



# BRAZIL DATA CUBE

- CUBOS DE IMAGENS DE SATÉLITES, BIG DATA E COMPUTAÇÃO EM NUVEM -

Karine Ferreira

INPE – Instituto Nacional de Pesquisas Espaciais





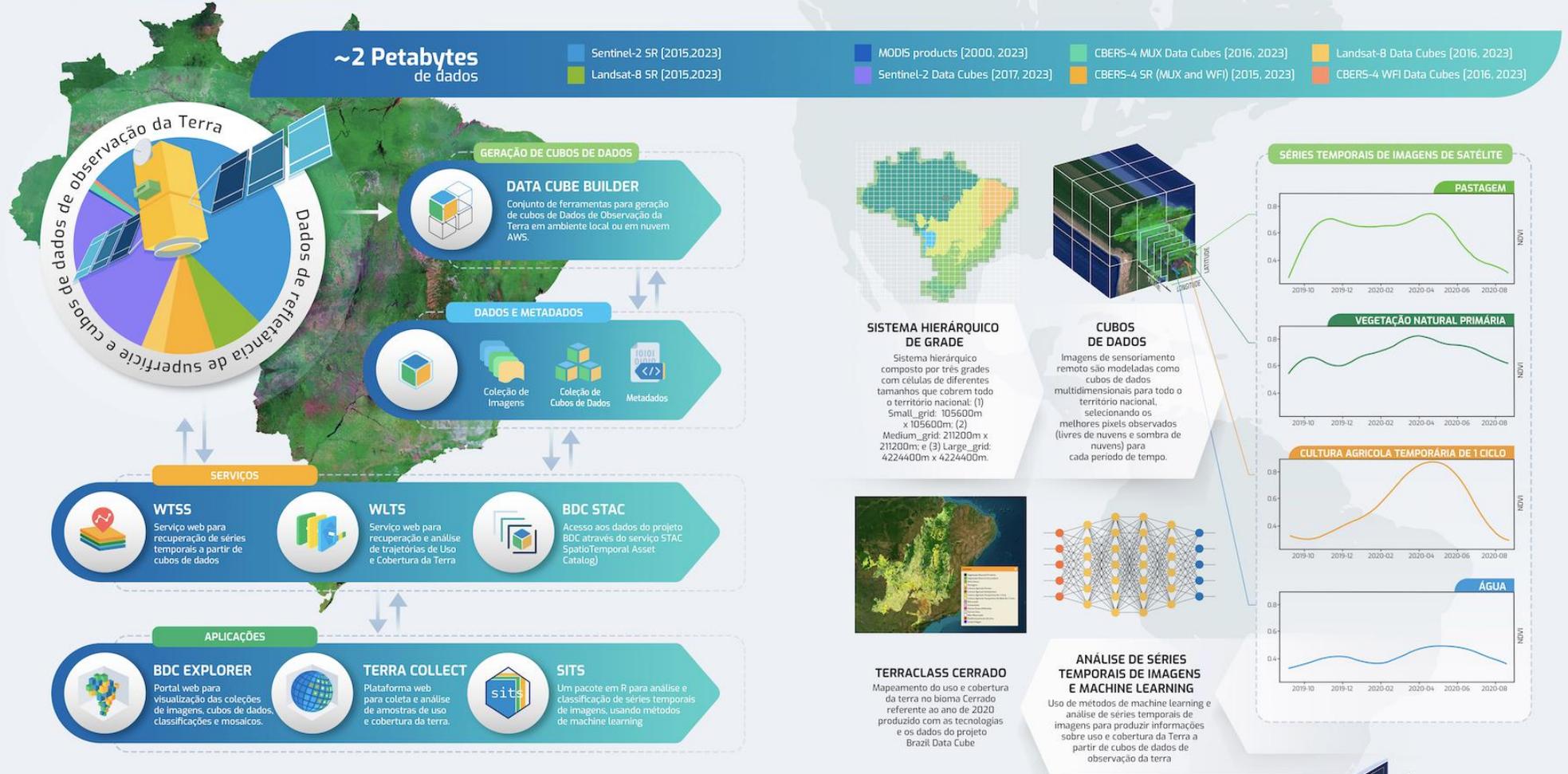
# BRAZIL DATA CUBE

Ambiente de computação em nuvem (INPE).

Cubos multidimensionais de imagens de satélites para todo o Brasil.

Ferramentas computacionais para acessar, processar e analisar esses dados.

## PLATAFORMA BRAZIL DATA CUBE

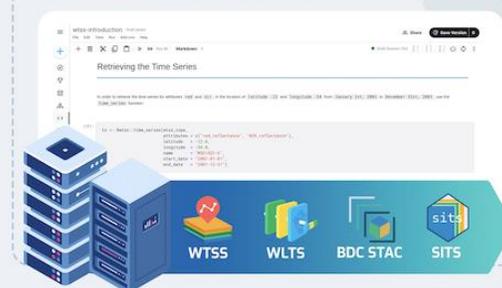


### BRAZIL DATA CUBE EXPLORER

Aplicação web responsável pela visualização das coleções de imagens, cubos de dados, classificações e mosaicos gerados pelo projeto BDC. Através do BDC Explorer, usuários podem acessar e visualizar os dados disponibilizados pela plataforma do projeto em um mapa interativo, usando um componente de controle temporal. Também fornece outros componentes com o intuito de auxiliar o usuário na navegação e recuperação dos dados, como: busca avançada de imagens, comparação de imagens, visualização de séries temporais, composição de imagens coloridas e de download.



### AMBIENTE DE CIÊNCIA DE DADOS GEOESPACIAIS - BRAZIL DATA CUBE





## National Institute for Space Research (INPE), Brazil

Produce official information about deforestation, fire and land use / cover in Brazil.



# National Institute for Space Research (INPE), Brazil

Identify what the deforested areas detected have become.



PRODES



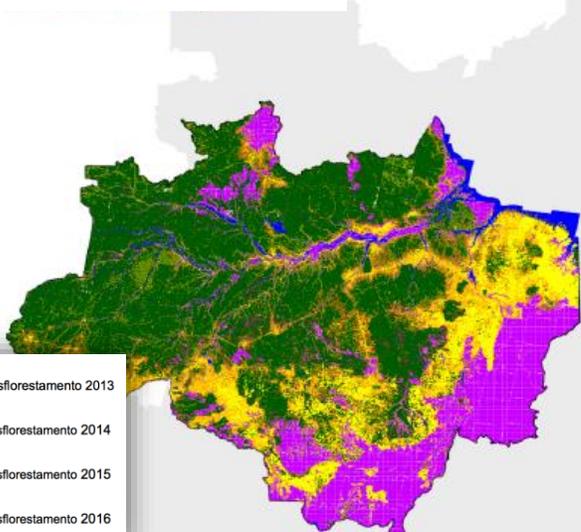
DETER



TERRACLASS

## Deforestation monitoring

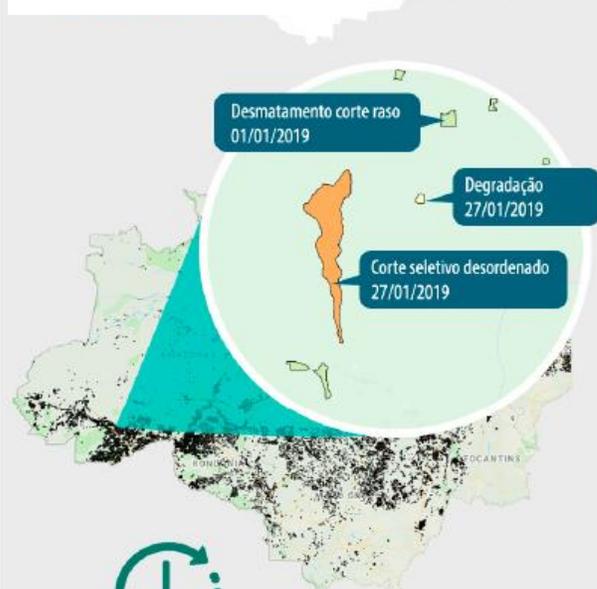
SINCE 1988



Annual maps

## Near real time deforestation alerts

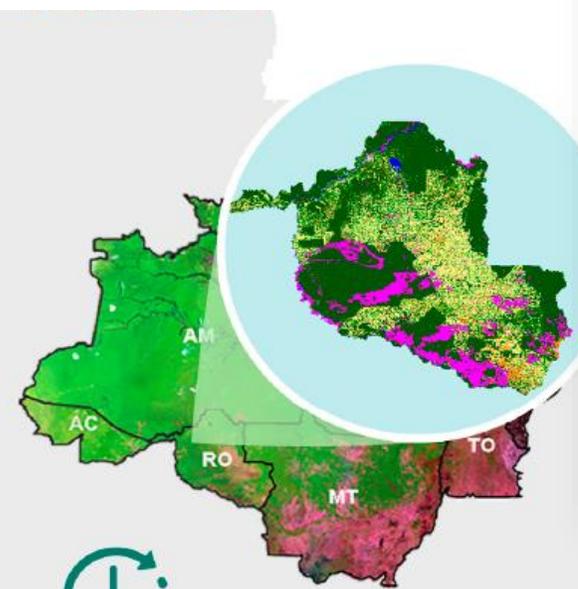
SINCE 2004



Daily alerts

## Land use monitoring in deforested areas

SINCE 2004



Biannual maps

**Legenda**

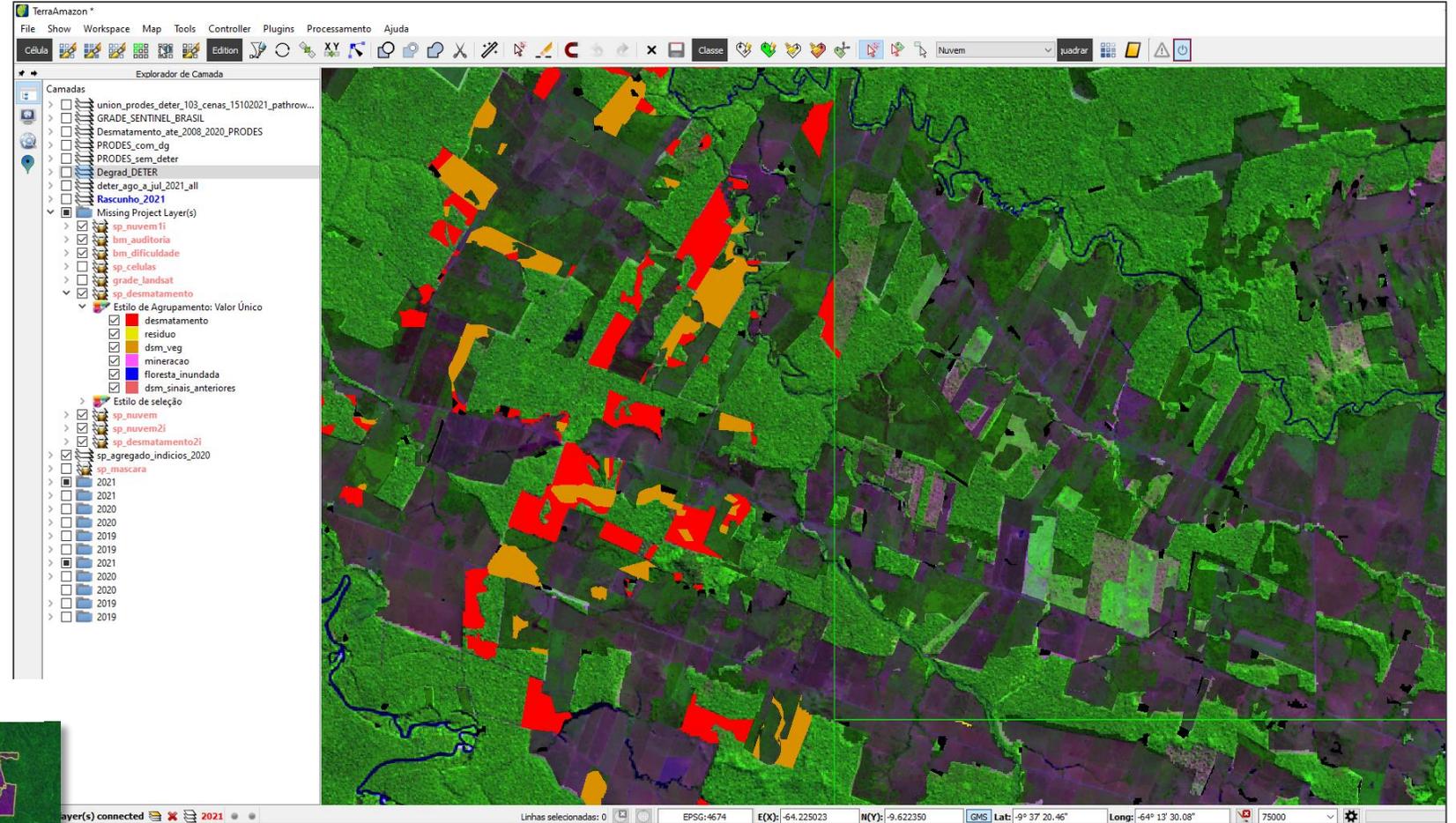
- Floresta
- Hidrografia
- Não floresta
- Desflorestamento 2008
- Agricultura anual
- Agropecuária
- Área urbana
- Mineração
- Outros
- Pasto com solo exposto
- Pasto limpo
- Pasto sujo
- Regeneração com pasto
- Vegetação secundária
- Área não observada



# PRODES

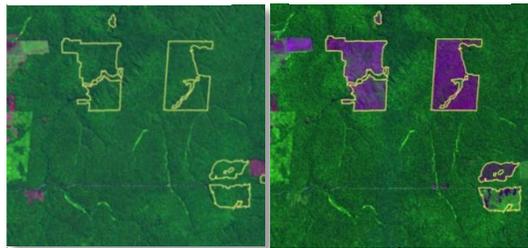
## PRODES 2021

Brasil



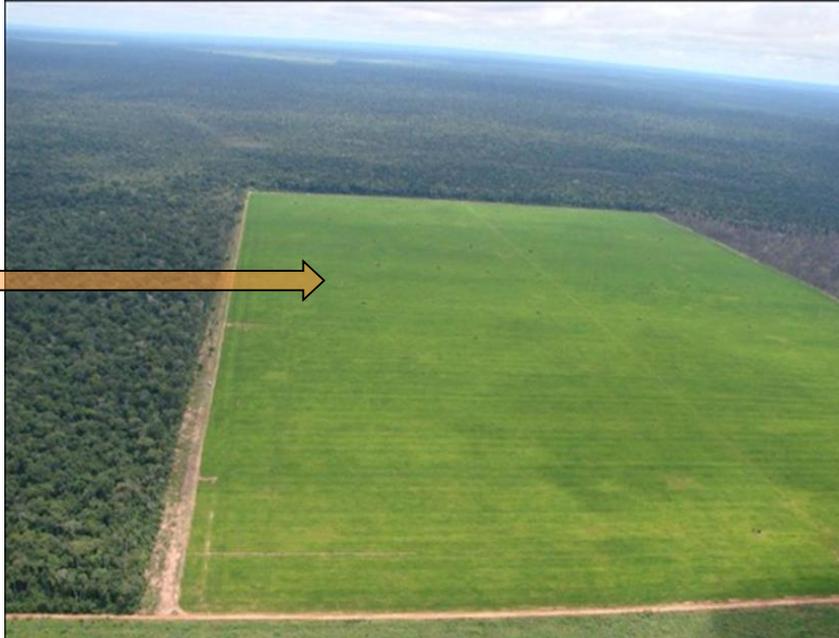
Previous year

Mapping year



- Incremental system
- Annual increase of deforestation
- Medium spatial resolution (10-30 m)
- Minimum Mapping Unit = 1 ha
- Visual inspection
- Expert team

Accuracy >93% (Maurano *et al.* 2019, Parente *et al.* 2021)



Landsat (30 meters)

## Clear-cut deforestation by PRODES

Landsat (30 meters)

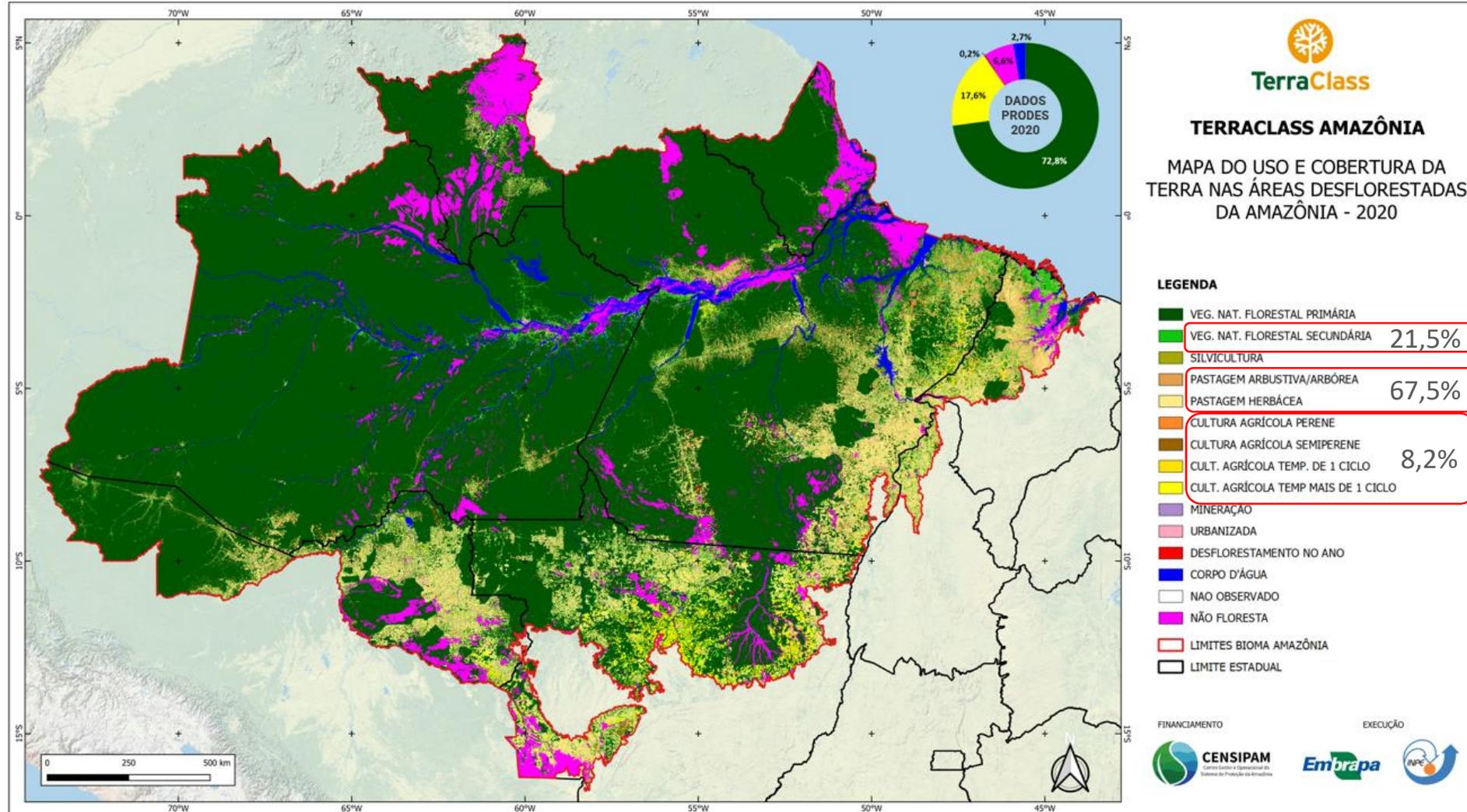




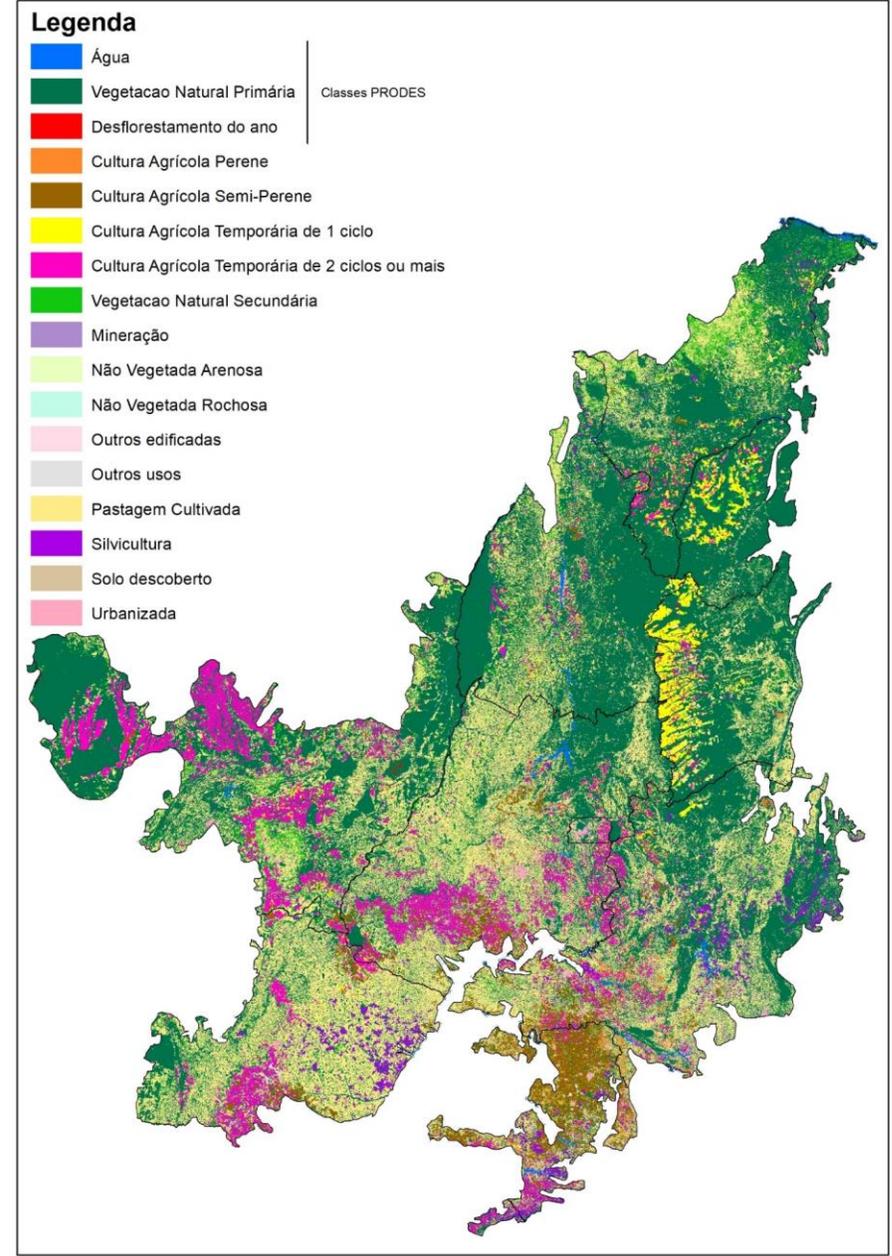
TerraClass



# Land use and land cover map – Amazon



# Land use and land cover map – Cerrado





INPE - Instituto Nacional de Pesquisas Espaciais  
**Programa Queimadas**  
 Monitoramento por Satélites

O **PROGRAMA QUEIMADAS DO INPE** pesquisa, desenvolve, opera e dissemina **dados e sistemas de informação para monitorar fogo na vegetação por satélite.**



### FOCOS DE QUEIMADAS

Mostra onde existe fogo ativo em tempo quase real por meio de imagens de satélites.



### ÁREA QUEIMADA

Delimita a extensão da área atingida pelo fogo na vegetação.



### RISCO DE FOGO

Previsão do risco de fogo na vegetação com base em informações meteorológicas.



Visualizações no BDQueimadas  
**502.860**



Usuários ativos  
**7.40**



Downloads  
**134.16**  
**4**



Visualizações de página  
**1.030.98**  
 Números deste último ano 2019/20



Vis. pág. Risco de Fogo & Meteorologia  
**78.436**



Boletins diários enviados  
**3.819**



## National Institute for Space Research (INPE), Brazil

Produce official information about deforestation, fire and land use / cover in Brazil.

Develop innovative software systems for geospatial information management.

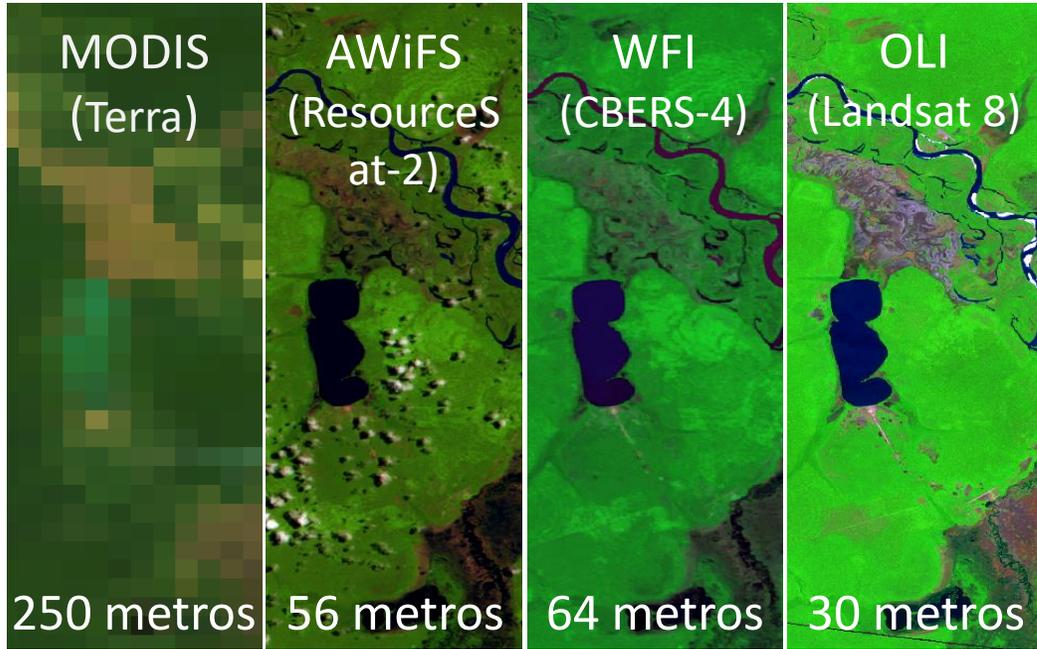
**Open  
Data**



**open** source



Software developed by INPE to produce deforestation and land use/cover data from EO satellite images.



Visual interpretation of EO satellite images with distinct spatial and temporal resolutions.

Polygons of deforested and degraded areas.

Landsat (30 meters)





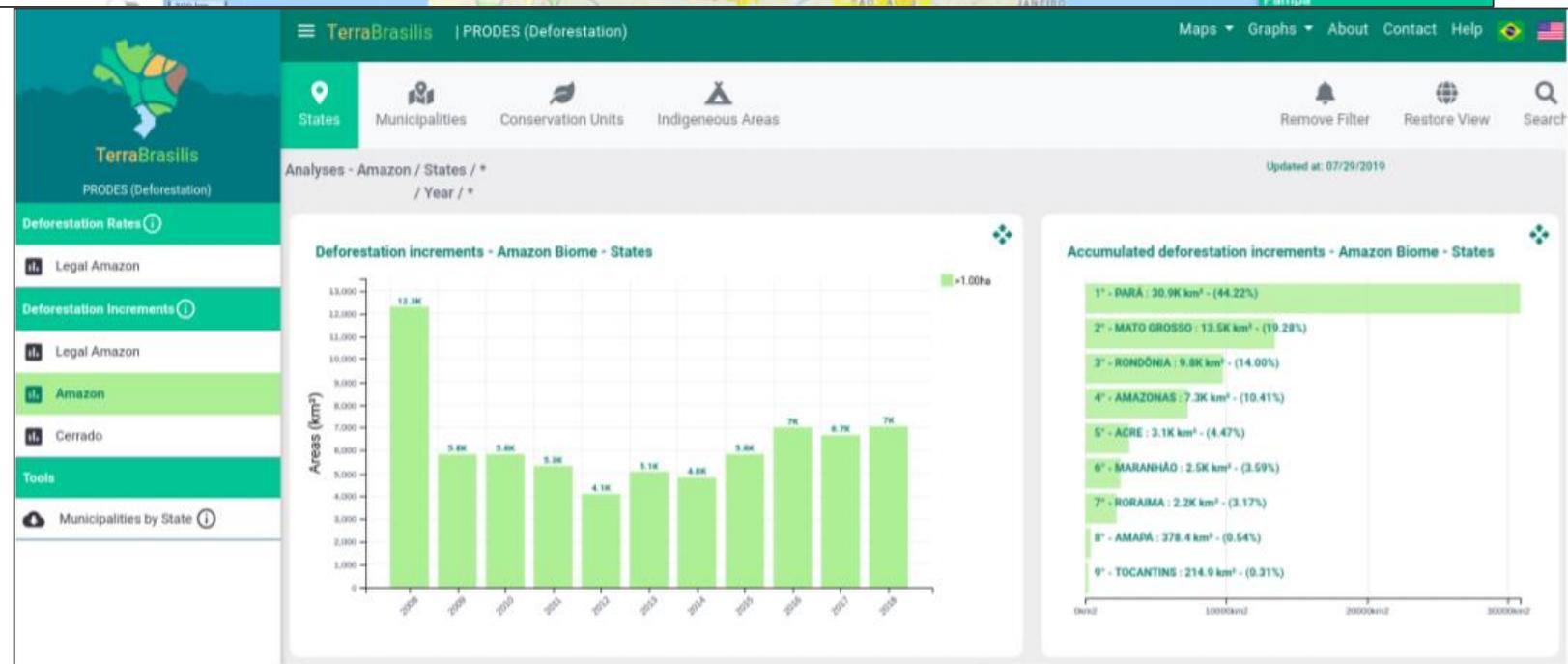
TerraBrasilis

Web portal to disseminate the deforestation data sets produced by PRODES and DETER.

Open data.

Map visualization and dashboards.

Spatial analysis tools.



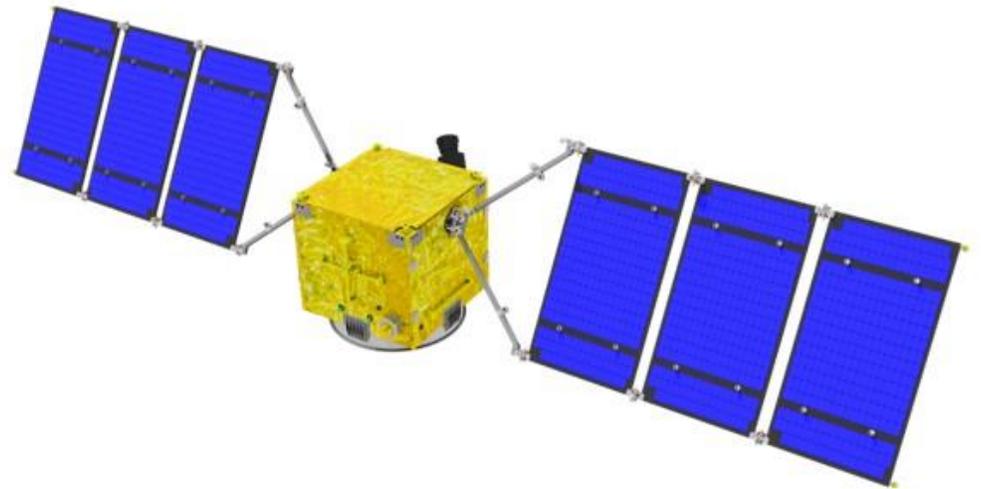


# National Institute for Space Research (INPE), Brazil

Produce official information about deforestation, fire and land use / cover in Brazil.

Develop innovative software systems for geospatial information management.

Build Earth observation satellites.



# CBERS 4A

Angra\_CBERS4A\_Câmera\_WPM:  
2m resolução espacial



## Ciência do Sistema Terrestre

### Conceito 6 nas últimas avaliações

O curso faz parte do **Programa de Excelência da CAPES (PROEX)**

↳ Doutorado com excelência em âmbito internacional

### Computação Aplicada:

Geoinformática e Ciência de Dados Geoespaciais,  
Inteligência Artificial para Aplicações Espaciais,  
Modelagem Computacional de Fenômenos Naturais

### A Meteorologia é a Ciência que Estuda o Tempo e o Clima

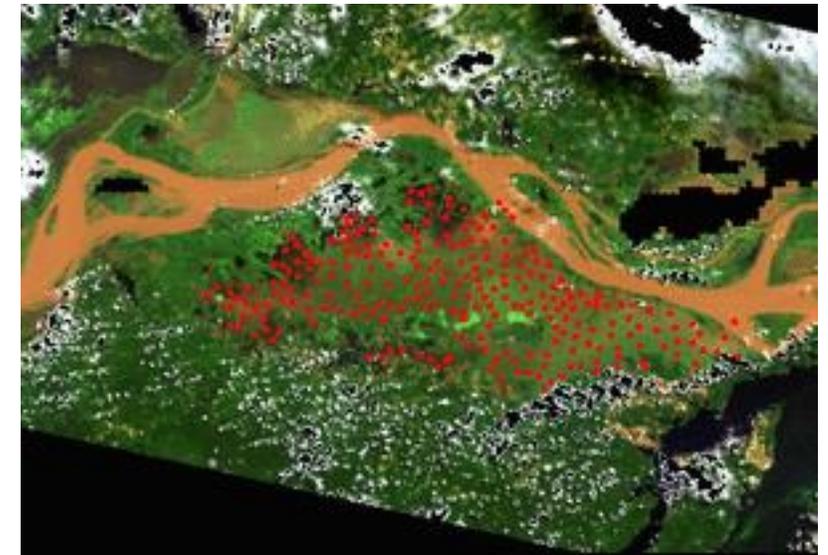
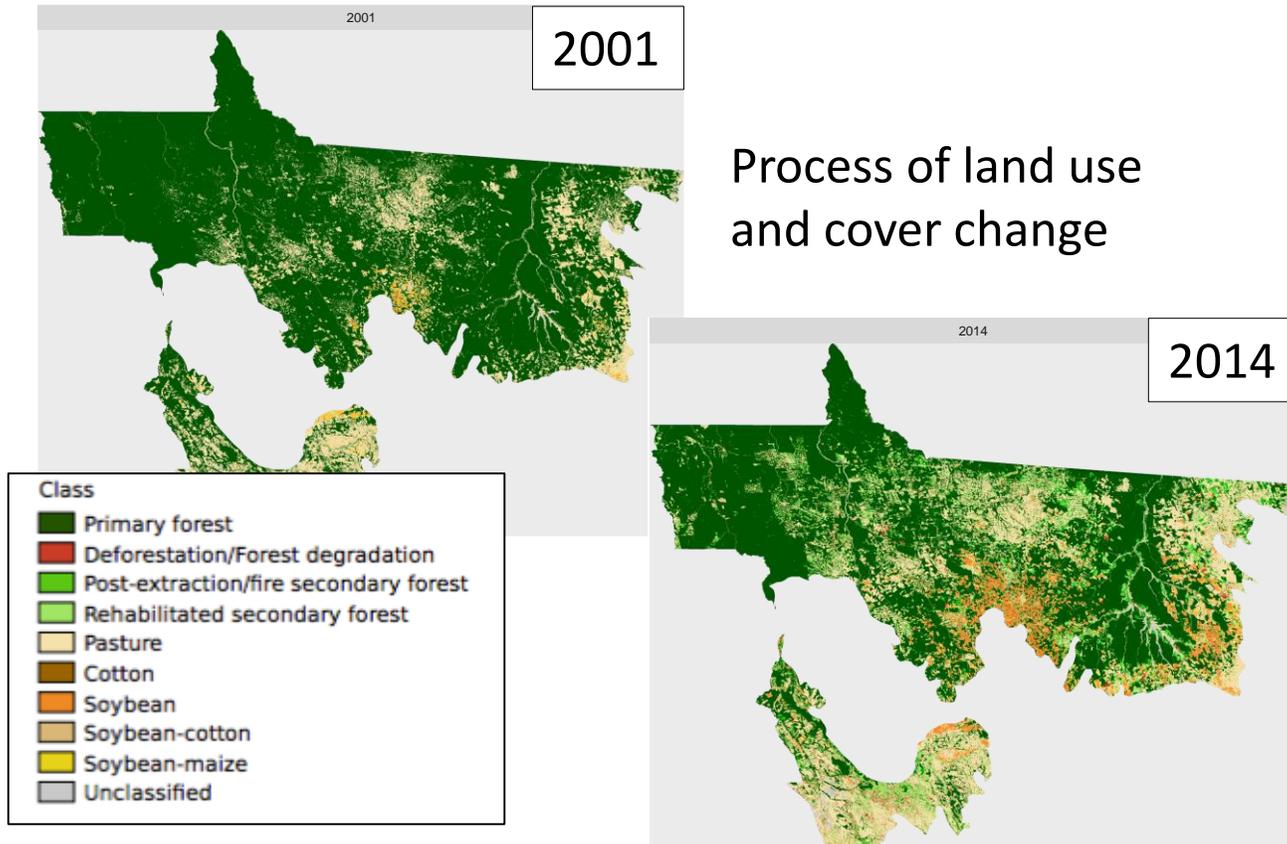
Programa de Excelência  
na CAPES Conceito = 6

### Programa de Pós-Graduação em Sensoriamento Remoto (PGSER)

Conforme resultado divulgado pela **Capex** recebeu, mais uma vez, a **nota máxima na avaliação quadrienal** (Nota 7), comprovando a excelência do programa

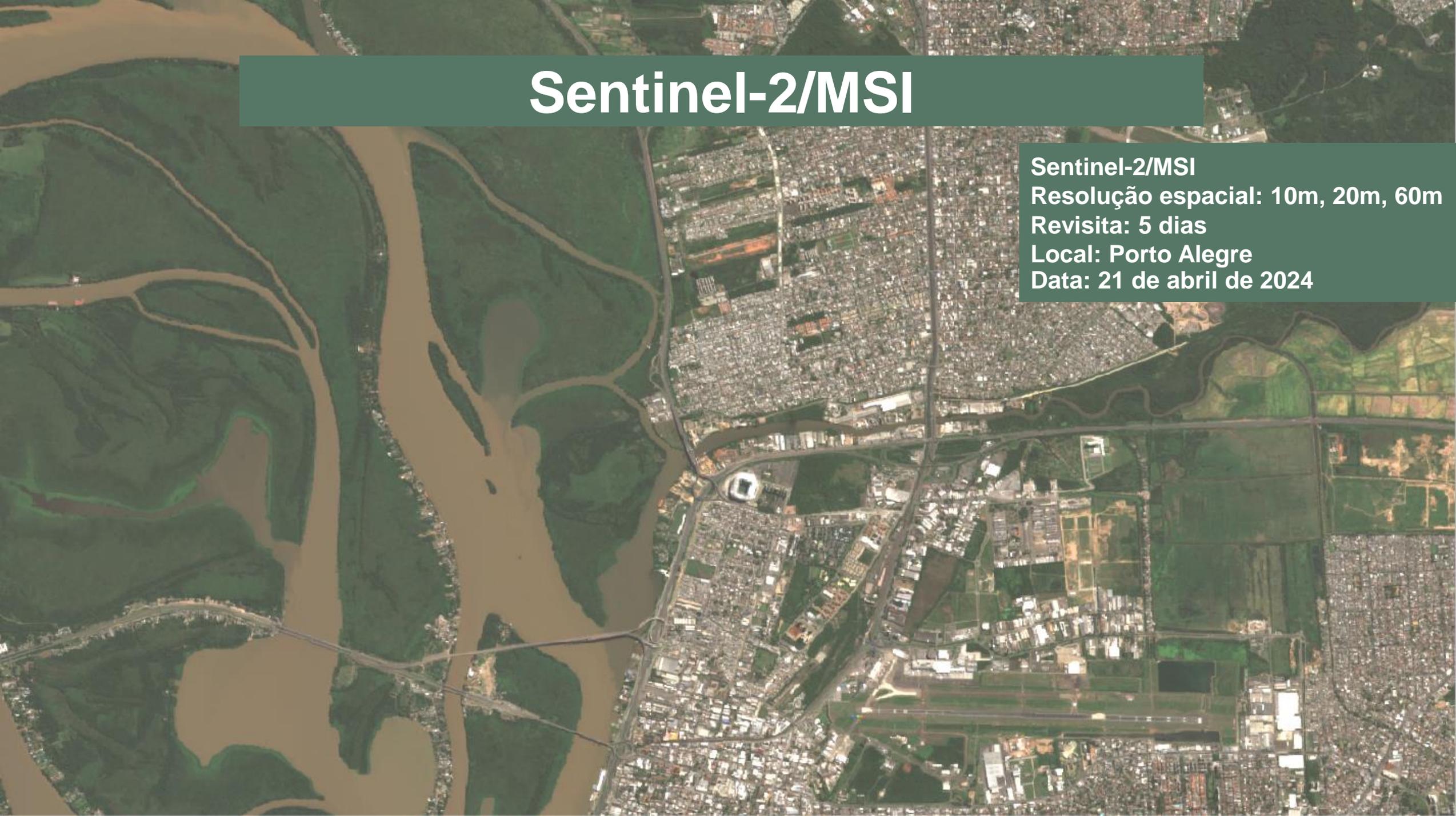
# CAP – Geoinformatics and Geo Data Science

Computational techniques, tools and methodologies for representation, storage, processing, analysis and modeling of spatiotemporal processes.



Variation of chlorophyll in an Amazon rainforest lake

# Sentinel-2/MSI



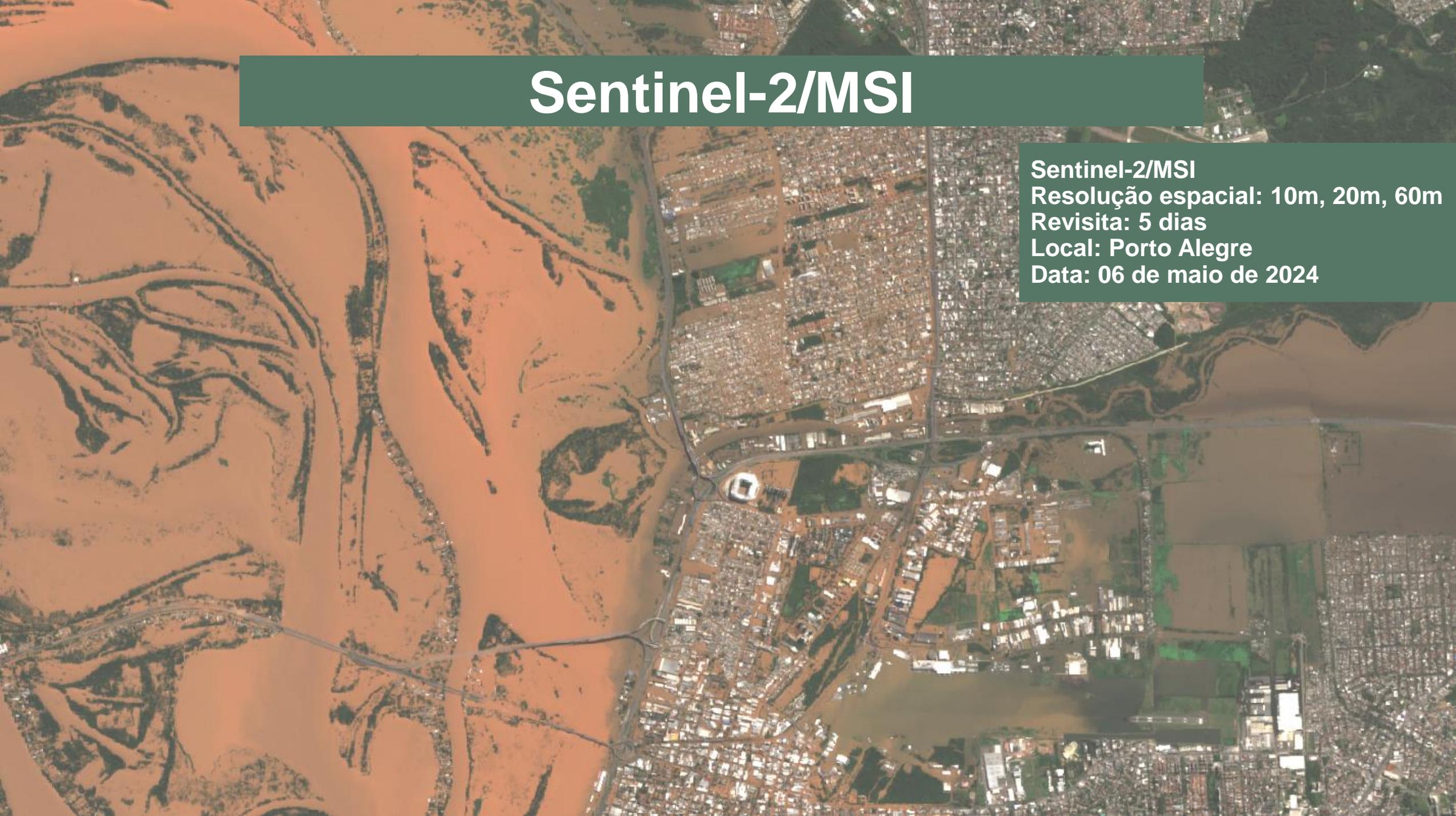
**Sentinel-2/MSI**

**Resolução espacial: 10m, 20m, 60m**

**Revisita: 5 dias**

**Local: Porto Alegre**

**Data: 21 de abril de 2024**



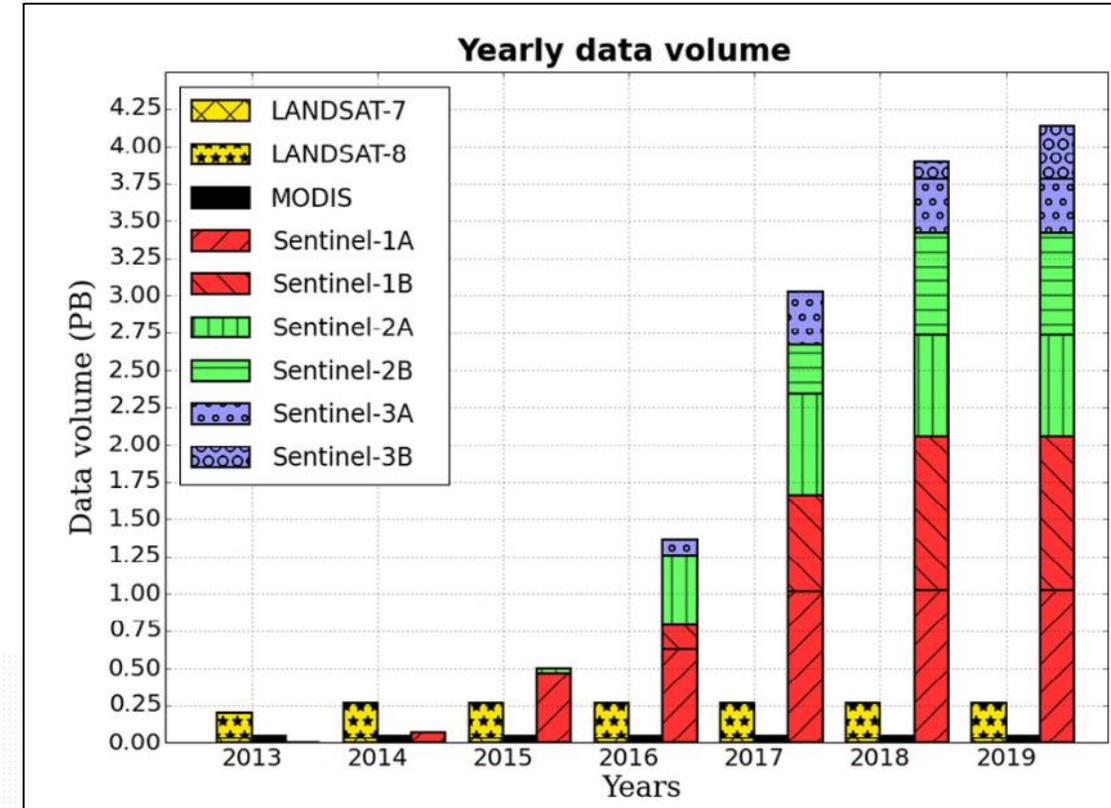
# Sentinel-2/MSI

**Sentinel-2/MSI**  
Resolução espacial: 10m, 20m, 60m  
Revisita: 5 dias  
Local: Porto Alegre  
Data: 06 de maio de 2024

# Challenge: Big data sets of EO satellite images



Source: eosps.nasa.gov



Source: (Soille et al., 2018)

## COPERNICUS AND ITS SENTINELS

European Earth Observation Programme Copernicus: observing our planet for a safer world

**SENTINEL-1**

- All-weather, day-and-night radar imaging satellite for land and ocean services
- Alta to "see" through clouds and rain
- Data delivery within 1 hour of acquisition
- Airbus Defence and Space developed ground user software

**SENTINEL-2**

- Medium Res Multispectral optical satellite for observation of land, vegetation and water
- 12 spectral bands with 10, 20 or 60m resolution and 200km swath
- Global coverage of the Earth's land surface every 2 days
- Airbus Defence and Space prime contractor for satellites and instruments

**SENTINEL-3**

- Measures sea surface topography with a resolution of 300m, sea and land surface temperatures and colour with a resolution of 1km
- Measures water vapor, cloud water content and far-ultraviolet radiation emitted by the Earth
- Determines global sea surface temperatures with an accuracy greater than 0.2 K
- Airbus Defence and Space supplies Microsatellite Rocketeer

**SENTINEL-5P**

- Global observation of key atmospheric constituents, including ozone, nitrogen dioxide, sulphur dioxide and other environmental pollutants
- Improves climate models and weather forecasts
- Provides data continuously during the year gap between the retirement of Sentinel-1 and the launch of Sentinel-2
- Airbus Defence and Space prime contractor for satellite and BPC44 instrument

**SENTINEL-4**

- Provides hourly updates on air quality with data on atmospheric aerosol and trace gas concentrations
- Spatial sampling 1 km and vertical resolution between 0.12 and 0.5 km
- Airbus Defence and Space prime contractor for spectrometer
- Central element ELMETSAT's Meteosat Third Generation (MTG) satellites

**SENTINEL-5**

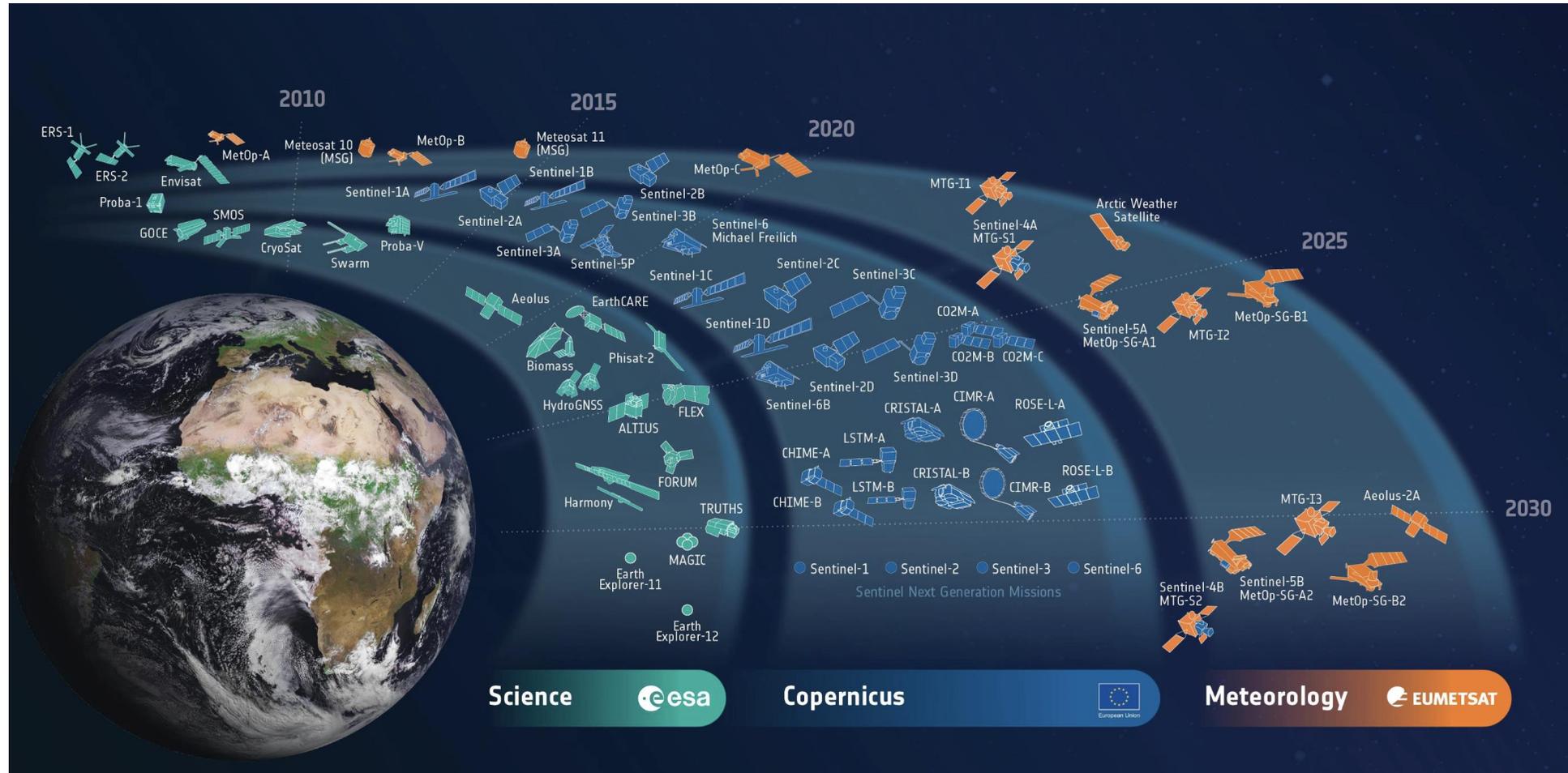
- Monitors air quality and water resources, including atmospheric ozone and the ozone hole
- Global coverage of Earth's atmosphere with an unprecedented spatial resolution
- Airbus Defence and Space prime contractor for instrument
- Central element ELMETSAT's Meteosat Third Generation satellites

**SENTINEL-6**

- Observes changes in sea surface height with an accuracy of 3 cm
- Global mapping of the sea surface topography every 10 days
- Enables precise observation of ocean currents and ocean level drainage, vital for predicting rises in sea levels
- Airbus Defence and Space prime contractor for satellite

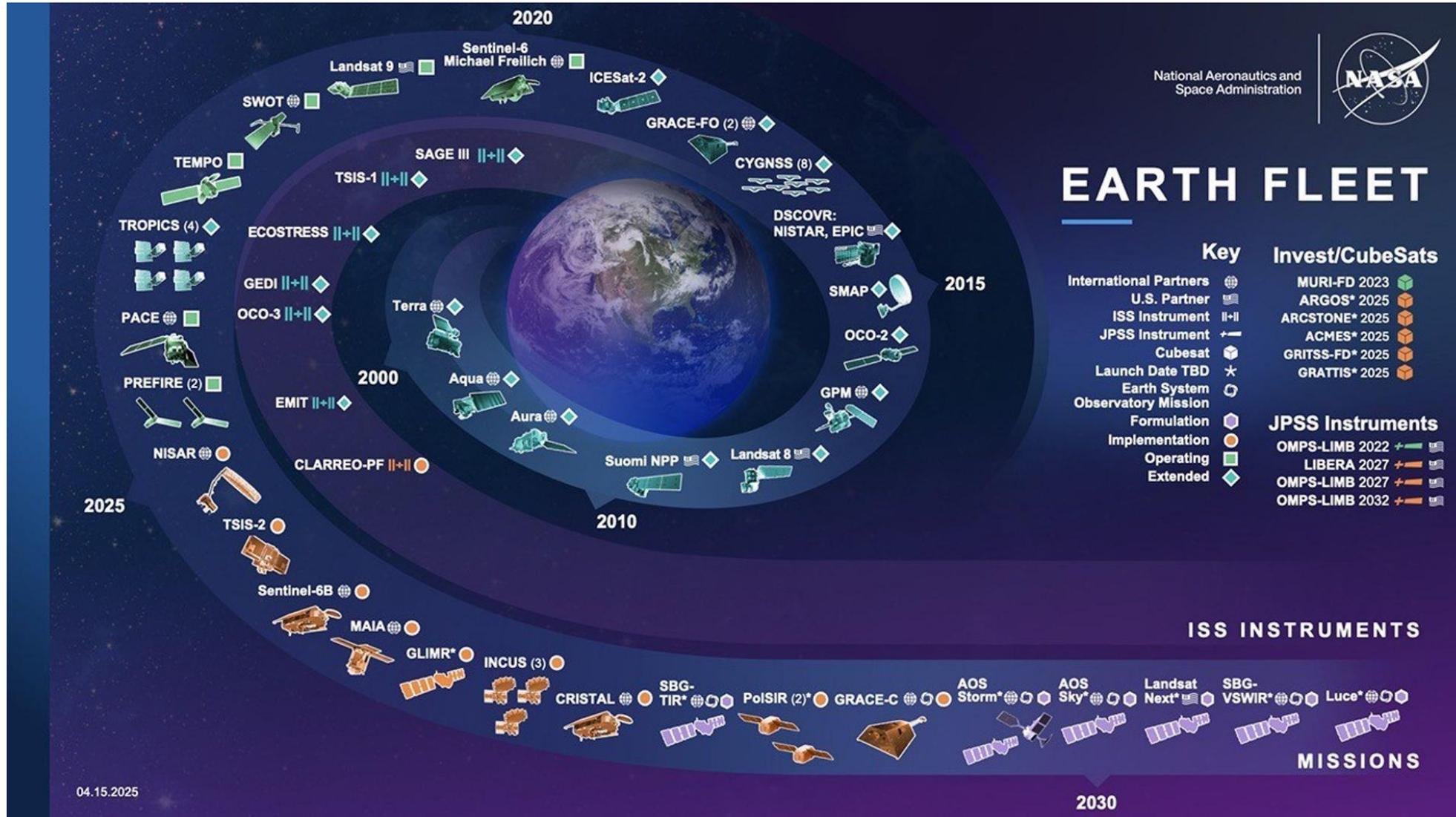
Source: www.copernicus.eu

# Big data sets of EO satellite images



Source: [https://www.esa.int/ESA\\_Multimedia/Images/2019/05/ESA-developed\\_Earth\\_observation\\_missions](https://www.esa.int/ESA_Multimedia/Images/2019/05/ESA-developed_Earth_observation_missions)

# Big data sets of EO satellite images

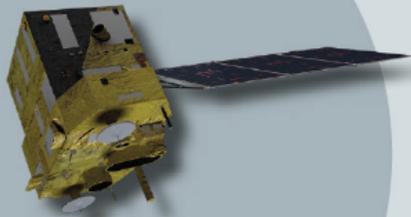


Source: <https://science.nasa.gov/earth-science/missions/>

# Big data sets of EO satellite images

## CBERS-4

O CBERS-4 é um satélite de observação da Terra fruto de parceria internacional com instituições chinesas. O seu nome remete a *China-Brazil Earth Resources Satellite*. Entrou em operação em 2017. Leva a bordo duas câmeras brasileiras – MUX e WFI – e duas chinesas – PAN e IRS. A câmera MUX possui resolução espacial de 20 metros, revisita de 26 dias e quatro bandas nos espectros visível e infravermelho próximo. Com isso, produz imagens coloridas RGB de alta qualidade. A câmera WFI, de campo largo de 900 km, possui resolução espacial de 63 metros, imagens coloridas RGB e revisita de 5 dias. A câmera chinesa PAN possui resolução em RGB de 10 metros e de 5 metros no modo pancromático. A câmera IRS possui bandas nos infravermelhos médio e termal.



