AARS: Advancing Agricultural Analysis by Remote Sensing

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***Abstract*—This paper summarizes six presentations in a session of the track "Advancing Agricultural Analysis by Remote Sensing". The research work deals with the following key issues of this track: Advanced technologies and artificial intelligence in precision agriculture, focusing on olive groves and vineyards in Spain. Some disruptive technologies such as Hyperspectral imaging are used captured attached to drones or UAVs has been used for classifying olive varieties and individual tree segmentation, vital for optimizing crop management and oil quality. Machine learning models and multisectoral data have been implemented for crop yield prediction in vineyards and extra virgin olive oil price estimation. Finally, Geospatial modeling is used to optimally locate agrivoltaic systems in olive groves, integrating solar energy production with sustainable agriculture. These technological innovations aim to enhance efficiency, sustainability, and profitability within the agricultural sector.**

Keywords-Precision agriculture; Artificial intelligence; Hyperspectral imaging; Machine/Deep learning; Agrivoltaic systems

I. Introduction

Precision Agriculture research aims to provide farmers and other stakeholders with reliable tools to optimize resource planning, reduce risks, and enhance agricultural sustainability. For these purposes some disruptive technologies are being utilized, including Unmanned Aerial Vehicles (UAVs) equipped with Hyperspectral Imaging (HSI), multispectral, RGB, and LiDAR sensors, alongside Geographic Information Systems (GIS), Deep Learning (DL) models like Convolutional Neural Networks (CNNs), and traditional computer vision techniques. The methodologies often involve the integration of multi-source and multi-scale data, efficient data management, and the design of cloud-based geospatial databases.

Specific applications and findings of these technologies in this framework are crop yield prediction for vineyards, integrating historical yield data, multispectral satellite images (from MODIS and ERA5), and climatic variables, with model validation using high-resolution drone data, aiming for outstanding accuracy in harvest prediction. Similar efforts are underway for olive groves, using satellite imagery and machine learning to improve early crop yield prediction. For olive variety classification, particularly distinguishing Arbequina and Picual, UAV-based HSI combined with Deep Learning (specifically 1D CNNs) has proven highly effective by capturing subtle spectral differences in leaf reflectance. Furthermore, research is advancing in the individual detection of olive trees across various planting distributions (traditional, intensive, super-intensive) using RGB drone imagery and 3D point clouds, combining computer vision and spatial algorithms to automate tree identification for improved monitoring and decision-making on health and maintenance.

Beyond crop-specific management, the research extends to broader agricultural economics and sustainable land use. A study on agrivoltaic systems in Jaén uses GIS and the Analytic Hierarchy Process (AHP) to identify optimal locations for integrating solar energy production with olive cultivation. Additionally, a Machine Learning approach is being developed for Extra Virgin Olive Oil (EVOO) price prediction in Jaén, incorporating multi-source variables such as historical EVOO prices, diesel prices, accumulated rainfall, reservoir levels, Consumer Price Index (CPI), and world production of olive and other vegetable oils.

Overall, these projects underscore a commitment to leveraging advanced geospatial and AI technologies for more predictive, efficient, and sustainable agricultural practices.

II. Submissions

The first article titled "Optimizing Picual Olive Variety Recognition through Deep Learning and Hyperspectral Imaging in Precision Agriculture" [1], investigates automated olive variety classification for resource optimization and quality enhancement in precision agriculture, specifically for Picual. The study utilized UAV-acquired Hyperspectral Imaging (HSI) data (270 bands, 400-1000 nm), processed with tree canopy segmentation (EVI, DBSCAN) and spectral filtering. A one-dimensional Convolutional Neural Network (CNN) was developed, with hyperparameters optimized via Bayesian optimization. This research successfully achieved its objectives: it eliminated manual sampling for real-time, high-throughput classification. The CNN model exhibited robust performance, achieving 88.04% accuracy and 96% recall for Picual on the test set. Its generalizability was confirmed with an 83% accuracy on unseen data. The findings assert that Deep Learning (DL) models, especially CNNs, significantly outperform traditional machine learning in processing high-dimensional HSI data, establishing UAV-based HSI with DL as a highly effective and scalable solution for automated olive variety identification in agriculture.

Individual olive trees recognition is essential to make detailed studies of each individual. The third article, entitled "Individual Detection of Olive Trees Under Different Olive Planting Distributions" [2], addresses the crucial challenge of accurately detecting individual olive trees in diverse planting densities and layouts using advanced computer vision techniques and environmental analysis via point clouds. This is essential for efficient orchard management, resource optimization, and precise decision-making regarding tree health, maintenance, and pruning. The study details a methodology involving high-resolution RGB imagery captured by UAVs, reconstruction of 3D point clouds, and a comparative analysis between neural networks (U-Net, YOLOv8-seg) and traditional computer vision for initial vegetation segmentation. It then applies 3D geometrical post-processing, including relative height thresholds, to filter out ground-level elements and isolate tree canopies. The achieved objectives include successfully demonstrating that traditional computer vision offers greater efficiency and generalizability for initial vegetation segmentation across various plantation types compared to early-stage neural networks. The methodology also effectively segments vegetation and isolates trees in 3D by discarding low vegetation based on height thresholds, thereby laying the groundwork for future clustering to identify individual olive trees. This robust system aims to spatially locate and monitor each tree entity for intelligent agricultural management.

