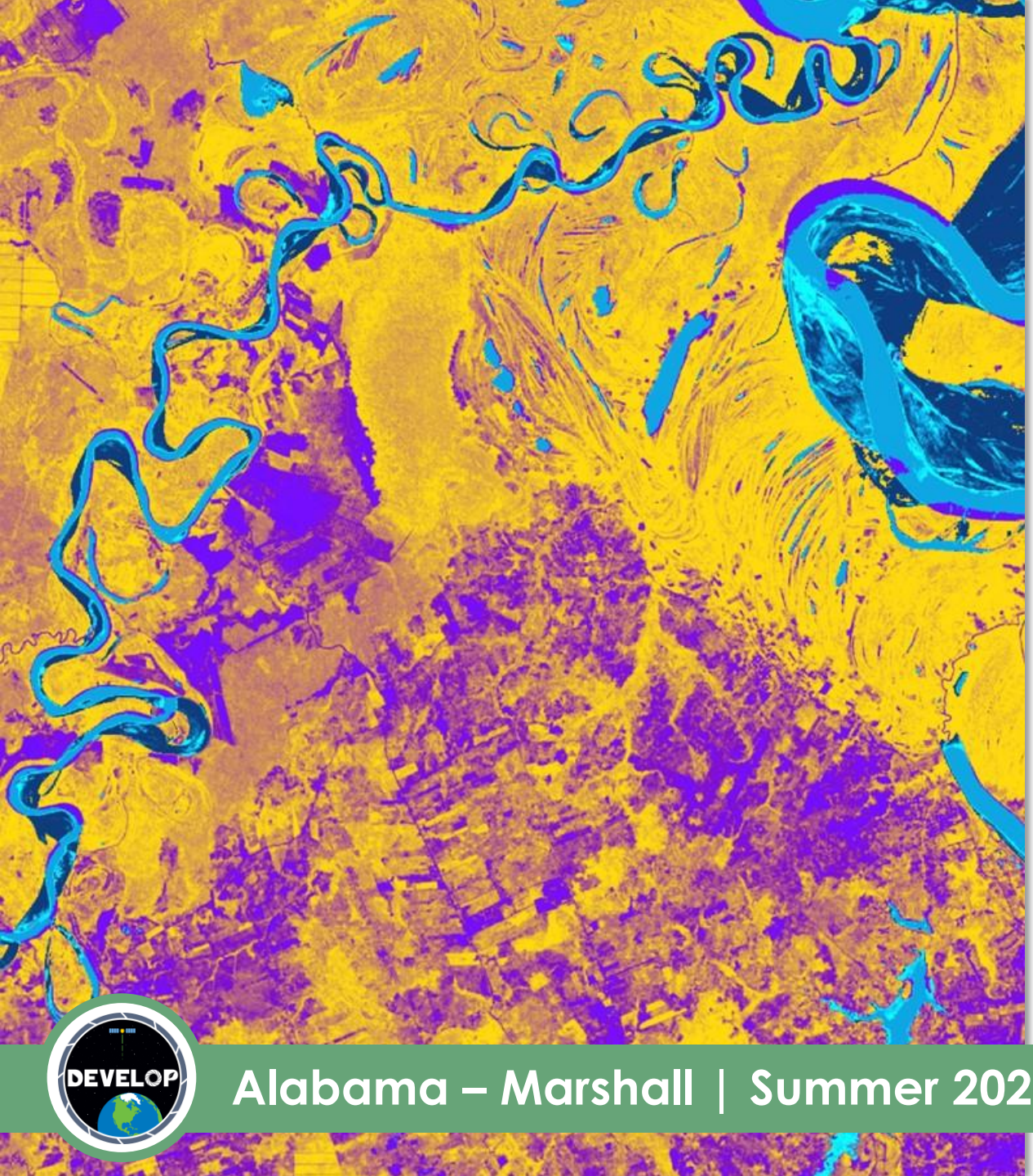


National Aeronautics and Space Administration

PERUVIAN AMAZON ECOLOGICAL CONSERVATION

Assessing Land Cover Changes in the Peruvian Amazon to Identify Exploitative Agriculture Using NASA EO and PerúSAT-1

Beck De Fazio

Ashley Laveriano

Brian Arruda

Margaret Cox

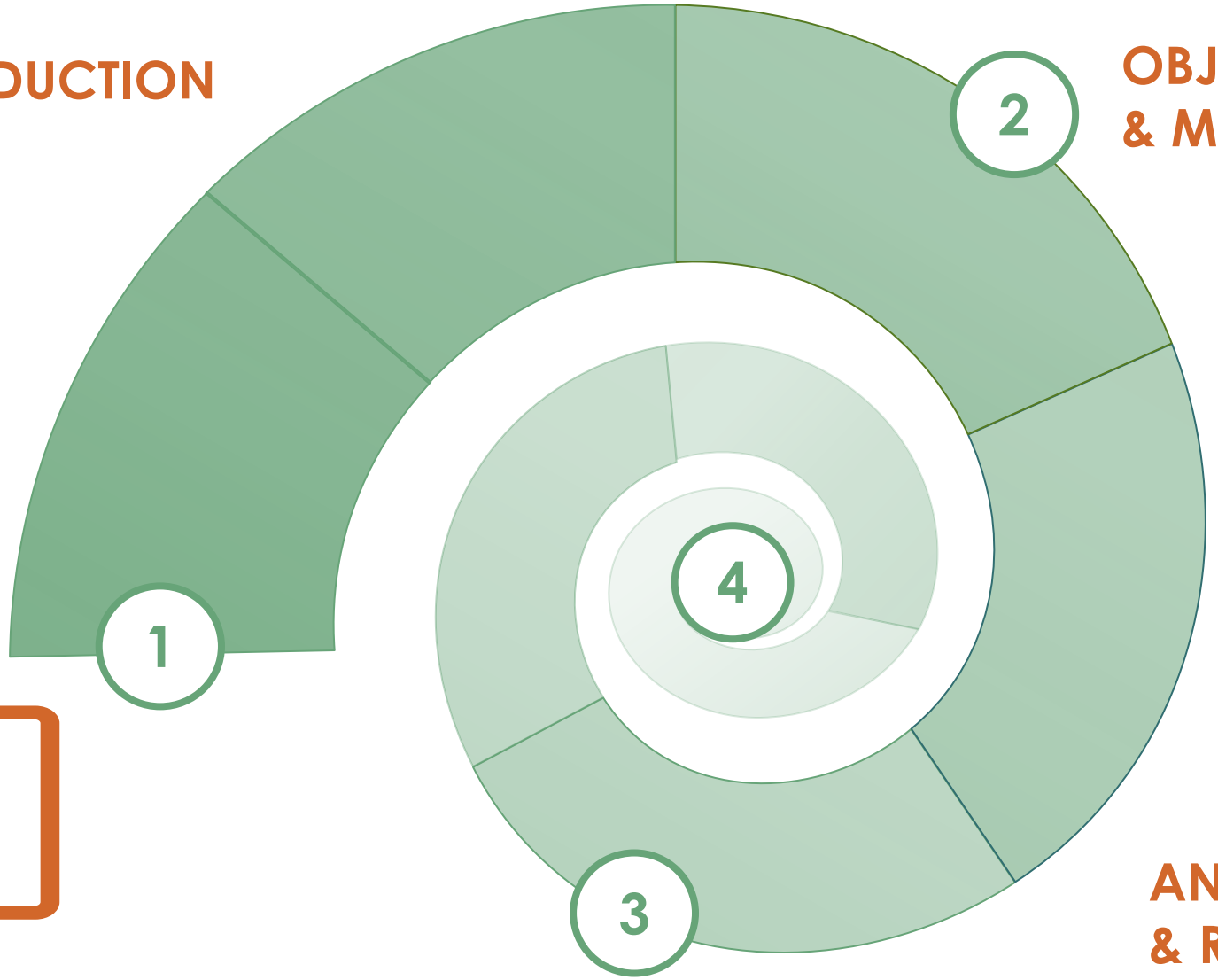
DEVELOP

Alabama – Marshall | Summer 2024

Roadmap

1 INTRODUCTION

OBJECTIVES & METHODS 2



4 DISCUSSION

3 ANALYSIS & RESULTS

Meet the Team



Brian Arruda



Beck De Fazio



Margaret Cox



Ashley Laveriano

Image Credit: Tom Fisk

The Amazon


Image Credit: Diego Perez


Image Credit: European Space Agency


Image credit: Diego Perez


Image Credit: Joelle Hernandez


Image Credit: Scott Kuo

Palm Oil in the Peruvian Amazon

93% Increase in exports since 2013

72% Expansion on forested land (2000-2010)

2000 Declared a commodity of national interest

5 Tons/ha crop productivity



Community Concerns


Image Credit: Management Sciences for Heal[illegible] Peru


Image Credit: Robert Guimaraes Vasquez


Image Credit: Rettet den Regenwald

People

- Smallholder farmers
- Industrial Corporations

Economy

- Partnerships
- Economic Disparities

Environment

- Land use differences
- Loss of ecosystem services

Project Partners

End User

Organismo de Evaluación y Fiscalización Ambiental (OEFA)

Evaluation and **prevention** of environmental impacts

Supervision and compliance with regulations

Collaborator

Comisión Nacional de Investigación y Desarrollo Aeroespacial (CONIDA)

