BRAZIL DATA CUBE
brazildatacube.org

Big data, satellite image data cubes and time series analysis

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MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

MINISTÉRIO DA
CIÊNCIA, TECNOLOGIA
E INOVAÇÕES

National Institute for Space Research (INPE), Brazil

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

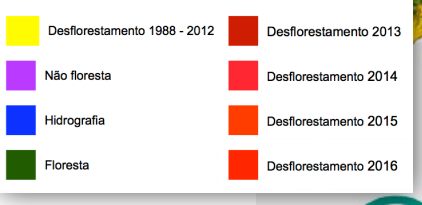
National Institute for Space Research (INPE), Brazil

Identify what the deforested areas detected have become.

PRODES

Deforestation monitoring

SINCE 1988

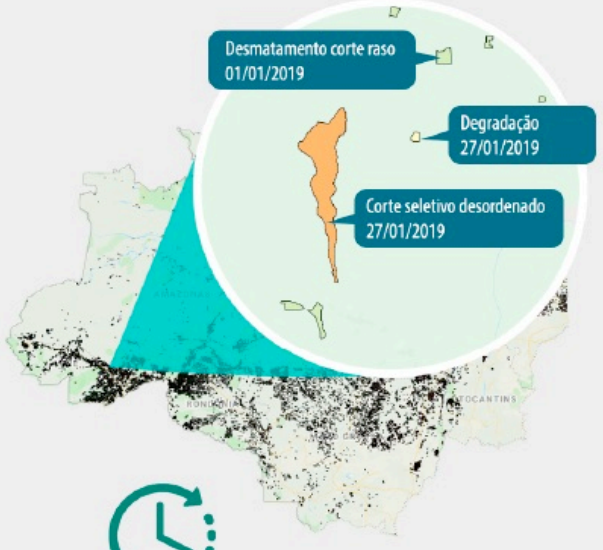


Annual maps

DETER

Near real time deforestation alerts

SINCE 2004

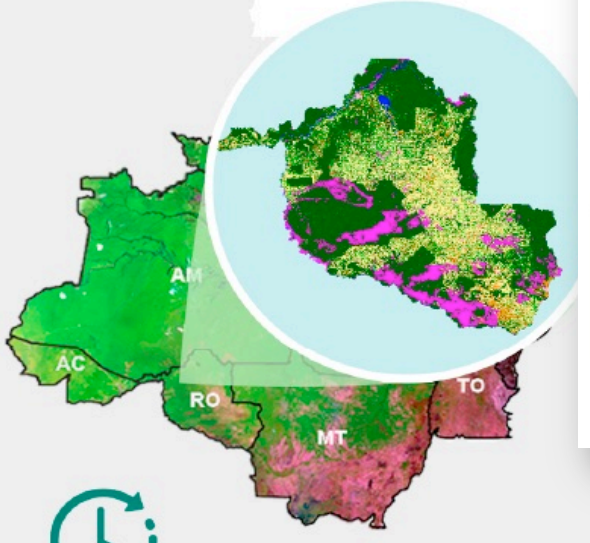


Daily alerts

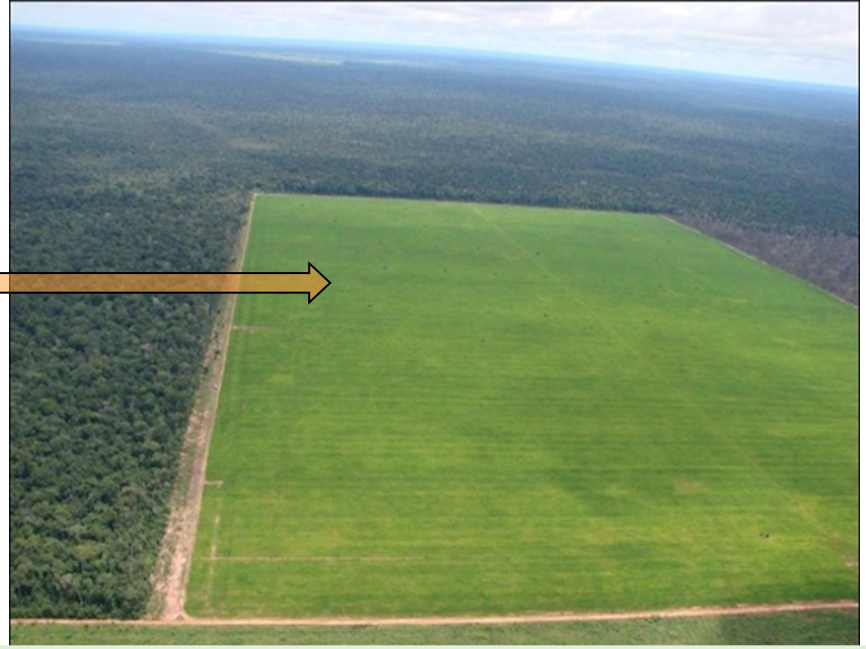
TERRACLASS

Land use monitoring in deforested areas

SINCE 2004



Biannual maps



Landsat (30 meters)

Clear-cut deforestation by PRODES

Landsat (30 meters)

Créditos: Luis Eduardo Maurano (INPE)

National Institute for Space Research (INPE), Brazil

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

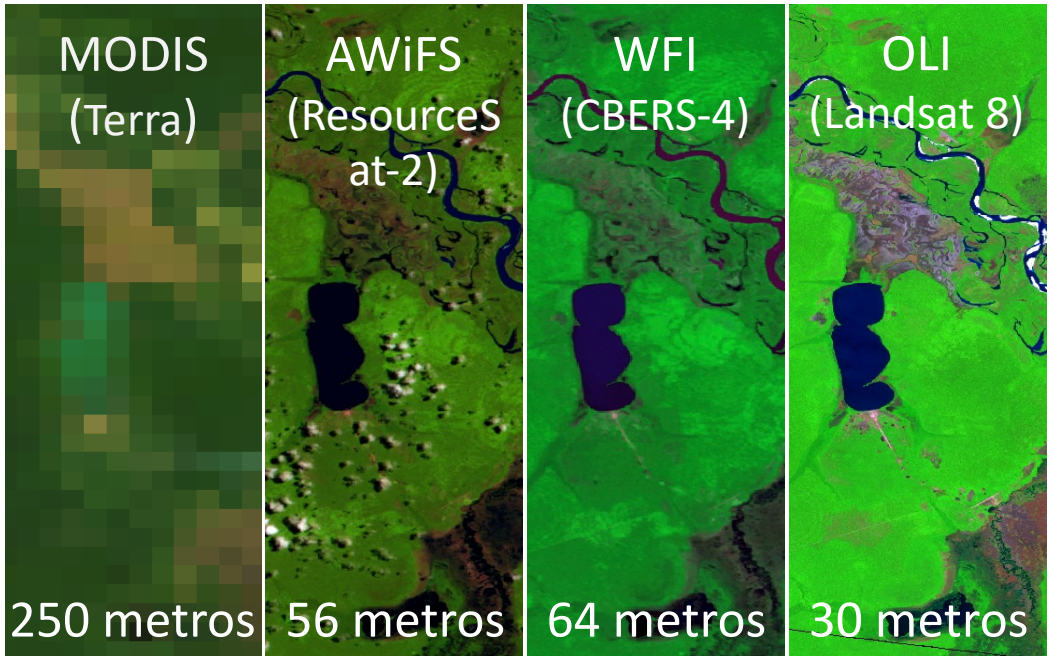
Develop innovative software systems for geospatial information management.

Open Data

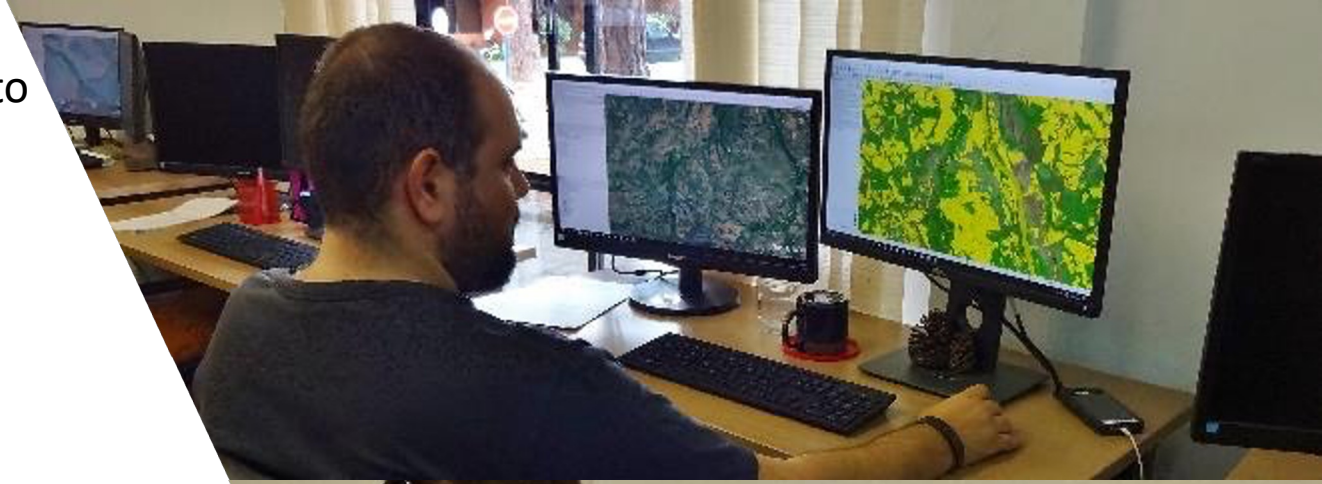
open source

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

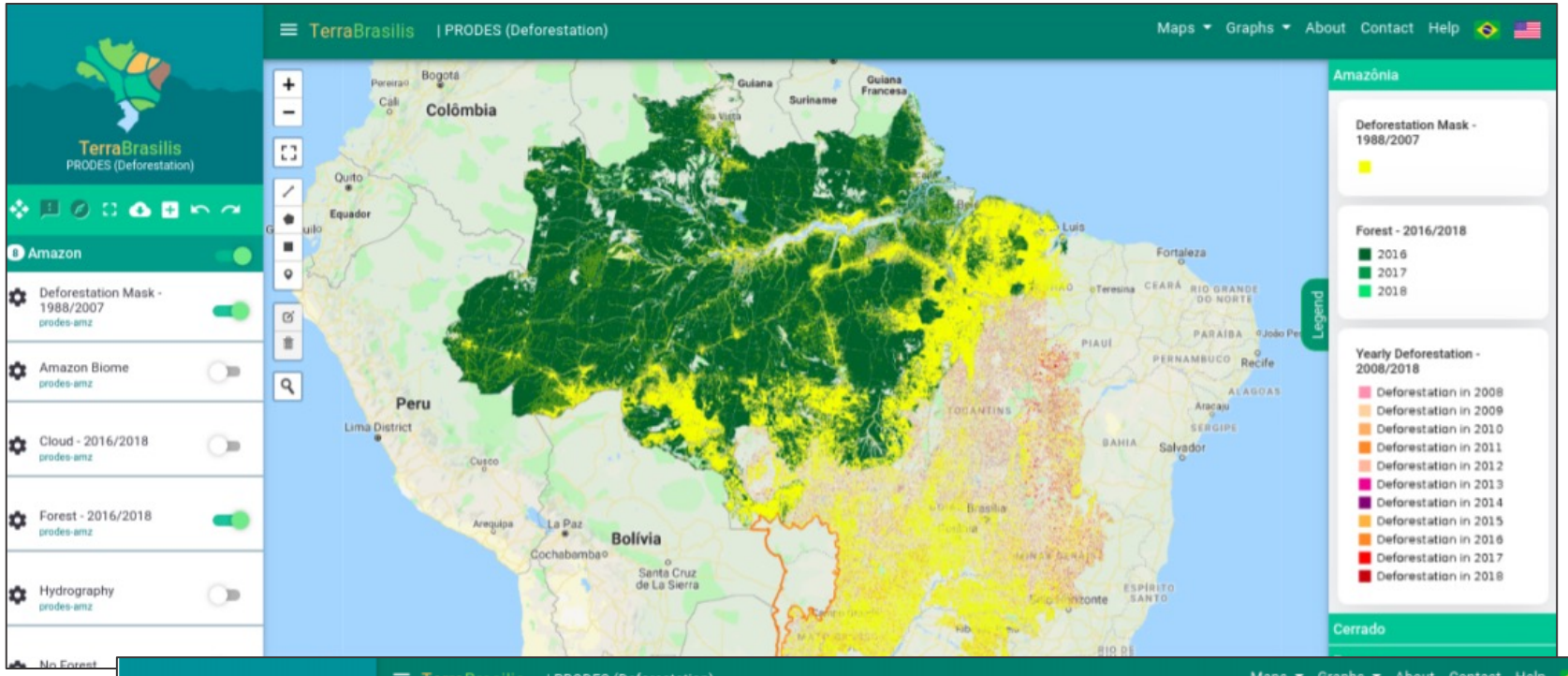
Web portal to disseminate the deforestation data sets produced by PRODES and DETER.

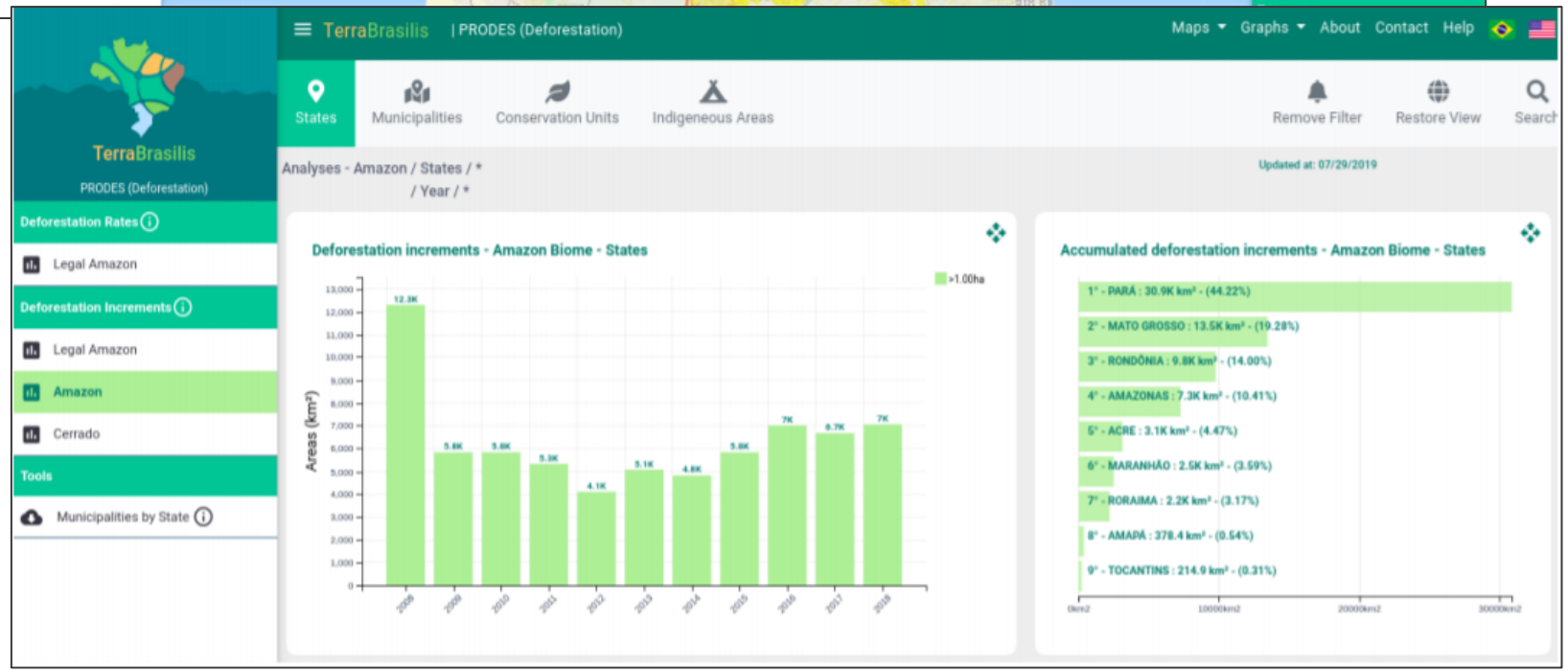
Open data.

Map visualization and dashboards.

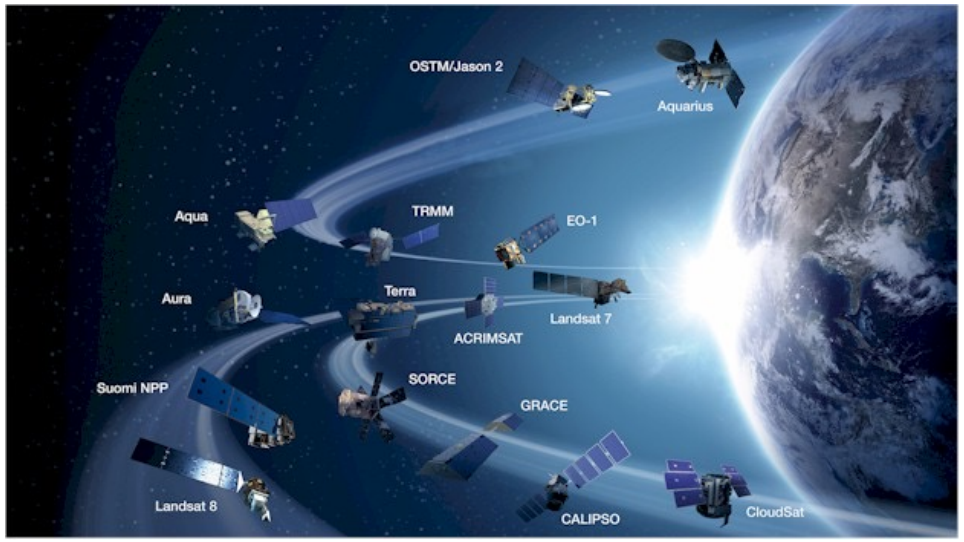
Spatial analysis tools.

INDE
Infraestrutura Nacional de Dados Espaciais

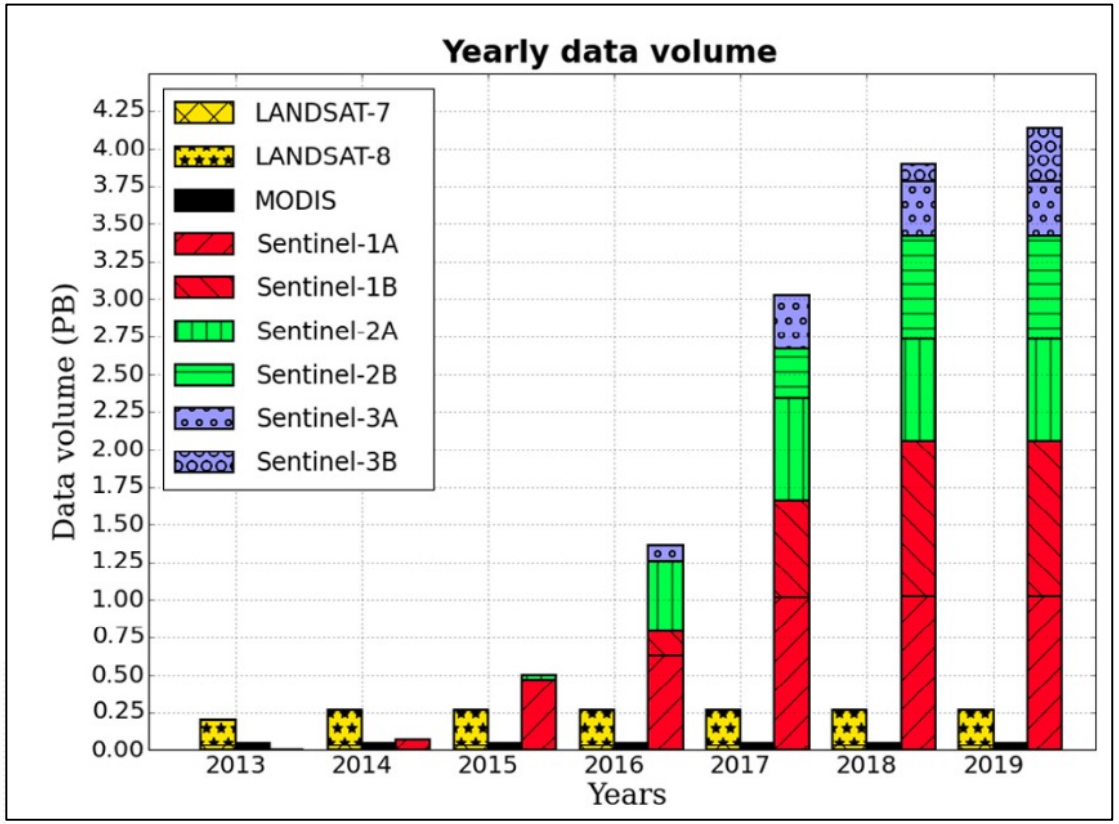




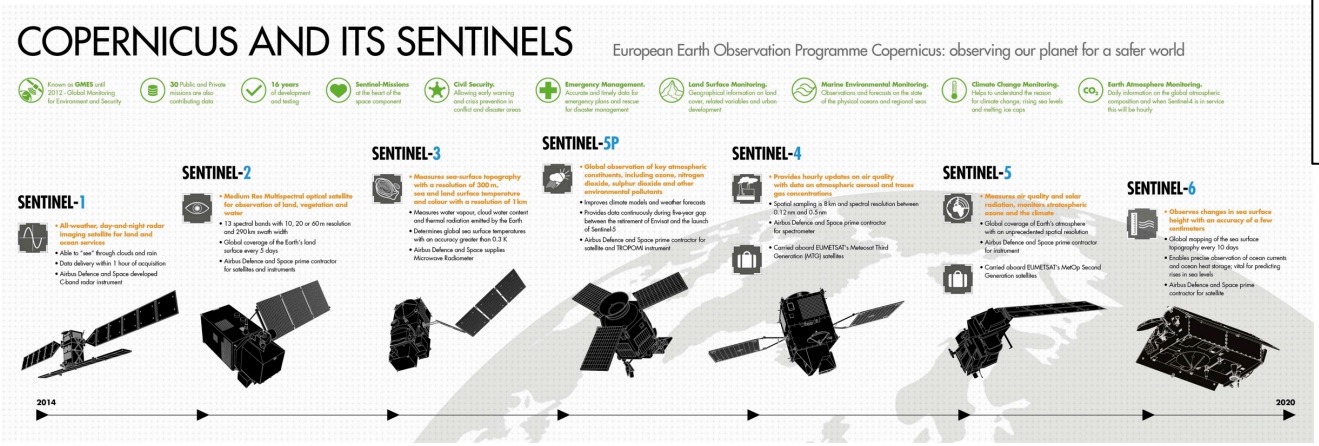
Challenge: Big data sets of EO satellite images



Source: eospso.nasa.gov



Source: (Soille et al., 2018)



Source: www.copernicus.eu

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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**.

