Earth Intelligence for Land Use and Sustainability

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What will we talk about

- Who I Am
- The Era of Big Satellite Data
- AI and Machine Learning on Satellite Data
- NASA And ESA ML Products on Satellite Data
- Digitalization of the Economy - a View from the Satellite
- ML&AI for Forest Monitoring
- ML&AI for Agri Monitoring
- ML&AI for war impact assessment

Who I am

2024 University of Maryland

NASA Harvest program

2021-2023 НТУУ «КПІ імені Сікорського»

Dept of Math Modelling and Data Analysis

1996-2020 Space Research Institute NASU

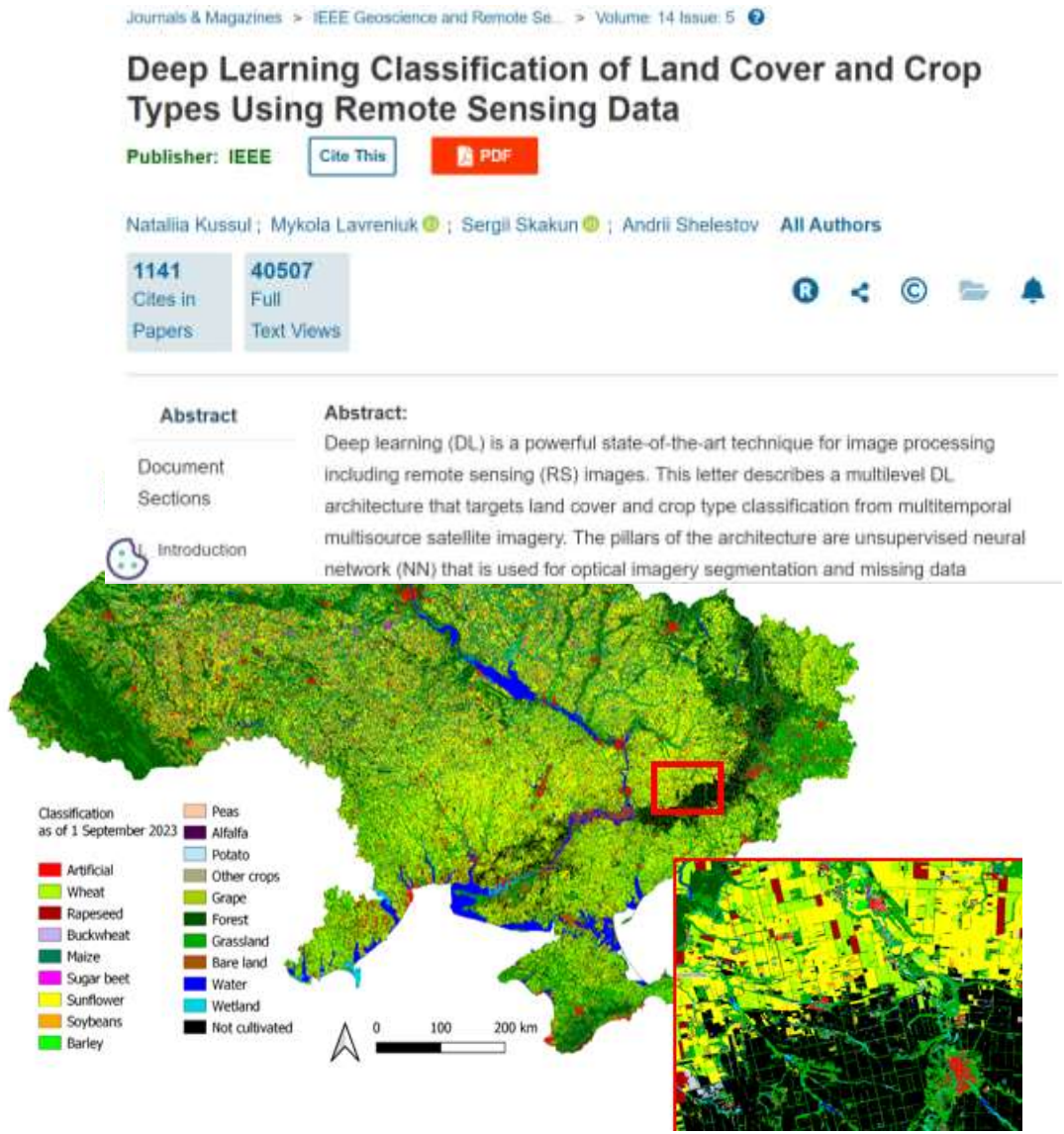
Dept of space technologies and systems

My expertise

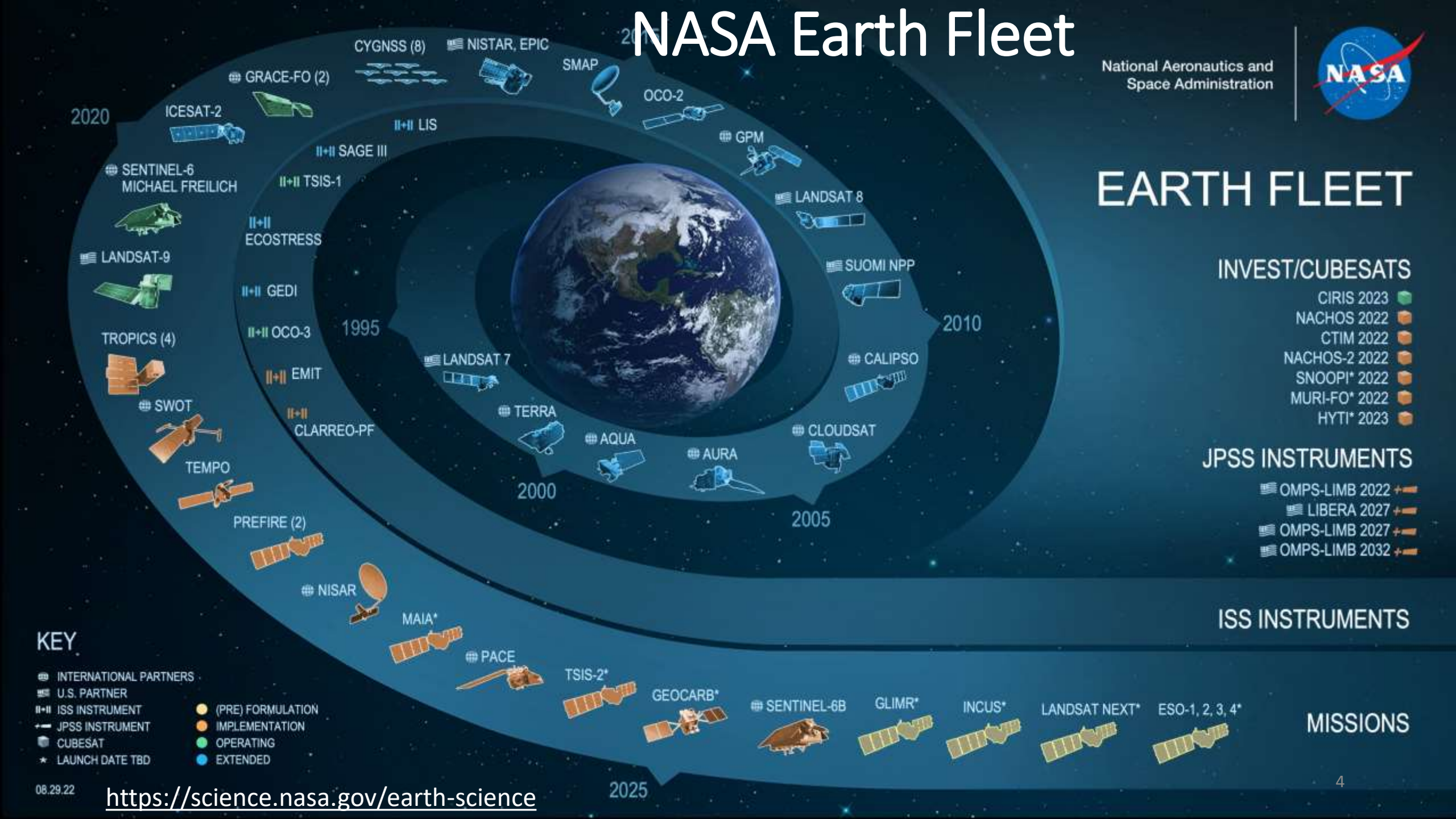
Machine learning on satellite data

Land cover/land use

Earth intelligence



NASA Earth Fleet



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

ESA Earth observation missions

Earth observation data and services market

https://www.euroconsult-ec.com/press-release/global-market-for-commercial-earth-observation-data-and-services-to-reach-7-6-billion-by-2032/

GEO (Group on Earth Observation)

The Group on Earth Observations (GEO) is an intergovernmental partnership established in 2005 that facilitates open access to Earth observation data, develops services, and **coordinates the enhanced use of Earth observation for the benefit of society**.

GEO is a unique global network connecting government institutions, academic and research institutions, data providers, businesses, engineers, scientists and experts to create innovative solutions to global challenges at a time of exponential data growth, human development and climate change that transcend national and disciplinary boundaries.

