EO FOR FORESTRY TRAINING 2024 (BELEM, BRAZIL)

Thanks to all ESA-EOP colleagues for their contributions

Thibault Taillade, Magdalena Fitrzyk

EO Activities, Initiatives and Tools for Forestry

ESA-EOP colleagues
Thibault Taillade, Magdalena Fitrzyk

Summary

I) – Projects and initiatives for Forestry

II)- Tools, EO platforms and opportunities

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Why forests?

esa

Livelihood for indigenous people

Income from timber and non-timber products

Food and medicine

Carbon sink

Flood control and tsunami mitigation

Biodiversity of plants and animals

Clean drinking water and air

Fuel wood and charcoal

Influence rainfall patterns

**Erosion control and landslide prevention**

Forests are under several stress

- **Deforestation: Agriculture and urbanization**

- **Climate Change: Rising Temperatures, altered rainfall, drought and fire risk**

- **Biodiversity Loss: Habitat fragmentation and invasive species**

- **Soil Degradation: Erosion, Nutrient Loss**

- **Pollution: Air, Water Contamination**

- **Illegal Logging & Poaching: Timber, Wildlife**

- **Human Encroachment: Mining, Unregulated Tourism**

Forest Degradation in Detail - Amazon

Rondonia, Brazil
Sentinel-2
29 June 2022
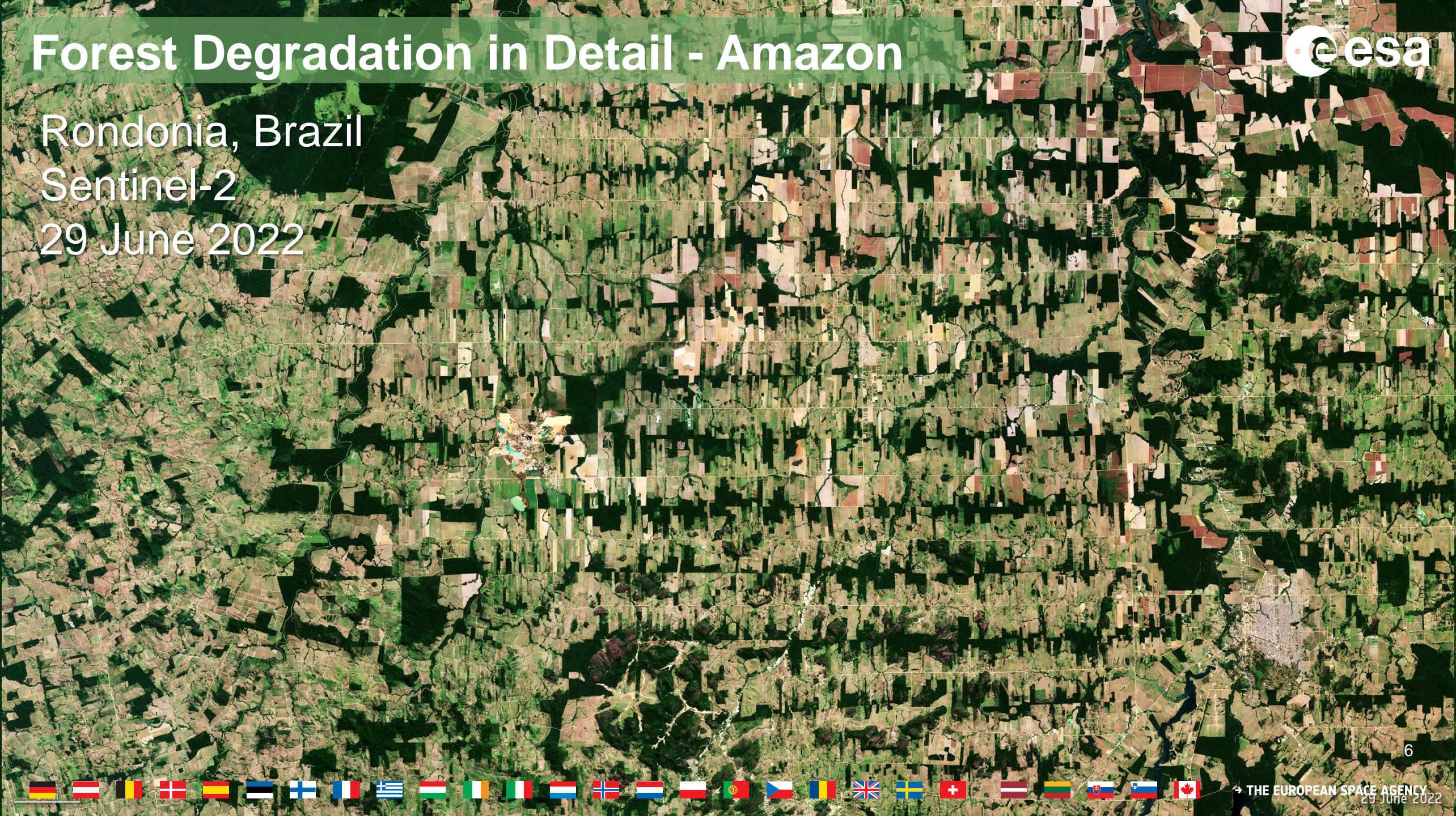
Kalimantan, Indonesia

Summer 2015

Sentinel-2A

Solimões River (Tefe Brazil) – source : Remembering the Amazon in flux | Science | AAAS

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October 8, 2023 (Landsat)

BRAZIL

Rio Negro

Manaus

Amazon River

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How to integrate EO data into decision making processes and address Global Agenda ?

- Attributes of EO: **global, transparent, independent, timely**

- Supporting of policies, in particular for

  - **policy analysis**,

  - **monitoring** and

  - **compliance** purposes

- **Collect and translate** policy needs into technical requirements for EO products and services

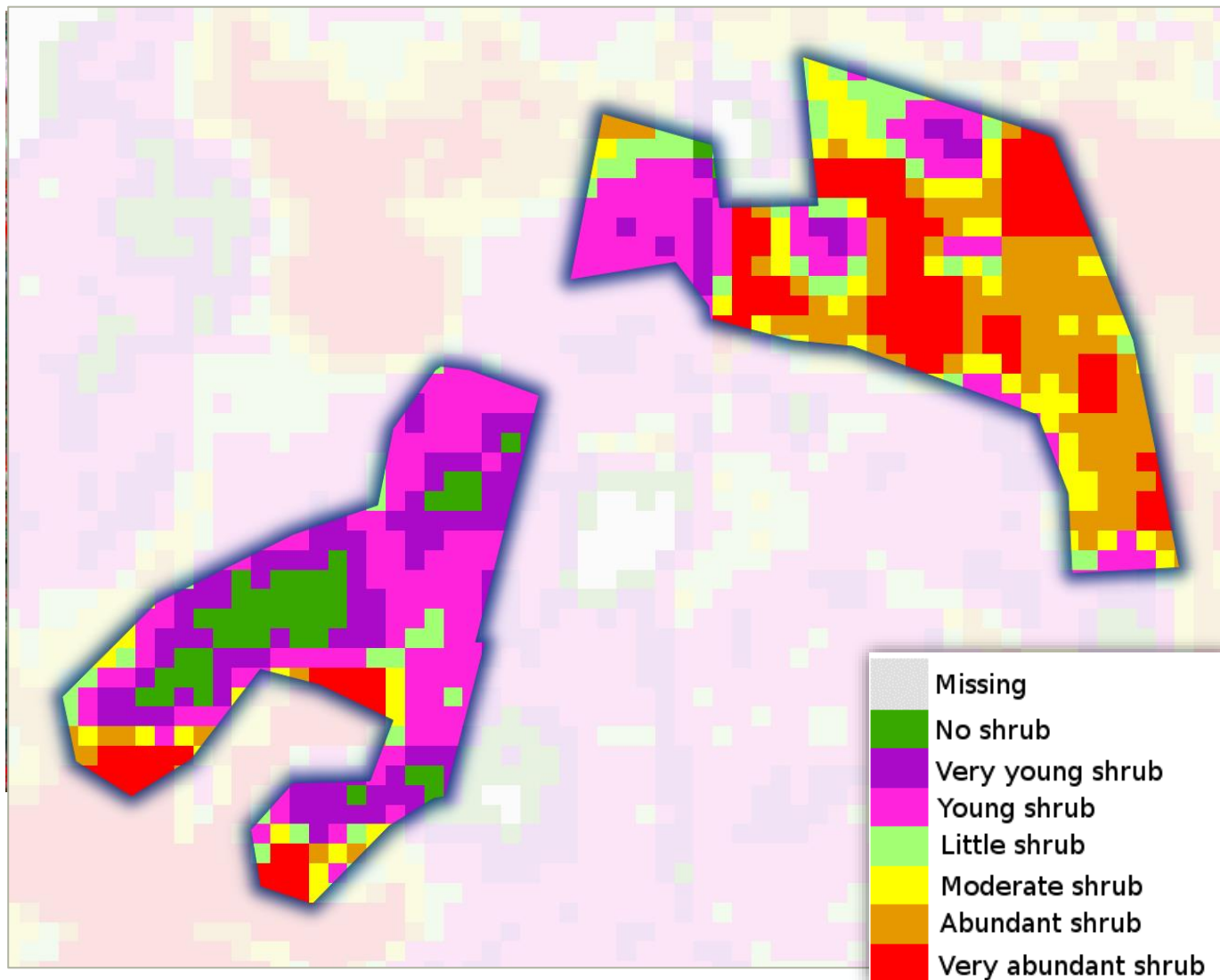- **Ensure** the delivery of concrete solutions or applications **meeting the policy needs**

Green Deal,
Forest Strategy,
Farm to Fork,
Biodiversity Strategy,
Bioeconomy Strategy,
FLEGT, …

→ **Importance of high quality EO value added products, to transfer data into information for decision maker**

https://eo4society.esa.int

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Information for Forest Management

