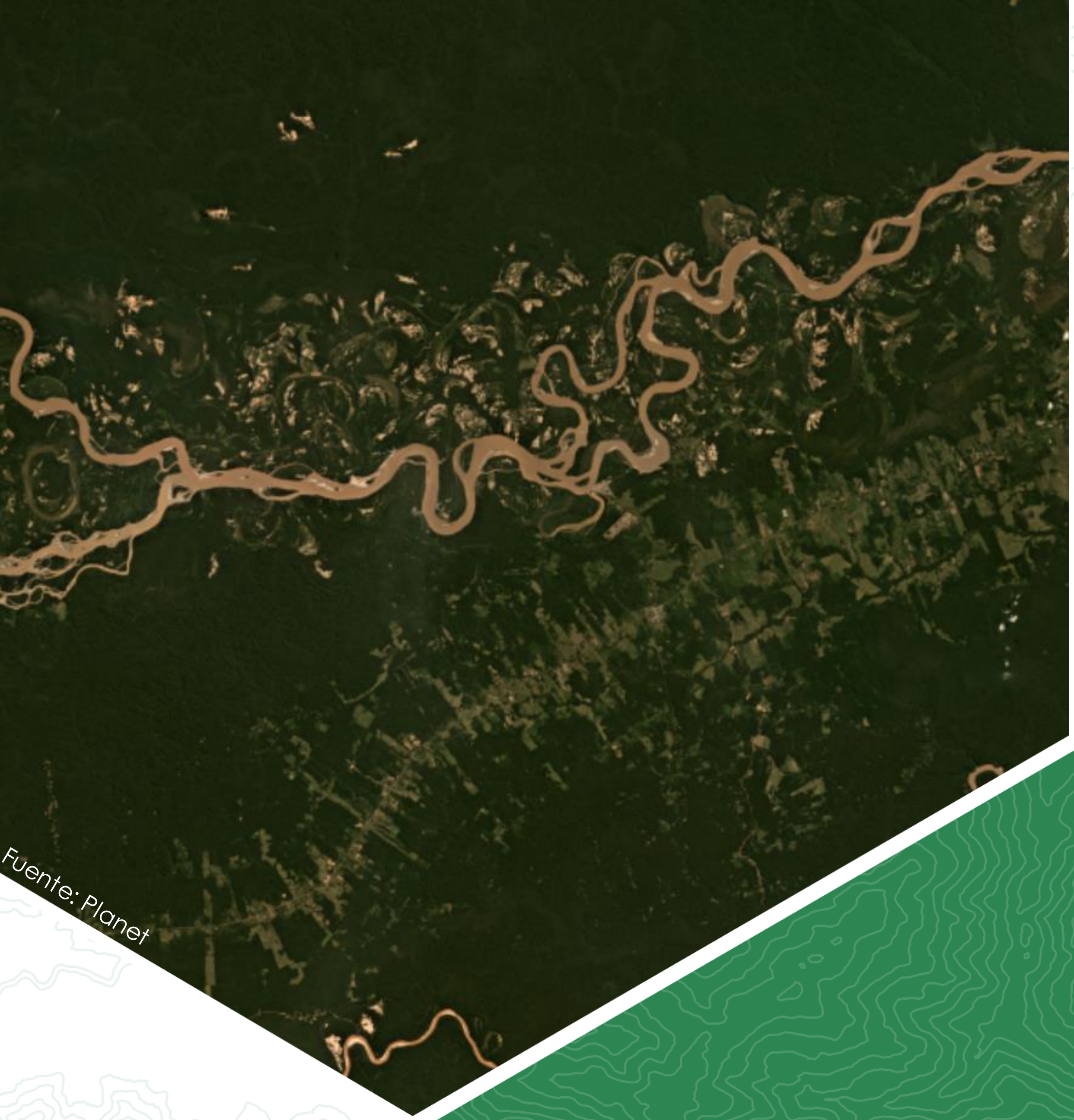


THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
SERVIR
NASA

DISTINCTION OF DRIVERS OF DEFORESTATION IN THE AMAZON USING SAR SENTINEL-1

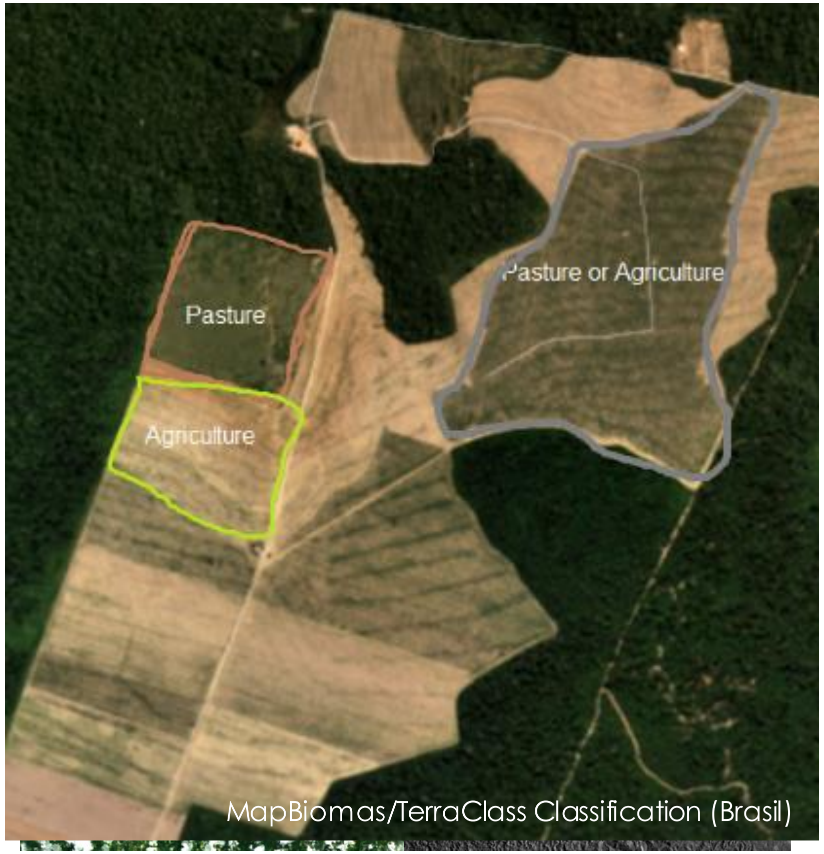
Thesis Research

Andréa Puzzi Nicolau

July 17, 2019

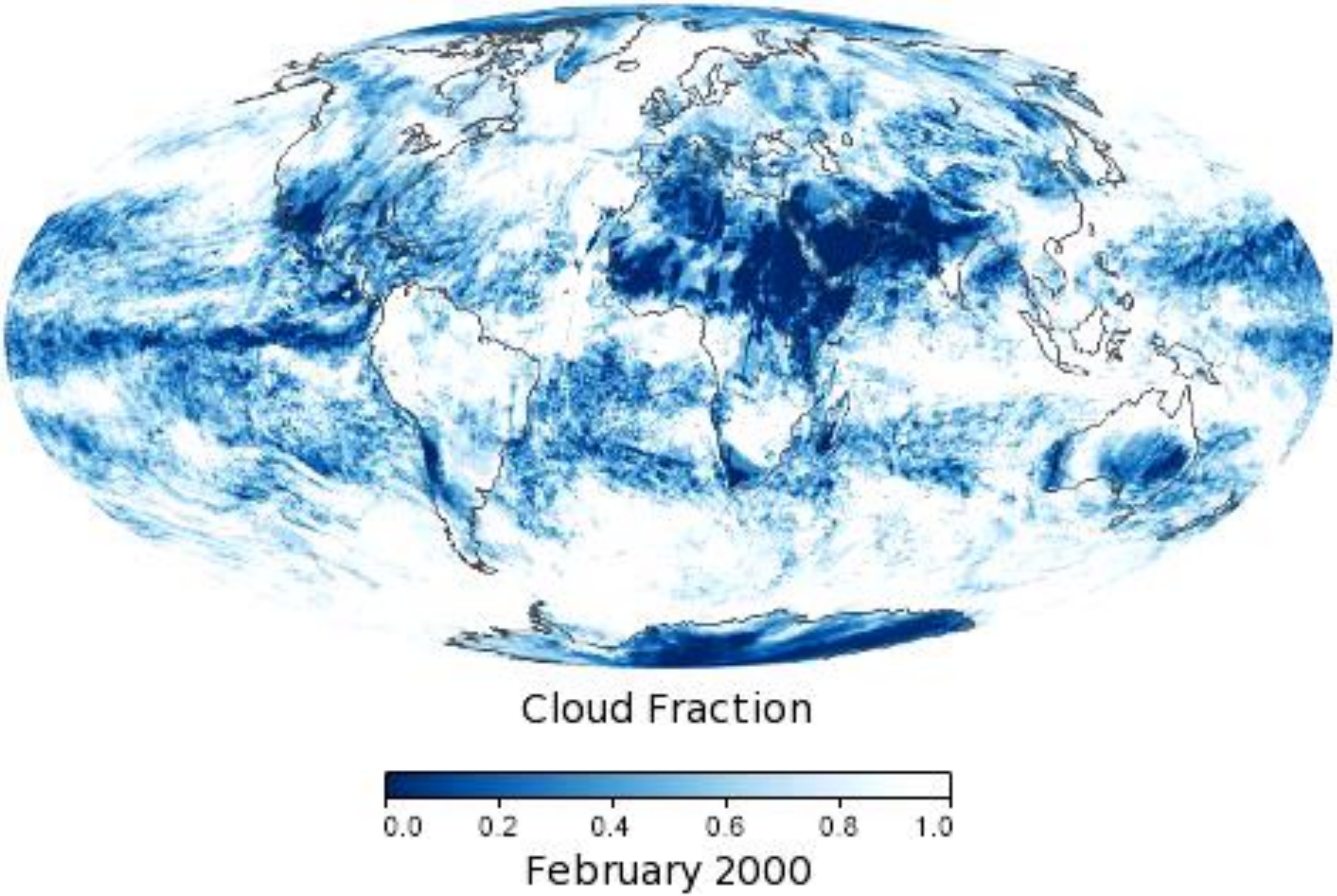
Motivation

- Is it possible to use Sentinel-1 data to distinguish drivers of deforestation?
  - Why is it important to distinguish drivers of deforestation?



Landsat 8 RGB and Sentinel-1 VV median composites
January-July 2019 (Ucayali, Peru)

- We know where and when deforestation is happening, but in order to have an impact in how to prevent deforestation, we need to know what is causing it
- Optical systems:
  - Cloud cover
