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Supplementary material

Modelling the potential for prescribed burning to mitigate carbon emissions from wildfires in fire-prone forests of Australia

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Description of parameters used in modelling fire regimes and fuel consumption in eucalypt forests

Three different fuel types (I, II and III), described by Hart (1995, fuel type I) and Raison *et al*. (1983, fuel types II and III), were modelled to represent the range of variation in accumulation rate and equilibrium load of surface fine fuel (i.e. <6-mm particle size) for temperate forest in south-eastern Australia. These fuel types included:

(i) Type I – relatively low rate of fine fuel accumulation and equilibrium load comparative to eucalypt fuel accumulation rates in general. Data from dry forests (mixed *Eucalyptus* spp. and *Callitris glaucophylla*-dominated) from the Pilliga region in northern inland south-eastern Australia (Hart 1995) were used as an indicative example.

(ii) Type II – relatively high rate of fine fuel accumulation but relatively low equilibrium load comparative to eucalypt fuel accumulation rates in general. Data from blackbutt (*Eucalyptus pilularis*-dominated) forests from coastal eastern Australia (Raison *et al*. 1983) were used.

(iii) Type III – moderate rate of fine fuel accumulation and high equilibrium load. Data from alpine ash (*Eucalyptus delegatensis*-dominated) forests in montane high-altitude environments in the south-east of Australia (Raison *et al*. 1983) were used.

For each of the three fuel types, we used maximum fuel loads of 30 t ha^{-1} for coarse woody debris, consistent with estimates of Cheney *et al*. (1980) and Hamilton *et al*. (1991) and 5 t ha^{-1} each for tree foliage, bark and shrub fuels (e.g. Raison *et al*. 1985; Hamilton *et al*. 1991; Gould *et al*. 2004; Table S1). The accumulation rate (k) was determined from studies of surface litter (Raison *et al*. 1983; Hart 1995), and was assumed to be the same for all fuel pools, but differed among fuel types.

Table S1. Fuel accumulation parameters for each fuel type and fuel component (litter, coarse woody, bark, foliage (Eqn 3))

Values of fuel decomposition rate (k) and maximum, quasi-equilibrium fuel load (W^{max}) are specified for the modified Olson model (Hart 1995 – Type 1; Raison *et al*. 1983, Fig. 3 main text). The value of k for surface litter was used to model accumulation for all fuel components within each fuel type

	k	W^{max} (t ha^{-1})				
Fuel type	Surface litter	Surface litter	Coarse woody	Bark	Tree foliage	Shrub foliage
Type I	0.13	17.3	30	5	5	5
Type II	0.31	16.8	30	5	5	5
Type III	0.16	26.2	30	5	5	5

No soil pool was modelled because the evidence of the impact of fire on the soil carbon in Australian forests is equivocal (e.g. Grove *et al*. 1986) and the potential range of response is small (e.g. Hopmans 2003).

The fine fuel load was computed using Eqn 4 (main text) of which a preset fraction was available for burning depending on the type of fire (see main text and Table S2). For prescribed fire, only 60% of fine fuel was used to estimate fire intensity (e.g. Raison *et al*. 1985). Therefore, litter and shrub pools were assumed to be combined into a single fine fuel pool. This combined fine fuel load was used as a parameter for the calculation of Byram's (1959) fire-line intensity (see below).

Table S2. Consumption rules for fuel components

Fuel component	Percentage of fuel consumed in fire	
	Prescribed fire	Unplanned fire
Surface litter	60	100
Shrub foliage	60	100
Coarse woody	25	Function of fire intensity (Eqn S1), reaching 100% at 10 000 kW m^{-1}
Bark	0	Function of fire intensity (Eqn S1), reaching 100% at 10 000 kW m^{-1}
Tree foliage	0	0 for fire intensity ≤3000 kW m^{-1} 100 for fire intensity >3000 kW m^{-1}

No bark fuel (B) was assumed to be consumed in prescribed fires, whereas for unplanned fires, its consumption (C_B) was assumed to follow a quadratic convex curve towards 100% consumption at intensities (I) ≥ 10 000 kW m^{-1}.

$$C_B = B \times \sqrt{} I/100 \quad \text{(S1)}$$

Only 25% of woody debris was assumed to be consumed in prescribed fires (e.g. Cheney *et al*. 1980), whereas consumption in unplanned fires was modelled by the same equation as used for bark fuel consumption in unplanned fires (Eqn S1). Field data indicate that these estimates are conservative (see Hollis *et al*. 2010).

