Fire Research Report

The Economic Cost of Wildfires

BERL

September 2009

This research covers three broad categories of wildfire costs. To estimate the cost of wildfires in New Zealand, BERL integrated two models, the Least Cost plus Loss (LC + L) model and the Cost plus Net Value Change (C + NVC) model. This research integrates these two models in order to capture both the immediate effects of wildfires as well as the medium and long-term economic costs. Additionally the economic cost has been divided into pre-suppression, suppression, and after fire costs. Suppression costs refer to the resources used to fight wildfires and after fire costs reflect the damage resulting from wildfires. Pre-suppression, or fire prevention, is not a direct cost of wildfire, but it is included as a third cost category in this research. Pre-suppression reduces the probability of wildfires and the associated fire damage.

New Zealand Fire Service Commission Research Report Number 99
ISBN Number 978-1-877539-08-4 (on-line)
ISBN Number 978-1-877539-09-1 (paperback)

Report to:

New Zealand Fire Service

THE ECONOMIC COST OF WILDFIRES

Prepared by

Jiani Wu

William Kaliyati

Kel Sanderson

September 2009

BERL ref #4730

Business and Economic Research Limited, BERL House, 108 The Terrace, PO Box 10277, Wellington 6143, New Zealand

T: 04 931 9200 F: 04 932 9202 info@berl.co.nz www.berl.co.nz

The Economic Cost of Wildfires

1 Executive summary 4

2 Introduction 6

3 Literature review 8

3.1 Cost components 8
3.2 Modelling the economic costs of wildfires 12
3.3 LC + L and C + NVC models 13
3.4 New Zealand wildfires 14

4 Research method 17

4.1 Our approach 17
4.2 Pre-suppression costs 19
4.3 Suppression costs 20
4.4 After fire costs 22
4.5 Data limitations 25

5 Results and discussion 26

5.1 Economic cost of wildfires 26
5.2 Pre-suppression costs 28
5.3 Suppression costs 28
5.4 Immediate economic costs 29
5.5 Medium-term economic cost 31
5.6 Long-term economic cost 31

6 Future research 34

6.1 Challenges and limitations 34
6.2 Designing an integrated data collection framework 34

7 Bibliography 35

Tables

Table 1.1 Economic cost of New Zealand wildfires, 2002-2007 (NPV 2008$m) 4
Table 4.1 Summary of cost components and data sources 18
Table 4.2 Average cost of fire prevention per year, ($/ha) 23
Table 5.1 Economic cost of New Zealand wildfires, 2002-2007 ($m) 26
Table 5.2 Annual economic cost of wildfires, 2002-2007($m) 27
Table 5.3 Pre-suppression costs, 2002-2007 ($m) 28
Table 5.4 Suppression costs, 2007-2007 ($m) 29
Table 5.5 Immediate economic costs of wildfires, 2002-2007 ($m) 29
Table 5.6 Total cost of carbon loss, 2002-2007 ($m) 30
Table 5.7 Medium-term economic cost of wildfires, 2002-2007 ($m) 31
Table 5.8 Long-term economic cost of wildfires, 2002-2007 ($m) 31
Table 5.9 Long-term economic cost of burnt forest wood, 2002-2007 ($m) 32
Table 5.10 Costs to other industries of burnt forest wood, ($m) 33

Figures

Figure 3.1 Integrated model of the economic costs of wildfires 11
Figure 4.1 Rural fire fighting fund claims, 2002-2007 ($m) 20
Figure 4.2 Total number of wildfires and area burnt, 2002-2007 21
Figure 4.3 Total area burnt by fuel type, 2002-2007 21

1 Executive summary

This project has been commissioned by the New Zealand Fire Service (NZFS) to estimate the economic costs of wildfires in New Zealand.

This research covers three broad categories of wildfire costs. We divide break the economic cost of wildfires into pre-suppression, suppression, and after fire costs. The latter two categories relate to the direct and flow-on effects of wildfires. Suppression costs refer to the resources used to fight wildfires and after fire costs reflect the damage resulting from wildfires. Pre-suppression, or fire prevention, is not a direct cost of wildfire, but it is included as a third cost category in this research. Pre-suppression reduces the probability of wildfires and the associated fire damage. These latter categories would be higher in the absence of pre-suppression efforts. It is therefore important to recognise the resources dedicated to pre-suppression contribute to reducing fire fighting costs and fire damage.

Table 1.1 summarises the total costs involved in preventing and fighting wildfires during 2002-2007, and the resulting economic costs following these wildfires.[1] Between 2002 and 2007, the total economic cost of wildfires in New Zealand was approximately $586.2 million.[2] Of this total, fire prevention costs accounted for $227.5 million or 38.8 percent of the total cost, while suppression and after fire costs accounted for $358.7 million or 61.2 percent.

Table 1.1 Economic cost of New Zealand wildfires, 2002-2007 (NPV 2008$m)

2002-2007	2008 $m	% of total
Pre-suppression	227.5	38.8
Suppression	46.0	7.9
After Fire	312.7	53.3
- Immediate	*92.6*	*15.8*
- Medium-term	*5.4*	*0.9*
- Long-term	*214.7*	*36.6*
Total Cost	586.2	100

Source: BERL

To estimate the cost of wildfires in New Zealand, BERL integrated two models, the Least Cost plus Loss (LC + L) model and the Cost plus Net Value Change (C + NVC) model. In 1987, as part of their research into fires, BERL developed a LC + L model. This model was

[1] These figures are the net present value of all wildfire costs, and are measured in constant 2008 dollar terms.

[2] This report uses financial year information for years to 30 June. All values are expressed in 2008 dollar terms.

used to establish forest fire costs for the New Zealand Forestry Service with a specific focus on prevention, pre-suppression, and suppression expenditure. Since the late 1980s, there have been significant improvements to the LC + L model, and the development of the C + NVC model. This research integrates these two models in order to capture both the immediate effects of wildfires as well as the medium and long-term economic costs.

The pre-suppression and suppression cost categories include:

- public campaigns or advertisements to increase the awareness of wildfire dangers
- fuel management costs
- general administration and operational costs of wildfire prevention
- cost of machinery and equipment used to fight wildfires.

As shown in Table 1.1, the economic cost of wildfires can be further broken down into immediate, medium-term, and long-term economic costs. These include:

- environmental impacts
- the cost to forestry-related industries, such as harvesting and wood processing
- damage to buildings, property, and capital equipment
- health costs
- carbon emissions.

To improve the data collection process for future wildfire research, we have also noted that a well-developed wildfire database would benefit future research in this area. This conclusion was supported by wildfire experts and stakeholder organisations.

2 Introduction

This project has been commissioned by the NZFS to estimate the economic costs of wildfires in New Zealand.

Fire management over our forest and rural areas is legislated under the Forest and Rural Fire Act 1977. The purpose of this Act is to safeguard life and property by the prevention, detection, control, restriction, suppression, and extinction of fires in forests and rural areas. Rural fire authorities are the legal entities responsible for these tasks. These entities include local Territorial Authorities, the Department of Conservation (DOC), the National Rural Fire Authority (NRFA), and the Ministry of Defence (MOD).

The first attempt to quantify rural fire management was in the mid 1980s when the New Zealand Forest Service engaged in a programme of research to gain a better understanding of the costs and financial consequences of wildfires in New Zealand. This research was restricted to information from the New Zealand Forest Service.

