Bushfire Penetration into Urban Areas in Australia: A Spatial Analysis

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Bushfire Penetration into Urban Areas in Australia: A Spatial Analysis

Commercial-In-Confidence

Prepared for the Bushfire CRC
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bushfire CRC

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Cover photos: Risk Frontiers 2009

1. Introduction

Bushfire CRC has engaged Risk Frontiers to provide a comprehensive study that quantifies bushfire penetration into urban areas in Australia. The main task is to examine spatial patterns of building damage in relation to surrounding bushland for a list of suburbs or towns that have been severely impacted by extreme bushfires over the past two decades. This list comprises:

- Marysville and Kinglake (Victoria), damaged by the 7 February 2009 “Black Saturday” bushfires
- Duffy (ACT), damaged by the 18 January 2003 Canberra bushfires
- Como-Jannali (NSW), damaged by the 7-8 January 1994 Sydney bushfires

Observations from this study will be compared with previously published results arising from another two extreme historical fires:

- 16 February 1983 “Ash Wednesday” bushfires in Victoria and South Australia
- 7 February 1967 Hobart bushfires

Our understanding is that this information will be used by the Bushfire CRC in its contribution to the 2009 Victorian Bushfires Royal Commission inquiry.

This study will first provide an overview of historical bushfire property damage in Australia, including time series and spatial distributions across States and affected locations. Then this study will focus on the events listed above in respect to spatial patterns of damage; details of data sources used - mainly pre- and post-fire high-resolution images for recovering historical damage footprints; as well as presentation of the analyses and comparative results. Finally, we provide a national upper estimate on the number of addresses vulnerable to bushfires and a brief general discussion about the potential impact of Global Climate Change on bushfire property loss occurrence.

2. Recent Building Damage from Bushfires

Bushfires are endemic to Australia and conflagrations may occur whenever favourable combinations of fuel, weather and ignition sources exist (Luke and McArthur, 1978; Cheney, 1979; Cary et al., 2003; Leicester and Handmer, 2007). On occasions, they cause significant loss of life and may destroy entire communities as evidenced most recently in the 7 February 2009 Victorian bushfires. Table 1 attempts to put this particular event into some historical perspective. We see that most of the big fires or, more exactly, fires resulting in the biggest property losses, have taken place in Victoria.

Table 1: Historical residential home losses from bushfire with greater than 500 homes destroyed (PerilAUS database, Risk Frontiers, Appendix A; updated from Ashe et al. (2009)). These figures have not been adjusted to take into account the increase in the exposure, i.e. the growth in the numbers of at-risk homes that has occurred over time.

Date	**States**	**Homes Destroyed**
January 8-13, 1939	Victoria and NSW	>750
Various fires over 1943-44 summer	Victoria	885
February 7, 1967	Tasmania	1,557
February 16, 1983	Victoria and South Australia	2,253
February 18, 2003	ACT	530
February 7, 2009	Victoria	2,029

In PerilAUS, House Equivalents (HEs) were used to normalise losses of various types of destroyed structures – residential homes, commercial buildings, churches, etc. – onto a common footing of equivalent residential houses using relative building costs and average floor areas. A time series of bushfire losses in House Equivalents (HE) over the last six decades (Figure 1) shows a background level of 'attritional' losses with episodic large losses. Note that HE is a surrogate for total loss and does not include damage to building contents, cars, machinery, aircraft, crops, etc.

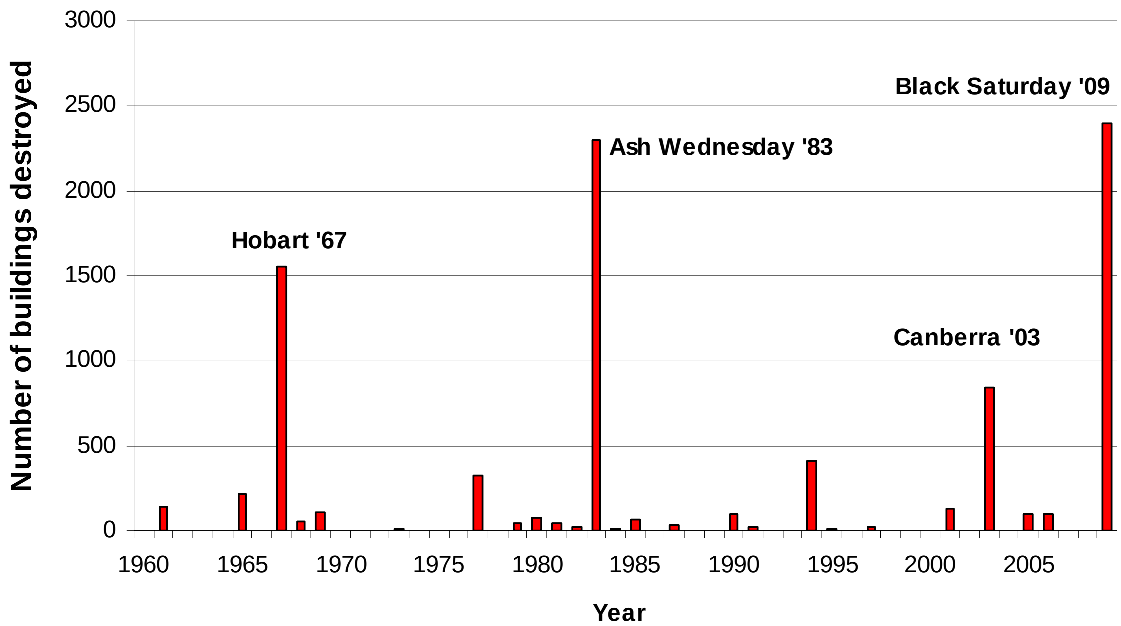


Figure 1: Annual number of buildings (House Equivalents) lost in bushfires between 1960 and 2009 (Source: PerilAUS). Note the use of HE rather than residential homes as reported in Table 1. Again this figure does not take into account the increase in at-risk homes that has occurred over time.

The average annual number of buildings destroyed by bushfires in Australia during 1900-2009 is about 105. Of 11,494 bushfire-related house equivalents lost over the 1900-2009 period, Victoria accounted for 6,625 (about 57%) and NSW for 2,145 (19%). Other states – Tasmania, South Australia, Western Australia and ACT – collectively only contributed 24% of total HEs (Figure 2).

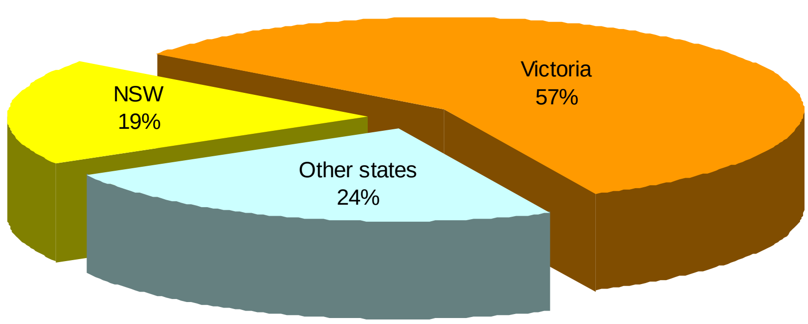


Figure 2: Proportions of bushfire-related building damage (House Equivalents) in Victoria, NSW and other states (Source: PerilAUS, 1900-2009).

The PerilAUS database also contains building damage information for affected locations. A single event may have multiple affected locations, and for some events no details of the affected locations can be identified. On average, about 85% of all bushfire-related total building damage in the database can be identified with an affected location, and Figure 3 shows the distribution of this damage. Some heavily affected areas in Victoria are close to the Greater Melbourne Region, including the Otway Ranges, Mount Macedon and Mt Dandenong.

