Quantifying tropical forest degradation in the Brazilian Arc of Deforestation: A multi-sensor, multi-scale approach

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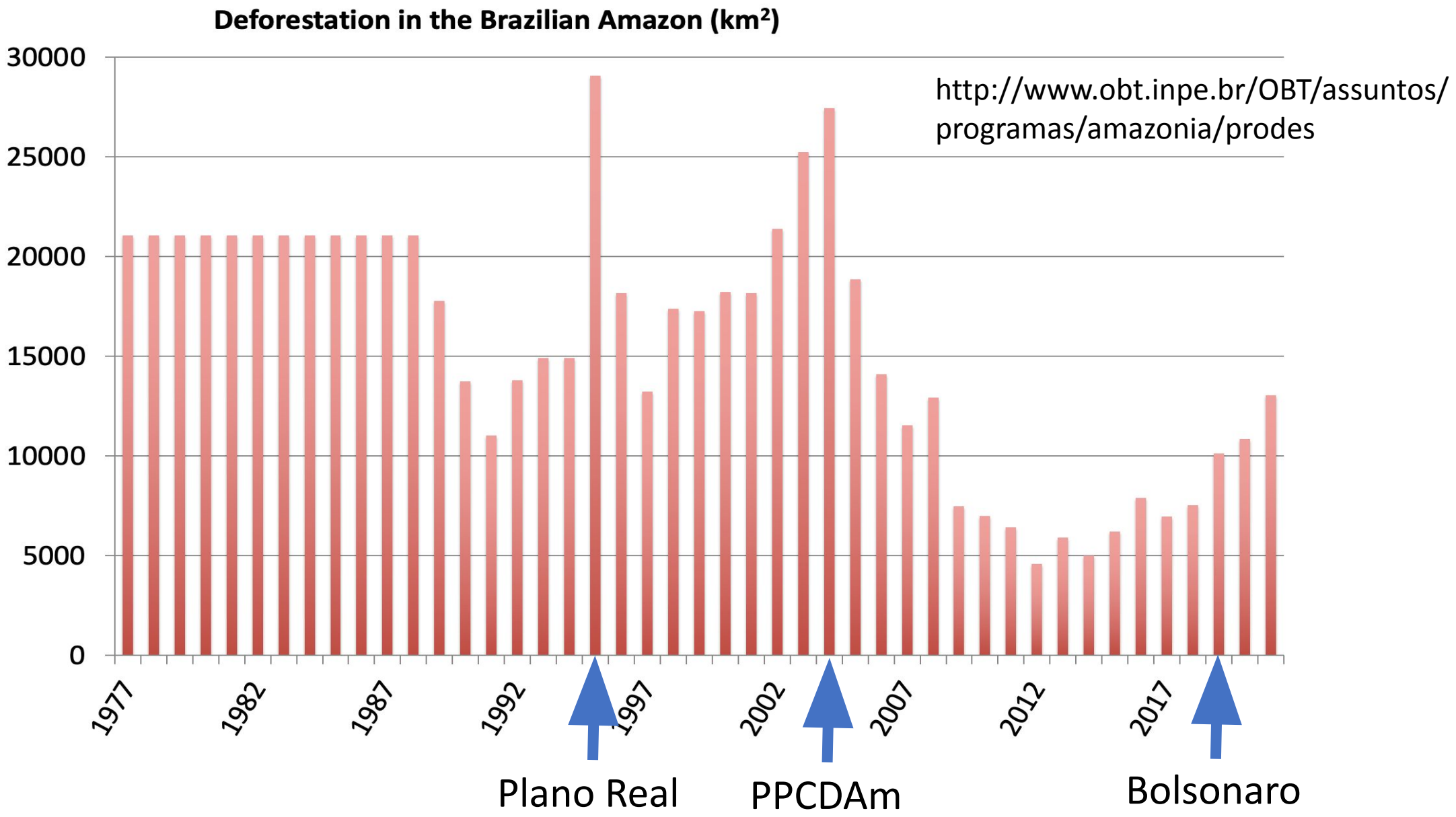
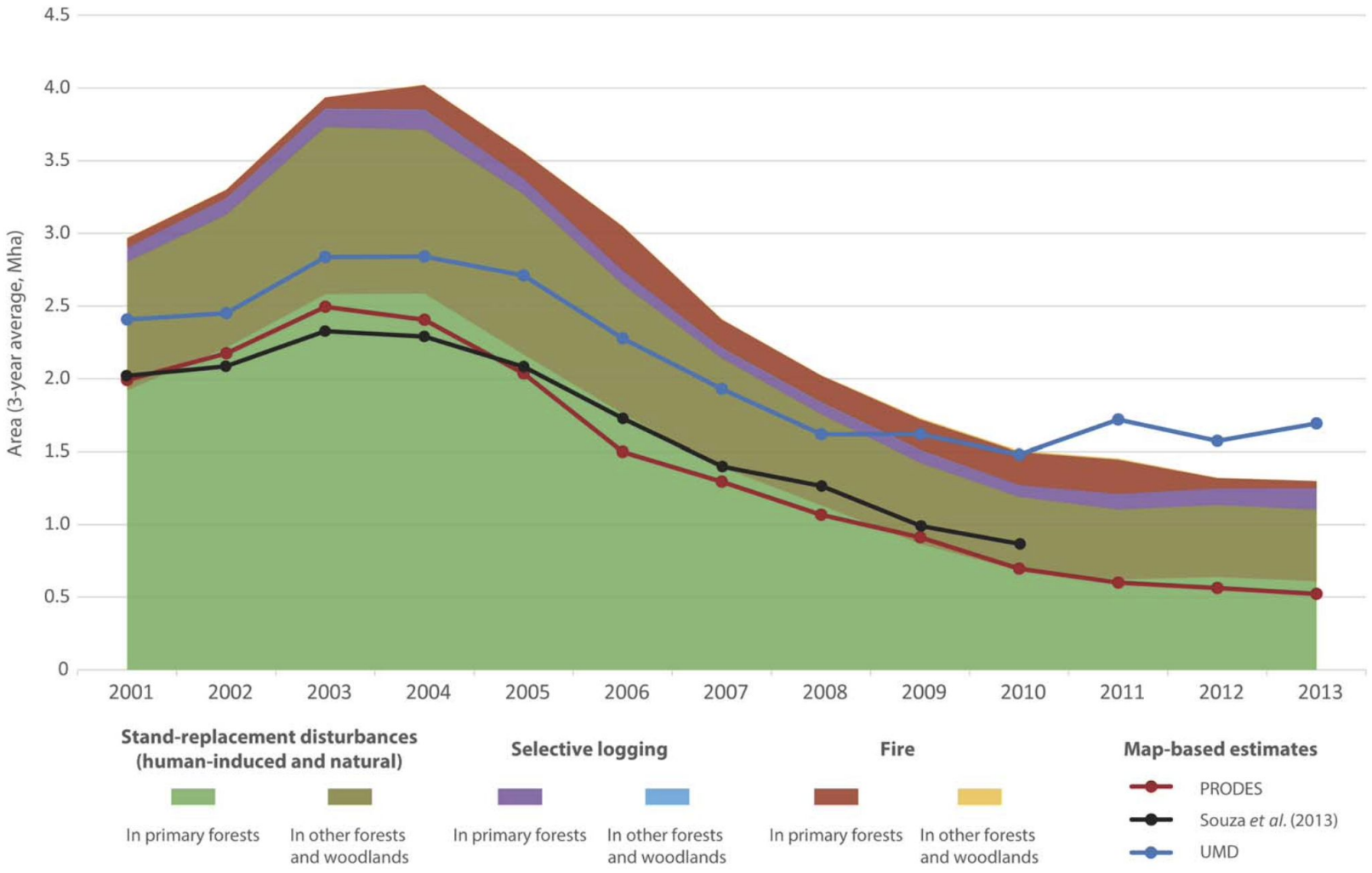
Deforestation in the Brazilian Amazon: An amazing record from INPE

