Synergizing Artificial Intelligence and Remote Sensing: A Systematic Review on Crop Yield Prediction and Crop Growth Parameter Estimation in the Mediterranean Agroecosystems

Wondimagegn Abebe Demissie[1], Luca Sebastiani[1], Rudy Rossetto[1]

[1]Institute of Crop Science Research, Scuola Superiore Sant'Anna, Pisa, Italy,

EGU25-8207

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

What did we want to learn?

- Due to increasing climate variability, population pressure, and resource scarcity, agricultural productivity in Mediterranean rim (MED-rim) agroecosystems faces mounting challenges requiring resilient, data-driven solutions[1,2,3].
- While conventional models have been used for crop yield prediction (CYP) and crop growth parameter estimation (CGPE), they often face limitations in scalability, data intensity, and adaptability to changing climate conditions[4,5].
- This study aims to review the integration of AI and remote sensing to improve CYP and CGPE in MED-rim agroecosystems.

How did we do it?

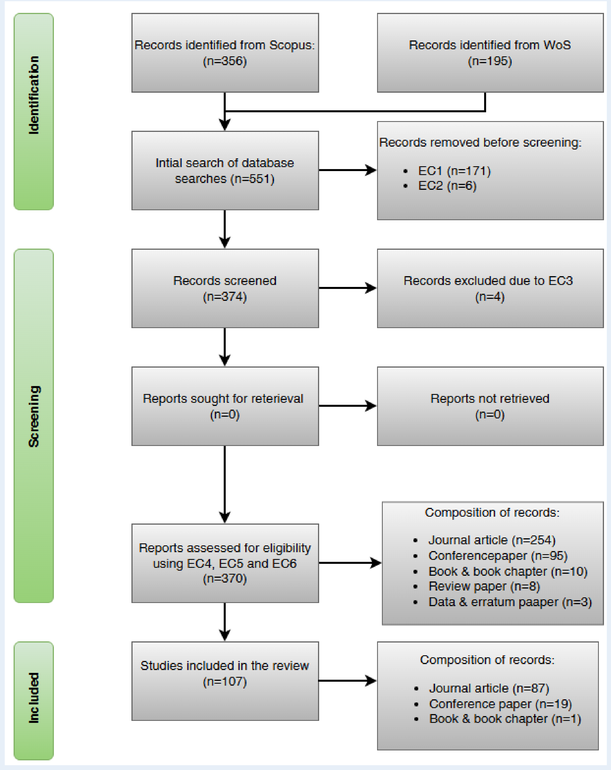
- Adopted the PRISMA guideline[6] to identify relevant publications on the research topic up to November 2024 (Fig. 1).
- Developed search queries and searched relevant papers in scientific databases (Web of Science (WoS) and Scopus).
- Exclusion criteria (EC) removed duplicates, non-regional studies, and unrelated topics.
- Inclusion criteria focused on English or French studies applying RS and AI techniques to CGPE or CYP within MED-rim agroecosystems

References

1. Miladinov, G. 2023. Impacts of population growth and economic development on food security in low-income and middle-income countries. *Frontiers in Human Dynamics*, *5*
2. Dlamini, L. 2023. A Global Systematic Review of Improving Crop Model Estimations by Assimilating Remote Sensing Data: Implications for Small-Scale Agricultural Systems. *Remote Sensing*, *15*
3. FAO, 2019). *State of Food and Agriculture 2019. Moving forward on food loss and waste reduction /Policy Support and Governance / Food and Agriculture Organization of the United Nations*
4. Rossetto, R. 2019. Software tools for management of conjunctive use of surface- and ground-water in the rural environment: Integration of the Farm Process and the Crop Growth Module in the FREEWAT platform. *Agricultural Water Management*, *223*
5. Pasquel, D. 2022. A review of methods to evaluate crop model performance at multiple and changing spatial scales. *Precision Agriculture*, *23*
6. Page, M. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed.)*, *372*

What did we find?

Fig.1 Systematic literature review flowchart based on PRISMA



- The publication trend is increasing, and most publications occurred in 2024.
- Authors mostly selected the Remote Sensing (MDPI) journal to publish their work.
- Italian institutes conducted most of the work both in Italy and in other parts of the ME-rim.
- Wheat is the most studied crop in CGPE and CYP, followed by olives and vineyards.
- Southern EURO-MED nations, notably Italy, dominate research efforts in MED-rim agroecosystems, while contributions from smaller and politically unstable MED-rim countries remain limited or absent.

