New bushfire threats to peri-urban areas from climate change: challenges for land use planning

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Abstract: High amenity areas in South East Australia are some of the world's most vulnerable areas to bushfires. The combination of amenity attractiveness and increasing risk is placing large numbers of people in dangerous locations, particularly in peri-urban localities. Policy makers consistently have failed to use land use planning systems to prevent risk by limiting urban and rural-residential development in high amenity and bushfire prone areas. This paper relates the concepts of liveability, amenity and well-being to those of risk by investigating how risk and hazard can affect the vulnerability of peri-urban areas to bushfires. It argues that two principal factors are increasing historical levels of bushfire risk, firstly the expansion of settlement into peri-urban areas, and secondly, changing environmental conditions principally climate change. The paper examines two case studies, South Eastern Australia and California USA to illustrate the trend to increasing vulnerability. It examines the potential effectiveness of land use planning as a means of reducing risk and argues the need for anticipatory planning to prevent an expansion of settlement into bushfire prone areas.

Keywords: Fire prevention, risk management, climate change, peri-urban development

Introduction

The paradox of peri-urban settlement is that as people move to peri-urban areas, they threaten to transform the features which originally attracted them. Peri-urban development can increase vulnerability to natural events by placing large numbers of people in high risk locations susceptible to extreme events, such as bushfire, flooding and coastal sea level rise. The potential nature and scale of such risks are so serious that they threaten to make extensive peri-urban areas uninhabitable in the future, perhaps leading to large scale abandonment of settlements under a changing climate. The peri-urban residents most vulnerable to inadequate infrastructure and limited access to services are low income, transport poor households.

The multiple functions of peri-urban areas have led them to be regarded as some of the world's most contested areas (Walker, 1999; Nelson, 1999; Furuseth and Lapping, 1999) notable for the competing interests of residents, visitors and wider metropolitan populations dependent on peri-urban resources. Most cities have been constructed on or close to coastal or riverine locations, usually on productive soils and in environmentally significant areas. These locations, and the range of existing and proposed land uses, inevitably lead to a wide range of conflicts between land users. The prioritising of natural amenity may conflict with traditional production such as agriculture (Gibbons et al, 2013) and with attempts to develop rural landscapes into residential or rural-residential subdivisions. Cultural assets such as attractive town streetscapes also contribute to creating the conditions for a 'commodified landscape to unfold' (Mitchell and Coghill, 2000: 88.). In North America, Europe and Australia, the built form of rural villages and country towns are important drivers of exurbanisation and counter-urbanisation (Stockdale, 2010; Lacour and Puissant, 2009; Costello, 2009). Built form and cultural heritage are also signs of authenticity distinct from contemporary urbanisation (Argent et al, 2007) and protecting them may positively influence property values (Nankervis, 1988; Armitage and Irons, 2013).

This paper relates the concepts of liveability, amenity and well-being to those of risk by investigating how risk and hazard can affect the vulnerability of peri-urban areas to bushfires. It argues that two principal factors are increasing historical levels of bushfire risk, firstly the large-scale expansion of settlement into peri-urban areas, and secondly, changing environmental conditions principally climate change. Increased risk is being experienced in countries historically susceptible to bushfires, such as Spain, Portugal and the United States, France and as a new threat in Sweden, Norway and South Korea and even in arctic regions such as Siberia and Alaska. The paper examines two case studies,

South Eastern Australia and California USA to illustrate the trend to increasing vulnerability. It examines the potential effectiveness of land use planning as a means of reducing risk and argues the need for anticipatory planning to prevent an expansion of settlement into bushfire prone areas.

