A data-based method to determine the regional impact of agriculture on fire seasonality

(or... Separating agricultural and non-agricultural fire seasonality at regional scales)

B.I. Magi[1], S. Rabin[2], E. Shevliakova[2,3], and S. Pacala[2]

(1) University of North Carolina, Charlotte, NC (2) Princeton University, Princeton, NJ (3) NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ

Princeton University EEB

Fire management widespread, unquantified

- **Cropland** and **pasture** management, **deforestation**, **suppression**
- Humans in **global fire models**—population density insufficient [1]
- Remote sensing challenges (esp. croplands, pasture)...
- No complete large-scale understanding
- Need for **attribution** of observed burning

Objective: Categorize observed fire

- Method presented here to statistically estimate the fraction of remote-sensed fire to different land use/cover types.
- Here, **agricultural vs. non-agricultural** land—but **generalizable** to any number of categories.
- Focus on **seasonality**—important for fire-vegetation-climate interactions, aerosol emissions & human health, etc.
- **Regional** analysis at **0.5°** resolution

Method: Attribution by "unpacking"

Definitions

- $p_{a,i}$ and $p_{n,i}$: Proportions of grid cell i that are agricultural and non-agricultural land, respectively. Sum to 1.
- E_i: Amount of fire estimated/expected in grid cell i

$$E_i = p_{a,i} * \overline{F_a} + (1 - p_{a,i}) * \overline{F_n}$$

- $\overline{F_a}$ and $\overline{F_n}$: Amount of fire in the average grid cell if entirely covered by agricultural and non-agricultural land, respectively. (Unknown, being estimated.)
- D: Observed fire activity (fire counts or burned area)

$$S = \sum_{i=1}^{N} (E_i - D_i)^2$$

Let $\frac{\partial S}{\partial \overline{F_n}} = 0$ Let $\frac{\partial S}{\partial \overline{F_a}} = 0$

(2) $$\overline{F_a} = \frac{\overline{D}}{\overline{p_a}} + \left(1 - \frac{1}{\overline{p_a}}\right)\overline{F_n}$$

(1) $$\overline{F_n} = \overline{D} - \frac{covariance(p_a, D)}{variance(p_a)}\overline{p_a}$$

Fig. 1

($\overline{F_a}$ and $\overline{F_n}$ constrained to ≥ 0)

Data sources

Attribution analysis
- Land use: History Database of the Global Environment (HYDE) v3 [2]
- Fire counts: MODIS Terra (11/2000–12/2009) and Aqua (7/2002–12/2009) [3].
- Burned area: Global Fire Emissions Database (GFED) version 3.1, 2000-2009 [4; 5]

Other data on result figures
- Lightning: NASA LIS/OTD [6]
- Flammability (calculated after ref. [1], but ignoring vegetation density)
  - Temp. and RH: National Center for Environmental Prediction reanalysis product [7]
  - Rainfall: Global Precipitation Climatology Project version 2.2 [8]

Study regions

Regions used in this study [after ref. 9]:

