Christchurch's peri-urban wildfire management strategy: How does it measure up with international best practice?

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Abstract

The 2017 Christchurch Port Hills Fires were an expression of increasing peri-urban wildfire threat in NZ. Internationally, traditional response management of wildfire threat has been complemented by place-based and pre-emptive social and spatial strategies. The formal recovery plans for the Port Hills Fires highlight the emerging role of social programmes but a distinct lack of landscape-scale spatial planning in New Zealand wildfire management practice and research. Spatial dynamics have had a clear impact on the nature of the Port Hills peri-urban wildfire threat, yet the current recovery process largely reinstates the spatial patterns which heightened the risk, scale and impact of the 2017 fires.

Keywords: *wildfire hazard, wildfire risk, wildfire threat, wildfire management strategies*

Wildfire is an unplanned and uncontrolled fire (Majorhazi & Hansford, 2011; Wooten, 2003). When it occurs in a peri-urban area, it poses a significant threat to human life, homes and infrastructure (Rundel & King, 2001). Wildfire risk in these areas, defined here as the probability of fuels within a landscape undergoing sustained burning (Syphard et al., 2013), tends to be high due to their multiple ignition sources and large amounts of fuel to support sustained ignition (Rundel & King, 2001). With climate change, wildfire risk and the level of threat it poses to peri-urban areas are expected to increase, particularly with continued peri-urban expansion, at the interface between rural and urban areas (Gibos & Pearce, 2007; H. G. Pearce et al., 2005; Smith et al., 2016). In international efforts to reduce these threats, management strategies have been developed for high risk peri-urban areas (for example: Paveglio & Edgeley, 2017; Syphard et al., 2013).

Using the peri-urban 2017 Port Hills, New Zealand as a case study, this paper asks the question, to what extent does Christchurch's peri urban wildfire management strategy reflect best practice? We summarize factors determining wildfire threat, management goals and strategies in light of international best practice strategies. We then examine the history of land use development in the Port Hills to determine its contribution to fire hazard levels. Lastly, we evaluate Christchurch's current fire management strategy for the Port Hills in light of best management practice for reducing peri-urban fire risk. We offer suggestions for improving Christchurch's peri urban wildfire management strategies toward a comprehensive and pre-emptive approach.

Wildfire threat

Best practice wildfire management strategies are place specific. A first step to developing or adapting a strategy is to determine the wildfire threat to an area of concern. This includes an analysis of current threats (Majorhazi & Hansford, 2011; UNISDR, 2017), and can also include possible future threats, under different land use development scenarios and risk management strategies (Miller & Ager, 2013). The factors that determine these threats include: the level of *wildfire risk*, meaning probability of the structures within a landscape undergoing sustained burning, the *level of hazard,* meaning the character and patterns of a landscape that contribute to the intensity, rate of movement and spread of a fire (for example: micro-climate, landforms and available fuels), and the number of people, resources and values placed on resources that are threatened by a wildfire (Majorhazi & Hansford, 2011; Wooten, 2003). Increases in any of these factors, both human and natural, can increase the level of threat (Spies et al., 2014).

Wildfire management goals

Goals for wildfire risk management are developed for threat factors depending on the phase of management, as shown in Figure 1, and whether it is occurring before, during or after a wildfire event (Gill, 2005; Smith et al., 2016). Goals are chosen depending on the phase of management according to the threat factors of concern. A matrix linking wildfire management phases, dimensions and goals, also shown in Figure 1, suggests the best time to manage fires is well in advance of their occurrence. Reducing all factors that determine the level of threat can only be achieved through pre-planning. As the time cycle of a fire event advances, management options become more limited. The readiness or capacity of residents or fire response staff, to reduce the level of hazard or values damaged by the fire and the speed at which this capacity is deployed, can be increased before and during the fire. However, this is too late to reduce the probability of a fire occurring. Finally, recovery works across all three dimensions to either restore or improve the risk, hazard and values of an area, with the option of improvement as a basis for entering into a wildfire management cycle (Pearce & Anderson, 2008).

Wildfire management strategies

A variety of strategies have emerged to address these goals, and are often used in combination (Champ, Brooks, & Williams, 2012; Gill, 2005; Gill, Stephens, & Cary, 2013; Smith et al., 2016). These strategies include: social development, spatial planning and land management. Each strategy involves a range of different methods, which in turn are realised through actions. One method within land management is fuel management which, through actions such as prescribed burning or mechanical pruning work to contain hazards, preventing sustained ignitions, preparing for and protecting values, and preparing and suppressing hazards (Fernandes & Botelho, 2003; Furlaud, Williamson, & Bowman, 2018; Gill, 2005; Schwab, Meck, & Simone, 2005). This example and the overall classification of wildfire management is shown below in Figure 2. The strategies are then discussed in the next section.

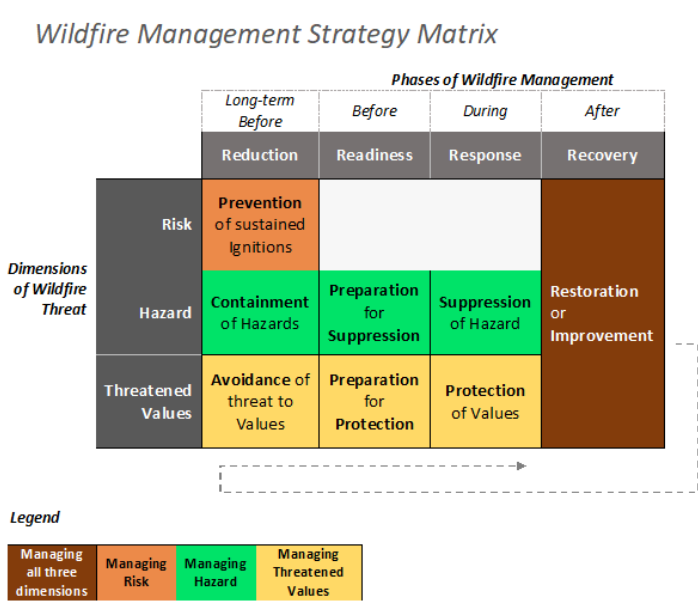

Figure 1. Wildfire management goals.