Promote R&D of space science and technology

Generate products for the socioeconomic development and security

Area of Interest

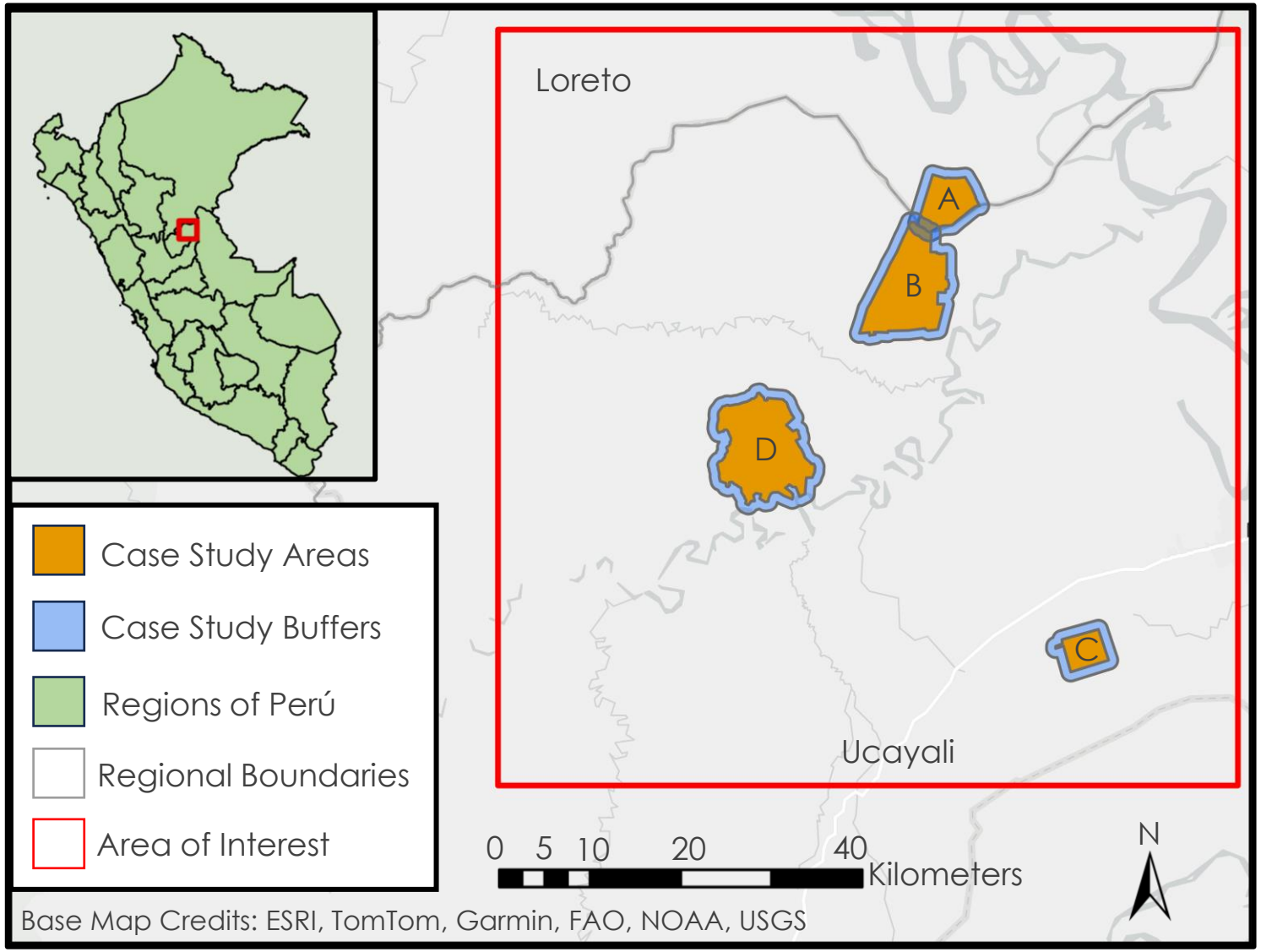
Study Area

- Peru: Ucayali & Loreto

Study Period

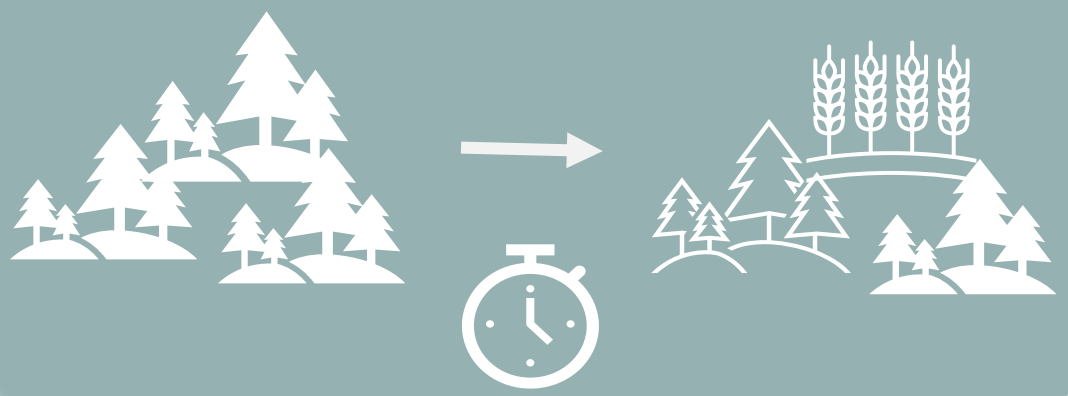
- Jan. 2017 – Dec. 2023

- Area of interest spans approximately **6,800 sq km** in the **Peruvian Amazon**
- **Four** focus case study areas that encompass designated **agroforestry** land

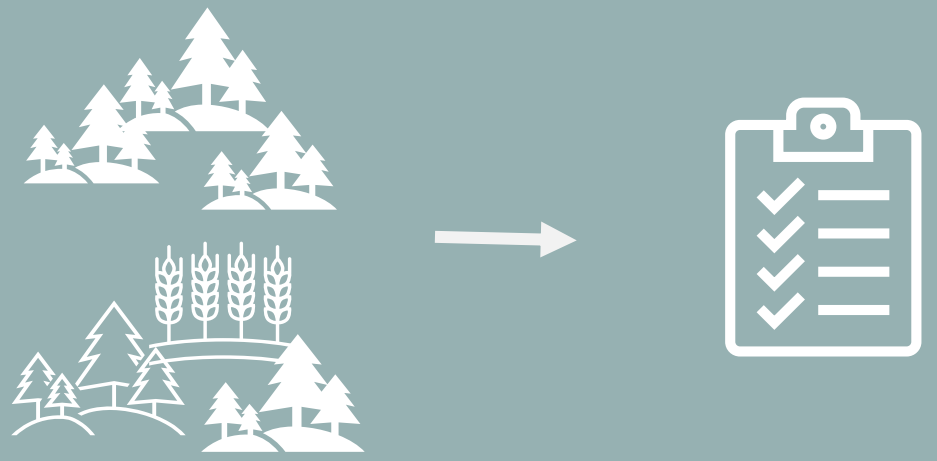


Objectives

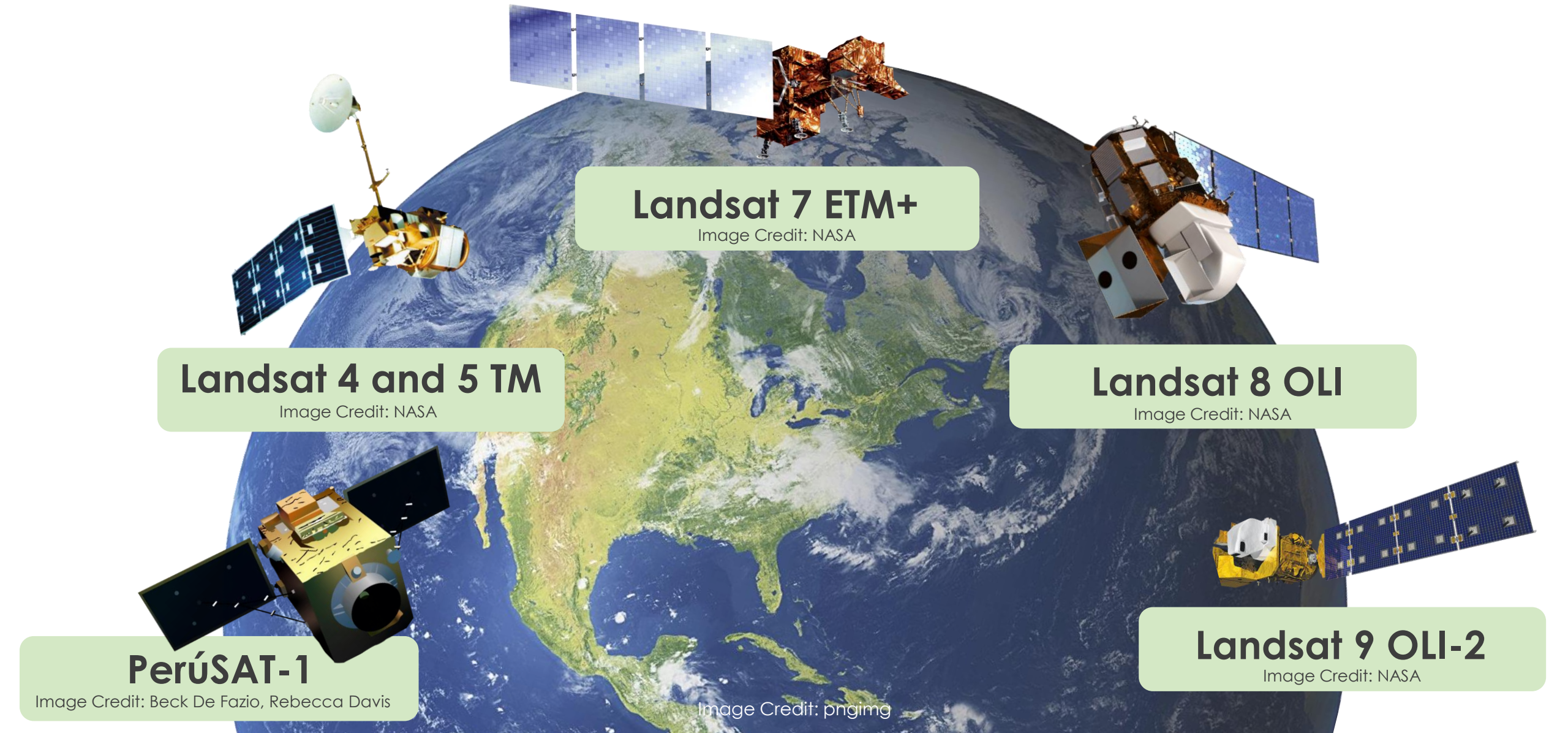
Quantify
deforestation in Perú using Landsat



