Lost in Space

Revealing human impacts on forests & fires

Dr James Millington

Pint of Science, 2024-05-13

These slides available at:
landscapemodelling.net/pres/POS24

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

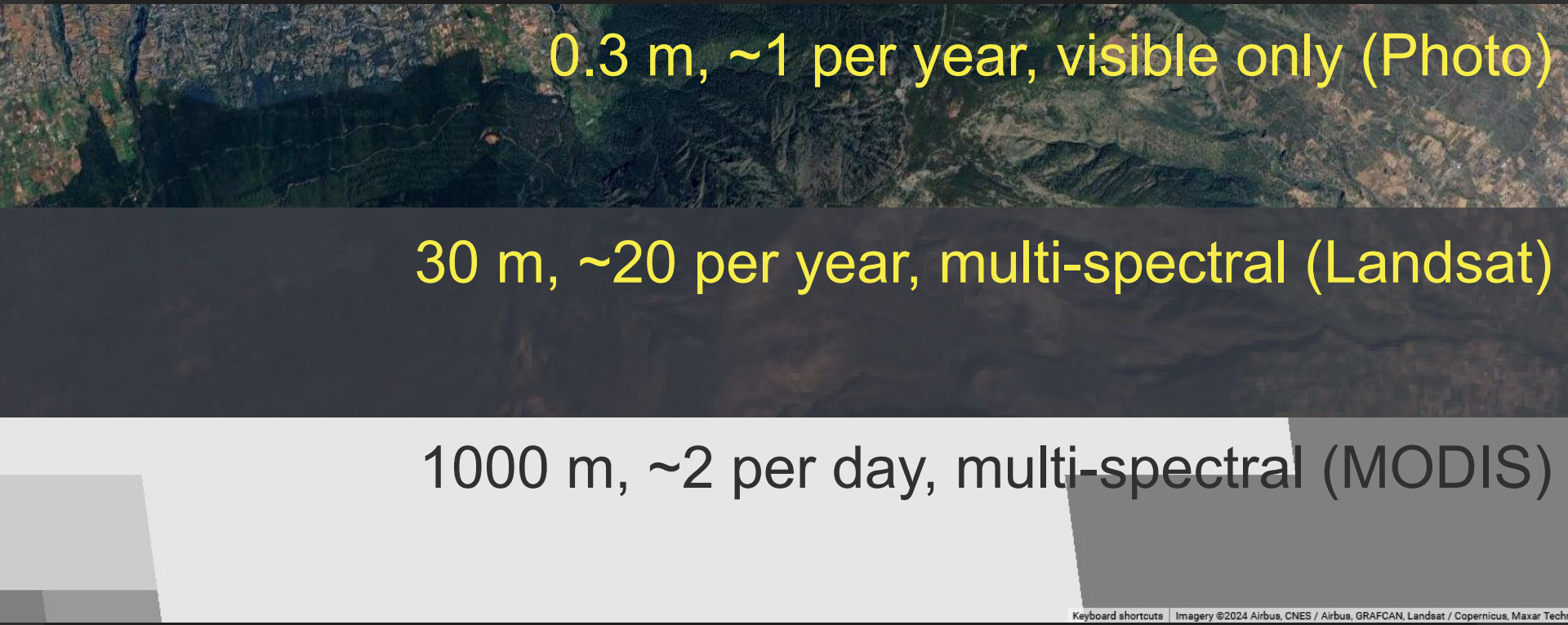
KING'S College LONDON
Geography

Revealing human impacts on forests & fires

We can’t simply rely on what we ‘see’ from space, which is largely about physical attributes.

Lost in Space - from 1960s to 2020s

Data Tradeoffs



Compare these data yourself (requires login): GEE code

From an expensive few, to a free-for-all

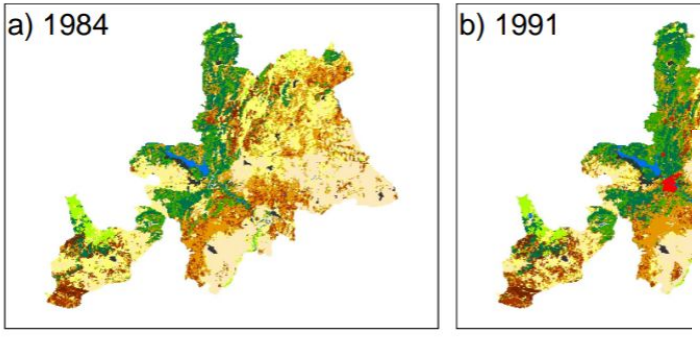


Figure 2.10 SPA 56 land-cover maps. a) 1984, b) 1991, c) 1999 distinguish 11 classes of land-cover and were derived from Landsat TM

V. PRICING

In accordance with OMB Circular A-130 and USGS Data P[illegible] selected satellite data products for retrieval via the Interne[illegible] at no charge to users. Other products that may be ordered by users from the NSLRSDA[illegible] are provided at no m[illegible]re than COFUR; this includes special arrangements made for users who require higher volumes of Landsat data products than can be provided by standard USGS distribution mechanisms.

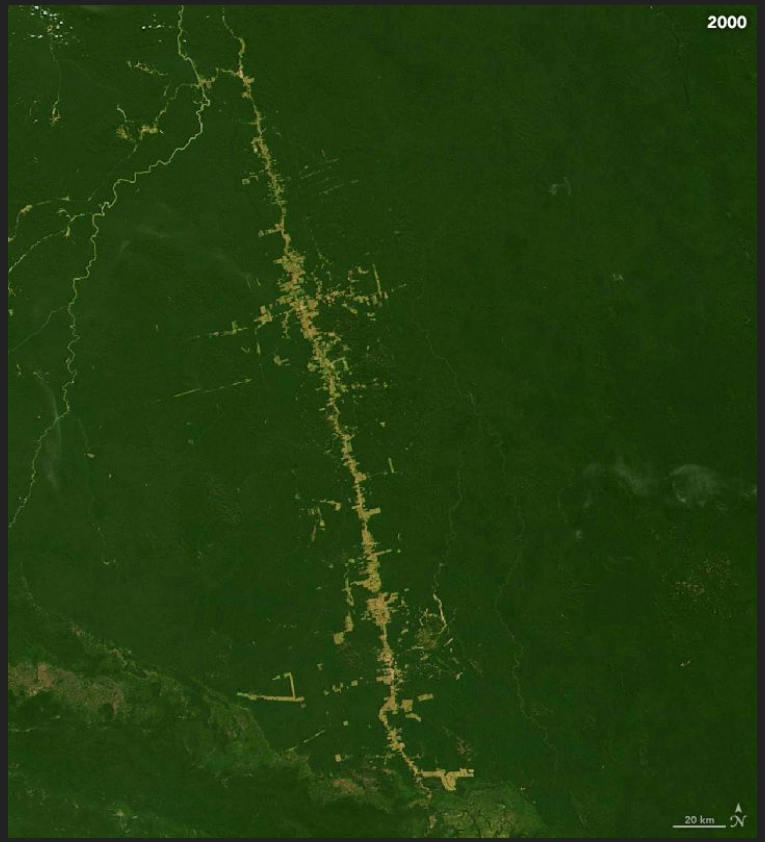
Barbara J. Ryan
Associate Director for Geography
U.S. Geological Survey

