advantages that I have suggested for owner-operator forestry can also be integrated within corporate forest ownership and its concomitant financial and servicing resources. Large manufacturing organizations contract out production of components and ingredients vital to the finished product; the food processing industry commonly purchases inputs from numerous small suppliers and/or contract growers. It seems reasonable to foresee independent farm forestry growers arranging forward wood supply contracts with processors for all or part of their annual harvestable increment. Given initiative and a willingness to experiment, the large companies/corporations may consider financing forest managers into established forests with current or oncoming yield that is regulated or predetermined by contracts from the management specialists. Contract logging and transport would function much as it does now in forestry. Additional harvest volumes or value through good practice could be treated as a bonus to efficient forest management. Restocking and tending treatments could also be handled by such management contracts. The "profit motive" would operate strongly in such situations and incentive would be far closer to the work face than in current company or corporation balance sheets.

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Economics of fire prevention in New Zealand plantations

A.N. Cooper and C. Ashley-Jones

ABSTRACT

The history of expenditure and other data on NZ Forest Service fire prevention confirms that fire prevention expenditure per hectare is greater in the high-risk districts compared with the moderate and low-risk districts. However, there has been considerable variation in expenditure over time. In the past, these expenditure levels have been based on management's experience, intuition, and local assessments. Such practices do not necessarily provide an optimal economic solution. This requires expenditure to be such that expected costs and losses are minimized. Managers are then required to trade-off between efficiency and risk associated with their fire prevention programme.

When exotic plantations were first established in New Zealand in the late 1800s fire prevention measures were very quickly found to be essential. Ideas on equipment strategies and legislation were gleaned from North America and as a result fire prevention costs became part and parcel of the plantation management (Cooper 1981).

Over the intervening years serious fires have occurred in both State and private plantations. They range up to 13,000 ha in the Tahorakuri Block during the 1946 Taupo fires (Fenton 1951, Church and Stanley - Harris 1967). Fires in the recent dry seasons of 1981-83 have kept forest managers on their toes and fire prevention costs are therefore still an essential item of expenditure in the management of exotic plantations today, especially as young forests planted in the 1960s increase in value with the approach of harvesting.

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Historic Costs 1900-1966

Data are difficult to obtain. A study of early annual reports of the Lands and Survey Department (which was responsible for State forests until 1918) from 1896 onwards reveal some crumbs, one being that the costs of plantation fire prevention was "6 pence per 100 acres" in the early 1900s.

In the 1912/13 annual report H.A. Goudie, superintending nurseryman, North Island, stated that "the present system of firebreaks is, on the whole, satisfactory, but as it entails an annual expenditure of 10 pence for every acre planted . . .". He went on to say that this sum compounded at four and a half percent amounted to 12 pounds in 60 years; it was better therefore to sow pasture and graze to bring in a "profit at the rate of seven and a half percent on the outlay".

A few more details are available from the State Forest Service annual report to the Commissioner of State Forests.

In the 1923 report the costs of protection, prevention, detection, and control amounted to 2297 pounds 4 shillings and sixpence and the plantations totalled 44,646 acres. Costs were therefore 12 pence or 1 shilling per acre. The value of timber destroyed totalled 6080 pounds but some of this was indigenous forest and an accurate costing is impossible to obtain. At that time wages for patrols amounted to 84 percent of costs with equipment and transport taking up the remainder. Cost analysis in annual reports ceased after 1928 and have not been continued to the present day.

Fire protection cost data appear to have been poorly recorded because managers had to rely on time-consuming handwritten, typewritten or the Hollerith commercial accounting systems. The advent of the first electronic commercial accounting systems in 1967 changed this situation.

Costs - 1967 to 1982

It is useful to consider these data together as a consistent system was employed over this time period. Examination of average costs/ha in 1983 dollars, by NZ Forest Service Conservancies, show changes from a low to a higher expenditure, or vice versa, from year to year which cannot always be accounted for by either wet seasons or high fire danger (Table 1). Improved salaries or wage awards such as occurred in 1977 translated into increased 1978 costs. In the case of Canterbury, windthrow, log salvage and the need for extreme care in the years 1975-1979 also reflected increased costs per hectare. In 1980-81 the onset of a dry spell with an increased number of days in high and extreme fire hazards resulted in some increase in prevention costs, particularly in Nelson, Westland and Canterbury.

