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Welcome from Editors

It is our pleasure to bring to you the compiled papers from the Research Forum of the AFAC and Bushfire CRC Annual Conference, held in the Perth Exhibition and Convention Centre on the 28th of August 2012.

These papers were anonymously referred. We would like to express our gratitude to all the referees who agreed to take on this task diligently. We would also like to extend our gratitude to all those involved in the organising, and conducting of the Research Forum.

The range of papers spans many different disciplines, and really reflects the breadth of the work being undertaken, The Research Forum focuses on the delivery of research findings for emergency management personnel who need to use this knowledge for their daily work.

Not all papers presented are included in these proceedings as some authors opted to not supply full papers. However these proceedings cover the broad spectrum of work shared during this important event.

The full presentations from the Research Forum and the posters from the Bushfire CRC are available on the Bushfire CRC website www.bushfirecrc.com.

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Economic analysis of bushfire management programs: a Western Australian perspective

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Abstract

Bushfires can cause considerable damage to ecosystems, life and property. Protecting human and environmental assets is becoming more difficult as the wildland–urban interface expands in Australia. Fire managers can plan for and manage bushfire events to a greater extent than other large natural disturbances such as cyclones and earthquakes. However, fire strategies that have sought to respond to the increasing bushfire threat with greater suppression capacity do not appear to solve the problem of catastrophic bushfires. Although suppression capacity and the use of technology in bushfire management have greatly increased, the frequency of disastrous fires appears to follow an increasing trend.

Improved understanding and comprehensive appraisals of bushfire costs and benefits are needed in order to devise fire mitigation and management programs that optimally allocate resources and express informed, evidence-based judgements about trade-offs between available options. The aim of this project is to provide a comprehensive economic evaluation of alternative fire management programs in Western Australia in order to determine the optimal allocation of scarce resources for bushfire management.

In this paper we present our initial investigations into the application of the cost plus net value change (C+NVC) model to bushfire management programs in Western Australia.

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Introduction

In Australia, bushfires are the deadliest natural disturbance. Although tropical cyclones, severe storms and floods have been the most costly natural disasters in economic terms (between 1967 and 1999), bushfires have been the most dangerous type of disaster in terms of risk to human life (Bureau of Transport Economics, 2001; Teague *et al.*, 2010). Between 1967 and 1999, bushfires accounted for 7 per cent of total economic losses due to natural disasters in Australia, which is a relatively small proportion of the total cost of disasters. However, during the same period bushfires were the cause of nearly 40 per cent of deaths and around 57 per cent of injuries (Bureau of Transport Economics, 2001). The difference between bushfires and disasters such as cyclones, floods and earthquakes, is that fire managers can plan for and manage bushfire events to a greater extent than other large natural disturbances (Venn and Calkin, 2011).

Despite greater suppression capacity, improved predictive systems, a remarkable increase in the use of technology in bushfire management and stronger cooperation between fire agencies, the frequency of large, disastrous fires appears to have increased in Australia and many other parts of the world in the last two decades (Calkin *et al.*, 2005; Morgan, 2009; Williams *et al.*, 2011). Catastrophic bushfires occurred in the summers of 2003, 2005, 2006-2007 in Australia, and in 2009 the bushfires of Black Saturday resulted in the highest loss of life and property from a bushfire in Australian history (Teague *et al.*, 2010). In the US, a similar pattern can be observed with several states suffering their worst bushfire in history in the past two decades (Williams *et al.*, 2011). In both locations annual suppression expenditures have increased remarkably over the past several years and the risk is that they might continue to increase without necessarily solving (or perhaps worsening) the problem of catastrophic wildfires (Morgan *et al.*, 2007). Fire protection managers and policy–makers have sometimes attempted to exclude fire from the landscape and avoid the disturbance in an effort to protect life and property. However, this often resulted in the accumulation of continuous, homogeneous fuel loads that increased the risk of high fire intensities (Williams *et al.*, 2011).