Date: 2 January 2008

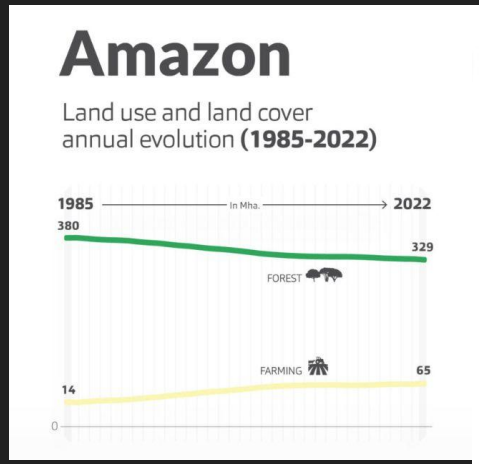
Michael H. Freilich, Director
Earth Science Division
National Aeronautics and Space Administration

Date: 7 Jan 08

Tracking land cover and land use change

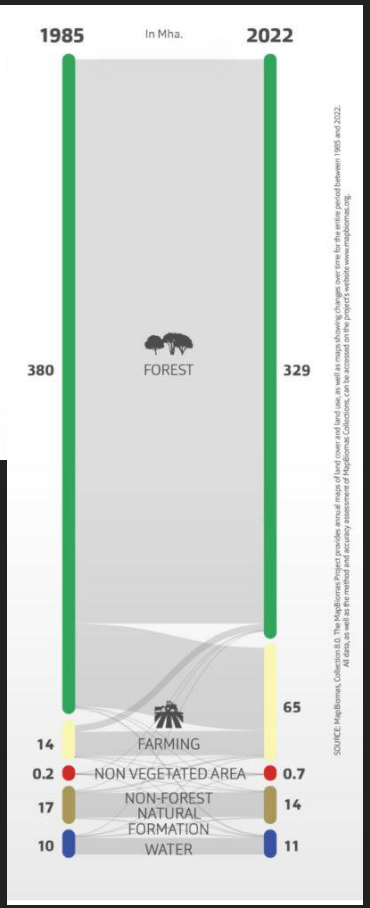


[PRODES]



[MapBiomas](#)

Explore the data yourself!



Tracking ownership: Rural Environmental Cadastre (CAR)

Image source

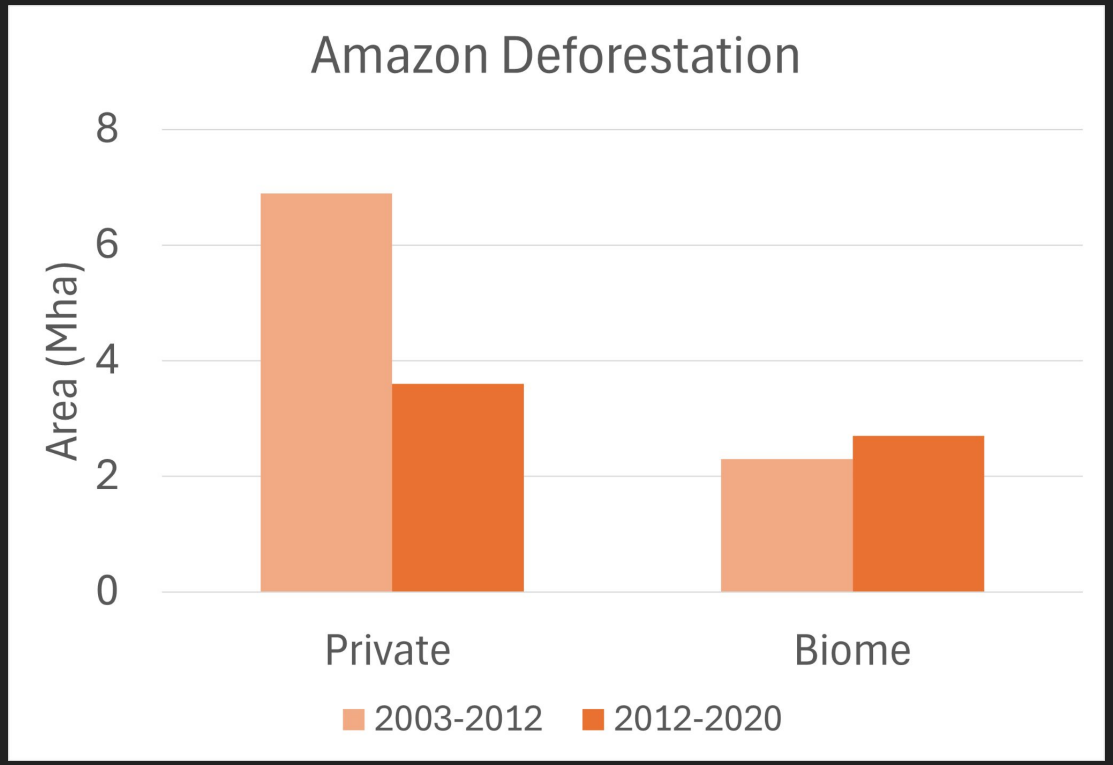
Tool to:

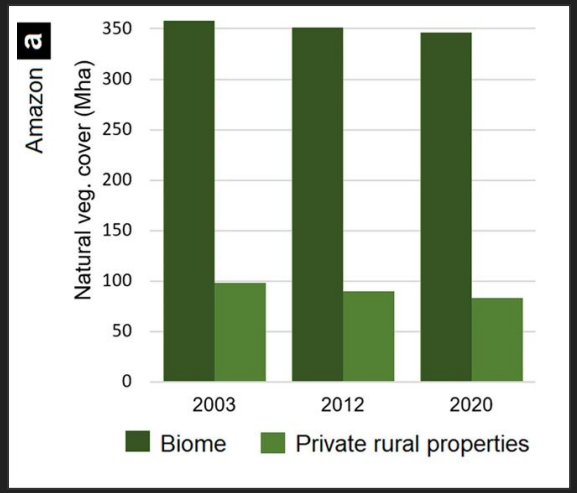
- obtain information about property for monitoring (e.g. deforestation)
- foster national forest code compliance

Data are self-declared by landowners

- >700,000 in Amazon

Who owns the land being deforested?





