

SOIL MOISTURE ESTIMATION IN OLIVE ORCHARDS USING SENTINEL-1 SAR AND NEURAL NETWORKS (ID: 136)

Ana Cláudia Teixeira^{1,2}, Pedro Marques^{1,3}, Matus Bakon^{1,4,5}, Anabela Fernandes-Silva^{1,3}, Domingos Lopes^{1,3,6} and Joaquim J. Sousa^{1,2}

¹University of Trás-os-Montes e Alto Douro, Vila Real, Portugal; ²Institute for Systems and Computer Engineering, Technology and Science, Porto, Portugal; ³Centre for the Research and Technology of Agro-Environmental and Biological Sciences, Vila Real, Portugal; ⁴Department of Environmental Economy and Management, Faculty of Management and Business, University of Presov, Presov, Slovakia; ⁵insar.sk Ltd, Presov, Slovakia; ⁶Fundacao Côa Parque, Rua Museu, Vila Nova De Foz Coa, Portugal



Introduction

- Climate change has intensified water scarcity, making efficient water use a global priority
- Agricultural systems must balance profitability with environmental sustainability
- Precision irrigation relies on accurate and timely soil moisture estimation.
- Remote sensing technologies offer scalable alternatives to traditional monitoring methods

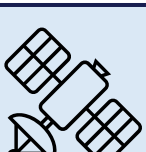


Main Objective

To estimate soil moisture in olive orchards located in the Vilariga Valley (northeastern Portugal) using artificial neural network (ANN) models trained with Sentinel-1 SAR data.

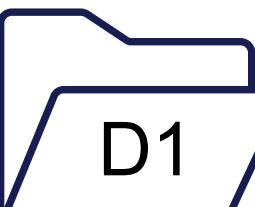


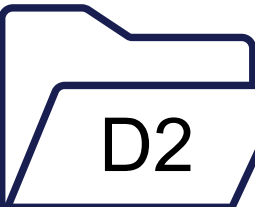
Data

**Sentinel-1**

SAR images (VV and VH polarizations) were acquired between July 2020 and December 2021, aligned with field measurements.

Two datasets were created to evaluate the impact of SAR orbit geometry on model performance:

**D1** 301 samples from ascending orbits only

**D2** 458 samples from both ascending and descending orbits

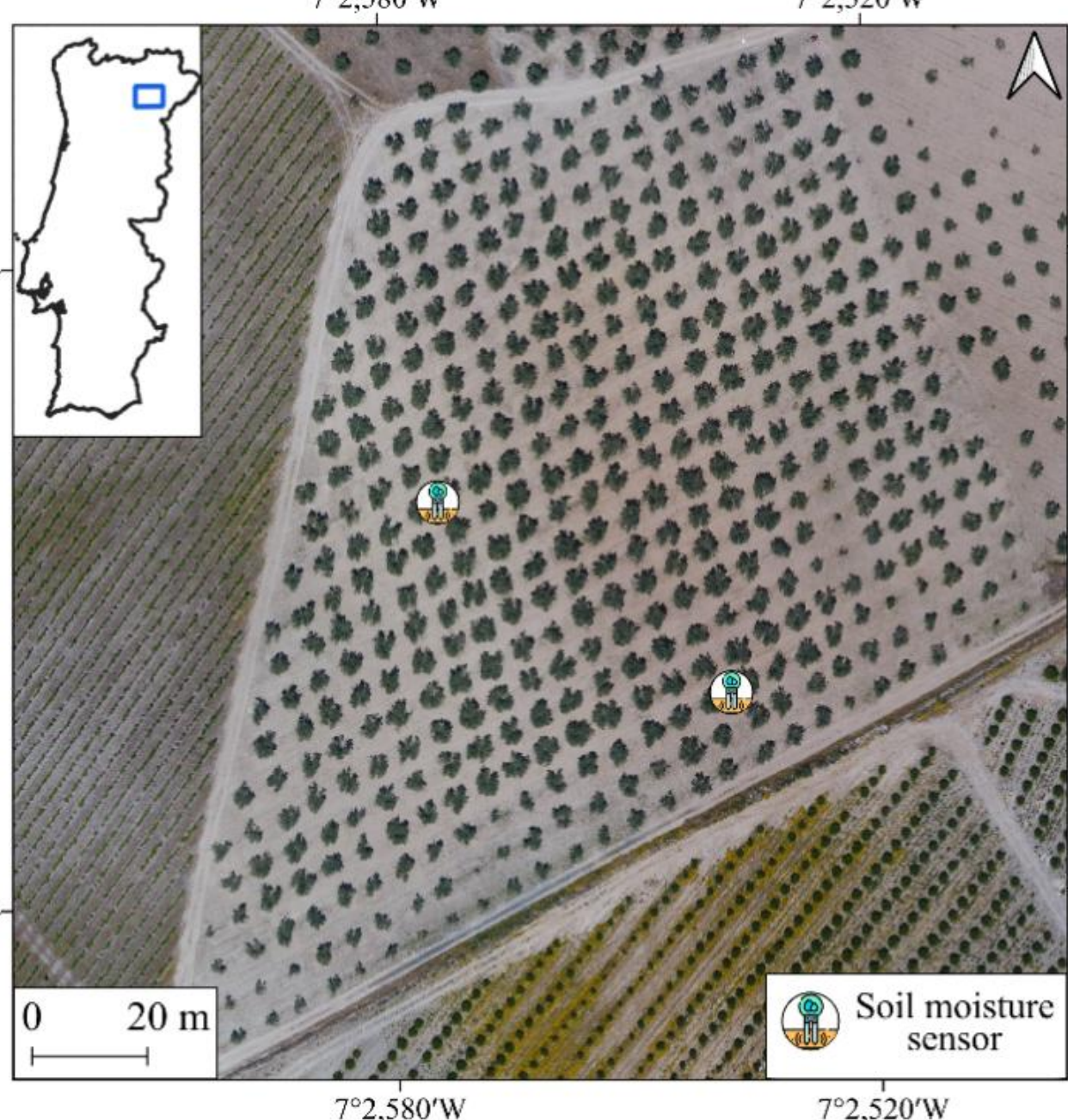
Each sample included 25 features: 24 extracted from SAR data and 1 in situ soil moisture measurement.