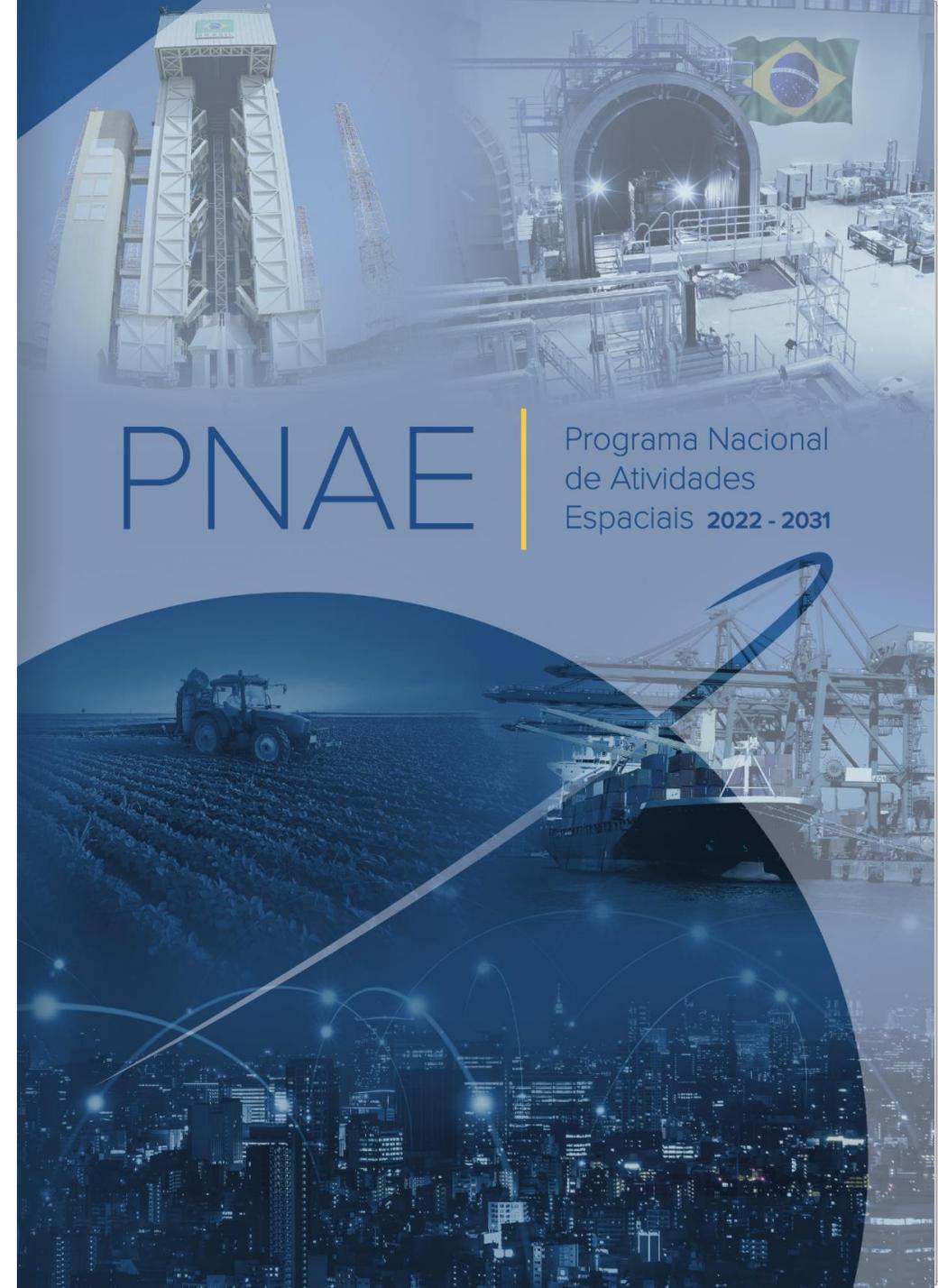
**Carga útil:** sensoriamento remoto e coleta de dados ambientais

**Operação:** INPE

**Prazo de operação:** dezembro de 2022

**Atendimento a OEEs:** OEE2, OEE3, OEE5 e OEE6

Source: <https://www.gov.br/aeb/pt-br/programa-espacial-brasileiro/programa-nacional-de-atividades-espaciais>



# PNAE

Programa Nacional  
de Atividades  
Espaciais 2022 - 2031

## CBERS 04A

O *CBERS 04A* é um satélite de observação da Terra fruto de parceria internacional com instituições chinesas. Entrou em operação em 2020. Opera em órbita heliossíncrona, em uma altitude de 628,4 km. Possui três sensores ópticos diferentes. A câmera MUX, brasileira, apresenta resolução espacial de 16 metros e revisita de 31 dias. A câmera WFI, também brasileira, apresenta resolução espacial de 55 metros e revisita de 5 dias. A câmera chinesa WPM tem resolução de 2 metros em modo pancromático e de 8 metros em RGB. Dessa forma, o *CBERS 04A* atende a demandas por imagens de média resolução e, também, a parcela relevante das demandas nacionais por alta resolução.



**Carga útil:** sensoriamento remoto e coleta de dados

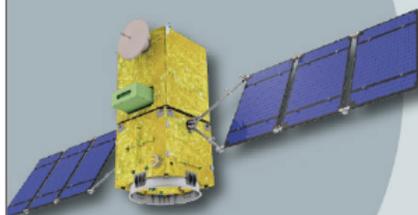
**Operação:** INPE

**Prazo de operação:** dezembro de 2023

**Atendimento a OEEs:** OEE2, OEE3, OEE5 e OEE6

## Amazonia 1

O *Amazonia 1* é o primeiro satélite brasileiro de observação da Terra com projeto e engenharia de sistemas totalmente nacionais. Entrou em operação em 2021 e qualificou em voo a *Plataforma Multimissão – PMM*. É um satélite de médio porte. Opera em órbita polar e provê imagens da Terra por meio de um imageador óptico de visada larga, com três bandas de frequências no espectro visível e uma banda próxima do infravermelho (*Near Infrared – NIR*). É capaz de observar uma faixa de aproximadamente 850 km, com 64 metros de resolução espacial.



**Carga útil:** sensoriamento remoto

**Operação:** INPE

**Prazo de operação:** dezembro de 2025

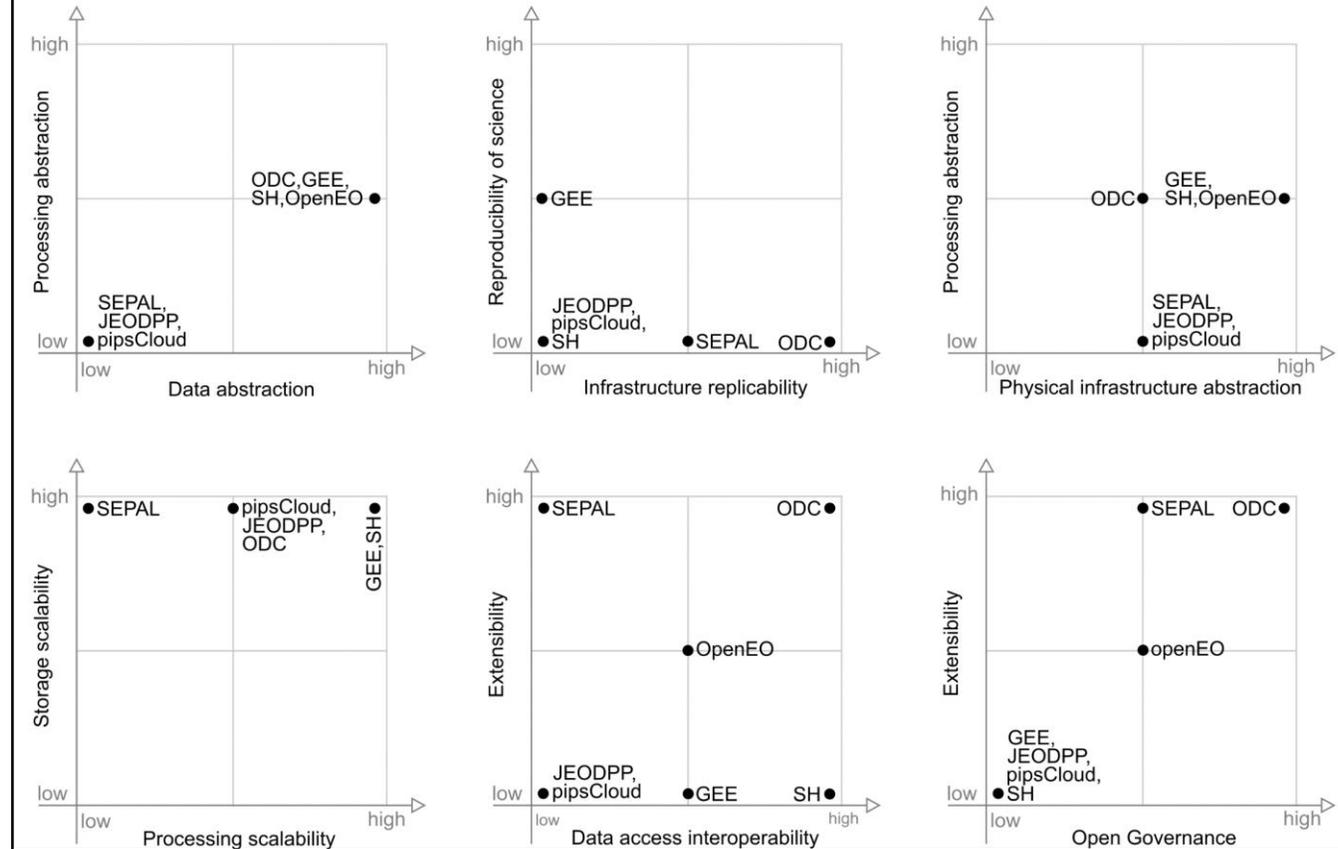
**Atendimento a OEEs:** OEE2, OEE3, OEE5 e OEE6

## Challenge: Big data sets of EO satellite images

How to extract information from these big EO data sets currently available?

# Platforms for big EO data management and analysis

## An Overview of Platforms for Big Earth Observation Data Management and Analysis



Open Data Cube (ODC)



Google Earth Engine (GEE)



SEPAL



openEO



JEODPP



pipsCloud



SentinelHub

Source: (Gomes et al., 2020)

# Cloud computing environments for big EO data

Google Earth Engine (GEE)



Google Earth Engine

Amazon Web Service (AWS)



Microsoft Planetary Computer



Microsoft

Planetary Computer

Copernicus Data Space Ecosystem (CDSE)

Plataforma Brazil Data Cube (BDC)



BRAZIL  
DATA CUBE



Google Earth Engine

Ambiente de computação em nuvem (Google).

Interface web e API em JavaScript e Python.

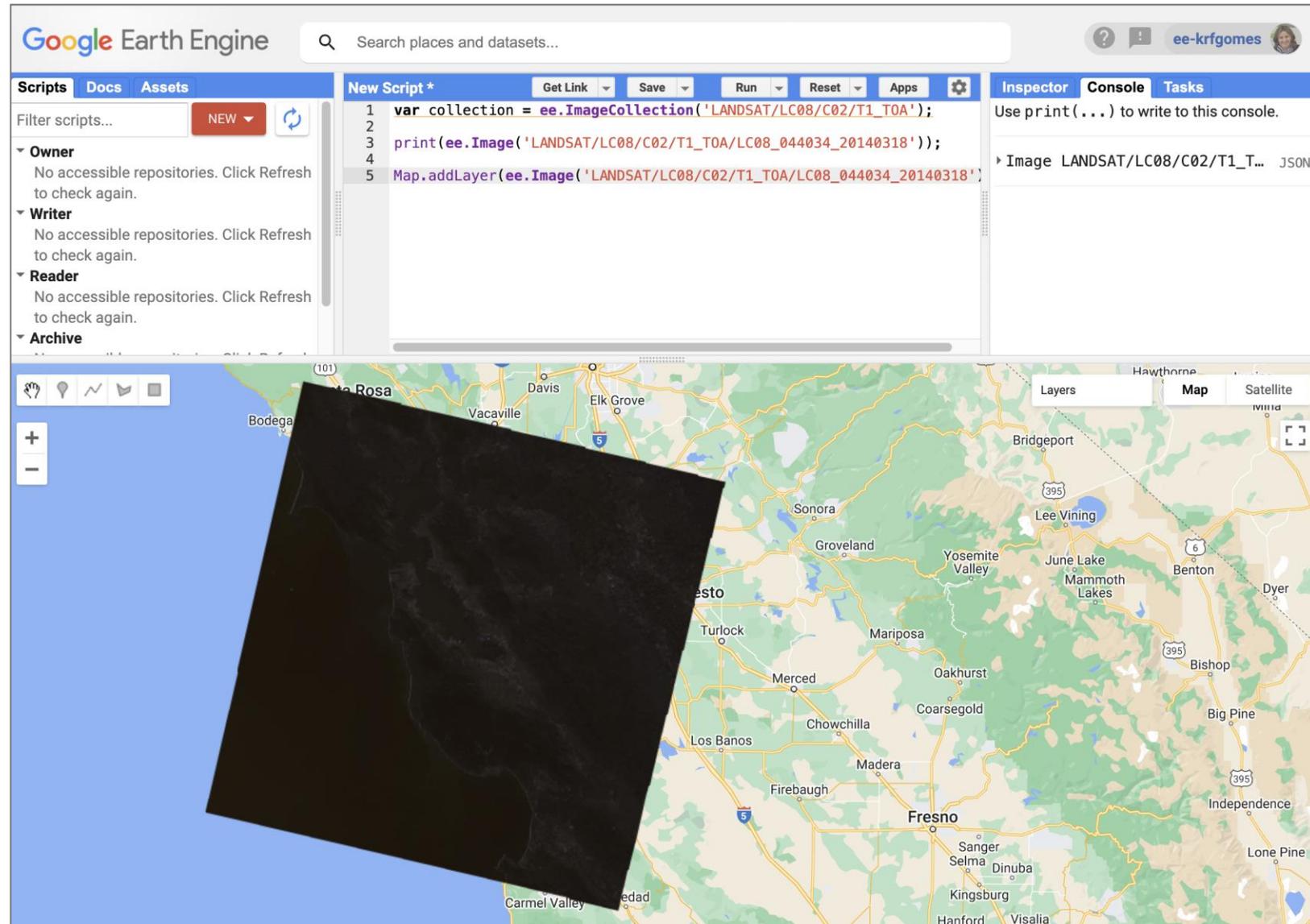
Coleções de imagens de satélites e outros dados.

Plataforma comercial.

Versão não comercial (pesquisa e capacitação) com limitação de processamento.

Source: <https://earthengine.google.com/>

Interface web – scripts, visualização, ...





Conjunto de serviços para armazenamento e processamento em nuvem (Amazon).

Earth on AWS: Open EO data (<https://aws.amazon.com/earth/>)

Sentinel, Landsat, CBERS-4/4A, Amazonia, ...

Serviços pagos por volume de processamento e armazenamento.

Créditos para pesquisa.



### Amazon EC2

Create and run virtual servers in the cloud



### Amazon S3

Object storage built to retrieve any amount of data from anywhere



### Amazon DynamoDB

Managed NoSQL database service



### Amazon RDS

Set up, operate, and scale a relational database in the cloud



### AWS Lambda

Run code without thinking about servers



### Amazon VPC

Isolated cloud resources



### AWS AI and ML decision guide

Evaluate AI and ML services, frameworks, and foundation models for your work



### AWS container decision guide

Evaluate AWS container services for your modern app development

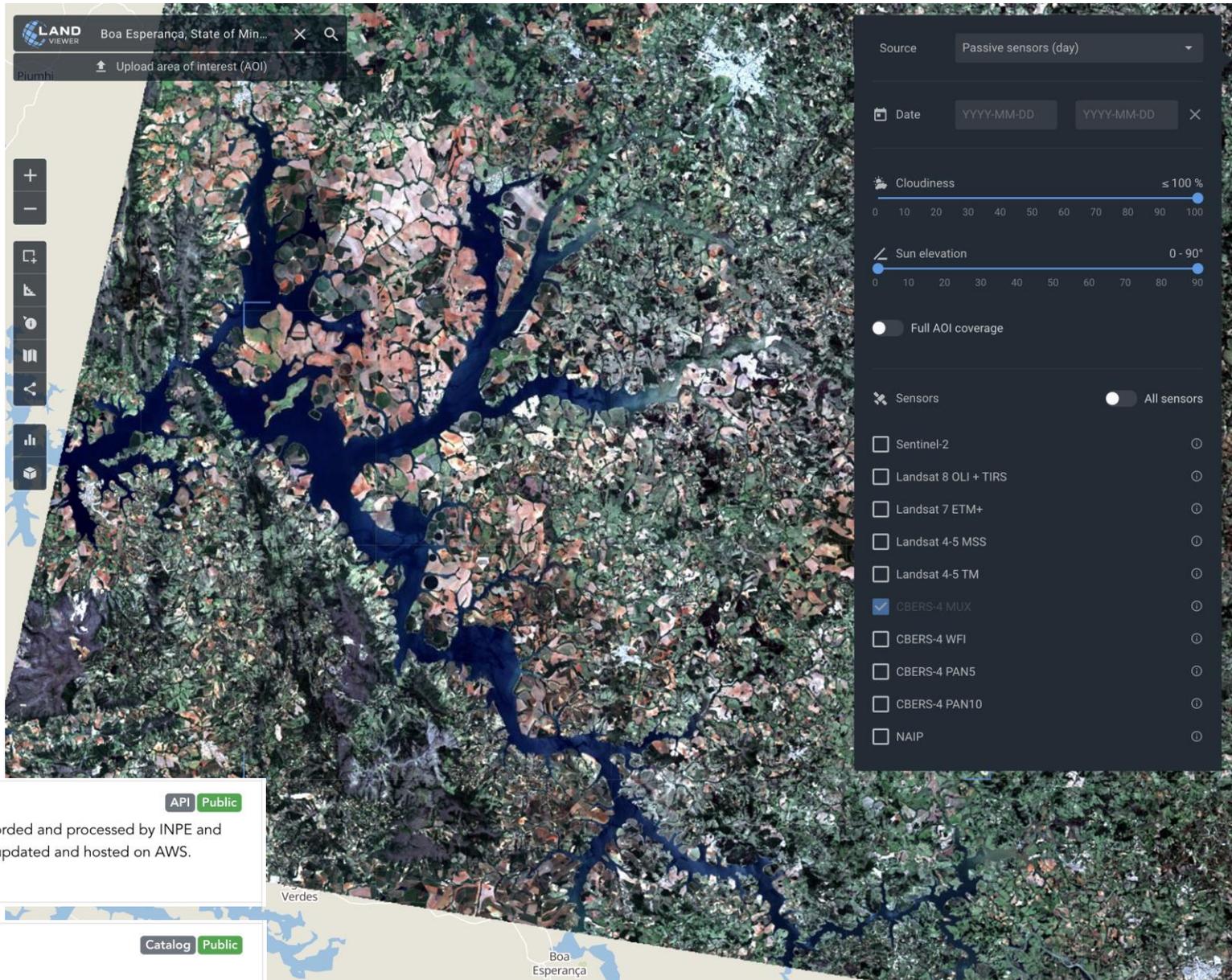


### AWS database decision guide

Evaluate databases and learn how to migrate from your existing database

```
stac.amskepler.com/v100/

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    "https://api.stacspec.org/v1.0.0-beta.1/item-search#query"
  ]
}
```



### CBERS and Amazonia-1 on AWS

API Public

Imagery acquired by the China-Brazil Earth Resources (CBERS) and Amazonia-1 satellites. The image files are recorded and processed by INPE and are converted to Cloud Optimized Geotiff format in order to optimize its use for cloud based applications. Daily updated and hosted on AWS.

<https://stac.amskepler.com/v100/>

### EO Data Cubes for Brazil - CBERS 4

Catalog Public

Catalogs of Brazil Data Cube (BDC) CBERS 4 Earth Observation data cube imagery on AWS.

<https://bdc-cbers.s3.us-west-2.amazonaws.com/catalog.json>

### EO Data Cubes for Brazil - Sentinel 2

Catalog Public

Catalogs of Brazil Data Cube (BDC) Sentinel-2 (A+B) Earth Observation data cube imagery on AWS.

<https://bdc-sentinel-2.s3.us-west-2.amazonaws.com/catalog.json>

Source: <https://eos.com/landviewer/>



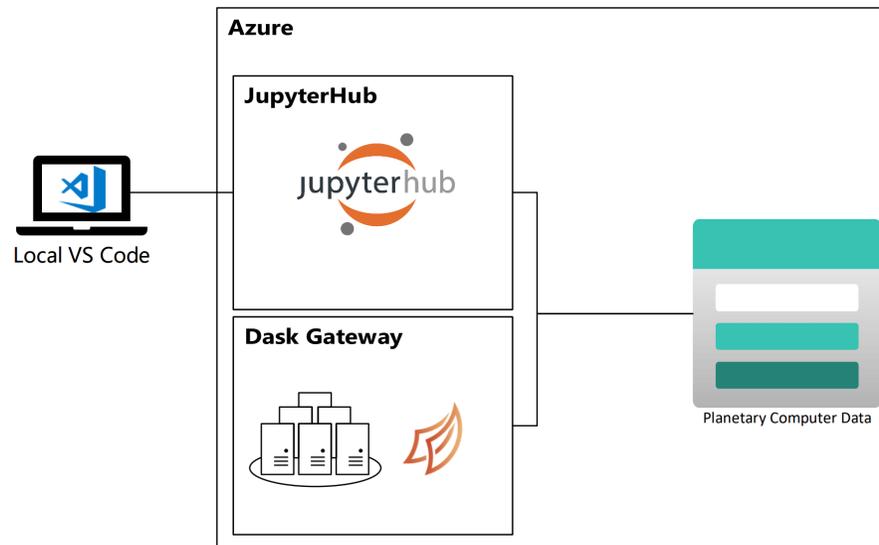
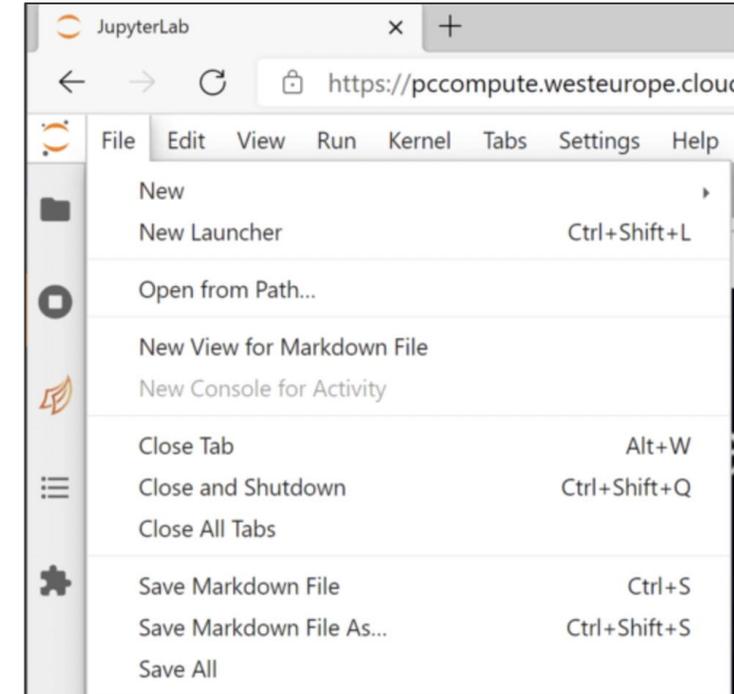
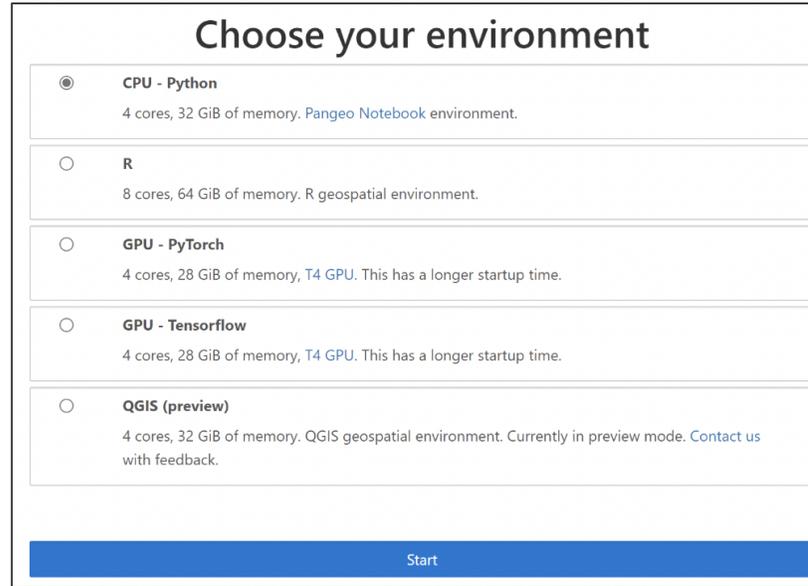
Ambiente de computação em nuvem (Microsoft Azure).

Planetary Computer Hub – JupyterHub

Coleções de imagens de satélites e outros dados: Sentinel-1, -2 e -3, Landsat, MODIS, etc.

Serviços pagos.

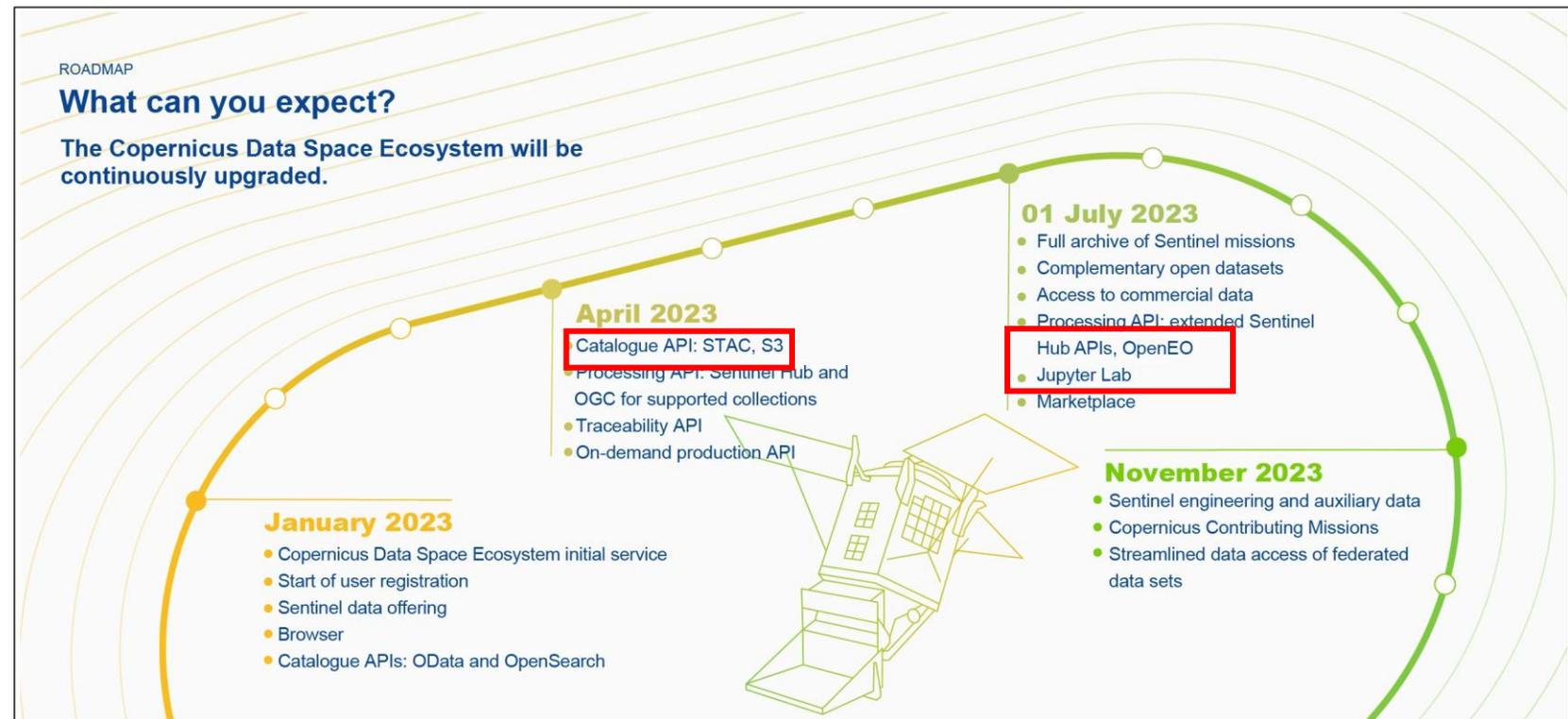
Créditos para pesquisa.



Welcome to the Copernicus Data Space Ecosystem, an open ecosystem that provides free instant access to a wide range of data and services from the Copernicus Sentinel missions and more on our planet's land, oceans and atmosphere.

The Copernicus Data Space Ecosystem not only ensures the continuity of the open and free access to Copernicus data but also extends the portfolio for data processing and data access possibilities.

# Copernicus Data Space Ecosystem (CDSE)





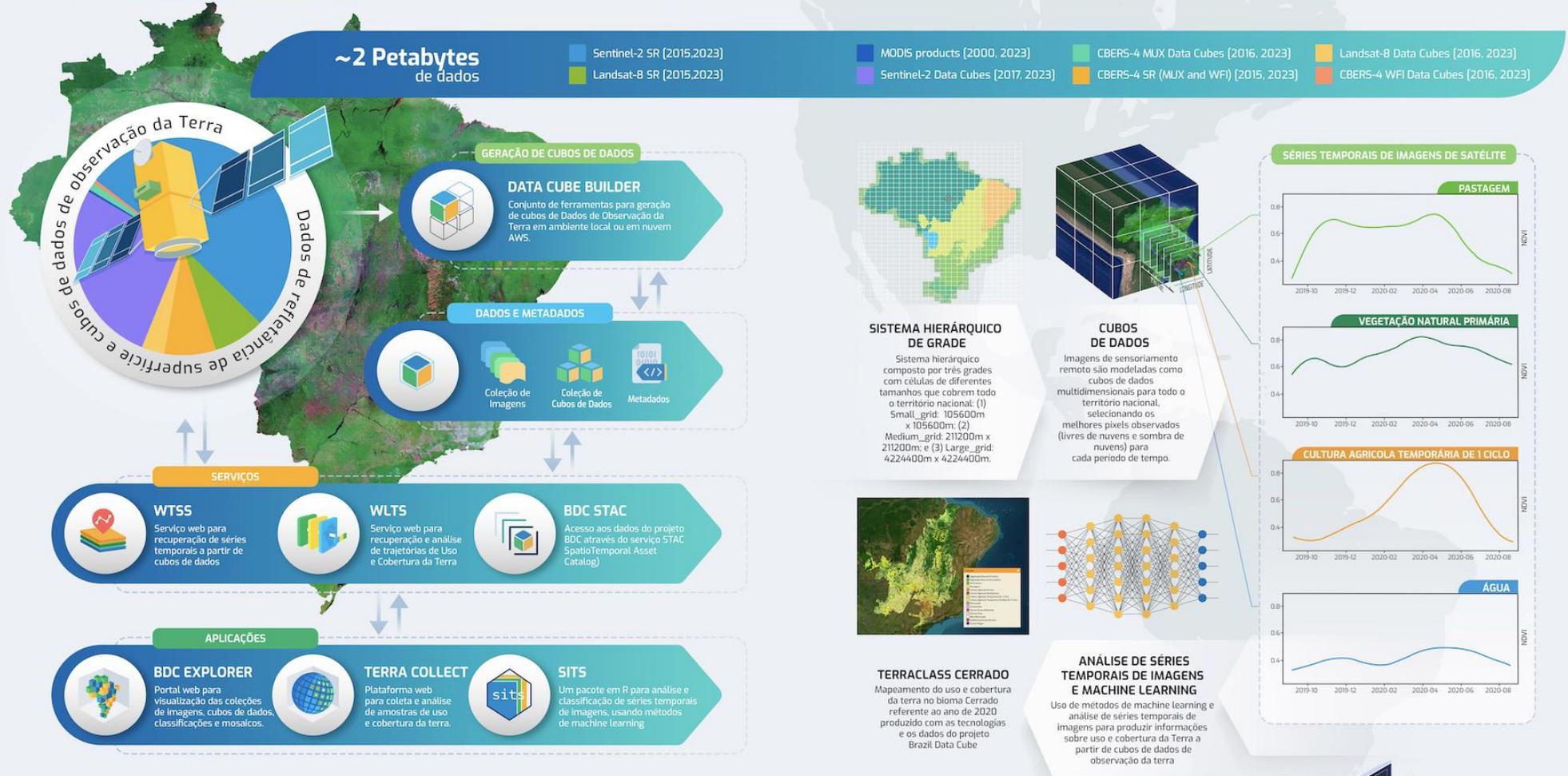
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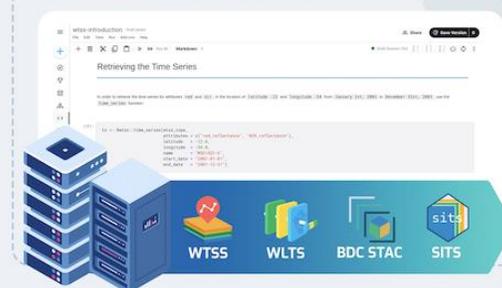


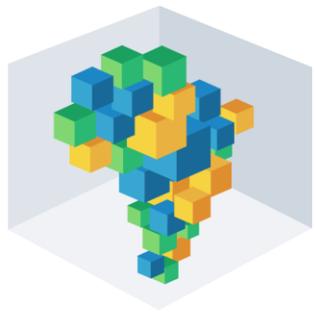
### BRAZIL DATA CUBE EXPLORER

Aplicação web responsável pela visualização das coleções de imagens, cubos de dados, classificações e mosaicos gerados pelo projeto BDC. Através do BDC Explorer, usuários podem acessar e visualizar os dados disponibilizados pela plataforma do projeto em um mapa interativo, usando um componente de controle temporal. Também fornece outros componentes com o intuito de auxiliar o usuário na navegação e recuperação dos dados, como: busca avançada de imagens, comparação de imagens, visualização de series temporais, composição de imagens coloridas e de download.



### AMBIENTE DE CIÊNCIA DE DADOS GEOESPACIAIS - BRAZIL DATA CUBE





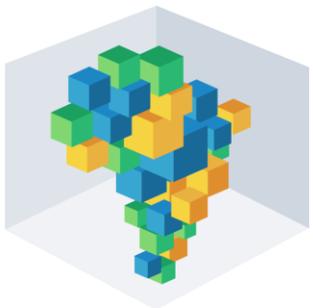
BRAZIL  
DATA CUBE



2019

Produce **technological innovation** for the environmental monitoring projects of INPE.

Potential of **image time series analysis** and **machine learning** to produce land use and cover information from **big EO data**.



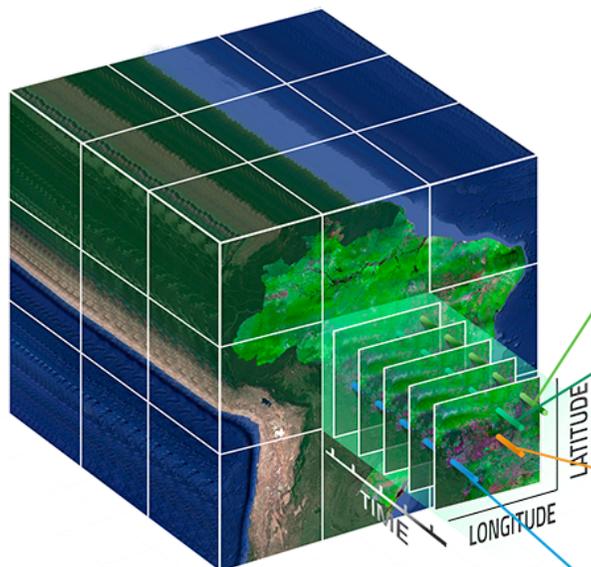
BRAZIL  
DATA CUBE

Big data of remote sensing  
images modeled as  
multidimensional data cubes

Big data technologies and  
machine learning

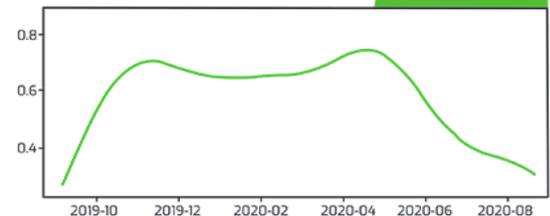
Image time series analysis

Land use and cover mapping

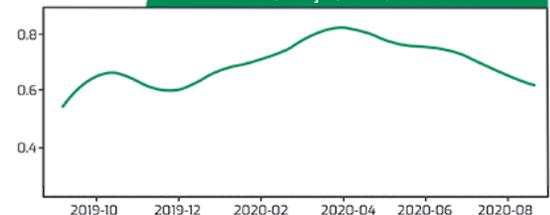


SÉRIES TEMPORAIS DE IMAGENS DE SATÉLITE

PASTAGEM



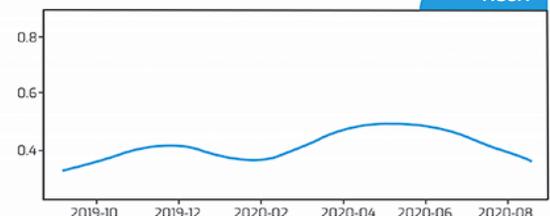
VEGETAÇÃO NATURAL PRIMÁRIA



CULTURA AGRÍCOLA TEMPORÁRIA DE 1 CICLO



ÁGUA

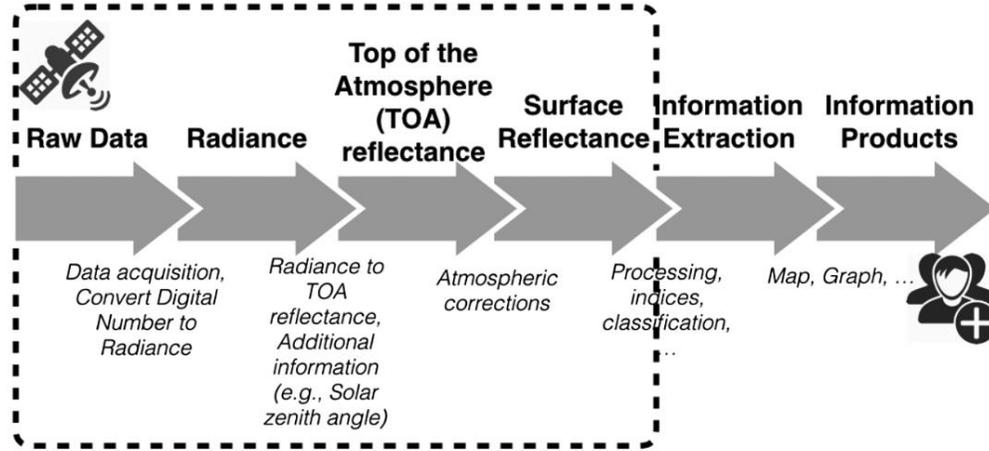




BRAZIL DATA CUBE

# ARD and EO Data Cubes for the entire Brazilian territory

2 Petabytes (PB) remote sensing images



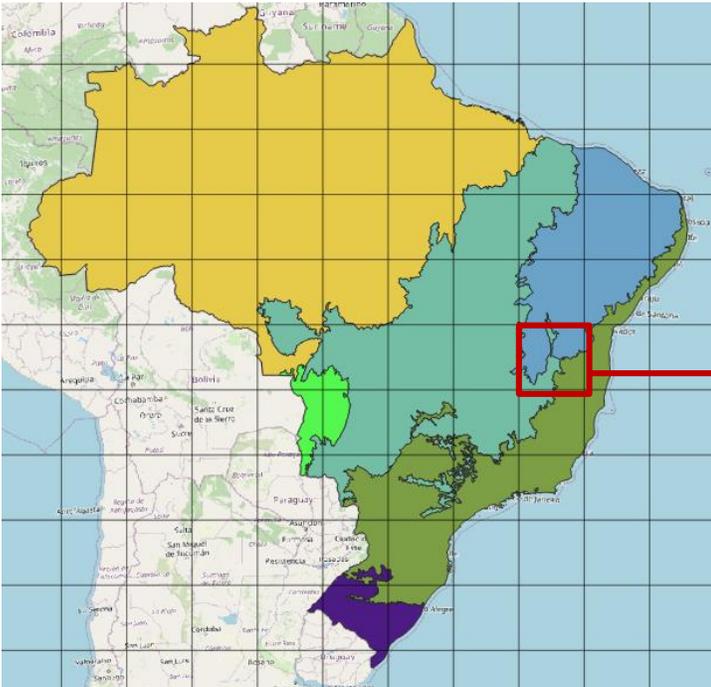
Analysis Ready Data production

Source: [Giuliani et al, 2017]

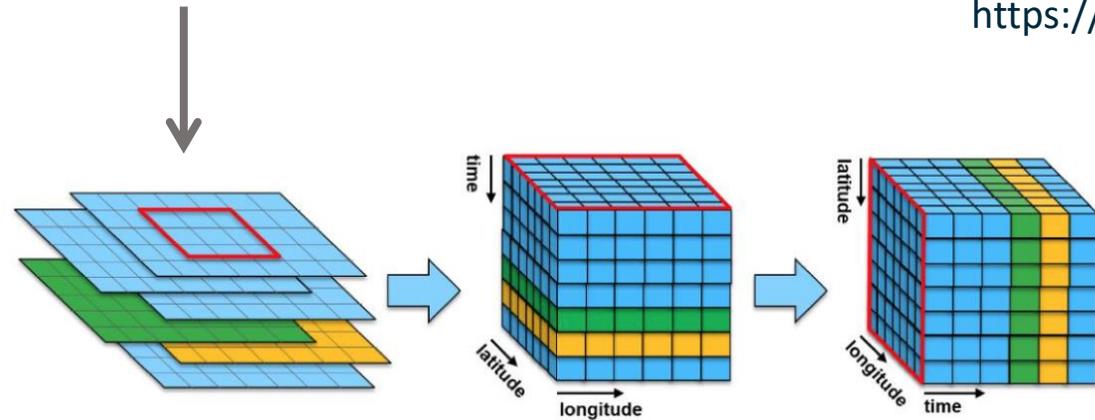
Sentinel-2  
Landsat-8 / -9  
CBERS-4 / 4A  
(MUX / WFI)



CEOS Analysis Ready Data (ARD) for Land:  
<https://ceos.org/ard/index.html>



BDC Hierarchical Tiling System



Collections of ARD satellite images

Multidimensional Data cubes

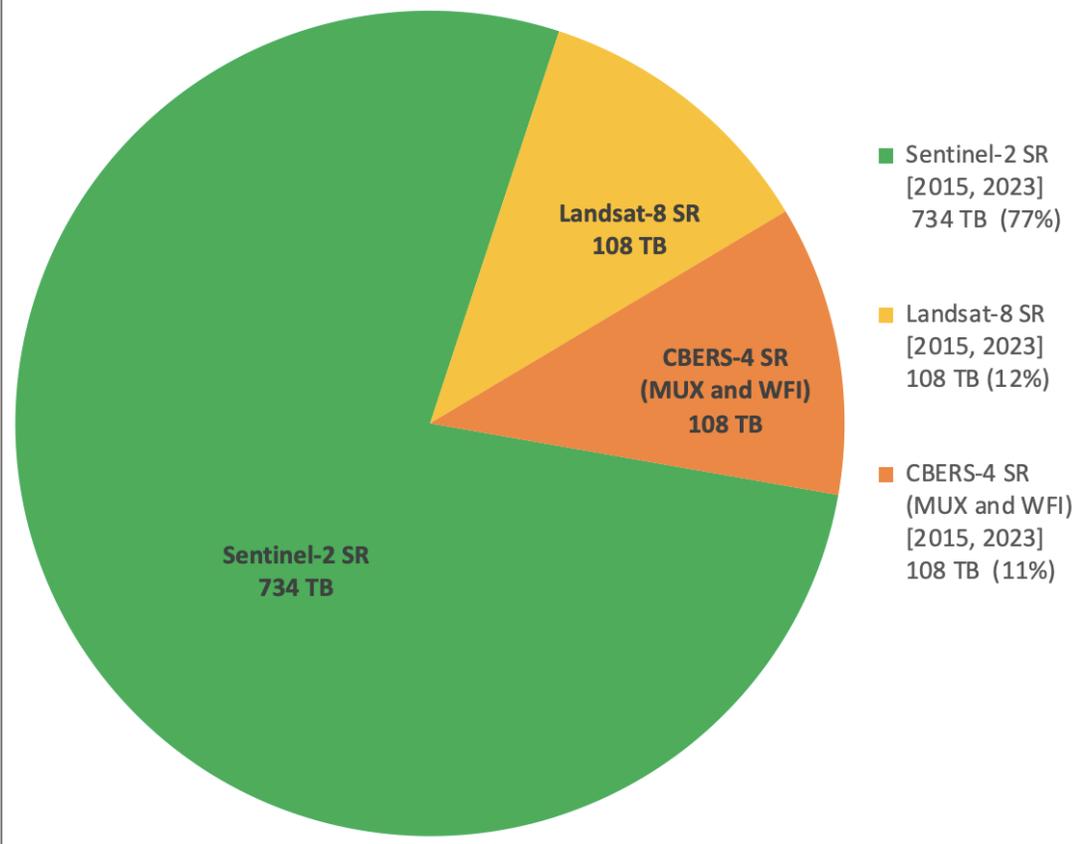
Source: [Kopp et al, 2019]



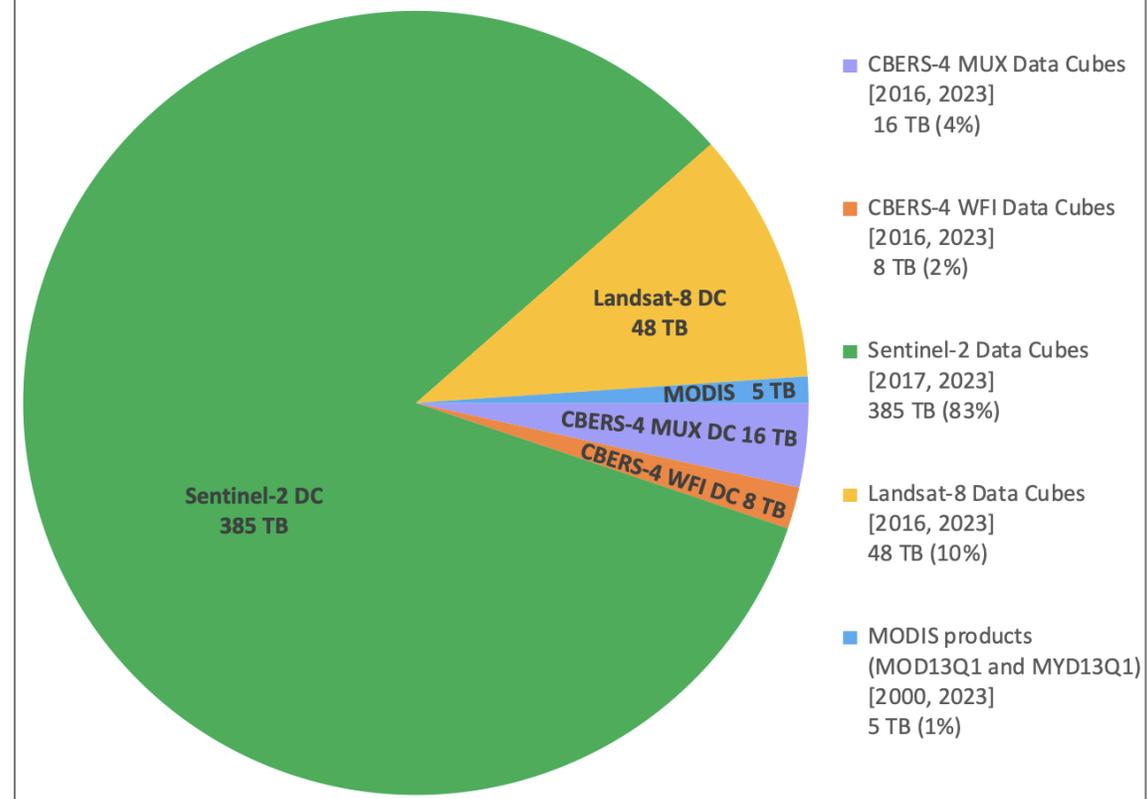
BRAZIL  
DATA CUBE

# Big data

### Data volume (TB) of surface reflectance (SR) images for Brazil



### Data volume (TB) of Earth observation data cubes (DC) for Brazil

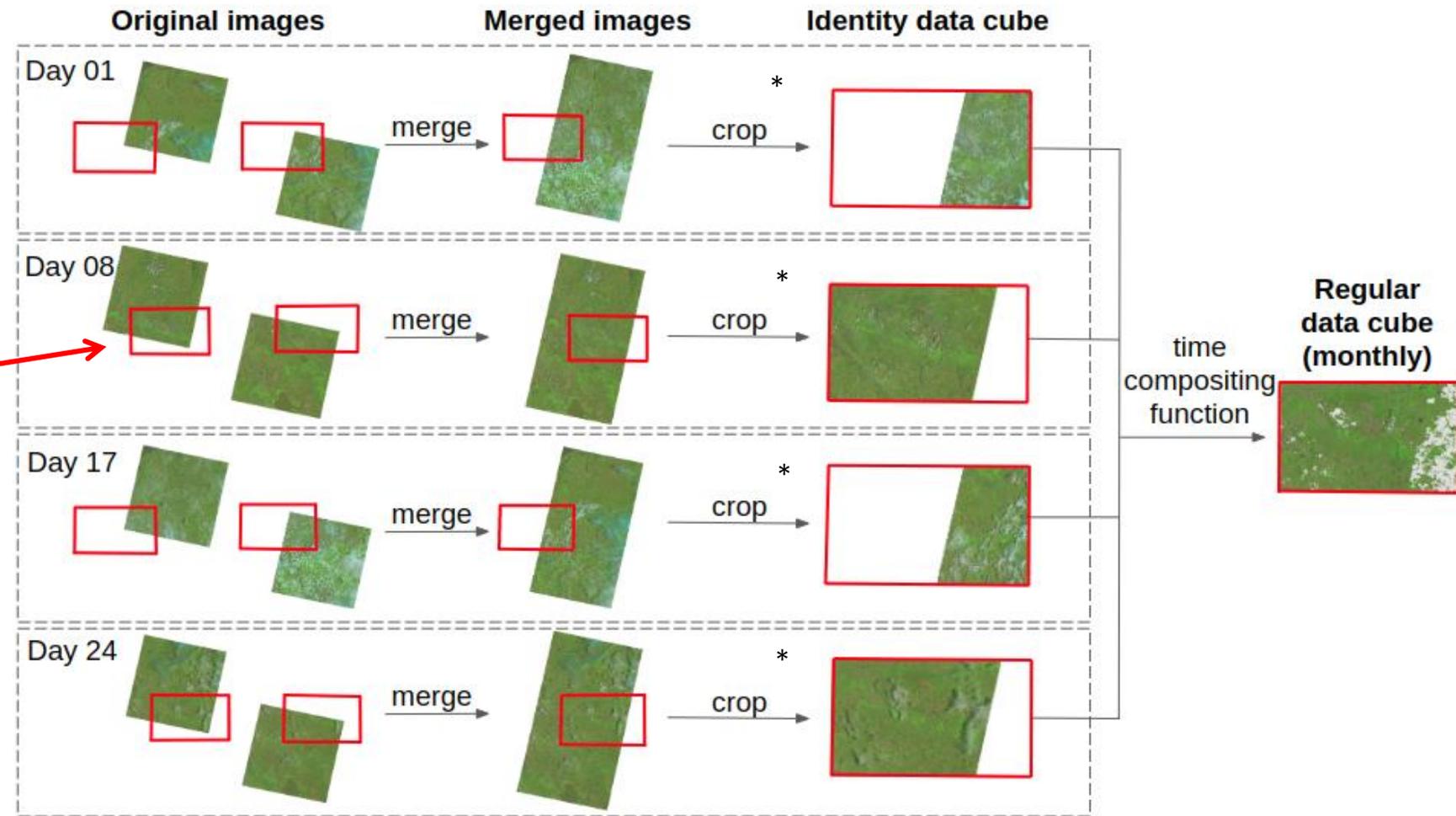
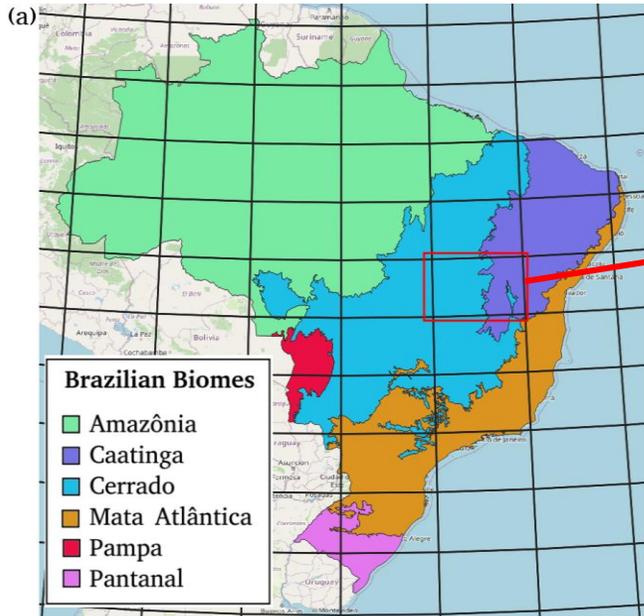


Source: [Ferreira et al., 2022]



# Building data cubes

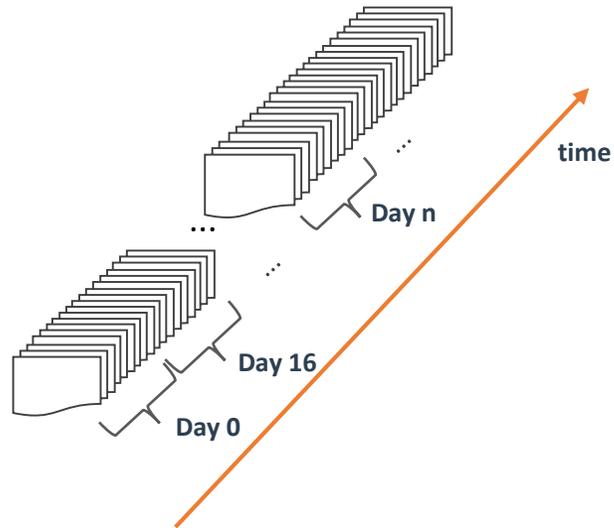
BRAZIL  
DATA CUBE



\*bilinear resampling for better spatial resolution band



[brazildatacube.dpi.inpe.br/porta1/explore](http://brazildatacube.dpi.inpe.br/porta1/explore)



For each *tile* and *time step*, there are a set of COG (Cloud Optimized GeoTIFF) files:

- (1) Spectral bands from original images;
- (2) Vegetation indices (EVI and NDVI);
- (3) Cloud mask; (4) number of valid observations (excluding cloud, cloud shadow..); (5) data provenance; ...

