



Urbano

ISSN: 0717-3997

ISSN: 0718-3607

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CHALLENGES FOR WILDFIRE-PRONE URBAN-RURAL INTERFACES: THE CASE OF MEL- BOURNE
Urbano, vol. 22, no. 39, 2019, May-October, pp. 88-105
Universidad del Bío Bío
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DOI: <https://doi.org/10.22320/07183607.2019.22.39.05>

Available in: <https://www.redalyc.org/articulo.oa?id=19860787006>

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CHALLENGES FOR WILDFIRE-PRONE URBAN-RURAL INTERFACES: THE CASE OF MELBOURNE

I. INTRODUCTION

Wildfires are an increasing threat for many residents who live in the growing urban sprawl and peri-urban areas of cities and regional settlements in wildfire-prone areas. Spatial planning is widely acknowledged as an important aspect of responding to wildfire risk (for instance: Browne & Minnery, 2015; Galiana-Martin, 2017; Galiana, Aguilar, & Lázaro, 2013; Groenhart, March, & Holland, 2012; March, 2016; March & Rijal, 2015; Moritz et al., 2014). Spatial planning has the potential to modify the design, location and human characteristics of settlements (March, 2016). Despite agreement about the need of integrating wildfire risk management and spatial planning, systems can often struggle to achieve this, given the range of uncertainties, contingencies, and conflicts involved in achieving integration. This research aims to examine the treatment responses to wildfire key risk factors in urban-rural interfaces and the challenges associated to these. The task is approached from the perspective of how spatial planning addresses wildfire, risk and related questions of physical structures and agency roles, interfaced with relevant components of establishing wildfire resilience, considering risk factors, physical treatment responses and the challenges these imply. While this research focuses on the physical aspects of wildfire risk and treatment, it is also acknowledged that these aspects must be complemented by non-physical measures, such as social, cultural, political, economic and technological vulnerabilities, along with community awareness and behavioural change (McEntire, 2001).

This paper is set out in five sections. First, a theoretical framework related to wildfires and their interactions with urban-rural interfaces is provided. Second, the research method is outlined. Third, the case study is presented and characterised from the perspective of key risk factors. Fourth, the current treatment responses to wildfires in urban-rural interfaces are considered, including mapping, strategic action and decision processes. Fifth, the challenges these present for spatial planning systems are explored, including human factors, willingness to act, competing demands, difficulties of implementation, and legacy issues. Lastly, a conclusion is provided.

II. BACKGROUND: WILDFIRES AND THEIR INTERACTIONS WITH SETTLEMENTS

The risks to human life and property posed by wildfires are typically greatest at urban-rural interfaces. Here, grass or forested

land may be in direct proximity to places where people live, work or recreate and their valued features including dwellings, fences, infrastructure, livestock and natural habitats. Human activities in these areas may, in themselves, be a source of ignition for wildfires (Martínez, Vega-García, & Chuvieco, 2009). Generally, wildfire emergencies, while serious, are manageable and routine (NERAG, 2015). However, when wildfires exceed human abilities to prevent large-scale impacts, they are commonly described as *disasters* (Mileti, 1999). Wildfire disaster risks can be broken down into two components: (1) their likelihood, which refers to the probability of ignition, spread and interaction with inhabited areas; and (2) the potential or actual consequences of the interaction (Atkinson et al., 2010). Accordingly, it is in wildfire-prone urban-rural interfaces and peri-urban areas that lives and properties are more exposed to wildfires and, therefore, greater risks (Gill & Stephens, 2009). Settlement patterns in urban-rural interfaces can affect the frequency and intensity of wildfires, influencing risks for humans, properties and the environment (Butt et al., 2009). Furthermore, climate change is increasing the occurrence of extreme fire weather in different contexts, such as in Australia's southeast (Steffen et al., 2017).

The way that a given fire moves through vegetated areas (its behaviour) and interacts with human settlements plays a key role in the risk profile of an urban area. There are three main factors that influence wildfire behaviour. The first is topography, as the slope of terrain influences fire speed and intensity; generally doubling speed for every 10° of slope uphill (Country Fire Authority, 2012b). The second factor is weather: humidity, wind, and atmospheric conditions affect wildfires' speed, direction, size, and intensity, promoting ignition and spread (CFA, 2012b). Additionally, strong winds push the flames forward and may carry embers beyond existing fire footprints and increase a fire's oxygen supply (Ramsay & Rudolph, 2003). Third, vegetation and characteristics of other available fuels: chemical composition, moisture content, size and shape (Ramsay & Rudolph, 2003) affect a fire's speed, width and intensity, and the embers' size (CFA, 2012b).

