Forest Carbon Monitoring
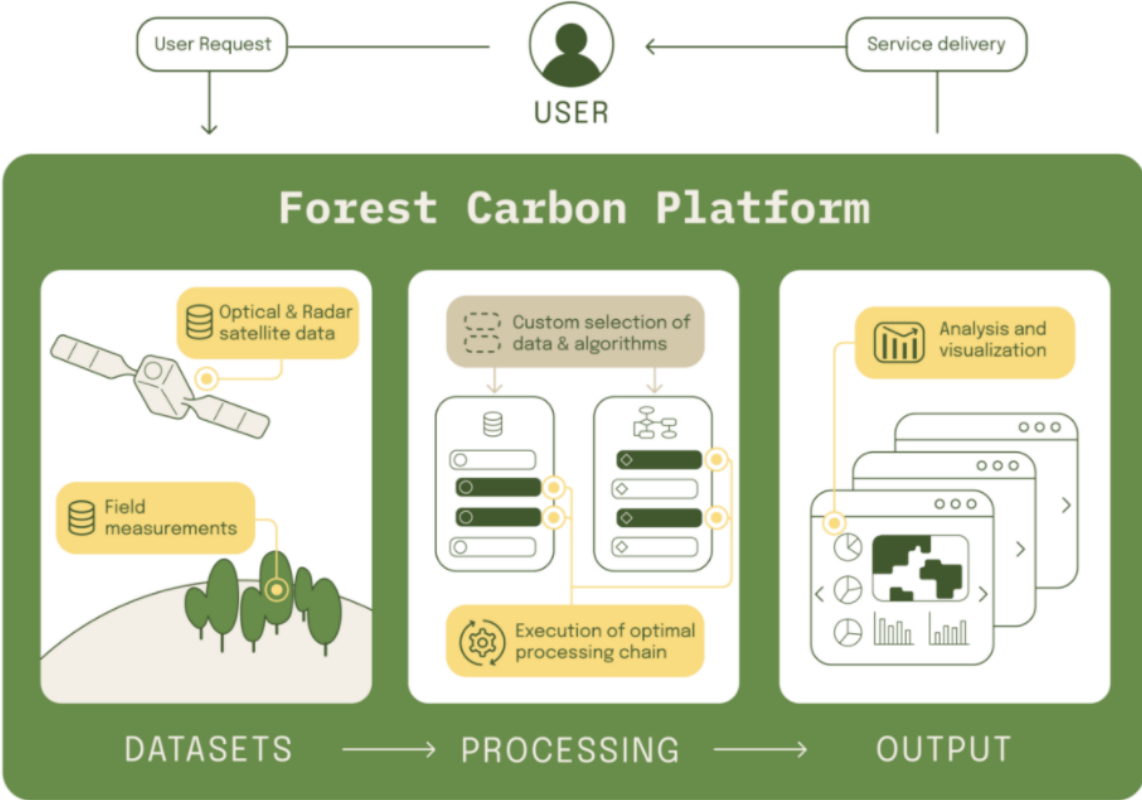## Contract No. 4000135015/21/I-NB
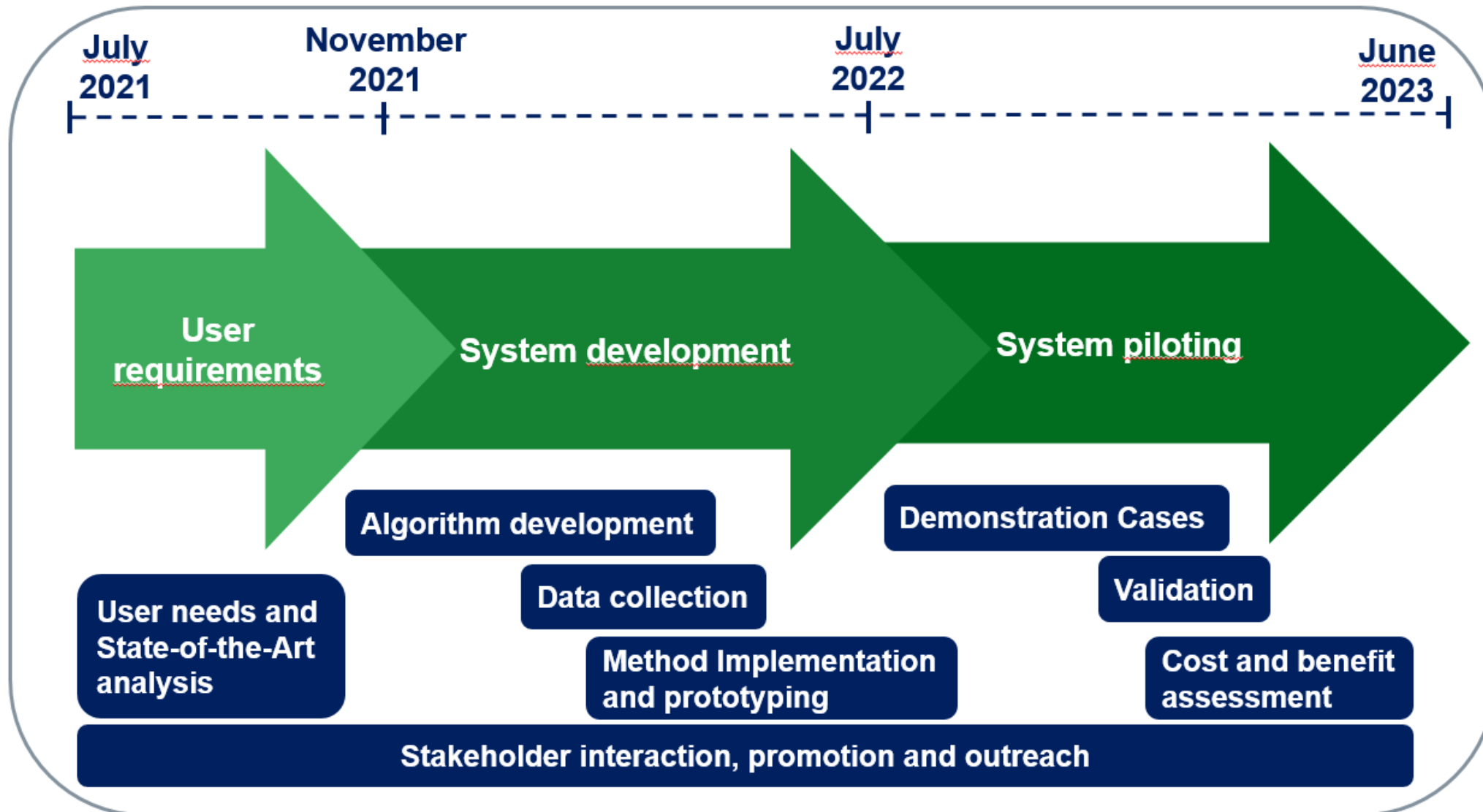
NoR summary

Project overview

Objective

The objective of the Forest carbon Monitoring project was to develop a prototype of a monitoring and accounting platform for forest carbon stock.