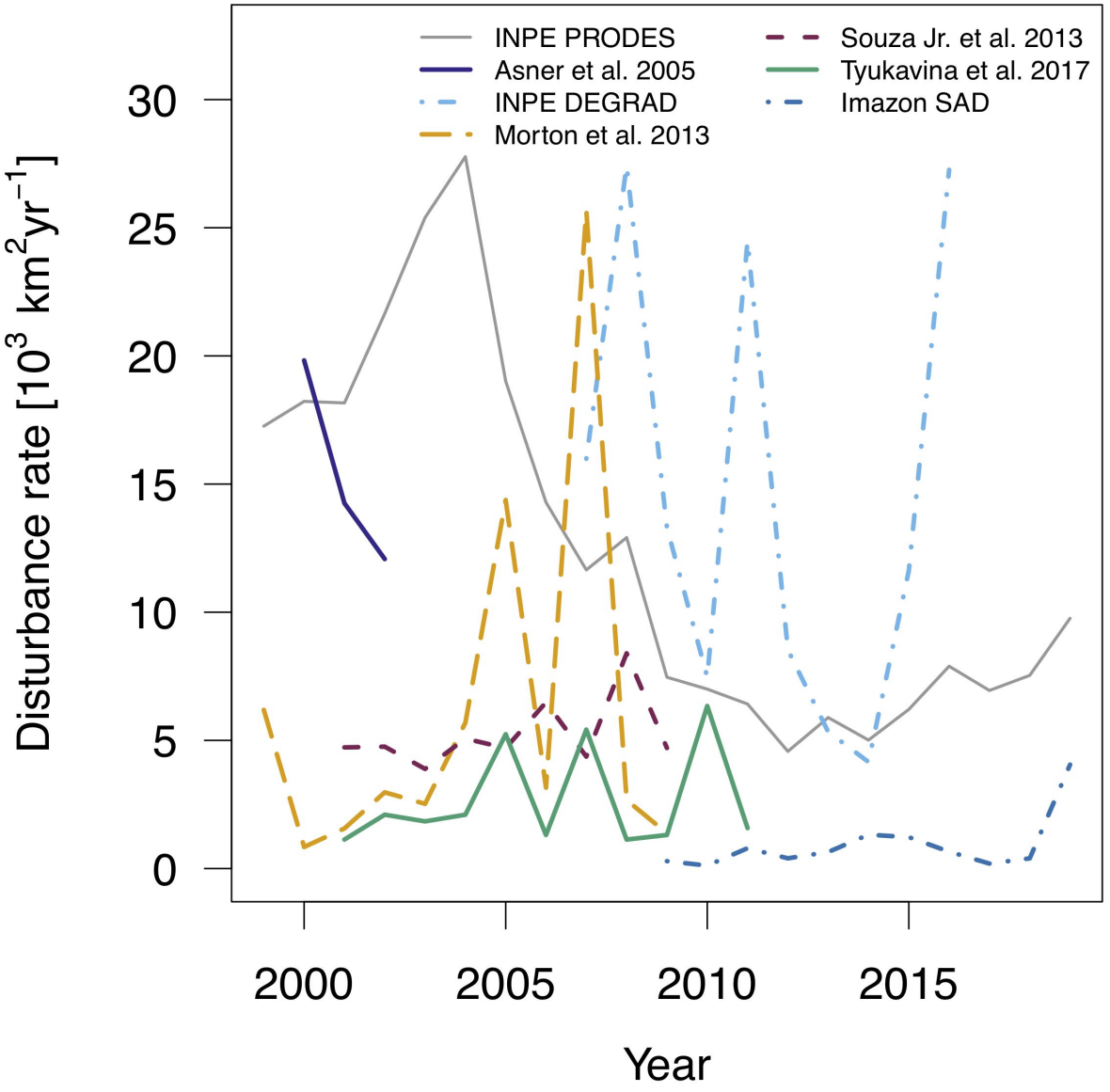


Deforestation estimates generally agree



Tyukavina et al. 2015

Forest degradation estimates disagree violently



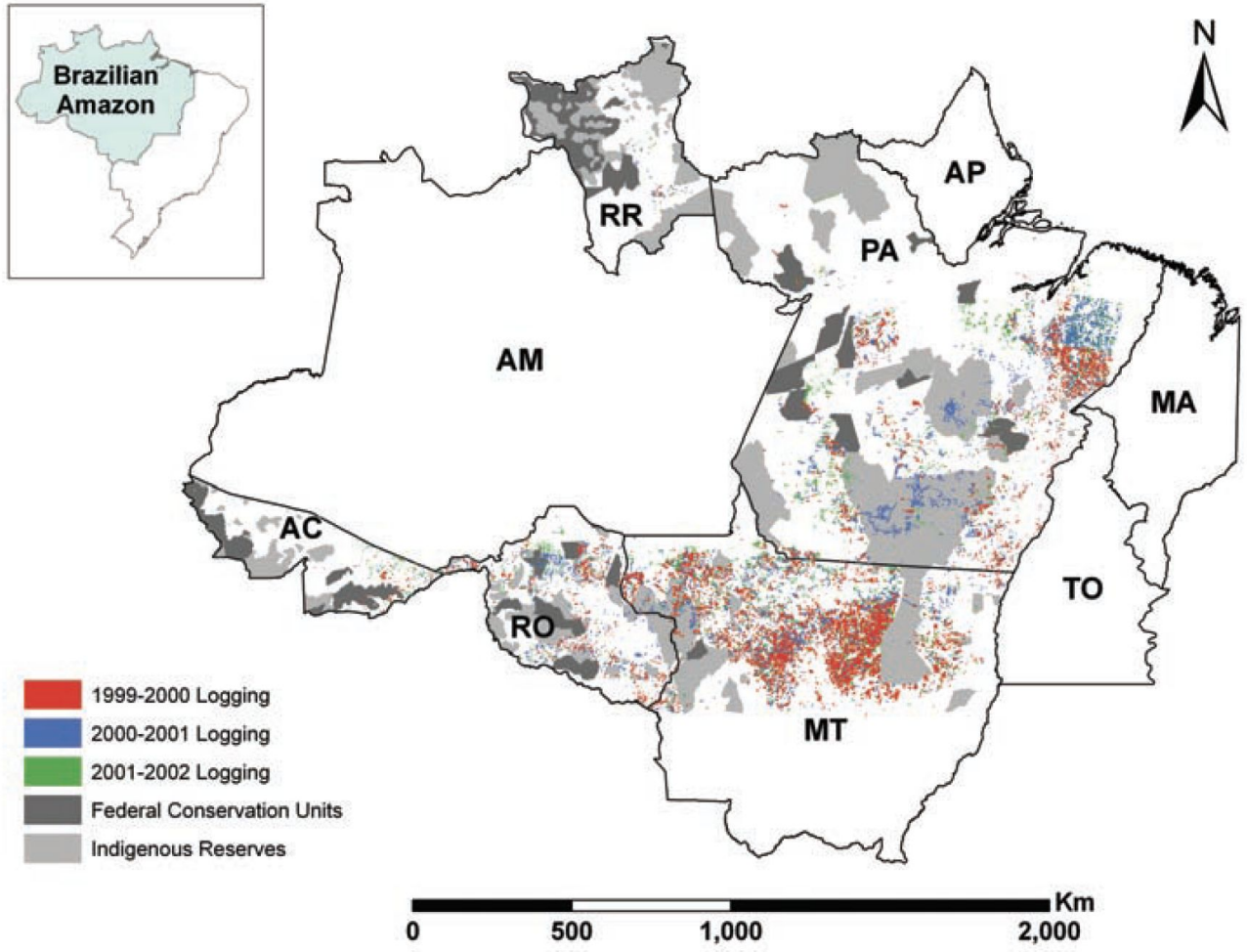
Selective logging

Chain sawyer
(Photo by L. Parry)

Skid trail

Selective logging in Mato Grosso
(Photo by R. Parente)

