Evaluating the Effectiveness and Economic Benefits of Fuel Management in the Wildland Urban Interface using Wildfire Simulation

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Introduction

Communities worldwide are exposed to severe wildfire risk given their proximity to native and introduced vegetation carrying high fuel loads (Bowman et al., 2009; Gill, 2005). Recent loss of life and property from wildfires has occurred in areas with Mediterranean climates, including Portugal, Greece, California and Australia. Such fires often occur in the wildland urban interface (WUI), due to arson or accidental ignitions, or are caused by lightning strikes. The risk to these communities may be mitigated by reducing fuel loads through prescribed burning when the fire danger is low. There is ongoing debate as to the effectiveness of fuel reduction in the WUI (Fernandes and Botelho, 2003; Penman et al., 2011) given the high cost of conducting treatment close to human habitations and the low probability of a wildfire encountering a treated area.

To get the highest benefits from prescribed burning strategies, fire managers must evaluate and compare alternative scenarios and answer questions such as: (a) what if fuel reduction treatments were distributed differently across the landscape, (b) what would happen to a given wildfire if the program had not been implemented, and (c) what are the costs and benefits of different options. Prior studies have used historical data to predict the number and severity of wildfire events (e.g. Butry et al., 2010; Mercer et al., 2007) or used wildfire simulation technology to evaluate a range of prescribed burning scenarios (Florec, 2016; Florec et al., 2012; Penman et al., 2015). A significant advantage of wildfire simulation over other methods is its capacity to evaluate large numbers of "what if" scenarios, many more than by using historical data. The effect of changes in weather conditions, fuel loads and ignition patterns can be observed (Bradstock et al., 2012; Cary et al., 2009) and management options that influence these factors assessed.

Determining the most effective prescribed burning strategies has become highly important due to increasing wildfire suppression costs (Gude et al., 2013; Thompson et al., 2013), increased challenges of prescribed burning due to climate change (Jolly et al., 2015) and expanding WUI. Here we demonstrate how wildfire simulation is used to evaluate the effectiveness of prescribed burning, and when coupled with an economic model, determine optimal long-term risk reduction strategies for a given input expenditure.

Methods

The Australis wildfire prediction system (developed at the University of Western Australia) is used to simulate multiple wildfires to determine the effect particular prescribed burning strategies has on the area burned by wildfires (Johnston et al., 2008; Kelso et al., 2015). Such simulation experiments determine the effectiveness of fuel reduction in the WUI in terms of reducing losses if a severe wildfire were to occur. We focused on a fire-prone region in the south-west of Western Australia (WA) and modelled the ignition of virtual wildfires in areas susceptible to lighting strikes and arson attacks. These experiments were conducted under severe fire weather conditions; high temperatures, low humidity and strong winds. Simulation "runs" captured the dynamics of how a fire progressed through time. Fuel loads in the WUI were adjusted to represent the frequency of prescribed burning in the area. Fire intensity at the boundary between fuels and assets such as homes was calculated by the Australis system, allowing us to determine the risk to assets via radiant heat and/or ember attack. We demonstrate this technique via the simulation of both a historical fire and a hypothetical fire close to a town.

The Mt Cooke fire wildfire in 2003 resulted from a dry lightning strike on a ridge line to the south-west of the city of Perth, WA. We simulated this fire under the same weather conditions using two scenarios for fuel loads. In one fuel loads matched those when the fire occurred, with those on the east flank of the fire being low as they had been prescribed burned the previous year prior, see Figure 1. In the other (Figure 2) fuel loads were increased to the high levels which existed prior to the fuel reduction burns.

We also simulated a virtual wildfire in forests close to the town of Harvey, south-west WA. With this fire we integrated the simulator output into an economic model based on the cost plus net value change (C+NVC) approach (Donovan and Rideout, 2003), an accepted model for evaluating bushfire management programs (Gebert et al., 2008). Our economic model (Florec, 2016) aggregates prescribed burning costs, wildfire suppression costs and potential asset damages. Prescribed burning costs depend on distance from towns and treatment size, suppression costs are a function of wildfire size, and damages depend on assets affected and fire intensity.

Results

The difference that fuel reduction burn-offs may make for a single fire is seen in Figures 1 and 2.