Paper: Silva *et al.* (2023)
Data: CAR, MapBiomas

Should they be doing that?

Forest code rules on ‘legal reserve’ of forest on rural property:

- 1965: 50% of property reserved as forest
- 1989: 80% of property reserved as forest
- 2012: amnesty for ‘lost’ forest removed prior to 2008

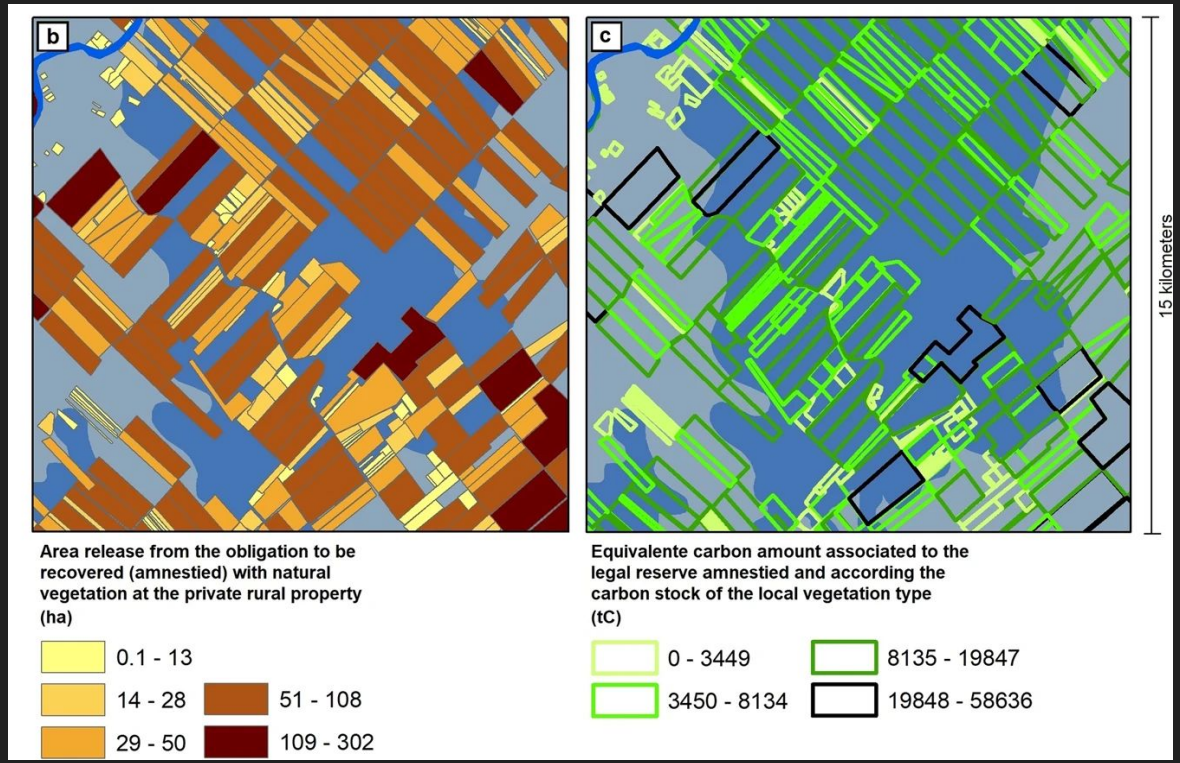
Read more: Santos *et al.* (2021)

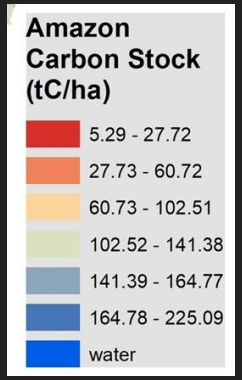
In the Amazon, we found:

Lost forest: 25.5 Mha

Amnesty applied to 14.6 Mha
(511,658 properties)