  - Hart to distinguish different land uses with similar land cover (Joshi et al., 2016; Hagensieker et al., 2017)
- The identification of drivers of deforestation is a need for early warning deforestation monitoring systems (International Forum of Early Warning Systems, Lima, July 2018)
- Important towards more sustainable land management and to aid global initiatives such as REDD+
- The use of SAR data is a priority by GFOI (GFOI, 2013)



Source: NASA

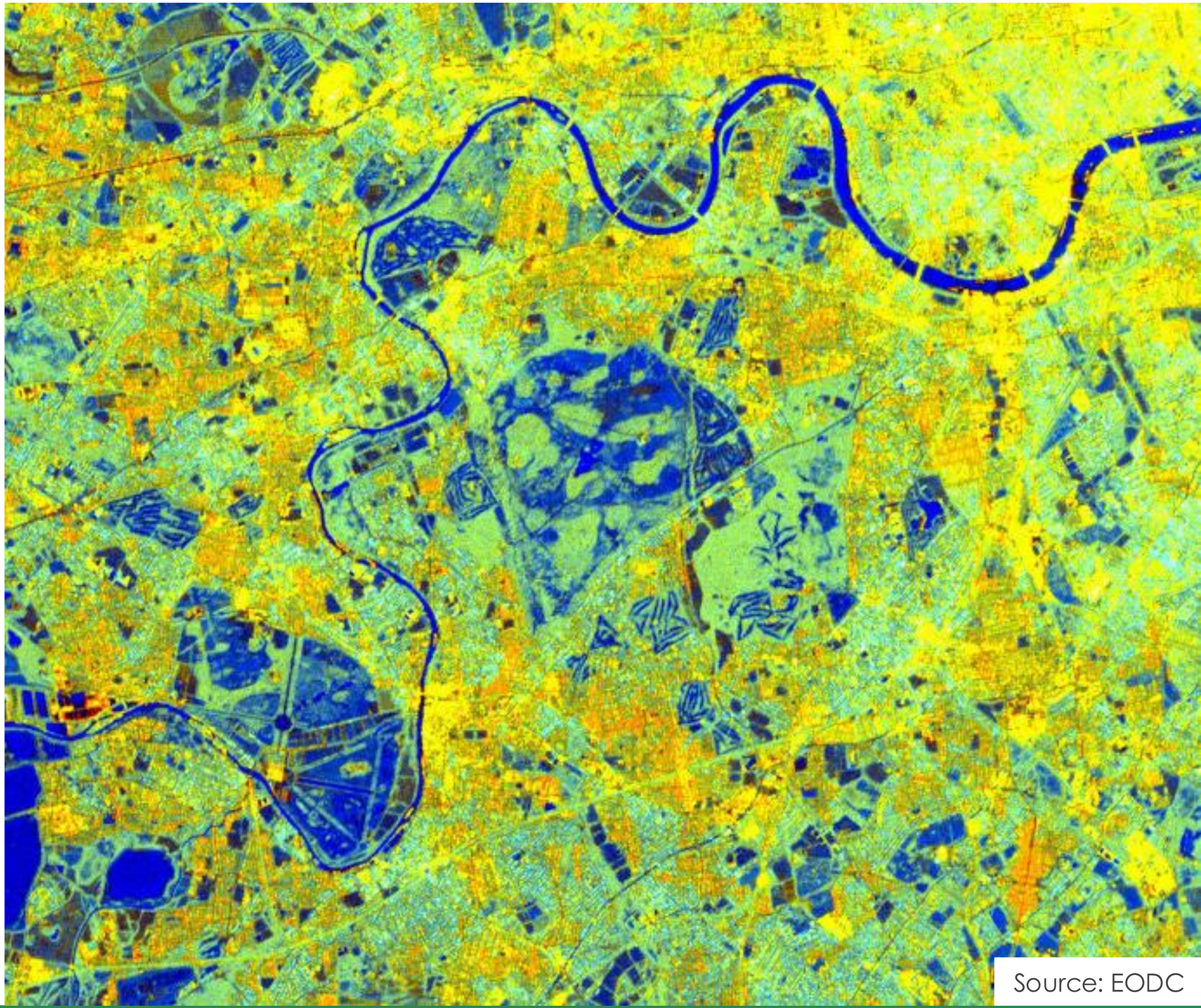
Research Questions

Main

- Can we use Sentinel-1 data to distinguish different land uses/covers

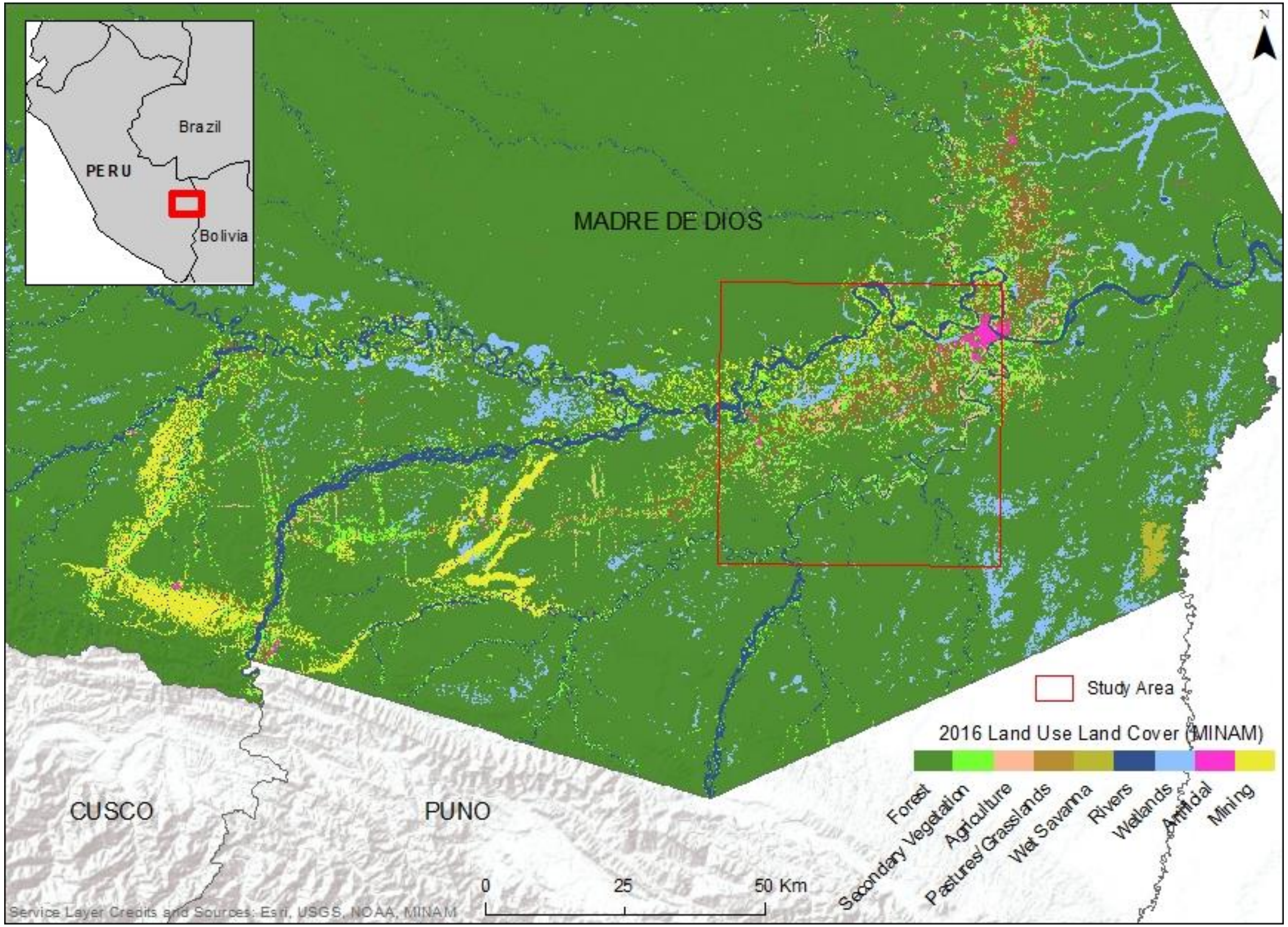
Specific

- Can we observe signature trends on Sentinel-1 time series data for different LULC?
- Which metrics are the best to distinguish LULC?
- Can LULC maps be produced with high accuracy?



