Theory into practice: A case study of vegetation management and house bushfire survival

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Abstract

Contemporary bushfire management acknowledges vegetation management around a building will aid its survival in a bushfire. Whilst this is accepted practice, there is little empirical evidence that vegetation management around a house has made a significant improvement to house survival during a bushfire. The Victorian bushfires of 2003 provided an opportunity to evaluate this aspect of bushfire management. The Country Fire Authority's *Building in a Wildfire Management Overlay Applicant's Kit* provides a theoretical method to assess vegetation hazard and the extent of management required to protect a house from direct flame/radiant heat of a bushfire. Forty seven houses in the bushfire area were surveyed. It was found that dwellings with vegetation conditions equivalent to those identified by the method, had a significantly ($P<0.05$) better survival rate compared to those with little or no vegetation management. It is concluded that the role of vegetation management in house survival during bushfire is important but the underlying mechanisms needs further research.

Introduction

Numerous post-fire studies have investigated the causes of house loss during bushfires (eg Wilson and Ferguson, 1986, CFA, 1995, CFA/DNRE 1997). As a result of these studies we have a good understanding of the mechanisms of house loss during bushfire. This knowledge of the risk of house ignition by embers or direct flame/radiant heat has led to the development and implementation of a number of risk treatments. The predominant treatments to address house loss are vegetation management, construction standards for buildings, occupant planning, preparedness and response and fire service intervention. It is believed that the best outcome is achieved by a mix of the available treatment alternatives.

This paper investigates the role of vegetation management around a house and its effect on house survival during a bushfire. There are two main and complementary approaches to encouraging vegetation management to reduce wildfire impact upon dwellings, via regulation and via community development approaches supporting residents in voluntary adoption. In Victoria, there are two regulatory controls over development in areas where people and property may be at risk from wildfire. One control, the Bushfire Prone Area (BPA), is targeted at building construction and is implemented through the Building Code of Australia which references the *Australian Standard 3959 Construction of buildings in bushfire-prone areas*. The other is a planning control implemented through *The Wildfire Management Overlay* (WMO) of the Victorian Planning Provisions. There is currently a process in train to align Bushfire Prone Areas with Wildfire Management Overlays.

The Victorian approach to voluntary adoption of vegetation management is concentrated in several community development programs. CFA currently facilitates the implementation of programs such as Community Fireguard and Bushfire Blitz. In addition several publications such as Living in the Bush (CFA, undated) and Landscape and Building Design for Bushfire Areas (Ramsay and Rudolph, 2003) provide a wealth of reference material.

The WMO aims to ensure that land use and development includes adequate fire protection measures, does not significantly increase the threat to life and property and, does not significantly increase the likelihood, occurrence or spread of wildfire.

CFA developed a Wildfire Management Overlay Applicant's Kit (CFA, 2002) to assist members of the community who plan to build a house in an area covered by a Wildfire Management Overlay. The kit takes the applicant through a process which includes the following:

- Assessment of the site to determine the potential impact of a bushfire on the proposed building. This assessment involves:
    - Identifying the vegetation type, and
    - Measuring the slope;
- Calculation of defendable space[1]– that is the width of zones designed to reduce the impact of flame or radiant heat on the building to a survivable level (defined as radiant flux less than 29kW/m^2 – wood ignition point, and no flame contact from the fire front);
- Description of vegetation management prescriptions to achieve this defendable space; and
- Specification of other infrastructure requirements such as water supply and access.

The site assessment method developed for the WMO Applicant's Kit[2] uses current fire behaviour models to calculate potential fire intensities and flame lengths using assumed 1 in 50 year fire weather conditions (as defined by a Forest Fire Danger Index of 120), slope and broad vegetation classifications. The resultant fire behaviour is then used to predict potential radiant heat flux incident on a building at a given distance. The calculations suffer the limitations of current fire behaviour models.

Concurrently, Australian Standard 3959 (1999) *Construction of buildings in bushfire-prone areas* provides minimum construction requirements for new dwellings in designated Bushfire-Prone Areas. The construction requirements are intended to improve the performance of buildings subjected to burning debris, radiant heat or flame contact. Based on an assessment of a site's vegetation type and proximity, the degree of potential wildfire attack is identified. Building permit applicants must then build to the level identified in the standard as necessary to mitigate that level of wildfire attack.

The Research Questions

To examine whether the vegetation management prescriptions outlined in the CFA WMO Applicant's Kit provides a true indication of vegetation management necessary to mitigate the direct flame/radiant heat risk, three questions were posed:

1. Do the prescriptions enable reduction of surface fire intensity to the level that structural building element integrity is not threatened by direct flame or radiant heat? and

[1] Defendable space is that which is required to prevent the building being ignited by direct flame or radiant heat.
[2] Maughan,D,, Krusel,N., Boura, J., Caling, T. (1999) House Safety Zones: *A Theoretical Model* Unpublished CFA internal paper.

2. Had the vegetation management prescriptions identified by the method been in place, would the house survival outcome have been different from that observed?

