We’re developing a quantitative model of human fire use to improve the simulation of fire in dynamic global vegetation models

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1. Our agent-based modelling approach accounts for qualitative differences in fire use

Representation of human fire in dynamic global vegetation models (DGVMs) has used functions of variables that are globally available (e.g., GDP). But human use and management of fire in landscapes is diverse globally, based on multiple factors. Agent-based modelling (Figure 1) allows representation of individual, qualitatively different entities using sets of computational rules.

To identify appropriate agent types we developed a conceptual framework (Table 1) that combines land use objectives (‘land system’) with management intensity and attitudes towards fire (‘anthropogenic fire regime’). Cross-tabulating these dimensions results in broad concepts (‘land fire systems’) from which to initiate literature searches (see Box 2).

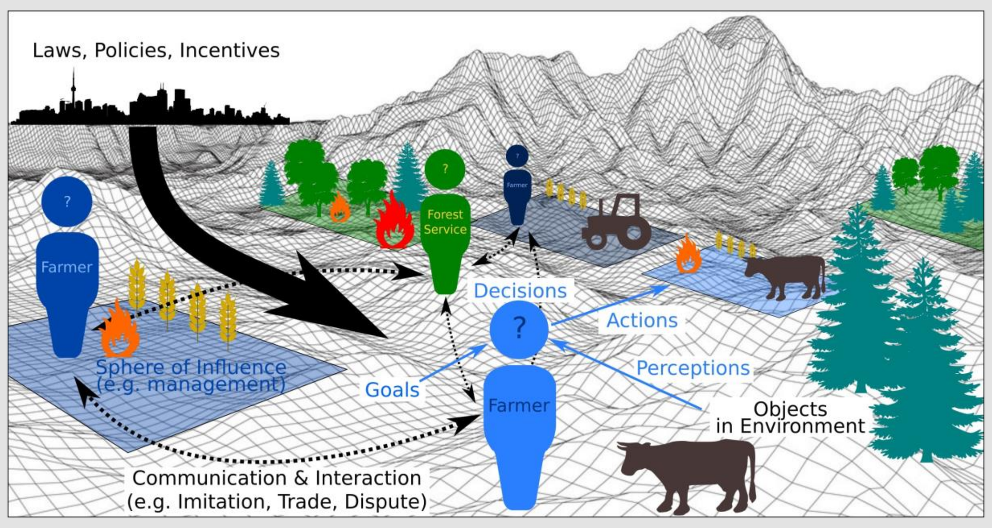

Figure 1. (Source: Ford *et al.* 2021)

Table 1.
After Perkins *et al.* (2022)

Anthropogenic Fire Regime	Land System: *Non-Extractive*	*Livestock*	*Arable*	*Forestry*
Pre-Industrial	Unoccupied	Pastoralism	Shifting cultivation	Hunting-Gathering
Transition	Limited Management	Extensive Ranching	Small-holdings	Logging
Industrial	State Management	Intensive Ranching	Intensive Farming	Managed Forests
Post-Industrial	Conservationist / Recreationalist	Subsidized Grazing	Abandoned	Pyro-diverse Management

2. To create our model, we created a new Database of Anthropogenic Fire Impacts (DAFI)

We constructed a freely available Database of Anthropogenic Fire Impacts (DAFI) from a meta-analysis of 523 papers containing 1,808 worldwide case studies (Perkins and Millington 2021). DAFI was developed in an iterative manner based the framework shown in Table 1. Analysis of DAFI reveals that seven main fire-use types (shown in Figure 2), which account for >90% of case studies. These seven fire-use types have distinctive quantitative signatures and spatial spread (Millington *et al.* 2022). As well as enabling parameterisation of our model (Box 3), DAFI facilitates analysis like that in Figure 3 which shows crop field preparation fires are prevalent in sub-Saharan Africa and South America, while crop residue burning prevails in Northern India and China.

