Probabilistic classification of forest degradation by selective logging and fires in the Amazon based on Sentinel-2 data

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Abstract. Tropical forests worldwide have been transformed by deforestation, logging, fragmentation, and fires. While estimates of deforested areas are relatively reliable in the Amazon, there is great divergence in forest degradation estimates due to the intrinsic characteristics of degradation events, their distribution in space and time, and the challenges detecting them with satellite observations. Existing forest degradation classification efforts have considerable detection uncertainty, which generally has not been considered when accounting for carbon emissions from degraded areas. Using textural metrics computed from Sentinel-2 images at 10-m resolution and then aggregated to a 500-m grid size, we implemented a probabilistic classification of forests degraded by selective logging and fires in six sites across the Brazilian Amazon. Our overall accuracy was 0.75 when including degradation events up to 5 years prior to the reference year. Fires were well detected by our classification approach (sensitivity = 0.83), whereas there was greater confusion between intact and logged forests (sensitivity: 0.73 and 0.72, respectively). We are refining the model to include shorter intervals of forest degradation, from which we expect increased accuracy. Subsequently, we will extend this approach across the Amazon Arc of Deforestation, a region that concentrates most forest disturbances in the Brazilian Amazon. Reliable classification of forest degradation area is critical for the quantification of carbon losses and gains in the Amazon region.

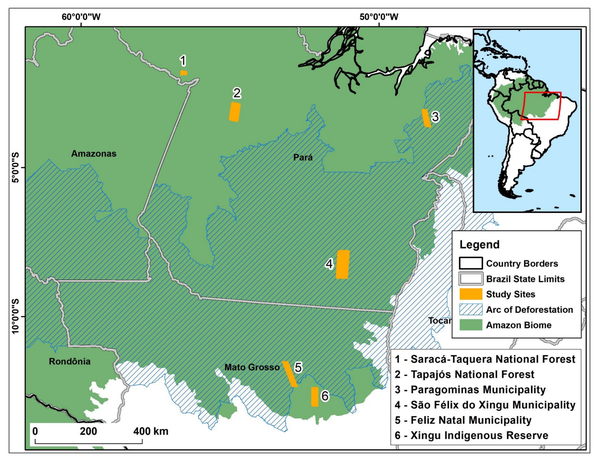

Figure 1. Reference sites for forest degradation classification in the Brazilian Amazon.

Forest degradation from selective logging and fires

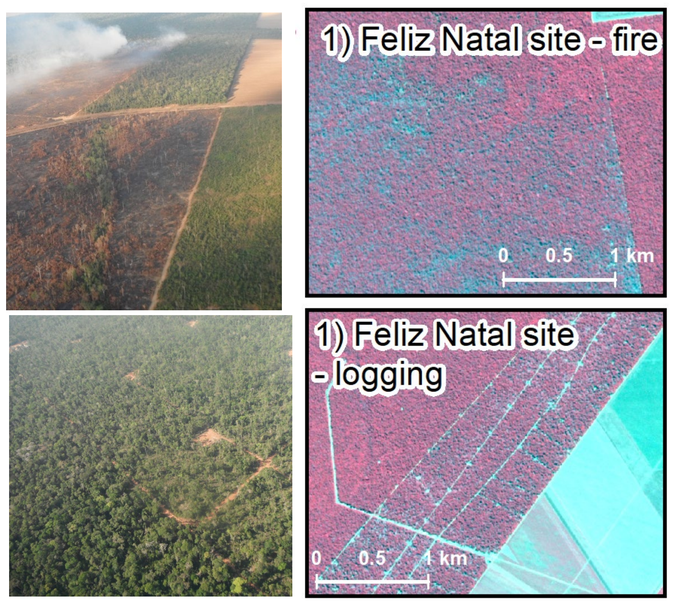

Figure 2. Burned forests (top left) and logged forests (bottom left) from aerival views, and on PlanetScope color composites (right) in Mato Grosso State, Brazilian Amazon.

