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Integration of sparse multi-source earth observation data with deep learning for crop type and yield estimation in smallholder farming areas

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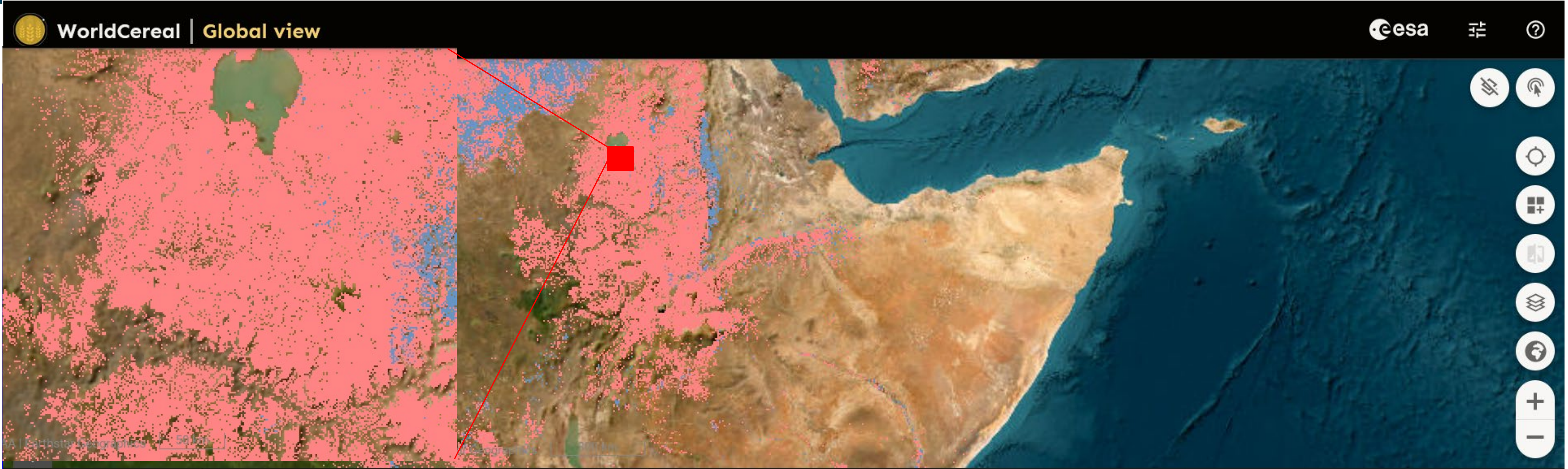
Introduction

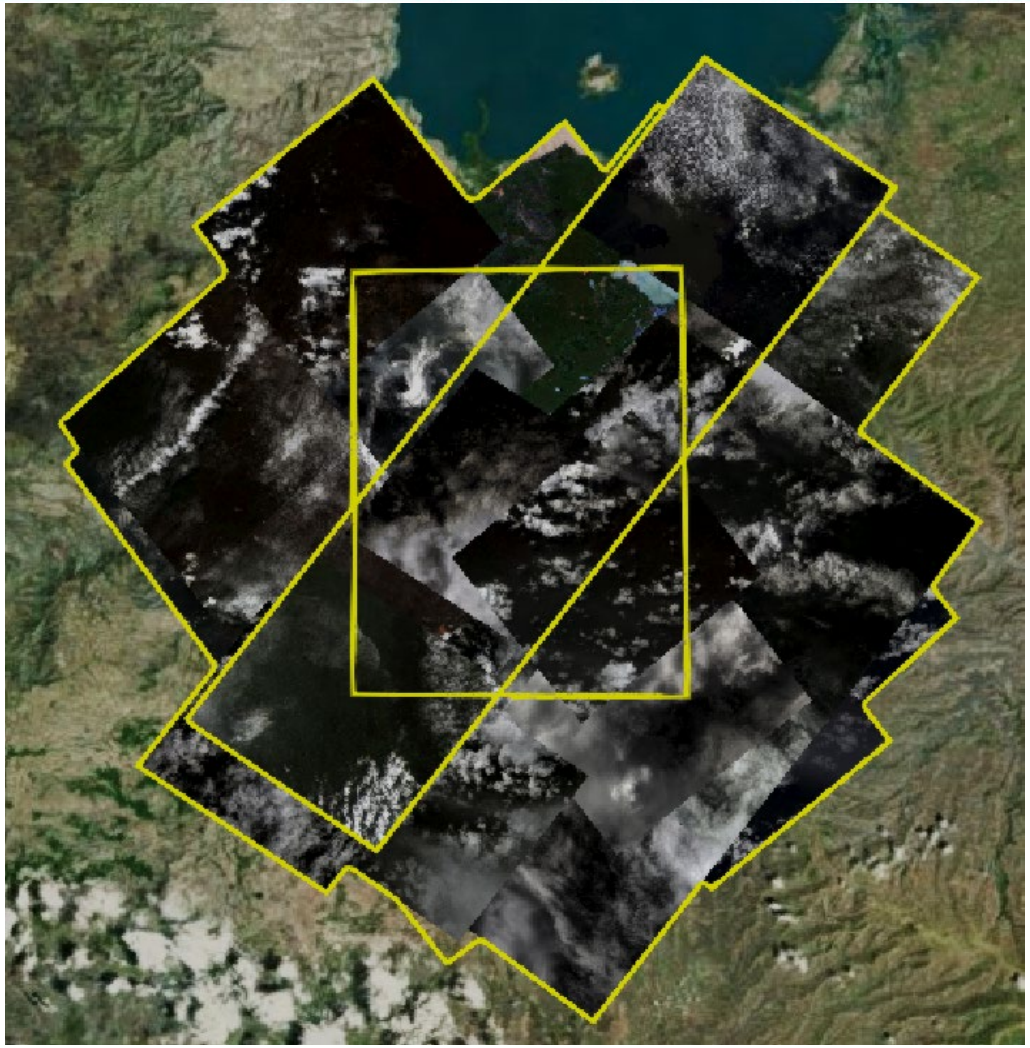
- Significant contribution to food crop production
  - Fragmented and small farm plot characteristics
  - Mixed cropping(landscape and farm level)
  - Complex terrain
- Crop area statistics and yield estimation from agricultural sample surveys
  - Efficiency, accuracy, practicality
- Spatially explicit mapping from earth observation imagery

