Retrieval of forest functional traits from PRISMA imagery

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➤ Quantitative and spatialised estimation of functional parameters of terrestrial vegetation plays a fundamental role in agro-forestry

➤ Reflectance spectroscopy has proved to be a promising system capable of providing quantitative estimates of biophysical and biochemical parameters and parameters related to photosynthetic processes in vegetation

➤ The current (PRISMA and EnMAP) and upcoming (CHIME) hyperspectral missions, by combining high spectral resolution, high spatial resolution and good temporal frequency, allows for the first time the estimation and temporal analysis of a number of vital parameters for various agricultural and forest ecosystem monitoring applications

➤ Evaluation of the potential of hyperspectral data collected by the new generation PRISMA hyperspectral sensor of the Italian Space Agency for plant trait estimation in mixed forest ecosystems

Specific objectives

➤ Development and testing of a hybrid retrieval workflow for forest trait mapping

  ➤ Leaf Chlorophyll Content

  ➤ Leaf Water content

  ➤ Leaf Nitrogen content

  ➤ Leaf Area Index

➤ Assessment of the accuracy of the proposed retrieval scheme against ground data collected in correspondence of PRISMA overpasses
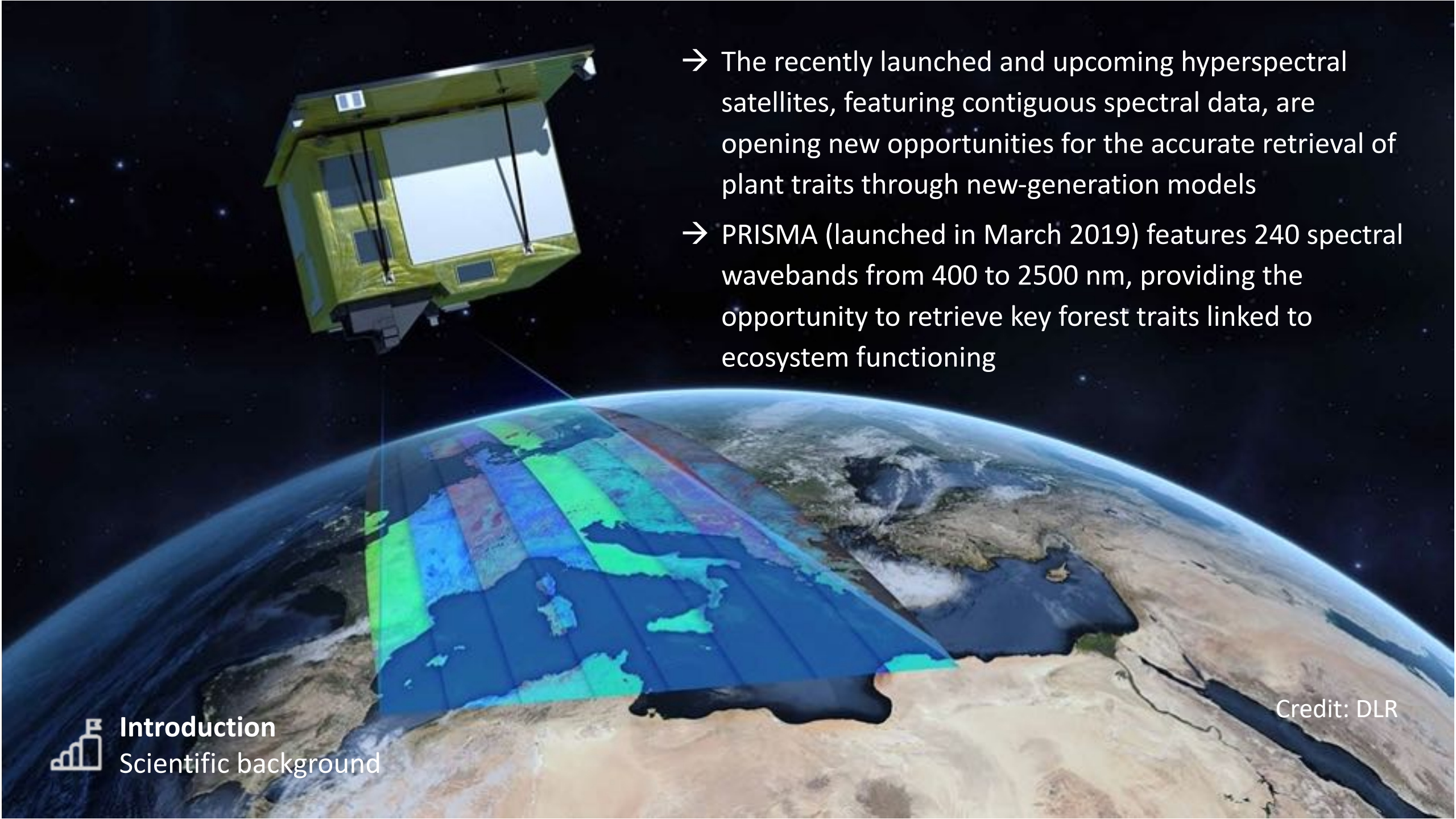
→ The recently launched and upcoming hyperspectral satellites, featuring contiguous spectral data, are opening new opportunities for the accurate retrieval of plant traits through new-generation models

→ PRISMA (launched in March 2019) features 240 spectral wavebands from 400 to 2500 nm, providing the opportunity to retrieve key forest traits linked to ecosystem functioning

