LEVERHULME

Centre for **Wildfires, Environment** and **Society**

Imperial College London

KING'S College LONDON

ROYAL HOLLOWAY UNIVERSITY OF LONDON

University of Reading

Towards INFERNO v2: peat, humans, intensity

Ol Perkins

With:
James Millington, Olivia Haas, Matt Kasoar, Cathy Smith, Apostolos Voulgarakis, Jay Mistry & others!

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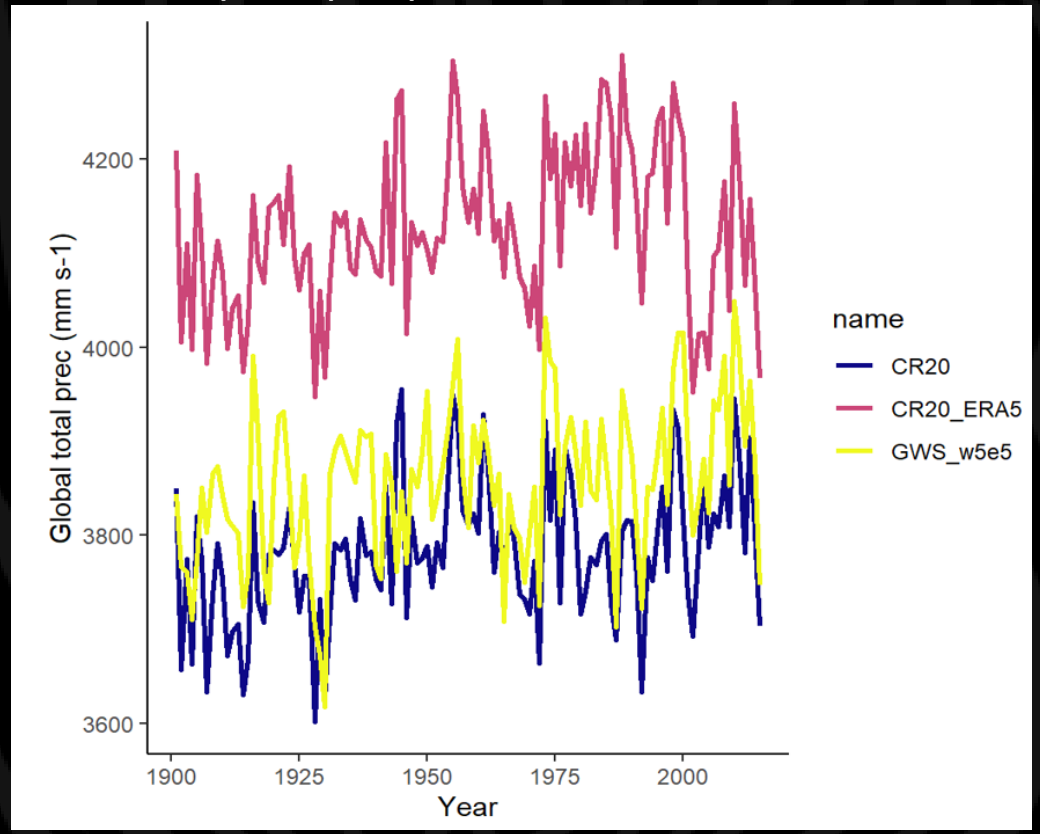
LEVERHULME TRUST

