

Energy-Efficient Crop Classification at Scale Using AgrUNet: A Multi-GPU Deep Learning Approach Within the MESEO Project

Miola Andrea†, Sebastiano Fabio Schifano

University of Ferrara, INFN Ferrara

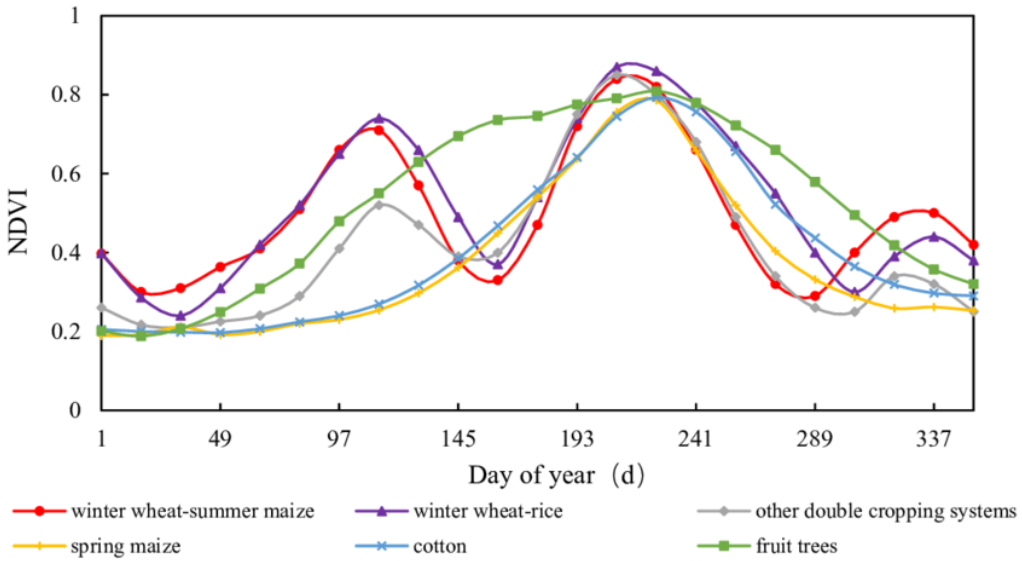
†now at MEEO S.r.l., Ferrara

2nd EO 4 Soil Symposium: ESA Symposium on Earth Observation for Soil Protection and Restoration



Università degli Studi di Ferrara

Crop type maps: what is grown where, and when



NDVI profiles of different crop systems over one year (Yang et al., 2023)

Baseline for soil monitoring

crop type and rotation drive soil cover, erosion risk, nutrient and carbon inputs

