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Supplementary Material

When soil becomes fuel: identifying a safe window for prescribed burning of Tasmanian vegetation growing on organic soils

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Table S1. Number of sites according to vegetation type, showing the number and proportion that burnt after exposure to vegetation fire, and average SDI on the first day of the vegetation fire

Vegetation	**Number of sites**	**Number of soil fires**	**Proportion of soil fires**	**Average of SDI**
Treeless				
alpine	11	8	0.73	57
grassland	2	2	1.00	99
moorland	35	12	0.34	26
rookery	1	1	1.00	109
wetland	10	6	0.60	73
scrub	53	45	0.85	46
Forest				
dry forest	2	2	1.00	87
pencil pine	1	1	1.00	54
rainforest	12	11	0.92	45
swamp forest	3	3	1.00	90
wet forest	8	8	1.00	57
All sites	**138**	**99**	**0.72**	**47**

Table S2. Contingency table showing the counts of predicted and actual burnt and unburnt treeless sites with a 'safe' SDI threshold of 10 for buttongrass moorland vegetation. Overall, 80% of observations [(17 +11)/35*100] were correctly predicted.

	Predicted Unburnt	Predicted Burnt	Total
Actual Unburnt	17	5	22
Actual Burnt	2	11	13
Total	19	16	35

Table S3. Comparison of the moisture indices standard vs downscaled SDI (soil dryness index), FFDI (forest fire danger index) and DF (drought factor) as explanators of whether soil burnt. The binomial response variable is whether soil burnt after exposure to vegetation fire. The table shows percent deviance explained relative to the intercept only model. Daily downscaled SDI values were calculated from the BARRA-TA reanalysis grids dataset (Su *et al.* 2021) for Tasmania at a 0.0135° resolution, which was available for the period 1990 through to 2018. These downscaled data were available for only 52 sites, and will not be available in this form in the future. By contrast, the standard SDI is published each day at https://www.fire.tas.gov.au/fire-danger-rating/sdi-map/. Therefore we used the standard SDI in this ms, despite it appearing less accurate than the downscaled SDI.

	Moisture index (MI)			
Model terms	SDI	SDI_downscaled	DF_downscaled	FFDI_downscaled
	Deviance explained (%)			
Moisture Index (MI)	10.9	22.4	20.9	10.2
MI +FFDI_downscaled	15.7	24.4	21.1	NA

Reference

Su CH, Eizenberg N, Jakob D, Fox-Hughes P, Steinle P, White CJ, Franklin C (2021) BARRA v1.0: kilometre-scale downscaling of an Australian regional atmospheric reanalysis over four midlatitude domains. *Geoscientific Model Development* **14**, 4357-4378.