The main objective of fire management is to maximise social welfare by optimally allocating the resources used before, during and after fire events to achieve the most efficient outcome in terms of costs and damages avoided (Ganewatta and Handmer, 2006). The limited human and financial resources available may be utilized in a variety of ways in fire management activities and their alternative uses have different implications for economic, environmental and social assets. The consequences of different uses of fire resources may be profound, thus society needs comprehensive assessments of bushfire costs and benefits and sound analyses of trade-offs between available options. Economics can provide such analyses and help fire mangers and policy–makers devise fire mitigation programs that optimally allocate resources (Handmer and Proudley, 2008).

However, the use of economics in the bushfire literature is still relatively limited. Empirical economic analyses of bushfire management are scarce (Mercer *et al.*, 2007). There is limited understanding of bushfire impacts on human communities and ecosystems and little empirical evidence about the extent of total economic damages (or benefits) due to bushfires (Abt *et al.*, 2008). But concerns about the growing number of mega–fires and the increasing trend of suppression expenditures have prompted the bushfire economics field to expand. Economic analysis is now being applied to fire management in countries where none was previously applied (e.g. Pedernera *et al.*, 2008; Rodriguez y Silva and Gonzalez-Caban, 2010).

In this paper, we apply the cost plus net value change (C+NVC) model to a synthetic landscape, representative of the northern jarrah forest of the south west of Western Australia (WA). The purpose of the study is to determine the most economically efficient pre-suppression strategy for the synthetic landscape and evaluate which parameters significantly affect the results. We focus on prescribed burning as the main pre-suppression strategy. The primary objective of this model is to provide preliminary results which may inform the development of a more complete model based on actual areas of WA.

Methods

In economic terms, fire impacts and fire management activities may be encapsulated in a three–stages cycle: (i) the pre–fire or pre–suppression stage, which is defined as all expenditures associated with activities carried out before the fire event occurs (or before the start of the fire season) such as prevention, education, detection, fuels management (e.g., prescribed burning, mechanical fuels reduction) and pre–positioning of fire–fighting resources; (ii) the during–fire or suppression stage, which is defined as all expenditures associated with activities carried out during a fire event, i.e. after the fire–fighting resources have been deployed; and (iii) the post–fire stage, which encompasses the resulting net damages and expenditures for rehabilitation projects.[2] Although these stages are presented in a linear sequence, they should be envisaged as a circle, where the post–fire stage corresponds to the pre–fire stage of the next period, and so on (Gebert *et al.*, 2008).

To date, most fire economics applications have focused on a single aspect or stage of the fire problem (Gebert *et al.*, 2008). Economic analysis of trade–offs between pre–suppression activities, suppression efforts and bushfire impacts remain extremely rare, despite considerable work on the economic theory of bushfire management (examples of theoretical studies include, among others, Donovan and Rideout, 2003; Hesseln and Rideout, 1999; Rideout and Omi, 1990; Rideout *et al.*, 2008; Rideout and Ziesler, 2008). Among the few studies that have examined all stages of the fire problem, the majority have used the C+NVC model (or modified versions of it). The C+NVC provides the theoretical foundation for bushfire economics and has become the commonly accepted model for evaluating bushfire management programs (Ganewatta, 2008; Gebert *et al.*, 2008).

The C+NVC is a monetary–based framework that minimises the total sum of pre-suppression costs, suppression costs and net fire damages (Venn and Calkin, 2011), analogous to a benefit–cost analysis. In this model, pre-suppression is the independent variable that determines suppression costs and damages. The underlying assumption in this

[1] Initial attack, which corresponds to the action taken by the first fire–fighters that arrive at the fire incident, is sometimes considered to be part of the pre–suppression effort and in other cases considered to be part of suppression activities (direct fire–fighting expenditures).

formulation is that investment in pre–suppression results in gains in terms of reduced damage and suppression costs (Ganewatta, 2008). In theory, damages decrease with an increase in suppression expenditure, and suppression costs decrease as pre–suppression investment increases (Rodriguez y Silva and Gonzalez-Caban, 2010). The most efficient level of fire protection is the level at which the total cost of fire management plus damages is minimised (Gonzalez-Caban, 2007).