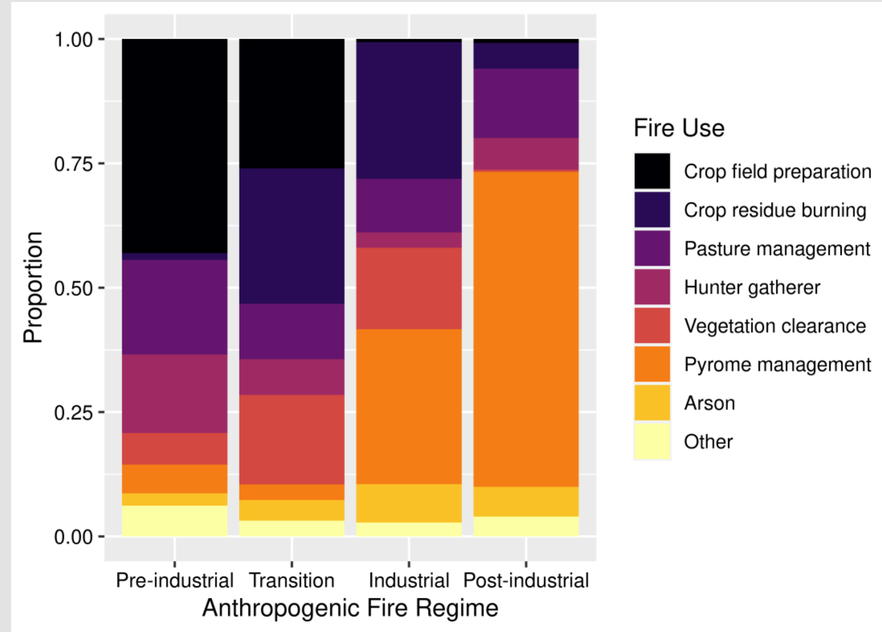

Figure 2. (Source: Millington *et al.* 2022)