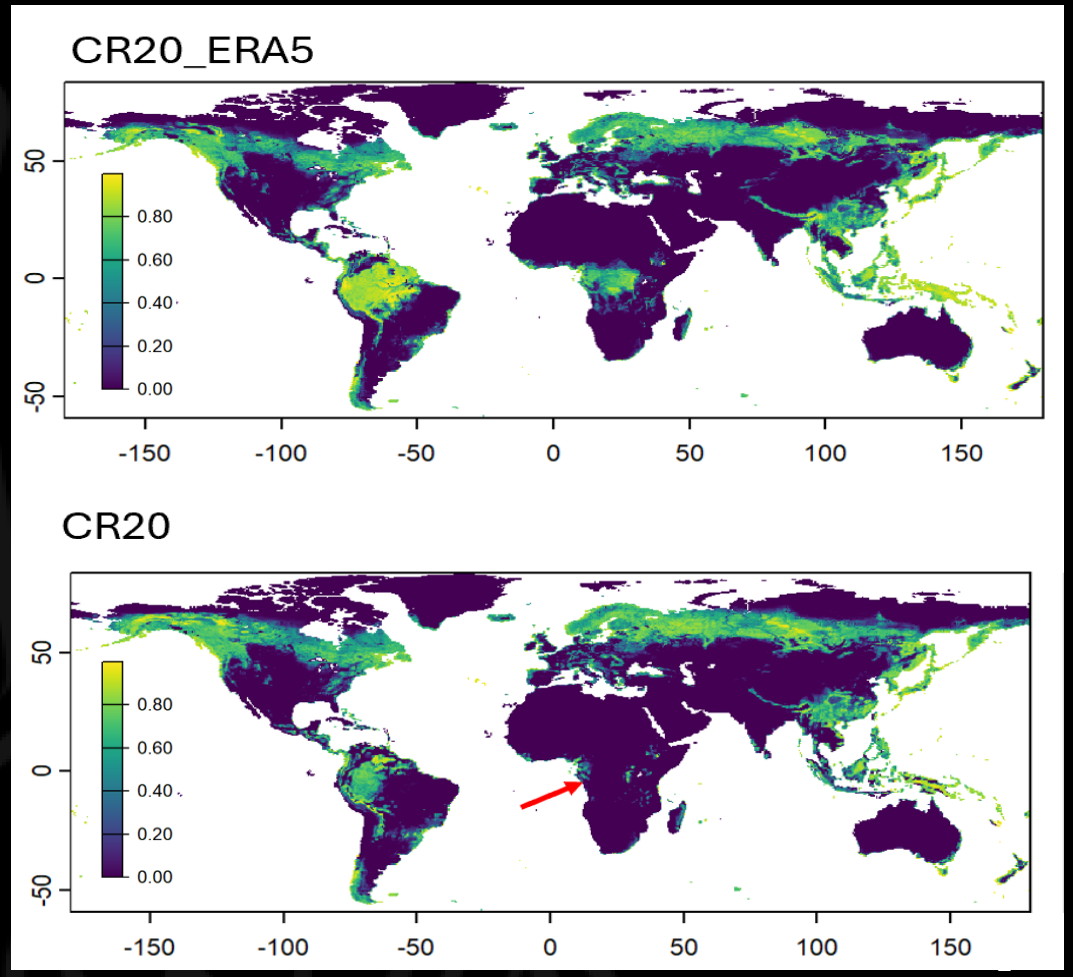
Some problems in INFERNO

- INFERNO is very sensitive to *instantaneous* precipitation

ISIMIP3a precip inputs

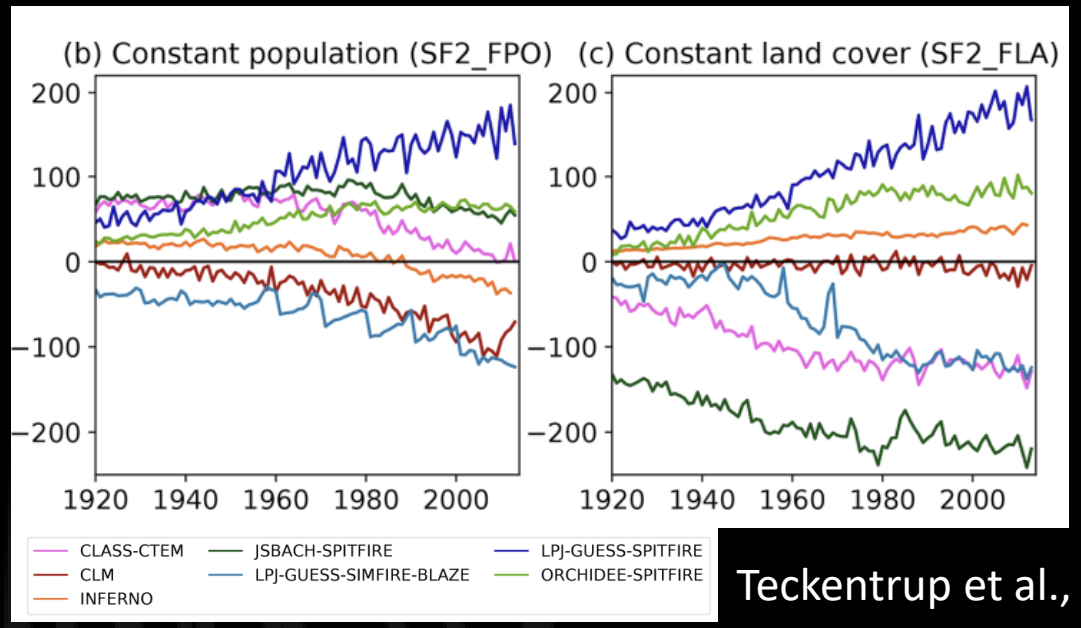


Tree cover in ISIMIP 3a

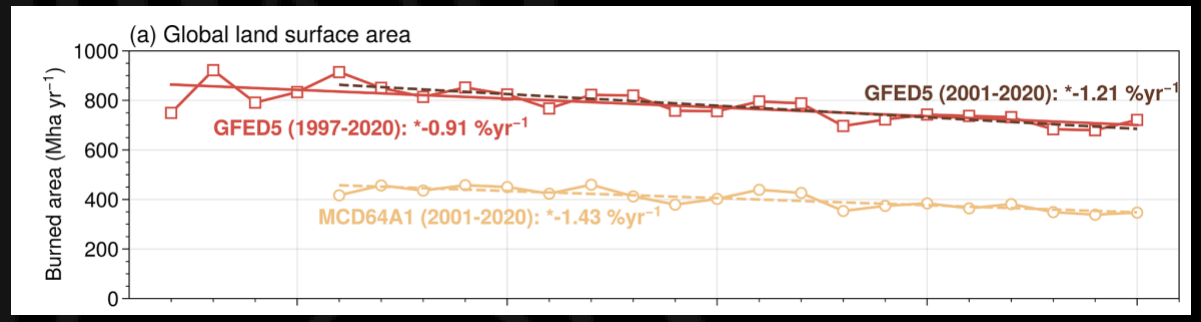


Some problems with all fire models…

- Fire models struggle with the declining global trend in fire…
- & struggle with interannual variability
- Large disagreement on impact of human factors
- & have 50% too little burned area



Teckentrup et al., 2019



Chen et al., 2023

What is to be done?

- New representation of human influences
- Reparameterization of flammability function for increased resilience
- New fireline intensity algorithm for spatially varying mortality

"Never let a good crisis go to waste"

These events do not have the same drivers

- WHAM! is a global agent-based model of human fire use & management
  - Parameterised with the DAFI database of human impacts on fire (Millington et al., 2022)
  - It seeks to capture these distinctions and pass that information to INFERNO