Key features
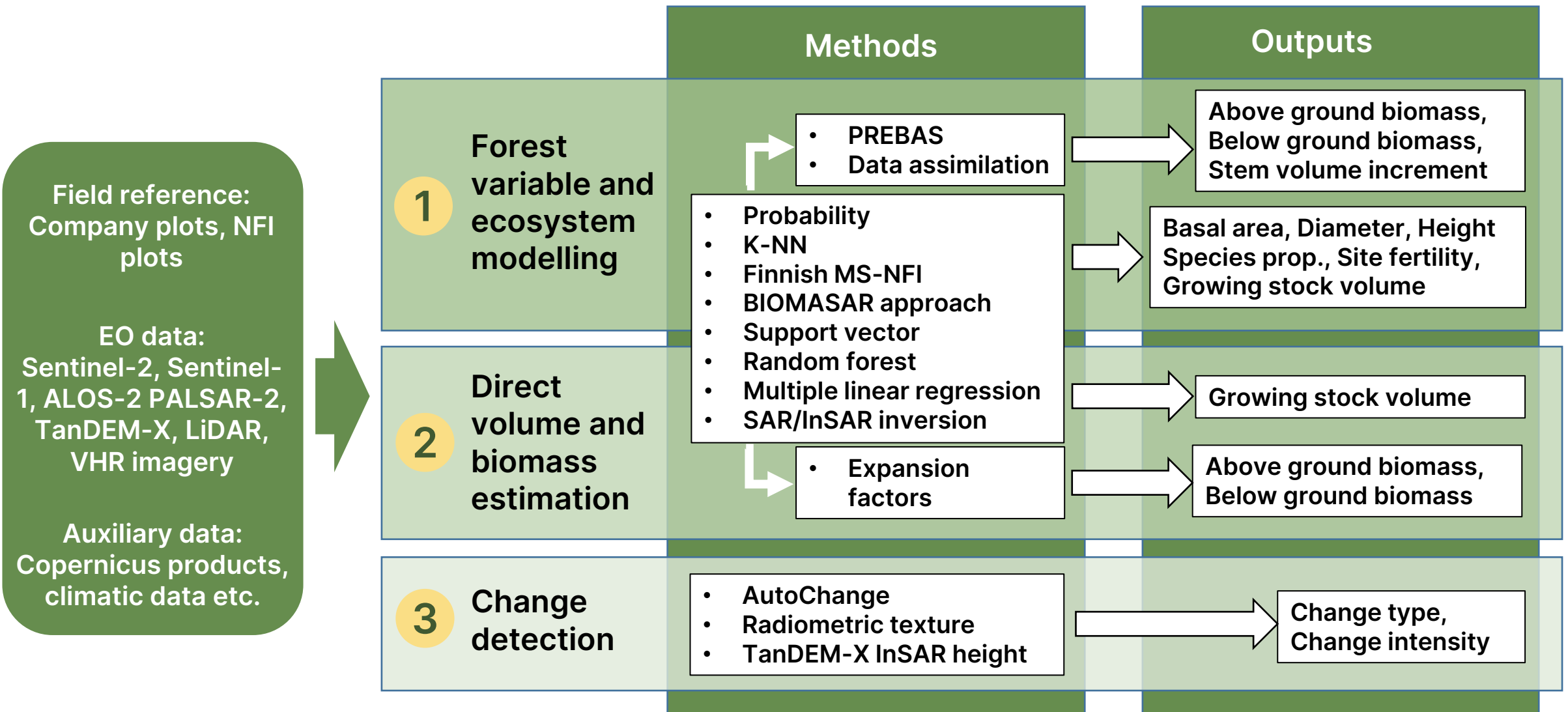
1 Close integration of in-situ and remotely sensed data.

2 Process-based forest ecosystem carbon modelling integrated into the system.

3 Flexibility to user needs ranging from private company area monitoring to continental analyses.
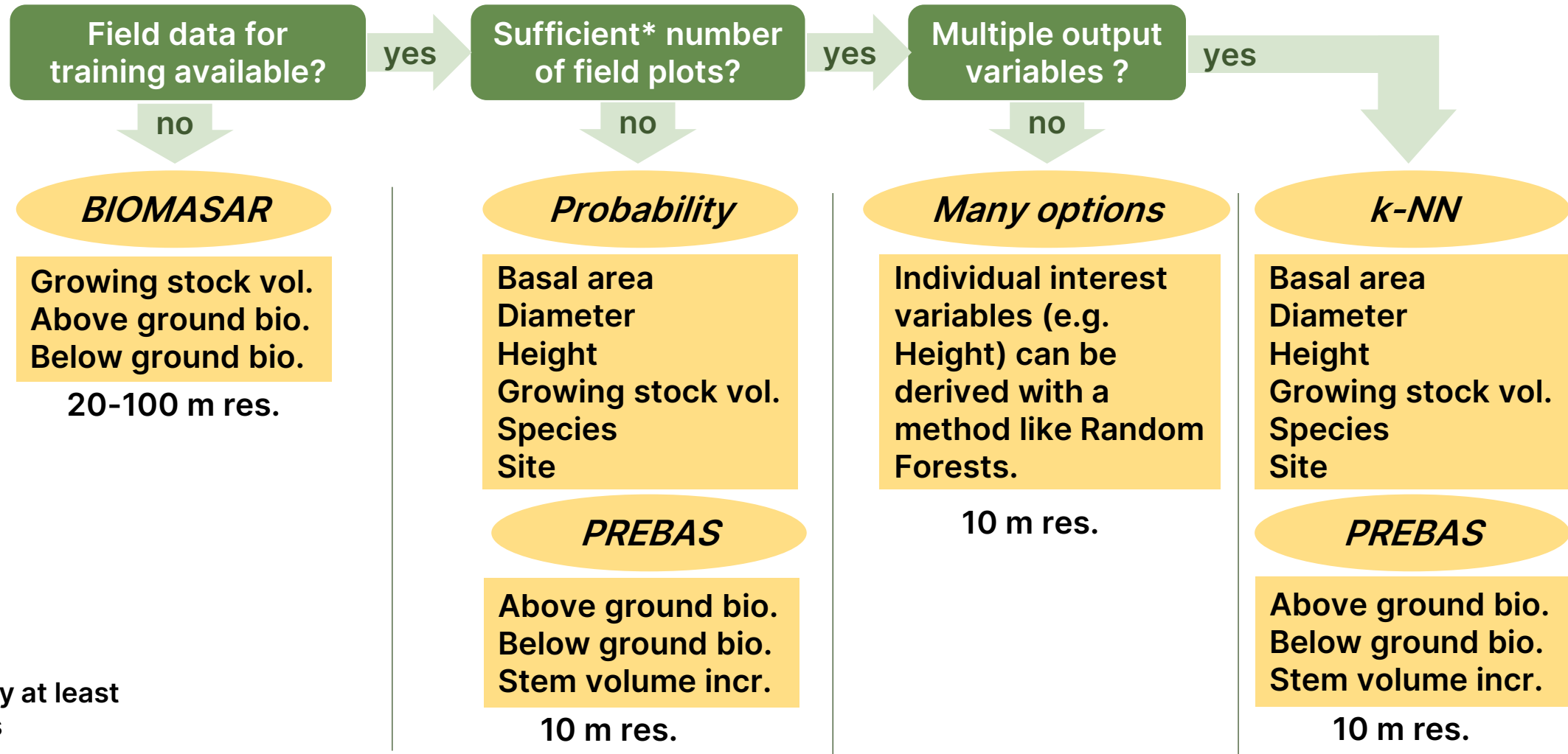
Project structure and timeline

Approaches chosen for demonstration implementation

| Field data for training available? | →yes | Sufficient* number of field plots? | →yes | Multiple output variables ? | →yes |

no ↓   **no** ↓   **no** ↓   ↓

BIOMASAR

Growing stock vol.
Above ground bio.
Below ground bio.