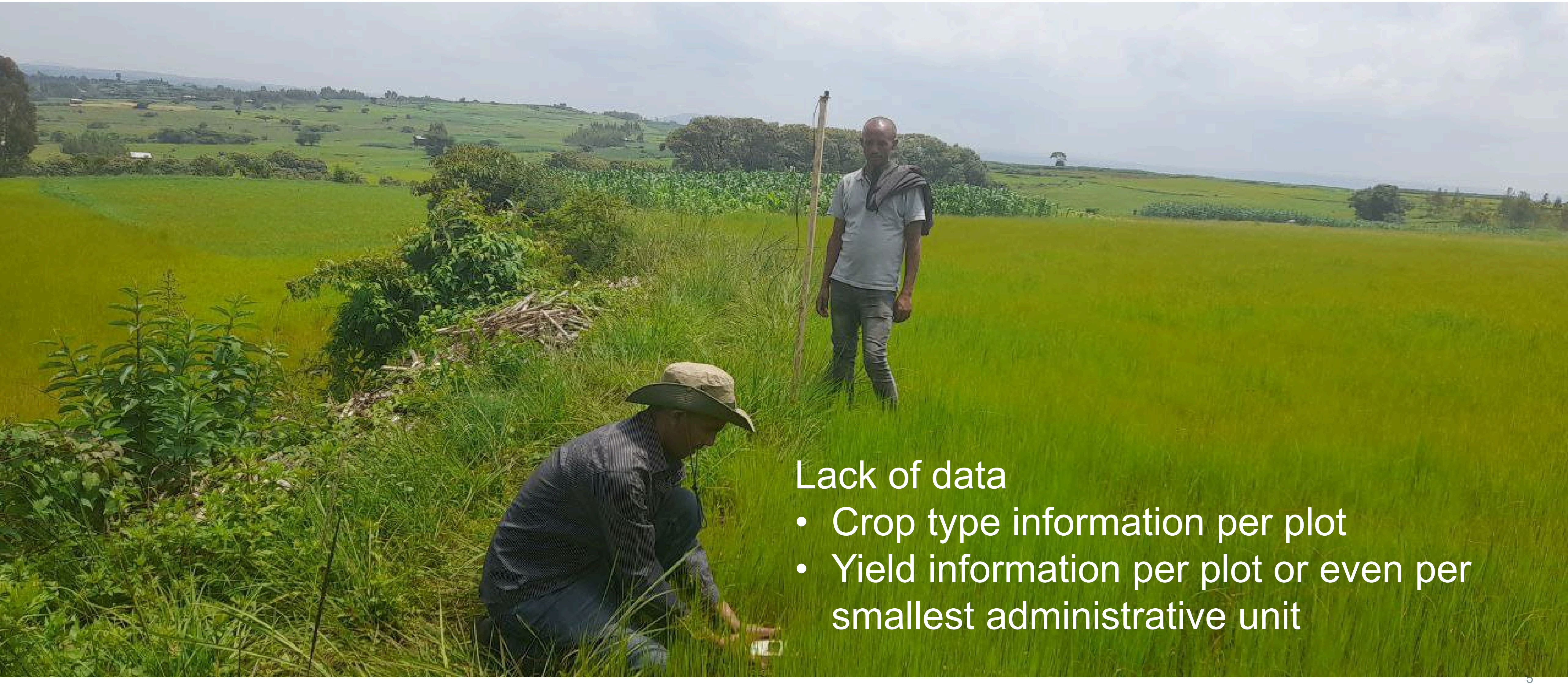
Representation of global crop data layers



	2021		
Temporary crops	tc-annual		
Winter cereals	tc-wintercereals		
Spring cereals	tc-maize-main		
Maize	tc-maize-main	tc-maize-second	
Active irrigation	tc-wintercereals	tc-maize-main	tc-maize-second
Active cropland	tc-wintercereals	tc-maize-main	tc-maize-second

Challenges of mapping crop types





Lack of data

- Crop type information per plot
- Yield information per plot or even per smallest administrative unit

