitation, Zone de spéculation et Zone d'insignifiance. En ce qui concerne la Zone d'exploitation, il a été proposé que les dommages causés à du bois vendable soient évalués à la valeur marchande du bois endommagé, diminuée de la valeur marchande du bois récupéré. Dans la Zone de spéculation, le bois arrivé à maturité mais inaccessible devrait être évalué à 80%, 40% ou 20% des valeurs marchandes du moment pour le bois des peuplements accessibles analogues les plus proches, le pourcentage dépendant du point de savoir si le peuplement considéré doit normalement devenir accessible dans 10 ans au maximum, dans 11 à 25 ans ou dans 26 à 45 ans. Le bois arrivé à maturité mais que l'on ne s'attend pas à voir devenir accessible d'ici 46 années au moins serait classé dans la Zone d'insignifiance. Il est proposé de ne procéder à aucune évaluation de dommages en ce qui concerne le bois sur pied ressortissant à cette zone.

REFERENCES

ANON. 1932. Seventy-first annual report of the Dept. of Lands and Mines. Fredericton, N.B.

——— 1956. Instructions to forest officers on policies and procedures. B.C. Forest Service, Victoria.

——— 1957. Report of the New Brunswick Forest Development Commission. Fredericton, N.B.

——— 1958. Proposed practices for economic analysis of river basin projects. U.S. Inter-Agency Committee on Water Resources. Washington, D.C.

——— 1960. Department of Forestry Act. Statutes of Canada, 1960, 8-9 Eliz. II, Vol. 1, Chap. 41.

CHAPMAN, H. H. and W. H. MEYER. 1947. Forest Valuation. McGraw-Hill Book Co. Inc., New York. (XIV+521).

CRAIG, R. B., MARBURG, T. F., and G. L. HAYES. 1946. Fire losses and justifiable protection costs in the coastal plain region of South Carolina. U.S. Dept. Agric., For. Serv. Southeast For. Expt. Sta. mimeo.

DAVIS, J., *et al.* 1957. The outlook for the Canadian forest industries. Royal Commission on Canada's Economic Prospects, Queen's Printer, Ottawa.

HIRSHLEIFER, J., DE HAVEN, J. C., and J. W. MILLIMAN. 1960. Water supply. Univ. of Chicago Press. (XII+378).

KEYNES, J. M. 1936. The general theory of employment, interest, and money. MacMillan & Co. Ltd., London. (XII+403).

KRUTILLA, J. V. and O. ECKSTEIN. 1958. Multiple purpose river development. Resources for the Future, Inc. publication. John Hopkins Press, Baltimore. (XIV+301).

LITTLE, I. M. D. 1957. Critique of welfare economics. Oxford Univ. Press, London.

MARGLIN, S. A. 1962. Economic factors affecting system design. *In* Design of water-resource systems, by Arthur Maass, *et al.* Harvard Univ. Press, Cambridge, Mass. (XVII+620).

——— 1963. The social rate of discount and the optimal rate of investment. Quart. Jour. Econ., LXXVII(1):95-111.

MITCHELL, J. A. 1954. Some thoughts on forest fire damage appraisal. U.S. Dept. Agric., For. Serv., Lake States For. Expt. Sta., Misc. Report 29.

PREBBLE, M. L. and L. M. GARDINER. 1958. Degrade and value loss in fire-killed pine in the Mississagi area of Ontario. For. Chron., 34:139-158.

REUBER, G. L. and R. J. WONNACOTT. 1961. The cost of capital in Canada. Resources for the Future, Inc., Washington, D.C. (IX+101).

SCITOVSKY, T. 1951. Welfare and competition. Richard D. Irwing, Inc., Chicago. (XVI+457).

SEWELL, W. R. D. *et al.* 1962. Guide to benefit-cost analysis. Resources for Tomorrow. Queen's Printer, Ottawa.

SKOLKO, A. J. 1947. Deterioration of fire-killed pulpwood stands in eastern Canada. For. Chron. 23:128-144.

VAUX, H. J. 1953. Content of forest economics. *In* Research in the economics of forestry, edited by W. A. Duerr and H. J. Vaux. Pack Foundation. Washington, D.C.

WEITZELL, E. C. 1953. Evaluation of public forestry programs. *In* Research in the economics of forestry, edited by W. A. Duerr and H. J. Vaux. Pack Foundation, Washington, D.C.

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