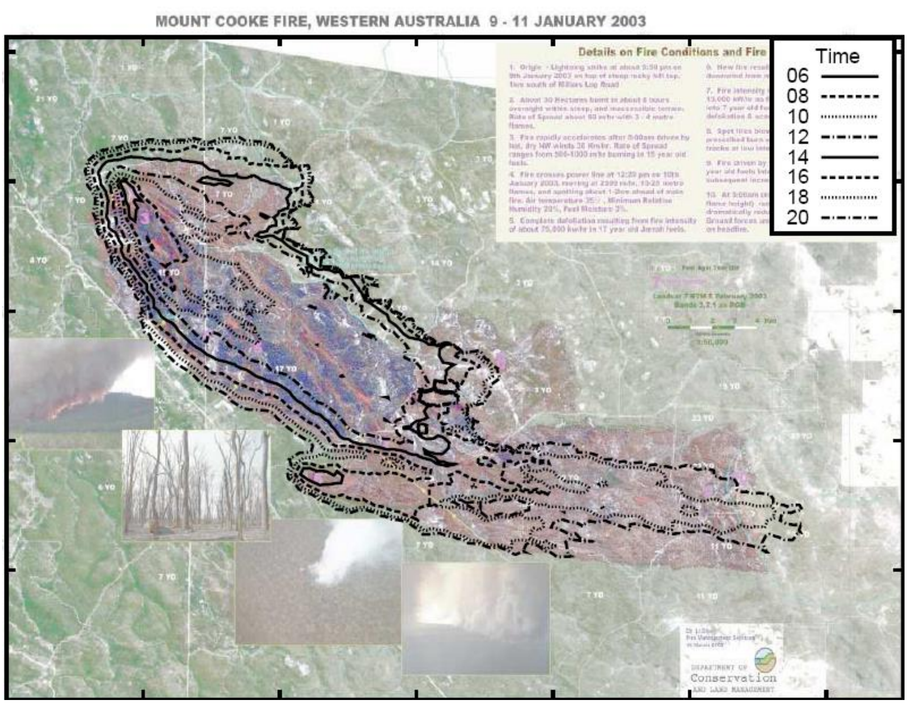

Figure 1. Fire scar of Mt Cooke fire with simulated fire perimeters overlayed.

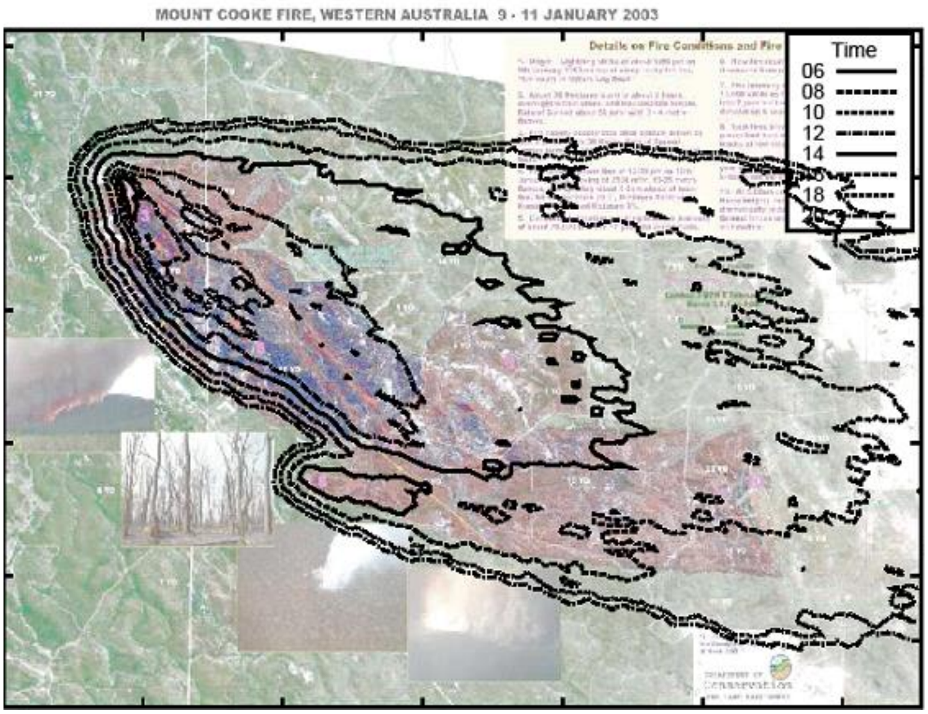

Figure 2. Simulated Mt Cooke fire with no previous fuel reduction burns on eastern flank

Both overlay the perimeters of the simulated fire onto a satellite image of the fire scar. This fire was caused by a lightning strike on Mt Cooke, part of the Darling Escarpment, and was used previously by the WA government conservation department to illustrate how fuel reduction burning significantly reduces the impact of wildfires. This poster included a description of the fire's key features on the top right, and photographs taken during and after the fire. The image of the defoliated eucalypt trees indicate the high fire intensity in fuels that were not subjected to prescribed burns, and the dark area on the west of the fire scar shows the totally defoliated forest areas.