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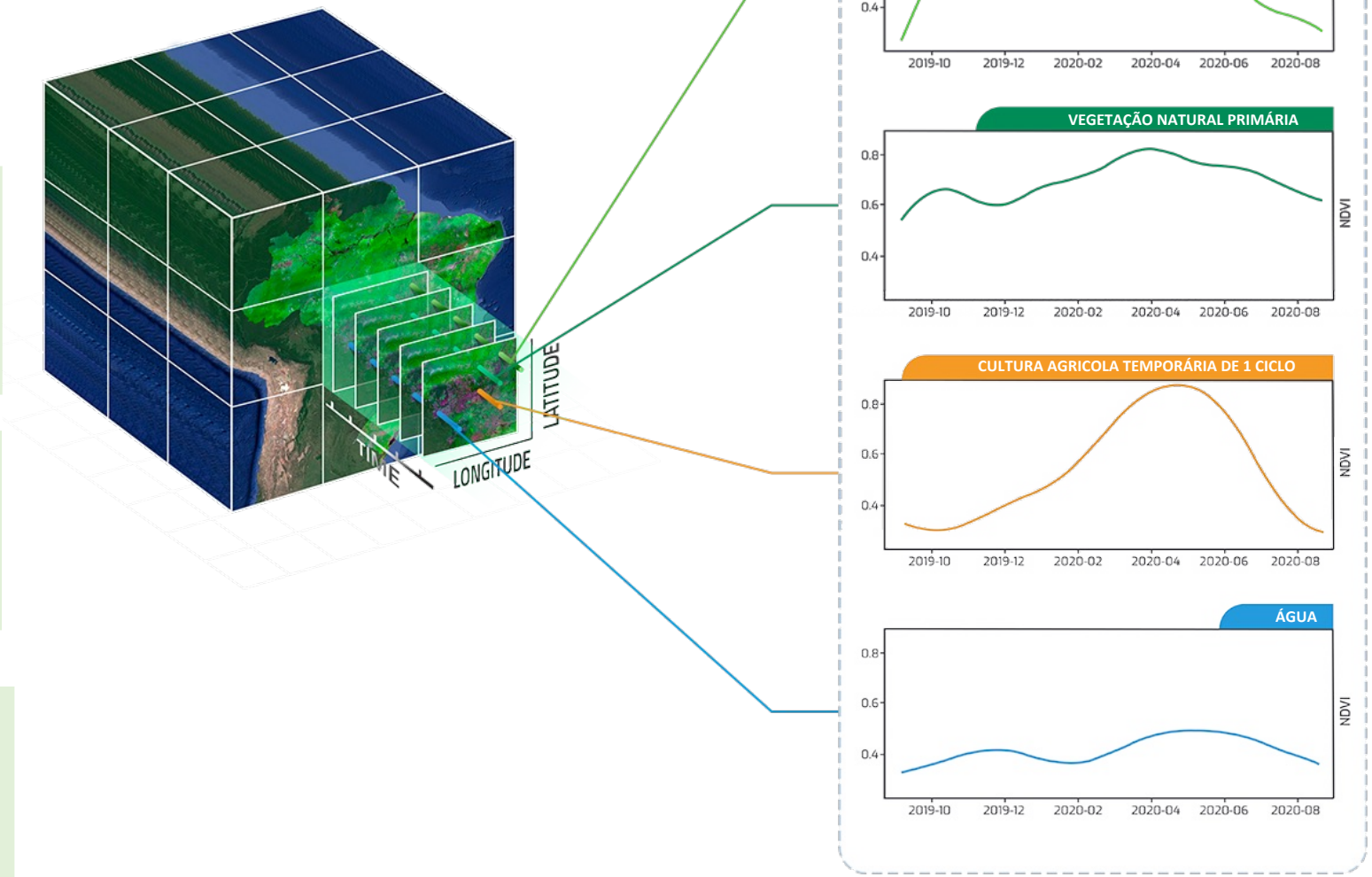
Big data of remote sensing images modeled as multidimensional data cubes

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

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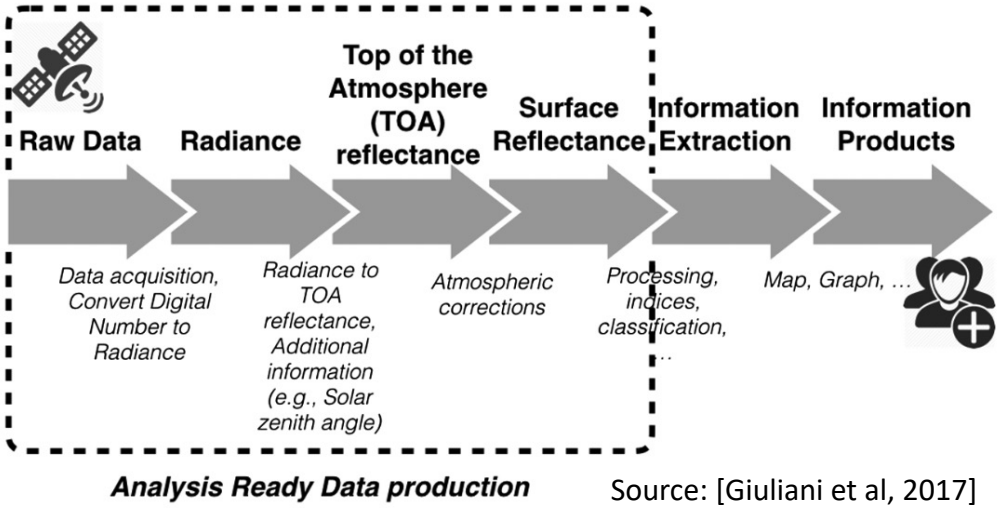
2 Petabytes (PB) remote sensing images

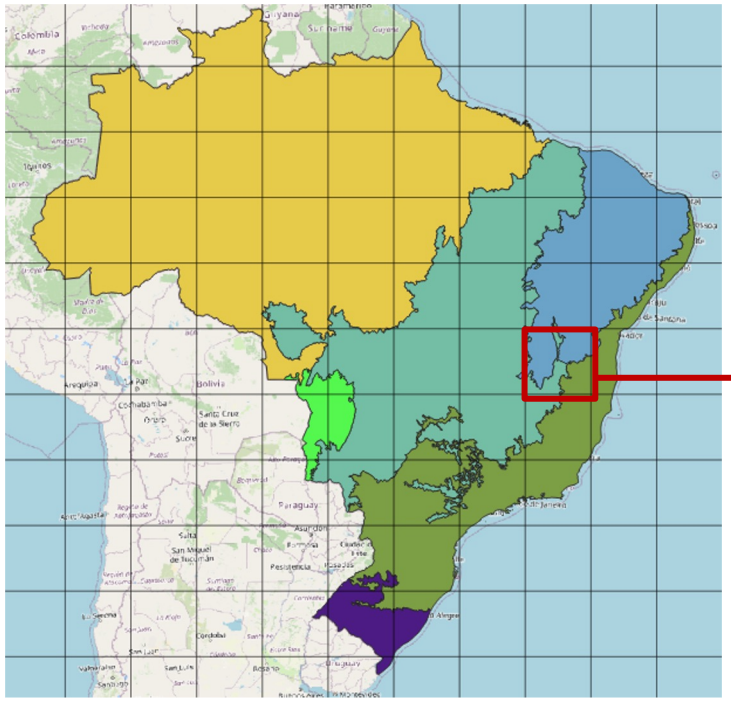


Analysis Ready Data production

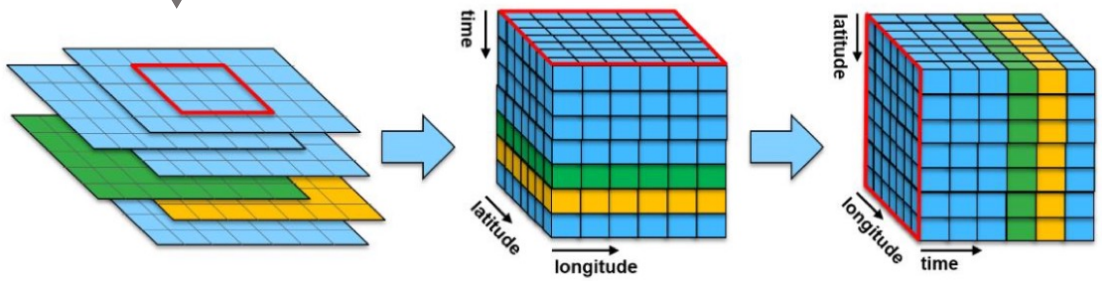
Source: [Giuliani et al, 2017]

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]

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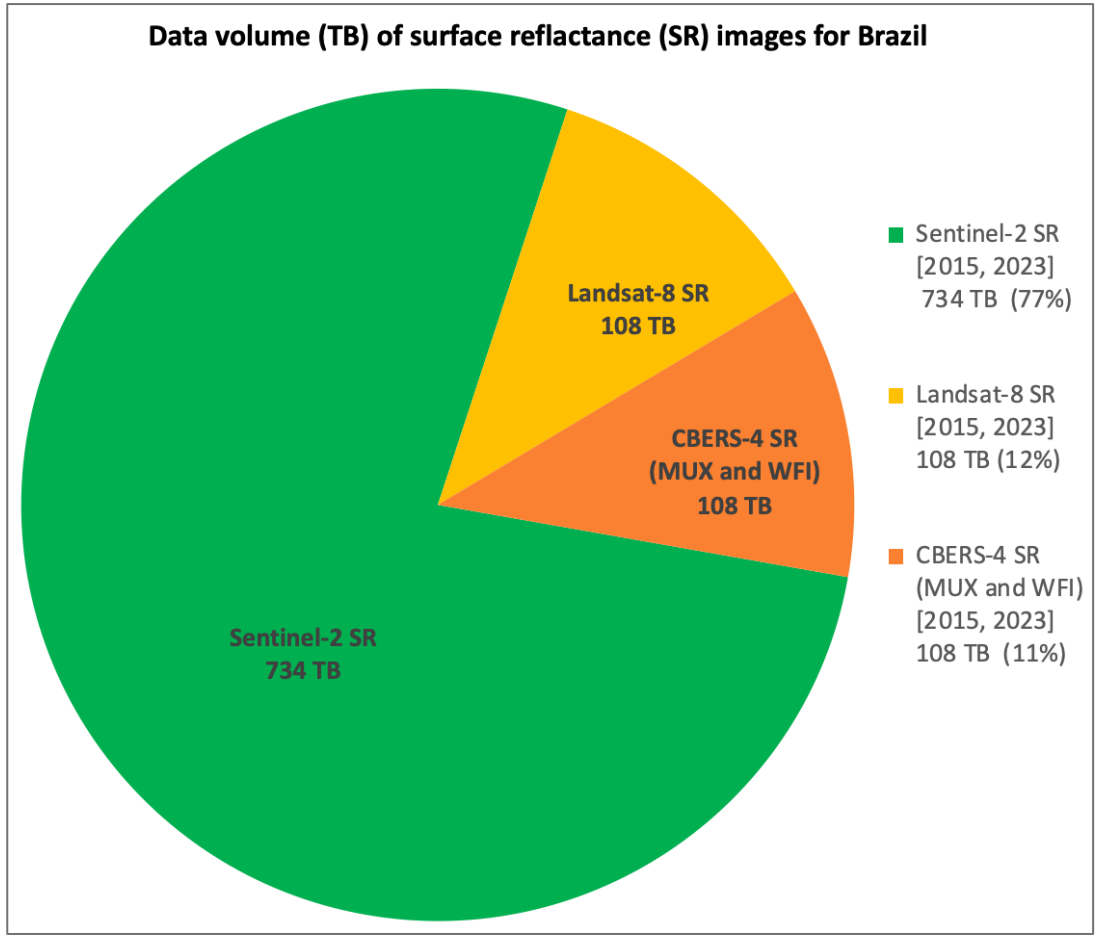
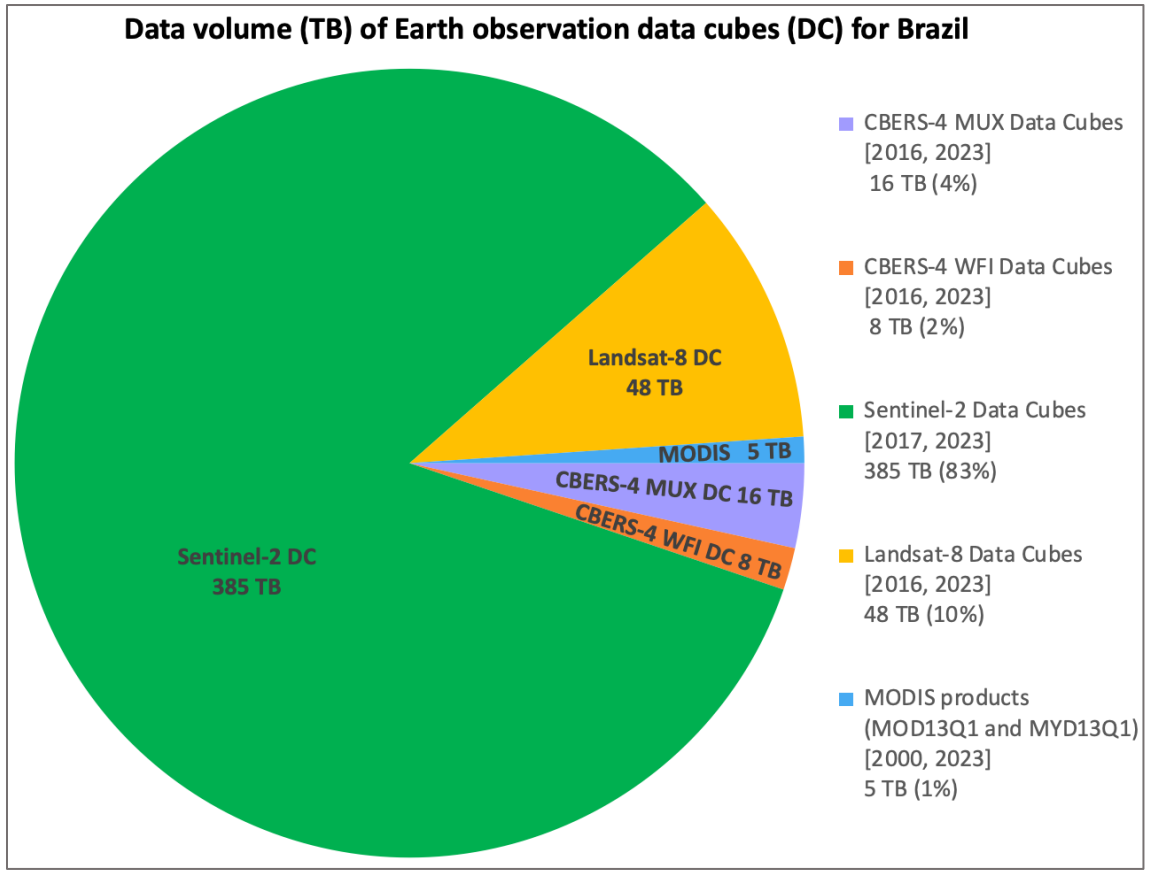
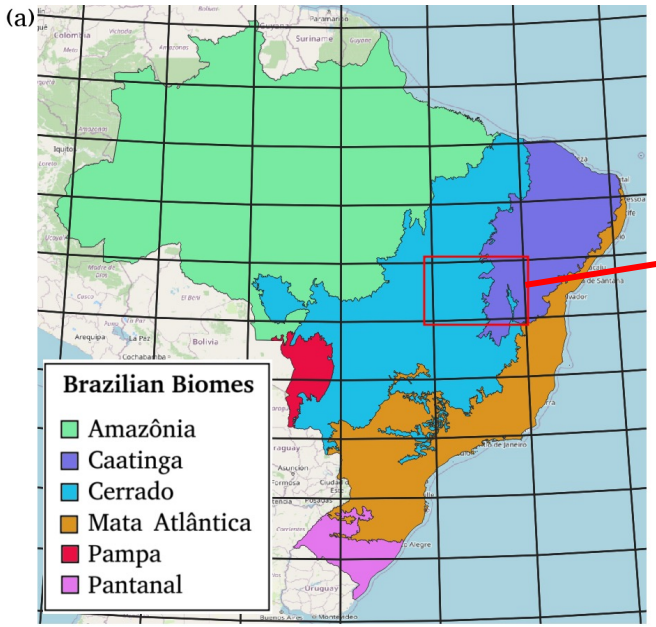
Big data

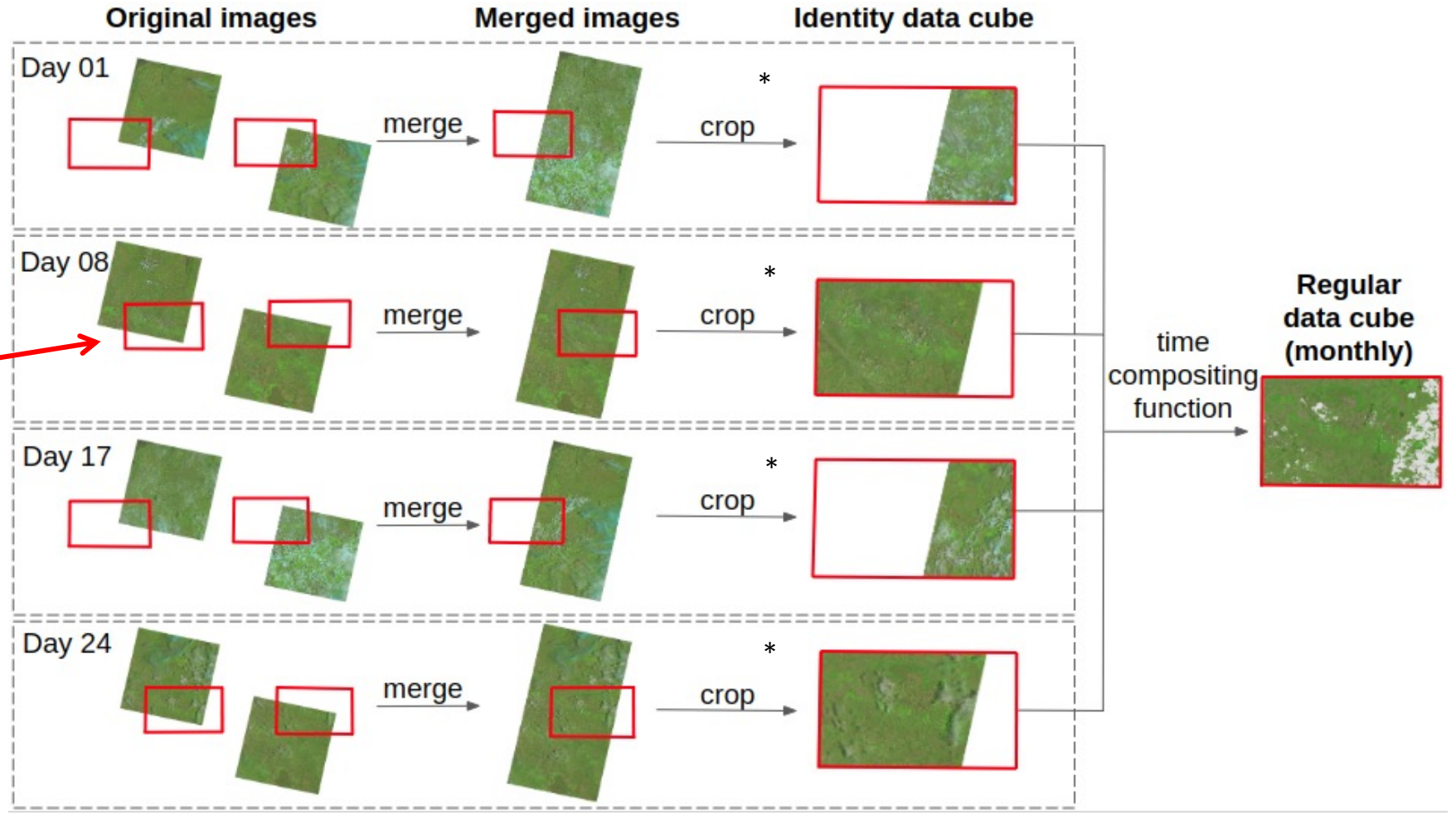




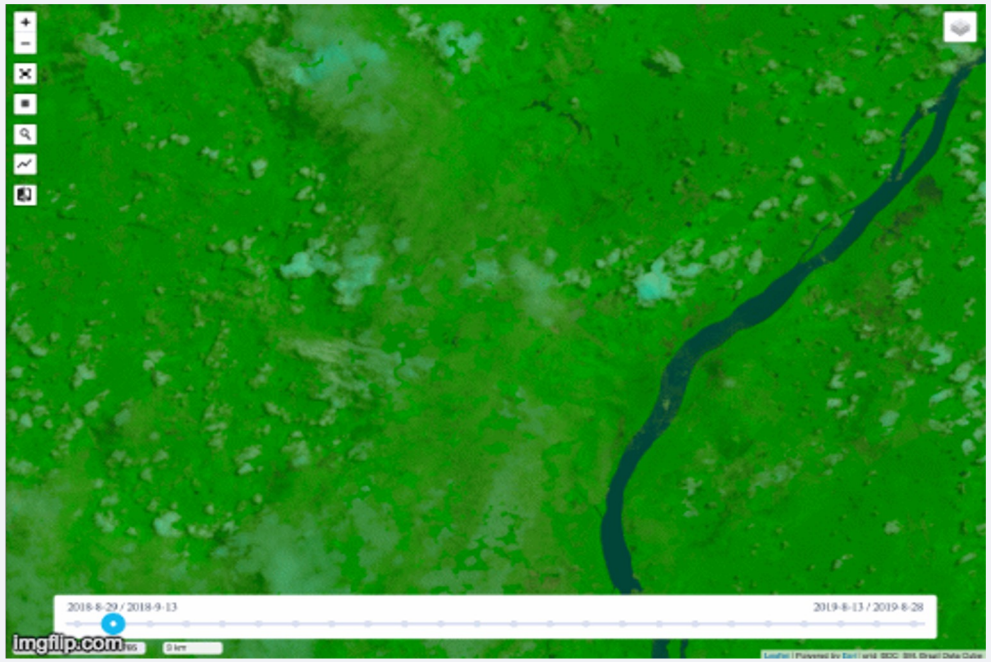
Source: [Ferreira et al., 2022]

Building data cubes

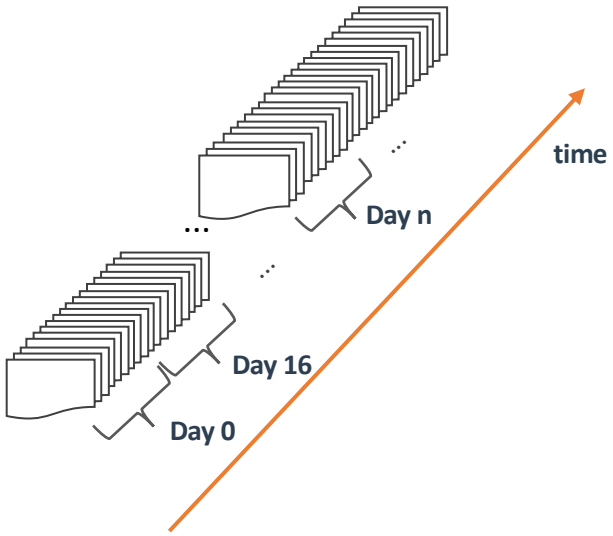




*bilinear resampling for better spatial resolution band



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; ...

