Geopública 2025 SotM BR 2025 STATE OF THE MAP BRASIL

BRAZIL DATA CUBE

BRAZIL DATA CUBE

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

Karine Ferreira

INPE – Instituto Nacional de Pesquisas Espaciais

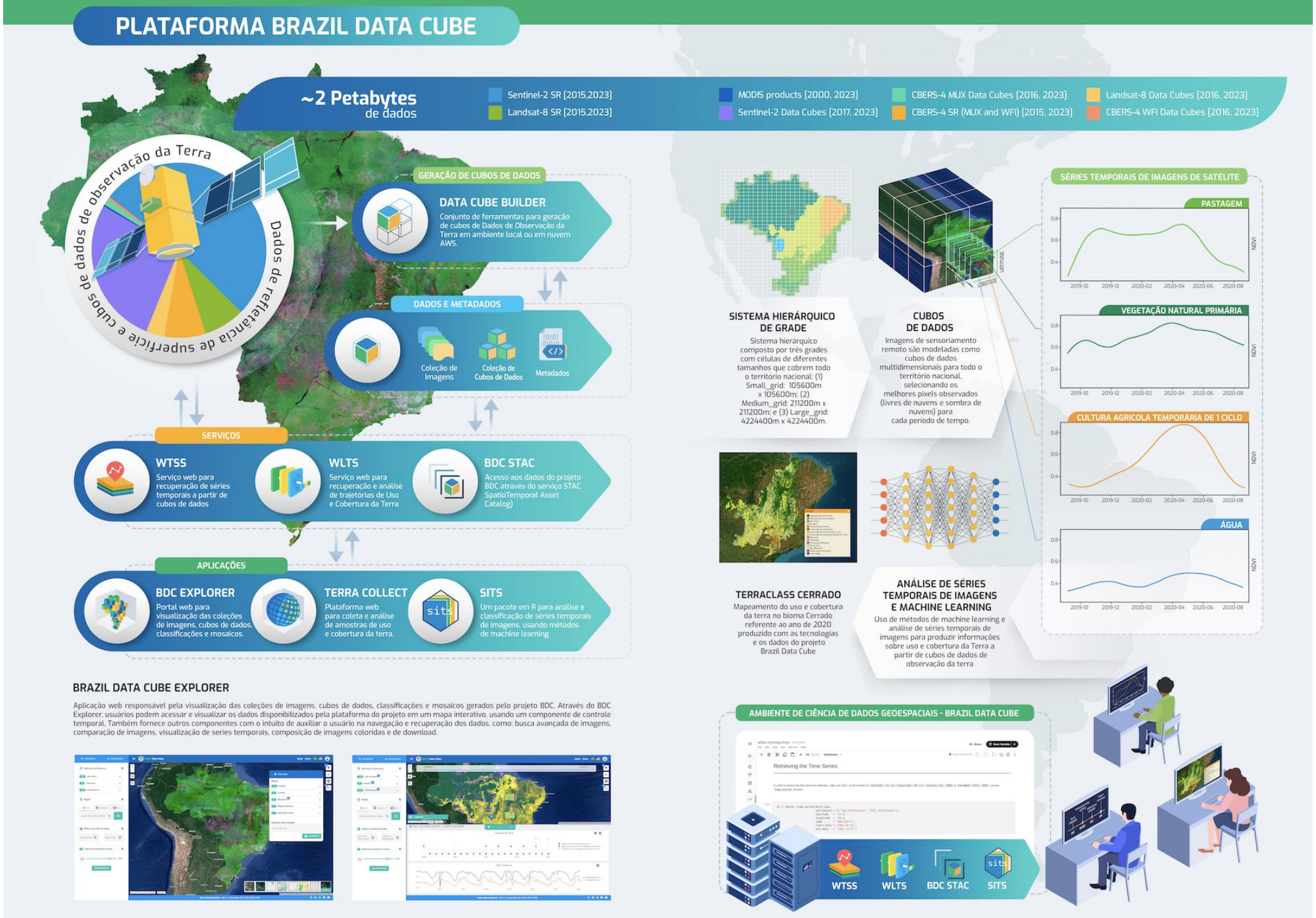
MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

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.



National Institute for Space Research (INPE), Brazil

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

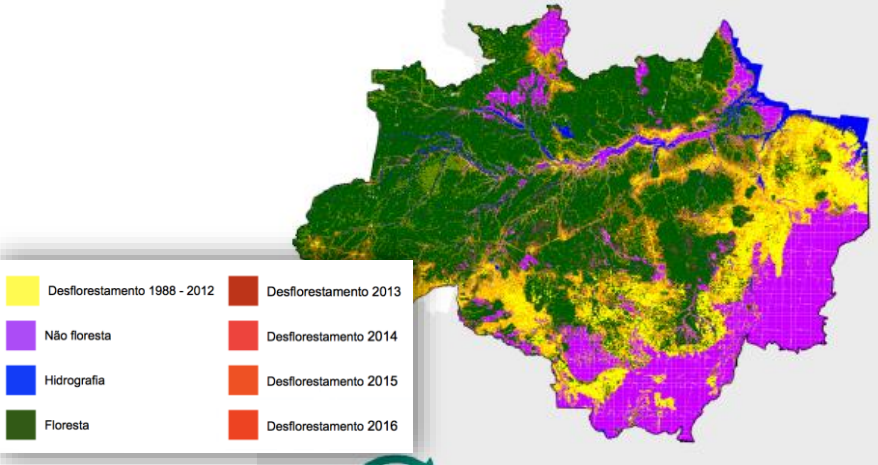
National Institute for Space Research (INPE), Brazil

Identify what the deforested areas detected have become.

PRODES

Deforestation monitoring

SINCE 1988

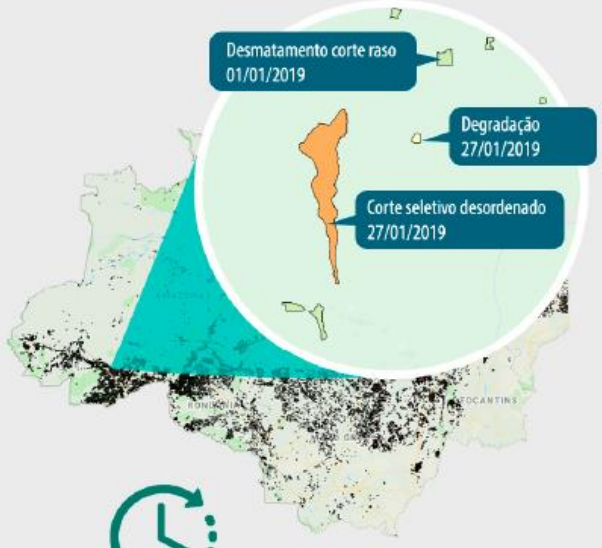


Annual maps

DETER

Near real time deforestation alerts

SINCE 2004

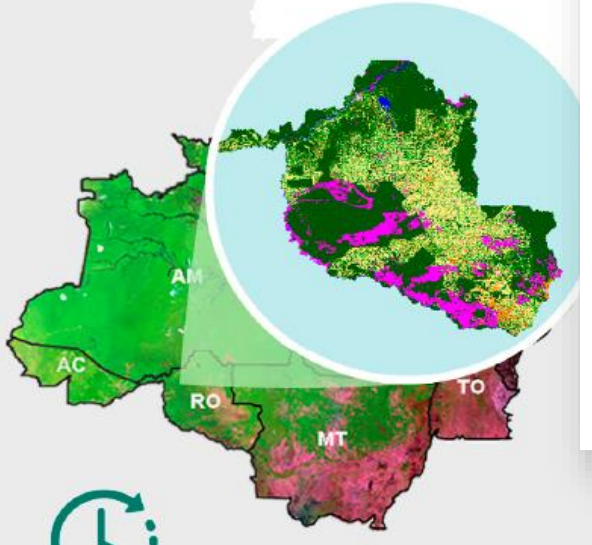


Daily alerts

TERRACLASS

Land use monitoring in deforested areas

SINCE 2004



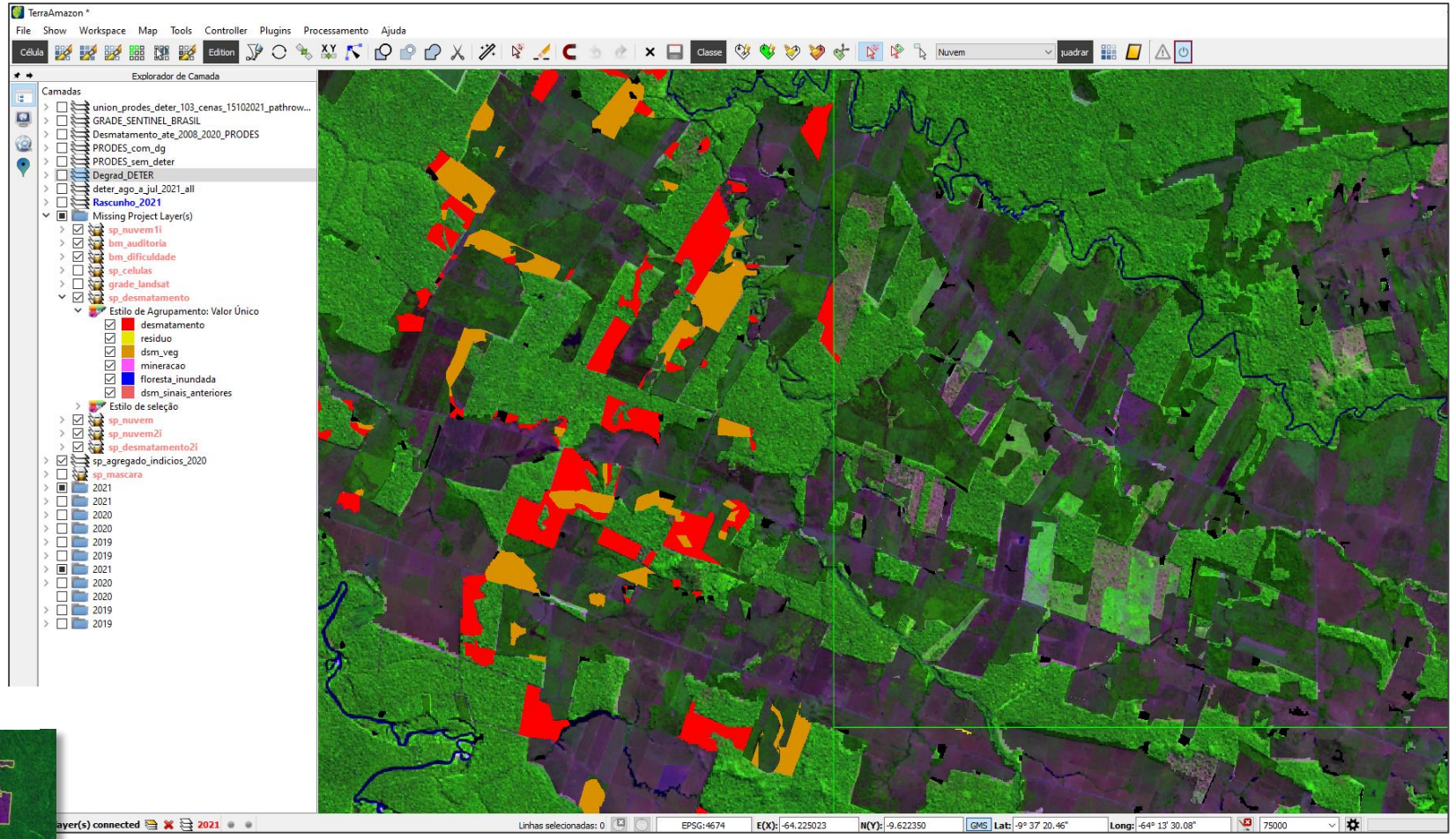
Biannual maps

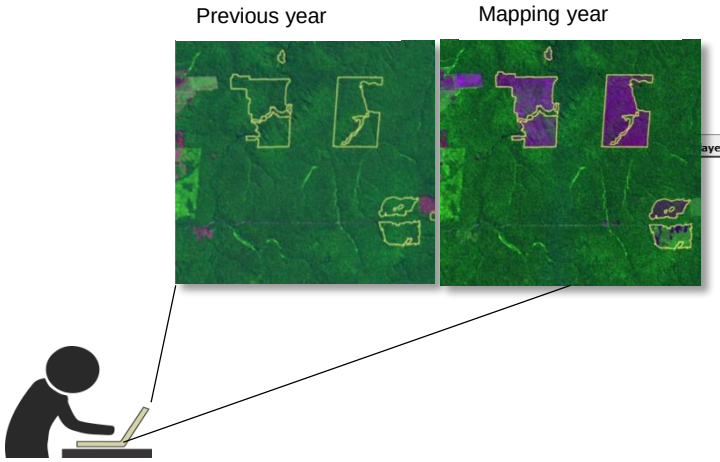
Legenda

- 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

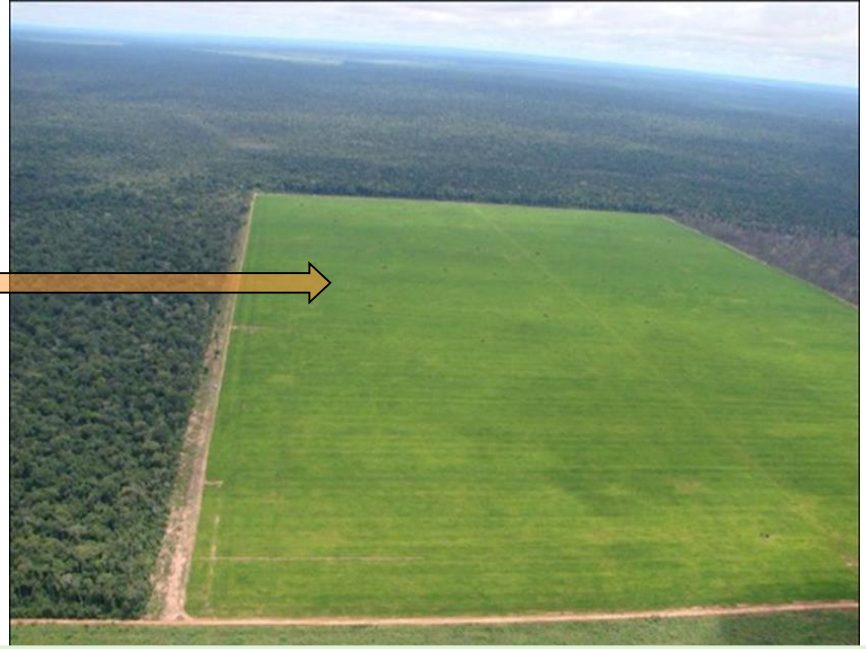
PRODES

Almeida *et al*. **Methodology for Forest Monitoring used in PRODES and DETER projects.** 2022.





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)



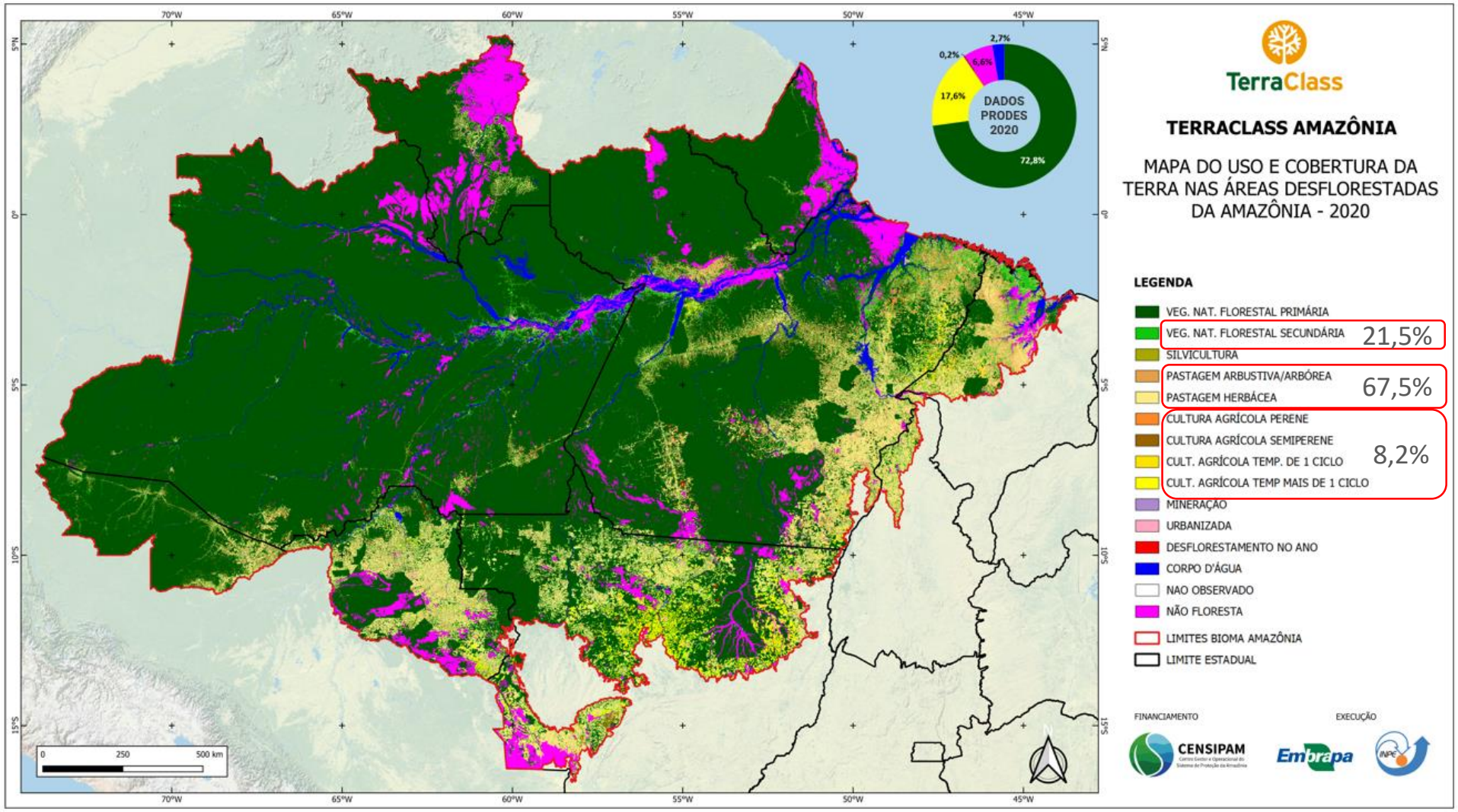
Landsat (30 meters)

Clear-cut deforestation by PRODES

Landsat (30 meters)

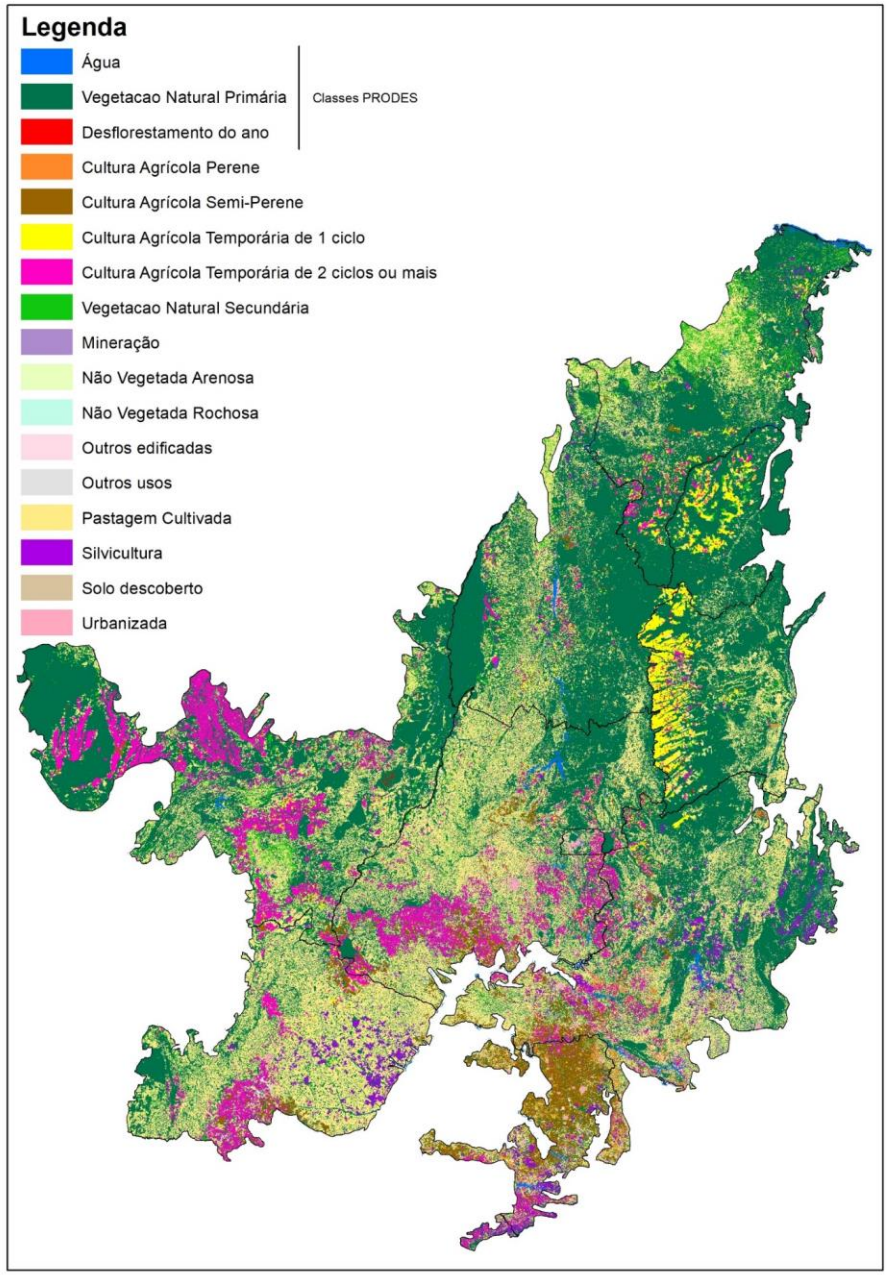
Créditos: Luis Eduardo Maurano (INPE)

Land use and land cover map – Amazon



TerraClass

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

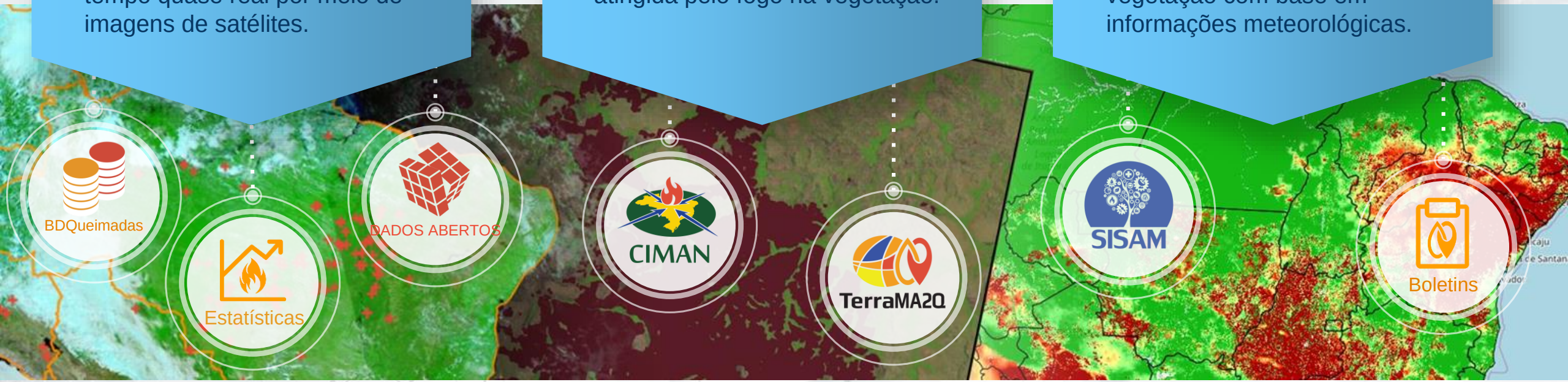
Mostra onde existe fogo ativo em tempo quase real por meio de imagens de satélites.

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

Vis. pág. Risco de Fogo & Meteorologia
78.436

Boletins diários enviados
3.819

Números deste último ano 2019/20

National Institute for Space Research (INPE), Brazil

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

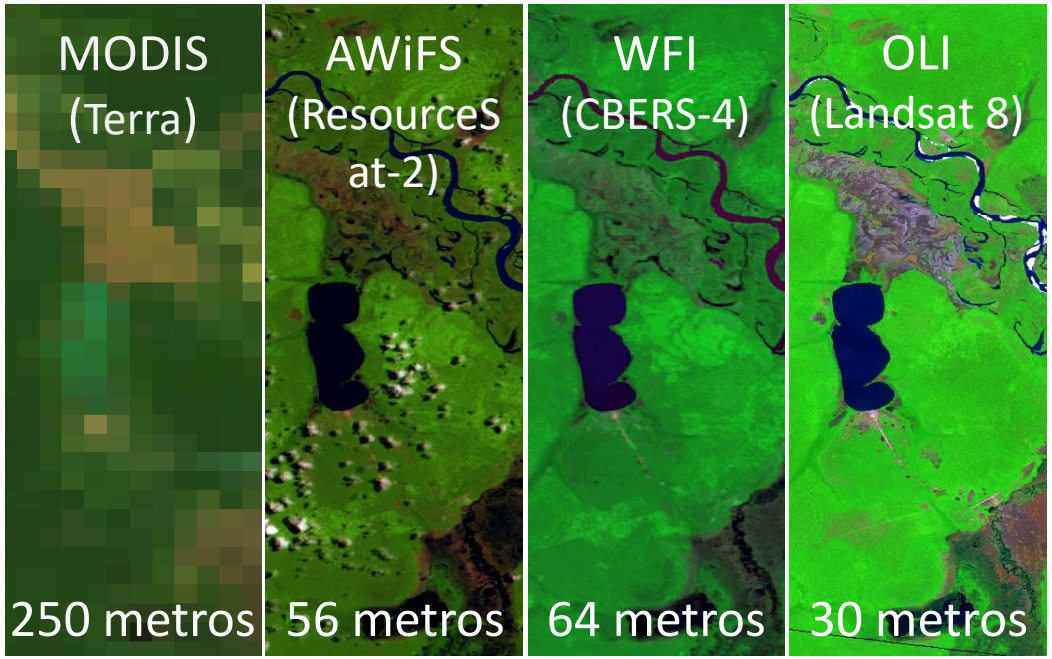
Develop innovative software systems for geospatial information management.

Open Data

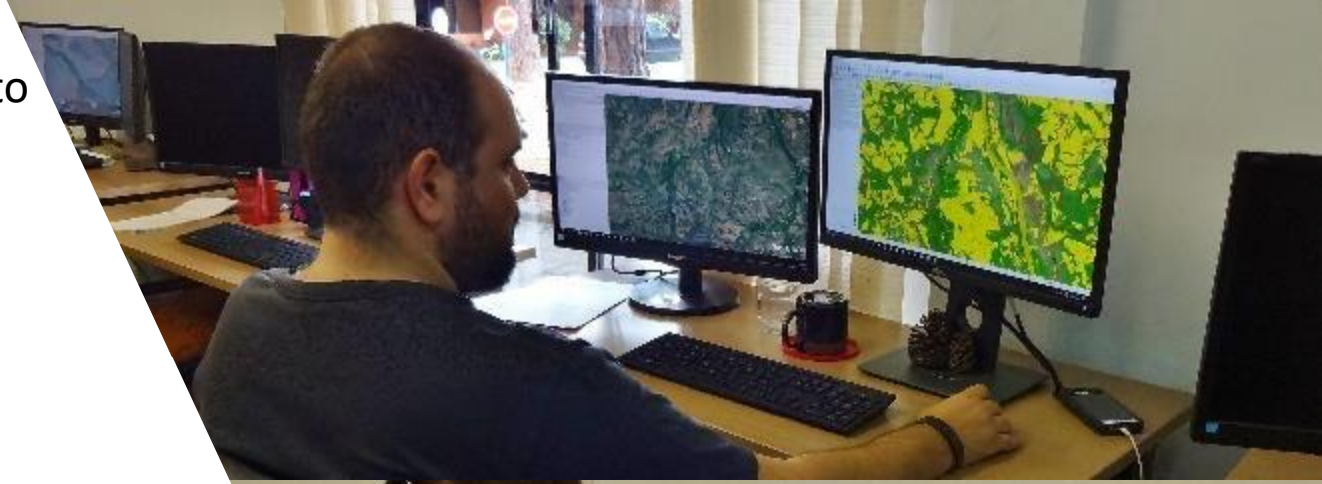
open source

TerraAmazon

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.



Landsat (30 meters)

Polygons of deforested and degraded areas.

TerraBrasilis

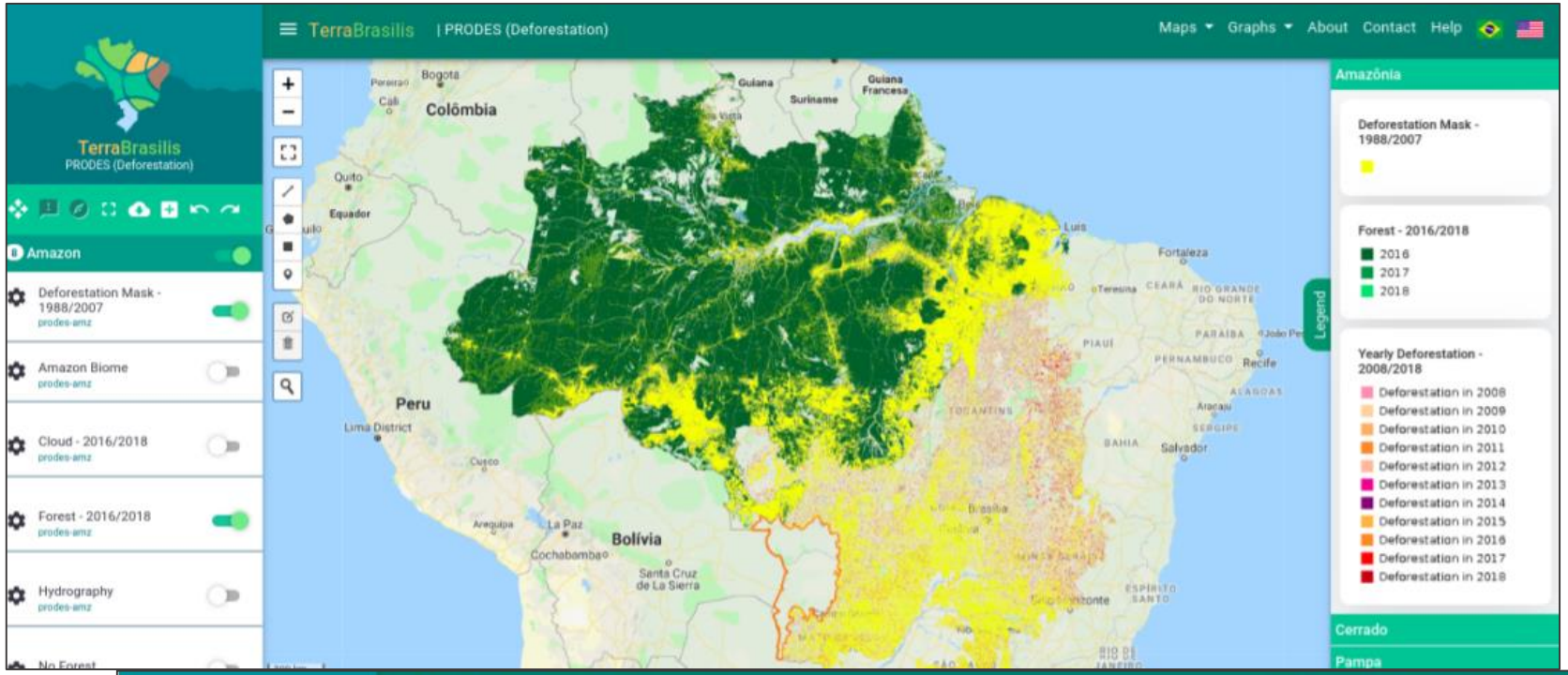
Web portal to disseminate the deforestation data sets produced by PRODES and DETER.

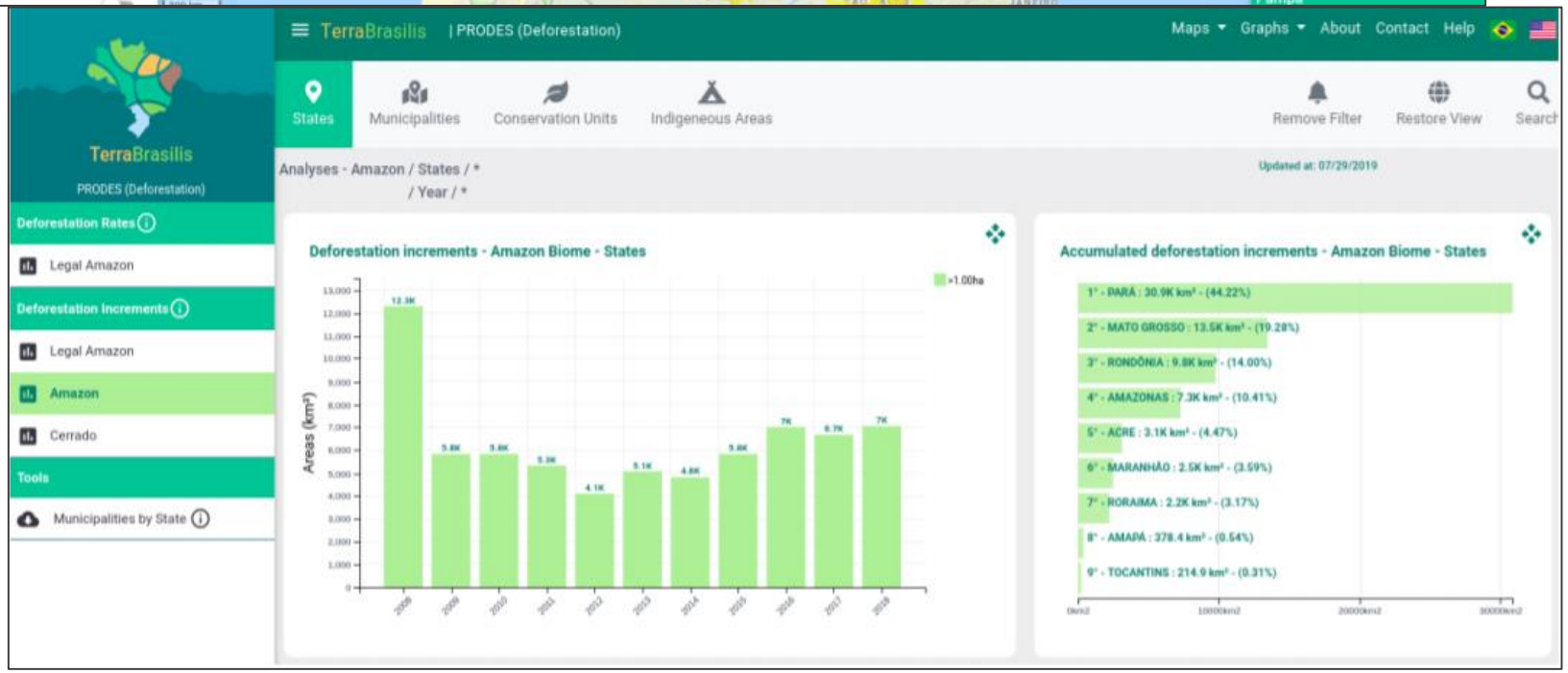
Open data.

Map visualization and dashboards.

Spatial analysis tools.

INDE
Infraestrutura Nacional de Dados Espaciais



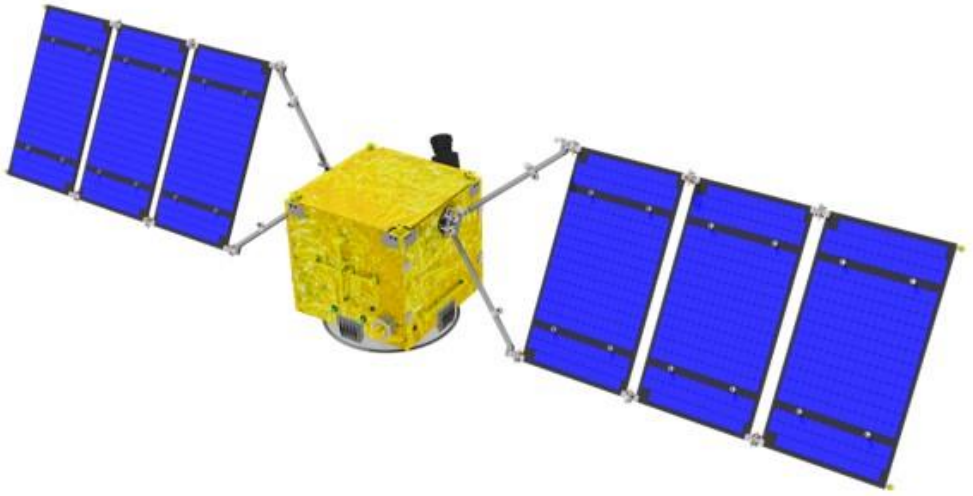


National Institute for Space Research (INPE), Brazil

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

INPE

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

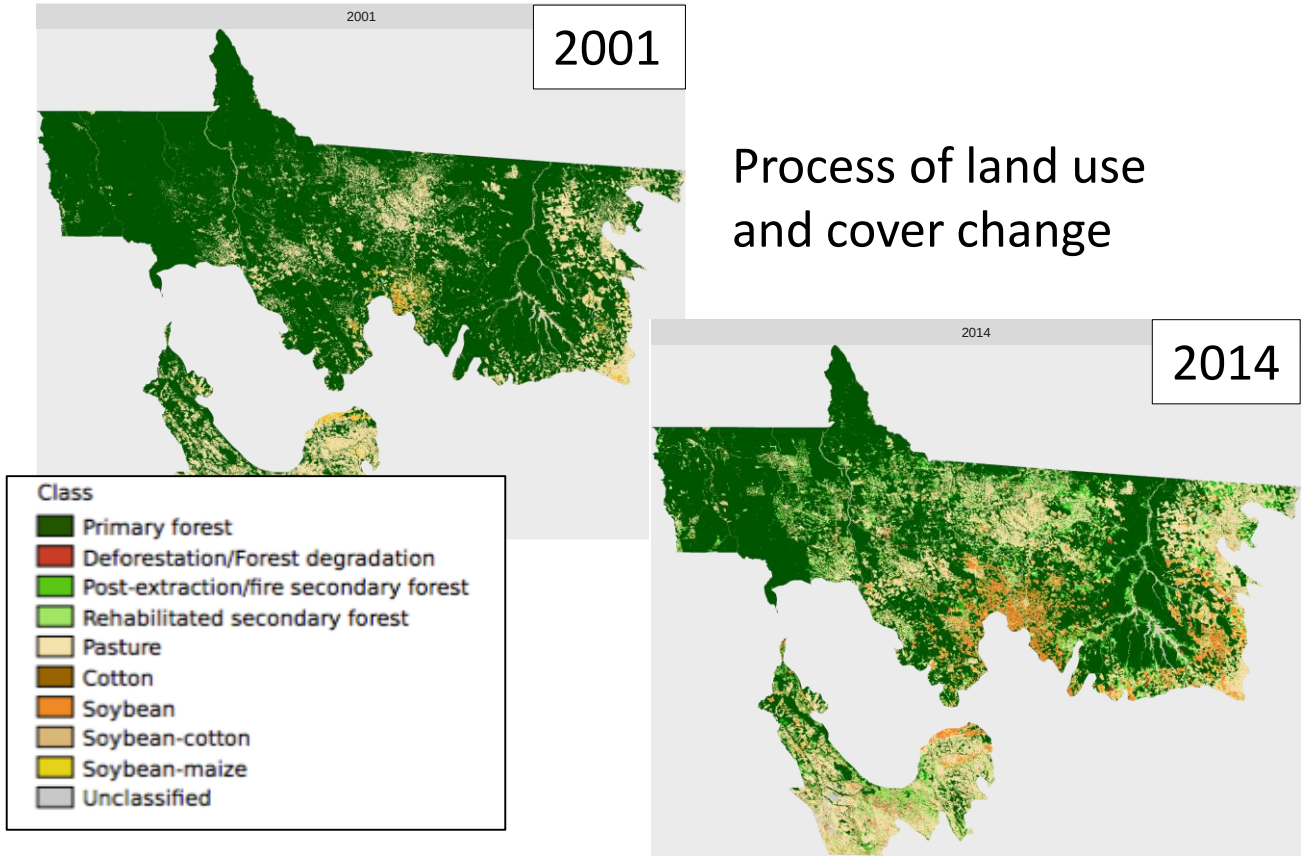
Programa de Excelência na CAPES Conceito = 6

Programa de Pós-Graduação em Sensoriamento Remoto (PGSER)

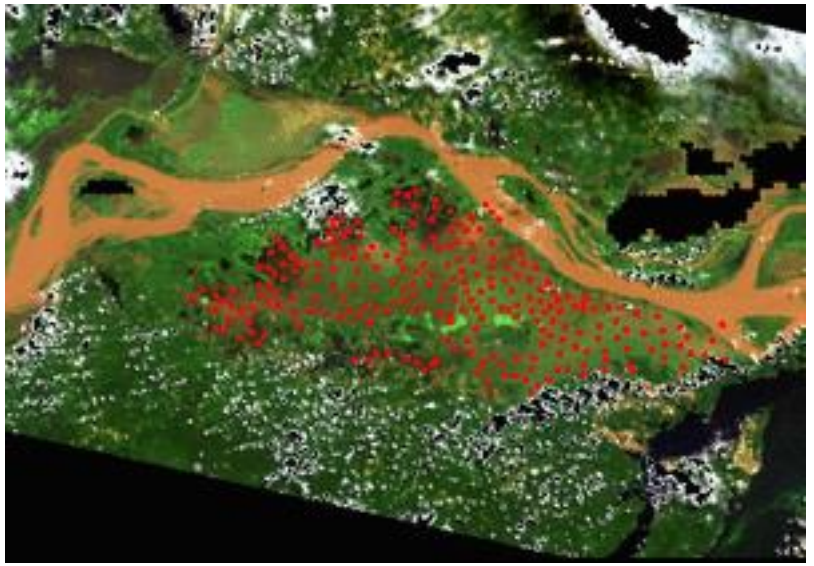
Conforme resultado divulgado pela **Capes** recebeu, mais uma vez, a **nota máxima na avaliação quadrienal** (Nota 7), comprovando a excelência do programa

CAP – Geoinformatics and Geo Data Science

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

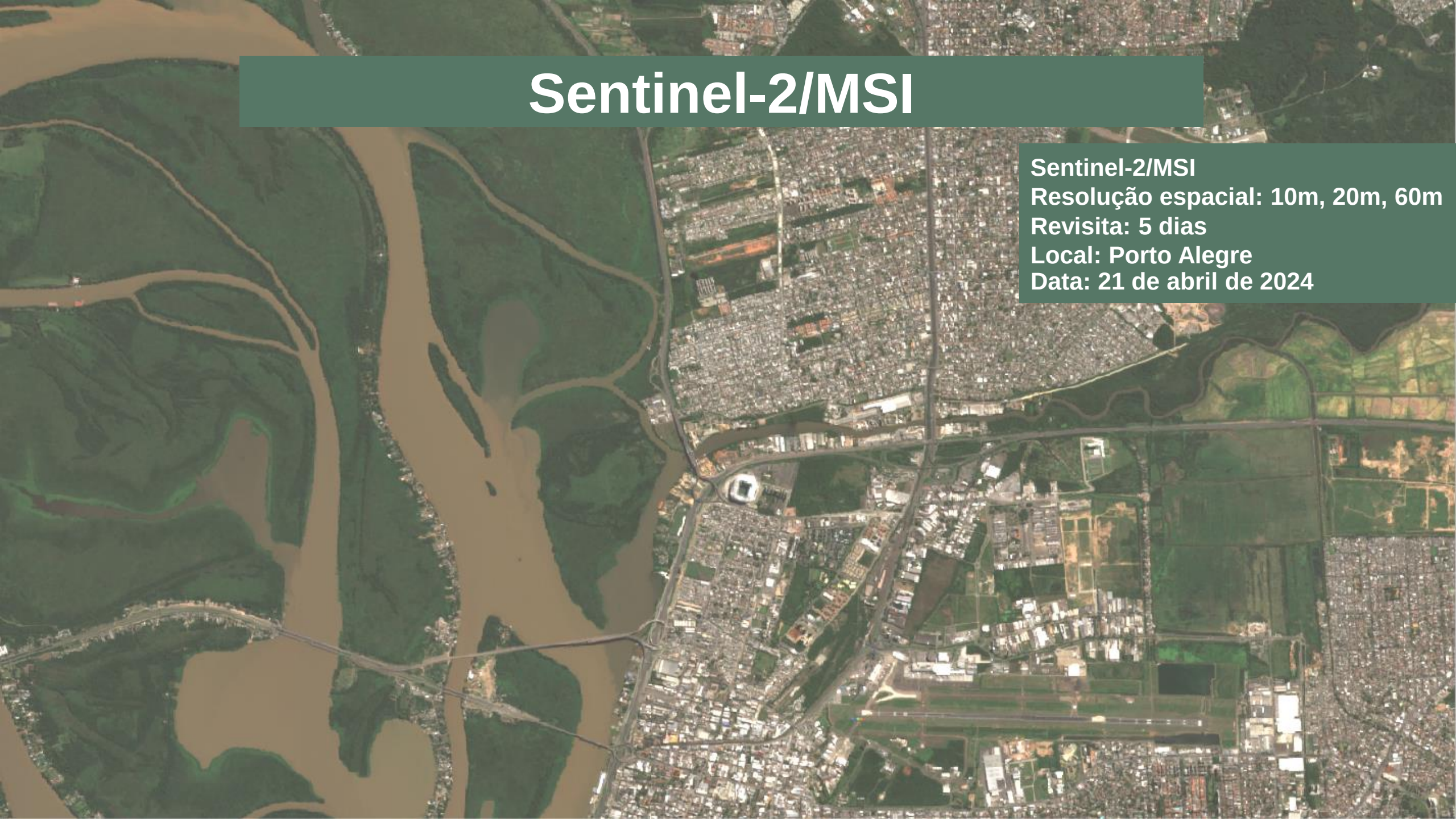


Process of land use and cover change



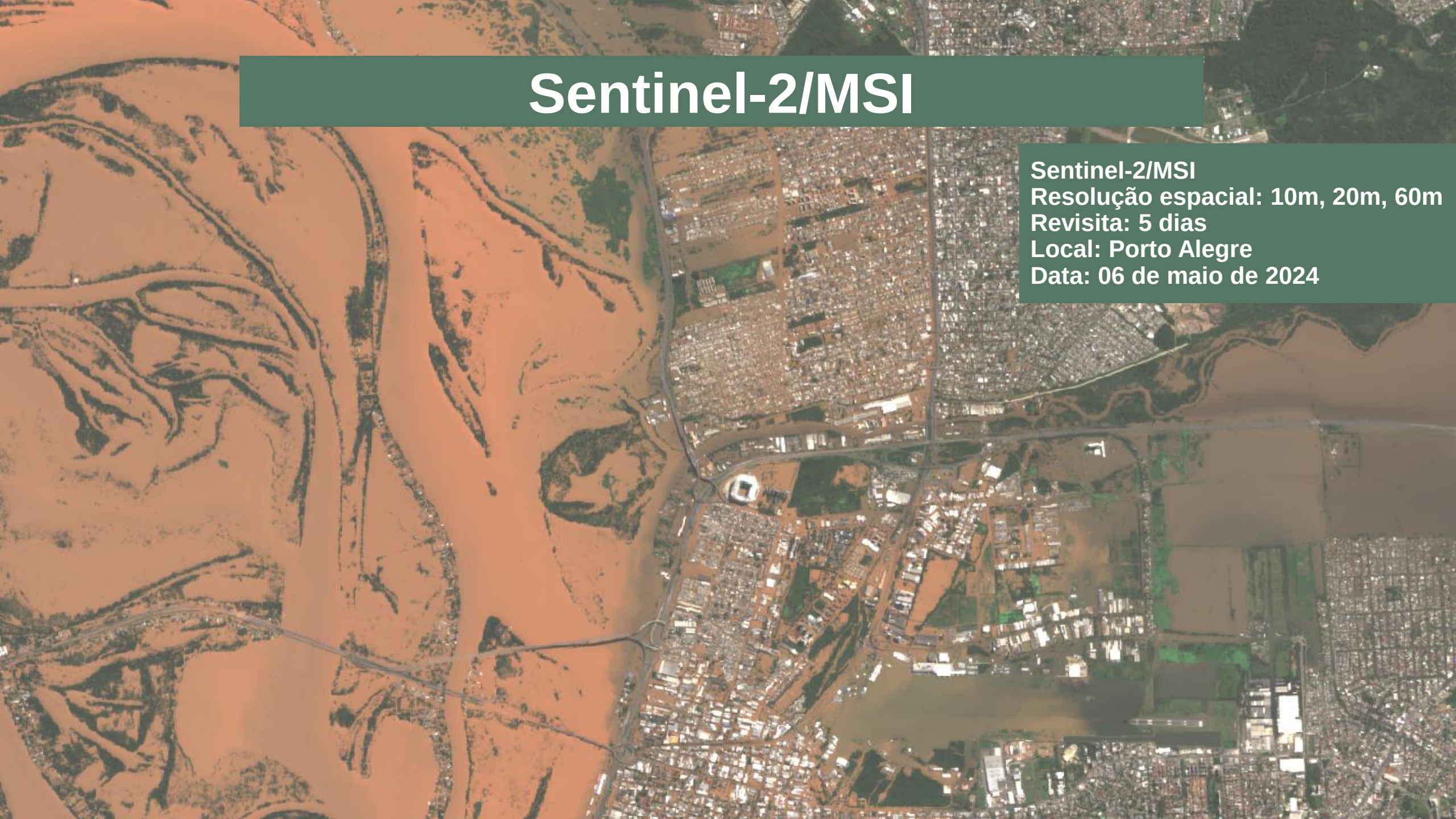
Variation of chlorophyll in an Amazon rainforest lake

Sentinel-2/MSI



Sentinel-2/MSI
Resolução espacial: 10m, 20m, 60m
Revisita: 5 dias
Local: Porto Alegre
Data: 21 de abril de 2024

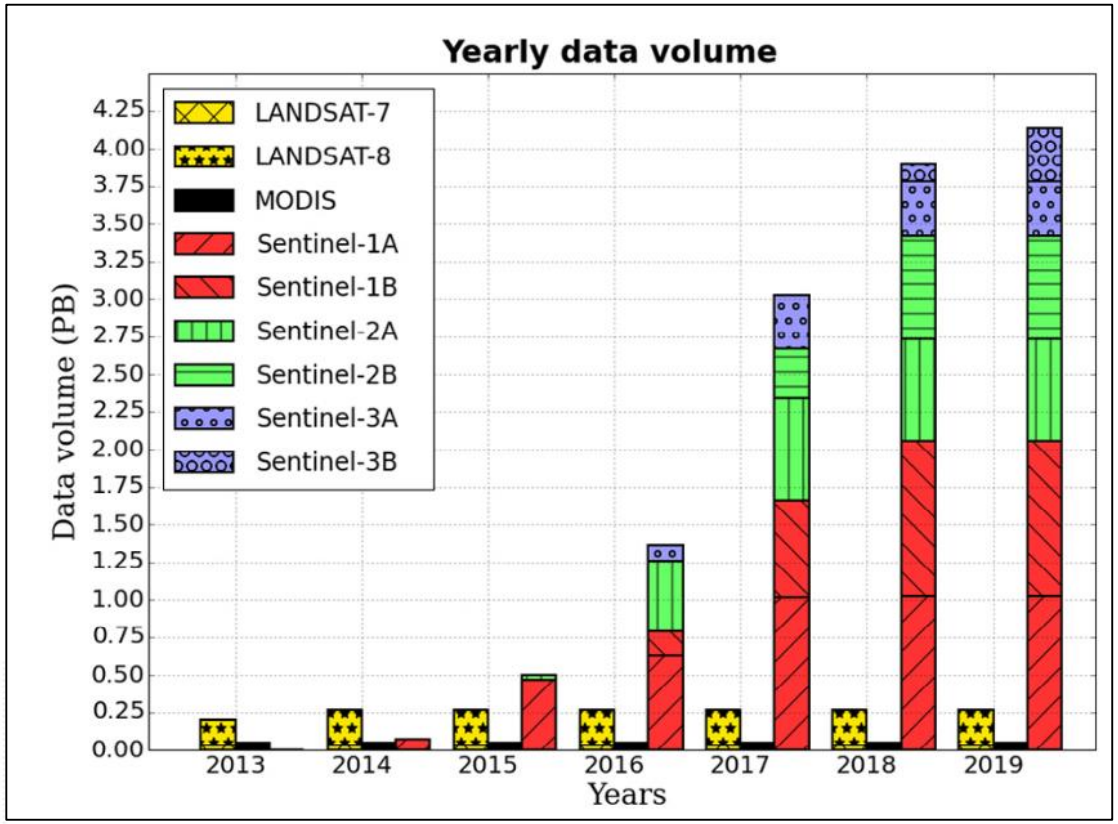
Sentinel-2/MSI



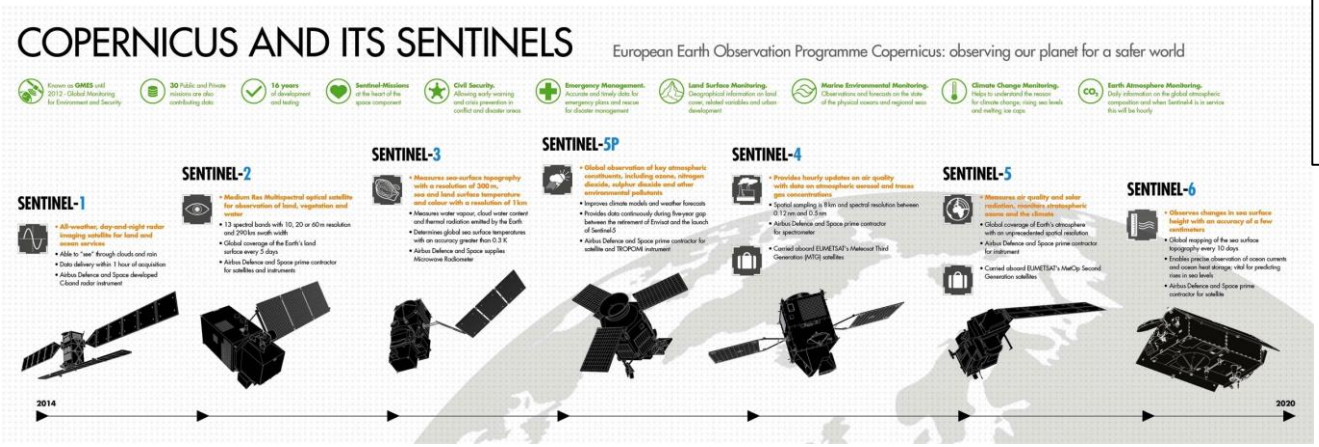
Sentinel-2/MSI
Resolução espacial: 10m, 20m, 60m
Revisita: 5 dias
Local: Porto Alegre
Data: 06 de maio de 2024

Challenge: Big data sets of EO satellite images

Source: eospso.nasa.gov

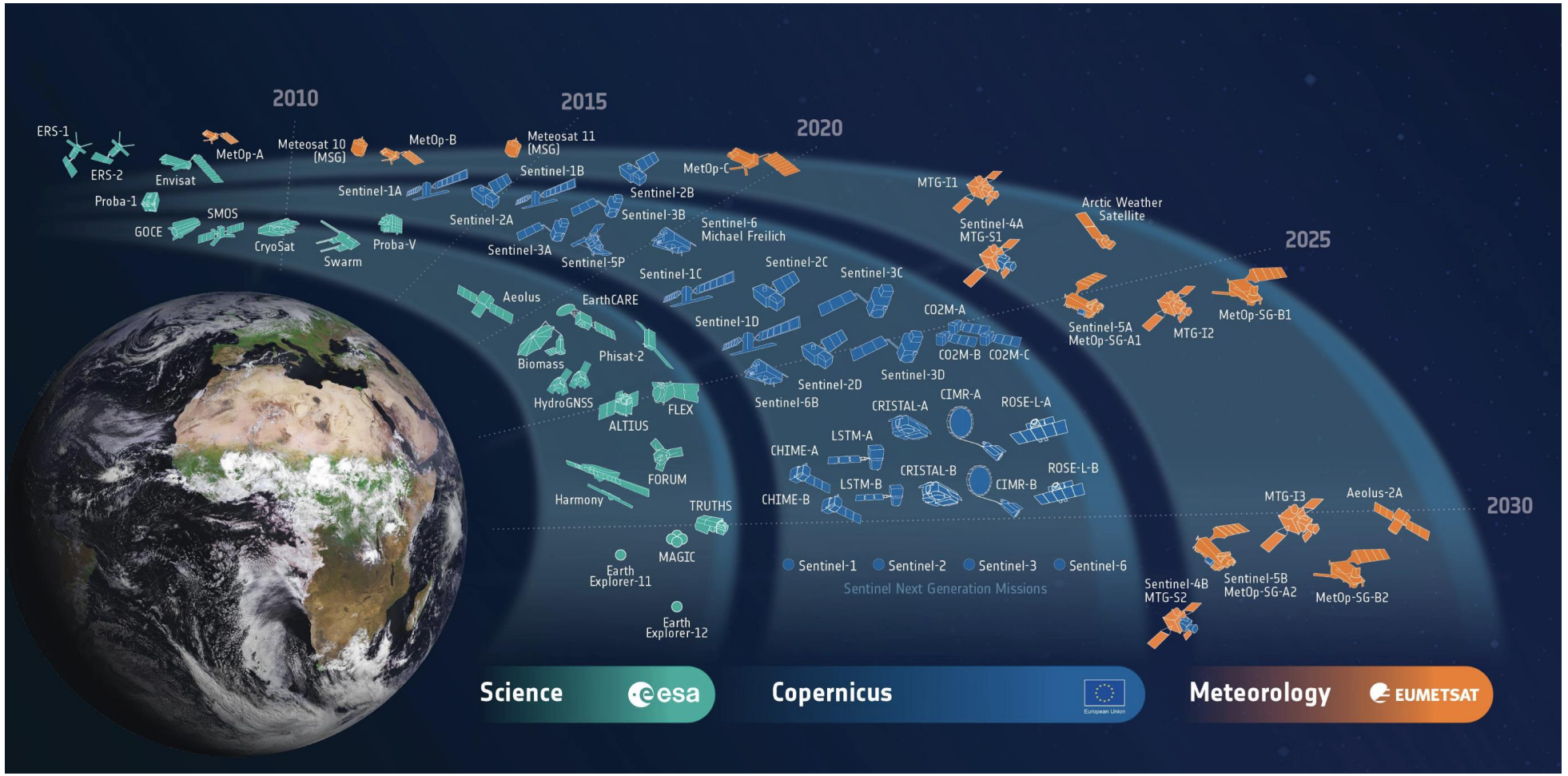


Source: (Soille et al., 2018)



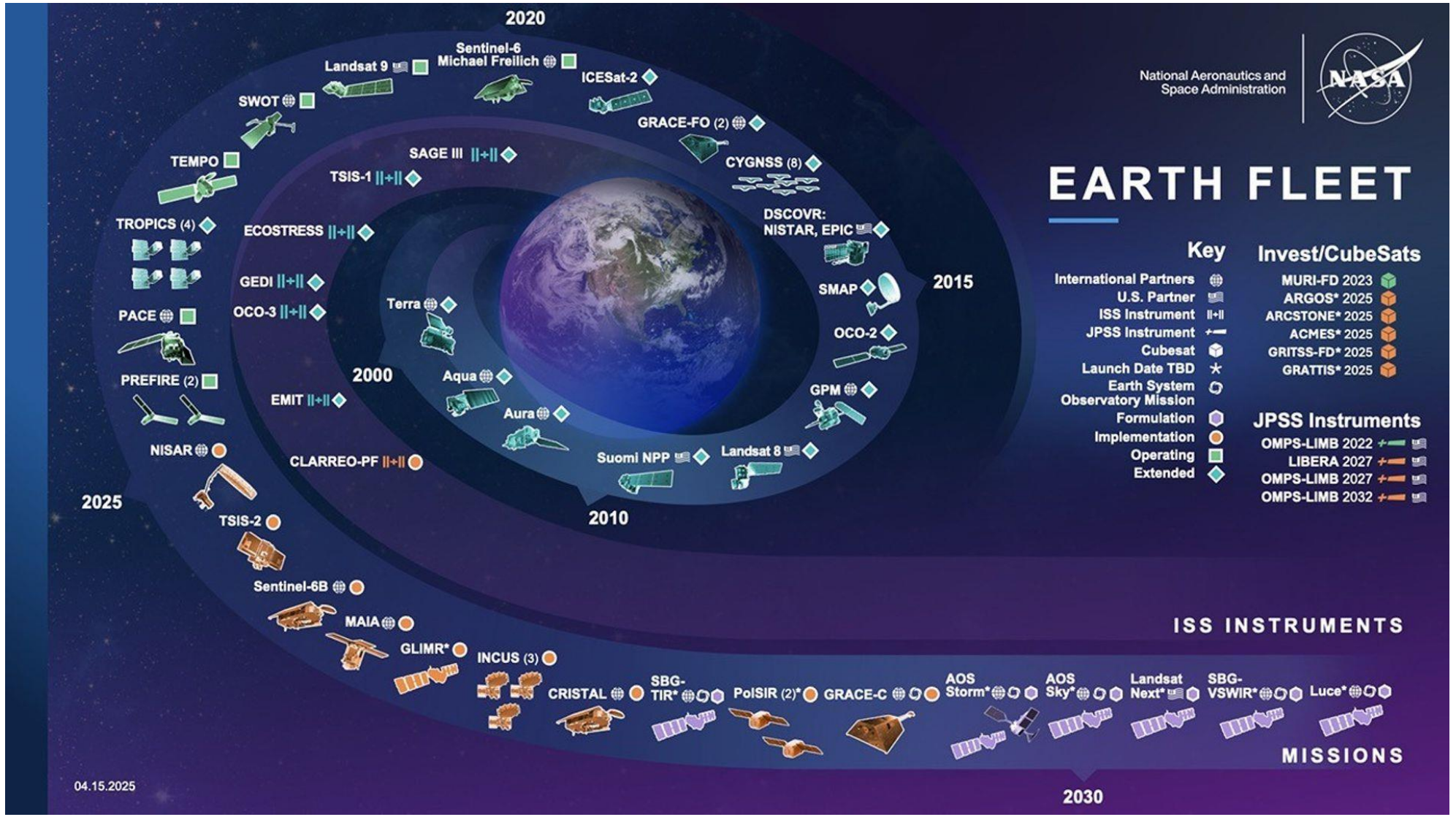
Source: www.copernicus.eu

Big data sets of EO satellite images



Source: https://www.esa.int/ESA_Multimedia/Images/2019/05/ESA-developed_Earth_observation_missions

Big data sets of EO satellite images

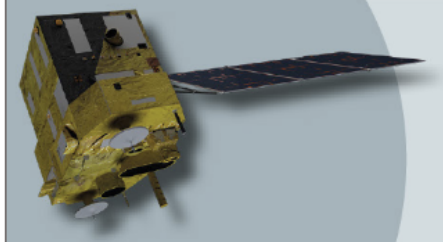


Source: https://science.nasa.gov/earth-science/missions/

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.