Classify & Validate
change detection using PerúSAT-1



Earth Observations



Landsat 7 ETM+
Image Credit: NASA

Landsat 4 and 5 TM
Image Credit: NASA

Landsat 8 OLI
Image Credit: NASA

PerúSAT-1
Image Credit: Beck De Fazio, Rebecca Davis

Landsat 9 OLI-2
Image Credit: NASA

Image Credit: pngimg

Remote Sensing Indices Used

CCDC-SMA: Continuous Change Detection and Classification Spectral Mixture Analysis

Combines deforestation detection time series and spectral mixture analysis through GEE

Endmembers: green vegetation (GV), soil, non-photosynthetic vegetation (NPV), shade, cloud

NDFI: Normalized Difference Fraction Index

$$\frac{GV_{shade} - (\text{NPV} + \text{Soil})}{GV_{shade} + (\text{NPV} + \text{Soil})} \quad \text{where} \quad GV_{shade} = \frac{GV}{1 - Shade}$$

Represents the fraction of each endmember in a pixel: ↑ Soil & ↓ NDFI = Disturbance (Soil – NDFI will always be > 0)

NDVI: Normalized Difference Vegetation Index

Proxy for vegetation health

$$\frac{NIR - Red}{NIR + Red}$$

EVI: Enhanced vegetation index

Corrects for atmospheric condition and canopy background noise

$$2.5 \text{ x } \frac{NIR - Red}{(NIR + (2.4\ x\ Red) + 1)}$$

Methods

Land Cover Maps

Utilizing Landsat 8 OLI & Landsat 9 OLI 2

Google Earth Engine

Normalized Difference Vegetation Index

Enhanced Vegetation Index

Vegetation Loss



Methods

Land Cover Maps

Utilizing Landsat 8 OLI & Landsat 9 OLI 2

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Enhanced Vegetation Index

Vegetation Loss

Time Series Change Detection

Via Landsat Series

Continuous Change Detection and Classification Spectral Mixture Analysis

Normalized Difference Fraction Index

Square km Lost & Forest % Remaining



Methods

Land Cover Maps

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Via Landsat Series

Continuous Change Detection and Classification Spectral Mixture Analysis

Normalized Difference Fraction Index

Square km Lost & Forest % Remaining

Land Cover Change Classification

PerúSAT-1

ArcGIS Pro 3.1.0

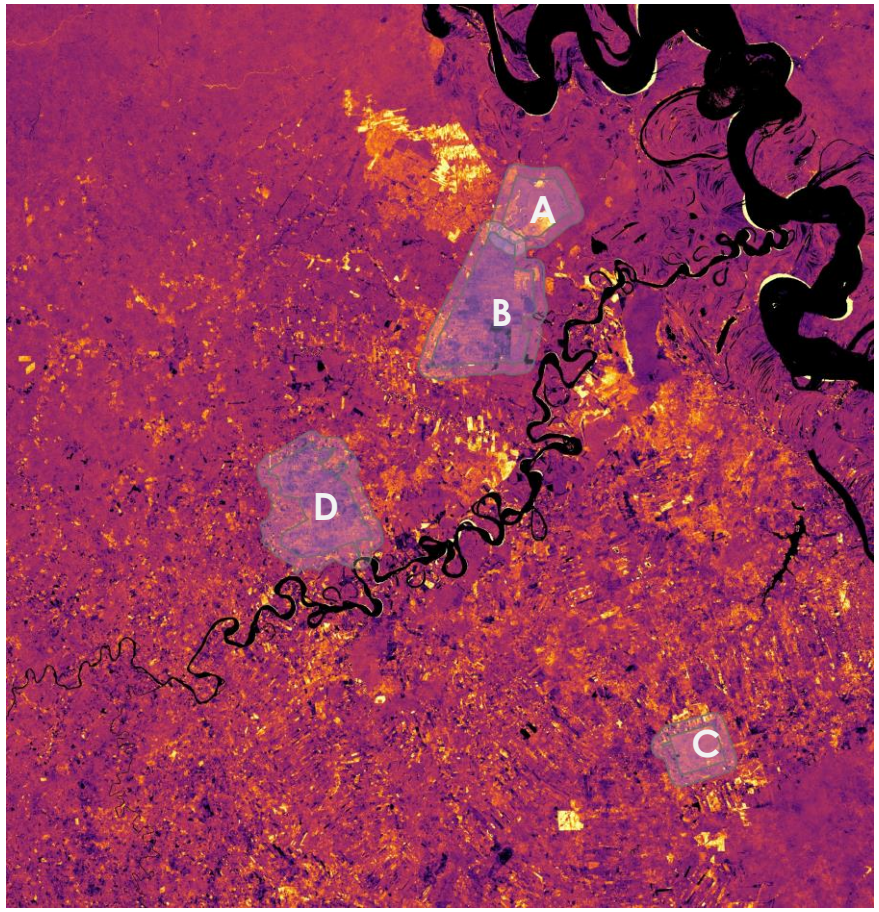