Legend:
- Missing
- No shrub
- Very young shrub
- Young shrub
- Little shrub
- Moderate shrub
- Abundant shrub
- Very abundant shrub

Mapping of harmful broadleaved shrubs in forest regeneration areas based on Sentinel-2 data

- Production: VTT
- Customer: Finnish Forest Centre
- Impact: Operational use planned
- Article: Space helps forests regenerate

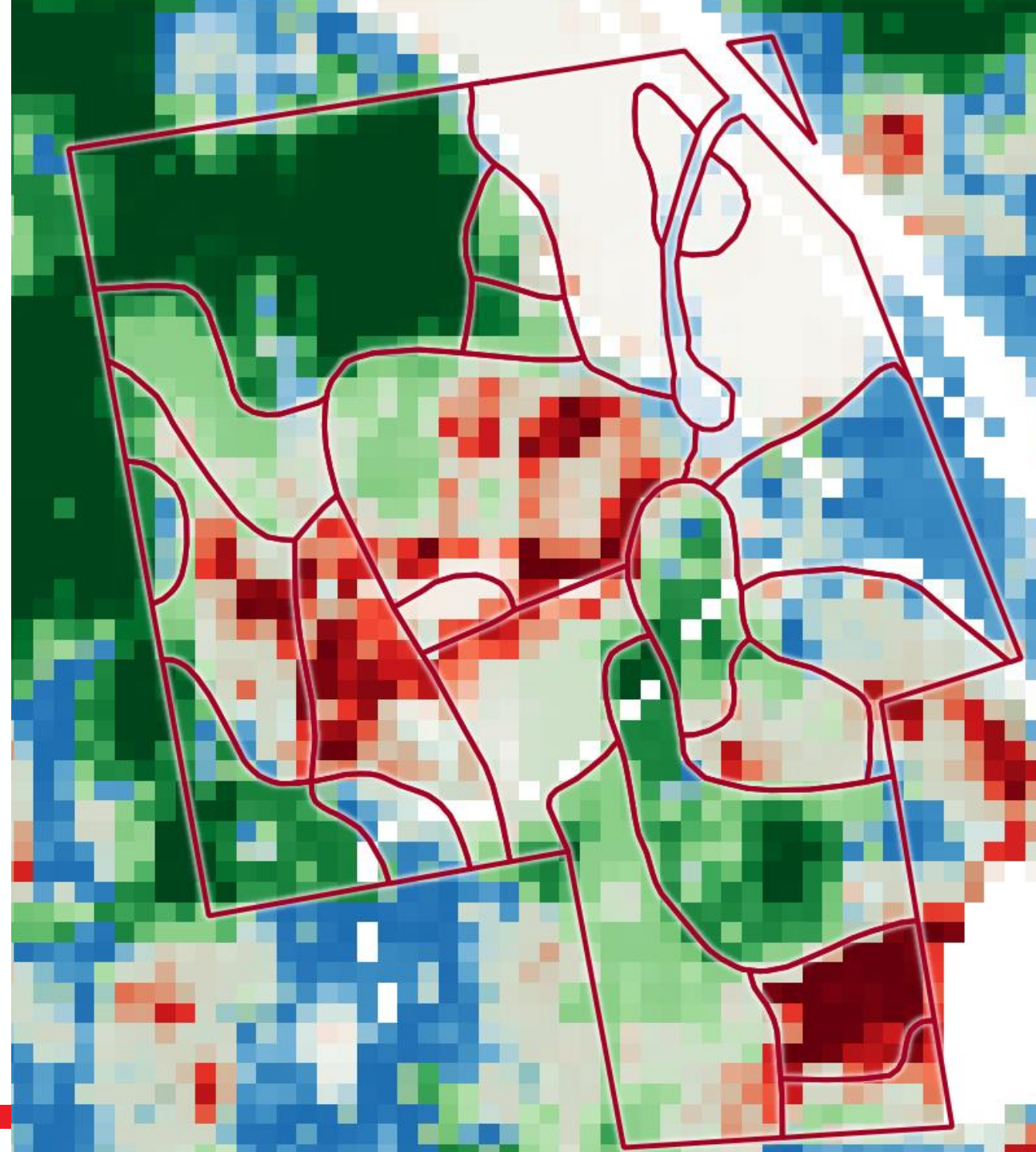*Image (left): detail - shrub abundance on two forest regeneration areas with stand borders*

https://f-tep.com/

Forest management-
Forest variable estimation

- Stem volume per species

Red = Broadleaved

Blue = Pine

Green = Spruce

https://f-tep.com/

Bark Beetle – Suspicious Areas

- Sentinel-2 scene from 28 September 2018
- Military training area Allentsteig

- Classification:
  RED = Suspicion for nests of bark beetles, Status: September 2018

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RADD (RAdar for Detecting Deforestation) Alerts - based on dense Sentinel-1 time series

Brazil –State of Parà
RADD Alerts
January 2020 – March 2024
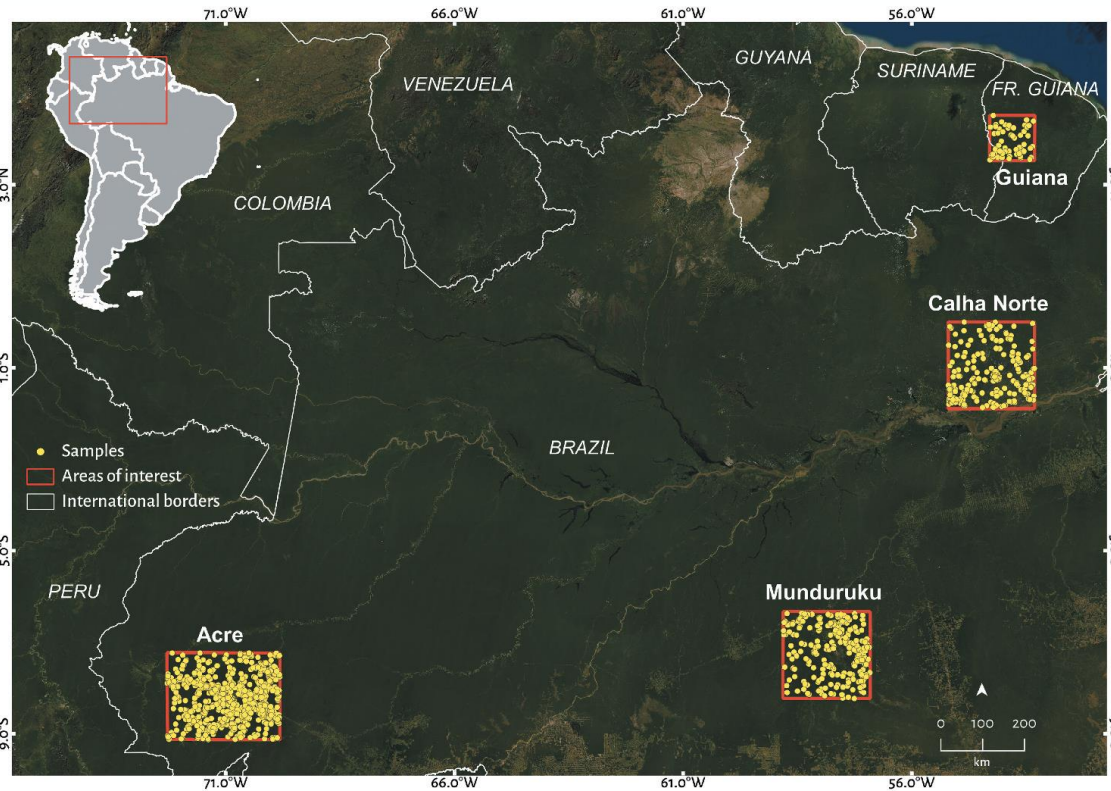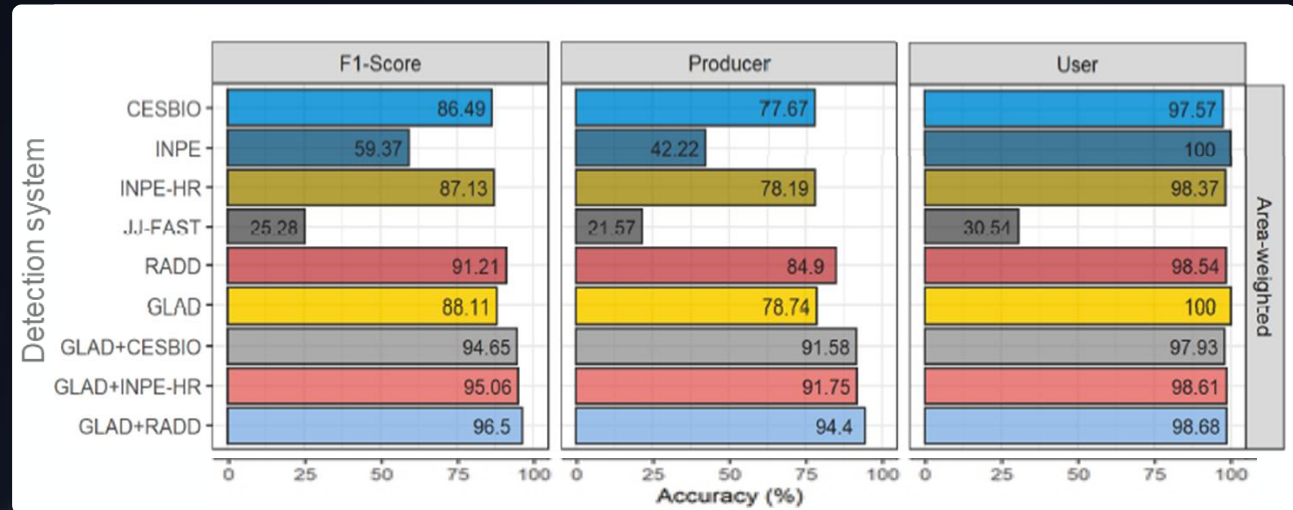Small scale forest clearing
and road development

http://radd-alert.wur.nl

WAGENINGEN
UNIVERSITY & RESEARCH

Reiche et al.(2021), ERL

Near Real Time Deforestation Alert System Comparison in the Amazon

Detection → **Analysis** → **Sharing** → **Law enforcement** → REPEAT

Results for 5 test areas across the Amazon Basin
(INPE, Doblas et al., 2023, IJRS)