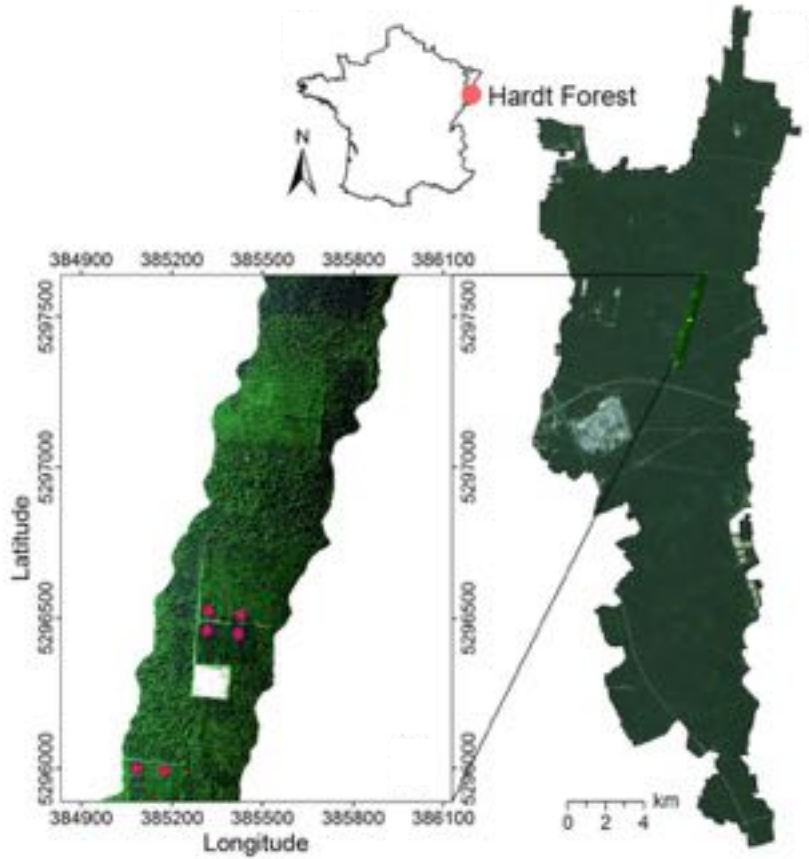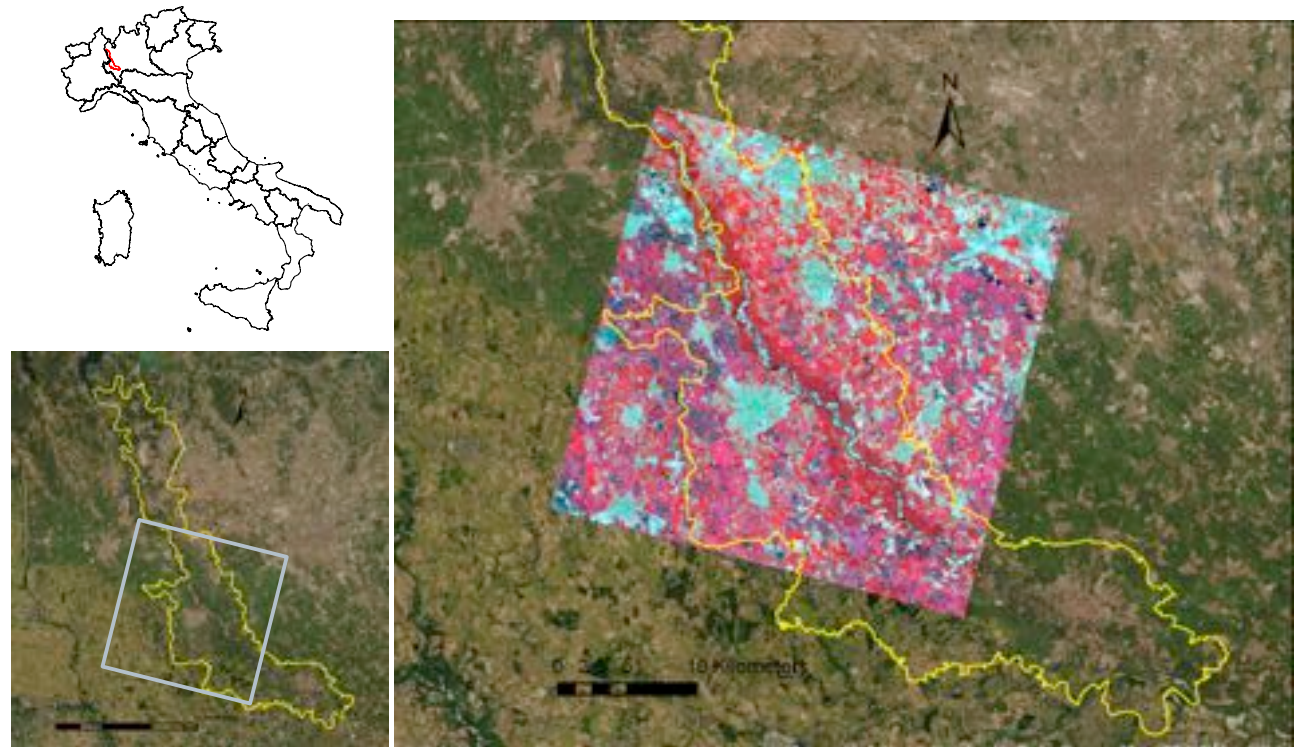Credit: DLR

Introduction
Scientific background

Hardt Forest (France)

Ticino Regional Park (Italy)

Study sites
Hardt forest and Ticino Park

Hardt Forest (France)

→ **Temperate mixed forest** (Carpinus betulus L., Quercus petraea (Matt.) Liebl., Quercus robur L., Acer campestre L., Tilia L., Pinus sylvestris L., Larix decidua (Mill.))

→ Relatively **large variability in terms of forest age** due to the presence of managed regeneration stands

→ June 2013: intensive field campaign (ESA HyFlex, ESA SEN2Exp)

Ticino Regional Park (Italy)

→ **Temperate mixed forest** (Quercus robur L., Carpinus betulus L., Castanea sativa Mill., Populus spp., Alnus glutinosa L., Prunus serotina Ehrh., Robinia pseudoacacia L., Pinus spp.)

→ Foreign invasive species were introduced into the area from the end of the 19th century producing a significant ecological problem. Periodic selective cutting is planned.