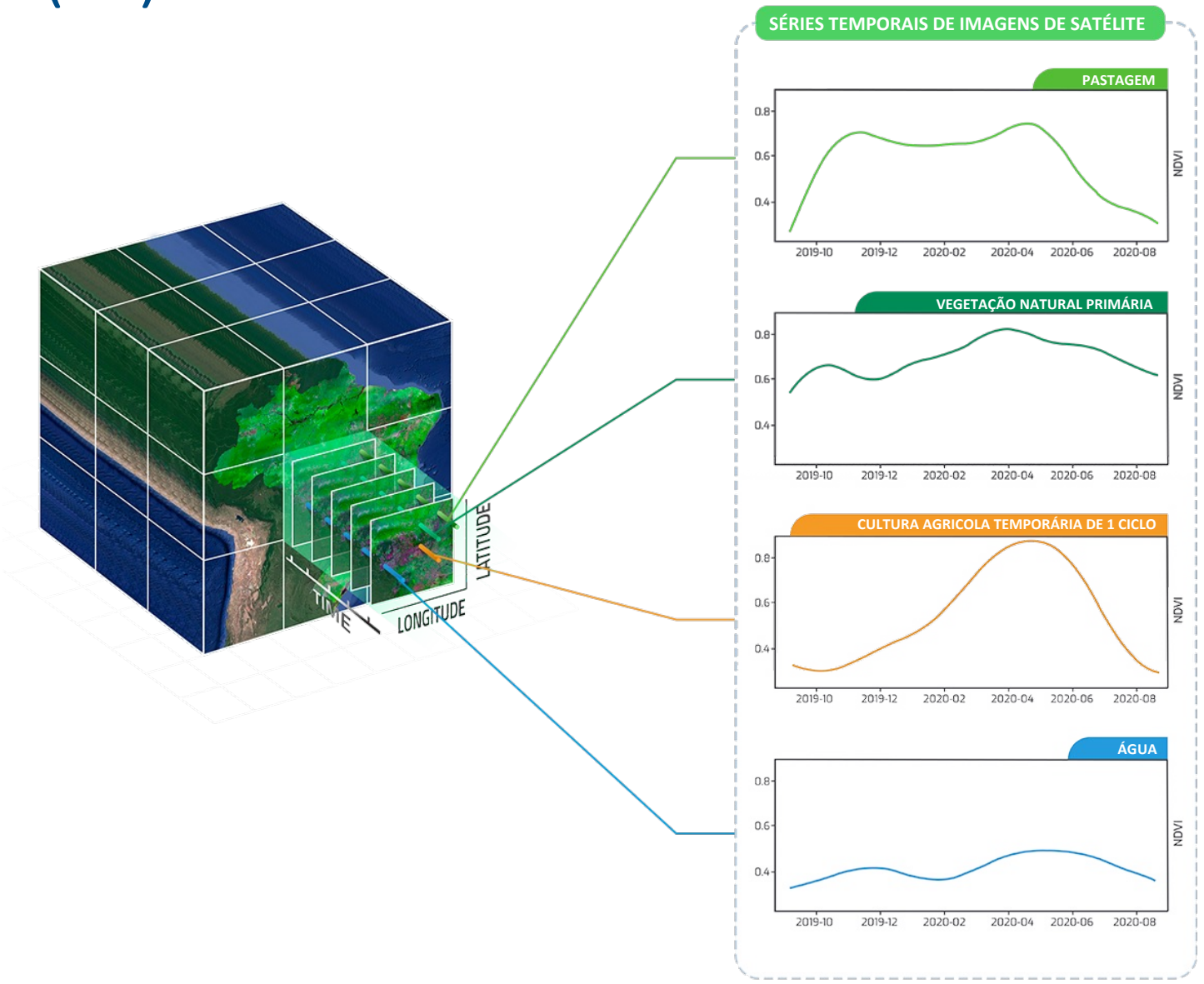
BDC – Small
Each tile: 105600m x 105600m

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

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

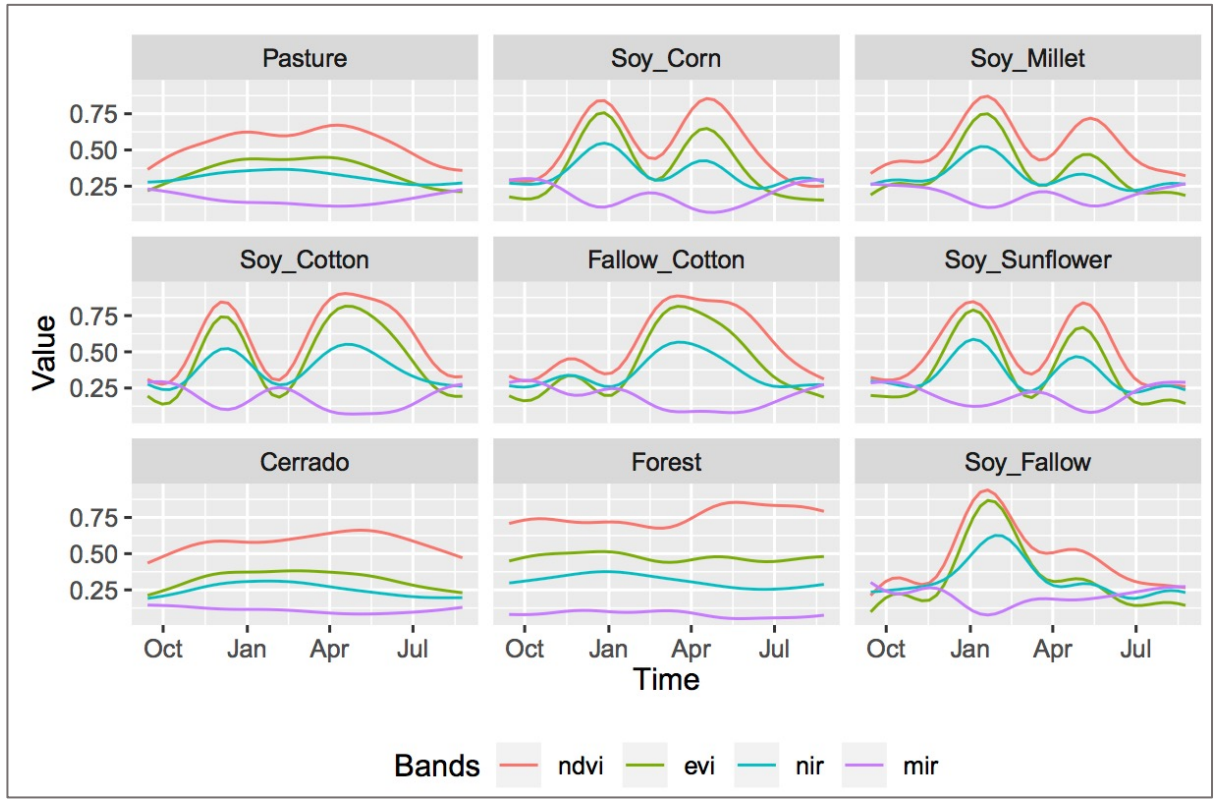
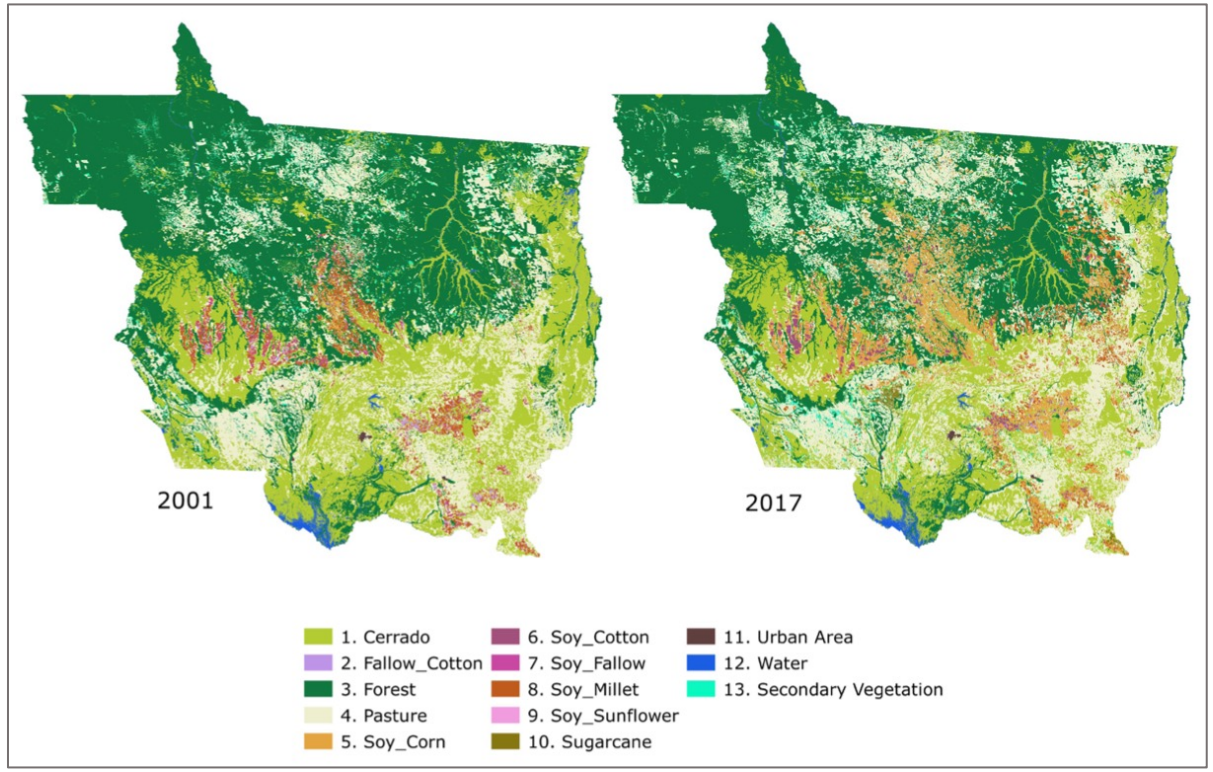


Image time series: NDVI, EVI, NIR, MIR (agriculture year)

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

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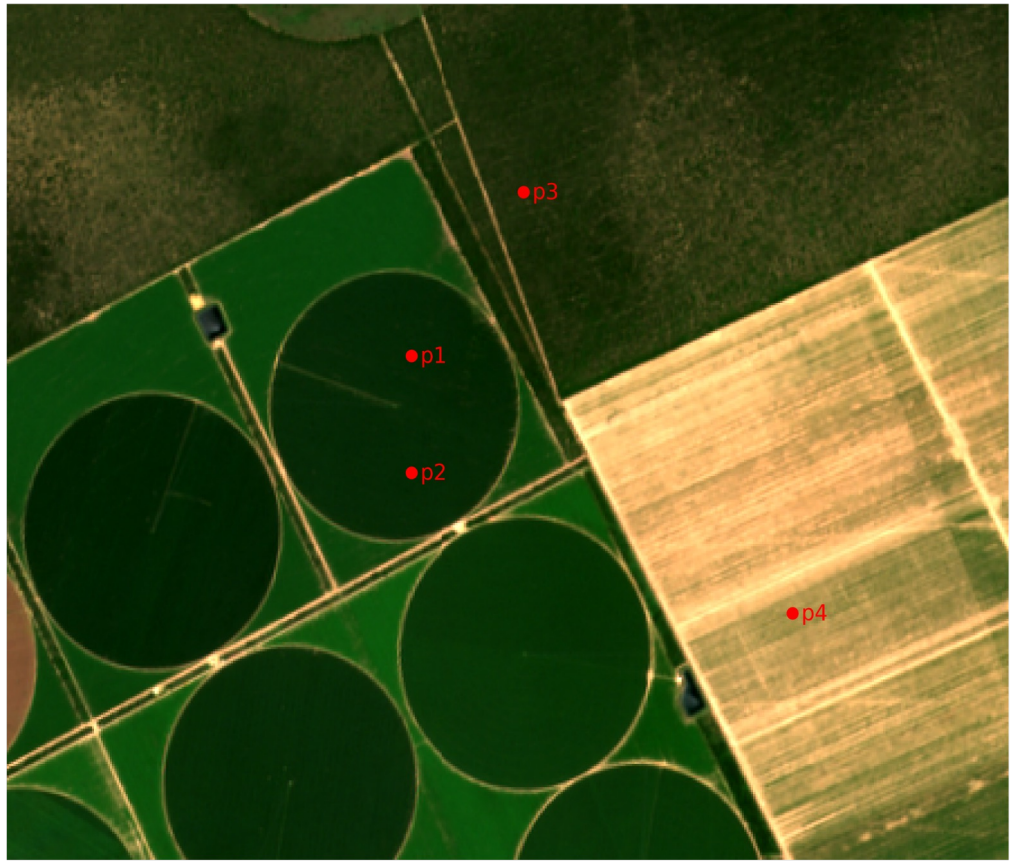
Satellite Image Time Series Analysis (SITS)

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

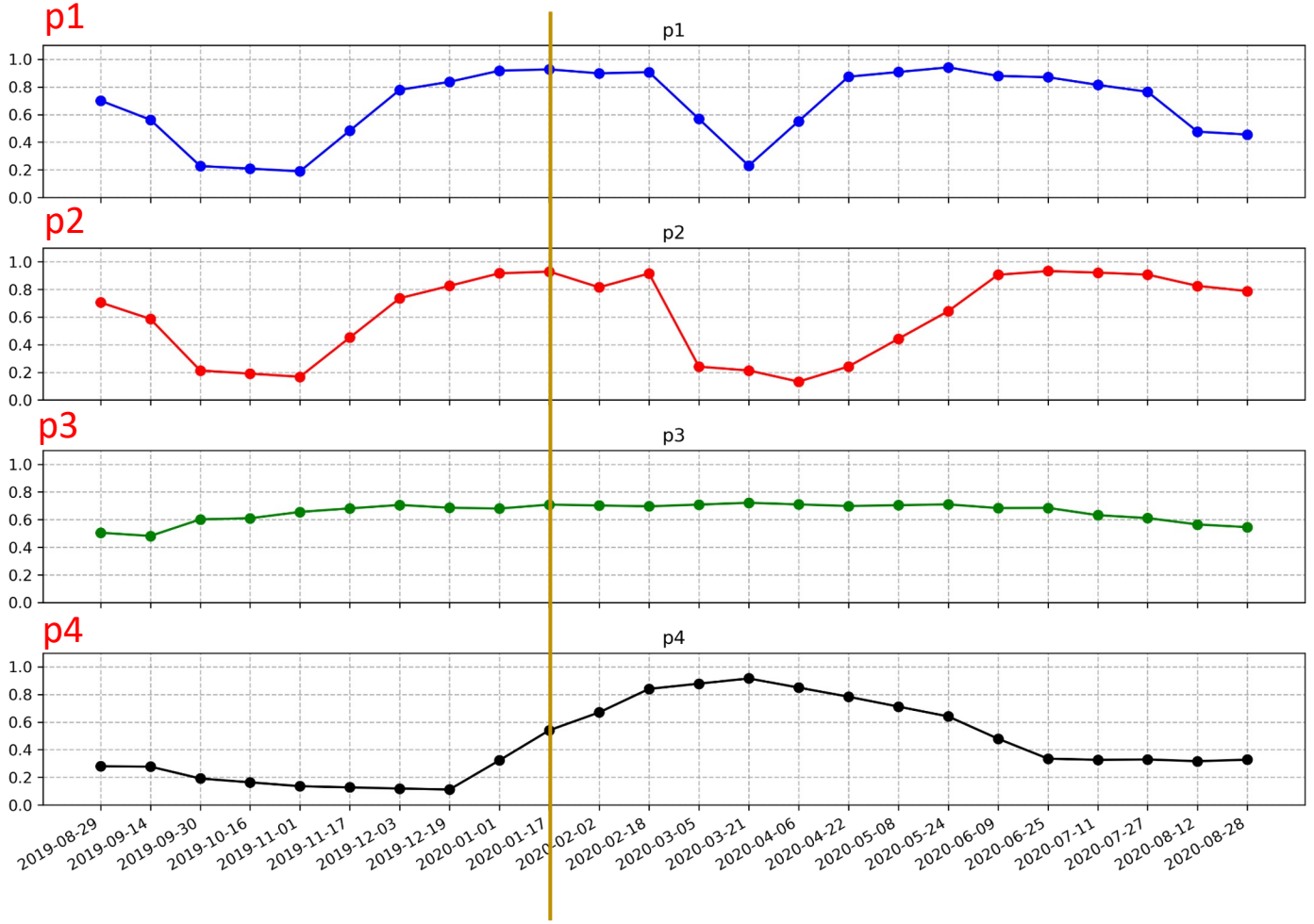
(Pasquarella et al., 2016)

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

Sentinel-2 RGB



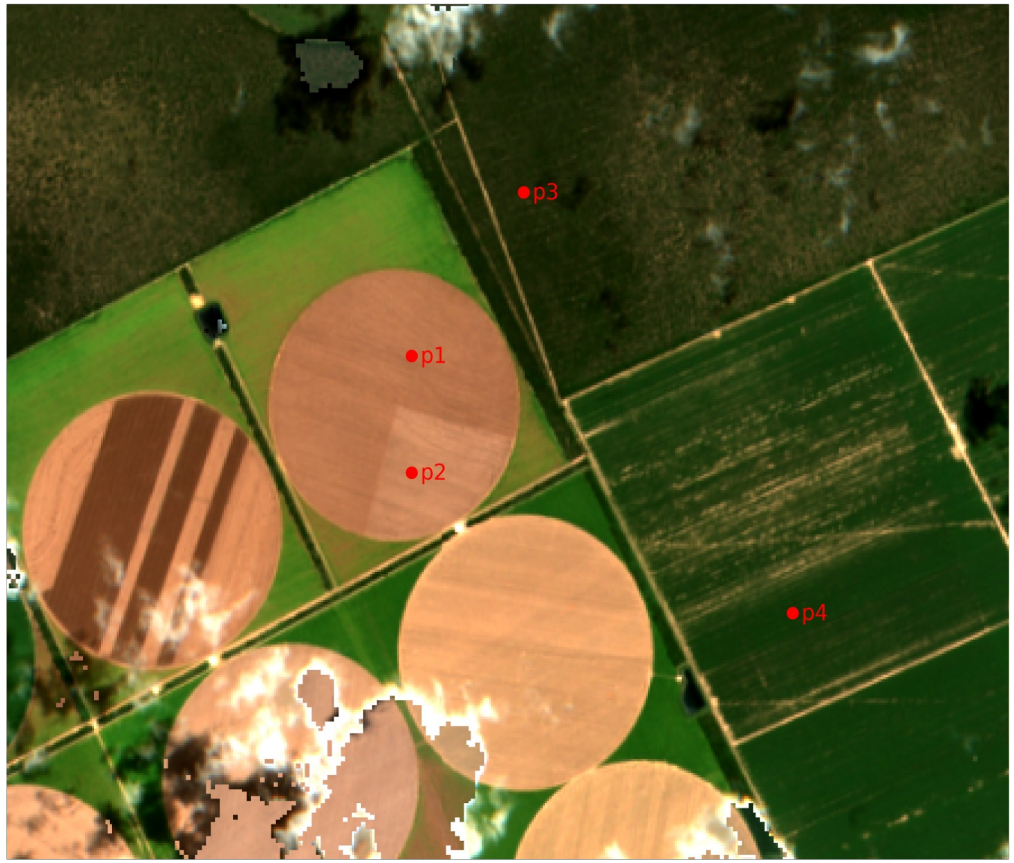
2020-01-17



2020-01-17

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

Sentinel-2 RGB



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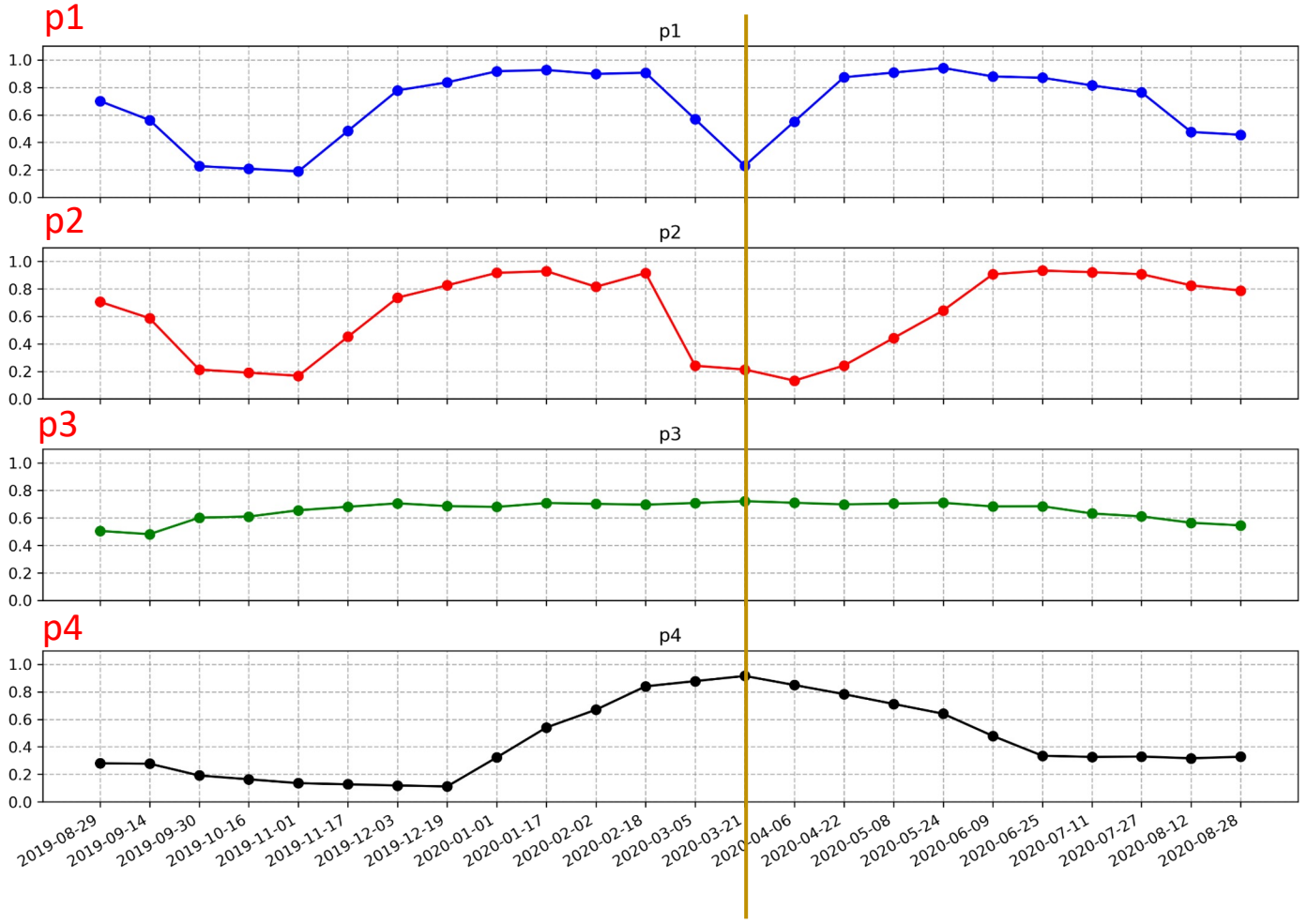

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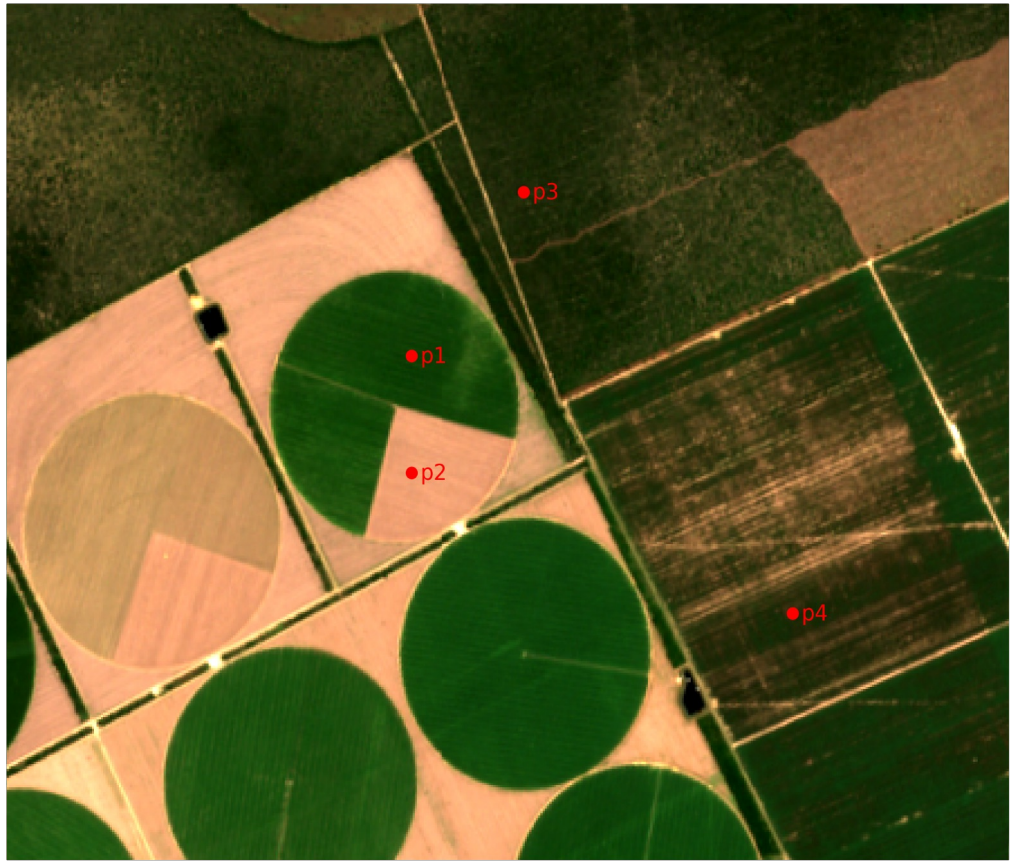
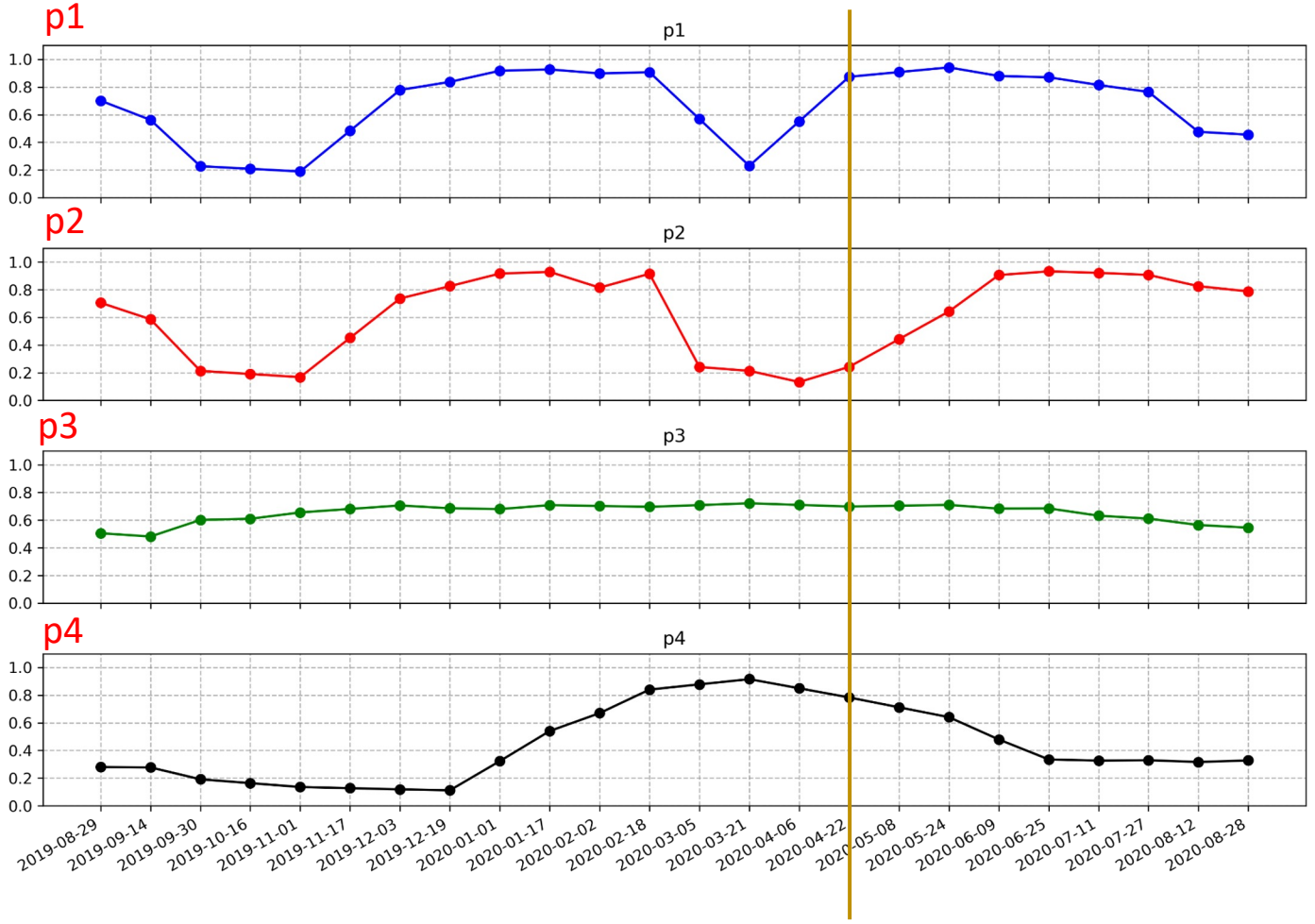
NDVI Time Series – Sentinel-2 Data Cube (16-days)