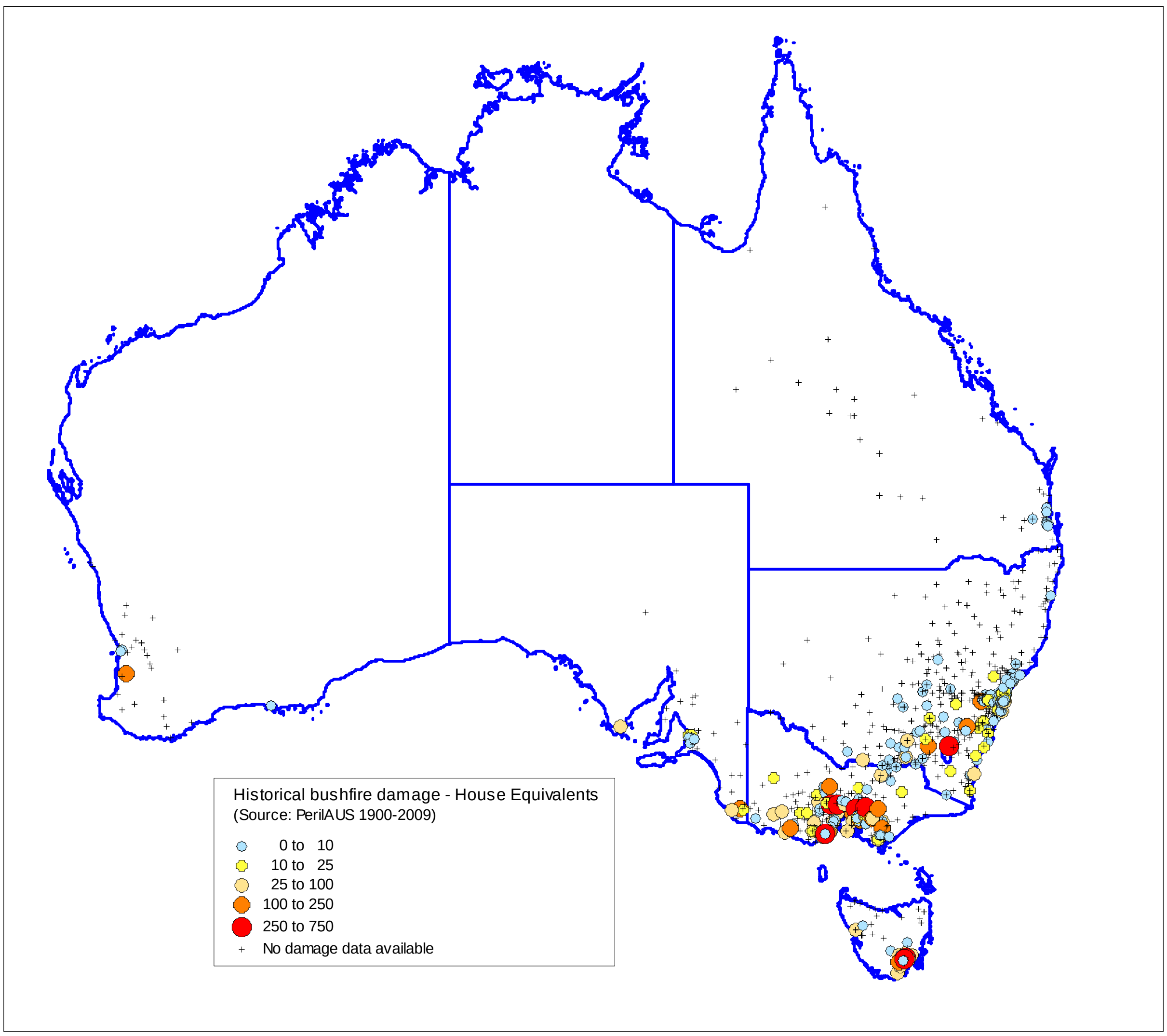


Figure 3: Annual number of buildings (House Equivalents) lost in bushfires during 1900-2009 in Australia (Source: PerilAUS, 1900-2009).

3. Data Sources

A predominant proportion of historical dwelling losses took place in a limited number of extreme bushfires. Extensive ground surveys soon after the fire are time-consuming and often impossible for many reasons: Marysville, for example, was closed by the police for forensic investigations and residents were only allowed to return home on Saturday 21 March 2009, six weeks after the 2009 “Black Saturday” fire. In this retrospective quantitative study, we resort to using very fine-spatial resolution pre- and post-fire aerial photographs and/or satellite images to recover historical damage footprints. Very fine-resolution imagery taken soon before and after the fires is a cost-effective means of identifying locations of destroyed homes and bushland boundaries. Table 2 lists the full set of aerial photographs and/or satellite imagery employed for this study. Figures 4-7 show pre- and post-fire images for Marysville, Kinglake, Duffy and Como-Jannali, respectively. Additional images to show local terrain are provided in Appendix B (Figures B1-B4). All map-accurate images were geo-referenced.

3.1 Marysville and Kinglake

Risk Frontiers undertook a field survey following the 7 February 2009 “Black Saturday” bushfires. On 11 February 2009 the team hired a helicopter and conducted an aerial reconnaissance for the Kinglake region and Melbourne’s north-eastern suburbs that are interfaced with extensive bushland. A Melbourne-based aerial survey company called Airtech (http://www.airtechaust.com/) provided 15cm-resolution, geo-referenced post-fire imagery for the Marysville and Kinglake areas.

Large areas of bushland surrounding Marysville and Kinglake were almost completely burned. For the distribution and extent of pre-fire bushland, we acquired 2.5m-resolution imagery from the online SPOTMaps 2009 series (http://access.spot.com/).

Table 2: Fine-spatial resolution image sources for suburbs damaged by extreme bushfires in Australia.

Suburbs	Pre-fire	Post-fire
Marysville, affected by the 7 February 2009 “Black Saturday” fires	2.5m-resolution SPOTMap 2009 imagery series from Spot Image	15cm-resolution aerial photographs; captured 22 March 2009 and provided by Airtech
Kinglake, affected by the 7 February 2009 “Black Saturday” fires	2.5m-resolution SPOTMap 2009 imagery series from Spot Image	15cm-resolution aerial photographs; captured 24 March 2009 and provided by Airtech
Duffy, affected by the 18 January 2003 Canberra fires	60cm-resolution QuickBird imagery; acquired 25 June 2002	60cm-resolution QuickBird imagery; acquired 29 January 2003
Como-Jannali, affected by the 7-8 January 1994 Sydney fires	65cm-resolution aerial photos from NSW Department of Lands; acquired 4 January 1994	65cm-resolution aerial photos from NSW Department of Lands; acquired 21 January 1994

Figure 4: Pre- and post-fire images for Marysville. Top: Pre-fire imagery from SPOTMap 2009 series: spatial resolution 2.5m. Bottom: Post-fire aerial photo captured on 22 March 2009: spatial resolution 15cm.