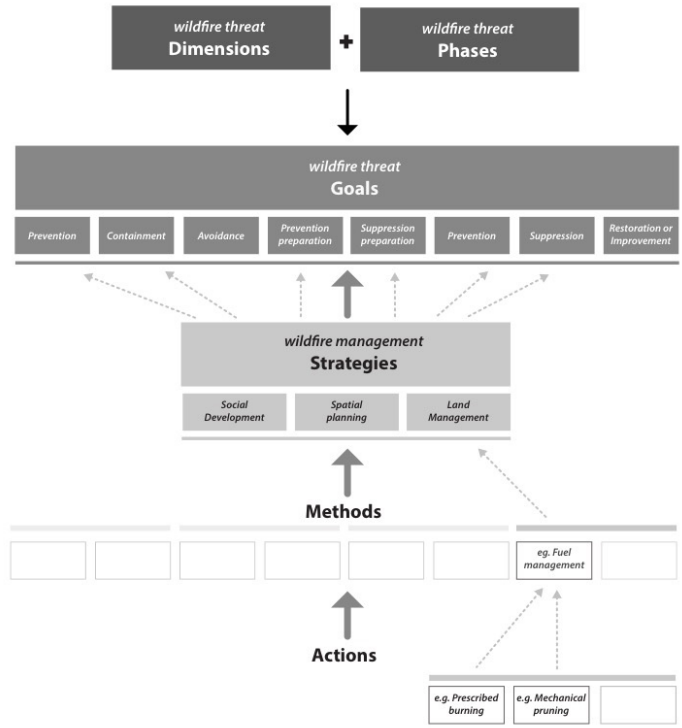

Figure 2. Wildfire management decision making framework.

Social development strategy and methods

There are four main methods that contribute to social development strategies for wildfire management: Warnings and emergency communication, one-way education, co-constructed education, and community recovery support. Warnings and emergency communication and community recovery support have long been key components of wildfire management. They have steadily improved with technological

developments, and the formalisation of communication hierarchies and support networks (Bones, 2005; Bridge, 2010; Gill, 2005). Educating communities about wildfire threat has historically been undertaken through one-way education with actions such as brochures and fire risk gauges which concentrate on prevention and readiness strategies (Gill, 2005; McCaffrey et al., 2012).

In the last two decades, co-constructed education has emerged as an alternative method for disseminating information on wildfire threat and its management in international contexts (McCaffrey et al., 2012; Paveglio & Edgeley, 2017; Toman, Shindler & Brunson, 2006). Co-constructed education works through the participatory development of wildfire management, ideally involving all stakeholders and thereby significantly increasing the uptake and comprehension of wildfire management among threatened communities (Toman et al., 2006). Co-constructed wildfire management can more effectively achieve forward-thinking goals of prevention, containment, preparing-for and protecting values, preparing for suppression and improvement-based recovery (Bones, 2005; Paveglio, Carroll, & Jakes, 2008; Toman et al., 2006). With increased participation in forward-thinking goals, co-constructed education has also been shown to improve the effectiveness of protection during wildfire events (Bones, 2005; Paveglio et al., 2008).

Warnings and emergency communication, and one-way education have been widely developed in New Zealand to reflect international standards. This is not the case for co-constructed education. Methods for co-constructed education are still emerging and there is uncertainty regarding their efficacy (Jakes, Kelly, & Langer, 2010; Jakes & Langer, 2012; Kelly, 2005; Langer & McGee, 2017; H. G. Pearce et al., 2005; SCION, 2015).

Land management strategies and methods

Land-management strategies typically contain two key methods, fuel management and emergency management. *Fuel management* involves the extent, layout and composition of any natural and human resources, which are likely to act as fuels in a wildfire event (Moritz et al., 2014). This involves actions such as designing a house with fire-retardant materials or and removing property vegetation to make defensible-space, and is largely applied to prevention, containment and both types of readiness, along with recovery (Graham, McCaffrey, & Jain, 2004).

Historically, fuel management has largely consisted of prescribed burning, but, with the effects of escaped burns being much higher in peri-urban areas, other forms of vegetation management have developed. These include mechanical pruning and specified grazing (Champ et al., 2012). The use of fire-retardant materials in and around buildings have similarly progressed with extensive technological developments (Calkin, Cohen, Finney, & Thompson, 2013). New Zealand has, for the last 30 years, worked towards similar standards of fuel management, with the momentum set by the National Rural Fire Authority. Wildfire management has been implemented through campaigns such as Fire Smart under the mandate of the restructured Fire and Emergency New Zealand (2017a; National Rural Fire Authority, 2004; Pearce et al., 2008).

Emergency management involves managing wildfire events to contain hazards, and minimise the impact upon values (Gill, 2005). Internationally, emergency management has resulted in early wildfire suppression and restorative recovery which has steadily become more effective with improved suppression preparation, and extensive technological developments (Cohen, 2008; Gill, 2005). However, over reliance on early suppression has resulted in fuel build-ups leading to hotter and more destructive fires. In response, emergency management strategies have refocused on a combination of suppression and protection (Cohen, 2008; Houtman et al., 2013). In New Zealand, early suppression is highly desirable in order to maximize the probability of survival for areas of exotic gorse (*ulex europaeus*). Gorse plays a highly-valued conservation role as a nursery environment for the restoration of indigenous vegetation seedlings. However, early fire suppression is often difficult to achieve given the high flammability of gorse (Fogarty, 2001; Forme Consulting Group, 1997). Overall, land management strategies have long been at the core of wildfire management in New Zealand, and globally, and continue to be technologically and strategically advanced (FENZ, 2017a).

Spatial planning strategies and methods

Spatial planning strategies include two key methods relevant to peri-urban wildfire management, the first is *peri-urban containment*, which works at a landscape

scale to direct development away from hazardous landscapes, avoiding the creation of perilous peri-urban areas (Gill, 2005; Syphard, Massada, Butsic, & Keeley, 2013). The second is *peri-urban mitigation* which involves locating development within and around established peri-urban areas in places best suited to avoid, prevent, contain and protect them against wildfire threat (Gill et al., 2013; Smith et al., 2016). Both spatial planning methods have emerged relatively recently in international contexts, but are already widely recognised for their role in wildfire management and are now applied as a key part of achieving more comprehensive wildfire management (Bihari, Hamin, & Ryan, 2012; Kocher & Butsic, 2017; Syphard et al., 2013).

The relationship between different wildfire management goals, and wildfire management strategies and their subset methods are shown in Figure 3. This diagram summarises international best practice, as well as showing approaches used in New Zealand, including during the recent 2017 Port Hills fires. It also notes aspects that appear to be underrepresented in NZ practice.

Overall, international best-practice strategies are moving away from responsive goals such as aggressive suppression (Champ et al., 2012; Smith et al., 2016). A new focus has been emerging which couples the refinement of responsive goals with more forward-thinking reduction, readiness and recovery. This involves improving social development, particularly through co-constructed education, alongside the integration of wildfire management into spatial planning (Penman et al., 2017; Smith et al., 2016). In New Zealand, there is a growing body of social development research (Bones, 2005; Jakes et al., 2010; Jakes & Langer, 2012; Pearce & Langer, 2017).

However, there appears to have been limited application or recognition of landscape-scale spatial planning for wildfire management. Examples of this type of spatial planning are limited by: demand from peri-urban stakeholders for wildfire threat to be considered at a territorial planning level (Hart & Langer, 2011), recognition of wildfire as a natural hazard in the Resource Management Act 1991 (NZ) and therefore requirements of territorial and regional councils to manage it. More recently, in response to the 2017 Port Hill Fires, an investigation into land use planning tools to better manage wildfire in high-threat area has been scheduled. This investigation is being led by Christchurch City Council and is scheduled to be completed by June 2019 as the last identified recovery action concerning the Port Hills fires (Christchurch City Council, 2017).