USA Crown fire

Credit: Wikimedia

Indigenous burn in Guyana

Credit: Kayla de Freitas

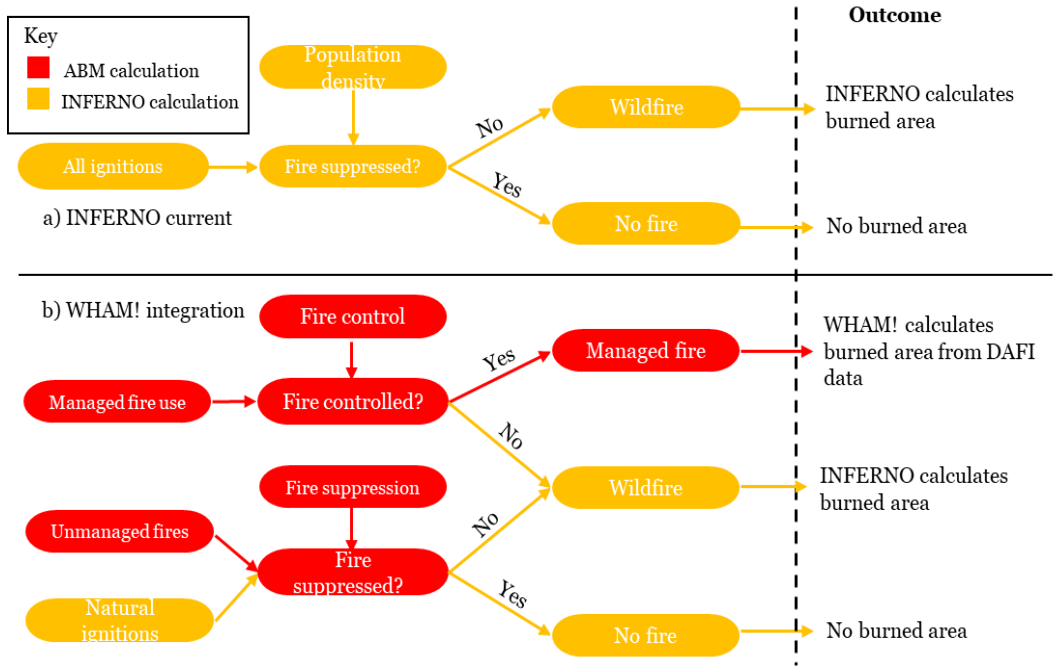
Rice fire in Punjab

Credit: Guardian Media

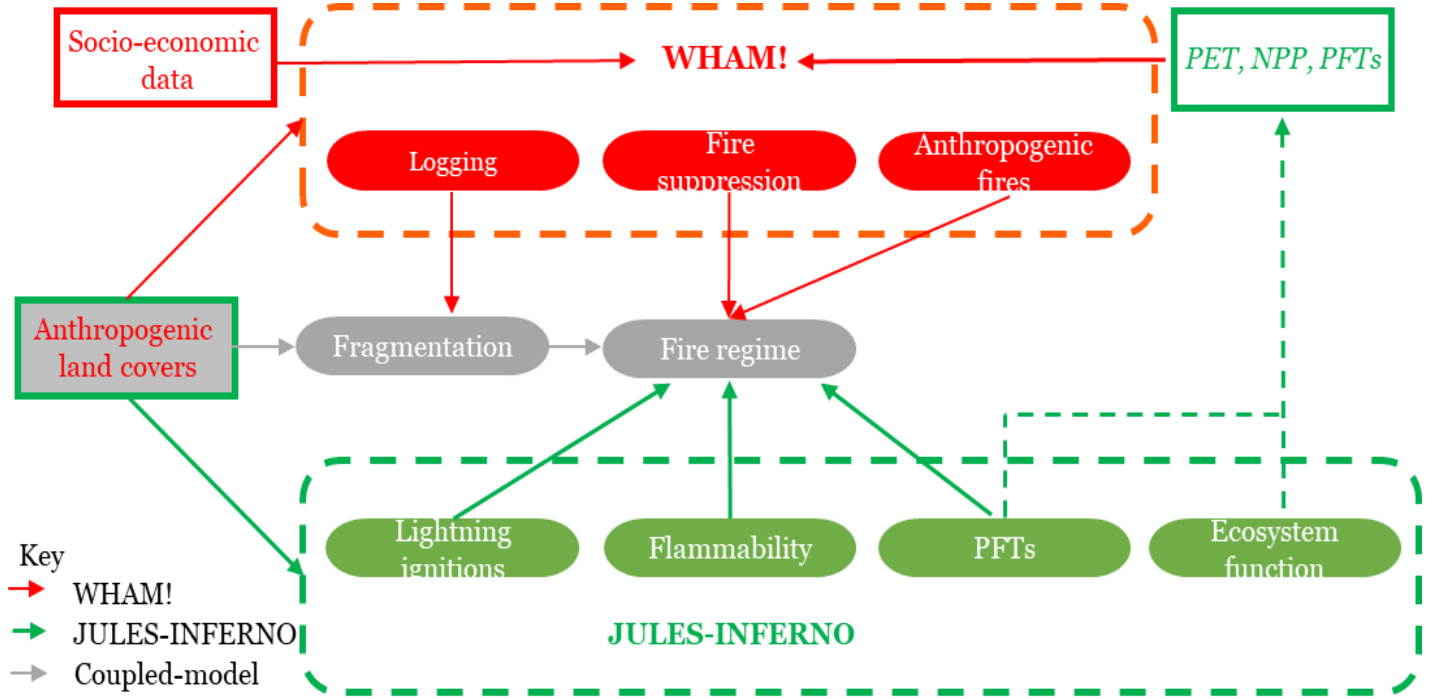
WHAM & INFERNO coupling

- WHAM-INFERNO coupling now up and running in a branch
  - l_inferno_wham = .true.
  - ignition_method = 4
  - Ticket #1618 working its way through [hopefully to next version]

/dev/oliverperkins/r30355_wham_inferno_integration/



Perkins et al., (2024), *GMD*

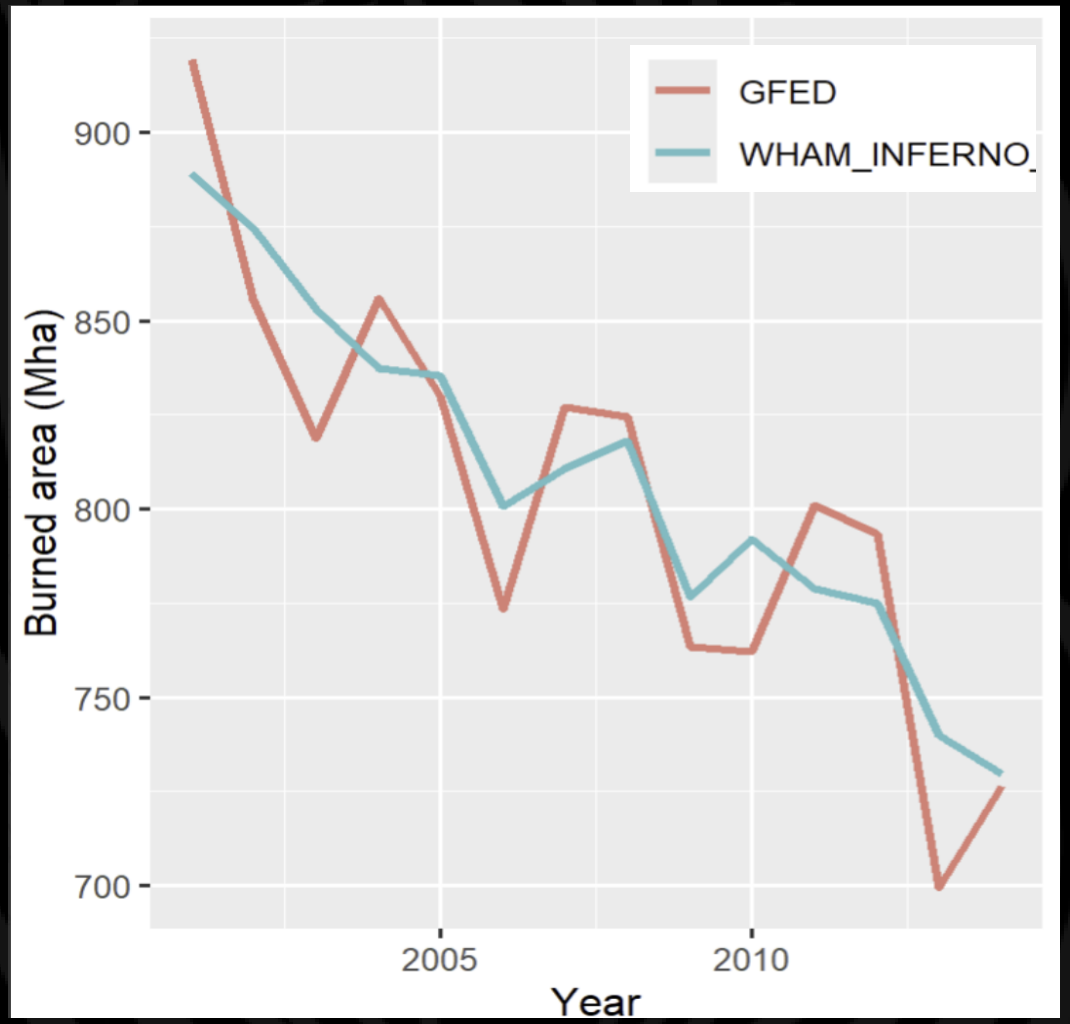


Perkins et al., (2025), *Earth's Future*

Does this help us to improve the biophysical model?

- YES - spatial correlation with observations: r = 0.78 [0.70 in FIREMIP]

Using flammability from INFERNO v1.0 [r = 0.78]

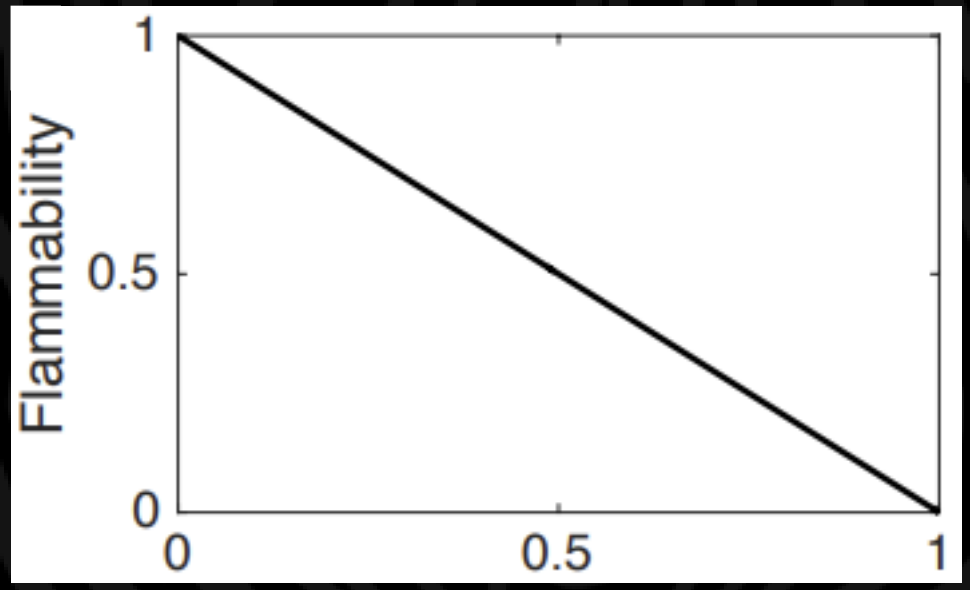


With new flammability calculation [r = 0.82]

Improved resilience of model?