Carbon lost due to deforestation amnesty

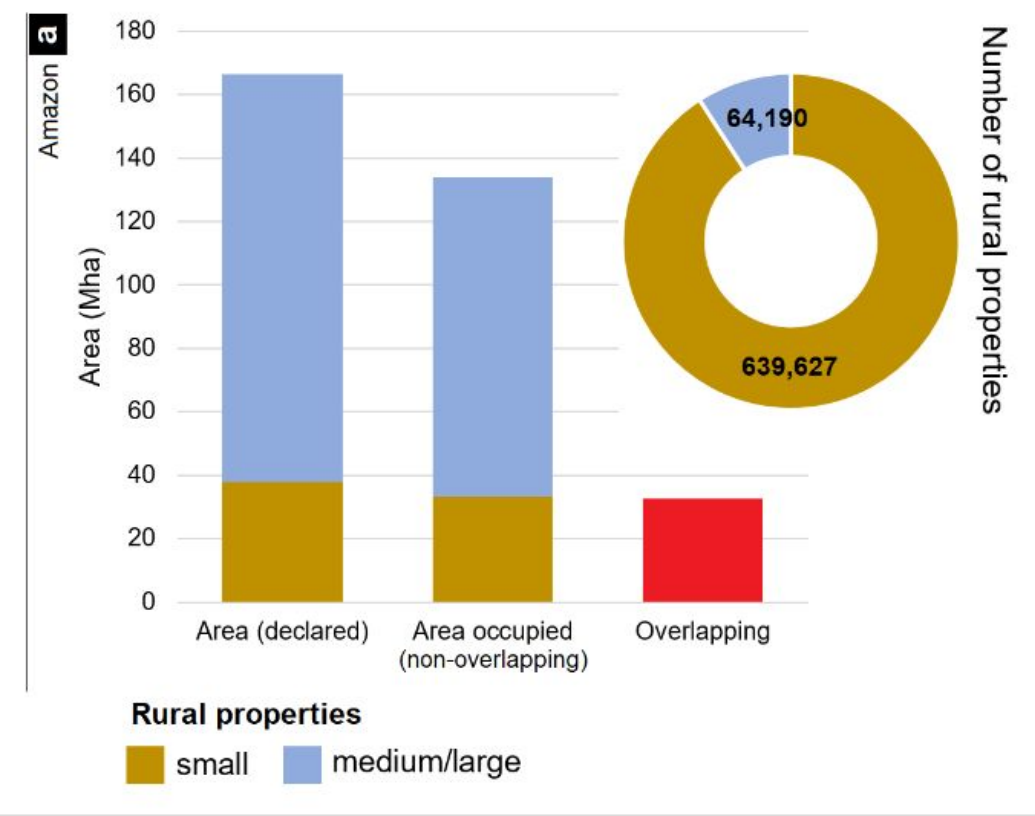




Paper: Silva *et al.* (2023)
Data: CAR, MapBiomas

We estimate 2.4 Gt of carbon lost due to amnesty

The data are by no means perfect



Overlaps of property polygons

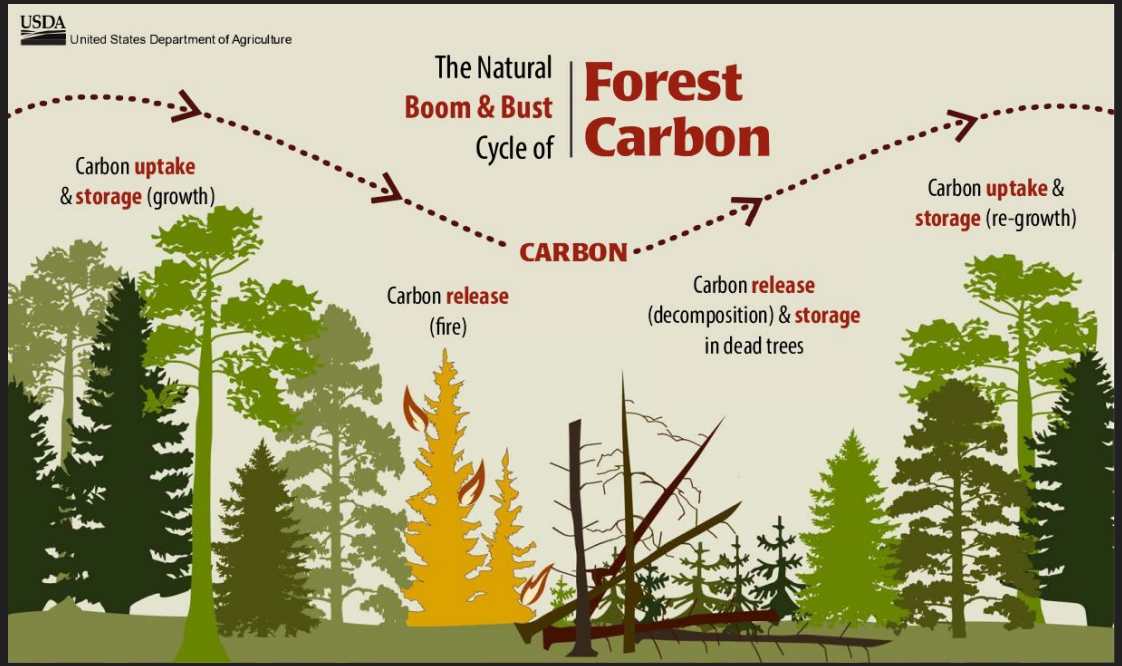
But also, 10% of conservation units in Amazon (20.5 Mha) marked private property!

- Mistakes
- Land grabbing

Silva *et al.* (2023), Santos *et al.* (2021)

Fire emissions

$$CO_2 = BA \times FL \times BE \times EF$$

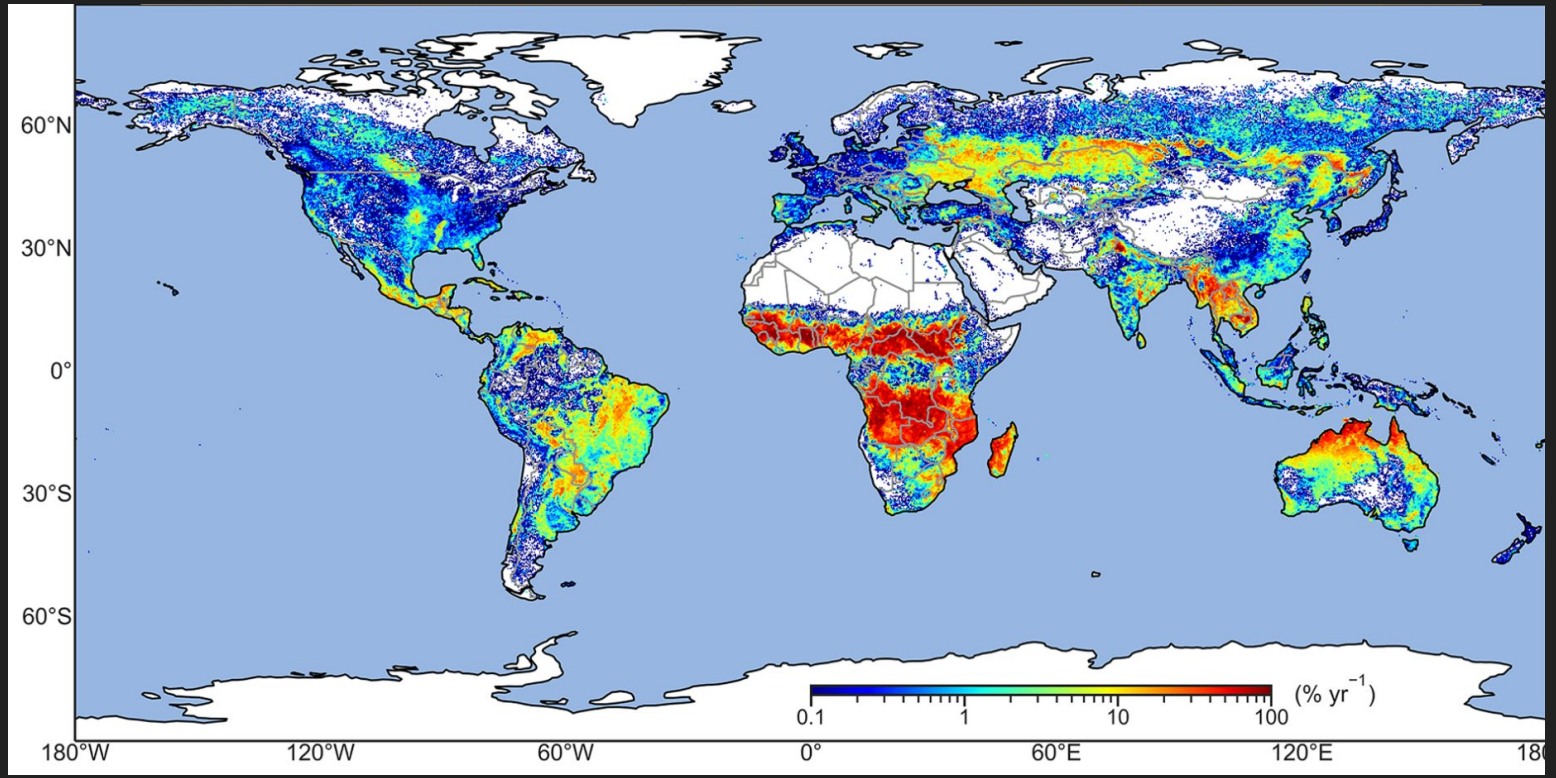


BA: Burned Area (ha)
FL: Fuel Load (kg ha^{-1})
CE: Combustion Efficiency
EF: Emissions Factor (g CO_2 kg^{-1})