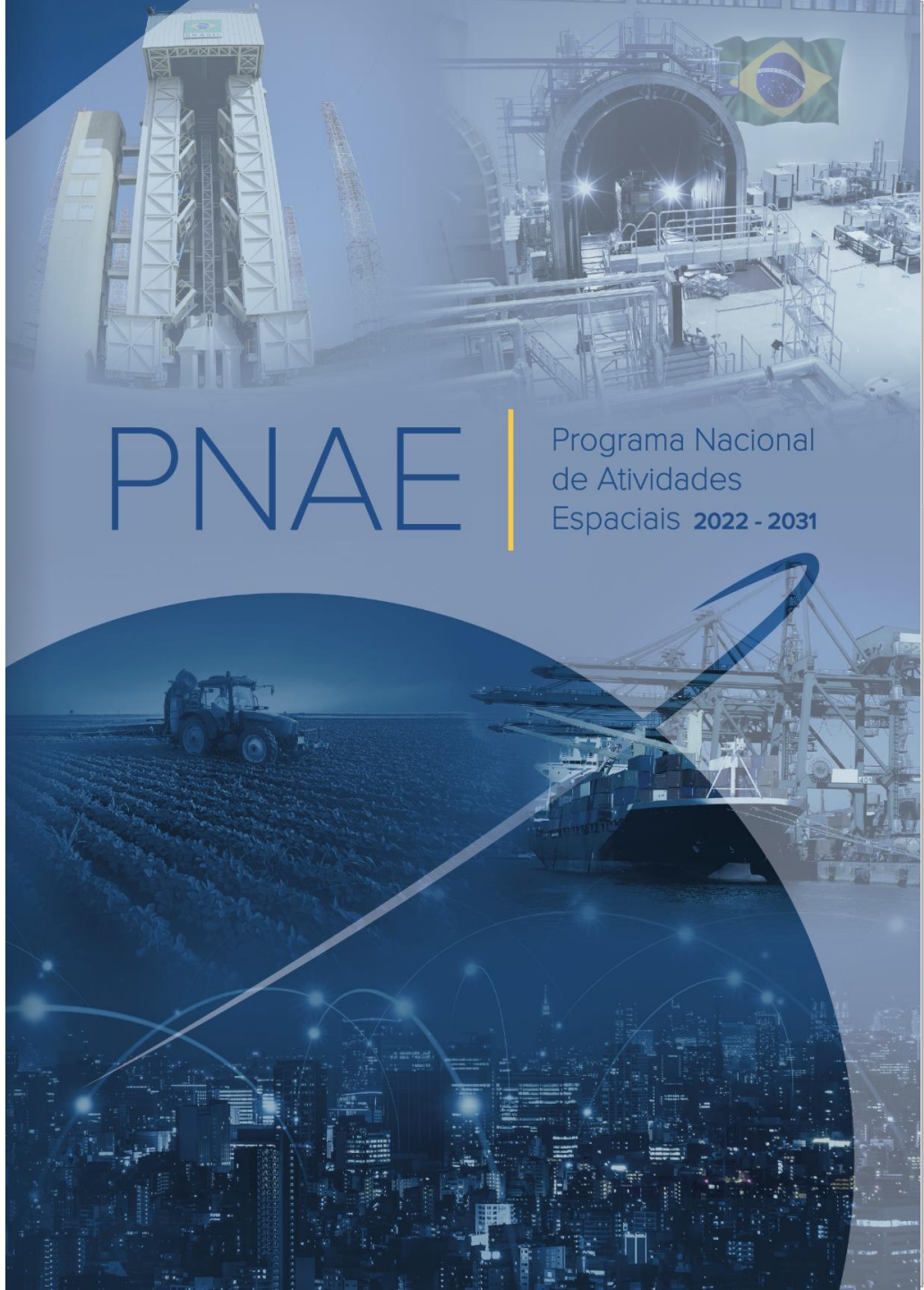
Carga útil: sensoriamento remoto e coleta de dados ambientais

Operação: INPE

Prazo de operação: dezembro de 2022

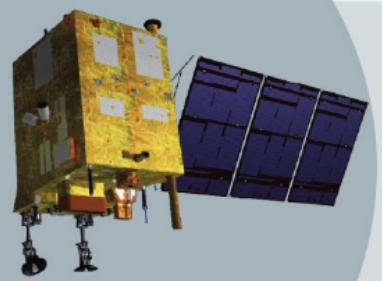
Atendimento a OEEs: OEE2, OEE3, OEE5 e OEE6

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



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 d

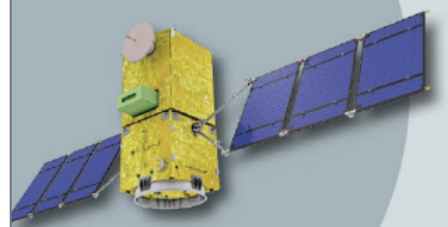
Operação: INPE

Prazo de operação: dezembro de 2023

Atendimento a OEEs: OEE2, OEE3, OEE5 e OE

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

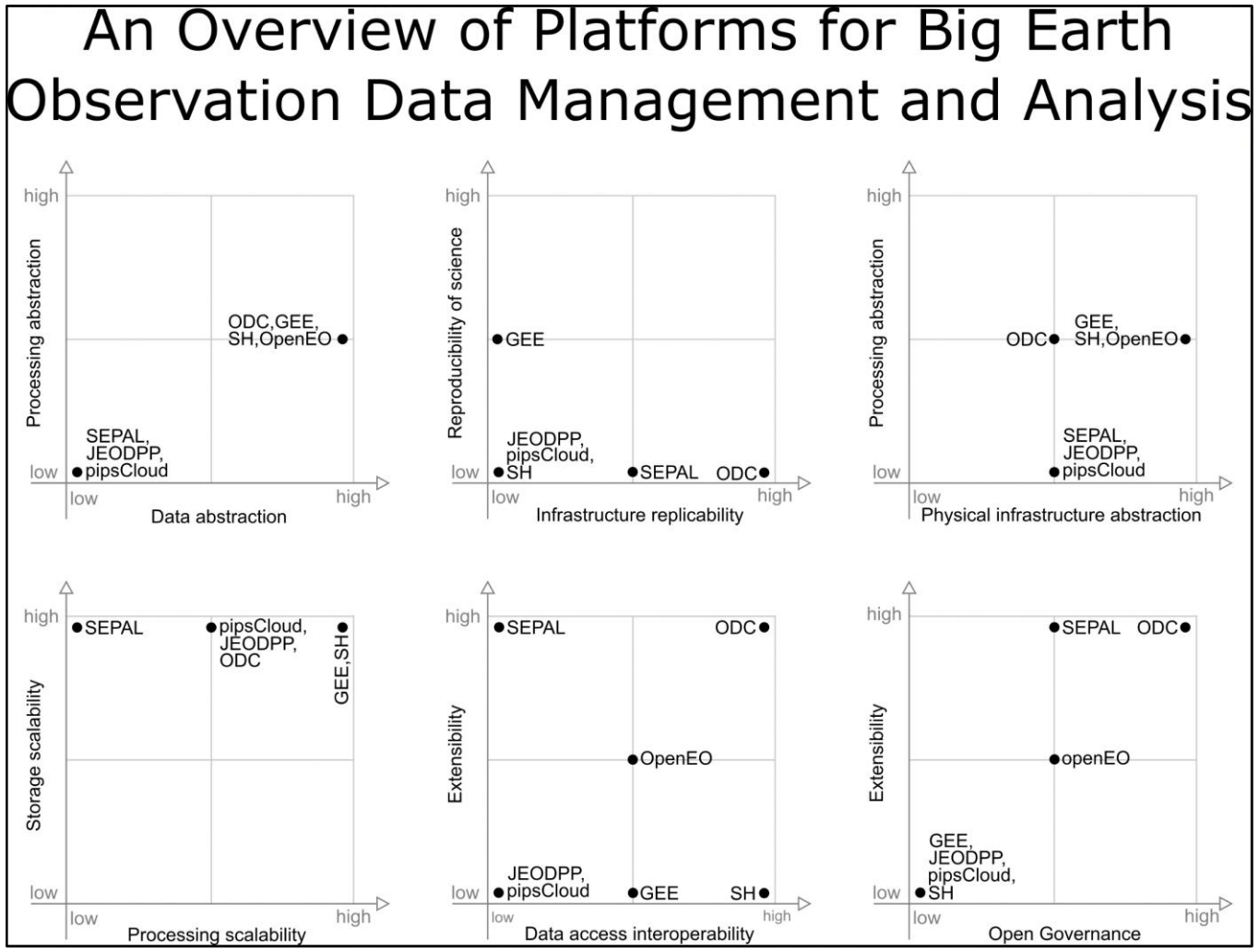
Prazo de operação: dezembro de 2025

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



Source: (Gomes et al., 2020)

- Open Data Cube (ODC)
- Google Earth Engine (GEE)
- SEPAL
- openEO
- JEODPP
- pipsCloud
- SentinelHub

Cloud computing environmets for big EO data

Google Earth Engine (GEE)

Amazon Web Service (AWS)

Microsoft Planetary Computer

Copernicus Data Space Ecosystem (CDSE)

Plataforma Brazil Data Cube (BDC)

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

Google Earth Engine

Ambiente de computação em nuvem (Google).

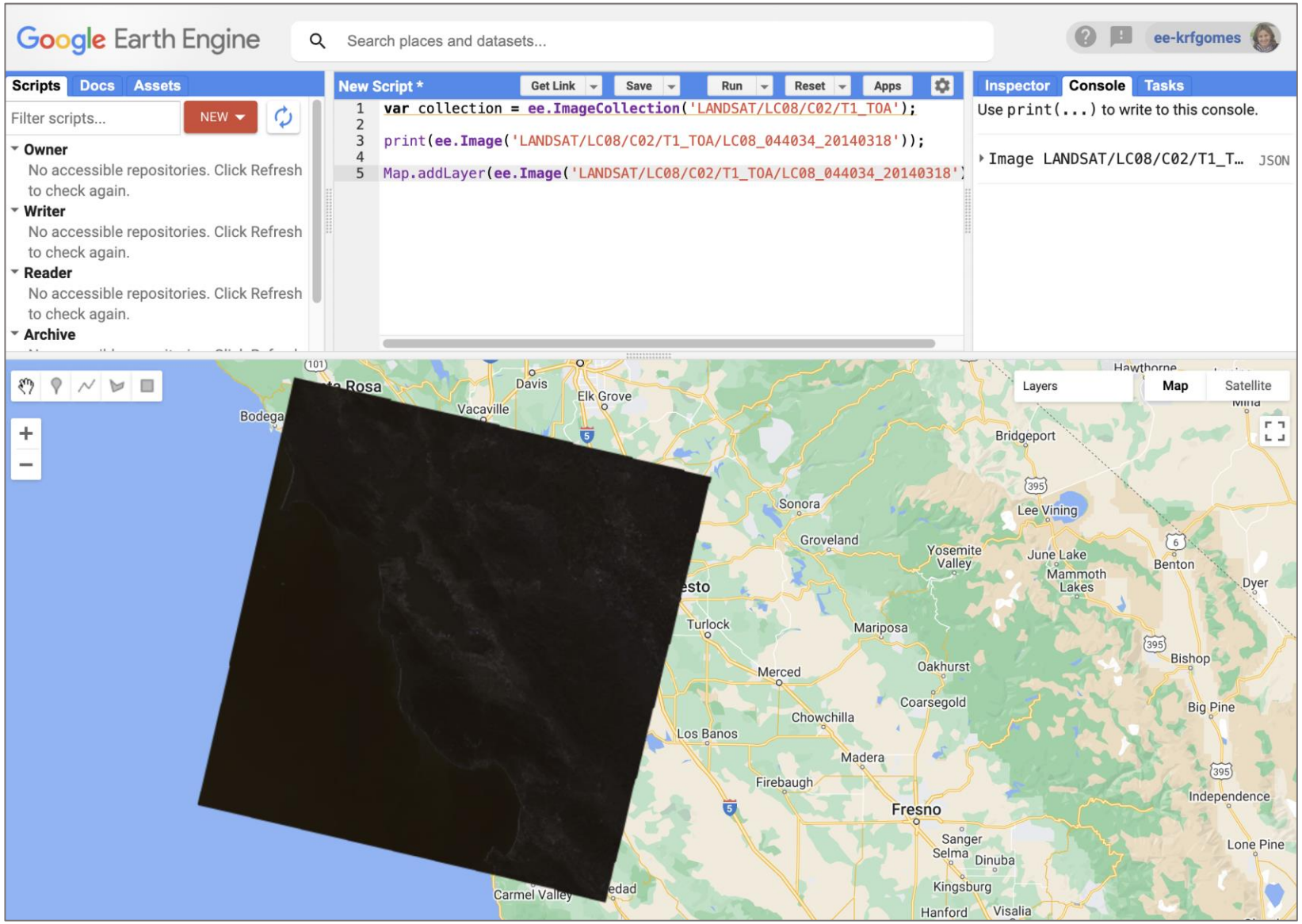
Interface web e API em JavaScript e Python.

Coleções de imagens de satélites e outros dados.

Plataforma comercial.

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

Interface web – scripts, visualização, ...



Source: https://docs.aws.amazon.com/

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

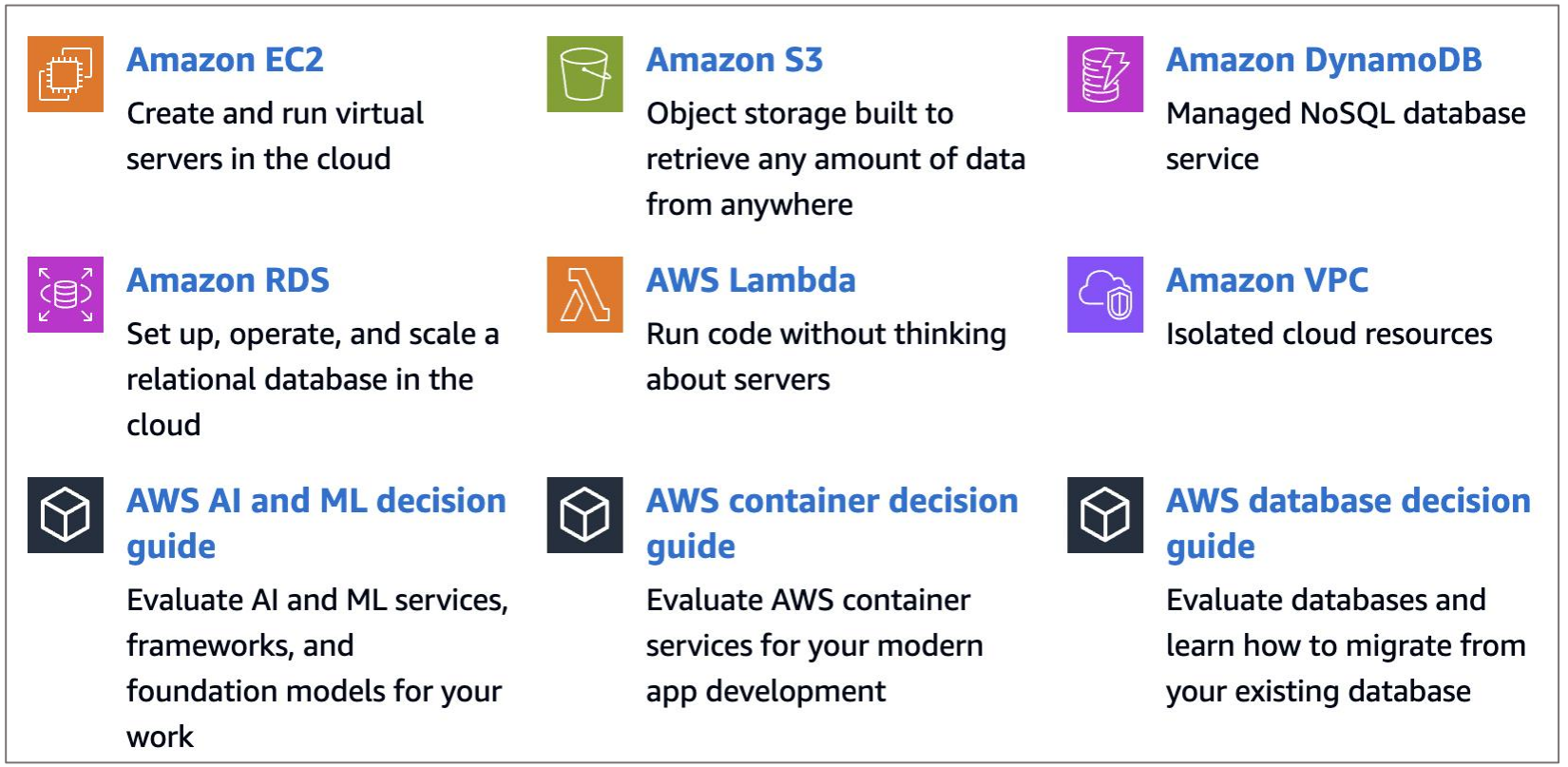
Earth on AWS: Open EO data

(https://aws.amazon.com/earth/)

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

Serviços pagos por volume de processamento e armazenamento.

Créditos para pesquisa.



stac.amskepler.com/v100/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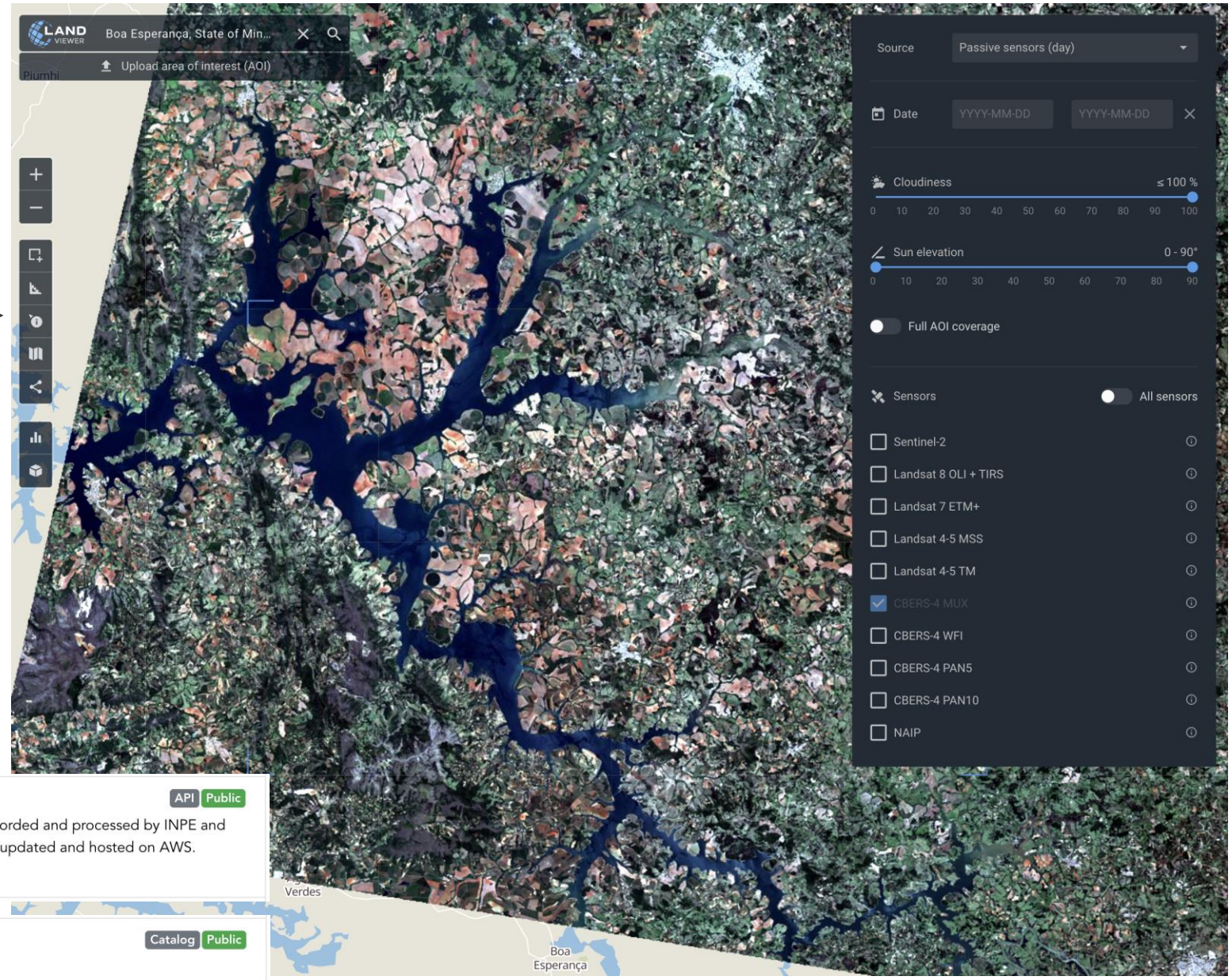
aws



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/

Microsoft | Planetary Computer

Source: https://planetarycomputer.microsoft.com/

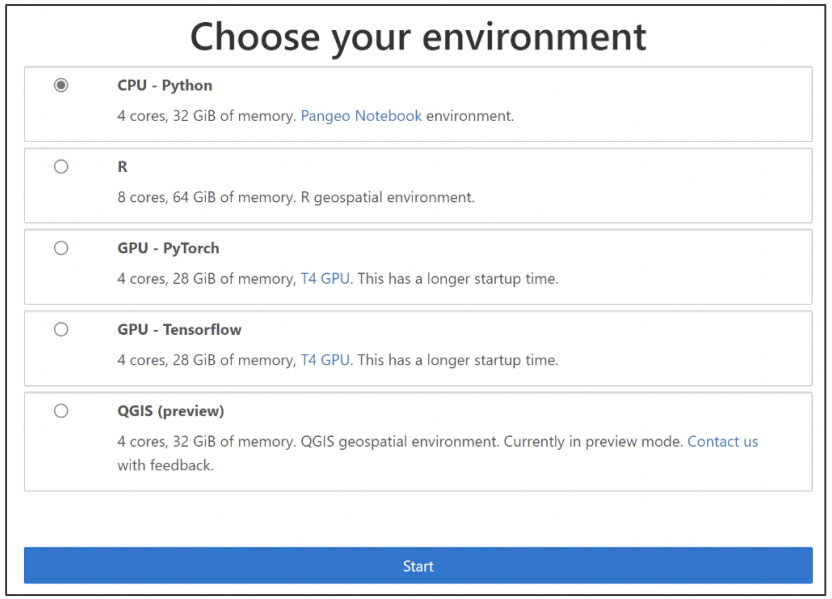
Ambiente de computação em nuvem (Microsoft Azure).

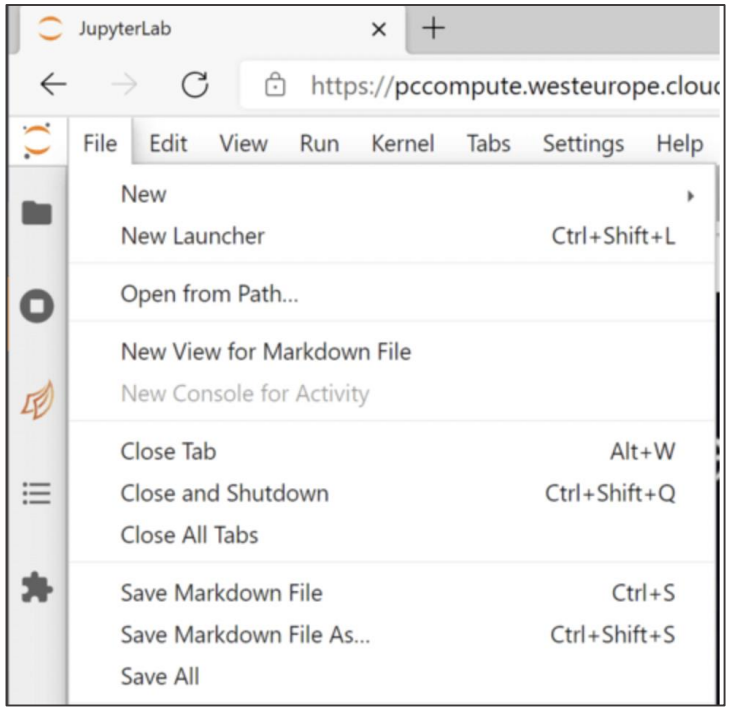
Planetary Computer Hub – JupyterHub

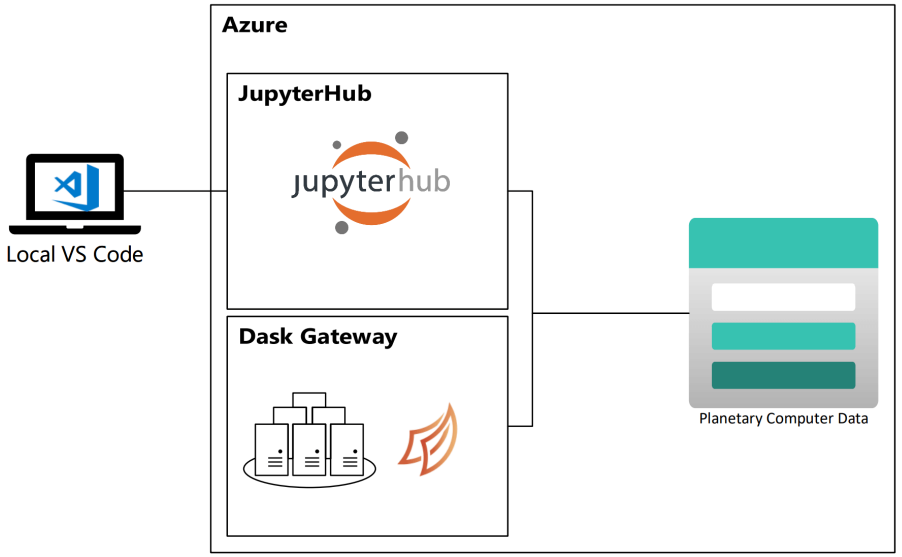
Coleções de imagens de satélites e outros dados: Sentinel-1, -2 e -3, Landsat, MODIS, etc.

Serviços pagos.

Créditos para pesquisa.



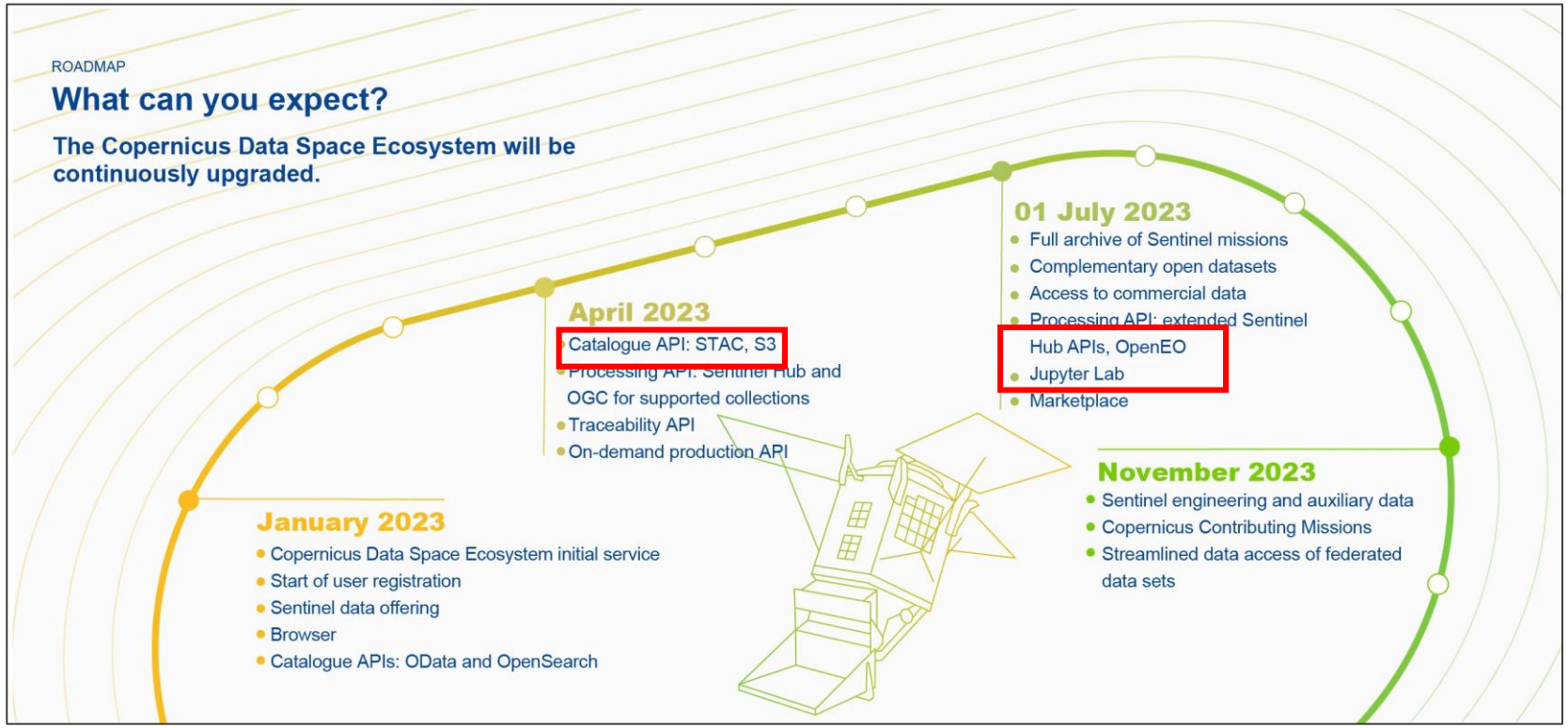




Copernicus Data Space Ecosystem (CDSE)

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.



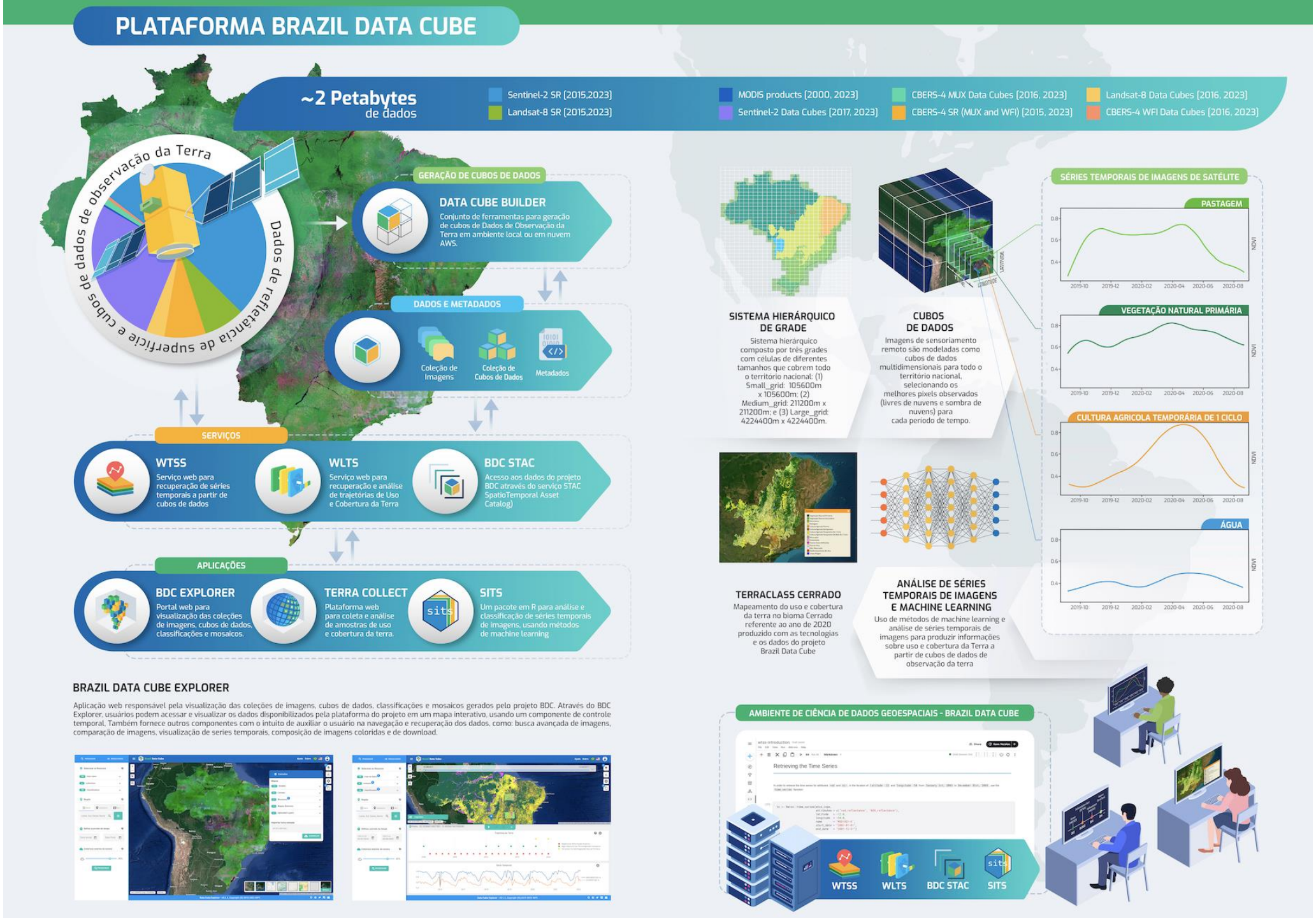
Source: https://dataspace.copernicus.eu/ecosystem/services/cap-area-monitoring-services

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.



BRAZIL
DATA CUBE

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**.

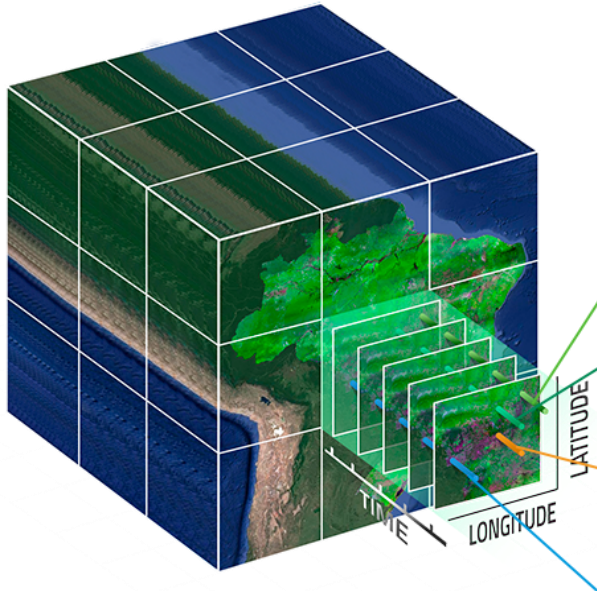
BRAZIL
DATA CUBE

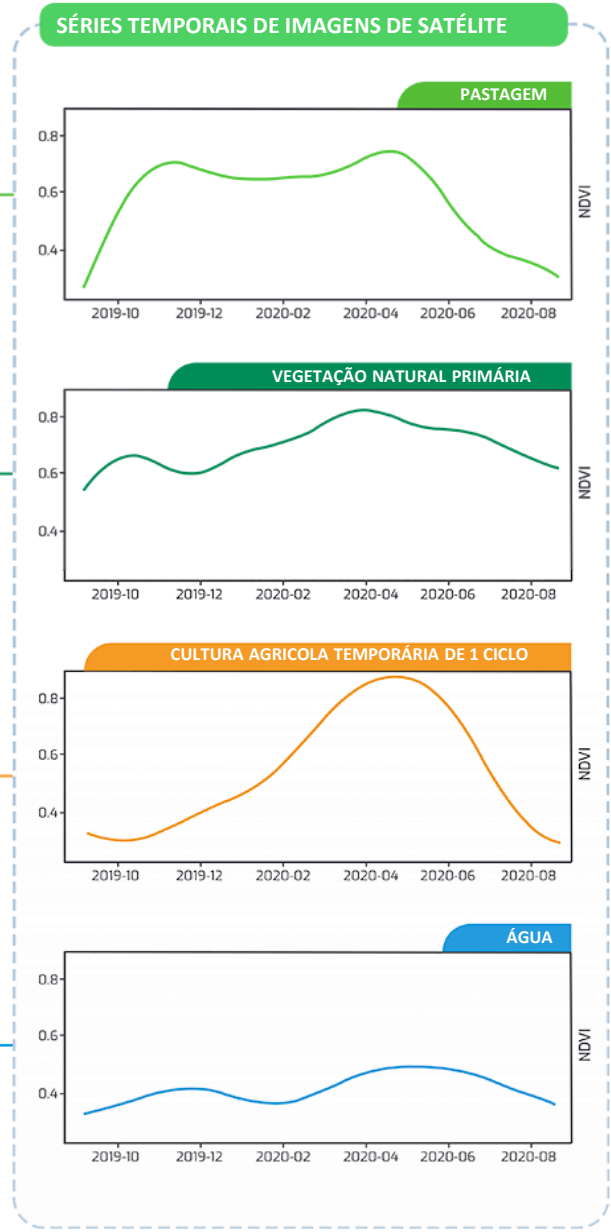
Big data of remote sensing images modeled as multidimensional data cubes

Big data technologies and machine learning

Image time series analysis

Land use and cover mapping

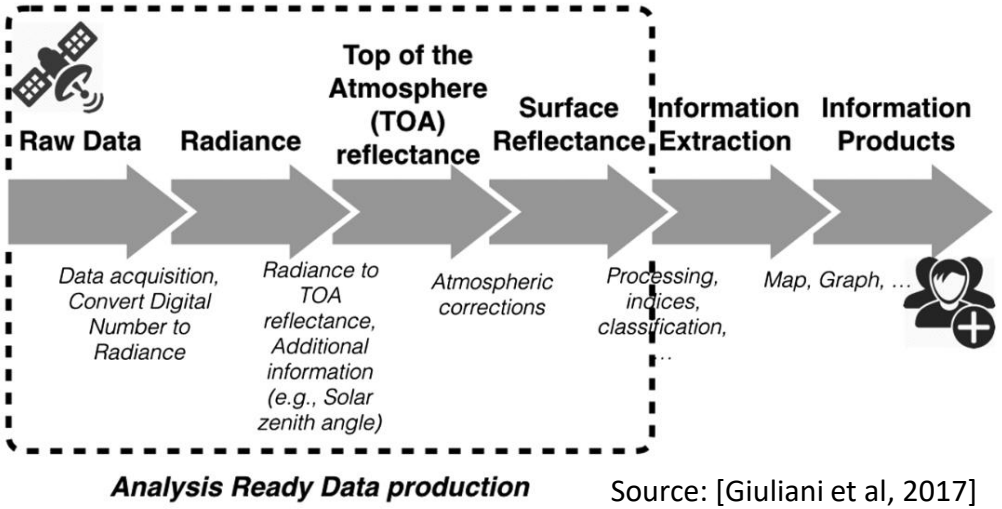




ARD and EO Data Cubes for the entire Brazilian territory

BRAZIL DATA CUBE

2 Petabytes (PB) remote sensing images

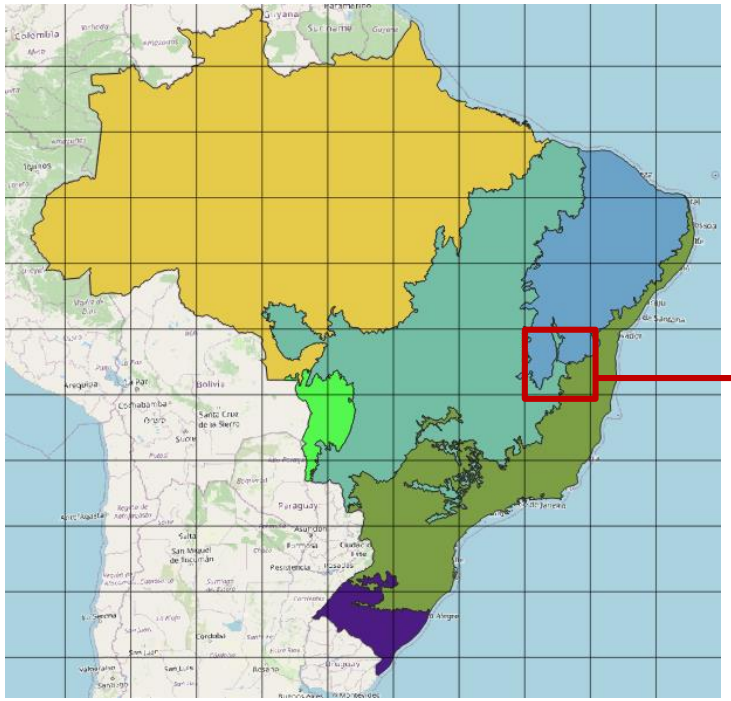


Analysis Ready Data production

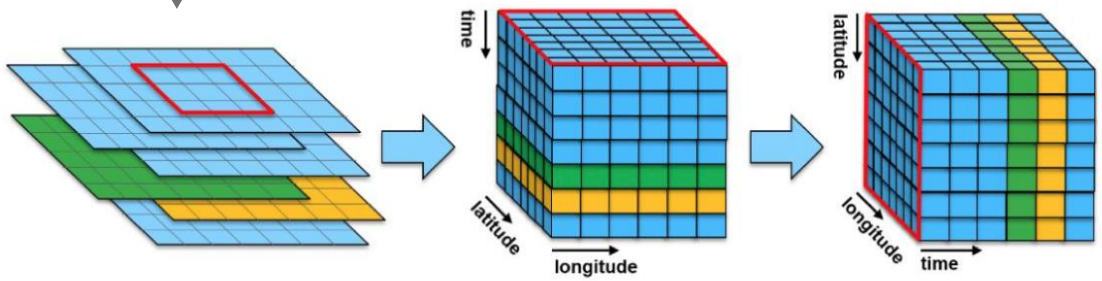
Source: [Giuliani et al, 2017]

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



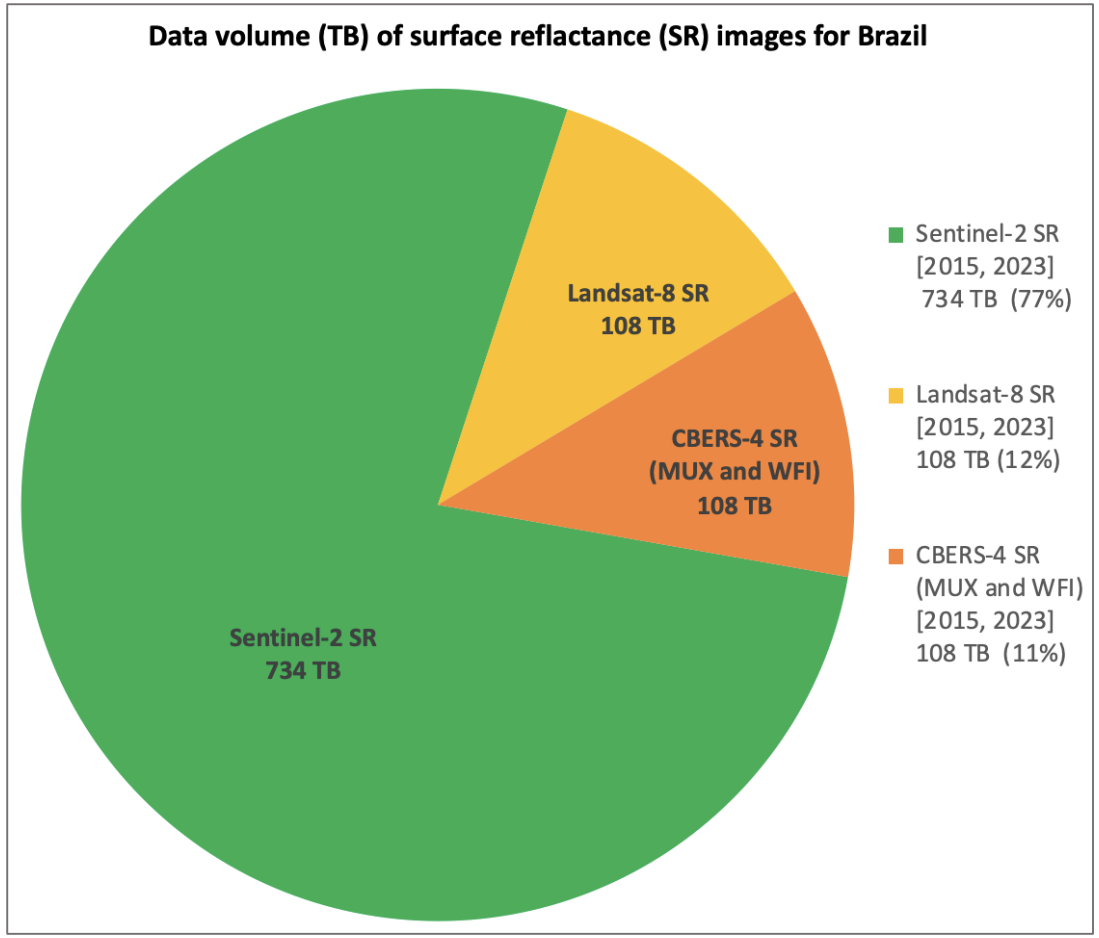
Collections of ARD satellite imagens

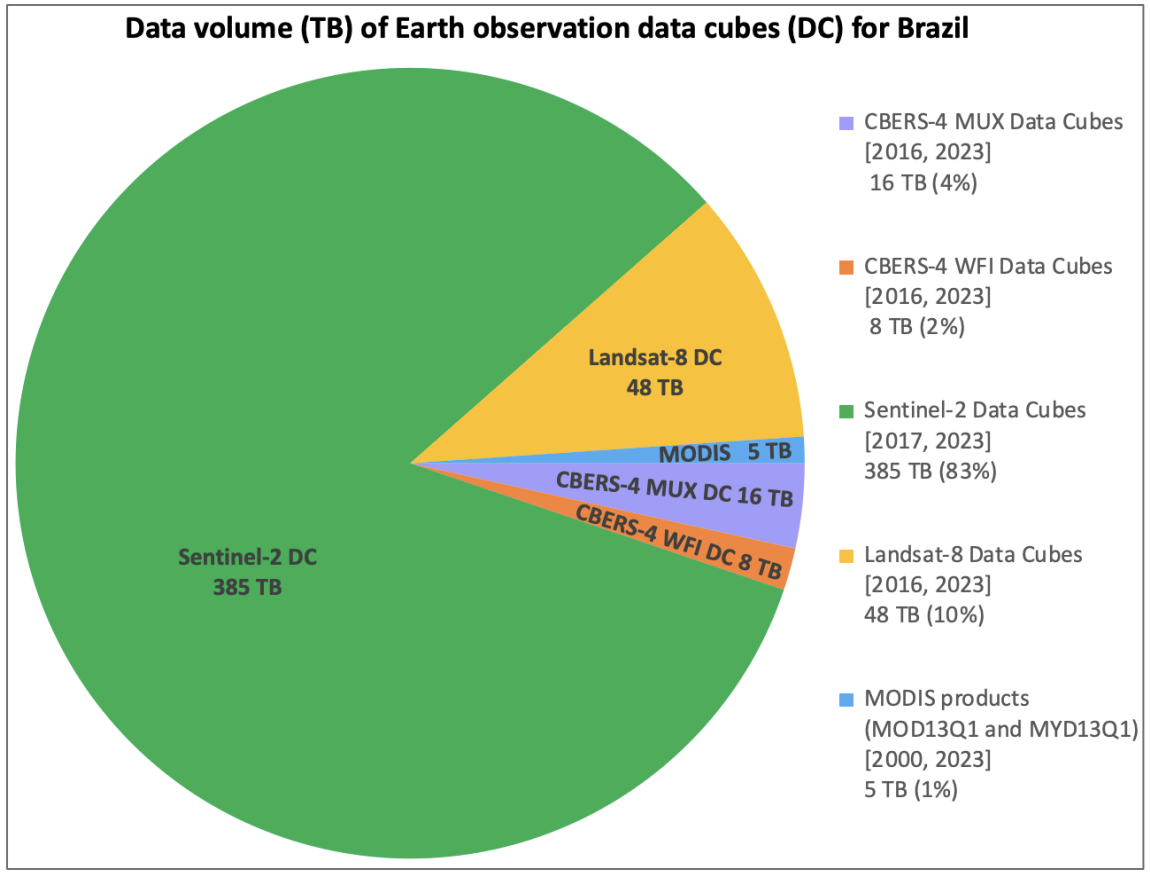
Multidimensional Data cubes

Source: [Kopp et al, 2019]

BRAZIL
DATA CUBE

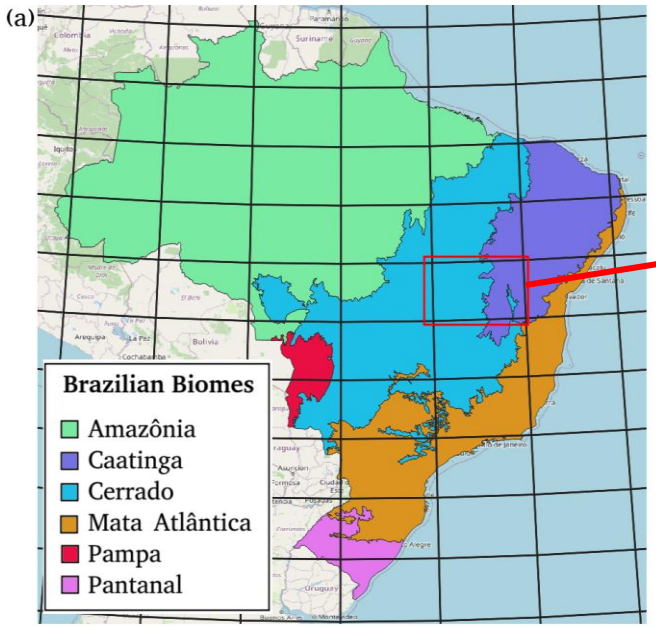
Big data

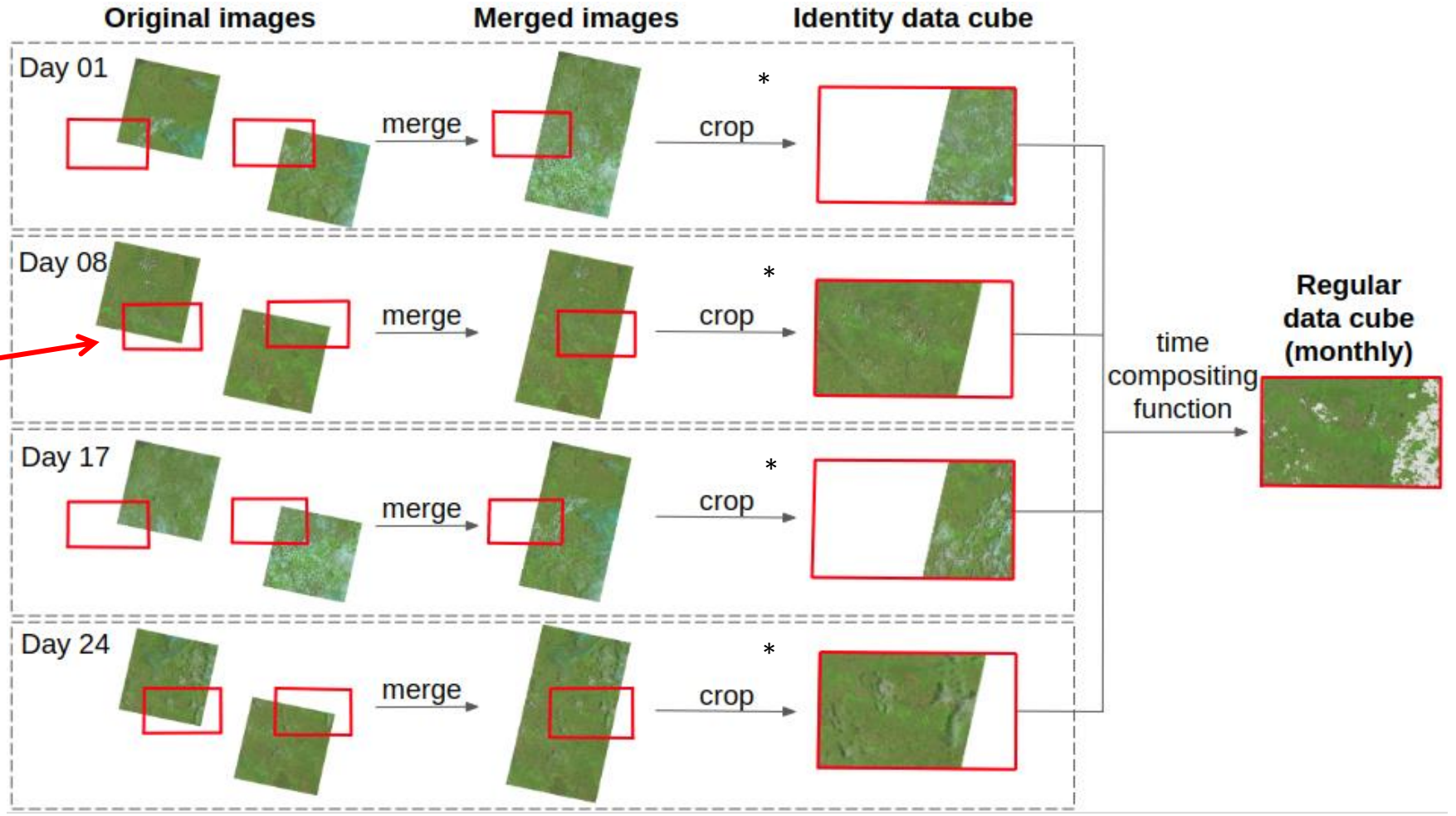




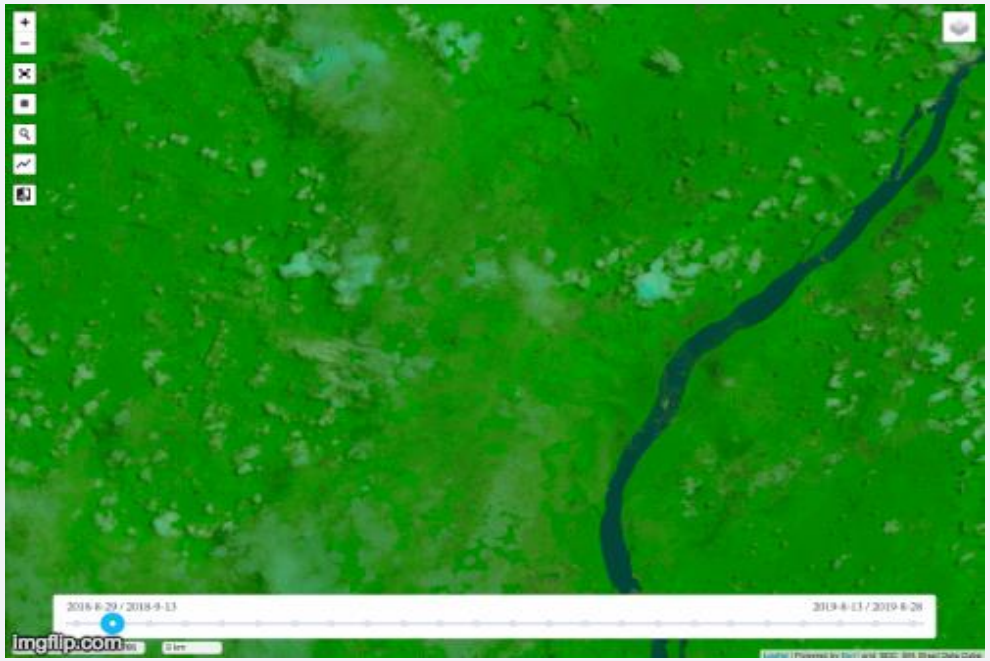
Source: [Ferreira et al., 2022]

Building data cubes

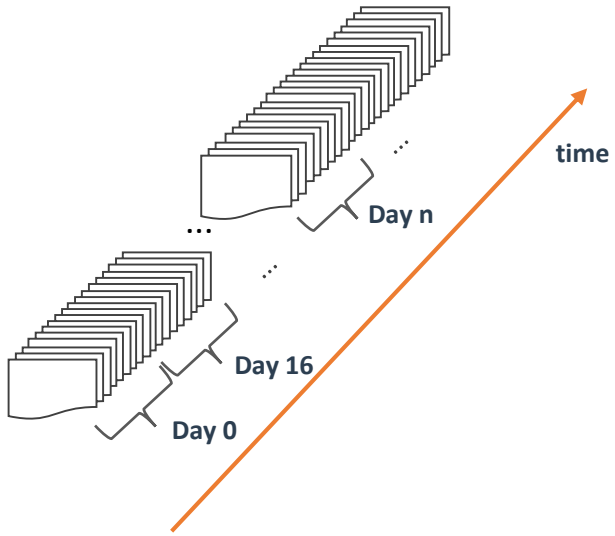




*bilinear resampling for better spatial resolution band



brazildatacube.dpi.inpe.br/portal/explore



For each *tile* and *time step*, there are a set of COG (Clould 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 provenace; ...