https://earthobservations.org/

GEO's Evolution

2005-2015

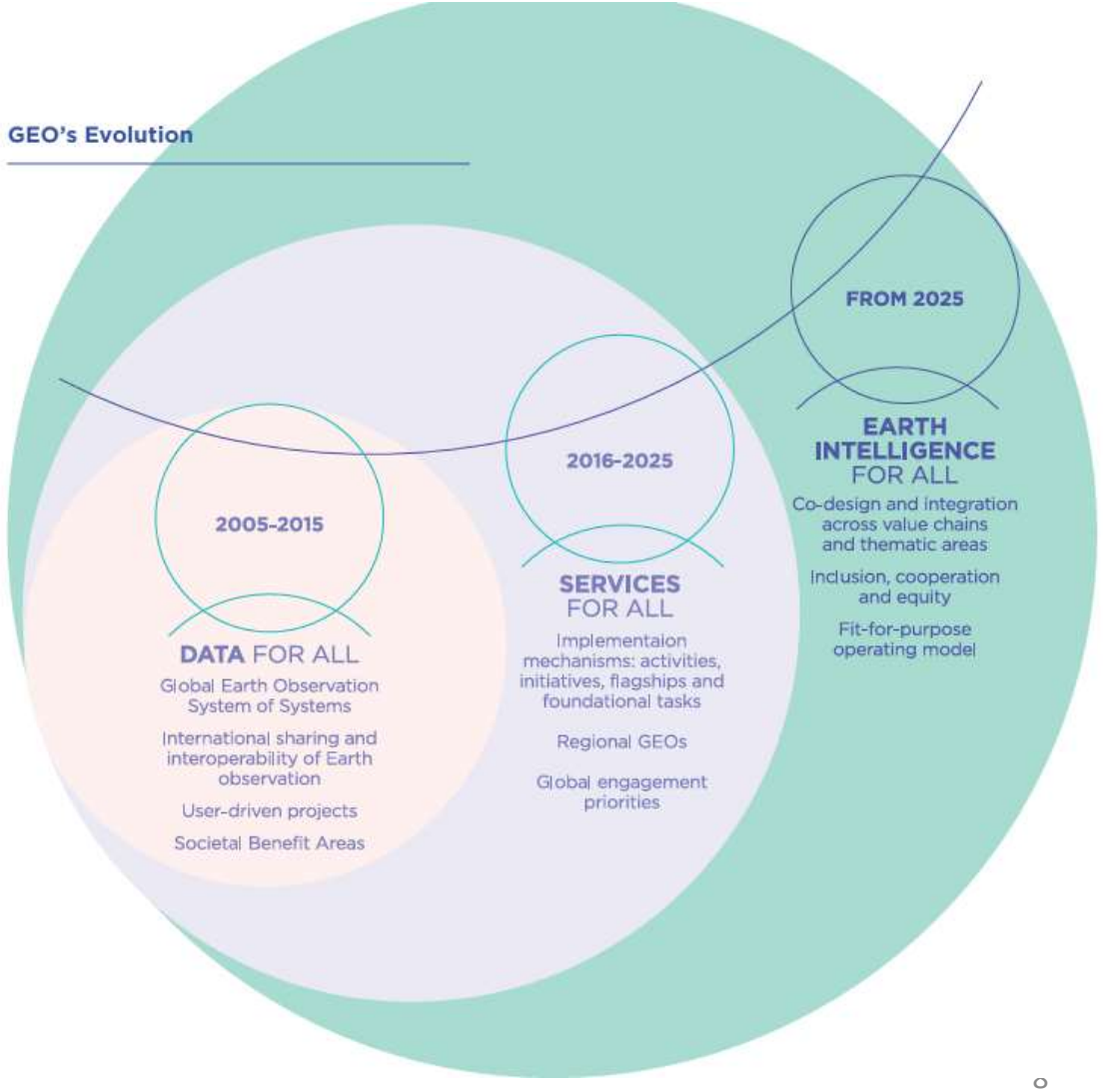
DATA FOR ALL

2016-2025

SERVICES FOR ALL

FROM 2025

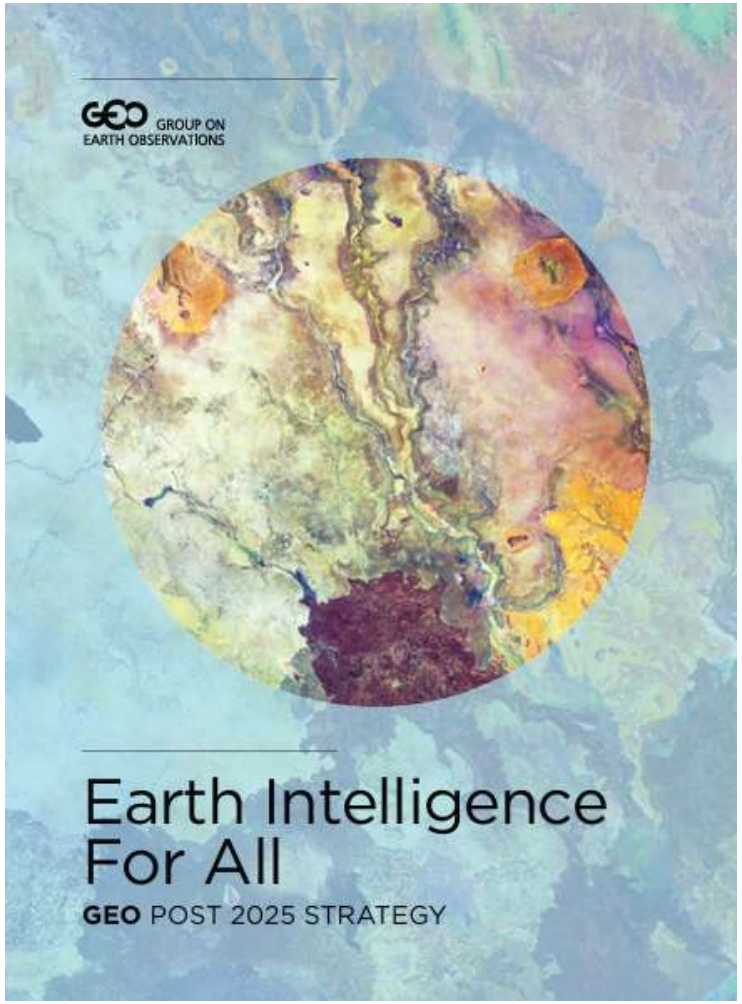
EARTH INTELLIGENCE FOR ALL



Earth Intelligence For All
GEO POST 2025 STRATEGY

Earth Intelligence (EI) comprises integrated Earth and social science-derived knowledge and insights that inform strategic decisions, build capacities, and empower society to address environmental, societal, and economic challenges.

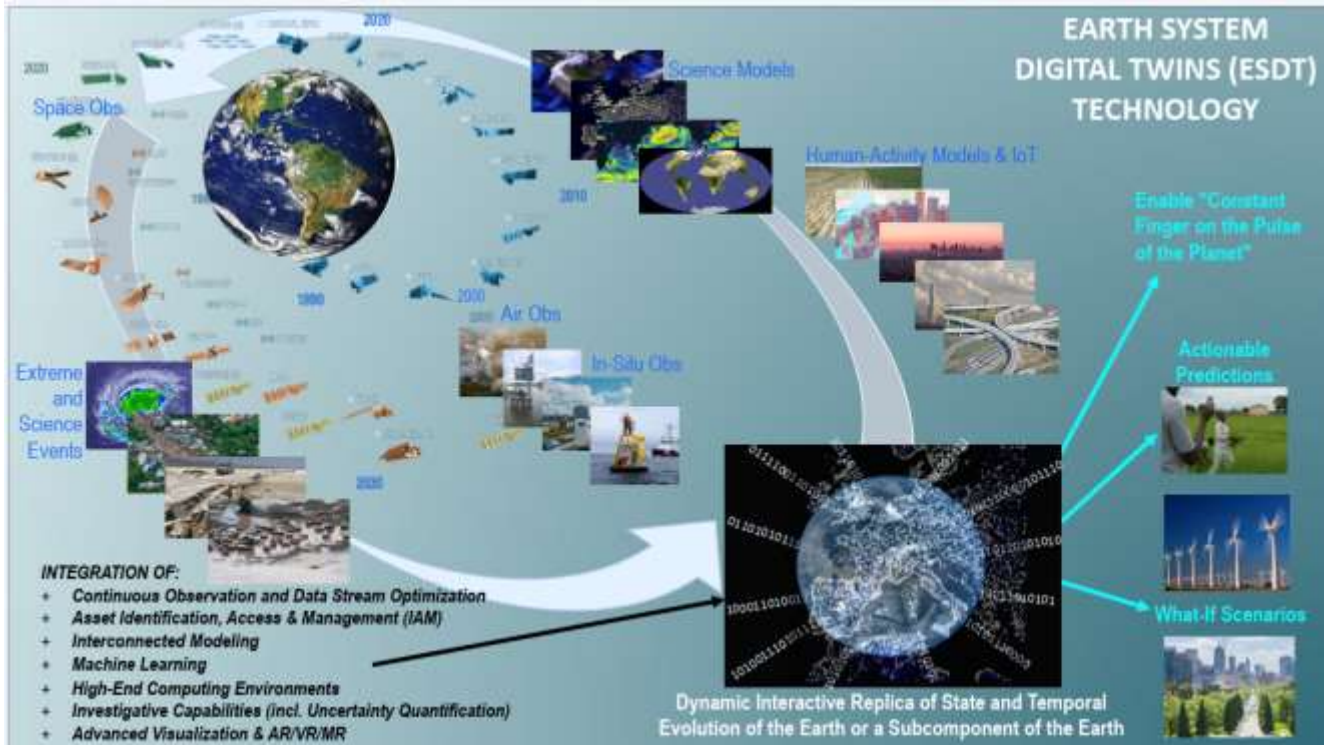
- based on user needs at all scales,
- integrates Earth observation data,
- socio-economic data,
- research and science,
- citizen observations,
- indigenous knowledge,
- modeling, prediction, and scenario analysis.



References or footnotes can be given here

NASA: Earth System Digital Twins (ESDT)

A digital twin is an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and fidelity.



2022

https://www.digitaltwinconsortium.org/initiatives/the-definition-of-a-digital-twin/

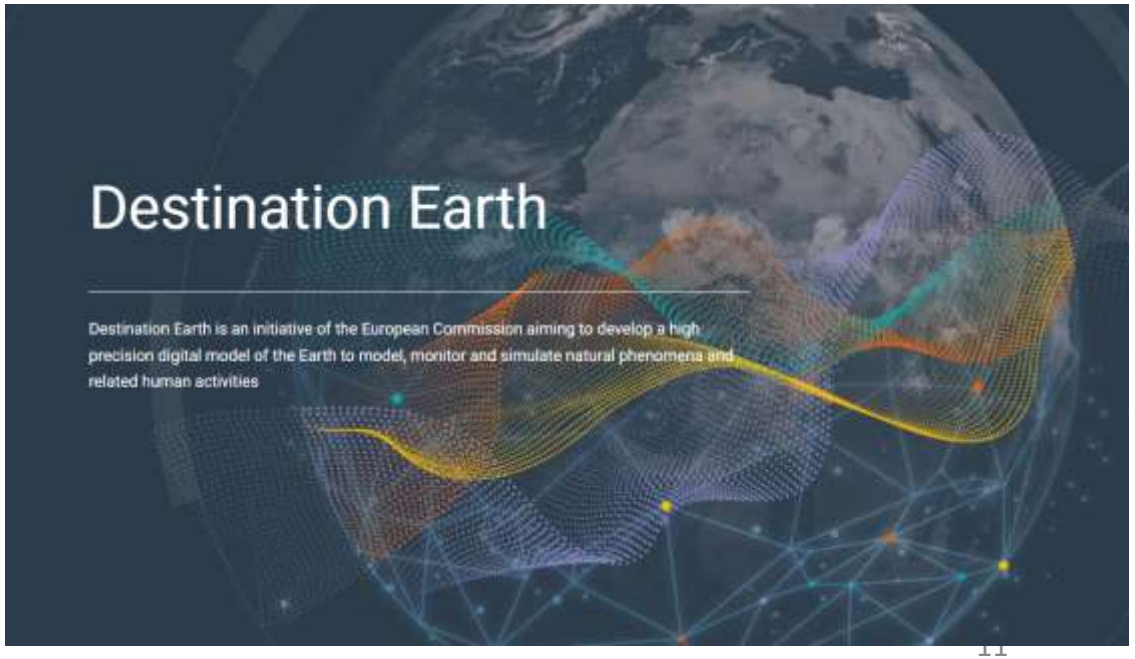
https://ntrs.nasa.gov/citations/20220007620