Sentinel-2 RGB



2020-04-22



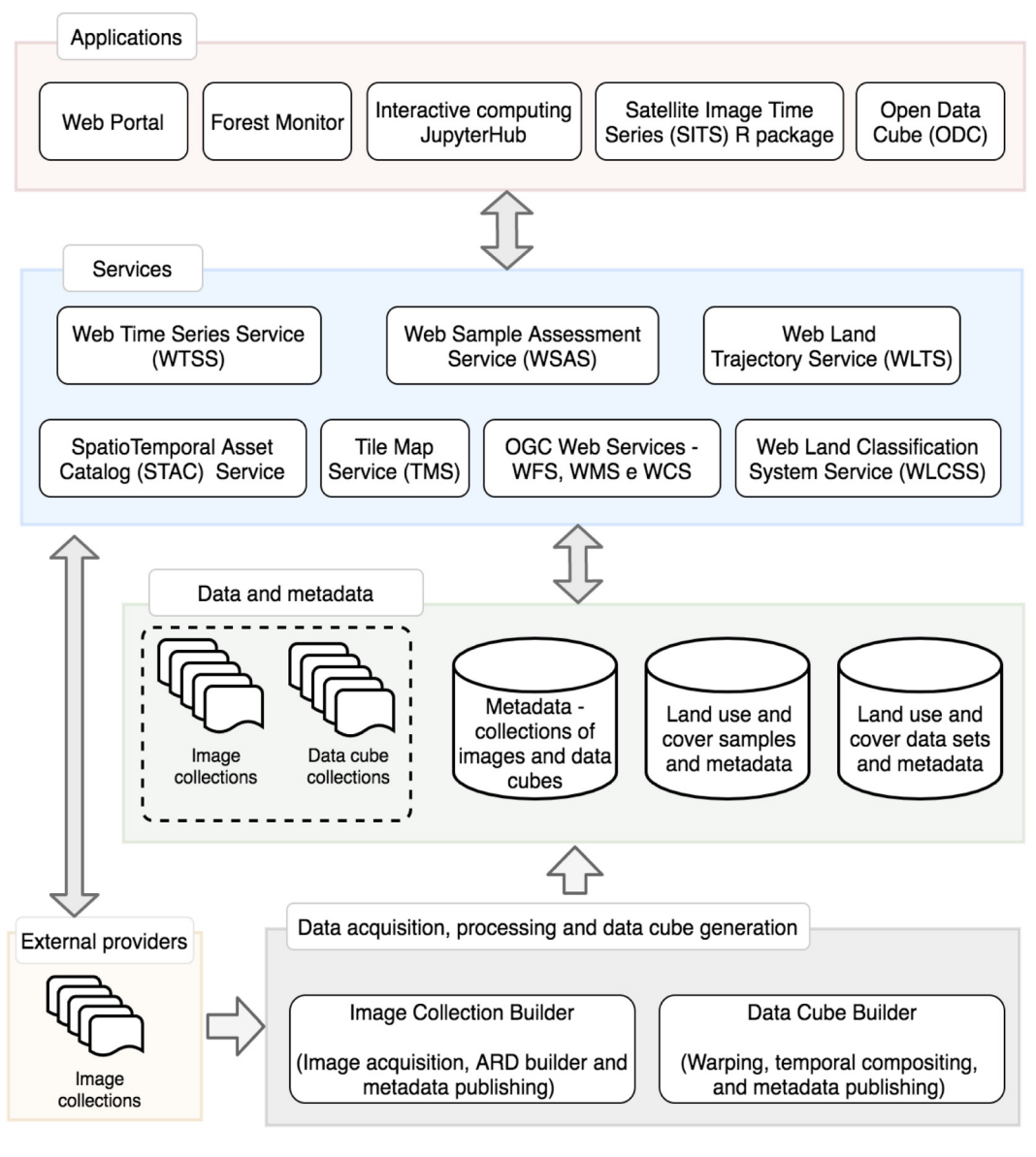
2020-04-22

Brazil Data Cube Platform

Open Data and Software Products

Software

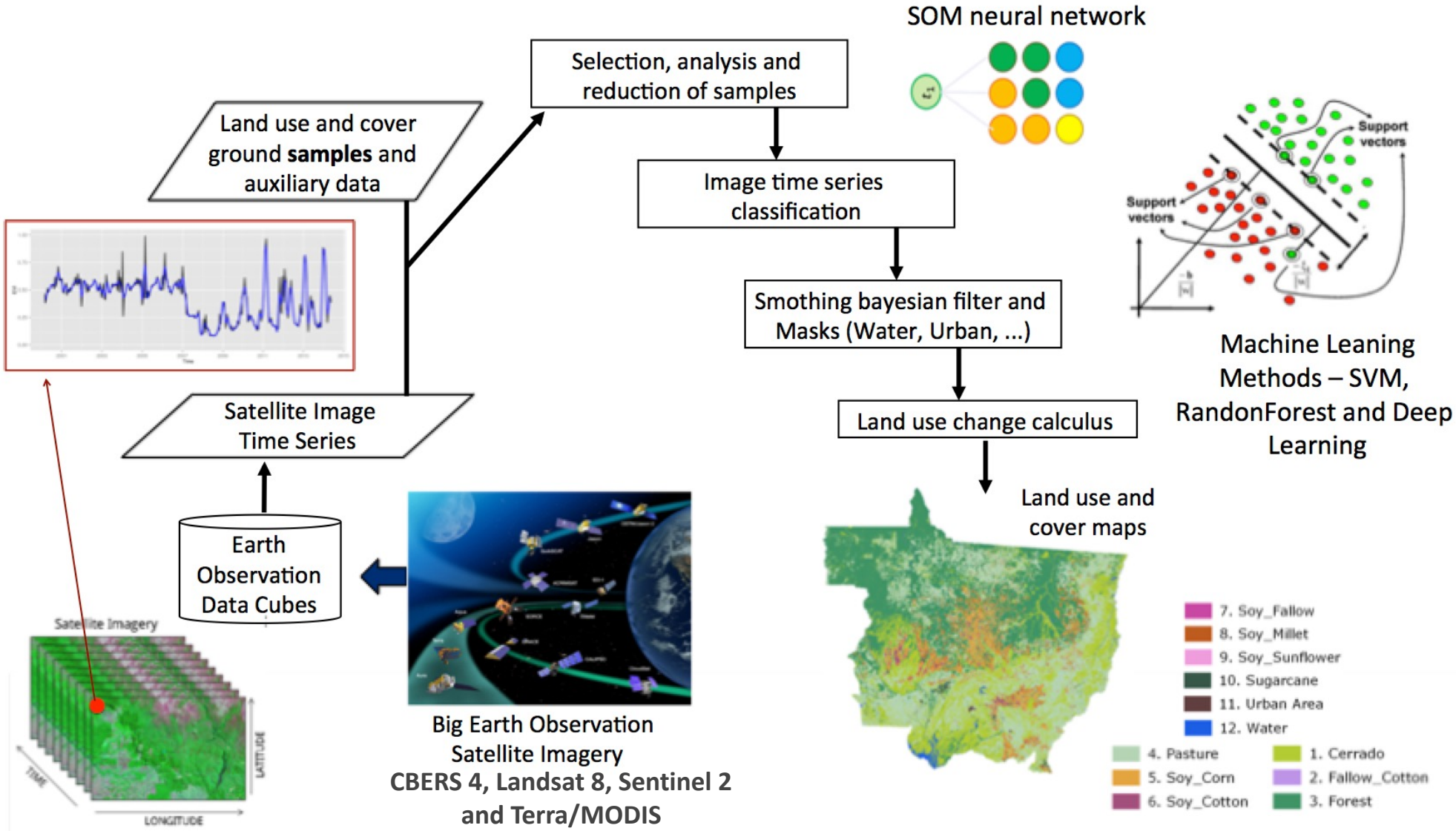
Data and metadata



Source: [Ferreira et al, 2020]

Source: [Ferreira et al., 2020]

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

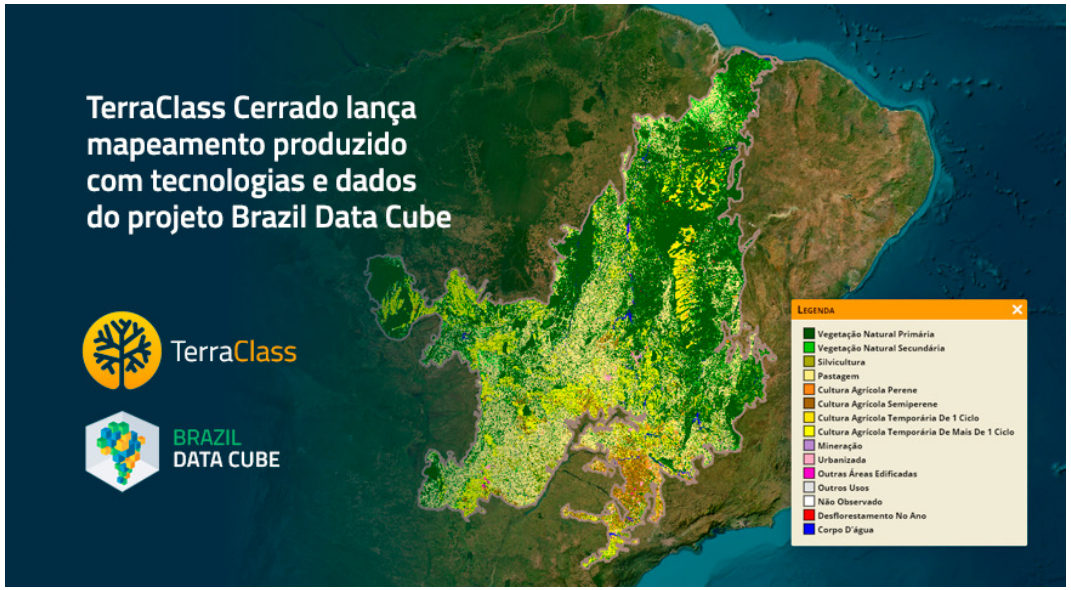


ARD and Data cubes available at:
http://brazildatacube.dpi.inpe.br/portal/explore

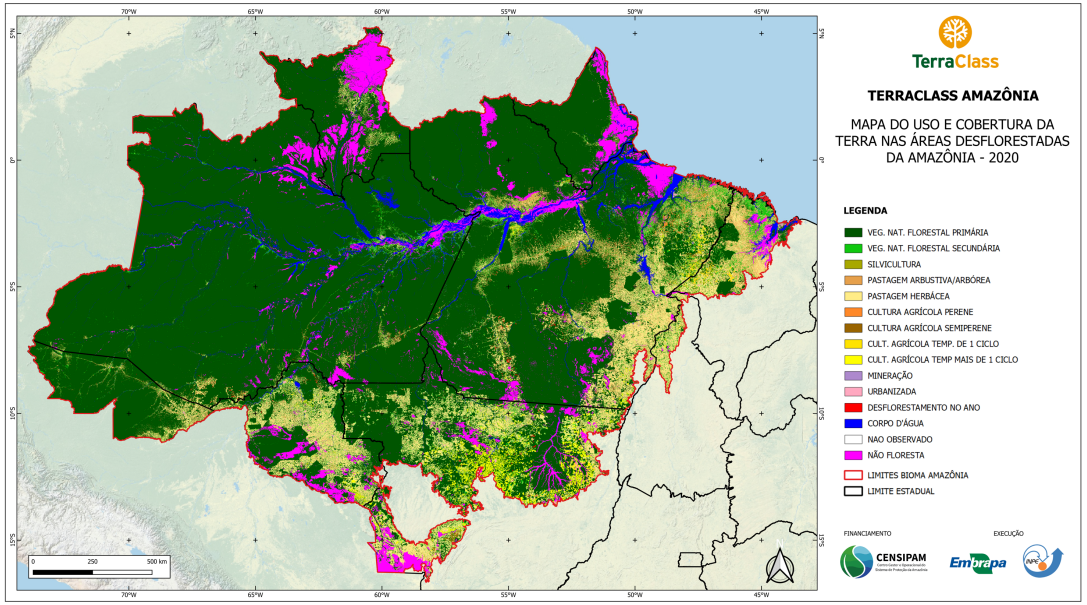
Land use and cover change maps:
http://brazildatacube.dpi.inpe.br/portal/explore

Land use and land cover maps: TerraClass project

TerraClass Cerrado 2020 (Launched in December 2022)



TerraClass Amazônia 2020



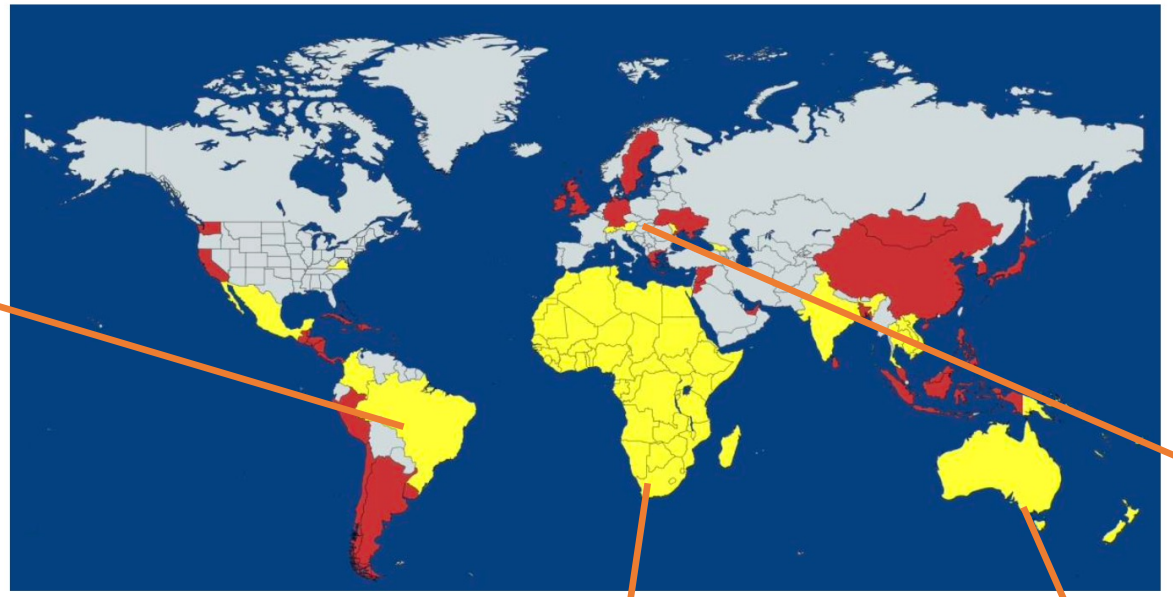
INPE UNIDADE DE PESQUISA DO MCTI

Embrapa

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

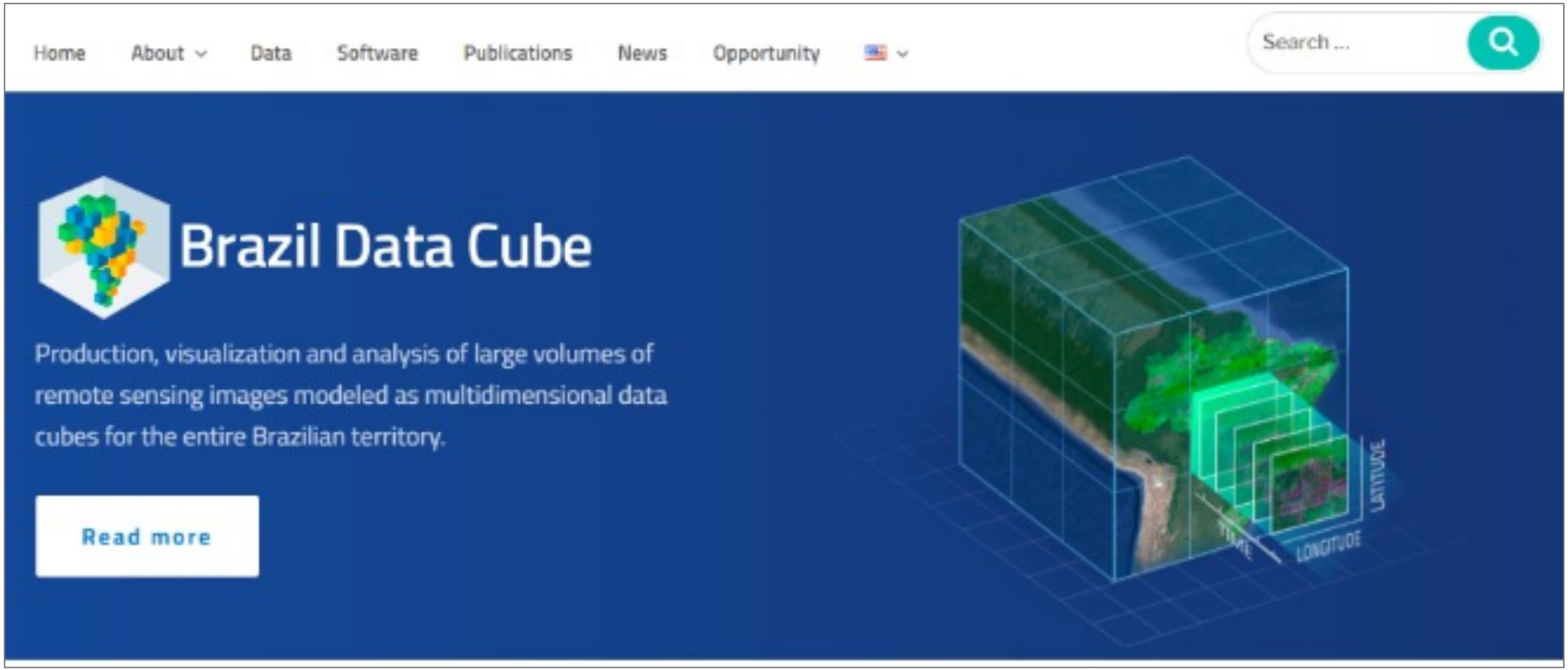
Digital Earth AFRICA

https://digitalearthafrica.org/

Digital Earth AUSTRALIA

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

http://brazildatacube.org



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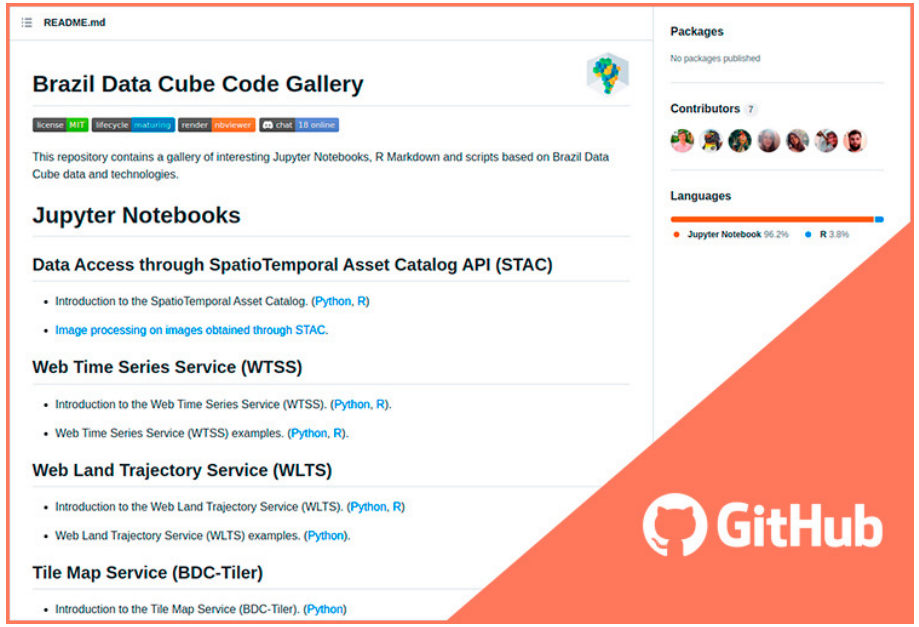
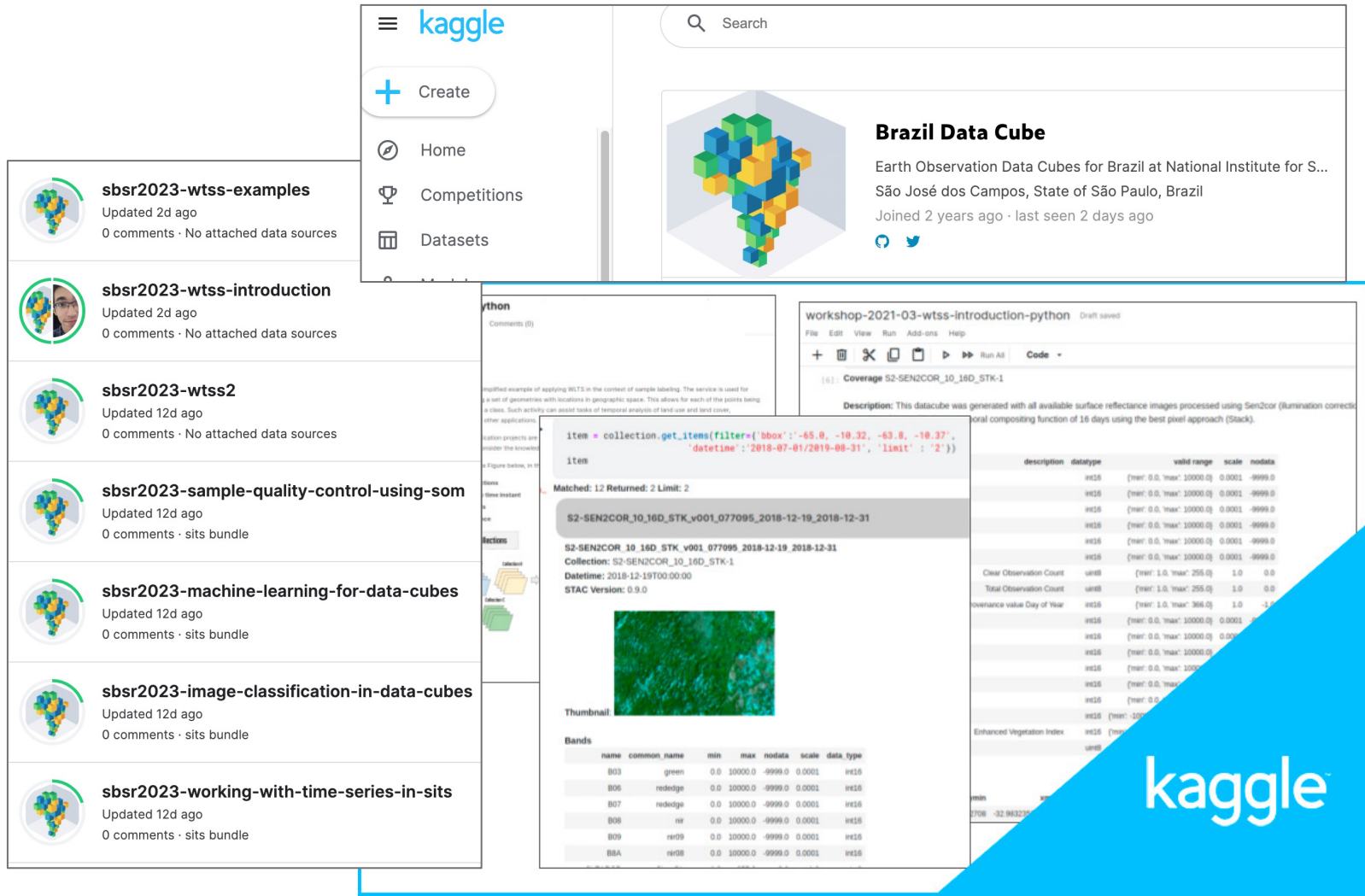
Code Galery