Currently, the true cost of rural fire management is not fully understood nor well quantified as many of the fixed costs of these activities are incorporated into other activities or carried as overhead costs. BERL has revisited this issue in order to estimate the cost and impacts of wildfires on New Zealand's forests and rural landscape. This report is the result of that work.

The research aimed to quantify the amount spent on wildfire pre-suppression, suppression and the resulting long-term costs of wildfires. Wildfires are likely to cause loss of business and jobs, and affect local, regional, and national economic performance. The long-term costs recognise that in addition to the forestry industry, other stakeholder industries suffer losses, such as harvesting and transport.

By examining these three categories of costs, we can compare the costs of pre-suppression against the costs that result from suppression and long-term losses. By investing in pre-suppression, the New Zealand economy avoids the direct and follow-on costs resulting from wildfires. This quantification could be used to weigh the costs of pre-suppression initiatives against the benefits, that is costs avoided, of reducing the resources wildfires drain from the economy.

The remainder of the report is organised into four sections. The literature review in Section 3 sets the scene for this research by discussing wildfire studies completed in New Zealand and internationally. The main objective of this review was to identify and establish wildfire cost components, and an economic model applicable to the New Zealand situation.

Section 4 discusses the research methods used in this project, detailing the broad techniques used, the calculation of particular cost components, the data sources and the data. This section also discusses the limitations of the data.

Section 5 contains the main findings of our research and highlights the main implications of these findings. The discussion contextualises the meaning and implications of the estimates.

The final section, future research, focuses on establishing a wildfire database that will help future studies to better estimate the costs of wildfires in New Zealand.

3 Literature review

This section discusses our literature review of wildfire studies completed in New Zealand and internationally. The main objective of this review was to identify and establish wildfire cost components, and an economic model applicable to the New Zealand situation. The literature we reviewed can be broadly categorised as discussing:

- cost components, including identifying different cost components and the methodology used to obtain and/or collate data
- optimisation models, which were used to minimise costs and damage
- the wildfire situation in New Zealand.

3.1 Cost components

The following cost components appeared most frequently in the literature that we reviewed.

3.1.1 Loss of timber value

The largest long-term economic cost identified in the literature was the impact on the forest industries.

Guild and Dudfield (2006)[3] discussed the effects of forest wildfires in New Zealand. These effects include a loss in timber value; a loss in flora, fauna and biodiversity; increased erosion; and an increase in atmospheric CO_2. Although Guild and Dudfield (2006) were unable to provide a figure for the loss in timber value and employment, they estimated these losses "would be in the billions of dollars".

Guild and Dudfield (2006) also argued that fire can be used as a land management tool, which can be "beneficial to nature". Landowners can, for example, use fires as part of a land use cycle.

In addition to a loss in timber value, Mercer, Pye, Prestemon, Butry and Holmes (2000)[4] discussed the impact of wildfires on the timber market. These effects can be short or long-term. In the short term, the effect can be an absolute loss in timber as the trees die and the timber is unsalvageable. In the long term, the loss can drive timber prices up, due to a large portion of the immature standing inventory being lost. Prestemon and Holmes (2000)[5] also

[3] Guild and Dudfield (2006), Fire management in the forest and rural landscape for New Zealand.

[4] Mercer, Pye, Prestemon, Butry and Holmes (2000), Economic effects of catastrophic wildfires: assessing the effectiveness of fuel reduction programs for reducing the economic impacts of catastrophic forest fire events.

[5] Prestemon and Holmes (2000), Timber price dynamics following a natural catastrophe.

argued that the loss of greater than 10 percent of the inventory in a region can drive up timber prices in the long run. They cited the Hurricane Hugo fire in coastal South Carolina as an example. This fire caused a price increase of more than 10 percent for sawn timber and pulpwood standing timber.

3.1.2 Other economic losses

The economic impact of wildfires flows on to other industries. This impact can include damage to buildings, property, and equipment, as well as environmental damage.

Hall (2008)[6] included the direct and indirect costs of fires when calculating the total cost of fire in the U.S. This included direct property damage and business interruption costs. Hall (2008) argued that wildfires can mean losses in labour, potential property and land values, and business efficiency, depending on the nature of the burnt areas.

There are various ways to estimate the impact of wildfires on retail or tourism businesses. Loomis, González-Cabán and Englin (1999)[7] and Loomis, González-Cabán and Englin (2001)[8] completed a survey to compare the economic benefit before and after a hypothetical wildfire. They asked respondents to indicate whether they would take part in recreational activities in a particular area if they knew there was a wildfire risk or after a wildfire had occurred. Both studies took the difference between economic profits before and after the hypothetical wildfire to determine the impact on retail or tourism.

3.1.3 Costs of fire departments

Pre-suppression costs tend to be the largest component of fire departments' costs, while suppression costs tend to be the smallest, in the absence of significant wildfires.

This pattern highlights the role of investing in fire prevention. Investments in fire prevention and pre-suppression reduce the probability of wildfires. This contributes to reducing the direct suppression costs and follow-on economic losses costs resulting from wildfires. It is unlikely that the ideal level of pre-suppression investment would avoid all wildfires. Rather the optimal investment would balance the costs of pre-suppression initiatives against the expected losses that would occur in their absence.

---

[6] Hall, John (2008), The total cost of fire in the United States, February 2008, National Fire Protection Association.

[7] Loomis, González-Cabán and Englin (1999), Effects of fire on the economic value of forest recreation in the intermountain west.

[8] Loomis, González-Cabán and Englin (2001), Testing for differential effects of forest fires on hiking and mountain biking demand and benefits.

Local fire protection and direct purchases by fire authorities were the two main categories identified by Hall (2008) in his "costs of fire departments" component. Hall (2008) obtained expenditure figures from local fire authorities and the Federal and State government.

In New Zealand, prevention, pre-suppression, and suppression costs are funded by organisations such as local government, the Department of Conservation, forest owners, and the National Rural Fire Authority.