Destination Earth

Destination Earth is an initiative of the European Commission (through DG CONNECT) aiming to develop a high precision digital model of the Earth to model, monitor and simulate natural phenomena and related human activities

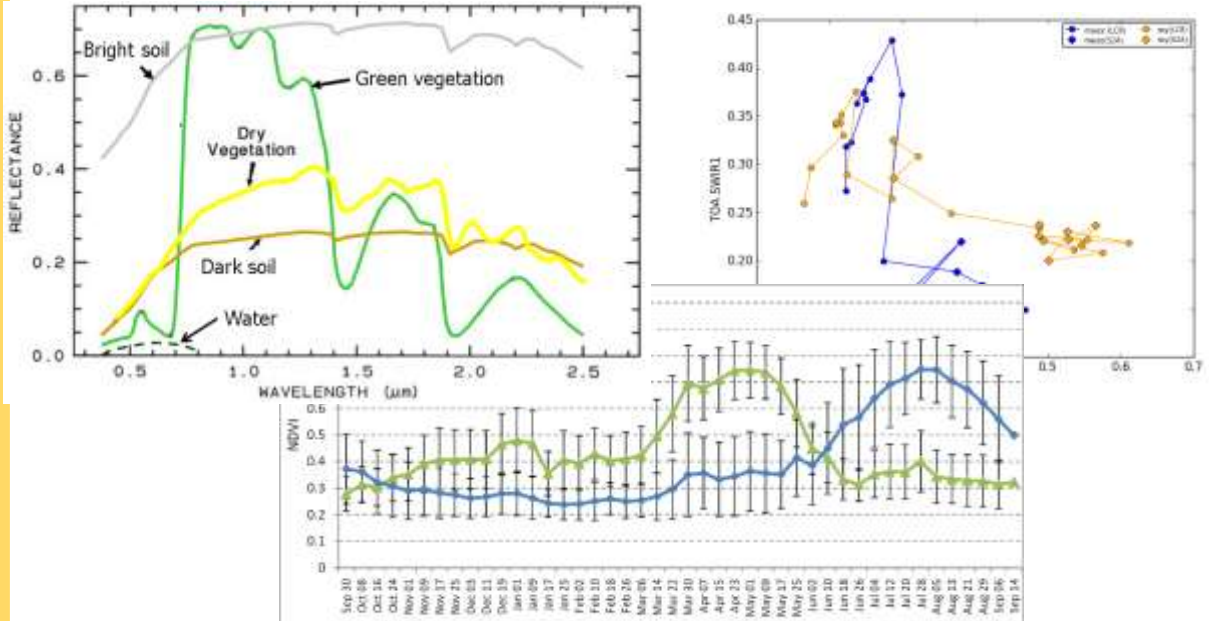
To implement Destination Earth
over **the next 7 – 10 years**

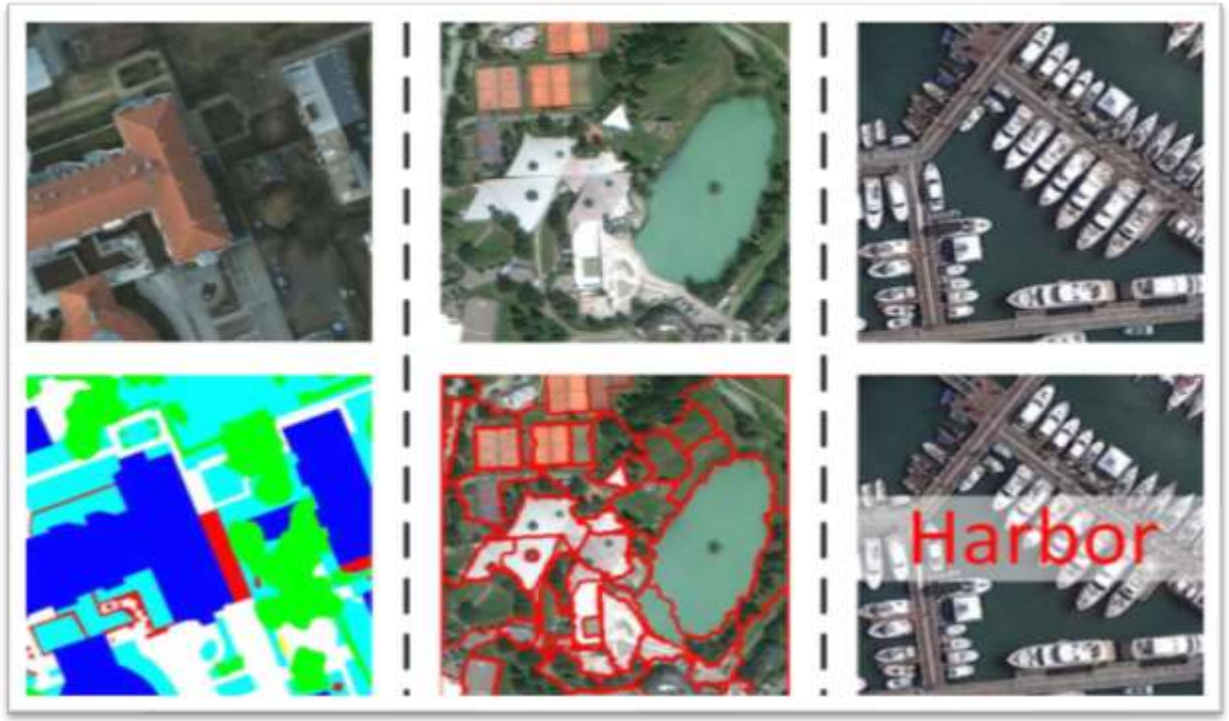
https://www.eumetsat.int/international-cooperation/destine



What is the state of the art? ML on Satellite Imagery

- **Classification**/**regression** is a mapping from measurements acquired by a remote sensing instrument to a **label**(s) (categorical/continuous) for each pixel that identifies it with what's on the ground
  - Domains:
    - **Spatial** (e.g. textures, moving window, Fourier transformation etc.)
    - **Spectral** (e.g. spectral curvatures)
    - **Temporal** (change detection, temporal profiles)

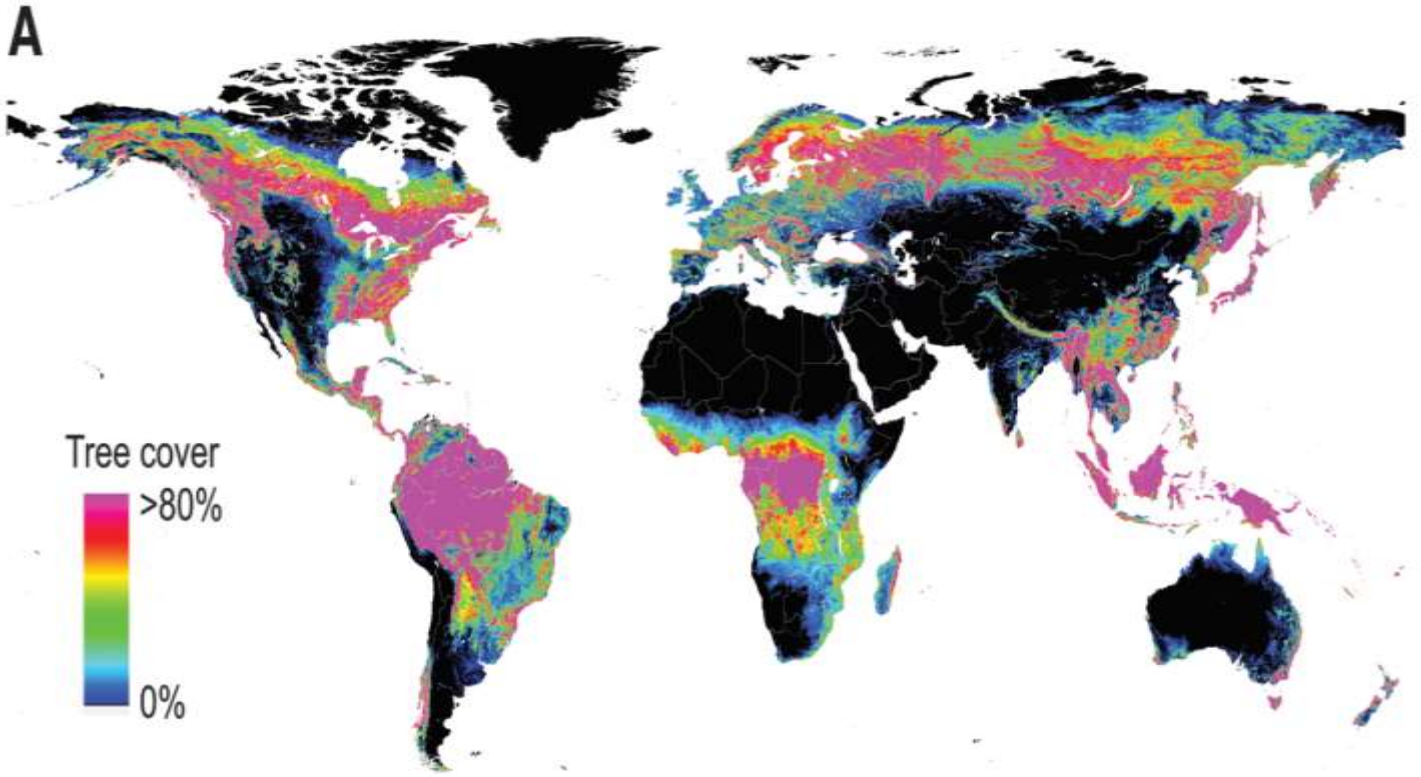




Semantic segmentation **Identifying objects** **Scene-level labelling**

Forest mapping

- High-Resolution Global Maps of 21st-Century Forest Cover Change
  - Satellite data
    - **Landsat 7** data at **30 m**
      - **654,178** Landsat 7 ETM+ analyzed on Google cloud
  - **Training data**
    - Image interpretation methods, including mapping of crown/no crown categories using very high spatial resolution data such as Quickbird imagery
  - Machine learning:
    - **Decision Trees**