Liveability, rural amenity and well-being

Peri-urban liveability is the ability of people to live in peri-urban areas, or "the general quality of a place which makes it pleasant or agreeable for people to reside in" (Tract Consultants and Deloitte Access Economics, 2015:17). It "represents the many characteristics that make a location a place where people want to live" (VCEC, 2008:xxv). Physical features and a range of environmental features often arouse interest in a peri-urban location, and economic and social factors also affect attractiveness. The most important of these are a range of 'objective' and 'subjective' factors. Liveability can be defined in terms of objective factors such as a temperate climate, diverse and affordable housing, physical infrastructure, social infrastructure, acceptable living costs, safety and stability. But liveability is best measured by citizen satisfaction, a subjective factor. Subjective factors include connectiveness to family and friends, personal satisfaction and identity, and a sense of personal and community 'wellbeing'.

The ways variables interact are vitally important. Each element contributes to well-being but the interaction between elements can multiply impacts. Many peri-urban residents prioritize amenity factors such as rural and natural landscapes and socially cohesive communities, tolerating lower income levels, accessible employment and inadequate transport and health facilities for a chosen lifestyle**.** Even if residents accept inadequate physical infrastructure, usually they are less tolerant of inadequate health, education and other social services. Young parents expect equal standards of primary and secondary education to those provided in cities. Major discrepancies in the provision of specialist and even general practitioner services still exist throughout Australian peri-urban areas.

Amenity is "agreeable ways or situations" or the attractiveness of a place and the benefits it provides inhabitants. Amenity also can be defined objectively in terms of physical conditions such as natural features, heritage buildings and infrastructure, and subjectively as personal perceptions, tolerance, diversity and safety. In a measurable sense, amenity is the value given by residents and visitors to attributes which are aesthetically attractive, and to access to services (Argent, Smailes and Griffin, 2007). Early commentators on amenity referred to two types of amenity attractors, "amenity resources" such as climate, coastal areas and landscapes (Perloff and Wingo, 1964:223), and cultural resources (Moss, 1987). Amenity is a necessary condition for 'liveability'. High amenity clearly enhances the value of particular locations and is highly prized apart from the productive value of land. Many factors can make communities attractive to residents, such as amenity, affordability, accessibility and productivity.

The notion of human 'wellbeing' can be related to an environmental context, with high wellbeing one outcome of a liveable and high amenity locality. Like the notions of liveability and amenity, wellbeing may also be defined in terms of objective indicators, such as lifespan, levels of personal interaction, participation in activities, and minimum levels of income, health and sustenance. But it also involves subjective factors and values encompassing fulfilment and happiness (Stanley et al, 2013).

In recent decades amenity has acted as a major factor in population movements to rural areas across the globe. The role of amenity in rural development is increasingly recognised as a significant factor in the shift from rural production to a mix of production, consumption of amenity and protection of the natural environment (Holmes 2006; Mather et al. 2006). Migrants who move to rural areas for their amenity can be said to be consumers of perceived landscape and heritage values. Amenity therefore is an important attractor of migrants to peri-urban areas who prefer such consumption values instead of adopting a traditional production role (Argent et al, 2010). Its role is linked to diversification processes and contributes to a rural comparative advantage of place (Argent et al; 2010, Galston and Baehler 1995). Natural amenity such as forests, coastal environments, lakes and mountains are powerful lures to migrants (Argent et al, 2010). However, accessibility to urban services, quality of local services particularly health, education and employment, and land prices, also are key influences on the growth of peri-urban and broader rural areas (McGranahan, 1999; Argent et al, 2010). Regions with a range of amenity factors such as landscape, heritage architecture, and access to metropolitan centres are particularly attractive to urban dwellers who desire the countryside ideal (Tonts and Grieve, 2002).

Various ways are used to value landscape amenity. Some are objective economic use and non-use assessments, others subjective. The economic value of amenity is usually regarded as a non-market service, so proxies are used such as market returns and measuring the value of uses to people, and personal preferences. Hedonic pricing estimates the non-productive value of landscapes, such as cultural heritage, wetlands and vegetation. Total Economic Value attempts to measure the economic use and non-use values of landscapes and so integrate environmental values into cost benefit analyses (Plottu and Plottu, 2012). Ultimately, however, 'amenity' is a concept based on values and on assessments of quality. The value placed on attributes such as landscapes may not be assessable in quantifiable terms and, to many people, may override other measured benefits and disadvantages (Barr, Wilkinson and Karunaratne, 2005). .