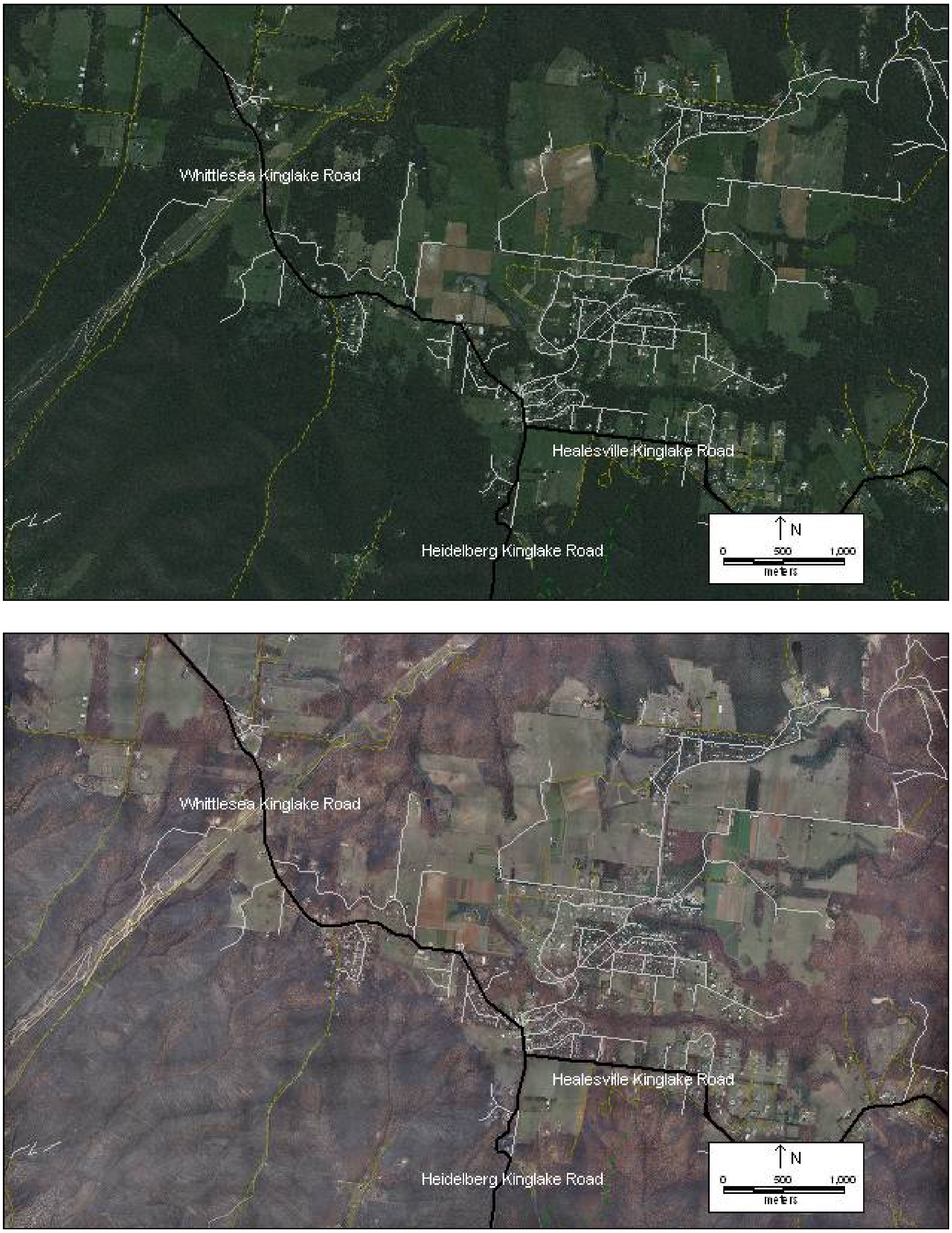


Figure 5: Comparison of pre- and post-fire images for Kinglake region. Top: Pre-fire imagery from SPOTMap 2009 series: spatial resolution 2.5m. Bottom: Post-fire aerial photo captured on 24 March 2009: spatial resolution 15cm.

3.2 Duffy

For the 18 January 2003 Canberra bushfires, pre- and post-fire images were purchased from DigitalGlobe (http://www.digitalglobe.com/). The satellite-based QuickBird imagery has a spatial resolution of 60 cm in the panchromatic band and 2.4 m in multispectral bands (blue, green, red and near infrared). A 1m-resolution IKONOS-2 image (http://www.spaceimaging.com/) acquired on 20 January 2003 and provided by the Geographic Information Management Unit, ACT government, and photos taken in field trips were also used for analyses.

Figure 6: False-colour images (with near infrared, green and blue bands) showing an overview of the suburb of Duffy, Canberra. Left: Pre-fire image acquired on 25 June 2002. Right: Post-fire image acquired on 29 January 2003. The post-fire image shows widespread home and vegetation destruction in the northern and western parts of Duffy. Healthy vegetation is shown in red, and burnt vegetation is black.

3.3 Como-Jannali

For the 7-8 January 1994 Sydney bushfires in Como-Jannali, pre- and post-fire aerial photographs were purchased from the Land Information Centre, NSW government. True-colour photographs were scanned to produce geo-referenced digital images with a spatial resolution of 65 cm. A photograph taken immediately after the fire showing the most damaged part of the suburb (near Lincoln Crescent, Soldiers Road and Bindea Street) was also used.

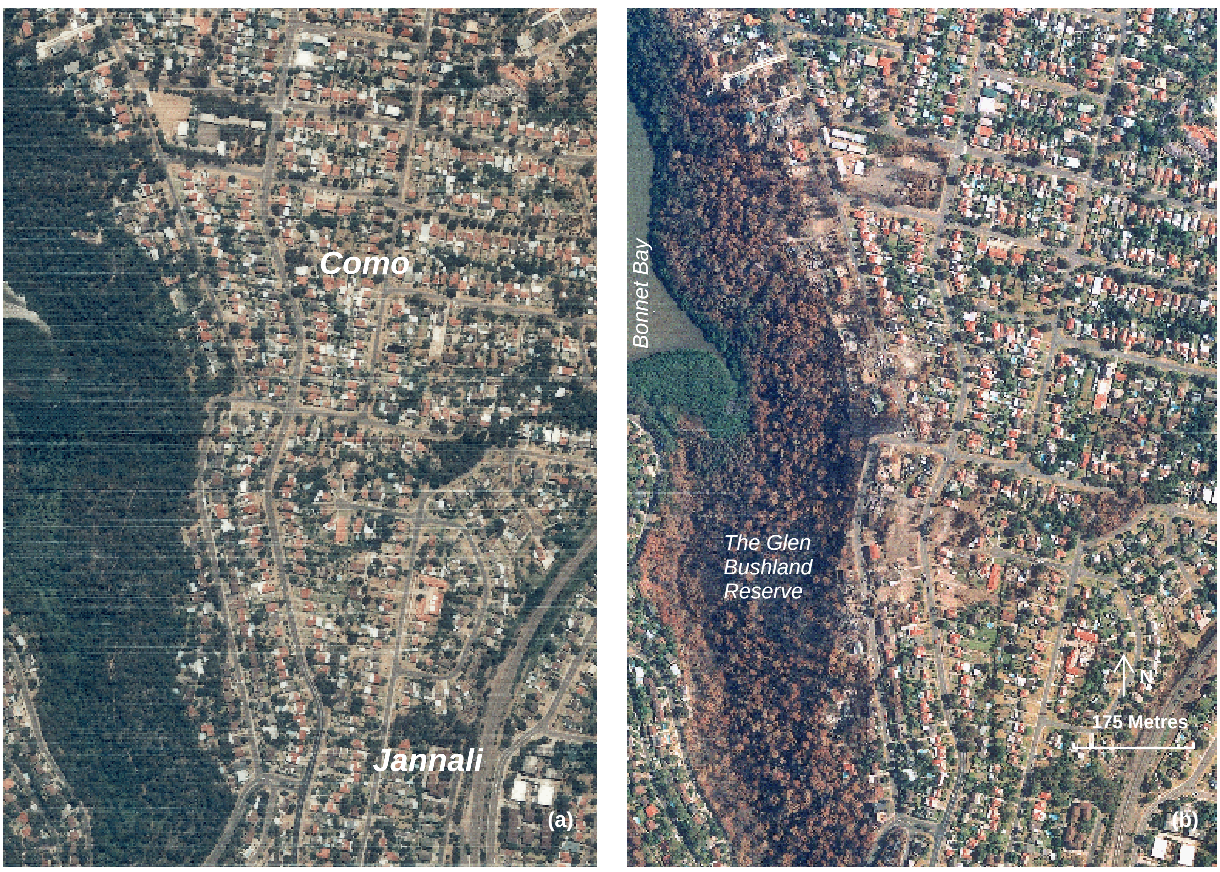


Figure 7: Aerial photographs for Como-Jannali, Sydney. Left: Pre-fire photo taken on 4 January 1994. Right: Post-fire photo taken on 21 January 1994. The post-fire photo shows damaged areas adjacent to the Glen Bushland Reserve.

