Representation of human fire in DGVMs needs to account for categorical differences between land systems

Agent-Based Model (ABM) of Human Fire

Fire Stage \ Land Use	Non-Extractive	Livestock	Crops	Forestry
Pre-Industrial	Unoccupied	Pastoralism (S)	Shifting (S)	Hunt & Gather (S)
Transition	Unmanaged	Ranching (Extensive, S|M)	Small-holding (S|M)	Logging (M)
Industrial	Pyro-exclusion	Ranching (Intensive, M)	Farming (Intensive, M)	Plantation (M)
Post-Industrial	Pyro-diverse	Subsidised	Abandoned	Abandoned

Non-Extractive = e.g. residential, parks | S = subsistence | M = market-oriented

Fire Use, Suppression

time *t*

time *t+1*

Land Cover, NPP, ET_0

JULES-INFERNO

Simulates:
Ignitions,
Burned Area

Completed: Database of Anthropogenic Fire Impacts (DAFI) to support ABM parameterisation

Current: Developing first global human fire ABM incl. spatial mapping of agent types

Future: Integrate ABM with JULES-INFERNO (loose or tight coupling?)

DAFI info

Advancing representation of anthropogenic fire in dynamic global vegetation models
EGU General Assembly 2021 | EGU21-9502 | doi.org/10.5194/egusphere-egu21-9502

James Millington, Oliver Perkins, Matt Kasoar, Apostolos Voulgarakis
Leverhulme Centre for Wildfire, Environment and Society

CC BY

Advancing Representation of Anthropogenic Fire in Dynamic Global Vegetation Models

James Millington, Oliver Perkins, Matt Kasoar, Apostolos Voulgarakis

KING'S College LONDON

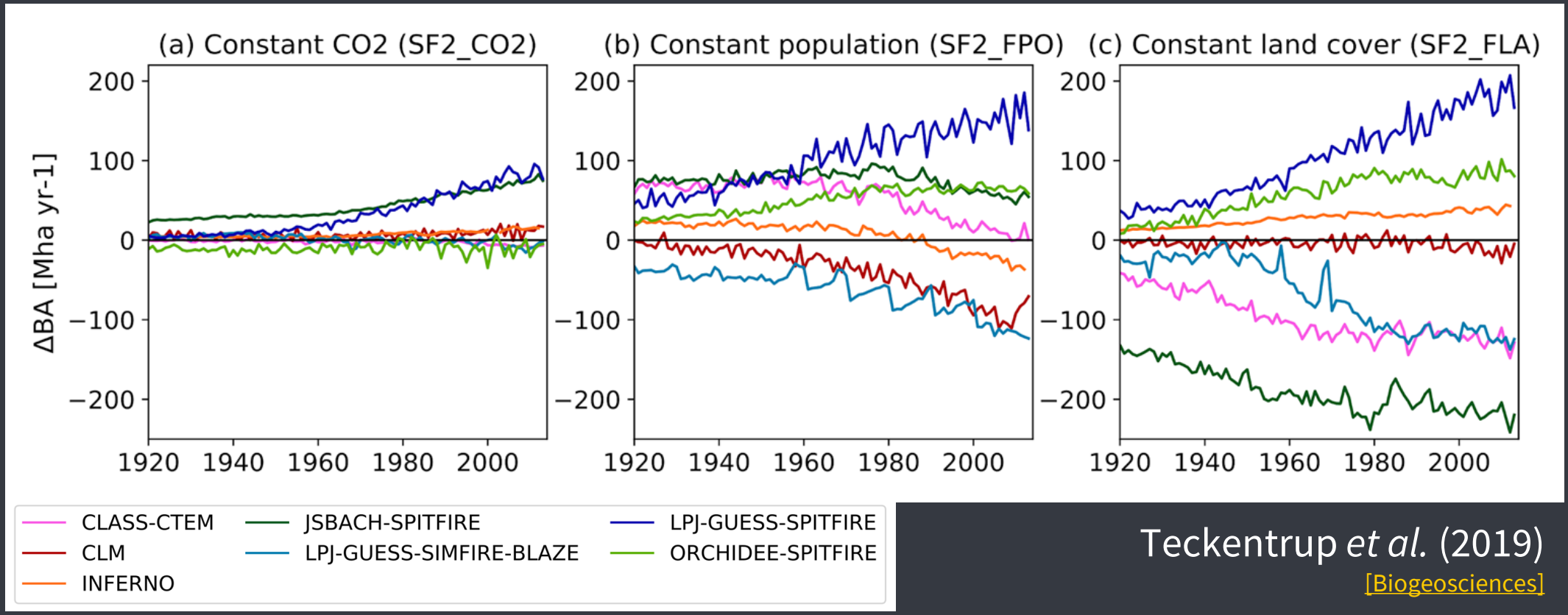
LEVERHULME Centre for Wildfires, Environment and Society

Imperial College London

CC BY

EGU General Assembly 2021 | EGU21-9502 | doi.org/10.5194/egusphere-egu21-9502

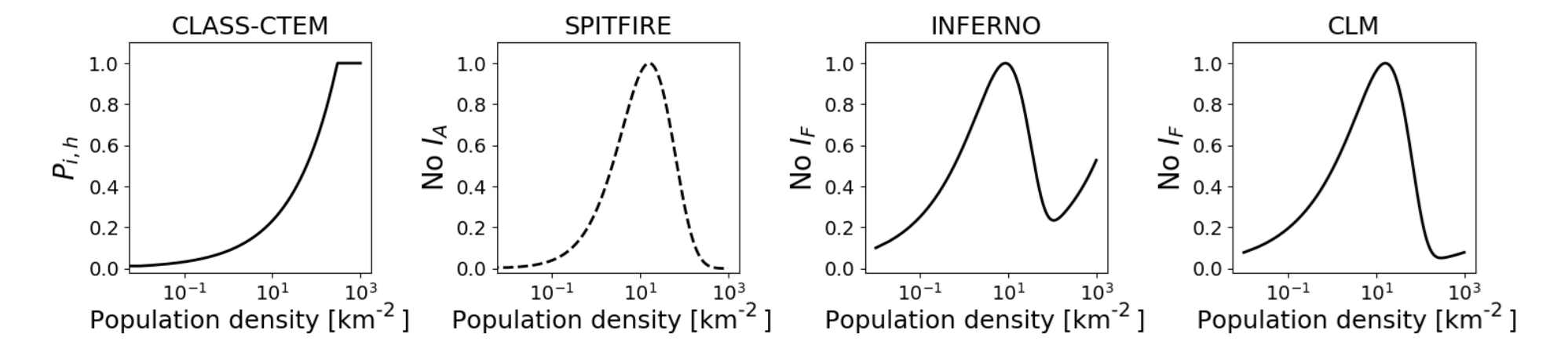
Human Activity in Models of Global Fire



Teckentrup *et al.* (2019)
[Biogeosciences]

DGVMs currently have large uncertainties in simulating historical burned area

Human Activity in Models of Global Fire



Teckentrup *et al.* (2019)
[Biogeosciences]

Dfferences in modelled BA due to functions relating fire to population density

Our argument: poor representation is because models don't account for categorical differences in land management related to fire