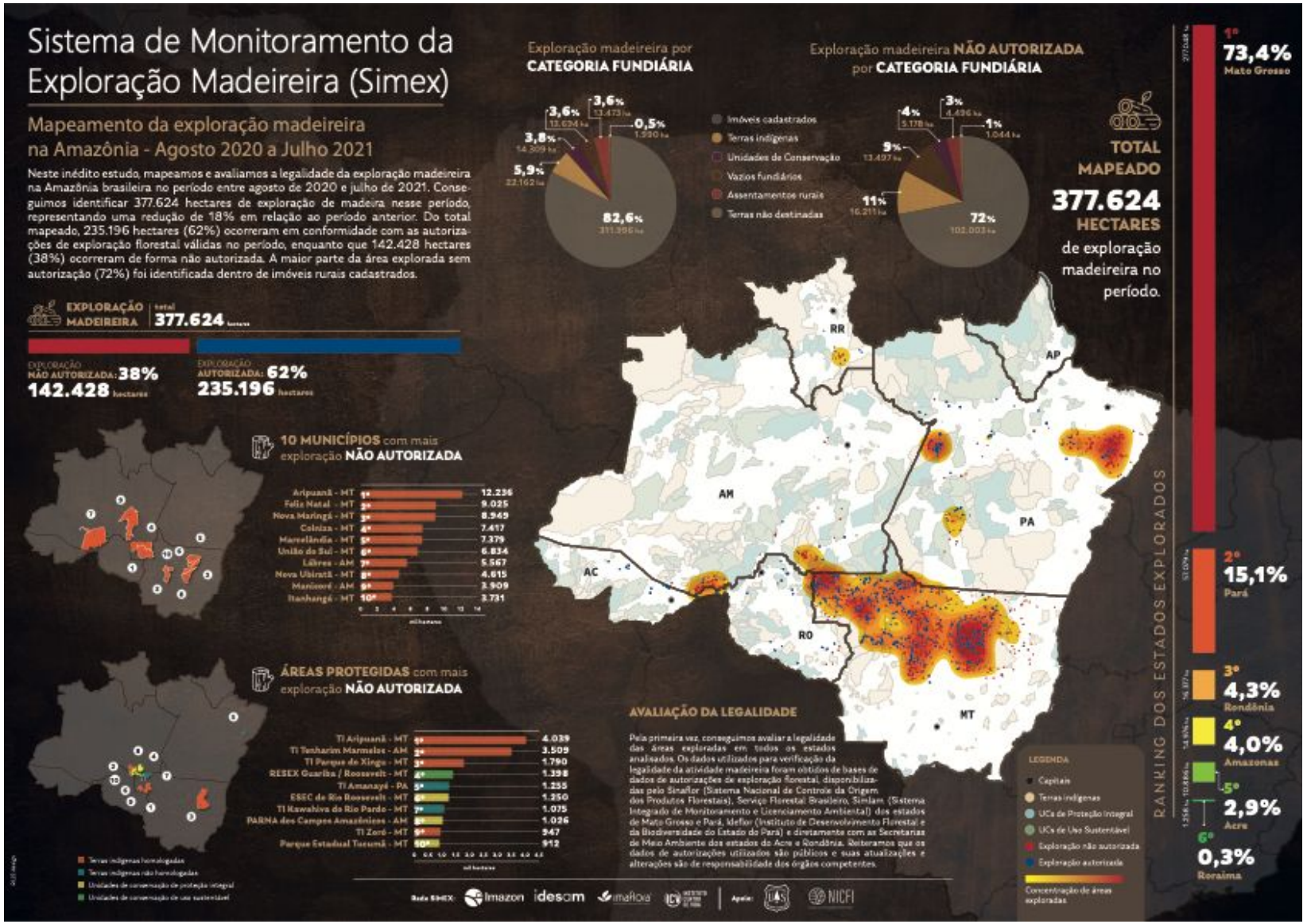
Area of the Brazilian Amazon affected by selective logging



- Logged areas ranged from 12,075 to 19,823 square kilometers per year (±14%) between 1999 and 2002, equivalent to 60 to 123% of INPE reported deforestation area.

Asner et al. *Science* 2005

SIMEX Brazilian Amazon logging monitoring (IMAZON)