BDC – Small
Each tile: 105600m x 105600m

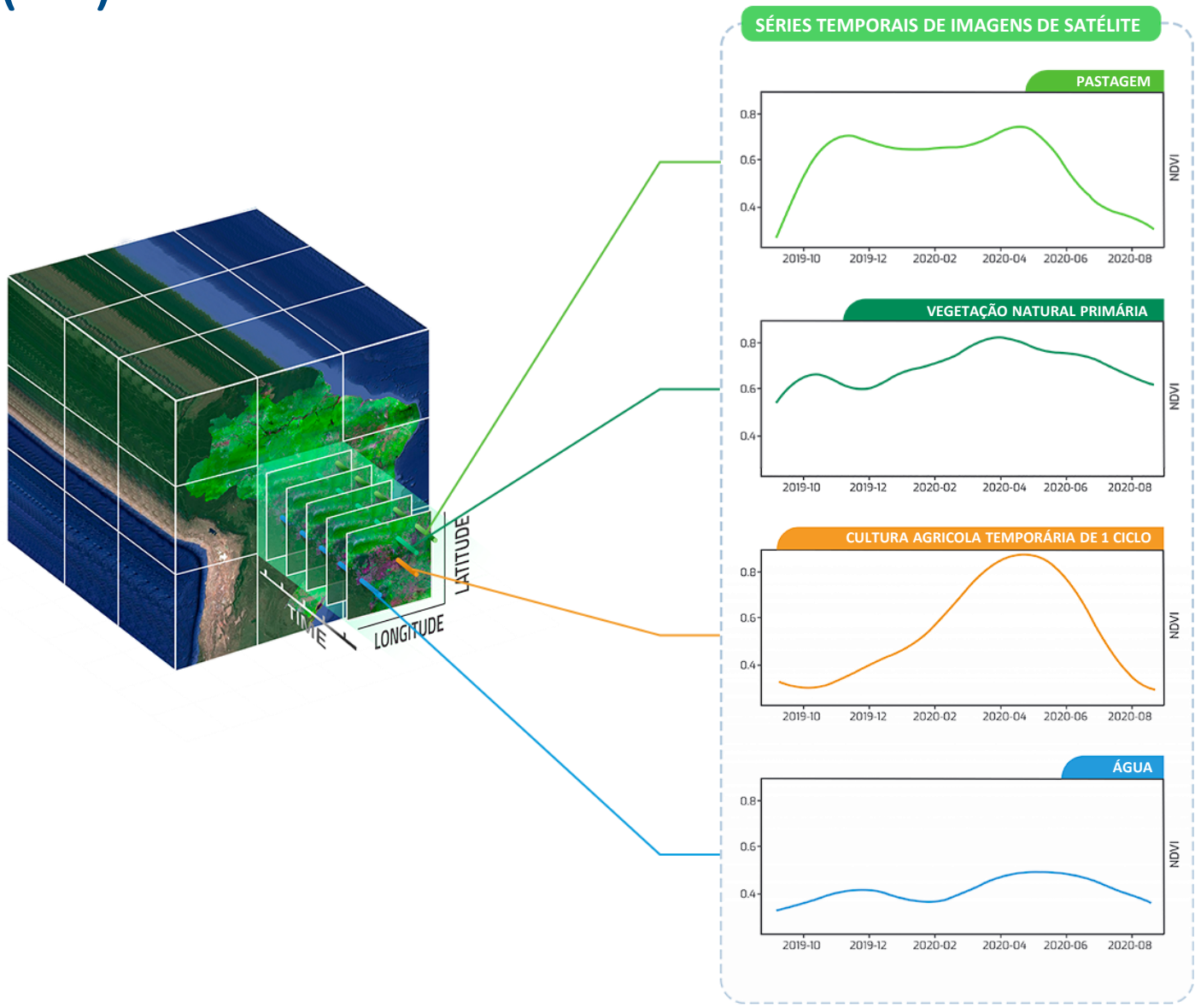
Sentinel-2/MSI – 10 meters
Each file (band/tile): 400 MB
Each tile: ~ 5.4 GB

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)



Potential of image time series and machine learning

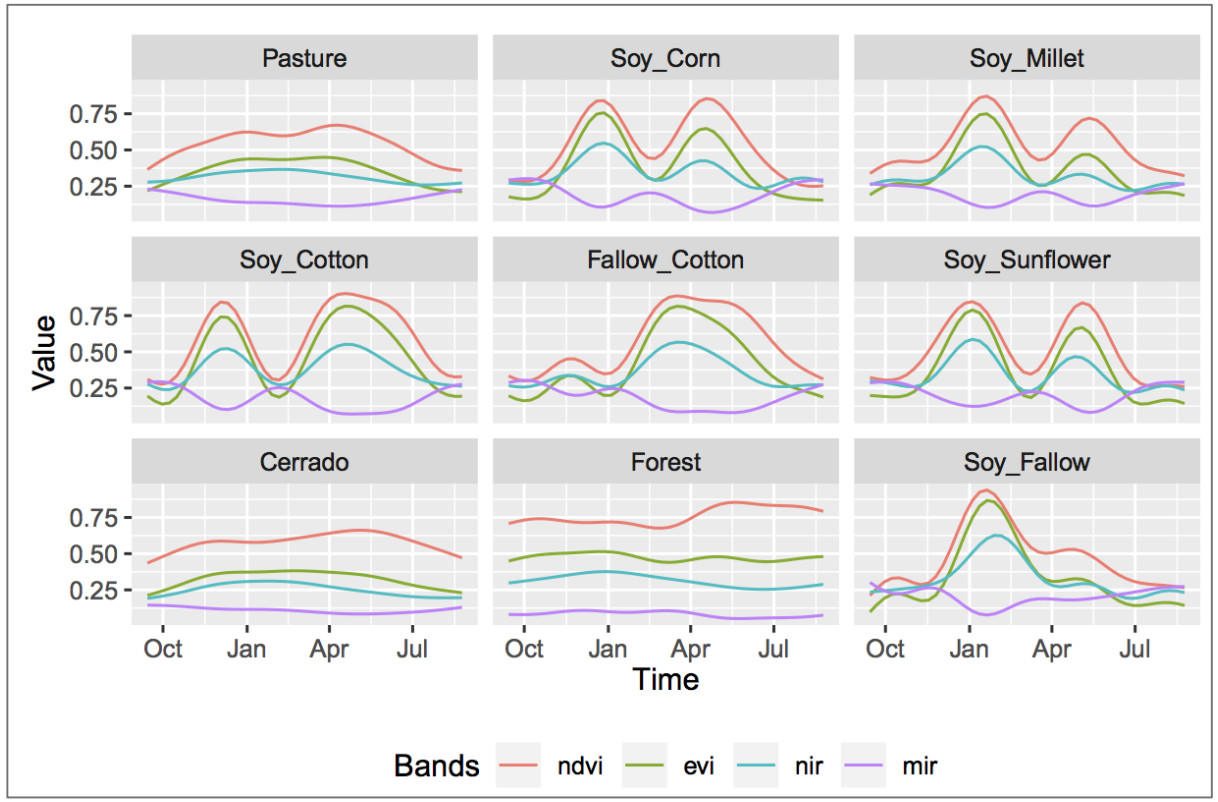
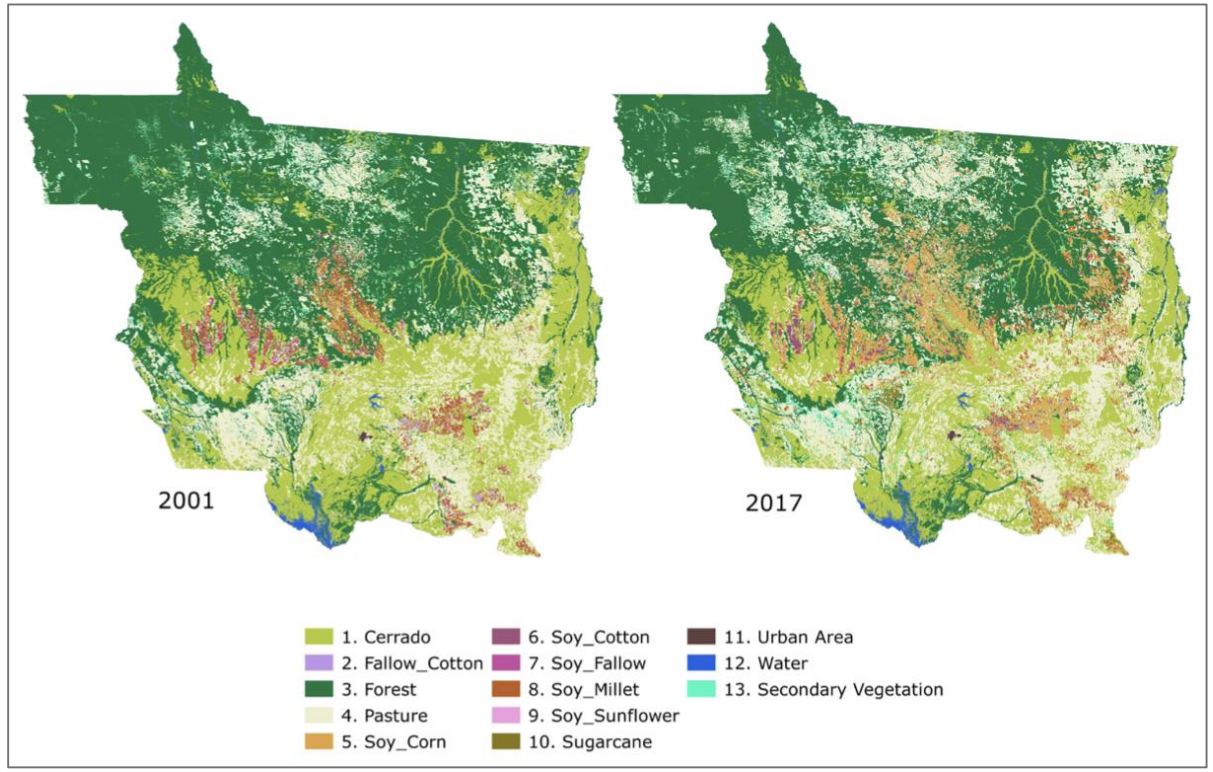


Image time series: NDVI, EVI, NIR, MIR (agriculture year)

MODIS (250 meters) – MOD13Q1 product

Method – SVM (Support Vector Machine)



Source: [Simoes et al., 2020]

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

Scientific Data, 2020

BRAZIL
DATA CUBE

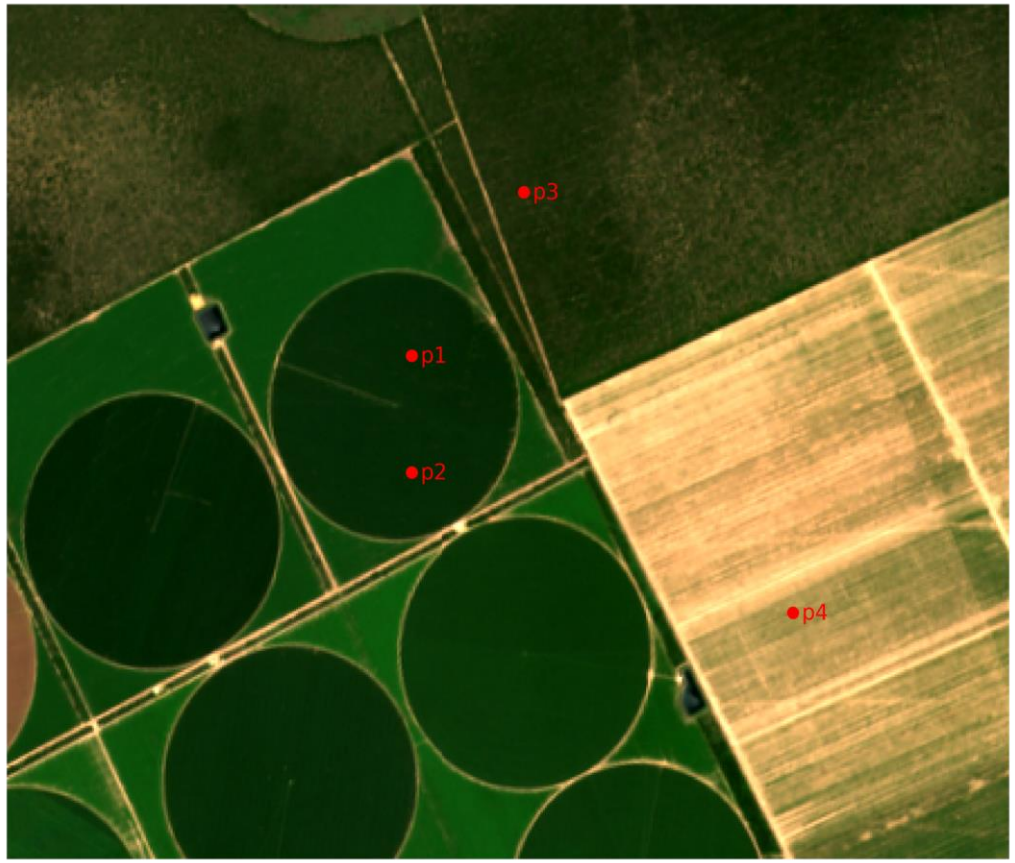
Satellite Image Time Series Analysis (SITS)

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

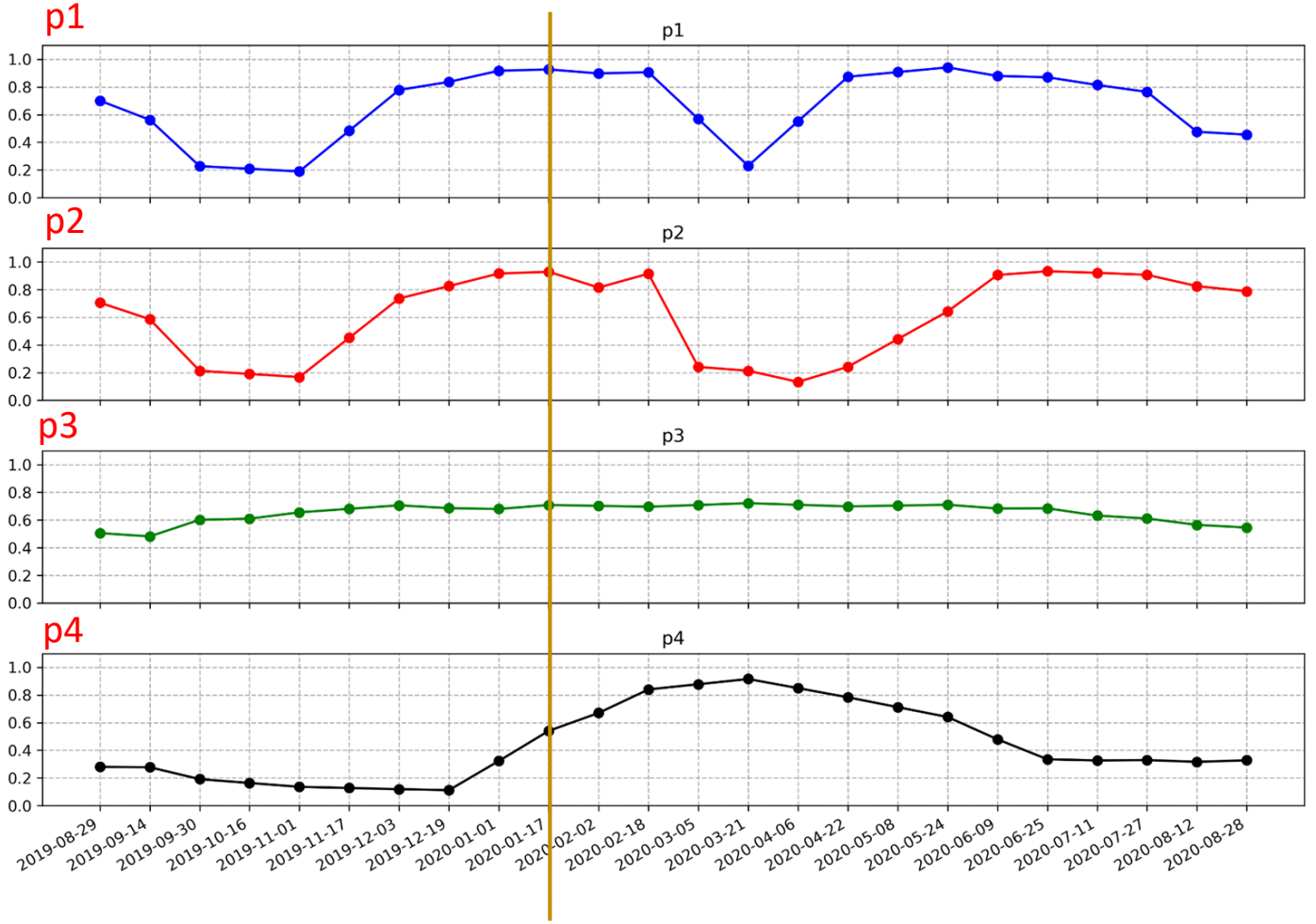
(Pasquarella et al., 2016)

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

Sentinel-2 RGB



2020-01-17

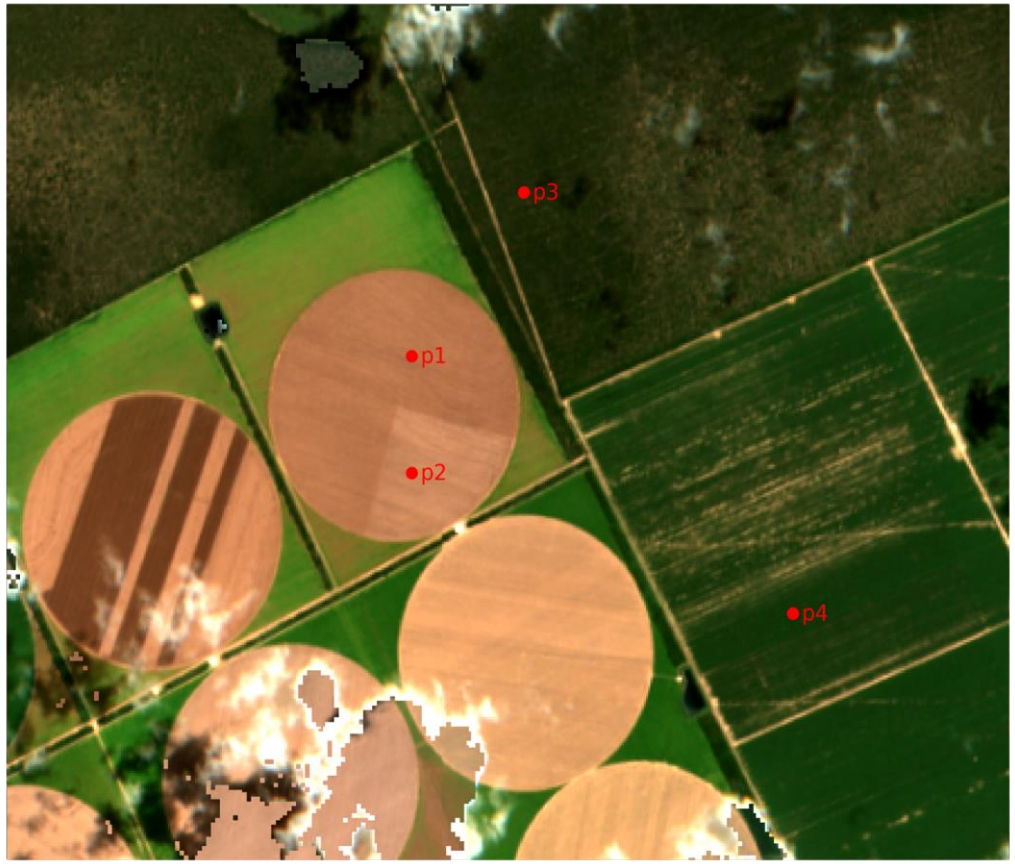


2020-01-17

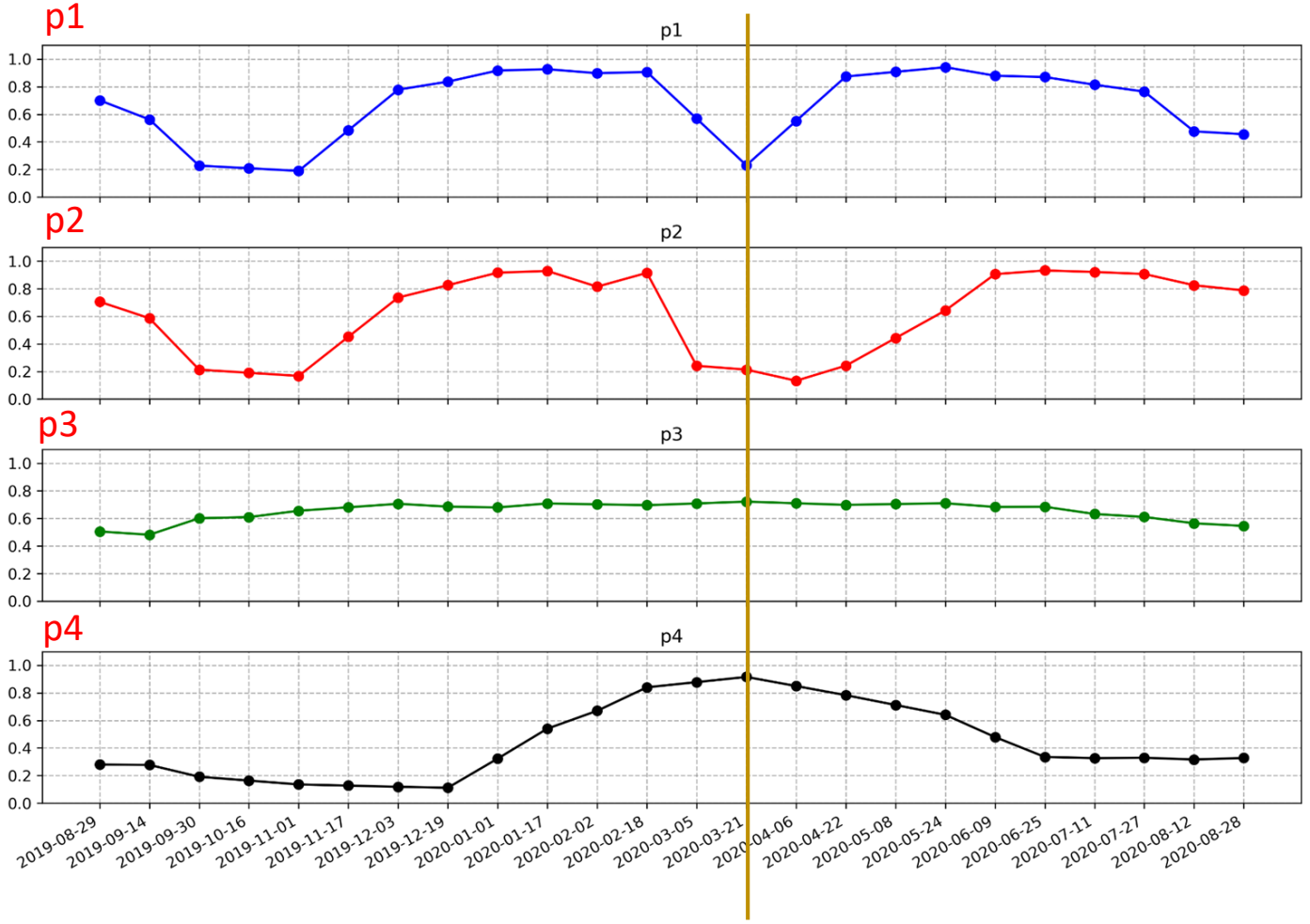
(Baggio, 2024)

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

Sentinel-2 RGB



2020-03-21

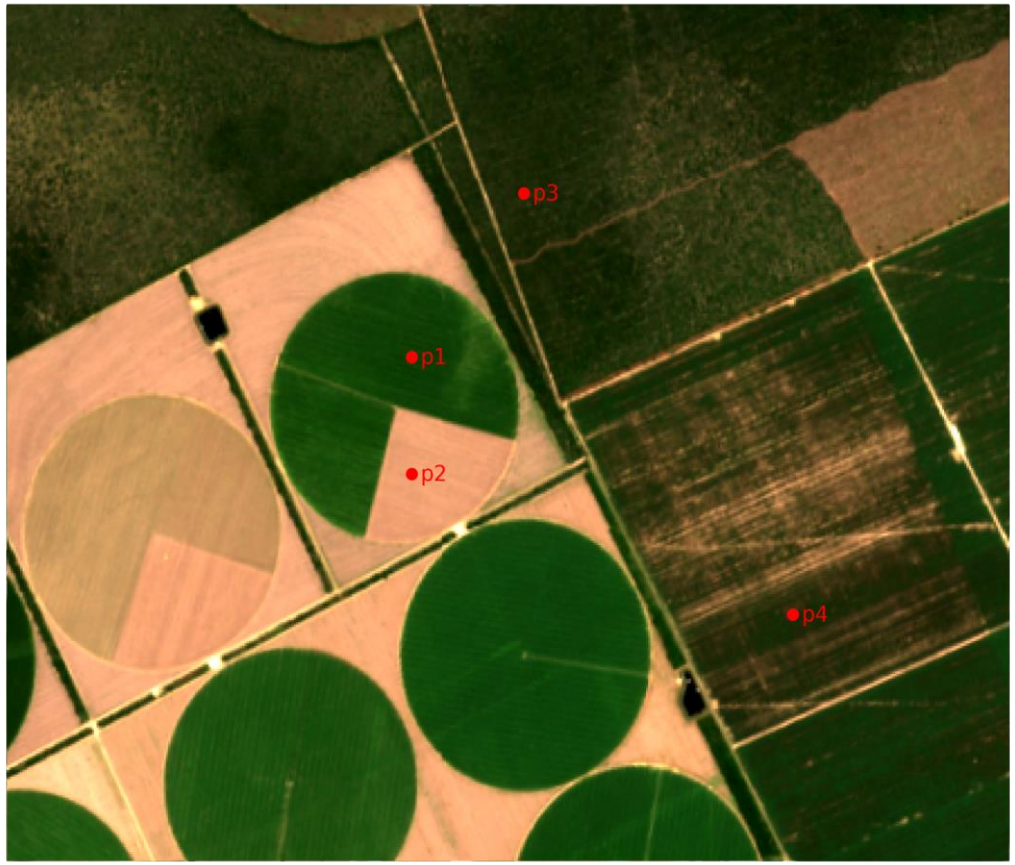


2020-03-21

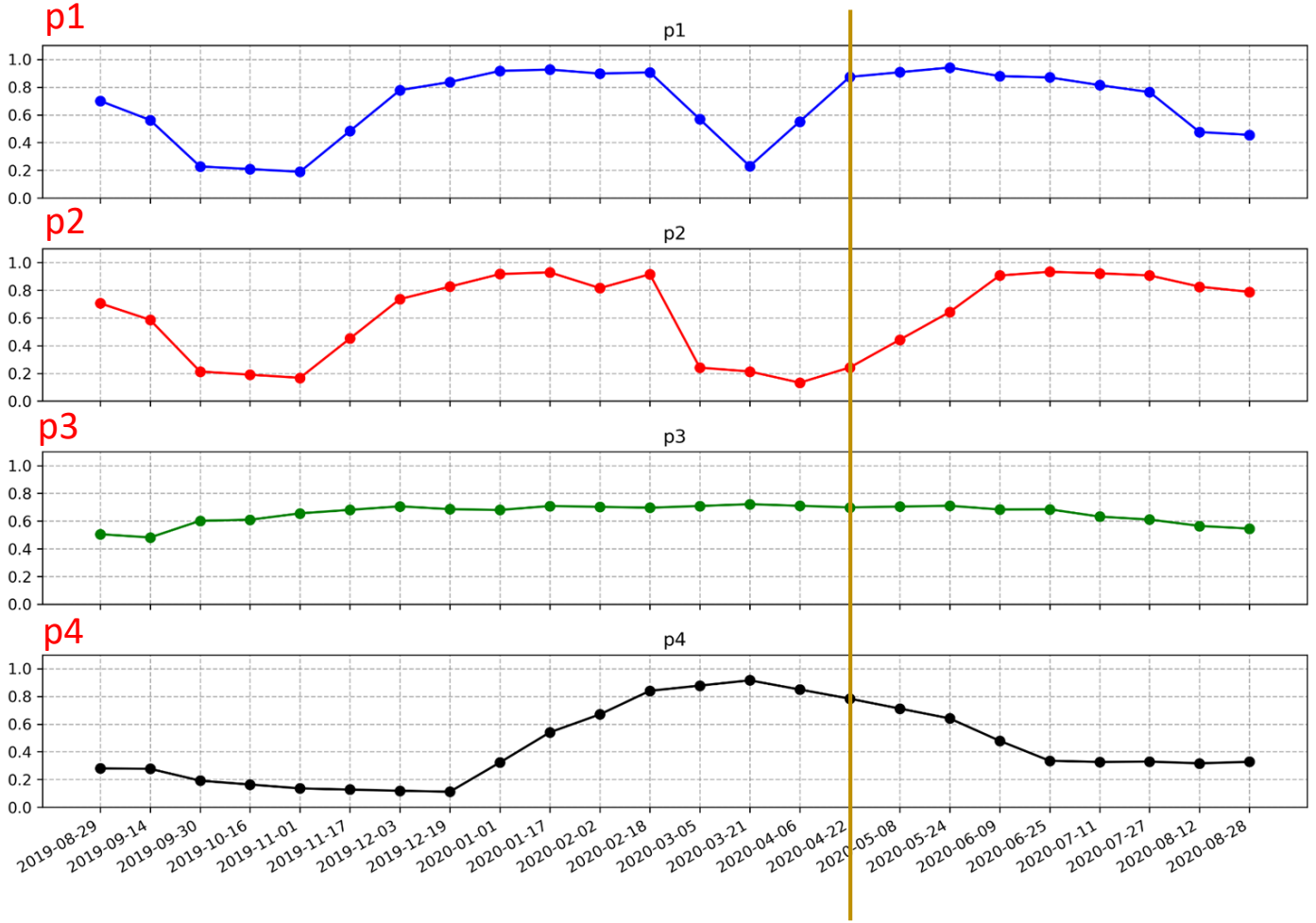
(Baggio, 2024)

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

Sentinel-2 RGB



2020-04-22



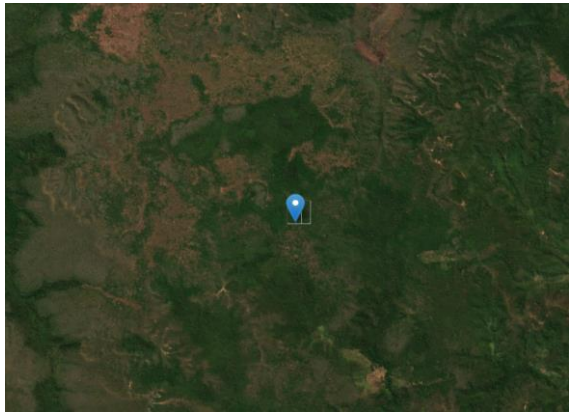
2020-04-22

(Baggio, 2024)

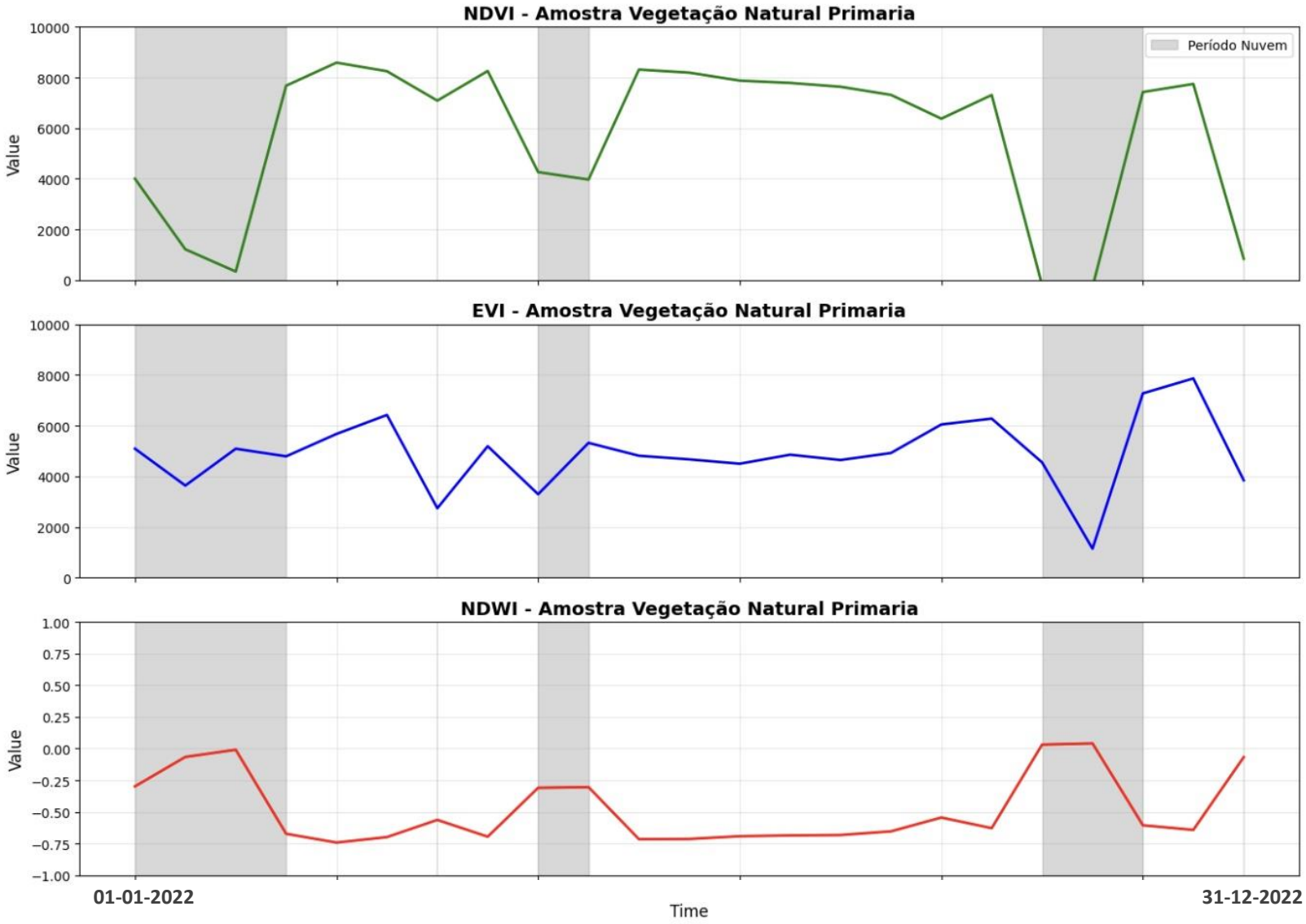
Vegetação Natural Primária – Cubos Sentinel 2

06-03-2022

12-07-2022



03-12-2022



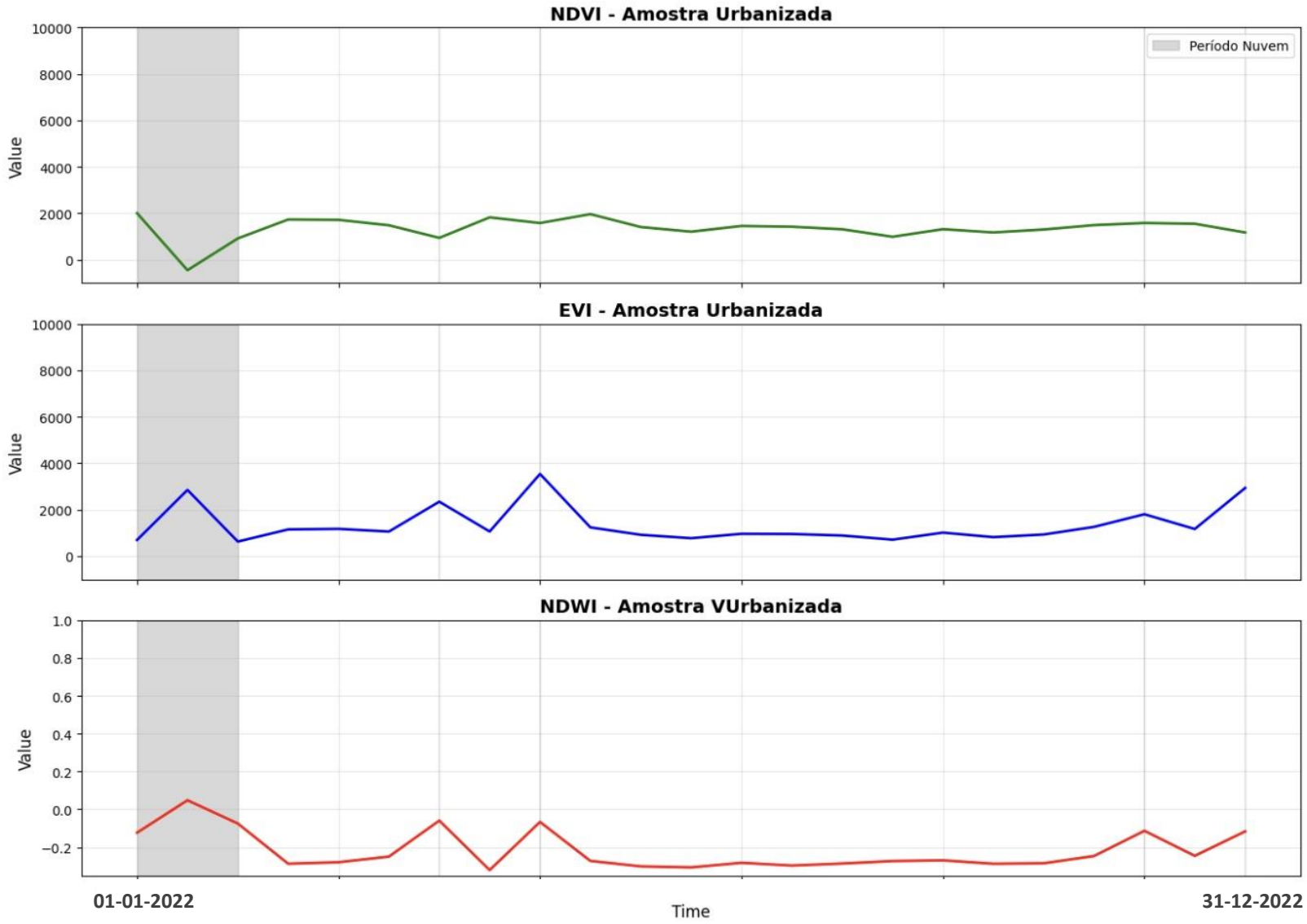
(Gabriel, 2025)

Área Urbana – Cubos Sentinel 2

18-02-2022

10-06-2022

16-10-2022



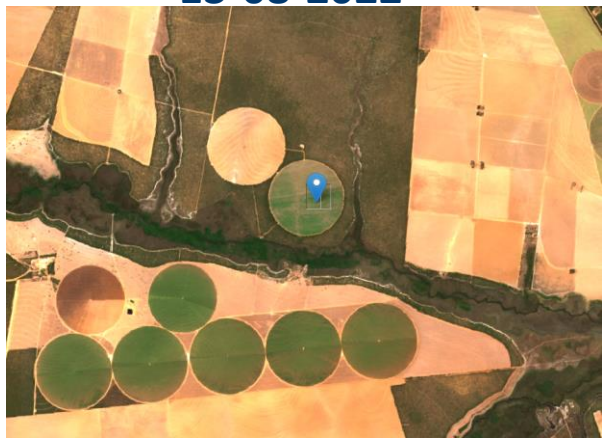
(Gabriel, 2025)

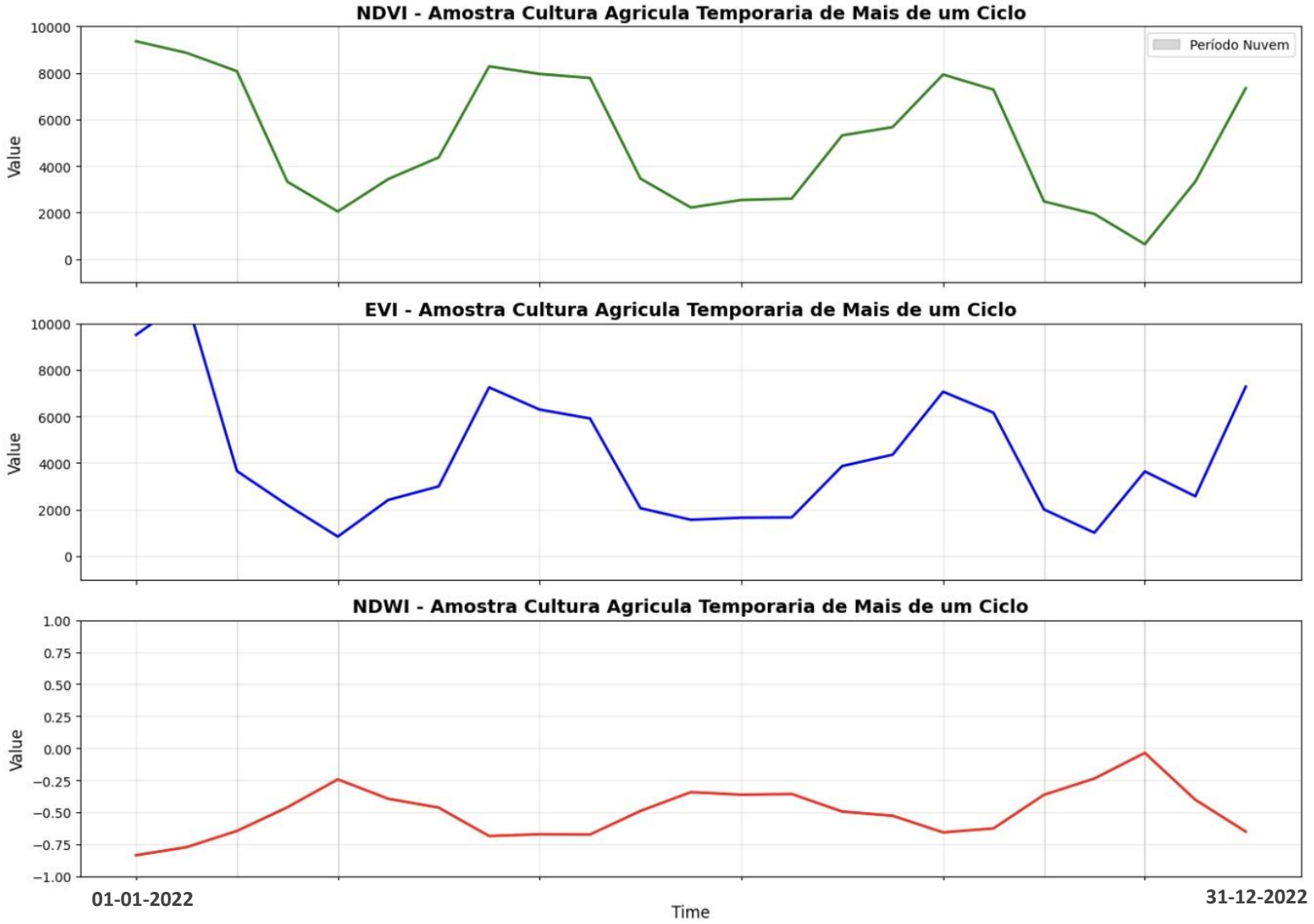
Agricultura - mais de 1 ciclo – Cubos Sentinel 2

01-01-2022

22-03-2022

13-08-2022



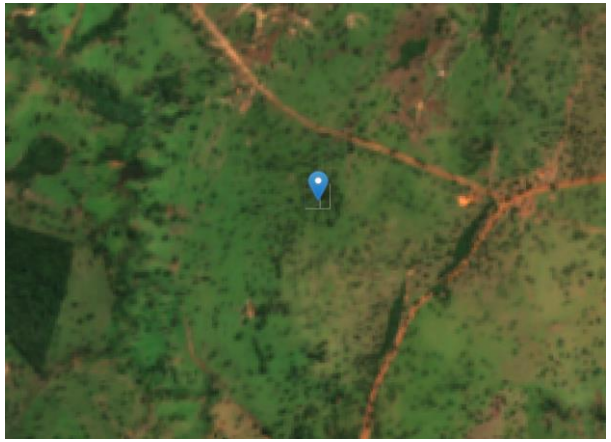


(Gabriel, 2025)

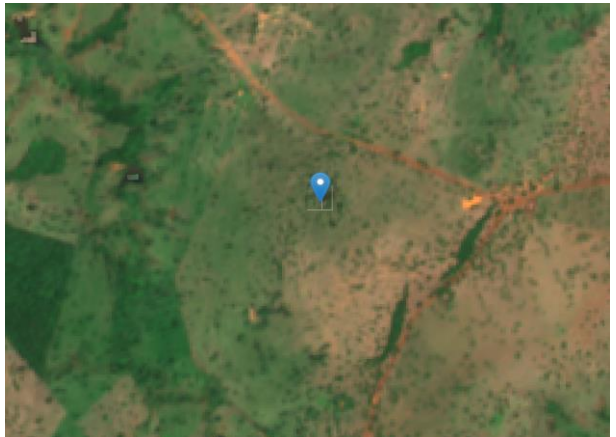
Pastagem – Cubos Sentinel 2

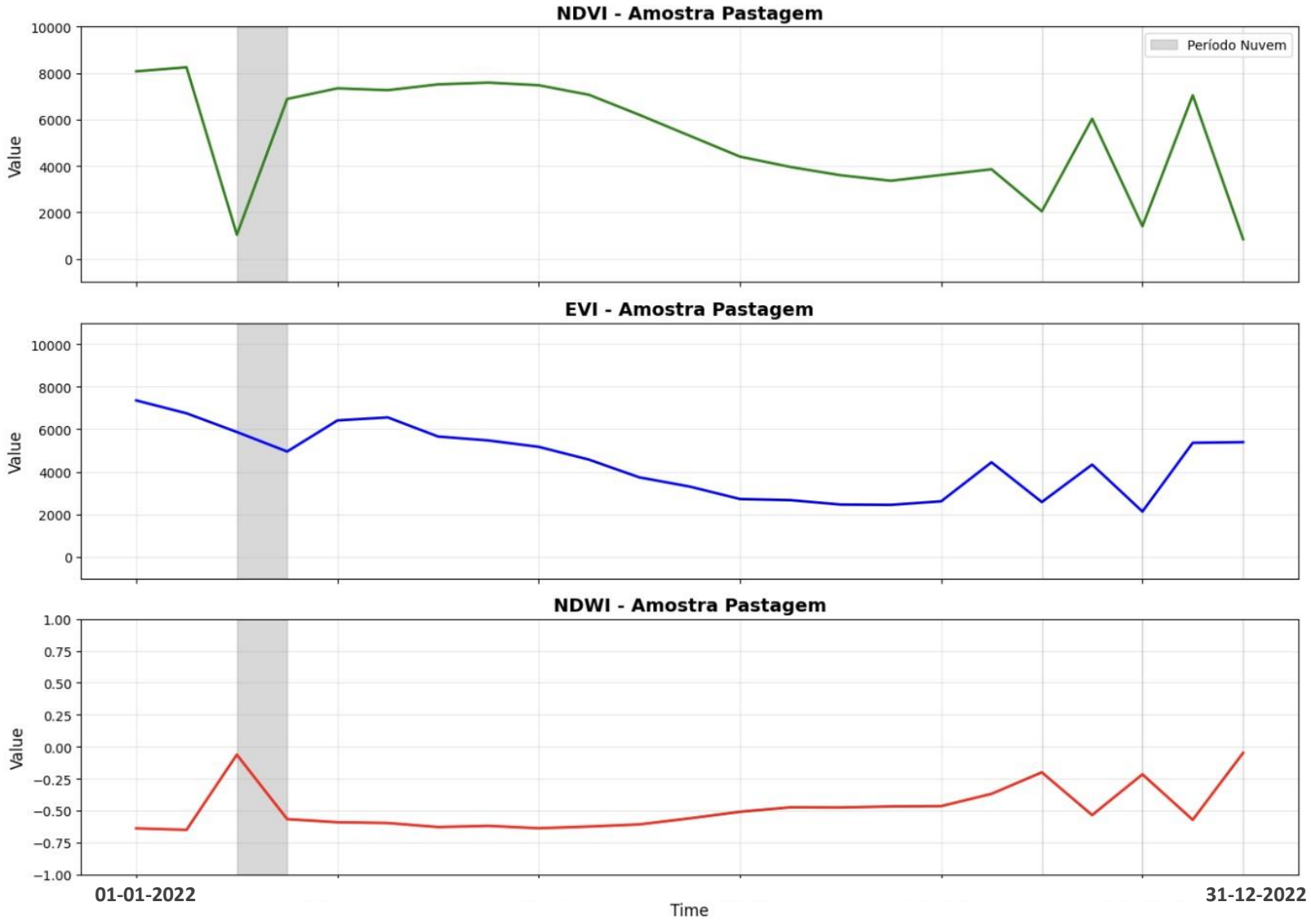
17-01-2022

09-05-2022



01-11-2022



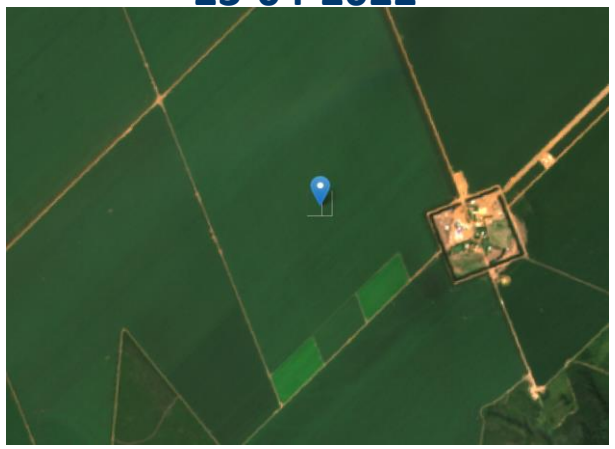


(Gabriel, 2025)

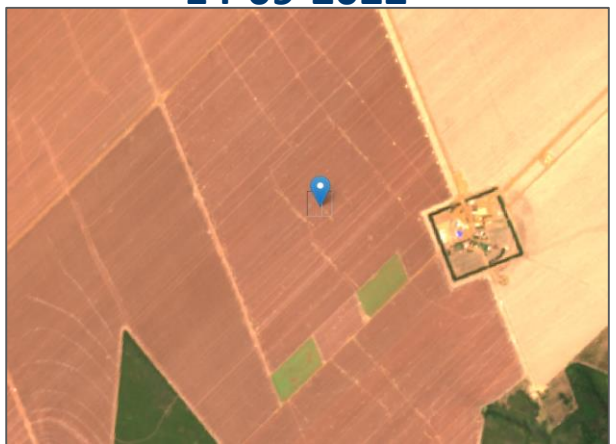
Agricultura – 1 ciclo – Cubos Sentinel 2