http://brazildatacube.org

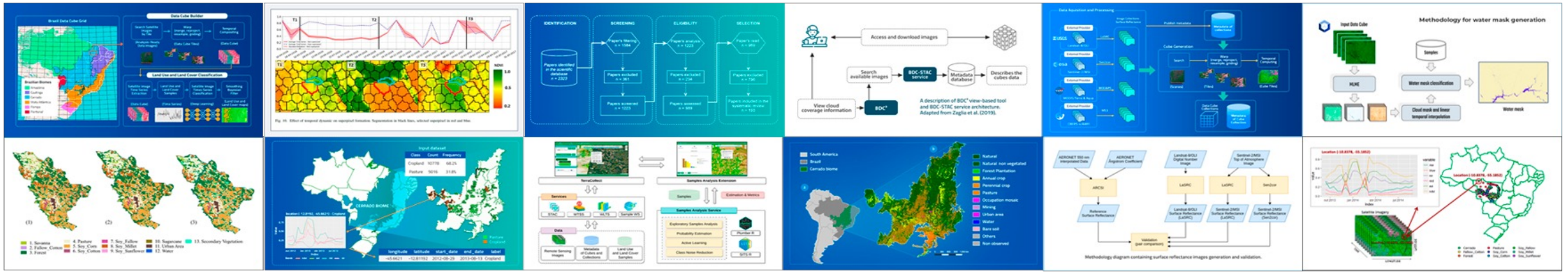




50 PUBLICAÇÕES

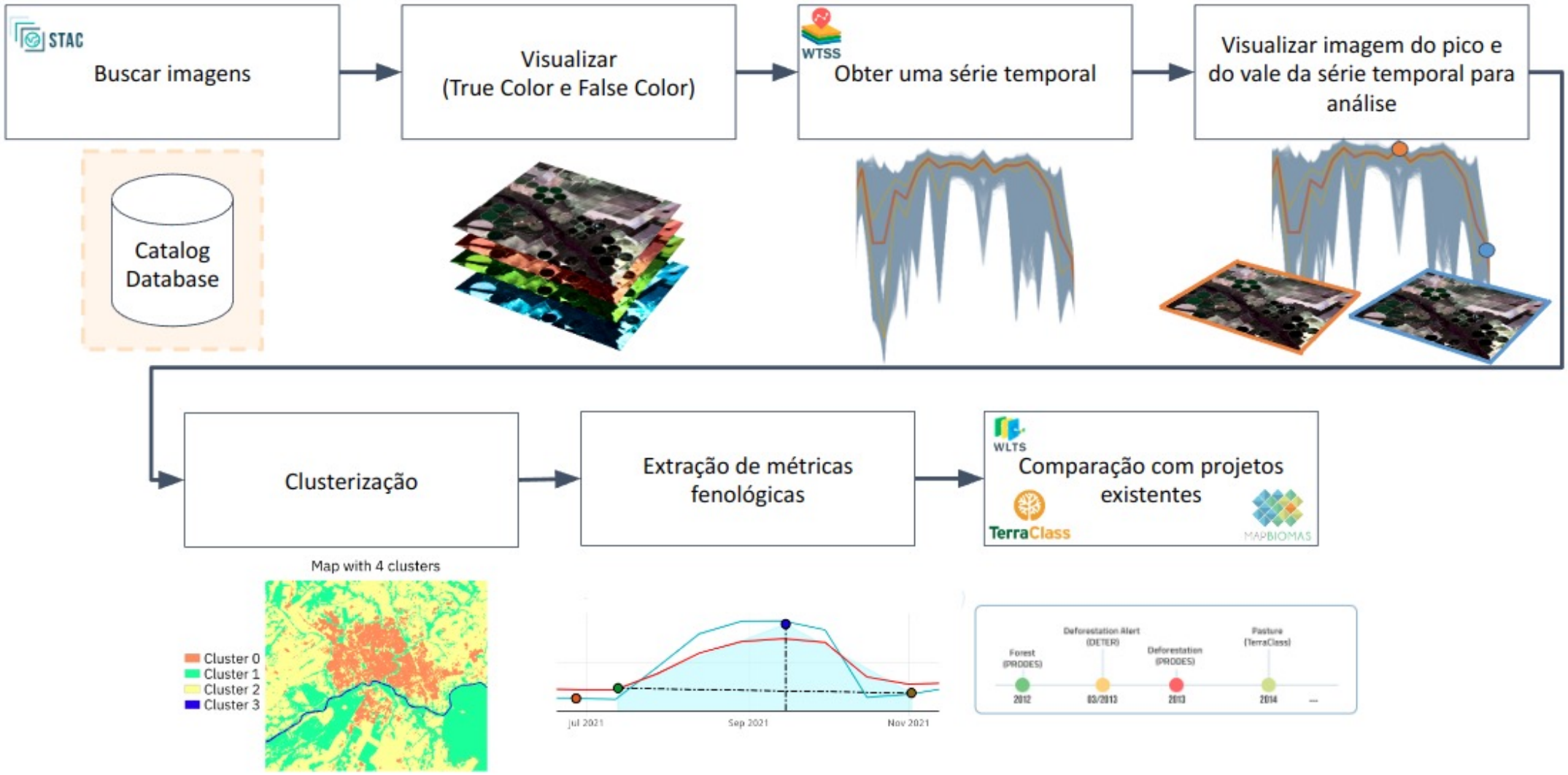
29 – Revistas e eventos internacionais

21 – Revistas e eventos nacionais



http://brazildatacube.org

SBSR 2025 - Course



Interoperabilidade

Google Earth Engine

Microsoft | Planetary Computer

Copernicus Data Space Ecosystem (CDSE)

BRAZIL DATA CUBE

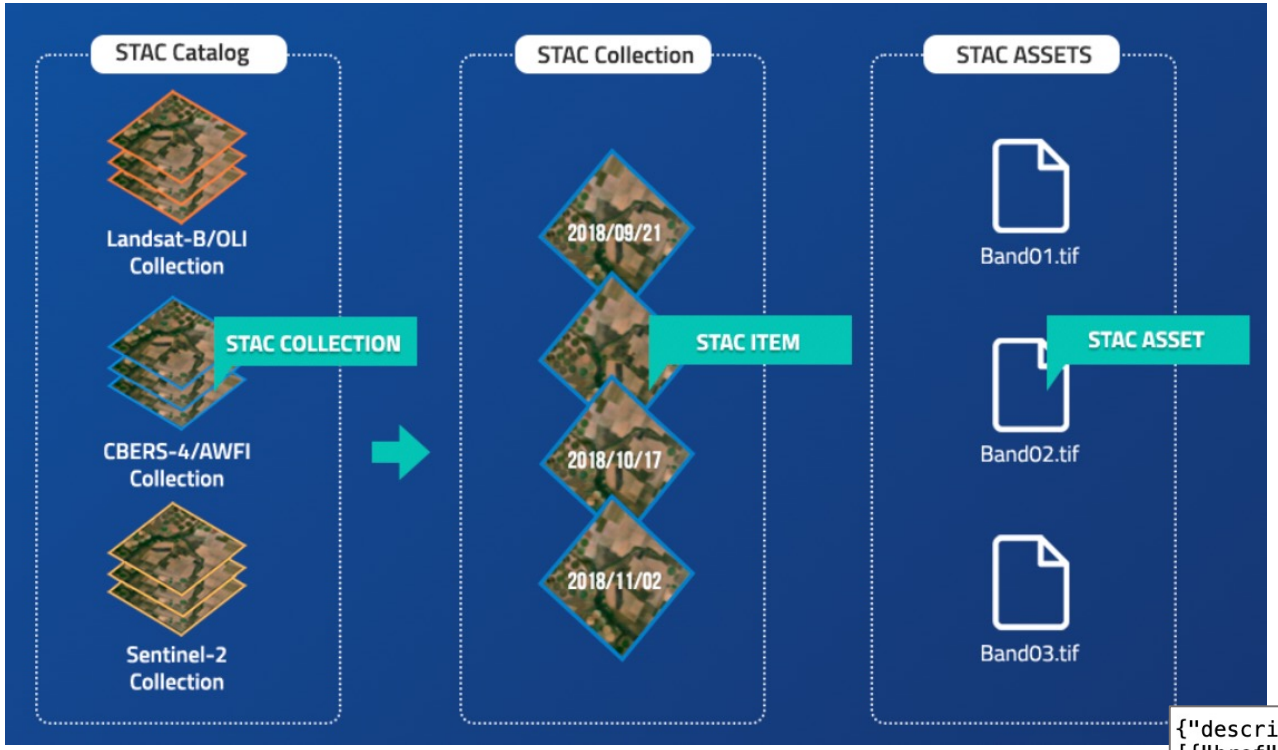
aws

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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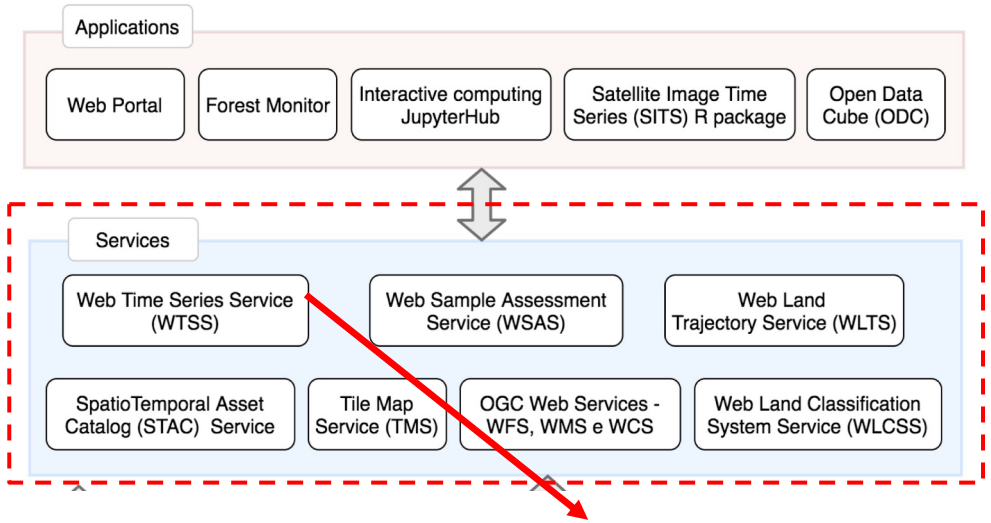
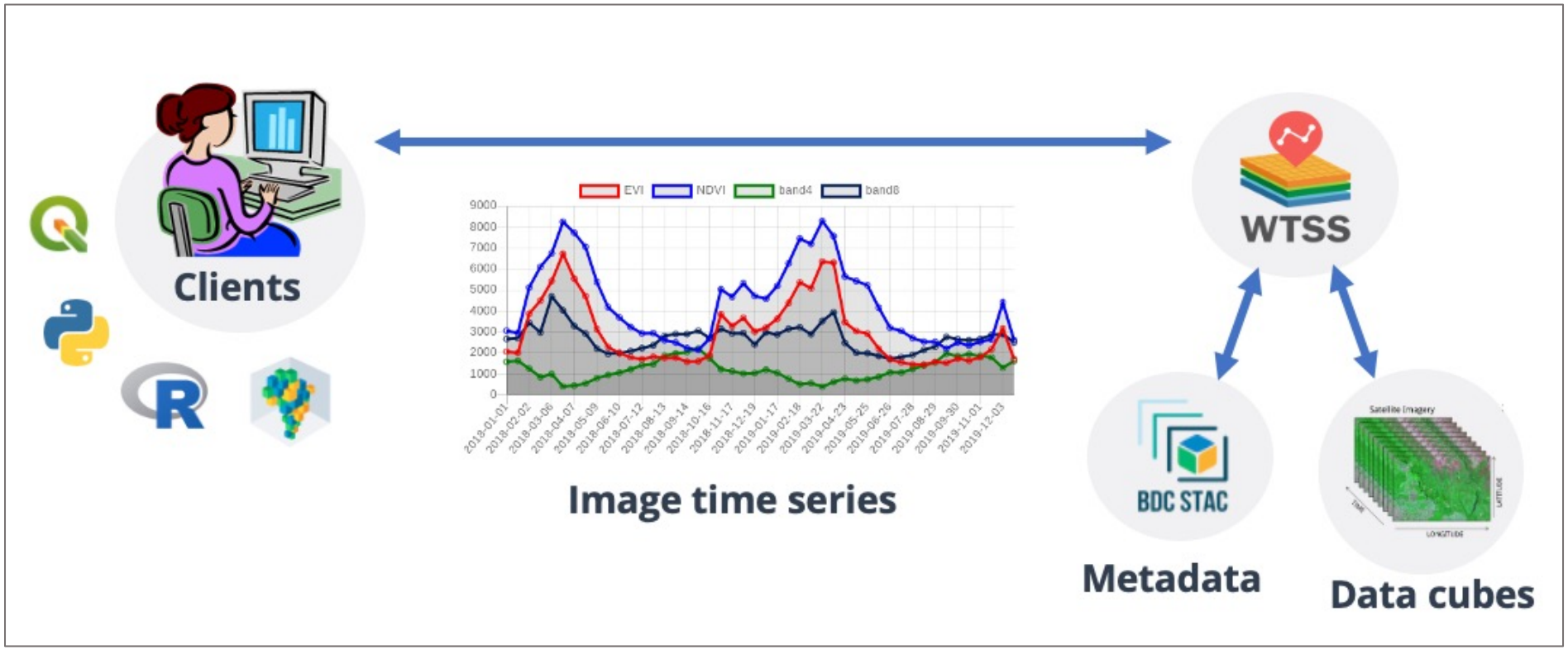
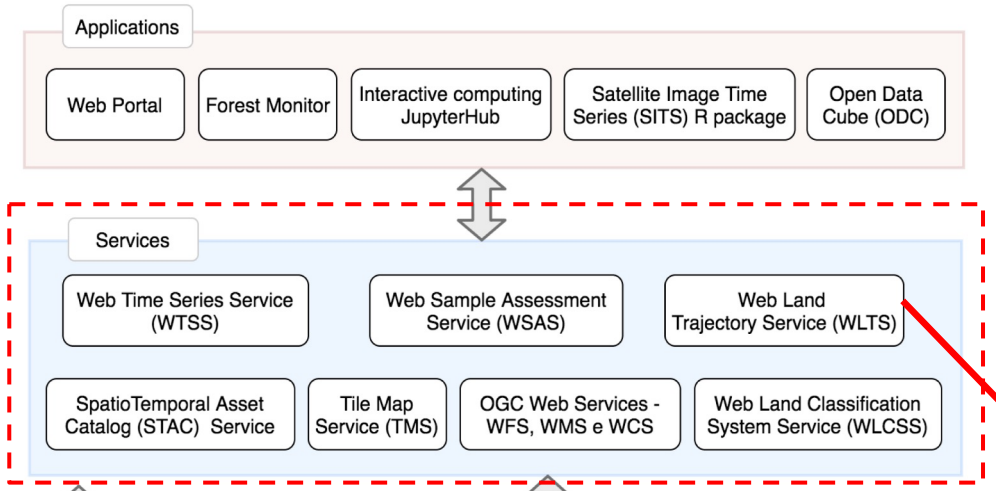
{"href":"https://brazildatacube.dpi.inpe.br/stac/collections/S2-MOSAIC-PARAIBA_10_3M_STK-

Source: https://brazildatacube.dpi.inpe.br/stac/

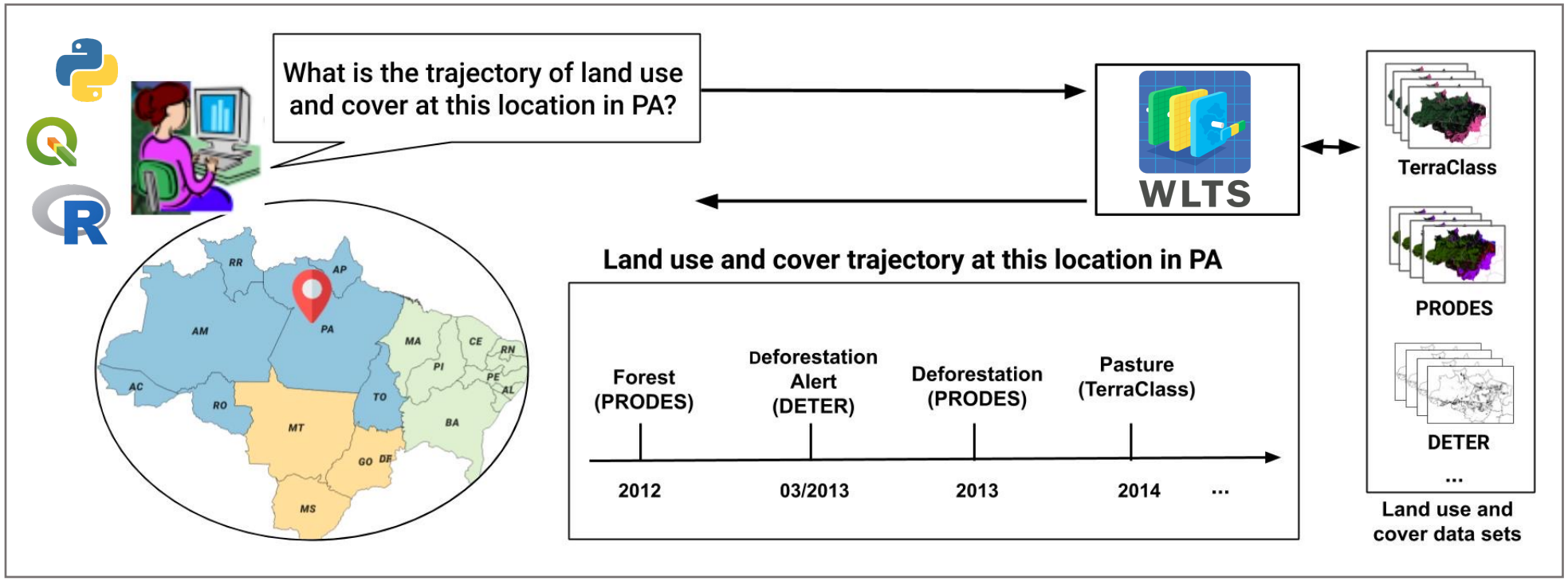


WTSS – Web Time Series Service



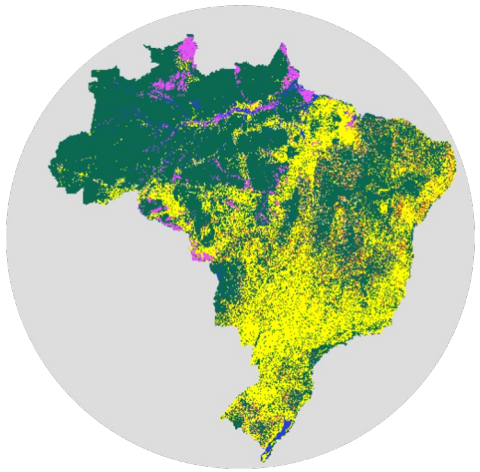


WLTS – Web Land Trajectory Service

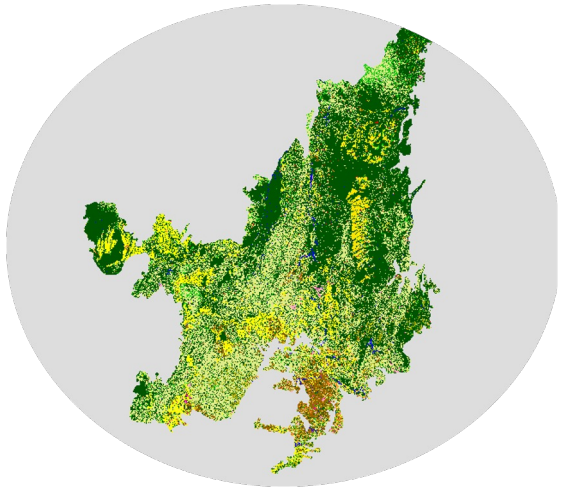


Source: [Zioti et al,. 2021]

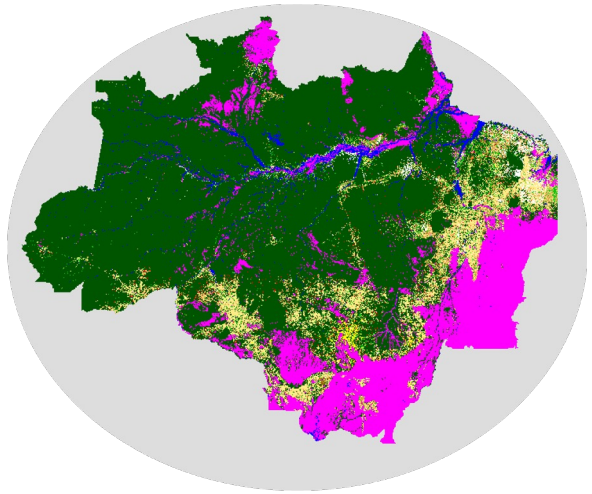
WLTS - Coleções



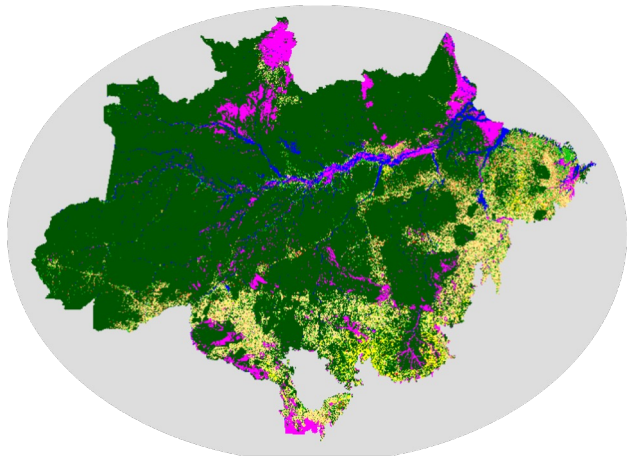
PRODES - Brasil
2007 - 2022
http://terrabrasilis.dpi.inpe.br/



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



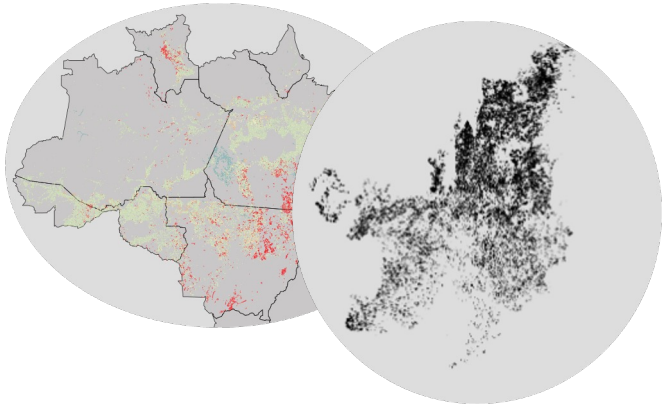
TerraClass - Amazônia
2004, 2008, 2010, 2012, 2014
https://www.terraclass.gov.br/geoportal-aml/



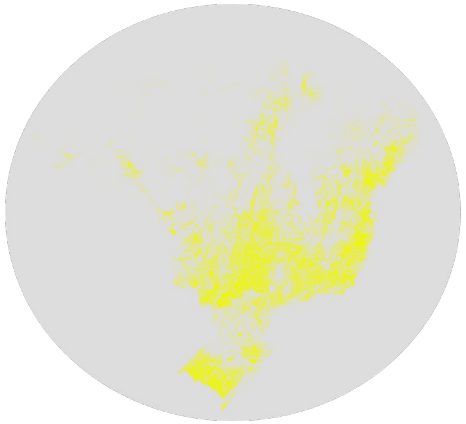
TerraClass - Amazônia
2020
http://terrabrasilis.dpi.inpe.br/