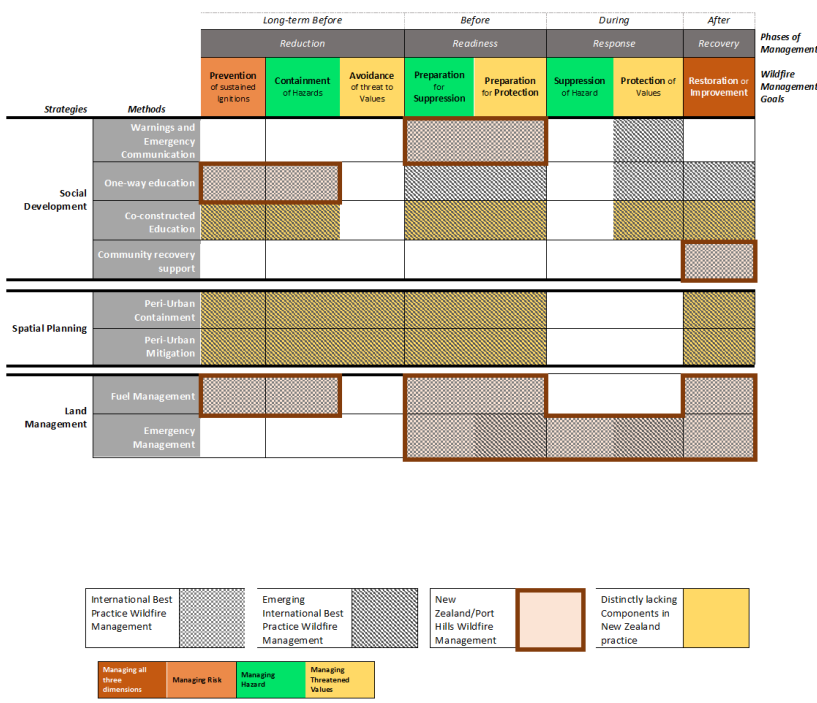

Figure 3. Relationship between the wildfire management goals and the strategies.

As the last recovery action to be undertaken and with a two-year delay, this timeframe forgoes the opportunity to capitalise on the policy window which is left open after wildfire events (Pearce et al., 2008). Many supportive policy conditions have been apparent in the wake of the 2017 Port Hill fires, for example: legislative support under the RMA 1991, increased demand for fire risk planning among public stakeholders, and the beginnings of localised planning reviews concerning wildfire management. However, there is little evidence of strong leadership for effective land use planning, which can be a key enabler for effective policy implementation (Mitchell, 1993). The following section returns to the case of the Port Hills fires, to better understand the spatial dimensions of peri urban wildfire, alongside the risks and opportunities arising from spatial configurations of peri urban land use and land cover.

The Port Hills: A brief history of land use patterns and their contribution to wildfire threat

The Port Hills lie immediately south of Christchurch City, whose suburbs climb up the lower slopes. These Hills were formed during an active volcanic period between eight to twelve million years ago, resulting in topography which strongly influences micro- climate and therefore fire hazard (Christchurch City Council, 2010a; Hampton & Cole, 2009; Orwin, 2008). Over many millennia, this volcanic land-form slowly eroded and an indigenous canopy forest emerged (Wilson, 2013). While the risk of wildfire was inherently high during the volcanic period (Carswell, 2017; Guild & Dudfield, 2009), the mature canopy forest had a low-flammability, and few fires were ignited naturally through lightning strikes (Guild & Dudfield, 2009).

Early Maori settlements in the 1300's led to frequent land clearance fires to enable hunting, access, settlements and croplands (Dwyer, 2014; Guild & Dudfield, 2009; Johnstone et al., 2016). A large portion of the Port Hills original forest-cover was burnt during this period (Christchurch City Council, 2010a; Wilson, 2013). Once the Port Hills was widely settled by Maori in the 1500´s, this period of intensive land clearance came to an end (Christchurch City Council, 2010a; Orwin, 2008), and the values associated with expanding settlements and *mahinga-kai* networks, valuing human dependence of natural resources, increased. Maori of this era have been reported to have a high awareness of wildfire threat. This likely led to actions observed elsewhere in *Te Wai Pounamu* (the South Island), such as early collective suppression, and watering settlements' roof thatch (Williams, 2009). In the meantime, scrubby succession vegetation took the place of mature forest. This vegetation was more flammable than the mature forest cover, introducing a new and extensive hazard on the Port Hills (Dwyer, 2014; Johnstone et al., 2016).

With the arrival of European settlers in the Port Hills in 1850, fire was again widely used for land-clearance, this time in preparation for seeding pasture (Guild & Dudfield, 2009; Ogilvie, 1978; Robertson, 2016). Isolated settlements emerged around the base of the Port Hills (Ogilvie, 1978), further increasing fire risk, and several large scale wildfires were recorded around this time (Robertson, 2016; The Press, 1889, 1897). European settlers introduced exotic species such as gorse and broom which have high flammability. Along with the new and expansive tracts of pasture, this introduced a new and seasonal hazard, especially when under-grazed (Carswell, 2017). However, the isolation of these settlements also led to a higher awareness of wildfire threat among inhabitants, and community actions such as early collective suppression (Rooney, 1993, December 17; Stapylton-Smith, 2009).

From 1900, suburban expansion extended around the lower flanks of the Port Hills, and an increasing demand for scenic preservation saw more public access and natural regeneration and conservation (Ministry for Culture and Heritage, 2012; Nightingale & Dingwall, 2003). These initiatives formed a peri-urban edge against the rural areas and wildlands of the Port Hills, leading to increased risk to the increased number of people present in the Port Hills area (Doherty, Anderson, & Pearce, 2008; Kirk-Anderson 2016; G. Pearce, 2017). New hazards were also introduced, such as the pine forest in Victoria Park, which in 1935 was all but burnt to the ground (The Press, 1935a). Peri-urban expansion occurred especially on the inland, Christchurch side, of the Port Hills. Many historic fires started at this edge. These fires were apparently set by residents and were spread up the Hills by seasonal northerly and north-westerly winds (The Press, 1889, 1897, 1908, 1935a, 1935b). Increased settlement also stimulated development of formal fire services. However, these services often struggled to effect suppression and protection due to the lack of both resources and access (Robertson, 2016; Stapylton-Smith, 2009).