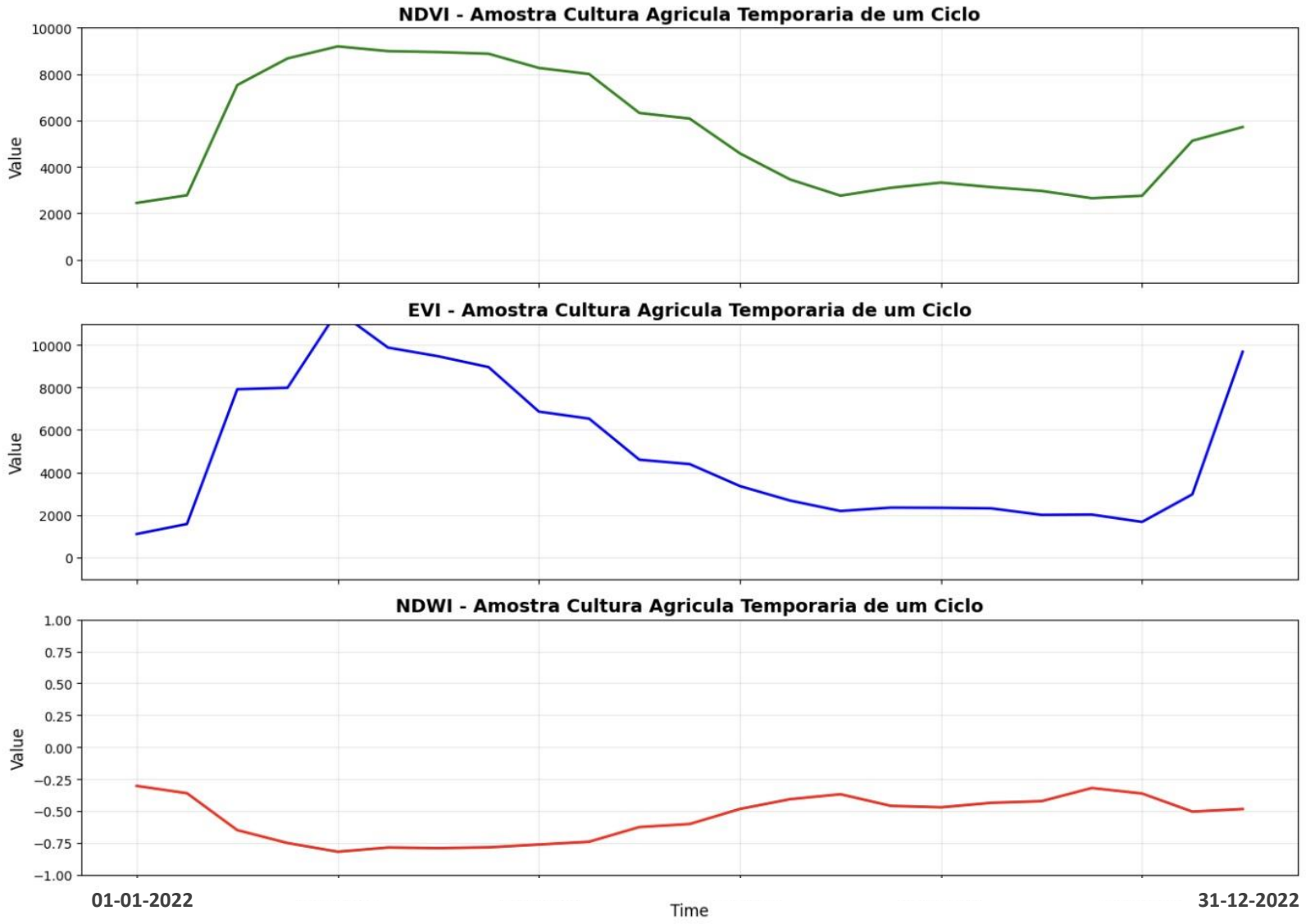
02-02-2022

23-04-2022



14-09-2022

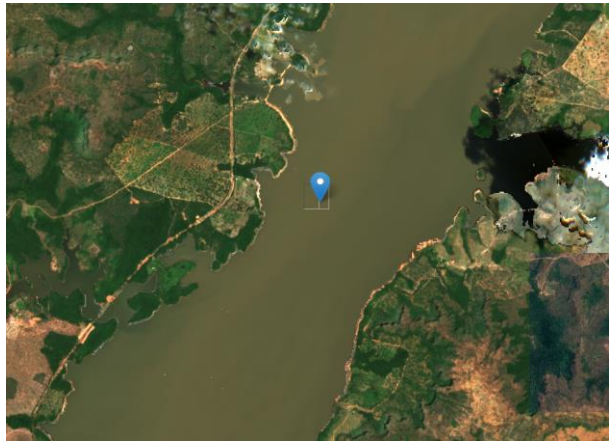




(Gabriel, 2025)

Água – Cubos Sentinel 2

14-09-2022



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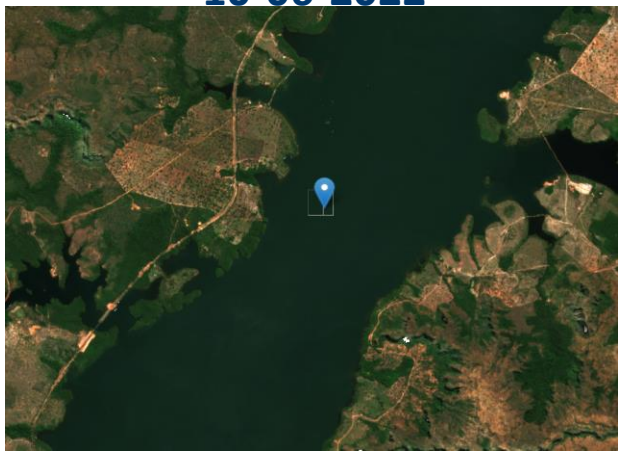

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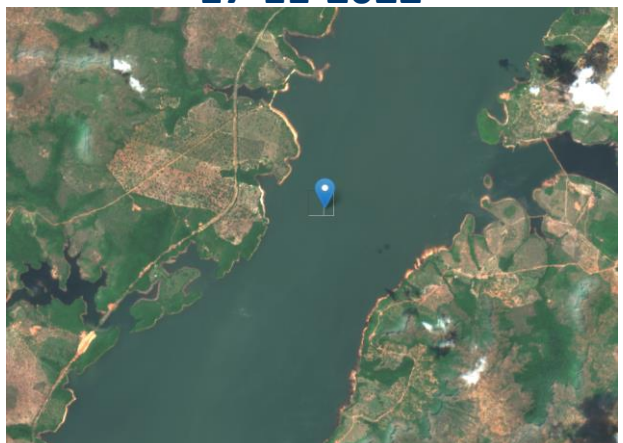
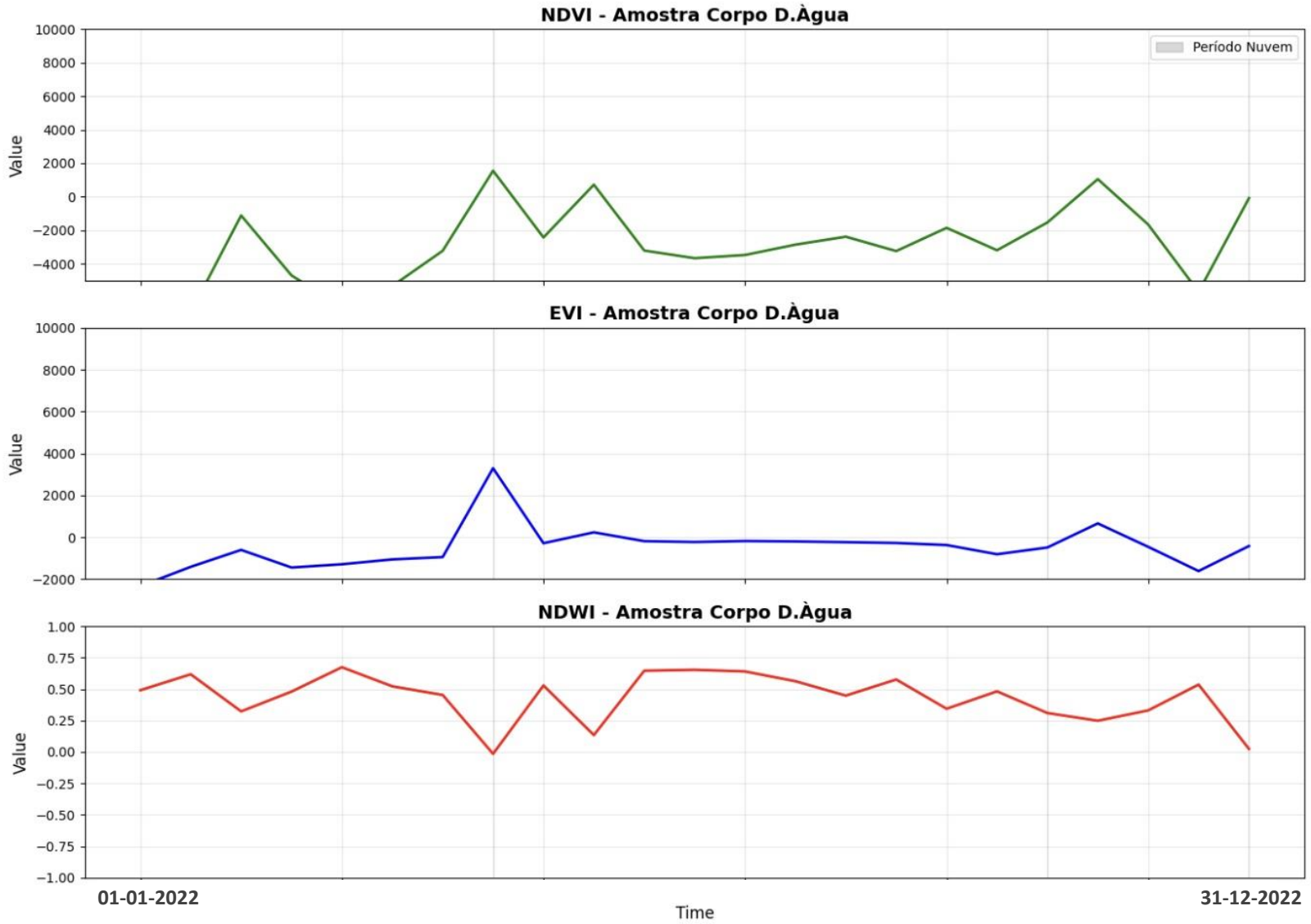




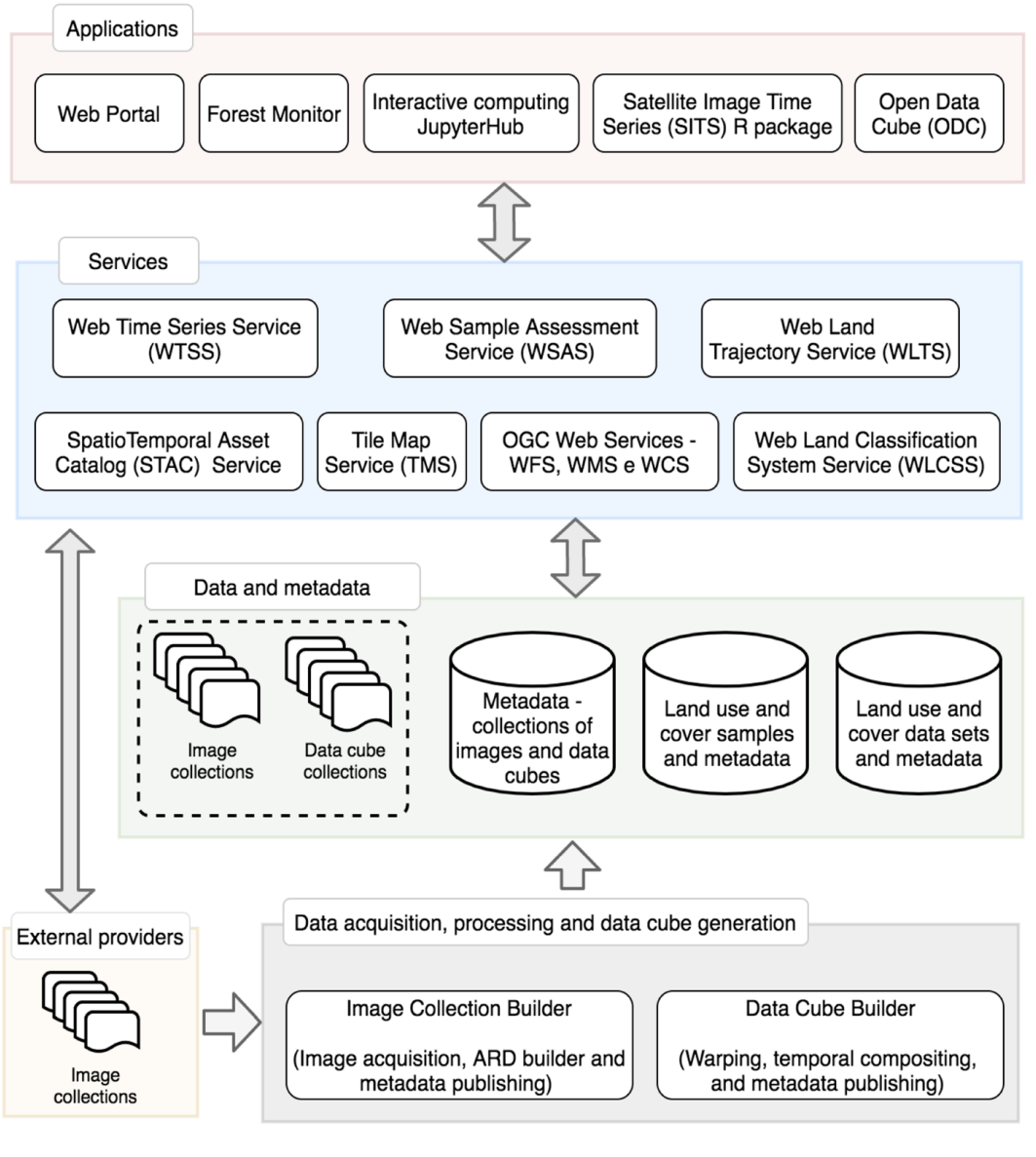
(Gabriel, 2025)

Brazil Data Cube Platform

Open Data and Software Products

Software

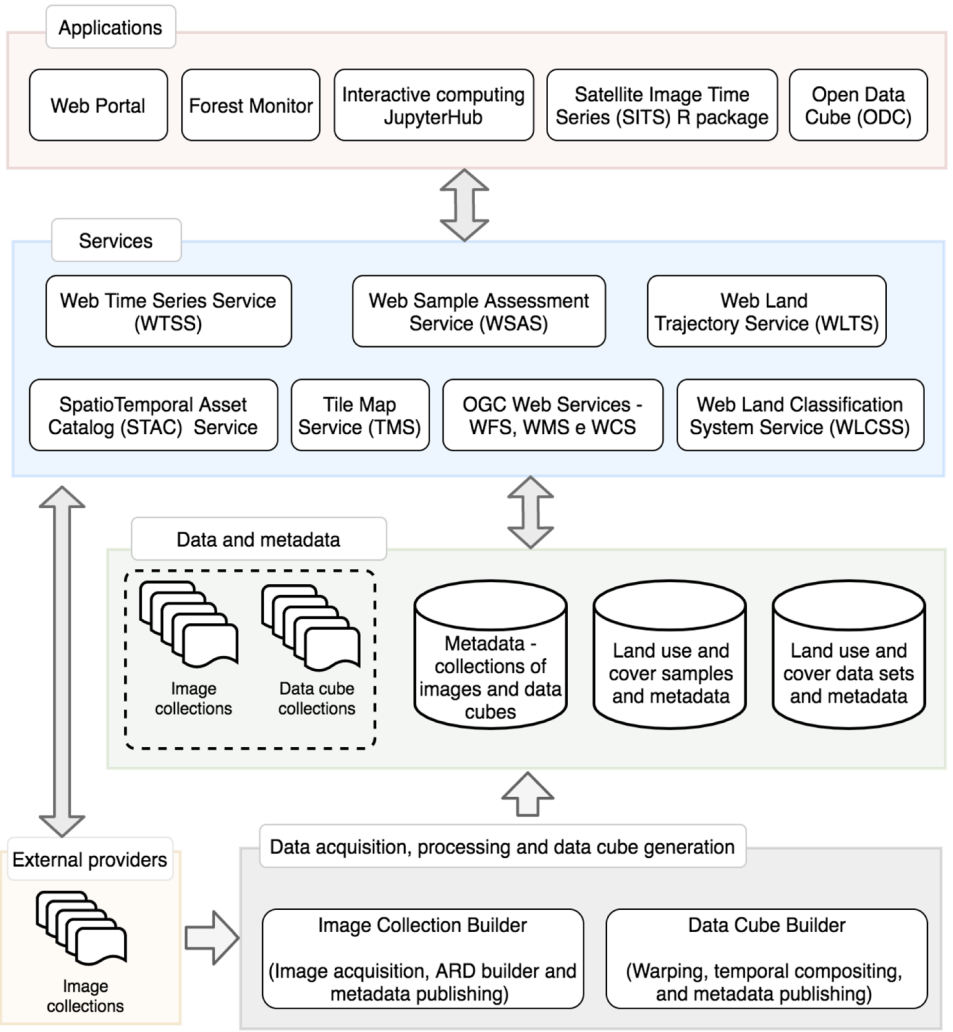
Data and metadata



Source: [Ferreira et al, 2020]

Source: [Ferreira et al., 2020]

Brazil Data Cube Platform



Source: [Ferreira et al, 2020]

Interoperabilidade

Google Earth Engine

Microsoft | Planetary Computer

Copernicus Data Space Ecosystem (CDSE)

BRAZIL DATA CUBE

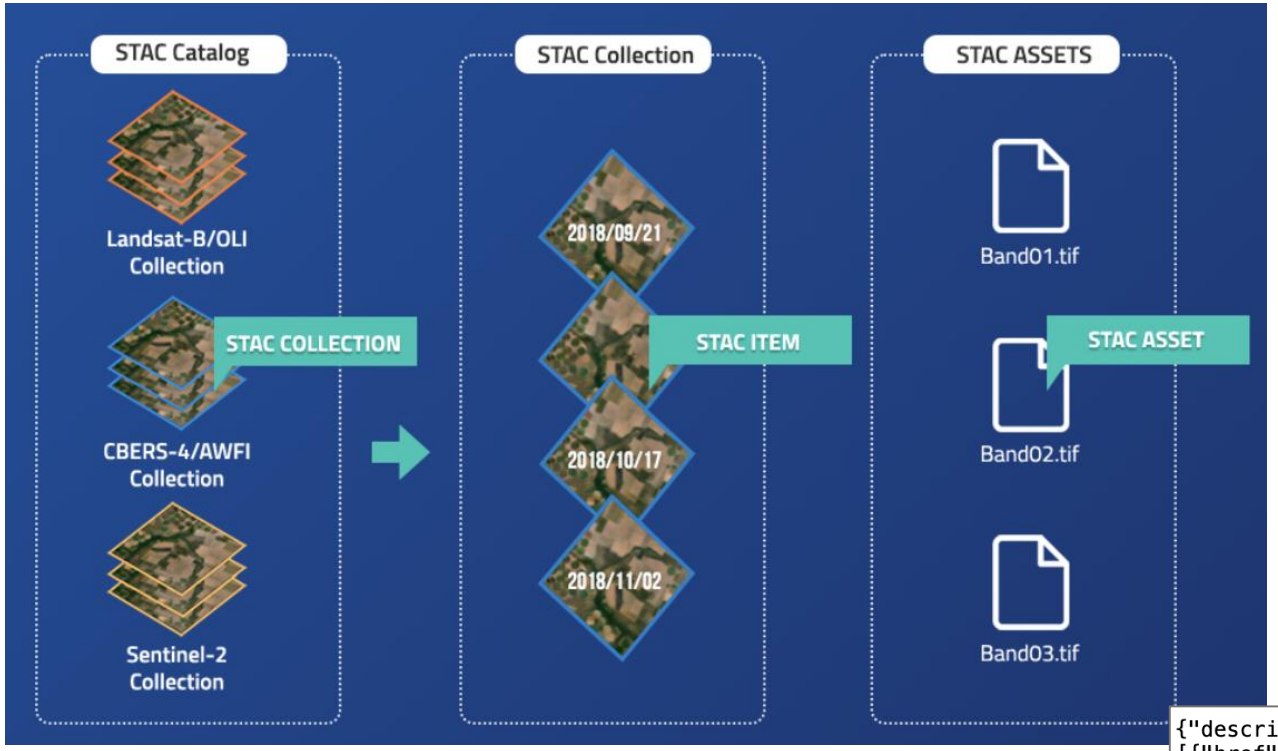
aws

STAC

SpatioTemporal Asset Catalog

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

Source: https://stacspec.org/en



STAC

SpatioTemporal Asset Catalog

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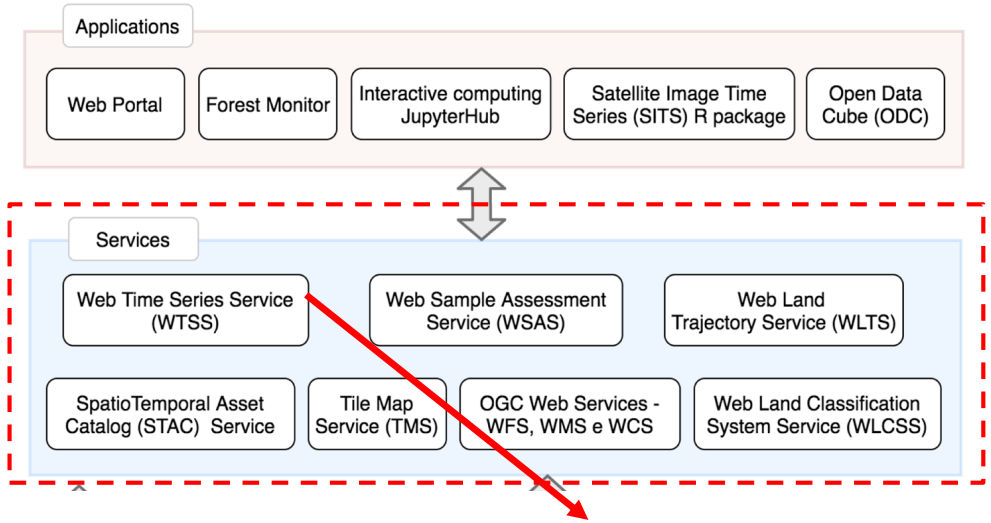
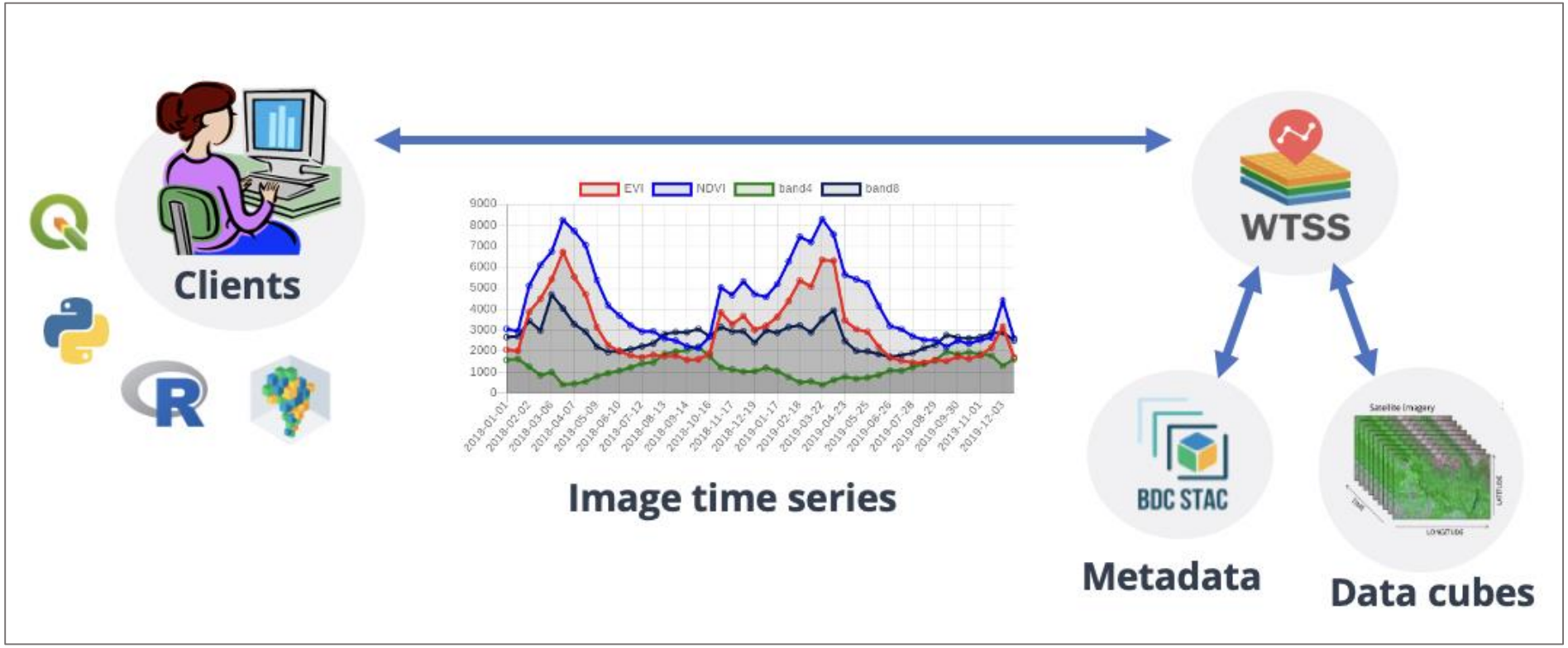
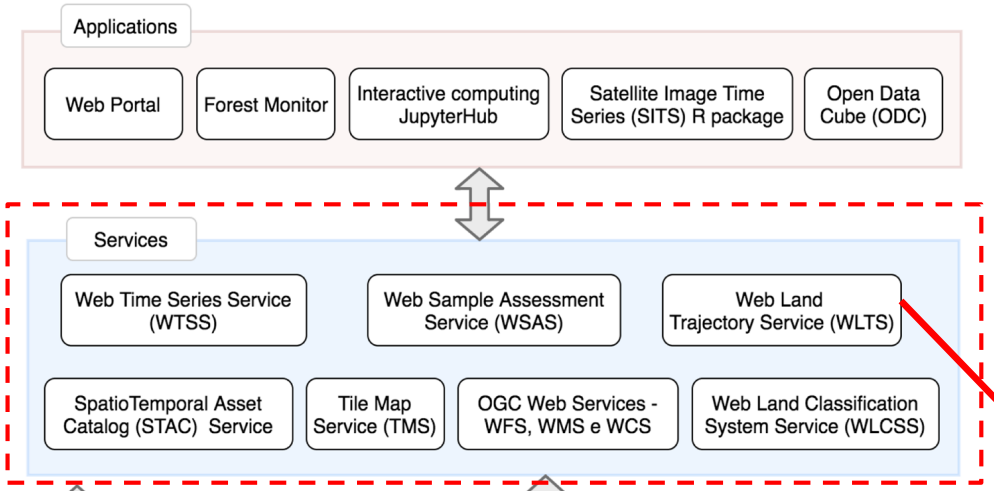
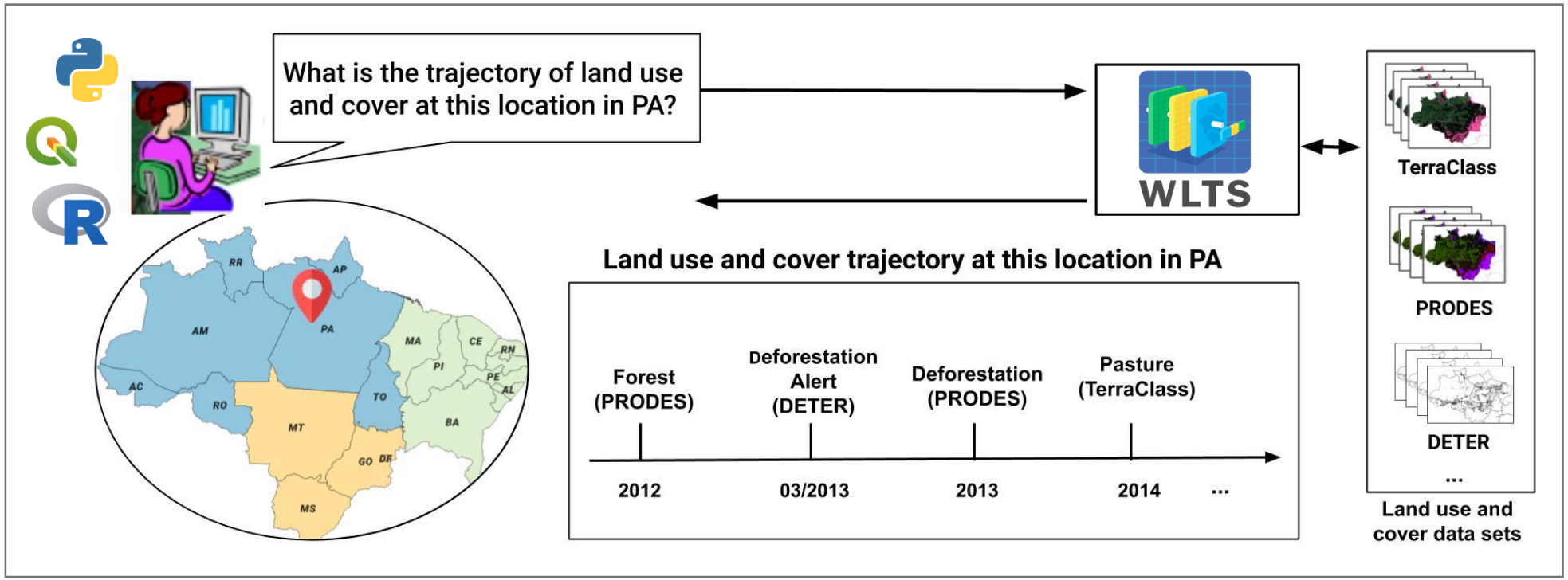


WTSS – Web Time Series Service



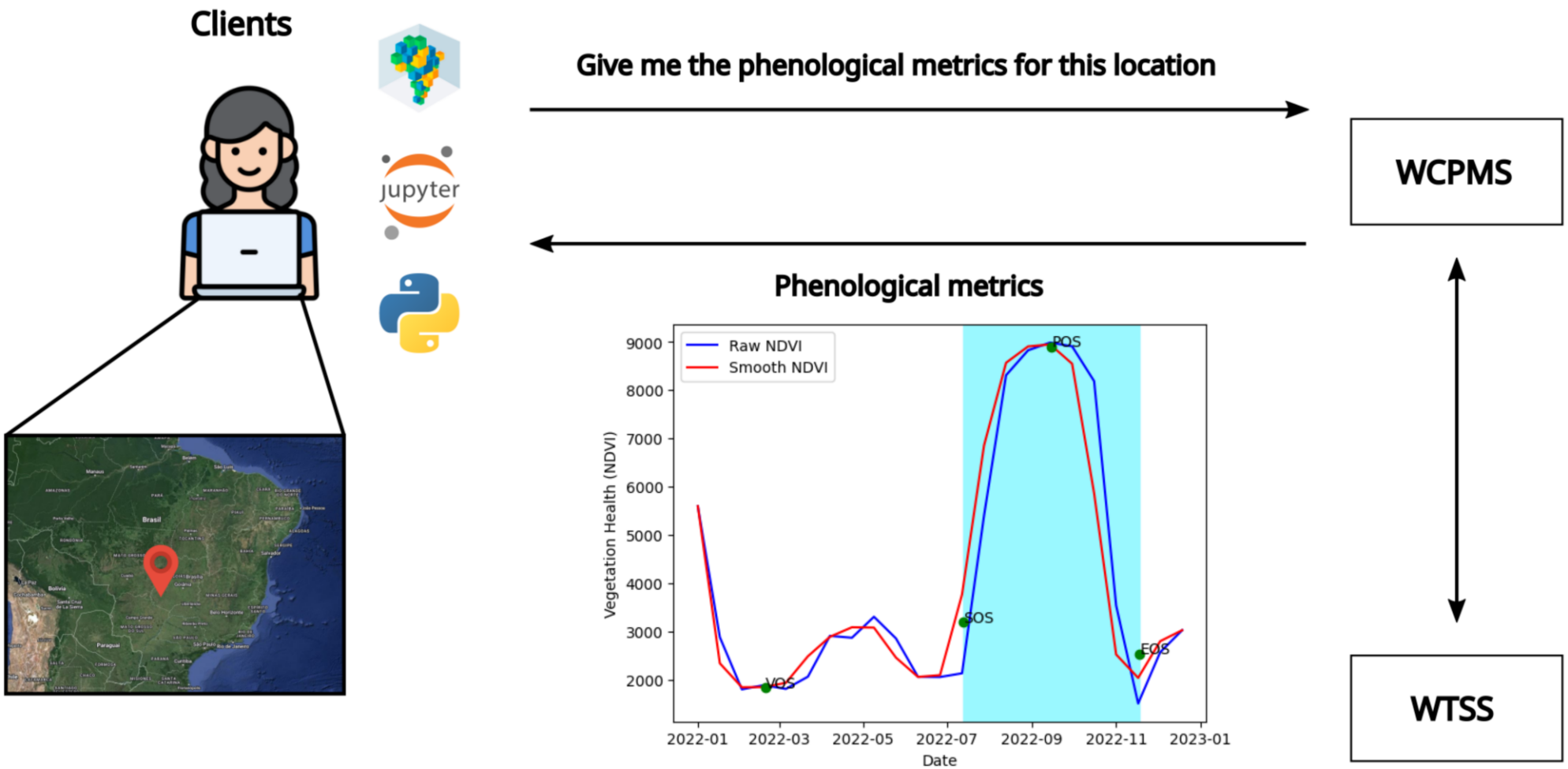


WLTS – Web Land Trajectory Service

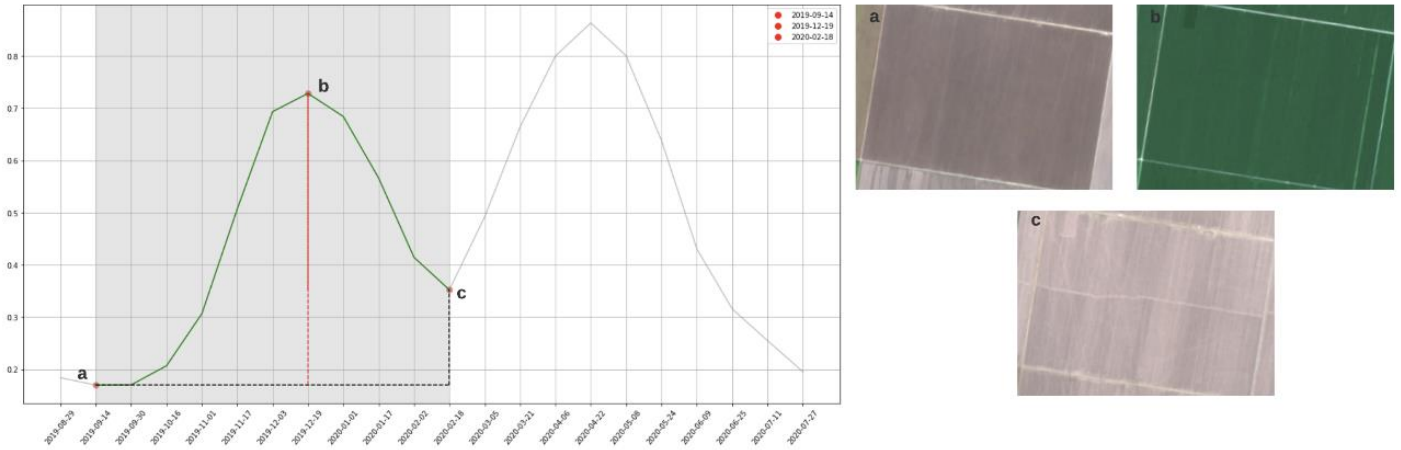


Source: [Zioti et al,. 2021]

Web Crop Phenology Metrics Service (WCPMS)



(a)



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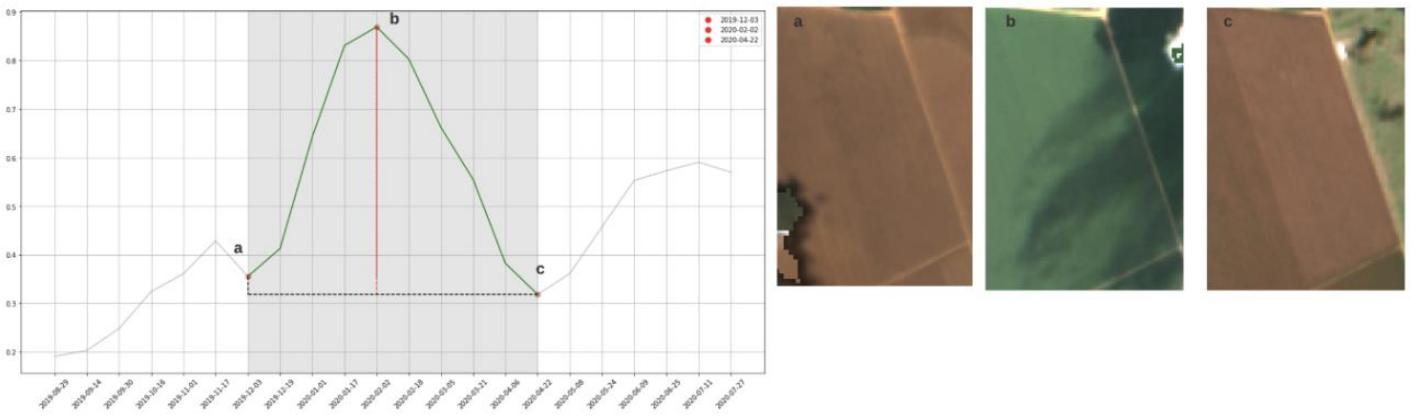
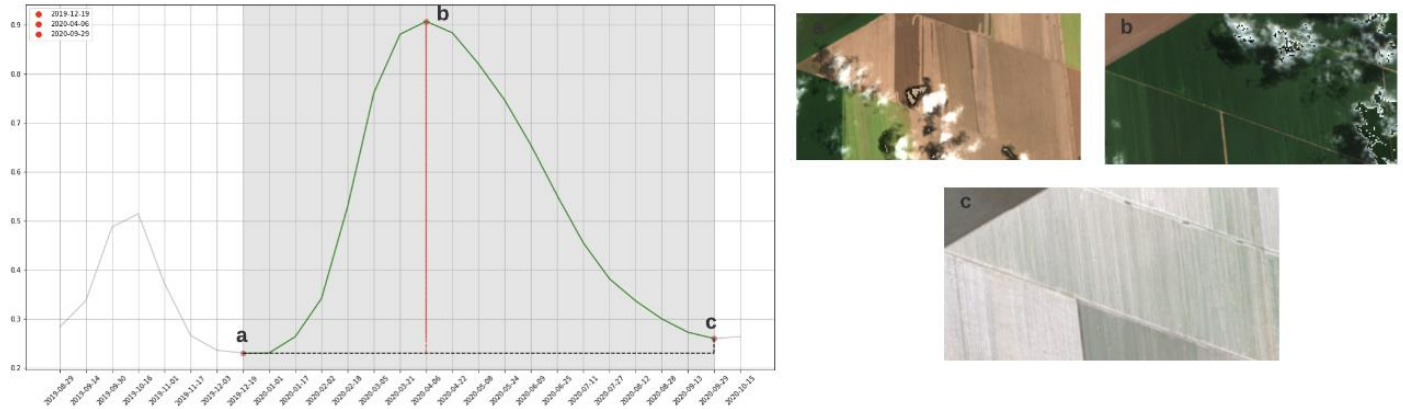
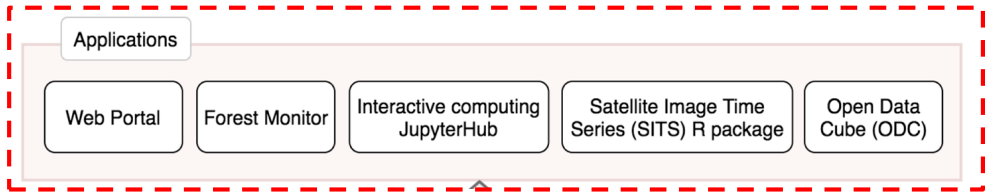


(c)

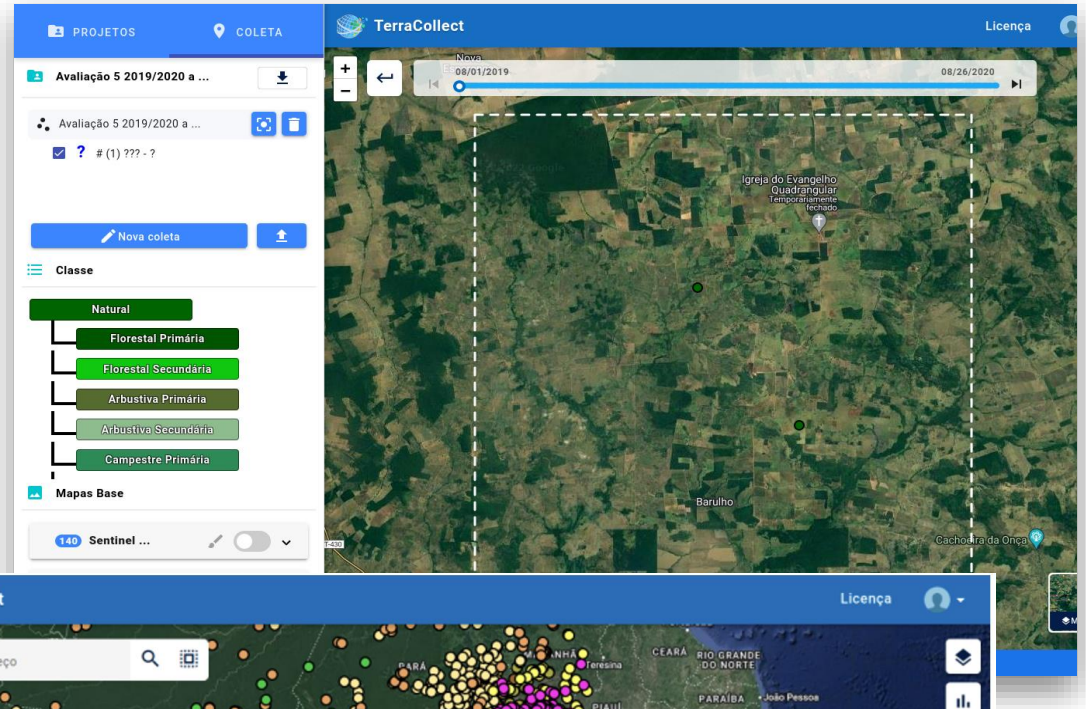


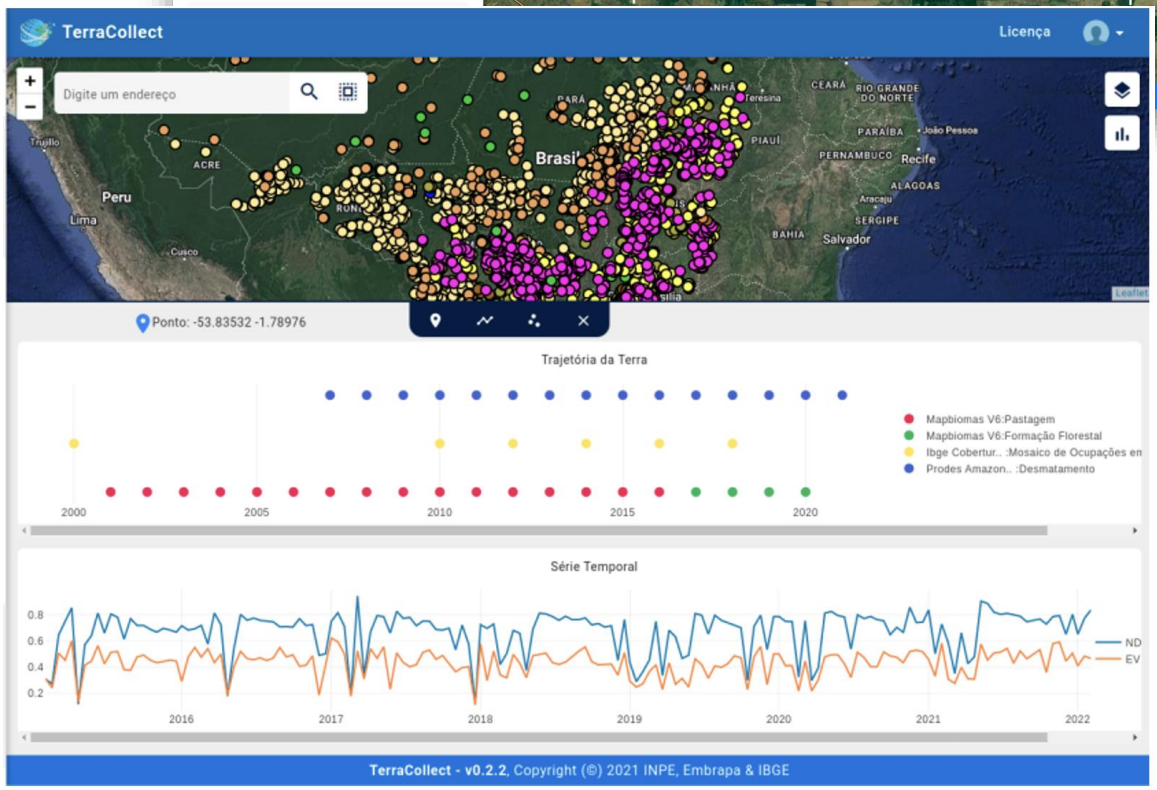
Métricas fenológicas de *início*, *fim* e *máximo* vigor vegetativo de plantio extraídas para soja (a), milho de primeira safra (b) e algodão (c) utilizando series temporais NDVI dos cubos Sentinel-2 (16 dias) do BDC.



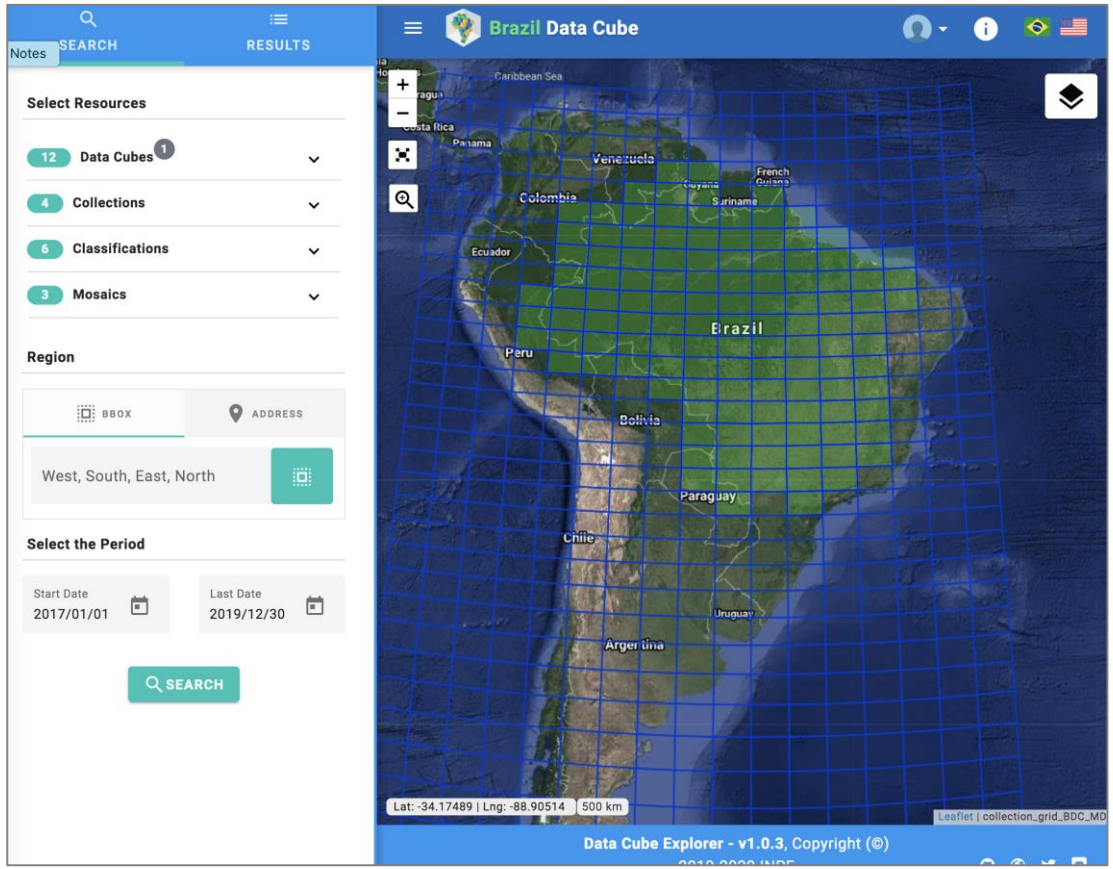
OPEN DATA CUBE

TerraCollect





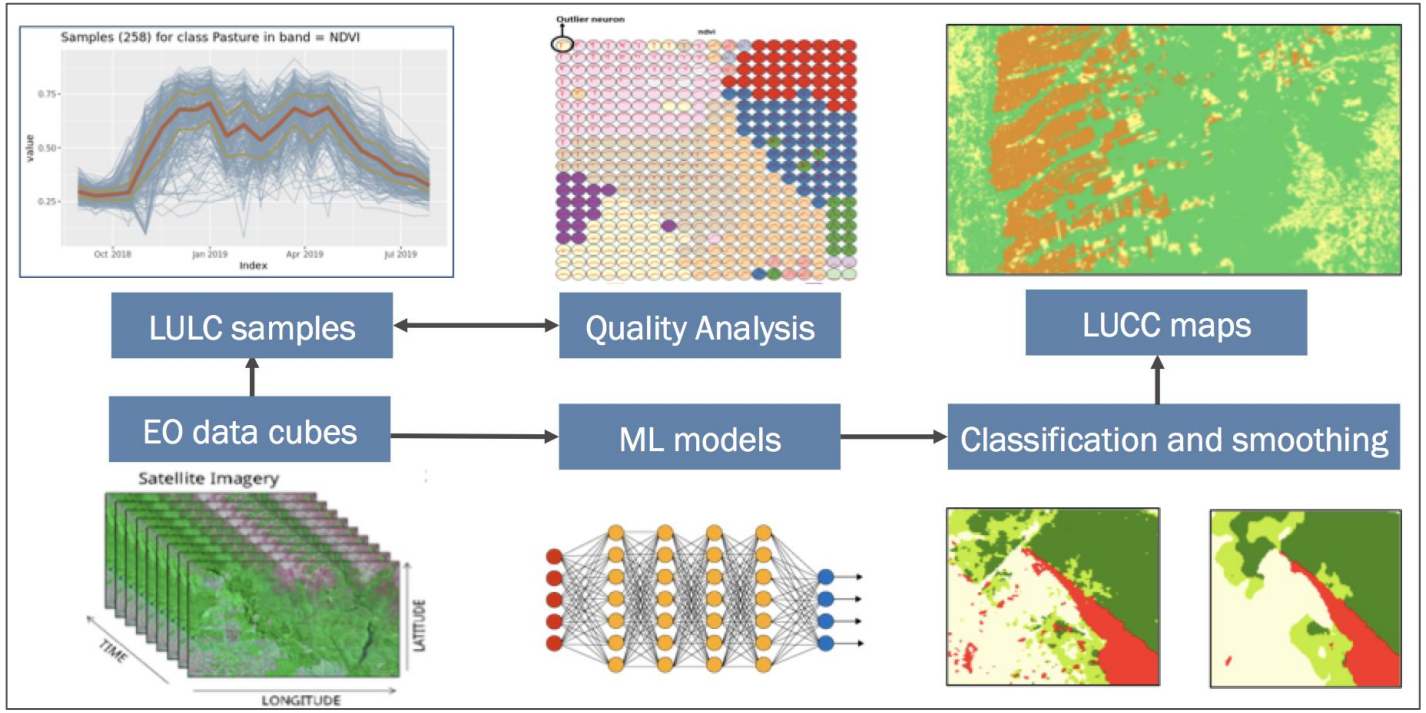
BDC Explorer



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

WTSS e WLTS – Interface gráfica – BDC Explorer e TerraCollect

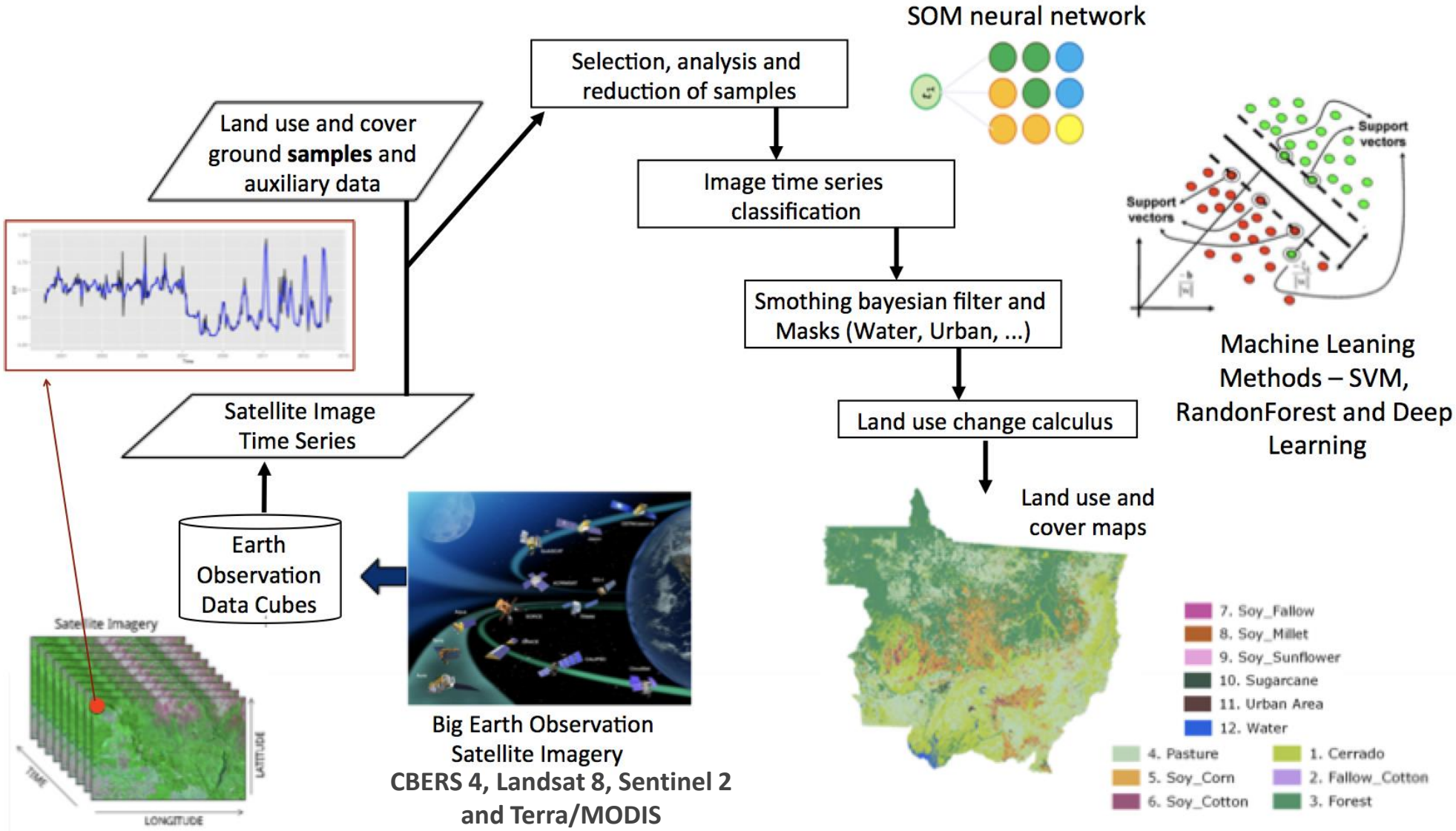
SITS (Satellite Image Time Series) R package




```
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())
```

https://github.com/e-sensing

SITS (Satellite Image Time Series) R package:
https://github.com/e-sensing

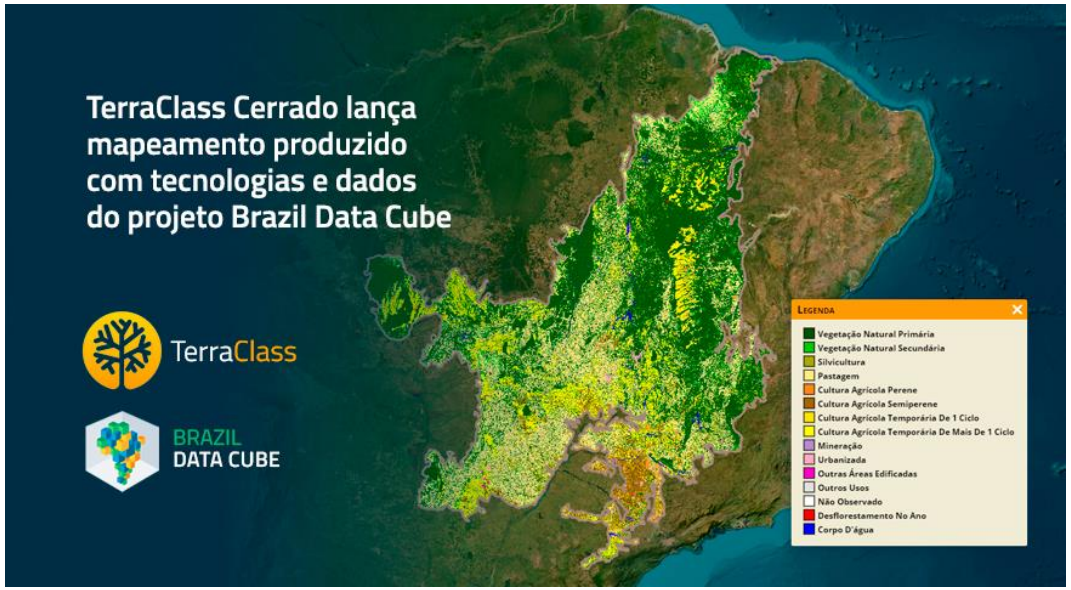


ARD and Data cubes available at:
http://brazildatacube.dpi.inpe.br/portal/explore