Source: EODC

Study Area



Madre de Dios

- Capital of Biodiversity (Peruvian Law N° 26311; Myers et al., 2000)
- Deforestation rates have been increasing since 2001 (MINAM, 2017)
- Presents a heterogeneous mosaic of LULC

Total area: ~2,500 km^2

Methodology

- Sentinel-1 band C (5.405 GHz) GRD 10 meters resolution
- Google Earth Engine (GEE) (Gorelick et al., 2017)
- Time series analysis of amplitude
  - VV, VH, VV/VH as bands
  - Metrics: Mean, Median, Standard Deviation, Max-Min ratio, Coefficient of Variation
  - Radar Forest Degradation Index (Sassan, 2019) modified, Separability Index (Wu et al., 2011)
  - Data since 2017
- Classes: Forest, Secondary Vegetation, Agriculture, Pasture, Mining, Urban/Artificial, Water
  - Land Use and Land cover map (2013-2016) from Geobosques platform
- Collect Earth Online (CEO) (Bey et al., 2016)
- Decision Tree

Google Earth Engine

COLLECT EARTH ONLINE

Methodology

CEO: sample design → GEE: Sentinel-1 time series → Metrics → Decision tree → Classification → Accuracy Assessment

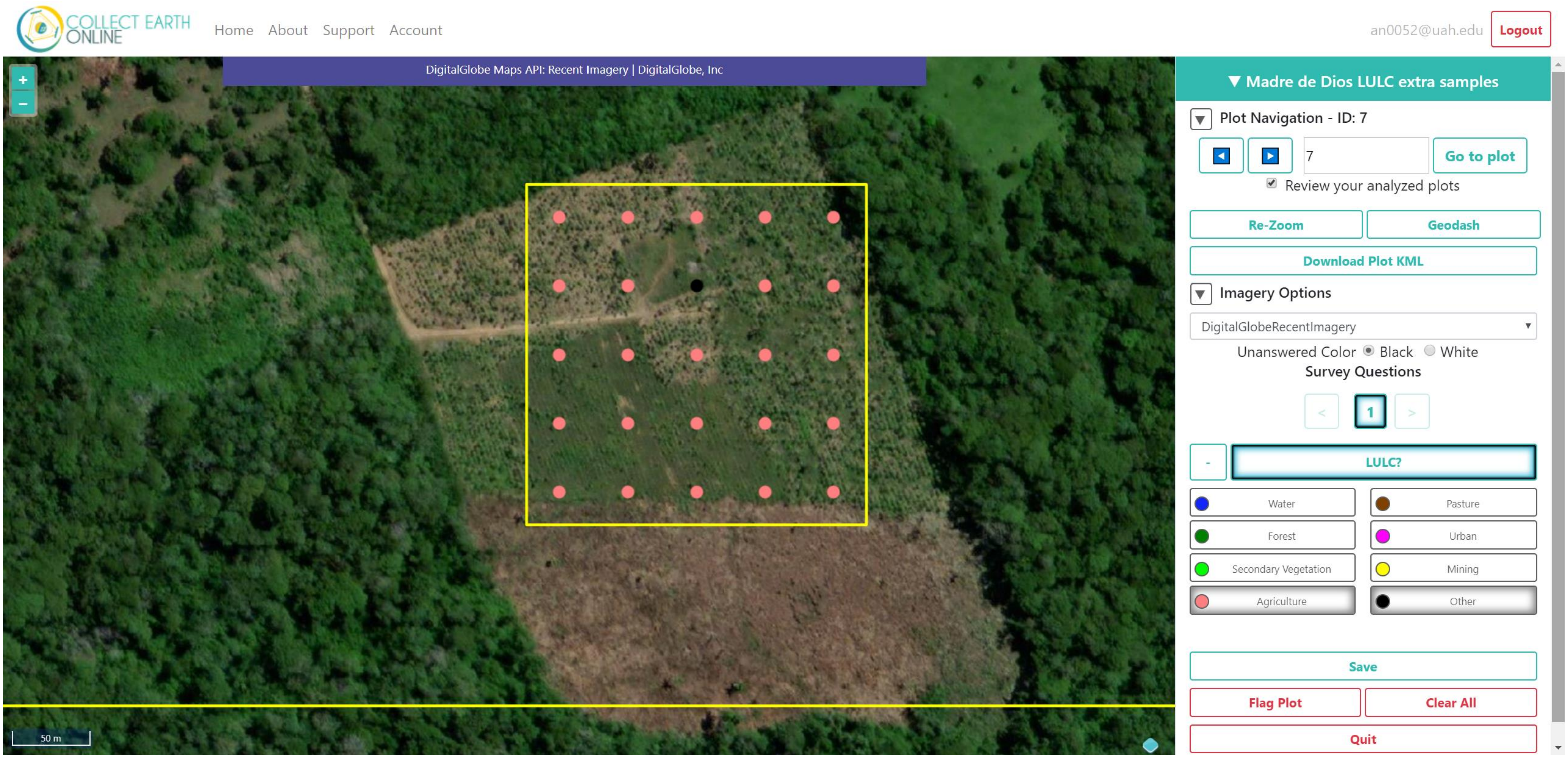
Methodology - CEO

- Land Use Land Cover Map (2016) from Geobosques
- Sample Design: Stratified Sampling (Olofsson et al., 2014)
  - 900 points for all classes
  - 88 random plots (5 ha) with 25 gridded points each
  - Minimum of 25 reference points each class
  - Addition of 4 and 6 extra for Agriculture and Mining classes, respectively (10 plots; 250 points)

	Forest	Sec. Veg.	Agriculture	Pasture	Mining	Urban	Water	Total
Plots	62	8	7	8	7	1	5	98
Points	1550	200	175	200	175	25	125	2450
Total Points	1718	163	75	53	73	25	66	2173

