Extended data for:

Benefits and limits of controlled burning for climate change adaptation

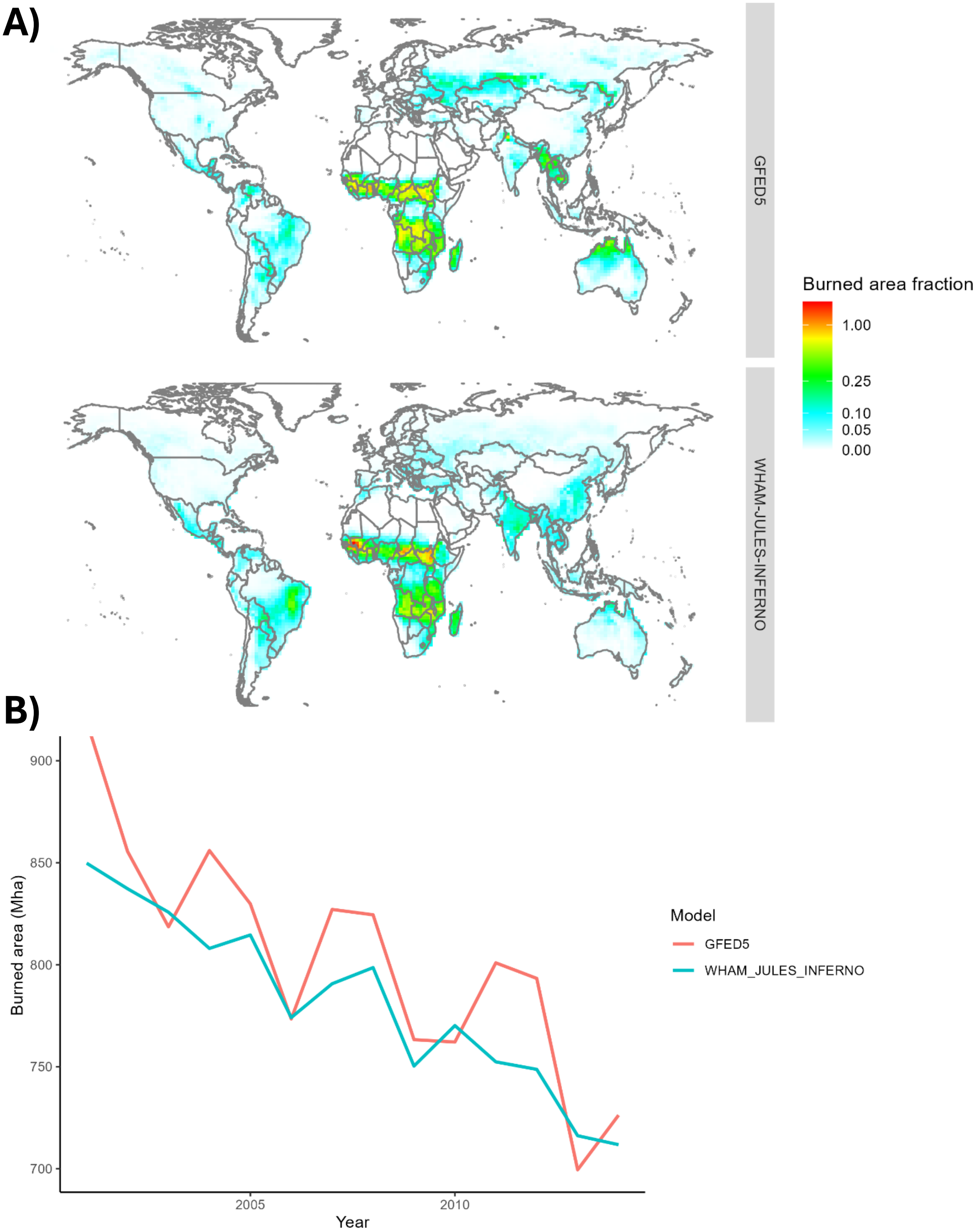


Figure S1: Evaluation of burned area outputs from WHAM-JULES-INFERNO coupling against GFED5[1]; A) mean burned fraction per pixel (2001-2014) and B) summed annual burned area. Period shown is the overlap between the CMIP6 historical era and GFED5.