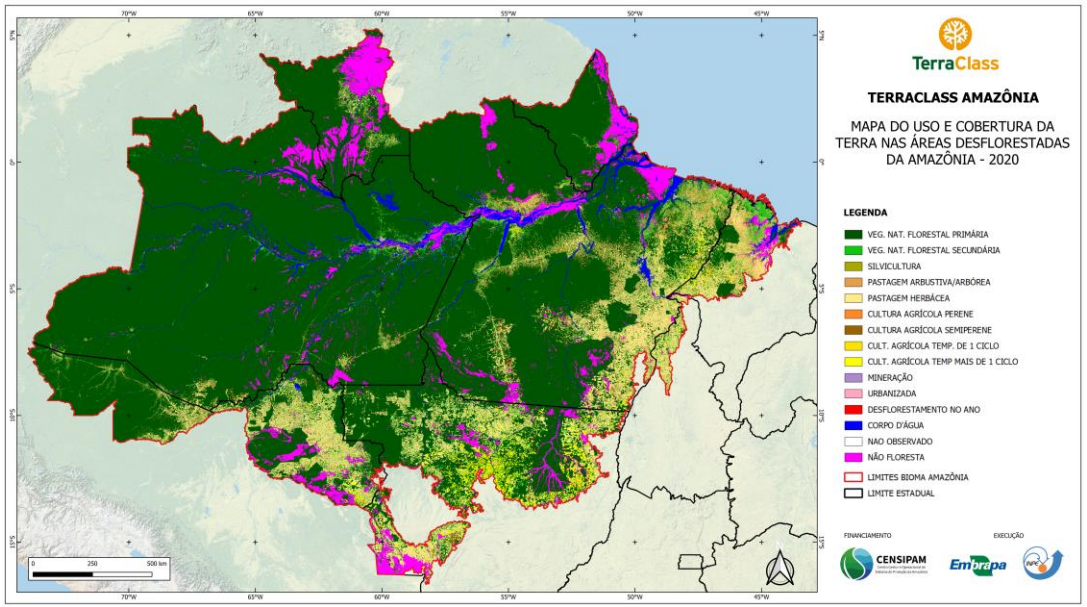
Land use and cover change maps:
http://brazildatacube.dpi.inpe.br/portal/explore

Land use and land cover maps: TerraClass project

TerraClass Cerrado 2020 (Launched in December 2022)



TerraClass Amazônia 2020



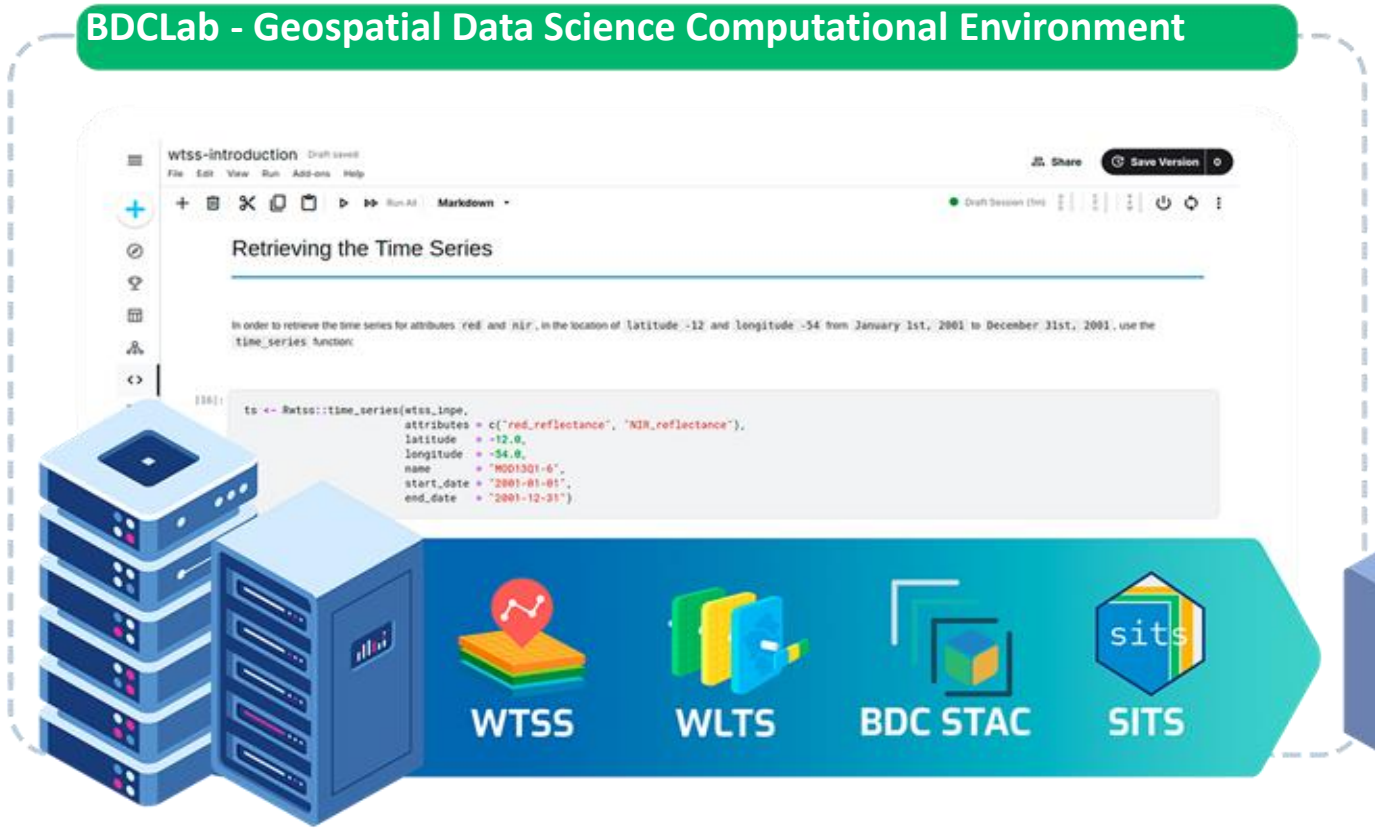
INPE UNIDADE DE PESQUISA DO MCTI

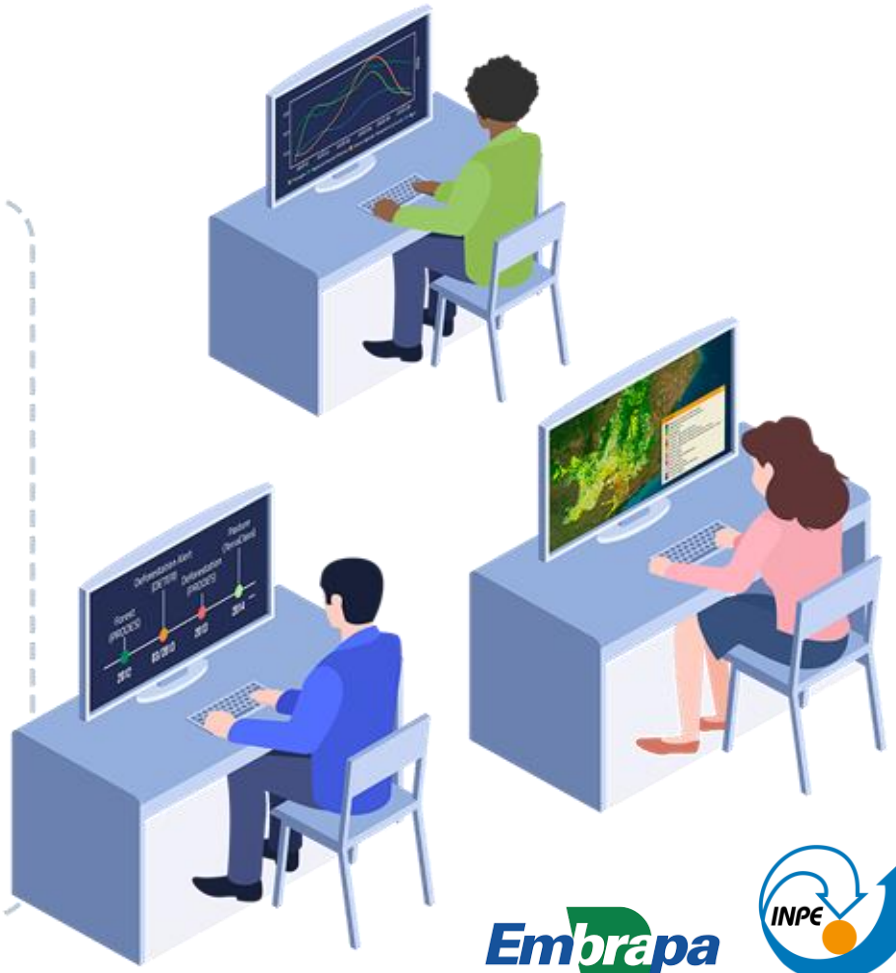
Embrapa

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.

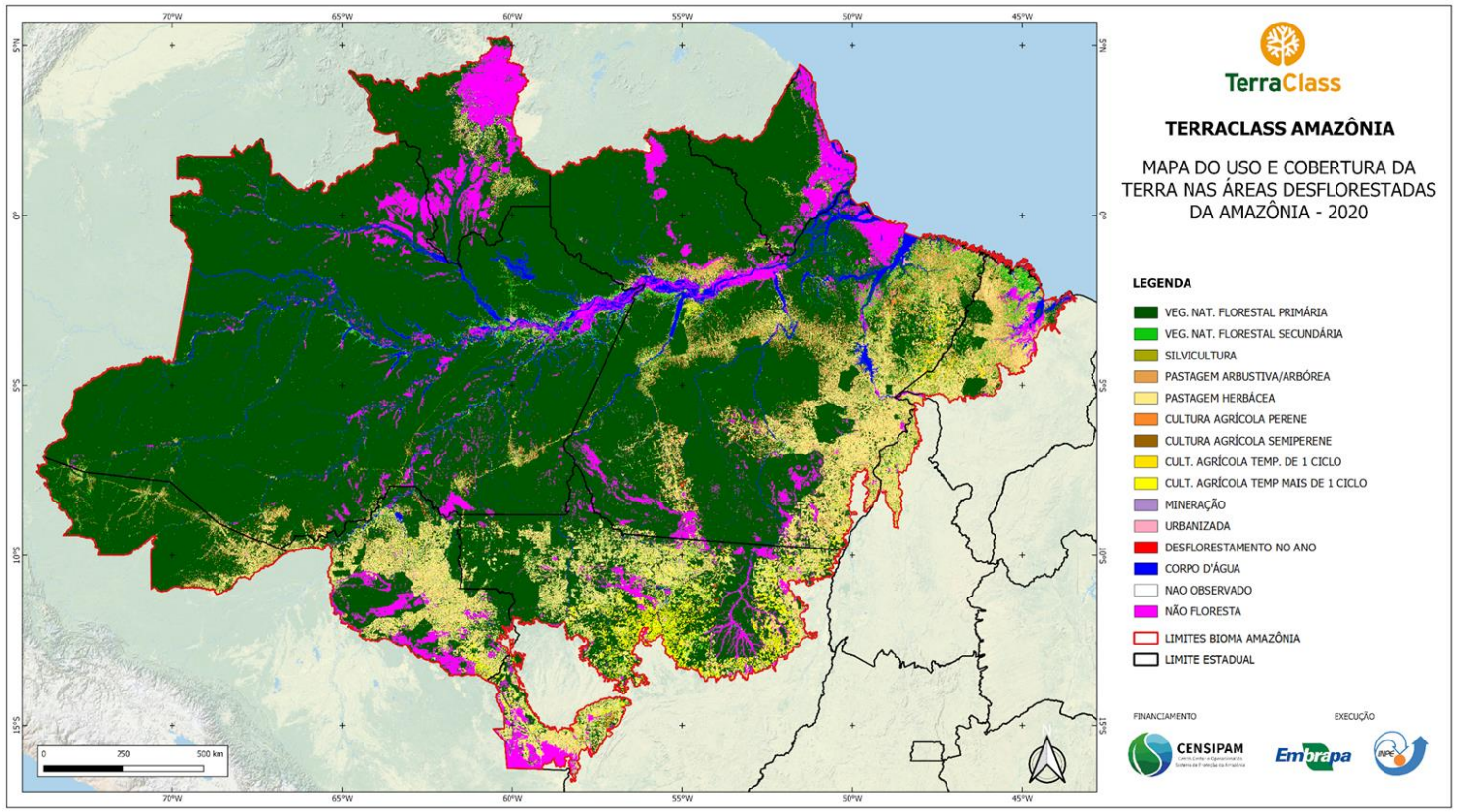




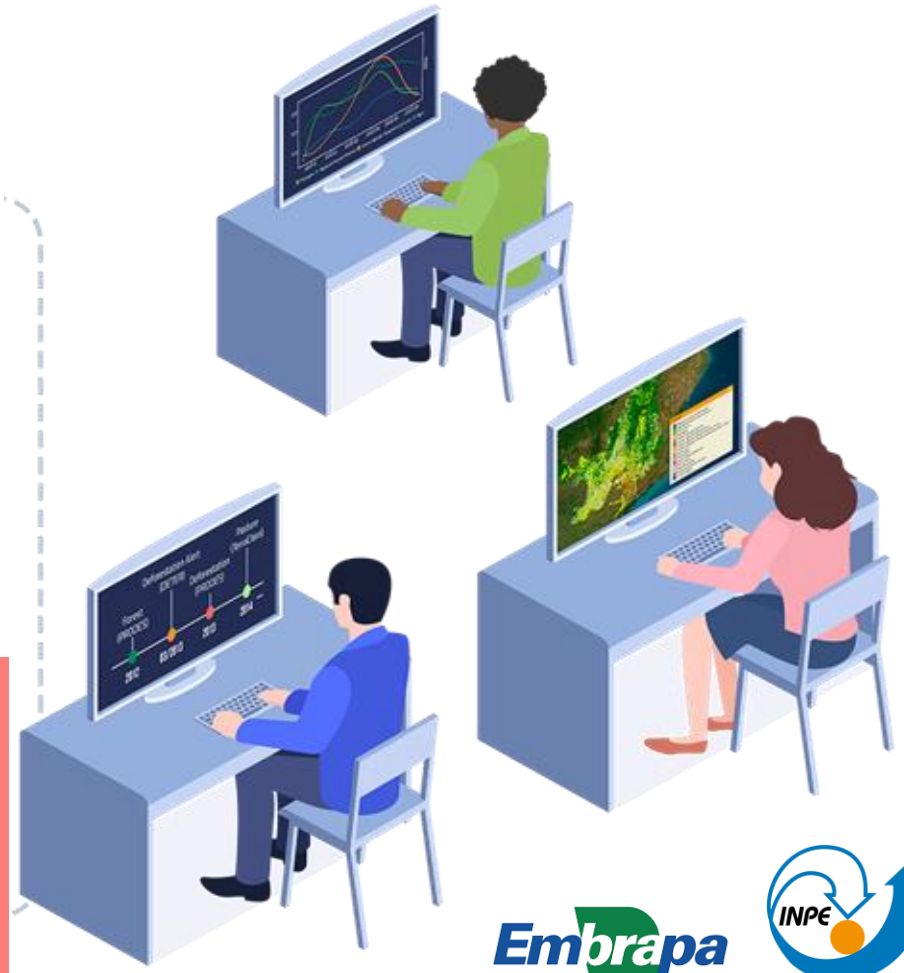
Embrapa

INPE
UNIDADE DE PESQUISA DO MCTI

IBGE



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



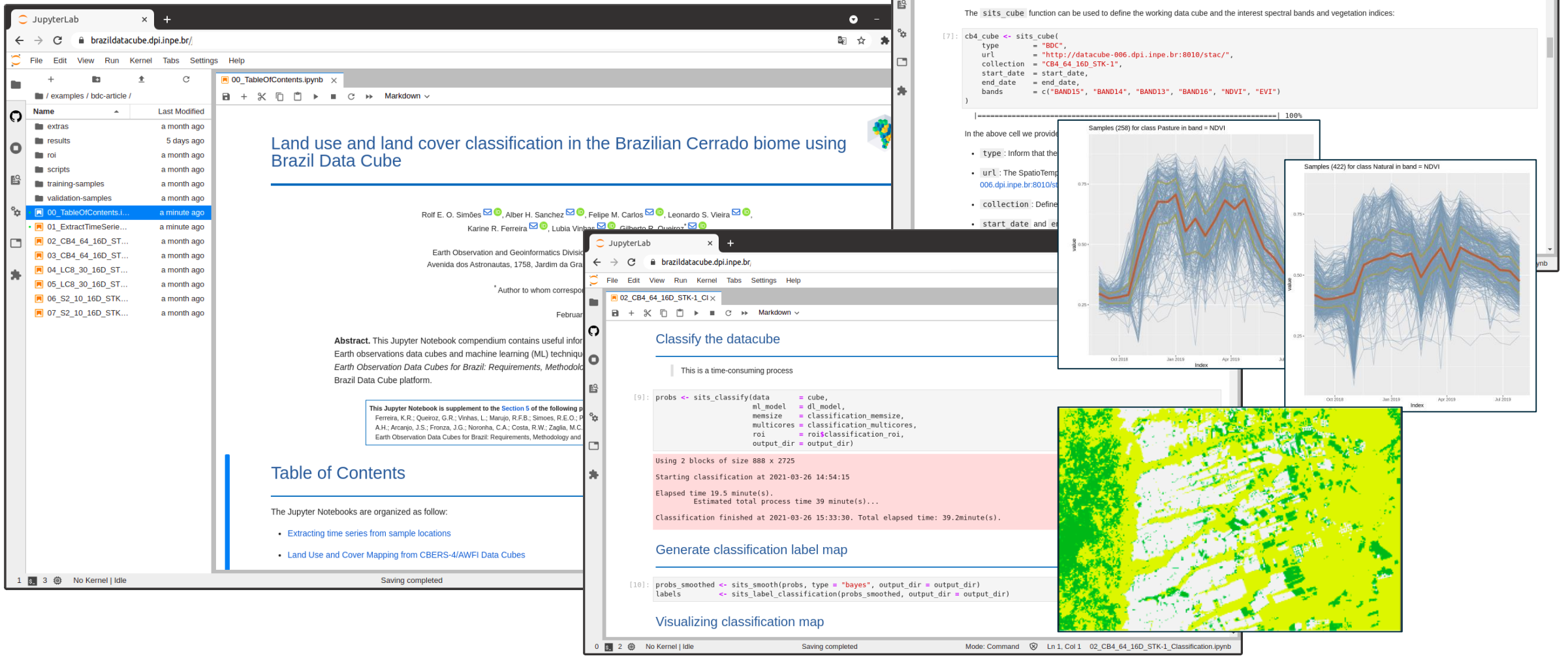
33 Terabytes (292 tiles)
Sentinel-2 data cubes (16-days)
25,000 samples
Random Forest / tempCNN

Embrapa

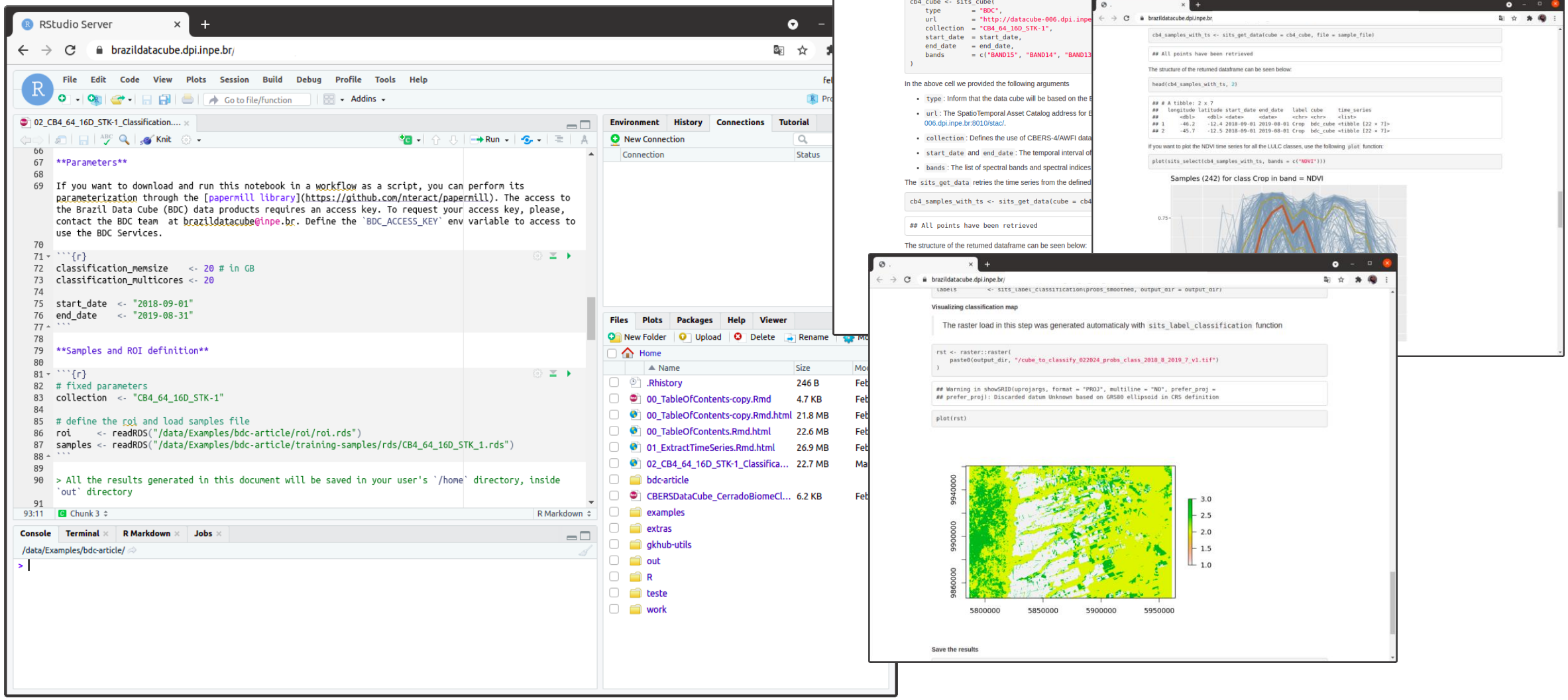
INPE
UNIDADE DE PESQUISA DO MCTI

IBGE

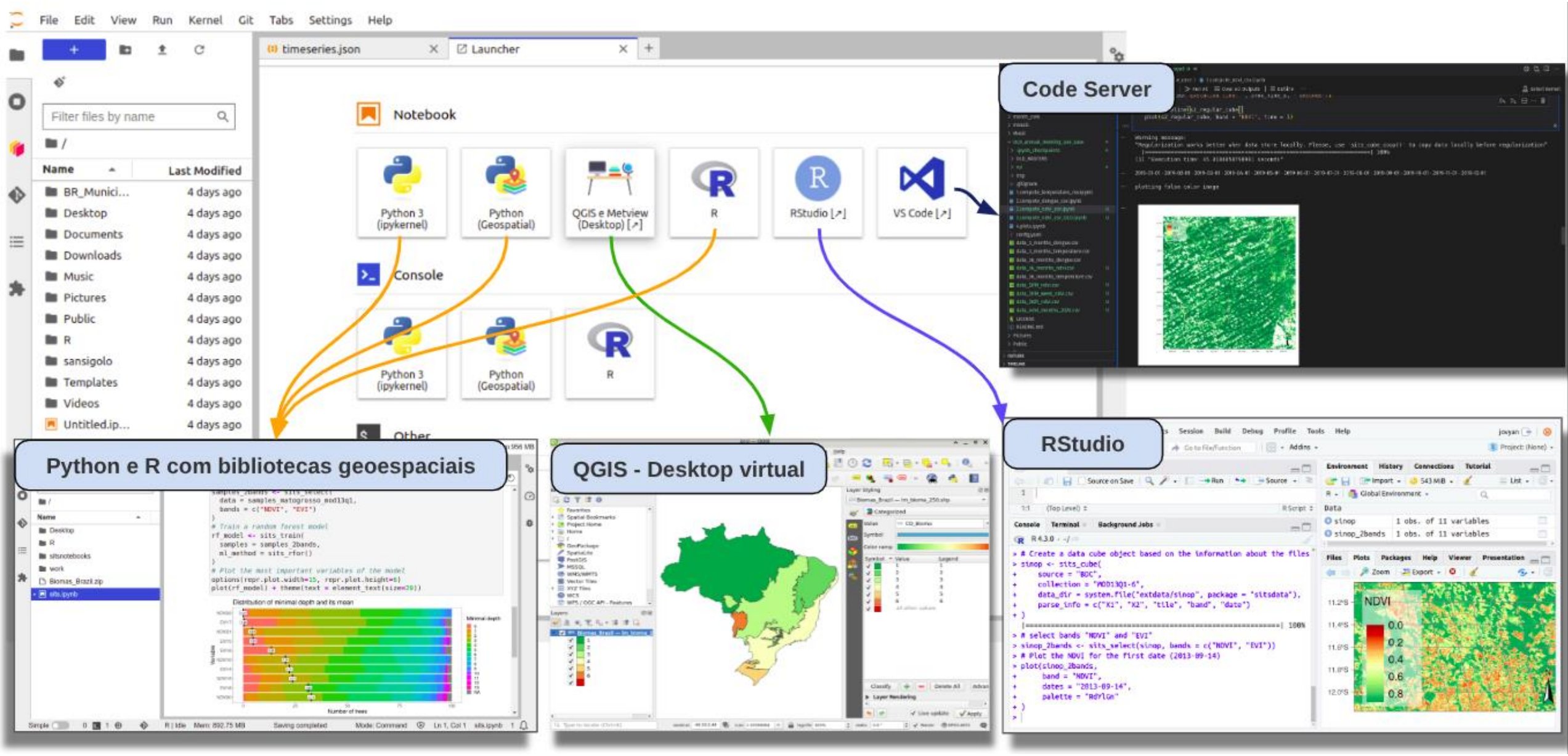
Ambiente de Computação Interativa: JupyterHub



Ambiente de Computação Interativa: RStudio



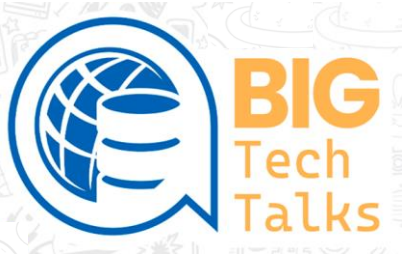
BDC-Lab 1.3.1 **(Maio/2025)**



Instâncias

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

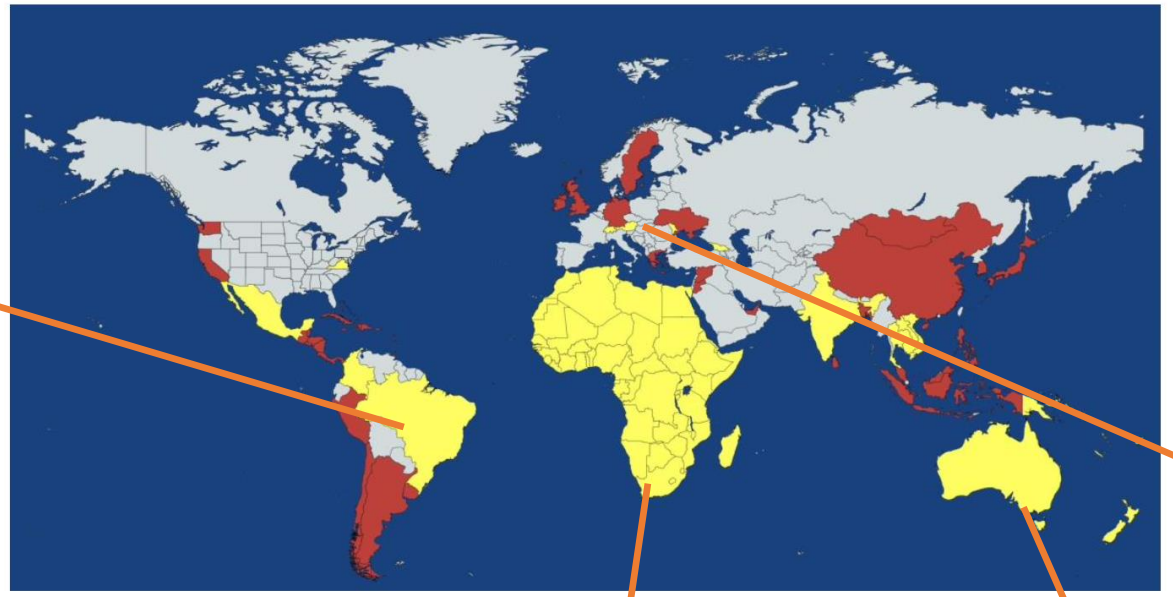
255 Servers, Data Storage with tiers (SSD, SAS and tape library) 12PB online and 4PB tape LTO

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 MDPI

Article

Paving the Way towards an Armenian Data Cube

Swiss Data Cube

https://www.swissdatacube.org/

Naciones Unidas CEPAL NASA INEGI

Digital Earth Americas

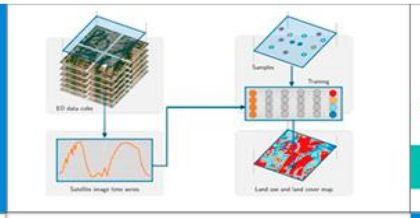
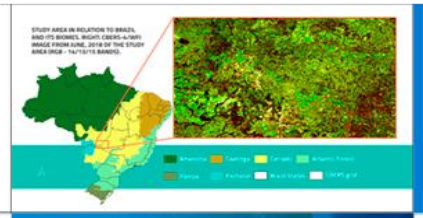
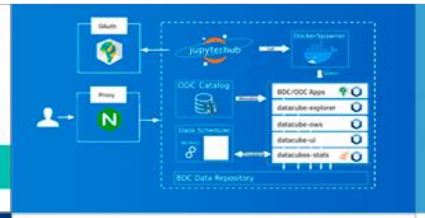
A vision for a solution that provides relevant Earth observation data for the benefit of the Americas

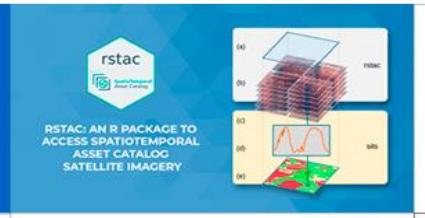
Digital Earth AFRICA

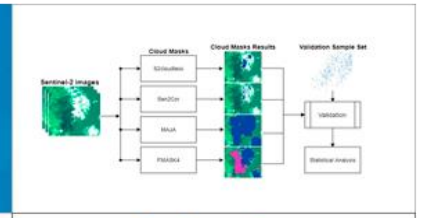
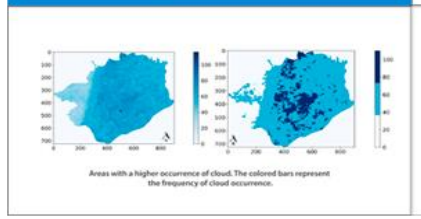
https://digitalearthafrica.org/

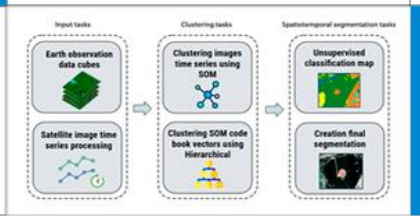
Digital Earth AUSTRALIA

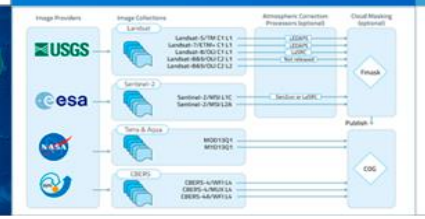
https://www.dea.ga.gov.au/

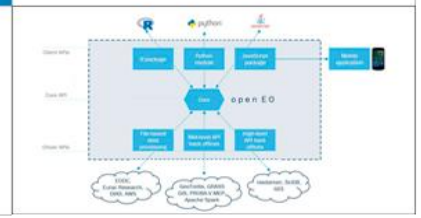






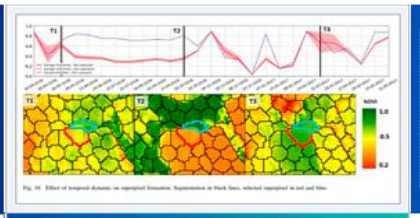


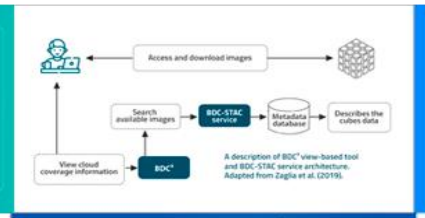


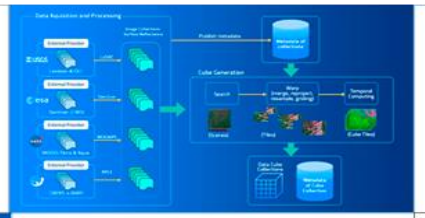
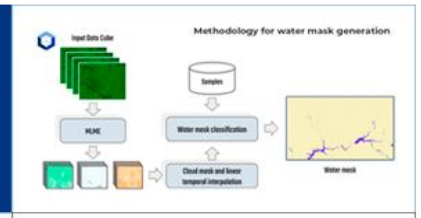


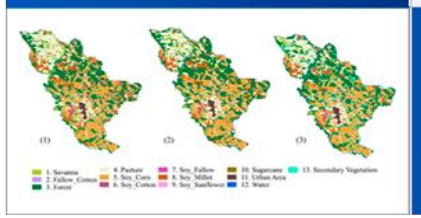
+ de 56 PUBLICAÇÕES desde 2019

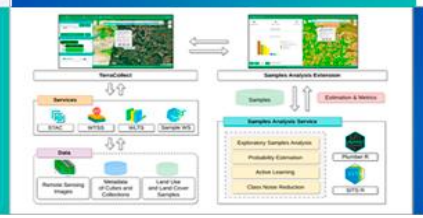
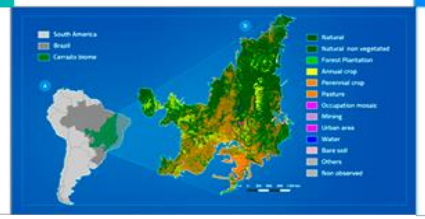
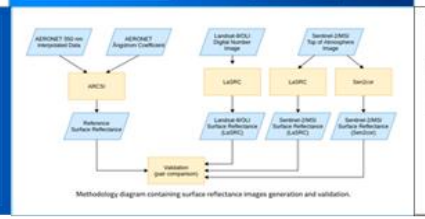
22 – em revistas/periódicos
34 – congressos nacionais e internacionais

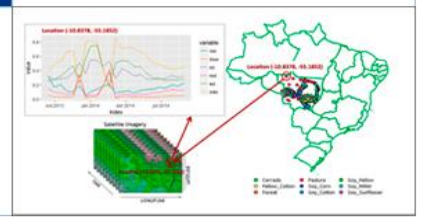








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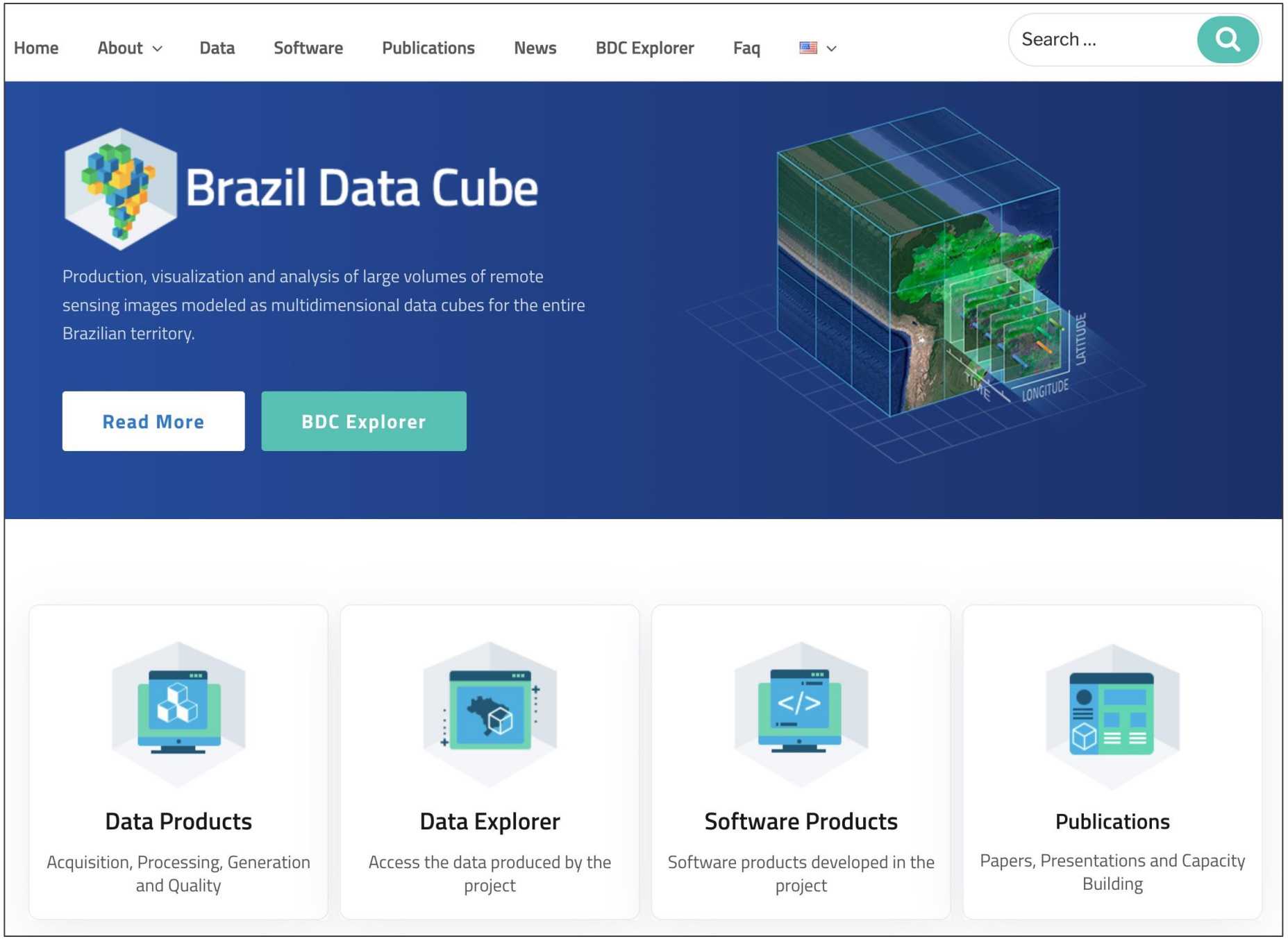
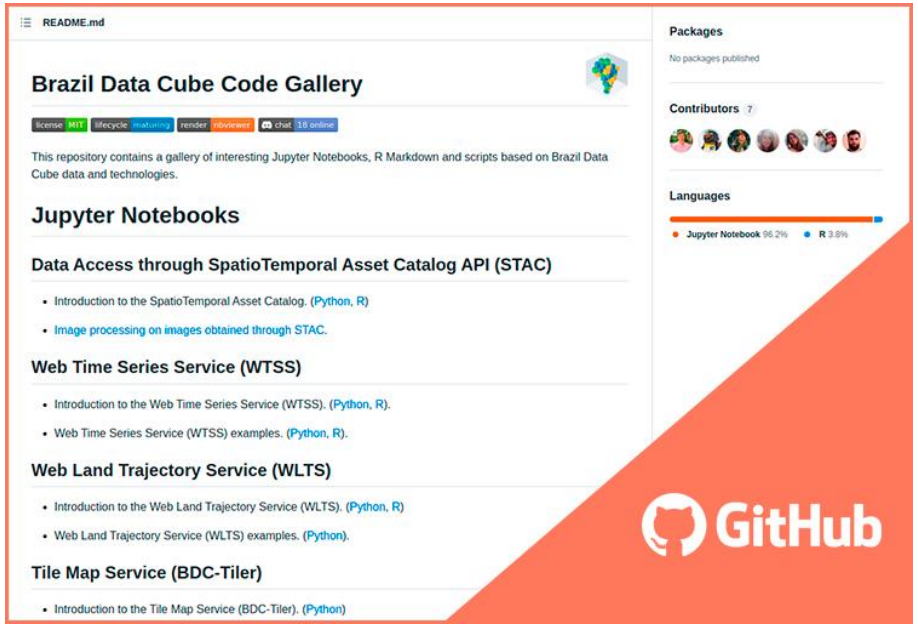
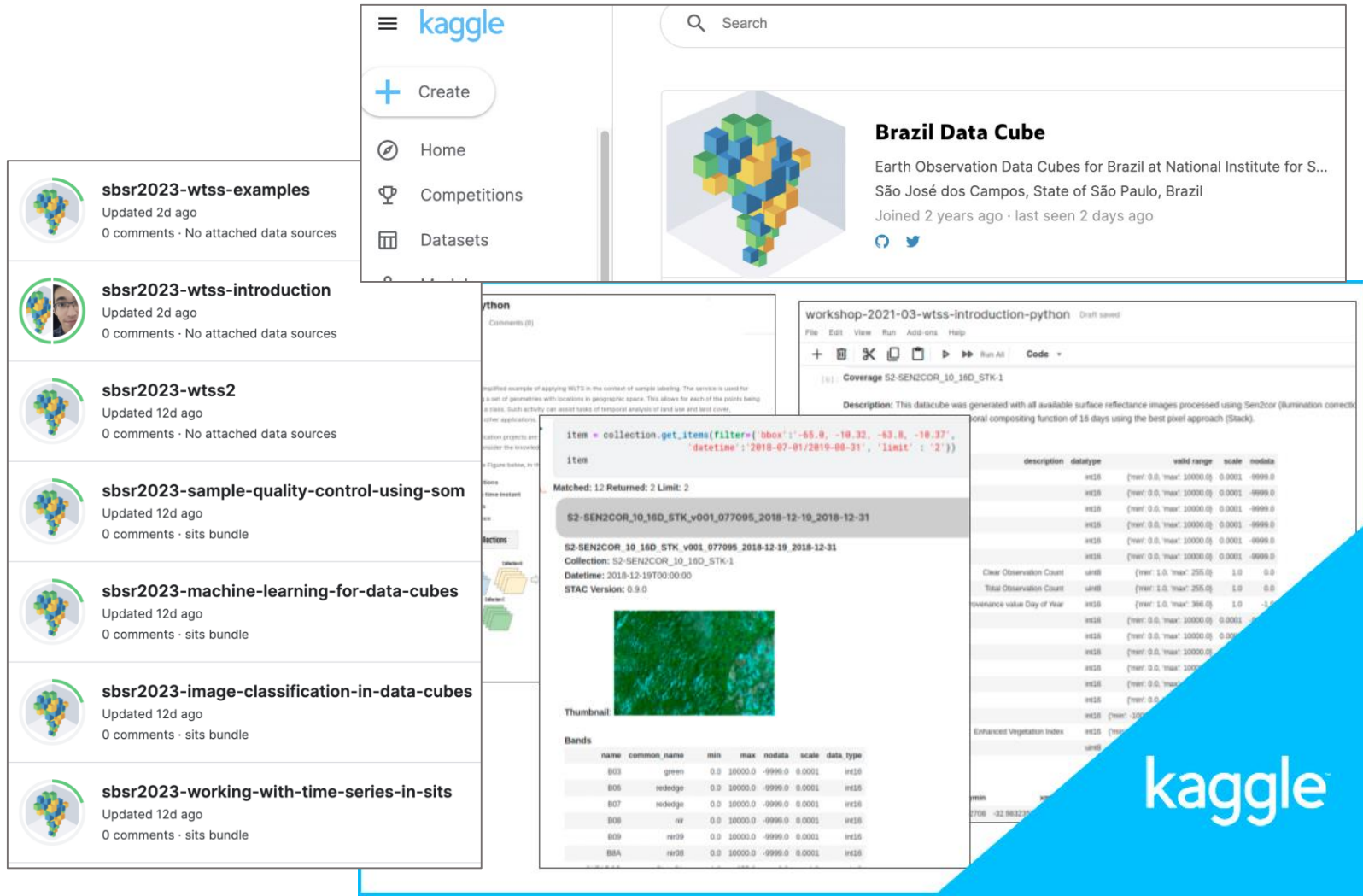


Code Galery

http://brazildatacube.org

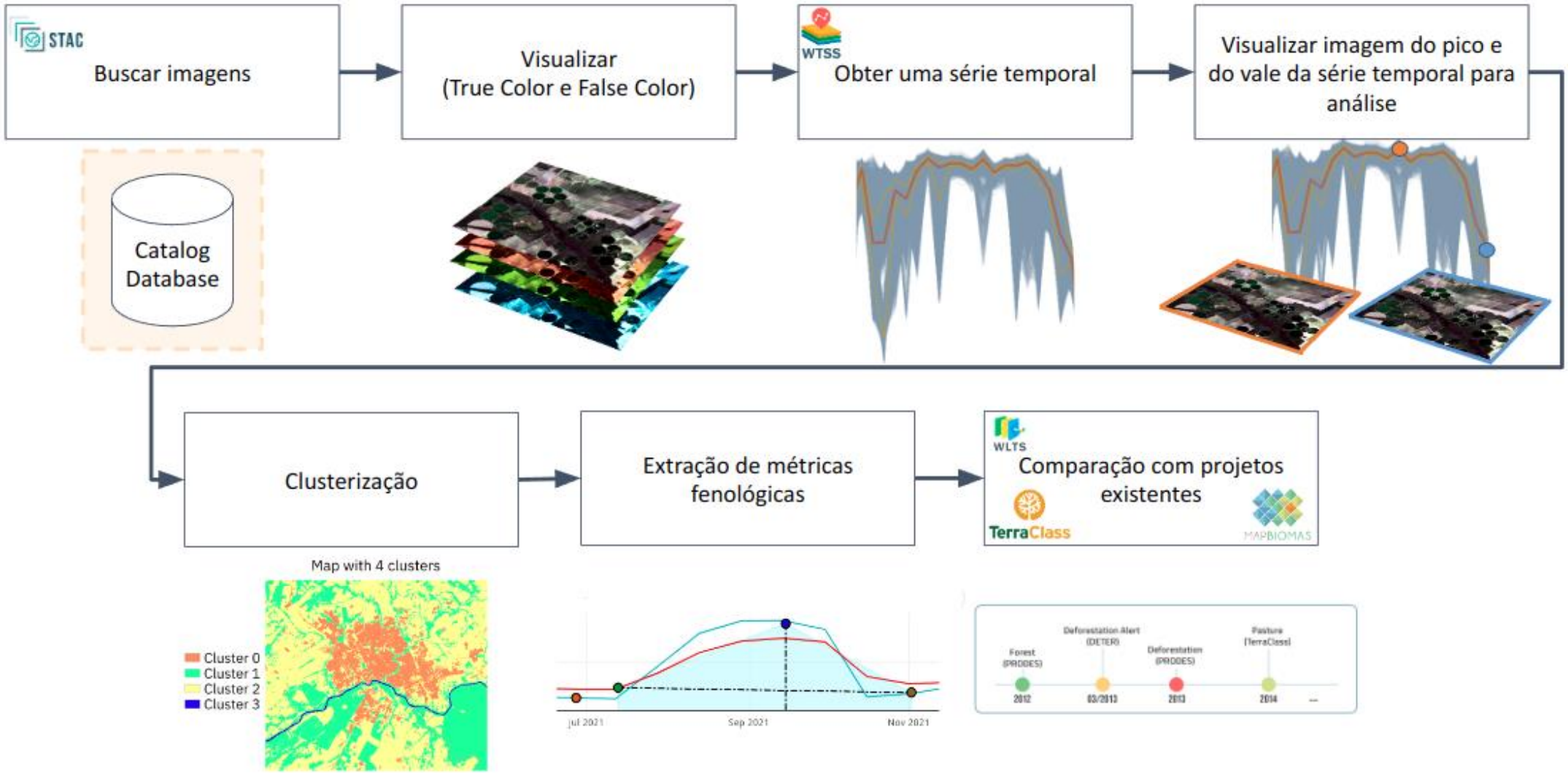




BRAZIL
DATA CUBE

Code Galery

http://brazildatacube.org



BRAZIL DATA CUBE
brazildatacube.org

brazildatacube.org

brazildatacube.dpi.inpe.br/portal/explore

OBRIGADA!

Karine R. Ferreira

karine.ferreira@inpe.br

@brazildatacube

INPE
MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
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

Clustering of SITS

Disturbance/Change Detection from SITS

Vegetation Phenological Metrics Extraction from SITS

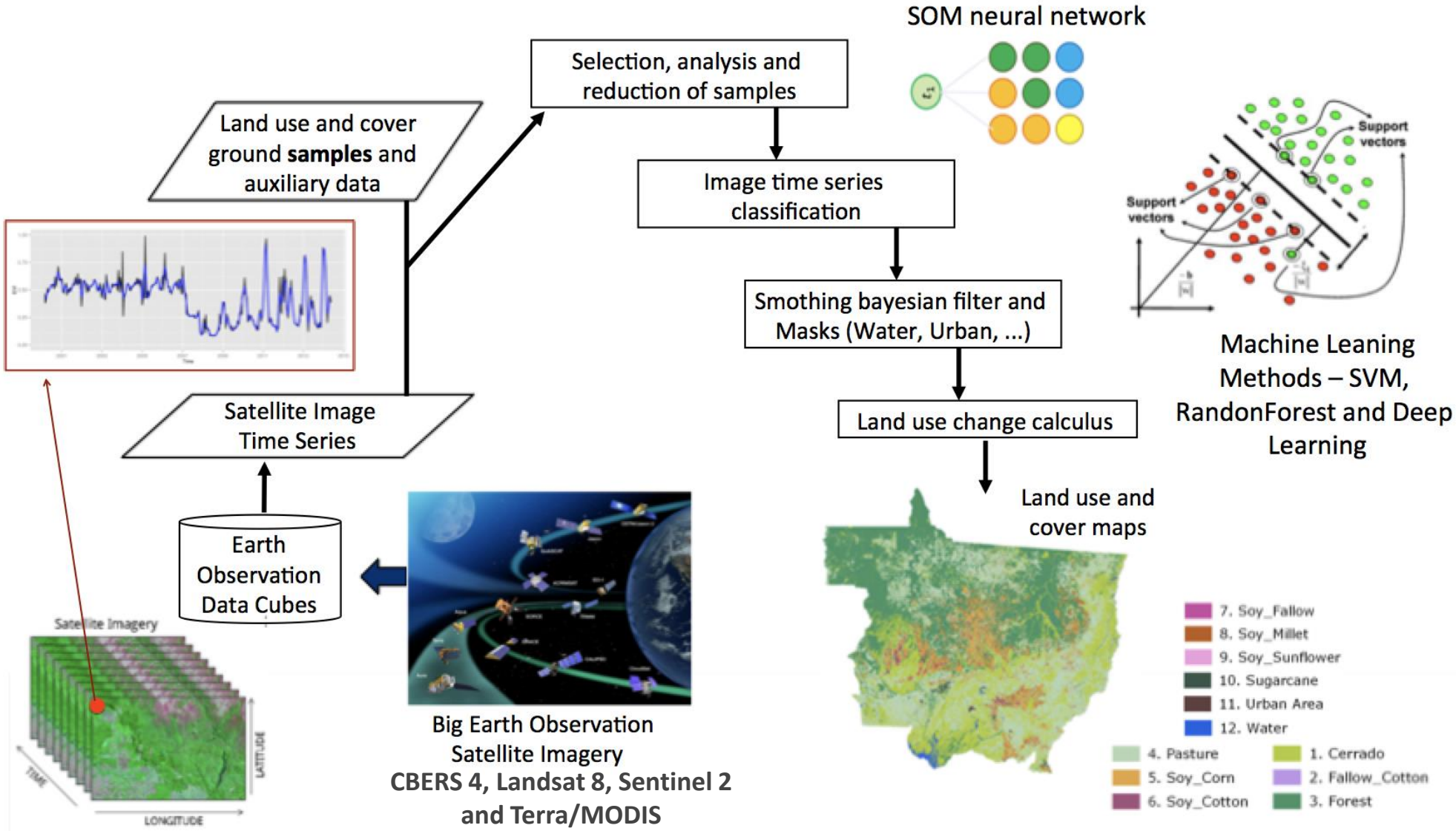
Machine and Deep Learning methods:

RandonForest

TempCNN

...

SITS (Satellite Image Time Series) R package:
https://github.com/e-sensing



Big Earth Observation Satellite Imagery
CBERS 4, Landsat 8, Sentinel 2 and Terra/MODIS

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

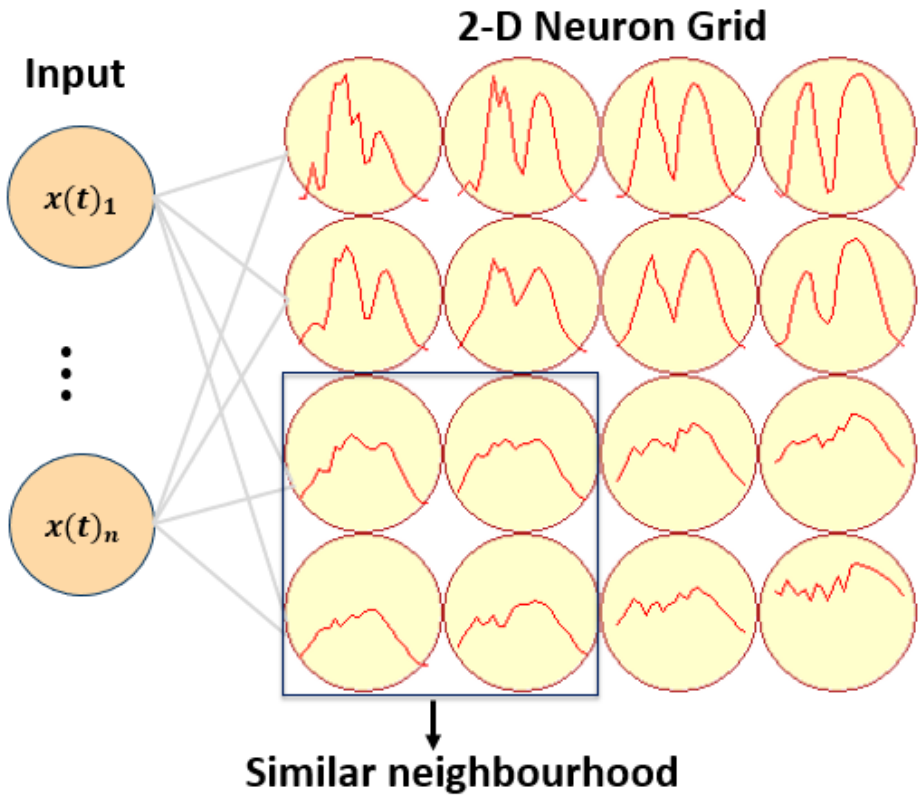
SOM (Self-Organizing Maps)

...