Risk and liveability

Risk and hazard are key factors in peri-urban liveability. High amenity areas in South East Australia are also some of the most vulnerable areas in Australia to bushfires. The combination of amenity attractiveness and increasing risk is placing large numbers of people in dangerous locations, particularly in peri-urban localities.

The concept of 'risk' is variously defined. The 2009 AS/NZS ISO 31000 Risk Management Guidelines replaced the definition of risk in the previous standard from "the chance of something happening that will have an impact on objectives" to "the effect of uncertainty on objectives". The 2018 Risk Management Guidelines reviewed the seven principles of the 2009 standard in replacing the 2009 edition. However, under the ISO guidelines, risk management will continue "to apply risk treatment options to ensure that the uncertainty of their agency meeting its objectives will be avoided, reduced, removed or modified and/or retained".

This emphasis on uncertainty draws from the precautionary principle - that we should act cautiously whenever uncertain and serious environmental risks are possible. This principle was developed as one way to anticipate harm through preventative action. It implies both that human measures which are likely to cause irreversible damage should not occur even if the science is uncertain, and that action to mitigate damage should be initiated if the damage from inaction is likely to be serious even under present scientific uncertainty. Risk assessment addresses identifiable hazards whereas uncertainty describes situations where the nature of future possible events may be either known or unknown but probabilities cannot be assigned to their outcomes (Peterson, 2006). The same event can be both certain and uncertain, that is, some events certainly will occur but the timing or the severity is unknown. Uncertainty analysis therefore extends beyond risk assessment but a "shortcoming of risk assessment is that rarely, if ever, is full scientific certainty achieved…[about]…environmental outcomes" Gullett, 2000:97).

The precautionary principle is rarely applied to decision making. Uncertainty is implied in earlier definitions of risk as the potential for human exposure to hazard (Ingles, 1991); of risk analysis, as the process of identifying and anticipating adverse events which might lead to harmful impacts on people, communities and the environment; and of risk management, as the process of developing and implementing a strategy for identifying and mitigating risks. Beer and Ziolkowski (1995) considered the 1985 US Society of Society of Risk Analysts list of thirteen definitions of risk to propose that risk involved the union of a set of possible consequences and their consequent probabilities of occurrence over a particular time frame. The (U.S.) Fourth National Climate Assessment (USGCRP, 2018:27), for example, defines risks "in a qualitative sense as threats to life, health and safety, the environment, economic well-being, and other things of value to society..[or].. in quantitative terms estimates how likely a given threat is to occur (probability) and the damages that would result if it did happen (consequences)".

Climate change and Risk

Anthropogenic climate change reinforces the notions of uncertainty and precaution. Risk multipliers such as climate change interact with other factors to create new risks or alter existing ones. Folke and others (2002) draw on Complex Systems Theory to propose a dynamic view of nature and society where continuous change places stress on relationships between human and other entities leading to uncertainty and non-linear impacts. Risk is increased through non-linear change which increases uncertainty. Uncertain and unpredictable change, in turn, require caution.

Many commentators have pointed to the implications of non-linear change for adaptation. O'Neill and Handmer (2012) apply the concept of transformative climate change to argue for transformative adaptation to effectively manage complex bushfire. The IPCC (2011) has defined transformative climate change adaptation as "the altering of fundamental attributes of a system (including value systems; regulatory, legislative or bureaucratic regimes; financial institutions; and technological or biological systems)". Transformative adaptation involves managing environmental risks, such as bushfire risk. But O'Neill and Handmer (2012) argue that it also requires a re-evaluation of how people conceive of themselves and others in relation to environmental factors and political processes.