Detection system	F1-Score	Producer	User (Area-weighted)
CESBIO	86.49	77.67	97.57
INPE	59.37	42.22	100
INPE-HR	87.13	78.19	98.37
JJ-FAST	25.28	21.57	30.54
RADD	91.21	84.9	98.54
GLAD	88.11	78.74	100
GLAD+CESBIO	94.65	91.58	97.93
GLAD+INPE-HR	95.06	91.75	98.61
GLAD+RADD	96.5	94.4	98.68

Accuracy (%)

Great value in alert integration

Integrating alerts leads to:

- Faster detection
- Higher confidence
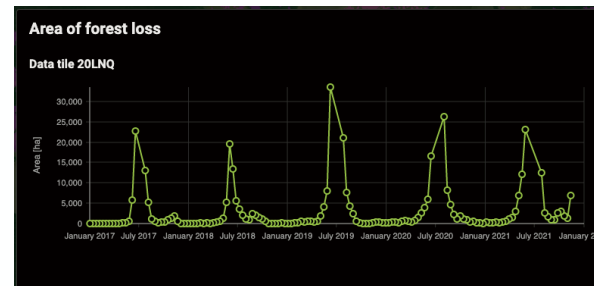- More resilience

Sentinel-1 for Science: Amazonas

Contributes to the ESA Carbon Science Cluster

Results

- Developed a Multi-temporal Change Detection (MCD) product from Sentinel-1 GRD
- Cross-validation with optical imagery (Planetscope)
- Pixel-wise confidence estimation
- Temporal coverage: 2017-2021
- Area: Amazon basin (5.2 mio. Ha)
- Spatial resolution: 20 m
- Open-Source algorithm and MCD product
- Implemented on CREODIAS
- Disseminated via open-access platform

https://sen4ama.gisat.cz/

Forest loss January 2017 - November 2021
250 km

Area of forest loss
Data tile 20LNQ

LAYERS
☑ Data tiles
☑ Confidence

Next Steps (2023-2025)

- Develop a transparent and user-independent validation methodology: automatic validation based on GFW alerts, and vegetation indices from Sentinel-2

- Estimate carbon loss from deforestation using ESA CCI Biomass 2020 product

- Improve scalability of MCD implementation – spatio-temporal AI/ML approach (U-NET CNN + convolutional LSTM)

- Expand spatial coverage: Mexico, West Africa

- Implement on **openEO Platform**

- Disseminate algorithm as openEO Process Graph

- Disseminate dataset as openEO collection and via **Open Science Data Catalogue**

EO OPEN SCIENCE

Estimating Carbon Loss Using Sentinel-1

"Sentinel-1 for Science: Amazonas" is an exploratory scientific project, funded by the European Space Agency (ESA), looking to assess how Sentinel-1 imagery can be used to **estimate forest carbon losses associated with land use and land cover changes in the entire Amazon basin**.

The Sentinel-1 for Science: Amazonas project presents a simple and transparent approach to **using Sentinel-1 satellite radar imagery to estimate forest loss**. The project uses a space-time data cube design (also known as StatCubes), where statistical information relevant to identify deforestation is extracted at each point in the radar time-series.

https://sen4ama.gisat.cz/

The team were able to detect forest loss of over 5.2 million hectares from 2017 to 2021, which is roughly the size of Costa Rica.

Amazon basin dynamic deforestation product, from Sentinel-1 time series

- Estimate Carbon loss from LULC (mainly forest loss)
- 5 years of data: 2017-2021
- Continental scale processing on CREODIAS (1 run in 48h)
- Sentinel-1 Forest loss Estimation
- **20 m scale, Openly available product**
- Time series of forest loss evolution
- Confidence layer (0-100%) for the detection of loss

Forest loss
January 2017 - November 2021

250 km

Forest loss
Tile 20LMQ

Chart: ESA • Source: S14Science Amazonas • Created with Datawrapper
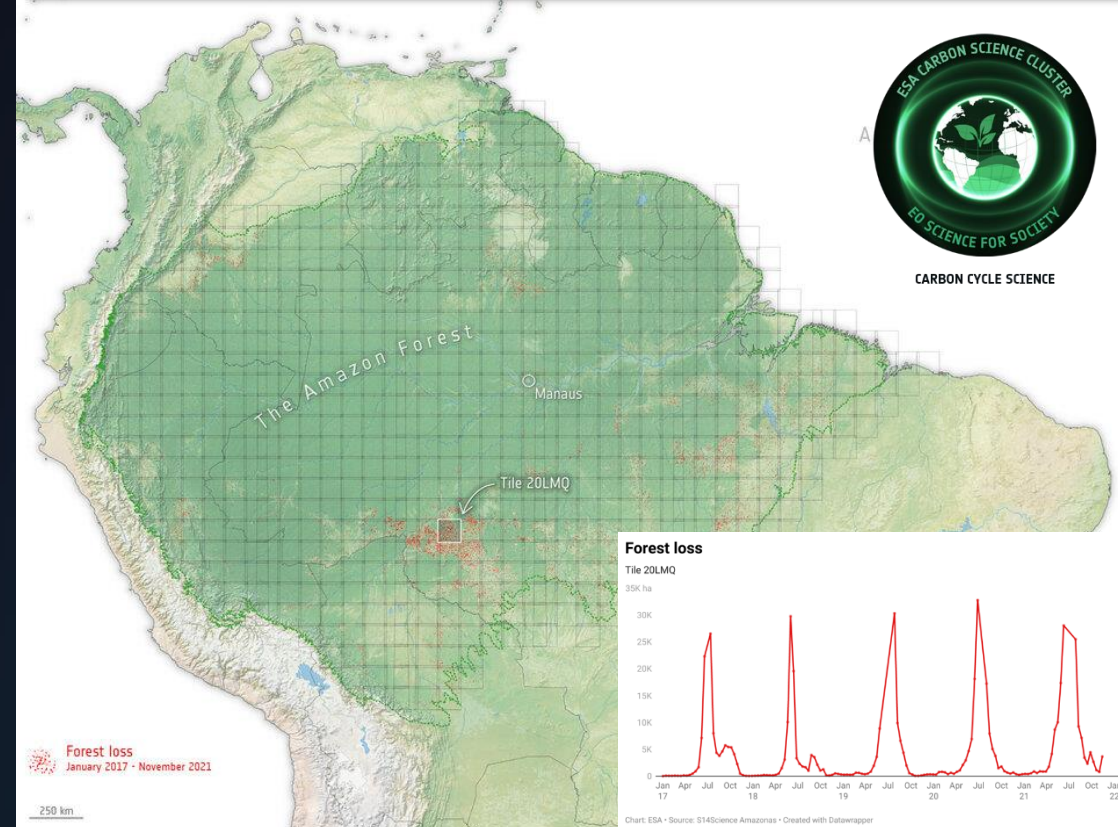
Climate Change and Land Cover Change Are Intimately linked

- Forest degradation has become the largest process driving carbon loss

- Net loss of 0.67 Pg C of above ground biomass over the last decade in the Brazilian Amazon

- Study uses LVOD from SMOS L-VOD

- Relevant for REDD+ and Paris

- Study undertaken via CCI's RECCAP-2 project which uses multiple ECV datasets to derive regional carbon budgets and their drives

Map credits: ESA/CCI Biomass project and Hansen/UMD/Google/USGS/NASA

Global Monitoring of land cover/use dynamics

Global land cover: WorldCover 2020/21 (ESA)

- 10x10 meters, fast generation (~8 months), 11 classes
- Independent validation: ~75% Accuracy
- Open data: **https://viewer.esa-worldcover.org/worldcover/**

Copernicus global land cover service (since 2015)

- 100x100m resolution,
- land cover and fractions
- Available until 2019, continuation starts soon
- Open data: https://land.copernicus.eu/global/products/lc

WORLDCOVER 2020 – 10 m

Tree cover | Shrubland | Grassland | Cropland | Built-up | Bare / sparse | Snow and ice | Permanent water | Herb. wetland | Mangroves | Moss & lichen
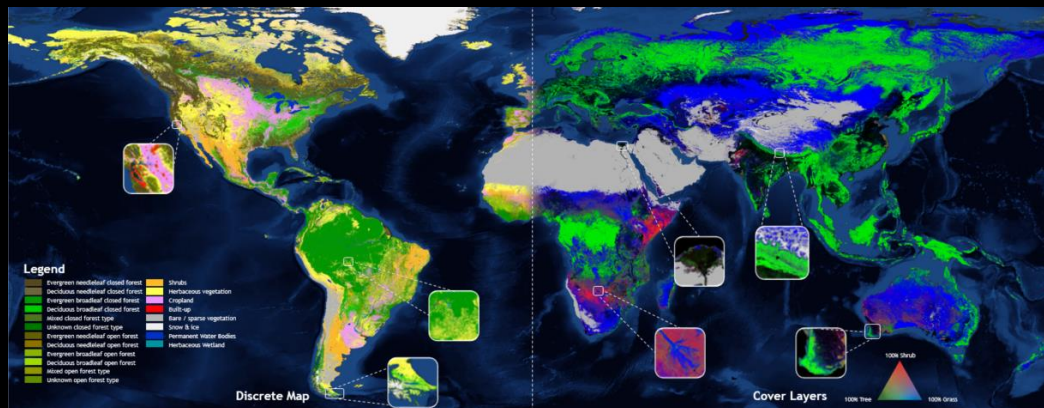
© ESA WorldCover project 2020 / Contains modified Copernicus Sentinel data (2020) processed by ESA WorldCover consortium
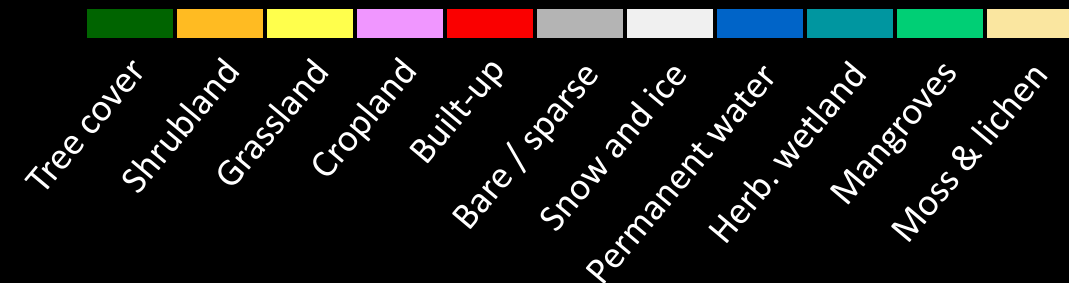
Biomass from Space