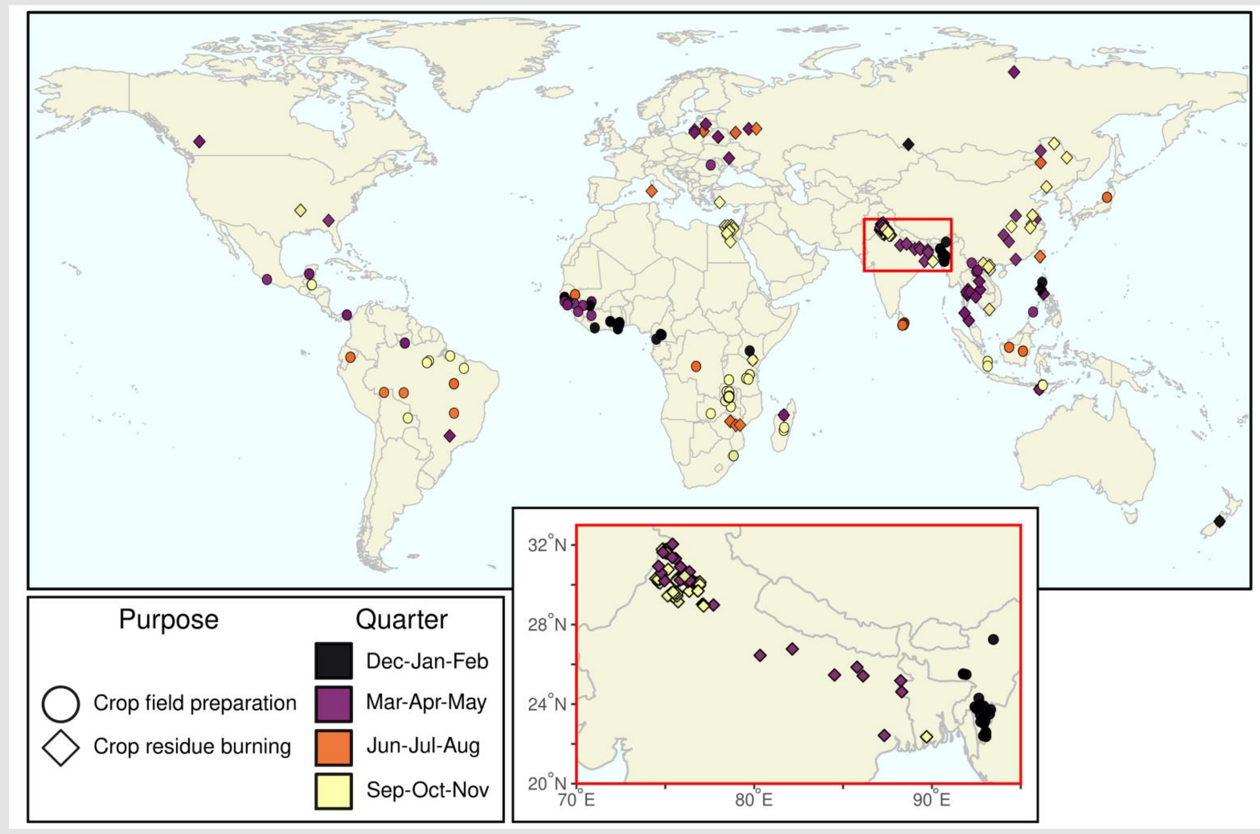

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Figure 3. (Source: Millington *et al.* 2022)

3. The Wildfire Human Agency Model (WHAM!) simulates the extent of human fire use globally

We used DAFI (Box 2) with ancillary data for predictor variables to model the global spatio-temporal distribution of land fire systems (LFS, Table 1). Classification trees (Figure 4) were used to estimate the fractional coverage of each LFS in each model grid cell. Grouping by anthropogenic fire regime (AFR; Table 1), we find the largest change is an increase in the industrial LFSs, accompanied by declines in the pre-industrial LFSs (Figure 5). This reflects how subsistence-focused fire uses are being replaced by market-focused fire uses, as found by Smith *et al.* (2022).

When we map WHAM! estimates of managed fire burned area we find greatest fire use in sub-Saharan Africa, Indian sub-continent and north-eastern Brazil (Figure 6). See Perkins *et al.* (2022) for model evaluation.

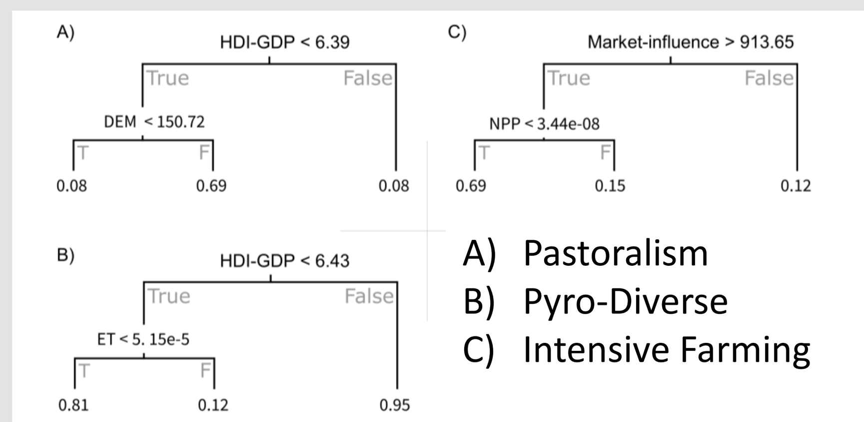

Figure 4. (Source: Perkins *et al.* 2022)

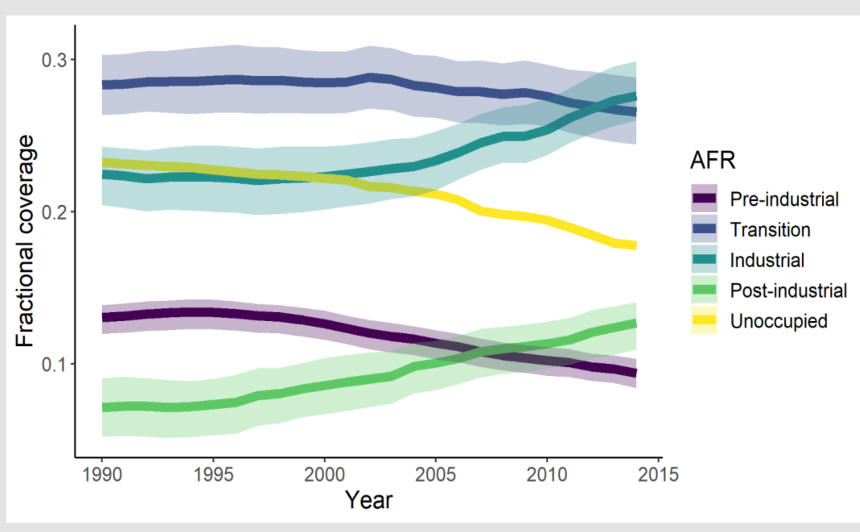

Figure 5. (Source: Perkins *et al.* 2022)