Adaptation is the process of adjustment by socio-ecological systems to meet the challenges of change. This process may be "reactive or anticipatory, autonomous or planned" (Stanley et al, 2013). Adaptation may involve substitution of threatened assets, structural defences to increased threats, greater support to threatened communities, or even abandonment, an increasingly likely response to sea level rise, bushfires and extreme events. Adaptive management, or progressive responses matched to changing circumstances, increasingly is regarded as the most effective way to build adaptive capacity in times of rapid and fundamental change. Adaptive management often is contrasted with regulation which by imposing stability as a "rigid control mechanism" is often seen as unable to adapt to a dynamic world (Folke et al, 2002). But a resilient community best "demonstrates preparedness" (Boon et al, 2002:23), and resilience is served best by prevention requiring anticipation of events. Regulation is often the most effective way to prevent harm either by preventing or minimising the impacts of hazardous events or by putting in place effective response measures well in advance of events.

The increased risk of bushfires from climate change is now widely accepted. The IPCC in 2018 stated that current pledges to cut CO2 emissions will push global warming to 3 degrees Celsius by 2100. (Rogelj, 2018). The south-east Australian coast has experienced every 10 years for the 40 years to 2010 a mean temperature increase of 0.1-0.3 degrees C, 2.5 more days above 35 degrees C, and a strong drying trend of 30-50 mm per decade (Stanley et al, 2013; Griggs, 2012).

The 2009 Victorian Royal Commission proposed that criteria identifying risk consider the "potential effects of climate change on the bushfire hazard in the area" (Teague et al, 2010, 226). The Western Australian Inquiry into the 2011 Perth bushfires argued that "recognition should be given to the changes in climate that might require a new approach to prevention against bushfires … there must be a limit to the time that it has taken for governments at the State and Local level to act upon the reality of climate change and reflect this reality in town planning and building approvals" (Keelty, 2011:11-12).

The CSIRO and BoM (2019) have produced new regional climate change projections for Australia based on data from up to 40 global climate models, using 21 climate variables for four 20-year time periods to 2090. There is high confidence that in south eastern Australia hot days will become more frequent and hotter, winter and spring rainfall will decrease, and the time in drought will increase, driving decreased soil moisture. The *State of Climate Report 2018* (CSIRO and BOM 2018) showed a decline of around 11 per cent in the April–October rainfall in the southeast of Australia since the late-1990s. Both reports showed a long-term increase in extreme fire weather measured in frequency and severity, and in the length of the fire season.

Settlement and bushfire risk

Increased bushfire risk poses a heightened danger to existing small and even large settlements in vulnerable areas. However, changing settlement patterns, coupled with the impacts of climate change, are increasing the level of risk experienced, particularly through a rapidly increasing peri-urban fringe development trend (O'Neill and Handmer, 2012 Extreme events affect the liveability of vulnerable areas in the most dramatic ways. Every person living in a fire prone peri-urban area is vulnerable to bushfire, and the risk is intensifying and expanding. The most vulnerable are lower income individuals and communities who already experience relatively low standards of infrastructure and services (McDougall and Maharaj, 2011). The Victorian Bushfires Royal Commission noted that 44 per cent of people who died as a result of the 2009 Victorian bushfires could be classified as vulnerable (Teague et al., 2010).

Increasing international bushfire risk provides an instructive context for Australian peri-urban areas. The 2017 California fires, for example, were the most destructive in the State's history destroying 9,470 structures, more than the total over the previous nine years. The 2018 fires repeated this level of damage, destroying about 8,000 structures. Climate change is projected to become more extreme in America (USGCRP, 2018), while a broad consensus points to the increasing fire risk from climate change (Keeley and Syphard, 2017; Romps et al 2014; Mason, 2018; Shugerman, 2018). California's Fourth Climate Change Assessment, concluded that the state is "one of the most 'climate-challenged' regions of North America," with a historically variable climate that is now seeing "extreme conditions more frequent and severe" (State of California, 2018).