Agent-based modelling approaches enable us to capture these differences

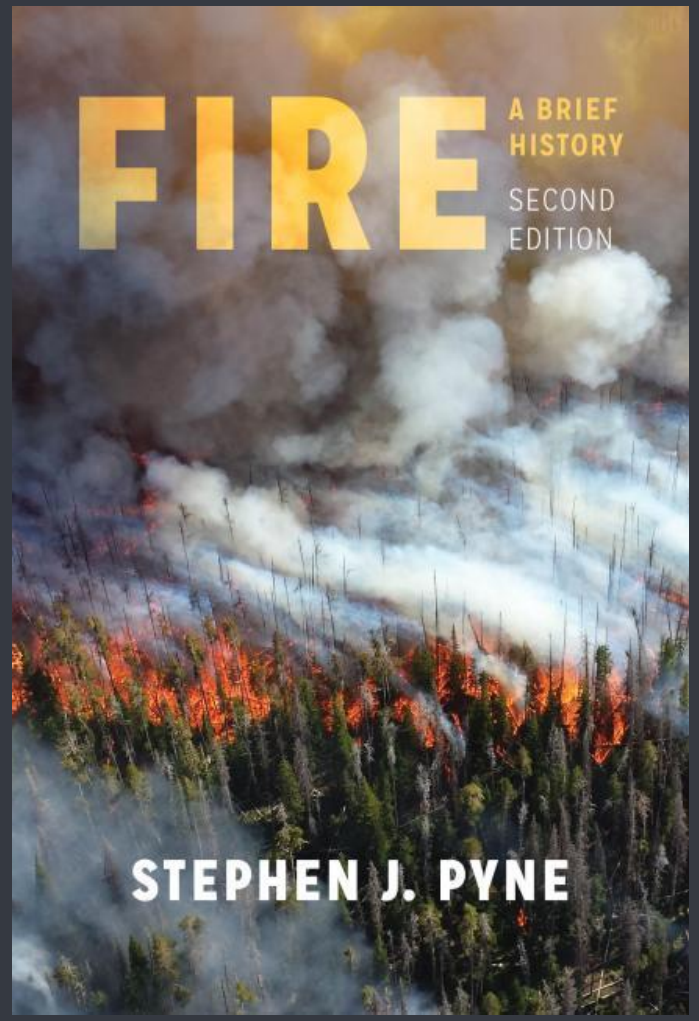
A Rational Conception of Human Fire

Fire ‘Stages’

Building on Pyne 2019 [FIRE], Seijo and Gray 2012 [RHE]

~~First Fire~~	~~Pre-human~~
Second Fire	Pre-industrial
2.5th Fire	Transition
Third Fire	Industrial
Pyrocene	Post-industrial

Stages are attitudes towards fire and land that imply differing use and management



A Rational Conception of Human Fire

Land Use

Non-Extractive

Livestock

Crops

Forestry

Land Systems

Combine land use intensity and land management practices

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

Land-Fire Systems

A type of Land System from combination of Land Use and Fire Stage

Fire Stage	Land Use: *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

What is the empirical basis?

- Empirical studies of human fire have been conducted in many different academic fields
- However, no global synthesis of human-fire interactions has yet been attempted that covers the breadth of human fire use and suppression

We constructed a freely available Database of Anthropogenic Fire Impacts (DAFI) from a meta-analysis of 1,800 worldwide case studies from over 105 countries between 1990-2020

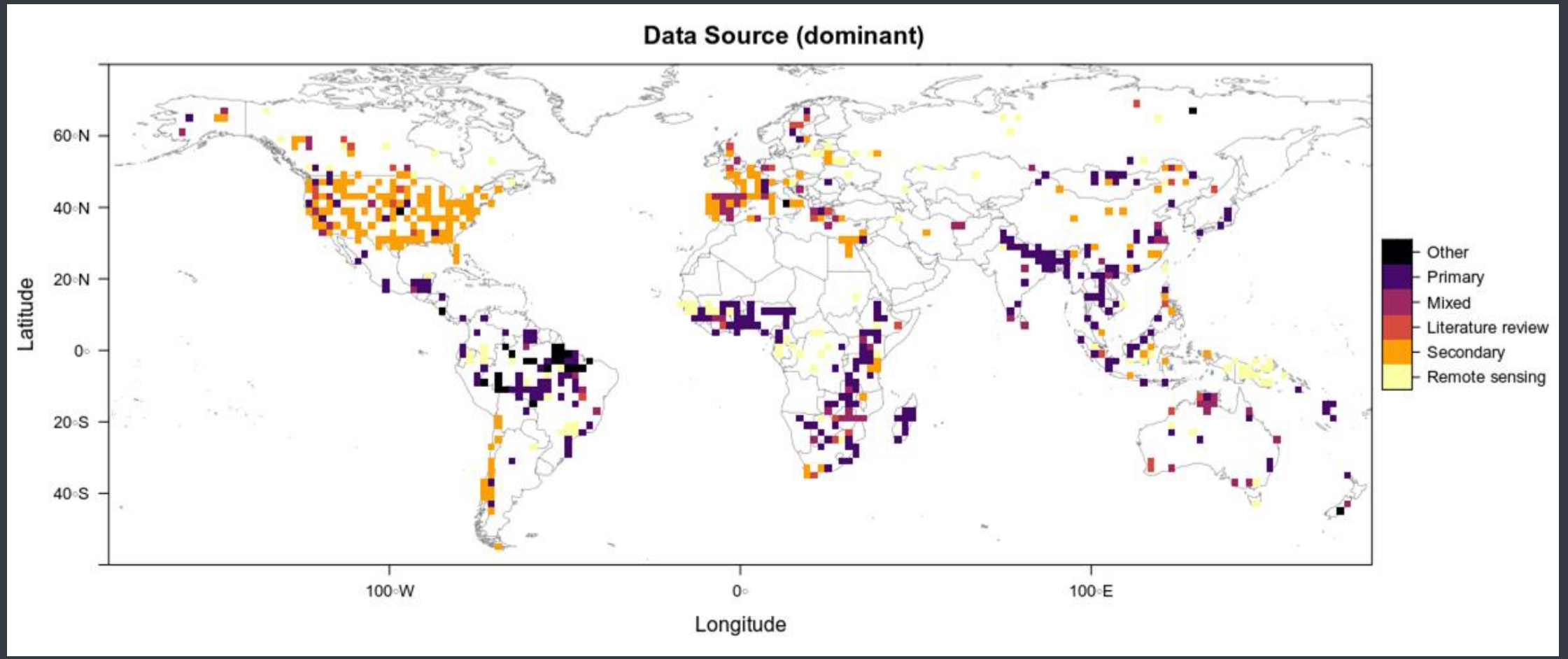
- DAFI was developed in an iterative manner based on the Land-Fire Systems matrix (previous slide)