Suburban encroachment continued through the 20th century, along with a new form of residential settlement in the 1970's, lifestyle blocks (Ogilvie, 2000; Robertson, 2016). This created isolated pockets of higher valued property which increased risk across tracts of the Port Hills area and its valleys (Carswell, 2017; Hart & Langer, 2011; Macfie, 2017). This coincided with the development of extensive plantation forestry on the mid-flanks of the Port Hills in the mid 20thcentury (Christchurch City Council, 1991) which dramatically increased wildfire hazards through the planting of particularly flammable pinus radiata trees (Gill, 2005). These plantations were located close to suburban expansion, thus further increasing fire risk to many neighbourhoods (AFAC, 2017).

Scenic preservation and biodiversity conservation continued through the 20th Century and into the 21st, with a network of areas on the upper reaches and steep valleys of the Port Hills being conserved and restored

as tussock lands or mature canopy forest (Ogilvie, 2000). Indigenous re-vegetation, using a strategy of succession planting (Summit Road Society, 2017), increased flammable scrubby vegetation, recreation and public access. These factors have also increased fire risk in many areas and were exemplified in 2016, when two fires were started from people lighting fireworks on Dyers Pass Road and Summit Road (Kirk-Anderson 2016). Expansion and improvement of both rural and urban fire services continued throughout this period. Fire management strategies concentrated on early suppression, while rural services also instigated wildfire risk awareness campaigns (Christchurch City Council, 2014; National Rural Fire Authority, 2016).

Despite increased risks associated with these land use patterns, statutory planning policy prior to the 2017 Port Hills fires continued to support continued urban expansion onto the valleys and lower slopes up to 160 metres, while retaining and expanding farming and forestry and intensive recreation and public networks, and expanding areas of indigenous vegetation

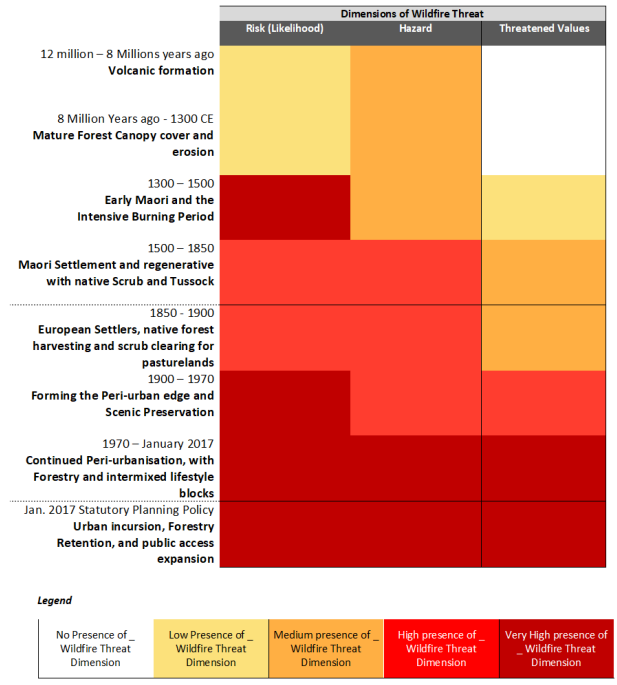

Figure 4. Diagram showing the development of Port Hills wildfire threat over time

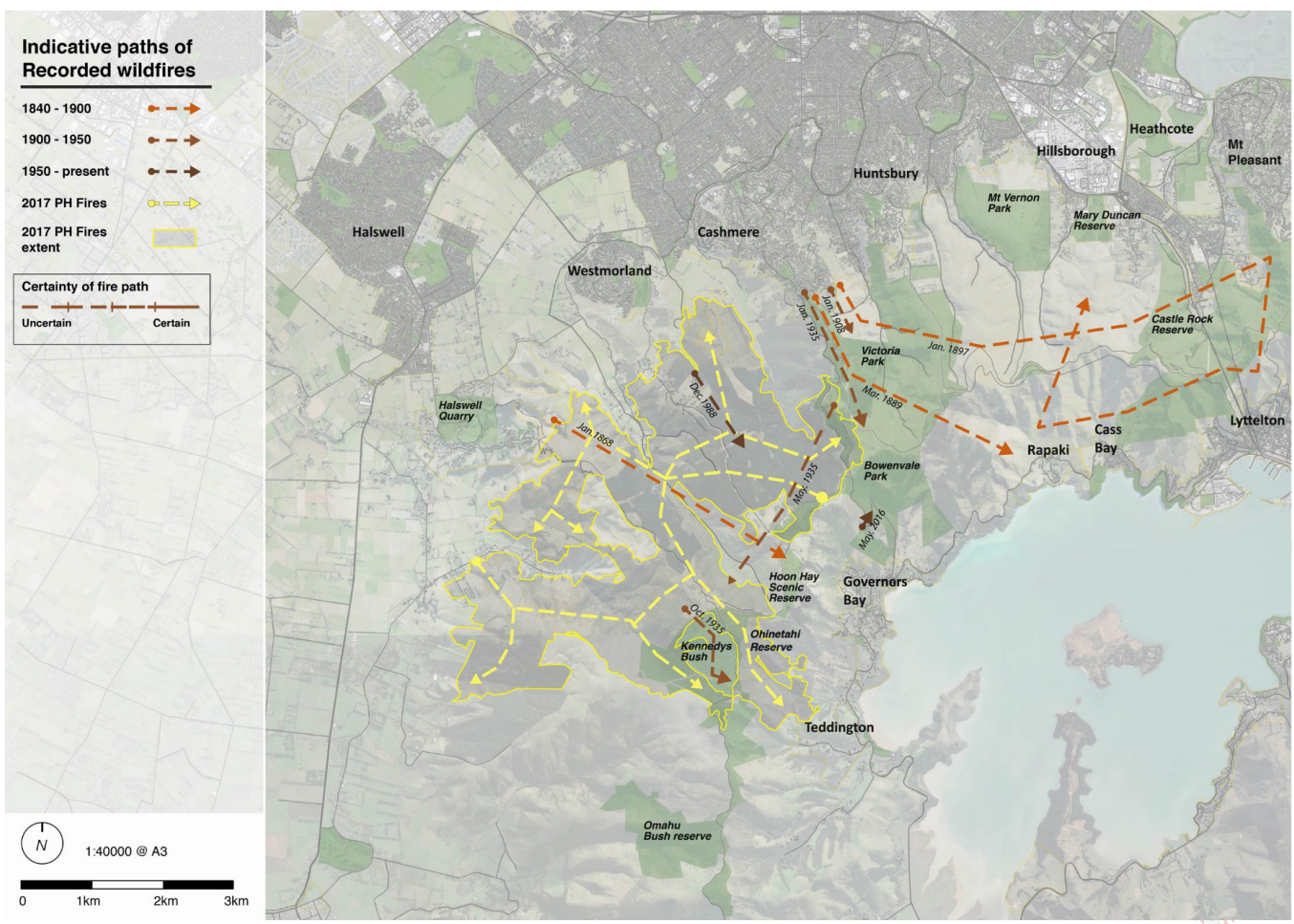

Figure 5. Recorded origins and paths of widlfires on the Port Hills.

restoration, especially on the upper flanks and valleys marked by high fire risk (Christchurch City Council, 2008, 2009, 2010b, 2016; Environment Canterbury, 2016; Rob Greenaway & Associates, 2004) . Figure 4 shows how the wildfire threat to the Port Hills has increased through time, while Figure 5 shows the location and trajectory of recorded wildfires since European settlement.