→ June, July, September 2022: intensive field campaigns (ASI PRIS4VEG)

Data acquisition
Airborne imagery

→ APEX (Airborne Prism EXperiment) was flown over the Hardt forest on 17 June 2013 at 12:30±30 in the framework of the SEN2Exp campaign funded by ESA

→ APEX features 288 spectral wavebands covering 380-2500 nm

→ 7 flightlines with 30% lateral overlap were acquired to cover the entire forest

→ APEX hyperspectral cubes were resampled to match PRISMA spatial and spectral resolution
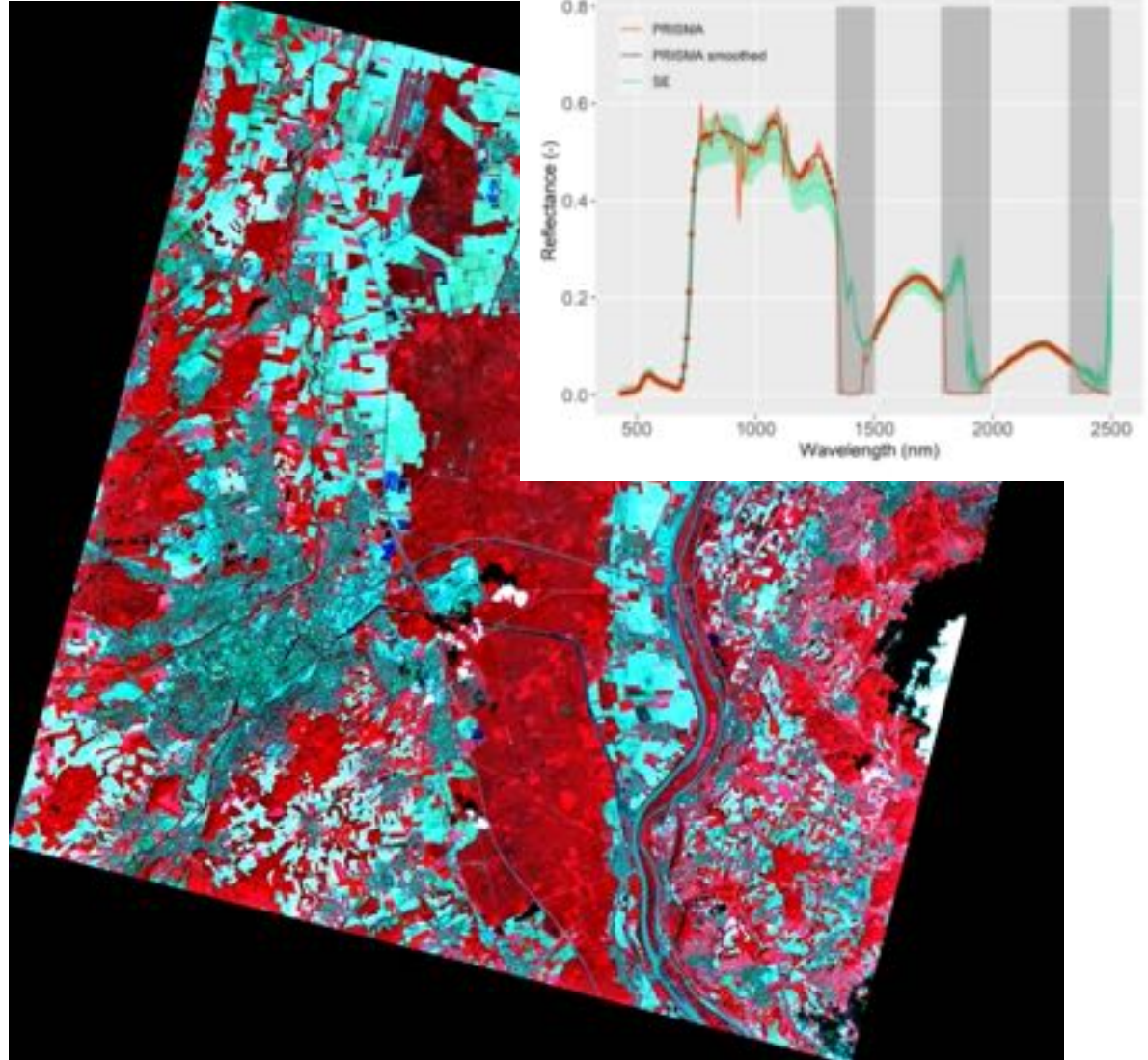
Data acquisition
Spaceborne imagery

→ **PRISMA** captured a spot image over

the **Hardt forest** on 11 June 2021

the **Ticino Park** on 28 June 2021, June 2022, July 2022 and September 2022

→ The sensor is a push broom imaging spectrometer featuring **240 spectral bands** (400-2500 nm)

→ PRISMA has a swath width of 30 km and a **ground spatial resolution of 30 m**

→ The L2D products (geocoded at-surface reflectance) were preprocessed **pre-processed to obtain smooth spectra** (Tagliabue et al. 2022)

Data acquisition
Field data

→ Leaf Chlorophyll Content (LCC)
→ Leaf Area Index (LAI)
→ Leaf Water content (LWC)
→ Leaf Mass Area (LMA)

Validation of retrieved functional trait maps

Hardt Forest (France)

Plant trait measurements (18 ESU)

Species composition (42 ESU)

Ticino Park (Italy)

Plant trait measurements (30 ESUs x 2 dates)

Species composition (60 ESUs)

Field campaigns in summer 2022

Elementary Sampling Units (ESU) → 30 x 30 m

Methods
Hybrid framework for plant trait retrieval

Simulation of canopy reflectance

Training of Machine Learning

GPR mapping on APEX and PRISMA

PROSPECT-PRO
+
INFORM

Gaussian Processes Regression (GPR)