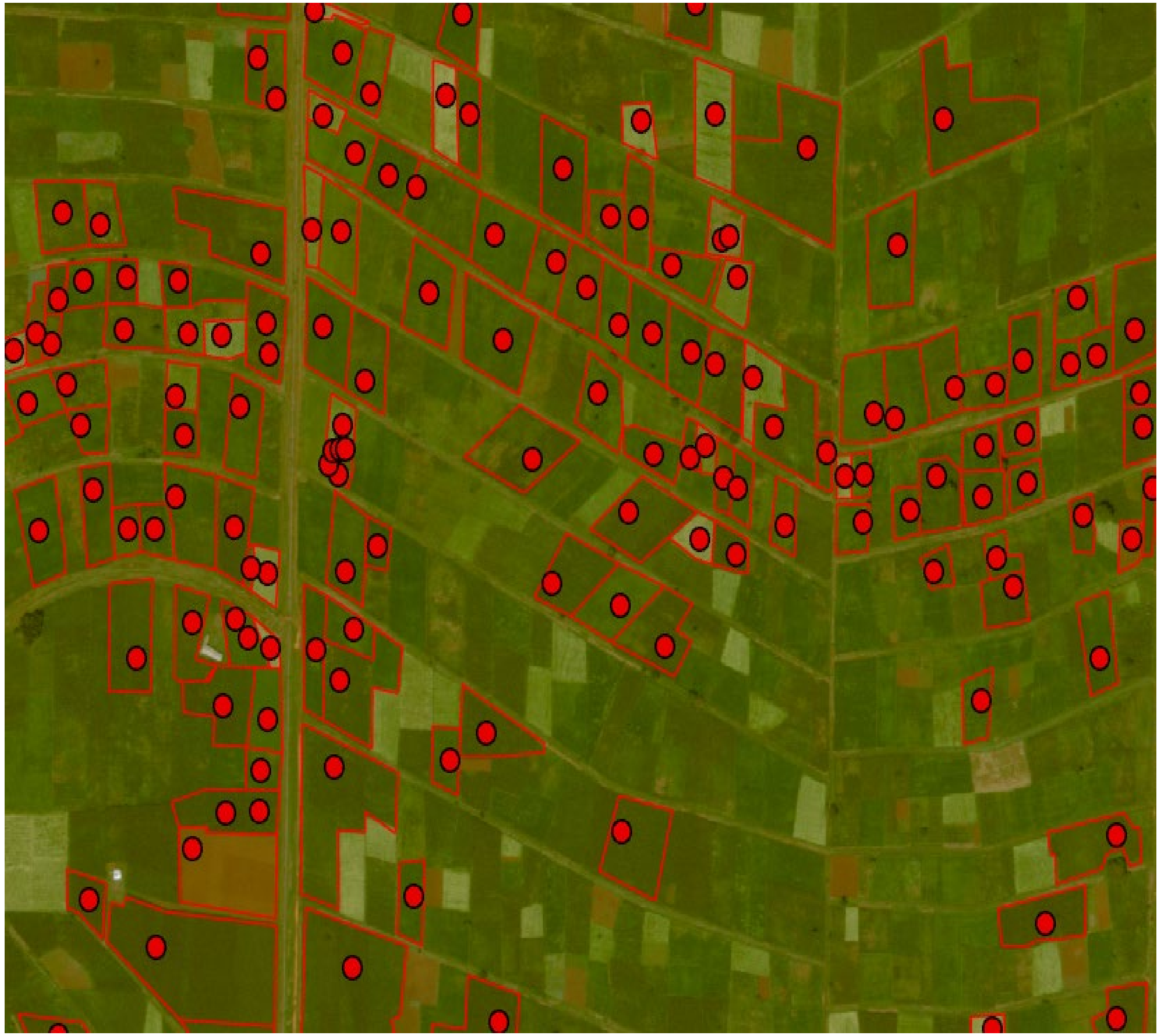
Methods: Study site

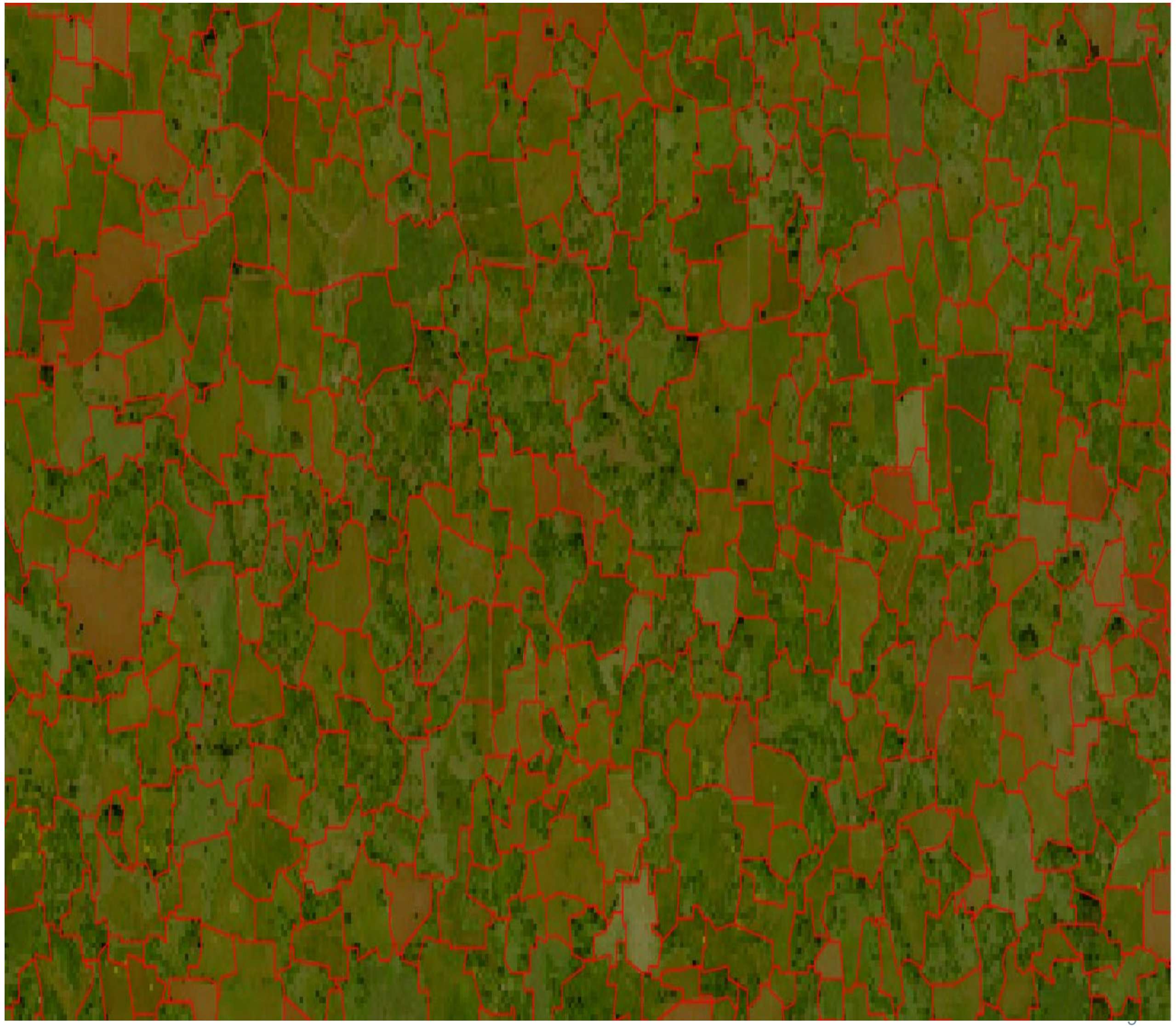
- Situated in north-western part of Ethiopia
- Dominated by smallholder farming system
- One extended rainy season extends from May to October and
- Maize and Teff are dominant crops

Methods: Data

Data	Processing level	Processing	Access mod	Domain
Sentinel-2	Atmospherically corrected surface reflectance	Cloud masking, gap filling and mosaic, resample	Archived	Optical
Planet scope	Atmospherically corrected, temporally composited analytic product	Cloud masking, mosaicking	Archived	Optical
SkySat	Bottom of atmosphere surface reflectance analytic product	Mosaicking	New tasking	Optical
TerraSAR-X	Ground range detected and radiometrically calibrated product	Speckle filter and resampling	New tasking	Radar