20-100 m res.

Probability

Basal area
Diameter
Height
Growing stock vol.
Species
Site

PREBAS

Above ground bio.
Below ground bio.
Stem volume incr.

10 m res.

Many options

Individual interest variables (e.g. Height) can be derived with a method like Random Forests.

10 m res.

k-NN

Basal area
Diameter
Height
Growing stock vol.
Species
Site

PREBAS

Above ground bio.
Below ground bio.
Stem volume incr.

10 m res.

*Typically at least 100 plots

Forest Carbon Monitoring

Demonstration sites

Demo area	Demo type	Method	Years
1. Finland	National	MS-NFI+ PREBAS	2017 + 2019
2. Ireland	Company 8 tiles	Probability+ PREBAS	2019 + 2020 +2021
3. Romania	Company 3 tiles	kNN + PREBAS	2019 + 2020 +2021
4. Catalonia	Regional 8 tiles	kNN + PREBAS	2019 + 2020
5. Galicia	Company 5 tiles	Probability+ PREBAS	2019 + 2020 +2021
6. Extremadura	Provincial 1 tile	Probability+ PREBAS	2017 + 2022
7. Peru	Provincial 16 tiles	Probability+ PREBAS	2020 + 2021
8. Europe	Continental 746 tiles	BIOMASAR	2020 + 2021
9. Austria	National 14 tiles	Variable	variable

EO data:
- **Peru Sentinel-2 + PALSAR-2 (mosaic)**
- **Europe Sentinel-1 + PALSAR2-2 (mosaic)**
- **All others Sentinel-2 + Sentinel-1**

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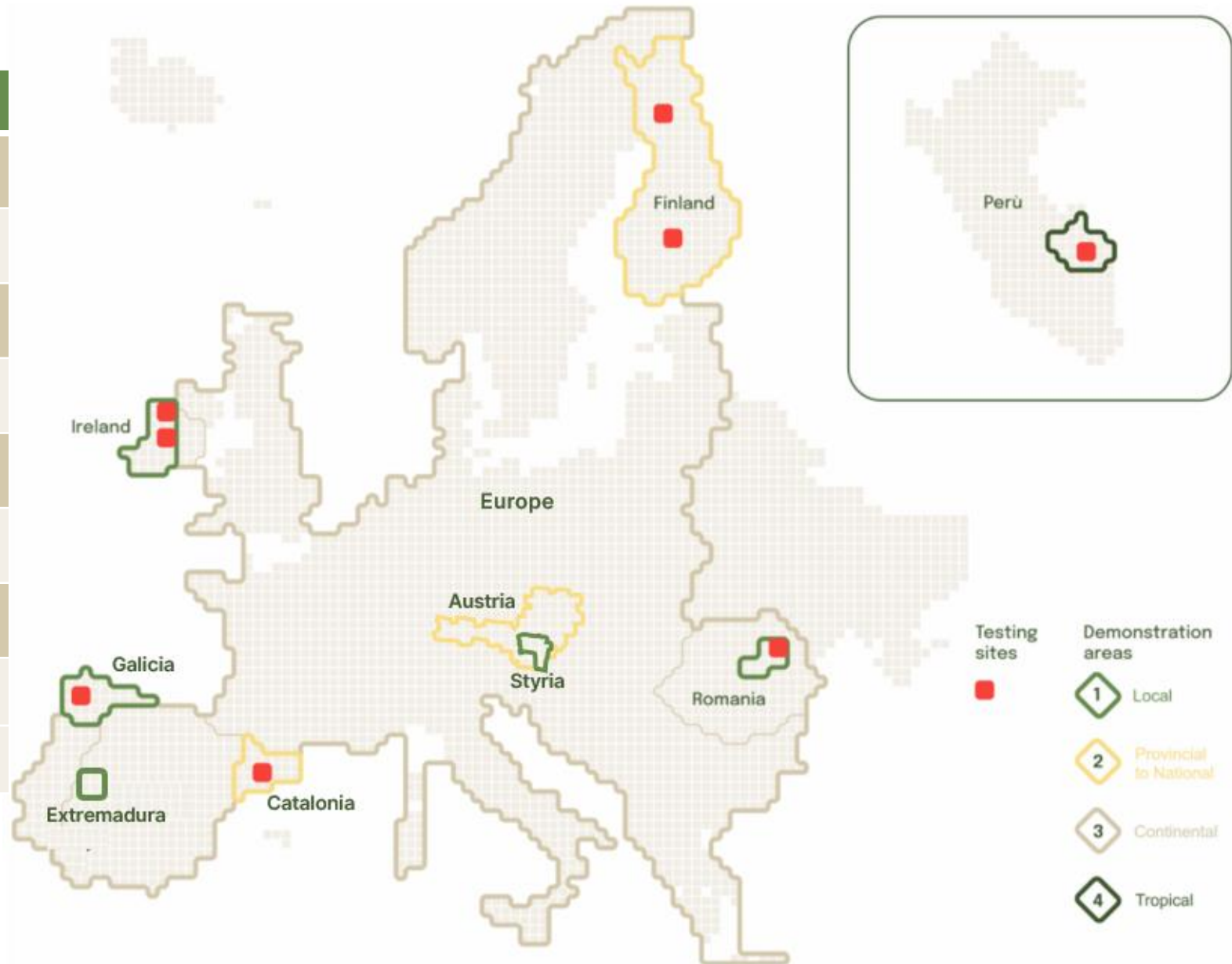
Forestry TEP