BDC – Small

Each tile: 105600m x 105600m

Sentinel-2/MSI – 10 meters  
Each file (band/tile): 400 MB

Each tile: ~ 5.4 GB

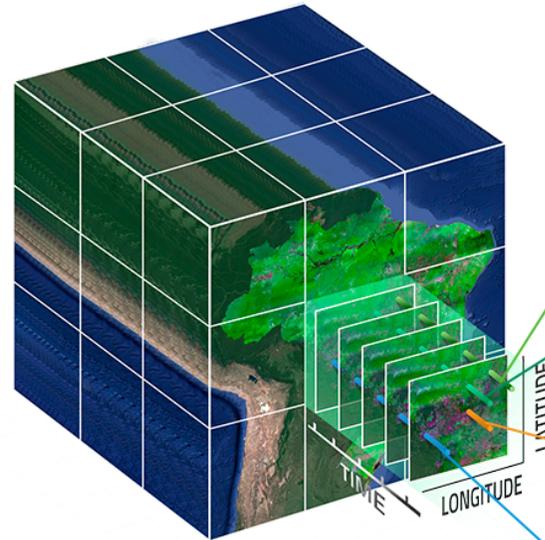


BRAZIL  
DATA CUBE

# Why Earth Observation (EO) Data Cubes ?

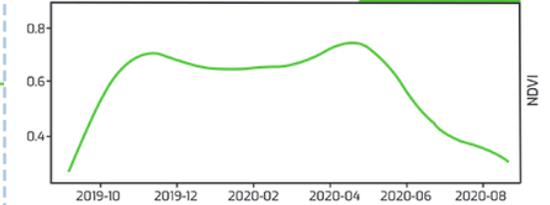
Multidimensional arrays of satellite images with four dimensions (latitude, longitude, time and attributes), mainly to support **image time series analysis**.

(Appel et al., 2019)

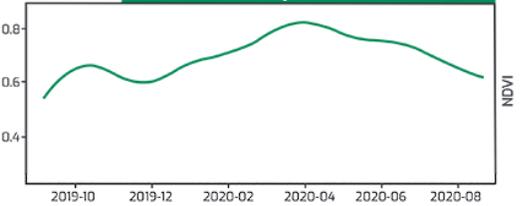


## SÉRIES TEMPORAIS DE IMAGENS DE SATÉLITE

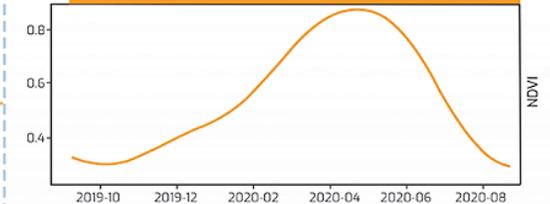
### PASTAGEM



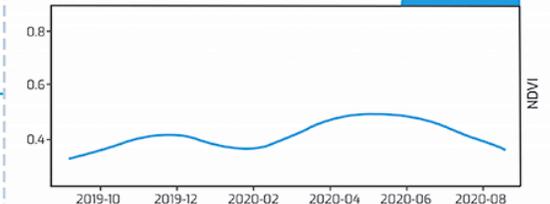
### VEGETAÇÃO NATURAL PRIMÁRIA



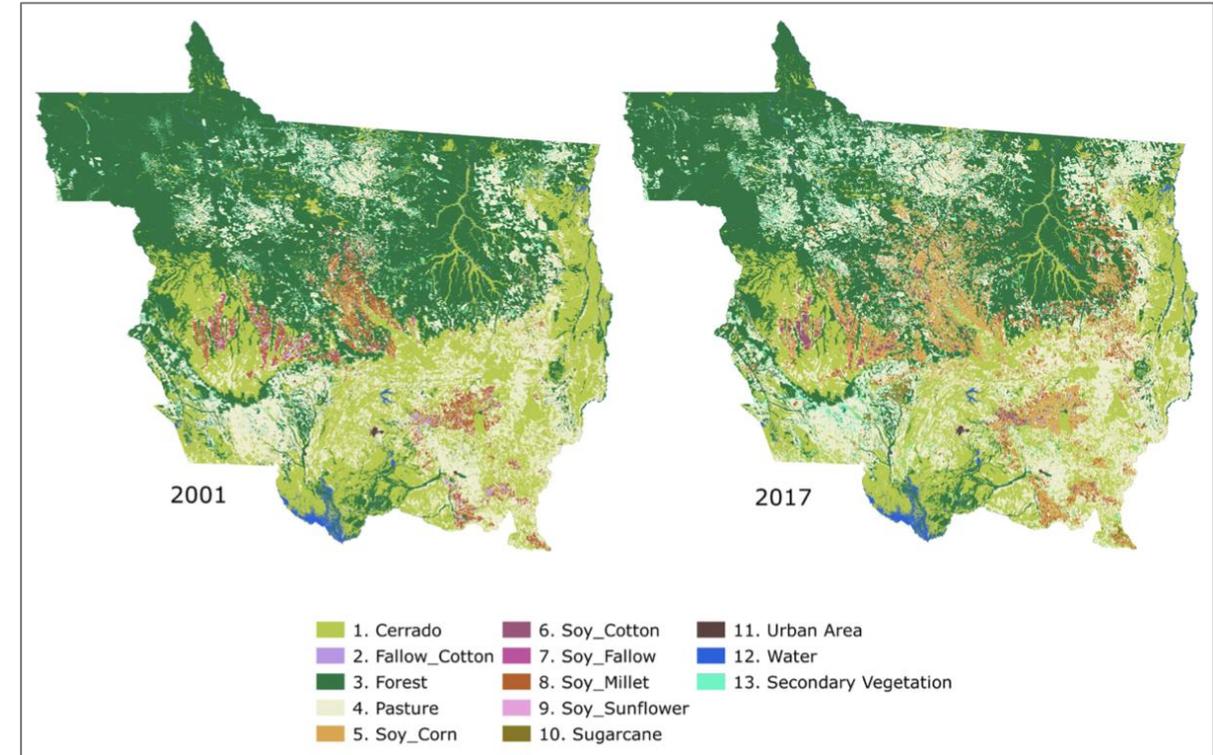
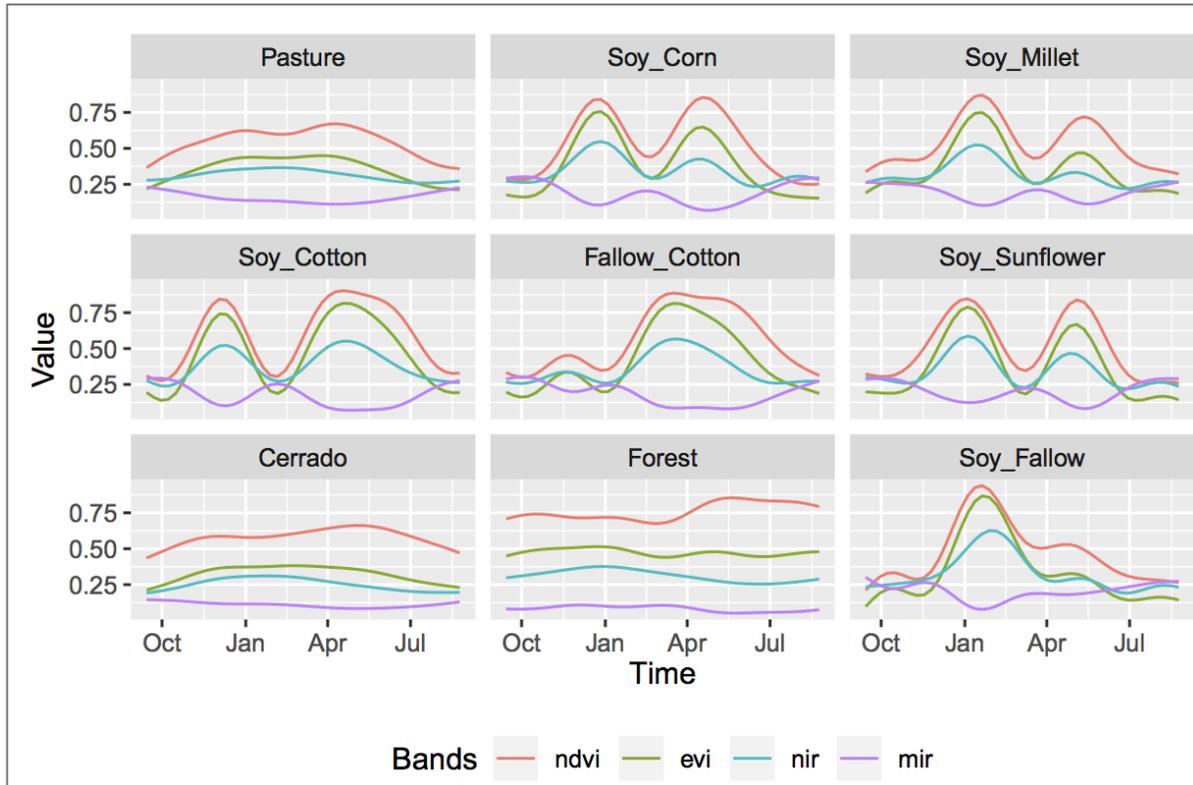
### CULTURA AGRÍCOLA TEMPORÁRIA DE 1 CICLO



### ÁGUA



# Potential of image time series and machine learning



Source: [Simoes et al., 2020]

Land use and cover maps for Mato Grosso State in Brazil from 2001 to 2017

Scientific Data, 2020

Image time series: NDVI, EVI, NIR, MIR (agriculture year)

MODIS (250 meters) – MOD13Q1 product

Method – SVM (Support Vector Machine)



BRAZIL  
DATA CUBE

# Satellite Image Time Series Analysis (SITS)

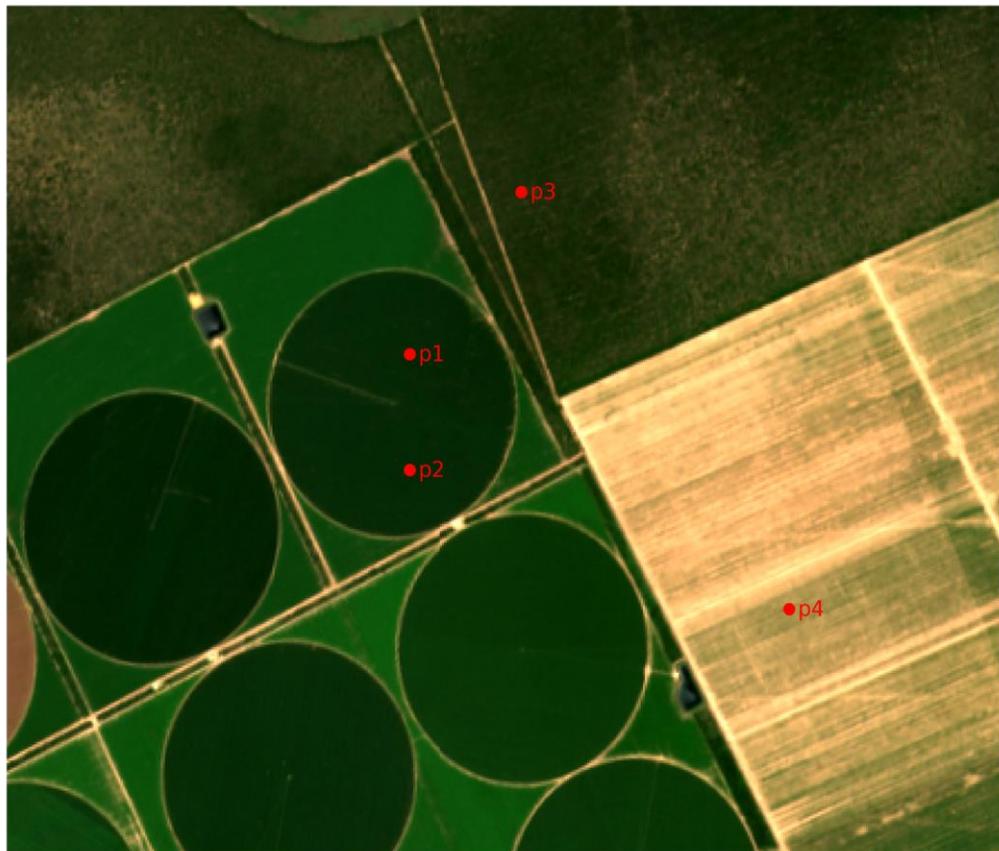
SITS reveal complex underlying processes that would be difficult to assess using bi-temporal or even annual change detection approaches.

(Pasquarella et al., 2016)

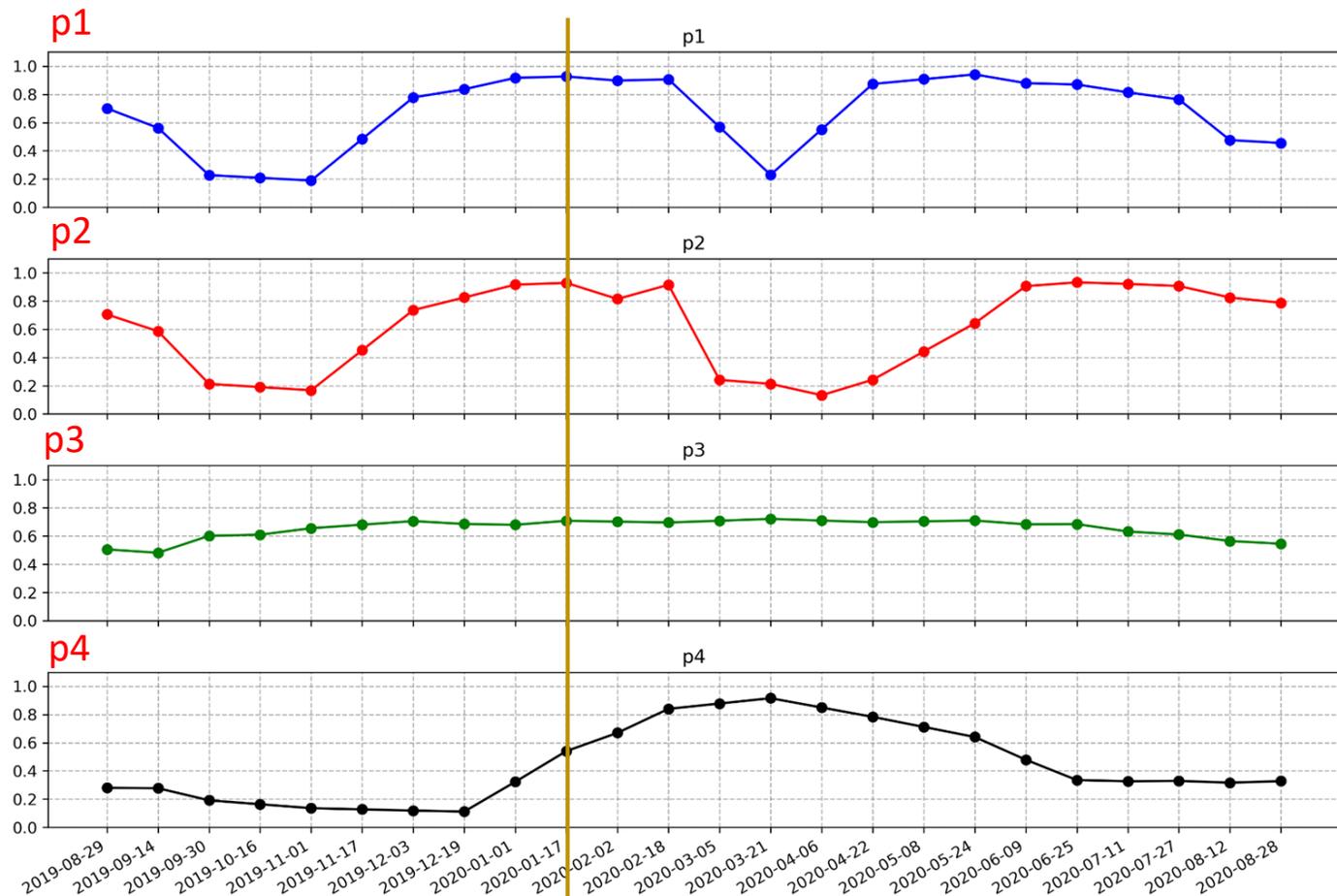


# NDVI Time Series – Sentinel-2 Data Cube (16-days)

## Sentinel-2 RGB



2020-01-17



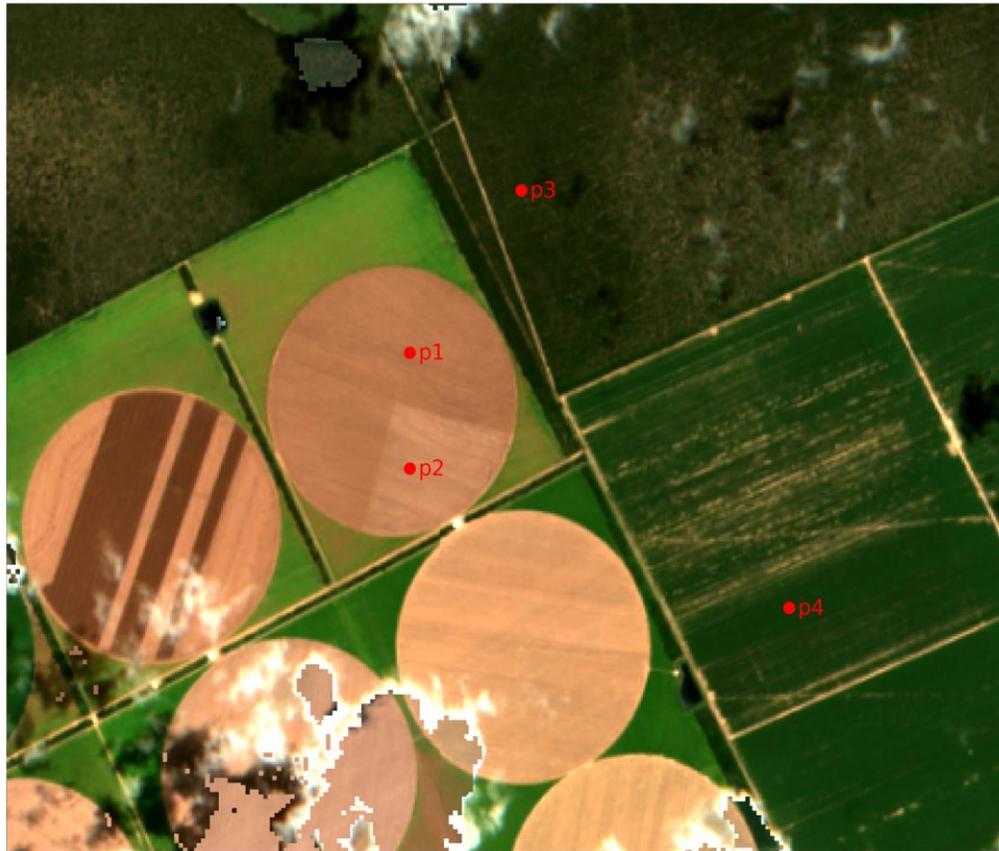
2020-01-17

(Baggio, 2024)

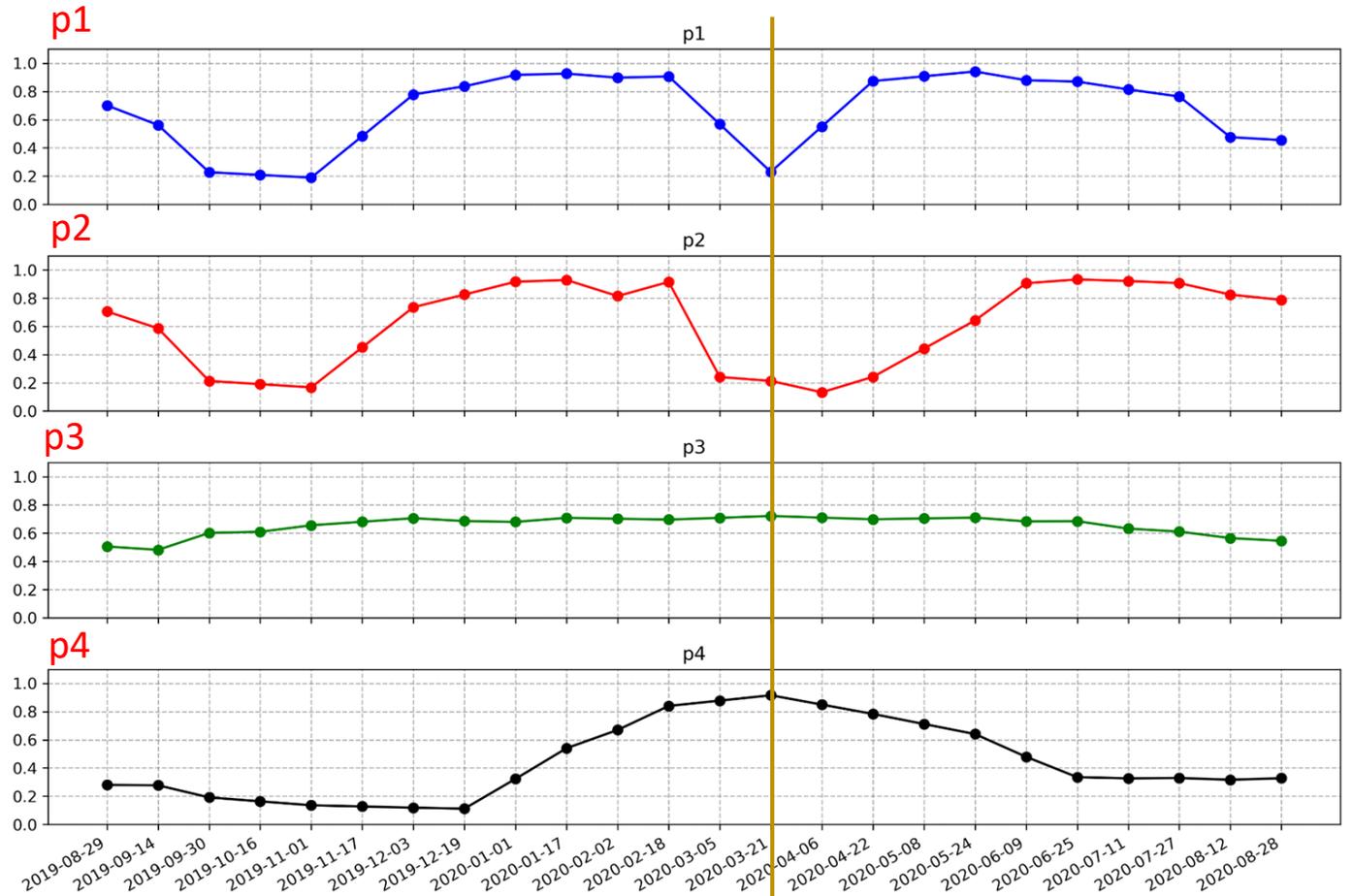


# NDVI Time Series – Sentinel-2 Data Cube (16-days)

## Sentinel-2 RGB



2020-03-21



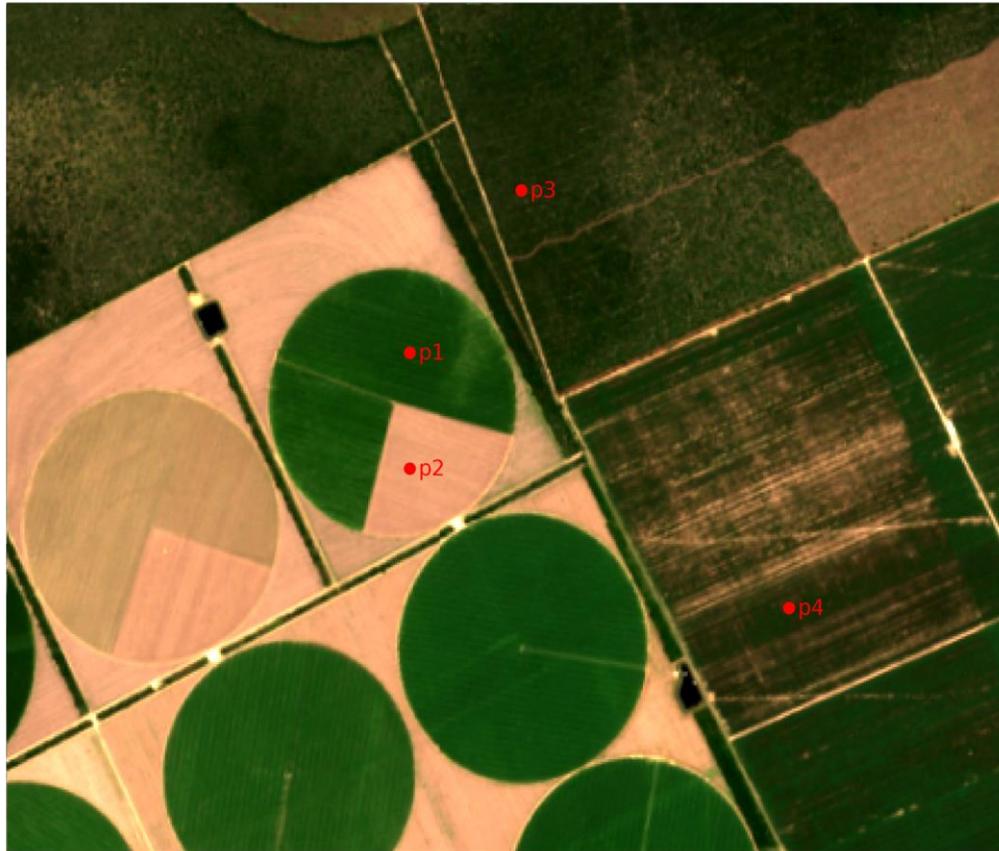
2020-03-21

(Baggio, 2024)

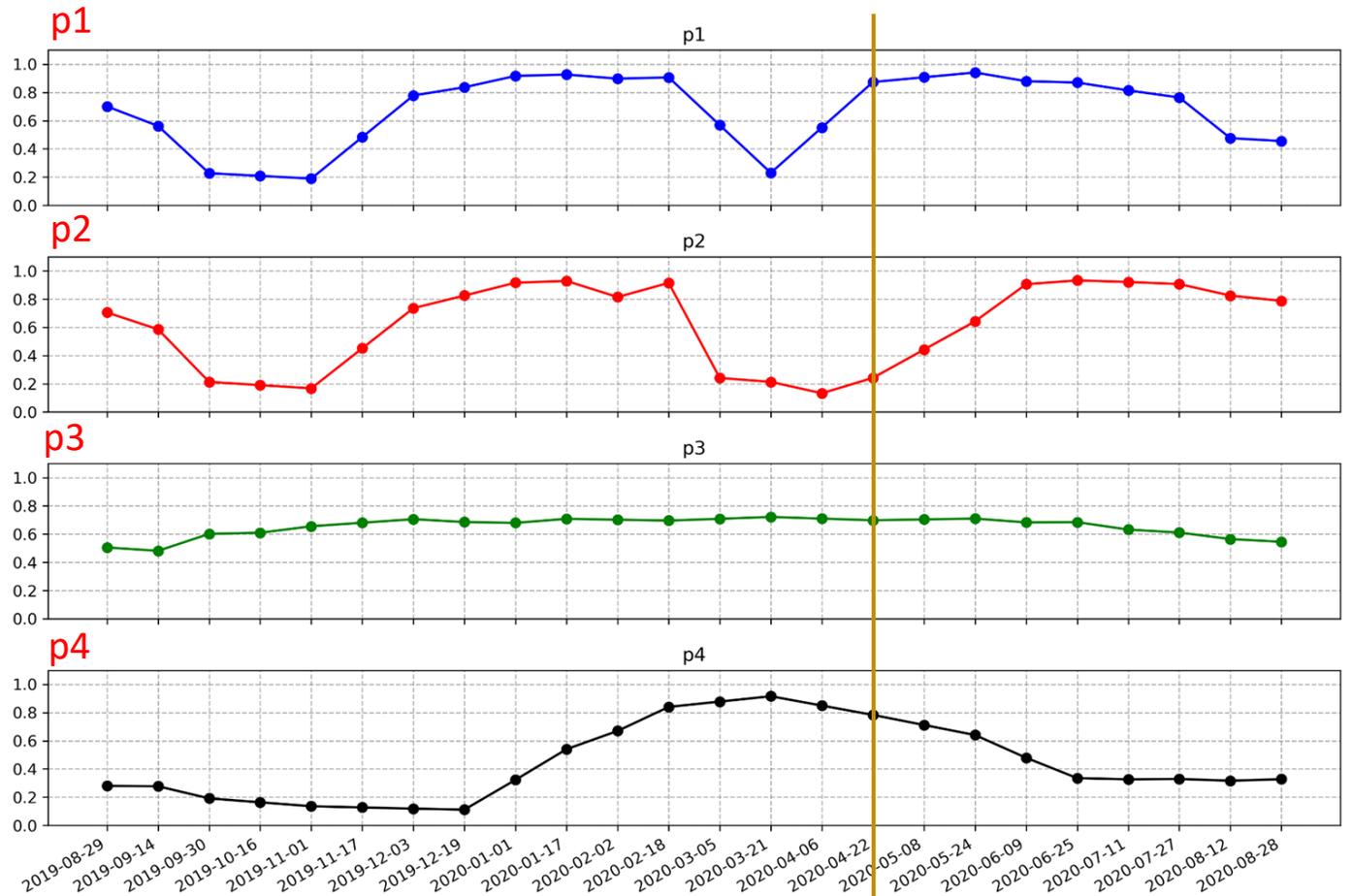


# NDVI Time Series – Sentinel-2 Data Cube (16-days)

## Sentinel-2 RGB



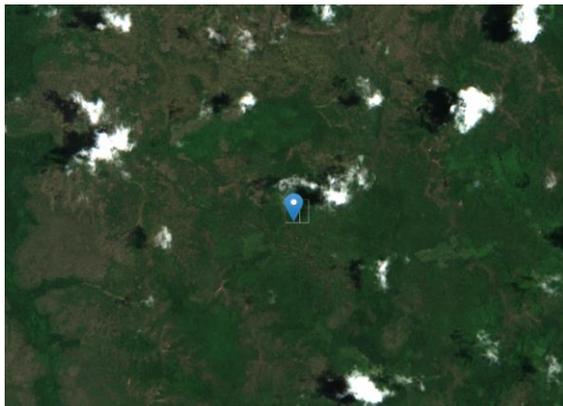
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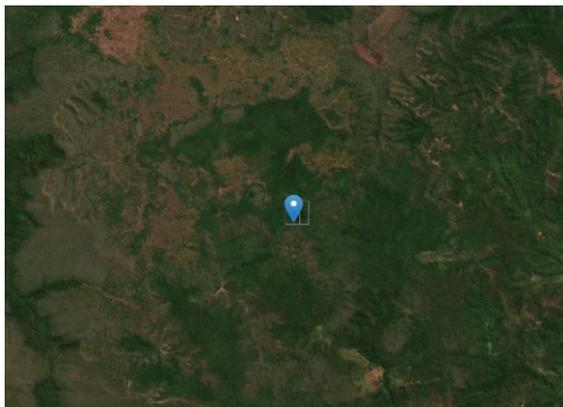
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(Baggio, 2024)

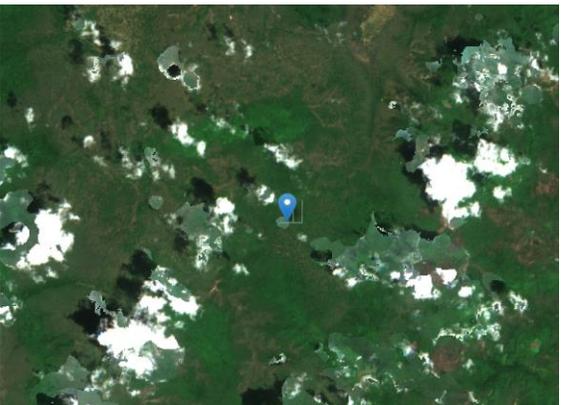
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12-07-2022



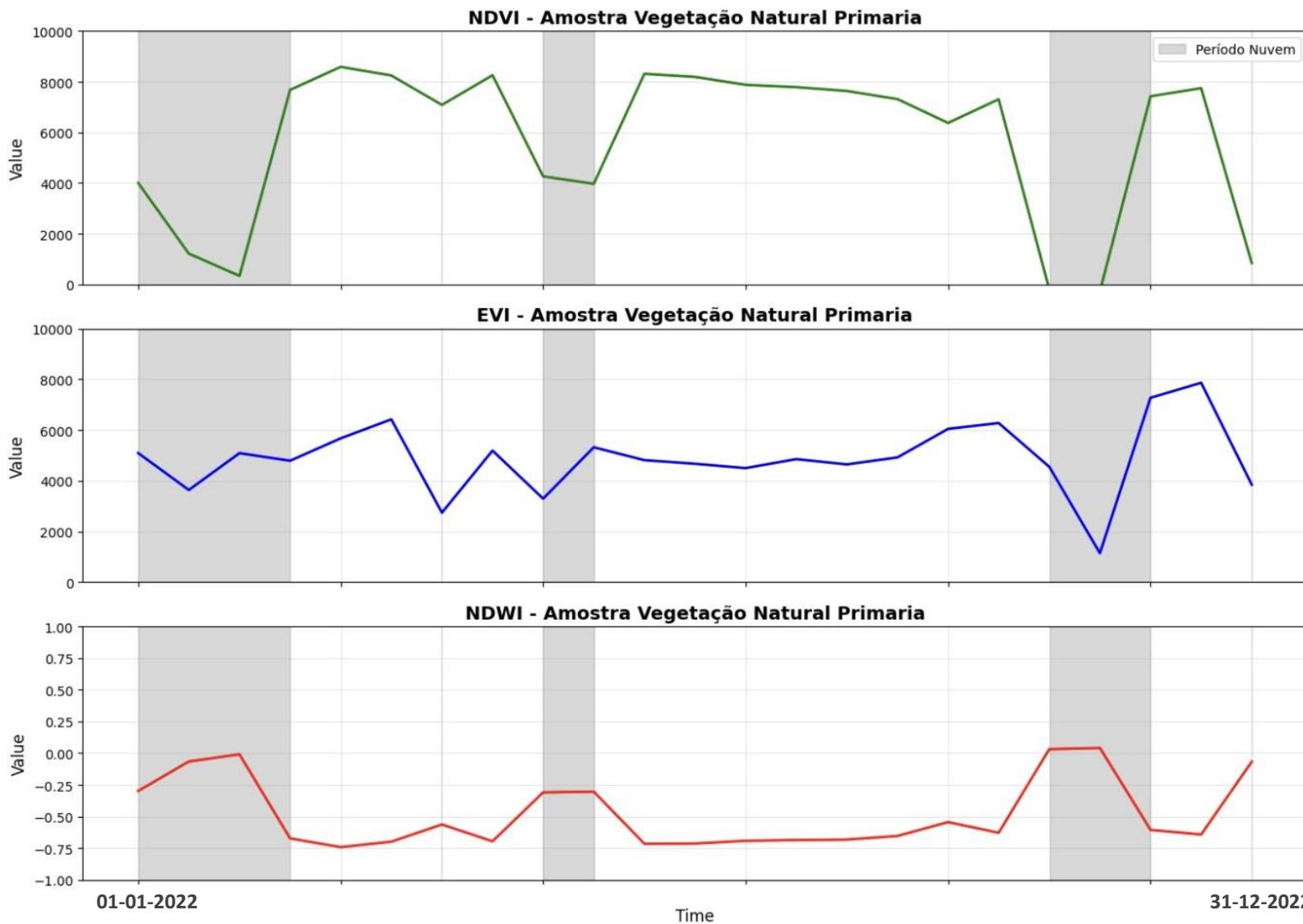
03-12-2022



# Vegetação Natural Primária – Cubos Sentinel 2



BRAZIL  
DATA CUBE



18-02-2022



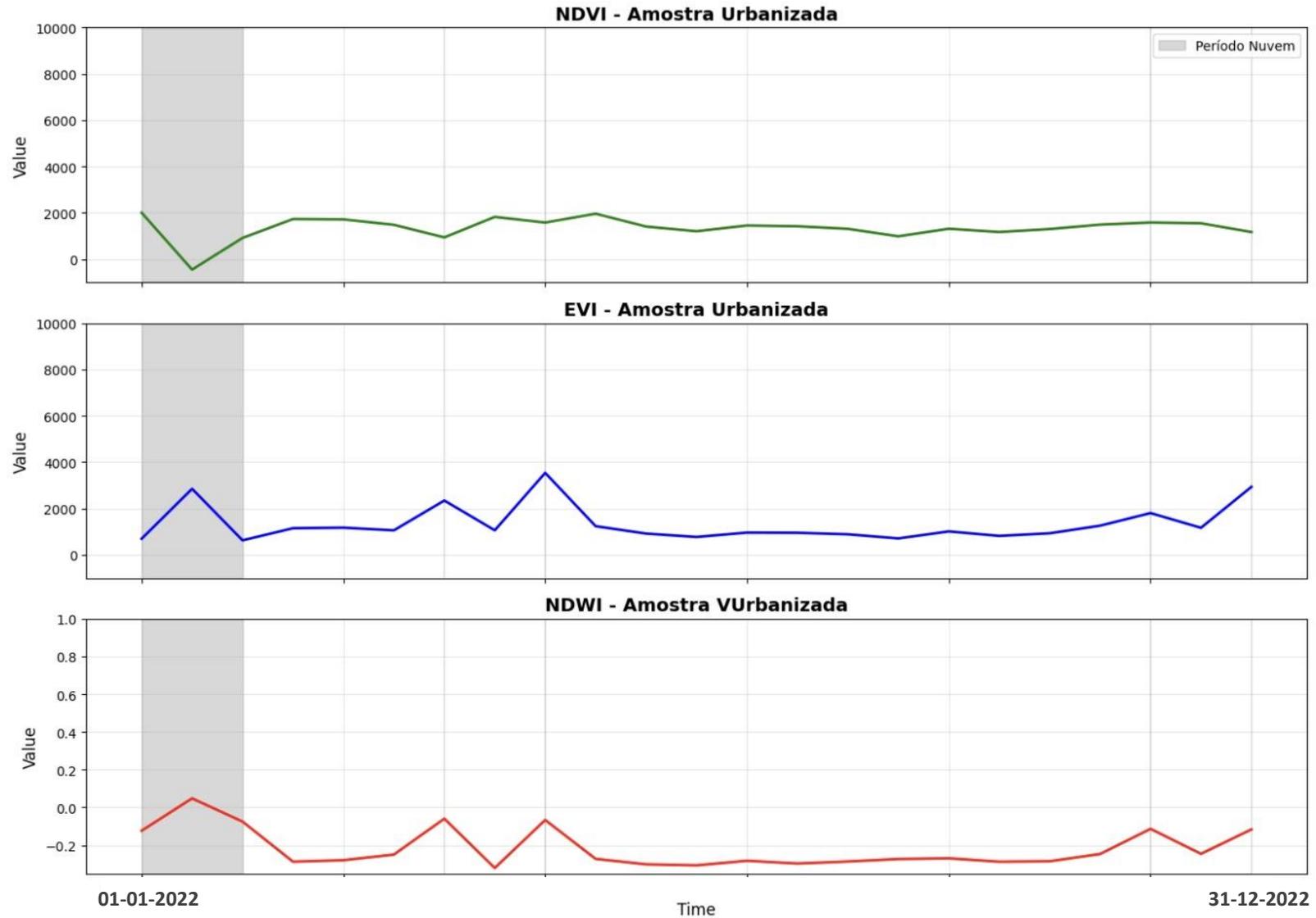
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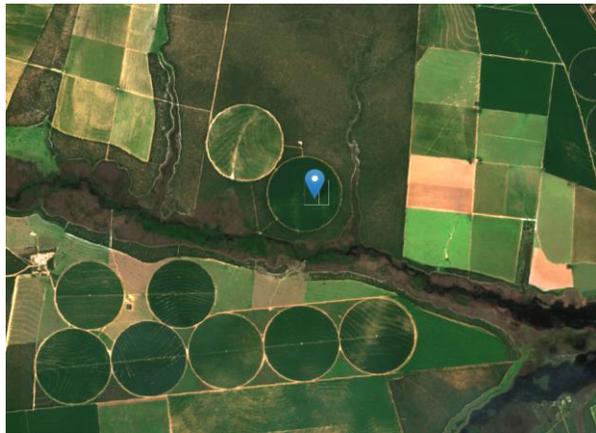
16-10-2022