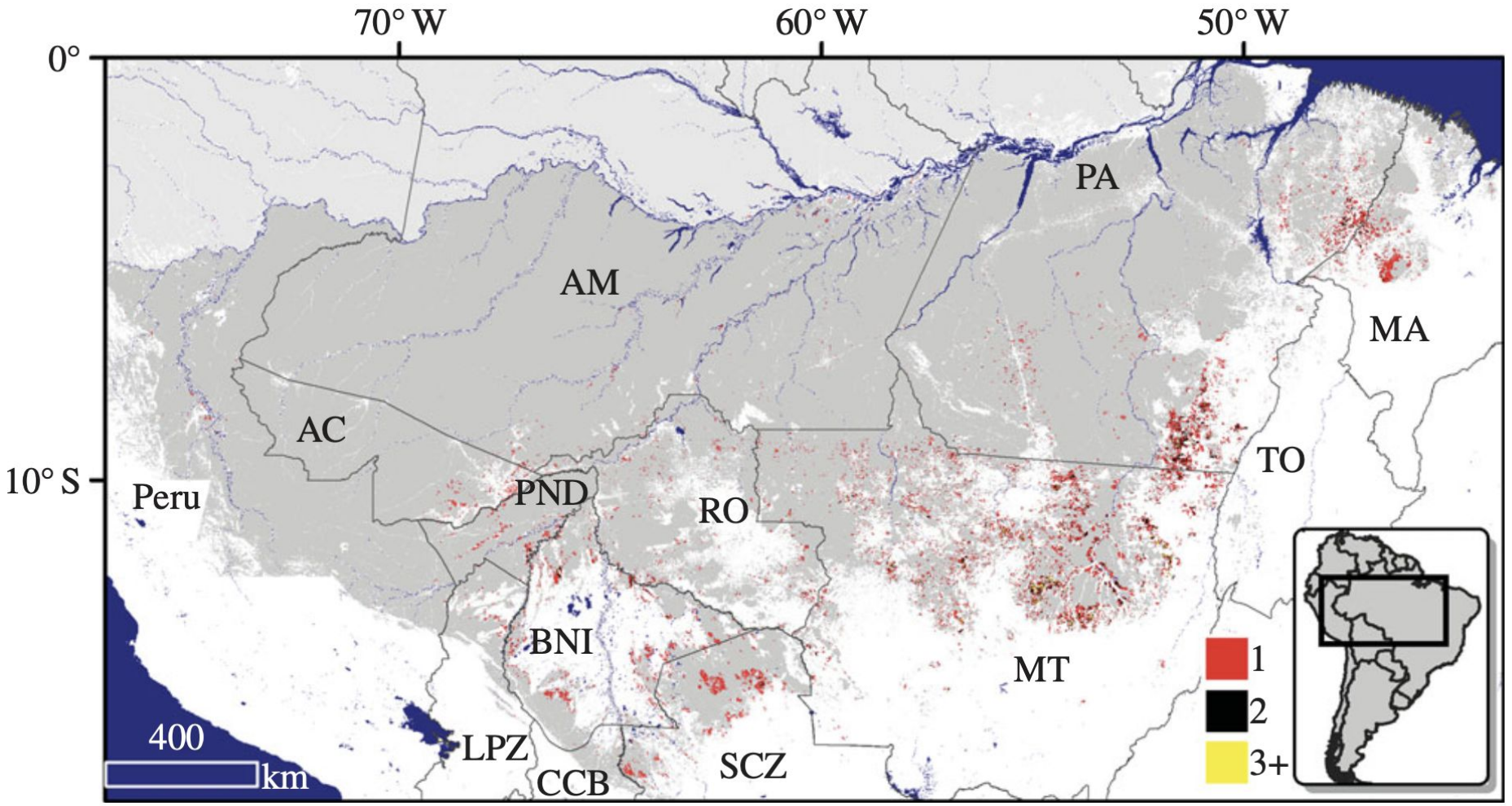
- Logging from August 2020 through July 2021 covered 3,774 km^2
- 38% of the logged area had no legal authorization

Forest fires

Understory fire
(Photo by P. Brando)

Burned forest in Mato Grosso
(Photo by E.R. Pinagé)

Understory forest fires in the Amazon



Morton et al. 2013

Using image textures with Planet and Sentinel-2 data

Rangel Pinagé *et al.*
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Carbon Balance and Management

RESEARCH Open Access

Effects of forest degradation classification on the uncertainty of aboveground carbon estimates in the Amazon

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Abstract

Background Tropical forests are critical for the global carbon budget, yet they have been threatened by deforestation and forest degradation by fire, selective logging, and fragmentation. Existing uncertainties on land cover classification and in biomass estimates hinder accurate attribution of carbon emissions to specific forest classes. In this study, we used textural metrics derived from PlanetScope images to implement a probabilistic classification framework to identify intact, logged and burned forests in three Amazonian sites. We also estimated biomass for these forest classes using airborne lidar and compared biomass uncertainties using the lidar-derived estimates only to biomass uncertainties considering the forest degradation classification as well.

Results Our classification approach reached overall accuracy of 0.86, with accuracy at individual sites varying from 0.69 to 0.93. Logged forests showed variable biomass changes, while burned forests showed an average carbon loss of 35%. We found that including uncertainty in forest degradation classification significantly increased uncertainty and decreased estimates of mean carbon density in two of the three test sites.

Conclusions Our findings indicate that the attribution of biomass changes to forest degradation classes needs to account for the uncertainty in forest degradation classification. By combining very high-resolution images with lidar data, we could attribute carbon stock changes to specific pathways of forest degradation. This approach also allows quantifying uncertainties of carbon emissions associated with forest degradation through logging and fire. Both the attribution and uncertainty quantification provide critical information for national greenhouse gas inventories.

Keywords Forest degradation, Selective logging, Forest fire, Very high-resolution imagery, Probabilistic classification, Airborne lidar, Biomass, Amazon