This fire is significant as the area to the east of the scar contains fuel that was 1 to 3 years old, having been subjected to a recent burn. Two ignition points can be seen, the lightning strike at the top right of the figures, and a later ignition point due to ember initiation below. The wind was from the north-west swinging round to the west. Figure 1 illustrates the use of the Australis simulation system to replicate the fire using actual wind direction and speed, temperature, humidity, fuel load, and rate-of-spread for the jarrah eucalypt forest fuel type. It shows how the wildfire is blocked from spreading eastwards after the wind changes to the west, when the fire runs into the previously burned area on the east flank. Figure 1 also illustrates how the Australis simulation technology accurately models wildfire dynamics, as discussed further in (Kelso et al., 2015). Figure 2 shows the results of a further simulation with the same weather conditions, but with the fuel loads on the eastern flank increased to the maximum. This scenario replicates what would have happened had the previous fuel reduction burns not occurred. The difference in area between the two scenarios quantifies the benefit of fuel reduction, reducing the fire area by a factor of 5.

A further example of the benefit arising from prescribed burning can be observed in Figure 3. Here we simulated a hypothetical fire twice under the same weather conditions, the only difference being a patch on the eastern side of the highway (west flank of fire) being prescribed burned, right pane Figure 3.

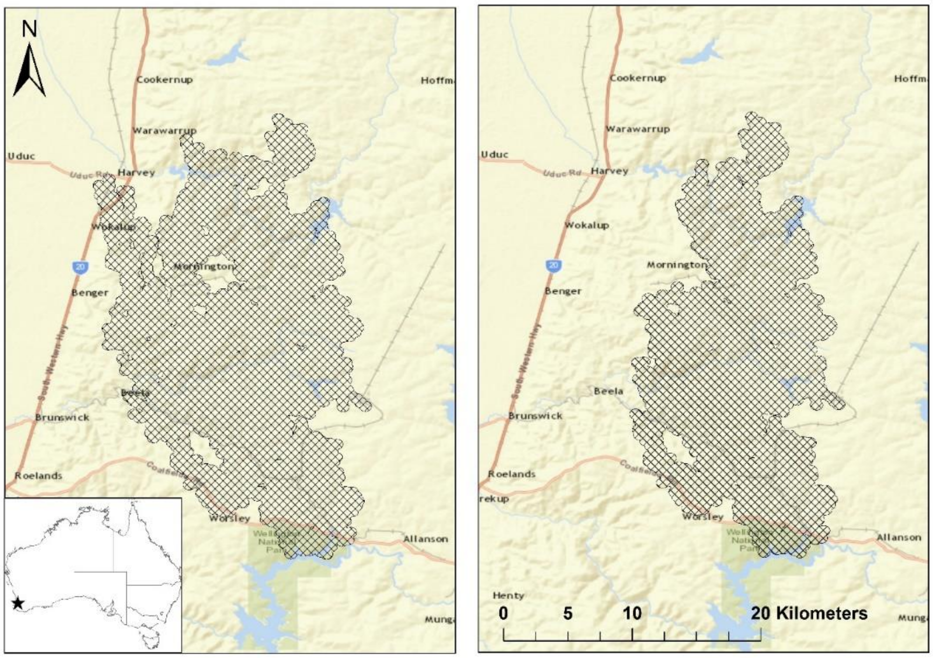

Fig 3: Simulated fire near town of Harvey in south-west WA. Left: using fuels in the landscape in January 2013. Right: simulation of the same fire *after* patch on the eastern side of highway prescribed burned.

The main difference between the two simulated wildfires (Figure 3) is the wildfire not reaching the town of Harvey (right hand side). The low fuel load to the east of town resulting from prescribed burning achieved this outcome, green hatched area on right Figure 4, showing the age of fuels in the area (i.e. time since last burn) and the area treated that prevented fire spread towards the town. While the lower area burned is significant (~8,750ha, reduction of 24%) the difference in economic losses is much more substantial. Using the economic model in Florec (2016) and (Florec et al., 2012) we estimated the economic damage, with and without fuel reduction to the east of the town. Table 1 shows potential losses for each scenario. If this area is not treated, estimated losses could amount to AUD 36 million; the wildfire would reach the town, destroying houses, infrastructure and other assets. If the area has fuels reduced estimated losses would be much lower, AUD 655,000 and damage to buildings would be marginal. For this specific wildfire, the *net benefit of prescribed burning* is high (Table 2) with the cost of fuel reduction treatments low compared to potential losses.