Methodology - CEO

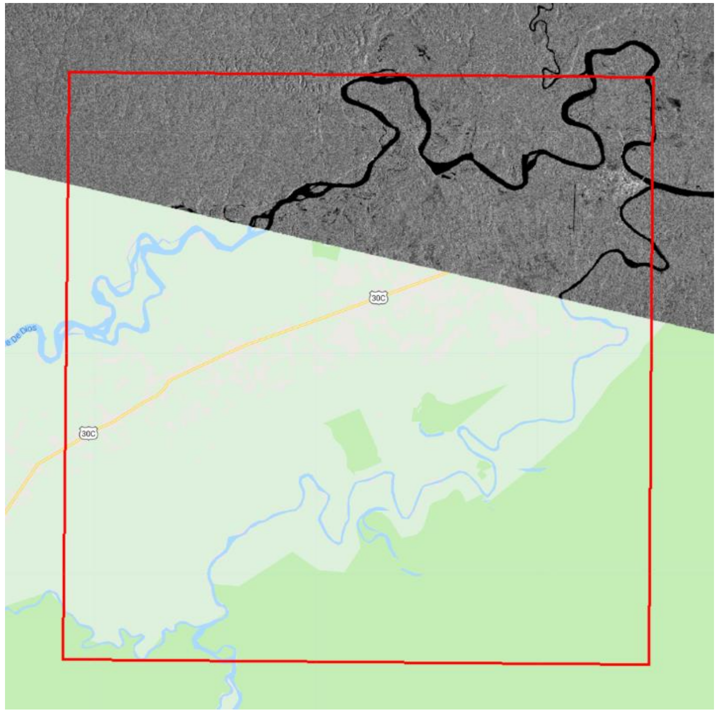
Methodology - CEO

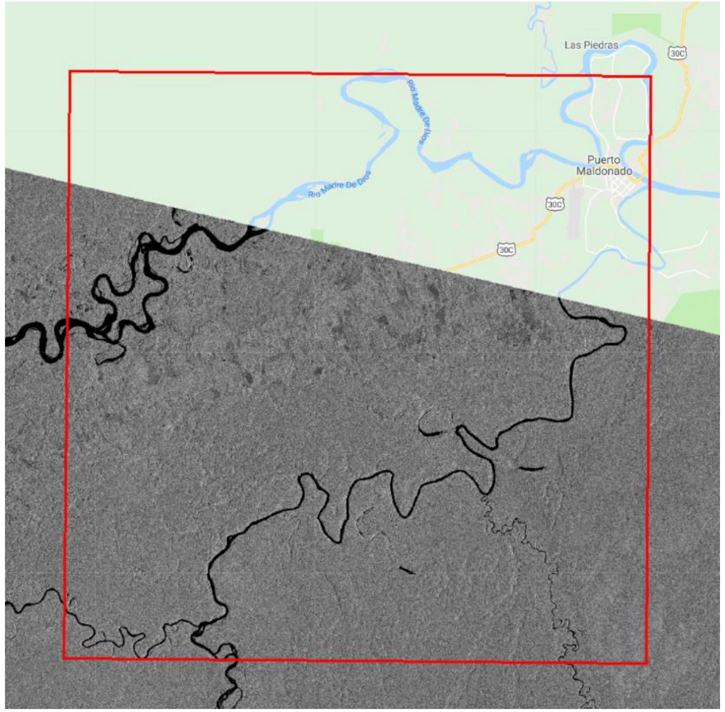


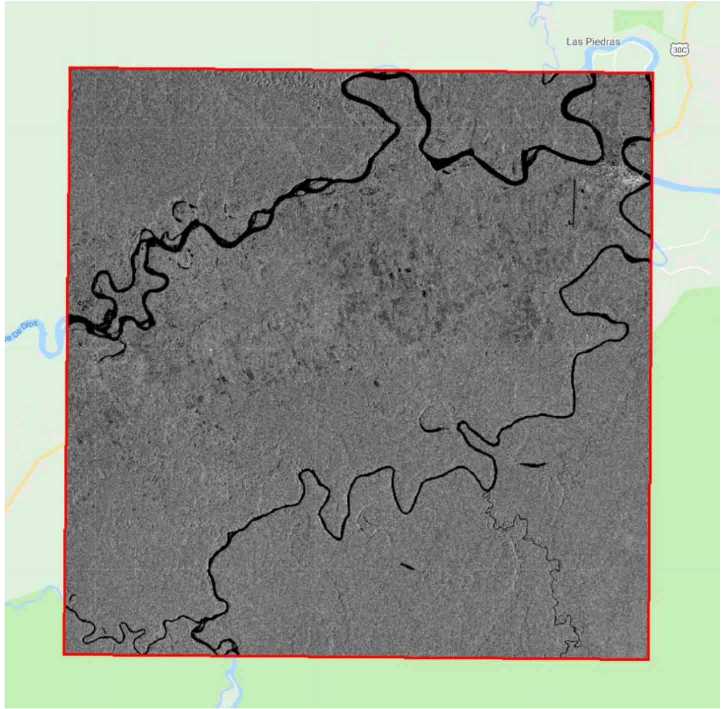
Methodology - GEE

1) Mosaicking images

Example: images from February 6, 2016







Methodology - GEE

2) Convert to gamma_o Amplitude

Decibels to Amplitude:

$$Amplitude = 10^{dB/20}$$

sigma_o to gamma_o:

$$\gamma_o = \frac{\sigma_o}{\cos(incidence\ angle)}$$

$$RFDI = \frac{\gamma^o_{HH} - \gamma^o_{HV}}{\gamma^o_{HH} + \gamma^o_{HV}}$$

$$RFDI\ mod. = \frac{\gamma^o_{VV} - \gamma^o_{HV}}{\gamma^o_{VV} + \gamma^o_{HV}}$$

$$S_{ab} = \frac{|\mu_a - \mu_b|}{|\sigma_a - \sigma_b|}$$

3) Create quarterly composites (noise/salt and pepper effect)

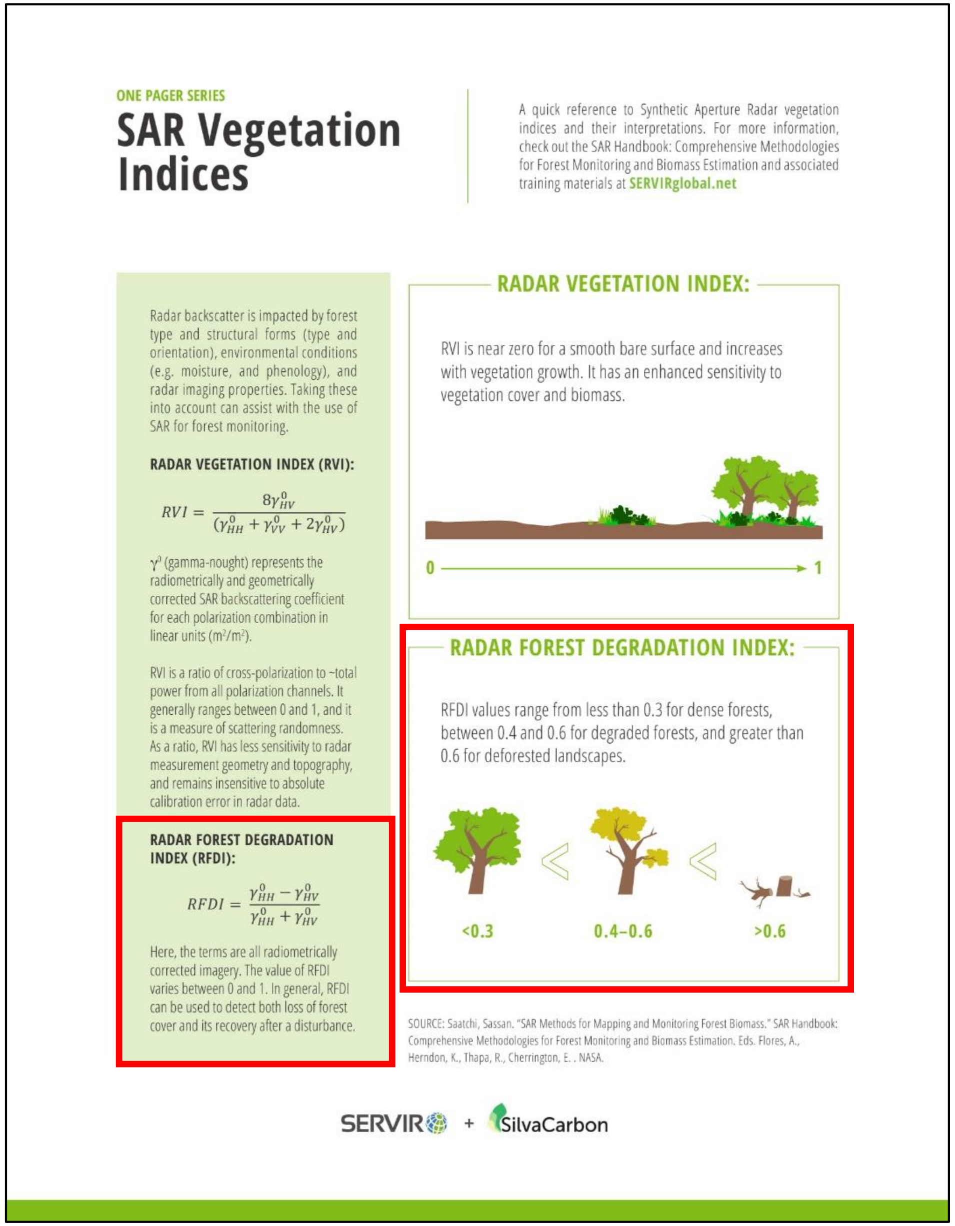
4) Time series analysis and metrics calculation for each class using the reference points from CEO

VV, VH, VV/VH, RFDI modified, Separability Index

Mean, Median, Standard Deviation, Max-Min ratio, Coefficient of Variation

5) Definition of thresholds for the Decision Tree - Classification

RFDI



ONE PAGER SERIES

SAR Vegetation Indices

A quick reference to Synthetic Aperture Radar vegetation indices and their interpretations. For more information, check out the SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation and associated training materials at **SERVIRglobal.net**

Radar backscatter is impacted by forest type and structural forms (type and orientation), environmental conditions (e.g. moisture, and phenology), and radar imaging properties. Taking these into account can assist with the use of SAR for forest monitoring.

RADAR VEGETATION INDEX (RVI):

$$RVI = \frac{8\gamma^0_{HV}}{(\gamma^0_{HH} + \gamma^0_{VV} + 2\gamma^0_{HV})}$$

γ^0 (gamma-nought) represents the radiometrically and geometrically corrected SAR backscattering coefficient for each polarization combination in linear units (m^2/m^2).

RVI is a ratio of cross-polarization to ~total power from all polarization channels. It generally ranges between 0 and 1, and it is a measure of scattering randomness. As a ratio, RVI has less sensitivity to radar measurement geometry and topography, and remains insensitive to absolute calibration error in radar data.