Data processing

```
graph TD
    A[Sentinel-1] --> B[Subset]
    B --> C[Apply Orbit File]
    C --> D[Calibration]
    C --> E[Calibration]
    D --> F[Beta, Sigma, Gamma]
    E --> G[Gamma]
    F --> H[Terrain Correction]
    G --> I[Terrain Flattening]
    H --> J[Band maths operations -, +, /, *]
    I --> J
```

In-situ soil moisture

Soil moisture was recorded at a 10 cm depth using two sensors.

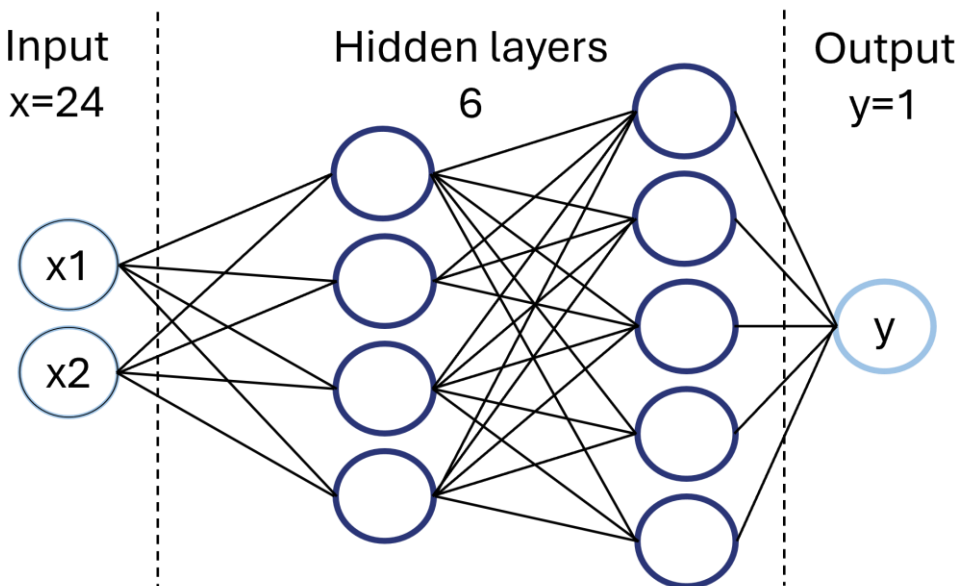




Methods

An artificial neural network with 6 hidden layers was used:

- ReLU used as an activation function
- Adam optimizer for weight updates
- Mean Squared Error (MSE) as the loss function
- K-fold cross-validation for model training