Collect Training Data

Imagery Pre-Processing

Supervised Classification

Identify Palm Expansion

NDVI & EVI

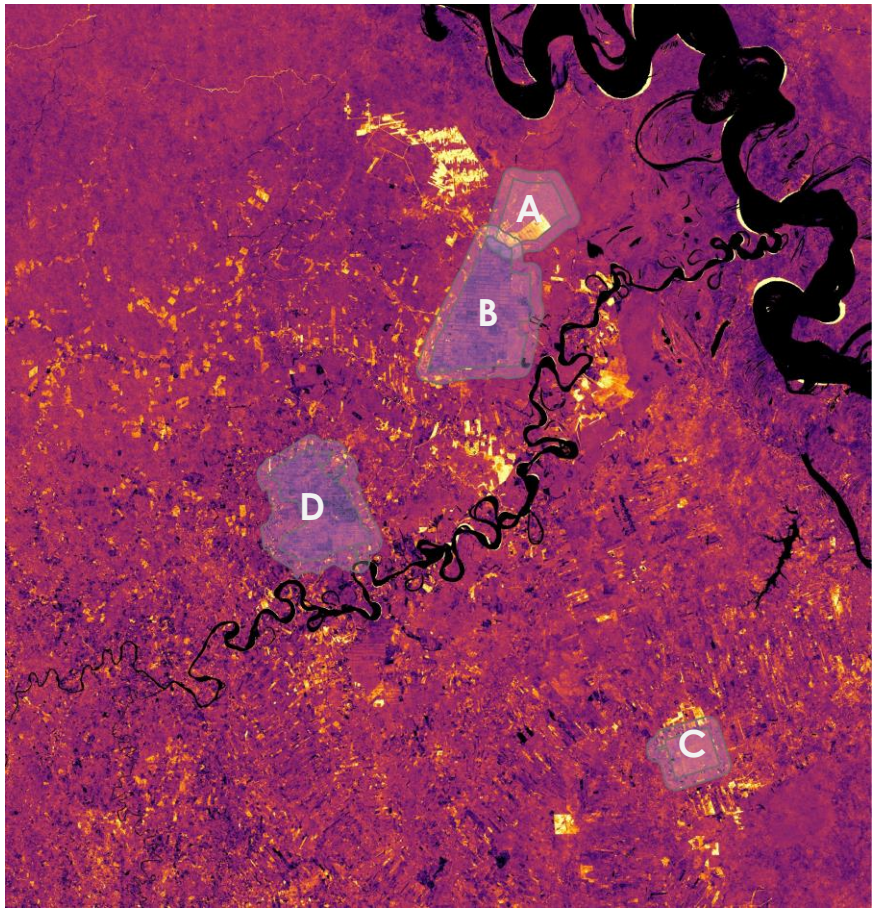


Difference in NDVI, 2017-2023

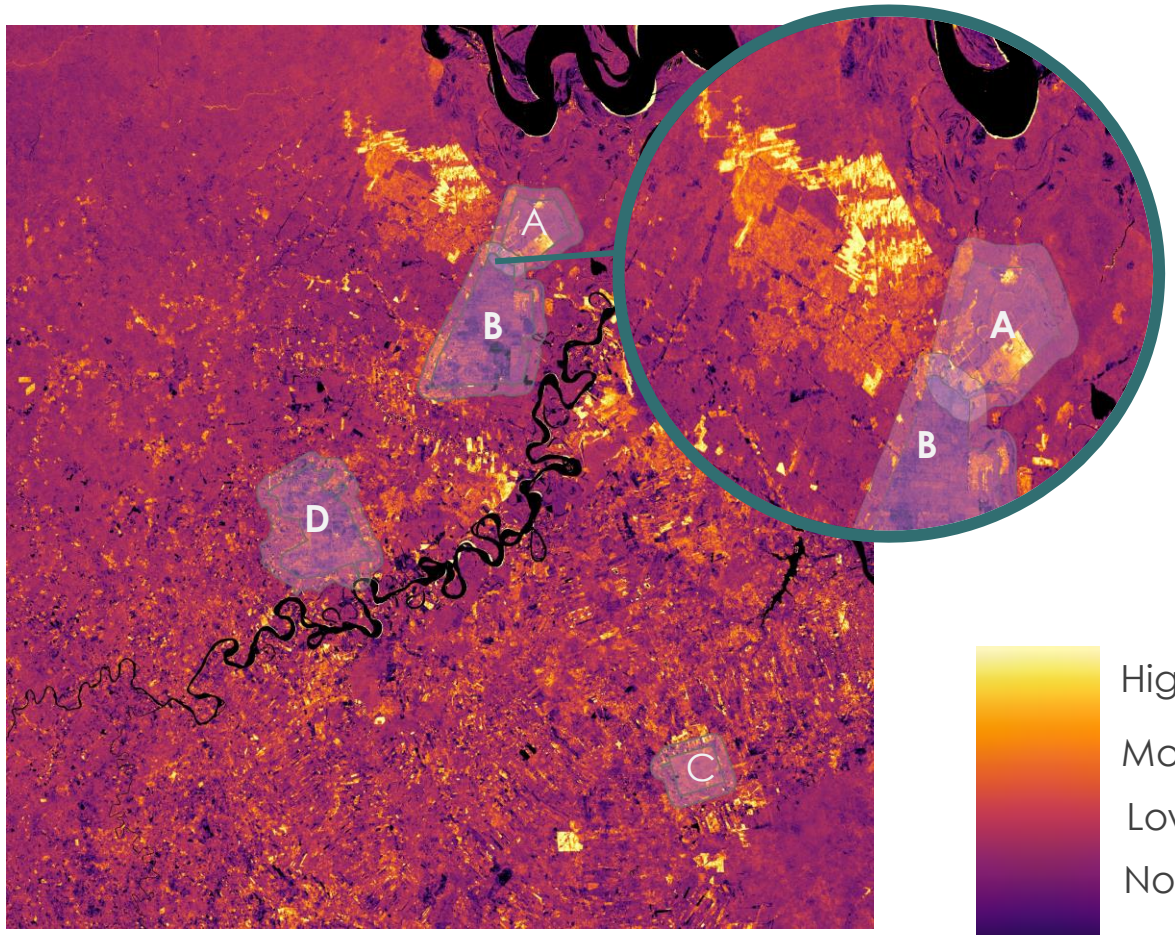




Difference in EVI, 2017-2023

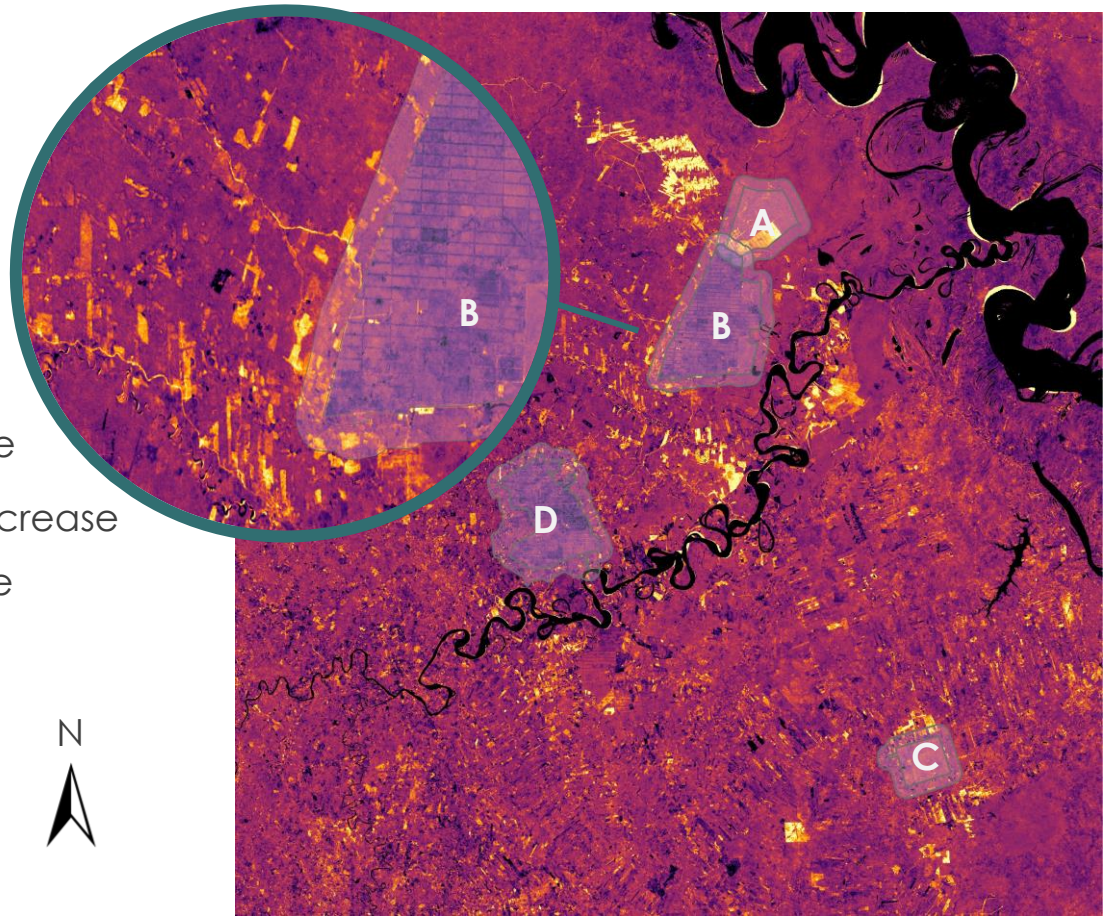


NDVI & EVI



Difference in NDVI, 2017-2023

Difference in EVI, 2017-2023



High Decrease

Moderate Decrease

Low Decrease

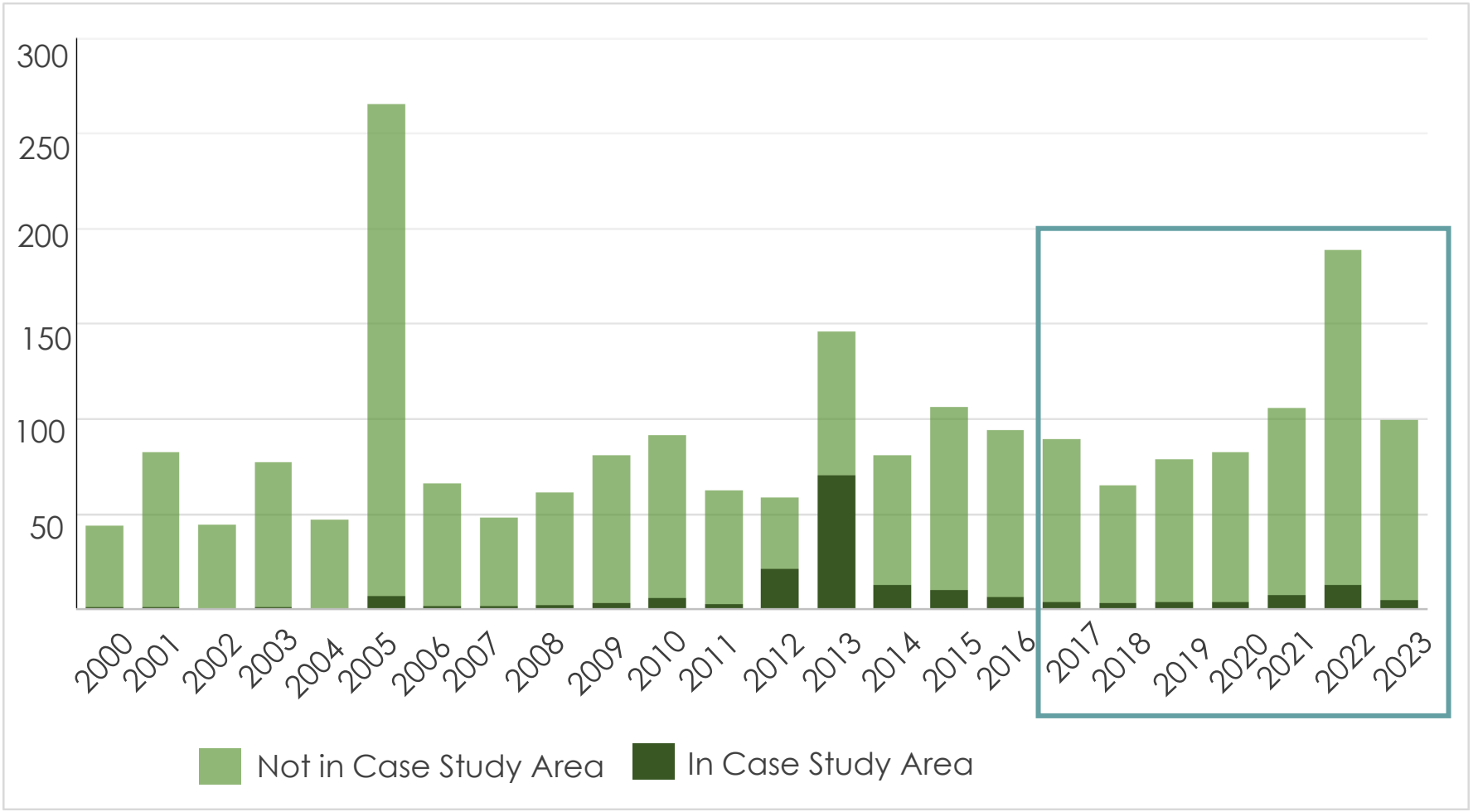
No Decrease

Water Mask

N

5 10 20 40

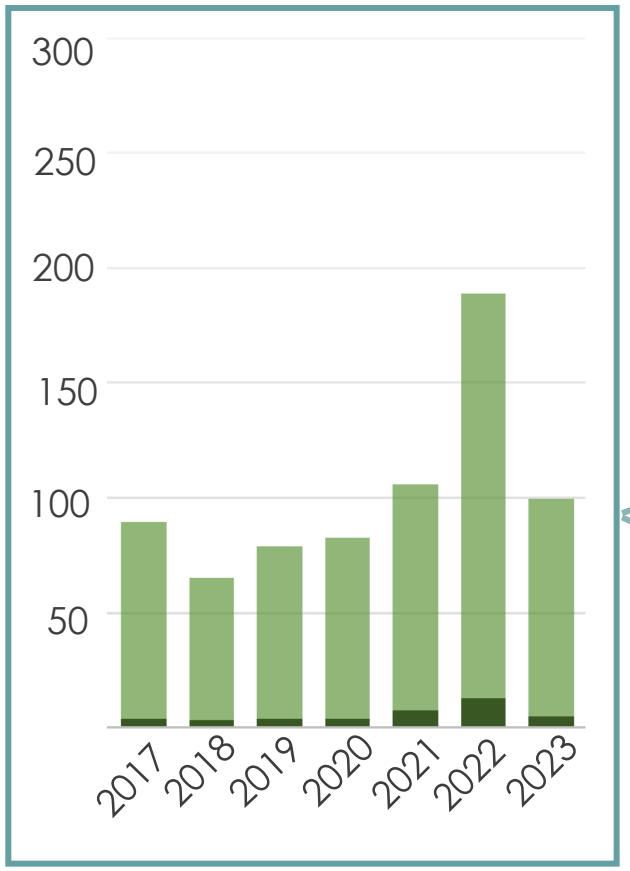
CCDC-SMA: Deforestation by Year



2165.2 km^2

Total Area Deforested, 2000-2023

CCDC-SMA: Recent Deforestation



Deforestation from 2017-2023:

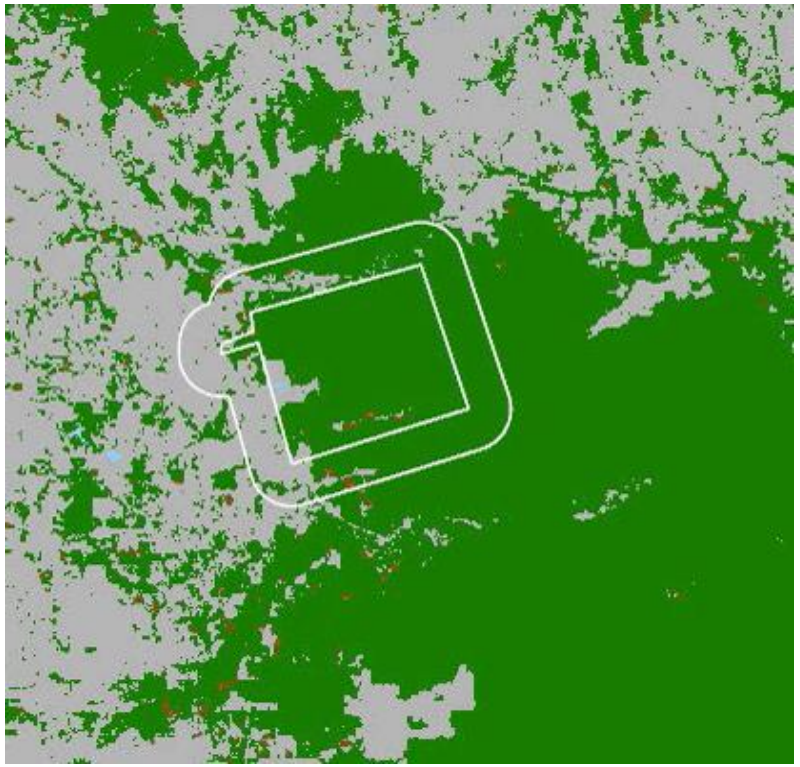
708.8 km²

Year	Deforested Area (km²)	% Total Loss
2022	189	26.6 %
2021	105	14.9 %
2023	99	14.0 %

Total Area Deforested: **2165.2 km²**

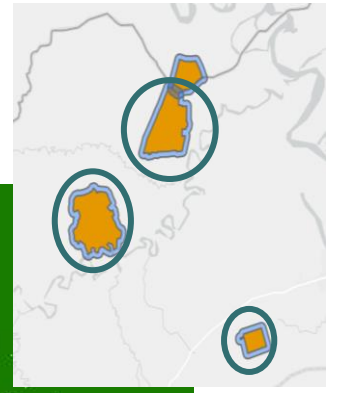
Percent Intact Forest: B, C, and D

Was the case study area > 30% forest as of 2023?