This historical record shows that the spatial configuration and dynamics of expanding forestry and lifestyle blocks, reduced grazing and revegetation, urban expansion, and increased public recreational access combined to increase wildfire threat on the Port Hills prior to the 2017 fires (AFAC, 2017; Jakes et al., 2010). A belt of settlement encroachment around the base of the Hills brought urban land uses and assets closer to the tall woody vegetation on the mid slopes. This increased risk and threatened values, and to a lesser extent, fire hazard. The mid-slopes of the Hills developed into an extensive fire hazard zone due to plantation forestry and lightly grazed farmland. An upper band of mixed hazard emerged, with scrublands and remnant native forest increasing, overlaid with an expanding public access and recreation networks. As shown in Figure 6, this brought many more people into the area, further increasing risk and threatening assets.

Christchurch fire management strategy: The Port Hills fires Recovery Plan

The Port Hills Fires Recovery Plan (PHFRP) was released in June 2017 and constituted an institutional framework for the recovery. The writing of this document involved a wide range of governing bodies including Christchurch City Council, Selwyn District Council, and Environment Canterbury (ECAN). It gave a strategic framework for the "coordinated recovery from the fires, responding to the short, medium and long-term social, built, economic and natural issues" (Christchurch City Council, 2017).

In November 2017, an independent Port Hills Operational Review (PHOR) was produced for Fire and Emergency New Zealand (FENZ). This document focused on

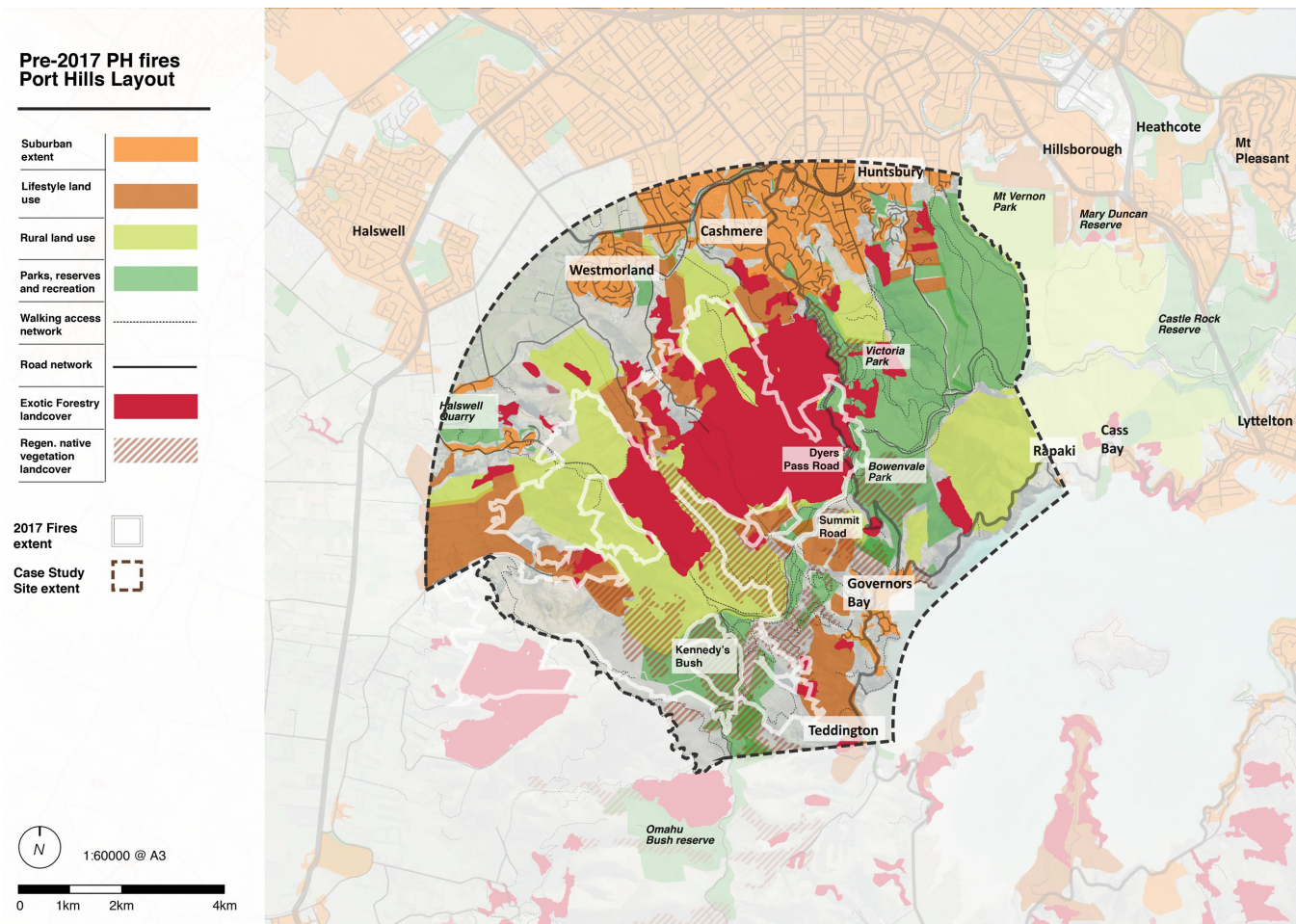

Figure 6. Distribution of land uses in the Port Hills prior to the 2017 fires

detailing and improving the operational management of wildfire events. It also evaluated and promoted more forward-thinking approaches to managing wildfire threat, which are to be realised by FENZ as outlined in the subsequent Action Plan (FENZ, 2017b). Other groups have also developed less formal recovery plans. These include the Ecological Recovery Group, that produced a management plan for vegetation recovery within a month of the fires occurring (Muerk, 2017).

Land-management strategies within the PHFRP and PHOR followed international best-practice by focusing on improving readiness, such as preparing emergency responses for future wildfire events (Christchurch City Council, 2017). A description of wildfire threat for the Port Hills had previously been undertaken, in 2011. However, this is still to be refined according to the Port Hills Operational Review (AFAC, 2017). Social development in the PHFRP focuses predominantly on one-way education, community recovery support and improving warnings and emergency communication, while the PHOR mandates research and the development of co-constructed education (AFAC, 2017).