- **The demonstration were implemented on Forestry TEP with NoR funding**
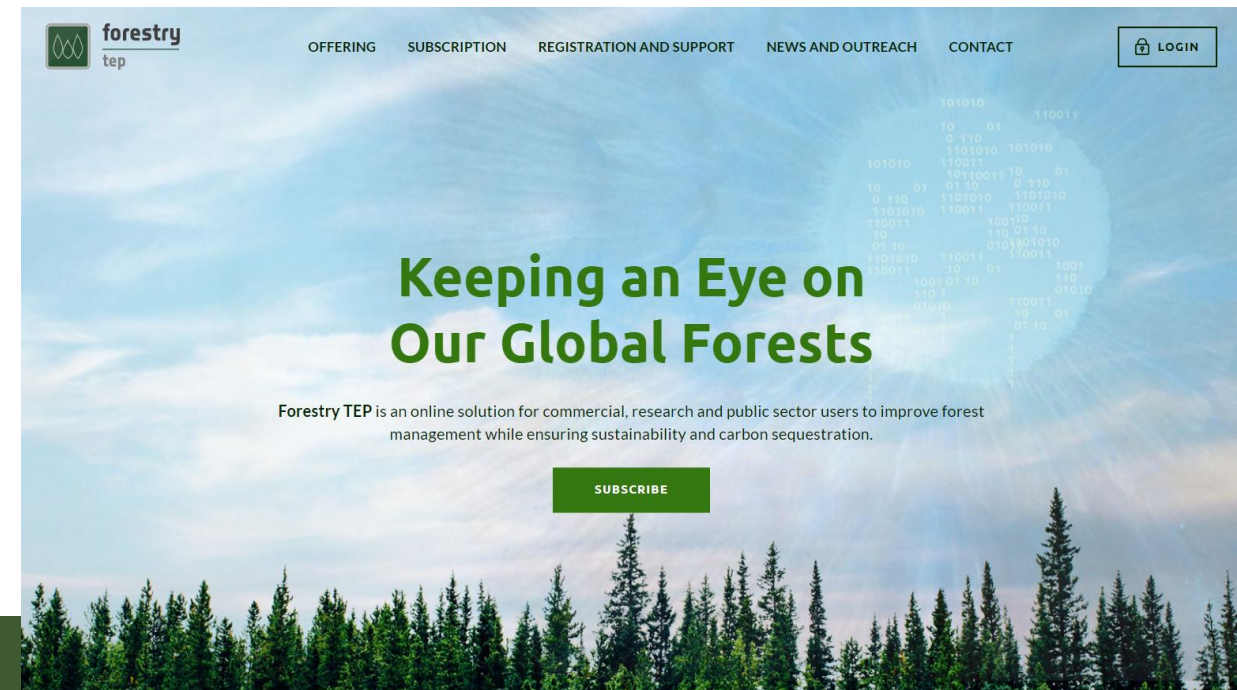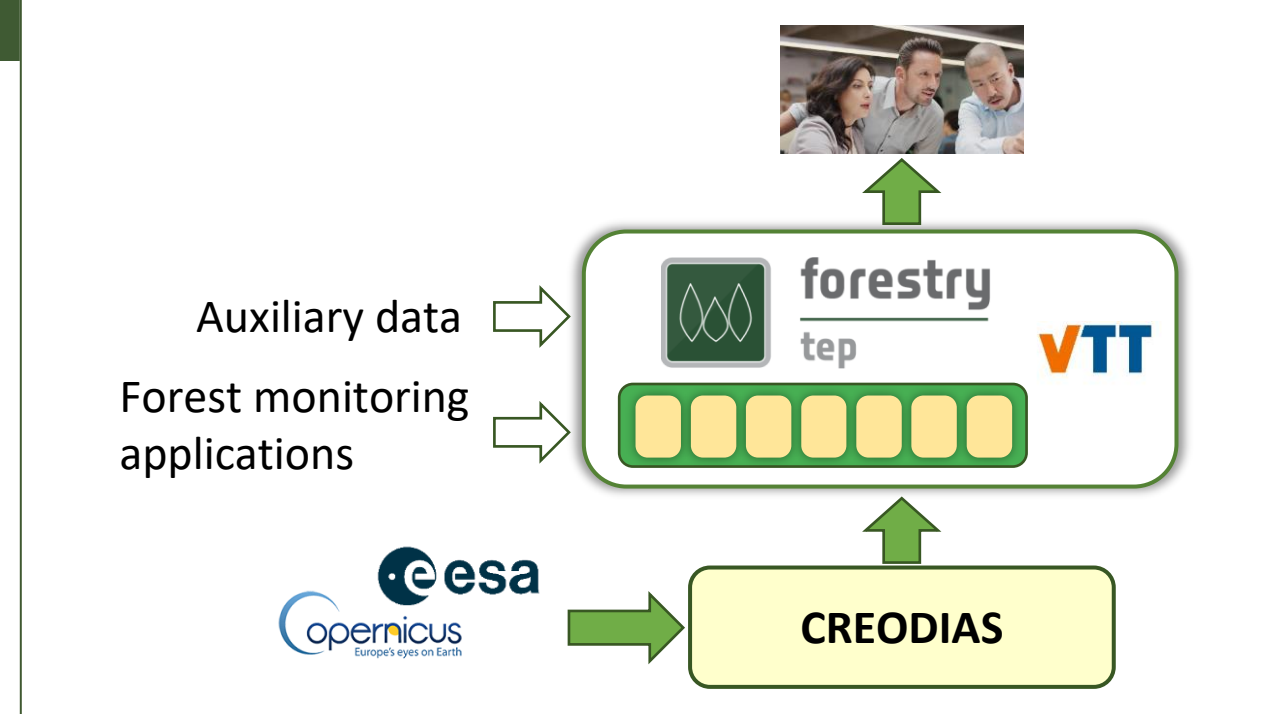
- **Ways to use the platform**
  - Use available applications that combine EO data and your own input datasets
  - Develop your own processing scripts
  - Share or license applications
  - Access or share output products

- **Two modes of usage**
  - Online web user interface
 - REST API for interconnecting between systems

- **All information available at: https://f-tep.com** ➤

Auxiliary data ➡

Forest monitoring applications ➡

CREODIAS

Keeping an Eye on Our Global Forests

Forestry TEP is an online solution for commercial, research and public sector users to improve forest management while ensuring sustainability and carbon sequestration.

SUBSCRIBE

Forest Carbon Monitoring

Examples of prototype output products

- **Products available for viewing and downloading at:**
  https://portal.forestcarbonplatform.org/