Download Poster

Download Data

DAFI: Database of Anthropogenic Fire Impacts

Data on fire use, suppression and policies

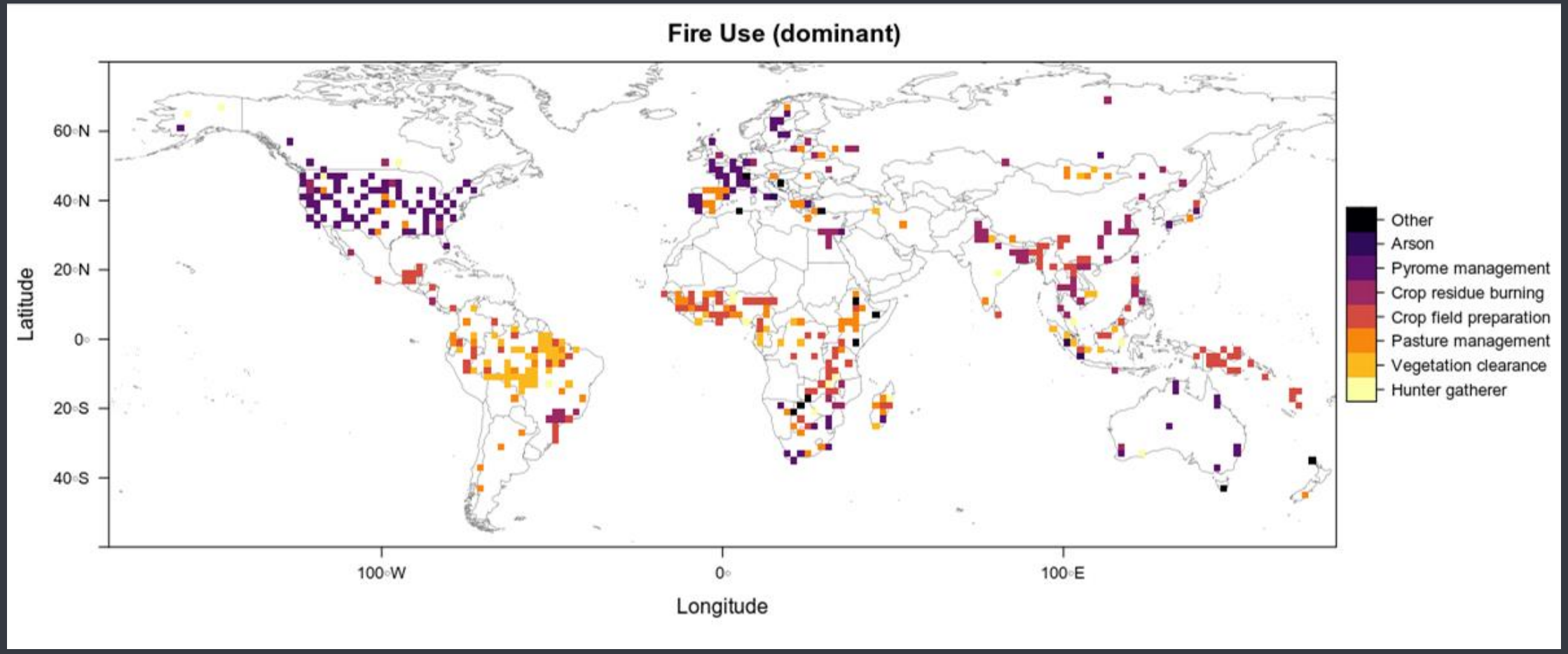


Perkins and Millington (2021)

[FigShare, GitHub]

DAFI Analysis

Seven fire use types describe 90% of the records

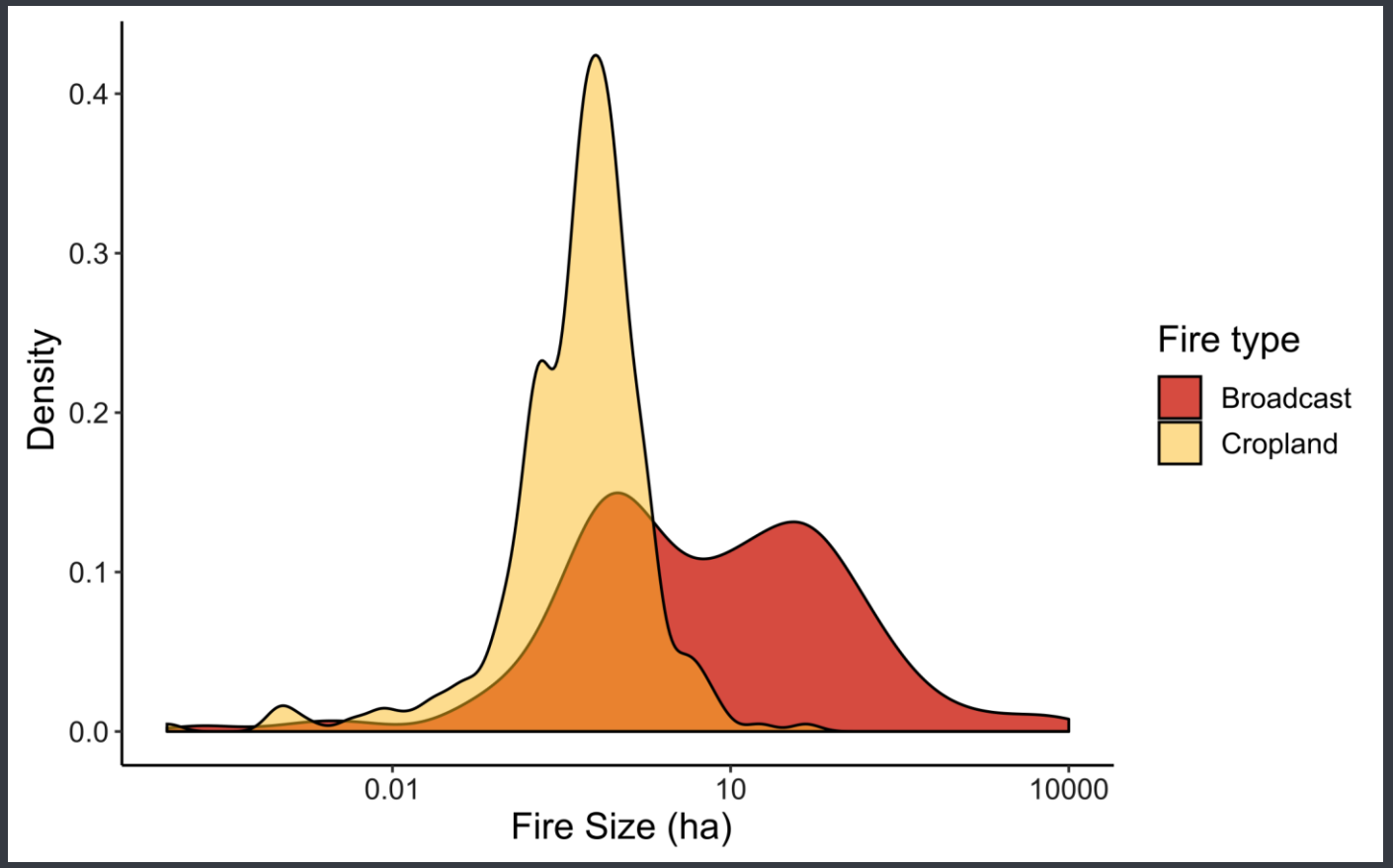


Perkins and Millington (2021)

[FigShare, GitHub]