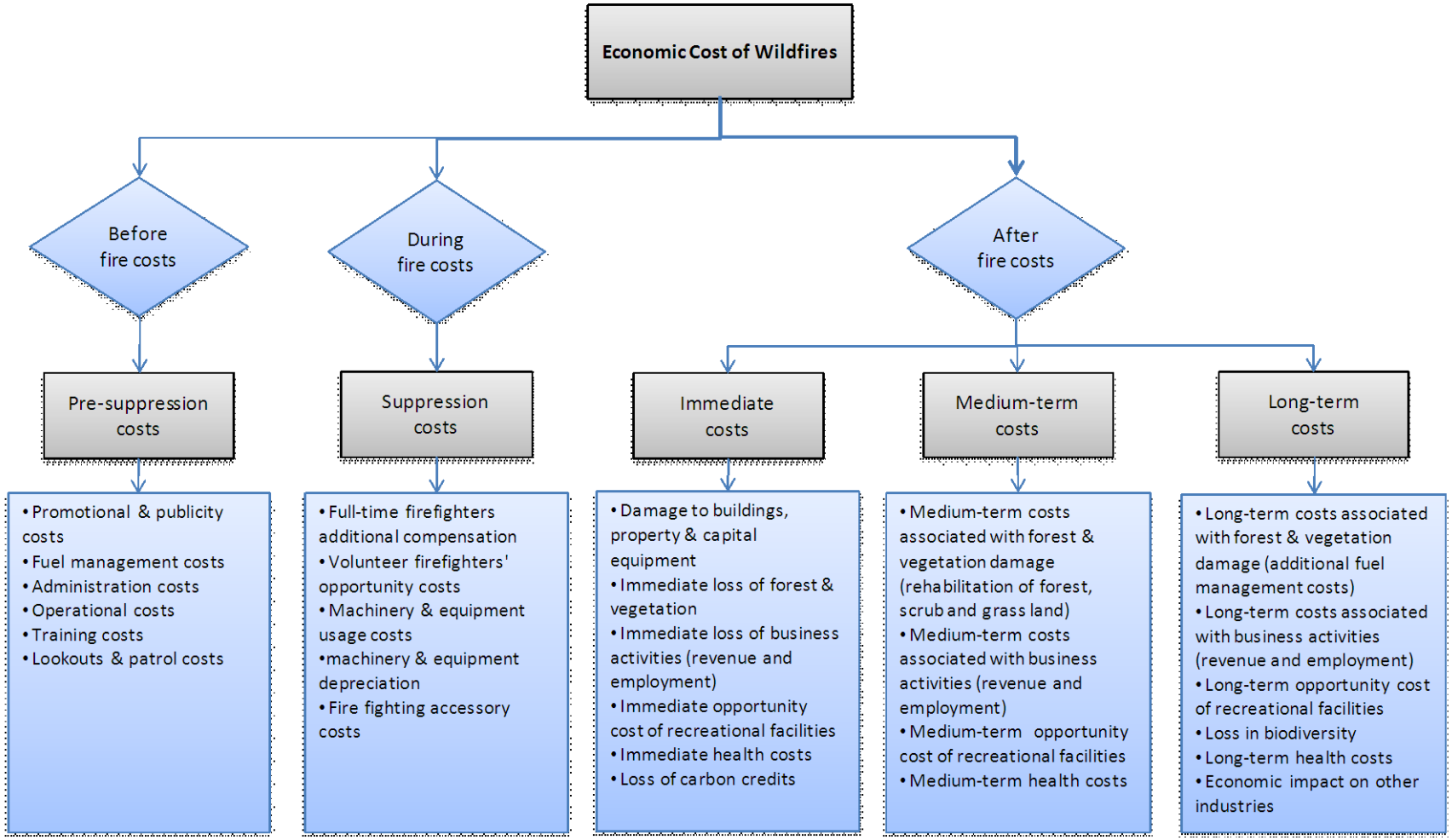
Apart from regular maintenance and suppression costs by the local fire authorities, BERL (1987)[9] also identified promotion and/or advertising expenditure to promote awareness a pre-suppression cost.

3.1.4 Fire insurance

Another large pre-suppression cost is fire insurance. Hall (2008) defined fire insurance costs as "the premium money taken by fire insurers and the money paid out for claims". Claims are based on owners' estimates of total fire loss. This calculation excludes items such as automobiles or vehicles (as they will be included in vehicle insurance).

[9] BERL (1987), Economics of fire control expenditure. Project commissioned by the New Zealand Forest Services.

Figure 3.1 Integrated model of the economic costs of wildfires



3.2 Modelling the economic costs of wildfires

The model in Figure 3.1 integrates BERL's 1987 "Least-Cost-plus-Loss" framework (*LC* + *L*) and the contemporary "Cost plus Net Value Change" model (*C* + *NVC*), detailed in the following section.

The net economic cost of wildfires in New Zealand can be expressed as a function of costs, as follows:

The Net Economic Cost of Wildfires = *C* + *NVC*

C is the sum of pre-suppression and suppression costs of the wildfires. Pre-suppression costs are incurred before wildfires occur. They are usually a fixed cost, as they are normally set by an annual organisational budget. Suppression costs are incurred in fighting a wildfire. This cost category is likely depend on the number and location of the wildfires, and therefore is significantly influenced by weather conditions.

NVC represents the net present value of immediate, medium and long-term economic costs of wildfires. These costs occur at different points in time, and were converted to net present values (NPVs) using a conventional technique. It involves converting future values to present day values (NPV), using an appropriate discount rate.[10] This allows costs that occur in different time period to be meaningfully combined and compared. The categories are defined as follows.

- Immediate economic costs are costs that occur straight after the wildfire is extinguished. Immediate costs include damage within a day of the wildfire.
- Medium-term economic costs are during a one-year period after the fire.
- Any damage, excluded from the immediate costs and medium-term costs calculation, are classified as long-term costs.

As we progressed with the research, we found that some of the information in Figure 3.1 was unavailable in New Zealand or some of the cost components were irrelevant in a New Zealand context. For example, all of the rural fire fighters are volunteers rather than full-time paid fire fighters. As a result, we modified the framework to fit the New Zealand situation.

[10] The process of discounting allows financial flows with differential timing (and value) to be compared in consistent terms. A discount rate is used to convert impacts from different, future time periods to values in current terms.

3.3 LC + L and C + NVC models

Hesseln and Rieout (1999)[11] stated that "the cost plus net value change (*C + NVC*) framework has been the most widely used economic fire management tool since its inception in 1916." Donovan and Rideout (2003)[12] defined the sum of all wildfires as *C + NVC*, where *C* represents all fire related suppression costs and *NVC* represents fire related damage. The *C + NVC* model is closely related to, and derived from, the "Least Cost plus Loss" (*LC +L*) model introduced by Sparhawk in 1925.[13] When the differences between the two models were reviewed, the papers argue that with time the *C + NVC* model has become more important. It is also highlighted that while the objective of Sparhawk's *LC + L* model was to "determine how much money can justifiably be spent for fire protection on national forests," the objective of the *C + NVC* model, is to identify the most efficient level of fire management expenditure.

Donovan and Rideout (2003) credited the *C + NVC* model as correctly categorising pre-suppression and suppression costs as independent variables in the *C* function, and keeping them related in the *NVC* function. Independence of pre-suppression and suppression implies that a particular level of one input does not determine the level of the other, as implicitly implied in the *LC + L* model. The *NVC* function is a function of pre-suppression and suppression, as the primary objective of the model is to establish the most efficient level of fire management expenditure.

Net value change (*NVC*) is the difference between the net present value of resource outputs and management costs without fires and the net present value of resource outputs and management costs with fires. This implies that:

$$NVC = NPV_{w/o} - NPV_{w}$$

Where, *NVC* = net value change

$NPV_{w/o}$ = net present value without fire

NPV_{w} = net present value with fire

[11] Hesseln and Rideout (1999), Using control theory to model the long-term economic effects of wildfire.

[12] Donovan and Rideout (2003), A reformulation of the cost plus net value change model of wildfire economics.

[13] Sparhawk (1925), The use of liability ratings in planning forest fire protection.

After wildfires in the Northern Rocky mountains in the United States of America, Flowers et al (1985a)[14] and Flowers et al (1985b)[15] used the *NVC* framework to calculate the change in the net value of timber, physical output, and recreation value.

Estimating the pre-suppression costs, also known as prevention costs, is relatively straightforward, compared to modelling the economic costs of wildfires. Hesseln and Rideout (1999), Donovan and Rideout (2003), and Ashley-Jones (1986) identified pre-suppression and suppression costs, which occur before and during a wildfire, as "straight-forward" calculations if costs are recorded and classified accordingly. Long-term economic costs, on the other hand, are not as straight forward to calculate.

Douglas et al. (2003) and Butry, Mercer, Prestemon, Pye and Holmes (2001) highlighted that the economic cost of wildfires depends on the definition of economic cost. The authors indicated that wildfires create short to medium/long-term economic impacts. Short to medium-term costs are associated with near-term losses resulting from large-scale economic disruptions; and long-term costs are associated with losses in vegetation management, timber, and other forest-related resources and industry.