Growing stock volume (GSV), Catalonia, Spain

100 km
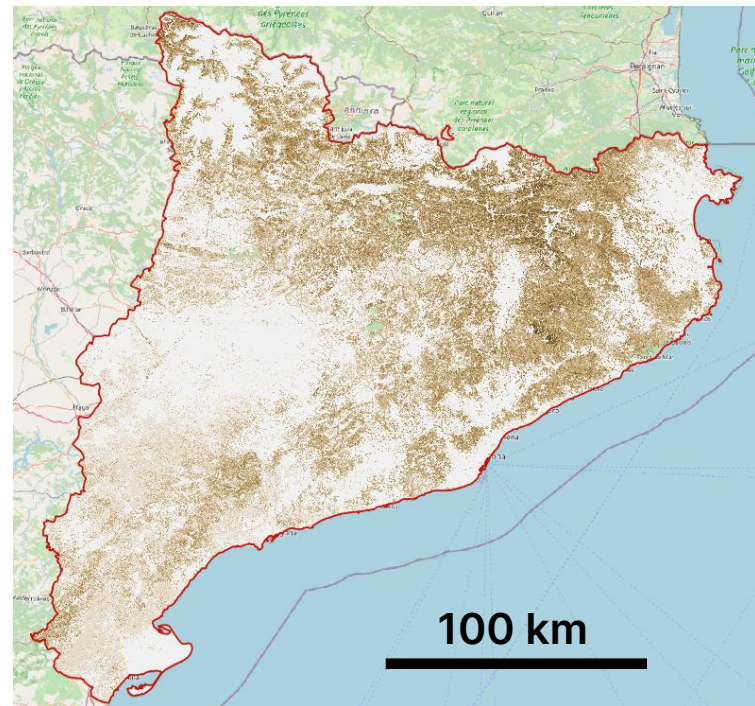
Growing stock volume (GSV)
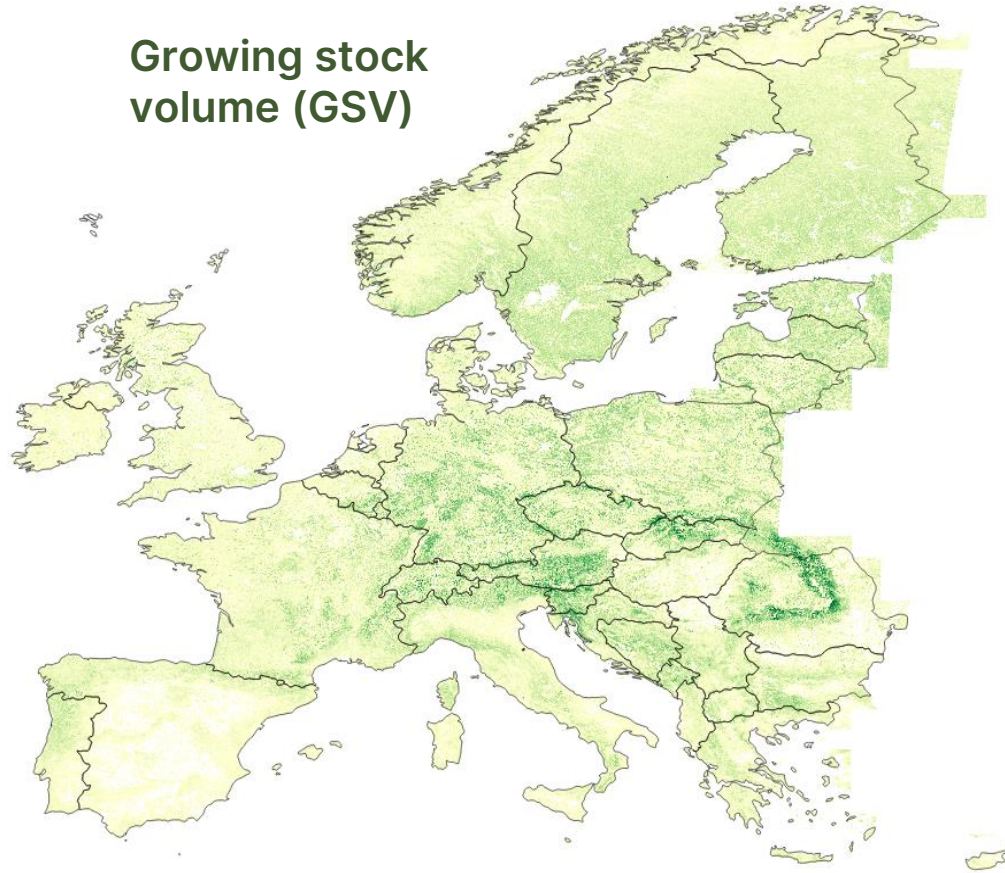
Stem volume increment, Finland

Stem volume increment	
No data (e.g. clouds)	
Non-forest	
0 m³/ha/a	
1 m³/ha/a	
2 m³/ha/a	
3 m³/ha/a	
4 m³/ha/a	
5 m³/ha/a	
6 m³/ha/a	
7 m³/ha/a	
8 m³/ha/a	
9 m³/ha/a	
10 m³/ha/a	
11 m³/ha/a	
12 m³/ha/a	
13 m³/ha/a	
≥ 14 m³/ha/a	

100 km

Forest Carbon Monitoring
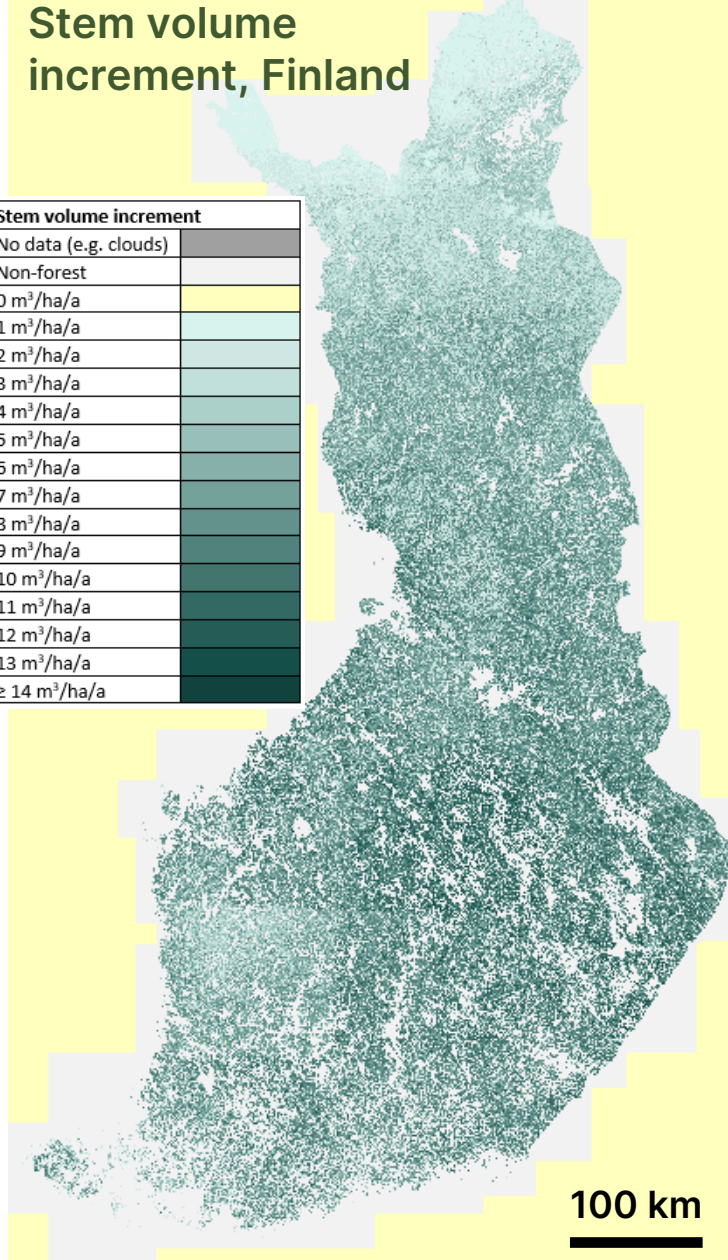
Use of cloud resources with NoR support