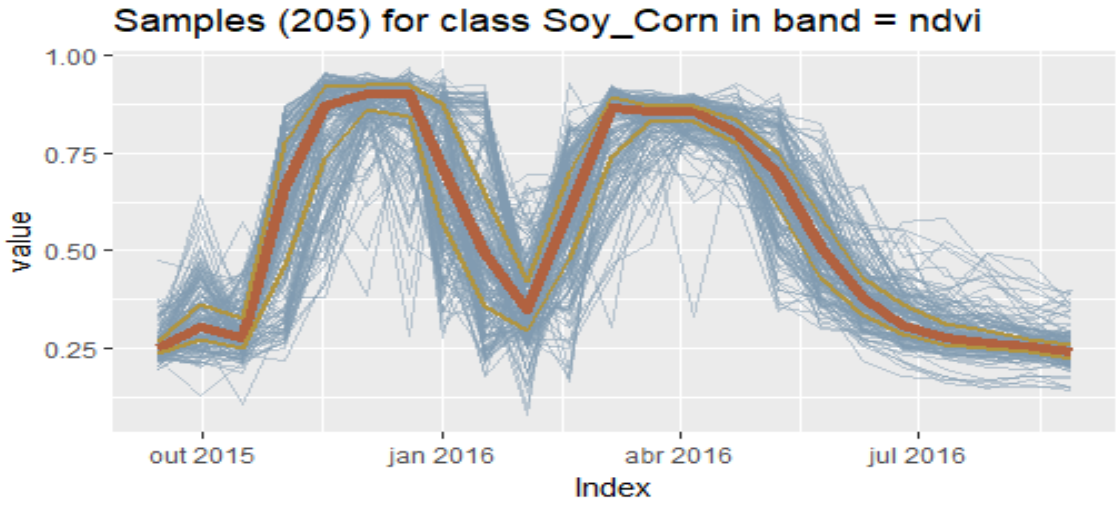
Disturbance/Change Detection from SITS

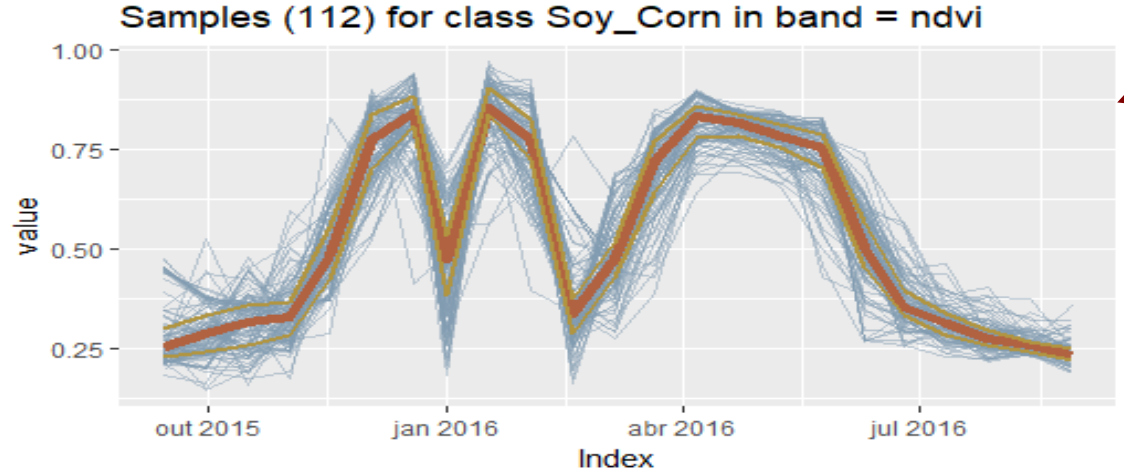
Vegetation Phenological Metrics Extraction from SITS

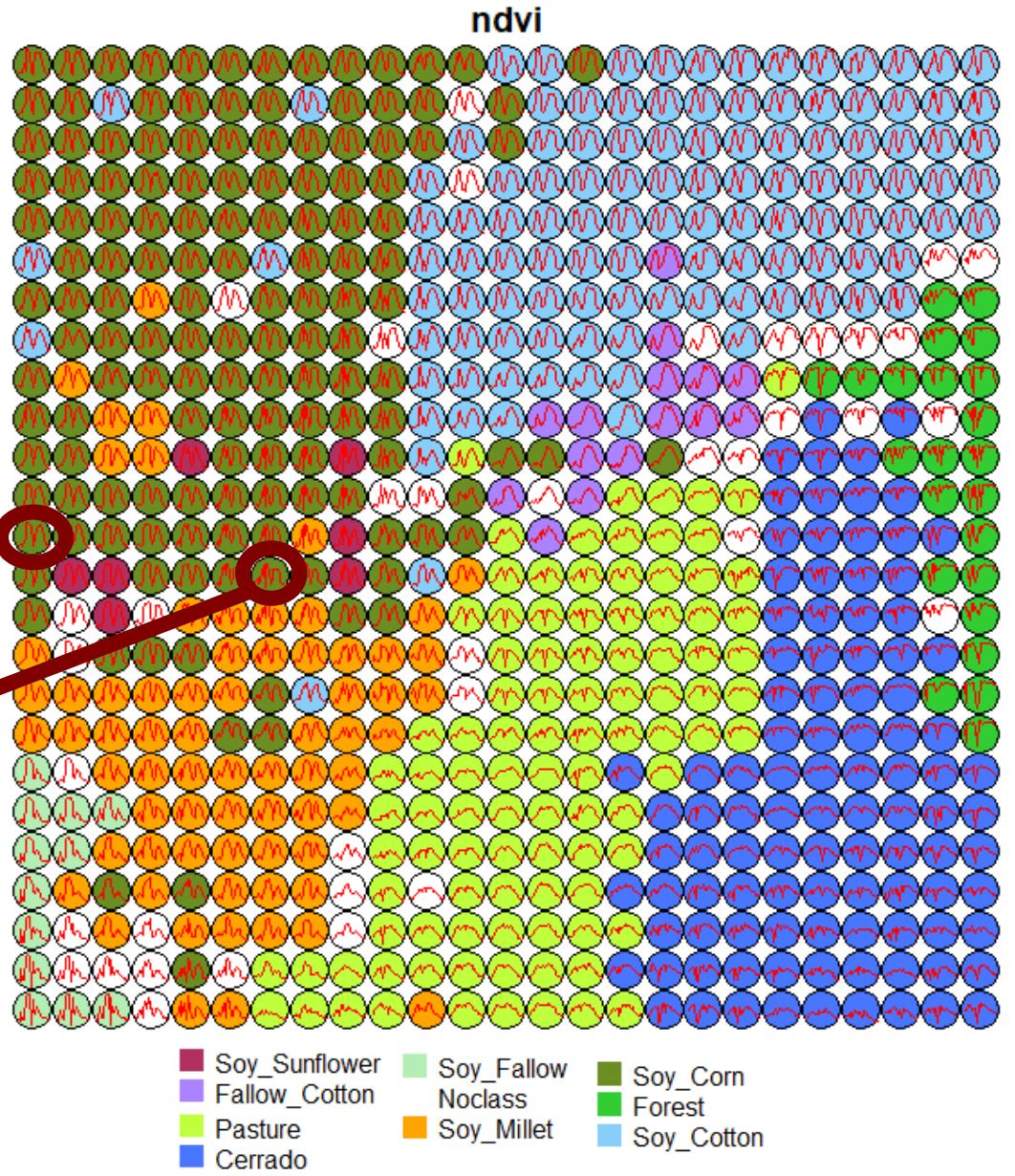
Self-Organizing Maps (SOM) neural network for SITS clustering



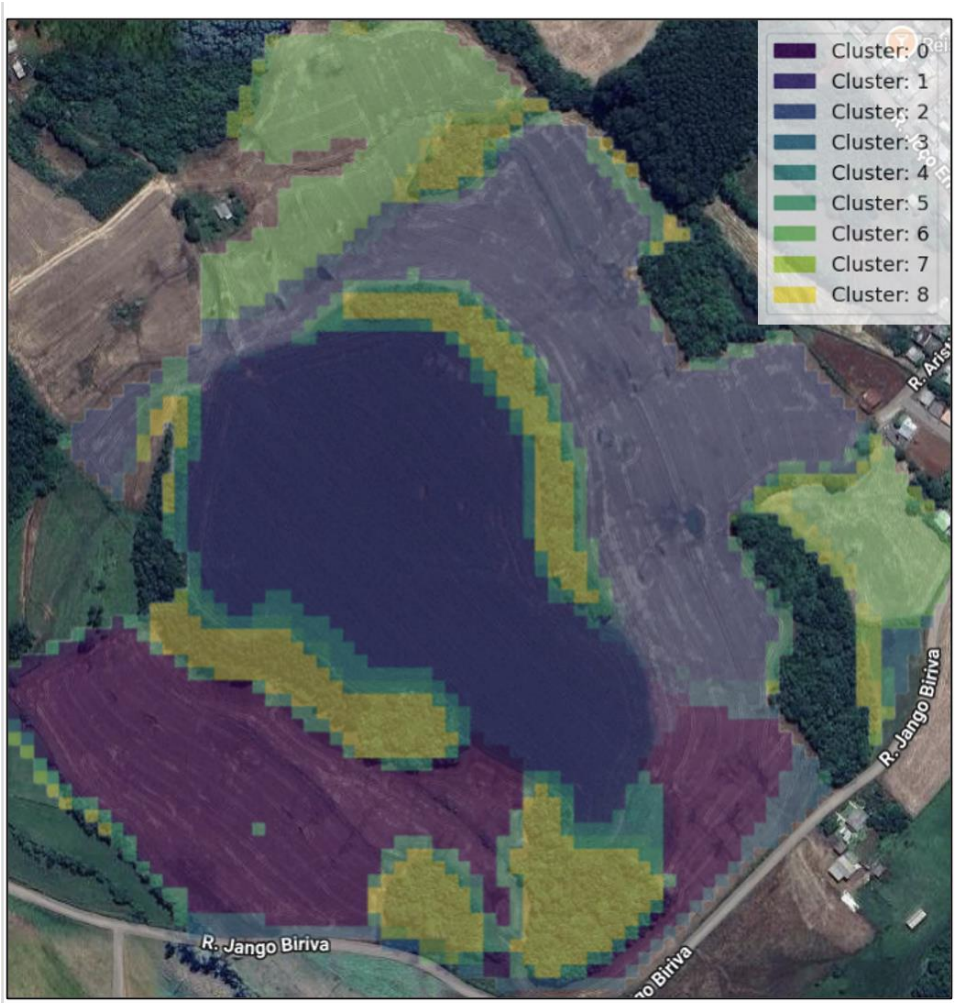
SOM to identify different SITS patterns



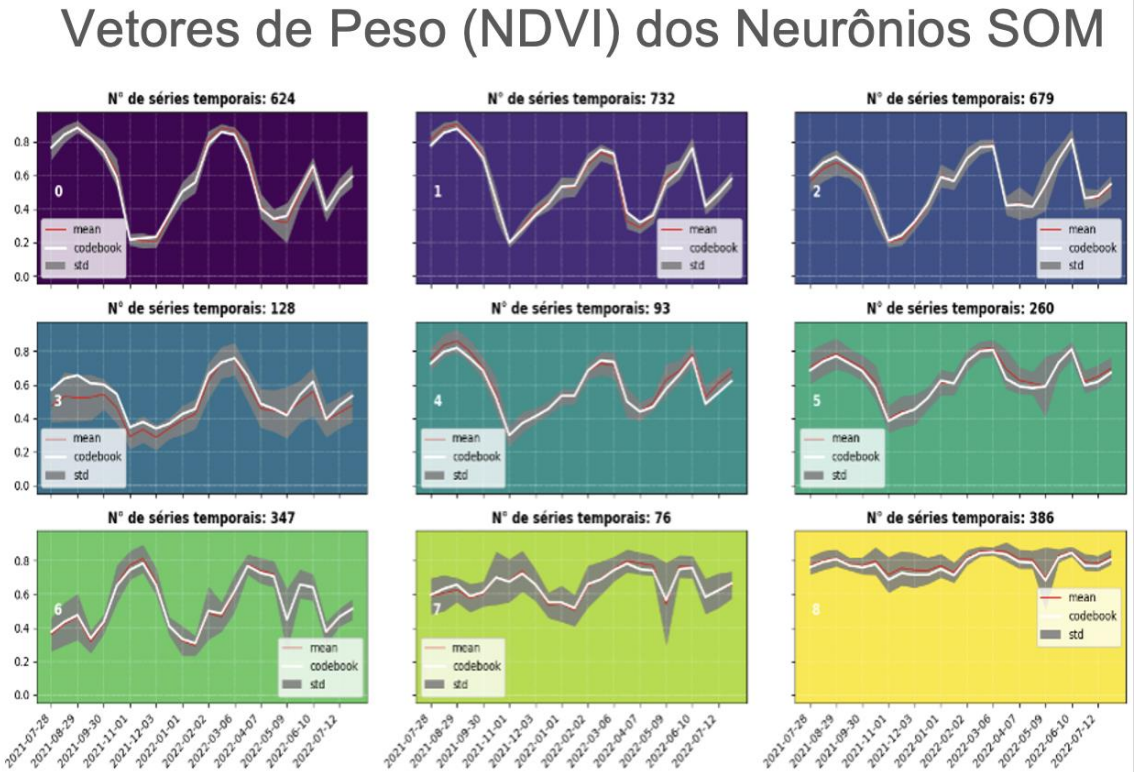




SITS patterns – dentro de uma gleba – Crédito Rural - SICOR

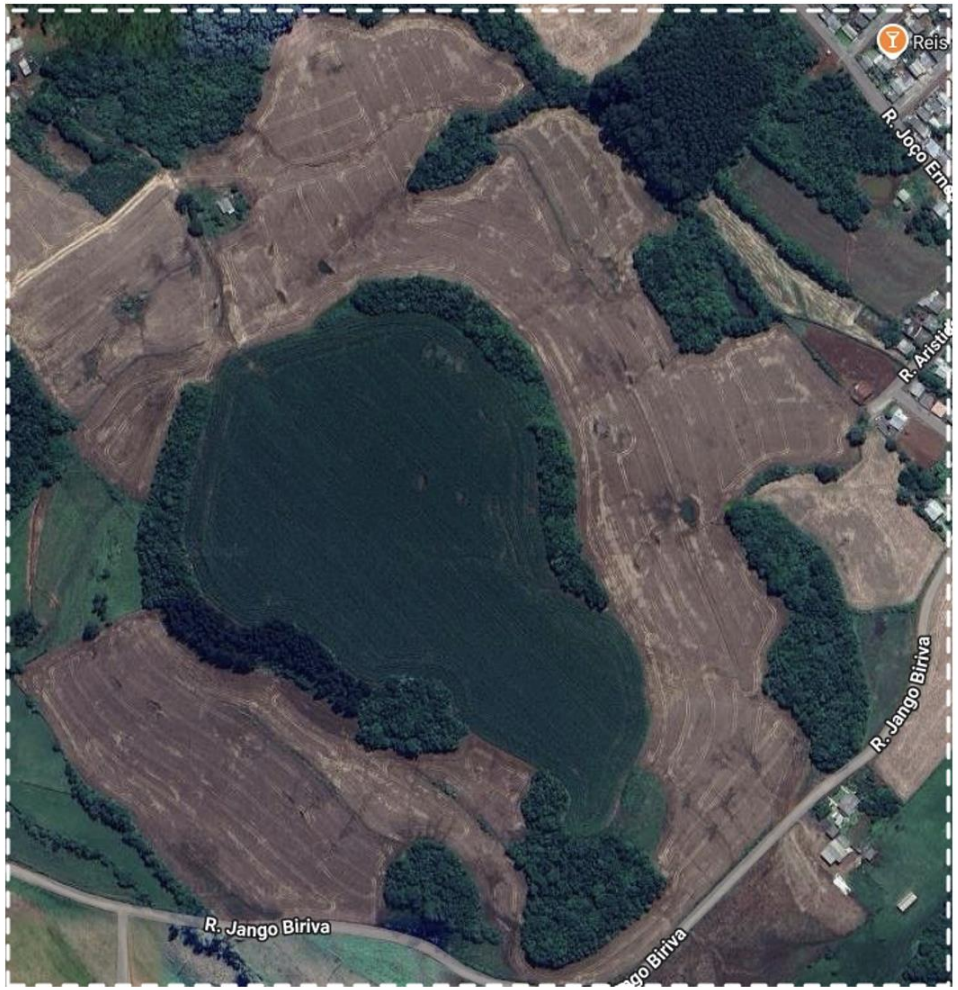


(A)

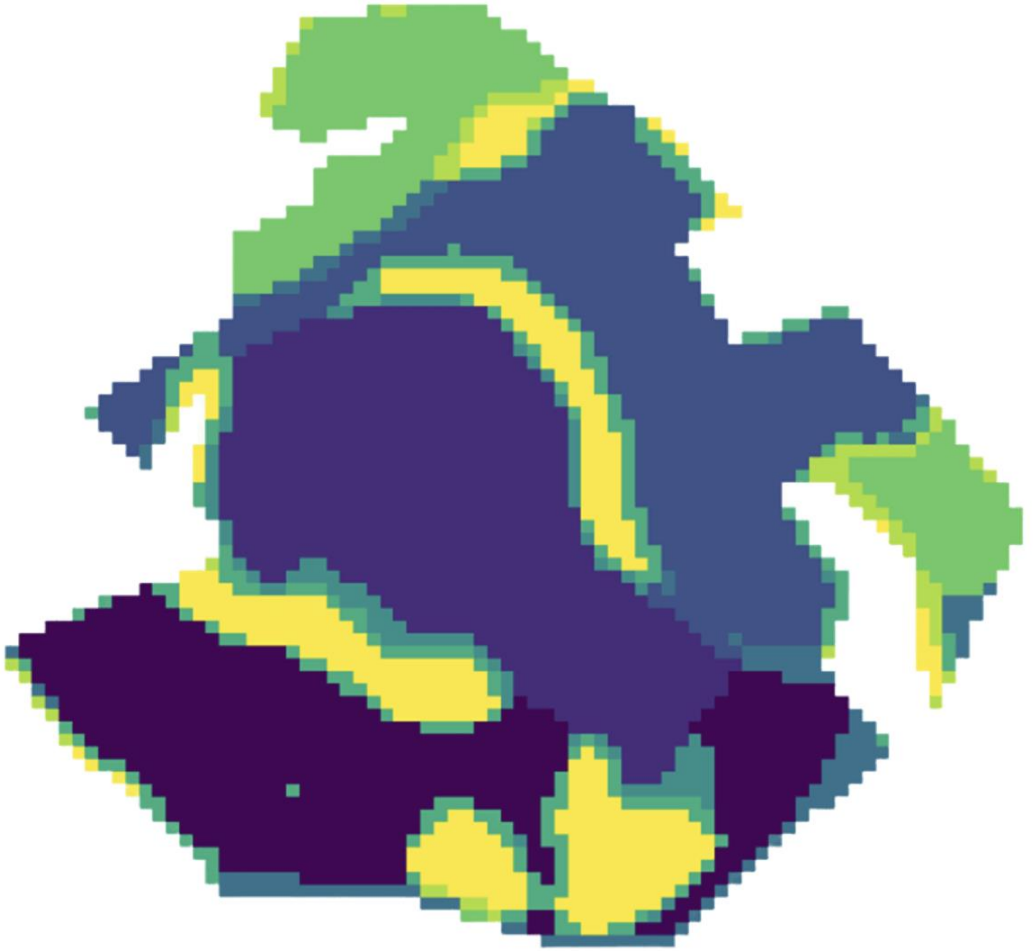


(B)

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

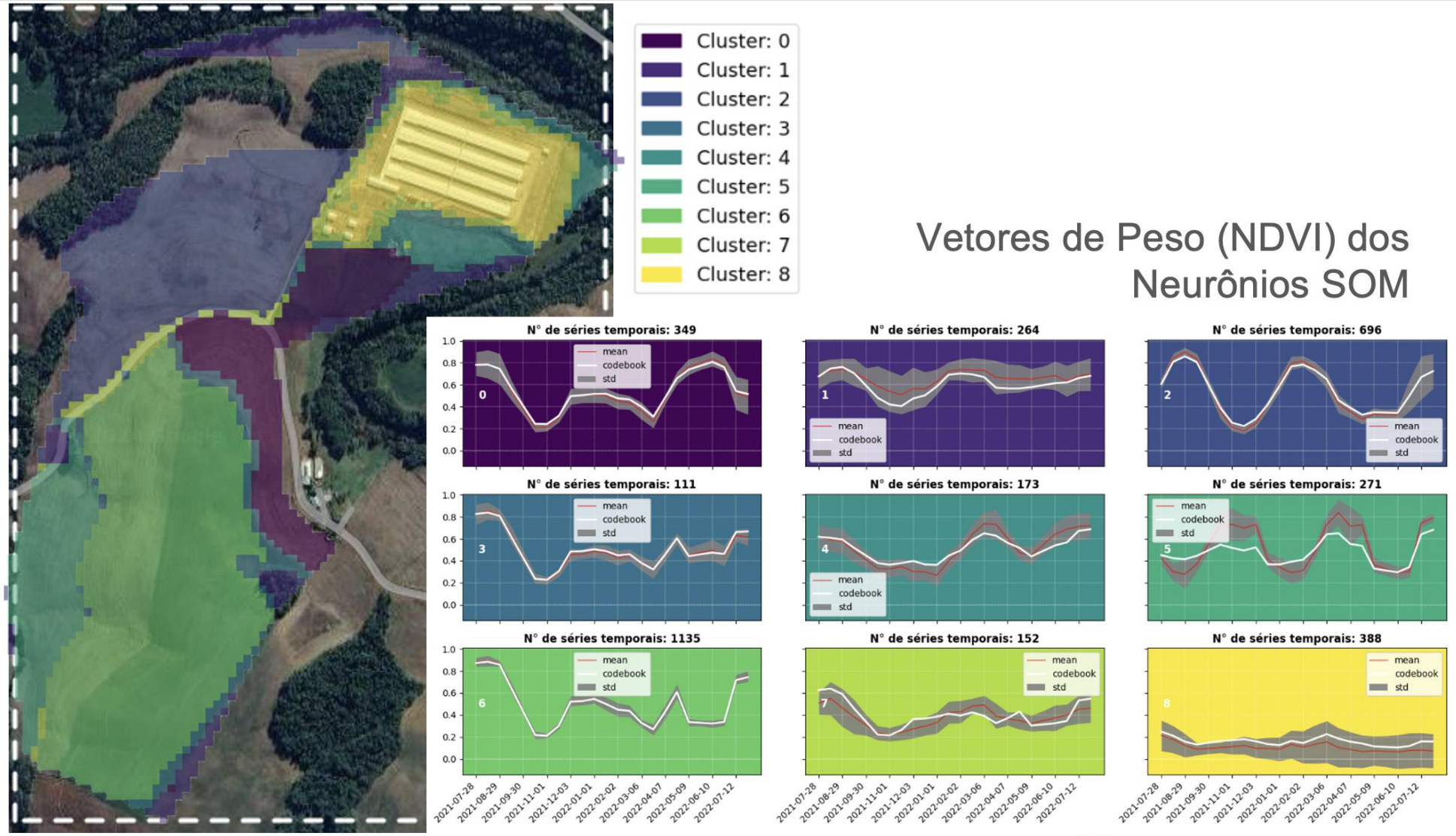


(A)



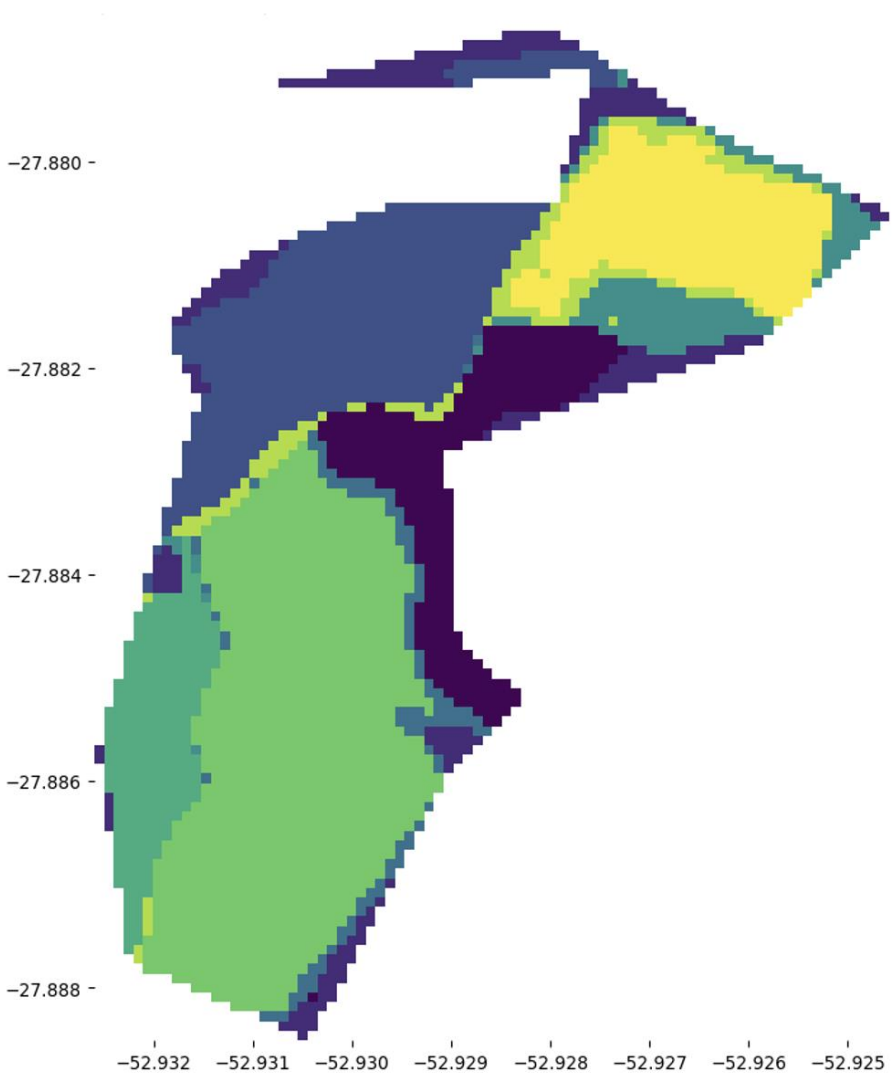
(B)

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



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

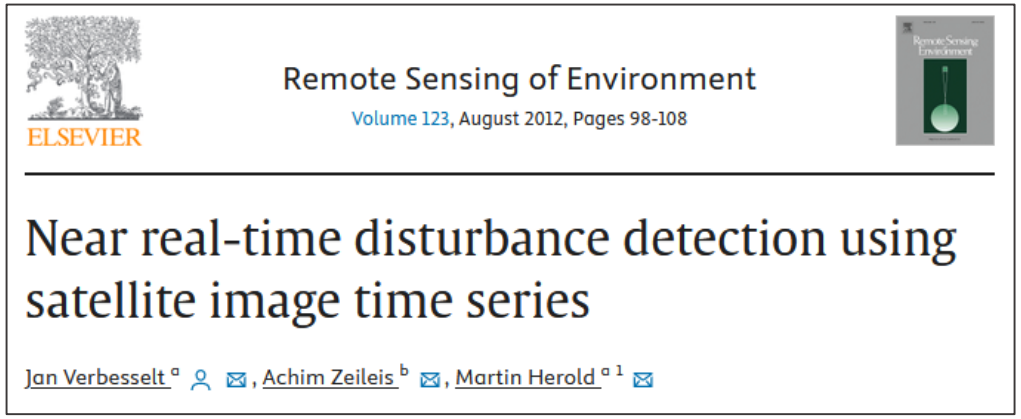
Processos naturais e antropogênicos

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

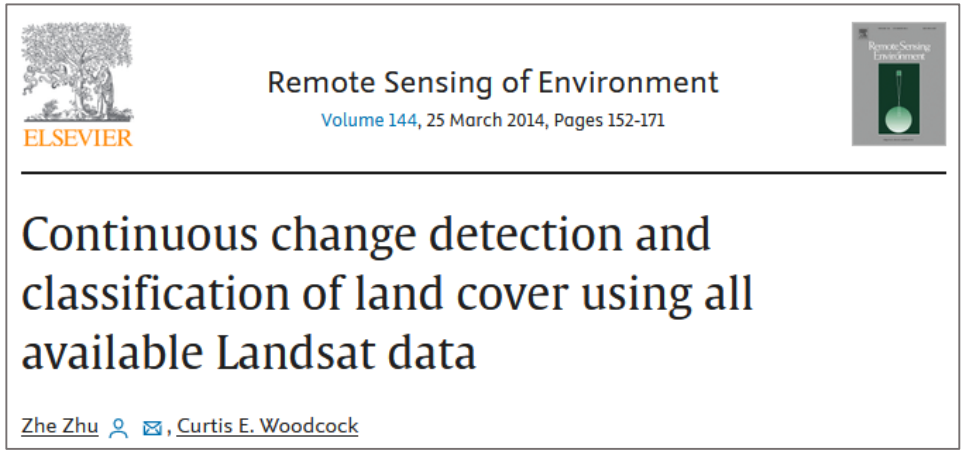
MAPEAMENTO DE DISTÚRBIOS FLORESTAIS NO ESTADO DO MARANHÃO POR MEIO DE SÉRIES TEMPORAIS E CUBOS DE DADOS

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

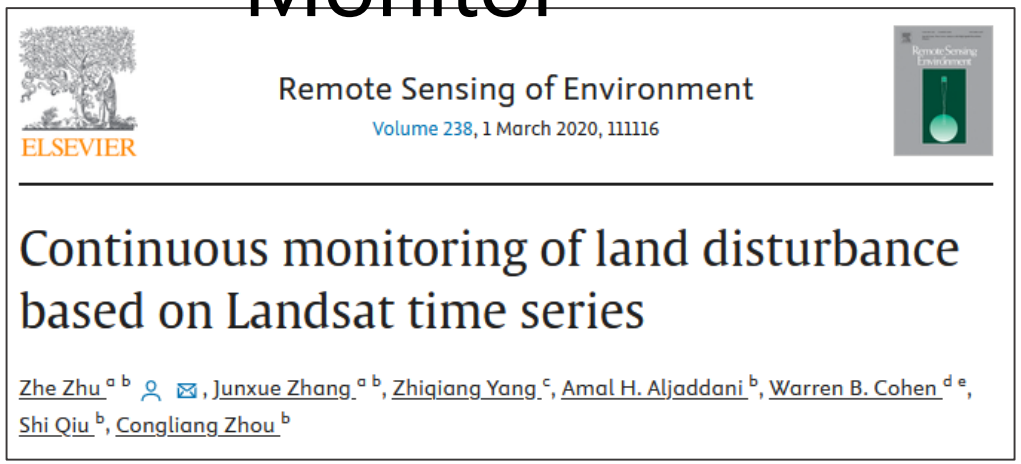
Disturbance/Change Detection Methods



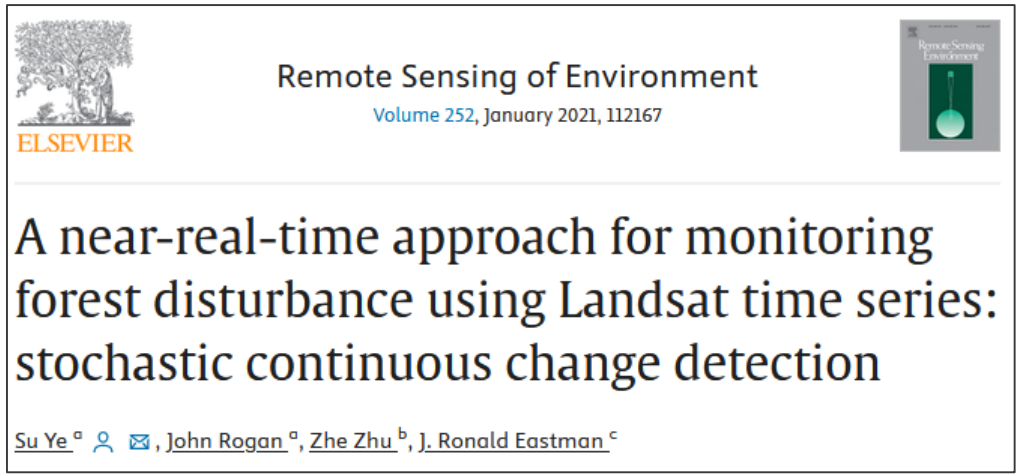
BFAST Monitor



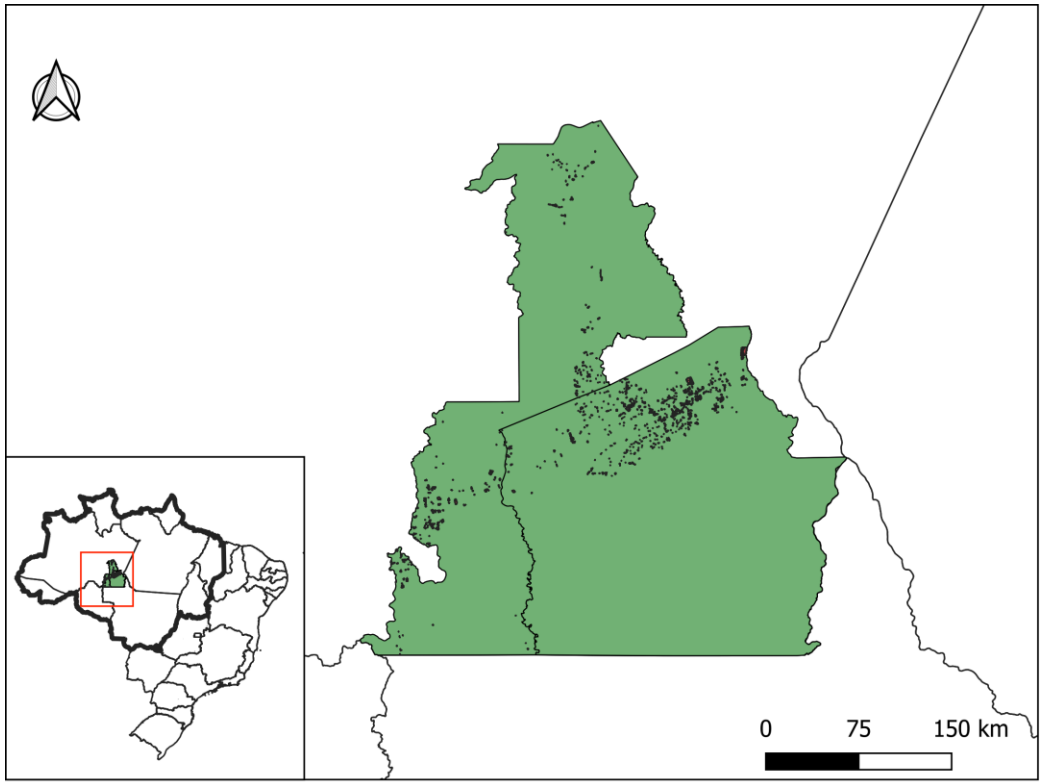
CCDC



COLD

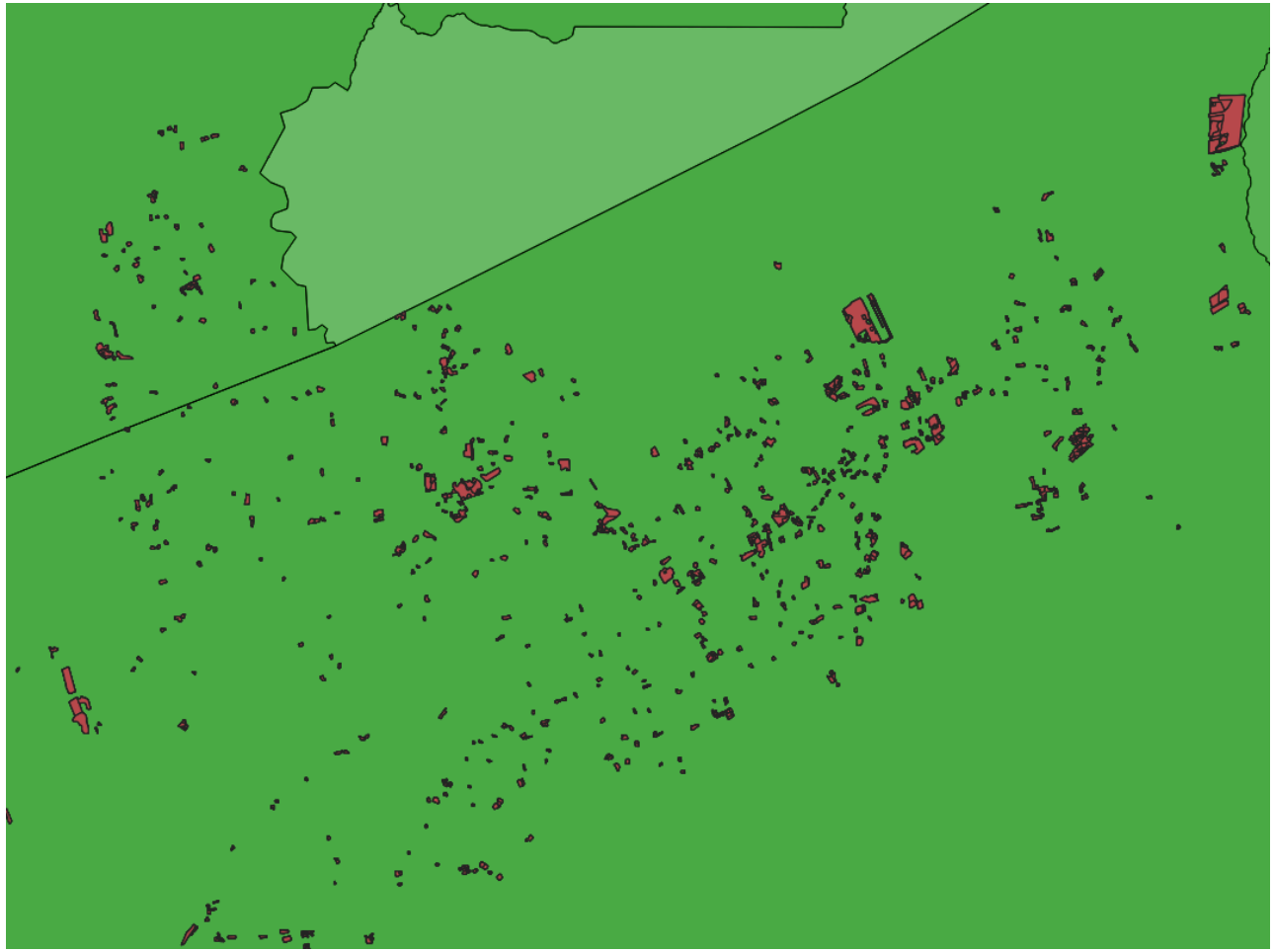


SCCD



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

Alerts of deforastation 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	0,51-0,85µm (PAN) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (NIR)	0,45-0,52µm (B) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (NIR)	0,45-0,52µm (B) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (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

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

Câmeras CBERS-4A			
Característica	**WPM**	**MUX**	**WFI**
Bandas Espectrais	0,45-0,52µm (B) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (NIR) 0,45-0,90µm (PAN)	0,45-0,52µm (B) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (NIR)	0,45-0,52µm (B) 0,52-0,59µm (G) 0,63-0,69µm (R) 0,77-0,89µm (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

CBERS-4A/WFI
Resolução espacial: 55 m
Revisita: 5 dias
Local: Barragem de Sobradinho, BA

CBERS-4A/MUX

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

CBERS-4A/WPM

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

AMAZONIA-1/WFI

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

AMAZONIA-1/WFI

Local: Búzios, RJ
Imagem: Emiliano Castejon

AMAZONIA-1/WFI

Local: Luis Eduardo Magalhães, BA
Imagem: Emiliano Castejon

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

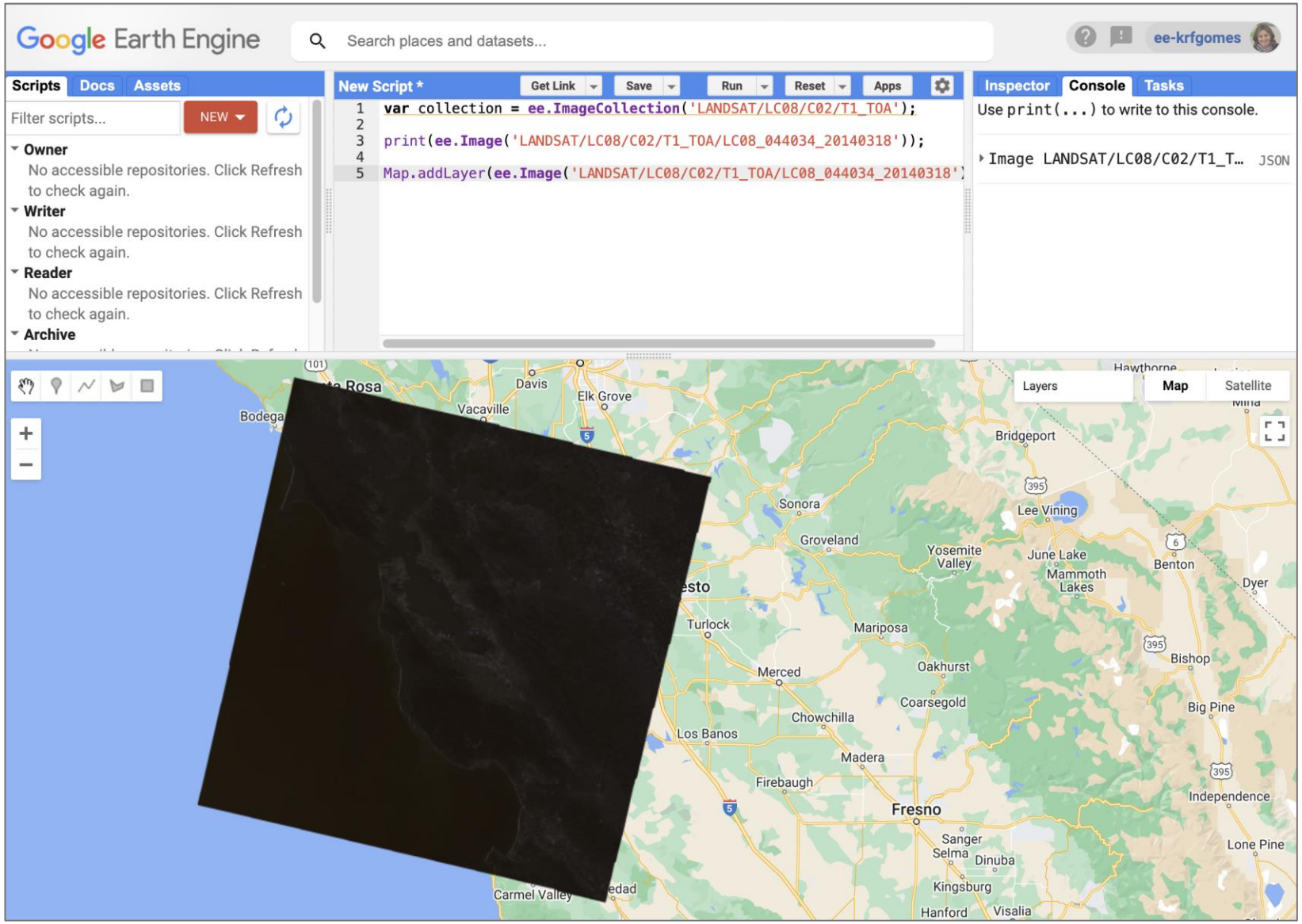
Google Earth Engine

Ambiente de computação em nuvem (Google).

Interface web e API em JavaScript e Python.

Coleções de imagens de satélites e outros dados.

Interface web – scripts, visualização, ...



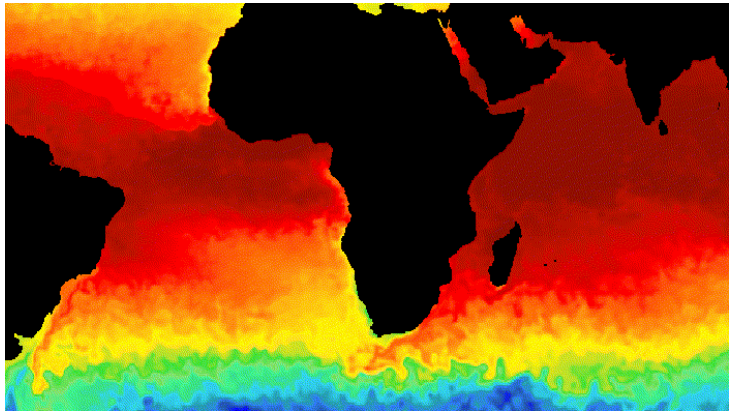
Google Earth Engine

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

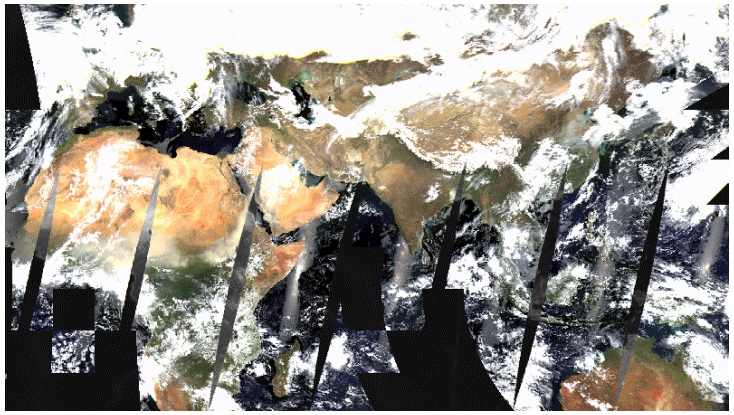
Landsat

Sentinel (1, 2 e 3)

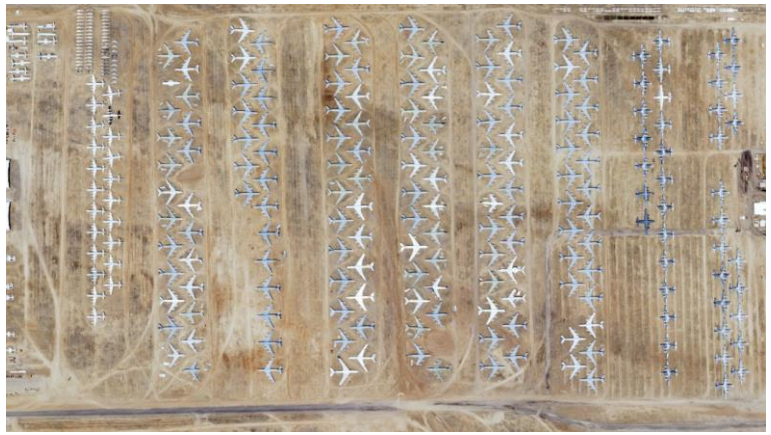
Land and sea surface temperature



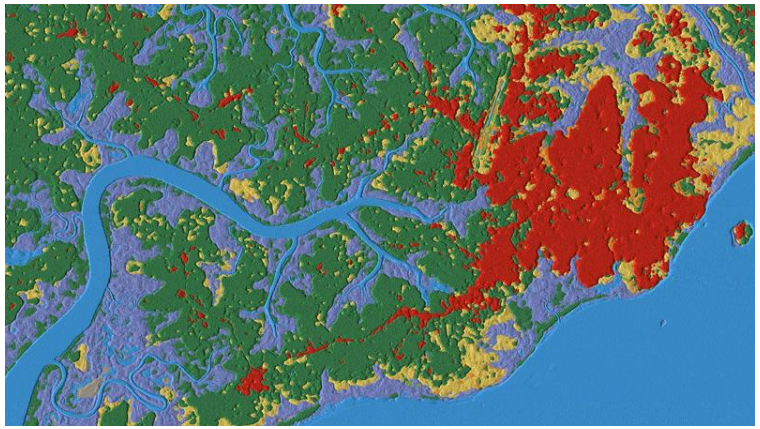
MODIS



High-resolution imagery – ex. Planet



Land cover map: ESA World Cover



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

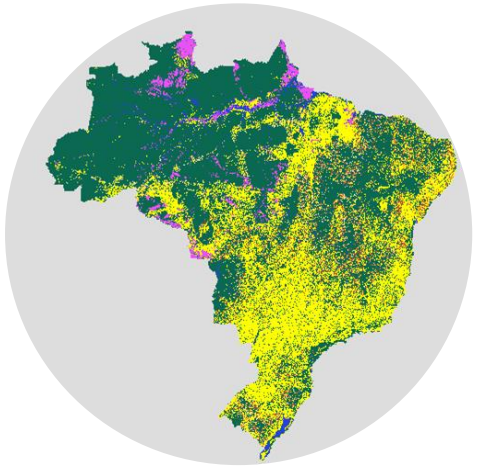
Jan Musial[1], Jedrzej Bojanowski [1], Jacek Leszczeński [1], Grega Milcinski [2], Andras Zlinszky [2], Anja Vrecko [2], Dennis Clarijs [3], Jeroen Dries [3], Uwe Marquard [4], Jurry de-la-Mar [4]

CloudFerro [1], Sinergise [2], VITO Remote Sensing [3], T-Systems [4]

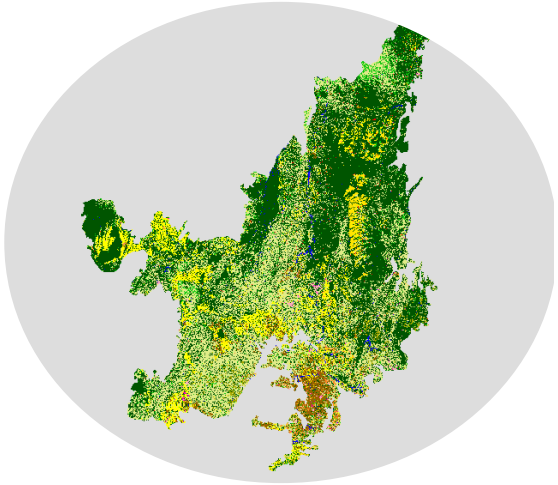
Big Data from Space 2023 (BiDS 2023):
https://dx.doi.org/10.2760/46796

Source: https://dataspace.copernicus.eu/ecosystem/services/cap-area-monitoring-services

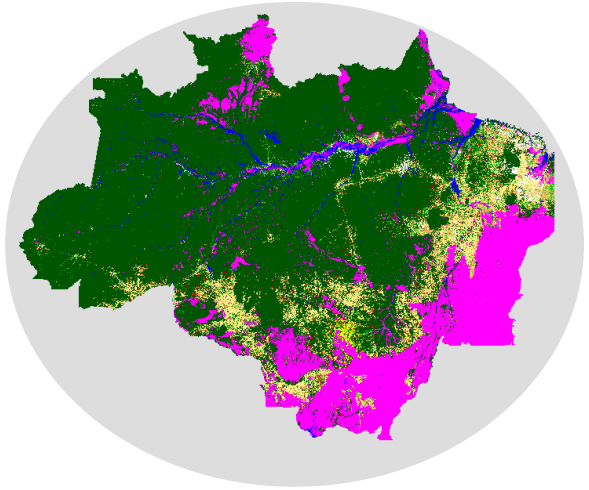
WLTS - Coleções



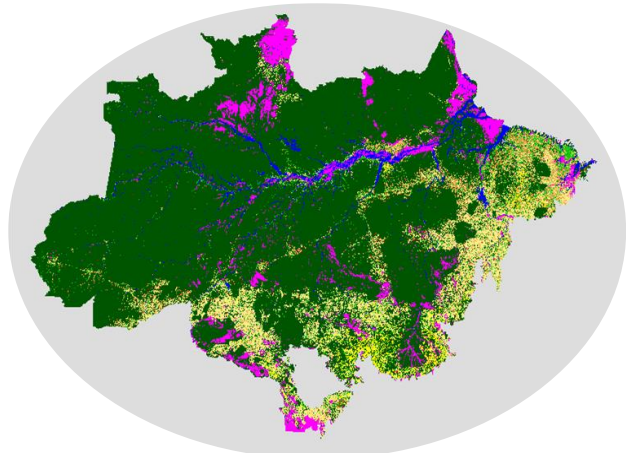
PRODES - Brasil
2007 - 2022
http://terrabrasilis.dpi.inpe.br/



TerraClass - Cerrado
2018 and 2020
https://www.terraclass.gov.br/



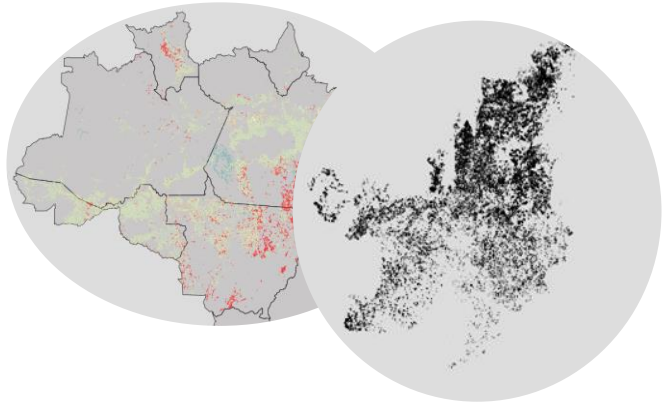
TerraClass - Amazônia
2004, 2008, 2010, 2012, 2014
https://www.terraclass.gov.br/geoportal-aml/



TerraClass - Amazônia
2020
http://terrabrasilis.dpi.inpe.br/

MapBiomas 8.0 - Brasil
1985 - 2022
https://mapbiomas.org/

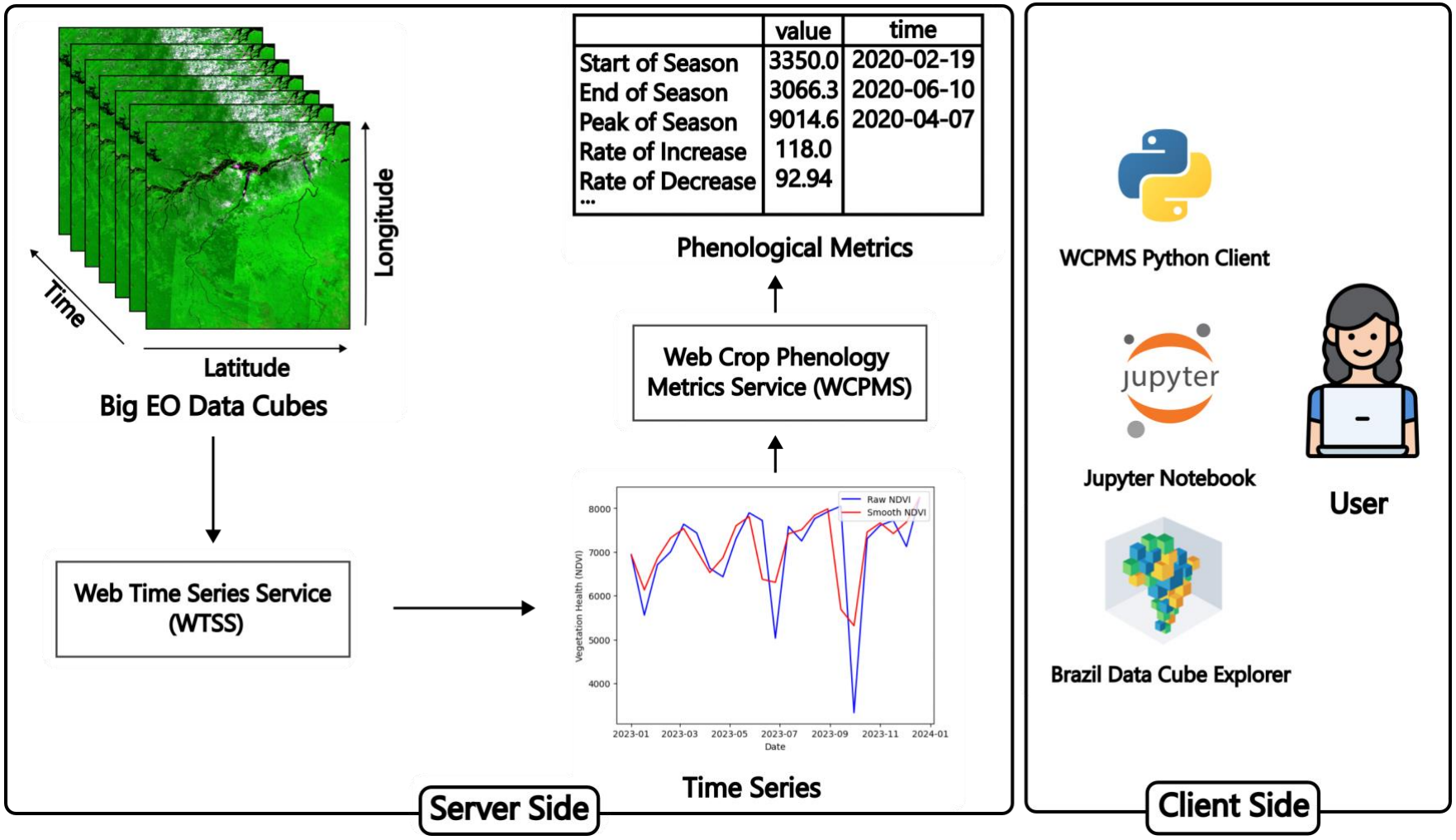
IBGE LULC - Brasil
2000, 2010, 2012, 2014, 2016, 2018
https://www.ibge.gov.br/