The data confirm generally what we would expect. Expenditure per hectare is greater in high-risk than moderate or low-risk areas — for example, in Canterbury compared to Auckland and Southland, respectively. It is difficult to pinpoint why fire prevention expenditure moves unevenly

TABLE 1
FIRE PREVENTION COSTS PER HECTARE (IN 1983 DOLLARS) BY NZ FOREST SERVICE CONSERVANCIES, 1967-1982

Conservancy	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Mean
Auckland	8.9	10.8	9.9	9.0	6.4	3.0	6.7	6.0	4.8	2.3	2.8	10.0	8.5	5.2	5.6	3.0	6.4
Rotorua	4.0	3.8	3.8	4.0	2.6	3.2	2.6	3.3	3.0	4.7	4.6	6.0	3.0	4.8	4.8	3.4	3.8
Wellington	3.9	5.8	4.8	6.0	4.6	3.2	5.0	4.8	4.2	3.7	4.3	7.7	6.8	4.8	5.7	3.7	4.9
Nelson	7.0	6.5	6.1	5.4	6.6	7.0	5.8	6.3	7.3	5.8	6.3	7.4	8.1	5.9	9.4	6.0	6.7
Westland	—	—	4.1	4.8	0.5	3.3	1.7	4.2	8.6	3.8	1.1	2.5	4.4	5.0	6.6	4.6	4.0
Canterbury	7.7	7.2	7.0	8.5	9.6	9.0	12.0	10.2	11.1*	15.2*	15.8	16.7*	13.0	8.0	11.5	7.3	11.6
Southland	2.7	3.5	4.1	3.1	2.5	2.8	2.8	3.1	2.9	6.2	6.8	5.3	5.4	4.0	4.2	4.0	4.0

*Costs for 1975-1978 include provisions made for extra danger — windthrow log salvage operations.

with time — perhaps budgets were not tightly controlled and consistently planned and there were no economic guidelines.

Recent Costs 1982-1986

From 1982, the Forest Service accounting system became more detailed and employed the System of Integrated Government Management Accounting (SIGMA). This system which compares budget against expenditure, has an individual code for every responsibility centre and a different SIGMA code for every operation and item numbers within each SIGMA code for a further breakdown of cost items. Countrywide expenditure again shows anomalies (Table 2). There was a sudden surge, for instance, in patrolling, with a jump from $790,441 in 31.3.85 to $1,072, 418 in 1986 (which was a moderate year for fire danger). Note that fire break expenditure has been decreasing since 1983/84. The cost on a per hectare basis looks very reasonable, as do the provisions for training and water supplies. Operations remain the largest single item which has been increasing sharply over the years even though fire dangers have been only moderate during that time. Operations include maintenance of gear and equipment, running costs, some depreciation and purchase of a multitude of day-to-day supplies.

Expenditure in Relation to Fire Hazard

The 18 Forest Service districts are reasonably well defined geographically and climatically and forests within each district tend to cooperate with fire control. Excluding Kaingaroa, the State plantation areas average 25,000 ha and generally contain a spread of age classes. Therefore expenditure for the 1984-85 season was related to fire hazard by districts (Table 3). Fire hazard was defined as the percentage of days in the fire season (November to March) with an extreme or high rating using the Fire Weather Index ratings from 1981 to 1985 (NZ Forest Service unpublished). The provision of capital equipment in the districts was also tabulated.

This analysis places Taupo district in the low hazard group whereas in fact it should be in the moderate hazard category because of the type of vegetation and the high

TABLE 2
FIRE PREVENTION EXPENDITURE IN PLANTATIONS OF THE FOREST SERVICE FROM 1982 TO 1986
(Year April 1 to March 31 and not corrected for inflation)

Item	1986	1985	1984	1983	1982
			$000		
Patrol	1072	790	755	768	5*
Look-out	170	127	119	123	132
Operations	2437	2236	1956	1655	1355
Fire Breaks	853	976	1021	779	543
Publicity	42	35*	60**	30**	95
Training	575	531	362	328	326
Water	307	462	366	201	245
TOTALS	5457	5159	4638	3884	2760
$/ha	9.2	9.1	8.5	7.4	5.5
Fire Fighting Cost ($000)	122	193	73	221	50