Forest degradation classification

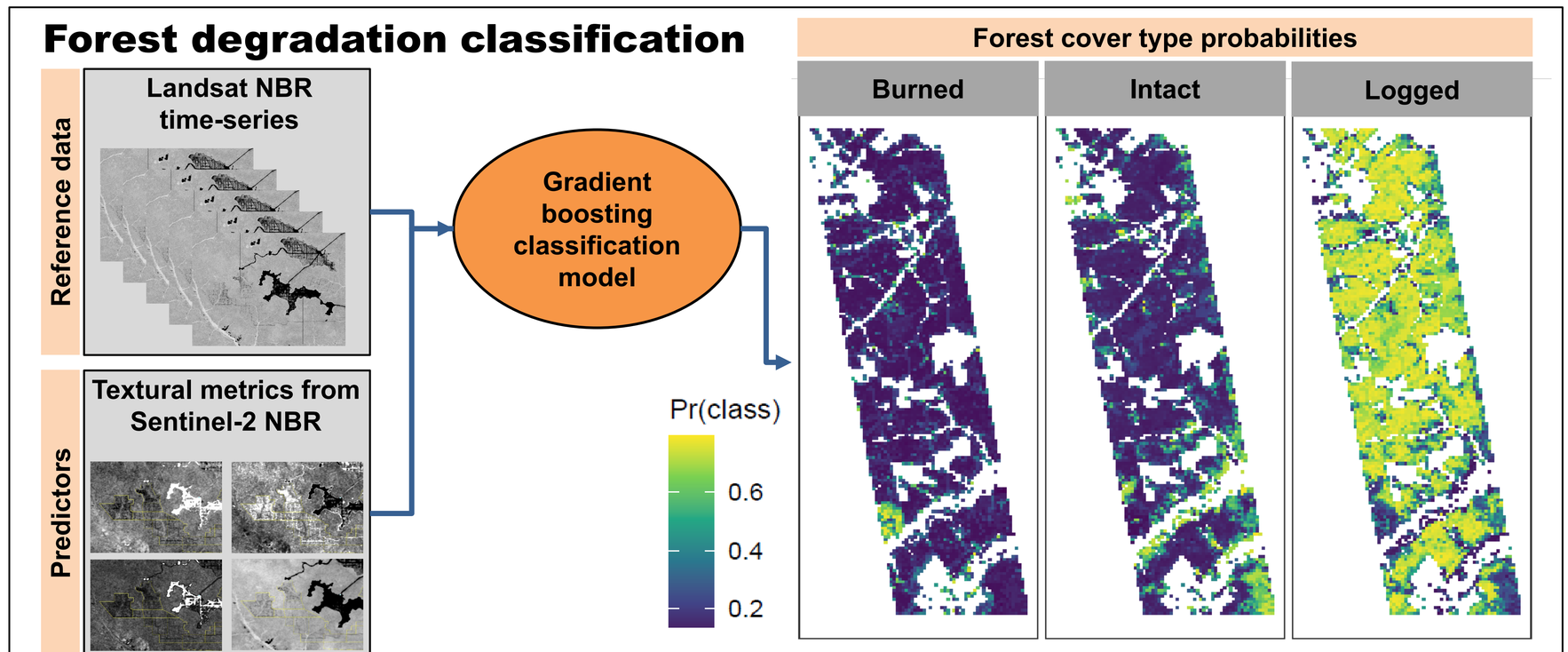

Figure 4. Our probabilistic classification approach (Rangel Pinagé et al. 2023) employed textural metrics (GLCM, Haralick et al. 1973) as predictors. We computed 17 GLCM metrics over a 15-pixel window size (150 m) from Sentinel-2 NBR images, and then aggregated them to 500-m resolution. Wetlands and cleared areas were masked out. A gradient boosting model was employed to derive the probability of each pixel being either intact, logged, or burned. The data were divided into 50% (training) and 50% (test) splits. Only disturbance events from the last 5 years were included in the reference data.

Results

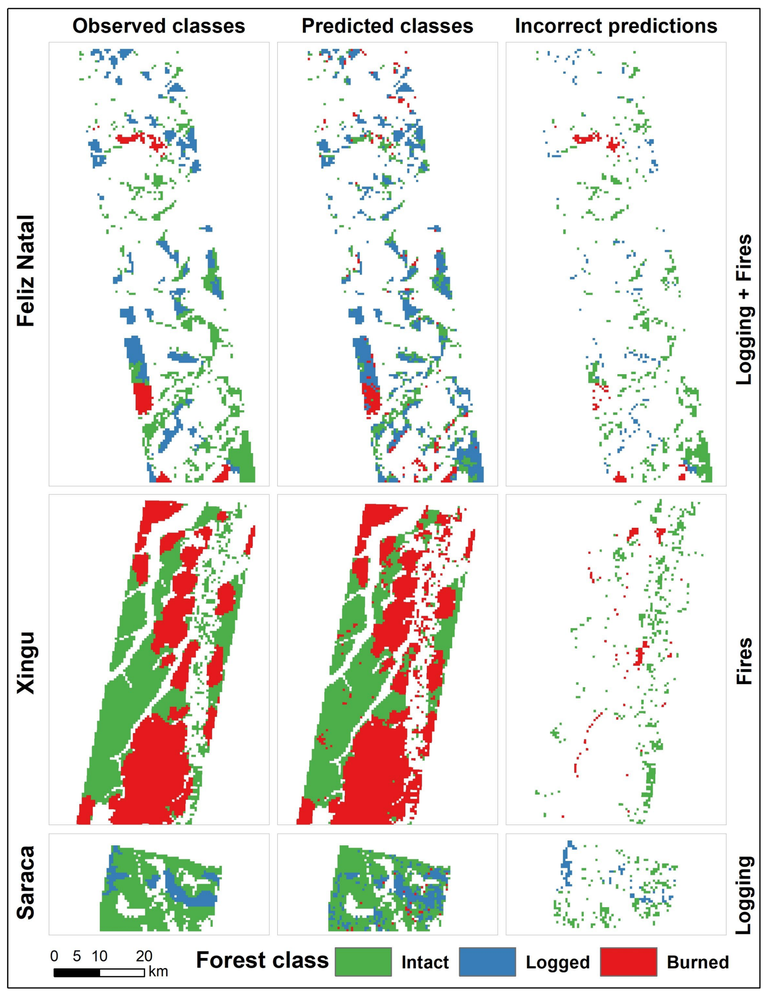

Figure 4. Observed (from reference data, left panel) versus predicted (center panel) classes, and incorrect class prediction (right panel) for the 500-m grid cells at 3 of our reference sites.

Table 1. Confusion matrix for the model using the 50% of the data held out for testing. Predicted classes are the rows and the reference classes are the columns. The main diagonal denotes correctly-classified grid cells, and the off-diagonal elements represent incorrect predictions.

		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			

Discussion

- Machine learning and textural metrics from Sentinel-2 images were useful to identify and distinguish forest degradation with good accuracy
- Confusion between intact and logged forests leading to low user's accuracy for the logged class
- We are testing shorter time since disturbance thresholds to minimize the regeneration signal in optical images
- Model improvements include the application of weights schemes for pixel purity, and the inclusion of an environmental variable (Chave et al. 2014) as predictor to account for climate and forest structure variability ➔ overall accuracy improved to ~95%
- We are testing the application of the model for the entire Arc of Deforestation in the Amazon.

Acknowledgements

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Citations

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