

SUPPLEMENTARY MATERIALS

Drivers of Fire Anomalies in the Brazilian Amazon: Lessons Learned from the 2019 Fire Crisis

Marcus V. F. Silveira ^{1,*}, Caio A. Petri ^{1†}, Igor S. Broggio ^{2†}, Gabriel O. Chagas¹, Mateus S. Macul¹, Cândida C. S. S. Leite¹, Edson M. M. Ferrari¹, Carolina G. V. Amim³, Ana L. R. Freitas¹, Alline Z. V. Motta⁴, Luiza M. E. Carvalho⁴, Celso H. L. Silva Junior¹, Liana O. Anderson⁵, Luiz E. O. C. Aragão^{1,6}

¹ Earth Observation and Geoinformatics Division, National Institute for Space Research, São José dos Campos 12227-010, Brazil; caio.petri@inpe.br (C.A.P.); gabriel.chagas@inpe.br (G.O.C.); mateus.macul@inpe.br (M.S.M.); candida.leite@inpe.br (C.C.S.S.L.); edson.ferrari@inpe.br (E.M.M.F.); ana.defreitas@inpe.br (A.L.R.F.); celso.junior@inpe.br (C.H.L.S.J.); luiz.aragao@inpe.br (L.E.O.C.A.)

² Laboratory of Environmental Sciences, Centro de Biociências e Biotecnologia, Universidade Estadual do Norte Fluminense Darcy Ribeiro (UENF), Campos dos Goytacazes 28 013 - 600, Brazil; igor@pq.uenf.br

³ Institute of Science and Technology, São Paulo State University (UNESP) / National Centre for Monitoring and Early Warning of Natural Disasters (CEMADEN), São José dos Campos 12247-004, Brazil; carolina.vergeti@unesp.br

⁴ Department of Forestry, Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM), Diamantina 39100-000, Brazil; alline.zagnoli@ufvjm.edu.br (A.Z.V.M.); luiza.esteves@ufvjm.edu.br (L.M.E.C.)

⁵ National Centre for Monitoring and Early Warning of Natural Disasters (CEMADEN), São Jose dos Campos 12227-010, Brazil; liana.anderson@cemaden.gov.br

⁶ College of Life and Environmental Sciences Amory Building, University of Exeter, Rennes Drive, Exeter EX4 4RJ, UK