DESIS	Level 1A	Almost all scenes are cloud contaminated and not used at this stage	New tasking	Hyperspectral
ESA land cover mask	Classified 10 meters resolution	Cropland mask generation	Archived	Thematic
Field data	Crop type samples and yield data from farmers			

Field data validation and super pixels





Mapping crop type and modelling yield

- ✓ Random forest
- ✓ Support vector machine

- ✓ RNN
- ✓ LSTM
- ✓ Transformer
- ✓ Temporal CNN
- ✓ InceptionTime

- ✓ Future label
- ✓ Decision label
- ✓ Contrastive pretraining

- ✓ Crop yield estimation

Modelling crop yield as a classical regression task

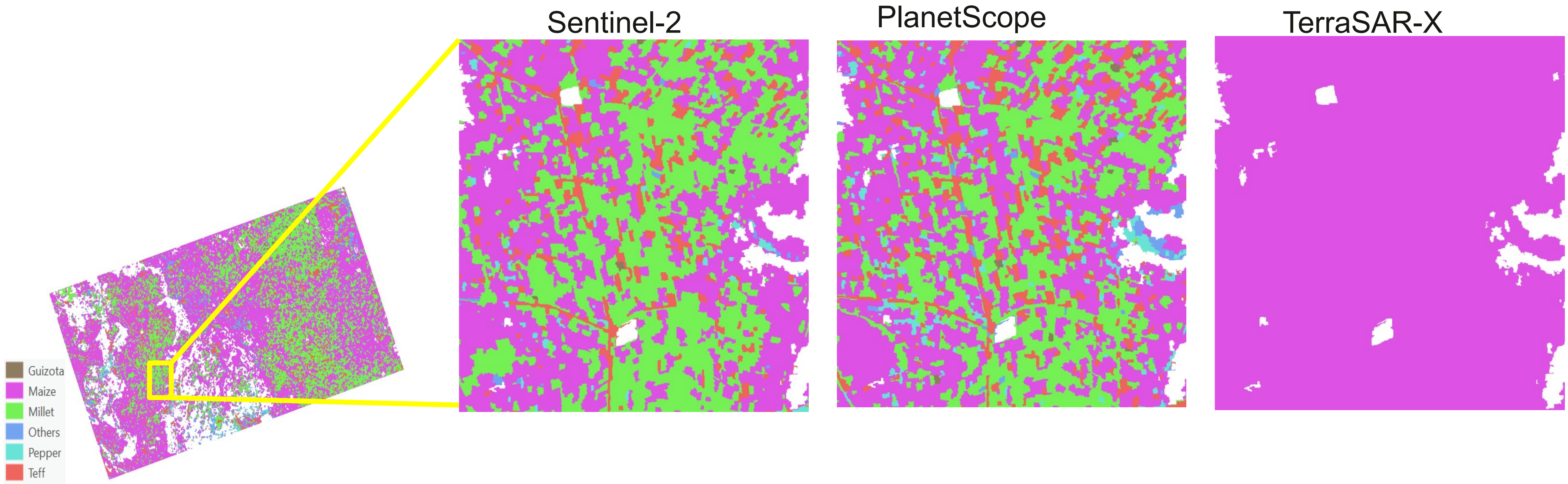
$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots \beta_n x_n$$

where *y* is predicted crop yield and α is regression line intercept, β_1 to β_n are slopes then select only statistically significant covariates which explain crop yield variance