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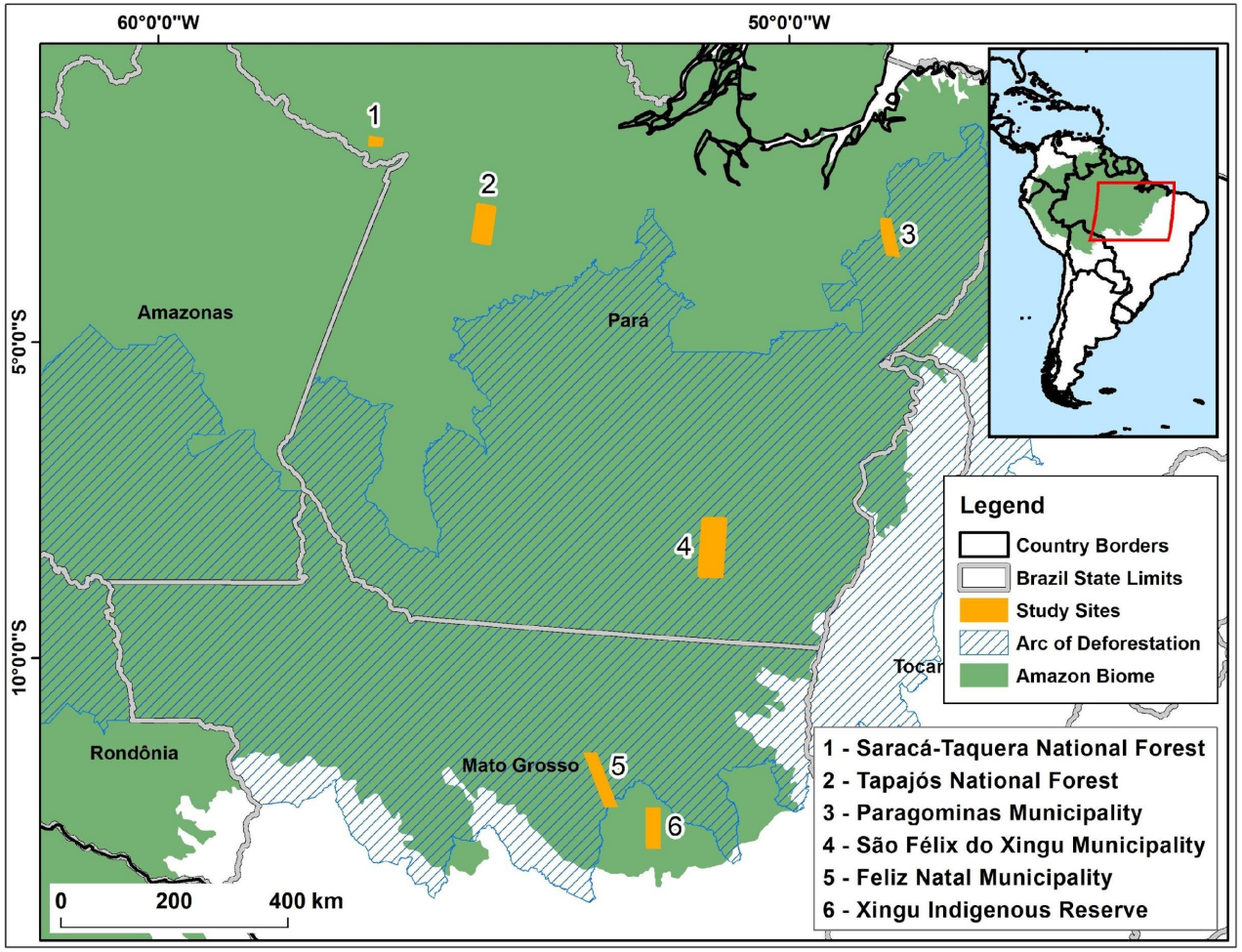
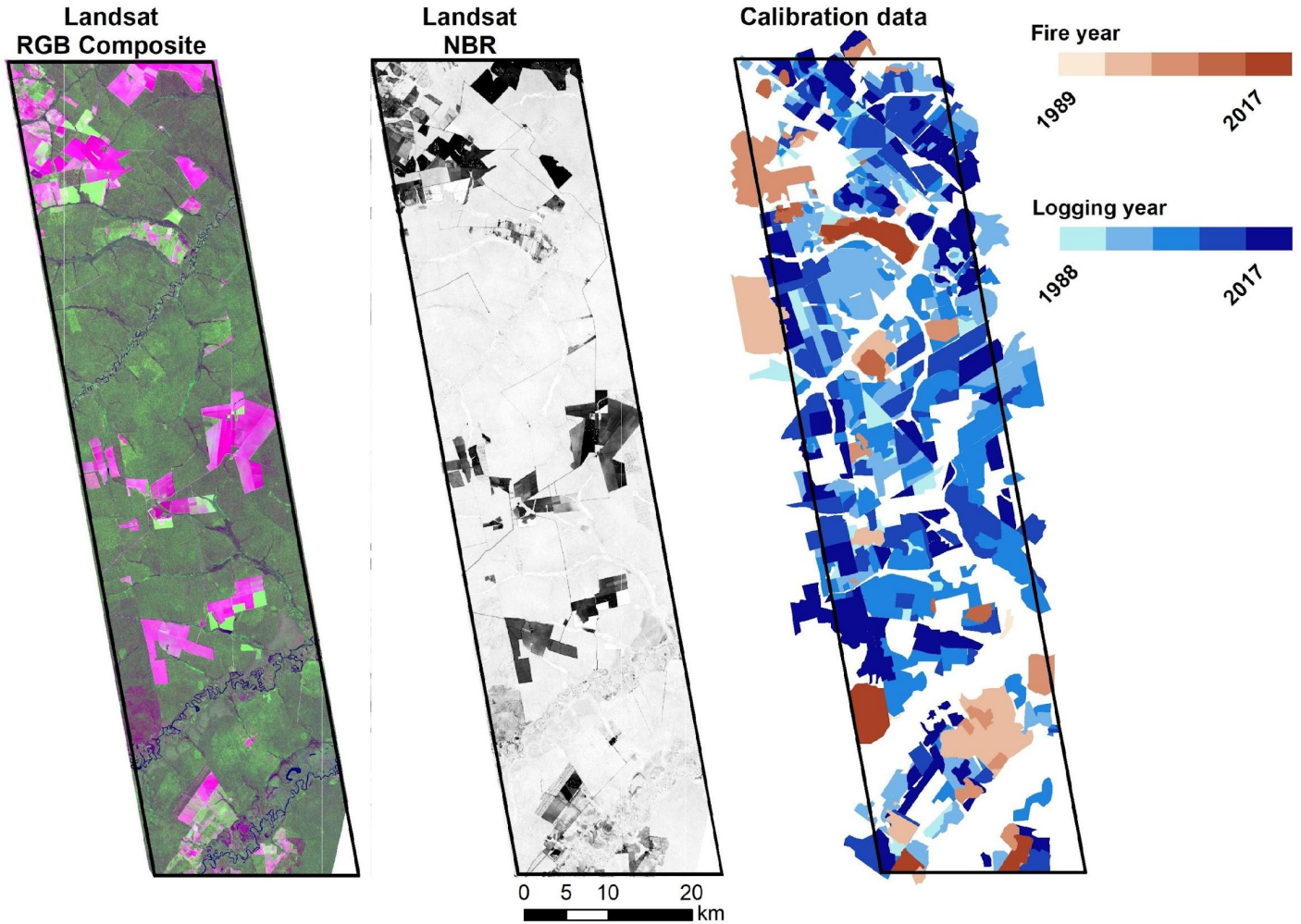
Background