In the U.S, 12.7 million more houses were built between 1990 and 2010 in the wildland-urban interface, housing 25 million more people (Pierre-Lewis and White, 2018). Volker et al (2018) show that even though the Wildland Urban Interface (WUI) comprises less than one tenth of the land area of the United States, 43 per cent of all new houses were built there in the 20 years to 2010, and that the new WUI area totalled 189,000 km^2, an area larger than Washington State. Between one third (Mason, 2018) and 43 per cent (United States Department of Agriculture, Forest Service, 2013) of California's homes are located in the wildland-urban interface, particularly in large areas north and south of the cities of San Francisco, Sacramento and Los Angeles. Other estimates state that over two million, or 15 per cent, of California's homes are concentrated in high or extremely high wildfire risk zones, and 12% are located in moderate risk areas (Barron, L and Gajanan, L, 2018). A 2019 analysis (McClatchy, 2019) showed that over 2.7 million Californians live in very high fire hazard severity zones, on rural properties, trailers and towns, including 350,000 people in towns and cities. The analysis identified 75 towns and cities with populations over 1,000 where at least 90 percent of residents live within the zones.

The international insurance industry has long recognised the interacting impacts of climate change and peri-urban development. Swiss Re (2018:1) for example, commented that "the losses from the 2018 series of events highlight the increasing vulnerability of the ever-growing concentration of humans and property values on coastlines and in the urban-wildlife interface". But U.S. cities, states, and federal officials rarely incorporate future climate risk into their decisions (Reidmiller et al, 2018; Volker et al, 2018) with "little said about how fires have become more catastrophic because there are more homes in their path" (Mason, 2018). Remedies continue to be focused on forest and vegetation management though "[wildfire] is not a land management and wildland fire management problem. It's an urban planning problem…an issue of where and how we build…" (Boxall and Rust, 2018).

The pattern of dwelling construction in areas of increasing risk is being repeated in Australia. Fire hazard is measured by the intensity of fire and this is calculated by a combination of fire danger and the type, quantity and dryness of fuel, topography, and meteorological conditions. Fire danger, or the exposure to harm, is measured commonly by the Macarthur Fire Danger Index (FFDI) which combines meteorological information on temperature, humidity and wind with fuel dryness to produce a measure between 0 and 100 in five categories of extreme, very high, high, medium or low. Fire risk however, "needs to incorporate some measure of the probability of ignition actually taking place" (Beer and Ziolkowsky, 1995:21). An FFDI reading of 50 or more is considered 'extreme' and the trigger for declaration of a Total Fire Ban. The FFDI readings for Victoria on 7 February 2009 were in excess of 300.

A series of Australian reports following the 1983 Ash Wednesday bushfires considered the need for techniques such as zoning, subdivision design, minimum lot sizes and siting of buildings.to reduce risk (Miller et al, 1984). Yet the populations of most Australian cities continue to encroach into surrounding bushland and grassland, increasing risk to life and property from bushfires. Even though south eastern Victoria comprises only 3% of the country's landmass, it has sustained around 50% of the economic damage from bushfires (Buxton et al, 2011) and over half, or 296, of the deaths between 1900–2008 (Haynes et al, 2010).

The Bushfire CRC (Norman, 2014) investigated 16 major bushfire inquiry reports from the 1939 Royal Commission report to the 2011 report into a series of Western Australian bushfires. It noted that the report into the 1967 Tasmanian bushfires (Chambers and Brettingham-Moore, 1967), identified

> "two issues that would be of significant concern in future bushfire inquiry reports: the expansion of the rural/urban interface and the fact that major bushfires could enter far into the suburbs,

> well beyond the urban edge ….[destroying]… buildings on the fringes of urban development…[and]…in high density suburbs" (Norman, 2014:47).