Background - The Victorian fires of 2003

Significant Victorian wildfires are generally compared to those of Ash Wednesday February 1983, often touted as a 1 in 50 year benchmark. Conservatively the Ash Wednesday weather conditions are the basis for the WMO Applicant Kit's method. On the two primary days of house loss during the 2003 fires, fire weather conditions were markedly less severe than those of Ash Wednesday. Data indicate maximum Forest Fire Danger Indices (FFDI) of 44 and 75, whereas Ash Wednesday FFDIs exceeded 100. Further, unlike the rapid onset fires of 1983, the temporal extent of the 2003 fires meant that many residents were aware that fire was hours or even days away. This provided them a rare opportunity to improve the preparedness of their properties in the face of actual threat.

Data collection

The houses for this study were selected principally on the basis that they had been or had the potential to be, directly impacted by a fire front, where the risk of direct flame contact or radiant heat was relatively high. As the WMO vegetation management prescriptions are not aimed at mitigating ember attack, it was considered that the study of houses destroyed by embers alone would not contribute to this research. Consequently 15 houses that were solely impacted by embers and had no potential to be impacted by the fire front were excluded from detailed survey and analysis. These 15 houses are not considered in the presented data.

House impact data was collected using standard wildfire investigation indicators (DCNR 1995) and the CSIRO protocol for surveying bushfire building damage (Leonard, pers comm). Data collected in the field included the CFA WMO Applicant's Kit site assessment, fire behaviour indicators and photographs. All data was geo-referenced and captured on a handheld computing device.

Data analysis

The WMO site assessment method was evaluated by comparing the theoretical direct flame or radiant heat impact potential, with the actual outcome and vegetation conditions. The fire weather conditions of Ash Wednesday (assumed to be approximately 1 in 50 year event) and those of 21st, 26th and 30th January 2003 (depending on the date a location was impacted by fire front) were used to calculate a predicted outcome.

The WMO site assessment methodology was then used to determine whether houses met the vegetation management prescriptions described in the Applicants Kit. The predicted outcome was then compared to the actual outcome, and a statistical analysis of vegetation management against house survival undertaken.

Although the condition of pre-fire vegetation is difficult to assess post-fire, standard fire investigation indicators (DCNR 1995) and vegetation maps were used to estimate pre-fire conditions. As no comprehensive fire behaviour analysis was undertaken for the entire event, at the time of this study, analysis was conducted on a site-by-site basis.

Results

The vegetation on the majority of private land within the fire perimeter was pasture, varying from 'natural' to heavily grazed or depleted. Fieldwork confirmed that the majority of dwellings within the fire perimeter were threatened by ember attack alone. As a result, only 47 of the approximately 1,100 dwellings within the fire perimeter were found to be relevant to this research. The status and mechanism of attack for each house are detailed in Table 1. Full details of all houses surveyed are contained in the CFA report on the North East and Gippsland Fires of 2003 (CFA, 2003).

Table 1 Status and damage mechanism for surveyed houses.

Status and damage	Number of houses
Lost	
Ember attack, potential flame or radiant heat	17
Combination of ember, direct flame and radiant heat attack	7
Mechanism unknown	2
Damaged	
Light to moderate damage from ember attack	3
Light damage from radiant heat	3
Survived	15
Total Houses Surveyed	47

The comparison of the outcome, in terms of house impact predicted by the model with the actual impact observed on the ground is summarised in Table 2

Table 2 Comparison of theoretical impacts compared to actual impact

	Theoretical number of houses impacted (1:50 yr event)	Theoretical number of houses impacted (adjusted for 2003 conditions)	Actual number of houses impacted
Impacted by direct flame, radiant heat	37	30	10
No direct flame contact or radiant heat impact	10	17	37
Mechanism unable to be ascertained	N/A	N/A	2 destroyed

The WMO site assessment methodology over-predicted the number of houses that would be impacted by flame or radiant heat and under estimated those that would survive. The difference between the predicted and actual impact can be attributed to a number of factors including:

- Influence of other mechanisms of house defence, particularly active defence by residents and firefighters (it should be noted the site assessment model only considers vegetation management). There were seven cases where active defence was the sole mechanism of defence and another six where it played a key role;
- The Forest Fire Danger Index may not have been at its peak at the time of impact and, as a result the potential fire behaviour would have been reduced;

- Fuel modification, whether deliberate or as a result of drought, would have meant fuel loads were at less than steady state, and therefore fire intensity and potential direct flame or radiant heat impacts would have also been reduced; and
- Limitations of current fire behaviour models.