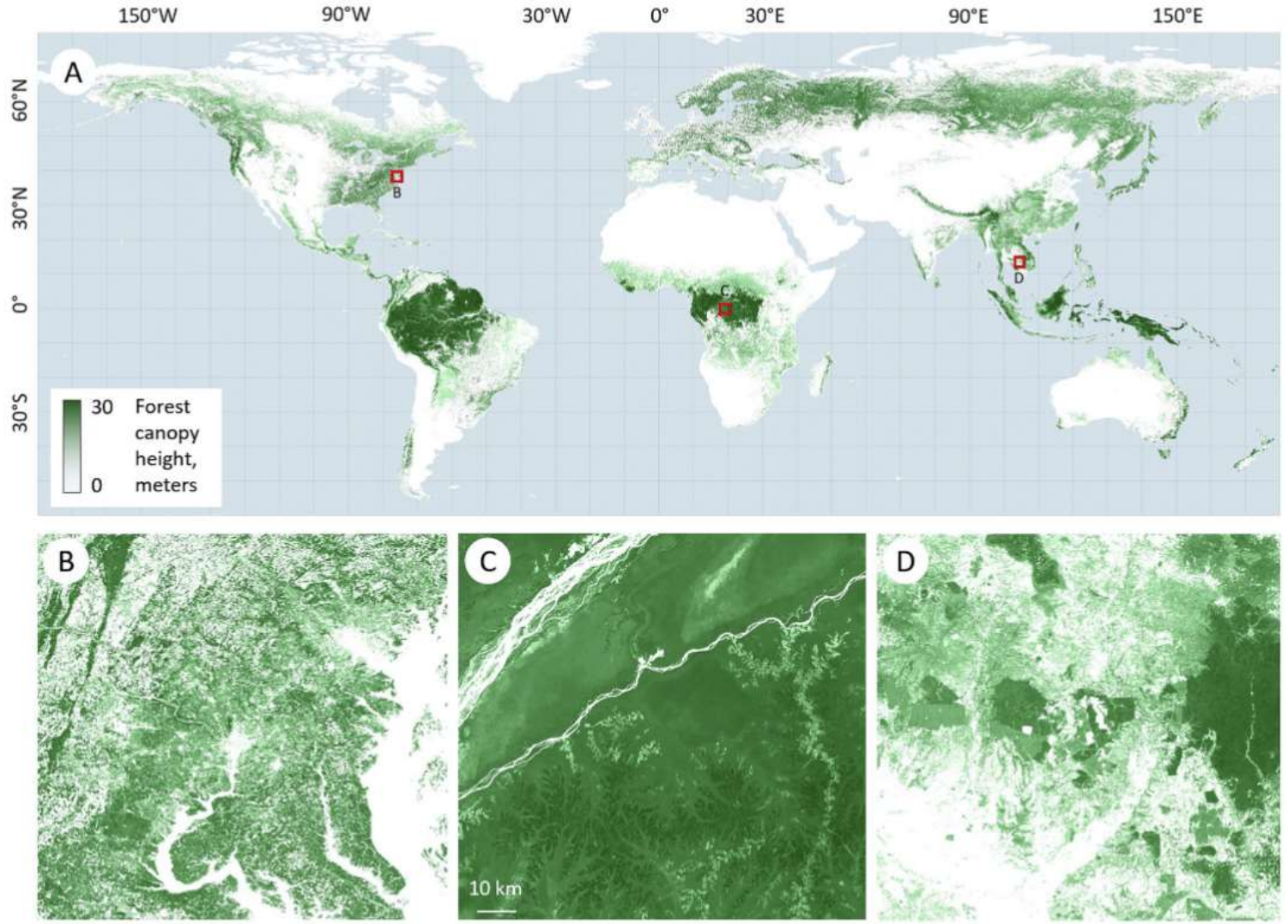


https://www.globalforestwatch.org/map/

[Source: Hansen *et al.*, Science 2015]

Tree height mapping

- Satellite data
  - **Landsat** + **GEDI** (Lidar)
  - Integration of **heterogenous** data
- Training data
  - GEDI-derived three canopy height
- Machine leaning
  - **Decision Tree** regression
- Performance
  - **RMSE ~ 6.6 m**



https://doi.org/10.1016/j.rse.2020.112165

https://glad.earthengine.app/view/global-forest-canopy-height-2019

Horizon Europe SWIFTT project

Innovative project 2022-2025

Coordinator: Wildsense (FR)

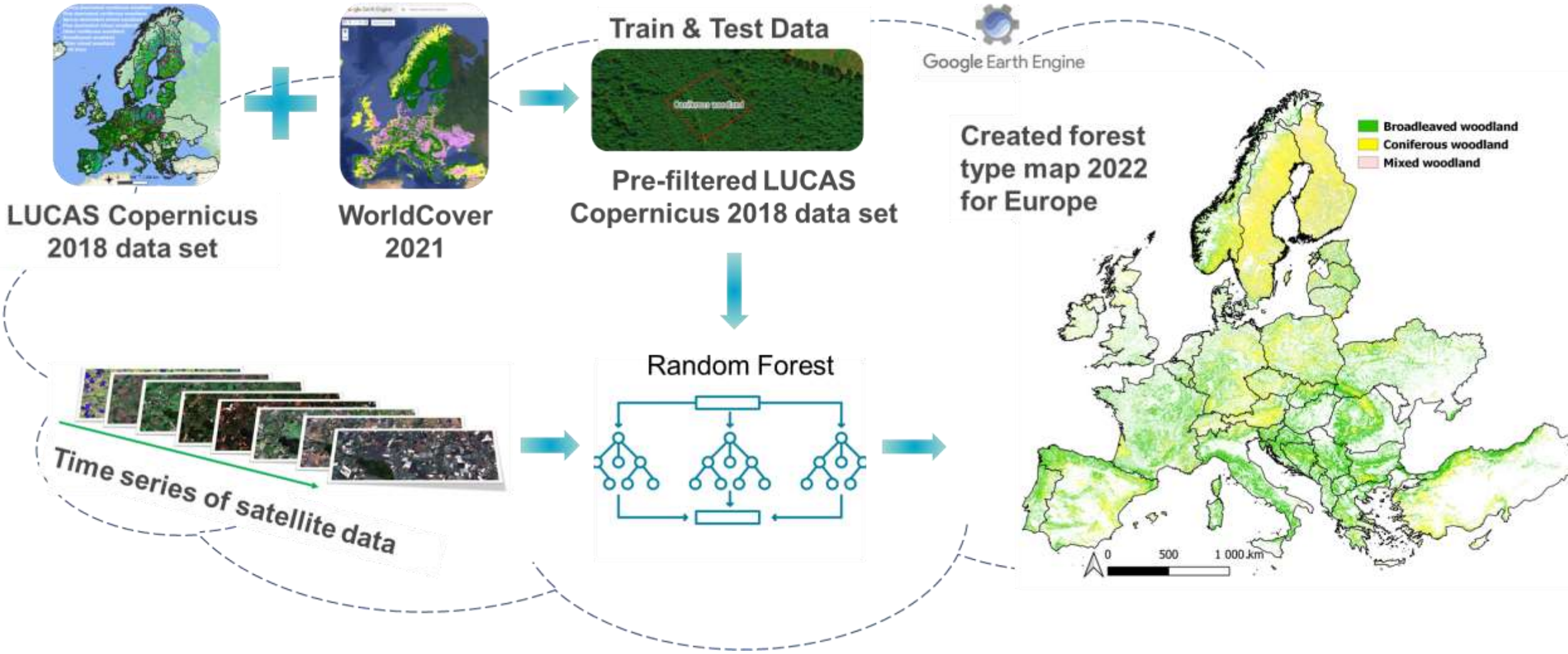
8 partners, e.g. Space Research Institute (UA)

https://swiftt.eu/

SWIFTT will provide forest managers with affordable, simple and effective remote sensing tools backed up by **powerful machine learning models**. Our solution will offer a holistic health monitoring service using Copernicus satellite imagery to detect and map the various risks to which forests and their managers are exposed:

- Forest fires
- Droughts
- Wind throws
- Diseases

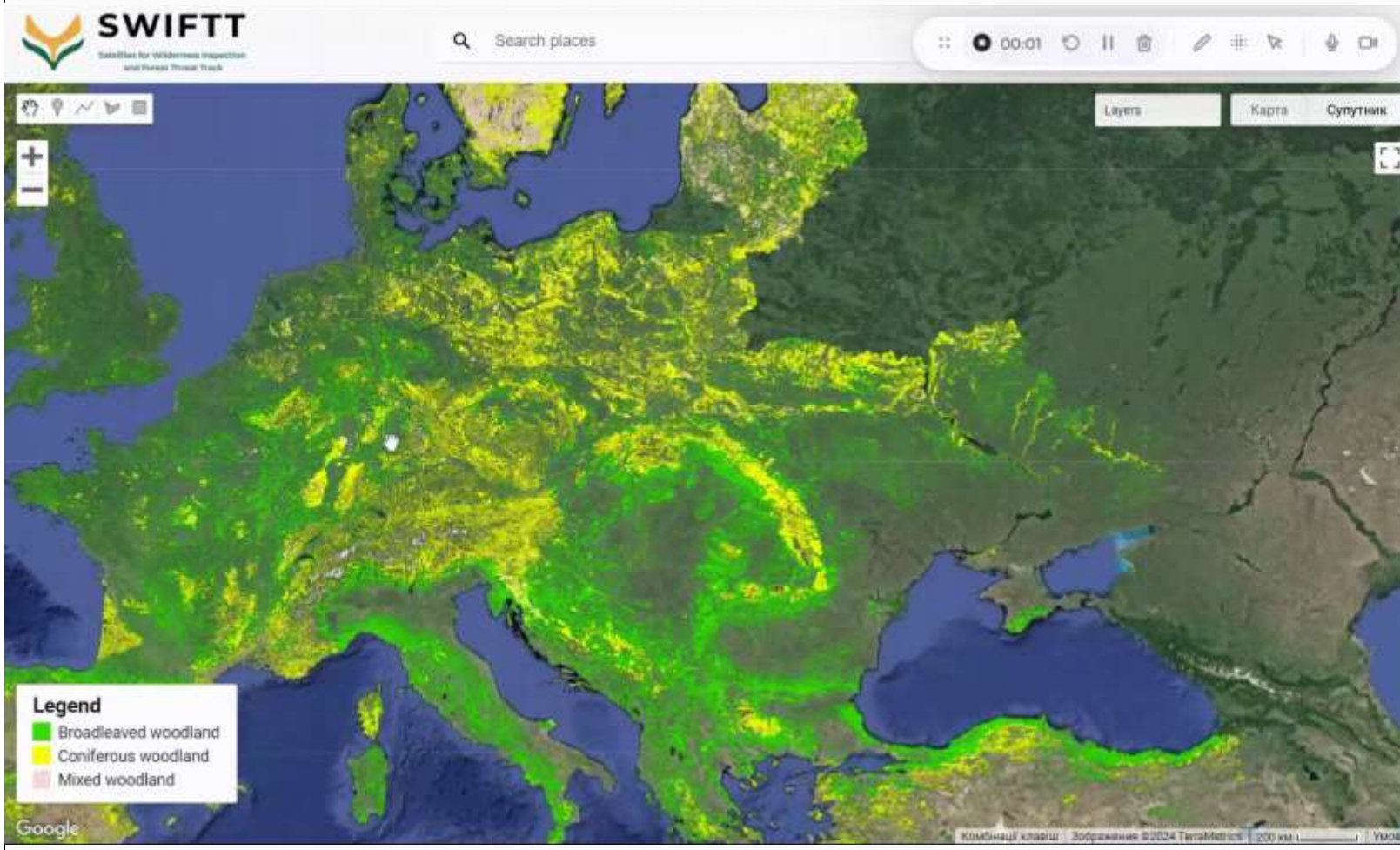
Our contribution:
Workflow for forest type mapping