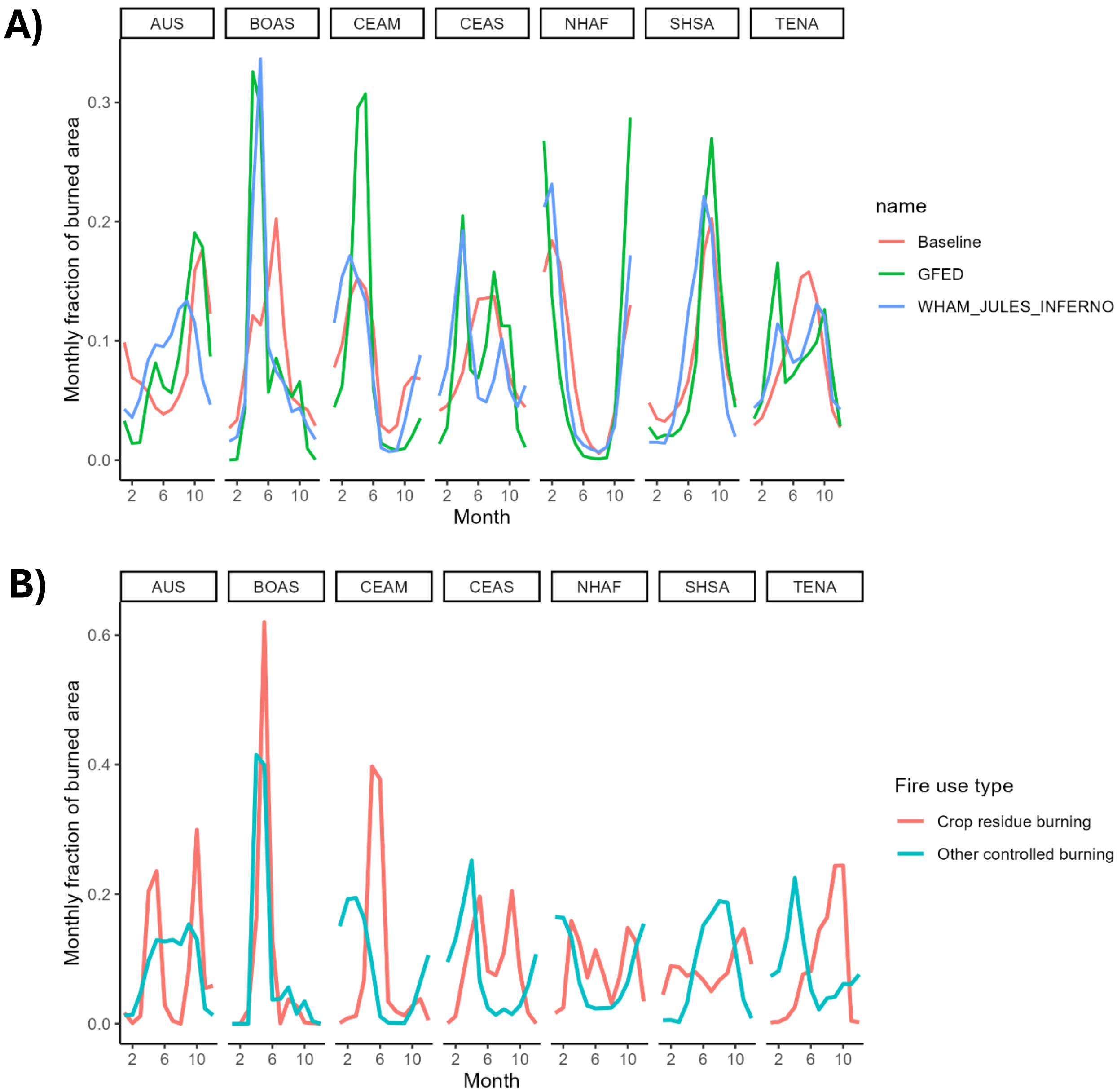


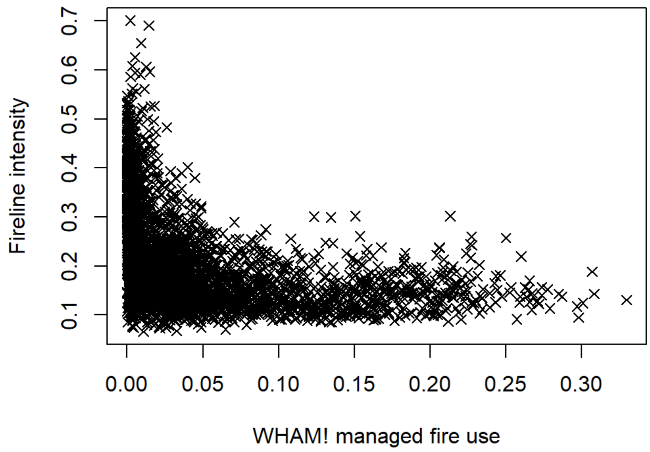
Figure S2: Evaluation of seasonality of burned area in WHAM-JULES-INFERNO. A) Fraction of burned area per calendar month in WHAM-JULES-INFERNO, baseline INFERNO ("Baseline"; as in Burton et al., 2019[2]) and GFED5; & B) Seasonal cycles of residue burning and other forms of fire use in WHAM. Overall, inclusion of human fire use seasonality in WHAM-JULES-INFERNO improves performance. Errors in WHAM-INFERNO seasonality in Australia ("AUS") are primarily caused by too little unmanaged fire present in central Australian xeric shrublands in INFERNO (see Figure S1a); this leads to overemphasis of the seasonal cycle of early dry-season Aboriginal burning.

