Unraveling the History of Deforestation in the Amazon Rainforest

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Context

- Deforestation is a major problem in the Amazon Rainforest
- Exact year of deforestation largely unknown for certain areas
- Effects of deforestation/importance of knowing exact deforestation year
  - CO2 Emissions
  - Regulation and planning
  - Community Impact
- Threat of deforestation driven by agricultural expansion

Goals

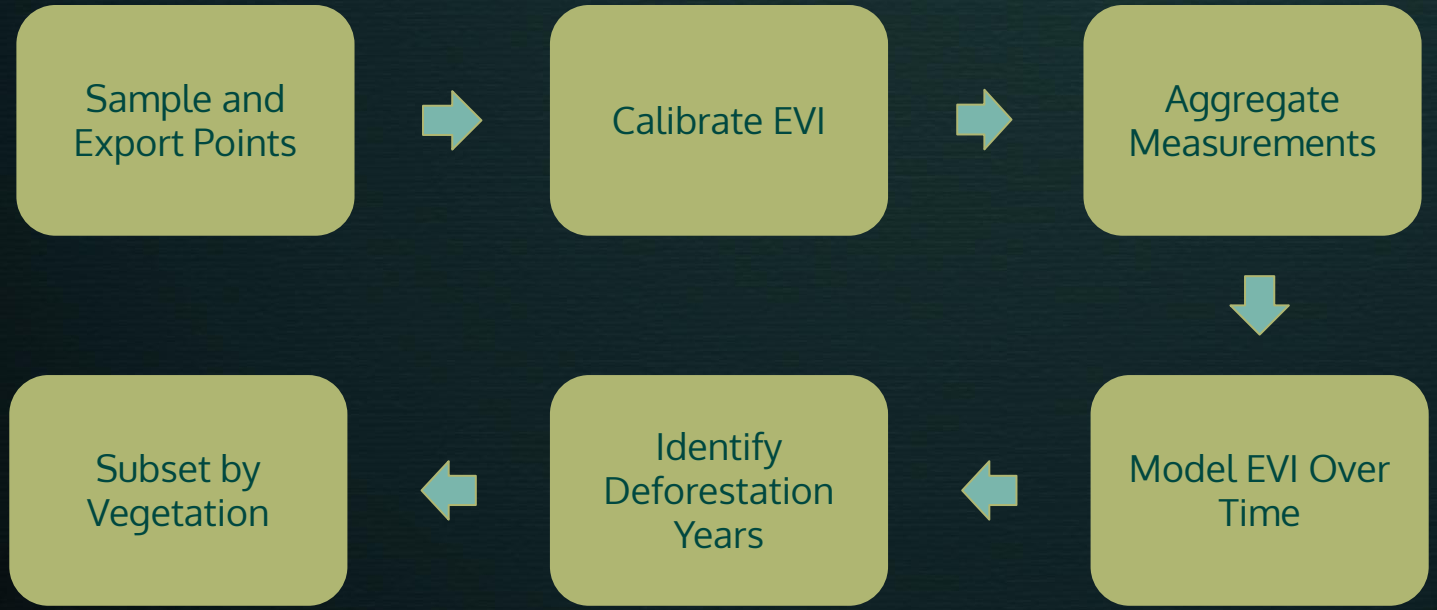
- Predict deforestation year for over 2,000 plantations in Peru and Brazil
- Use data from satellites to predict deforestation year
    - Landsat Satellite
        - Enhanced Vegetation Index (EVI)
            - Measure of photosynthetic activity in vegetation
    - ALOS-PALSAR-2 Satellite
        - Horizontal-Horizontal Polarization (HH)
            - Measure surface and vegetation roughness
        - Horizontal-Vertical Polarization (HV)
            - Measure of vertical structure of the surface and vegetation

Goals

- Compare the results of the Landsat and ALOS methods
- Adapt the "*LandsatTS*" R package to work with tropical areas
- Create a reproducible workflow for expansion to other areas of interest