Phenology evolution

one date is often cloudy or uninformative

Sentinel-2 time series

10 m resolution, ~5-day revisit, open data

Cost grows with area

processing time and energy scale with the AOI

Goal

accurate crop maps, cheap enough to rerun every season at national scale



Università degli Studi di Ferrara

Context: the MESEO project

Horizon Europe project

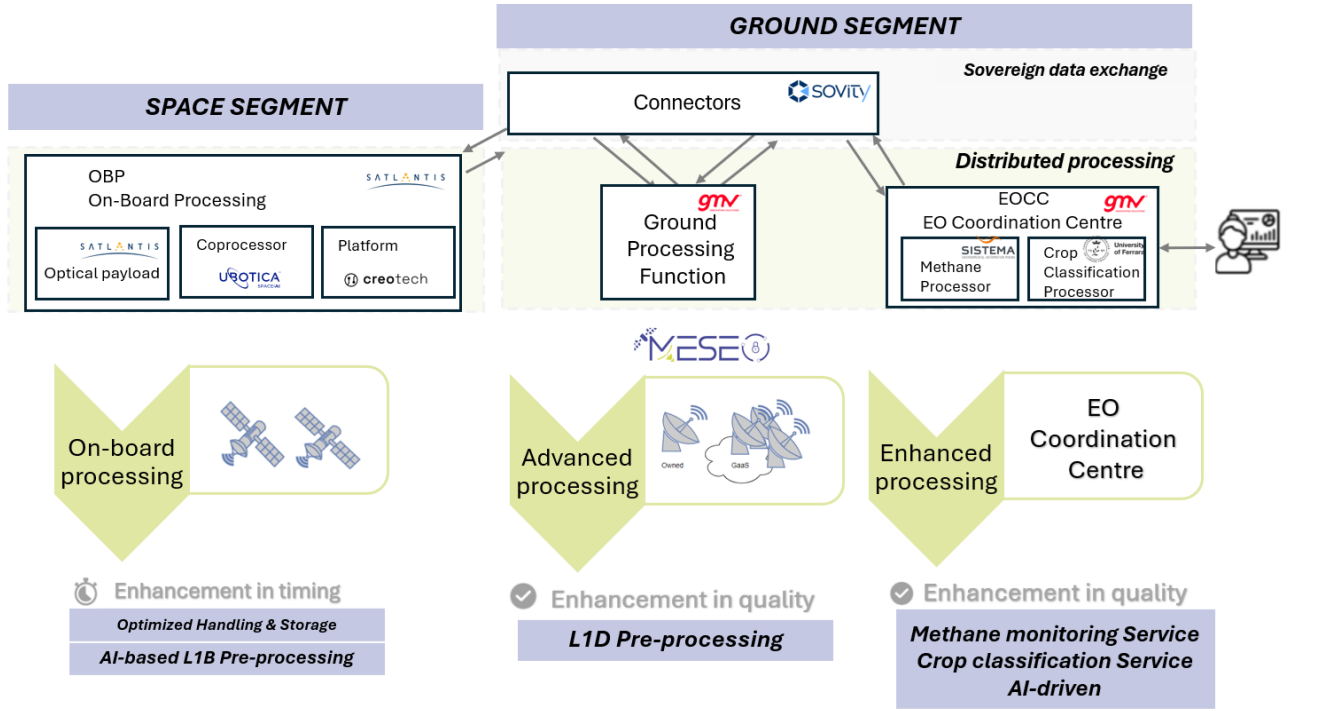
open, scalable, multi-mission E2E EO, AI on board and on ground

Our role

AI models for on-ground processing in the EO Coordination Centre

On-demand use case

crop classification needs months of catalogue data, not real-time



MESEO end-to-end architecture: crop classification runs in the EO Coordination Centre

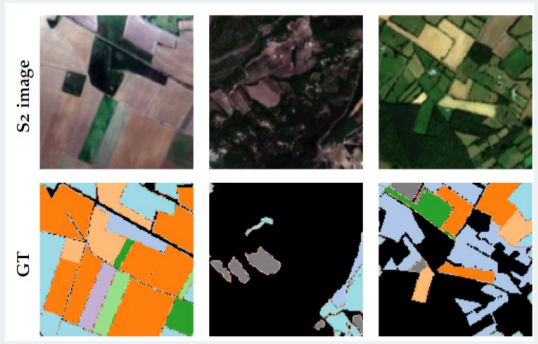


Università degli Studi di Ferrara

Data: Sentinel-2 image time series with pixel labels

OrthoPASTIS - France

Rebuilt from PASTIS (Sainte Fare Garnot & Landrieu, 2021) with orthorectified imagery



2,433 patches, 128 × 128 px

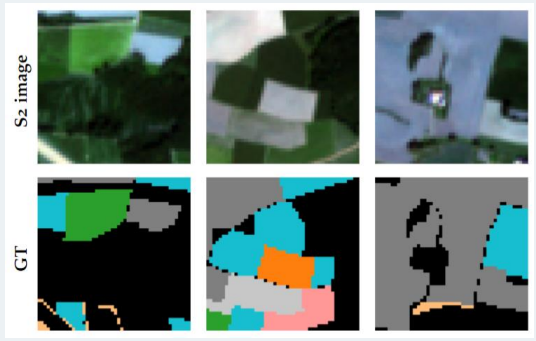
19 dates, Jan–Jul 2019

10 spectral bands

18 crop classes

Munich - Germany

MTLCC (Rußwurm & Körner, 2018)