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

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

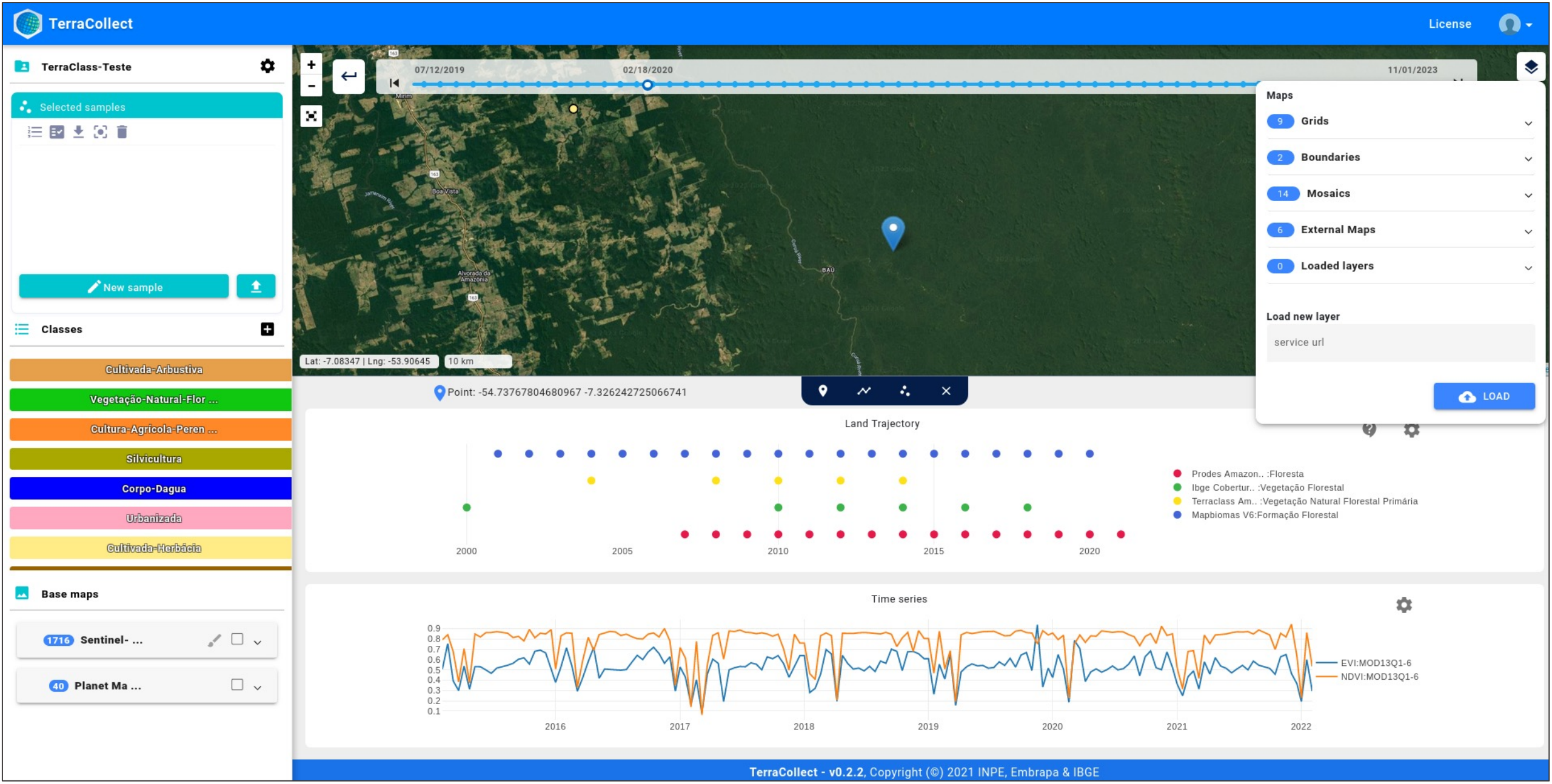


DETER - Amazônia e Cerrado
2018 - 2022
http://terrabrasilis.dpi.inpe.br/

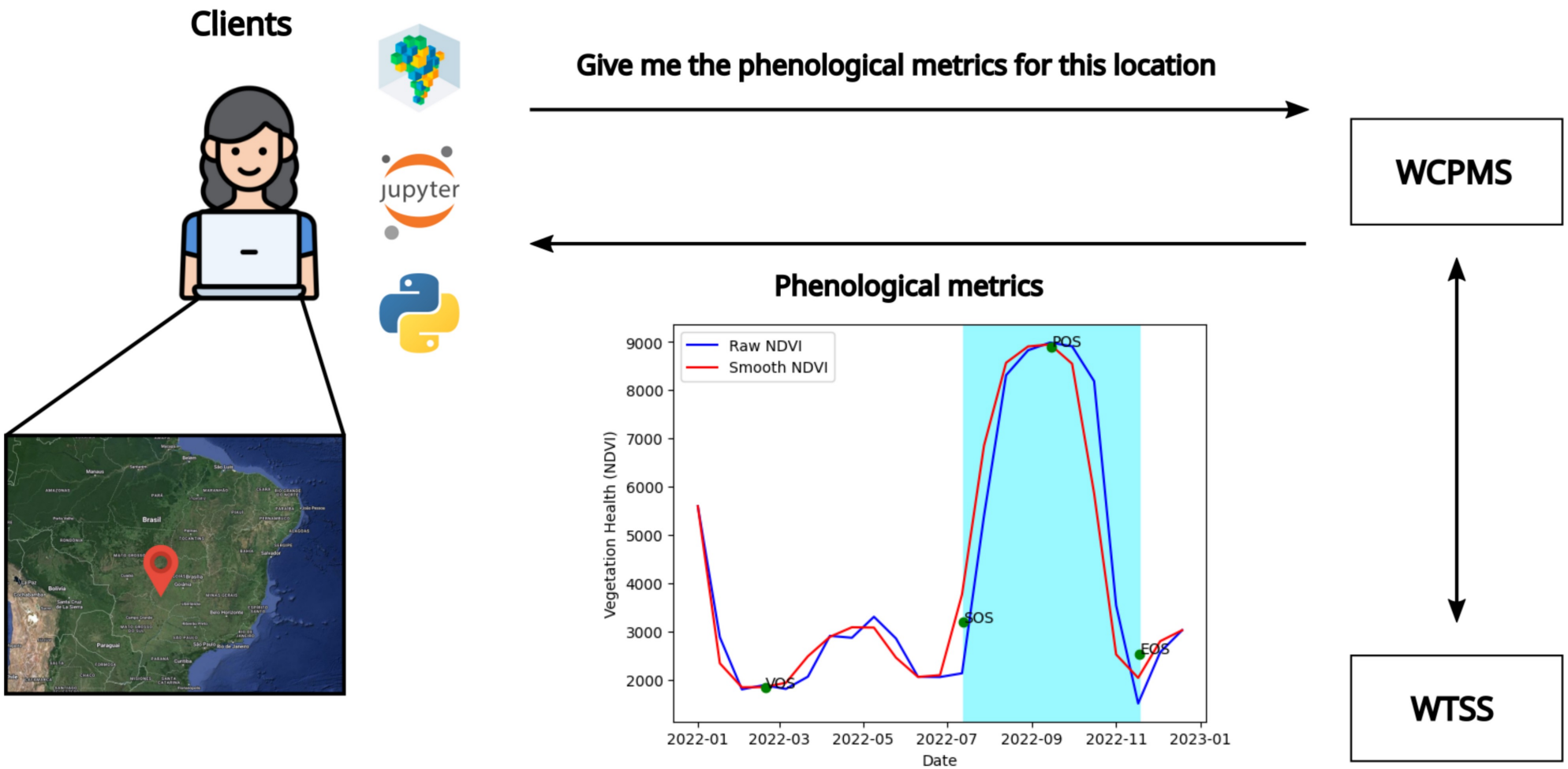


Lapig Pastagem - Brasil
1985 - 2021
https://atlasdaspastagens.ufg.br/map

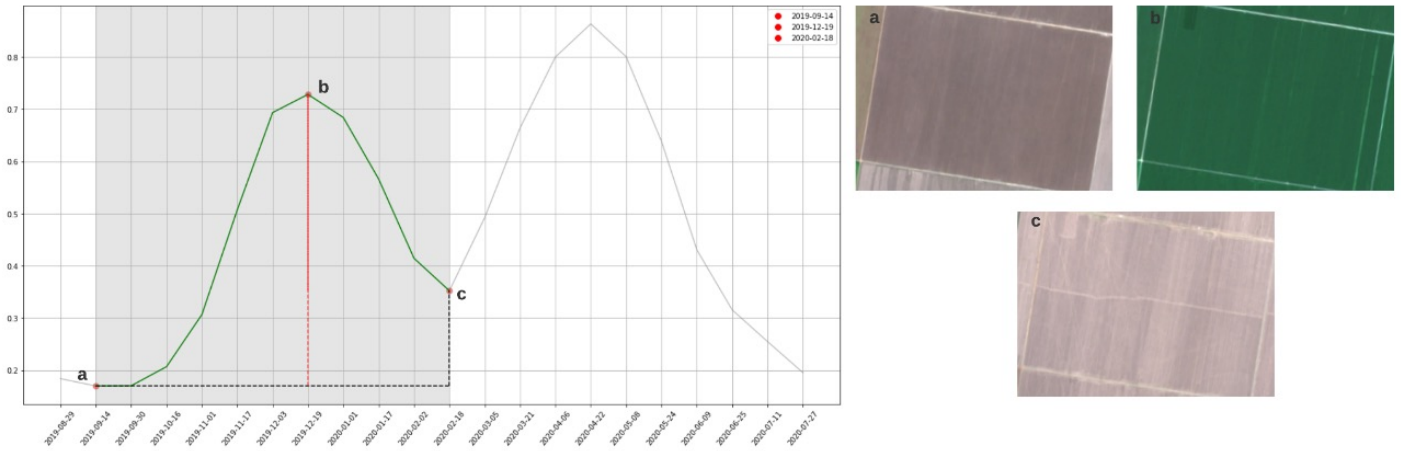
WTSS e WLTS – Interface gráfica – BDC Explorer e TerraCollect



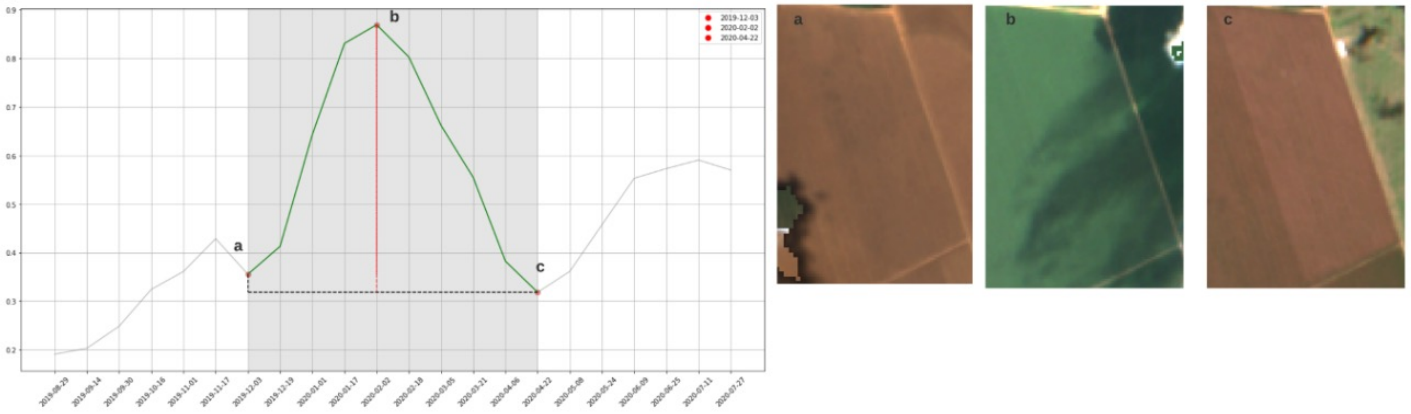
Web Crop Phenology Metrics Service (WCPMS)



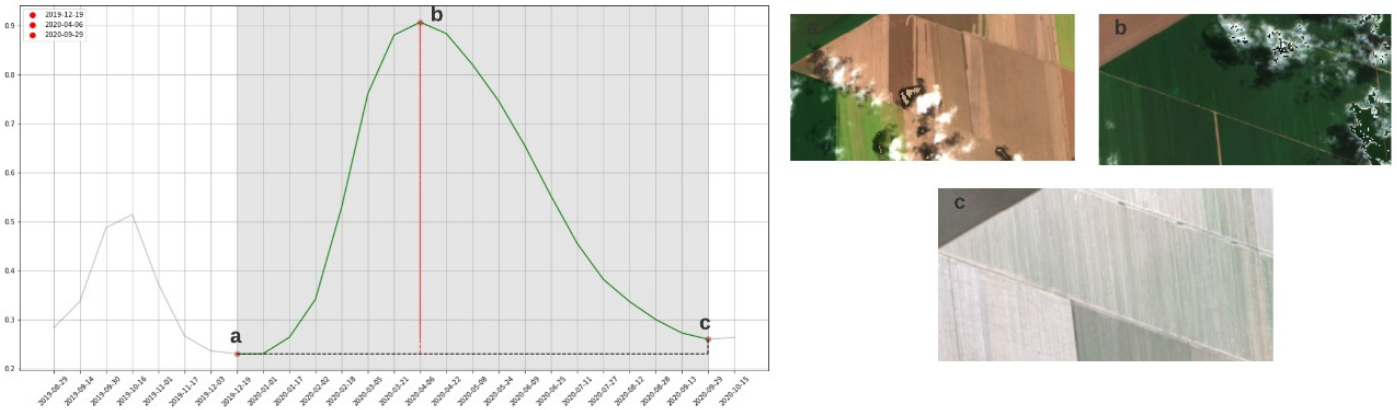
(a)



(b)

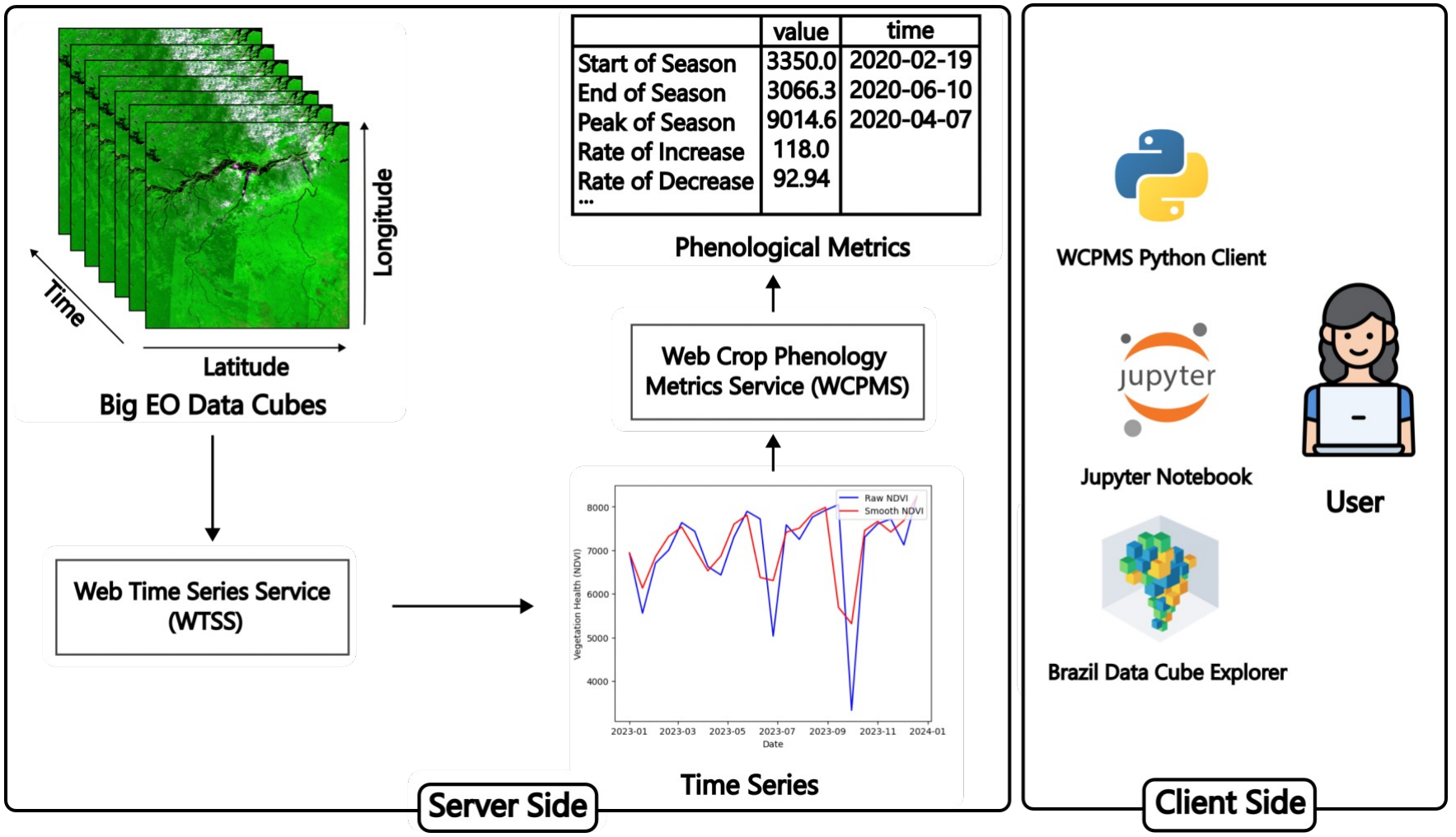


(c)



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.

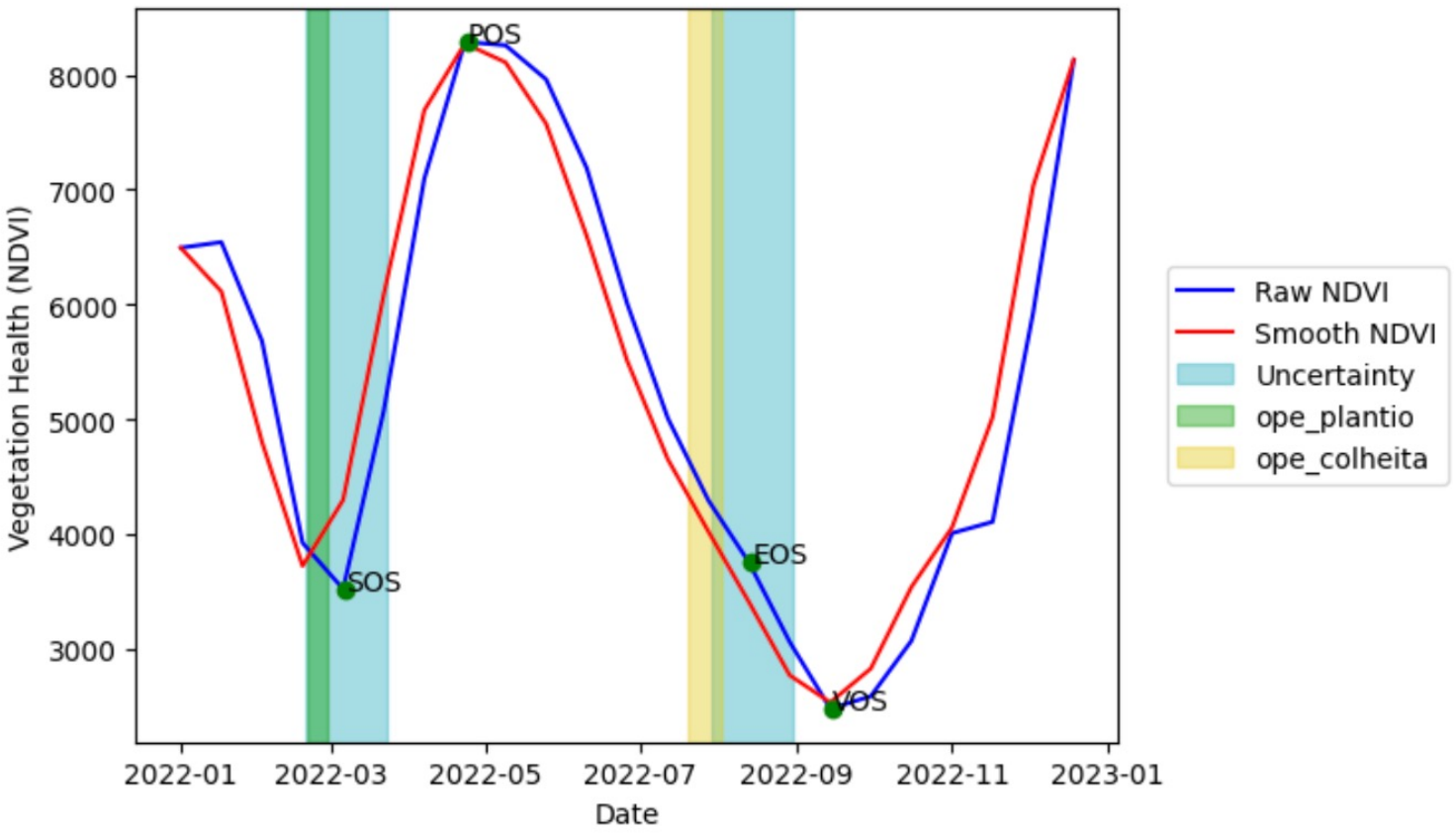
Web Crop Phenology Metrics Service (WCPMS)



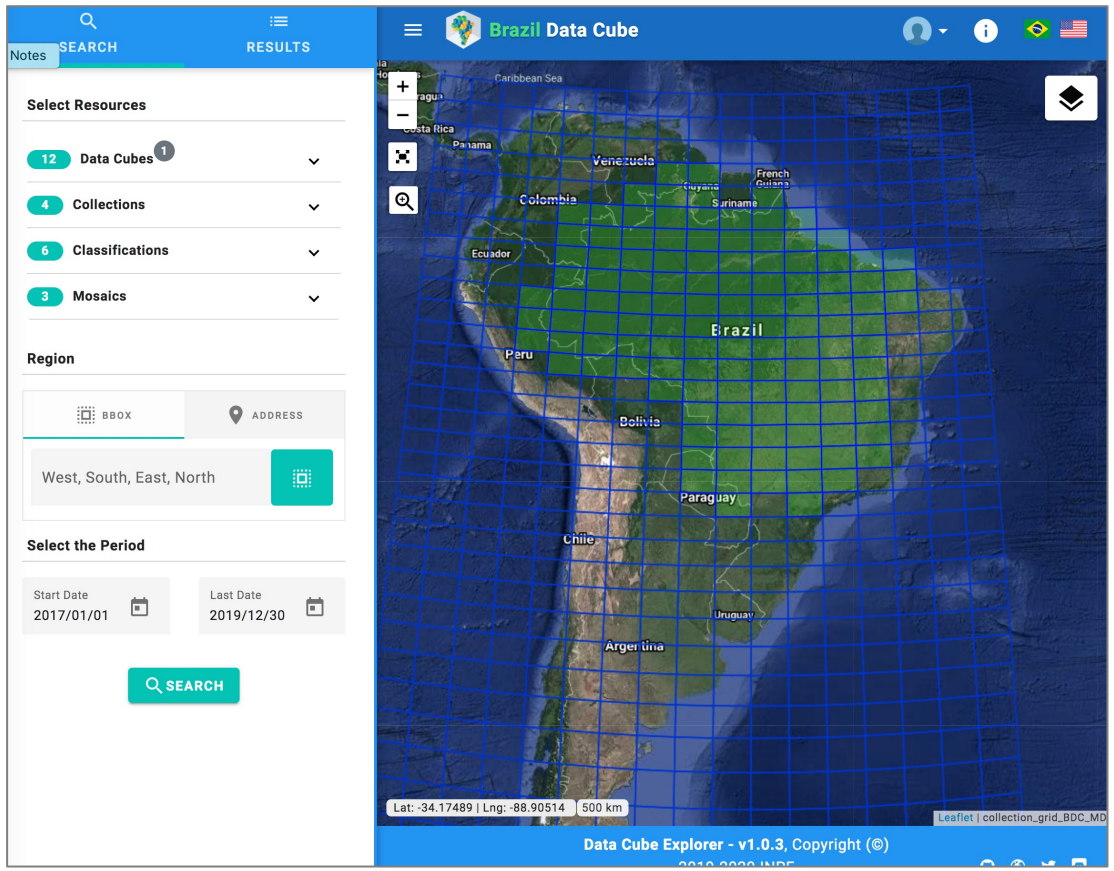
	value	time
Start of Season	3350.0	2020-02-19
End of Season	3066.3	2020-06-10
Peak of Season	9014.6	2020-04-07
Rate of Increase	118.0	
Rate of Decrease	92.94	
...		