- Version 4 with global maps from 2010, 2017, 2018, 2019 and 2020 in cooperation with

JAXA

biomass cci

Consistency: a decade of change

Forest above ground biomass (tonnes/ha) – 2018

0   100   200   300   >350

Land use following tropical deforestation
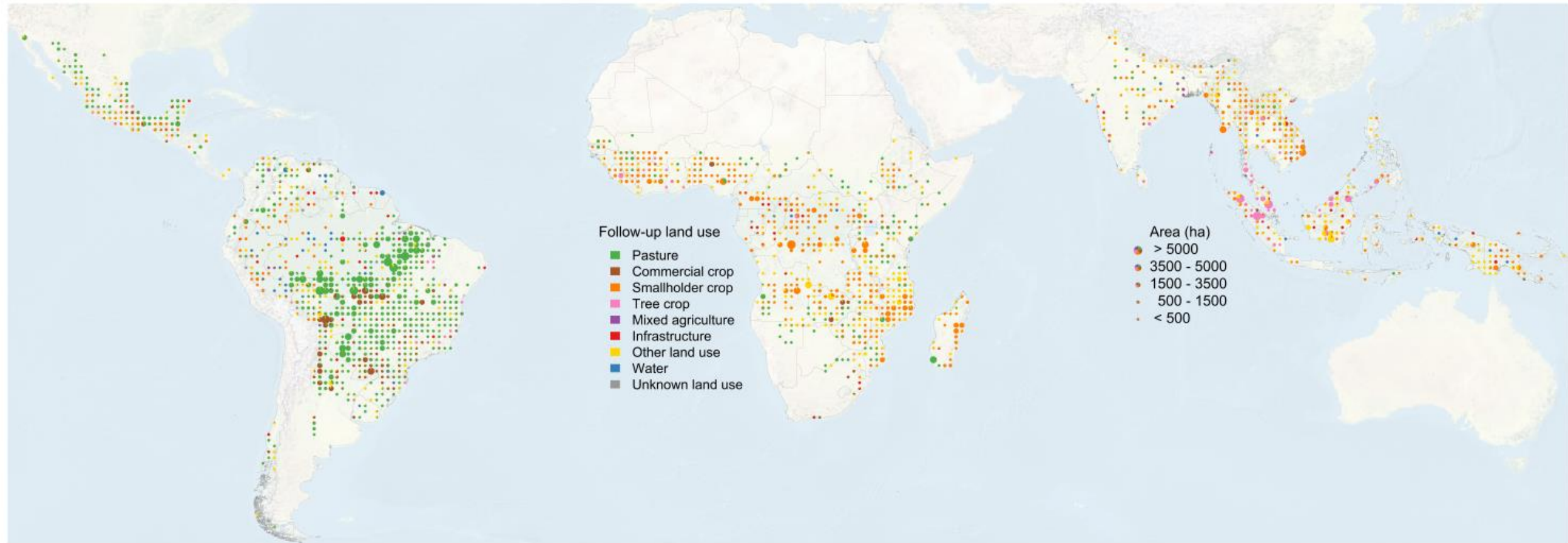
De Sy et al., 2019, Tropical deforestation drivers and associated carbon emission factors derived from remote sensing data, ERL

Recovering Forests (Study within CCI RECCAP2 led by INPE & Uni. Bristol)

3 km

1985

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- International collaboration to:
  - foster sustained availability of satellite and ground observation in support of national forest information systems

  - support countries in the use of observations for their national forest information systems

Supporting National & international Obligations under UNFCCC

Some areas on Earth have greater uncertainty about current and projected emissions of GHGs than others: The Amazon is one of them.

➔ Setting up a **large-scale field experiment**, to bring together a complete suite of observations an models to better understand the spatio-temporal variation in carbon stocks and fluxes associated with different land cover types

➔ Measure relevant parameters by **combining ground based** (proximal sensing + in-situ) **and airborne systems** (remote sensing + in-situ)

➔ **Activity to start in 2024** in very close collaboration with Brazilian partners (INPE leads) and selected partners in Europe
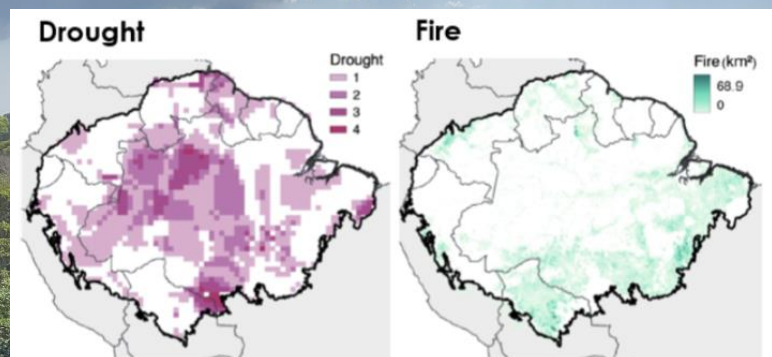
Fawcett et al., 2022

LBA KM67 site

Take home message: EO applications in forestry

- Sustainable forest management
- Illegal logging
- Forest health
- Insect infestation
- Storm damage
- Forest certification
- Forest fires & burned area
- Forest restoration
- Biomass and -energy
- Carbon accounting
- Sustainable supply chains
- Climate change mitigation – REDD+
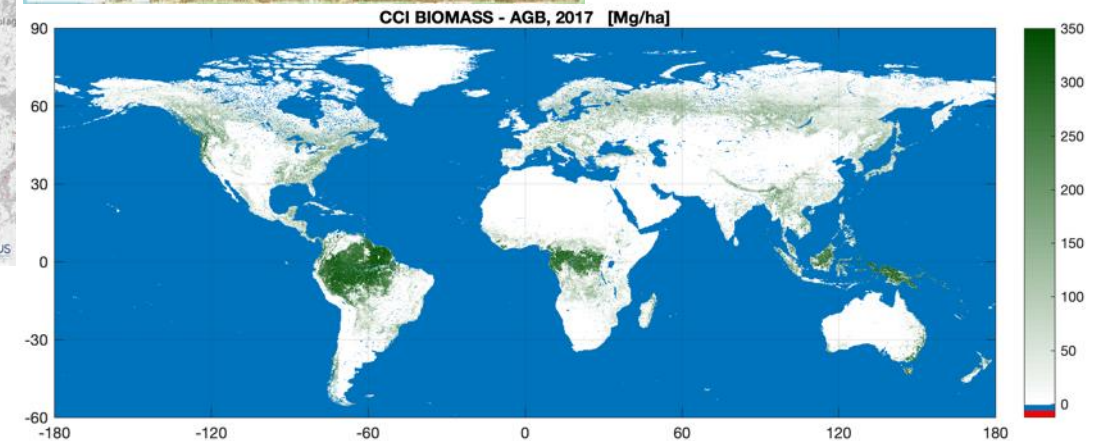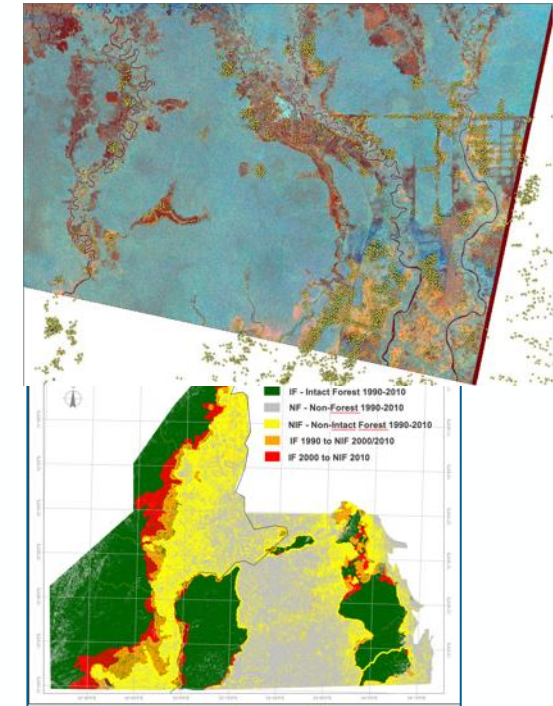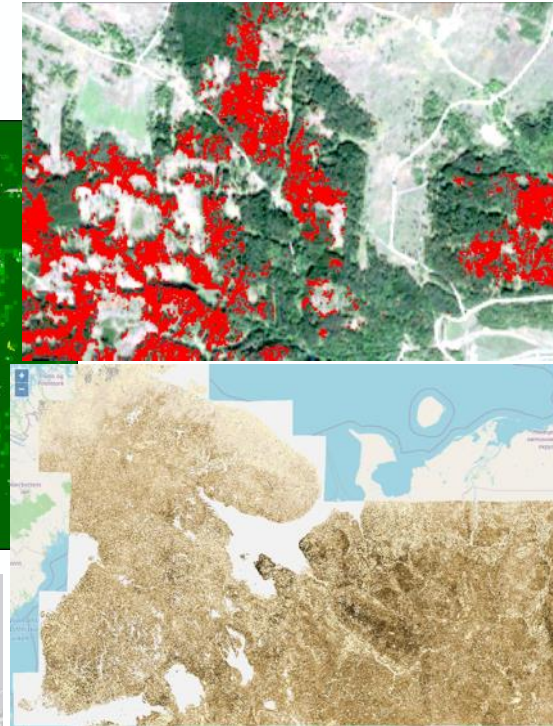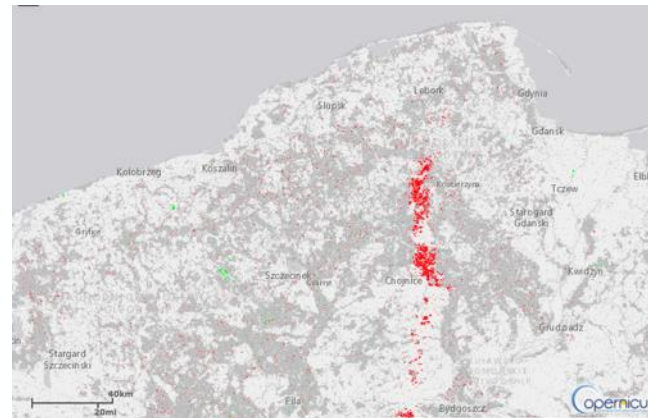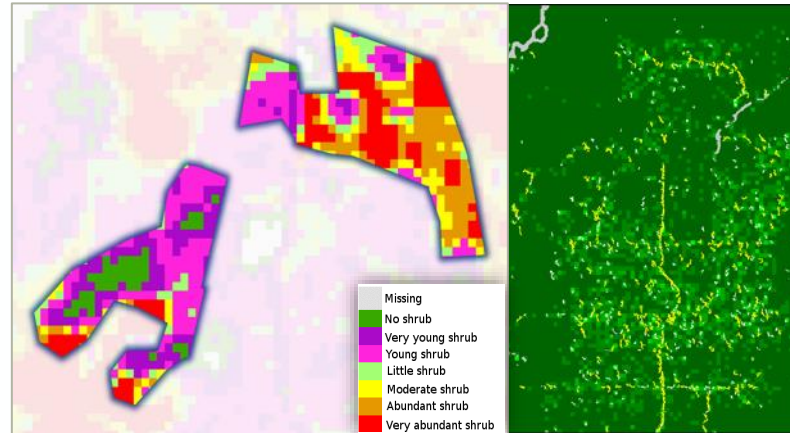
Take home message: EO forestry and ESA role