N

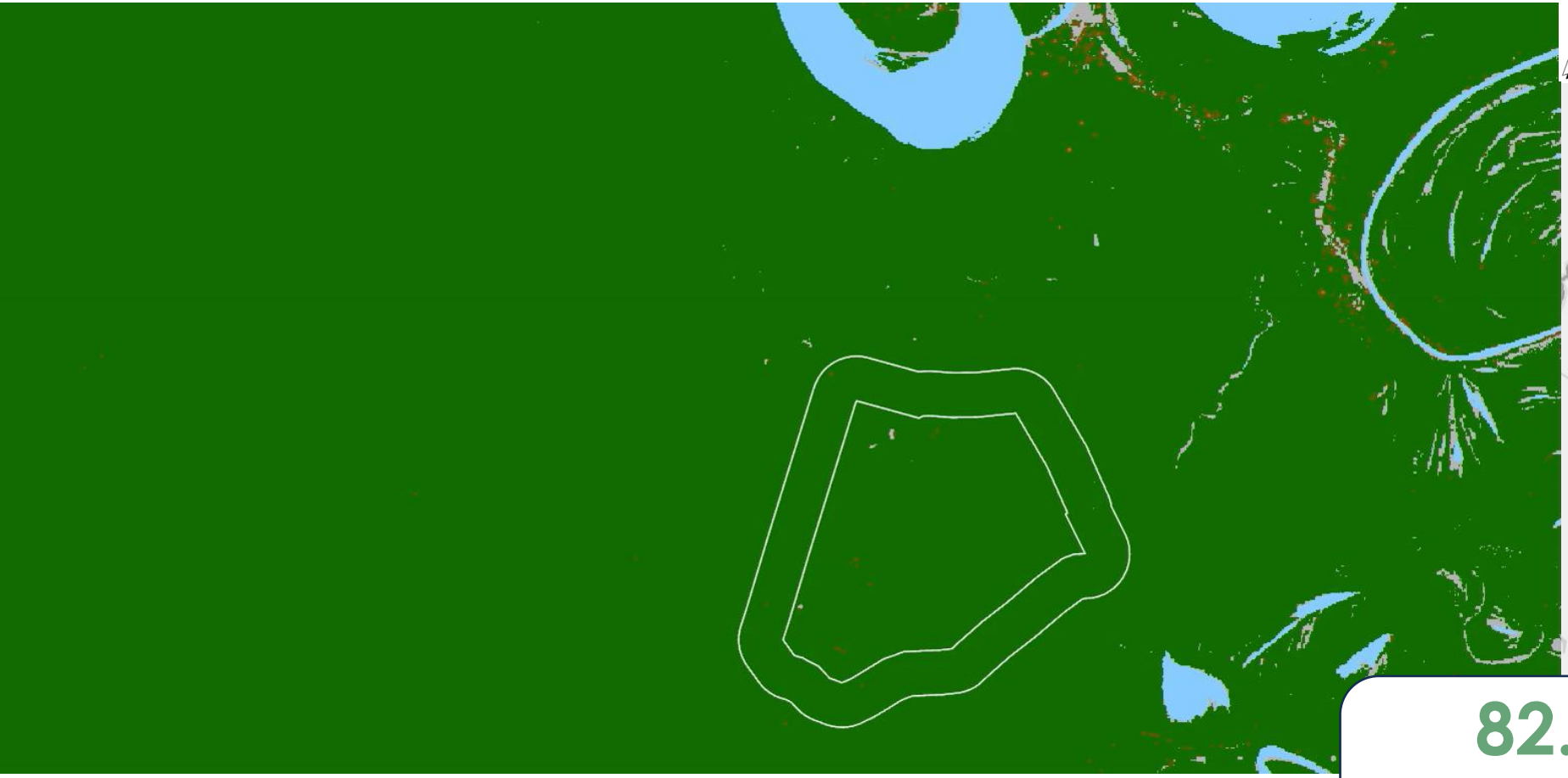
0 2 4
Kilometers

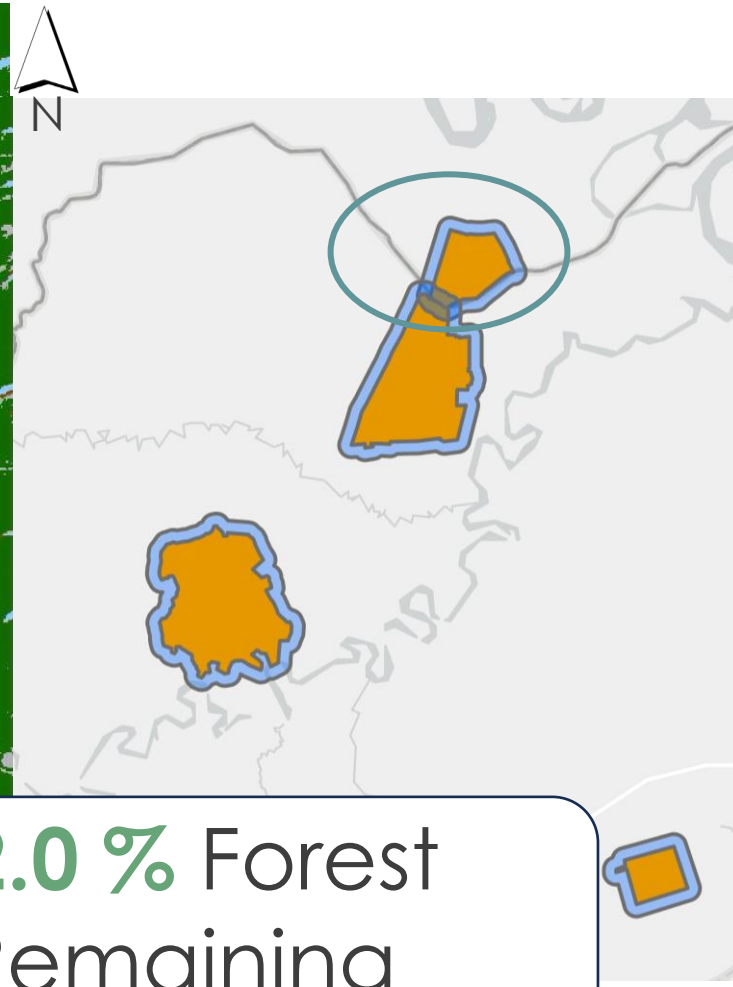
C: 68.2%

B: 12.8%

D: 25.7%

Percent Intact Forest: A



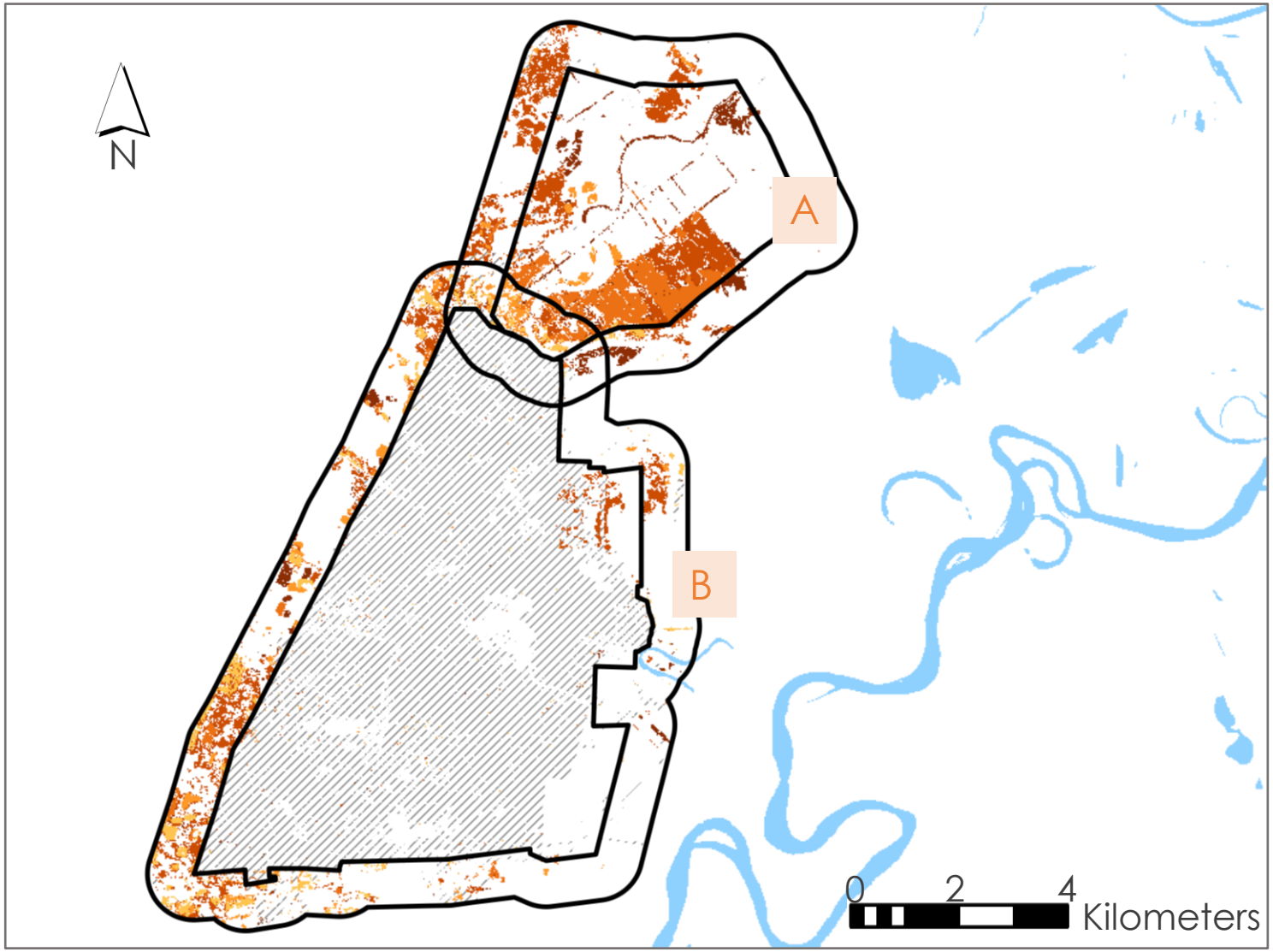


0 2 4
Kilometers

82.0 % Forest Remaining

As of 2023

Deforestation in Case Study A & B



Recent Forest Disturbance

- 2019
- 2020
- 2021
- 2022
- 2023

Previous Disturbances in Mid 2010s

- 2012- 2015

- 1 km Around Case Study
- Bodies of Water

PerúSAT-1 Imagery

Image, PerúSAT-1, 2018



N

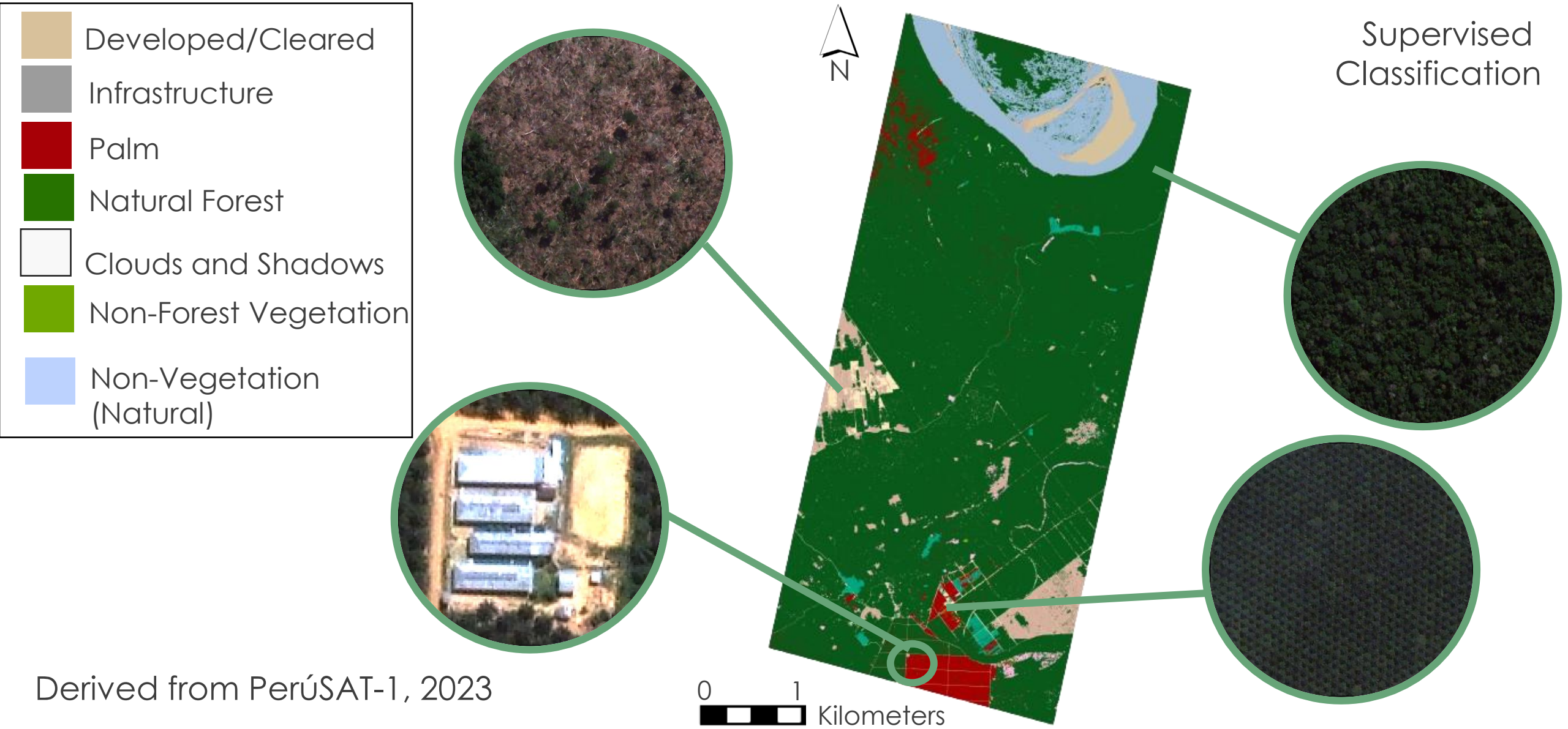
0 1 Kilometers

Image, PerúSAT-1, 2023



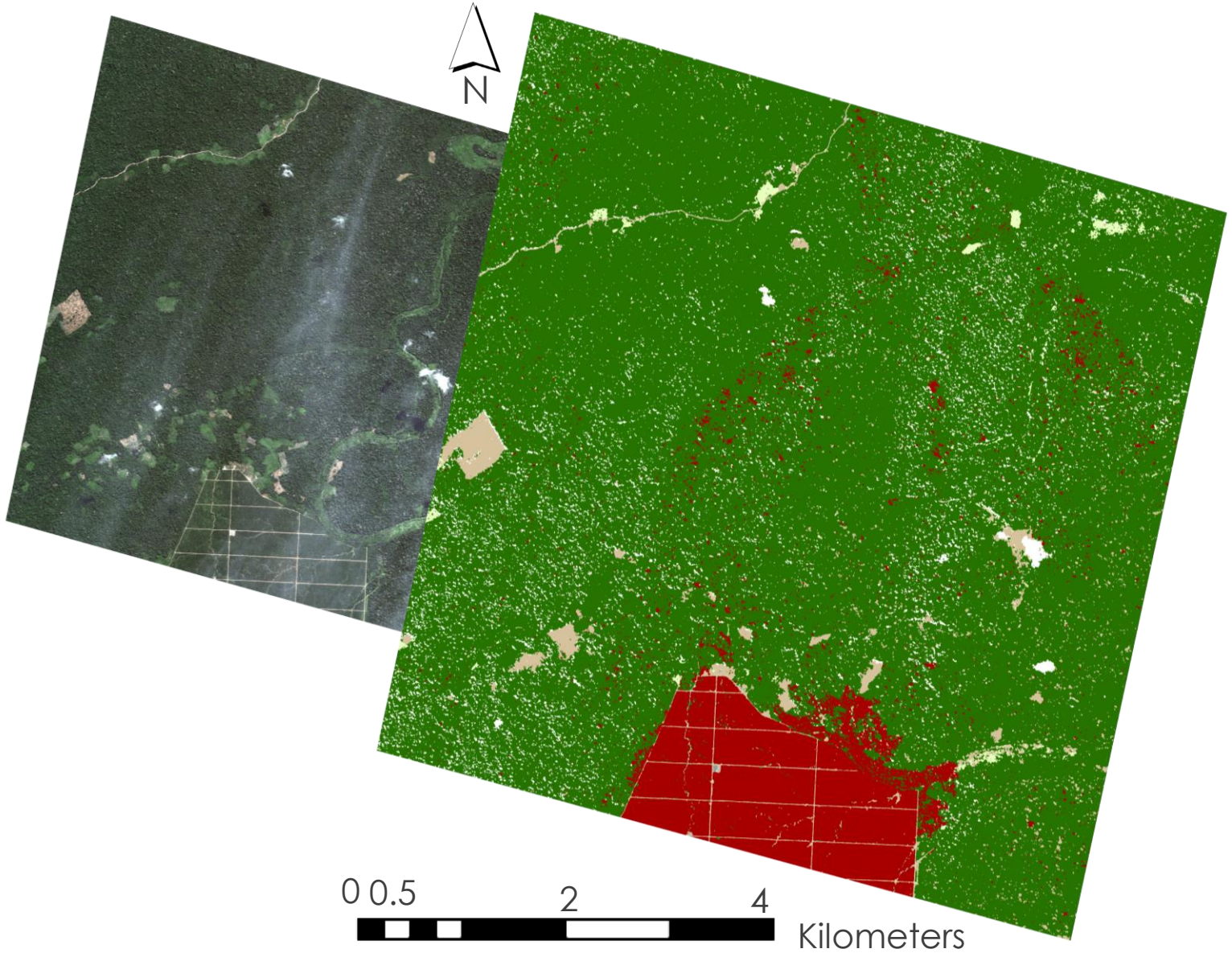
0 1 Kilometers

PerúSAT-1: Classification (2023)