Forest map with 10 m resolution (2022-2024)

Classes	UA	PA	F1
Forest	87,9	92,8	90,3
Broadleaved woodland	76,1	84,3	80,0
Coniferous woodland	75,9	78,2	77,1
Mixed woodland	64,1	39,1	48,5
Non forest	98,1	99,0	98,6
Overall accuracy	93,2		

UA – User accuracy
PA – Producer accuracy
F1 – F1-score



N. Kussul, A. Shelestov, B. Yailymov, H. Yailymova, **Semi-Supervised Forest Type Mapping in Europe on Satellite Data**, 2023 IDAACS, vol. 1, (2023) pp. 454-458. 10.1109/IDAACS58523.2023.10348948

Horizon Europe FutureFor (2024-2026)

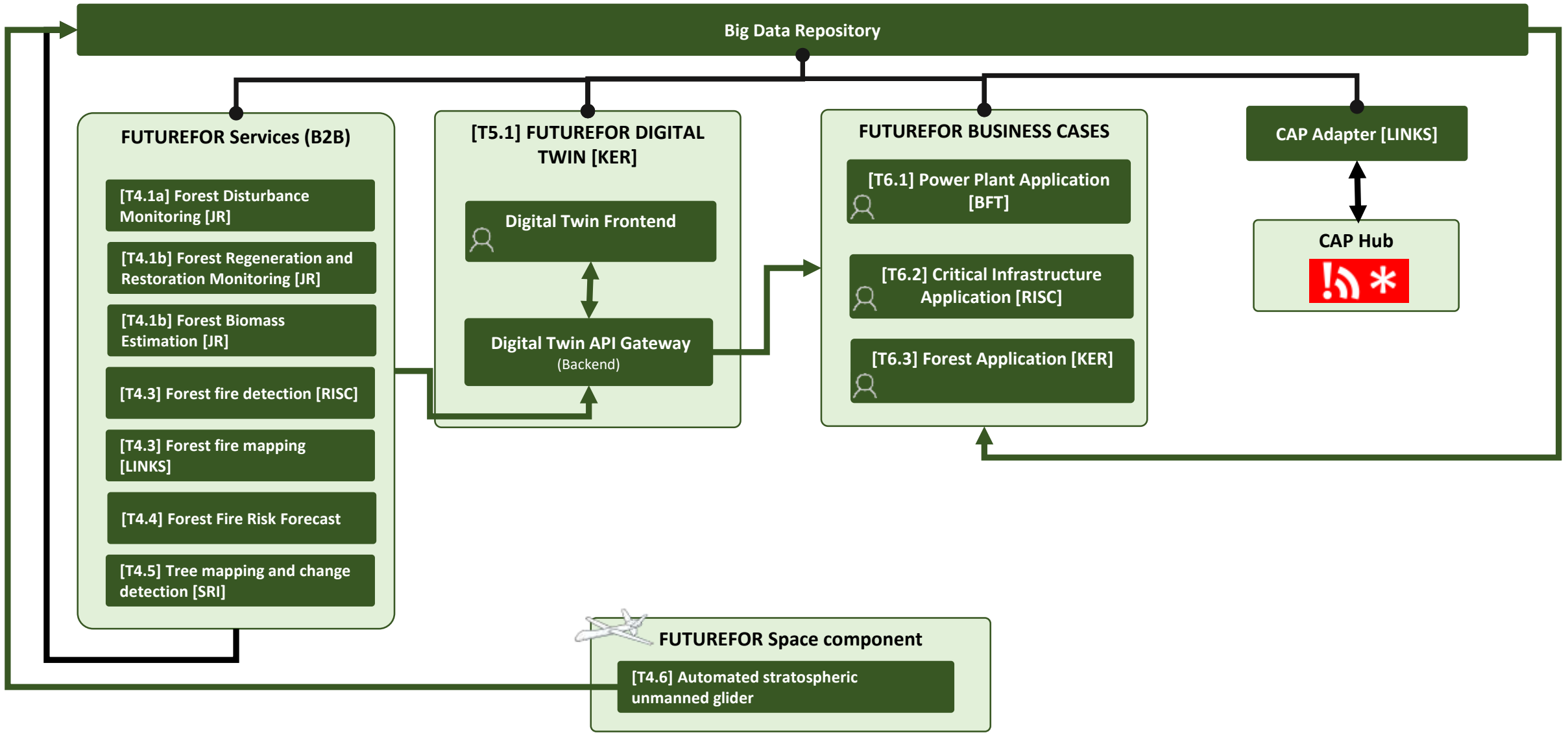
FUTUREFOR: COPERNICUS APPLICATIONS FOR NEXT-GENERATION FOREST MONITORING

This project aims to implement a **monitoring framework** for resilient European forests using **Copernicus Earth Observation** imagery and **innovative remote sensing** techniques to support **biodiversity conservation**, **forest bioeconomy**, **climate change efforts**, and the **European Green Deal**, while delivering sustainable solutions tailored to public authorities (**Forest Monitoring Regulation - FMR**).

FUTUREFOR Macro Architecture

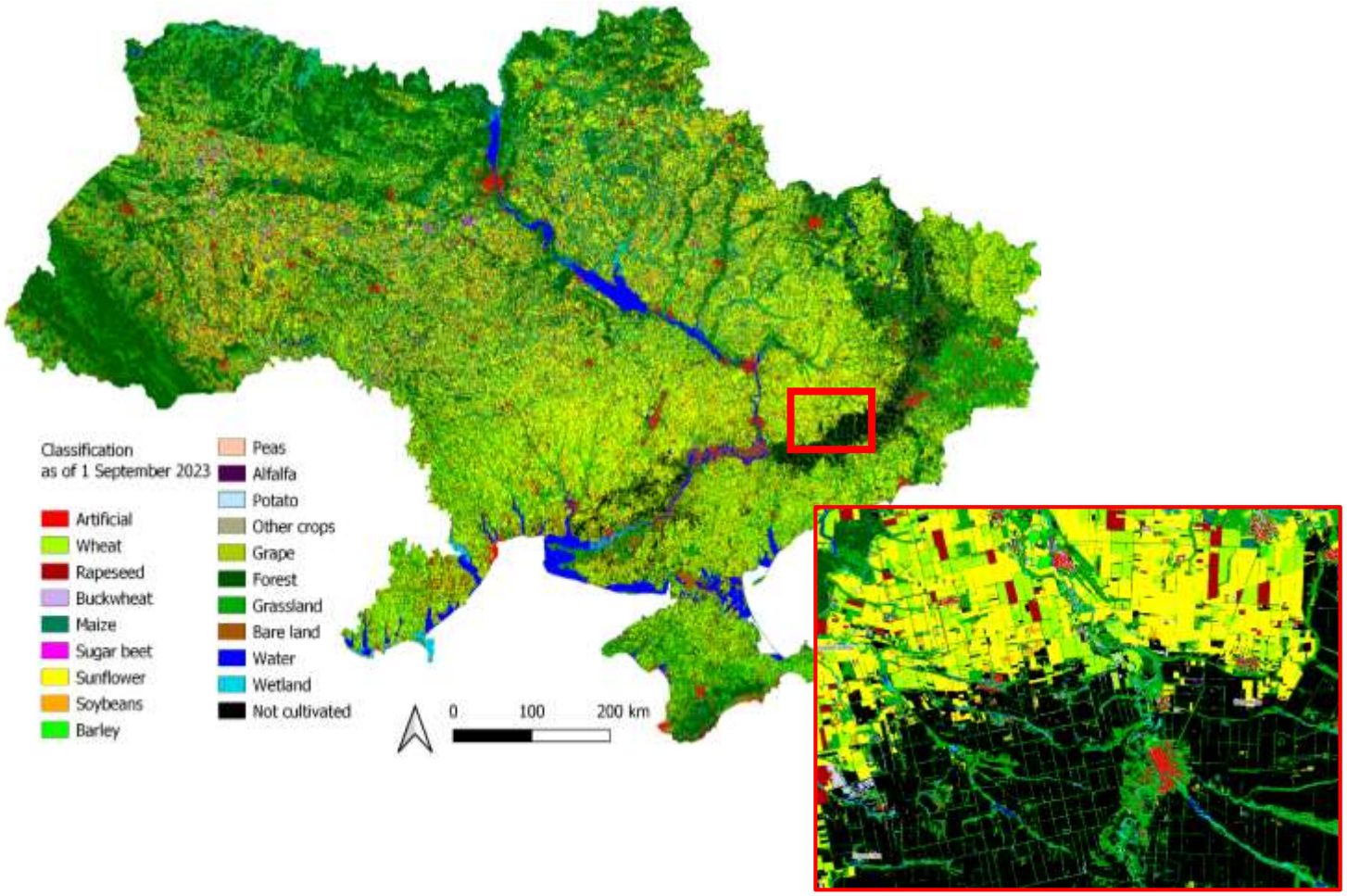
HTTPS REST APIs with JSON payload.
B2B authentication through API key.