Areas of Interest

Landsat Workflow



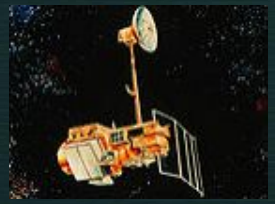
Sample and Export Points

- Computational Limits
- Random sample of points/pixels based on plantation size
- Measurements from 1984 to 2024
- Gaps due to weather conditions and orbital nature of the satellite

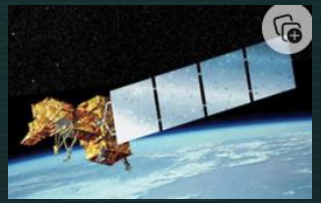
Sample and Export Points → Calibrate EVI → Aggregate Measurements → Model EVI Over Time → Identify Deforestation Years → Subset by Vegetation

Calibrate EVI

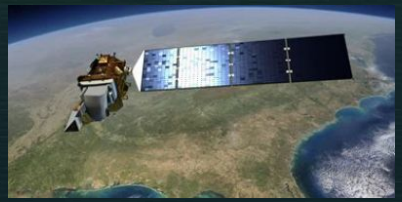
- Multiple Landsat Satellites
  - Landsat 5, 7, and 8
- In orbit for different years with some overlap
- Two random forest models
  - Predict EVI 7 from EVI 5
  - Predict EVI 7 from EVI 8