~28,000 patches, 48 × 48 px

1-51 dates (2016 & 2017)

7 spectral bands

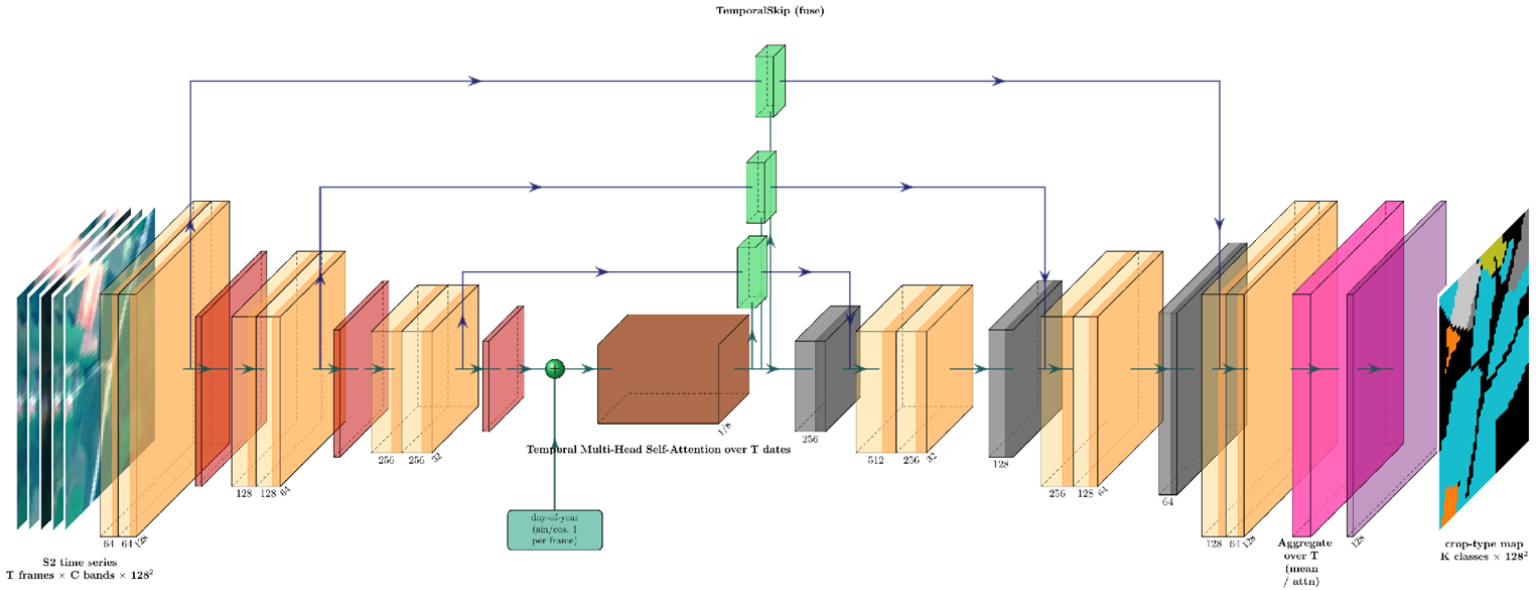
17 crop classes

Strong class-imbalance



Università degli Studi di Ferrara

AgrUNet: a U-Net for satellite image time series



Space

3D-convolution U-Net encoder and decoder

Time

multi-head self-attention over the dates, day-of-year encoding, any length

Compute