DAFI Analysis: Fire Size

Crop fires much smaller than other landscape fires

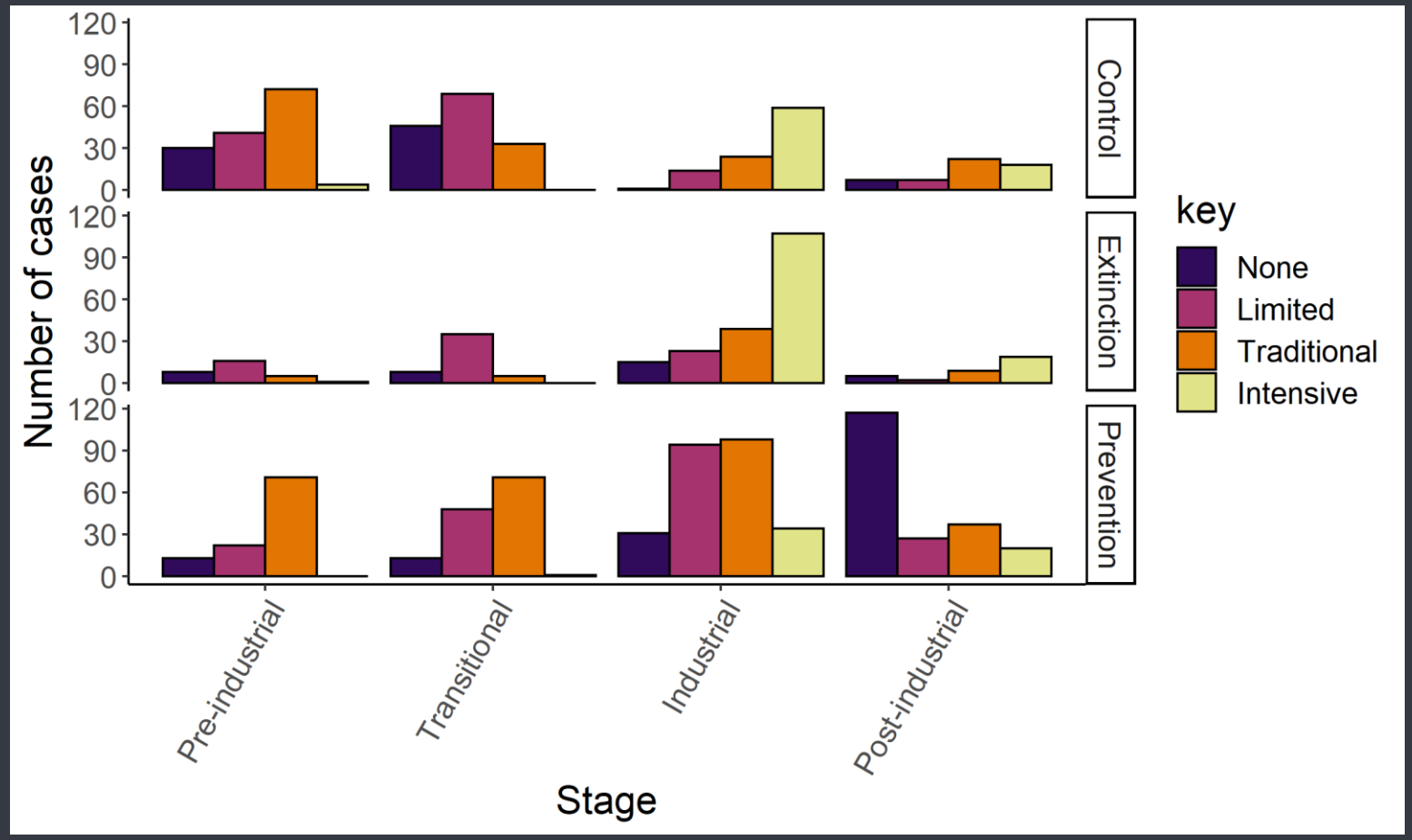


Perkins *et al.* (2021)

[AAG '21]

DAFI Analysis: Suppression

Differences in suppression by fire stage

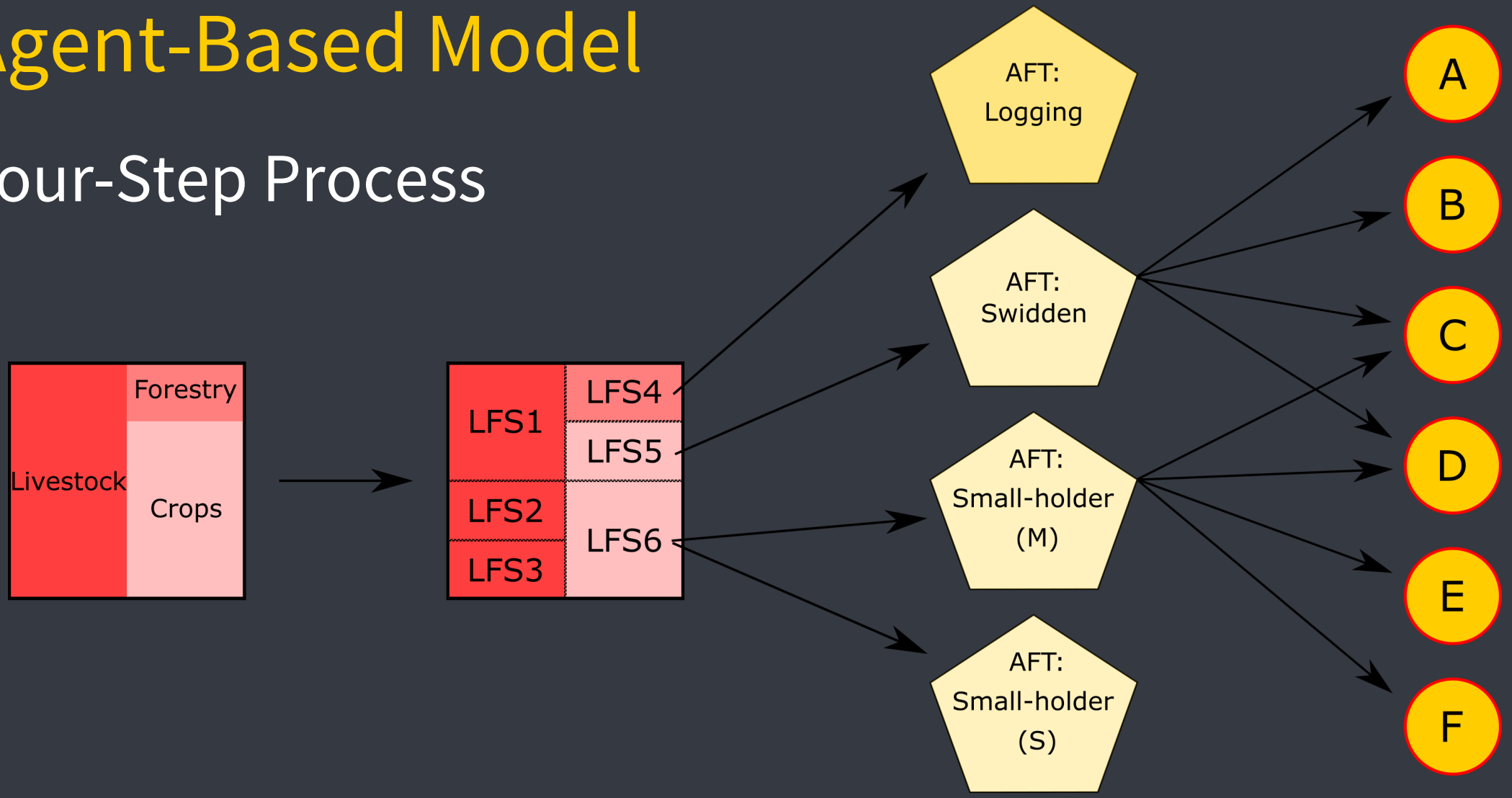


Perkins *et al.* (2021)

[AAG '21]

Agent-Based Model

Four-Step Process



1. Fractional land use in cells of global grid
2. Land-Fire Systems distributed globally
3. Some LFS have multiple Agent Functional Types
4. AFTs have fire uses & suppression actions

1. Fractional Land Use (per cell)

- Cell fractional coverage of land uses from prescribed inputs
- Arable, livestock and urban fraction derived from CMIP6 landcover inputs (Hurtt et al. 2020 [GMD])
- Competition between non-extractive land uses (except urban) and forestry for the remaining space
  - Based on decision trees, similar to those for Land-Fire Systems (see Step 2, next slide)
- In the coupled simulation model, land uses will be derived from JULES-INFERNO outputs

2. Global Distribution of Land-Fire Systems

- Based on decision trees (DT)
  - Structures derived empirically from DAFI with ancillary data
- One DT per Land-Fire System
  - DT probabilities are interpreted as 'competitiveness scores' (CS)
  - CS are compared to determine the global distribution
- Bootstrapping used to find a single resilient tree structure
  - We do not grow an *ensemble* of trees (as others usually do)
  - Our approach establishes numeric distributions for thresholds and probabilities

2. Global Distribution of Land-Fire Systems

1) Model performance (AUC)