The Ash Wednesday bush fires resulted in 47 deaths and the loss of over 2000 properties in Victoria, and 28 deaths and the loss of over 380 homes in South Australia. The 2009 Victorian bushfires burnt 430,000 hectares, led to the deaths of 173 people and the loss of over 2130 homes, and injured 5,000 people, ranking as one of the world's ten most deadly recorded bushfires (Teague et al, 2010). They destroyed a number of townships, including Marysville and Kinglake, but a feature of these fires was their devastation of a large area of rural land in Melbourne's broader peri-urban area.

The 2003 Canberra fire, destroying over 480 houses and killing four people, is the most notable example of a bushfire causing devastation in Australian suburban environments. As a planned city, Canberra adopted a clearly defined urban edge. Farmland seemed to present "a low fire risk", and "the fact that no urban houses had been lost to bushfire since 1952 had given rise to a belief that the houses of suburban Canberra were not vulnerable" (McLeod, 2003:172). The Sydney 2001-02 bushfires and the 2009 Narre Warren and Bendigo fires entered established urban areas, sometimes for considerable distances, resulting in the loss of over 100 Sydney and 53 Bendigo homes. More recently, bushfires have been encroaching onto land with little or no history of major fire risk. Every Australian state now experiences major bushfires, including cool temperate, tropical and subtropical areas, and coastal areas of New South Wales.

Planning systems to regulate and prevent risk

Some studies have described scenarios which illustrate how climate change might affect settlements and natural systems. But relatively few have quantified ways hazardous events might affect the liveability and resilience of communities (Handmer et al, 2013). Renaud et al. (2010) argue that the complexity of socio-ecological systems involved make the identification of 'tipping points', where the resilience of communities to change is overwhelmed, difficult to determine. Since 2008, however, some Australian studies have sought to define the features of a 'climate resilient community'. NCARF has produced historical Australian case studies of extreme climatic events or conditions to examine their impacts and has sought to identify the characteristics of a climate-adapted settlement (Stanley et al, 2013).

Alberti and Marzluff (2004) argued that resilience should be understood in terms of a socio-ecological system and that dynamic interactions between socio-economic and biophysical processes operate over multiple scales. The possibility of rapid, non-linear change, once critical thresholds are exceeded, requires anticipatory planning for alternative futures and rigorous alternative policies to achieve such ends. The concept of risk, illustrated by Ulrich Beck's *Risk Society*, has become increasingly important as human settlement extends into areas affected by climate change. Lagadec (2009) has proposed a paradigm shift in the way we think and act in relation to hypercomplex crises such as bushfires. Planning for uncertainty should involve anticipatory planning for risk from factors such as climate change at the upper levels of scenarios, a precautionary approach to decision making, and the introduction of regional cross-sectoral policies designed to sustain peri-urban values. Yet policy-making is largely reactive for peri-urban regions, orientated to current market preferences and presumed future performance. In a context of increased uncertainty these approaches are inadequate responses to new levels of risk.

Great emphasis is placed in Victoria on fuel management as the primary tool for reducing bushfire risk. The government has adopted a 70 per cent residual risk target for bushfire risk to life and property and uses the Phoenix RapidFire bushfire behaviour modelling tool to estimate the effectiveness of planned burning strategies at reducing risk to human life and settlement. The government spends about $30 million annually on this approach. The U.S. State of California uses a compulsory population evacuation policy to reduce risk. However, comparatively less emphasis is placed on land use planning systems as the most important tool for anticipating risk to prevent or limit harm.

In Victoria, regulation has concentrated on increasing the potential for dwellings to survive bushfire through higher construction standards and maintaining 'defendable space' around dwellings. The 2009 Victorian Bushfires Royal Commission made 19 recommendations for improved building and planning controls. As a result, the government declared most of the state outside metropolitan areas a Bushfire Protection Area (BPA) requiring buildings to be constructed according to Bushfire Attack

Level (BAL) 12.5. A BAL measures the severity of a building's potential exposure to ember attack, radiant heat and direct flame contact. The Australian standard for construction of buildings in bushfire prone areas AS 3959-2009 identifies six BAL levels. The government also introduced the Bushfire Management Overlay to replace the Wildfire Management Overlay requiring permit control for new buildings and meeting of construction standards to the required BAL rating, siting, access, water supply and defendable space requirements. Building applications must be accompanied by bushfire hazard assessment and other statements. Three bushfire hazard levels inform the planning and building provisions based on vegetation classes in Australian Standard 3959, along with appropriate planning and building responses.