Butry, Mercer, Prestemon, Pye and Holmes (2001) defined seven major categories of economic cost. These are: pre-suppression costs, suppression costs, disaster relief expenditure, timber losses, property damage, tourism-related losses, and human health effects. Although they focused on these seven economic costs, the authors also suggested that other potential wildfire costs include lost wages, decreased quality of life, higher fire fighting expenditure, landscape rehabilitation, and environmental degradation. The seven major categories of economic costs of wildfires, including a loss of wages and biodiversity, form the basis of the model suggested shown in Figure 3.1.

3.4 New Zealand wildfires

The majority of the literature we studied came from research centres in the United States of America, where wildfires have caused death and property losses, and impacted on recreational activities (especially mountain activities). The situation in New Zealand is different, due to our lower population density and therefore the lower risk of death and injury due to wildfires.

[14] Flowers, Shinkle, Cain and Mills (1985), Timber net value and physical output changes following wildfire in the northern rocky mountains estimates for specific fire situations.

[15] Flowers, Vaux, Gardener and Mills (1985), Changes in recreation values after fire in the northern rocky mountains.

Fire causes

The majority of New Zealand wildfires are likely to be caused by land clearing (20.1 percent) and vehicles (16.5 percent), according to the Rural Fire Research Update.[16] Wildfires caused by incendiary, smokers, and lightning account for a low proportion of New Zealand's wildfires.

Fuel types

Grass fires have accounted for 47.1 percent of total wildfires over the last 10 years, from 1991/92 to 2007/08, while scrub fires accounted for 45.2 percent. Forest wildfires (7.6 percent) are a relatively small component compared to the other two fuel types.

Around 56.5 percent of the grass areas burnt during this period were in the Otago region, followed by Nelson/Marlborough (15.6 percent), Waikato (10.9 percent), and the Eastern North Island (5.4 percent). There have been two substantial fires - Alexandra Fires in Otago that burnt a total of 9,600 hectares of grass, and Blenheim fires that burnt 6,500 hectares.

Around 27 percent of the total scrub area burnt was has been in the Otago region. The Canterbury (12.3 percent), Northland (14.6 percent), and Eastern North Island (8.5 percent) regions have also had substantial scrub area burnt. Nationally, 37,287 hectare of scrub area was burnt over the last 10 years.

Although forest wildfires only accounted for six percent of the total reported area burnt, the economic costs can be large. Forest wildfire incidents were spread across Nelson/Marlborough (21.6 percent), the Eastern North Island (19.7 percent), and Northland (12.1 percent) regions.

The latest series of this data recorded a new fuel type category - indigenous forest. This change in recording will enable the estimation of indigenous forest wildfire damage in the future.

Regional difference

Looking at regional differences, the South Island represented approximately 75 percent of the total areas burnt but 34 percent of the total number of fires. Around 42 percent of the total area burnt over the last 10 years was in the Otago region, although the number of fires was only around six percent. Nelson/Marlborough had around 12.4 percent of the total area

[16] Rural Fire Research. (2009). Analysis of New Zealand's wildfire records. Rural Fire Research Update. 3. 1178-7776.

damaged by wildfires in New Zealand, followed by Canterbury (11.5 percent), and Northland (7.5 percent).

Based on the literature above, we developed a framework that calculates the economic cost of wildfires in New Zealand, taking into consideration the availability of wildfire data. We explain this framework in the following section.

4 Research method

This section is an account of our research method. To estimate the total cost of wildfires in New Zealand, BERL reviewed and established the most appropriate modelling technique; reviewed and established the cost components of the model; and estimated values for each cost component.

4.1 Our approach

There are strong arguments for the use of the cost plus net value change (*C + NVC)* model as presented in Section 3. BERL has adopted this model as it is an improvement over Sparhawk's 1925 model (least cost plus loss, *LC +L*) used in 1987 by BERL. We have used this model to sum all costs of wildfires in New Zealand.

In our model, *C* is the total sum of all costs, which is pre-suppression and suppression expenditure on New Zealand wildfires. *NVC* is the total sum and net present value of all economic costs associated with wildfires.

Two criteria dictated what cost components were included in the cost categories. The first criterion was theoretical and economic relevance to New Zealand wildfires, and the second was availability of data.

Table 4.1 lists individual cost components used in this research project, as well as major data sources.

Table 4.1 Summary of cost components and data sources

Category			Cost component	Data source
Pre-suppression costs		1	Promotional & publicity cost	• DIA • DOC • NZFOA
		2	Fuel management cost	
		3	Administration cost	
		4	Operational cost	
		5	Training cost	
		6	Lookouts & patrol cost	
Supression costs		7	Volunteer firefighters' opportunity cost	• NZFOA • NZFS
		8	Machinery & equipment usage cost	
		9	Fire fighting accessory cost	
After fire costs	Immediate costs	10	Damage to building, property & capital equipment	• DOC • FMG • MoH • NZFOA • NZFS • Scion • Landcare Research
		11	Immediate loss of forest & vegetation	
		12	Immediate business activity cost associated with wildfire	
		13	Immediate health costs associated with wildfire	
		14	Immediate cost – carbon emissions	
	Medium-term costs	15	Medium-term costs associated with forest & vegetation damage	
		16	Medium-term business activity cost associated with wildfire	
		17	Medium-term health cost associated with wildfire	
	Long-term costs	18	Long-term cost associated with forest & vegetation damage	
		19	Long-term business activity cost associated with wildfire	
		20	Long-term health cost associated with wildfire	

4.2 Pre-suppression costs

Pre-suppression cost data was obtained from the Department of Internal Affairs (DIA), the Department of Conservation (DOC), and the New Zealand Forest Owners Association (NZFOA).

The Department of Internal Affairs provided pre-suppression cost data for 75 territorial authorities, which they surveyed in 2004.[17] The Department of Conservation provided average pre-suppression costs for the last three years, and the NZFOA's 2006/07 report detailed the average cost per hectare of fire prevention, pre-suppression, suppression, and damage.

To avoid double counting we took out any possible transactions between these three organisations. For example, the New Zealand Forest Owners Association pays various fire organisations through Territorial Authority rates and levies. We have excluded these payments in our calculations since these costs were captured in the expenditure of the other two organisations.

Because of the commercially sensitive nature of the data, it was provided at an aggregate level. However, we employed assumptions to estimate figures for the sub cost categories. We have discussed these assumptions with industry experts.

The Department of Internal Affairs survey of 75 territorial authorities revealed that pre-suppression costs were $9.25 million for the 2003/04 year.

Pre-suppression costs from the Department of Conservation indicate that between 2005/06 and 2007/08, on average $4.2 million was spent annually on pre-suppression.[18] For the three years prior to 2005/06, we have assumed that pre-suppression expenditure increased by four percent per annum until it reached $4.2 million in 2005/06.

After discussions with wildfire experts from DOC and FMG[19], BERL has concluded that from 2003/04, pre-suppression costs have been increased at a rate of between 2.5 and 5 percent.

---

[17] Preston N. (2004). Results of a survey of Territorial Authorities about resources involved in fighting rural fires. Wellington: The Department of Internal Affairs.

[18] These figures are expressed in nominal, or current year, terms. They are converted to consistent 2008 dollar terms in our main study estimates.