DETER - Amazônia e Cerrado
2018 - 2022
http://terrabrasilis.dpi.inpe.br/

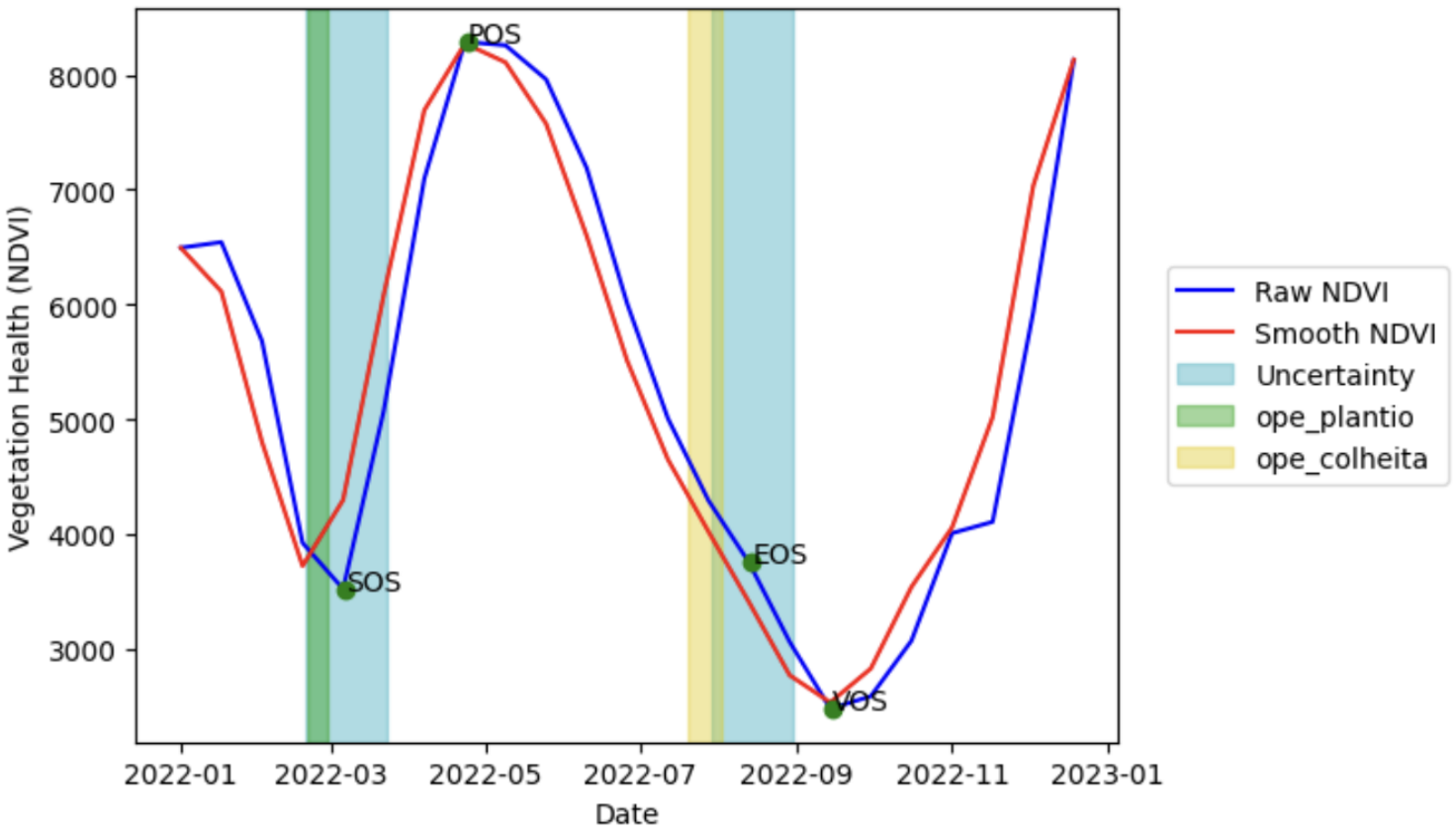
Lapig Pastagem - Brasil
1985 - 2021
https://atlasdaspastagens.ufg.br/map

Web Crop Phenology Metrics Service (WCPMS)



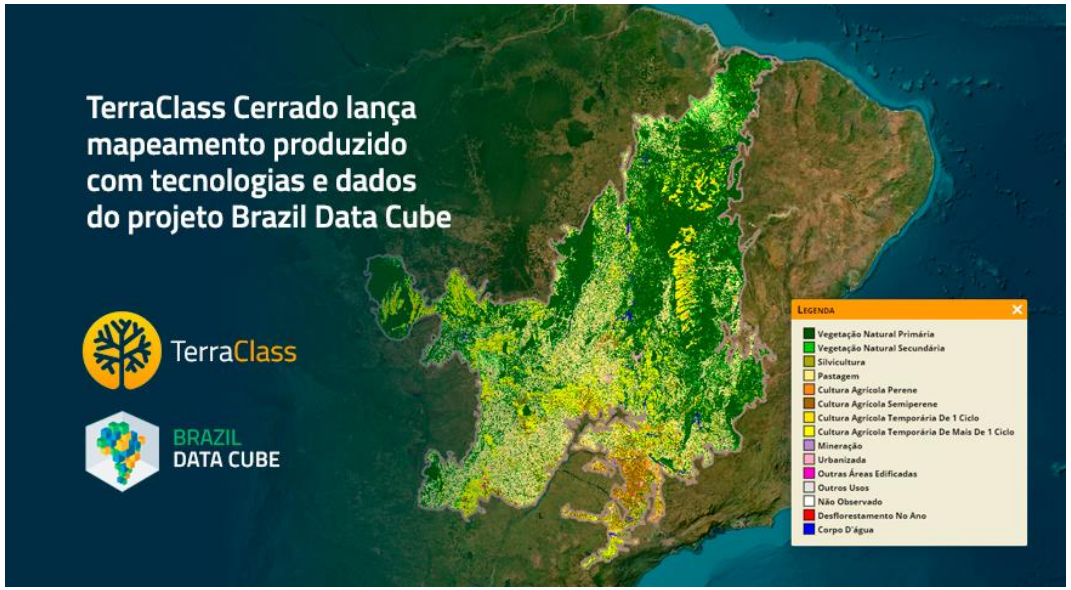
Web Crop Phenology Metrics Service (WCPMS)

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

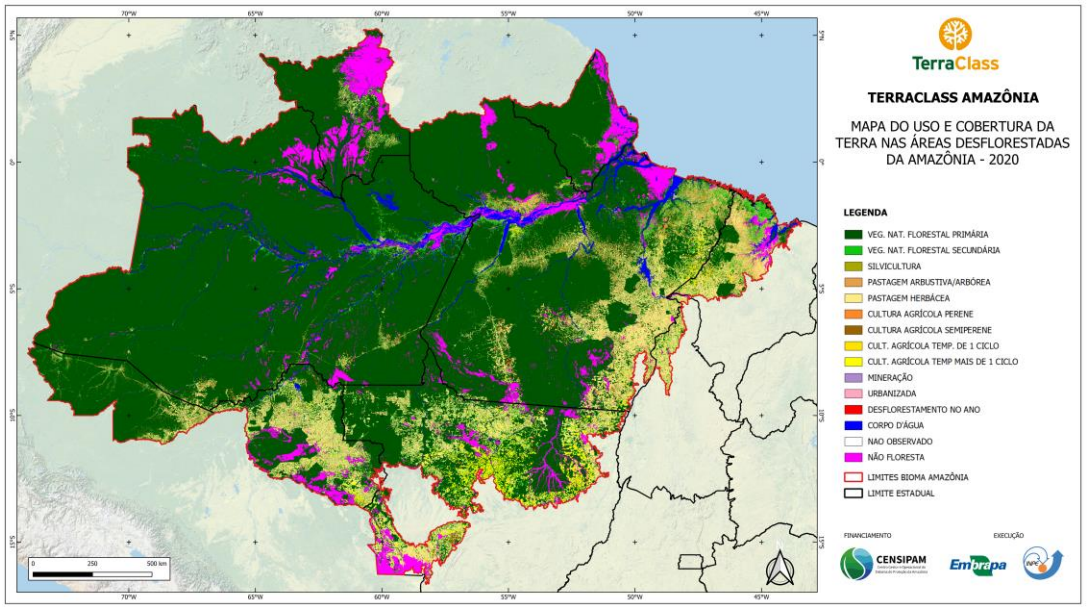


Land use and land cover maps: TerraClass project

TerraClass Cerrado 2020 (Launched in December 2022)



TerraClass Amazônia 2020



INPE UNIDADE DE PESQUISA DO MCTI

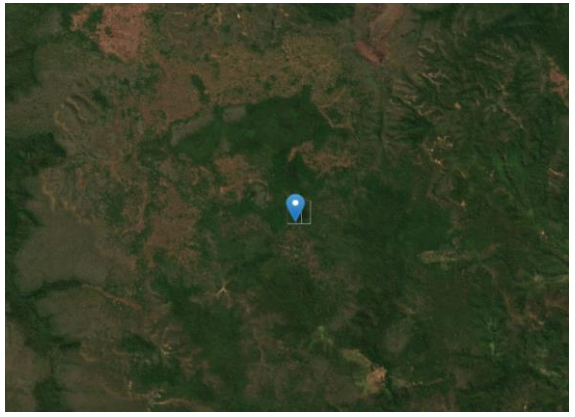
Embrapa

Vegetação Natural Primária – Cubos Sentinel 2

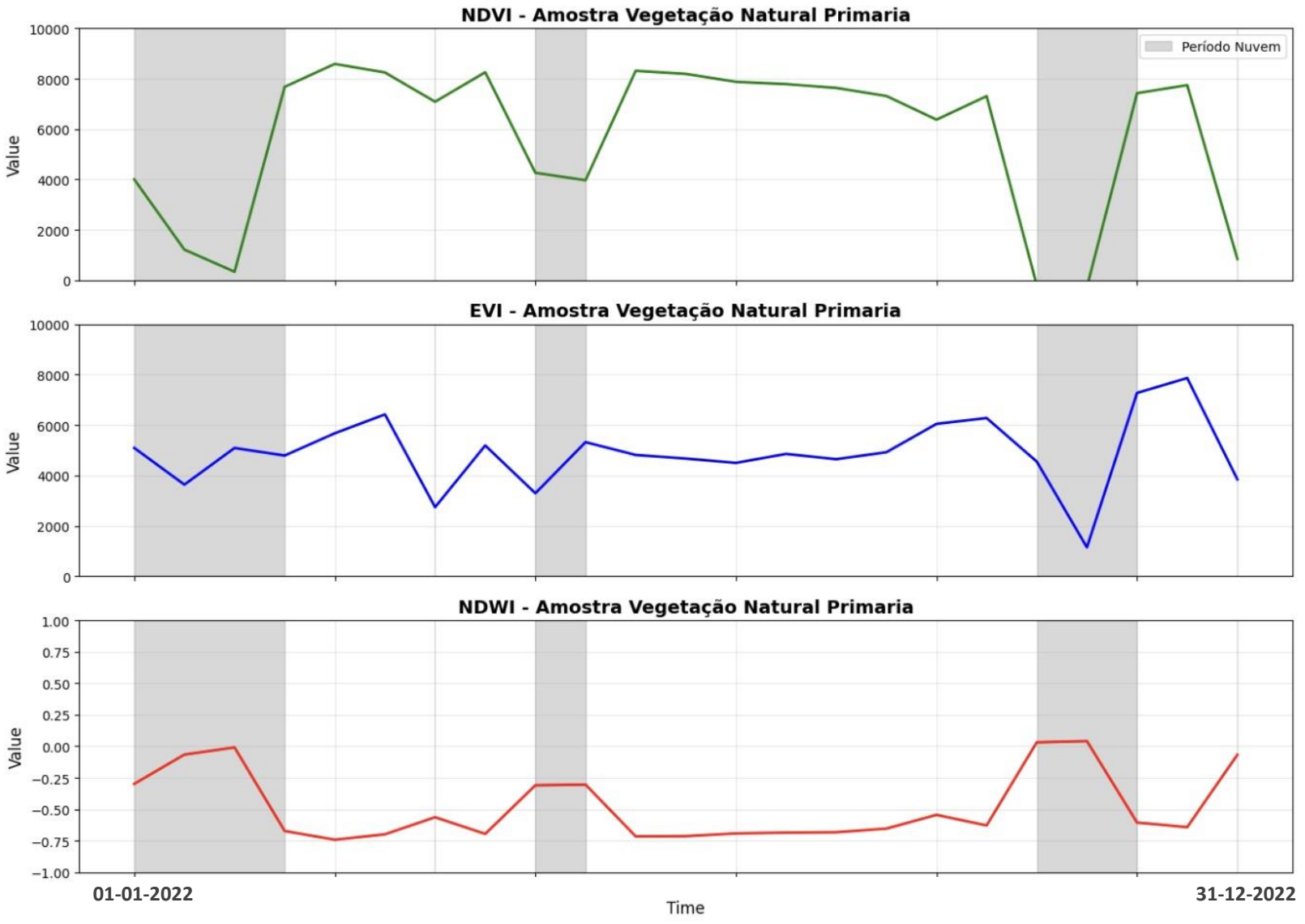
BRAZIL DATA CUBE

06-03-2022

12-07-2022



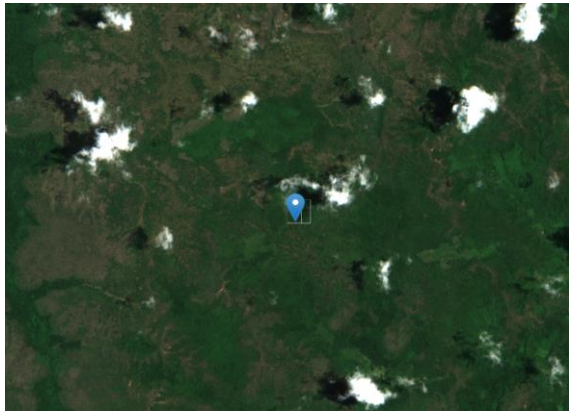
03-12-2022



Vegetação Natural Primária – Cubos Sentinel 2

BRAZIL DATA CUBE

06-03-2022



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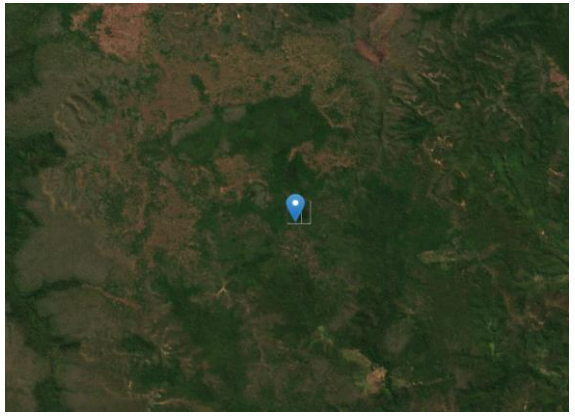
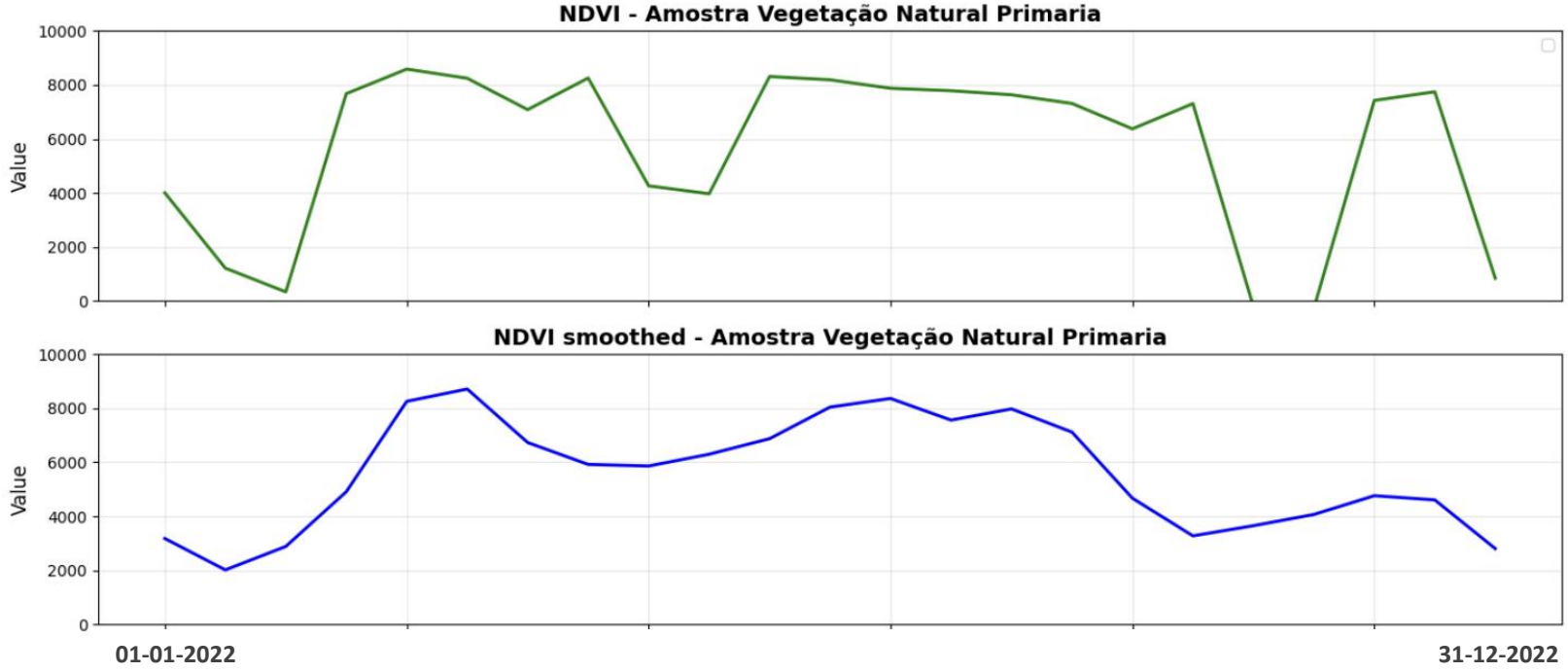


03-12-2022



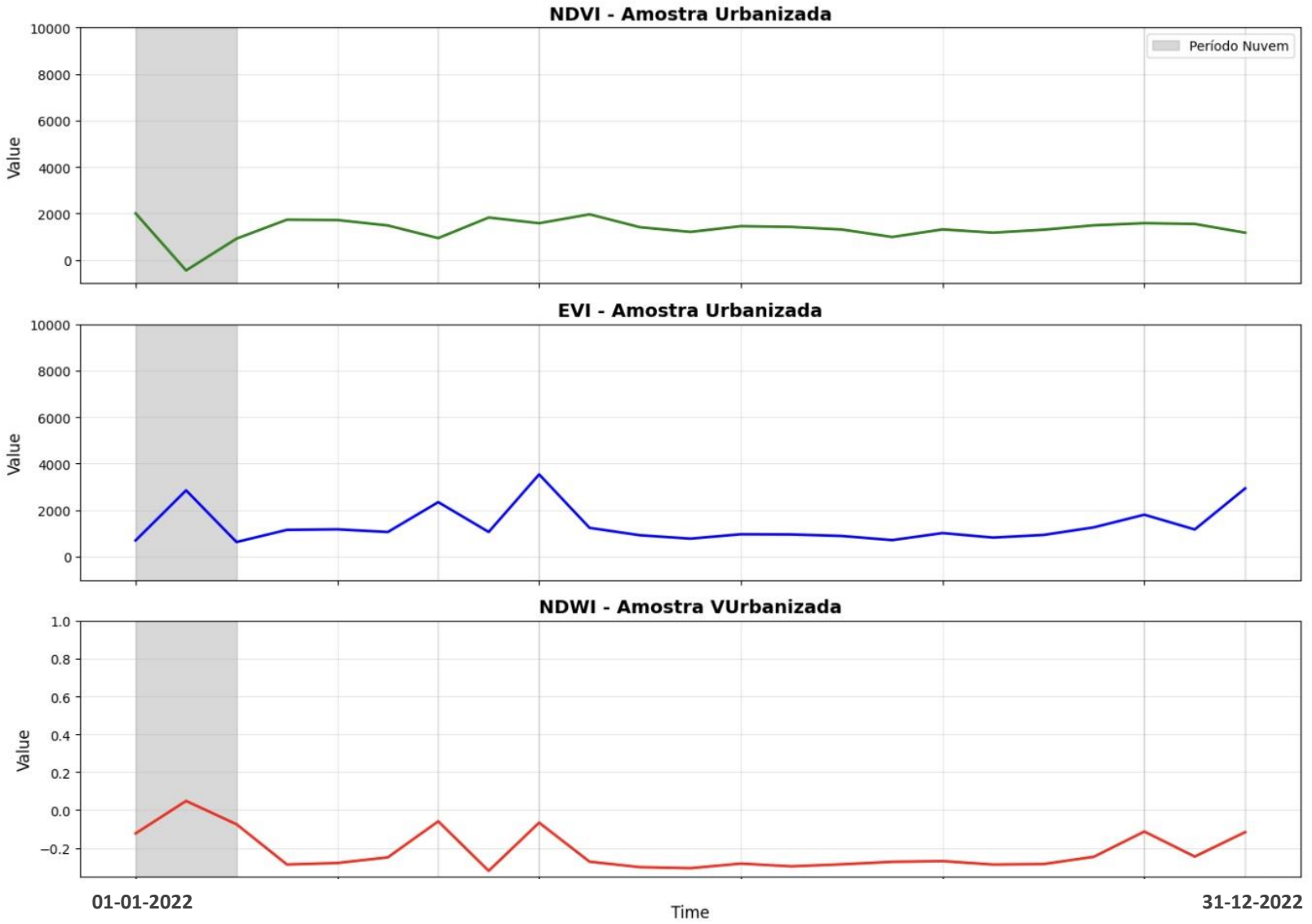
Área Urbana – Cubos Sentinel 2

BRAZIL DATA CUBE

18-02-2022

10-06-2022

16-10-2022



Área Urbana – Cubos Sentinel 2

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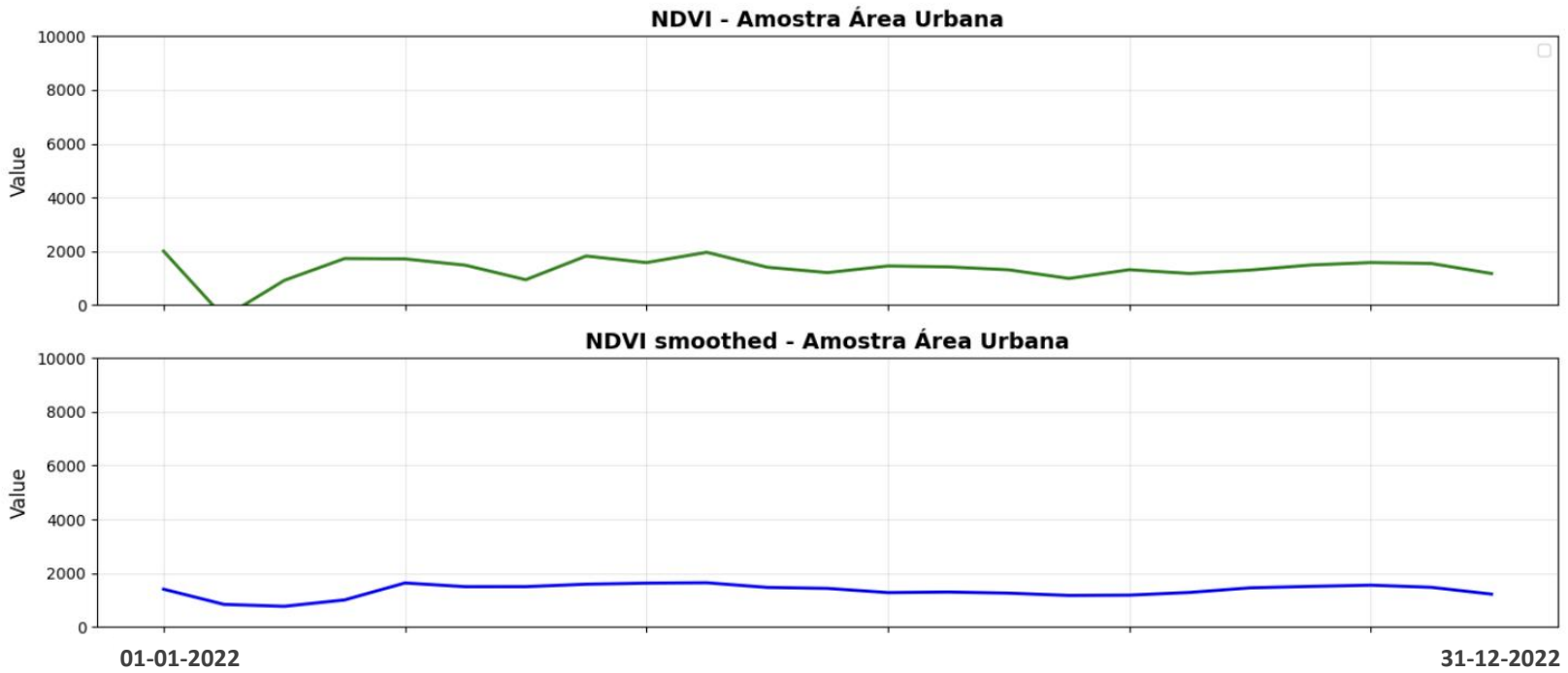
10-06-2022

16-10-2022



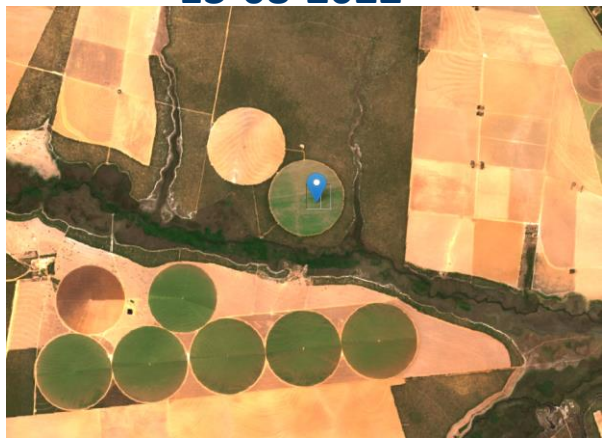
Agricultura - mais de 1 ciclo – Cubos Sentinel 2

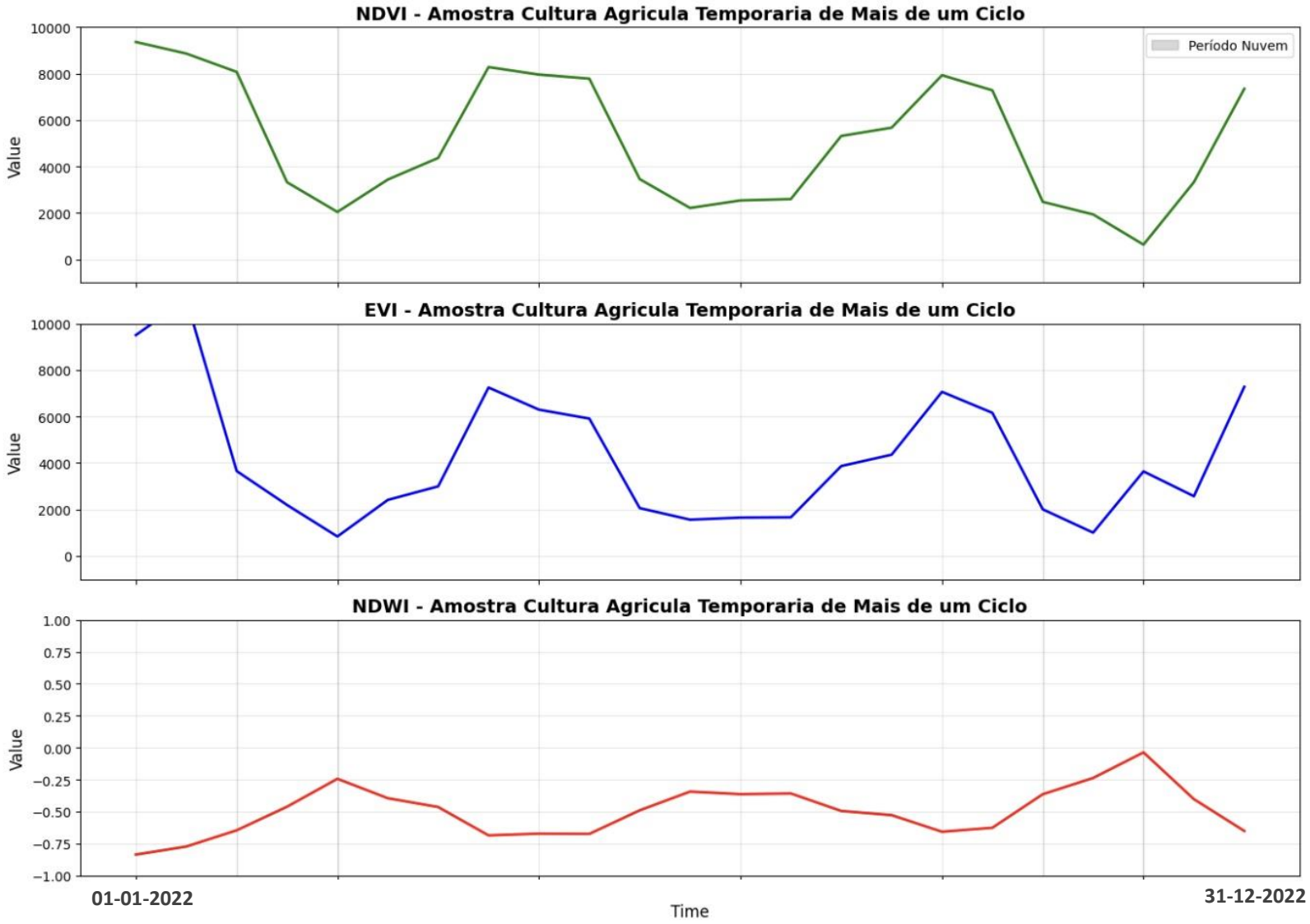
BRAZIL DATA CUBE

01-01-2022

22-03-2022

13-08-2022





Agricultura - mais de 1 ciclo – Cubos Sentinel 2

BRAZIL DATA CUBE

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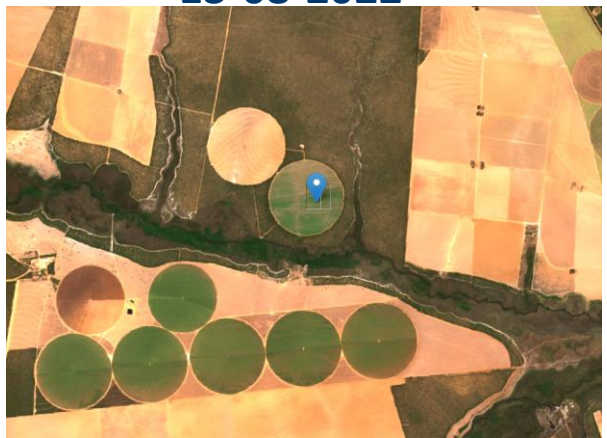
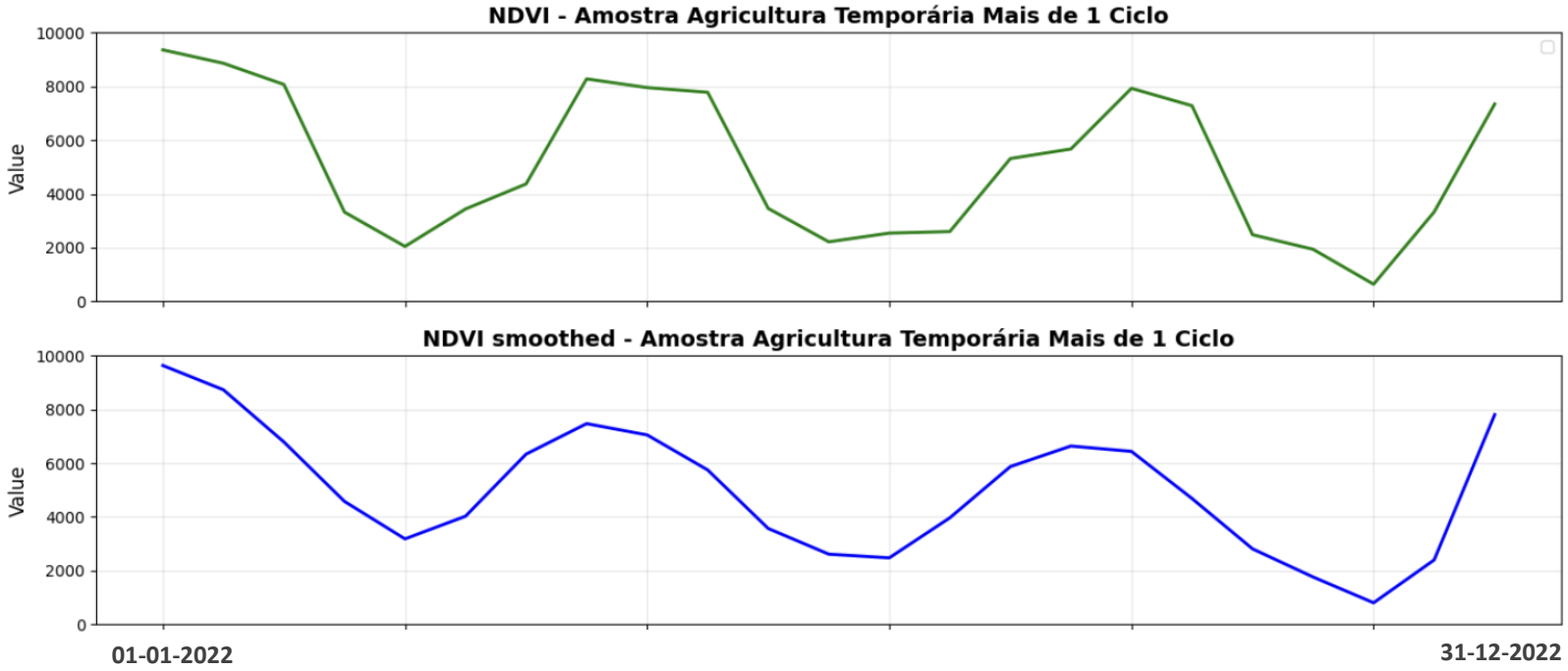
22-03-2022

13-08-2022



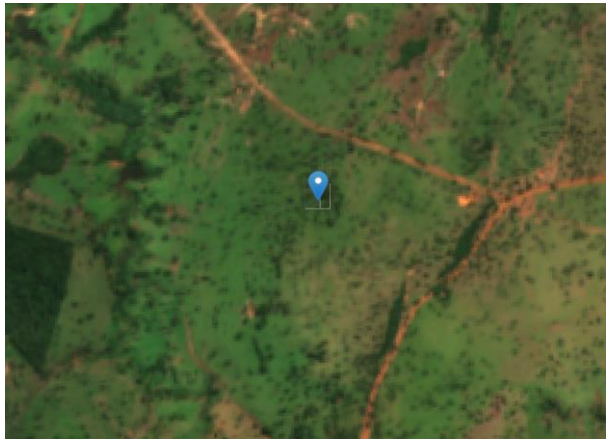


Pastagem – Cubos Sentinel 2

BRAZIL DATA CUBE

17-01-2022

09-05-2022



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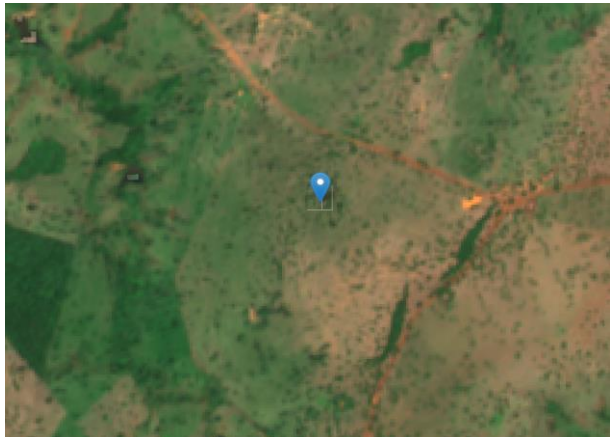
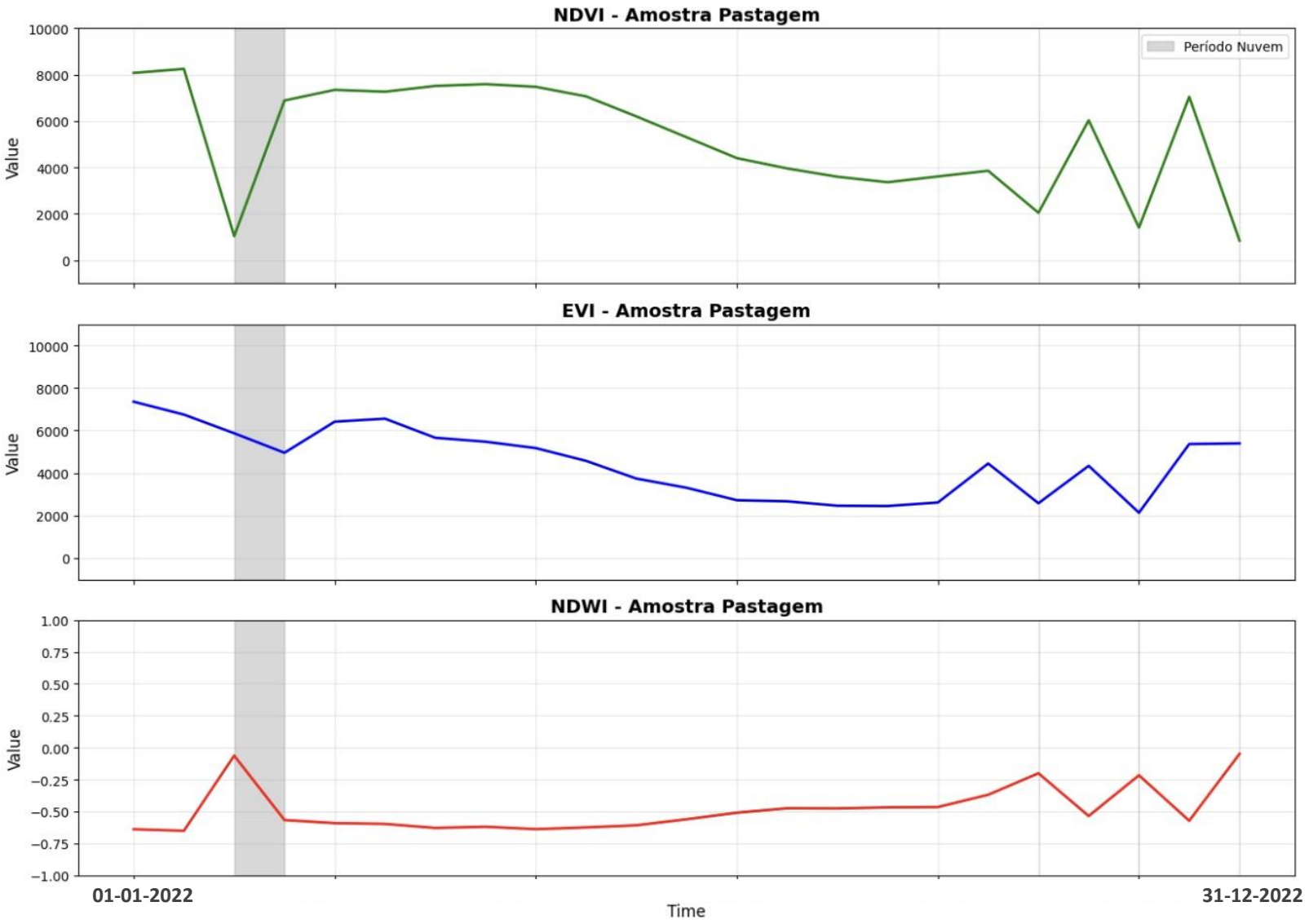
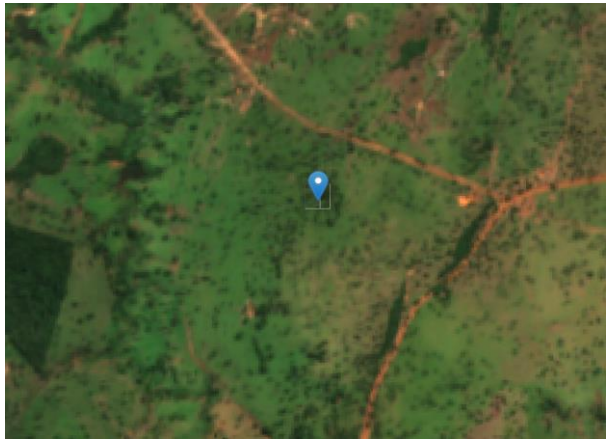




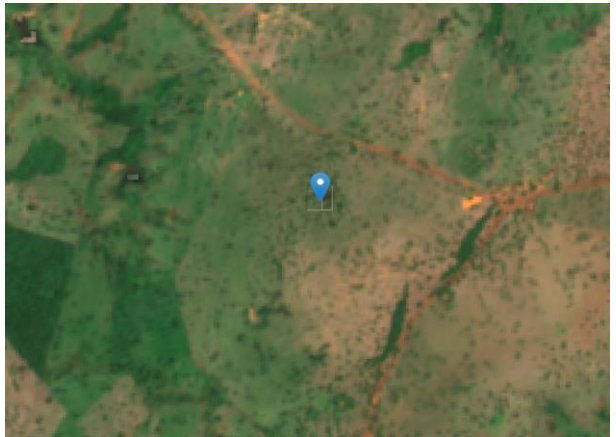
Pastagem – Cubos Sentinel 2

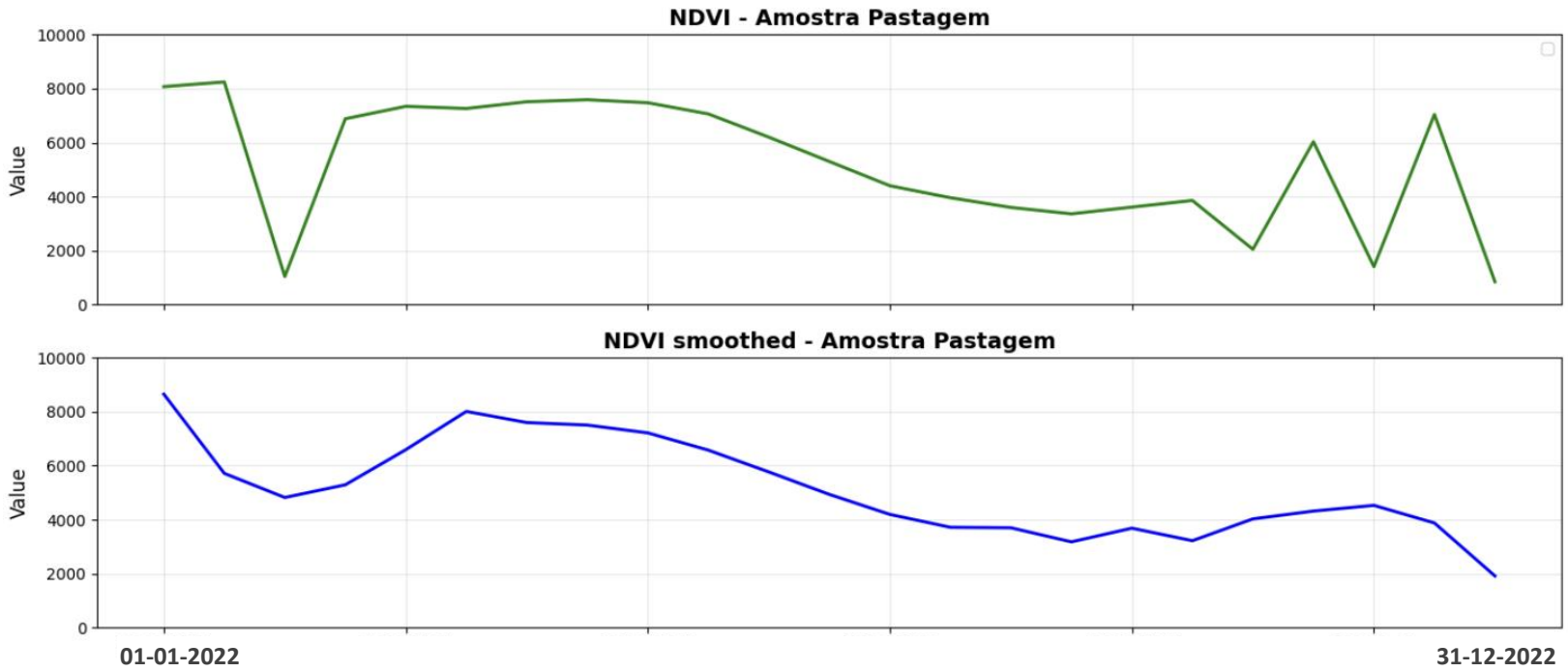
17-01-2022

09-05-2022



01-11-2022



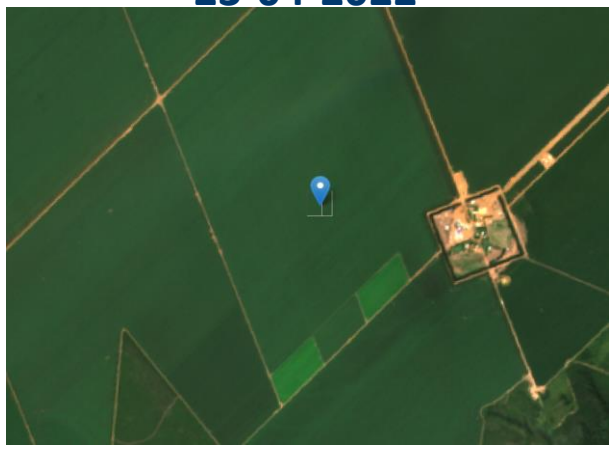


Agricultura – 1 ciclo – Cubos Sentinel 2

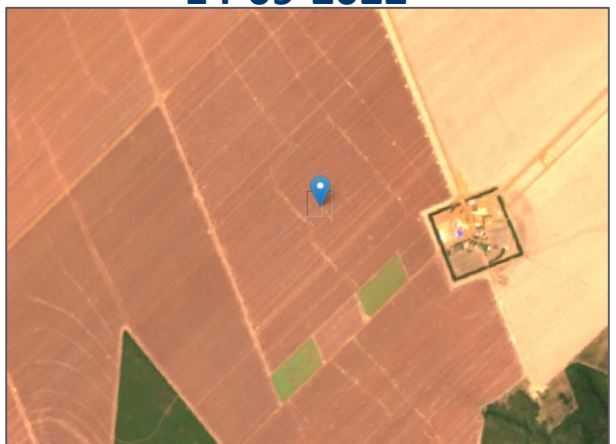
BRAZIL DATA CUBE

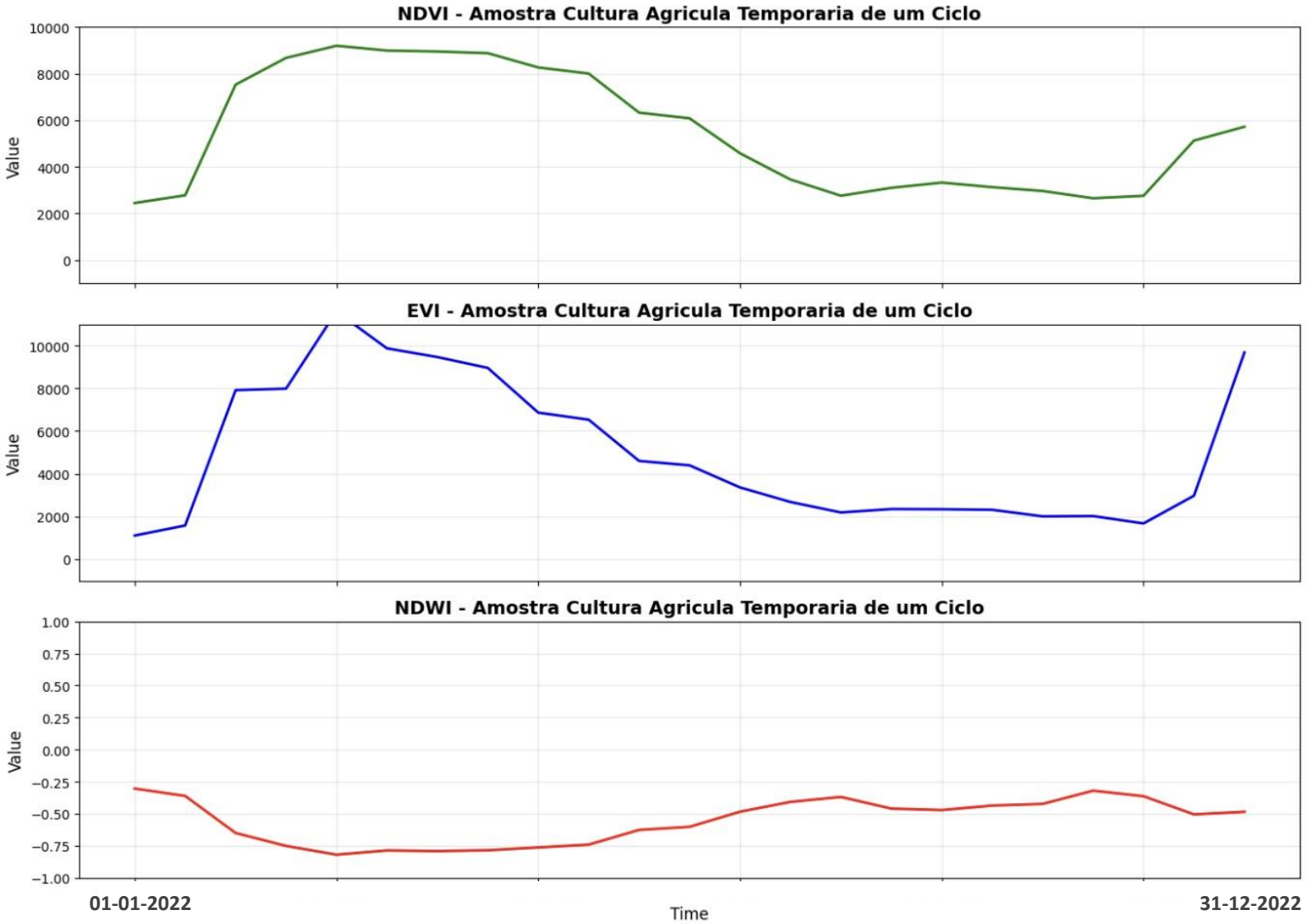
02-02-2022

23-04-2022



14-09-2022

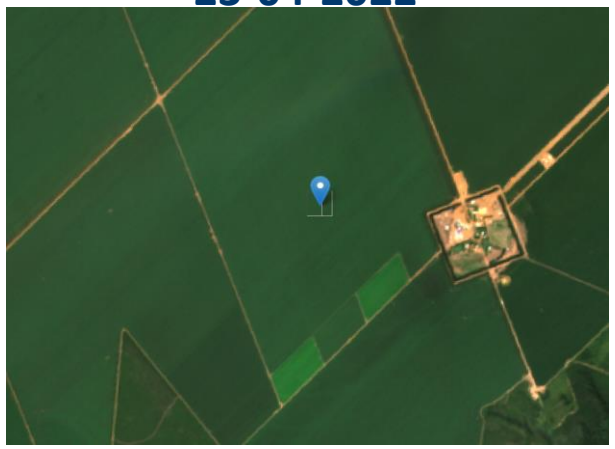




Agricultura – 1 ciclo – Cubos Sentinel 2

02-02-2022

23-04-2022



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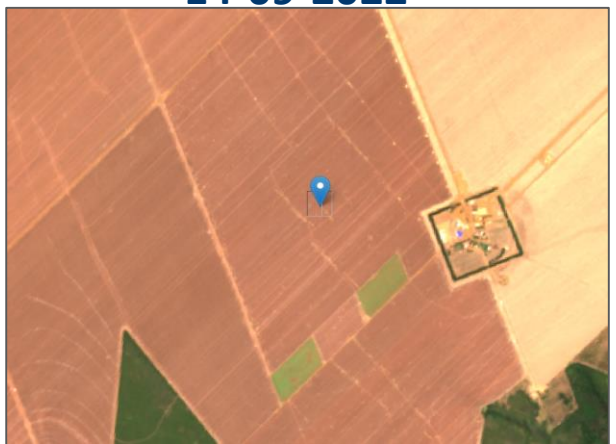

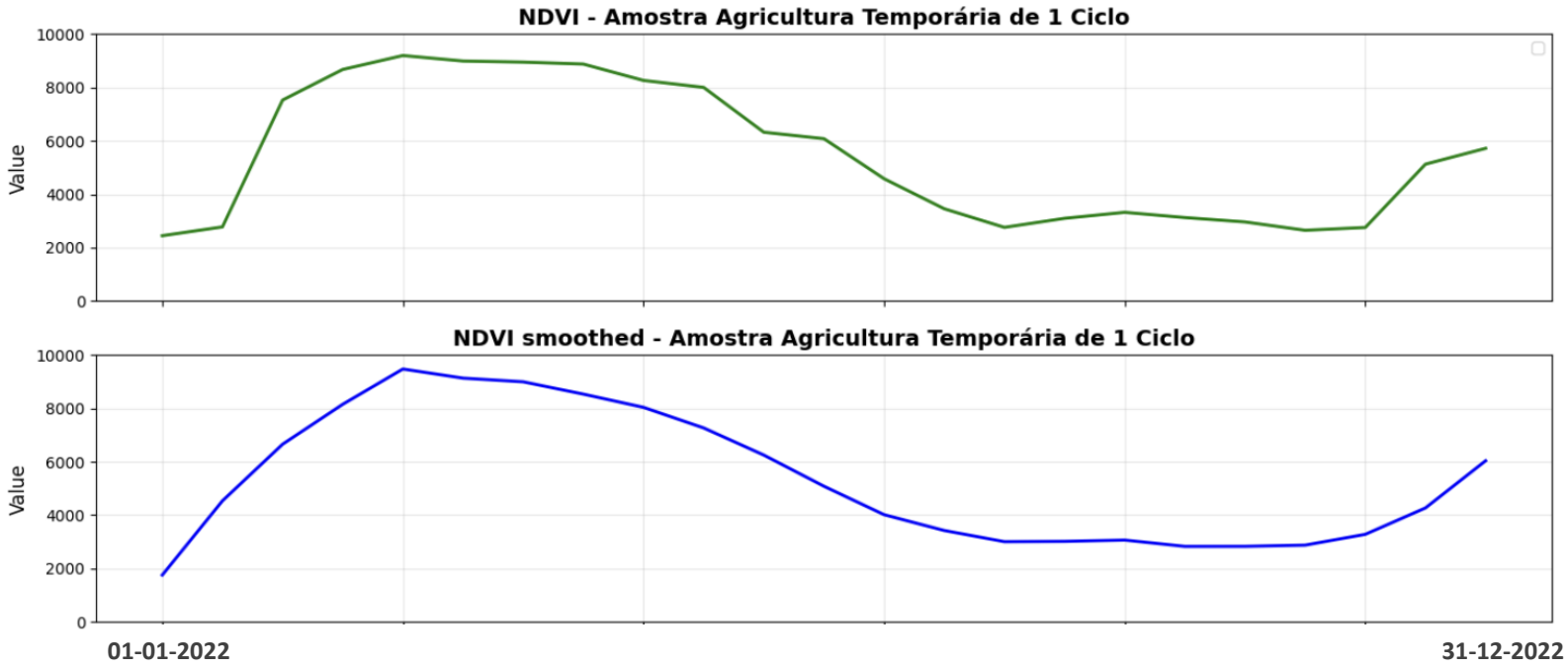

Água – Cubos Sentinel 2

BRAZIL DATA CUBE

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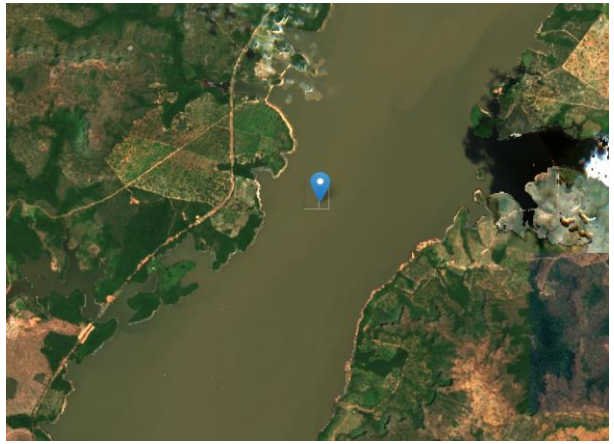