We used the following expression of the C+NVC, from Donovan and Rideout (2003):

$$\text{Min } C + NVC = W^P P + W^S S(P) + NVC\big(P, S(P)\big) \quad \textbf{(1)}$$

with W^P the price of pre–suppression; P the pre–suppression effort; W^S the price of suppression; S the suppression effort, which is dependent on pre–suppression; and NVC the net fire damage (fire damage less fire benefit). Generally, the analysis yields a U-shaped function known as the C+NVC curve. The minimum point of the C+NVC curve corresponds to the most efficient level of pre-suppression investment (Gonzalez-Caban, 2007; Mills and Bratten, 1982; Rodriguez y Silva and Gonzalez-Caban, 2010). In Figure 1 this corresponds to the level of pre–suppression expenditure P^*.

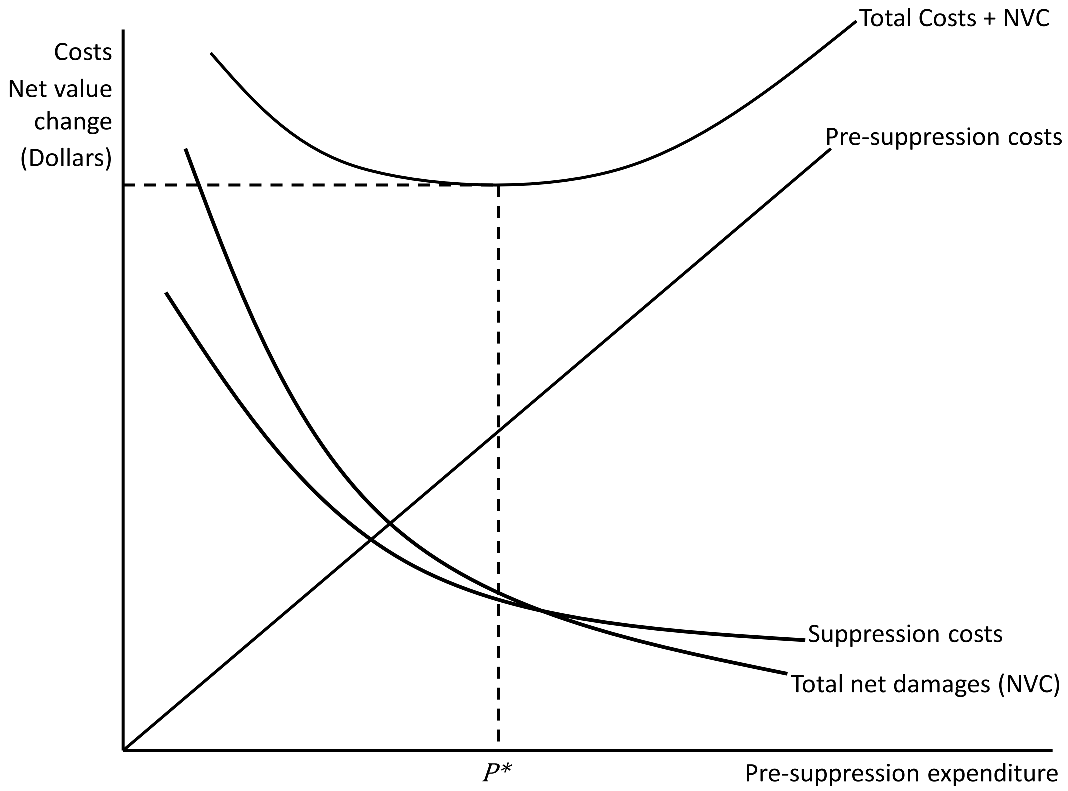

Figure 1.
The cost plus net value change (C+NVC) model

We applied the C+NVC to a square synthetic landscape of 100,000 ha with a flat, homogenous jarrah forest. This landscape is the type of landscape usually found in the northern jarrah forest of the south west of Western Australia (WA). Using the AUSTRALIS Wildfire Simulator[3], we simulated 1,200 bushfires under varying climatic conditions and different prescribed burning (pre-suppression) strategies. We tested three prescribed burning strategies with different patch sizes and a no-strategy case where the fuel age was uniformly set at 15 years across the entire synthetic landscape (see Florec *et al.*, 2012 for a detailed description of the construction of the scenarios tested and the simulator settings for prescribed burning experiments). Fire ignition points were generated across the entire landscape according to a random uniform distribution and each scenario was tested under 30 random ignitions. The outcomes of the simulated fires were multiplied by the probability of occurrence of the event under the specified weather conditions. Table 2 presents a summary of the scenarios tested.