Related to the economic result of the olive grove, the article "Extra Virgin Olive Oil Price Prediction from Multi-source Variables and Machine Learning" [3], underscores the vital need for accurate Extra Virgin Olive Oil (EVOO) price prediction, especially in Andalusia, Spain, due to its significant economic and social impact on inflation, trade, and stability. The study's central objective was to develop a Machine Learning (ML) approach using diverse historical and current data from official sources to predict EVOO prices. The methodology involved acquiring extensive multi-source historical data (2009-2023), including EVOO base prices, seasonality, diesel prices, accumulated rainfall, reservoir levels, Consumer Price Index (CPI), world olive oil production, world production of other vegetable oils, and early predictions of olive crop and oil yields. These variables were processed using Oracle Data Mining, and various ML algorithms, such as Linear Regression, Support Vector Machines, Neural Networks, Random Forest, Gradient Boosting, and K-Nearest Neighbors, were evaluated. The research successfully demonstrated the feasibility of enhancing prediction accuracy, with Gradient Boosting and Random Forest models proving most effective in capturing the complex, non-linear relationships within the EVOO market and achieving higher accuracy. The high accuracy of the models confirmed their suitability in reflecting market dynamics and that the data sources and processing methods were appropriate for building robust predictive models. Ultimately, this work contributes to advancing predictive modeling research within the agricultural sector, promising market stabilization, optimized distribution, and improved agricultural budgeting.

A different study, but related to olive orchards is the work titled "Geospatial modelling for the optimal location of solar panels for agrivoltaic systems. A case study in olive groves" [4], which addresses the crucial need to optimize land use and enhance farmer profitability in Jaén, Spain, by integrating solar energy production with olive cultivation. The study's central objective was to identify the most suitable sites for agrivoltaic systems using Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP). The comprehensive methodology involved defining detailed evaluation criteria based on climatology, orography, and location (such as solar radiation, terrain slope, and proximity to roads/transmission lines) alongside environmental constraints like protected areas and water bodies. These criteria were processed through thematic layers created in QGIS and weighted using AHP based on expert judgment, with solar radiation and terrain slope identified as the most influential factors. The research successfully achieved its key objectives: it identified that 19% of the studied area (33,840 km^2) is highly suitable for agrivoltaic projects, demonstrating that the integration of GIS, AHP, and 3D modeling effectively maximizes agricultural land efficiency without compromising crop production, thereby promoting both food security and renewable energy generation. This robust approach is also presented as replicable in other agricultural regions for sustainable development.

The article entitled "Development of a Geospatial Predictive System of Crop Yield in Vineyards - A Case Study in Spain" [5], is focused on another important crop in the Mediterranean basin, the vineyard. The work describes the work in progress methodology of an Artificial Intelligence (AI)-based system for early crop yield prediction in vineyards. The central objective is to equip farmers with a reliable tool to optimize resource planning, mitigate risks, and enhance crop sustainability. The methodology integrates multi-source and multi-scale data, encompassing historical yields, multispectral satellite imagery (MODIS), and climatic variables (temperature, humidity, precipitation from ERA5). It leverages advanced AI techniques, including image processing and regression models, managed through a cloud-based geospatial database. A critical step involves validating and fine-tuning the predictive model using high-resolution drone-captured data. The project aims to achieve outstanding accuracy in harvest prediction, which will lead to a significant reduction in uncertainty, improved operational efficiency, and enhanced grape quality. Ultimately, it intends to transform viticulture into a more predictive and sustainable discipline, offering insights into key influencing variables and enabling growers to anticipate yields accurately months in advance.

Finally, the article "Aerial Hyperspectral Analysis: Distinguishing Olive Varieties for Precision Agriculture" [0], investigates the potential of Unmanned Aerial Vehicle (UAV)-mounted hyperspectral sensors to classify olive varieties, focusing on Arbequina and Picual. The main objective is to demonstrate the feasibility and effectiveness of Hyperspectral Imaging (HSI) as a non-invasive and efficient alternative for varietal differentiation. The study achieved its goals through an integral methodology that included drone-based HSI data collection, precise tree canopy segmentation using EVI and DBSCAN, and a two-step spectral filtering process to reduce noise. Results showed consistent spectral trends within the same olive varieties and clear differentiation between them. The effectiveness of the extracted spectral features for distinguishing varieties was validated with a Random

Forest classifier, achieving an accuracy of 1.0. This research establishes that UAV-based HSI is a scalable and effective method for olive variety classification, offering significant advantages for precision agriculture by enabling large-scale varietal monitoring and more efficient and sustainable orchard management.

III. Conclusions

These papers in the "Advancing Agricultural Analysis by Remote Sensing (AARS)" special issue, collectively showcase the transformative impact of advanced geospatial and AI technologies on precision agriculture, particularly for olive and vineyard management. They employ UAVs, Hyperspectral Imaging (HSI), Deep Learning (DL), Machine Learning (ML), and Geographic Information Systems (GIS). Key objectives fulfilled include automated olive variety classification, achieving high accuracy and eliminating manual sampling; individual olive tree detection for precise monitoring; and early vineyard yield prediction for resource optimization and risk mitigation.

Further research covers accurate Extra Virgin Olive Oil (EVOO) price prediction using ML for market stability. It also identifies optimal agrivoltaic system sites in olive groves via GIS and AHP, promoting dual land use and farmer profitability. Collectively, these works achieve more efficient, sustainable, and data-driven agricultural practices, reducing manual labor and enhancing decision-making across the sector for improved crop quality and economic resilience.

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