4. Analyses and Results

Using the fine-resolution images, we were able to manually interpret and digitise locations of both destroyed buildings and those that survived. In each case, a reasonably large number of samples (destroyed homes) were obtained enabling statistical analysis.

All images were geo-referenced and loaded into a GIS platform (MapInfo Professional). Other topographic layers, including road networks and terrain, were also displayed in GIS for easy visual interpretation and on-screen digitising.

Current image processing technology and software is limited for automated classification of small, discrete features such as buildings and human interpretation is still the most reliable way to fulfil this task. For Marysville and Kinglake region, we first digitised the approximate boundary (polygon) for each damaged building, and then identified the centroid of each polygon as the location of the damaged building. The same procedure was used for undamaged buildings. This provides an objective and consistent way for determining building location, especially from the 15cm-resolution aerial photograph, compared to the direct pinpointing of dwelling locations. For very small suburbs, Duffy and Como-Jannali, locations of destroyed and survived buildings were determined by direct pinpointing of the building sites.

Unlike the determination for discrete buildings, vegetation areas are usually large and continuous and can be routinely classified from images at various resolutions. For the Marysville and Kinglake regions, we tested various supervised and non-supervised image classifiers (in image processing software IDRISI) with the 2.5m-resolution SPOTMap imagery to objectively determine pre-fire bushland boundaries adjoining settlements. It was possible to reliably evaluate the best classification results from a supervised classifier in IDRISI (Kohonen’s Self-Organizing Map) given the fine-resolution of imagery employed and the relative small size of the study area. For the suburbs of Duffy and Como-Jannali, bushland boundaries were manually interpreted and digitised.

Locations of buildings (destroyed and unscathed) and classified burned vegetation in four suburbs, Marysville, Kinglake, Duffy and Como-Jannali, are illustrated in Figures 8-11.

4.1 Digitised building locations and classified burned vegetation

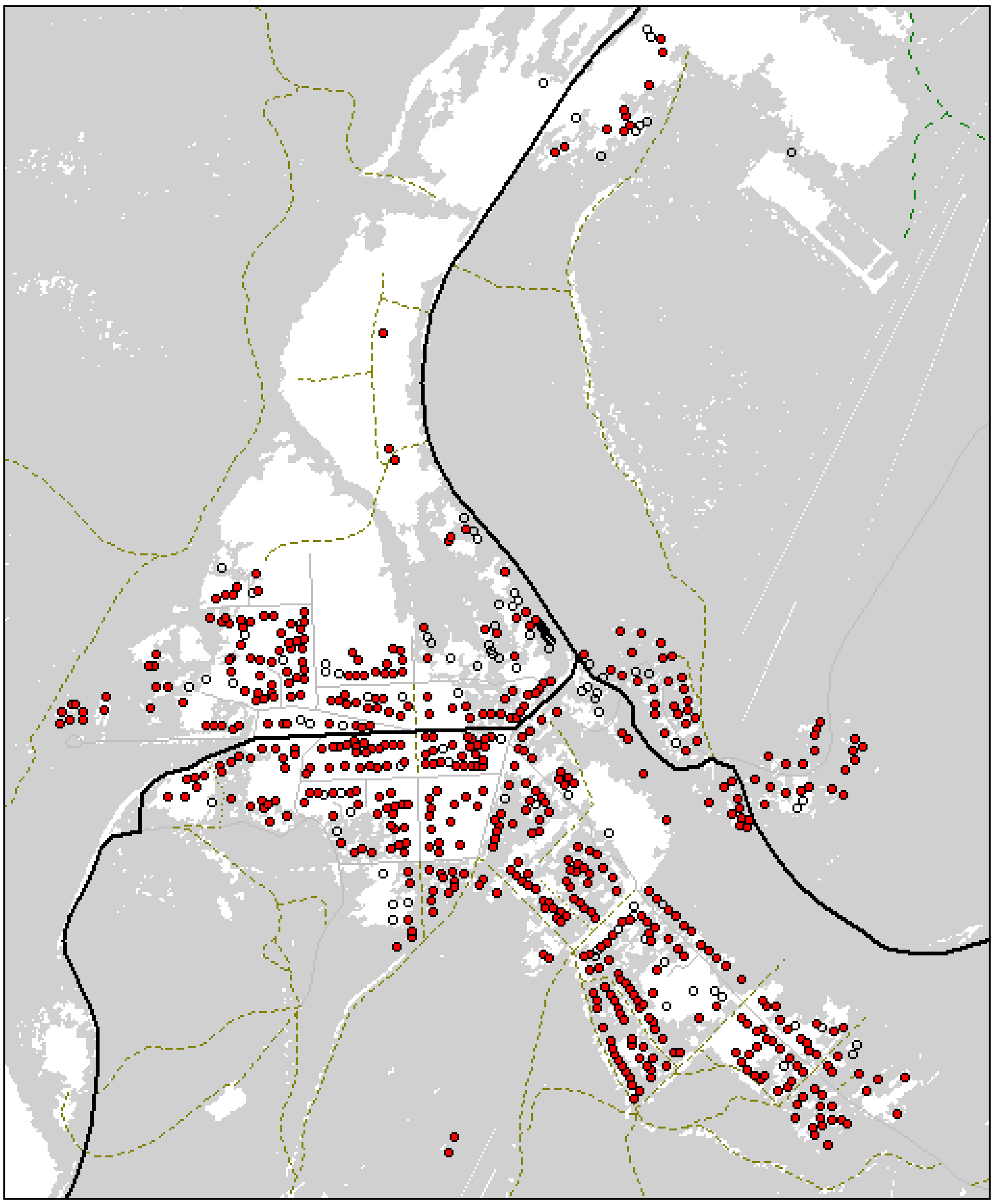


Figure 8: Distribution of destroyed buildings (red dots, N = 540 samples) and those that survived (black circles, N = 104 samples) in Marysville. Burned vegetation is shown in grey.