In the PHFRP, spatial planning is identified as an opportunity, but is only weakly supported in policy under a "where practical" proviso (Christchurch City Council, 2017, p. 9). Notably, the review of spatial planning opportunities for wildfire management is only focused on the urban component. Furthermore, it appears that the review will only consider the period from mid-2019 onwards, when approximately two thirds of the recovery capital will have already been invested elsewhere (Christchurch City Council, 2017, 2018). The PHOR does not make mention of spatial planning (AFAC, 2017) and there is little overall recognition of spatial land use planning as a wildfire management strategy.

While the PHOR concentrates more on social and land-management components of wildfire management, the PHFRP approaches the recovery with a largely restorative approach. This involves reinstating the pre-fire land uses and built environment, with the specific preservation and rebuilding of residential, commercial and utility structures and assets within the Port Hills (Christchurch City Council, 2017). This will intensify the spatially-tiered composition of the Port Hills, within a context of high and likely increasing wildfire threat. The current restorative approach is therefore likely to further intensify many spatial drivers of peri-urban wildfire threat which have significantly contributed to the extent of damage from the 2017 fires.

Conclusion

The focus and content of the 2017 Port Hills Recovery Plan suggests that local wildfire management and governance in New Zealand are failing to take opportunities, and legislative obligations, to apply landscape-scale spatial planning strategies that would better manage peri-urban wildfire threats. As with the Christchurch City Council (2014) Rural Fire Management Plan, the Recovery Plan primarily contains a combination of social development and land management strategies. Internationally, its recognised that wildfire needs to be managed by considering the complex combination of social, physical, and political factors driving wildfire threat (Smith et al., 2016). Applying a combination of social development and land management reflects the move towards a multi-consideration approach in New Zealand. However, it does not significantly use spatial planning to reduce this threat, in contrast to the growing number of examples of spatial planning being applied internationally, to manage social, physical, and political implications of land development for wildfire threat (Burby, Deyle, Godschalk, & Olshansky, 2000; Buxton, Haynes, Mercer, & Butt, 2011; Gill, 2005; Gill et al., 2013; Rasker & Barrett, 2016; Syphard et al., 2013).

Current land use planning is inadvertently increasing this threat through the expansion of residential, recreational access and flammable plantation forest blocks within high fire risk areas of the Port Hills. Strong and sustained leadership is needed to implement land use planning that reduces, rather than increases, wildfire risk within these peri-urban areas. This is particularly important in the wake of a wildfire when public, and political, concern over wildfire impacts are high; and correspondingly, the will to dedicate resources to reducing these risks through best practice strategies, including land use planning. The absence of more progressive land use planning also runs contrary to Resource Management Act 1991 (NZ) requirements to manage wildfire threat through the management of the use, development, and protection of natural and physical resources.

Christchurch, and New Zealand as a whole, need to develop more explicit land use planning strategies for fire risk management if they are to effectively reduce future peri-urban wildfire threats. This is particularly relevant under climate change dynamics which are predicted to further exacerbate wildfire risks. However, more research is needed to understand how spatial planning could be effectively implemented as a tool to manage wildfire within the New Zealand local contexts,

and as a demand which needs to be effectively met by a combination of local governance instigation and collaborative processes (Bihari et al., 2012; Burby et al., 2000; Smith et al., 2016).

References

AFAC. (2017). *Independent Operational Review*. Retrieved from https://fireandemergency.nz/assets/Documents/Files/AFAC-Port-Hills-Review.pdf

Bihari, M., Hamin, H., & Ryan, R. (2012). Understanding the Role of Planners in Wildfire Preparedness and Mitigation. *ISRN Forestry*, *2012,* 1-12. doi:10.5402/2012/253028

Bones, H. (2005). Wildfires and communities: International perspectives. Retrieved from https://fgr.nz/documents/download/1193

Bridge, J. (2010). Mitigating wildfire disaster: Early detection and commitment. *Disaster Recovery Journal, 1629*. www.drj.com/articles/online-exclusive/mitigating-wildfire-disaster-early-detection-and-commitment.html

Burby, R., Deyle, R., Godschalk, D., & Olshansky, R. (2000). Creating hazard resilient communities through land-use planning. *Natural Hazards Review, 2000*, 99-106. doi: 10.1061/(ASCE)1527-6988(2000)1:2(99)

Buxton, M., Haynes, R., Mercer, D., & Butt, R. (2011). Vulnerability to bushfire risk at Melbourne's urban fringe: The failure of regulatory land use planning. *Geographical Research, 49*, 1-12. doi: 10.1111/j.1745-5871.2010.00670

Calkin, D., Cohen, J., Finney, M., & Thompson, M. (2013). How risk management can prevent future wildfire disasters in the wildland-urban interface. *Environmental Sciences, 111*, 746-751. doi: 10.1073/pnas.1315088111

Carswell, F. (2017, March). Port Hills fires: Lessons for the entire country. *Stuff*. Retrieved from www.stuff.co.nz/science/90199389/port-hills-fires-lessons-for-the-entire-country

Champ, J., Brooks, J., & Williams, D. (2012). Stakeholder understandings of wildfire mitigation: A case of shared and contested meanings. *Environmental Management, 50*, 581–597. doi: 10.1007/s00267-012-9914-6

Christchurch City Council. (1991). *Cashmere Spur and Bowenvale Valley Reserves Management Plan*. Retrieved from https://ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/park-management-plans/cashmere-spur-and-bowenvale-valley-reserves-management-plan/

Christchurch City Council. (2008). *Biodiversity Strategy 2008*. Retrieved from www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/strategies/biodiversity-strategy-2008/

Christchurch City Council. (2009). *South-West Christchurch Area Plan.* Christchurch, New Zealand: Christchurch City Council.

Christchurch City Council. (2010a). *Fact sheet: Port Hills*. Christchurch, New Zealand: Christchurch City Council.

Christchurch City Council. (2010b). *Public Open Space Strategy 2010-2040*. Retrieved from www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Strategies/PublicOpenSpaceStrategy.pdf

Christchurch City Council. (2014). *Rural Fire Management Activity Management Plan*. Retrieved from www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Long-Term-Plan/ActivityManagementPlanRuralFireManagement.pdf

Christchurch City Council. (2016). *Christchurch District Plan*. Retrieved from www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/christchurch-district-plan

Christchurch City Council. (2017). *Port Hills Fires Recovery Plan*. Christchurch, New Zealand: Christchurch City Council.

Christchurch City Council. (2018). *Capital Programme overview*. Retrieved from www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Long-Term-Plan/draft2018/Capital-Programme-Schedules-2.pdf

Cohen, J. (2008). The wildland-urban interface fire problem: A consequence of the fire exclusion paradigm. *Fremontia, 38,* 16-22. www.fs.fed.us/rm/pubs_other/rmrs_2008_cohen_j002.pdf

Doherty, J. J., Anderson, S. A. J., & Pearce, G. (2008). *An analysis of wildfire records in New Zealand: 1991-2007.* Retrieved from https://scion.contentdm.oclc.org/digital/collection/p20044coll13/id/42/

Dwyer, C. (2014). *The stories of Banks Peninsula: Connecting Maori oral traditions, European history, and geological and ecological perspectives.* Christchurch, New Zealand: University of Canterbury.