A wildfire, when interacting with human settlements, has four mechanisms of spread, growth, and damage. The first is embers and burning debris that find their way inside structures. This is the highest cause of building ignition (CFA, 2012b; NSW Rural Fire Service, 2006). The second mechanism is heat radiation - the energy that the fire emits in all directions, drying and heating fuel sources nearby (and sometimes igniting it) - which is the most dangerous for humans (CFA, 2012b). The third is direct flame contact, which can ignite structures if they are close to fuel sources, considering that their range is extended by the wind (Ramsay & Rudolph, 2003). Fire-driven wind can be included as a potential fourth mechanism of fire attack (CFA, 2012b; Ramsay & Rudolph, 2003). This refers to cases where a structure is damaged due to the wind, subsequently affecting humans who may be sheltering there, and potentially allowing embers to enter the structure and ignite it.

If a structure is located directly alongside flammable vegetation, then it is more likely to be subjected to a range of fire impacts.

Importantly, heat transfer diminishes quickly the farther this is from the fire, as does the potential for direct flame contact (AS3959, 2009). However, these elements often include complexities, such as fuel combinations that can transfer fire. Some fire weather behaviours include strong updrafts, potentially lifting embers and carrying them significant distances away from the fire front. Alongside this, while most embers are short-lived, certain species have bark or other associated detritus that are prone to ember longevity and can be borne significant distances, up to two or three kilometres (CFA, 2012).

Settlements contain significant fuels in various forms. These include vegetation in parks, gardens, regrowth or native remnants. In addition, dwellings, commercial buildings, sheds, and outbuildings often include significant flammable materials, including associated materials such as wood-piles, rubbish, and fuel stores for heating or cooking. The arrangement of potential fuel sources can have a significant influence upon the potential for fires to ignite and continue to progress within settlements (Syphard et al., 2012). For example, low dwelling density settlements may contain significant vegetation between structures providing a flammable environment which can perpetuate the fire's progress through settlements, or initiate ignition when embers land on fuels. In higher dwelling density settings, houses may become a risk source if they ignite and fire is transferred to other dwellings.

The initial design, ongoing maintenance, and management of houses and their surroundings play a key role in fire risks (Syphard, Brennan, & Keeley, 2017). Openings in buildings that allow embers into walls, roofs or other cavities, failure to remove leaves and debris build ups in key locations such as corners of roofs or against windows often provide a key starting point for ignition (Ramsay & Rudolph, 2003). Flammable materials including grasses that are near under-floor areas, windows and other weak points may also ignite structures. A build-up of leaf detritus, grass, shrubs or understories of trees may aid the progress of a fire that might otherwise have been prevented (CFA, 2012b).

Variable human factors also affect vulnerability and the ability to prepare for or mitigate fire risks. Generally, people with experience of past fires, who have established systems and resources for taking concerted action, are more able to deal with wildfires (Toman et al, 2013). In contrast, settlements containing significant numbers of transient or at-risk populations may be less able to manage risks and organise risk reduction, response and recovery. Furthermore, the proximity of human settlements to fire-prone areas in itself has been shown to lead to higher levels of ignitions, often associated to intentional acts (CFA, 2012b).

In the case of wildfire, facilitating response capabilities for citizens and fire services plays a key role in risk management. This response depends on evacuation capabilities, access for fire services, provision of water supply points, signage and places of last resort (Gonzalez-Mathiesen & March, 2018). However, in peri-urban areas, road systems are often constrained and historically narrow in hilly areas (Bond & Mercer, 2014) and it is frequently

challenging to widen these due to costs, fragmented land tenure and restrictions on land clearing. As populations increasingly move into these areas, road systems that are difficult to improve continue to restrict access for fire services that remain focused on vehicle response methods.

III. METHODOLOGY

This paper's method uses a case study qualitative research approach that draws on the current understanding of issues and responses as presented in the literature. The selected case study is the outer and peri-urban area of Melbourne, Australia, as shown in Figure 1. Figure 2 shows the footprint of urban Melbourne in blue with the outer fringes bordering the forest and grassland areas. The case is presented from the perspective of its wildfire key risk factors in urban-rural interfaces.