RADAR FOREST DEGRADATION INDEX (RFDI):

$$RFDI = \frac{\gamma^0_{HH} - \gamma^0_{HV}}{\gamma^0_{HH} + \gamma^0_{HV}}$$

Here, the terms are all radiometrically corrected imagery. The value of RFDI varies between 0 and 1. In general, RFDI can be used to detect both loss of forest cover and its recovery after a disturbance.

RADAR VEGETATION INDEX:

RVI is near zero for a smooth bare surface and increases with vegetation growth. It has an enhanced sensitivity to vegetation cover and biomass.

0 → 1

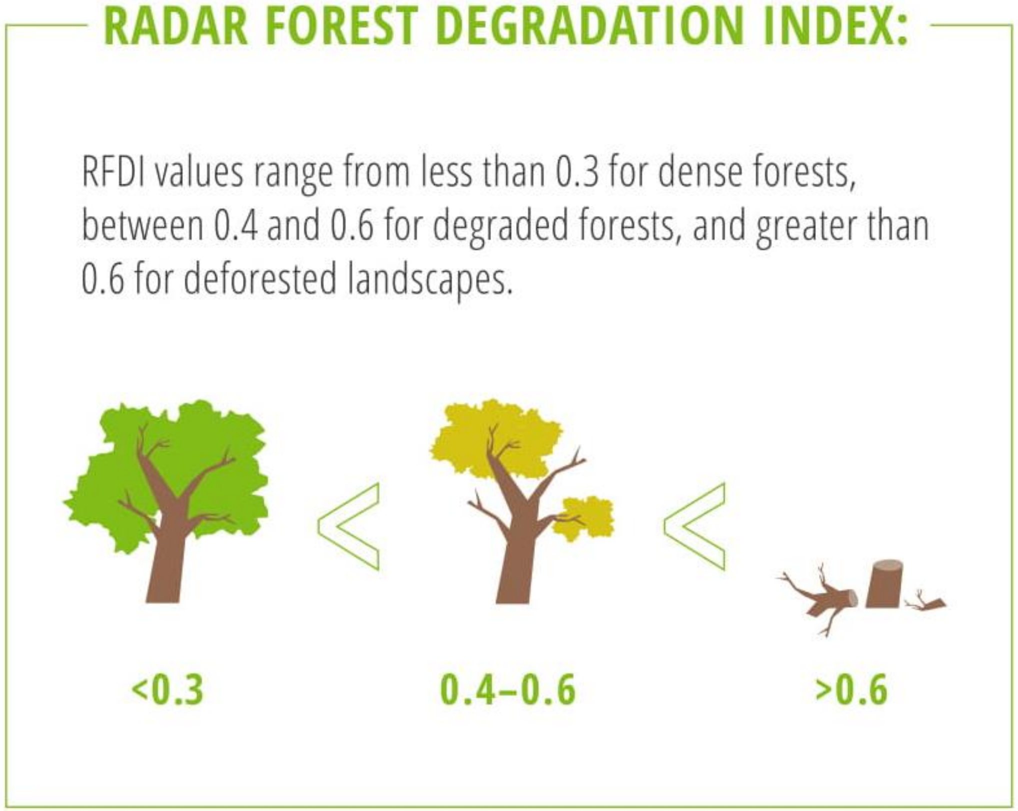
RADAR FOREST DEGRADATION INDEX:

RFDI values range from less than 0.3 for dense forests, between 0.4 and 0.6 for degraded forests, and greater than 0.6 for deforested landscapes.

<0.3 < 0.4–0.6 < >0.6

SOURCE: Saatchi, Sassan. "SAR Methods for Mapping and Monitoring Forest Biomass." SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation. Eds. Flores, A., Herndon, K., Thapa, R., Cherrington, E. . NASA.