Environment Canterbury. (2016). *Greater Christchurch Urban Development Strategy update*. Retrieved from http://greaterchristchurch.org.nz/assets/Uploads/5243-PLAN-Urban-Development-Strategy-Update-Aug2016-SCREEN-Final.pdf

FENZ. (2017a). *Fire and Emergency New Zealand Blueprint 2017-2020*. Retrieved from https://fireandemergency.nz/assets/Documents/About-FENZ/Key-documents/FENZ-Blueprint-2017-20-Final-v2017-11-30.pdf

FENZ. (2017b). *Port Hills Fires - 2017 Operational Action Plan*. Retrieved from https://fireandemergency.nz/assets/Documents/Files/Action-Plan-Summary.pdf

Fernandes, P., & Botelho, H. S. (2003). A review of prescribed burning effectiveness in fire hazard reduction. *International Journal of Wildland Fire, 12*, 117-128. doi: 10.1071/WF02042

Fogarty, L. (2001). *Flammability guide for some common New Zealand native tree and shrub species.* Retrieved from https://fireandemergency.nz/assets/Documents/Research-and-reports/Report-20-A-Flammability-Guide-for-Some-Common-New-Zealand-Native-Tree-and-Shrub-Species.pdf

Forme Consulting Group. (1997). *Interface fire hazard susceptibility: Study areas for Wellington City, Hutt Valley (including Wainuiomata and Eastbourne) and Porirua*. Tawa, New Zealand: Forme Consulting.

Furlaud, J., Williamson, G., & Bowman, D. (2018). Simulating the effectiveness of prescribed burning at altering wildfire behaviour in Tasmania, Australia. *International Journal of Wildland Fire, 27*, 15–28. doi: 10.1071/WF17061

Gibos, K. E., & Pearce, G. (2007). *Lessons learned from implementation of national and regional Wildfire Threat Analysis in New Zealand*. Christchurch, New Zealand: Scion.

Gill, A. M. (2005). Landscape fires as social disasters: An overview of 'the bushfire problem'. *Environmental Hazards, 6*, 65-80. doi: 10.1016/j.hazards.2005.10.005

Gill, A. M., Stephens, S., & Cary, G. (2013). The worldwide "wildfire" problem. *Ecological Applications, 23*, 438–454. doi: 10.1890/10-2213.1

Graham, R., McCaffrey, S., & Jain, T. (2004). *Science basis for changing forest structure to modify wildfire behavior and severity*. Retrieved from www.fs.fed.us/rm/pubs/rmrs_gtr120.pdf

Guild, D., & Dudfield, M. (2009). A history of fire in the forest and rural landscape in New Zealand. *Journal of Forestry, 59*, 34-38. http://nzjf.org.nz/free_issues/NZJF54_1_2009/5C127D1A-CDFF-4cde-B272-23362D00A078.pdf

Hampton, S., & Cole, J. (2009). Lyttelton Volcano, Banks Peninsula, New Zealand: Primary volcanic landforms and eruptive centre identification. *Geomorphology, 104*, 284–298. doi: 10.1016/j.geomorph.2008.09.005

Hart, M., & Langer, L. (2011). *Mitigating the risk of human caused wildfires: Literature review and stakeholder study*. Christchurch, New Zealand: Scion.

Houtman, R., Montgomery, C., Gagnon, A., Calkin, D., Dietterich, T., McGregor, S., & Crowley, M. (2013). Allowing a wildfire to burn: estimating the effect on future fire suppression costs. *International Journal of Wildland Fire, 22*, 871–882. doi: 10.1071/WF12157

Jakes, P. J., Kelly, L., & Langer, L. (2010). An exploration of a fire-affected community undergoing change in New Zealand. *The Australian Journal of Emergency Management, 25*, 48-53. https://ajem.infoservices.com.au/items/AJEM-25-03-10

Jakes, P. J., & Langer, L. (2012). The adaptive capacity of New Zealand communities to wildfire. *International Journal of Wildland Fire, 21*, 764-772. doi: 10.1071/WF11086

Johnstone, J., Allen, C., Franklin, J., Frelich, L., Harvey, B., Higuera, P., . . . Schoennagel, T. (2016). Explaining fire-driven landscape transformation duringthe Initial Burning Period of New Zealand's prehistory. *Frontiers in Ecology and the Environment., 14*, 369-378. doi: 10.1111/j.1365-2486.2011.02631.x

Kelly, L. (2005). *Wildfires and communities: Australasian perspectives*. Retrieved from https://fgr.nz/documents/download/1215

Kirk-Anderson , J. (2016). Fireworks said to have caused large fire on Christchurch's Port Hills. Retrieved from https://www.stuff.co.nz/the-press/news/79635645/fireworks-said-to-have-caused-large-fire-on-christchurchs-port-hills

Kocher, S., & Butsic, V. (2017). Governance of Land Use Planning to Reduce FireRisk to Homes Mediterranean France and California. *Land, 6*, 24. doi: 10.3390/land6020024

Langer, L., & McGee, T. K. (2017). Wildfire risk awareness and prevention by predominantly Māori rural residents, Karikari Peninsula, Aotearoa New Zealand. *International Journal of Wildland Fire, 26*, 820-828. doi: 10.1071/WF16133

Majorhazi, K., & Hansford, A. (2011). *New Zealand wildfire threat analysis: Workbook documentation for National Rural Fire Authority*. Retrieved from www.pdffiller.com/37113665-WTA_Wookbookpdf-New-Zealand-Wildfire-Threat-Analysis-National-Rural-Fire-Authority-nrfa-org-Various-Fillable-Forms

McCaffrey, S., Toman, E., Stidham, M., & Shindler, B. (2012). Social science research related to wildfire management: An overview of recent findings and future research needs. *International Journal of Wildland Fire, 22*, 15-24. doi: 10.1071/WF11115

Macfie, R. (2017). *The new age of fire: Why infernos like Port Hills could become more common*. Retrieved from www.noted.co.nz/currently/social-issues/the-new-age-of-fire-why-infernos-like-port-hills-could-become-more-common/

Miller, C., & Ager, A. (2013). A review of recent advances in risk analysis for wildfire management. *International Journal of Wildland Fire, 22*, 1-14. doi: 10.1071/WF11114

Ministry for Culture and Heritage. (2012). 'Pressure groups'. *Scenery preservation 1903-1953.* Retrieved from https://nzhistory.govt.nz/culture/scenery-preservation/pressure-groups

Moritz, M. A., Batllori, E., Bradstock, A., Gill, A. M., Handmer, J., Hessburg, P., . . . Syphard, A. (2014). Learning to coexist with Wildfire. *Nature, 515*, 58–66. doi: 10.1038/nature13946

Muerk, C. (2017). *A vegetation recovery scenario with required actions for the Port Hills* (unpublished meeting summary).