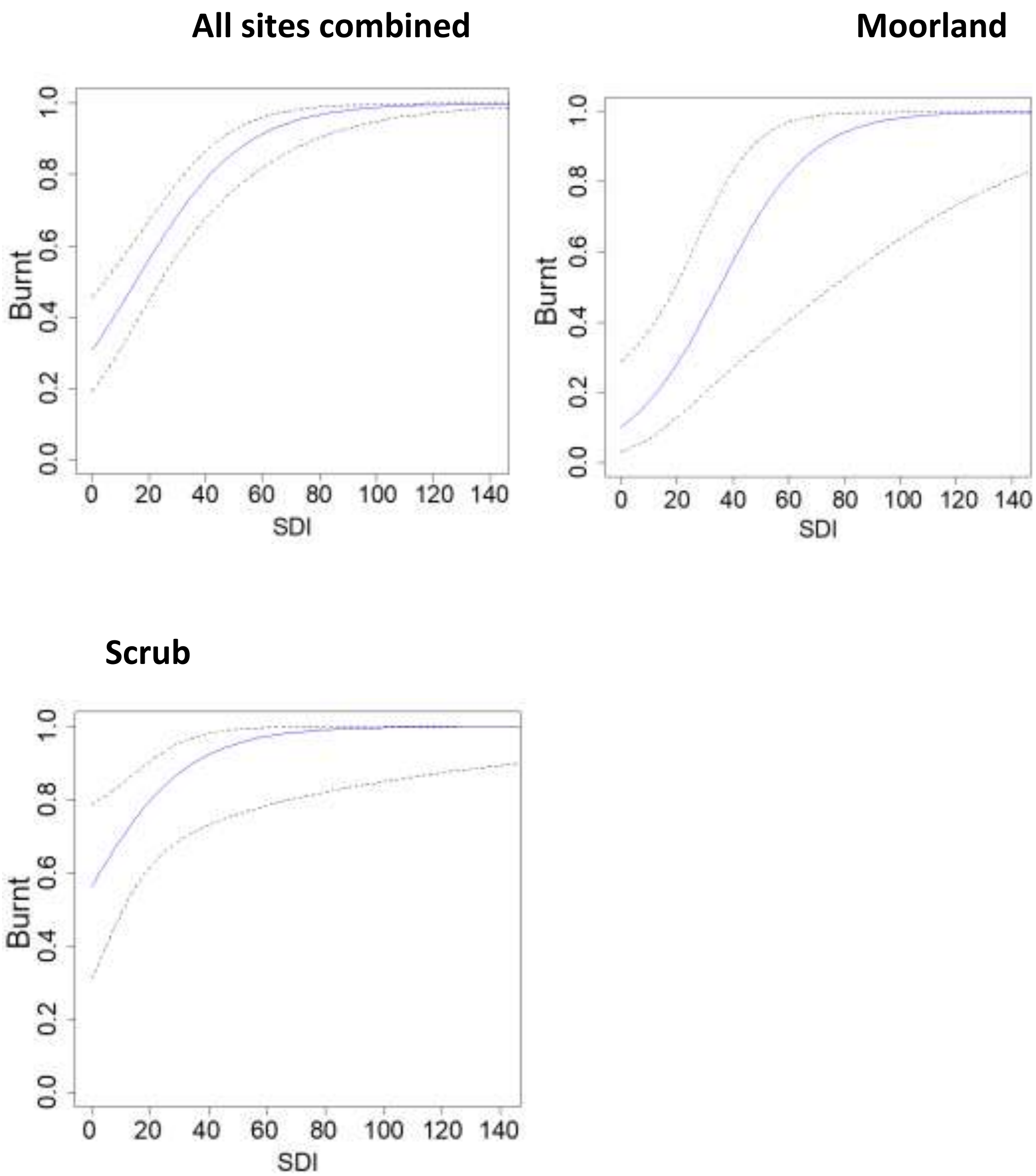

Fig. S1. Probability of soil fire (Burnt), if exposed to vegetation fire, for all sites combined, and moorland and scrub sites, predicted by binomial modelling. Dotted lines show 95% confidence intervals

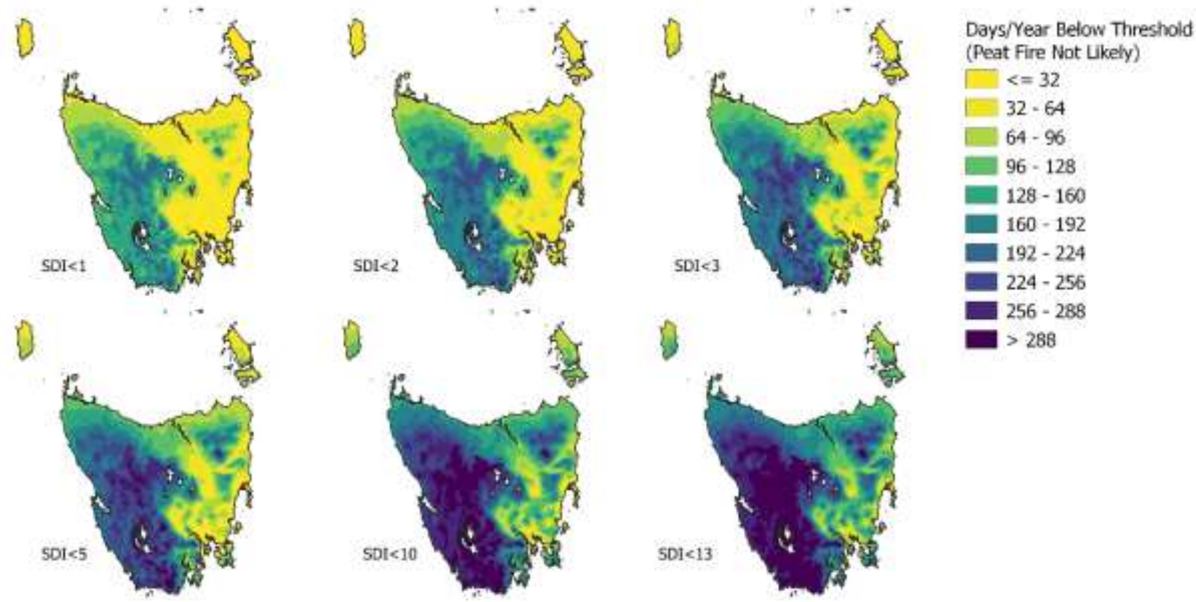

Fig. S2. Comparison of the average number of 'safe' days per year according to the specified SDI threshold. These SDI values correspond to a risk of soil fire in buttongrass moorland of 10.7%, 11.3%, 12%, 13%, 17% and 20% (for SDI of 1, 2, 3, 5, 10 and 13 respectively).

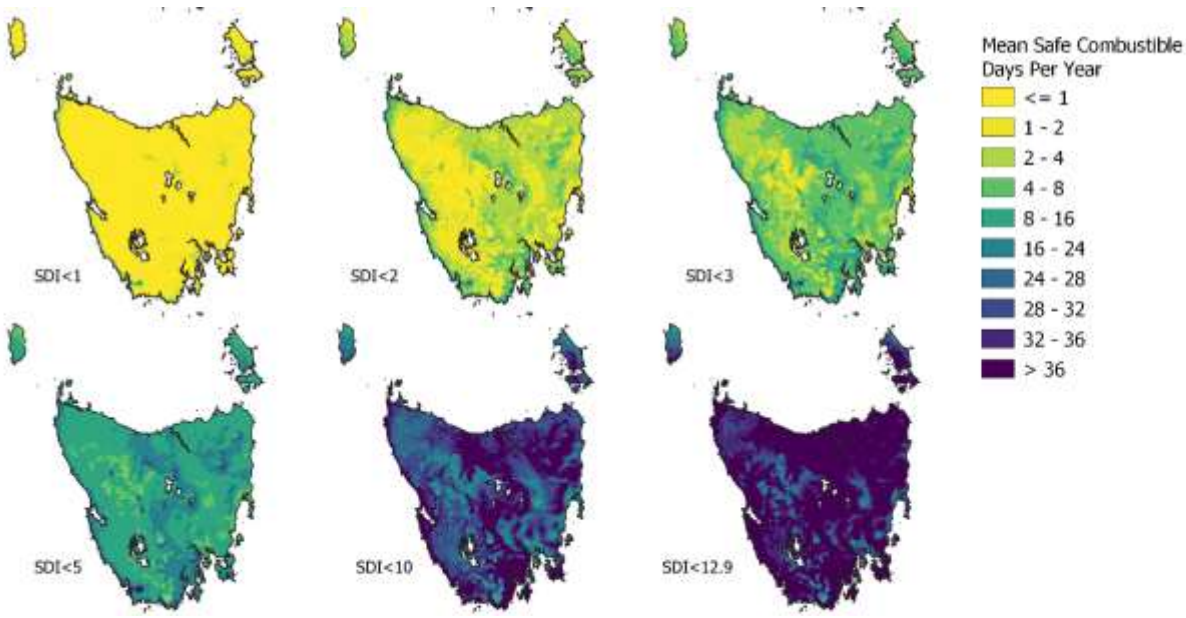

Fig. S3. Variation in the average number of 'safe combustible' days per year according to the 'safe' SDI threshold selected. The maps here assume vegetation is combustible when fine fuel moisture content is below 28.9%. The SDI values shown here correspond to a risk of soil fire in buttongrass moorland of 10.7%, 11.3%, 12%, 13%, 17% and 20% (for SDI of 1, 2, 3, 5, 10 and 13 respectively).

Supplementary Material 1. Odds ratio analysis

Our overarching aim was to identify the window for prescribed burning on organic soils across Tasmania. We developed two approaches to quantify risk, each of which embodies different assumptions about the data. The first approach was to calculate absolute risk of an organic soil igniting if exposed to a vegetation fire. This used binomial generalised linear models with whether a soil fire started as the response variable. Soil dryness on the day the fire started, and whether vegetation was treeless or forest, were used as predictors. This approach will, however, overestimate risk if the data are biased towards occurrence of soil fire. Here, we describe a second approach, based on only positive reports of soil fire. These can be used to derive odds ratios, comparing the risk of organic soil fire on days below a specified soil dryness threshold to that on days above it. The underlying assumptions here are that soils in all days at all locations covered in the study are equally likely to be exposed to an ignition source, and that all soil fires are equally likely to be reported. Because these assumptions differ from those used to predict absolute risk, using both approaches will provide a more robust assessment than relying on only one approach.

Methods

Comparing the distributions of days with soil fire and total days in our space-time domain allowed us to calculate the odds ratio for the likelihood of soil fire on days below a specified soil dryness relative to that on days above it. In order to maximise the amount of data, we used all treeless sites for this comparison. Remotely sensed imagery was used to class sites as having either forest or treeless vegetation. Treeless sites included those dominated by the sedge *Gymnoschoenus sphaerocephalus*, grassland, scrub, agricultural land and coastal complexes and heathland. We defined our time-space domain as the days between May 2005 and August 2021, and the grid cells containing the 95 treeless sites in which organic soils were exposed to vegetation fire and the soil response was known (soil fire present or absent).

We plotted the cumulative frequency distributions of SDI for all 576,080 grid cell-days and for all soil fire days. We calculated the odds ratio for SDI of x for all values of x between 0 and 141 (the range of SDI on days with soil fire) as follows. First, we calculated the total number of days when SDI was ≤ x, the number of soil fire days when SDI was ≤ x, the total number of days when SDI was >x and the number of soil fire days when SDI was >. We then calculated the odds ratio, the ratio of the likelihood of soil fire when SDI is below or equal to x compared to that when it is above x (Szumilas 2010):

[(count of soil fire days when SDI ≤ x)/ (count of all days when SDI ≤ x)] / [(count of soil fire days when SDI > x)/ (count of all days when SDI >x)]

Results

Binomial generalised linear modelling showed that in treeless vegetation, at SDI of zero there was a 28% chance (95% confidence interval 16 – 44%) that it would ignite if exposed to vegetation fire. This apparent risk increased to 30% at SDI of 3 (95% confidence interval 17 – 48%), 50% at SDI of 22, and 90% at SDI of 72 (Fig. S4).

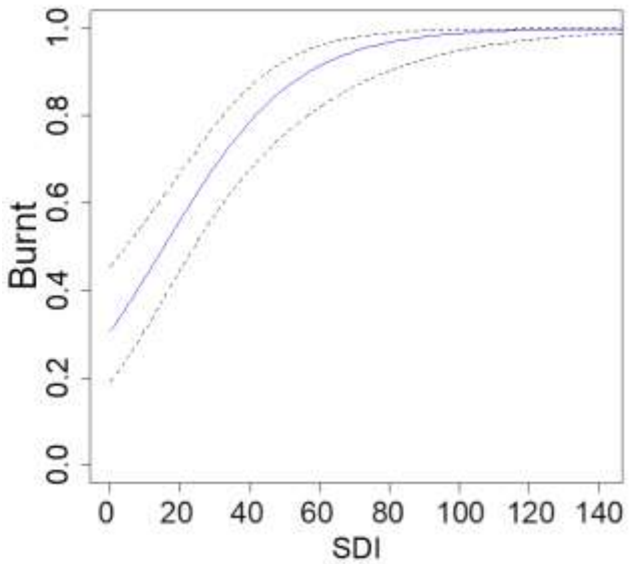

Fig. S4. Proportion of treeless sites where soil burnt after exposure to vegetation fire, in relation to soil dryness index (SDI). Dashed lines indicate 95% confidence intervals.

In the treeless vegetation in our space-time domain, 30% of days had SDI ≤ 1, 40% of days had SDI ≤ 3, 50% of days had SDI ≤ 7, and 90% days had SDI ≤ 64 (Fig. S5). By contrast, no soil fires occurred when SDI ≤ 1, only 4 % of soil fires occurred when SDI ≤ 3, 10% of soil fires occurred when SDI ≤ 7, and 57% of soil fires occurred when SDI ≤ 64. This confirms that soil fires are far more likely at high than low SDI. The odds ratio (calculated only using positive reports of soil fire) increased with the specified SDI value, although it was sensitive to the stochasticity of occurrence of soil fire, especially for the very low proportion of days with high values of SDI. The odds ratio for soil fire when SDI ≤ 3, compared to when it is >3, was 0.061. When SDI was 7, the odds ratio was 0.111, and when SDI was 64, the odds ratio was 0.142.

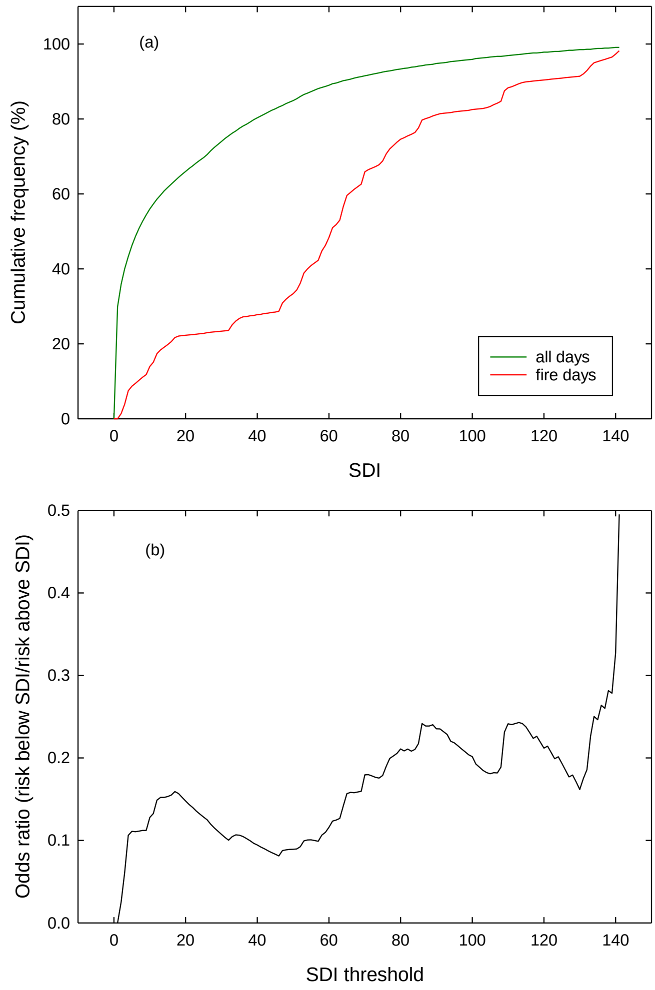

Fig. S5. Data for treeless sites showing: (a) cumulative frequency distribution of all days, and days when soil fire started; and (b) from this, we calculated the odds ratio for soil fire starting on days when SDI was below the specified threshold, relative to that above it.

Discussion and conclusion

Treeless sites overall appeared to carry a greater risk of soil fire than buttongrass moorland sites. Based on both our binomial modelling of the probability of organic soil igniting, and our derivation of the odds ratios for the risk of organic soil fires above and below specified SDI values, for demonstration purposes we selected SDI of 3.0 as a low-risk threshold for prescribed burning in treeless vegetation. Our binomial modelling showed that the risk of treeless organic soil igniting if exposed to vegetation fire was 30% when SDI was 3.0, but this is likely an overestimate because of the dataset bias towards positive observations. Our analysis based on only positive observations suggest that when SDI is below 3.0, the risk of organic soil fire is 0.061 times the overall risk than when SDI is above it. Only 4% of fires occurred on the 40% of days with SDI less than or equal to 3.0.

Future predictions of risk should be based on binomial modelling rather than the odds ratio approach. The main assumption behind the binomial modelling, that positive and negative observations are equally likely to be recorded, is far more tractable than the assumptions behind the odds ratio approach. Defining a suitable space-time domain for the odds ratio approach is problematic, given some grid cells do not have organic soils, so soil fire is impossible in these cells, and others will not be exposed to fire during a specified period. More fundamentally problematic, if most prescribed fires are lit to target particular conditions, organic soil fire will become apparently more likely under these conditions without any change in the absolute risk.

Reference

Szumilas M (2010) Explaining Odds Ratios. *Journal of the Canadian Academy of Child and Adolescent Psychiatry* **19**, 227-229.