PyTorch Lightning: multi-GPU / multi-node (DDP), AMP, deep supervision



Università degli Studi di Ferrara

Segmentation accuracy

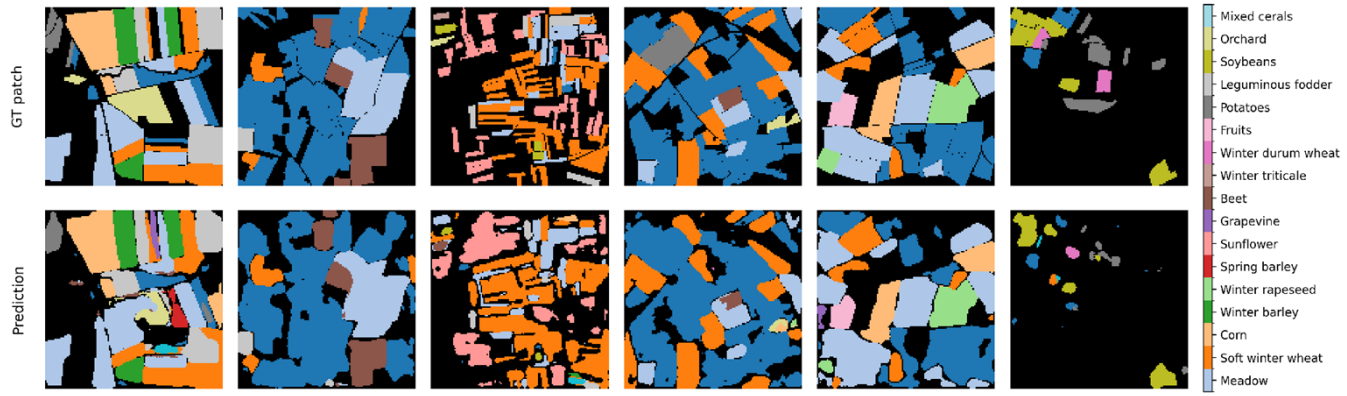
	AgrUNet intra-crop Dice	*U-TAE intra-crop Dice*	*Micro Dice*	*Macro Dice*	*OA*
OrthoPASTIS	**0.86**	0.82	0.77	0.72	0.94
Munich	0.90	**0.93**	0.88	0.82	0.96

Jan–Jul series, same splits for both models. Intra-crop: Dice with background excluded

Per-class Dice (OrthoPASTIS)