Crop type classification performance

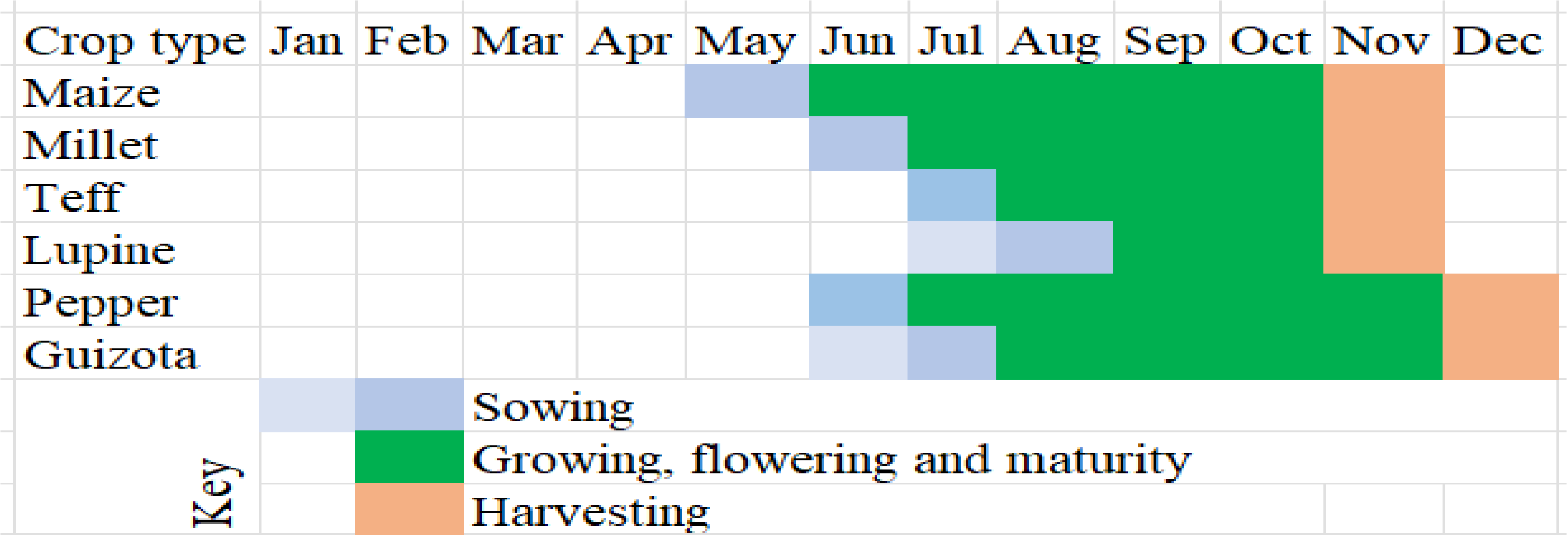
	RF	SVM	RNN	LSTM	Transformer	InceptionTime	TempCNN
TerraSAR-X	0.64	0.66	0.47	0.49	0.54	0.68	0.66
PlanetScope	0.81	0.80	0.72	0.77	0.77	0.82	0.80
Sentinel-2	0.72	0.80	0.72	0.75	0.75	0.77	0.79
Feature fused	**0.79**	**0.81**	**0.78**	**0.78**	**0.76**	**0.83**	**0.82**
Decision fused	0.78	0.81	0.71	0.76	0.76	0.81	0.81
Contrastive pretraining						0.84	0.83