* Correspondence: markgvenf@gmail.com

† These authors contributed equally to this work

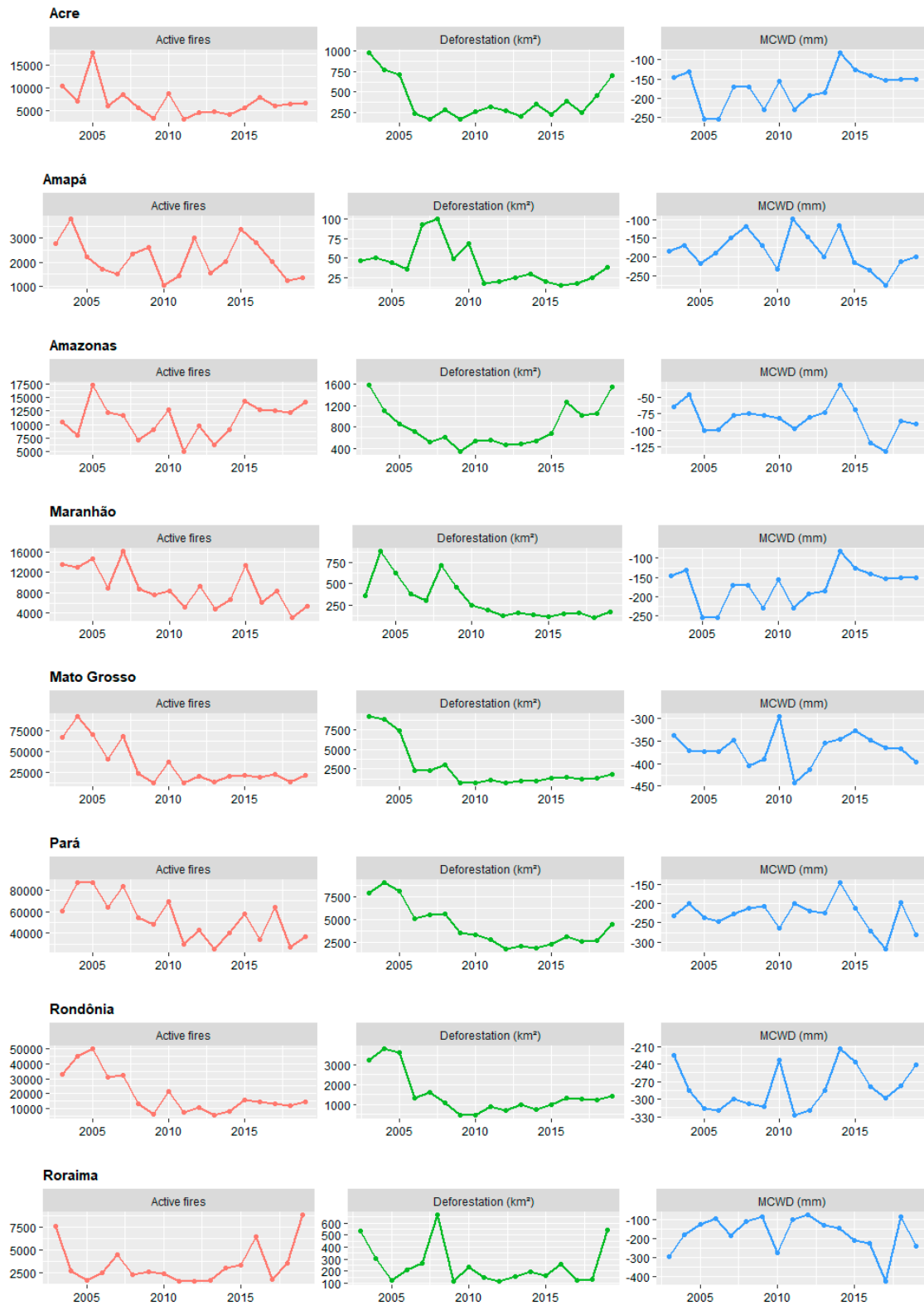


Figure S1. Annual time-series of active fire occurrence, old-growth deforestation and mean Maximum Cumulative Water Deficit (MCWD) for Amazonian states.

Table S1. Distribution of fire anomalous cells in 2019 across Amazonian states.

State	Proportion (%) from total number of cells in each anomaly type	
	Across-grid anomaly	Maximum fire count
AC	5.60	8.04
AM	13.71	21.98
AP	0.31	0.63
MA	2.26	2.00
MT	22.08	16.89
PA	32.01	21.36
RO	14.78	9.12
RR	9.25	19.48
Total number of cells	1590	1119

Table S2. Proportion of fire anomalous cells in 2019 intersecting each respective land tenure category.

Land Tenure categories	Proportion (%) from total number of cells in each anomaly type	
	Across-grid anomaly	Maximum fire count
Undesignated public lands	57.92	57.64
Indigenous lands	9.69	23.59
Protected areas of strict use	6.29	7.95
Protected areas of sustainable use	17.74	22.43
Agrarian settlements	38.99	25.02
Private lands	89.31	75.96
Total number of cells	1590	1119

Table S3. Proportion of monthly and total burned area in 2019 in the biome within across-grid anomalous cells in 2019.

Month	Biome	Burned area (km ²)	Proportion of burned area (%) within anomalous cells from the biome's total
		2019 across-grid anomalous cells	
Jan.	2373.00	204.50	8.62
Feb.	2032.50	312.25	15.36
Mar.	4252.25	2715.00	63.85
Apr.	1280.25	741.75	57.94
May.	880.25	178.50	20.28
Jun.	747.00	160.50	21.49
Jul.	1842.00	769.25	41.76
Aug.	13694.75	9215.75	67.29
Sept.	11488.75	5974.50	52.00
Oct.	2496.75	397.00	15.90
Nov.	3395.75	473.25	13.94
Dec.	415.50	36.50	8.78
Total	44898.75	21178.75	47.17