The mechanisms to generate treatment responses are taken from the Victoria Planning Provisions(VPP) (Department of Environment, Land, Water and Planning, 2018). The VPP is a reference document that provides standardised state-wide provisions as templates for developing local land-use planning schemes to ensure the consistency of local planning schemes throughout the state of Victoria. The main provisions of the VPP linked to bushfires are clauses 13.02; 44.06; Clause 52.12; 53.02; and 66.03. The treatment responses are framed – based on international and academic literature review – as: mapping; strategic action; and decision processes.

The challenges and complexities posed in forming a best-practice planning response to wildfire risks are taken from the Victoria Planning Provisions and the case study on Melbourne. The challenges and complexities are framed as: human factors; willingness to act; competing demands; difficulties of implementation; legacy issues.

IV. CASE STUDY: MELBOURNE AND WILDFIRE RISKS

Melbourne is the capital of Victoria, Australia. The Greater Melbourne area covers over 9,990 km² and has over 4.5 million inhabitants (Australian Bureau of Statistics, 2016). The much smaller and highly urbanised Central Business District has a high population and building density. Residential densities in Melbourne generally range from 11 to 30 dwellings per hectare. However, densities, while averaging 20.1 dwellings per hectare, are markedly lower in the outer suburbs (Victorian Planning Authority, 2017). The outer edges of Melbourne are characterised by extensive peri-urban areas that are neither completely urbanised nor entirely rural. Two peri-urban areas can be identified in Melbourne, namely the inner and outer peri-urban zones (Buxton et al., 2008). The inner zone is a green belt that extends from the urban growth boundary to the outer rural boundaries of fringe area municipalities and the outer zone is the

next band that corresponds to rural municipalities also influenced by regional cities.

Melbourne has experienced significant growth and change recently, with the population growing by approximately one million people over the ten-year period from 2006 to 2016 with 57.5% of this growth occurring in the outer Melbourne area (Australian Bureau of Statistics, 2016). This growth is projected to continue and accelerate, reaching almost 8 million by 2051 (DELWP, 2017). A significant proportion of housing and population growth is associated with developments on the urban fringes and in the peri-urban areas, despite strategic planning documents specifying a more compact urban form (Butt & Fish, 2016). In fact, Kennedy, Butt, and Amati (2016) identify that Australia has been through a peri-urbanisation process for at least a generation. Wildfires (also known as bushfires in Australia) refer to uncontrolled grass, scrub or forest burning over a large area (Ramsay & Rudolph, 2003). They can be ignited by human activities or natural processes such as lightning, depending on the ecosystems' fire regimes and human interactions with these (Moritz et al., 2014). Indeed, some 85% to 90% of fires are as a result of human activities (Faivre et al., 2014, Balch et al., 2017). Work done ten years ago, found that about half of wildfires are deliberately lit, with one-third accidentally lit and about 16% due to a range of other causes (Bryant, 2008). However, these figures are only approximate, as the causes of most fires in Australia are not investigated. Certain landscapes – such as in Australia's case – are naturally fire-prone (although humans often modify these significantly) and their ecosystems often rely on fire as a process that enhances habitat maintenance, natural hydrologic functioning, and nutrient cycling among other factors (Moritz et al., 2014).

Victoria has a long history of wildfires. In February 2009, Black Saturday – Australia's worst recorded disaster in terms of deaths and injury – occurred as a consequence of a decade of drought, the hottest heat wave on record and strong winds. In this event, 430,000 hectares of land were affected, 173 people died, and more than 2,000 dwellings and 61 commercial buildings were destroyed at the estimated insurance cost of \$1.2 billion. The total cost of tangible and intangible impacts was \$7 billion (Butt et al., 2009; CFA, 2012a; Holland et al., 2013; Teague, McLeod, & Pascoe, 2010). After the event, the 2009 Victorian Bushfires Royal Commission was set up to look into the causes, preparedness and response to the Black Saturday fires, providing 67 recommendations, 19 regarding planning and building controls (Teague et al., 2010). The 2009 fires led to acknowledging land-use planning's role in wildfire risk reduction in Victoria (Groenhart et al., 2012).