0.96 meadow → **0.60** sorghum

rare, spectrally similar crops are the hardest

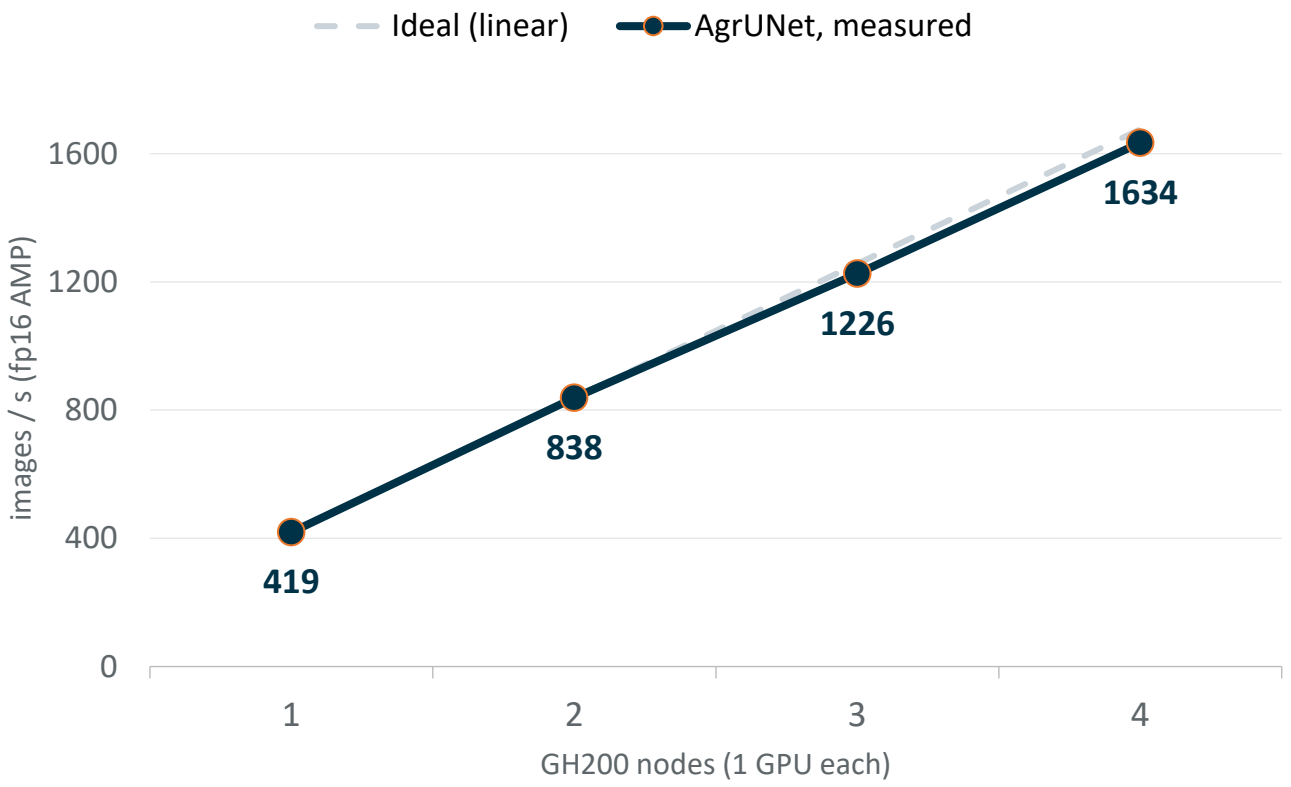


OrthoPASTIS test patches: ground truth (top) and AgrUNet prediction (bottom)



Università degli Studi di Ferrara

Near-linear scaling: 1,634 images/s on 4x GH200 cluster(*)



vs. U-TAE, same hardware

1.6× faster, same precision and accuracy

2.0× faster with mixed precision

2.1× more energy-efficient

97.6% parallel efficiency on 4 nodes

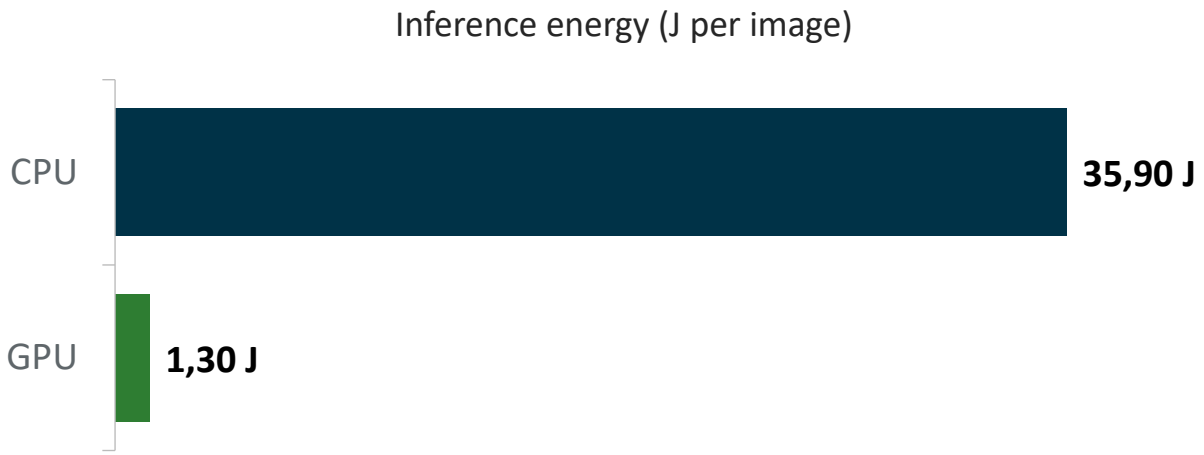
weak scaling, 1 GPU per node, T = 19 dates