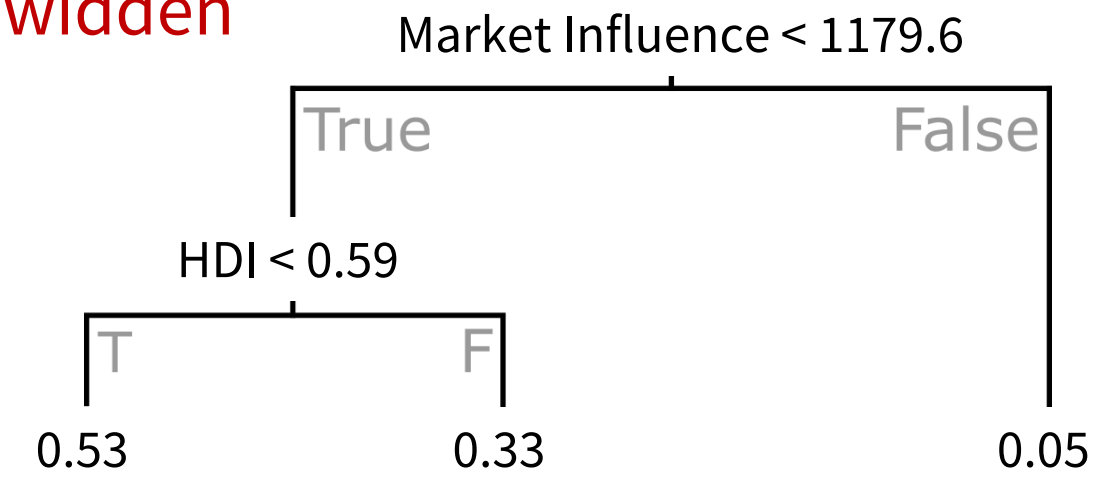
Model	Non-extractive	Livestock	Crops	Forestry	Overall (weighted)
Multinomial	0.752	0.723	0.798	0.928	0.785
Decision trees	0.787	0.785	0.802	0.913	0.814

2) Variable frequency – NB population density is a second order effect

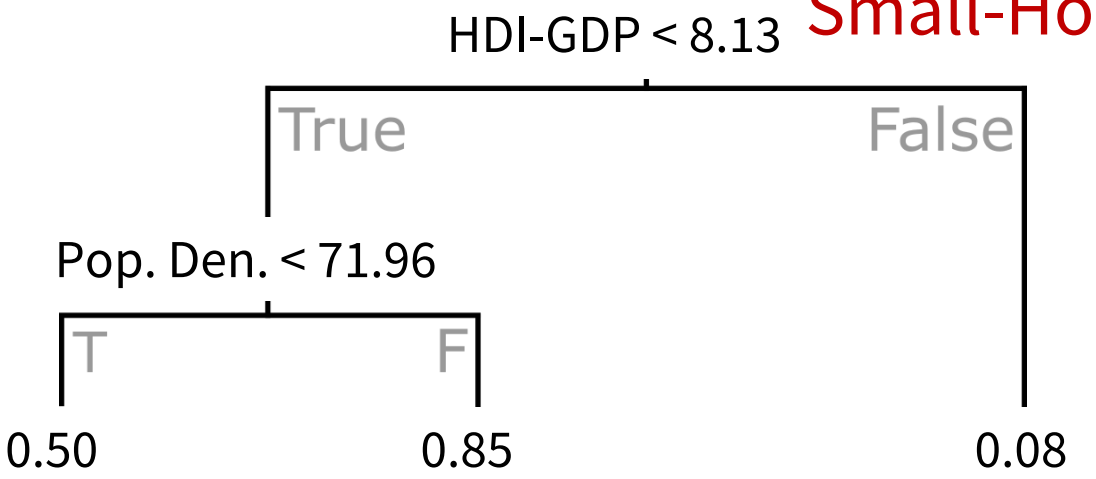
Variable	1st node	2nd / 3rd node
HDI & GDP	12	5
Market access & influence	3	1
Population Density	-	3
ET0 / NPP	1	8
Topography (DEM / TRI)	-	4