From the perspective of facilitating response capabilities for citizens and fire services, Victoria road systems are often constrained and compulsory evacuation is not practiced, so there is a reliance on voluntary systems and public community safety campaigns. Furthermore, as part of this shared responsibility approach, householders may choose to stay and defend their properties. While this may be effective in many circumstances, it relies on appropriate prior decision making, preparation of

properties and training. Accordingly, peri-urban areas combine complex agency based, organised and individual decision-making in a large and highly variable landscape.

As noted above, Melbourne and its surroundings are particularly at risk from wildfire disasters due to the proximity of flammable vegetation and the penetration of urban settlements into these risk areas.

V. TREATMENT RESPONSES

While the task is complex, there is a range of responses that link planning and risk management, which could be undertaken to reduce the risk of a wildfire occurring and/or turning into a disaster. An overview of these is given below, with specific reference to the situation in Victoria and the case study of Melbourne.

Mapping

The first step to act on wildfire risk is to analyse the context of the fire risk. The need to include disaster risk assessments in the planning process is emphasised by the Global Facility for Disaster Reduction and Recovery (GFDRR, 2016) and the United Nations International Strategy for Disaster Reduction (UNISDR, 2005, 2015). Characteristics of different fire-prone environments and vegetation types should provide actions for risk management (Moritz et al., 2014). This can be integrated into spatial planning systems in different ways depending on the information available and the scales of analysis. Place-based approaches identify the specific characteristics of a given area (Groenhart et al., 2012). Furthermore, a multi-scale approach that considers the regional development model, the nature of the landscape, and the typology of the urban-rural interface allows contextualising smaller areas within wider territories (Galiana-Martin, Herrero, & Solana, 2011).

In Victoria, land-use planning is determined by hazard-based zoning using the Victoria Planning Provisions. Mapping identifies wildfire hazards (not risk), based on vegetation or fuel, topography, and weather conditions. Two overlays are prepared: Bushfire Prone Area (BPA) and Bushfire Management Overlay (BMO). BPA refers to areas where a fire is likely. As shown in Figure 3, it covers most of the territory. The BMO is applied in the territory within the BPA, where the hazard is the greatest and there is the potential for extreme fire behaviour, as shown in Figure 4.

Strategic action

Strategic actions in spatial planning can play a crucial role when dealing with wildfire risk by defining longer-term actions and growth, through framing instruments (Albrechts, 2010). At this level, restricting development in the highest risk areas and guiding new development to appropriate locations can be the most effective pre-emptive mechanism to manage exposure to wildfires (Burby, 1998; Troy & Kennedy, 2007) and limit the scope of the problem (Galiana-Martín, 2017). Such an approach

facilitates providing an adequate separation between settlements and wildfire hazards (Gonzalez-Mathiesen & March, 2018) and allows conserving and restoring natural areas, taking into account the sustainable management of fire regimes over the broader landscape (Moritz et al., 2014).

In the case of the Victorian planning system, it is assumed that the resilience of settlements and communities to wildfires can be strengthened through risk-based planning. According to the Planning Policy Framework (DELWP, 2018), the protection of human life is to be prioritised (clause. 13.02 of the VPP). Moreover, the BMO indicates that development is only permitted where wildfire risk to life and property can be reduced to an acceptable level (clause 44.06 of the VPP). Regulatory instruments set construction and subdivision requirements for new developments depending on hazard-based zoning (BPA or BMO). For the BPA, the building code sets construction requirements for new structures depending on the Bushfire Attack Level (BAL). For the BMO, similar requirements apply to new constructions as well as subdivision requirements for new developments.

Strategic land use and spatial planning also needs to be used as a treatment to reduce the occurrence of human-lit fires (Stanley & Read 2015). In Melbourne, the outer fringe suburbs are the most disadvantaged, having a significant shortfall in infrastructure and services (NIEIR and Stanley & Co. 2018). This issue needs to be addressed given the strong association between socio-economically disadvantaged youth lighting wildfires and the suburbs' proximity to flammable vegetation (, Ioane y Randell, 2015, Stanley & Read 2015). Improving opportunities for these youths will also serve to reduce wildfires, although this is a longer-term project. Moreover, greater attention to situational fire prevention, largely a local place-based approach, would be valuable to reduce wildfire lighting. This includes approaches drawn from crime prevention, as outlined by Cornish and Clarke (2003) from a potential offenders' perspective:

- Increasing efforts, for instance by reducing access
- Increasing risks to offenders, for example by surveillance
- Reducing rewards, such as peer approval
- Reducing provocation causes, like conflicts, dumped rubbish
- Removing excuses, such as setting rules within a school context

Decision Processes

The decision-making process for treating wildfire risks can benefit from integrating spatial planning and disaster risk management practices in a contextualised manner. There is an ongoing need to improve interdisciplinary practices around disaster risks, including spatial planning, to ensure a comprehensive approach to wildfire risk management (Haigh & Amaratunga, 2010; March & Rijal, 2015; UNISDR, 2005, 2015). A more coordinated approach should occur in terms of: (1) institutional arrangements; (2) modes of action coordination and social integration; (3) knowledge and decisions; and (4) temporal and spatial scales (March, 2016).

In the case of Melbourne, the BMO requires a detailed planning permit application including appropriate wildfire protection measures: siting, defensible space, access to water and emergency services access. Permit applications require site-by-site re-assessments of hazards, which allow a trade-off between construction mechanisms and wider subdivision design depending on the attack level determined for sites. In addition, the Country Fire Authority is a key referral authority that must assess permit applications based on a range of wildfire considerations. They advise Local Governments, who are ultimately responsible for approving or rejecting a permit application.

IV. CHALLENGES IN COMPLEX SYSTEMS

While many of the approaches outlined above are available, many are not used in practice or only used in part, with the two components, planning and risk management, acting in isolation. As a result, Victoria is not using all its available opportunities to reduce the risk of wildfire, and the economic, social and environmental losses due to fire, remain. From the perspective of spatial planning, stakeholders must not only be aware of wildfire risk, but be willing to act on it.

The challenges associated with willingness to act and implementation difficulties will be discussed below.

Human Factors

Implementing wildfire risk reduction policies, especially in relation to human factors, presents significant challenges for spatial planning. As previously mentioned, while this paper largely focuses on the physical components of resilience to wildfires, the physical structures nevertheless influence human behaviour. For example, it is the lack of infrastructure, such as higher education facilities, a lack of public transport and the lack of jobs available in the outer fringe areas and peri-urban areas of Melbourne, that fail to respond to the youth's needs, leaving them isolated and detached from society, often with behavioural problems (Stanley & Read 2015). Such a situation promotes anger and other dysfunctional behaviours that are associated with fire-lighting (see for example, Papalia, Ogloff, et al., 2018; Gannon, 2015)

Willingness to act

Wildfire risk management and decision-making takes place within political imperatives and direct or indirect political influences and changes (March, 2016). Politicians, together with the private sector, "drive legislative change with planners acting primarily as respondents and facilitators" (King et al., 2016). In this context, politicians may favour politically appropriate but technically less sound alternatives. This can be illustrated by the aftermath of the 2009 wildfires in Victoria. As March (2016) describes, the Royal Commission in charge of investigating the causes of, and responses to, the 2009 wildfires, identified locations where the wildfire risk was too high to use or develop the land; however,

this recommendation went against the State Premier's promise that all properties could be rebuilt. This was resolved by taking a very different approach for rebuilding projects. Structures were allowed to be rebuilt without a permit, while new projects were required to comply with highly stringent standards, which led to highly divided communities, placing great pressure upon the Planning Minister. Alongside other conflicts, this led to the Minister using extraordinary powers to lower the risk assessment standard, allowing most land in wildfire prone areas to be used and developed.

Competing Demands

Under the paradigm that new development must be encouraged, the private sector is in a privileged position to apply pressure for less stringent actions when dealing with wildfire risks. In certain settings in Australia, planning has a strong orientation to facilitate and even promote new development, one of the most fundamental constraints to integrate wildfire risk management considerations into spatial planning systems (King et al., 2016). In this context, risk management considerations are often seen as minor issues (King et al., 2016), thus there is a tendency to 'balance' wildfire risk against other factors when making spatial planning assessments (Groenhart et al., 2012).