* No standby included this year
** Estimated Costs

TABLE 3
STATE FIRE PREVENTION EXPENDITURE IN RELATION TO FIRE HAZARD BY NZ FOREST SERVICE DISTRICTS

NZ Forest Service Forest Districts	Days in Extreme and High Danger 1981/85 (%)	State Plantation Area (000 ha)	Prevention Expenditure 1984/85 ($ per ha)	*Capital Value of Fire Equipment ($ per ha)
High				
Masterton	30	12.7	9.9	24.6
Napier	29	36.0	5.0	16.7
Canterbury	28	34.2	9.1	41.0
Nelson	26	44.2	12.1	13.5
Gisborne	24	37.9	7.8	13.7
Wanganui	20	22.2	4.6	16.9
Mean			8.2	
Moderate				
Kaikohe	18	33.3	6.9	19.5
Tauranga	16	9.4	4.3	24.8
Blenheim	16	14.8	9.3	17.7
Dunedin	14	26.9	7.3	15.5
Waitemata	13	17.0	7.2	24.1
Thames	13	23.9	4.3	14.4
Kaingaroa**	12	127.6	4.3	4.7
Mean			5.2	
Low				
Taupo	7	52.6	7.9	9.5
Te Kuiti	5	9.0	7.6	19.3
Western Southland	3	16.8	5.9	15.5
Tapanui	3	19.5	6.2	19.4
Westland	0	21.8	9.6	16.8
Mean			7.6	

* Capital value fire equipment included fire engines, smoke chasers, pumps and hoses. Buildings excluded.
** Kaingaroa includes Whaka SFP and other blocks in region.

recreational use. The analysis also shows that several North Island districts have a similar fire hazard to Canterbury, the area which foresters have traditionally considered one of the worst in New Zealand. The high capital expenditure per hectare of plantation in Canterbury may tend to reflect this belief, but it also results from the large area of high country that is under its jurisdiction.

Table 3 shows that for the fire season 1984/85 (which was a moderate one for numbers of fires and area burnt) the cost of fire prevention per hectare was greater for those districts in the high category ($8.2). than for those in the moderate hazard range ($5.2). Without Kaingaroa Forest figures, with its advantages of size, the cost rises from $5.2 to $6.3, which is still substantially less than for high-hazard districts. There is a big difference, however, between Wanganui and Napier Districts at about $5 a ha and Nelson at $12. In Nelson extra firebreak and water supply work for this year resulted in higher costs.

The only anomaly in the moderate districts is the high figure of $9.3 for Blenheim which is perhaps disadvantaged by a relatively small area of plantation as well as the fact that the Forest Service provides assistance to others in the area.

In the low hazard areas the average per hectare is greater than those districts in the moderate category. The Taupo position has been examined earlier. Westland costs are high but that area has a unique prolem in that exotic plantations are intermixed with indigenous forest, second growth areas, and farms which use fire to control gorse and other weeds. In addition equipment is held to fight fires on other State land.

No guidelines are available on how much capital fire equipment should be held on plantations to extinguish fires. There is no research or other data to determine what suppression capability is necessary to deal with fires in radiata pine plantations where pruning and thinning to waste have been carried out, and which often have a considerable amount of understorey.

Experience, intuition and local assessment over the past 20 years in State exotic plantations have resulted in the provision, on average, of one fire engine per 5000 ha approximately, one fire fighting pump per 1000 ha, 500m of hose per pump and 0.50 m hose per ha.

Without the benefit of research, it appears that State forest managers in New Zealand have organized their major equipment at a reasonably effective level. Fire data show that fires in exotic forests do not become large unless weather conditions are adverse. The Hira fire in 1981 was an example of extreme wind conditions. The percentage of State forest loss has been reduced from 0.2 percent in the 1950s to 0.05 percent average for the years 1978-1983. This is slightly less than 300 ha per annum (NZ Forest Service unpublished data).