1984-2013

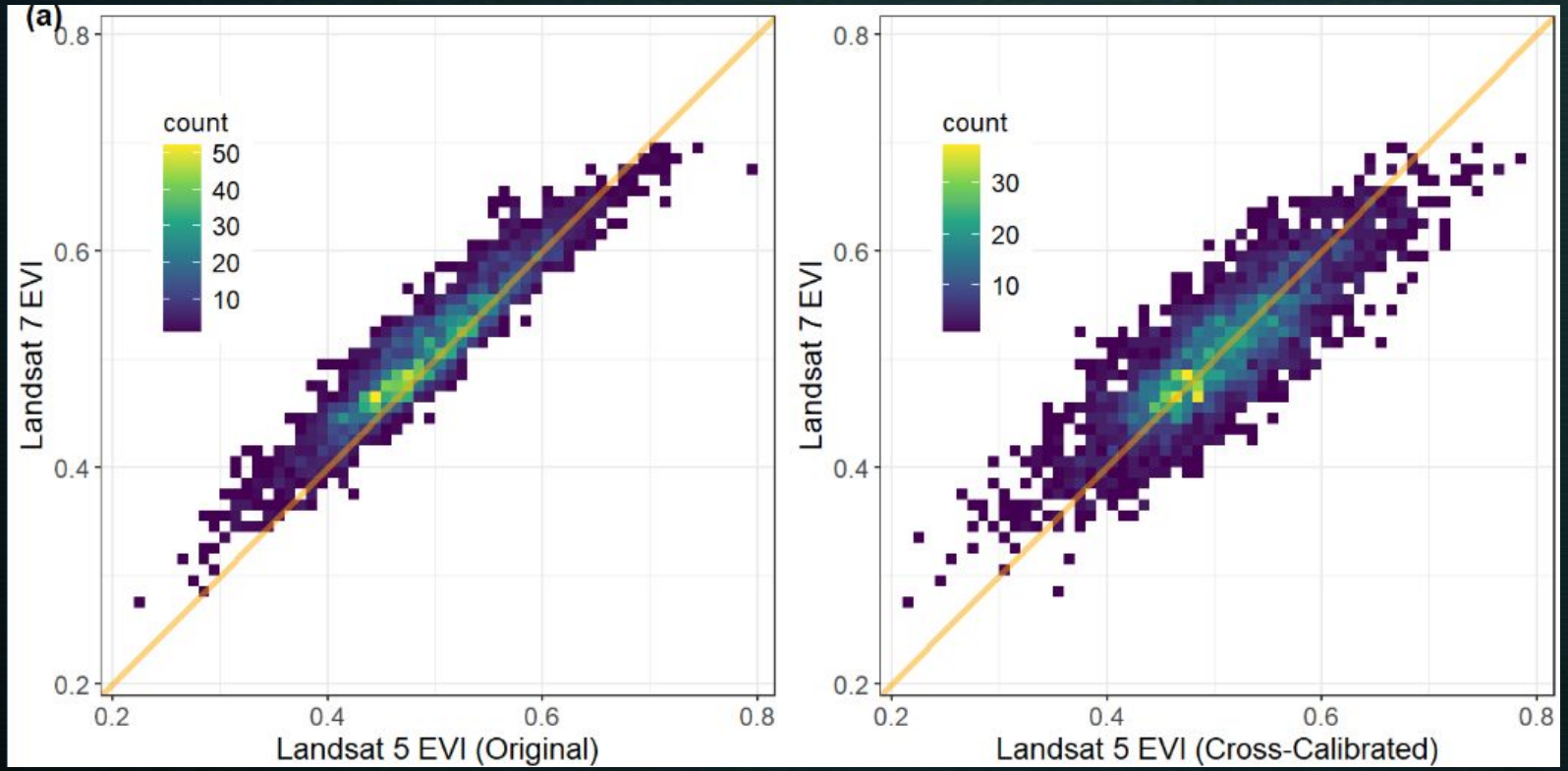


1999-2022



2013-2024

Sample and Export Points → Calibrate EVI → Aggregate Measurements → Model EVI Over Time → Identify Deforestation Years → Subset by Vegetation


(a)
count
50
40
30
20
10
Landsat 7 EVI
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
Landsat 5 EVI (Original)
count
30
20
10
Landsat 7 EVI
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
Landsat 5 EVI (Cross-Calibrated)