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")
```

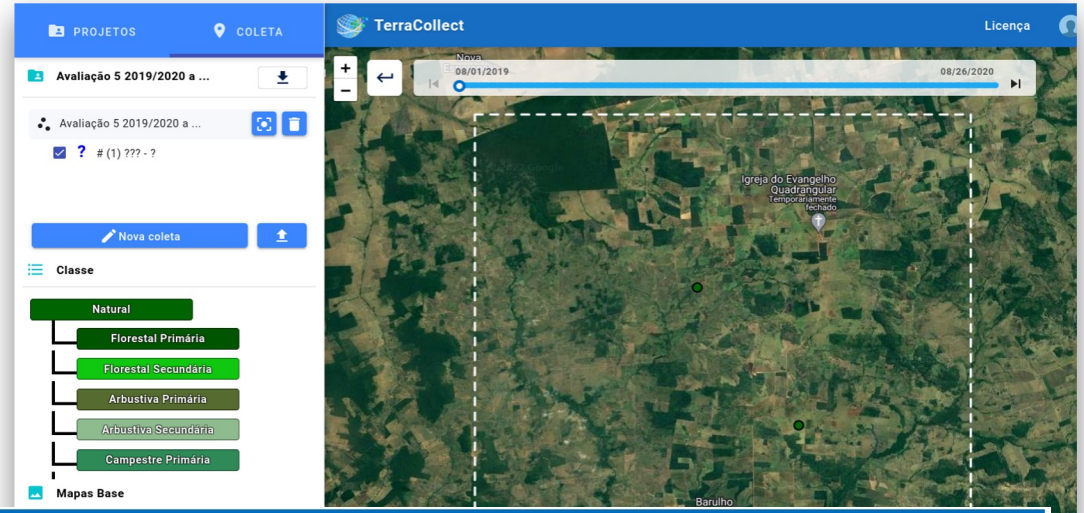


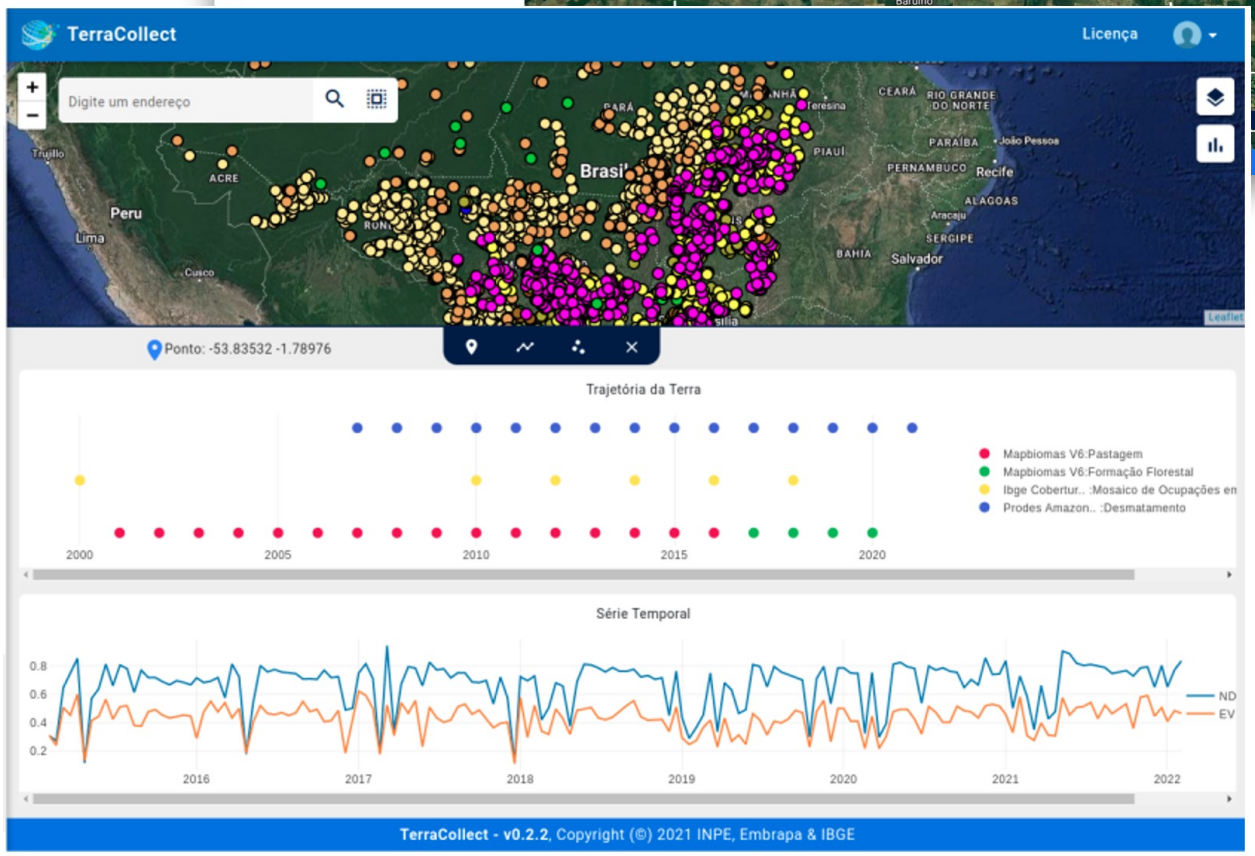
BDC Explorer



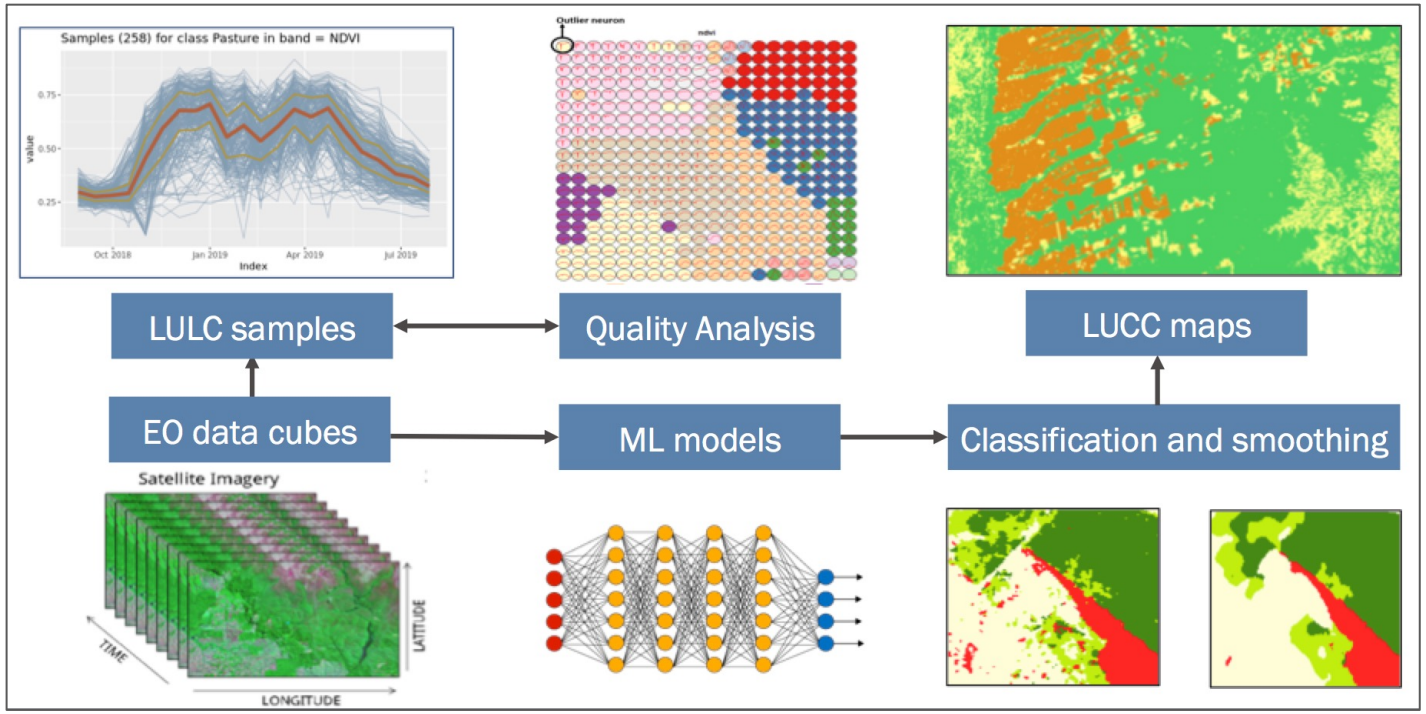
https://data.inpe.br/bdc/explorer/explore

TerraCollect





SITS (Satellite Image Time Series) R package

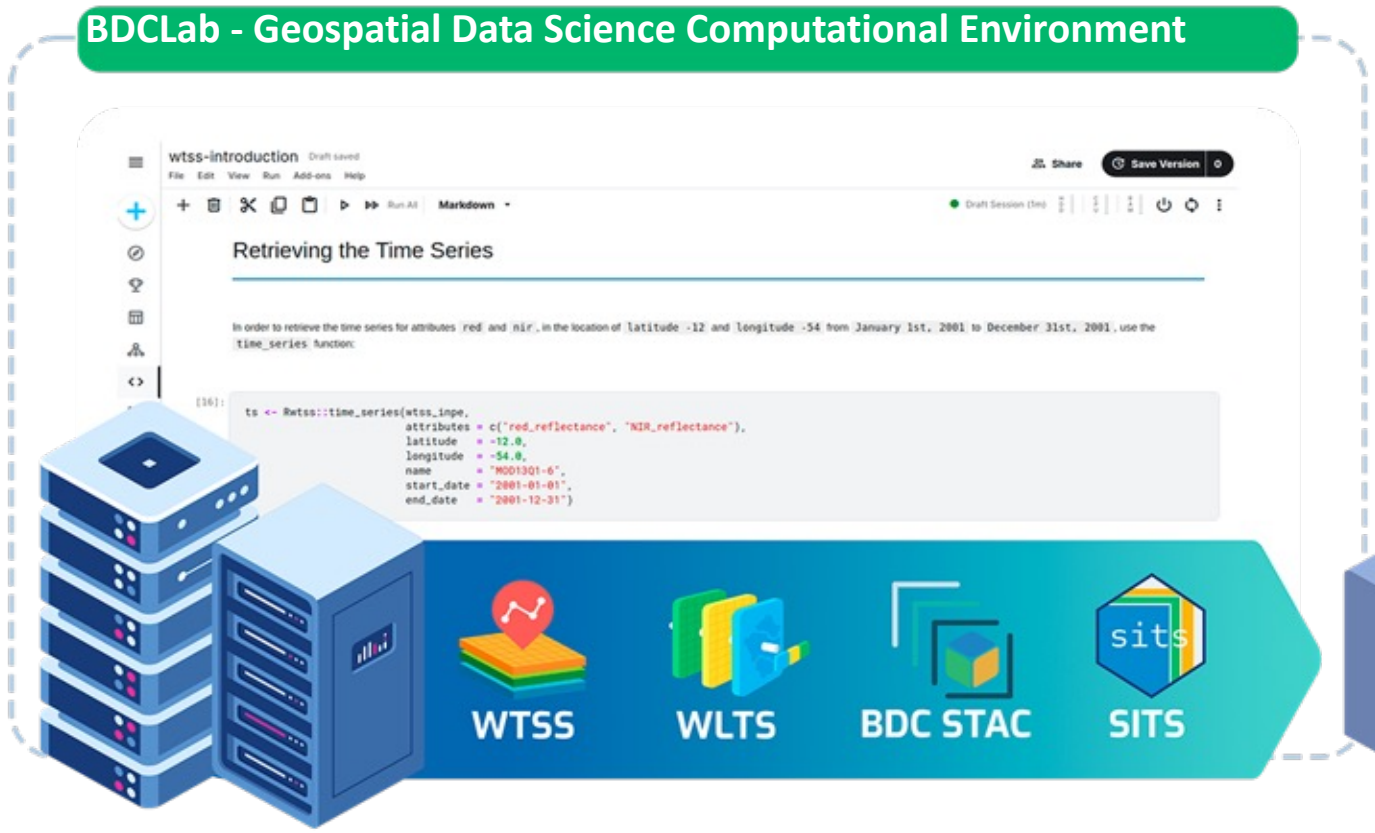



```
cube <- sits_cube(source = "BDC",
                  collection = "S2_10_16D",
                  name = "s2_cube",
                  bands = c("NDVI", "EVI"),
                  tiles = "022024", start_date = "2018-09-01", end_date = "2019-08-28")

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

BDC-Lab: Geospatial Data Science Computational Environment

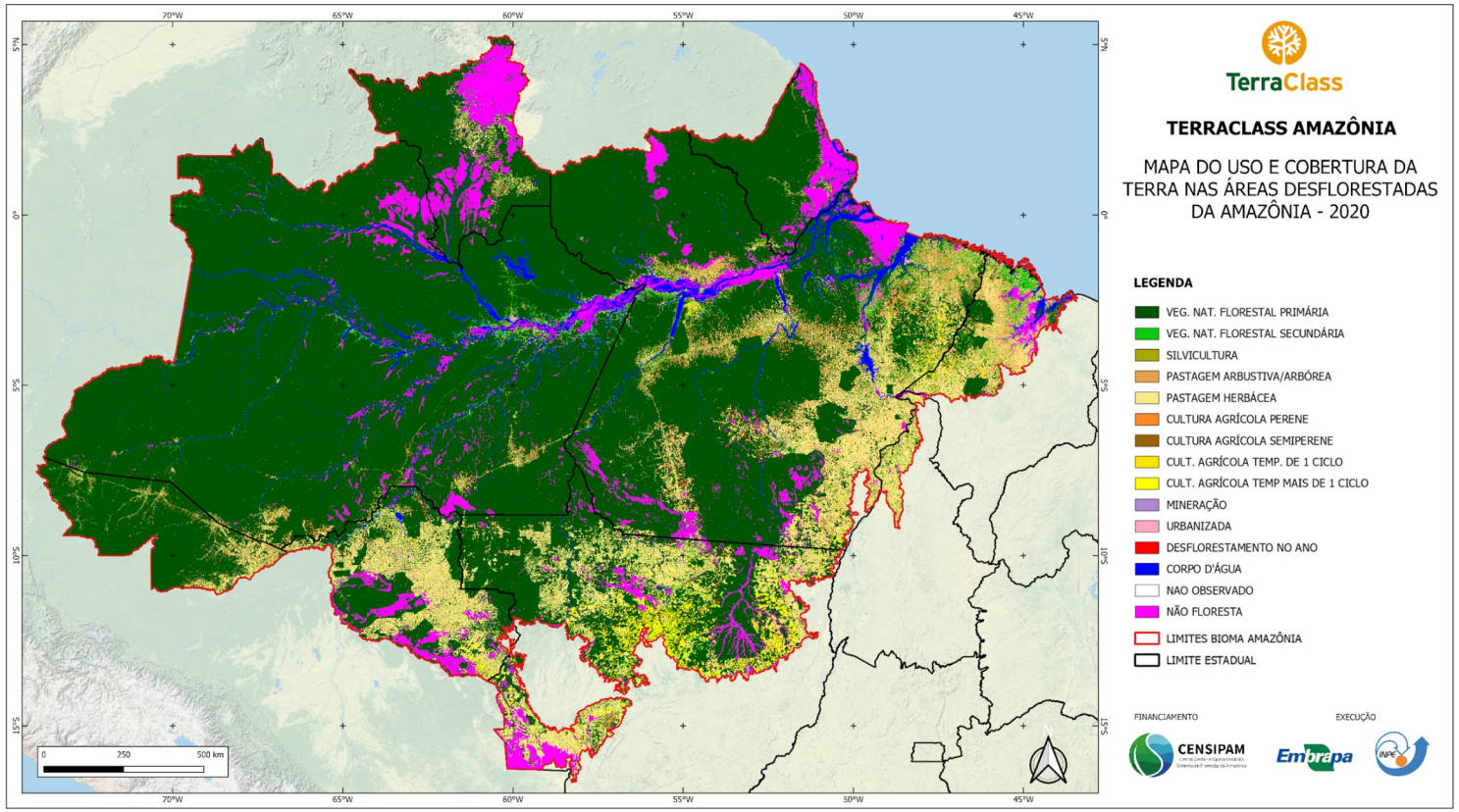
Server-side processing in the INPE's infrastructure, without needing to download images in personal computers.



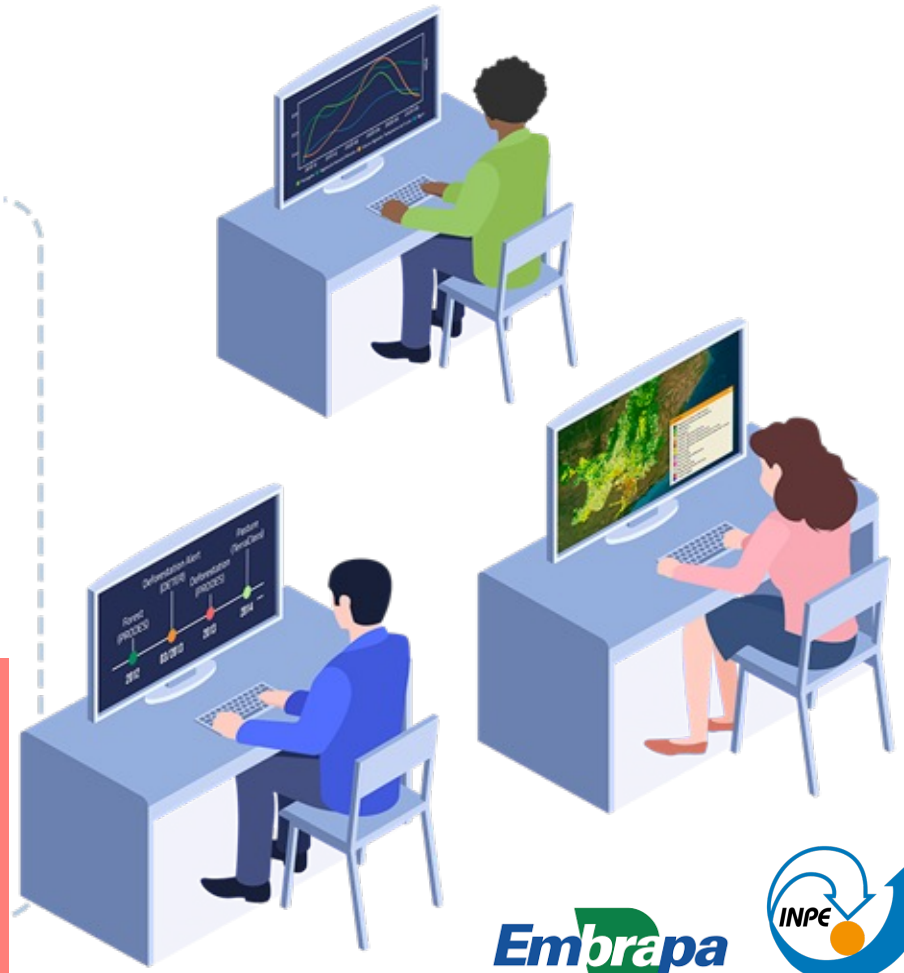
Embrapa

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

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

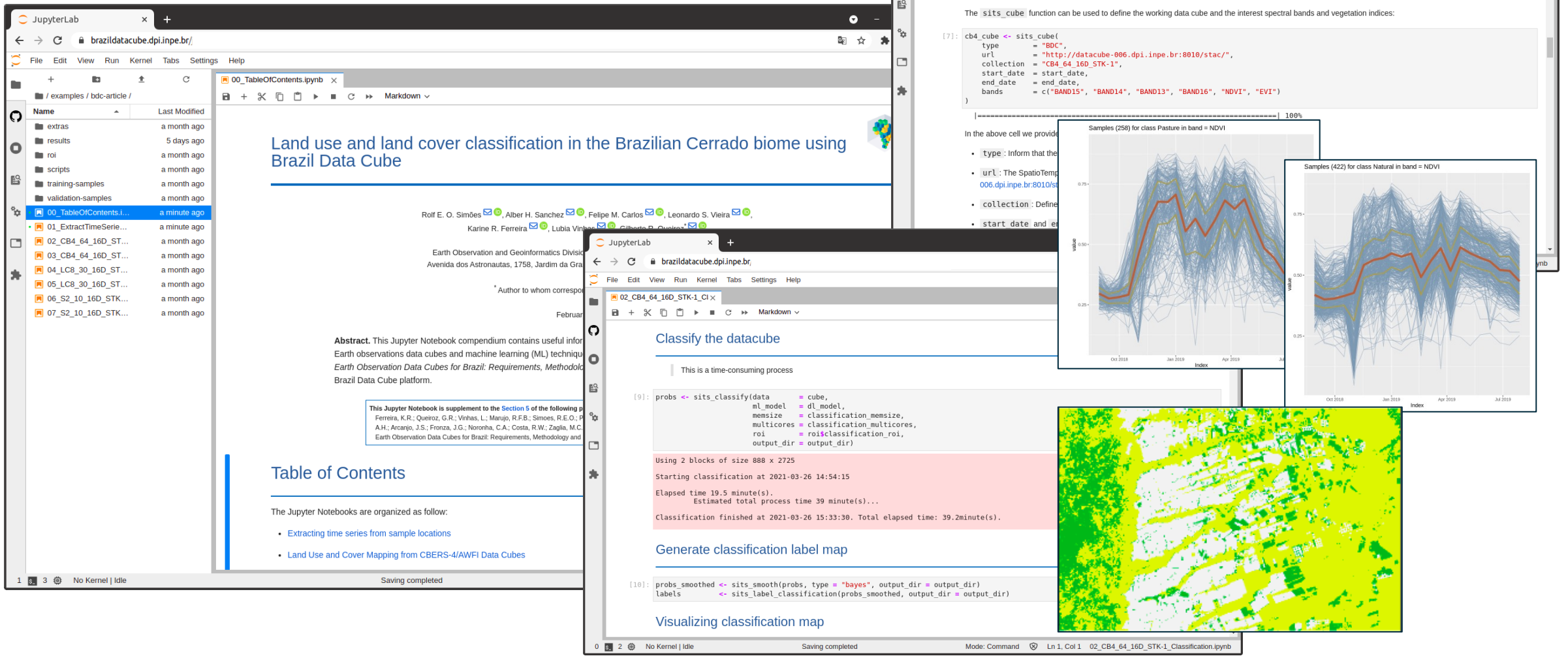
Courtesy: Ivan Márcio Barbosa

INPE Data Center

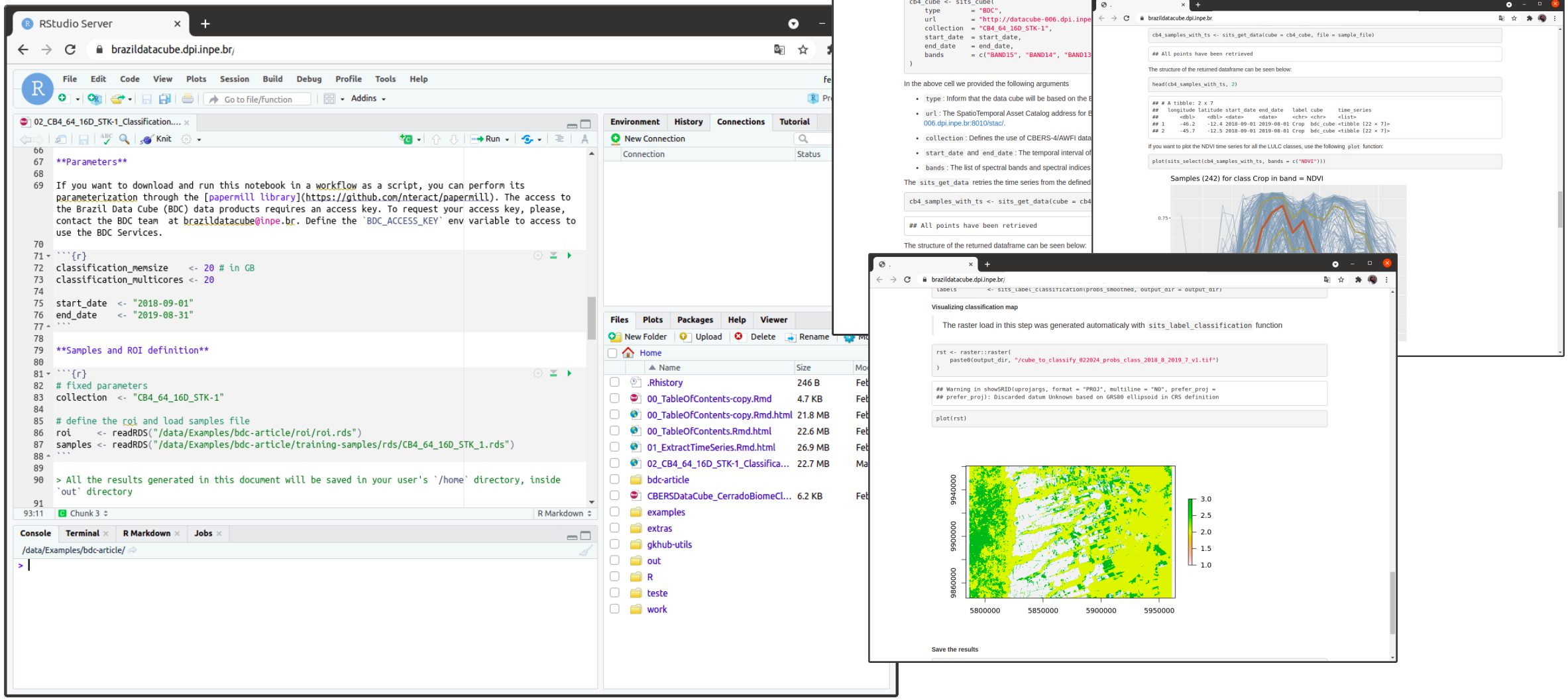
255 Servers, Data Storage with tiers (SSD, SAS and tape library) 12PB online and 4PB tape LTO