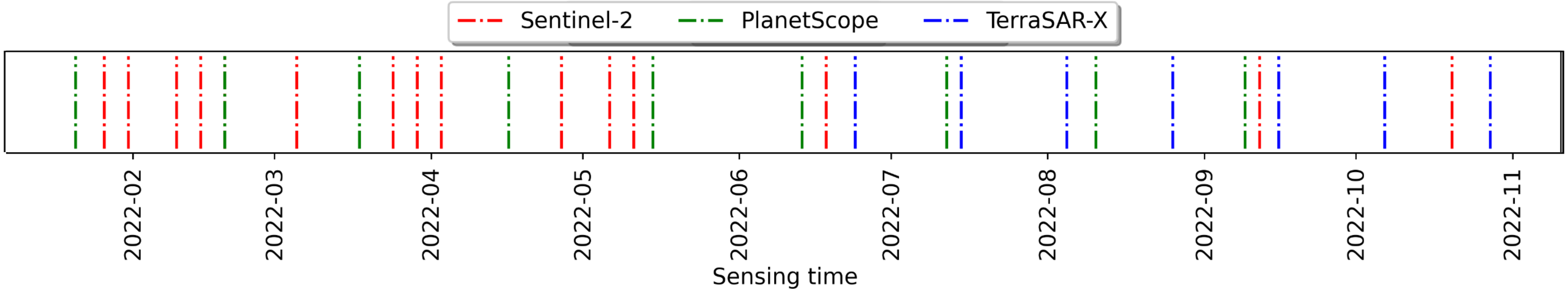
Crop type spatial outputs



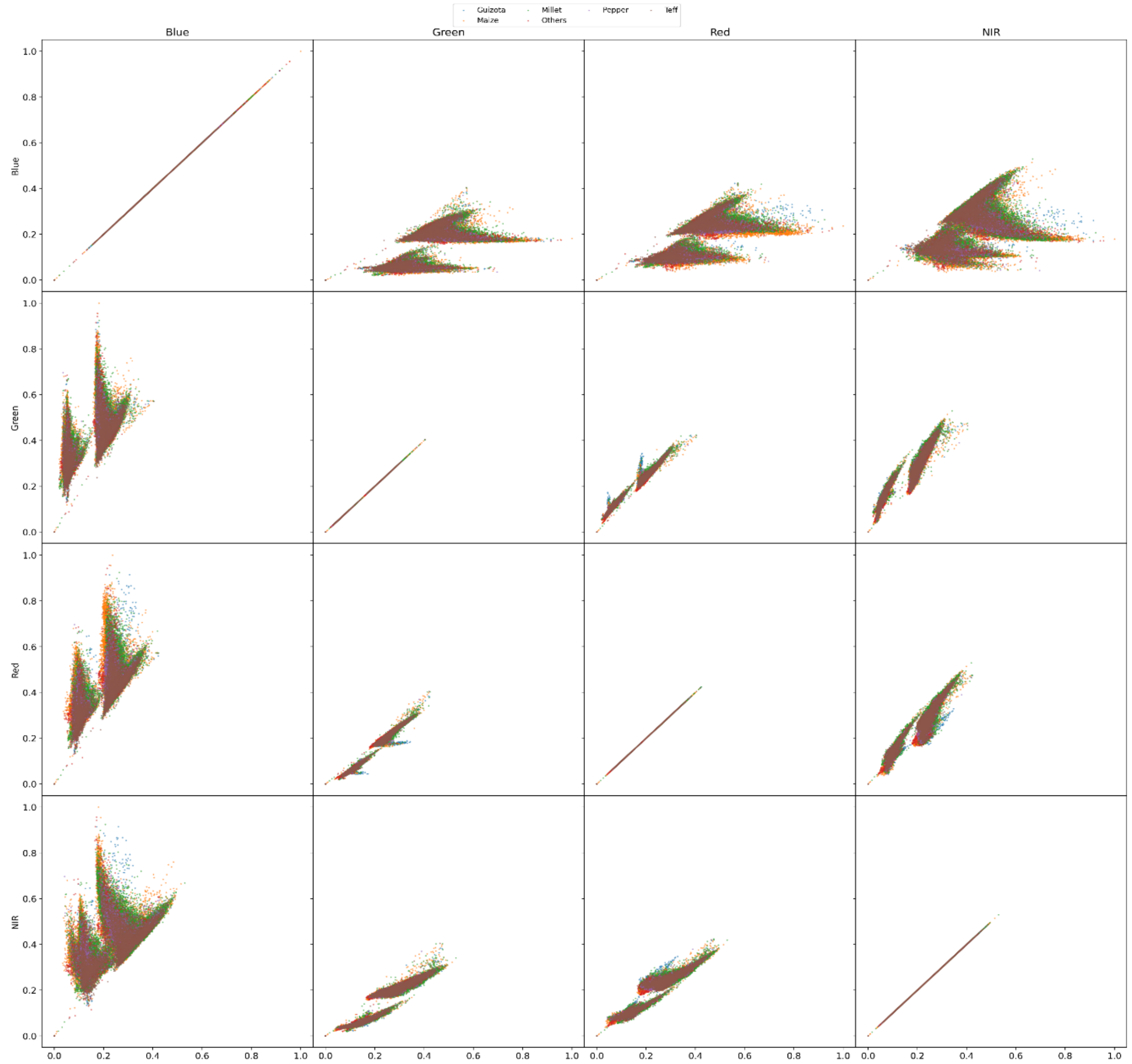