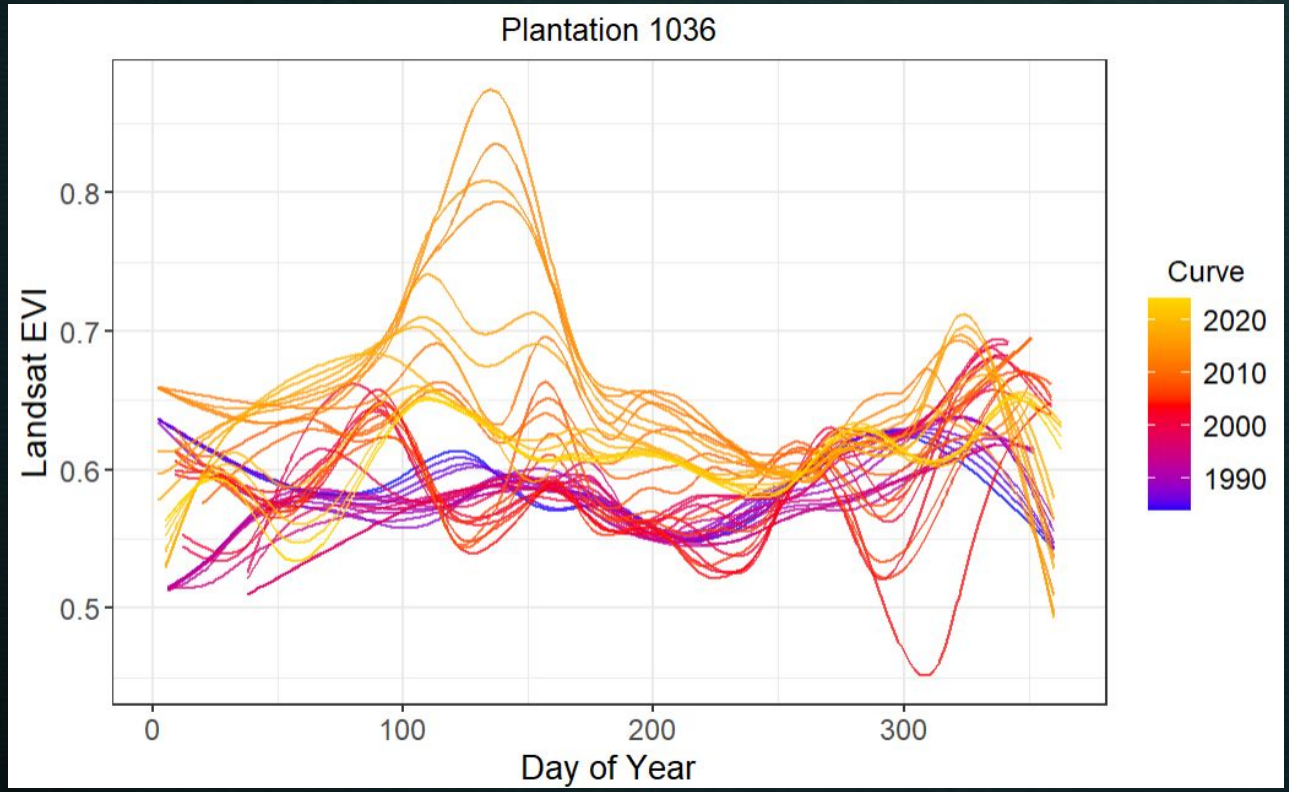
Aggregate Measurements

- Currently have data for multiple points within each plantation
- Average the EVI measurements grouped by date
- End with 1 measurement for each time for each plantation

Sample and Export Points → Calibrate EVI → **Aggregate Measurements** → Model EVI Over Time → Identify Deforestation Years → Subset by Vegetation