Asynchronous Messaging System:
Publish/Subscribe Bus



Classification in CREODIAS Cloud

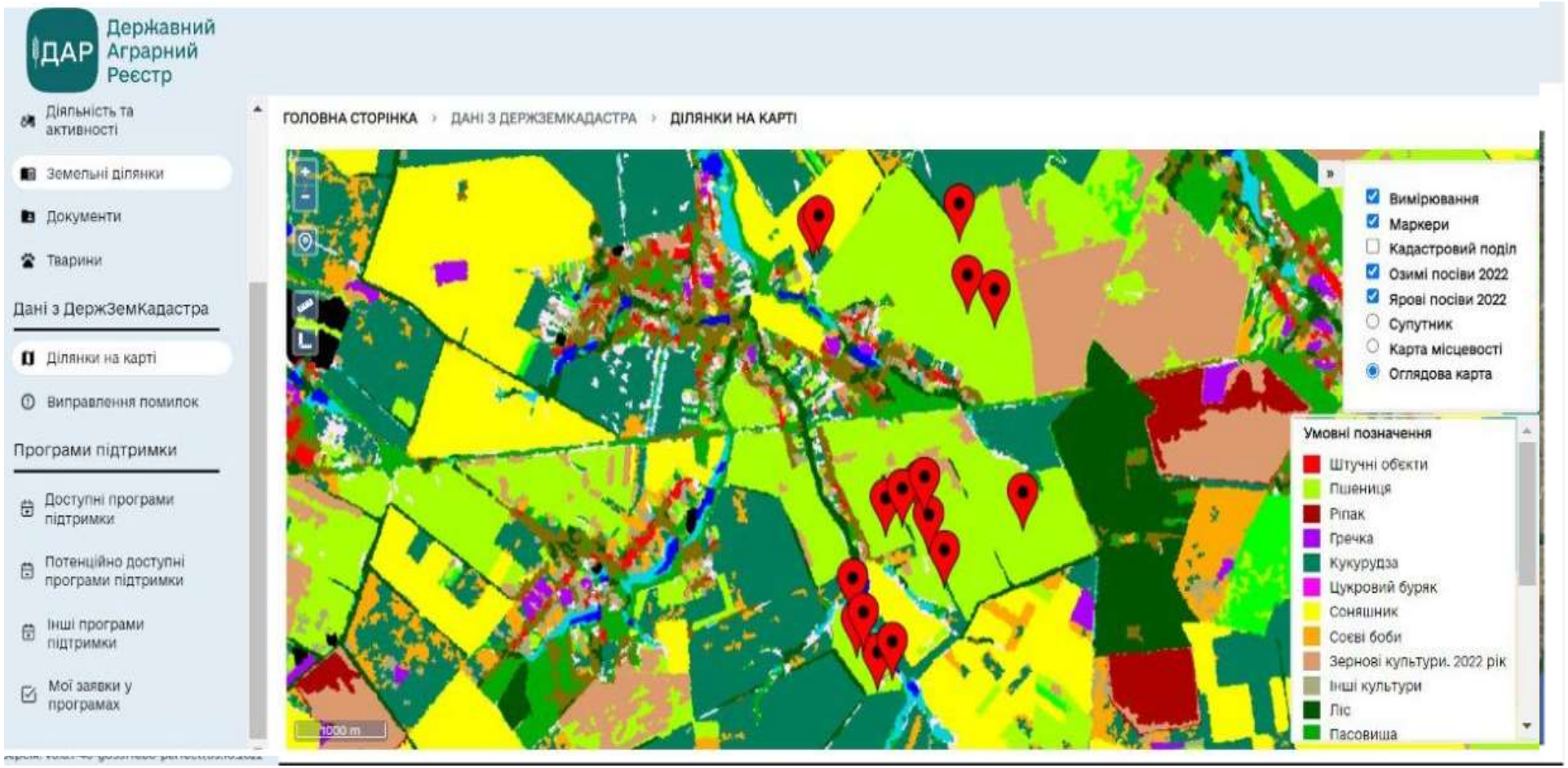
Ukraine 2023



Class	PA	UA	F1
Artificial	88,7	81,9	85,2
Wheat	98,7	90,6	94,5
Rapeseed	96,1	98,6	97,3
Buckwheat	54,8	92	68,7
Maize	93,6	91,3	92,4
Sugar beet	95,7	93,2	94,5
Sunflower	98,6	97,6	98,1
Soybean	88,8	88,5	88,7
Other crops	75,1	67,5	71,1
Forest	100	97,8	98,9
Grassland	90,9	85,9	88,3
Bareland	72,6	85	78,3
Water	100	99,4	99,7
Wetland	94	92,7	93,4
Barley	62,7	90,1	73,9
Peas	80,9	100	89,5
Alfalfa	29,3	87,5	43,8
Grape	87,6	51,2	64,7
Not cultivated	88,2	96,6	92,2
Potato	72,8	18,9	30,1
Overall Accuracy	OA = 93,1%		

Classification map in the State Agrarian Register (since 2022)

activity supported by World Bank



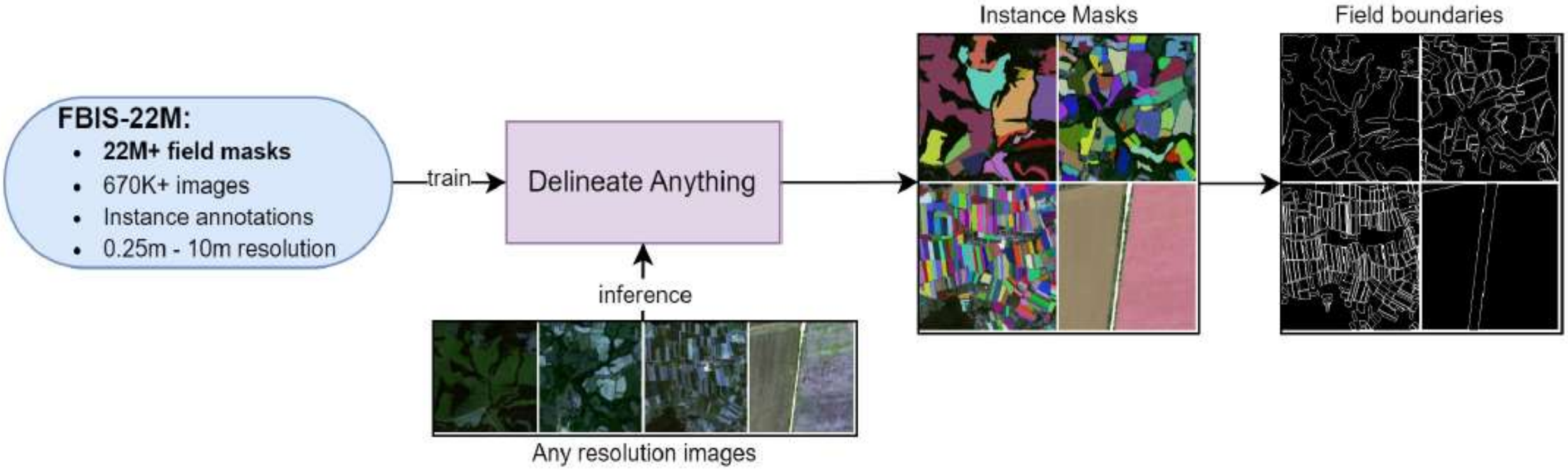
https://reg.dar.gov.ua/farmer/landparcelsonmap

CV Challenge of Field Delineation

- Assessing the Impact of Spatial Resolution on the Monitoring and Mapping of Smallholder Farm Fields in Ukraine

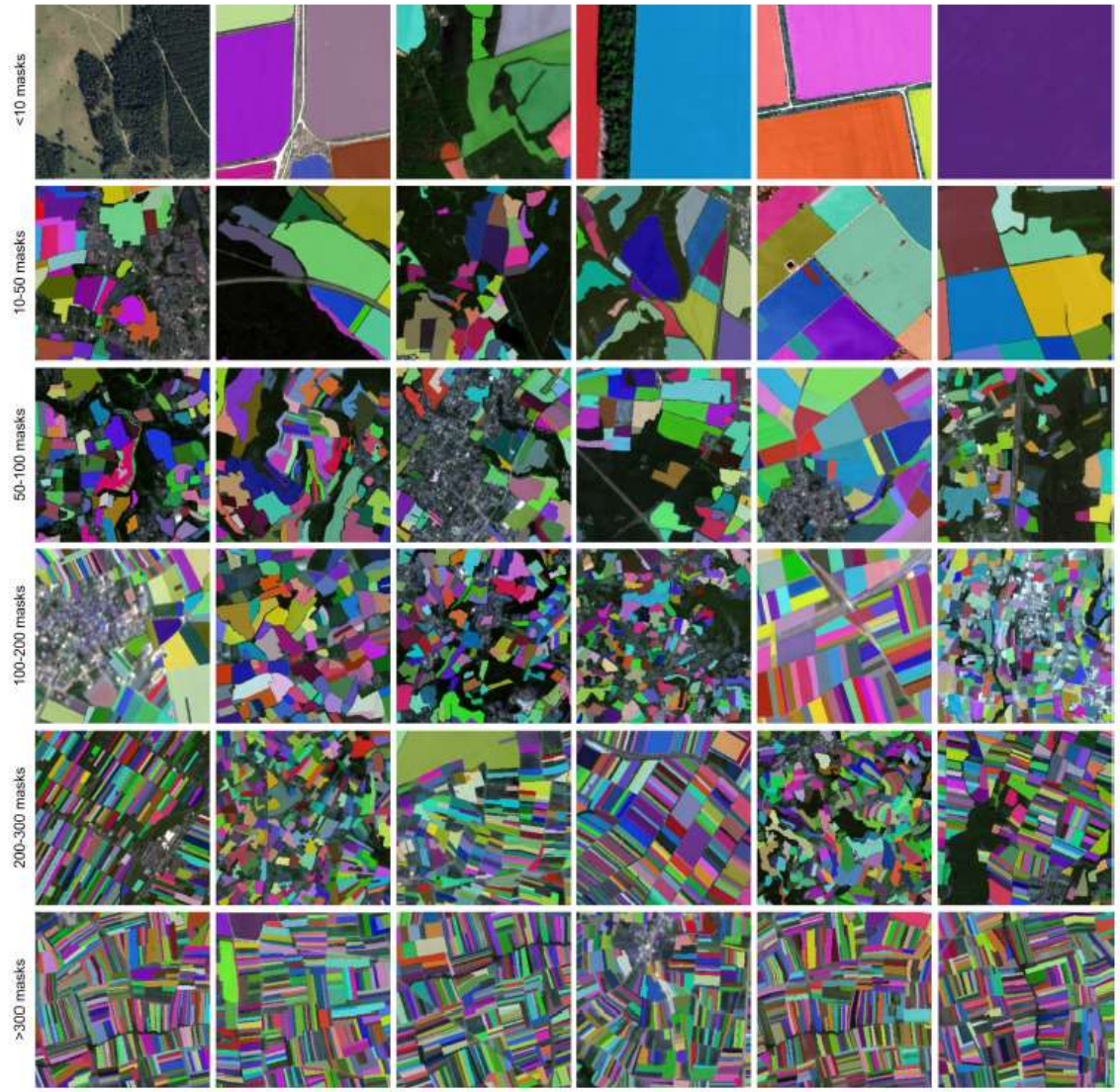
- Funding
  NASA+World Bank
- Consortium
  UMD+NTUU “KPI”