The role of vegetation management

Table 3 Vegetation condition and house survival for houses surveyed

Vegetation Conditions, house status and Damage Mechanism	Number of Houses
Met WMO Applicant's Kit Prescriptions	
Survived	8
Destroyed (ember attack)	2
Did not meet WMO Applicant's Kit Prescriptions	
Survived	7
Damaged (Embers)	3
Damaged (Flame/Radiant Heat)	3
Destroyed (Embers)	15
Destroyed (Flame/Radiant Heat)	7
Destroyed (Mechanism Unknown)	2

A summary of vegetation conditions and house survival is presented in Table 3. For seven of the twenty four destroyed houses examined the actual impact matched that predicted by the method. That is, the method indicated that because the vegetation conditions did not match those prescribed in the Applicant's Kit there was a potential for direct flame or radiant heat impact and, dwelling loss *was* attributed to varying combinations of radiant heat, direct flame contact and ember attack. This was true whether 1:50 year or 2003 fire weather conditions were used. It should be noted that in two cases, some active defence was attempted but was unsuccessful.

There were three cases where the site assessment method indicated that because the vegetation conditions did not match those prescribed in the Applicant's Kit there was a potential for direct flame or radiant heat and, the dwelling sustained some damage due to radiant heat as well as ember attack. In all cases, prevention of more substantial damage was attributed to active defence. Radiant heat damage tended to be sustained on windows. In two cases the proximity of 'medium forest' type vegetation was considered to have contributed directly to the radiant heat damage sustained.

There were ten cases where the existing vegetation conditions were equivalent to those identified by the method and surface intensity was reduced to the level where structural building element integrity was not threatened. In eight of these cases, the vegetation conditions also enabled active defence of the dwellings from ember attack, that is defendable space was provided.

In the remaining two cases although the vegetation conditions equated to those identified by the method as necessary to avoid direct flame or radiant heat impacts, the dwellings were destroyed. In both cases, the dwellings survived the passage of the fire front but were lost due to a lack of active defence from post-fire front ember attack.

These ten cases provide preliminary evidence to suggest that theoretical fire behaviour modelling can provide a useful indication of the appropriate extent of vegetation management to mitigate an identified risk.

In two cases, the primary mechanism of dwelling loss could not be ascertained. Whilst embers clearly would have played a role, small clumps of burnt 'woodland' type vegetation immediately adjacent to the dwellings may have contributed some radiant heat. It is known that neither dwelling was actively defended.

Discussion

Overall, the research suggests that the site assessment method adequately identifies vegetation conditions where radiant heat and direct flame may impinge on a dwelling during the passage of a fire front. The results also suggest that the vegetation conditions identified by the Applicant's Kit vegetation management prescriptions would reduce fire intensity to a level where structural building element integrity is not threatened by direct flame or radiant heat during the passage of the fire front. Whilst the theoretically based method over-predicted impact even when adjusted for fire weather conditions less severe than the model's 1:50 year basis, with respect to bushfire safety, a conservative approach is preferred.

A Chi-squared analysis indicated a significant difference (at 0.05) in the ratio of survived to destroyed dwellings (Table 3). This analysis suggests that the likelihood of a relationship between application of the method's vegetation prescriptions and house survival is very strong and that there is a very low probability this is pure chance. This indicates that vegetation management (as defined by this method) is a significant factor in house survival. The underlying mechanism of why vegetation management (ie. prevention of flame contact, radiant heat, embers, support to occupant defence, etc) is, however, not well understood. Given that the vegetation conditions identified by the prescriptions are not aimed at addressing ember attack and that the majority of dwellings lost during these fires were lost due to ember attack, the vegetation management prescriptions alone do not provide the sole means of ensuring house survival during a bushfire. However, the fact that there was a significantly higher survival rate ($P=0.05$) where the vegetation conditions were equivalent to those identified by the method, suggests that had this been the case at those sites where houses were lost or damaged due to direct flame or radiant heat, the overall survival rate of these dwellings may have been higher.

Moreover, in the two instances where active defence was overwhelmed due to the number of buildings requiring defence or the fuel hazards present, application of both vegetation management and building construction treatments may have reduced the complexity of the defence required. Appropriate building construction may have supported dwelling capacity to withstand ember attack and short-term direct flame or radiant heat impacts, diminishing the complexity of defence demanded of the residents.

Conclusion

It was found that the WMO Site Assessment Method overestimates radiant heat and direct flame impingement on a dwelling during the passage of a fire front. The method also over-predicted impact when adjusted for the 2003 fire conditions. Generally an over prediction is considered acceptable because with respect to community safety, a conservative approach is preferred.

Opportunities to investigate the efficacy of the vegetation management prescriptions described in the WMO Applicant's Kit were limited as dwellings within the fire perimeter were constructed before declaration of the WMO in East Gippsland and there were relatively few cases of direct flame or radiant heat impact. However, analysis showed a significantly (P=0.05) better survival rate for dwellings with vegetation conditions equivalent to those prescribed in the WMO Applicant's Kit. The underlying mechanisms of how vegetation management assists house survival were not researched.

It is suggested that had the relevant regulations been in place prior to 2003 and, as a result the dwellings constructed and vegetation managed to the required conditions, fewer dwellings may have been lost.

It is concluded that the important role of vegetation management around a house needs to be further researched in relation to its contribution to house survival during bushfire. Improved understanding of these factors would not only provide an opportunity to refine risk management treatments, it would offer increased flexibility in addressing community bushfire safety needs.

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