Resource Allocation for Forest Fire Protection[1]

J. CANTWELL[2]

Abstract

IN this paper a practical procedure for assisting forest management in allocating funds for fire protection in plantations is proposed and its application to a specific situation discussed. The procedure can also be used to establish norms for expenditure on protection in individual plantations and assist towards ensuring that the same standards of protection apply in all plantations.

1 Introduction

Each year forest management has to decide on the level of funds to be allocated for fire protection in the plantations under its control.

Traditionally this decision has been based on experience and judgment with due regard for local conditions and the success or failure of previous policies. This practice can give rise to wide disparities in protection policy between different plantations and make it difficult for management to control expenditure or to ensure that funds are being allocated effectively.

In this paper a practical procedure for assisting forest management in allocating funds for protection is proposed and its application to a specific situation discussed. The procedure can also be used to establish norms for expenditure on protection in individual plantations and assist towards ensuring that the same standards of protection apply in all plantations.

In order to deal with the complexities of the situation it has been found necessary to make several simplifying assumptions and to adopt a fairly crude approach. Thus it is important to stress that this procedure is not expected to provide an optimal solution. At best it is no more than an attempt to introduce an analytical base for decision-making into a situation where management tends to rely heavily on experience and judgment. In addition, it should be noted that the procedure is still very much at the development stage and much work remains to be done.

A plantation can be damaged by a fire which may start outside the plantation and then sweep in through the vegetation which

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1. Paper presented to the 2nd National Conference of the Operations Research Society of Ireland, October 1973.

2. Government Operations Research Unit, Dublin.

usually grows along the perimeter. Alternatively, fires can start inside the boundaries of the plantation and spread from there. Various protective measures can be taken ranging from the posting of fire warning notices, to patrolling or to clearing vegetation from around the edge of the plantation. The actual measures taken depend on local conditions, the nature of the hazard and the judgment of the local forester.

The system which usually operates is that each year the local forester submits his proposals for protection for the following year together with the cost of the work for approval by district management. These proposals depend to a large extent on the forester's expectation of what may happen next year and can be influenced by what has happened in previous years. Other factors taken into account include the type of land surrounding the plantation and the use to which this land is put, the habits of the local farmers or sheep owners in relation to the burning of vegetation, the size, value and vulnerability of the plantation, its accessibility, the extent to which it is frequented by the public and finally the degree of confidence he places in his ability to control a fire if one should occur.

The district manager receives similar proposals from the other foresters in his area and may suggest certain modifications before giving his approval. Again, because of the lack of objective criteria upon which to base his decisions, he has to rely heavily on his own experience and judgment.

2 The Model

It is proposed that protection should be allocated in proportion to the relative values of index numbers calculated for each plantation. These index numbers are calculated as the product of two other numbers, one indicating the risk or chance that the plantation will be threatened by a fire and the other the value of the plantation.

$$\text{or } \frac{E_1}{E_2} = \frac{R_1V_1}{R_2V_2}$$

where E_1 = proposed expenditure on plantation 1
E_2 = ,, ,, ,, plantation 2
R_1V_1 = the risk/value index number for plantation 1
R_2V_2 = ,, ,, ,, ,, ,, ,, plantation 2

A risk/value index is calculated for each plantation and the protection budget allocated according to their relative values.

The level of expenditure per unit of the risk/value index number provides an objective method for comparing protection expenditure on different plantations. An examination of the distribution of expenditure per unit of risk/value index will draw attention to plantations which on this basis appear to be over or under protected. The means of the distribution indicates a norm for expenditure on protection and can be used as a guide-line for control purposes.

In Sections 3 and 4 following, the components of the model are discussed in greater detail and methods for assessing risk and value described. The calculation of the risk/value index is described in Section 5. In Section 6 the application of the procedure to a practical situation is demonstrated and suggestions for its use as a control mechanism for expenditure outlined.

3 Calculation of Risk

It can be shown that the number of fires which occur in a sample of plantations can be characterised by the Poisson distribution. This hypothesis was tested with data relating to fires which occurred in or near 36 plantations over a 10 year period, i.e. 360 readings in all.