Fire-line intensity (kW m^{-1}) was calculated from an empirical equation for eucalypt forest in Gill *et al*. (1987), which combines the fire spread equation of Noble *et al*. (1980) and the intensity equation of Byram (1959):

$$I = 0.67 \times \text{FFDI} \times W^2 \quad \text{(S2)}$$

where FFDI is the McArthur's Forest Fire Danger Index and W is fine fuel load (t ha^{-1}). FFDI, a function of rainfall, wind speed, air temperature and relative humidity (Noble *et al*. 1980), is widely used in Australia as an index of potential fire danger and rate of spread in eucalypt forests (Noble *et al*. 1980; Gill *et al*. 1987).

Prescribed fires were assumed to burn under low fire-danger conditions, here characterised by FFDI = 10. For unplanned fires, the FFDI was sampled from the distribution of daily FFDI values exceeding 25 (i.e. representing Very high to Extreme fire danger) at Sydney Airport weather station. This station provides a representative record of long-term fire weather for south-eastern Australia (Lucas *et al*. 2007).

At the beginning of each simulation, the fuel load was set to zero. Fuel was then allowed to accumulate with fires occurring according to the parameters specified (leverage *L*, mean prescribed fire treatment rate *P*, fuel type and FFDI). The first 100 years of each simulation were considered transient; model results were estimated using data for the last 400 years only of each simulation.

Values of prescribed burning rate (*P*) beyond 5 and 10% of the area of the landscape treated per annum were not simulated for values of leverage $L = 1$ and 0.50. Such treatment rates equate to complete replacement of unplanned fire with prescribed fire if $U^* = 5\%$ of the area of the landscape per annum (see main text).

Simulated effects of prescribed burning rate on fire frequency

The simulated mean inter-fire interval (i.e. resulting from interaction of prescribed and unplanned fires) experienced within a 1-ha plot declined with increasing prescribed fire treatment rate in all fuel types (Fig. S1), except at a leverage of unity. This result was consistent with the predicted trend (Fig. 1*c* main text). Mean inter-fire interval (IFI) also decreased with decreasing leverage at any given treatment rate, as predicted.

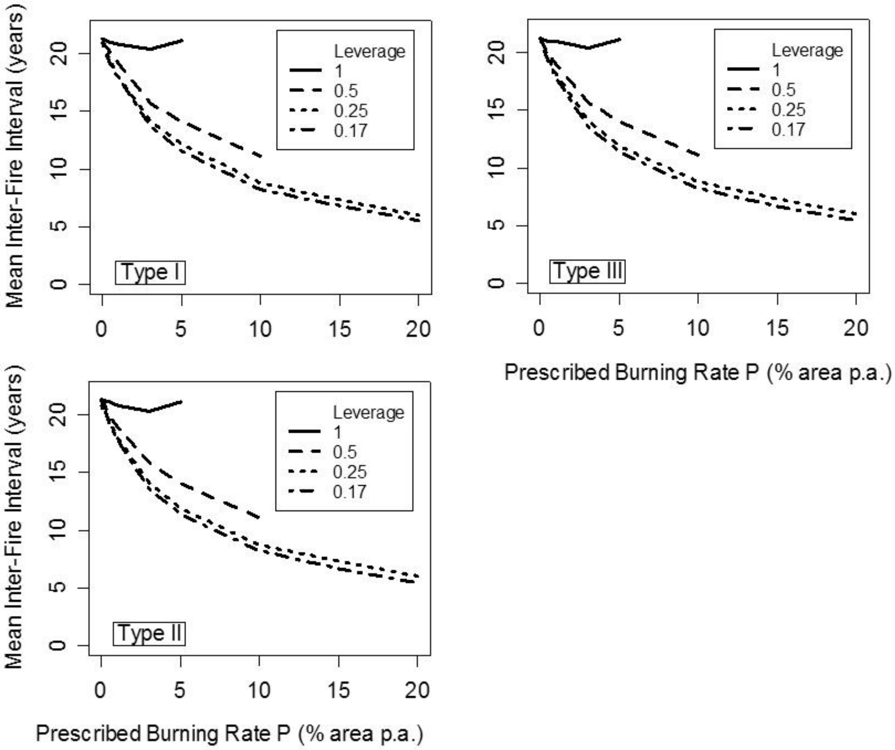

Fig. S1. Simulated changes in the inter-fire interval in three eucalypt forest fuel types under different rates of prescribed fire and different leverage values. Values are for a hypothetical 1-ha forest patch with a mean annual unplanned fire probability of 5% (i.e. $U^* = 0.05$) equating to a 20-year cycle.

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