2. Example: Decision Trees for Crops LFS

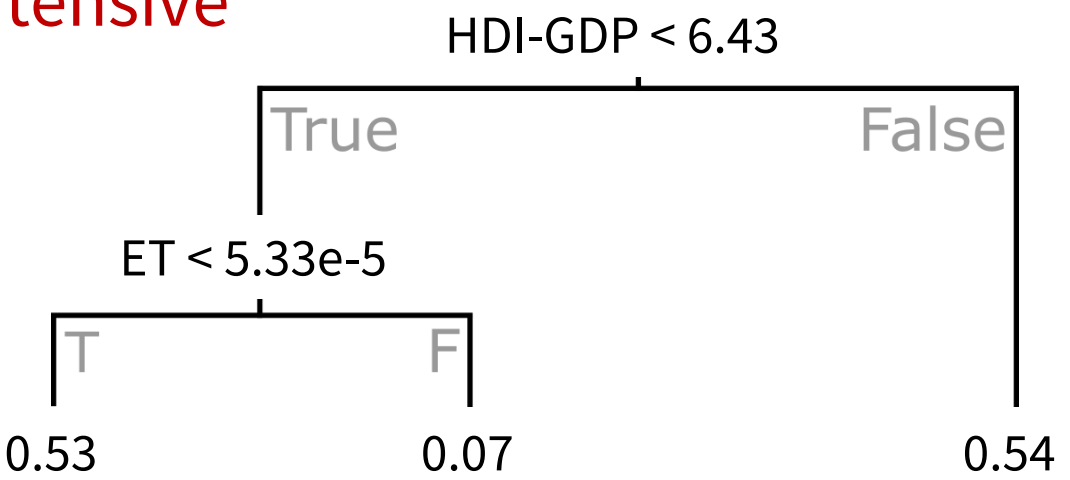
Swidden



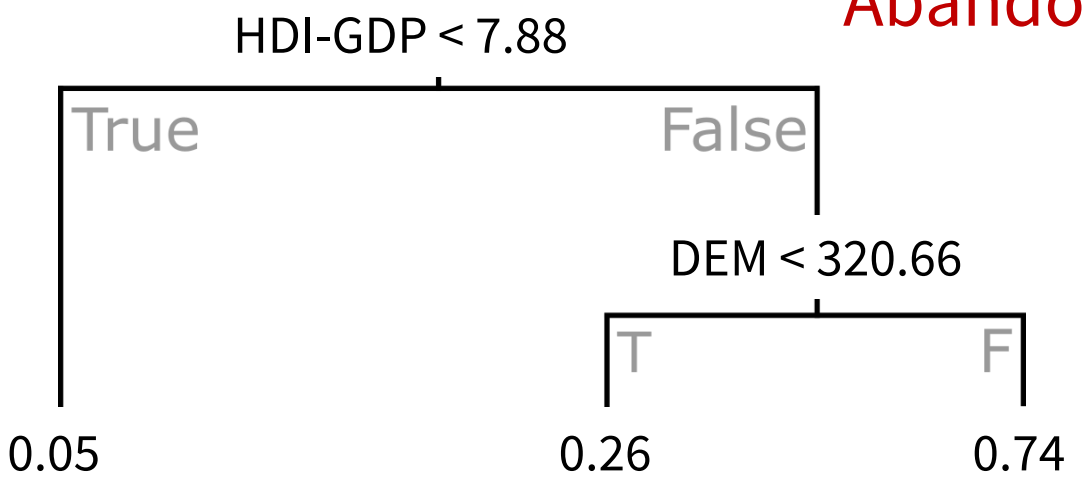
Small-Holder



Intensive

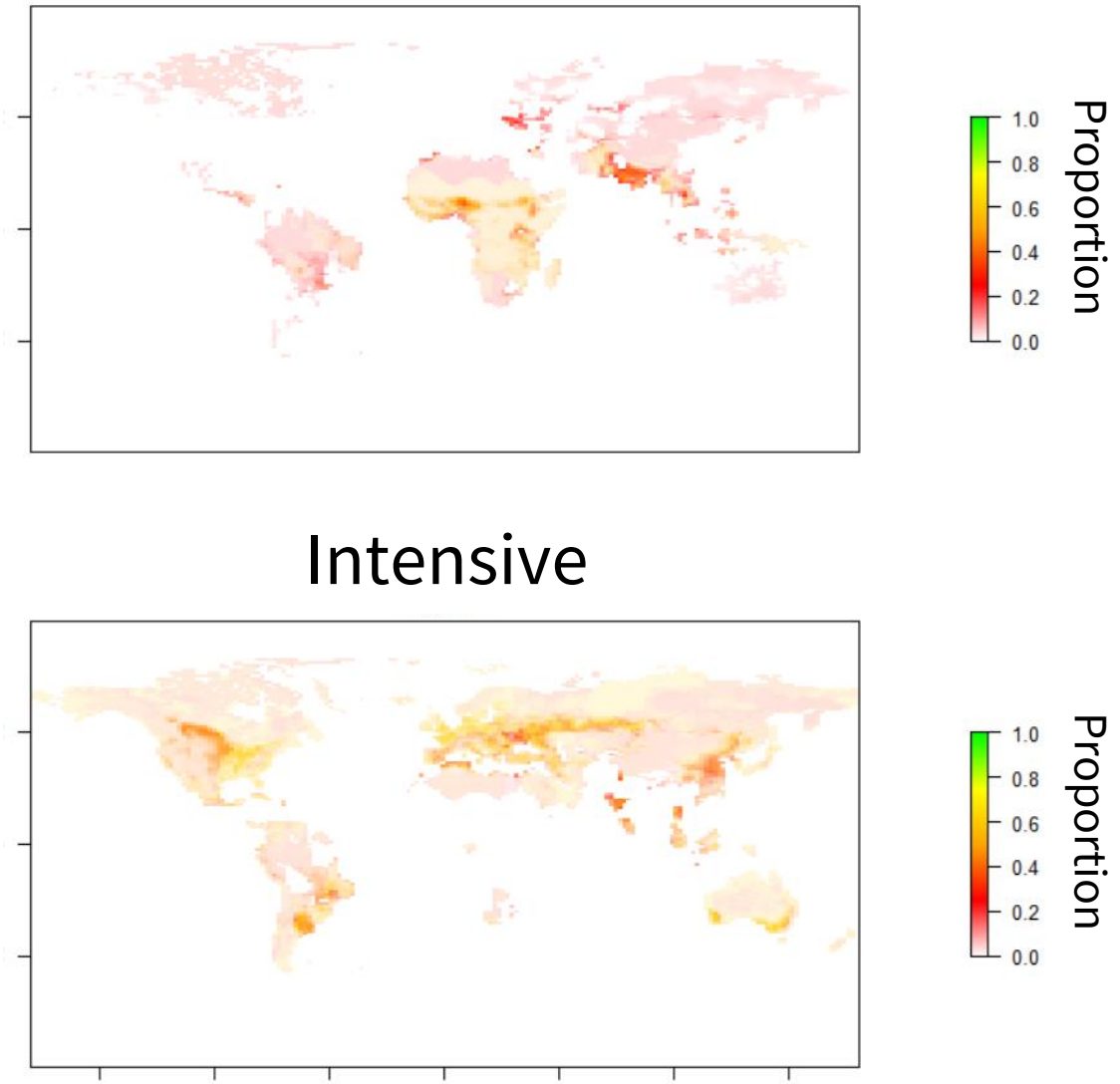


Abandoned

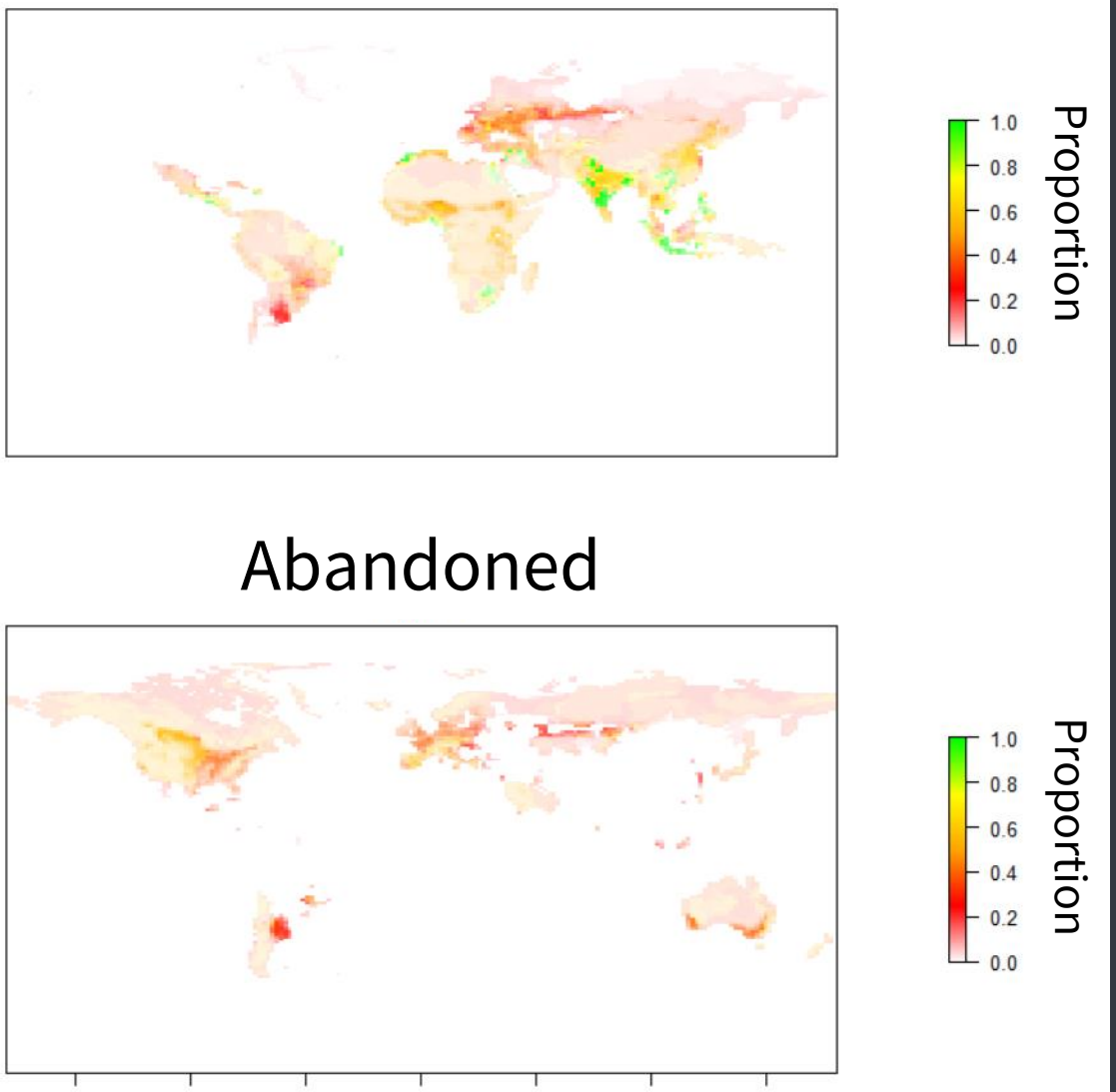


2. Example: Decision Trees for Crops LFS

Swidden



Small-Holder



Intensive

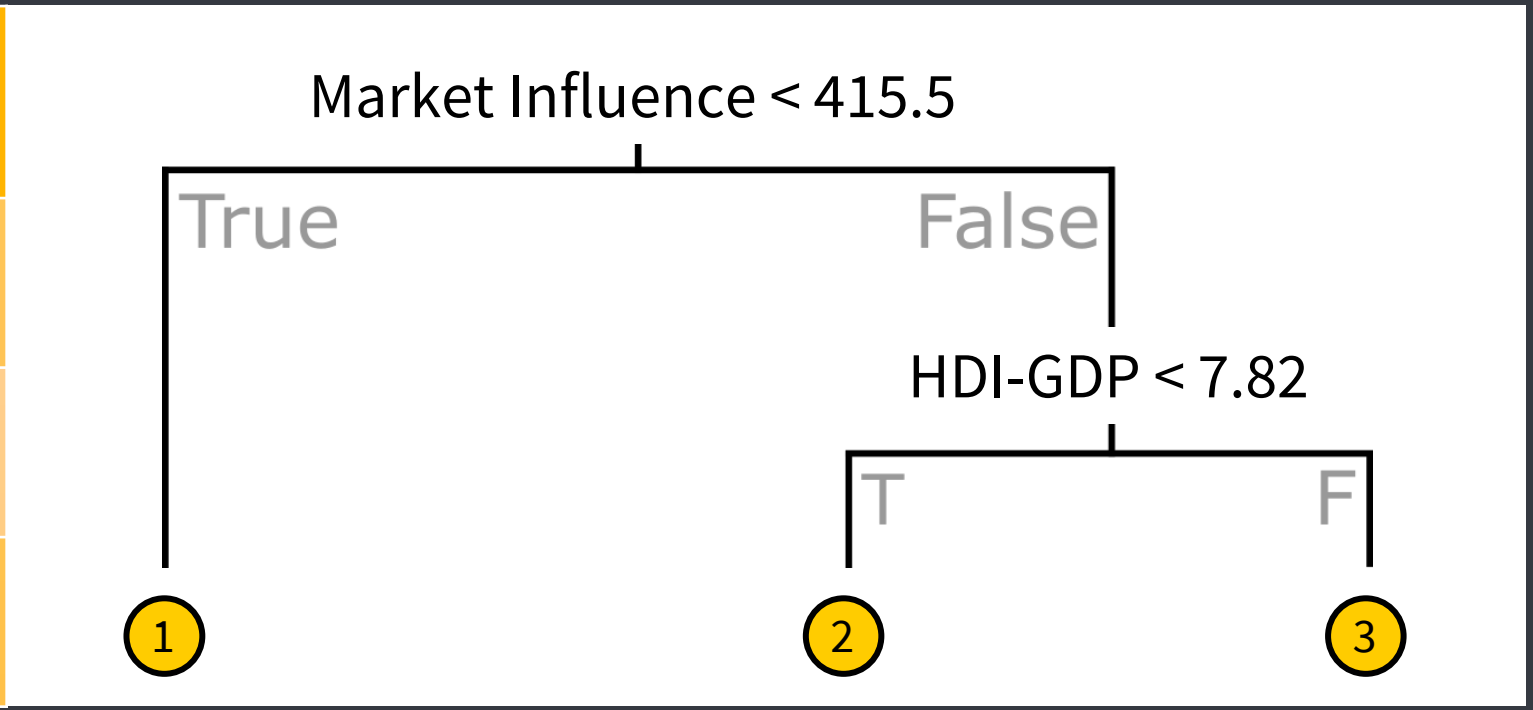
Abandoned

3. Split some LFS to AFT (Example: Crops)