The data are tabulated in Table 1 below.

The probability density function of the Poisson distribution is

$$P(n) = \frac{u^n e^{-u}}{n!} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where u = the average or expected number of fires per plantation per year

In this case $u = 0.25$

Solving equation (1) for $n=0$, 1, 2 and 3 gave the expected

TABLE 1
ACTUAL AND EXPECTED NUMBER OF FIRES OCCURRING IN A PLANTATION IN A YEAR

Number of fires occurring in a plantation in a year	Actual frequency of occurrence	Expected frequency of occurrence
0	285	280
1	61	71
2	13	8
3	1	1

$X^2 = 4.62$

number of fires predicted by the Poisson distribution as shown in Table 1.

Comparing the expected frequency with the actual frequency of occurrence and applying a X^2 goodness of fit test indicated that the Poisson distribution could be regarded as a reasonable predictor of the number of fires to be expected in the future. In other words, past data on the occurrence of fires is a useful guide to future behaviour.

Although the number of fires which occur can be predicted reasonably accurately by the Poisson distribution it is obviously more important to be able to predict where the fires are likely to occur. A close examination of past data on the incidence of fires in individual plantations will indicate that some plantations appear to be more suseptible to fires than others. In other words some plantations have a higher probability of fires than others and it is probably reasonable to assume that high risk plantations in the past are likely to be high risk plantations in the future. This assumption may not be true in every case, land may be reclaimed or indeed neglected, new plantations will be established but, as a first approximation, it can be assumed that data on where fires occurred in the past are a useful guide to where fires are going to occur in the future.

Assume that data on the number of fires which have threatened two plantations over, say, the last twelve years can be tabulated as in Table 2.

TABLE 2
NUMBER OF FIRES THREATENING TWO PLANTATIONS OVER THE YEARS 1962 TO 1973

Plantation	62	63	64	65	66	67	68	69	70	71	72	73
Carrigatubrid	1	1		1		1			1			
Mullenbeg	1		2			3			2	1		

On the basis of these data Carrigatubrid is assigned a risk index of $^5/_{12}$ and Mullenbeg $^9/_{12}$. If no fires had threatened either plantation in that period the risk is set arbitrarily at $^1/_{20}$, i.e. it recognises that there is no such thing as a plantation which cannot in any circumstances have a fire, but on the other hand the historical data is respected by assigning a value of risk which implies that on average there will be only one fire every two decades.

This crude measure of risk has the advantage that it is easy to calculate as records of the occurrence of fires which threaten plantations are usually available.

4 Calculation of the Value Index

The actual cash value of a plantation is difficult to establish apart altogether from the question of its amenity value. If one assumes an annual appreciation rate and ignores all considerations of amenity a value index can be calculated on the basis of the area and age of the plantation together with a measure of the type and quality of timber in the plantation. The type and quality of the timber in a plantation is usually described in terms of yield class. Yield class is essentially a measure of the quantity of timber a plantation will yield during one complete cycle. It is calculated from measurements taken during the early years of growth. A "good" plantation would be described as 22 yield class, whereas a "poor" plantation may belong to the 6 or 8 yield class category

If we assume that the value of a plantation increases at the rate of x% per annum then the value index (V_t) at time t is given by

$$V_t = AY\left(1 + \frac{x}{100}\right)^t$$

where A = area
Y = average yield class
t = average age of the plantation
x = annual appreciation rate

It is necessary to use average age and average yield class because a plantation is usually composed of a number of sections or compartments of various ages and yield class. Furthermore, the composition of a plantation can change over time, parts of it may be cut down and replanted, parts which have failed may be cleared and replanted or enriched by replacing some of the failed trees.

As an example of the calculation of the value index assume the data shown in Table 3 is available for the two plantations mentioned previously, also assume an annual appreciation rate of 5% per

TABLE 3

AREA, AVERAGE AGE AND AVERAGE YIELD CLASS FOR TWO PLANTATIONS

Plantation	Area (hectares)	Average age (years)	Average yield class
Carrigatubrid	82	11	10
Mullenbeg	19	17	9

annum, then the value index for Carrigatubrid is 1,403 and for Mullenbeg 393.