(*) COKA cluster installed at UNIFE and operated in collaboration with INFN



Università degli Studi di Ferrara

From CPU to GPU: 96% less energy per image



Efficiency via throughput
the GPU draws more watts but finishes much sooner

≈ 10 kWh → 0.36 kWh
per million image patches

CO_2 falls by the same factor
for a given grid mix

Large areas become affordable
repeated, country-scale mapping

–96% energy and CO_2 per classified image



Università degli Studi di Ferrara

Operational in the MESEO platform

User request
AOI + season

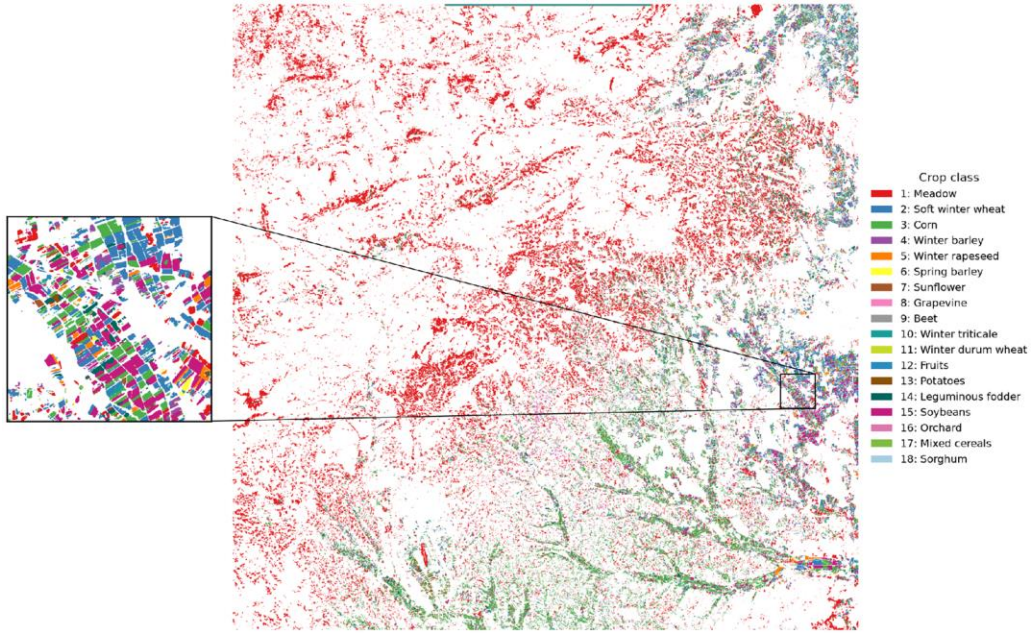
GMV Prodigi®
orchestrator

Data retrieval
~20 dates, Jan–Jul

Pre-processing
10 m, 128 px tiles

AgrUNet
Docker, GPU

Crop map
GeoTIFF + SHP



AgrUNet crop map, Sentinel-2 tile 33TWN (Austria), 2025 season

12,100 km²
one full S2 tile

87% OA
18 classes, wrt INVEKOS (IACS) parcels

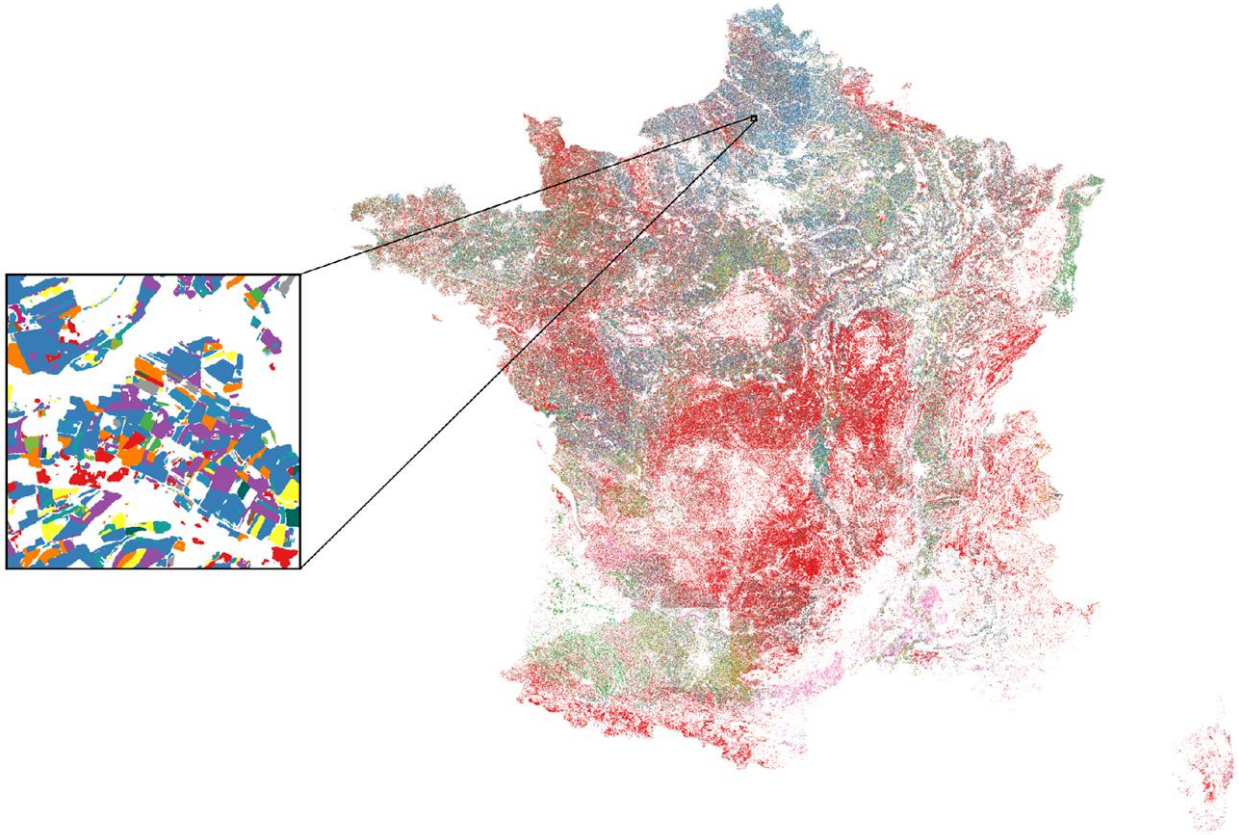
~30 min
E2E on one V100 (MESEO-like)

Unseen
country: trained on France only



Università degli Studi di Ferrara

Scaling up: a national crop layer for France, 2023



550,000 km²
86 Sentinel-2 tiles

78% OA
18 classes, wrt EuroCrops dataset

~11 h
on 4× NVIDIA GH200

12–61
images per tile, Jan-Jul

Limitation
seams between tiles due to different time-series lengths



Università degli Studi di Ferrara

Take-home

Accurate	intra-crop Dice 0.86 (OrthoPASTIS), 0.90 (Munich)
Scalable	1,634 img/s on 4 GH200 nodes, 1.6-2.0× faster than U-TAE
Efficient	96% less energy per image on GPU than on CPU
Operational	on-demand in MESEO: a crop layer every season, from a small area to a whole country

Next: New regions & other sensors

Code + models
baltig.infn.it/meseo/agrunet
doi:10.1109/ACCESS.2024.3487267

Thank you for the attention!

MESEO is co-funded by the European Union under grant agreement N° 101135067 (HADEA). Views and opinions expressed are those of the authors only.