Need more on fire emission calc.?
See e.g. Shiraishi & Hirata (2021)

Image source

Global Burned Area (from space)



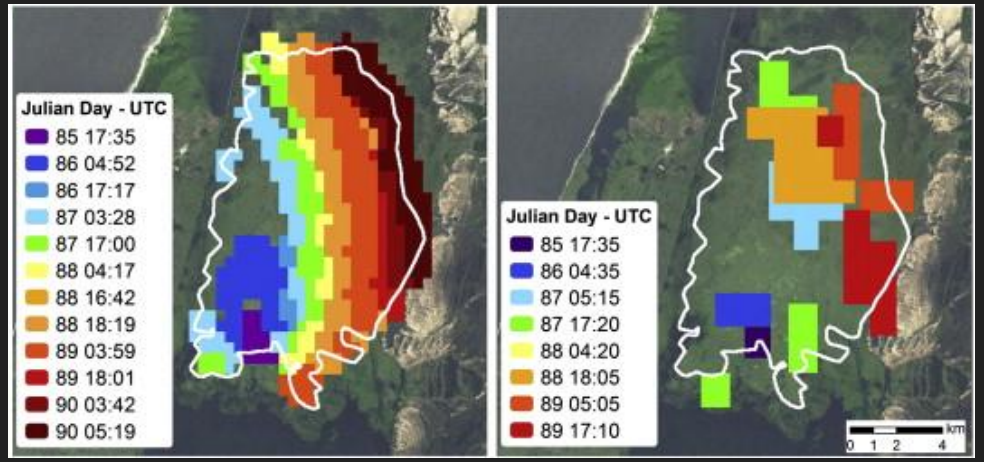
GFED 0.25° (~25 km at equator)

Annual mean %/yr

Paper: Chen *et al.* 2024 | Data: *via* Zenodo

Observing fires from space

Active Fires (thermal IR)



VIIRS 375 m
Twice daily
Smallest fire: 10 m²

MODIS 500 m
Twice daily
Smallest fire: 21 ha

Burned Area (SWIR)

Landsat 30 m
Twice monthly
Smallest fire: 900 m²

Paper: Schroeder *et al.* 2014 | Data: *via* FIRMS

Observing fires from space

Pre-fire

Post-fire

Burned Area (SWIR)

Landsat 30 m
Twice monthly
Smallest fire: 900 m²

How these images were made: GEE code

Science by WhatsApp

EGU 2022
J. Randerson

landscapemodelling.net

We constructed a freely available **Database of Anthropogenic Fire Impacts (DAFI)** from a meta-analysis of 1,800 worldwide case studies. We find seven main fire-use types, linked to land user intention.

Poster: Perkins *et al.* 2021
Paper: Millington *et al.* (2022)
Data: *via* FigShare

Human-Fire Interactions: A Global Database

Oliver Perkins[1,3], Cathy Smith[2,3], James D.A. Millington[1,3]
[1]King's College London, [2]Royal Holloway, University of London, [3]Leverhulme Centre for Wildfires, Environment and Society

Presented at the American Association of Geographers Annual Meeting, April 2021

KING'S College LONDON · ROYAL HOLLOWAY UNIVERSITY OF LONDON · LEVERHULME Centre for Wildfires, Environment and Society

Poster · Data

Studies of landscape fire vary in approach around the world. DAFI synthesises these studies.

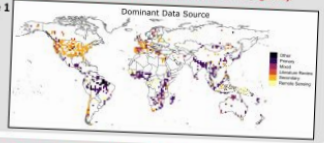
Empirical studies of human use and management of fire in landscapes around the world have been conducted in many different academic fields, including geography, anthropology, land economics and ecology. Studies have varied in approach, from quantitative and broad-scale (e.g., remote sensing) to qualitative and local-scale case studies (e.g., anthropological). No global synthesis of human-fire interactions has yet been attempted that covers the breadth of human fire use and suppression.

We present the most comprehensive meta-analysis of global fire use to date, spanning all key land systems and policy regimes from over 105 countries on all continents (except Antarctica) between 1990-2020. Our study has produced a database comprising data (Table 1) from 523 papers containing 1808 case studies that we call the Database of Anthropogenic Fire Impacts (DAFI; Perkins and Millington 2021). Because existing studies vary across disciplines and approaches, DAFI was developed in an iterative manner but based on a framework that accounts for fire 'stages' (after Pyne 2019) and land system. Fire stages are pre-industrial, transition, industrial & post-industrial while land systems are cropland, pasture, forest & non-extractive. **The types of study included in DAFI vary across space, with a prevalence of secondary studies in Europe and North America *versus* a dominance of primary studies in Asia and Africa (Figure 1).**

Table 1

Information	Data Format (case study)	Data Type (DAFI)	Example Variables (DAFI)
Fire Use	Quantitative	Continuous	Intended or actual fire size
Suppression	Mixed	Ordinal	Activity type & effort level
Policies	Qualitative	Boolean	Existence of laws or incentives
Land Use & Cover	Mixed	Continuous & Nominal	Land use intensity & type

Figure 1



Quantitatively distinct fire regimes arise from local interactions between fire use, suppression and policy.

Analysis of DAFI reveals that seven fire-use types (listed in Table 2) account for >90% of case studies. **The seven fire-use types have distinctive quantitative signatures (Table 2) and spatial distributions (Figure 2).** Shifting cultivation field preparation has a similar mean fire size to non-shifting crop residue burning. However, the relatively low fire-return period and high density of fields when compared to shifting cultivation combine to produce a much greater proportional mean burned area. Pyrome management activities dominate in North America and Europe, while vegetation clearance is a primary use across much of Brazil, and crop residue burning is dominant across parts of Asia.

Table 2

Fire-use Type	DAFI Records (%)	Mean Size (ha)	Mean Burned Area (% LS)	Mean Return Period (yrs)	Escaped (%)
Field Prep.	19.8	0.8	14.2	10.2	0.05
Crop Residue Burning	16.7	3.9	36.3	2.0	0.01
Pasture Prep.	12.3	33.9	32.1	3.4	4.97
Hunt/Gather	6.4	2.1	14.3	5.0	2.90
Veg. Clearing	14.2	9.2	2.5	N/A	3.23
Pyrome Mgmt.	17.7	357.2	14.0	5.9	0.30
Arson	3.3	N/A	N/A	N/A	N/A

Figure 2

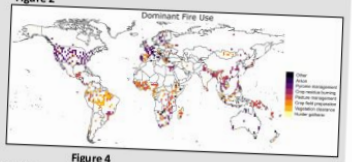
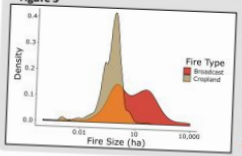
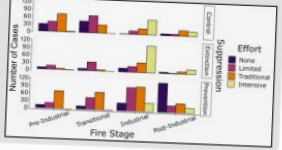


Figure 3



DAFI enables examination of fire regime characteristics as a function of broader fire use approaches and how fire uses vary between fire stages. For example, cropland fires tend to be smaller than fire broadcast across pasture and forest landscapes (Figure 3). We find distinct differences in fire suppression between fire stages (Figure 4). **Code for analysis of DAFI and plots is available (Perkins 2021).**

Figure 4



Representation of anthropogenic fire in global models demands consideration of land use context.

Attempts to systematise human-fire interactions have sought to configure human impacts as deviations from underlying 'natural' axes of vegetation and moisture (e.g., McWethy *et al.* 2013). Such approaches have not yet developed a coherent overall framework to capture human impacts on wildfire. A key finding of the Fire Model Intercomparison Project was that the lack of a systematic empirical basis for understanding human impacts on wildfire regimes presents a challenge to incorporating anthropogenic fire into Dynamic Global Vegetation Models (DGVMs; Teckentrup *et al.* 2019). The work presented here contributes to improving this empirical basis. **DAFI is freely available (see Perkins and Millington 2021) and continues to grow.**

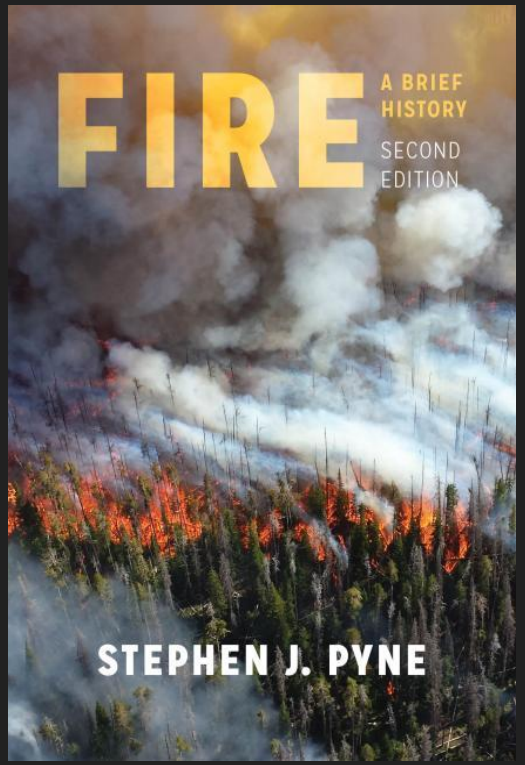
We plan to use DAFI to support the development of agent-based modelling approaches to better represent human fire in DGVMs. Representation of anthropogenic fire in DGVMs still relies on few readily-available metrics of human activity, such as population density and GDP. The poor performance of models using these variables in globally-uniform relationships may be due to the disregard for how people use and manage fire in the context of different land systems. To provide this context, we will use DAFI to develop 'agent functional types' that characterise anthropogenic fire use and suppression as a function of underlying land use objectives. Examples may include shifting cultivation farmer, large-scale industrial logger, and conservationist. We expect that by mapping these types globally using ancillary data, we will be able to improve simulation model representation of human fire, including feedbacks with vegetation and climate.

References: Mcwethy *et al.* (2013) *Global Ecology and Biology*; Perkins (2021) *Antifire/v008* https://github.com/OliPerkins1987/Antifire/tree/v008; Perkins and Millington (2021) *FigShare* https://doi.org/10.6084/m9.figshare.c.5290792.v1; Pyne (2019) *Fire: A Brief History*; Teckentrup *et al.* (2019) *Biogeosciences*. **Contact:** Oliver Perkins, oliver.perkins@kcl.ac.uk; Cathy Smith, c.smith@rhul.ac.uk; James Millington, james.millington@kcl.ac.uk; http://www.landscapemodelling.net

1. Anthropogenic Fire Regimes

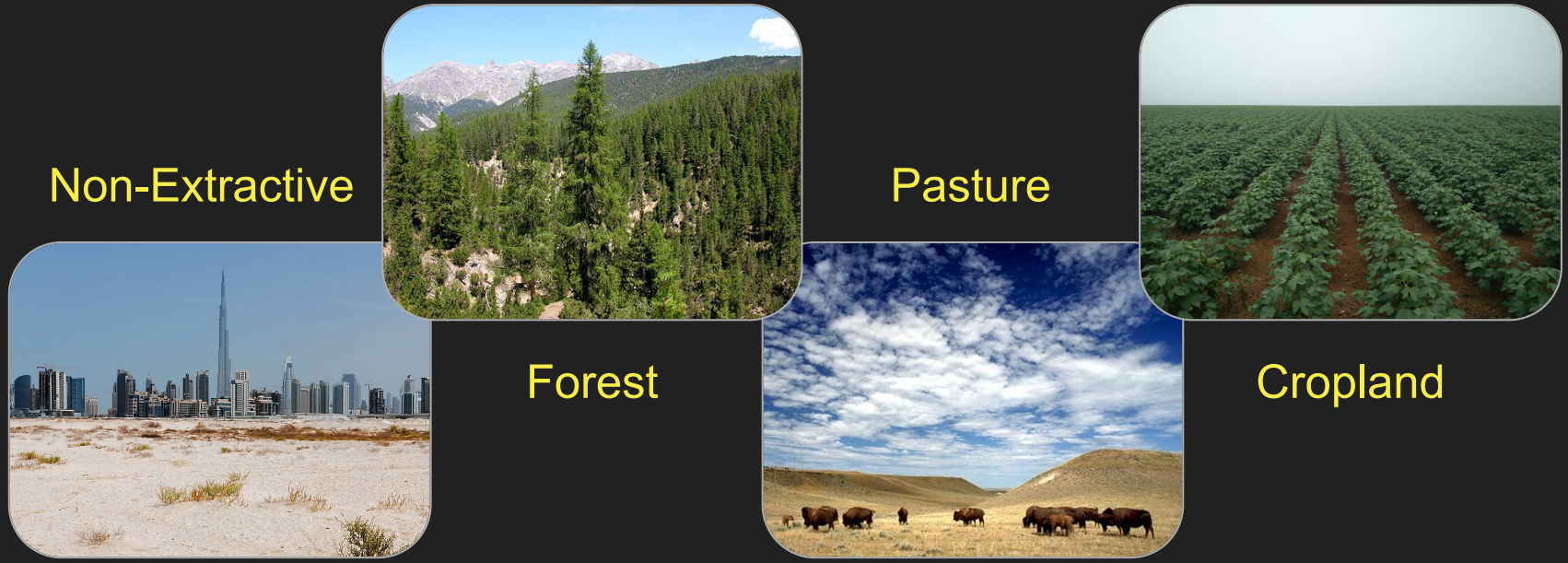
- ~~First Fire — pre-human~~
- Second Fire — pre-industrial
- 2.5th Fire — transition
- Third Fire — industrial
- Pyrocene — post-industrial

After Pyne's Fire 'stages', AFRs reflect available resources and management perspectives



[TED 15 min summary]

2. Land Use Systems



Combine land use intensity and land management practices

See Václavík *et al.* 2013 [GEC], Dou *et al.* 2021 [Lsp Ecol]

Land-Fire Systems

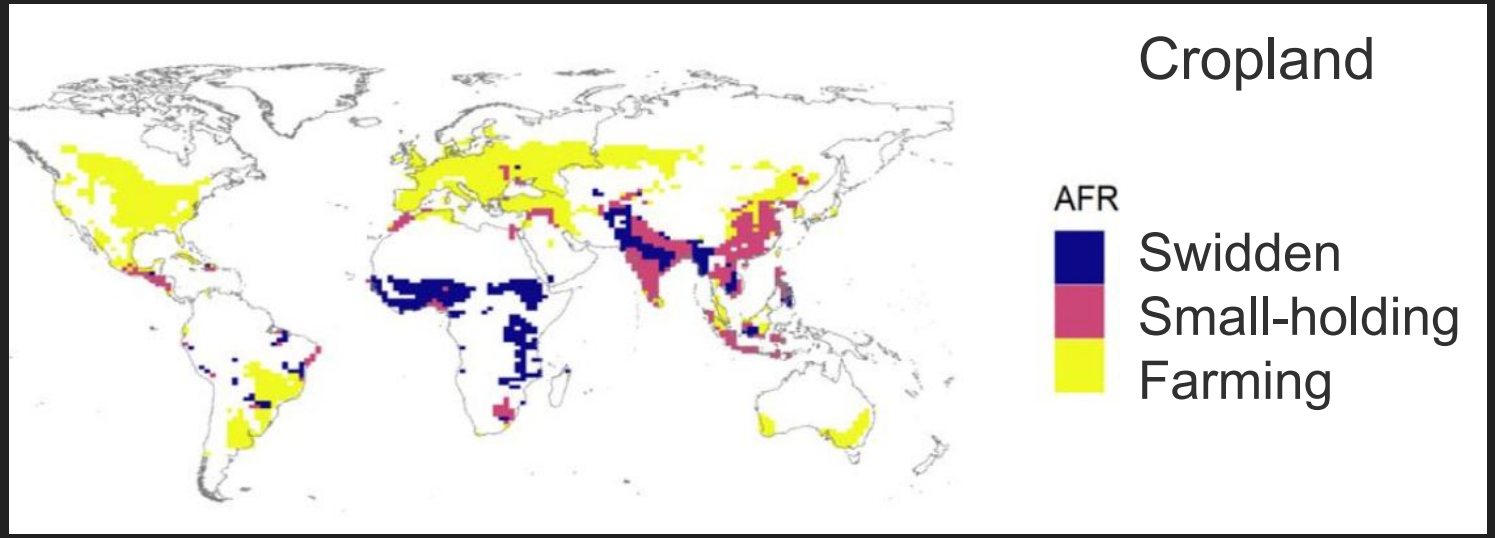
From combination of Anthro. Fire Regimes and Land Use Systems

More here: Perkins *et al.* (2024)

Anthro. Fire Regime	Land Use System: *Non-Extractive*	*Livestock*	*Crops*	*Forestry*
Pre-Industrial	Unoccupied	Pastoralism (S)	Swidden (S)	Hunt & Gather (S)
Transition	Unmanaged	Ranching (Extensive, S|M)	Small-holding (S|M)	Logging (M) (Primary Forest)
Industrial	Pyro-exclusion (State Manager)	Ranching (Intensive, M)	Farming (Intensive, M)	Managed (M) (Plantation or Second Forest)
Post-Industrial	Pyro-diverse (Fuel Load Management)	Grazing (Subsidised, Fuel Mgmnt)	Abandoned	Abandoned