Outputs from TempCNN

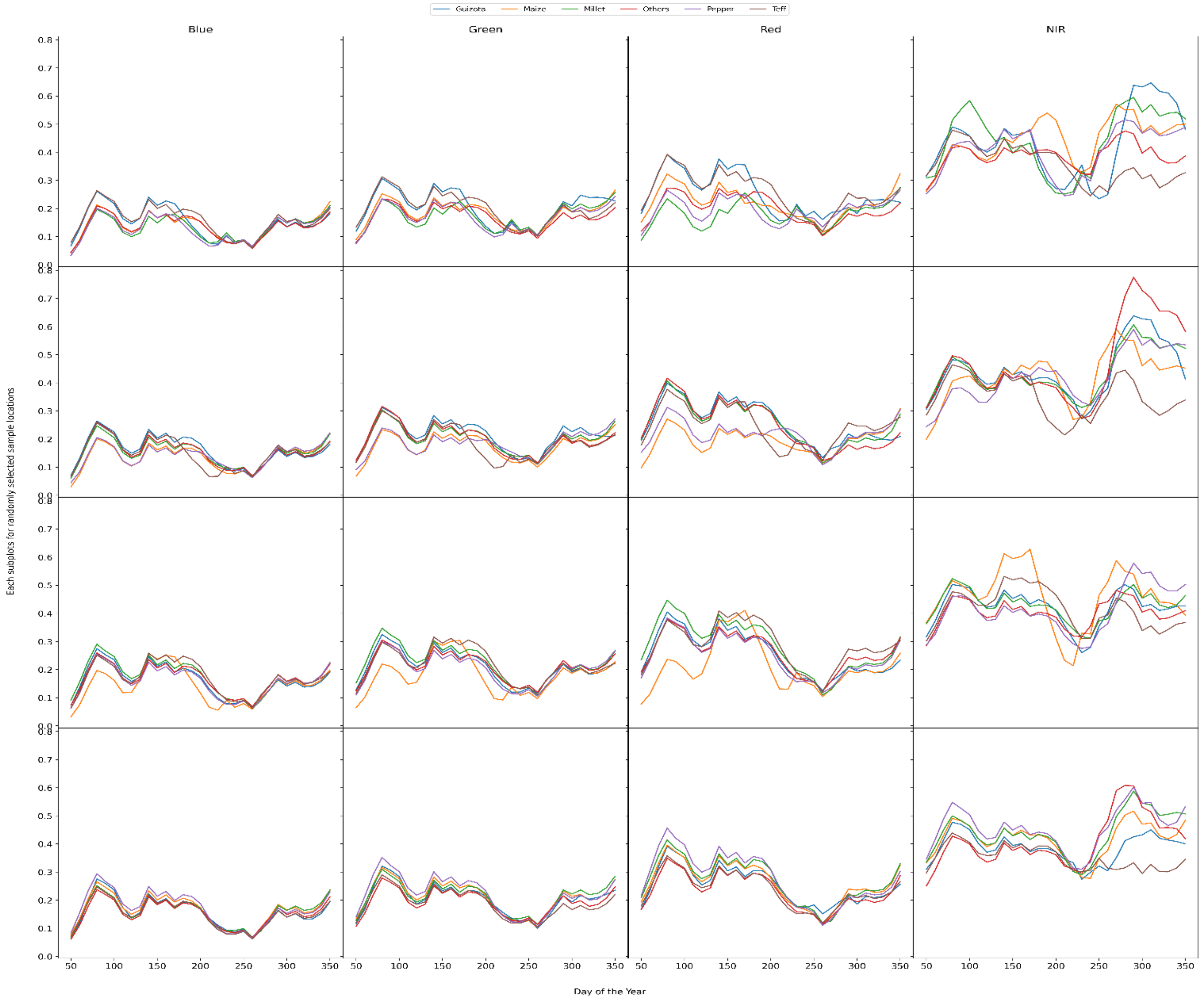
Sparse observations during the critical growing season