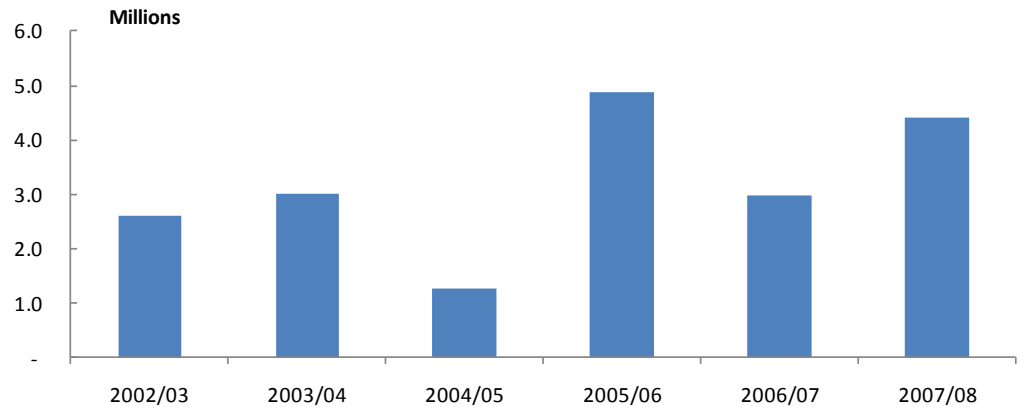
[19] Information provided by Department of Conservation and Farmers Mutual Group, July 2009.

4.3 Suppression costs

Claims from the Rural Fire Fighting Fund (RFFF) formed the basis of our suppression cost data. This data was supplied by the New Zealand National Rural Fire Authority. It includes costs associated with rural fire fighting activities between 1998/99 and 2007/08.

The data is categorised as personnel costs, retardant costs, aircraft costs, NZFS costs, and other costs. BERL extracted all claims from the RFFF for the period 2002/03 to 2007/08, Figure 4.1 summarises these RFFF claims.

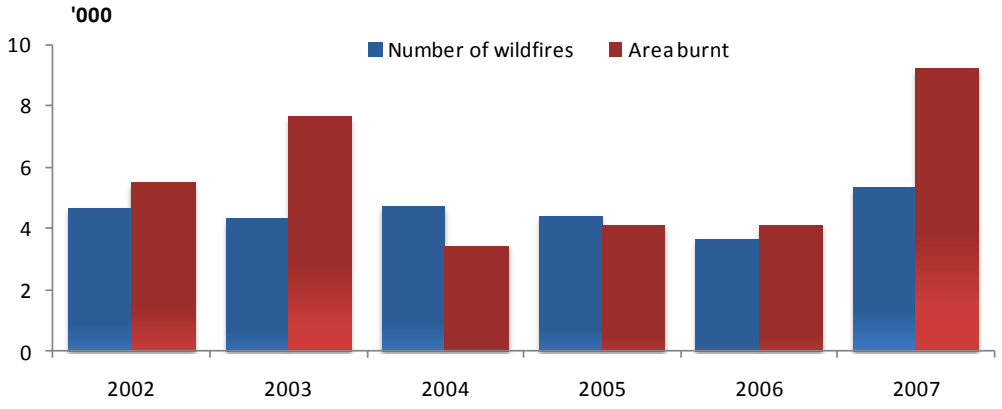
Figure 4.1 Rural fire fighting fund claims, 2002-2007 ($m)



Source: BERL

As shown in Figure 4.2 below, the number of wildfires has steadily increased over the last 10 years and the total number of hectare burnt per year has averaged around 5,000-6,000 hectare. One or two large wildfires in a region/area have lead to a significant amount of burnt area, but these wildfires should be treated as special cases and their impact estimated separately. This is particularly the case for the 2003 and 2007 years.

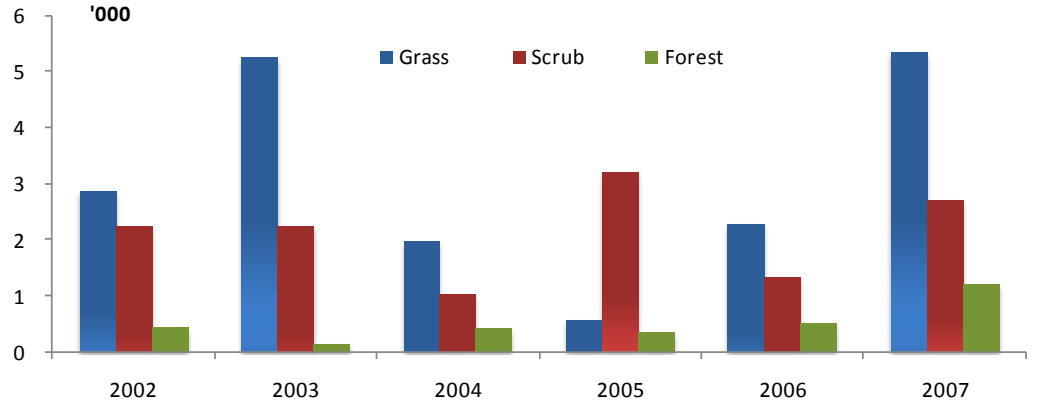
Figure 4.2 Total number of wildfires and area burnt, 2002-2007



Source: BERL

Figure 4.3 below shows the total number of hectare burnt by fuel type. Although the largest areas burnt by wildfires were grass land, we believe the impacts of grass land fires are mainly short-/medium-term. In contrast, the impact of forest wildfires are likely to be over a longer time period as it takes longer to replant and harvest trees, and generate economic values.

Figure 4.3 Total area burnt by fuel type, 2002-2007



Source: BERL

The Department of Conservation also provided average suppression costs for the last three years, over and above claims from the RFFF. For the 2003/04 year, the average suppression cost was $2.4 million. Similarly to the pre-suppression costs, we assumed a constant rate of growth for this figure from 2004/05 to 2007/08.

Fire suppression costs from the Department of Conservation is categorised using the 4 R's, prescribed in the Civil Defence Emergency Management Act 2002 - reduction, readiness, response, and recovery. We grouped the first two categories – reduction and readiness – as pre-suppression, response as suppression, and recovery as after fire cost.

Research indicates that weather conditions are a large influence on wildfires, and in turn suppression costs. A survey of New Zealand Forest Owners Association members also suggests weather conditions, such as wind speed and humidity, are important in estimating the probability of wildfires. For example, when New Zealand experiences longer wet seasons, suppressions costs can be significantly lower.[20] However, it is not reflected in our calculations as estimating the probability of wildfires is out of the scope of this research.

4.4 After fire costs

This section details the data and data sources of economic cost components, including damage to property and vegetation, health costs, damage to forests, impact on other industries, and carbon loss.

4.4.1 Damage to property and vegetation

Fire management data from the Department of Conservation included a recovery category. This category has been counted as a medium-term economic cost as it includes all replanting activities on Department of Conservation land, any investigation work regarding a wildfire, and community rebuilding work after wildfires. Annually, the Department of Conservation spent $800,000 on recovery after wildfires.

The Farmers' Mutual Group Ltd (FMG) provided annual estimates of damage to farm crops, property, and capital equipment from wildfires. They estimated the damage to property and capital equipment averaged $2.4 million per annum, and vegetation $250,800 per annum. Damage to rural dwellings was the most significant, averaging at $1.2 million annually, closely followed by damage to farm tractors at $1 million. These estimates are from an analysis of their claims over the last six years.[21]

Rather than survey all the insurance companies in New Zealand, we used FMG's market share to calculate national levels of damage to property, capital equipment, and vegetation. We have superimposed the remaining market share into their figures to arrive at damage to property and capital equipment at a national level. This equates to a national annual

[20] Information provided by Farmers Mutual Group, July 2009

[21] Information provided by Farmers Mutual Group, July 2009

estimate of $6.6 million for property and capital equipment damage, and $1.0 million for vegetation damage. These economic costs have been classified as immediate economic costs in our analysis.