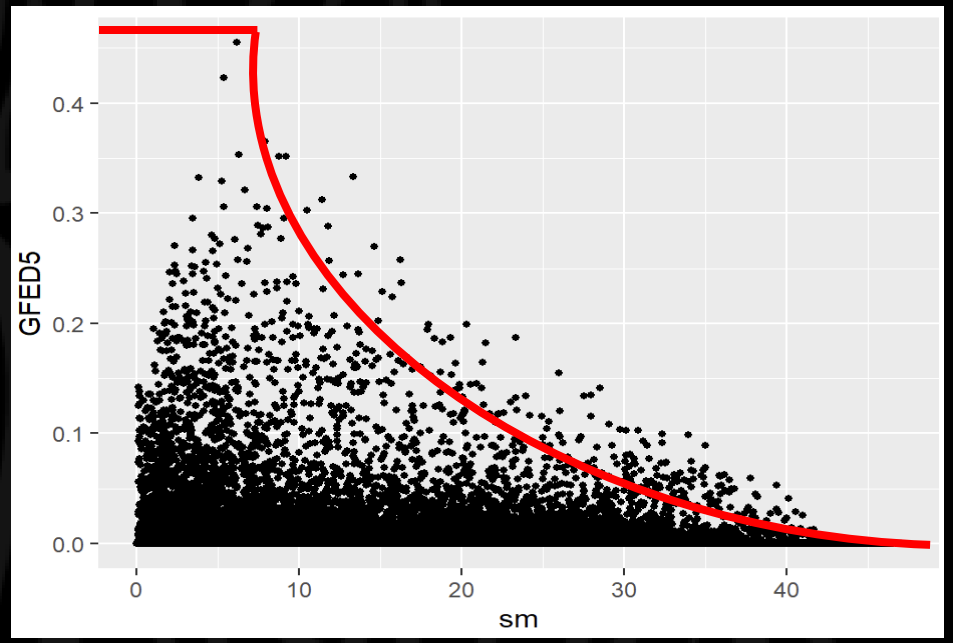
INFERNO v1.0:

- Instantaneous rainfall
- Linear response to soil moisture



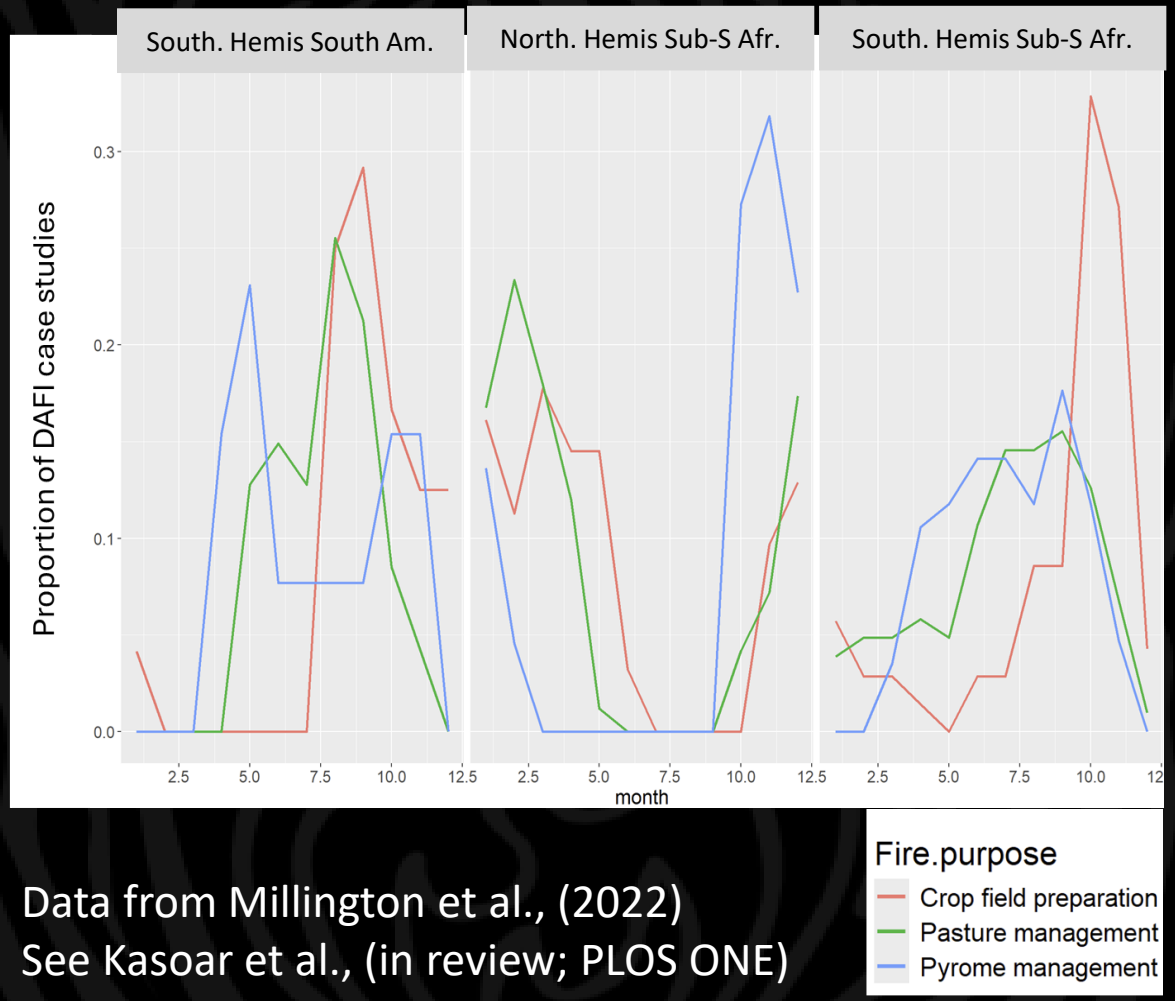
INFERNO *v2.0*

- Monthly smoothed rainfall
- Exponential response to soil moisture

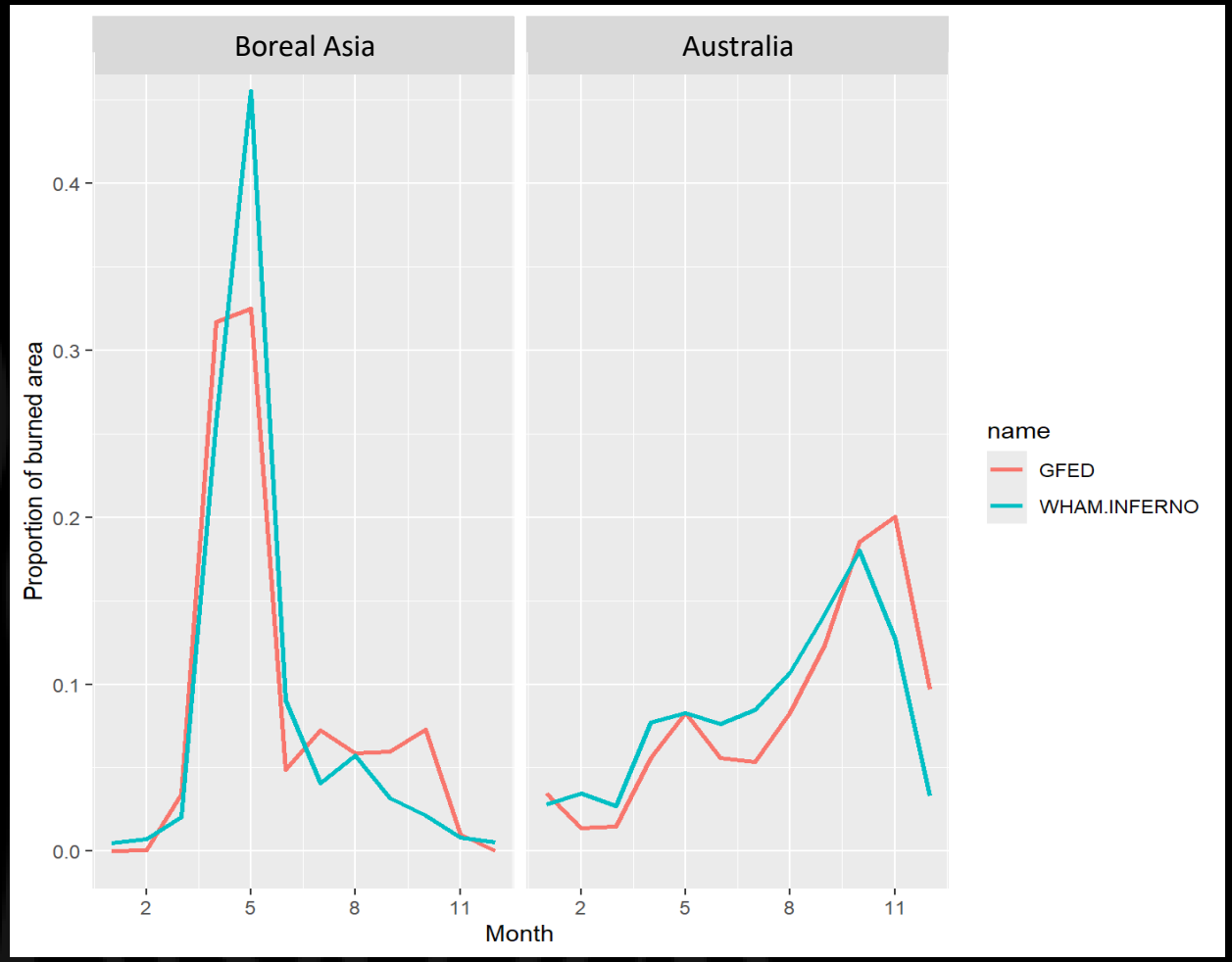


Seasonality is key…

- We have added representation of the seasonality of human fire use to WHAM!
  - ➢ In combination with revised flammability this improves seasonality



Data from Millington et al., (2022)
See Kasoar et al., (in review; PLOS ONE)

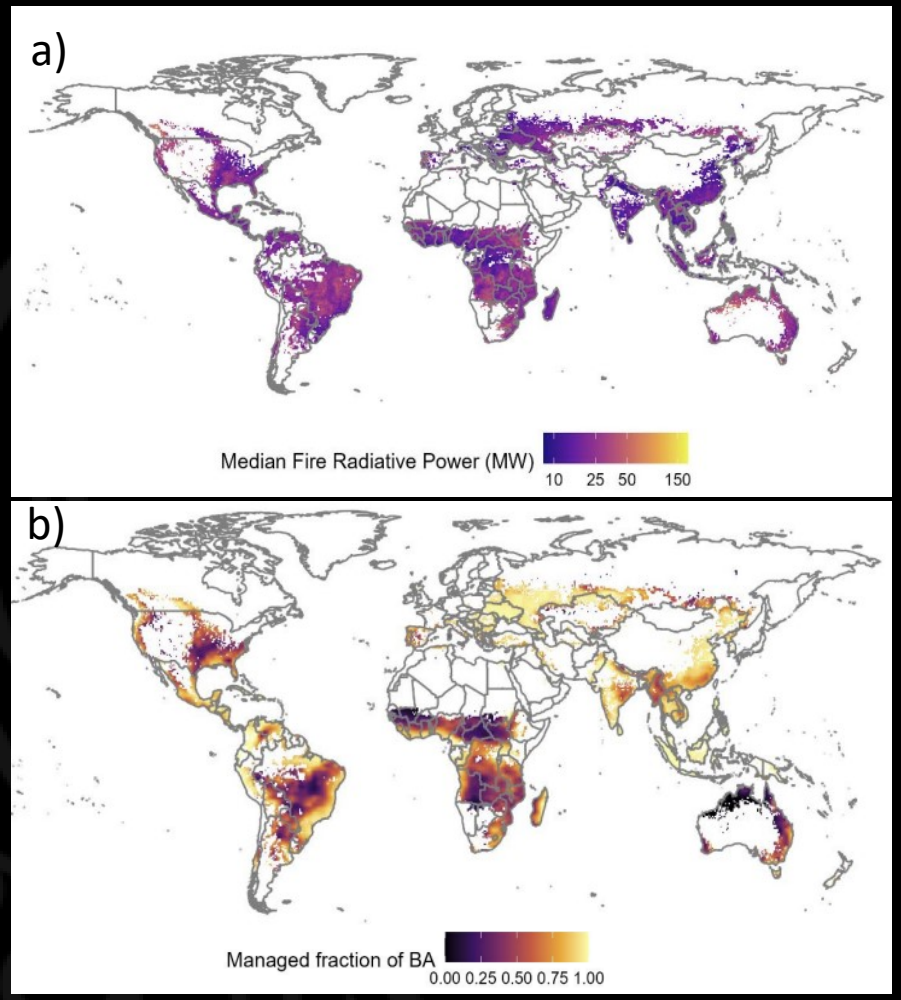


Managed fire impact on FRP

- We find an emergent relationship in our modelling (r^2 = 0.2) between the proportion of managed fire and Fire radiative power (it works)

- Accounting for human fire use & therefore vegetation mortality can help us reconcile GFED5 burned area levels within JULES

➢ *JULES currently calculates mortality as a linear scaling per PFT*



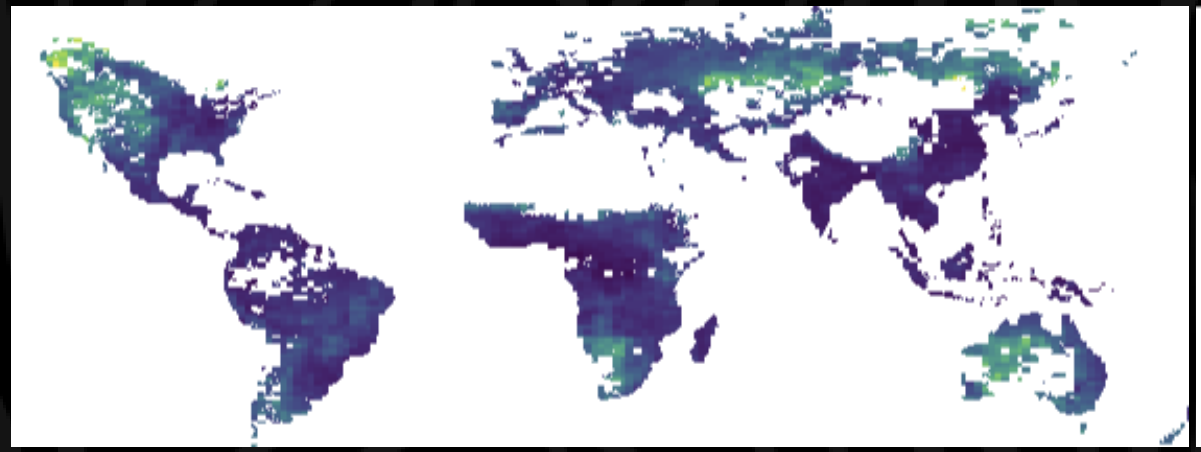
Perkins et al., (2025), *Earth's Future*