Strategy **(% of total area burned)**	no-strategy, 5, 10, and 20
Patch size **(in ha)**	50, 500 and 4000
Forest Fire Danger Conditions **(FFDI)**	High, Very High, Extreme, and Catastrophic

Table 2. Summary of scenarios

Prescribed burning decreases the intensity with which bushfires burn, and hence it is generally expected to improve the probability of successful suppression (Fernandes and Botelho, 2003). Therefore, in our model we assumed a negative relationship between prescribed burning investment and suppression costs (see Florec *et al.*, 2012 for details on the functional relationships).

One of the major challenges that fire managers and policy–makers face is the growth of areas where highly flammable vegetation and human assets are intermingled in the landscape, i.e. the rapid development of the wildland-urban interface (WUI) (Marzano *et al.*, 2008). In order to incorporate this issue in our analysis, we assumed that a small town of 1,500 ha is located within the synthetic landscape and analysed bushfire impacts on urban structures and public infrastructure and smoke and fire-related (prescribed or bushfire) health costs.

[2] The AUSTRALIS Wildfire Simulator was developed at the School of Computer Science and Software Engineering, The University of Western Australia (see Johnston *et al.*, 2008 for a description of the fire simulator).

Results and Discussion

In our simulated landscape, the most efficient level of prescribed burning is the 5% strategy, where 5% of the area is prescribe-burned per year, corresponding to an annual investment of approximately AU$405,000 for the 100,000 ha (with our assumed costs of prescribed burning equalling AU$80/ha). The minimum of the C+NVC curve, i.e. the sum of prescribed burning costs, suppression costs and damages, amounts to about AU$785,000 (see Figure 2).