Tropical forests account for more than half of terrestrial aboveground biomass carbon stocks, and host 60–70% of terrestrial species, despite covering only 7–10% of the land [1–3]. Deforestation, selective logging, fires, and fragmentation have greatly altered forests in recent decades across the tropics [4–6]. Second growth and degraded forests cover more area today than intact forests, although the full extent of tropical forest degradation is highly uncertain [7–11]. Likewise, carbon losses attributed to degradation may be similar to or exceed deforestation-related losses [12–20]. The uncertainty for

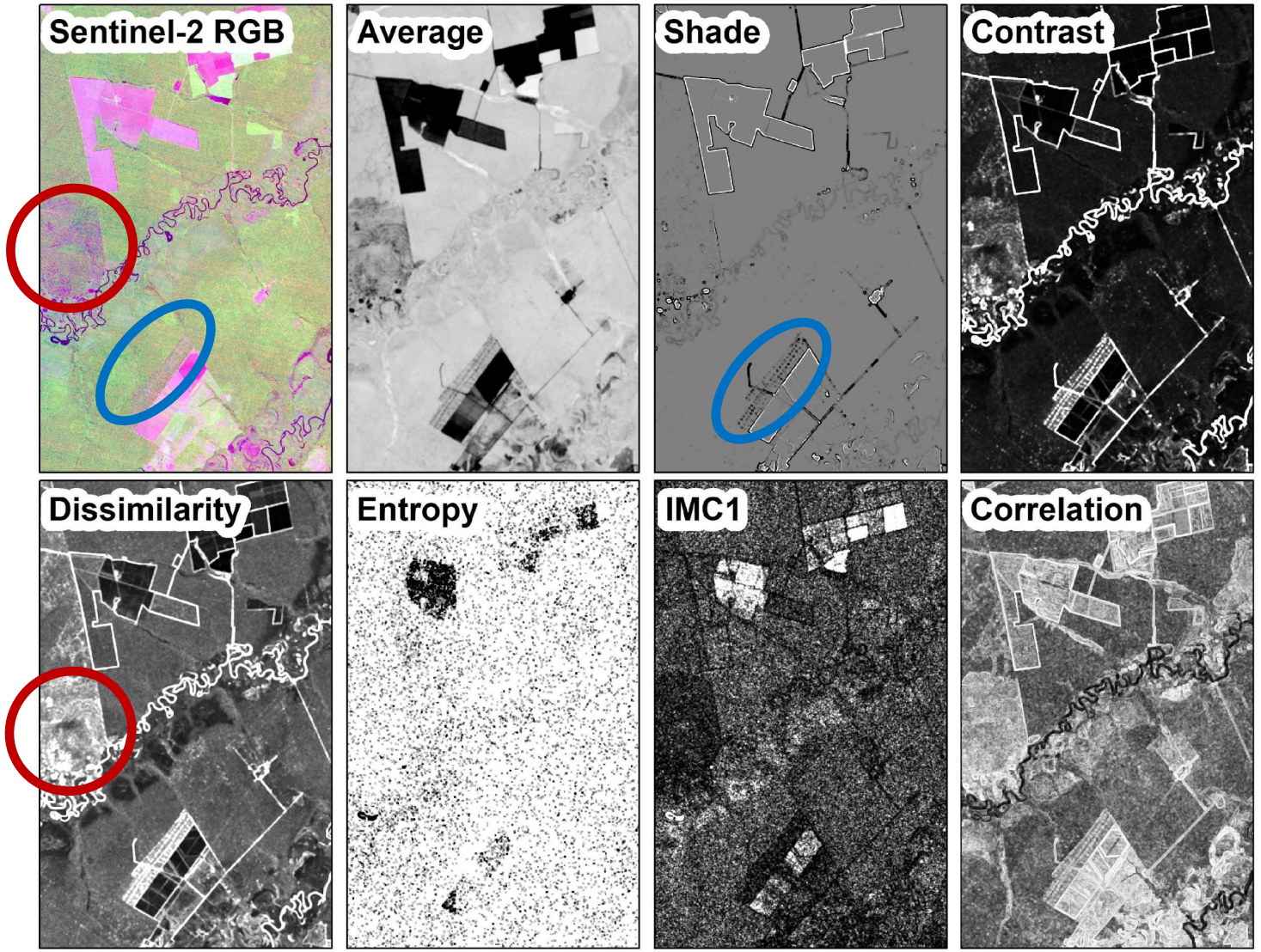
Calibration Sites



Calibration data from Landsat time series



Gray Level Co-occurrence Matrix (**GLCM**)



*Grey level co-occurence matrix (GLCM) (Haralick et al. 1973).