4.4.2 Health costs

Health costs associated with wildfires were obtained from the Ministry of Health. The Ministry of Health record the number of hospitalisations due to “exposure to uncontrolled fire, not in building and structure", and cost weighted discharges. The number of cost weighted discharges suggests the severity of the incident and provides an estimation of health costs due to wildfires. Over the last six years, there have been 82 hospitalisations due to uncontrolled fire.

4.4.3 Damage to forests

Annual statistics from the New Zealand Forest Owners Association and the New Zealand National Rural Fire Authority provided data on the long-term cost of forest damage and the per hectare cost of fire prevention.

The New Zealand Forest Owners Association has completed research on aspects of rural fire management in plantation forests. This research included two surveys of their members. The first survey covered fire administration, prevention, preparedness and suppression activities and associated expenditures, fire occurrence reporting, and loss/damage information. It had responses from 61 organisations from 35 major NZFOA members, representing 60 percent of the total net stocked area. Based on the total number of hectares of NZFOA’s members, and the total spending on wildfire prevention, the survey calculated fire prevention costs per hectare. The second survey focused on relative trends in fire protection expenditure over the past three to four decades.

Table 4.2 Average cost of fire prevention per year, ($/ha)

Costs ($/ha)	On Total Protected Area	On Total Stocked Area
Fire Organisation	5.08	6.89
Fire Administration	4.78	5.95
Fire Prevention	1.24	1.76
Pre-Suppression	3.31	4.14
Suppression	1.44	1.64
Damages	2.75	3.16
Average	12.36	15.48

Source: NZFOA

The amount of forest burnt was multiplied by the average price and the average volume of wood that a New Zealand radiata pine tree can produce.

The New Zealand Forest Owners Association supplied the average price for radiata, which was used to estimate the dollar value of burnt forest, as shown in Table 4.2. The report noted that due to the use of medians and exclusion of zero values in the base data, the figures in the columns do not equal the average.

The discount rate we applied was 6.4 percent. This was obtained from the Treasury's estimation of the opportunity cost of capital.[22] The discount rate reflects the risk-free rate of return. That is, this rate reflects what capital currently used in the forestry industry would return if it were invested in 10 year New Zealand government bonds instead. The discount rate is a critical parameter in determining the net present value of future gains and losses.

4.4.4 Impact on other industries

The economic impact of wildfires on other industries refers to the flow-on effects of wildfire damage. We used Input-Output tables to quantify the direct, indirect, and induced costs of forestry damage caused by wildfires on other industries. In this case, the initial cost calculated was the potential value of timber lost due to wildfires over the six year period.

4.4.5 Carbon loss

To calculate the loss in carbon credits from wildfires we broke down the total area burnt annually into three fuel types - grass, scrub, and forest. The area under each fuel type stores different levels of carbon. There were five assumptions we imposed in the carbon credits loss calculation:

1. According to SCION[23], 50 percent of tree biomass (dry weight) is carbon and a mid-rotation pine stand would comprise approximately 100 tonnes of carbon per hectare.[24]

2. Carbon sequestration rates established by Landcare Research indicate that there is approximately 34 tonnes of carbon per hectare of scrubland.[25]

---

[22] The Treasury (2008). Estimation of Crown's opportunity cost of capital.

[23] SCION is a New Zealand Crown Research Institute providing science expertise for biomaterials development and the forestry sector.

[24] Richardson B, Anderson S, Kimberley M and Pearce G. (2003). An Economic Case For Rural Wildfire research. Forest Research Report.

[25] Information provided by Landcare Research, July 2009.

3. Carbon sequestration rates from the Ministry of Agriculture and Forestry indicate that there is approximately seven tonnes of carbon per hectare of grass land.[26]

4. SCION also argues that it is reasonable to assume that 50 percent of the carbon in all three fuel types is consumed in a fire.

5. The Treasury has pegged the price of carbon at approximately $26 per tonne of carbon. [27]

Carbon lost for each fuel type is a multiplication of hectares burnt by fuel type and carbon sequestration rate. This is then multiplied by the price of carbon, resulting in the dollar value of loss in carbon credits.

4.5 Data limitations

BERL had hoped to obtain pre-suppression, suppression, and economic cost data from some major forest management groups. However, there were issues around business/data confidentiality. For the same reason, we found that the data could not be split into lower-level cost components as some of the significant fires can be easily identified at that level.

We had also hoped to review some major wildfires on a case-by-case basis. However, key contacts felt it was commercially sensitive to disclose the monetary impacts of catastrophic wildfires in the past since they could be easily identified.

We were also unable to establish the value of disruptions to business activities caused by wildfires, loss in revenue or the opportunity cost of recreational facilities, loss in biodiversity (plant and animal), soil erosion, and other impacts on the land.

[26] Ministry of Agriculture and Forestry. (2009).Carbon Sequestration Rates. http://www.maf.govt.nz/forestry/pfsi/carbon-sequestration-rates.htm, accessed on 14 July 2009.

[27] The Treasury, June 2008, Price Estimation of Kyoto Compliant Emission Units.

5 Results and discussion

This section analyses and discusses the results of our research.

5.1 Economic cost of wildfires

Between 2002 and 2007, the total economic cost of wildfires in New Zealand was approximately $586.2 million. This total cost figure can be broken down into pre-suppression, suppression, and after fire costs. Of the $586.2 million, pre-suppression costs accounted for $227.5 million or 38.8 percent of the total cost, while during and after fire costs accounted for $358.7 million or 61.2 percent of the total cost, as shown in Table 5.1.[28]

Table 5.1 Economic cost of New Zealand wildfires, 2002-2007 ($m)[29]

2002-2007	2008 $m	% of total
Pre-suppression	227.5	38.8
Suppression	46.0	7.9
After Fire	312.7	53.3
- Immediate	*92.6*	*15.8*
- Medium-term	*5.4*	*0.9*
- Long-term	*214.7*	*36.6*
Total Cost	586.2	100

Source: BERL

Long-term economic costs are the most substantial economic cost. Over the six years to 2007, they accounted for 53.3 percent of the total cost of wildfires. This cost category mainly consists of the potential value of timber lost through forest wildfires, and the impact of wildfires on related industries, such as harvesting, transport, and wood processing.

Expenditure on pre-suppression was the second largest cost category over the last six years. This cost category accounted for 38.8 percent of the total cost of wildfires. On the other hand, medium-term economic costs contributed less than one percent to the total cost of wildfires, while suppression costs accounted for 7.4 percent of the total cost, at $46 million.

Medium-term costs were the smallest cost category (7.9 percent of total costs). This cost category includes damage to scrub, which requires a longer time period to be recover

[28] Note, these costs are all in 2008 dollars, using various price indices. An example of this is the Capital Price Index was used to estimate the dollar value of property damaged between 2002/03 and 2007/08.

[29] This report uses financial year information for years to 30 June. All values are expressed in 2008 dollar terms.

compared to grass. Compared to forest wildfires, however, scrub wildfires do not greatly affect other productive industries.