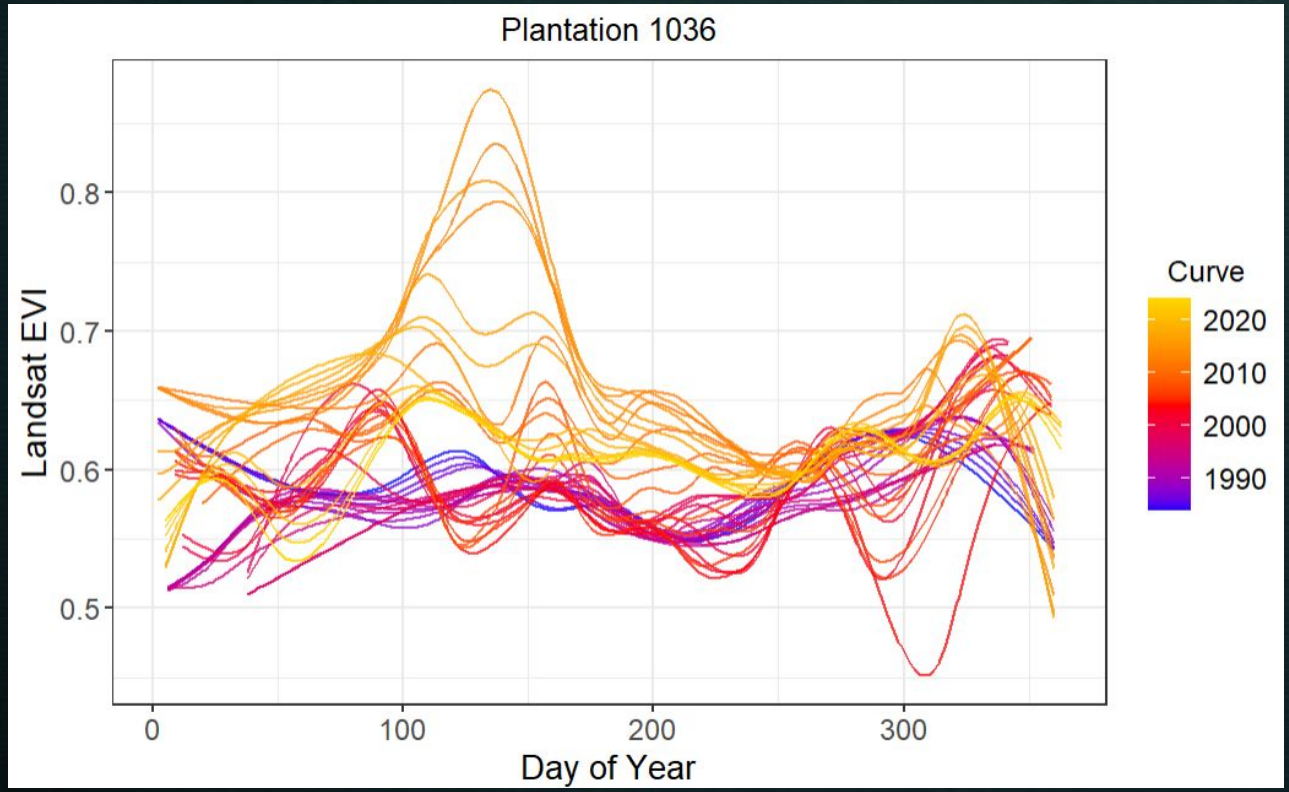
Model EVI Over Time

- Fit cubic splines by year for each plantation
- Refit until all predicted EVI values for observed time points fell within 30% of each other
- Robustness to outliers


Plantation 1036
Landsat EVI
0.8
0.7
0.6
0.5
0
100
200
300
Day of Year
Curve
2020
2010
2000
1990

Identify Deforestation Years

- Year in which the predicted EVI value was at a minimum selected as deforestation year
- Small EVI value signals low greeness
- Deforested areas typically have small EVI values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0.8
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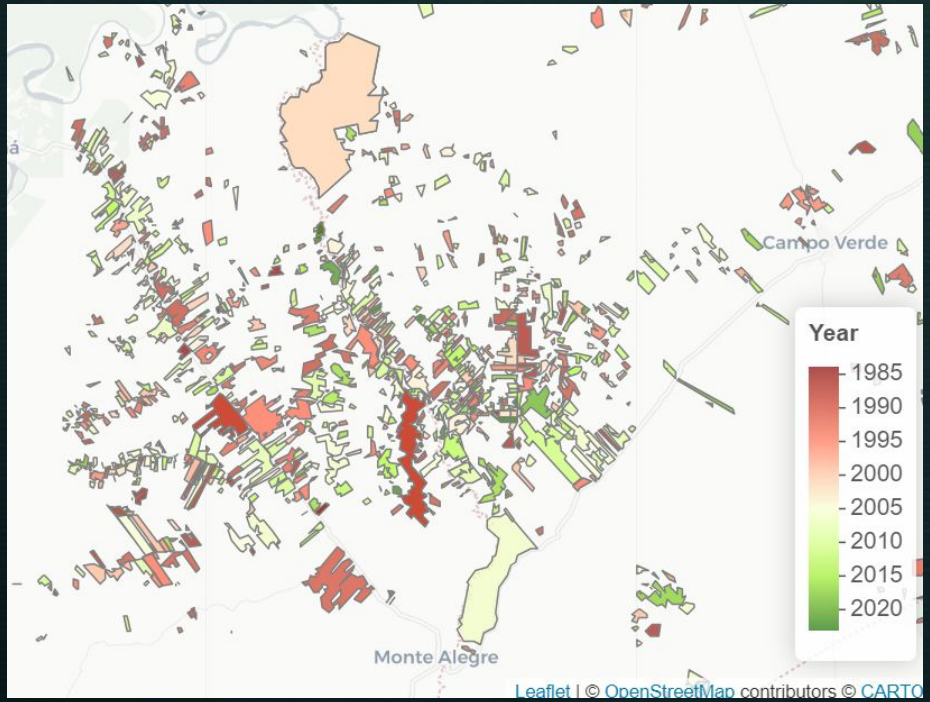
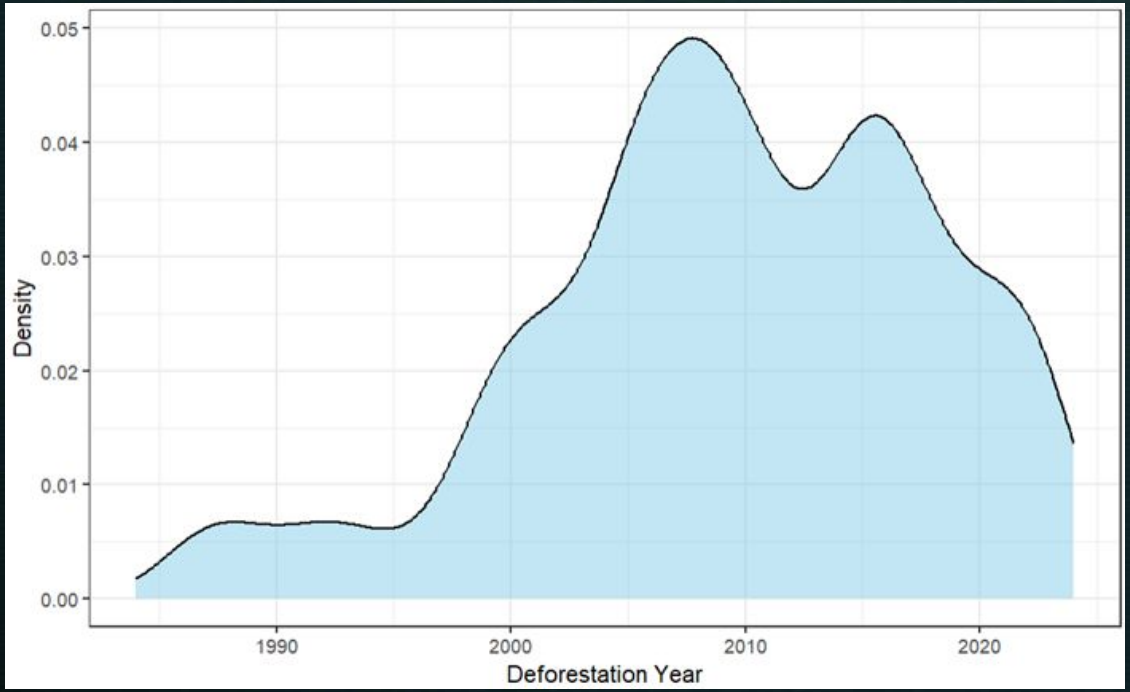
1990