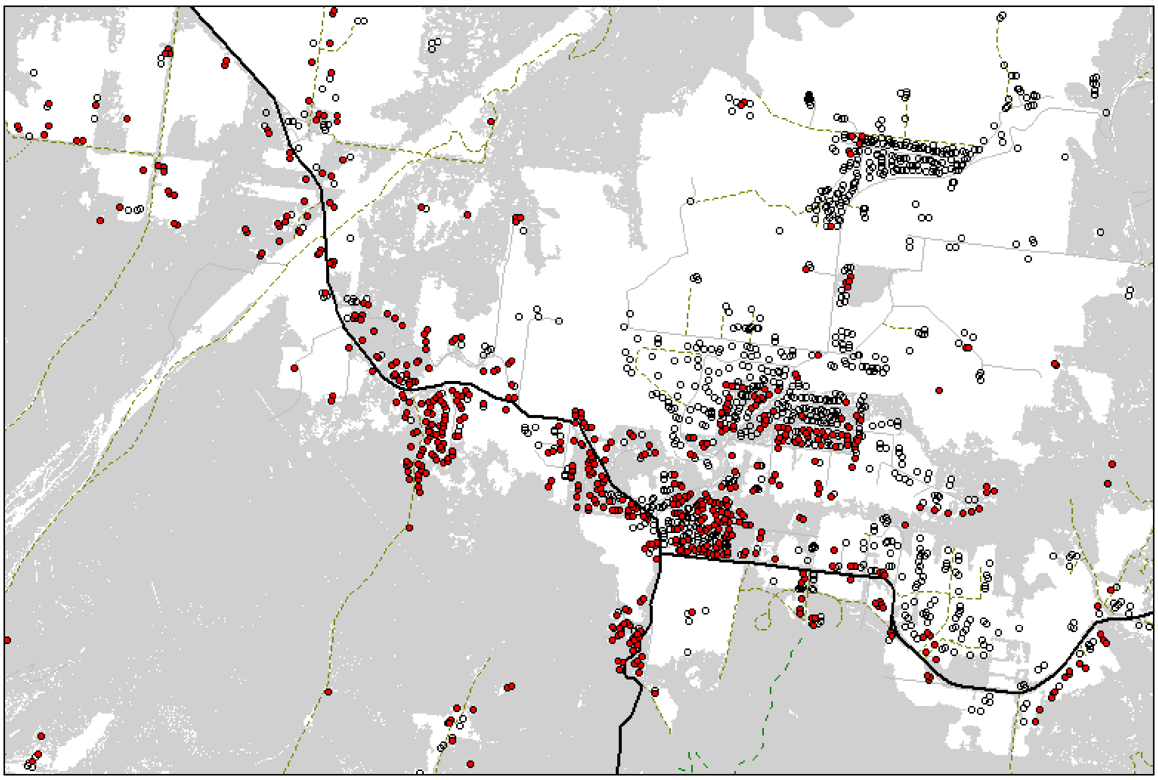


Figure 9: Distribution of destroyed buildings (red dots, N = 616 samples) and those that survived (black circles, N = 915 samples) in the Kinglake region. Burned vegetation is shown in grey.

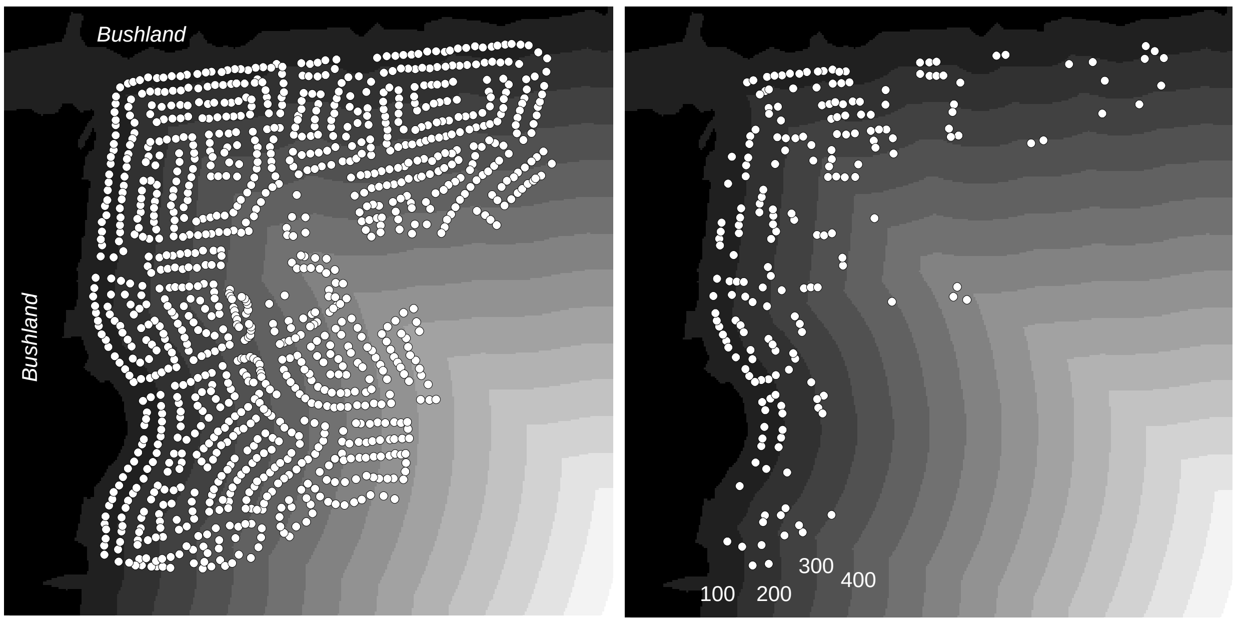


Figure 10: Distance ranges (interval 100 m) from adjacent bushland superimposed by home locations in Duffy. Left: Pre-fire homes. Right: Destroyed homes (N = 206 samples) (Source: Chen and McAneney, 2004).

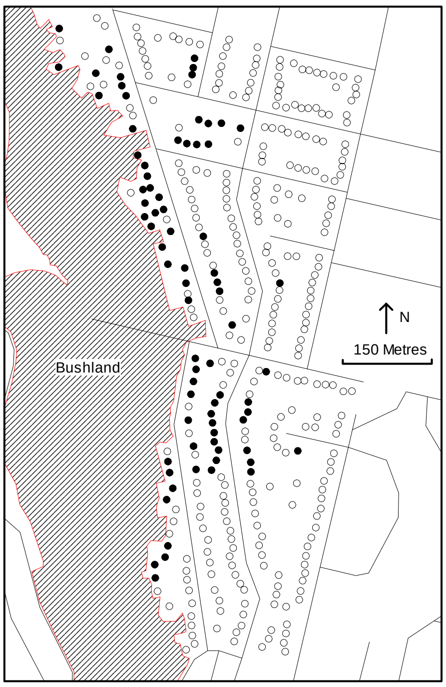


Figure 11: Pre-fire and destroyed buildings in Como-Jannali. Black dots represent locations of destroyed homes (76 samples), and black open circles homes that survived (Source: Chen and McAneney, 2004).

4.2 Historical evidence on bushfire penetration into urban areas

Once the location of buildings and bushland boundaries were known, we then quantified the trajectory of bushfire penetration into urban areas. In this study we mainly report the distance-based statistic that is closely relevant to urban planning: *the cumulative percentage of destroyed buildings in relation to nearby burned bushland*.

4.2.1 Individual data

Figure 12 shows the distribution of destroyed homes as a function of the shortest distance to adjacent bushland that was totally burned. The data are presented in cumulative form for easy comparison with other published results (Ahern and Chladil, 1999).

The salient results are as follows:

- About 50% of destroyed buildings in Como-Jannali (from the 1994 Sydney fires), Otway Ranges (from the 1983 Ash Wednesday fires) and Hobart (from the 1967 Hobart fires) occurred at distance less than 50 m from bushland. In Marysville and Kinglake, about 25% of destroyed buildings were located physically within bushland and 60% located within 10 m of bushland. Homes or small hamlets scattered amongst or distributed along the boundary of extensive bushland will be subject to flames, radiant and perhaps convective heating as well as ember attack and will in our view be very difficult to defend.

- While the Como-Jannali curve shows reasonable agreement with results of previous fires – the Otway Ranges and Hobart fires, the Duffy experience is clearly different. The median distance (50th percentile) for Duffy is about three times that of the Como-Jannali fire (145 m versus 45 m). In Duffy, more than 90% of homes were destroyed beyond a separation distance of 50 m, suggesting the main cause of home ignition was airborne embers rather than direct flame contact or radiant heat. (No homes lay closer than 37 m to the nearest edge of the forest owing to the presence of two major roads (Eucumbene Drive and Warragamba Avenue) that separated the pine plantation from residential areas.)

- Excluding the 2003 Canberra bushfires, 80-90% of all destroyed buildings occurred within 100 m of bushland, and 50% of all destroyed buildings occurred less than 50 m from bushland. These distances have implications for urban interface planning.

