Landscape and Urban Planning 174 (2018) 10–17

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Options for reducing house-losses during wildfires without clearing trees and shrubs

Philip Gibbons[a,*], A. Malcolm Gill[a], Nicholas Shore[a], Max A. Moritz[b], Stephen Dovers[a], Geoffrey J. Cary[a]

[a] Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia
[b] University of California Cooperative Extension Division of Agriculture and Natural Resources & Bren School of Environmental Science & Management, Earth Research Institute, UC Santa Barbara, CA 93106, USA

GRAPHICAL ABSTRACT

Two houses impacted by a wildfire in southeastern Australia. Our study indicates that the "greenness", spatial arrangement and proximity (relative to the wind direction) of trees and shrubs close to houses (within red circle) can be manipulated to reduce the risk of house losses during wildfires without necessarily clearing trees and shrubs. (Imagery supplied by South Australian Government.)

ARTICLE INFO

Keywords:
Bushfire
Wildfire
House loss
Fuel reduction
Hazard reduction
Wildland-urban interface

ABSTRACT

Removing vegetation close to houses is at the forefront of advice provided to home owners by fire management agencies. However, widespread clearing of trees and shrubs near houses impacts aesthetics, privacy, biodiversity, energy consumption and property values. Thus, stakeholders may oppose this practice. Regulators and property owners therefore require options for vegetation management that reduce risk to houses during wildfires without complete removal of trees and shrubs. Using data from 499 houses impacted by wildfires, we tested three hypotheses: (1) maintaining 'green' vegetation affords houses additional protection during wildfires; (2) risk posed by trees and shrubs near houses is reduced where they are arranged as many discrete patches; and (3) trees and shrubs retained in the upwind direction from which wildfires arrive represent greater risk to houses than trees and shrubs retained in the downwind direction. We found empirical support for each hypothesis. Increasing the mean Normalised Vegetation Difference Index (NDVI) (a measure of "greenness") of vegetation near houses had the same effect on reducing house losses as removing some trees and shrubs. Trees and shrubs within 40 m of houses arranged as many discrete patches posed less risk than the same cover of trees and shrubs arranged as few discrete patches. Trees and shrubs retained downwind from houses represented less risk than

* Corresponding author at: Fenner School of Environment & Society, The Australian National University, Acton, ACT 2601, Australia.
E-mail addresses: philip.gibbons@anu.edu.au (P. Gibbons), nicholas.shore@anu.edu.au (N. Shore), mmoritz@ucsb.edu (M.A. Moritz), stephen.dovers@anu.edu.au (S. Dovers), geoffrey.cary@anu.edu.au (G.J. Cary).

https://doi.org/10.1016/j.landurbplan.2018.02.010
Received 8 June 2017; Received in revised form 15 February 2018; Accepted 20 February 2018
Available online 03 March 2018

trees and shrubs retained upwind. Our findings represent options for regulators or home owners seeking to balance risk posed by wildfires with benefits associated with retaining trees and shrubs near houses.

1. Introduction

House losses during wildfires are increasing in fire-prone regions of the world because of growing housing density at the wildland-urban interface (Crompton, McAneney, Chen, Pielke, & Haynes, 2010; Hughes & Mercer, 2009; McAneney, Chen, & Pitman, 2009). Houses are destroyed during wildfires when exposed to flame contact, radiant heat and/or burning embers. Because the likelihood or severity of flame contact, radiant heat and embers increase closer to burning vegetation (Cohen, 2000; Koo, Pagni, Weise, & Woycheese, 2010; Maranghides & Mell, 2011), it follows that the characteristics of vegetation close to houses is strongly associated with house loss during wildfires (Abt, Kelly, & Kuypers, 1987; Barrow, 1944; Gibbons et al., 2012; Ramsay, Macarthur, & Dowling, 1996; Syphard, Brennan, & Keeley, 2014; Wilson & Ferguson, 1986). Intensive management of vegetation (e.g., removal of trees and shrubs) close to houses is therefore at the forefront of advice provided to home owners by fire management agencies around the world (Gill & Stephens, 2009; Massada, Radeloff, & Stewart, 2011; Nelson, Monroe, & Johnson, 2005).

This advice results in widespread removal of trees and shrubs within, and adjacent to, the wildland-urban interface (Radeloff et al., 2005). The removal of this vegetation can have negative impacts on aesthetics and privacy (Nelson et al., 2005), biodiversity (Driscoll et al., 2010) and energy consumption (Bowler, Buyung-Ali, Knight, & Pullin, 2010); it can be associated with health effects (Tzoulas et al., 2007), influence property values (Pandit, Polyakov, Tapsuwan, & Moran, 2013) and be expensive for residents (Penman, Eriksen, Horsey, & Bradstock, 2016). Thus, there are different attitudes to vegetation clearing among stakeholders across the wildland-urban interface (Nelson et al., 2005). This limits the ability to achieve effective fuel reduction across those parts of the wildland-urban interface where there is considerable tree and shrub cover around houses, thereby placing some communities or individuals within them at increased risk from wildfire. Policy-makers and residents therefore require options for fuel management that can achieve a balance between the protection of houses from wildfire and the services provided by retaining trees and shrubs.