Terramonitor NoR usage (I)

- Terramonitor implemented a service for producing a mosaic of cloudless Sentinel-2 image composites in Forestry TEP using the methods described at Miettinen et al. 2021

- Parameters: S2 tile number, time range and output resolution (60 m or 10 m)

- Data discovery
  - S2 Metadata search based on cloud coverage
  - SCL filtering by downloading 60m SCL band for S2 images

- Mosaicking
  - Download S2 products
  - Resample to preferred resolution
  - Pixel-based merging using
  - Output saved as GeoTiff in F-TEP
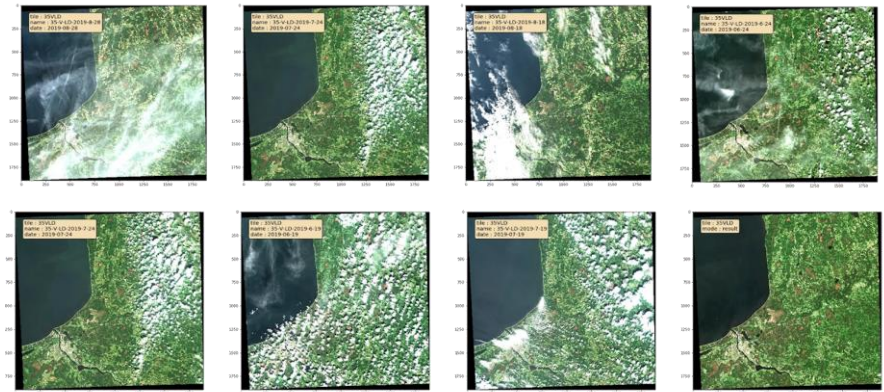
Miettinen, J., Carlier, S., Häme, L., Mäkelä, A., Minunno, F., Penttilä, J., Pisl, J., Rasinmäki, J., Rauste, Y., Seitsonen, L., Tian, X., & Häme, T. (2021). Demonstration of large area forest volume and primary production estimation approach based on Sentinel-2 imagery and process based ecosystem modelling. *International Journal of Remote Sensing*, *42*(24), 9492-9514. https://doi.org/10.1080/01431161.2021.1998715
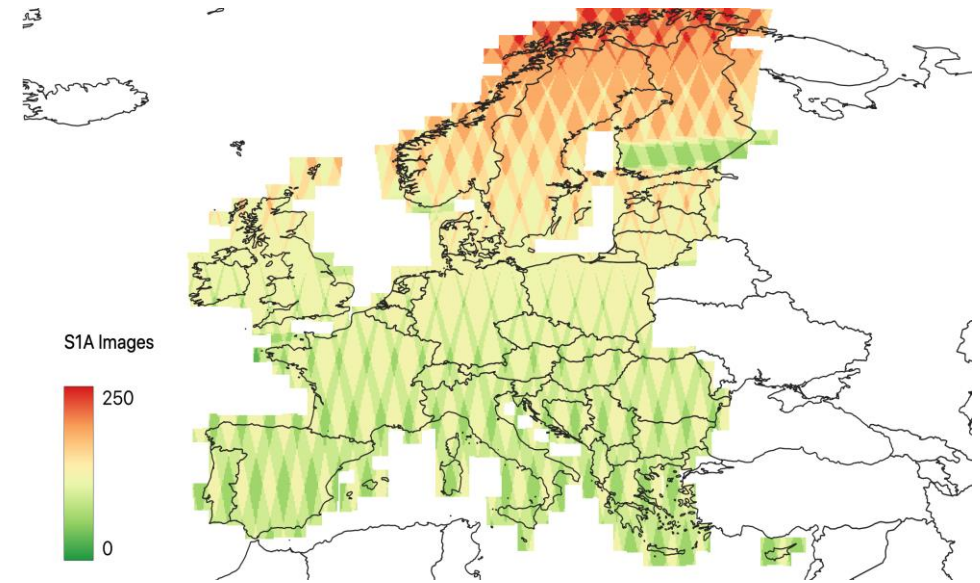
Terramonitor NoR usage (II)

- The compositing method was used to produce two yearly Sentinel-2 composite image mosaics of Europe

- 2020 and 2021 mosaics were produced

- The mosaics were used to produce the 2020-2021 forest change/disturbance prototype output product

- The mosaics are available at: https://portal.forestcarbonplatform.org/
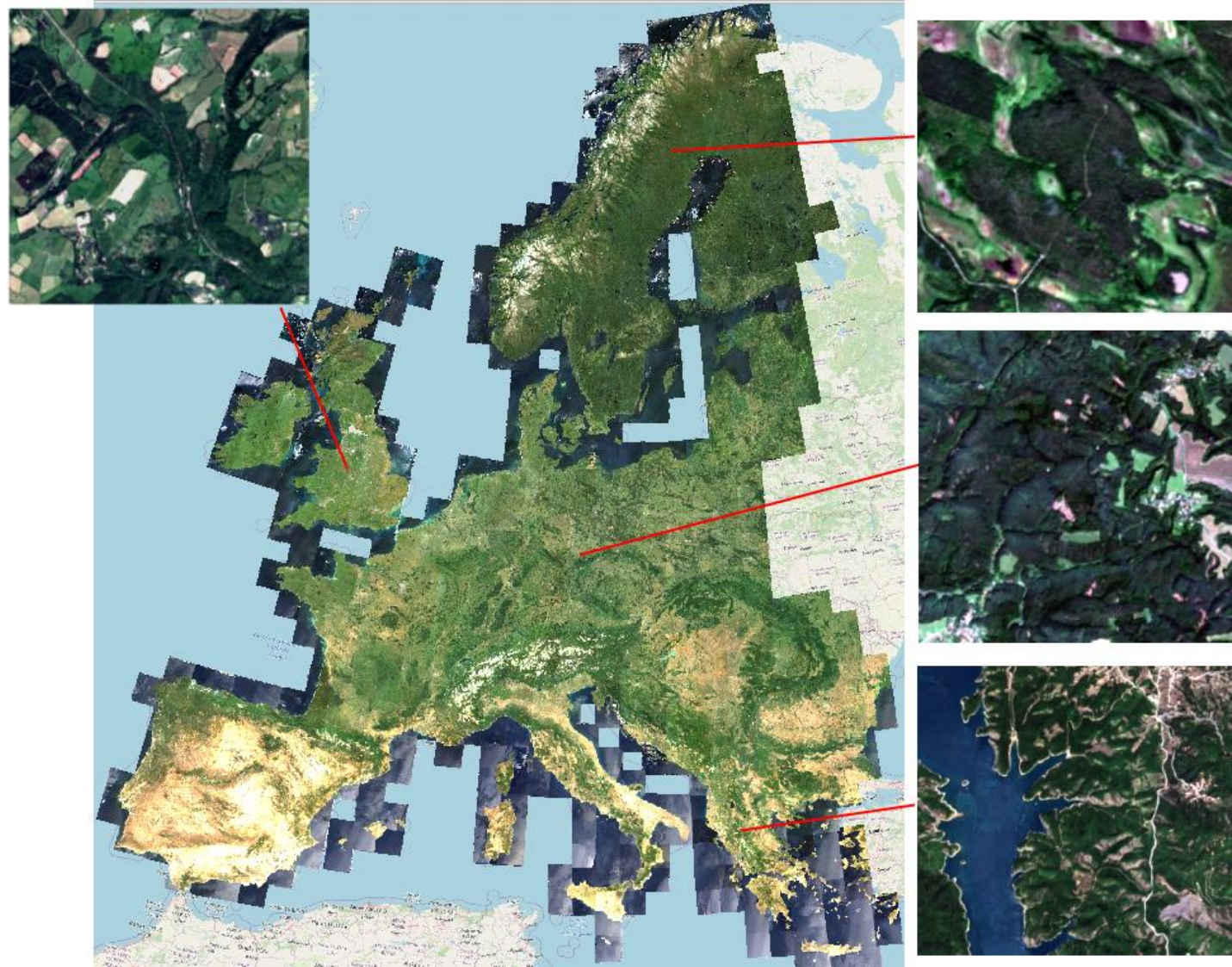
Gamma Remote Sensing NoR usage (I)