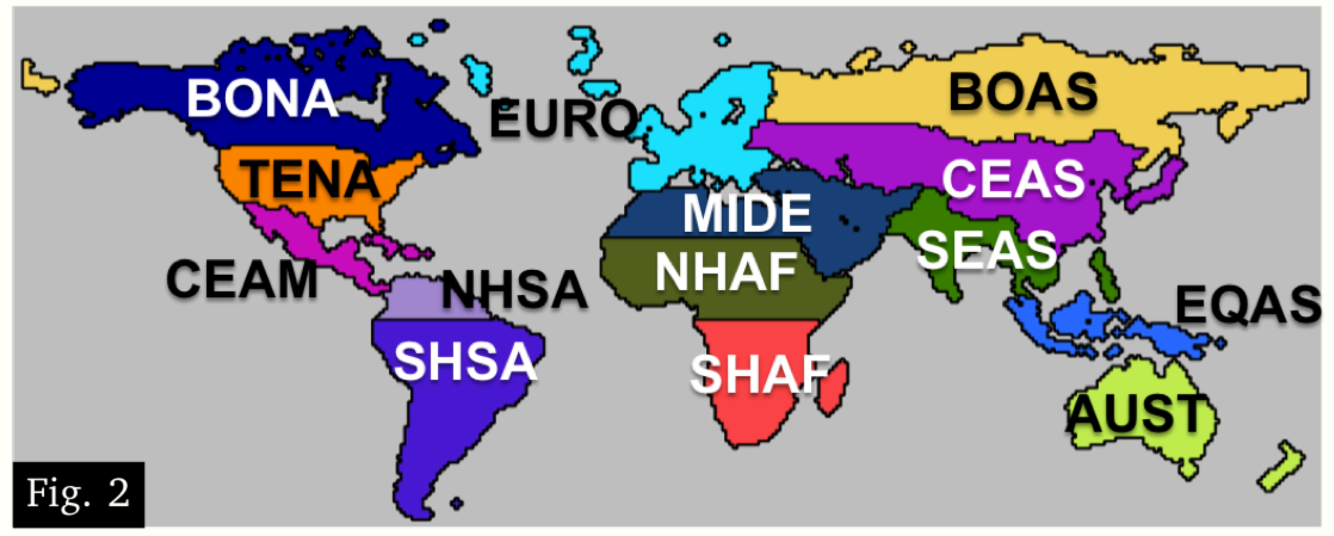


Fig. 2

Global distribution (top) and composition (bottom) of agriculture [data from HYDE; 2]:

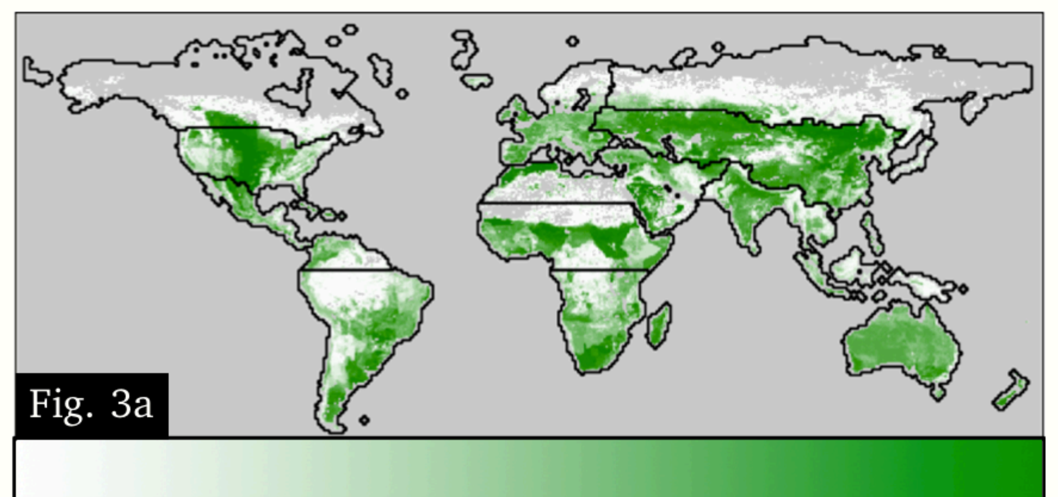


Fig. 3a

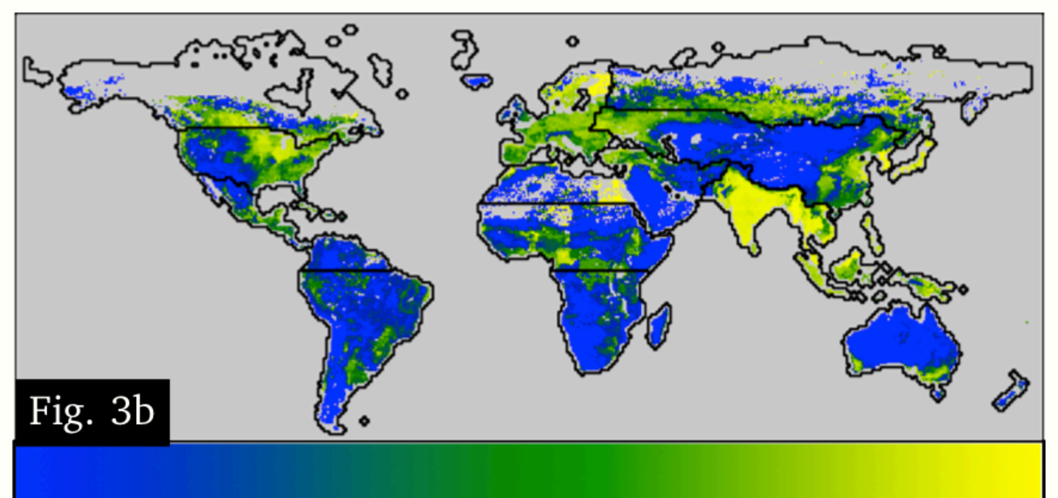
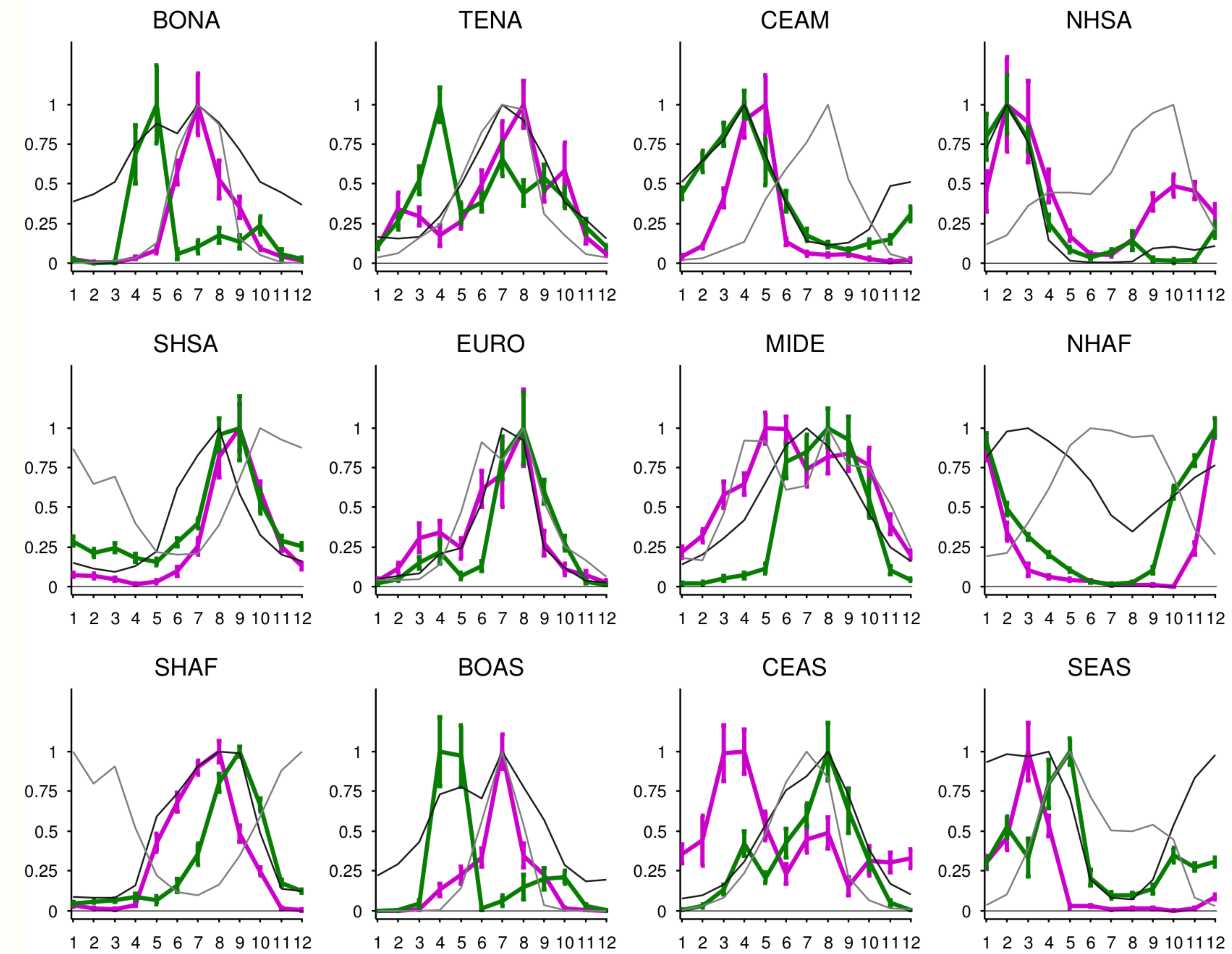


Fig. 3b

Average monthly seasonality of agricultural and non-agricultural burning

Compared with flammability and lightning; each curve normalized to its maximum.