Regions are as per GFED. Key: AUS – Australia; BOAS – Boreal Asia; CEAS – Central and Eastern Asia; NHAF – North Hemisphere Sub-Saharan Africa; SEAS – Southeast Asia; SHSA – Southern Hemisphere South America; TENA – temperate North America.

A)

Algorithm component (main text equation)	**Data source** (offline)	**Spearman's rho** (cumulative)	**Pearson's r** (cumulative)
Relative humidity (5)	ERA5[3]	0.31	0.33
Soil moisture (6)	JULES ISIMIP3a[4]	0.45	0.43
Wind speed (4)	ERA5[3]	0.50	0.47
Fuel load: PFTs (7)	JULES ISIMIP3a[4]	0.60	0.57
Managed fire use (8)	WHAM![5]	0.69	0.66
Road density (9)	GRIP[6]	0.73	0.70
Management mortality (12)	WHAM![5]	0.74	0.70

B)



C)

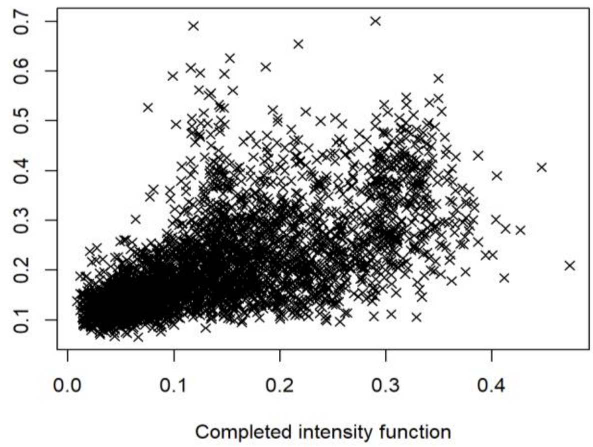


Figure S3: Overview of components of fire intensity algorithm. A) contribution of each function component to correlation with observations; B) relationship of WHAM!'s modelled distribution of managed fire use (pixel fraction burned) with fireline intensity; C) relationship of modelled fireline intensity to observations. Data sources in A) give data used to parameterise the algorithm offline. When run as a part of JULES-INFERNO, climate variables were taken endogenously from within model simulations.