Acknowledgment: This work was supported by the National Recovery and Resilience Plan (PNRR) under the program "Digital and Environmental Transitions" (Mission 4, Component 1, Investment 3.4), pursuant to Ministerial Decree No. 629/2024. The authors gratefully acknowledge this support, which has contributed significantly to the advancement of this research.

What did we find?

Fig.2 Geographical distribution of case studies over MED-rim

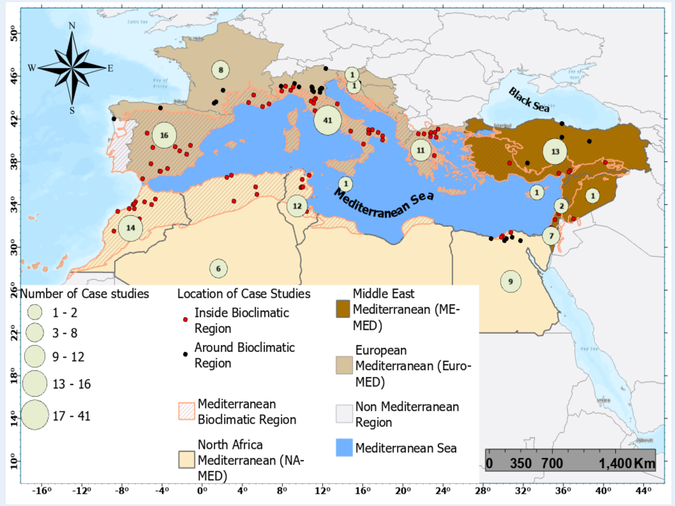
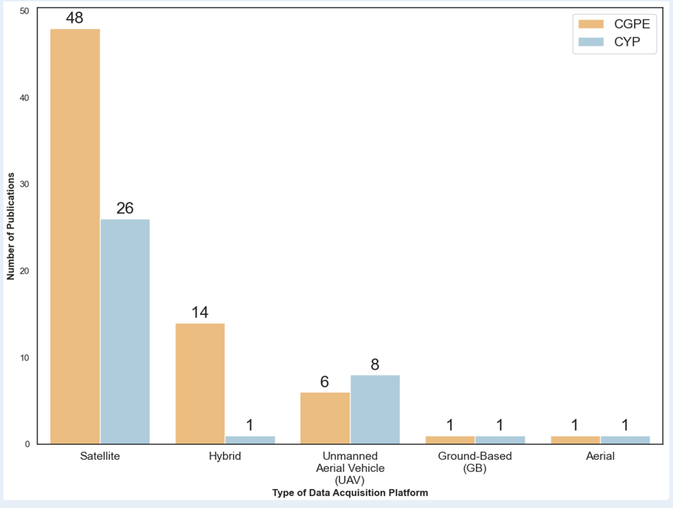


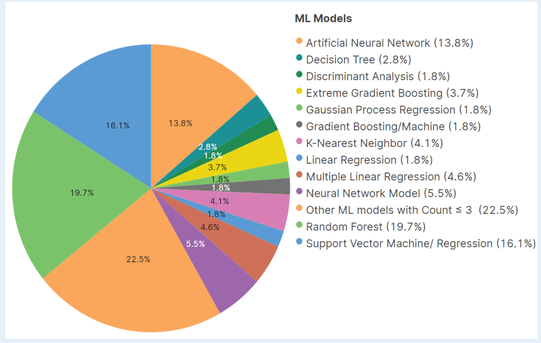
Fig.3 Commonly utilized data acquisition platform



- 69% of the study utilized satellite RS, which is the most widely used data acquisition platform
- Sentinel-2 and Sentinel-1 are among the highly exploited platforms, followed by Landsat-8 and Landsat-7 for large-scale agriculture.
- All UAV platforms were utilized for field-level agricultural studies

What did we find?

Fig.4 Commonly utilized AI algorithms



- ML models were utilized in 89 studies
- DL models such as CNN and LSTM were used in 10 studies
- 8 studies used hybrid methods (DL+ML)

Conclusion

The integration of RS technologies and AI algorithms has revolutionized the CGPE and CYP in several ways

1. Multi-source data fusion
2. Temporal integration and data assimilation
3. Dimensionality reduction
4. Data processing pipeline

- Limitations and research gaps include

1. Limited scope and generalizability
2. Data quality
3. Temporal and spatial coverage gaps
4. Computational and technical constraints

- Prospects

1. Scalable and adaptive models: Generalize across regions, crops, and environments using interpretable, phenology-aware, and adaptive ML.
2. Enhanced data integration: Fuse RS, IoT, UAV, next-gen satellite
3. Open and standardized ecosystem: Create shared databases for validation, benchmarking, and model transparency.