# Área Urbana – Cubos Sentinel 2



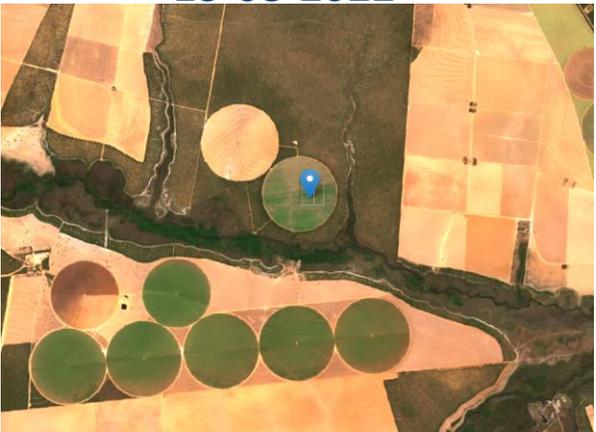
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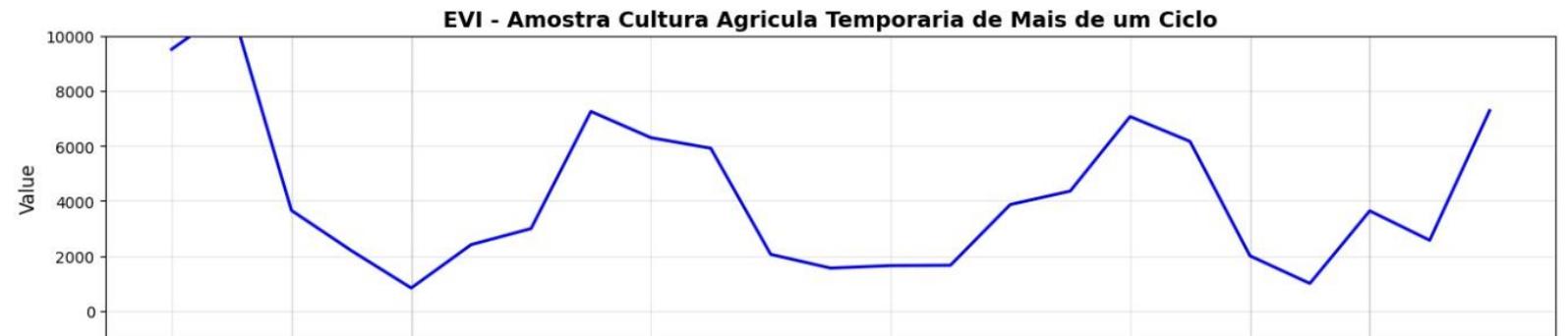
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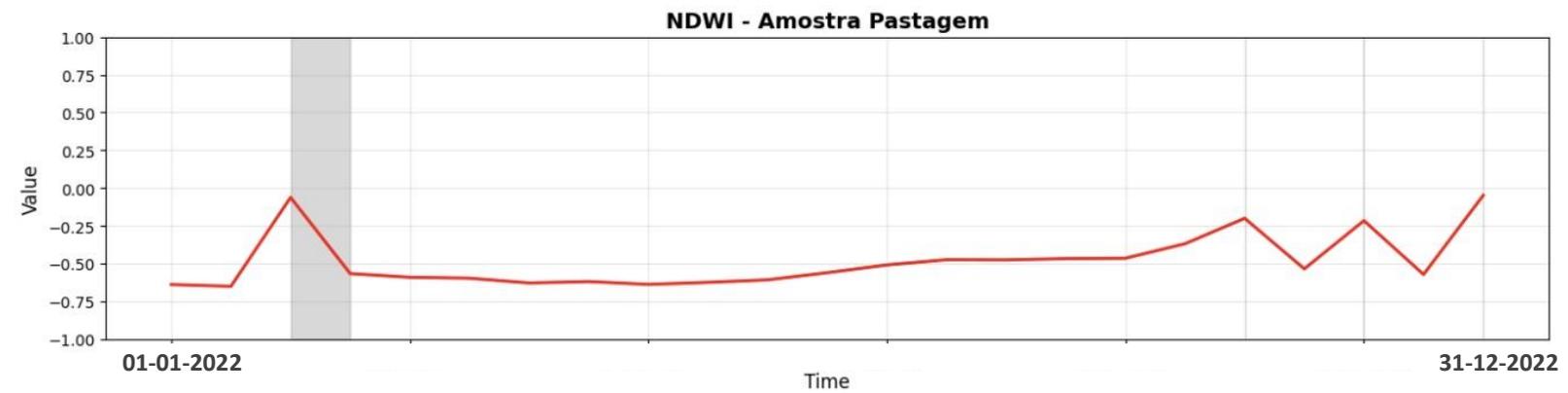
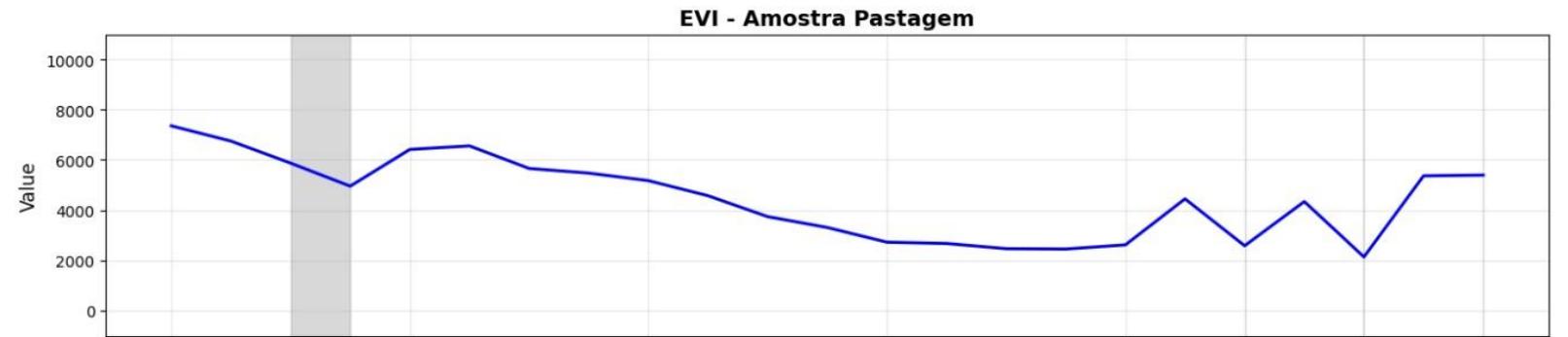
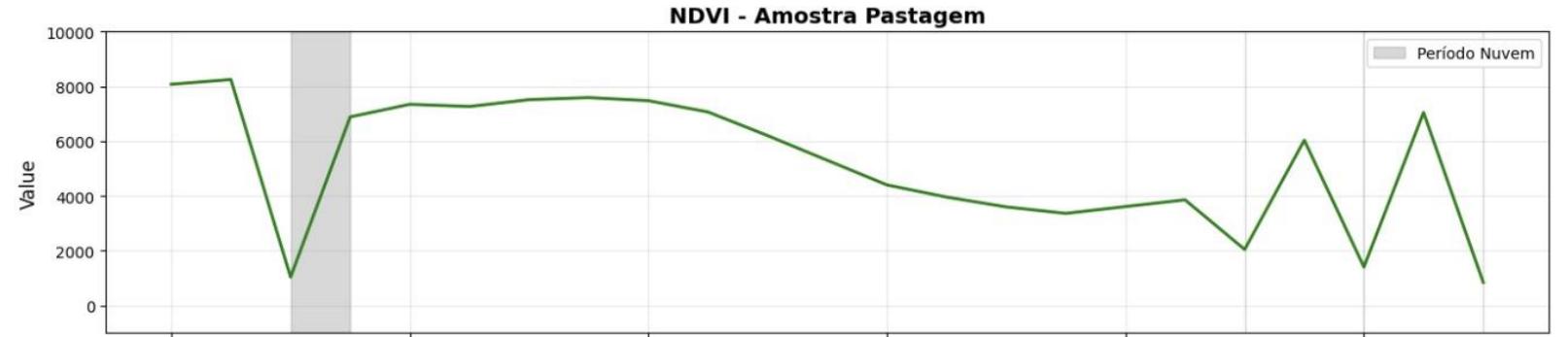
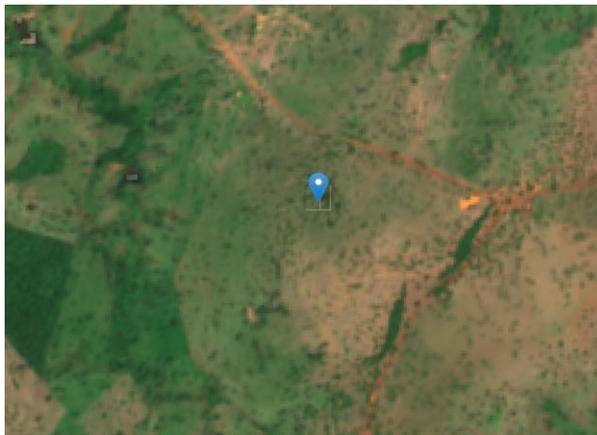
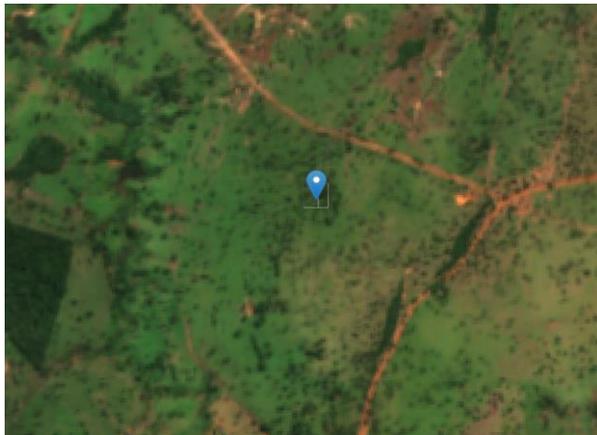
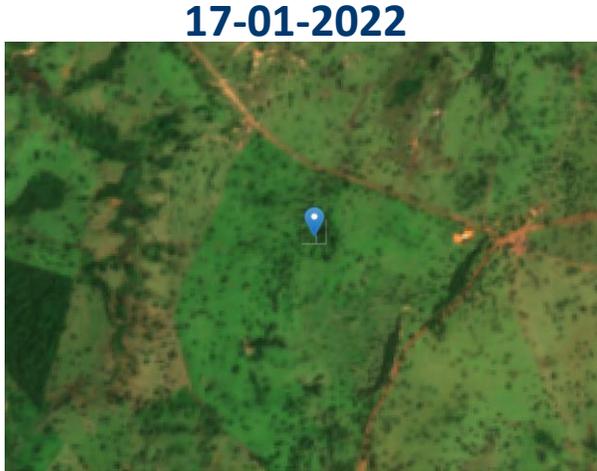
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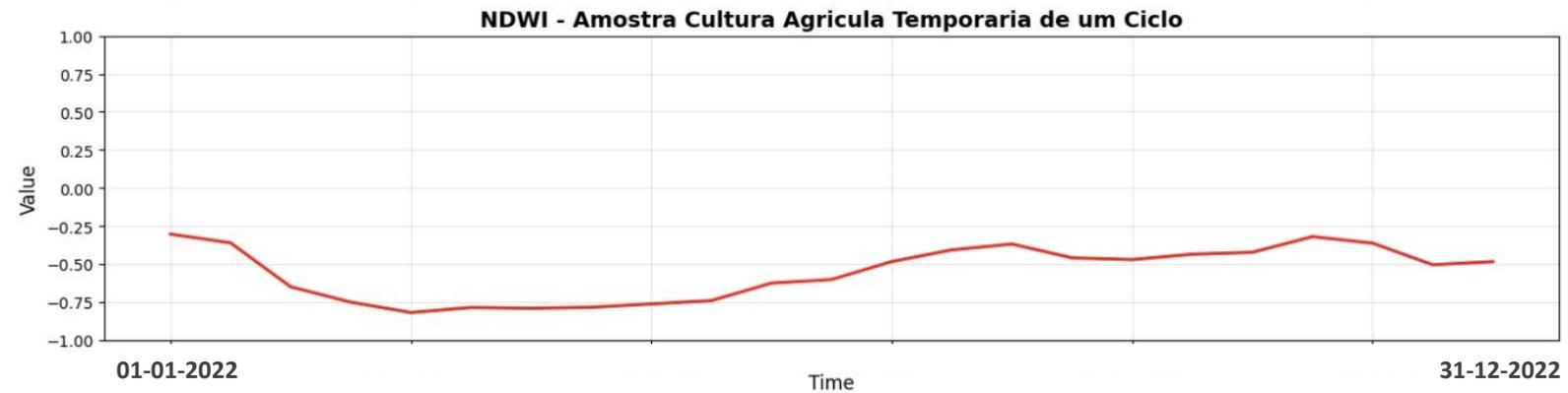
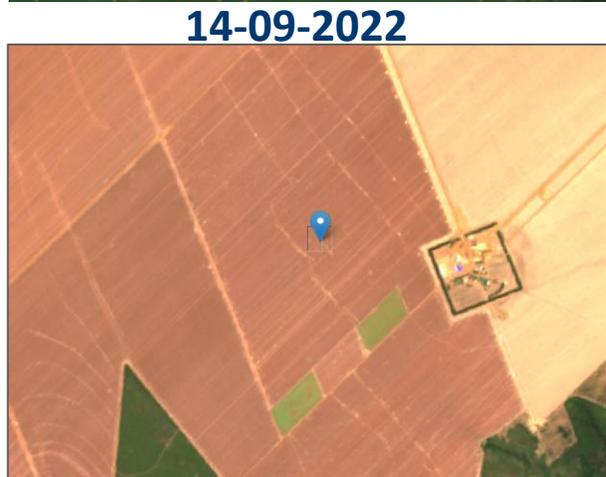
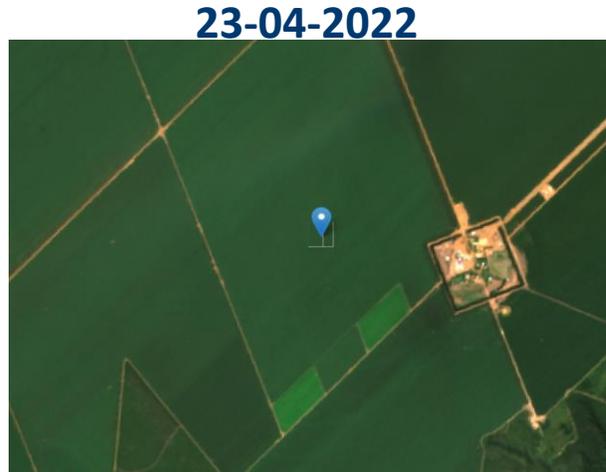
# Agricultura - mais de 1 ciclo – Cubos Sentinel 2



# Pastagem – Cubos Sentinel 2



# Agricultura – 1 ciclo – Cubos Sentinel 2







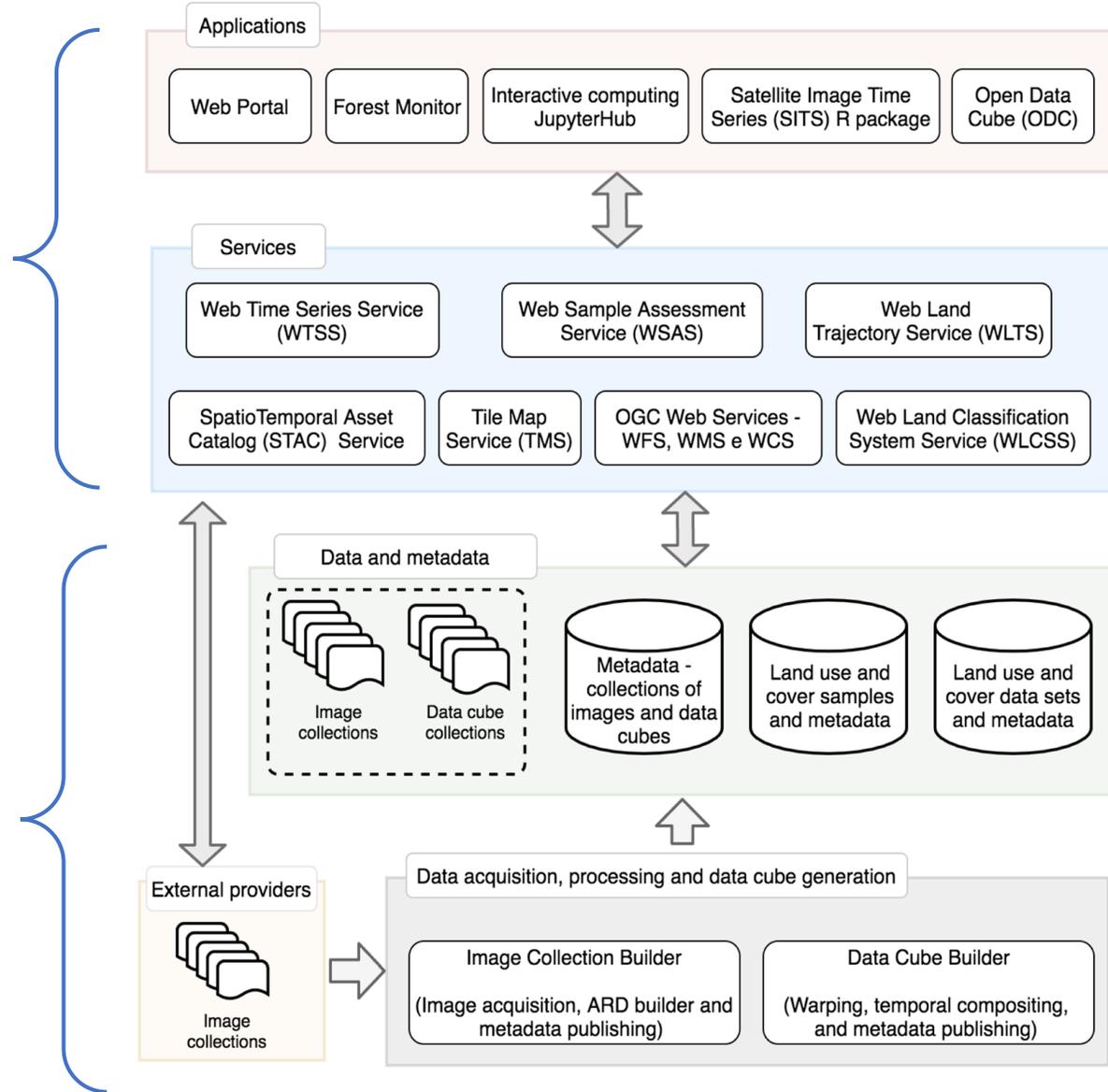
BRAZIL DATA CUBE

# Brazil Data Cube Platform

Open Data and Software Products

Software

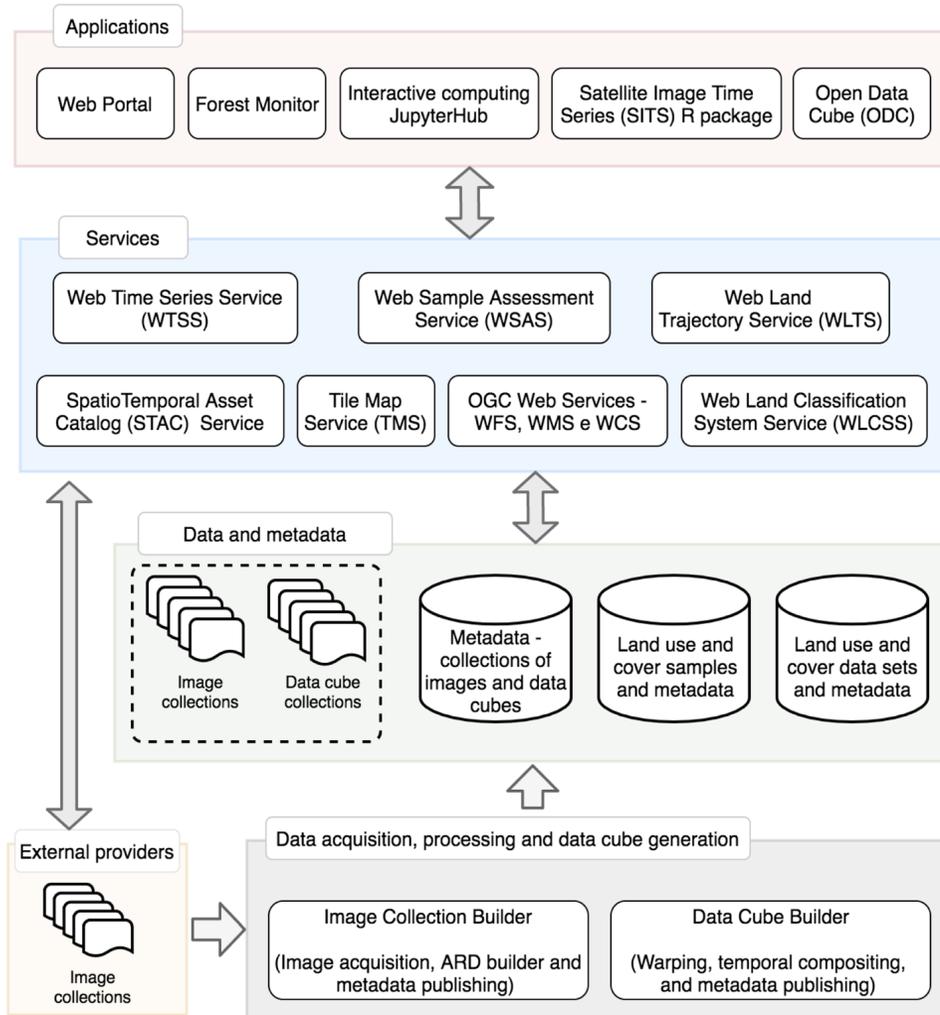
Data and metadata





# Brazil Data Cube Platform

BRAZIL  
DATA CUBE



# Interoperabilidade



Google Earth Engine



Microsoft



Planetary Computer

Copernicus Data

Space Ecosystem (CDSE)



BRAZIL  
DATA CUBE



SpatioTemporal Asset Catalog

Especificação que define uma estrutura comum, em arquivos JSON e GEOJSON, para descrever e catalogar dados geográficos.




# STAC

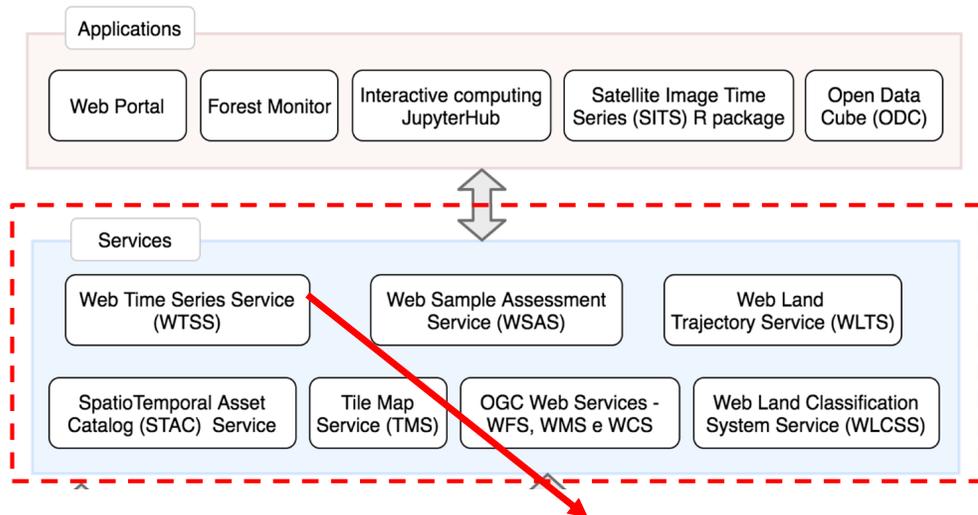
SpatioTemporal Asset Catalog

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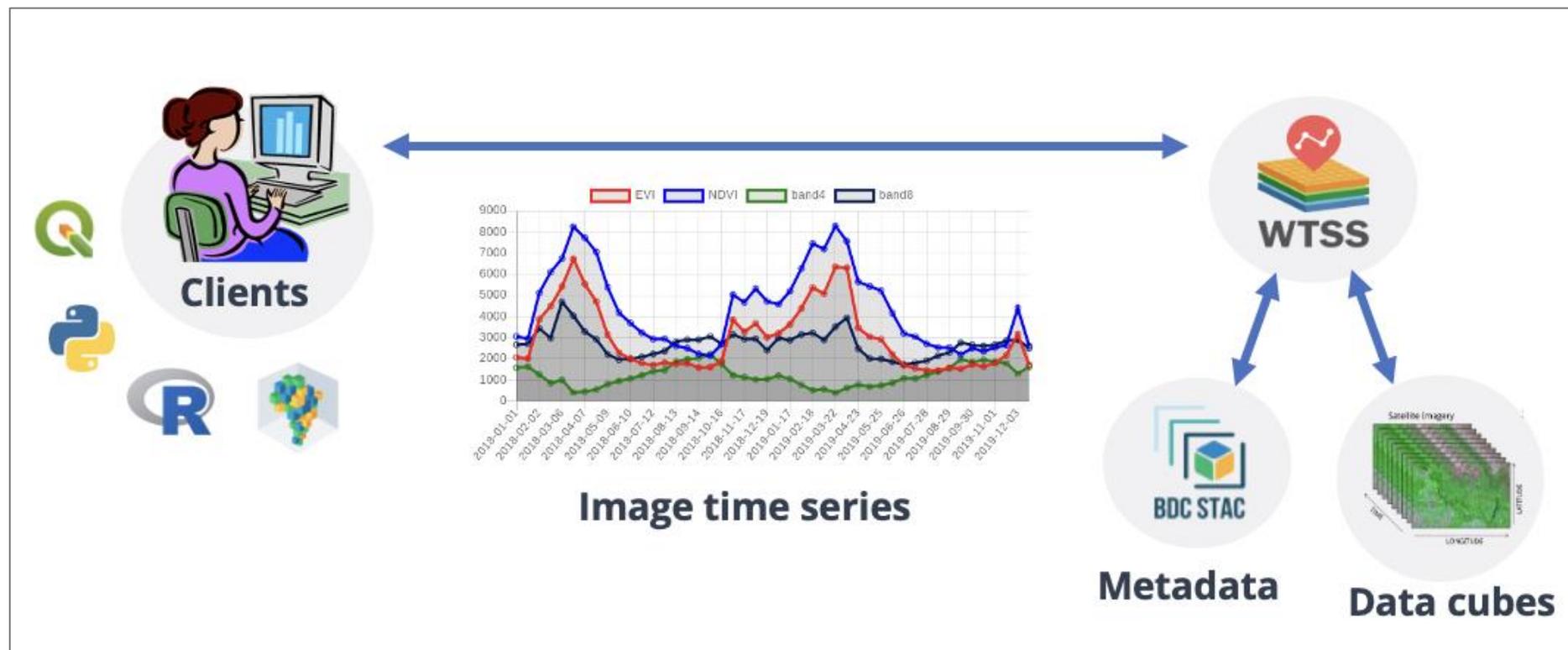
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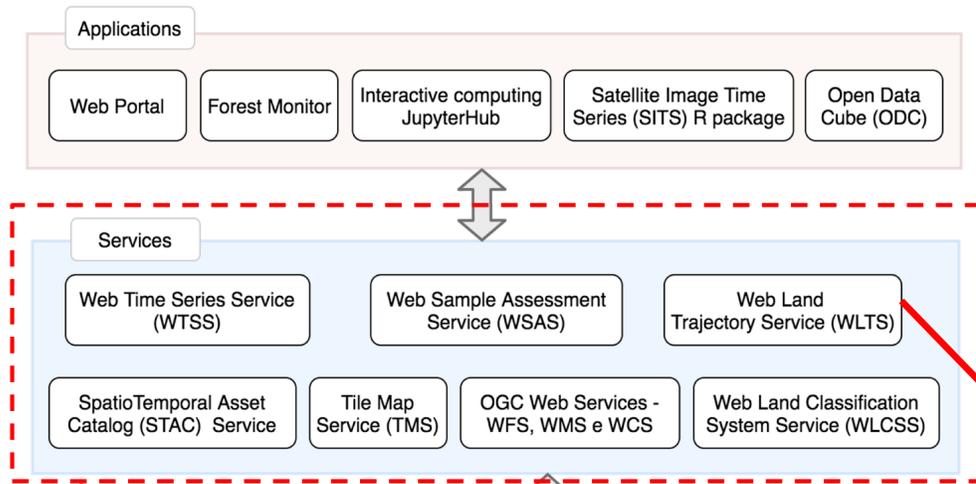
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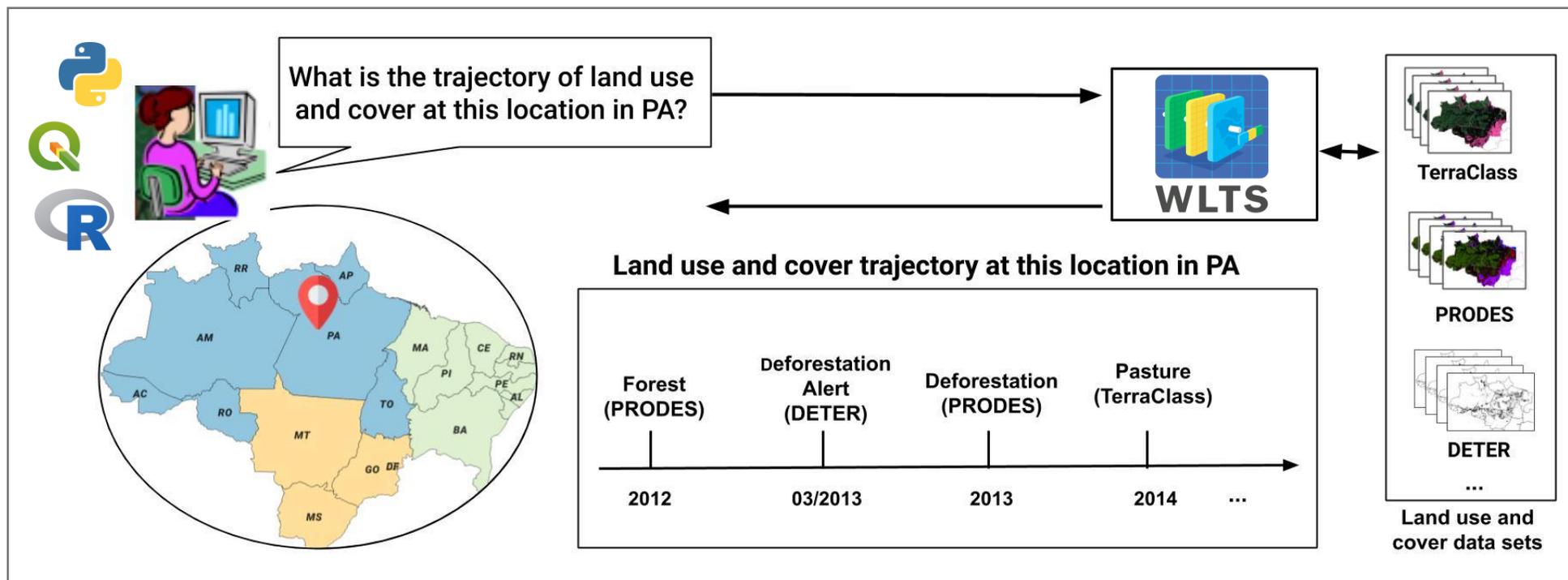


## WTSS – Web Time Series Service

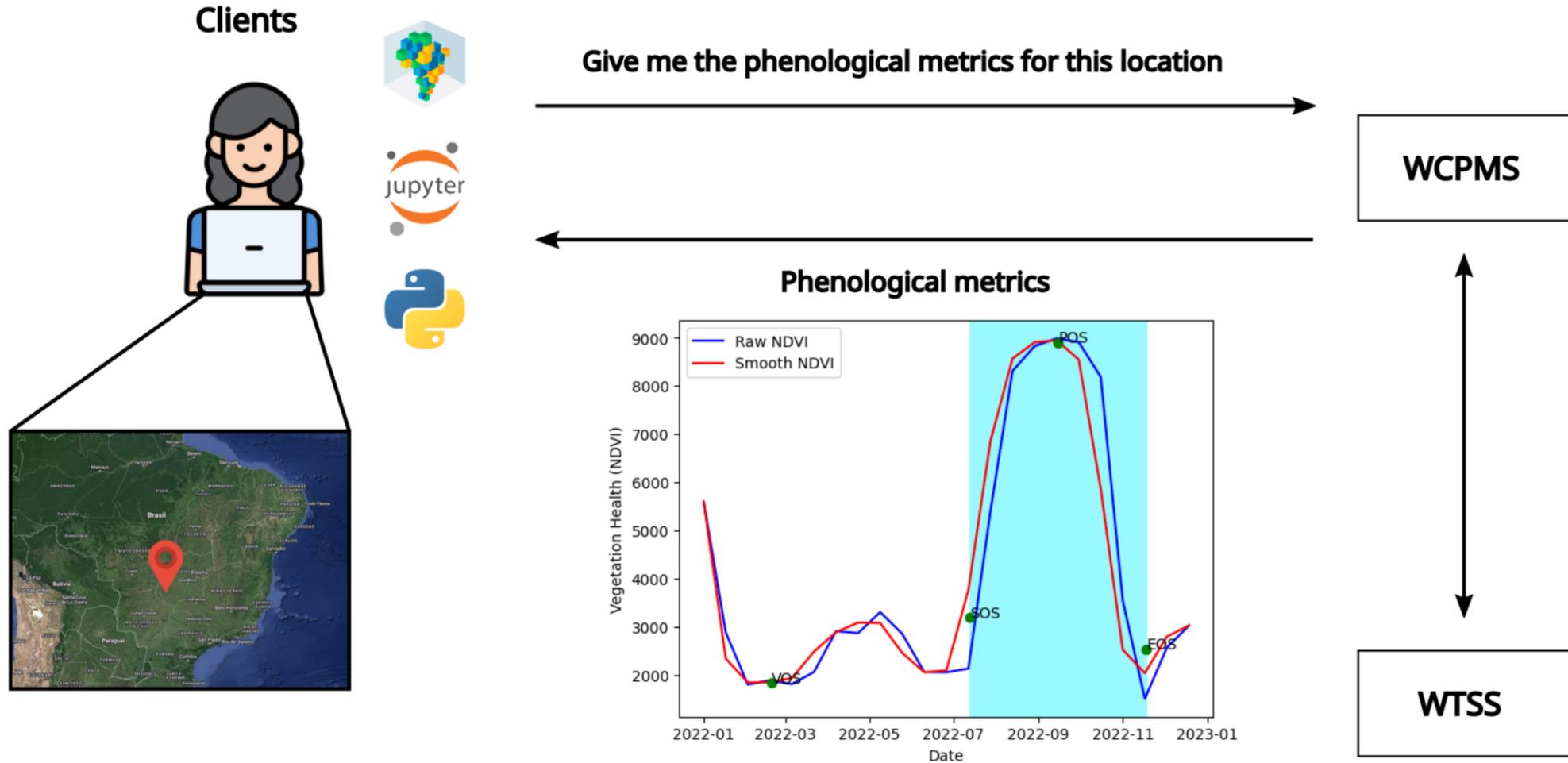




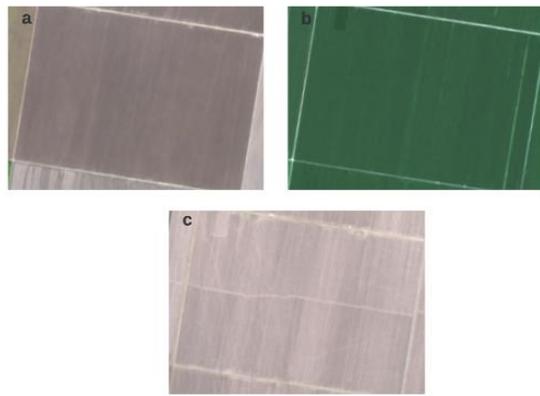
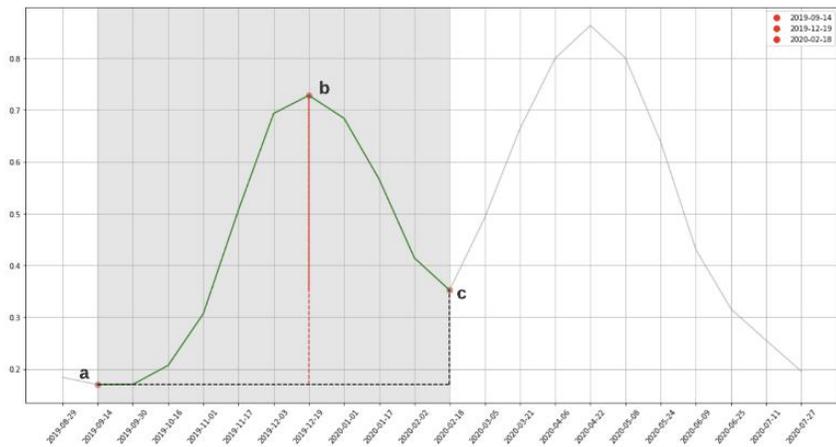
## WLTS – Web Land Trajectory Service



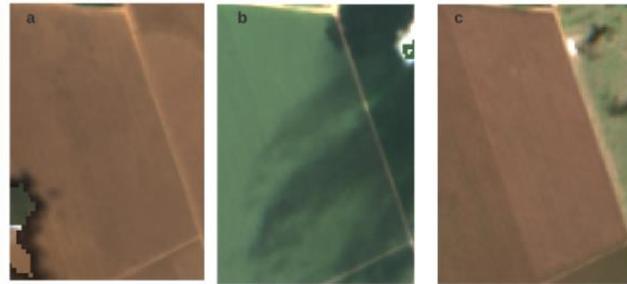
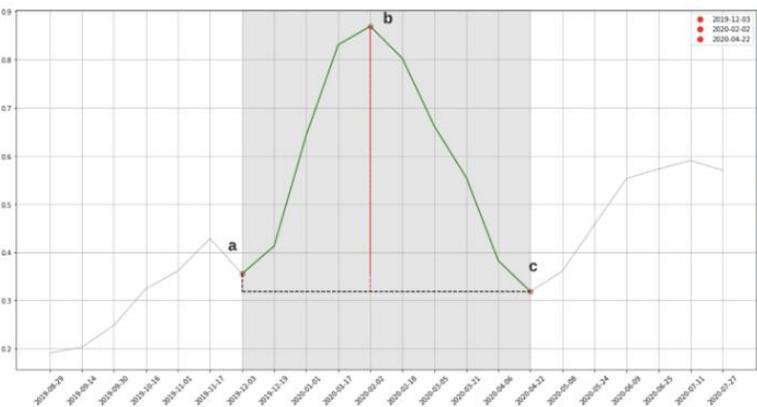
# Web Crop Phenology Metrics Service (WCPMS)



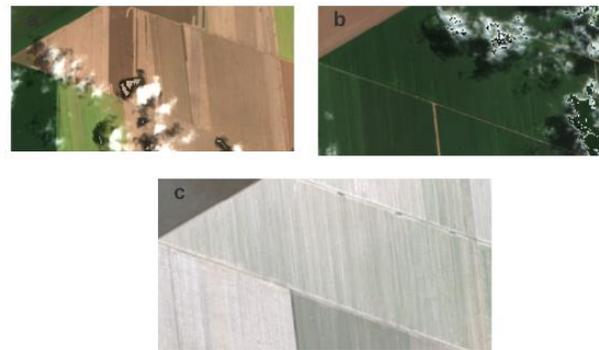
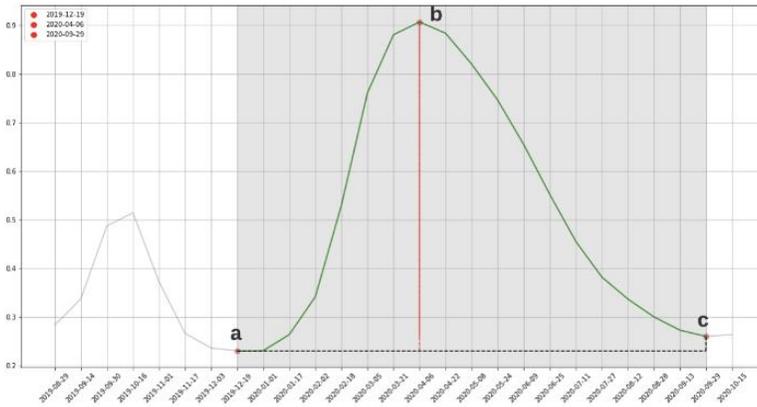
(a)



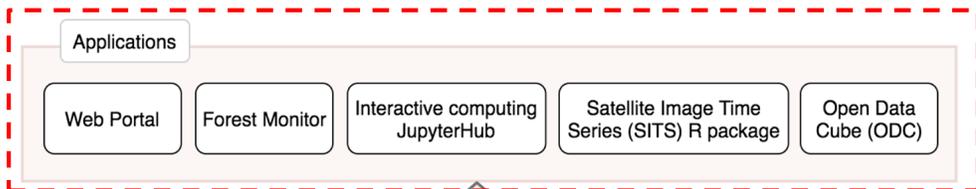
(b)



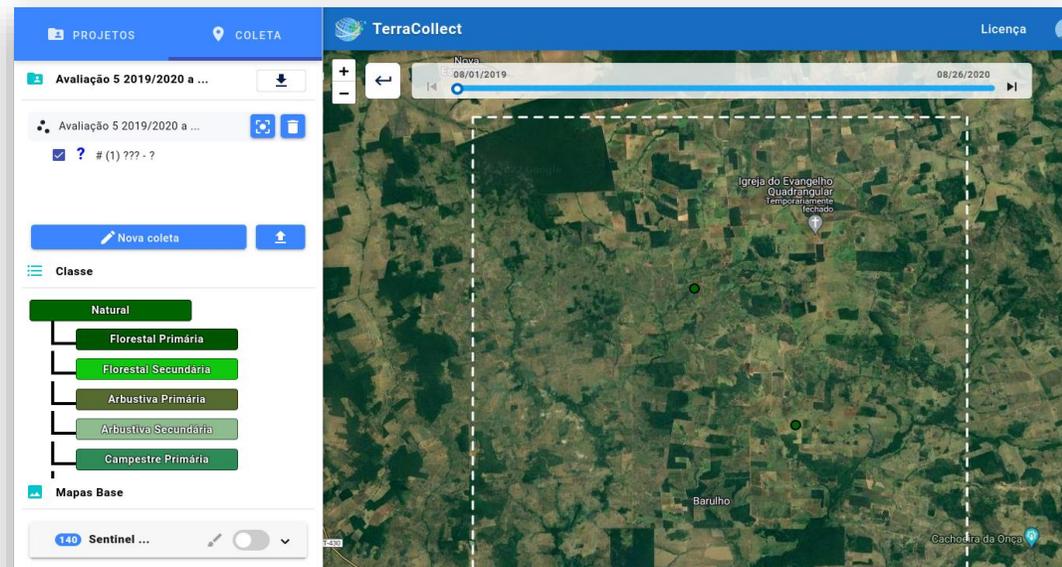
(c)



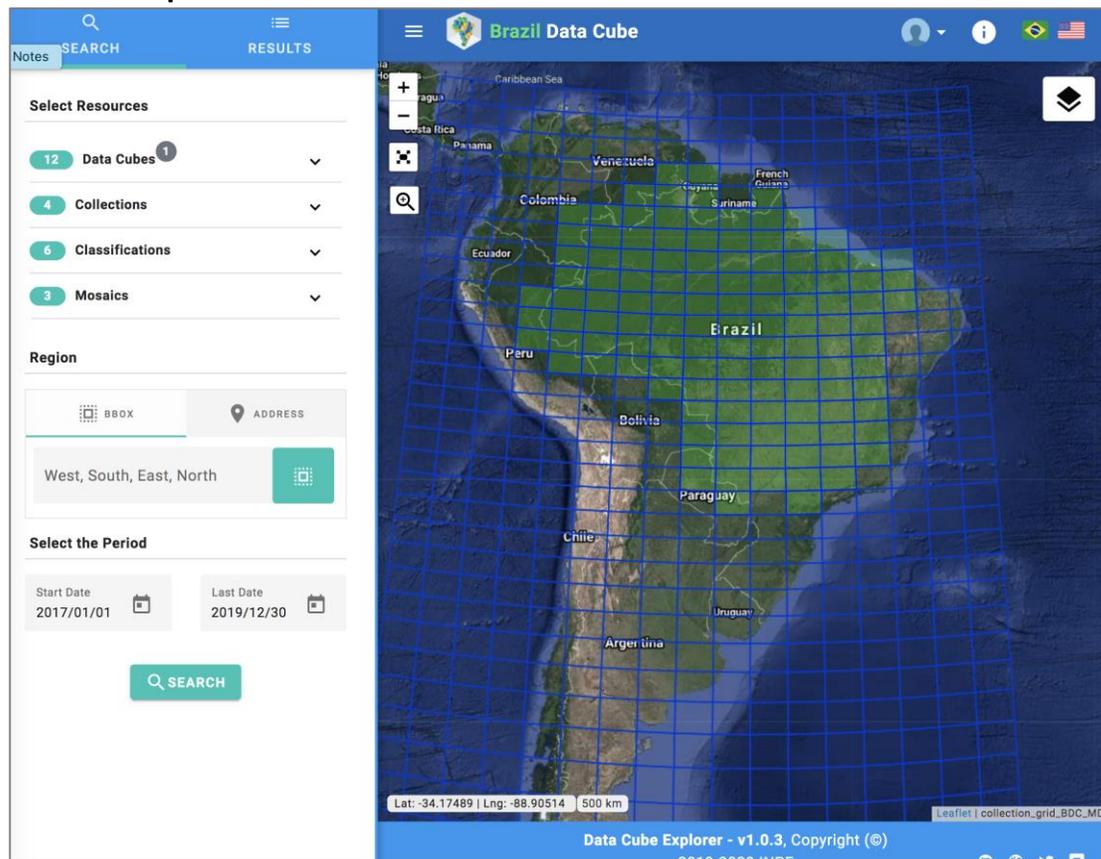
Métricas fenológicas de *início, fim e máximo vigor* vegetativo de plantio extraídas para soja (a), milho de primeira safra (b) e algodão (c) utilizando series temporais NDVI dos cubos Sentinel-2 (16 dias) do BDC.



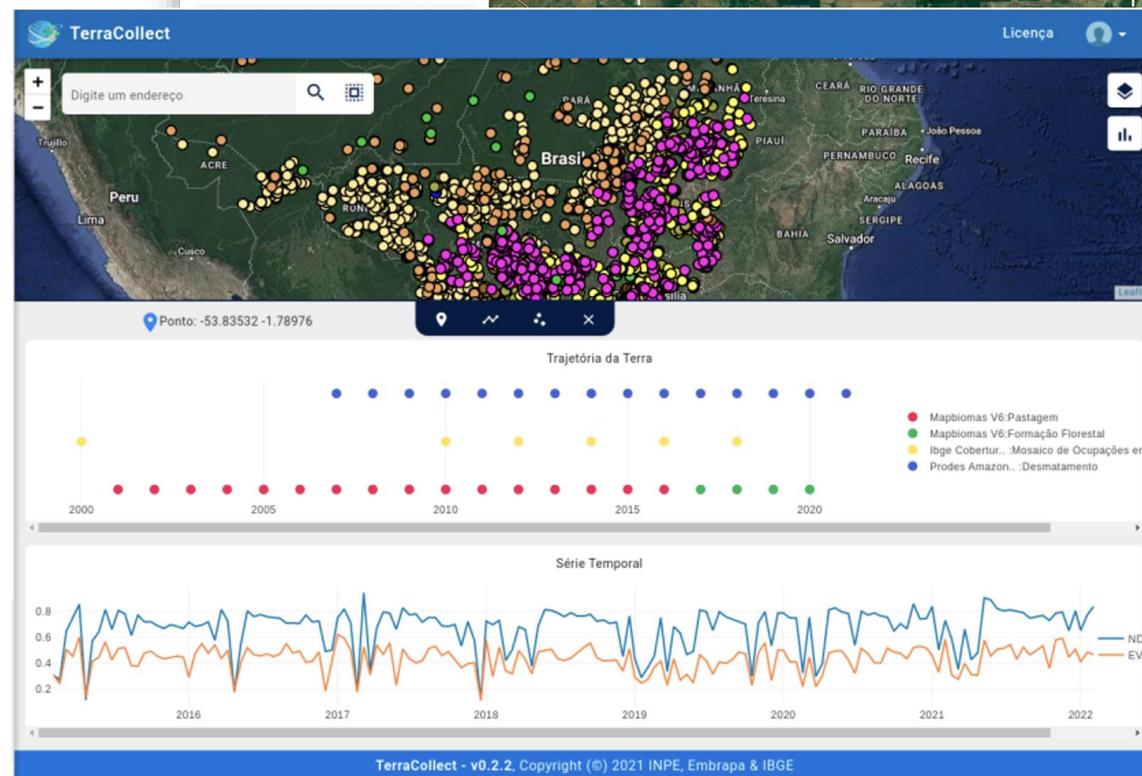
# TerraCollect



## BDC Explorer



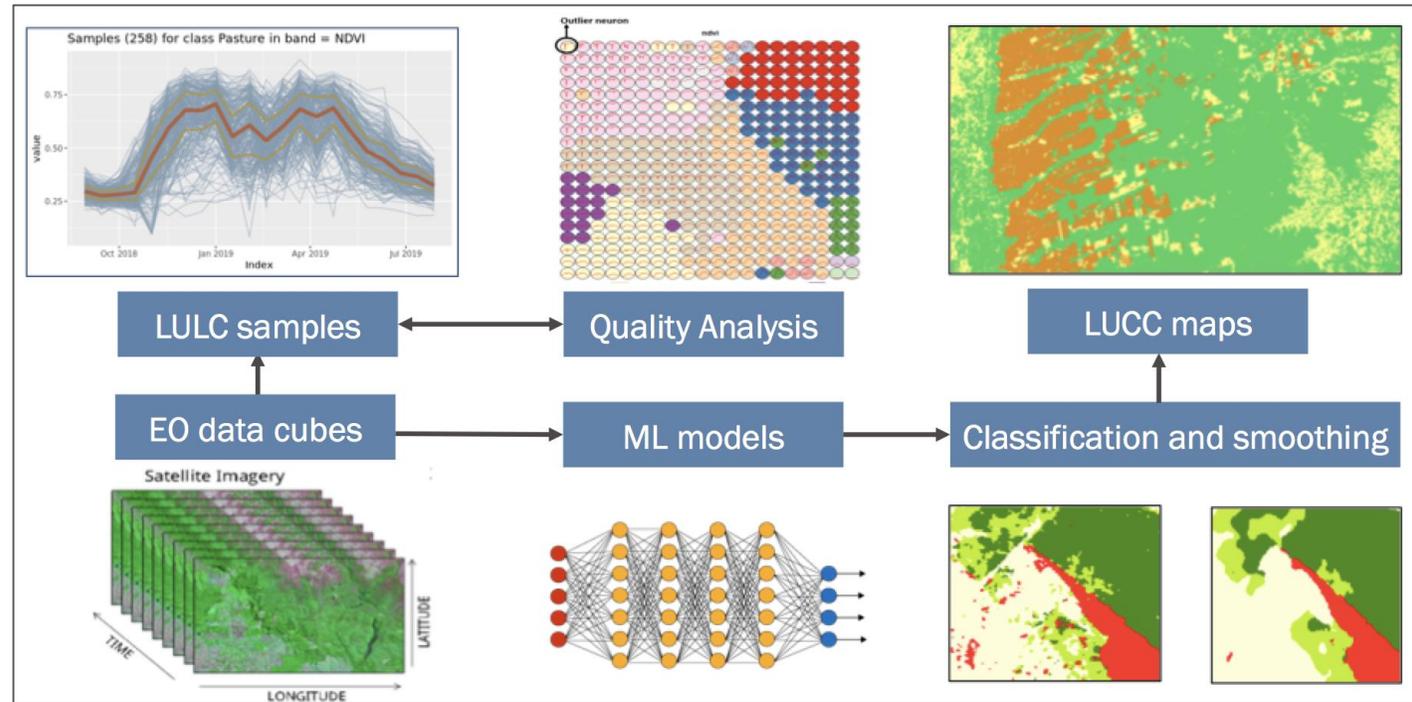
<http://brazildatacube.dpi.inpe.br/portal/explore>



# WTSS e WLTS – Interface gráfica – BDC Explorer e TerraCollect



# SITS (Satellite Image Time Series) R package



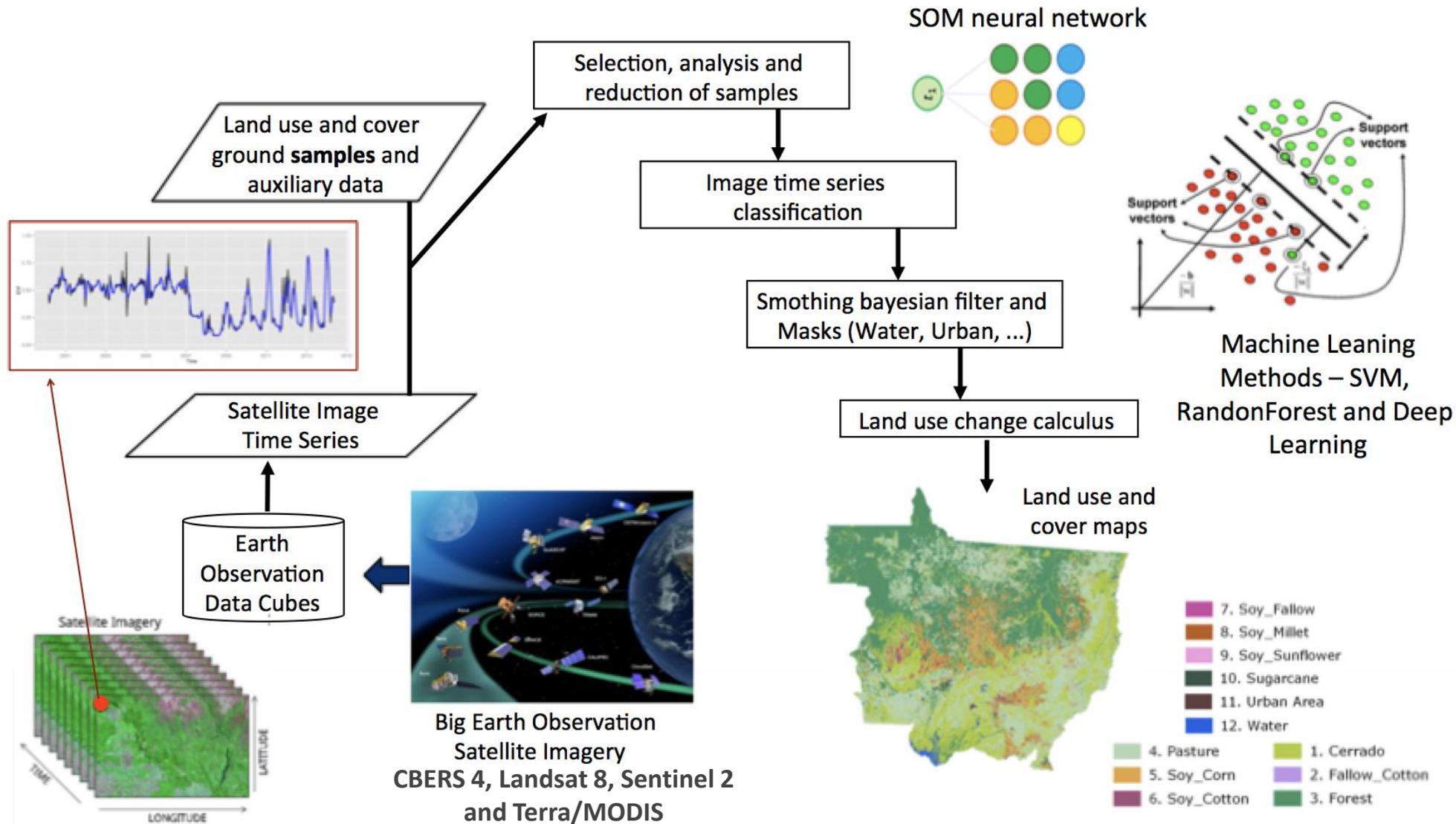
```
cube <- sits_cube(source = "BDC",  
  collection = "S2_10_16D",  
  name = "s2_cube",  
  bands = c("NDVI", "EVI"),  
  tiles = "022024", start_date = "2018-09-01", end_date = "2019-08-28")
```

```
samples <- readRDS(url("https://bdc.dpi.inpe.br/rds/S2_10_16D.rds"))
```

```
mlp_model <- sits_deeplearning(layers = c(512, 512, 512, 512, 512), activation = "relu")
```

```
dl_model <- sits_train(samples, mlp_model)
```

```
result <- sits_classify(data = cube, ml_model = dl_model, output_dir = tempdir())
```



ARD and Data cubes available at:  
<http://brazildatacube.dpi.inpe.br/portal/explore>

Land use and cover change maps:  
<http://brazildatacube.dpi.inpe.br/portal/explore>



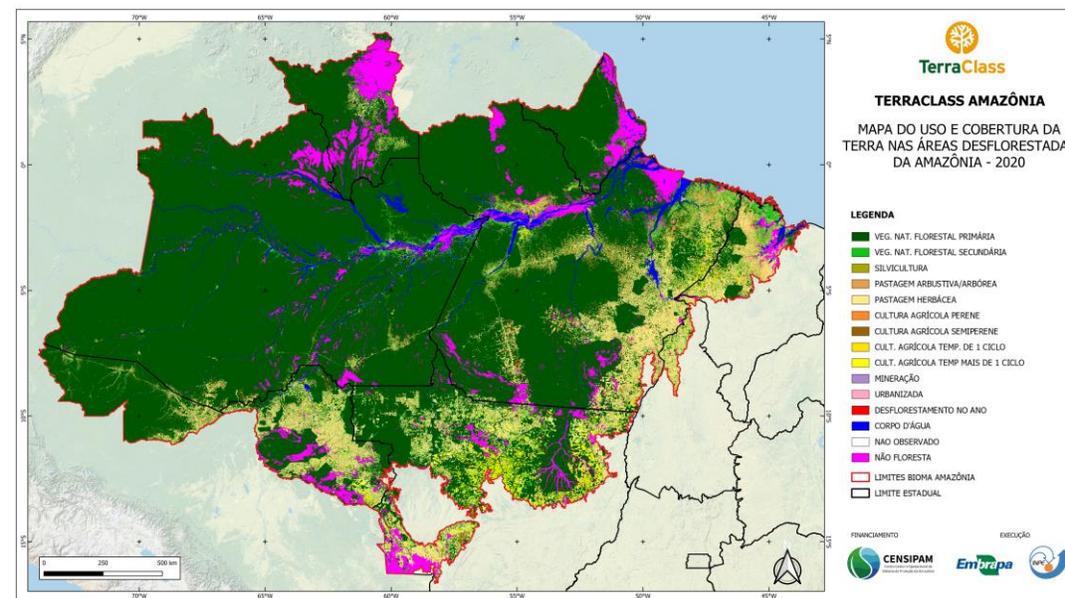
BRAZIL  
DATA CUBE

# Land use and land cover maps: TerraClass project

TerraClass Cerrado 2020 (Launched in December 2022)



TerraClass Amazônia 2020





BRAZIL  
DATA CUBE

# BDC-Lab: Geospatial Data Science Computational Environment

Server-side processing in the INPE's infrastructure, without needing to download images in personal computers.