Derived from PerúSAT-1, 2023

PerúSAT-1: 2018 Classification



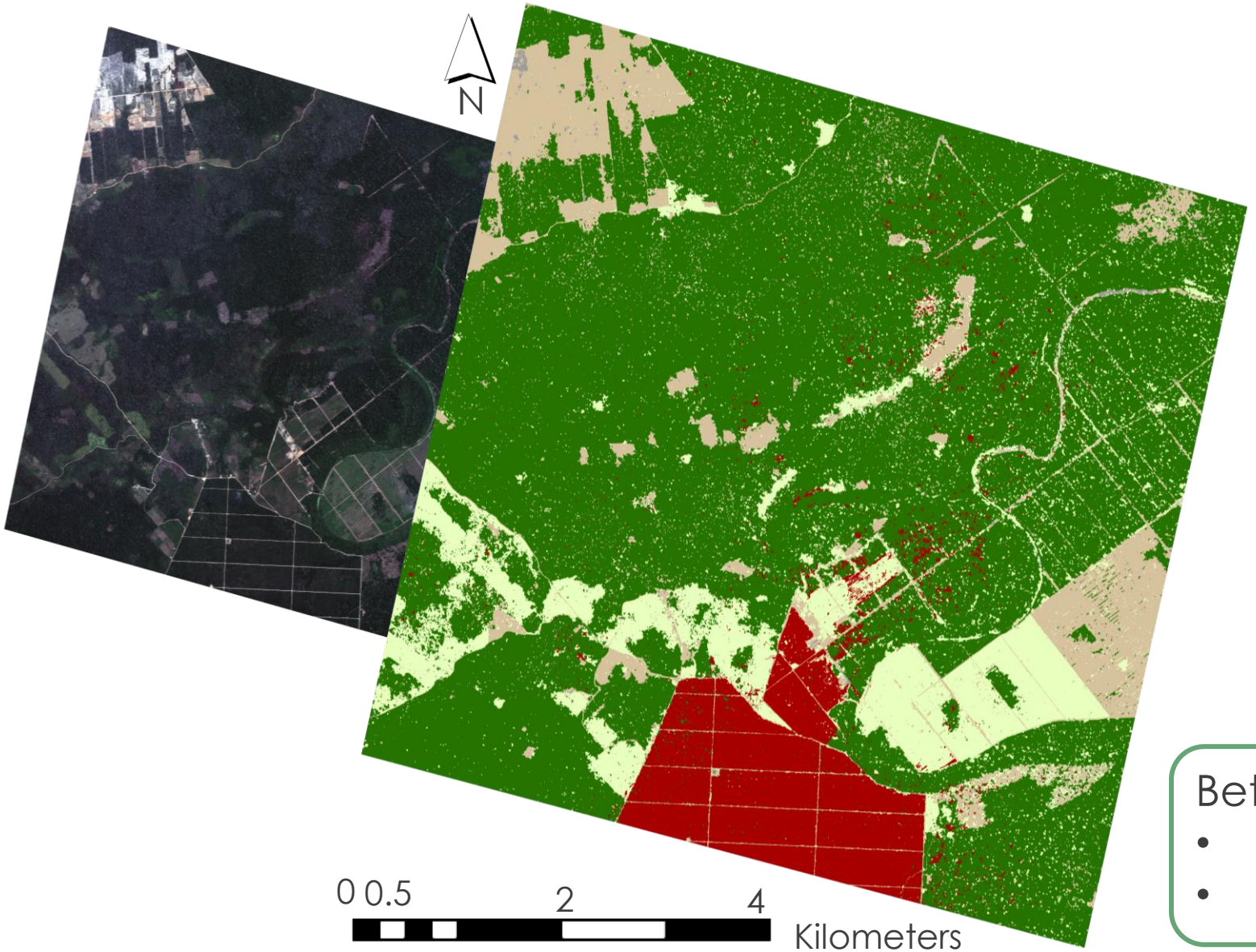
Class [2018]	% of Area
Natural Forest	83.37%
Palm (Agriculture)	8.98%
Developed/Cleared	3.01%
Non-Forest Vegetation	0.86%
Clouds and Shadows	3.72%

0.06% of Area is 'Other'

Land Classes

- Natural Forest
- Palm
- Non-Forest Vegetation
- Developed and Cleared
- Clouds and Shadows

PerúSAT-1: 2023 Classification



Class [2023]	% of Area
Natural Forest	68.07%
Palm (Agriculture)	8.61%
Developed/Cleared	10.21%
Non-Forest Vegetation	12.70%

0.41% of Area is 'Other'

Land Classes

- Natural Forest
- Palm
- Non-Forest Vegetation
- Developed and Cleared

Between 2018 and 2023:

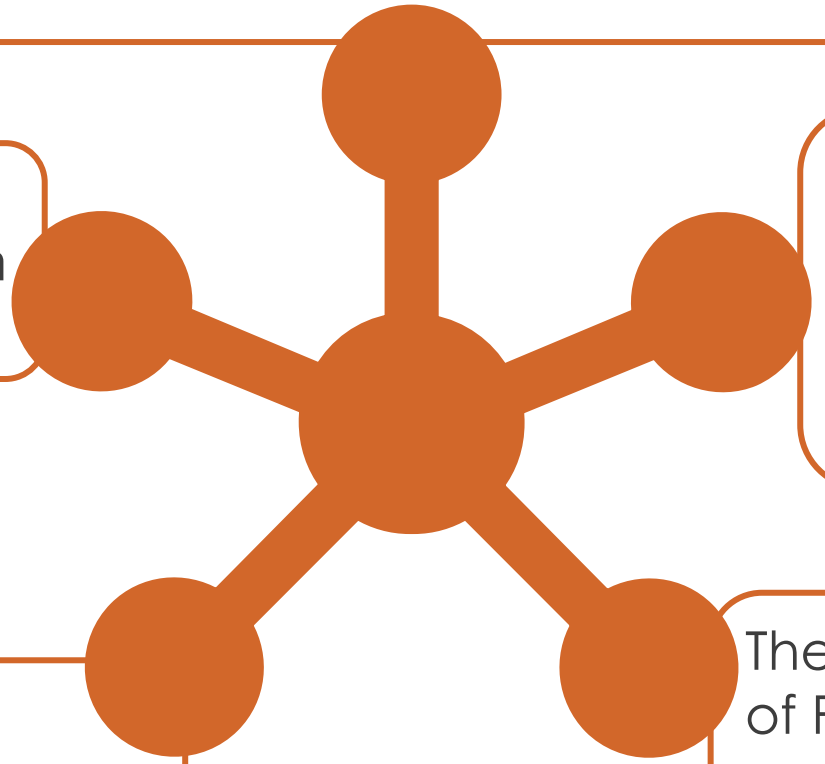
- 15.30% decrease in Natural Forest
- 7.19% increase in developed land

Conclusions

Total area deforested in the region from 2000-2023 was **2165.2 km²**

NDVI and EVI indicate an overall **decrease in vegetation** health over 2017-2023

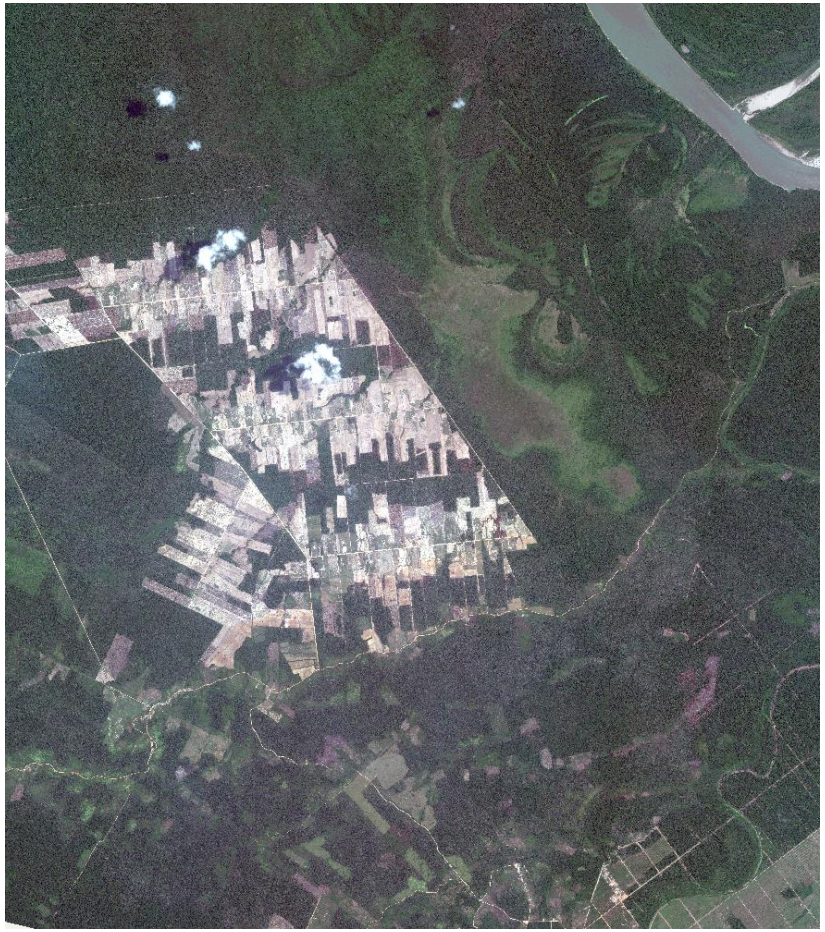
Supervised Classification using PerúSAT-1 showed a **15.30% decline in forest cover** from 2018 to 2023 in the observed images



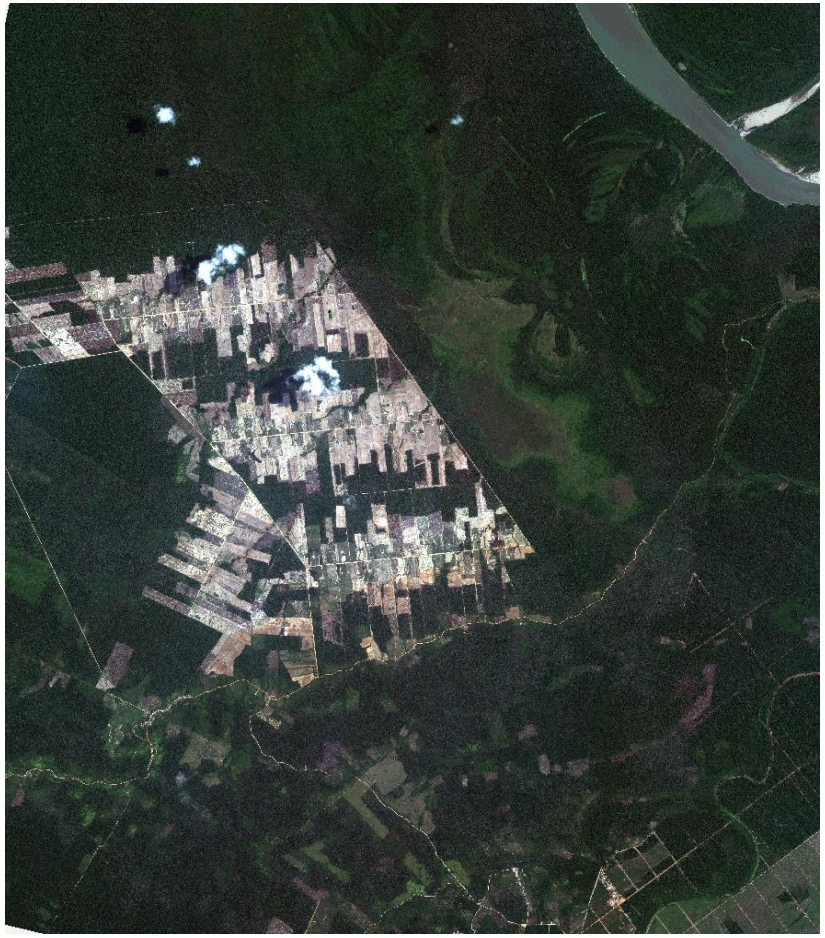
Case Studies A & B are **less than 30% forest** as of 2023

The low **temporal resolution** of PerúSAT-1 limited the coverage Potential for Supervised Classification

PerúSAT-1 Imagery Modifications



VS



Radiance Image, PerúSAT-1

Reflectance Image, PerúSAT-1

PerúSAT-1 Imagery Modifications

Classification with Radiance



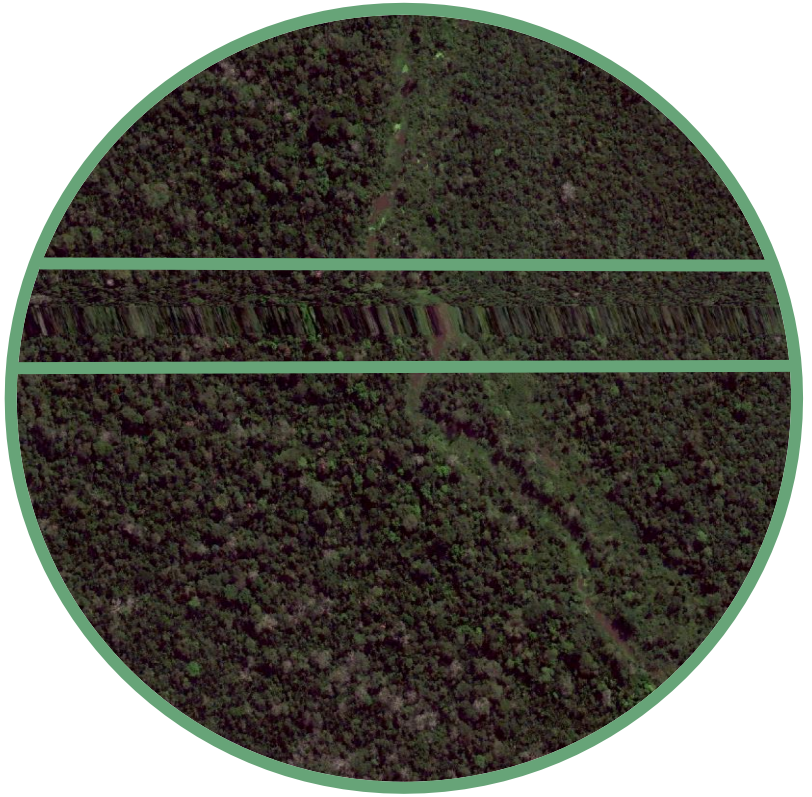
VS

Classification with Reflectance



Errors & Uncertainties

- Inconsistency between Landsat Series
  - Cloud cover availabilities
  - Sensor functionalities: ETM+ and OLI
- Data collection process of satellite imagery (See Image)
- Geolocation inconsistencies
  - PerúSAT-1 to ArcGIS Pro
- Training data by visual selection



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