Data for the calculation of this index are usually available in plantation census documents and planting files.

5 **Calculation of Risk/Value Index**

A risk/value index for each plantation can be calculated by multiplying the risk as measures in Section 3 by the value index described in Section 4.

For Carrigatubrid and Mullenbeg plantations the risk/value index would be calculated as in Table 4.

TABLE 4

THE RISK/VALUE INDEX FOR CARRIGATUBRID AND MULLENBEG PLANTATIONS

Plantation	Risk index	Value index	Risk/value index
Carrigatubrid	$^5/_{12}$	1,403	585
Mullenbeg	$^9/_{12}$	393	295

The risk/value index of 585 for Carrigatubrid compared to 295 for Mullenbeg indicates that, on the basis of the value of the plantations and the risk that they will be threatened by a fire, management would be justified to spend practically twice as much protecting Carrigatubrid as Mullenbeg.

6 **Application**

The application of this procedure is demonstrated by the following example. The pattern of fires over twelve years for 15 plantations was found. This is shown in Table 5 below. The final column shows the risk index calculated according to the method outlined in Section 3.

The value index for each plantation was then calculated and combined with the risk index to give the risk/value index shown in Table 6.

The pattern of expenditure on protection for the 15 plantations over a two year period 1971 and 1972 is compared with the risk/value index profile in Figure 1.

The model postulates that the ratio of expenditure on protection per unit of risk/value index should be constant for every plantation. This ratio for the 15 plantations is shown in Table 7, and the distribution of the ration is shown in Figure 2. An examination of the

TABLE 5
INCIDENCE OF FIRES IN 15 PLANTATIONS OVER A 12 YEAR PERIOD AND THE CONSEQUENT RISK INDEX ASSIGNED TO EACH PLANTATION

Plantation	62	63	64	65	66	67	68	69	70	71	72	73	Risk
Carrigatubrid	1	1		1		1			1				$^{5}/_{12}$
Listrolin (1)													$^{1}/_{20}$
Listrolin (2)		1	1	1								1	$^{4}/_{12}$
Corbally													$^{1}/_{20}$
Dowling													$^{1}/_{20}$
Ashtown													$^{1}/_{20}$
Mountain Grove													$^{1}/_{20}$
Templeorum													$^{1}/_{20}$
Gortrush													$^{1}/_{20}$
Glenbower	1												$^{1}/_{12}$
Garryduff													$^{1}/_{20}$
Beatin													$^{1}/_{20}$
Bregaun		1	1	1						2		1	$^{6}/_{12}$
Mullenbeg	1		2				3		2	1			$^{9}/_{12}$
Moonveen							1						$^{1}/_{12}$

TABLE 6
THE RISK/VALUE INDICES FOR THE 15 PLANTATIONS

Plantation	Risk Index	Value Index	Risk/Value Index
Listrolin (2)	$^{4}/_{12}$	2,561	854
Carrigatubrid	$^{5}/_{12}$	1,403	585
Corbally	$^{1}/_{20}$	6,371	319
Mullenbeg	$^{9}/_{12}$	393	295
Bregaun	$^{6}/_{12}$	512	256
Gortrush	$^{1}/_{20}$	2,527	124
Garryduff	$^{1}/_{20}$	2,238	112
Glenbower	$^{1}/_{20}$	974	81
Dowling	$^{1}/_{20}$	1,343	67
Mountain Grove	$^{1}/_{20}$	861	43
Moonveen	$^{1}/_{20}$	473	39
Ashtown	$^{1}/_{20}$	532	27
Listrolin (1)	$^{1}/_{20}$	288	24
Beatin	$^{1}/_{20}$	295	15
Templeorum	$^{1}/_{20}$	72	4