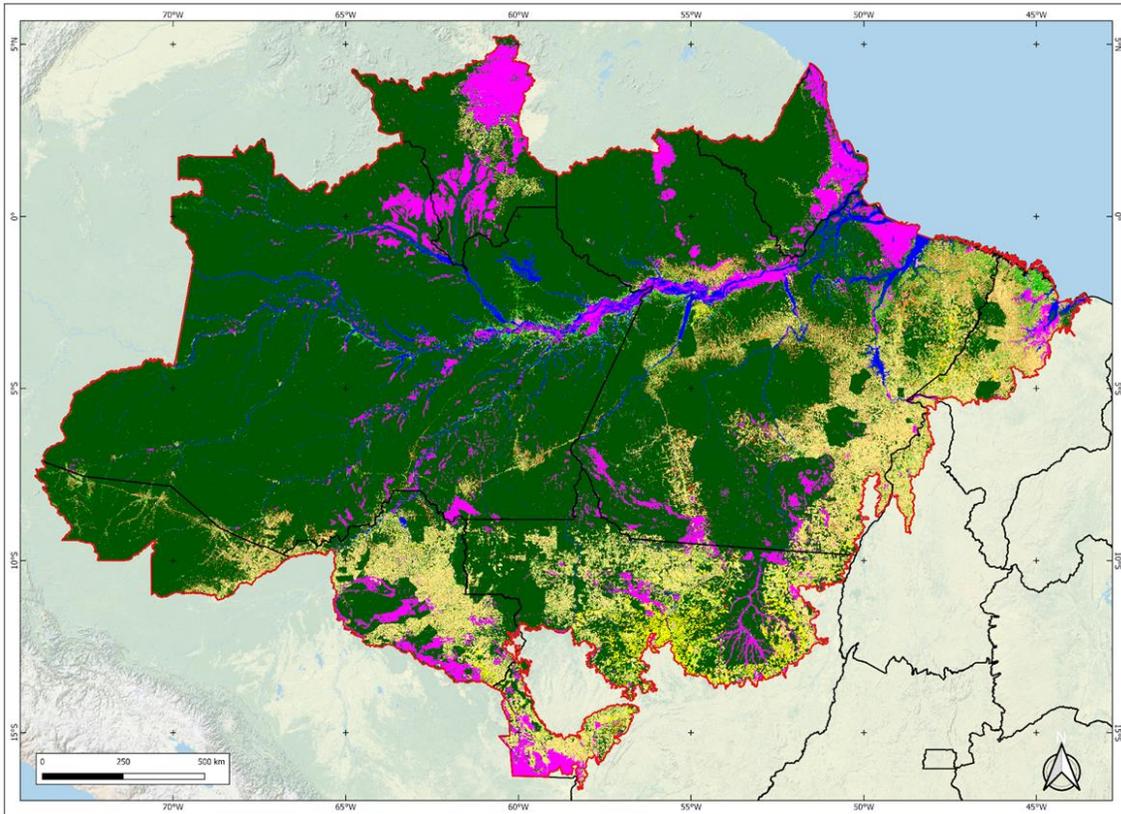
## BDCLab - Geospatial Data Science Computational Environment

```

wttss-introduction Draft saved
File Edit View Run Add-ons Help
+ - X Copy Paste Run All Markdown -
Draft Session (1st)
Retrieving the Time Series
In order to retrieve the time series for attributes red and nir, in the location of latitude -12 and longitude -54 from January 1st, 2001 to December 31st, 2001, use the time_series function:
138:
to <- Rttss::time_series(wttss_inpe,
  attributes = c("red_reflectance", "NIR_reflectance"),
  latitude = -12.0,
  longitude = -54.0,
  name = "M001301-0",
  start_date = "2001-01-01",
  end_date = "2001-12-31")

```





**TerraClass**

**TERRACLASS AMAZÔNIA**

MAPA DO USO E COBERTURA DA TERRA NAS ÁREAS DESFLORESTADAS DA AMAZÔNIA - 2020

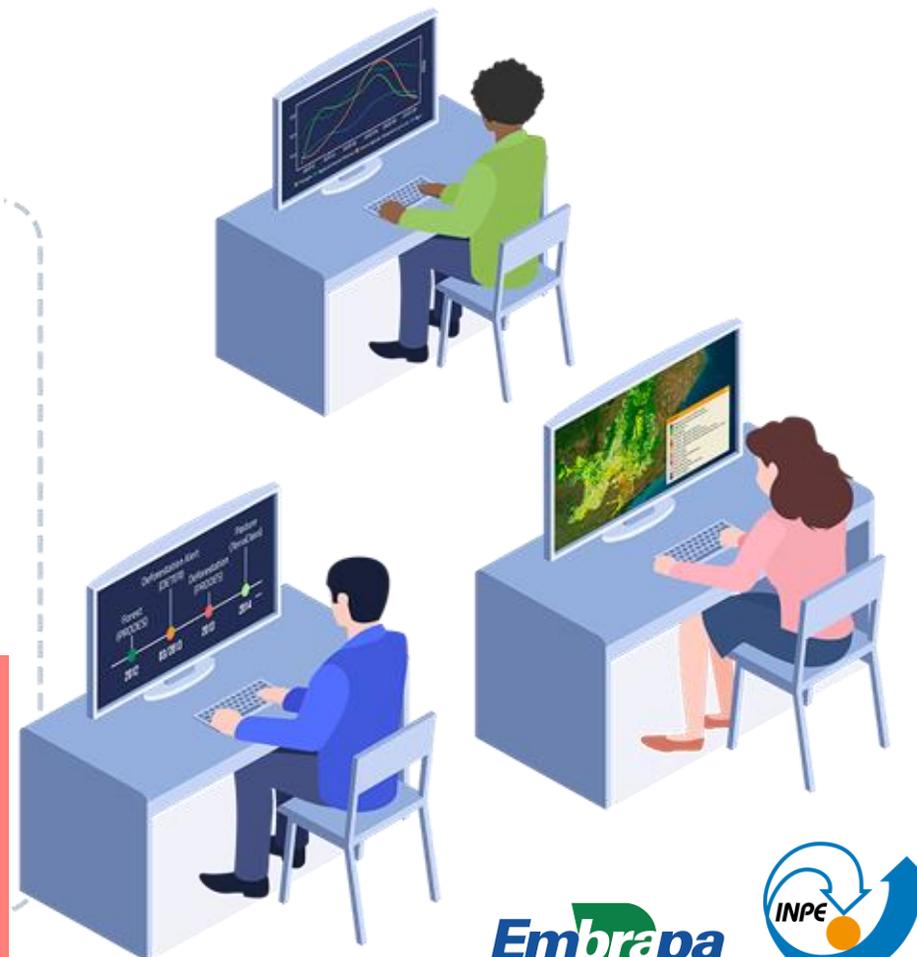
**LEGENDA**

- VEG. NAT. FLORESTAL PRIMÁRIA
- VEG. NAT. FLORESTAL SECUNDÁRIA
- SILVICULTURA
- PASTAGEM ARBUSTIVA/ARBÓREA
- PASTAGEM HERBÁCEA
- CULTURA AGRÍCOLA PERENE
- CULTURA AGRÍCOLA SEMIPERENE
- CULT. AGRÍCOLA TEMP. DE 1 CICLO
- CULT. AGRÍCOLA TEMP. MAIS DE 1 CICLO
- MINERAÇÃO
- URBANIZADA
- DESFLORESTAMENTO NO ANO
- CORPO D'ÁGUA
- NÃO OBSERVADO
- NÃO FLORESTA
- LIMITES BIOMA AMAZÔNIA
- LIMITE ESTADUAL

FINANCIAMENTO:

EXECUÇÃO:

Server-side processing in the INPE's infrastructure, without needing to download images in personal computers.



**33 Terabytes (292 tiles)**  
**Sentinel-2 data cubes (16-days)**  
**25,000 samples**  
**Random Forest / tempCNN**





# Ambiente de Computação Interativa: JupyterHub

**Land use and land cover classification in the Brazilian Cerrado biome using Brazil Data Cube**

Rolf E. O. Simões, Alber H. Sanchez, Felipe M. Carlos, Leonardo S. Vieira, Karine R. Ferreira, Lúbia Vinhas, Gilberto R. Queiroz

Earth Observation and Geoinformatics Division  
Avenida dos Astronautas, 1758, Jardim da Graciosa, São José do Rio Preto, SP, Brazil

Author to whom correspondence should be addressed

February 2021

**Abstract.** This Jupyter Notebook compendium contains useful information about Earth observations data cubes and machine learning (ML) techniques for the Earth Observation Data Cubes for Brazil: Requirements, Methodology and the Brazil Data Cube platform.

This Jupyter Notebook is supplement to the Section 5 of the following paper: Simões, R.E.O.; Queiroz, G.R.; Vinhas, L.; Marujo, R.F.B.; Simoes, R.E.O.; P. A.H.; Arcanjo, J.S.; Fronza, J.G.; Noronha, C.A.; Costa, R.W.; Zaglia, M.C. Earth Observation Data Cubes for Brazil: Requirements, Methodology and the Brazil Data Cube platform. *Remote Sensing* 2021, 13, 1000. <https://doi.org/10.3390/rs13051000>

### Table of Contents

The Jupyter Notebooks are organized as follows:

- Extracting time series from sample locations
- Land Use and Cover Mapping from CBERS-4/AWFI Data Cubes

### Time Series Extraction

CBERS-4/AWFI (16 days 'stack')

The `sits_cube` function can be used to define the working data cube and the interest spectral bands and vegetation indices:

```
[7]: cb4_cube <- sits_cube(  
  type = "BDC",  
  url = "http://datacube-006.dpi.inpe.br:8010/stac/",  
  collection = "CB4_64_16D_STK-1",  
  start_date = start_date,  
  end_date = end_date,  
  bands = c("BAND15", "BAND14", "BAND13", "BAND16", "NDVI", "EVI")  
)
```

In the above cell we provided the following parameters:

- `type`: Inform that the data is from the Brazil Data Cube.
- `url`: The SpatioTemporal Datacube API endpoint: `http://006.dpi.inpe.br:8010/stac/`
- `collection`: Define the collection name.
- `start_date` and `end_date`: Define the time range.

Samples (258) for class Pasture in band = NDVI

Samples (422) for class Natural in band = NDVI

```
[9]: probs <- sits_classify(data = cube,  
  ml_model = dl_model,  
  memsize = classification_memsize,  
  multicores = classification_multicores,  
  roi = roiclassification_roi,  
  output_dir = output_dir)
```

Using 2 blocks of size 888 x 2725  
Starting classification at 2021-03-26 14:54:15  
Elapsed time 19.5 minute(s).  
Estimated total process time 39 minute(s)...  
Classification finished at 2021-03-26 15:33:30. Total elapsed time: 39.2minute(s).

### Generate classification label map

```
[10]: probs_smoothed <- sits_smooth(probs, type = "bayes", output_dir = output_dir)  
labels <- sits_label_classification(probs_smoothed, output_dir = output_dir)
```

### Visualizing classification map



# Ambiente de Computação Interativa: RStudio

The screenshot shows the RStudio Server interface. The main window displays a notebook with R code and R Markdown text. The code includes parameter definitions, sample loading, and a note about saving results. The file explorer on the right shows a directory structure with files like .Rhistory, 00\_TableOfContents-copy.Rmd, and 02\_CB4\_64\_16D\_STK-1\_Classification... The console at the bottom shows the prompt > |.

```
66 **Parameters**
67
68 If you want to download and run this notebook in a workflow as a script, you can perform its
69 parameterization through the [papermill library](https://github.com/interact/papermill). The access to
70 the Brazil Data Cube (BDC) data products requires an access key. To request your access key, please,
71 contact the BDC team at brazildatacube@inpe.br. Define the 'BDC_ACCESS_KEY' env variable to access to
72 use the BDC Services.
73
74
75 ***{r}***
76 classification_memsize <- 20 # in GB
77 classification_multicores <- 20
78
79 start_date <- "2018-09-01"
80 end_date <- "2019-08-31"
81
82 **Samples and ROI definition**
83
84 ***{r}***
85 # fixed parameters
86 collection <- "CB4_64_16D_STK-1"
87
88 # define the roi and load samples file
89 roi <- readRDS("/data/Examples/bdc-article/roi/roi.rds")
90 samples <- readRDS("/data/Examples/bdc-article/training-samples/rds/CB4_64_16D_STK-1.rds")
91
92 > All the results generated in this document will be saved in your user's `~/home` directory, inside
93 `out` directory
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```

The screenshot shows a browser window with the URL brazildatacube.dpi.inpe.br. The page title is "Time Series Extraction" and the subtitle is "CBERS-4/AWFI (16 days 'stack')". The text explains that the `sits_cube` function can be used to define the working data cube and the interest spectral bands and vegetation indices.

```
cb4_cube <- sits_cube(
  type = "BDC",
  url = "http://datacube-006.dpi.inpe.br",
  collection = "CB4_64_16D_STK-1",
  start_date = start_date,
  end_date = end_date,
  bands = c("BAND15", "BAND14", "BAND13")
)
```

- In the above cell we provided the following arguments
- `type`: Inform that the data cube will be based on the BDC
  - `url`: The SpatioTemporal Asset Catalog address for BDC: `006.dpi.inpe.br:8010/stac/`
  - `collection`: Defines the use of CBERS-4/AWFI data
  - `start_date` and `end_date`: The temporal interval of interest
  - `bands`: The list of spectral bands and spectral indices

The `sits_get_data` retrieves the time series from the defined cube

```
cb4_samples_with_ts <- sits_get_data(cube = cb4_cube, file = sample_file)
```

## All points have been retrieved

The screenshot shows a browser window with the URL brazildatacube.dpi.inpe.br. The page title is "Time Series Extraction" and the subtitle is "CBERS-4/AWFI (16 days 'stack')". The text explains that the `sits_cube` function can be used to define the working data cube and the interest spectral bands and vegetation indices.

```
cb4_samples_with_ts <- sits_get_data(cube = cb4_cube, file = sample_file)
```

## All points have been retrieved

The structure of the returned dataframe can be seen below:

```
head(cb4_samples_with_ts, 2)
```

```
## # A tibble: 2 x 7
##   longitude latitude start_date end_date label cube time series
##   <dbl> <dbl> <date> <date> <chr> <chr> <list>
## 1 -46.2 -12.4 2018-09-01 2019-08-01 Crop bdc_cube <tibble [22 x 7]>
## 2 -45.7 -12.5 2018-09-01 2019-08-01 Crop bdc_cube <tibble [22 x 7]>
```

If you want to plot the NDVI time series for all the LULC classes, use the following plot function:

```
plot(sits_select(cb4_samples_with_ts, bands = c("NDVI")))
```

Samples (242) for class Crop in band = NDVI

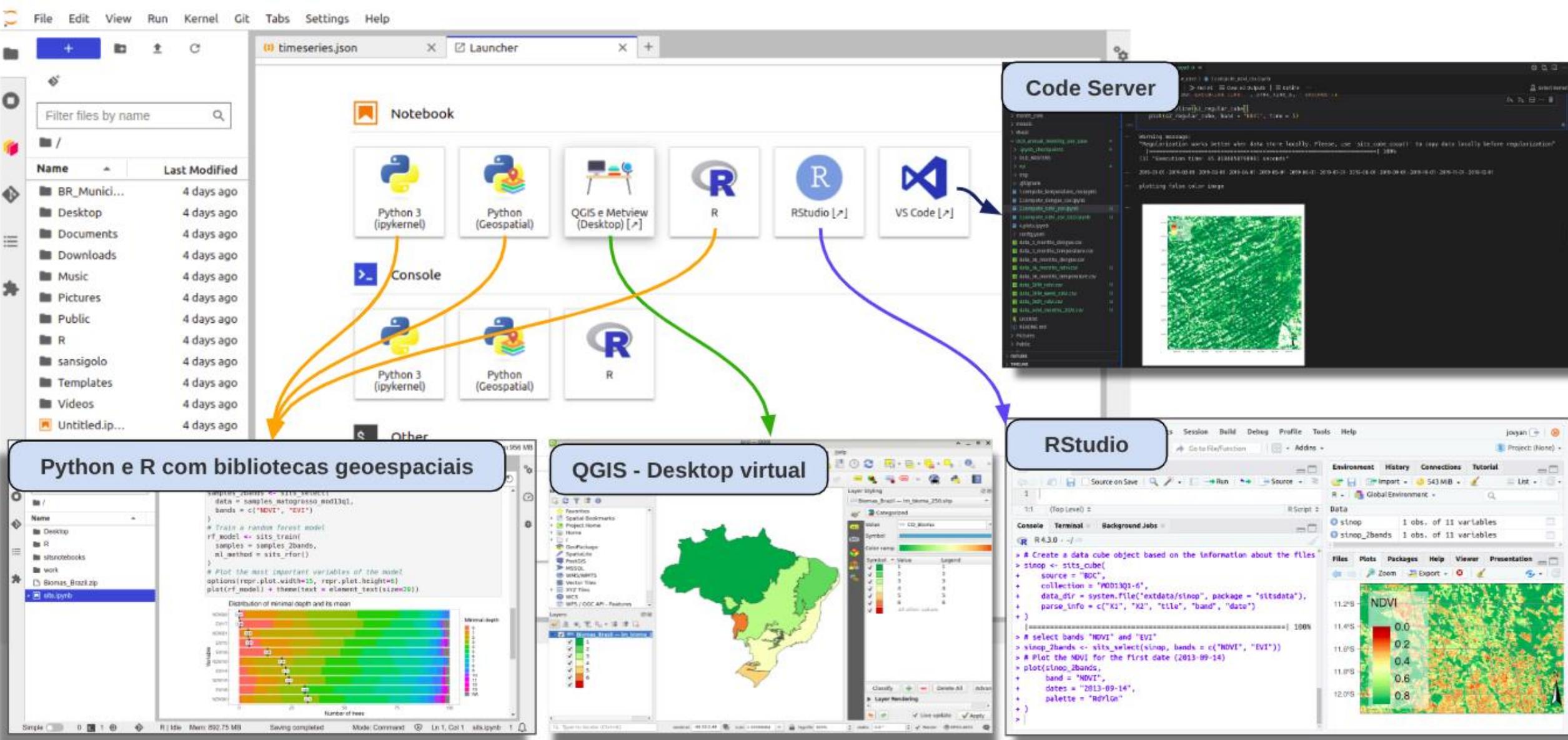
The screenshot shows a browser window with the URL brazildatacube.dpi.inpe.br. The page title is "Visualizing classification map" and the subtitle is "The raster load in this step was generated automatically with `sits_label_classification` function".

```
rst <- raster::raster(
  paste0(output_dir, "/cube_to_classify_022024_probs_class_2018_8_2019_v1.tif")
)
```

## Warning in showSRID(uprojargs, format = "PROJ", multiline = "NO", prefer\_proj = FALSE): Discarded datum Unknown based on GRS80 ellipsoid in CRS definition

```
plot(rst)
```

# BDC-Lab 1.3.1 (Maio/2025)



The main interface shows a notebook titled "timeseries.json" with a "Launcher" tab. The launcher displays several environment options:

- Python 3 (ipykernel)
- Python (Geospatial)
- QGIS e Metview (Desktop) [↗]
- R
- RStudio [↗]
- VS Code [↗]

Arrows indicate that the Python, QGIS, and RStudio options lead to their respective detailed views:

- Python e R com bibliotecas goespaciais:** Shows a Jupyter Notebook with R code for training a random forest model and plotting the results. The code includes: 

```
samples_2bands <- s1ts_select( data = samples_matogrosso_res13q1, bands = c("NDVI", "EVI2")) # Train a random forest model rf_model <- s1ts_train( samples = samples_2bands, ml_method = s1ts_rfml ) # Plot the most important variables of the model options(repr.plot.width=15, repr.plot.height=5) plot(rf_model) + theme(text = element_text(size=20))
```

 The output shows a "Distribution of minimal depth and its mean" plot.
- QGIS - Desktop virtual:** Shows a virtual desktop environment with QGIS installed. A map of Brazil is displayed with a color-coded legend for "CD\_Biomass".
- RStudio:** Shows the RStudio interface with a script containing R code for creating a data cube object and plotting NDVI. The code includes: 

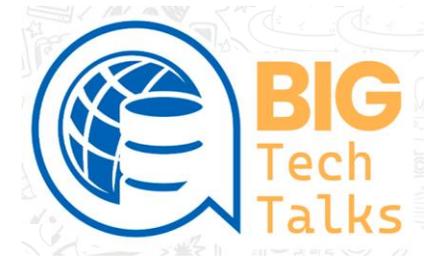
```
# Create a data cube object based on the information about the files s1nos <- s1ts_cube( source = "BDC", collection = "W0013Q1-6", data_dir = system.file("extdata/s1nos", package = "s1tsdata"), parse_info = c("K1", "K2", "title", "band", "date") ) # select bands "NDVI" and "EVI2" s1nos_2bands <- s1ts_select(s1nos, bands = c("NDVI", "EVI2")) # Plot the NDVI for the first date (2013-09-14) plot(s1nos_2bands, band = "NDVI", dates = "2013-09-14", palette = "RDYlgn")
```

 The output shows an NDVI map of Brazil with a color scale from 0.0 to 0.8.

## Operacional



## Acadêmica



# INPE Data Center

## Dell EMC HPC egeon



66 processadores e 200 Teraflops  
BeeGFS (Alta performance) 500 TB  
Dell ME484 (Alta densidade) 1 PB

## Cray XE6 and CRAY XC50



880 processadores e ~413 Teraflops  
XE6 Lustre (Alta performance) 860 TB  
XE6 StorNext (Alta densidade) 2.65 PB  
XC 50 Cray Sonextion (Alta performance) 986 TB

**Courtesy:** Ivan Márcio Barbosa

# INPE Data Center

255 Servers, Data Storage with tiers (SSD, SAS and tape library) 12PB online and 4PB tape LTO

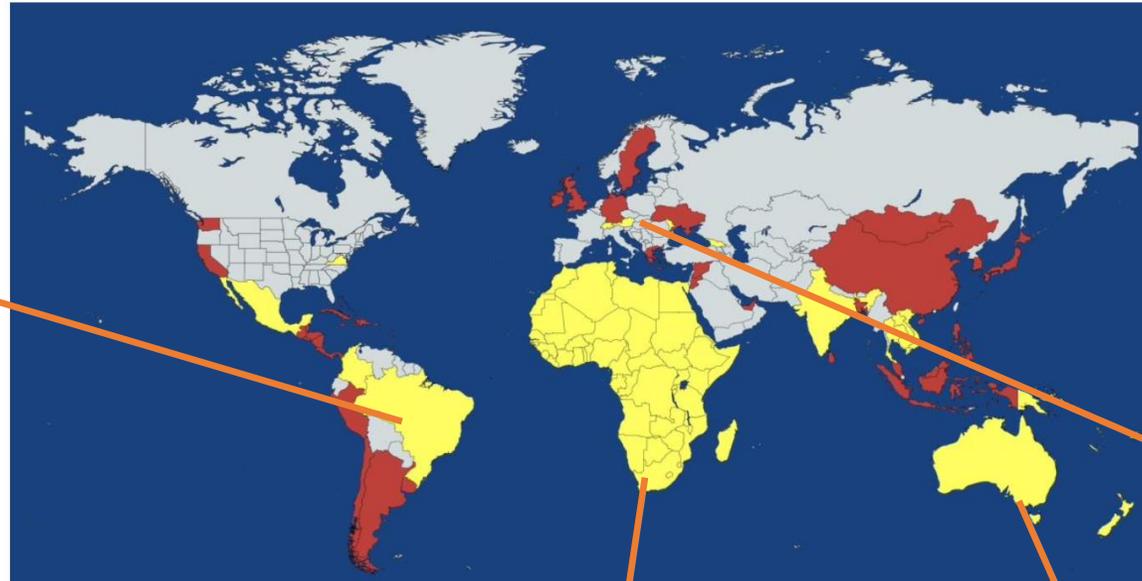


**Courtesy:** Ivan Márcio Barbosa

# Partnership with international and similar initiatives

Source: [Sudmanns et al, 2022]

Yellow: operational  
Red: under development



**BRAZIL  
DATA CUBE**

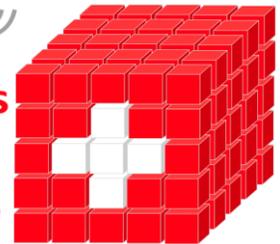
<http://brazildatacube.org>

 **data** 

Article  
**Paving the Way towards an Armenian Data Cube**



**Swiss  
Data  
Cube**



<https://www.swissdatacube.org/>

**Digital Earth Americas**

*A vision for a solution that provides relevant Earth observation data for the benefit of the Americas*



**Digital Earth  
AFRICA**

<https://digitalearthafrika.org/>



**Digital Earth  
AUSTRALIA**

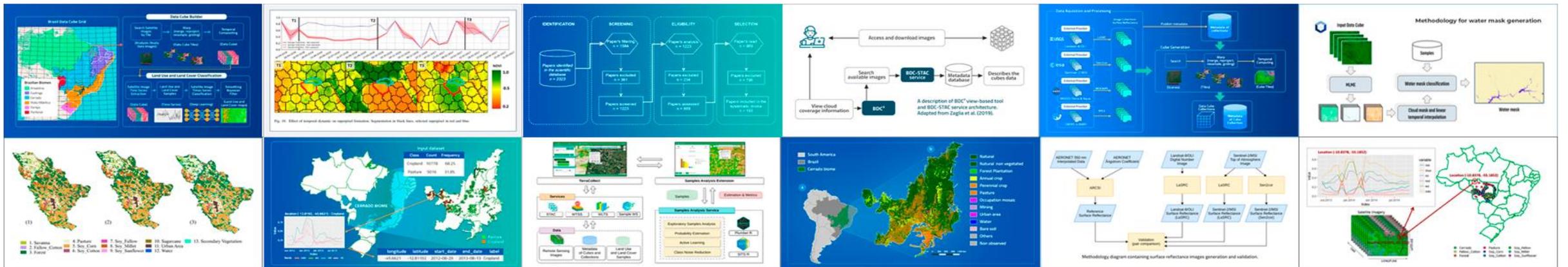
<https://www.dea.ga.gov.au/>



# + de 56 PUBLICAÇÕES desde 2019

22 – em revistas/periódicos

34 – congressos nacionais e internacionais

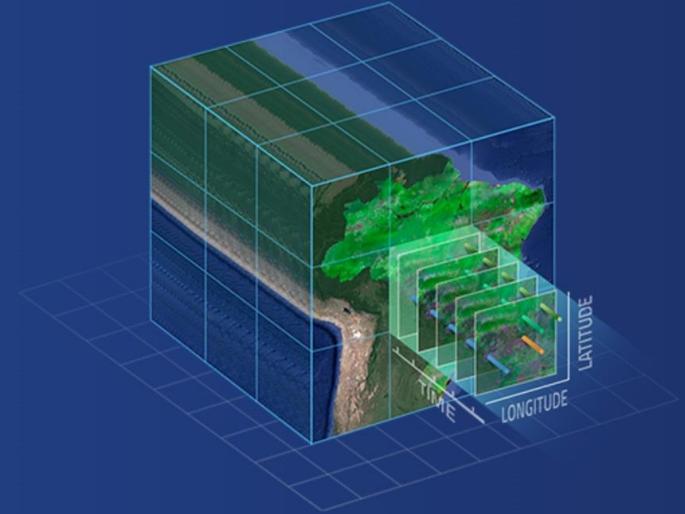


<http://brazildatacube.org>



# Brazil Data Cube

Production, visualization and analysis of large volumes of remote sensing images modeled as multidimensional data cubes for the entire Brazilian territory.



[Read More](#)

[BDC Explorer](#)



## Data Products

Acquisition, Processing, Generation and Quality



## Data Explorer

Access the data produced by the project



## Software Products

Software products developed in the project



## Publications

Papers, Presentations and Capacity Building



BRAZIL DATA CUBE

# Code Galery

<http://brazildatacube.org>

README.md

## Brazil Data Cube Code Gallery

license MIT lifecycle maintainers render notebooks chat 18 online

This repository contains a gallery of interesting Jupyter Notebooks, R Markdown and scripts based on Brazil Data Cube data and technologies.

### Jupyter Notebooks

### Data Access through SpatioTemporal Asset Catalog API (STAC)

- Introduction to the SpatioTemporal Asset Catalog. (Python, R)
- Image processing on images obtained through STAC.

### Web Time Series Service (WTSS)

- Introduction to the Web Time Series Service (WTSS). (Python, R).
- Web Time Series Service (WTSS) examples. (Python, R).

### Web Land Trajectory Service (WLTS)

- Introduction to the Web Land Trajectory Service (WLTS). (Python, R)
- Web Land Trajectory Service (WLTS) examples. (Python).

### Tile Map Service (BDC-Tiler)

- Introduction to the Tile Map Service (BDC-Tiler). (Python)

Packages  
No packages published

Contributors 7

Languages  
Jupyter Notebook 96.2% R 3.8%



-  **sbsr2023-wtss-examples**  
Updated 2d ago  
0 comments · No attached data sources
-  **sbsr2023-wtss-introduction**  
Updated 2d ago  
0 comments · No attached data sources
-  **sbsr2023-wtss2**  
Updated 12d ago  
0 comments · No attached data sources
-  **sbsr2023-sample-quality-control-using-som**  
Updated 12d ago  
0 comments · sits bundle
-  **sbsr2023-machine-learning-for-data-cubes**  
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-  **sbsr2023-image-classification-in-data-cubes**  
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## Brazil Data Cube

Earth Observation Data Cubes for Brazil at National Institute for S...  
São José dos Campos, State of São Paulo, Brazil  
Joined 2 years ago · last seen 2 days ago

Python

workshop-2021-03-wtss-introduction-python