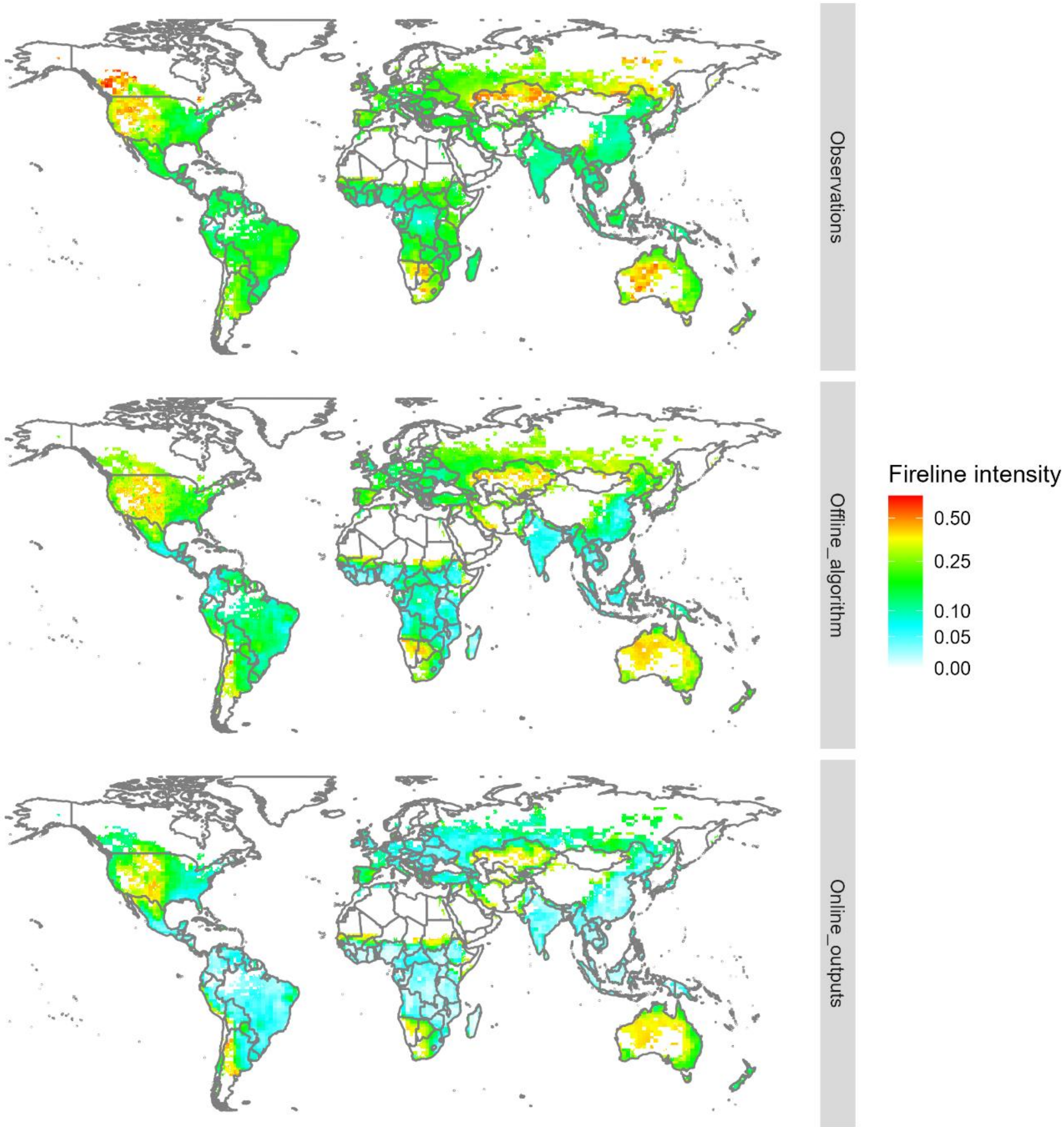


Figure S4: Evaluation of fireline intensity algorithm against observations (after Haas et al.,2022[7]), intensity outputs calculated offline using empirical inputs, and online outputs of WHAM-JULES-INFERNO.

Table S1: Benchmarking of WHAM-JULES-INFERNO. Burned area distribution, temporal trend and seasonality are taken from GFED5[1]; fireline intensity from Haas et al., (2022[7]). Outputs from this study in bold, benchmarking model outputs & trends in data follow. Benchmarking for the fire model intercomparison project (FIREMIP) is given both for INFERNO as well as the ensemble of participating models.

Model aspect	Source	Metric	Performance
Spatial burned area distribution	**This study**	Pearson's R	0.82
	FIREMIP[a]		0.64-0.70 (INFERNO) 0.51-0.80 (ensemble)
	INFERNO v1.0[b]		0.66
Temporal trend in burned area	**This study**	Percentage decrease (%)	-1.41
	JULES-INFERNO-HDI[c]		-2.72
	INFERNO v1.0[b]		-0.51
	GFED5[d] (observations)		-1.99
	This study	Areal decrease (Mha)	-10.62
	JULES-INFERNO-HDI[c]		-7.58
	INFERNO v1.0[b]		-2.24
	GFED5[d] (observations)		-14.86
Seasonality of burned area	**This study**	Pearson's R	0.79
	INFERNO v1.0[b]		0.75
Fireline intensity	**This study** (online)	Pearson's R	0.66
	This study (offline)		0.70
	Haas et al., (2022)[7]		0.73

[a]Teckentrup et al., (2019)[8]; [b]Mangeon et al., (2016)[9]; [c]Teixeira et al., (2025)[10]; [d]Chen et al., (2023)[1].

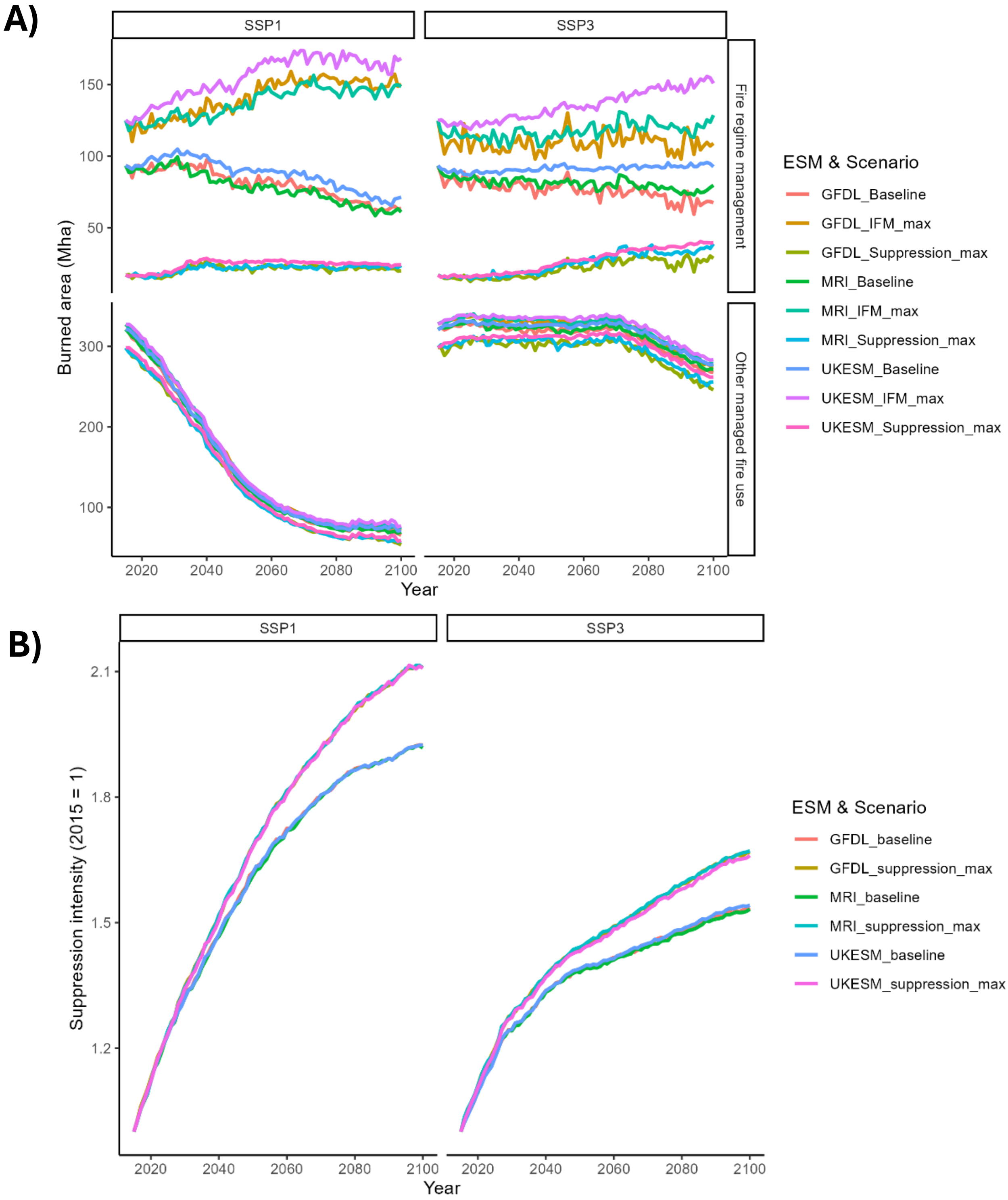


Figure S5: Overview of WHAM! management scenarios – A) Managed fire use, B) Fire suppression. Other managed fire uses (A) include crop residue burning, fire use in shifting cultivation, hunting and gathering and pasture management. These are distinct from fire use specifically to reduce the intensity of wildfires ("Fire regime management"). Scenarios have a greater proportional impact on fire regime management fire than other fire uses, which are only impacted by the societal acceptance of fire use parameter (see Table 1, main text).

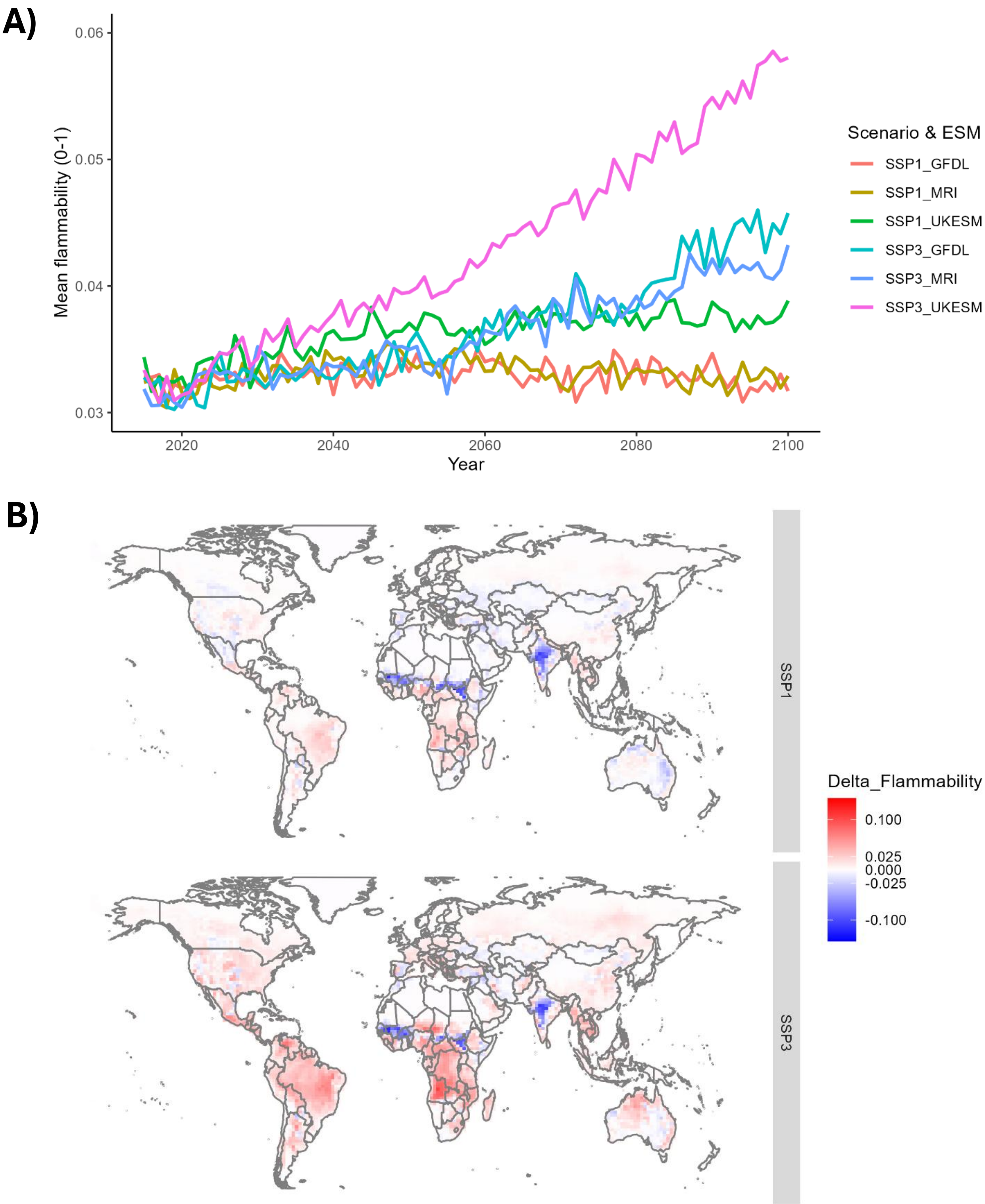


Figure S6: Flammability outputs from WHAM-JULES-INFERNO. A) mean annual values by SSP and ESM and B) Mean change across ESMs from 2015-2100. Values are for baseline SSP scenarios.

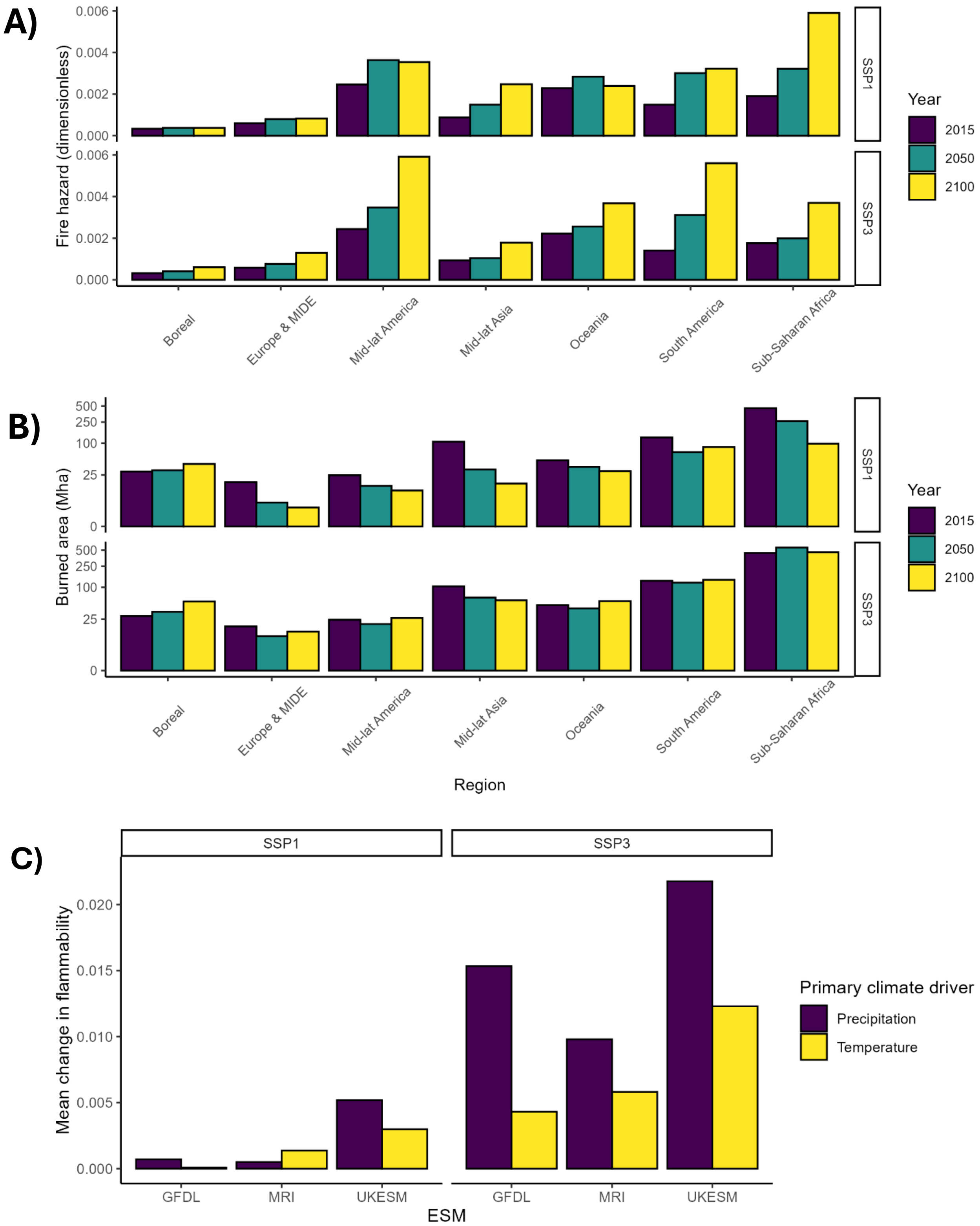


Figure S7: Regional variation & sensitivity of WHAM-JULES-INFERNO. A) Mean fire hazard regionally, B) Total burned area by region, & C) mean flammability where the decrease in precipitation or increase in temperature was proportionally larger. Regions aggregate GFED regions. Key: Boreal: BONA & BOAS, Mid-lat America: TENA & CENA, Mid-lad Asia: CEAS & SEAS, Oceania: EQAS & AUS, South America NHSA & SHSA.

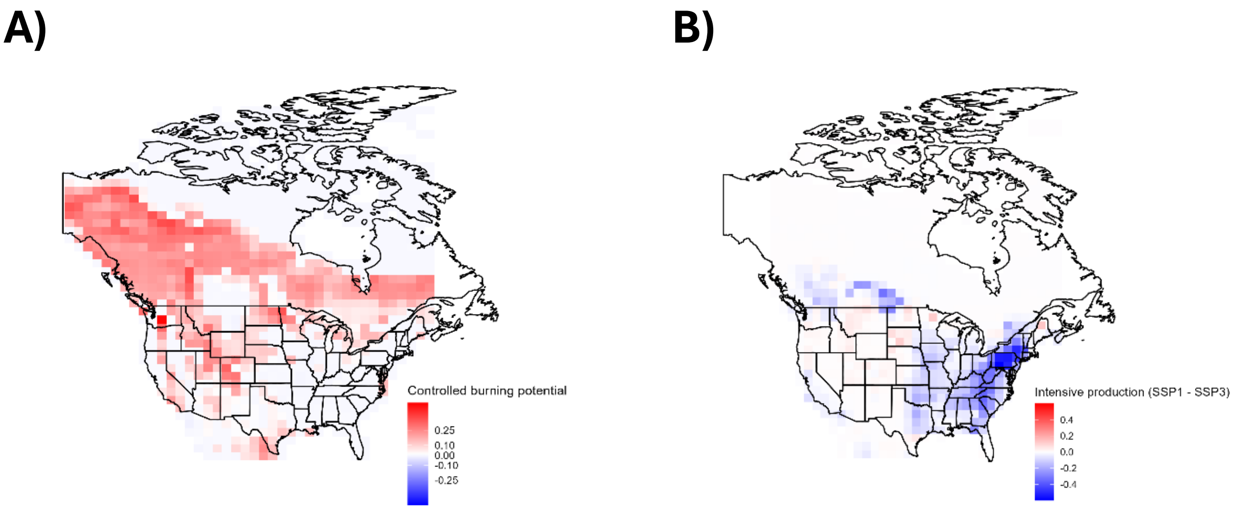


Figure S8: A case study of the impact of intensive agriculture and forestry on controlled burning for climate adaptation. A) shows the difference in controlled burning impact on fire intensity between the Suppression-max and IFM-max scenarios in SSP3.70, whilst B) shows the difference in the distribution of intensive agriculture and forestry agent functional types in WHAM! in 2100, where blue values indicate a greater concentration in SSP3.70. Overall, areas of intensive agriculture and forestry inhibit adoption of controlled burning. By contrast, Boreal Canada sees widespread uptake of controlled burning in the IFM-max scenario.