Validation on APEX

→ **Workflow for the retrieval of plant functional traits using hybrid models**

ARTMO
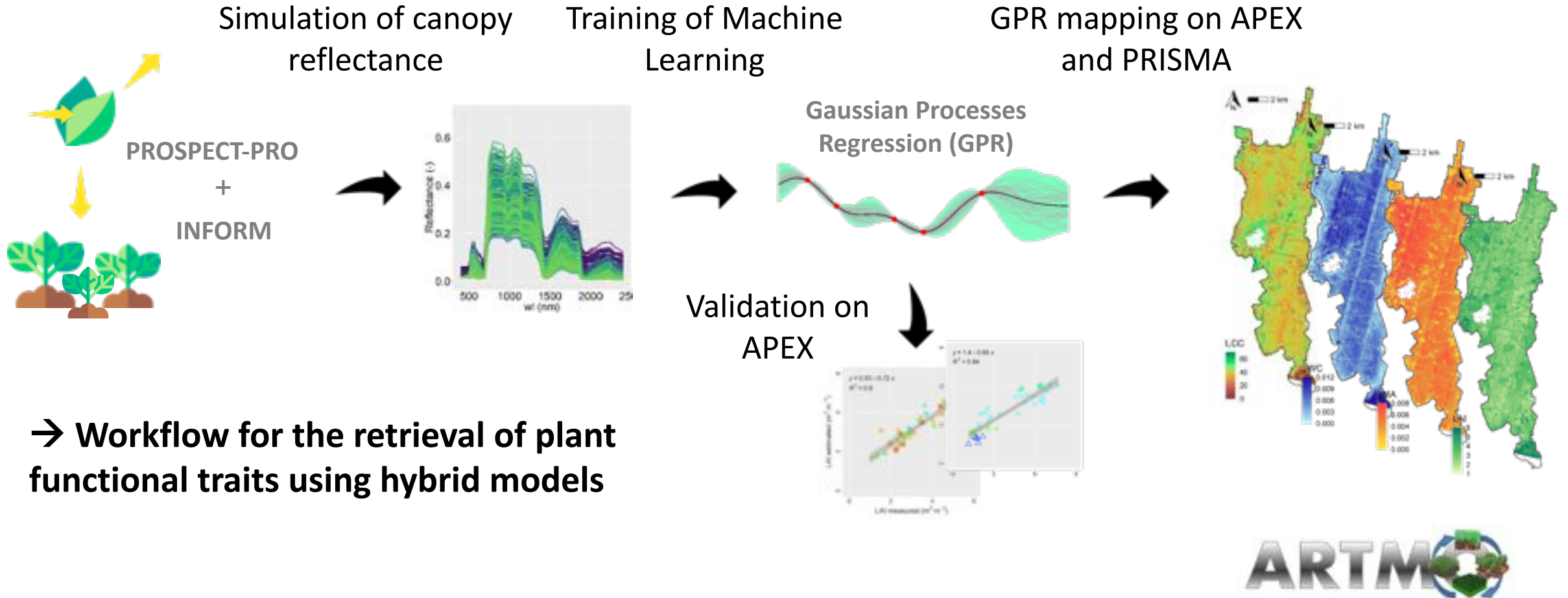
Results
Plant trait retrievals from APEX