Support for sustainable Forest Management

→ ESA programs and EO missions provide critical data for monitoring forest health, biomass, and carbon storage, aiding sustainable forestry practices globally

Promote Global Collaboration for Forest Conservation:

→ ESA contributes to forest conservation efforts and helps nations achieve environmental and climate goals, through partnerships with international organizations and other space agencies

Data-Driven Decision Making:

→ ESA's data supports policymakers and forest management entities in designing effective conservation strategies, aiding climate adaptation and biodiversity preservation

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Summary

I) – Projects and initiatives for Forestry

II)- Tools, EO platforms and opportunities

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SOFTWARES

PolSARPro

What is PolSARpro?

- Developed by the Institute of Electronics and Telecommunications of Rennes (IETR) under ESA-ESRIN contracts

- educational software for self-learning in Polarimetric SAR (PolSAR) data analysis
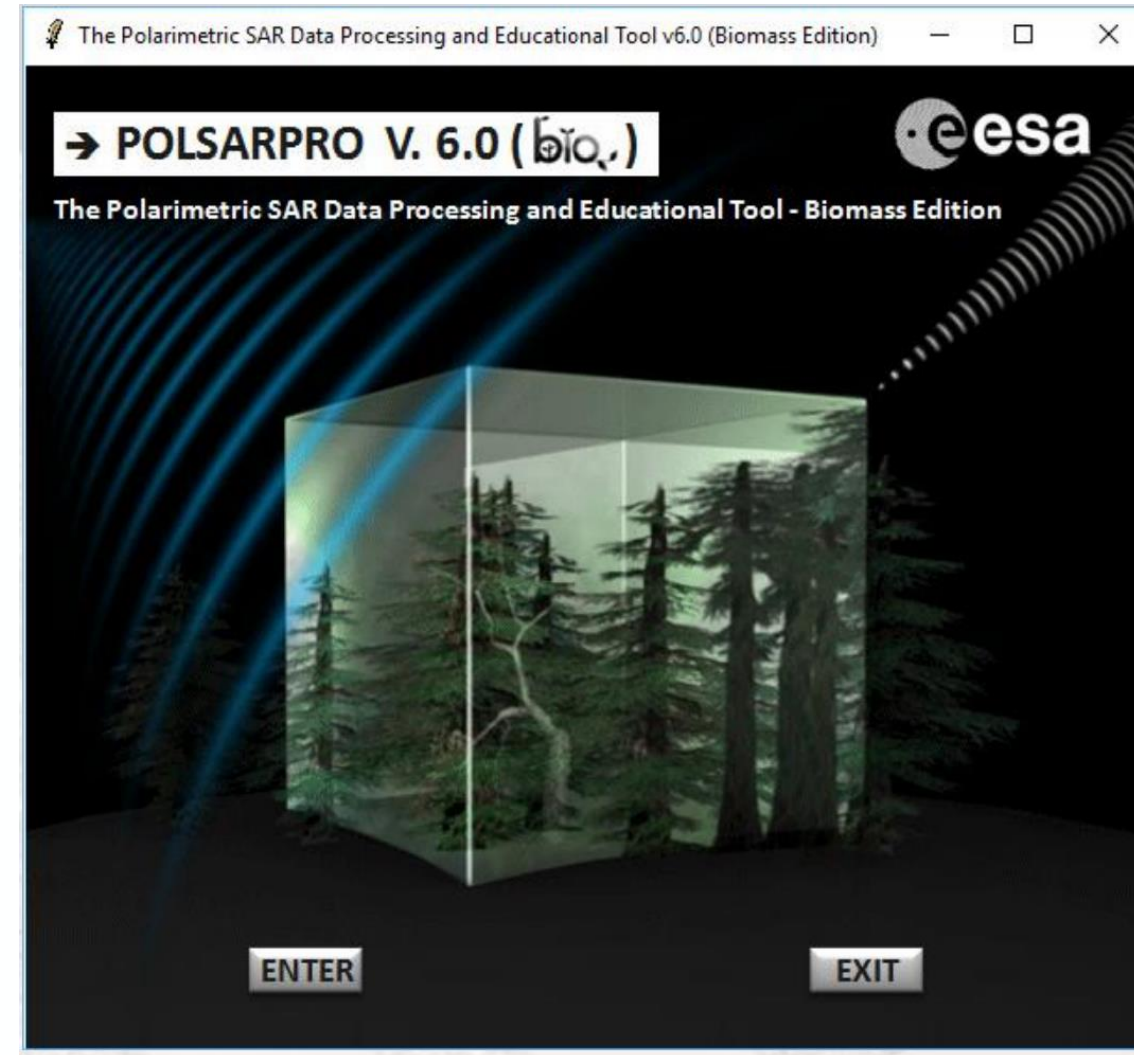
Main Features:

- Large collection of established algorithms/decomposition and tools for PolSAR analysis
- Supports scientific research using Pol-SAR, Pol-InSAR, Pol-TomoSAR techniques.
- It is a Complete end-to-end processing interface—no additional software needed

Integration and Compatibility:

- Compatible with major polarimetric missions (spaceborne and airborne)

Being transferred in Python through an ESA project

SNAP

→ SNAP | Sentinels Application Platform

Reading module storage...

esa
seom
scientific exploitation
of operational missions

Download it at
step.esa.int

SNAP forum
forum.step.esa.int

SNAP

Optical Toolbox

Microwave toolbox

SMOS toolbox

✓ Free and open source software

✓ Common Java core framework

✓ Joint development of SNAP platform for Sentinel and other toolboxes

✓ Interchangeable Java/Python plugins

✓ Portable engine to Cloud infrastructure

✓ User friendly: single installation, intuitive GUI, online help, tutorials, active user forum
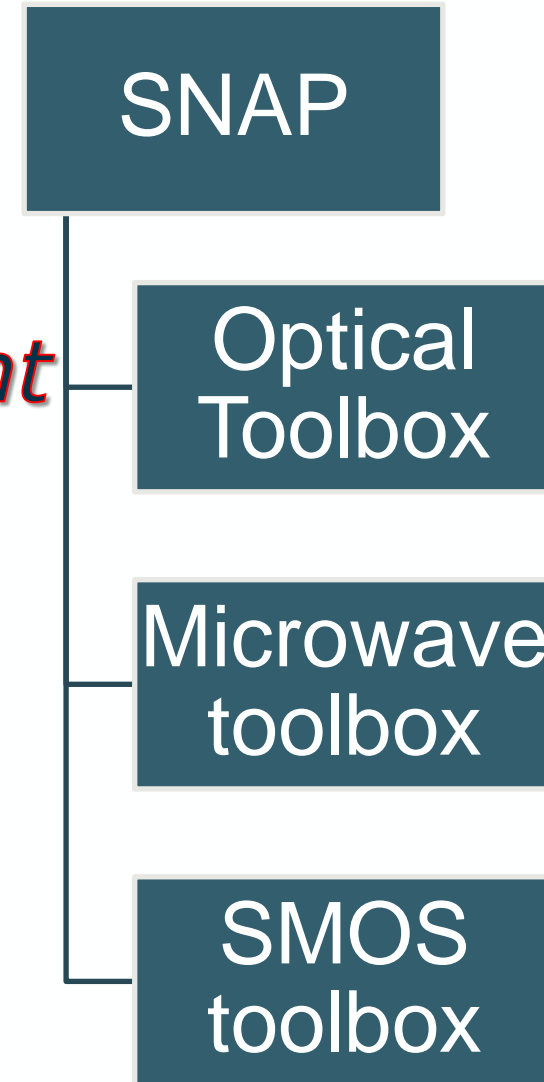
SNAP cumulative download by month and OS
(2015/06/15 – 2024/09/30)