Burnt stand of *Pinus radiata* — Balmoral Forest Fire, 1955. (Photo: J.H. Johns, ARPS, NZ Forest Service)

Private Forest Owners' Costs

Where large blocks of private forest are close together, owners can form a rural fire district with a representative committee as the rural fire authority under the fire legislation. The committee can then levy forest owners for the cost of mutual fire prevention measures and a rate per hectare is struck. Figures vary at the present time between $1.30 and $2.60 per ha. Additional costs to the large companies who hold the major equipment and do fire prevention work on their own account usually amount to an extra $3 to $5 per ha.

For plantations outside rural fire committee districts, owners do not have the advantage of mutual cooperation, but still appear to keep costs reasonably low by good public relations, grazing, planting within the fire safety margin of State areas (thereby getting umbrella protection), making arrangements with rural fire parties, volunteer fire brigades and by working with the County or District Council rural fire authority. The latter may take the form of 'forest area' fire status. Costs of fire prevention in moderate to high fire areas vary between almost $1 per hectare and $10 (personal communication). The average cost over 127,000 hectares is $5.80 per hectare.

As with prevention costs, there is a big variation in insurance premiums. This is due to the age and consequently the value of the crop being insured. The range is from $1/ha for young crops to $10/ha for mature crops. There does not appear to be any relationship between insurance premiums and fire hazard ratings.

Total expenditure on fire prevention for the private plantations appears to average about $11/ha. No data are available on overheads or capital value of equipment.

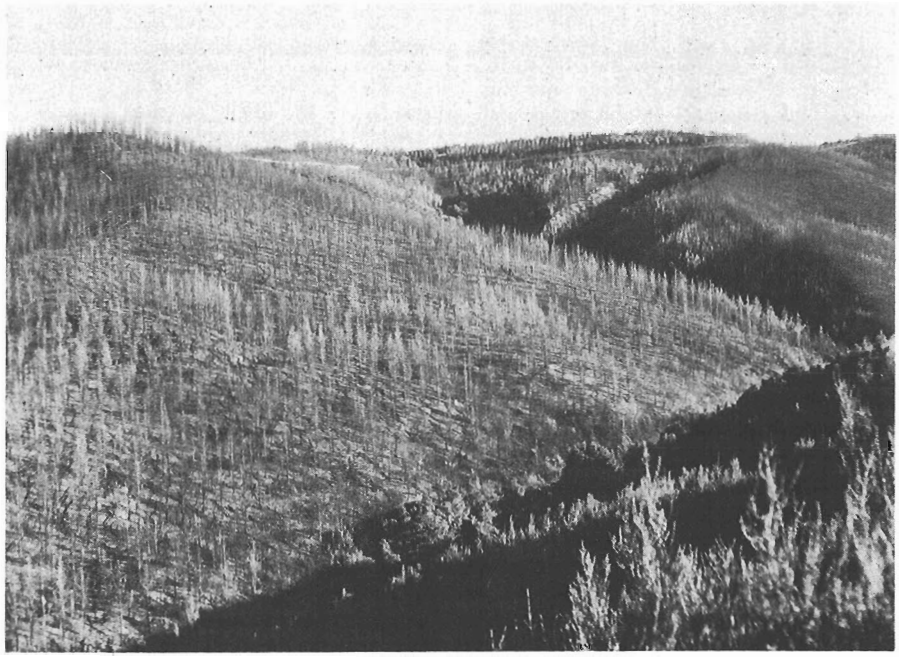
Fire Prevention Costs and Economics

The preceding analysis of expenditure does not necessarily provide an optimum economic solution. At best it introduces a basis for decision-making under situations where management tends to rely heavily on experience and judgement.

Economics is about the best allocation of limited resources. Likewise, forest fire economics is about allocating resources to fire management and distributing them among the various fire management activities. The economic approach to fire management, although more complicated, attempts to address the problem of relating the overall level of fire management to the benefits provided by the system.