Difficulties of implementation

The complexity of spatial planning systems can challenge their capacity to effectively integrate wildfire risk management considerations. Moritz et al. (2014) recognise that the institutional adaptation learning process, triggered by disaster experiences, underlies complexities that not only may provide a particular set of solutions for each case, but may also create challenging constraints. Furthermore, one of the weaknesses of spatial planning is that it has limited capacity to act on certain dynamics of the evolution of land use and development (Galiana et al., 2013). Some issues that affect wildfire risks, such as agricultural abandonment or lack of forest management, are beyond the scope of what planning agencies mandate. This is related to the fact that planning is usually approached purely in sectoral terms (Galiana-Martin, 2017).

Legacy Issues

Settlements built with little or no consideration of wildfire risk have brought about a legacy of risk that is particularly challenging to address. Most existing settlements were built before wildfire mitigation was included in planning and building controls (Groenhart et al., 2012). Moreover, extensive land subdivision and tenure fragmentation in Melbourne's peri-urban areas has occurred (Buxton et al., 2008). This means that settlements and lots can be limited in their capacity to treat wildfire risk, for instance, they might be constrained in providing the necessary separation from hazards, and road layouts may not facilitate adequate responses. Therefore, retrofitting actions might be used to modify fuel levels or increase the resistance of structures (Gonzalez-Mathiesen & March, 2018). However, these interventions are difficult, contested and often limited in their effectiveness.

VII. CONCLUSIONS

This paper considers the treatment responses to wildfire key risk factors of urban-rural interfaces and the challenges associated to this task in the case of Melbourne, Australia. On the fringes of the city, there are extensive peri-urban areas that can be considered among the most vulnerable to wildfire hazards worldwide (Buxton et al., 2010). In this context, landscape features, structures' proximity to fires, the nature of fuels within settlements, the design and maintenance of structures and settlements, as well as human factors including the traits of people occupying a settlement and the influence this may have upon vulnerability and the response capabilities of citizens and fire services, play a key role in the intensity and nature of fire interactions with settlements.

The core elements of spatial planning's treatment responses to wildfire risks in urban-rural interfaces are analysed considering the case of Melbourne. The first step to act on wildfire risk is analysing the context of the fire risk, which can be integrated into the planning system in various ways. In Victoria, mapping identifies wildfire hazards based on vegetation or fuel, topography, and weather conditions and land-use planning is determined by hazard-based zoning through the Victoria Planning Provisions. At a strategic level, spatial planning's role can be crucial when dealing with wildfire risk to enable long-term change. In this case, the strategic level focuses on strengthening the resilience of settlements and communities to wildfires through risk-based planning; but this could also be used to reduce the occurrence of human lit fires (Stanley & Read 2015) by improving opportunities of disadvantaged youth within Melbourne's outer fringe suburbs. Greater attention to situational fire prevention, drawing on crime prevention approaches, would be valuable to reduce human lit fires. Furthermore, the decision-making process could benefit from integrating and coordinating spatial planning and disaster risk management practices. BMO planning permit applications require appropriate wildfire protection measures, including siting, defensible space, access to water and access for emergency services. While the permit application and their referral to the Country Fire Authority for advice, establish the procedural integration and coordination between them.

Melbourne's situation highlights the challenges faced by spatial planning mechanisms addressing wildfire risk. The willingness of politicians and the private sector to act on wildfire risk is directly or indirectly influenced by pragmatic politics. The approach taken to rebuilding destroyed properties after the 2009 fires illustrates how more politically pragmatic alternatives were favoured even though it was less appropriate to manage wildfire risk in the long term. Moreover, the demands of encouraging new development compete with integrating wildfire risk management considerations into spatial planning systems, constraining them. Implementing treatments can also be challenging. The complexity of spatial planning systems, and the often-sectoral approach to these, can limit their capacity to effectively integrate wildfire risk management considerations. Existing settlements

built before wildfire mitigation was included in planning and building controls imply a legacy of risk that is even more challenging to address, often limiting their capacity to face wildfire risk. Meanwhile, rapid growth in Melbourne's fringe areas is going to exacerbate wildfire dangers unless a coordinated approach to land use, spatial and emergency planning is seen as an urgent requirement, and people are willing to take risks when planning instead of when tackling fires. There is the opportunity for further research which considers the key risk factors and treatment responses to wildfire risks in urban-rural interfaces in other wildfire prone cases. Whether the challenges identified apply to other spatial planning systems and contexts also needs further research. Furthermore, the ways the physical measures examined are or should be complemented by non-physical measures, such as community awareness and behavioural change, could be investigated.