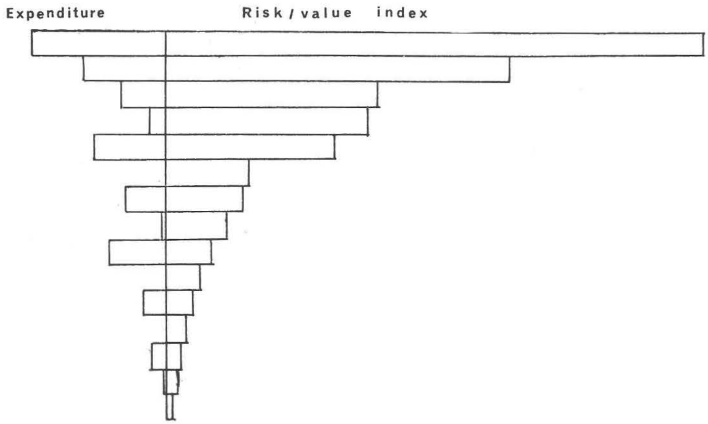

FIGURE 1: Comparison of risk/value index profile with protection spending profile for 1972 and 1972.

distribution immediately draws attention to those plantations which on this basis appear to be over or under protected. The means of the distribution indicates what the norm for expenditure on protection has been and can be used as a guide-line for control purposes. In this case a norm of £1.50 per unit of risk/value index could be used.

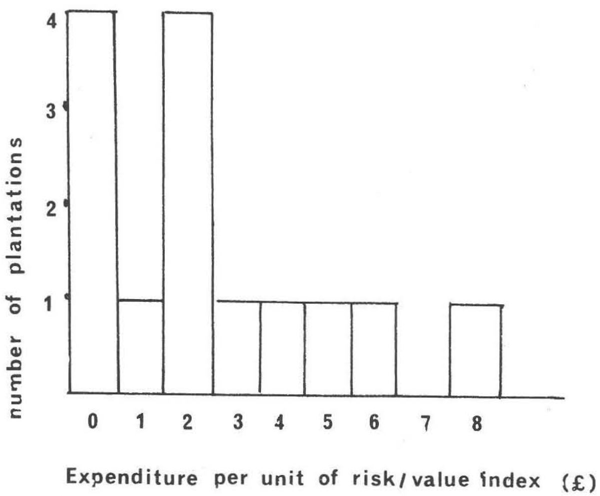

FIGURE 2: The distribution of expenditure per unit of risk/value index.

TABLE 7
THE AMOUNT SPENT ON PROTECTION DURING 1971 AND 1972 PER UNIT OF RISK/VALUE INDEX

Plantation	Risk/Value Index	£ Spent on Protection (1971 and 1972)	£ / Unit of RV
Listrolin (2)	854	1,057	1.24
Carrigatubrid	585	671	1.15
Corbally	319	376	1.18
Mullenbeg	295	133	0.45
Bregaun	256	597	2.33
Gortrush	124	0	0
Garryduff	112	347	3.10
Glenbower	81	49	0.61
Dowling	67	480	7.16
Mountain Grove	43	0	0
Moonveen	39	195	5.00
Ashtown	27	0	0
Listrolin (1)	24	121	5.04
Beatin	15	22	1.47
Templeorum	4	0	0

7 Conclusion

The procedure described in this paper is by no means complete. Much work remains to be done. The use of historical data as the only indicator of risk ignores many factors which may influence the situation, in particular, the age of a plantation. Current studies are attempting to identify and quantify these factors to differentiate between the risk that a plantation will be threatened by a fire and the vulnerability of the plantation. A way must also be found to take account of the amenity value of a plantation. However, the procedure as it stands has the advantage that it is easy to understand and can be calculated from data already available. As was pointed out in the introduction it represents a first attempt to introduce an objective decision-making mechanism into a situation where management has traditionally relied on experience and judgment.

8 Acknowledgments

The author wishes to thank the Forest and Wildlife Service for permission to publish this paper, and to acknowledge the contribution which his colleague Mr. N. Honeyman has made to the study on which this paper is based, and the active assistance given by the Divisional Inspector, District Inspectors and Foresters in the Kilkenny Division, and the Work Study and Statistics Sections at Headquarters throughont the period of the study.