Predicted Deforestation Year Map

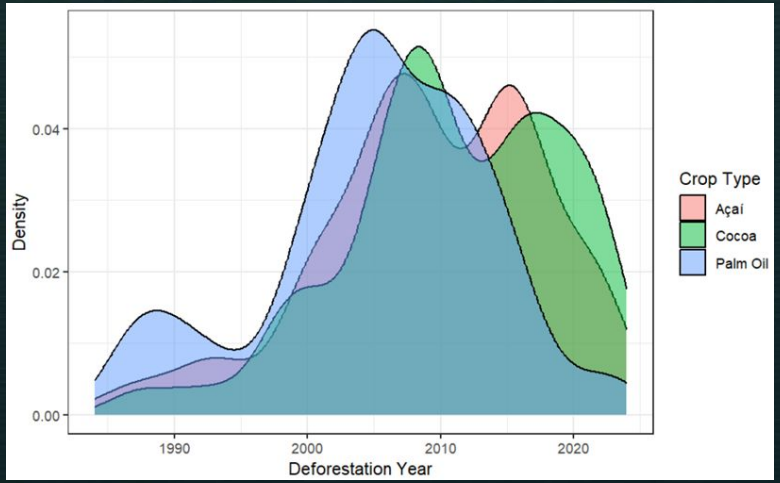


Predicted Deforestation Year Density Plot



Subset by Vegetation

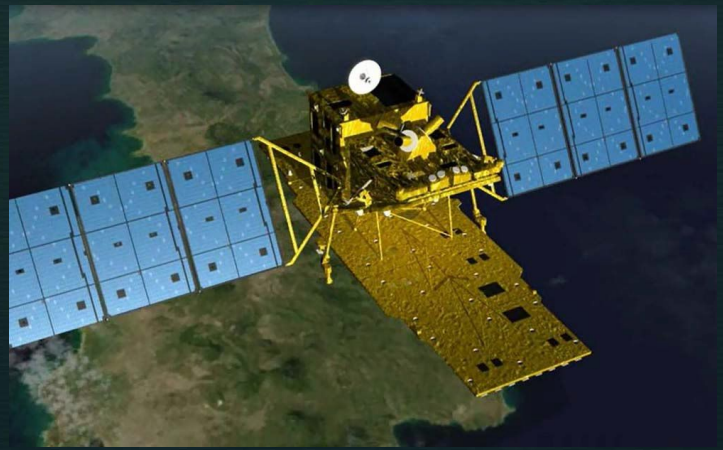
- In Brazil there were palm oil, cocoa, and acai plantations
- Association between certain types of plantation and year of deforestation