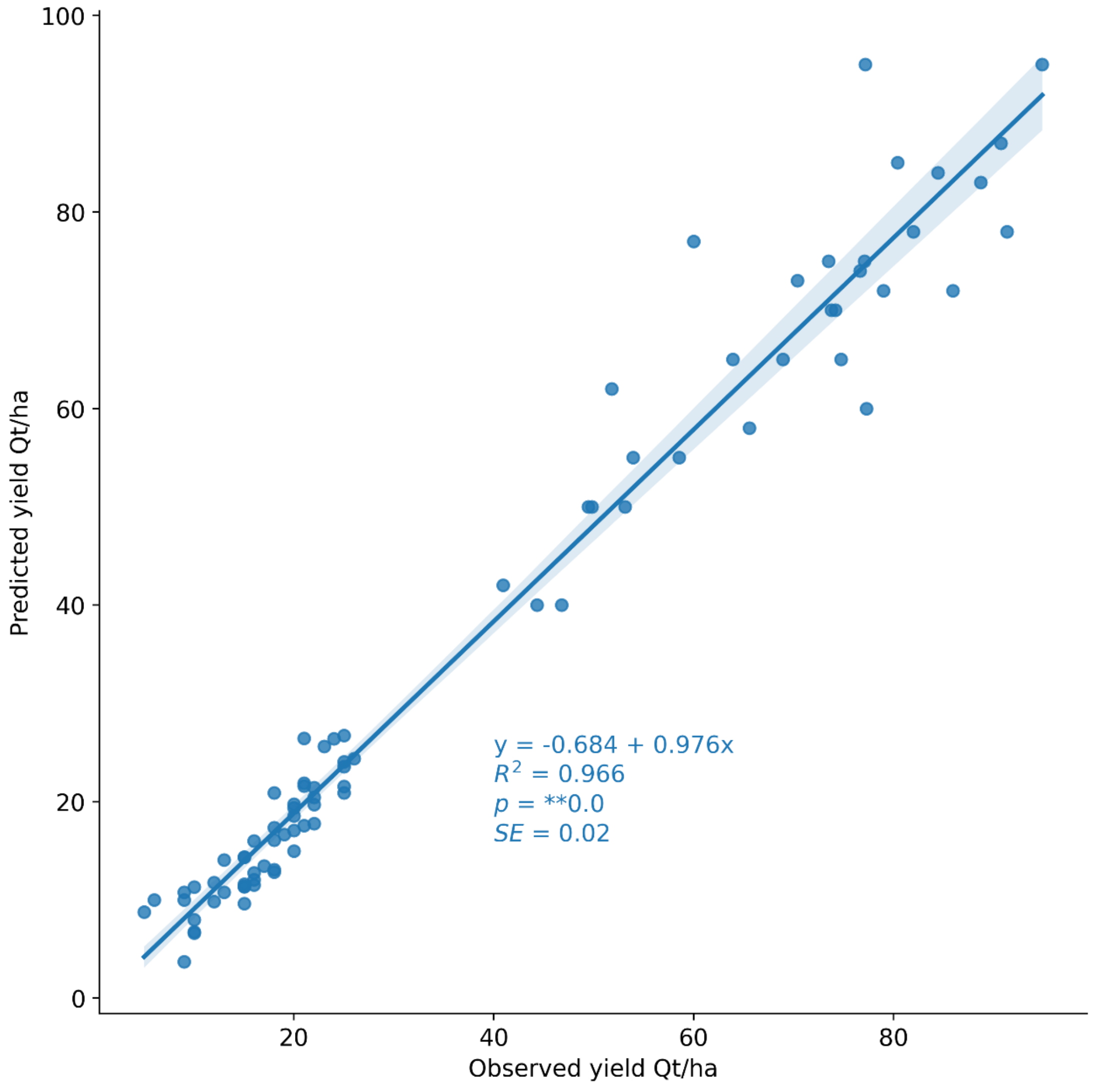


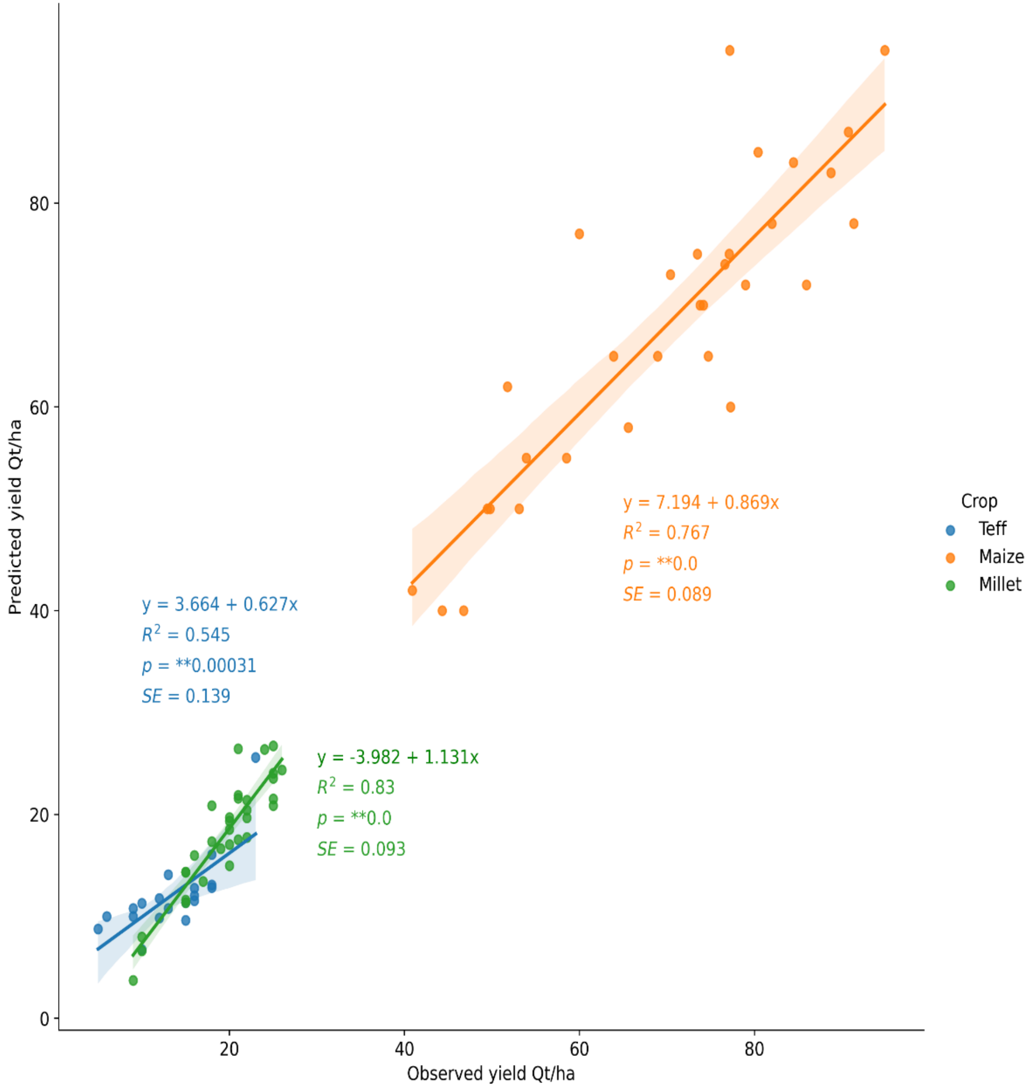
Resembling spectral and temporal profiles





Crop yield estimation





Conclusions and remarks

- With sparse time series data, machine learning models can have comparative performance with deep learning models
- TerraSAR-X underperform others in all experimental setups
- Feature-level fusion and pretraining show better results
- Further work on the inclusion of field management, climate and terrain-related parameters in mapping and incorporating uncertainty to yield estimation

Acknowledgement

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Research and Development Facility

eo science for society

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- ✓ DLR for DESIS hyperspectral imagery
- ✓ Local farmers who are willing to cooperate for yield data