Courtesy: Ivan Márcio Barbosa

Ambiente de Computação Interativa: JupyterHub

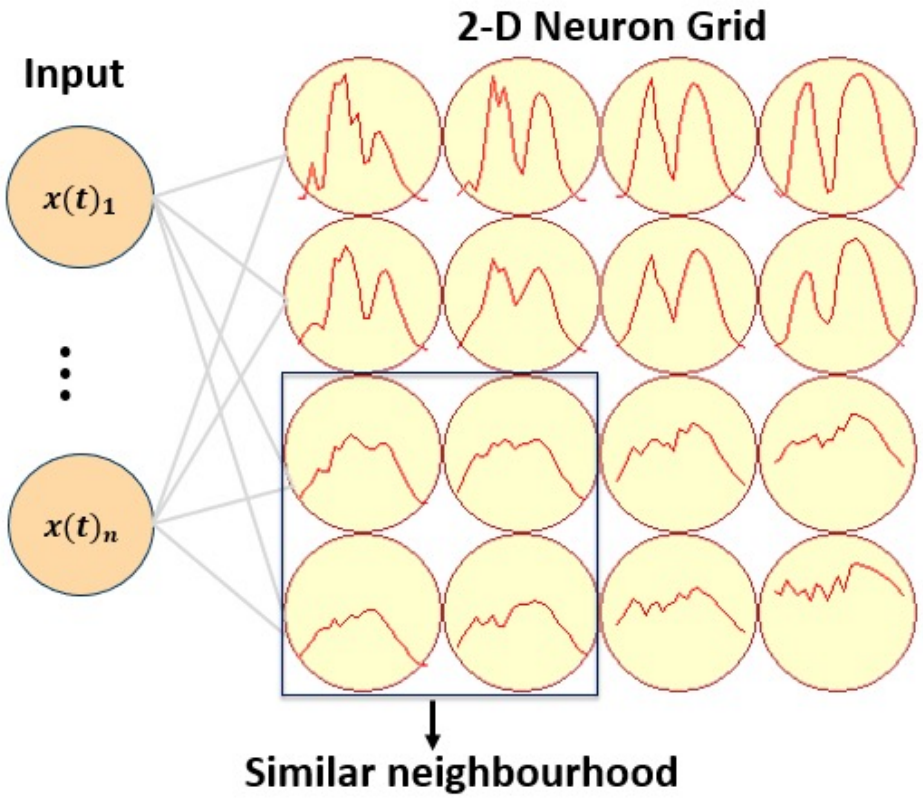


Ambiente de Computação Interativa: RStudio

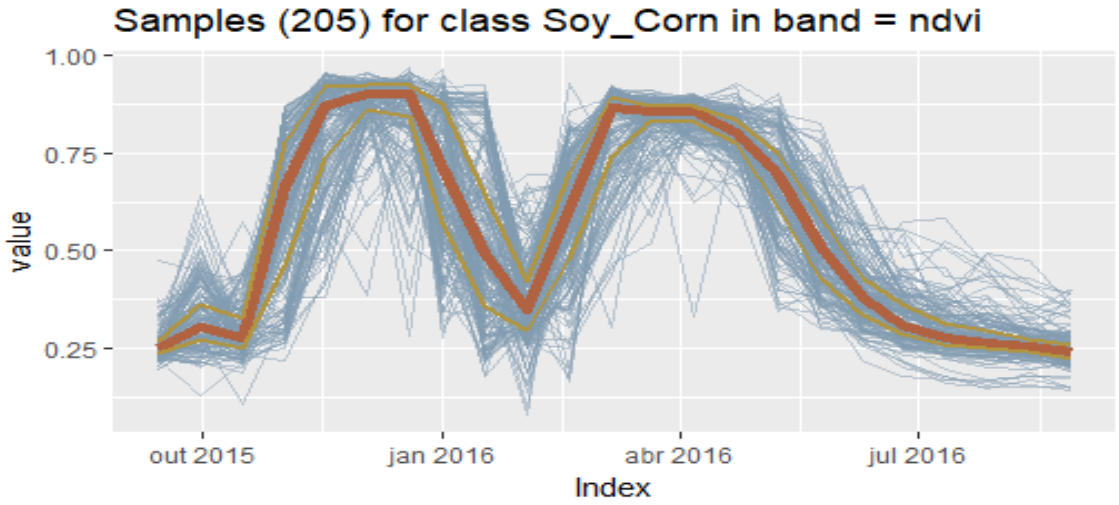


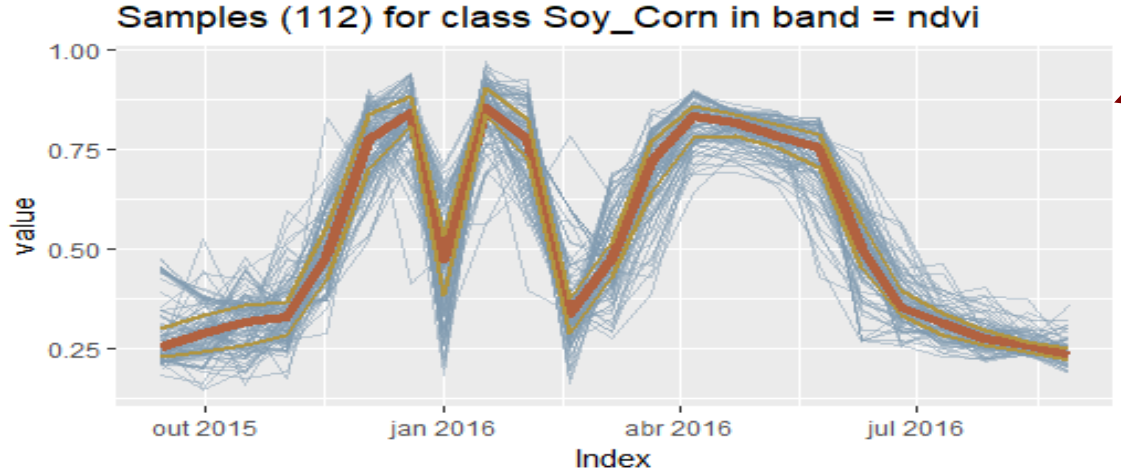
Clustering of SITS

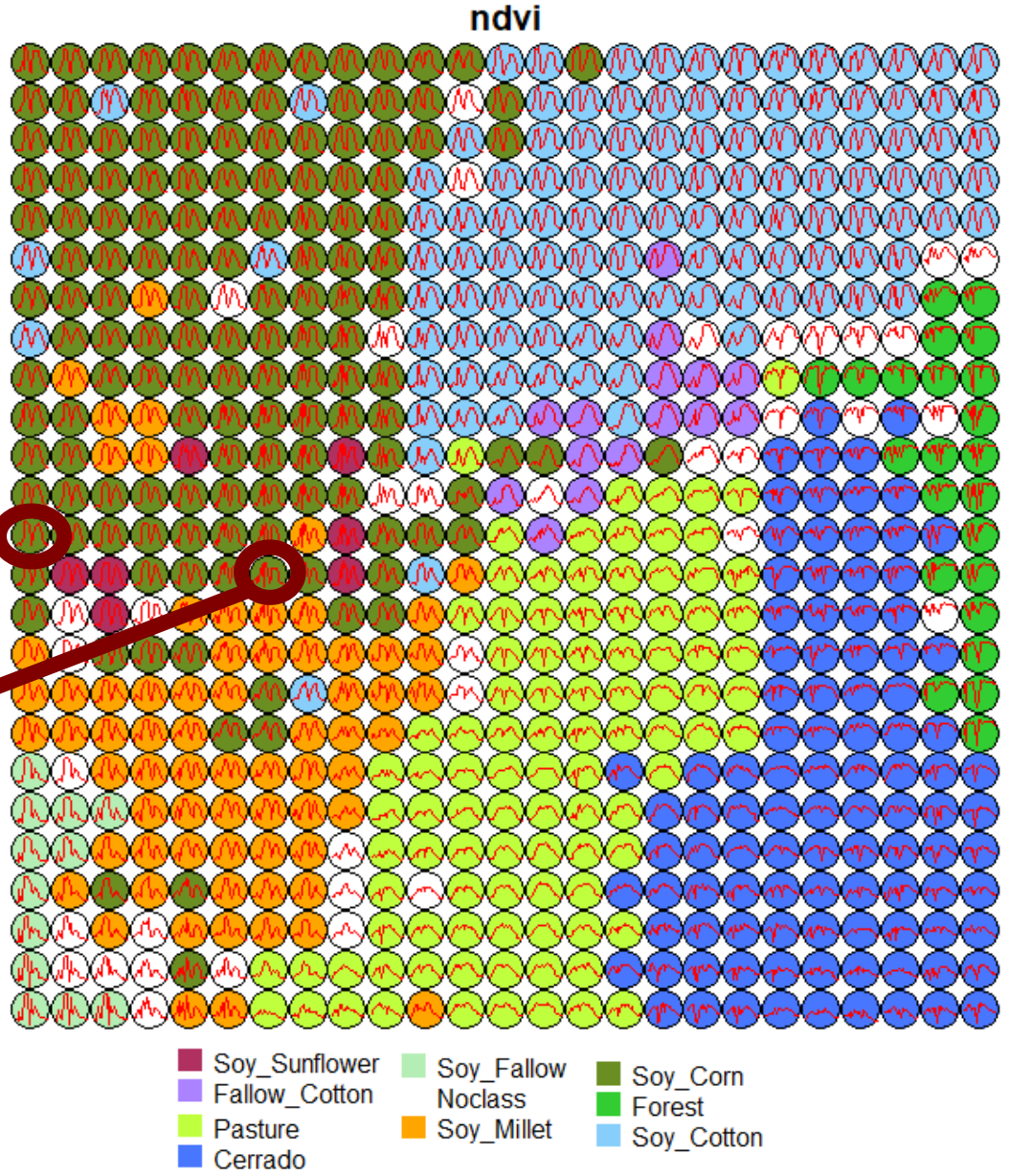
Self-Organizing Maps (SOM) neural network for SITS clustering



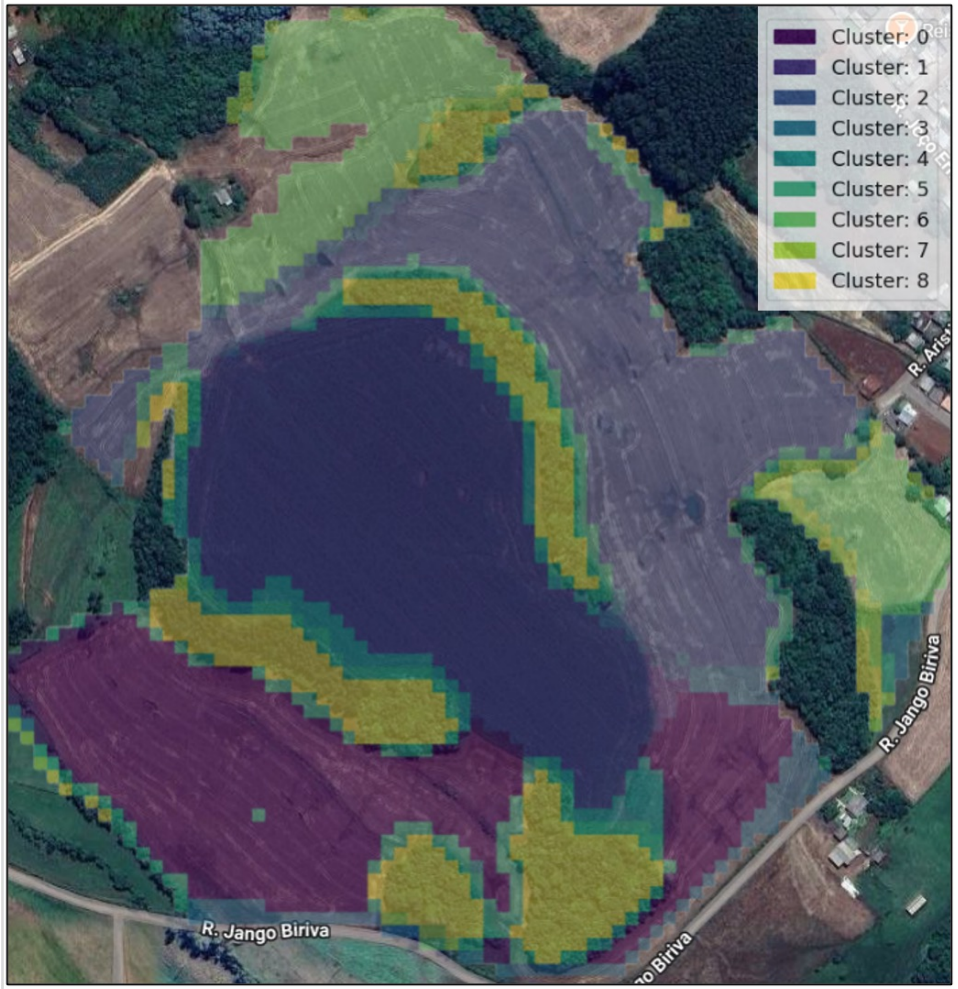
SOM to identify different SITS patterns



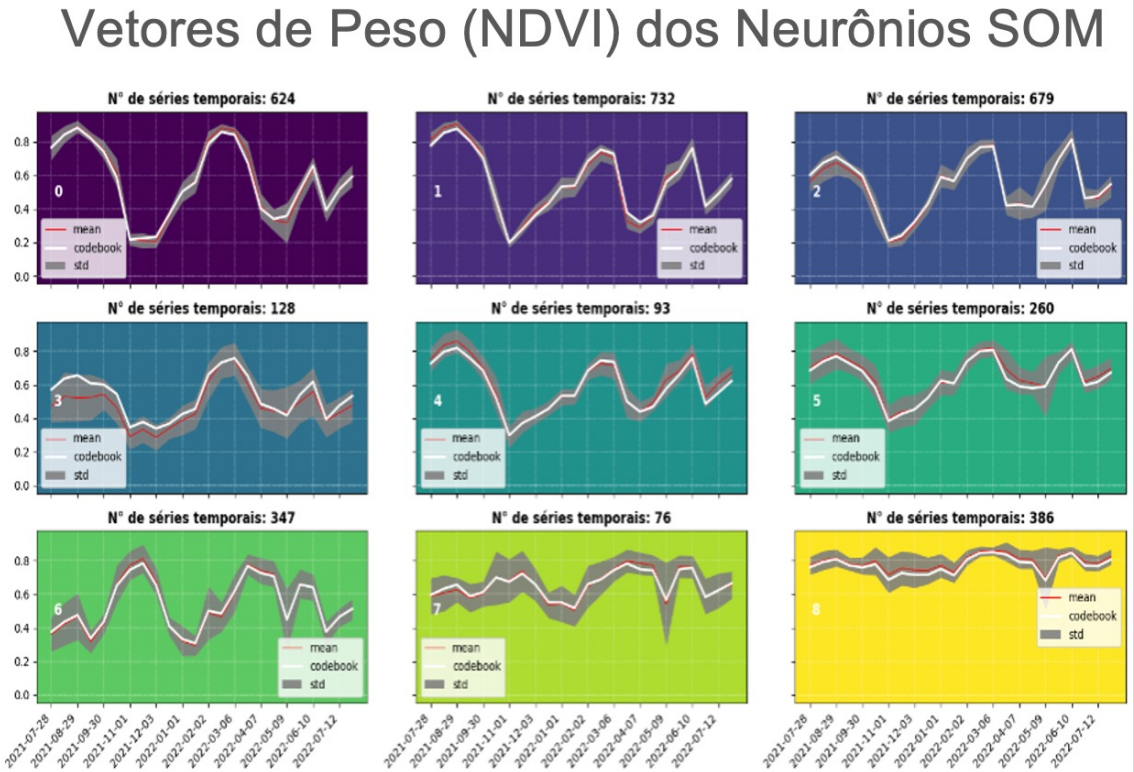




SITS patterns – dentro de uma gleba – Crédito Rural - SICOR

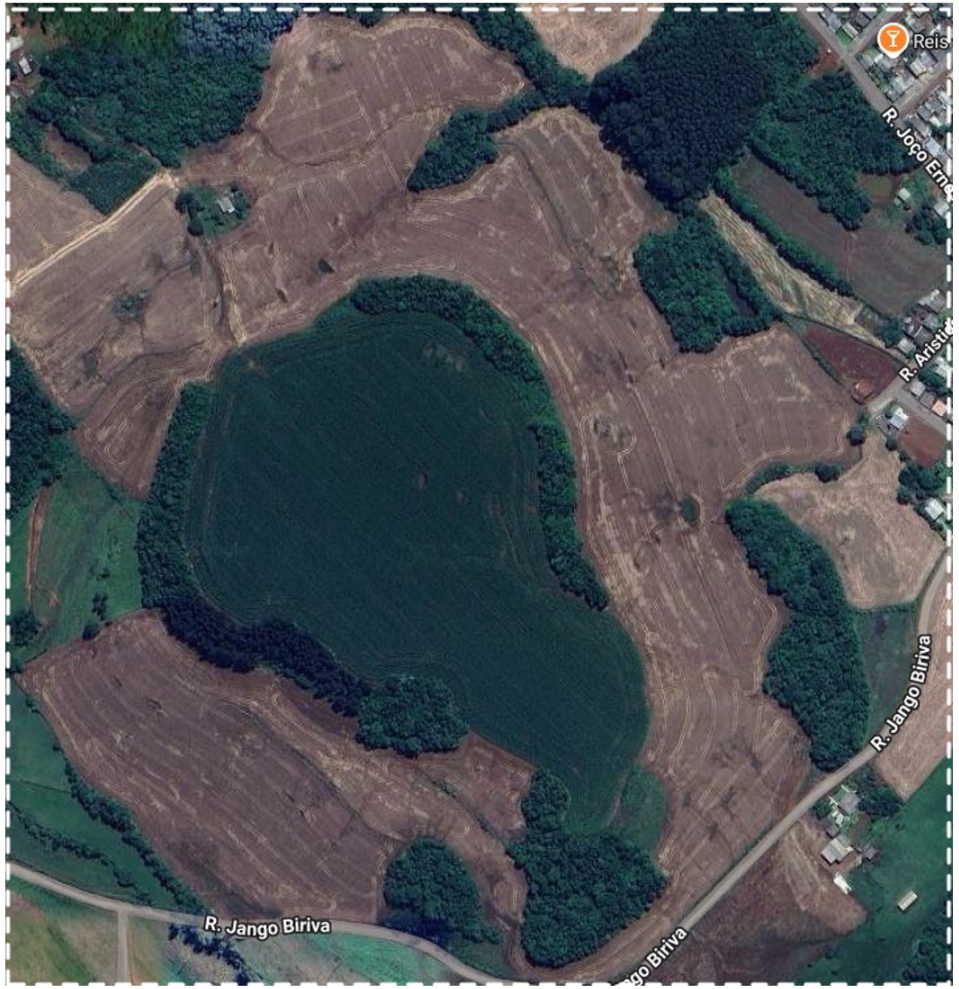


(A)



(B)

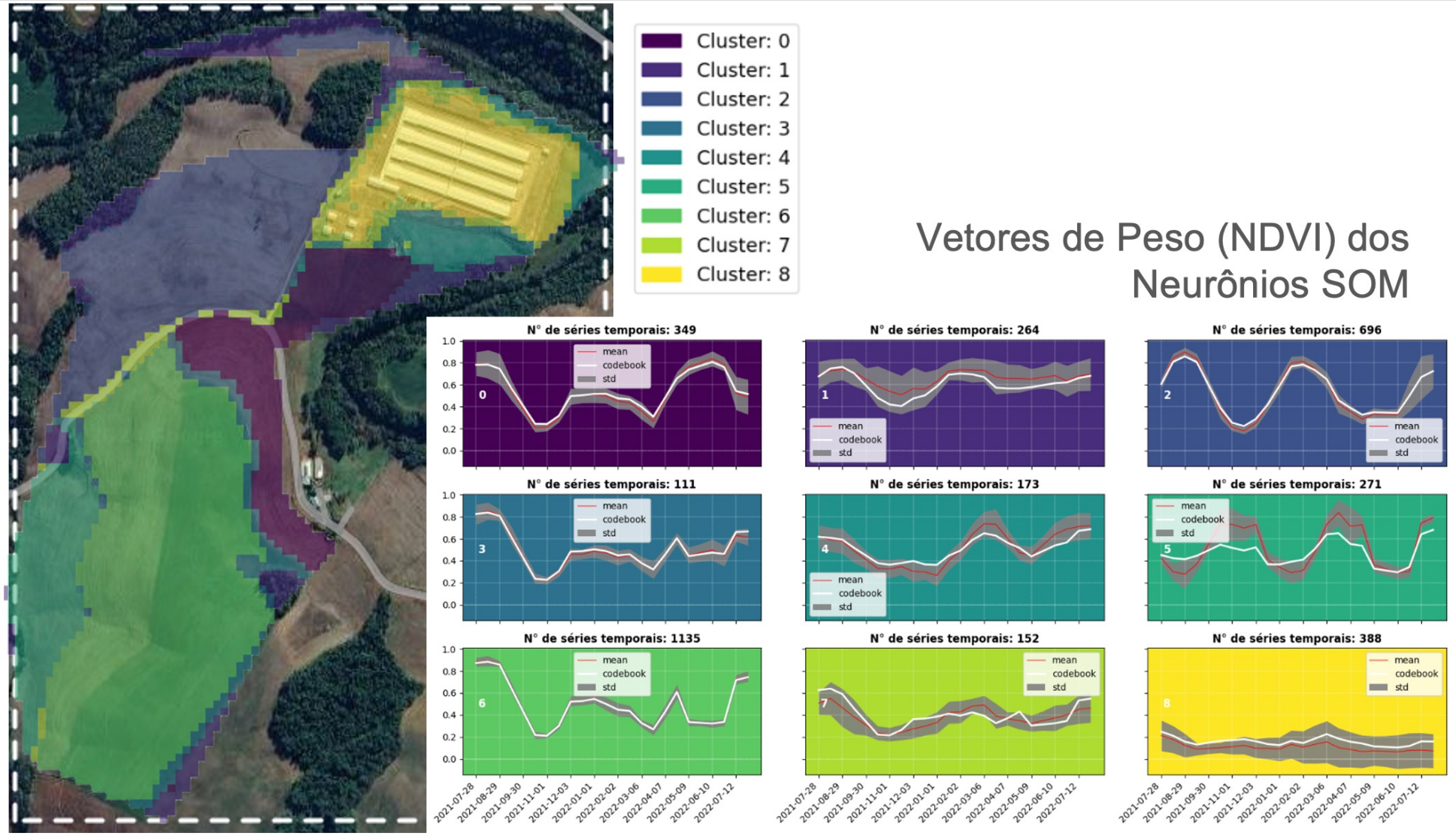
SITS patterns – dentro de uma gleba – Crédito Rural - SICOR



(A)

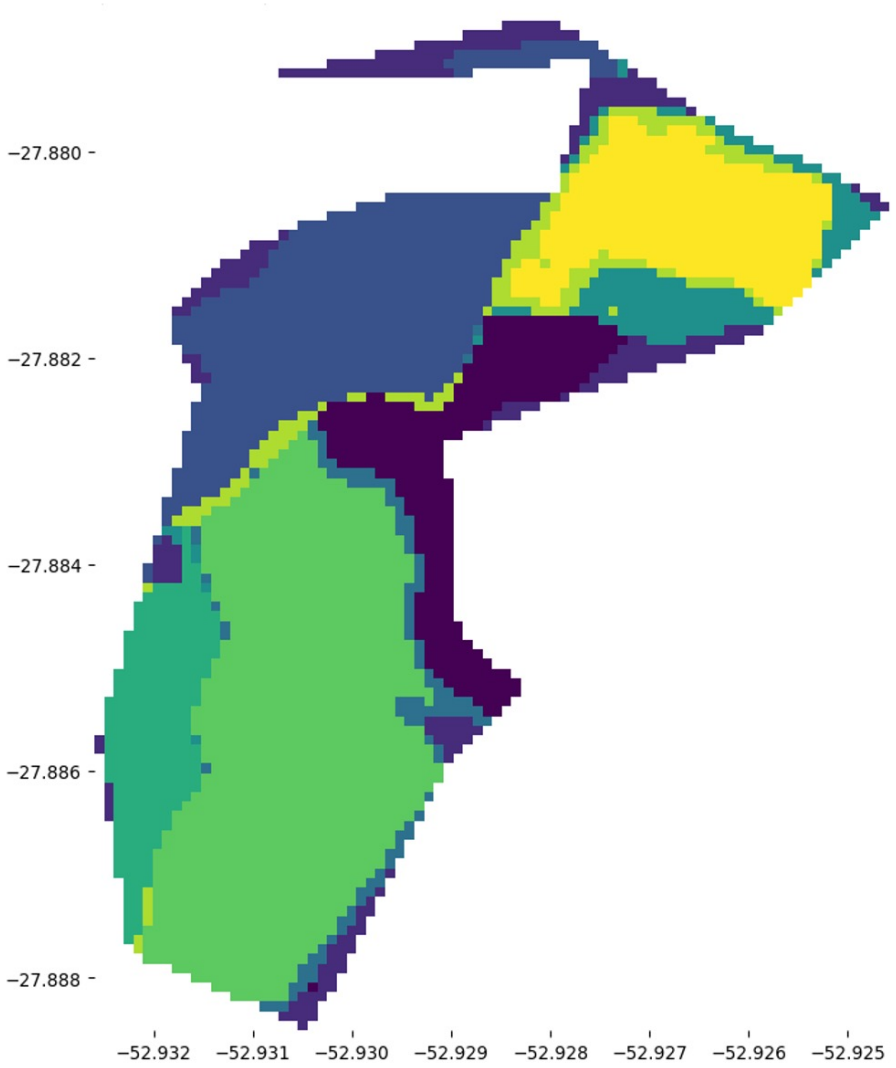
(B)

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



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

(A)



(B)

BRAZIL DATA CUBE
brazildatacube.org

brazildatacube.org

brazildatacube.dpi.inpe.br/portal/explore

OBRIGADA!

Karine R. Ferreira

karine.ferreira@inpe.br

@brazildatacube

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MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES