COUNTING BUSHFIRE-PRONE ADDRESSES IN THE GREATER SYDNEY REGION

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ABSTRACT

Greater Sydney is one of the more bushfire-prone areas in Australia, a fact exacerbated by the region being home to a quarter of Australia's population and a concentration of high-value real estate and industrial and commercial assets. Long-term projections of climate change suggest that the region is likely to experience more fire-weather days. Altogether, bushfires pose a significant risk for the region.

Risk Frontiers' *FireAUS* project aims to quantify bushfire risk for all addresses in Australia. This paper introduces the main methodology that comprises two components: (1) revealing evidence of spatial patterns of fire penetration into urban areas using data from major historical fires; and (2) quantifying site-specific environmental attributes that may predispose properties to bushfire risk. For the Greater Sydney region, a total of 2.87 million addresses have been analysed, and some 6.6% (about 190,000) of all addresses may be at a relatively greater risk owing to their close proximity - within about 80 m - to areas of extensive bushland.

Results are further detailed at two different spatial units: Local Government Areas and CRESTA (Catastrophe Risk Evaluation and Standardizing Target Accumulations) zones as used by the insurance industry. The results will be useful for local councils, the insurance industry and emergency management, and help risk managers prioritise resources and make more realistic bushfire prevention planning.

INTRODUCTION

Bushfires are endemic to the Australian continent and Australians are living with bushfires. Over the past few decades, major or extreme bushfires in the Southern Hemisphere summer (between December and February) have caused significant human fatalities, substantial property losses, interruption to business activities, and air pollution to large urban centres (Cheney, 1995; Leonard and McArthur, 1999; Chen and McAneney, 2004). Devastating bushfires in the southeastern parts of the continent are greatly exacerbated by relatively high population densities and other elements at risk. This is particularly the case for those major capital cities such as Sydney, Canberra, Melbourne, Hobart and Adelaide, where extensive bushland abuts the urban boundary. Bushfire risk to major urban areas is the focus of our study.

As with other natural hazards, bushfire risk assessment addresses the interaction between a hazard agent and a vulnerable community. Risk is seen as a function of hazard, exposure (elements at risk), and exposure-related vulnerability; that is:

Risk = f (Hazard, Exposure, Vulnerability)

While previous scientific research has largely focused on the physical attributes of fires and their landscape-level impacts, *FireAUS* emphasises exposure and vulnerability components. It concentrates on properties at risk at the urban-bushland interface. This focus represents a paradigm shift for bushfire risk assessment, from hazard-centric to integrative risk assessment involving exposure and vulnerability analyses. The project develops *FireAUS* bushfire risk ratings at an *address level*, information that is important to property owners, the insurance industry, city councils and emergency services.

Using *FireAUS* address-based risk ratings, statistical results can be summarised at various spatial units: the entire country, states and territories, statistical divisions, Local Government Areas, and insurance CRESTA zones. This paper briefly reviews the *FireAUS* project and demonstrates the importance of separation distance between addresses and neighbouring bushland in quantifying bushfire risk. Using the distance-based *FireAUS* address database, upper estimates of the number of bushfire-prone addresses for the Greater Sydney region are summarised at both Local Government Area and CRESTA zone levels.

METHODS

Quantifying bushfire penetration into urban areas

Using data from major historical fires in the Australian landscape, Chen and McAneney (2004) examined spatial features of fire penetration into urban areas. Spatial patterns of destroyed homes in two severely damaged suburbs – Duffy from the 18 January 2003 Canberra fires and Como-Jannali from the 7-8 January 1994 Sydney fires, and comparing with results reported by Ahern and Chladil (1999) – illustrated the critical importance of distance from the bushland edge in determining the likelihood of home destruction. Important findings with potential planning and emergency applications include the following:

- Of the destroyed homes in Como-Jannali, Otway Ranges in the 1983 "Ash Wednesday" fires, and Hobart in the 1967 Hobart fires, 80% (90%) were located within 100 m (135 m) from nearby bushland. In contrast, only 35% of destroyed homes in Duffy were within 100 m of bushland. These numbers are useful for urban planners and bushfire risk managers.

- The maximum distance at which homes were destroyed was typically less than 700 m. While this is an interesting feature, as far as *acceptable risk* is concerned, it has limited utility in bushfire prevention planning

- The probability of home destruction decreases almost linearly with increasing distance from the bushland boundary, but with a variable slope that probably reflects different fire regimes. The collective data suggest that the probability of home destruction within the first 50 m of the forest edge is about 60%. This provides an empirical basis for pricing and differentiating bushfire risk to homes at the bushfire-prone urban boundary.