Non-Extractive = e.g. parks S = subsistence M = market

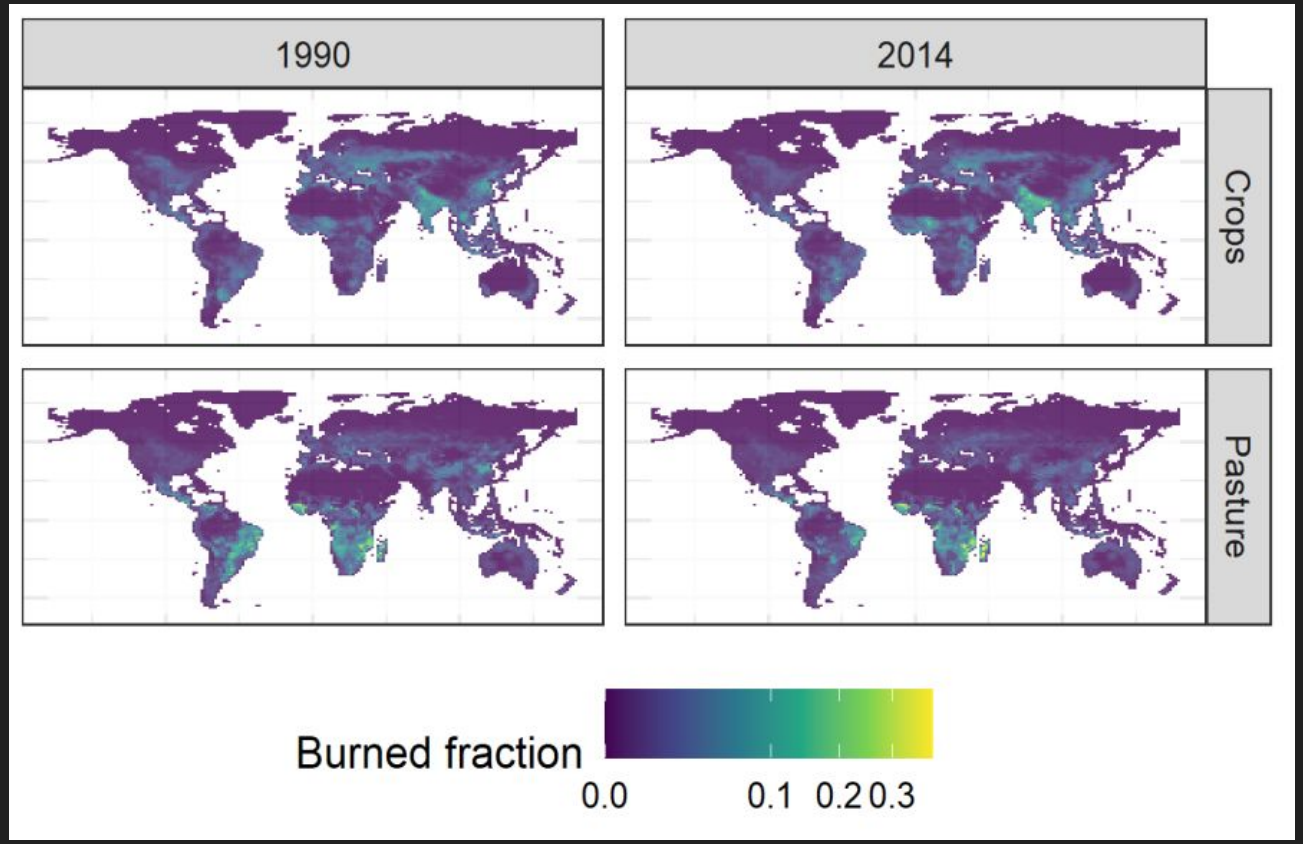
Modelled Spatial Distribution of LFS



Combine density of LFS with
data from DAFI to
estimate human Burned Area

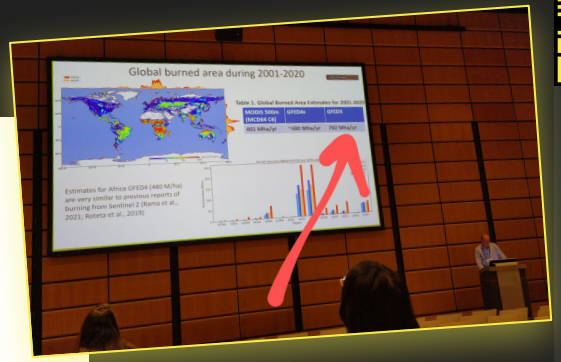
Paper: Perkins *et al.* (2022)

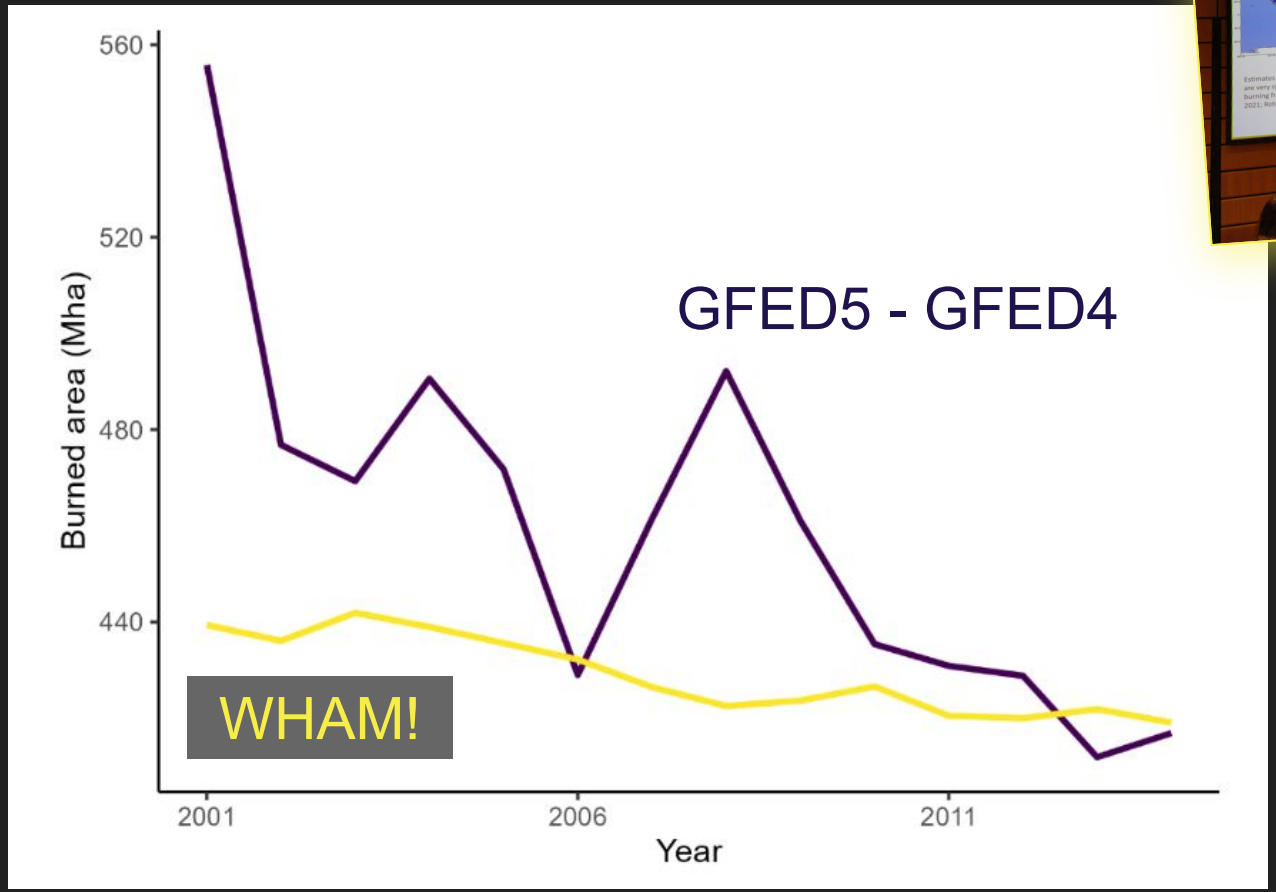
Anticipating the ‘lost’ fires



Paper:
Perkins *et al.* (2024)

Anticipating the ‘lost’ fires





Paper:
Perkins *et al.* (2024)

Revealing human impacts on forests & fires

We can't simply rely on what we 'see' from space, which is largely about physical attributes.

We need to think about what humans are doing on the ground and whether that is detectable from space.

Usually it won't be, so then we need to work on ways to generate data about people and institutions on the ground.

That could be user-generated (like CAR for forests), or it could be modelled (like WHAM! with DAFI for fires)