Suppression expenditure reflects the significant effort that is put into wildfire prevention. Typical suppression expenditure includes publicity campaigns alerting the general public and business about the consequences of wildfires; fuel management activities such as monitoring the density of forests, grass and scrub lands; patrols; and data recording.

The immediate cost category includes damage to property, capital equipment and vegetation immediately after a fire, as well as damage to forestry and carbon loss. This cost category also includes health costs. Between 2002 and 2007, immediate costs were approximately $92.6 million or almost 16 percent of the total cost of wildfires.

Table 5.2 shows the annual cost of wildfires by cost category. The annual costs in this table exclude long-term costs, as long-term costs are derived from future values incurred over several years.

Table 5.2 Annual economic cost of wildfires, 2002-2007($m)

$m	Pre-suppression	Suppression	Immediate	Medium-term	Total
2002	37.6	11.0	14.8	0.94	64.4
2003	38.2	6.3	15.3	0.94	60.8
2004	37.9	4.3	14.7	0.90	57.8
2005	37.9	8.2	15.7	0.88	62.7
2006	38.0	6.1	15.2	0.87	60.2
2007	37.8	10.1	16.9	0.84	65.7
Total	227.5	46.0	92.6	5.36	371.5

Source: BERL

Pre-suppression costs include regular maintenance costs, which are relatively constant throughout the year. However, the other cost categories vary as they are dependent on the number, cause, and location of wildfires. Weather conditions can also affect the damage from wildfires.

5.2 Pre-suppression costs

The majority of pre-suppression costs are management costs, which are fixed annually. Table 5.3 illustrates how these costs have changed little over the last six years.

Table 5.3 Pre-suppression costs, 2002-2007 ($m)

$m	TAs	DOC	NZFOA	Total
2002	10.4	4.6	22.7	37.6
2003	10.8	4.7	22.6	38.2
2004	10.9	4.6	22.5	37.9
2005	11.0	4.6	22.3	37.9
2006	11.3	4.5	22.2	38.0
2007	11.3	4.4	22.1	37.8
Total	65.7	27.4	134.4	227.5

Source: BERL

The pre-suppression costs of the 75 territorial authorities throughout New Zealand have increased by almost 8.7 percent over the last six years. This increase has been inflation-adjusted using the local government expenditure index developed by BERL.

Expenditure on pre-suppression by the Department of Conservation has been fairly constant, averaging around $45,700 a year, while the pre-suppression expenditure of the New Zealand Forest Owners Association has declined slightly.

While some of the associated costs of pre-suppression are fixed and irrelevant to the total number of forest hectares, we note that the net stocked forest area has declined due to harvesting or natural causes. According to the figures published on the New Zealand Forest Owners Association website, each year the net stocked forest area has been reduced by around 11,000 hectare.

5.3 Suppression costs

The cost of wildfire suppression is a variable cost that depends on the number of wildfires. The probability of a wildfire is unlikely to be closely related to the wildfire situation of the previous year, but may be substantially affected by weather conditions in a particular year. Therefore, we have not drawn simple year-on-year comparisons.

Table 5.4 Suppression costs, 2007-2007 ($m)

$m	Pre-suppression Cost	Suppression Cost
2002	37.6	11.0
2003	38.2	6.3
2004	37.9	4.3
2005	37.9	8.2
2006	38.0	6.1
2007	37.8	10.1
Total	227.5	46.0

Source: BERL

Table 5.4 indicates that fire fighting costs were relatively small compared to the pre-suppression cost of wildfires. The table suggests that although the total cost of wildfires has been relatively stable over the past six years, this is mainly driven by relatively stable pre-suppression costs rather than suppression costs, which vary with the number of wildfires in a particular year.

It is important to note that the effort put in to preventing wildfires through monitoring and public education is likely to have significantly reduced the probability of wildfires. Hence, although pre-suppression costs may seem large relative to suppression costs, reductions in one category are likely to be associated with increases in the other.

5.4 Immediate economic costs

Table 5.5 shows the detailed results of our analysis of the immediate economic costs of wildfires.

Table 5.5 Immediate economic costs of wildfires, 2002-2007 ($m)

$m	Property & Equipment Damage	Damage to Vegetation	Damage to Forestry	Health Cost	Carbon Loss	Total
2002	6.64	0.69	5.84	0.05	1.56	14.78
2003	6.64	1.12	5.82	0.12	1.66	15.35
2004	6.64	1.11	5.78	0.02	1.17	14.72
2005	6.64	1.11	5.75	0.30	1.86	15.66
2006	6.64	1.11	5.72	0.28	1.44	15.18
2007	6.64	1.11	5.69	0.20	3.27	16.91
Total	39.82	6.25	34.60	0.97	10.96	92.60

Source: BERL

The largest contribution to immediate economic costs was from damage to property and capital equipment, totalling $39.8 million over the six year period examined. This estimate is based on annual claims made to the Farmers Mutual Group.

The cost of damage to vegetation is wildfires among grass, either on the roadside or on dairy farms. Farmers Mutual Group also provided the research that estimated the damage if grass fires occurred on dairy farms, which is more likely to cause economic losses.

Damage to forestry averaged $5.8 million per annum, and includes the loss of timber, as recorded by a survey of New Zealand Forest Owners Association members. The immediate loss of timber is less significant as it only captures the value of wood burnt in a wildfire, ignoring the potential value of the forests. This component was the second largest over the six year period, totalling $34.6 million, following damage to property and capital equipment.

Health costs were estimated at $970,000. This figure is relatively small and reflects the New Zealand's low population density, as noted in the literature review.

Carbon loss due to the loss of forest was also included in our estimation, and totalled $10.96 million for the period 2002 to 2007. The results presented in Table 5.6 are annual summations of loss in carbon credits for the three fuel types.

Table 5.6 Total cost of carbon loss, 2002-2007 ($m)

$m	Grass	Scrub	Forest	Total Carbon Loss
2002	0.00	0.99	0.57	1.56
2003	0.48	0.99	0.19	1.66
2004	0.18	0.45	0.54	1.17
2005	0.00	1.41	0.46	1.86
2006	0.21	0.58	0.65	1.44
2007	0.48	1.19	1.59	3.27
Total	1.35	5.62	4.00	10.96

Source: BERL

5.5 Medium-term economic cost

The medium-term economic cost of wildfires in New Zealand is predominantly the cost of damage to scrub and vegetation. This cost was broken down into an annual figure, as shown in Table 5.7.

Table 5.7 Medium-term economic cost of wildfires, 2002-2007 ($m)

$m	Damage to Vegetation
2002	0.94
2003	0.94
2004	0.90
2005	0.88
2006	0.87
2007	0.84
Total	5.36

Source: BERL

Compared to the damage to grass and forest caused by wildfire, damage to scrub is a relatively small component. Between 2002 and 2007, 12,707 hectare of scrub was burnt in New Zealand, smaller than the 18,234 hectare of grass burnt during the same period.

5.6 Long-term economic cost

This cost category mainly consists of the potential value of timber lost through forest wildfires, and the impact of wildfires on related industries such as harvesting, transport, and wood processing. Between 2002 and 2007, the long-term economic cost of wildfires was almost $215 million. This included an estimated loss of $15.9 million of forest owners' net profit, and flow-on losses of $47.0 million in harvesting, $30.5 million in transport/freight, and $121.4 million in wood processing.