No bushfire risk mitigation measures are required for existing developments. In 2011, over 3.3 million people or 25 per cent of Australia's metropolitan population lived in 24 fast-growing local government areas on the edges of Australia's major cities, with this population predicted to grow to 4.5 million by 2021 (McGuirk and Argent, 2011). Melbourne's rural-urban fringe is among the most vulnerable in the world to the bushfire hazard. About 250,000 people on the fringes of Melbourne and another 250,000 in regional areas live in high risk areas.

Royal commissions, inquests and other such investigations have rarely focused on the potential for planning to prevent risk. The 2004 National Inquiry on Bushfire Mitigation and Management did, referring to land use planning as "the single most important mitigation measure in preventing future disaster losses in areas of new development (Ellis, Kanowski and Whelan, 2004:57)". The 2009 Victorian Royal Commission similarly referred to the potential for planning for settlement, land use and development to "reduce bushfire risk by, among other things, restricting development in the areas of highest risk, where people's lives may be gravely endangered in the event of extreme bushfire." It also proposed that criteria identifying risk consider the "potential effects of climate change on the bushfire hazard in the area" (Teague et al, 2010, 226). The Western Australian Inquiry into the 2011 Perth bushfires argued that "recognition should be given to the changes in climate that might require a new approach to prevention against bushfires … there must be a limit to the time that it has taken for governments at the State and Local level to act upon the reality of climate change and reflect this reality in town planning and building approvals" (Keelty, 2011:11-12).

Without preventative planning, the bushfire risk to people and property in peri-urban areas will increase. However, most planning systems do not address satisfactorily the key risk factor in preventive bushfire planning, that is, the continuing extensive construction of dwellings in bushfire prone areas. The two contributing elements to this risk factor are existing rural land fragmentation resulting in a large number of existing small rural lots without dwellings, and new residential and rural-residential subdivision in rural areas on the fringes of rural towns. Dispersed houses on rural residential lots and residential pockets outside townships in rural balance areas are at particular risk from catastrophic bushfire.

Many reports (Ellis et al, 2004; Miller et al, 1984; New South Wales Joint Select Committee on Bushfires, 2002) have argued that the proliferation of small rural-residential lots outside townships and the boundaries to cities have place large numbers of Australian residents in areas of high risk. The Bushfires Royal Commission (Teague et al., 2010, 13) devoted considerable attention to the potential danger from the proliferation of small rural lots in rural landscapes and around major cities and towns. It considered at some length the possible impacts of future fires on increased regional and rural populations arguing that it is vital that regional planning "deals with bushfire risk management – in particular, in the context of small undeveloped rural lots and the urban growth of Victoria's regional cities." Development of many rural lots "scattered across the landscape has the potential to greatly increase bushfire risk, especially if the blocks are too small to create defendable space around dwellings." A 2011 RMIT Study (Buxton et al, 2011) showed that over 52,000 lots without dwellings exist in the rural areas of five outer peri-urban Melbourne municipalities. Almost 30 per cent of lots without dwellings in the Farming Zone in these municipalities were under four hectares and about 60 per cent under 20 hectares. Extensive further subdivision can occur. In the ten years to 2009, over 4,000 houses were built in the rural zones of these five peri-urban councils, 75 per cent on lots less than 20 hectares in size and almost 60 per cent on lots less than 8 hectares. Large numbers of dwellings destroyed in the 2009 fires were constructed relatively recently in the Rural Living Zone, with 37 per cent of fire affected lots sized 2 hectares or less. Yet, some councils are continuing to approve small lot subdivisions in vulnerable landscapes.