A new fireline intensity algorithm for JULES-INFERNO

Fire intensity ~ f(RH, windspeed, soil moisture, dead fuel, fragmentation, human mgmt, PFT)

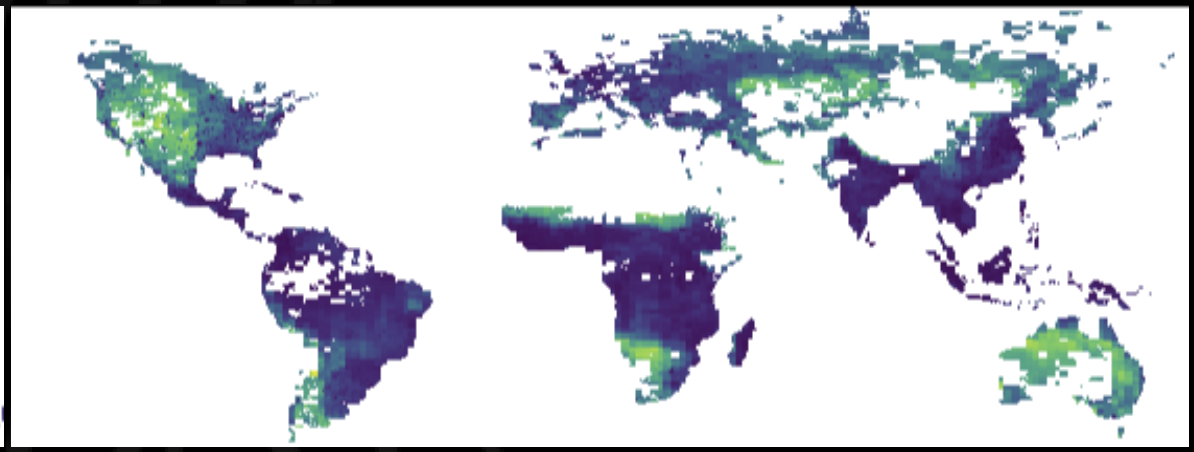
- Assumes fire intensity ~ veg mortality [could be adjusted for, e.g., canopy height in future
- Performs OK against observations (r = 0.75)
- Available with & without WHAM! adjustment [set mortality_method = 3]

A) Normalised fire line intensity ($^{FRP}/_{\sqrt{Fire\ size}}$)



Data from Haas et al., (2022)