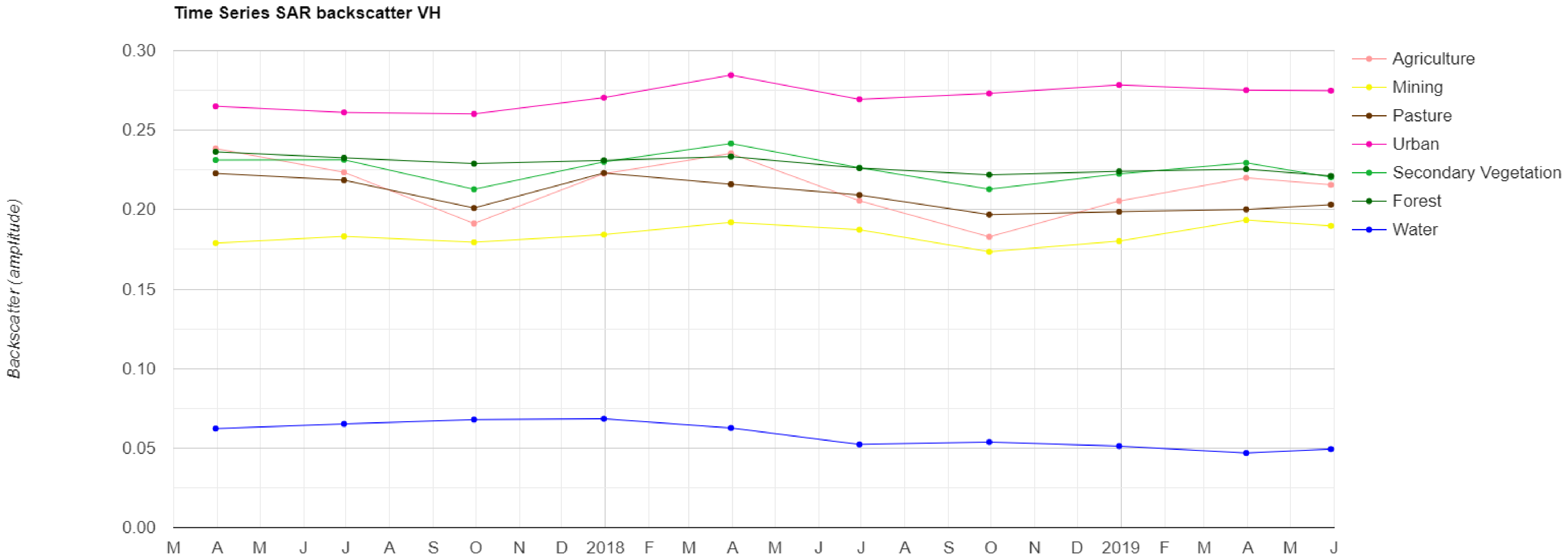
SERVIR + SilvaCarbon



SAR Handbook

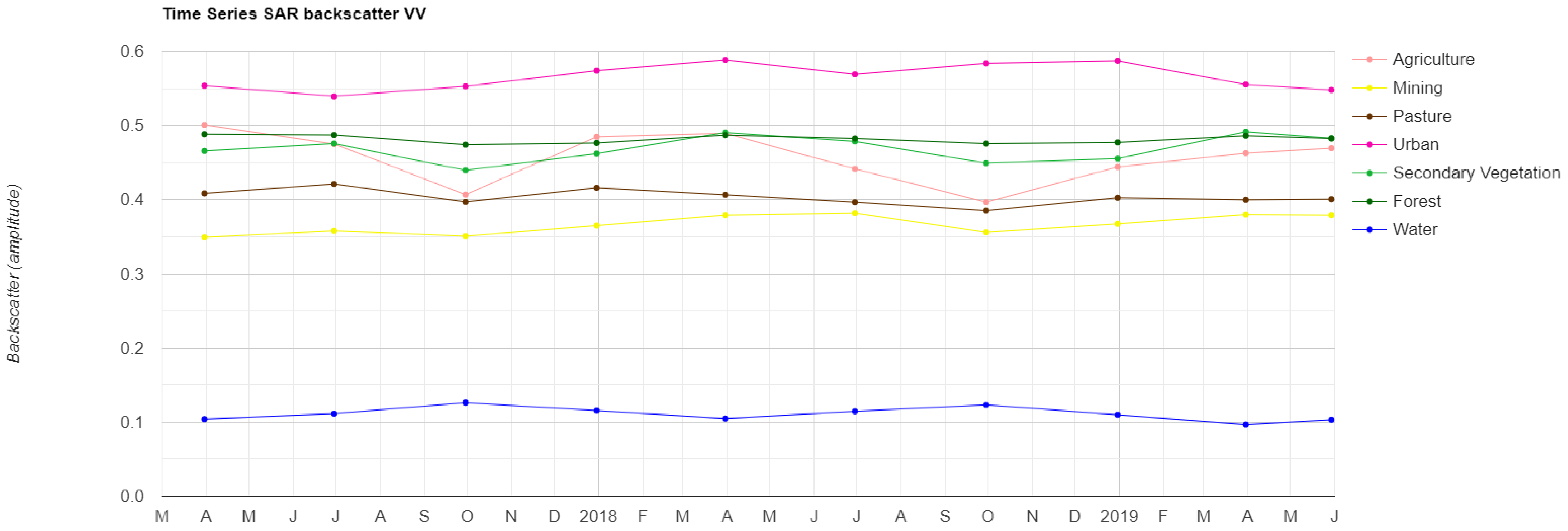
Results

Time series - VH



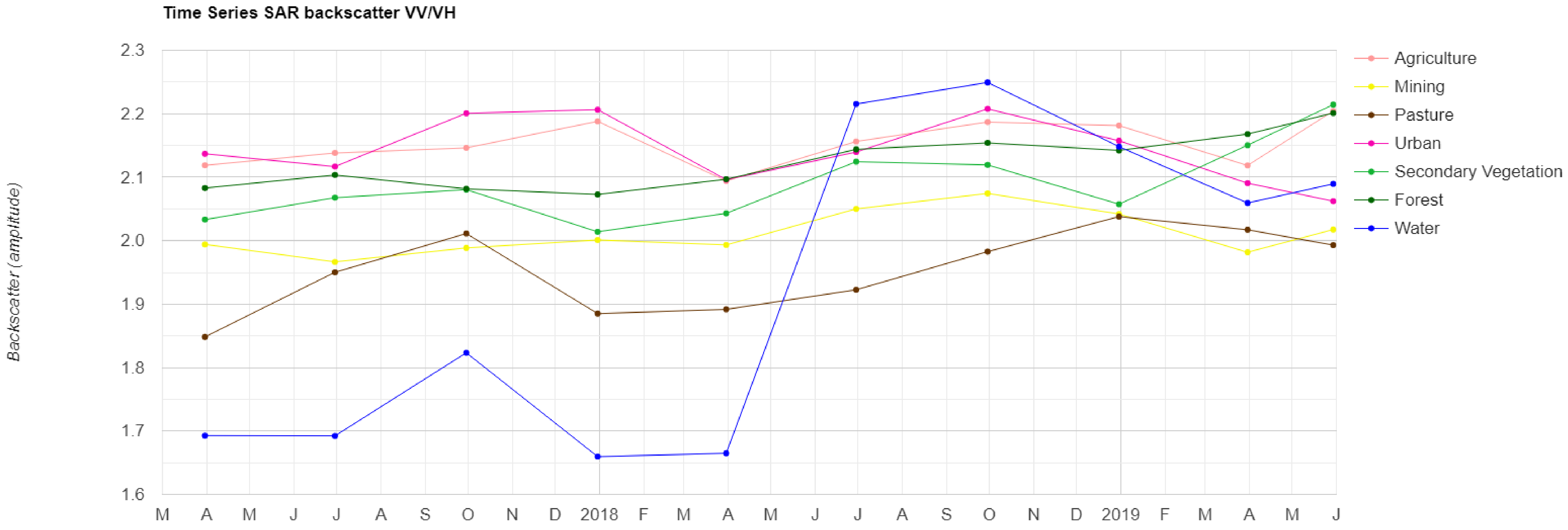
Results

Time series - VV



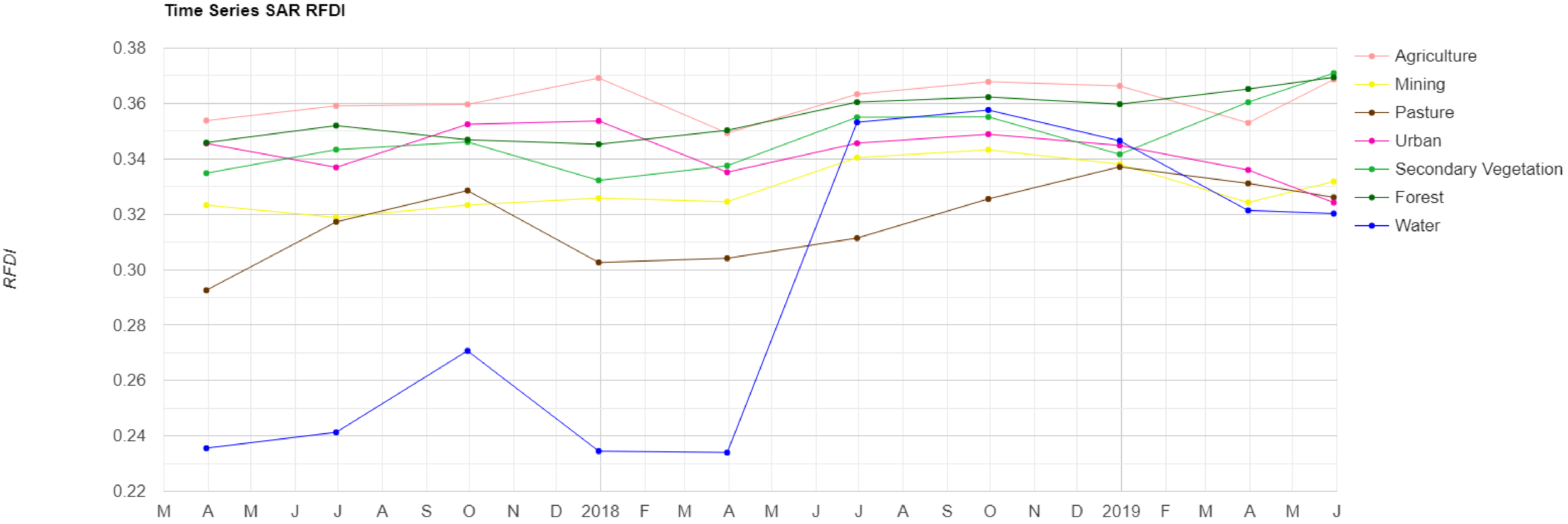
Results

Time series – VV/VH



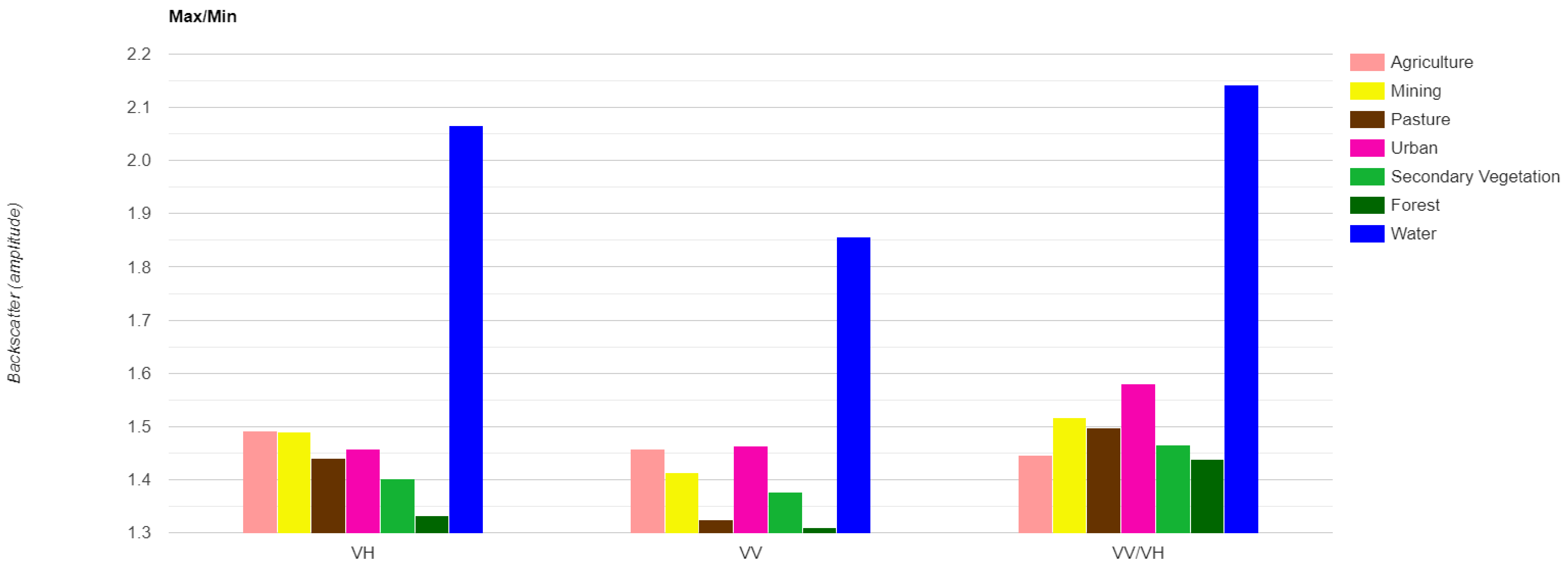
Results

Time series - RFDI



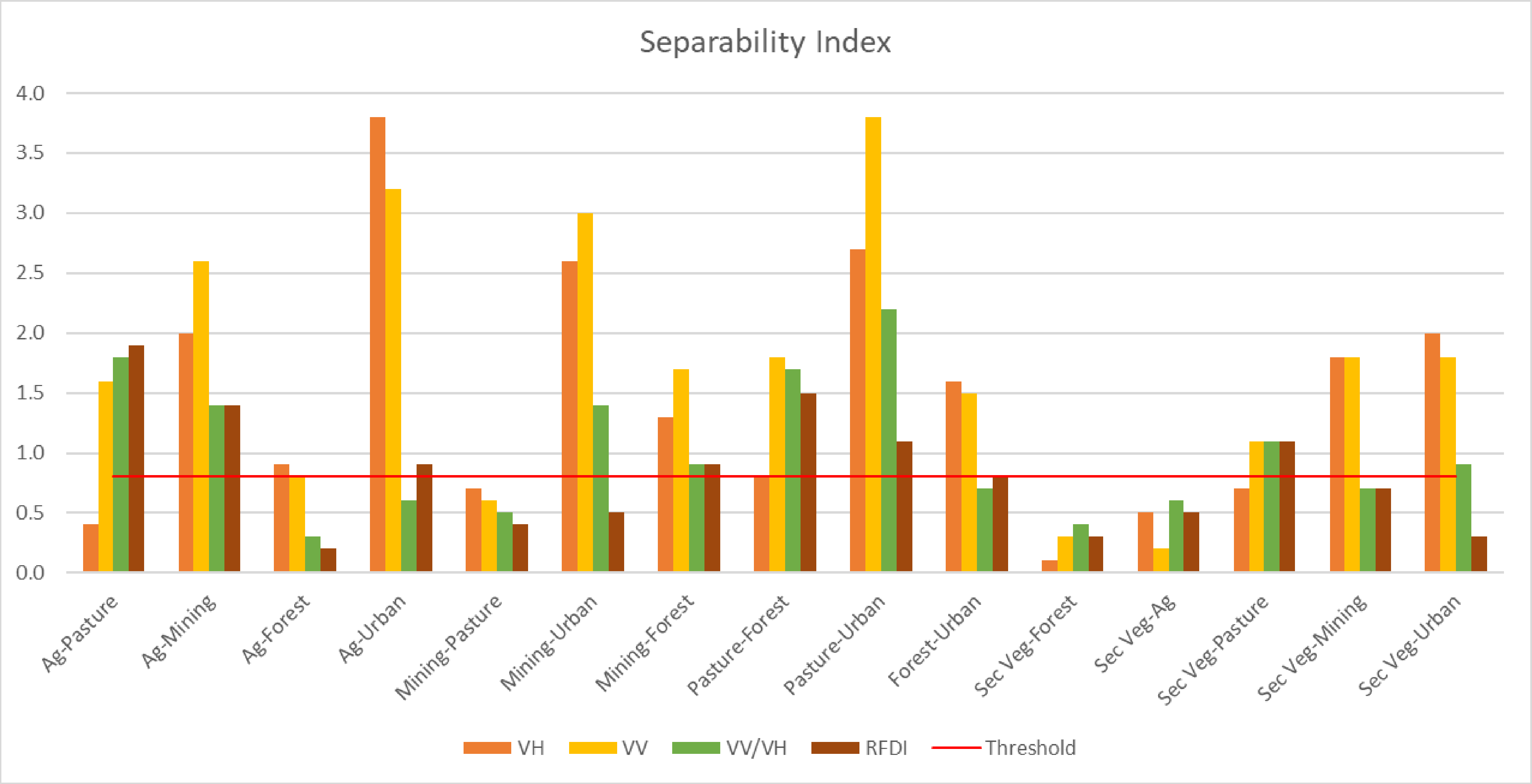
Results

Metrics – Max/Min

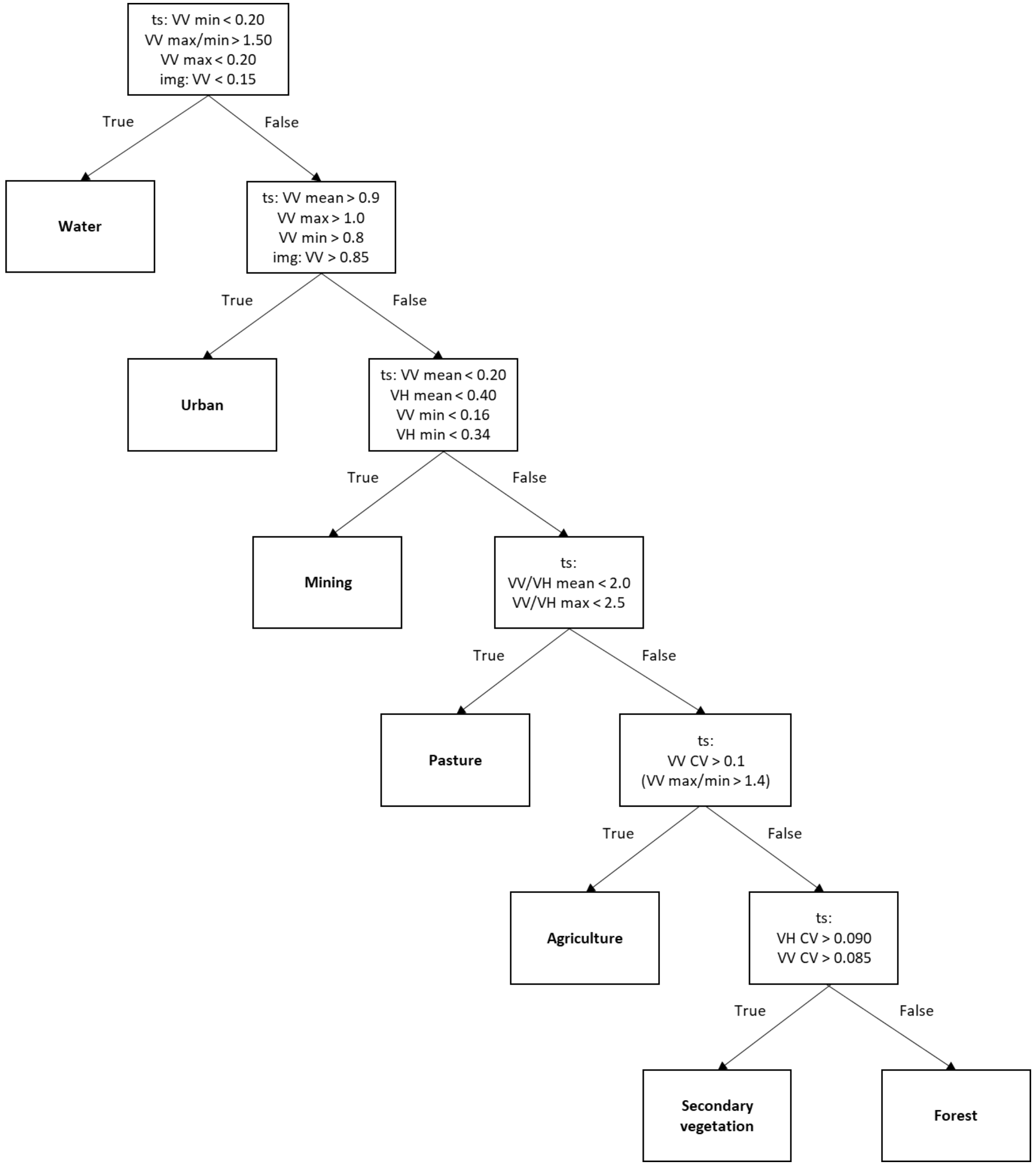


Results