SNAP cumulative download stats by month and OS

SNAP downloads exceeded 1´490´000 from June 2015 until today
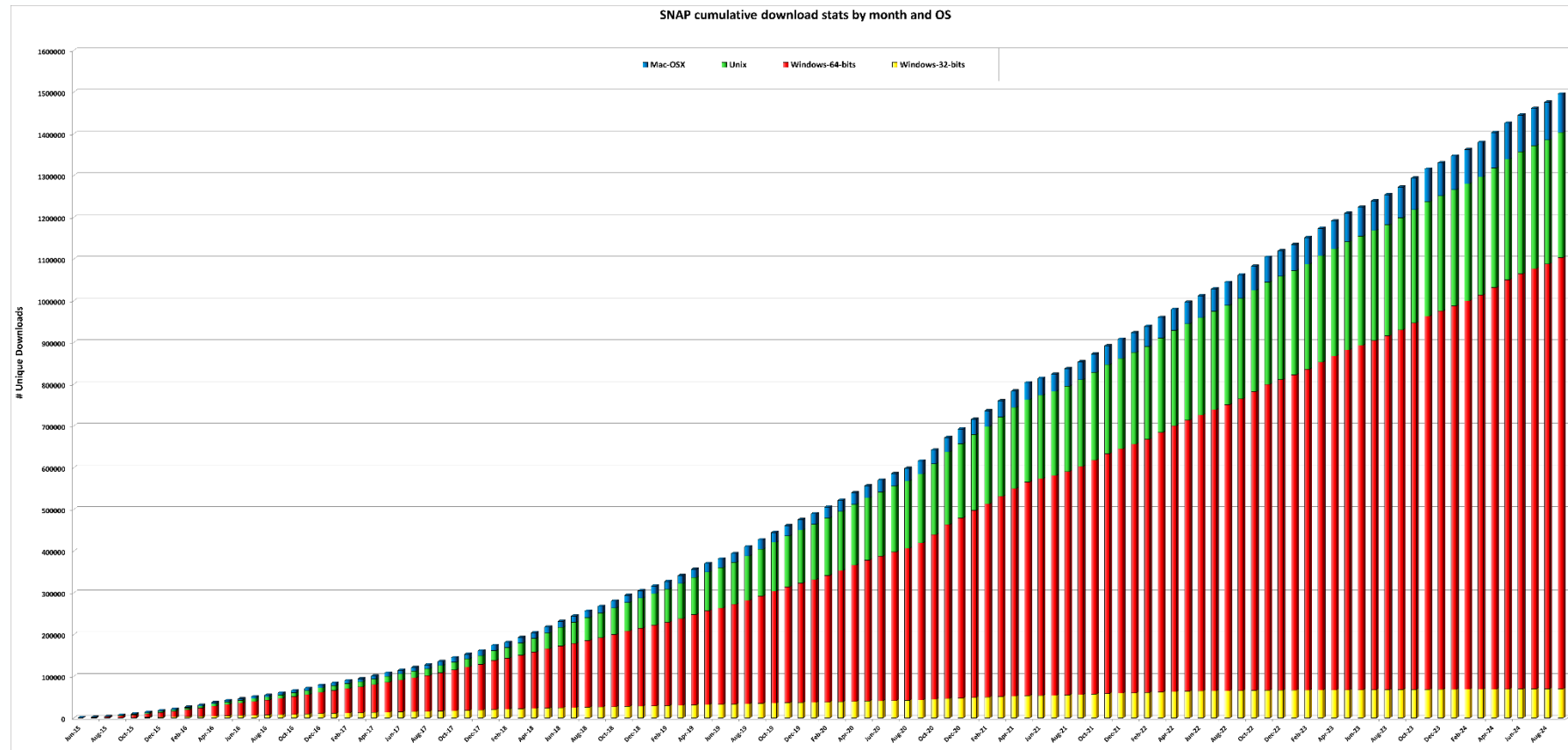
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World Map of visits on STEP
(2015/06/15 – 2024/09/30)

2.2m visits

	1
	41.3k
	138.3k
	471.9k
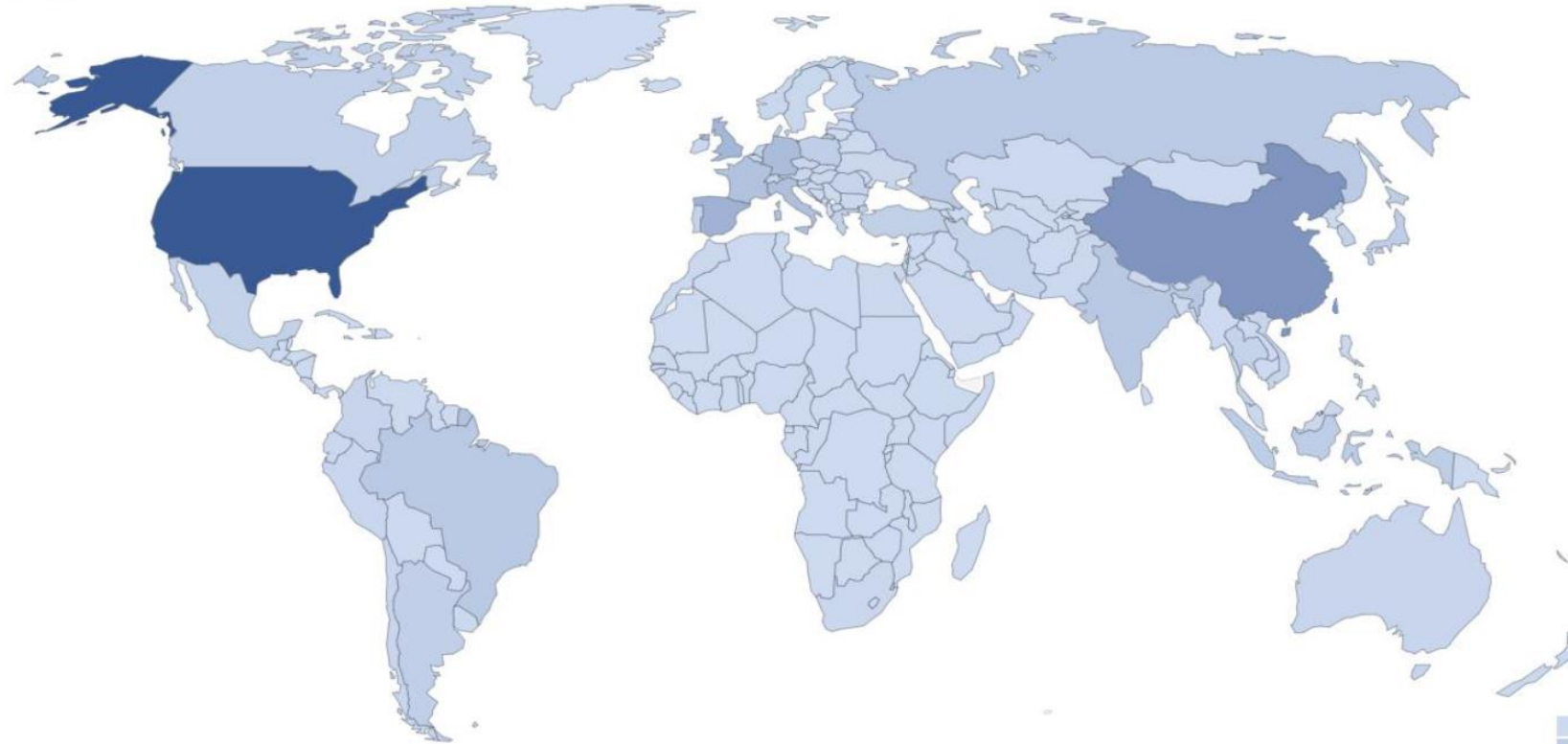
STEP Forum
✓ *Since June 2015 STEP website exceeded **2˙190˙000** visit sessions*
✓ ***13˙181** discussion topics have been created, with a total of **89'165** posts since 15/06/2015*
✓ *During September 2024, **73** new users on the forum, with **294** "active/reading users" and **91** "posting users"*

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SNAP & SAR
(Microwave Toolbox)

Sentinel-1   ENVISAT   ERS-1   TerraSAR-X   RADARSAT   KOMPSAT-5   ALOS 1&2   ICEYE   COSMO-SkyMed
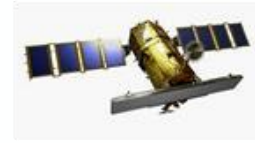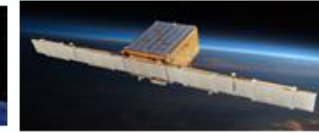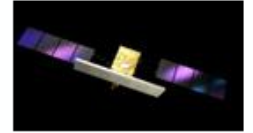
Main features:

- ✓ Absolute calibration, Multilooking, Speckle filtering, Precise orbits handling
- ✓ Coregistration of detected and complex products
- ✓ Full support of Sentinel-1 TOPS interferometry, debursting, slice assembly
- ✓ Terrain Correction
- ✓ SAR simulation and Layover and shadow masks
- ✓ Applications: oil spill detection, ship detection, wind field estimation etc.
- ✓ Fully integrated and featured InSAR tools for Stripmap and Zero-Doppler focused data
- ✓ Compatibility with PolSARpro Toolbox (Reader, Writer)
- ✓ Integrated Export to SNAPHU (interferometric phase unwrapping) and STAMPS (PS InSAR)

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SNAP & Optical HR
(Optical Toolbox)

Sentinel-2 · SPOT · Pleiades · Landsat · ALOS AVNIR · RapidEye · Kompsat · Ikonos · Worldview ......