```

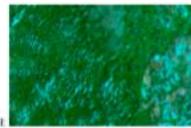
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                                     'datetime': '2018-07-01/2019-08-31', 'limit': '2'})
item

```

Matched: 12 Returned: 2 Limit: 2

S2-SEN2COR\_10\_160\_STK\_v001\_077095\_2018-12-19\_2018-12-31

Collection: S2-SEN2COR\_10\_160\_STK-1  
Datetime: 2018-12-19T00:00:00  
STAC Version: 0.9.0



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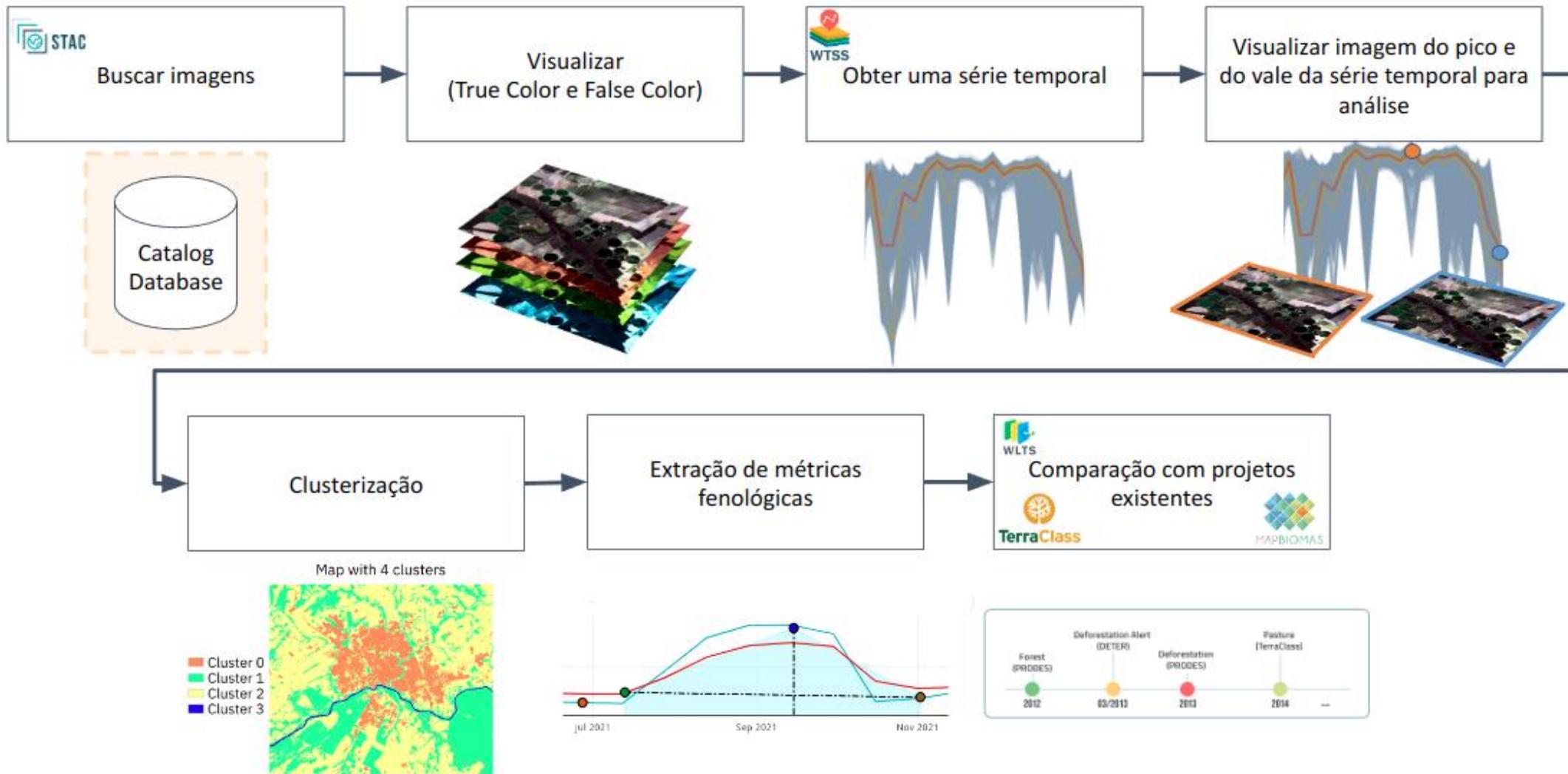
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BRAZIL  
DATA CUBE

# Code Galery

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[brazildatacube.dpi.inpe.br/portal/explore](http://brazildatacube.dpi.inpe.br/portal/explore)

**Karine R. Ferreira**

[karine.ferreira@inpe.br](mailto:karine.ferreira@inpe.br)

**OBRIGADA!**

**@brazildatacube**



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**INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS**

MINISTÉRIO DA  
**CIÊNCIA, TECNOLOGIA  
E INOVAÇÕES**



# Satellite Image Time Series (SITS) Analysis

Classification of  
SITS

Clustering of SITS

Disturbance/Change  
Detection from SITS

Vegetation  
Phenological Metrics  
Extraction from SITS

# Satellite Image Time Series (SITS) Analysis

Classification of  
SITS

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Detection from SITS

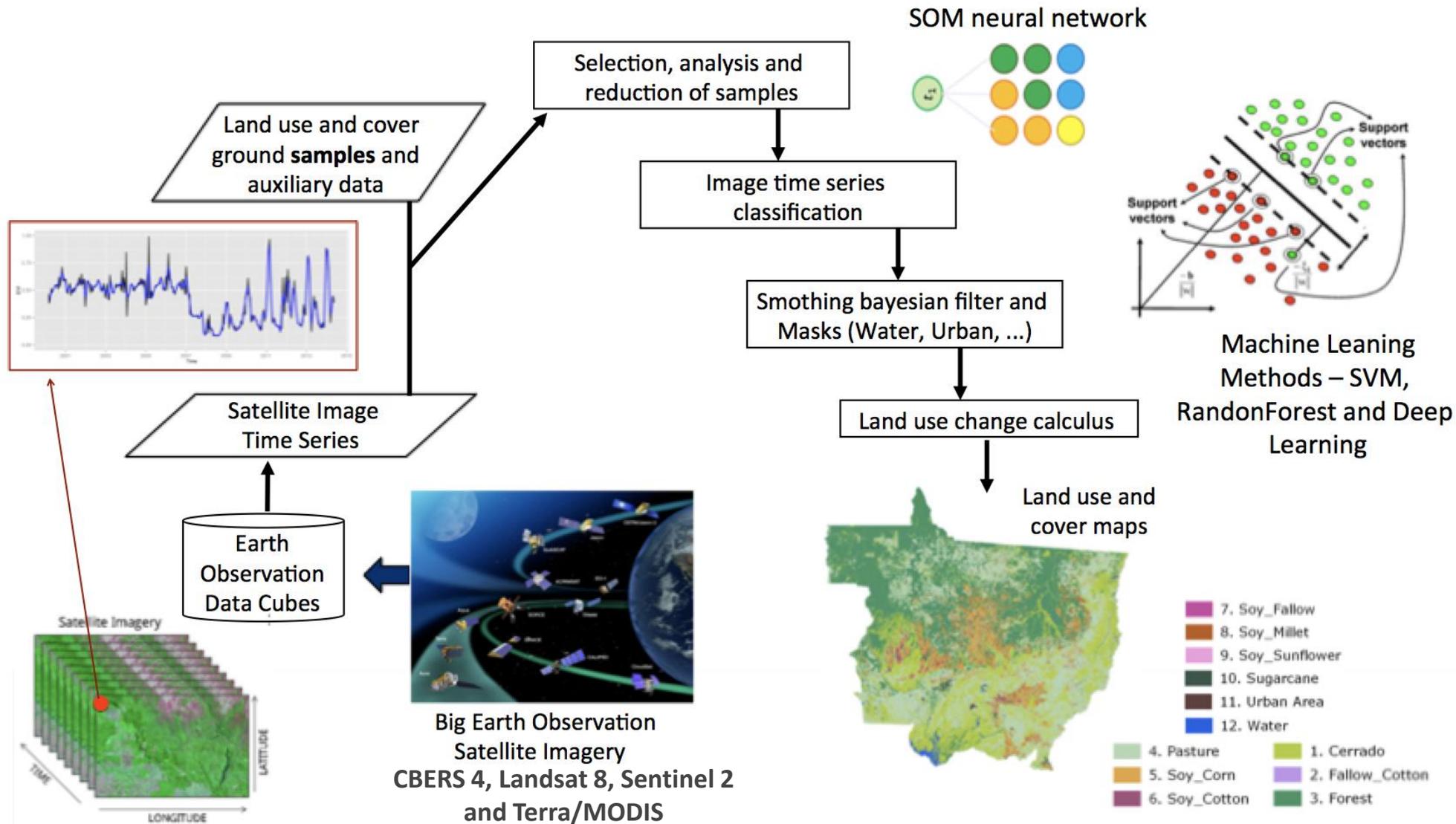
Vegetation  
Phenological Metrics  
Extraction from SITS

Machine and  
Deep Learning  
methods:

RandomForest

TempCNN

...



ARD and Data cubes available at:

<http://brazildatacube.dpi.inpe.br/portal/explore>

Land use and cover change maps:

<http://brazildatacube.dpi.inpe.br/portal/explore>

# Satellite Image Time Series (SITS) Analysis

Classification of  
SITS

Clustering of SITS

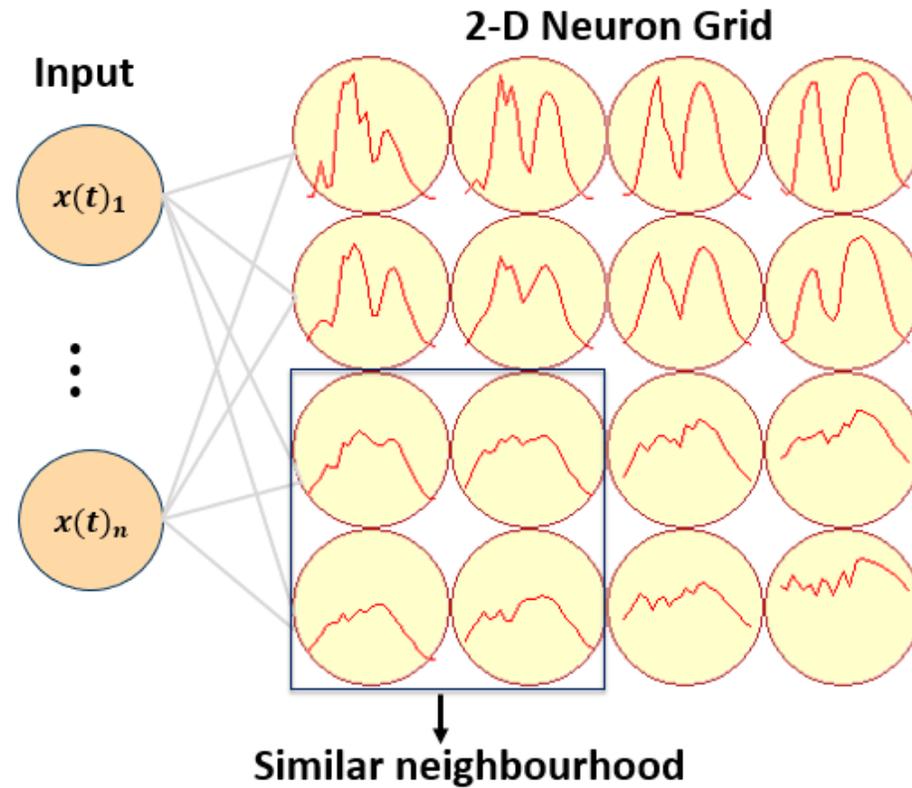
Disturbance/Change  
Detection from SITS

Vegetation  
Phenological Metrics  
Extraction from SITS

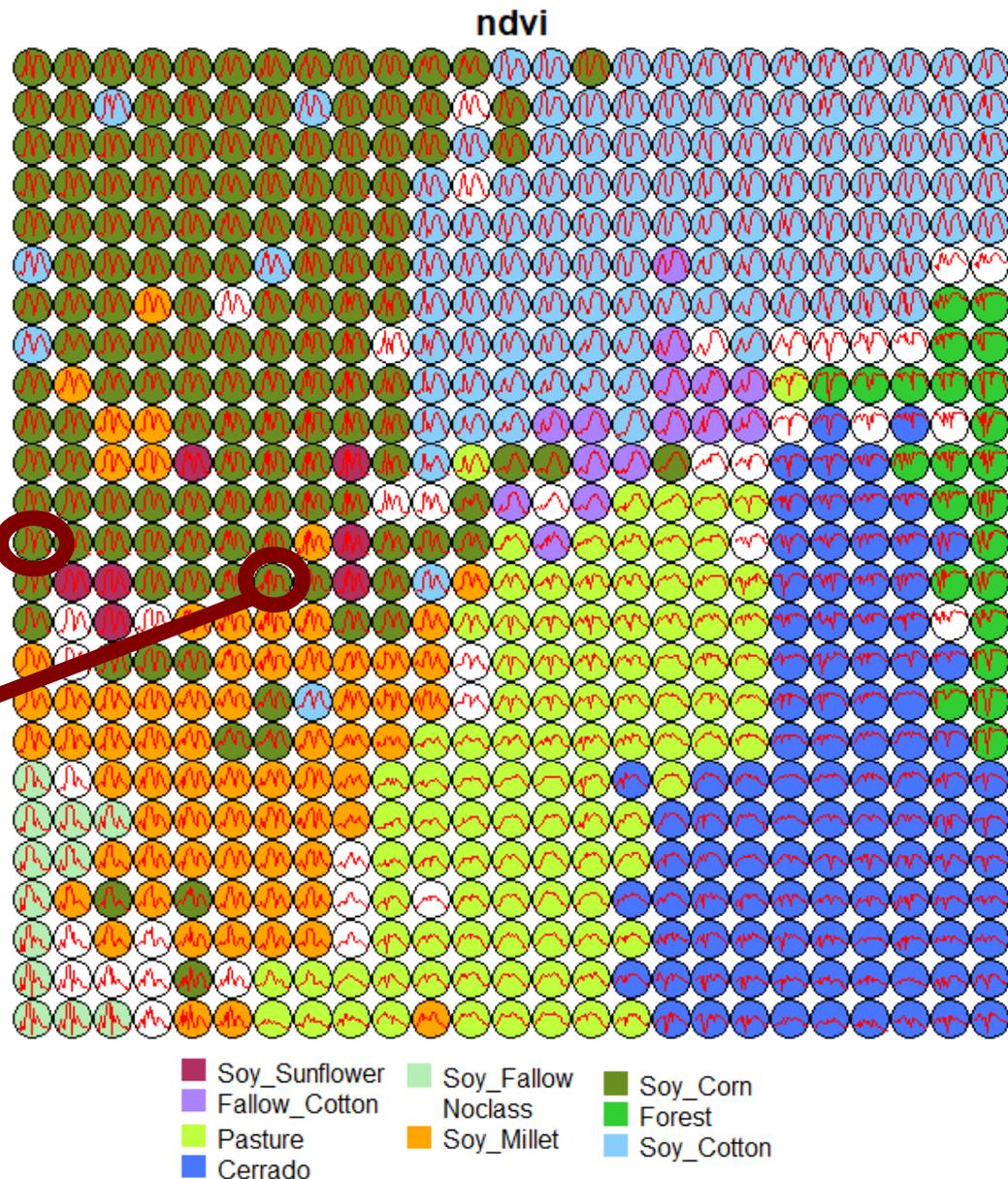
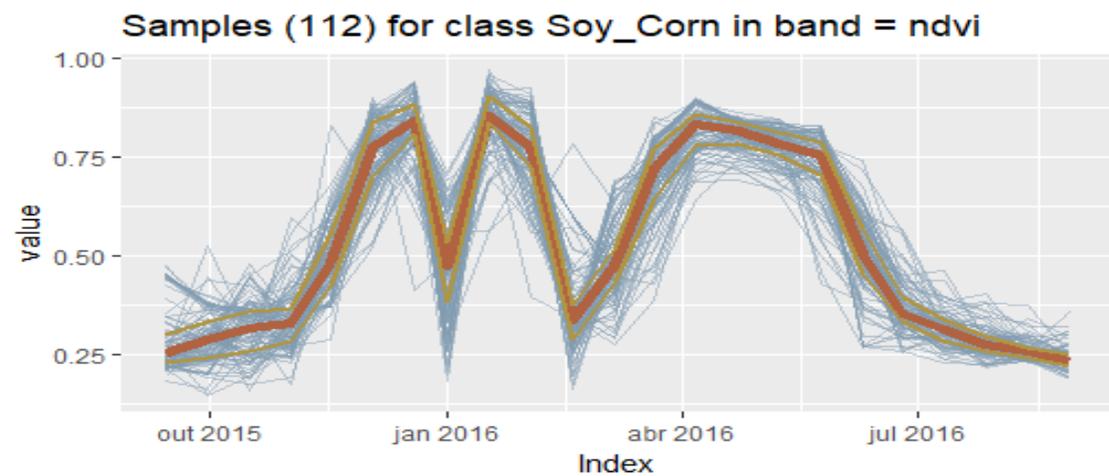
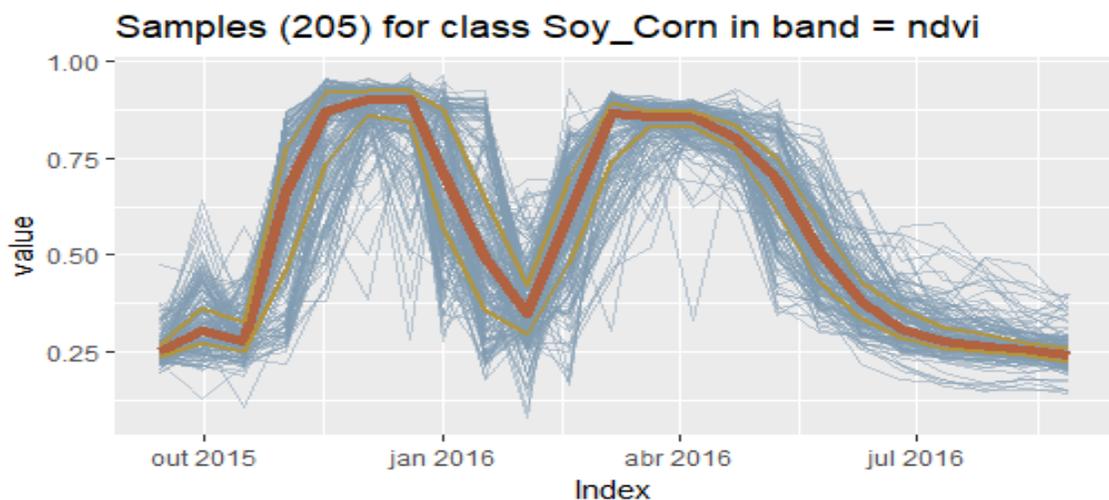
SOM (Self-  
Organizing Maps)

...

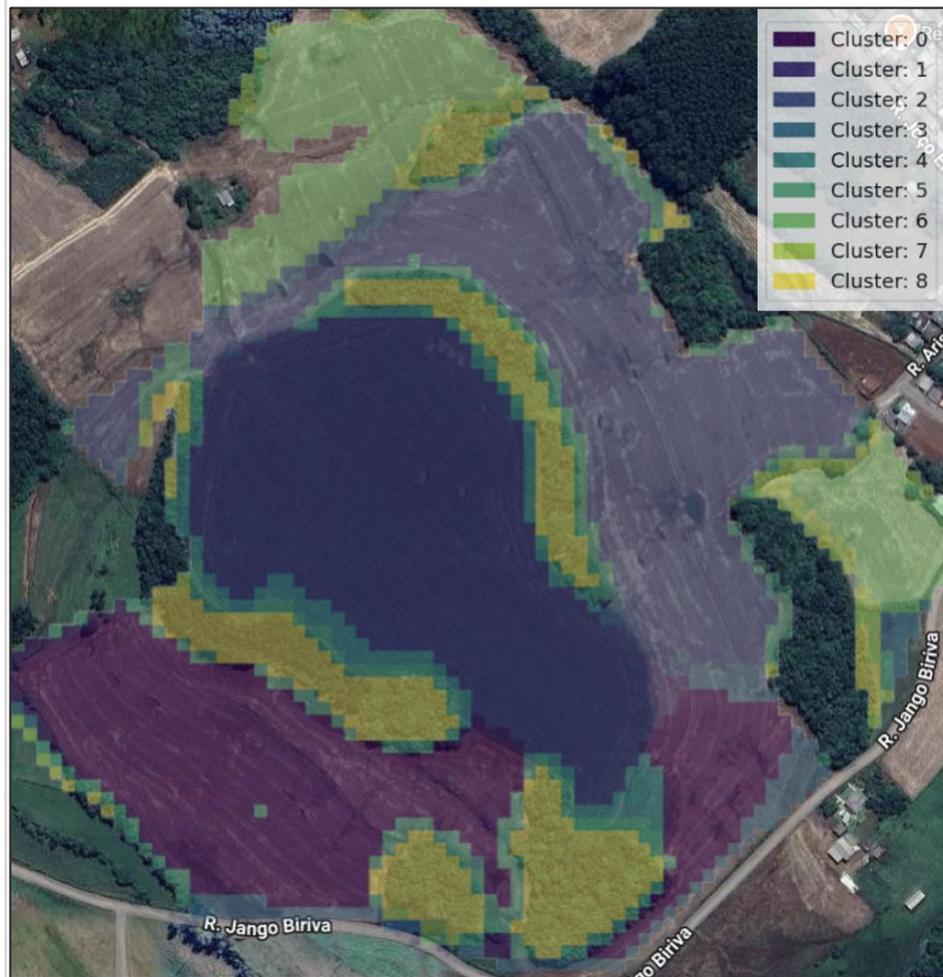
# Self-Organizing Maps (SOM) neural network for SITS clustering



# SOM to identify different SITS patterns

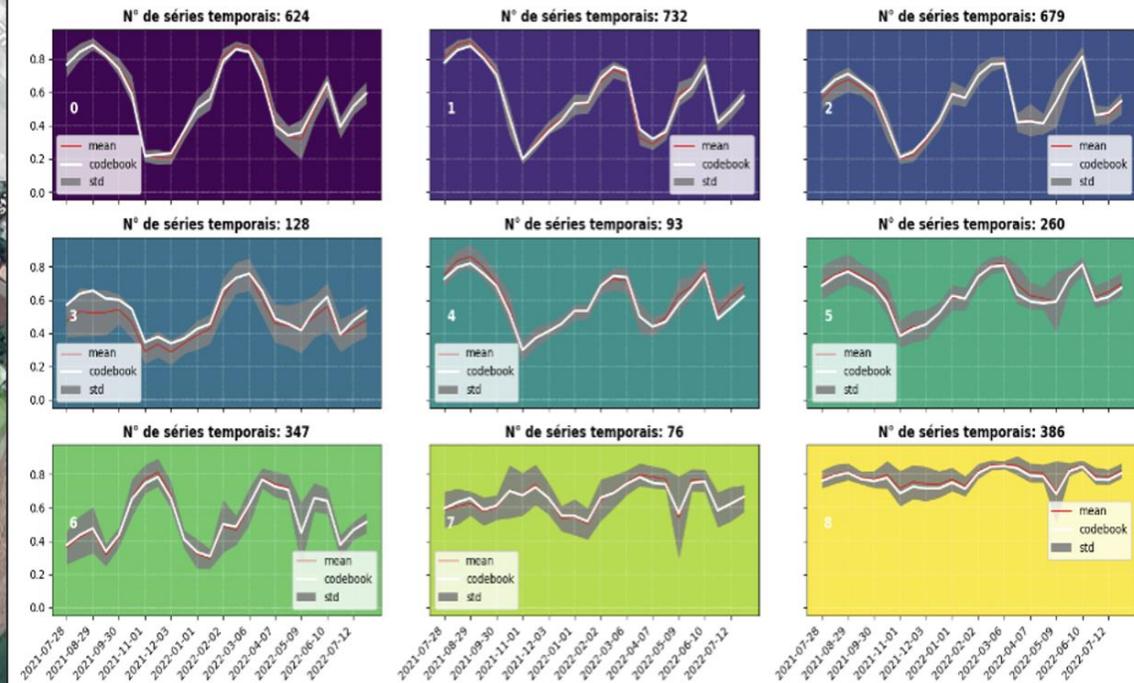


# SITS patterns – dentro de uma gleba – Crédito Rural - SICOR



(A)

## Vetores de Peso (NDVI) dos Neurônios SOM



(B)

# SITS patterns – dentro de uma gleba – Crédito Rural - SICOR

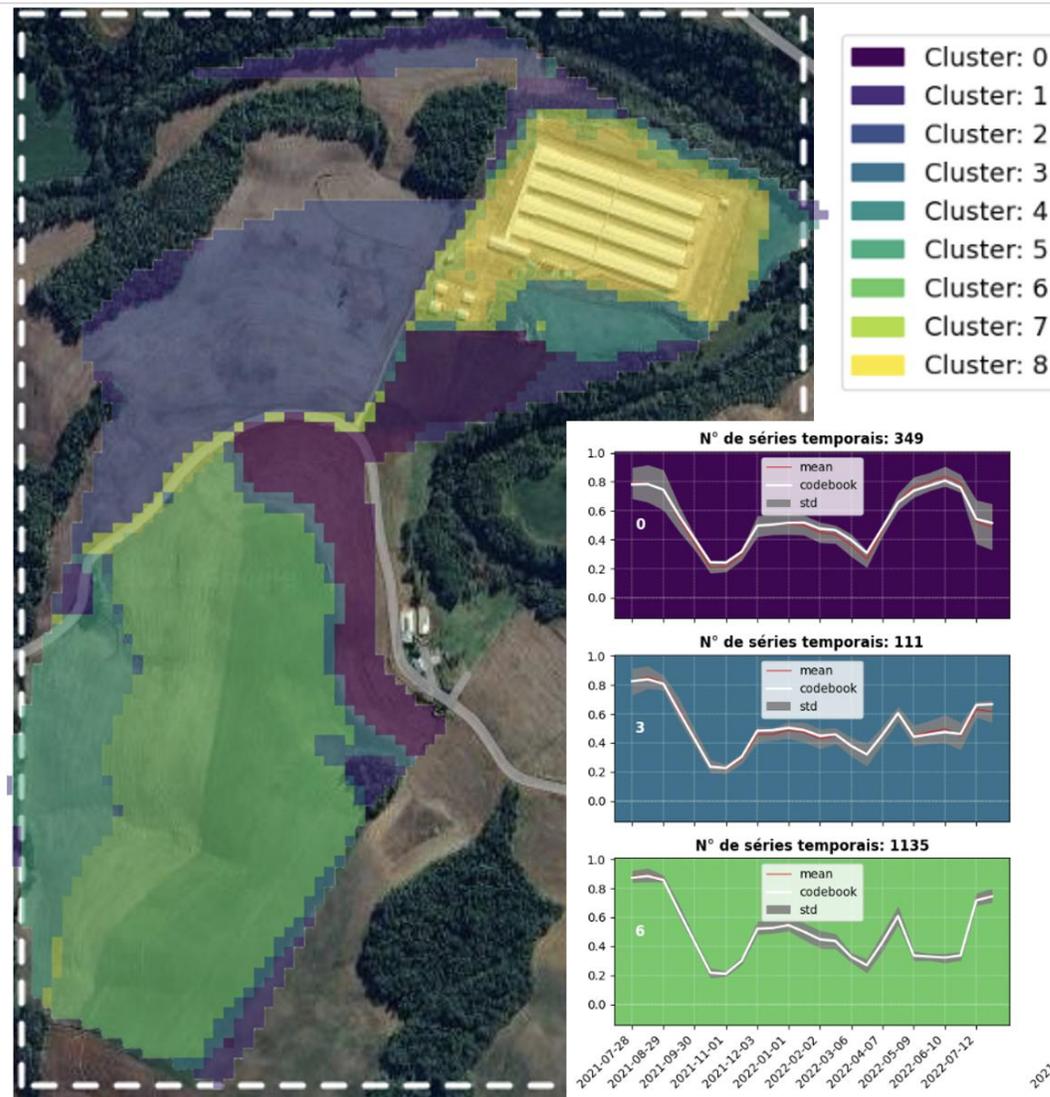


(A)



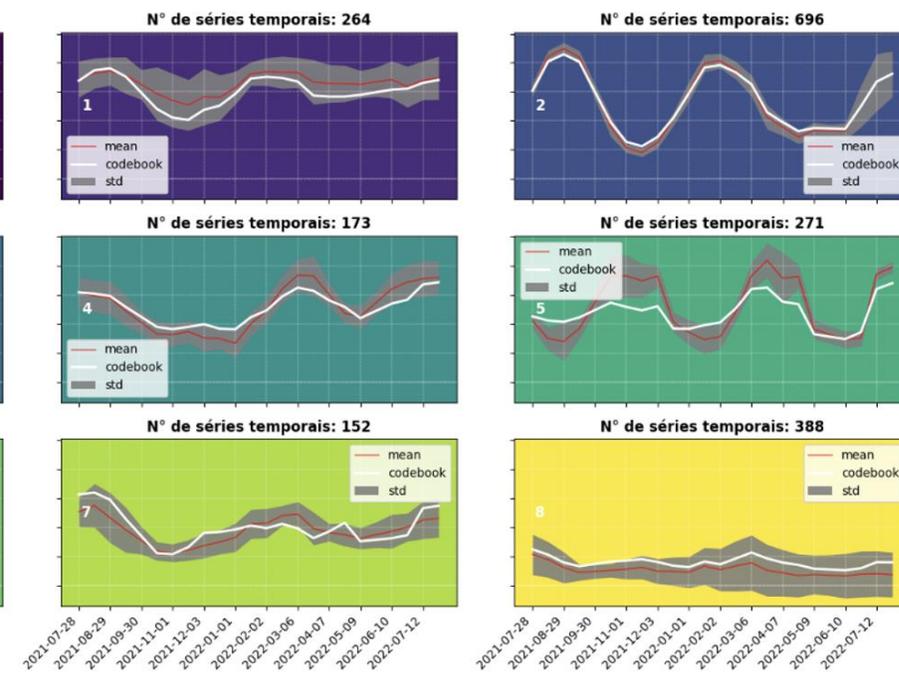
(B)

# SITS patterns – dentro de uma gleba – Crédito Rural - SICOR



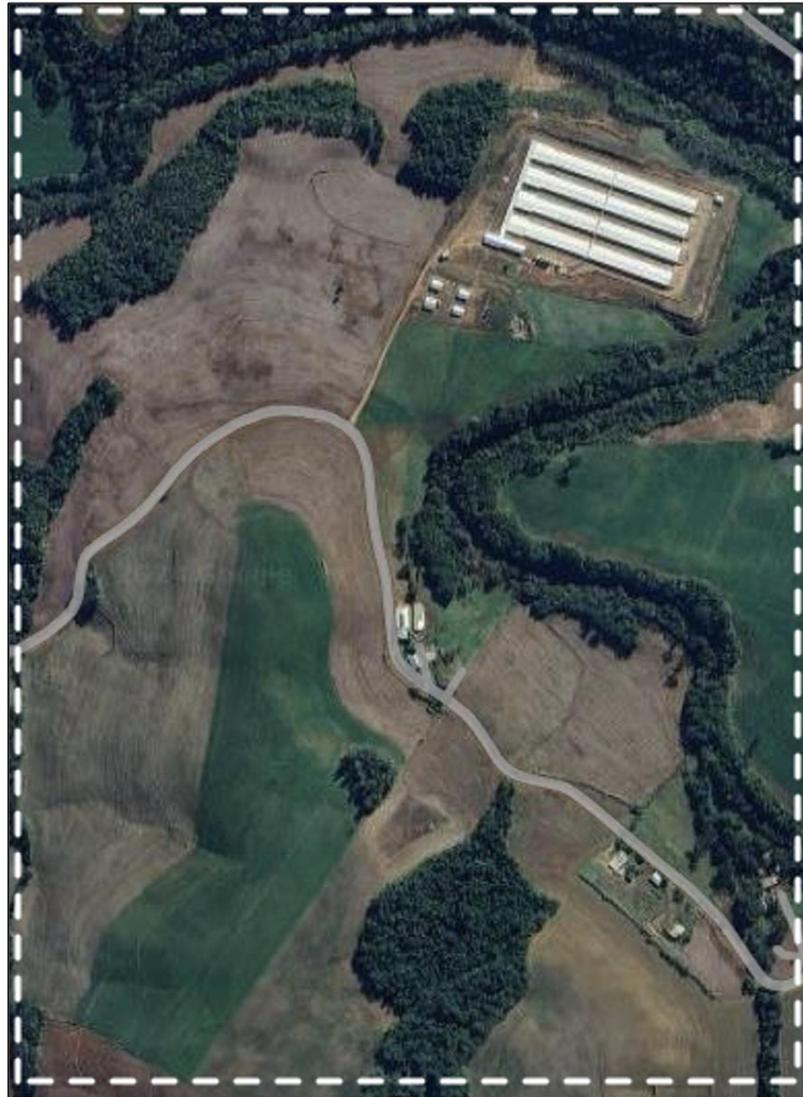
(A)

Vetores de Peso (NDVI) dos Neurônios SOM

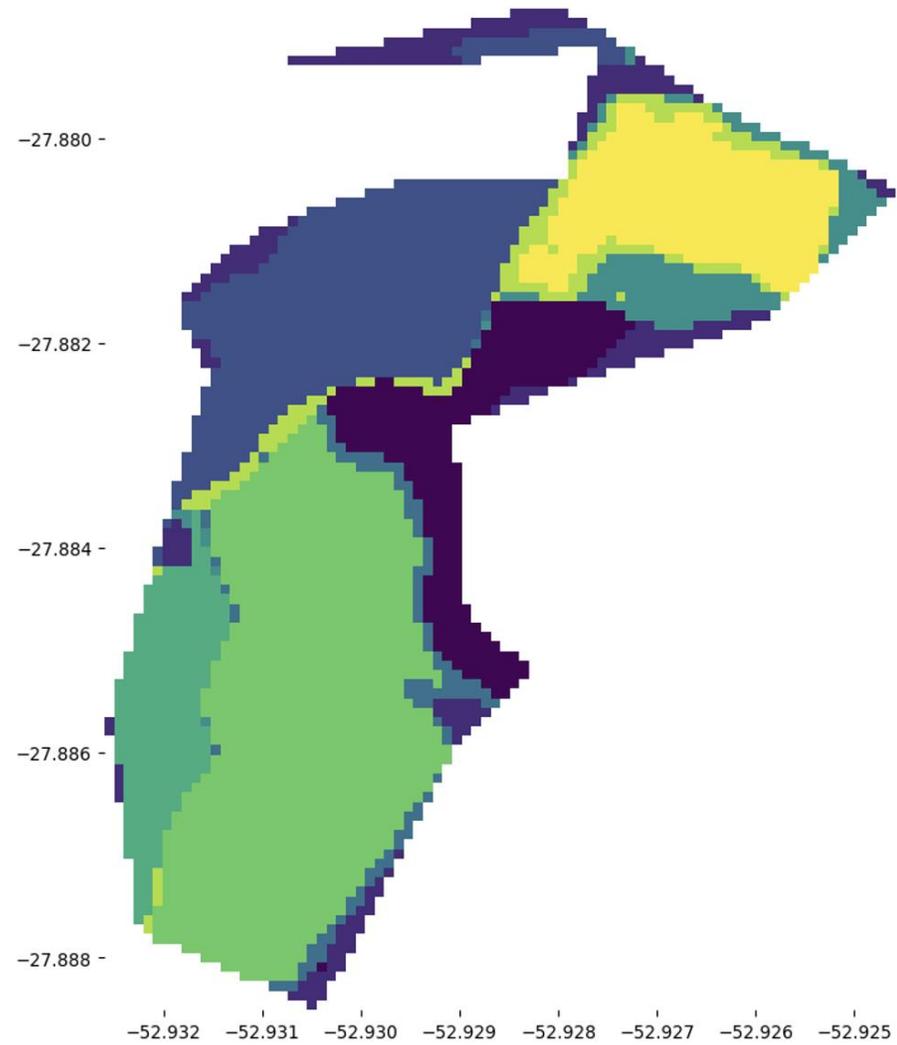


(B)

# SITS patterns – dentro de uma gleba – Crédito Rural - SICOR



(A)



(B)

# Satellite Image Time Series (SITS) Analysis

Classification of  
SITS

Clustering of SITS

Disturbance/Change  
Detection from SITS

Vegetation  
Phenological Metrics  
Extraction from SITS

CCDC (Continuous Change  
Detection and  
Classification)

BFAST (Breaks For Additive  
Seasonal and Trend)

LSTM (Long Short-Term  
Memory)

...

# Distúrbios Florestais

Um distúrbio pode ser entendido como um evento relativamente discreto que ocorre durante um curto período de tempo e que perturba a organização de um ecossistema, comunidade ou população

Processos naturais e antropogênicos



Anais do XX Simpósio Brasileiro de Sensoriamento Remoto

ISBN: 978-65-89159-04-9

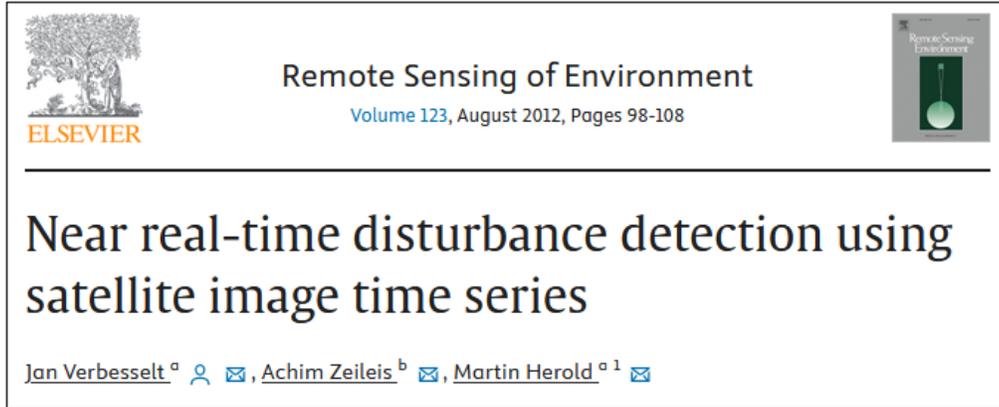
2 a 5 de Abril de 2023

INPE - Florianópolis-SC, Brasil

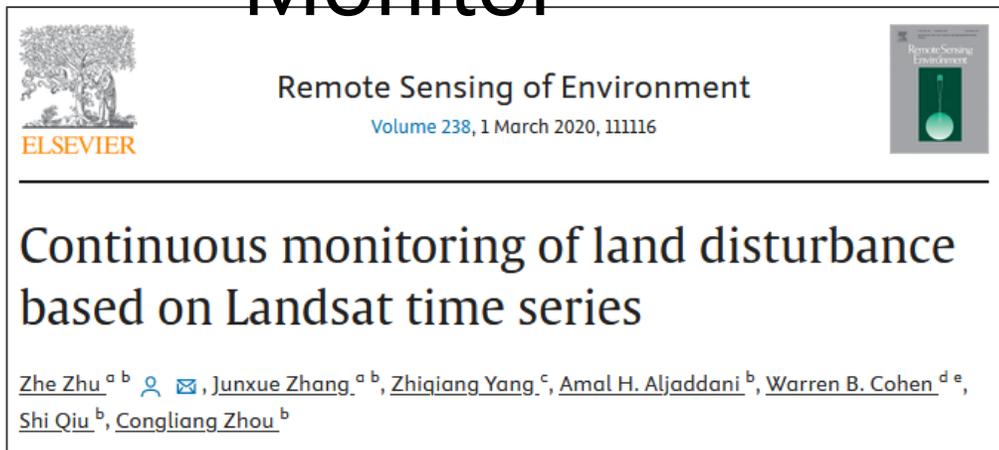
## MAPEAMENTO DE DISTÚRBIOS FLORESTAIS NO ESTADO DO MARANHÃO POR MEIO DE SÉRIES TEMPORAIS E CUBOS DE DADOS

*Wesley Augusto Campanharo<sup>1</sup>, Celso H. L. Silva-Junior<sup>2,3</sup>, Mateus de Souza Macul<sup>1</sup>, Karine R. Ferreira<sup>1</sup> e Gilberto Ribeiro de Queiroz<sup>1</sup>*

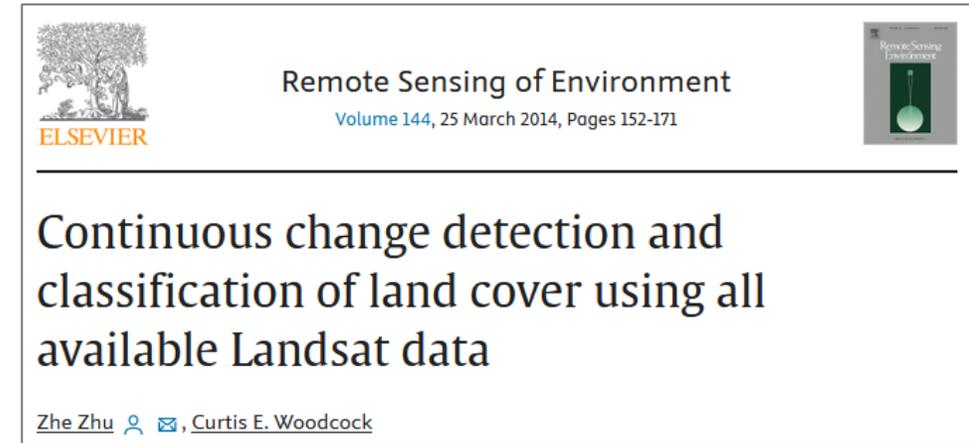
# Disturbance/Change Detection Methods



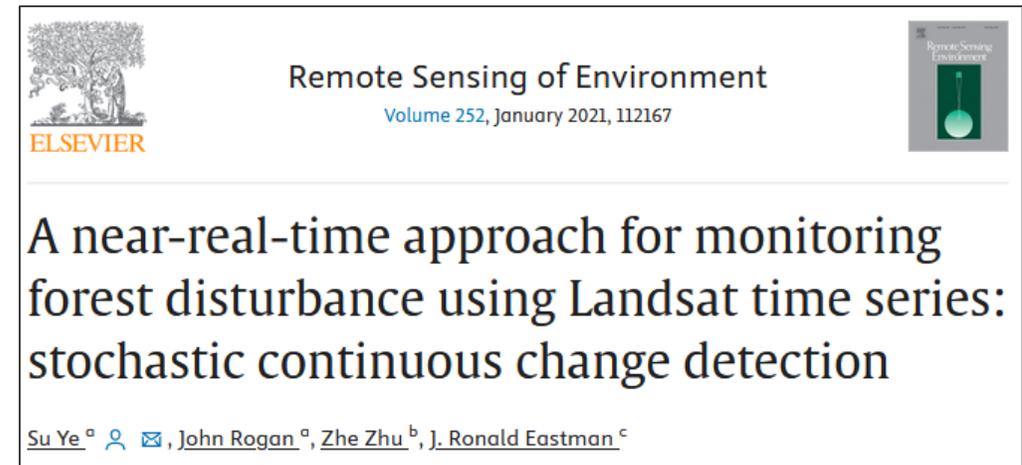
**BFAST  
Monitor**



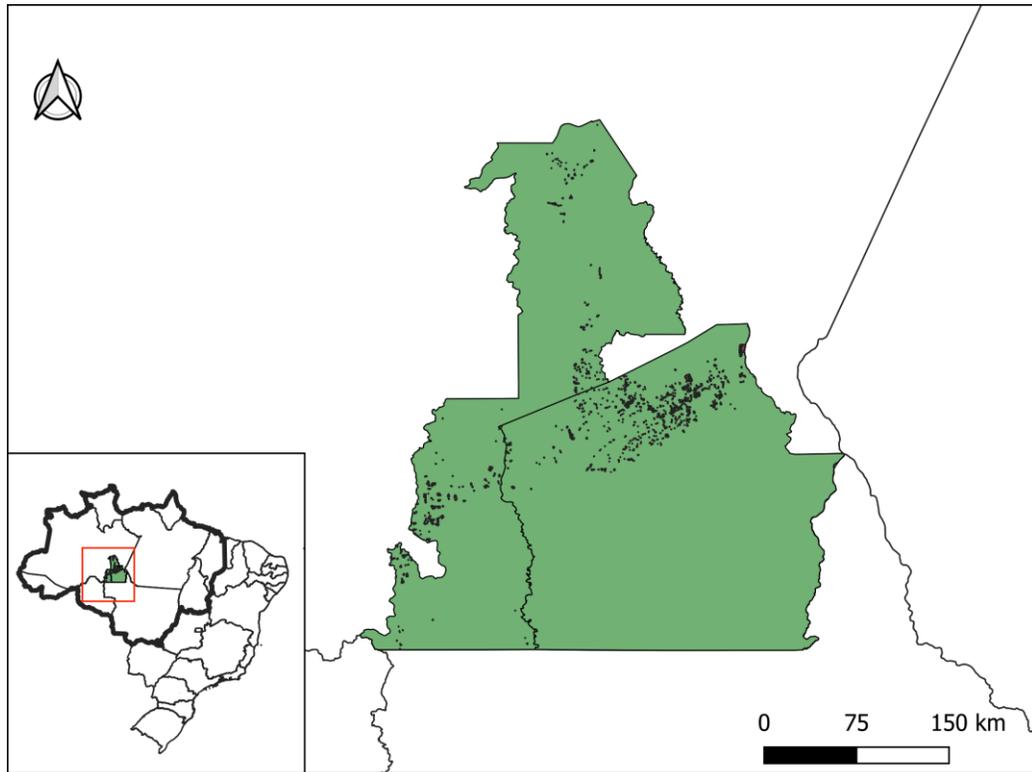
**COLD**



**CCDC**

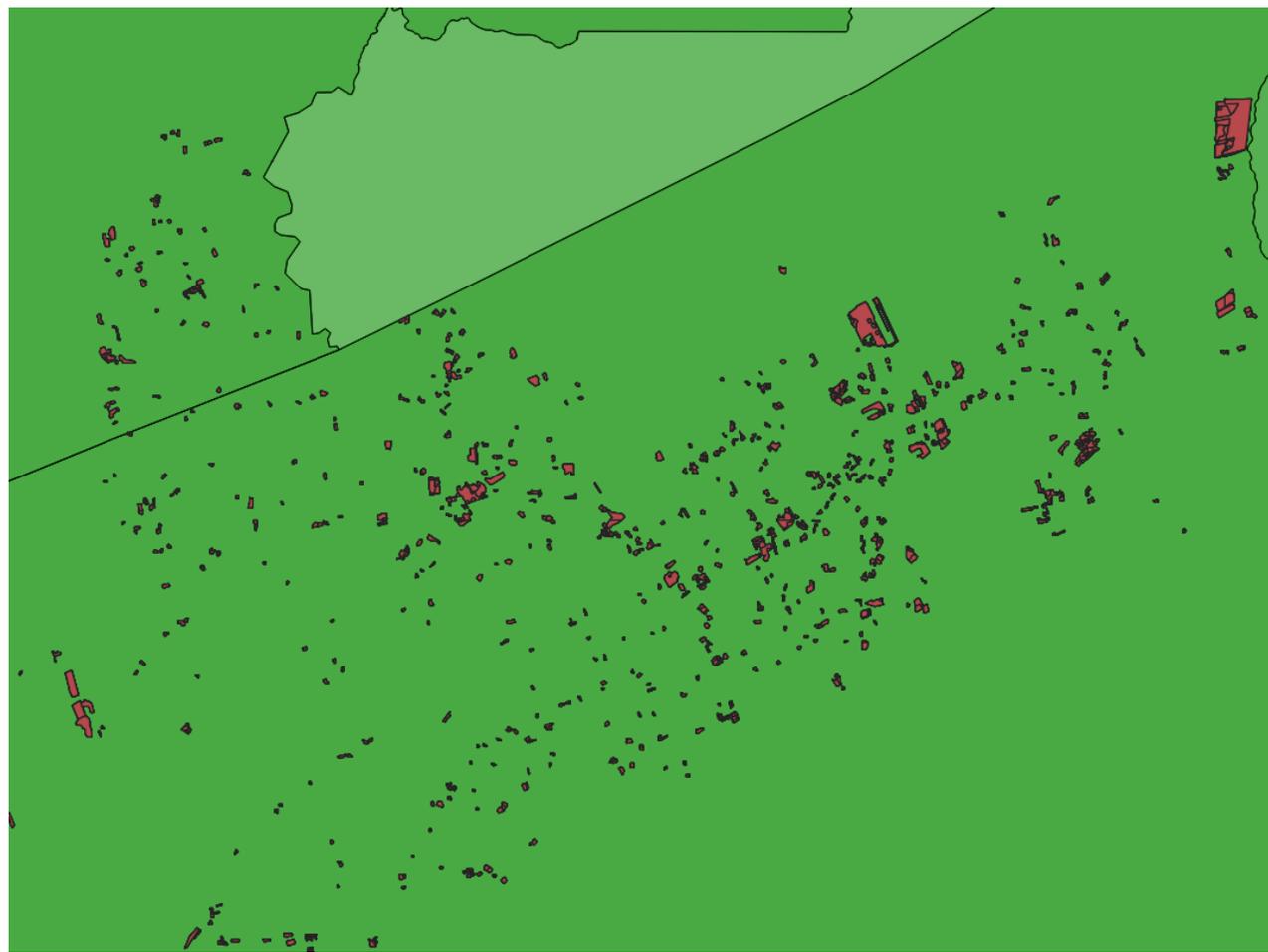


**SCCD**



- Federative Units of Brazil
- Brazilian Legal Amazon
- Municipalities of Apuí and Novo Aripuanã
- 2020 DETER Alerts

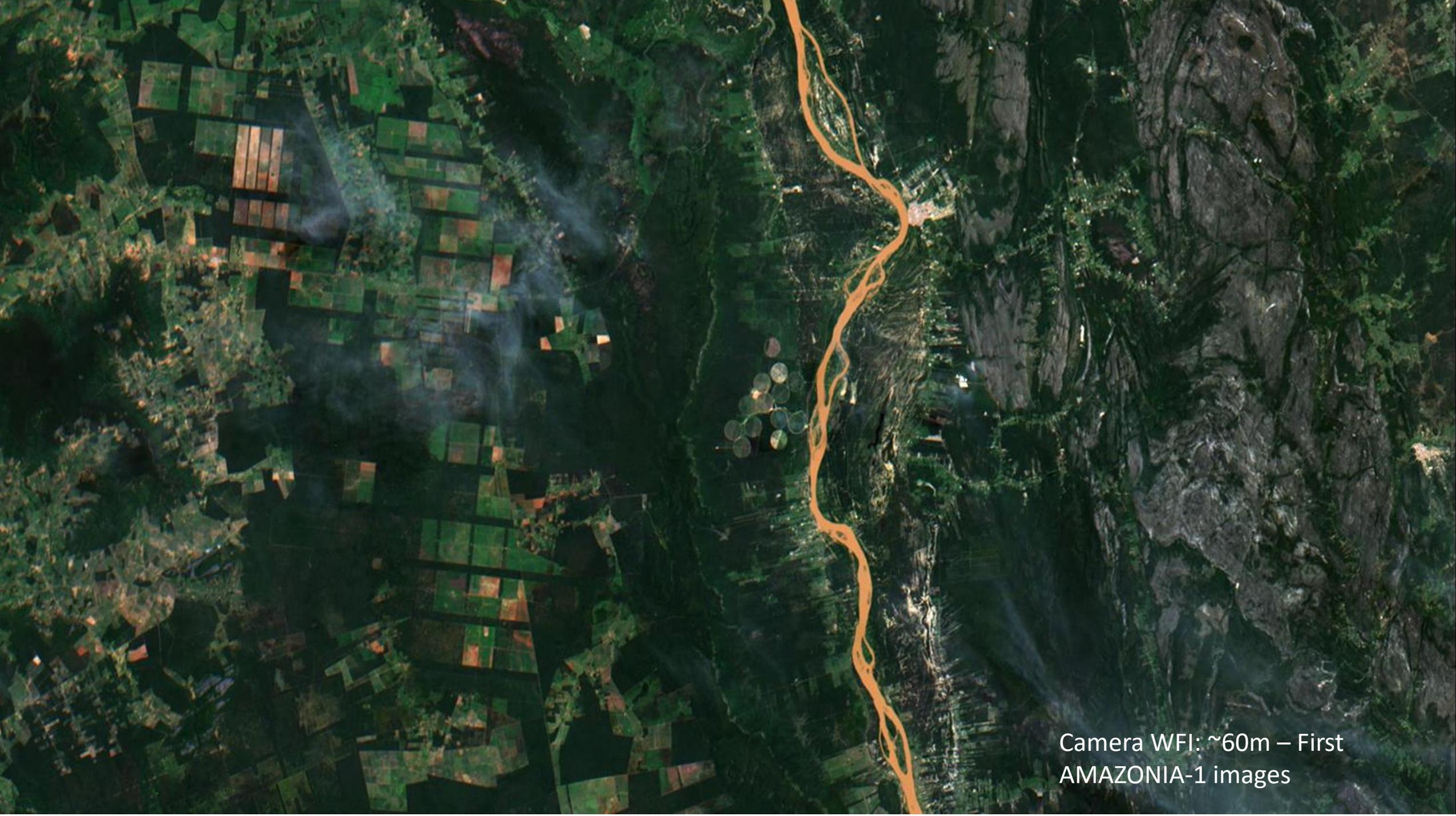
## Alerts of deforestation detected in 2020 by DETER



# CBERS 4

Rio\_CBERS4\_Camera PAN: 5m resolução espacial





Camera WFI: ~60m – First AMAZONIA-1 images

## Câmeras CBERS-4

Característica	PAN	MUX	WFI
Bandas Espectrais	0,51-0,85 $\mu$ m (PAN) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)
Resolução Espacial	5 m / 10 m	20 m	64 m
Largura da Faixa Imageada	60 km	120 km	866 km
Revisita	52 dias	26 dias	5 dias
Quantização	8 bits	8 bits	10 bits

# CBERS-4/WFI



CBERS-4/WFI  
Resolução espacial: 64 m  
Revisita: 5dias  
Local: Oeste Bahia

# CBERS-4/MUX



**CBERS-4/MUX**  
Resolução espacial: 20 m  
Revisita: 26 dias  
Local: Oeste Bahia

# CBERS-4/PAN10



**CBERS-4/PAN10M**  
Resolução espacial: 10 m  
Revisita: 52 dias  
Local: Oeste Bahia

# CBERS-4/PAN5

This is a grayscale satellite image from the CBERS-4/PAN5 mission. The image shows a large area of agricultural land, characterized by a grid of circular plots. The plots are arranged in a regular pattern, with some larger plots and some smaller ones. In the center of the image, there is a cluster of buildings, likely a farm or a small settlement. The overall appearance is that of a well-organized agricultural landscape. The image is presented in a grayscale format, which highlights the geometric patterns of the fields and the structure of the buildings.

**CBERS-4/PAN5M**  
Resolução espacial: 10 m  
Revisita: 52 dias  
Local: Oeste Bahia

## Câmeras CBERS-4A

Característica	WPM	MUX	WFI
Bandas Espectrais	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR) 0,45-0,90 $\mu$ m (PAN)	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)
Resolução Espacial	2 m e 8 m	16 m	55 m
Largura da Faixa Imageada	92 km	95 km	684 km
Revisita	31 dias	31 dias	5 dias
Quantização	10 bits	8 bits	10 bits

# CBERS-4A/WFI

A satellite image showing a large reservoir on the left side, with a winding river or canal extending from it towards the right. The surrounding terrain is a mix of brownish and greenish hues, indicating a semi-arid or agricultural landscape. There are some white patches that could be snow or clouds. The image is taken from a high angle, showing the intricate details of the water bodies and the land.

**CBERS-4A/WFI**

**Resolução espacial: 55 m**

**Revisita: 5 dias**

**Local: Barragem de Sobradinho, BA**

# CBERS-4A/MUX

A satellite image showing a large reservoir on the left side, with a winding river or canal extending from it towards the right. The surrounding area is a mix of agricultural fields, some appearing as green patches and others as brown or tan, indicating different stages of crop growth or land use. The image is taken from a high angle, providing a clear view of the landscape's features.

**CBERS-4A/MUX**  
**Resolução espacial: 16 m**  
**Revisita: 31 dias**  
**Local: Barragem de Sobradinho, BA**

# CBERS-4A/WPM

A satellite image showing a dam structure across a river. The river is dark and occupies the lower half of the image. The land on either side is divided into agricultural plots, some green and some brown, indicating different crops or stages of growth. The dam is a long, straight structure with a small building or structure at its base. The overall scene is a rural landscape with significant agricultural activity.

**CBERS-4A/WPM**

**Resolução espacial: 8m**

**Revisita: 31 dias**

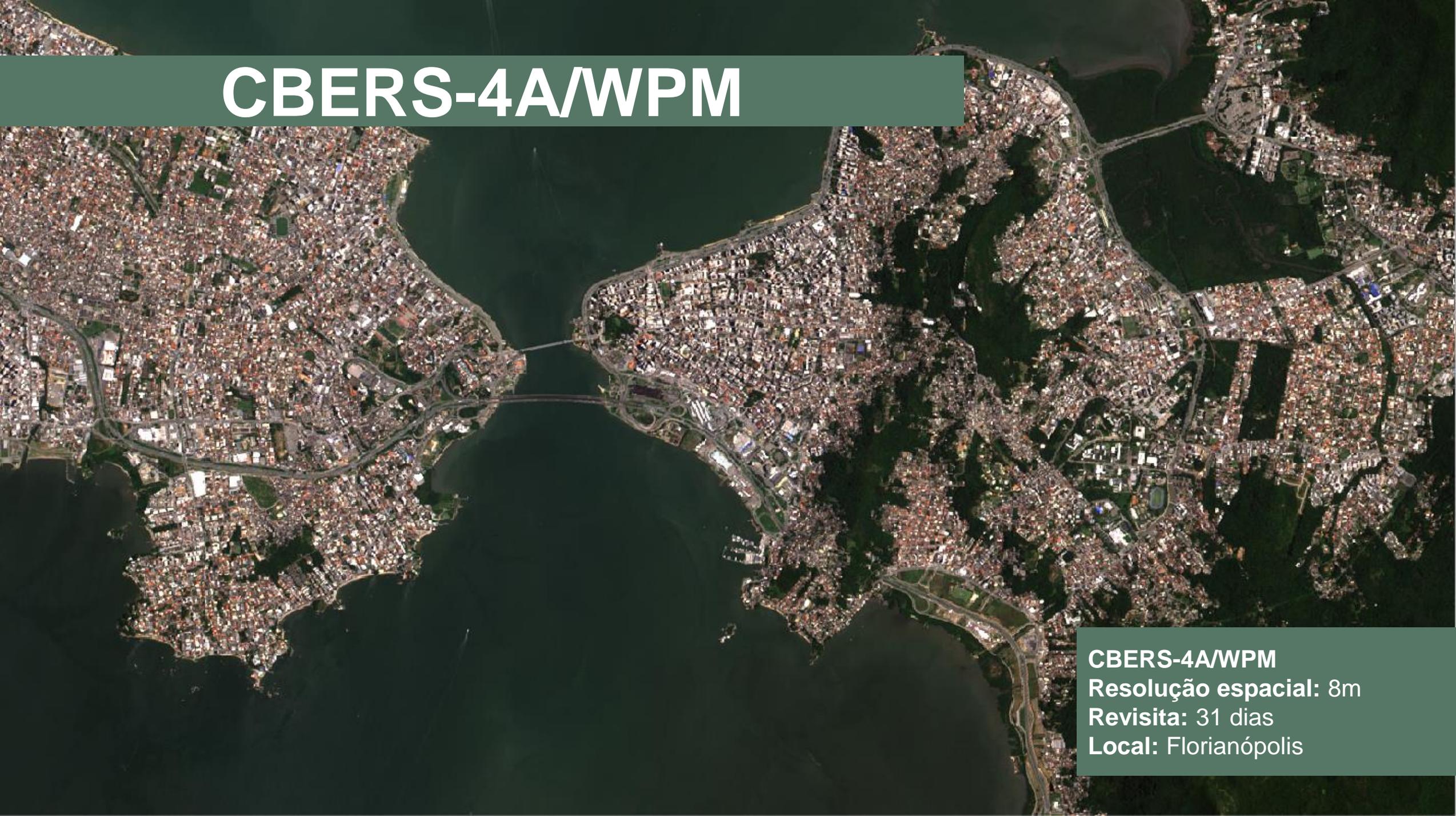
**Local: Barragem de Sobradinho, BA**

# CBERS-4A/WPM



**CBERS-4A/WPM**  
Resolução espacial: 2m  
Revisita: 31 dias  
Local: Guarda Mor, MG

# CBERS-4A/WPM



**CBERS-4A/WPM**

**Resolução espacial: 8m**

**Revisita: 31 dias**

**Local: Florianópolis**



# CBERS-4A/WPM-pan

**CBERS-4A/WPM**

**Resolução espacial: 2m**

**Revisita: 31 dias**

**Local: Florianópolis**

# CBERS-4A/WPM-fusionado



**CBERS-4A/WPM**

**Resolução espacial: 2m**

**Revisita: 31 dias**

**Local: Florianópolis**

## Câmera AMAZONIA-1

<b>Característica</b>	<b>WFI</b>
Bandas Espectrais	0,45-0,52 $\mu$ m (B) 0,52-0,59 $\mu$ m (G) 0,63-0,69 $\mu$ m (R) 0,77-0,89 $\mu$ m (NIR)
Resolução Espacial	64 m
Largura da Faixa Imageada	850 km
Revisita	5 dias
Quantização	10 bits

# AMAZONIA-1/WFI

A satellite image showing a coastal region with a complex river delta system. The land is predominantly green, indicating dense vegetation, with some brownish areas suggesting cleared land or urban development. The water is a deep blue, and the coastline is irregular with many inlets and peninsulas.

**Amazonia-1/WFI**  
**Resolução espacial: 64 m**  
**Revisita: 5dias**  
**Local: Ilha do Mel, PR**  
**Imagem: Emiliano Castejon**

# AMAZONIA-1/WFI

An aerial satellite image showing a coastal region. The top half of the image is dominated by dense, dark green forest. Below the forest, there is a coastline with some buildings and infrastructure. A large body of water, likely a bay or a large river, is visible on the right side of the image. The water is a deep blue color. The overall scene is a mix of natural and human-made elements.

**Local:** Búzios, RJ  
**Imagem:** Emiliano  
Castejon



# AMAZONIA-1/WFI

**Local:** Luis Eduardo Magalhães,  
BA

**Imagem:** Emiliano Castejon



Google Earth Engine

Ambiente de computação em nuvem (Google).

Interface web e API em JavaScript e Python.

Coleções de imagens de satélites e outros dados.

Source: <https://earthengine.google.com/>

## Interface web – scripts, visualização, ...

The screenshot displays the Google Earth Engine web interface. At the top, there is a search bar and a user profile for 'ee-krfgomes'. Below this, the interface is divided into several sections:

- Scripts:** A sidebar on the left with a 'Filter scripts...' search box and a 'NEW' button. It lists categories like Owner, Writer, Reader, and Archive, each with a message: 'No accessible repositories. Click Refresh to check again.'
- New Script \*:** A central editor window with a code editor containing the following JavaScript code:

```
1 var collection = ee.ImageCollection('LANDSAT/LC08/C02/T1_TOA');
2
3 print(ee.Image('LANDSAT/LC08/C02/T1_TOA/LC08_044034_20140318'));
4
5 Map.addLayer(ee.Image('LANDSAT/LC08/C02/T1_TOA/LC08_044034_20140318'));
```

Buttons for 'Get Link', 'Save', 'Run', 'Reset', and 'Apps' are visible above the code editor.
- Inspector Console Tasks:** A panel on the right showing the output of the script. It contains the text: 'Use print(...) to write to this console.' and a log entry: 'Image LANDSAT/LC08/C02/T1\_T... JSON'.
- Map:** A satellite map of a region in California, centered around Fresno. A large black rectangular area is overlaid on the map, representing the image being processed by the script. The map includes labels for various cities and geographical features.



Google Earth Engine

Source: <https://earthengine.google.com/>

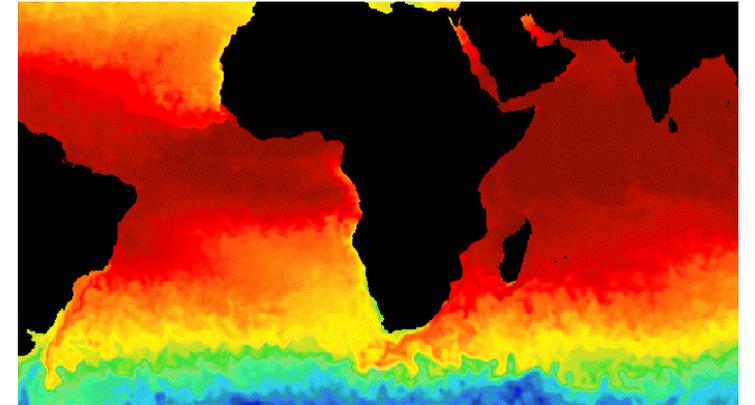
Landsat



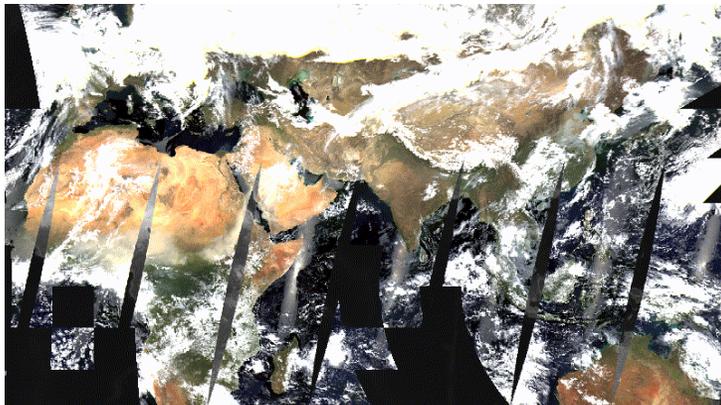
Sentinel (1, 2 e 3)



Land and sea surface temperature



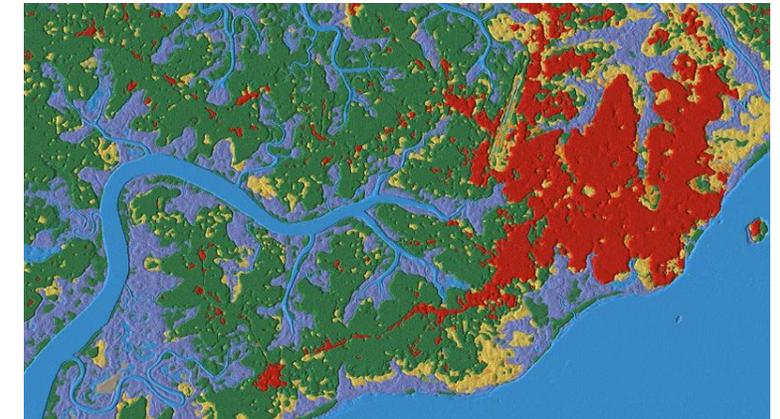
MODIS



High-resolution imagery – ex. Planet



Land cover map: ESA World Cover



# **BIG EO DATA STREAMING SERVICES PROVIDED BY THE COPERNICUS DATA SPACE ECOSYSTEM**

*Jan Musial<sup>1</sup>, Jędrzej Bojanowski<sup>1</sup>, Jacek Leszczeński<sup>1</sup>, Grega Milcinski<sup>2</sup>, Andras Zlinszky<sup>2</sup>,  
Anja Vrecko<sup>2</sup>, Dennis Clarijs<sup>3</sup>, Jeroen Dries<sup>3</sup>, Uwe Marquard<sup>4</sup>, Jurry de-la-Mar<sup>4</sup>*

*CloudFerro<sup>1</sup>, Sinergise<sup>2</sup>, VITO Remote Sensing<sup>3</sup>, T-Systems<sup>4</sup>*

Big Data from Space 2023 (BiDS 2023):

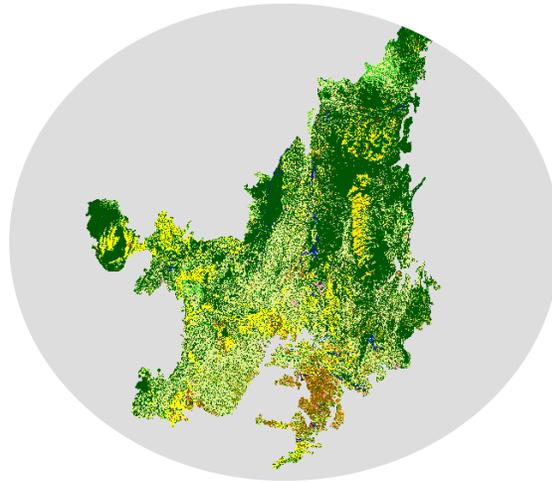
<https://dx.doi.org/10.2760/46796>

# WLTS - Coleções



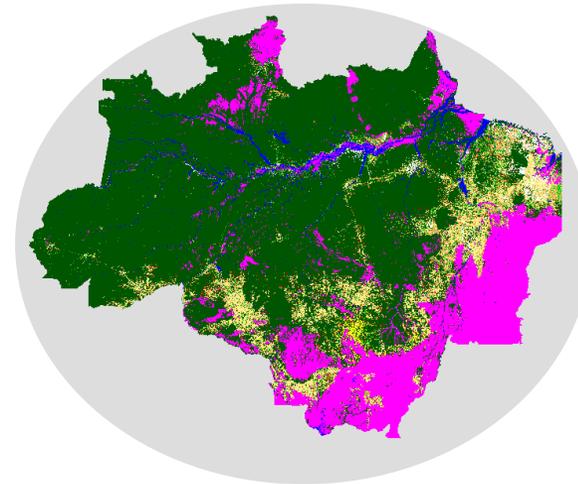
**PRODES - Brasil**  
2007 - 2022

<http://terrabilis.dpi.inpe.br/>



**TerraClass - Cerrado**  
2018 and 2020

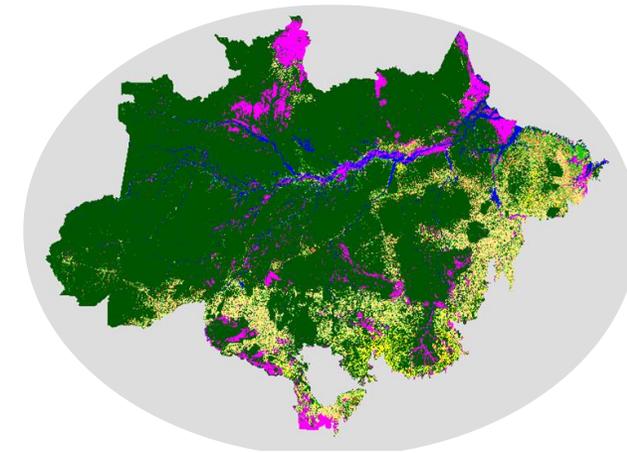
<https://www.terraclass.gov.br/>



**TerraClass - Amazônia**

2004, 2008, 2010, 2012, 2014

<https://www.terraclass.gov.br/geoportal-aml/>



**TerraClass - Amazônia**  
2020

<http://terrabilis.dpi.inpe.br/>



**MapBiomias 8.0 - Brasil**  
1985 - 2022

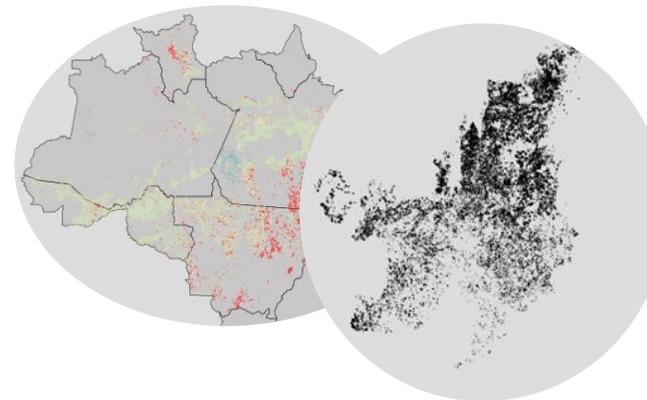
<https://mapbiomas.org/>



**IBGE LULC - Brasil**

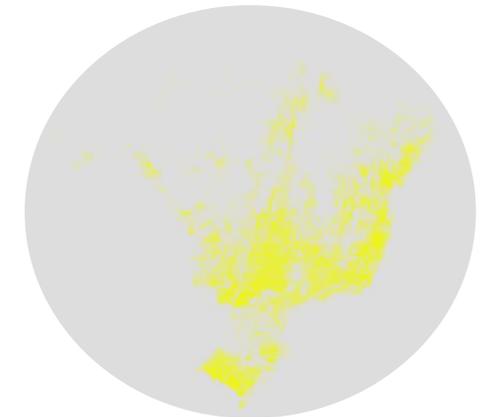
2000, 2010, 2012, 2014, 2016, 2018

<https://www.ibge.gov.br/>



**DETER - Amazônia e Cerrado**  
2018 - 2022

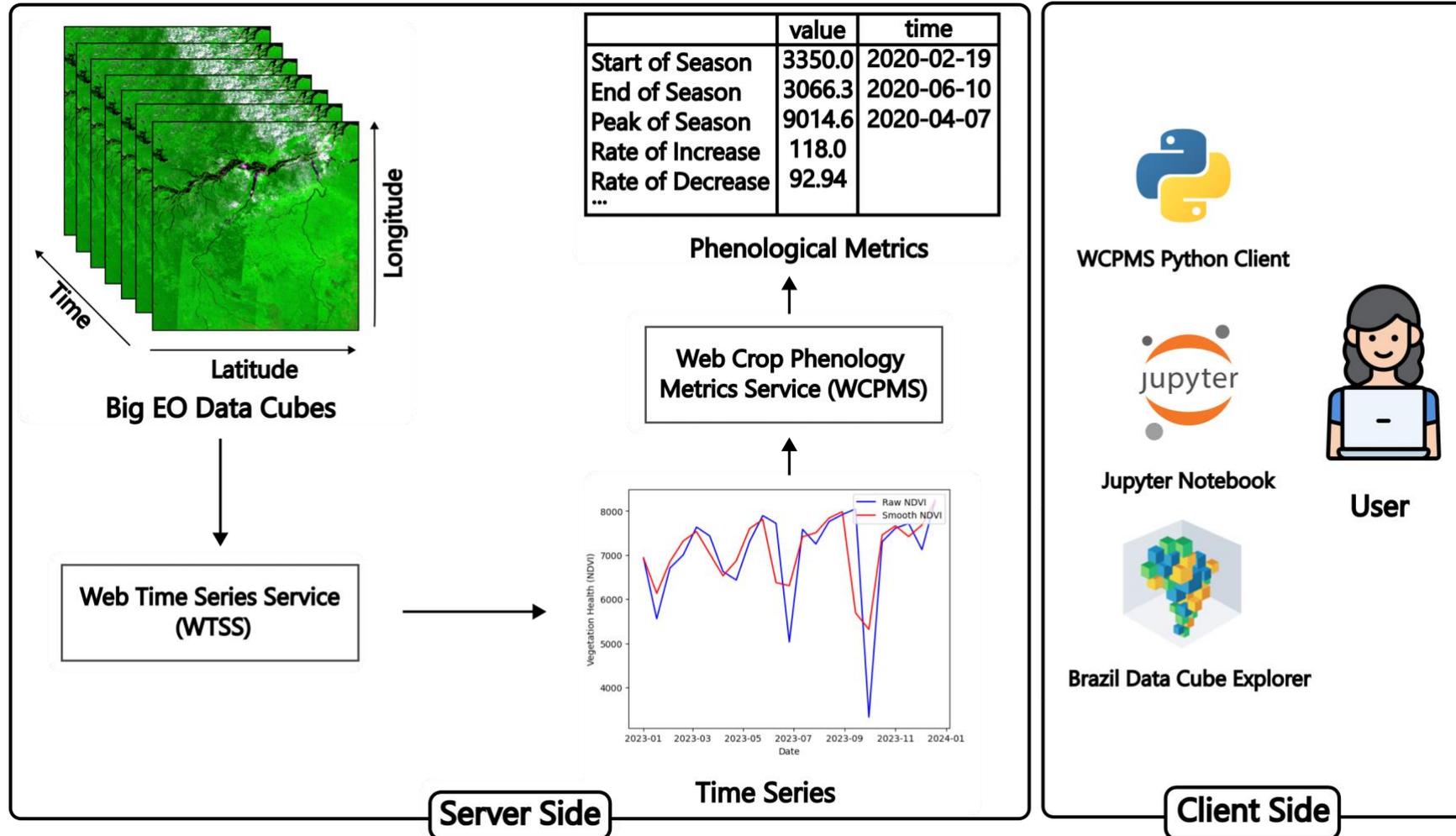
<http://terrabilis.dpi.inpe.br/>



**Lapig Pastagem - Brasil**  
1985 - 2021

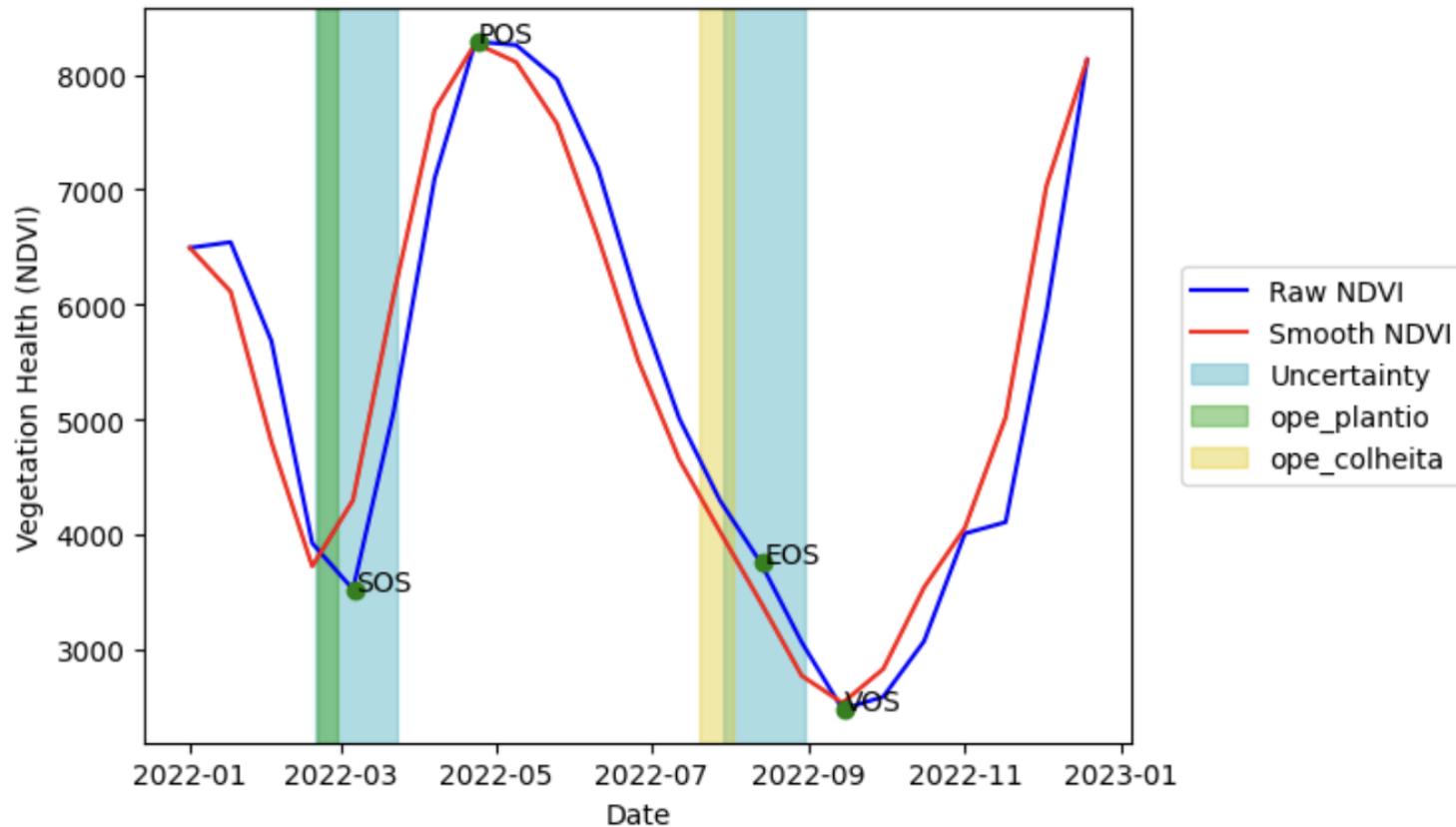
<https://atlasdaspastagens.ufg.br/map>

# Web Crop Phenology Metrics Service (WCPMS)



# Web Crop Phenology Metrics Service (WCPMS)