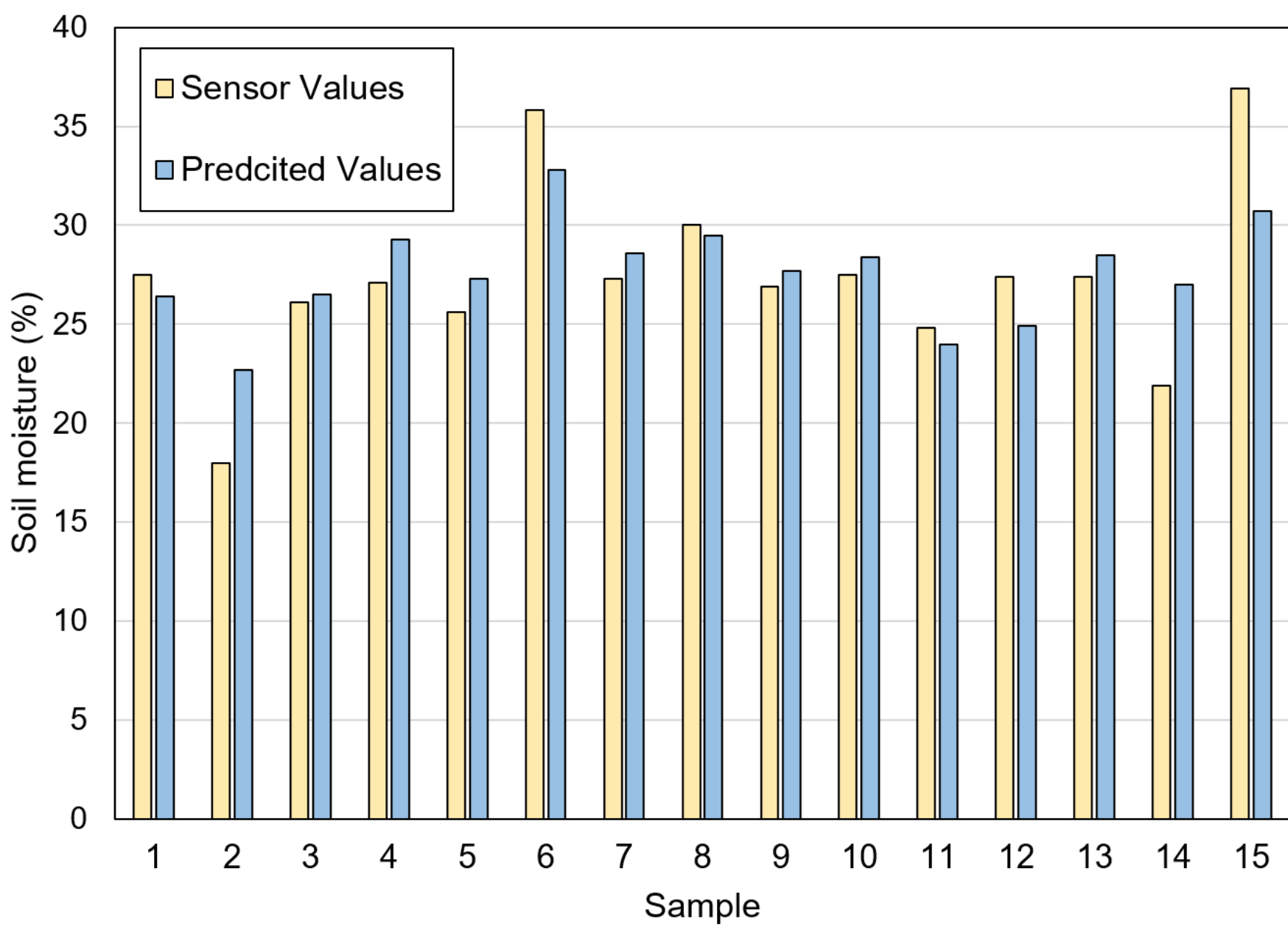
Conclusions

The ANN model effectively predicted soil moisture in olive orchards using Sentinel-1 SAR data. Integrating remote sensing with in situ measurements shows strong potential for precision irrigation. However, performance under low moisture conditions remains limited, emphasizing the need for more balanced datasets.