Main features:

➤ **Sen2Cor** and **i-Cor** for Atmospheric Correction

➤ L2B **biophysical processor** (LAI, fAPAR, …)

➤ Reflectance to Radiance Processor

➤ **Radiometric Indices**

  ✓ *Vegetation indices:* DVI, RVI, PVI, IPVI, WDVI, TNDVI, GNDVI, GEMI, ARVI, NDI45, MTCI, MCARI, REIP, S2REP, IRECI, PSSRa

  ✓ *Soil indices:* SAVI, TSAVI, MSAVI, MSAVI2, BI, BI2, RI, CI

  ✓ *Water indices:* NDWI, NDWI2, MNDWI, NDPI, NDTI

➤ **IdePix Processor:** pixel classification

➤ **OTB tools:** Pansharpening, Rasterization, Segmentation, …

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SNAP & Optical/Thermal MR
(Optical Toolbox)

Sentinel-3   ENVISAT   ERS   Proba-V   SPOT VGT   MODIS   AVHRR   VIIRS   ......

Main features:

- Visualizing spectrum of pixels
- **Uncertainty** visualization and propagation of uncertainty in BandMaths
- Pixel extraction tool
- Specific sensor processors:
  - ✓ *S3 OLCI Radiometry, S3 SLSTR PDU stitching*
  - ✓ *AATSR/SLSTR Regridding*
  - ✓ *Performs radiometric corrections on MERIS*
- Optical water type classification based on atmospherically corrected reflectances
- FU (Forel-Ule) Classification used to derive the hue angle and FU value
- **IdePix Processor:** pixel classification
- FLH (Fluorescence Line Height) / MCI (Maximum Chlorophyll Index) retrieval
- FUB/WeW processor

SNAP cumulative download by month and OS
(2015/06/15 – 2024/09/30)

SNAP cumulative download stats by month and OS

Legend: Mac-OSX, Unix, Windows-64-bits, Windows-32-bits

SNAP downloads exceeded 1˙490˙000 from June 2015 until today

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EO Platforms

Platforms – Bring the People to the Data!
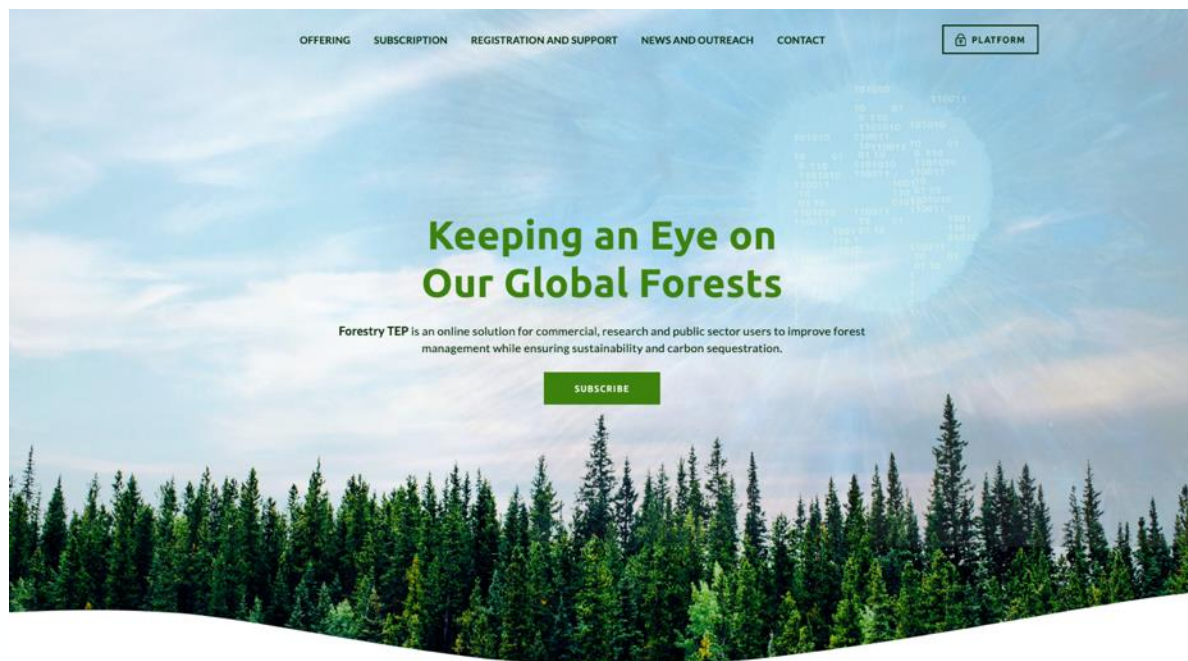
One-stop shop for forestry remote sensing services for the academic, public and commercial sectors.

http://f-tep.com

https://youtu.be/KLQ1ot3FY_E
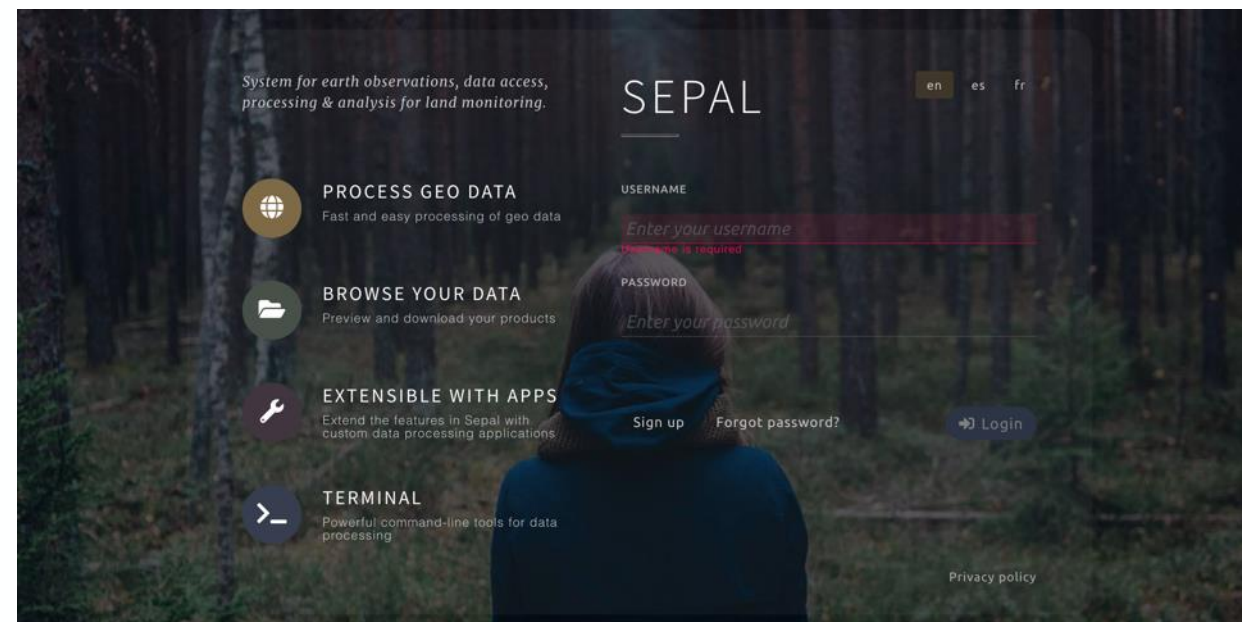
System for Earth Observation, Data Access, Processing and Analysis for Land Monitoring

Part of the geospatial tools OpenForis at FAO

http://sepal.io

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Network of Resources today ...   https://nor-discover.org/
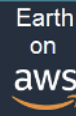
Explore the Copernicus Data Space Ecosystem

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. Delve into the data via the Copernicus Browser and register to create an account and have an even better comprehensive exploration experience.

EXPLORE THE COPERNICUS BROWSER ⧉
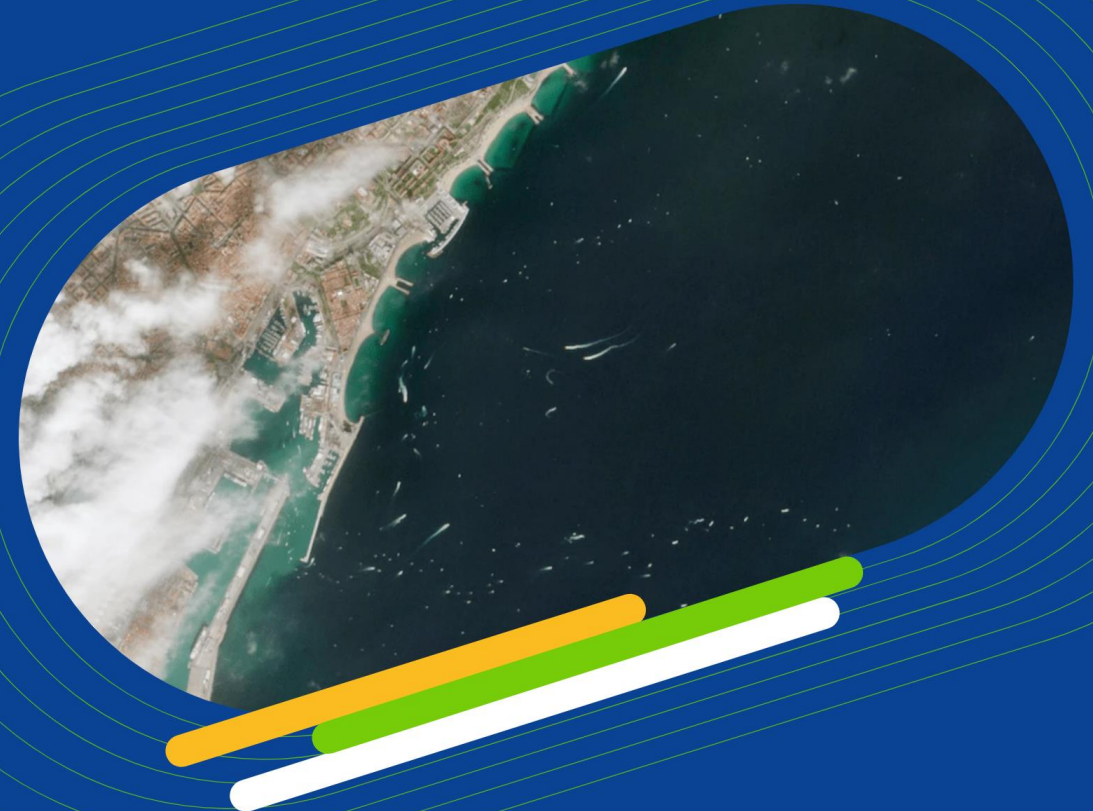
Tools and opportunities in the frame of the BIOMASS Mission