Economic Criteria and Efficiency

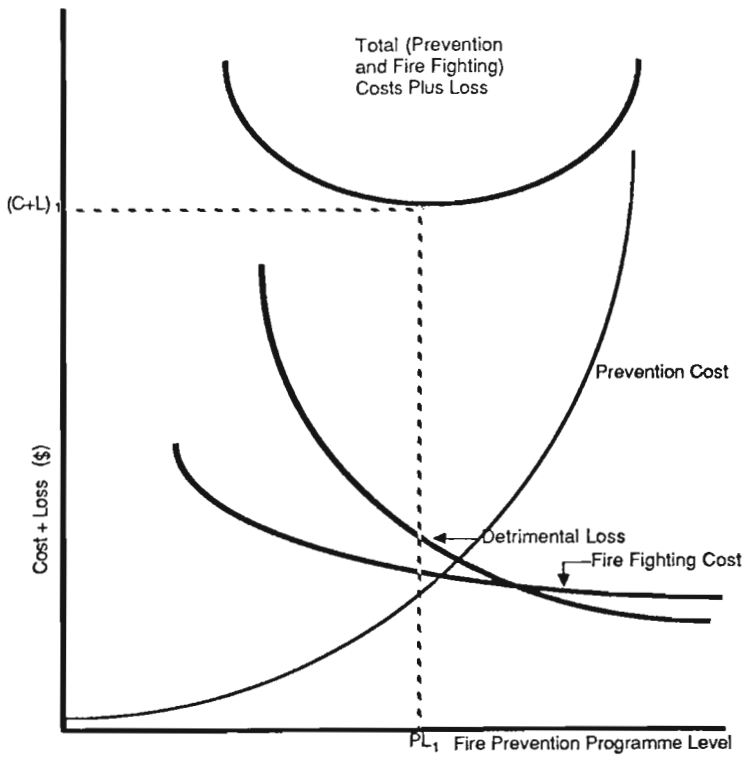
There is no dispute in the economics of fire management literature (e.g. Sparhawk 1925) about the appropriate economic theory to address the problem of the allocation of fire control expenditure. The method that should be used involves setting the fire management programme level in the region or nation such that expected costs (fire prevention and fire-fighting costs) and losses are minimized. This is called the least cost-plus-loss criteria. The criteria have two main components : Economic Efficiency and Risk.



A 10-year-old thinned and pruned radiata pine stand destroyed by fire at Ashley Forest (1973) (Photo: NZ Forest Service).

The best way to measure the efficiency of any fire protection organization is to assess the net results accomplished. In fire control planning, the net results accomplished are measured as reductions in losses rather than net revenue.

FIGURE 1



The Least Cost-Plus-Loss Criteria

In essence, the theory states that as prevention costs are increased, damage plus fighting costs decrease at a decreasing rate (Fig. 1). Total expenditures are simply the sum of these two, the optimal prevention programme level being PL1 where the total expenditure is minimized. This optimal point is also the point where marginal damage is equal to marginal cost. Thus the optimal solution can also be found by using marginal analysis.

Risk arises in fire management because the probability of a fire starting varies from season to season according to the weather, wind, moisture and also because of the variation in the dispersion of fires among different fuels and terrain within a region.

Ideally, the probabilities of fires of a different size, in different climatic conditions, on different terrain, and under different fuel management situations should be included as entire probability distributions. Alternatively, the more practical approach is to control some of these factors by classifying the fire loss and cost data by size, behaviour, etc., thus eliminating some of the differences in risk. Hence we would decide on the most important factors effecting risk and use these to classify the data.

In the final analysis, however, there is a trade-off between efficiency and risk. A risk-averse manager may select a fire prevention programme with higher costs. For example, if the fire induced loss was large in comparison to the total size of the company, there could be a cash-flow problem, and the decision-maker would tend to be risk-averse.

Nevertheless, a risk-averse manager may not necessarily want to increase costs on fire prevention to compensate. Taking out in-

surance is another option. There are also other ways in which forest managers can reduce their risk exposure. For example, having some forest in a different climatic zone or under different fire hazard conditions can reduce a forest owner's risk of fire.