Field Delineation (ESA+UMD+NTUU "KPI"+SRI)



Field Delineation

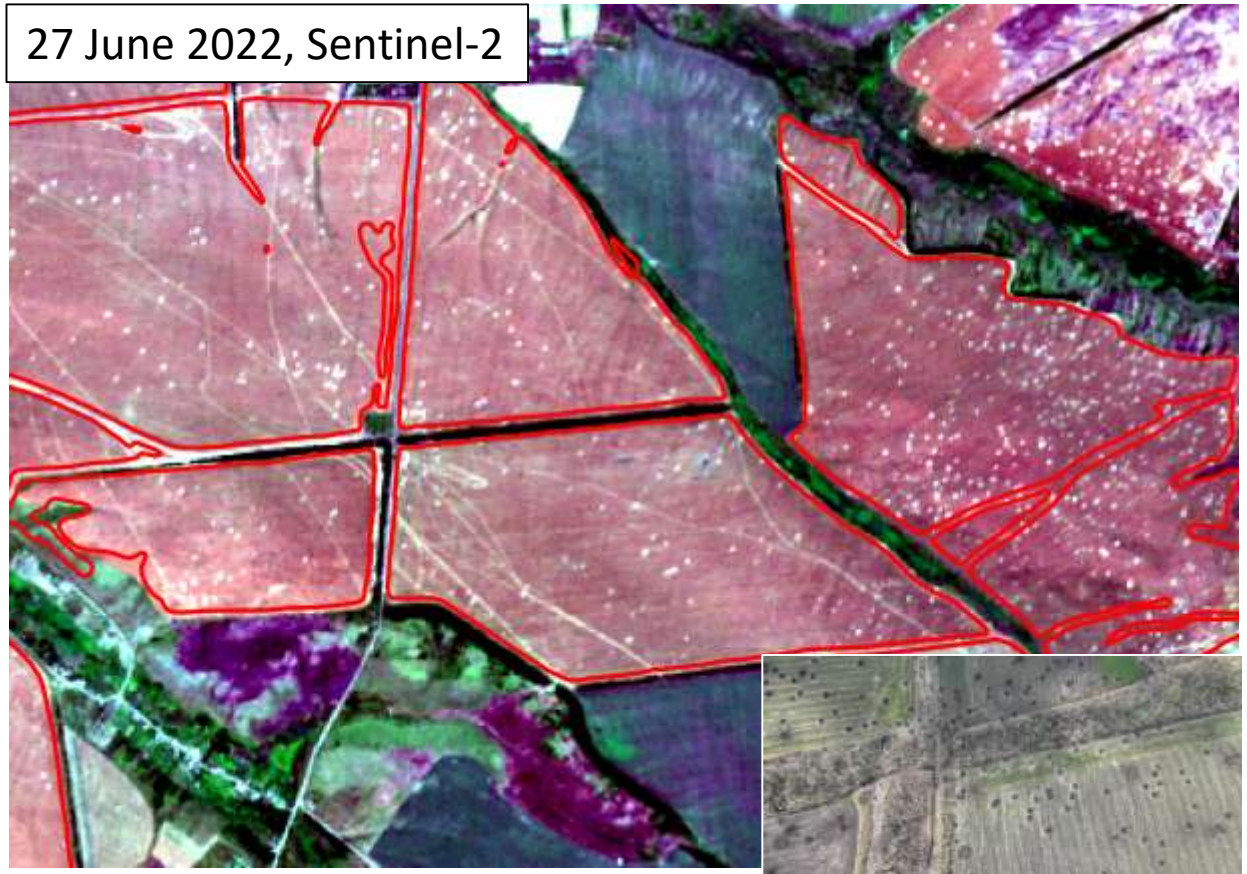
- ESA+UMD+NTUU “KPI”+SRI
- 22M+ Dataset
- Instance segmentation model
- **Delineate Anything**