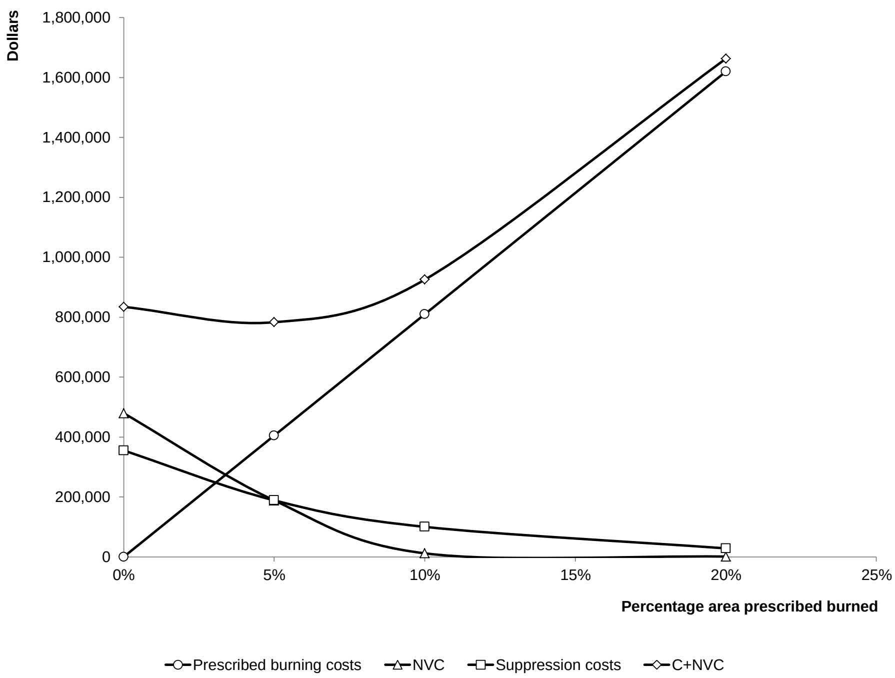

Figure 2.
Results for the cost plus net value change curve

To test the robustness of the results and identify the parameter values that most influence the results, we conducted a sensitivity analysis. We increased and reduced each parameter value by 50% and estimated the change in the minimum of the costs plus net value change curve. We found that prescribed burning costs (in average dollars per hectare), the probabilities of fire occurrence, urban area values (in average dollars per hectare) and suppression costs, are the parameters to which the results are most sensitive. Figure 3 shows the change in the minimum of the costs plus net value change curve in dollars when these parameter values are increased or reduced by 50%. The sensitivity of these parameters captures the key challenges faced by fire managers in developing sustainable fire mitigation programs: climate change, the wildland-urban interface and the effectiveness of suppression.

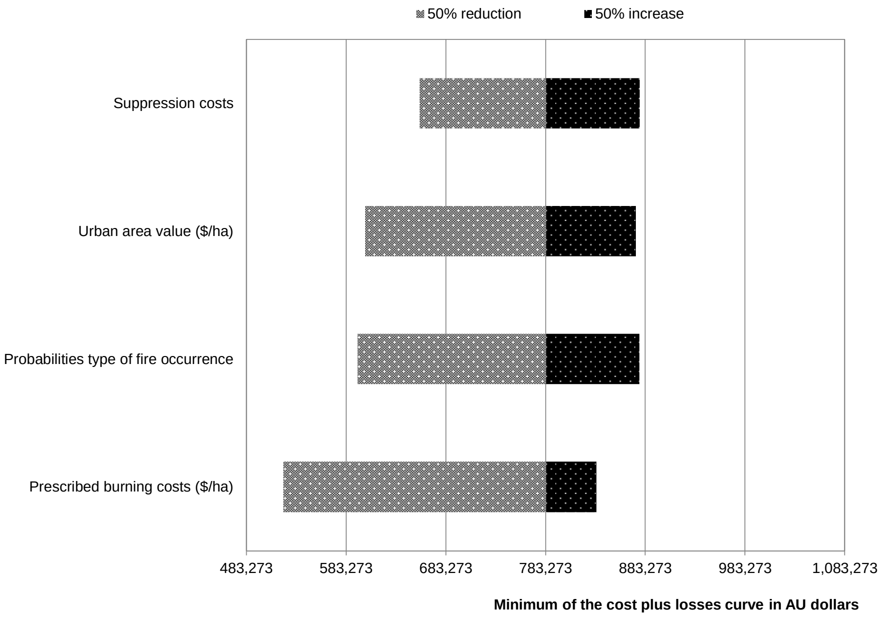

Figure 3.
Change in the minimum of the costs plus net value change curve with an increase and a decrease of 50% in selected parameter values

In our analysis, prescribed burning costs quickly become a large proportion of the C+NVC curve. The rate of change in prescribed burning costs (i.e. the slope of the line representing prescribed burning costs in Figure 2), the rate at which prescribed burning costs increase, is for the most part greater than the rate of change in suppression costs and damages, i.e. the rate at which these curves decline. Hence a change in average dollars per hectare for prescribed burning has generally a greater impact on the results than a change in the value of the other parameters.

The minimum of the C+NVC curve corresponds to a strategy of 0% of prescribe-burned area when the average cost per hectare for prescribed burning is very high. Conversely, the minimum value of the C+NVC curve corresponds to a strategy between 5 and 10% area prescribe-burned per year when the average prescribed burning cost per hectare is reduced by 50% (see Figure 4). In this case, the corresponding value in dollars of the minimum of the C+NVC curve decreases by 34% (see Figure 3). Comparing the three curves of the C+NVC curve in Figure 4, it can be seen that for the curve that represents our initial estimation, there is a wide range of prescribed burning levels near the optimal solution, but this is not the case when the cost of prescribed burning is increased or reduced by 50%.