```
plot_advanced_phenometrics(cube=datacube, ds_phenos=pms[9], shape=polygon, start_sowing="ope_inici  
o_plantio", end_sowing="ope_fim_plantio", start_harvesting="ope_inicio_colheita", end_harvesting  
="ope_fim_colheita")
```

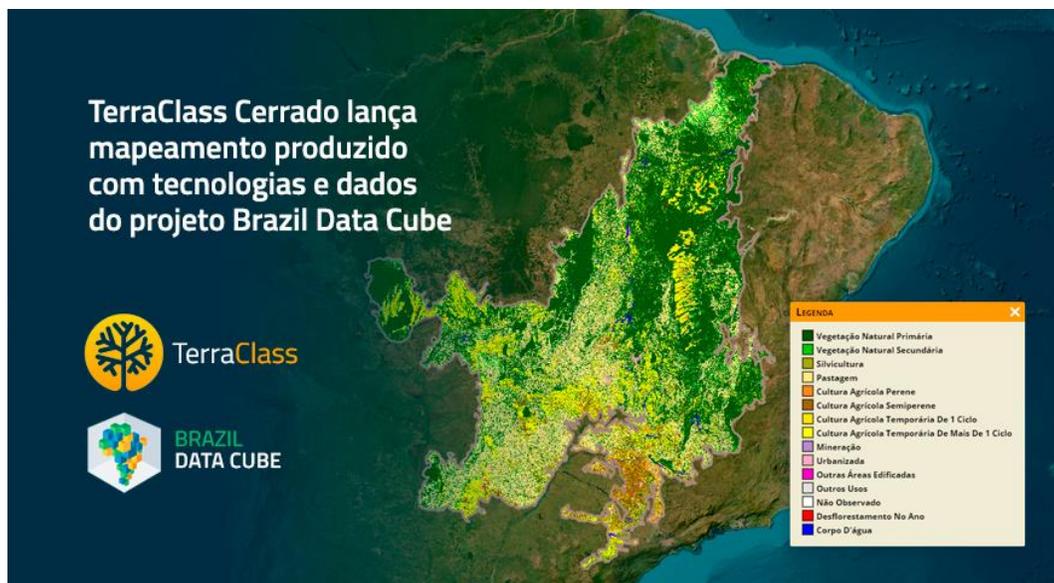




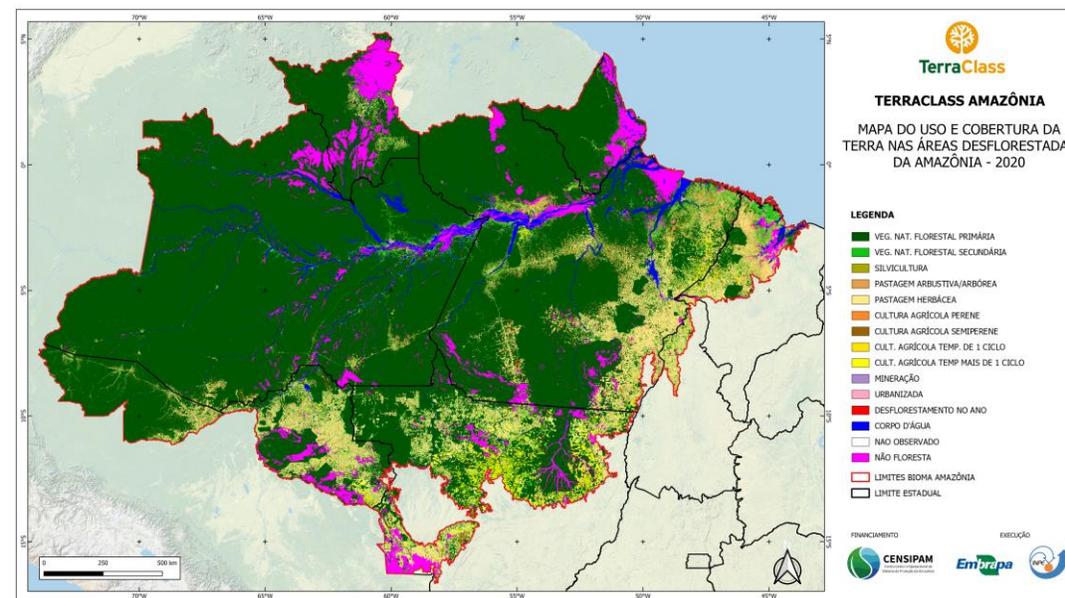
BRAZIL  
DATA CUBE

# Land use and land cover maps: TerraClass project

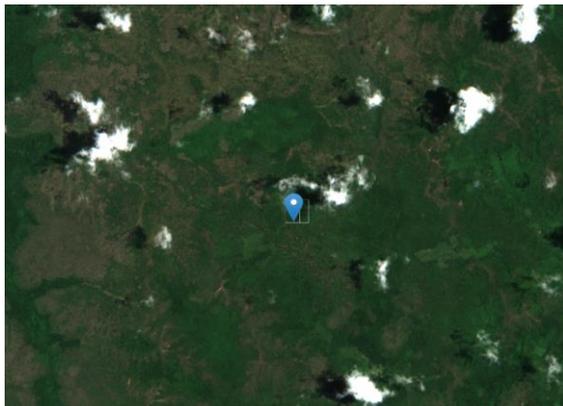
TerraClass Cerrado 2020 (Launched in December 2022)



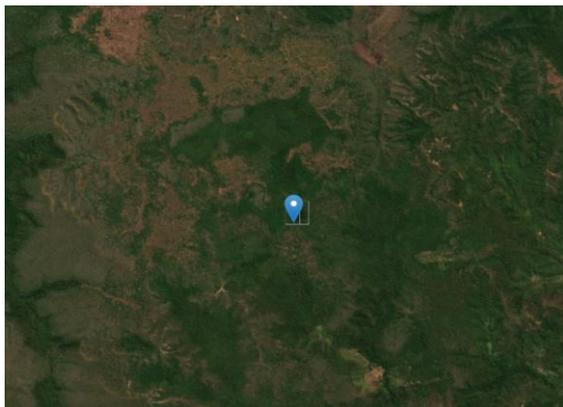
TerraClass Amazônia 2020



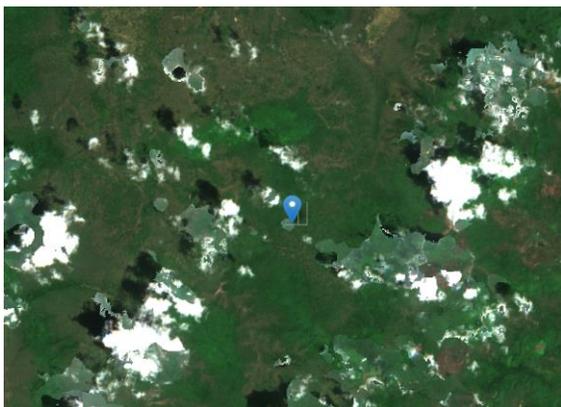
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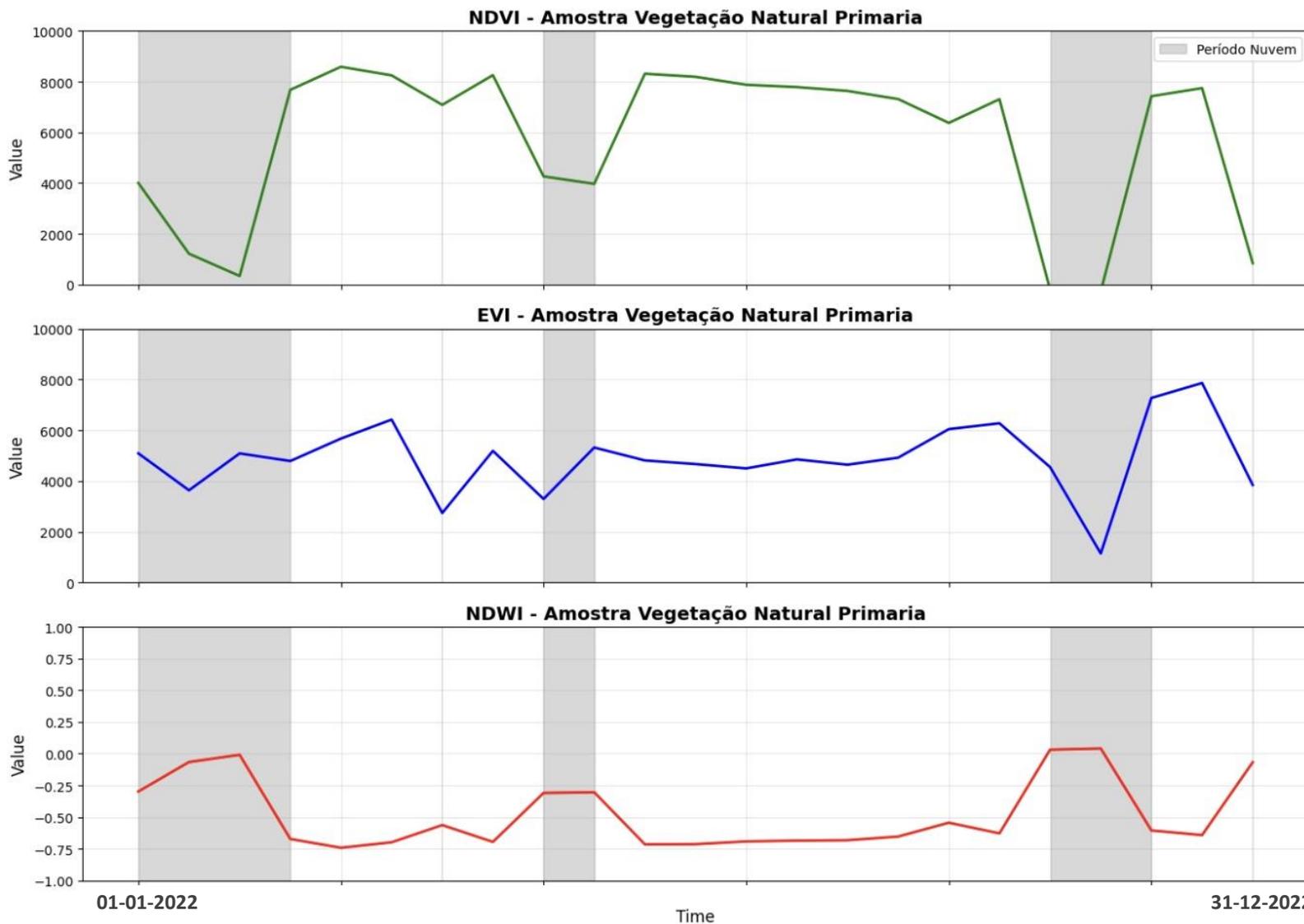
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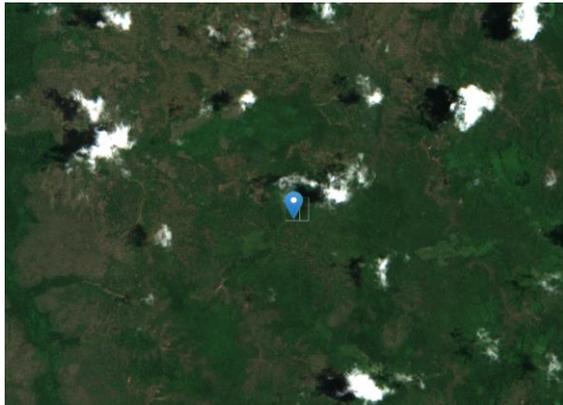
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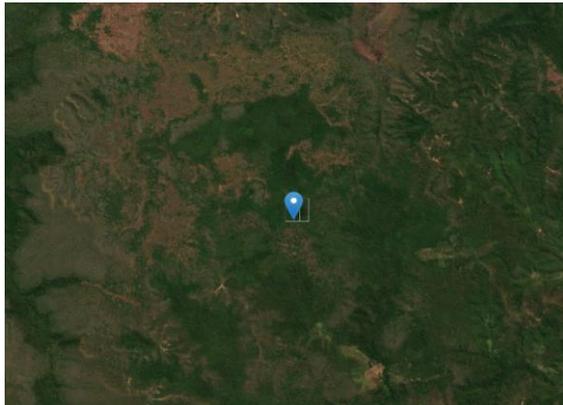
# Vegetação Natural Primária – Cubos Sentinel 2



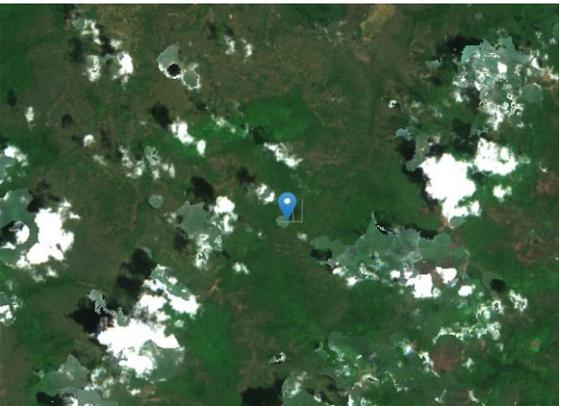
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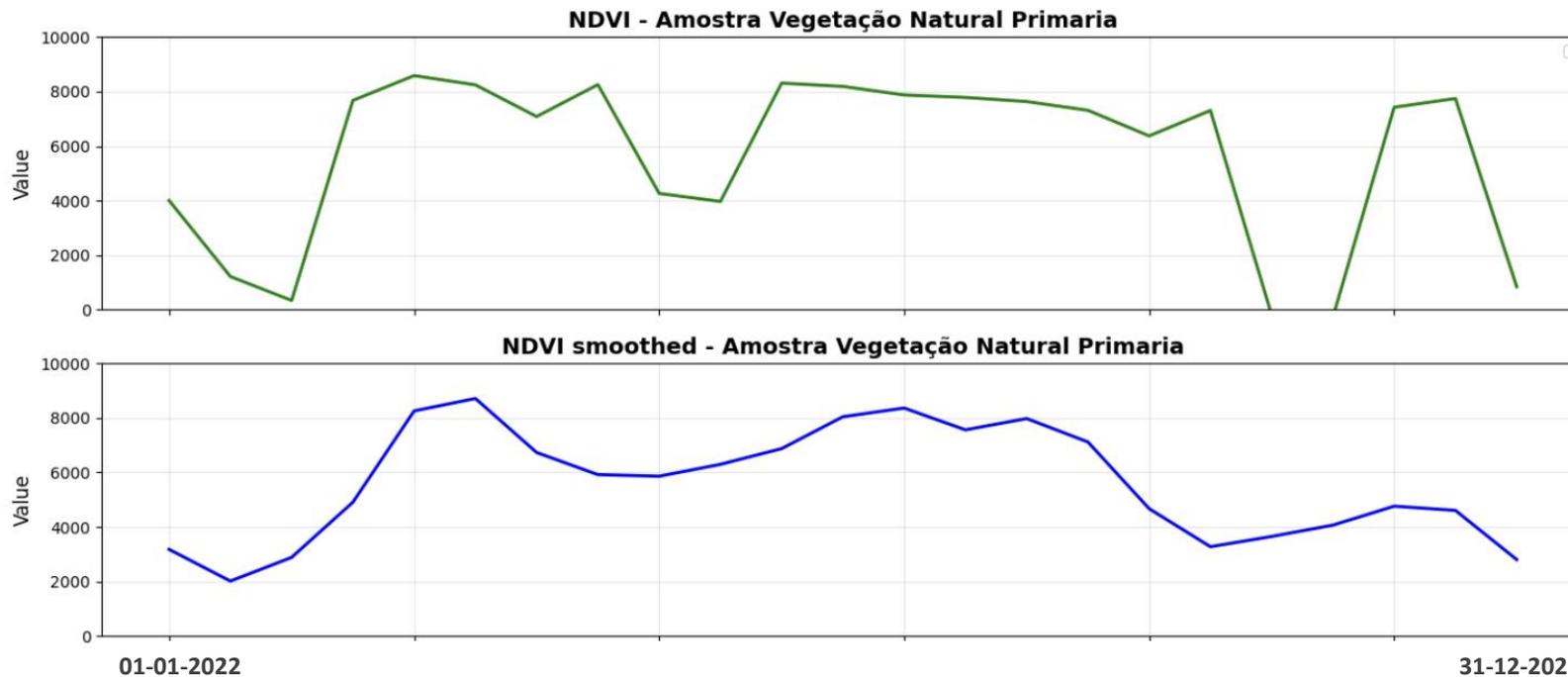
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03-12-2022



# Vegetação Natural Primária – Cubos Sentinel 2



18-02-2022



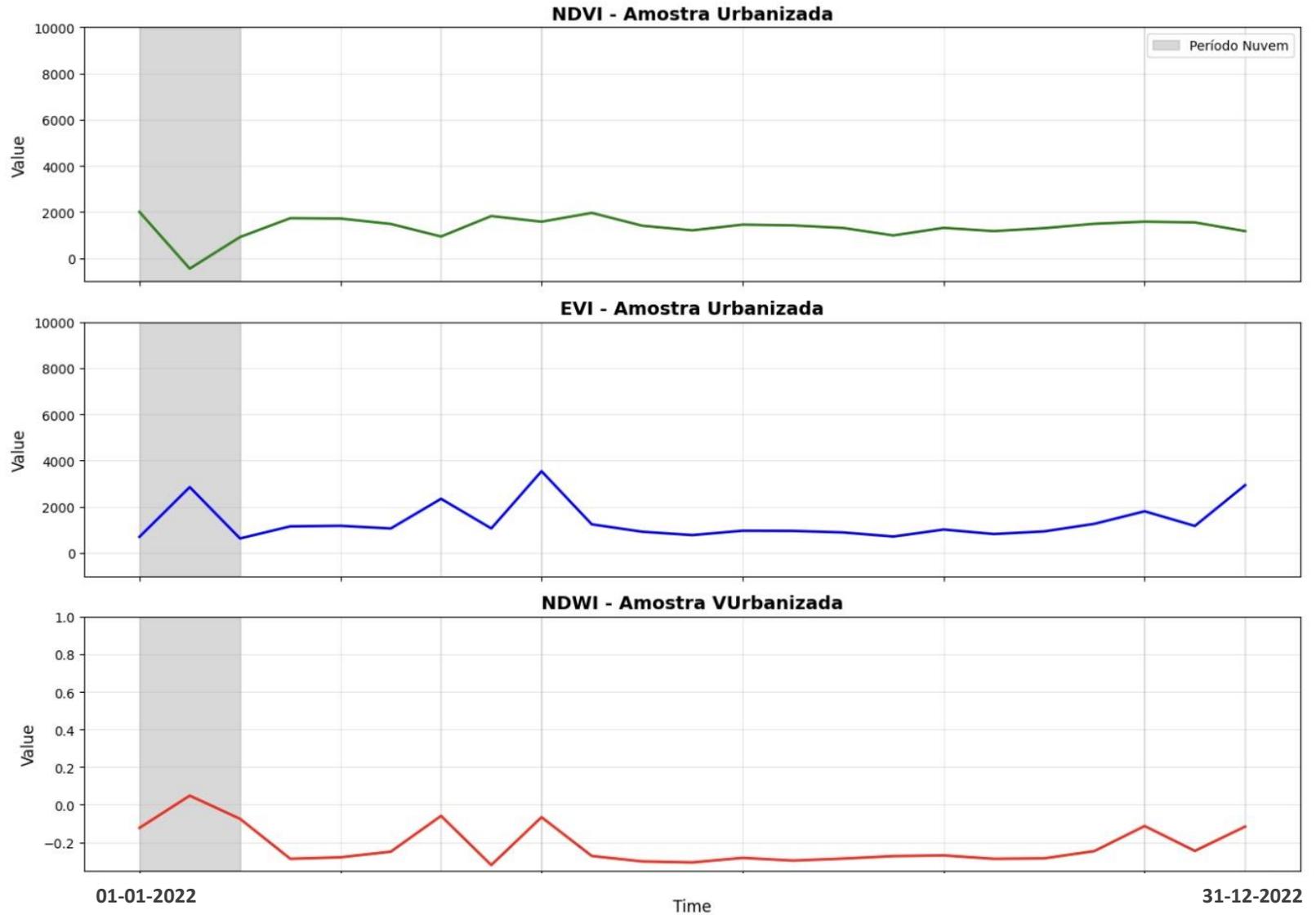
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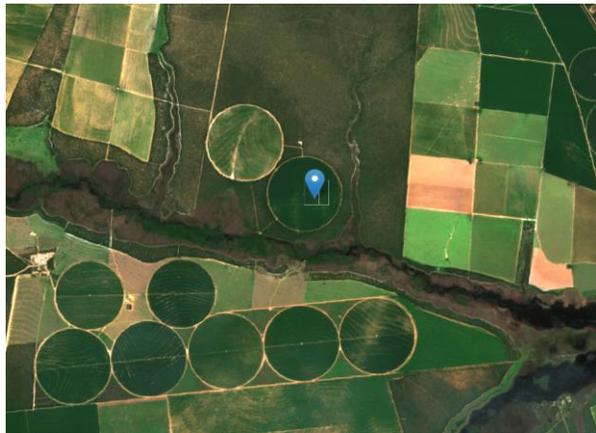


# Área Urbana – Cubos Sentinel 2





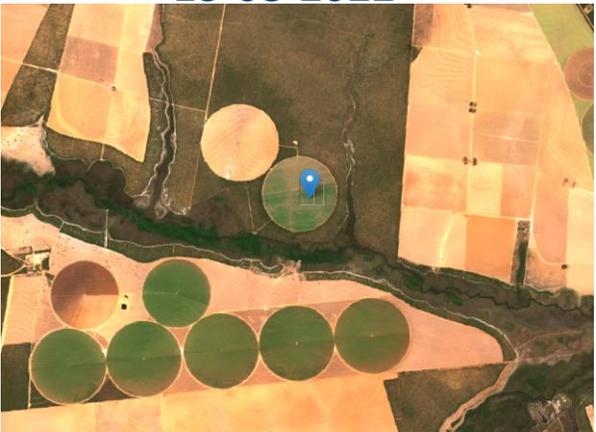
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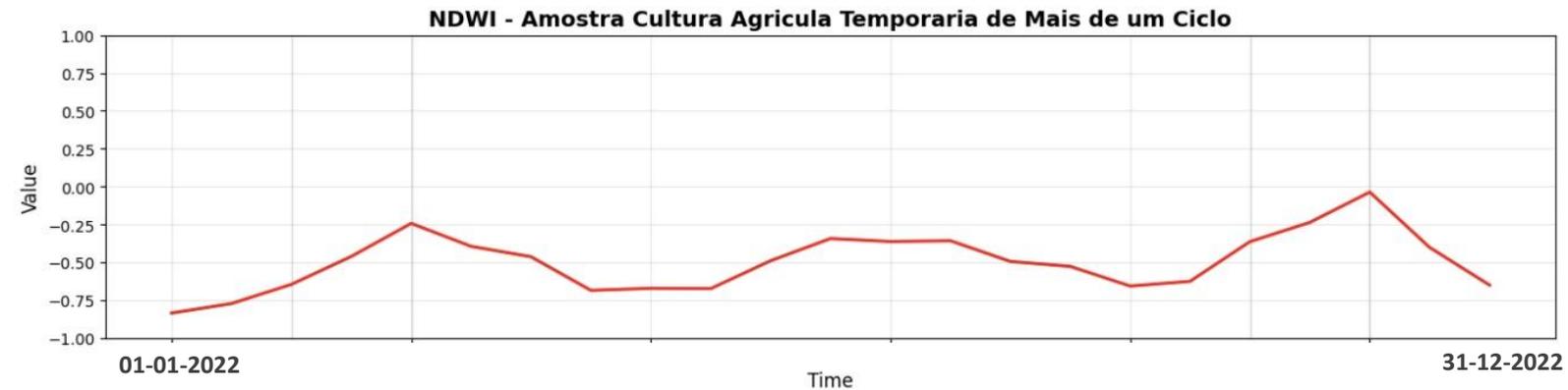
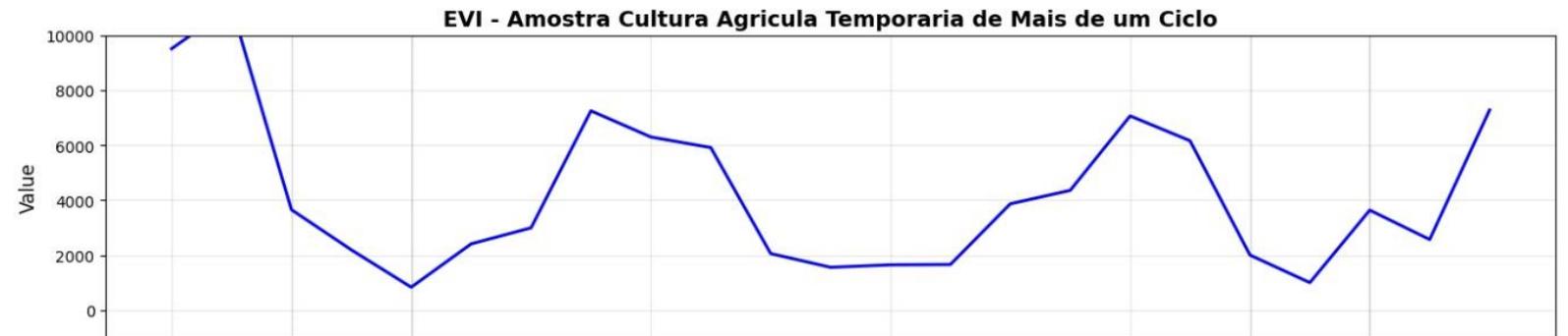
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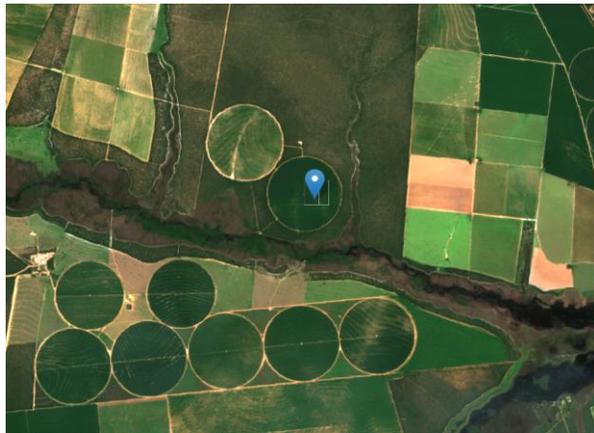
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# Agricultura - mais de 1 ciclo – Cubos Sentinel 2



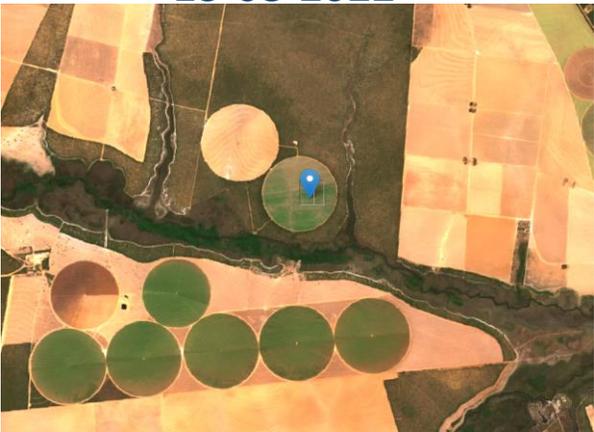
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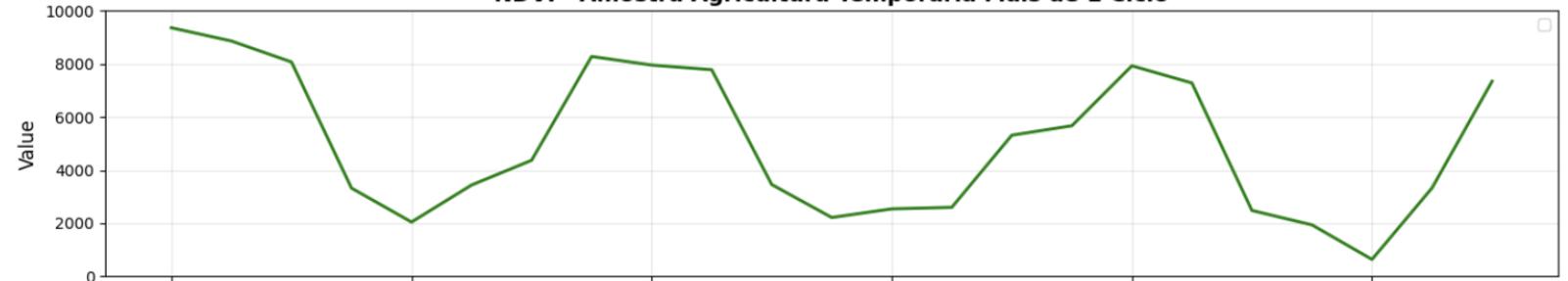


# Agricultura - mais de 1 ciclo – Cubos Sentinel 2

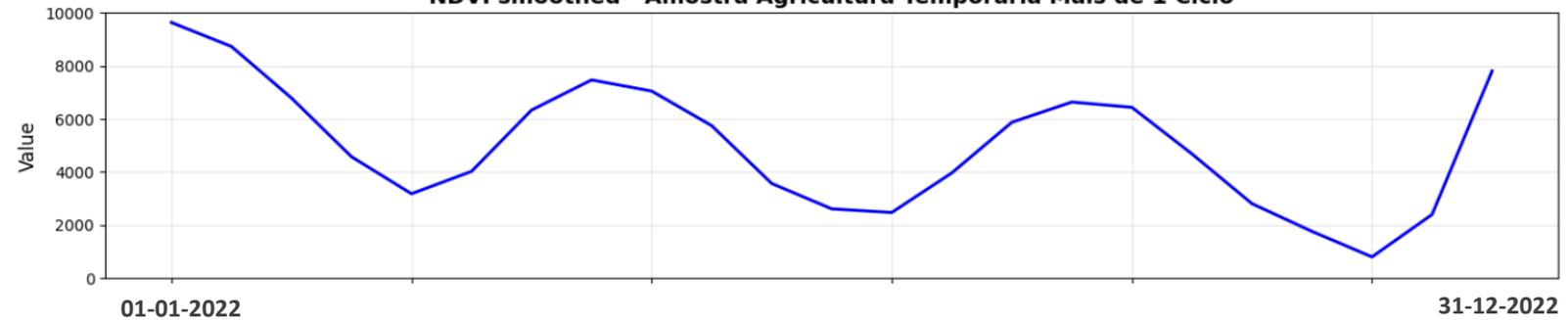


BRAZIL  
DATA CUBE

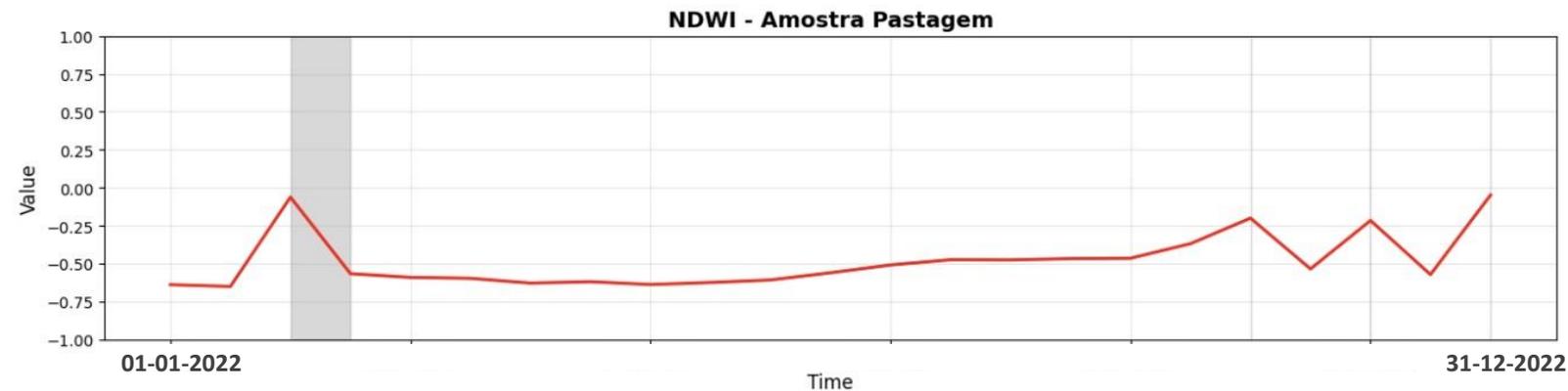
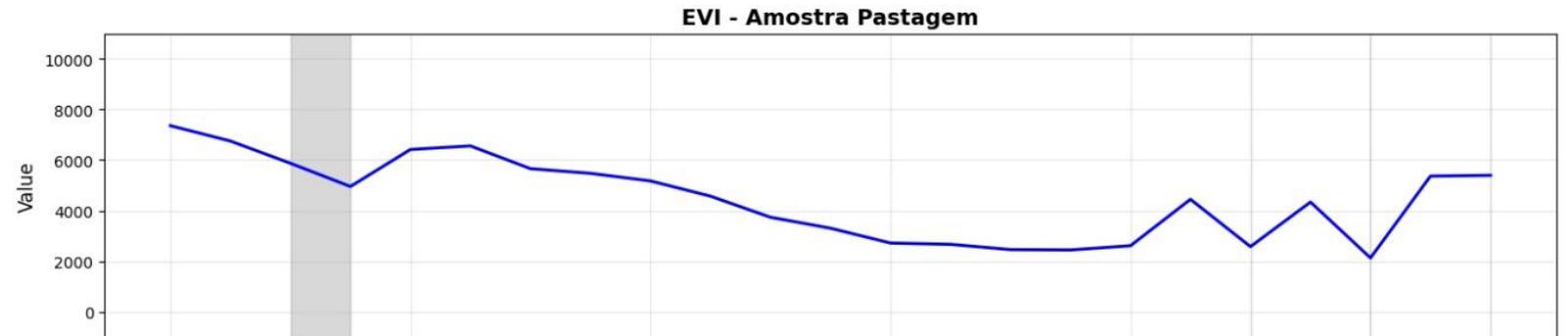
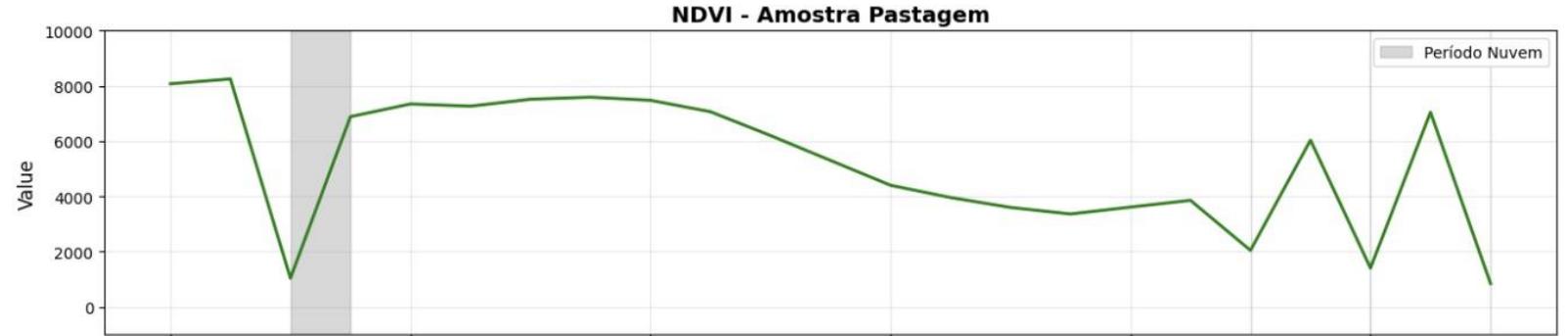
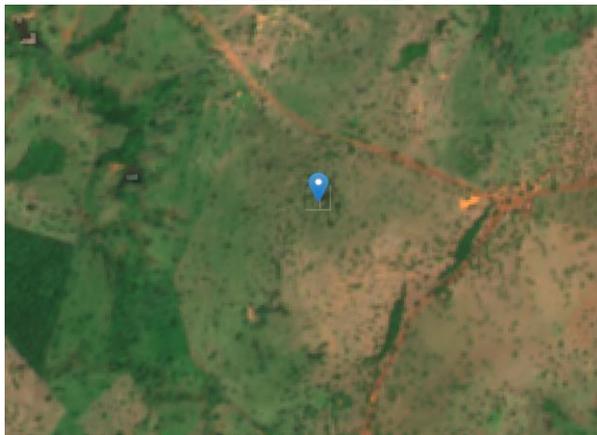
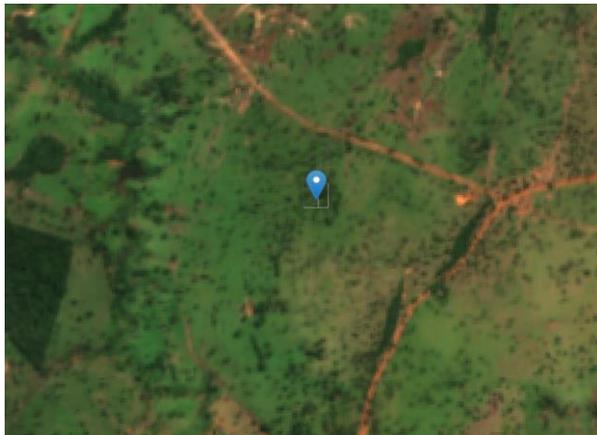
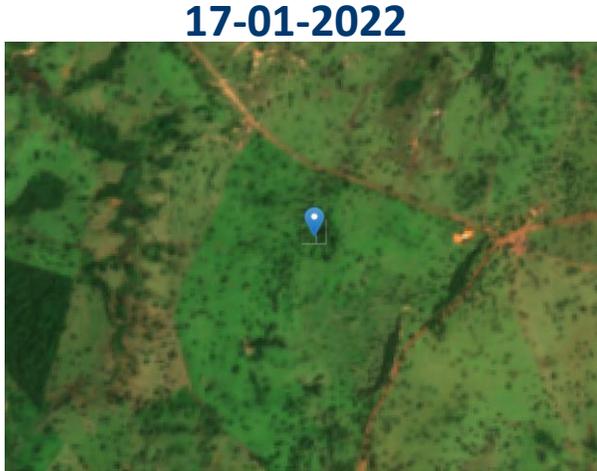
NDVI - Amostra Agricultura Temporária Mais de 1 Ciclo



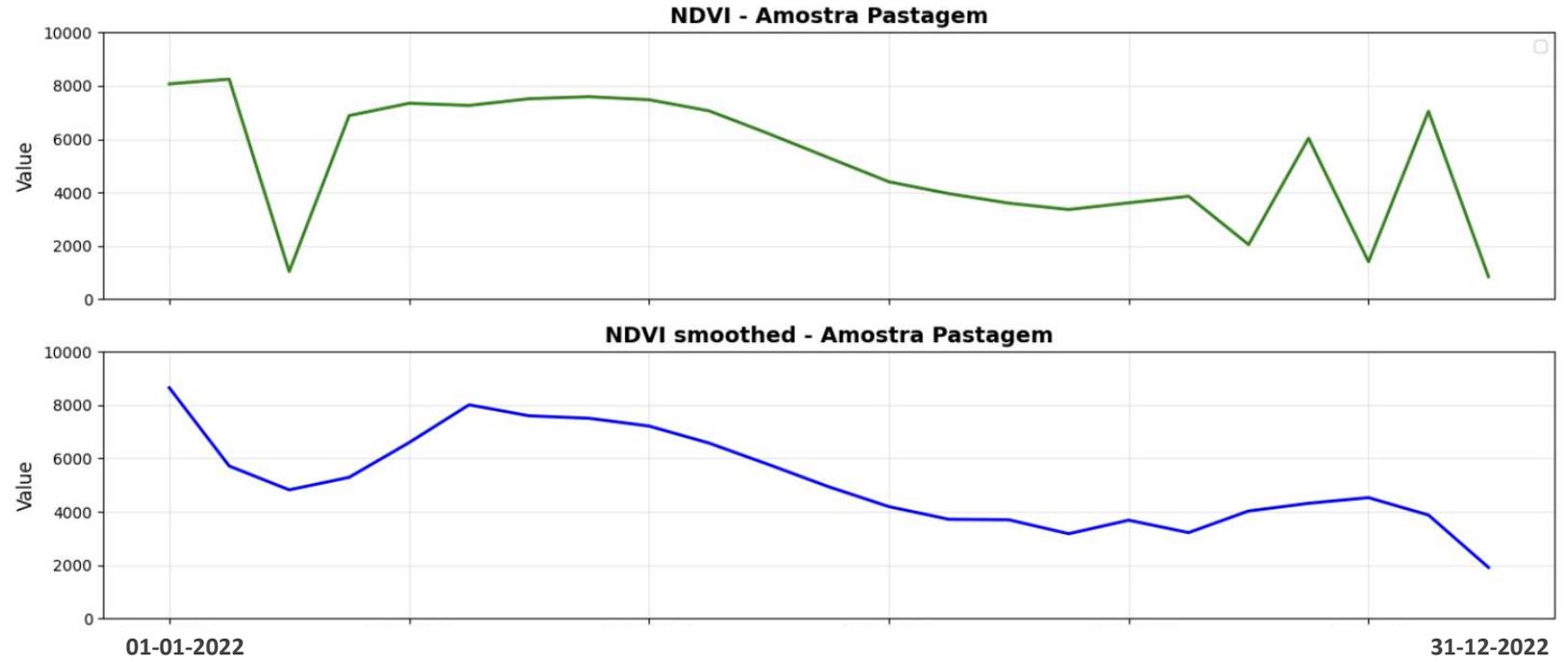
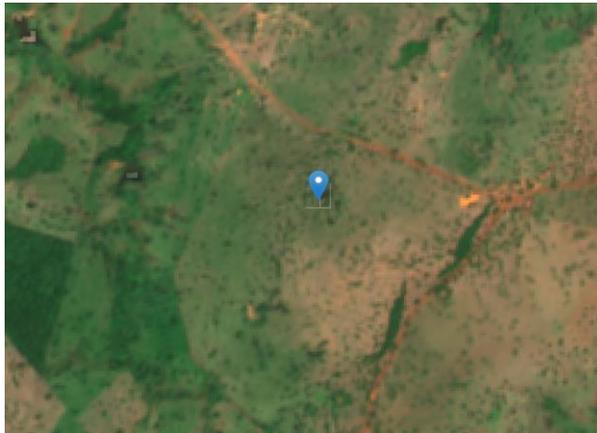
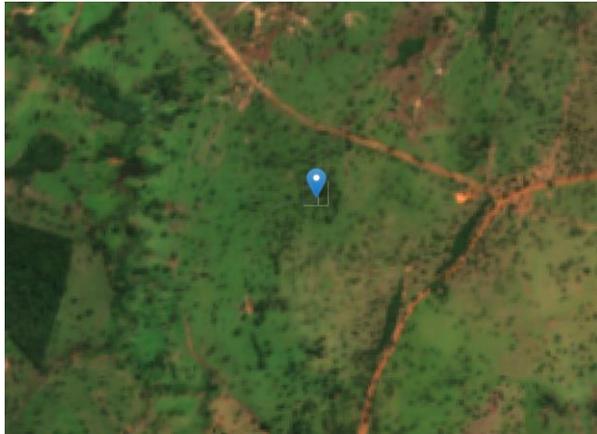
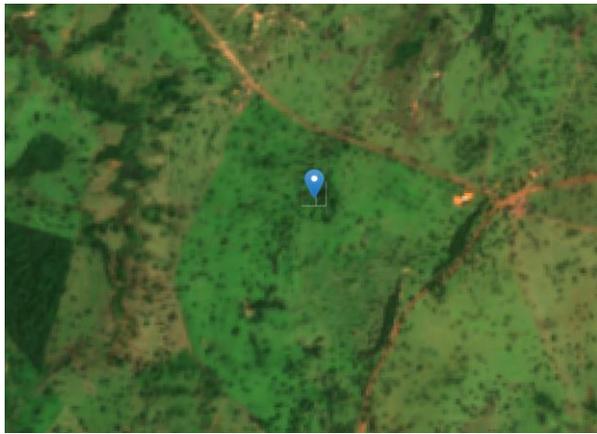
NDVI smoothed - Amostra Agricultura Temporária Mais de 1 Ciclo



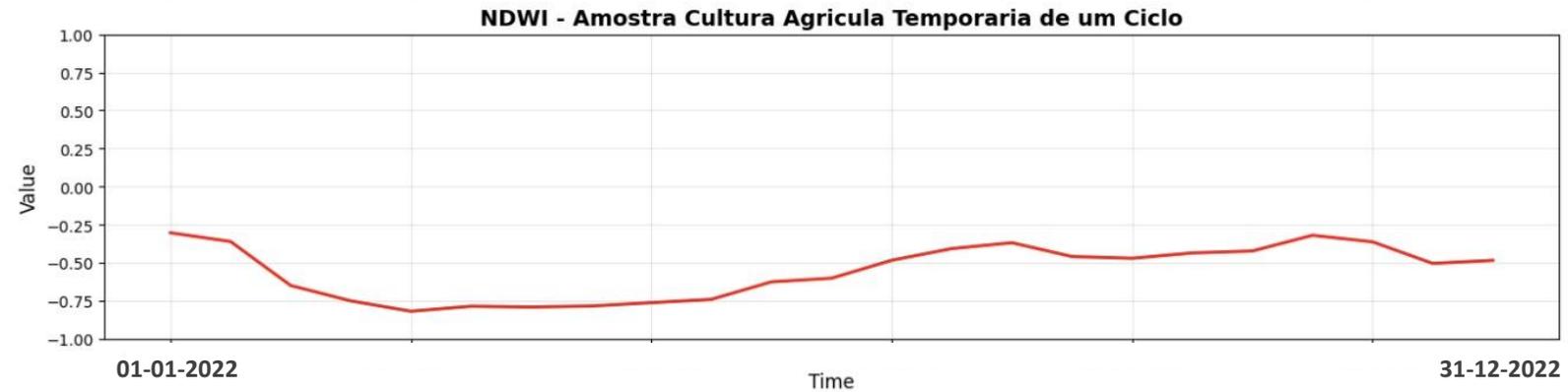
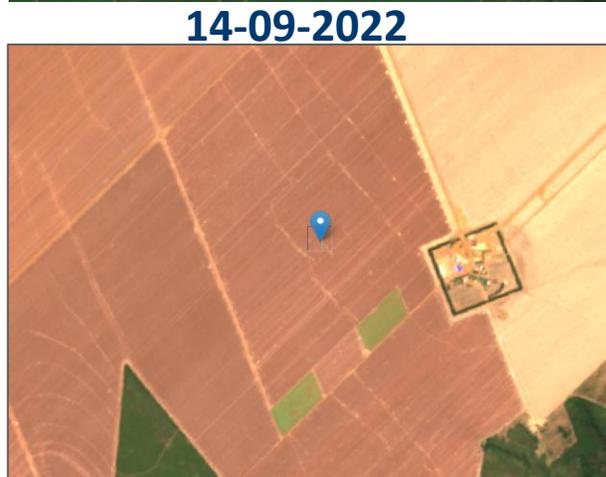
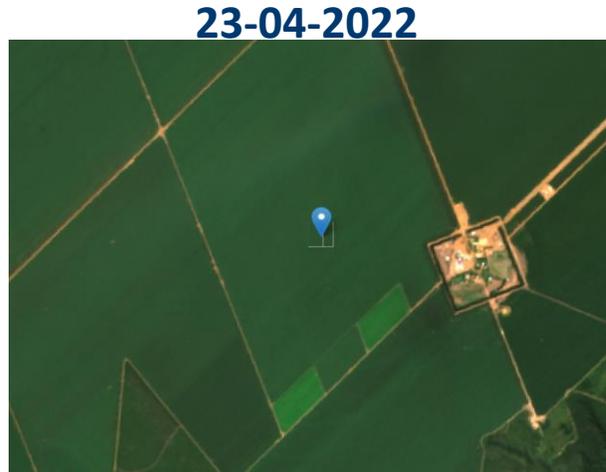
# Pastagem – Cubos Sentinel 2



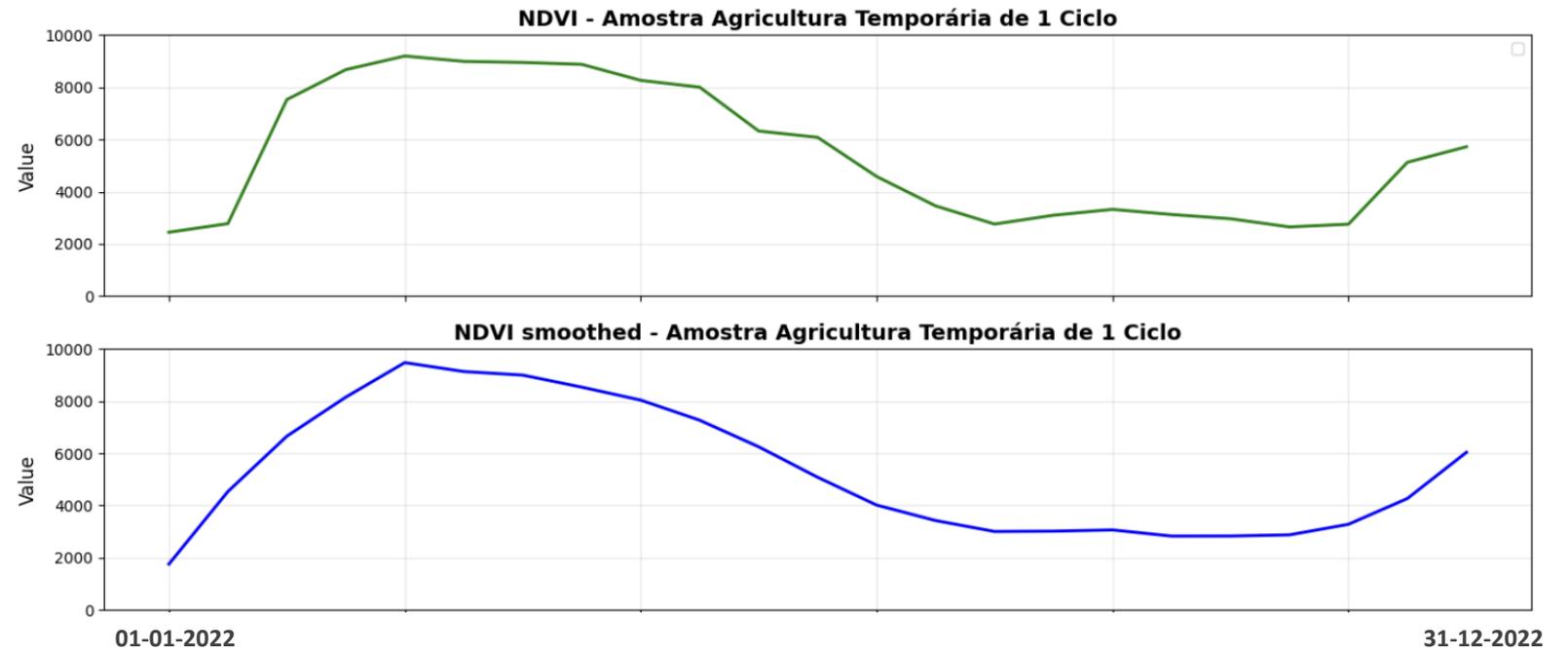
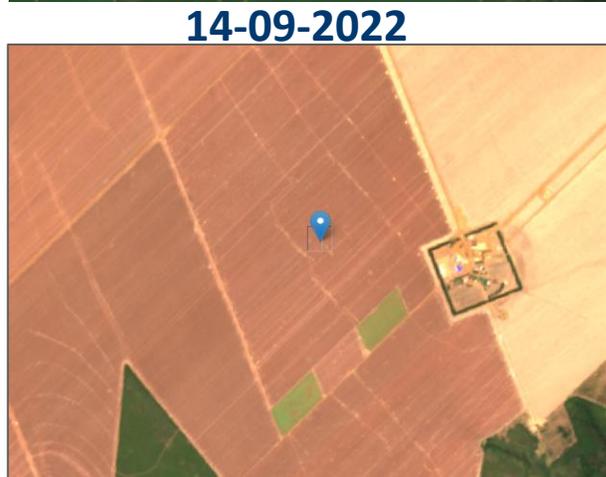
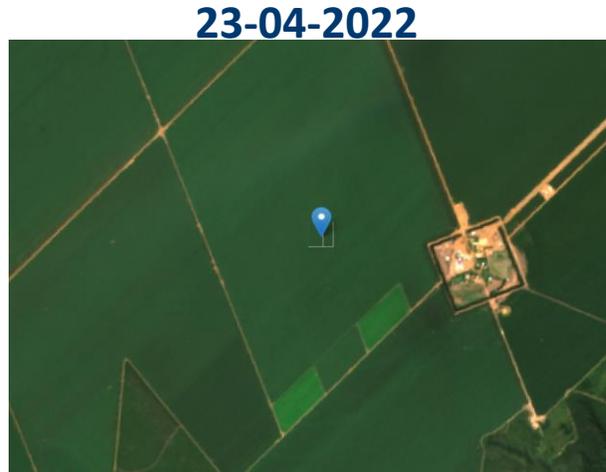
# Pastagem – Cubos Sentinel 2



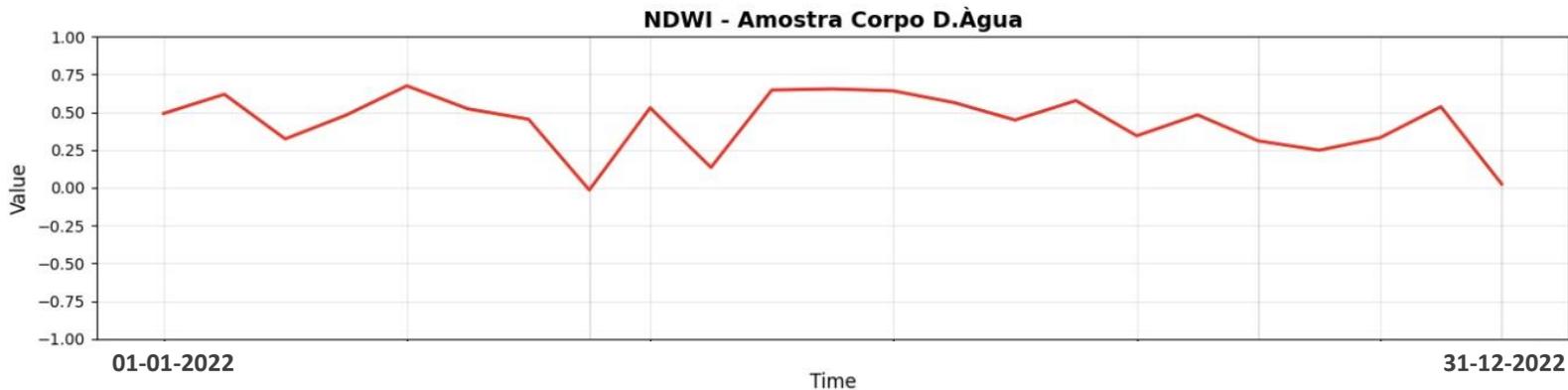
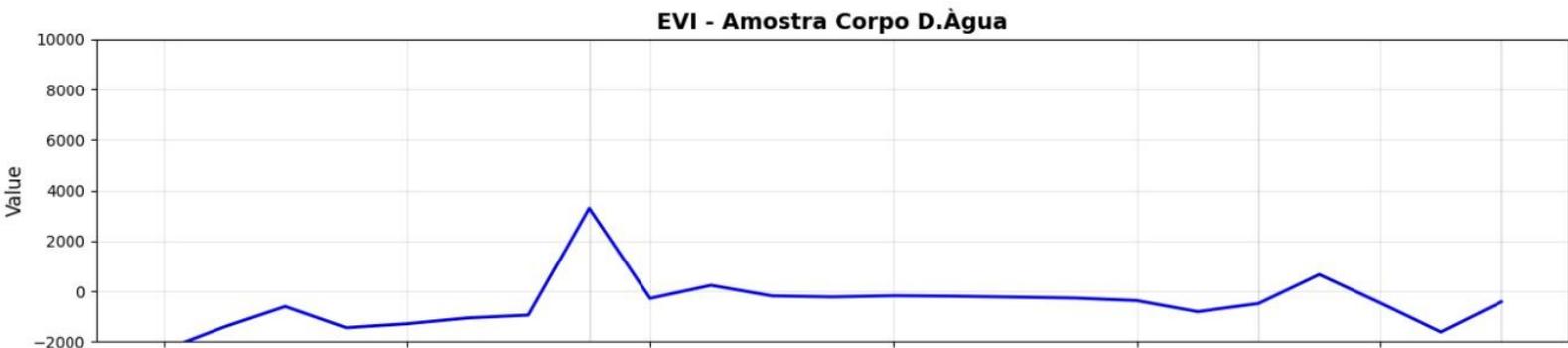
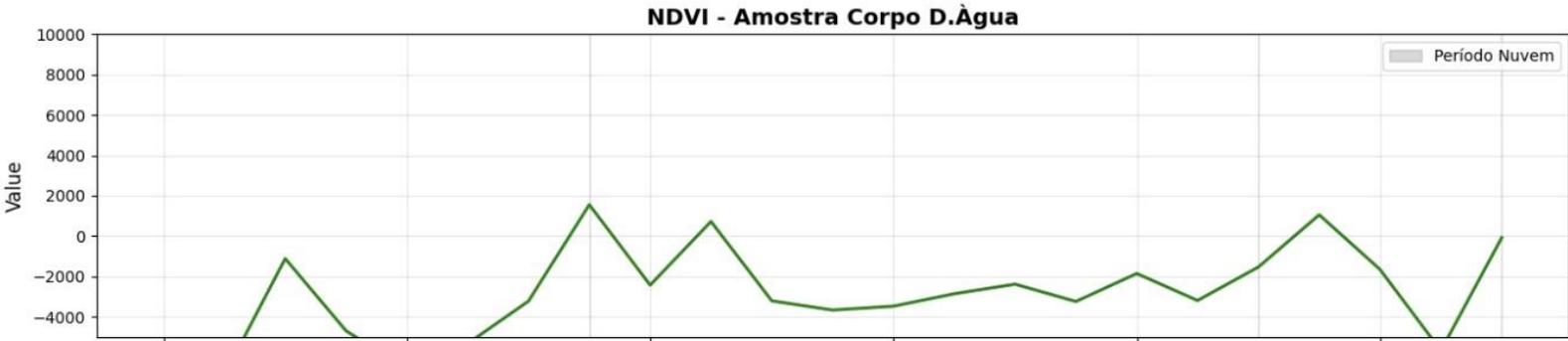
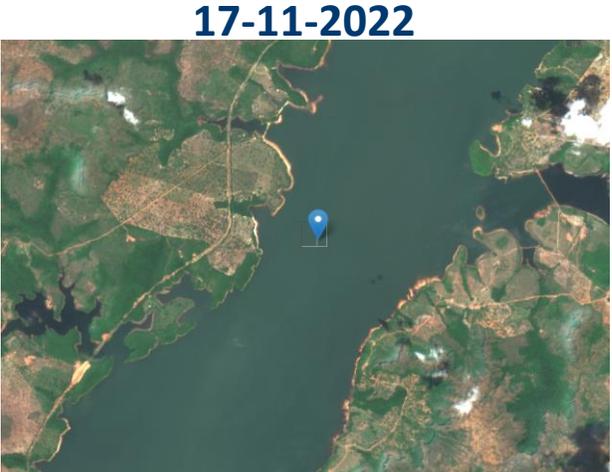
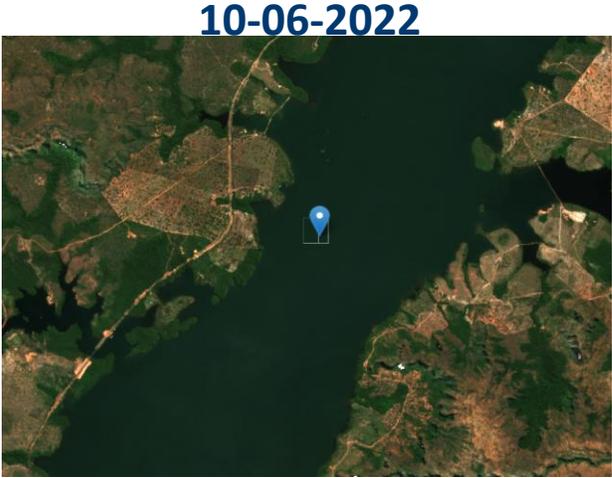
# Agricultura – 1 ciclo – Cubos Sentinel 2



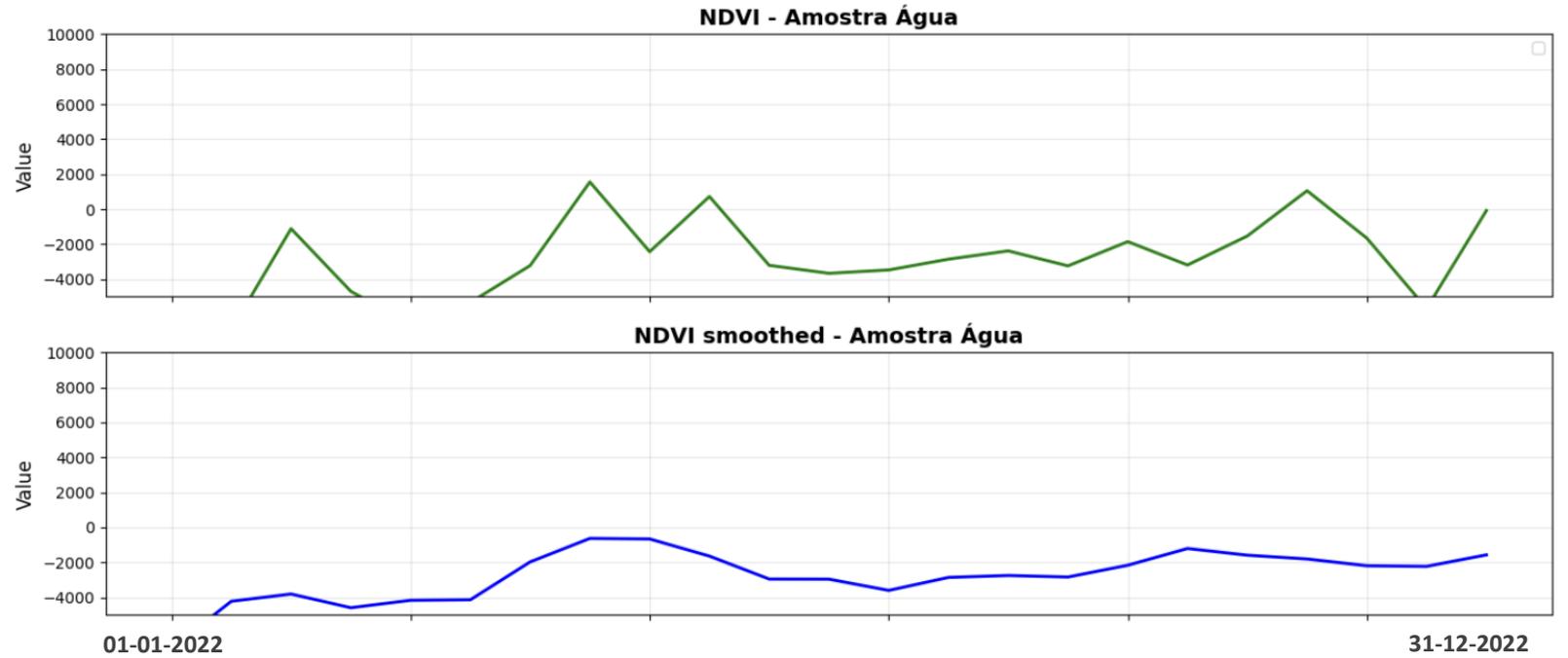
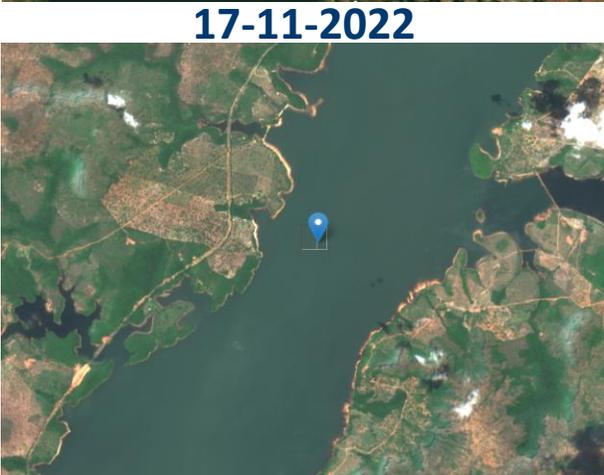
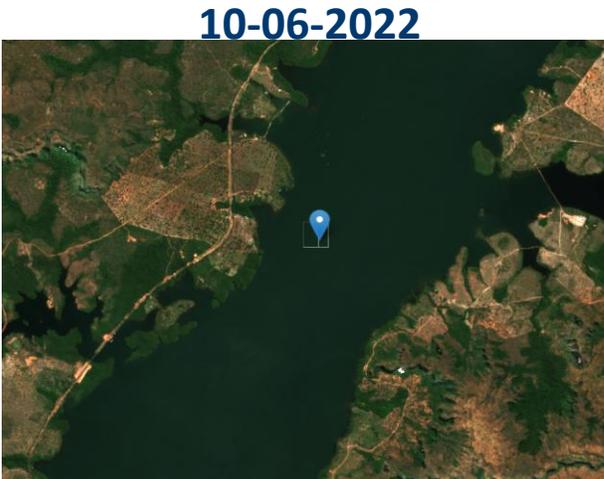
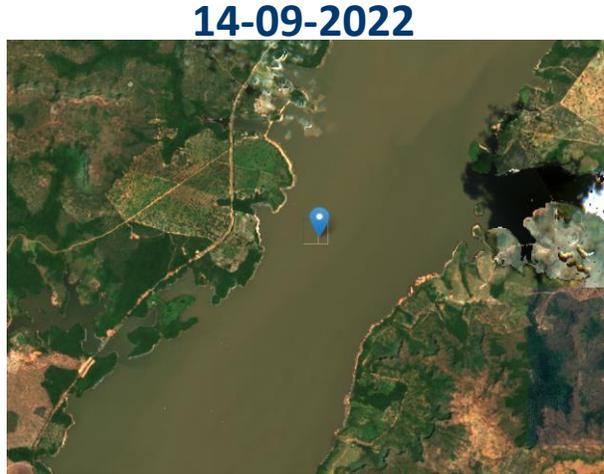
# Agricultura – 1 ciclo – Cubos Sentinel 2



# Água – Cubos Sentinel 2



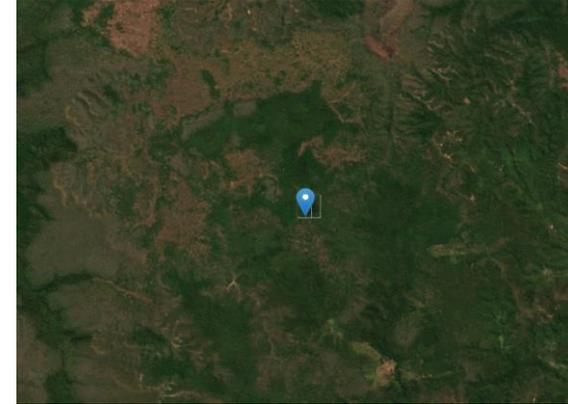
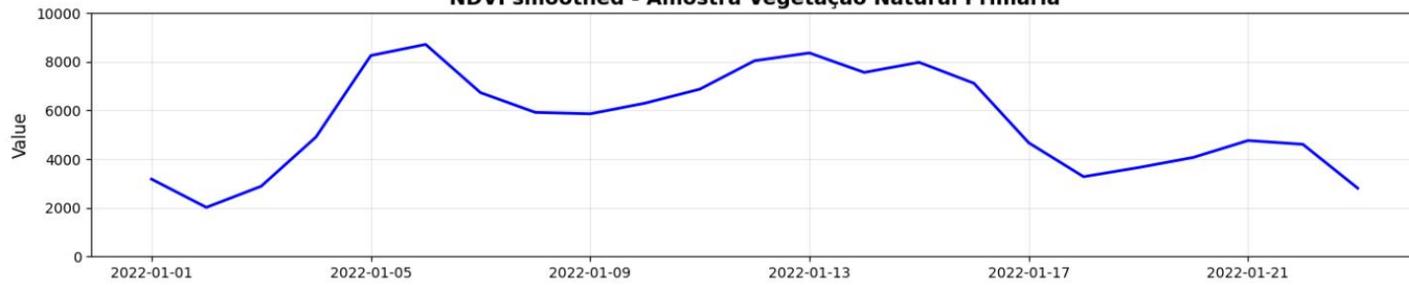
# Água – Cubos Sentinel 2



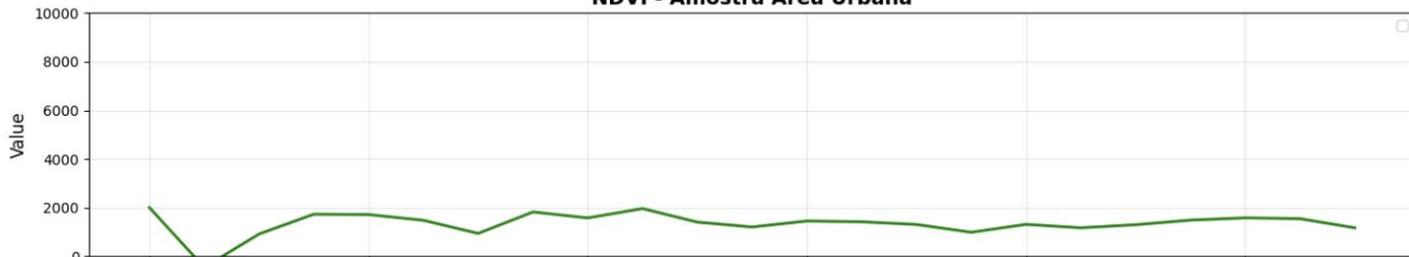
**NDVI - Amostra Vegetação Natural Primária**



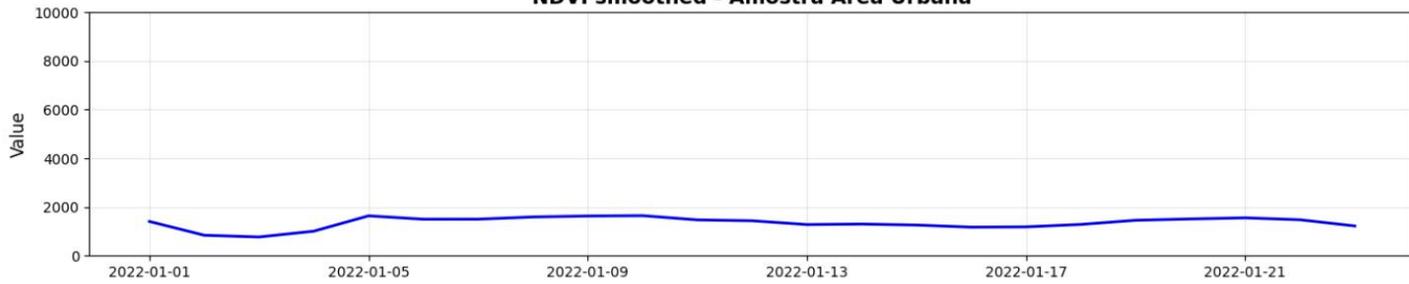
**NDVI smoothed - Amostra Vegetação Natural Primária**



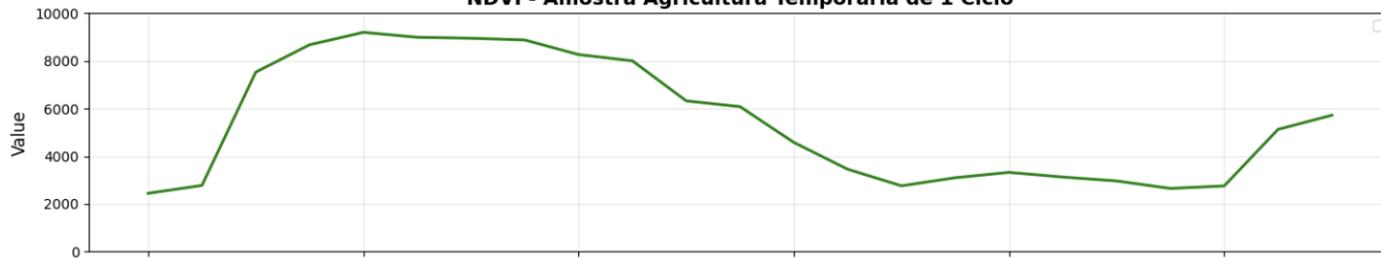
**NDVI - Amostra Área Urbana**



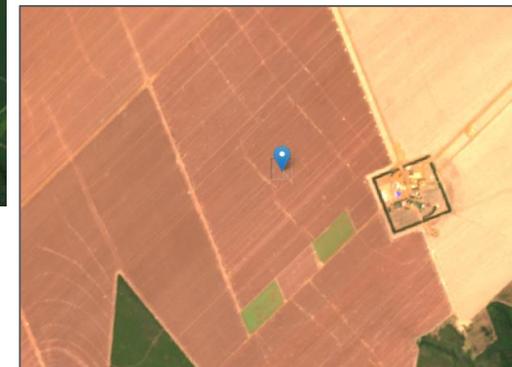