Our understanding of fire behaviour and the mechanisms that cause damage to houses during wildfires invite the following hypotheses:

(1) Maintaining ‘green’ vegetation affords houses additional protection during wildfires. Vegetation with a high moisture content requires more energy to ignite than cured vegetation. Fuel moisture plays an important role in the self-extinction of fires (Wilson & Ralph, 1985) and therefore fuel moisture influences the rate of spread of fires (Rothermel, 1972). Thus, maintaining “greener” landscaping is likely to result in a reduced probability of house loss during wildfires than drier gardens supporting equivalent cover of trees and shrubs.
(2) Risk posed by trees and shrubs near houses is reduced where they are arranged as many discrete patches. The propagation of fire depends on the properties of the flame and the properties of the fuel ahead of the flame (Catchpole, Hatton, & Catchpole, 1989) and so the spatial heterogeneity of fuels affect the rate at which fires spread (Burrows, Ward, & Robinson, 1991). This suggests that trees and shrubs arranged in a patchy distribution around houses will represent less hazard than an equivalent cover of trees and shrubs arranged in a more continuous distribution.
(3) Trees and shrubs in the upwind direction from which wildfires arrive represent greater risk to houses than trees and shrubs in the downwind direction. The effect of wind on the direction of flames, radiant heat and embers (Rothermel, 1972) suggests that trees and shrubs in the downwind direction from which wildfires arrive will have less effect on the likelihood of house loss than trees and shrubs close to houses in the upwind direction from which wildfires arrive.

We tested these hypotheses using data from three wildfires in south-eastern Australia.

2. Methods

2.1. Study area and sampling strategy

We sampled 499 houses from three wildfires that ignited on 7 February 2009 in south-eastern Australia (145°0′–146°50′E, 37°10′S–38°30′S). These wildfires, known as the East Kilmore, Murrindindi and Churchill fires, collectively burnt 194,403 ha and destroyed 1925 houses (Teague, McLeod, & Pascoe, 2010). The landscapes affected by these wildfires included rural areas where most native tree cover had been cleared, plantations dominated by introduced radiata pine (*Pinus radiata*), *Eucalyptus* forests managed for wood production and *Eucalyptus* forests managed as conservation estate. Housing occurred as a mix of rural, semi-rural and urban areas. Prior to sampling we stratified the study area by the three principal drivers of wildfire behaviour: weather, terrain and fuel (Countryman, 1972). Weather (measured using the Forest Fire Danger Index or FFDI) (McArthur, 1967), ranged from 5 to 189 (mean = 47.6). Slope ranged from 0.3° to 22.6° (mean = 8.5°). Fuel, measured as the % of land upwind from houses that had been burnt within ≤5 years and as the % of trees and shrubs cleared upwind from houses, ranged from 0% to 36% (mean = 2.8%) and 0% to 100% (mean = 32.3%) respectively. Houses were sampled using random points allocated in approximate proportion to the area of each stratum within a Geographical Information System (GIS). We sampled the nearest house to each random point using fine-scale (35 cm–50 cm pixel resolution) aerial imagery taken 1–37 months prior to the wildfires. We recorded damage to each sampled house as a binary variable (intact or destroyed) based on a visual inspection of fine scale (8–15 cm pixel resolution) aerial imagery in the visible spectrum taken 17–23 days after the wildfires. At each house we recorded a set of potential explanatory variables representing terrain; weather; and the amount, configuration, distance and direction to fuels from houses (Appendix A).

2.2. Statistical analysis

We used an information-theoretic approach (Burnham & Anderson, 1998) and Generalised Linear Modelling (GLM) to test our hypotheses. We commenced with a base model containing variables representing weather and fuel (measured at different scales) that are significantly ($p < 0.05$) associated with house loss during these wildfires as reported in a previous study (Gibbons et al., 2012). These variables were: weather (measured with FFDI), upwind distance to forest burnt within five years, the % cover of trees and shrubs and type of vegetation within 40 m of houses, total buildings within 40 m of houses, upwind distance to patches of trees and shrubs, upwind amount of private land and an ‘autocovariate’ to account for spatial autocorrelation between adjacent houses (Appendix A). We then compared this base model reported in Gibbons et al. (2012) with the following alternative models representing our hypotheses.

Hypothesis 1. Maintaining ‘green’ vegetation affords houses additional