- Gamma Remote Sensing implemented a Sentinel-1 pre-processing service to Forestry TEP.

- The processing workflow conducted independent processing of each individual S1 GRD, i.e., the service was initiated for each S1 GRD image to be processed.

- Processing resulted in radiometric terrain corrected backscatter images with 20 m resolution that were geocoded to the S2 tiling grid.

Number of S1 observations at each location across the European demonstration area.

- Ca. 52 000 Sentinel-1 GRD images that had been acquired over the European demonstration area in 2020 and 2021 were processed

- All images were processed to 20 x 20 m² pixel posting, matching the Sentinel-2 composite mosaic tiles produced by Terramonitor.

- The processing was conducted using the REST-API interface available at Forestry TEP.

Forest Carbon Monitoring

Gamma Remote Sensing NoR usage (II)

- For producing GSV, AGB, and BGB maps for the European demonstration area, the Gamma Remote Sensing implemented the BIOMASAR algorithm into Forestry TEP.

- The three-step process resulted in a combination of C- and L-band derived GSV maps. Conversion factors were then applied to convert GSV to AGB and finally AGB to BGB.

- In total, the service needed to be run 3730 times (Step 1: 746 tiles * 2 sensors, Step 2: 746 tiles * 2 sensors, Step 3: 746 tiles). The processing on FTEP/Creodias may be initiated via the FTEP API.

- The operational processing of the biomass maps was handled by AFRY with support from Gamma Remote Sensing.

- The biomass maps are available at:
https://portal.forestcarbonplatform.org/
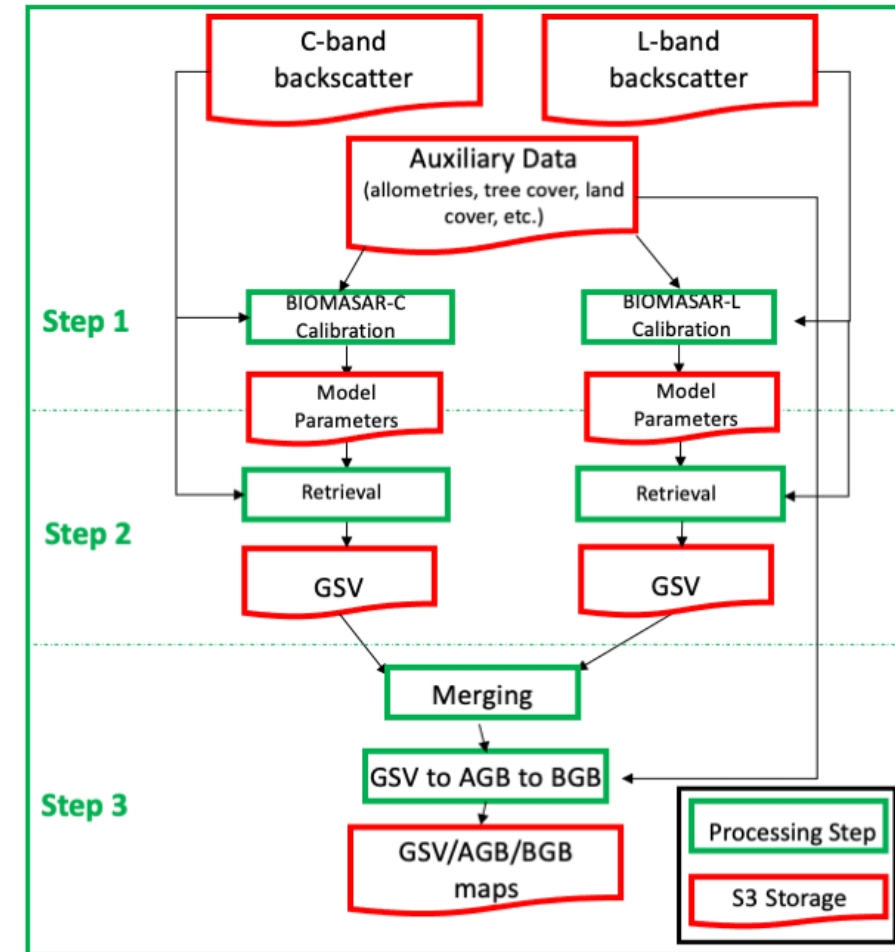
Flow chart illustrating the sequence of steps to derive GSV, AGB, and BGB maps from S1 and ALOS-2 C- and L-band backscatter data.
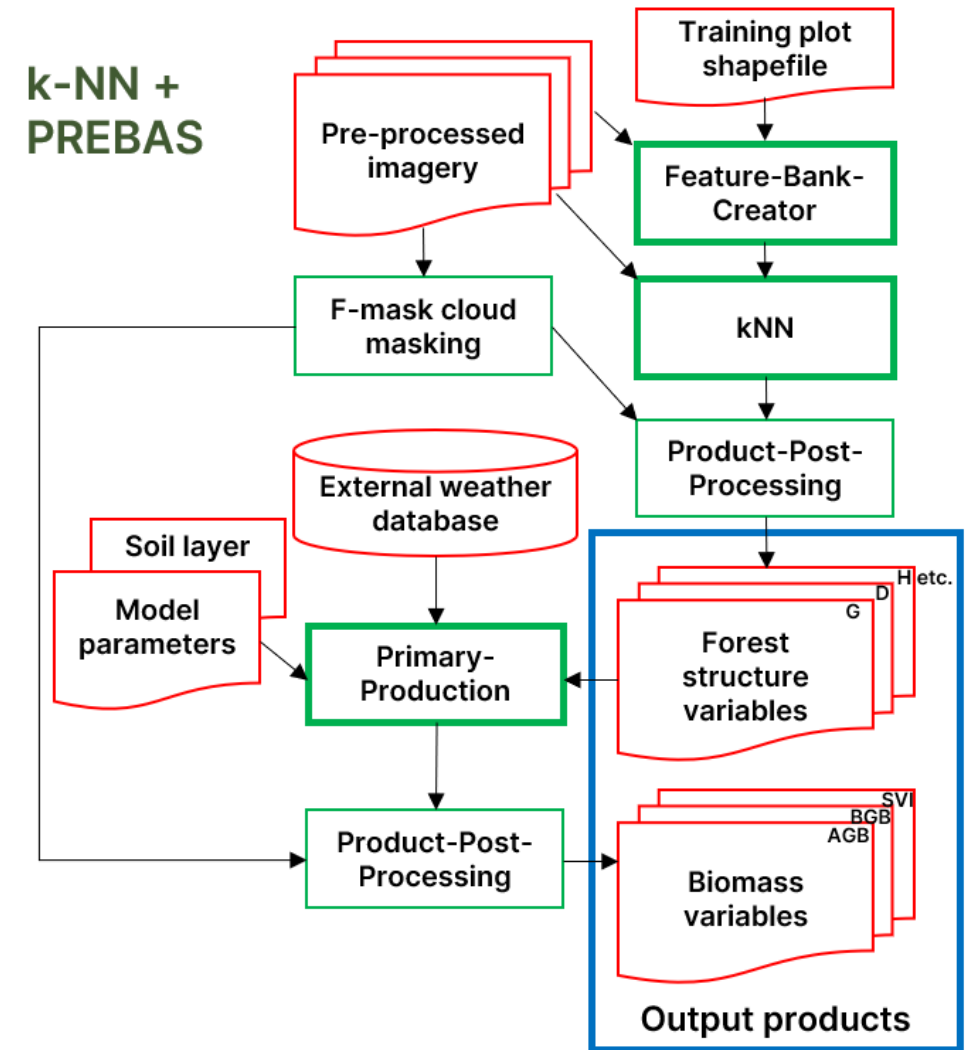
Forest Carbon
Monitoring