1. Open-source Processors

Open source

Today:
Level-2 prototype algorithms

Tomorrow:
Level-1 (as much as possible), Level-2 and Level-3 operational algorithms, other open-source algorithms (Tomo, DTM, etc.)

biopal@esa.int

biopal.org

github.com/BioPAL

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2. GEO-TREES: open forest biomass reference sites

GEO-TREES consists in a collection of permanent, well-studied, and locally supported sites to support the Cal/Val of the BIOMASS (but also GEDI and NISAR) missions

Sites for validation must be extensive, and cover a range of forest types: tropical, temperate and boreal.

Each site should have:

1. At least 10 1-ha permanent forest plots – established to the highest forest monitoring standards
2. At least 1000 ha of Airborne Lidar Scanning coverage
3. The capacity for Terrestrial Lidar Scanning
4. The capacity to remeasure plots
5. Ancillary data (weather)
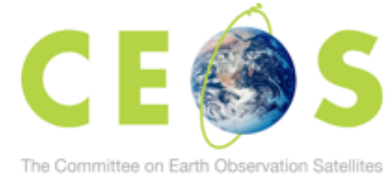
> *Following the CEOS WGCV LPV Above Ground Biomass Validation Good Practices*

43

3. "Mission Algorithm and Analysis Platform"

→ *It's a Virtual open and collaborative environment that…*

Baseline for future ESA missions!

Enables researchers to easily discover, process, visualize, and analyze large volumes of data.

Provides tools and infrastructures to bring data into the same coordinate reference frame to enable comparison, analysis, data evaluation, and data generation.
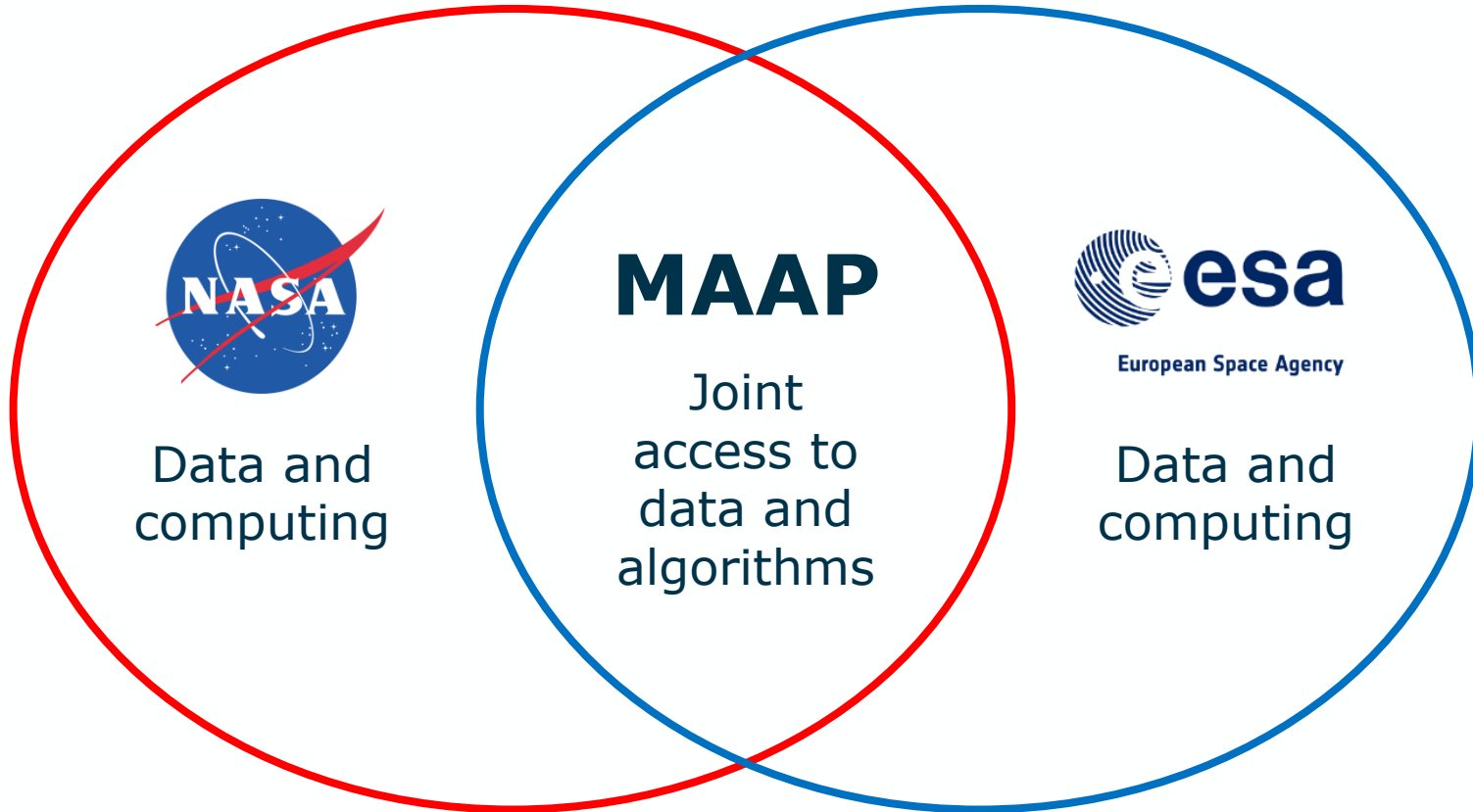
Provides a version-controlled science algorithm development environment that supports tools, co-located data, and processing resources.

Addresses intellectual property and sharing issues related to collaborative algorithm development and sharing of data and algorithms.
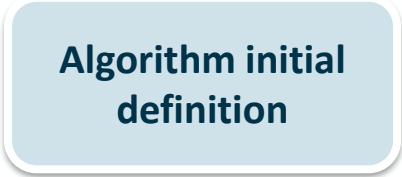
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ESA-NASA Multi-Mission Algorithm and Analysis Platform

Unified user access to the functions of joint ESA-NASA MAAP

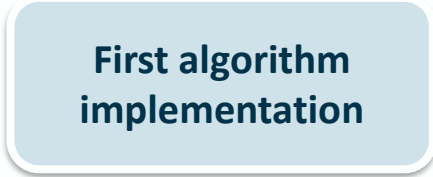**NISAR** — NASA - ISRO SAR Mission

GEDI — ECOSYSTEM LIDAR

NASA — Data and computing

MAAP — Joint access to data and algorithms

esa — European Space Agency — Data and computing

biomass

Up to date data and algorithms + Collaborative community

→ THE EUROPEAN SPACE AGENCY
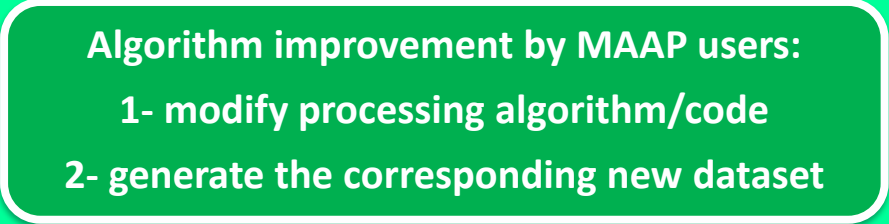
ESA: Product Algorithm Laboratory

New approach!

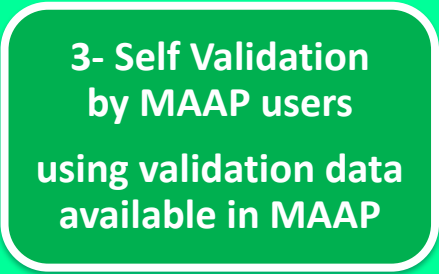Algorithm initial definition → First algorithm implementation →

Algorithm improvement by MAAP users:

1- modify processing algorithm/code

2- generate the corresponding new dataset

4- Verification and approval of new official dataset

3- Self Validation by MAAP users

using validation data available in MAAP

Mission Algorithm and Analysis Platform (MAAP)

➤ *Processing algorithms evolution is easier as the development and implementation are made within the same environment*

➤ *Allow to arrive faster to stable algorithms for R&D missions on a user cooperative approach*

➤ *People outside the core science team can contribute to the product improvement cycle*

Concepts of "Open Science" → *Well adapted to R&D EO missions*

Living Planet Fellowship

Supporting young scientists to undertake cutting-edge research in EO, Earth System Science or Climate Research

Co-funded 2-year post-doctoral full-time projects proposed by new scientists through their Host Organisation

https://eo4society.esa.int/communities/scientists/living-planet-fellowship/

Last update: 2021

EOP-SD

LIVING PLANET FELLOWSHIP

17/09/2021

47

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Thanks for your attention!

https://eo4society.esa.int

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