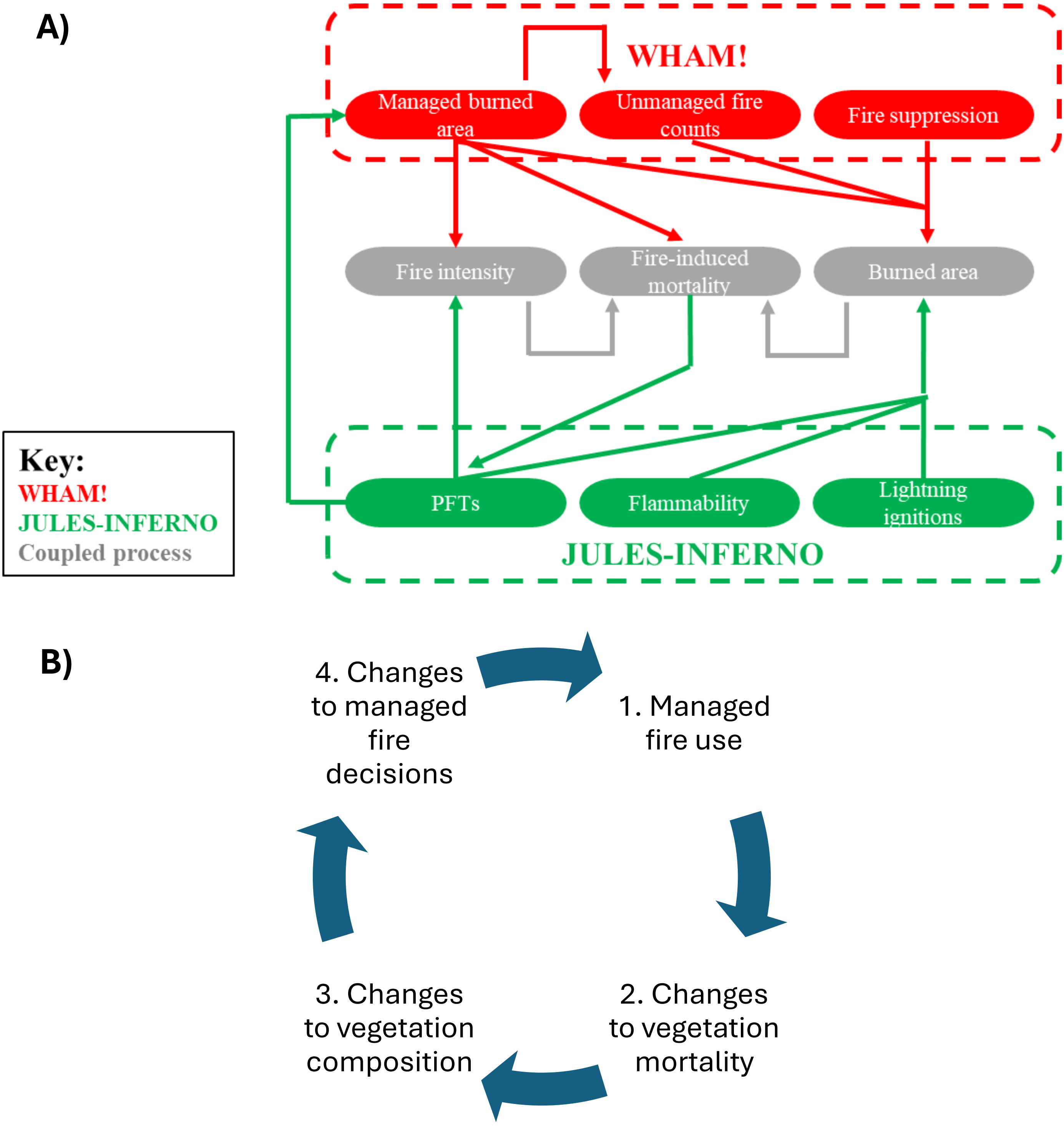


Figure S9: Schematic overview of the coupled WHAM-JULES-INFERNO ensemble: A) process flow of the coupled fire regime, and B) inter-temporal feedbacks between human fire use and vegetation cover. Controlled fire use (managed burned area) impacts fire intensity and burned area, which then changes fire-induced vegetation mortality. Controlled fires may escape to become unmanaged fires, so are indirectly impacted by changes in vegetation through changes in managed fire use decisions.

References

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