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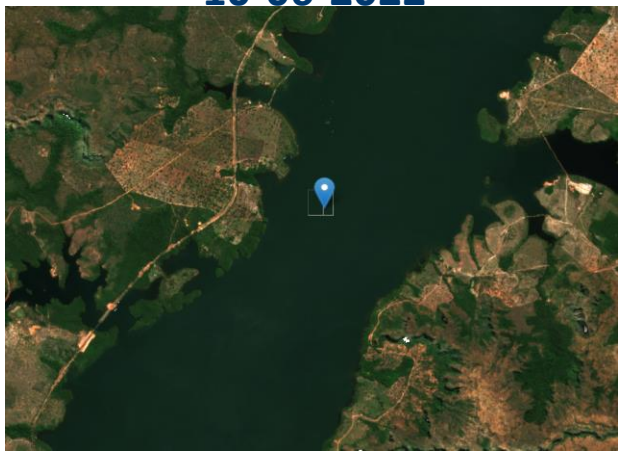
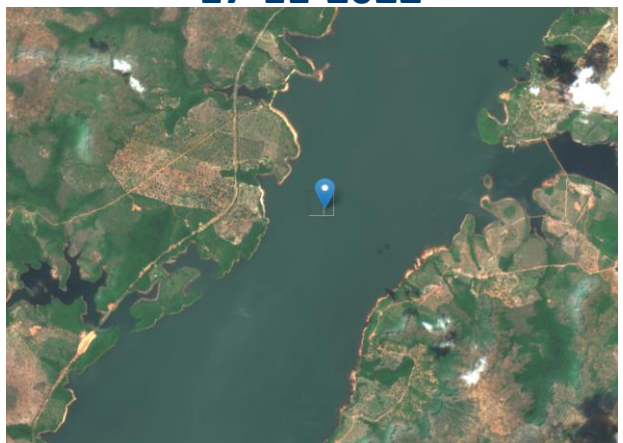
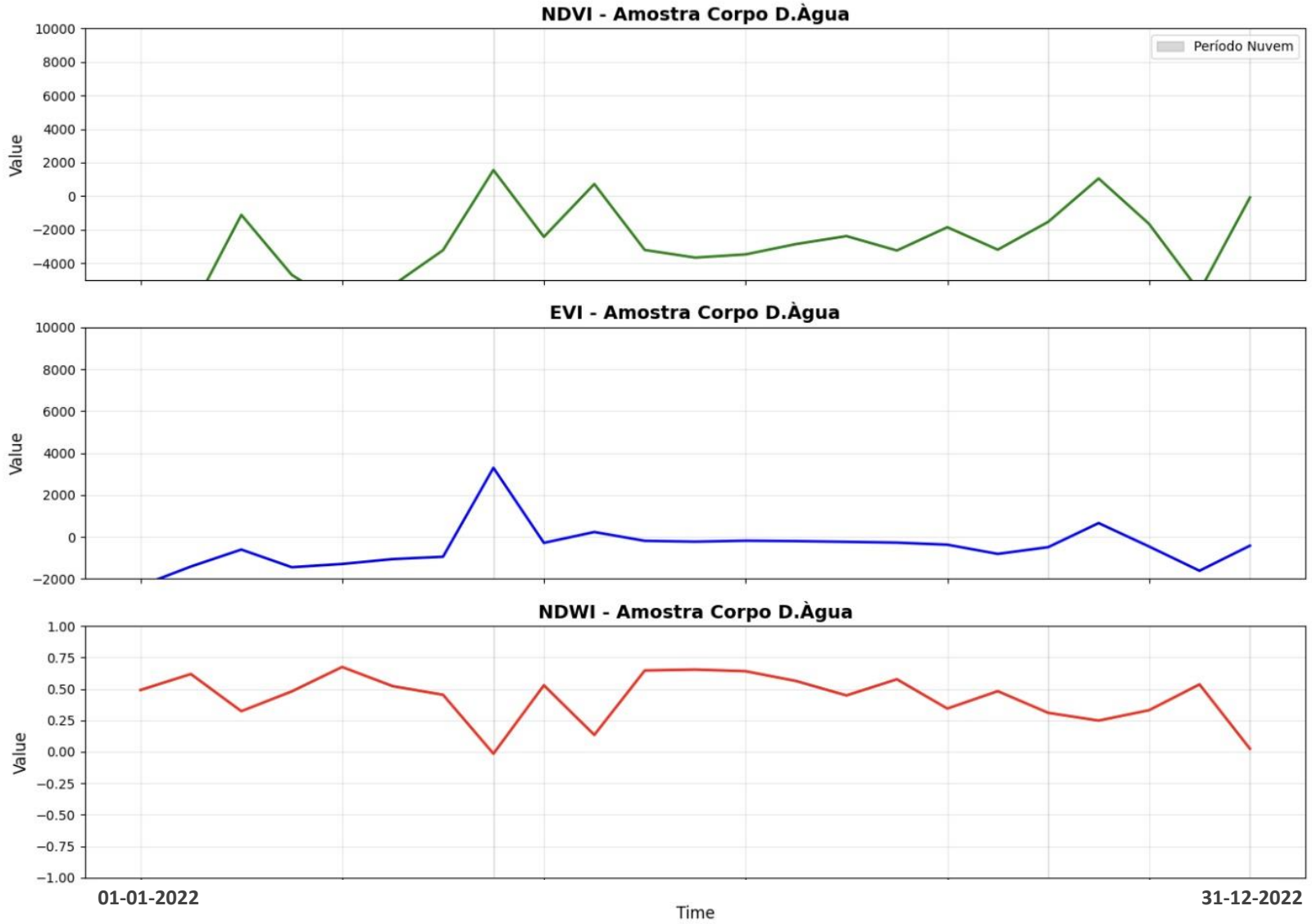


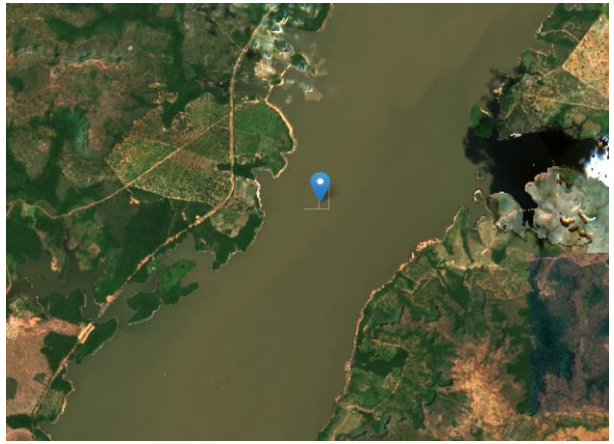
17-11-2022





Água – Cubos Sentinel 2

14-09-2022



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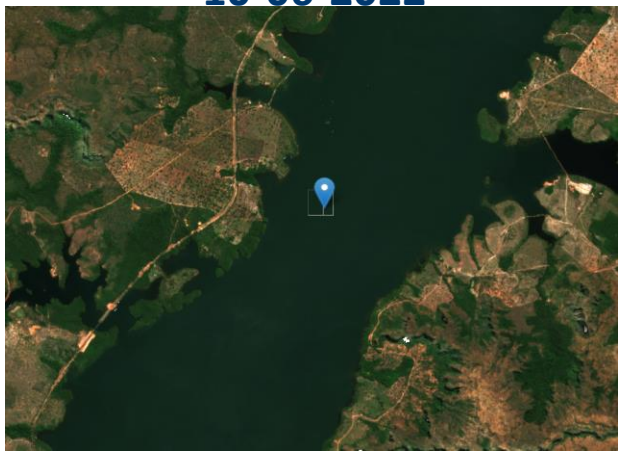

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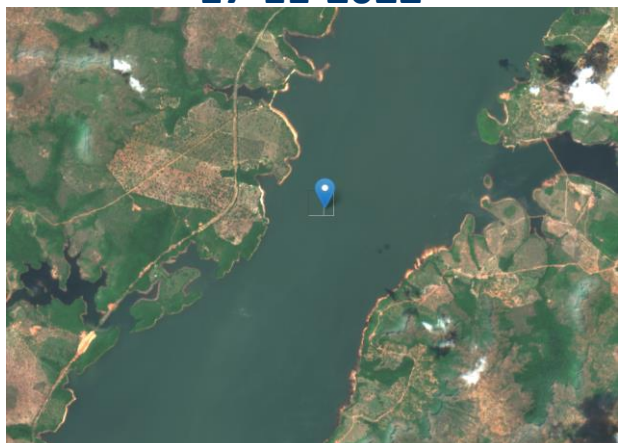
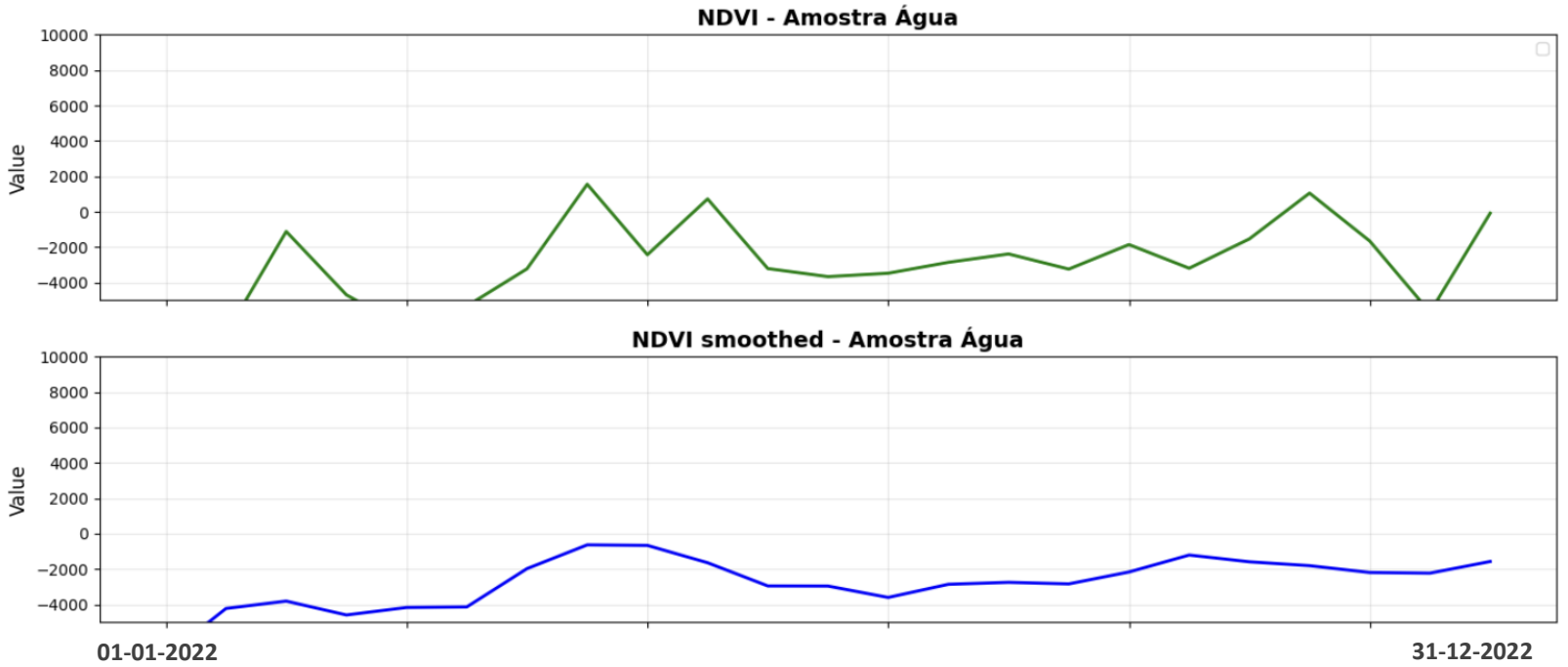
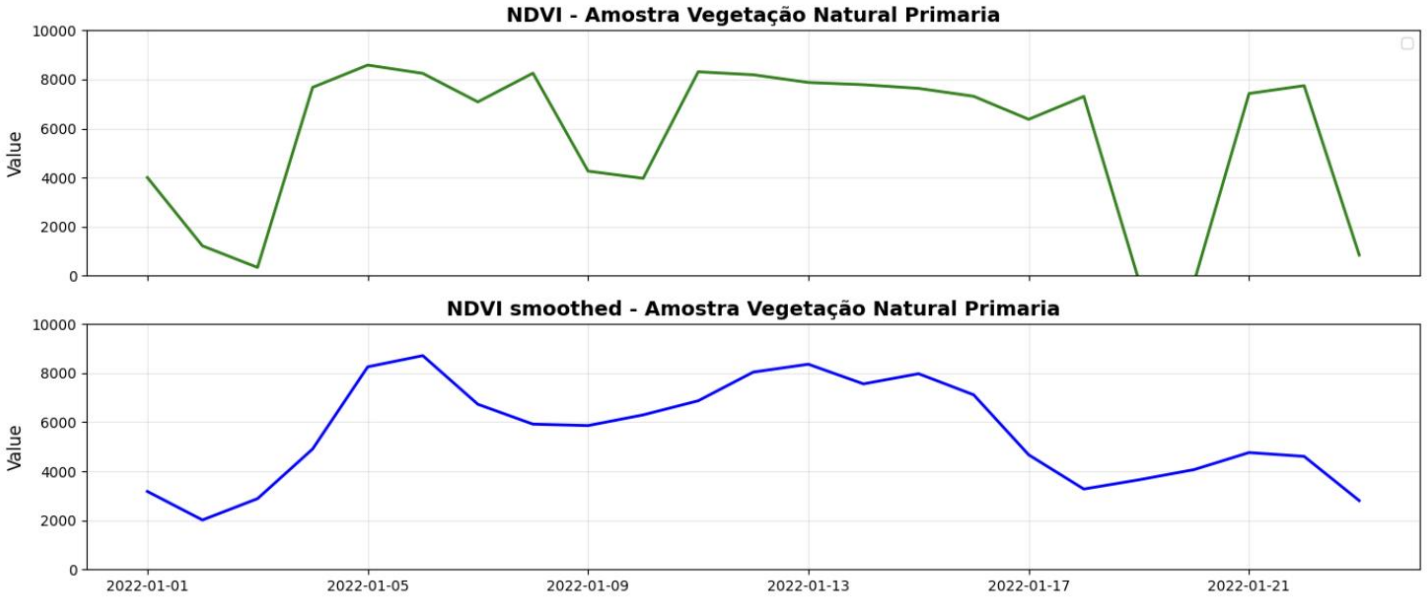
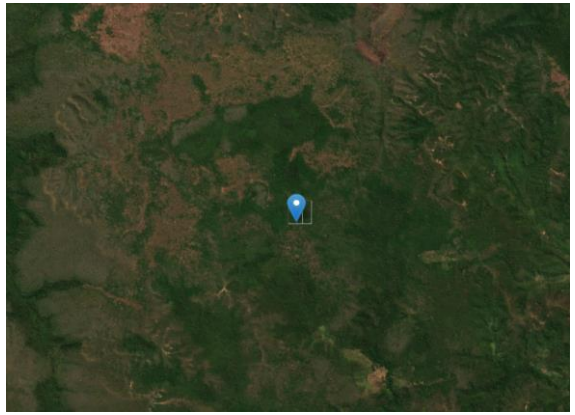
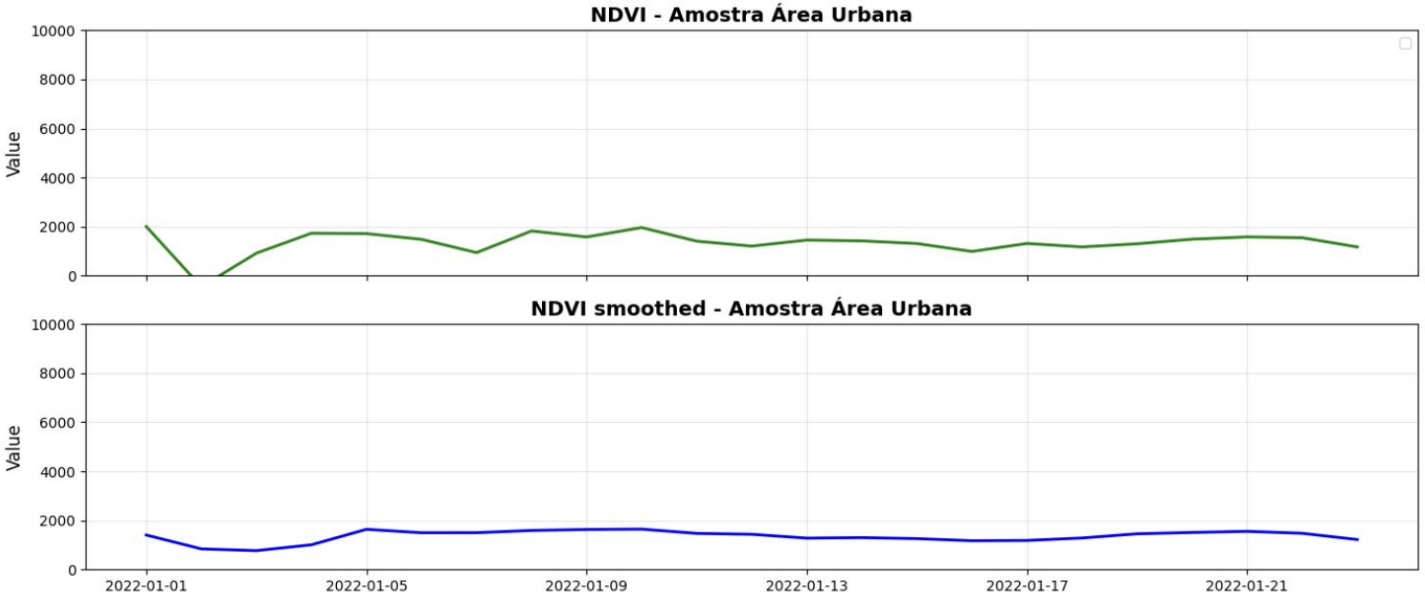
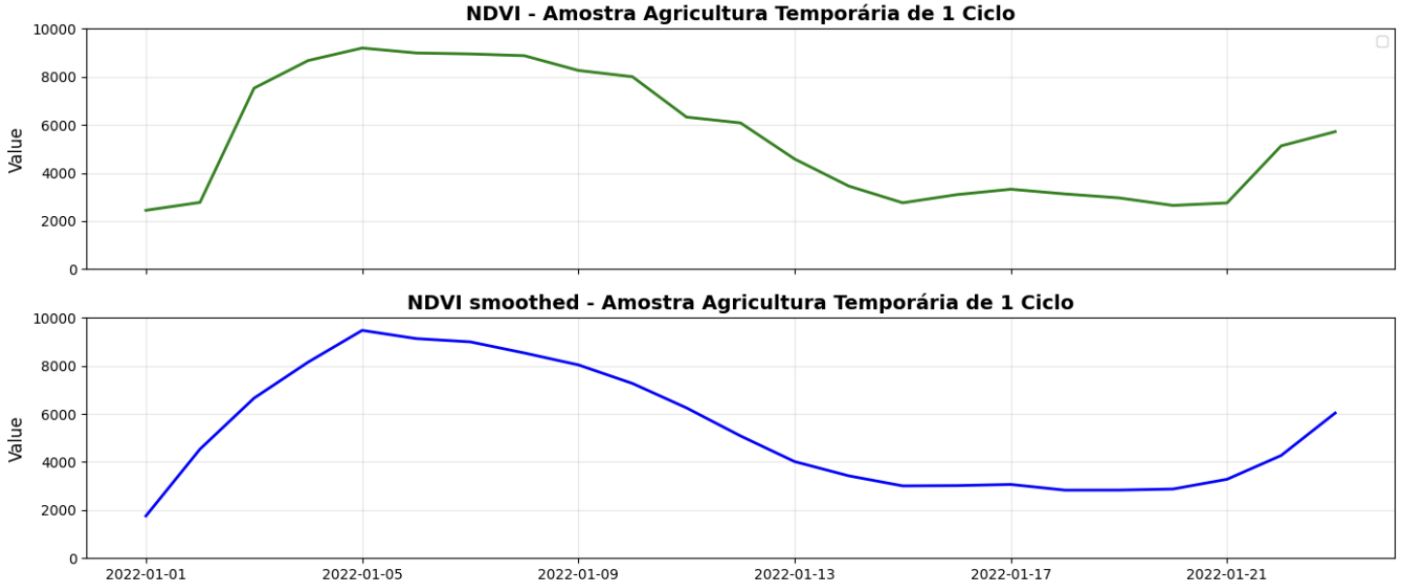


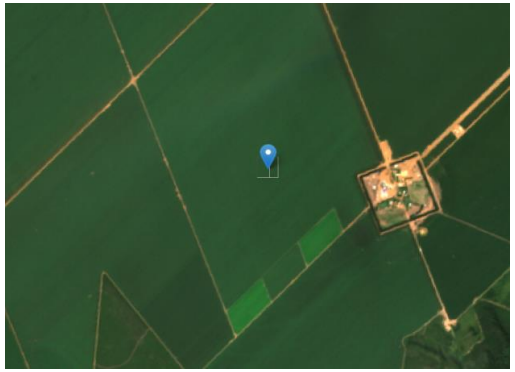


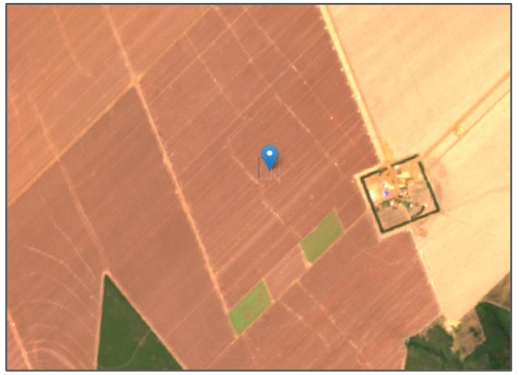

NDVI - Amostra Vegetação Natural Primaria
NDVI smoothed - Amostra Vegetação Natural Primaria
Value
10000
8000
6000
4000
2000
0
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21

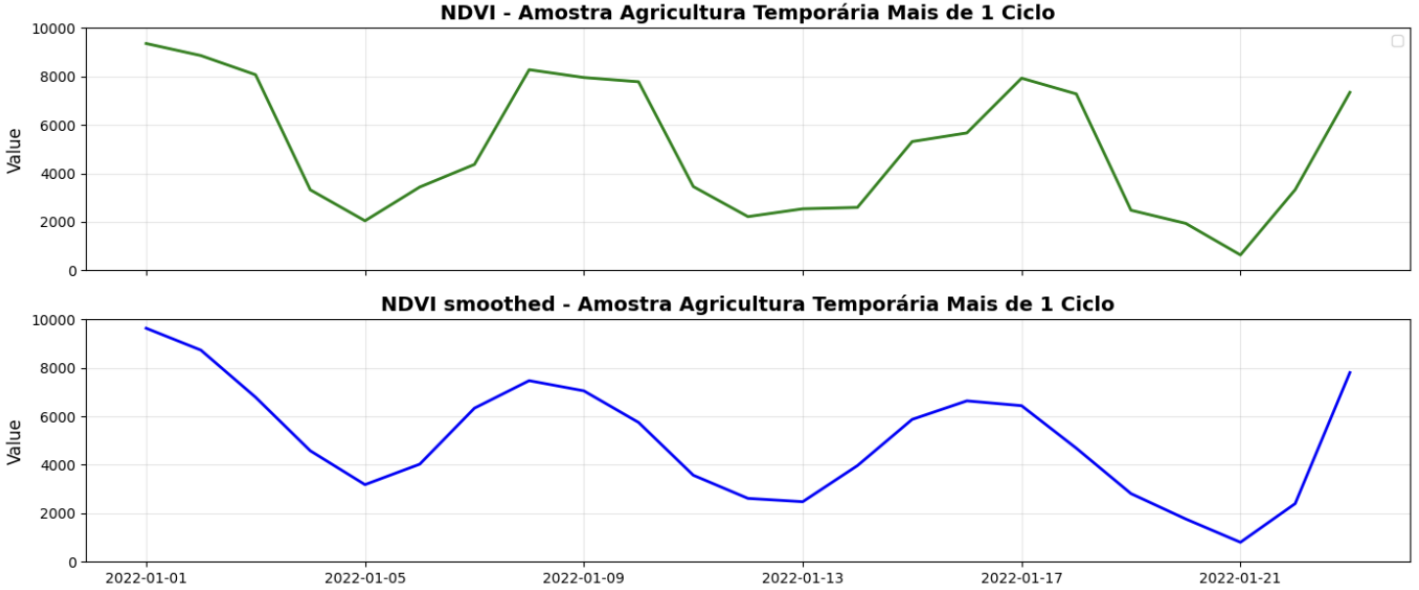


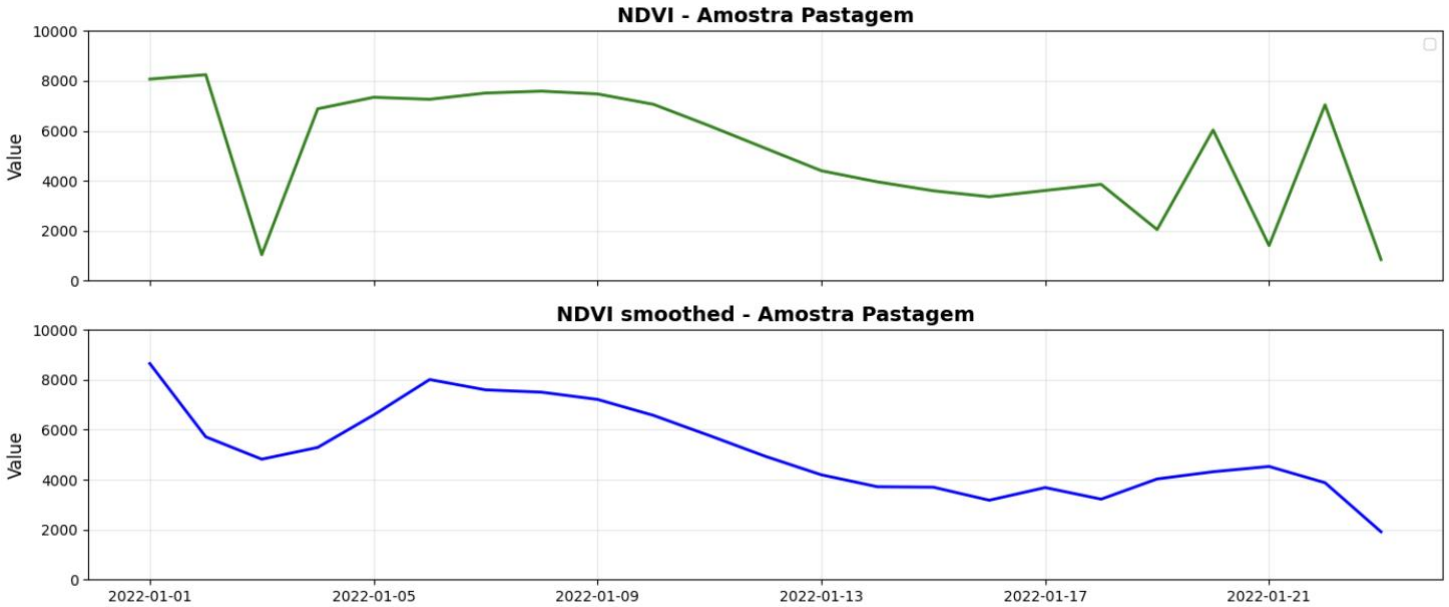

NDVI - Amostra Área Urbana
NDVI smoothed - Amostra Área Urbana
Value
10000
8000
6000
4000
2000
0
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21

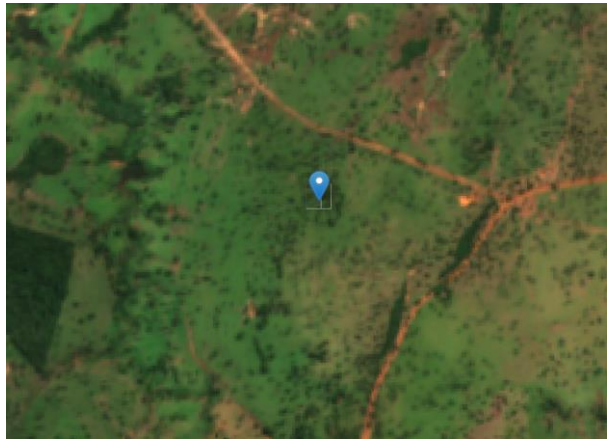

NDVI - Amostra Agricultura Temporária de 1 Ciclo
NDVI smoothed - Amostra Agricultura Temporária de 1 Ciclo
Value
10000
8000
6000
4000
2000
0
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21

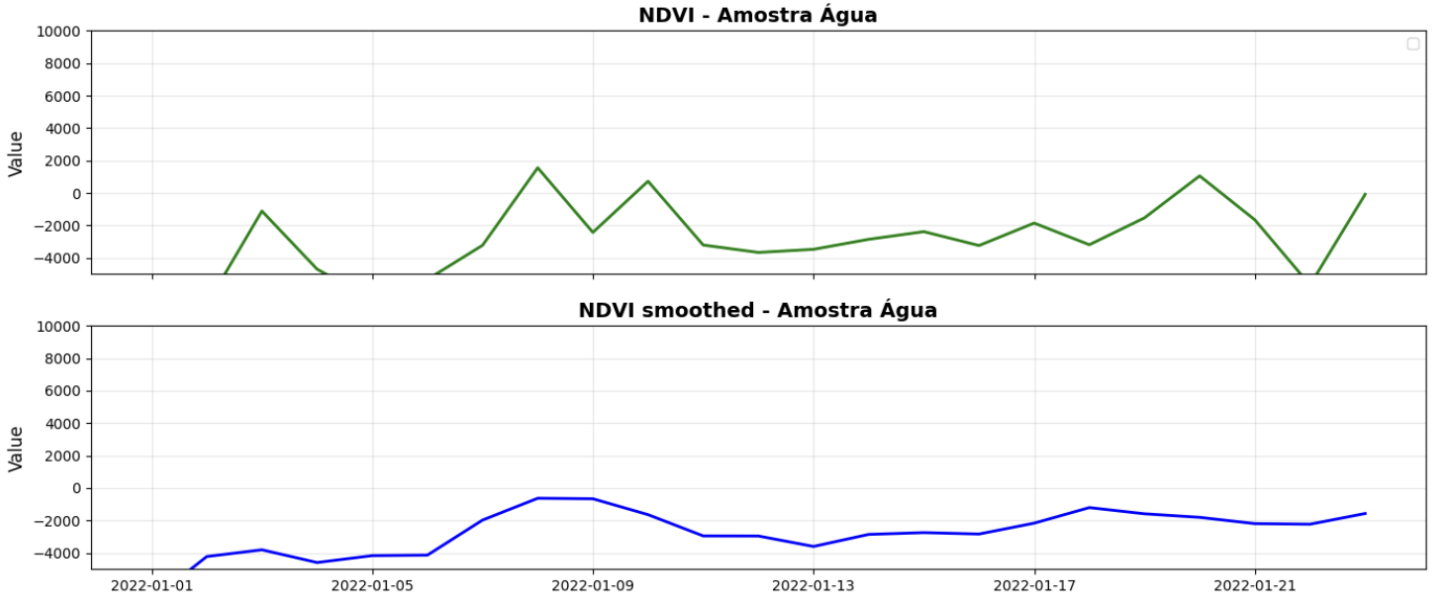


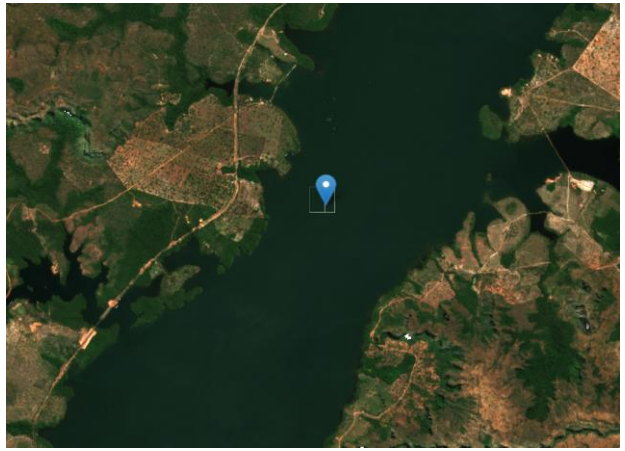



NDVI - Amostra Agricultura Temporária Mais de 1 Ciclo
NDVI smoothed - Amostra Agricultura Temporária Mais de 1 Ciclo
Value
10000
8000
6000
4000
2000
0
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21

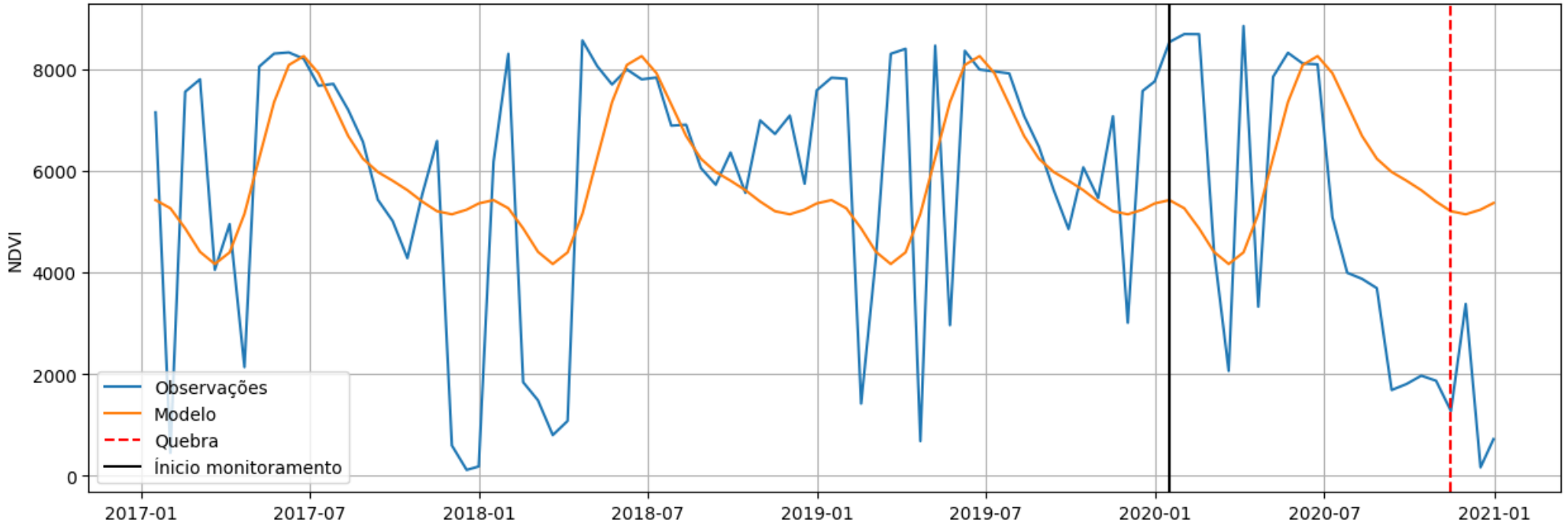

NDVI - Amostra Pastagem
Value
10000
8000
6000
4000
2000
0
NDVI smoothed - Amostra Pastagem
Value
10000
8000
6000
4000
2000
0
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21

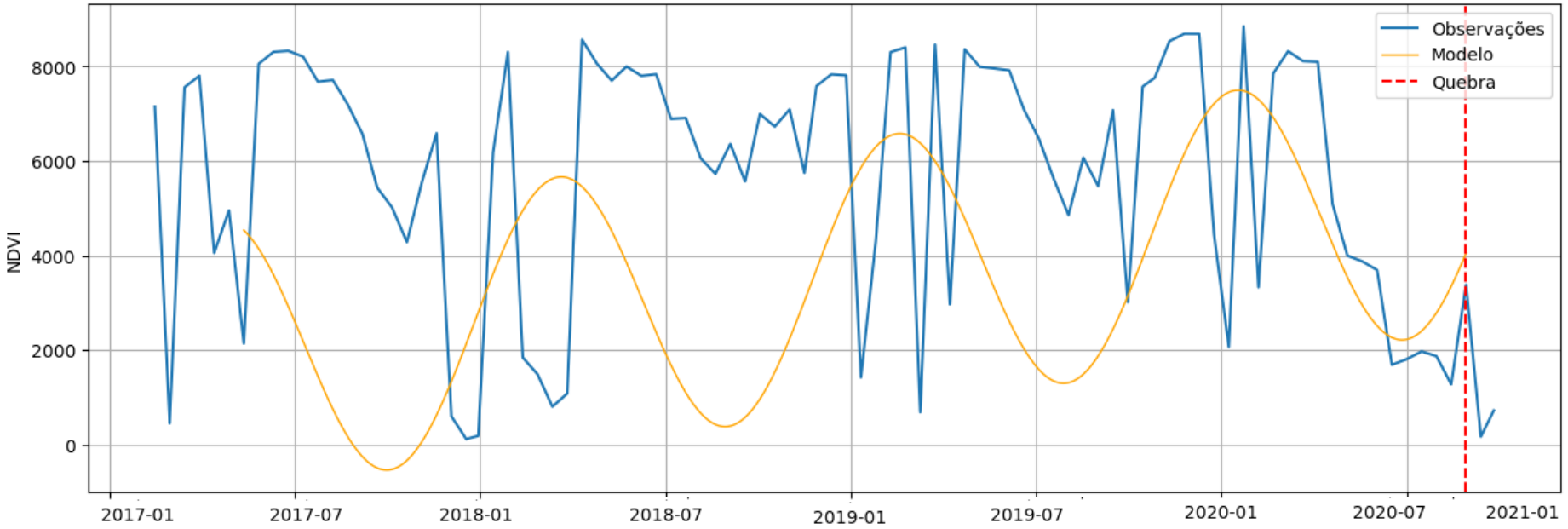



NDVI - Amostra Água
Value
10000
8000
6000
4000
2000
0
−2000
−4000
NDVI smoothed - Amostra Água
Value
10000
8000
6000
4000
2000
0
−2000
−4000
2022-01-01
2022-01-05
2022-01-09
2022-01-13
2022-01-17
2022-01-21



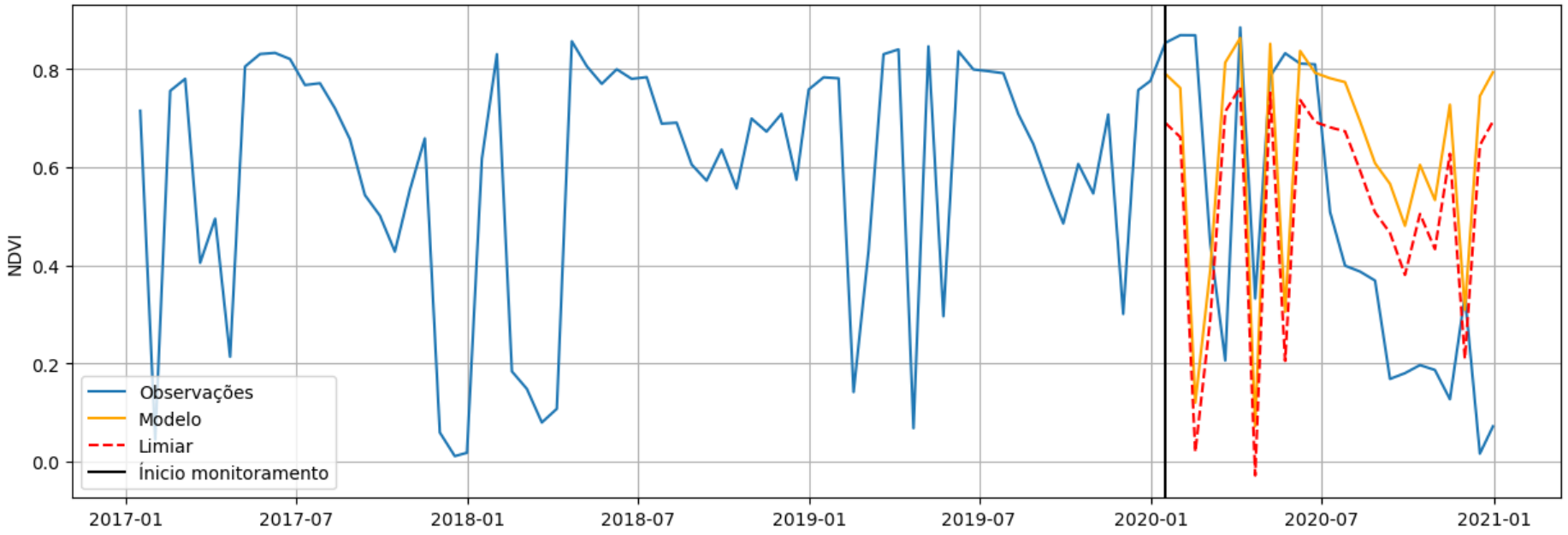
BFAST Monitor





CCDC

LSTM


NDVI
0.0
0.2
0.4
0.6
0.8
2017-01
2017-07
2018-01
2018-07
2019-01
2019-07
2020-01
2020-07
2021-01
Observações
Modelo
Limiar
Ínicio monitoramento

Satellite Image Time Series (SITS) Analysis

Classification of SITS

Clustering of SITS

Disturbance/Change Detection from SITS

Vegetation Phenological Metrics Extraction from SITS

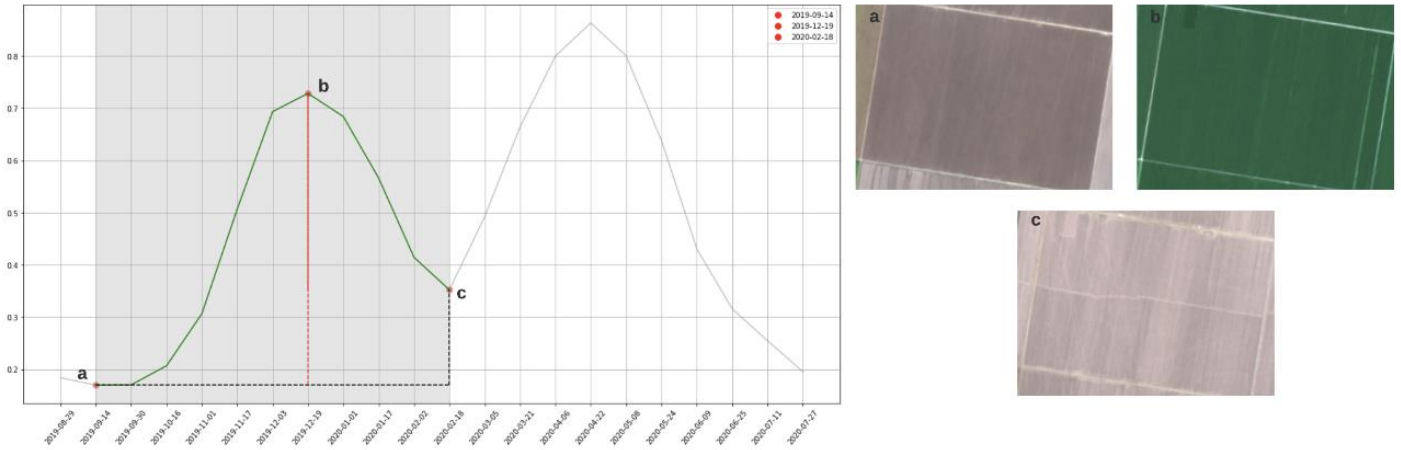
Methods to extract vegetation phenological metrics

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

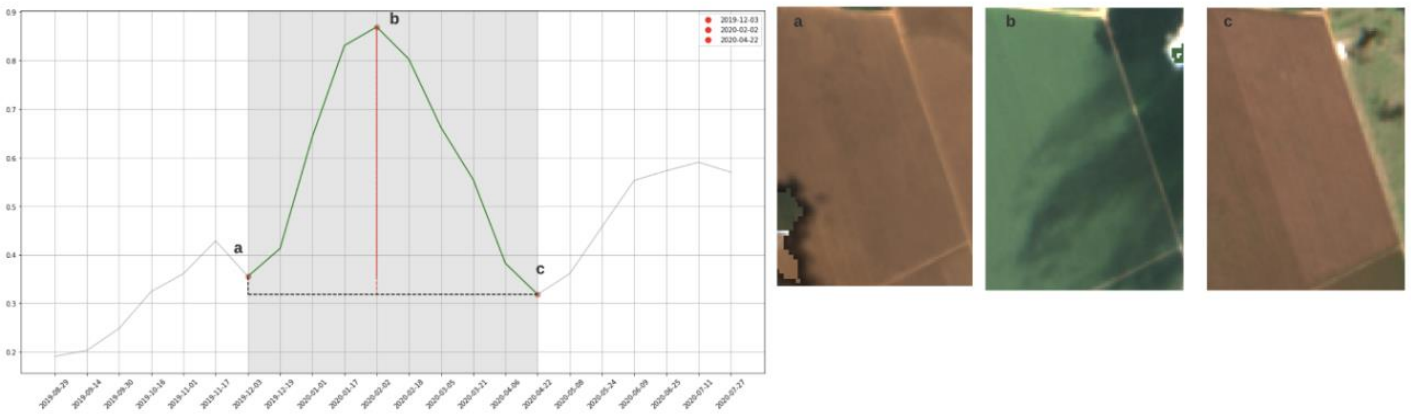
Table 4
Summary of main phenological metrics extraction methods for species-specific vegetation types from satellite imagery.

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	Duchemin et al. (1999)
Inflection points determined by derivative	Rice	MODIS	Physiological-based phenological stages	Planting, heading, and harvesting	Empirical method	Sakamoto et al. (2005)
Based on the parameters derived from the best fitted polynomial curve	Potato	MODIS	General phenological stages	12 metrics for potato	Empirical method	Islam and Bala (2008)
Use TIMESAT software to detect rice phenological stages	Rice	MODIS	General phenological stages	Start, peak and end of season	Empirical method	Boschetti et al. (2009)
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	Sakamoto et al. (2010)
Regress the ground measure degree days and VI values	Sugarcane	ASTER	Physiological-based phenological stages	6 stages	Simulation	Mobasheri et al. (2010)

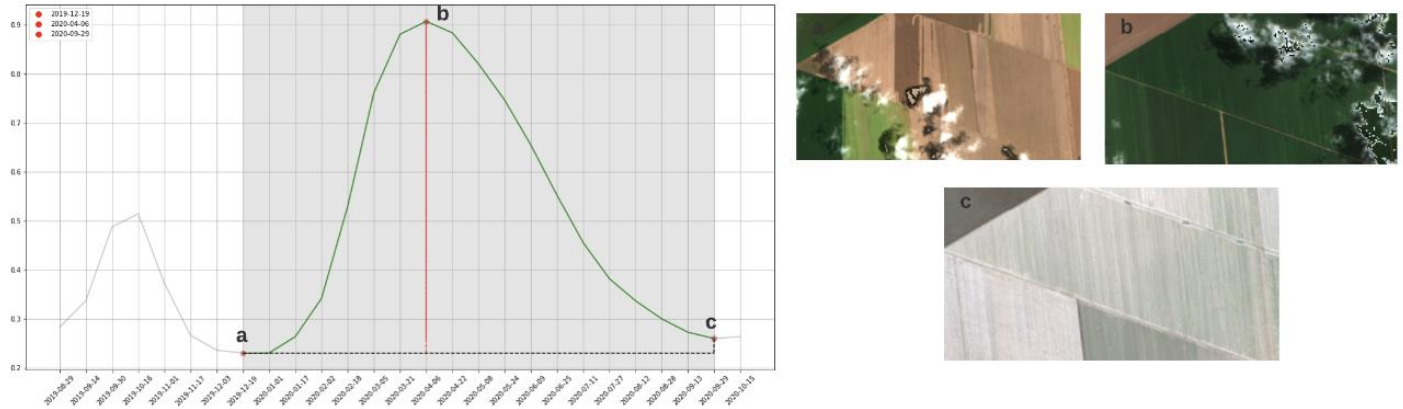
(a)



(b)

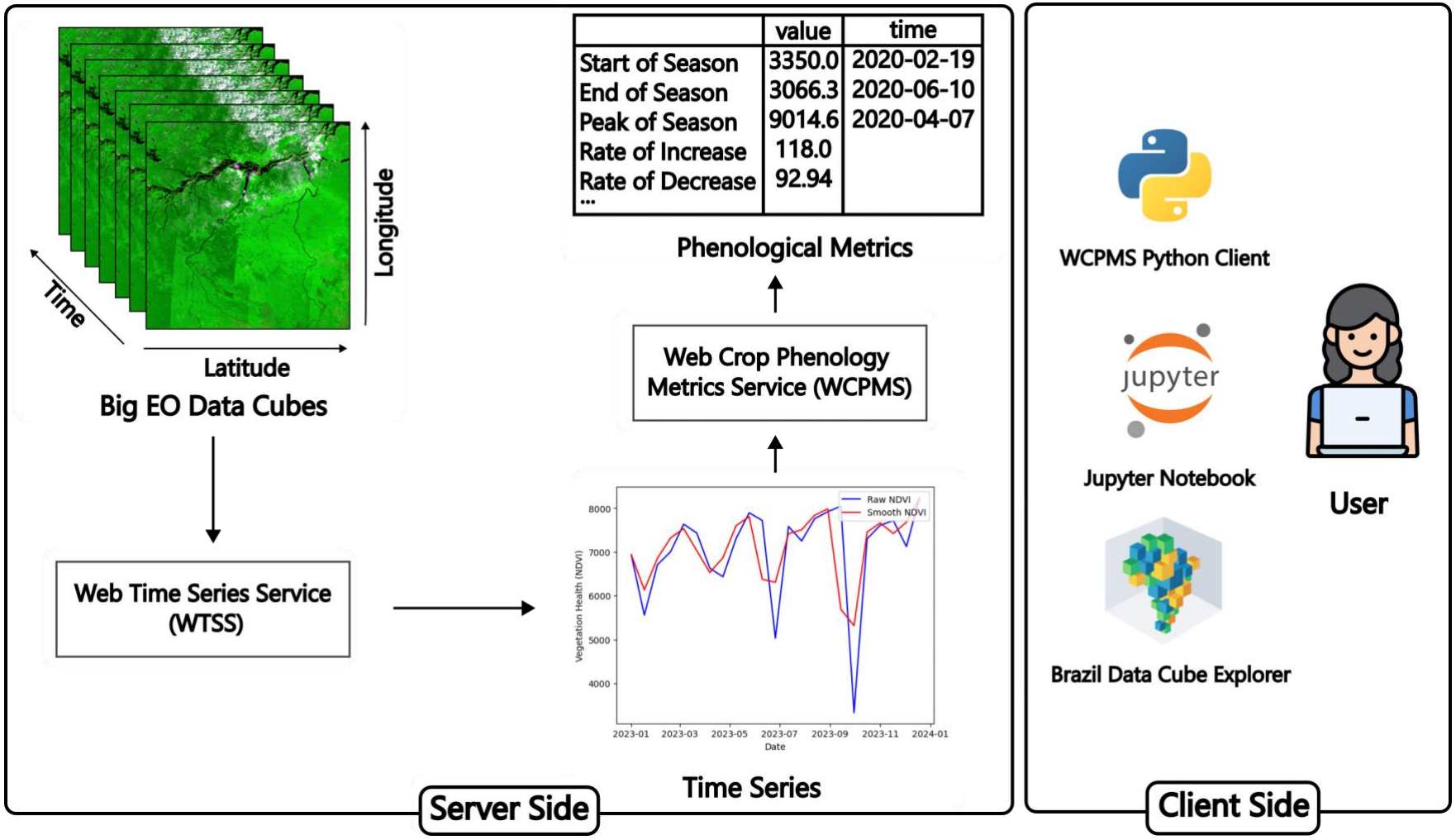


(c)

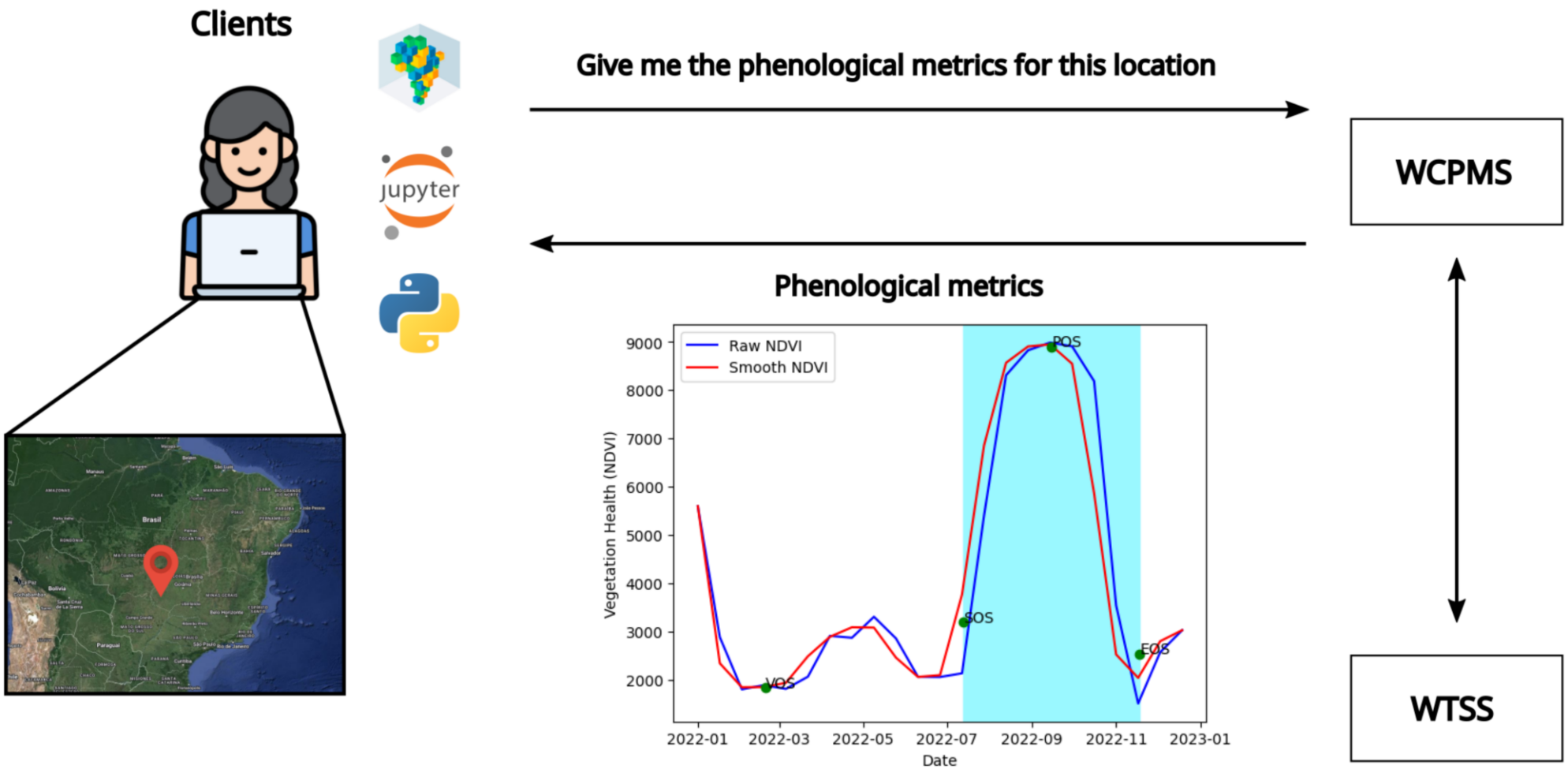


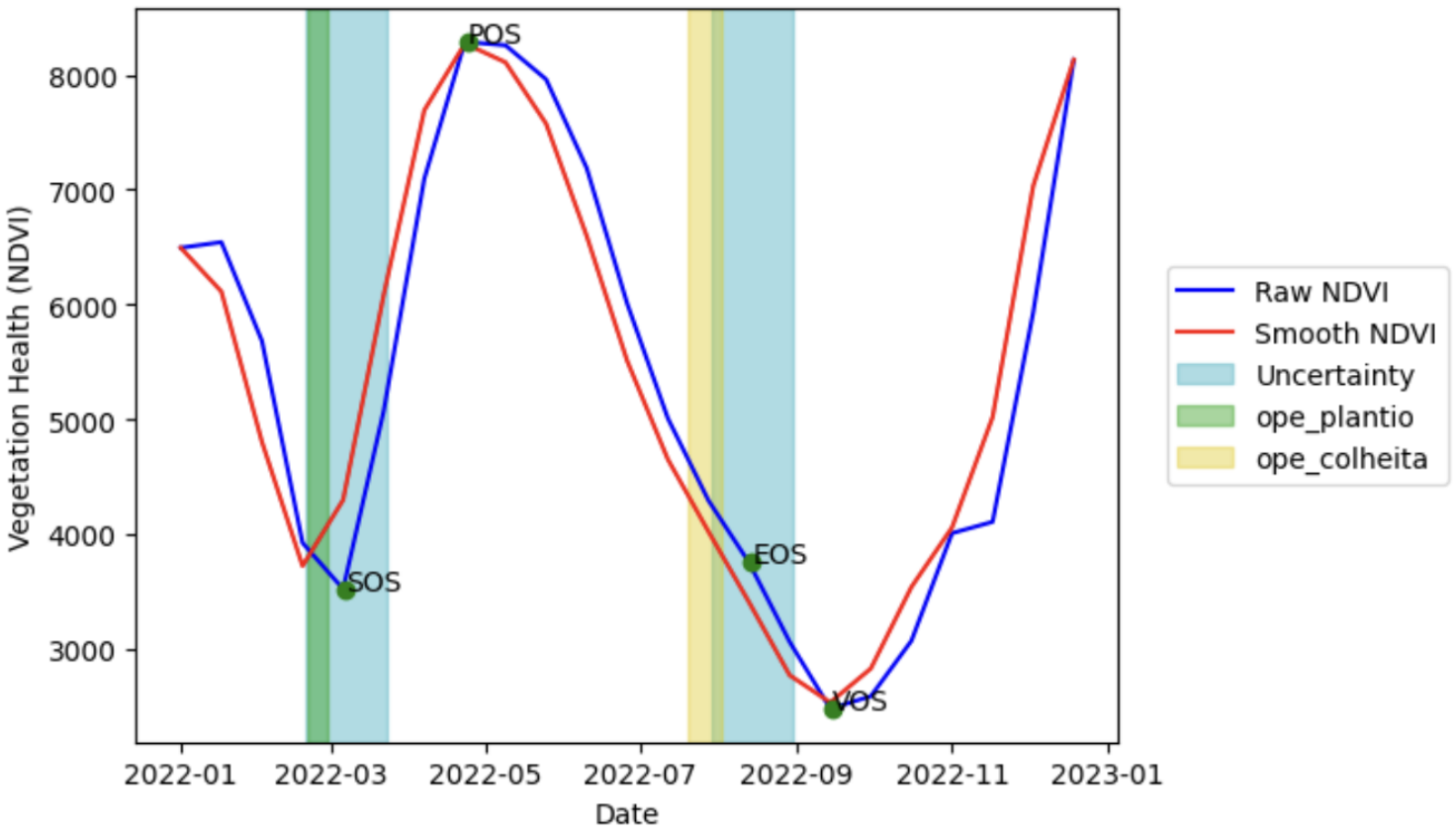
Métricas fenológicas de *início*, *fim* e *máximo* vigor vegetativo de plantio extraídas para soja (a), milho de primeira safra (b) e algodão (c) utilizando series temporais NDVI dos cubos Sentinel-2 (16 dias) do BDC.

Web Crop Phenology Metrics Service (WCPMS)



Web Crop Phenology Metrics Service (WCPMS)



Web Crop Phenology Metrics Service (WCPMS)

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