Agricultural burning = *green* *Flammability* = *gray*
Non-agricultural burning = *pink* *Lightning flash rate* = *black*



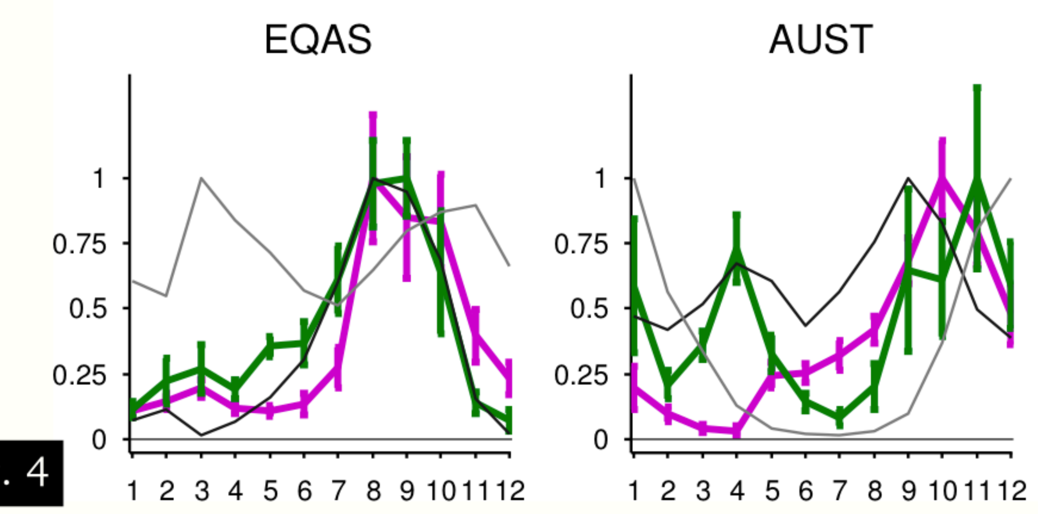


Fig. 4

Illustrative **examples**:

Northern hemisphere Africa (NHAF): Early-dry-season preventative burning practice [10] apparent—agricultural fire begins earlier.

Boreal Asia (BOAS): Non-agricultural burning strongly linked to flammability peak. Agricultural burning timed differently, matches previous results [11] for cropland.

Next steps

- Improve **regionalization**
- **Finer-scale** analysis in some regions
- Expand to **more land uses** (separate cropland/pasture, add deforestation)
- Analyze fire counts / burned area explicitly, **not just seasonality**

Works cited

[1] O. Pechony, D. T. Shindell, *J. Geophys. Res.* **114** (2009).

[2] K. Klein Goldewijk, A. Beusen, G. Van Drecht, M. De Vos, *Global Ecology and Biogeography* **20**, 73 (2010).

[3] L. Giglio, I. Csiszar, C. O. Justice, *J. Geophys. Res.* **111** (2006).

[4] L. Giglio, *et al.*, *Biogeosciences* **7**, 1171 (2010).

[5] G. van der Werf, *et al.*, *Atmos. Chem. Phys.* **10**, 11707 (2010).

[6] H. Christian, *et al.*, *J Geophys Res-Atmos* **108** (2003).

[7] E. Kalnay, *et al.*, *Bulletin of the American Meteorological Society* **77**, 437 (1996).

[8] G. J. Huffman, R. F. Adler, D. T. Bolvin, G. Gu, *Geophys. Res. Lett.* **36** (2009).

[9] L. Giglio, G. van der Werf, J. Randerson, G. Collatz, P. Kasibhatla, *Atmos. Chem. Phys.* **6**, 957 (2006).

[10] P. Laris, *Hum Ecol* **30**, 155 (2002).

[11] S. Korontzi, J. McCarty, T. Loboda, S. Kumar, C. Justice, *Global Biogeochemical Cycles* **20** (2006).

Acknowledgements

Sam has received fellowship support from Princeton's **Department of Ecology & Evolutionary Biology**. The **Carbon Mitigation Initiative** has also provided much research funding, including for this conference.

srabin@princeton.edu