- For Crops Land-Fire Systems there is a one-to-one correspondence with AFTs for all fire stages *except* Transition
  - The Crops-Transition LFS is split using the tree as below:

Proportions

	Swidden	Small-holder (S)	Small-holder (M)
1	0.47	0.30	0.22
2	0.08	0.51	0.41
3	0.00	0.00	1.00

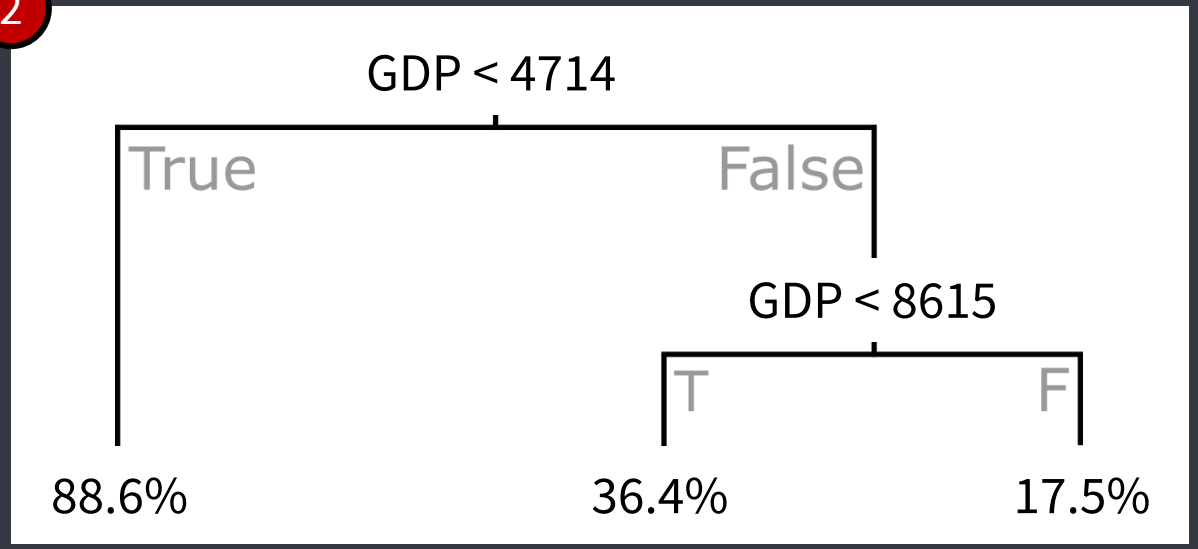


4. Fire Use (Example: Crop Residue Burning)

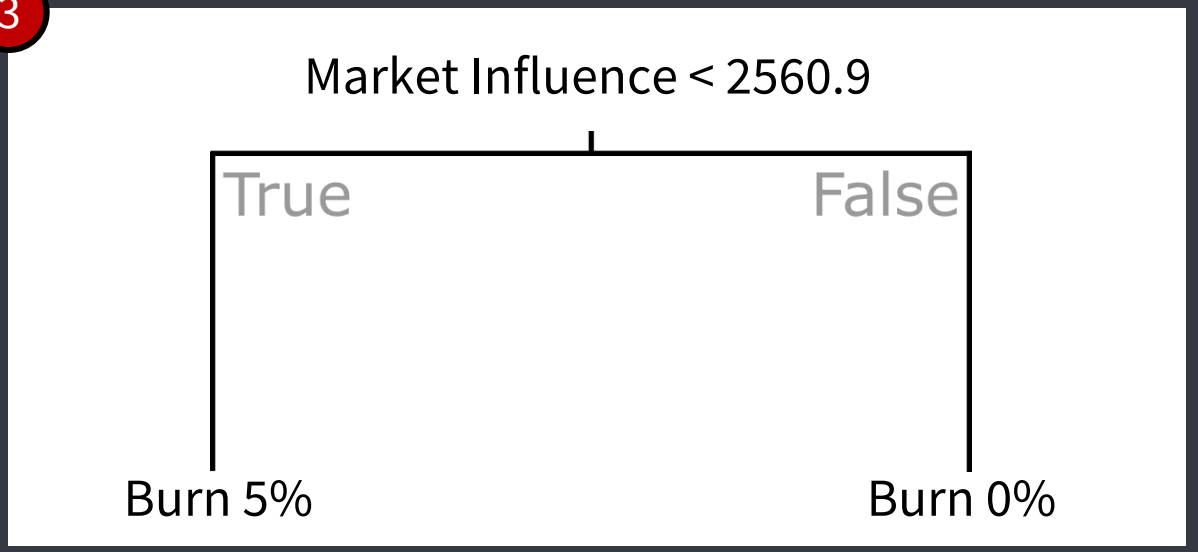
Each AFT is parameterised for fire use and suppression action, also using decision trees