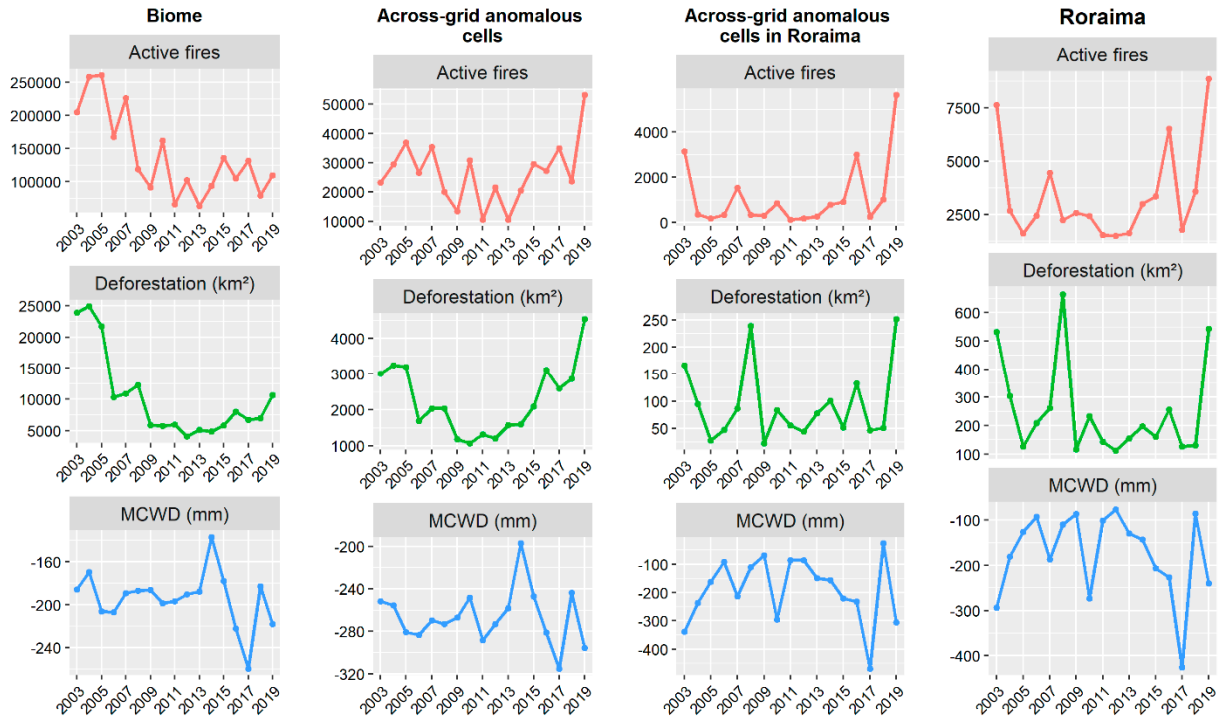


Figure S2. Time-series of fire occurrence, old-growth deforestation, and mean Maximum Cumulative Water Deficit (MCWD) for the biome, total across-grid anomalous cells in 2019, across grid anomalous cells in Roraima, and total cells in Roraima.

Table S4. Welch's t-test results for differences between across-grid anomalous cells in 2019 and cells with non-anomalous fire occurrence at the 5% significance level, for the biome in general.

Variable	Mean value		p-value alternative: greater mean for anomalous	p-value alternative: lower mean for anomalous
	non-anomalous fire cells	across-grid anomalous cells		
Previous fire activity (fire count)	16	54	<0.0001	
Deforestation in 2019 (km²)	0.47	2.85	<0.0001	
Previous deforestation (km²)	1.5	7.71	<0.0001	
Pasture (km²)	28.21	30.77	<0.0001	
Cropland (km²)	3.19	1.54	1	<0.0001
Forest Age I (km²)	3.61	3.35	1	0.0005
Forest Age II (km²)	2.83	1.68	1	<0.0001
Forest Age III (km²)	2.6	1.33	1	<0.0001
Total Forest Edge (km)	251.13	267.26	<0.0001	
Mean Fragment Area (ha)	8.73	4.25	1	<0.0001
Number of fragments	69	65	1	0.0028
MCWD (mm)	-299.41	-295.77	0.1546	0.8454
Distance to roads (km)	63.57	64.89	0.2471	0.7529
Rural population density	271	120	1	<0.0001