Delineate Anything

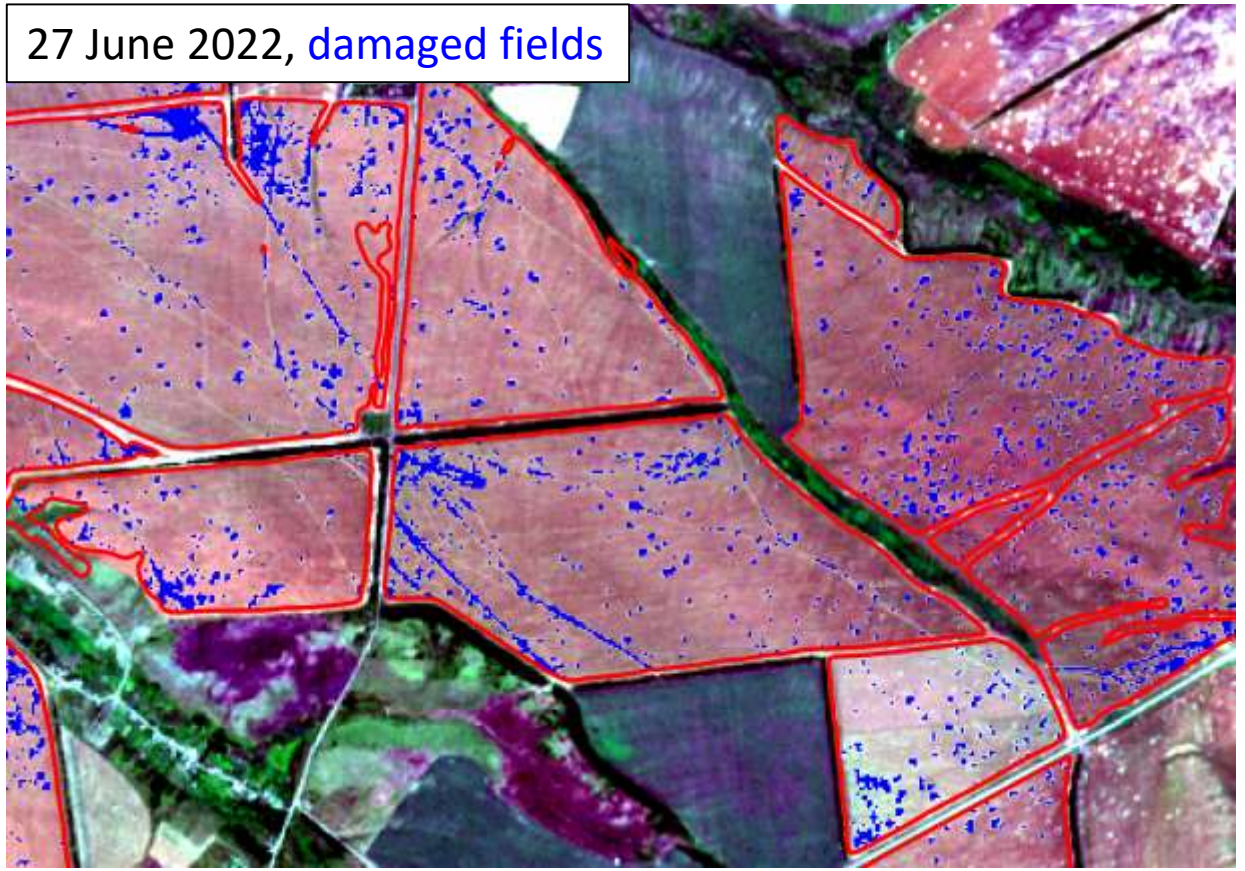
Damages for agricultural fields

27 June 2022, Sentinel-2

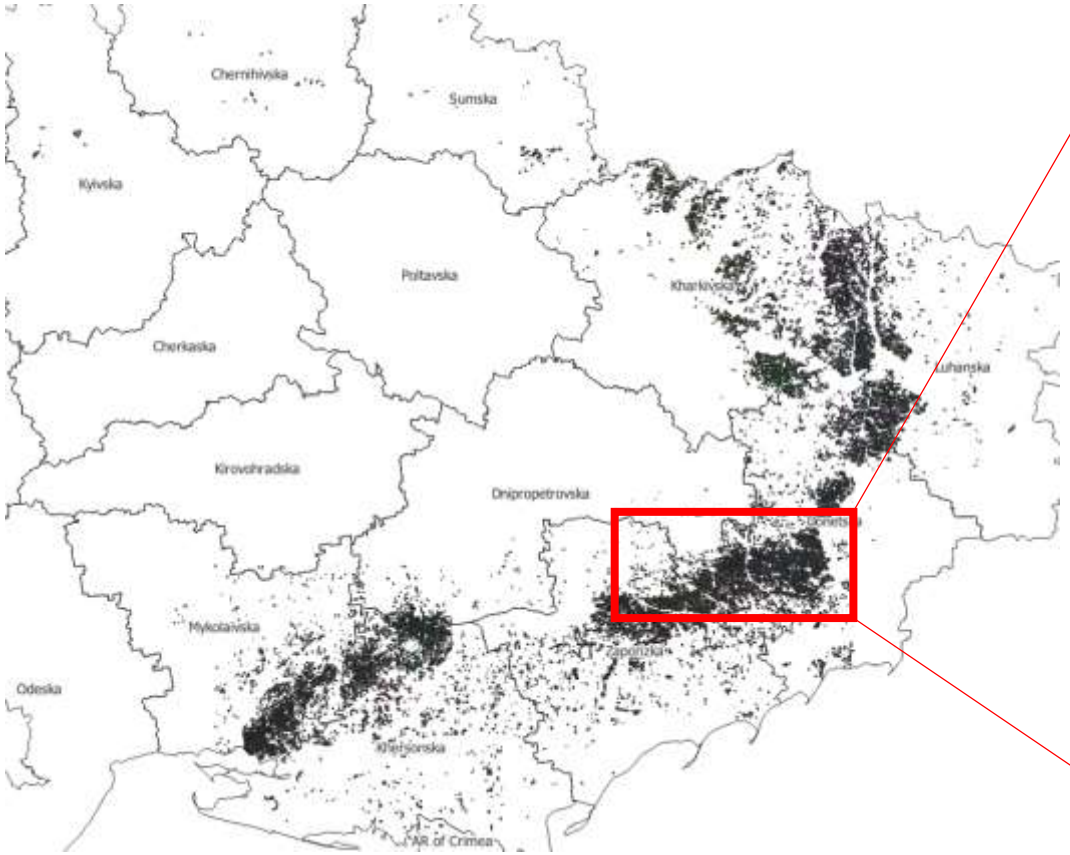


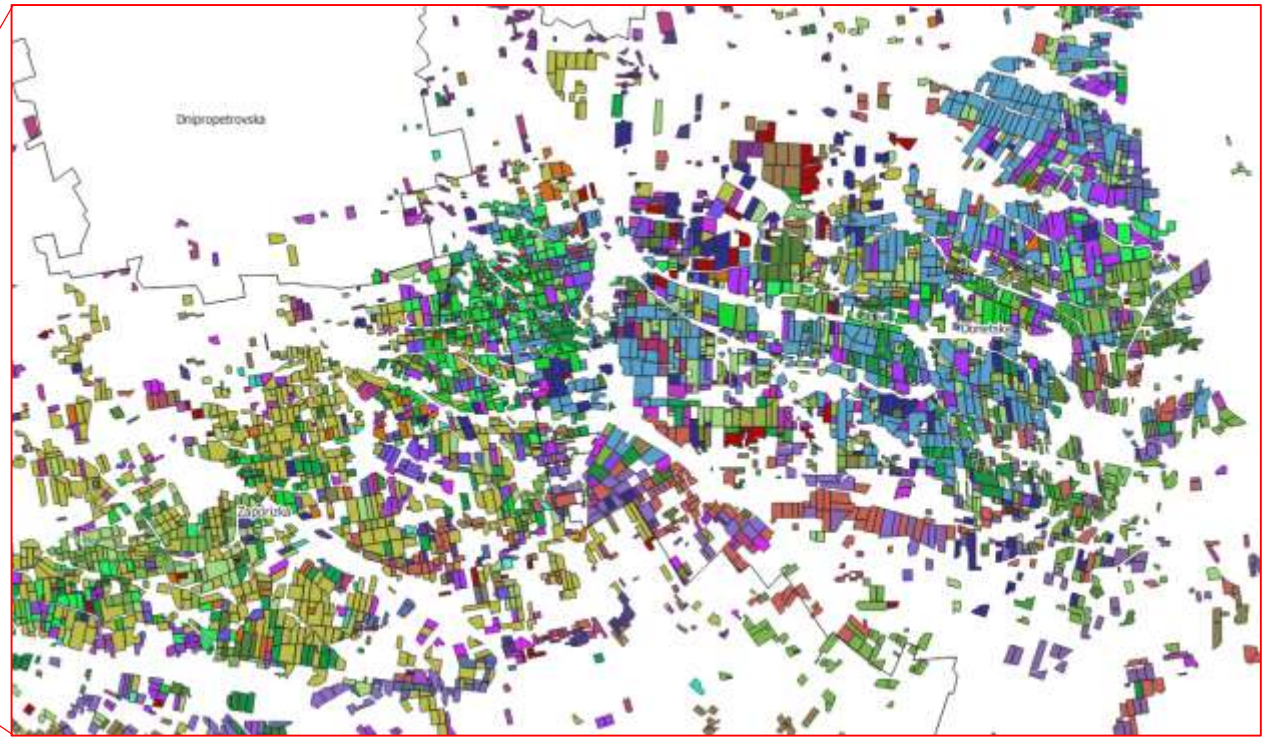
An example of craters from a drone

27 June 2022, damaged fields



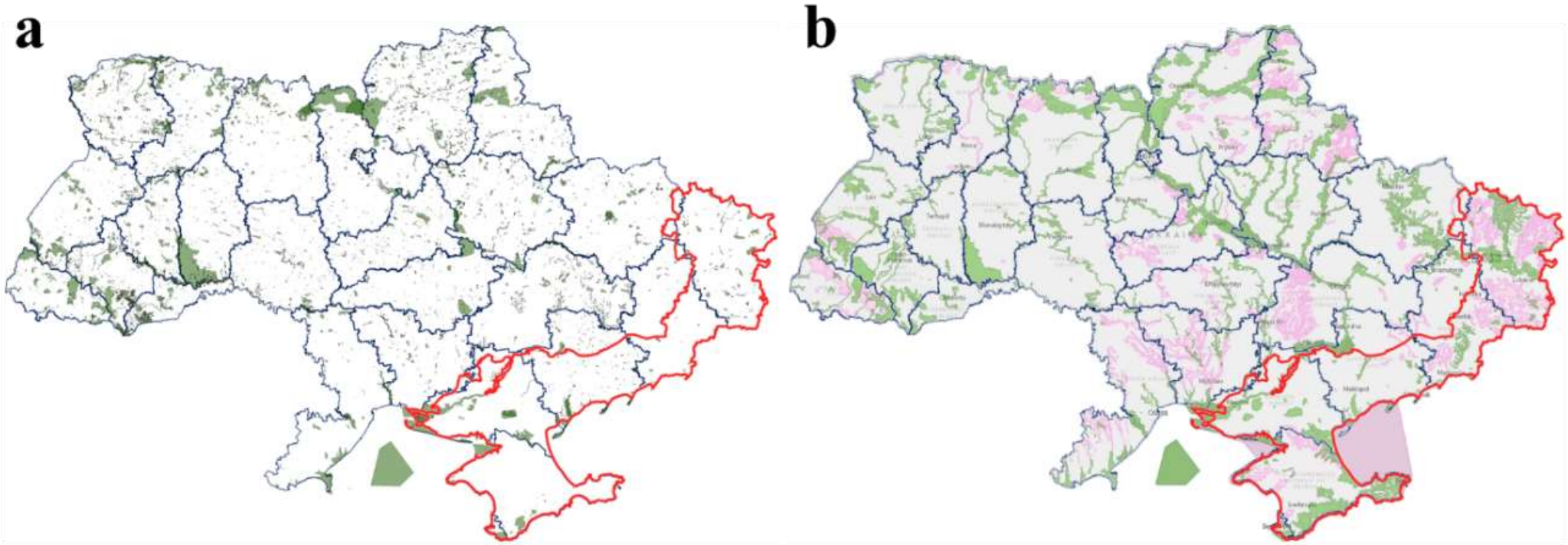
Damaged agricultural fields as a result of hostilities (2022 – 2025)





NASA “Assessment of the impact of war in Ukraine on national protected areas”

- NASA funded project
- 2025-2026

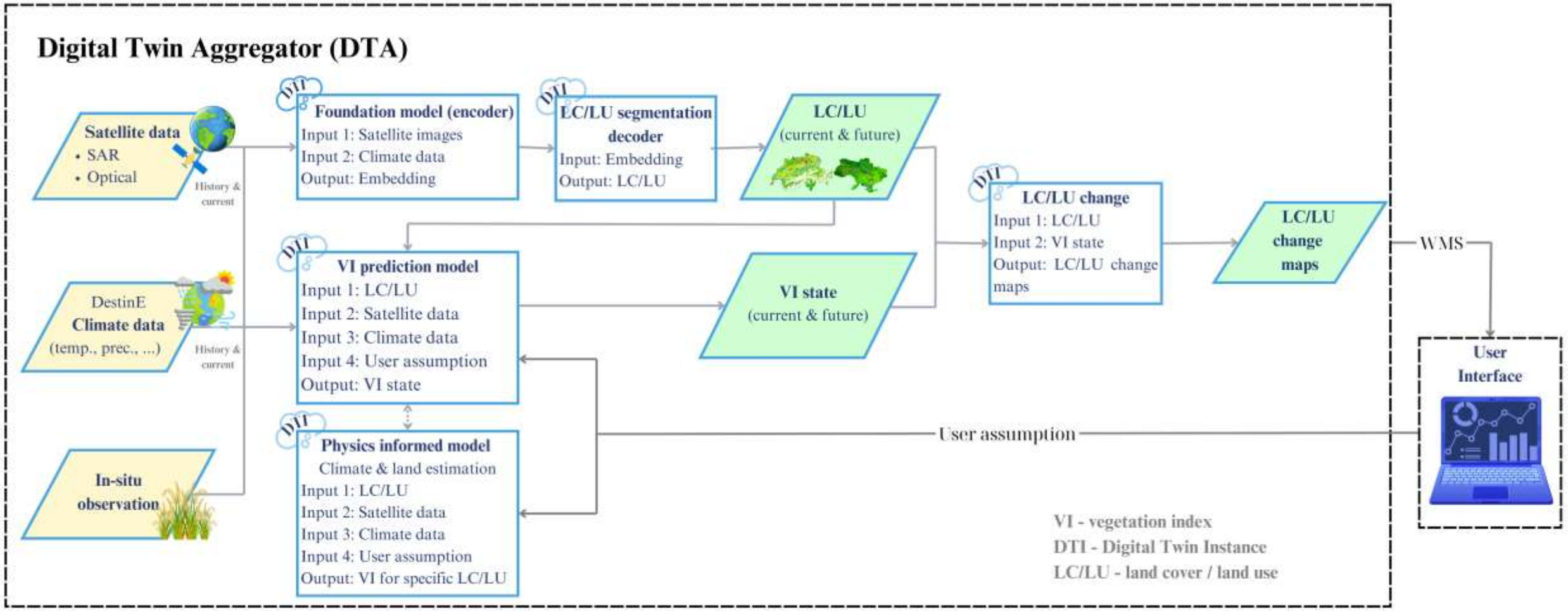


DT4LC - Developing scalable Digital Twin models for Land cover Change detection using machine learning

- 2025-2028
- Ukrainian-Swiss Joint Research Programme (USJRP)

- **The goal** of DT4LC is to develop scalable DTs that will combine satellite data and artificial intelligence (deep neural networks and PINN) to detect complex land cover changes (**active changes in ecosystems and land cover of both countries**) based on harmonized data and Open Data Cube cloud technologies.

Common Approach



Напрямки співпраці

- Foundation models
- Earth Digital Twins
- Agricultural monitoring of smallholder farm fields
- War impact assessment

Keep going!