The work of Ahern and Chladil (1999) has been very influential in the prescription of Asset Protection Zones in bushfire-prone areas (NSW Rural Fire Service, 2001), and the above results provide another perspective that mat help refine related guidelines.

Figure 1 shows the suburb of Como-Jannali immediately before and after the 7-8 January 1994 Sydney bushfires. True-colour, ortho-corrected photographs were scanned to produce geo-referenced digital images and then superimposed with street networks and addresses. If the distance to neighbouring bushland is expressed in another form - street blocks from bushland, the roughly linear and decreasing relationship still holds (Figure 2).

Figure 1: Aerial photographs for Como-Jannali, Sydney. (a) Pre-fire photo: 4 January 1994. (b) Post-fire photo: 21 January 1994. The post-fire colour photo shows damaged areas adjacent to the Glen Bushland Reserve. Aerial photographs were purchased from NSW Land Information Centre, Bathurst.

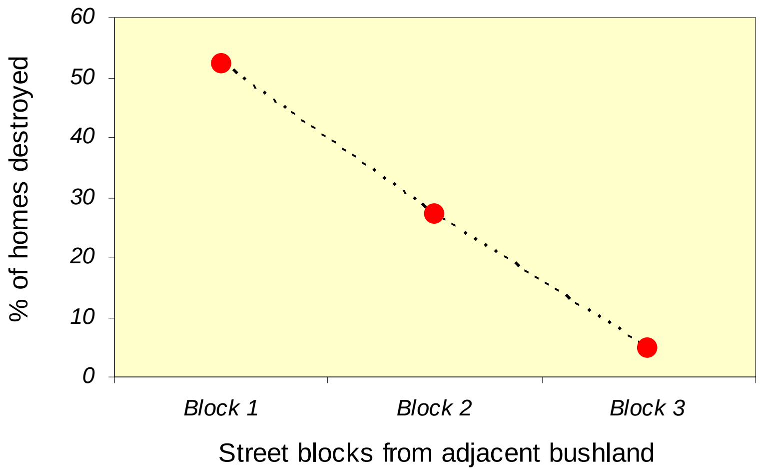

Figure 2: Percentage of homes destroyed as a function of street blocks from bushland.

These findings are hardly surprising but the distance statistics and relationships that emerge are both intriguing and useful, shedding light on the mechanism of fire penetration and trajectories into urban areas. Separation distance between address and bushland is not the only factor important in determining home vulnerability but it is likely the most critical and universal.

Quantifying property site-specific environmental attributes

Property survival during bushfires can be seen as a local process, and other site-specific attributes, such as the percentage of surrounding tree cover, are also important (e.g., Cohen, 2000). The *FireAUS* project calculates a series of attributes that are physically-based and quantifiable, including separation distance, surrounding tree density, local aspect and slope. Integrating these elements into composite risk ratings will allow insurers and local government councils alike to identify the most at-risk zones.

The separation distance between addresses and bushland for the majority of Australian addresses has been calculated. Prerequisites for this analysis are: (1) accurate location of property addresses, and (2) a map of the bushland distribution. For the former, we employed the latest G-NAF (Geocoded National Address File) address database, which is regarded as Australia's most authoritative and complete. Location here refers to the centroid of each land parcel in cadastre; as expected, the locational accuracy for smaller residential land parcels is better than that for larger commercial/industrial or rural land parcels.

Due to the extremely high cost of high-resolution satellite images, recent generation Landsat ETM+ imagery with a medium spatial resolution (30 m in multi-spectral bands) was used for classifying extensive and continuous bushland that is likely to cause major or extreme bushfires and bring devastating losses. Details of image classification and comprehensive validation tests are reported in Chen and McAneney (2005). For an area with thousands of bushfire-prone addresses, the overall percentages of addresses located within distance ranges from bushland have proved very accurate. For the locational accuracy evaluated on an address-by-address basis, it increases as the distance range relaxes. For instance, for all addresses situated within 130 m from bushland (first row + 100 m), the overall locational accuracy is 76%; if a more broadly distance range (230 m) is defined, the overall accuracy is 89%. This might be sufficient for redlining high-risk bushfire-prone zones.

Given the location of all addresses and classified bushland, the calculation of the shortest distance between them is straightforward using in-house *FireAUS* tool sets.

RESULTS

The *FireAUS* database can be provided in traditional spreadsheet forms and/or GIS data formats. Each address is provided with the following fields/attributes, including the calculated separation distance.

- Unique GNAF address ID
- Postcode
- Locality name
- Street number first
- Street name / Street type
- Distance group

An entire study area level

The Greater Sydney region was chosen as an example study area. Of the 2,875,775 addresses analysed, 189,364 (6.6%) are exposed to greater bushfire risks, being either immediately adjacent or very close to extensive bushland (about 80 m); 274,327 (9.6%) are located within 130 m from bushland; and 70.7% of all addresses stand beyond 700 m (Figures 3a and 3c).

Results at the national level have already been reported in Chen and McAneney (2005). A total of 8,261,680 addresses, or about 80% of all known addresses in Australia (10.9 million), have been analysed for all major capital cities and their surrounding areas with the exception of Darwin. A total of 337,946 (4.1%) and 489,218 (6.0%) addresses are located within 80 m and 130 m from bushland, respectively (Figures 3b and 3d). More than half (56%) of all national addresses that are within either 80 m or 130 m of bushland are from the Greater Sydney region.

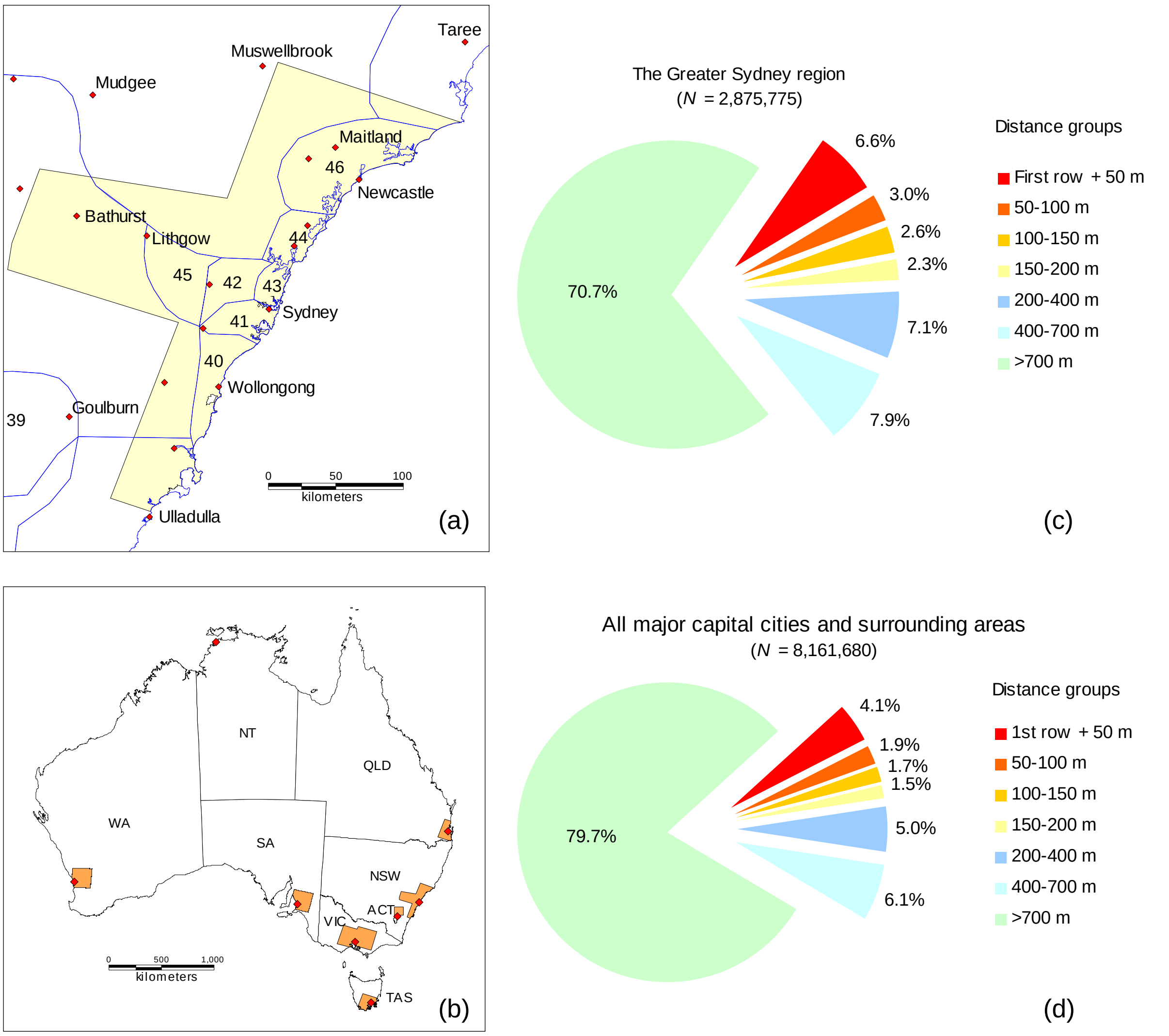

Figure 3: (a) The Greater Sydney region. (b) *FireAUS* study areas - all major capital cities and surrounding area. Percentages of addresses falling within different distance ranges from bushland for the Greater Sydney region (c) and nationwide (d).

Further analyses were undertaken to examine the spatial variation of bushfire-prone addresses at smaller area units: 59 Local Government Areas and seven CRESTA zones.

Local Government Areas

Figure 4 shows the distribution of the percentages of all addresses that are within 130 m from bushland at Local Government Areas. In Blue Mountains, 73% of all addresses belong to this high-risk category (Table 1). Ku-ring-gai and Hornsby are the only two LGAs close to Sydney CBD and to have more than 30% of high-risk addresses.

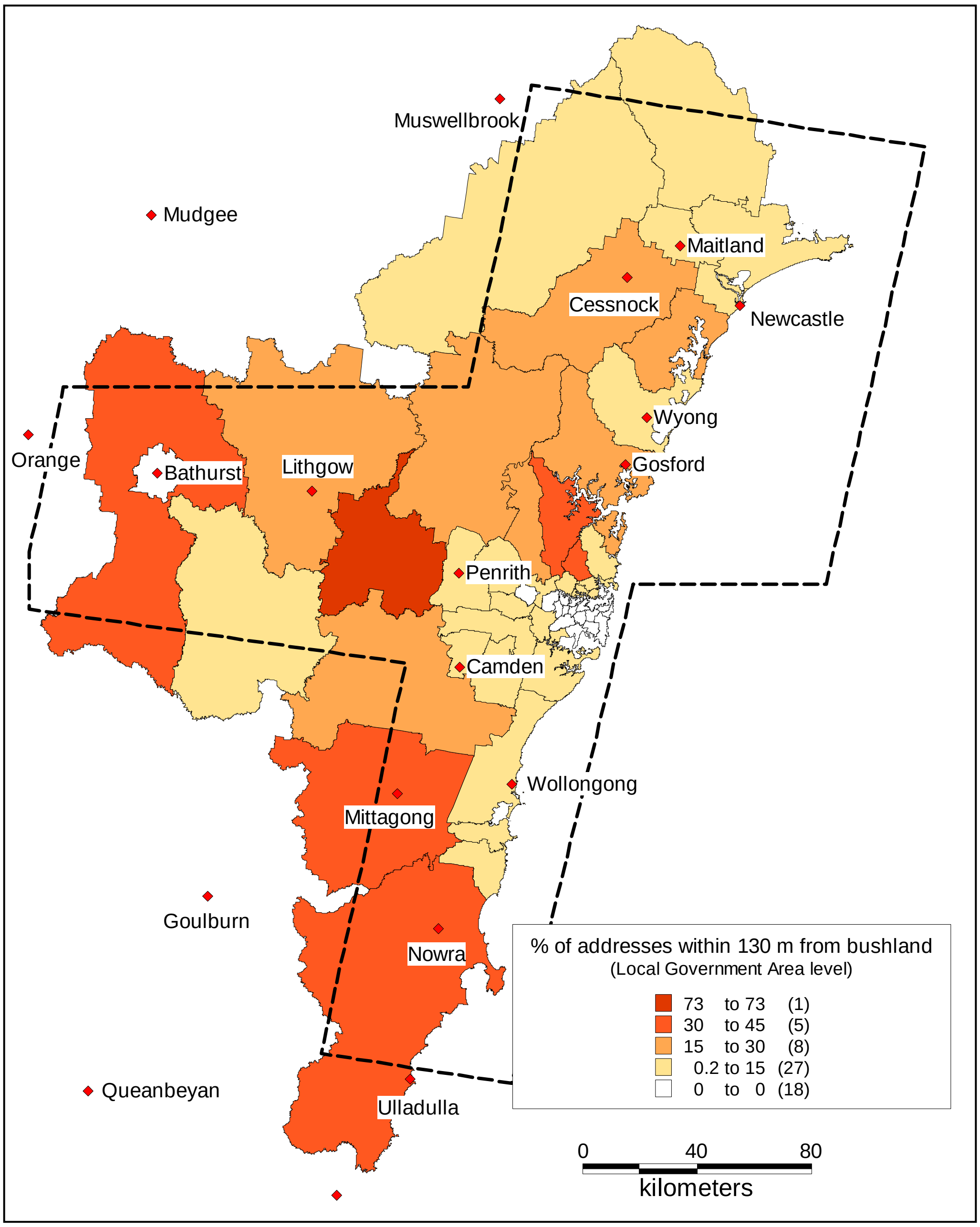

Figure 4: Percentage of addresses located within 130 from bushland at LGA level. All addresses within the bold dashed polygon have been analysed for reporting LGA-based statistics.

Table 1: Percentage of addresses located within 130 m from bushland. A total of 59 LGAs in the Greater Sydney region were analysed.

LGA Code	LGA Name	%	No. addresses analysed	LGA Code	LGA Name	%	No. addresses analysed
10900	Blue Mountains	73.0	45,025	14700	Lane Cove	2.5	25,166
16950	Shoalhaven *	39.7	55,143	14100	Hunter's Hill	2.1	6,854
14500	Ku-ring-gai	36.0	45,478	16900	Shellharbour	1.5	30,743
18350	Wingecarribee *	36.0	23,740	14150	Hurstville	1.5	41,607
12800	Evans *	32.4	3,256	14900	Liverpool	1.3	68,280
14000	Hornsby	31.1	66,813	15150	Manly	1.1	27,447
18400	Wollondilly *	27.6	17,768	16250	Parramatta	1.1	93,619
13100	Gosford	27.0	102,501	11450	Camden	0.7	21,396
16370	Pittwater	26.4	30,083	15950	North Sydney	0.4	59,773
13300	Greater Lithgow *	24.9	14,356	12850	Fairfield	0.2	86,178
13800	Hawkesbury *	23.6	31,086	16550	Randwick	0	70,162
10500	Baulkham Hills	19.7	66,145	10200	Auburn	0	29,294
11720	Cessnock	16.3	24,062	18500	Woollahra	0	39,585
14650	Lake Macquarie	15.0	87,178	10450	Bathurst	0	14,756
18550	Wyong	14.6	77,275	18050	Waverley	0	43,222
17150	Sutherland Shire	14.5	111,146	17100	Strathfield	0	15,507
16400	Port Stephens	14.5	36,705	17070	South Sydney	0	93,771
12700	Dungog *	12.2	5,248	11100	Botany Bay	0	20,325
16700	Ryde	10.1	59,021	11300	Burwood	0	16,838
16100	Oberon *	9.5	3,287	14800	Leichhardt	0	39,764
18450	Wollongong	8.8	101,966	11550	Canterbury	0	69,949
18250	Willoughby	8.4	47,682	10150	Ashfield	0	28,512
18000	Warringah	8.1	71,747	11900	Concord	0	15,348
11500	Campbelltown	7.3	66,032	12550	Drummoyne	0	24,290
14400	Kiama	5.3	10,606	15350	Mosman	0	20,424
10350	Bankstown	5.0	83,029	15200	Marrickville	0	49,653
10750	Blacktown	4.5	116,445	13950	Holroyd	0	52,422
17000	Singleton *	4.2	12,071	16650	Rockdale	0	63,661
15050	Maitland	3.5	28,764				
16350	Penrith	3.2	81,968				
15900	Newcastle	3.0	78,476				

* denotes LGAs located at boundary of *FireAUS* study areas. For these nine LGAs, partial addresses used in analysis may cause the statistical result to be biased. For other 50 LGAs, the analysis was complete.

From Table 1, a total of 18 LGAs have no or little bushfire risk. Except for Bathurst, all these LGAs are located in either South Sydney or inner Western Sydney.

CRESTA zones

CRESTA zones, also locally known as ICA (Insurance Council Australia) zones, are often used in collecting and reporting (re)insurance-related damage and loss data by the international insurance industry. There are 49 CRESTA zones in Australia, and the average size of CRESTA zones for populated areas such as state capital cities are much finer than those covering sparsely populated areas. Results reported at CRESTA zone level can be used for high-level risk decision management.

The Greater Sydney region includes seven CRESTA zones (Figure 5), which are located entirely within *FireAUS* study areas. In CRESTA zone 45 (Blue Mountains), 52% of 72,927 addresses are located within 130 m of bushland.

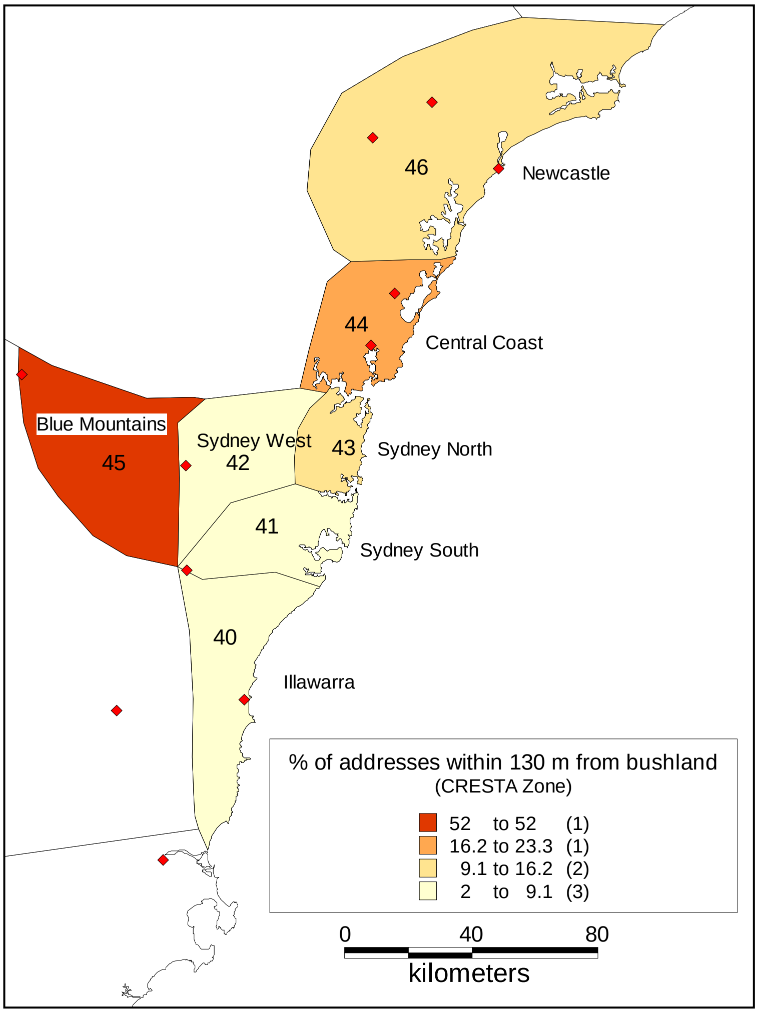

Figure 5: Percentage of addresses that are located within 130 of bushland for seven CRESTA zones in the Greater Sydney region.

Table 2: Percentage of addresses located within 130 m of bushland for seven CRESTA zones in the Greater Sydney region.

CRESTA zone	Name	%	No. of addresses analysed
40	Illawarra	8.1	166,906
41	Sydney South	2.0	1,173,350
42	Sydney West	6.8	427,124
43	Sydney North	12.6	422,275
44	Central Coast	21.4	170,861
45	Blue Mountains	52.0	72,927
46	Newcastle	12.2	269,747

CONCLUSIONS

An integrated approach for bushfire risk assessment is advocated. The *FireAUS* project focuses on exposure and vulnerability components and is complementary to hazard-centric risk assessment undertaken by other agencies. Examination of exposures, both in terms of quantity and their spatial distributions, should prove useful.

The *FireAUS* database of address risk ratings can be used to determine whether an address is located within bushfire-prone areas, and to estimate risk-adjusted premiums. For the Greater Sydney region, about 190,000 (275,000) addresses are located within 80 m (130 m) of bushland. The percentages of addresses most at risk are also estimated at LGA and CRESTA zone levels with high accuracy. In spite of population increase and urban encroachment, the overall percentages of addresses adjacent to bushland for these large spatial units are unlikely to alter significantly in the near future. It is anticipated that the results will be useful for supporting broad bushfire risk management and decision-making.

As the separation distance between address and nearby bushland is not the only factor determining bushfire risk, the results reported here are upper estimations. Improvements to include other site-specific environmental factors are underway and will allow these estimates to be refined.

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