Table 1. Potential losses per type of asset for the simulated fires close to Harvey

Type of asset destroyed	Potential losses if area is not treated (2018 AUD)	Potential losses if area is treated (2018 AUD)
Nature conservation	461,432	400,156
Plantation forestry	23,913	17,159
Agriculture (crops, horticulture, livestock, fences)	808,989	232,365
Buildings (residential, commercial, industrial)	35,092,000	6,000
Total	36,386,334	655,680

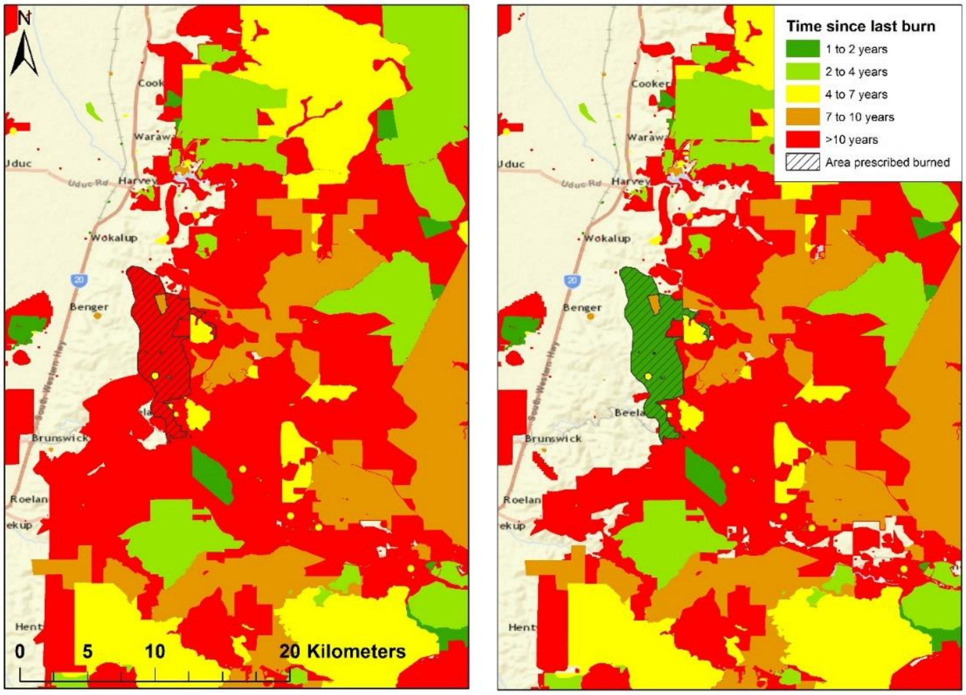

Figure 4: Fuel age in the area. Left: patch on the east of highway is unchanged. Right: patch on the east of highway had fuel load reduced.

Table 2. Net benefits of prescribed burning for a single fire

Area prescribed burned (ha)	2,800
Estimated costs of treating the area (2018 AUD)*	123,200
Potential losses if area is not treated (2018 AUD)	36,386,334
Potential losses if area is treated (2018 AUD)	655,680
Potential suppression costs if area is not treated (2018 AUD)	42,876,990
Potential suppression costs if area is treated (2018 AUD)	32,647,680
Benefits (reduced losses + reduced suppression costs) (2018 AUD)	45,959,964
Net benefits (2018 AUD)	45,836,764

* Costs of prescribed burning correspond only to operational costs and do not include the costs of setting up and running a prescribed burning program.

Discussion

With two examples we have illustrated the value of using wildfire simulation technology to evaluate the effectiveness and cost-effectiveness. We demonstrated the importance of integrating fire simulation and economic modelling for evaluating different fuel reduction scenarios. The benefit of simulation coupled with economic modelling is that simple scenarios as presented here can be replicated many times, over larger areas and under many alternative weather conditions, to evaluate the outcomes of a range of alternative prescribed burning strategies. The value of simulation lies in its capacity to test large numbers of "what if" scenarios and thereby compare the effects of changing the distribution of treatments across the landscape, or the impact of not implementing a given fuel reduction program. In addition, for the economic analyses of prescribed burning, the large number of observations obtained through simulation leads to robust results (e.g Florec 2016). Our approach provides a comprehensive economic analysis allowing trade-offs between prescribed burning costs, wildfire suppression and wildfire damage to be made, allowing fire managers to make informed decisions on appropriate levels of investment for fuel reduction.

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