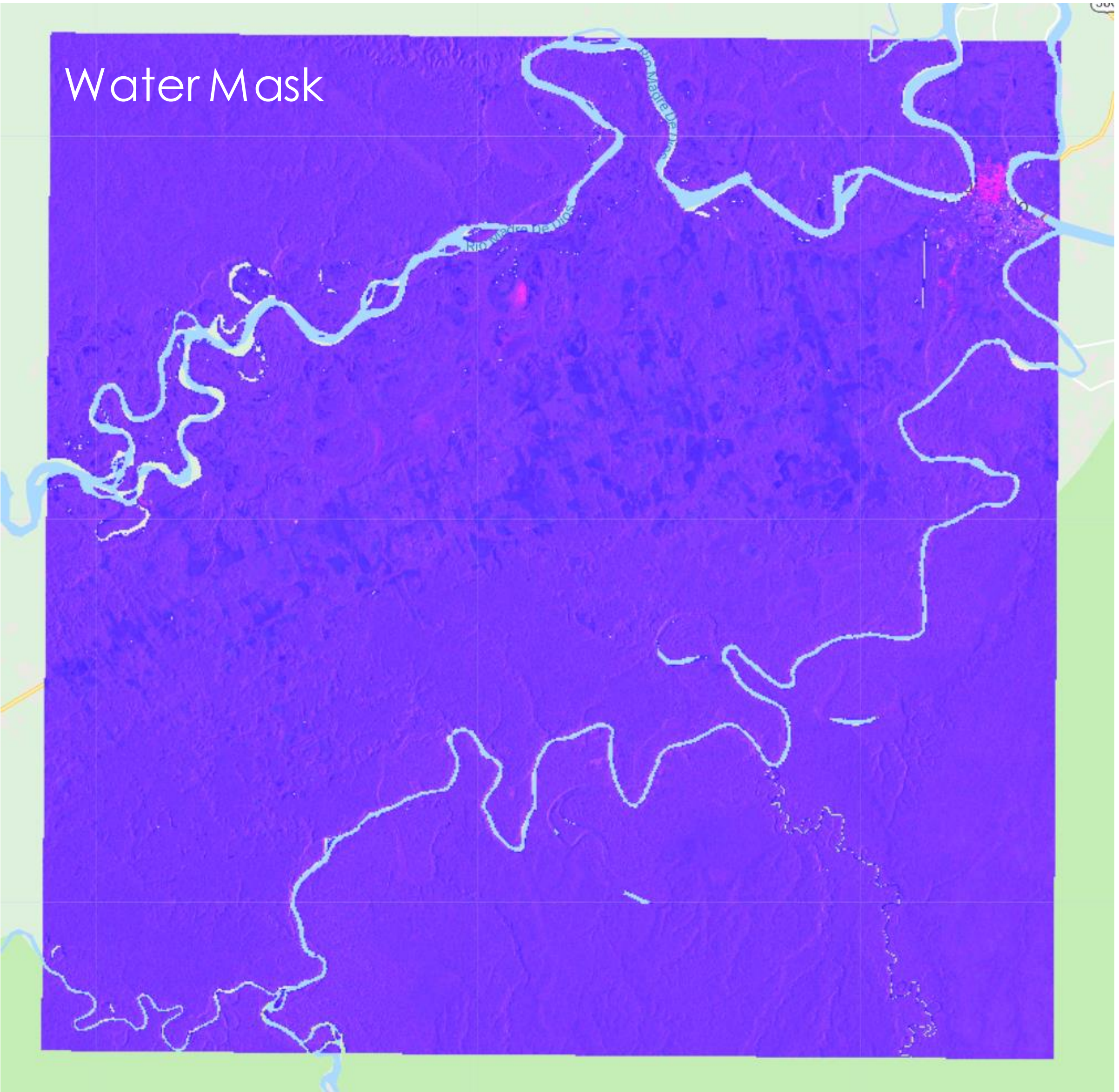
Separability Index (Wu et al., 2011)

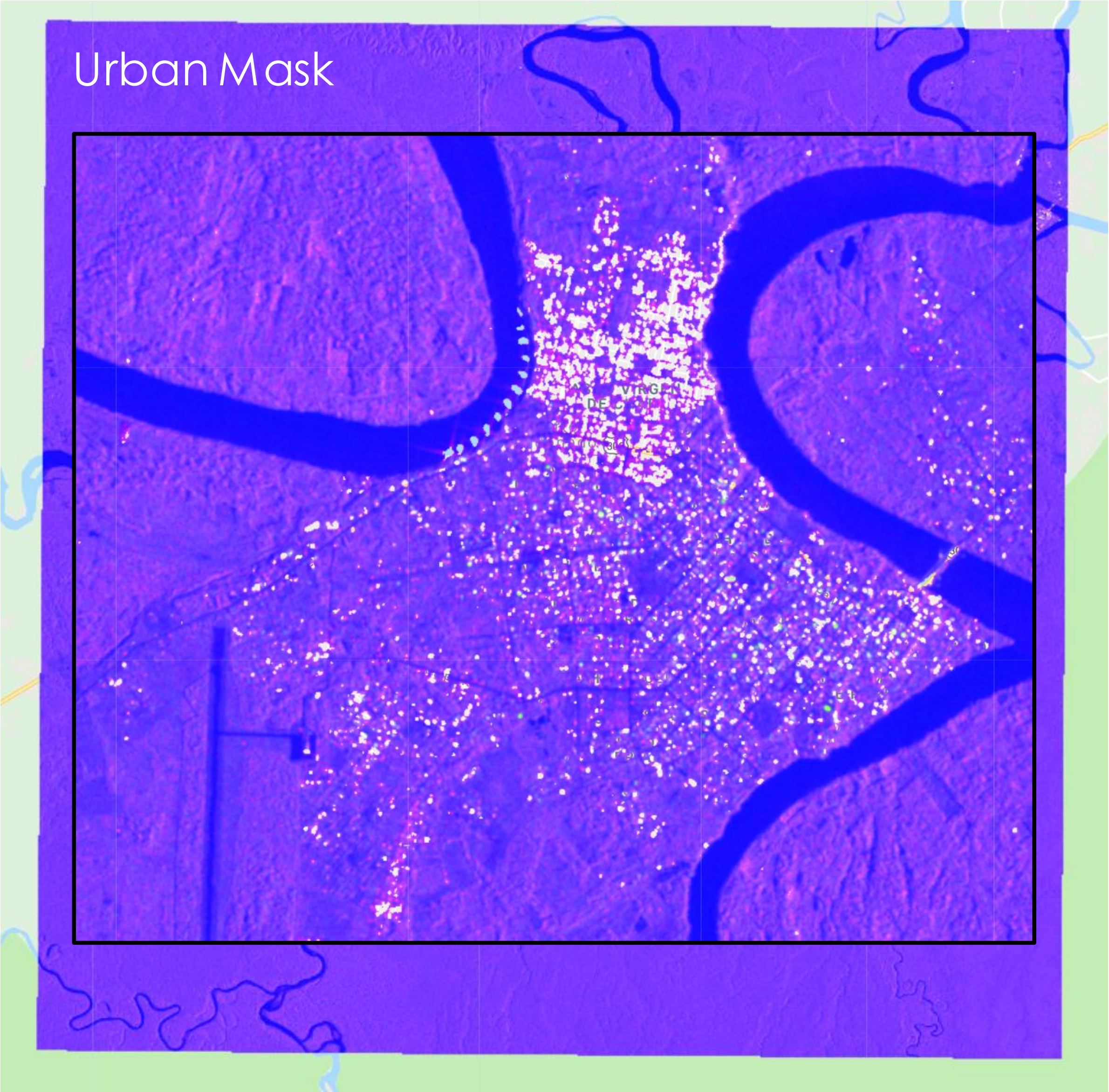


Decision tree



Decision Tree





Conclusions and Future Work

- Similar amplitude values when analyzing Forest, Secondary Vegetation, Agriculture, and Pasture
- Some seasonality trends are observed – info for classification
- Limitations: only two polarizations; noise; airport area
- Finish aplication of decisión tree and classification