17 metrics calculated over 15-pixel windows (150 m) from Sentinel NBR images, that were later aggregated to 500 m.

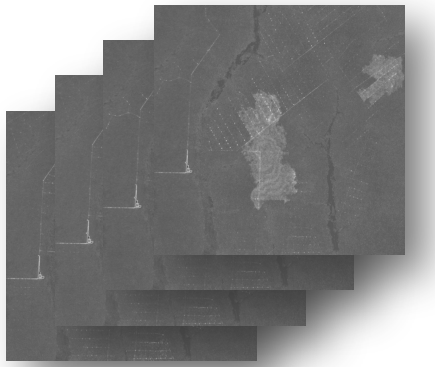
= recent fire

= recent logging

Workflow

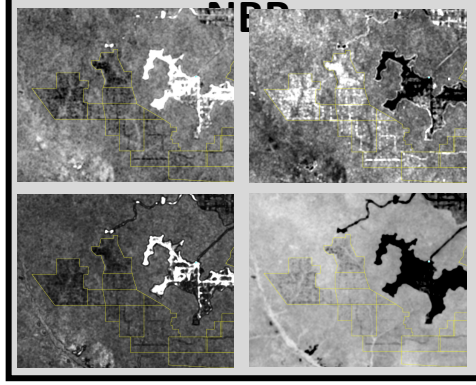
Calibration data

Landsat NBR time-series



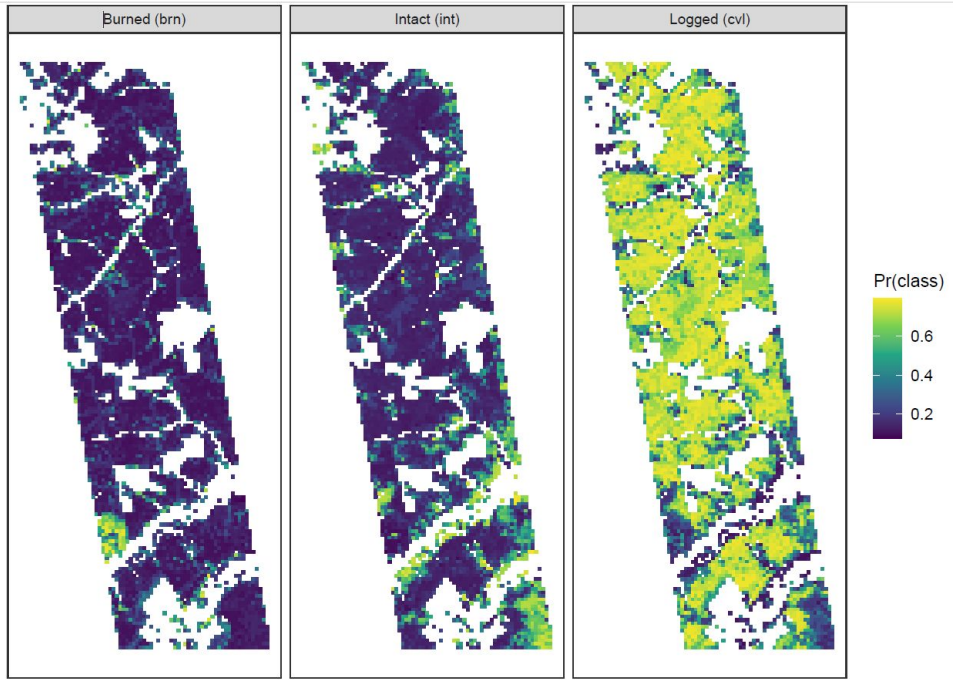
Predictors

Textural metrics from Sentinel-2 NBR



Gradient boosting classification model

Forest cover type probabilities



Intermediate results
(sites disturbed within 5 years of the image date)

		Reference						
	Class	Burned	Logged	Intact	Total	Producer's accuracy	User's accuracy	Overall accuracy
Predicted	Burned	3076	25	1197	4298	0.84	0.75	0.75±0.1
	Logged	159	658	1757	2574	0.71	0.25	
	Intact	429	236	7898	8563	0.73	0.92	
	Total	3664	919	10852	15435			

- Reasonable model for burned and intact forest
- Substantial confusion between intact and logged forest
- Approaches to improve the model
  - Better and more logged forest training data
  - Narrow the time window for disturbance prior to the image date

Next steps

- Model improvements
- Testing shorter time since disturbance thresholds to minimize the regeneration signal in optical images
- Application of the model for the entire Arc of Deforestation in the Amazon

- **For more details: Ekena Rangel Pinagé (Poster Session 2, Wednesday 5:00-7:00)**