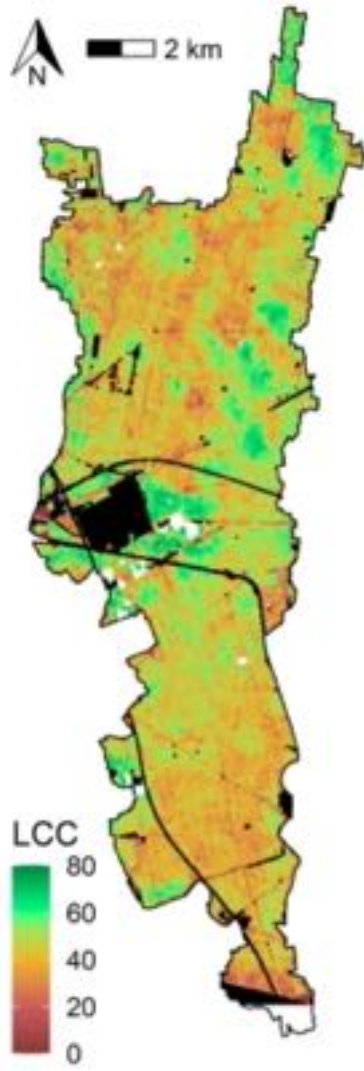**GPR mapping applied on APEX imagery**
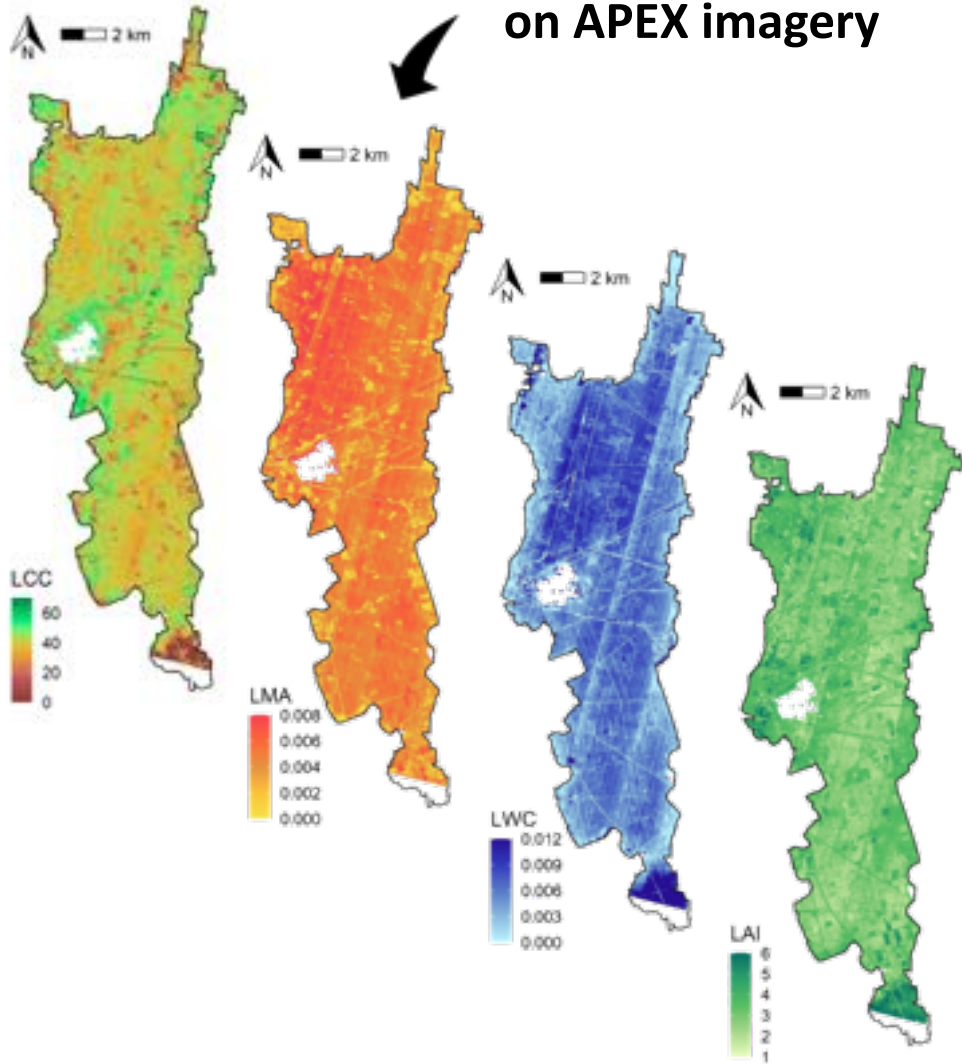
Validation of the models against field data
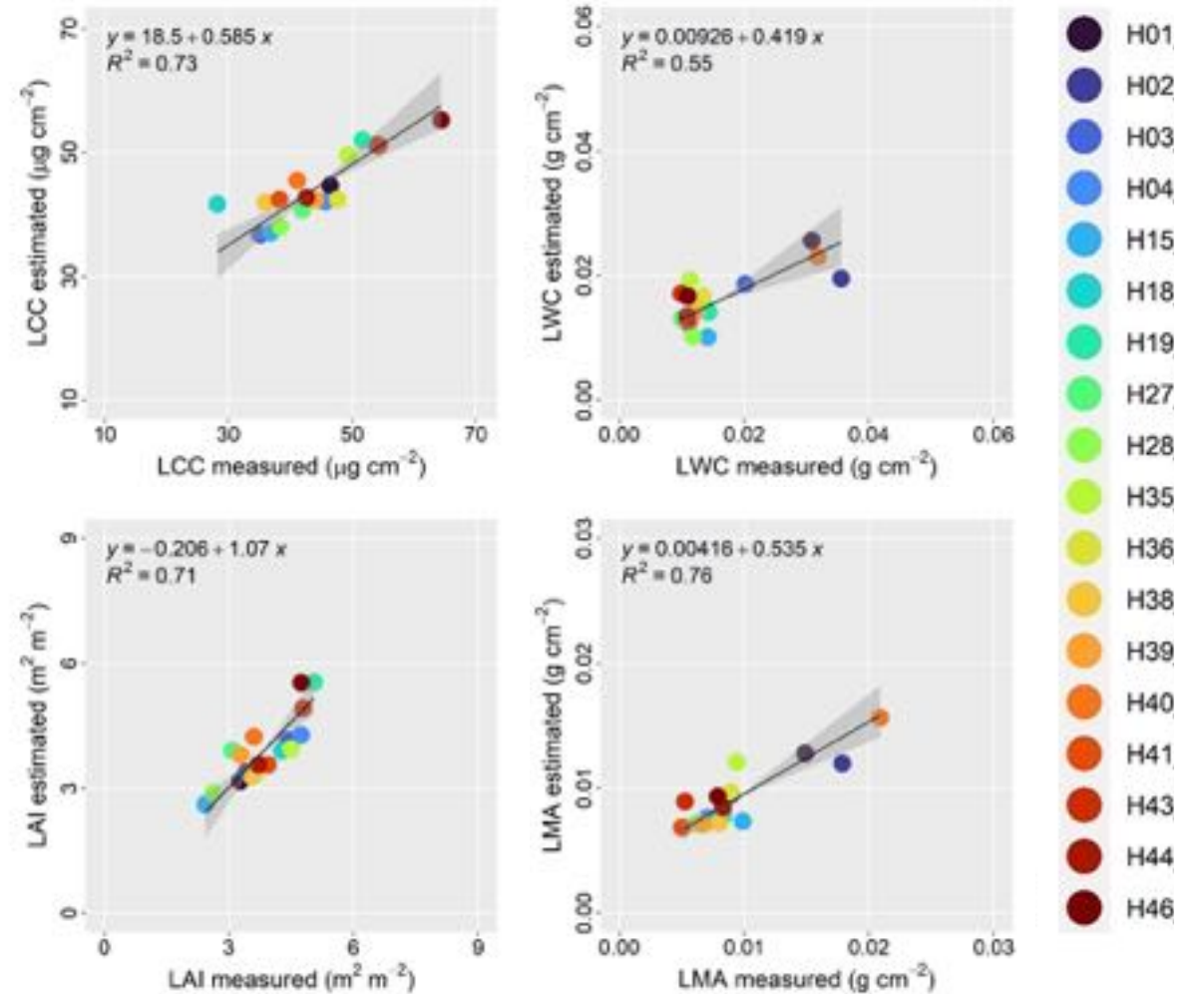
Results