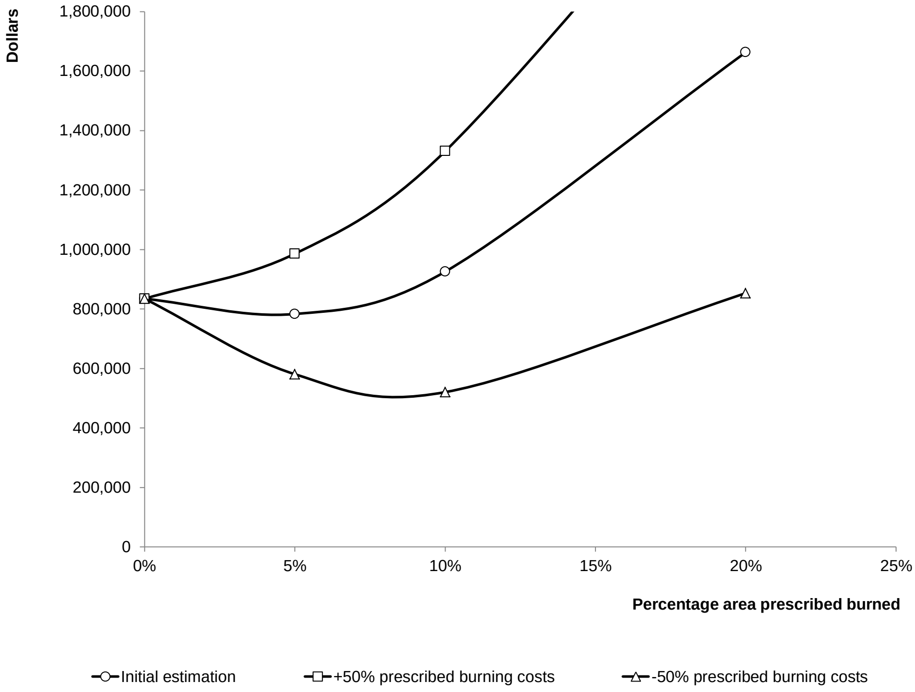

Figure 4.
Change in the cost plus net value change curve with different prescribed burning costs

Changes in the patch size of the prescribed burns had no significant effect on the results of the economic analysis. Other studies using simulation to examine the efficacy of prescribed burning have found similar results, e.g. Finney *et al.* (2007) and King *et al.* (2008).

Conclusion

We applied the C+NVC to a square synthetic landscape of 100,000 ha with a flat, homogenous jarrah forest, representative of the northern jarrah forest of WA's south west. Using the AUSTRALIS Wildfire Simulator we simulated 1,200 bushfires under varying climatic conditions to test three different prescribed burning strategies with different patch sizes and a no-strategy case.

Our results show that the most efficient level of prescribed burning is the 5% strategy, totalling an annual investment of AU$405,000 for the 100,000 ha. Our sensitivity analysis shows that prescribed burning costs, the probabilities of fire occurrence, urban area values and suppression costs, greatly affect the results. With prohibitive prescribed burning costs, the minimum of the C+NVC curve shifts to a strategy of 0% of prescribed burned area. Conversely, when the probabilities of fire occurrence, urban values or suppression costs are very low, the most efficient prescribed burning strategy is the no-strategy case.

The C+NVC model and, more generally, the bushfire economics literature mostly approach the bushfire management problem from an annual budgeting perspective. Fire agencies generally attempt to minimise the sum of fire management costs and damages for one single fire season, repeating the process every year for each fire season. Thus each fire season is treated as an independent problem, without necessarily being linked with previous or subsequent fire seasons. However, is it possible that because of the long term attributes of fuel accumulation processes and fire dynamics this paradigm of annual budgeting is not the most comprehensive approach to bushfire management issues? In addition to short term seasonal changes to bushfire risk, fuel management strategies together with land management practices and unplanned fire patterns may have long term effects on the ecology of a region and on incident probabilities (Hesseln and Rideout, 1999).

In the past two decades, the C+NVC model has been through some reformulation. But despite the limitations that have been identified in the model, the application of the C+NVC model in its current formulation can help fire managers recognise potential benefits and costs of different options for a given year, even if a global minimum is not obtained for the C+NVC curve (Rodriguez y Silva and Gonzalez-Caban 2010). We recognise the limitations of the model and their implications, and hope to address them in future work. Here we have used the C+NVC as a first step towards a more comprehensive analysis.

Acknowledgments

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