Successive Victorian governments at State, Local and Regional levels in the 20 years to 1992 provided a model for addressing these twin problems. In the Upper Dandenong Ranges and Upper Yarra Valley region, in 1979, 42 per cent of the 43,334 urban lots were vacant and the number of vacant lots could potentially double through existing subdivision controls (Loder and Bayly, 1980). A Review Panel (UYVDRA, 1981) believed that the region's urban population of 71,198 could increase to 150,000 people in sensitive areas without further rezoning for residential use. In addition, the potential for extensive rural dwelling construction on small lots existed, with 4,727 of the total of 17,273 rural lots 0.4 ha or less, while 86 per cent of existing rural lots were below 10 ha, and over half were below 2 ha. About 62 per cent of non urban lots did not contain dwellings (Review Panel, 1981, Norman, 1979). The Investigations Report (UYVDRA, 1980:4) concluded that "it is important to realize the possible impact on landscape and water quality…if all this potential for additional development is realized". The three levels of government collaborated through the purchase, compulsory restructure or amalgamation of tens of thousands of fire prone and high conservation value lots in declared fire buffer and conservation zones.

Governance and policy

Ultimately, preventive policy addressing risk from bushfires must be cross-sectoral. Norman and Sullivan (2011) point out the need for integrated governance arrangements to address bushfire risk, arguing that integrated urban and regional planning offers a crucial cross-sectoral, multi-disciplinary, adaptive framework to address interrelated critical challenges. Spatial planning measures will need to address the increasing risk from climate change, the resulting social disruption and economic costs. The *World Conservation Strategy* model for anticipatory planning (IUCN, 1980) envisages the need for multi-sectoral consideration of reciprocal impacts and the adoption and implementation of overarching strategy applicable to all sectors.

The 2009 Bushfires Royal Commission (Teague et al., 2010, 252) devoted an entire section to planning and was the first Australian report to consider the vulnerability of such small rural lots to bushfires. The Commission's view was that bushfire risk is best managed by "concentrating urban and semi-rural settlements in defined areas with adequate buffers, good road access, emergency services and fire refuges…dealt with in a regional settlement policy." It listed some techniques: land swaps, minimum lot sizes for dwellings, restructured lots, tenement controls and transfer or purchase of development rights, favoured strengthening of existing zones and planning controls, and the use of minimum lot sizes for dwellings in rural areas, not just for subdivision. Another study of sever outer peri-urban Victorian councils (Buxton et.al., 2014), modelled two techniques in scenarios to reduce rural dwelling construction on existing lots, the use of a minimum lot size, and a tenement control. Applying a minimum lot size of 40 hectares in the Farming and Rural Conservation zones and 16 hectares in the Rural living zone reduced the number of developable lots from 49,449 to 10,657 lots. A tenement control would not restrict dwelling construction on the 32,896 singly owned lots but would reduce significantly the development potential of the multiple lots held in single ownerships. When applied to the 46,179 multiple lots on the 10,196 properties comprising combinations of lots, dwelling construction fell under a 25 hectare control to 14,597, and a 40 hectare control to 7,395 dwellings. The Commission argued that there are some areas where the bushfire risk is so high that development should be restricted, and that "even a combination of protective measures might not be enough to reduce the risk to an acceptable level" in such locations. Ultimately, the government should "implement a retreat and resettlement strategy for existing developments in areas of unacceptably high bushfire risk, including a scheme for non-compulsory acquisition by the State of land in these areas" (Teague et al, 2010, 252).

Successful long term policy of the type which has prevented dwelling construction on flood plains and more recent risk analysis of coastal erosion will have to be applied to terrestrial peri-urban areas. Most Australian governments have shown little interest in preventive measures such as strict regulatory prohibitions on dwelling construction in peri-urban areas. Ultimately, if the more likely recent national and international climate scenarios eventuate, this failure of anticipatory policy may lead to wide spread abandonment of peri-urban rural residential properties and a heightened risk to peri-urban townships.

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