Plant trait retrievals from PRISMA
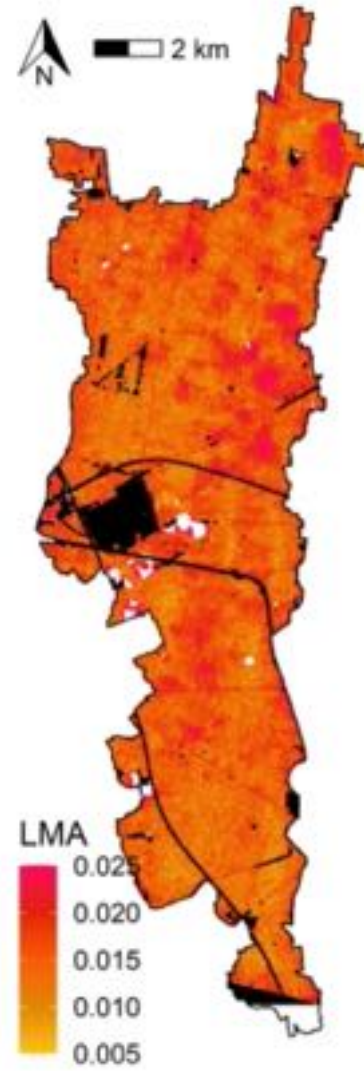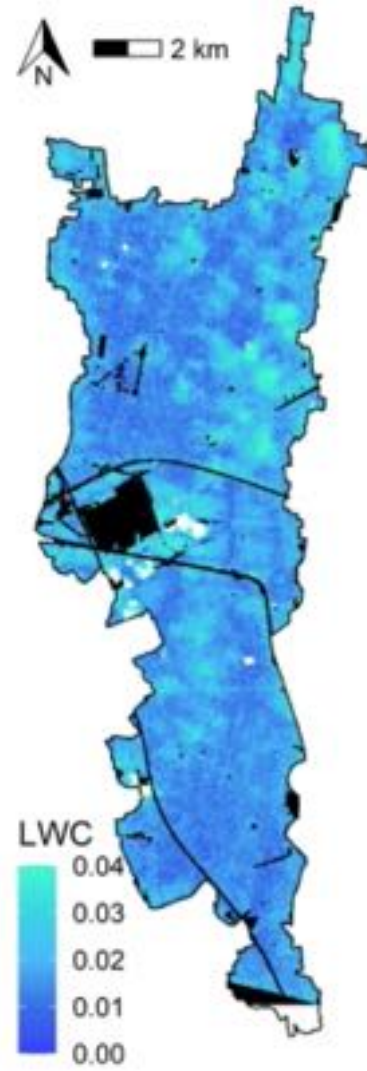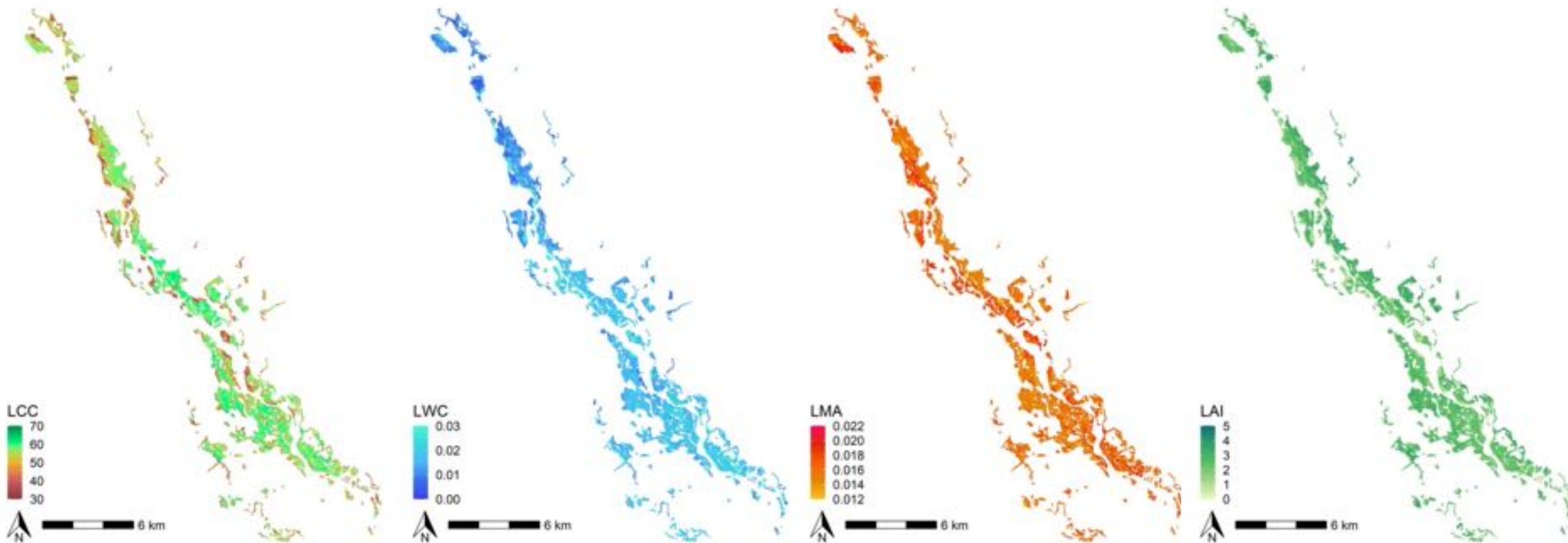

Hardt Forest (France)