National Rural Fire Authority. (2004). *Partners in protection*. Wellington, New Zealand: National Rural Fire Authority.

National Rural Fire Authority. (2016). *Public awareness*. Wellington, New Zealand: National Rural Fire Authority.

Nightingale, T., & Dingwall, P. (2003). *Our picturesque history: 100 years of scenery preservation in New Zealand*. Wellington, New Zealand: Department of Conservation.

Ogilvie, G. (1978). *The Port Hills of Christchurch*. Wellington, New Zealand: AH and AW Reed.

Ogilvie, G. (2000). *Enjoying the Port Hills*. Christchurch, New Zealand: Caxton.

Orwin, J. (2008). *Port Hills - protect and enjoy; A guide to restoration and recreation on the hills above Christchurch.* Christchurch, New Zealand: Summit Road Society.

Paveglio, T., Carroll, M. S., & Jakes, P. J. (2008). Alternatives to evacuation—protecting public safety during wildland fire. *Journal of Forestry, 106*, 65-70. https://watermark.silverchair.com/jof0065.pdf

Paveglio, T., & Edgeley, C. (2017). Community diversity and hazard events: understanding the evolution of local approaches to wildfire. *Natural Hazards, 87*, 1083–1108. doi: 10.1007/s11069-017-2810-x

Pearce, G. (2017). *Previous Port Hill fires*. Christchurch, New Zealand: Scion.

Pearce, G., & Anderson, A. (2008). The role of research in managing forest and rural fire risk. *NZ Journal of Forestry, 53*, 23-26. http://nzjf.org.nz/free_issues/NZJF53_3_2008/F4F55056-7154-4e73-AEE3-F0D19E1384E1.pdf.

Pearce, G., Cameron, G., Anderson, S., & Dudfield, M. (2008). An overview of fire management in New Zealand forestry. *NZ Journal of Forestry, 53*, 23-26. http://nzjf.org.nz/free_issues/NZJF53_3_2008/F4F55056-7154-4e73-AEE3-F0D19E1384E1.pdf

Pearce, G., & Langer, L. (2017). *Improving community resilience to wildfire*. Retrieved from www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/issue-15,-march-2015/improving-community-resilience-to-wildfire

Pearce, H. G., Mullan, A. B., Salinger, M. J., Opperman, T. W., Woods, D., & Moore, J. R. (2005). *Impact of climate change on long-term fire danger.* Retrieved from www.researchgate.net/publication/299196629_Impact_of_climate_change_on_long-term_fire_danger

Penman, T., Erikson, C., Horsey, B., Green, A., Lemcke, D., Cooper, P., & Bradstock, R. (2017). Retrofitting for wildfire resilience: What is the cost? *International Journal of Disaster Risk Reduction, 21*, 1-10. doi: 10.1016/j.ijdrr.2016.10.020

Rasker, R., & Barrett, K. (2016). *Land Use Planning to Reduce Wildfire Risk: Lessons from Five Western Cities*. Retrieved from https://headwaterseconomics.org/wp-content/uploads/Planning_Lessons_Full_Report_Print.pdf

Rob Greenaway & Associates. (2004). *Port Hills Recreation Strategy*. Retrieved from www.ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Strategies/13-57537-Port-Hills-Recreation-Strategy-2004-theporthills.pdf

Robertson, J. (2016). *Head of the harbour*. Christchurch, New Zealand: Philip King.

Rooney, D. (1993, December 17). Forest fire bills alarm. *The Press,* pp. 13.

Rundel, P., & King, P. (2001). Ecosystem processes and dynamics in the urban/wildland interface of Southern California. *Journal of Mediterranean Ecology, 2*, 209 - 219. www.jmecology.com/

Schwab, J., Meck, S., & Simone, J. (2005). *Planning for wildfires*. Washington, DC: American Planning Association.

SCION. (2015). Improving community resilience to wildfire. *Scion Connections, 15*, 4-5. www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections

Smith, A., Kolden, C. A., Paveglio, T. B., Cochrane, M. A., Bowman, D. M. J. S., Moritz, M. A., . . . Abatzoglou, J. T. (2016). The science of firescapes: Achieving fire-resilient communities. *Bioscience Journal, 66*, 130-146. doi: 10.1093/biosci/biv182

Spies, T., White, E., Kline, J., Fischer, A., Ager, A., Bailey, J., . . . Hammer, R. (2014). Examining fire-prone forest landscapes as coupled human and natural systems. *Ecology And Society, 19*, 9. doi: 10.5751/ES-06584-190309

Stapylton-Smith, M. (2009). *Adderley to Bradley; A history of the southern bays of Lyttelton Harbour*. Lyttleton, New Zealand: Friends of Diamond Harbour Library.

Summit Road Society. (2017). Ohinetahi Bush Reserve. *Summit Road Society. Retrieved from* www.summitroadsociety.org.nz/resource-management/ohinetahi-bush-reserve/

Syphard, A., Massada, A., Butsic, V., & Keeley, J. E. (2013). Land use planning and wildfire: Development policies influence future probability of housing loss. *PLOS One, 8*, e71708. doi: 10.1371/journal.pone.0071708

The Press. (1889). *Bush and grass fires*. Retrieved from https://paperspast.natlib.govt.nz/newspapers/press

The Press. (1897). *Serious grass fire*. Retrieved from https://paperspast.natlib.govt.nz/newspapers/press

The Press. (1908). *Cashmere Hills Fire*. Retrieved from https://paperspast.natlib.govt.nz/newspapers/press

The Press. (1935a). *Beating back a fire*. Retrieved from https://paperspast.natlib.govt.nz/newspapers/press

The Press. (1935b). *Gorse fire On Cashmere Hills.* Retrieved from https://paperspast.natlib.govt.nz/newspapers/press

The Resource Management Act 1991 (NZ). Retrieved from www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

Toman, E., Shindler, B., & Brunson, M. (2006). Fire and fuel management communication strategies: citizen evaluations of agency outreach activities. *Society & Natural Resources, 19*, 321-336. doi: 10.1080/08941920500519206

UNISDR. (2017). *Wildfire hazard and risk assessment*. Retrieved from https://www.unisdr.org/files/52828_06wildfirehazardandriskassessment.pdf

Williams, E. (2009). Māori fire use and landscape changes in southern New Zealand. *Journal of the Polynesian Society, 118*, 175-189. www.jps.auckland.ac.nz/docs/Volume118/Volume%20118%20No%202/5%20Maori%20fire.pdf

Wilson, H. (2013). *Plant life on Banks Peninsula*. Christchurch, New Zealand: Manuka Press.

Wooten, G. (2003). *Fire and fuels management: Definitions, ambiguous terminology and references.* Retrieved from www.nps.gov/olym/learn/management/upload/fire-wildfire-definitions-2.pdf