From Pixels to Plants: Deep Learning-Based Olive Tree Detection Across Apulia

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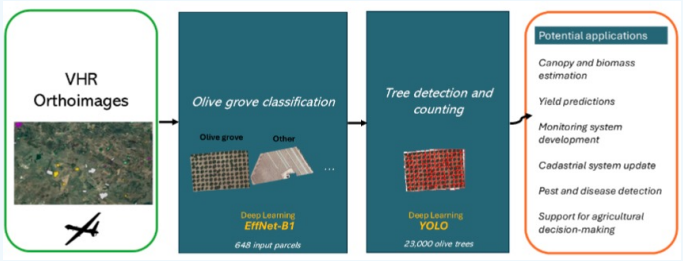
WORKFLOW



PROBLEM STATEMENT

As part of the WADIT (Water Digital Twin) project, this study introduces the first navigable catalog of olive trees in Apulia (Italy). Olive canopies, key to understanding regional water dynamics and land use, were mapped using YOLO11n-seg algorithm, trained on 23,000 annotated olive trees across 250 parcels in the Barletta-Andria-Trani province. The model achieved robust performance, with sensitivity and precision exceeding 92% and a mAP(50) of approximately 95%.

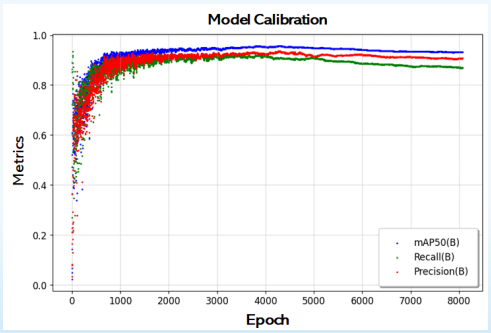


Figure 1. Bounding Box Prediction Metrics mAP50 (blue), Recall (green) and Precision (red) over epochs of the YOLO11n-seg object detector algorithm. Assessment on a calibration set consisting of 250 parcel plots and 23,000 olive tree annotations.

Generalization to the entire Apulian territory was conducted via inference on AGEA2019 orthophotos accessed through WMS services, processing 460,000 tiles (200m x 200m) in parallel across 254 threads in just 36 hours. Results were refined using an active learning approach, addressing issues such as duplicate detections, omissions, and false positives. Post-processing relied on PostGIS and spatial filtering through Dask-Geopandas. We finally relied on the Copernicus Crop Type 2019 layer to avoid false positives caused by other tree species. The predicted number of olive trees according to our procedure is 59 million (2019) compared to official figures of 60M (before Xylella outbreak).

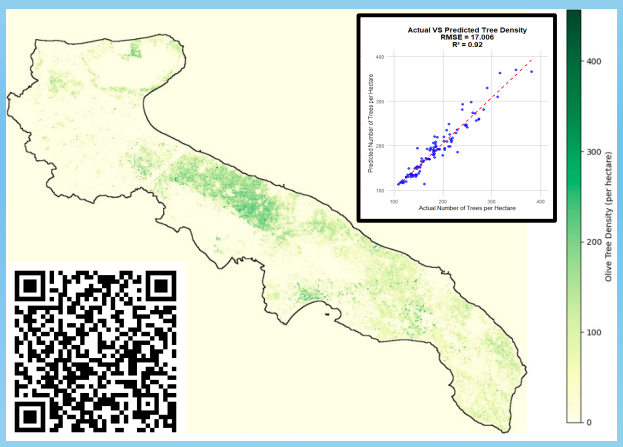


Figure 2. Estimated olive tree density per hectare across the Apulian Region, calculated at a spatial resolution of 200 meters. Top right: performance assessment, on the calibration set, of the YOLO11n-seg object detection model based on its predicted tree density per hectare.

WORKFLOW SUMMARY

- Yolo11n-seg Model Calibration
- Distributed processing of +3TB aerial imagery
- Grid-based analysis using 200m×200m tiles (at 0.2m/px)
- On-the-fly WMS image retrieval → detection → cleanup workflow
- Output: Georeferenced shapefiles per tile with confidence scores
- Postprocessing: NMS @ 0.1 IoU threshold
- Predictions filtered using Copernicus Crop Types 2019 Layer
- Fast Inference: 36-hour processing time for the whole Apulia region on a NVIDIA A100-PCIE-40GB (total area 20,000 Km^2).

Figure 3. YOLOn11 predictions for olive tree detection on an independent set of orthoimages from the AGEA2019 dataset. Location: Barletta-Andria-Trani province.

CONCLUSIONS AND FUTURE PERSPECTIVES

This catalog lays the groundwork for integrating vegetation data into a regional water digital twin of the Apulia region, enhancing our ability to model water resource dynamics and the impact of agricultural practices on water sustainability.
Future work will focus on refining these outputs to produce an accurate and fully automated catalog to further support agricultural monitoring, land management, and the monitoring water consumption in the Apulia region. We are evaluating to extend this analysis to subsequent years to follow the development of the Xylella infection.

KNOWN LIMITATIONS

After our visual assessment of the olive tree map, we still observe a performance degradation due to:

- **Regional bias**: Reduced accuracy in Capitanata and Salento due to limited training samples.
- **Intensive cropping systems**: Omission errors occur where trees are tightly clustered, or herbaceous understory reduces canopy contrast.
- **Xylella-infected areas**: Damaged canopies impair detection reliability.
- **Lighting artifacts:** False positives occasionally arise from canopy shadows in off-nadir or heterogeneous acquisition conditions