GPR mapping applied on PRISMA imagery

Results

Plant trait retrievals from PRISMA

Ticino Park (Italy) – June 2021

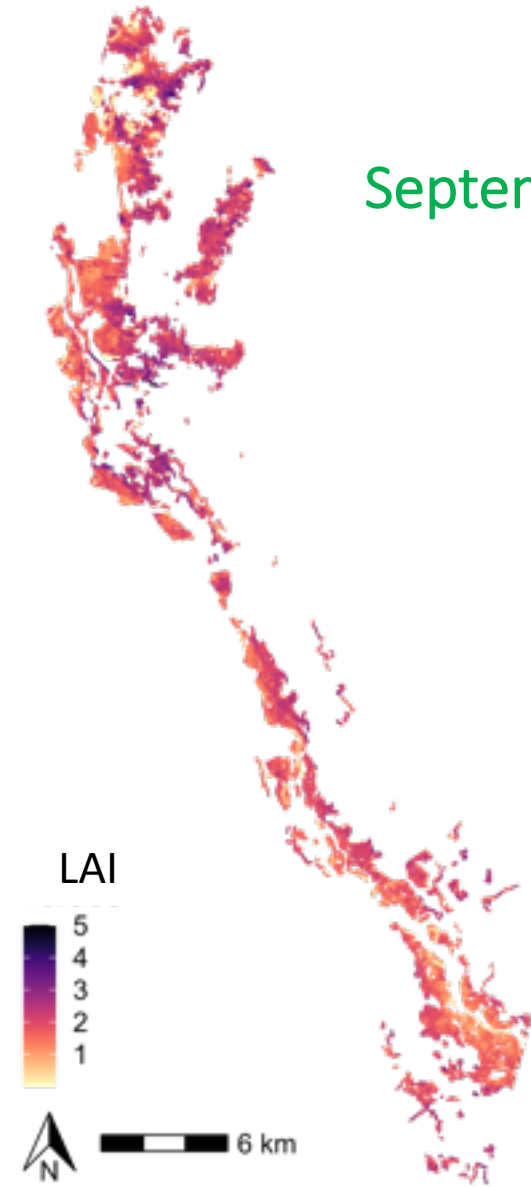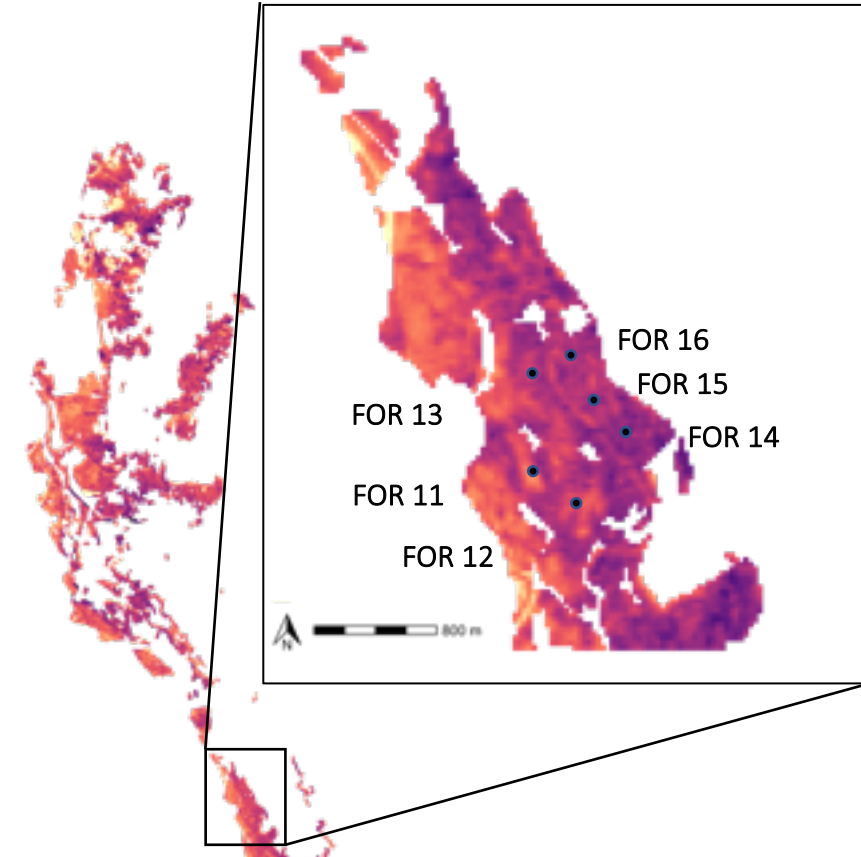**GPR mapping applied on PRISMA imagery**

Results
Plant trait retrievals from PRISMA

Ticino Park (Italy)

2022

June

September

GPR mapping applied
on PRISMA imagery

Results
Plant trait retrievals from PRISMA

Ticino Park (Italy)

2022

June

September

LAI

LAI
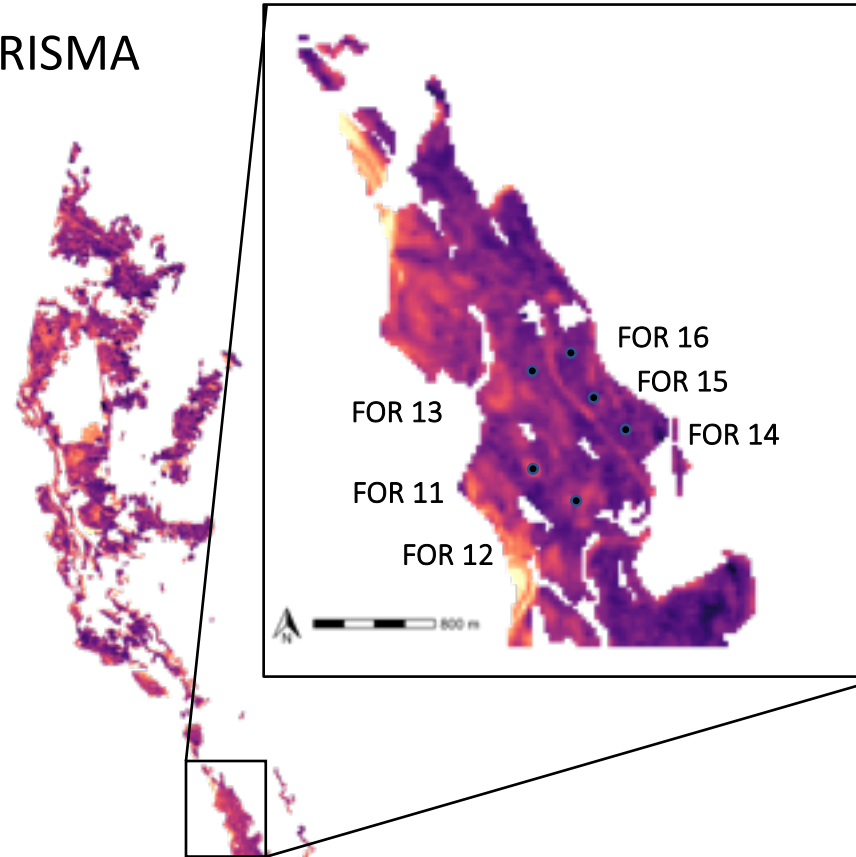
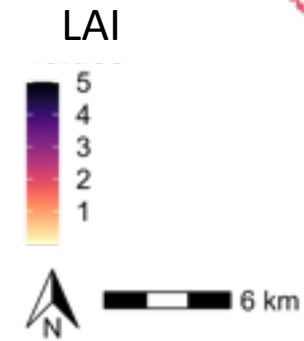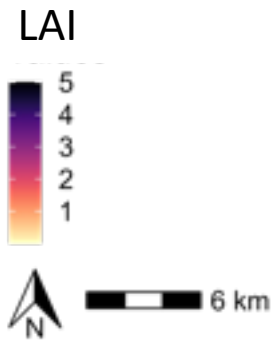GPR mapping applied
on PRISMA imagery