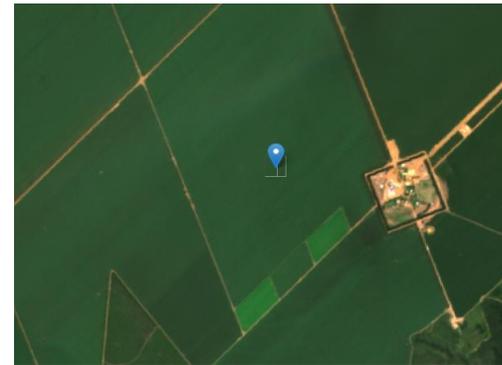
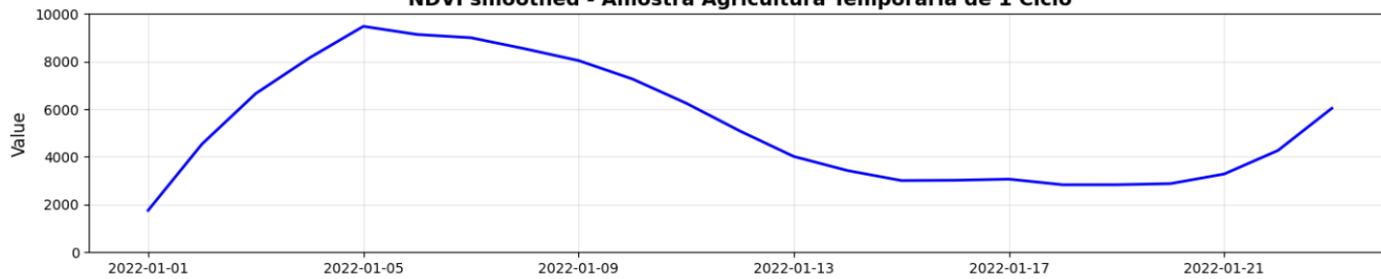
**NDVI smoothed - Amostra Área Urbana**



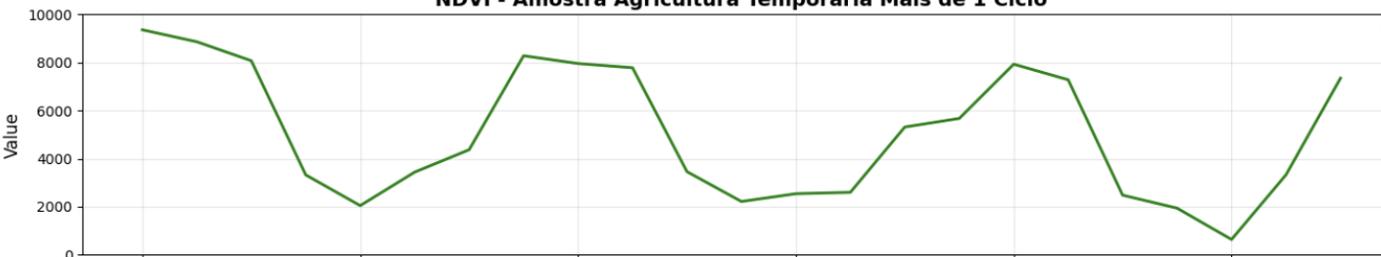
**NDVI - Amostra Agricultura Temporária de 1 Ciclo**



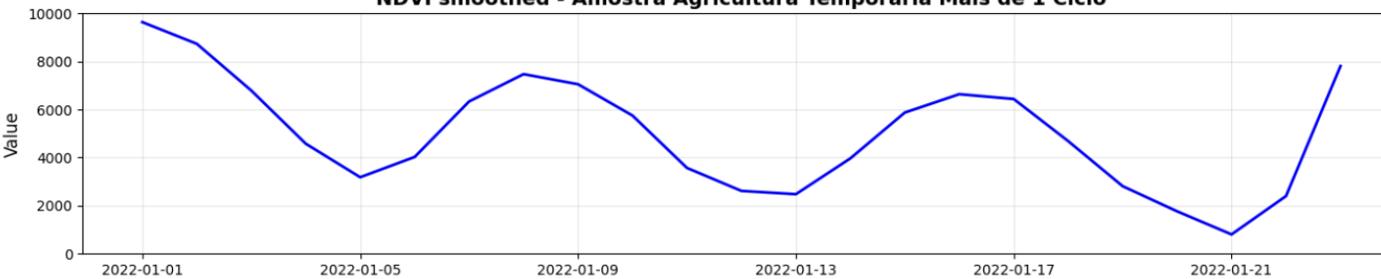
**NDVI smoothed - Amostra Agricultura Temporária de 1 Ciclo**



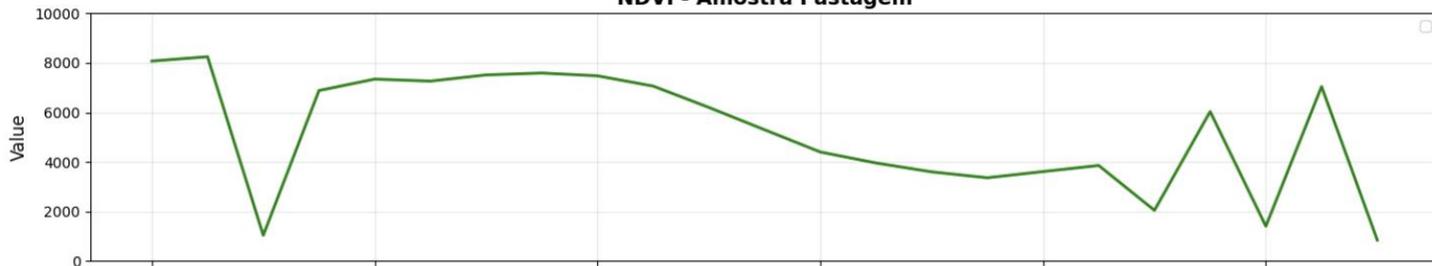
**NDVI - Amostra Agricultura Temporária Mais de 1 Ciclo**



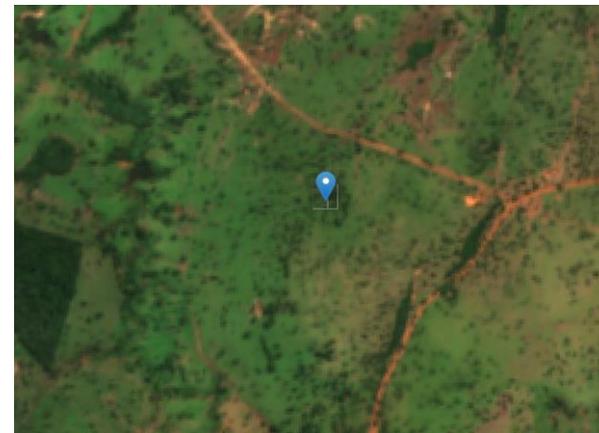
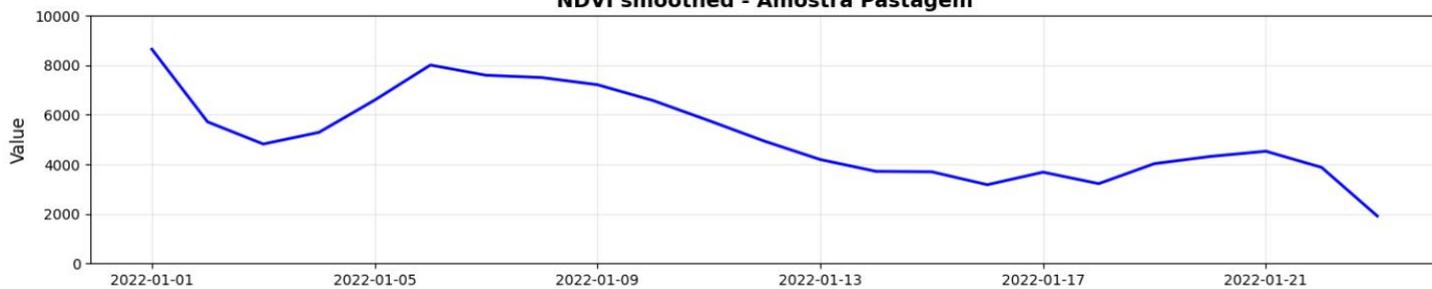
**NDVI smoothed - Amostra Agricultura Temporária Mais de 1 Ciclo**



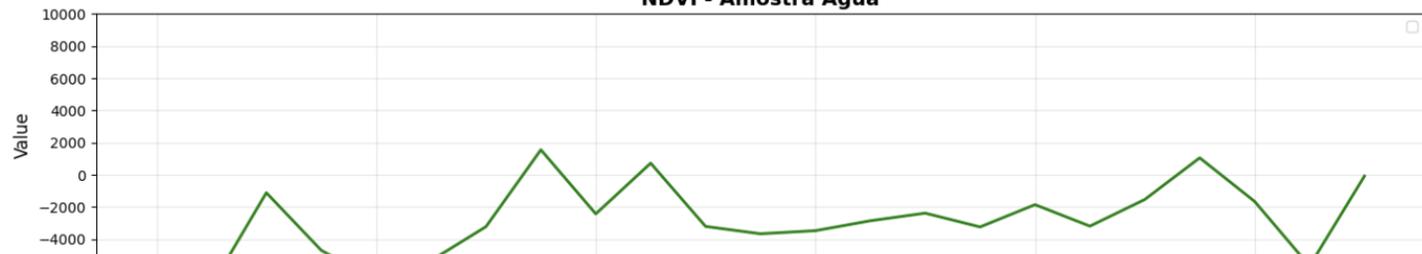
**NDVI - Amostra Pastagem**



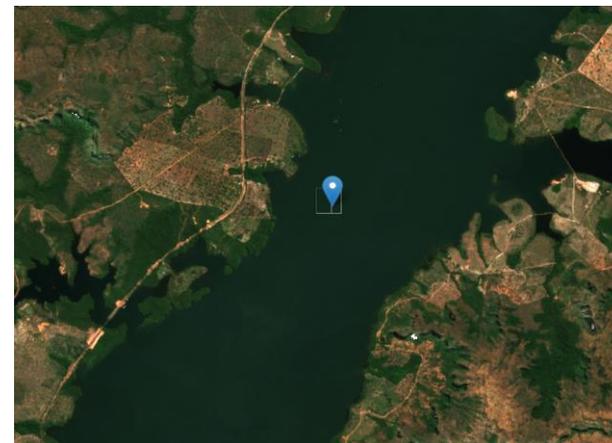
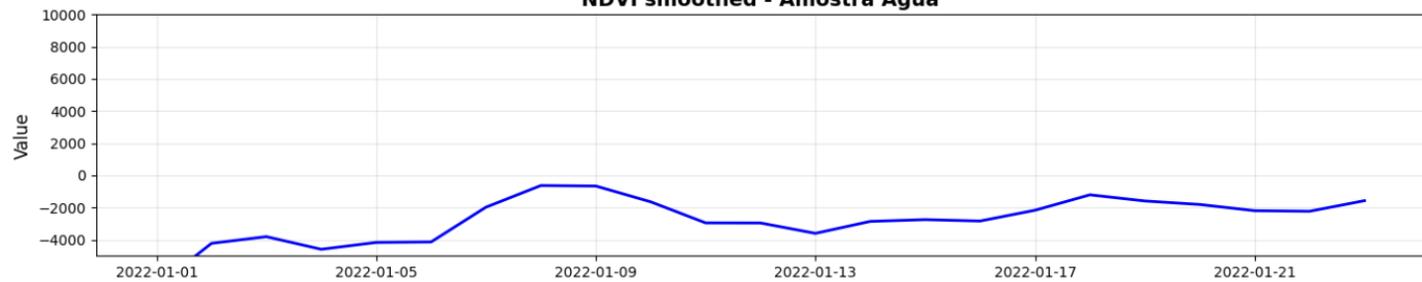
**NDVI smoothed - Amostra Pastagem**



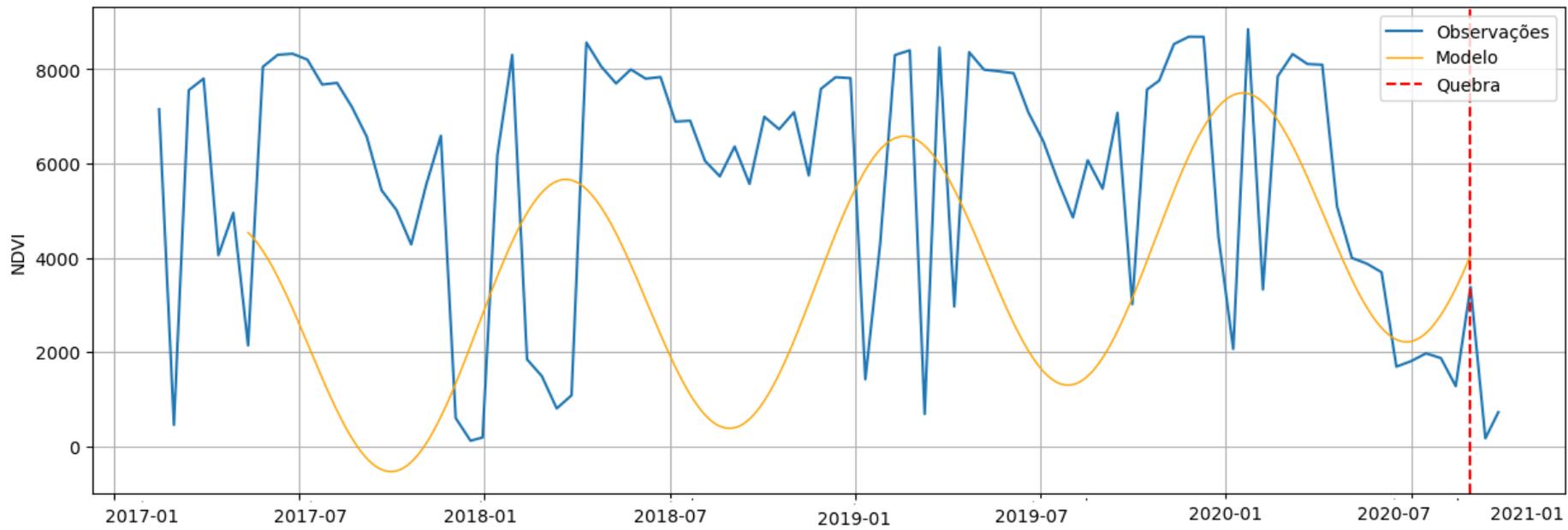
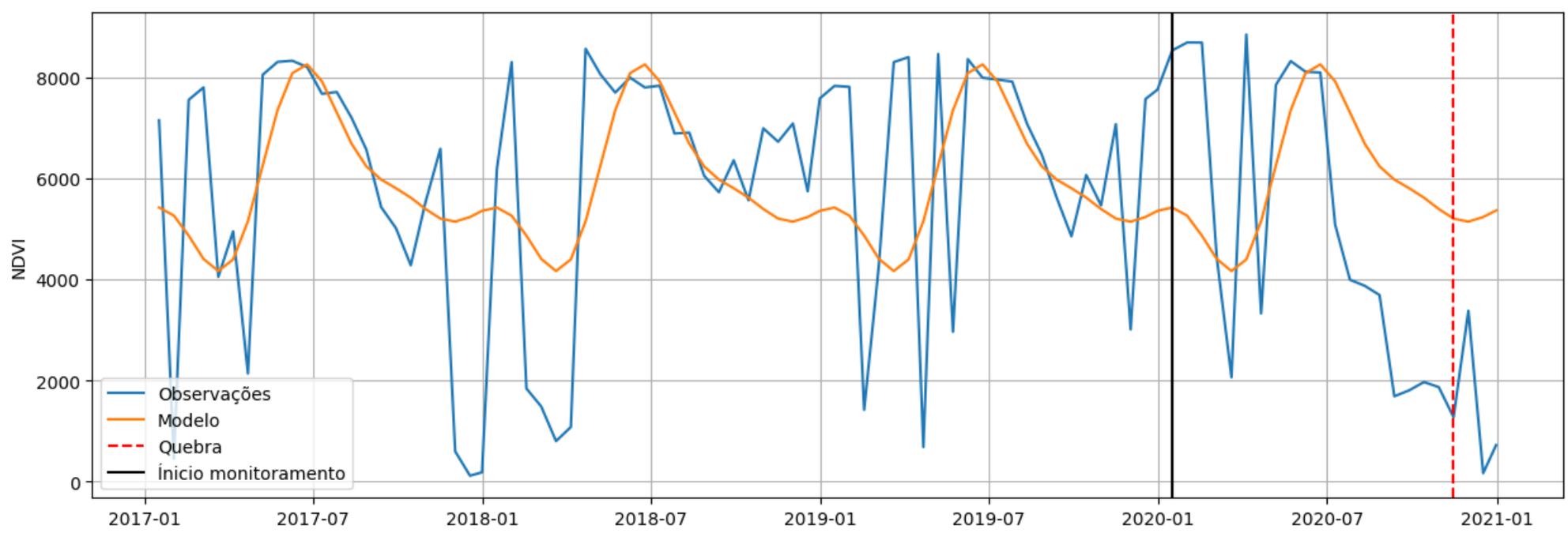
**NDVI - Amostra Água**



**NDVI smoothed - Amostra Água**

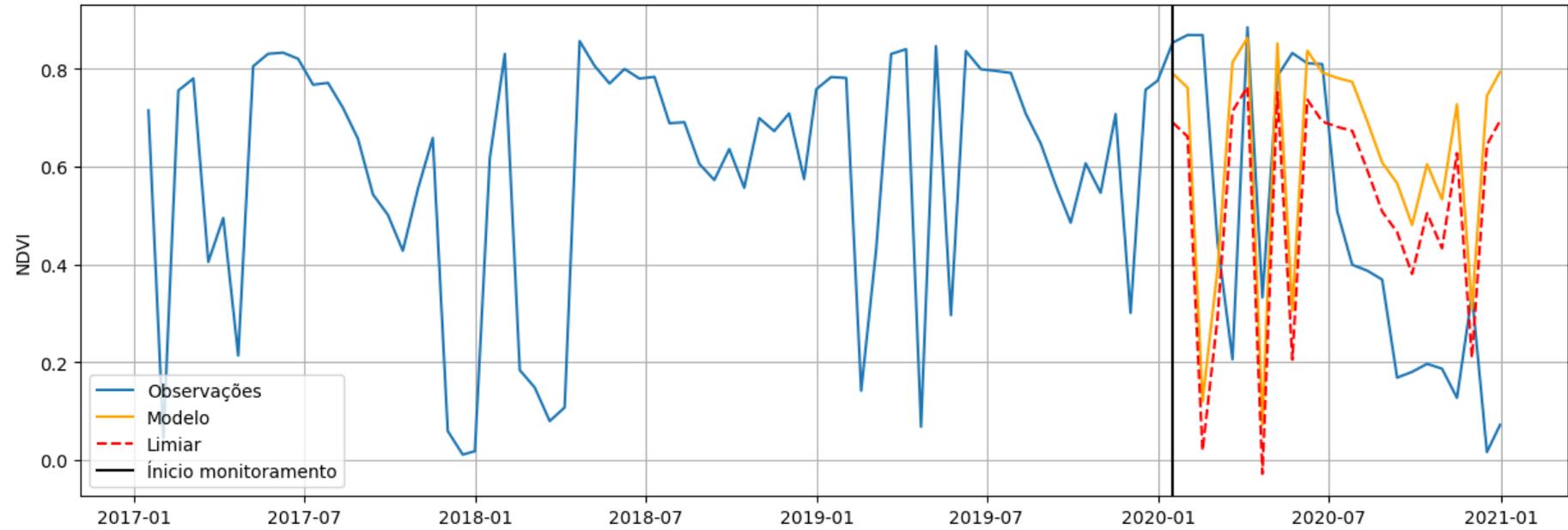


# BFAST Monitor



CCDC

# LSTM



# Satellite Image Time Series (SITS) Analysis

Classification of  
SITS

Clustering of SITS

Disturbance/Change  
Detection from SITS

Vegetation  
Phenological Metrics  
Extraction from SITS

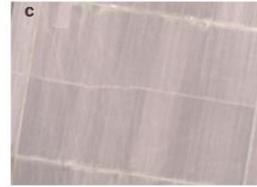
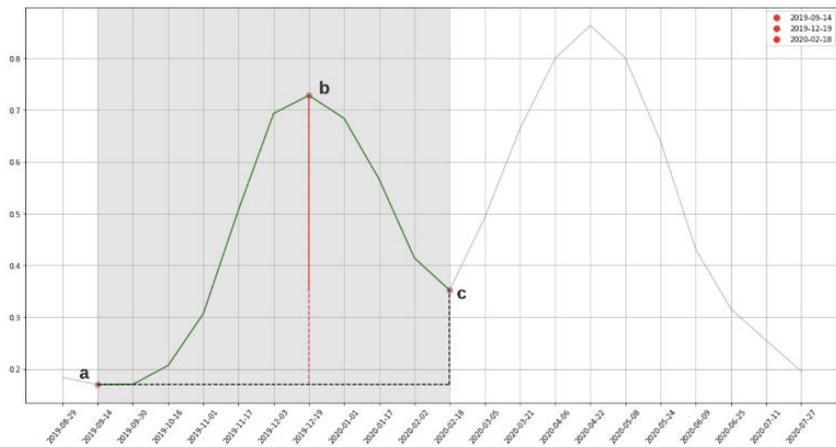
# Methods to extract vegetation phenological metrics

A review of vegetation phenological metrics extraction using time-series, multispectral satellite data, Remote Sensing of Environment, 2020 (Zeng et al., 2020)

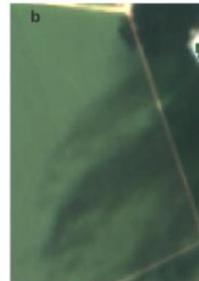
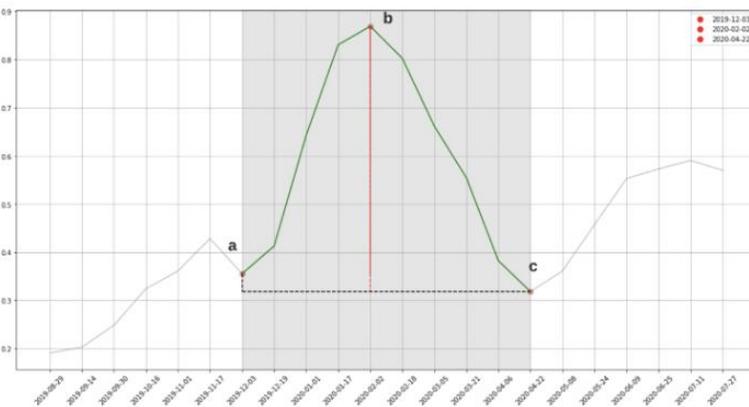
**Table 4**  
Summary of main phenological metrics extraction methods for species-specific vegetation types from satellite imagery.

Methods	Vegetation types	Sensors	Stage classification	Specific Stages	Method Classification	Reference
Line segment fitted parameters and statistics	Quercus petraea, Fagus ylvatica L	AVHRR	Physiological-based phenological stages	Budburst, senescence	Empirical Statistics method	<a href="#">Duchemin et al. (1999)</a>
Inflection points determined by derivative	Rice	MODIS	Physiological-based phenological stages	Planting, heading, and harvesting	Empirical method	<a href="#">Sakamoto et al. (2005)</a>
Based on the parameters derived from the best fitted polynomial curve	Potato	MODIS	General phenological stages	12 metrics for potato	Empirical method	<a href="#">Islam and Bala (2008)</a>
Use TIMESAT software to detect rice phenological stages	Rice	MODIS	General phenological stages	Start, peak and end of season	Empirical method	<a href="#">Boschetti et al. (2009)</a>
Derive phenological dates based on the optimum scaling parameters and shape model.	Corn and soybeans	MODIS	Physiological-based phenological stages	8 stages for corn and soybeans respectively	Phenology matching	<a href="#">Sakamoto et al. (2010)</a>
Regress the ground measure degree days and VI values	Sugarcane	ASTER	Physiological-based phenological stages	6 stages	Simulation	<a href="#">Mobasheri et al. (2010)</a>

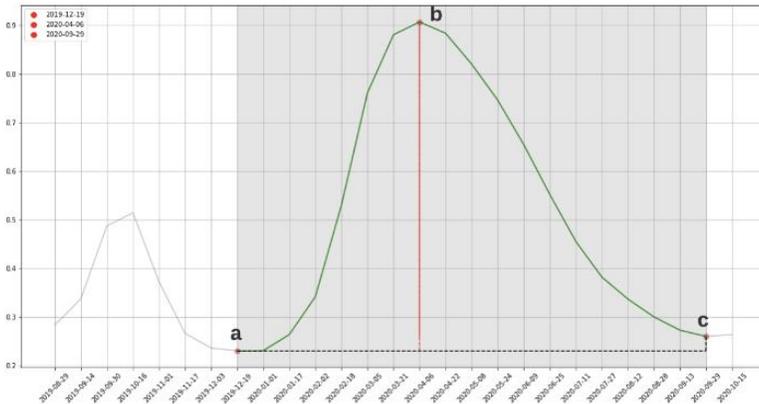
(a)



(b)

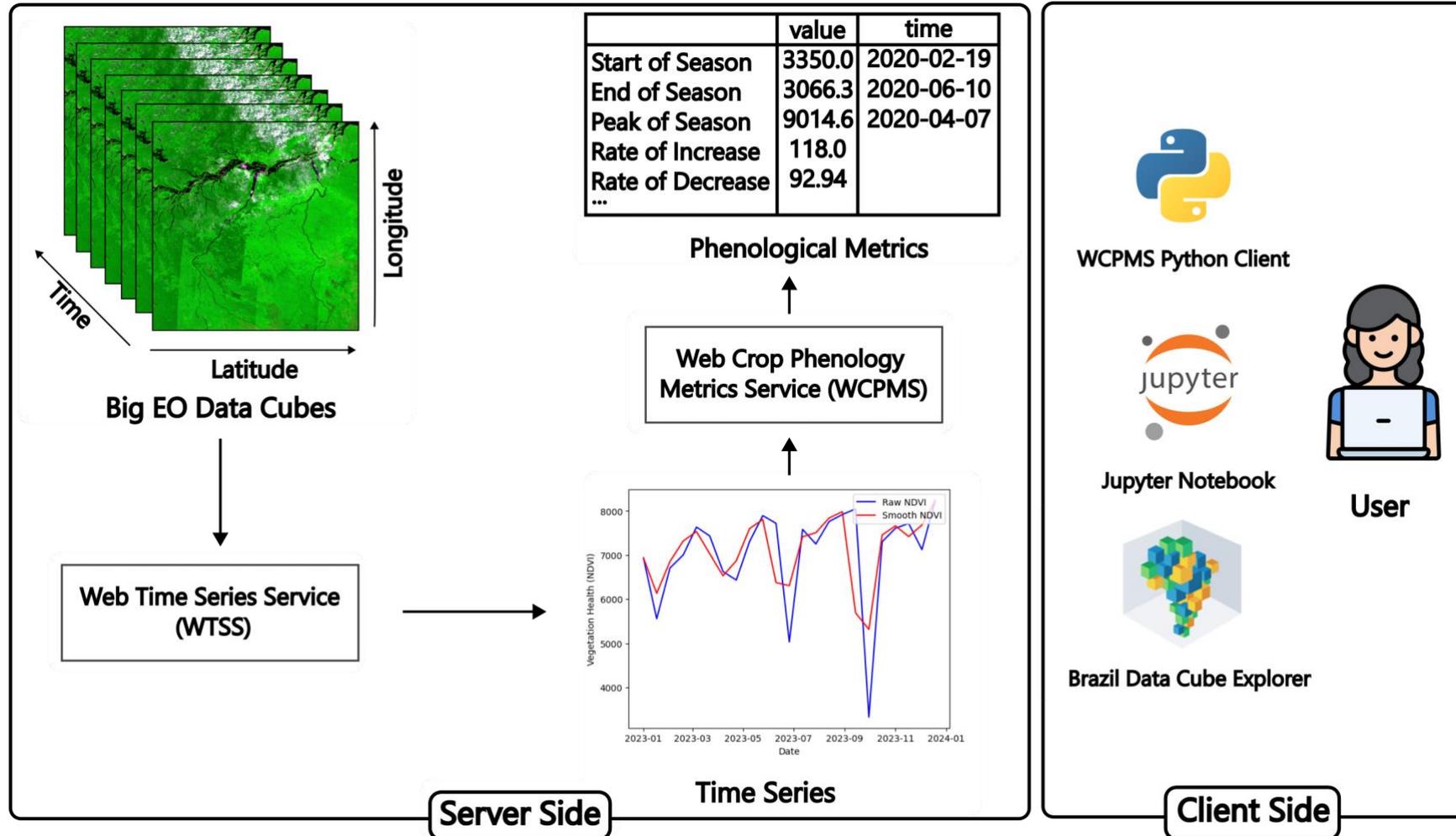


(c)

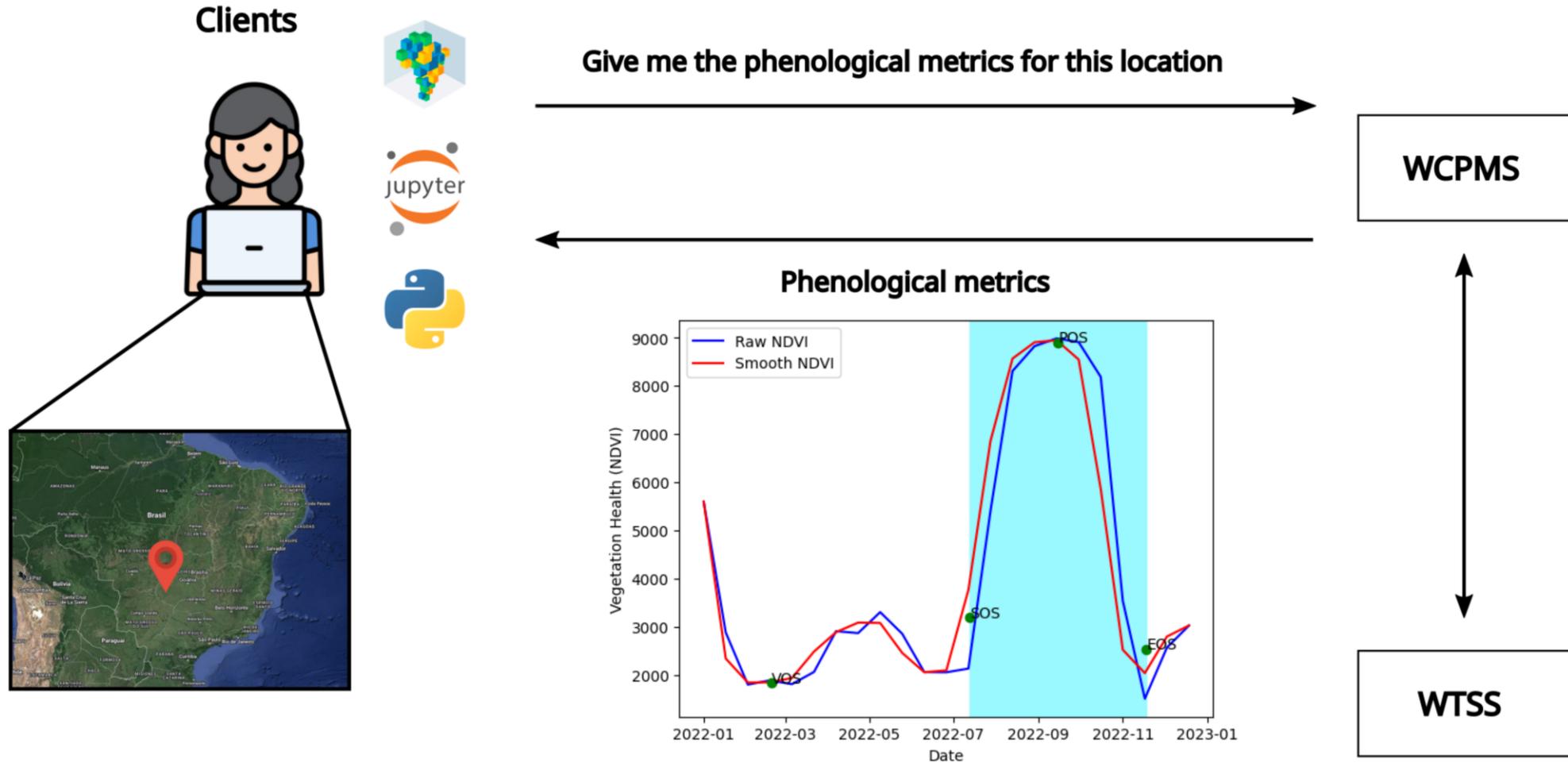


Métricas fenológicas de *início, fim e máximo vigor* vegetativo de plantio extraídas para soja (a), milho de primeira safra (b) e algodão (c) utilizando series temporais NDVI dos cubos Sentinel-2 (16 dias) do BDC.

# Web Crop Phenology Metrics Service (WCPMS)



# Web Crop Phenology Metrics Service (WCPMS)



# Web Crop Phenology Metrics Service (WCPMS)

```
plot_advanced_phenometrics(cube=datacube, ds_phenos=pms[9], shape=polygon, start_sowing="ope_inici  
o_plantio", end_sowing="ope_fim_plantio", start_harvesting="ope_inicio_colheita", end_harvesting  
="ope_fim_colheita")
```