Sample and Export Points → Calibrate EVI → Aggregate Measurements → Model EVI Over Time → Identify Deforestation Years → Subset by Vegetation

ALOS Analysis

- New predictions using information from the ALOS-PALSAR 2 Satellite
- Shoots radar signals and measures how they bounce back from the ground
- Horizontal-Horizontal (HH) and Horizontal-Vertical (HV) polarization measurements
- Compare deforestation predictions from ALOS to Landsat



ALOS Workflow

Sample and Export Points

- Measurements from 2015 to 2024
- Only use plantations that were predicted to be deforested 2015 and more recently from Landsat analysis
- Random sample of 30 points/pixels
- Attempted to retrieve one HH and one HV measurement per month per point

Sample and Export Points → Aggregate Measurements and HH to HV Ratio → Model HH to HV Ratio Over TIme → Identify Deforestation Years

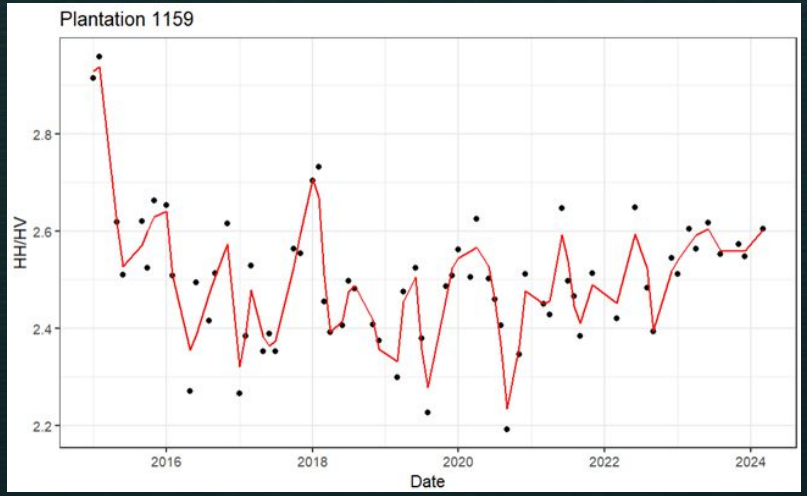
Aggregate Measurements and HH to HV Ratio

- Average the HH and HV measurements grouped by date
- End with 1 measurement of HH and 1 measurement of HV for each time for each plantation
- Calculate HH to HV ratio

Sample and Export Points → Aggregate Measurements and HH to HV Ratio → Model HH to HV Ratio Over TIme → Identify Deforestation Years

Model HH to HV Ratio Over Time

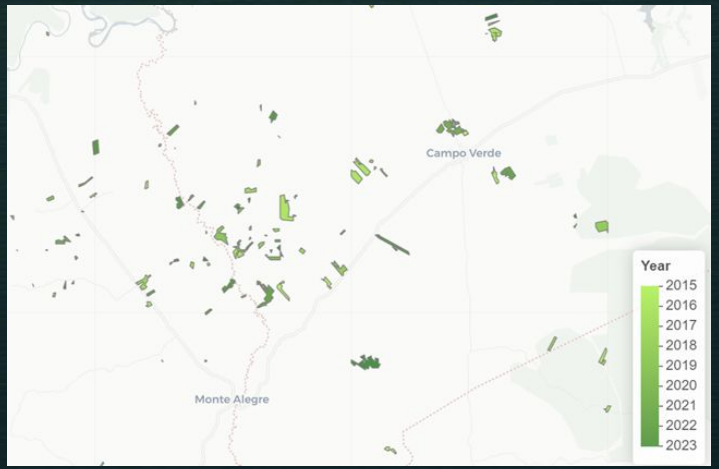
- Fit a spline over time for each plantation with a smoothing parameter of .2



Sample and Export Points → Aggregate Measurements and HH to HV Ratio → Model HH to HV Ratio Over TIme → Identify Deforestation Years