Download Perkins *et al.* (2022)

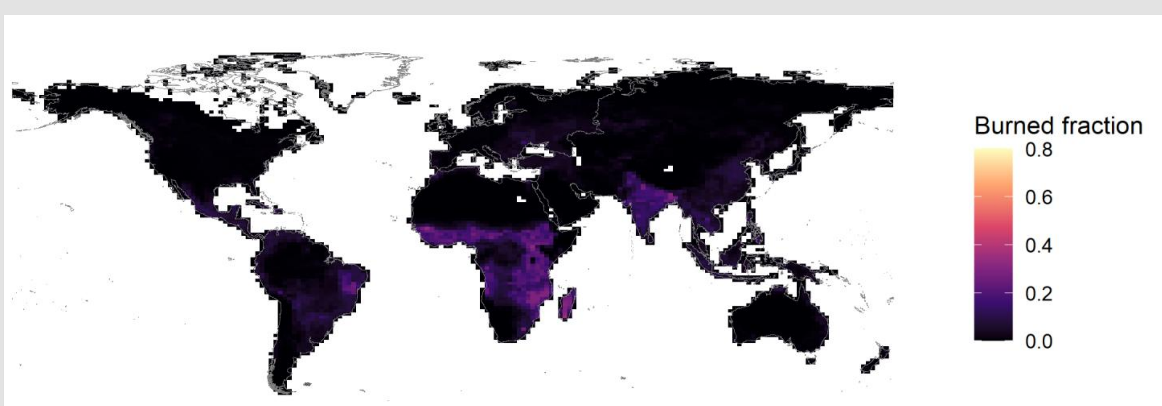

Figure 6. Managed fire estimates from WHAM!