1

2

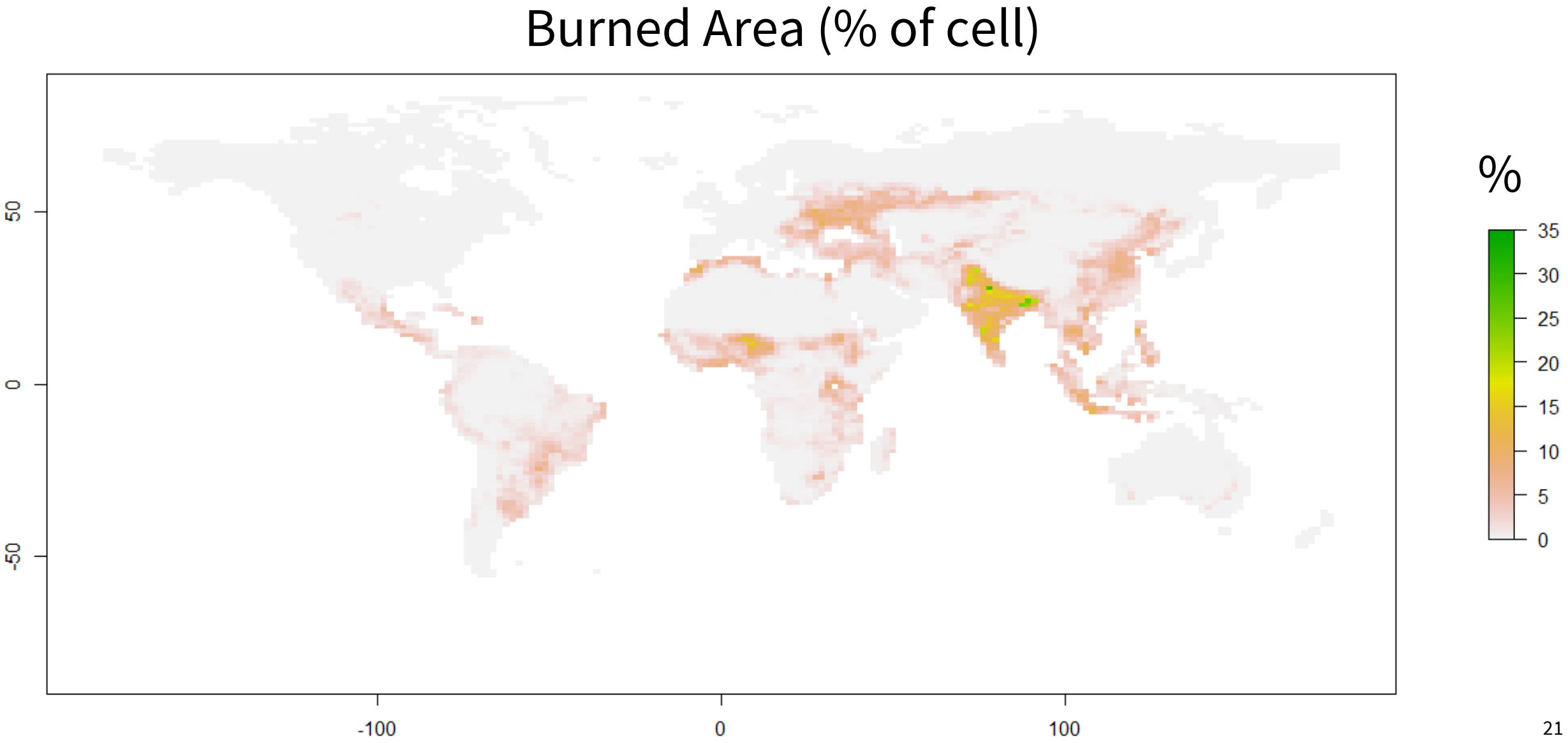


3



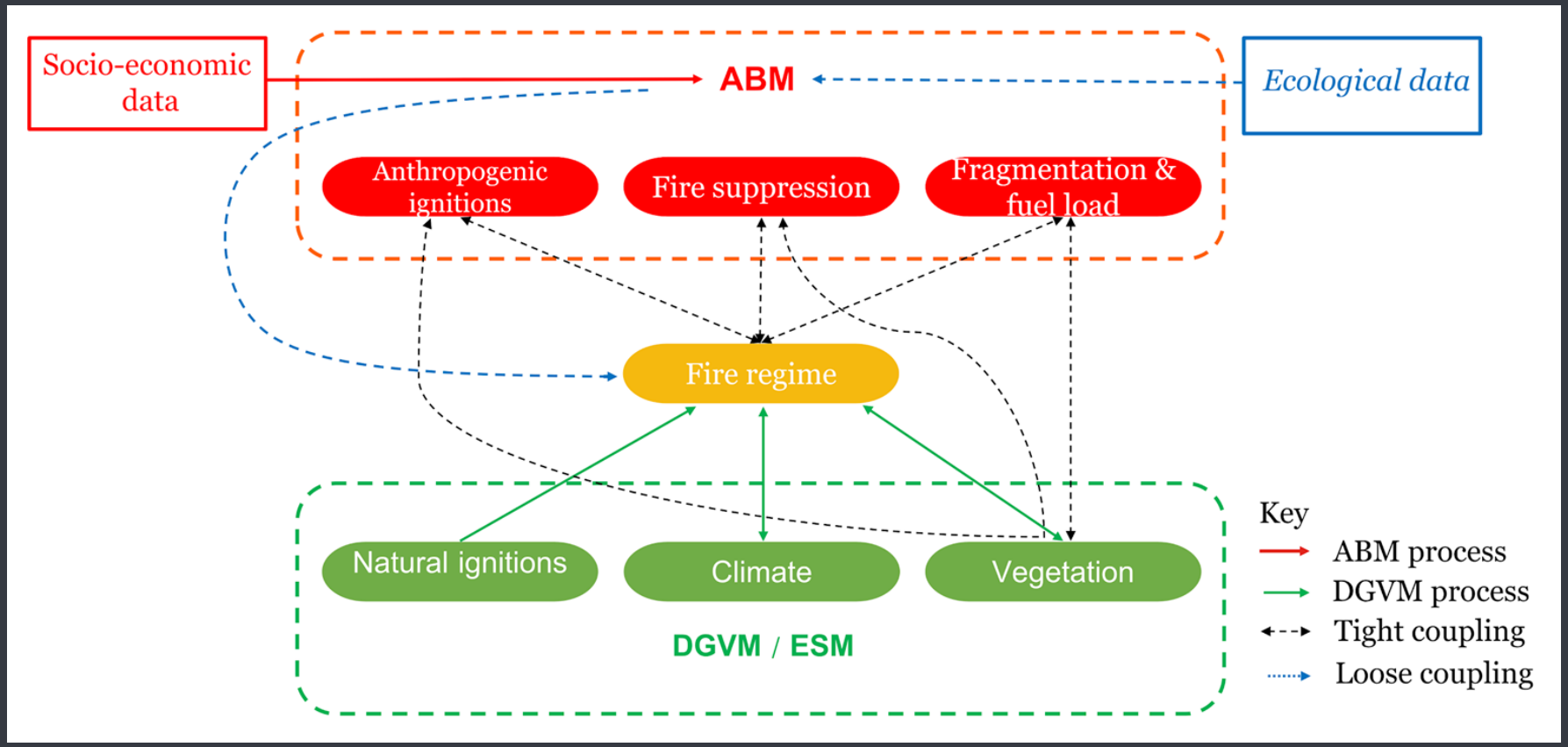
1. Small-holder (subsistence, intended %BA)
2. Small-holder (market-oriented, intended %BA)
3. Intensive farmer (Boolean)

4. Fire Use (Example: Crop Residue Burning)



Next Steps and Challenges

- Coupling ABM with JULES-INFERNO (e.g. below)
- Verification - e.g. MODIS detection of small agricultural fires



Ford *et al.* (In Review)