Table 5.8 Long-term economic cost of wildfires, 2002-2007 ($m)

$m	NPV in 2008
Forest owners' net profit	15.9
Harvesting	47.0
Truck/transport	30.5
Wood processing	121.4
Total	214.7

Source: BERL

From 2002 to 2007, there were a total of 3,050 hectare of forests burnt, which would translate to a loss of 2.2m^3 of timber in the future. This equates to around $66.4 million in lost revenue to forest owners in 2008 dollars, before deducting business costs.

The two components of business costs that are directly linked to the wood burnt are the cost of harvesting and transport. These figures were estimated to be around $27.9 million and $22.6 million respectively. After deducting these costs from the lost revenue estimate of $66.4 million, the loss of forest owners' net profit due to wildfires equates to $15.9 million in 2008 dollars.

Table 5.9 Long-term economic cost of burnt forest wood, 2002-2007 ($m)

$m	NPV in 2008
Value of wood	66.4
- Harvesting costs	27.9
- Truck costs	22.6
- Forest owners' net profit	15.9

Source: NZFOA, BERL

Generally speaking, an initial expenditure in an industry creates flows of expenditure that are magnified, or "multiplied", as they flow on to the wider economy. The three major industries that will be affected are harvesting, transport/freight, and wood/pulp processing. The impacts have two aspects – the loss of business profit and the loss of employment.

An industry purchases materials and services from supplier firms, who in turn make further purchases from their suppliers. The first-round of purchases is captured by the term "direct" effect, while further purchases generate the "indirect" effect.

People employed in the industry and in firms supplying services earn an income (mostly from wages and salaries, but also from profits) which, after tax is deducted, is spent on consumption. There is also an allowance for some savings. These are the "induced" effects.

Table 5.10 presents a breakdown of direct, indirect, and induced costs due to forest wildfires. These impacts will occur in the future, as a result of past fires. For comparative purposes, the future impacts are expressed in 2008 NPV dollar terms.

Table 5.10 Costs to other industries of burnt forest wood, ($m)

$m	Initial	Direct	Indirect	Induced	Total
Harvesting	27.9	17.7	16.8	12.5	47.0
Truck/transport	22.6	11.4	9.3	9.8	30.5
Wood processing	66.4	42.4	46.9	32.1	121.4
Total	116.9	71.5	72.9	54.4	198.9

Source: BERL

Wildfires will cost the harvesting industry approximately $47.0 million in the future due to the loss of wood burnt in a wildfire. Similarly, the transport industry would lose around $30.5 million. The most substantial loss in future output due to the forests damaged during the period 2002-2007 is borne by the wood/pulp processing industry. This long-term loss amounts to an estimated $121.4 million.

6 Future research

The objective of this section is to improve the data collection process for future wildfire research.

This section is driven by interest generated by wildfire experts and stakeholder organisations, who would like a collective approach to wildfire data recording and collection for future research.

6.1 Challenges and limitations

The following are the main data challenges and limitations encountered in this research project. These are listed in no particular order:

- Data was not provided due to commercial sensitivity of the material
- Data was not readily available and requires a significant amount of time to generate
- Data was at an aggregated level
- Some cost components were not tracked by key organisations.

6.2 Designing an integrated data collection framework

To establish a data collection framework that will provide suitable data for an integrated economic cost model, NZFS will need to undertake the following steps:

1. Identify all the cost components that best represent New Zealand's total cost, including pre-suppression, suppression, and after fire costs, of wildfires.
2. Establish the uses of this data, including primary and alternative uses as the data may be useful for research projects other than wildfires/fires.
3. Identify data sources (i.e. which organisation collects what data).
4. Develop a database that is available to key stakeholder organisations.
5. Install checks and balances, including data integrity, auditing and revision procedures for the database.

Figure 3.1 presents an integrated model that highlights the key wildfire cost components. We are happy to discuss with NZFS and other stakeholder organisations the detailed steps required to develop a database for wildfire research.

7 Bibliography

BERL. (1987). Economics of fire control expenditure. Project commissioned by the New Zealand Forest Services.

Butry, Mercer, Prestemon, Pye and Holmes (2001). What is the price of catastrophic wildfire. *Journal of Foresetry*, November 2001, 9-17.

Donovan and Rideout. (2003). A reformulation of the cost plus net value change (C+NVC) model of wildfire economics. *Forest Science*, 49 (2), 318-323.

Flowers, Vaux, Gardner and Mills. (1985). Changes in recreation values after fire in the northern rocky mountains. United States Department of Agriculture (Research Note PSW-373).

Flowers, Shinkle, Cain and Mills. (1995). Timber net value and physical output changes following wildfire in the northern rocky mountains estimates for specific fire situations. United States Department of Agriculture (Research Note PSW-179).

Guild and Dudfield (2006). Fire management in the forest and rural landscape for New Zealand.

Hall J. (2008). The total cost of fire in the United States. National Fire Protection Association. National Fire Protection Association Fire Analysis and Reserch.

Hesseln and Rideout. (1999). Using control theory to model the long-term economic effects of wildfire. *USDA Forest Service Gen. Tech.* PSW-GTR-173, 1999, 107-113.

Loomis, González-Cabán and Englin (2001). Testing for differential effects of forest fires on hiking and mountain biking demand and benefits. *Journal of Agricultural and Resource Economics* 26(2), 508-522.

Loomis, González-Cabán and Englin (1999). Effects of fire on the economic value of forest recreation in the intermountain west. *USDA Forest Service Gen. Tech*. Rep. PSW-GTR-173.

Maxwell, Sandberg and Ward. (2003). Fuels and fire in land-management planning. United States Deparment of Agriulture, General Techinical Report PNW-158.

Mercer, Pye, Prestemon, Butry and Holmes. (2000). Economic effects of catastrophic wildfires: assessing the effectiveness of fuel reduction programs for reducing the economic

impacts of catastrophic forest fire events. Topic 8 of the Research Grant “Ecological and Economic Consequences of the 1998 Florida Wildfires”.

Ministry of Agriculture and Forestry (MAF). (2009). *Carbon sequetration rates*. http://www.maf.govt.nz/forestry/pfsi/carbon-sequestration-rates.htm, accessed 14 July 2009.

NZFOA. New Zealand Forest Industry Facts and Figures series.

Parker, Ashby, Pearce and Riley. (2007). Review of methods and data on rural fiire suppression resource productivity and effectiveness. ENSIS Bushfire Research.

Payton, I.J.; Pearce, H.G. (2009) Fire-induced changes to the vegetation of tall-tussock (Chionochloa rigida) grassland ecosystems. *Science for Conservation (290*), 42 .

Pearce, Cameron, Anderson and Dudfield. (2008). An overview of fire management in New Zealand forestry. *New Zealand Journal of Forestry,* 53 (3).

Prestemon and Holmes. (2000). Timber price dynamics following a natural catastrophe. *American Journal of Agricultural Economics.* 2000, 82 (1).

Preston N. (2004). Results of a survey of Territorial Authorities about resources Involved in fighting rural fires. Wellington: The Department of Internal Affairs.

Richardson, Anderson, Kimberley and Pearce. (2003). An economic case for rural wildfire reserch. *Foreset Research Report*, September 13.

Rural Fire Research (2009). Analysis of New Zealand's wildfire records. *Rural Fire Research Update Issue 3*. 1178-7776.

Sparhawk, W. (1925). The use of liability ratings in planning forest fire protection. *Journal of Agricultural Research 30(8)* , 693-792.

The Treasury (2008). Estimation of Crown’s opportunity cost of capital – public sector discount rates for cost benefit analysis.

The Treasury (2008). Price estimation of Kyoto compliant emission units. The Treasury carbon price information releases.