B) Modelled fire line intensity

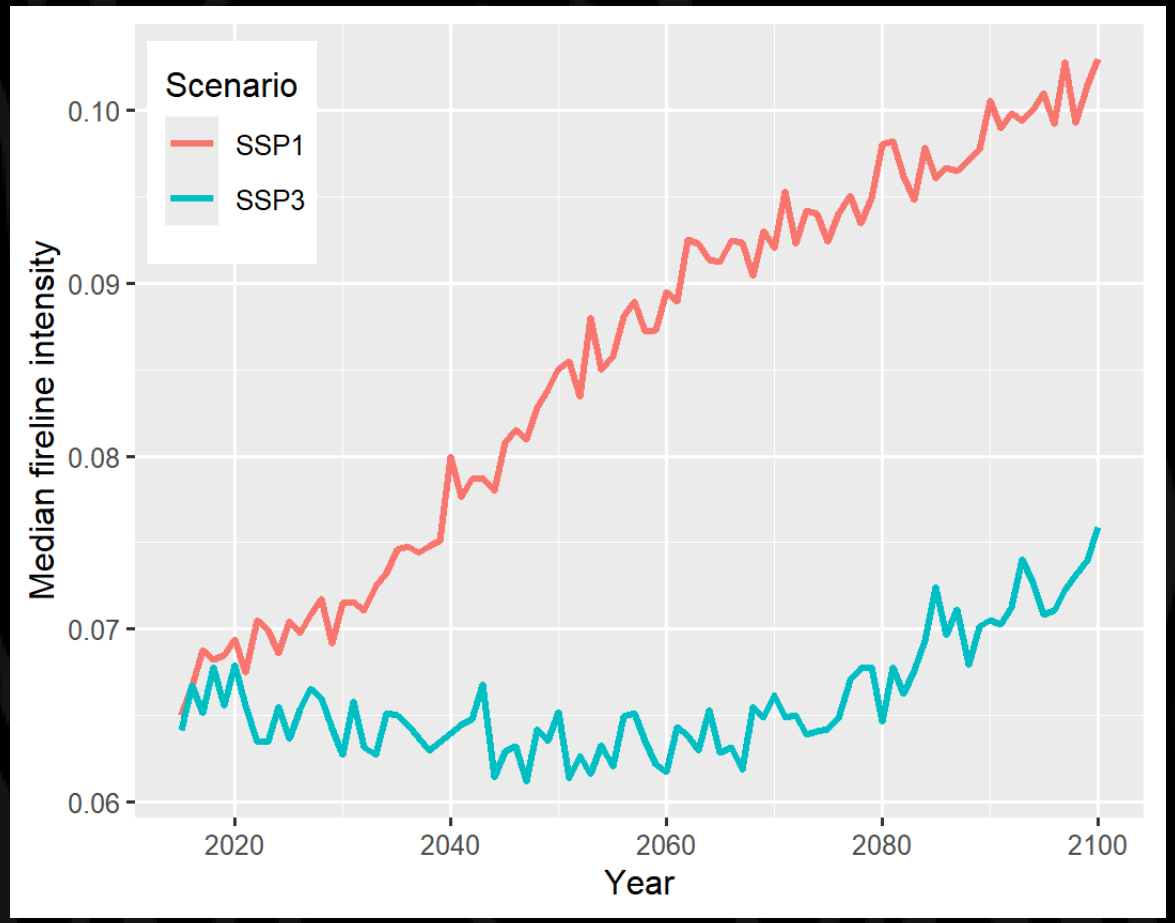


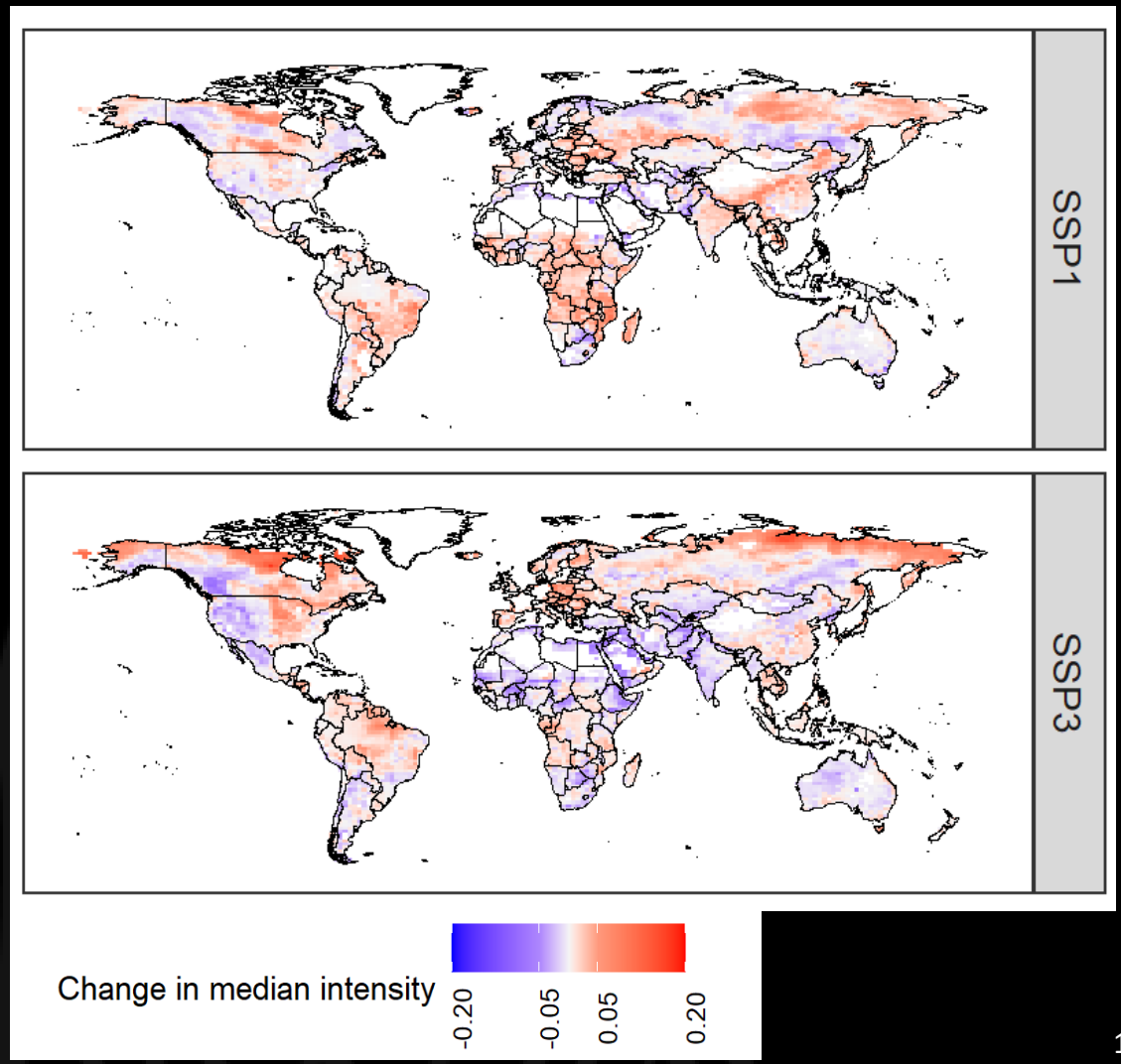
Perkins, et al. (*Nat Sust.* in prep)

/dev/oliverperkins/r30355_wham_inferno_integration/

Future fire intensity

- A new fireline intensity algorithm for JULES-INFERNO accounting for changes in human fire use





Perkins, et al. in prep.

Timeline

- Hope to get WHAM! managed & unmanaged fire counts into trunk @ next version [ticket in review]
- Carbon cycle impacts of intensity algorithm need evaluation [hopefully commit by year end]
- Changes to flammability next year
  - Still a substantial performance boost without new flammability calculation
- INFERNO v2 [peat, humans, intensity] is a 2026/27 project

Refs & questions?

- Millington, J.D.A., Perkins, O., & Smith, C. (2022). Human fire use and management: A global database of anthropogenic fire impacts for modelling, Fire, 5(4), 87. https://doi.org/10.3390/fire5040087

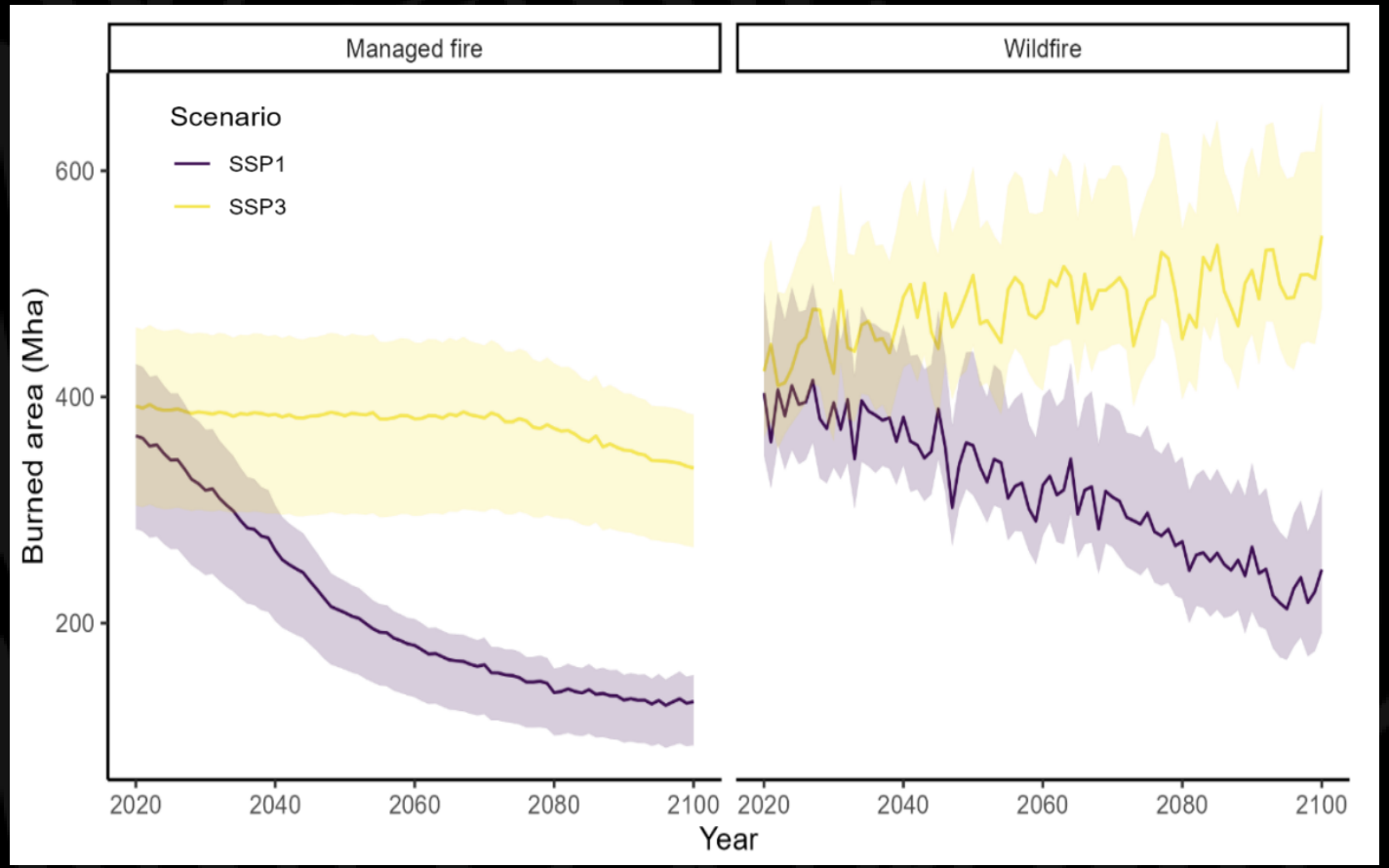
- Perkins, O., Kasoar, M., Smith, C., Mistry, J., Voulgarakis, A., Millington, J.D.A. (2024). A global behavioural model of human fire use and management: WHAM! v1.0. Geoscientific Model Development, 17 (9), 3993–4016. https://doi.org/10.5194/gmd-17-3993-2024