- Accuracy assessment (Confusion matrix following Oloffson et al., 2014)
- Adapt the algorithm to be applied only on areas that were deforested
- SERVIR-Amazonia: expected that this project can contribute with the Amazon basin conservation

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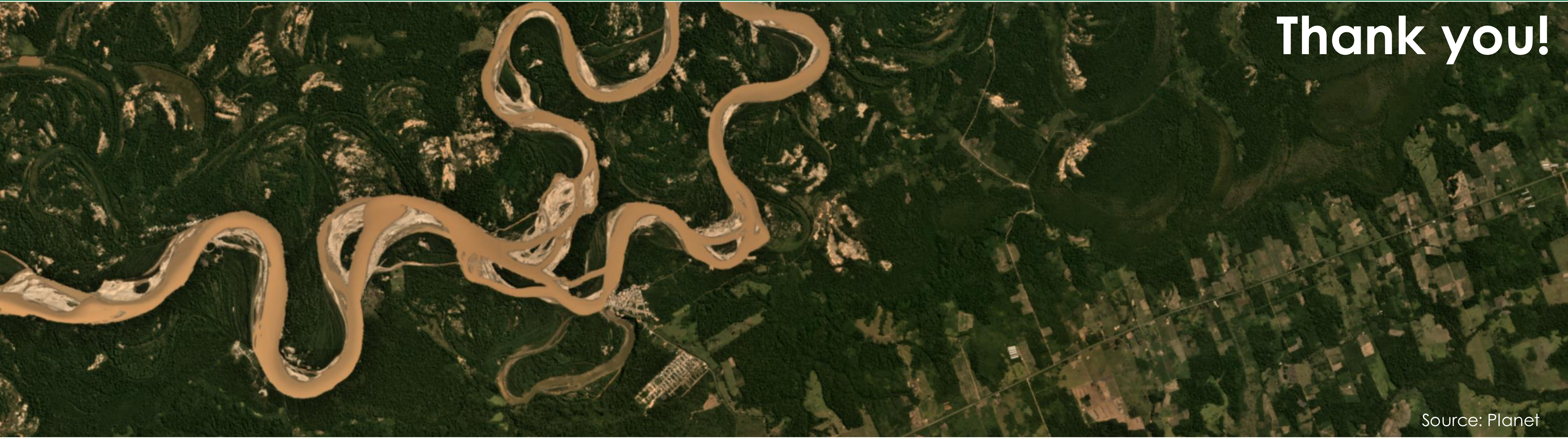
Thank you!



Source: Planet

Questions?

Andréa Puzzi Nicolau

Graduate Research Assistant

SERVIR-Amazonia

Email: andrea.puzzinicolau@nasa.gov / an0052@uah.edu

Backup Slides

- backup