Results
Plant trait retrievals from PRISMA
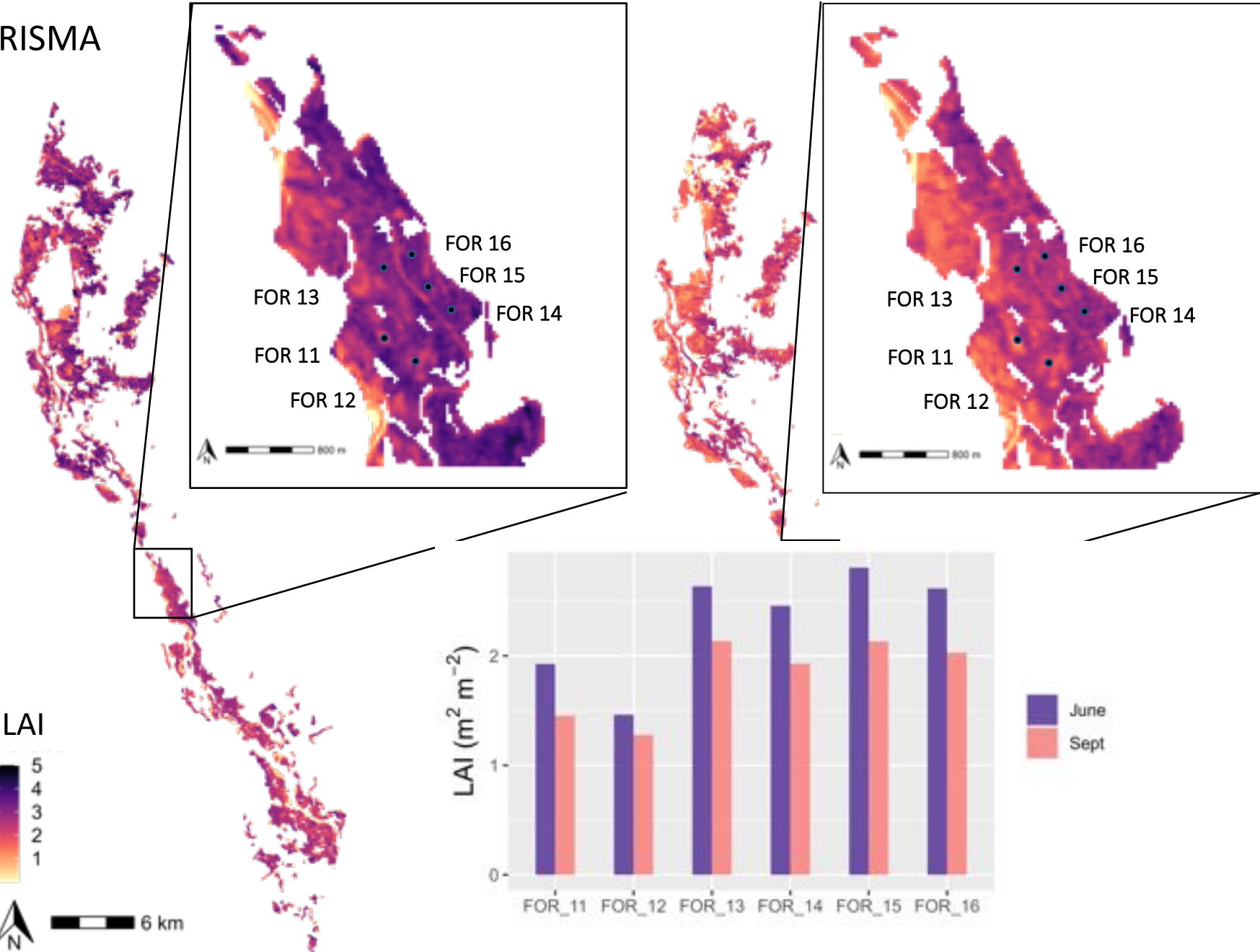
Ticino Park (Italy)

2022

GPR mapping applied
on PRISMA imagery

Results
Plant trait retrievals from PRISMA
Ticino Park (Italy)
2022

GPR mapping applied
on PRISMA imagery

➢ Key plant functional traits have been retrieved from PRISMA images in forest

➢ The trait estimates show reliable range of variations and spatial patterns, demonstrating that the retrieval of leaf and canopy traits from space using hybrid retrieval schemes is feasible

➢ The evaluation of model exportability is ongoing using ground data collected during the 2022 field campaigns

➢ Forest trait maps will serve as a basis for estimating plant functional diversity from hyperspectral satellite remote sensing

➢ These results demonstrate that the retrieval of leaf and canopy traits from space using hybrid retrieval schemes is feasible, paving the way for future operational algorithms for vegetation trait and functional diversity mapping from hyperspectral satellites (PRISMA, CHIME, EnMap)

Thank you!

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