4. Loose coupling of WHAM! with JULES-INFERNO improves spatial estimation of fire

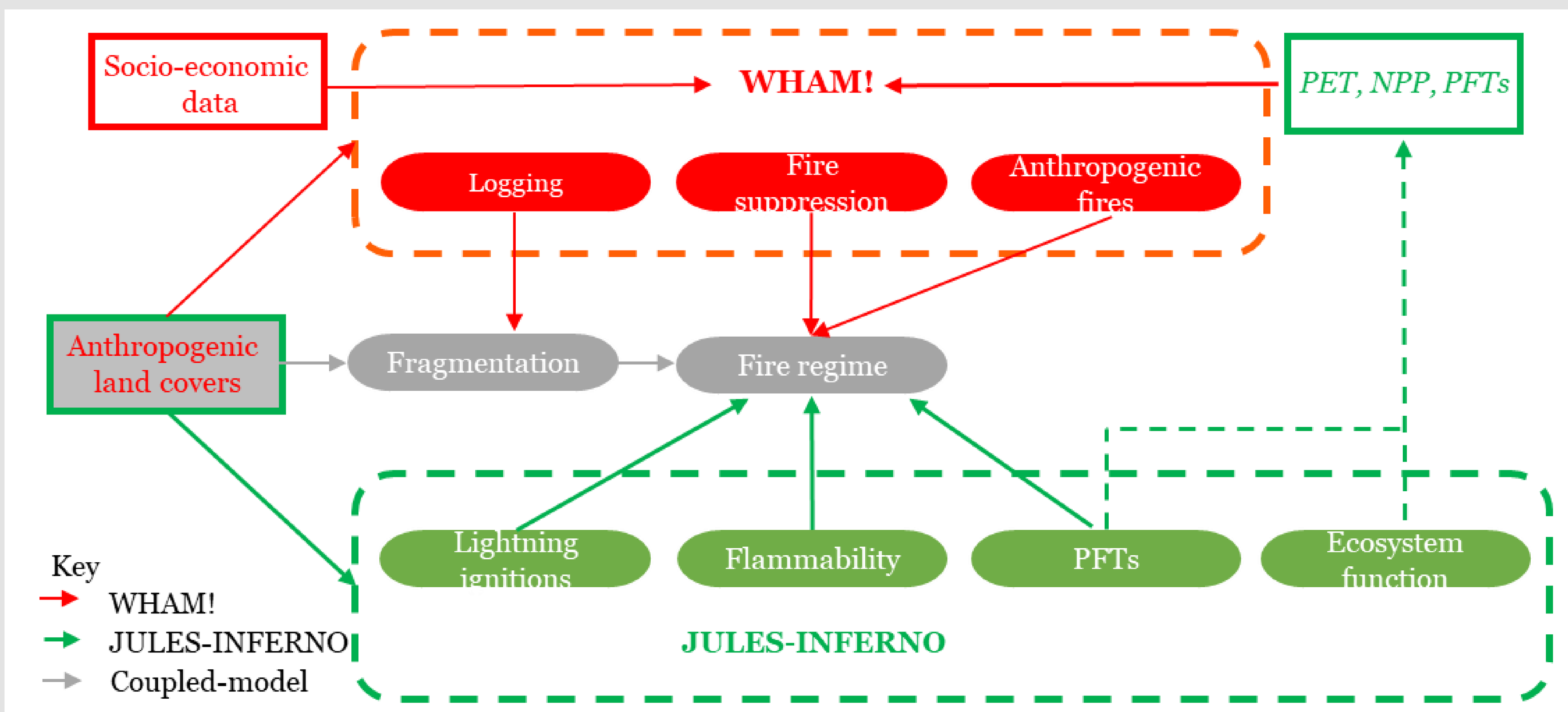

Figure 7.

WHAM! is now loosely coupled to the JULES-INFERNO dynamic global vegetation model (Figure 7). Initial results indicate that managed human fire accounts for around half of global burned area. Coupled model evaluation is ongoing, but mapping combined wildfire and managed fire burned area (Figure 8) shows improved correlation with Sentinel-2 data for sub-Saharan African *vs* JULES-INFERNO alone. We plan to evaluate against forthcoming GFEDv5 data.

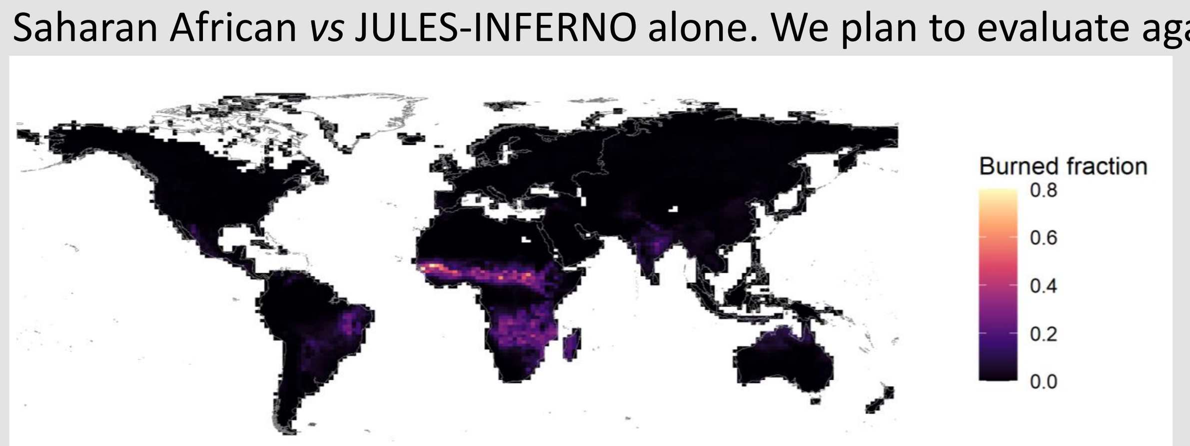

Figure 8. Wildfire & managed fire from JULES-INFERNO-WHAM!

Download Ford *et al.* (2021)

References: Ford *et al.* (2021) *Frontiers in Env Sci.* 10.3389/fenvs.2021.649835, Millington *et al.* (2022) *Fire* 10.3390/fire5040087, Perkins and Millington (2021) *FigShare* doi: 10.6084/m9.figshare.c.5290792.v1, Perkins *et al.* (2022) *SESMO* 10.18174/sesmo.18130, Smith *et al.* (2022) Nature Sustainability 10.1038/s41893-022-00867-y

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