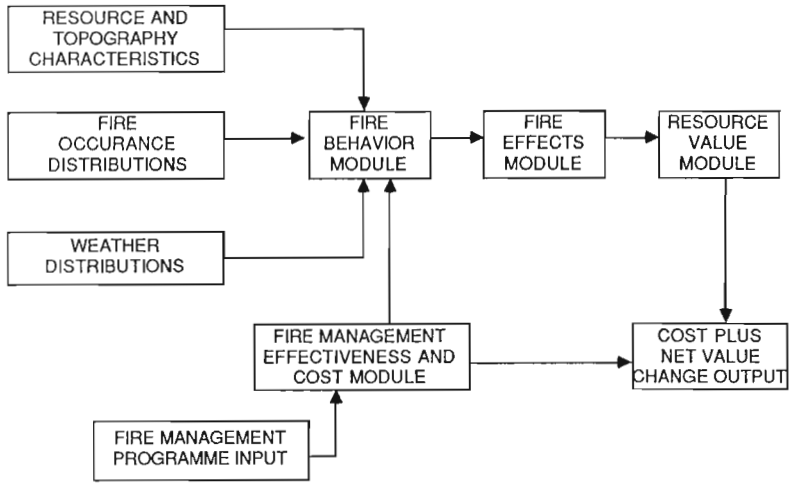
Applying the Criteria

While the economics of fire management was first discussed in the 1920s in the US and the least cost-plus-loss method recommended, the application of these techniques has evolved very slowly.

There have been two broad approaches adopted in implementing the criteria. First, there are a series of studies that investigate the dependencies underlying the relationships in Figure 1. After classifying forest fire data according to risk, both costs and losses are typically regressed as a function of some measure of the fire prevention level. The second, more recent approach, has been to develop comprehensive simulation models. Such models reconstruct hypothetical fires and determine the impact of different programme levels on the resource.

The complexity of the situation is shown by Figure 2 which demonstrates the structure of the simulation models developed in the United States to determine the minimum cost-plus-loss of their fire expenditure programme (Schweitzer et al 1982).

FIGURE 2.



Components of a Complete Fire Economics Evaluation Model

RECOMMENDATIONS

Although the analysis of past performance has provided useful insight, we believe a fuller economic evaluation needs to be attempted. The first approach should be to investigate the basic economic relationships underlying the fire management systems (as in figure 1) as this will lead to a better understanding of the cost effectiveness of various fire programmes.

In the meantime we should take no risks. The British Forestry Commission found in 1981 that prevention costs were ten times their losses (Teasdale, 1981). Expenditure was reduced to a level just above the loss figure. Within two or three years losses exceeded prevention costs — they are still studying the problem!

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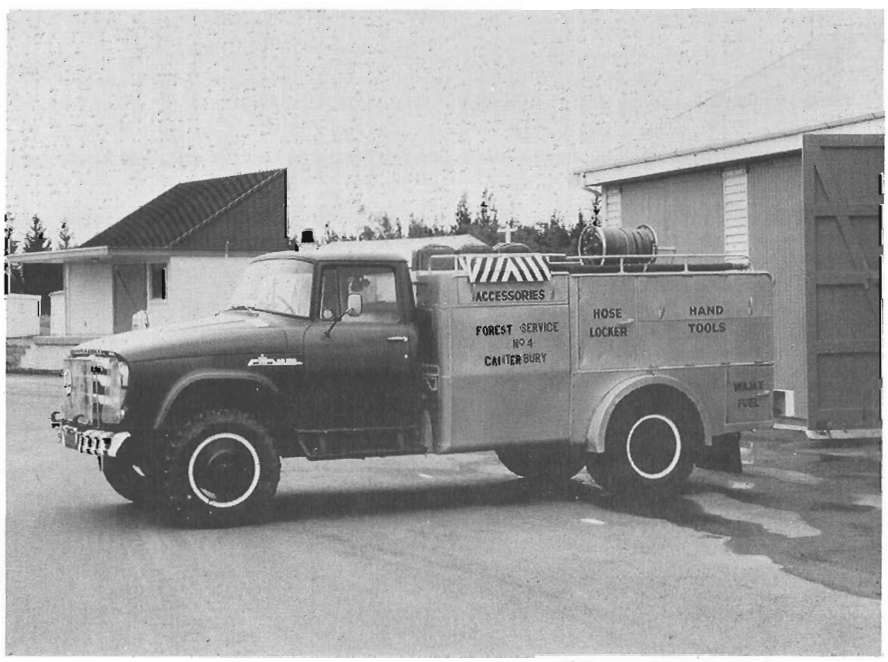
Eyrewell Forest Fire Tower (Photo: A.N. Cooper)



International fire engine belonging to the NZ Forest Service. (Photo: A.N. Cooper)