- The maximum distance at which homes are destroyed is typically less than 700 m. For Kinglake and Duffy, this distance was 696 m and 674 m, respectively. While the maximum distance of fire spotting can be up to many kilometers (Luke and McArthur, 1978), the maximum distance at which home destruction is observed from all of these fires is less than 700 m.

The Duffy damage pattern is very different from other fires included in Figure 12, and *statistically speaking*, could be seen as an outlier - meaning that the distance at each damage percentile level is beyond the mean plus two times the standard deviation (also see raw data in Table 3). The term “outlier” is specific to the damage data alone and is not a broad description for the fire event. As far as the hazard is concerned, each extreme fire that results in significant property damage can be seen as an exceptional or “outlier” event especially compared with smaller fires that may be amenable to control by the fire services. It would be a mistake to dismiss the Duffy experience as an outlier; rather, it should be seen as a manifestation of what could occur on the urban-bushland fridge of some of our major cities – Melbourne, Sydney, Adelaide and Hobart. Unique features of Duffy are that it was once surrounded by extensive pine plantation, compulsory evacuation took place and the main cause of property damage was ember attack.

4.2.2 Combined data and summary table

For exploratory analysis, we combine all samples (destroyed buildings) in order to distil the generalised behaviour of historical losses. Figure 13 shows two composite curves:

– **Combined curve including Duffy:** Raw distance measurements for all 2,456 samples were used, including those for Marysville (N = 540), Kinglake (N = 616), Duffy (N = 206), Como-Jannali (N = 76), Otway Ranges (N = 648) and Hobart (N = 370).

– **Combined curve excluding Duffy:** As above but excluding the data for Duffy. The total number of samples is 2,250.

Figure 13 now shows the cumulative distribution of ALL of the buildings destroyed in various major bushfires in Australia in relation to distance from nearby bushland. Both curves, with and without the Duffy samples, show the same general behaviour. Three salient features can be summarised as follows:

- 12-13% destroyed homes were virtually located within bushland (i.e. identified with separation distances close to zero meters).
- 50% destroyed buildings were located within 15-19 m from nearby bushland.
- 83-88% of destroyed buildings were located within 100 m from nearby bushland.

Detailed distances at various percentile levels for each individual fire and all combined fires are provided in Table 3.

One may wonder which composite curve is more suitable or should be taken into consideration in relation to land planning for the bushland interface at a national level in general and for Victoria in particular. But as has been mentioned already, each curve is to some extent unique and the composite curve is no substitute for any individual case. The composite curve is also a reflection of simple statistics, in particular, the number of samples (destroyed buildings) in each of the various fires. For example if we were to have another or several 'Canberra-like' scenarios with large numbers of buildings destroyed, then the composite curve could end up looking more like Duffy and less like Marysville.

Notwithstanding the above remarks, the composite curve may be useful in defining some broad-level of "acceptable risk" for risk decision-making at a high level. It is very clear that about 85% of damaged buildings occurred within 100 m of nearby bushland, a very stable result and regardless of the exclusion or inclusion of Duffy samples (N = 206), which only accounted for 8.4% of all national samples analysed. In other words, if we were to avoid building structures within 100 m, of bushland boundaries, then the majority of building damage would be avoided. As with any other natural hazard, be it tropical cyclones or earthquakes, achieving a zero-risk solution for society will never be practical. In the case of bushfire, this would involve ensuring that no building occurred within 700 m of bushland.

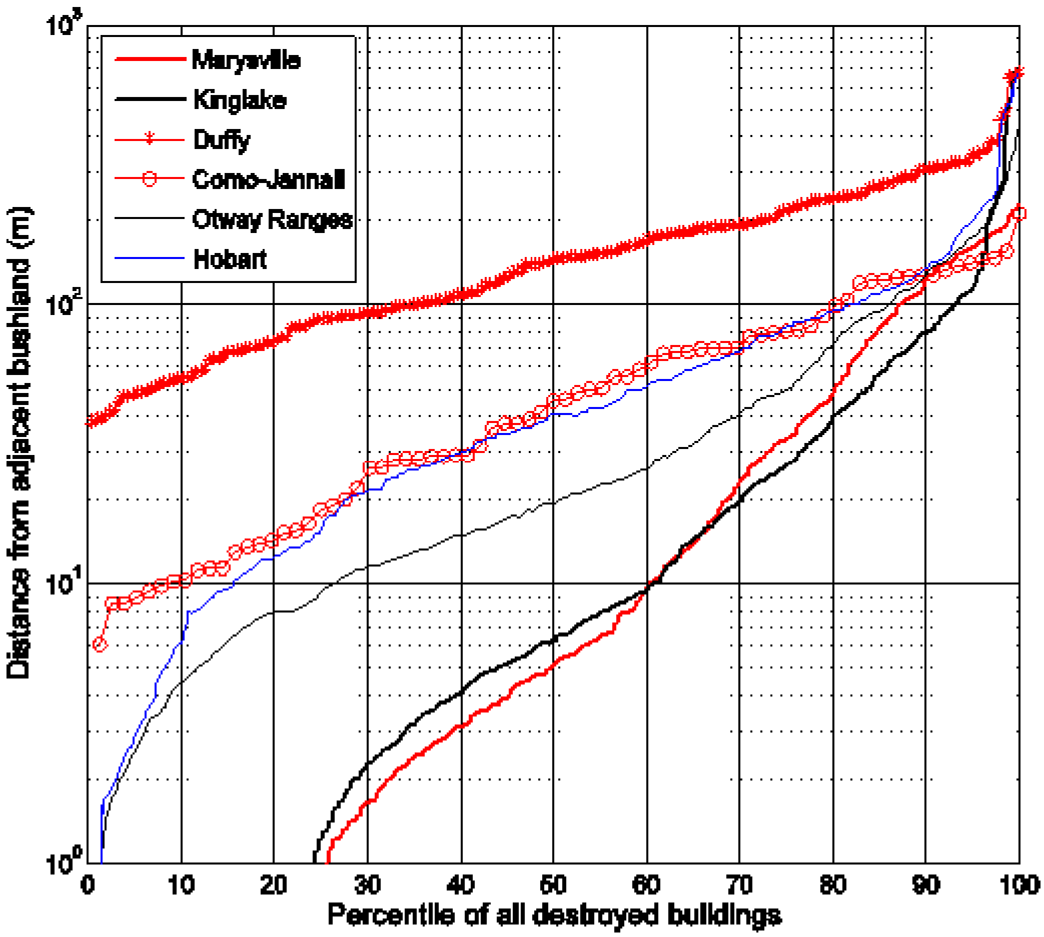


Figure 12: Cumulative distribution of buildings destroyed in major bushfires in Australia in relation to distance from nearby bushland. The number of samples for Marysville, Kinglake, Duffy and Como-Jannali is 540, 616, 206 and 76, respectively. The Otway Ranges curve (648 samples) from the "Ash Wednesday" fires and the Hobart curve (370 samples) from the 7 February 1967 Hobart (Tasmania) fires reported by Ahern and Chladil (1999) are also shown. Note that the vertical axis is logarithmic, where 10^0 = 1m; 10^1=10m; 10^2=100 m and 10^3= 1000 m.