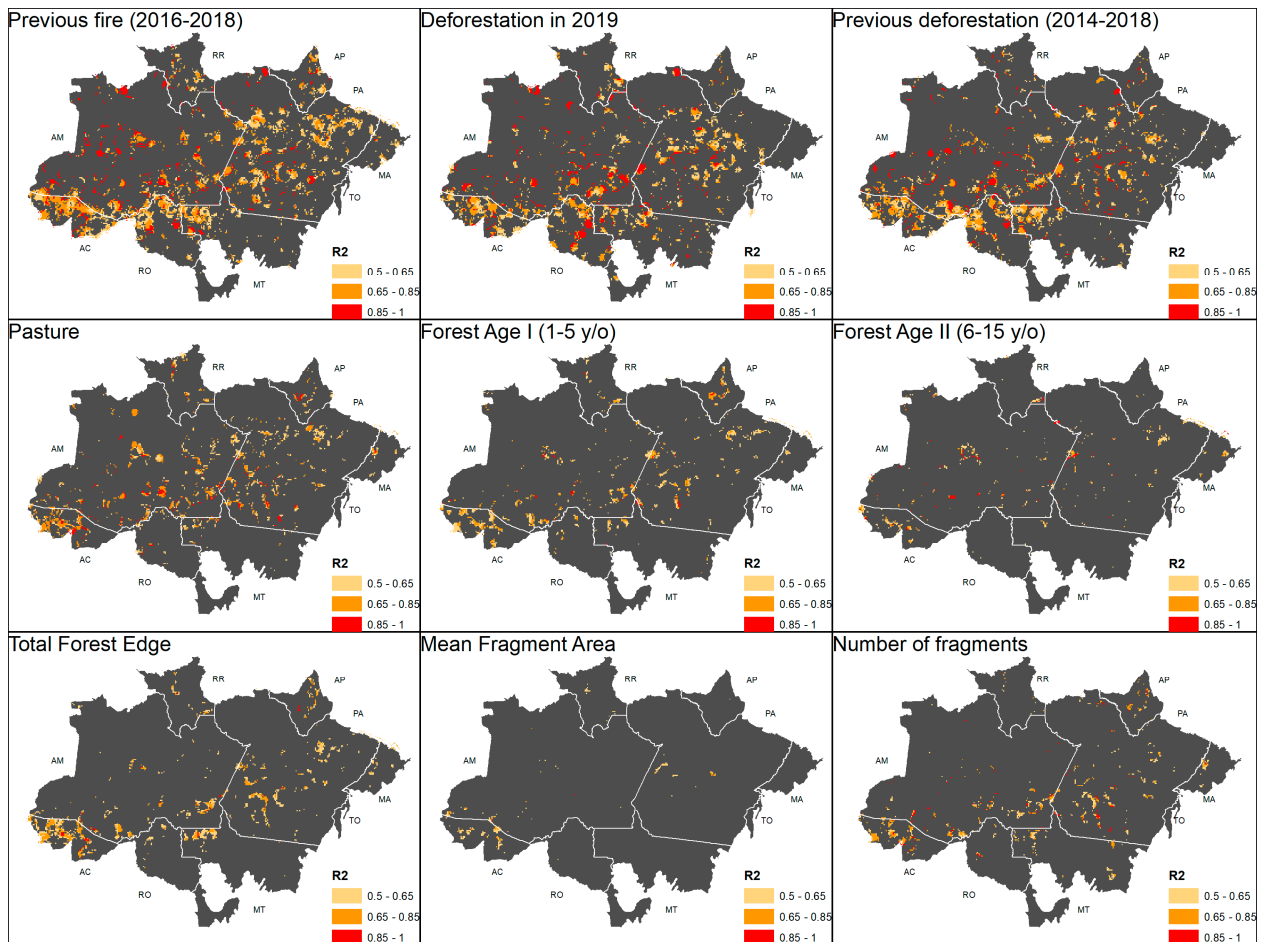


Figure S3. Local bivariate relationships between each driver and fire occurrence in 2019. Each 10 km pixel in this map is representing a statistically significant relationship of a given driver and fire occurrence in 2019 within a region comprised by the pixel and its 40 nearest neighbors. Only positive relationships with fire occurrence are shown for all variables, with the exception of mean fragment area for which only negative relationships are shown.