AFRY NoR usage

- AFRY and VTT were responsible for running the prototype demonstration outputs in Forestry TEP.

- AFRY created a Microservice Platform manager to orchestrate the demonstration processing from their own system via the Forestry TEP REST-API connection.

- The major task was to conduct the BIOMASAR processing using the service implemented by Gamma Remote Sensing.

- The BIOMASAR service needed to be run 3730 times. In addition, AFRY conducted the PREBAS ecosystem model processing in all of the demonstration areas and the European wide Autochange change detection processing.

AFRY Microservice Platform
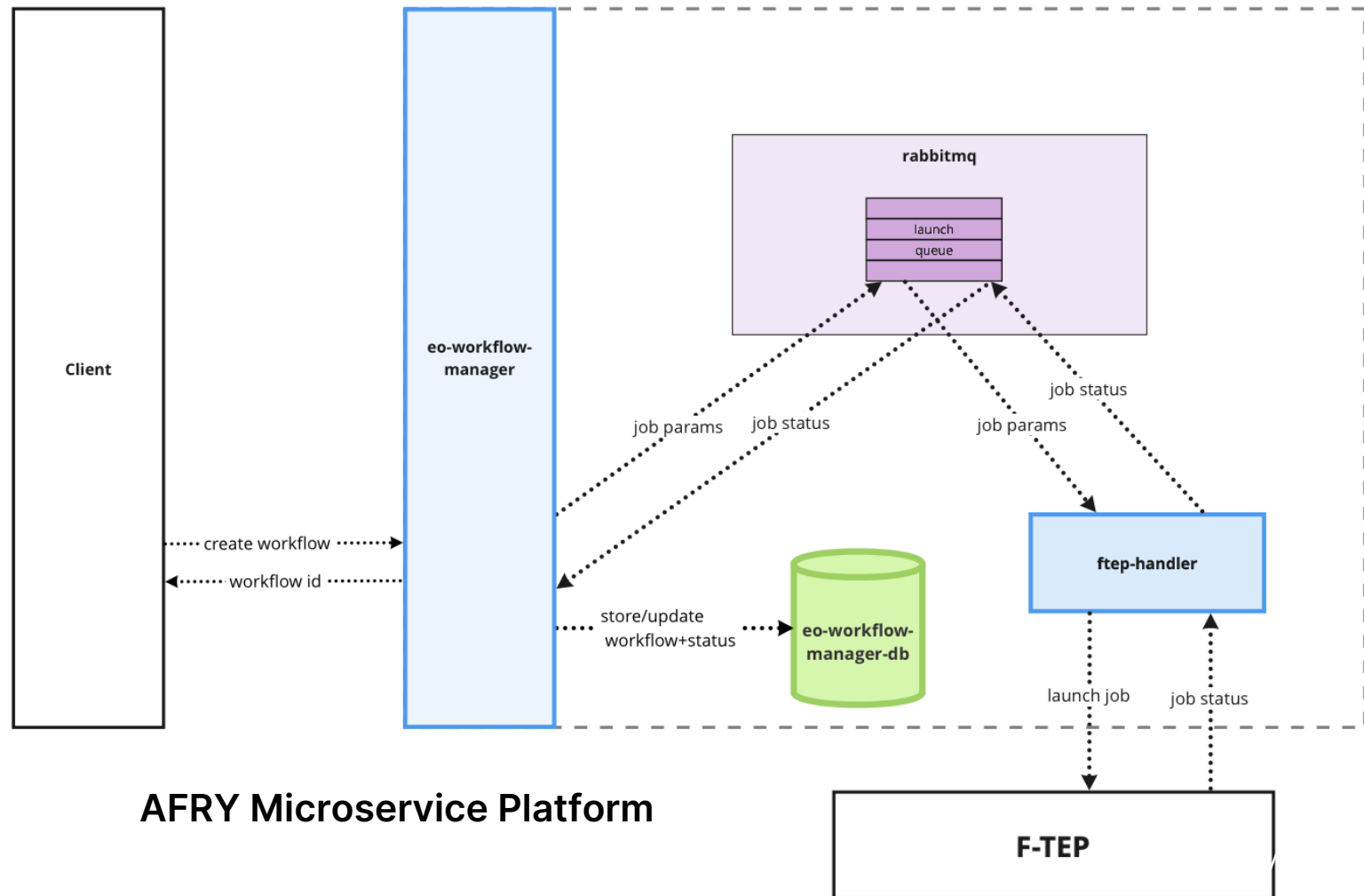
VTT NoR usage

- AFRY and VTT were responsible for running the prototype demonstration outputs in Forestry TEP.

- VTT designed processing pipelines and updated Forestry TEP services to meet the needs of the FCM project.

- VTT run the processing for all the forest structure variable prototype outputs for all demonstration areas.

- These layers were used as input for the PREBAS processing conducted by AFRY.

- VTT also run all the Autochange processing in the demonstration areas except the European wide demo, which was conducted by AFRY.

Example of a processing pipeline used in Forestry TEP to create prototype outputs with kNN and PREBAS methods