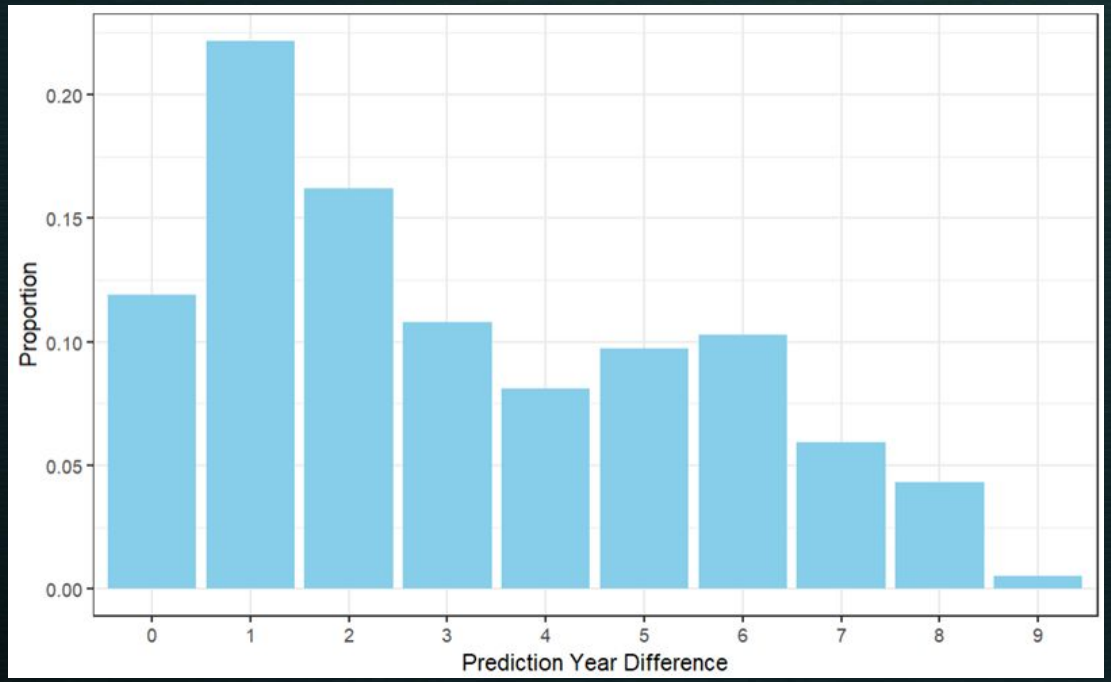
Identify Deforestation Years

- Year in which the predicted HH to HV ratio was at a maximum selected as deforestation year
- Large HH to HV ratio signals deforestation
- Increase in HH, decrease HV



Sample and Export Points → Aggregate Measurements and HH to HV Ratio → Model HH to HV Ratio Over TIme → Identify Deforestation Years

Comparing Methods



Conclusion

- Predicted deforestation years (1984-2024) from Landsat Satellite data
- Predicted deforestation years (2015-2024) from ALOS Satellite data
- Some disagreement between the two methods
- Comprehensive codebase and documentation in GitHub for continued development and application to new areas of interest/plantations in the Amazon

Future Work

- Dealing with larger polygons which could be made up of multiple plantations
- Exporting pixels more efficiently, leading to being able to sample more points
- Considering different metrics to signal deforestation
- Quantifying confidence in predictions

Reproducibility

Workflow Section	Landsat Functions	ALOS Functions
Sample & Export	num_pts_per_poly(), sample_pts(), lsat_export_ts()	sample_pts(), export_alos(), export_points()
Calibration/Metrics	lsat_calc_spectral_index(), lsat_calibrate_rf()	calc_ratio()
Aggregation	extract_group(), calc_grouped_means()	extract_group(), calc_grouped_means()
Modeling Over Time	curve_fit_mean(), curve_fit()	fit_splines()

Workflow Section	Landsat Functions	ALOS Functions
Identify Deforestation Years	predict_deforestation_lsat()	predict_deforestation_alos()

Questions?