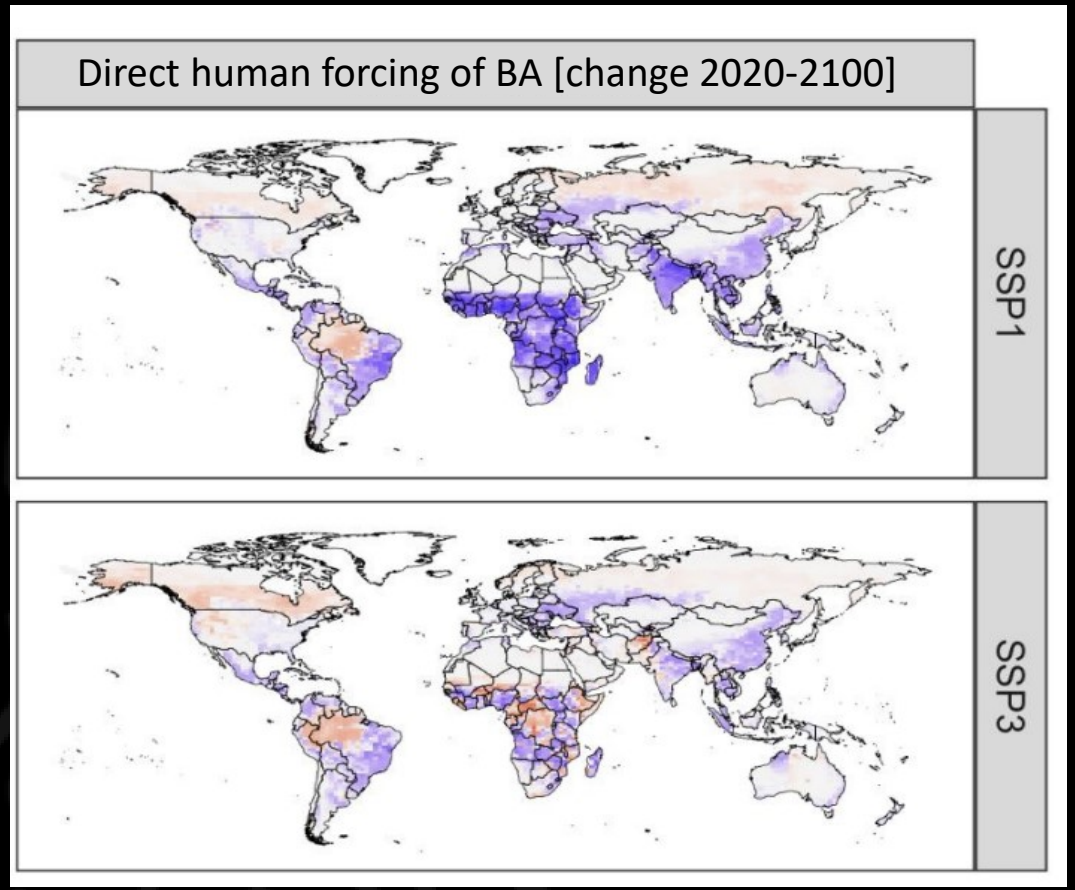
- Perkins, O., Kasoar, M., Voulgarakis, A., Edwards, T., Haas, O., & Millington, J.D.A. (2025). The spatial distribution and temporal drivers of changing global fire regimes: a coupled socioecological modelling approach. Earth's Future. https://doi.org/10.1029/2024EF004770

- Perkins, O., Haas, O., & Millington, J.D.A. (2025). The impact of livestock farming on global fire regimes. Environmental research letters. https://doi.org/ 10.1088/1748-9326/adeff5

Future WHAM scenarios

- *Do changes in human fire use & mgmt under a "sustainable growth" future (SSP1) imply large increases in fire intensity?*





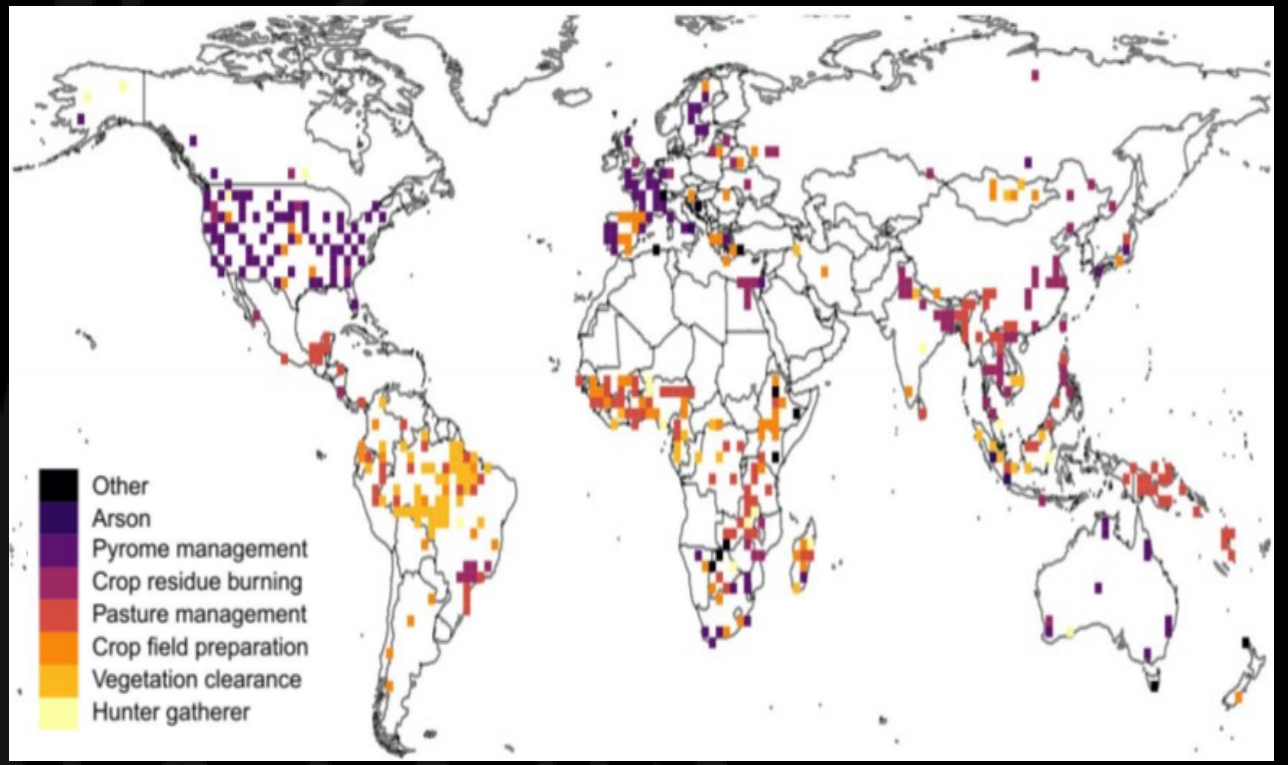
Perkins, et al. (in review, ESD)

Empirical parameterisation: DAFI

- Meta-analysis of human fire literature, spanning 1809 case studies in 504 papers
- ➢ *Different land use systems produce different fire regimes with different distributions*

Fire Use	Median Size (ha)	Mean Burned Area (% LS)	Escaped (%)
Crop Field Preparation	0.7	14.2	0.05
Crop Residue Burning	3.6	36.3	0.01
Pasture Management	10.7	32.1	4.97
Hunter-Gatherer	1.3	14.3	2.90
Pyrome Management	40.8	14.0	0.30
Vegetation Clearing	4.7	2.5	3.23
Arson	N/A	N/A	N/A

Distribution of fire uses (dominant) in DAFI data



Get the data! - doi.org/10.3390/fire5040087

Millington et al., 2022