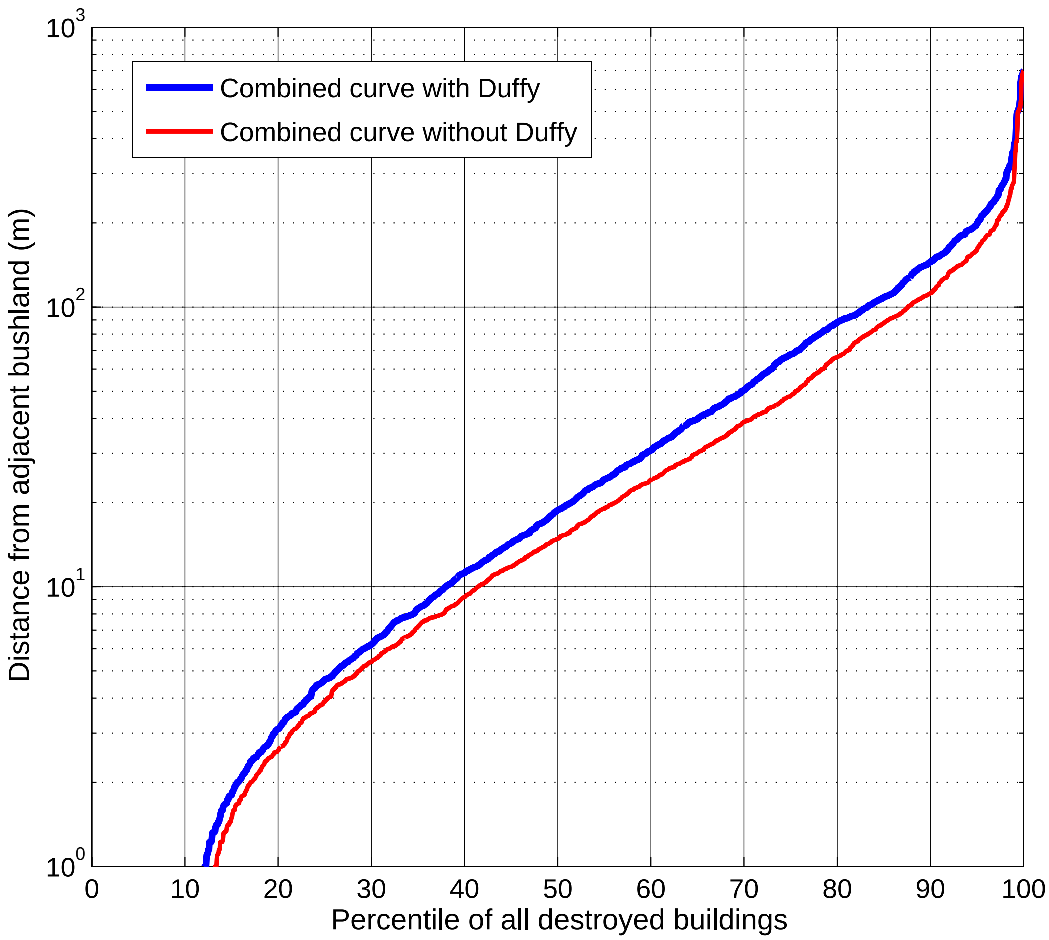


Figure 13: Cumulative distribution of ALL buildings destroyed in various major bushfires in Australia in relation to distance from nearby bushland. The samples (destroyed buildings) are from Marysville, Kinglake, Duffy and Como-Jannali, Otway Ranges and Hobart. Raw data for Otway Ranges and Hobart were contributed by Mark Chladil (Tasmania Fire Service).

Table 3: Approximate distances in meters at 50th, 60th, 70th, 80th, 85th, 90th and 95th percentiles of destroyed buildings. The column labelled the 50th percentile shows the distance from bushland within which 50% of building destruction took place. Raw data for Otway Ranges and Hobart comprised the data source for Ahern and Chladil (1999) and were provided courtesy of Mark Chladil (Tasmania Fire Service).

Percentiles	**50th**	**60th**	**70th**	**80th**	**85th**	**90th**	**95th**
Marysville (N = 540)	5	10	23	48	83	126	159
Kinglake (N = 616)	6	10	20	40	56	79	114
Duffy (N = 206)	145	170	192	238	265	305	340
Como-Jannali (N = 76)	45	60	72	97	122	135	142
Otway Ranges (N = 648)	19	26	41	72	93	125	175
Hobart (N = 370)	39	49	66	92	104	127	191
Combined data with Duffy (N = 2,456)	19	31	51	88	108	145	198
Combined data without Duffy (N = 2,250)	15	24	39	66	88	112	160

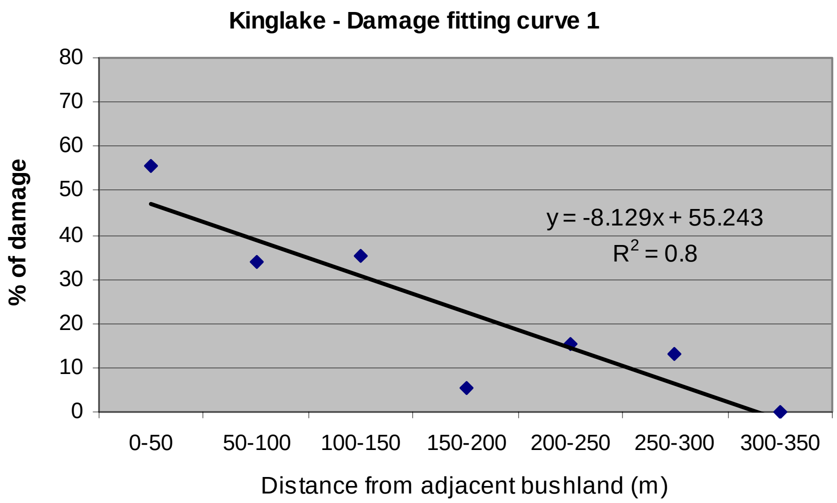
4.2.3 The percentage of building damage in Marysville and Kinglake

Figures 12 and 13 only consider populations of destroyed homes. Another useful statistic is the proportion of buildings that burn down at a given distance from the bushland boundary.

Marysville was a small and heavily-treed township, with high amounts of fuels around and between the houses. It was also closely surrounded by hills and mountains (see Appendix Figure B1) and the shortest distance between city centre and nearby bushland is only about 230 m. About 90% building damage is observed irrespective of distance to bushland. Its basin-shaped location was subject to multiple wind directions modulated by the effect of local topography. This would tend to “homogenize” the pattern of destruction. The multiple directions of the fire attacks to Marysville are in contrast to the situation in Duffy and Como-Janalli where the attack was from a single predominant direction.

Figure 14 shows the proportion of damaged buildings in Kinglake as a function of distance from adjacent burned bushland. The pattern is very similar to what we have seen in other fires (Chen and McAneney, 2004) where on average, about 60% of all buildings within the first 50 m were destroyed and the likelihood of damage decreases linearly as a function of increasing distance (Figure 14, Top, R^2 = 0.8). In short, the further a building is located away from bushland the lower is the likelihood of its destruction given a large fire.

Due to the larger number of destroyed buildings within the first 50 m of bushland around Kinglake, it is possible to examine the damage ratios at finer distance ranges: 0-10 m, 10-20 m, 20-30 m, 30-40 m and 40-50 m (Figure 14, Bottom); it shows a steep rise in the likelihood of destruction as distance to bushland decreases. This reinforces the point made earlier that buildings very close to bushland will be subjected to all fire perils – flames and radiant and convective heating - and not just ember attack.