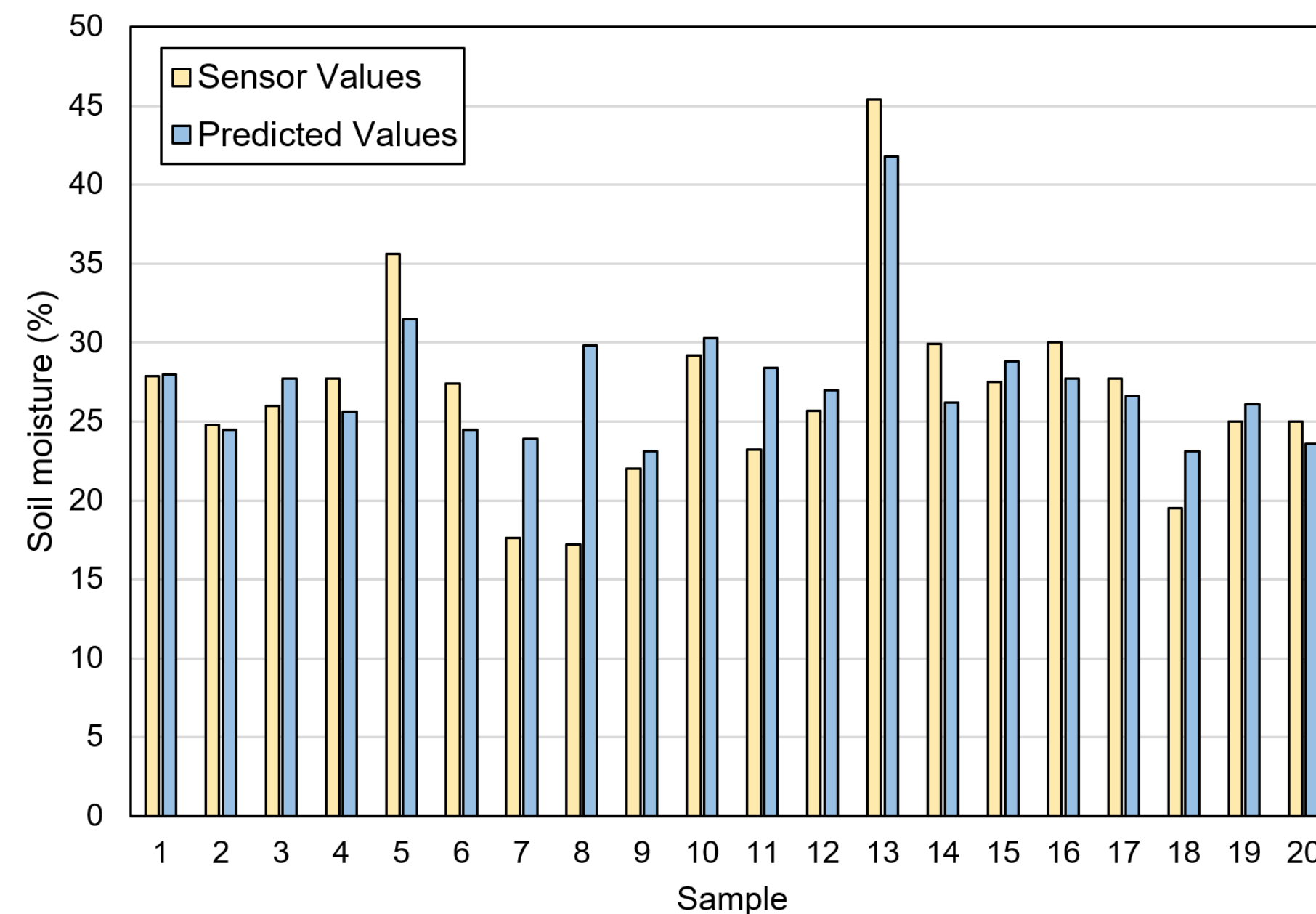


Results

Comparison between predicted and observed soil moisture values using the ANN model trained with the D1 dataset (ascending orbits only)



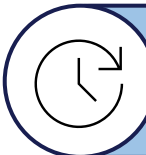
Comparison between predicted and observed soil moisture values using the ANN model trained with the D2 dataset (mixed orbit geometries)



Performance comparison of ANN models trained on D1 (ascending orbits) and D2 (mixed orbits) datasets using standard regression metrics

Dataset	Metrics		
	RMSE	R ²	MAPE (%)
D1	2.78	0.69	8.26
D2	3.96	0.59	12.41

- The D1 dataset (ascending orbits only) outperformed D2 due to reduced variability in acquisition geometry
- The D1 model showed strong agreement with in situ measurements, especially for moisture levels above 20%.
- Predictions below 20% were less accurate, as these cases represented fewer than 4% of all samples.



Future Work

(1) Extend the methodology to other regions and crop types; (2) Incorporate topographic and additional auxiliary variables; (3) Expand the dataset with more diverse and representative samples; (4) Improve model performance, particularly under extreme soil moisture conditions



Acknowledgements

This work was conducted under the Dragon 6 cooperation programme between the European Space Agency (ESA) and the Ministry of Science and Technology (MOST) of China. Supported by FCT – Fundação para a Ciência e a Tecnologia, I.P., under project reference PRT/BD/154871/2023, DOI: 10.54499/PRT/BD/154871/2023