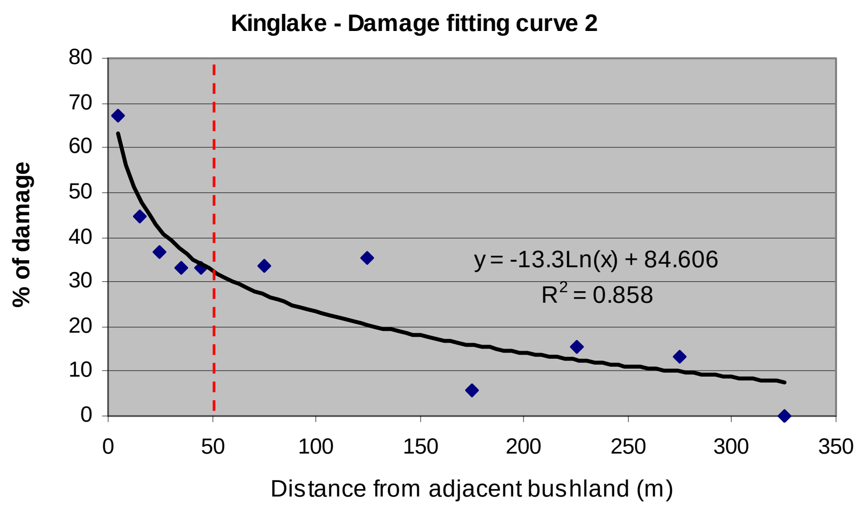


Figure 14: Different mathematical descriptions of building destruction in Kinglake as a function of distance from bushland boundaries. In the lower figure, more detailed observational data at 10m intervals is used for the 0-50 m distance.

4.3 Analysis uncertainty

4.3.1 Samples

Since this quantitative analysis is based on building locations and burned vegetation derived from fine-resolution aerial photographs and satellite imagery, it is likely that there will be some slight differences between our reported results and the absolute numbers and/or locations of destroyed buildings reported by others, especially those based on detailed field surveys conducted by various government agencies immediately after the fires. A very small number of buildings used for temporary post-fire accommodation could also have been wrongly identified as survived buildings. It is also possible that a few destroyed sites or buildings were totally cleared prior to the acquisition of aerial photos and hence not recorded - this is unlikely to be the case for Marysville since the aerial photo was taken there only one-day after the lift of the site closure. However, given the aggregate nature of the statistics reported in Figures 12 13 and 14, any uncertainties associated with identified locations of destroyed buildings and classified bushland boundaries should have minimal effect on the overall findings.

Apart from the quality of samples, another concern is about the number of samples included in this study. We have assembled and analysed about 40% of all damage data (about 6,000 buildings) from a total of five extreme fires over the past five decades (see Table 1 and Figure 1). This is the largest pool of the damage data from Australian bushfires in modern days. Only suburbs or towns with large and concentrated damage were analysed. For the many scattered and small numbers of properties damaged or destroyed in all minor, major and extreme fires, it is reasonable to assume that the majority of these would occur within the vicinity of bushland, say less than 100 m from bushland. If they were included in analysis, larger percentiles of destroyed buildings would be associated with the first 100 m from bushland. This suggests that our estimates on the damaged building percentile-specific distances are conservative.

4.3.2 Bushland delineation

Bushland surrounding damaged parts of those suburbs (Marysville, Kinglake, Duffy and Como-Jannali) was totally burned. This is evident by comparing the pre- and post-fire high-resolution imagery. For the two very small study areas (Duffy and Como-Jannali) that abutted bush only on one or two streets, bushland areas were subjectively digitised from imagery. For Marysville and Kinglake, which had very long and complex urban-bushland interfaces, bushland was objectively classified from pre-fire imagery. We observed that the classified bushland associated with building damage is typically continuous and large, with the smallest patch size of 1.6 hectares.

The above classification of bushland is different from the criteria used by the CFA for mapping the Wildfire Management Overlay, namely over 80% vegetation density with a minimum patch size of 5 hectares and a minimum gap in tree cover of 0.1 hectares. We suspect that the CFA's definition is probably geared towards pre-fire bushland mapping using medium-resolution (e.g. 30m) satellite imagery. Bushland mapping performed at various spatial resolutions or scales usually has different applications and decision-making tasks in mind. For pre- and post-fire bushland mapping in relation to nearby building damage at a site- or address-specific level, the high-resolution imagery as employed in this study is the best data input that can be used.

The bushland delineated in our analysis is close to a lay-person's understanding and perception about bushland. Here it is perhaps helpful to differentiate the two main tasks in bushland mapping: "area (size)" mapping and "boundary (perimeter)" mapping. From Risk Frontiers' experience with the *FireAUS* project (Chen and McAneney, 2005), either medium- or high-resolution imagery can classify and identify the overall (aggregate) shape and size of bushland well. But when it comes to the delineation of bushland boundary at a sufficient accuracy level (e.g., more than 75%), which is critical for determining the 100 m separate distance, high-resolution imagery is usually required. Medium-resolution imagery cannot fulfil this task reliably.

5. Discussion

Understanding how historical fires have penetrated into urban areas is essential for categorising bushfire risk to properties at the bushland-urban interface. Distance between building location and bushland is not the only variable determining bushfire vulnerability, but it is demonstrably the most important. Risk Frontiers has previously reported that in Australia, about 550,000 addresses are located within 100 m of larger and continuous bushland with an area threshold of 0.5 km^2 (Figure 15). Group 1 comprises addresses within 100 m of bushland and thus the most at-risk addresses. The other four groups are in intervals out to and beyond 700 m from bushland, the maximum extent to which we have seen building loss in Australia.

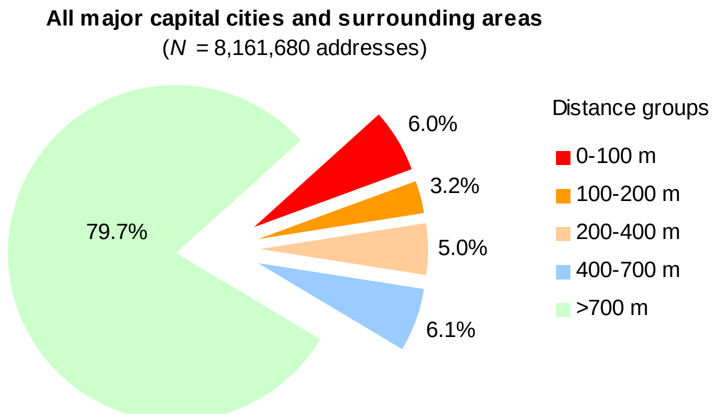


Figure 15: Percentage breakdown of Australian addresses by distance category from large areas of bushland (Source: Chen and McAneney, 2005).

Global climate change may increase the likelihood of conditions that lead to bushfires (Hennessy et al., 2005; Lucas et al., 2007; Pitman et al., 2007; Hasson et al., 2008) and through unknown influences on the El Niño – Southern Oscillation cycle that affects Australian climate and weather (Powers et al., 1999). The IPCC (Intergovernmental Panel on Climate Change) frequently warn that no single catastrophic event can be attributed to global warming although such reticence is often lacking when scientists are asked to comment on extreme weather events. Nonetheless, the evidence for rising global air temperatures points to an increasing likelihood of weather predisposing SE Australia to bushfires. In line with this observation, modelling that forecasts increasing numbers of extreme (or worse) fire weather days (Lucas et al., 2007; Pitman et al., 2007) cannot be ignored. However we must also acknowledge the many uncertainties, *inter alia*:

- uncertainty in the climate projections,
- what does the Forest Fire Danger Index (FDI) really measure,
- the likelihood of an extreme fire given extreme values of the FDI, and
- the uncertainty, given an extreme fire, about whether any property damage occurs.

Thus the correlation between meteorological conditions and outcomes in terms of property damage is not exact and the necessary studies to properly evaluate this chain of correlation have not yet been done.

In our view, the main menace to property will continue to be the occasional extreme fires against which fire fighting activities are largely ineffective. This being the case, we believe that the near future impacts of global climate change on such losses are unlikely to be as dramatic as the combined changes of all of the other factors that have so far collectively failed to materially affect the likelihood of building losses from bushfire over the last century (Table 1 and McAneney et al., 2009). We have had large event losses from bushfire in the past and the future promises to be little different with or without global climate change. In the view of the authors, the threat to property and lives can only be diminished by improved enforcement of planning regulations that restrict where and how people live with respect to distance from bushland. The analyses revealed in this study show the very clear relationship between the probability of damage and proximity to bushlands.

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